2012 Southeast Louisiana and Southern Mississippi Flooding Due to Hurricane Isaac

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ABSTRACT

Slow-moving Hurricane Isaac affected the northern gulf coast between August 28th and August 31st, 2012. The most severe flooding impacts from storm surge and heavy rainfall occurred in southeast Louisiana and southern Mississippi. The slow movement of Isaac was a major contributor to this flooding. The National Weather Service (NWS) Lower Mississippi River Forecast Center (LMRFC) coordinated the creation of flood survey teams to document the impacts and discuss forecast services with our customers and partners. Survey team members obtained anecdotes from persons living in impacted areas, high water marks, and in some cases, established river crests at forecast locations. Notes from the survey teams were compiled and summarized by river system. Post survey action items included establishing crests for non-automated gauge locations and investigating anecdotes provided by members of the public. Multiple methods for estimating storm total precipitation were compared and contrasted, leading to discovery of an isolated extreme rainfall maximum across portions of New Orleans. Recommendations for service improvement were provided to the relevant NWS Weather Forecast Offices (WFOs).

1. Introduction

Hurricane Isaac was a very slow moving tropical system that affected the central Gulf Coast over several days, starting with outer rain bands arriving on August 28th, 2012. By August 31st, 2012, the very heavy rainfall in conjunction with storm surge had caused numerous forecast locations to exceed flood stage. The region most impacted by flooding associated with Hurricane Isaac included the forecast areas of National Weather Service (NWS) Weather Forecast Office (WFO) Lake Charles, NWS WFO New Orleans/Baton Rouge, NWS WFO Jackson, and NWS WFO Mobile, and was almost entirely within the hydrologic service area (HSA) of the Lower Mississippi River Forecast Center (LMRFC) (Figure 1). By mid-September, flooding associated with Isaac had subsided, leaving behind 16 minor flood stage crests, 5 moderate flood stage crests, and 12 major flood stage crests; out of these, 3 were new record crests. Recognizing the widespread, significant nature of the flood event, the NWS LMRFC coordinated the creation of flood survey teams to document the impacts and discuss forecast services with our customers and partners. This document provides the results of the survey teams' activities and some suggestions for improving service in the future.

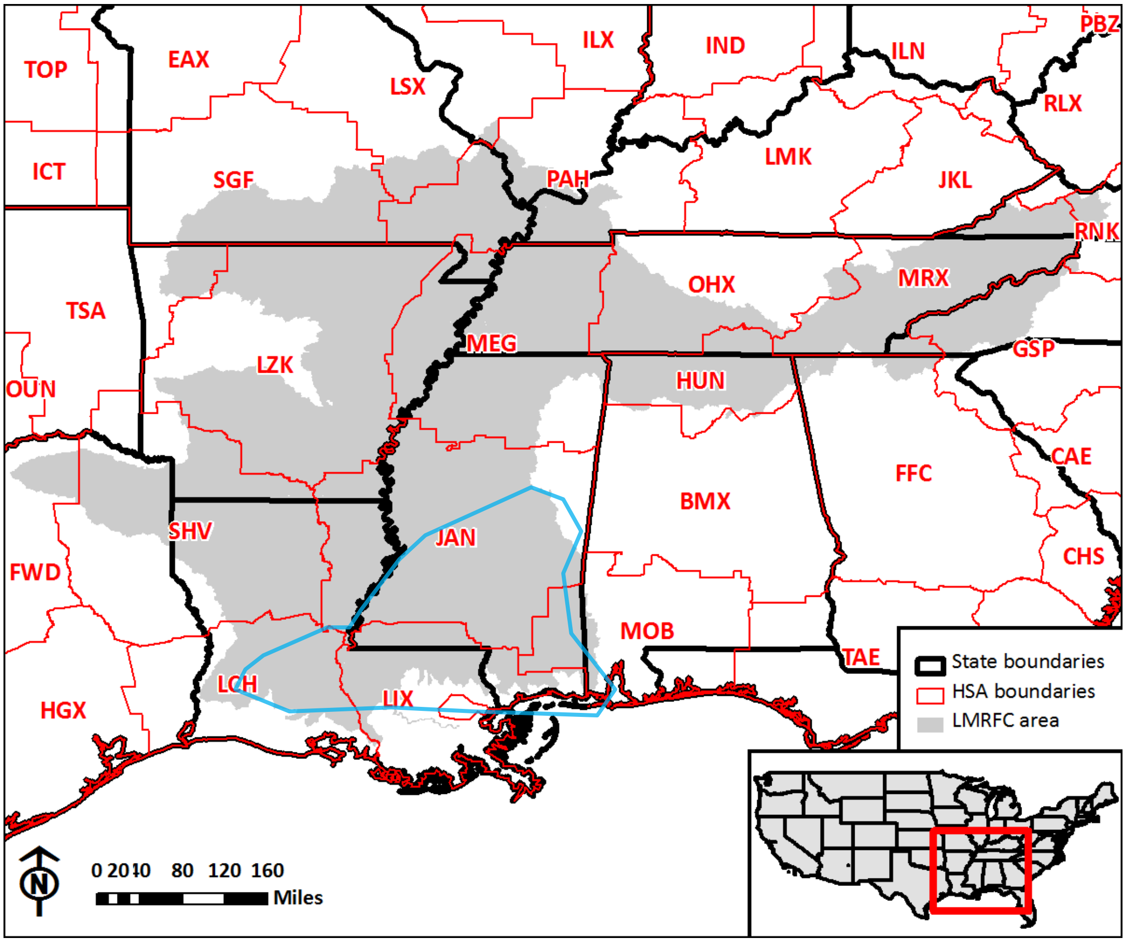


Figure 1. Map of central Gulf Coast region, with the LMRFC forecast area shaded in gray and individual NWS WFO hydrologic service areas (HSAs) delineated in red. The area of significant flooding from Hurricane Isaac - determined by locations climbing above the 90th percentile of streamflow by the USGS – is circled in blue.

a. Post-flood Survey Methodology

Surveys of areas impacted by Hurricane Isaac's flood-producing rainfall were conducted from Wednesday, September 5th, 2012, through Saturday, September 8th, 2012. National Weather Service staff members from several different offices were involved in the survey team, which was composed of:

1. Dr. Suzanne Van Cooten, Hydrologist-in-Charge, NWS Lower Mississippi River Forecast Center
2. Jeffrey Graschel, Service Coordination Hydrologist, NWS Lower Mississippi River Forecast Center
3. Katelyn Costanza, Senior Hydrologist, NWS Lower Mississippi River Forecast Center
4. W. Scott Lincoln, Hydrologist, NWS Lower Mississippi River Forecast Center
5. David Schlotzhauer, Hydrologist, NWS Lower Mississippi River Forecast Center
6. Jonathan Brazzell, Service Hydrologist, NWS Lake Charles
7. Roger McNeil, Service Hydrologist, NWS Birmingham
8. Marty Pope, Service Hydrologist, NWS Jackson

During each day of surveys, individuals were split into different teams (typically 2-4 persons) and sent to the affected areas in Louisiana and Mississippi. The survey team members sought to document evidence of flooding and speak with our partner agencies such as the local emergency management officials. The survey teams also spoke with local residents impacted by the flooding to get a feel for how our forecasts were received and note potential issues that should be resolved to improve our services.

b. Flood Category Descriptions

Most official forecast points and even some non-forecast gauging data points have a stretch of river reach associated with the point location. Flood categories – action/bankfull, minor, moderate, major – are determined for river reaches based upon the impacts typically observed for particular stages. It is typically the responsibility of the service hydrologist or hydrology focal point of a NWS WFO to create and maintain these categories. Although flood categories can be adjusted based upon the needs of the local community and criteria may differ between NWS WFOs, NWS Manual 10-950 (OCWWS, 2012) defines the flood categories as follows:

- Minor Flood Stage: Minimal or no property damage, but possibly some public threat.
- Moderate Flood Stage: Some inundation of structures and roads near stream. Some evacuations or people and/or transfer of property to higher elevations.
- Major Flood Stage: Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations.
- Record Flood Stage: Flooding which equals or exceeds the highest stage or discharge observed at a given site during the record-keeping period. The highest stage on record is not necessarily above the other three categories. It may be within any of them or even less than the lowest, particularly if the period of record is short.

In the following sections, the flood category listed is determined first by categories already in place (as provided by the responsible NWS WFO), but if the surveyed location is not a gauged location or has not been surveyed, the flood category is estimated as objectively as possible using the criteria from NWS Manual 10-950, but partially expanded:

- Minor flooding: River/stream is above flood stage, but the expected impacts are of minor severity. Typically water inundates floodplain areas and/or agricultural areas, but causes minimal property damage. Rural roads that are prone to water may flood.
- Moderate flooding: River/stream is above flood stage with impacts of moderate severity. Water begins to inundate roads and may also flood a few structures, especially those prone to flooding in the 1%-chance FEMA floodplain.
- Major flooding: River/stream is above flood stage with impacts of major severity. Water starts to inundate numerous residents and businesses. Water may also severely disrupt travel on major roads. Inundation extent may extend beyond that of the 1%-chance FEMA floodplain and may also near the flood of record.

2. Meteorological Synopsis

a. Track and Forecast Overview

Hurricane Isaac became the ninth tropical depression of the 2012 hurricane season about 715 miles east of the Leeward Islands around daybreak on Tuesday, August 21. By early evening, Depression 9 had strengthened to a tropical storm located about 500 miles east of Guadeloupe. Isaac was expected to strengthen slowly, reaching hurricane intensity prior to landfall in Hispaniola late Friday night on August 24.

The morning of Saturday, August 25, tropical storm Isaac moved off the coast of Haiti. At daybreak Sunday, August 26, satellite imagery showed Isaac was poorly organized. The National Hurricane Center (NHC) noted that the SFS, HWRF, and GFS ensemble showed Isaac turning northward toward the eastern Gulf Coast but later that day the forecast track was shifted westward significantly, with forecasters noting a "Large spread among the more reliable track models" in the midday discussion. The European Center for Medium Range Weather Forecasting (ECMWF) forecast model was about 300 nautical miles east of the Global Forecast System (GFS) model solution for Day 3. As result, a Hurricane Watch was issued for the Louisiana coast and did include metropolitan New Orleans and Lake Pontchartrain. On Sunday evening, the center of Isaac was just south of Key West, Florida. NHC highlighted two critical elements: 1) the abnormally large extent of the wind field and 2) the decrease in the forward speed of the storm. The public was advised that over the next 48 hours, tropical storm conditions were expected to reach the northern Gulf by late Monday and Hurricane conditions would arrive Tuesday. With its Sunday evening product suite, NHC added wording highlighting storm surge and rainfall threats. Initial predictions were 6-12ft of storm surge for areas from Morgan City, LA, to Destin, FL, and total rainfall amounts of 5-10 in with maximum amounts up to 15 in possible along the central and eastern Gulf Coast.

At daybreak Monday, August 27, the minimum pressure of Isaac had fallen to 990 mb, but the inner core structure remained disorganized. The center of Isaac was located 405 miles southeast of the mouth of Mississippi River. Numerical weather models were now locking into a landfall along the central portion of the Gulf of Mexico. NHC products continued to highlight the fact that Isaac had an abnormally large wind field and significant storm hazards extended well away from the storm's center. Aircraft, buoy, ship, and oil platform observations indicated that although Isaac's maximum sustained winds were below Hurricane strength (65 mph) tropical storm force winds extended outward up to 240 miles from the center. It was also noted that Isaac would slow in its forward speed and take a turn to the northwest on Tuesday. By Monday evening, forward movement slowed to northwest at 12 mph and the center of Isaac was located 255 miles southeast of the mouth of the Mississippi River. Total rainfall amounts up to a maximum of 18 in were forecast for southeastern Louisiana, southern Mississippi, southern Alabama, and the extreme western portions of the Florida Panhandle. Overnight Monday (August 27) into Tuesday (August 28), NHC reported a drop in Isaac's minimum pressure, but observations indicated maximum sustained winds remained just below hurricane strength. The NHC's discussion stated "The threat of heavy rainfall and flooding is also expected to spread inland over the lower Mississippi valley region during the next few days" with rainfall amounts of 7 to 14 inches total and isolated maximum amounts of 20 inches. Enhanced wording was added, "In southeastern Louisiana…southern Mississippi…southern Alabama….and the extreme western Florida Panhandle these rains could result in significant lowland flooding." NHC maintained its forecast of 6 to 12 feet of storm surge for southeast Louisiana and Mississippi.

Hurricane Isaac remained relatively unchanged until midday Tuesday, August 28, when aircraft reported maximum winds with Isaac near 75 mph and Isaac was upgraded to hurricane strength about 75 miles south-southeast of the mouth of the Mississippi River. By afternoon, data from numerical weather models showed atmospheric wind speeds decreasing in the upcoming 36 to 48 hours. This decrease in the mid and upper level steering flow would slow the forward speed of Isaac and normally result in intensification as wind shear diminishes and the storm remains over warm ocean water longer. By evening, the center of Isaac was 20 miles SSW of the mouth of the Mississippi River with maximum sustained winds of 80 mph and movement northwest at 8 mph. Hurricane force winds extended outward up to 60 miles mainly to northeast and east of the center with tropical storm force winds extending outward up to 185 miles. At 6:45 PM CDT, Hurricane Isaac brushed the Mississippi River Delta. The center jogged westward and re-entered the Gulf of Mexico around 10PM CDT. The minimum central pressure continued to fall to 968 mb yet observations indicated no significant increase in maximum sustained wind speeds. NHC stated that "National Ocean Service tide gauges indicate that storm surge heights of 6 to 10 feet are occurring along portions of the coast of southeastern Louisiana and Mississippi. Given the long duration of onshore flow in these areas...water levels are expected to remain high for the next 12 to 24 hours." Hurricane Isaac became nearly stationary just off the coast of Louisiana for several hours before wobbling westward and making a second landfall near Port Fourchon, LA. By Tuesday morning, radar indicated areas of intensifying convection in the northern and eastern quadrants of the storm.

On the morning of Wednesday, August 29th, Isaac was moving west northwest at 8 mph centered 30 miles south southeast of Houma, LA. Convective rain bands continued to intensify and increase in coverage in the eastern quadrant of the circulation. Hurricane Isaac continued to slow, and by Wednesday afternoon Isaac was creeping northwest at only 6 mph. At 2PM CDT, NHC downgraded Hurricane Isaac to a tropical storm with maximum sustained winds of 70 mph with a center located 55 miles south southeast of Baton Rouge. By late evening Wednesday, the NHC noted that "Isaac is expected to produce total rainfall amounts of 7 to 14 inches...with possible isolated maximum amounts of 25 inches...over much of Louisiana, southern and central Mississippi, southwest Alabama, and southern and central Arkansas through Friday." Isaac maintained its abnormally large wind field after landfall with tropical storm force winds extending outward up to 175 miles primarily in the southeast quadrant of the storm.

On the morning of Thursday, August 30th, mid and upper level wind speeds began to increase. With the center located 55 miles southeast of Alexandria, Louisiana, the forward motion of Isaac increased to 8 mph. The forward motion continued to increase into Friday, August 31st, with only a few lingering bands of showers affecting southeast Louisiana and southern Mississippi.

Climatologically, heaviest rainfall totals with coastal storms are closely tied to the landfall location and forward speed. The uncertainty with Isaac's forecast track, forward speed, and ultimate point of landfall was problematic for quantitative precipitation forecasts, the primary forcing for medium-term river forecasting. Between August 24th and August 29th, forecast landfall locations ranged from near Panama City, FL, in the east to near Grand Isle, LA, in the west, a distance of about 270 miles (Figure 2 and Figure 3). Final landfall was just to the west of this range. The final landfall location was within the forecast cone of uncertainty for the advisories issued on August 24th between 03 GMT and 18 GMT, and again from August 26th at 09 GMT through landfall.

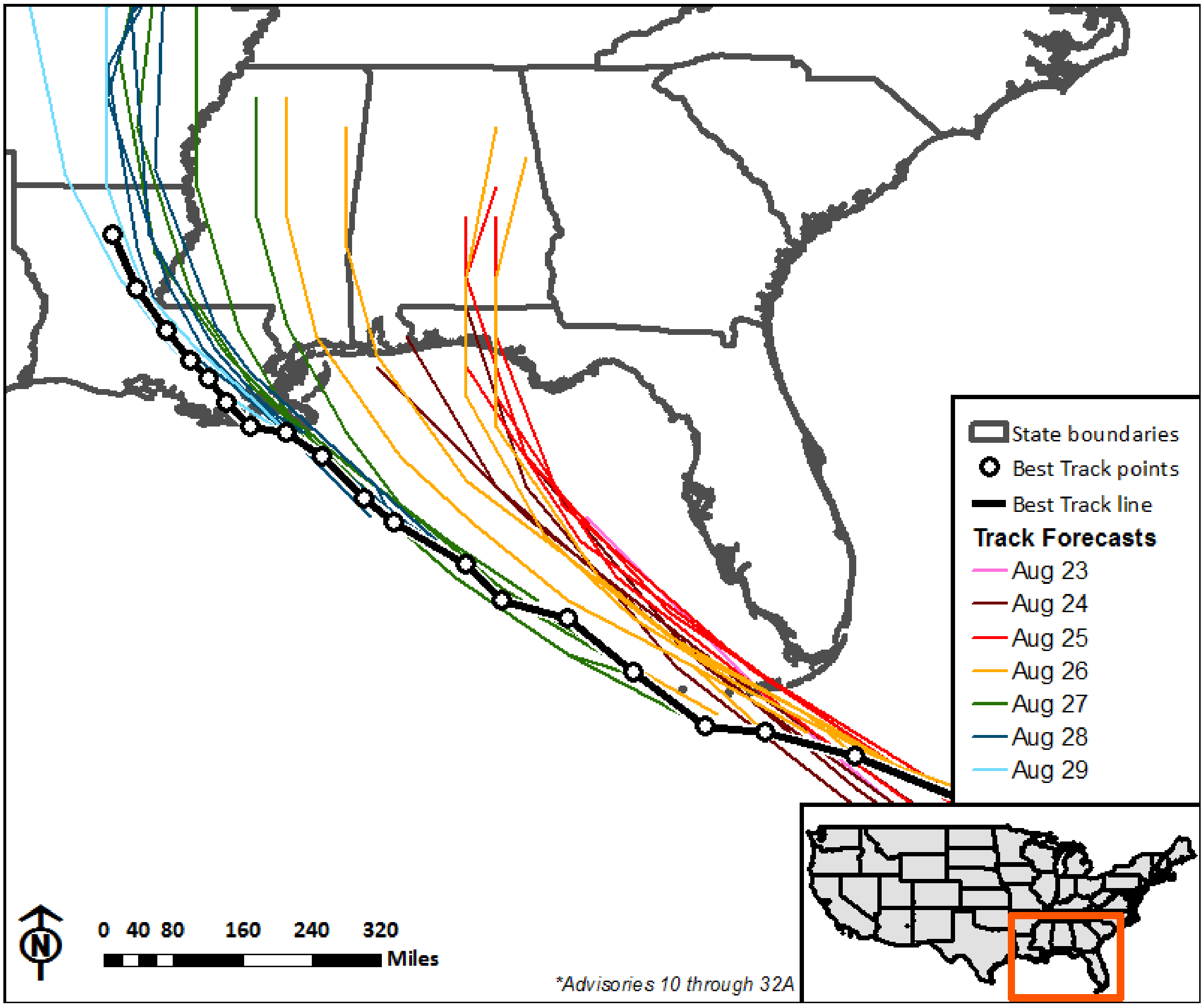


Figure 2. Five day track forecasts issued by the National Hurricane Center with the preliminary best track for Hurricane Isaac.

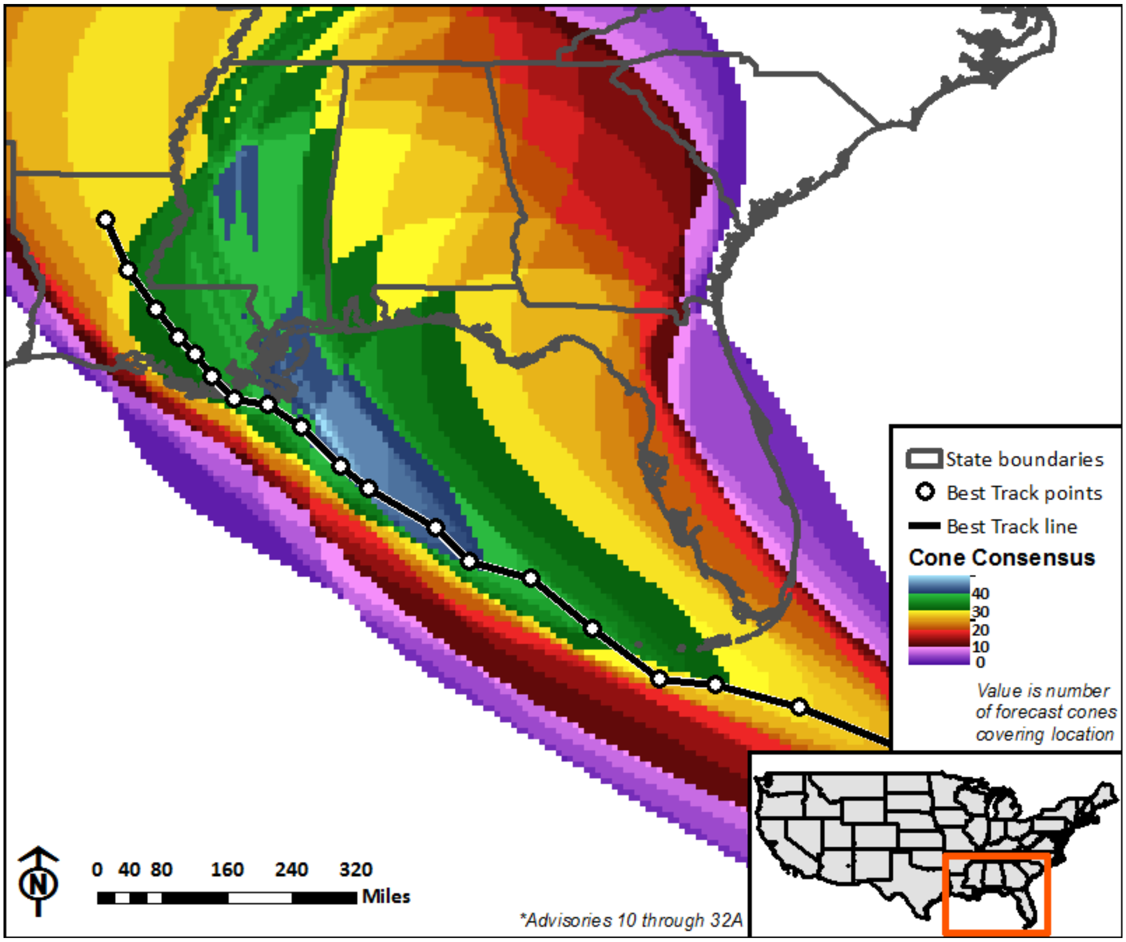


Figure 3. A "forecast cone consensus" for Hurricane Isaac forecasts issued by the National Hurricane Center. Value is the number of overlapping uncertainty cones for a given location.

b. Estimated Rainfall

1) OFFICIAL SOURCES

The slow movement speed of Hurricane Isaac prior to and during landfall contributed to very significant rainfall amounts across southeast Louisiana and southern Mississippi. Heavy rainfall associated with the core of Isaac occurred for almost three days, starting on August 29th and ending on August 31st. The remnant low pressure area of Isaac continued to pull bands of rainfall from the Gulf of Mexico on September 1st and 2nd, although amounts were substantially less.

Gauge reports from United States Geological Survey (USGS), United States Army Corps of Engineers (USACE), and NOAA stations in Louisiana and Mississippi were collected for August 28th – August 30th when the heaviest rain rates occurred. These point values were interpolated to a grid (Figure 4) using the kriging geo-statistical interpolation method to enable comparisons to the other gridded estimates. The kriging technique also produces an estimate of the standard error due to the interpolation (Figure 5). This data set showed the highest rainfall totals (12-16" range) near New Orleans. Unfortunately, several rain gauges in the impacted area produced erroneous data and had to be removed from the analysis.

Data from the National Severe Storms Laboratory (NSSL) National Mosaic & Multisensor QPE (NMQ) project were also retrieved. The NMQ project creates a national radar mosaic every 5 minutes across the continental U.S. and applies the Z-R relationship equations on a gridded basis based upon vertical profile reflectivity and atmospheric conditions. This is in contrast to the operational gridded rainfall data sent to NWS RFCs where the Z-R relationship is chosen by the WFO and then applied to the entire radar field. The highest rainfall totals in the

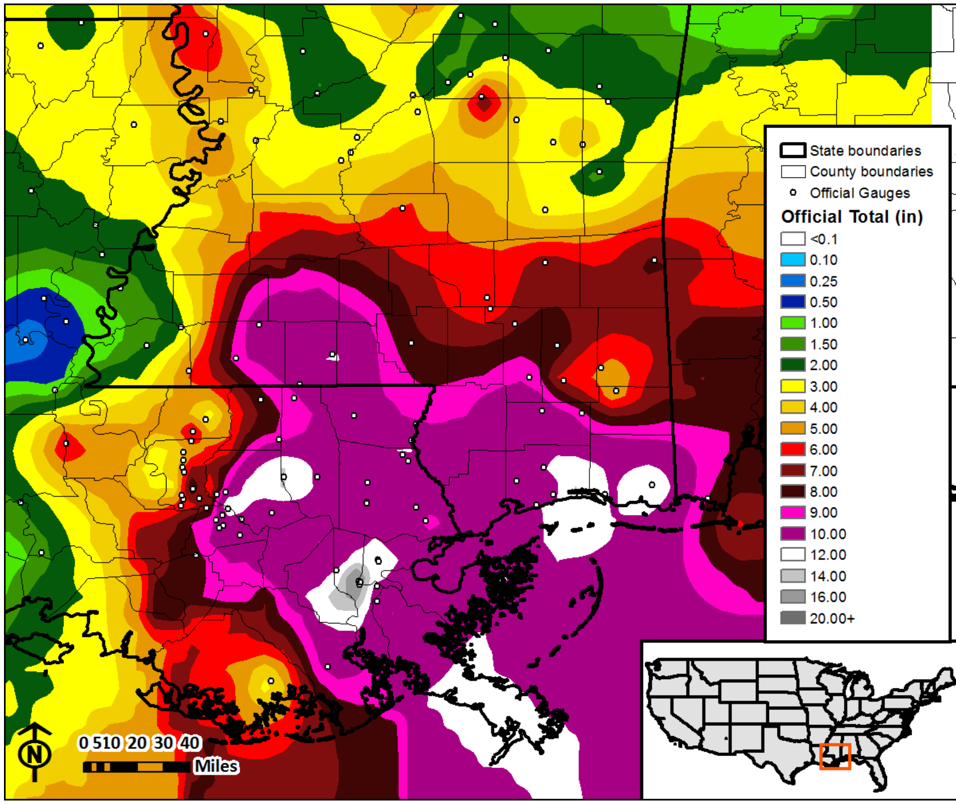
NMQ data were about 16” near New Orleans, LA, and about 20” near Columbia, MS (Figure 10). Also of note were bands of heavier rainfall showing up in the NMQ data that were not evident in data-sparse regions of the gauge-only data, as well as areas of apparent radar over-estimation, apparently in central Mississippi (Figure 11 & Figure 12).

The operational quantitative rainfall estimate (QPE) used by the NWS RFCs is the multi-sensor best-estimate rainfall product, also referred to as Stage IV. This product is created by mosaicing individual gridded radar estimates, bias correcting the radar rainfall grids with automated rain gauges, then subsequently quality controlling the grids every hour. QPE created by the LMRFC indicated rainfall totals exceeding 10” over large portions of southeast Louisiana and southern Mississippi, with a few areas of 12-16” (Figure 9). Rainfall totals and spatial characteristics of the LMRFC MPE rainfall product were similar to the NMQ data in most areas (within a few inches), although the NMQ data appeared to overestimate rainfall overall which was particularly significant in south central Mississippi (Figure 11).

Rainfall data from the NWS Cooperative Observer (COOP) sites was not available in realtime during Hurricane Isaac but was obtained by the NWS New Orleans-Baton Rouge WFO staff in the subsequent weeks. WFO New Orleans maintains 11 of these sites within their County Warning Area (CWA) (WFO New Orleans staff, personal communication, Dec 2012). Of these 11 sites, it appeared that 8 did not fully capture the storm total rainfall from Isaac. Because of these issues, the COOP sites were only of limited use in this this report, but a few sites in metropolitan New Orleans and the Mississippi gulf coast were used. It was not made clear which particular sites recorded accurate data.

2) UN-OFFICIAL SOURCES

When available, rainfall data from private weather station networks were retrieved and compared to the realtime gauges and radar estimates typically available in realtime to RFC forecasters. The most extensive set of data was made available by Weather Underground, and came from their Personal Weather Station (PWS) network. Personal Weather Station data comes from volunteer observers who purchase weather observing hardware of varying cost and quality, and then choose to share their information with Weather Underground servers. Weather Underground has archived this data for a number of years for thousands of weather stations across the United States (http://www.wunderground.com/weatherstation/index.asp, Dec 2012). Weather Underground staff indicated that there was no mechanism in place to batch download/retrieve numerous stations over a several day time frame, but data could be exported for a single site at a time in comma-delimited CSV format (Jeff Masters & Shaun Tanner, personal communication, Dec 2012). A PHP-based web application was written to speed up the retrieval of this data from their database; ultimately over 150 stations were manually retrieved and entered into a data format that could be read into and analyzed using GIS software. After the original analysis of Hurricane Isaac was completed for this report, a more extensive process for data retrieval was developed which automates most steps (Appendix D: Data mining of the Weather Underground Raingauge Network). Unfortunately, due to the lower reliability of private stations compared to official USGS/USACE/NWS stations, there were some locations that could not be used for the event. There were also a number of time frames for some stations when data was not available; these time periods typically corresponded to the landfall of Hurricane Isaac and may be due to power outages in the area. Gridded rainfall interpolated from unofficial data sources (Figure 6) produced generally similar results to official gauges. We also created a combined data set of both official and private weather stations (Figure 8), which yielded a slightly lower kriging standard error in some areas (Figure 7).



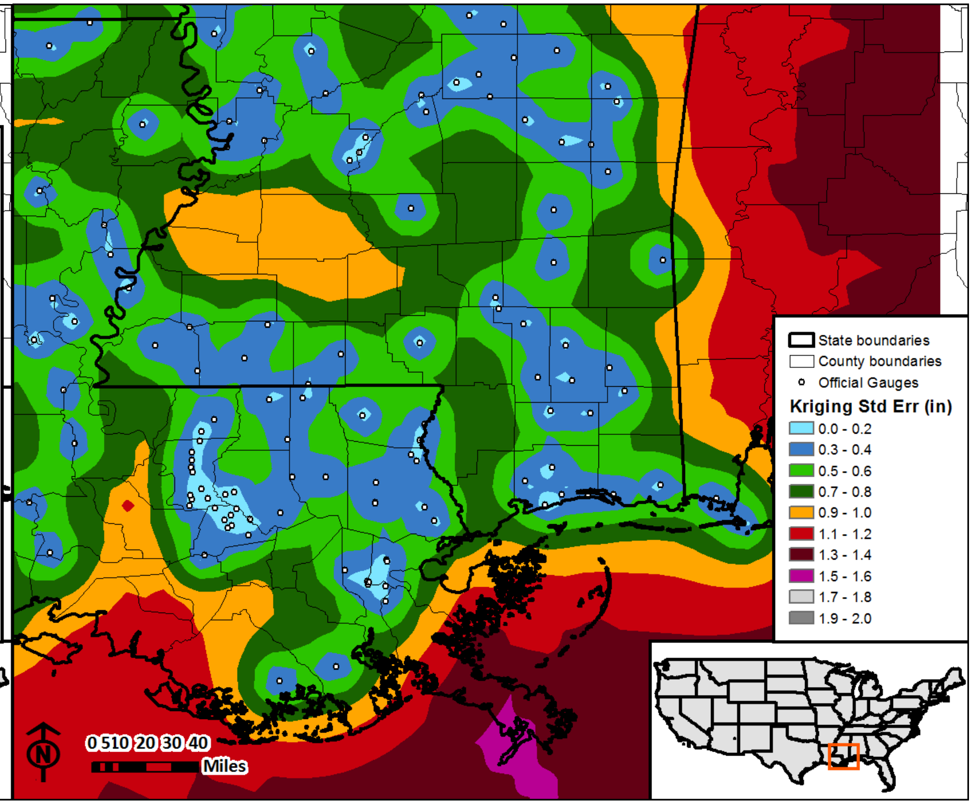


Figure 4. Storm total rainfall as observed by official precipitation gauges. Observations were interpolated by the Kriging method, which also estimates standard error due to interpolation (Figure 5). Gauge data in this plot ends at 12 GMT on 08/30/12.

Figure 5. Standard error due to kriging interpolation of data in Figure 4. Interpolation uncertainty is closely related to the density of the gauge network and observed variability between neighboring gauges.

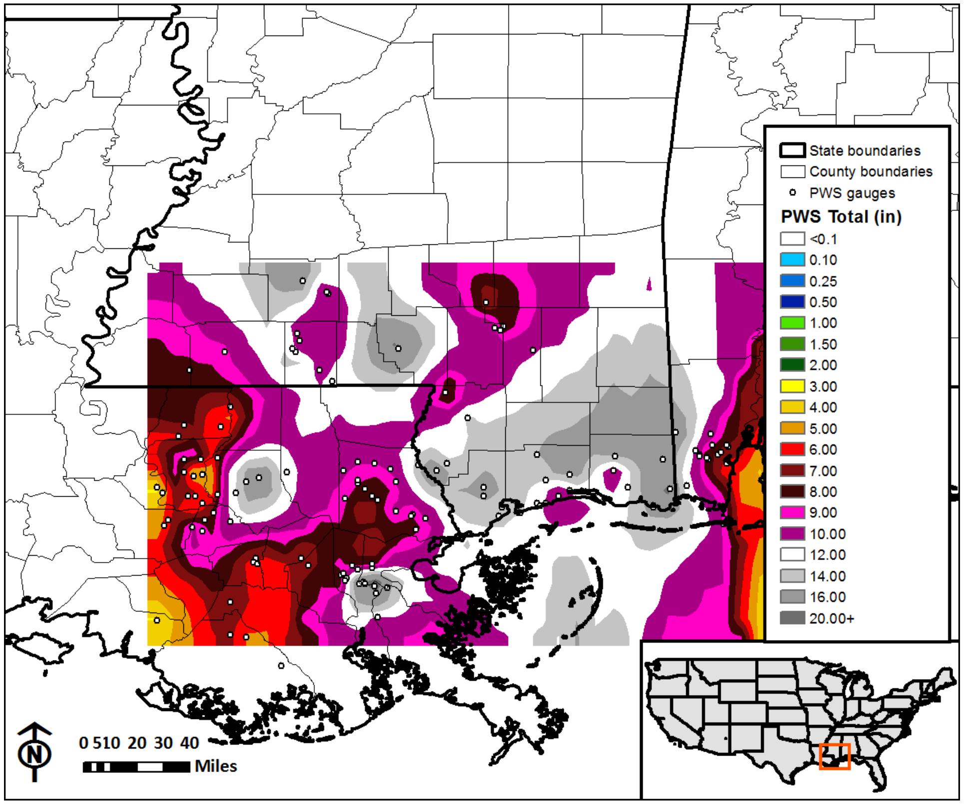


Figure 6. Storm total rainfall as estimated from QCed private weather station data. Data was mostly obtained through Weather Underground PWS sites with a few from AWS/WeatherBug and other individuals contacted by the survey team. Observations were interpolated by the Kriging method as with the official gauges, and heavily extrapolated areas were removed. Gauge data in this plot ends at 5 GMT on 09/02/12.

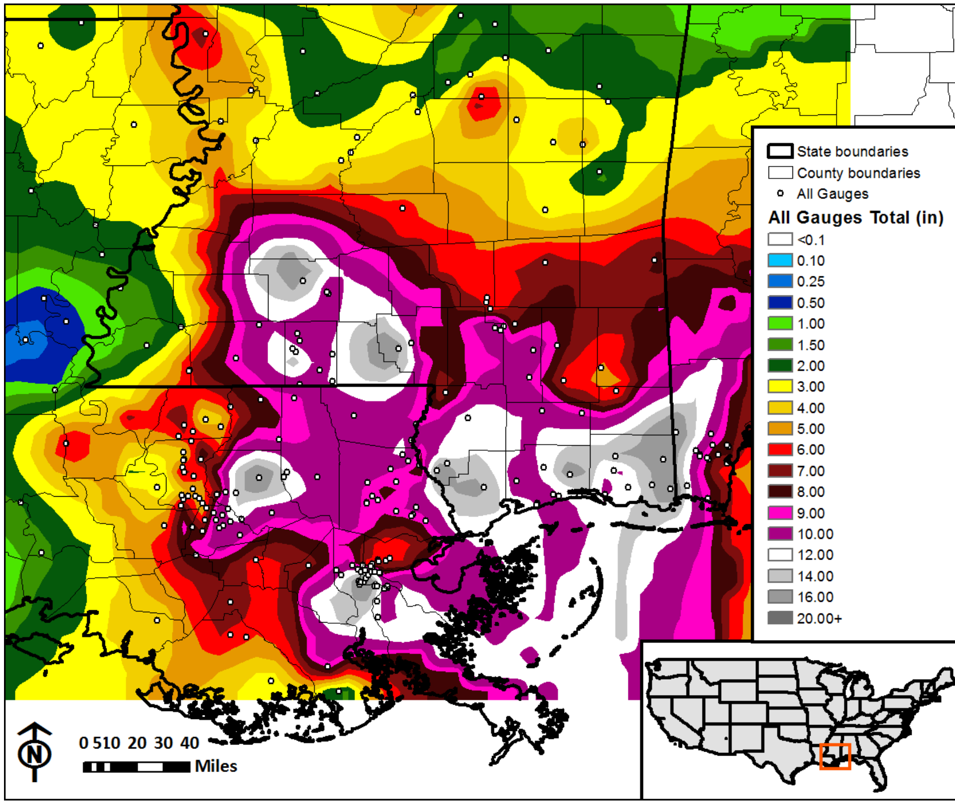


Figure 8. Storm total rainfall as estimated from a combination of official and QCed private weather stations. Observations were interpolated by the Kriging method, which also estimates standard error due to interpolation (Figure 7). Precipitation data from official stations ends at 12 GMT on 09/03/12, and data from private stations ends at 5z on 09/03/12. This small discrepancy should cause minimal issues with the data, as most rainfall had ended by 09/02/12.

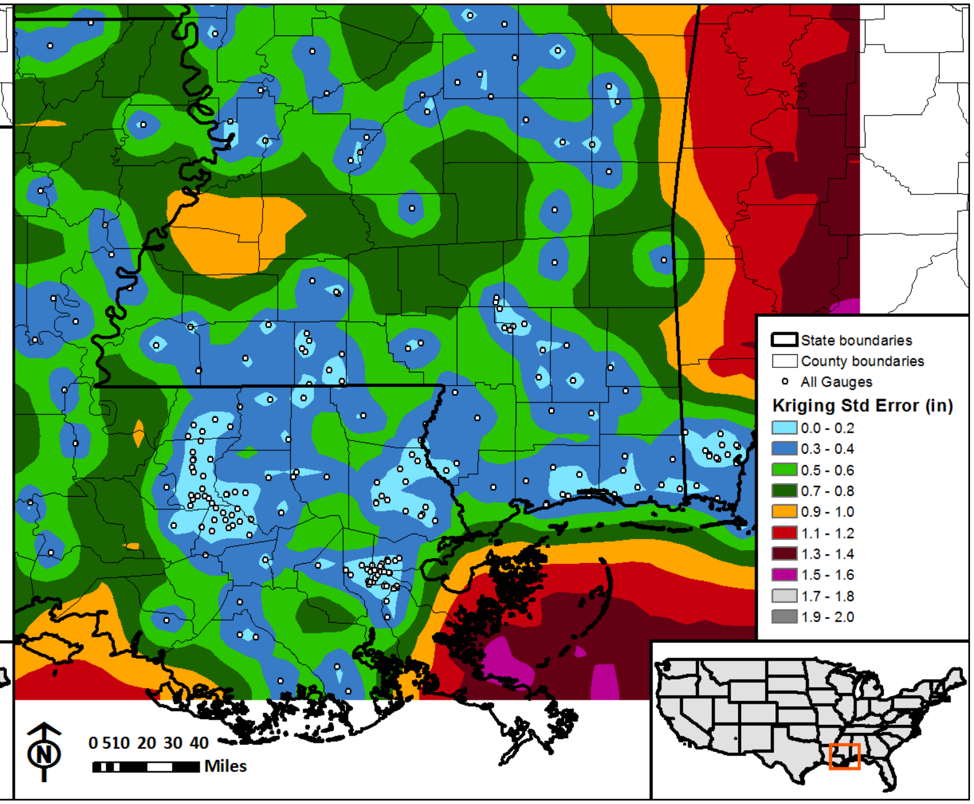
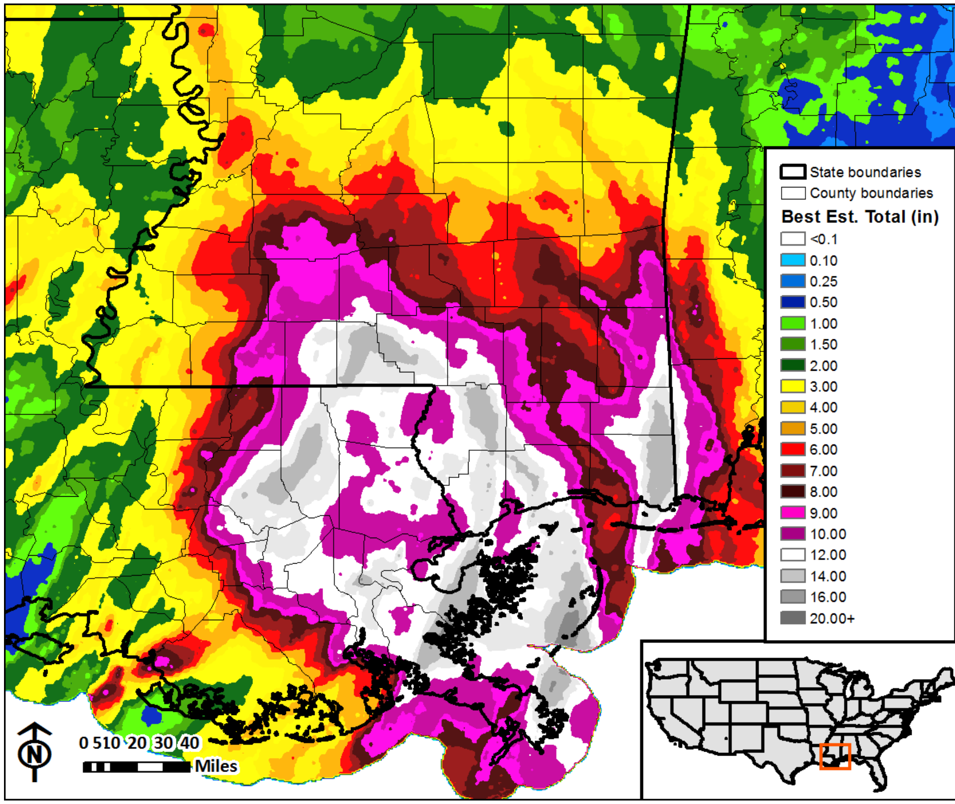


Figure 7. Standard error due to kriging interpolation of data in **Error! Reference source not found.**. Interpolation uncertainty is closely related to the density of the gauge network and observed variability between neighboring gauges.



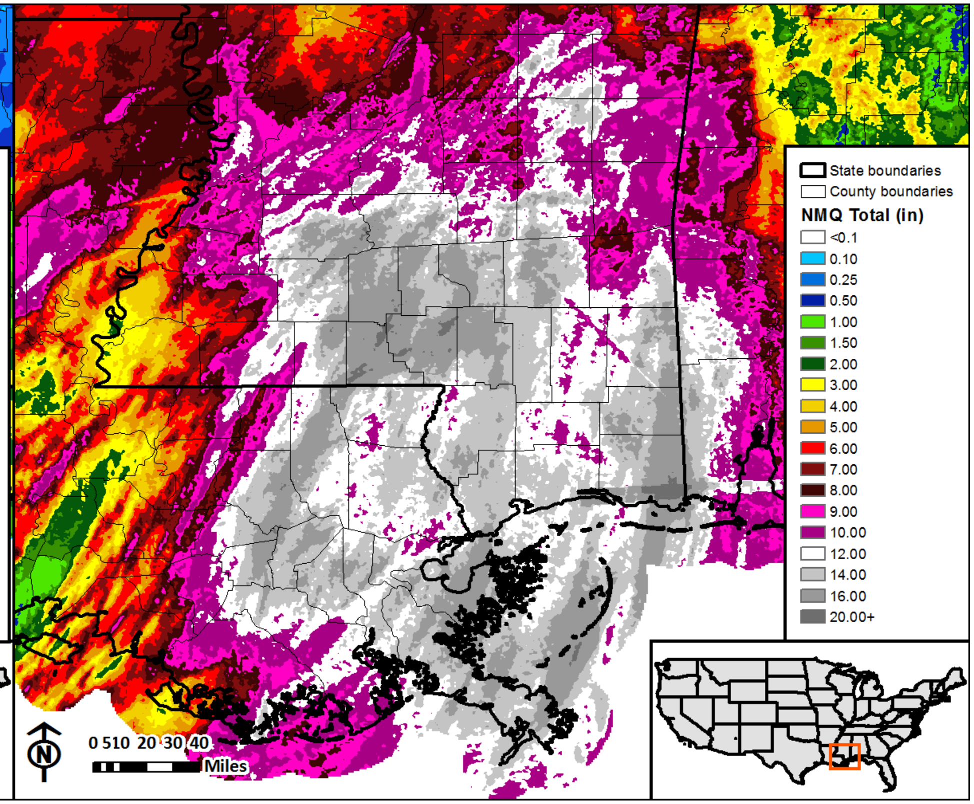


Figure 9. Storm total rainfall as estimated by a combination of official gauges, radar data, and forecaster experience in the NWS RFC MPE product. Precipitation data in this plot ends at 12 GMT on 09/03/12.

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Figure 10. Storm total rainfall as estimated from radar data by the National Severe Storms Laboratory's NMQ/Q2 product. Precipitation data in this plot ends a day later than the gauge data, at 12 GMT on 09/03/12.

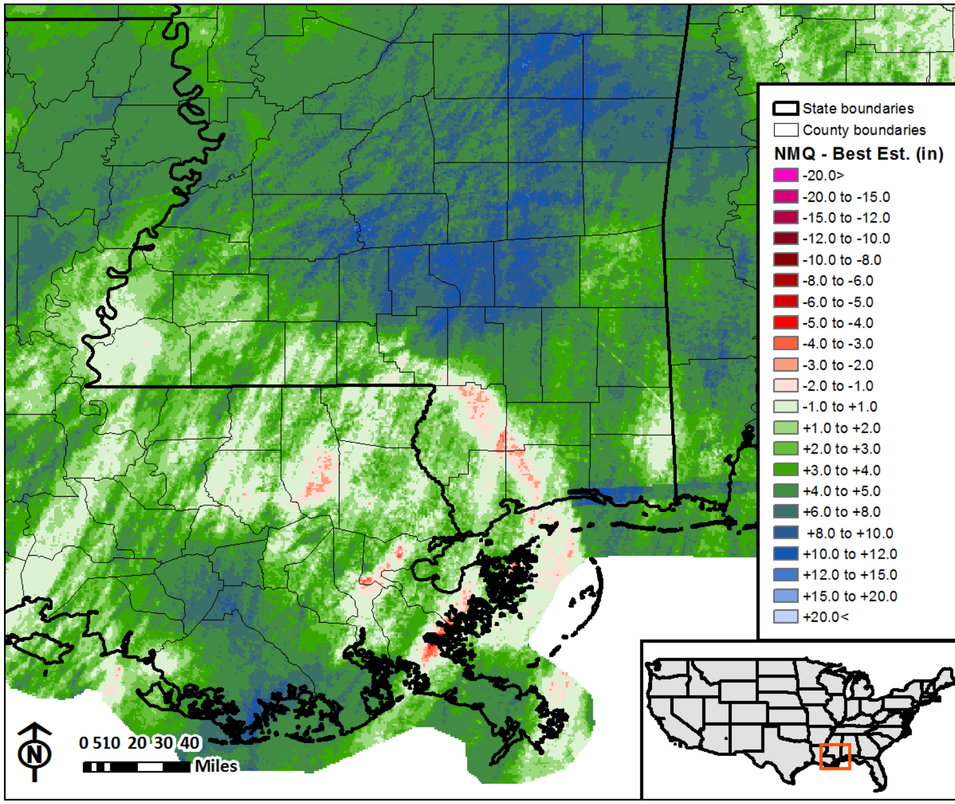

Figure 11. Difference between the NSSL NMQ rainfall product (Figure 10) and the LMRFCs best-estimate rainfall product (Figure 9).

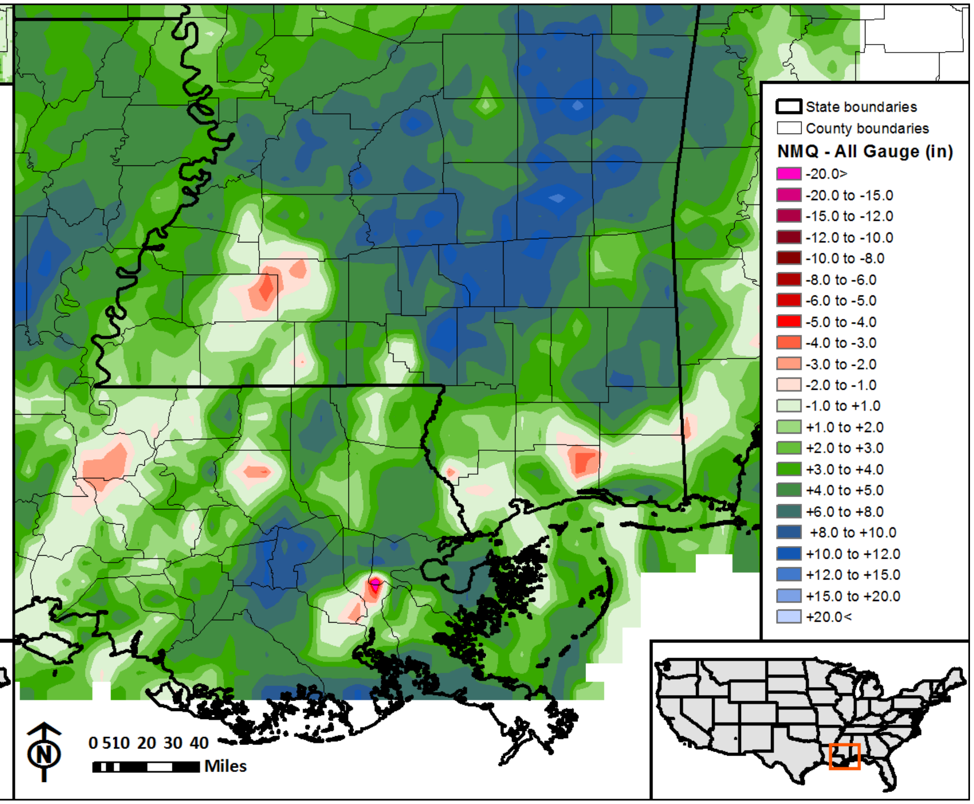

Figure 12. Difference between the NSSL NMQ rainfall product (Figure 10) and the interpolation of all gauges (**Error! Reference source not found.**).

4) NOTABLE HEAVY RAINFALL AREAS

A few areas of rainfall stood out as particularly anomalous or notable when looking at the gauge and radar rainfall estimates. One such swath of heavy rainfall occurred near the Mississippi/Alabama Border, near Pascagoula. This heavy rainfall mostly drained into the Escatawpa River watershed. This rainfall maximum likely ranged from 14-18 inches of storm total accumulation, as estimated by the various products discussed in the preceding section. Another swath of heavy rainfall occurred in coastal Mississippi stretching from roughly Gulfport to Poplarville. The swath mostly followed the path of the Wolf River and drained into its watershed. This rainfall maximum likely ranged from 14-20 inches of storm total accumulation, as estimated by the various precipitation products.

A particularly notable swath of heavy rainfall occurred over an isolated portion of the New Orleans metropolitan area in southeast Louisiana. Water in this area mostly drains into Lake Pontchartrain through the city's storm sewer system. Several official and private rain gauges indicated 20-24 inches of rainfall in a small area, with a sharp gradient down to roughly 10-15 inches a few miles away (Appendix C: Isolated Rainfall Maximum in Uptown New Orleans).

3. Wolf River

a) NWS Post-Event Flood Survey

Flood surveys for the Wolf River watershed were conducted by the NWS teams over a several day period from September 5th to7th, 2012. Findings from the survey are summarized by river reach in the subsequent sections. A map of the Wolf River watershed and subbasins defined by surveyed locations is shown in Figure 13 below.

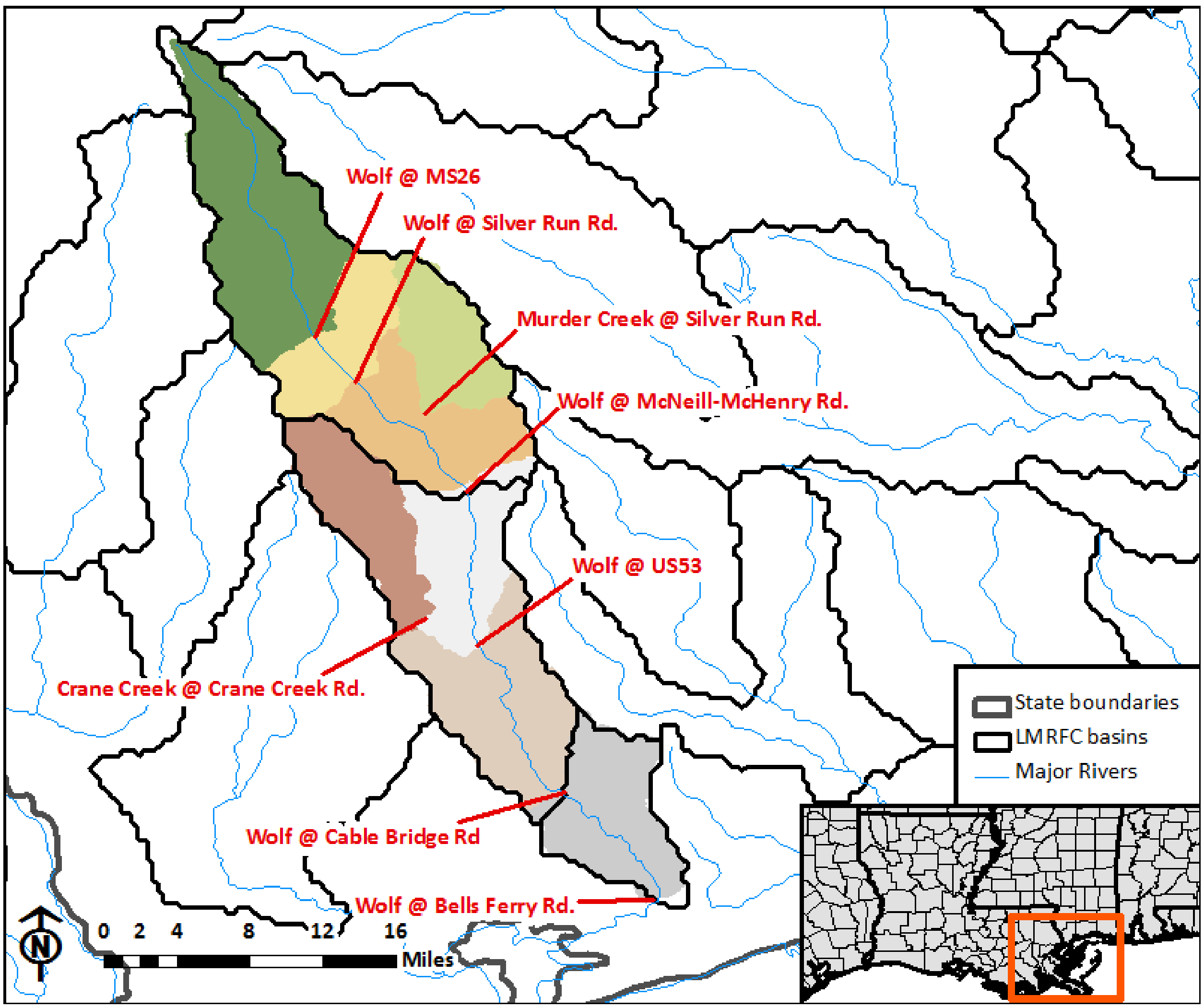

Figure 13. Wolf River subbasins as defined by locations surveyed by the post-storm survey teams. Subbasins defined by the current model configuration of LMRFC are also indicated for comparison.

1) WOLF HEADWATERS TO MS26

Flood Category: Major Flooding, *NEW RECORD*
River Gauge: USGS crest stage gauge on MS26 bridge
Period of Record: 1952-1971, 1998-Present
Crest: 34.5 ft sometime before 12:05 PM CDT 08/30/2012

Widespread bent and snapped trees/brush were observed in the floodplain near the MS26 bridge. A fence on the southeast side of the bridge appeared to have been washed out, with a metal gate separated from the fence and washed up against a tree.

The Pearl River County Emergency Manager (EM) indicated to the flood survey team that water was over the southbound lanes of I-59 during the peak of the event. The EM office believed that this was at the Wolf River bridge, but indicated that it was the first bridge north of I-59 exit 29. Based upon this information, it appeared likely that this flooding was from Beaverdam Creek. Further investigation yielded an article by the *Picayune Item*, which stated the southbound lanes of Interstate 59 were closed at mile marker 32 near Poplarville by the Wolf River, with the northbound lanes threatened as of 6:00 AM August 30th (Farrell, 2012). Mile marker 32 on I-59 is two miles north of the Beaverdam Creek bridge, very close to the bridge over Wolf River.

A Twitter update from the Mississippi Department of Transportation Handle "MDOT I-59" indicated that MS26 was flooded – but not closed - 3 miles east of I-59 (https://twitter.com/mdot_i59/status/241167172318134272). This is likely not referring to the Wolf River bridge (located ~1.3mi east of I-59), but instead the Alligator Creek (located ~3.4 mi east of I-59). The survey team did not survey this location.

2) MS26 TO SILVER RUN RD

Flood Category: Major Flooding
River Gauge: None
Crest: Possibly highest since 1934

Widespread bent and snapped trees/brush were observed in the floodplain near the Silver Run Rd bridge. Evidence of damage was up to about 1.0 ft higher than the bridge deck. Scouring was noted on downstream side of bridge approach guardrails (Figure 14). Anecdotal evidence from an individual residing at the corner of Silver Run Rd and Oscar Lee Rd suggests that the flood elevation may have exceeded that of any flood since at least 1934.

Figure 14. Guardrails on downstream side of the Silver Run Rd. bridge showing evidence of scouring.

3) Silver Run Rd to McNeill-McHenry Rd

Flood Category: Major Flooding
River Gauge: None, RFC modeled location at McNeill-McHenry Rd bridge (SVRM6)

Water elevation in small camp near the river off of Go Go Rd appeared to reach 8.0-10.0 ft above the ground level in many places. A camper appeared to have been moved about 100 yds downstream from its original site (identified by what appeared to be a light pole and power hook-ups). The camper was dropped against trees and a pile of damaged brush.

Some bent trees and brush were noted along the edges of Murder Creek near the Silver Run Rd bridge. Evidence suggested a flash flood that remained below the elevation of the bridge deck.

Widespread bent and snapped trees/brush were observed in the floodplain near the McNeill-McHenry Rd bridge. Water appeared to have reached an elevation about 1.0 ft higher than the road at the bridge approaches. The bridge itself was an arch design, thus the higher middle portion of the bridge did not flood. Large branches and other tree debris were noted on top of the bridge support pilings of the upstream side.

4) MCNEILL-MCHENRY RD TO CONFLUENCE CRANE CREEK

Flood Category: Major Flash Flooding
River Gauge: None

Widespread bent and snapped trees/brush were observed in the small floodplain near the Crane Creek bridge on Crane Creek Rd. Mud marks and debris suggested that flash flooding reached an elevation 1.0-3.0 ft over the bridge deck.

5) CONFLUENCE CRANE CREEK TO CONFLUENCE SANDY CREEK

Flood Category: Moderate Flooding
River Gauge: None

Widespread bent trees/brush were observed in the floodplain near the US53 bridge. Evidence suggested that water reached within 1.0-3.0 ft of the bridge deck and did not inundate the road.

6) CONFLUENCE SANDY CREEK TO I-10

Flood Category: Major Flooding (perhaps Moderate), *NEW RECORD*
River Gauge: USGS automated gauge on Cable Bridge Rd bridge (LNDM6)
Period of Record: 1971-Present
Crest: 31.4 ft about 3:00 PM CDT 08/31/2012

Widespread bent trees/brush were observed in the floodplain near the Cable Bridge Rd bridge (Figure 15). Evidence suggested that water reached within 1.0-3.0 ft of the bridge deck and did not inundate the road. Although official flood category for this stage was "major," damage for this river reach appeared to be closer to that expected for the moderate category.

Information from Harrison County Emergency Management Office indicated that the water elevation was very near the elevation of I-10 near the bridge. Evidence from the survey suggested that water may have reached the shoulder of the bridge approaches, but did not inundate the road or bridge deck (Figure 16).

Figure 15. Downstream view from Cable Bridge Rd. Widespread damage to trees and brush were noted.

Figure 16. Wolf River floodplain between the eastbound and westbound bridges of I-10. Widespread tree/brush damage was noted along with scouring of the overbank areas.

7) I-10 TO ST. LOUIS BAY

Flood Category: Major Flooding, *NEW RECORD*
River Gauge: Manual staff gauge on Bells Ferry Rd bridge (GLFM6)
Period of Record: 1981-Present
Crest: 16.0 ft about 12:00 PM CDT 09/01/2012

Widespread bent brush and trees in the floodplain, covering a width roughly 0.5-1.0 miles along Bells Ferry Rd. Mud marks were noted several feet above the road level throughout this stretch, reaching heights of 3.0-4.0 ft in places. Numerous properties were affected near the gauge location, especially along Magnolia Dr and Tucker Rd where some homes received water damage. Magnolia Rd appeared to have been under several feet of moving water, especially away from intersection with Bells Ferry Rd, and drifts of sand 1.0-2.0 ft high lined the road in places.

Flood damage also occurred downstream of the staff gauge location toward Menge Ave. USGS personnel obtained high water marks for tidal locations that also received surge flooding, so the NWS survey teams mostly stayed upstream to avoid duplication of efforts. The survey team did visit the Wolf River Campground, where a guest stated that the water nearly reached the top of the steps of the laundry building and was just a few feet from flooding most of the property.

Numerous residents were interviewed by the survey team along this river reach, along both Magnolia Dr. and Tucker Rd. A resident with a clear high water mark in a garage at the corner of Magnolia and Bells Ferry gave permission for the team to use her property to survey the mark to the staff gauge. Resident directly across the street indicated location of high water on his home, which was used for QC. Other residents provided comparisons of this event to the crest from the 1995 event.

Home #1: 3rd house in on west side of Magnolia Rd. This house took ~1" of water during 1995 even, as relayed by previous owners to current owner. Current resident estimated ~9" of water inside his home during this event. Resident also indicated that he believed the staff gauge was reading several inches too high.

Home #3: The Montgomery home, the first house in on east side of Magnolia Dr. House had clearly visible high water mark in garage and in trees near river (**Error! Reference source not found.**). The crest stage of 16.0 ft was surveyed to the Harrison County staff gauge by using this high water mark. This crest estimate was consistent - within 1-3" - of another high water mark across the street, as well as anecdotal evidence provided by interviewed residents.

Home #4: First house in on west side of Magnolia Dr. Occupant indicated that water reached several bricks up from foundation to bottom of brick that was outside window sill. This elevation was compared with high water mark from home #3 using surveying equipment. Elevation was estimated to be about 2" different at this location.

Home #5: The Russell home, on the east side of Magnolia Dr. Owner, Garner Russell, indicated that he was an engineer. The residents indicated that they believed the river was falling at the time of 16.5ft observation, although they were not home during crest of flood. Residents also indicated believe that staff gauge is reading 1.0-1.5 ft too high. Occupants stated that their slab was surveyed at 8.0 ft which typically floods at 9.5 ft on the staff gauge. The elevated first floor of their home was surveyed to ~16.1ft elevation, which was several inches above floodwater. Residents also made mention that the forecast crest of 19.0 ft briefly appeared on NWS/AHPS page, but no evidence of this was found in the LMRFC database. Forecasters working this forecast point could not recall such a forecast being issued.

Home #6: The Erby home, 3rd house in on the east side of Magnolia Dr. Occupant indicated that he was an engineer. The resident also indicated that he believed the staff gauge to be ~1.0 ft too high. The resident stated that his elevated slab was surveyed at ~15.1 ft with floodwater cresting about 4” lower. This resident had printed AHPS page for GLFM6 several times a day during height of event, which he showed to the survey team. The survey team could find no evidence of a 19.0 ft crest forecast. The resident made mention of differences between “latest stage” values that show up on AHPS vs. those in text products.

Home #8: The Feil home, at the end of Tucker Rd. Joe Feil owns the canoe rental business in the area. Occupant lived in area about 30 yrs, purchased home after previous owners left just after 1995 flood event. Occupant indicated that elevated slab was surveyed at ~13.0 ft with measured ~4.0 ft of water in home based upon a high water mark. The resulting 17.0 ft elevation estimate for this location seems somewhat inconsistent with other observations.

Home #9: Home of Joanne, at the end of Tucker Rd and next to Joe Feil. Occupant indicated that elevated floor of home was surveyed at 18.6 ft with water reaching elevation “just under.” Water was measured as covering concrete slab with ~87” of water, but concrete slab elevation unknown. Occupant indicated that crest likely occurred before issuance of the 17.0 ft forecast crest... probably before 1400 GMT 09/01/2012.

Home #10: The Larson home, at the end of Tucker Rd next to Joanne, back away from the road. The resident, Jennifer Larson, indicated that she remained during the crest and closely monitored the river stage under her elevated home. Resident indicated that the elevated slab was surveyed at ~16.8 ft, and water crested about 6” below. Resident estimated the crest time as 1630-1800 GMT on 09/01/2012.

Figure 17. The Montgomery home on Magnolia Dr. had a clear high water mark inside of the attached garage. Flood survey team members Marty Pope (pictured) and W. Scott Lincoln used this high water mark to help estimate the crest for the Wolf River at Bells Ferry Rd. (GLFM6) forecast point.

b) Discussion

Based upon all of the anecdotal information gathered for the Wolf River at Bells Ferry Rd location and river reach, questions existed as to the actual datum of the staff gauge. In the months following the original survey, more information from the USGS office in Jackson, MS, was made available. USGS staff collected high water marks in the area of Bells Ferry Rd during the post-storm flooding associated with Hurricane Isaac (K. Van Wilson, personal communication, Sep 2012 and June 2013). Of these high water marks, two were on the Bells Ferry Rd bridge over the Wolf River (14.6 ft NAVD88), and another was east of the river at a campground (14.7 ft NAVD88). These numbers are about 1.3ft lower than the estimated high water mark determined by the survey team (16.0 ft), and this strongly suggests that the datum for GLFM6 is not 0.0 ft NAVD88 (as set during Hurricane Isaac). Based upon all available information, we find that the datum for GLFM6 should be set to -1.0 ft NAVD88. This number is roughly the same as suggested, and is rounded off to take into account measurement uncertainty. Although an offset of -1.0 ft would make our estimated crest of 16.0 ft (15.0 ft

NAVD88) much closer to USGS high water marks, a discrepancy of 0.2-0.3 ft will remain that is likely due to measurement uncertainty.

In response to the concerns raised by the Russell's (Home #5), LMRFC and WFO LIX staff checked the southern region NWS and local WFO archives in January, 2013, for evidence of the 19.0 ft crest at GLFM6. It was hypothesized that one way such a crest could make it to AHPS was via the HMLLIX product instead of the RVFLIX product from LMRFC. Unfortunately, the archives did not extend back into September of 2012. Neither a verification of crest issuance, nor a mechanism of crest issuance without LMRFC as the source has been found.

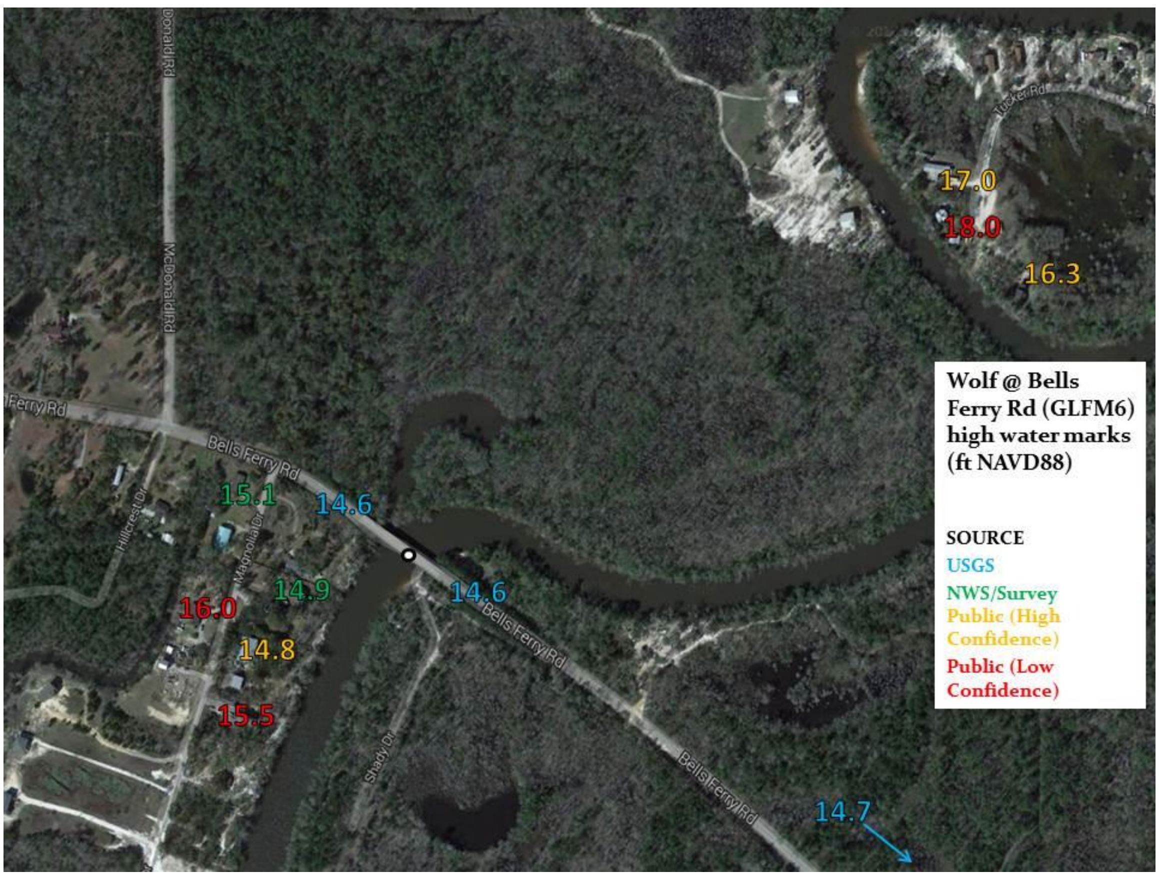

Figure 18. High water marks near the Wolf River at Bells Ferry Rd (GLFM6) gauge color-coded by confidence level. High water marks were adjusted to NAVD88 based upon the assumed staff gauge datum of -1.0 ft NAVD88.

4. Tchoutacabouffa River

a) NWS Post-Event Flood Survey

A flood survey for the lower Tchoutacabouffa River watershed area was conducted by the NWS teams on September 6th, 2012. The survey was focused on the area around the Harrison County manual staff gauge on Lamey Bridge.

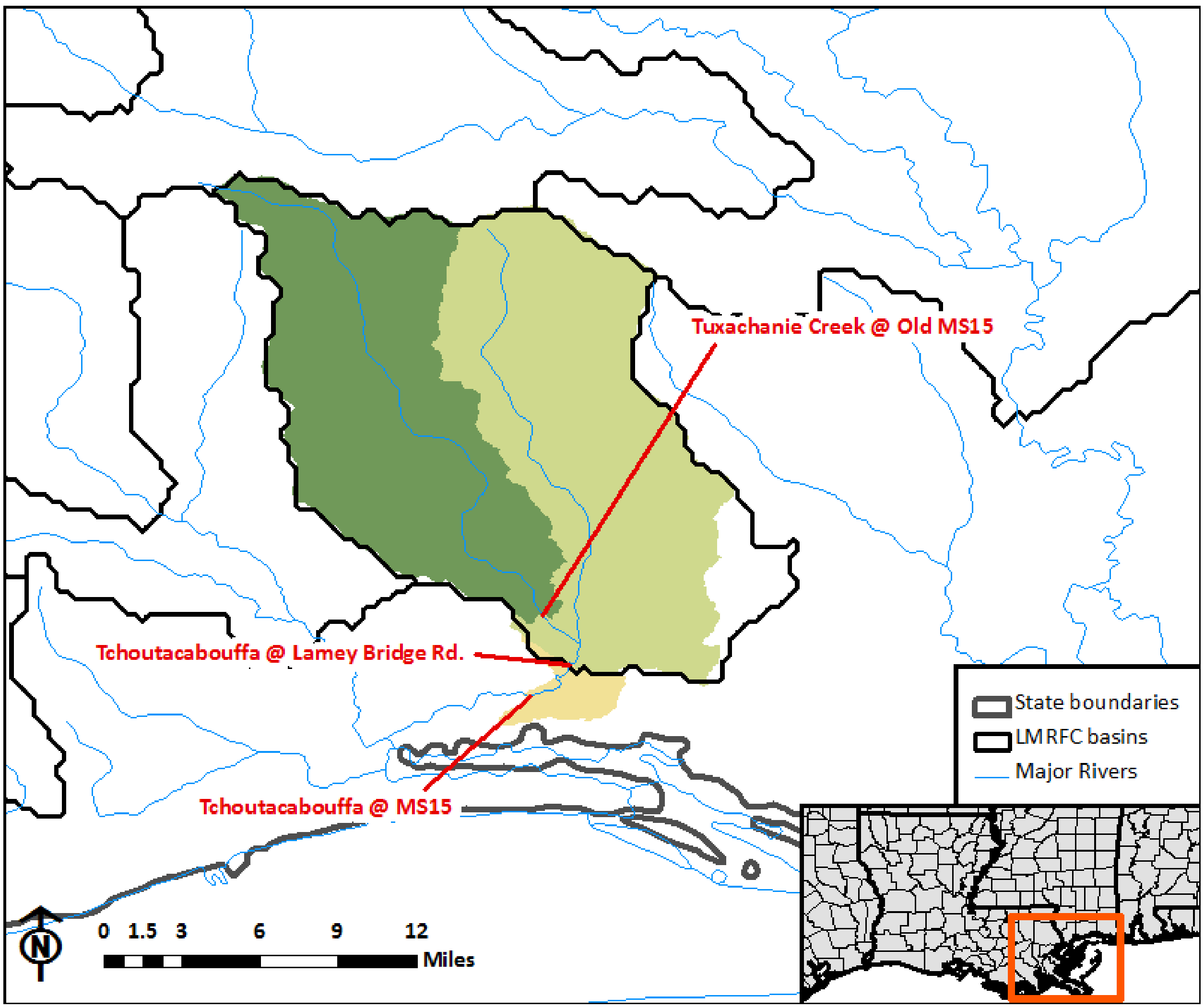

Figure 19. Biloxi River subbasins as defined by locations surveyed by the post-storm survey teams. Subbasins defined by the current model configuration of LMRFC are also indicated for comparison.

1) TWO MILES UPSTREAM/DOWNSTREAM OF LAMEY BRIDGE RD

Flood Category: Minor Flooding (possibly Moderate)
River Gauge: Manual staff gauge on Lamey Bridge Rd bridge (DIBM6)
Period of Record: 1973-Present
Crest: 14.5 ft about 9:00 AM CDT 08/31/2012

Some bent brush and trees were observed on the point bar of a large meander bend at Lamey Bridge Rd crossing of Tchoutacabouffa. New apartments and condos built very near the cut bank of the meander bend experienced small slides from scouring in their back yards, which workers were attempting to fill with dirt during the time of the surveys. Based upon road closure information provided by Harrison County Emergency management, it is possible that water neared or inundated Lamey Bridge Rd. somewhere between Mallet Rd. and Longwood Dr. Another area was surveyed just off of Lamey Bridge Rd. along Tuxachanie Creek just upstream of the confluence with the Tchoutacabouffa. No damage or evidence of water was noted along Longwood Circle. Just upstream, some evidence of water was noted along the lower portions of H Street, with evidence that some homes may have taken water damage.

The survey team interviewed one resident of the Riverbend Cove Apartment complex, Wendell Green, who stayed during most of the event. Mr. Green indicated to the survey team that water had crested right at the line of the highest patch of sod, and marked the location (Figure 20). He also indicated that at the crest, water was just below the crest of a light pole on the dock the opposite bank, as well as being almost level with the bottom of the horizontal beams placed upon the Lamey Bridge Rd crossing’s support pilings. Mr. Green provided some photographs of the river several hours before the crest. The survey team surveyed the staff gauge level of the light pole and the estimated high water mark on the riverbank. A substantial difference in elevations was noted between the elevation of the light pole (14.4 ft) and that of the riverbank behind the apartments (16.5 ft).

Figure 20. Flooding from the Tchoutacabouffa River caused substantial scouring to the cut bank behind the Riverbend Cove Apartments just off Lamey Bridge Rd. Resident Wendell Green (pictured), who stayed during most of the flood event, indicated the high water level to the NWS flood survey team which they used to help estimate the crest for Tchoutacabouffa River at Lamey Bridge Rd (DIBM6).

b. Discussion

After the survey for the Tchoutacabouffa River at Lamey Bridge Rd. was conducted, NWS survey team members looked for additional information to aid in determining the exact crest at the staff gauge. It was hypothesized that the substantial meander bend in the river right at the location of the bridge and the apartments could explain most of the discrepancy in crest elevations between each side of the river. Historical crests for Tuxachanie Creek at Old Hwy 15 and Tchoutacabouffa River at MS67 were retrieved and compared to historical crests at Lamey Bridge Rd. The shape of the hydrograph for the the Lamey Bridge Rd. location was also analyzed using the data available before/after the time of crest. Based upon the shape of the hydrograph, a crest of about 14.0-15.0 ft seemed most likely. Previous similar events on the Tuxachanie and Tchoutacabouffa in 2002 and 2003 also produced crests at DIBM6 of about 14.5 ft. It was determined that the crest most consistent with our surveyed elevations, anecdotes, and post-survey analysis was about 14.5 ft on the morning of 8/31.

The survey team did not talk with any residents that had known survey elevations of their property or structures. Because of this, the current datum for Tchoutacabouffa River at Lamey Bridge Rd. (DIBM6) was not able to be evaluated.

5. Biloxi River

a. NWS Post-Event Flood Survey

A flood survey for the lower Biloxi River watershed area was conducted by the NWS teams on September 6th, 2012. The survey was focused on the area around the Biloxi River at Three Rivers Rd bridge, including areas downstream along Lorraine Rd.

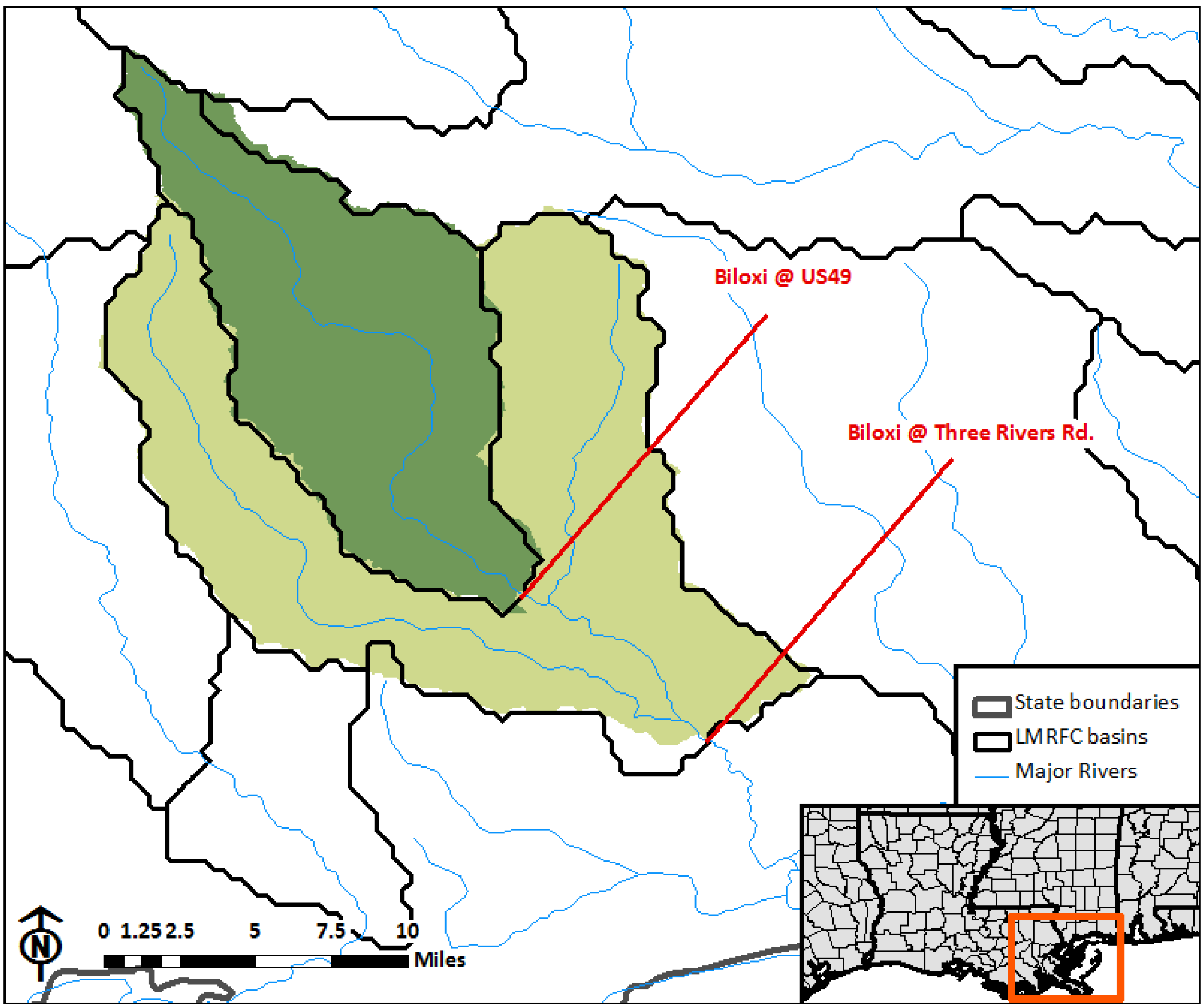

Figure 21. Biloxi River subbasins as defined by locations surveyed by the post-storm survey teams. Subbasins defined by the current model configuration of LMRFC are also indicated for comparison.

1) STONE/HARRISON CO. LINE TO THREE RIVERS RD. BRIDGE

Flood Category: Major Flooding
River Gauge: USGS automated gauge on US49 bridge (BLWM6)
Period of Record: 1953-Present
Crest: 26.4 ft about 1:00 PM CDT 08/30/2012

NWS survey teams did not visit the gauge location or vicinity. Although the crest reached a level set as the major flood stage, current information on the E-19s does not indicate any major impacts from flooding of this magnitude. Information from Harrison County Emergency Management suggests that at least minor flood impacts may have occurred to at least one residence. Analysis of aerial imagery indicates some development in the area.

2) CONFLUENCE WITH LITTLE BILOXI RIVER TO I-10

Flood Category: Major Flooding
River Gauges: USGS crest stage gauge on Three Rivers Rd bridge;
Estimates of stage via improvised wire-weight dropped from bridge
Period of Record: 1964-Present
Crest: 19.2 ft about 1:00 AM CDT 08/31/2012

Some bent brush and trees were noted in the floodplain near the gauge location. Scouring, debris marks, and sand deposition was noted in the small park near the Three Rivers Rd. bridge. Mud marks were evident in the trees lining the floodplain several feet above the ground in places. Information from Harrison County Emergency Management indicated that the MS605 bridge, an official evacuation route, was inundated by floodwaters during the event. It appeared as if some homes may have taken water damage along River Rd. near and just downstream of the MS605 bridge.

Flooding was also surveyed downstream along Lorraine Rd. Numerous residences and businesses east of the Lorraine Rd. bridge along the river appeared to have sustained water damage.

b. Discussion

The USGS maintains a crest staff gauge on the Three Rivers Rd. bridge. For realtime observations, Harrison County measures the distance to the surface of the water from the center of the Three Rivers Rd. bridge deck. The USGS gauge datum is set to 3.0 ft lower than the datum referenced by both Harrison County and the NWS historical flood crests. This presented some initial confusion when trying to compare observations before and after the crest with the data provided by the USGS.

6. Escatawpa River

a. NWS Post-Event Flood Survey

The flood survey for the lower Escatawpa River watershed area was conducted by the NWS teams on September 6th, 2012. The survey was focused on the area around the Escatawpa River at I-10 USGS automated gauge, including areas of Helena affected by flooding from Black Creek.

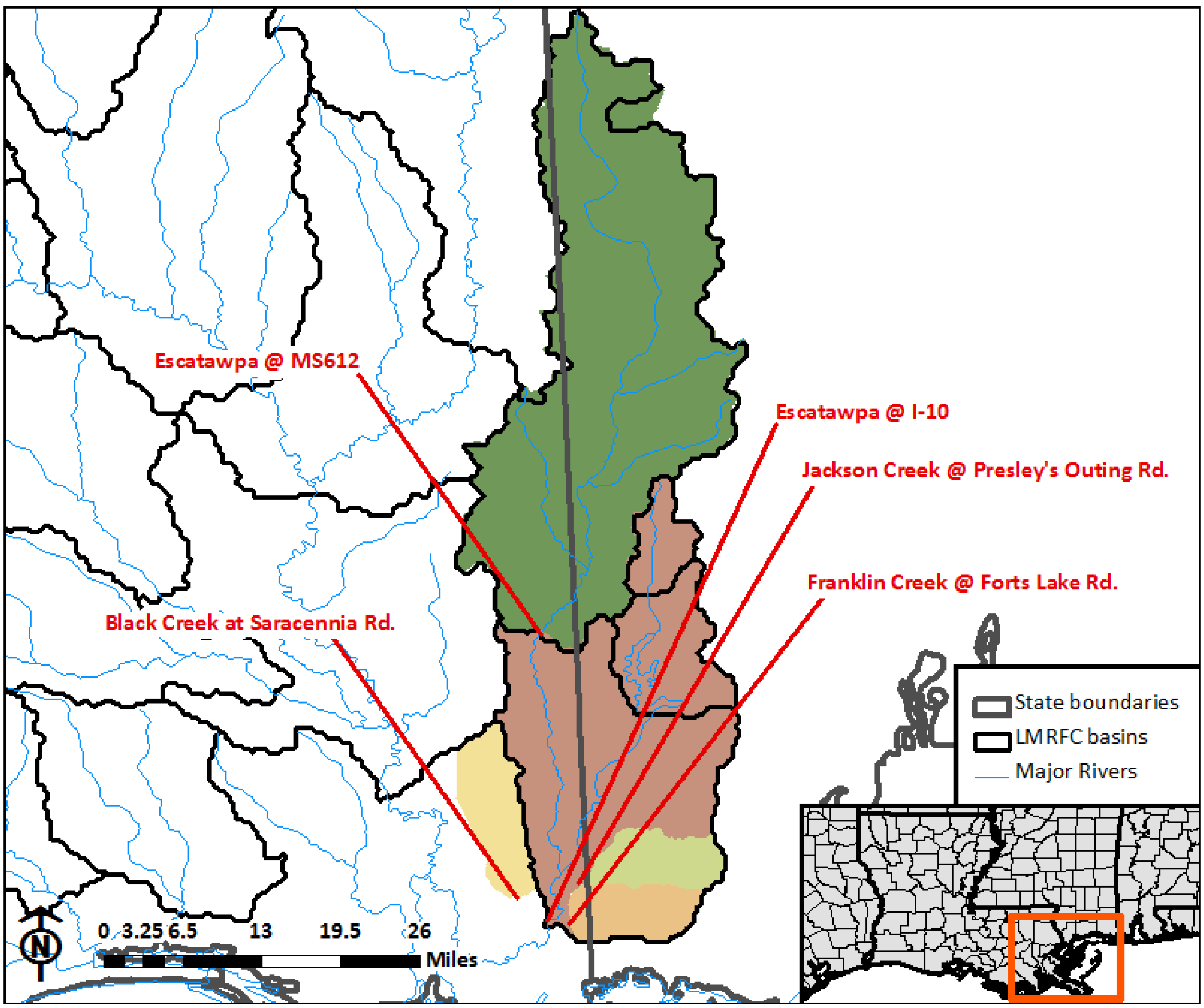

Figure 22. Escatawpa River subbasins as defined by locations surveyed by the post-storm survey teams. Subbasins defined by the current model configuration of LMRFC are also indicated for comparison.

1) VICINITY OF MS612 BRIDGE

Flood Category: Minor Flooding
River Gauge: USGS automated gauge on MS612 bridge (AGRM6)
Period of Record: 1974-Present
Crest: 20.8 ft about 9:00 AM CDT 08/31/2012

NWS survey teams did not visit the gauge location or vicinity. The crest reached flood stage, but current information on the E-19s and NWS AHPS page does not indicate any impacts from flooding. Information from USGS suggests that flows of this magnitude have only been exceeded 3-4 times since 1946.

2) I-10 TO MOSS POINT

Flood Category: Minor Flooding (possibly Moderate)
River Gauge: USGS automated gauge on I-10 bridge (ORAM6)
Period of Record: 2001-Present
Crest: 10.9 ft about 10:00 AM CDT 08/31/2012

NWS survey teams did not survey most of this reach of river, as most impacts appeared to be near the gauge or upstream of the gauge. Few, if any, areas of bent trees or brush were noted by the survey team. Widespread mud marks on trees and houses were observed, however, and evidence suggested that numerous homes and a church were impacted near the gauge, especially along Franklin Creek Rd., where it appeared likely that some homes took 1.0-2.0 ft of water.

Presley's Outing Campground: The campground was surveyed by NWS teams and staff members were interviewed. Water was still elevated during the time of the survey. Staff indicated that water was within 1.0 ft of flooding the clubhouse at the campground. Staff also indicated that crest was about 1.0 ft lower than crest during Hurricane Georges in 1998, which corresponds exactly with the crest difference at the USGS gauge.

Home #1: Thomas Marthaler residence at the corner of Marthaler Rd. and Independence Rd. was visited by a survey team. Mr. Marthaler kept a personal record of water levels moving up the road toward his house and shed during the event (Figure 23). This notes suggested that the water crested between 10:00 AM and 12:00 AM on 8/31, which is consistent with the gauge readings just downstream. Mr. Marthaler indicated that the crest was about 1.0 ft below what he experienced after Hurricane Georges in 1998, which corresponds exactly with the crest difference at the USGS gauge.

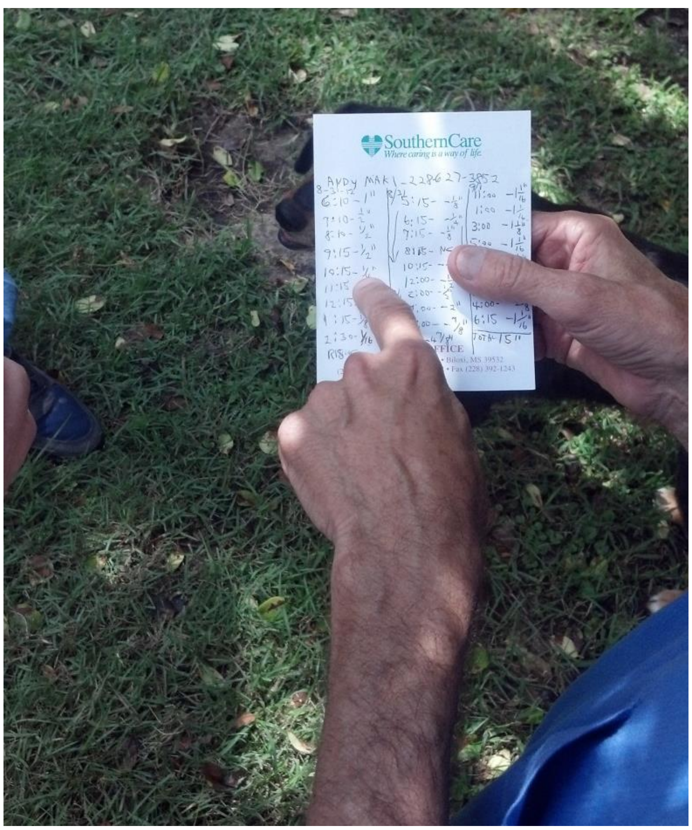

Figure 23. Flooding from the Escatawpa River nearly affected the property of Thomas Marthaler. Mr. Marthaler made frequent note of the water elevation near his home and shared his observations with the survey team.

3) BLACK CREEK AT SARACENIA RD IN HELENA

Flood Category: Moderate Flash Flooding (possibly Major)
River Gauge: None
Crest: Thursday morning; Early Saturday morning

NWS survey team noted numerous homes in the Helena area appeared to be impacted by high water. Some evidence of high water was noted on Coda Rd. east of Helena. Evidence of more substantial flooding was noted along Hans Rd. on the north side of Helena near Black Creek.

Home #1: Resident of red brick home, 2nd in on southwest side of road, indicated that water crested about "6 bricks up," or an estimated 1.0-1.5 ft above floor elevation. Resident indicated that water began rising in his area around 8:30 AM on 8/29, with a first crest occurring Thursday morning. A second crest occurred early Saturday morning, which was lower than the Thursday crest. Resident indicated that he decided to evacuate his home after receiving an emergency alert on his phone indicating that floodgates had been opened upstream at the power plant (see discussion in *b. Discussion*). Using the timing information provided by the resident and the hydrograph for the downstream gauge on the Escatawpa River, it appeared likely that the first crest was due to flash flooding and the second crest was due to backwater from the Escatawpa.

b. Discussion

The anecdote made by the resident near Black Creek in Helena about the floodgates being opened up at the power plant was investigated further by the survey team. Maps and aerial imagery indicate a power plant, owned by Mississippi Power, has a cooling reservoir on Black

Creek just upstream of Helena. This reservoir appeared to have a spillway but specifics are unknown. A search for news articles about a potential release of water from this reservoir did not turn up any additional information. The main mechanism by which an emergency alert would be sent to a phone would be from an NWS Flash Flood Warning, but no NWS warning text was found that indicated floodgates opening at this power plant.

7. Tangipahoa River

a. NWS Post-Event Flood Survey

A flood survey for the Tangipahoa River watershed area was conducted by the NWS teams from September 6th-8th, 2012. The survey covered areas from Lake Tangipahoa dam in the headwaters downstream to just south of Robert, LA, where river flooding impacts became mixed with storm surge flooding impacts.

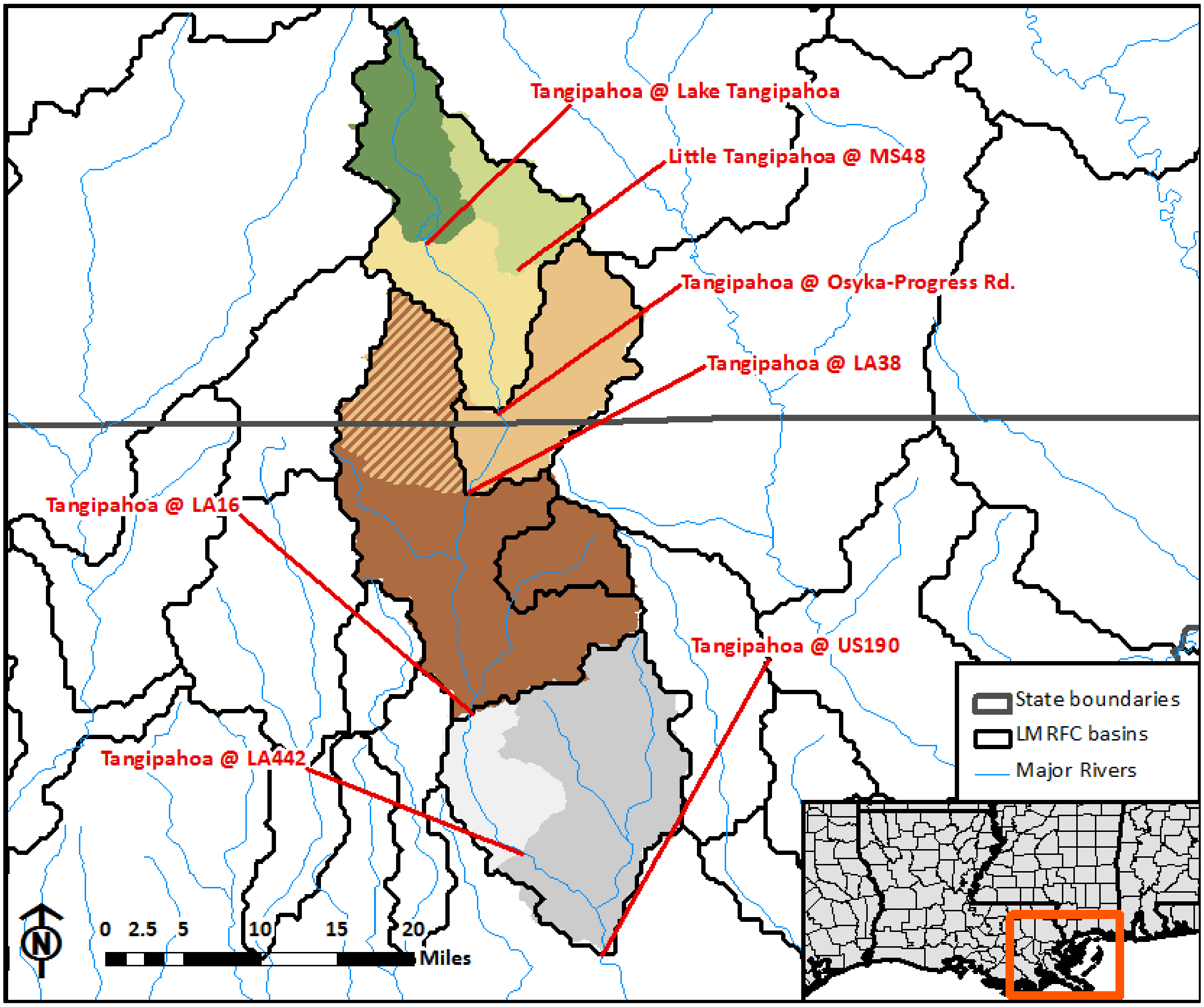

Figure 24. Tangipahoa River subbasins as defined by locations surveyed by the post-storm survey teams. Subbasins defined by the current model configuration of LMRFC are also indicated for comparison. The subbasins upstream of LA16 (AMIL1) and LA38 (KENL1) have an "overlapping" section indicated with hatching; during normal, within-bank flow conditions the Terrys Creek tributary parallels the Tangipahoa River under the LA38 bridge and merges with it just below the gauge, but during high flow conditions Terrys Creek likely combines with the Tangipahoa upstream of the bridge.

1) LAKE TANGIPAHOA TO LA38

Flood Category: Minor Flooding
River Gauge: USGS automated gauge on Osyka-Progress Rd bridge (OSYM6)
Period of Record: 1998-Present
Crest: 17.8 ft about 8:00 PM CDT 08/30/2012

During the flood event, the Lake Tangipahoa Dam was damaged, briefly causing fears of an imminent dam failure. Thousands of persons were put into an evacuation area in Louisiana near the River, from the MS/LA state line to the mouth of the river at Lake Pontchartrain. The emergency spillway was also utilized during the event, which seems to be the source of reports that the dam had already failed with a 100 ft breach. Actual damage to the dam consisted of two slides - one on the tailwater side at the main spillway outflow, and another minor slump between the emergency spillway and the main spillway. The emergency spillway of Lake Tangipahoa was still being utilized during the time of the surveys and water was also being pumped across the spillway to help drop the pool elevation more quickly. Interviews with representatives from the U. S. Army Corp of Engineers Vicksburg District office and Mississippi Department of Environmental Quality at the site indicated that an estimated 130,000 gal/min was being pumped over the spillway. It was also indicated that at crest, water of about 3 ft depth was moving over the spillway. It was also indicated during survey of this location that the current spillway crest is 333 ft; a new spillway was with a crest of 331 ft.

Downstream at Muddy Springs Rd, a high water mark was estimated at about 5.0 ft below the bridge deck. Information from Pike County EM indicated that water came over the roadway near the bridge during the event. Further downstream at Hamp Lea Rd, a high water mark was also estimated at about 5.0 ft below the bridge deck, but no evidence of water over the roadway was noted.

2) LITTLE TANGIPAHOA AT MS48

Flood Category: N/A
River Gauge: None

Flooding was also surveyed in the Magnolia, MS, area from the Little Tangipahoa River. The Little Tangipahoa River is a significant contributor to the Tangipahoa upstream of Osyka. The Pike County EM indicated that water flooded some Entergy power trucks just east of the MS48 bridge, on Union Church Rd. The NWS survey team found a high water mark in the area on the south side of the building (and the building interior) located at 31.14243, -90.45377. A water depth about 4.6 ft above ground was estimated, with the elevation estimated at 300.0 ft via USGS topo maps, yielding a water surface elevation of about 304.6 ft. The Pike County EM also indicated that flooding was reported on the Little Minnehaha Creek which runs through Magnolia and has a confluence with the Little Tangipahoa just downstream of MS48, but no further information was available.

3) MS/LA STATE LINE TO CONFLUENCE BIG CREEK

Flood Category: Major Flooding
River Gauge: USGS automated gauge on LA38 bridge (KENL1)
Period of Record: 1951-Present
Crest: 16.9 ft about 1:00 AM CDT 08/31/2012

NWS survey teams visited the area near the LA1054 bridge. The floodplain was very wide and flat with several channels & sloughs noted. No impacts from high water were noted.

Farther downstream at the LA38 bridge near Kentwood, survey teams estimated that water crested near the bottom of the horizontal supports. The floodplain was also noted as very broad in this location. It was also noted that water was close to impacting an electrical substation on the west side of the floodplain near the LA38 and Ave F intersection.

At the LA440 bridge just east of Tangipahoa, the survey team noted that the roadway appeared to be about 15.0 ft higher than the estimated crest elevation. A high water mark was noted along LA440 west of the bridge near the intersection with Easley Rd (30.87517 -90.49884) with a water depth of 0.0 ft above ground elevation on the center line of the roadway estimated at 168.6ft NAVD88 via LiDAR elevation data. The survey team also interviewed Sharon & Mike Broussard, who indicated that water was halfway up the banked curve of LA440 west of the river, near the high water mark.

Off LA440, a high water mark was taken near the end of Easley Rd (30.86843 90.49368) with a water depth of 0.0 ft above ground elevation estimated to be 162.0-163.0 ft NAVD88 via LiDAR elevation data and about 162.0ft via USGS topo maps. Down at the end of the road, the water depth was estimated to be about 3.6 ft via surveying a nearby high water mark. The high water mark was estimated to be a depth of 0.9 ft above ground elevation estimated to be 162.0-163.0 ft NAVD88 and 162.0ft via USGS topo maps. These two nearby high water marks yielded water surface elevations of about 162.0 ft and about 163.0 ft, respectively.

The NWS survey team also visited the Tangipahoa River at the LA10 bridge, where no flood damage was noted.

4) CONFLUENCE BIG CREEK TO LA40

Flood Category: Minor Flooding
River Gauge: USGS automated gauge on LA16 bridge (AMIL1)
Period of Record: 1949-Present
Crest: 23.3 ft about 9:00 PM CDT 08/31/2012

Mud marks were noted by the survey team near the gauge site on the LA16 bridge. Water elevation was estimated to be just under the elevation of the highway road surface, and likely exceeding the elevation of some nearby driveways and side roads.

The survey team interviewed staff at the nearby veterinary clinic just east of the bridge. Staff indicated that water covered the driveway of the clinic for the first time in 18 years, and neared the structure. The staff also indicated that water was 1.0-2.0 ft deep over Thomas Rd, cutting off residents behind the clinic.

Just east of the clinic, the survey team discussed the flood event with a resident in his shop. Water reached right up to the edge of his shop. The ground elevation at this location was estimated at 102.0-103.0 ft via LiDAR elevation data and 103 ft via USGS topo maps.

Downstream at LA40, a large section of roadway appeared to be overtopped based upon the elevation of mud marks. The overtopped area was estimated to be from a structure at the speed zone sign east of Amite to just west of the DOTD building, or a stretch of highway about 0.5-1.0 mi long.

5) LA40 TO CONFLUENCE CHAPPAPEELA CREEK

Flood Category: N/A
River Gauge: Staff gauge on LA442 bridge no longer in service (TIKL1)
Period of Record: 1985-?

At the LA442 bridge, a dead tree was wedged into a bridge piling and left high and dry. Light debris was also noted in trees & brush in the floodplain, as well as about halfway up the abutments of the bridge. The staff gauge indicated by the E-19 could not be found on the bridge. Based upon information in the E-19, the roadway elevation was assumed to be 67.3 ft. The high water mark of light debris was estimated to be about 7.2 ft below the top of road surface, yielding a water elevation of about 60.1 ft. The missing staff gauge's datum was given as 34.5 ft, which means the estimated high water elevation would be a stage of about 25.6 ft.

Further downstream at LA443, water inundated a substantial section of the roadway and caused damage to the downstream slope of the embankment. Louisiana DOTD crews were working on the damage during the time of the survey. The survey team spoke with DOTD workers in the area, who indicated that water was estimated to be 1.0-3.0 ft deep over the roadway, and water covered an almost 1 mile long stretch. It was also indicated by the workers that water overtopped the bridge by about 0.5 ft.

5) CONFLUENCE CHAPPAPEELA CREEK TO LAKE PONTCHARTRAIN

Flood Category: Major Flooding
River Gauges: USGS automated gauge on US190 bridge (ROBL1)
Period of Record: 1939-Present
Crest: 24.0 ft about 8:00 PM CDT 09/01/2012

Flooding from roughly US190 downstream toward Lake Pontchartrain is assumed to be from a combination of both river flooding and surge flooding, tending more toward surge impacts closer to the lake. High water marks from surge flooding have been taken by other agencies and were not the main focus on the NWS surveys.

Along US190, the survey team noted that mud marks in the trees and brush were about at road level for a section roughly 1.0 mi long.

Flooding of a few sections of Thibedeaux Rd were noted. A brown house on the road near Big Branch appeared to have taken water. Just to the east, along Eli Joiner Rd. and River Rd., the NWS survey team interviewed a resident. It was indicated that water reached the edge of his property and flooded a portion of the road where it switches from parish to private maintenance. Elevation at the high water mark indicated by the resident was estimated to be about 21.0-22.0 ft via LiDAR and 21.0 ft via USGS topo maps. It was also noted from mud marks that water was over the road where River Rd marks a sharp right turn to the south near the river. The roadway elevation was estimated to be at 18.0-19.0 ft via both LiDAR and USGS topo maps.

The area along Will Richards Rd. was also surveyed. Heavy accumulation of sand was noted across the roadway and under elevated homes.

Farther downstream, at Lees Landing near the end of LA445, several structures appeared to have taken water. Mud marks were also noted several feet above the ground level. East of Lees Landing, several sections of Traino Rd. appeared to have flooded, with numerous more homes appearing to have taken water.

6) CHAPPAPEELA CREEK

Flood Category: N/A
River Gauges: None

Although not surveyed by the NWS survey team, Chappapeela Creek is a significant contributor to the Tangipahoa River just upstream of the US190 bridge. It has been noted in past floods that local runoff from between the gauging station at LA16 and the gauging station at US190 can cause flooding in this reach. It is hypothesized that Chappapeela Creek, the largest tributary through this reach, is responsible for a large portion of this.

Unfortunately, in addition to the lack of survey information, no automated or manual gauge information is available anywhere along this creek.

b. Discussion

LiDAR elevation data was analyzed in the area just east of the Tangipahoa River at LA40 bridge, where high water elevations were estimated. It was estimated by the elevation data that floodwaters were about 2.0 ft from overtopping LA40 in the lowest spot just east of the bridge. Elevation data also suggested that the roadway west of the bridge would not be overtopped until a crest about 4.0 ft higher than observed during this event.

LiDAR elevation data was analyzed in the area along LA40 east of Independence, where water was noted to have inundated the roadway for a substantial section. Elevation data from LiDAR and notes from the survey suggest that the water elevation reached at least 72.0-74.0 ft in this area.

LiDAR elevation data was analyzed in the area along LA442 east of Tickfaw, where a high water mark was estimated against a benchmark on the bridge. Elevation data from LiDAR suggested that the roadway would be threatened both east and west of the bridge at about 62.0-63.0 ft elevation, or about 2.0-3.0 ft higher than the estimated crest at this location.

LiDAR elevation data was analyzed in the area along LA443 southeast of Tickfaw where water was noted to have inundated the roadway for a substantial section and damaged the embankment. Elevation data from LiDAR indicated that the roadway on both the east and west approaches to the bridge were about 47.0-48.0 ft in elevation, suggesting a crest in the 48.0-51.0 ft range at this location based upon survey notes.

8. East/West Hobolochitto Creeks

a. NWS Post-Event Flood Survey

A flood survey for the East/West Hobolochitto Creek watershed area was conducted by the NWS teams from September 6th-7th, 2012. The survey covered areas from the gauges on East and West Hobolochitto Creeks as well as the Lake Hide-a-Way and Anchor Lake dams upstream of Picayune, MS.

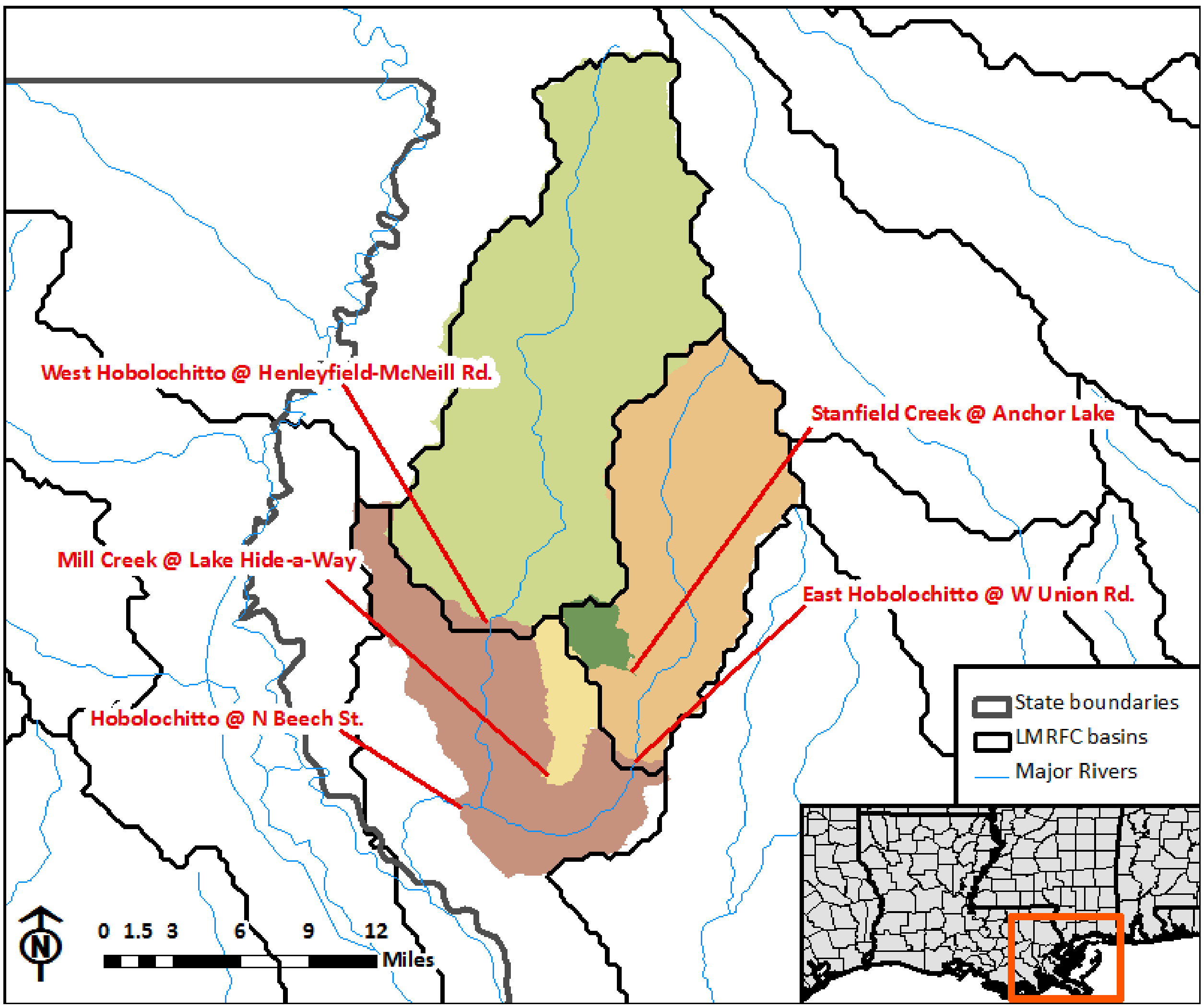

Figure 25. Hobolochitto Creek subbasins as defined by locations surveyed by the post-storm survey teams. Subbasins defined by the current model configuration of LMRFC are also indicated for comparison.

1) E. HOBOLOCHITTO FROM W. UNION RD. TO CONFLUENCE WITH W. HOBOLOCHITTO

Flood Category: Major Flooding, *NEW RECORD*
River Gauge: USGS automated gauge on W. Union Rd. bridge (CREM6)
Period of Record: 1997-Present
Crest: 21.5 ft about 3:00 AM CDT 08/31/2012

The survey team visited Anchor Lake, which is an impoundment of Stanfield Creek and also considered a high hazard dam. During the survey on 09/06/2012, water was still going over the emergency spillway to a depth of a few inches. A few high water marks were noted, and brush was flattened in the floodplain of the creek at the toe of the dam (Figure 26). A survey of the high water marks yielded +3.1 ft on the left face (SW), +4.5 ft in a fence at the right face (NE), and +3.2 ft on the right bank under trees (NE), all with respect to the center of the spillway.

Figure 26. Downstream side of Anchor Lake Dam. Trees and brush in the floodplain below the emergency spillway were bent and patches of soil showed signs of scouring.

2) W. HOBOLOCHITTO FROM HENLEYFIELD-MCNEILL RD. TO CONFLUENCE WITH PEARL RIVER

Flood Category: Major Flooding , *NEW RECORD*
River Gauges: USGS automated gauge on Henleyfield-McNeill Rd. bridge (MNLM6)
Period of Record: 1966-Present
Crest: 24.6 ft about 6:00 AM CDT 08/31/2012

The survey team visited the MS43 bridge crossing of W. Hobolochitto Creek just north of Picayune, MS. It was noted that the high water mark on the bridge was just to the base of the bridge. Water appeared to encroach upon the highway and perhaps overtop it. The survey team made note of a surveyed elevation marker on the bridge of 25.5 ft.

3) E. & W. HOBOLOCHITTO CREEKS BELOW GAUGED LOCATIONS

Flood Category: N/A
River Gauges: None
Period of Record: N/A
Crest: N/A

The survey team visited Lake Hide-a-Way, which is an impoundment of Mill Creek and also considered a high hazard dam. The team spoke with the lake superintendent, who indicated that the valves were opened on the dam embankment Friday evening (August 24th) prior to the arrival of Hurricane Isaac. It was indicated that although the lake level was lowered 2 ft prior to Isaac's arrival, water began to overtop the spillway beginning Tuesday night (August 28th).

Figure 27. Spillway at Lake Hide-a-Way after heavy rainfall from Hurricane Isaac. Image is a capture from video taken by Bruce Devillier. Lake elevation appears to have reached the top of the concrete lining the guide channel at the time of the video.

The survey team also visited the confluence of East and West Hobolochitto Creeks near Picayune, MS. Along N. Beech St and Inside Rd., flooding of residential areas was noted to have occurred one to two blocks from the creek. It was noted by the survey team that water depths likely exceeded 2-3 ft in places.

9. Lower Pearl River

a. NWS Post-Event Flood Survey

A flood survey for the Lower Pearl River watershed area was conducted by the NWS teams on September 7th, 2012.

1) US98 TO CONFLUENCE WITH BOGUE CHITTO RIVER

Flood Category: Major Flooding
River Gauge: USGS automated gauge on LA10 bridge (BXAL1)
Period of Record: 1938-Present
Crest: 21.0 ft about 5:00 AM CDT 09/03/2012

2) I-59 TO LAKE BORGNE

Flood Category: Major Flooding
River Gauges: USGS automated gauge on I-59 bridge (PERL1)
Period of Record: 1900-Present
Crest: 18.5 ft about 12:00 AM CDT 09/04/2012

3) E. PEARL AT WALKIAH BLUFF

Flood Category: Likely Minor to Moderate
River Gauges: USGS automated gauge along Parkside Dr (WSWM6)
Period of Record: 2007-Present
Crest: 43.4 ft about 1:00 AM CDT 09/03/2012

The survey team noted that water was likely around 1 ft deep throughout the area along Parkside Dr., just upstream of the Walkiah Bluff gauge. It was also noted that water likely inundated the one road into and out of the residential area.

4) PEARL RIVER NAVIGATION CANAL

Flood Category: Not determined.
River Gauges: USGS automated gauges at L&D1 (PRUL1), L&D2 (PRDL1), and L&D3 (PRTL1)
Period of Record: 2007-Present
Crest: 43.4 ft (L&D2) about 1:00 AM CDT 09/03/2012

Near the time of crest of the Pearl and Bogue Chitto Rivers in this area, it was reported by St. Tammany Parish officials that failure of the small dam at Lock and Dam 2 (L&D2) was imminent. Through an as of yet unknown combination of forecasting difficulties, confusion, and misunderstanding of maximum potential threat in regards to L&D2, a substantial portion of St. Tammany Parish near the canal was evacuated and some citizens in the Slidell area became concerned. Most of these individuals were never in any danger from a failure of L&D2. More discussion on this situation can be found in

Appendix A: Potential Dam Failures During Hurricane Isaac.

10. Bogue Chitto River

a. NWS Post-Event Flood Survey

1) US98 TO THE LA/MS BORDER

Flood Category: Major Flooding
River Gauge: USGS automated gauge on US98 bridge (TYTM6)
Period of Record: 1953-Present
Crest: 26.4 ft about 1:00 PM CDT 08/30/2012

The survey team also visited the Bogue Chitto Water Park. High water marks suggested that the river level almost reached the circle drive at the top of the boat ramp. The survey team spoke with a staff member, Scott, at the water park, who indicated that backwater flooding up Bars Branch floods Dogwood Trail (cutting off the entrance road) before water reaches the main sections of the water park. He also indicated that MS27 was the only road he knew of that flooded from the storm. He also indicated that Nola Rd. bridge over Little Fair River could be used as a proxy for flooding at the water park; when the bridge flooded, the water park would flood within 24 hrs (see further discussion in section *b. Discussion*). Scott also provided a contact (Elmore Riles of Wright Rd.) for further information about the Bogue Chitto River and past floods.

Scott from the Bogue Chitto Water Park also indicated that a section of Mesa Walkers Bridge Rd west of Tylertown may have flooded to a depth of over 1 ft. The location may be the crossing of Sweetwater Creek, but this was not made clear to the survey team.

At the US98 bridge, high water marks were noted in the trees about 14-15 ft above bank level, but this was below the bridge elevation.

2) TWO MILES DOWNSTREAM OF TYLERTOWN TO LA437

Flood Category: Major Flooding
River Gauges: USGS automated gauge on LA10/16 bridge (FRNL1)
Period of Record: 1964-Present
Crest: 19.2 ft about 1:00 AM CDT 08/31/2012

The survey team discussed flooding impacts with the Washington Parish emergency manager. It was mentioned that areas west of the MS10/16 bridge flooded. Upon visiting the area, the survey team noted that the area may have flooded up to several feet in depth, especially along VFW Rd. which was nearest to the river.

A few homes appeared to have flooded along LA437.

Flooding was noted in the area of True Light Church Rd.

Flooding was also noted in the Isabel, LA, area just west of Bogalusa, especially near the Bogue Chitto Canoeing & Tubing Park along Choctaw Rd. Staff members at the Bogue Chitto Canoeing & Tubing Park indicated to the survey team that the crest at Choctaw Rd. occurs about 24-36 hrs after FRNL1 and about 12hrs before BSHL1.

3) LA437 TO CONF. WEST PEARL RIVER

Flood Category: Major Flooding
River Gauges: USGS automated gauge on LA21 bridge (BSHL1)
Period of Record: 1964-Present
Crest: 19.2 ft about 1:00 AM CDT 08/31/2012

The survey team did not record any notes of flood impacts through this river reach. River flood category was determined through impact statements.

b. Discussion

The anecdote regarding Little Fair River being a predictor of flooding for Bogue Chitto Water Park was investigated further. Little Fair River flows into Fair River between Brookhaven, MS, and Monticello, MS, which is a tributary of the Pearl River just upstream of Monticello. Although the headwaters of the Fair River are near the headwaters of the Bogue Chitto River and may see similar rainfall amounts during events, flooding at Nola Rd. cannot impact any location on the Bogue Chitto.

11. Black Creek

a. NWS Post-Event Flood Survey

A survey of the Black Creek watershed area was conducted by hydrologists from the LMRFC in September of 2012 separately from the main Isaac flood survey. The survey covered areas from the Black Creek gauge on the US49 bridge as well as the Little Black Creek dam.

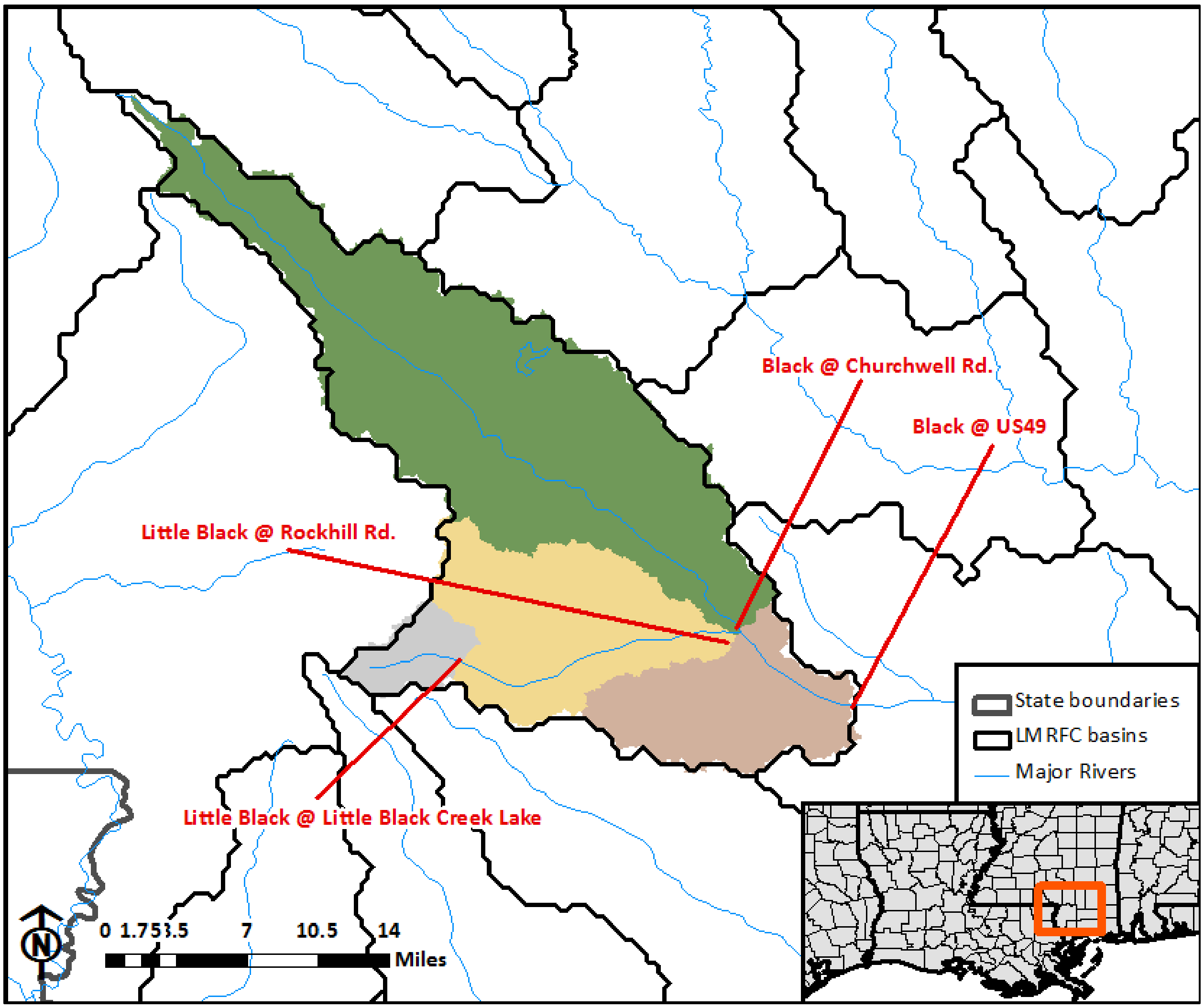

Figure 28. Black Creek subbasins as defined by locations surveyed by LMRFC/WFO Jackson staff. Subbasins defined by the current model configuration of LMRFC are also indicated for comparison.

1) LAKE SERENE

Flood Category: Unknown
River Gauges: None

Lake Serene is actually a complex of multiple smaller lakes separated by small embankments and connected by small spillways or conduits. An embankment on one of the smaller lakes received damage during the heavy rainfall and there was concern over a possible failure. The lake was drained successfully and no dam failure occurred (Marty Pope, personal communication). This location was not visited by the survey team.

2) LITTLE BLACK CREEK LAKE

Flood Category: Most likely moderate or major
River Gauges: None
Period of Record: ????-Present
Crest: Estimated to be 2nd highest since constructed

Although staff drained the lake almost 3.0 ft prior to the onset of heavy rainfall, the elevation of Little Black Creek Lake reached an elevation high enough for water to move around the side of the dam into the emergency spillway channel (Little Black Creek Water Park staff, personal communication, September 2012). It was indicated to the survey team that the lake level's crest was lower after Isaac than during the flooding of 1983.

3) 5MI UPSTREAM OF US49 TO 5MI DOWNSTREAM OF US49

Flood Category: Major Flooding
River Gauge: USGS automated gauge on US49 bridge (BKNM6)
Period of Record: 1971-Present
Crest: 26.7 ft about 4:00 PM CDT 08/31/2012

Staff members from the Forrest County Emergency Mangement office guided NWS hydrologists to a few flooded areas along Black Creek in the Brooklyn area. Although flooding impacts to the town of Brooklyn itself were minimal, a few elevated structures near the river west of town did experience flooding. One known flood prone area, referred to as Camp Dantzler, again received flooding near the river from this event. Most structures are elevated, but road access was flooded.

NWS hydrologists also visited Beaver Lake which impounds Little Beaver Creek upstream of Camp Dantzler and the gauging location on Black Creek. Mud marks and debris appeared to indicate flooding of a few structures just downstream of the dam. The dam is privately owned and was inaccessible by the surveyors during the visit. Previous surveys of the location have noted trees and brush growing out of the earthen dam structure as well as evidence of possible dam overtopping.

b. Discussion

The Black Creek at Brooklyn basin is complex to model and forecasting challenges include complex land use changes. Although a trend of increasing heavy precipitation events appears likely based upon rainfall data available to LMRFC staff, streamflow response for the automated gauging location on the US49 bridge suggests stable or reduced flood activity. A substantial number of retention ponds and small lakes were evident in satellite imagery (Figure 29) analyzed by LMRFC staff in late 2012.

Due to the close proximity of this basin to the LMRFC office, the forecast point and upstream areas have been visited numerous times in recent years. Hydrologists have noted a fairly incised channel for the downstream half of the basin, including a gravelly or rocky channel bottom in some locations with unusually clear water for the area. It has been hypothesized that land use changes, particularly the slow addition of multiple private retention ponds and small lakes, may have changed the response characteristics of the basin enough to mitigate flood risk. This remains an area of active research and study, and as such, the hypothesis should be considered preliminary at this time.

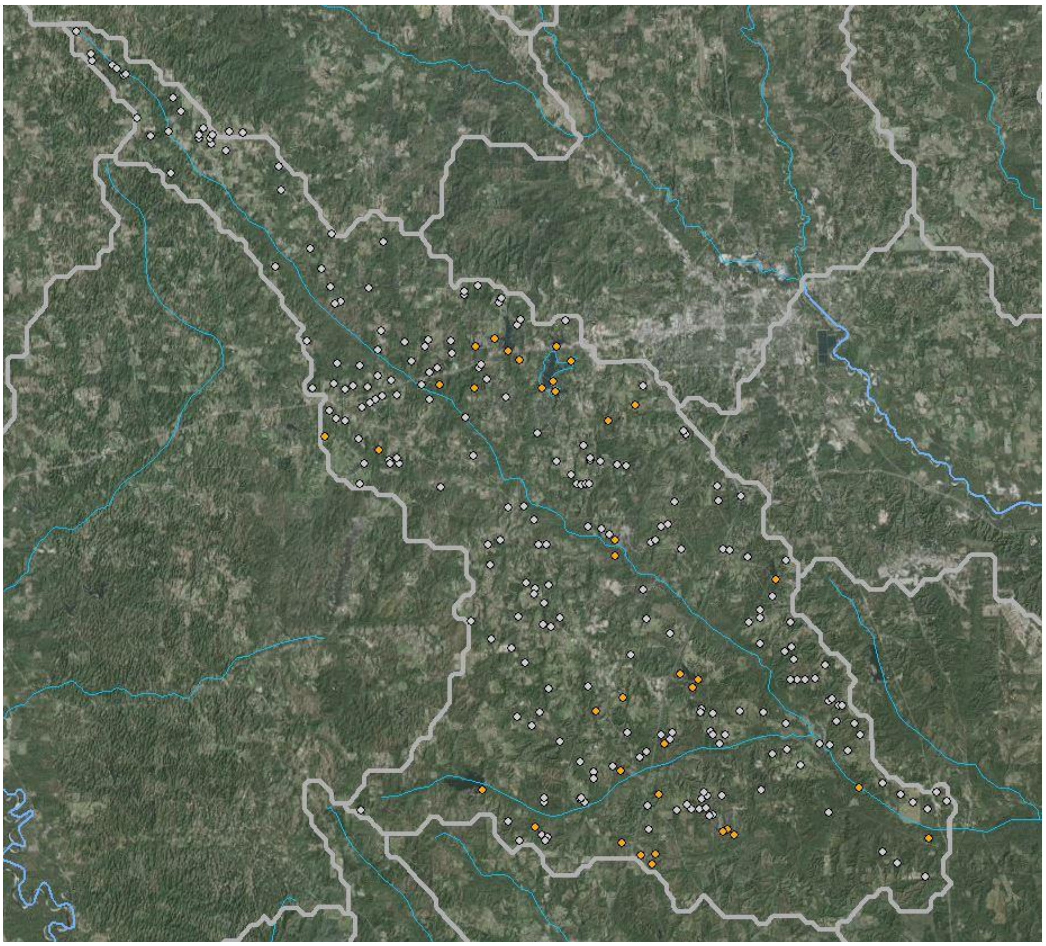

Figure 29. Map of the Black Creek at Brooklyn (BKNM6) subbasin with structures showing both known dams and unlisted ponds/lakes identified from satellite imagery. Known dams are indicated as yellow (37), and manually-added dams are indicated as white (230).

12. Post-Survey Discussion

Some differences between actual impacts and the forecasted impacts based upon E19s and AHPS information was noted by the various survey teams. A break-down of these differences was provided to the responsible NWS WFOs. It was also noted that both flash flooding and longer-term river flooding occurred due to heavy rainfall from Hurricane Isaac. This highlights the necessity of a multi-pronged forecasting approach including FFG/FFMP, RFC forecasts, and new experimental techniques such as DHM-TF for the transitional events.

The Audubon Park COOP station (AUD) started at a notably high accumulation before the storm, and then during the period of highest intensity rainfall, the reported accumulation remained relatively constant once it exceeded the design capacity of the gauging equipment (Figure 30). This highlights the need for NWS staff to make sure gauging equipment is in working order and properly emptied prior to high-impact events with a substantial lead time such that important mission-critical data is not lost. Because of the loss of some official data, private data was acquired to help fill in the gaps.

During Hurricane Isaac, the number of watches, warnings, and statements in effect for some areas made it particularly difficult to use a warning map such as the one provided by the NWS. This is likely to only get worse with the additional of new hurricane products. Flood warnings would be issued for entire counties, even when flooding was only to impact areas near the river, and this would overlap other warning products that were probably more relevant to other portions of the county. Multiple NWS service assessments have recommended the usage of polygon warnings tied to river forecast locations (NWS, 2011b) (NWS, 2012). Methodology already exists to work around default WFO system configuration and issue polygon-based river flood warnings. Isaac highlights the type of situations where polygon-based river flood warnings can greatly improve our warning dissemination.

Forecasters could also greatly improve our decision support services by using severity-based product wording (NWS, 2010) (NWS, 2011a) (NWS, 1999). Even when observations were beginning to indicate that some areas were experiencing an extreme event, rarely was heightened wording used to make it clear that this was not just an ordinary flood event. Some areas flooded by Hurricane Isaac experienced record and/or life-threating stages. Severity-based product wording helps our customers and partners put an event such as that in context.

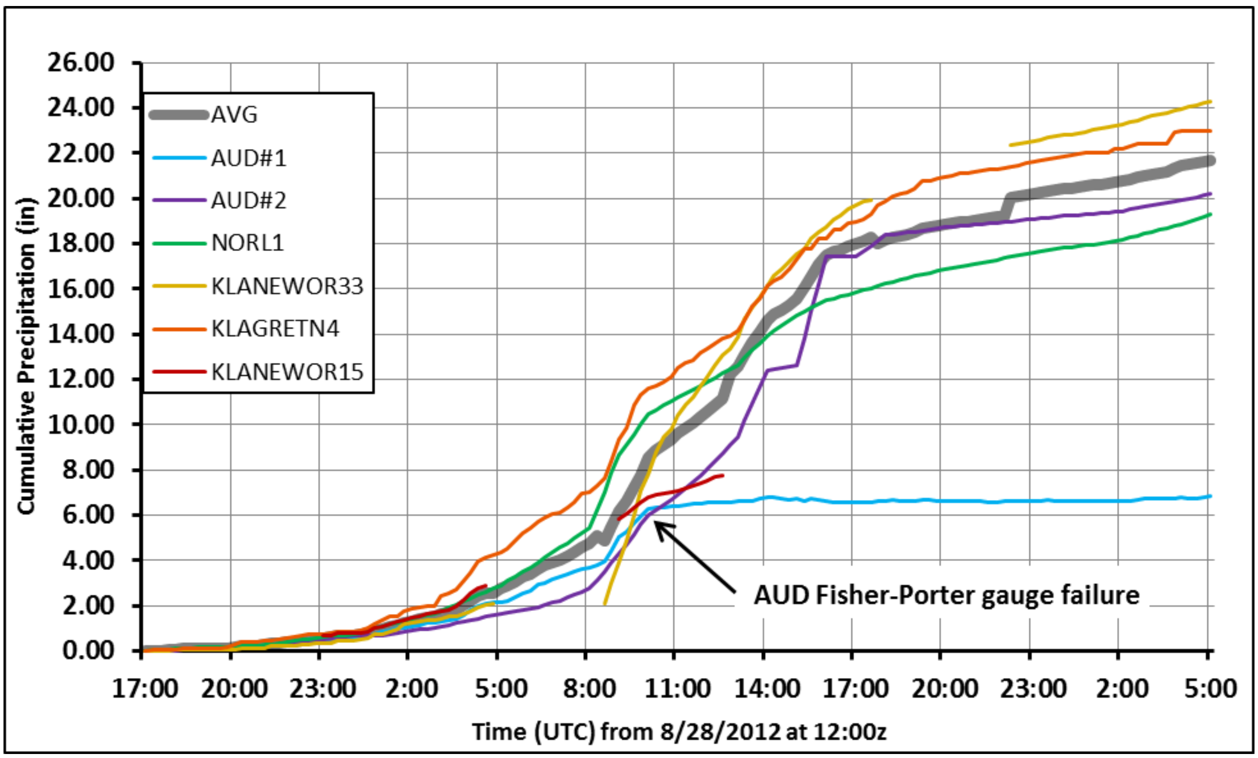

Figure 30. Accumulated precipitation plots for gauges near the Audubon Park cooperative observer site. The Fisher-Porter rain gauge (AUD#1) failed after exceeding about 6.0 inches of accumulation during the period of heaviest rainfall.

13. Summary and Final Remarks

Hurricane Isaac's slow movement at landfall during late August of 2012 set the stage for substantial storm surge and river flooding impacts. Moderate and major flooding was observed along numerous river reaches in Louisiana and Mississippi. This widespread, significant flooding lead to the creation of survey teams tasked with documenting the flood's impacts and discussing our hydrologic forecast service with our customers and partners.

From the summaries of post-flood survey notes, it was determined that numerous roads were inundated, several residential and business structures were flooded, and impacts for a few areas were of a historic nature. The Wolf River floodplain was one of those areas, but flood impacts were limited due to most of the floodplain being undeveloped. In contrast, some areas experienced significant flooding but not of a record magnitude, and numerous structures were affected. New development was noted in areas that were just outside of the limit of inundation, in areas that have flooded in the past and will flood again. These contrasting anecdotes suggest that we must continue to work with our partner agencies to educate the public on past floods and likely future floods to mitigate risk.

It was also found that many individuals kept a close watch on river forecasts as they were updated using the NWS Advanced Hydrologic Prediction Service. Many of these individuals also were knowledgeable in their surveyed elevation, the base flood elevation determined for their area, and how to correlate a nearby river gauge to impacts in their area. From this event we have further evidence of the diverse range of hydrology knowledge found amongst our public customers, and can also see our methods of product dissemination in action.

The survey team also found areas where the National Weather Service offices in the affected area could improve the service provided to our customers and partners. Flood categories may need adjustment in some areas, and flood impacts need updating to reflect recent development. It has been indicated through numerous NWS service assessments that the frequent updating of impact statements is very important to our customers and partners; the best way to keep them useful and relevant is to visit a flooded area during or soon after the event (NWS Eastern Region Headquarters, 2012) (NWS, 2011b) (NWS, 2012).

15.0 Acknowledgements

The survey team was composed of several members of the NWS Lower Mississippi River Forecast Center staff as well as some additional hydrologists from other offices. Service hydrologist Roger McNeill from WFO Birmingham, AL, service hydrologist Marty Pope from WFO Jackson, MS, and service hydrologist Jonathan Brazzell from WFO Lake Charles, LA, were brought into the New Orleans area on short notice to aid with the flood surveys. Their time and expertise was necessary for the creation of this report, and should be acknowledged.

The authors would also like to thank Jeff Zogg, service hydrologist at WFO Des Moines, IA, for providing independent peer review of the original survey notes and recommendations provided to the local NWS WFOs. The authors would like to acknowledge Dr. Jeff Masters and Shaun Tanner from WeatherUnderground, and Carl Arredondo from WWL-TV, for helping us obtain private weather station data. Daryl Herzmann and the Iowa Environmental Mesonet from Iowa State University should also be acknowledged as the source for processed NMQ/Q2 radar precipitation data and daily NWS COOP observer reports. The authors would also like to acknowledge the New Orleans Sewerage and Water Board for their daily rainfall data.

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Appendix A: Potential Dam Failures During Hurricane Isaac

This report, authored by Katelyn Costanza, summarizes the potential dam failures encountered during Hurricane Isaac and ways to improve our forecast methodology for those situations.

Three potential dam break situations occurred due to flooding from Hurricane Isaac's heavy rainfall – Lake Tangipahoa, Lock & Dam #2 of the Pearl River Navigation Canal and Lake Serene. Lake Tangipahoa is in the headwaters of the Tangipahoa River and is in the National Weather Service (NWS) Weather Forecast Office (WFO) New Orleans/Baton Rouge (LIX) HSA . Lock & Dam #2 is one of three locks on the Pearl River Navigation Canal that parallels the Pearl River in southeast Louisiana, and is also within the NWS WFO LIX HSA. Lake Serene is a combination of small suburban lakes in the headwaters of Black Creek and is in the NWS WFO Jackson HSA. Lake Tangipahoa and Lock & Dam #2 presented several challenges to forecasters at the NWS Lower Mississippi River Forecast Center (LMRFC) and NWS WFO LIX. This appendix summarizes the dam break response of both offices as determined by personal communications and review of shift logs, and also offers recommendations for improvement.

A.1 Lake Tangipahoa

A.1.1 EVENT TIMELINE

NWS WFO LIX received notification by email on the morning of August 30th that a dam failure at Lake Tangipahoa, located in the headwaters of the Tangipahoa River at Percy Quin State Park, could occur. Percy Quin personnel notified the Amite County EM who contacted the Mississippi Emergency Management Agency (MEMA). In response to the notification, the duty forecasters at LIX issued a Flash Flood Warning for southwestern Pike

County, which included the low lying areas along the Tangipahoa River downstream to Osyka, MS. LIX coordinated with the LMRFC to run a dam break analysis for the dam. Once completed, the LMRFC coordinated the dam break analysis with LIX and updated the river forecast guidance products (RVFs) for Osyka and further downstream at Kentwood, LA, to reflect the potential flood wave caused by a failure at the Lake Tangipahoa Dam. At 11:07 AM a Civil Emergency Message (CEM) was composed for Lake Tangipahoa Dam area. WFO LIX coordinated wording with MEMA and the Louisiana Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP). At 11:11 AM, LIX issued another Flash Flood Warning for Pike County and Northern Tangipahoa Parish to now include the Kentwood area. Dam safety officials from Mississippi Department of Environmental Quality (MDEQ) arrived on site and determined that although two slumps in the earthen dam had occurred, they were not indicative of imminent failure. At 2:00 PM, the LIX WFO issued a Flash Flood Statement, updating the warning in effect, which indicated that the warning would expire for Pike County and Tangipahoa Parish, but would be monitored and a warning reissued if conditions deteriorated. On the evening of August 30th, LMRFC staff members coordinated with United States Army Corps of Engineers (USACE) Vicksburg District (MVK) personnel on floodwave timing and inundation extents should failure occur. LMRFC forwarded the inundation map provided by MVK which included the areas downstream of the dam.

Mid-morning, September 1st, WFO-LIX contacted the Pike County EM to discuss the status of the dam. The EM indicated that the lake draw down was still occurring, and provided an estimate of the lake at normal pool (331.0 ft NGVD29). WFO LIX staff used this estimate of pool elevation in conjunction with lake surface area and lake storage values from DAMCAT to determine a lake depth. WFO LIX staff assumed that the average lake depth (determined by dividing the lake's pool storage by the surface area) would be applicable to the lake depth right at the dam.

The Lake Tangipahoa Dam is known to have structural issues due primarily to steep side slopes. During significant rainfall, the earthen dam can become saturated compromising slope stability.

A.1.2 DISCUSSION

The average depth is not typically representative of the height of water right at the dam, which is the height of water that could potentially spill from the dam should failure occur. A better estimate would be to use the difference between the dam top elevation and the lowest floodplain elevation just downstream, or to use the given value for hydraulic head in the National Inventory of Dams (NID) as well as DAMCAT. During potential dam break situations, these calculations are typically done by hydrologists at an NWS River Forecast Center (RFC), not by staff at a WFO.

B.2 Lock & Dam #2 on the Pearl River Navigation Canal

A.1.1 EVENT TIMELINE

The WFO LIX was notified at 2:44 PM, September 1st, via a twitter message by St. Tammany Parish that failure of Lock and Dam #2 was imminent and would affect properties along the Pearl River Navigation Canal. A Flash Flood Warning was issued – originally for portions of Washington Parish by mistake, then subsequently for eastern St. Tammany Parish. The NWS Southern Region's Regional Operations Center (ROC) and LMRFC were notified of the situation. The LMRFC subsequently began working on a quantitative dam break analysis, although Lock & Dam #2 was not a typical dam break situation trained for by LMRFC staff. A Flash Flood Warning was issued at 3:04 PM for St. Tammany Parish downstream of Lock and Dam #2 to Highway 36 including the heightened “Flash Flood Emergency” wording. The LMRFC provided LIX with a quantitative dam break analysis based on preliminary data to provide the potential impacts should the lock fail. The WFO LIX conveyed this information in a subsequent Flash Flood Statement issued at 4:37 PM. LMRFC staff visited the site of the lock and dam to discuss the impacts with emergency management officials and the USACE. The USACE conveyed that they were able to stop the overtopping of the lock chamber and prevent further scour to the downstream wing wall of the structure which had received the most damage. The USACE was monitoring the situation and would continue to do so until structural engineers were able to arrive at the site the next day to assess the structural damage, but indicated that the situation had stabilized. The USACE also conveyed that if conditions should worsen or failure occurs, the floodwave would be captured in the pool of Lock and Dam #1 just downstream on the Pearl River Navigation Canal. Unless Lock & Dam #1 were also to fail (which was considered very unlikely), this floodwave would have been contained within the navigation canal and would not continue to the main channel of the Pearl River. LMRFC called WFO LIX after leaving the site (approximately 7 PM) to communicate this updated information so that it could be conveyed in the warnings. The WFO re-issued a Flash Flood Statement at 9:03 PM with the preliminary information from early evening; this warning included areas east of Hwy 41 and north of Hwy 36. The Flash Flood Warning was continued at 2:51 AM, again using preliminary information. These issuances did not include an updated assessment or qualitative analysis and were not coordinated with the LMRFC. At 3:44 AM, LMRFC staff re-coordinated updated information provided earlier on the situation which was acquired at the dam site to WFO LIX.

The WFO reissued the Flash Flood Warning indicating that pressure had been relieved and was being monitored by USACE officials. This verbiage was maintained in the 9:00 AM issuance of the Flash Flood Warning.

B.2.2 DISCUSSION

A contact list of appropriate state personnel should be developed for Louisiana and Mississippi to discuss dam emergency situations with the appropriate personnel. All information should be communicated with the RFC before providing any quantitative information related to a potential dambreak. The RFC staff is trained in evaluating a dam break scenario and providing quantitative forecasts of downstream impacts.

The first flash flood watch/warning issued for a potential dam failure should extend downstream just enough to cover the time needed by the RFC to do the dambreak calculations. Empirical data from past dam break flood waves indicates that the waves travel at 10 mph or less, even in the steepest of mountain terrain. A Flash Flood Warning length of roughly 10 miles for every 1hr of required calculation time by the RFC would be a reasonable assumption. In accordance with National Weather Service Policy Directive NWS 10-921 and Supplement 02-2006, a quantitative analysis is the responsibility of the RFC and all flood warnings should be coordinated with the responsible RFC.

Appendix B: Private Weather Station Data

A large amount of private weather station data was obtained to help the analysis in this post-flood report. Over 160 sites were originally hand-entered into a spreadsheet program for later comparison in ArcGIS with official gauging location data and radar derived precipitation estimates. Most of these sites came from the Weather Underground Personal Weather Station (PWS) project. In additional to the PWS data, estimates from a wastewater treatment plant and a few functioning stations from the AWS/WeatherBug network were used. This section discusses the data acquisition and quality control process further than the main body of the report.

As discussed in the main report (*Section 2) Un-Official* Sources), a PHP script was created to speed up this process of retrieving data from the PWS and AWS stations (http://www.meteor.iastate.edu/~slincoln/stationdata/). Even with this script, data still had to be hand-entered one gauge at a time. After obtaining this data, a limited amount of quality control was applied by to eliminate obvious erroneous gauges. To obtain as much useful data as possible, the gauges were evaluated independently for each day using the following criteria:

1. Any gauge that did not have more than a few hours of data available was automatically eliminated.
2. Many gauges had periods of time where no data was reported. This was likely due to intermittent power outages. If the gauge data returned before 12:00 AM and a reasonable daily rainfall value was reported, the site was kept for that day (this is due to the private stations reporting daily totals to Weather Underground instead of rates).
3. If gauge data stopped and did not return before 12:00 AM, the station was only kept for that day if the lost data period was shorter than 1 hr in duration.

4. Some gauges reported rainfall rates that were unrealistic or did not follow a shape that appeared to be natural. These sites were typically removed for that day, especially if other problems were noticed.
5. As is typical even for official sites during heavy rainfall coincident with high winds, many rainfall gauges appeared to underestimate when compared to nearby sites. Typically this did not cause a gauge to be excluded for that day unless the discrepancy was substantial (for example, 5” or more) and aerial imagery suggested poor siting of the gauge.

Although an attempt was made to reduce errors in the private station data and improve the data quality, it cannot be guaranteed that all data are accurate or that a particular site is located in an adequate location to properly measure rainfall. A table of daily and storm total rainfall values, ordered from highest to lowest, is shown by Table 1.

Table 1. Summary of QCed rainfall totals from private weather stations (mostly Weather Underground PWS sites) in southeast Louisiana and south Mississippi during Hurricane Isaac. Questionable values highlighted yellow. Site PWWTP measured at 7 AM rather than 12 AM.

PWS_ID	Lat	Lon	Location	State	Source	08_28_12	08_29_12	08_30_12	08_31_12	09_01_12	Total
KLANEWOR33	29.93	-90.11	New Orleans (Uptown)	LA	WU	2.10	24.34	0.94	0.00	0.00	27.38
KLAGRETN4	29.91	-90.05	Gretna	LA	WU	4.37	18.66	0.87	0.06	0.00	23.96
PWWTP*	30.54	-89.71	Picayune Treatment Plant*	MS	Other	1.00	13.00	5.50	1.20	0.00	20.70
KMSBROOK3	31.58	-90.44	Brookhaven	MS	WU	0.08	8.10	9.08	1.22	0.14	18.70
KMSMOSSP1	30.60	-88.47	Moss Point	MS	WU	1.52	9.08	7.65	0.19	0.00	18.44
MCKWM6	30.52	-88.98	Woolmarket	MS	WU	1.54	9.30	7.22	0.33	0.00	18.39
KLABELLE5	29.90	-89.98	Belle Chasse	LA	WU	1.33	14.46	1.77	0.00	0.00	17.56
KLANEWOR26	30.01	-90.06	New Orleans	LA	WU	3.21	9.64	1.65	0.00	0.00	14.50
KMSMCCOM2	31.21	-90.50	McComb	MS	WU	0.14	8.39	5.02	0.48	0.21	14.24
IMSPOPLA2	30.83	-89.54	Poplarville	MS	WU	0.23	7.69	6.23	0.04	0.00	14.20
KMSHATTI12	31.32	-89.39	Hattiesburg	MS	WU	2.97	6.10	3.64	0.40	0.01	13.12
KMSLONGB5	30.36	-89.16	Long Beach	MS	WU	1.57	9.60	1.93	0.00	0.00	13.10
KMSCARRI3	30.58	-89.65	Carriere	MS	WU	0.73	9.18	3.05	0.03	0.00	13.07
KMSOSYKA2	31.03	-90.28	Osyka	MS	WU	0.15	4.99	5.12	0.80	1.27	12.55
KALMOBIL52	30.65	-88.29	Mobile	AL	WU	3.16	4.50	4.62	0.25	0.01	12.54
KALMOBIL40	30.68	-88.20	Mobile	AL	WU	4.53	5.59	2.03	0.23	0.01	12.52
KLAHAMMO3	30.53	-90.53	Hammond	LA	WU	0.06	8.11	2.74	1.37	0.12	12.42
MTT090	31.20	-89.18	Hattiesburg	MS	WU	1.12	5.78	4.48	0.64	0.06	12.18
KLASTAMA2	30.26	-90.84	Gonzales	LA	WU	0.08	8.57	2.94	0.58	0.00	12.17
KALGRAND3	30.46	-88.34	Grand Bay	AL	WU	1.32	7.42	2.72	0.21	0.00	11.67
KLABELLE4	29.74	-90.03	Belle Chasse	LA	WU	2.91	6.89	1.85	0.00	0.00	11.65
KLAMETAI14	30.02	-90.17	Metairie	LA	WU	3.38	6.88	0.64	0.01	0.01	10.92
KLACARVI2	30.23	-91.05	Gonzales	LA	WU	0.00	9.53	0.71	0.63	0.04	10.91
KMSSUMMI2	31.29	-90.47	Summit	MS	WU	0.75	6.24	3.27	0.00	0.16	10.43
KMSMAGNO2	31.09	-90.35	Magnolia	MS	WU	0.15	5.21	4.33	0.54	0.01	10.24
KLAPRAIR4	30.31	-90.93	Prairieville	LA	WU	0.02	7.11	2.53	0.42	0.05	10.14
KLAABITA1	30.55	-89.96	Abita Springs	LA	WU	0.24	6.85	2.68	0.00	0.00	10.12
KALMOBIL7	30.74	-88.21	Mobile	AL	WU	2.98	4.90	1.90	0.22	0.01	10.10
KMSVANCL4	30.54	-88.74	Van Cleave	MS	WU	1.29	5.49	2.45	0.08	0.31	9.66
KLARIVER3	29.97	-90.23	River Ridge	LA	WU	1.00	7.75	0.80	0.01	0.01	9.57
KLABATON23	30.40	-91.07	Westminster	LA	WU	0.00	5.70	3.11	0.62	0.05	9.48
KALMOBIL44	30.63	-88.27	Mobile	AL	WU	3.07	3.04	3.20	0.16	0.00	9.47
KLAABITA2	30.48	-89.93	Abita Springs	LA	WU	0.49	4.61	4.24	0.04	0.00	9.41
KLAGEISM2	30.21	-90.99	Gonzales	LA	WU	0.05	5.97	2.03	0.62	0.62	9.29
KLACENTR2	30.60	-91.00	Greenwell Springs	LA	WU	0.00	5.92	1.85	0.97	0.44	9.19
KALMOBIL27	30.62	-88.27	Mobile	AL	WU	3.28	4.25	1.49	0.14	0.00	9.16

PWS_ID	Lat	Lon	Location	State	Source	08_28_12	08_29_12	08_30_12	08_31_12	09_01_12	Total
KMSBROOK4	31.52	-90.31	Brookhaven	MS	WU	0.32	2.37	5.58	0.51	0.01	8.79
KLASLIDE10	30.30	-89.84	Slidell	LA	WU	0.72	4.79	2.88	0.00	0.00	8.39
KMSHATTI10	31.31	-89.36	Hattiesburg	MS	WU	0.92	4.28	2.81	0.30	0.00	8.31
KMSGULFP20	30.40	-89.04	Gulfport	MS	WU	0.85	6.22	1.23	0.00	0.01	8.31
KMSHATTI7	31.33	-89.34	Hattiesburg	MS	WU	1.07	4.95	2.07	0.18	0.01	8.28
KALMOBIL17	30.60	-88.22	Tillmans Corner	AL	WU	2.98	3.56	1.36	0.28	0.00	8.19
KMSMCCOM4	31.25	-90.46	McComb	MS	WU	0.19	5.73	1.39	0.38	0.19	7.89
KLATHIBO3	29.82	-90.84	Thibodaux	LA	WU	0.28	4.52	2.26	0.82	0.00	7.89
KLASLIDE7	30.29	-89.85	Slidell	LA	WU	0.98	4.62	2.27	0.00	0.00	7.88
KLAMANDE14	30.40	-90.06	Mandeville	LA	WU	0.77	6.06	0.84	0.00	0.00	7.67
KLAMANDE15	30.38	-90.03	Mandeville	LA	WU	0.66	5.16	1.80	0.00	0.00	7.62
KLASCHRI3	29.64	-90.84	Bayou Cane	LA	WU	0.66	3.53	2.99	0.24	0.00	7.42
KLABATON3	30.40	-91.03	Shenandoah	LA	WU	0.00	5.75	0.87	0.75	0.04	7.41
KLANORCO2	30.02	-90.41	Norco	LA	WU	0.72	4.54	1.50	0.48	0.08	7.32
KALMOBIL32	30.61	-88.23	Tillmans Corner	AL	WU	2.91	2.66	1.26	0.29	0.00	7.12
KALMOBIL49	30.68	-88.12	Mobile	AL	WU	2.39	3.45	0.72	0.52	0.00	7.08
KALMOBIL42	30.63	-88.17	Mobile	AL	WU	2.54	3.19	0.90	0.37	0.00	7.00
KLAMETAI13	30.00	-90.14	Metairie	LA	WU	1.63	3.10	1.80	0.01	0.01	6.55
KLASLAUG1	30.73	-91.12	Slaughter	LA	WU	0.00	3.21	1.78	0.46	0.11	6.29
KALTHEOD3	30.58	-88.12	Tillmans Corner	AL	WU	2.66	2.77	0.47	0.39	0.00	6.29
KMSSEMIN2	31.46	-89.44	Seminary	MS	WU	0.90	2.88	1.81	0.63	0.03	6.25
KMSPOPLA1	30.97	-89.66	Poplarville	MS	WU	0.16	5.25	0.65	0.01	0.00	6.07
KLALUTCH2	30.05	-90.70	Lutcher	LA	WU	0.66	1.07	2.77	1.54	0.00	6.04
KALFAIRH16	30.51	-87.84	Fairhope	AL	WU	3.24	2.21	0.06	0.32	0.00	5.83
KLAHOUMA4	29.63	-90.75	Bayou Cane	LA	WU	0.83	4.07	0.66	0.24	0.00	5.80
KLANEWOR13	30.03	-90.06	New Orleans	LA	WU	2.87	0.98	1.86	0.00	0.01	5.72
KALFAIRH6	30.52	-87.82	Fairhope	AL	WU	3.64	1.49	0.16	0.28	0.00	5.57
KMSHATTI2	31.31	-89.36	Hattiesburg	MS	WU	1.29	2.20	1.70	0.34	0.00	5.53
KALFAIRH13	30.54	-87.90	Fairhope	AL	WU	3.83	1.50	0.02	0.15	0.00	5.50
KLAPLAQU3	30.24	-91.20	Plaquemine	LA	WU	0.00	3.82	0.95	0.68	0.00	5.45
KALROBER2	30.53	-87.73	Robertsdale	AL	WU	4.21	0.94	0.00	0.16	0.00	5.31
KALFAIRH9	30.45	-87.83	Fairhope	AL	WU	3.13	1.47	0.07	0.24	0.00	4.91
KLACLINT2	30.78	-90.89	Clinton	LA	WU	0.00	2.16	1.82	0.31	0.03	4.32
KALDAPHN2	30.60	-87.91	Daphne	AL	WU	2.17	1.65	0.10	0.24	0.00	4.16
KALGULFS7	30.25	-87.72	Gulf Shores	AL	WU	3.35	0.48	0.03	0.00	0.00	3.86
KLABERWI2	29.72	-91.24	Morgan City	LA	WU	0.03	1.94	1.78	0.06	0.00	3.82
KLAPORTA4	30.45	-91.24	Port Allen	LA	WU	0.00	1.59	0.55	1.31	0.01	3.46
KALDAPHN3	30.59	-87.91	Daphne	AL	WU	1.42	1.42	0.07	0.17	0.00	3.08
KLAPRIAI2	30.27	-90.98	Prairieville	LA	WU	0.03	2.17	0.68	0.04	0.01	2.99

PWS_ID	Lat	Lon	Location	State	Source	08_28_12	08_29_12	08_30_12	08_31_12	09_01_12	Total
KALGULFS5	30.25	-87.79	Gulf Shores	AL	WU	1.96	0.75	0.08	0.09	0.00	2.88
KALORANG4	30.28	-87.58	Orange Beach	AL	WU	2.50	0.15	0.10	0.02	0.00	2.77
KALORANG6	30.29	-87.51	Orange Beach	AL	WU	1.64	0.09	0.03	0.15	0.00	1.91
KALDAUPH3	30.25	-88.14	Dauphin Island	AL	WU	-999.00	2.41	0.09	0.40	0.00	
KALMOBIL45	30.64	-88.15	Mobile	AL	WU	3.71	4.05	0.62	-999.00	-999.00	
KLAMONTE2	29.47	-90.56	Chauvin	LA	WU	1.59	3.44	0.57	0.00	-999.00	
KLAPLAQU4	30.27	-91.18	Plaquemine	LA	WU	0.00	4.65	0.45	-999.00	0.00	
KLAPORTA8	30.42	-91.21	Port Allen	LA	WU	0.00	3.70	0.69	0.86	0.00	
KLAWATSO2	30.61	-90.91	Edmonds	LA	WU	0.00	8.67	1.67	0.92	0.17	
KMSLIBER2	31.19	-90.87	Liberty	MS	WU	0.06	4.99	2.91	0.05	0.04	
KMSLONGB8	30.35	-89.14	Long Beach	MS	WU	1.23	10.64	1.78	-999.00	-999.00	
KMSPASSC14	30.31	-89.25	Pass Christian	MS	WU	1.24	4.12	0.11	-999.00	-999.00	
KMSWAVEL6	30.29	-89.37	Waveland	MS	WU	1.51	3.60	2.35	0.00	-999.00	

Appendix C: Isolated Rainfall Maximum in Uptown New Orleans

Although several locations recorded rainfall accumulation near 20 inches for the duration of Isaac's slow landfall, one rainfall maximum is particularly notable due to its isolated nature, the validation with several sites in the close vicinity, and the apparent lack of significant flood impacts. Two official gauges near Audubon Park in New Orleans reported notably high totals for the event, defined as August 28th, 2012, 17 GMT through August 30th, 2012, 17 GMT. NORL1, which is operated by the USACE, reported 21.1 in, and one of the two gauges at AUD, which is operated by NWS LIX, reported 21.0 in. One hourly report at the AUD site appeared to be so much higher than neighboring gauges that WFO LIX staff suspected the gauge data of being faulty for that day, and replaced the raw values with estimated values before they were used in the Hurricane Isaac Tropical Cyclone Report and the official climate data reported to NCDC (LIX staff, personal communication). When compared to other rainfall data available at the time for New Orleans, these values appeared significantly higher than any other location. For example, data from rain gauges at pump stations operated by the New Orleans Sewerage and Water Board ranged from 4.6 inches to 12.4 inches.

To validate the NORL1 and AUD gauges, additional data from private weather stations (see *Appendix B: Private Weather Station Data*) was obtained. Rainfall accumulations and rainfall rates for stations closest to Audubon Park were compared to the official sites in question. The locations and storm total rainfall of all quality-controlled gauges available in the New Orleans area (official and private) is illustrated by Figure 33. The storm total rainfall amount for the other AUD gauge was not plotted due to the gauge failure in the middle of the heaviest rainfall band.

Staff members from WFO LIX and LMRFC – Suzanne Van Cooten, W. Scott Lincoln, and Tim Erickson – also visited some of these gauges on January 9th, 2013, in particular the

Weather Underground PWS site KLANEWOR33, which reported the highest storm total of 27.4 inches. Station KLANEWOR33 was located on the roof of a three floor residential structure, roughly 30 ft above ground level (Figure 35). The rain gauge was a tipping bucket sensor attached to the side of a pole used for the anemometer. The rain gauge and anemometer were estimated to be roughly 3 ft and 5 ft above roof level, respectively. The residential structure was the tallest building in the neighborhood, greatly limiting the impact of trees and buildings on the rainfall measurement. Although the station was sited such that rainfall should not be blocked by taller objects, two sources of potential over-estimation were identified. The rain gauge was attached to, and within just a few inches of, the pole holding the anemometer. The pole was located to the northeast of the rain gauge, which we hypothesize may have provided a mechanism for dripping water to enter the gauge during specific wind conditions. It was also hypothesized that the strong winds observed at the station (during the time of heaviest rainfall rates, frequent gusts in the 55-70 mph range were recorded) may have caused false tips in the rain gauge. Neither of these hypotheses were thoroughly tested.

Another way to validate the data reported by the NORL1 and AUD gauges is to look at running accumulation (Figure 31) and hourly rainfall rates (Figure 32). NORL1 and AUD appear to be consistent, both in timing and magnitude, with nearby private gauges. One private gauge in the area, Weather Underground PWS site KLANEWOR15, was in disagreement with rainfall rates reported by the other stations, especially between roughly 9GMT and 1230GMT on August 29th, 2012 (a brief time period when the station reported between power interruptions). Because this site is located just 3 blocks from site AUD, the discrepancy was investigated. The rainfall gauge was located in a small backyard area within just a few feet of nearby structures and trees (Figure 34). The anemometer for the site, located on an out building near the rain gauge, reported lower wind speeds than other stations in the area. It seems likely that this station under-reported rainfall due to these issues.

The number of gauges consistently reporting very high values of rainfall in the uptown New Orleans area strongly suggests that the two gauges in question were not reporting incorrect values. Typically, gauges are biased toward under reporting rainfall during the landfall of tropical systems. The chance of four rainfall gauges operated by different entities all failing in the same atypical direction is considered remote. Questions still remain, however, including reasons why no major flooding was reported during and after these extreme rainfall amounts were observed. To further corroborate data summarized in this section, pumping records from the Sewerage and Water Board of New Orleans (SWBNO) should be compared to rainfall estimates.

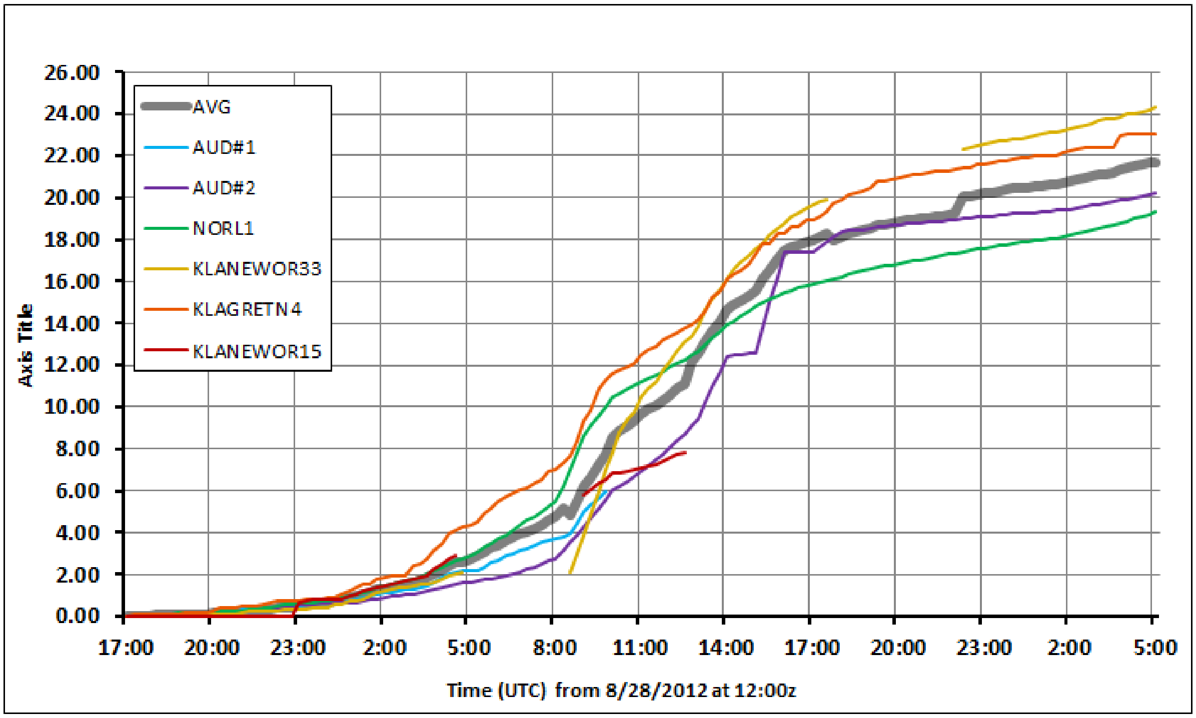

Figure 31. Cumulative rainfall for several official and private gauging sites near Audubon Park in New Orleans. Note the large hourly jump by AUD#2; this hourly value was originally discounted, but in the context of running accumulation seems to have been related to a gauge clog. Also note the substantially lower rainfall rates reported by KLANEWOR15, located 3 blocks from AUD – this rain gauge was likely impacted significantly by nearby structures and trees, based upon information from the owner and a site visit by NWS staff.

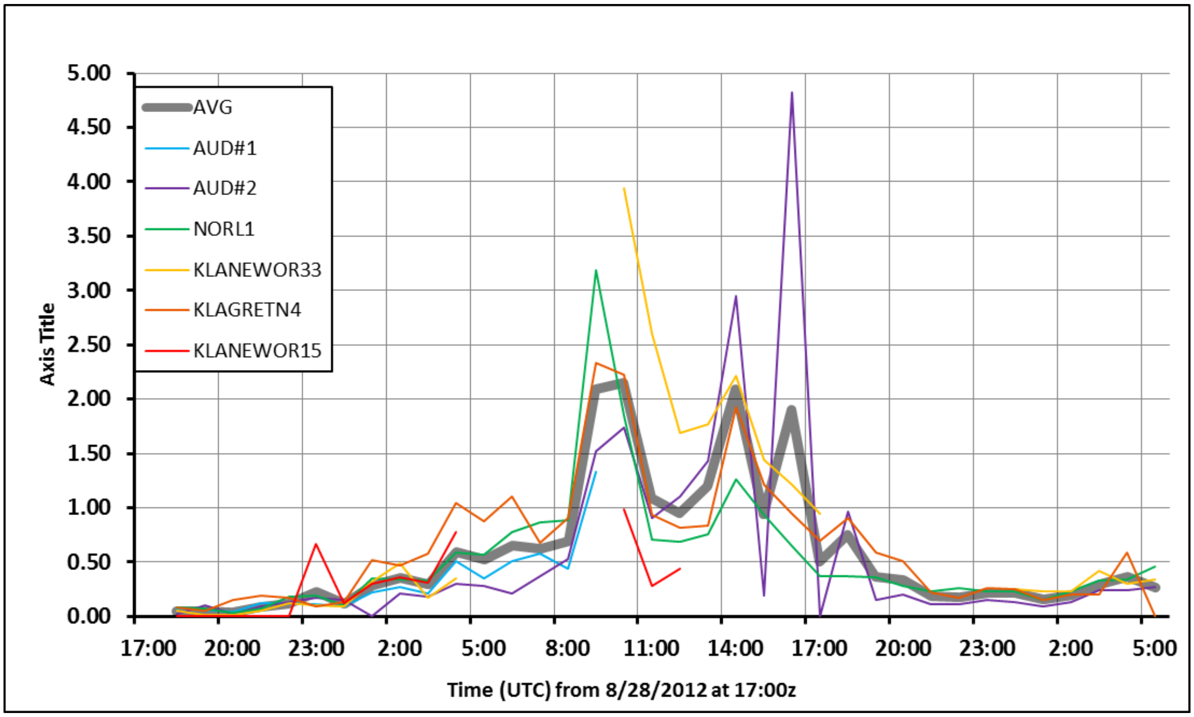

Figure 32. Hourly rainfall rates for several official and private gauging sites near Audubon Park in New Orleans. Note the large hourly jump by AUD#2; this hourly value was originally discounted, but in the context of running accumulation seems to have been related to a gauge clog. Also note the substantially lower rainfall rates reported by KLANEWOR15, located 3 blocks from AUD – this rain gauge was likely impacted significantly by nearby structures and trees, based upon information from the owner and a site visit by NWS staff.

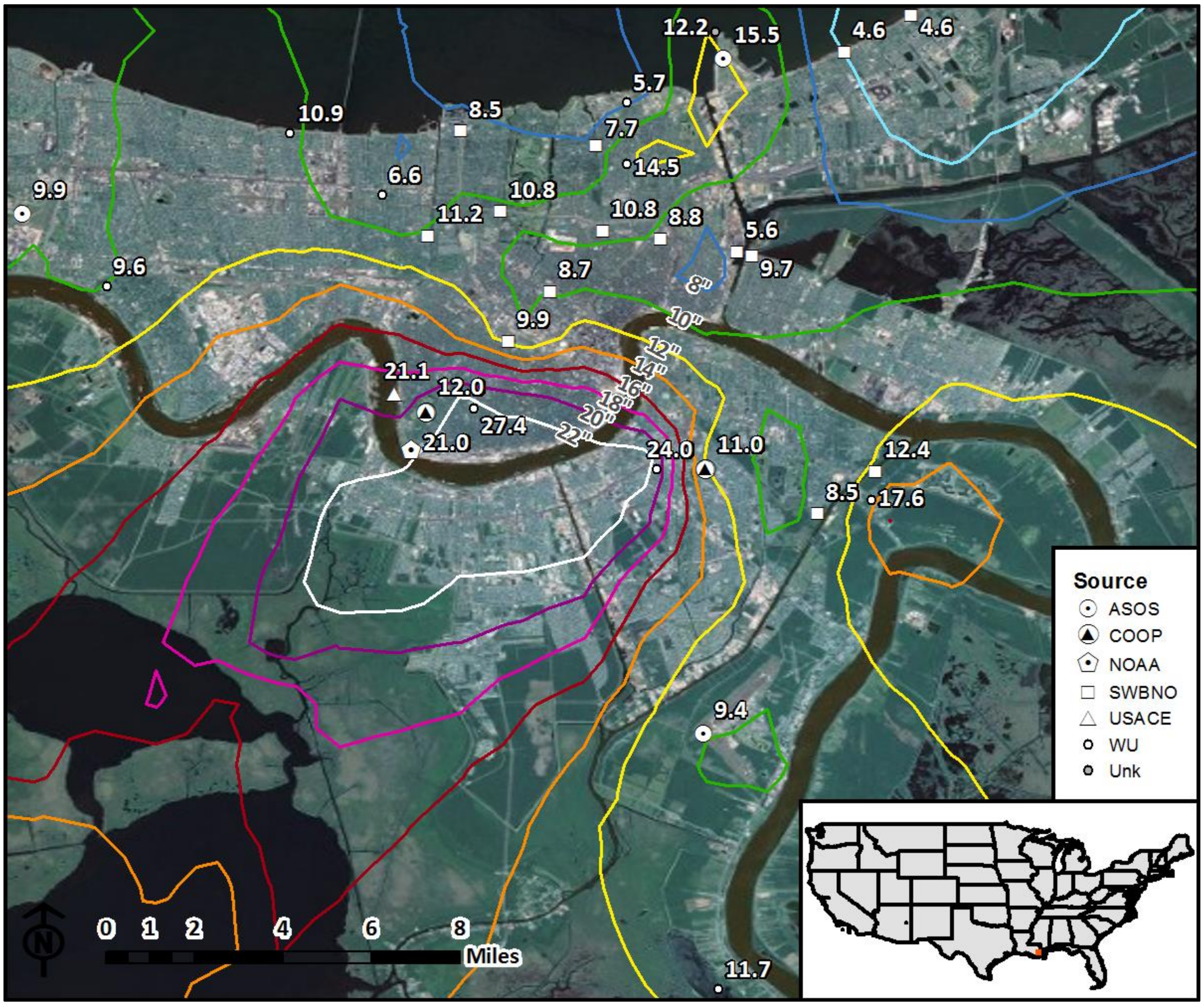

Figure 33. Storm total rainfall reported from all official and private gauges in the New Orleans area during Hurricane Isaac. Contours were produced from a Kriging interpolation of all official and private gauges. Note the particularly high values evident along the Mississippi River from roughly Gretna to Audubon Park.

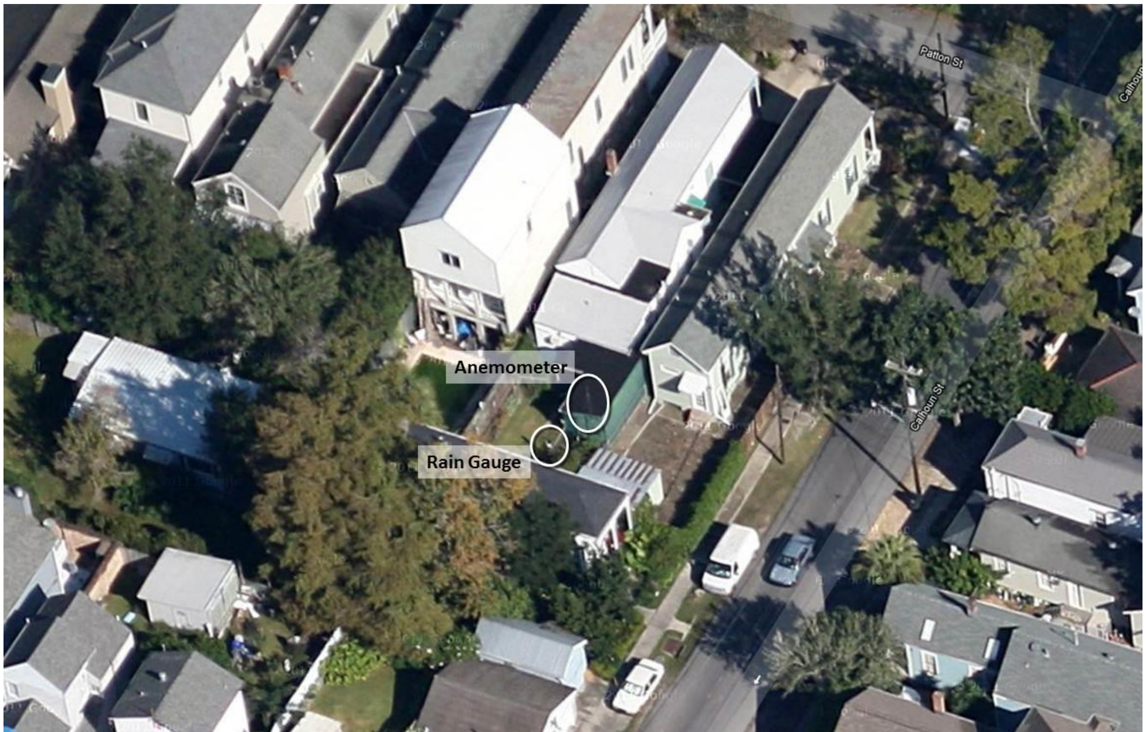

Figure 34. Aerial imagery showing location of Weather Underground PWS site KLANEWOR15 in relation to nearby trees and buildings. The predominant wind direction during the heaviest period of rainfall, roughly 3 AM-2PM on August 29th, 2012, was from the east, which likely caused an under-estimate.

Figure 35. NWS personnel W. Scott Lincoln (pictured, middle), Tim Erickson (pictured, right) and Suzanne Van Cooten visited Weather Underground PWS site KLANEWOR33 owned by Andy Brott (pictured, left) in January, 2013. The station is located on top of Brott’s residence in the Uptown Neighborhood of New Orleans. Rain gauge is the box located halfway up the pole with the anemometer on top. The station is high above almost all trees and structures in the area. Photo credit: Uptown Messenger.

Appendix D: Data mining of the Weather Underground Raingauge Network

As discussed in Appendix C, private weather station data can be very valuable in responding to and analyzing extreme events such as Hurricane Isaac. However, the collection of the data can be very manpower intensive and time consuming even though it is readily available via the internet.

In the summer of 2013, the process of collecting rain gauge data one station at a time was automated using a Python scripting language routine. The method is described below. Thanks are due to Weather Underground for providing access to their internal data listing the location of each PWS in their network.

- Via the Weather Underground website, collect the names/identifiers of each PWS on a "state-scale" basis.
- Using the accessibility to the internal data, collect the latitude and longitude coordinates for each station. This enables the data to be georeferenced using Geographic Information System (GIS) software.
- Define the area of interest (AOI) for the given storm event and, using the GIS functionality, collect the names of the PWSs within that area.
- Using the list of PWSs in the AOI, collect the corresponding daily rainfall amount from the internet for the time-frame of interest (the script must be re-run for each day). The "day" is defined as 12Z to 12Z; if data is missing an error code is generated.

This script can save significant amounts time in the data collection process. As a test of the script, data was collected for all 30,000+ stations across the continental United States -- the process took over 15 hours. While this seems like a significant amount of time, the labor involved in doing the data collection by hand would take many, many, many times as long. In general, an AOI for a given event will probably involve a County Warning Area, or at most a

River Forecast Office area of responsibility. For the 160 stations referenced in Appendix C, the data collection process takes a matter of minutes. Additionally, the data is recorded electronically and can be readily merged back into the GIS processing framework.