National Weather Service Flood Surveys & Post-Event Analysis of Hurricane Isaac

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After the substantial impact to the United States East Coast from Hurricane Sandy, Hurricane Isaac may become the forgotten hurricane of 2012. With its above average size and slow forward motion, Isaac produced higher storm surge than typically seen by a storm of its wind category, and also dropped notably heavy rainfall across portions of southeast Louisiana and south Mississippi. Over a four day period from August 28th to August 31st, rainfall totals ranged from 10-15 inches across most of the area, with a few areas seeing more than 20 inches. This significant rainfall caused flooding of numerous rivers in the forecast area of the National Weather Service (NWS) Lower Mississippi River Forecast Center, especially areas within the county warning area of the New Orleans/Baton Rouge Weather Forecast Office. Because of the rare nature of the event, a team composed of NWS staff from multiple offices was assembled to record the impacts, survey flood crests when necessary, and discuss the event with local residents. Post-event flood surveys were conducted over a number of days in early September, 2012, particularly across the Wolf, Tchoutacabouffa, Biloxi, and Escatawpa River watersheds in Mississippi and the Tangipahoa River watershed in Louisiana. A vast amount of observations, anecdotal data, and recommendations were collected by the survey teams and summarized in a report for the River Forecast Center and the Weather Forecast Office. Flooding of numerous locations was of a magnitude seen only on very rare occasions and may have been the worst flooding yet-experienced by numerous long term residents. Luckily, due to the sparse population density in most of the river floodplain areas, impacts were not as severe as would typically be expected. Findings from the post-event flood surveys and analysis of data from numerous sources will be presented to further our understanding of Isaac's hydrologic impact.

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 highlights some of the findings of the survey teams and discusses post-event analysis of collected data. The full, detailed technical report based upon the Hurricane Isaac flood surveys can be found on the NWS LMRFC website (http://www.weather.gov/lmrfc).

Track and Forecast Overview

Hurricane Isaac became the ninth tropical depression of the 2012 hurricane season about 715 miles east of the Leeward Islands on Tuesday, August 21. By daybreak Sunday, August 26, the National Hurricane Center (NHC) noted that several computer models 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. 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. 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.

By Monday, August 27, numerical weather models had locked 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. It was also noted that Isaac would slow in its forward speed and take a turn to the northwest on Tuesday. Isaac eventually became a marginal category 1 hurricane near the time of landfall, but remained almost stationary near the Louisiana coastline through the day on Wednesday and Thursday (August 29th and 30th). The forward motion began to increase by 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. Over the course of just two days, forecast landfall locations ranged from near Panama City, FL, in the east to near the mouth of the Mississippi River, in the west (Figure 2). Final landfall was just to the west of this range.

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.

Post-flood Timeline

Data gathering and data analysis for Hurricane Isaac took a substantial amount of time to complete. The following is a brief overview survey and analysis activities:

- September 5th-8th, 2012: The National Weather Service (NWS) Lower Mississippi River Forecast Center (LMRFC) coordinated flood survey teams
    - Document impacts
    - Discuss forecast services with customers/partners
    - Surveys occurred from September 5th-8th, 2012
- September-December, 2012: Survey note compilation and analysis
    - Summarizing notes
    - GIS analysis
- January 2013: Report delivered to New Orleans Weather Forecast Office (WFO)
    - Summary compiled into 90+ page report including 5 appendices
    - Findings, lessons learned, future action items
- January 2013: New Orleans rain gauge site visit
- June 2013: Finalized coordination of crests with USGS
- September 2013: Collaboration with Sewerage and Water Board of New Orleans (SWB-NO)

Flood Survey Summary

Most survey notes were hand written and provided varying detail of observed impacts. This is due to surveys being conducted by numerous different persons independently at the same time, each with different opinions of information to include, and each with different handwriting styles. It was decided that the easiest way to compile and visualize this information was to digitize the locations and plot the notes on a map (Figure 3) using the Google Maps editor. The map was shared with everyone who participated in the surveys and allowed for additional information to be added or edited.

It was made apparent that significant flooding had occurred in many areas, with possible record flooding occurring along the Wolf River in Mississippi. Two river forecast locations without automated gauge information did not have any gauge readings near the time of crest. It was determined that those locations would need to have crests estimated to maintain the data period of record. The following sections highlight the flooding along the Wolf River and the Tchoutacabouffa River, where crests had to be estimated.

Wolf River

Flood surveys for the Wolf River watershed were conducted by the NWS teams over a several day period from September 5th to 7th, 2012. A map of the Wolf River watershed is shown in Figure 4.

Widespread bent and snapped trees/brush were observed in the floodplain near the MS26 bridge. 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. Information from the EM office and local media suggested that this flooding was at the Wolf River bridge.

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 5). 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.

Flooding of a small camp near the river off of Go Go Rd moved a camper about 100 yards 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.

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.

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.

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.

Widespread bent trees/brush were observed in the floodplain near the Cable Bridge Rd bridge (Figure 6). Evidence suggested that water reached within 1.0-3.0 ft of the bridge deck and did not inundate the road.

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 7).

Widespread bent brush and trees were observed 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.

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 survey the mark to the staff gauge (Figure 8). 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.

USGS staff also 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). Estimated elevations from the NWS survey, the USGS survey, and anecdotal information from local residence is illustrated by Figure 9.

Tchoutacabouffa River

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 10).

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. 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 who stayed during most of the event. The resident showed the survey team where water had crested (Figure 11). 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. 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).

It was hypothesized after the survey 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 (Figure 12). NWS survey members used historical crests and the shape of the hydrograph both before and after the Hurricane Isaac flooding to estimate the crest.

Post-Event GIS Analysis

Rainfall

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 13) using the kriging geo-statistical interpolation method to enable comparisons to the other gridded estimates. 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.

The operational quantitative precipitation estimate (QPE) used by the NWS river forecast centers to forecast river stages is based upon both rain gauges and remotely-sensed radar data. This product is created by mosaicking 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 14).

When available, rainfall data from private weather station networks were retrieved and compared to the official gauges data. 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). Gridded rainfall interpolated from private gauges combined with official gauges is shown by Figure 15.

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+ inches of rainfall in a small area, with a sharp gradient down to roughly 10-15 inches a few miles away (Figure 16).

Other

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 (267) were evident in satellite imagery (Figure 17) 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.

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. Notes from the survey teams was compiled and placed on a map. Crests were estimated for river forecast locations that lacked automated gauge information. Various rainfall estimation techniques were contrasted. Data from private weather stations was also compared to data from official stations. We found that several isolated areas received very substantial rainfall amounts, including the narrow swath of 20+ inches in the New Orleans area that resulted from the eye wall of Hurricane Isaac.

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 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.

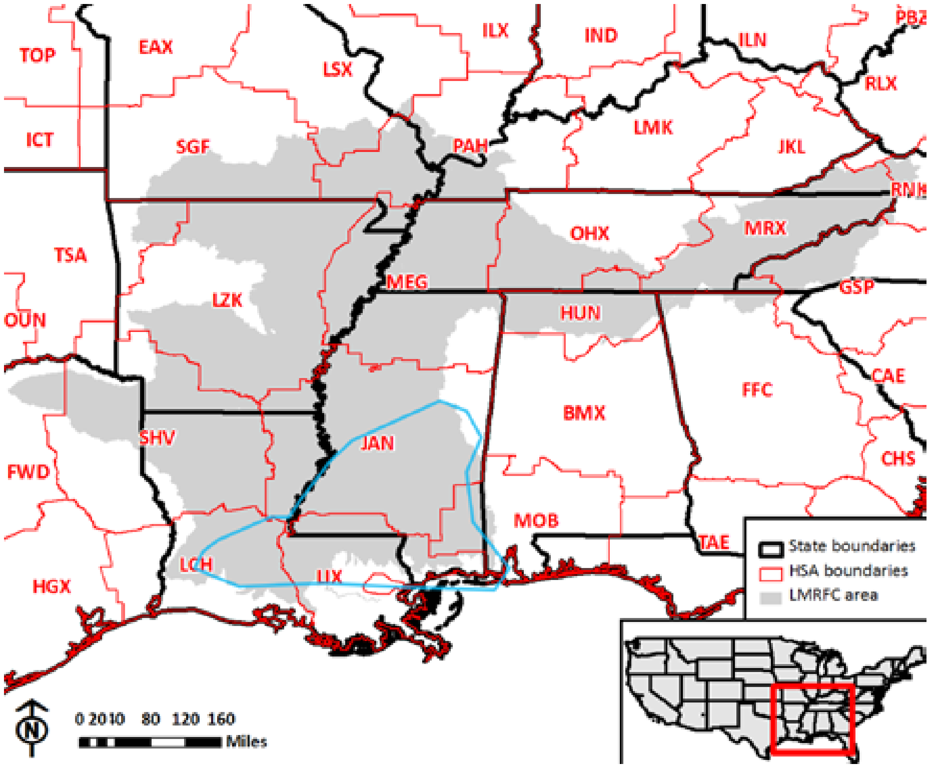

Figure 1. Map of central Gulf Coast region, with the LMRFC forecast area shaded in gray and individual NWS WFO hydrologic service areas (HSAs) delineated in red. The area of significant flooding from Hurricane Isaac - determined by locations climbing above the 90th percentile of streamflow by the USGS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

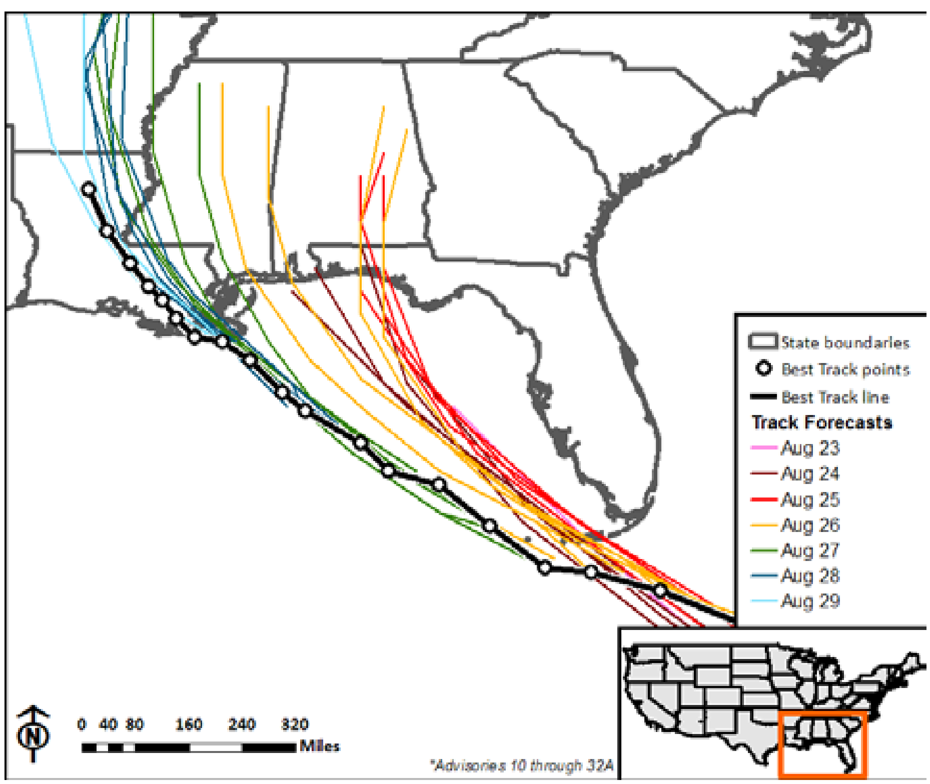

Figure 2. Five day track forecasts issued by the National Hurricane Center with the preliminary best track for Hurricane Isaac.

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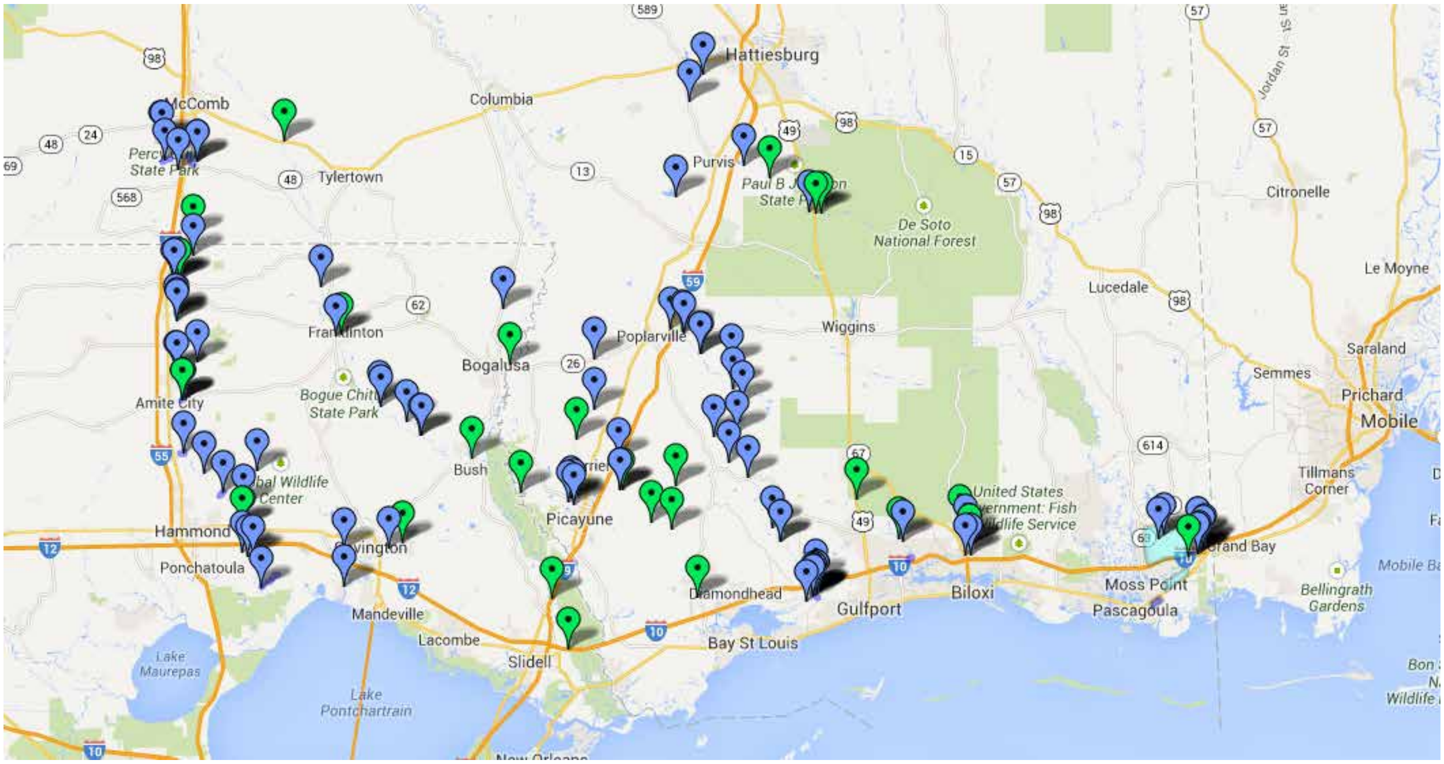

Figure 3. Digitized notes that were compiled from the NWS survey teams.

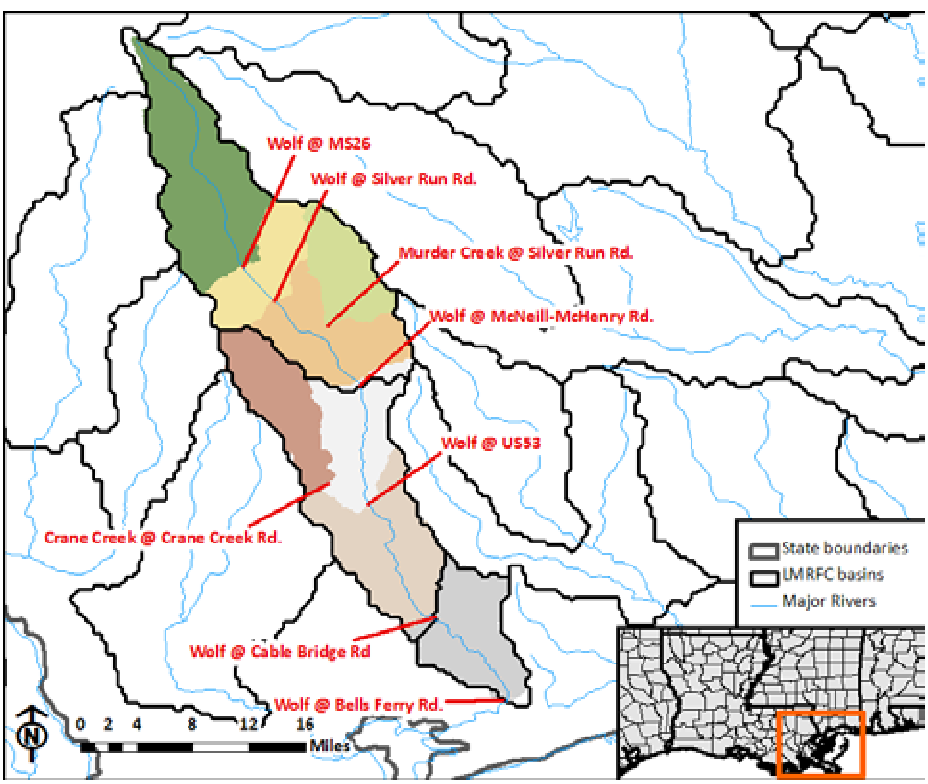

Figure 4. Wolf River subbasins as defined by locations surveyed by the post-storm survey teams. Subbasins defined by the current model configuration of LMRFC are also indicated for comparison.

Figure 5. Guardrails on downstream side of the Silver Run Rd. bridge showing evidence of scouring.

Figure 6. Downstream view from Cable Bridge Rd. Widespread damage to trees and brush were noted.

Figure 7. 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.

Figure 8. This 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.

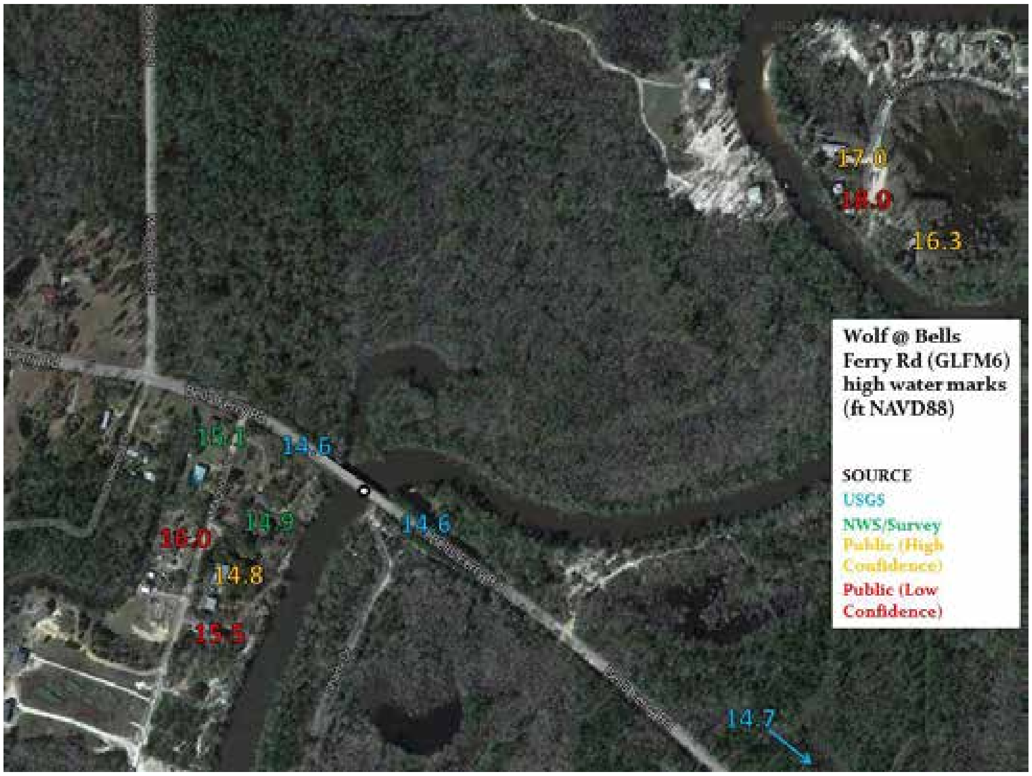

Figure 9. High water marks near the Wolf River at Bells Ferry Rd (GLFM6) gauge color-coded by confidence level. High water marks were adjusted to NAVD88 based upon the assumed staff gauge datum of -1.0 ft NAVD88.

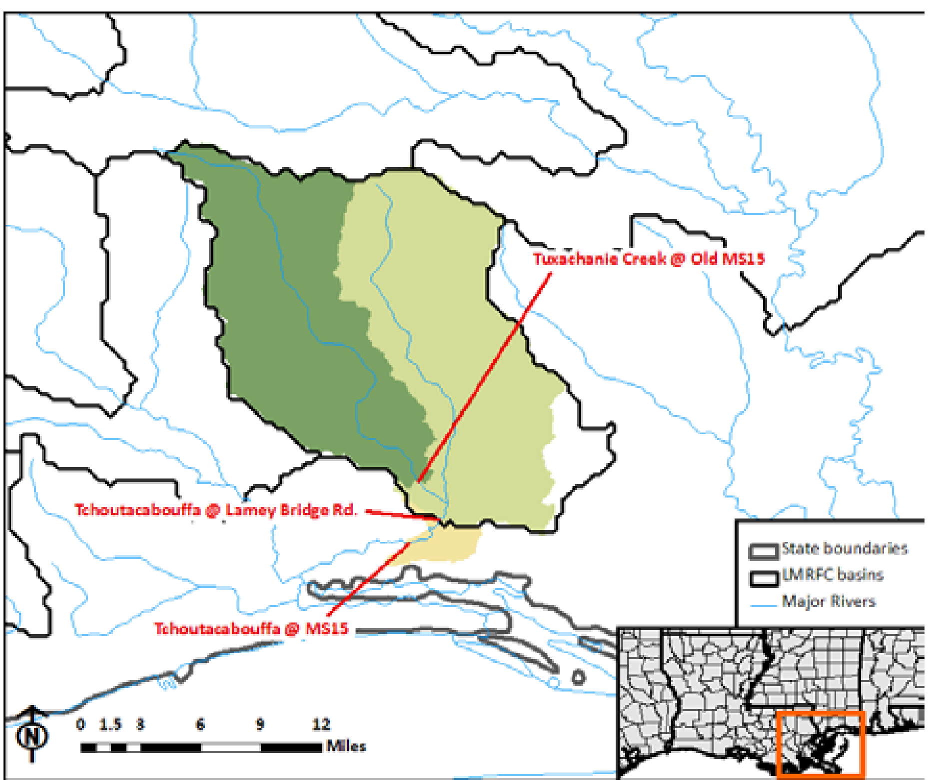

Figure 10. Biloxi River subbasins as defined by locations surveyed by the post-storm survey teams. Subbasins defined by the current model configuration of LMRFC are also indicated for comparison.

Figure 11. Flooding from the Tchoutacabouffa River caused substantial scouring to the cut bank behind the Riverbend Cove Apartments just off Lamey Bridge Rd. A resident (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).

Figure 12. High water marks near the Tchoutacabouffa River at Lamey Bridge Rd (DIBM6).

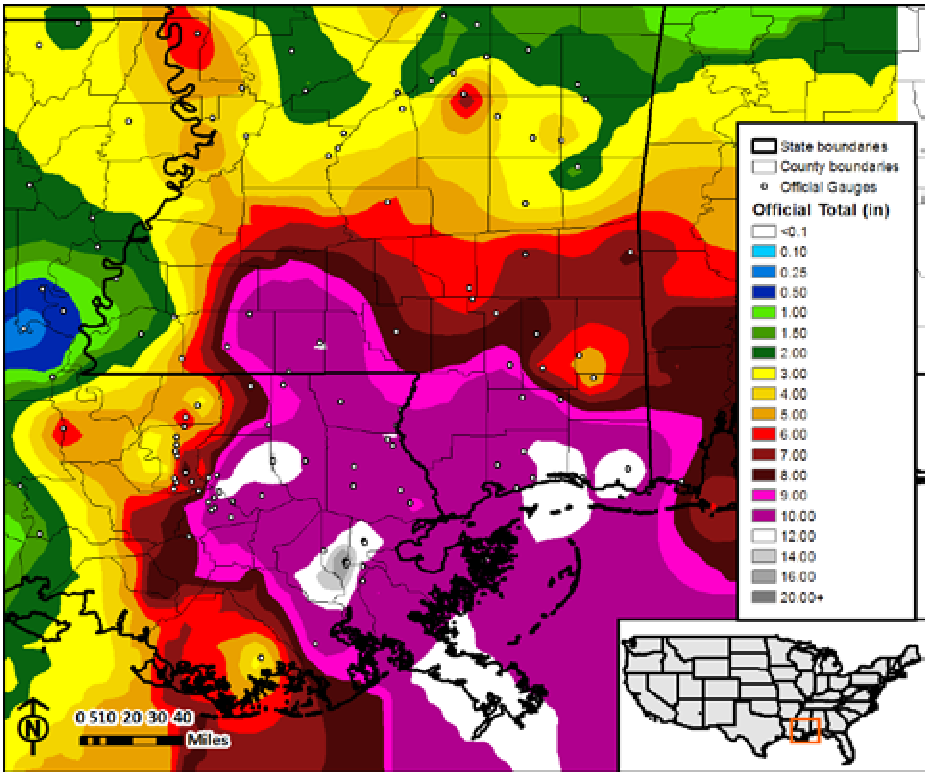

Figure 13. Storm total rainfall as observed by official precipitation gauges. Observations were interpolated by the Kriging method.

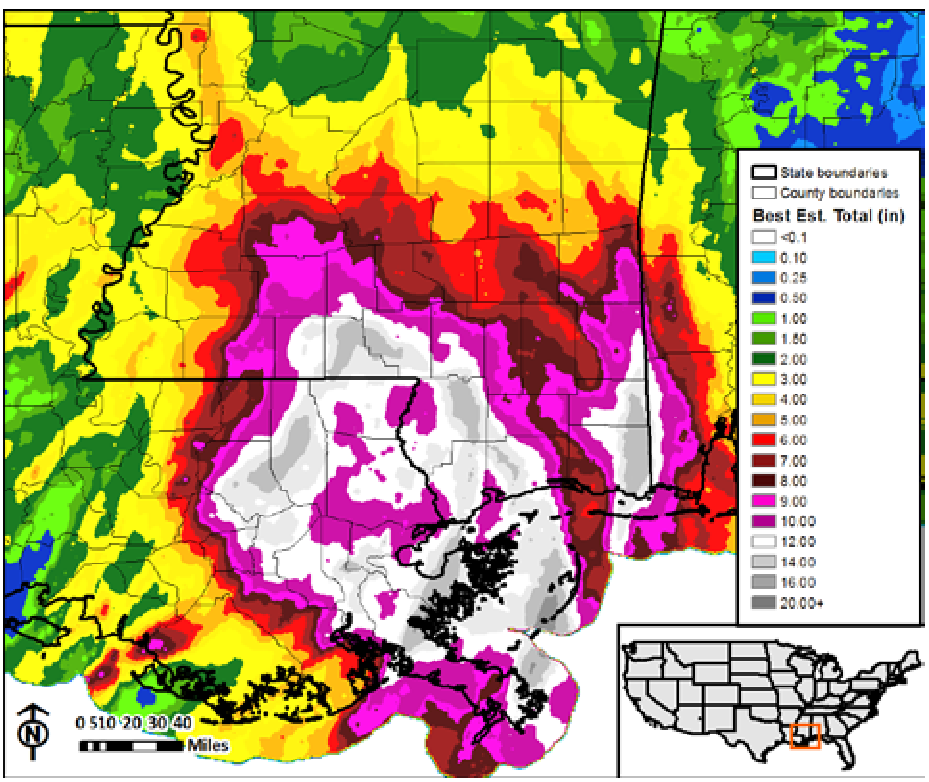

Figure 14. Storm total rainfall as estimated by a combination of official gauges, radar data, and forecaster experience in the NWS RFC QPE product.

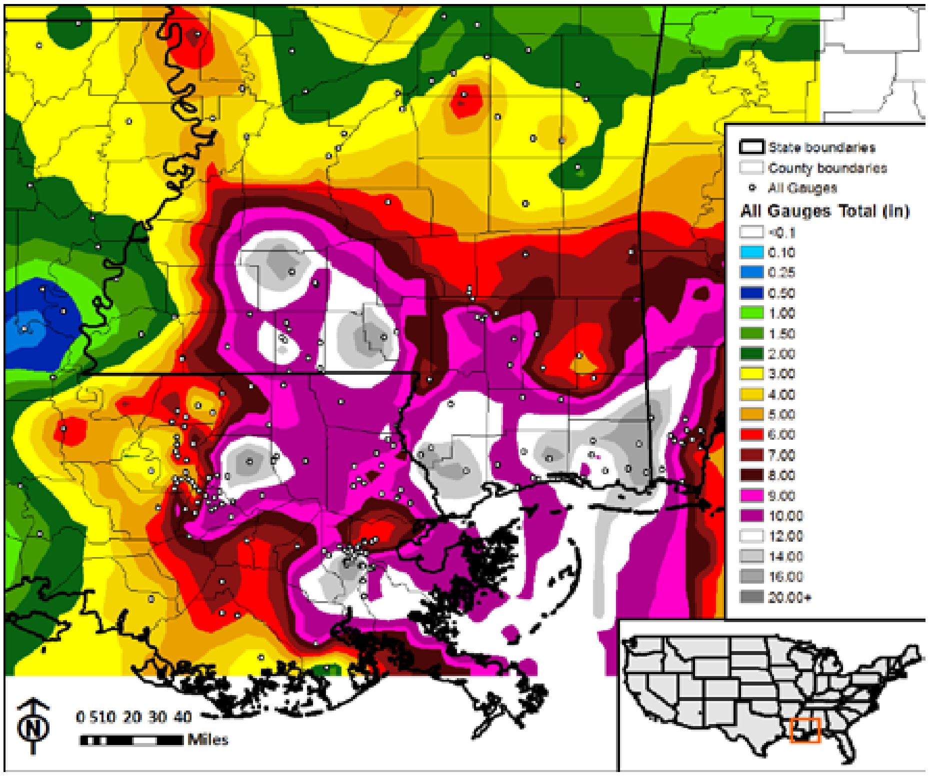

Figure 15. Storm total rainfall as estimated from a combination of official and QCed private weather stations. Observations were interpolated by the Kriging method.

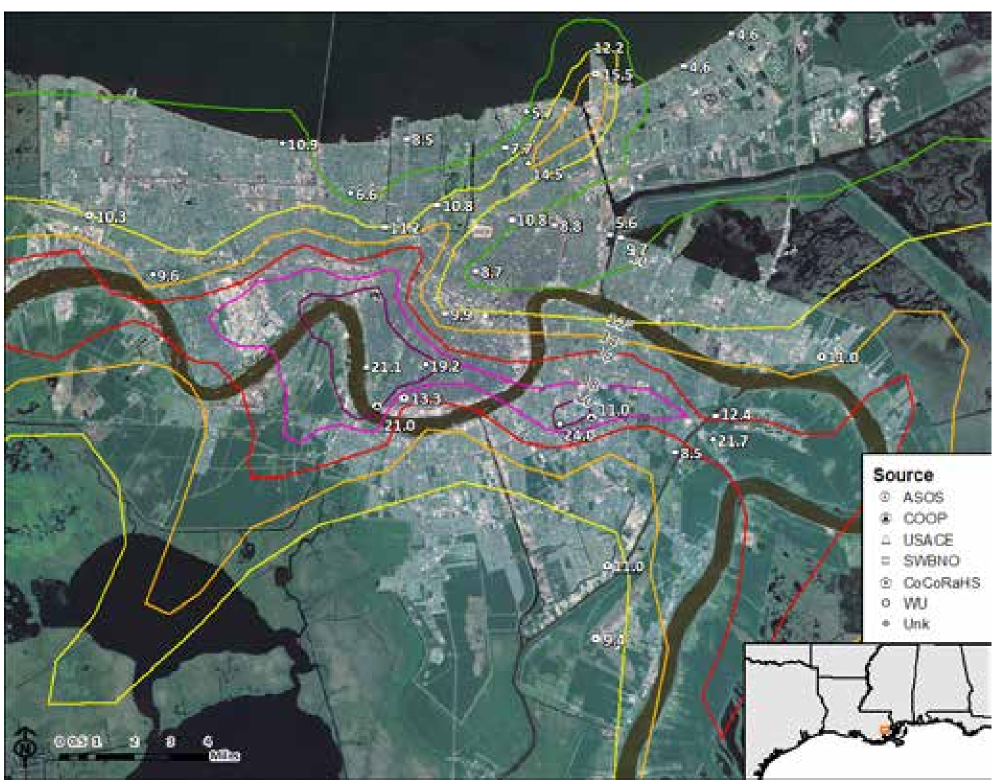

Figure 16. Storm total rainfall reported from all official and private gauges in the New Orleans area during Hurricane Isaac. Contours were produced from a Kriging interpolation of all official and private gauges. Note the particularly high values evident along the Mississippi River from roughly Gretna to Audubon Park.

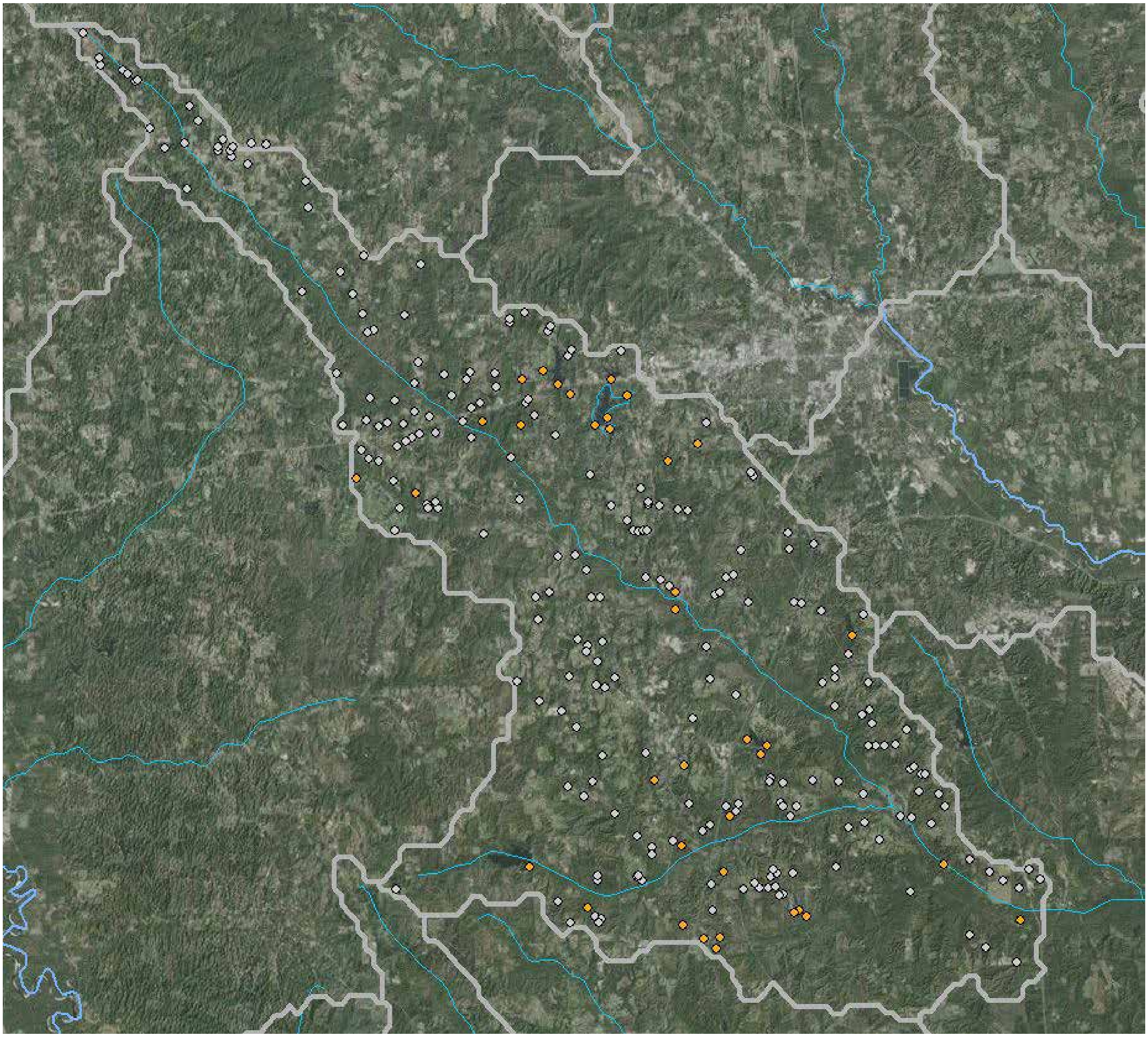

Figure 17. Map of the Black Creek at Brooklyn (BKNM6) subbasin with known dams (yellow) and manually identified dams from satellite imagery (white) added for reference.