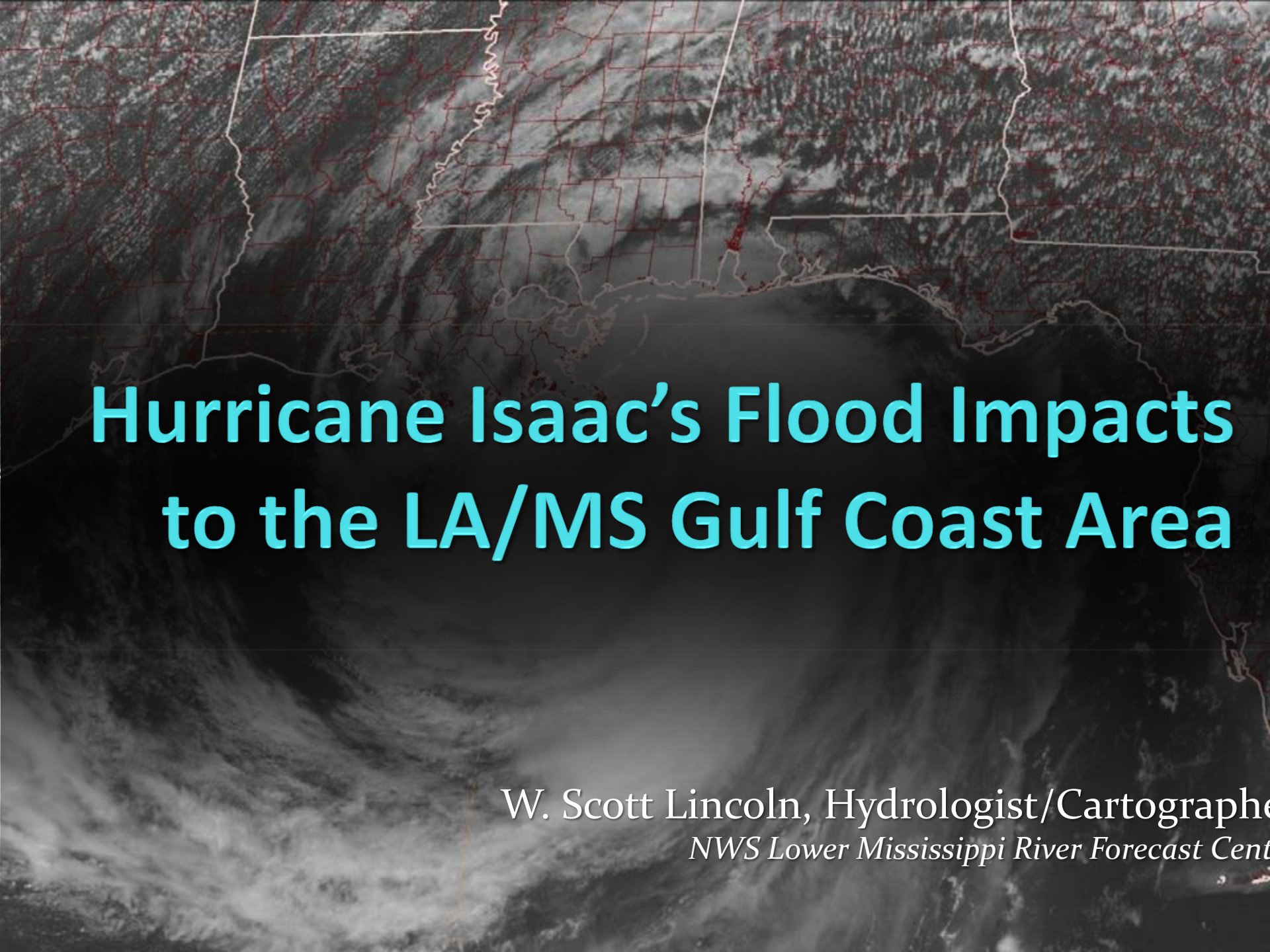


Hurricane Isaac's Flood Impacts to the LA/MS Gulf Coast Area

W. Scott Lincoln, Hydrologist/Cartographe
NWS Lower Mississippi River Forecast Cent

Introduction

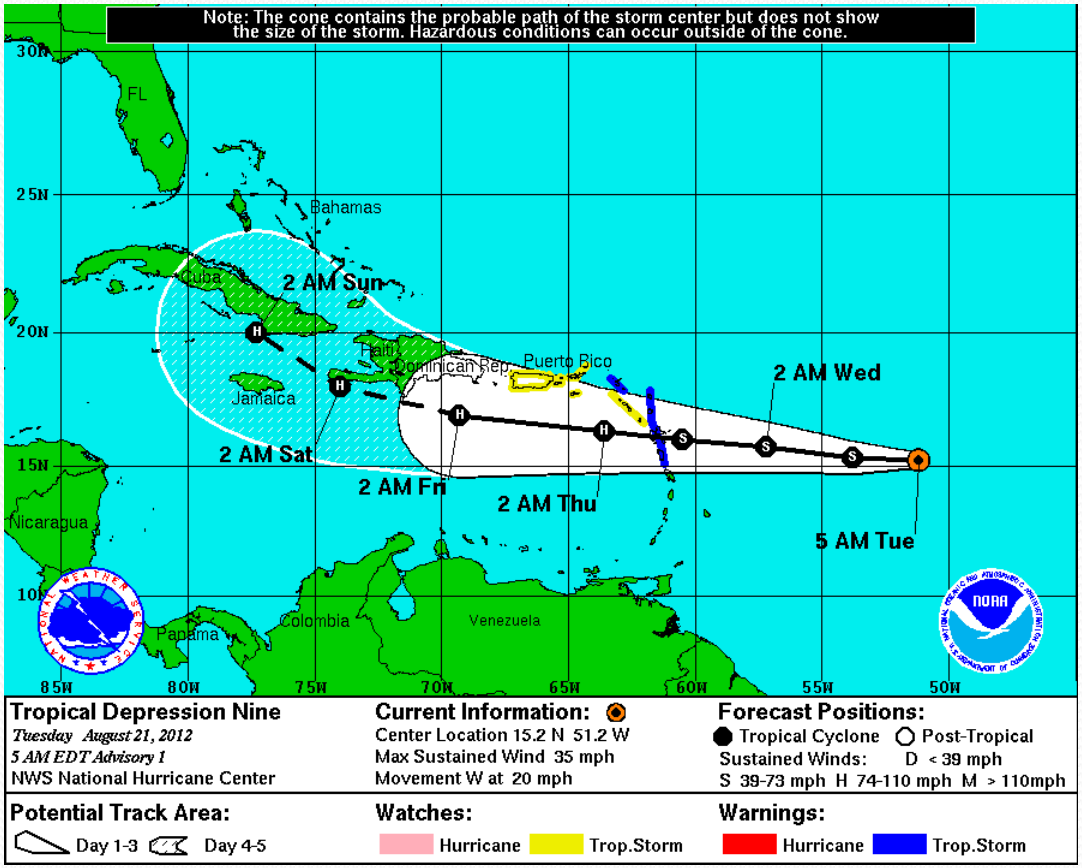
- Hurricane Isaac affected central Gulf Coast August 28th-31st, 2012
- Very slow moving
- Storm surge and heavy rainfall impacts
- Numerous flood crests of moderate and major severity
- A few new records

Outline

- Storm Timeline
  - Pre-Landfall
  - Landfall
  - Post-Landfall
- Storm surveys
- Follow-up Analyses

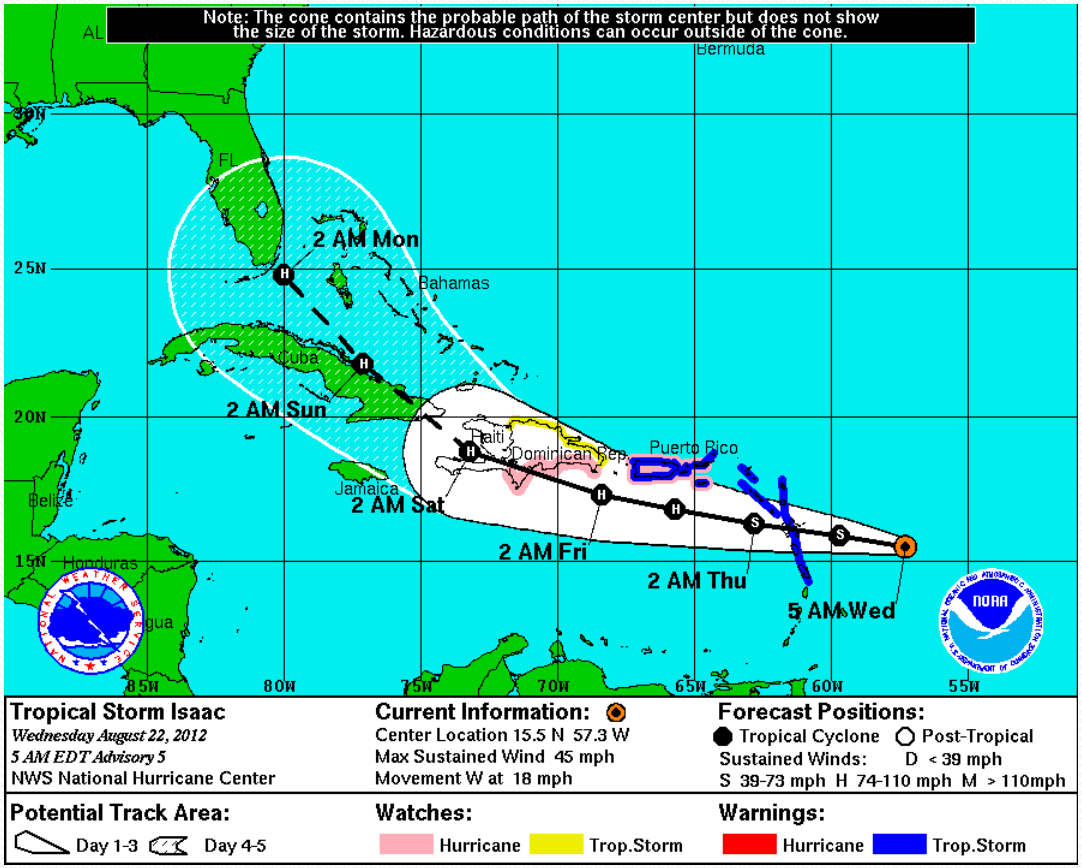
Hurricane Isaac: Pre-Landfall

Pre-Isaac Forecasts



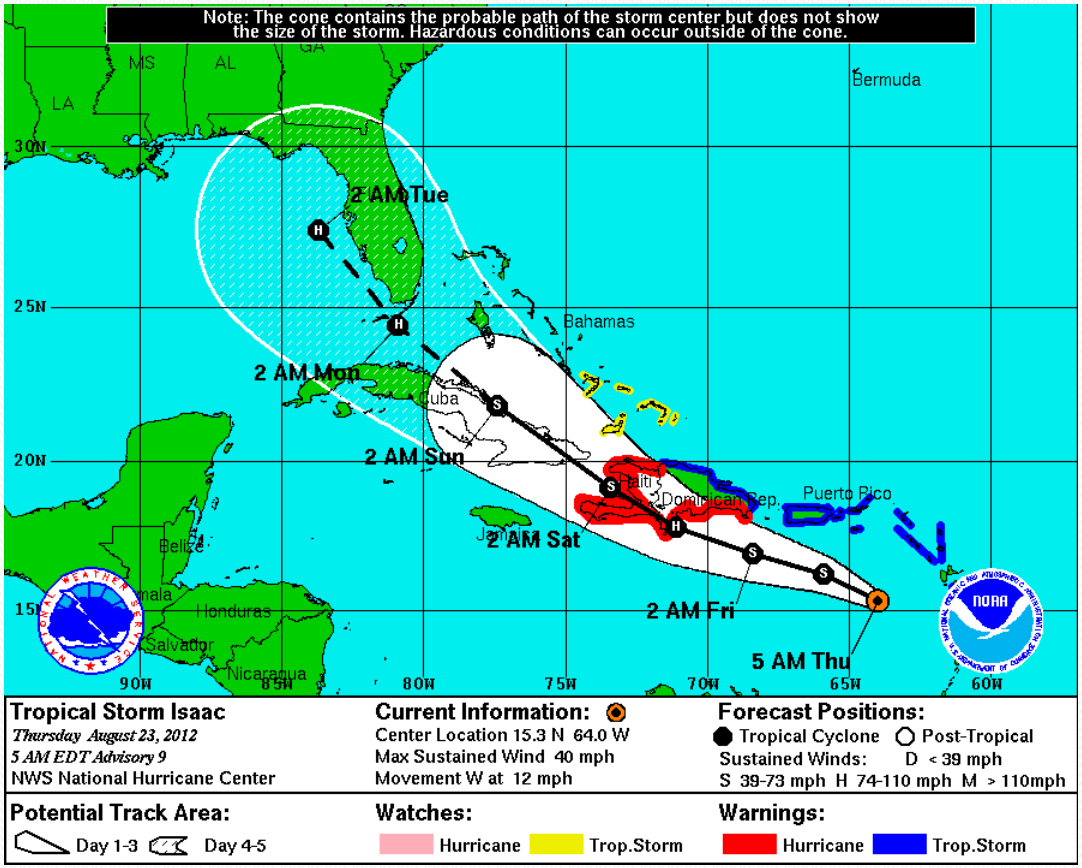
- Tuesday, August 21 4AM CDT
- T.D. 9 forms

Pre-Isaac Forecasts



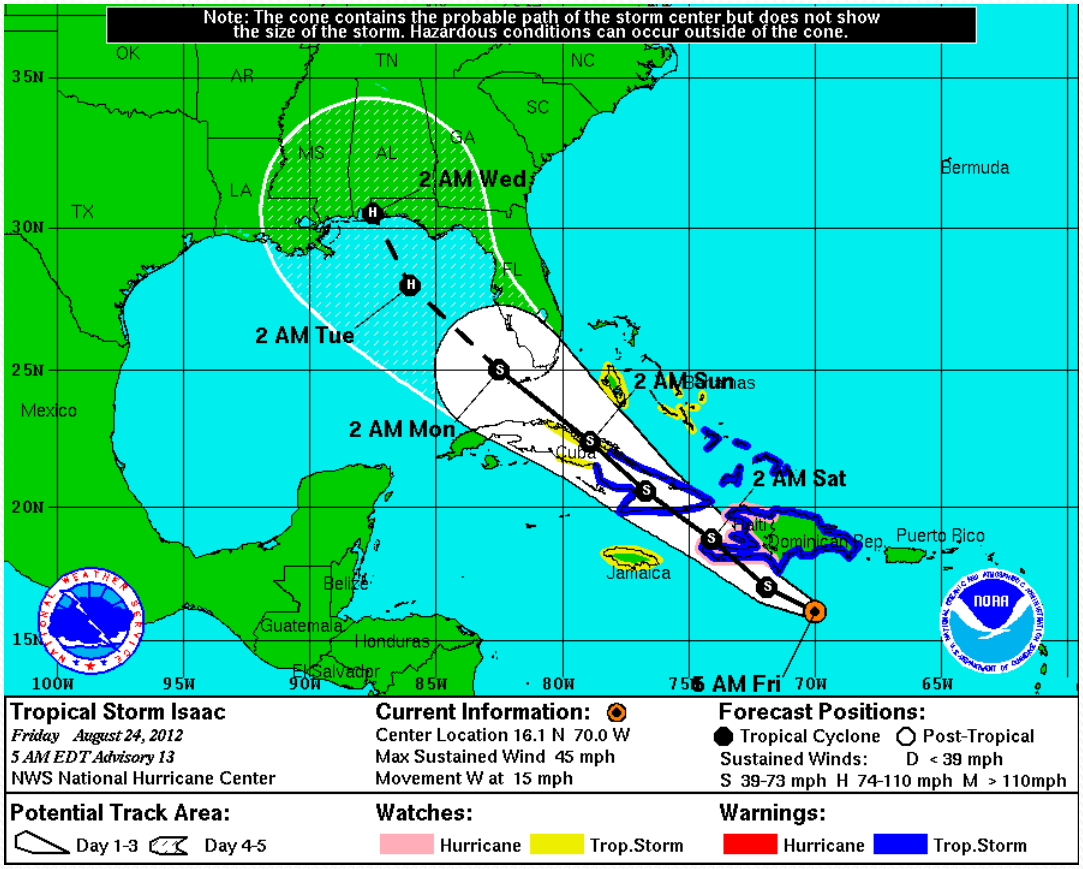
- Wednesday, August 22 4AM CDT
- Upgraded to T.S. as of 4PM CDT Tuesday

Pre-Isaac Forecasts



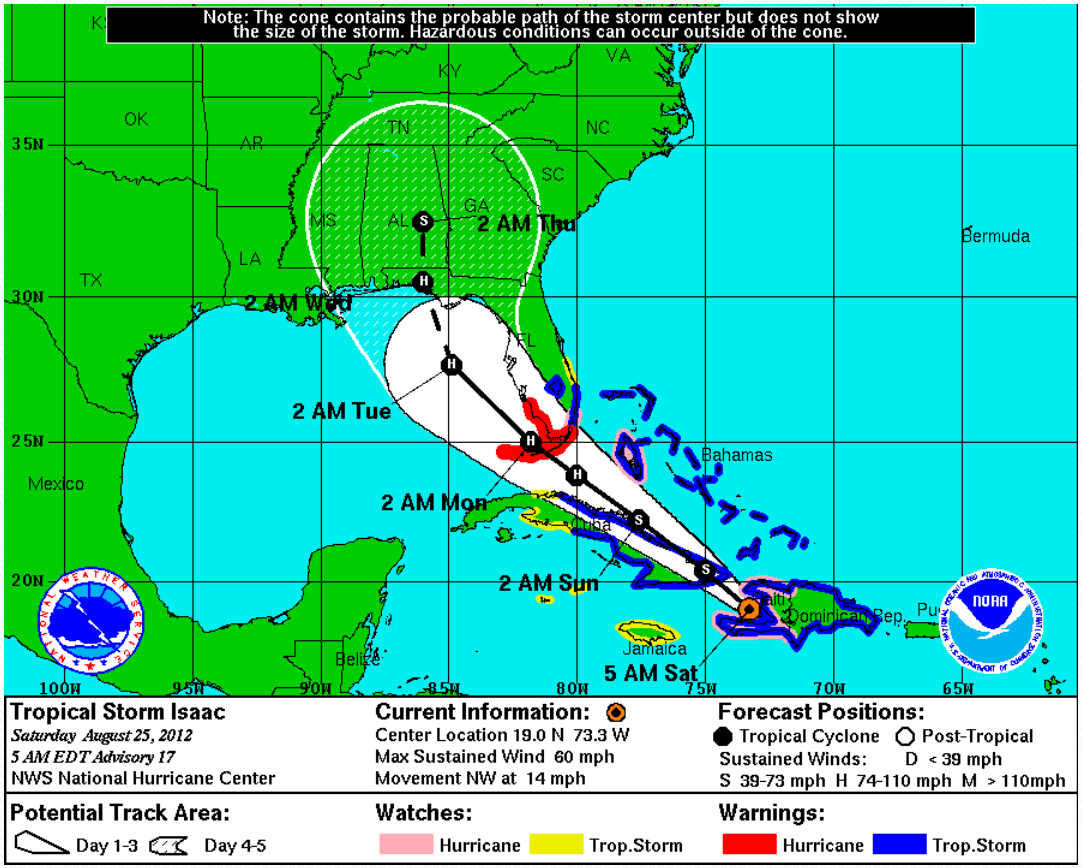
- Thursday, August 23 4AM CDT

Pre-Isaac Forecasts



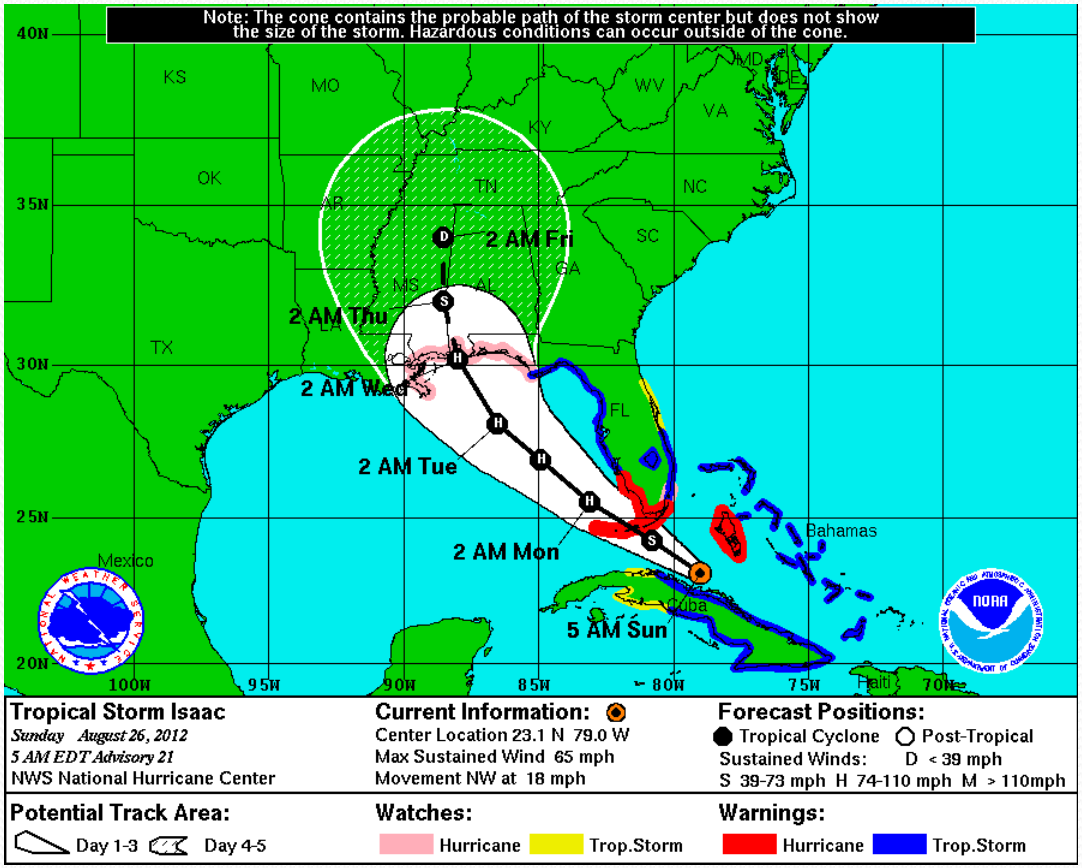
- Friday, August 24 4AM CDT

Pre-Isaac Forecasts



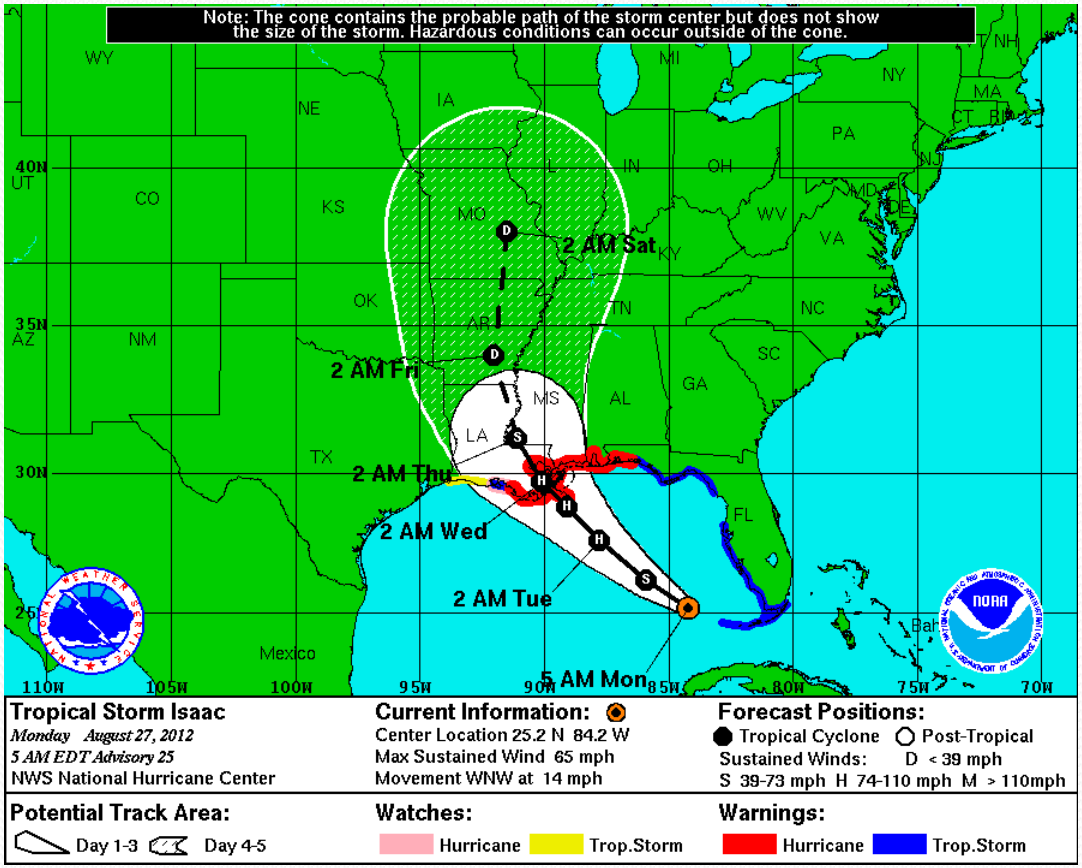
- Saturday, August 25 4AM CDT

Pre-Isaac Forecasts



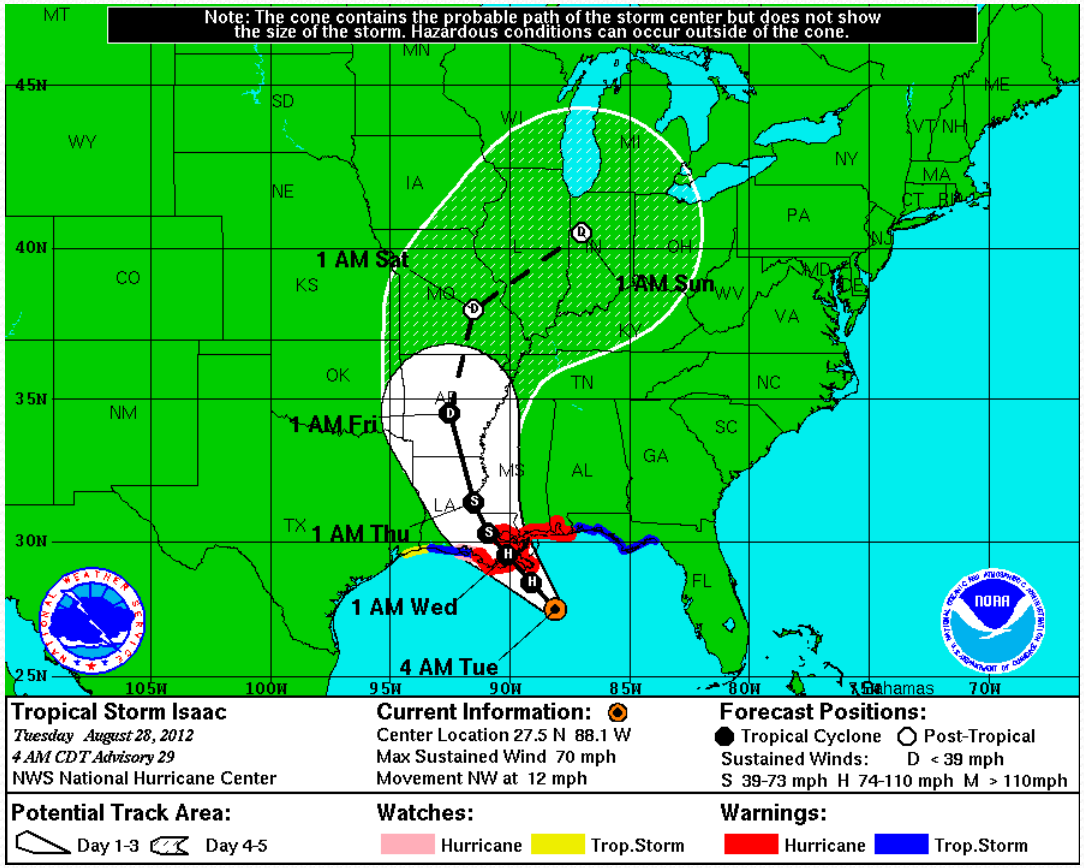
- Sunday, August 26 4AM CDT

Pre-Isaac Forecasts



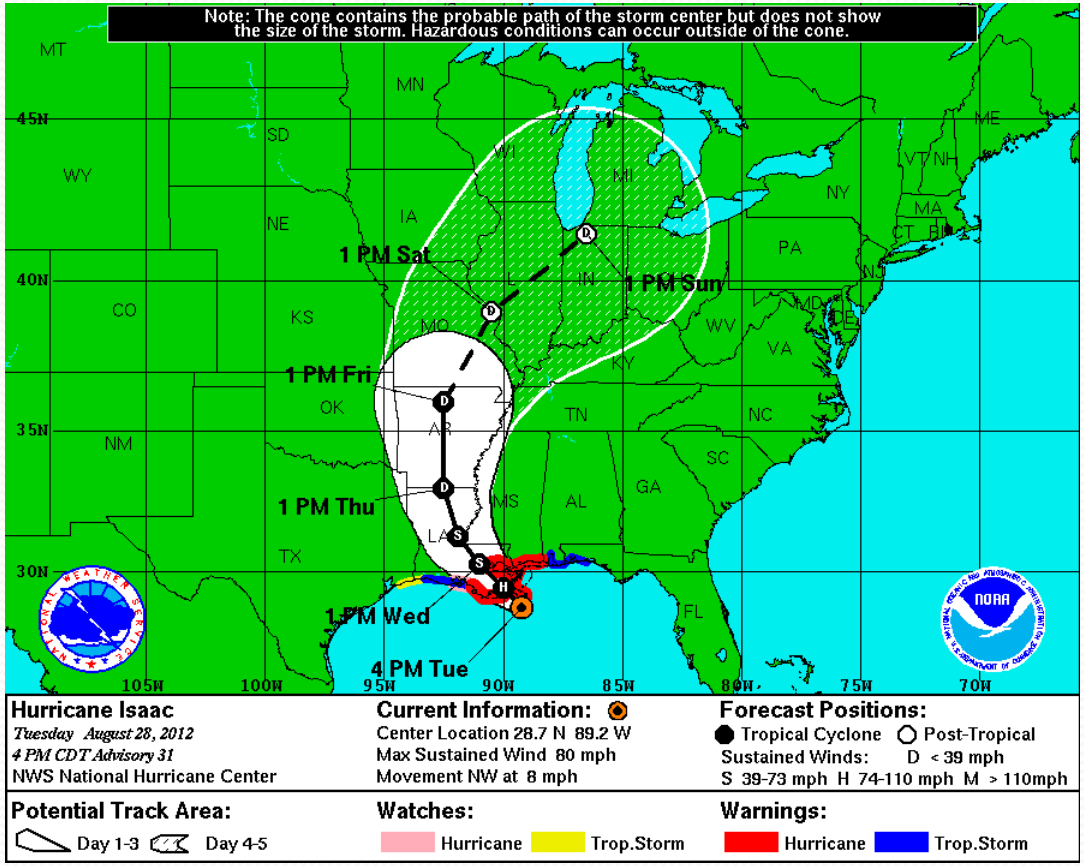
- Monday, August 27 4AM CDT

Pre-Isaac Forecasts



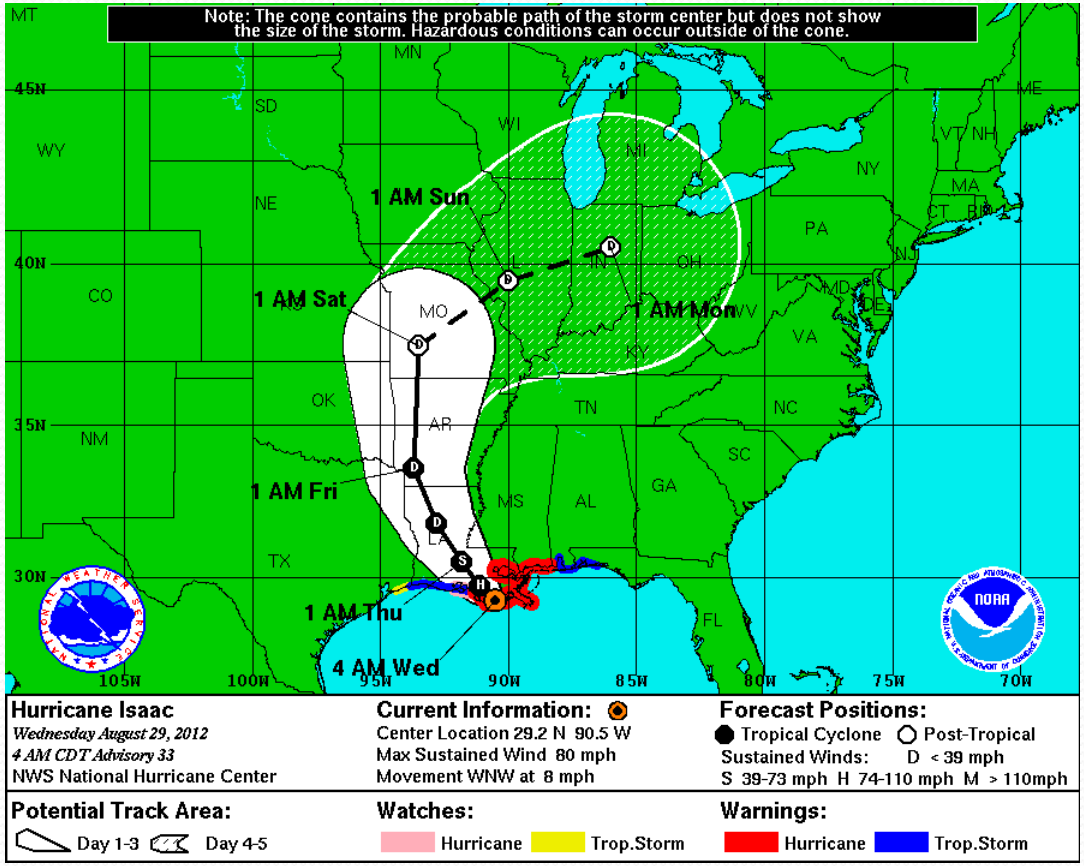
- Tuesday, August 28 4AM CDT

Pre-Isaac Forecasts



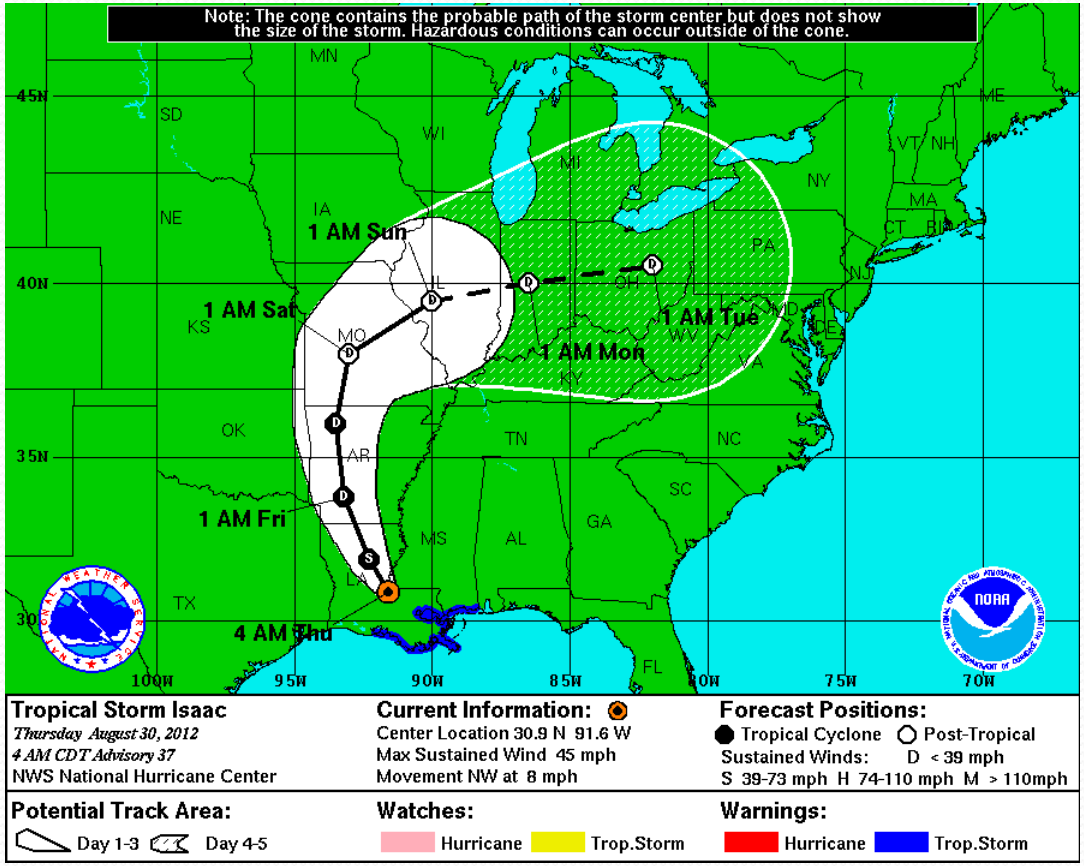
- Tuesday, August 28 4PM CDT
- Upgraded to hurricane as of 1PM Tuesday
- First landfall

Pre-Isaac Forecasts



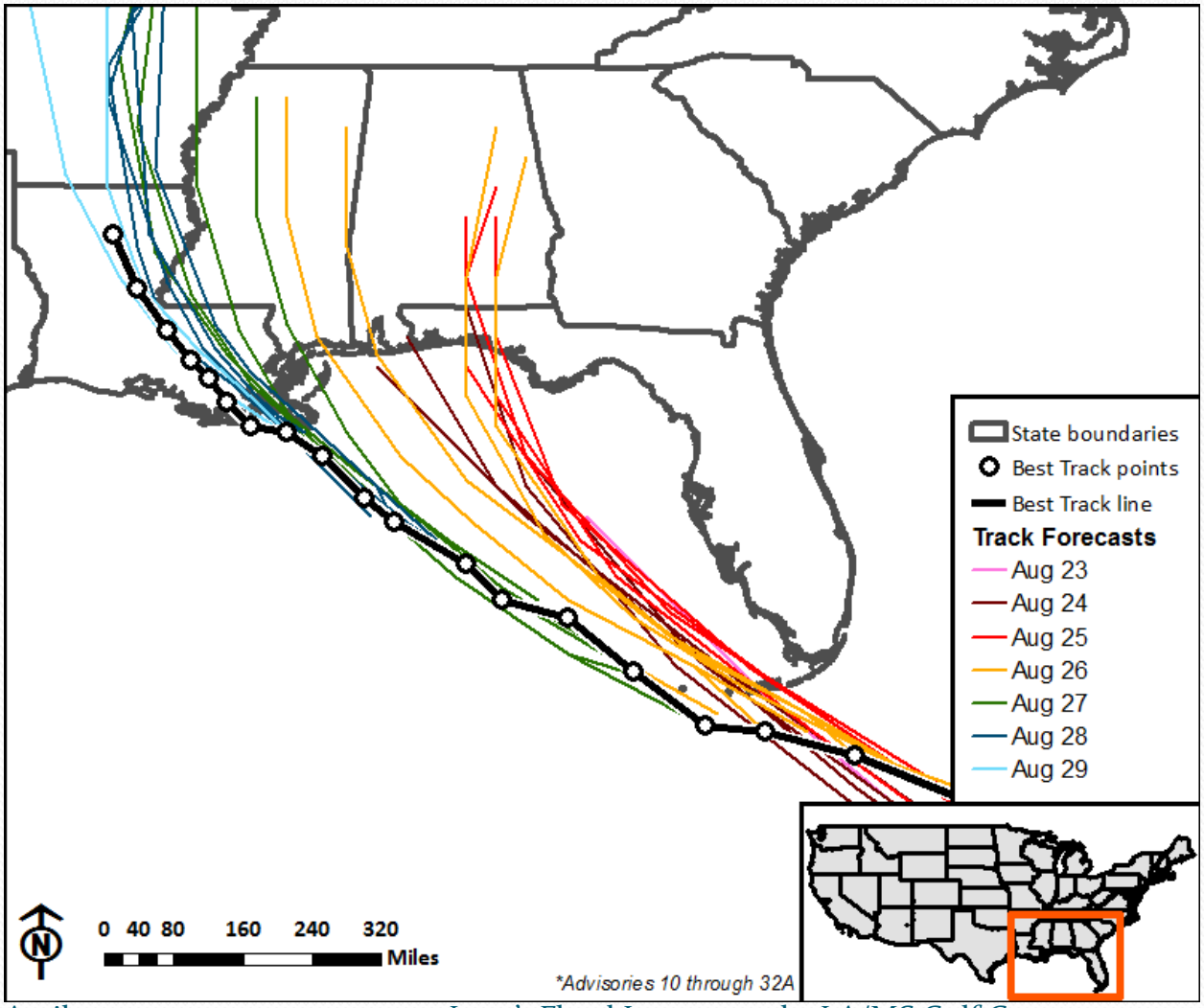
- Wednesday, August 29 4AM CDT
- Second landfall

Pre-Isaac Forecasts



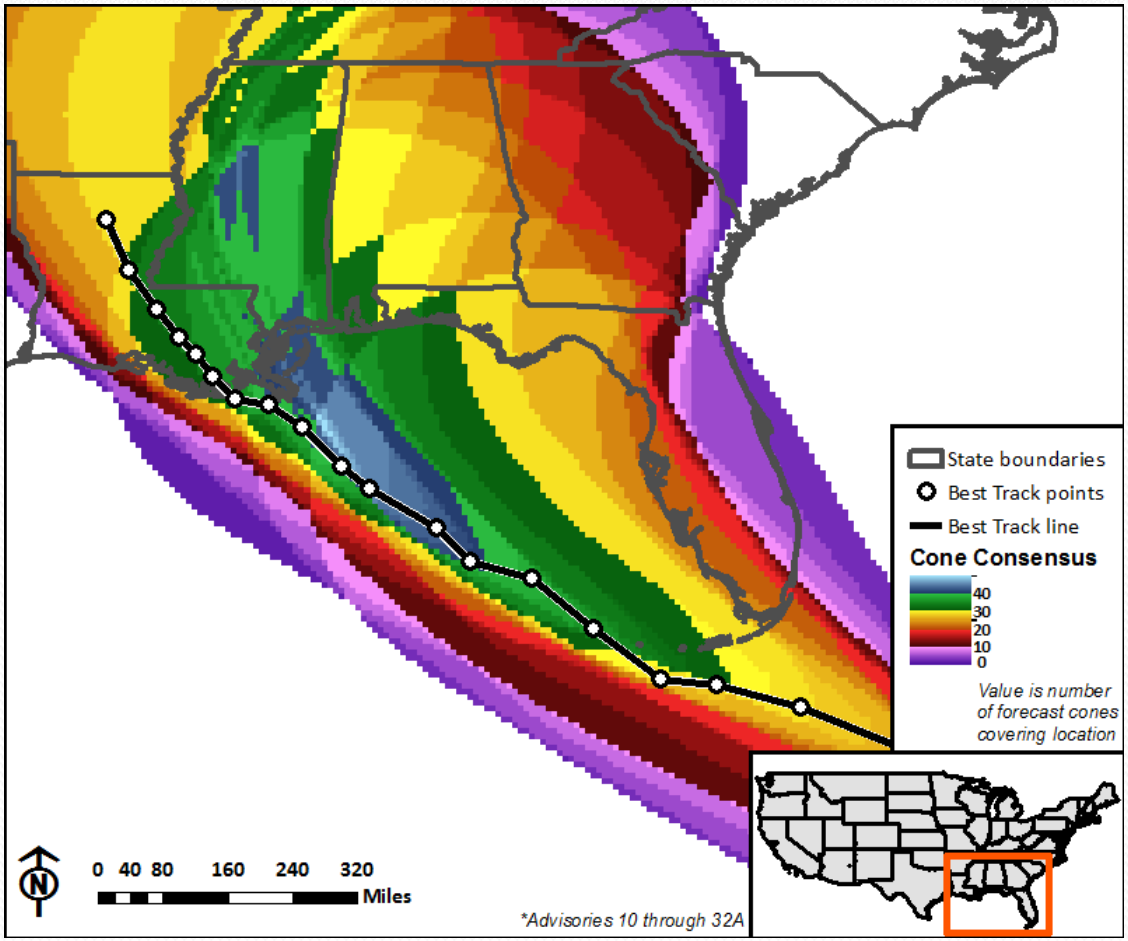
- Thursday, August 30 4AM CDT
- Downgraded to T.S. as of 2PM Wednesday

Pre-Isaac Forecasts



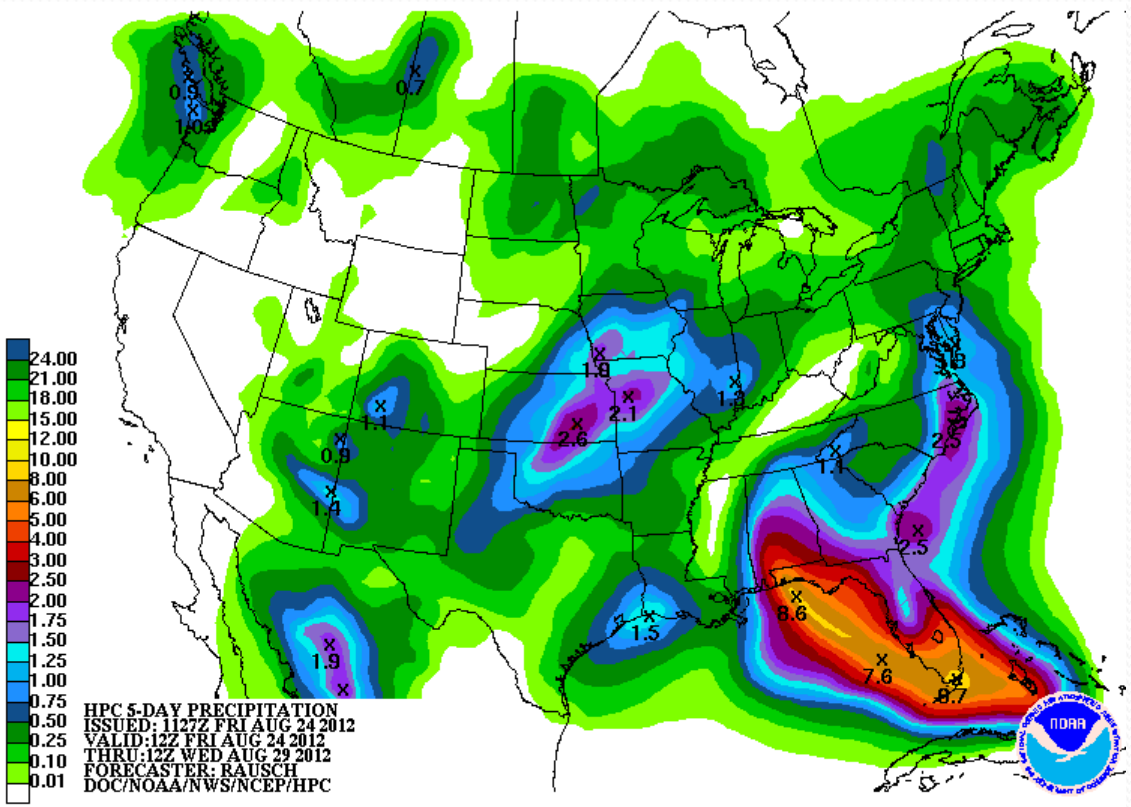
- Center of track forecasts from Aug 23-29 compared with final NHC "best track"

Pre-Isaac Forecasts



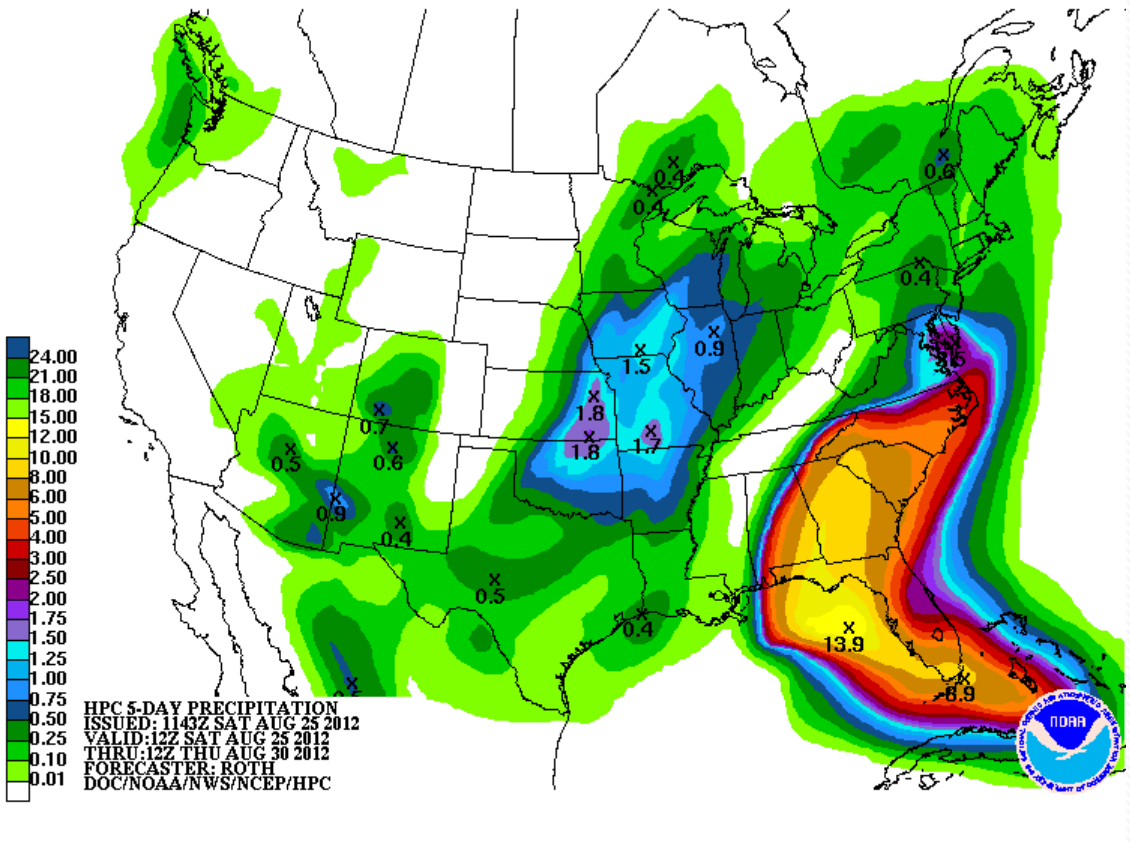
- Consensus of forecast cones Aug 23-29

Pre-Isaac Forecasts



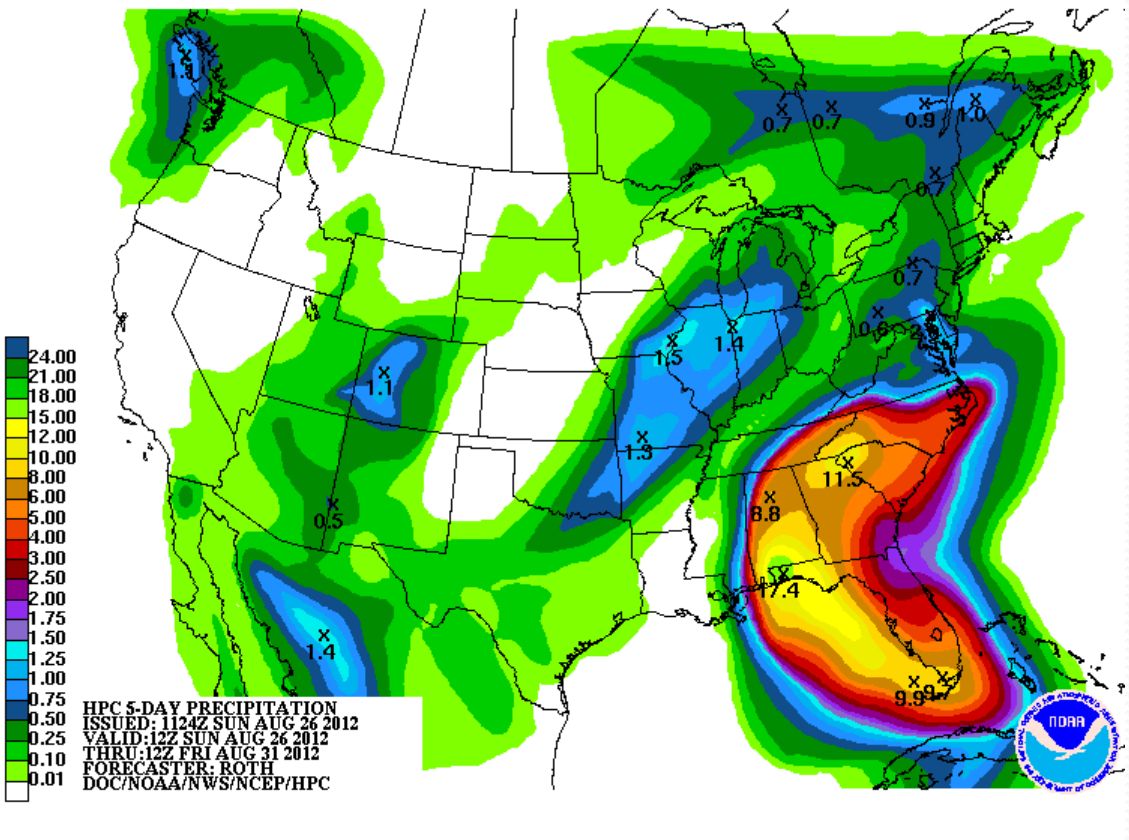
- 5-day rainfall (QPF) forecast
- Issued Friday, August 24th 7AM
- Highlights Florida landfall
- <0.5in across coastal LA/MS

Pre-Isaac Forecasts



- 5-day rainfall (QPF) forecast
- Issued Saturday, August 25th 7AM
- Increased totals
- ~0.oin across coastal LA/MS

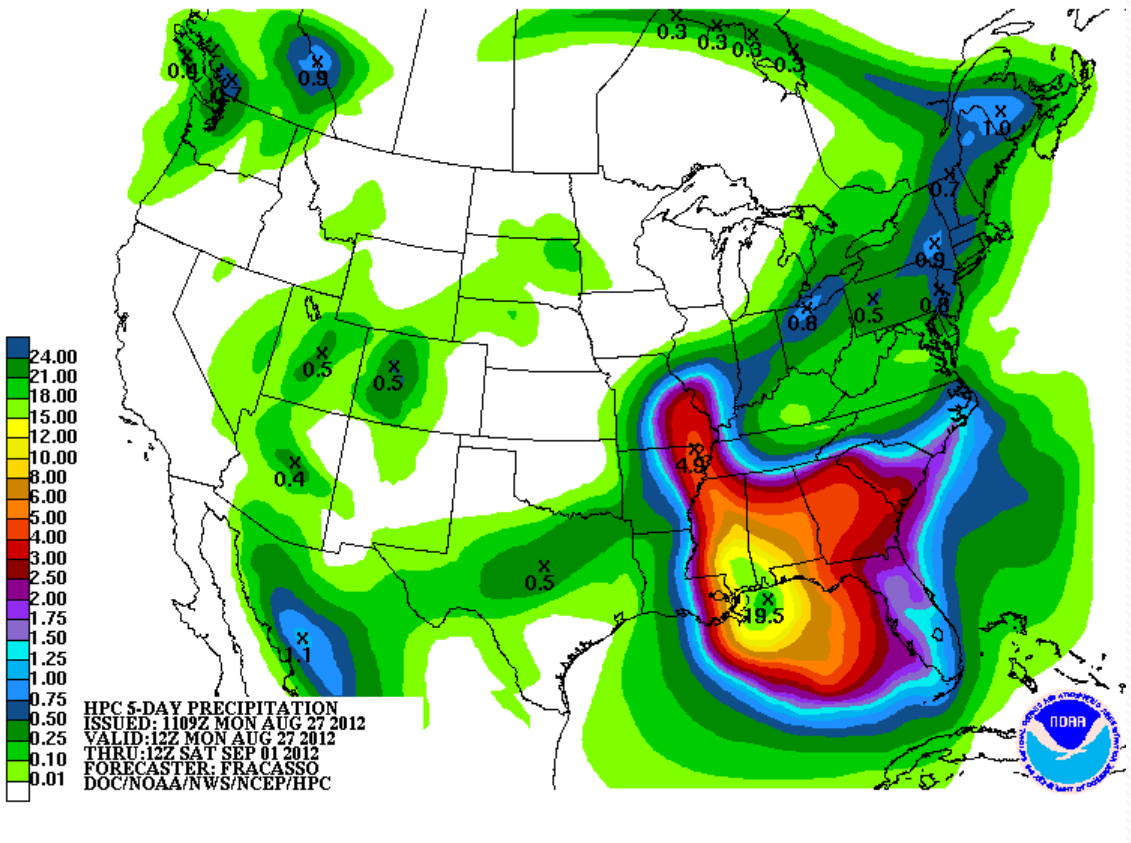
Pre-Isaac Forecasts



- 5-day rainfall (QPF) forecast
- Issued Sunday, August 26th 7AM

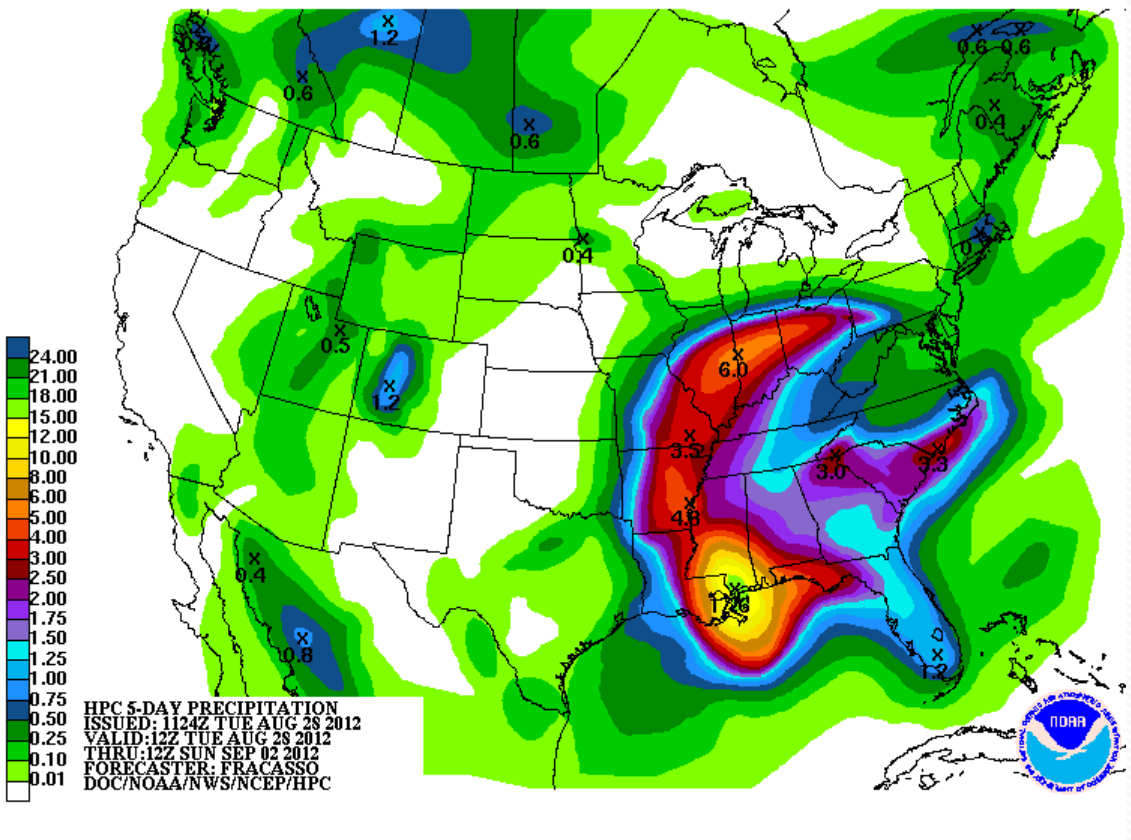
- Increased totals
- Higher amounts now into coastal MS with sharp gradient

Pre-Isaac Forecasts



- 5-day rainfall (QPF) forecast
- Issued Monday, August 27th 7AM
- Very high maxima just offshore, with >15.0in forecasted in MS
- Sharp gradient into LA

Pre-Isaac Forecasts



- 5-day rainfall (QPF) forecast
- Issued Tuesday, August 28th 7AM
- Slight westward adjustment
- Final forecast before heavy rain bands begin impacting coast

Pre-Isaac Forecasts

- Forecast track became much closer to observed landfall by evening August 27th

- Once track forecast was more accurate, storm surge forecast accuracy also improved
  - Official forecasts indicated up to 9ft storm tide in Lake Pontchartrain and Lake Borgne by late August 27th

Pre-Isaac Forecasts

- First bands of Isaac reached coast by August 28th

- Official storm tide forecasts for Lake Borgne now 10-12ft
- Northern Lake Pontchartrain now nearing 10ft
- Southern Lake Pontchartrain now nearing 10ft

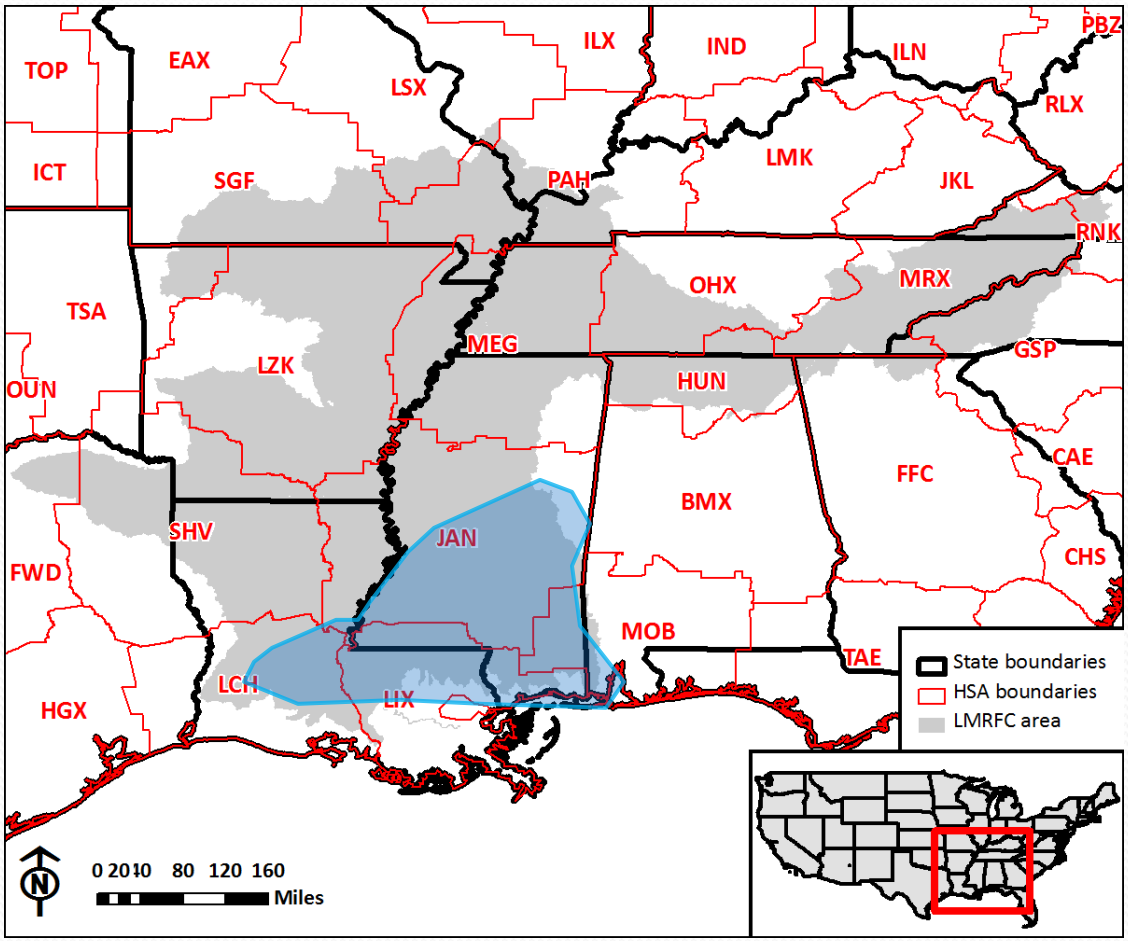
- Experimental ADCIRC runs indicated areas outside federal hurricane protection levees (Braithwaite, La Place) flooding (midday Aug 28 model runs)

Hurricane Isaac: Landfall

Isaac Landfall

- Significant flood impacts observed across numerous counties/parishes during and right after landfall
- Major flooding forecasted for several rivers due to rainfall
- Loss of some manual gauge readings due to high water levels
- Some areas farther (waterway distance) from the coast took several days to crest and recede from surge
- Surge evident on Mississippi River as far upstream as Red River Landing (~300 river miles).

Isaac Landfall



- Area of most significant flooding impacts
- Defined by streamflow above USGS 90th percentile

Hurricane Isaac: Post-Landfall

Post-Isaac Timeline

- 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
  - Addressing concerns and action items
  - GIS analysis

Post-Isaac Timeline

- January 2013: Report delivered to New Orleans Weather Forecast Office (WFO)
  - Summary compiled into 90+ page report including 5 appendeces
  - 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 (SWBNO)

Hurricane Isaac: Post-Landfall Flood Surveys

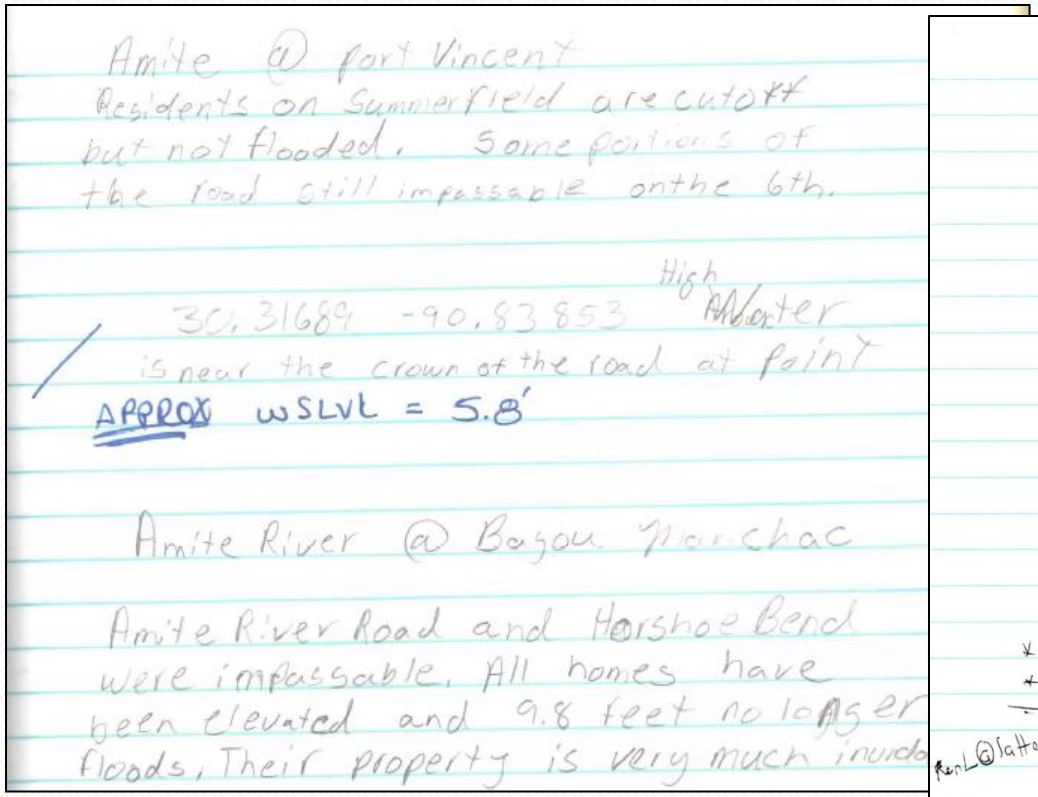
Post-Isaac Flood Surveys

- Survey Team:
  - Dr. Suzanne Van Cooten, Hydrologist-in-Charge, NWS Lower Mississippi River Forecast Center
  - Jeffrey Graschel, Service Coordination Hydrologist, NWS Lower Mississippi River Forecast Center
  - Katelyn Costanza, Senior Hydrologist, NWS Lower Mississippi River Forecast Center
  - W. Scott Lincoln, Hydrologist, NWS Lower Mississippi River Forecast Center
  - David Schlotzhauer, Hydrologist, NWS Lower Mississippi River Forecast Center
  - Jonathan Brazzell, Service Hydrologist, NWS Lake Charles
  - Roger McNeil, Service Hydrologist, NWS Birmingham
  - Marty Pope, Service Hydrologist, NWS Jackson

Post-Isaac Flood Surveys

- Several different survey team members means several different note-takers
- Different formats, different observations deemed important
- Different handwriting

Post-Isaac Flood Surveys



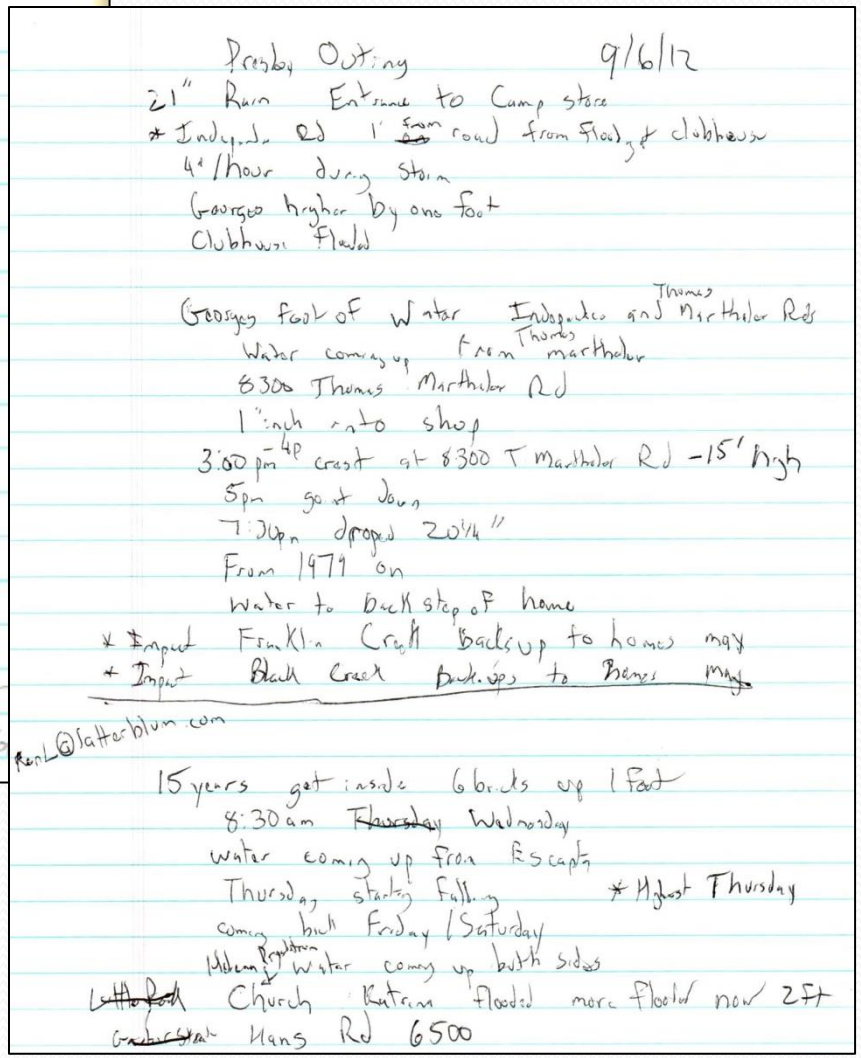
Amite @ Port Vincent
Residents on Summerfield are cut off but not flooded. Some portions of the road still impassable on the 6th.

30.31689 -90.83853 High Water is near the crown of the road at point

APPROX WSLVL = 5.8'

Amite River @ Bayou Manchac

Amite River Road and Horshoe Bend were impassable. All homes have been elevated and 9.8 feet no longer floods. Their property is very much inund



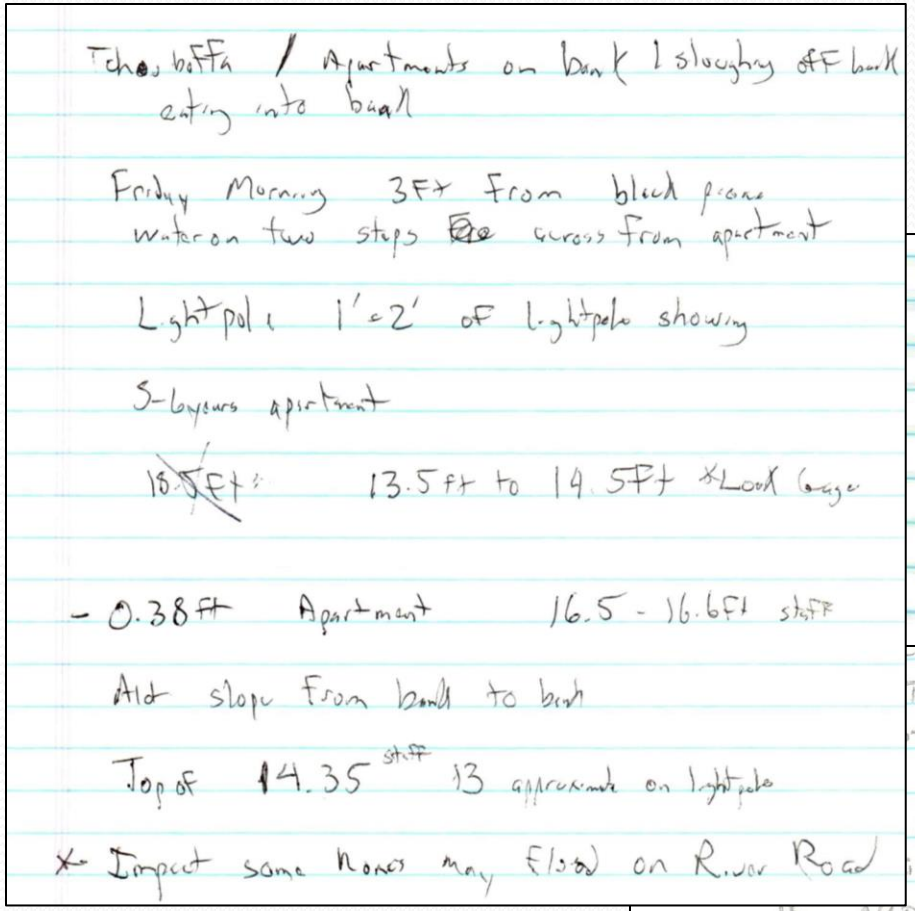
Presby Outing 9/6/12
21" Rain Entrance to Camp store
* Independence Rd 1' from road from Floor of clubhouse
4"/hour during storm
Georges higher by one foot
Clubhouse Flooded

Georges Foot of Water Independence and Thomas Marthaler Rds
Water coming up from Thomas marthaler
8300 Thomas Marthaler Rd
1" inch into shop
3:00 pm 4P crest at 8300 T Marthaler Rd -15' high
5pm go t down
7:30pm dropped 20¼"
From 1979 on
Water to back step of home
* Impact Franklin Creek backs up to homes may
* Impact Black Creek Back ups to Homes may

@latterblum.com

15 years get inside 6 bricks up 1 Foot
8:30 am ~~Thursday~~ Wednesday
water coming up from Escapta
Thursday starting Falling * Highest Thursday
coming back Friday / Saturday
Water coming up both sides
~~Little Rock~~ Church Kutrom flooded more flooded now 2Ft
~~Crabtree~~ Hans Rd 6500

Post-Isaac Flood Surveys



Tchoubaffa / Apartments on bank / sloughing off bank eating into bank

Friday Morning 3Ft from black picnic water on two steps across from apartment

Light pole 1'-2' of lightpole showing

5-buyours apartment

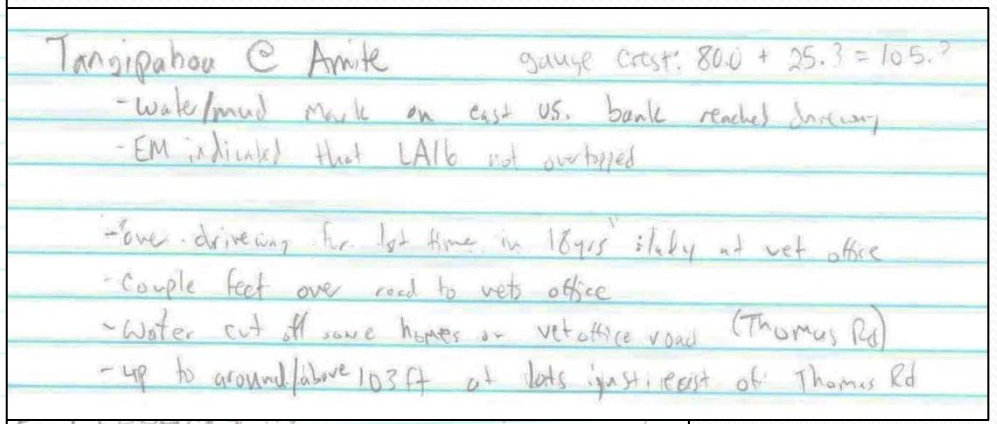
~~15.5Ft~~ 13.5 ft to 14.5Ft *Look Gauge

- 0.38 ft Apartment 16.5 - 16.6 ft staff

Aldt slope from bank to bank

Top of 14.35 staff 13 approximate on lightpole

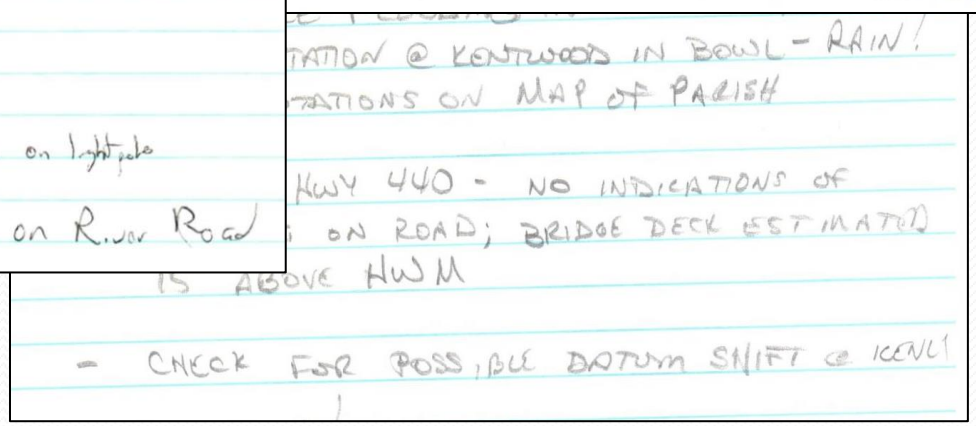
* Impact some homes may flood on River Road



Tangipahoa @ Amite gauge crest: 80.0 + 25.3 = 105.3

- water/mud mark on east US. bank reached driveway
- EM indicated that LA16 not overtopped

- over driveway for 1st time in 18yrs stuck at vet office
- couple feet over road to vets office
- water cut off some homes on vet office road (Thomas Rd)
- up to around/above 103 ft at lots just east of Thomas Rd



TATION @ KENTWOOD IN BOWL - RAIN!
TATIONS ON MAP OF PARISH

HWY 440 - NO INDICATIONS OF
ON ROAD; BRIDGE DECK ESTIMATED
IS ABOVE HWM

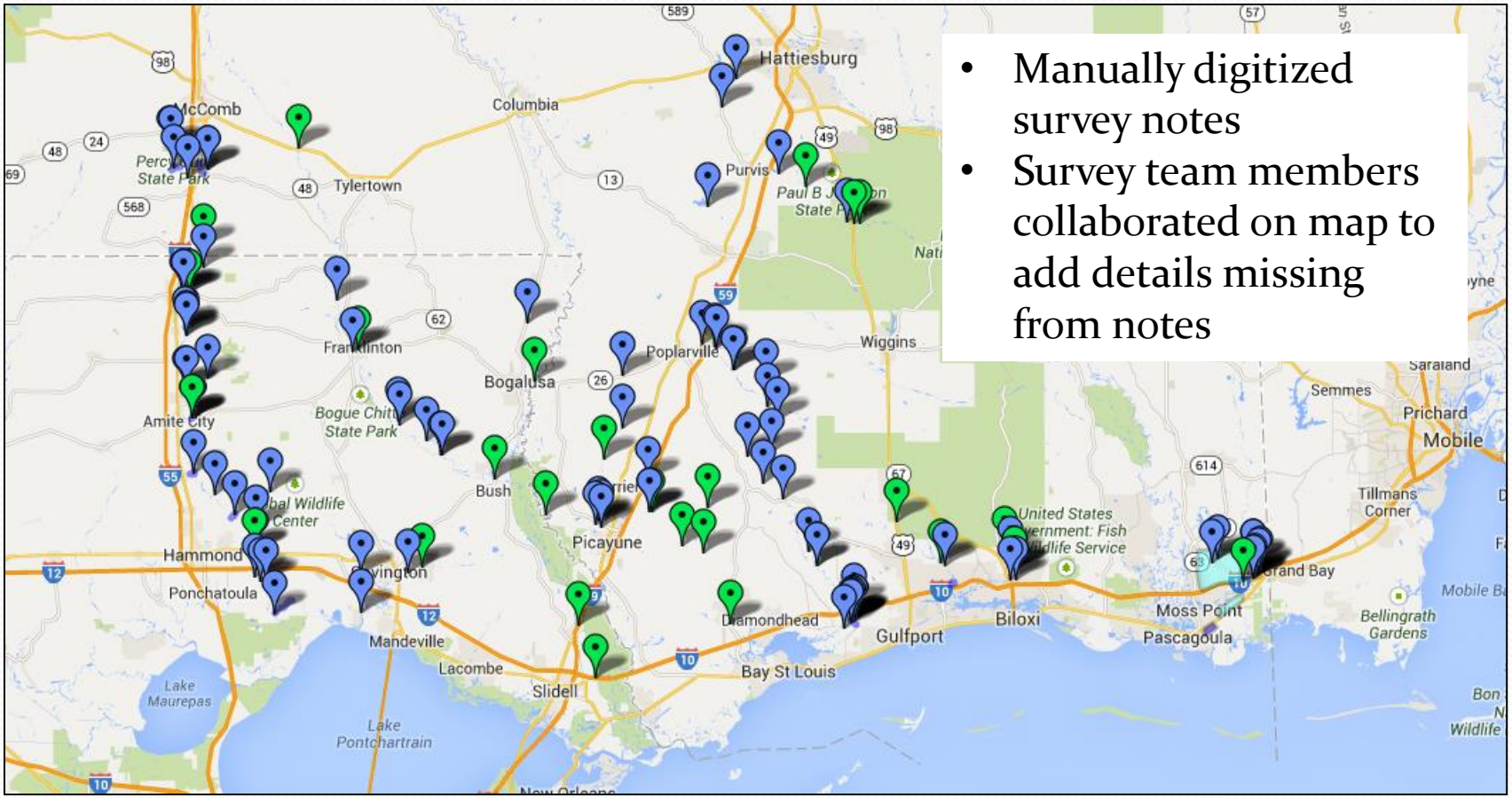
- CHECK FOR POSSIBLE DATUM SHIFT @ ICENCI

Post-Isaac Flood Surveys

What to do with all of this different information?

Post-Isaac Flood Surveys

Digitize it and plop it on a map, of course!



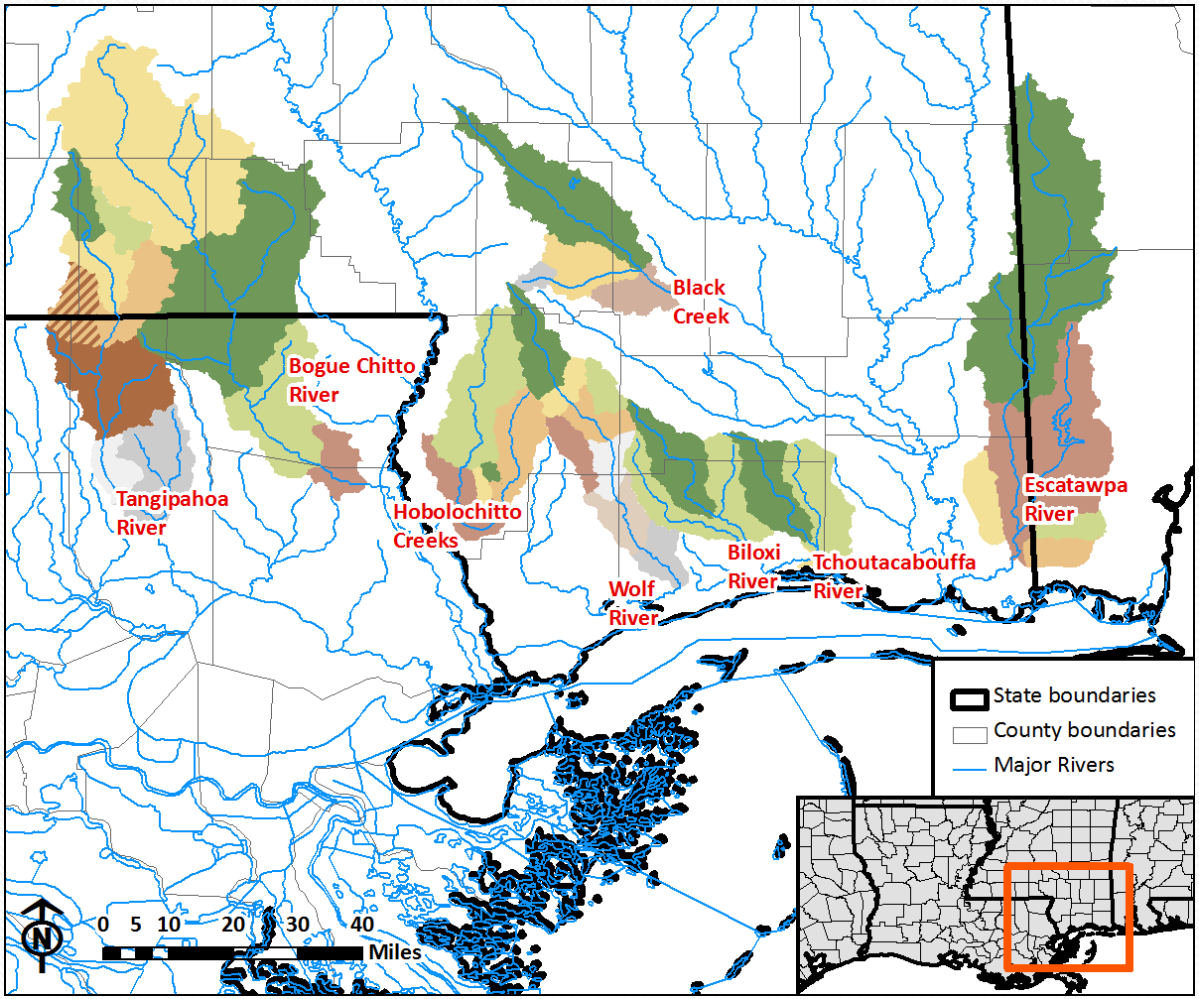
- Manually digitized survey notes
- Survey team members collaborated on map to add details missing from notes

Post-Isaac Flood Surveys

This leads to a nearly year long period of:

- Compiling notes and mapped locations into a survey report
- Analyzing data
- Answering questions raised by the survey
- Compiling recommendations for improving our service

Flood Survey Report Summary



Sept 5th

- Wolf

Sept 6th

- Wolf River
- Tchoutacabouffa
- Biloxi
- Escatawpa
- Tangipahoa
- E./W. Hobolochitto

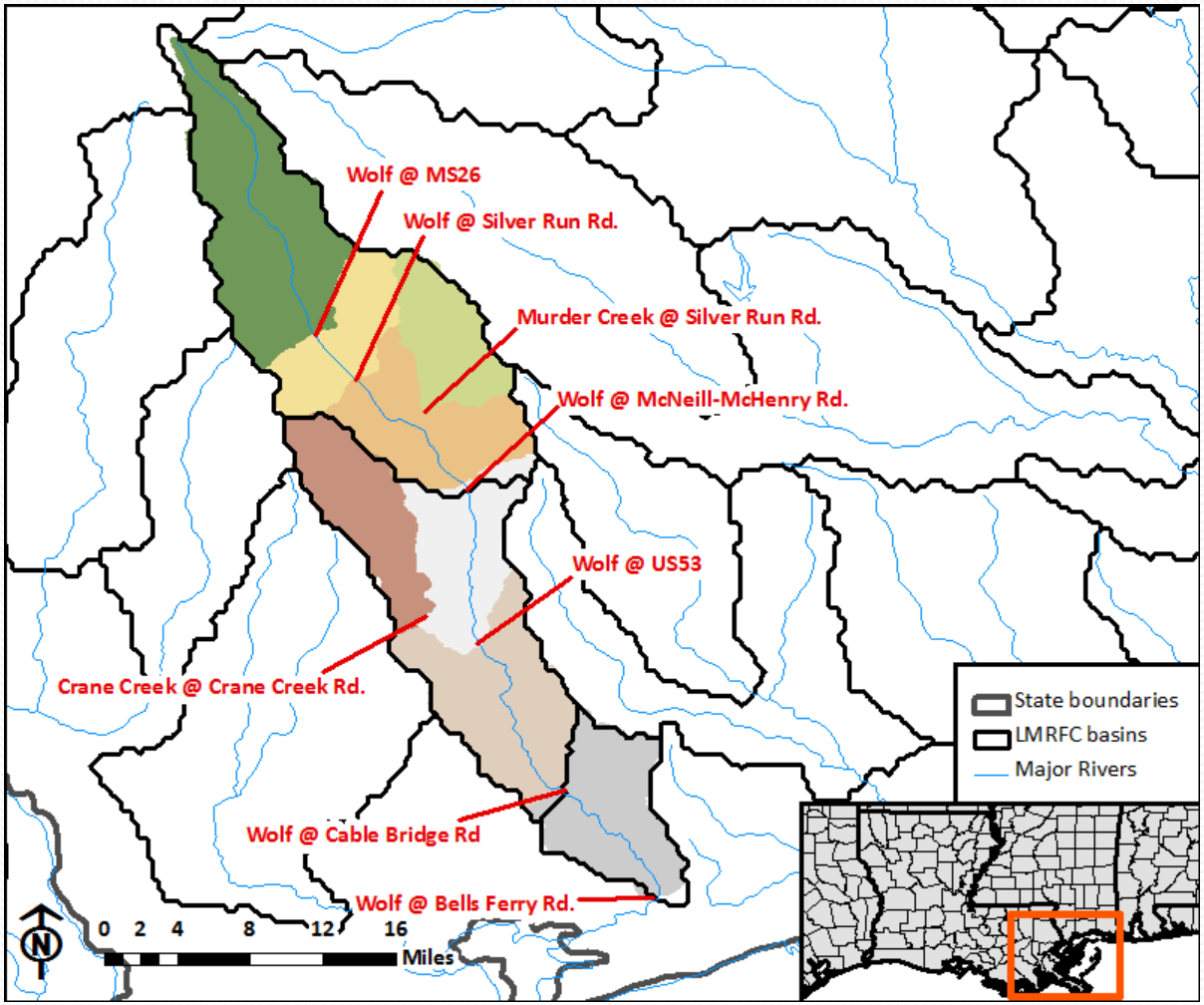
Sept 7th

- Wolf River
- Tangipahoa
- E./W. Hobolochitto
- Pearl

Sept 8th

- Tangipahoa

Flood Survey Report Summary



Wolf River

- Surveys Sept 5-7th
- I-59 flooded
- New record at MS26 bridge
- Many bridges over-topped
- New record at Cable Bridge Rd
- I-10 threatened
- Numerous homes flooded near Bells Ferry Rd
- Bells Ferry Rd crest?

Flood Survey Report Summary

Wolf River

Silver Run Rd (left). Scouring on road surface.
Cable Bridge Rd (below). Flattened trees/brush.

Flood Survey Report Summary

High water mark location near Bells Ferry Rd (above)

Wolf River

Conducted interviews with numerous residents near staff gauge.

- Many comparisons to 1995 flood
- Several anecdotes of water a few inches higher than 1995
- Some anecdotes suggesting discrepancy with gauge datum
- Numerous surveyed elevations and estimate water levels
- Two very clear high water marks near staff gauge

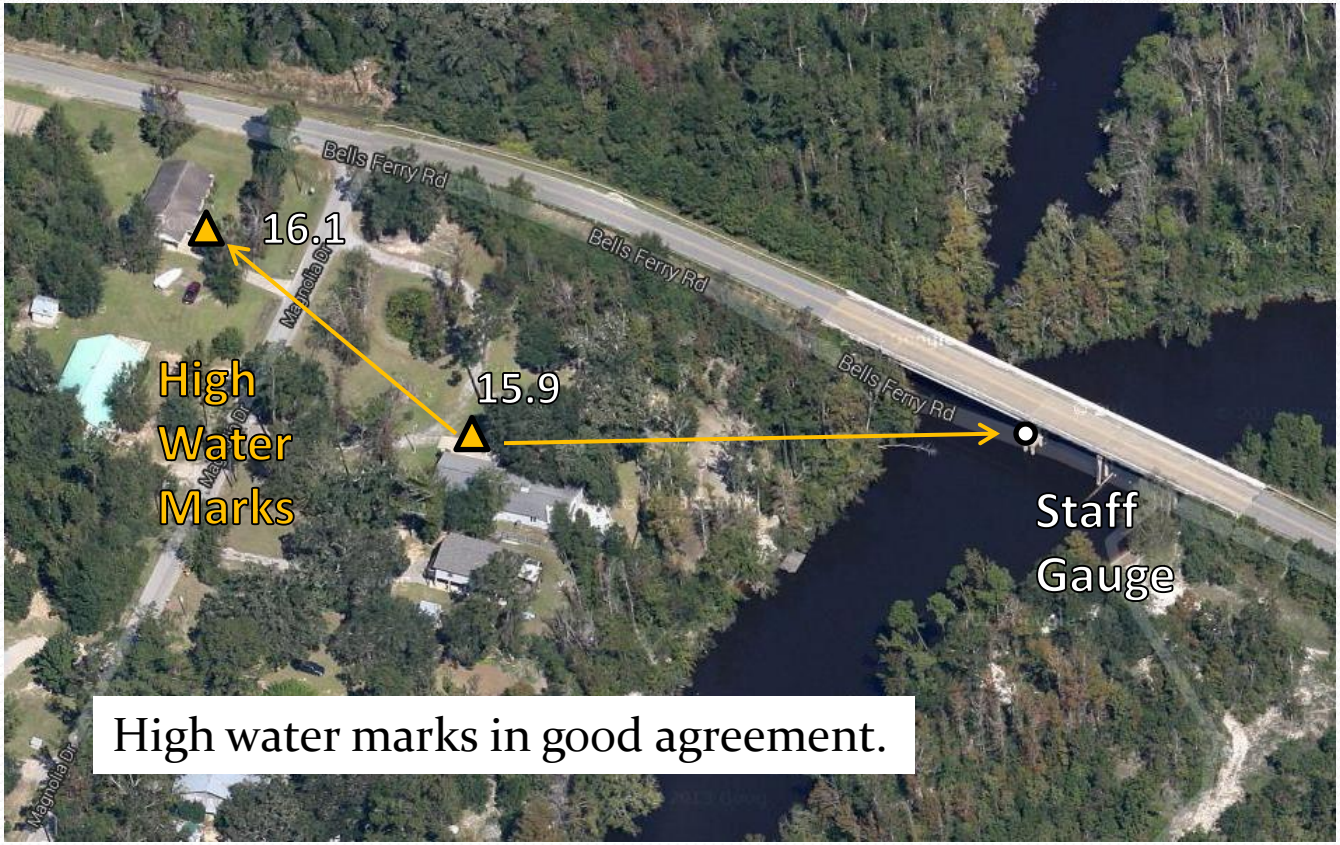
Flood Survey Report Summary

Wolf River

Questions remain…

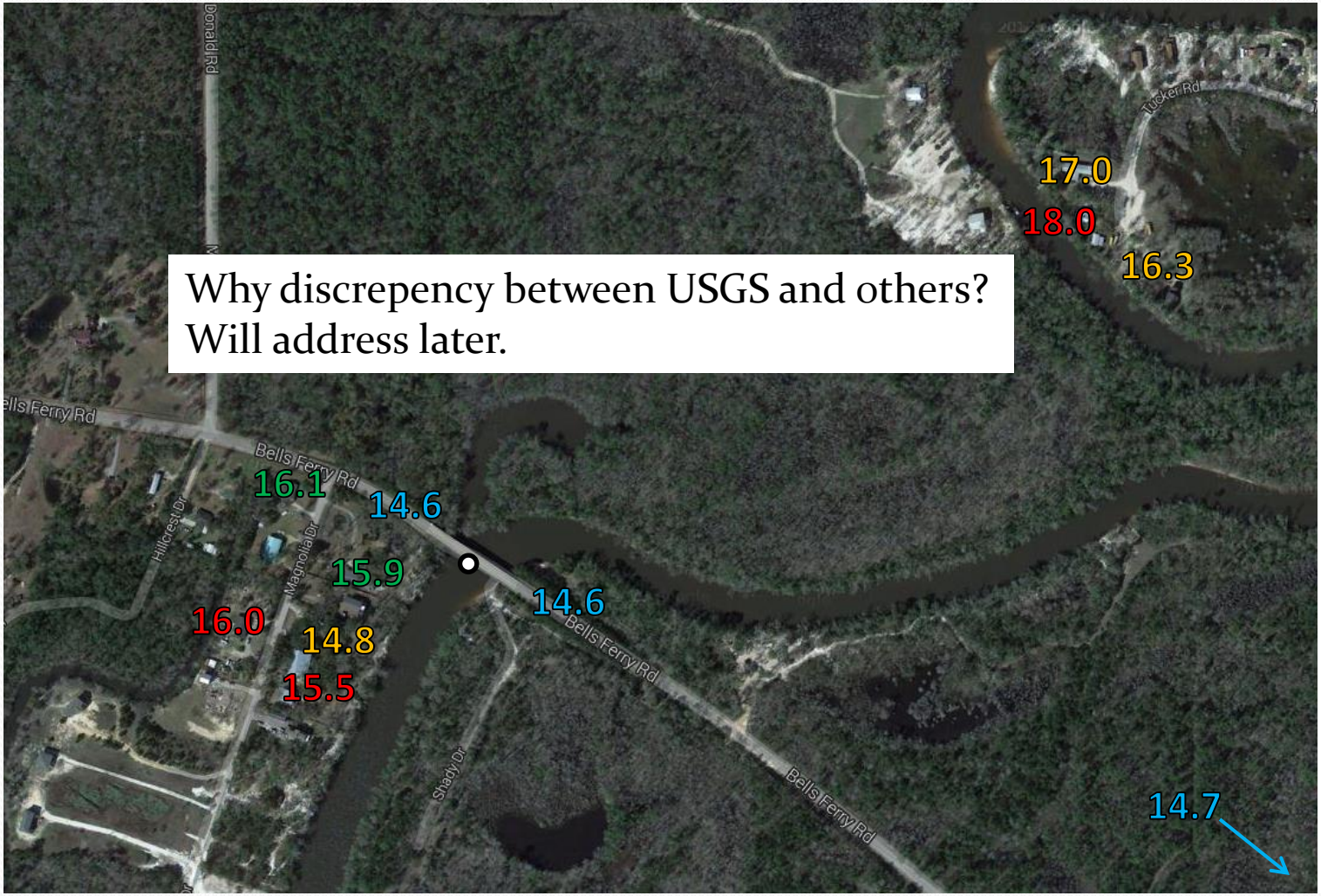
- What is the crest for Wolf @ Bells Ferry Rd?
- What's the datum of the staff gauge?

Flood Survey Report Summary



- High water mark surveyed to staff gauge
- High water mark across road used for QC
- High water marks of 15.9ft and 16.1ft (referenced to the gauge) surveyed

Flood Survey Report Summary



Bells Ferry Rd high water marks

SOURCE

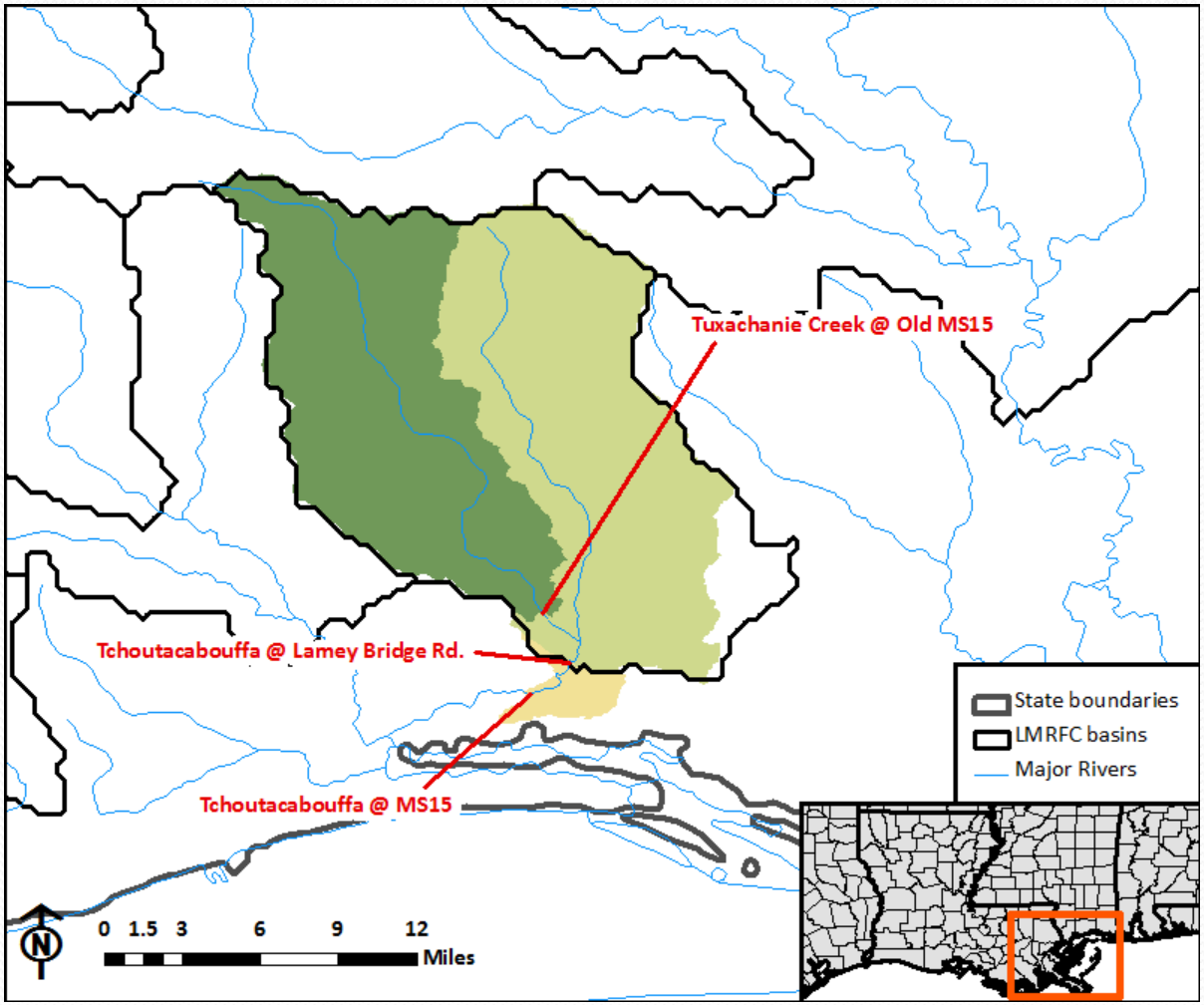
USGS

NWS/Survey

Public (High Confidence)

Public (Low Confidence)

Flood Survey Report Summary



Tchoutacabouffa River

- Survey Sept 6th
- Cut-bank scouring
- Lamey Bridge Rd threatened
- A few homes possibly flooded
- Lamey Bridge Rd crest?

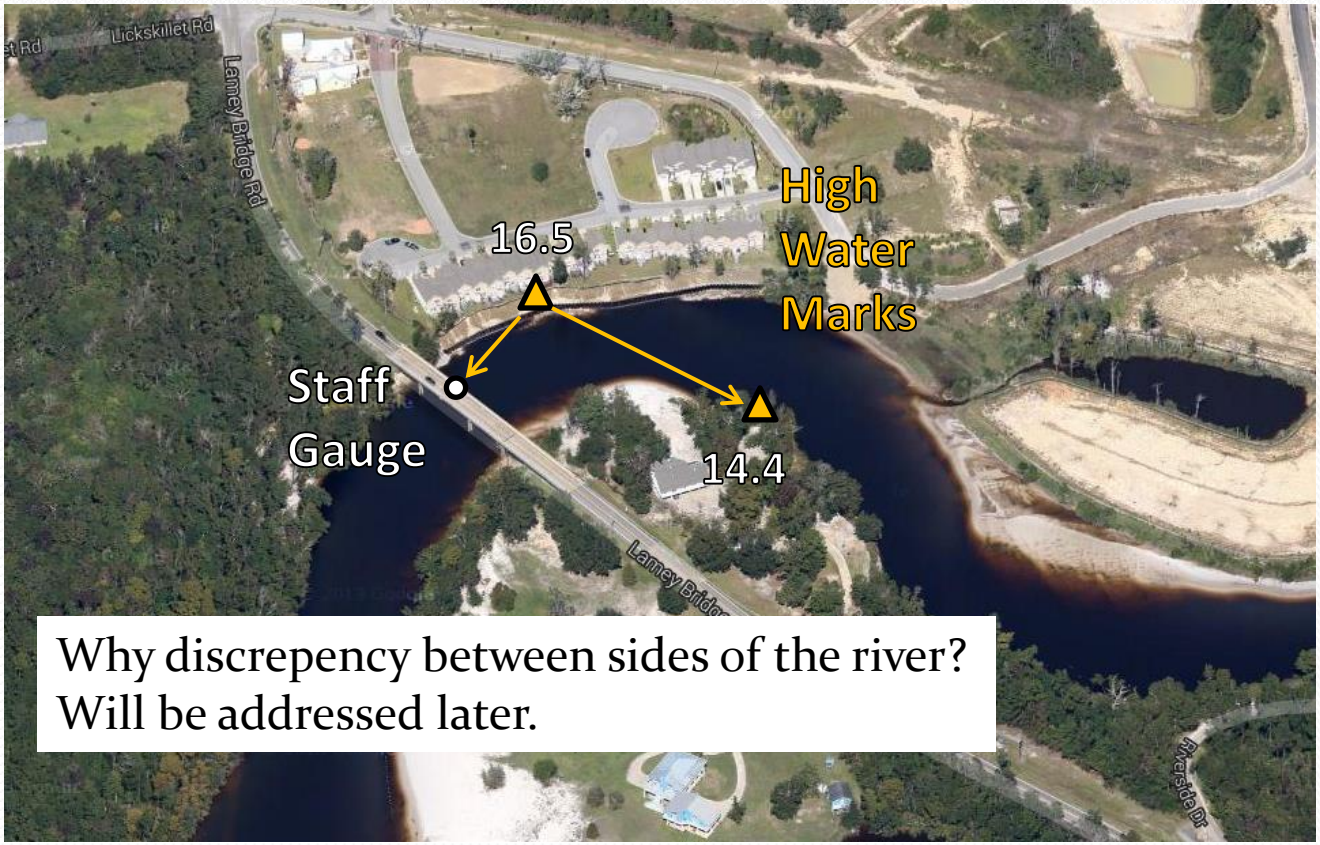
Flood Survey Report Summary

Tchoutacabouffa River

Lamey Bridge Rd (Left).

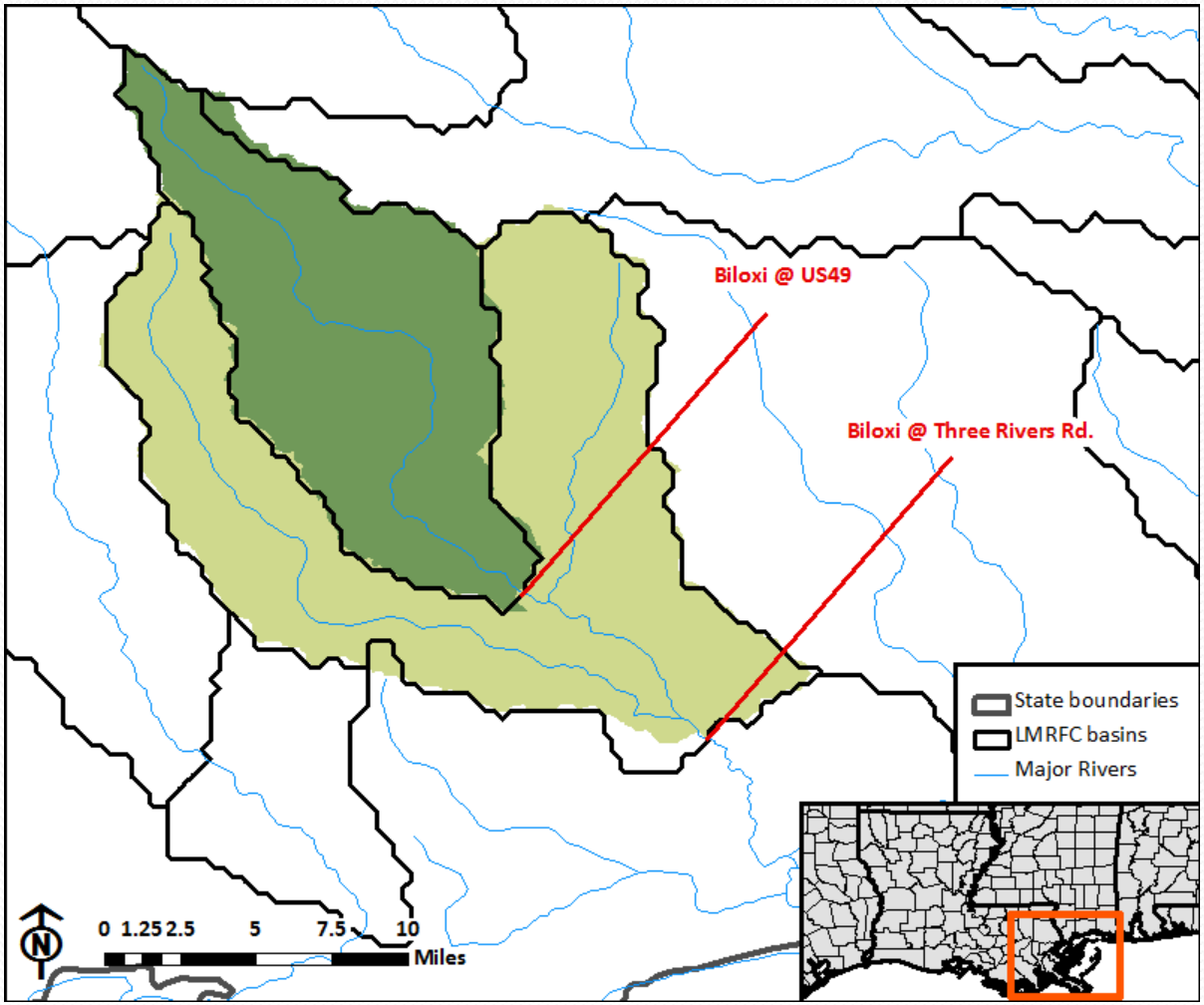
Resident indicates to survey team the crest behind the Riverbend Cove Apartments.

Flood Survey Report Summary



- High water mark surveyed to staff gauge
- High water anecdote on dock across river used for QC
- High water marks of 16.5ft and 14.4ft (referenced to the gauge) surveyed

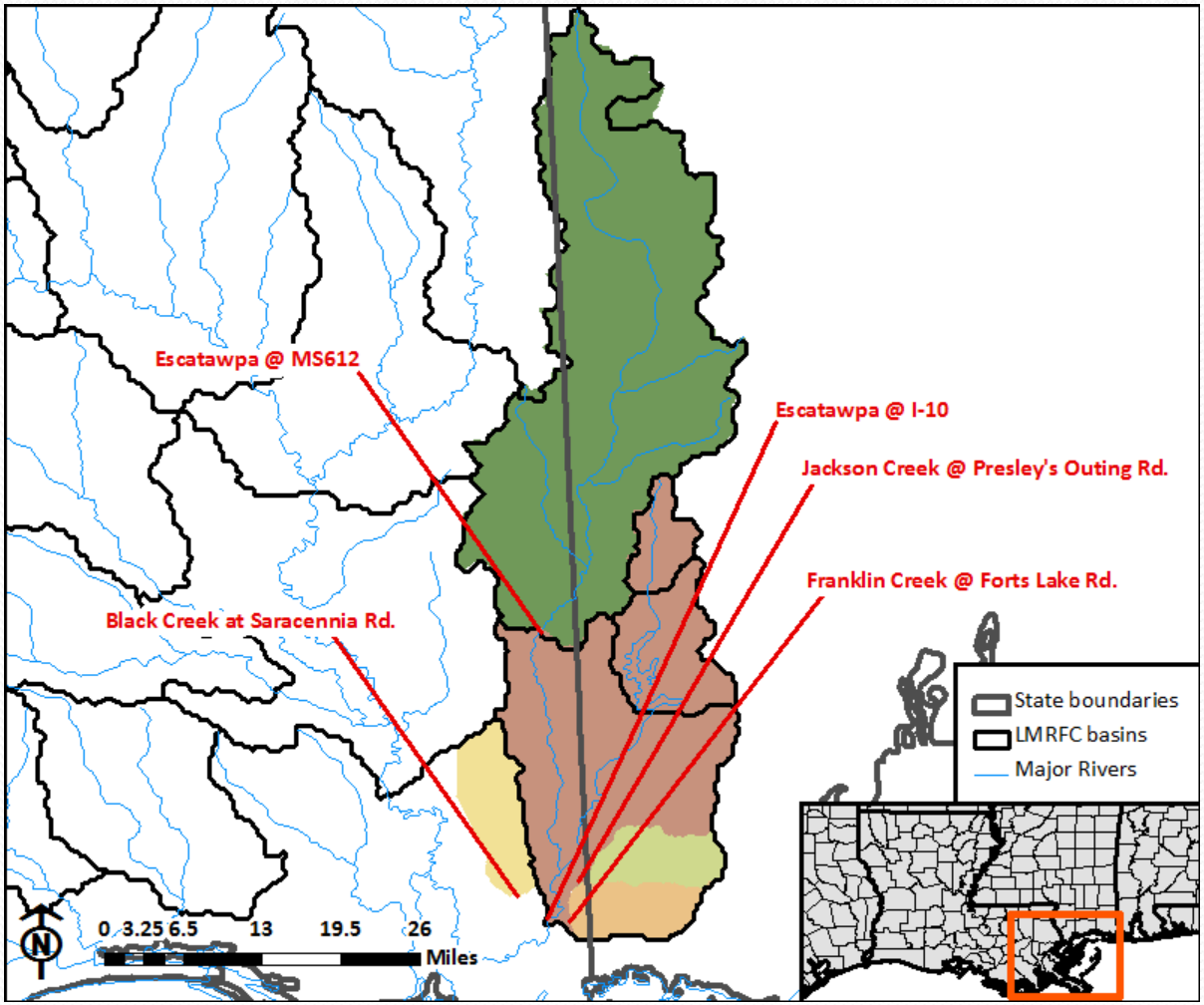
Flood Survey Report Summary



Biloxi River

- Surveys Sept 6th
- MS605 flooded (official hurricane evacuation route)
- A few residences possibly flooded

Flood Survey Report Summary



Escatawpa River

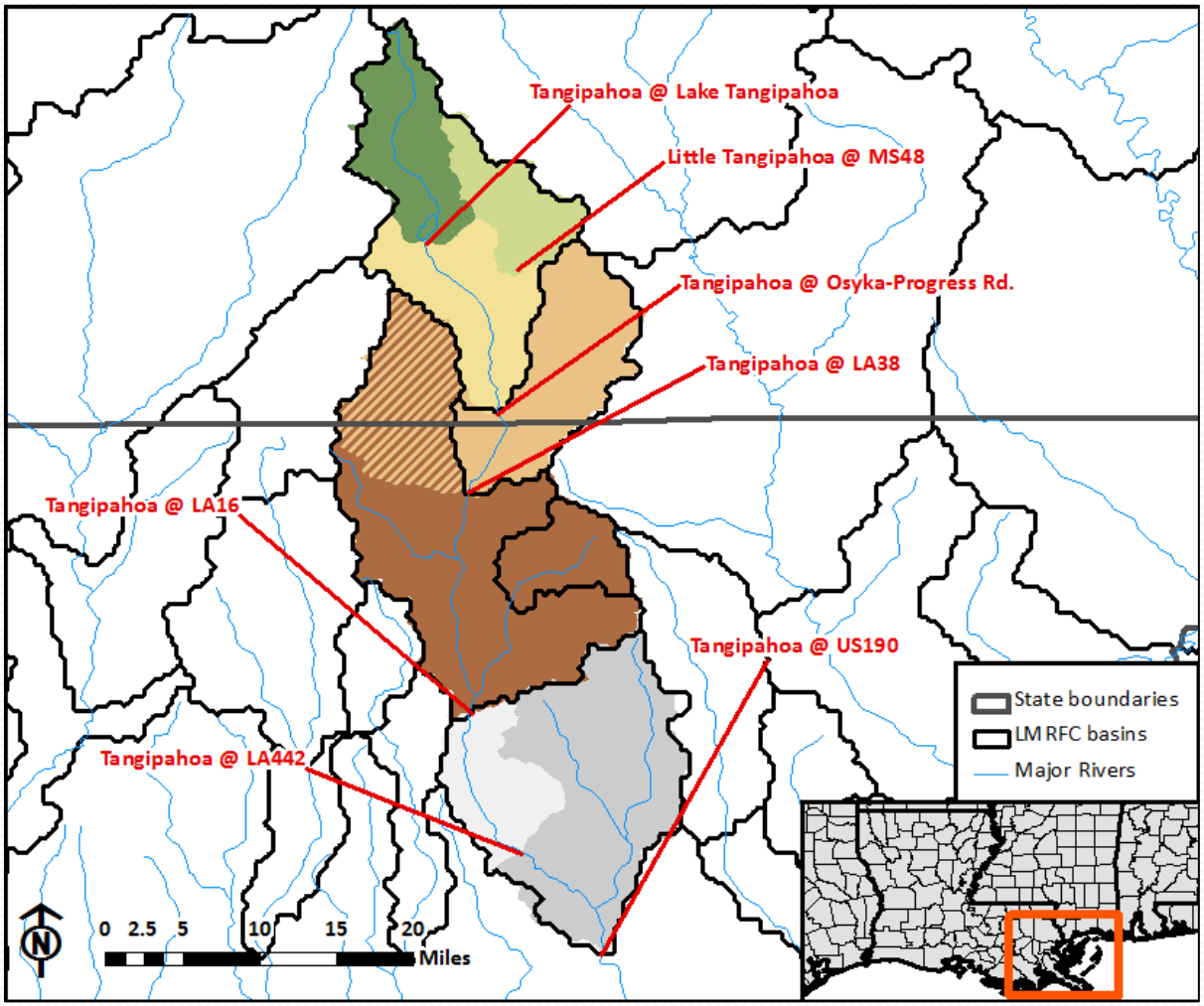
- Survey Sept 6th
- Campground threatened
- Numerous homes flooded

Flood Survey Report Summary

Escatawpa River

Resident near I-10 gauge recorded water levels near his home at frequent intervals. Anecdote matched almost perfectly to gauge readings.

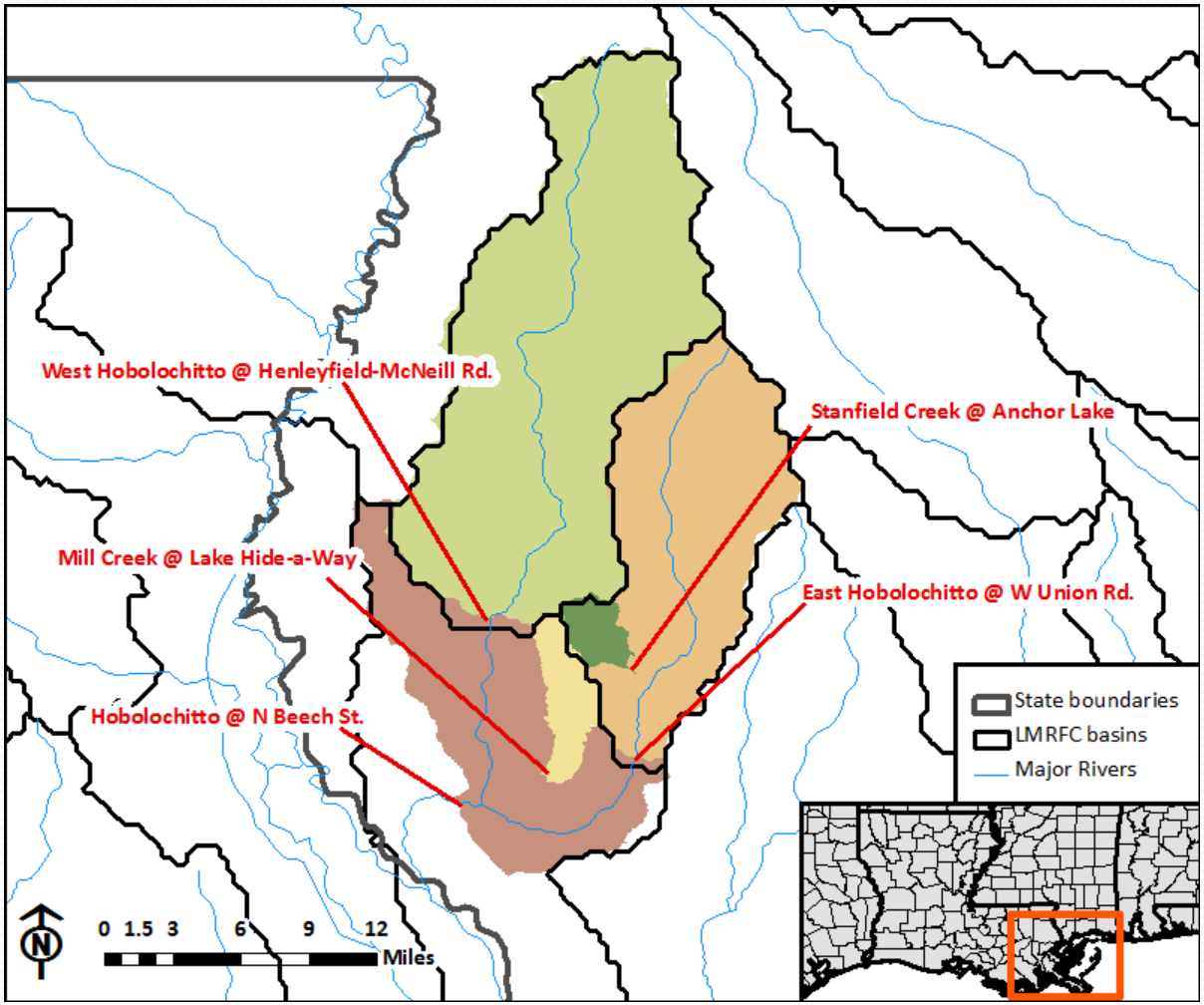
Flood Survey Report Summary



Tangipahoa River

- Surveys Sept 6-8th
- Lake Tangipahoa dam threatened
- Numerous residences flooded, both from river and surge
- Numerous high water marks between gauging stations

Flood Survey Report Summary



E./W. Hobolochitto Creeks

- Surveys Sept 6-7th
- High water at two high hazard dams
- A few residences flooded downstream of gauged locations

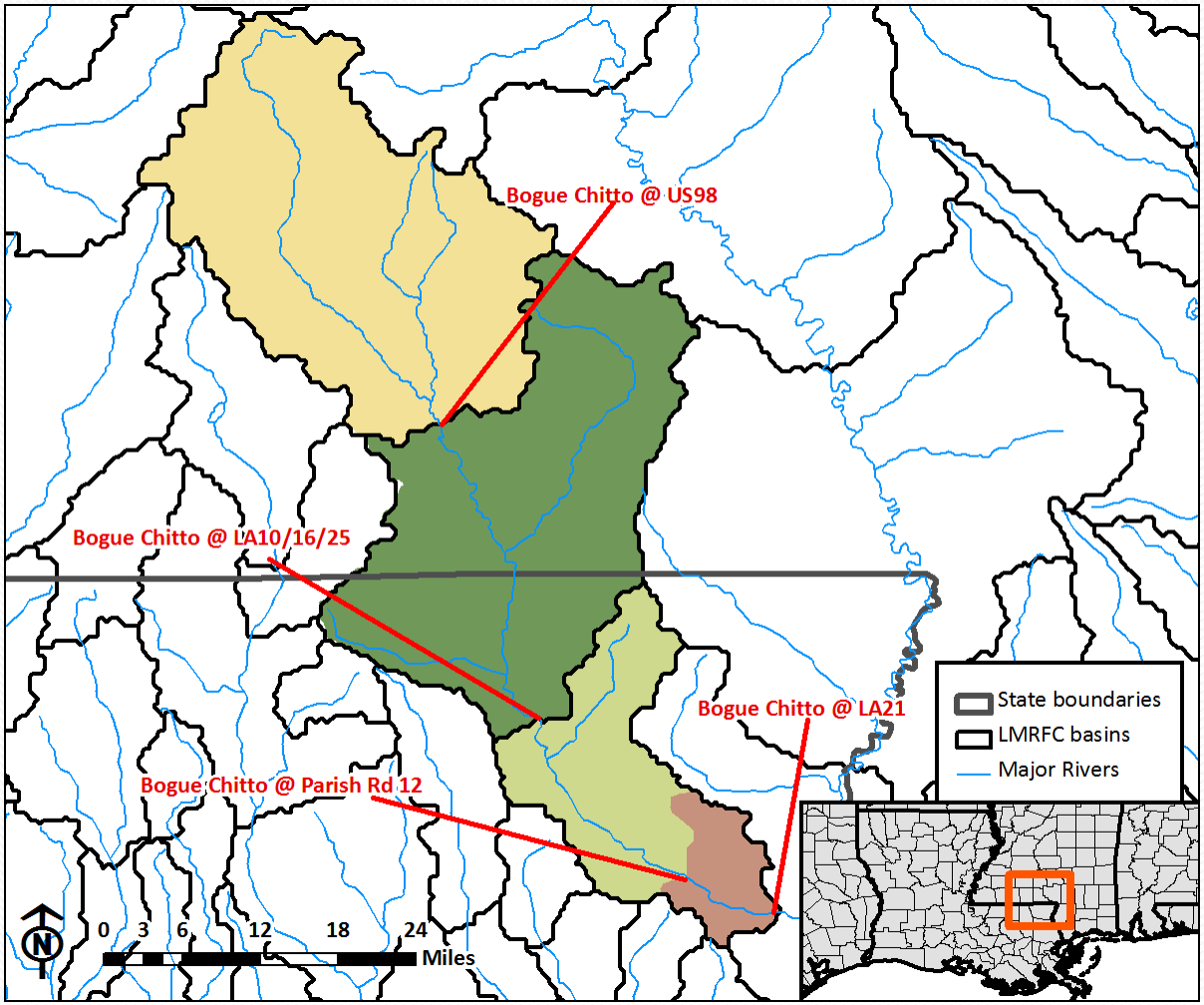
Flood Survey Report Summary

Flattened brush downstream of Anchor Lake spillway and emergency spillway (right).

E./W. Hobolochitto Creeks

Water near top of spillway guide channel at Lake Hide-a-Way (left). Capture from video by Bruce Devillier.

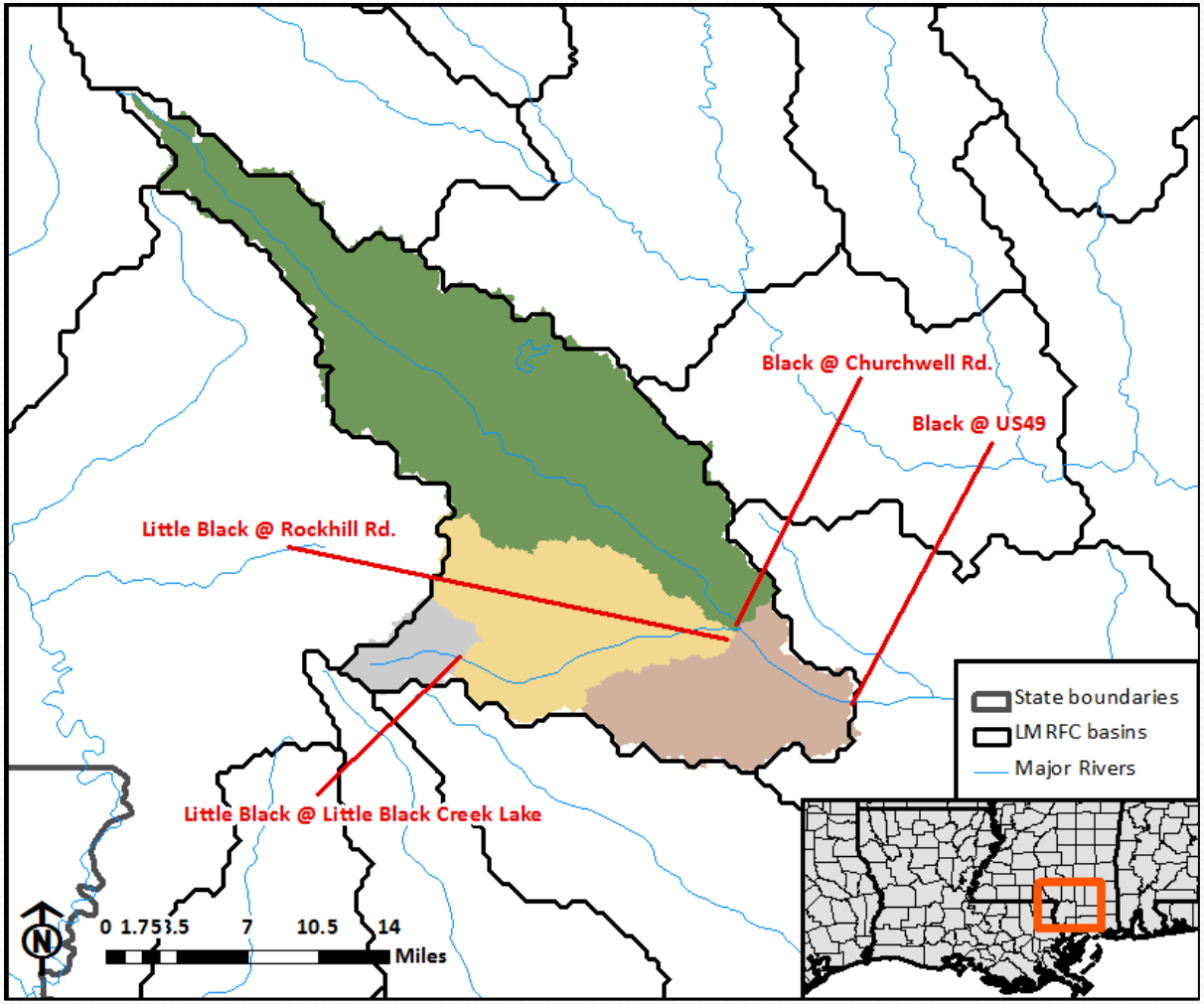
Flood Survey Report Summary



Bogue Chitto River

- A few roads threatened
- A few residences flooded

Flood Survey Report Summary



Black Creek

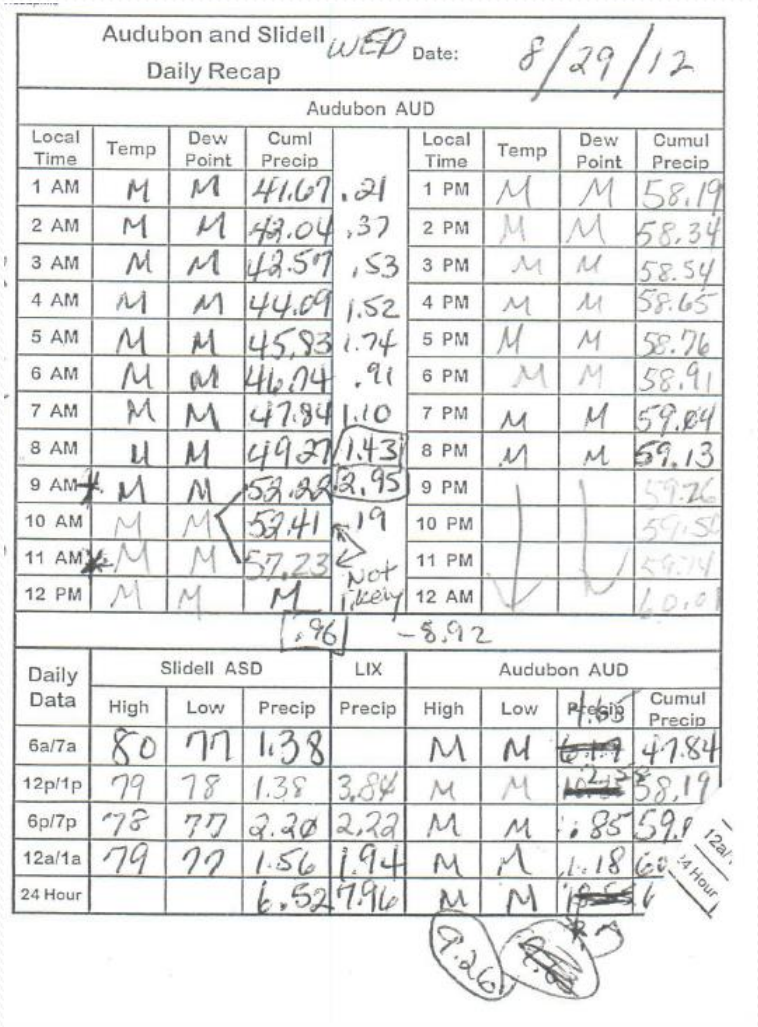
- Surveys late Sept
- Lake Serene dams threatened
- Little Black Creek Lake emergency spillway utilized
- A few residences flooded
- Isaac rainfall did not cause crest as high as expected based upon past events. Will address later.

Hurricane Isaac: Post-Landfall Rainfall Analysis

Rainfall Analysis

- During/after storm, high rainfall totals in some areas was apparent, but some controversy
  - Anecdotes of 20+ inches near Pascagoula from private sources
  - One official gauge of 20+ inches in New Orleans area discounted by NWS local office
- Rainfall data available from numerous sources:
  - Official rain gauges (point data)
  - Radar-only data (gridded data)
  - QC-ed radar+gauge data (gridded data)

Rainfall Analysis



Audubon and Slidell Daily Recap WED Date: 8/29/12

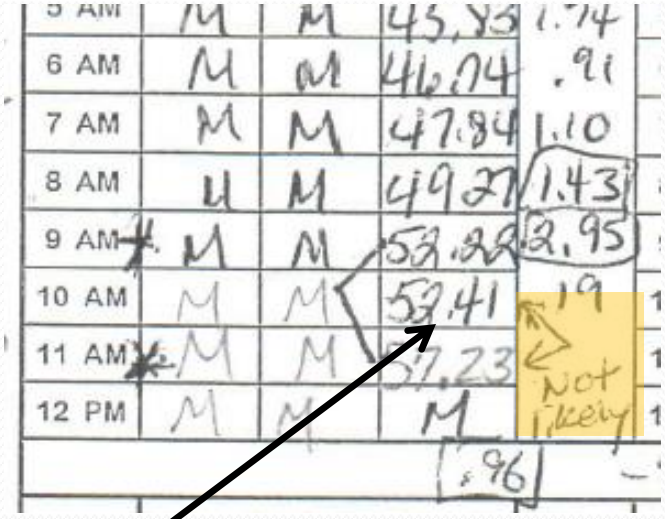
Audubon AUD

Local Time	Temp	Dew Point	Cuml Precip		Local Time	Temp	Dew Point	Cumul Precip
1 AM	M	M	41.67	.21	1 PM	M	M	58.19
2 AM	M	M	43.04	.37	2 PM	M	M	58.34
3 AM	M	M	42.57	.53	3 PM	M	M	58.54
4 AM	M	M	44.09	1.52	4 PM	M	M	58.65
5 AM	M	M	45.83	1.74	5 PM	M	M	58.76
6 AM	M	M	46.74	.91	6 PM	M	M	58.91
7 AM	M	M	47.84	1.10	7 PM	M	M	59.04
8 AM	M	M	49.27	1.43	8 PM	M	M	59.13
9 AM	M	M	52.22	2.95	9 PM			59.26
10 AM	M	M	52.41	.19	10 PM			59.58
11 AM	M	M	57.23	Not likely	11 PM			59.14
12 PM	M	M	M		12 AM			60.01
			.96					-8.92

Daily Data	Slidell ASD			LIX	Audubon AUD			
	High	Low	Precip	Precip	High	Low	Precip	Cumul Precip
6a/7a	80	77	1.38		M	M	~~1.19~~ 1.65	47.84
12p/1p	79	78	1.38	3.84	M	M	~~1.25~~ 1.35	58.19
6p/7p	78	77	2.20	2.22	M	M	1.85	59.1
12a/1a	79	77	1.56	1.94	M	M	1.18	60
24 Hour			6.52	7.96	M	M	~~1.85~~ 1	

- Second official site in New Orleans area also reported high rainfall totals, but was discounted
- No major flood issues reported in New Orleans during storm
- *"New Orleans has never received that rainfall rate and not had significant flooding"* – common justification.

Rainfall Analysis



~4.8in/1hr

Analysis Questions:

1. How can we compare different rainfall estimates of different types?

2. How can we confirm/discount rainfall maxima in New Orleans?

Rainfall Analysis

1. How can we compare different rainfall estimates of different types?

Convert point data to gridded data using interpolation.

- **IDW** best for data where minima and maxima are well sampled. Can cause contour bullseyes. Can create mass.
- **Spline** best for data where minima and maxima need to be interpolated. Typically has higher interpolation errors than IDW, but not quantified. Can create mass.
- **Kriging** good for data that is spatially-correlated. Can provide information on how correlation changes with distance. Can assume measurement and interpolation uncertainty right at measurement point (nugget). Provides built-in methods for minimizing creation of mass.

Rainfall Analysis

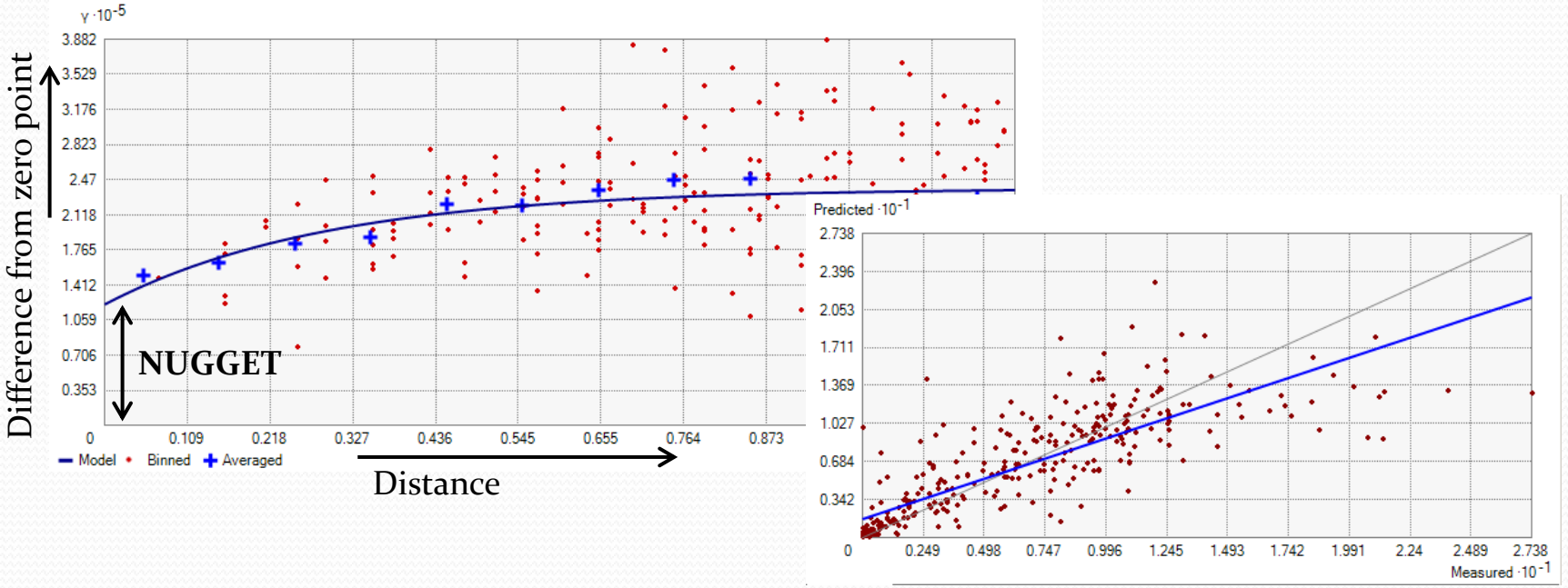
Kriging

Semivariogram (left)

Equations that describe how data correlates spatially

Interpolation error analysis(right)

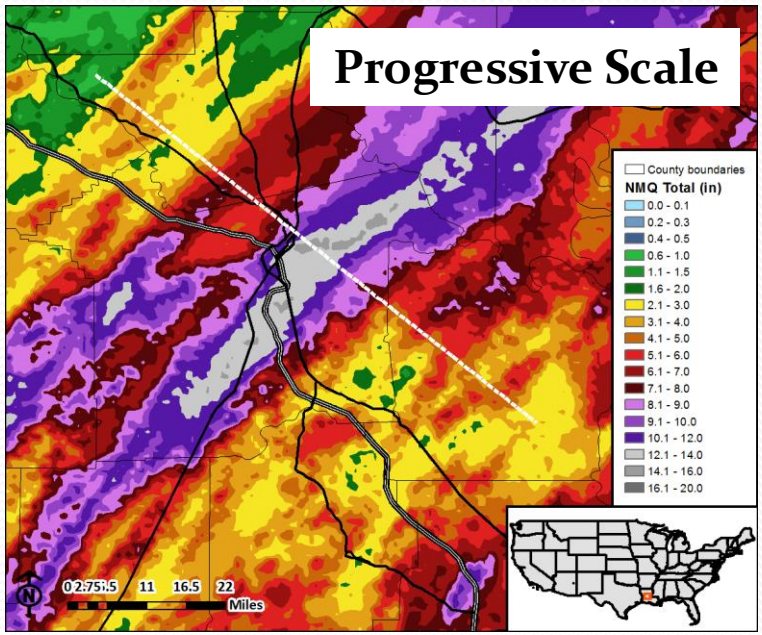
Removal of each point, comparison of predicted to actual

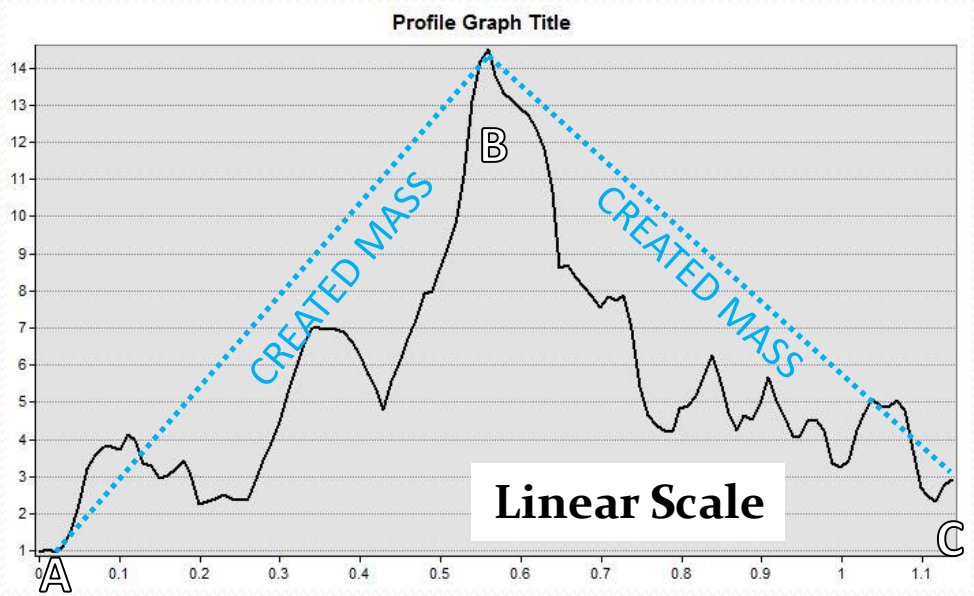


Rainfall Analysis

New analysis question…
1A. How can interpolation "create" mass?

Character of rainfall distribution typically "ramps up" toward maxima. This effect is somewhat masked by visualizations due to progressive color scales.





Rainfall Analysis

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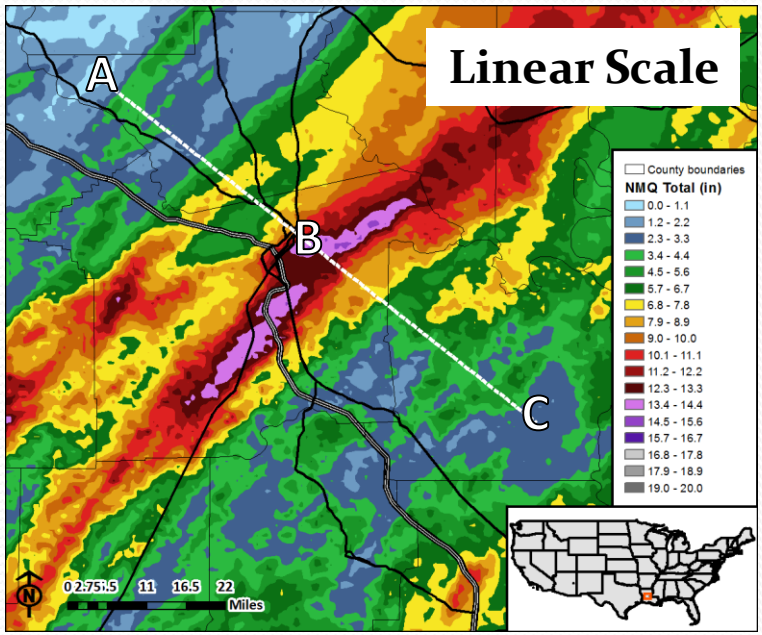
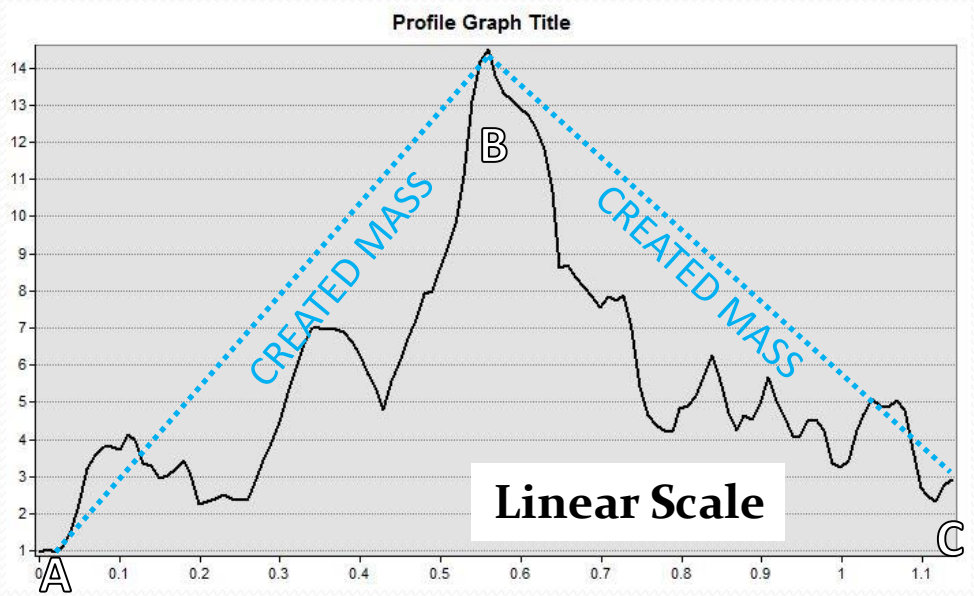




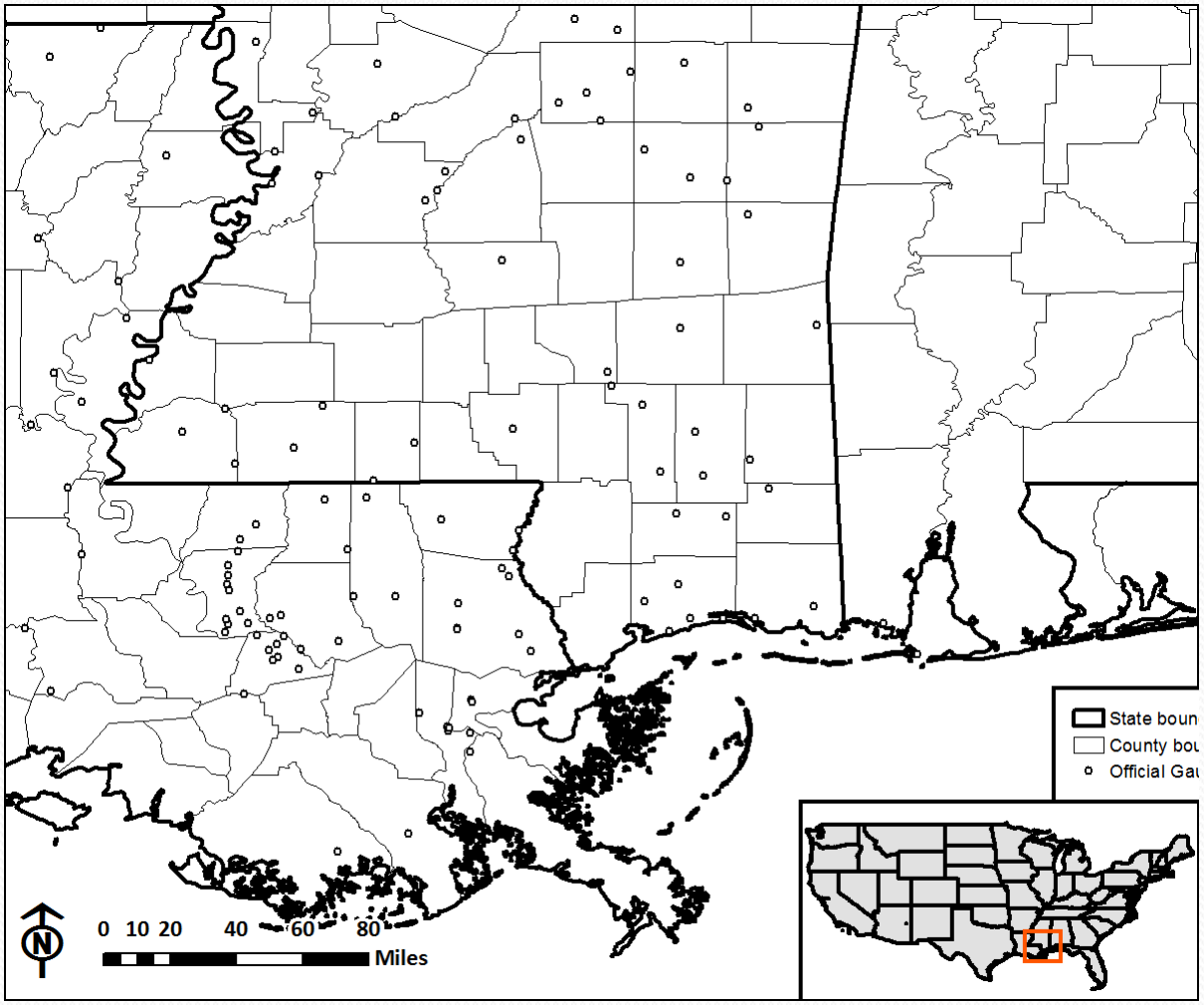
Rainfall Analysis

New analysis question…
1A. How can interpolation "create" mass?

- Interpolation works best with Gaussian distribution
- Square root transform (square rooting the input data before interpolation) gets data closer to Gaussian; less "created" mass
- Semi-variogram equations in Kriging interpolation – the equations that describe how data correlates spatially – also reduce this issue

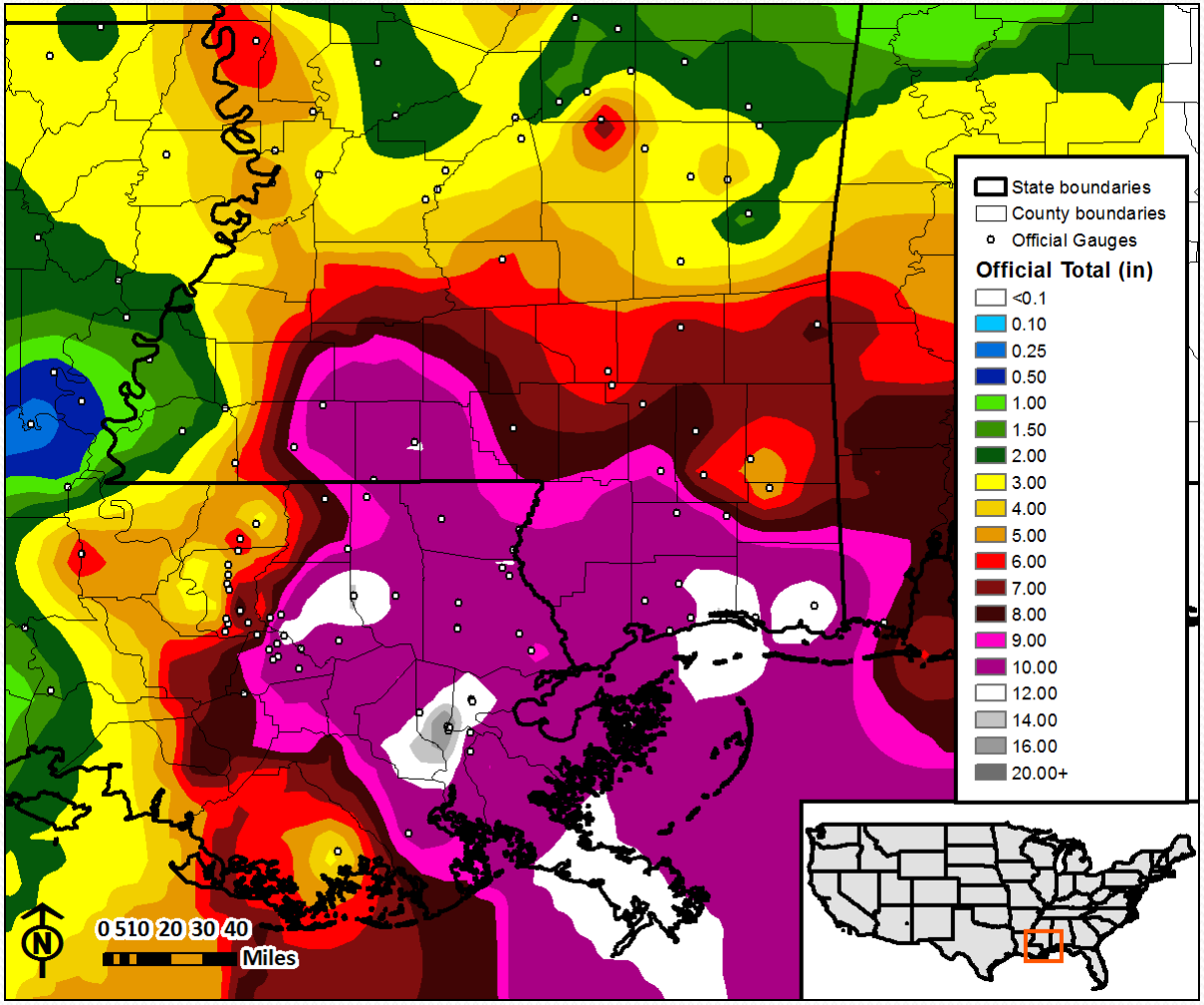
Based upon this reasoning, we chose Kriging for interpolation.

Rainfall Analysis



- Official gauge locations
- USGS, USACE, NOAA

Rainfall Analysis

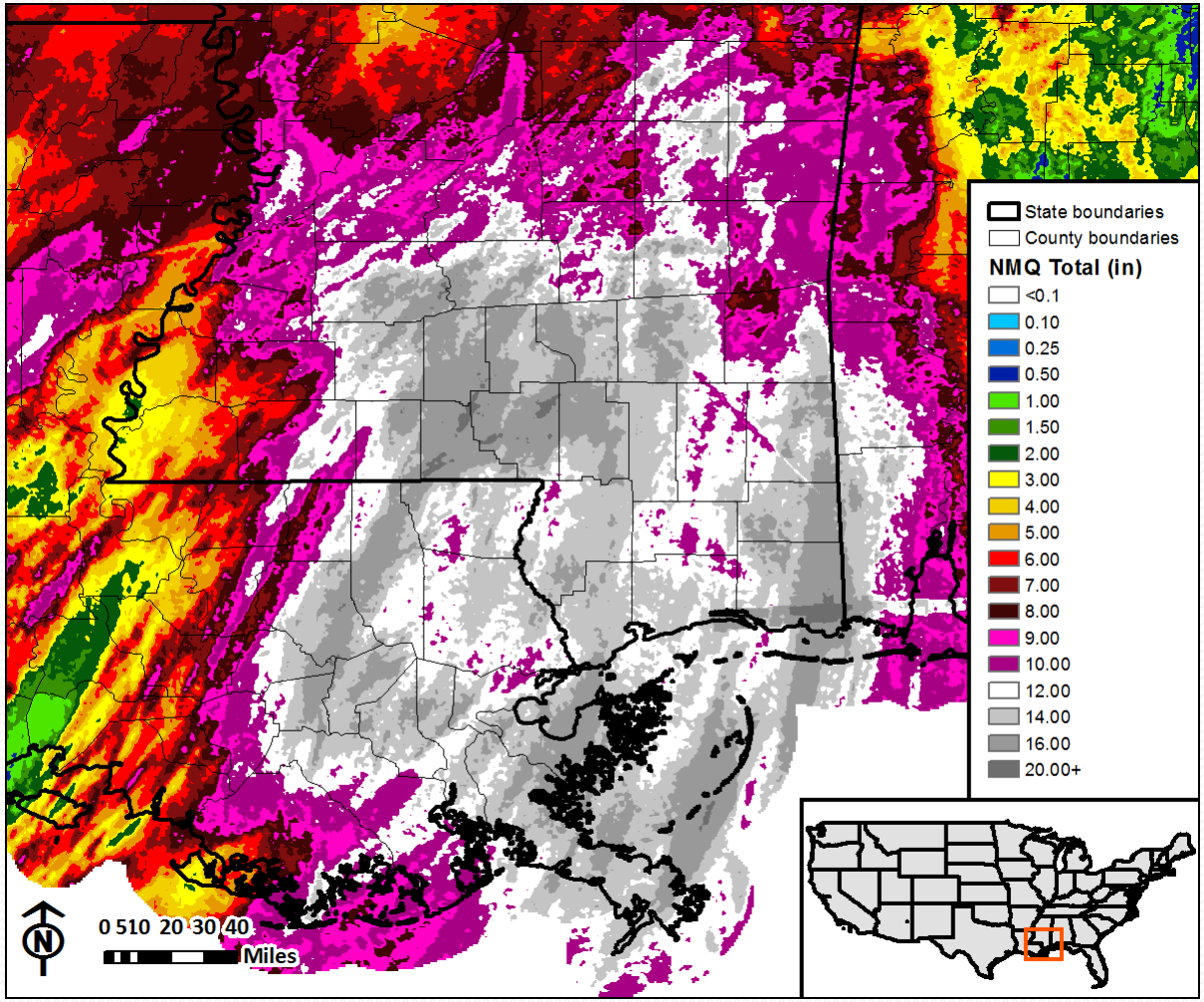


- Official gauge locations

Kriging Interpolation

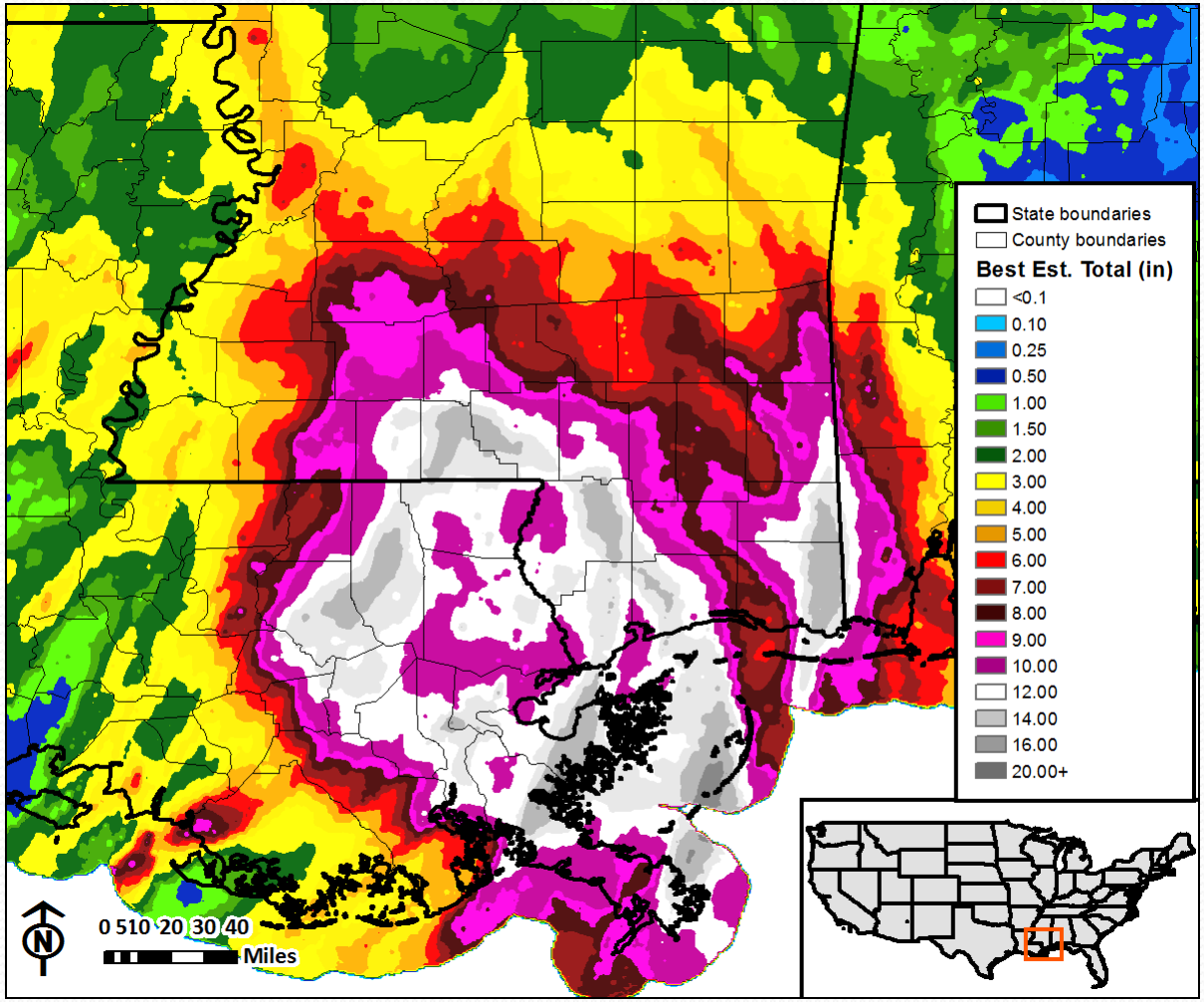
Assumption of gauges being fairly accurate: "0.0" for Nugget

Rainfall Analysis



- Radar only NMQ/Q2

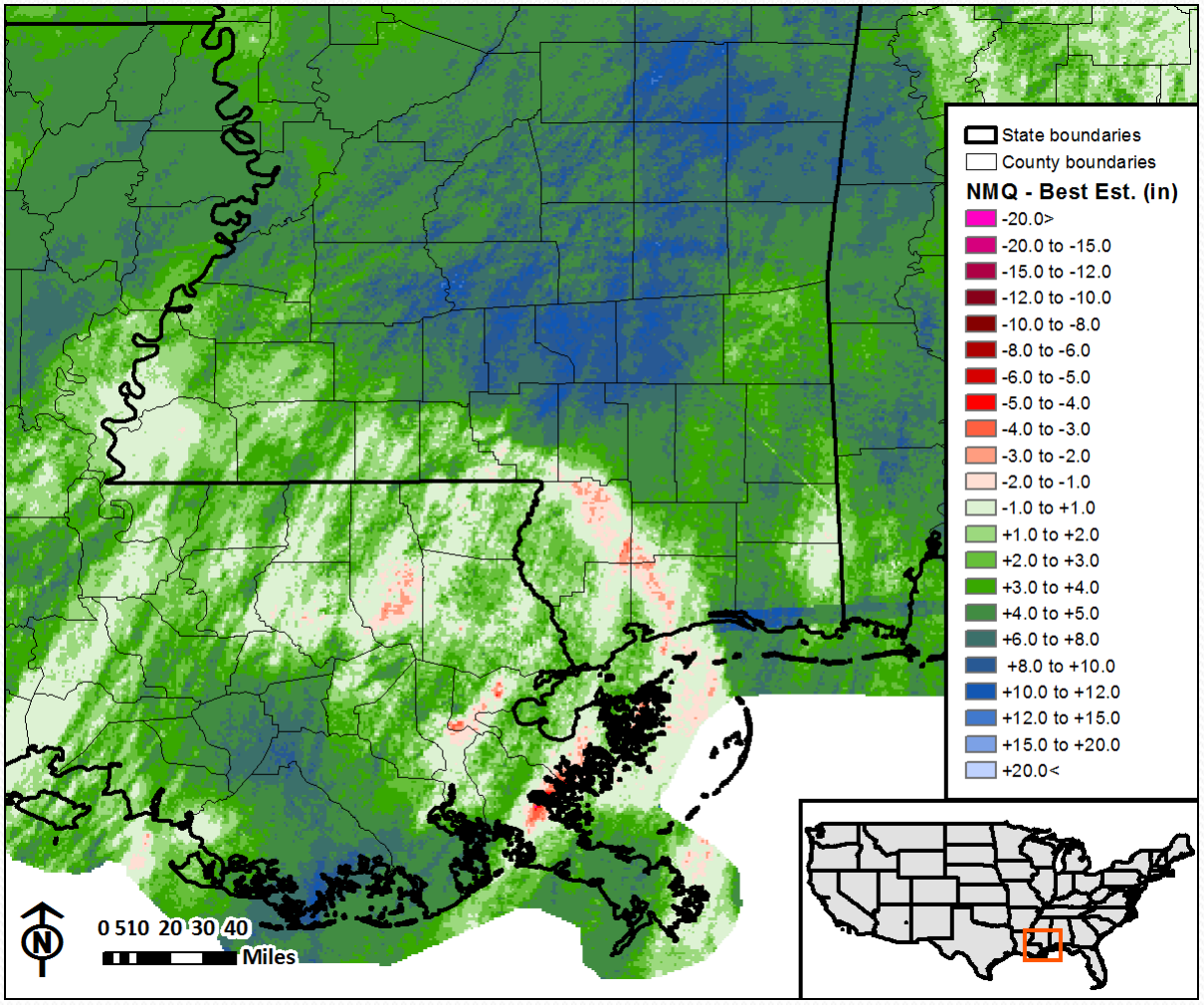
Rainfall Analysis



- NWS Multi-sensor Best Estimate

Gridded radar data from multiple NWS offices mosaiced, then bias-corrected o official gauge stations

Rainfall Analysis



- Radar only compared to multi-sensor Best Estimate

Can have widespread error without bias correction.

Radar helpful, but **cannot** replace gauging stations!

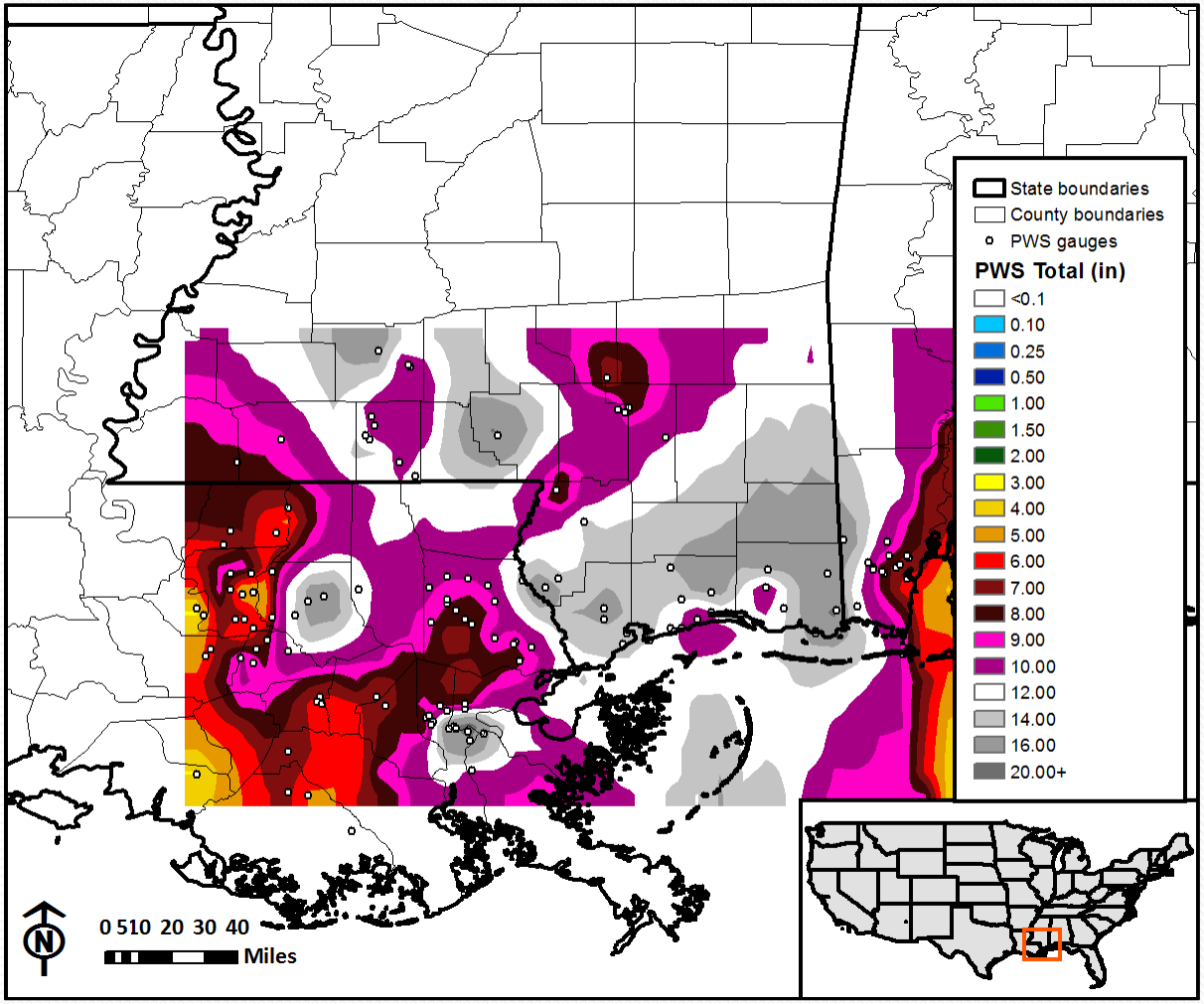
Rainfall Analysis

2. How can we confirm/discount rainfall maxima in New Orleans?

Get additional rainfall data.

- WeatherUnderground maintains a Personal Weather Station (PWS) network of private weather observers.
  - Thousands of stations across the country.
  - Data available for download online.
- AWS/Weather Bug maintains a few stations in the area.
- Private rainfall data from survey interviews

Rainfall Analysis

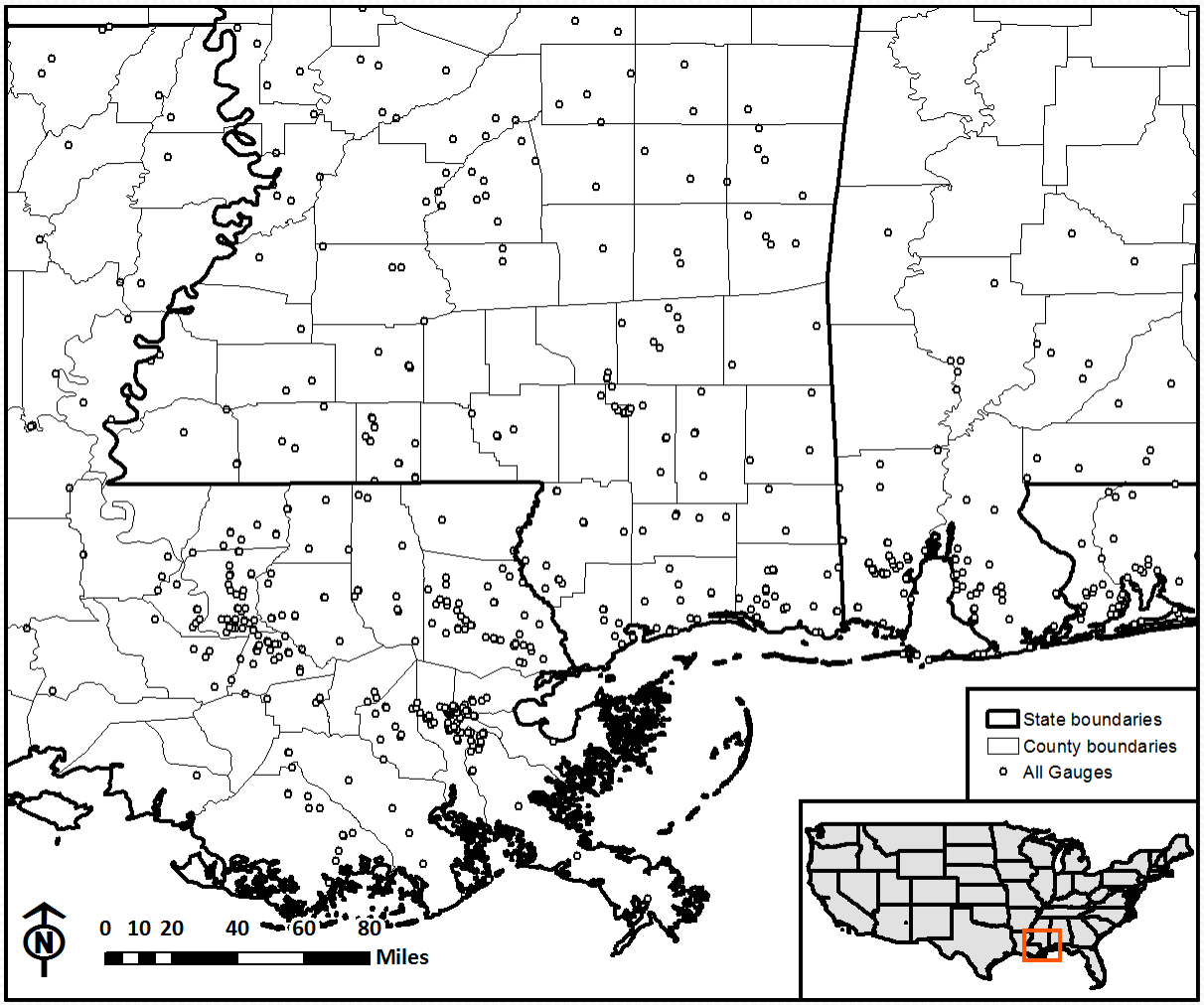


- Private gauge stations
- Weather Underground, AWS, others

Kriging Interpolation

Assumption of gauges being fairly accurate: “0.0” for Nugget

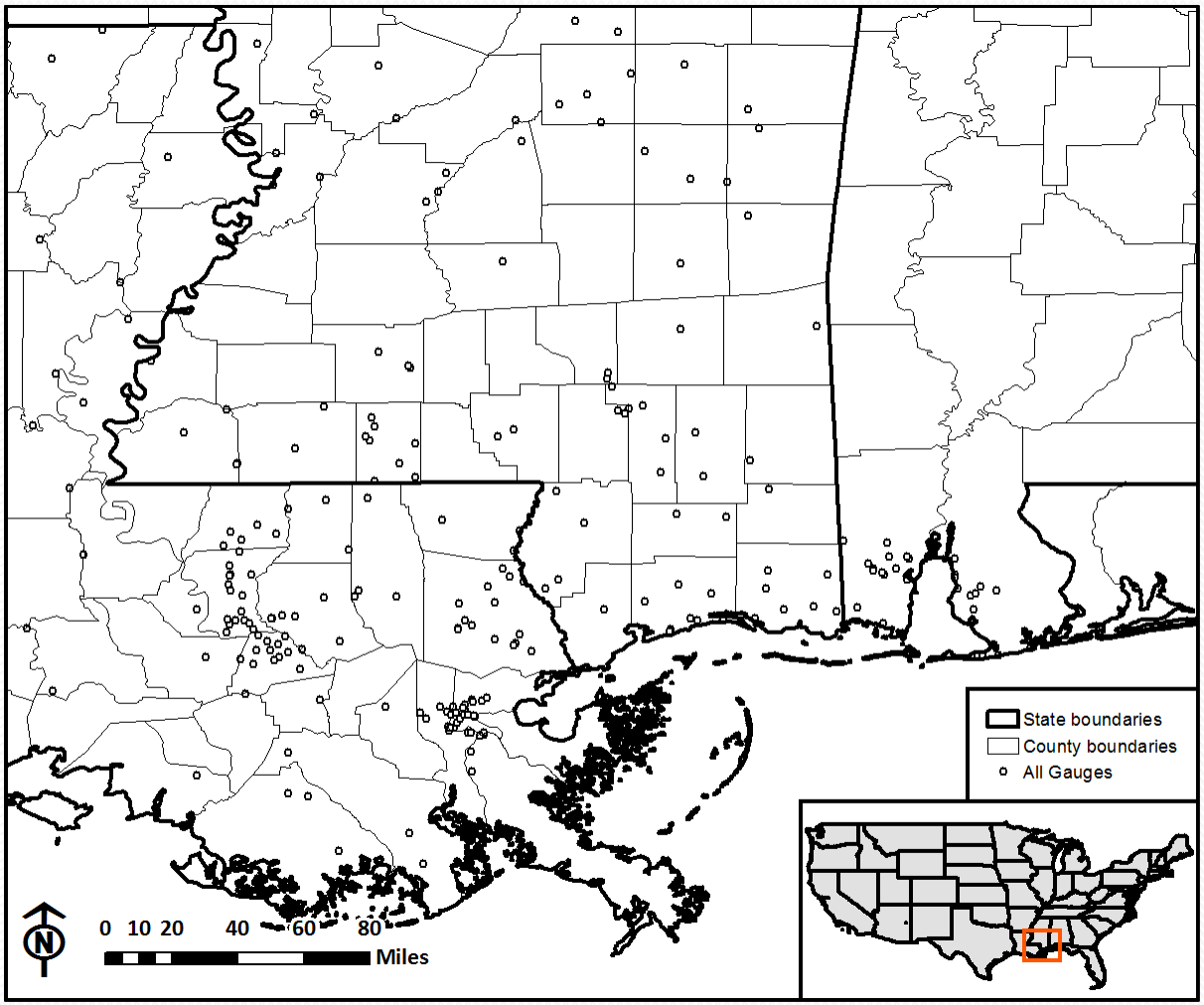
Rainfall Analysis



- Official and private gauge stations

All possible stations

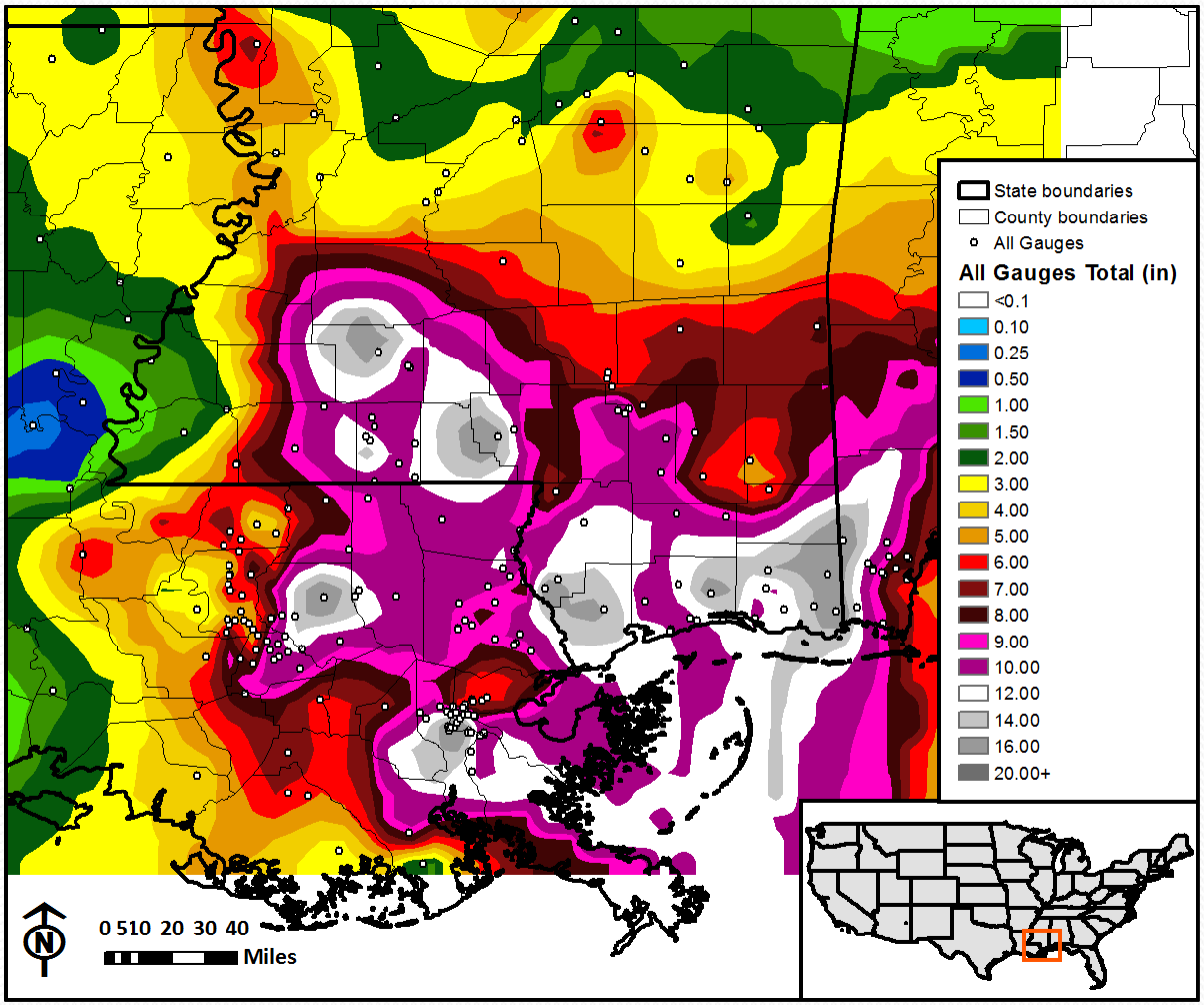
Rainfall Analysis



- Official and private gauge stations

Stations near the coast considered "good" after manual QC

Rainfall Analysis

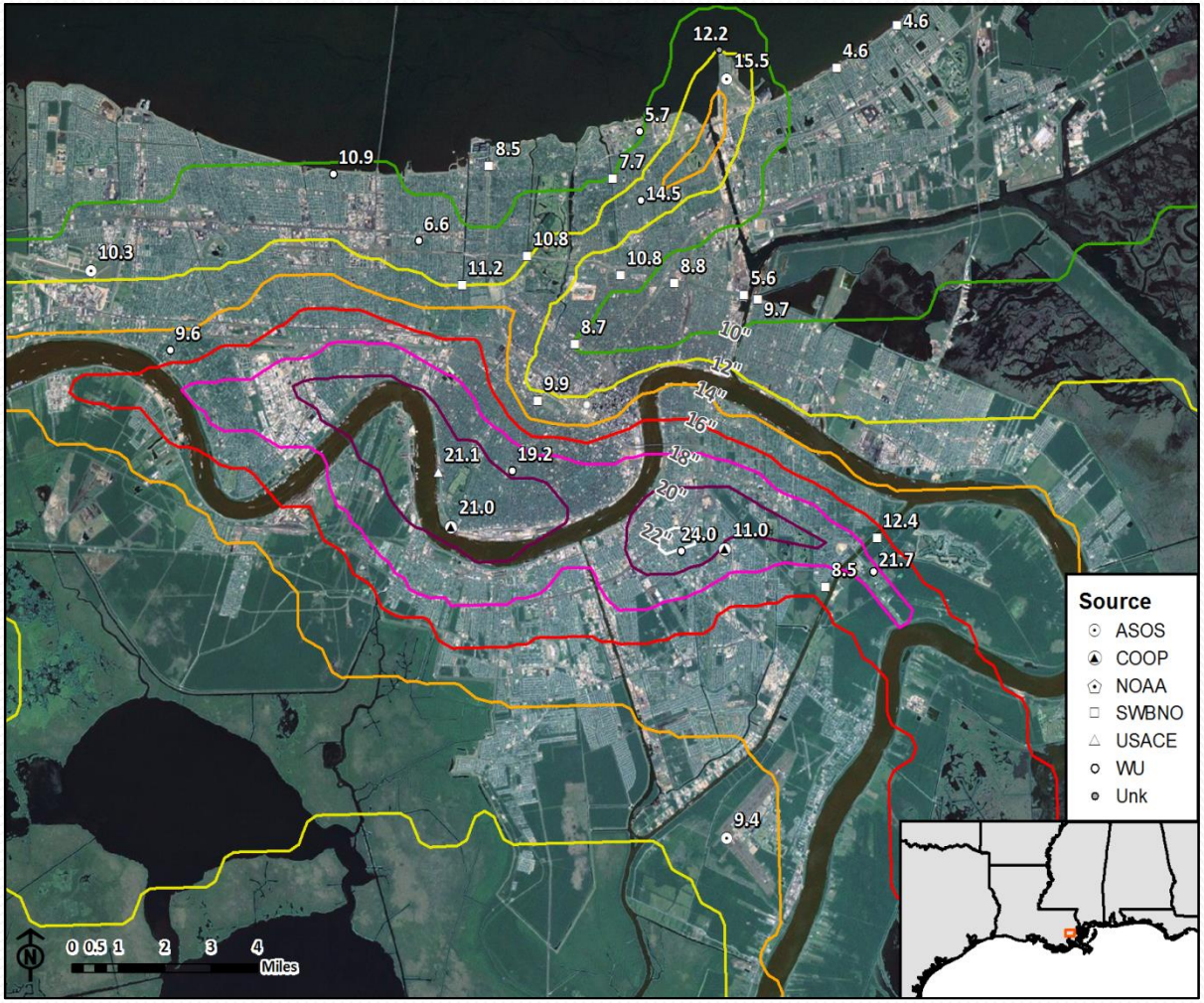


- Official and private gauge stations

Kriging Interpolation

More detail than official only, but not as much detail as radar-based products.

Rainfall Analysis

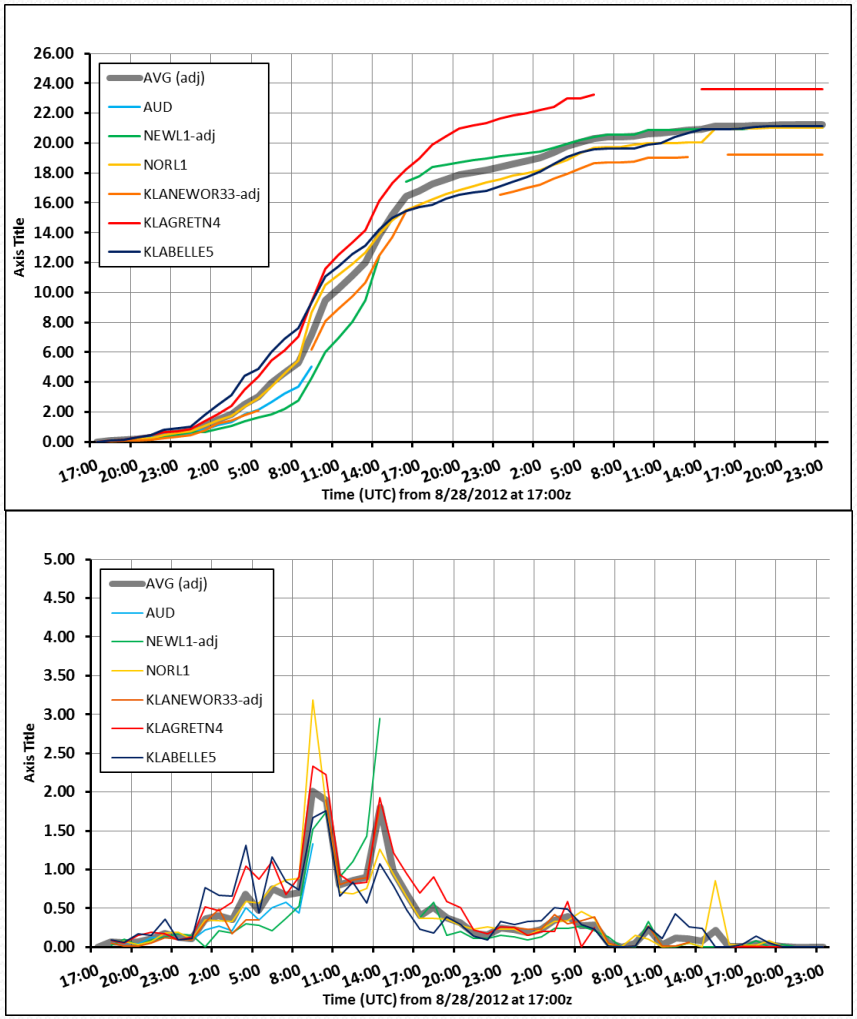


- New Orleans: Official and private gauge stations

Several gauges back up isolated heavy rainfall maxima in New Orleans

Sharp gradient…10" difference in just 2-3 miles

Rainfall Analysis



- Cumulative and hourly rainfall plots of New Orleans gauges

Remember 4.8in/1hr jump in data labeled "not likely?" (AUD#2)
Gauge total rainfall consistent with other gauges.

In context of big picture?

Appears to be **good** data.

Rainfall Analysis

2. How can we confirm/discount rainfall maxima in New Orleans?

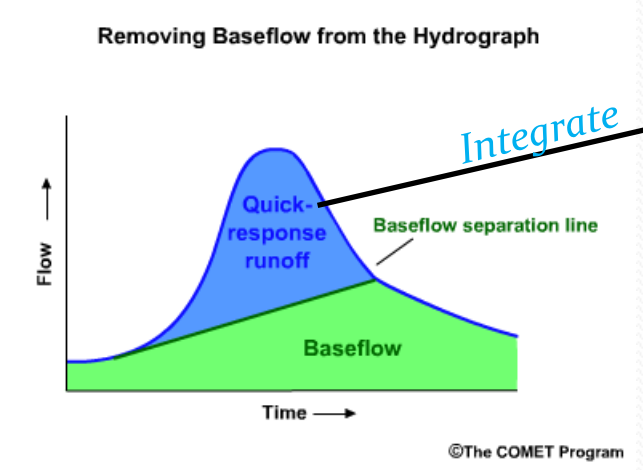
Estimate storm runoff as proxy for minimum basin-averaged rainfall.

- In typical watersheds with gauges at outlet point, we can estimate runoff using a rating curve and the discharge hydrograph.
- New Orleans is not a typical watershed
  - Runoff does not flow downhill into streams
  - Runoff flows into storm drains which have to be pumped into canals, then pumped into Lake Pontchartrain

Rainfall Analysis

2. How can we confirm/discount rainfall maxima in New Orleans?

Estimate storm runoff as proxy for minimum basin-averaged rainfall.



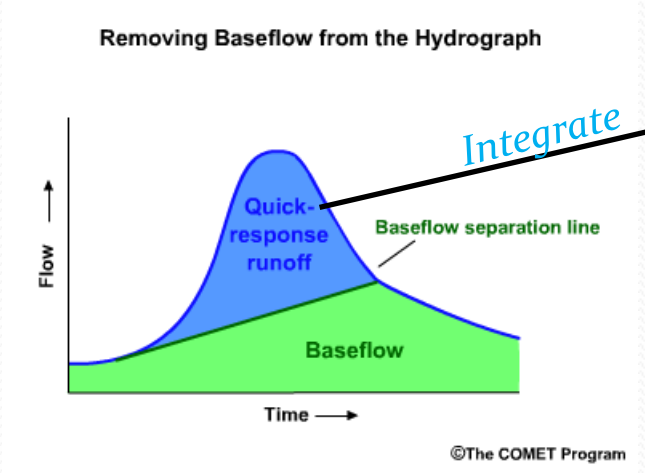
Integrate → **Total Event Flow** → Divide by area → **Watershed runoff**

Rainfall Analysis

2. How can we confirm/discount rainfall maxima in New Orleans?

For New Orleans, will have to use pumping logs from Sewerage & Water Board in combination with pump curves to estimate volume pumped from city.

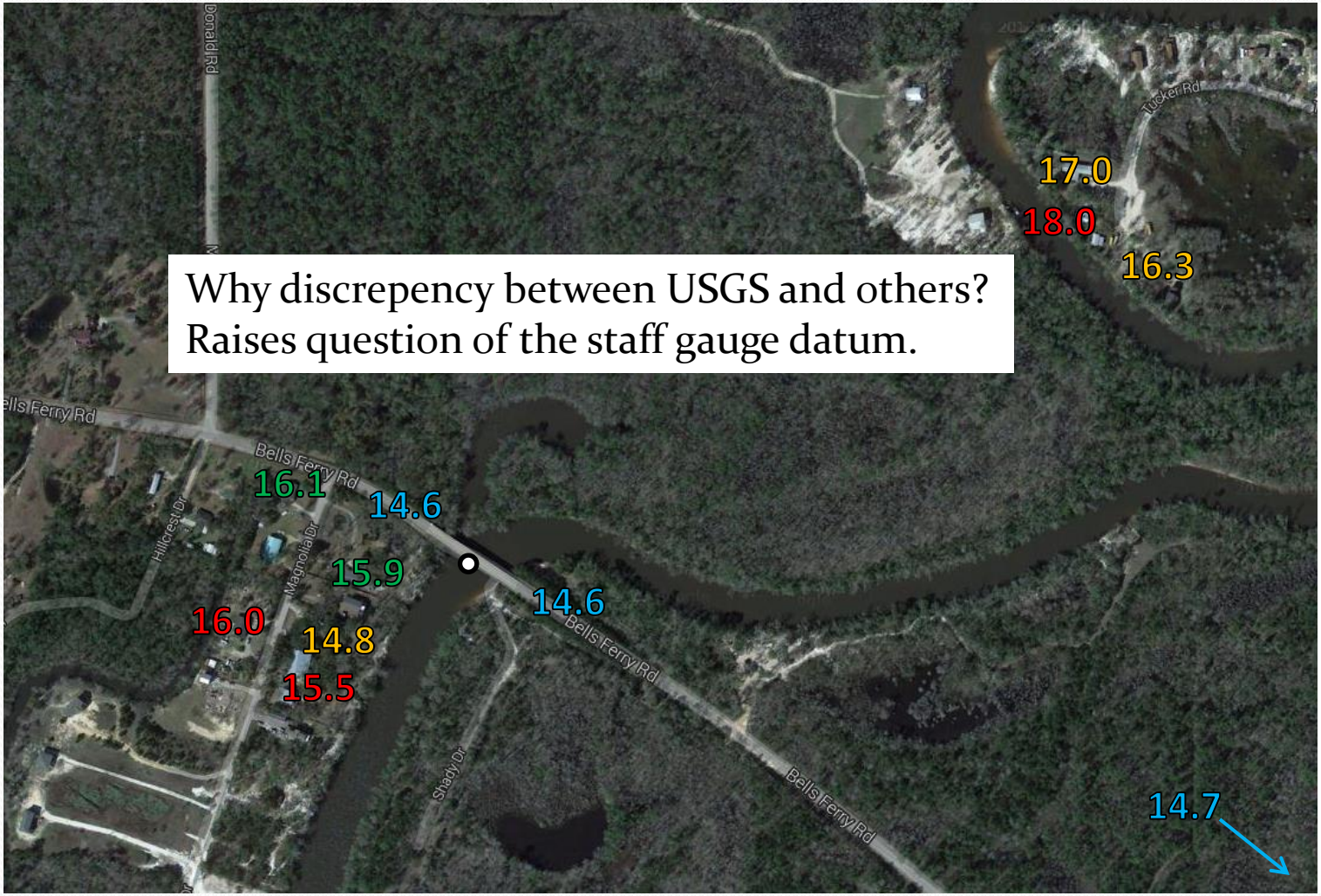
This remains an area of ongoing analysis.



Integrate → **Total Event Flow** → Divide by area → **Watershed runoff**

Hurricane Isaac: Post-Landfall Establishing Crests

Establishing Crests



Wolf @ Bells Ferry Rd HWMs

SOURCE

USGS

NWS/Survey

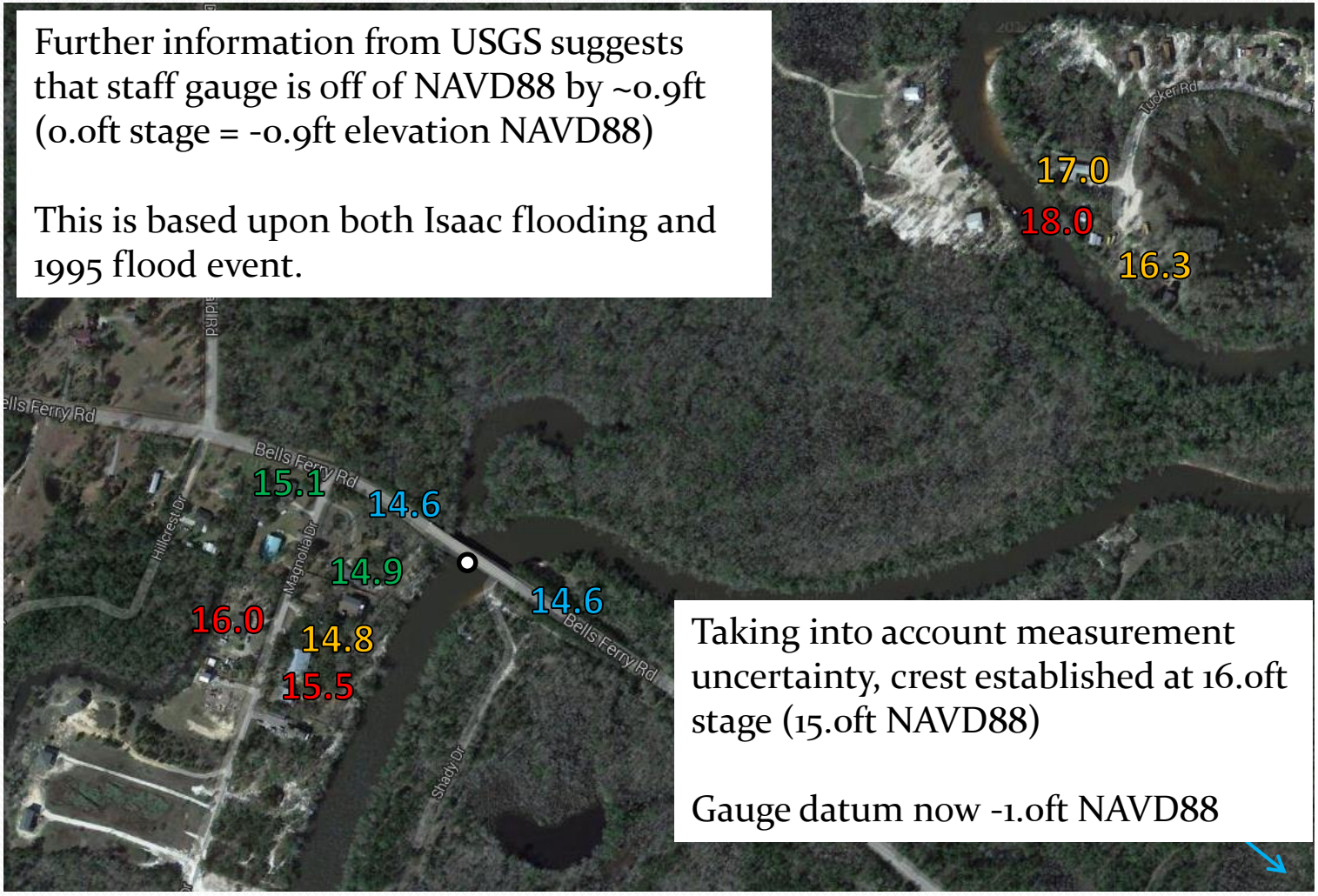
Public (High Confidence)

Public (Low Confidence)

Establishing Crests

Further information from USGS suggests that staff gauge is off of NAVD88 by ~0.9ft (0.0ft stage = -0.9ft elevation NAVD88)

This is based upon both Isaac flooding and 1995 flood event.



Taking into account measurement uncertainty, crest established at 16.0ft stage (15.0ft NAVD88)

Gauge datum now -1.0ft NAVD88

Wolf @ Bells Ferry Rd HWMs (ft NAVD88)

SOURCE

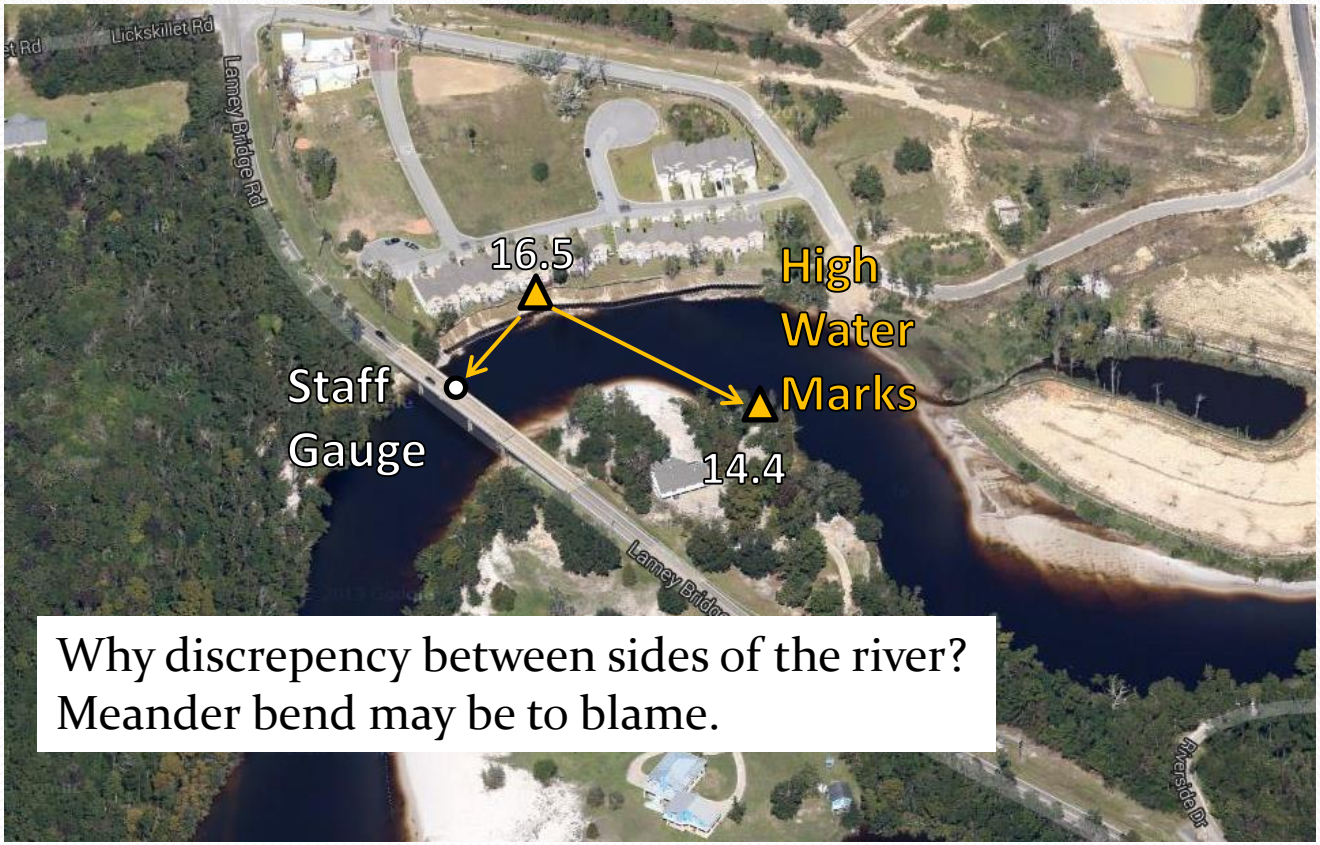
USGS

NWS/Survey

Public (High Confidence)

Public (Low Confidence)

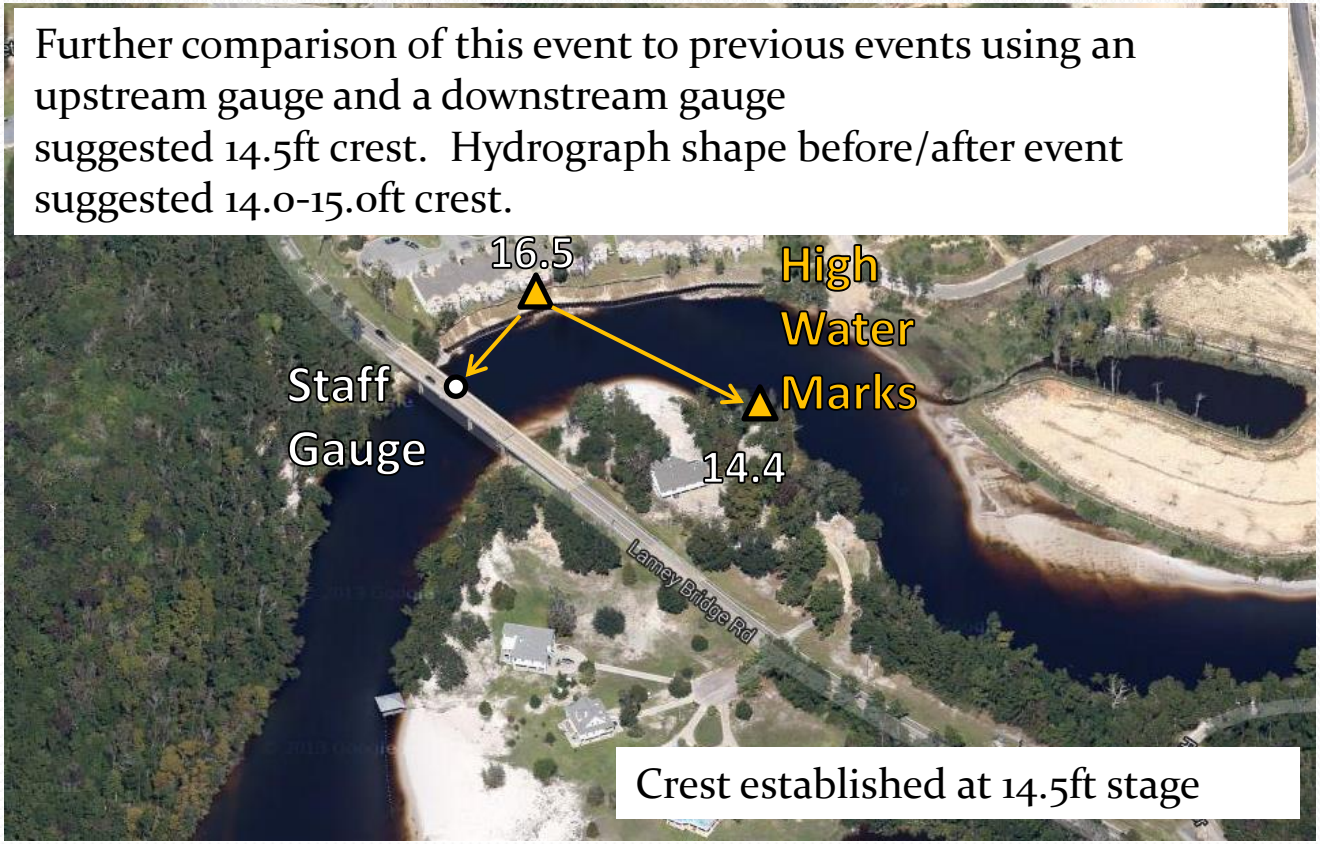
Establishing Crests



Tchoutacabouffa @ Lamey Bridge Rd HWMs

Establishing Crests

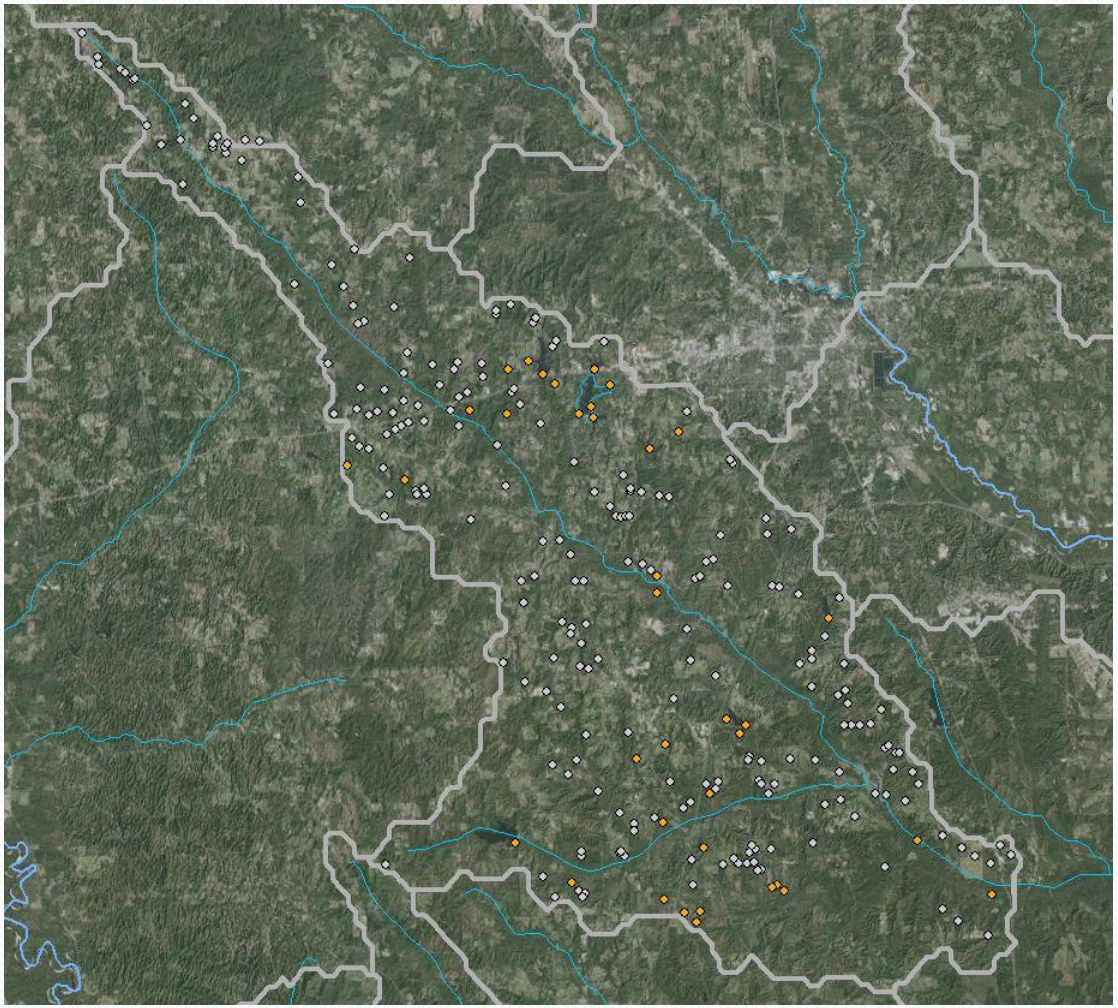
Further comparison of this event to previous events using an upstream gauge and a downstream gauge suggested 14.5ft crest. Hydrograph shape before/after event suggested 14.0-15.0ft crest.



Tchoutacabouffa @ Lamey Bridge Rd HWMs

Hurricane Isaac: Other Post-Storm Analyses

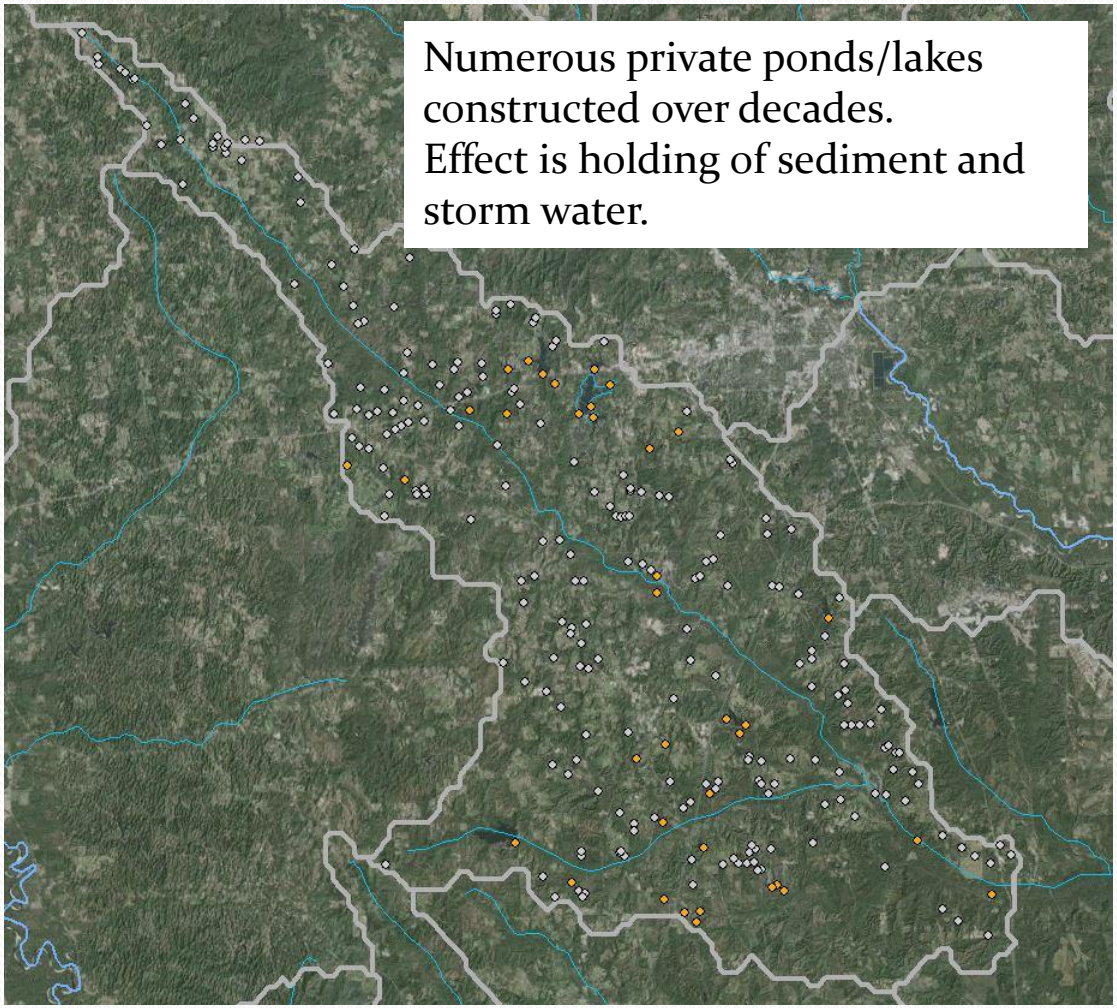
Flood Survey Report Summary



Black Creek

Why the lower crest with similar rainfall to past events?

Flood Survey Report Summary



Black Creek impoundments

Known Dams

Manually Digitized Dams

Conclusions and Final Remarks

Conclusions and Final Remarks

- Hurricane Isaac's slow movement at landfall set the stage for storm surge and heavy rainfall impacts to coastal Louisiana/Mississippi
- NWS staff surveyed flood impacts after the storm to document impacts
- Numerous individuals kept close watch on river forecasts using the NWS's AHPS
- Numerous individuals were aware of their surveyed elevation and how to correlate to nearby gauges

Conclusions and Final Remarks

- Proper analysis requires putting data in the context of the big picture
- Realtime, in-situ observation networks are essential; remote-sensed data (such as radar) more uncertain without ground truth
- Post-event analysis can improve with more data
- Larger variety of tools/models, used properly, improve forecasting and analysis

Questions/Comments/Complaints?

Showing off safe procedures while surveying Isaac flooding.

W. Scott Lincoln
Hydrologist, Cartographer
NWS Lower Mississippi River Forecast Center

scott.lincoln@noaa.gov