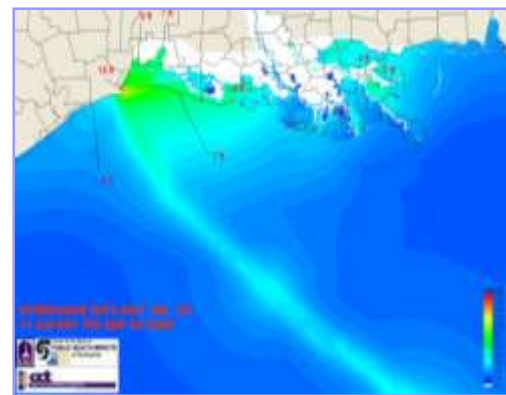
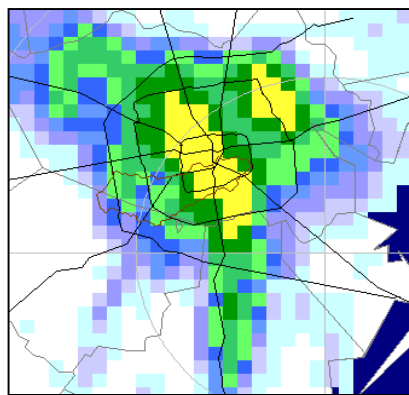


An Operational Radar-based Flood Warning System for Highly Urbanized Area in Texas



Nick Z. Fang¹, Ph.D., P.E. and Philip Bedient², Ph.D., P.E.,

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². Civil and Environmental Engineering Dept., Rice University/SSPEED Center

Catchment-based Hydrologic Model Data Assimilation
and Hydrologic Ensemble Prediction Experiment Joint Workshop
Austin, TX, September 9, 2014



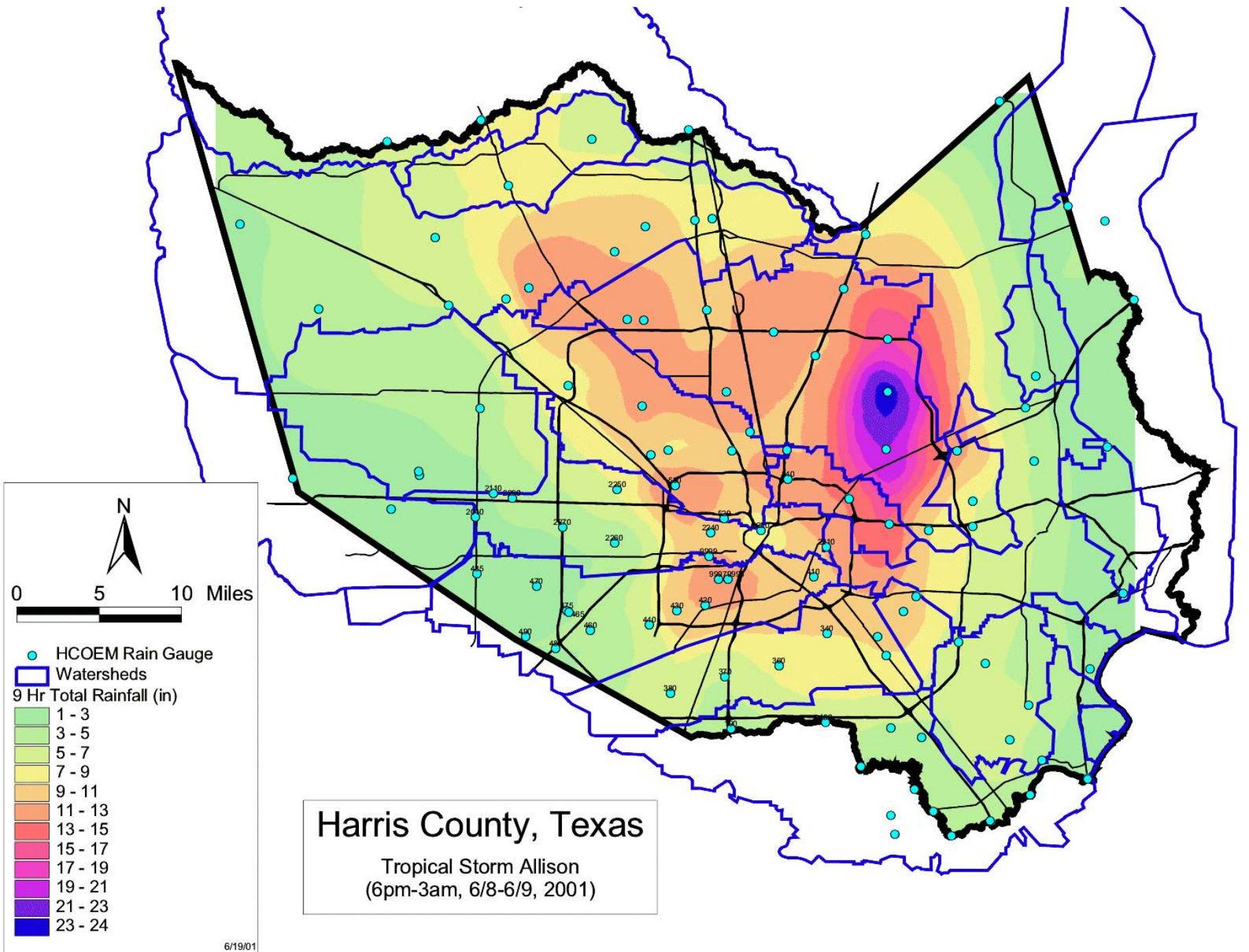
UNIVERSITY OF
TEXAS
ARLINGTON



RICE
Unconventional Wisdom

Highway 59 After TS Allison (2001)





Development of FAS (1997 -2014)



- 1997 - Developed for Brays Bayou
 - Tested on more than 40 events since 1997
- 2001 - System tested on TS Allison
- 2003 - System was upgraded to FAS2
- 2005 to 2013 -The core hydrologic model was calibrated and improved
- 2009 - Floodplain Map Library (FPML) implemented within Google Maps
- 2010 - FAS2 was upgraded to FAS3

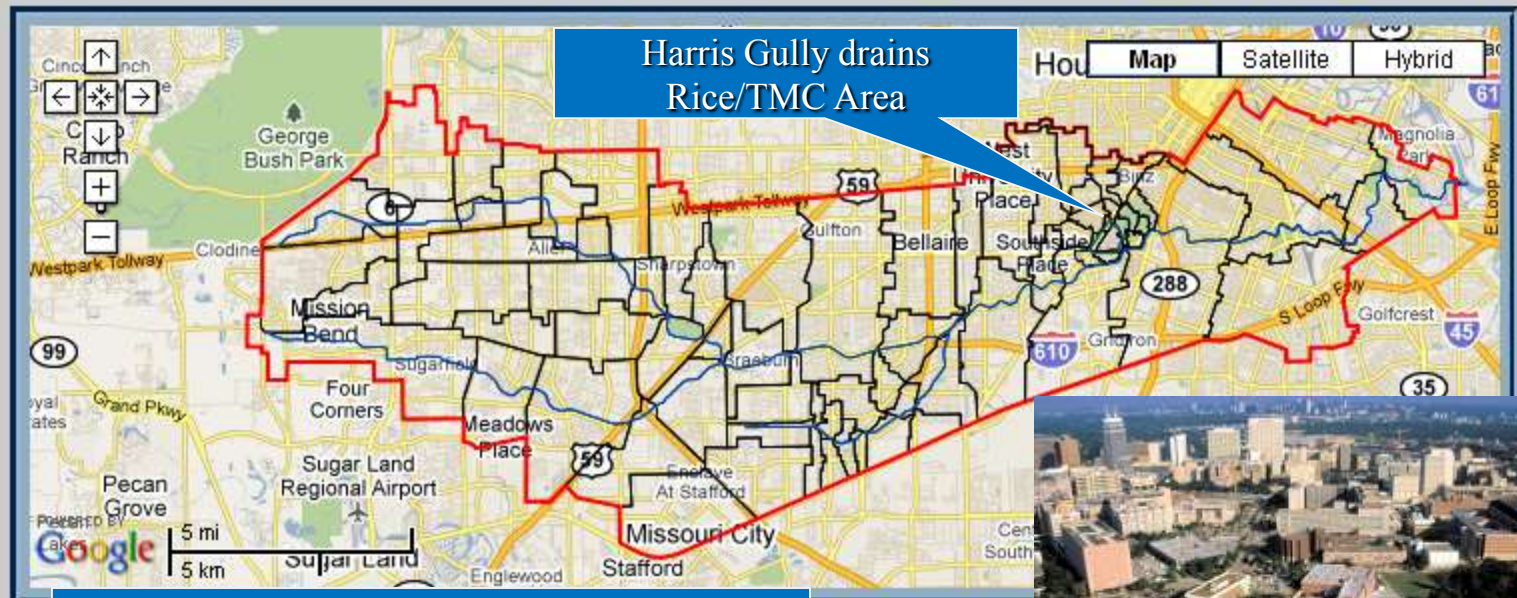


Brays Bayou and Harris Gully



THE RICE UNIVERSITY AND TEXAS MEDICAL CENTER FLOOD ALERT SYSTEM

- Home
- Radar
- Rainfall
- Cameras
- Hydrology
- Case Studies
- News



Harris Gully: 4.5 sq. mi.
Brays Bayou: 129 sq. mi.



Needs for Inland Flood Protection



- Rapidly moving weather systems - **explosive** rainfalls
- Urban developments exceeded the original **design capacity** of the channels
- Severe **street flooding** occurs during routine rainfalls
- Many **older areas** are very prone to floods
- Timely information for flooding and **evacuations**
- **Damage costs** continue to increase



What does Flood ALERT System do?



- Increase lead time for flood warning
- Provide accurate real-time radar rainfall estimates (1998-2014)
- Google Earth/Maps technologies integrated
- Radar rainfall can be visualized over the watershed in Google Maps
- Provide frequent information updates via the web site fas3.flood-alert.org
- Provide communication – emergency response and operations



Rice/TMC Flood Alert System (FAS3)

NEXRAD

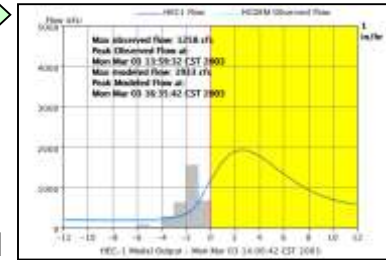


QPE & Rain Gages

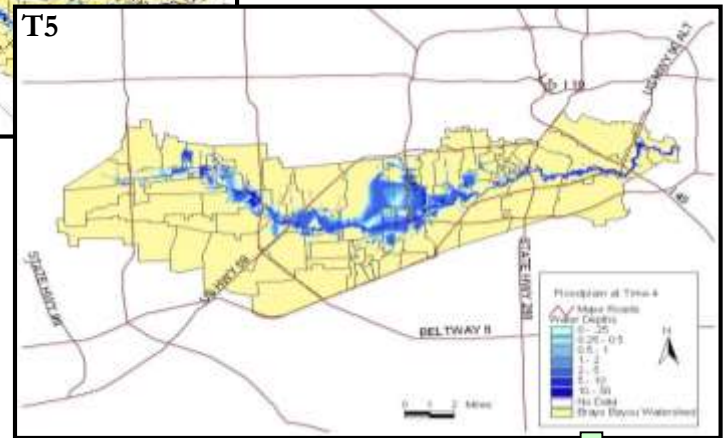
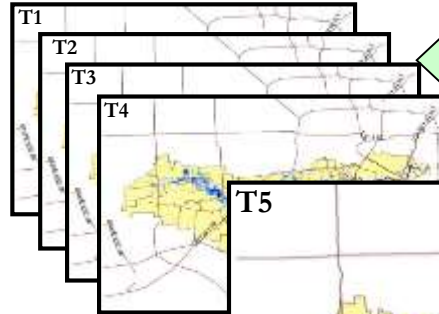
Flood Prediction Module

Real-Time Rainfall/
Runoff Prediction

Real-Time Hydrographs



Flood Plain Map Library



Warnings & Communication Module

Rice/TMC

- Internet
- Fax
- E-mail
- Phone

Alert Levels



&
Flood Protection
Action Levels

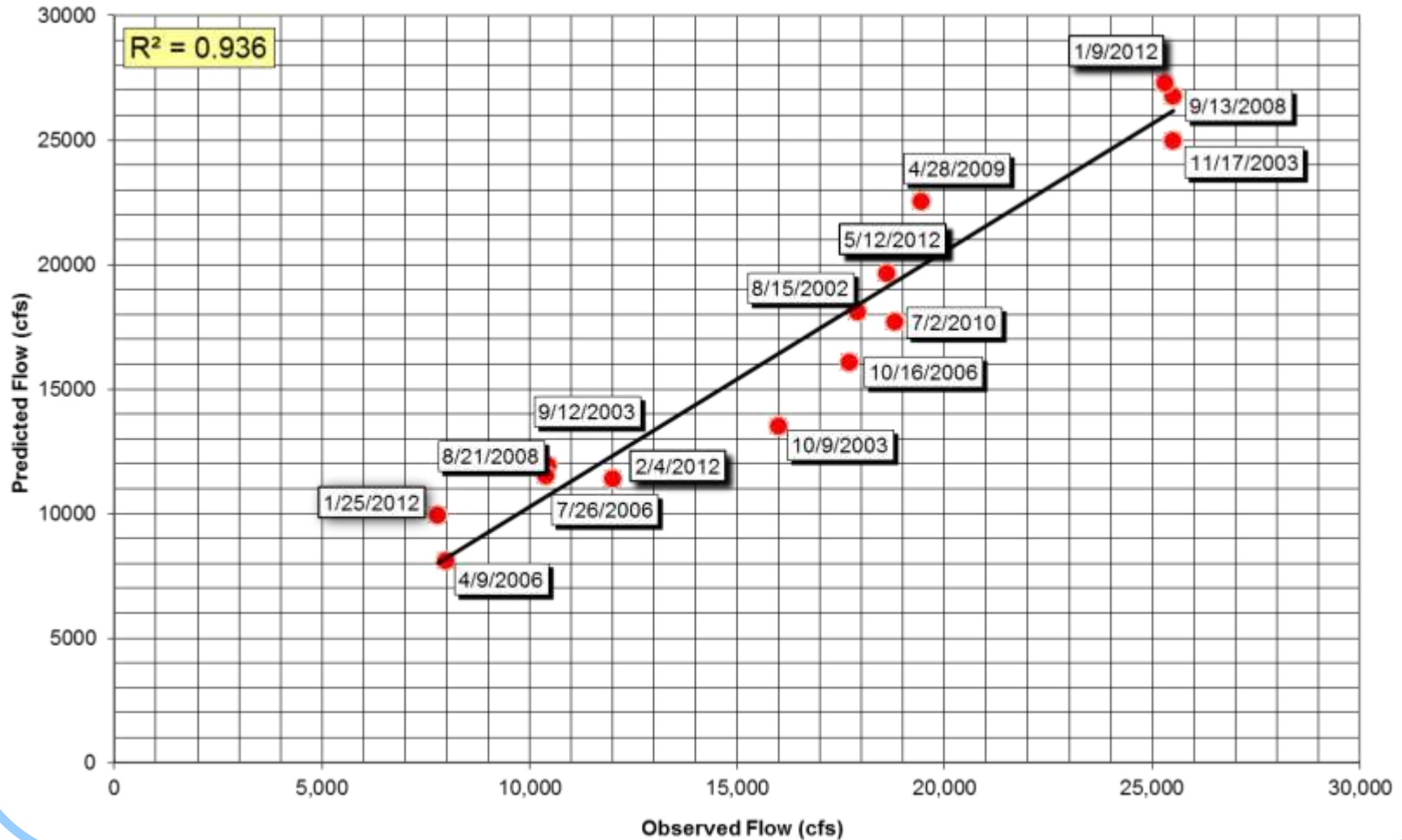
Flood Protection &
Emergency Actions

- Evacuations
- Recall of Personnel
- Flood door closure
- Backup Power

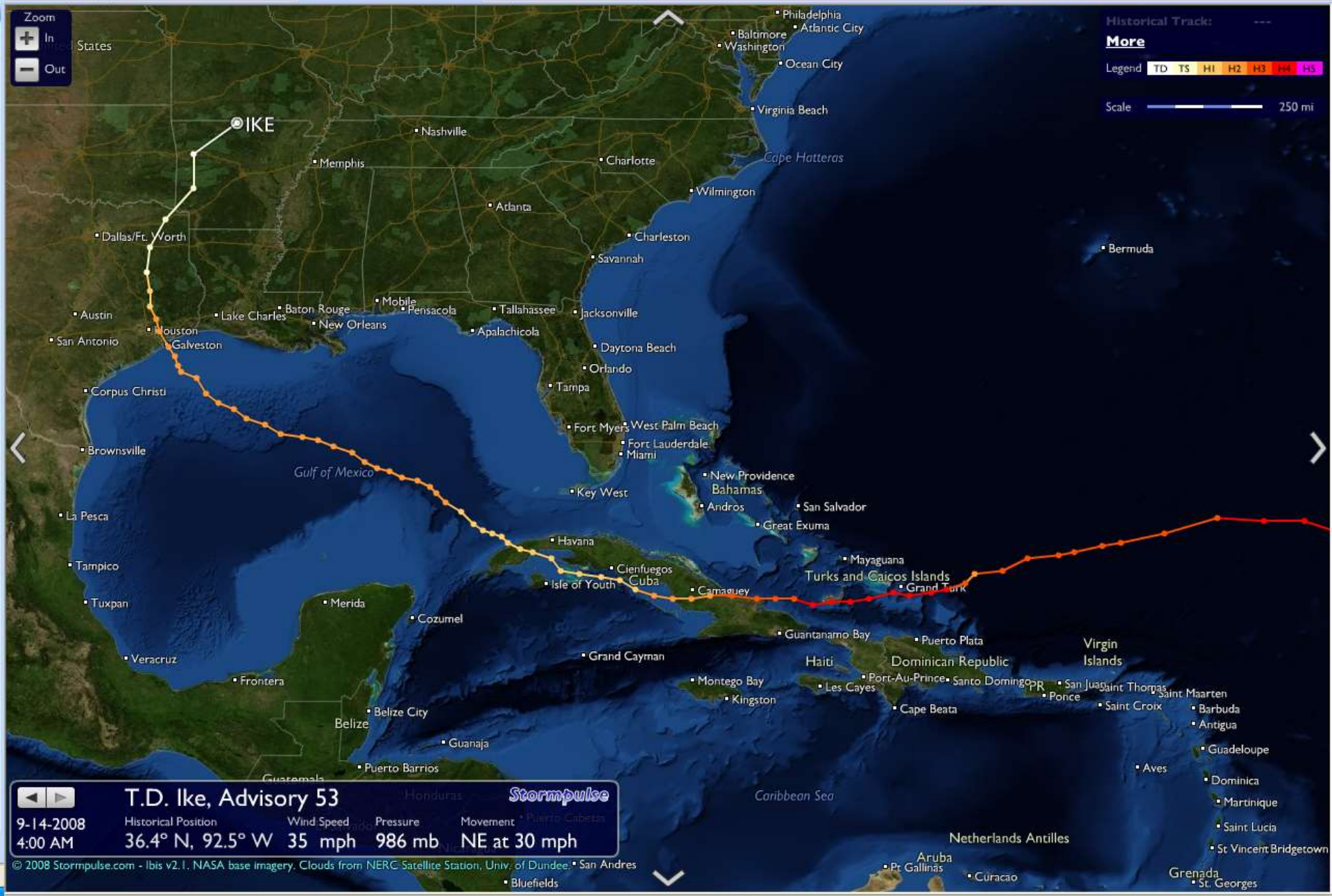
Visual Confirmation (Bayou Cameras)



FAS3 Performance (2002-2012)



Hurricane Ike Track (Sept. 2008)



Flooding During Hurricane Ike



Onlookers pause on a bridge to survey floodwater covering I-45 just north of downtown Houston.



Men walking on flooded I-10 in downtown Houston.

Flooding in TMC during Hurricane Ike

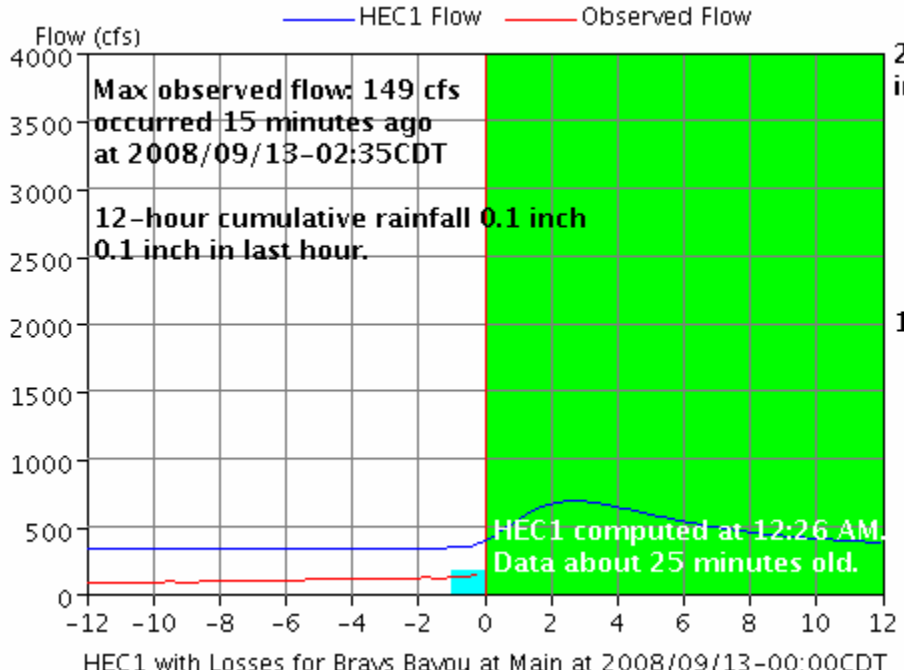
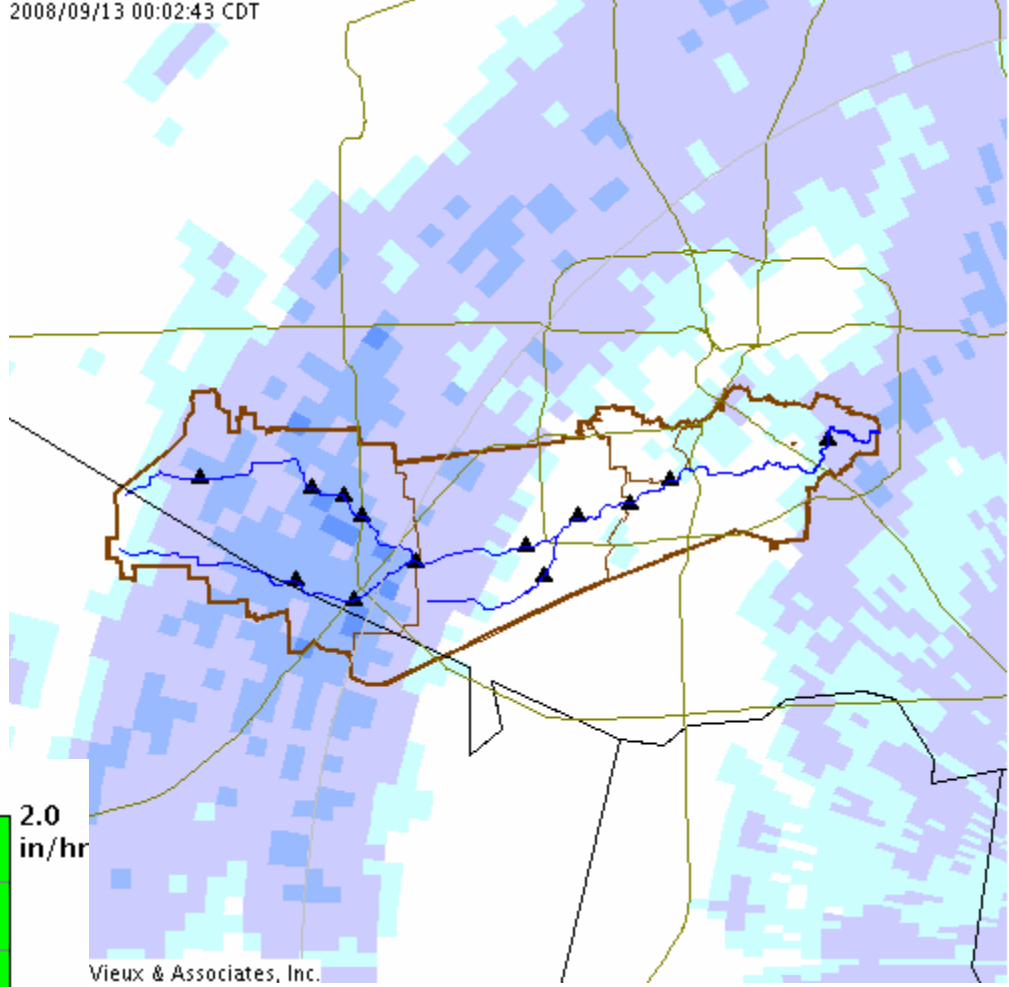
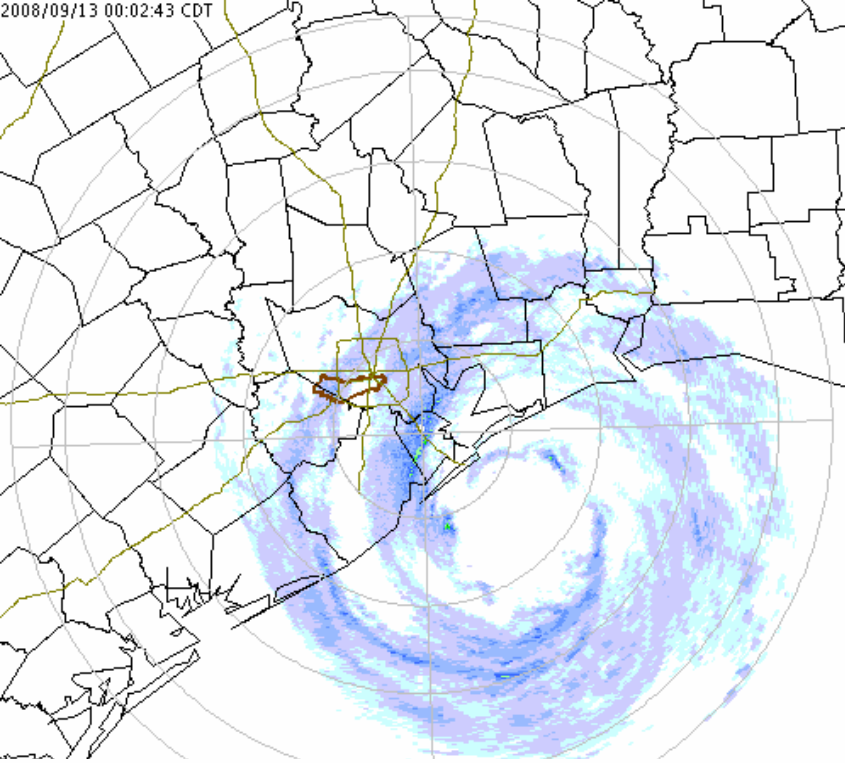


After Hurricane Ike (Sep. 14, 2008)



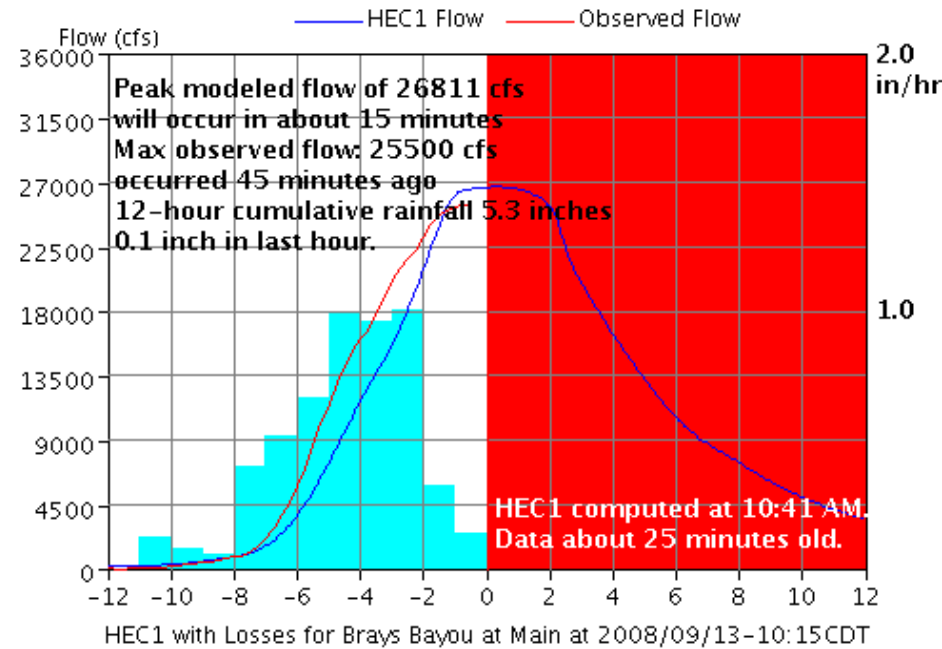
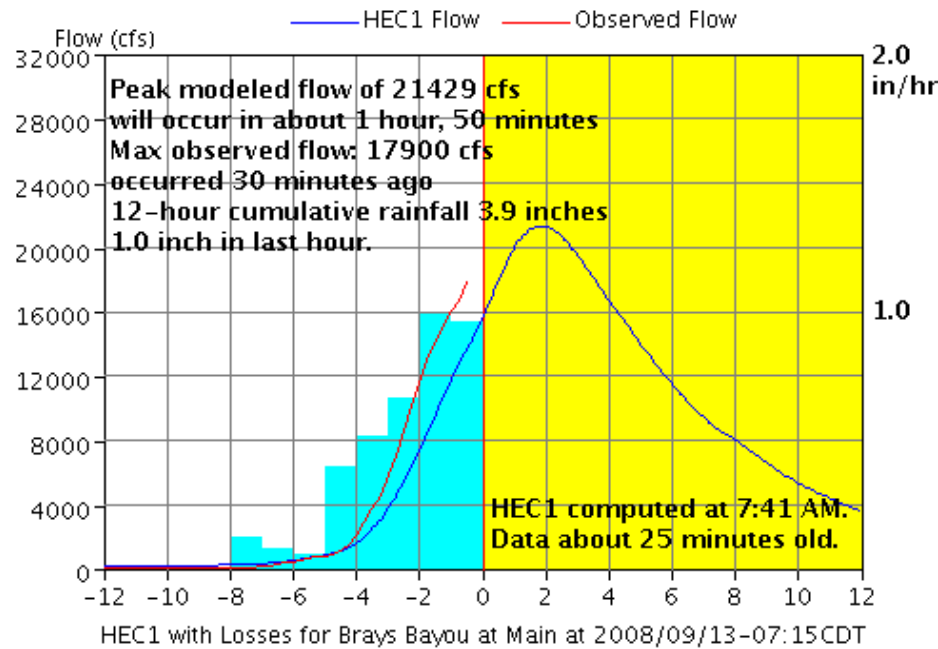
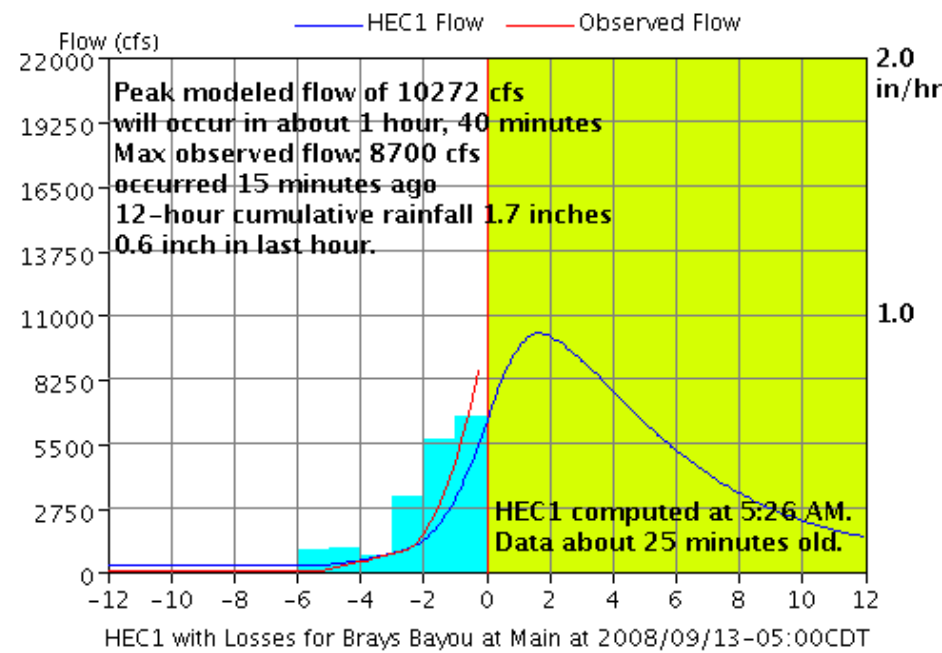
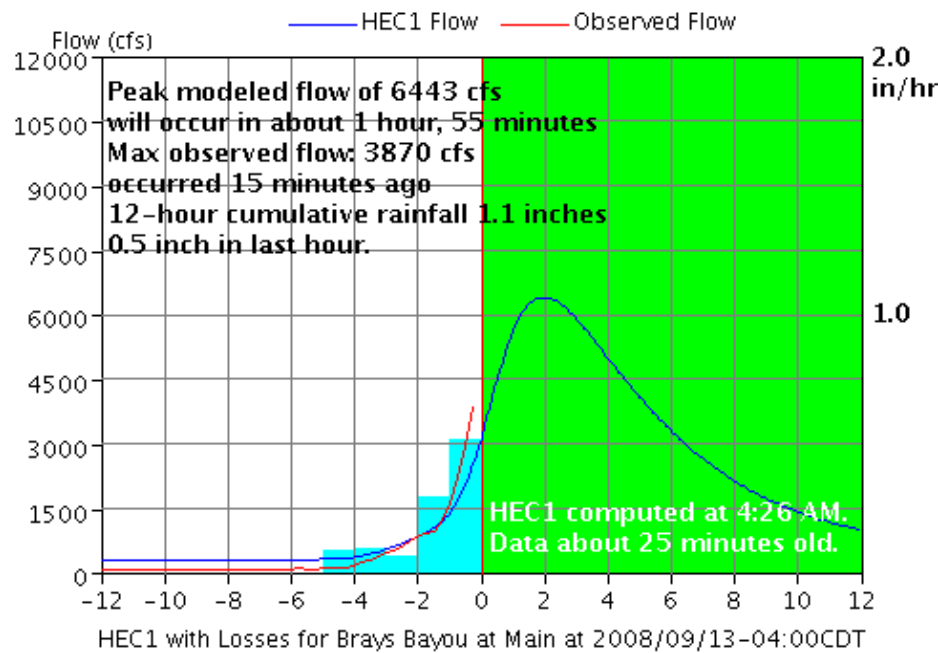
Channel at normal conditions





Hurricane Ike (September 13) and FAS2 Prediction

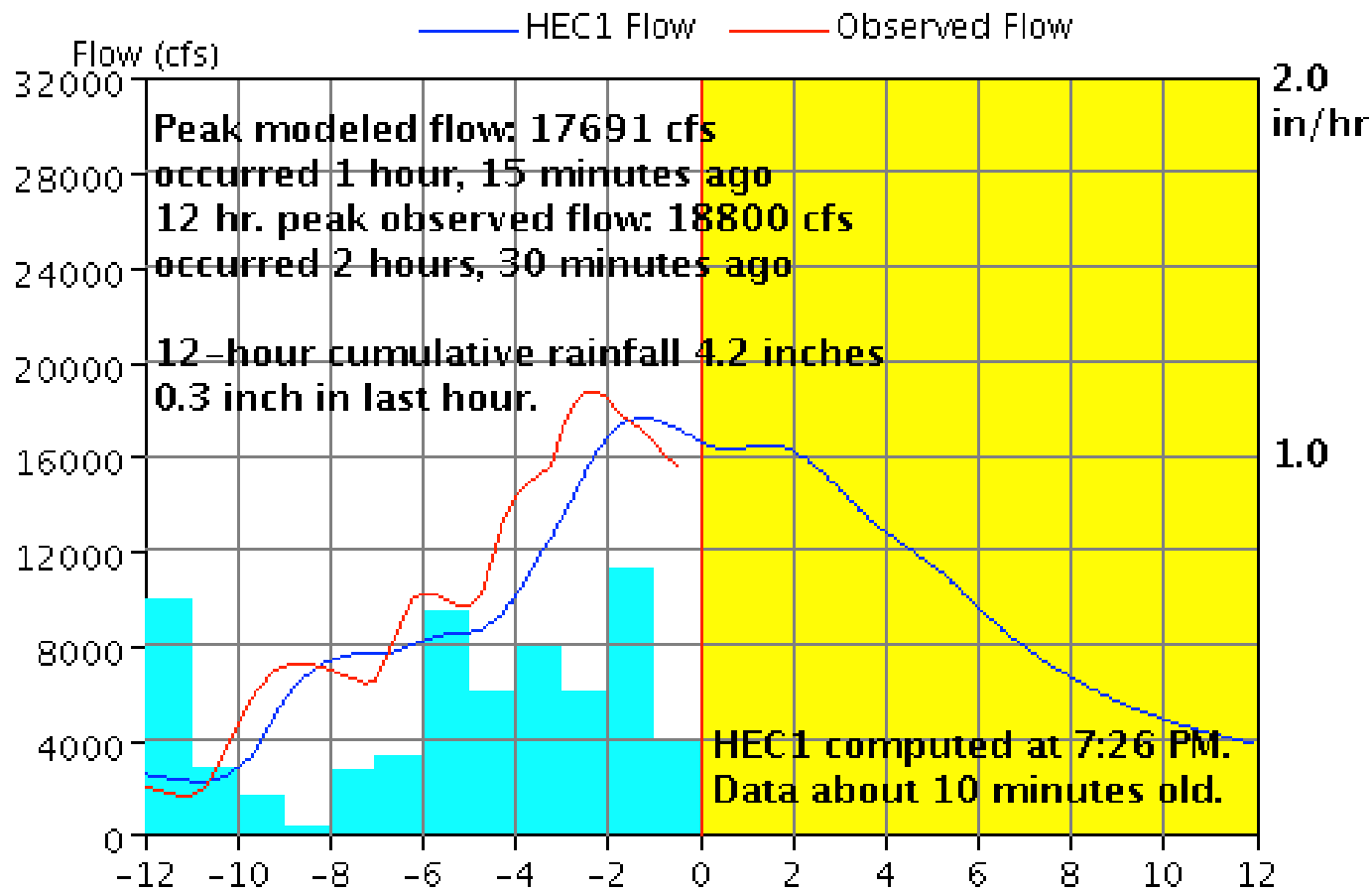




Flood Alert System Performance



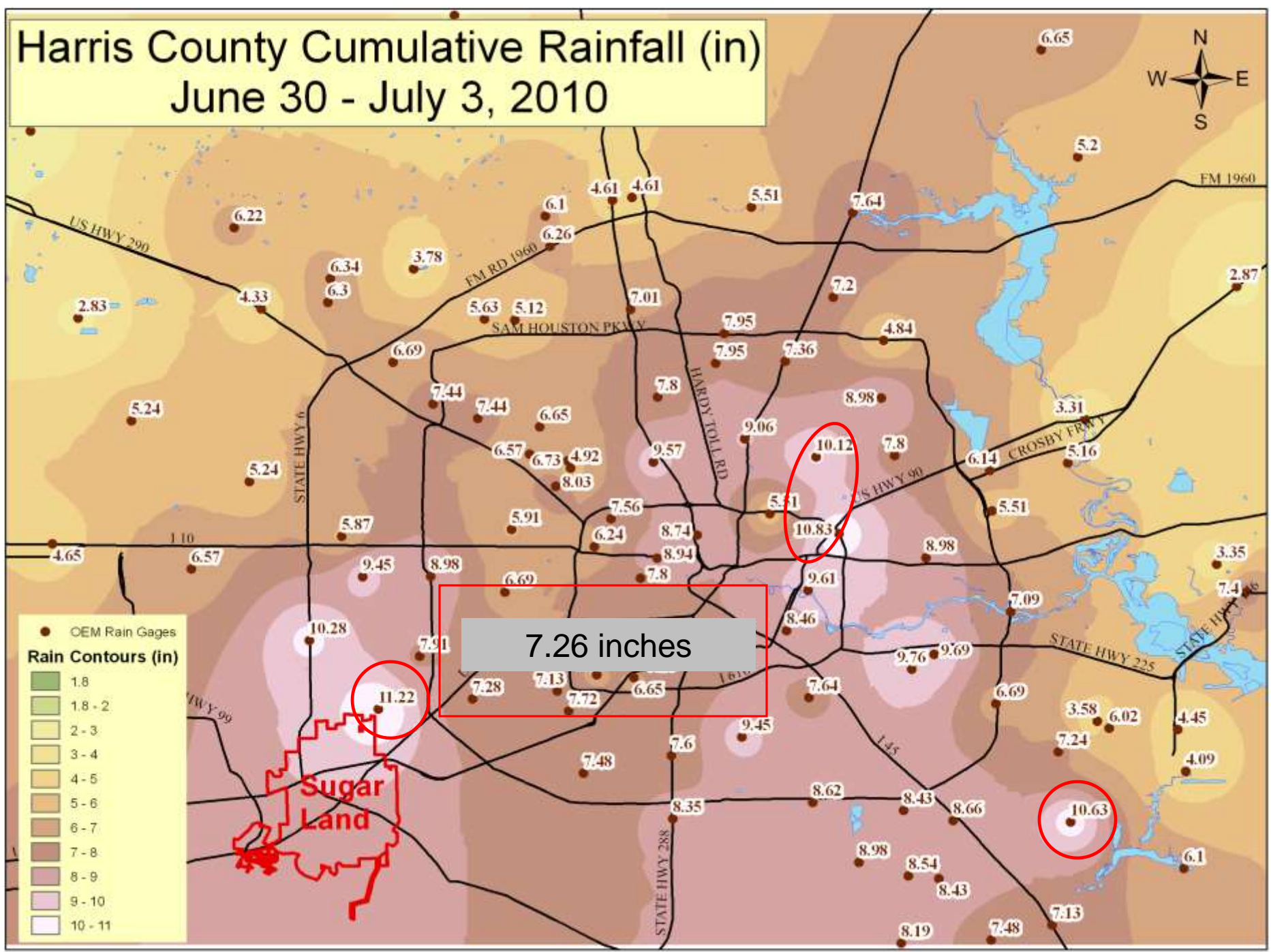
July 2, 2010 Event



HEC1 lowloss estimate for D100-16 at 2010/07/02-19:15CDT



Harris County Cumulative Rainfall (in) June 30 - July 3, 2010



● OEM Rain Gages

Rain Contours (in)

- 1.8
- 1.8 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 11

7.26 inches

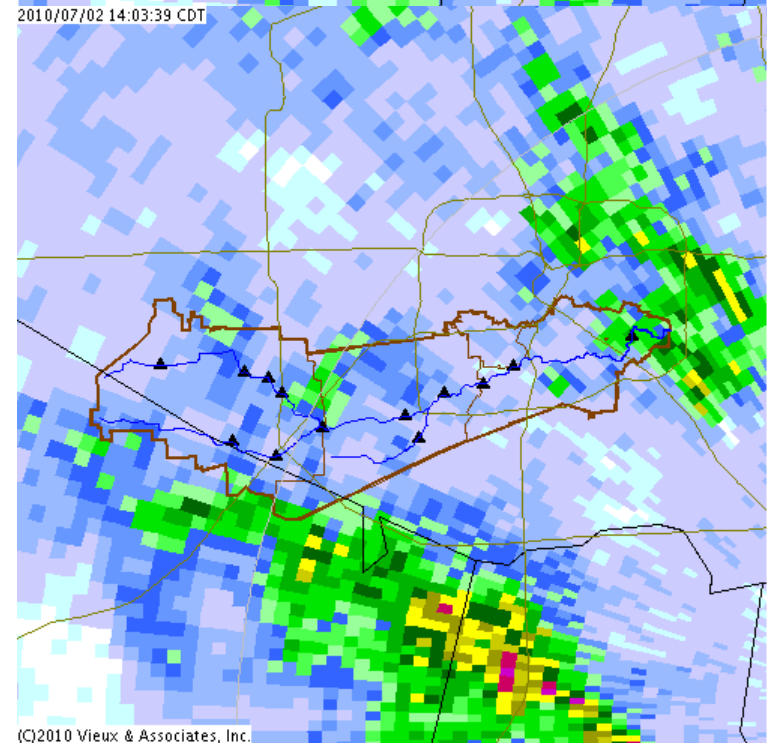
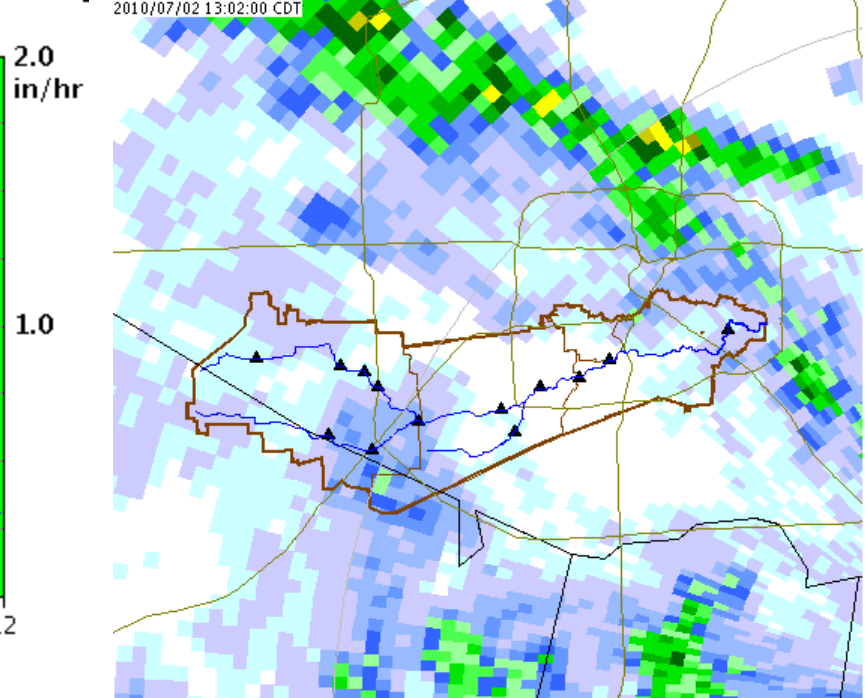
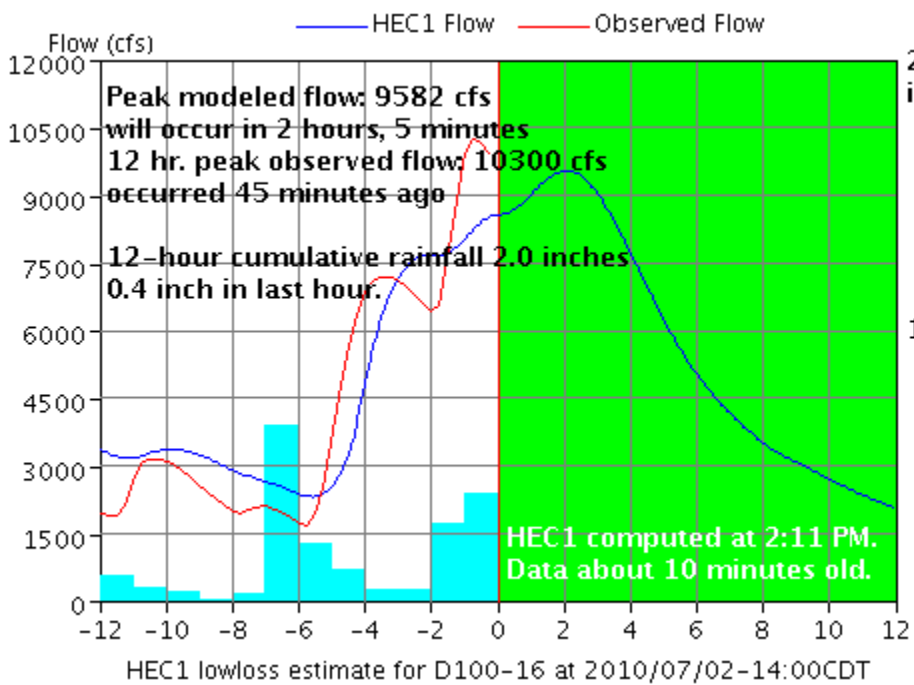
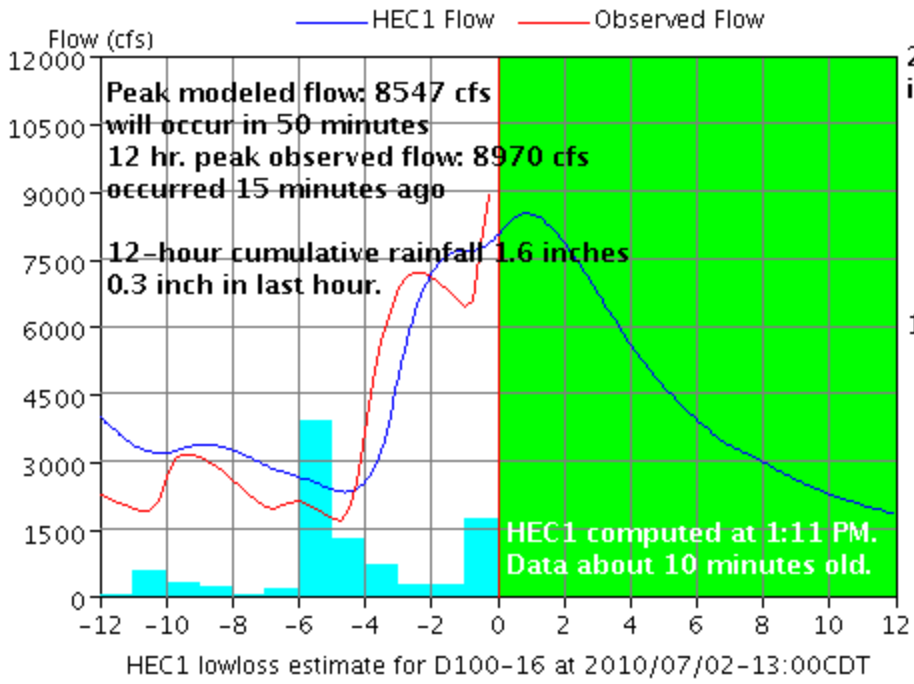
11.22

10.12

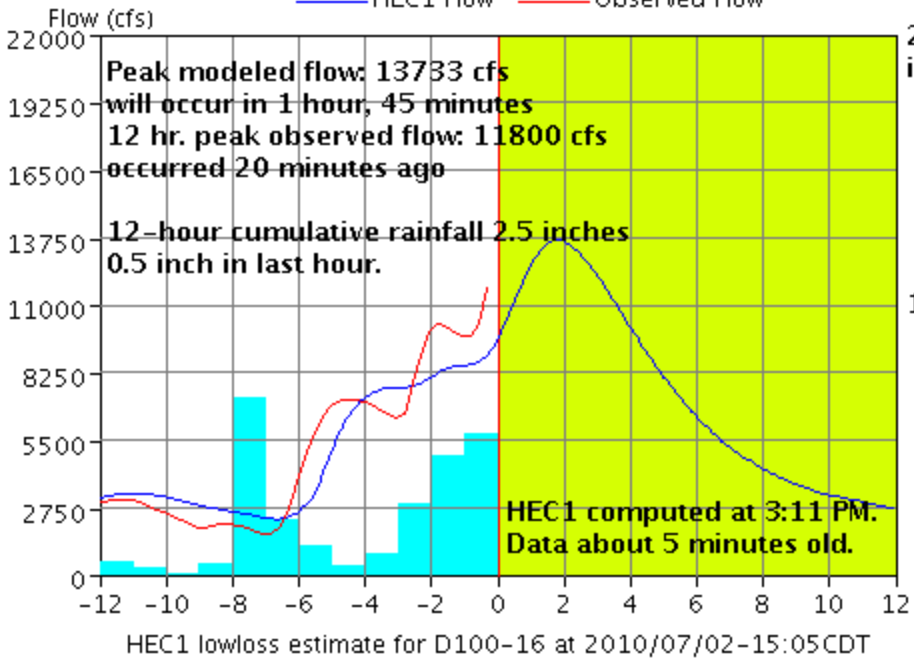
10.83

10.63

Sugar Land

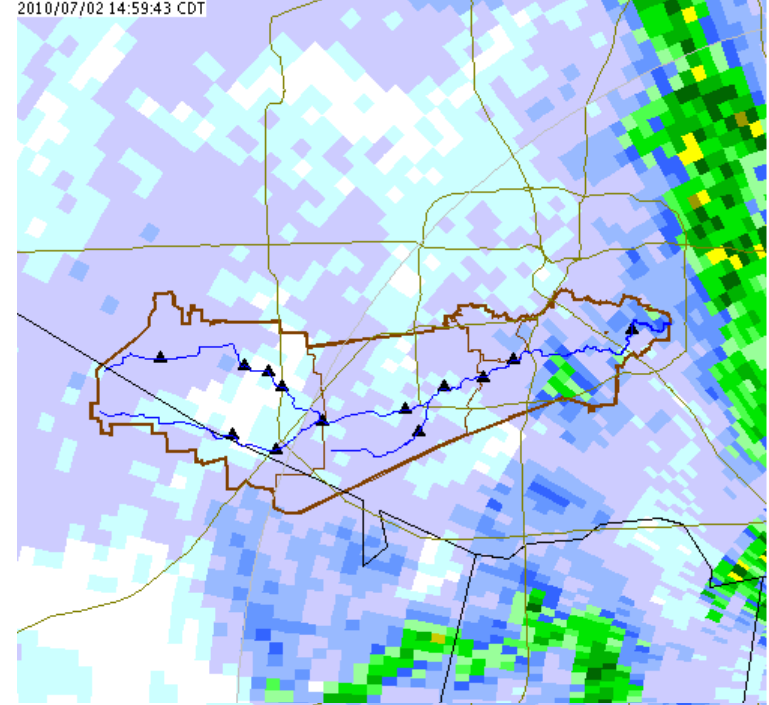


— HEC1 Flow — Observed Flow



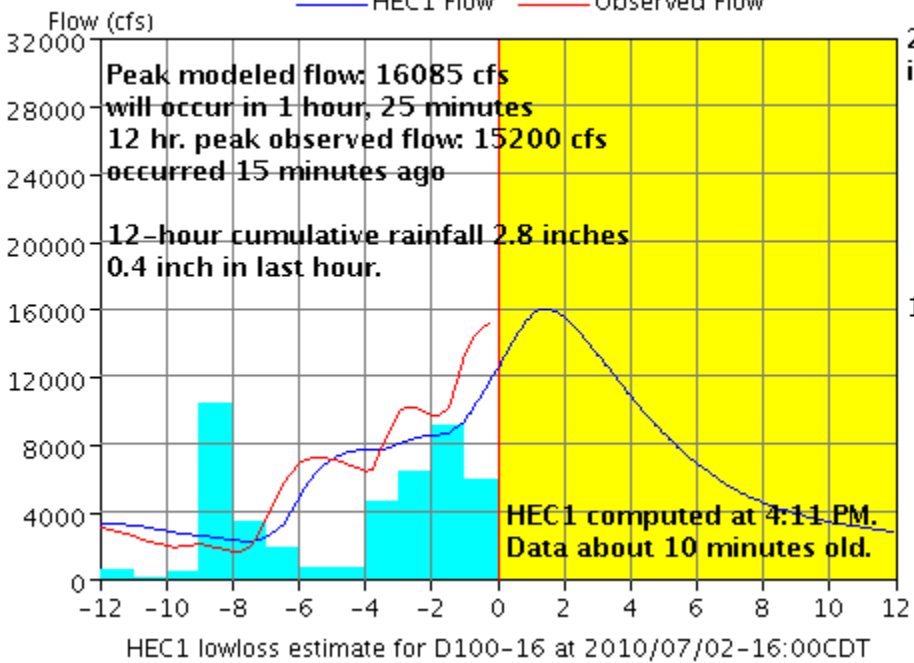
2.0 in/hr

1.0



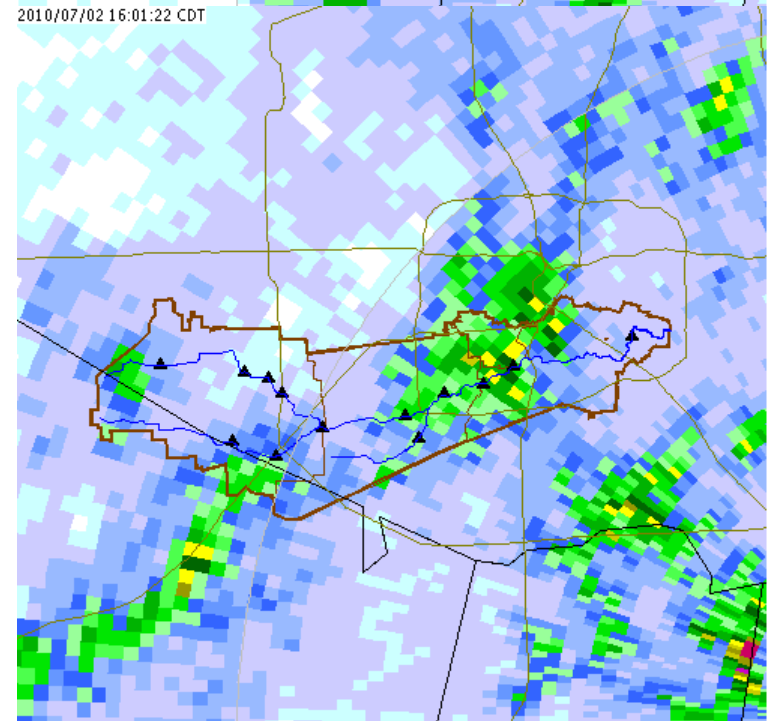
2010/07/02 16:01:22 CDT

— HEC1 Flow — Observed Flow

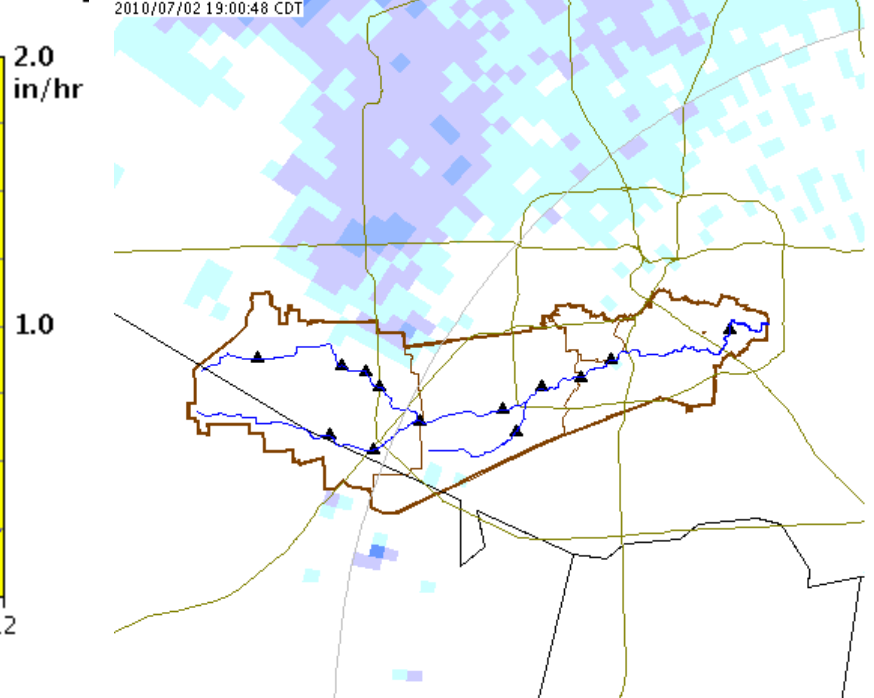
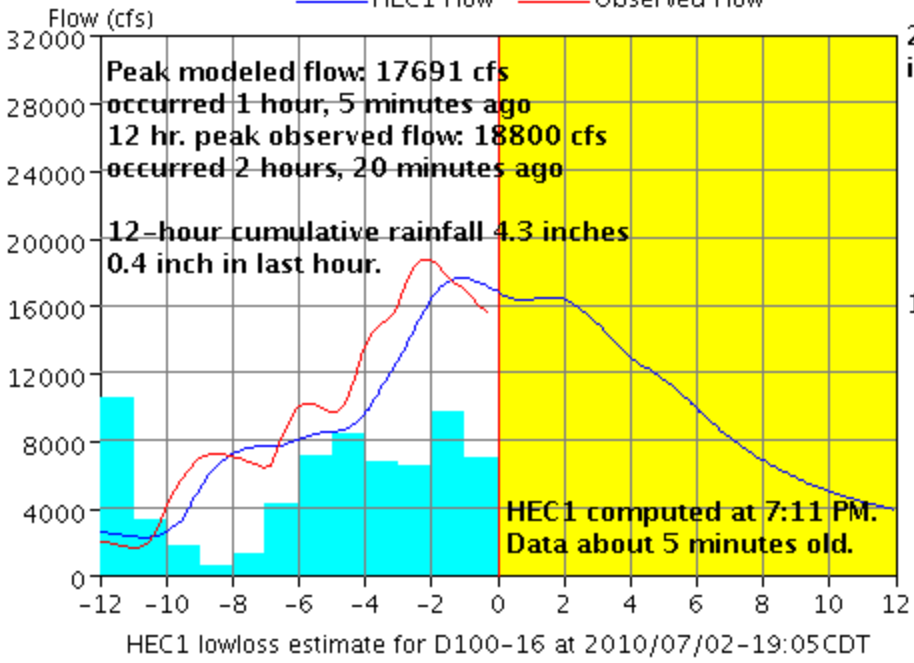


2.0 in/hr

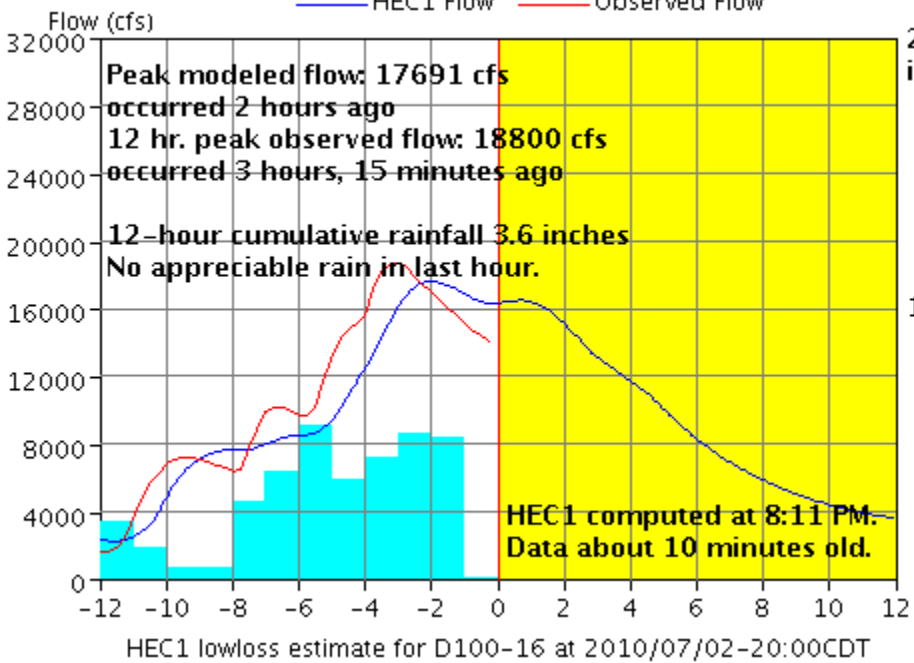
1.0



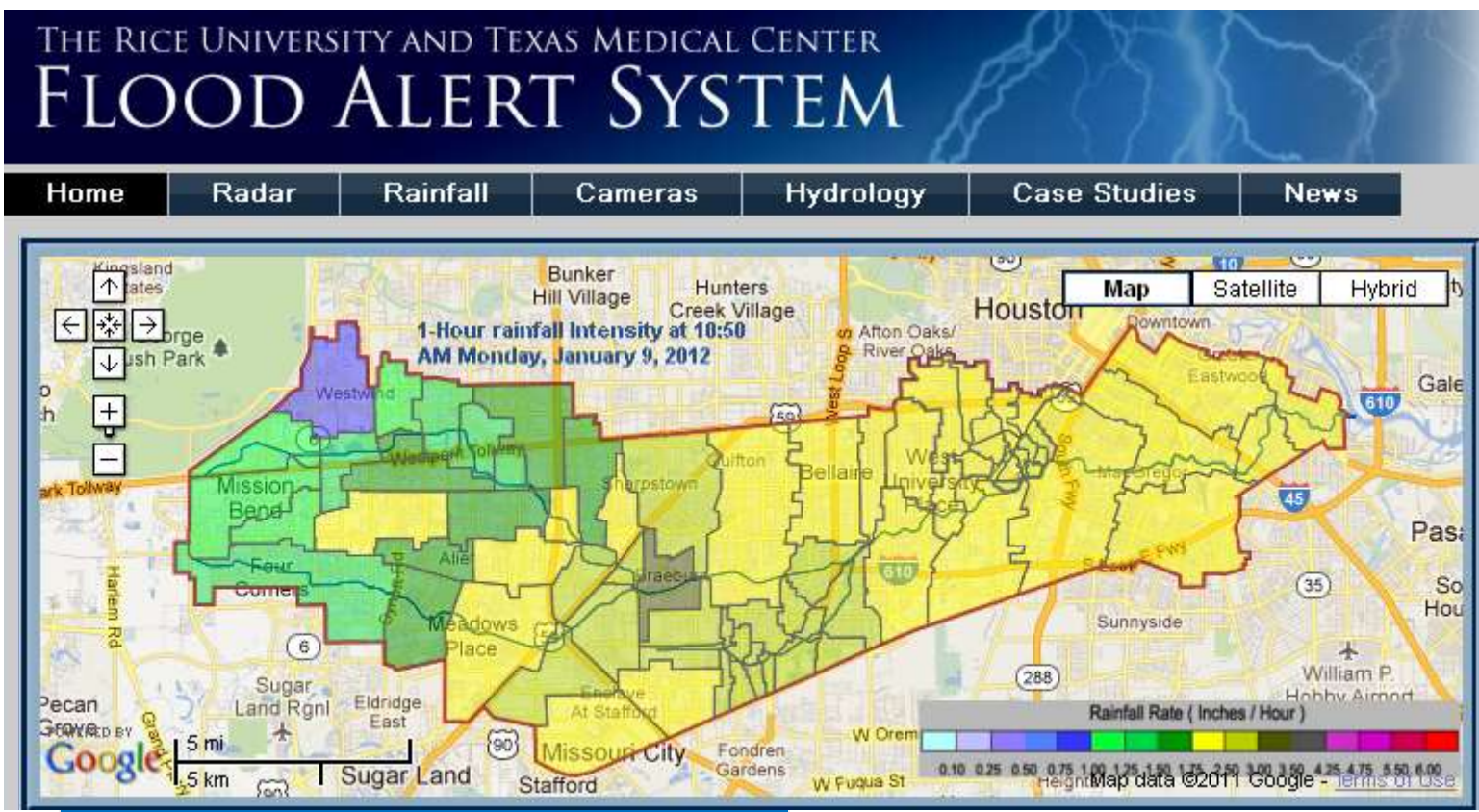
HEC1 Flow Observed Flow



HEC1 Flow Observed Flow



Brays Bayou Rainfall Map - January 9, 2012 Event



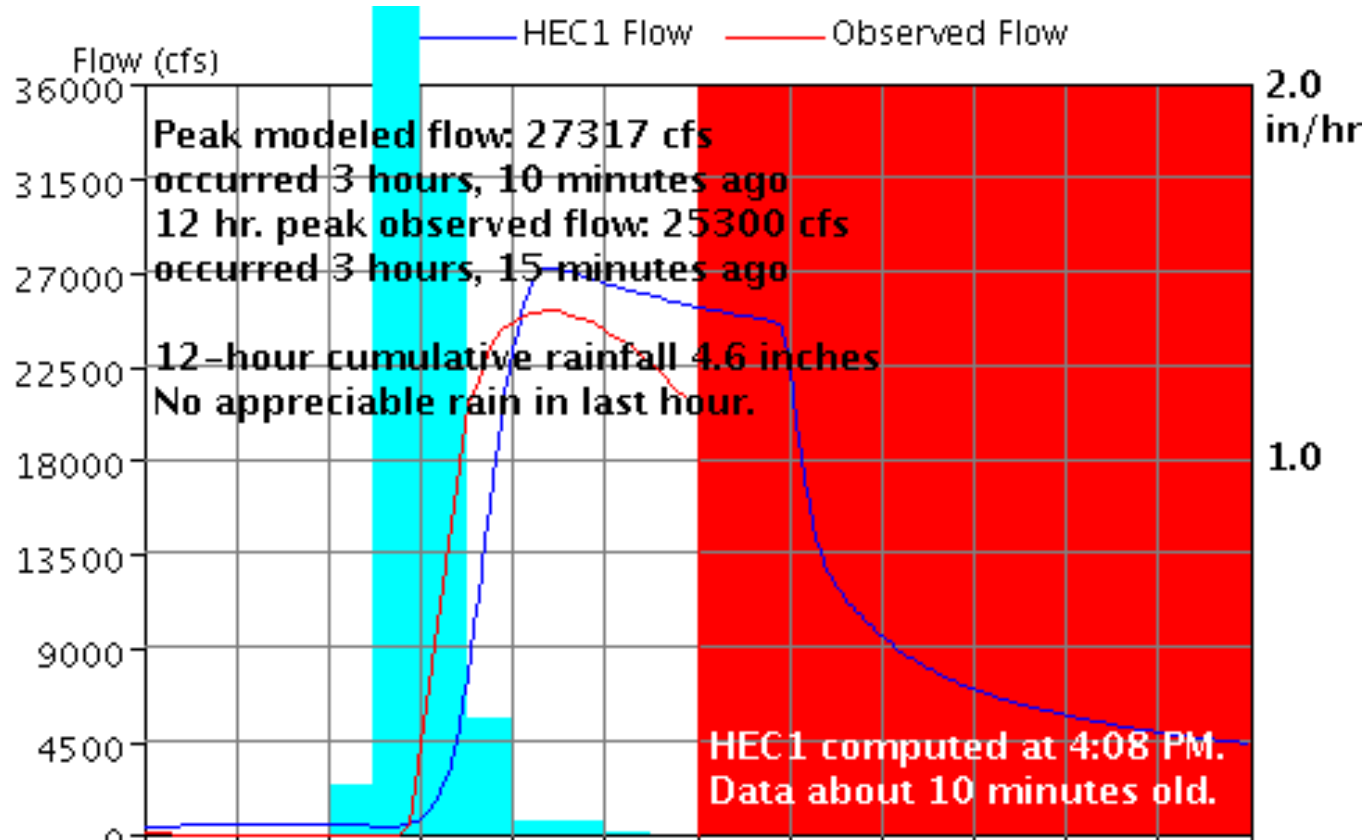
Highest Intensity >2.5 in/hr
4.5 in. of Rainfall in 4 hrs



Jan 9 – 2012 Event at Cambridge crossing Brays Bayou



Flood Alert System Performance during the January 9, 2012 Event



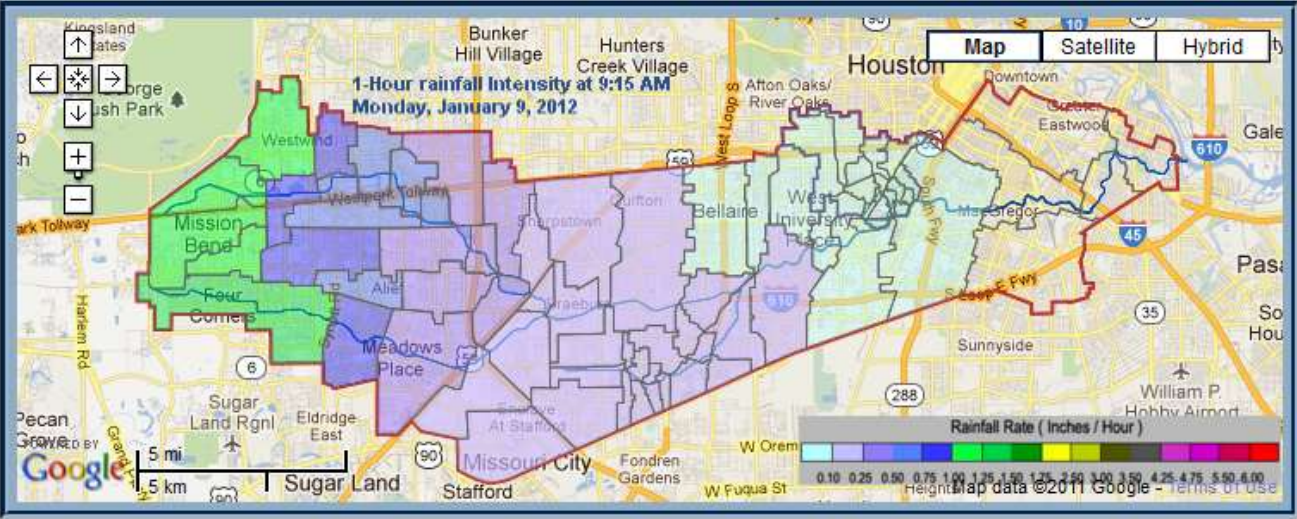
Predicted flow: 27,317 cfs @ 14:50 on Jan 9, 2012
Observed flow: 25,300 cfs @ 14:45 on Jan 9, 2012



THE RICE UNIVERSITY AND TEXAS TECHNOLOGICAL CENTER FLOOD ALERT SYSTEM



- Home
- Radar
- Rainfall
- Cameras
- Hydrology
- Case Studies
- News



SubBasins Intensity: 1-Hour 3-Hour 6-Hour

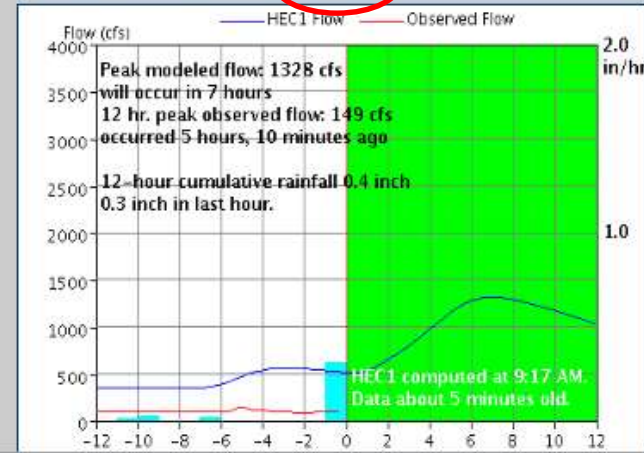
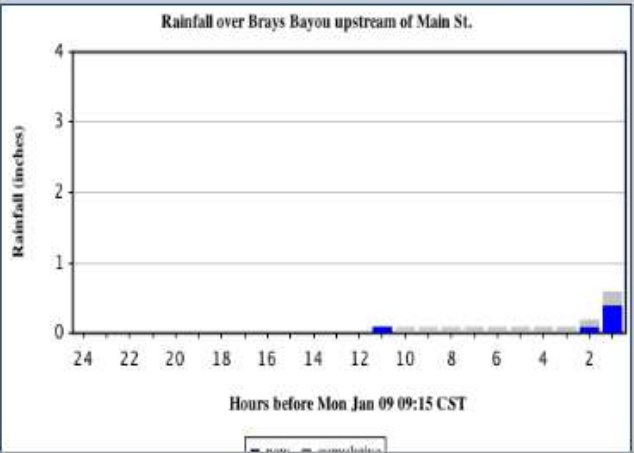
Intensity: 3-Hour

MajorBasins Total: 3-Hour 6-Hour

The map overlay depicts rainfall intensity (inches per hour) in SubBasins from the most recent 1-Hour cumulative rainfall estimate. The legend from the radar page is also used here.

Jan 9 – 9:23 am

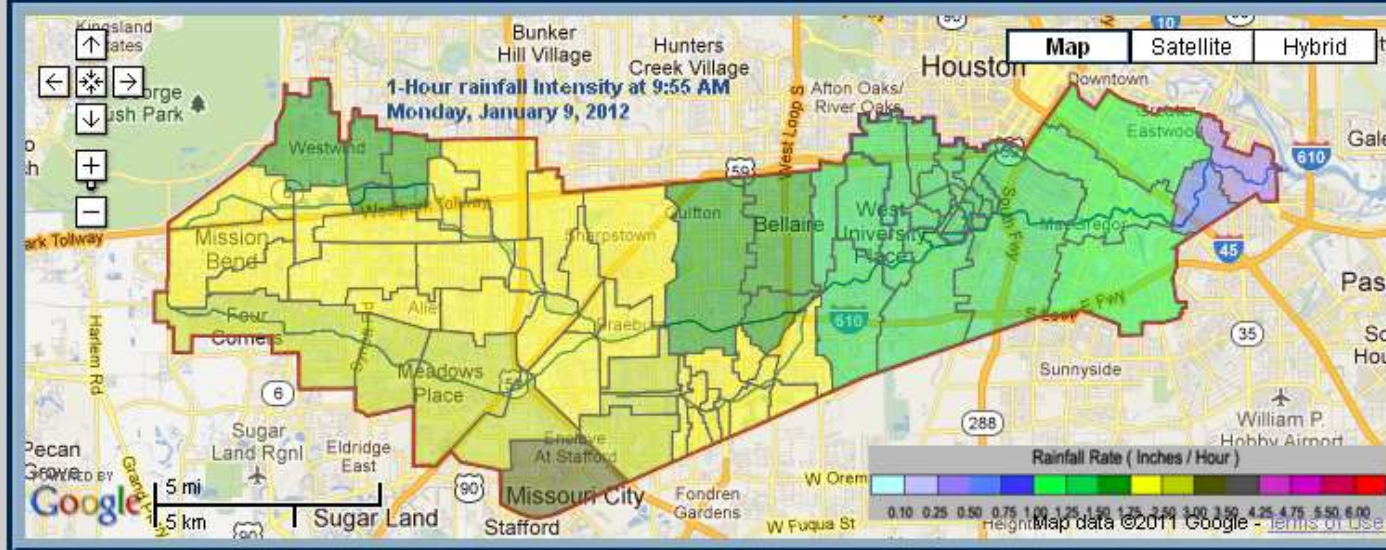
Last 1/2-inch rainfall: 0 days ago on Mon, Jan 9 (0.5 in.)



525 CFS, Rising at 9:15 AM
 Last Retrieval: 9:23 AM
 Page Refresh: every 30 sec.
 Next Check: 9:27 AM



- Weather Links**
- National Hurricane Center
 - Watches and Warnings
 - National Weather Service



Last Retrieval: 10:08 AM
 Page Refresh: every 30 sec.
 Next Check: 10:12 AM

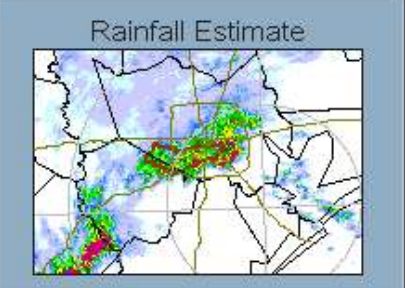
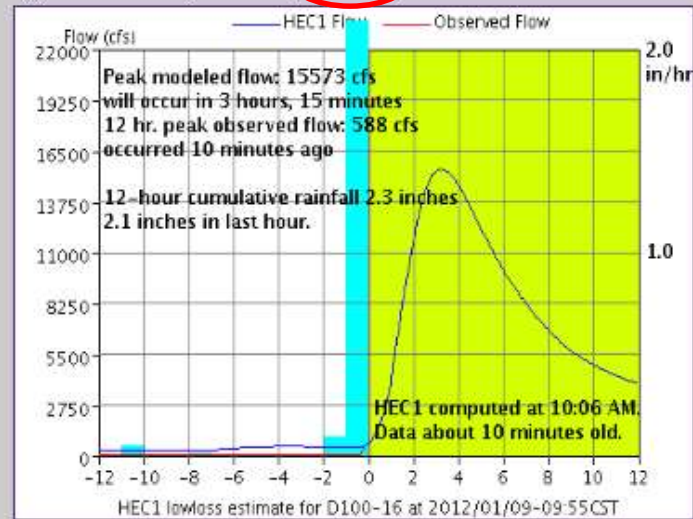
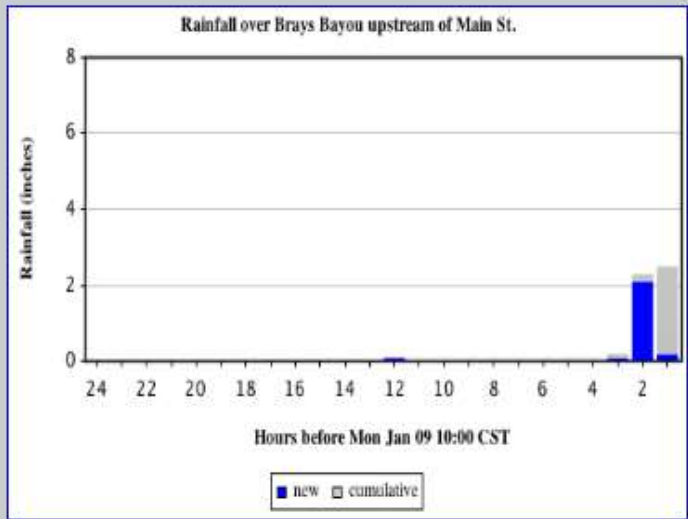


SubBasins Intensity: 1-Hour 3-Hour 6-Hour
 MajorBasins Intensity: 3-Hour
 Total: 3-Hour 6-Hour

The map overlay depicts rainfall intensity (inches per hour) in SubBasins from the most recent 1-Hour cumulative rainfall estimate. The legend from the radar page is also used here.

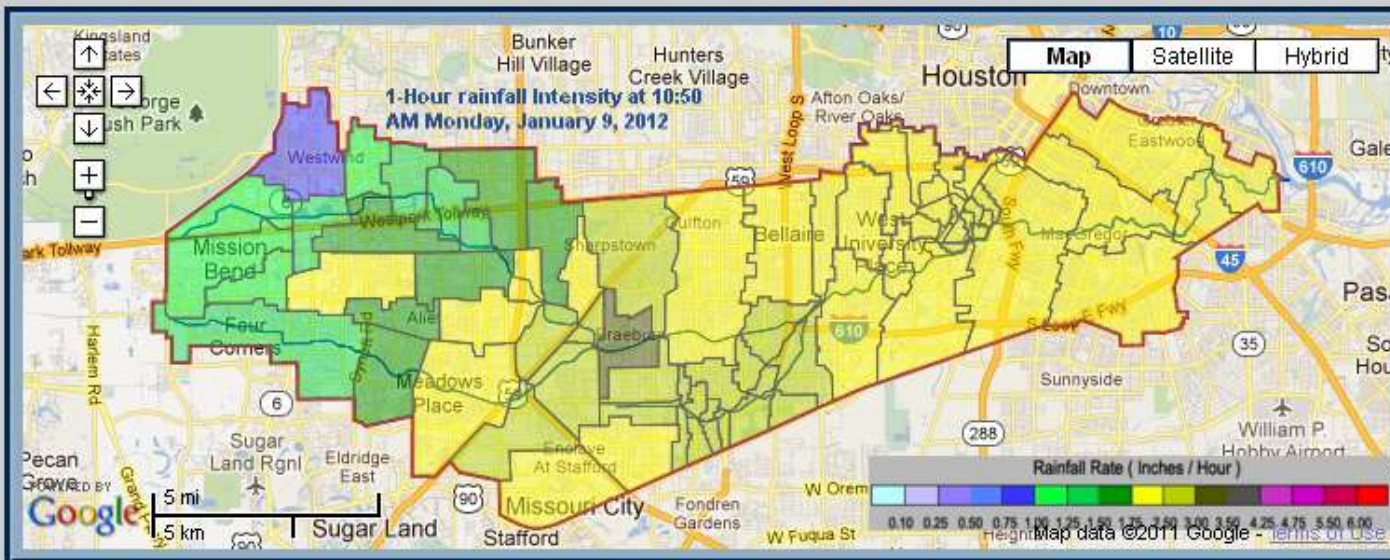
Jan 9 – 10:08 am

Last 1/2-inch rainfall: 0 days ago on Mon, Jan 9 (2.5 in.)



Weather Links
[National Hurricane Center](#)
[Watches and Warnings](#)
[National Weather Service](#)
[KHX Dickinson](#)

Other Radar
[KEWX New Brauntels](#)
[KGRK Central Texas](#)
[KLCH Lake Charles](#)



5267 CFS, Rising at 10:50 AM
 Last Retrieval: 11:01 AM
 Page Refresh: every 30 sec.
 Next Check: 11:05 AM
 Check Now

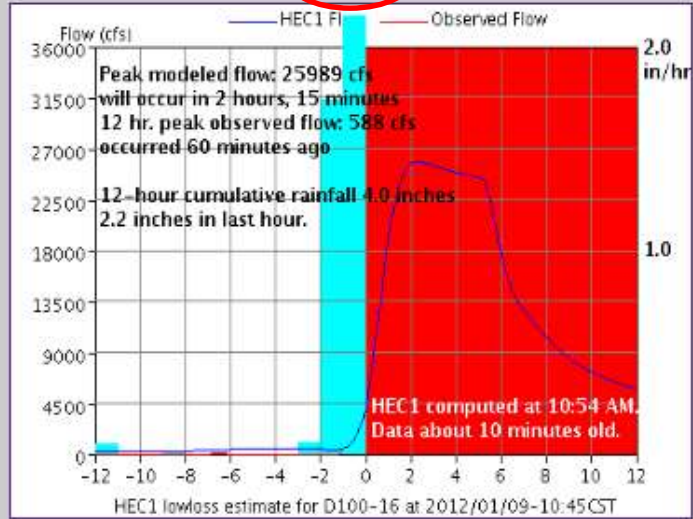
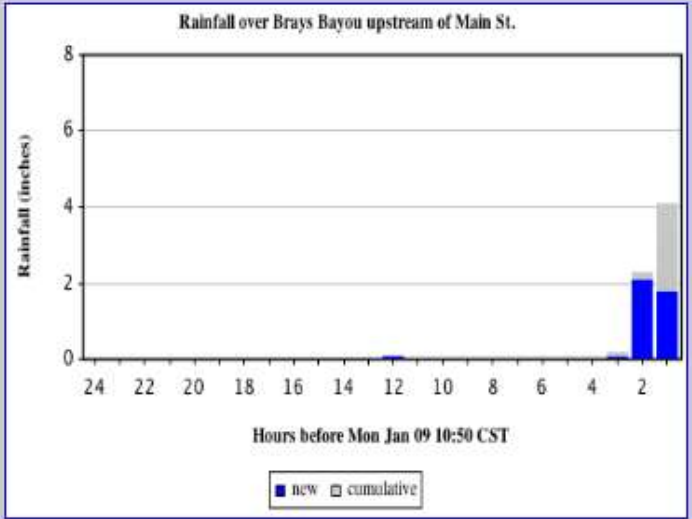


SubBasins Intensity: 1-Hour 3-Hour 6-Hour
 MajorBasins Intensity: 3-Hour
 Total: 3-Hour 6-Hour
 Hide Rainfall Show Floodplain

The map overlay depicts rainfall intensity (inches per hour) in SubBasins from the most recent 1-Hour cumulative rainfall estimate. The legend from the radar page is also used here.

Jan 9 – 11:01 am

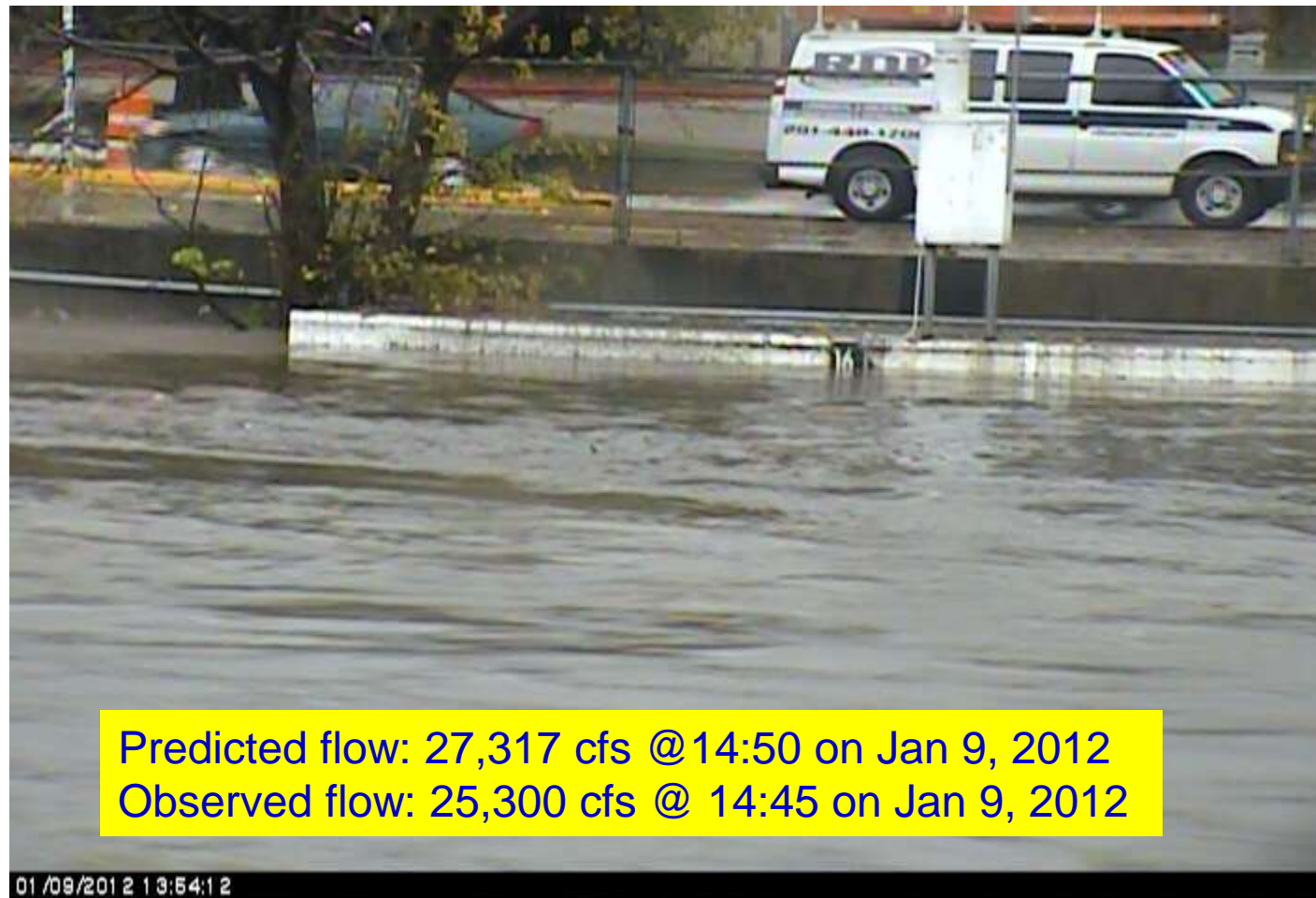
Last 1/2-inch rainfall: 0 days ago on Mon, Jan 9 (4.2 in.)



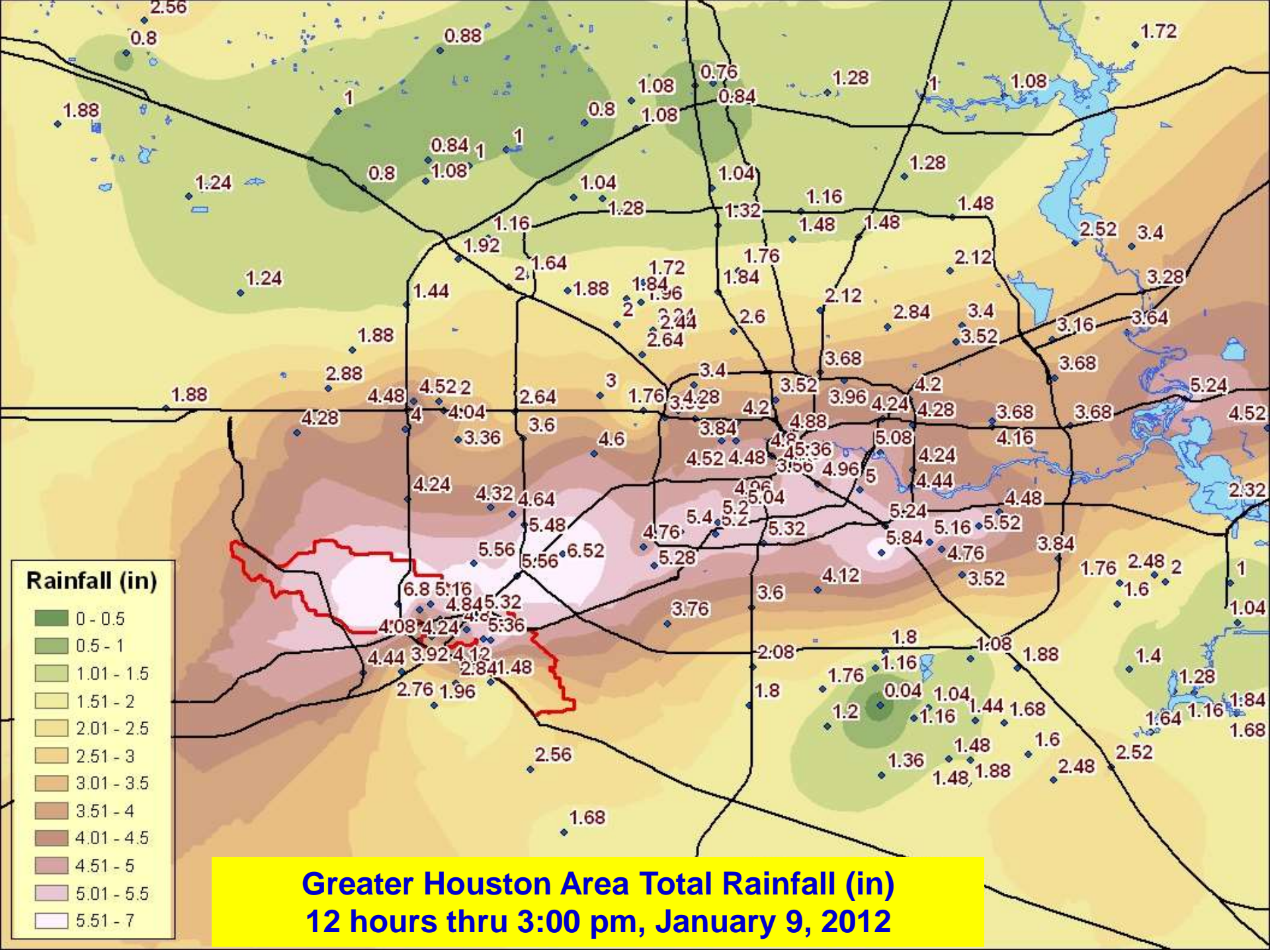
Weather Links
 National Hurricane Center
 Watches and Warnings
 National Weather Service
 KHGX Dickinson



Flood Alert System Performance during the January 9, 2012 Event



Predicted flow: 27,317 cfs @14:50 on Jan 9, 2012
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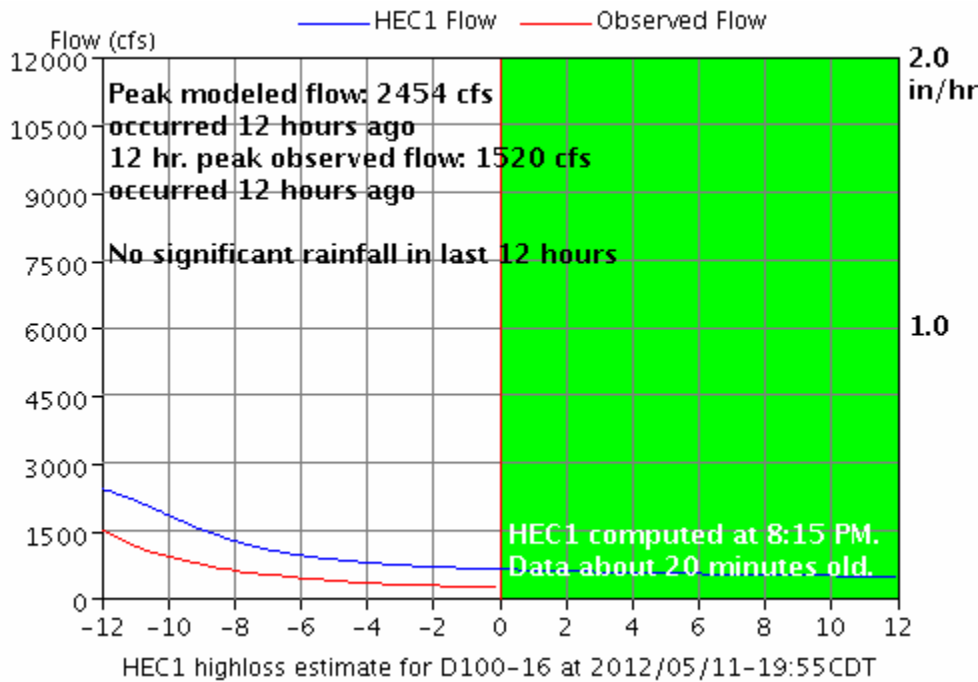
Rainfall (in)

- 0 - 0.5
- 0.5 - 1
- 1.01 - 1.5
- 1.51 - 2
- 2.01 - 2.5
- 2.51 - 3
- 3.01 - 3.5
- 3.51 - 4
- 4.01 - 4.5
- 4.51 - 5
- 5.01 - 5.5
- 5.51 - 7

**Greater Houston Area Total Rainfall (in)
12 hours thru 3:00 pm, January 9, 2012**

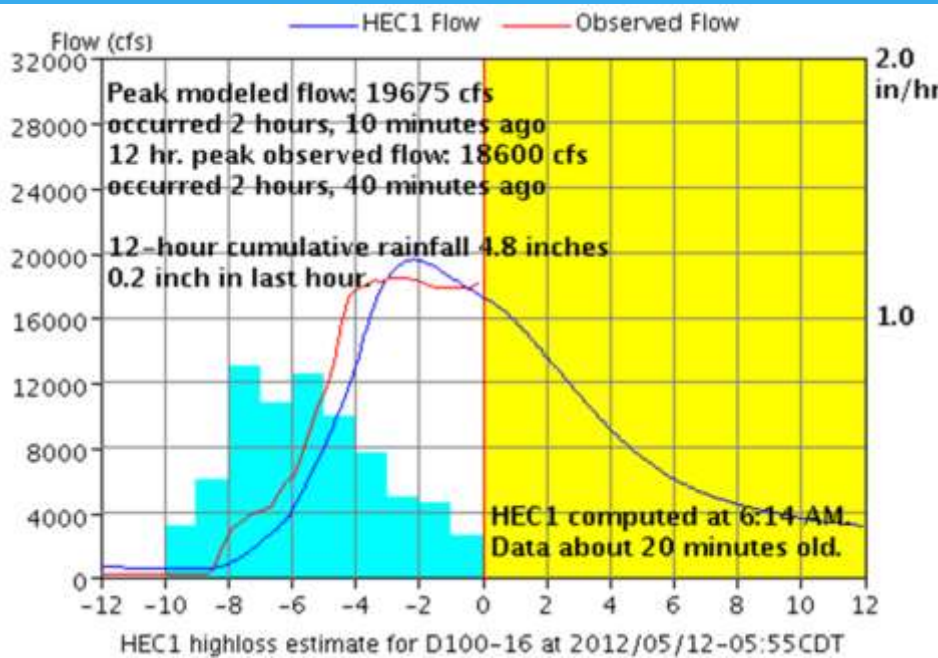


FAS3 Performance during the May 12, 2012 Event

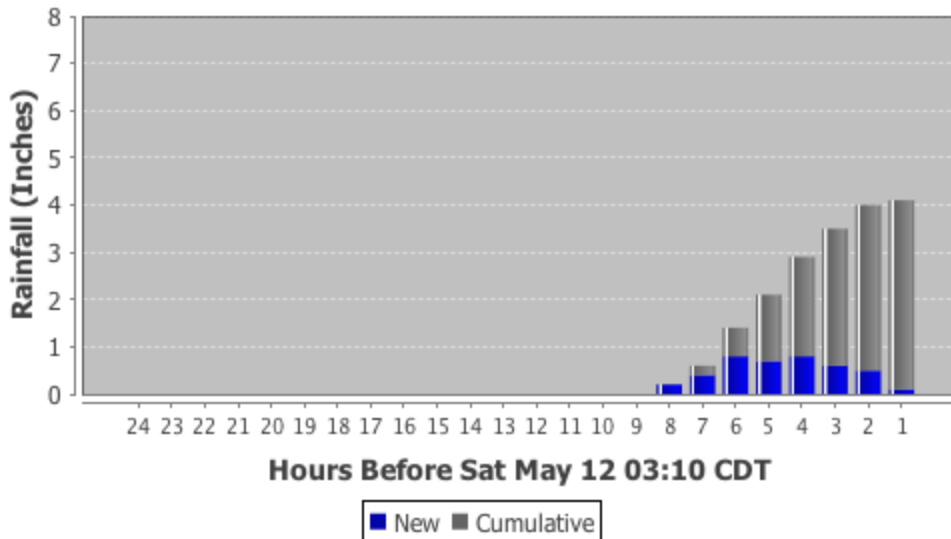




FAS3 Performance during the May 12, 2012 Event

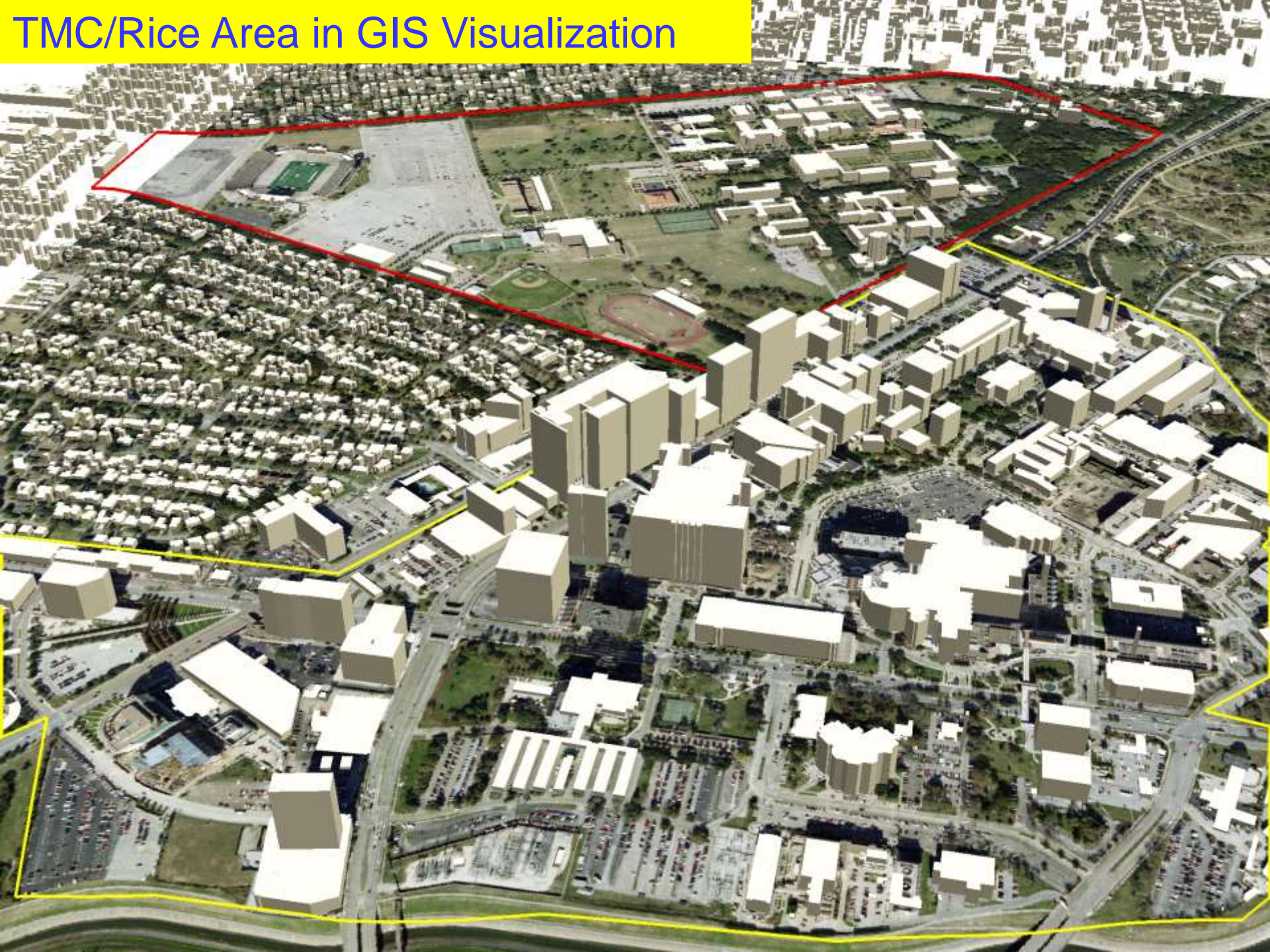


Rainfall over Brays Bayou upstream of Main St.

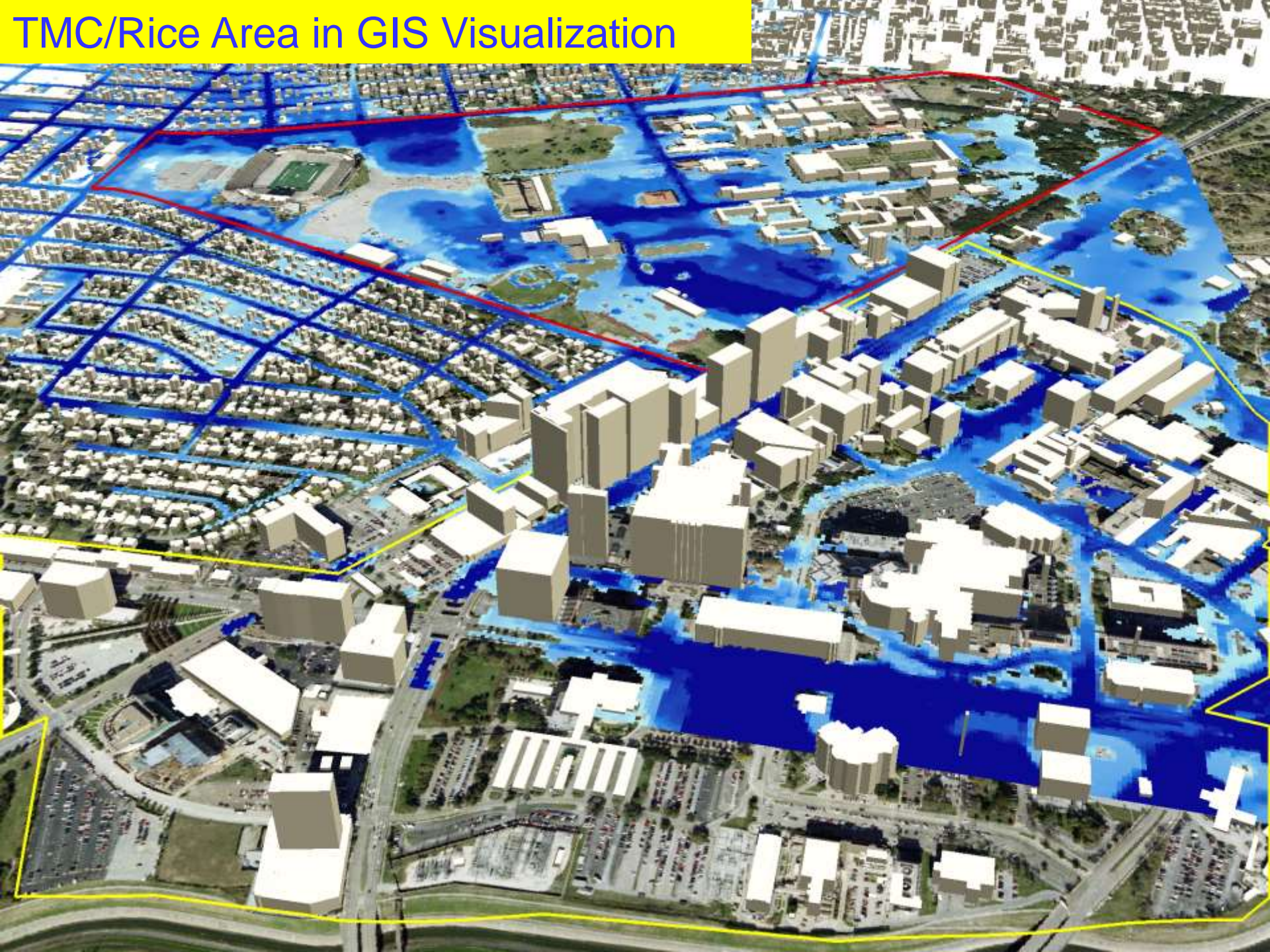


| Watershed Totals | 3 hours | 6 hours | 9 hours | 24 hours |
|------------------|---------|---------|---------|----------|
| West of Main | 1.0 | 3.1 | 4.6 | 4.6 |
| Whole Bayou | 0.9 | 2.8 | 4.3 | 4.3 |
| Harris Gully | 0.3 | 2.0 | 3.4 | 3.4 |
| Gessner West | 1.2 | 3.3 | 4.9 | 4.9 |
| Gessner to Main | 0.9 | 2.9 | 4.3 | 4.3 |
| East of Main | 0.4 | 2.1 | 3.4 | 3.4 |

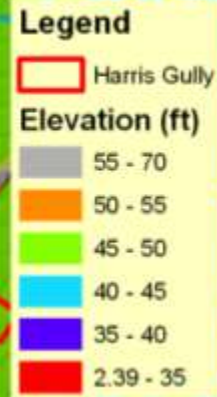
TMC/Rice Area in GIS Visualization



TMC/Rice Area in GIS Visualization



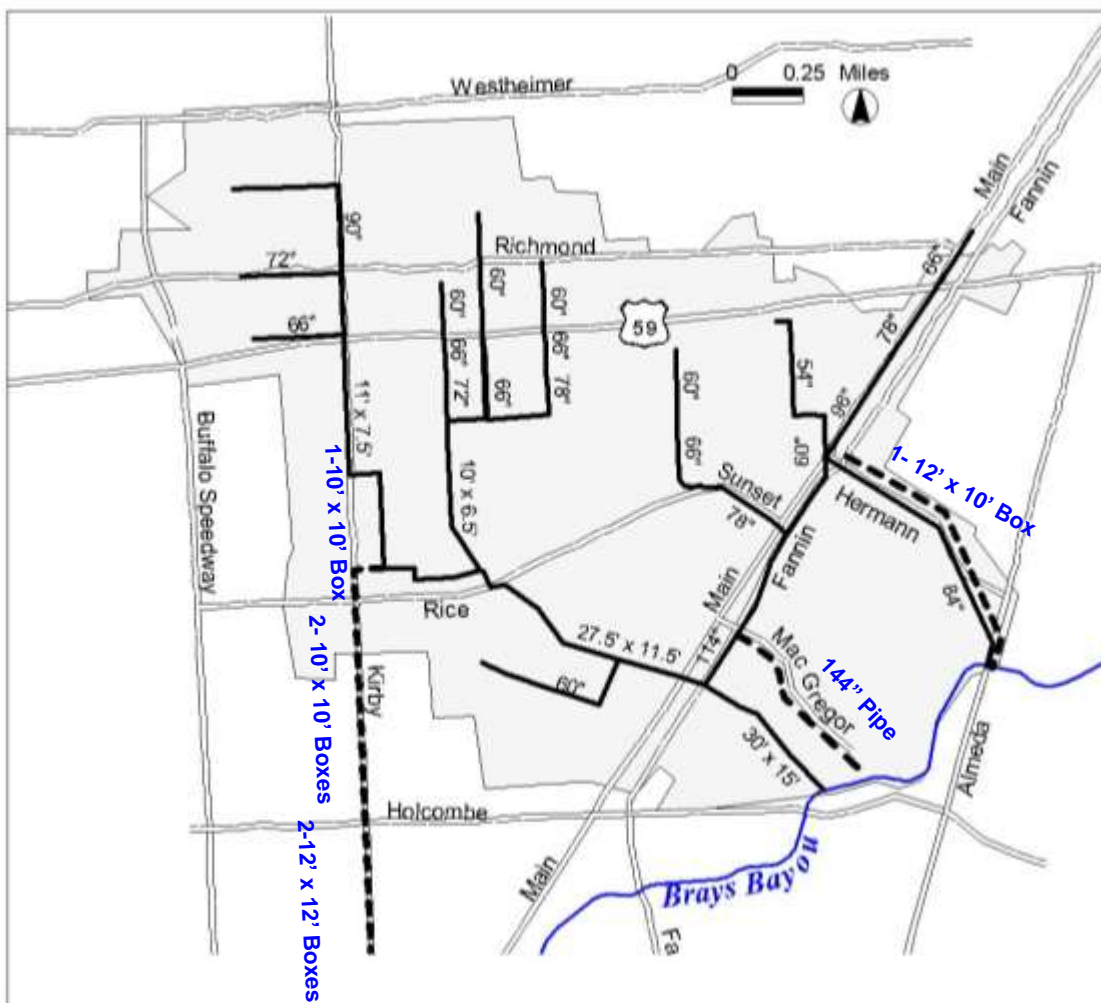
Harris Gully Digital Elevation



- High tailwater in Brays reduces the flow capacity of the minor system up to 80%
- ***Elevation*** and ***Duration of Elevation*** are extremely important

0 1,250 2,500 5,000
Feet

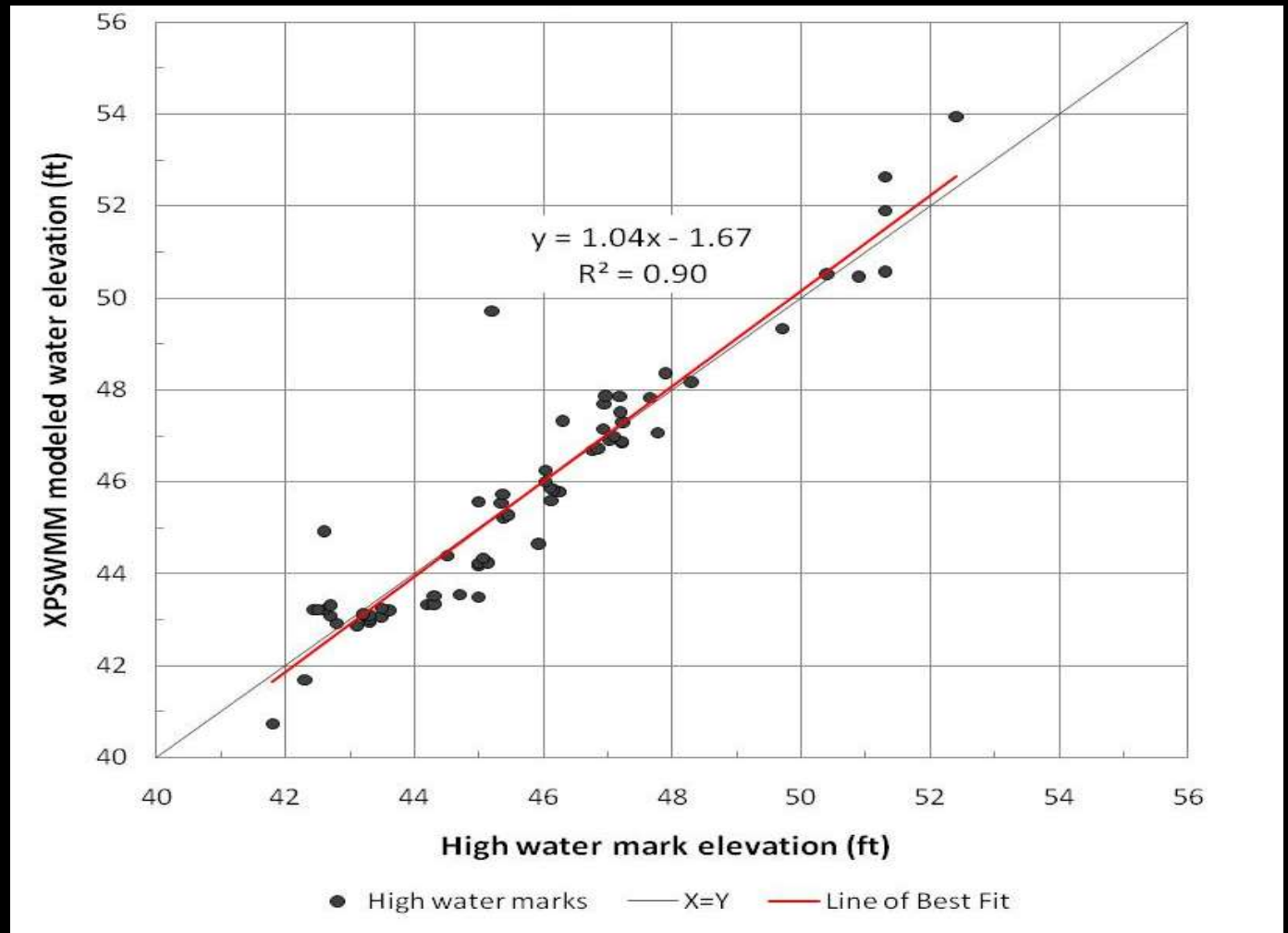
Drainage Improvements



The installation of large new culverts under Kirby, Cambridge, & Hermann

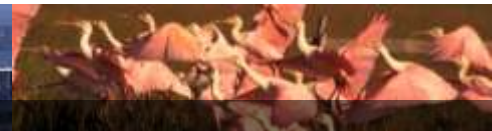


The Dynamic Inundation during Tropical Storm Allison (June, 2001)



Local Flood Gates

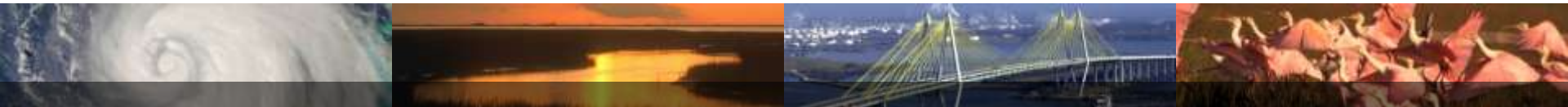




Major Hurricane History

Data from 1949 in the Pacific, from 1851 in the Atlantic





Mission



To be recognized as the Gulf Coast's top university-based center for research and education in the prediction, analysis and impacts of severe storms.

- SSPEED Center: Severe Storm Prediction, Education and Evacuation from Disasters
- Established in 2007 as a university-based research and education organization



UNIVERSITY OF
TEXAS
ARLINGTON

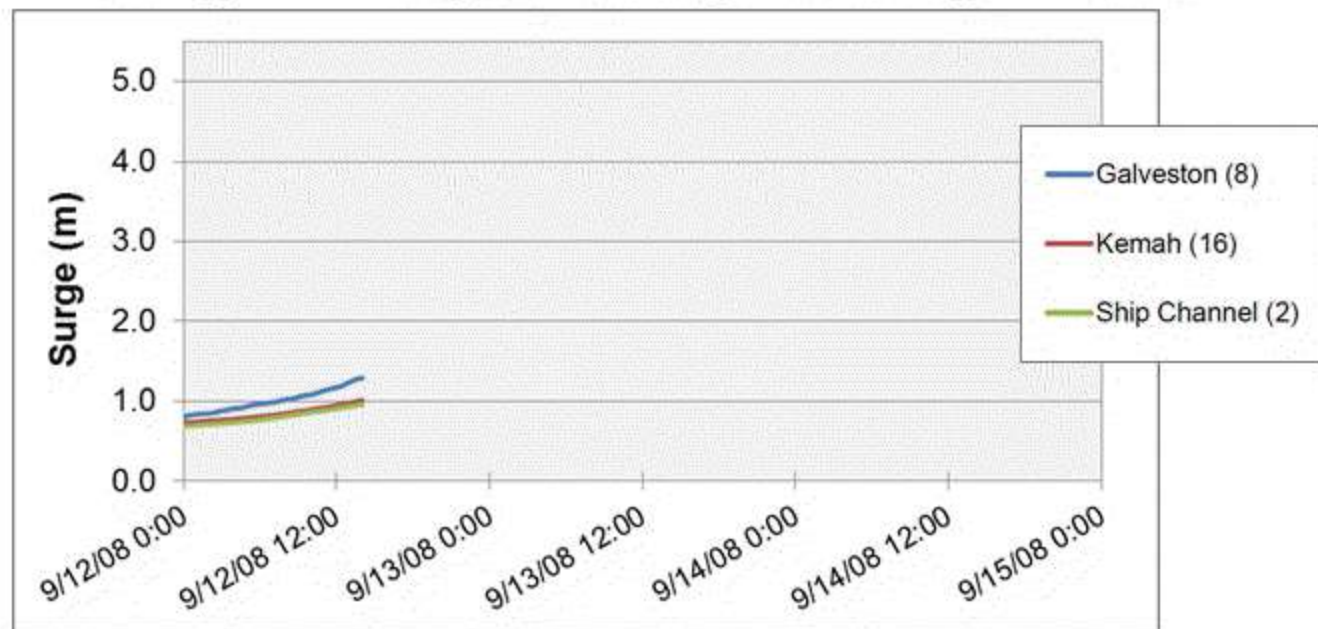
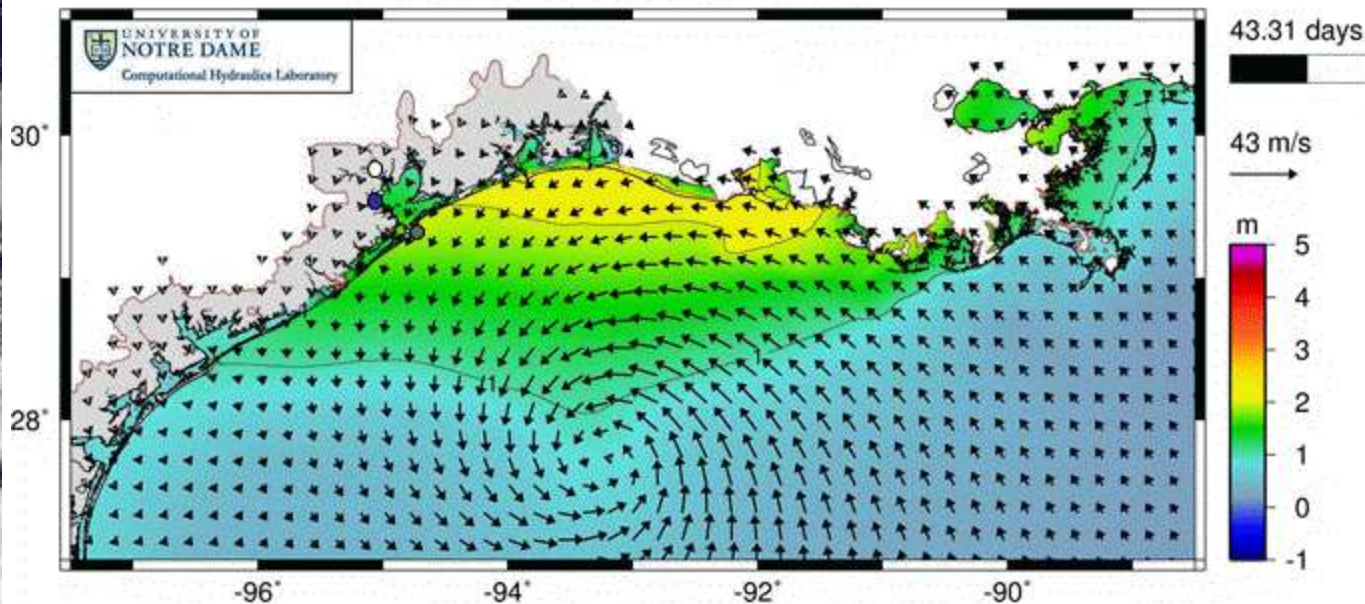


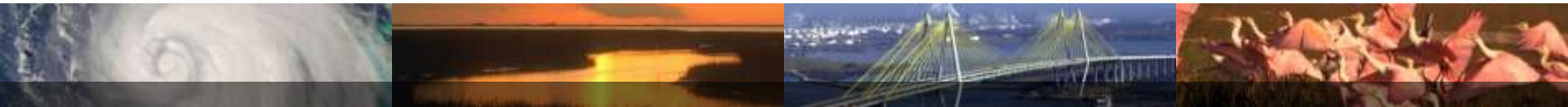
WALTER P MOORE



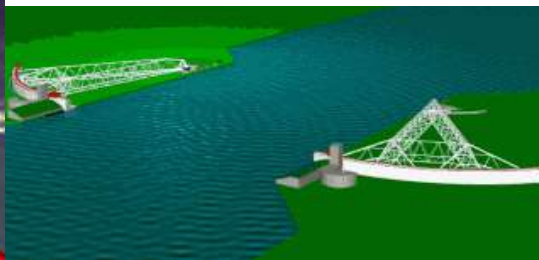
Surge Propagation at - 12 hours (9/12/08 2:00 PM)

r09 c8+tides Water Surface Elevations + Winds





Houston Ship Channel: Gate Structure

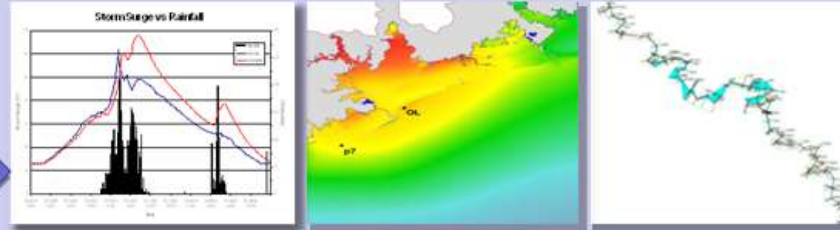


Images courtesy of SSPEED Center

Coastal Flood & Surge Alert System



Flood and Surge Prediction Module



Models result in maps for floodplain and surge inundation depth

Data Collection



Calibrated radar rainfall and gage data

Communication and Response



Surge and flood alert levels relayed to emergency personnel

Workflow of a Coastal
Flood and Surge Alert System

FAS Summary



- Existing FAS works well (12 yrs, 10 major storms, and prediction accuracy of $R^2 = 0.94$)
- Inland flooding prediction (FAS) will be linked with surge models to improve evacuation strategies
- Better inform TMC emergency personnel to deal with flood disasters
- The current system is being expanded to other critical transportation locations (TxDOT, Sugar Land, and Clear Creek)
- Storm surge predicted information will be added to FAS3 within Google Maps

