A wide-angle photograph of the Nashville skyline across the Tennessee River. The river is in the foreground, with some greenery and a small boat visible. The skyline features several prominent skyscrapers, including the AT&T Building. The sky is blue with scattered white clouds.

# A Predictive Design Approach to Resiliency

Resiliency for Stormwater Professionals

April 26, 2019



Roger D. Lindsey, P.E., CFM  
Practice Leader – Stormwater and Floodplain Management  
Metro Nashville Water Services

# Resiliency Defined

- The Capacity to Recover Quickly
- The Ability to Bounce Back
- On a continuing basis, the CRS Program will lead your city to a state of increased resilience, and reduce your vulnerability to floods



May 2010, Nashville

*Photo: The  
Tennessean*



May 2010, Nashville  
*I-24*

*Photo: WKRN*



May 2010, Nashville  
*Downtown*

*Photo: Larry McCormack, The Tennessean*



**May 2010, Nashville**

*Opryland Hotel and Opry Mills Mall*

*Photo: Samuel M. Simpkins, The Tennessean*



May 2010, Nashville  
*Opryland Hotel*



May 2010, Nashville  
*Titans Stadium*

As a City Considers Resilience and Readiness.....

We must assume that the next big event  
is right around the corner....

# Extreme Events – Occurring with unsettling regularity

- Rain Bombs
- Atmospheric Rivers
- Snow or Bomb Cyclones
  - Winter Storm Ulmer....set records for low pressure and extreme winds
  - Led to extreme snowfall, followed by warm weather, rapid snowmelt, and extreme flooding in the plains

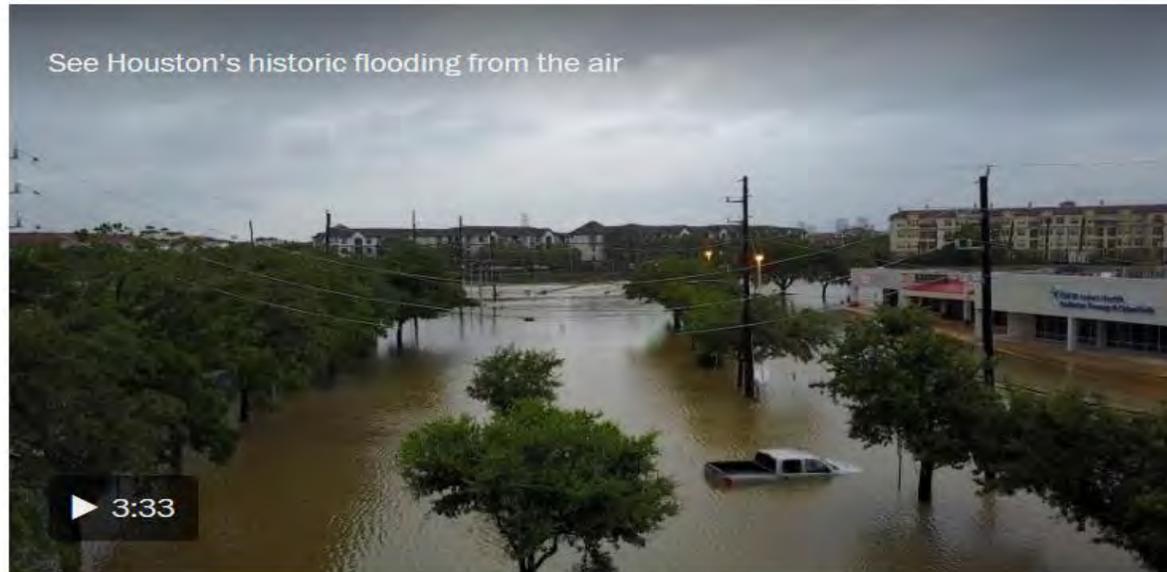
# A Rain Bomb...over Phoenix



Wonkblog • Analysis

# Houston is experiencing its third ‘500-year’ flood in 3 years. How is that possible?

By **Christopher Ingraham** August 29, 2017 [✉ Email the author](#)



This drone video taken Aug. 27 shows the historic flooding in Houston caused by Hurricane Harvey. (ahmed.gul/Instagram)



U.S.

## Historic Maryland Town Hit by a Second Devastating Flood Since 2016

National Guardsman reported missing in Ellicott City; some businesses not sure they can recover again



The second flash flood in two years hit Ellicott City, Md., on Sunday, sweeping away cars and covering streets in mud. Photo: Getty

Capital Weather Gang

# Cedar Rapids, Iowa, braces for second biggest river flood on record

By **Jason Samenow** September 26, 2016 [✉ Email the author](#)

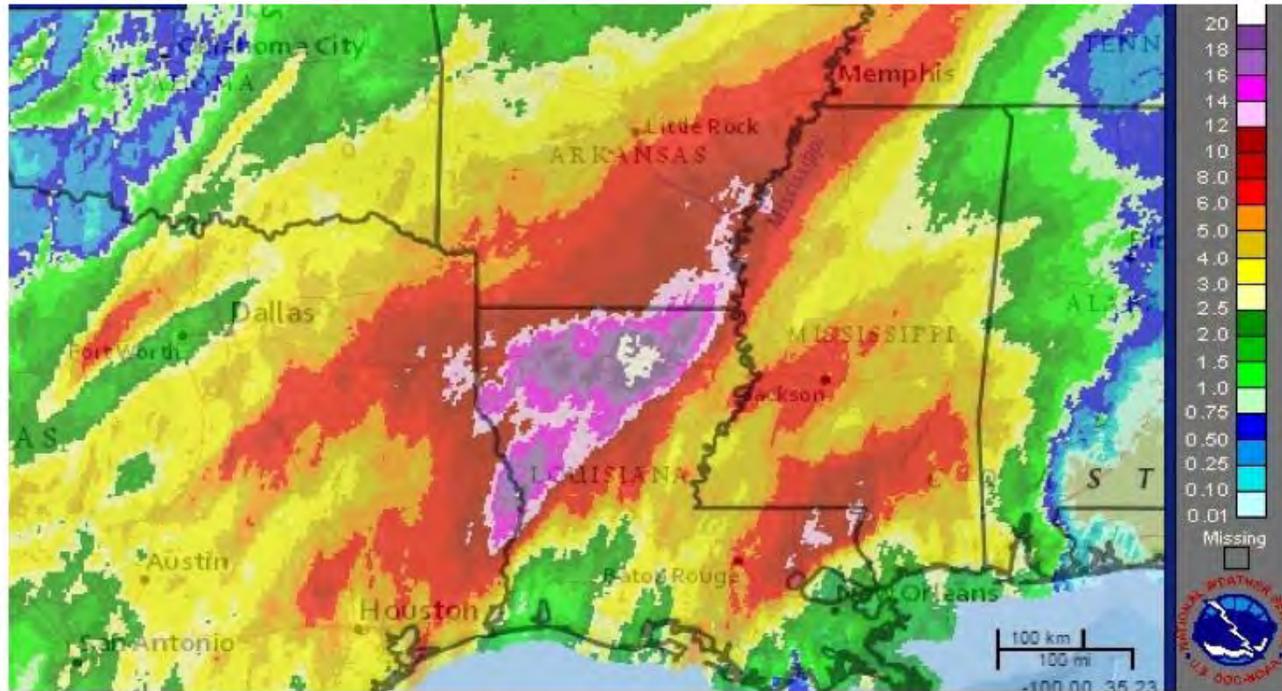


Jason Mann, of Cedar Rapids, Iowa, loads sandbags onto a truck in the New Bohemia District, on Sept. 23. (David Scrivner/Iowa City Press-Citizen via AP)

Capital Weather Gang

# State of emergency in Louisiana, as atmospheric river unloads disastrous rains

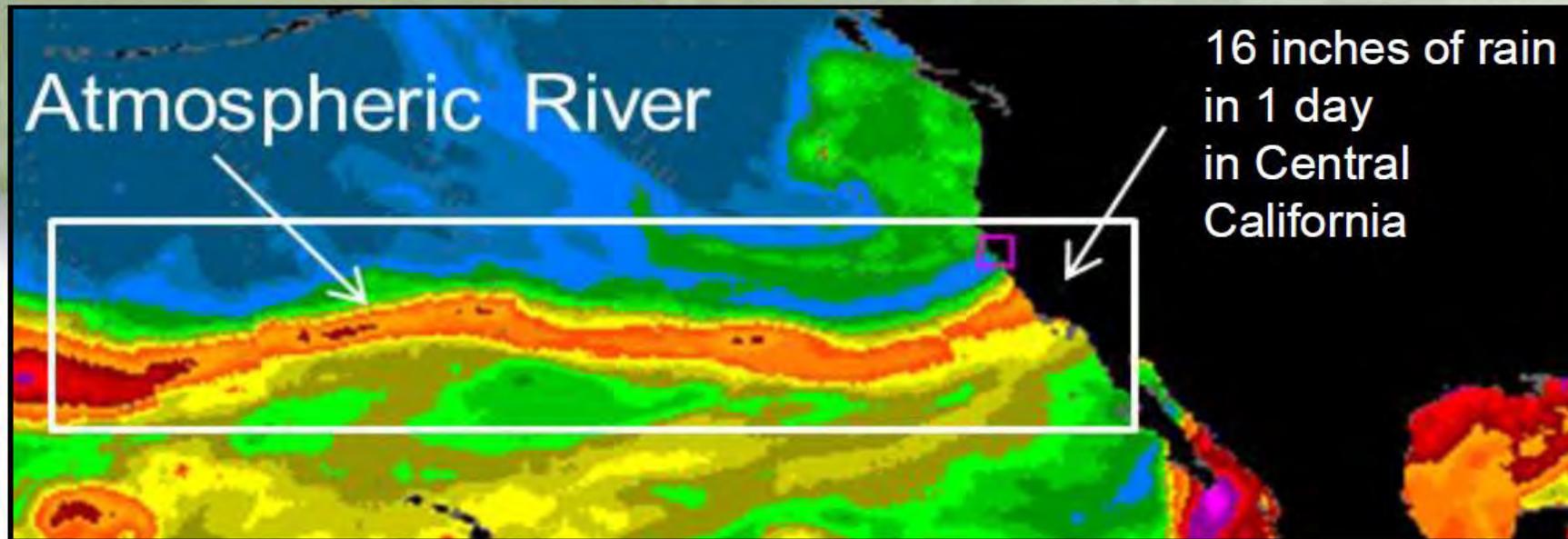
By Jason Samenow March 11, 2016 [✉ Email the author](#)



Doppler estimated rainfall over the last four days in South Central U.S. (NWS)

Up to two feet of rain have fallen in Louisiana and three people have died, as historic flood event swamps parts of the South and Gulf Coast states.

# Atmospheric Rivers



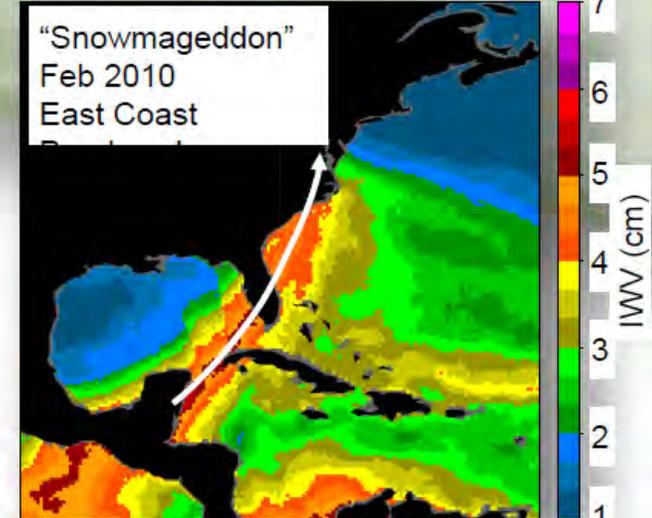
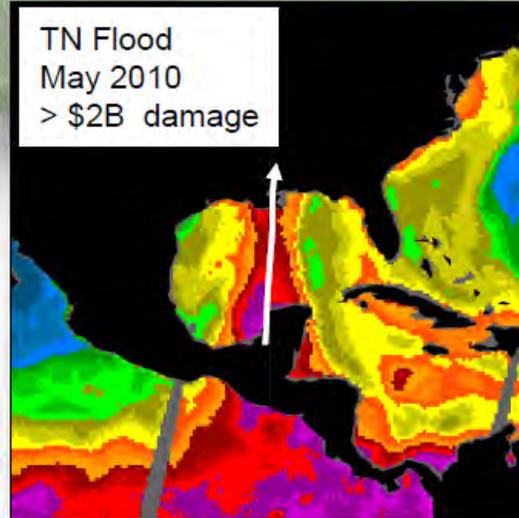
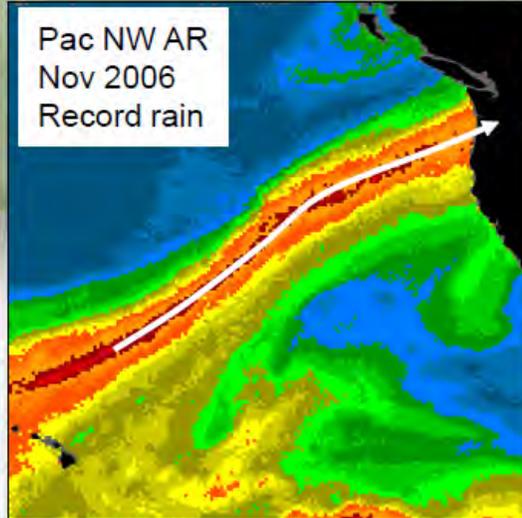
- A narrow “conveyor belt” of water vapor extending from thousands of miles out at sea, carrying, on average, ~10 Mississippi Rivers
- Generally provide 35-50% of annual rainfall across California

*Dettinger et al., Atmospheric Rivers, “Floods and the Water Resources of California.” Water, 2011*

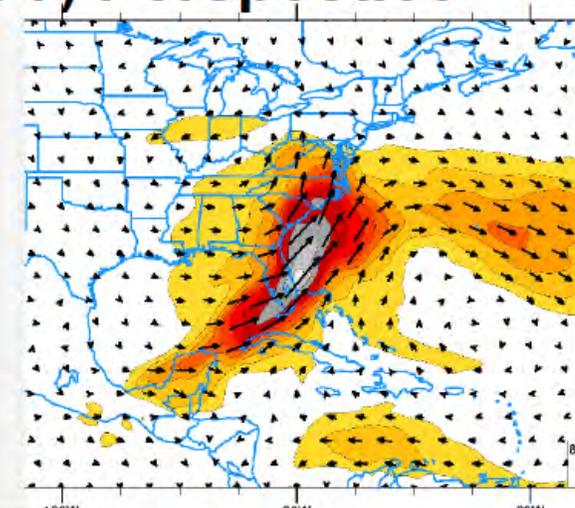
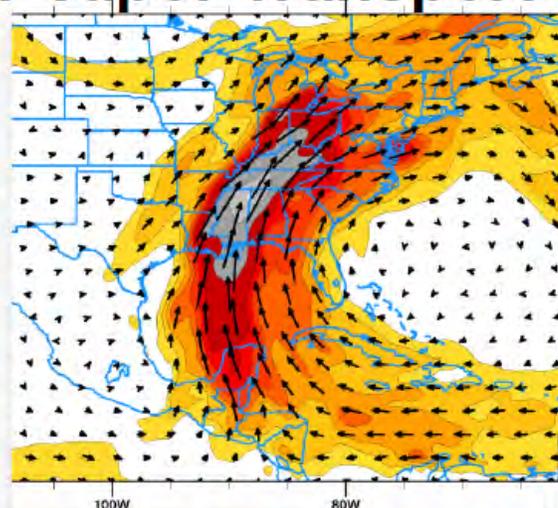
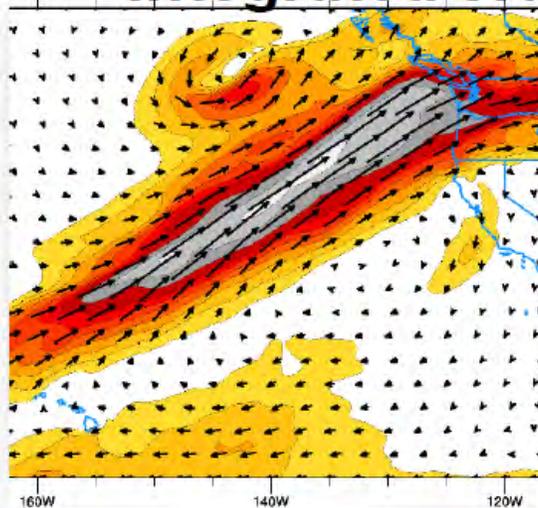


# Atmospheric Rivers: Not just a West Coast Issue

## Integrated Water Vapor (IWV) Perspective



## Integrated Water Vapor Transport (IVT) Perspective



BUILDING STRONG®

200 300 400 500 600 700 800 1000 1200 1400 1600

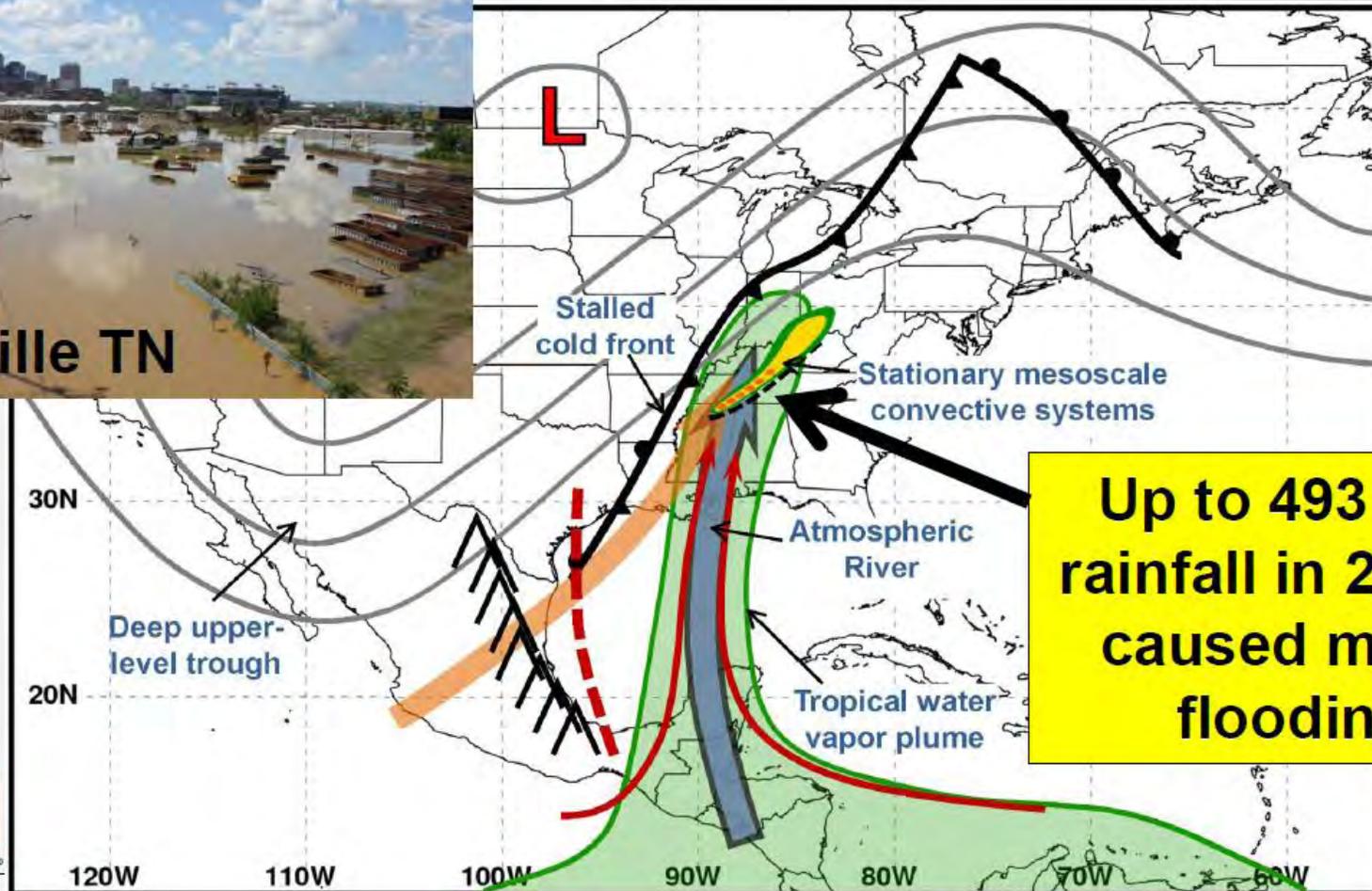
for a safer, better world

$\text{kg m}^{-1} \text{s}^{-1}$

Slide courtesy Marty Ralph

# Physical Processes Associated with Heavy Flooding Rainfall in Nashville, Tennessee, and Vicinity during 1–2 May 2010: The Role of an Atmospheric River and Mesoscale Convective Systems

Ben Moore, Paul Neiman, Marty Ralph, Faye Barthold  
Monthly Weather Review (2012)



**Up to 493 mm  
rainfall in 2 days  
caused major  
flooding**



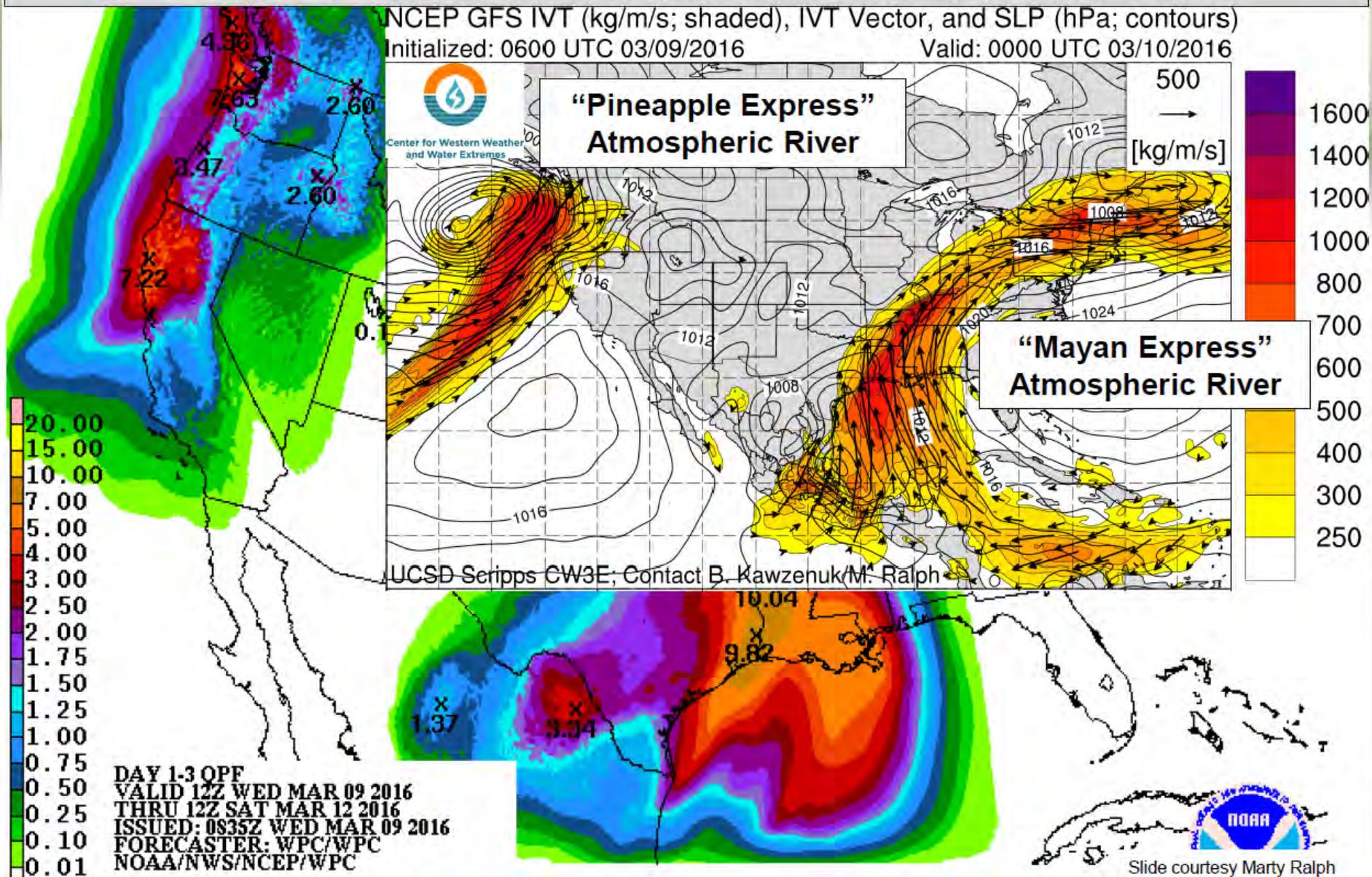
BUILDING STRONG®



Innovative solutions for a safer, better world

# Atmospheric rivers and current extreme precipitation events in the Southeast & West Coast

F. M. Ralph (CW3E at Scripps Institution of Oceanography)



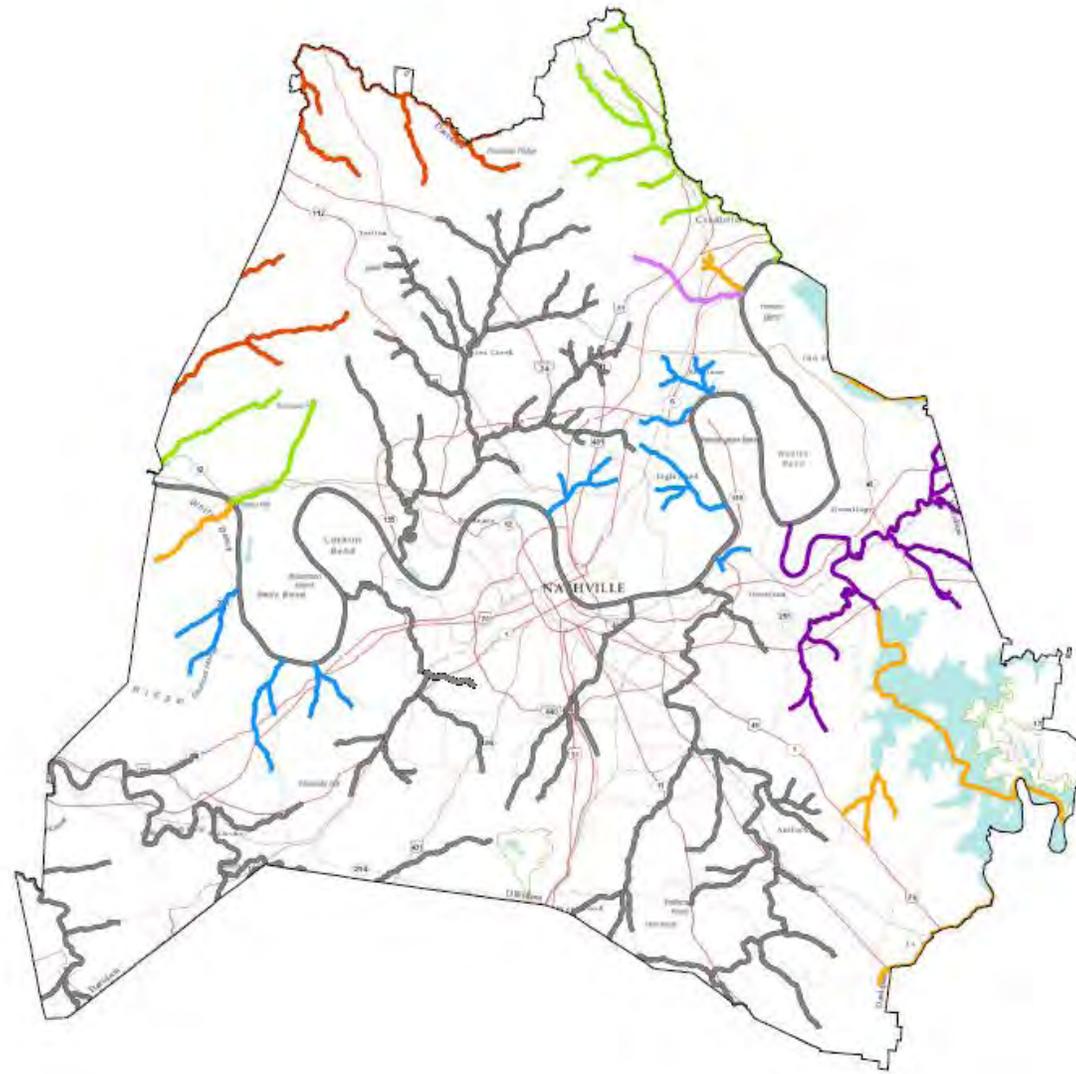
# Building Resilience.....after the Flood

- Post-Disaster Response
  - Public Infrastructure
  - Private Property
- Buyouts – 370 homes that will never flood again
  - Continuing to purchase homes with HMGP, USACE and Metro Money
  - We will buy hundreds more as money becomes available
- Elevating Substantially Damages homes
- Significant private mitigation – Opryland Hotel and Schermerhorn
- Nashville SAFE, NERVE and HEC-RTS
- New Flood Insurance Rate Maps

Nashville Flood Preparedness  
Metro Nashville  
Davidson County, TN  
FIS Study Limits

**Legend**

-  Phase 2 (Complete)
-  Phase 3 (Complete)
-  Phase 4A (Complete)
-  Phase 4AA (Complete)
-  Phase 4B (Complete)
-  Phase 4C (Complete)
-  Phase 4D (Complete)



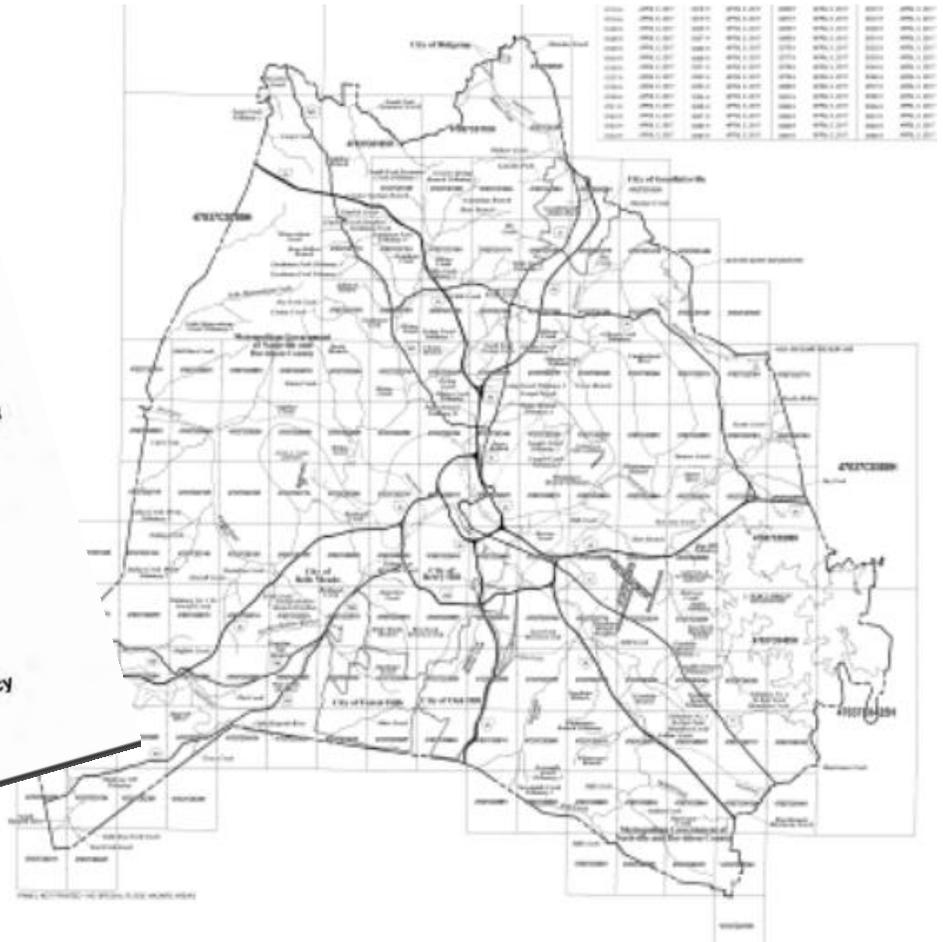
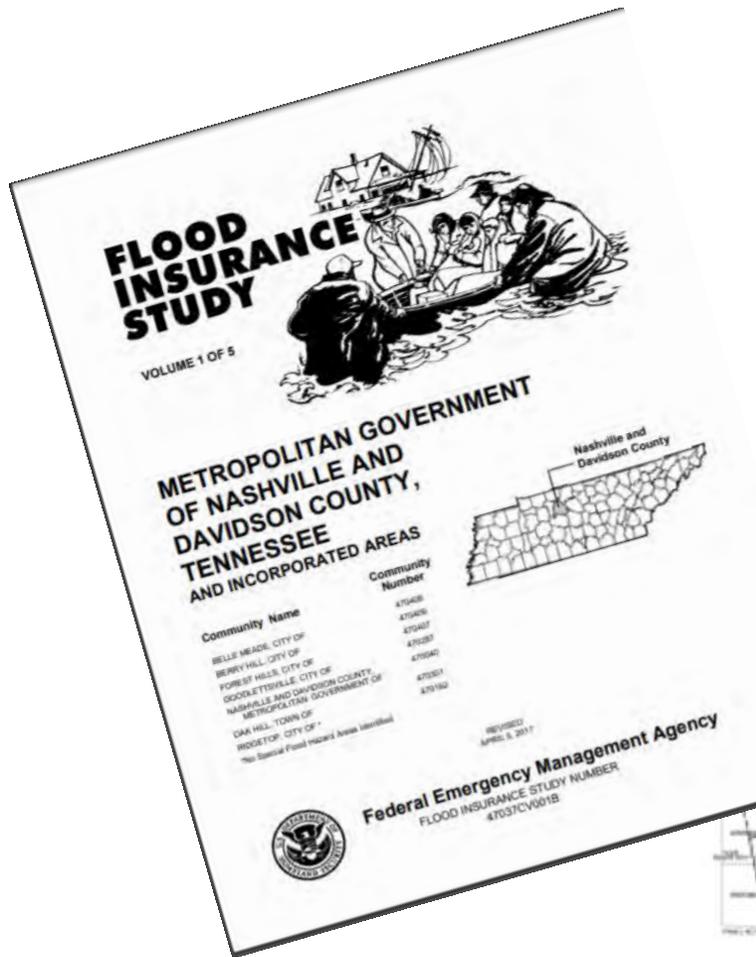
0 1.5 3 6 Miles



**US Army Corps  
of Engineers**®  
Nashville District

Updated: August 30, 2016

All New H&H....county-wide!! Led to....



150 New FIRM Panels

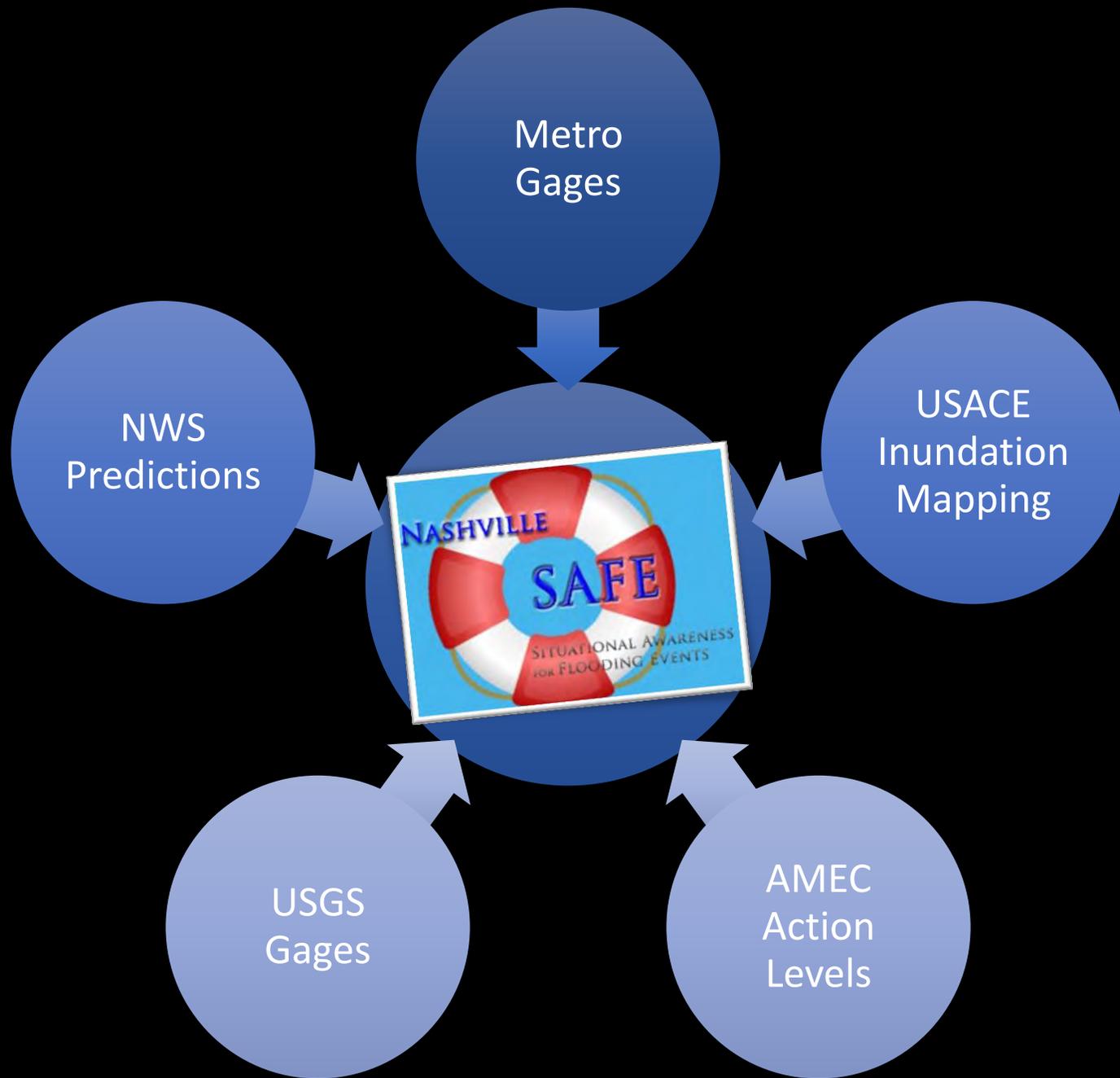
# Nashville SAFE & NERVE

Initial efforts began during the months after the 2010 Flood

- Nashville SAFE – a flood forecasting and response tool
- Nashville NERVE – a Public Information Tool



# Service Assessment Recommendations





- Current Readings
- NWS Highest Predicted
- User Set Predicted

#### Additional Layers

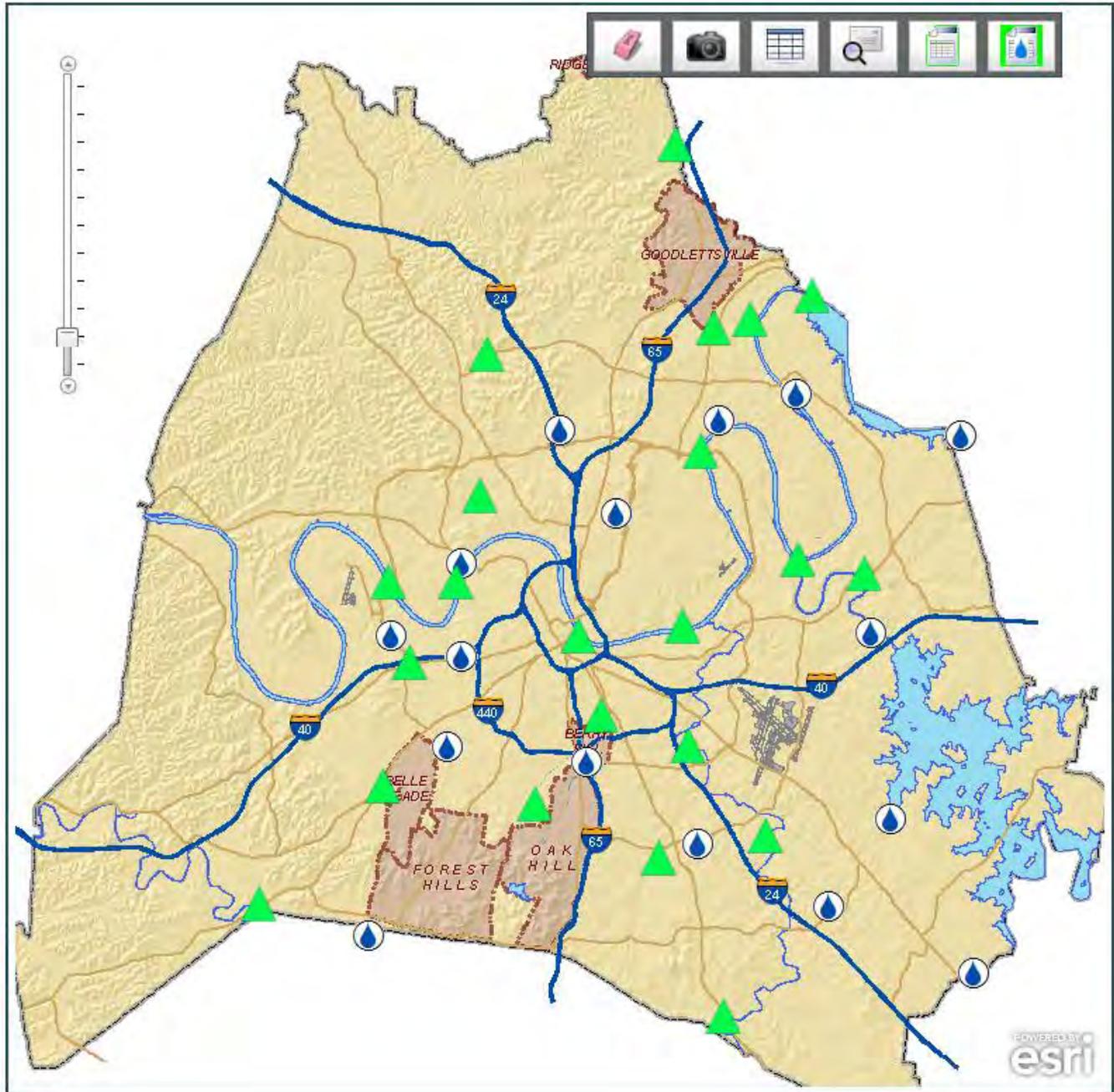
Select Additional Layers

- 2010 Aerial Photography
- Addresses
- FEMA Floodplain/Floodway
- Population Density by Blockgroup
- Stream Gauges
- Rain Gauges
- Population - Hispanic
- Population Over 65
- Road Closures
- Police Incidents
- OEM Incidents

Cameras

Links

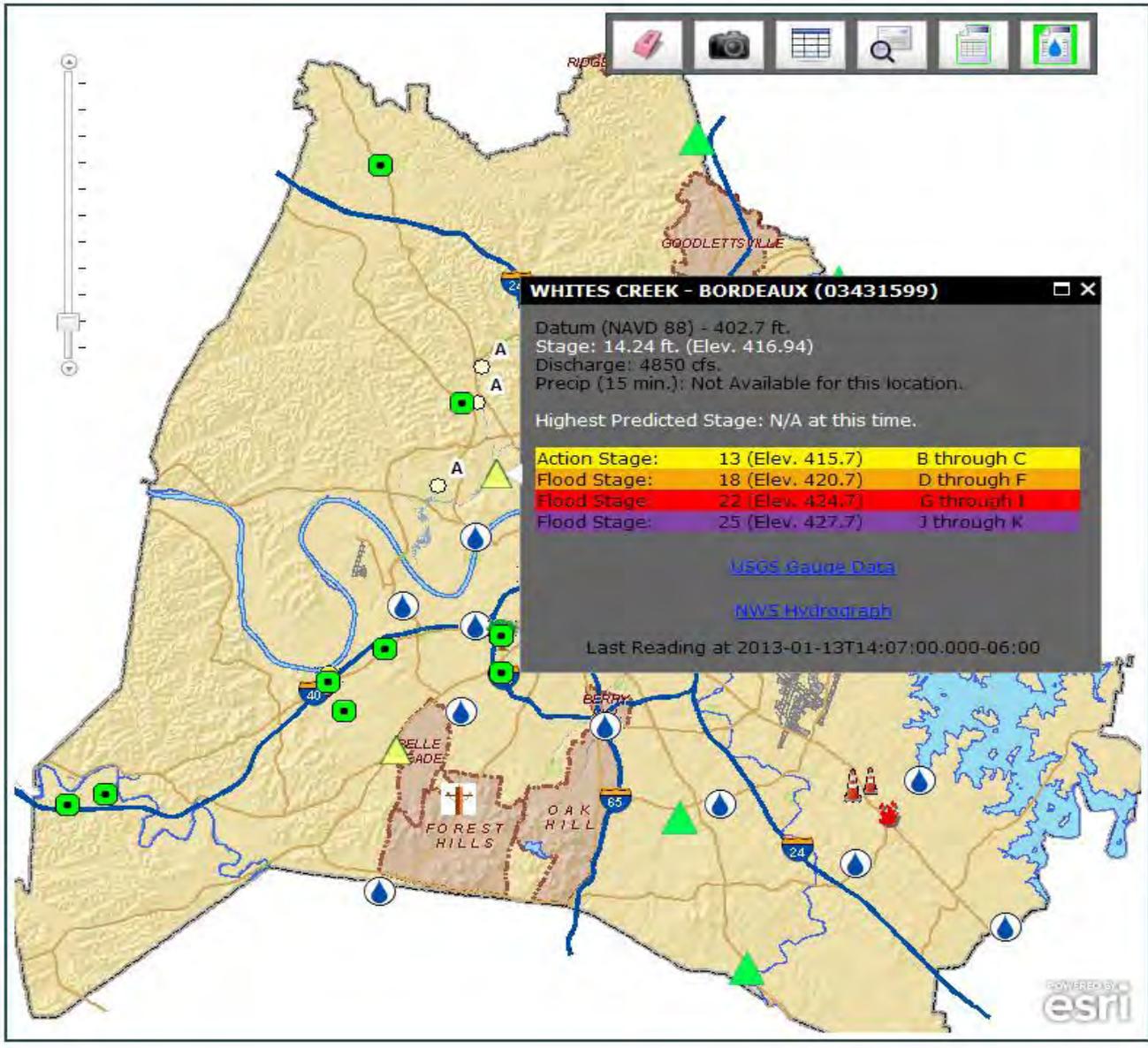
Set Predicted Levels



**NASHVILLE SAFE**  
 SITUATIONAL AWARENESS FOR FLOODING EVENTS

- Current Readings
- NWS Highest Predicted
- User Set Predicted

- Additional Layers**
- Select Additional Layers
- 2010 Aerial Photography
  - Addresses
  - FEMA Floodplain/Floodway
  - Population Density by Blockgroup
  - Stream Gauges
  - Rain Gauges
  - Population - Hispanic
  - Population Over 65
  - Road Closures
  - Police Incidents
  - OEM Incidents
- Cameras
- Links
- Set Predicted Levels



# WHITES CREEK - BORDEAUX (03431599)



Datum (NAVD 88) - 402.7 ft.

Stage: 5.96 ft. (Elev. 408.66)

Discharge: 180 cfs.

Precip (15 min.): Not Available for this location.

Highest Predicted Stage: N/A at this time.

Action Stage:	13 (Elev. 415.7)	B through C
Flood Stage:	18 (Elev. 420.7)	D through F
Flood Stage:	22 (Elev. 424.7)	G through I
Flood Stage:	25 (Elev. 427.7)	J through K

[USGS Gauge Data](#)

[NWS Hydrograph](#)

Last Reading at 2013-01-15T16:30:00.000-06:00

**SAFE - Windows Internet Explorer**

http://hobsvpcie01/safe\_js/

File Edit View Favorites Tools Help

Nashville > Home ASFPM Annual National Conf... Intellicast - Interactive Weat... SAFE

**NASHVILLE SAFE**  
SITUATIONAL AWARENESS FOR FLOODING EVENTS

- Current Readings
- NWS Highest Predicted
- User Set Predicted

**Additional Layers**

Select Additional Layers

- 2010 Aerial Photography
- Addresses
- FEMA Floodplain/Floodway
- Population Density by Blockgroup
- Stream Gauges
- Rain Gauges
- Population - Hispanic
- Population Over 65
- Road Closures
- Police Incidents
- OEM Incidents

Cameras

Links

Set Predicted Levels

**WHITES CREEK - BORDEAUX**

Datum (NAVD 88) - 402.7 ft.  
 Stage: 14.24 ft. (Elev. 416.94)  
 Discharge: 4850 cfs.  
 Precip (15 min.): Not Available for this location.

Highest Predicted Stage: N/A at this time.

Action Stage: 13 (Elev. 415.7)	B through C
Flood Stage: 18 (Elev. 420.7)	D through F
Flood Stage: 22 (Elev. 424.7)	G through I
Flood Stage: 25 (Elev. 427.7)	J through K

[USGS Gauge Data](#)

[NWS Hydrograph](#)

Last Reading at 2013-01-13T14:07:00.000-06:00

USGS Real-Time Water Data for USGS 03431000 MILL CREEK NEAR ANTIOCH, TN - Windows Internet Explorer

http://waterdata.usgs.gov/t/nwis/lev/?site\_no=03431000&PARAMeter

File Edit View Favorites Tools Help

USGS Real-Time Water Data for USGS 03431000 MILL...

## USGS 03431000 MILL CREEK NEAR ANTIOCH, TN

### PROVISIONAL DATA SUBJECT TO REVISION

Available data for this site Time-series: Real-time data GO

This site is operated in cooperation with

U.S. Army Corps of Engineers, Nashville District  
 District

This station managed by the Nashville Field Office.

Available Parameters	Output format	Days
<input type="checkbox"/> All 3 Available Parameters for this site	<input checked="" type="radio"/> Graph	7 (1-120) GO
<input checked="" type="checkbox"/> 00060 Discharge	<input type="radio"/> Graph w/ stats	
<input checked="" type="checkbox"/> 00065 Gage height	<input type="radio"/> Graph w/o stats	
<input type="checkbox"/> 00045 Precipitation	<input type="radio"/> Table	
	<input type="radio"/> Tab-separated	

**WHITES CREEK NEAR BORDEAUX**

Universal Time (UTC)

22Z Jan 12	10Z Jan 13	22Z Jan 13	10Z Jan 14	22Z Jan 14	10Z Jan 15	22Z Jan 15	10Z Jan 16	22Z Jan 16	10Z Jan 17	22Z Jan 17
<p>Latest observed value: 5.95 ft at 3:30 PM CST                      15-Jan-2013. Flood Stage is 18 ft</p> <p>Major: 25.0' Record: 25.8'</p> <p>Moderate: 22.0'</p> <p>Minor: 18.0'</p> <p>Action: 13.0'</p> <p>16.28 ft</p>										

Flow (cfs)

Site Time (CST)

Graph Created (4:50PM Jan 15, 2013) Observed

Done

BORT1(plotting HGIRG) "Gage 0" Datum: 402.87'

Observations courtesy of US Geological Survey



- Current
- MWS Highest Predicted
- User Set Predicted

Gauge Report

Enter Address or Intersection

Search Address

Additional Layers  
Set Predicted Levels

Update with Predicted Levels

Browns Creek - Fairgrounds

Stage	Level
<input type="text"/>	<input type="text"/>

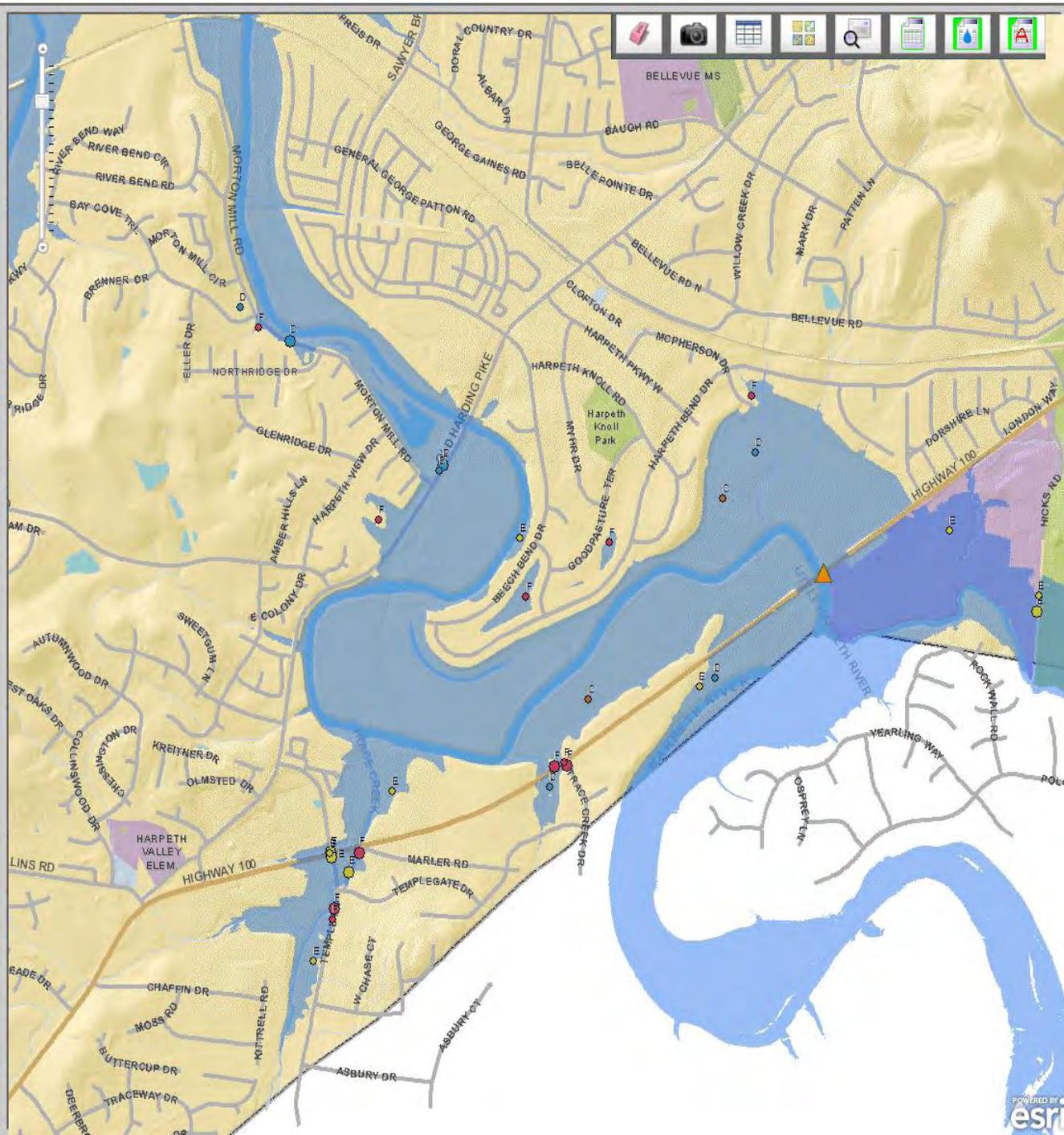
WF Browns Creek - Glendale Ln

Stage	Level
<input type="text"/>	<input type="text"/>

Cumberland River - Woodland

Stage	Level
<input type="text"/>	<input type="text"/>

Harpeth River - Bellevue



# NWS – Quantitative Precipitation Forecasts

weather.gov

National Weather Service  
Weather Prediction Center

Site Map News Organization Search  Go

DOC NOAA NWS | NCEP Centers: AWC CPC EMC NCO NHC OPC SPC SWPC WPC

Local forecast by "City, St" or Zip Code  
City, St  Go

Search WPC  
 Go

NCEP Quarterly Newsletter

WPC Home  
Analyses and Forecasts  
National Forecast Charts  
National High & Low  
WPC Discussions  
Surface Analysis  
Days 1/2-2 1/2 CONUS  
Days 3-7 CONUS  
Days 4-8 Alaska  
QPF  
PQPF  
Excessive Rainfall  
Mesoscale Precip Discussion  
Flood Outlook  
Winter Weather  
Storm Summaries  
Heat Index  
Tropical Products  
Daily Weather Map  
GIS Products  
Current Watches/Warnings

## Quantitative Precipitation Forecasts

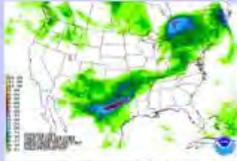
<a href="#">Day 1</a>	<a href="#">Days 1-2</a>	<a href="#">5- and 7-day Totals</a>
<a href="#">Day 2</a>	<a href="#">Days 1-3</a>	
<a href="#">Day 3</a>	<a href="#">Days 4-5 and Days 6-7</a>	

Loop of All [6-hourly](#) or [24-hourly](#) Forecasts for Days 1-3  
[View 12-Hour QPFs for Days 1-3](#)

[WPC QPF Archive](#)

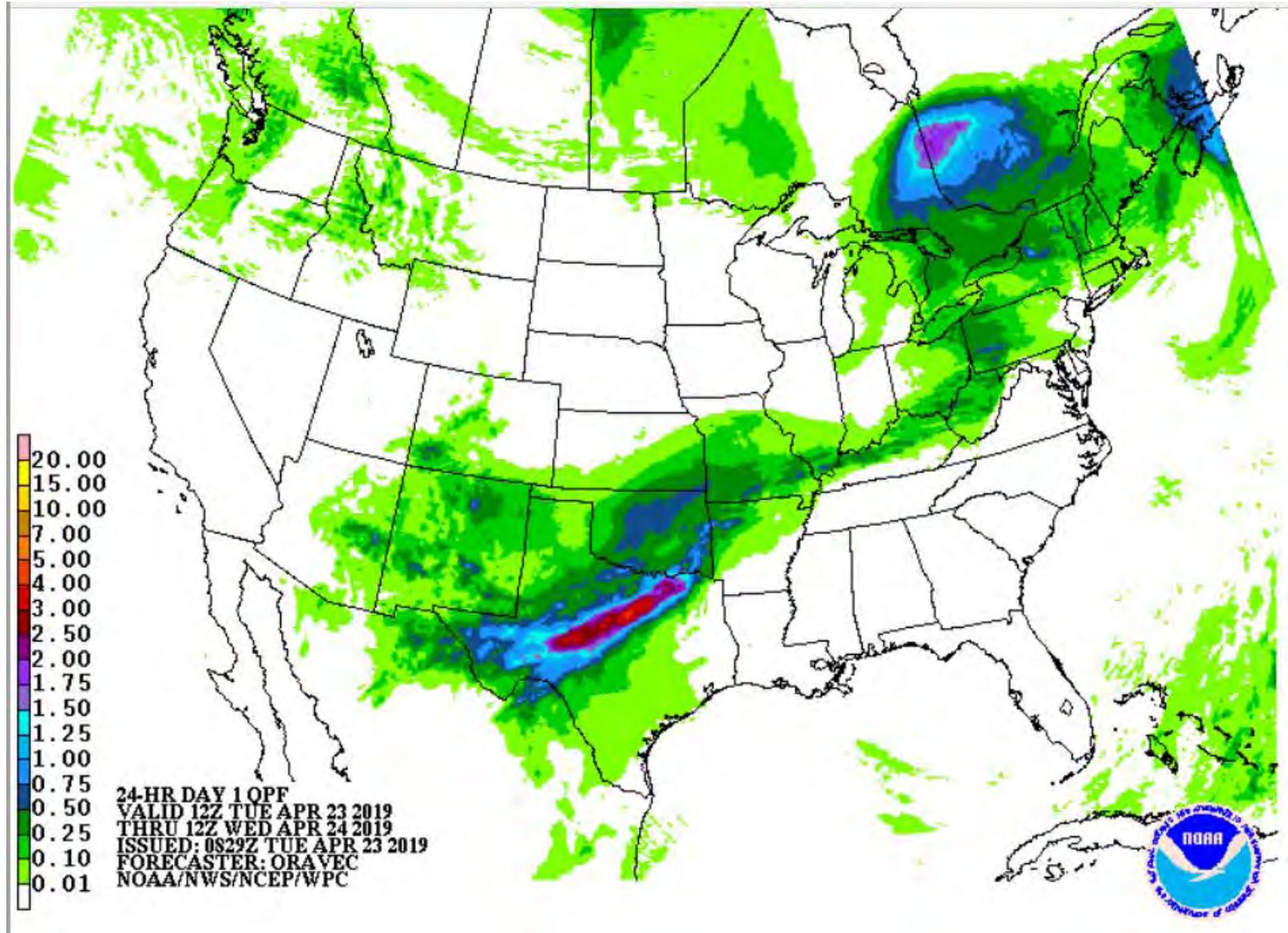
[Experimental Extreme Precipitation Monitor](#)

### 24 Hour Precipitation Total - Day 1



Day 1 QPF  
[contours only]

# NWS – Quantitative Precipitation Forecasts



# Nashville NERVE

**NERVE**  
NASHVILLE EMERGENCY RESPONSE VIEWING ENGINE

ter is currently NOT activated. OEM is monitoring

**Evacuation Areas**

- Shelters
- Disaster Information Centers
- Disaster Recovery Centers
- Food Distribution Centers
- Clothing Distribution Centers
- Water Distribution Centers

**Legend**

**Road Closure / Opening**

- Closed
- Recently Opened (Past 2 Hours)

**Facilities**

Nashville-Davidson Metro Governm, Esri, HERE, Garmin, USGS, ...

The screenshot displays the Nashville NERVE web application. The interface includes a search bar at the top with the text "Find address or place". Below the search bar is a navigation toolbar with icons for home, refresh, and other map functions. The main map area shows a topographic view of the Nashville region, with various roads and landmarks labeled. A legend in the bottom-left corner of the map area defines symbols for road closures (red line) and recently opened roads (green line). The application also features a sidebar on the left with a list of facility types: Shelters, Disaster Information Centers, Disaster Recovery Centers, Food Distribution Centers, Clothing Distribution Centers, and Water Distribution Centers. A status message at the top of the sidebar indicates that a certain feature is currently not activated and that OEM is monitoring. The map is powered by Esri and includes data from HERE, Garmin, and USGS.

Transitioning to Real Time Simulation  
became the logical next step....

# Post May 2010 Flood Efforts - USACE

- Immediately started working with Nashville and other federal agencies
    - Building models and developed mapping products to better understand flood risk
    - USGS added stream gauges further up in watersheds
    - Created the Nashville SAFE program to better understand NWS forecasts
    - Performed hundreds of miles of updates to flood insurance rate maps in coordination with FEMA
  - **Work culminated in the development of HEC-RTS modeling**
-

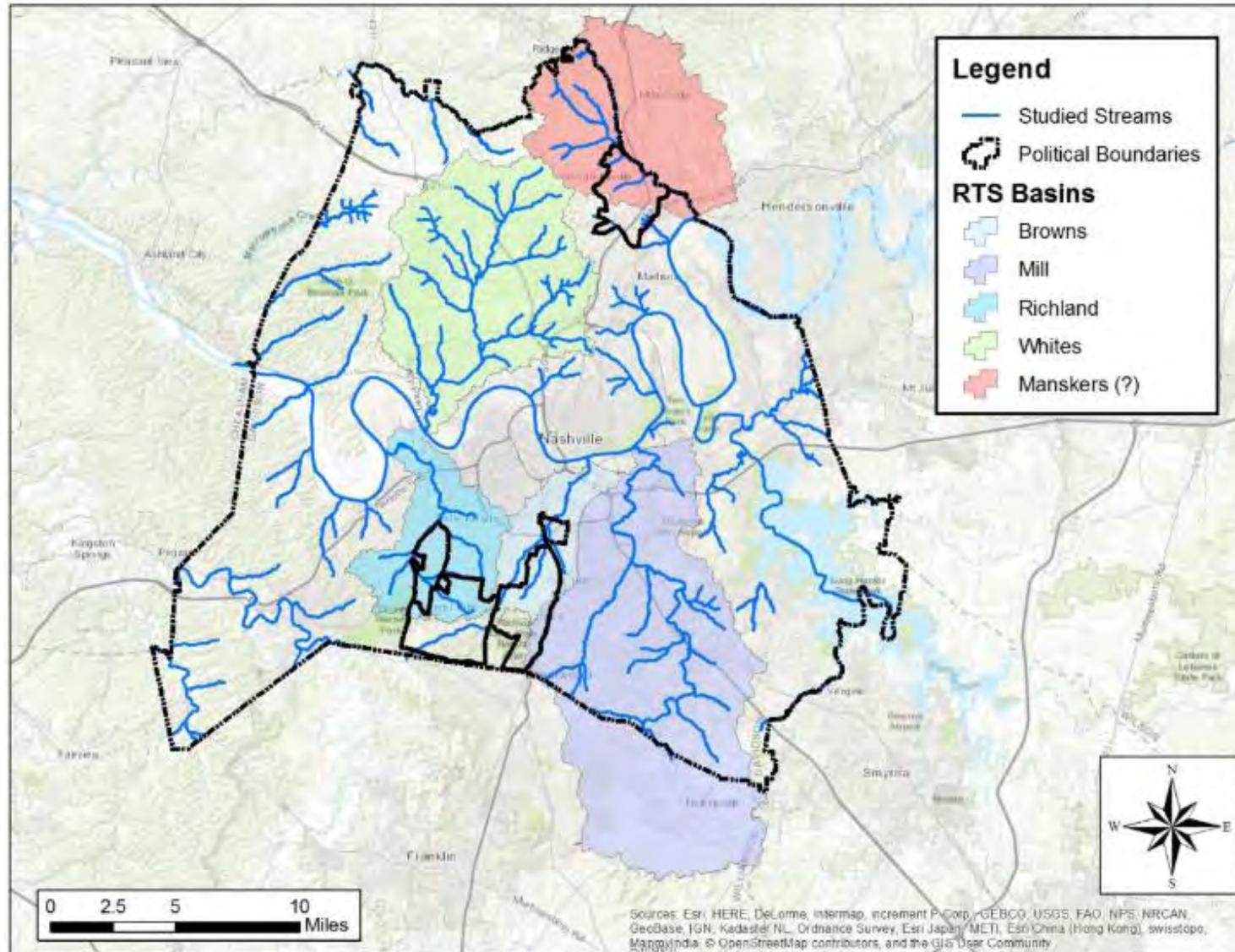
# Real Time Simulation (HEC-RTS)

- What is HEC-RTS?
  - Real-time decision support system developed by the USACE - Hydrologic Engineering Center
  - Relies on suite of HEC software (HEC-HMS, HEC-RAS, etc.)
  - Provides a real-time flood forecasting environment integrating HEC software
  - Utilizes python scripts to import real-time data from the internet
  - Utilizes python scripts to publish and disseminate results to necessary stakeholders

# Real Time Simulation (HEC-RTS)

- Why is it important?
  - LIFE SAFETY
  - Time matters – Most basins in Nashville have a very short reaction time
- Who is the suite of Nashville HEC-RTS models intended for?
  - Modelers
    - National Weather Service (NWS)
    - Metro-Nashville Staff/Contractors
  - Beneficiaries
    - Metro emergency services
    - NWS forecasters
    - Public

# Nashville HEC-RTS Watersheds

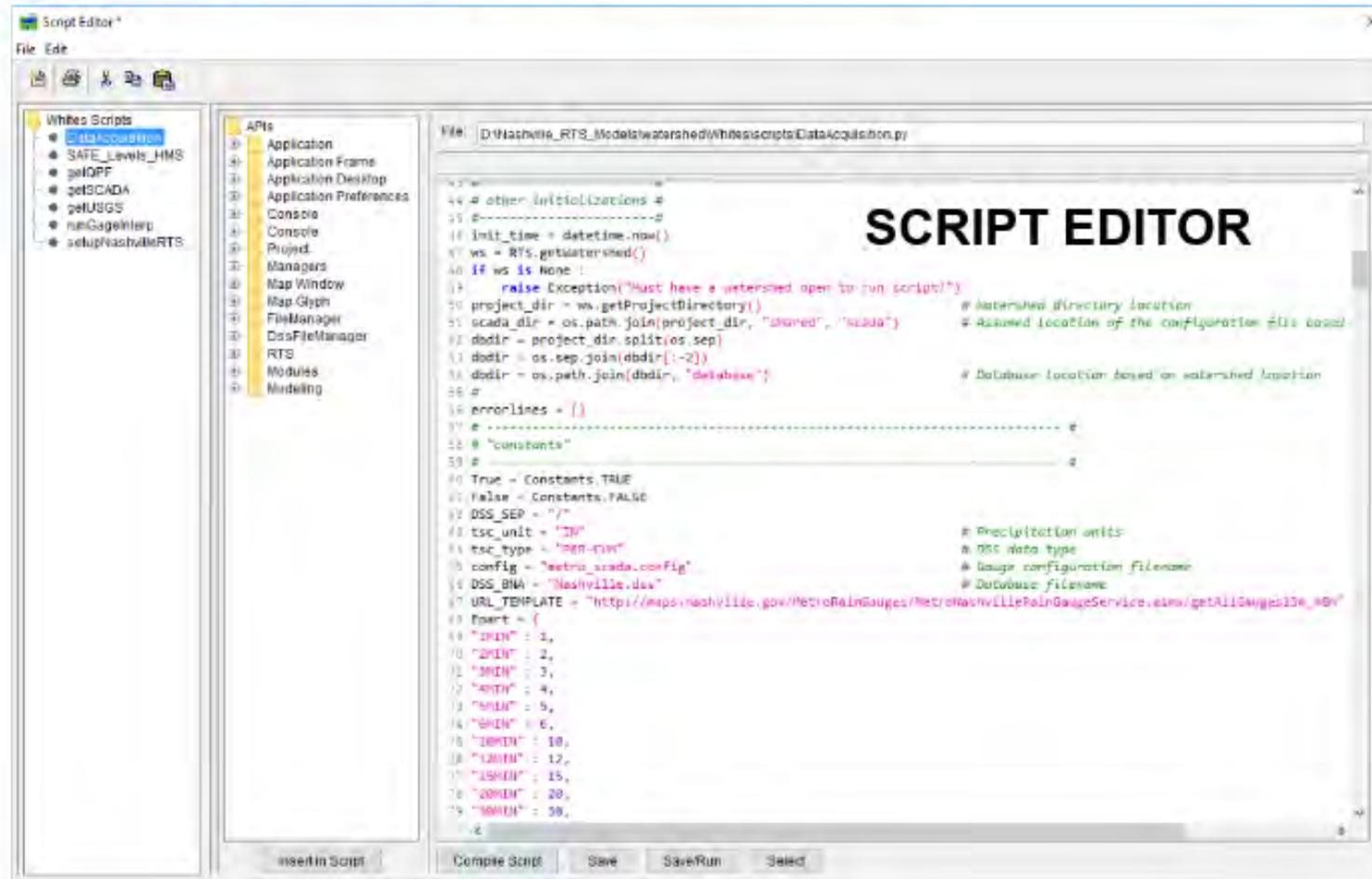


# Input Data to the Model

- Data is very important to the model performance
- All data derived from publicly available web sources
- HEC-RTS model relies on several sources of data
  - Stage/Flow Time Series Data – USGS
  - Gridded Precipitation
    - Lookback – GageInterp-derived (15-min); NWS QPE (1-hr)
    - Forecasted – NWS/NOAA QPF (6-hr); NWS NOAA HRRR (1-hr)

# Input Data to the Model

- Python scripting is used to download and format input data into



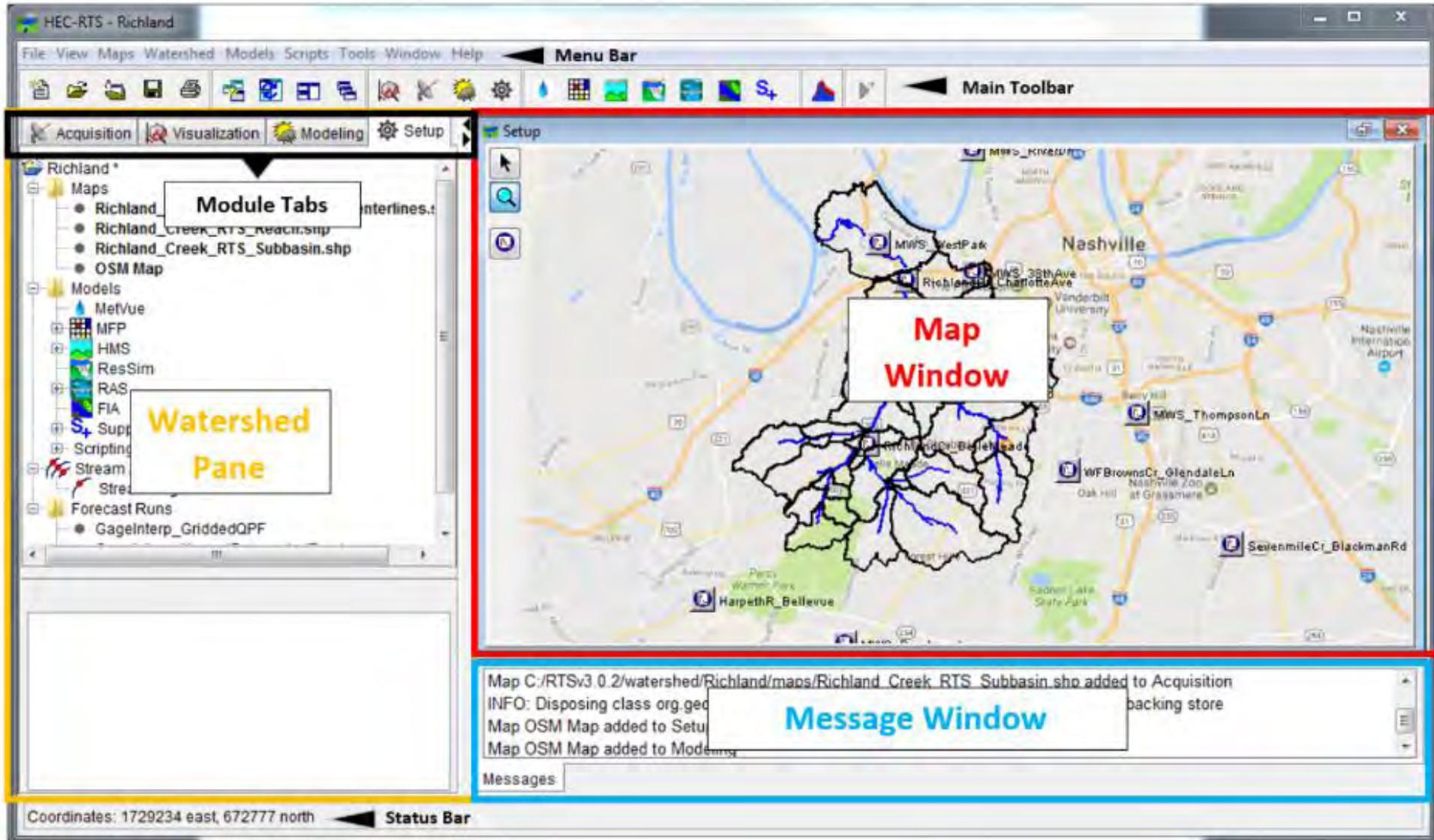
The screenshot shows a Python Script Editor window titled "Script Editor". The interface includes a menu bar (File, Edit), a toolbar, and a sidebar with two panels: "Whites Scripts" and "APIs". The "Whites Scripts" panel lists several scripts, with "DataAcquisition" selected. The "APIs" panel lists various system components like Application, Application Frame, Application Desktop, etc. The main editor area displays a Python script for data acquisition. The script includes comments and code for setting up project directories, database connections, and defining constants for data acquisition parameters.

```
File: D:\Nashville_RTS_Model\watershed\Whitescripts\DataAcquisition.py

44 # other initializations #
45 # -----#
46 init_time = datetime.now()
47 ws = RTS.getwatershed()
48 if ws is None:
49     raise Exception("Must have a watershed open to run script!")
50 project_dir = ws.getProjectDirectory() # watershed directory location
51 scada_dir = os.path.join(project_dir, "shared", "scada") # assumed location of the configuration files based
52 dbdir = project_dir.split(os.sep)
53 dbdir = os.sep.join(dbdir[:-2])
54 dbdir = os.path.join(dbdir, "database") # Database location based on watershed location
55 #
56 errorlines = []
57 # -----#
58 # "constants"
59 # -----#
60 True = Constants.TRUE
61 False = Constants.FALSE
62 DSS_SEP = "/"
63 tsc_unit = "D" # Precipitation units:
64 tsc_type = "METRO-QPW" # DSS data type
65 config = "metro_scada.config" # Gauge configuration filename
66 DSS_BNA = "Nashville.dss" # Database filename
67 URL_TEMPLATE = "http://maps.nashville.gov/MetroRainGauges/MetroNashvilleRainGaugeService.aspx/getAllGaugesData_00"
68 Export = {
69     "2010" : 1,
70     "2011" : 2,
71     "2012" : 3,
72     "2013" : 4,
73     "2014" : 5,
74     "2015" : 6,
75     "2016" : 10,
76     "2017" : 12,
77     "2018" : 15,
78     "2019" : 20,
79     "2020" : 30,
80 }
```

- Scripts
  - USGS Data
  - Nashville SCADA Precip Gauges
  - GageInterp
  - NOAA QPE
  - NOAA QPF
  - NOAA HRRR
  - Action Level Tool
- Scripts can be run on a schedule

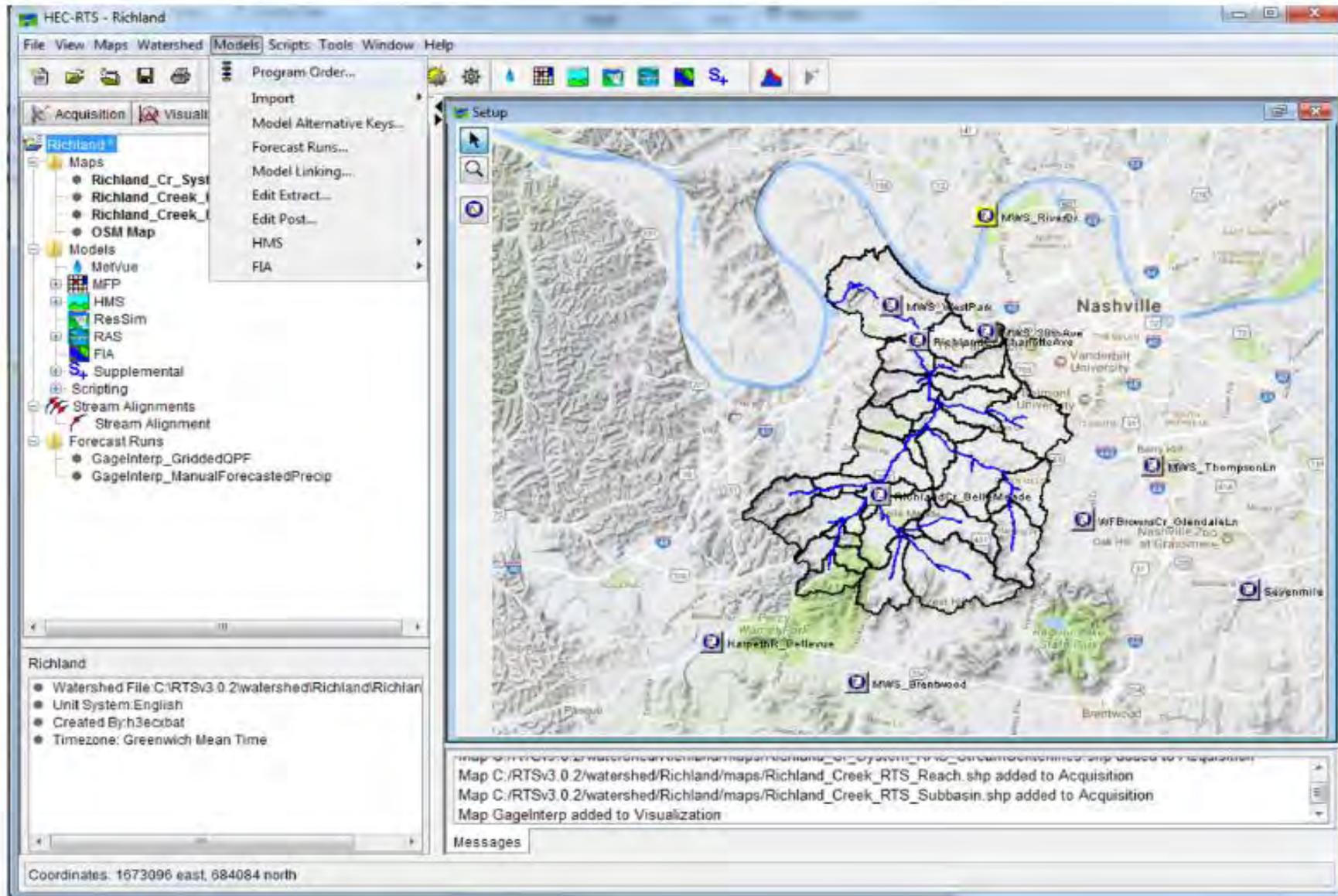
# HEC-RTS Tour



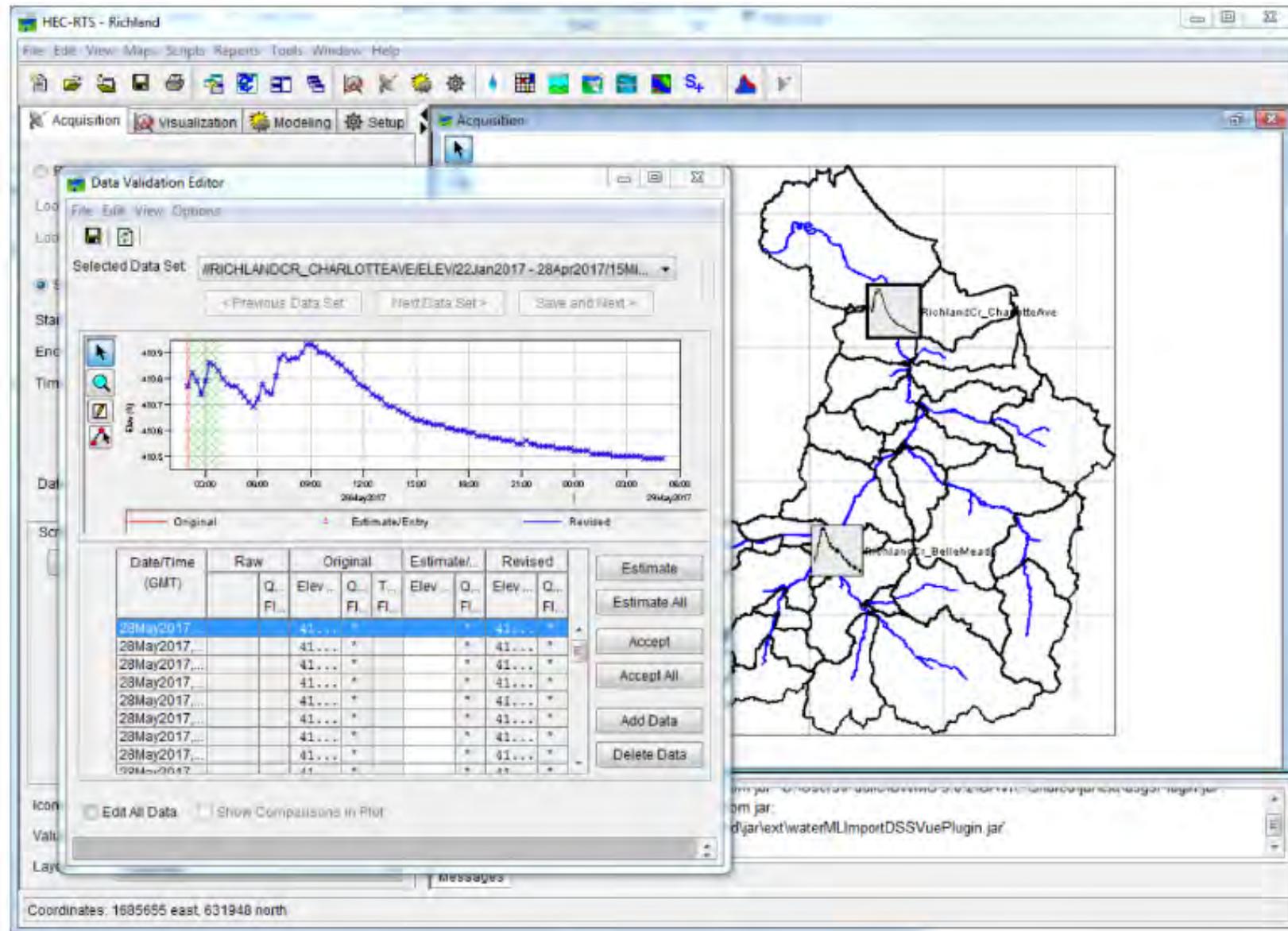
# HEC-RTS Modules

- Setup
  - Models imported
  - Program order (MFP ► HMS ► RAS)
  - Data Setup
- Acquisition
  - Data Acquisition
  - Data QC
- Visualization
  - Visualize data and make initial forecasting decisions
- Modeling
  - Where all the magic happens
  - Create forecasts and execute individual modeling components

# Setup Module



# Data Acquisition Module



# Data Visualization Module

The screenshot displays the HEC-RTS - Richland Data Visualization Module interface. The window title is "HEC-RTS - Richland". The menu bar includes File, View, Maps, Data Visualization, Scripts, Tools, Window, and Help. The toolbar contains various icons for file operations and visualization. The main interface is divided into several sections:

- Acquisition**: Includes options for "Relative to Current Time" and "Specific Time Window". Under "Specific Time Window", the Start Date is 28May2017, End Date is 29May2017, and Time is 0000. A "Refresh" button and "GageInterp" label are also present.
- Visualization**: The central area shows a map of a watershed with a blue color gradient. Two gage locations are highlighted: "RichlandCr\_CharlotteAve" (top) and "RichlandCr\_BaltimoreAve" (bottom). A white rectangular box is overlaid on the left side of the map.
- Scripts**: A section with playback controls and a timestamp of "29 May 2017, 05:00".
- Messages**: A log area at the bottom right showing messages such as "Map GageInterp added to Visualization" and "GageInterp saved successfully to C:\RTSv3.0.2\watershed\Richland\caw\GageInterp.xml".
- Coordinates**: The bottom status bar shows "Coordinates: 1671105 east, 682759 north".

# Modeling Module

HEC-RTS - Richland

File View Maps Forecast Scripts Tools Window Help

Acquisition Visualization Modeling Setup

Modeling - 2017.07.10-1500 GMT - GageInterp\_GriddedQPF

Name: 2017.07.10-1500 GMT

Time Window

Time Window

Forecast Time: 10Jul2017 Time: 1500

Extract Start: 09Jul2017 Time: 1500

Start Time: 09Jul2017 Time: 1500

End Time: 12Jul2017 Time: 1500

Display Time Zone: GMT

Forecasts

- GageInterp\_GriddedQPF: F0G0S0
- GageInterp\_GriddedQPF
- Richland\_GageInterp
- Richland System RTS Plan

Scripts

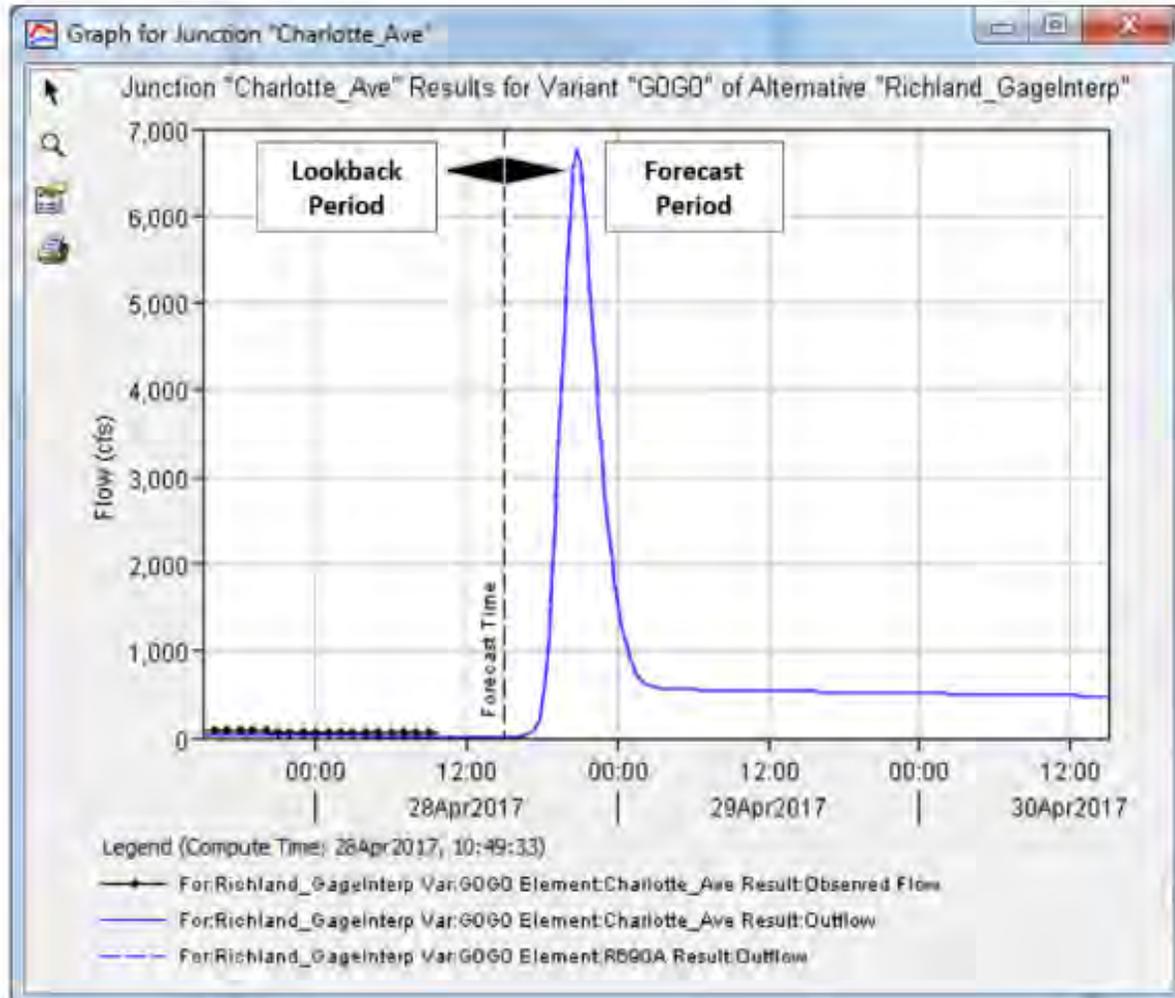
- SAFE Output Tool
- getQPF
- getSCADA
- getUSGS
- runGageInterp

Coordinates: 1688452 east, 637851 north

Messages Forecast Run Mapping Messages \*

HMS Reach R110 has no stream  
Placed HMS reach R110 on stream Richland\_Crk at upstation 16932.578665747187 to downstation 250.7765440401199  
HMS Reach R630 has no stream

# Modeling



- Setting up a forecast
- Set a forecast time, lookback period, and forecast period
- Choose a forecast run from a pre-defined list of model alternatives
- Model Alternatives
  - MFP – sources for observed and forecasted precip
  - HMS – dry, normal, wet antecedence conditions
  - RAS – seasonally varied roughness
- Scheduled Forecasts

# Modeling - Precipitation

The screenshot displays the HEC-RTS software interface with the 'MFP Alternative Editor' dialog box open. The dialog is configured for a precipitation model named 'Richland Creek RTS MFP Model' using a 'GageInterp\_Richland' meteorologic model. The forecast table shows a total future precipitation of 2.650 inches for the 'Richland' zone.

**HEC-RTS - Richland**

File View Maps Forecast Scripts Tools Window Help

Acquisition Visualization Modeling

Name: 2017\_07-12-1600 GMT

Time Window

Forecast Time: 12Jul2017 Time: 16:00

Extract Start: 11Jul2017 Time: 16:00

Start Time: 11Jul2017 Time: 16:00

End Time: 14Jul2017 Time: 16:00

Display Time Zone: GMT

Forecasts

- GageInterp\_ManualForecastedPrecip - G00
- GageInterp\_ManualForecastedPrecip
- Richland\_GageInterp
- Richland System RTS Plan

Scripts

- SAFE Output Tool
- getOPF
- getSCADA
- getUSGS
- runGageInterp

Actions Reports Scripts Icon Layers Workflow

Coordinates: 1701079 east 672881 north

**MFP Alternative Editor**

Edit

Precip Alt: GageInterp\_ManualForecastedPrecip Zone Configuration: Richland\_MFP

Description: Richland Creek RTS MFP Model using a gridded precip mat model developed using GageInterp

Grid Cell File: RichTrib.mod Meteorologic Model: GageInterp\_Richland

Specific Start Time Start Date: 12Jul2017

Relative Start Time Start Time: 1600

Time Interval: 15 Minutes Duration of Future Precip: 24 Hours

Forecast Precip: Obs Precip

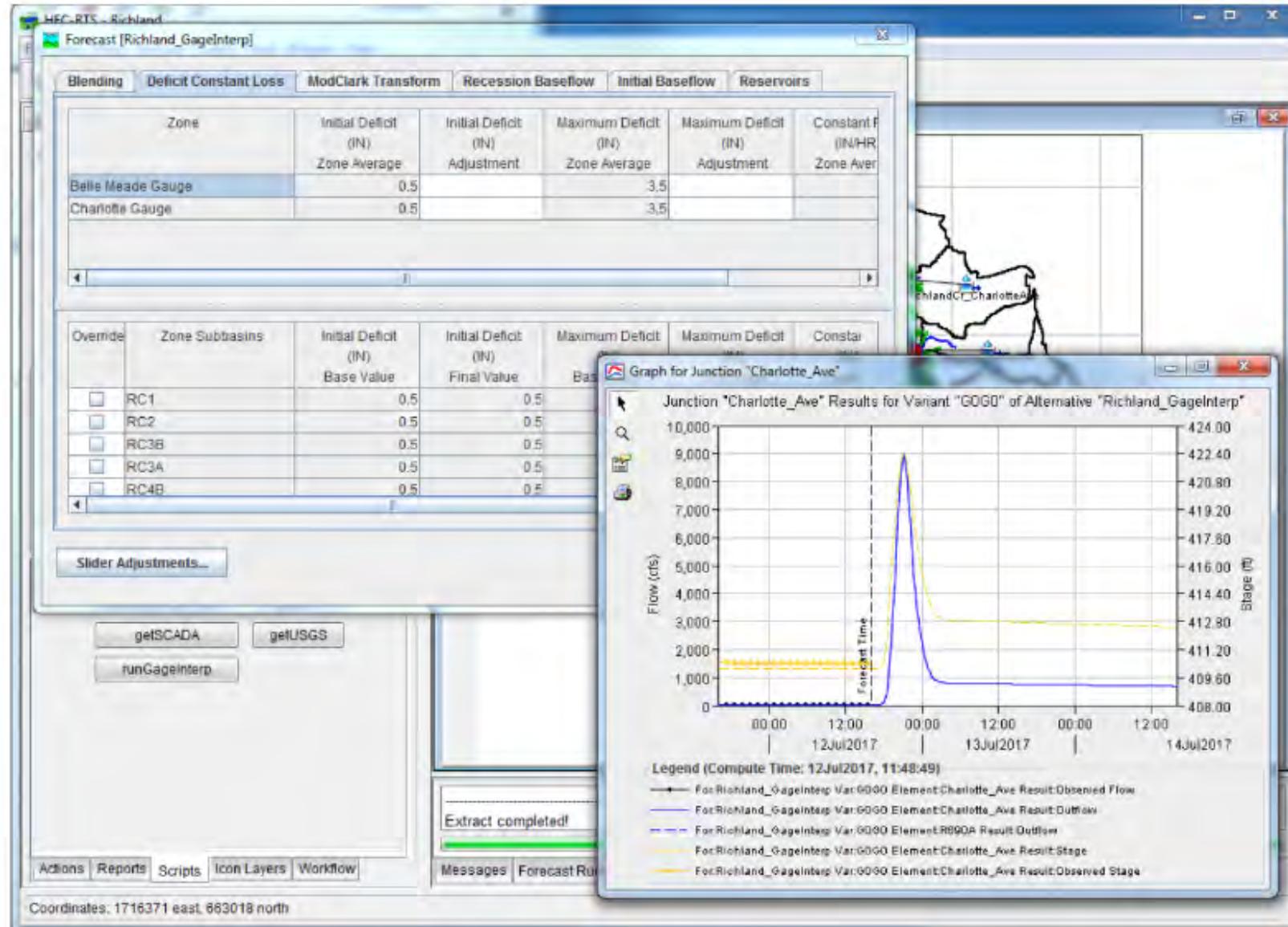
Manual  Time Series  Gridded Pathname:

Time	Zone
	Richland
Time of Forecast	
+0 hr. 15 min.	0.000
+0 hr. 30 min.	0.000
+0 hr. 45 min.	0.000
+1 hr. 00 min.	0.000
+1 hr. 15 min.	0.100
+1 hr. 30 min.	0.100
+1 hr. 45 min.	0.250
+2 hrs. 00 min.	0.250
+2 hrs. 15 min.	0.250
+2 hrs. 30 min.	0.500
+2 hrs. 45 min.	0.500
Total Future Precip:	2.650

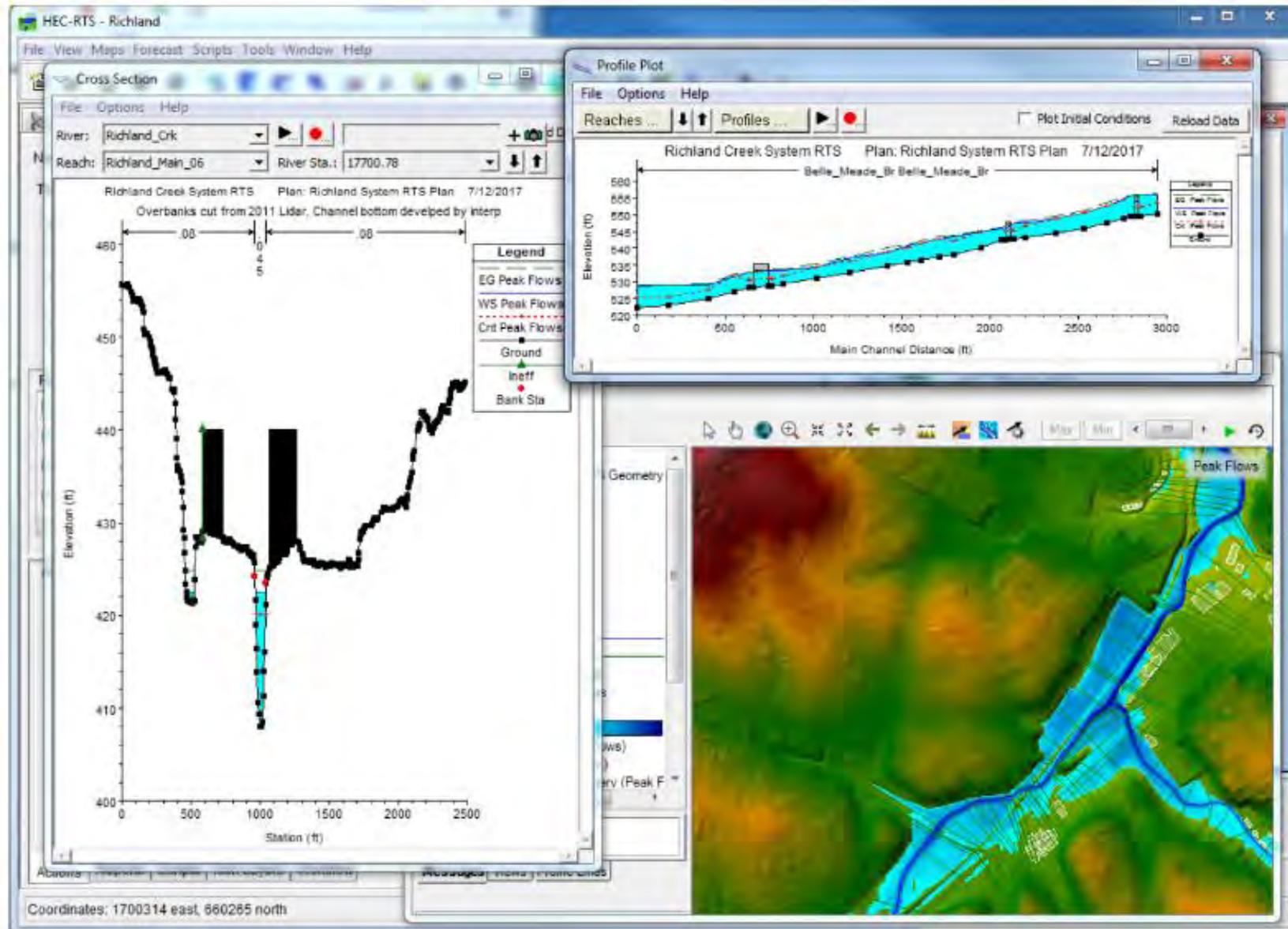
Graphical Edit

OK Cancel Apply

# Modeling - Hydrology



# Modeling - Hydraulics



# Data Dissemination

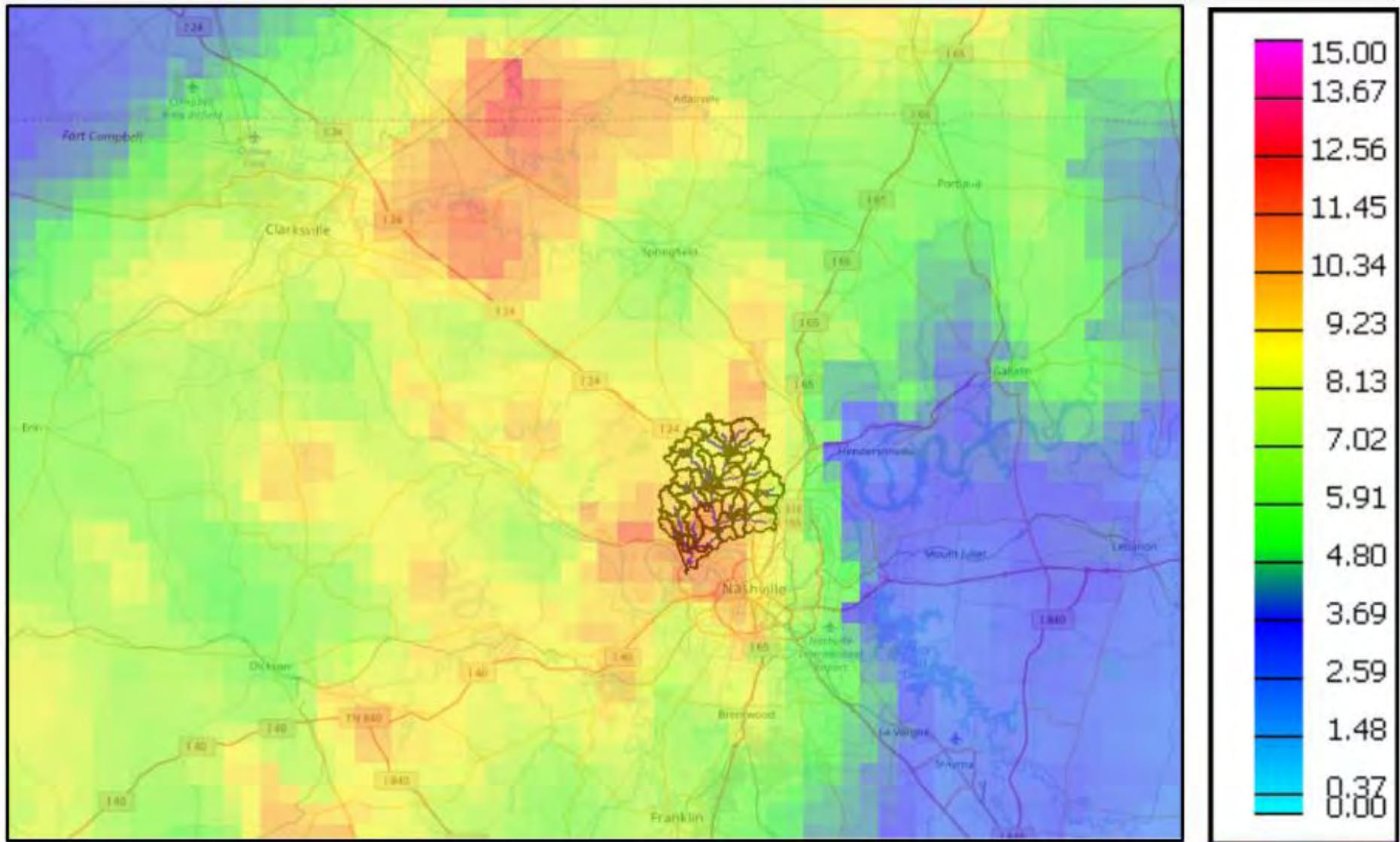
- Models are great...
- But if the results can't be communicated to the necessary people at the critical time; they're WORTHLESS!
-  Still under construction 
- Currently looking at two sources of dissemination:
  - Metro – Linkages to the Nashville SAFE program
  - NWS – Leave the forecasting to the experts.  
Already have the dissemination tools in place
- Action Level Tool

# Real World Application – Remnants of Harvey Event

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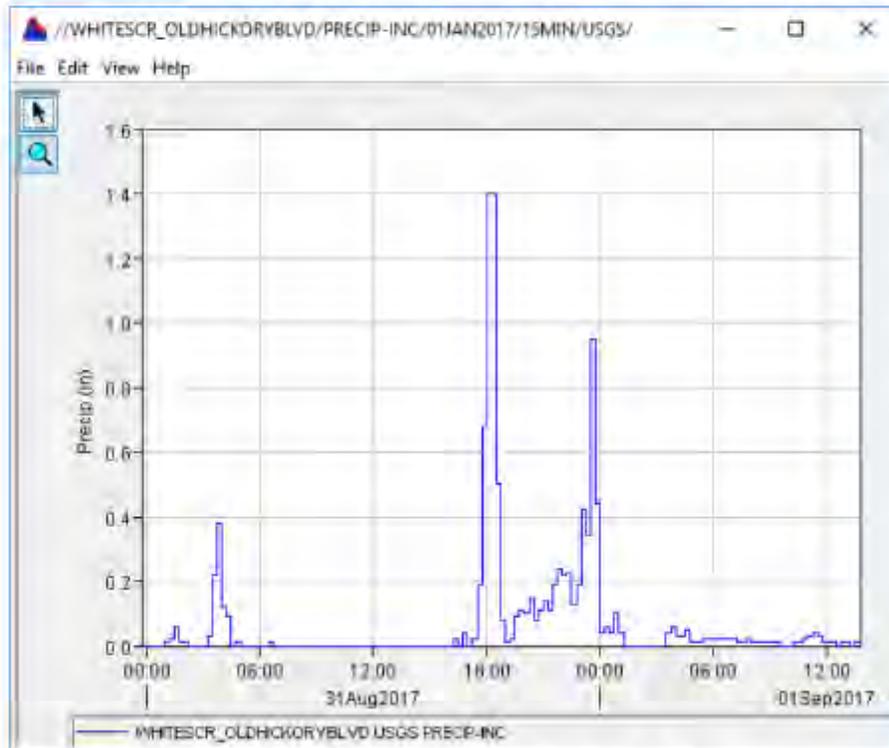
- Hurricane Harvey devastated the Texas coast from 25-29 August 2017
- Harvey system eventually worked its way to middle Tennessee a couple days later
- The system stalled over Nashville on the evening 31 August
- The event resulted in flooding throughout Nashville
- About 30 water rescues were performed mostly in the Whites Creek Basin (a trib to the Cumberland River)
- Event also produced several tornadoes in the Middle Tennessee area including Davidson Co.

# Harvey Event Cumulative Rainfall

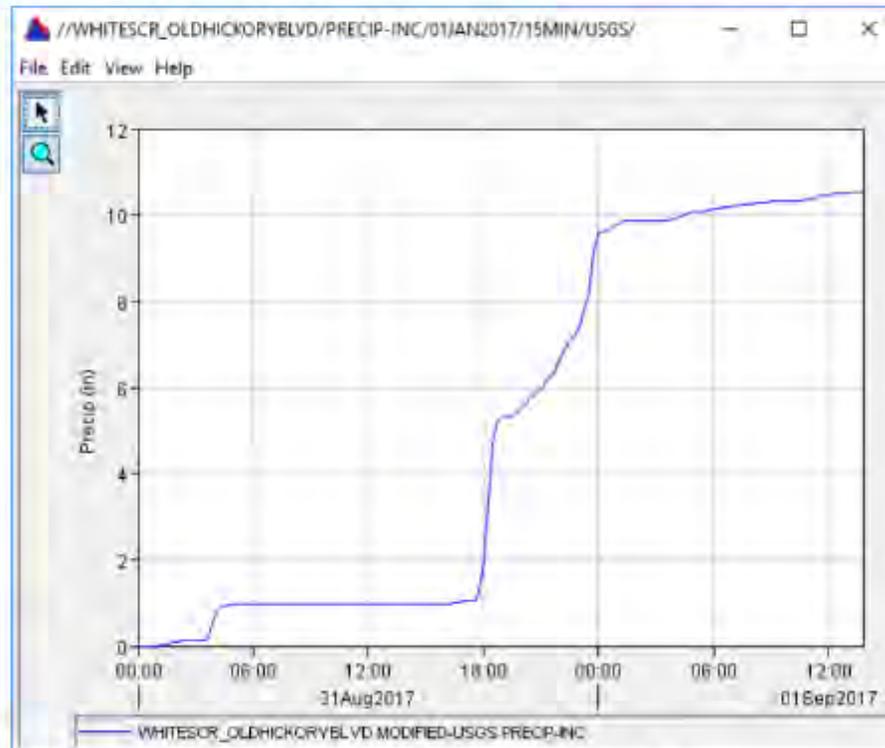


# Harvey Event Precipitation Totals

- About an inch of rain occurred early in the morning of 31 August
- Around 4 pm on 31 Aug, an intense rain event began
- From 4 – 7 pm, the initial event dropped about 5.5 inches of rain
- From 7 – 11 pm, it continued to rain steadily totaling ~3” of rain
- From 11 pm to midnight, another relatively intense 2” event occurred

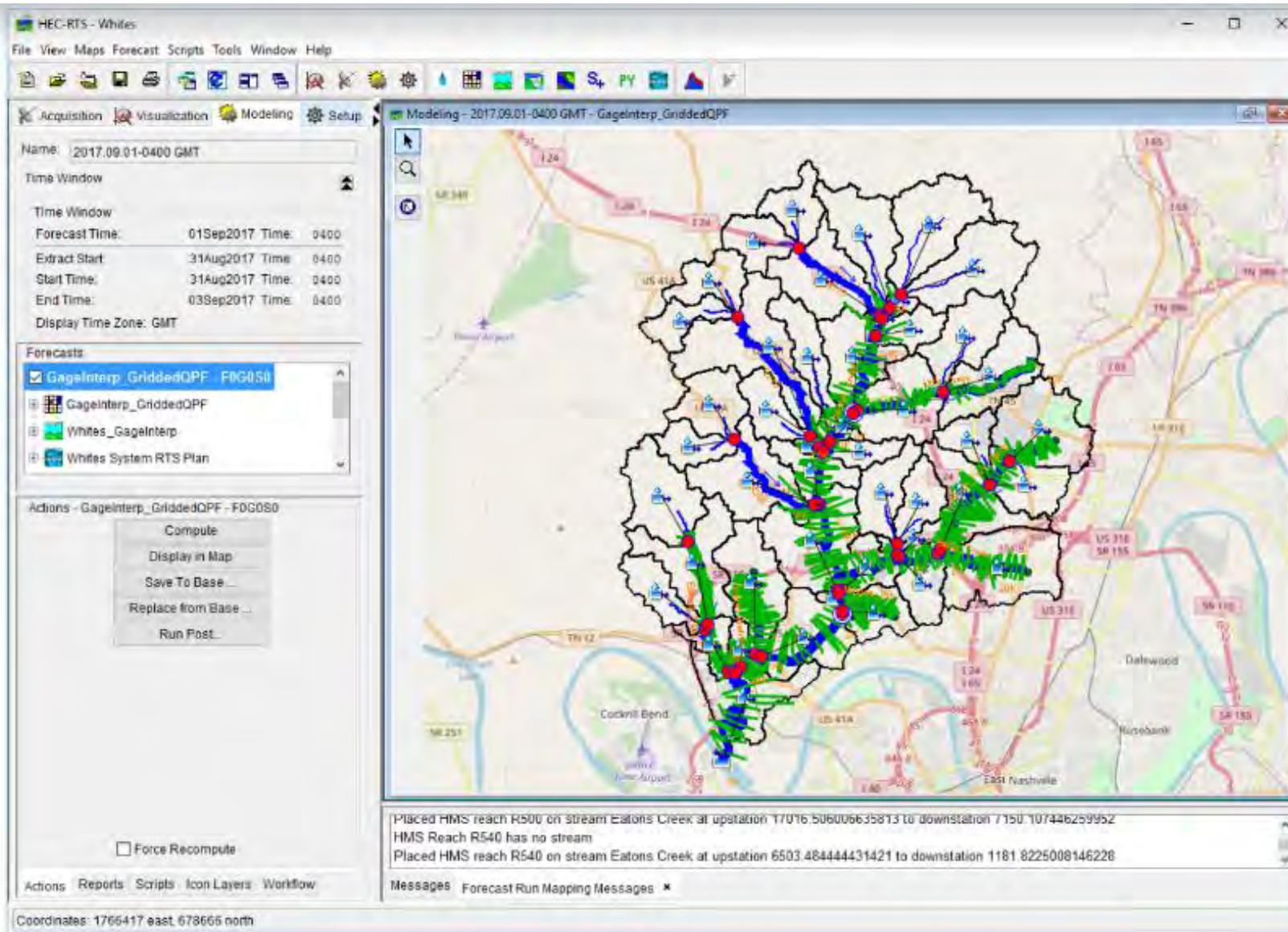


Incremental Rainfall

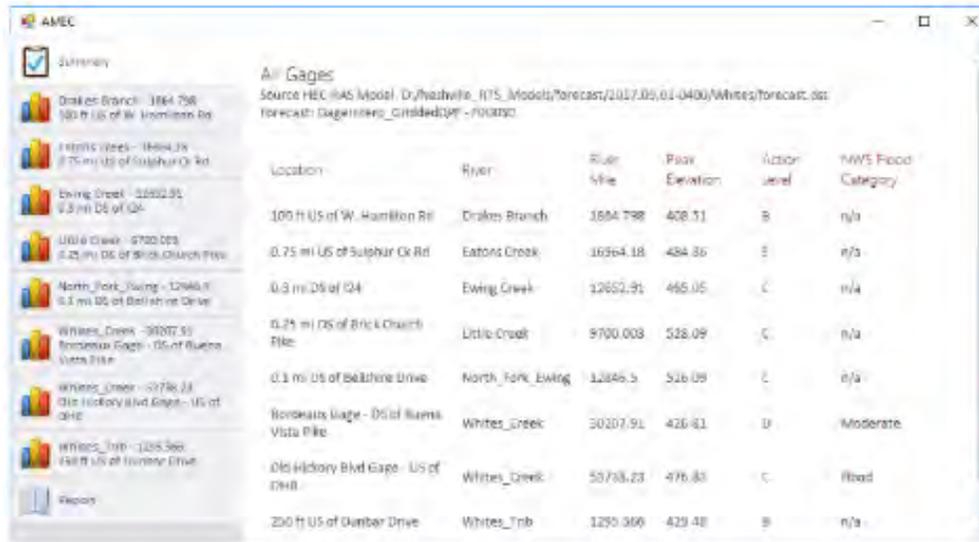


Cumulative Rainfall

# Whites Creek Watershed HEC-RTS Model



# Action Level Tool



AMEC

Summary

All Gages  
Source HEC-HAS Model: D:\hadwin\RTS\_Models\Forecast\2017.09.01-0400\Whites\Forecast.dsr  
Forecast: Gages\res\_cmsled\prf - r000.prf

Location	River	River Mile	Peak Elevation	Action Level	NWS Flood Category
100 ft US of W. Hamilton Rd	Drakes Branch	1664.798	408.51	B	n/a
0.75 mi US of Sulphur Cr Rd	Easton Creek	16964.18	484.86	B	n/a
0.3 mi DS of 124	Ewing Creek	12652.91	465.05	C	n/a
0.25 mi DS of Brick Church Pike	Little Creek	9700.003	526.09	C	n/a
0.1 mi US of Bellshire Drive	North Fork Ewing	12846.5	526.09	C	n/a
Bordeaux Gage - DS of Buena Vista Pike	Whites Creek	30207.91	426.81	D	Moderate
Old Hickory Blvd Gage - US of OHS	Whites Creek	50736.23	476.81	C	Flood
250 ft US of Dunbar Drive	Whites Trlb	1290.369	429.48	B	n/a

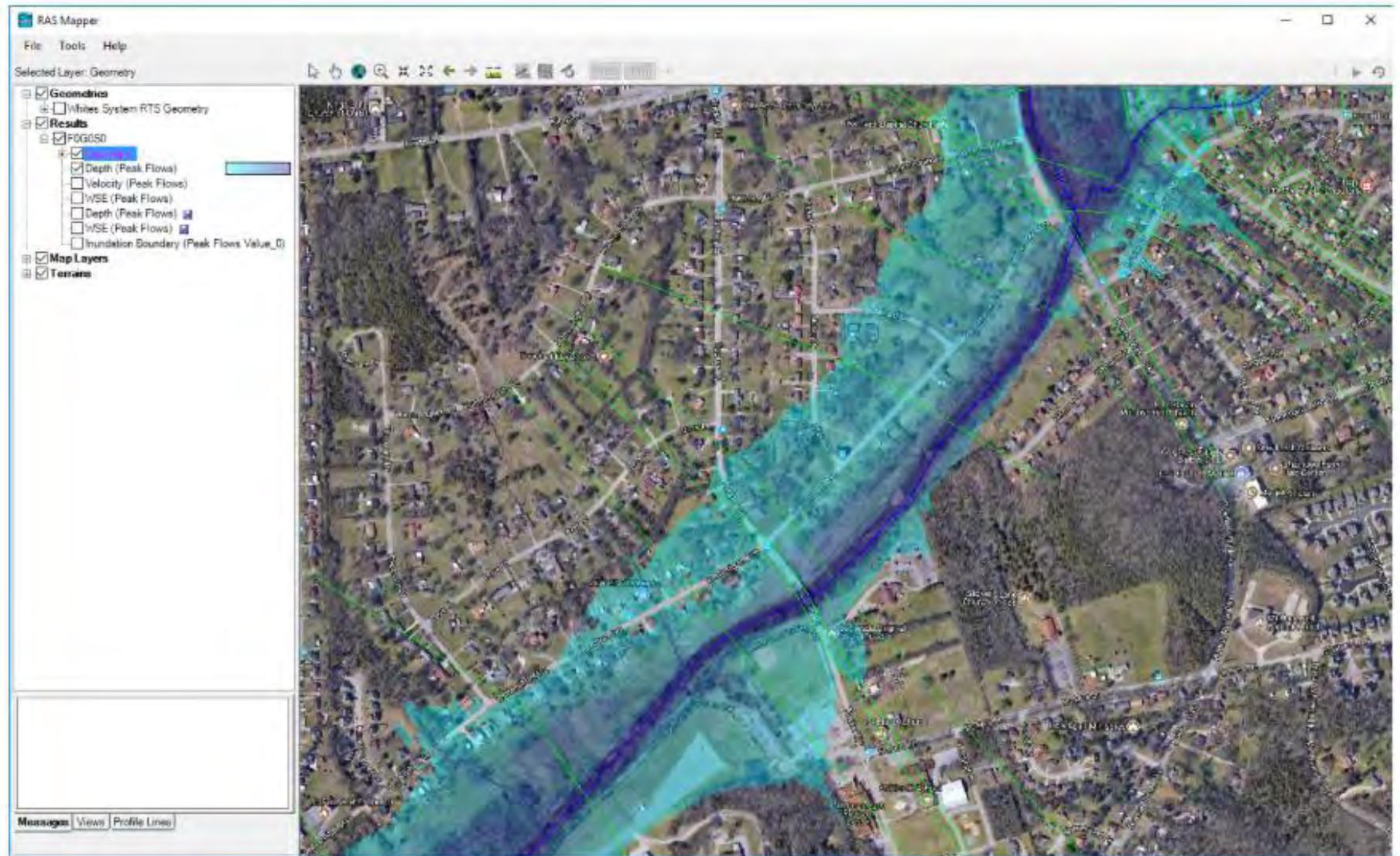
Report

- Provides action level information for forecast points throughout the watershed
- Nashville SAFE and NWS Action Levels

- Summary Table (above)
  - Summarizes action levels throughout the basin
- Forecast Point Information (right)
  - Accessed through left portion of the tool
  - Peak elevation and timing
  - Action Level
  - Stage Hydrograph

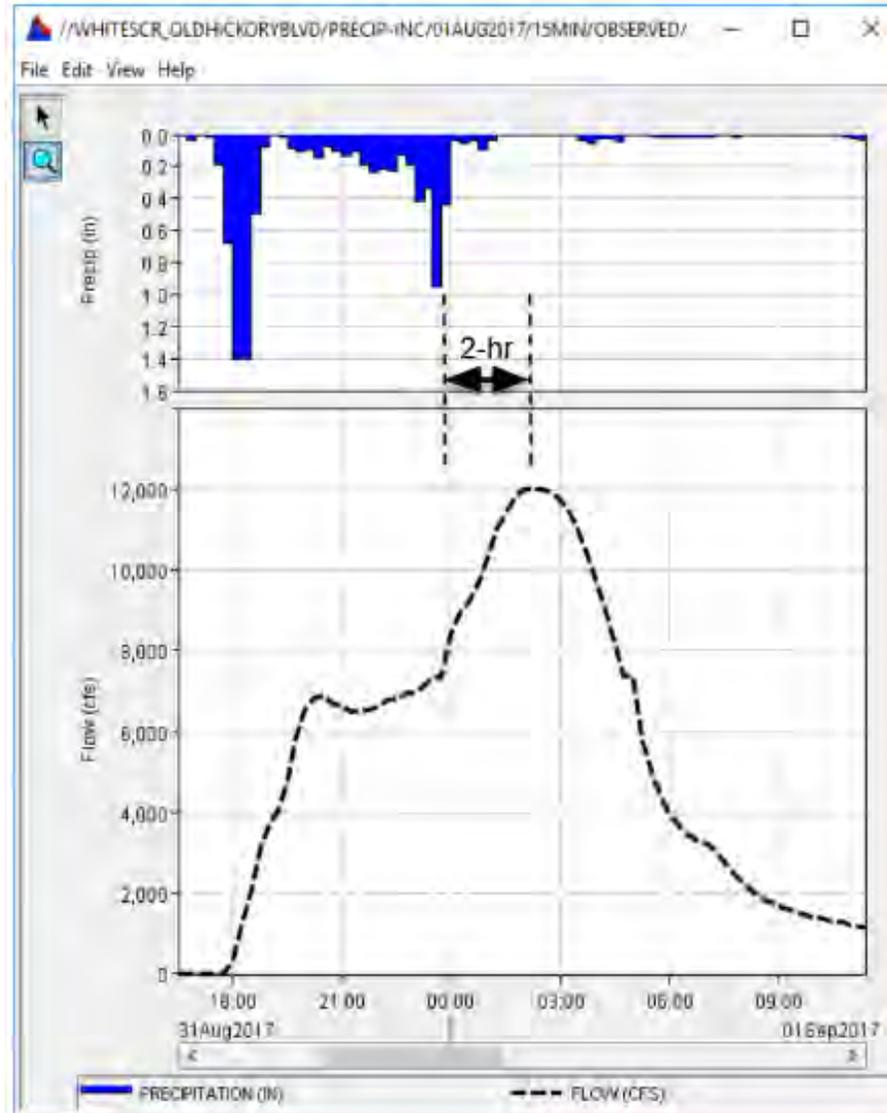


# Inundation Mapping



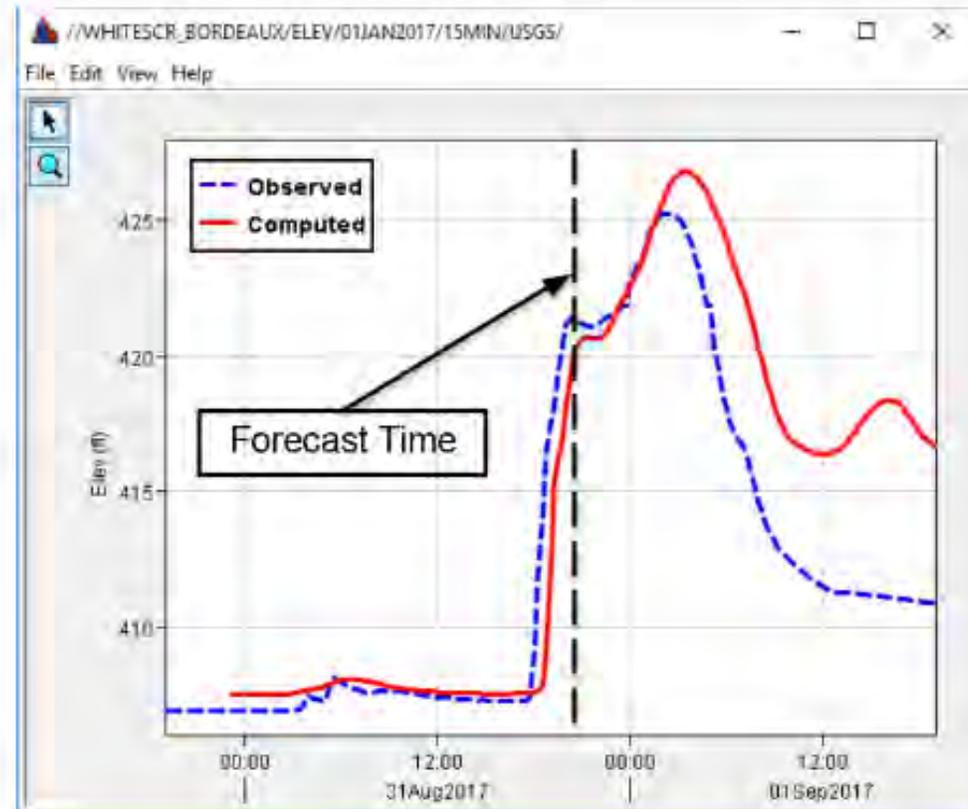
# Characteristics of the Event

- Observed data from event
- Double event
- First event saturated the basin
- About 2 hour response time
- HEC-RTS can be run continuously through event



# Post-Flood Evaluation

- Information aided Metro staff with warnings and evacuations
- Forecasted flood stages and timing aligned relatively well
- Forecasted inundation represented the observed flooding
- Based on temporally distributed 6-hr QPF



# Next Steps

- Develop processes and outputs that will provide the most useful information to the necessary decision makers and emergency personnel in the Nashville Government
- A flood exercise will be held in August to better understand the needs of emergency managers
- Expand HEC-RTS model development to the remaining major watersheds in Metro
- Build a comprehensive HEC-RTS model for the entire Metro region as opposed to individual basin models
- Incorporate HEC-FIA to provide real-time structure by structure damages and population at risk

# Conclusions

- HEC-RTS provides an integrated environment to conduct flood forecasting using detailed H&H modeling software developed by HEC
- Interface is relatively user-friendly and provides direct access to commonly used H&H software packages
- Ability to create output products useful to emergency person is only limited by our imagination
- The speed at which information and warnings can be distributed can save lives and property
- Supports collaborative relationships between local, state, and federal agencies
- Once completed and implemented, the Nashville HEC-RTS system will be one of the most advanced systems nationally

# Questions??

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