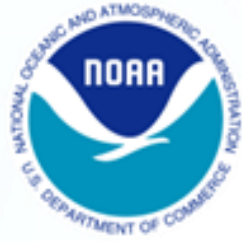


NOAA'S NATIONAL WATER CENTER



Informing Decisions for a Water-Prepared Nation

Edward Clark

Director, Geo-Intelligence Division

National Water Center

National Weather Service, NOAA

Outline

- **Stakeholder Priorities**
- **NWC Status and Plans**
 - National Water Model
 - *Water Intelligence*
- **Multi-Year Strategic Science and Services Plan**

National Academy of Sciences Report:

Weather Services for the Nation: Becoming Second to None

Findings



Recommendations

NWS Modernization and Restructuring (MAR) did not directly address hydrologic prediction services

A significant gap exists between the state of hydrologic science today and current NWS hydrologic operations

The level of sophistication, representation of processes, and characterization of uncertainties in external research and operational communities outpace those used in NWS hydrology operations

NWS Hydrologic Forecasters are extensively *“in the forecast loop”*

Qualifications for hydrologist positions were not updated in the MAR to require degreed hydrologists

Lack of skill in modern computational programming, construction and use of new Earth System Models, current hydrologic data assimilation methodologies, and preparation and interpretation of meaningful ensemble predictions

Prioritize core capabilities - a MAR-like effort is needed to address long-standing and deep-seated issues in hydrology

Improve pathways for collaboration & accelerate R2O

Establish a hydrologic prediction testbed as part of the National Water Center

Implement a consistent framework for hydrologic prediction skill assessment

Transition RFC forecasters to “over the loop” enabling a shift in focus to model and product development, forecast interpretation, and decision support

Hydrologist staff require re-education and continual retraining to enable adoption of state-of-the-art prediction methodologies

Instill evolutionary culture

Add value to hydrologic forecasts through the use of more advanced models, data assimilation and employment of more sophisticated ensemble techniques

Stakeholder Priorities



Flooding



Water
Quality



Water
Availability



Drought



Climate
Change

Need integrated understanding of near- and long-term outlook and risks

Actionable Water Intelligence

High Resolution, Integrated Water Analyses, Predictions and Data

Transform information into intelligence by linking hydrologic, infrastructural, economic, demographic, environmental, and political data

National Water Center

Initial Operating Capacity: May 26, 2015

A catalyst to transform NOAA's water prediction program



Mission: Nationally Integrated Water Prediction

- Earth system modeling and geo-intelligence for water prediction
- Operations Center for water resources common operating picture
- Decision support services for spectrum of water stakeholders
- Proving ground to accelerate research to operations
- Interagency and Academia Collaboration

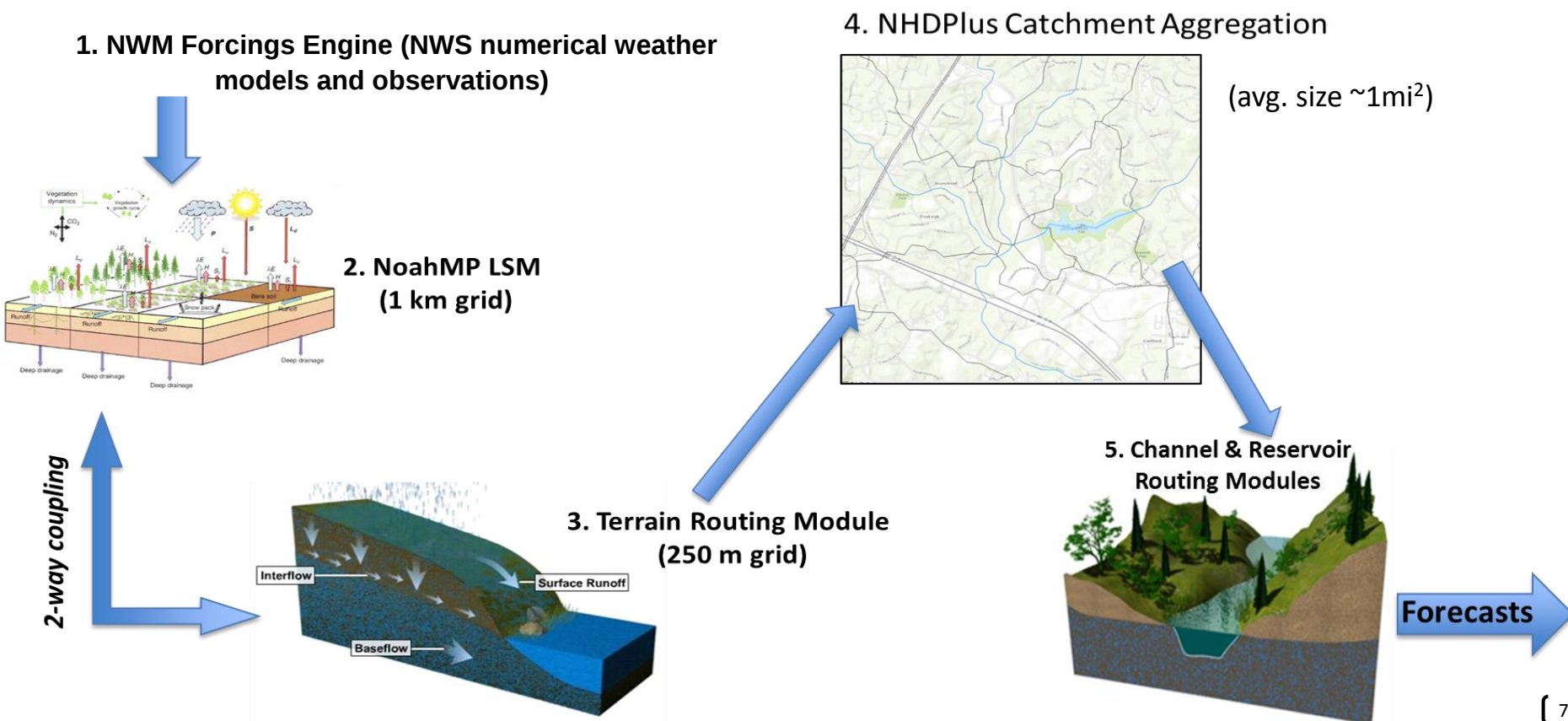
National Water Model Version 1.0

- **WCOSS Implementation and experimental product availability in FY16 Q4**
 - Leveraged strong NWC/NCAR/NCEP partnership
 - Build upon NCAR's, community-based, WRF-Hydro coupling architecture
 - Implementation accelerated by 2 years, and benefited from close collaboration with CUASHI through NSF
- **Foundation for sustained growth in operational hydrologic forecasting capability**
- **Goals for NWM V1.0**
 - Provide forecast streamflow guidance for underserved locations
 - Produce spatially continuous national estimates of hydrologic states (soil moisture, snow pack, etc.)
 - Implement a modeling architecture that permits rapid infusion of new data and science, and allows for geointelligence linkages

National Water Model (NWM) Core: WRF-Hydro

- WRF-Hydro forms the foundation of the National Water Model
- A community-based, ESMF compliant hydrologic modeling *framework* supported by NCAR being put into operations by an NWC, NCAR and NCEP partnership
- *Not dependent* on a particular forcing data source or choice of LSM
- Able to operate over multiple scales and with multiple physics options

IOC System Flow



NWM V1.0 Operational Configuration

Analysis &
Assimilation

Short-Range

Medium-Range

Long-Range

Cycling Frequency

Hourly

Hourly

Daily

Daily Ens (16 mem)

Forecast Duration

- 3 hrs

0-18 hours

0-10 days

0-30 days

Meteorological Forcing

MRMS blend/
HRRR/RAP bkgnd.

Downscaled
HRRR/RAP blend

Downscaled GFS

Downscaled &
bias-corrected CFS

Spatial Discretization & Routing

1km/250m/NHDPlus
Reach

1km/250m/NHDPlus
Reach

1km/250m/NHDPlus
Reach

1 km/NHDPlus Reach

Assimilation of 8k USGS Obs

Reservoirs (1240 water bodies parameterized with level pool scheme)

NWM V1.0 EXPERIMENTAL OUTPUT

- **Hydrologic Output**

- River channel discharge and velocity at 2.7 million river reaches
- Reservoir inflow, outflow, elevation
- Surface water depth and subsurface flow (250 m CONUS+ grid)

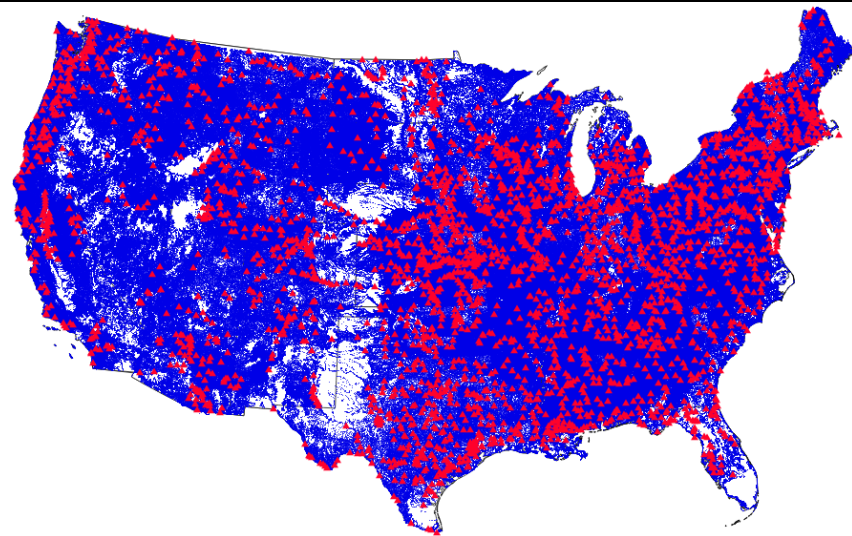
- **Land Surface Output**

- 1km CONUS+ grid
- Soil and snow pack states
- Energy and water fluxes

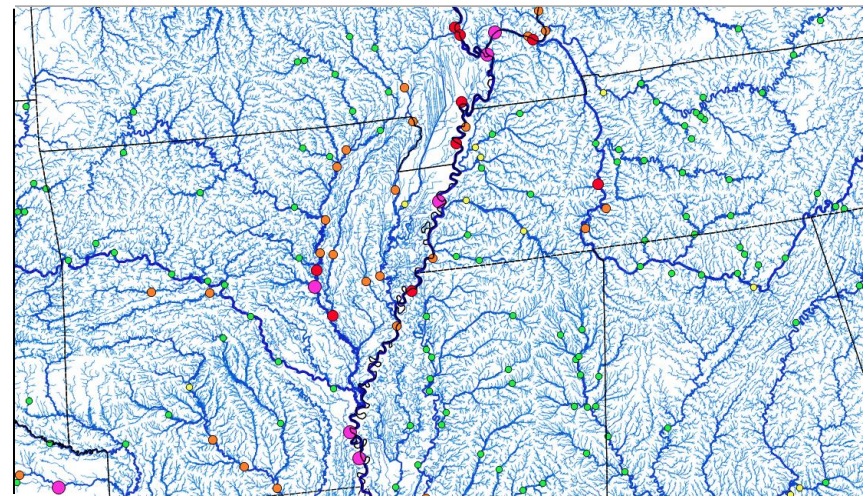
- **Direct-output and derived products** (e.g. stream flow anomalies)

- **Three pronged dissemination strategy**

- NOMADS
- Web
- Direct to field



Current NWS AHPS points (**red**)
NWM output points (**blue**)



Current NWS River Forecast Points (circles)
Overlaid with NWM Stream Reaches

Transforming NOAA Water Prediction

TODAY	THE FUTURE
Approximately 4000 forecast locations at points	Approximately 2,700,000 forecast stream reaches
Forecast river flow/stage, from summit to coastal zone	Forecast all hydrologic parameters which define the water budget, from summit-to-sea
Driven by large catchment “lumped” modeling	Driven by high/hyper resolution Earth System modeling
Forecaster “in the loop” – serial, basin to basin, modeling of flow through the river network	Forecaster “over the loop” – simultaneous modeling of the nation’s entire river network
Average basin size greater than 420 square miles	Average basin size ~1 square mile
13 RFCs developing separate versions of the same regional model	13 RFCs, NWC, academia, and federal partners developing/evolving same state-of-the-science national, community-based, model (working with NSF, CUASHI, and other Federal agencies to establish community development version of NWM)
RFC-generated river forecasts coordinated with WFOs to deliver Impact-based forecasts at selected points	National Water Model-based predictions coordinated among NWC, RFCs, and WFOs and linked with detailed local infrastructure data to communicate street level impacts

For the hydrology community, the implementation of the NWM and the leap ahead capability it provides parallels the implementation of mesoscale atmospheric models in the 1970s (i.e., model resolution substantially greater than available observational network)

NATIONAL WATER CENTER OPERATIONS CENTER



“Street Level” Water Prediction and Impact-Based Decision Support

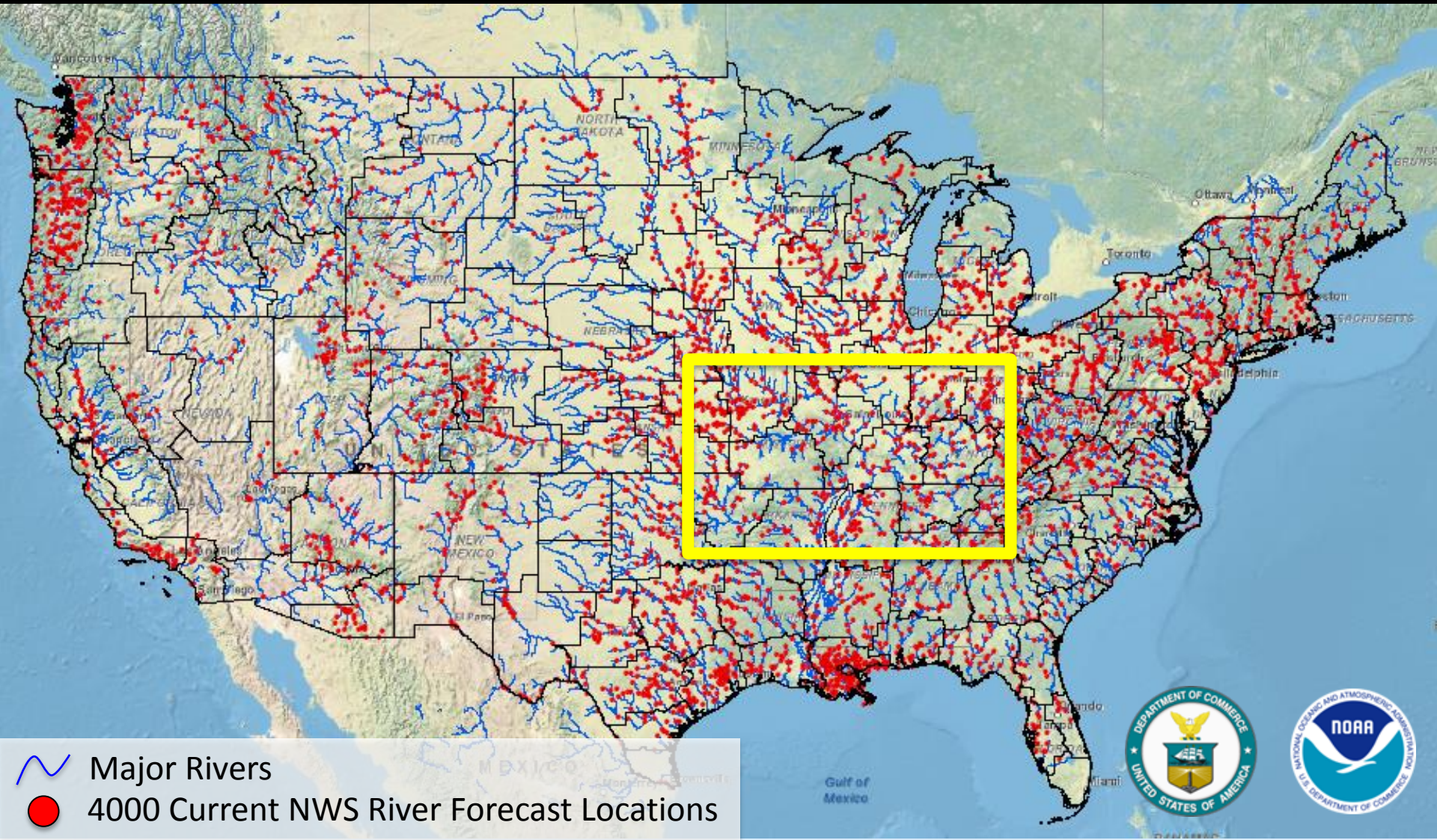
WATER PREDICTION

+

GEO-INTELLIGENCE

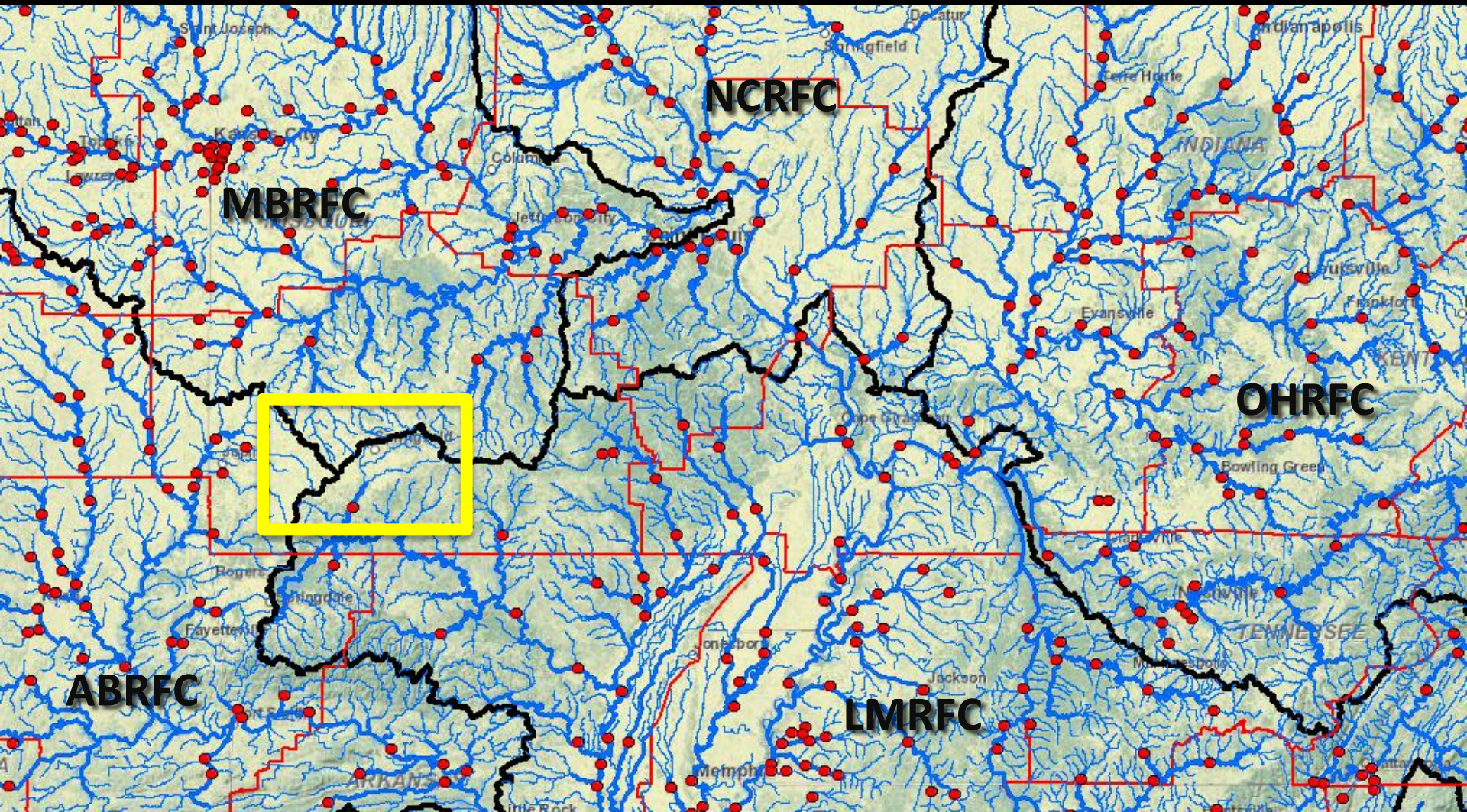


Major Rivers and NWS Hydrologic Forecast Locations (Today)



River Forecast Centers, Major Rivers, and NWS Hydrologic Forecast Locations (Today)

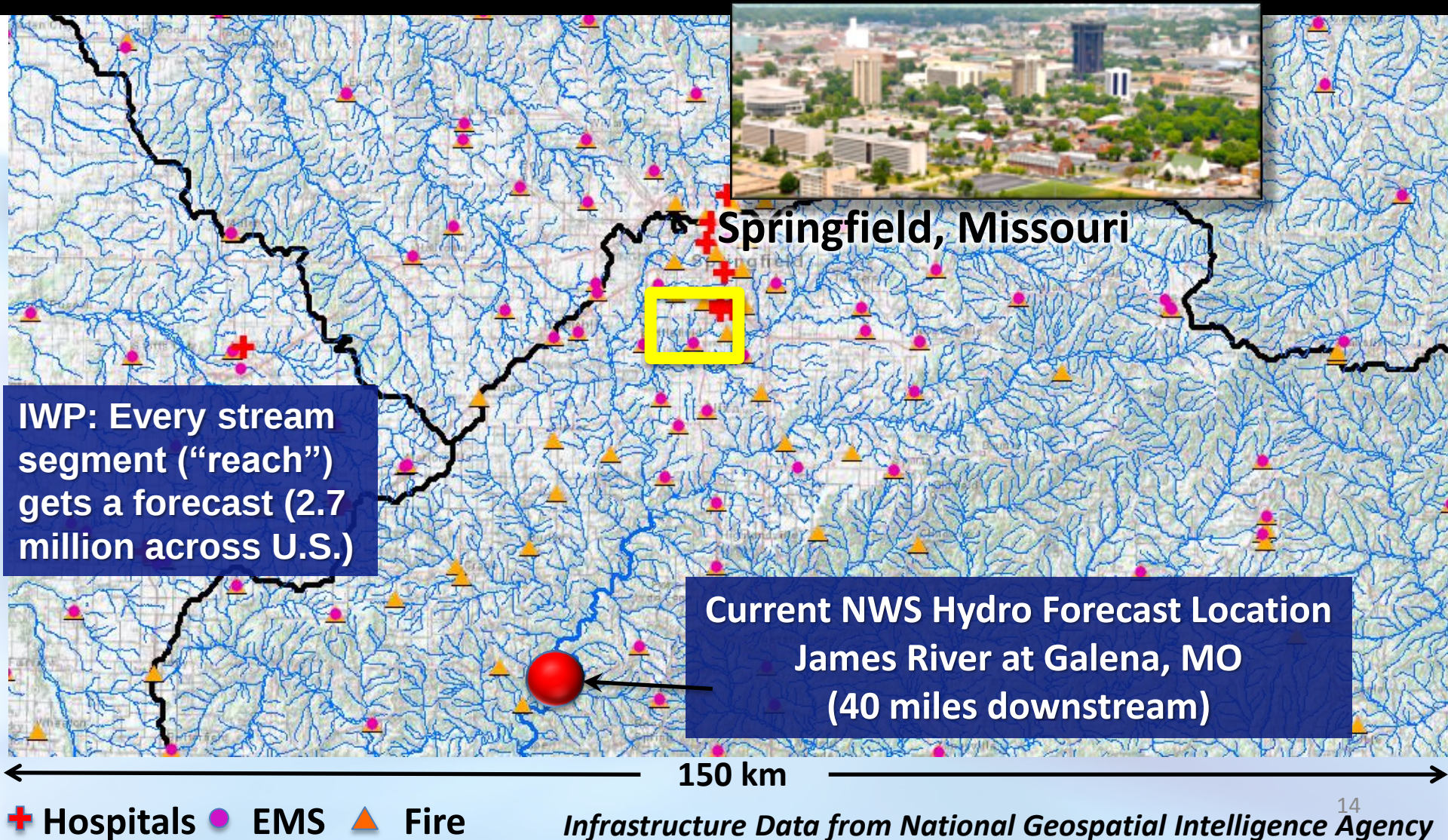
Middle Mississippi River



Full Resolution National Hydrography Dataset NHD+

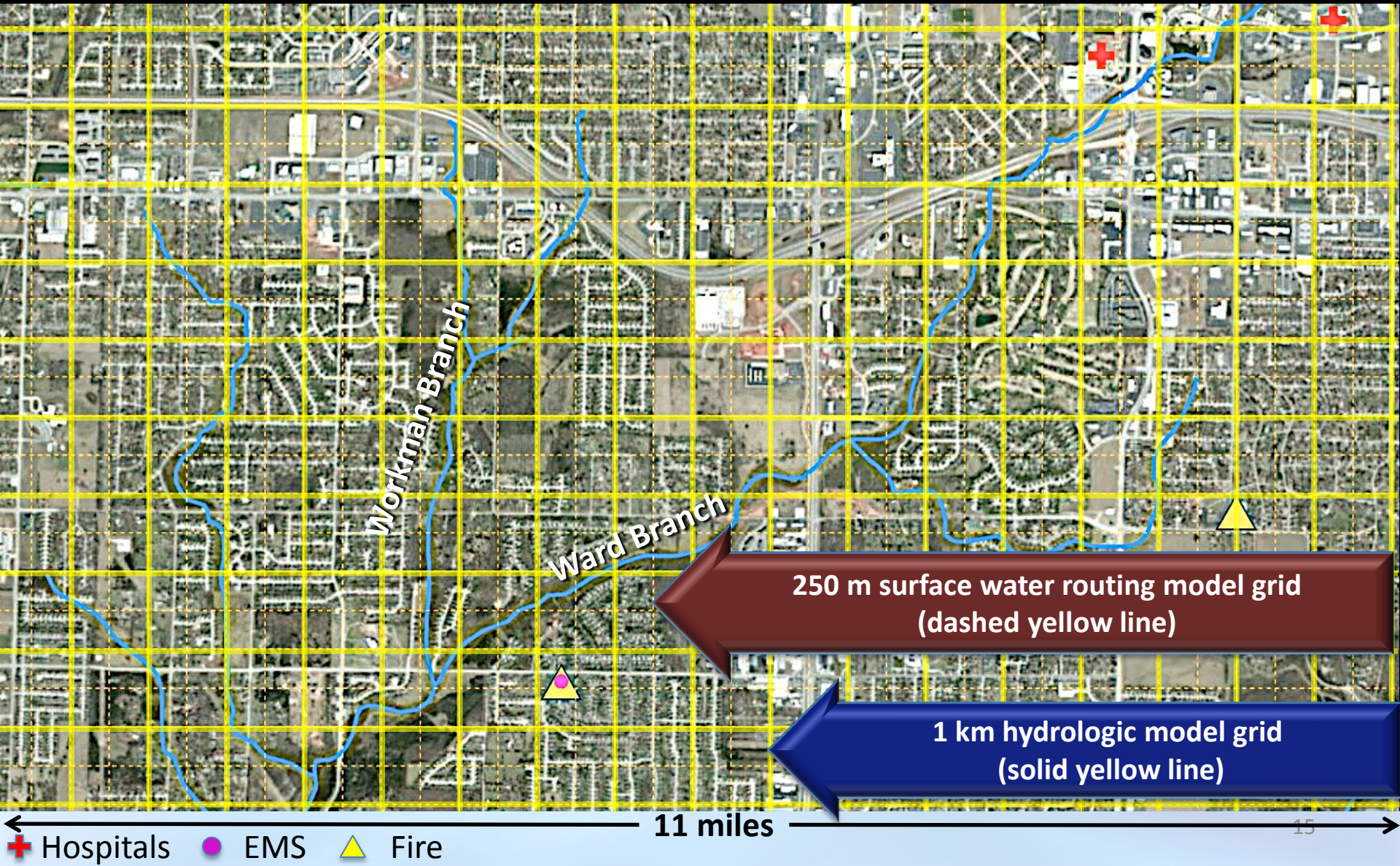
Forecasts for every stream reach (2.7 million across U.S.)

WATER PREDICTION + NATIONAL INFRASTRUCTURE = WATER INTELLIGENCE



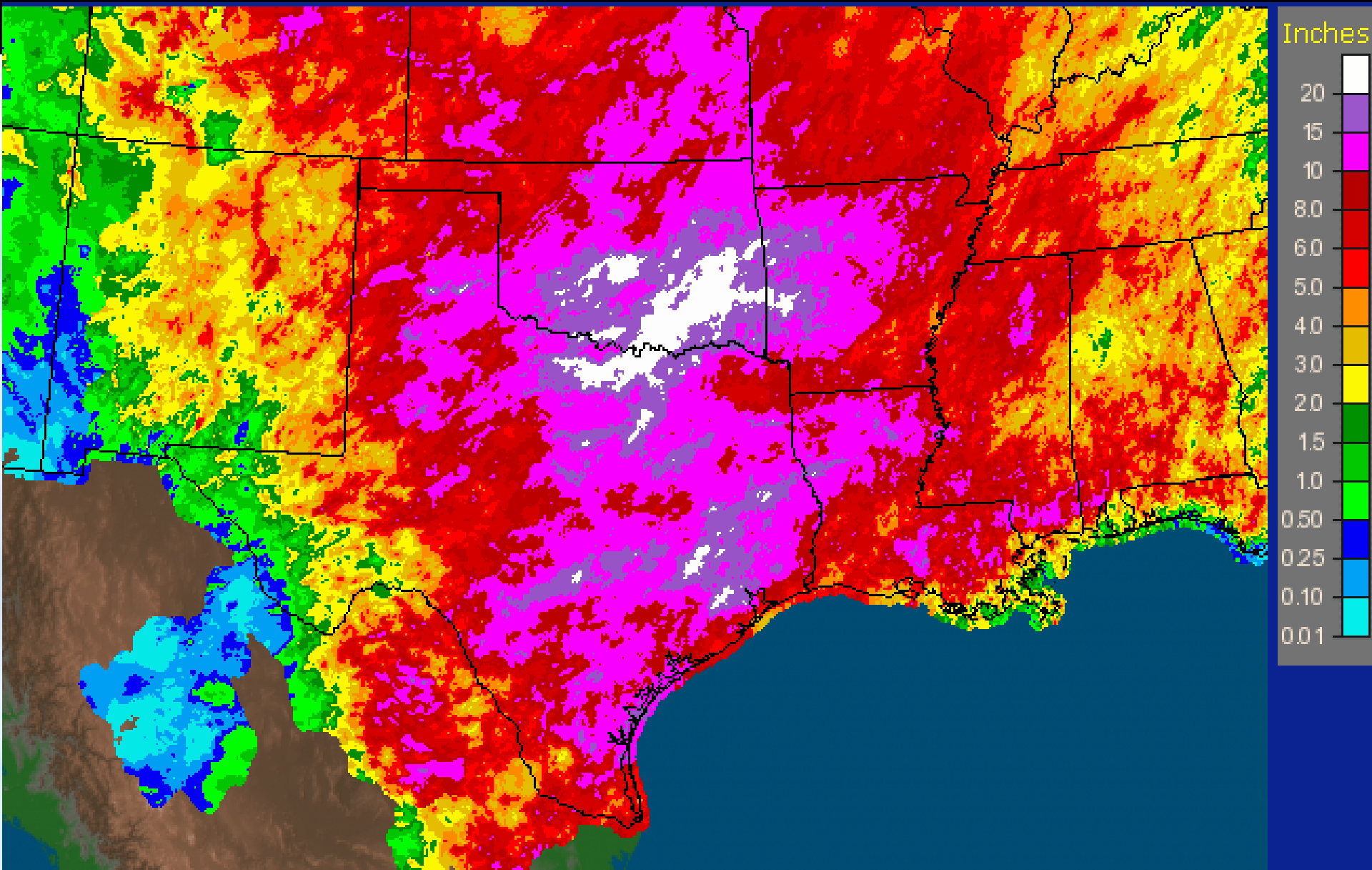
WATER PREDICTION + NATIONAL INFRASTRUCTURE

Hospitals, EMS & Fire Stations

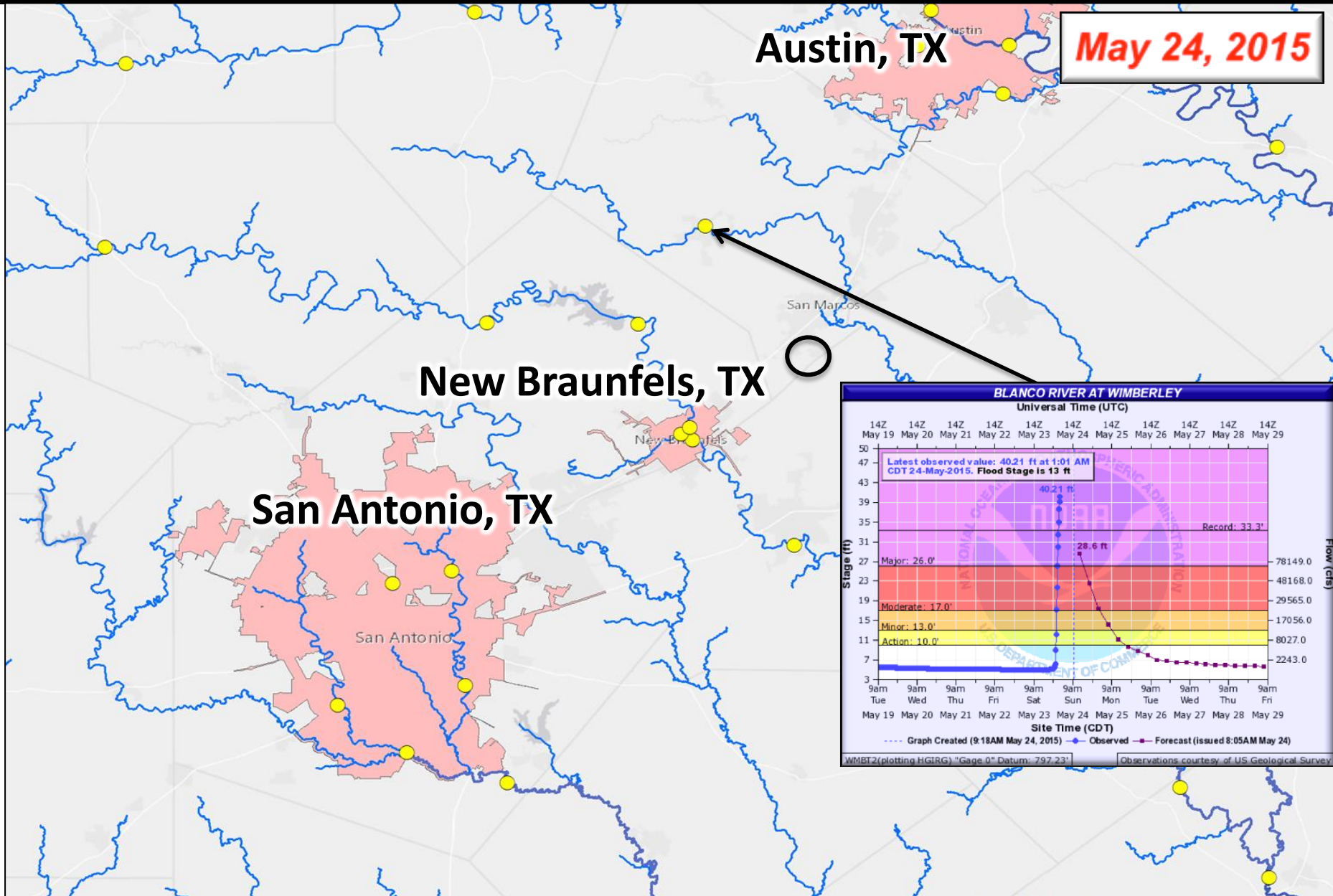


Southern Plains Observed Precipitation

May 2015



Current Advanced Hydrologic Prediction Services (AHPS) Streamflow Information

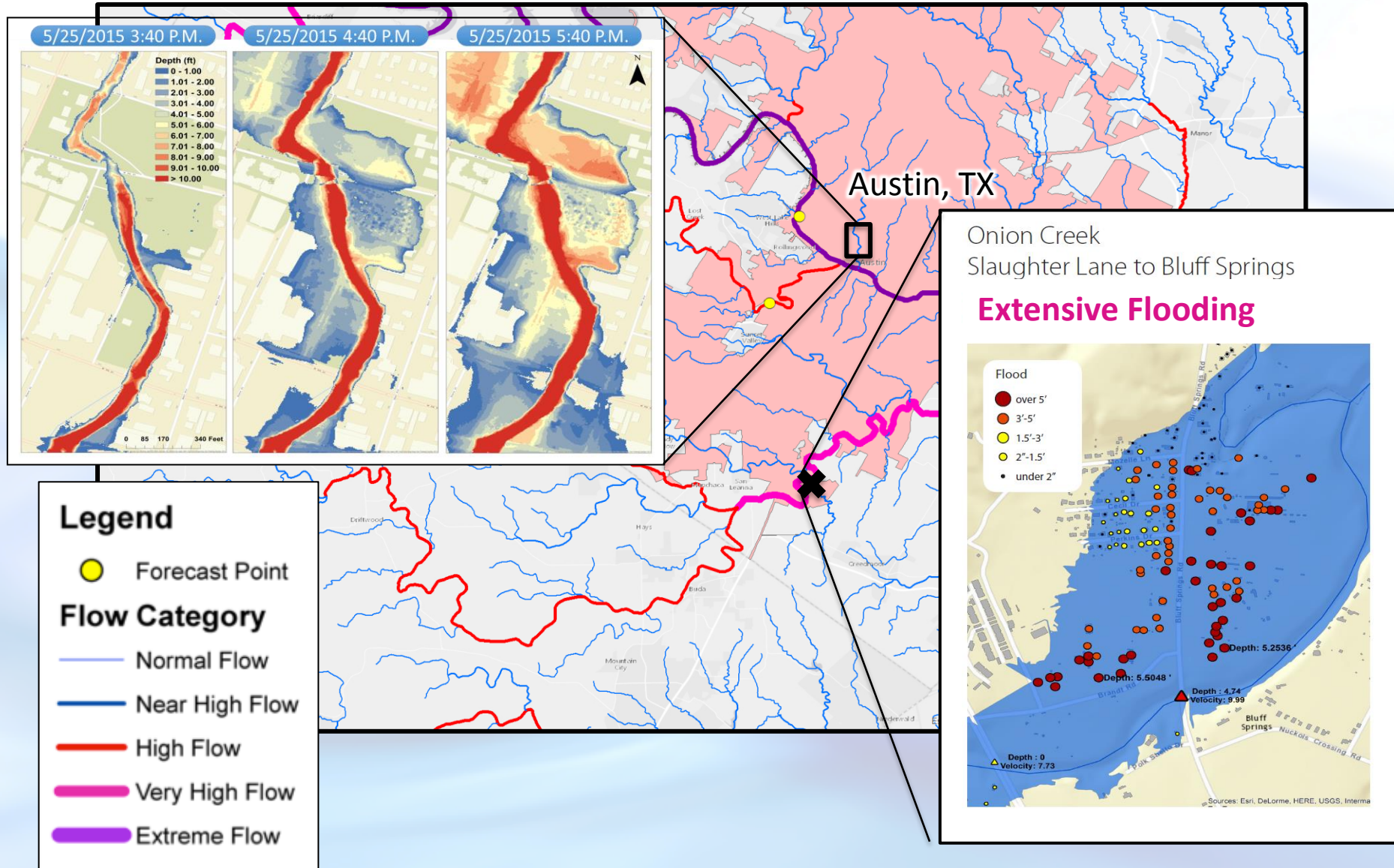


National Water Model Streamflow



Experimental Flood Depth and Extent Mapping

Converting High Resolution Forecasts into Actionable Water Intelligence

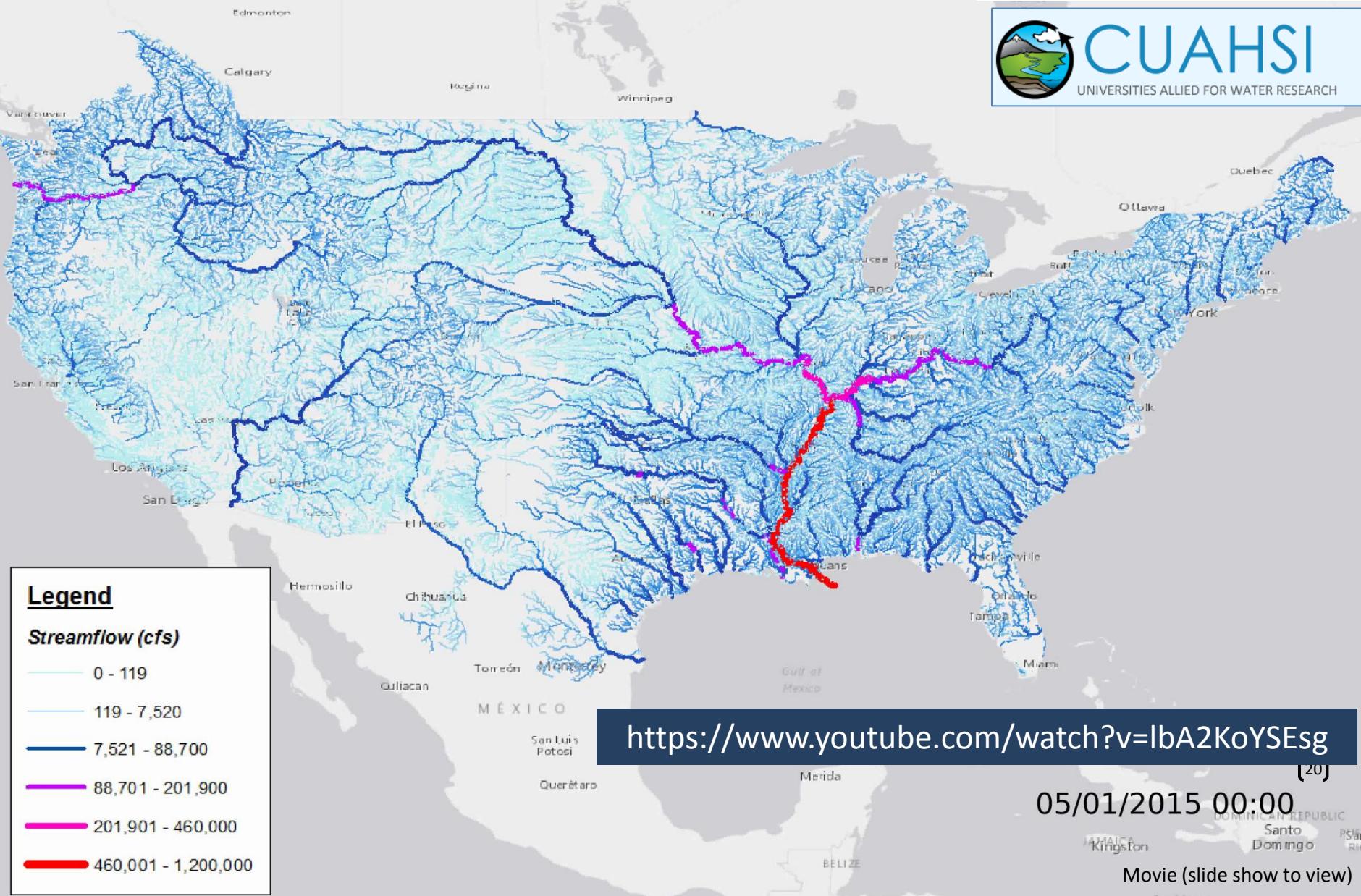




National Water Model



CUAHSI
UNIVERSITIES ALLIED FOR WATER RESEARCH



<https://www.youtube.com/watch?v=lbA2KoYSEsg>

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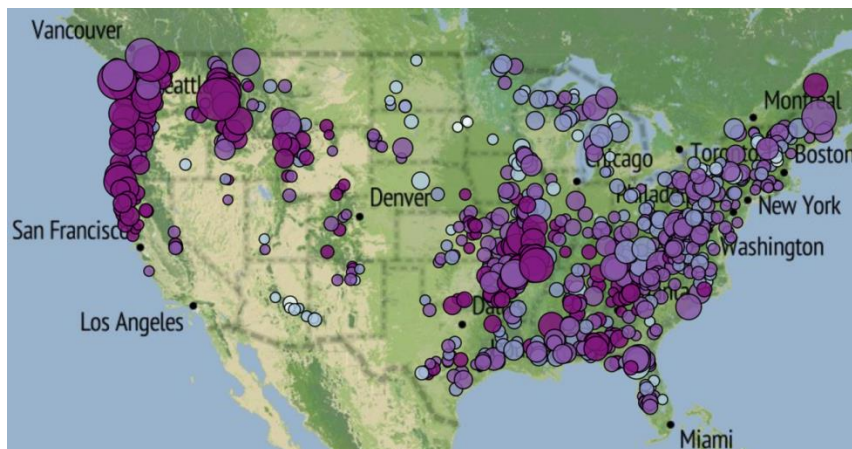
Movie (slide show to view)

Initial NWM CONUS Evaluations: Streamflow

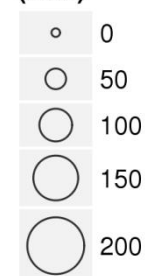
Average Daily Streamflow Correlation Over Gages II Unregulated Basins

Simulation With NLDAS2 Forcing, Final Parameters, No Data Assimilation (Oct 2014 - Feb 2016)

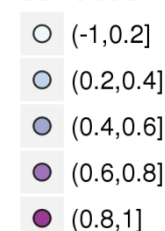
Correlation:



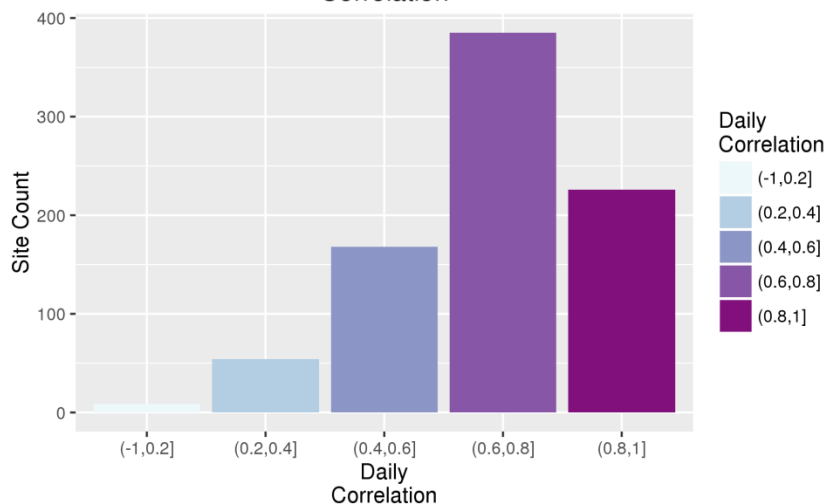
Mean Flowrate (cms)



Daily Correlation



Distribution of Daily Correlation

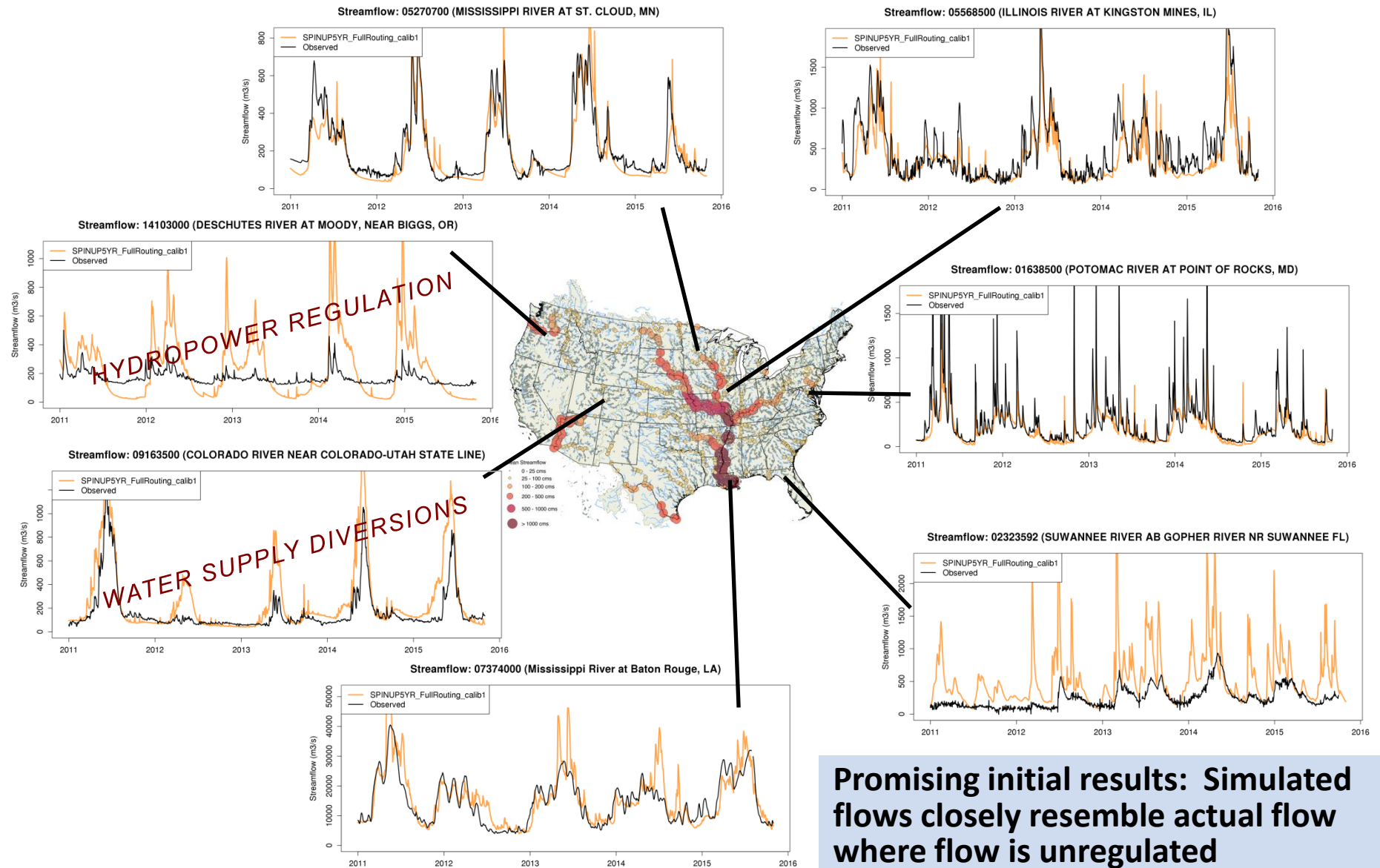


- 73% of basins have correlation > 0.6

- Correlation high despite no assimilation of stream gage data

Initial NWM CONUS Evaluations: Streamflow

Regional Breakouts of Big River Flows:



Multi-Year Strategic Science and Service Plan: Integrated Water Prediction

Centralized Water Forecasting Demonstration (FY15):

National Water Model Development and Demonstration

- Implement and enhance first-ever NWM
- Increase from current 4000 forecast locations to 2.7 million stream reaches across CONUS
- Simultaneous, CONUS scale modeling of the nation's entire river network¹
- Forecast all hydrologic parameters which define the water budget, from summit-to-sea (not just flow/stage)

Centralized Water Resources Data Services (CWRDS)

- Internal and external provision of enhanced water forecasts and information to core partners and stakeholders

Water Resources Test and Evaluation Service (WRTES)

- Comprehensive objective verification and validation of the skill and utility of the NWM
- Inter-comparison of skill between current operational forecast paradigm and new NWM

¹ National implementation pending availability of NHD
Plus for Alaska

Enhanced Water Prediction Capability (FY16):

Hyper-Resolution Modeling

- Enhance NWM with nested hyper-resolution zoom capability to capture urban and other fine-scale hydrologic processes
- Heighten focus on regions of interest (e.g. follow storms/issue of the day)

Real-Time Flood Forecast Inundation Mapping

- Develop, demonstrate and implement real-time street-level flood inundation forecasts
- Provide critical information on areal extent, depth and timing of flood waters

Enhance Impact-Based Water Resources Decision Support Services

- Evolve NWM-based guidance to NWS field offices to improve consistency and services for flash floods
- Forecasts linked to geospatial information to assess impacts/risks
- NWC and NWS field offices generate actionable water intelligence to provide enhanced IDSS at appropriate scales

Integrated Water Prediction (FY17 Proposed):

New and improved water prediction services

- Stand up the National Water Center Operations Center to coordinate Federal water prediction activities and provide water intelligence to national level stakeholders
- Generate total water predictions in the coastal zone accounting for the combined impacts of surge, tide, wave and freshwater contributions

New service delivery model for coastal and inland communities

- Engage technical experts from multiple disciplines to provide integrated, high fidelity water resource information and services needed by a spectrum of stakeholders
- Routine engagement with stakeholders to strengthen partnerships, deliver and continually enhance actionable water intelligence

Model integration and forecast assessment

- Link state-of-the science terrestrial freshwater and coastal estuary models to create fully coupled "summit-to-sea" IWP modeling system
- Begin development of the next generation integrated Earth System model for IWP
- Secure the high performance computing, storage and networking necessary to evolve the NWM

Summary

- **NOAA's Water Services are Evolving**
 - Deliver comprehensive, integrated actionable water intelligence
 - Compliment current services with new information spanning Summit-to-Sea, Floods to Droughts, Treetops to Bedrock
- **Implementing State-of-the-Art Technical Approach**
 - Water prediction through state-of-the-science earth system modeling
 - Impact-based decision support services underpinned by geo-intelligence
- **Scale Change: Orders of Magnitude More Data**
 - Reach-based “Street Level” prediction
 - High Performance Computing
- **New Organization, Cornerstone Facility and Philosophy**
 - National Water Center
 - Transforming NWS Hydrology Program to NWS *Water Resources* Program
 - Collaborative, cross-NOAA, interagency, academic partnerships



Upper Provo River by Brett Neilson

*Eventually, all things merge into one,
and a river runs through it.*

- Norman McLean

Multi-Year Strategic Science and Services Plan

Integrated Water Prediction and the National Water Center (NWC)

FY 15-19

Core Capability

Centralized Water Forecasting

National Water Model (NWM) operational [V1.0 July 2016]

- ✧ Water forecasts for 2.7 million stream reaches
- ✧ Expand from only flow/stage forecasts to forecasts of **full water budget**
- ✧ **100 million people get a terrestrial water forecast for first time**
- ✧ Forecasts linked to geospatial information to **provide water intelligence**

FY 16-20

Key Enhancement

Flash Flood and Urban Hydrology

Enhance NWM with nested hyper-resolution zoom capability and urban hydrologic processes

- ✧ Heightened focus on regions of interests (e.g. follow storms)
- ✧ **Street level flood inundation forecasts** for selected urban demonstration areas
- ✧ NWC increases guidance to NWS field offices to **improve consistency and services for flash floods**

FY 17-21

Major Integration

Coastal Total Water Level

Couple NWM with marine models to predict combined storm surge, tide, and riverine effects

- ✧ **More complete picture of coastal storm impacts**
- ✧ **Summit-to-sea** water prediction information linked to geospatial risk and vulnerability
- ✧ **New service delivery model implemented** – increased stakeholder engagement and integrated information
- ✧ **NWC operations center opens and provides national decision support services and situational awareness**

FY 18-22

Key Enhancement

Dry Side: Drought and Post-Fire

Couple NWM with groundwater and transport models to predict low flows, drought and fire impacts

- ✧ Add NWM processes that capture subsurface water movement and storage during dry conditions
- ✧ Add NWM ability to track constituents (e.g. sediment, contaminants, nutrients) through stream network
- ✧ New decision support services for water shortage situations and waterborne transport
- ✧ **NWC operations center expands to include drought and post-fire decision support services**

FY 19-23

Major Integration

Water Quality

Integrate enhanced NWM with key water quality data sets, models and tools to begin water quality prediction

- ✧ *Incorporate water quality data from federal and State partners into NWM*
- ✧ *Link NWM output to NOAA ecological forecasting operations*
- ✧ *New decision support services for predicting water quality issues such as Harmful Algal Blooms*
- ✧ *New decision support services for emergencies such as chemical spills*
- ✧ **NWC operations center expands to include water quality decision support services**



National Water Model



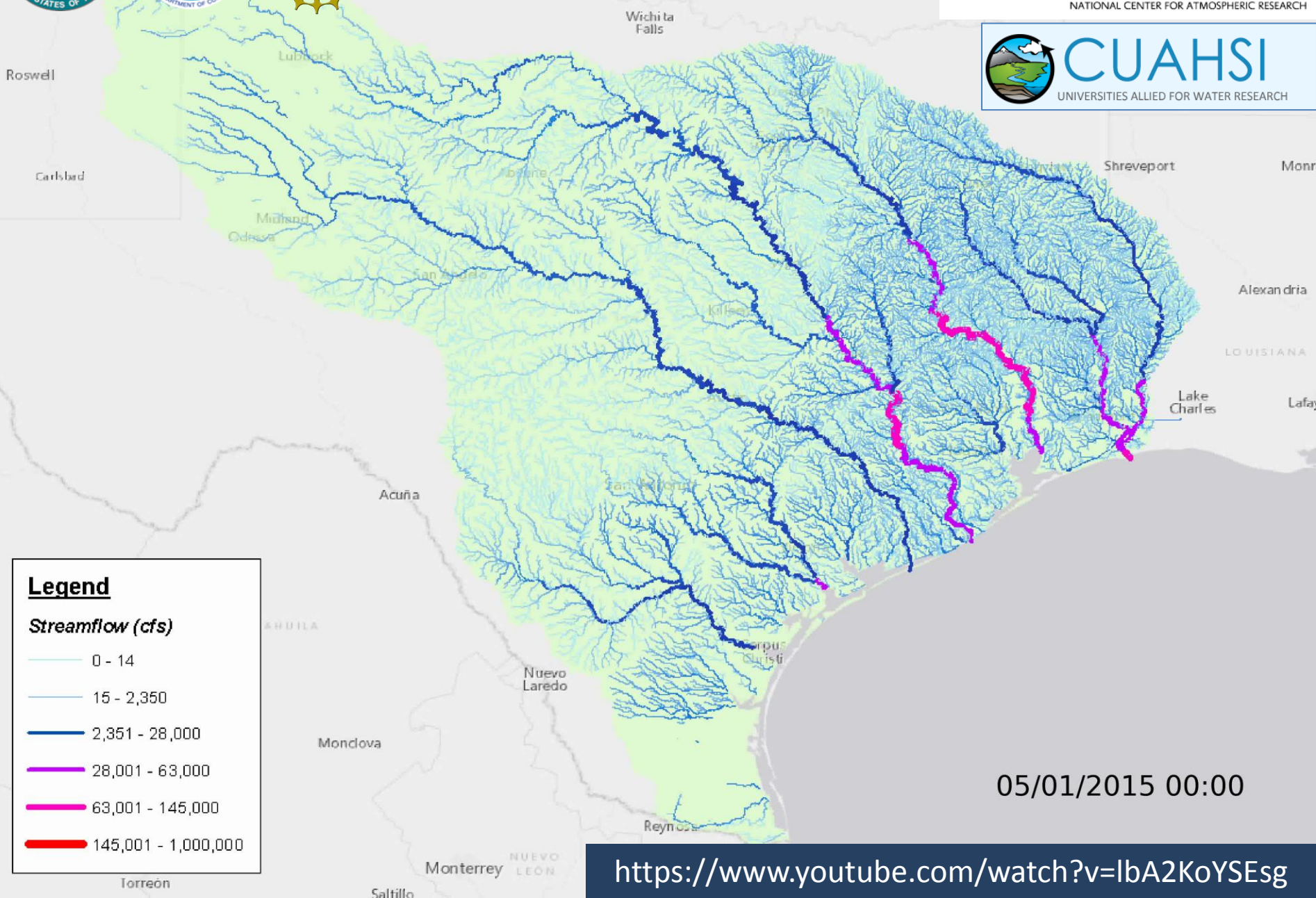
NCAR

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Legend

Streamflow (cfs)

- 0 - 14
- 15 - 2,350
- 2,351 - 28,000
- 28,001 - 63,000
- 63,001 - 145,000
- 145,001 - 1,000,000

05/01/2015 00:00

<https://www.youtube.com/watch?v=lbA2KoYSEsg>