Hydroinformatic Services for Missouri

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MWEA Stormwater/Watershed Management Conference
September 17, 2019

I. Hydroinformatics

- The application of information technology to the practice of hydrology, hydraulics, water resources and quality.
- It's the basis for developing digital exchange systems and interoperable hydrologic data.

Reference: CUAHSI

I. Hydroinformatics

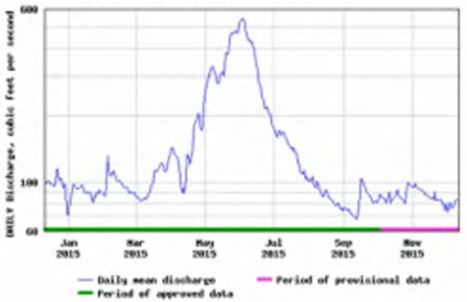
- Hydrology in the Digital World is a Team Sport
  - It's data and computationally intensive
  - Requires integration of information from many sources
  - Requires collaboration between professions and agencies.

Reference: CUAHSI

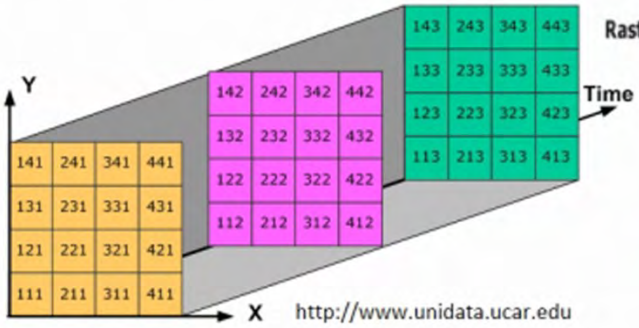
Hydroinformatics

The digital data and models used by hydrologists include…

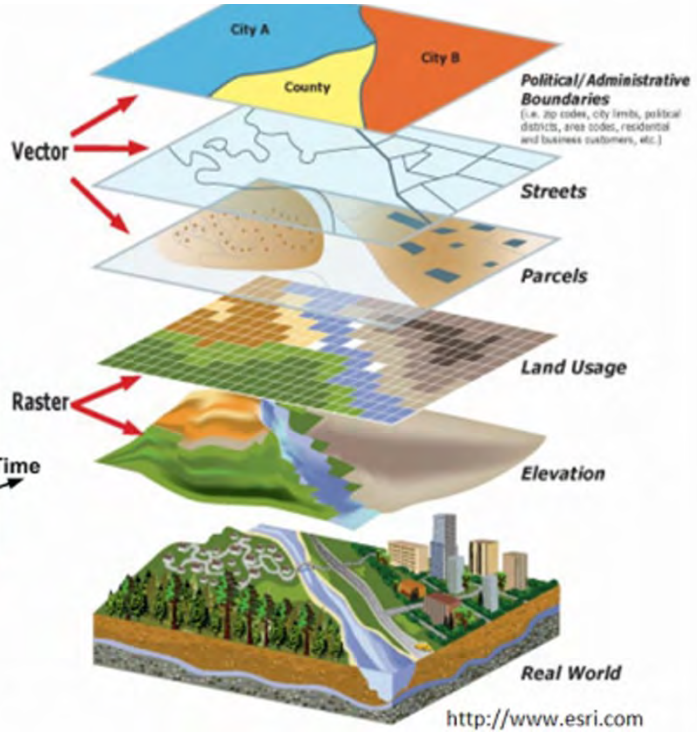
- Time series
- Geographic rasters
- Geographic features
- Multidimensional space/time
- Model programs
- Model instances



http://www.usgs.gov



http://www.unidata.ucar.edu



http://www.esri.com

Reference: CUAHSI

Hydroinformatics

- Begins by establishing a description of all those informational pieces.
- Vocabulary
  - Rain
  - Precipitation
  - Drizzle, Mist, Downpour
- Distinction is not clear to a computer
- The terms need to match.
- Making them match across a subset of science becomes a challenge.

Reference: CUAHSI

Hydroinformatics

Semantic Mediation

- Hyponymy

  Parameter “Groundwater level”, “Stream stage”, “Reservoir level” versus “Water level”, which Water Level?

- Polysemy

  Parameter have multiple meanings, for example “stage”, i.e. a water level measurement versus an art performance venue

- Synonymy

  ‘Total Kjeldahl Nitrogen’ vs. ‘Ammonia+Organic Nitrogen’, or ‘Stream Gauge’ ⇔’Stream Stage’ ⇔ ‘Gauge Height’ ⇔ ‘Gauge’

Reference: CUAHSI

Hydroinformatics

- Description of the information goes beyond vocabulary.
- Representation must tell us….
  - What kind of element is it; physical, abstract, chemical, biological, thermal?
  - Is it measurable, units?
  - Is it observed, estimated, computed, statistical, forecast, historic, current?
  - Singular or averaged?

Reference: CUAHSI

Hydroinformatics

- Even more attributes….
  - Referenced to a particular datum, spatial coordinate, computational method, time standard, ID number, rating curve or model instance?
  - What is the provenance of the data?
  - Who authored/published it?
  - Was it original or a product derived from previous sources?
  - Series or static?
  - Preliminary , provisional or approved QC’d product?

Reference: CUAHSI

Hydroinformatics

- All of that information is assembled to form an "Ontology".
- Ontology is.. *a formal description of knowledge as a set of concepts within a domain and the relationships between them.*

Reference: CUAHSI

Hydroinformatics

- Ontology is the underpinning of digital data exchange & machine learning.
- Ontology is the basis for structuring our data systems & exchange protocols.

Reference: CUAHSI

CUAHSI

- The Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI).
- A consortium of 145 research universities, 7 affiliate members, and 16 international affiliates

CUAHSI

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Hydrologic Information System (HIS)

- The CUAHSI Hydrologic Information System (HIS) is common framework of standards, service functions and software for sharing water and geospatial information.
- Distributed internet-based network of data sources comprised of databases and servers, using a web services architecture accessible to client applications.

Reference: CUAHSI

CUAHSI HIS

CORE COMPONENTS

- Hydrologic Ontology (Observations Data Model)
- Observations Data Model: database schema (ODM)
  - *Representation of the ontology*
- WaterML
  - *Exchange protocol, used to represent the ontology*
- Water One Flow services (WOF)
  - *API service (REST, SOAP and SOS)* <time series>
- CUAHSI catalog -
  - *directory to search for services*
- Client Applications (HydroDesktop, HydroClient, HydroR)

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CUAHSI HIS
Sharing hydrologic data

DataTypeCV Values

Back to CV Page | DataTypeCV ▾

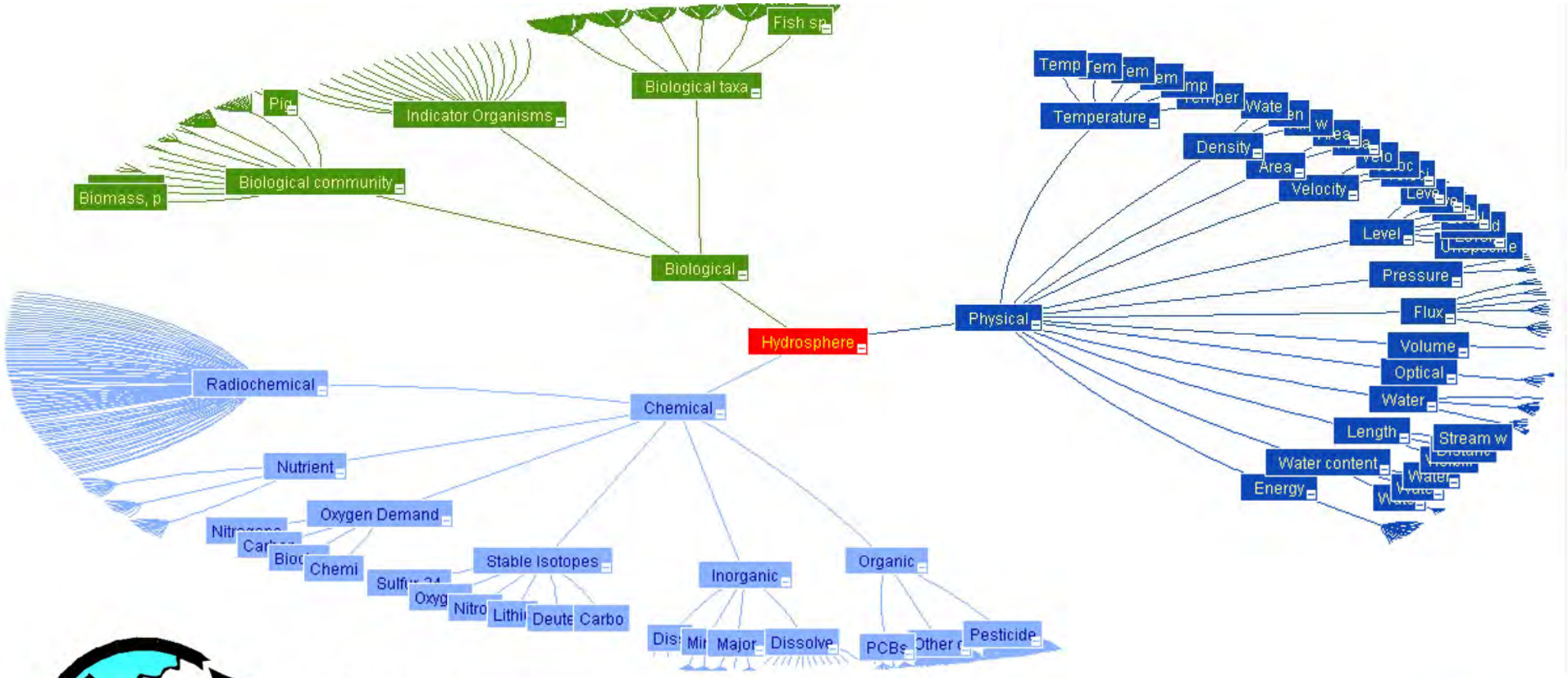
- CensorCodeCV
- DataTypeCV
- GeneralCategoryCV
- SampleMediumCV
- SampleTypeCV
- SiteTypeCV
- SpatialReferences
- SpeciationCV
- TopicCategoryCV
- Units
- ValueTypeCV
- VariableNameCV
- VerticalDatumCV

Used to populate the ariables table

New	Term	
Edit	Average	epresent the average over a time interval, such as daily mean discharge or daily mean temperature.
Edit	Best Eas Systemat Estimato	ystematic Estimator BES = (Q1 +2Q2 +Q3)/4. Q1, Q2, and Q3 are first, second, and third quartiles. See F. and Engel, C., 2005: Operational Consensus Forecasts.Weather and Forecasting, 20, 101-111. bom.gov.au/nmoc/bulletins/60/article_by_Woodcock_in_Weather_and_Forecasting.pdf) and Wonnacott, T. . Wonnacott, 1972: Introductory Statistics. Wiley, 510 pp.
Edit	Categori	are categorical rather than continuous valued quantities. Mapping from Value values to categories is through yDefinitions table.
Edit	Constant Interval	are quantities that can be interpreted as constant for all time, or over the time interval to a subsequent nt of the same variable at the same site.
Edit	Continuo	pecified at a particular instant in time measured with sufficient frequency (small spacing) to be interpreted as s record of the phenomenon.
Edit	Cumulative	The values represent the cumulative value of a variable measured or calculated up to a given instant of time, such as cumulative volume of flow or cumulative precipitation.
Edit	Incremental	The values represent the incremental value of a variable over a time interval, such as the incremental volume of flow or incremental precipitation.
Edit	Maximum	The values are the maximum values occurring at some time during a time interval, such as annual maximum discharge or a daily maximum air temperature.

CUAHSI HIS

- Hydrologic Ontology (Observations Data Model)



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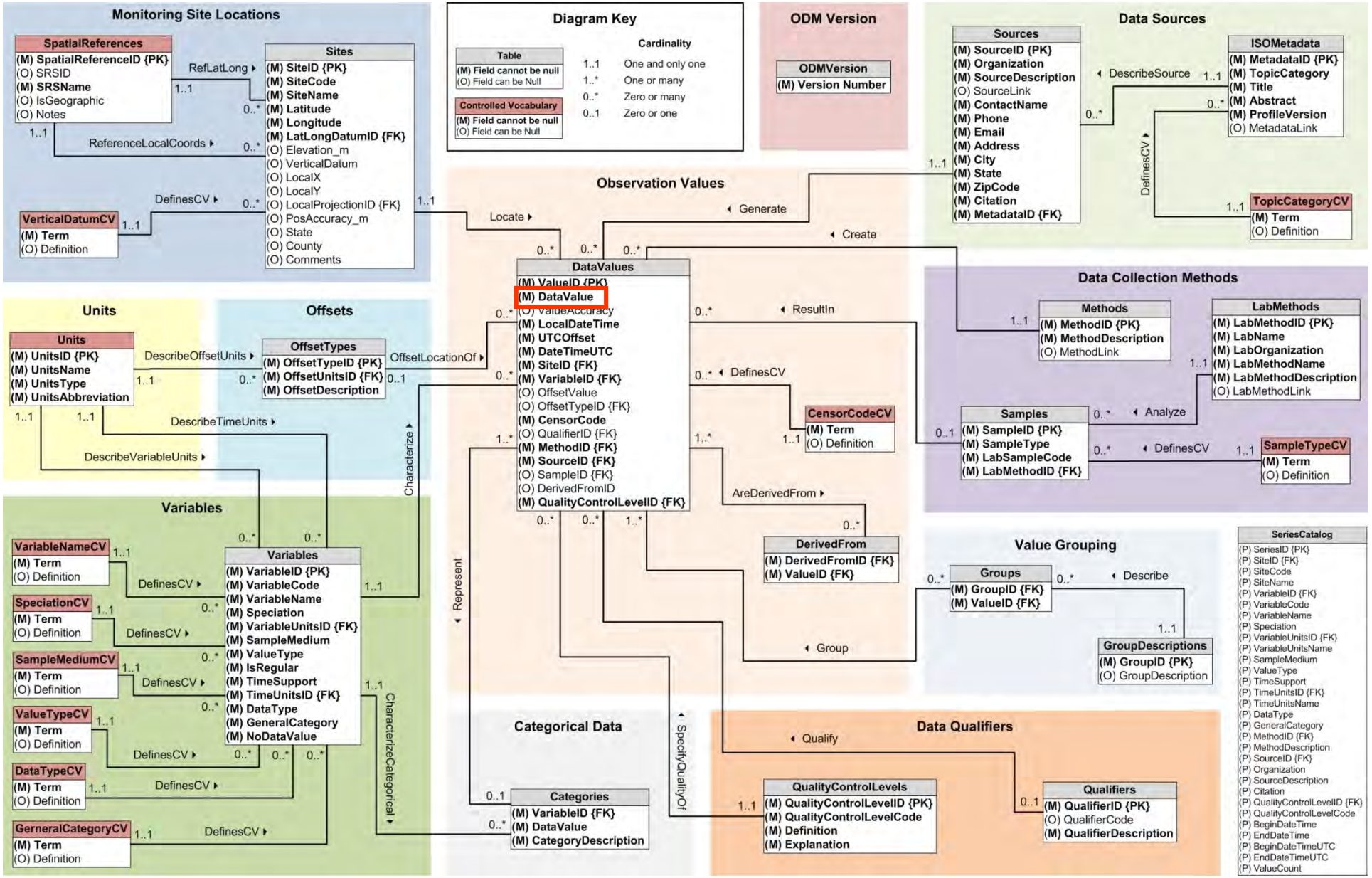
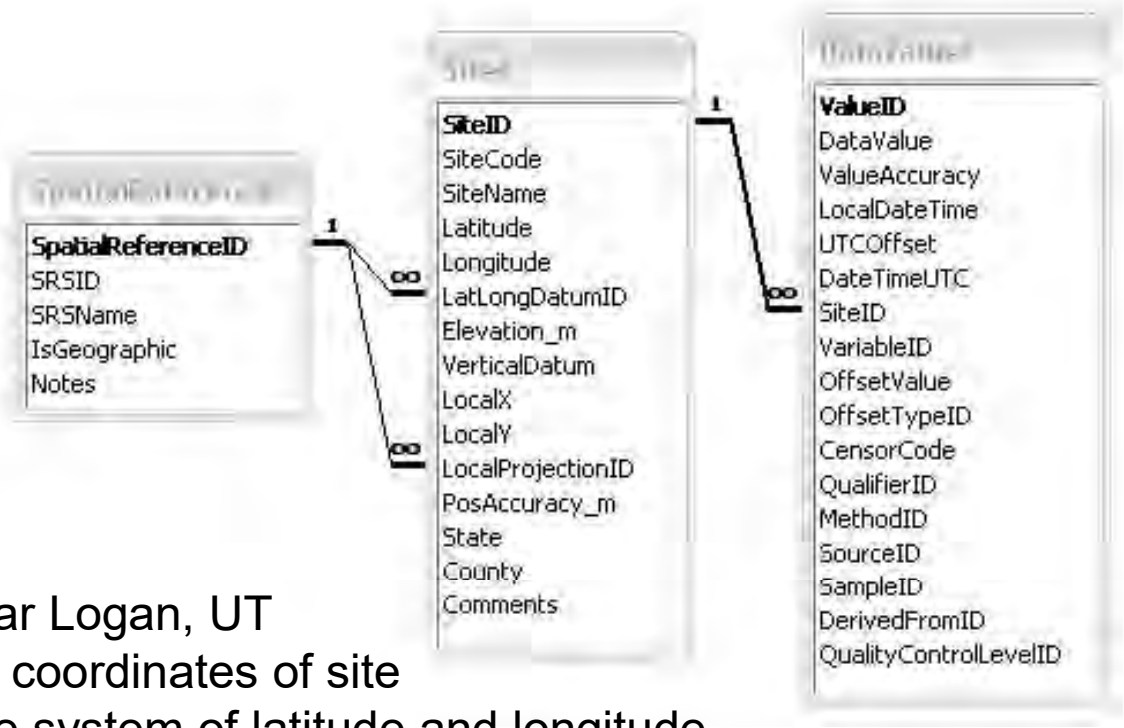
NSF

CUAHSI Observations Data Model http://his.cuahsi.org/odmdatabases.html



Horsburgh, J. S., D. G. Tarboton, D. R. Maidment and I. Zaslavsky, (2008), A Relational Model for Environmental and Water Resources Data, *Water Resour. Res.*, 44: W05406, doi:10.1029/2007WR006392.

Site Attributes



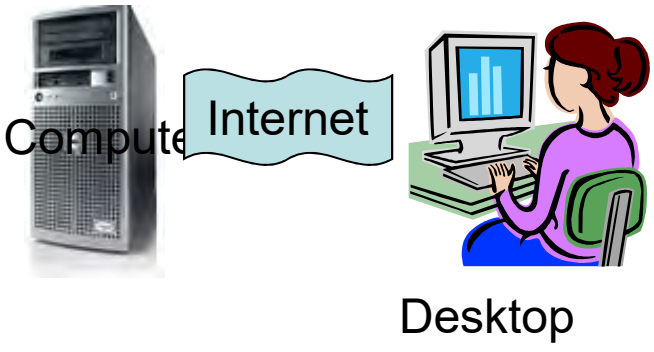
SiteCode, e.g. NWIS:10109000
SiteName, e.g. Logan River Near Logan, UT
Latitude, Longitude Geographic coordinates of site
LatLongDatum Spatial reference system of latitude and longitude
Elevation_m Elevation of the site
VerticalDatum Datum of the site elevation
Local X, Local Y Local coordinates of site
LocalProjection Spatial reference system of local coordinates
PosAccuracy_m Positional Accuracy
State, e.g. Utah
County, e.g. Cache

Horsburgh, J. S., D. G. Tarboton, D. R. Maidment and I. Zaslavsky, (2008), A Relational Model for Environmental and Water Resources Data, *Water Resour. Res.,* 44: W05406, doi:10.1029/2007WR006392.

II. Interoperability - Open Data Standards

- Building a framework in hydrology for sharing distributed data resources with common formats and access protocols

- Web services



People interact with a remote information server

- Web services

Networks of information servers provide services to one another

Reference: CUAHSI

WaterML

- The Water Markup Language (WaterML) is an XML schema for the transfer of water data between a server and a client
  - Time series data and metadata.
- WaterML generally follows the information model of ODM (Observation Data Model)
- It is the format used by HIS for the exchange of water data messages.
- WaterML 2.0 is an international standard as adopted by the Open Geospatial Consortium (OGC)
  - http://www.opengis.net/waterml/2.0

Reference: CUAHSI

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WaterML -

A Web Language for Time –Series Data

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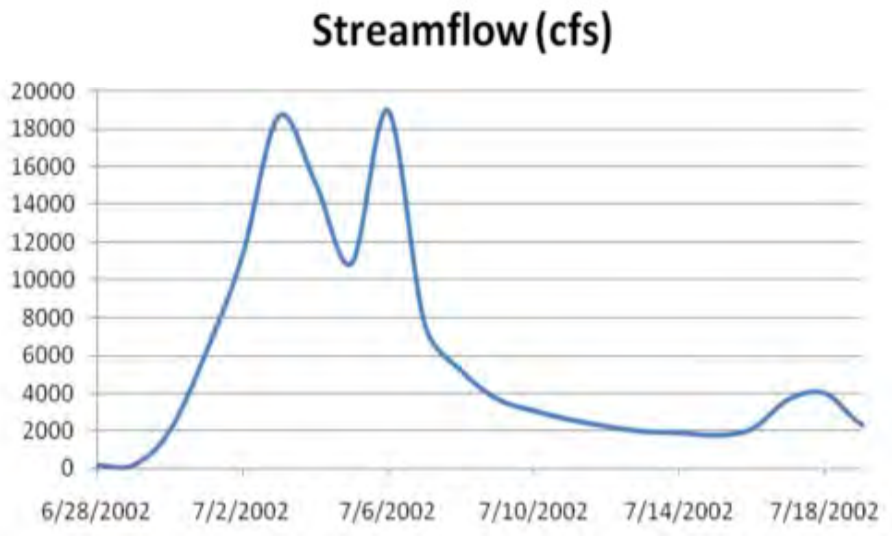
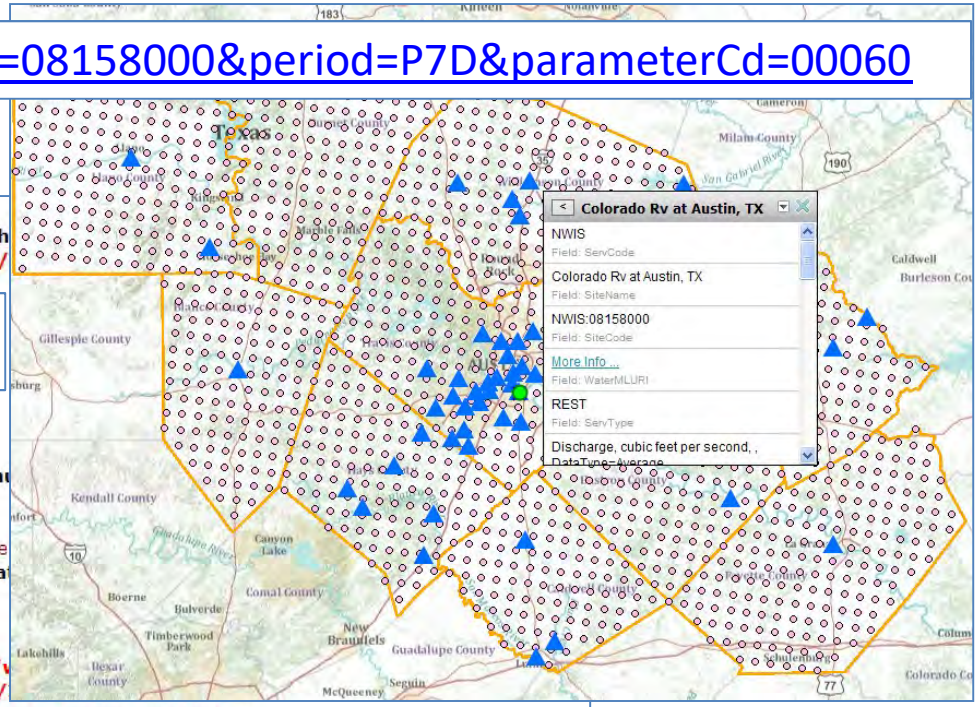


http://waterservices.usgs.gov/nwis/iv?sites=08158000&period=P7D&parameterCd=00060

USGS REST service

An observations service in time

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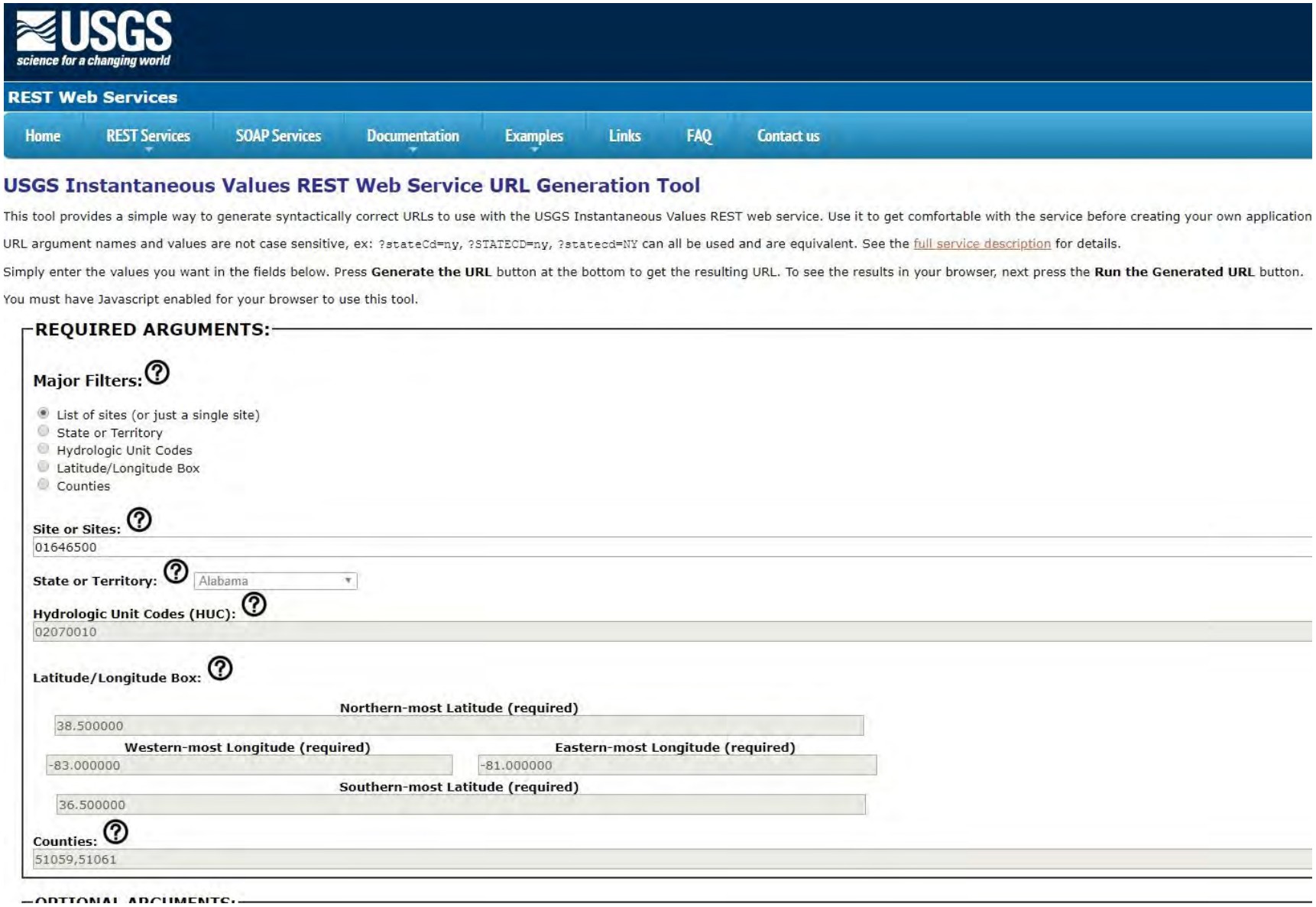
USGS Instantaneous Values Web Service Portal



https://waterservices.usgs.gov/rest/IV-Test-Tool.html

WaterML: Example

//waterservices.usgs.gov/nwis/iv/?format=waterml,2.0&sites=01646500&parameterCd=00060,00065&siteStatus=all

Reference: CUAHSI

WaterML: Implemented by…

- USACE
  - CWMS
  - A2W
    (*Access 2 Water*)
  - RADAR-WS
    (*CWMS RESTful API Data Retrieval Web Service*)
- Kisters
  - WISKI
- Deltares
  - Delft-FEWS
- USGS
  - Aquarius/NWIS
- NWS
  - CHPS
    (*Community Hydrologic Prediction System*)
  - NWM
    (*National Water Model*)
- ESRI
  - ArcGIS Server

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OGC®
Making location count.
The Open Geospatial Consortium

Integrated Water Resources Science and Services (IWRSS): Partners and Missions

USGS science for a changing world

Water Science: **Collects and disseminates reliable, impartial, and timely information needed to understand the Nation's water resources to minimize loss of life and property from natural disasters**

US Army Corps of Engineers

Water Management: **Strengthens our Nation's security, energizes the economy, and reduces risks from disasters**

Water Prediction: **Provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy.**

FEMA

Response and Mitigation: **Supports our citizens and first responders to ensure that as a nation we work together to build, sustain, and improve our capability to prepare for, protect against respond to, recover from and mitigate all hazards**

Additional IWRSS Participants:

CUAHSI

NRCS

IWRSS

- Collaborate on a shared water effort with participating federal agencies and state and regional partners.
- develop new data capabilities, models, and decision support systems
- integrate information delivery and simplify access to data
- produce the comprehensive information to support next-generation adaptive water planning and preparedness
- provide high resolution water resources information and forecasts

III. Applications

North Texas Hydrologic Data Project

- Initial phase funded through…
  - University Corporation for Atmospheric Research (UCAR) COMET Partners Program
- Purpose…
  - Develop Hydrologic data server for time series access to current and historic MPE data
- Pilot IWRSS Project

UCAR
UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

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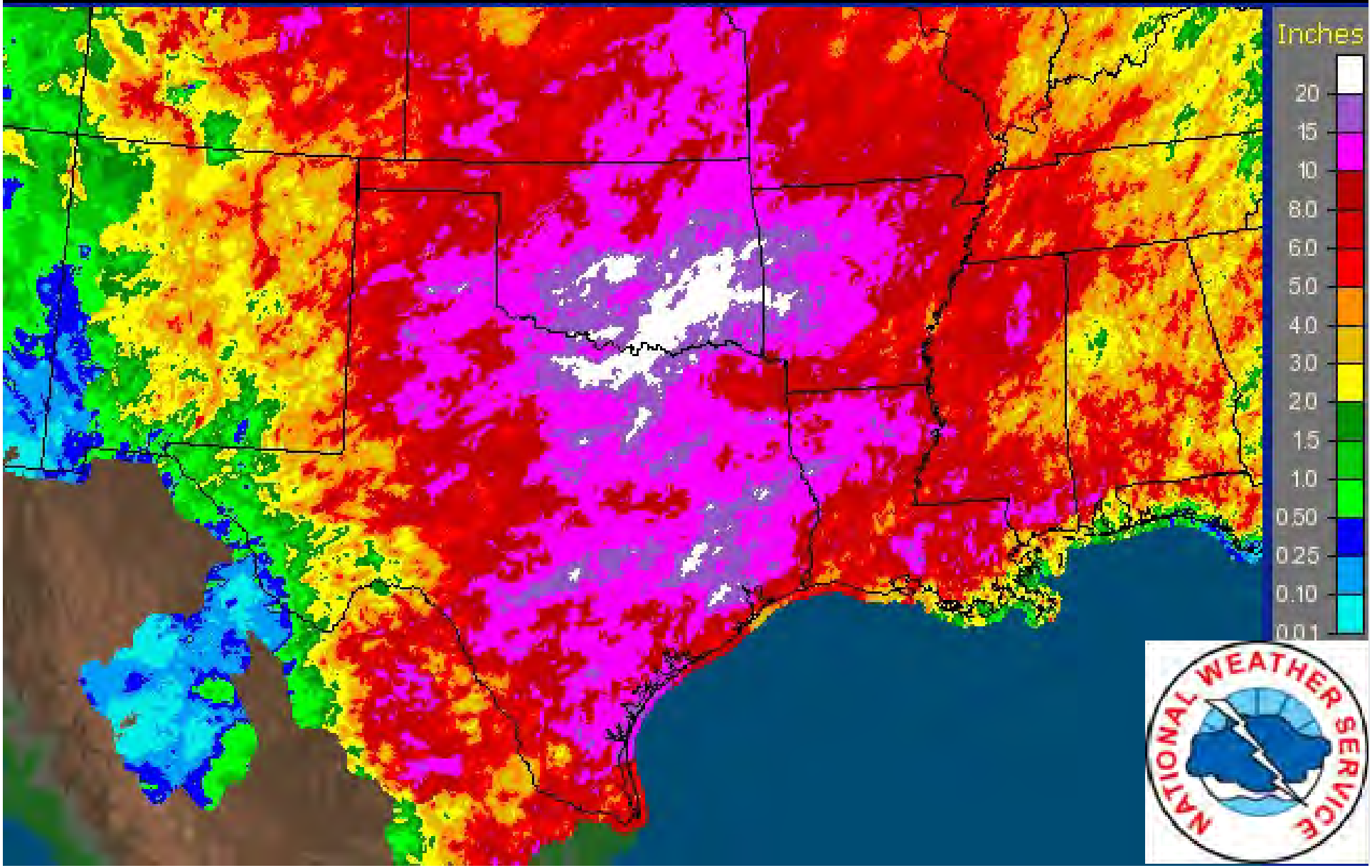
North Texas Hydrologic Data Project

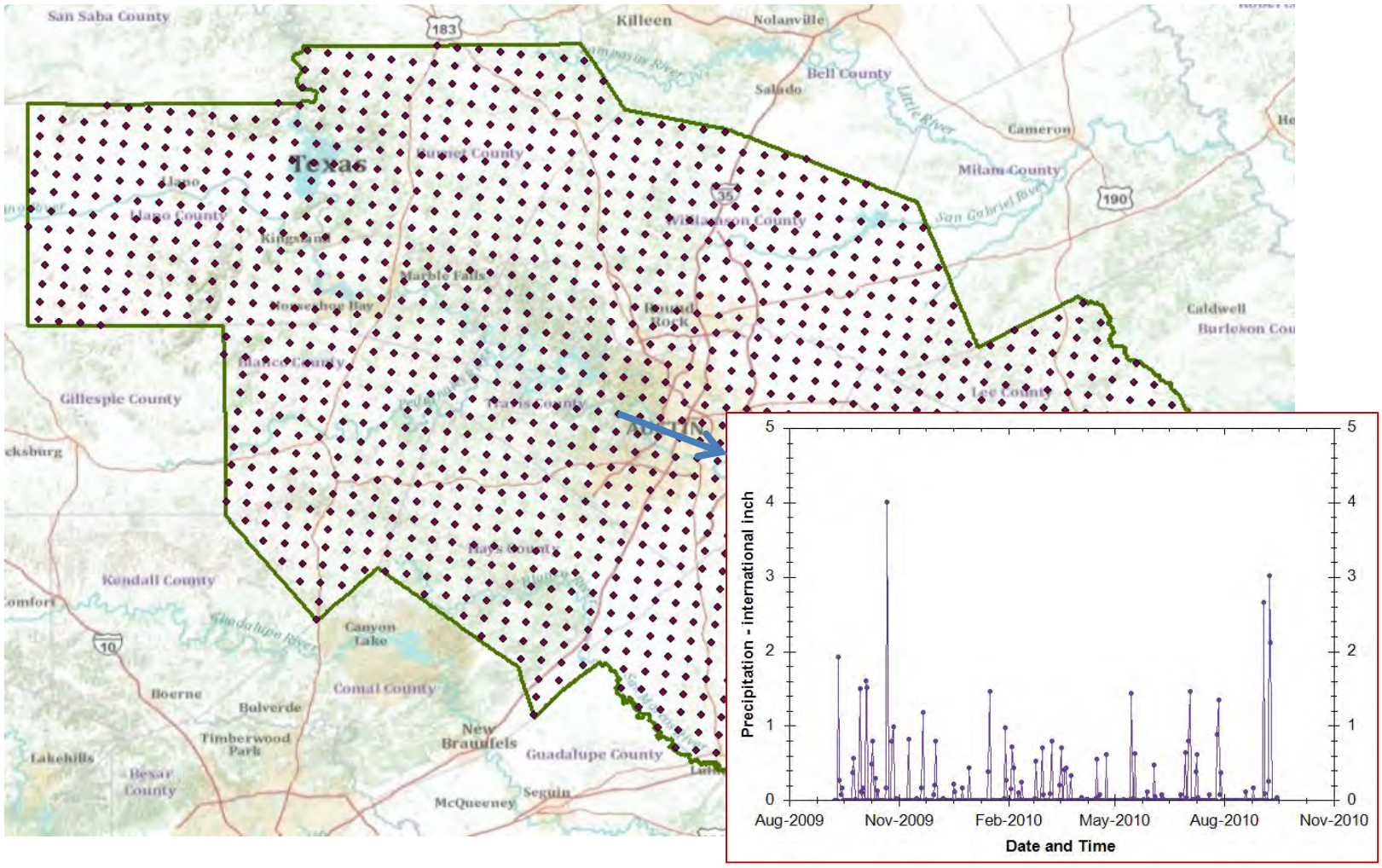
- Collaboration of…
  - National Weather Service - West Gulf River Forecast Center
  - National Weather Service - Lower Mississippi River Forecast Center
  - National Weather Service - Arkansas-Red Basin River Forecast Center
  - National Weather Service - Southern Region Headquarters
  - U.S. Army Corps of Engineers – Fort Worth District
  - U.S.G.S. - Texas Water Science Center
  - Tarrant Regional Water District
  - City of Fort Worth, Texas
  - The Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)

Southern Plains Observed Precipitation

NEXRAD Radar



MPE Rainfall Time Series in WaterML

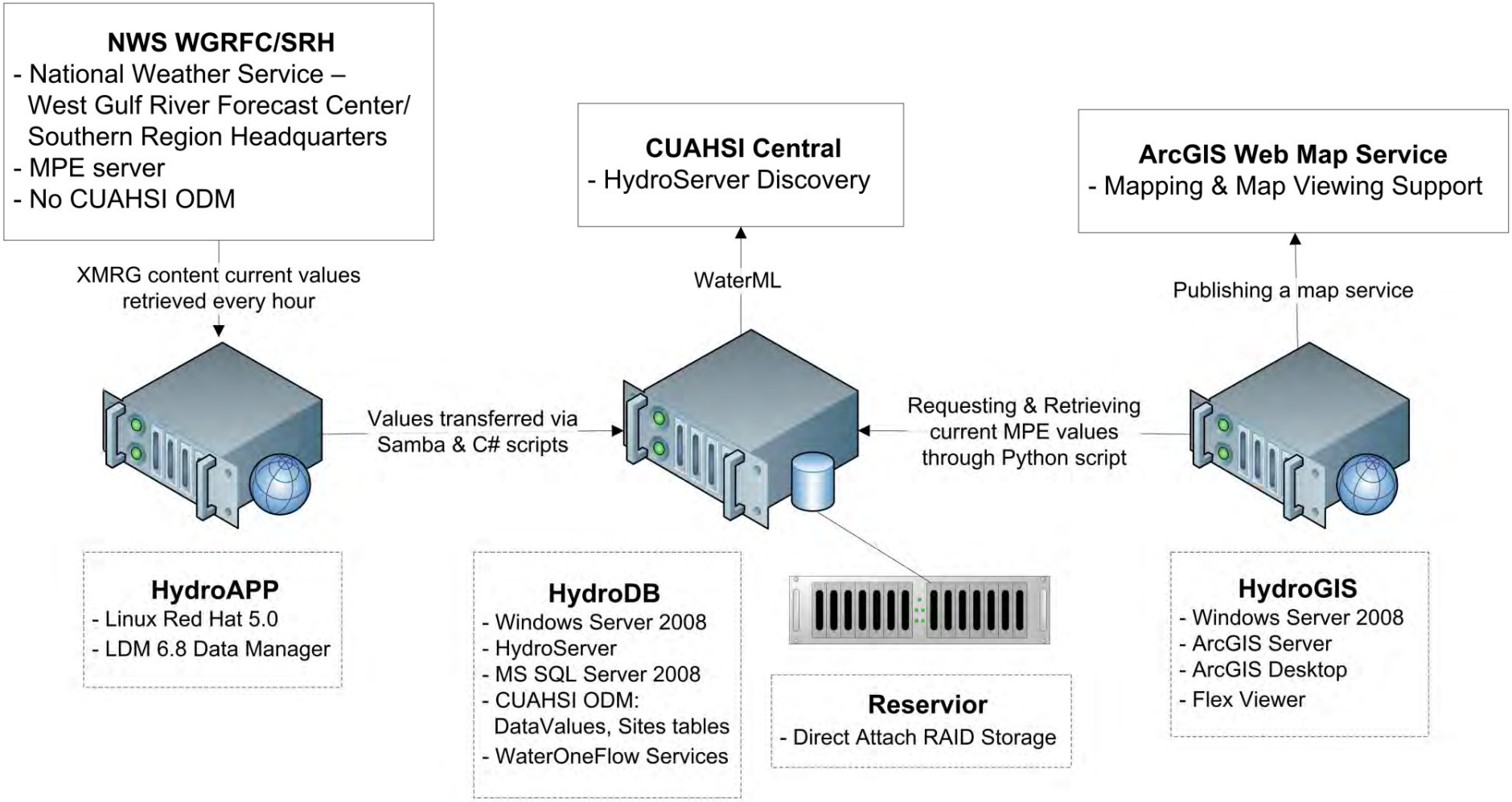


Operational System

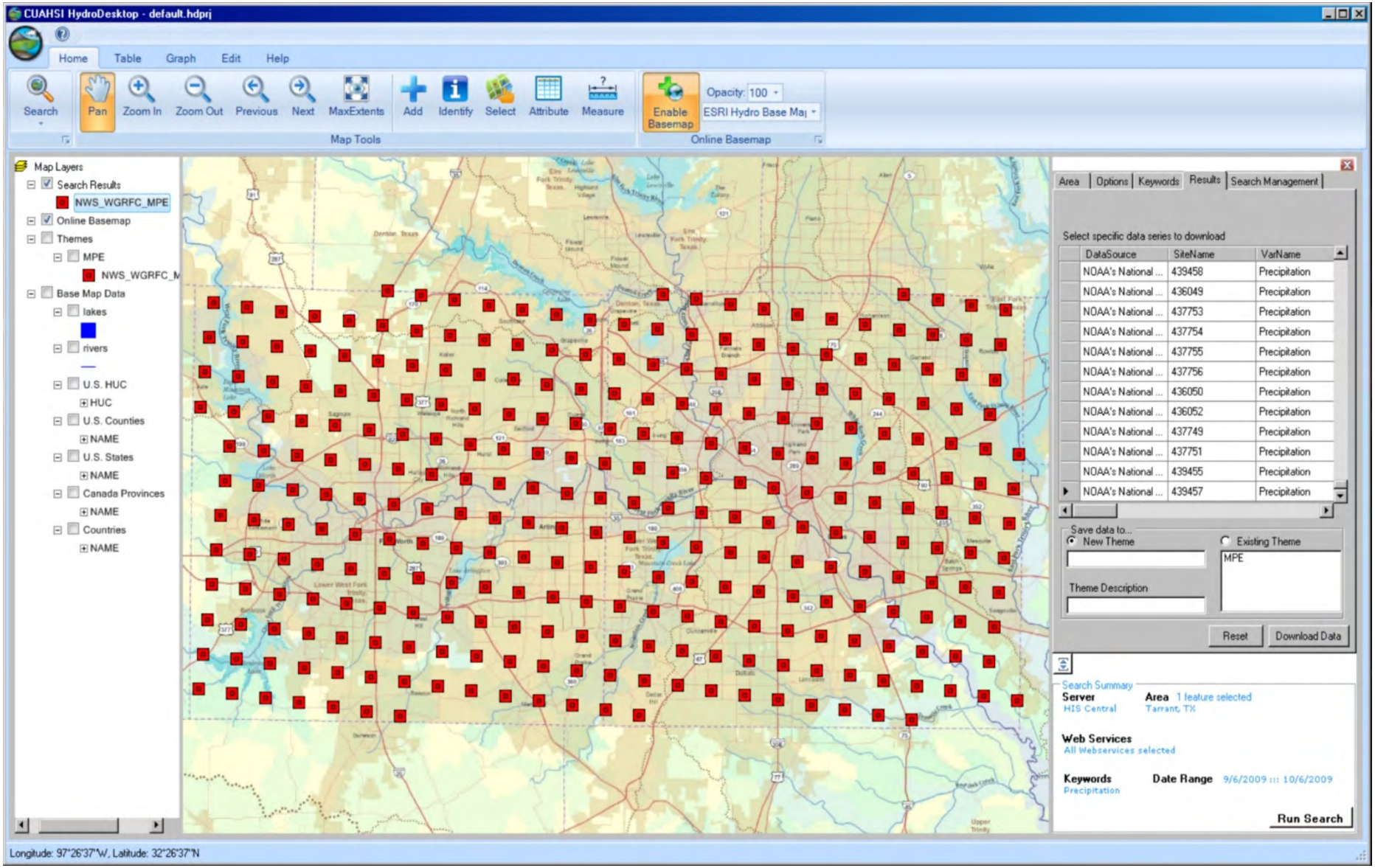
- Enterprise class data server
- 12 - 3.5 GHz HT processing cores
- 96 Gb memory
- 2TB disk system for OS and log files in separate RAID 1 and RAID 10 arrays
- 18 TB integrated storage for fast IO functions in RAID 5 array
- MS Server 2008, SQL Server 2008 & ArcGIS Server

Computer System

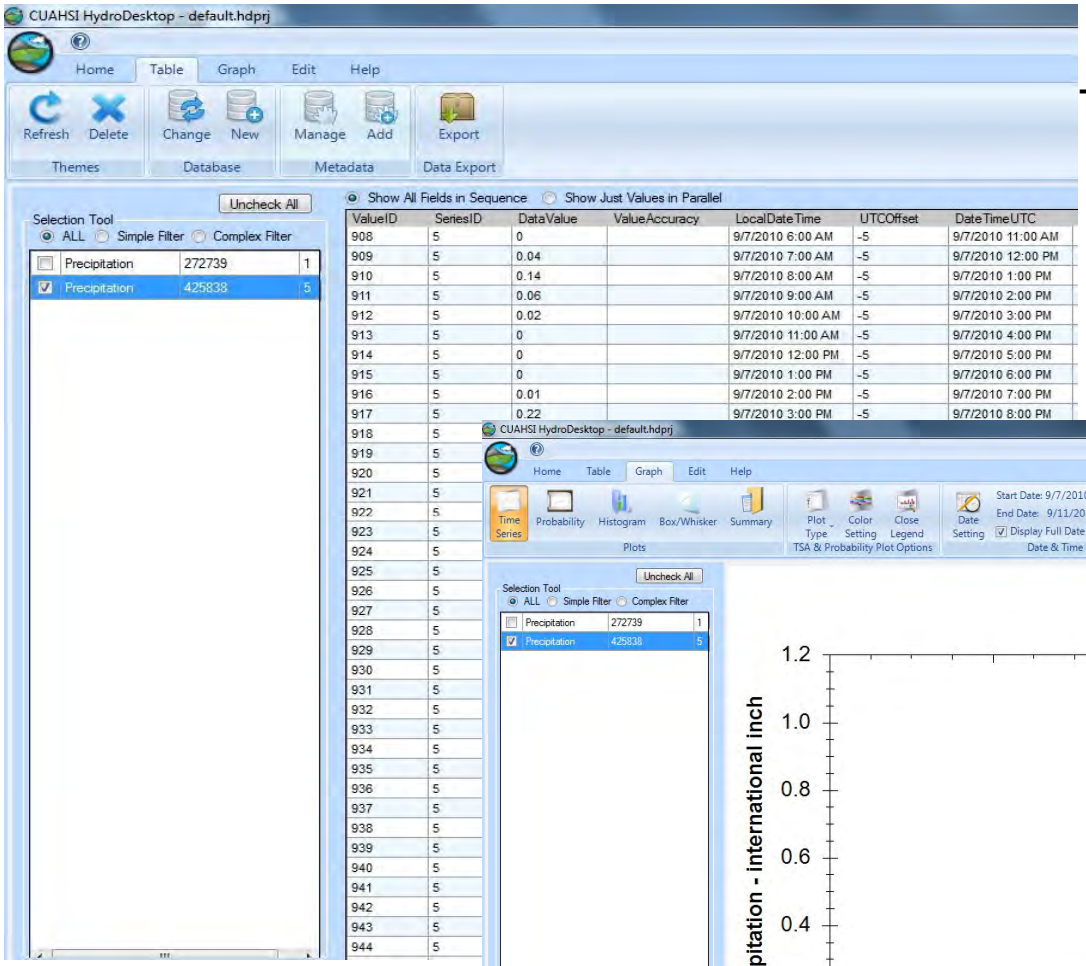
MPE HIS Architecture



Dataset within Tarrant / Dallas Counties

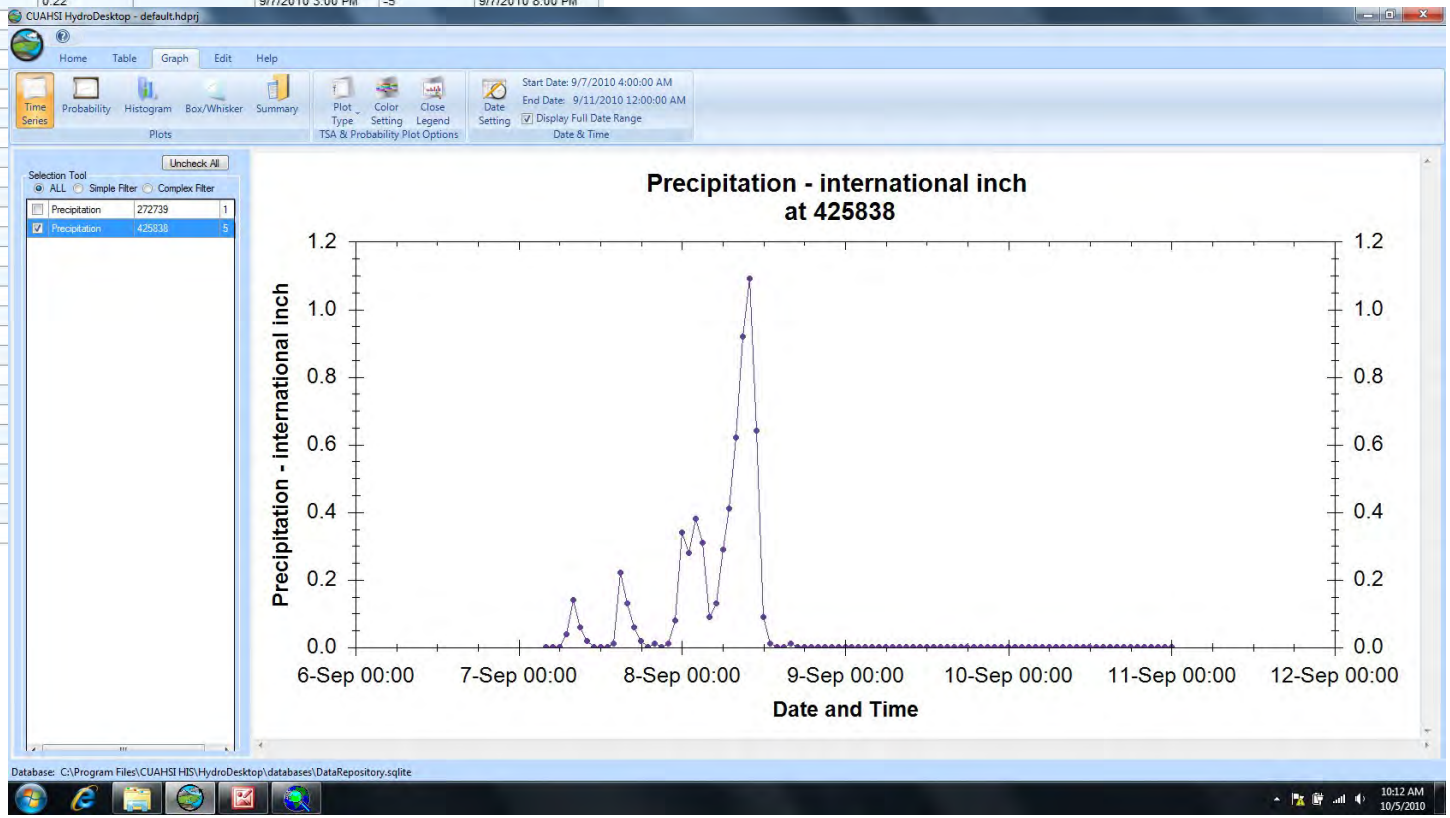


Tropical Storm Hermine - Hourly Time Series Arlington, TX

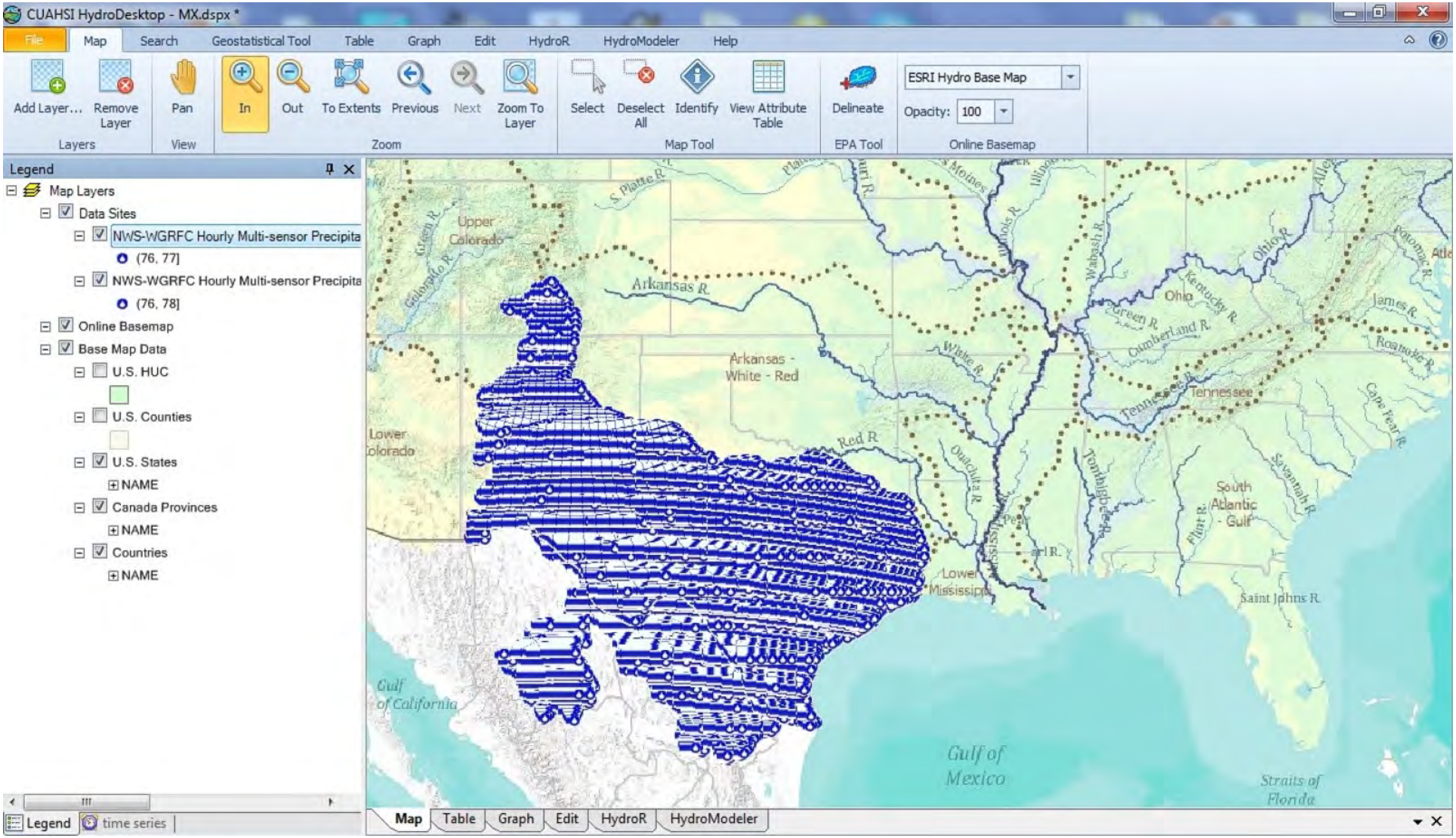


Tabular Data

Time Series Data



WGRFC-MPE (HRAP centers) U.S. & Mexico



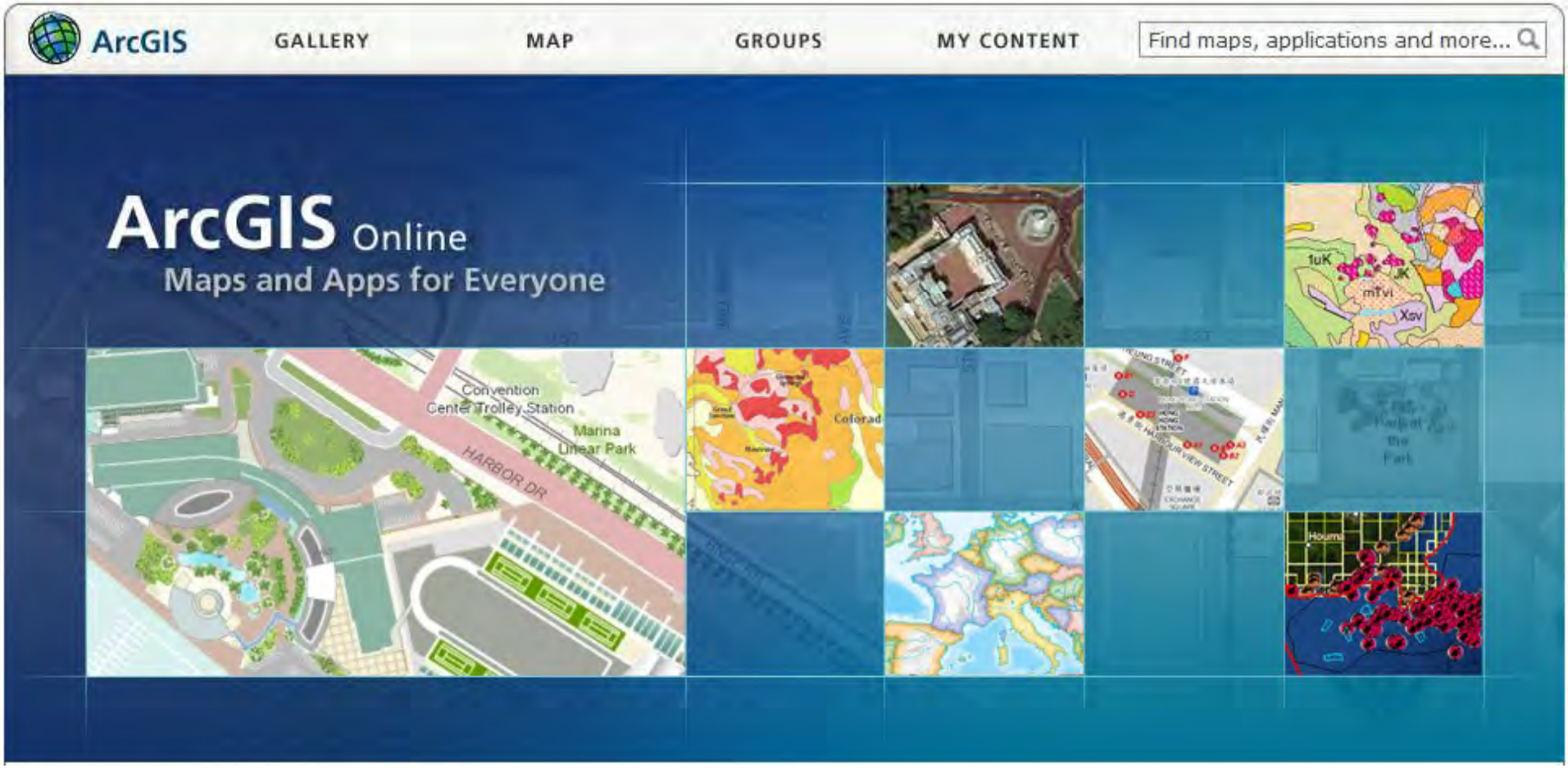
MPE – HIS Coverage

MPE - HIS Coverage

- 4 entire U.S. States
  - Texas, Oklahoma, Arkansas, Louisiana
- 9 partial U.S. States and parts of Mexico
- 136,166 HRAP cell centers at 4 km x 4km
- Approximately 840,000 square miles of coverage
- Updated Hourly
- Project created a mesh of “virtual rain gages” stretched over the landscape.

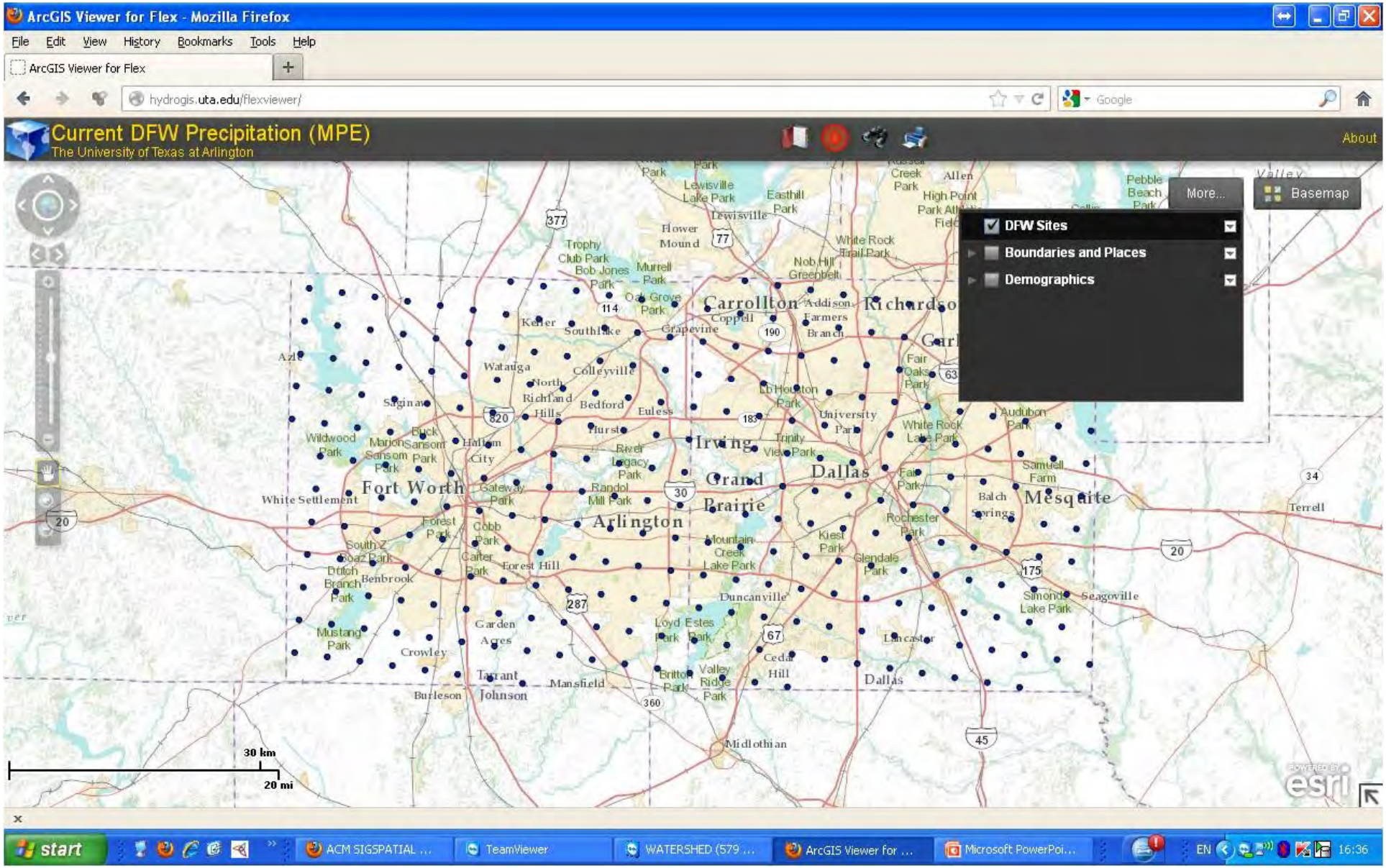
ArcGIS Online

GIS on the web – online map services



http://www.arcgis.com

Map Feature Service



North Texas Data Hub Expanded Coverage

- 20+ year Nexrad MPE historic record
  - and updated with latest values hourly
- National Weather Service QPF
  - Quantitative Precipitation Forecast
- USACE reservoir discharges
  - All 23 reservoirs in Texas
  - Current observations and forecast values
- USGS stream gauges
- City of Fort Worth ALERT gauge observations
- Regional Water District SCADA data

IV. Why are we doing this?

Reference: NWS


Steak 'n Shake
DRURY
Comfort, made from scratch


FLOODING IN ST. CHARLES AT ON WHEEL STORAGE
SKY FOX
SPONSORED BY
Bommarito
AUTOMOTIVE GROUP

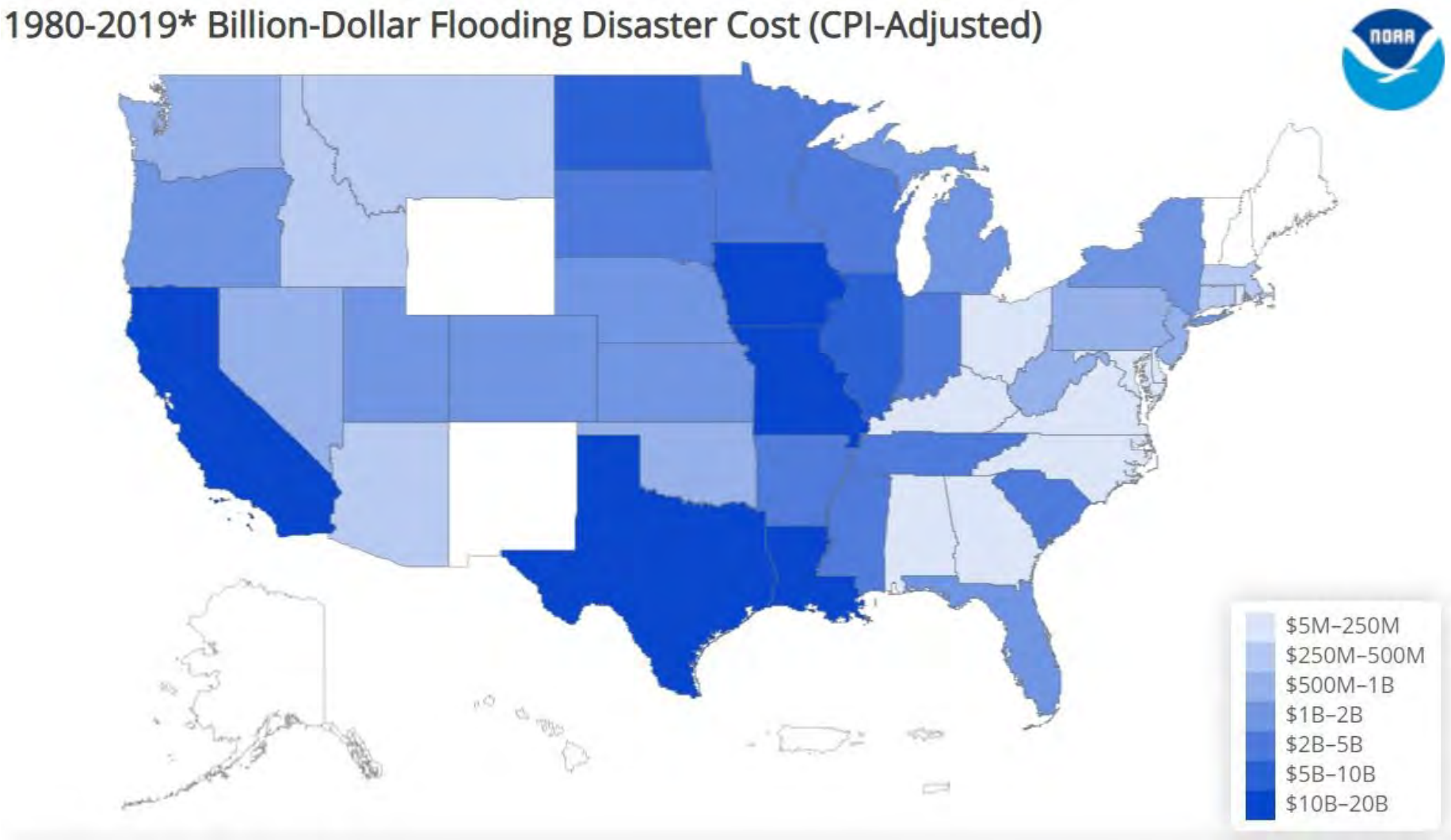
Flood Disaster – Kaw Valley - 1951

- Record flooding in the Kansas, Neosho, Marais Des Cygnes, and Verdigris river basins.
- At Kansas City, the crest was 14 feet above flood stage
- 1951 damage in Kansas and Missouri, exceeded $935 million
- Adjusting for inflation, is nearly $8.52 billion in 2019
- 28 lives lost and 518,000 displaced.

5,847 Flood fatalities for the 48 contiguous states & DC (1958-2019)

Rank	State	Fatalities	Rank	State	Fatalities
1	Texas	1062	26	Alabama	75
2	Pennsylvania	292	27	Kansas	66
3	California	267	28	New Jersey	60
4	Virginia	261	29	Minnesota	57
5	South Dakota	251	30	Utah	55
6	**Missouri**	**235**	31	Iowa	53
7	North Carolina	206	32	Montana	51
8	Colorado	205	33	Oregon	49
9	Arkansas	196	34	West Virginia	47
10	Kentucky	187	35	Washington	40
11	Mississippi	182	36	Michigan	36
12	Tennessee	172	37	Nevada	33
13	Ohio	167	38	Nebraska	23
14	Oklahoma	164	39	North Dakota	22
15	Wisconsin	161	40	Wyoming	22
16	New York	149	41	Connecticut	18
17	Georgia	123	42	Vermont	18
18	Louisiana	123	43	Delaware	16
19	Arizona	118	44	Maine	14
20	Maryland	109	45	New Hampshire	13
21	Indiana	96	46	Massachusetts	7
22	Illinois	86	47	District of Columbia	5
23	South Carolina	85	48	Idaho	5
24	New Mexico	83	49	Rhode Island	0
25	Florida	82		Updated: 9/5/19	5847

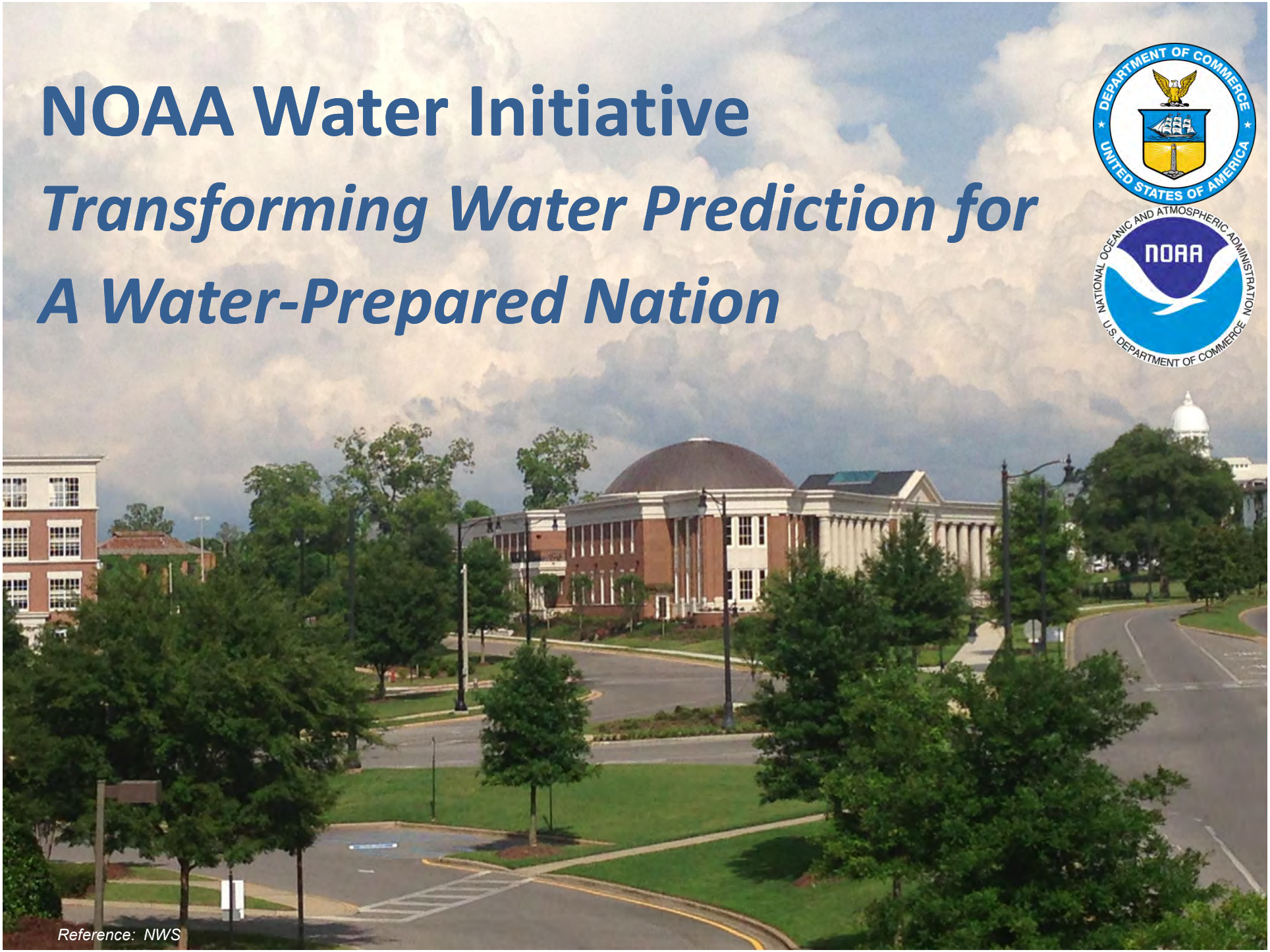
Costs of Flooding



Reference: NWS

NOAA Water Initiative

Transforming Water Prediction for A Water-Prepared Nation




NWC
NATIONAL
WATER
CENTER
NATIONAL WATER CENTER
DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

NATIONAL WATER MODEL
OPERATIONS CENTER

Interoperable Water Prediction and Impact-Based Decision Support

WATER PREDICTION

+

GEO-INTELLIGENCE

Reference: NWS

The National Water Model

August, 2016

- Operating on NOAA's Cray XC40 supercomputers.
- Data from more than 8,000 U.S. Geological Survey gauges.
- Simulates conditions for 2.7 million locations in the contiguous United States.
- Generates hourly forecasts for the entire continental river network.

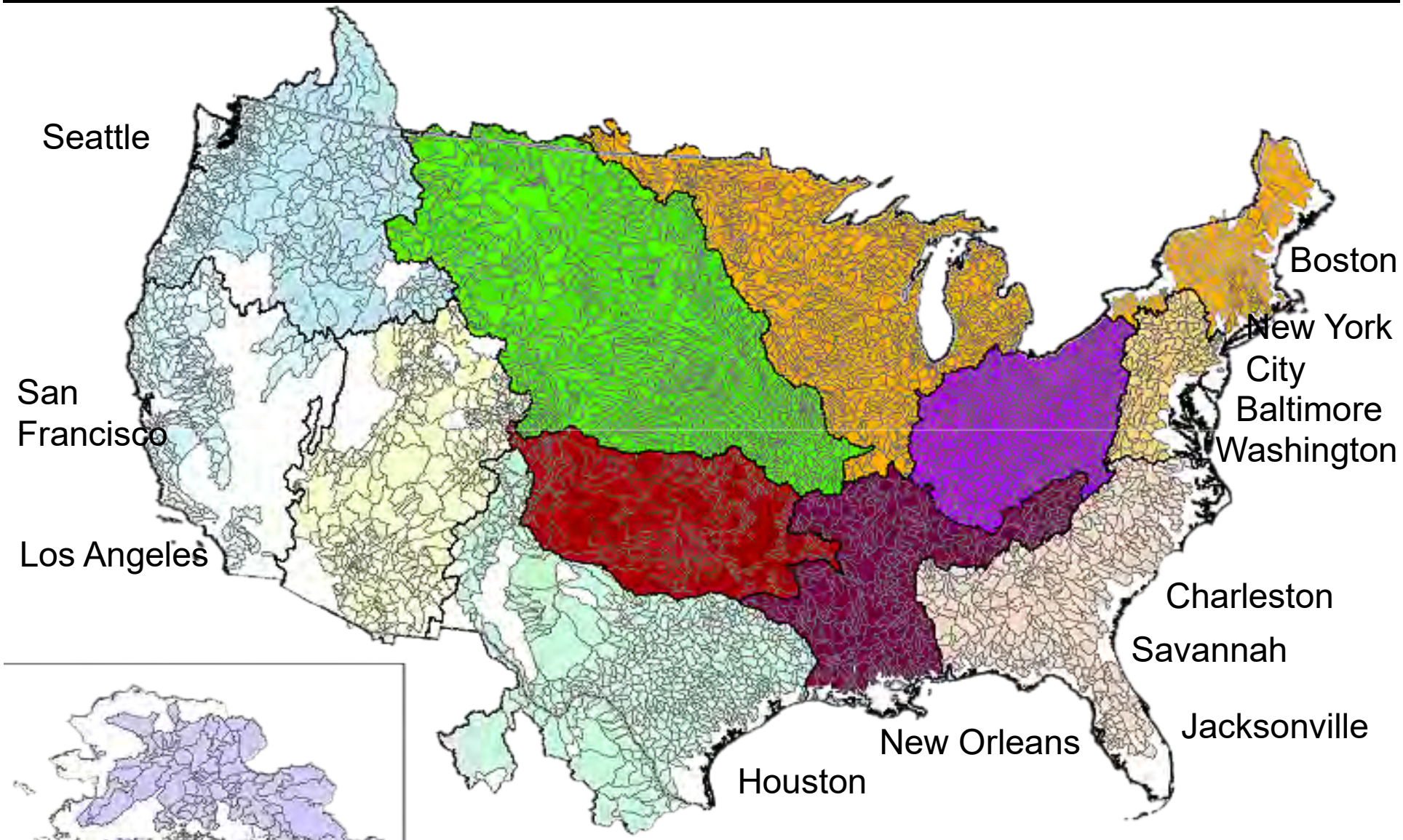
NOAA launches America's first national water forecast model

New tool hailed as a game changer for predicting floods, informing water-related decisions

Weather | forecasting weather modeling

August 16, 2016 — NOAA and its partners have developed a new forecasting tool to simulate how water moves throughout the nation's rivers and streams, paving the way for the biggest improvement in flood forecasting the country

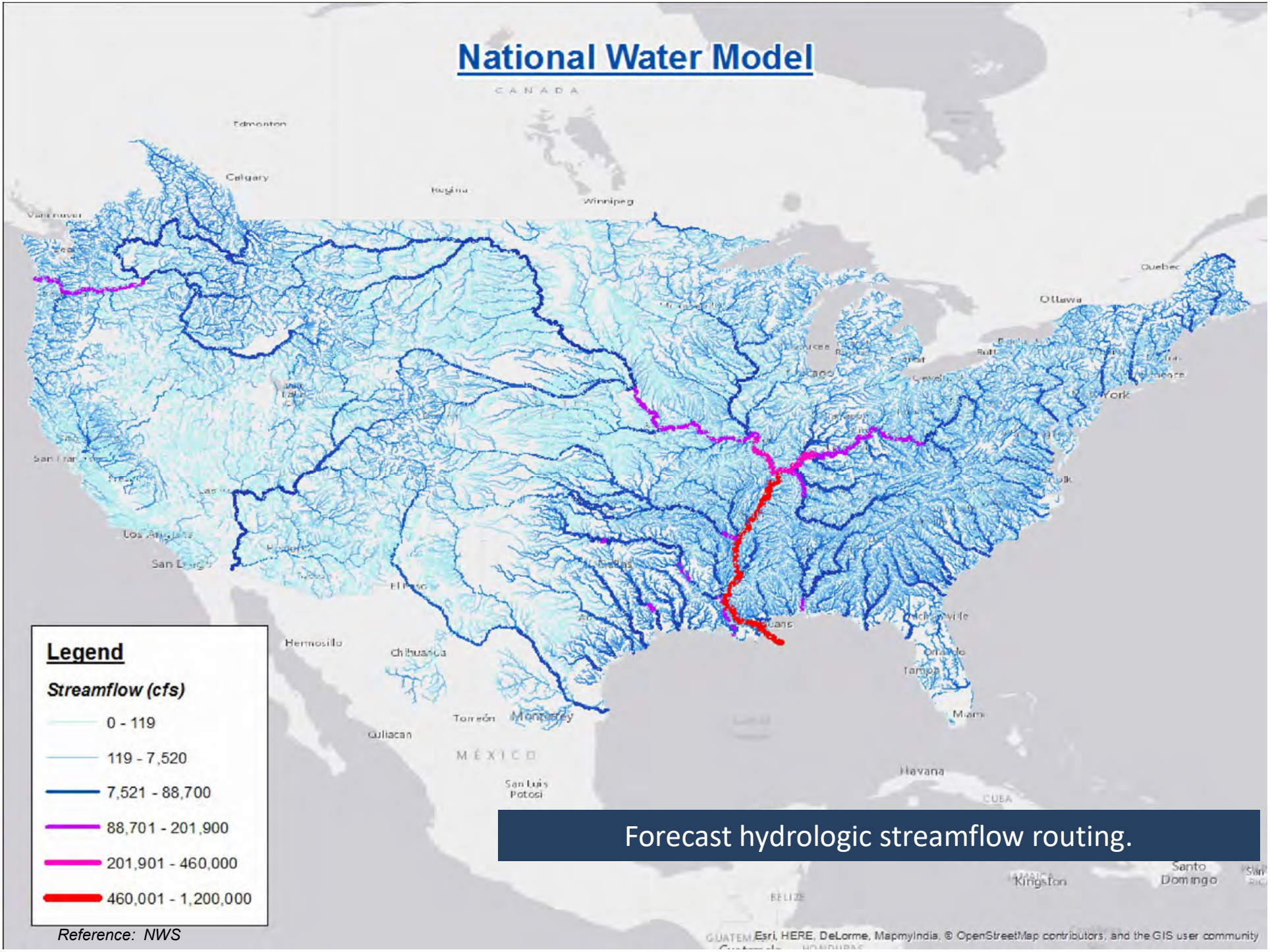
NWS River Forecast Centers



Reference: NWS

Shaded areas are current NWS river forecast basins.

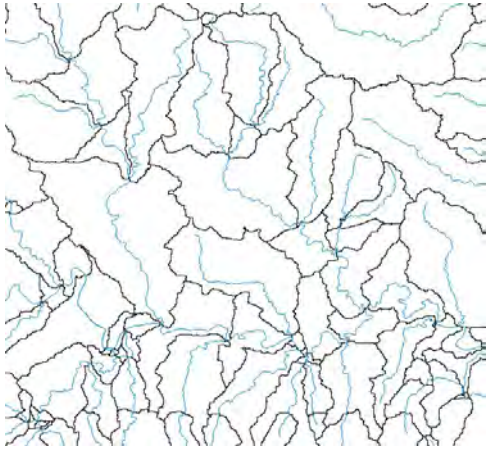
National Water Model



Forecast hydrologic streamflow routing.

Reference: NWS

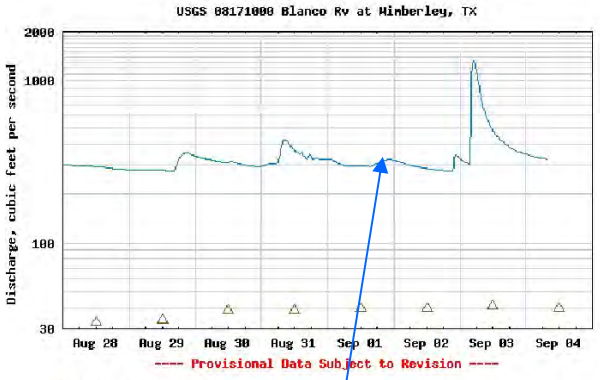
A Digital Watershed connects geospatial and temporal water resources data

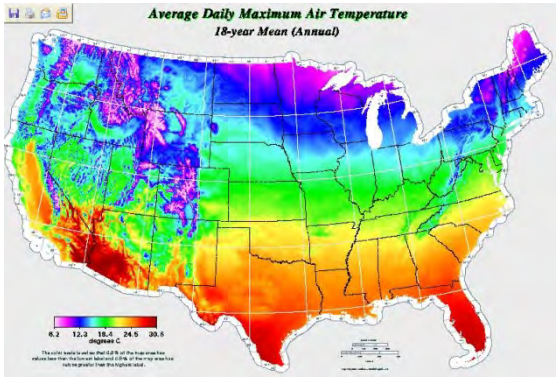


NHDPlus

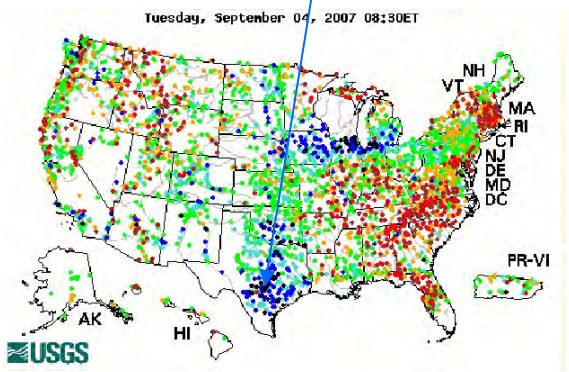
Digital Watershed

Streamflow



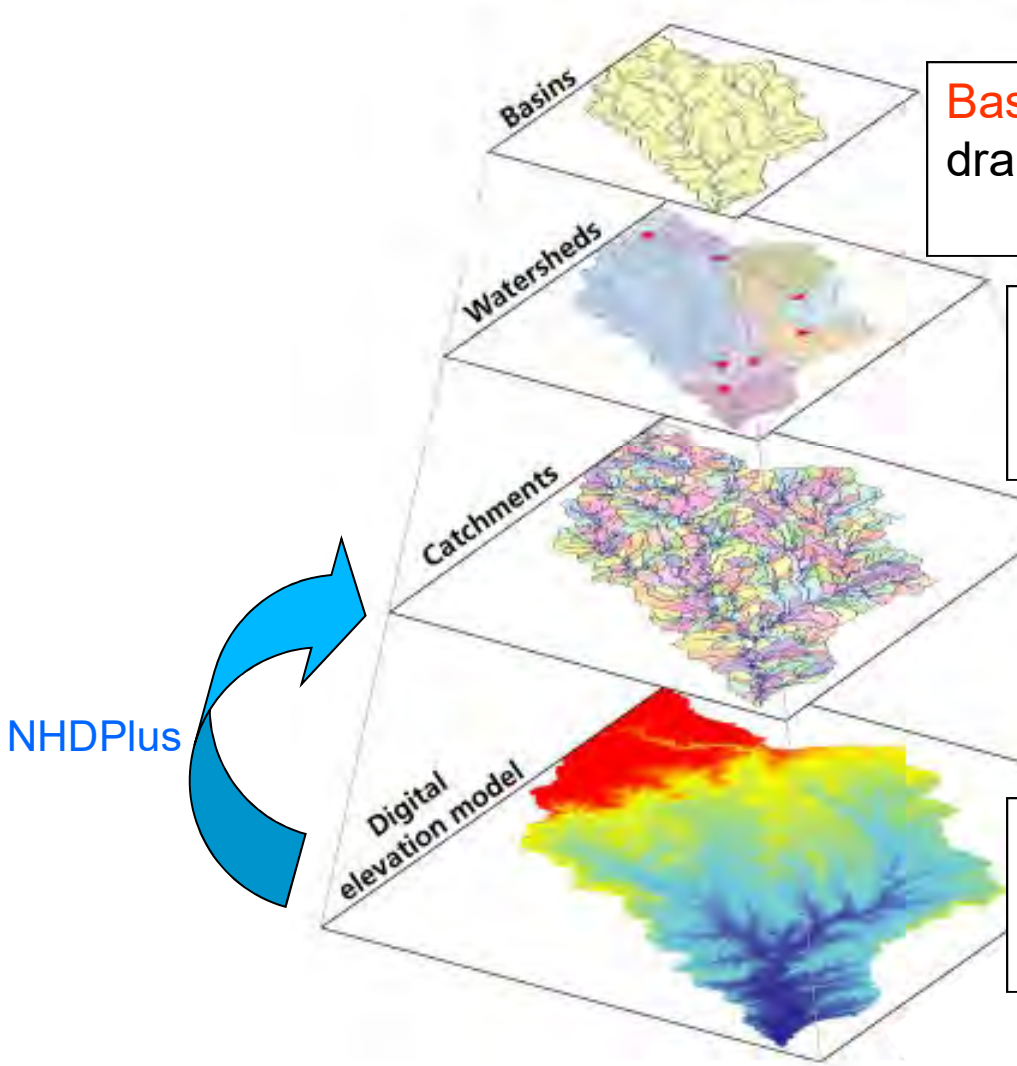


Weather



Reference: NWS

NHDPlus as a foundation for Digital Watersheds



Basins: Administratively chosen drainage areas

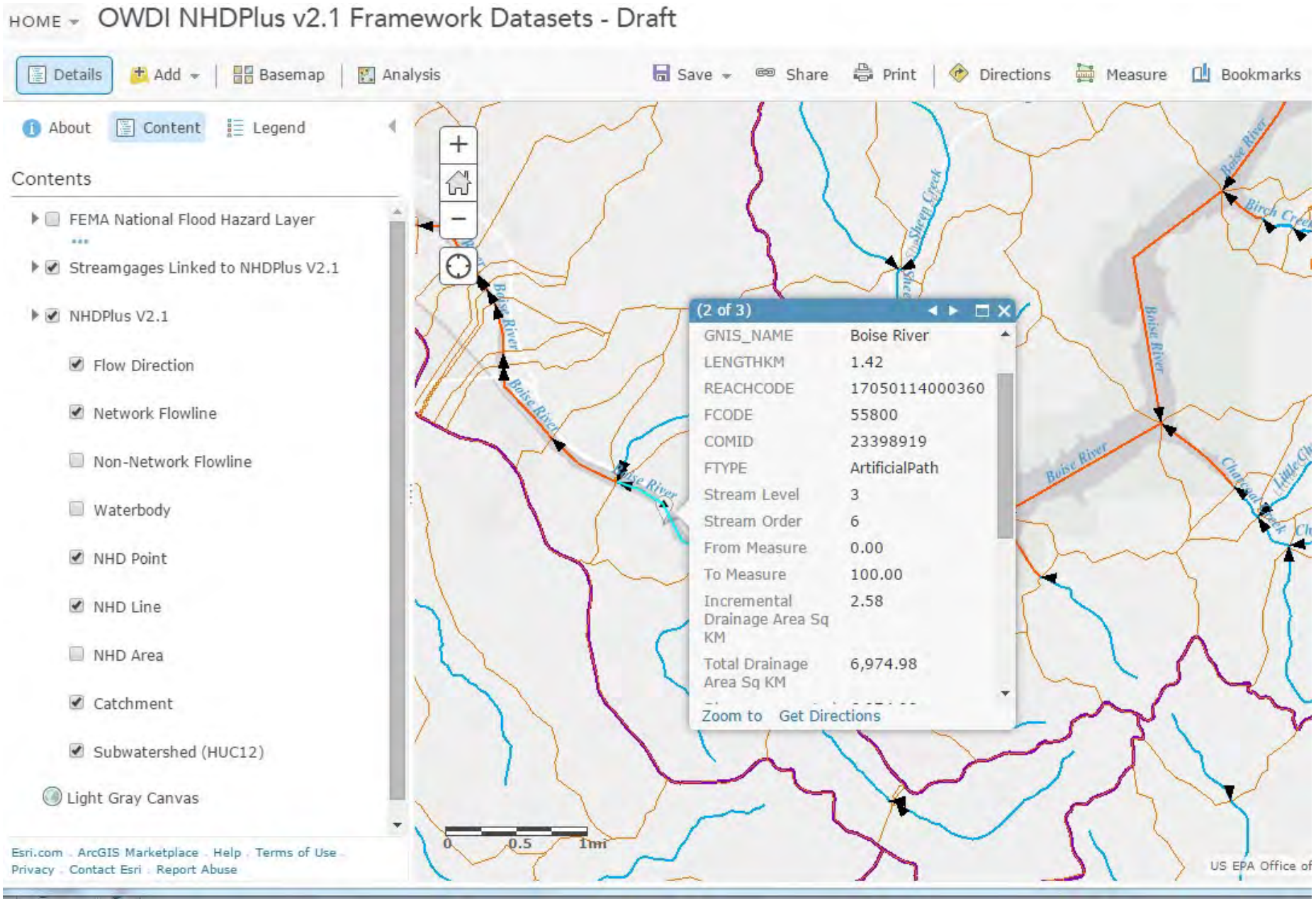
Watersheds: A tesselation of a basin for a particular purpose

Catchments: A tesselation of a basin using physical rules

Digital Elevation Model: a representation of the land surface as a spatial continuum

Reference: NWS

Foundation for Digital Watersheds



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

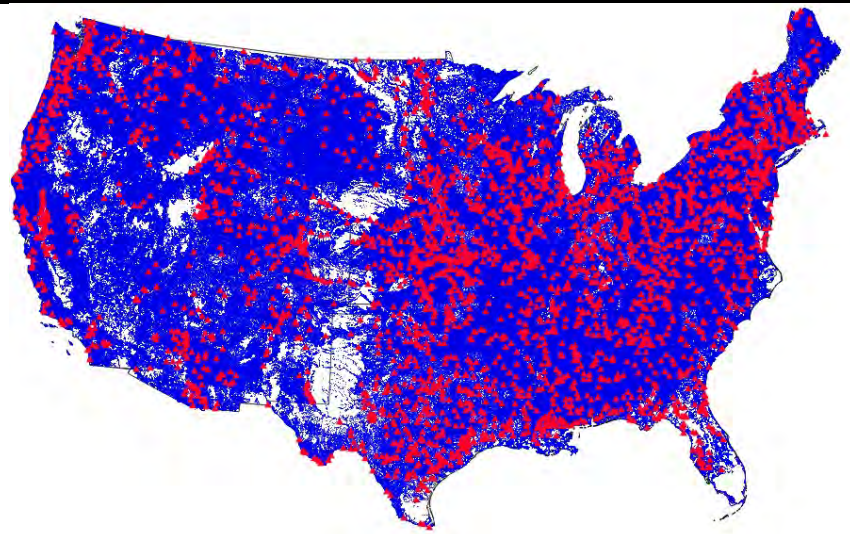
Reservoirs (1240 water bodies parameterized with level pool scheme)

Reference: NWS

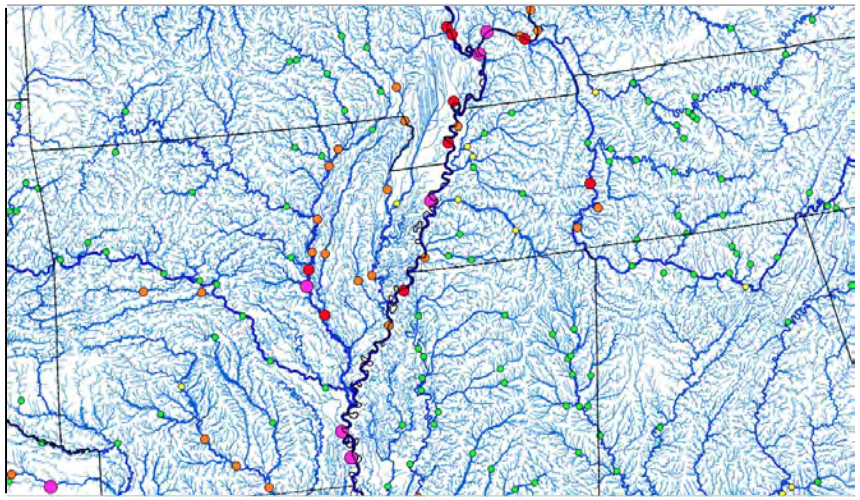
NWM OUTPUT

- **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

Reference: NWS

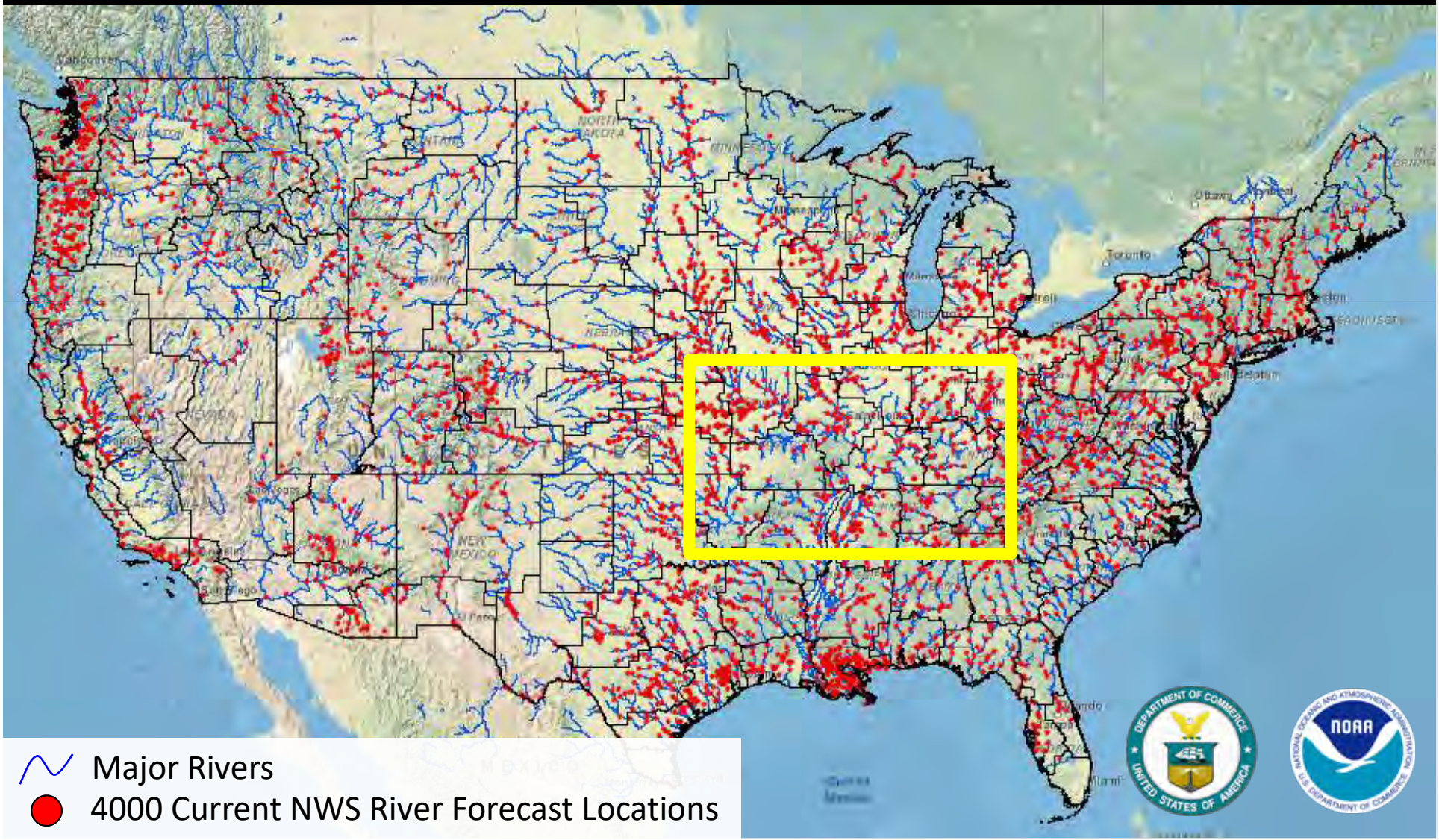


Current NWS AHPS points (red)
NWM output points (blue)



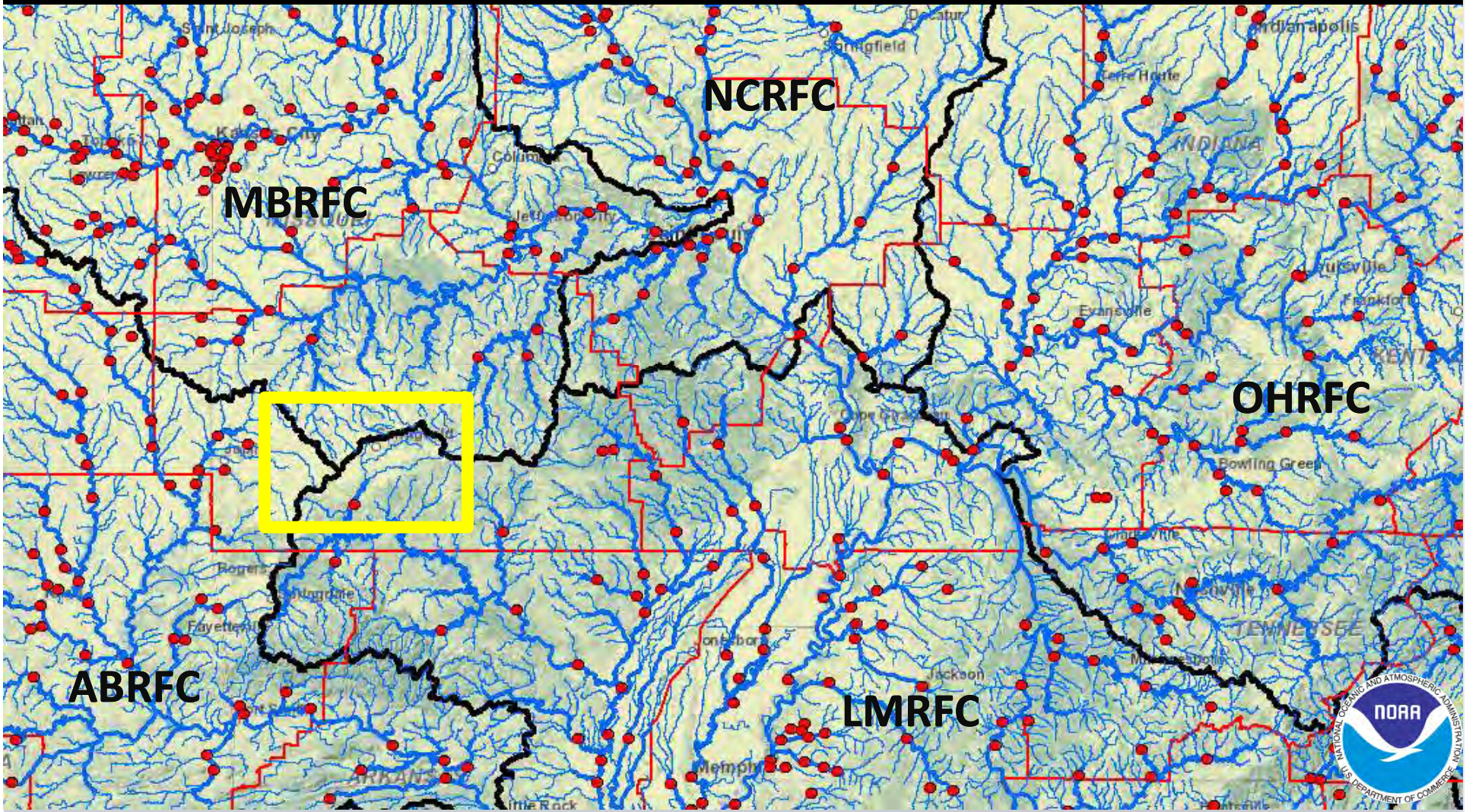
Current NWS River Forecast Points (circles)
Overlaid with NWM Stream Reaches

Major Rivers and NWS Hydrologic Forecast Locations (Today)



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

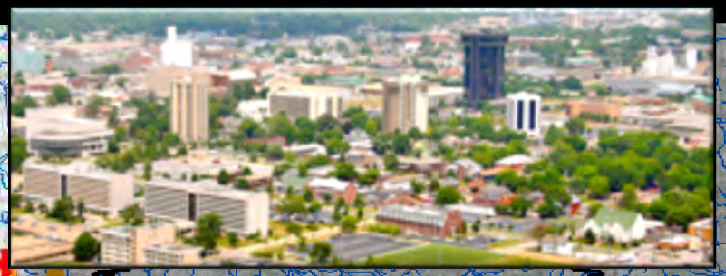
Middle Mississippi River



Full Resolution National Hydrography Dataset NHD+

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

WATER PREDICTION + NATIONAL INFRASTRUCTURE = WATER INTELLIGENCE



Springfield, Missouri

IWP: Every stream segment ("reach") gets a forecast (2.7 million across U.S.)

Current NWS Hydro Forecast Location
James River at Galena, MO
(40 miles downstream)

150 km

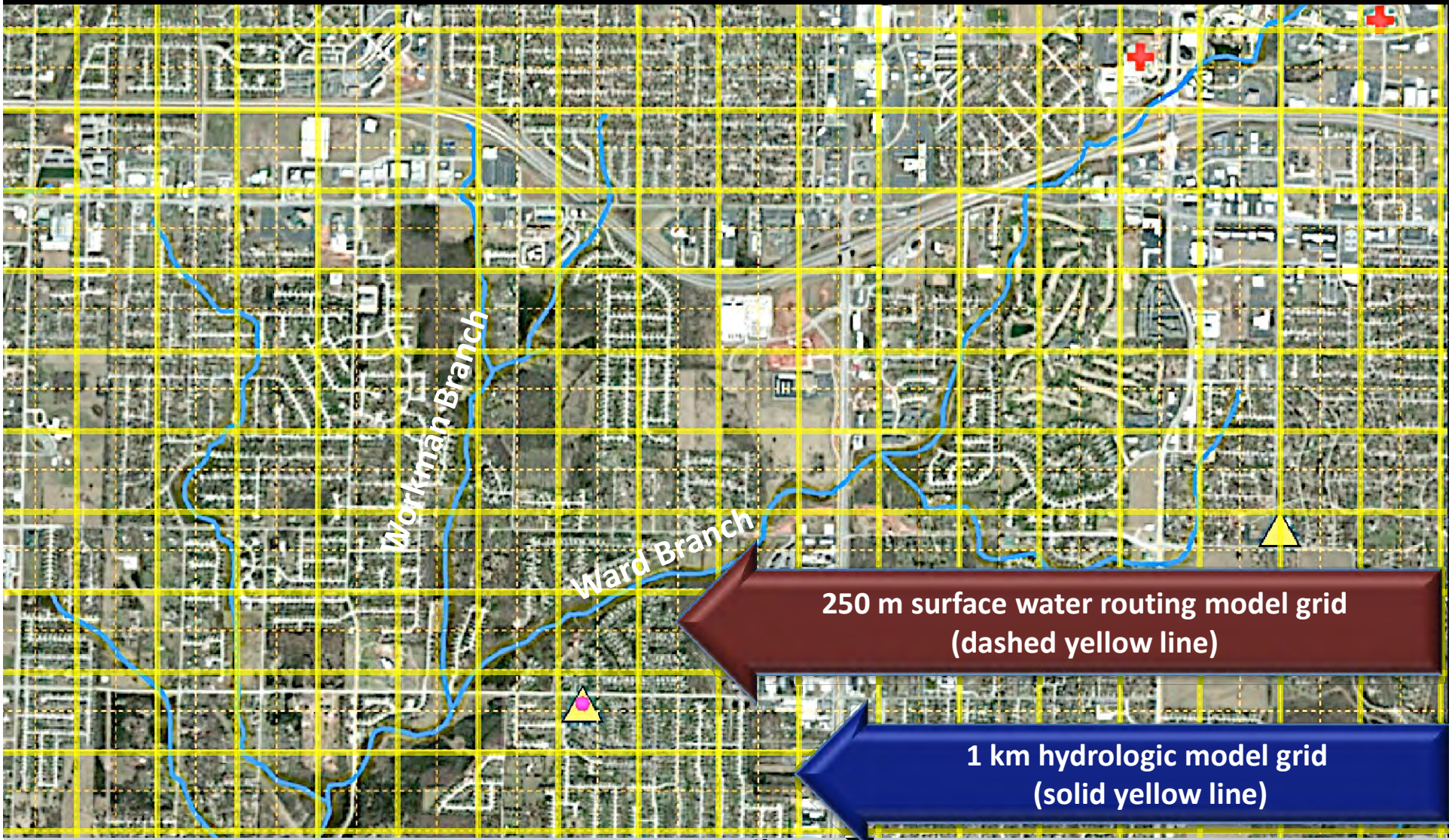
✚ Hospitals ● EMS ▲ Fire

Reference: NWS

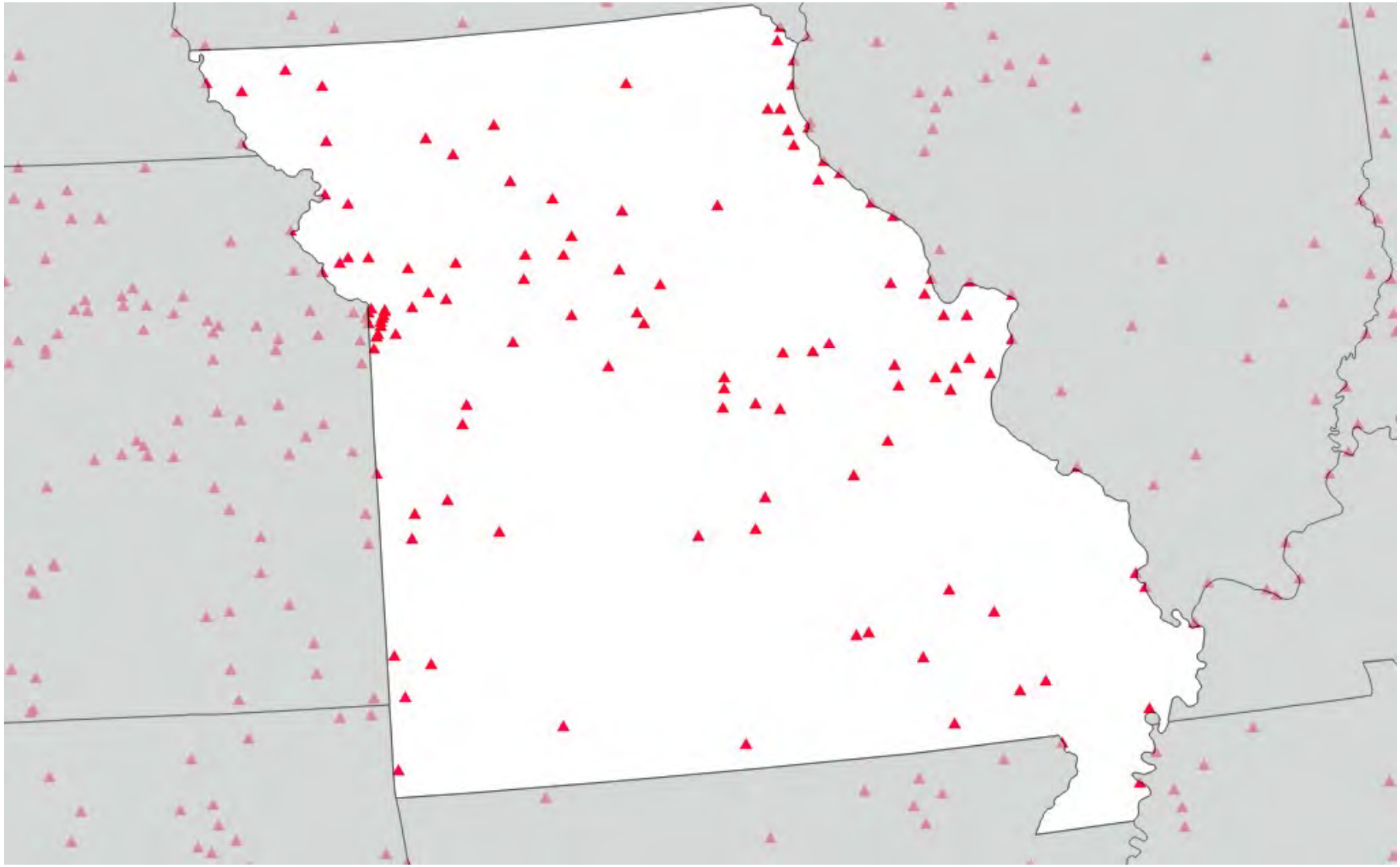
Infrastructure Data from National Geospatial Intelligence Agency

WATER PREDICTION + NATIONAL INFRASTRUCTURE

Hospitals, EMS & Fire Stations

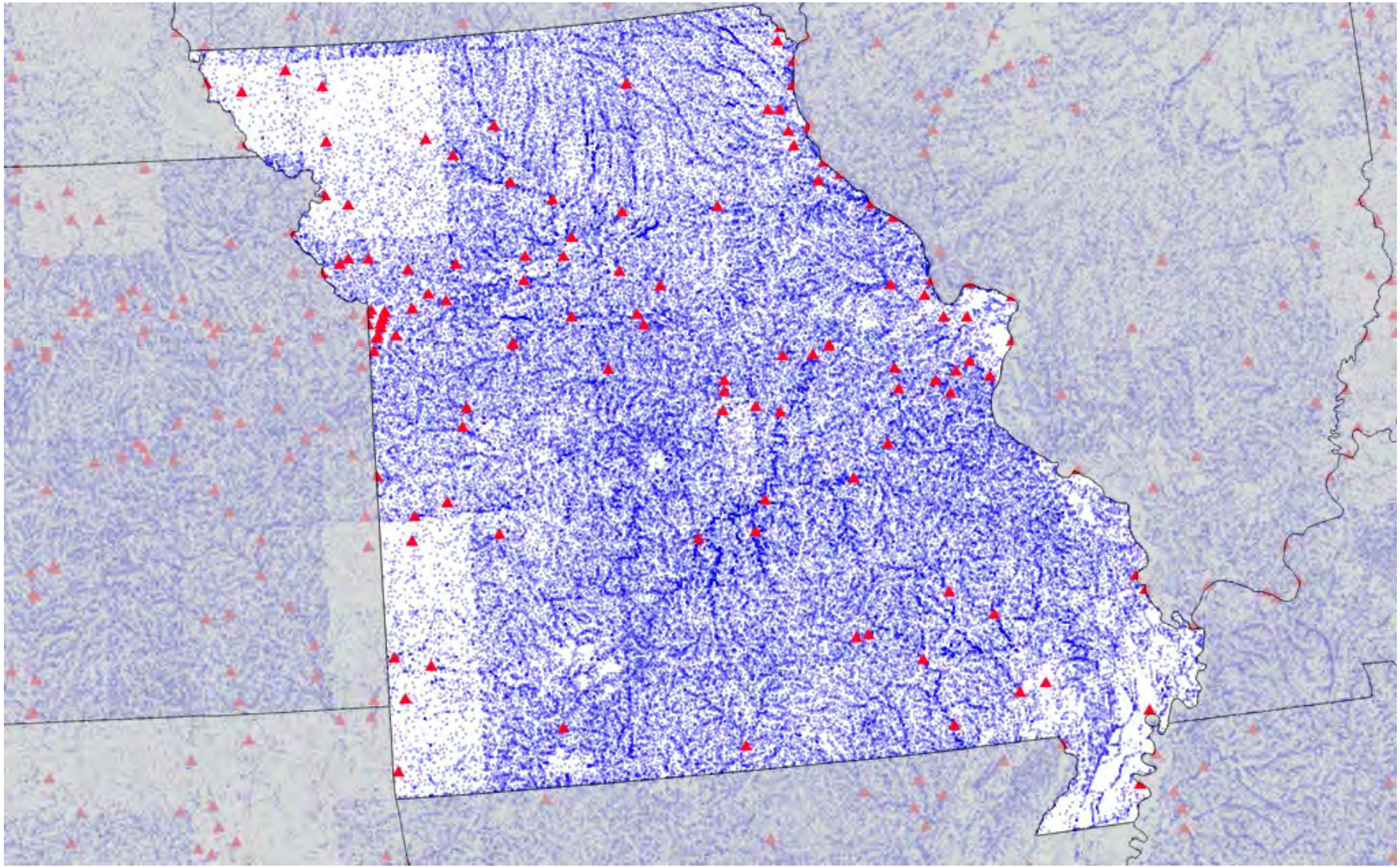


RFC forecast points for Missouri



Reference: NWS

NWM for Missouri



Reference: NWS

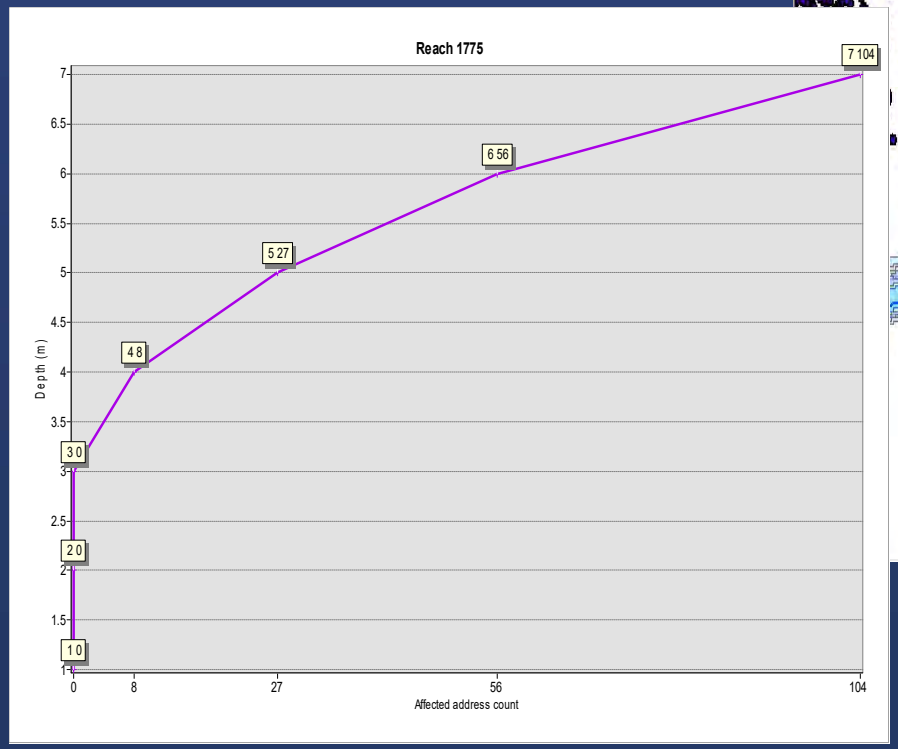
V. What Next?

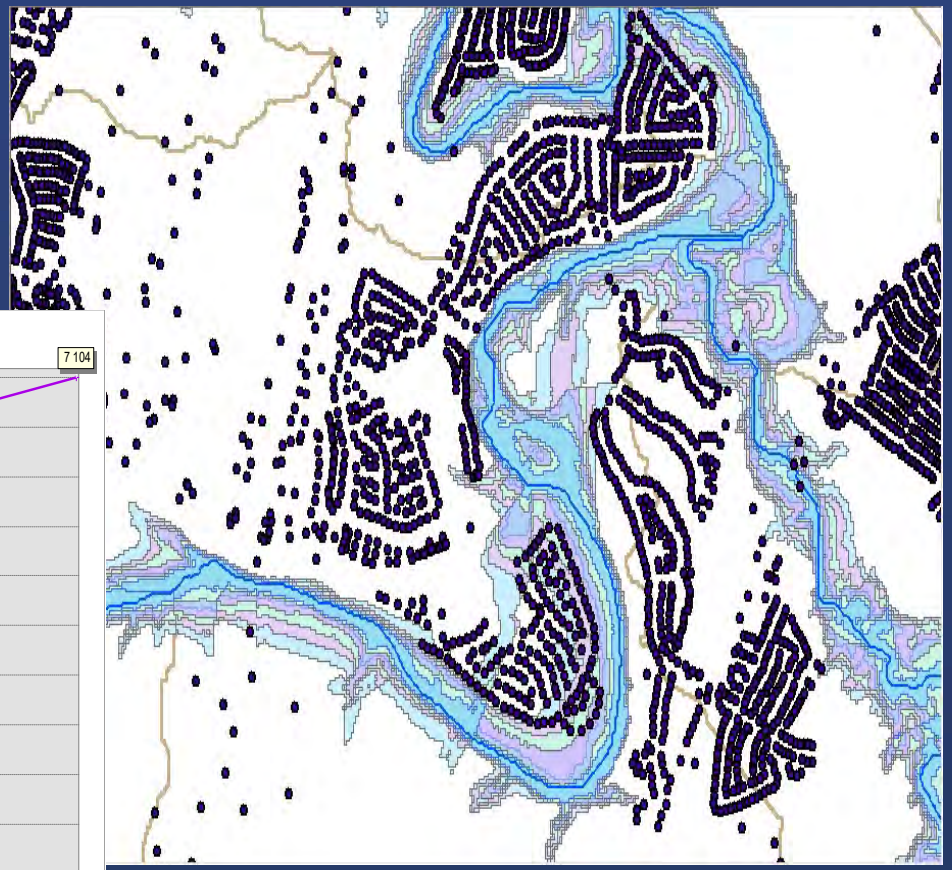
- Missouri Water Data Hub
  - MRMS National Severe Storms Laboratory
    - *Multi-Radar Multi-Sensor Q2 MPE product: 15 min 1km*
  - HRRR National Center for Environmental Prediction
    - *High-Resolution Rapid Refresh QPF: 15min 2.5km*
- Adapting NWM Forecast Data to Local H&H Models
  - NWM flows translated with synthetic rating curves
  - Flood inundation mapping
- SCIRA

Locally map the runoff forecast

Relate stage to local topography and impact with synthetic rating curves

Relating stage/water surface elevation to depth and extent of flooding and to affected addresses

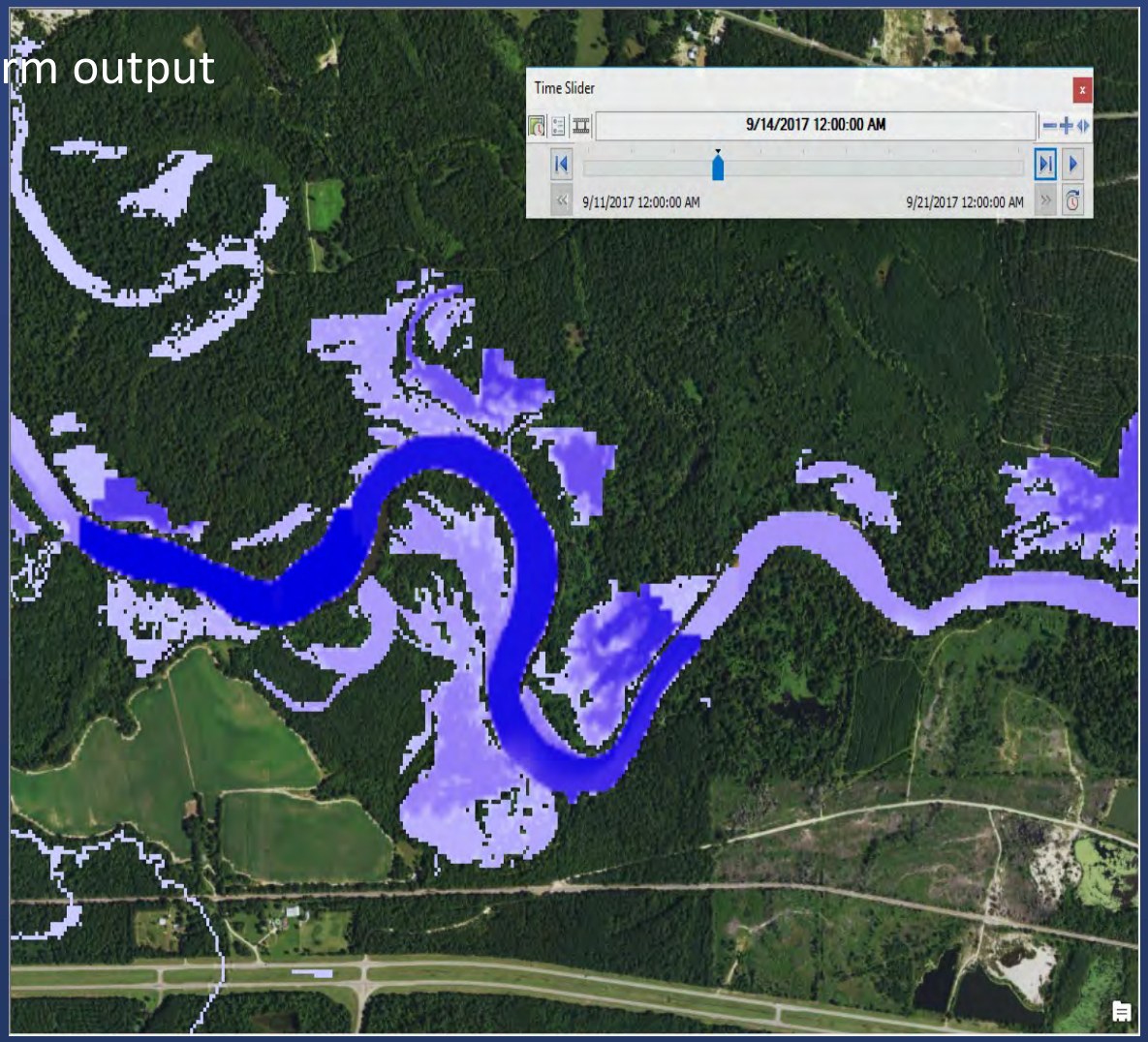




Reference: ESRI

Flood depth mapping – utilizing time

- NHDPlusHR – based
- NWM near-term output



Reference: ESRI

- Developing observational apps from St. Louis sensor deployment.

OGC®
Making location count.
The Open Geospatial Consortium

Discussion / Feedback

Contact by E-mail: John@McEneryWater.com