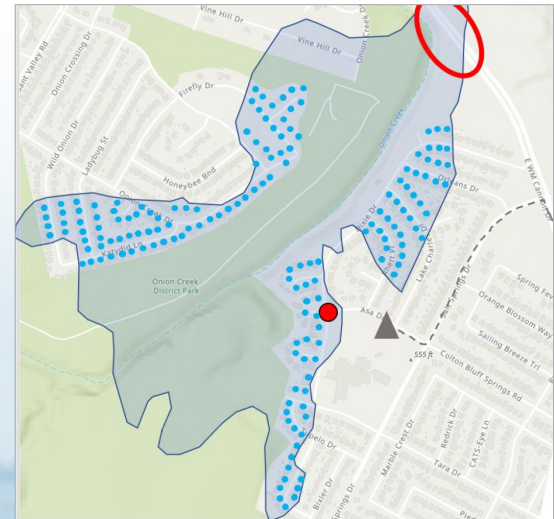
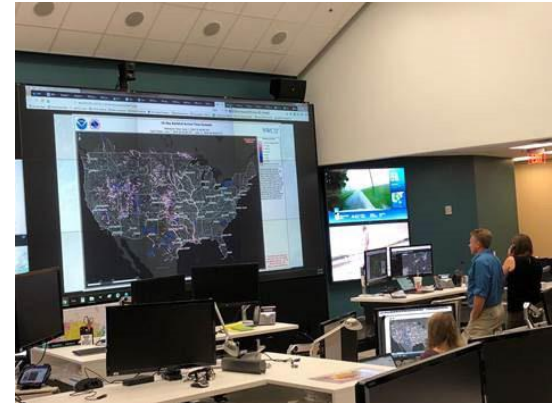


Mapping for Real-Time Flood Emergency Response

From National ... to ... Local

Presented by David R. Maidment
Center for Water and the Environment
University of Texas at Austin

ESRI Water Resources and Hydro Meeting
San Diego, CA
10 July 2022

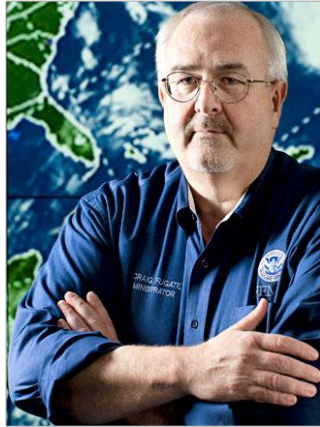


Acknowledgments: National Water Center, Texas Department of Transportation
Christine Thies, UT Austin

Conversations in 2013 – 2014

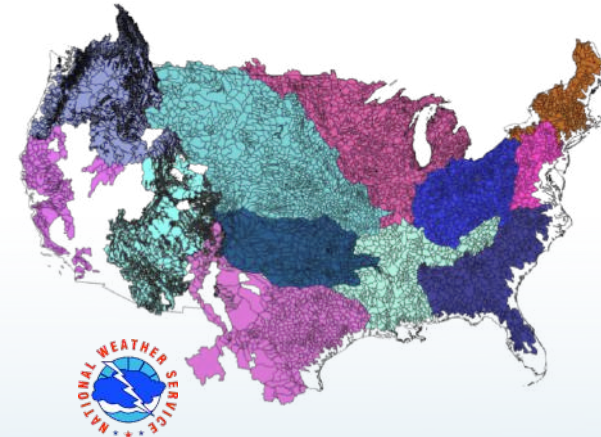


Jack Dangermond
President, ESRI

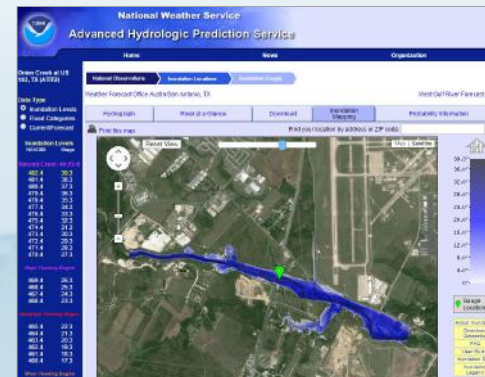


Craig Fugate
FEMA
Administrator

“We need a *national* system for flood forecasting and real-time inundation mapping”



Regional flood forecasting
for large watersheds



Flood Inundation mapping
at some forecast points



“Yes, Jack,
but not yet”

“Can we
do better?”

National Flood Forecasting



Established in 2014 in Tuscaloosa, AL

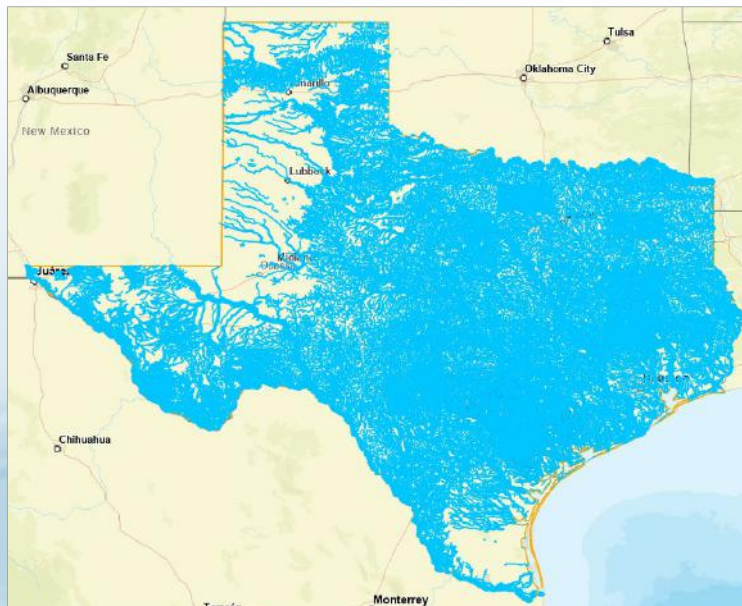


National Water Model

Water forecast like weather 24/7/365

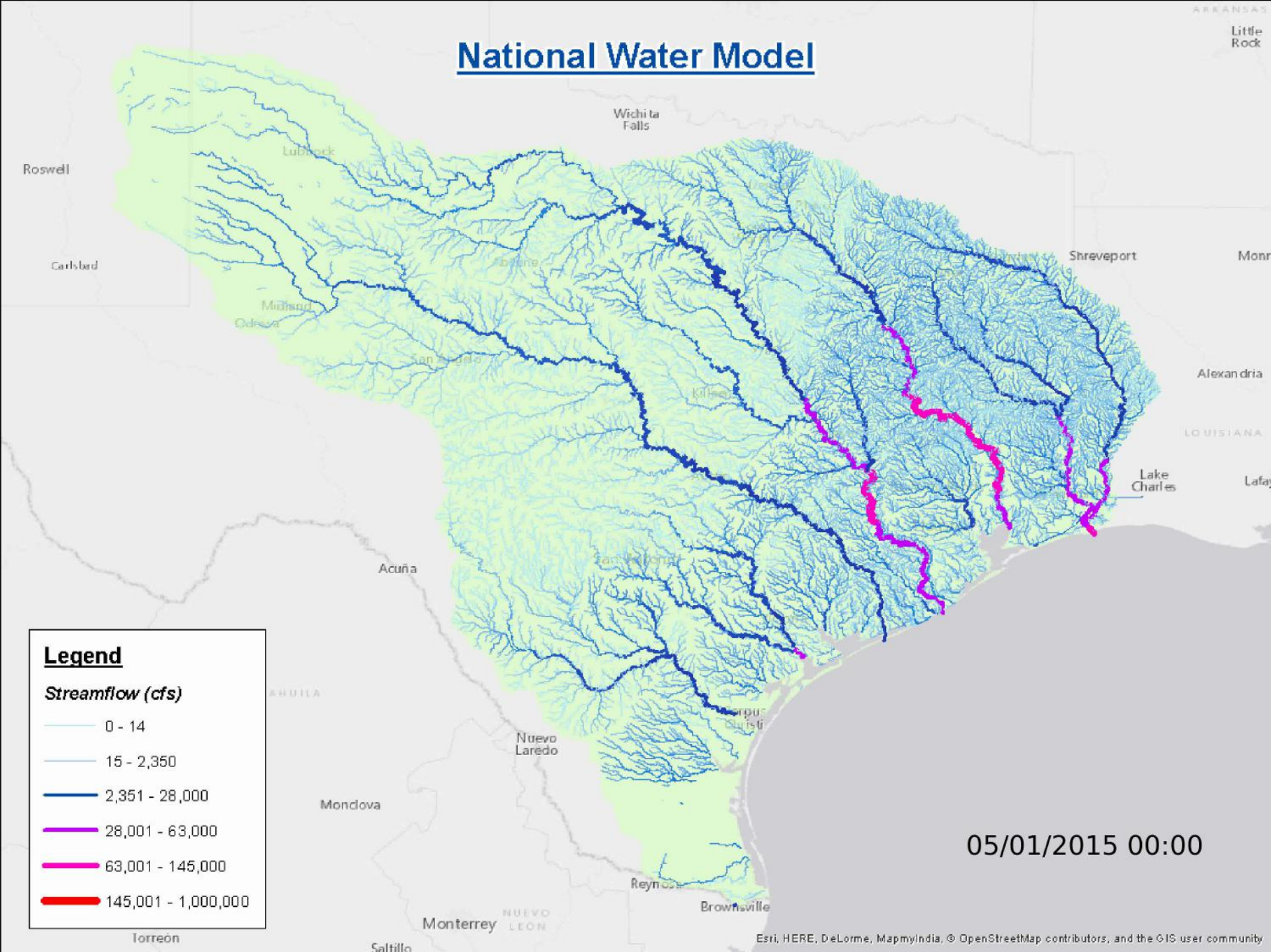
Four model outputs:

- **Assimilation** (Current conditions)
- **Short Range Forecast** (18 hours ahead)
- **Medium Range** (10 days ahead)
- **Long Range Forecast** (30 days ahead)



Water flow forecasts on 190,000 miles of streams and rivers in Texas

National Water Model



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

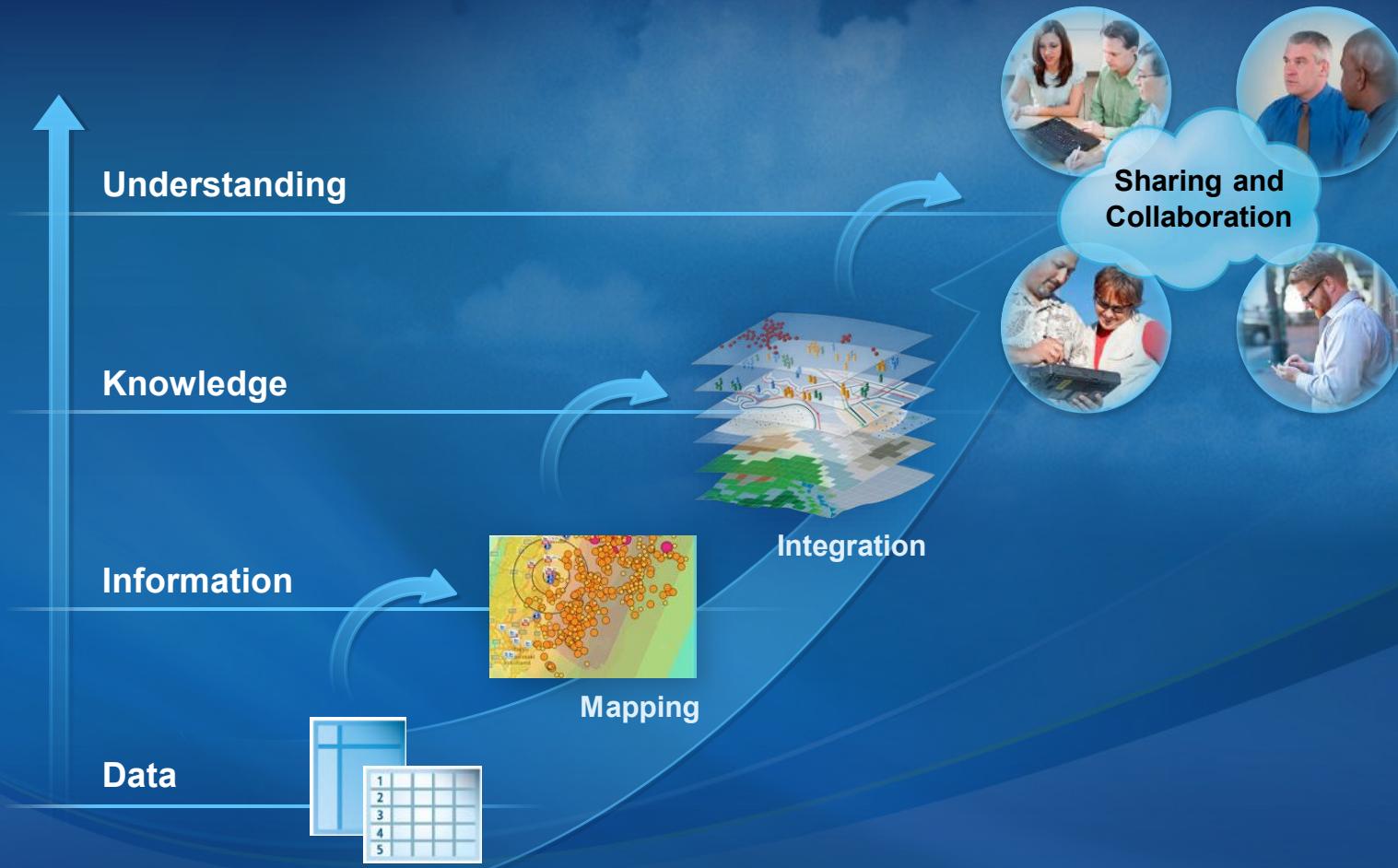
Operations Room at the National Water Center



Geospatial Systems Are Helping Us Understand



Slide: Jack Dangermond



... Helping Us Make Better Decisions

40 New Water Forecast Map Services

<https://maps.water.noaa.gov/server/rest/services>

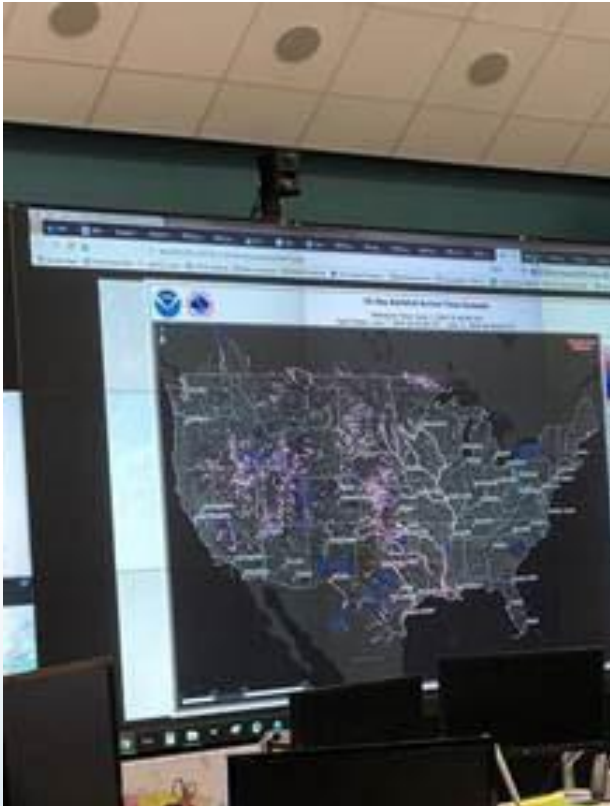
Free and publicly available

Medium Range Forecast	21 Maps
Rapid onset flooding	10 Day Arrival Time
	10 Day Duration
	Length flooded
Rapid onset probability	Day 1 probability
	Day 2 probability
	Day 3 probability
	Days 4-5 probability
	Days 1-5 probability
High water arrival time	Days 1-5 hotspots
	3-Day arrival time
	10 Day arrival time
High flow magnitude	10 Day end time
	3-Day Annual Exceedance Probability (AEP)
	5-Day AEP
High water probability	10-Day AEP
	Day 1
	Day 2
	Day 3
	Days 4-5
	Days 1-5
	Days 1-5 Hotspots

Short Range Forecast	12 Maps
Rapid onset flooding	18 hour arrival time
	18 hour duration
	18 hour length flooded
Rapid onset flooding probability	Hours 1-6 probability
	Hours 7-12 probability
	Hours 1-12 probability
High water arrival time	Hours 1-12 hotspots
	18 hour arrival time
	18 hour end time
High flow magnitude	18 hour AEP
High water probability	12 hour high water probability
	12 hour Hotspots
Current and Past Conditions	5 Maps
High flow magnitude	Annual exceedance probability
Anomaly	7-Day Average Streamflow Percentile
	14-Day Average Streamflow Percentile
Past 14 day Max high flow magnitude	Past 7-days AEP
	Past 14 days AEP
Main stem river forecasts	2 Maps
Forecast point	Max status -- forecast trend
Downstream river	

Through open water services everyone can see ...

<https://www.weather.gov/owp/operations>



Medium Range Forecast	21 Maps		
Rapid onset flooding	10 Day Arrival Time		
	10 Day Duration		
	Length flooded	Short Range Forecast	12 Maps
Rapid onset probability	Day 1 probability	Rapid onset flooding	18 hour arrival time
	Day 2 probability		18 hour duration
	Day 3 probability		18 hour length flooded
	Days 4-5 probability	Rapid onset flooding probability	Hours 1-6 probability
	Days 1-5 probability		Hours 7-12 probability
	Days 1-5 hotspots		Hours 1-12 probability
High water arrival time	3-Day arrival time		Hours 1-12 hotspots
	10 Day arrival time	High water arrival time	18 hour arrival time
	10 Day end time		18 hour end time
High flow magnitude	3-Day Annual Exceedance Probability	High flow magnitude	18 hour AEP
	5-Day AEP	High water probability	12 hour high water probability
	10-Day AEP		12 hour Hotspots
High water probability	Day 1	Current and Past Conditions	5 Maps
	Day 2	High flow magnitude	Annual exceedance probability
	Day 3	Anomaly	7-Day Average Streamflow Percentile
	Days 4-5		14-Day Average Streamflow Percentile
	Days 1-5	Past 14 day Max high flow magnitude	Past 7-days AEP
	Days 1-5 Hotspots		Past 14 days AEP
		Main stem river forecasts	2 Maps
		Forecast point	Max status -- forecast trend
		Downstream river	



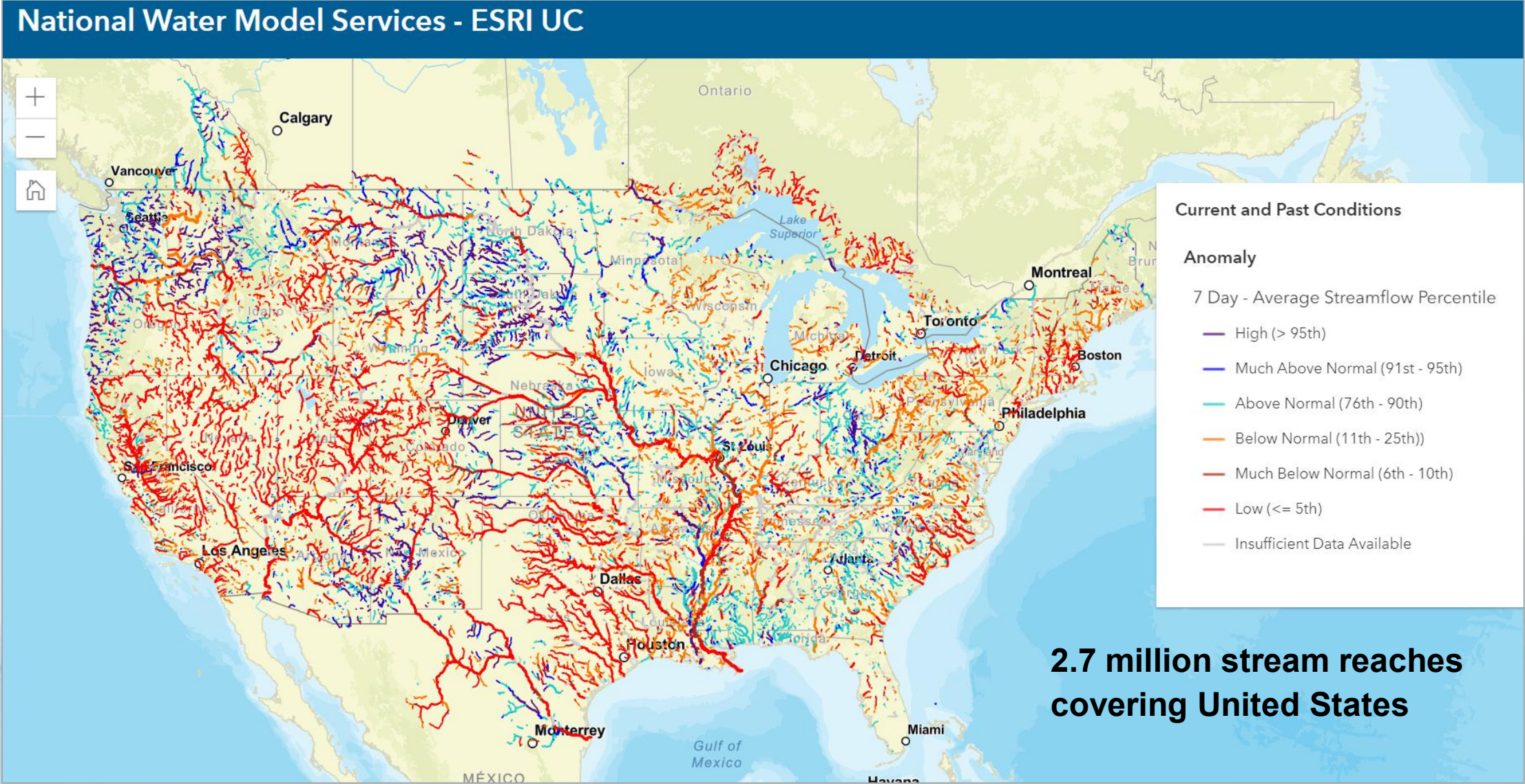
NWC Visualization Services

Experimental geospatial services depicting forecasts from the River Forecast Centers and the National Water Model. Services available via the prototype NWS National Map Viewer, or directly via URLs hosted on the Hydrologic Visualization and Inundation Services (HydroVIS) cloud resource. Refer to the "Public Handbook" for additional details.

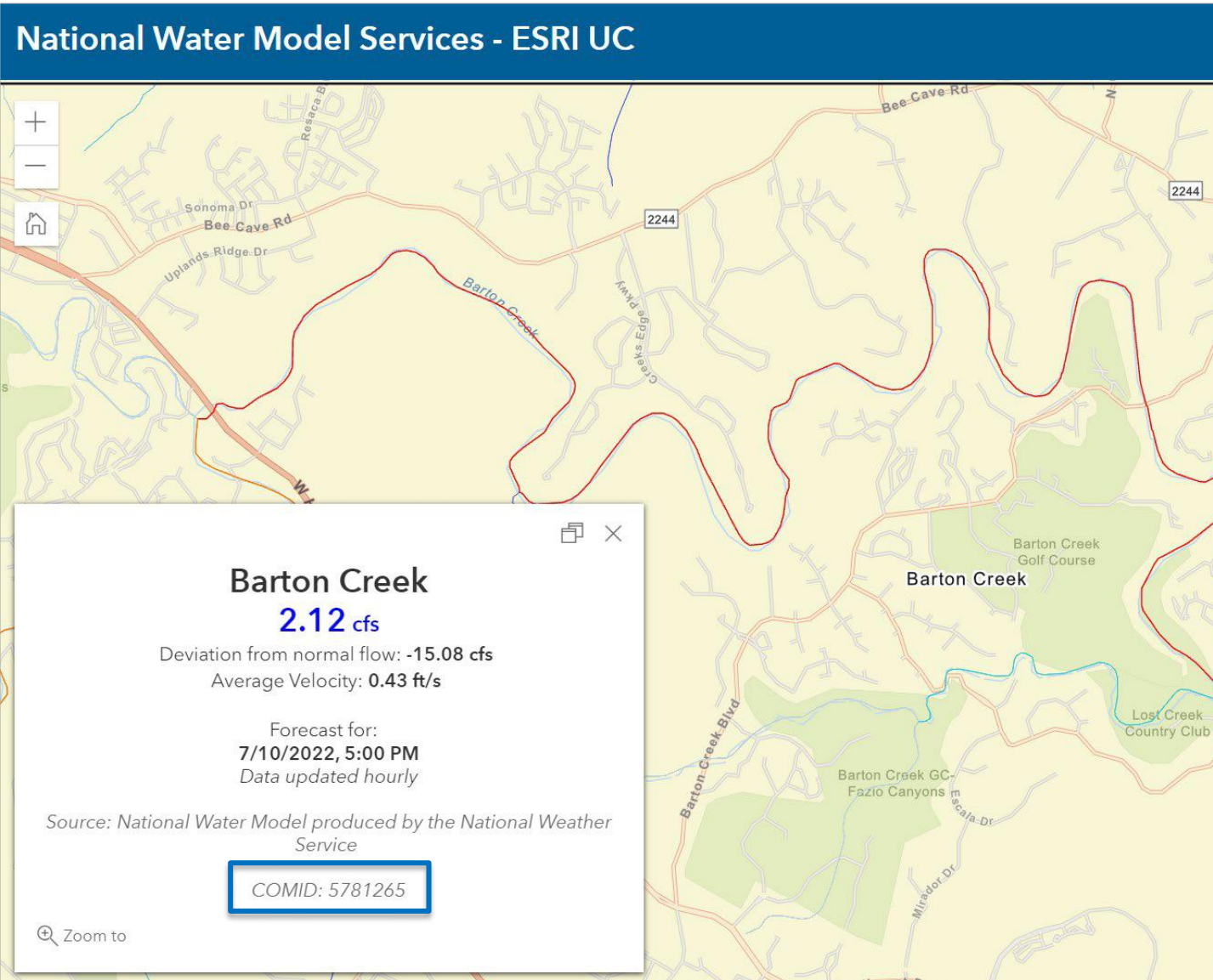
... what is seen at the National Water Center

Water Flow Anomaly – Comparison with Average Flow Conditions

Average for last 7 days



ESRI Living Atlas Water Flow Map -- Conditions at *Local Scale*



- ESRI Living Atlas
- National Water Model (Hourly Forecast)

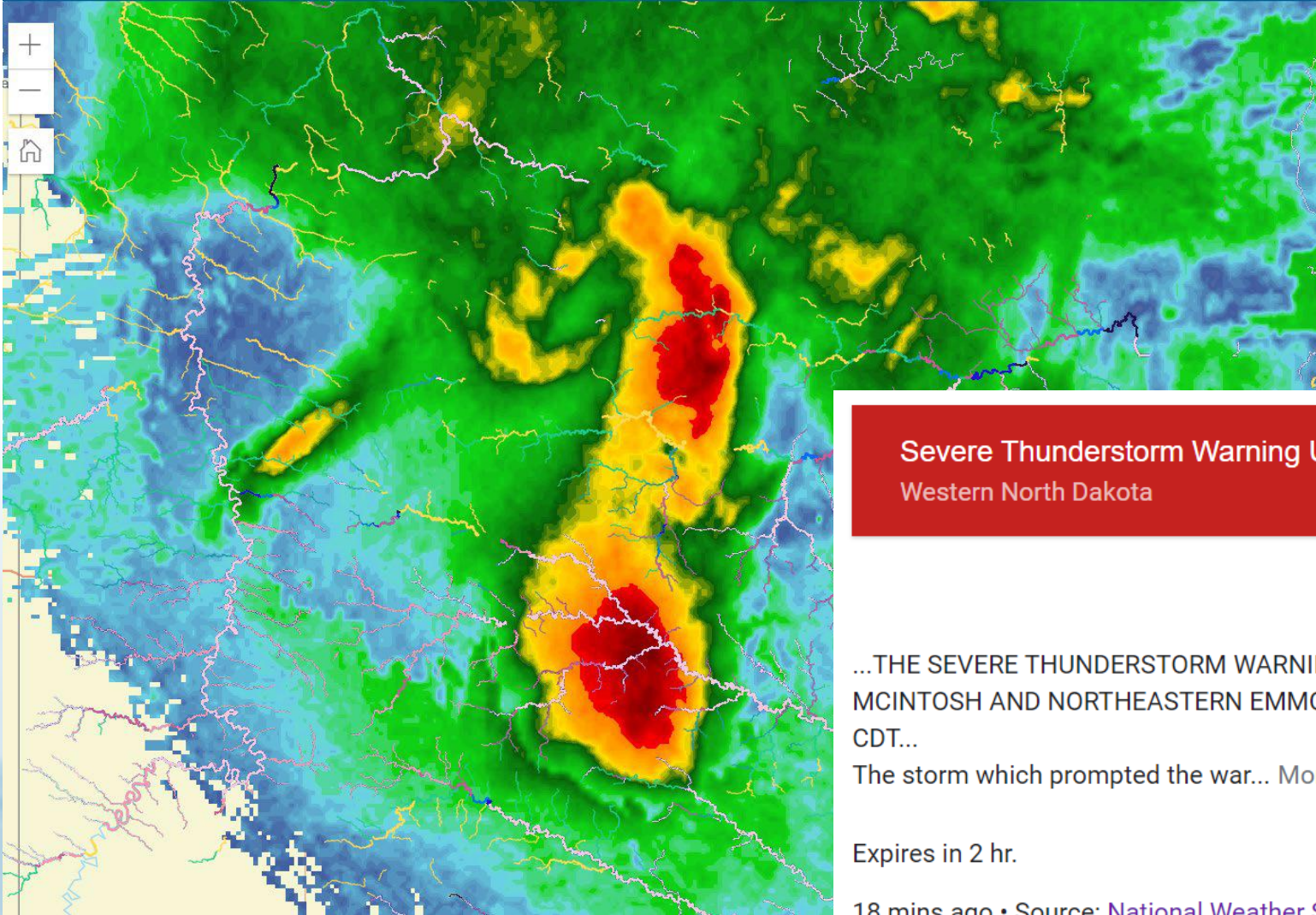
Barton Creek is near my home in Austin, Texas

It is reach 5781265 in the national stream network

Forecast for:
7/10/2022, 5:00 PM
Data updated hourly

A Storm Occurring in North Dakota this Morning (10 July 2022)

National Water Model Services - ESRI UC



Severe Thunderstorm Warning Update

Western North Dakota



...THE SEVERE THUNDERSTORM WARNING FOR WESTERN LOGAN...NORTHWESTERN MCINTOSH AND NORTHEASTERN EMMONS COUNTIES WILL EXPIRE AT 615 AM CDT...

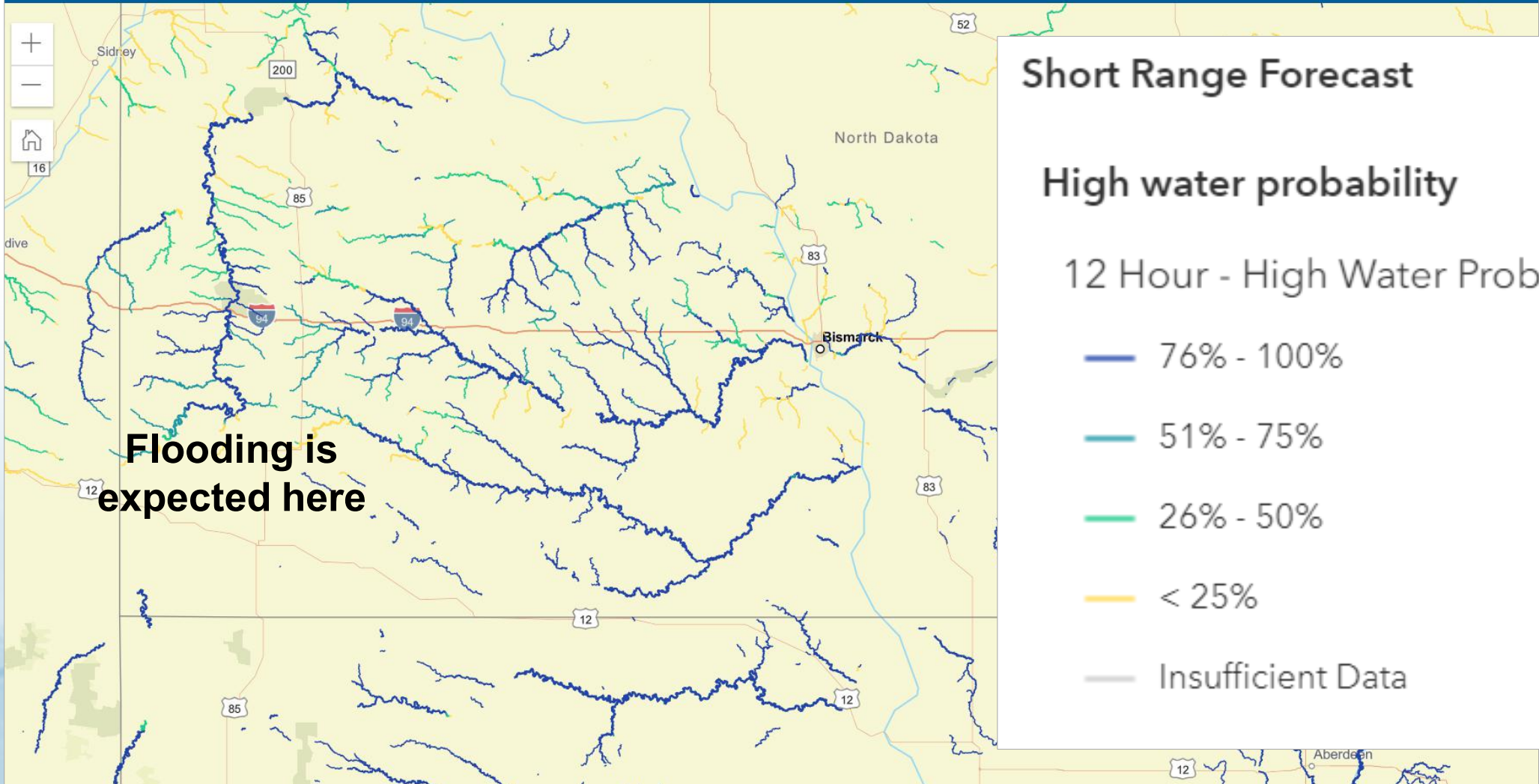
The storm which prompted the war... [More](#) ▾

Expires in 2 hr.

18 mins ago • Source: [National Weather Service](#)

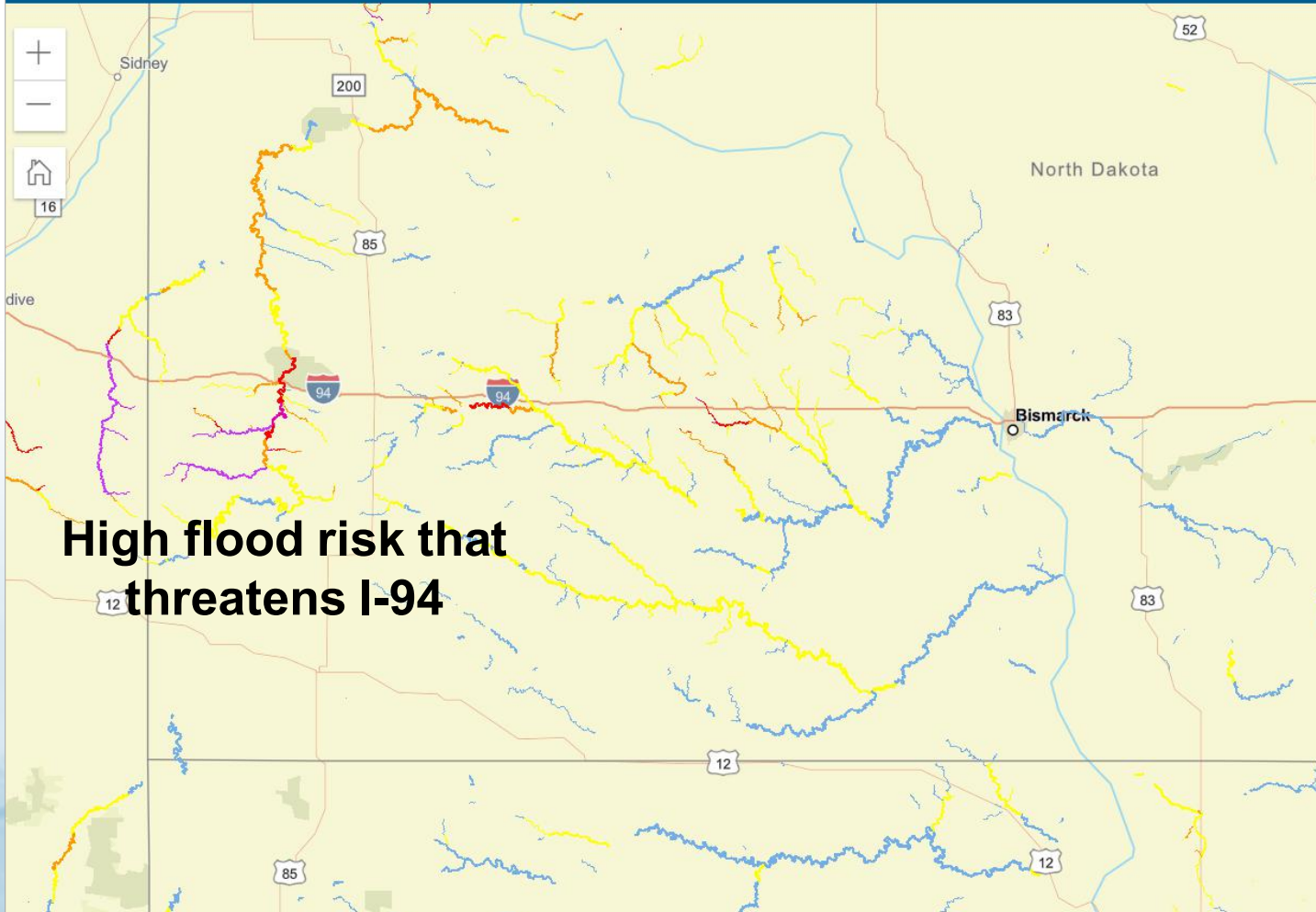
Probability of High Water in Next 12 Hours

National Water Model Services - ESRI UC



High Flow Magnitude Measured as Annual Exceedance Probability

National Water Model Services - ESRI UC



Short Range Forecast

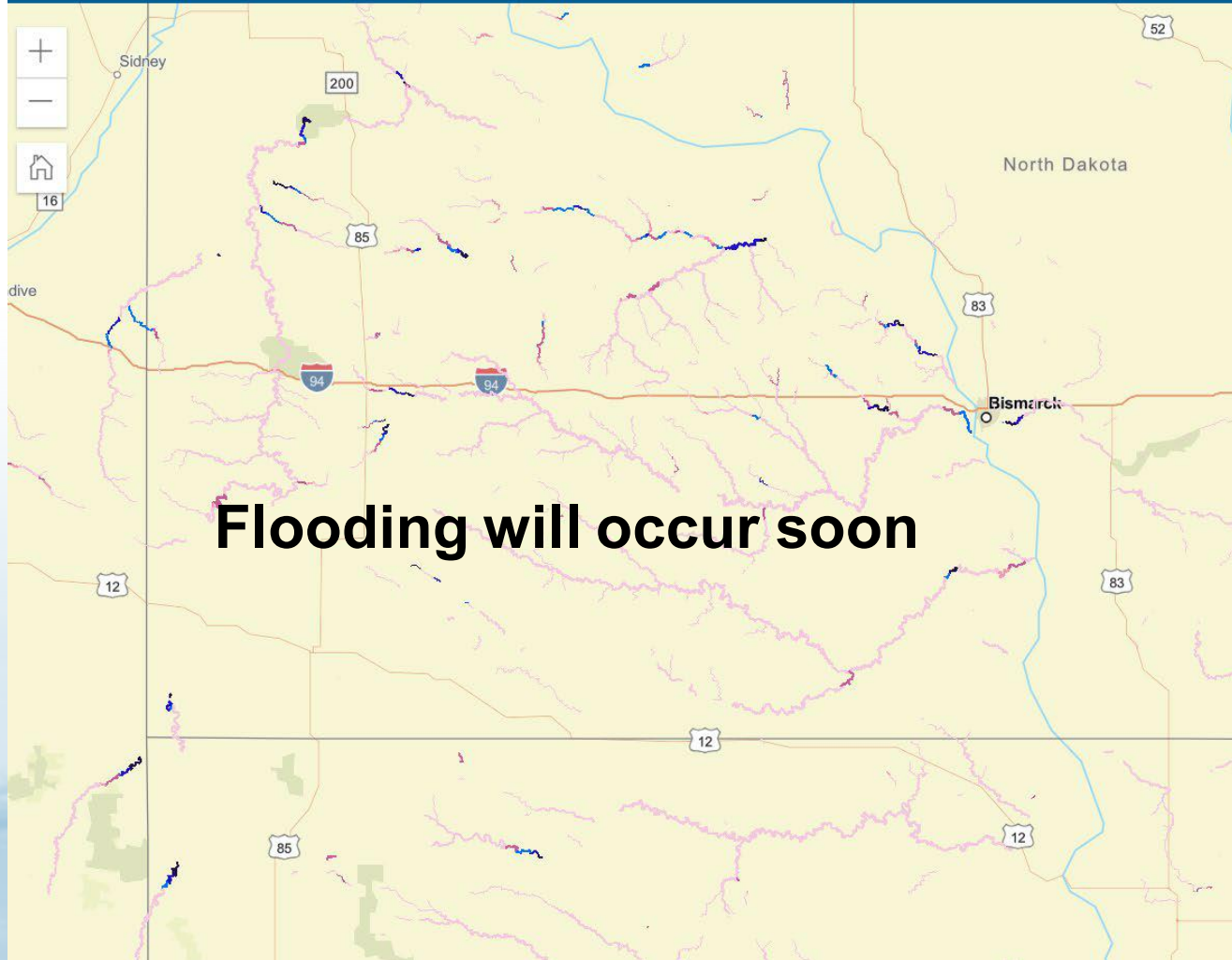
High flow magnitude

18 Hour - Est. Annual Exceedance Probability

- 2%
- 4%
- 10%
- 20%
- 50%
- > 50% AND > High Water Threshold
- Insufficient Data

High Water Arrival Time

National Water Model Services - ESRI UC



Short Range Forecast

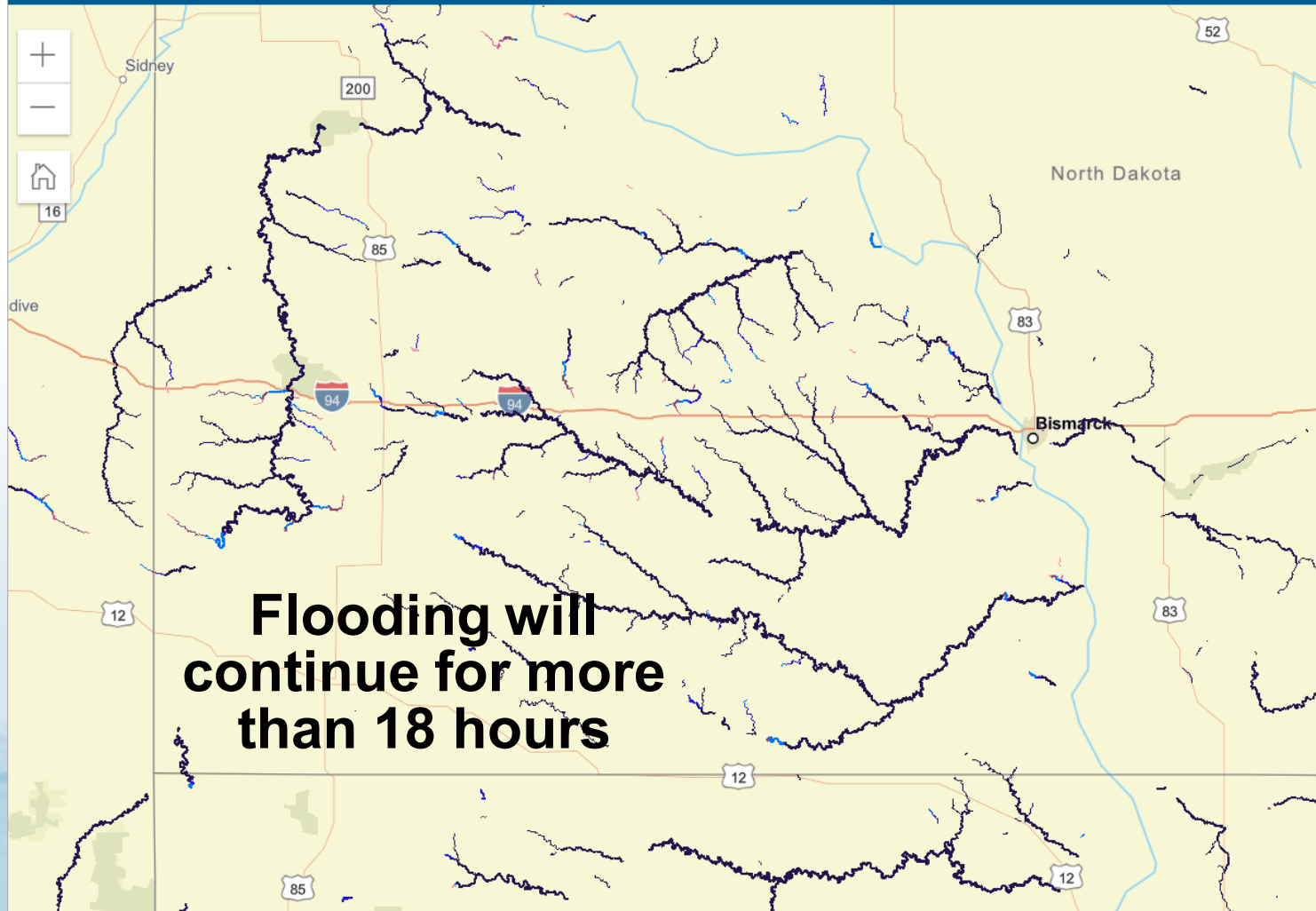
High water arrival time

18 Hour - High Water Arrival Time

- Ongoing or 1 hour
- 2 hours
- 3 hours
- 4 - 6 hours
- 7 - 9 hours
- 10 - 13 hours
- 14 - 18 hours
- Insufficient Data

Ending Time of High Water (Short Range Forecast up to 18 hours ahead)

National Water Model Services - ESRI UC



Short Range Forecast

High water arrival time

18 Hour - High Water End Time

- 1 hour
- 2 hours
- 3 hours
- 4 - 6 hours
- 7 - 9 hours
- 10 - 13 hours
- 14 - 18 hours or Beyond Forecast
- Insufficient Data

Ending Time of High Water (Medium Range Forecast up to 10 days ahead)

National Water Model Services - ESRI UC



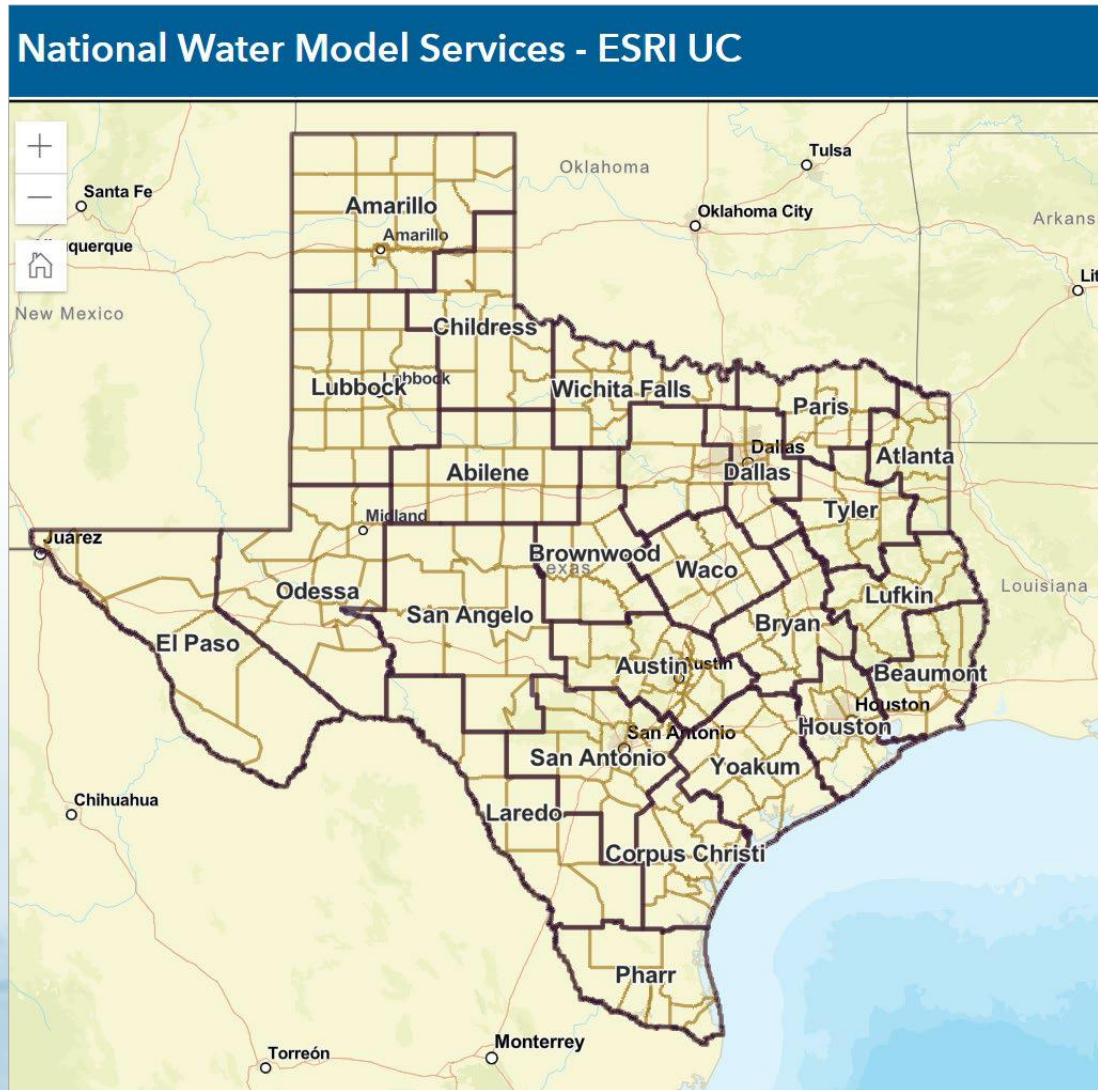
Medium Range Forecast








High water arrival time

10-Day High Water End Time

- 3 - 12 hours
- 13 - 24 hours
- 25 - 48 hours
- 3 days
- 4 - 5 days
- 6 - 7 days
- 8 - 10 days or Beyond Forecast
- Insufficient Data

Flood Web Map Services for Texas Department of Transportation



- ▶  Medium Range Forecast
- ▶  Short Range Forecast
- ▶  Current and Past Conditions
- ▶  Recent Weather Radar Imagery
- ▶  Main Stem River Forecasts
- ▶  ESRI Living Atlas
- ▶  TxDOT Reference Layers

Texas Department of Transportation

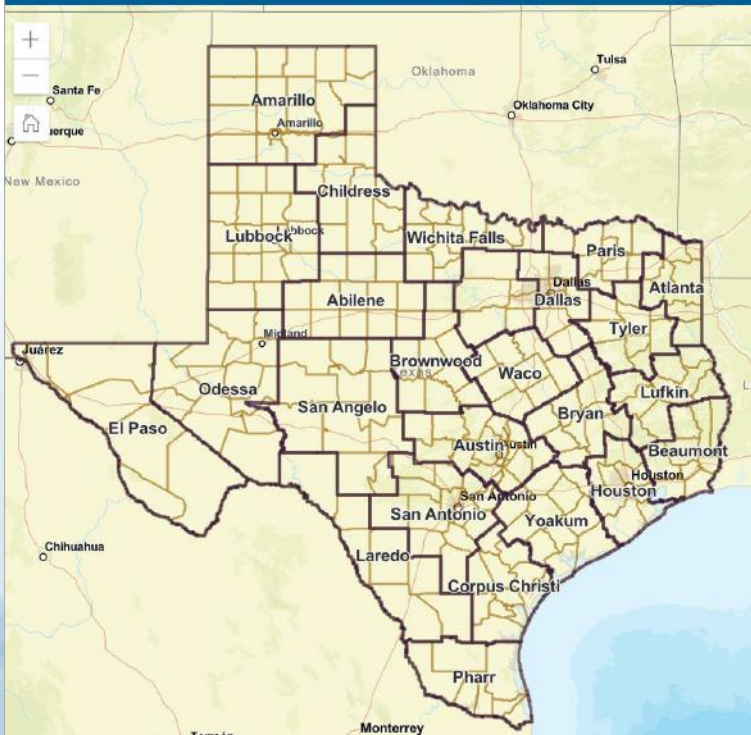
👁 TxDOT_Districts

👁 TxDOT Maintenance Sections

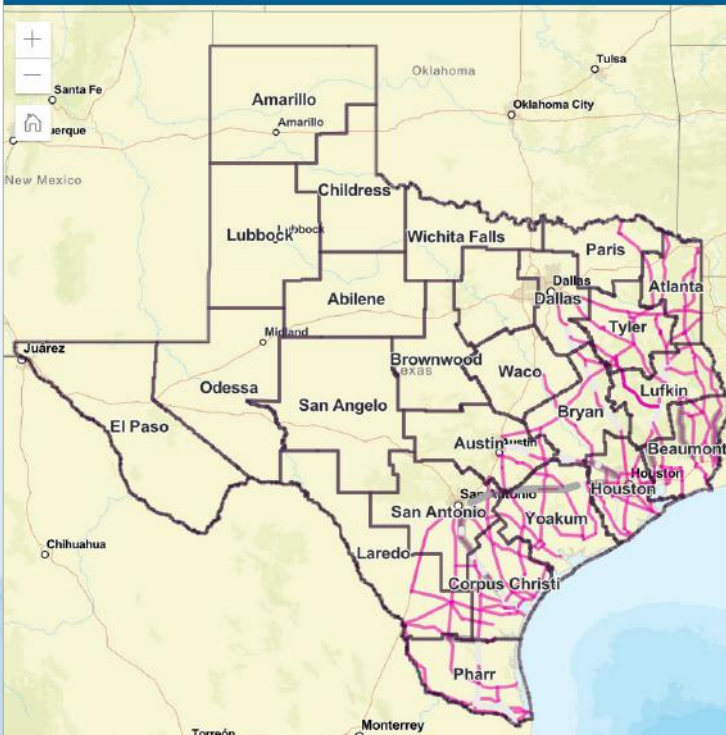
👁 TxDOT Evacuation Routes

👁 Scour Critical Bridges

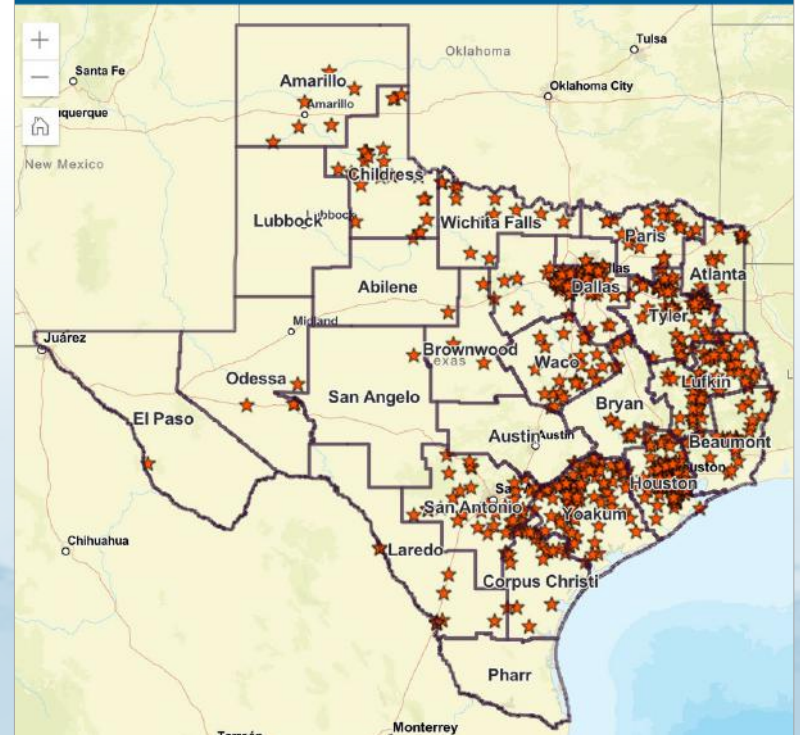
National Water Model Services - ESRI UC



National Water Model Services - ESRI UC



National Water Model Services - ESRI UC



TxDOT wants to move from Reactive response to Proactive response

Reactive Response

Maintenance Staff
observing **current**
flood conditions



EOC staff



Decisions based on
current conditions

TxDOT wants to move from Reactive response to Proactive response

Proactive Response

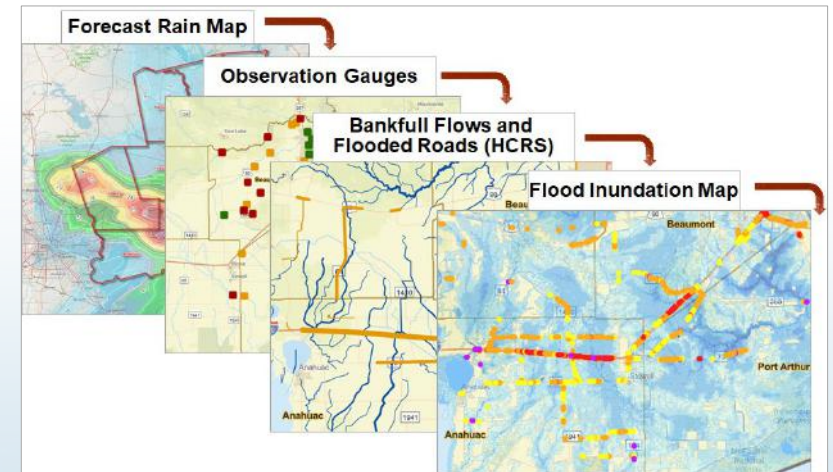
Maintenance Staff observing **current flood conditions**



EOC staff



Predictive Storm and Flood Maps



Decisions based on current and predicted conditions

Advance warning of location, extent and severity of flooding

Some Thoughts I have Heard

“It’s the guys in the field who tell us what’s going on”

Keith Horn, Logistics Coordinator, BMT

“I want technology to be my eyes on the landscape”

Martin Gonzalez, District Engineer, BMT

“We want to move from being reactive to being proactive”

Chris Henry, Director of Maintenance, BMT

“We need all the data in one place”

Eliza Paul, District Engineer, HOU

“I want to know if there’s going be another Harvey”

Eliza Paul, District Engineer, HOU

“We could close IH-10 in 3-6 hours”

Chris Henry, Director of Maintenance, BMT

“At the SOC, we need warning 24-48 hours in advance”

Jared Browder, Maintenance Assessment Specialist, MNT

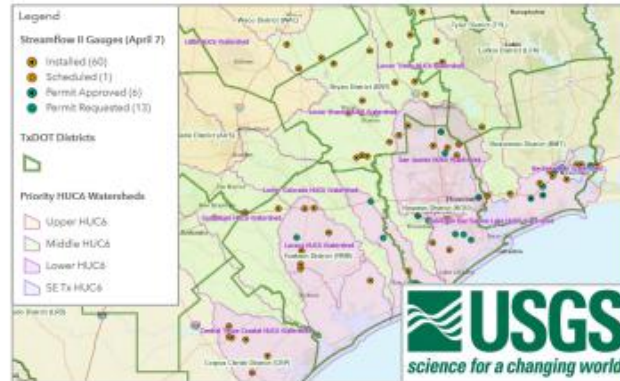
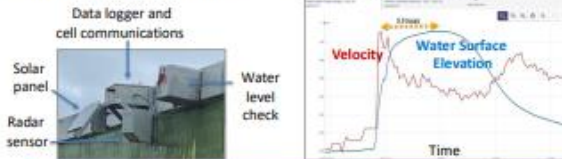


Flood Forecasting Project with Texas Department of Transportation

Streamflow Measurement ...

Radar gauges measure both water surface elevation and velocity

- Discharge = velocity * cross-section area
- Install on bridge in 3 hours
- Solar power and cell phone communications



... using radar gauges on 80 TxDOT bridges

Emergency Response ...

Move from reactive to proactive response

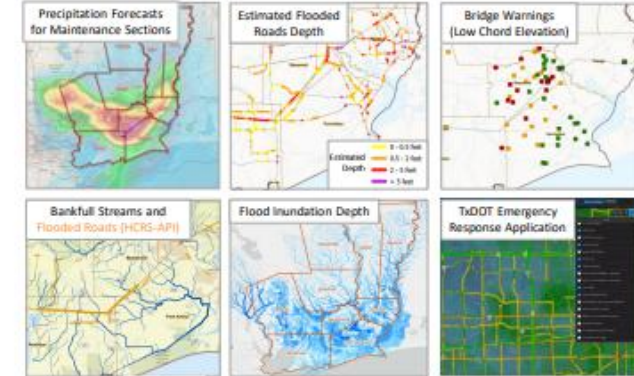
Infrastructure Investment and Jobs Act

Definition of Resilience

"Ability to anticipate, prepare for, and adapt to changing conditions, and to withstand, respond to, and recover quickly from disruptions."



Maps from an emergency response exercise in Beaumont District for Tropical Storm Imelda



... using web maps in TxERA

Flood Forecasting ...

Forecast the discharge on 190,000 miles of streams and rivers in Texas

- Impacts on 64,000 Texas bridges including 26,000 On-System bridges
- Operates 24/7/365
- Updated hourly

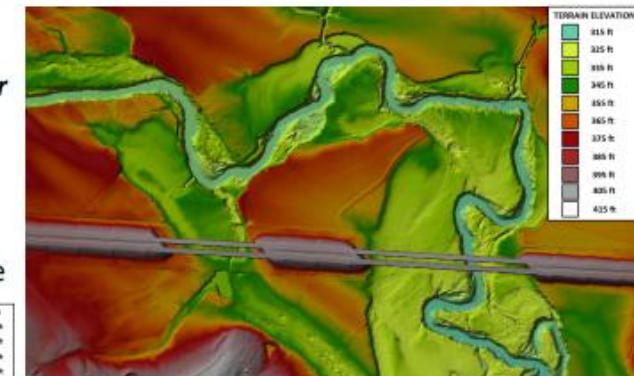
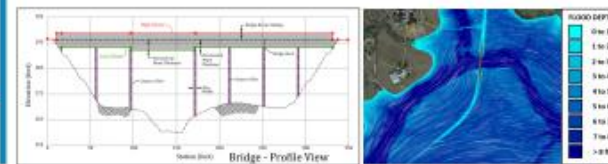


... using the National Water Model

Hydraulic Modeling ...

Use 2D HEC-RAS to convert discharge to water surface elevation

- Compute water surface elevation at bridges
- Map water depth over landscape and roads
- Detailed modeling from plans at key bridges
- Approximate modeling using LIDAR elsewhere

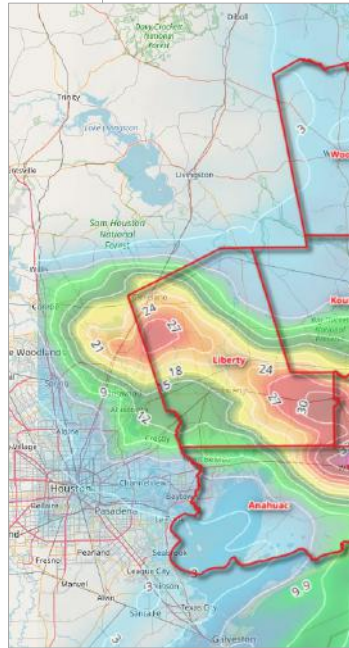


... using LIDAR data on bridges and roads

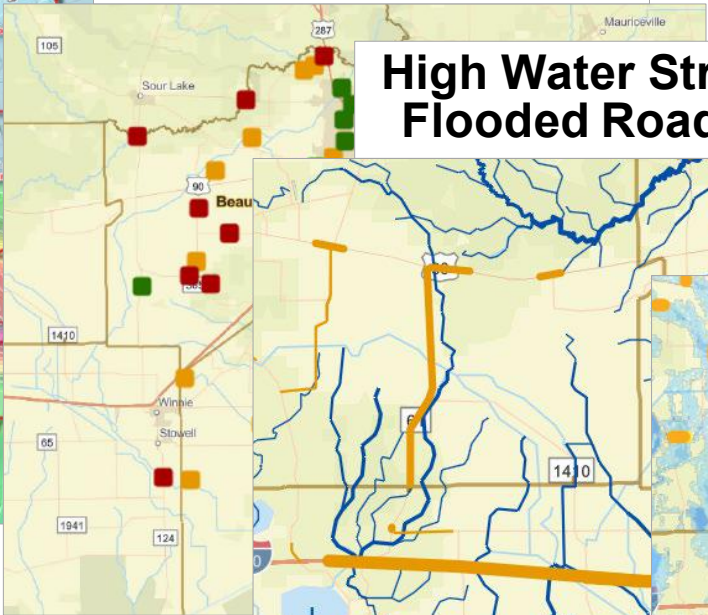
Largest research project ever supported by TxDOT (\$6.38 million)

Rainmap in the Sky to Floodmap on the Ground

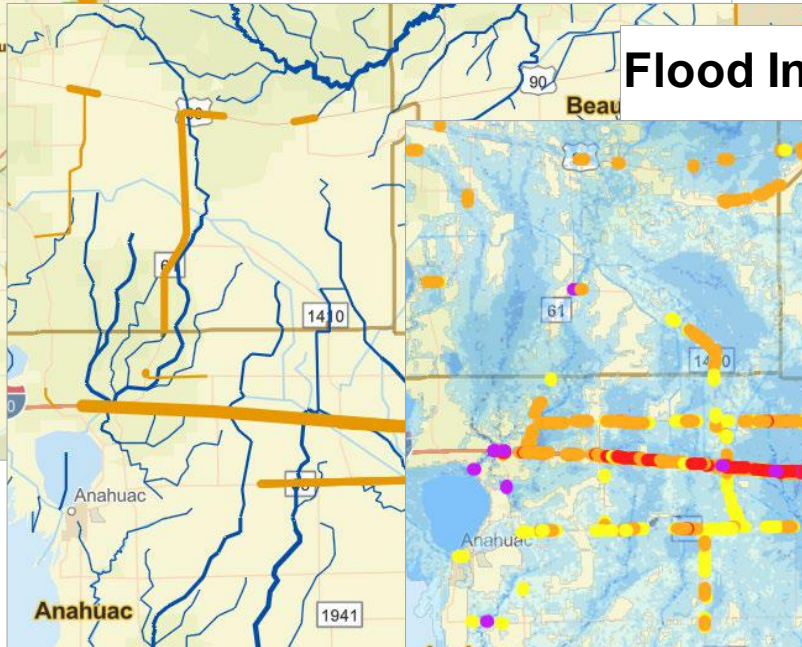
Forecast Rain Map



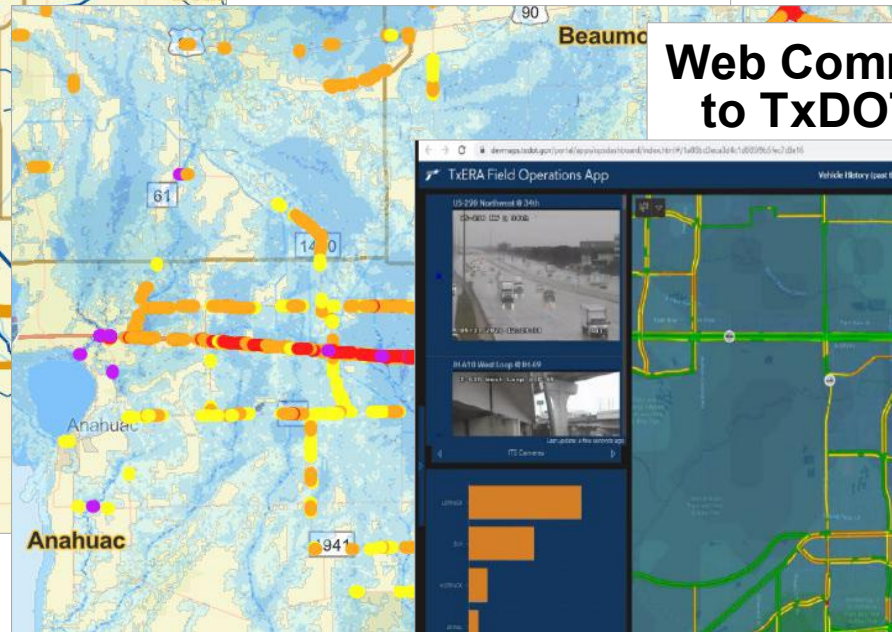
Observation Gauges



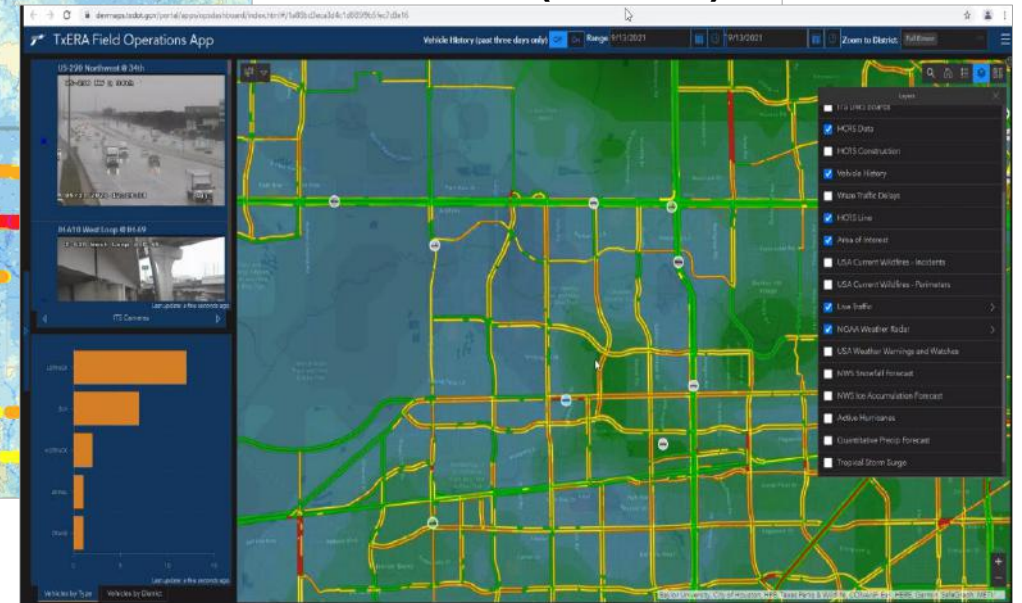
High Water Streams and Flooded Roads (HCRS)



Flood Inundation Map



Web Communication to TxDOT (TxERA)

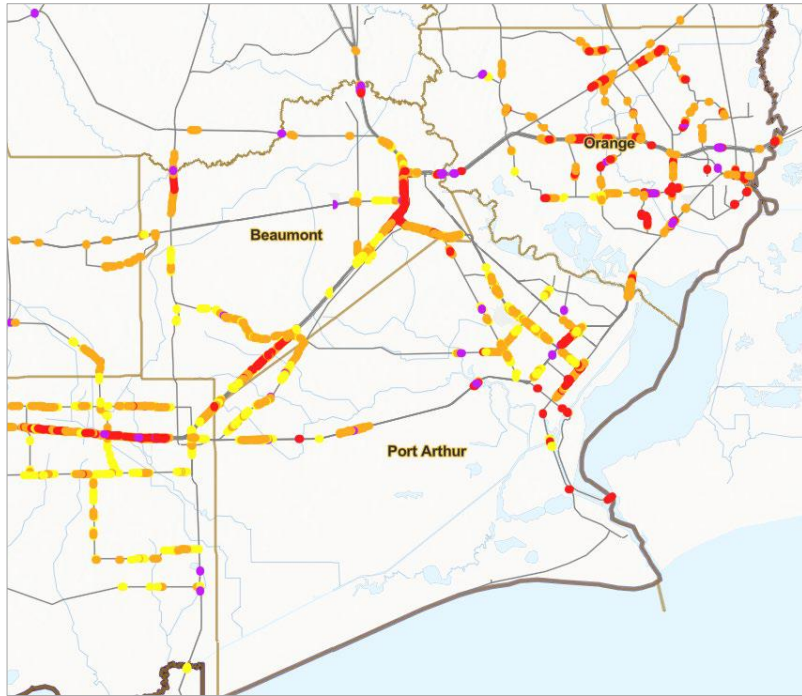


Maps accessible through ESRI StoryMap
<https://arcg.is/0LLLXX>

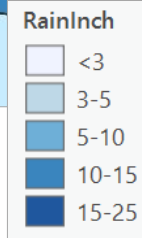
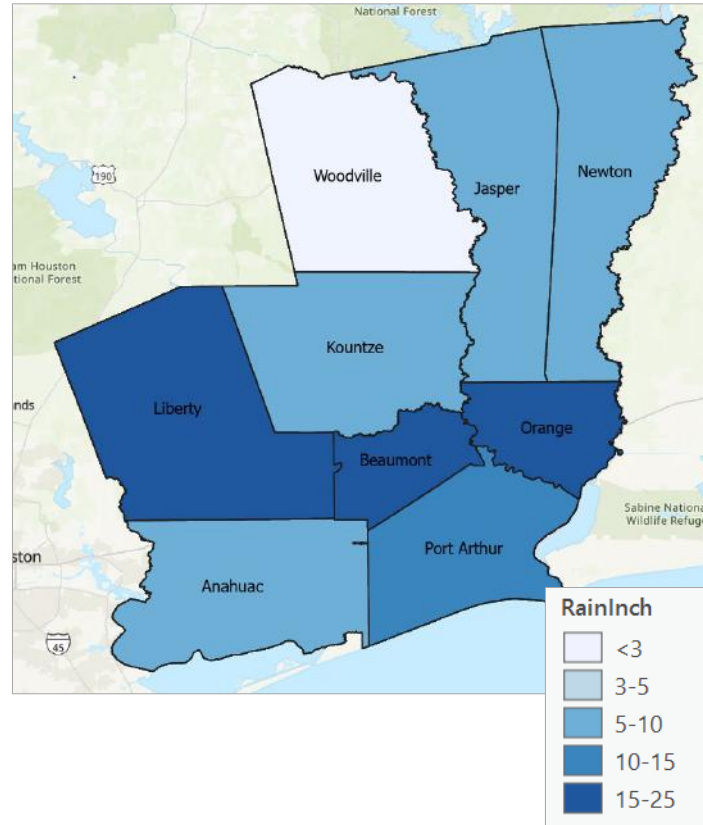
Maps prepared for a flood emergency response exercise in Beaumont District of TxDOT February 2022

Top New Products

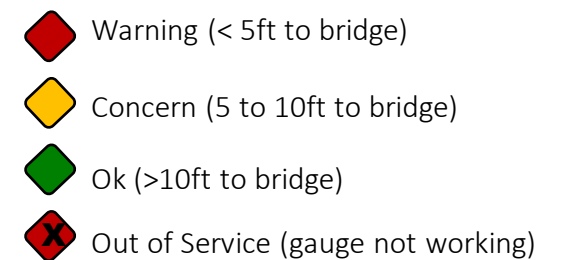
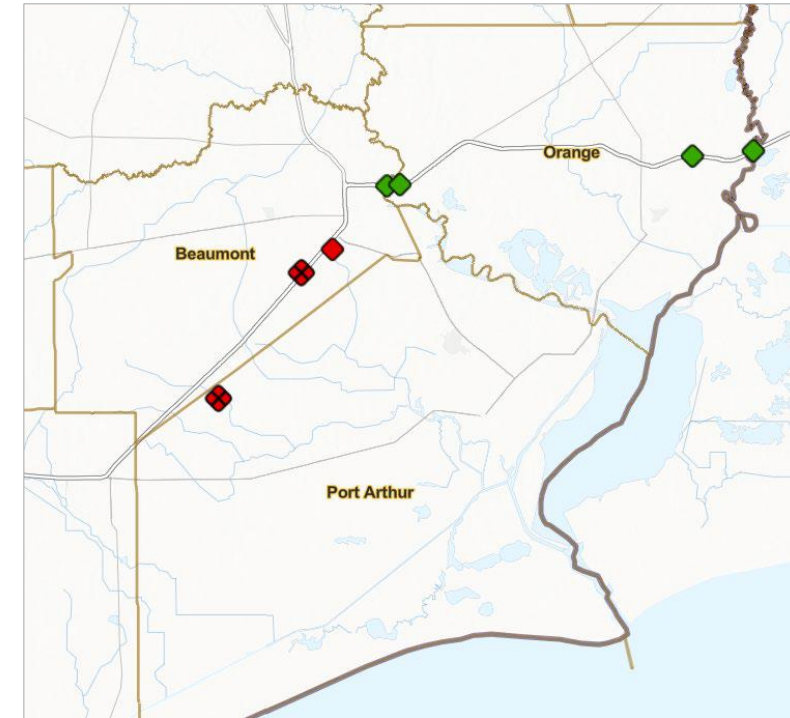
Flooded Road Estimates



Precipitation Forecast by Section



Bridge Warnings



Predictive and Observational Flood Inundation Mapping

West Gulf River
Forecast Center



State Operations Center



State Operations Center

Local EOC

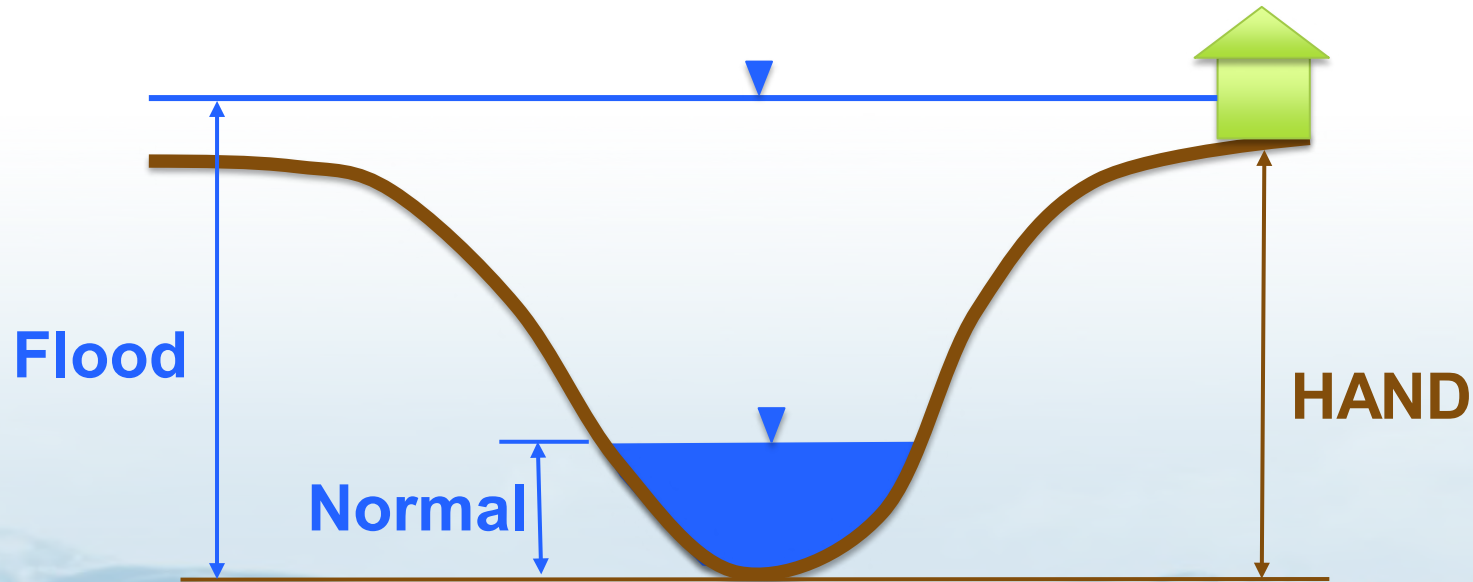
First responders in field



NWC Flood Inundation Map Services are based on ...

Height Above Nearest Drainage (HAND)

*Flooding occurs when **Water Depth** is greater than **HAND***



Pin2Flood on Onion Creek

14 October 2021



**Based on Height Above
Nearest Drainage (HAND)
and 1m LIIDAR DEM**

During Flood – Common Operating Picture



During Flood – Common Operating Picture

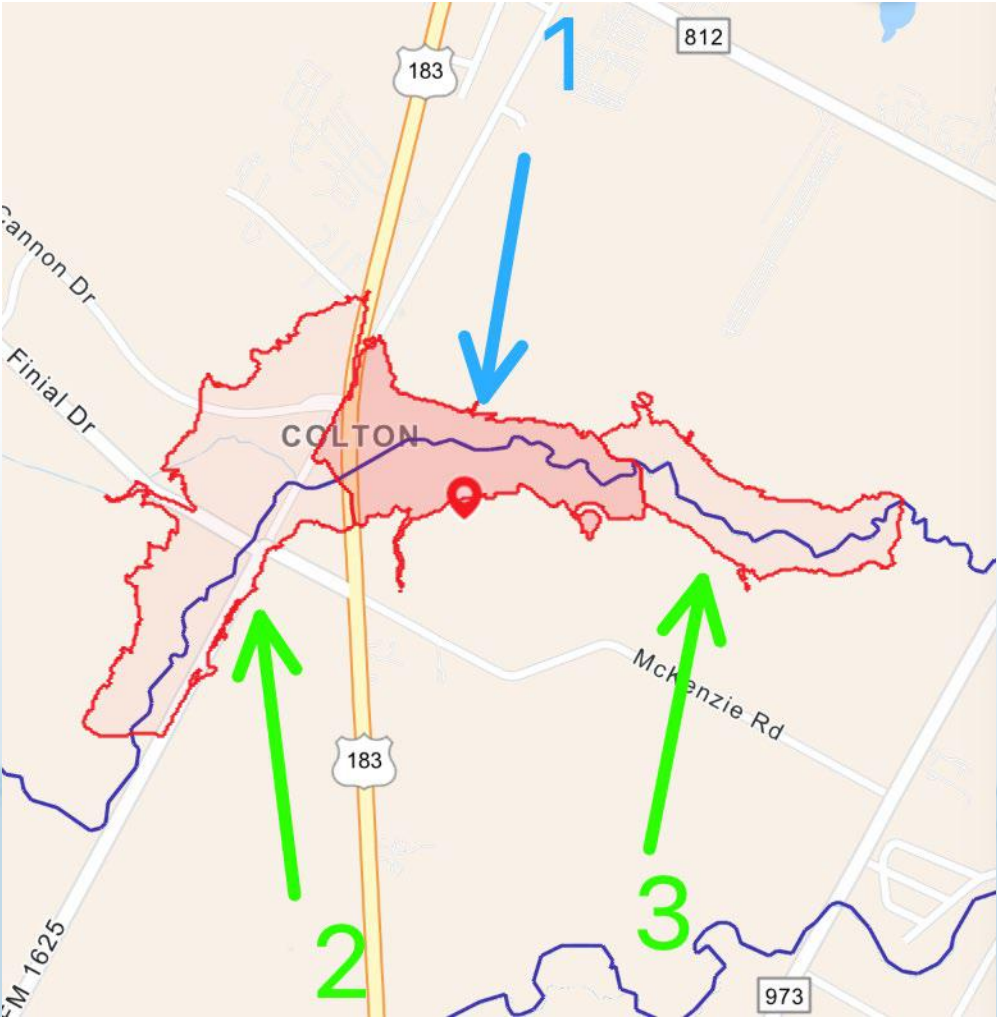


- ✓ The first responder knows the scope and extent of the flood before them!
- ✓ Emergency Managers can support and resource the response
- ✓ Provides Common Operating Picture

<https://gis.tdem.texas.gov/pin2flood/#>

Adding Adjacent Flood Polygons

A function requested by first responders in field exercises



Pin2Flood Dashboard for Emergency Operations Center

Pin2Flood - Emergency Management Dashboard Test1

Apply Filters

Filter by Date
7/13/2022 and before

Filter by User
All Users

Filter by County
All

+ Add Pins (P2F)

+ Search Addresses

Active Pins
📍 285

Addresses
🏠 1.4k

Est Population
👤 5.4k
(4 people per address)

TDEM Admin | 7/12/2022, 5:48 PM

TDEM Admin | 7/12/2022, 5:47 PM

Christine Thies | 7/12/2022, 4:24 PM

Brandon Lammy | 7/11/2022, 4:24 PM

Brandon Lammy | 7/11/2022, 4:01 PM

Brandon Lammy | 7/11/2022, 3:45 PM

Christine Thies | 7/10/2022, 4:08 PM

Christine Thies | 7/10/2022, 10:18 AM

Christine Thies | 7/10/2022, 10:18 AM

View Poi...

Esri, CGIAR, USGS | Austin Community College, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI... Powered by Esri

<https://gis.tdem.texas.gov/portal/apps/dashboards/4520d2fb7ceb41e180cdf29d97b0d2eb>

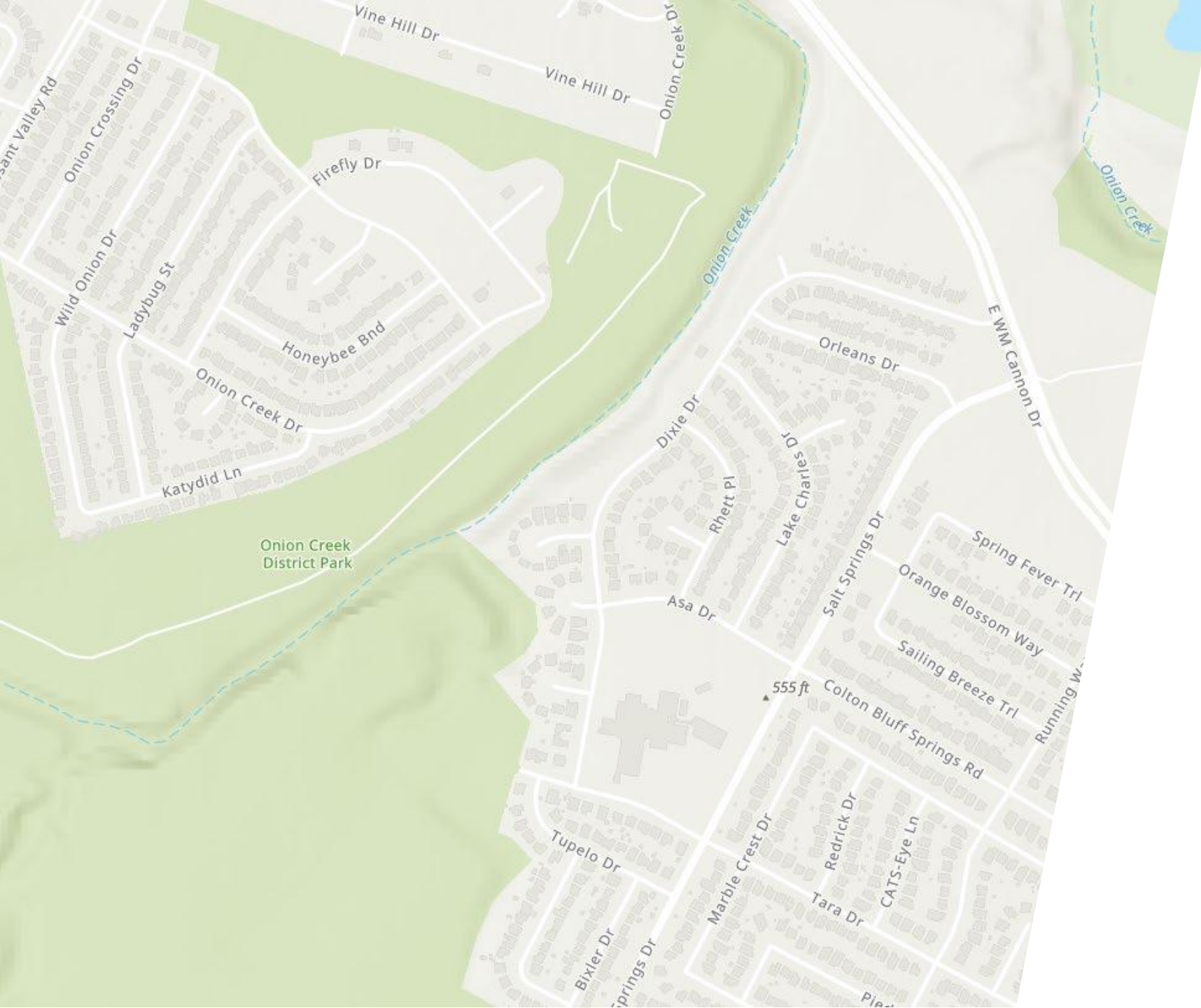
Pin2Flood



Pin2Flood Vision *Arrival of Response Units*

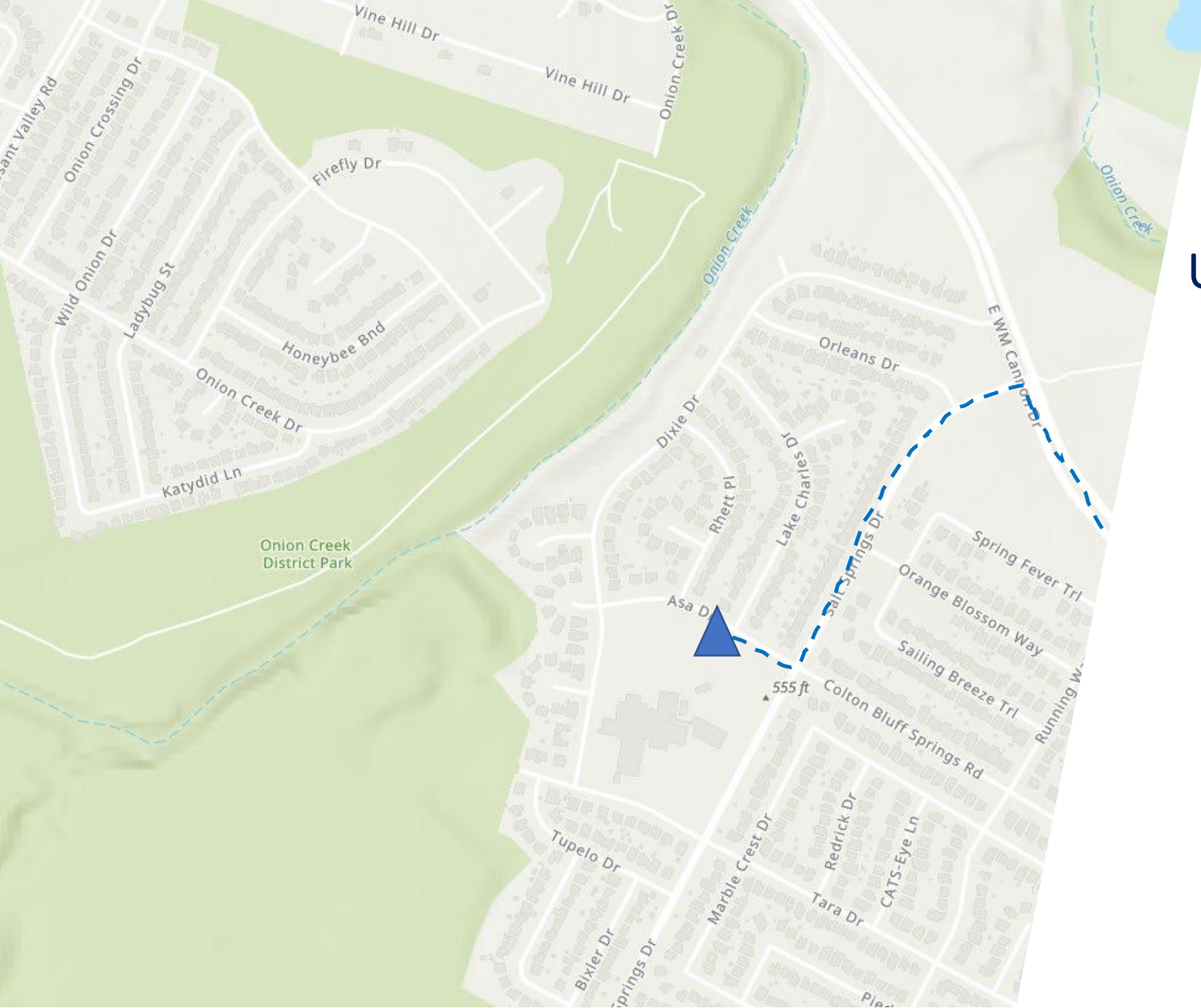
02:00

Flood calls start coming in..



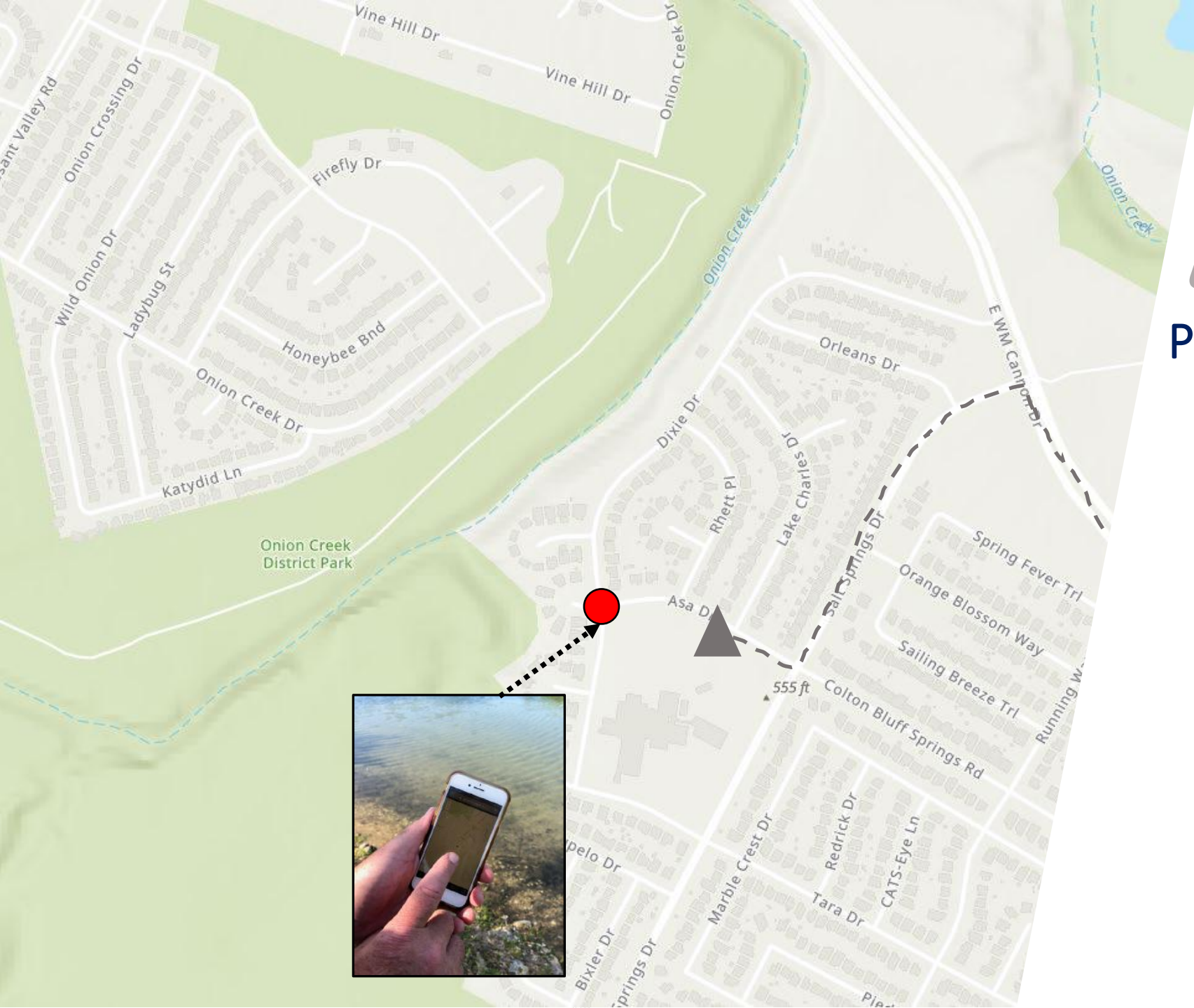
02:05

Flood calls start coming in..
Units Arrive on-scene



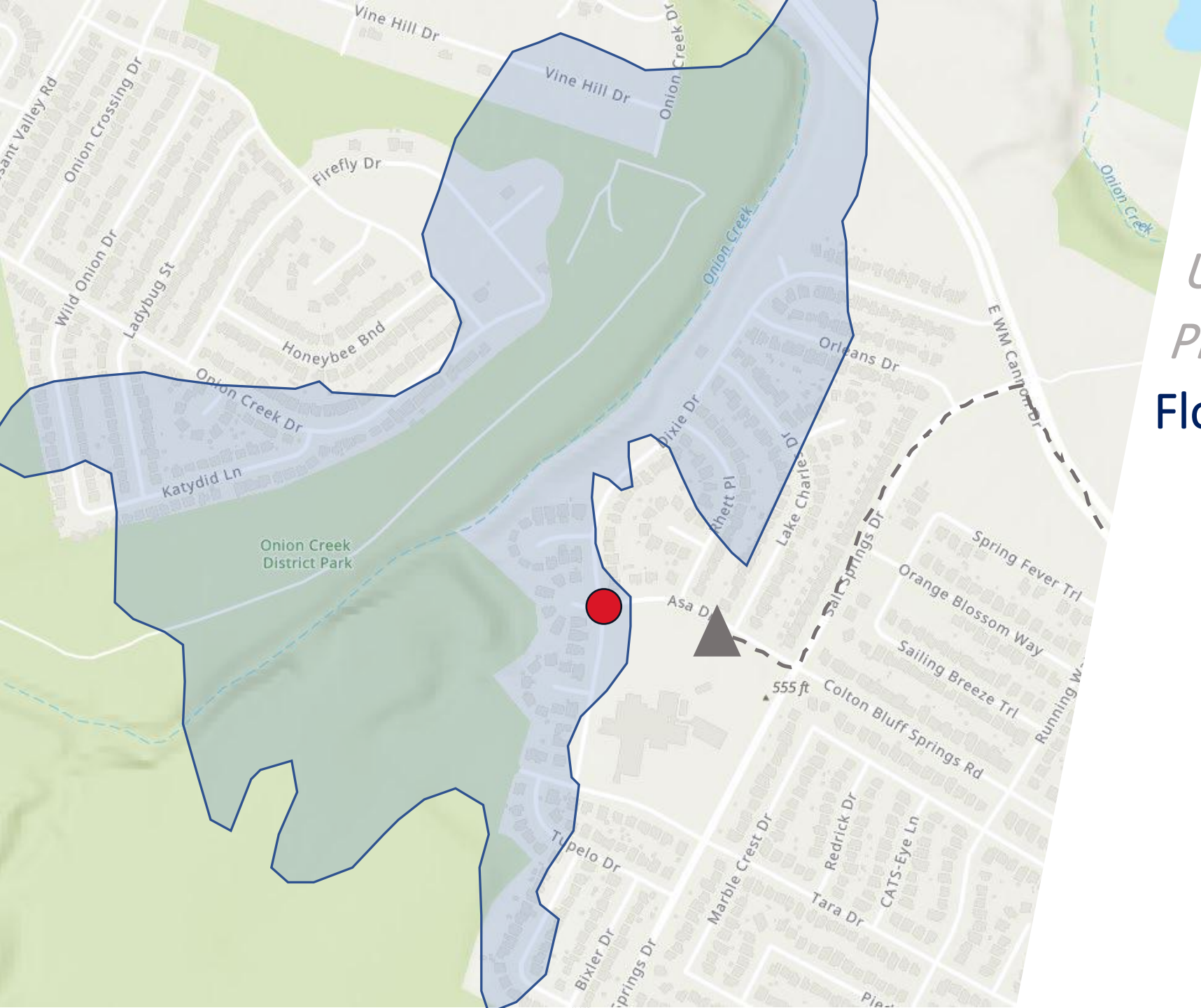
02:07

Flood calls start coming in..
Units Arrive on-scene
Pin dropped at water's edge



02:09

Flood calls start coming in..
Units Arrive on-scene
Pin dropped at water's edge
Flood inundation calculated



02:10

Flood calls start coming in..

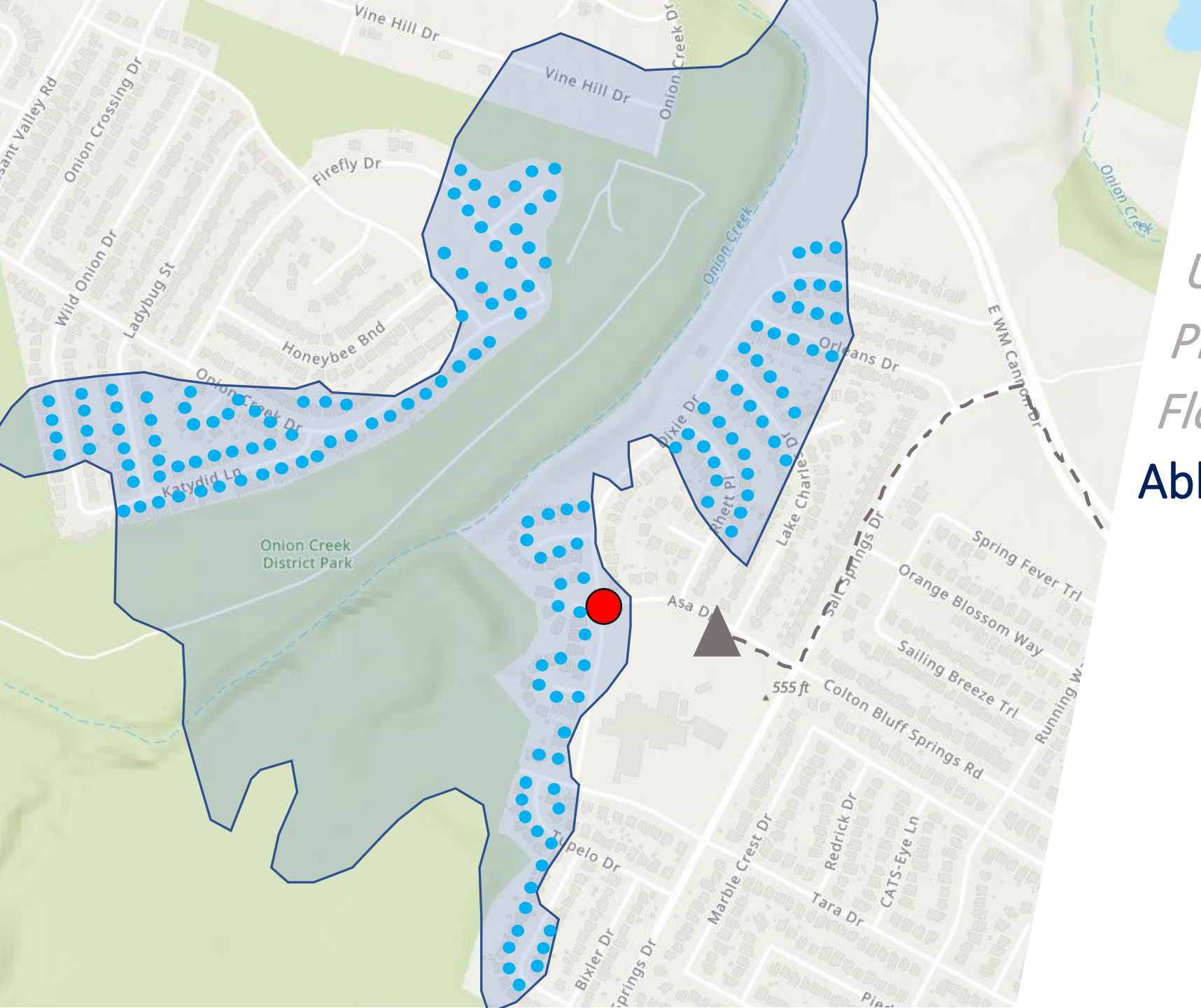
Units Arrive on-scene

Pin dropped at water's edge

Flood inundation calculated

Able to identify....

- **Homes Impacted**

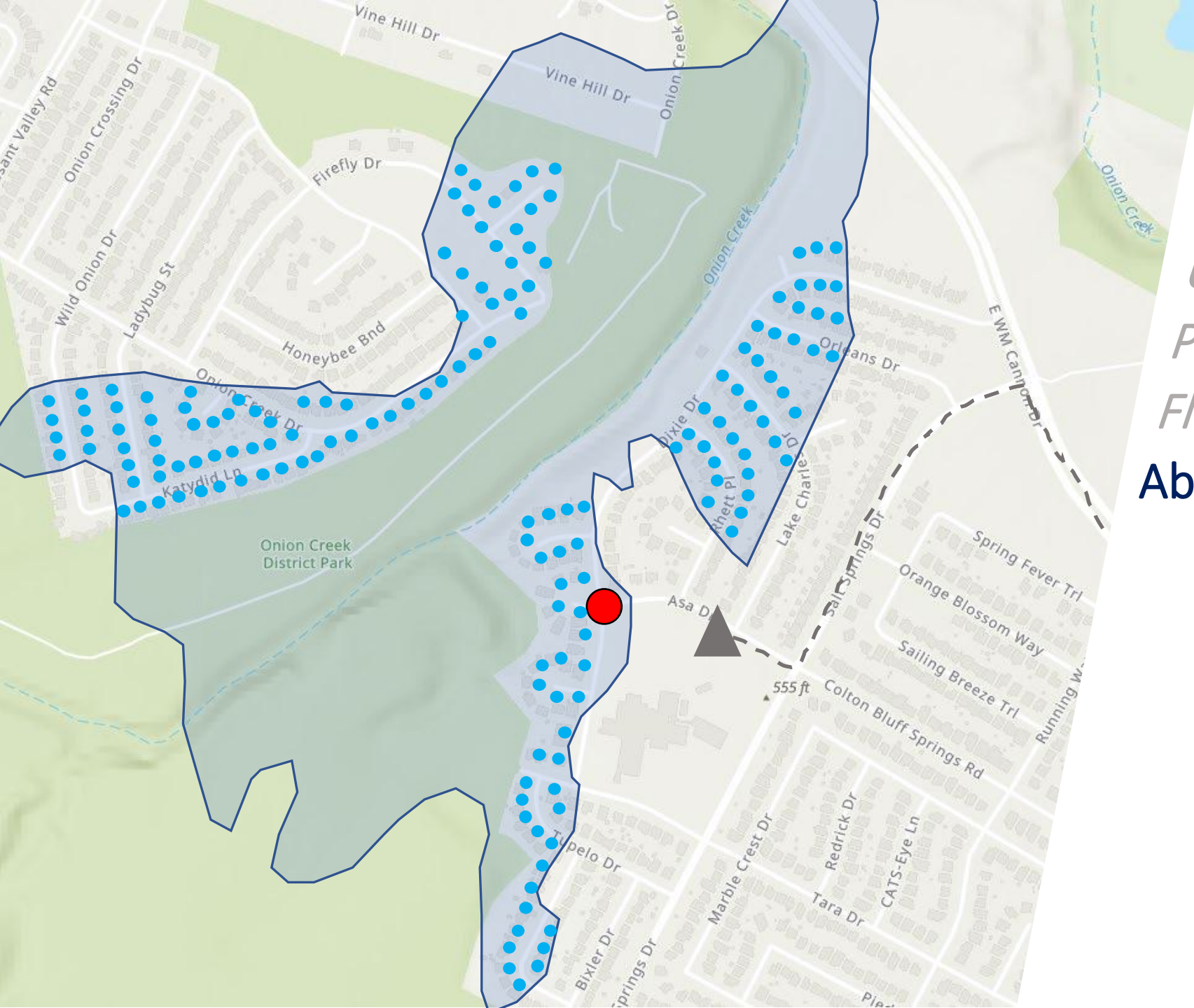


02:10

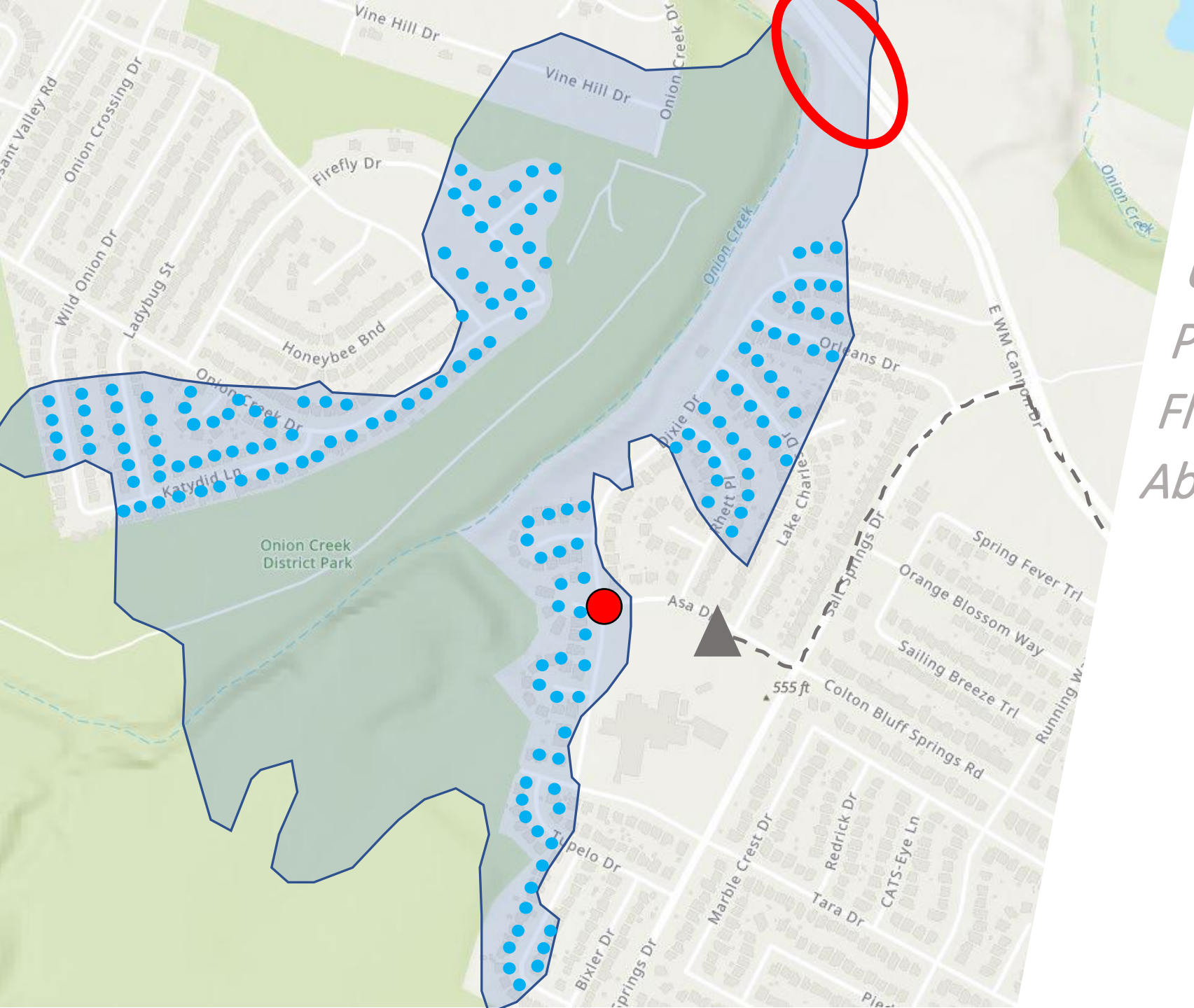
Flood calls start coming in..
Units Arrive on-scene
Pin dropped at water's edge
Flood inundation calculated

Able to identify....

- *Homes Impacted*
- **Population**



02:10



*Flood calls start coming in..
Units Arrive on-scene
Pin dropped at water's edge
Flood inundation calculated
Able to identify....*

- *Homes Impacted*
- *Population*
- **Flooded Roads**

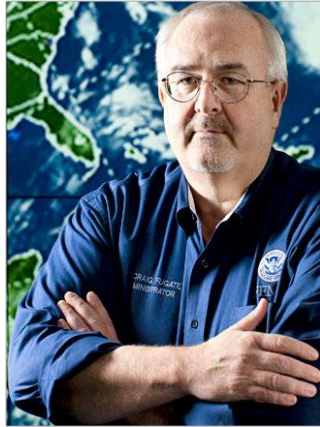
Progress in 9 years

National

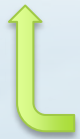
Local



Jack Dangermond
President, ESRI



“Can we
do better?”



“Ok, Jack
We’re doing
better now”

