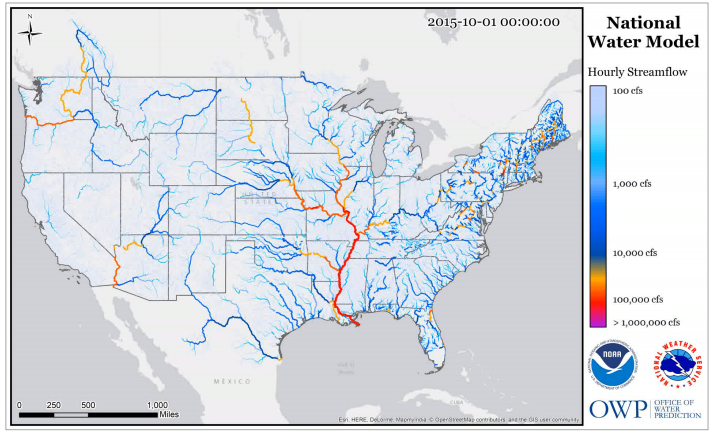
Local and Regional Flood Inundation Mapping

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



Presentation for GIS Hydro Workshop, ESRI International User Conference, 8 July 2019, San Diego CA

Acknowledgements: National Weather Service, Texas Division of Emergency Management, Austin Fire Department, Kisters, ESRI, Harry Evans, Xing Zheng, David Arctur, and Christine Thies.

Flood Inundation Mapping

A journey over the last four years…

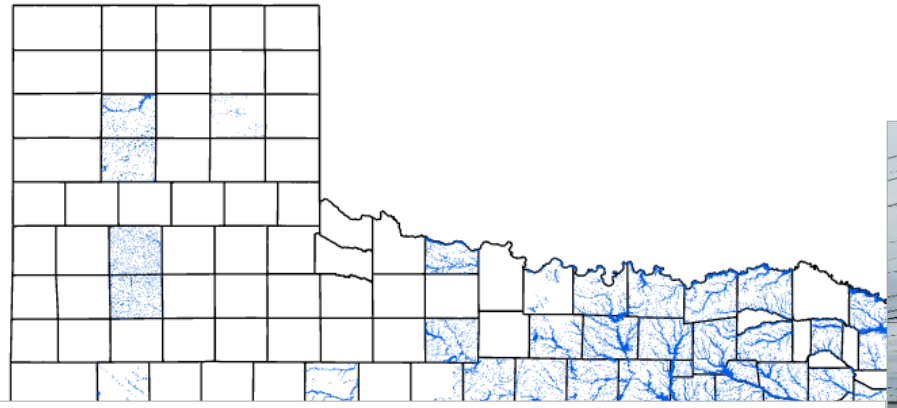
If you want to go fast, go alone …
… If you want to far, go together

African Proverb

FEMA floodplain mapping in Texas

Large areas of Texas lack flood information

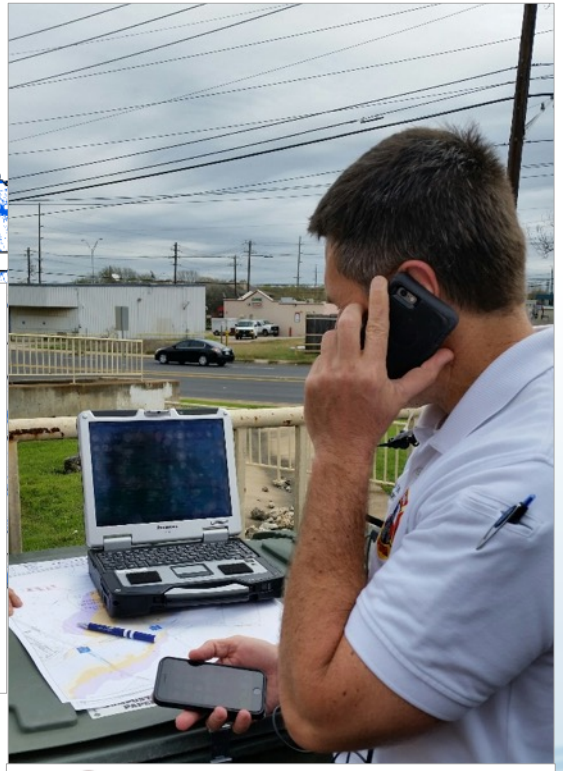
FEMA maps are static for 100 or 500 year flood



Flood emergency response needs a *new kind of map* that covers all of Texas and supports:

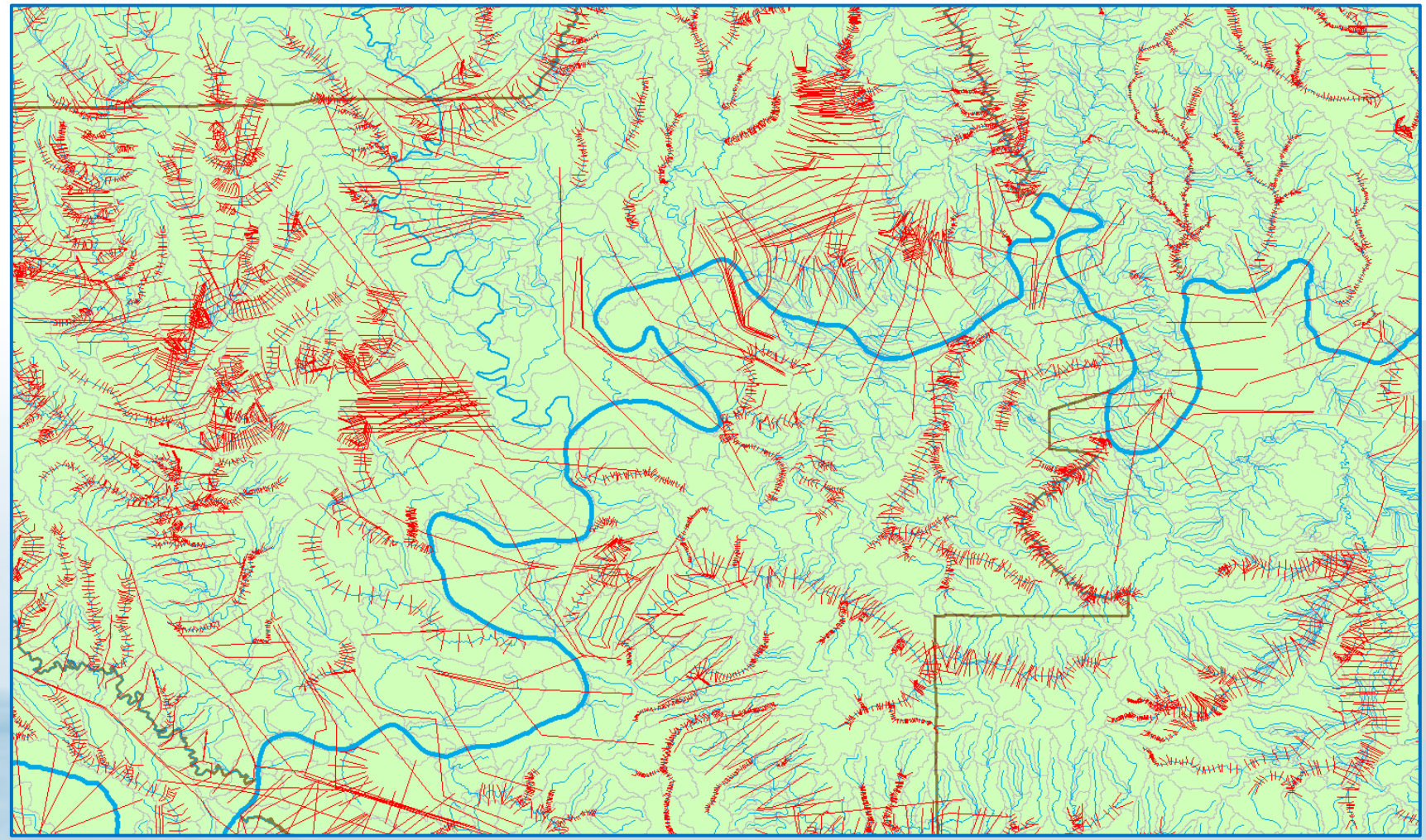
- ***Observational*** **mapping by emergency responders**
- ***Predictive*** **mapping from flood forecasts**

Flood emergency response is *dynamic*



Pin2Flood

Inundation Mapping



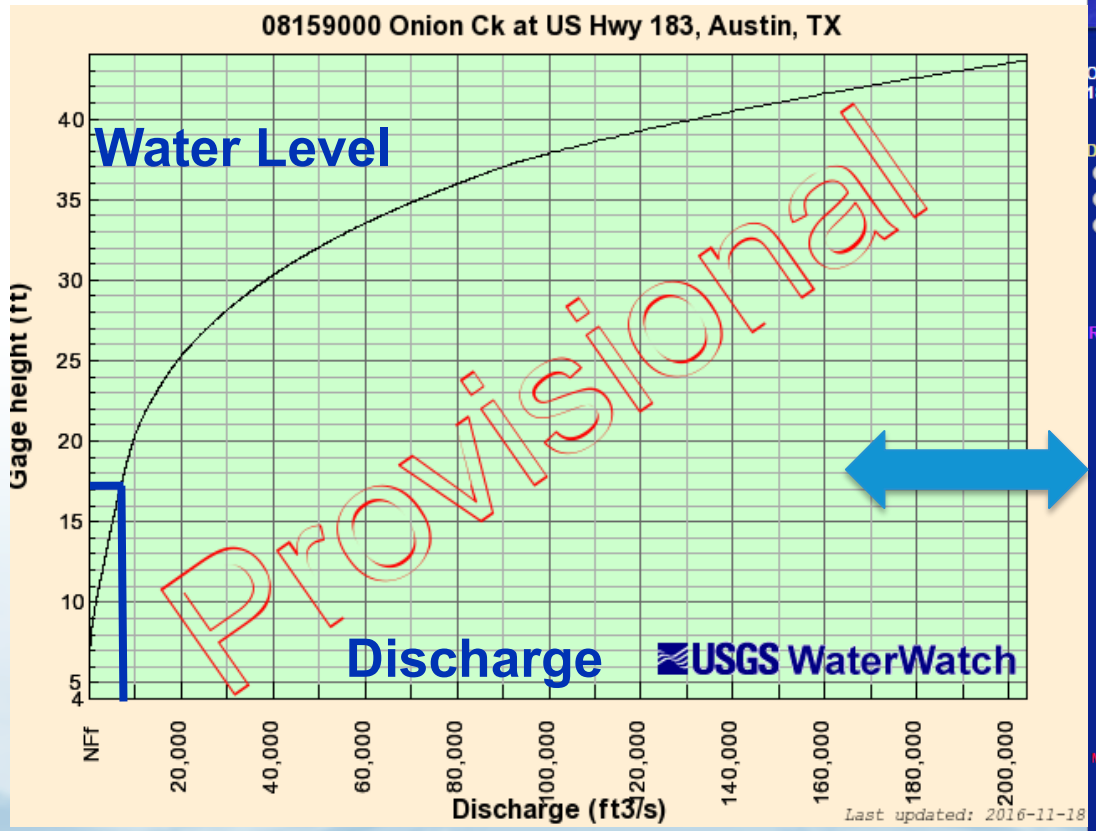
Source: Xing Zheng, 2015 Summer Institute, National Water Center

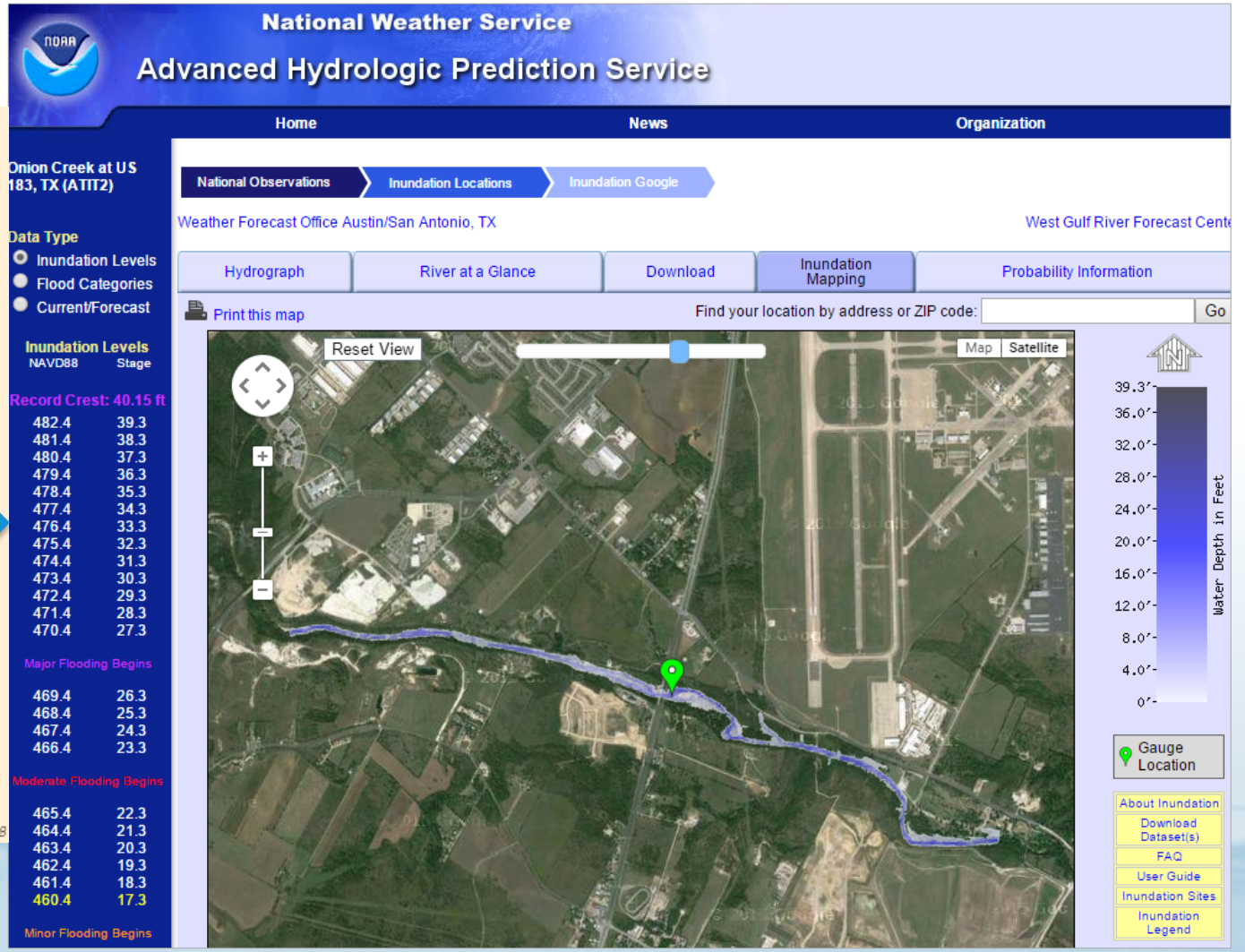
HEC-RAS Cross Sections in Alabama

Thousands of independent models and overlapping cross-sections!

Real-Time Flood Inundation Mapping
Onion Creek at Highway 183

Rating Curve

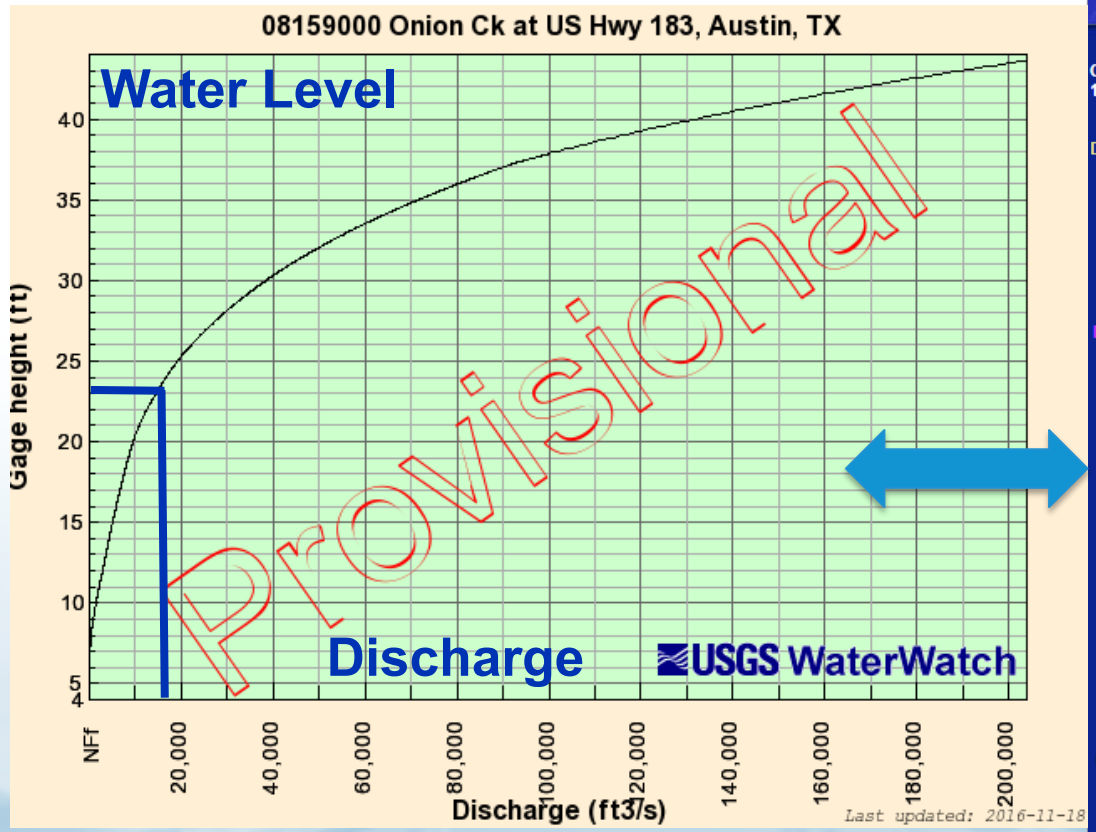


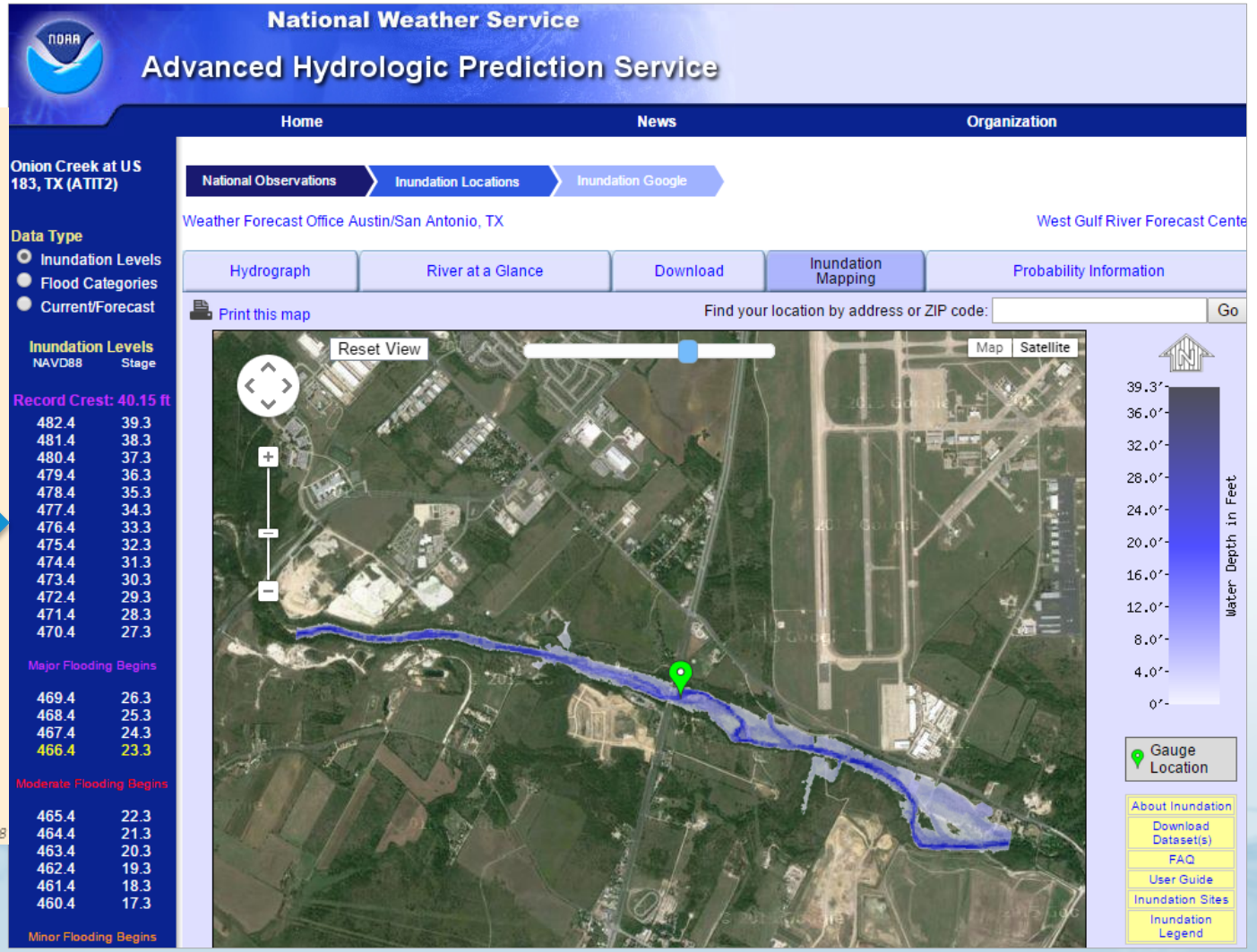


http://water.weather.gov/ahps2/inundation/inundation_google.php?gage=atit2

Real-Time Flood Inundation Mapping
Onion Creek at Highway 183

Rating Curve





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Real-Time Flood Inundation Mapping
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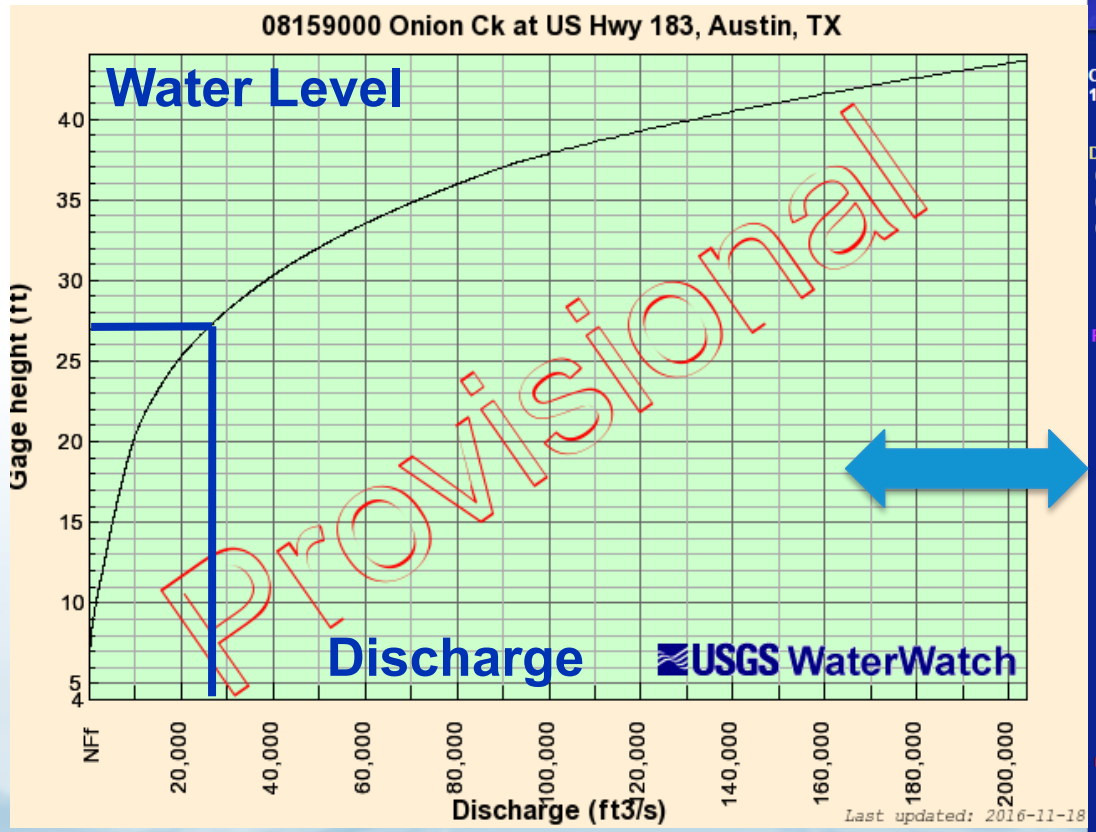

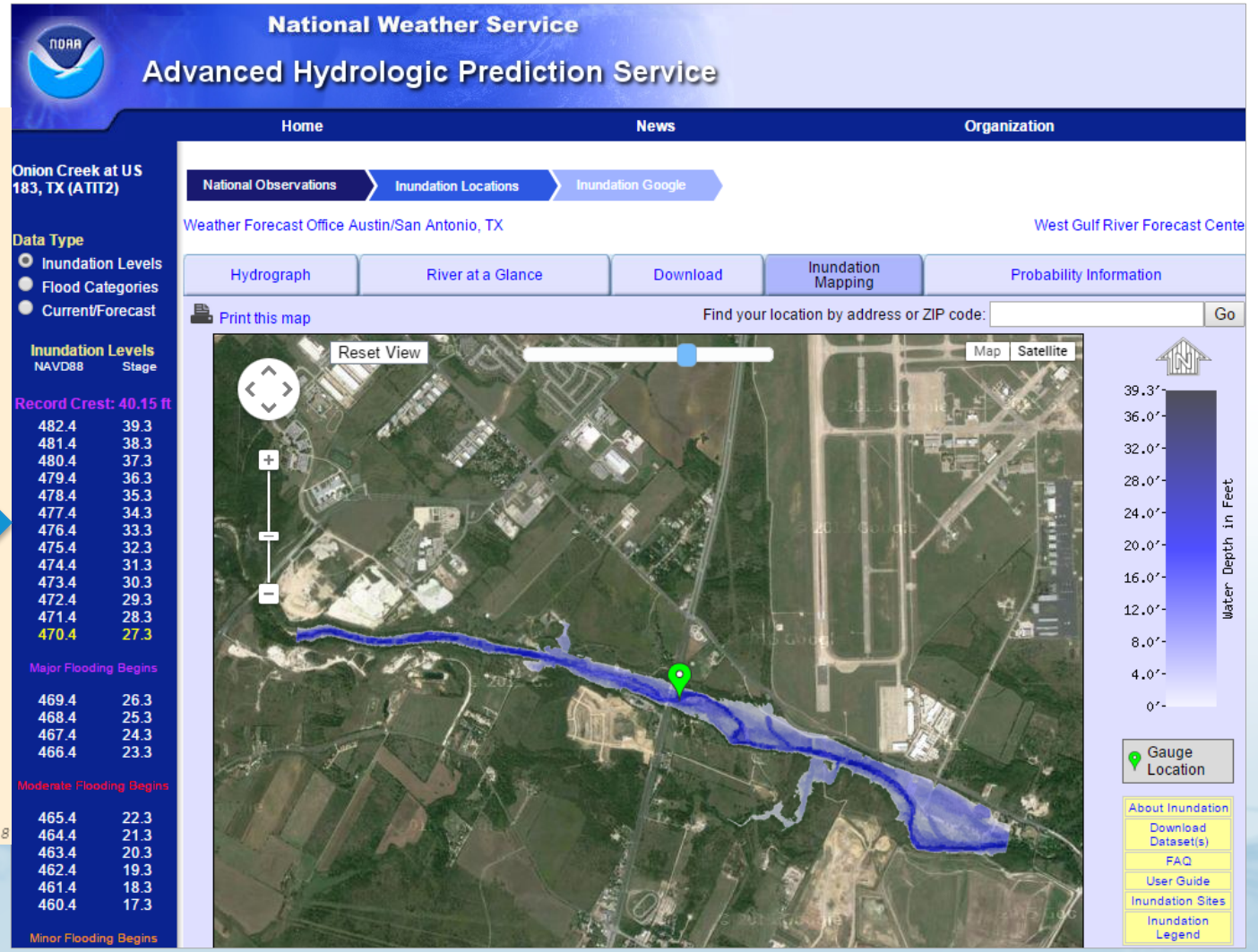

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Real-Time Flood Inundation Mapping
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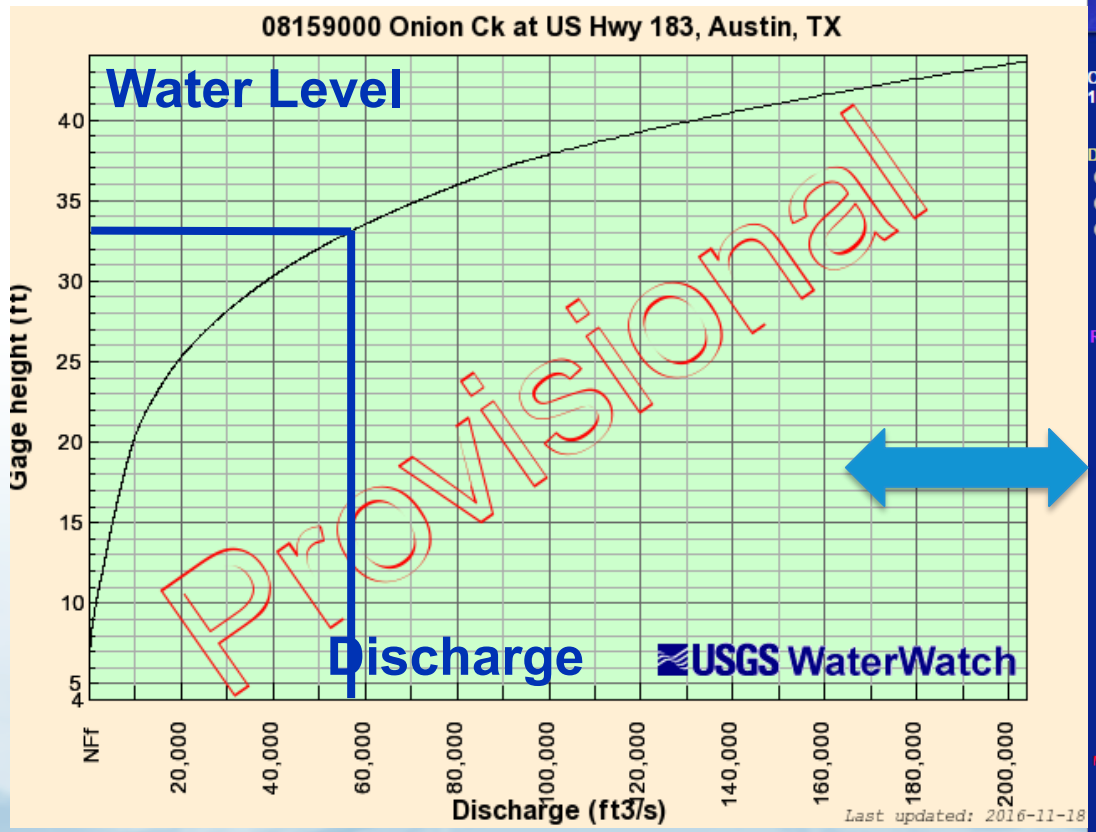

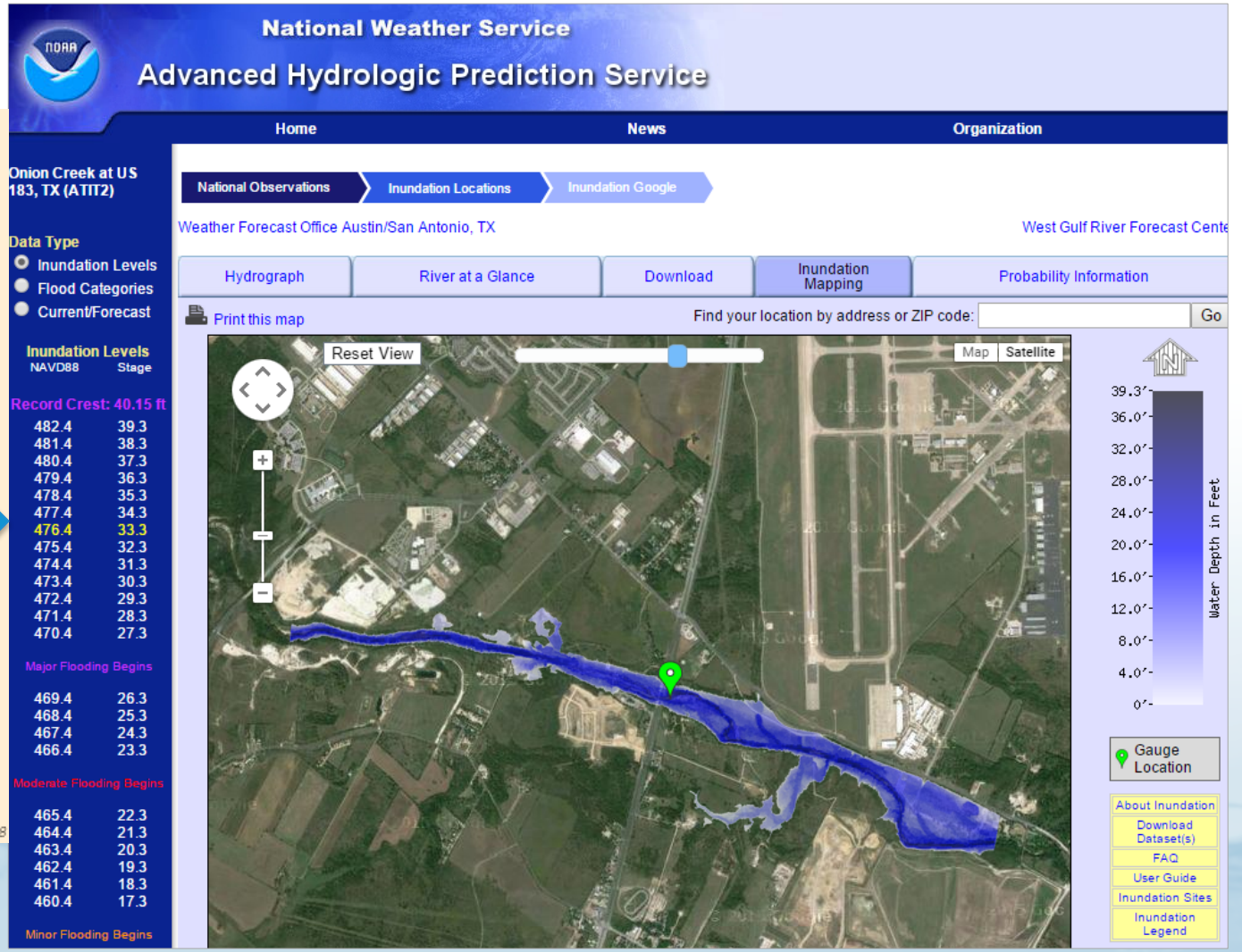

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Real-Time Flood Inundation Mapping
Onion Creek at Highway 183

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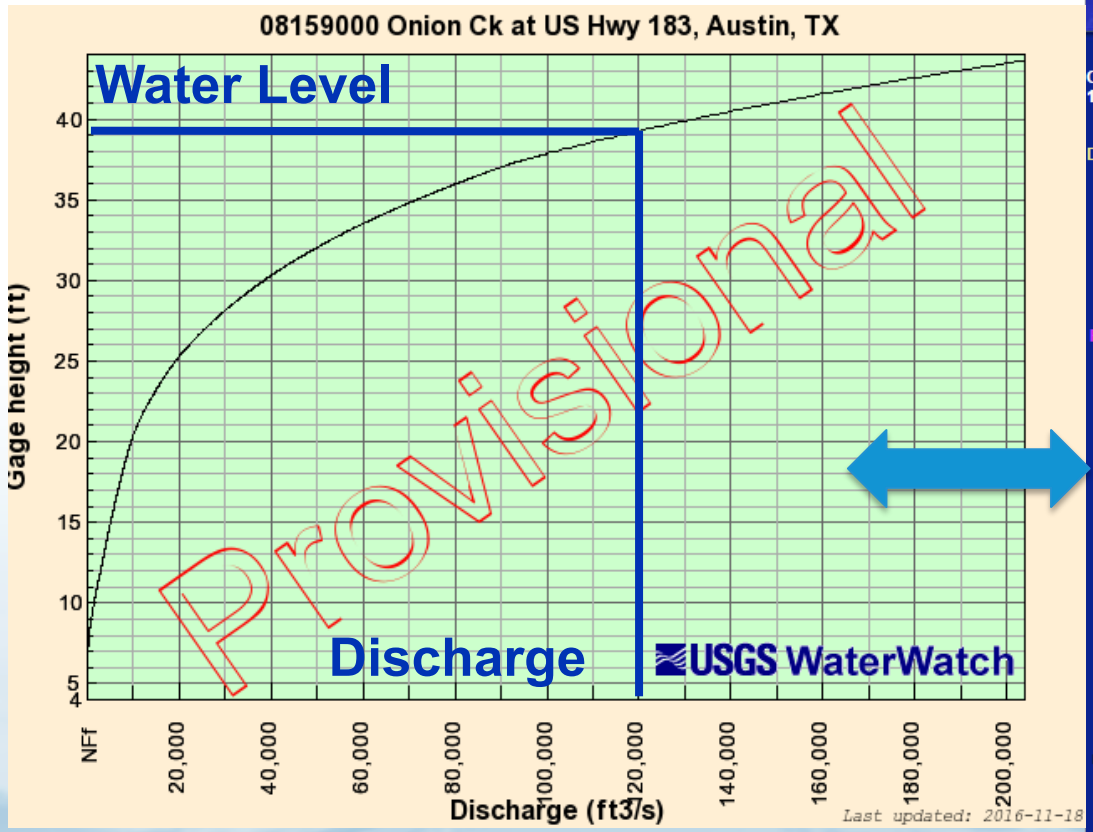
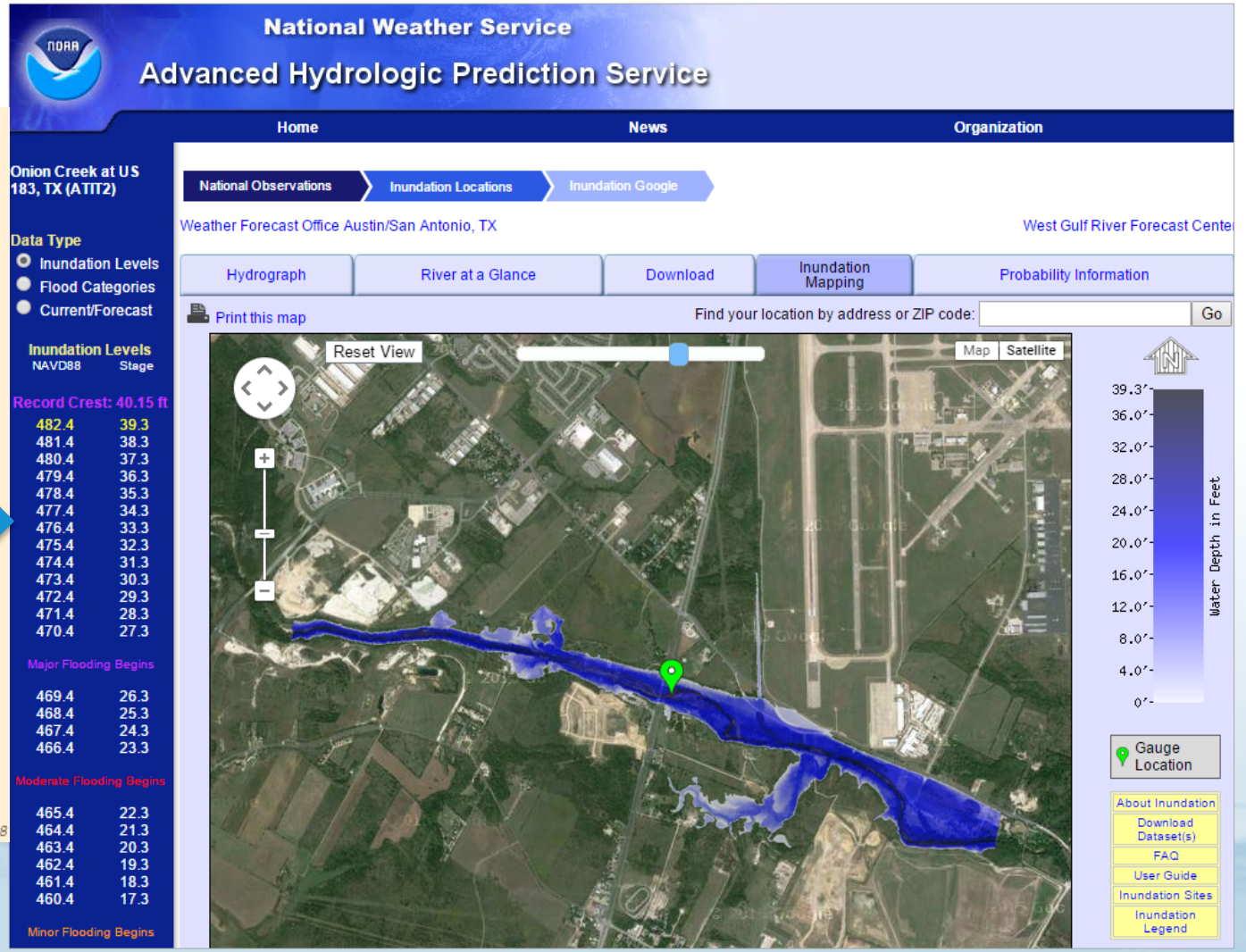
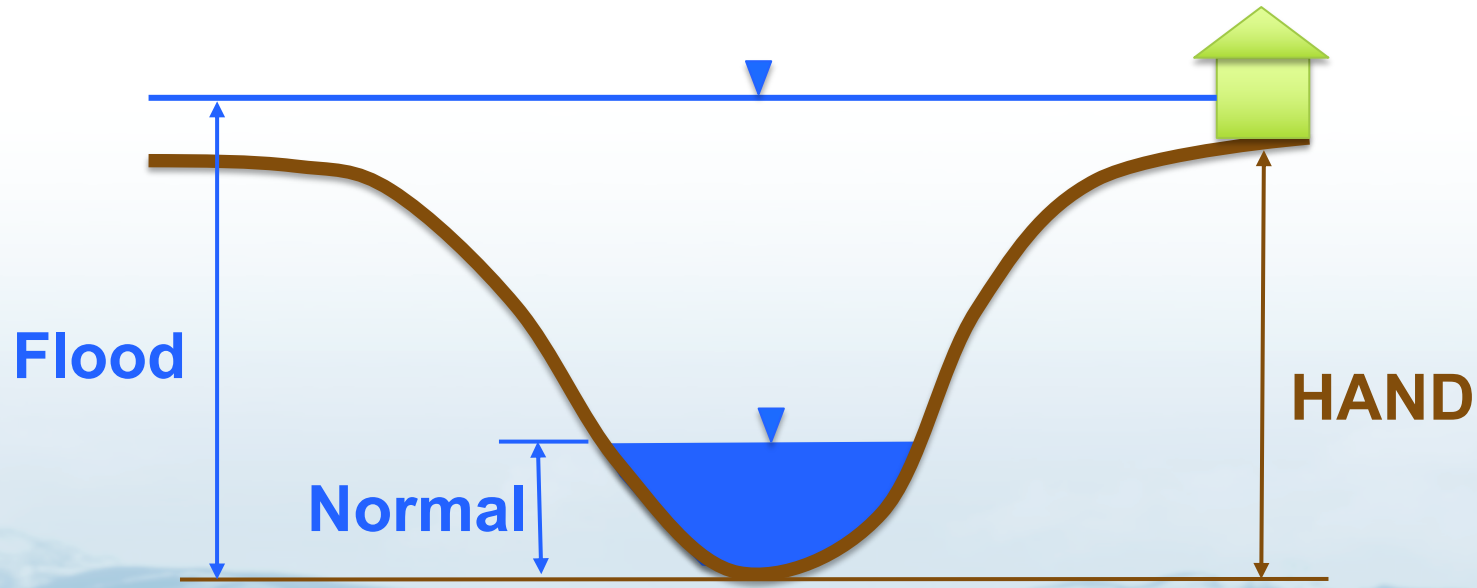




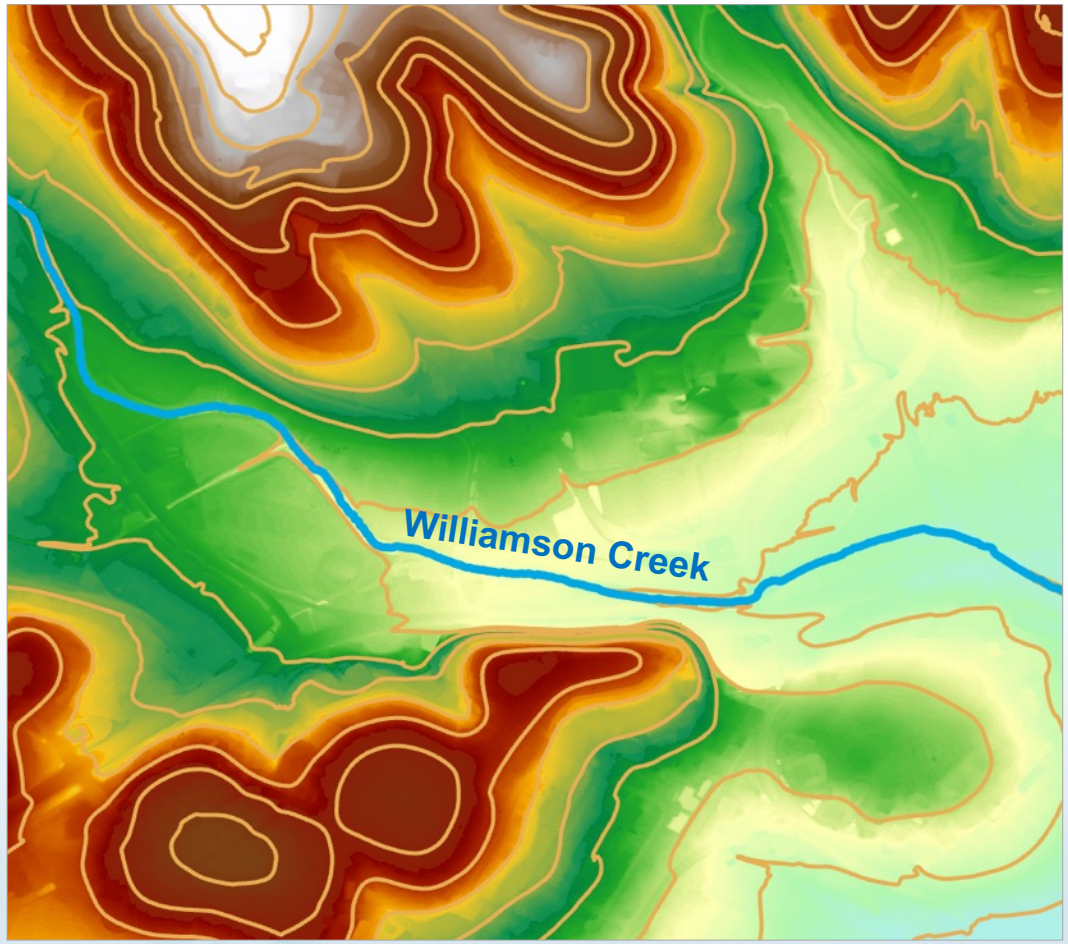
http://water.weather.gov/ahps2/inundation/inundation_google.php?gage=atit2

Method for Determining Flood Risk:
Height Above Nearest Drainage (HAND)

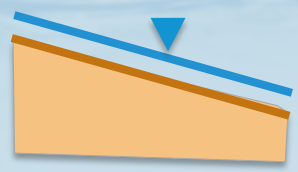
Flooding occurs when Water Depth is greater than HAND



HAND: Relative Elevation above Creek Bed



Elevation of Land Surface



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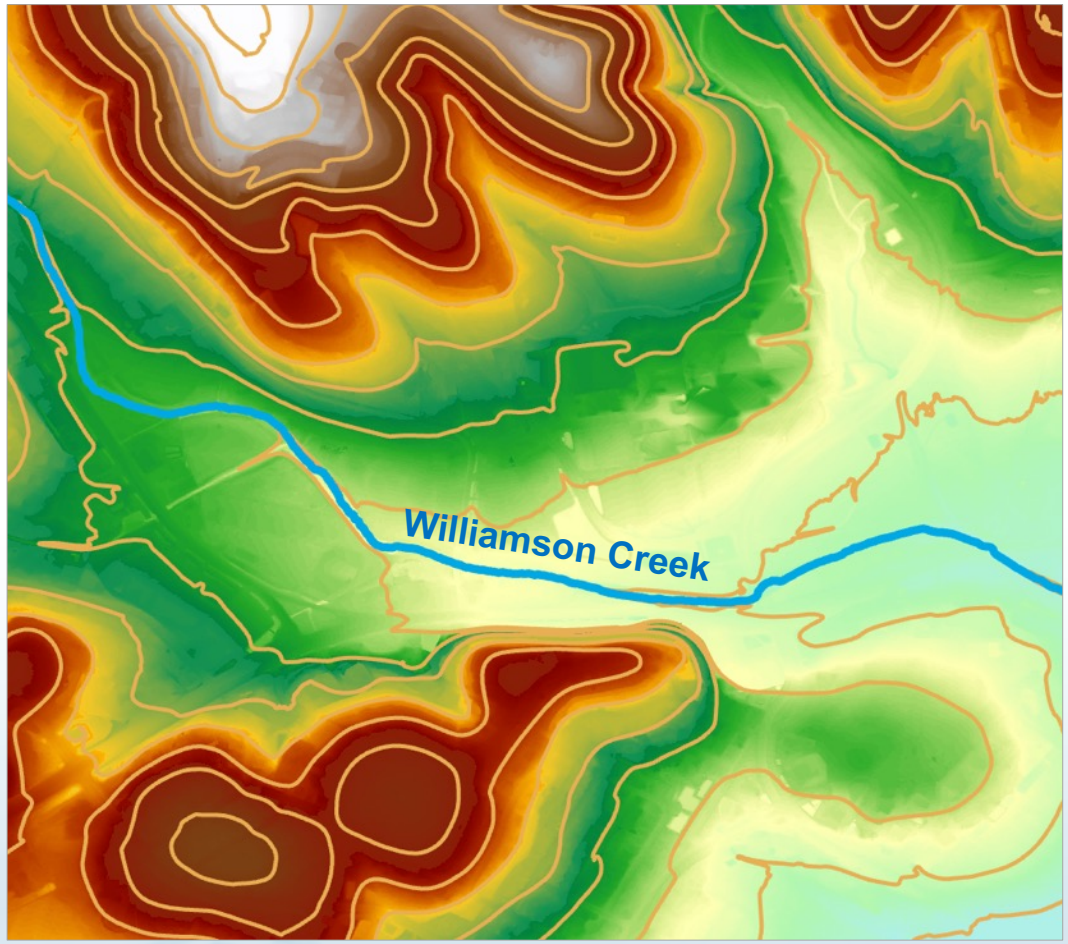

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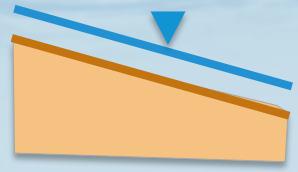

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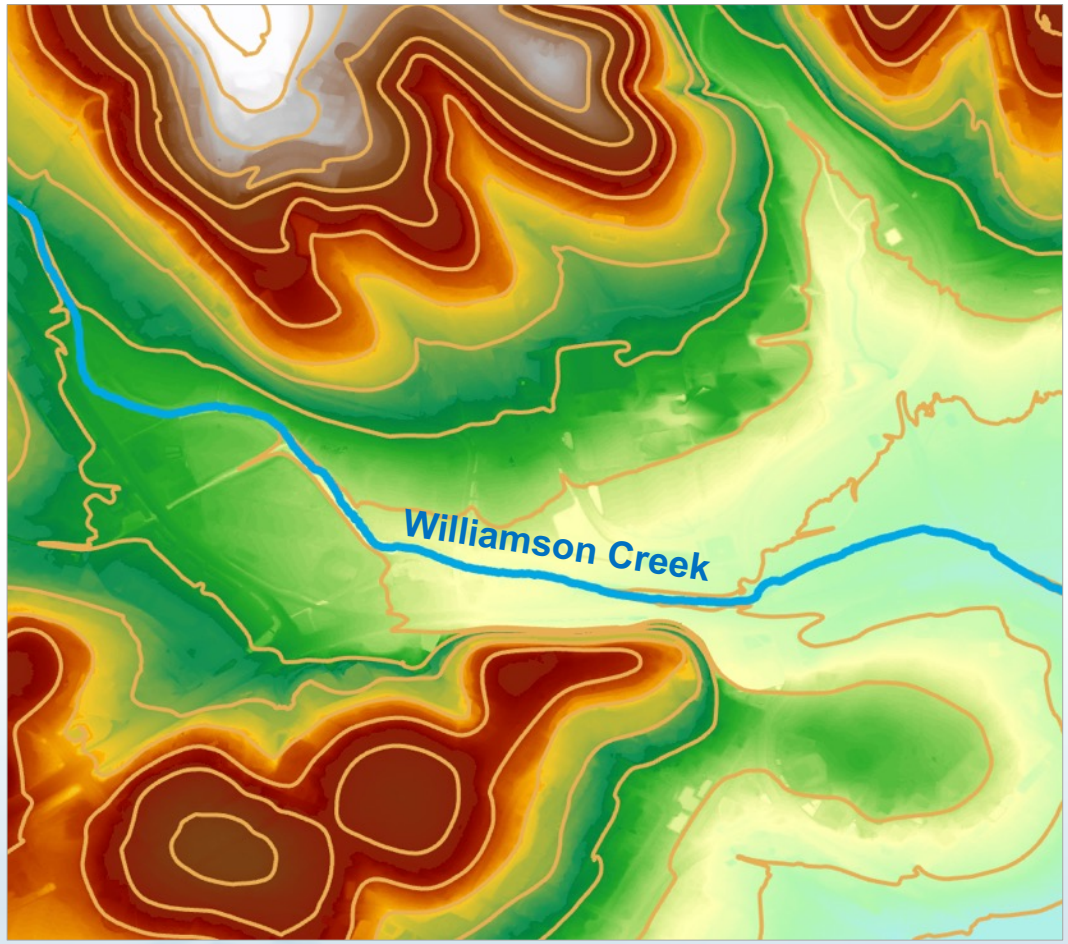

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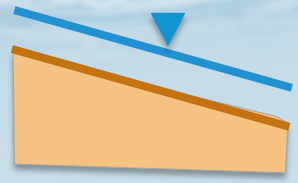

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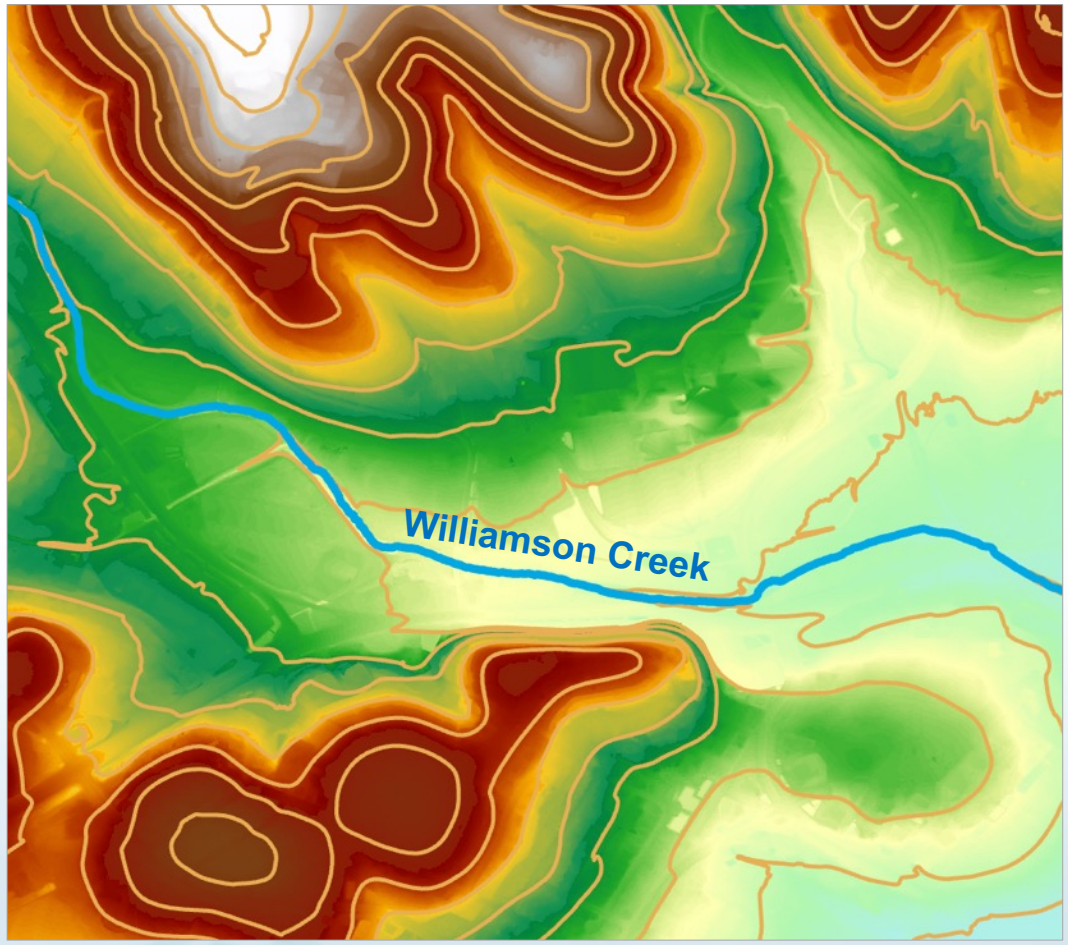

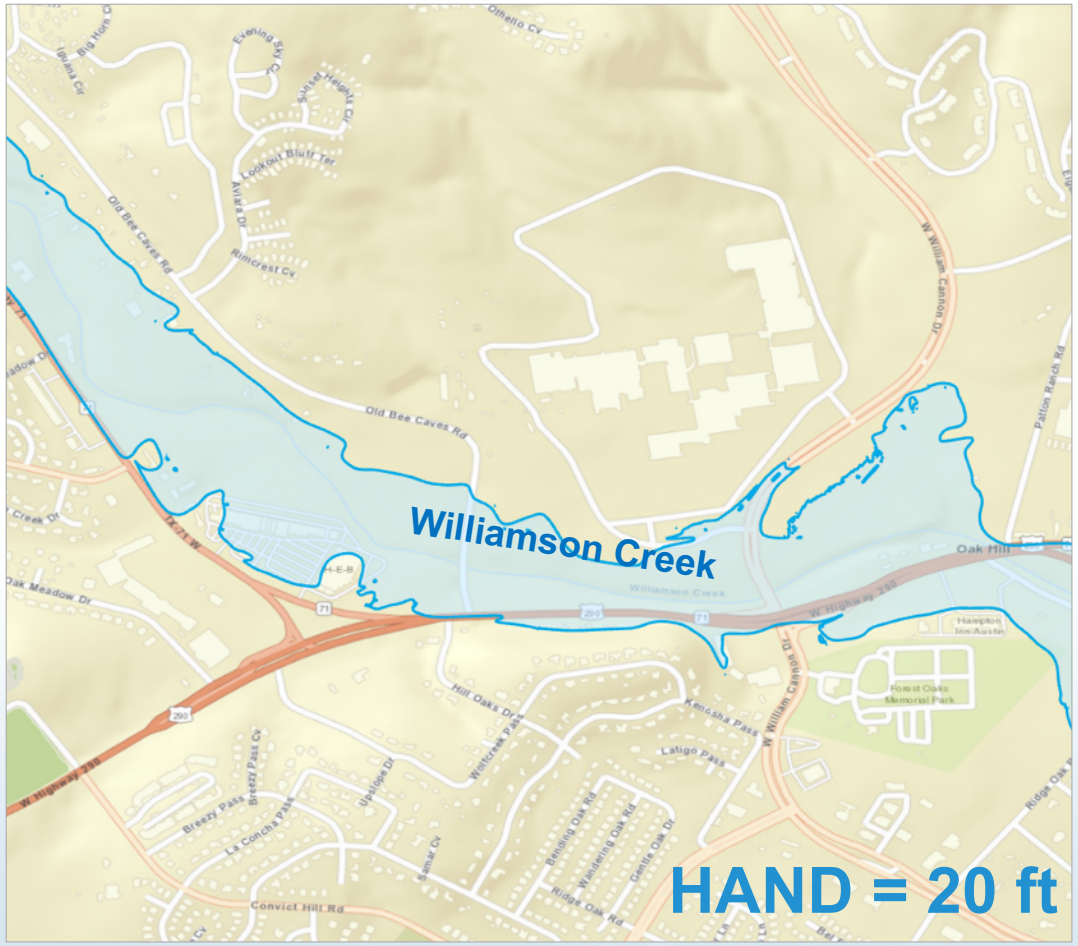

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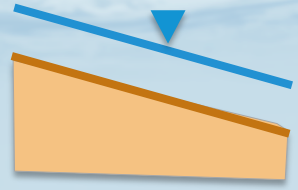

Elevation above Creek Bed

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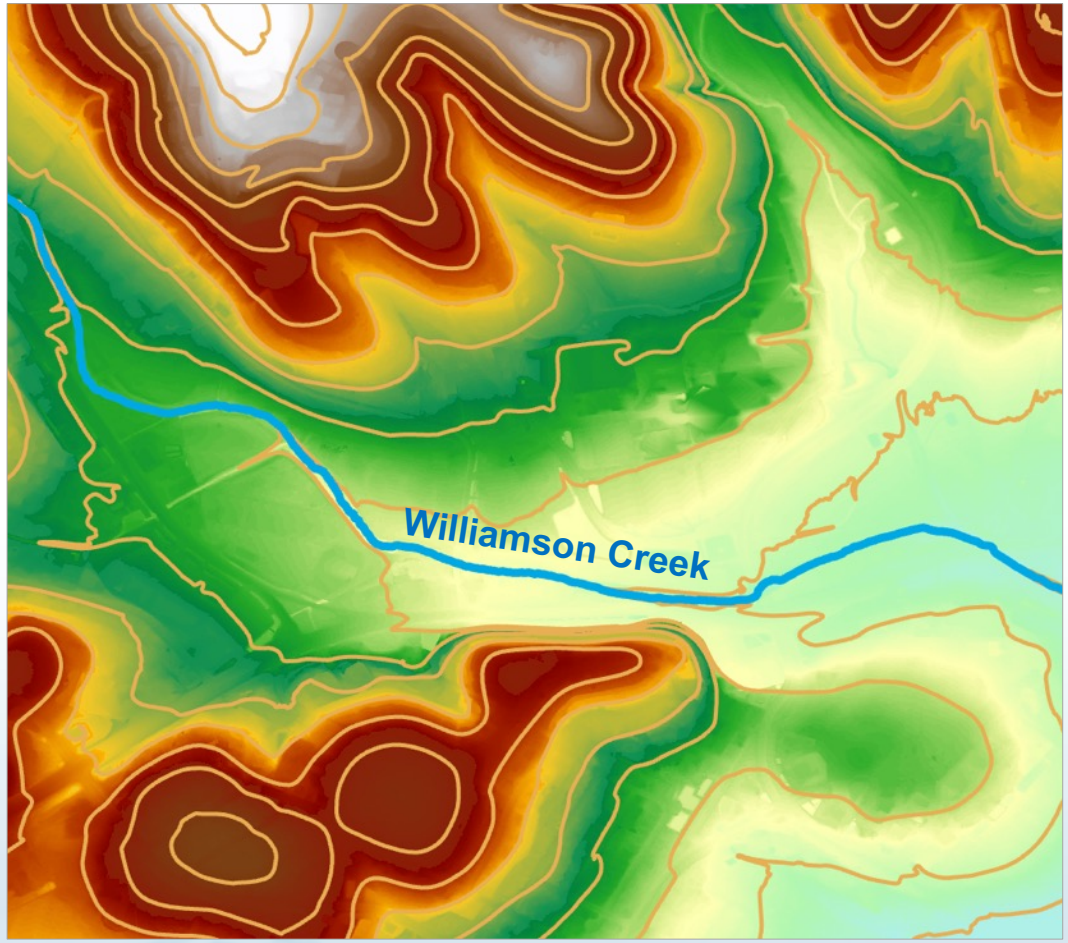

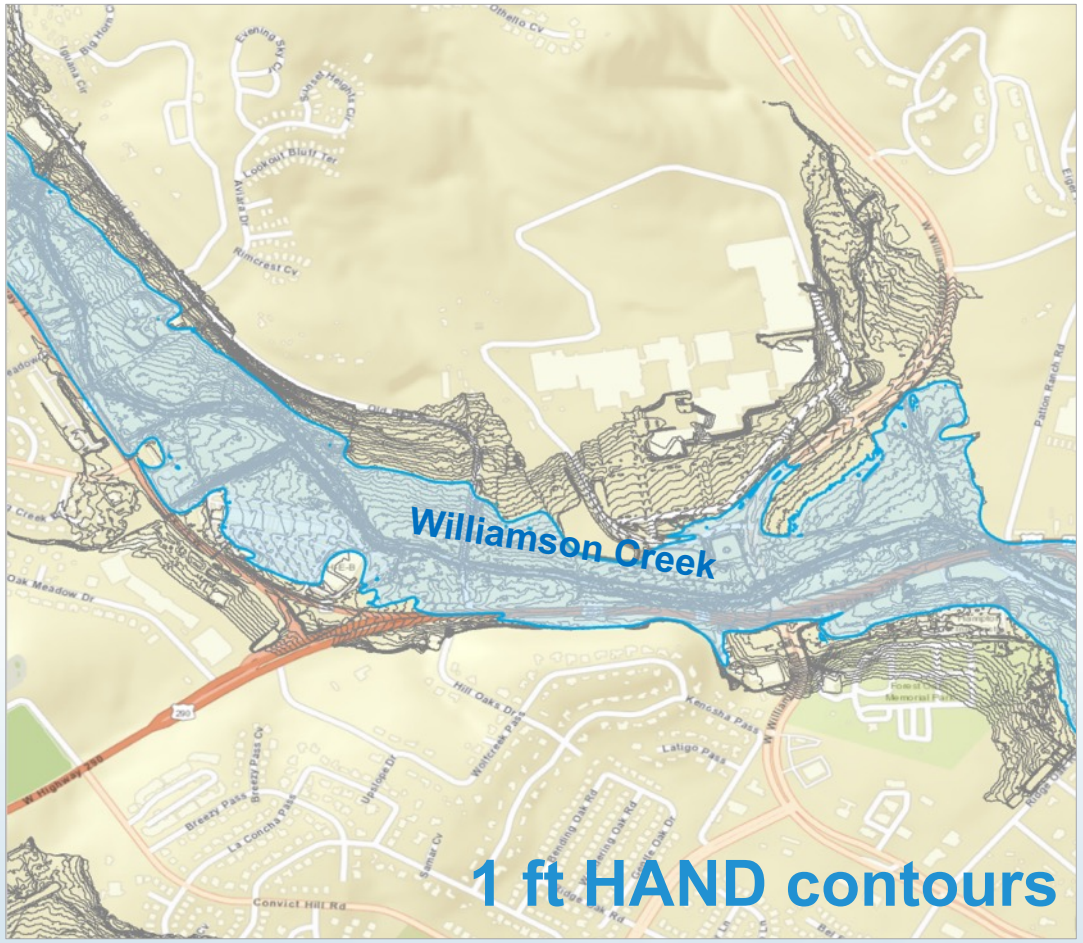

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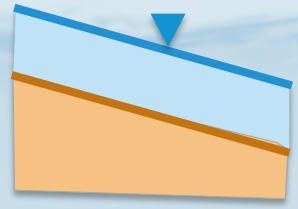


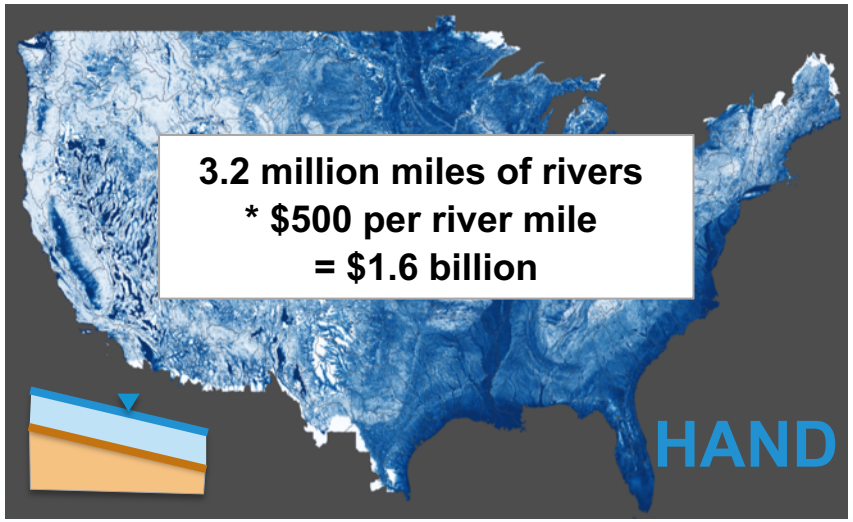
Elevation above Creek Bed

Application at Continental Scale

National Hydrography Dataset

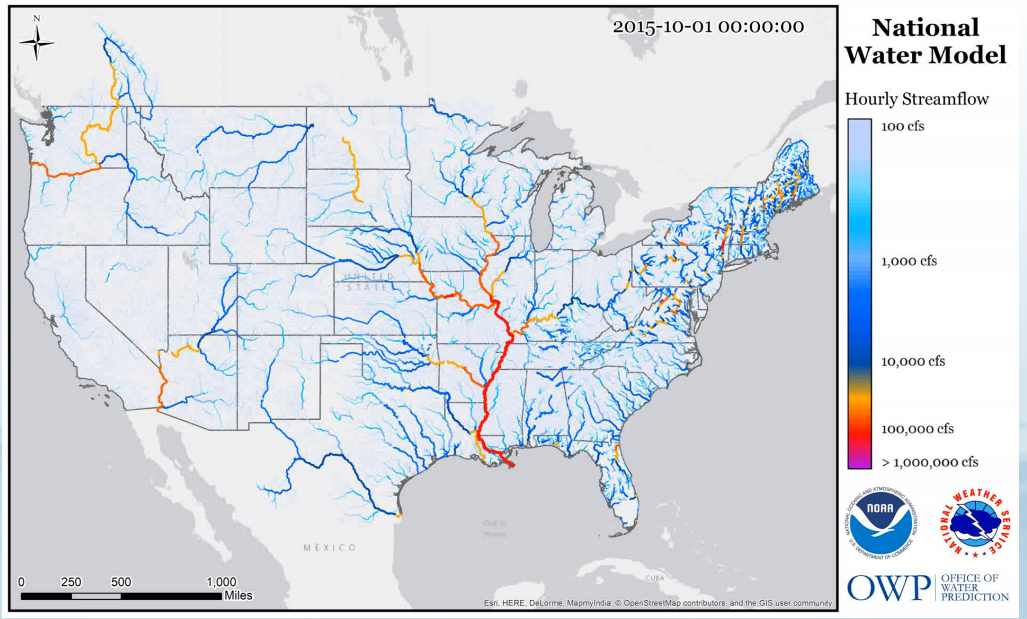
10m National Elevation Dataset

Supercomputer

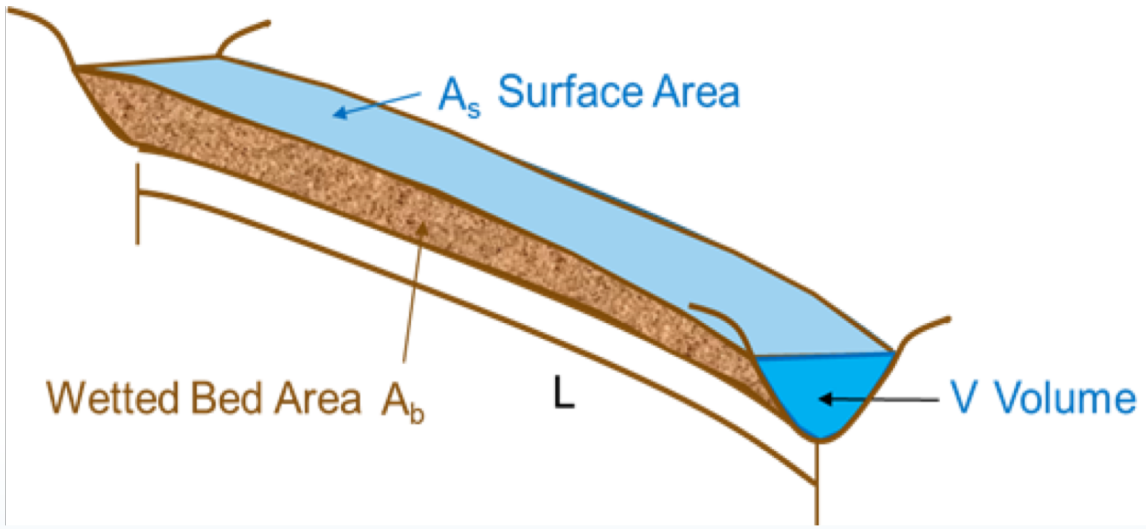


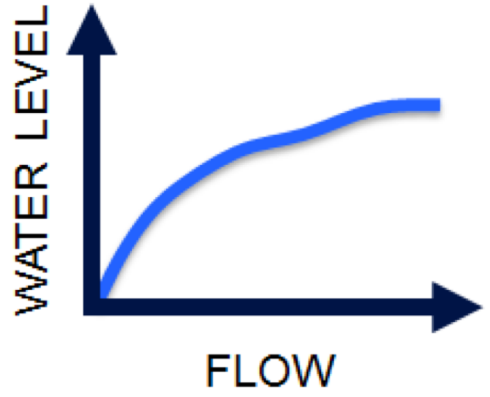
National Water Center

Tuscaloosa, Alabama



Rating Curves Connect Flow with Water Level





Reach scale channel parameters

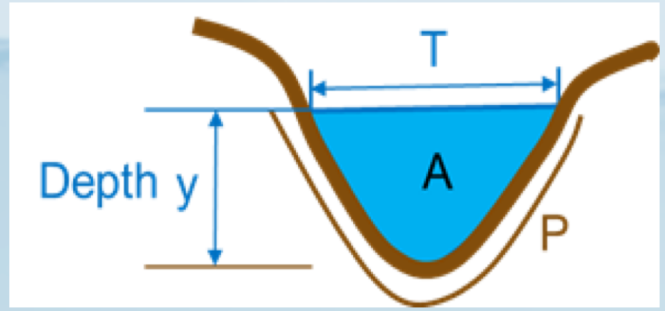
A = V/L Cross Section Area T = A_S/L Top Width

P = A_b/L Wetted Perimeter R = A/P Hydraulic Radius

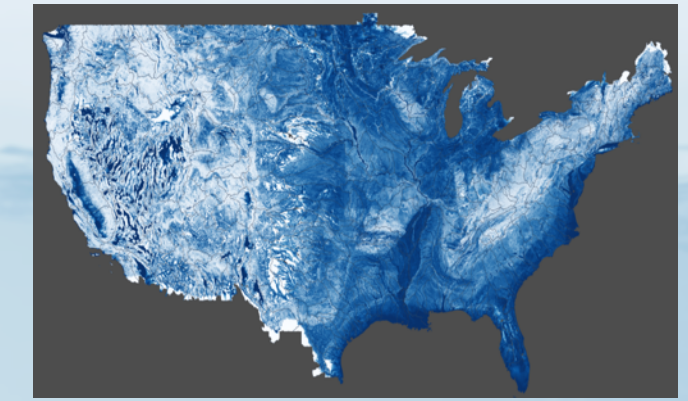
$$Q = \frac{1.49}{n} A R^{2/3} S_o^{1/2}$$

Innovators Program
NWC Summer Institute

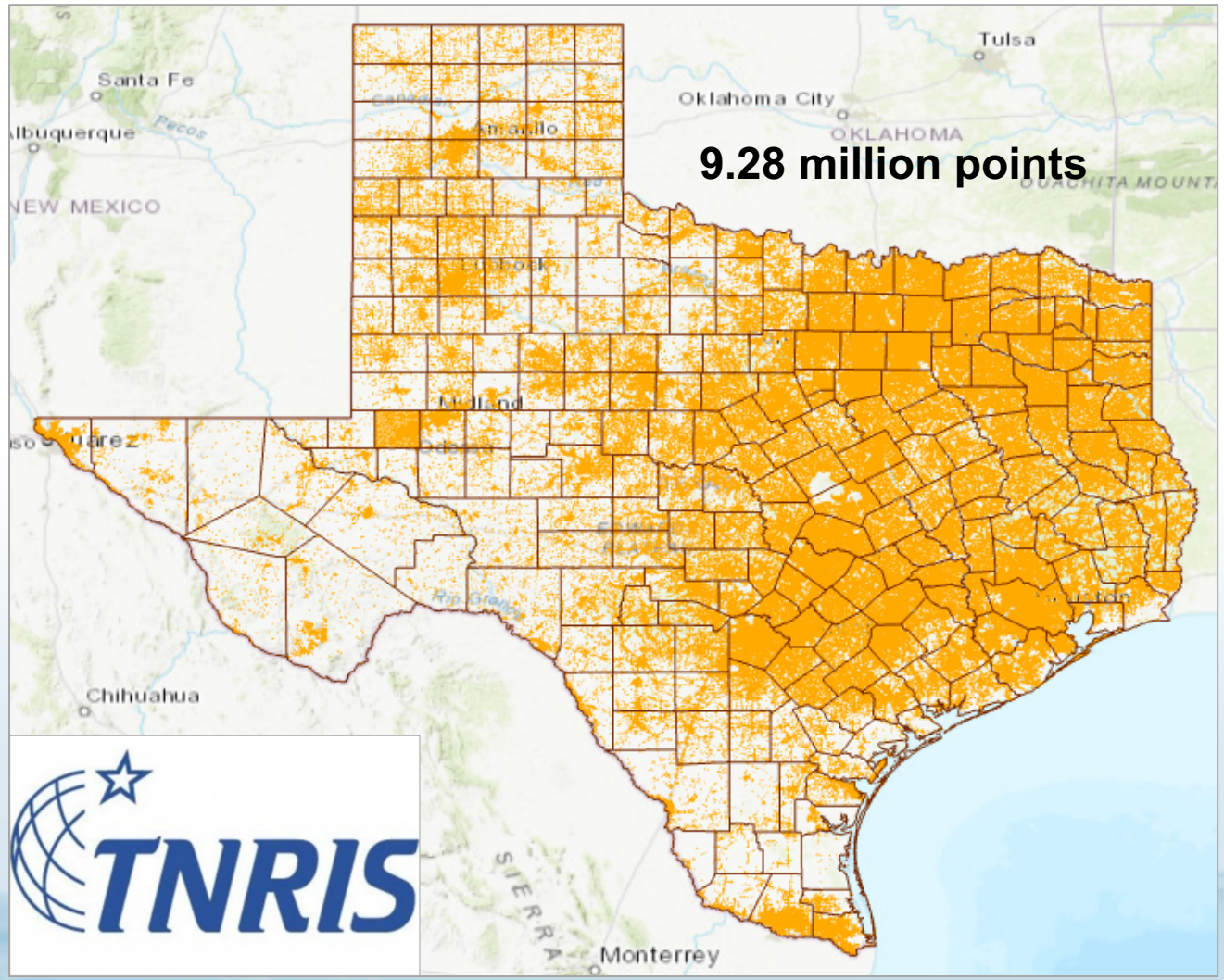
Liu et al., 2019
Zheng et al., 2019



Rating curves for each river segment



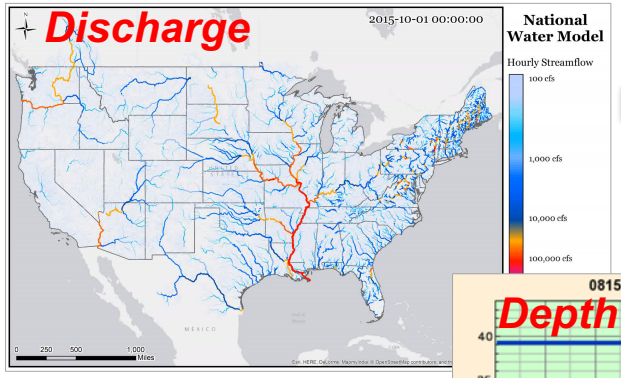
Address Points for Emergency Response



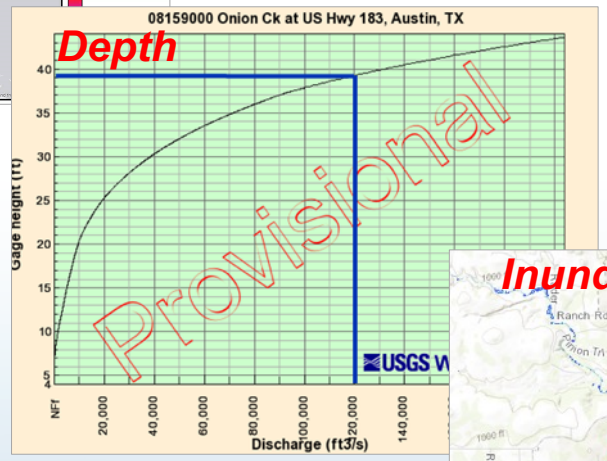
Points used for dispatching emergency response vehicles by 911 systems

Texas Flood Response System

Forecast from National Water Model

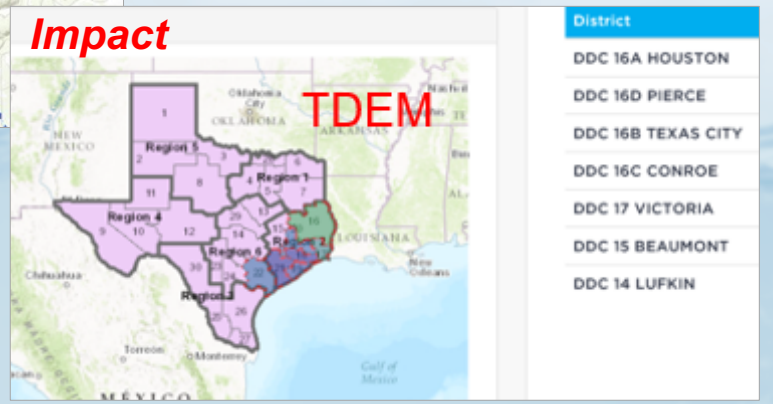


Depth using a rating curve



Inundation map using HAND

Impact using Address Points



Developed with Texas Division of Emergency Management …

TEXAS DEPARTMENT OF PUBLIC SAFETY ★ EMERGENCY MANAGEMENT ★

KISTERS

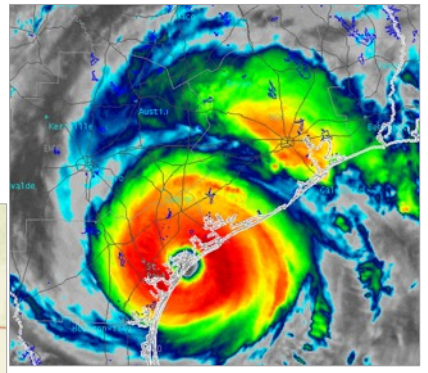
Operating in the cloud

esri

Hurricane Harvey

A major stress test

Storm Track for Hurricane Harvey

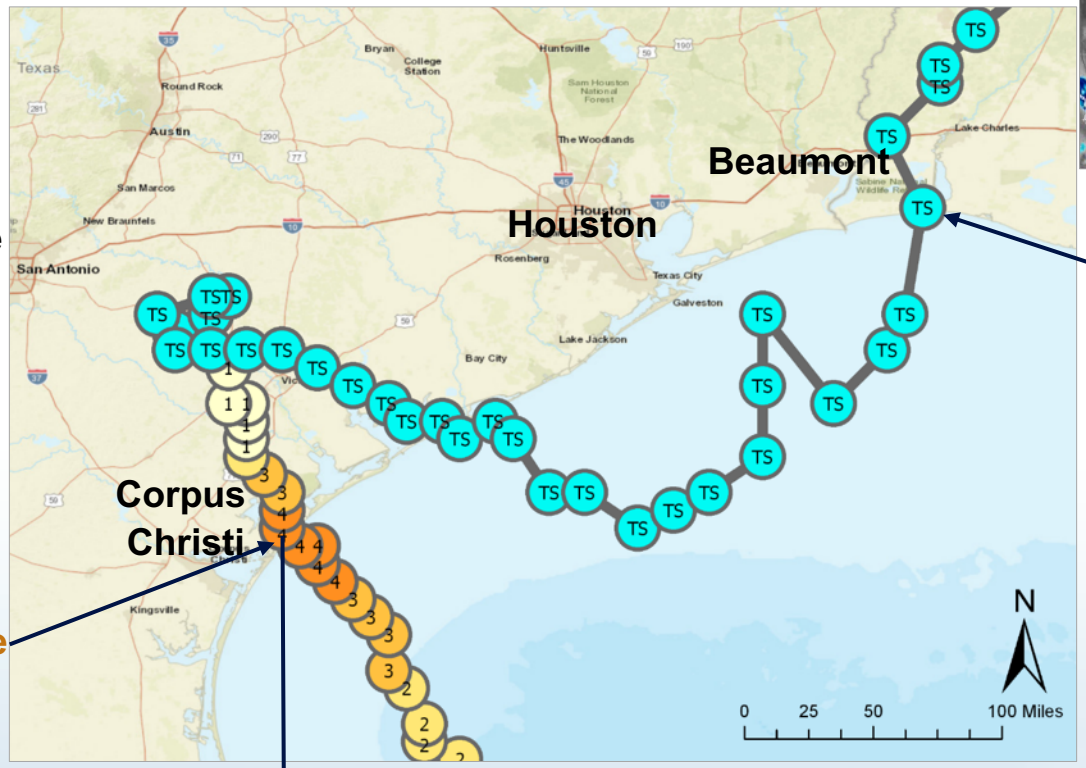


Strength

4
3
2
1

Hurricane Category

Tropical Storm



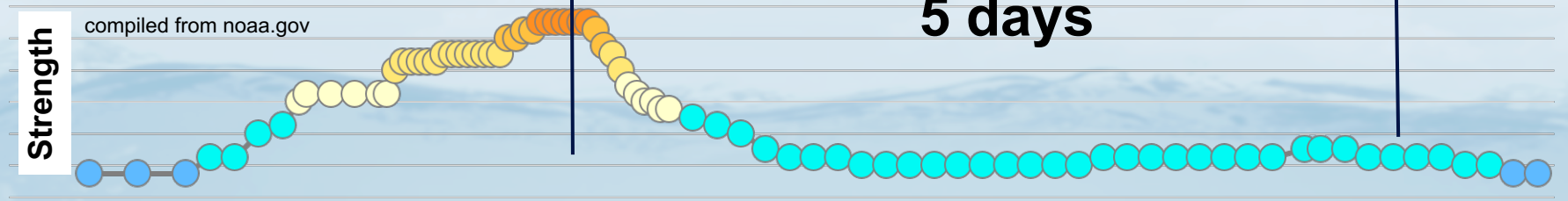
First Landfall as Category 4 Hurricane at 10PM on Friday 25 August

Second Landfall as Tropical Storm at 4 AM on Weds 30 August

5 days

compiled from noaa.gov

Strength



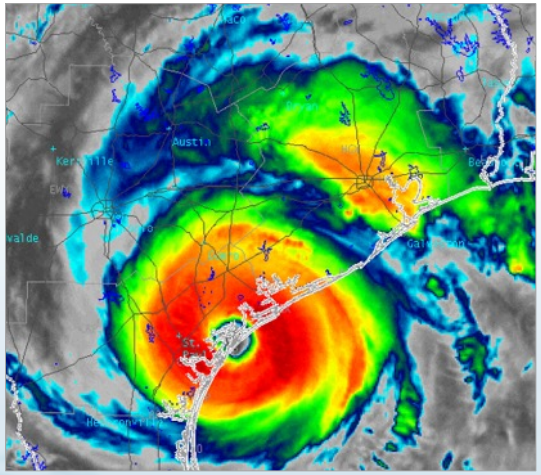
Wednesday Thursday Friday Saturday Sunday Monday Tuesday Wednesday

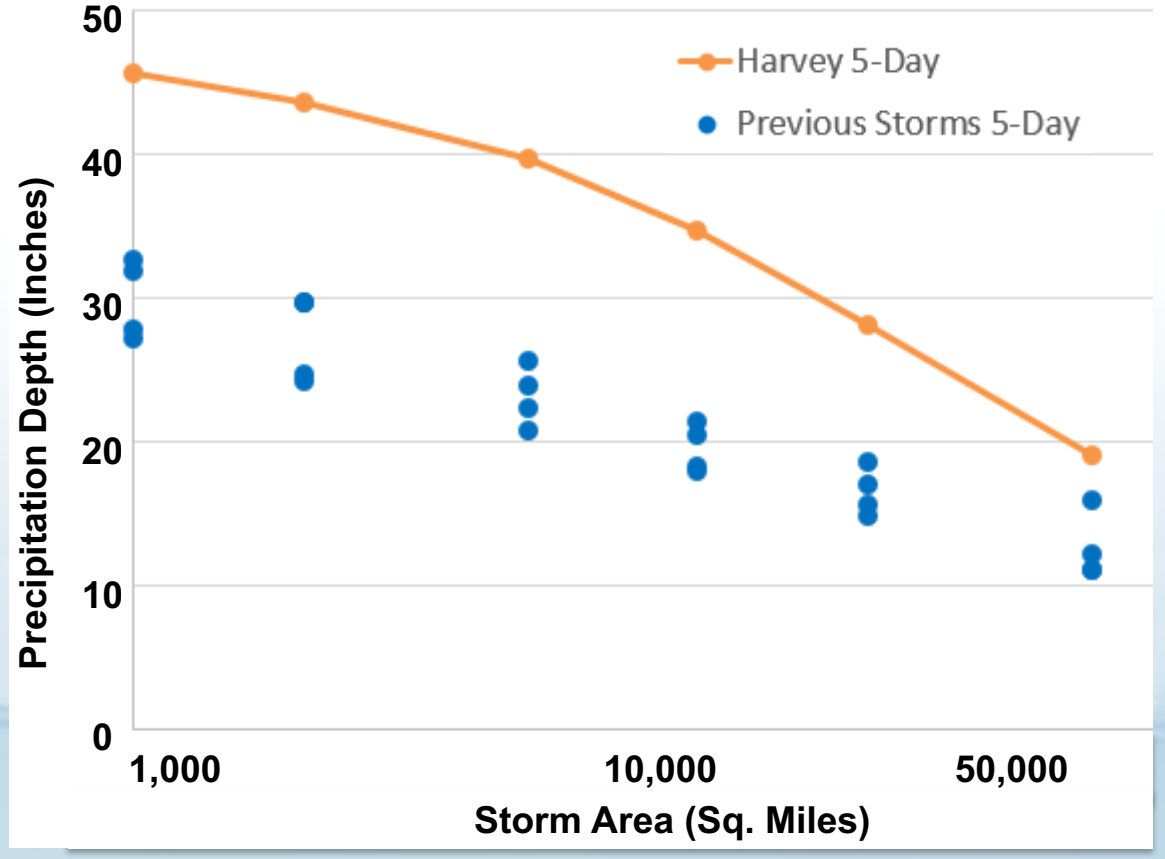
Hurricane Harvey – Record Precipitation

Harvey **2-day** precipitation was the **worst recorded storm** in US history

Harvey **3-day** Precipitation averaged **5 inches more** than previous worst storms

Harvey **5-day** Precipitation averaged ***11 inches more*** than previous worst storms



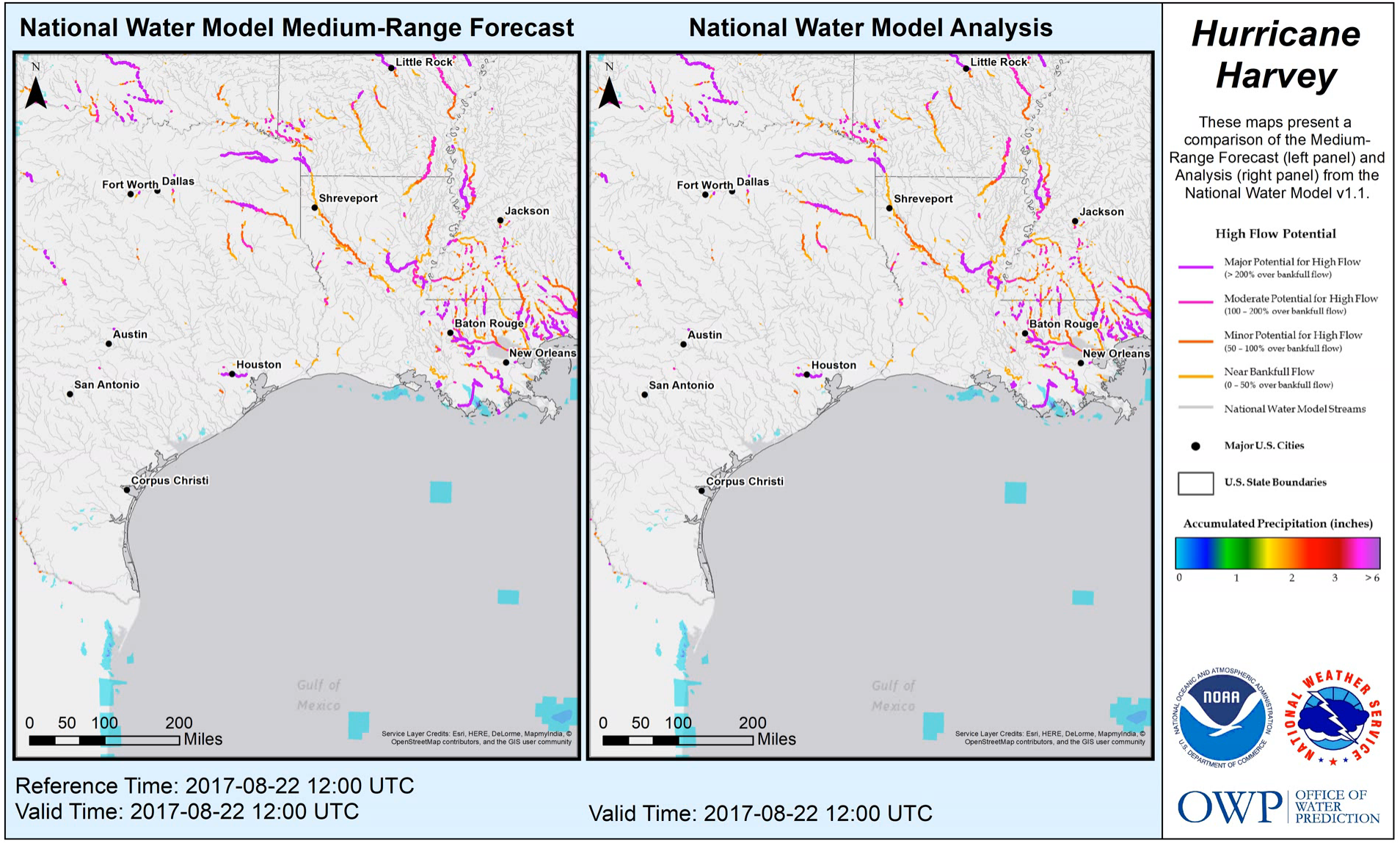


Data Sources: NWS River Forecast Centers; Applied Weather Associates, Inc., NASA.
Analysis: John Nielsen-Gammon and Brent McRoberts, Texas A&M University

Forecasting Hurricane Harvey using the National Water Model

10-day Ahead Forecast

Actual



Texas Division of Emergency Management, Austin

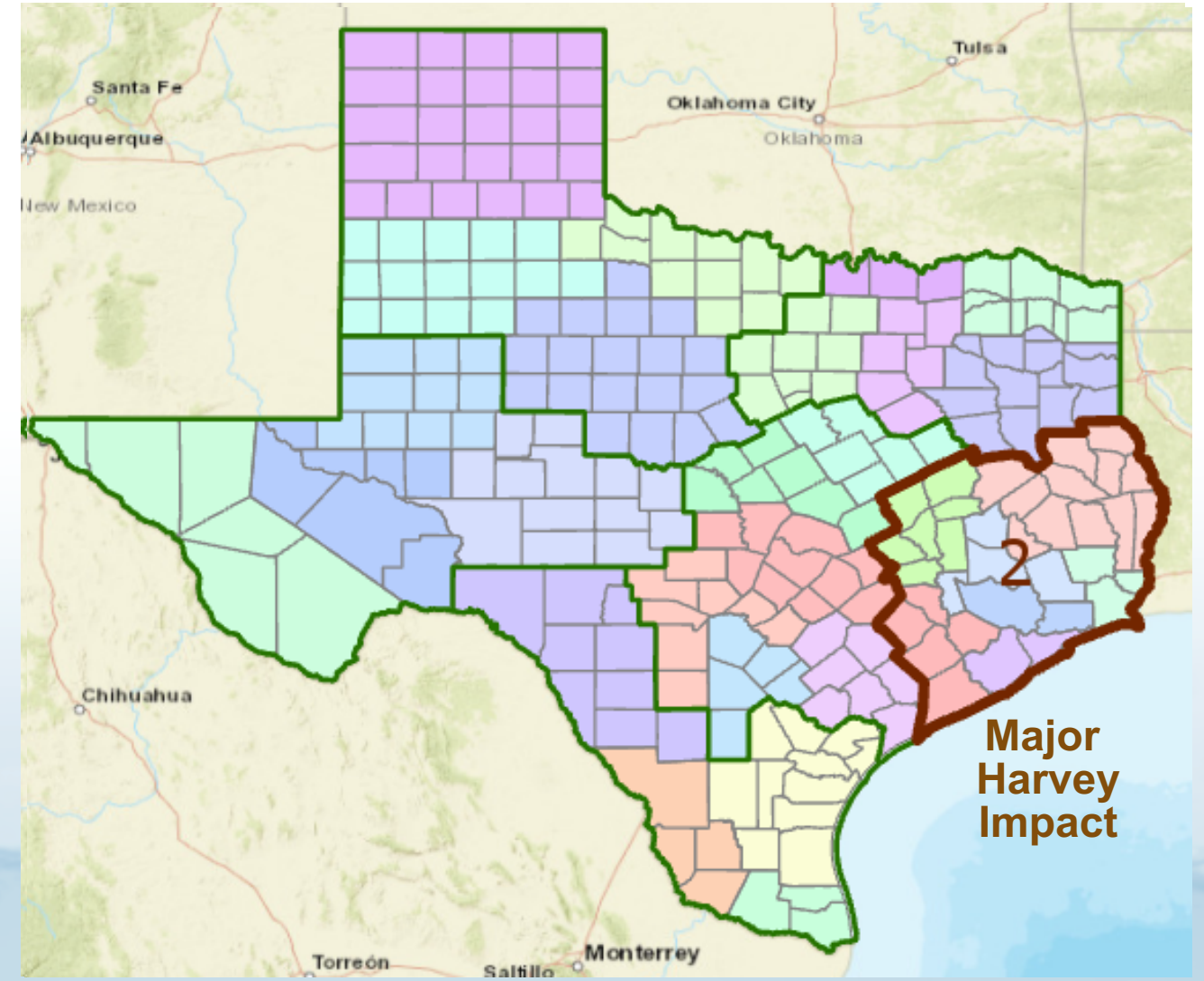
State Operations

Regions

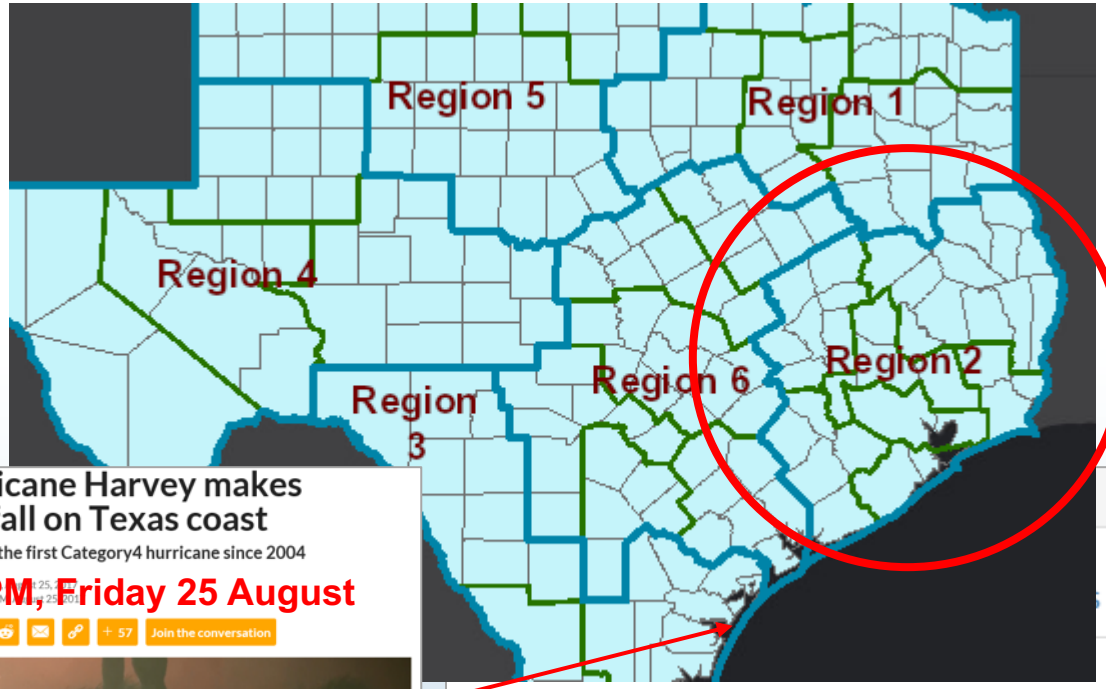
Districts

Counties

Chief Nim Kidd
Director, TDEM

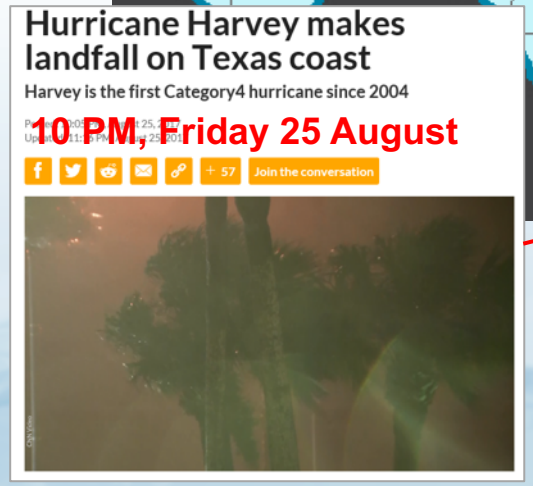


Flood Impact from National Water Model forecast at 3PM Friday 25 August



Using National Water Model Medium Range forecast

Houston is going to get inundated

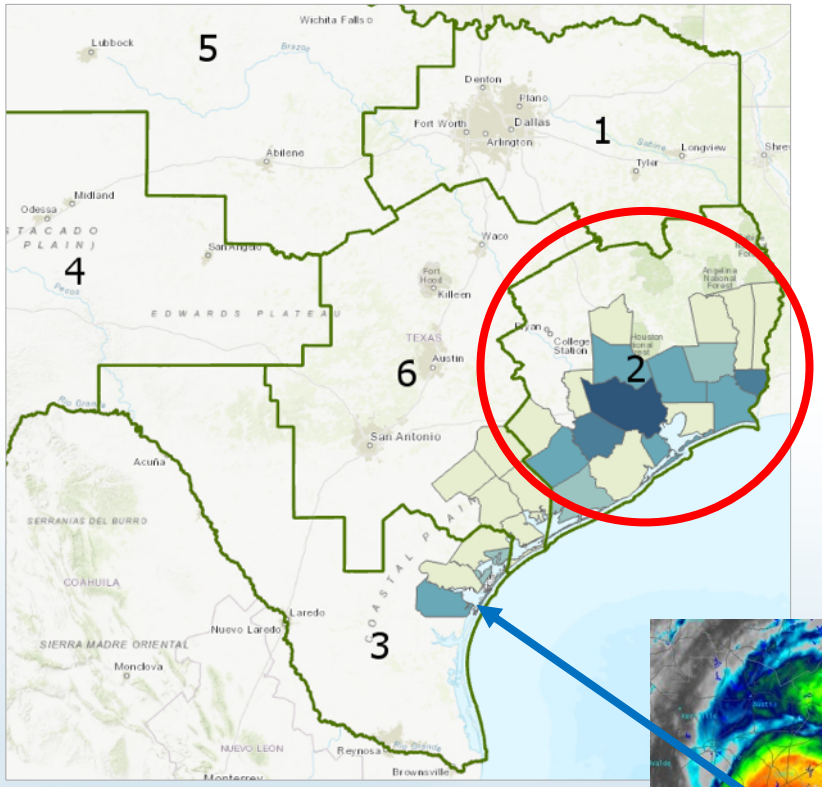


DETAILS

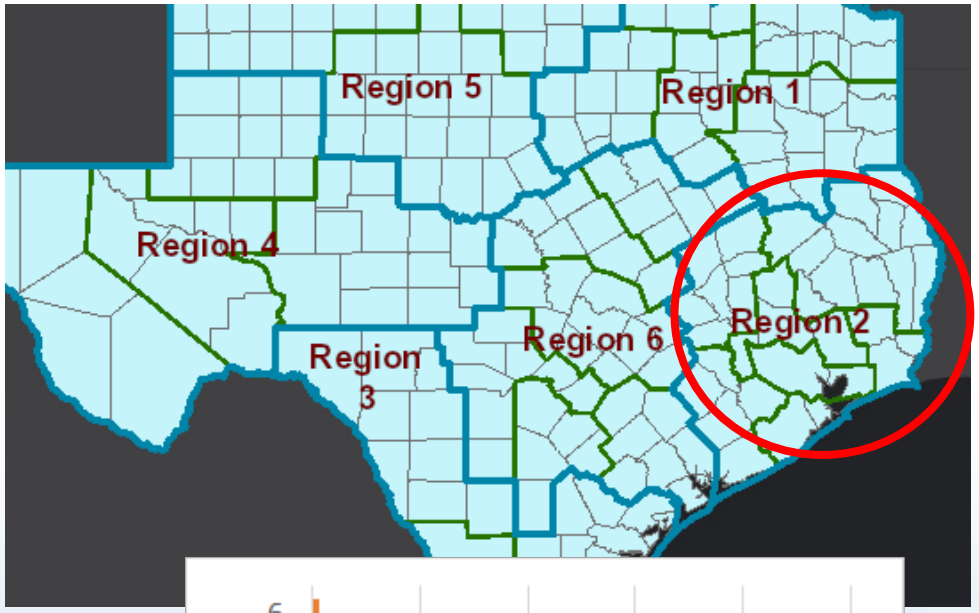
Region	Address Count	Time At Max
Region 2	238465	8/29/2017 6:00:00 AM
Region 6	22120	8/27/2017
Region 1	3209	9/2/2017
Region 4	1761	8/27/2017 3:00:00 AM
Region 3	1425	9/4/2017 12:00:00 PM
Region 5	103	9/4/2017 6:00:00 AM

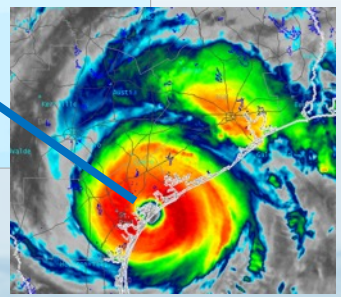
Texas Flood Response System correctly located the major damage zone before the hurricane reached the coast

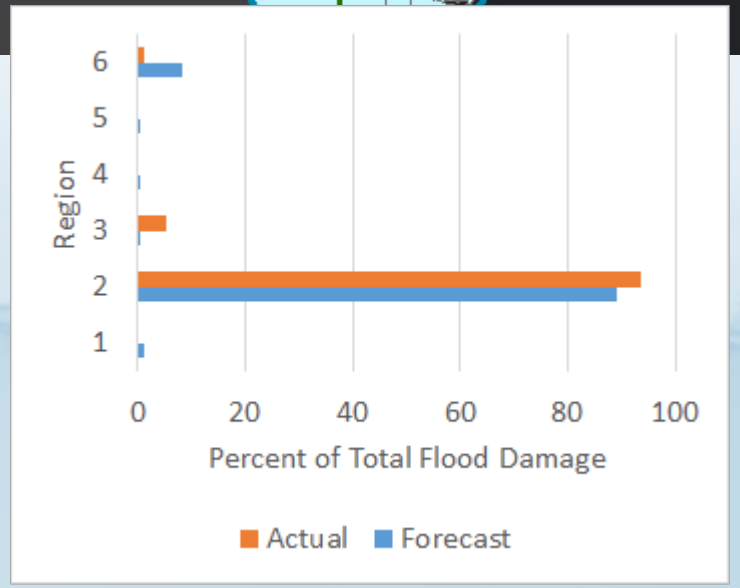
Actual Damage



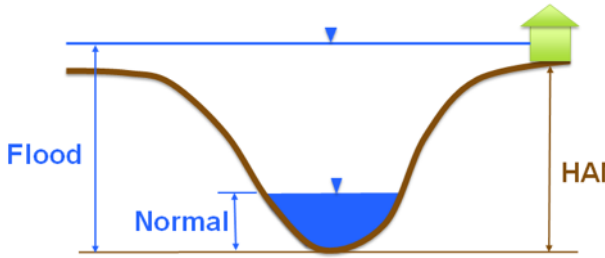
Forecast Damage

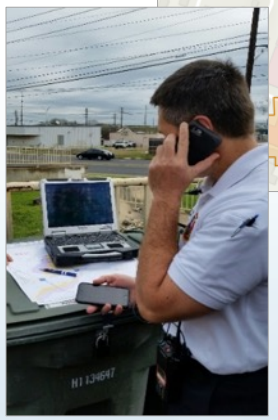


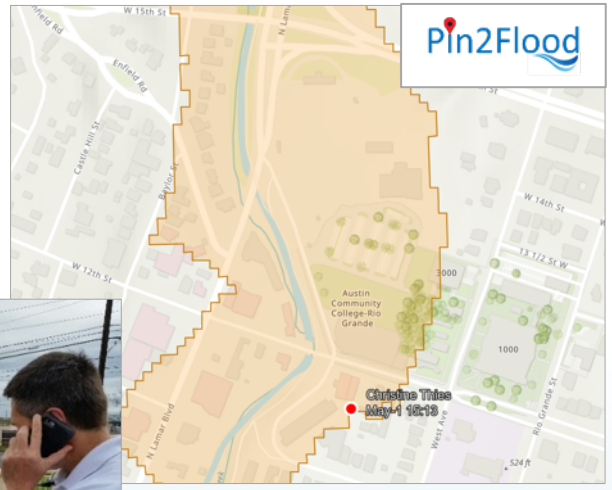




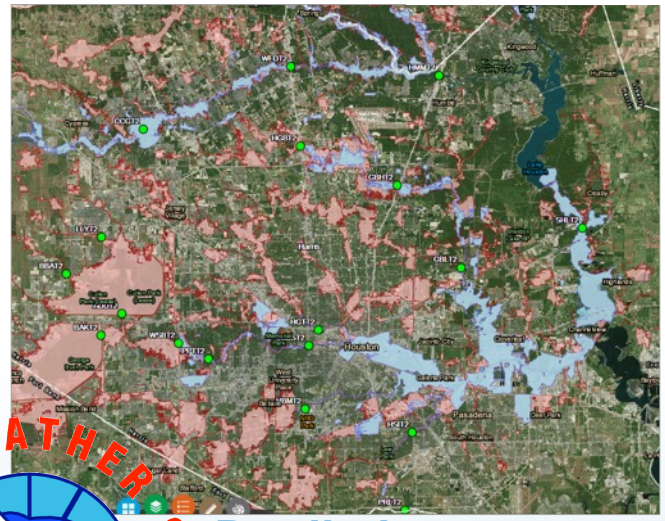
HAND: Flood Inundation Mapping at Landscape Scale



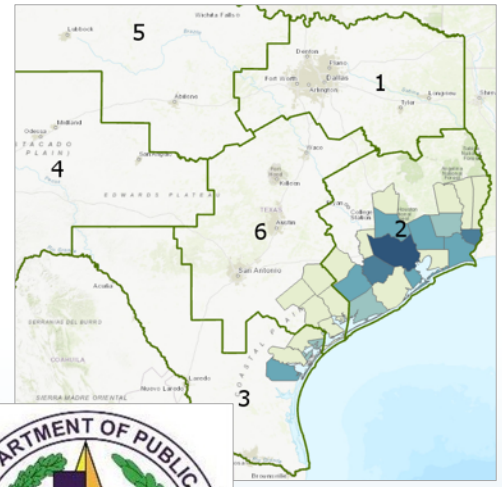




Observational Flood Mapping



Predictive Flood Mapping



Strategic Assessment

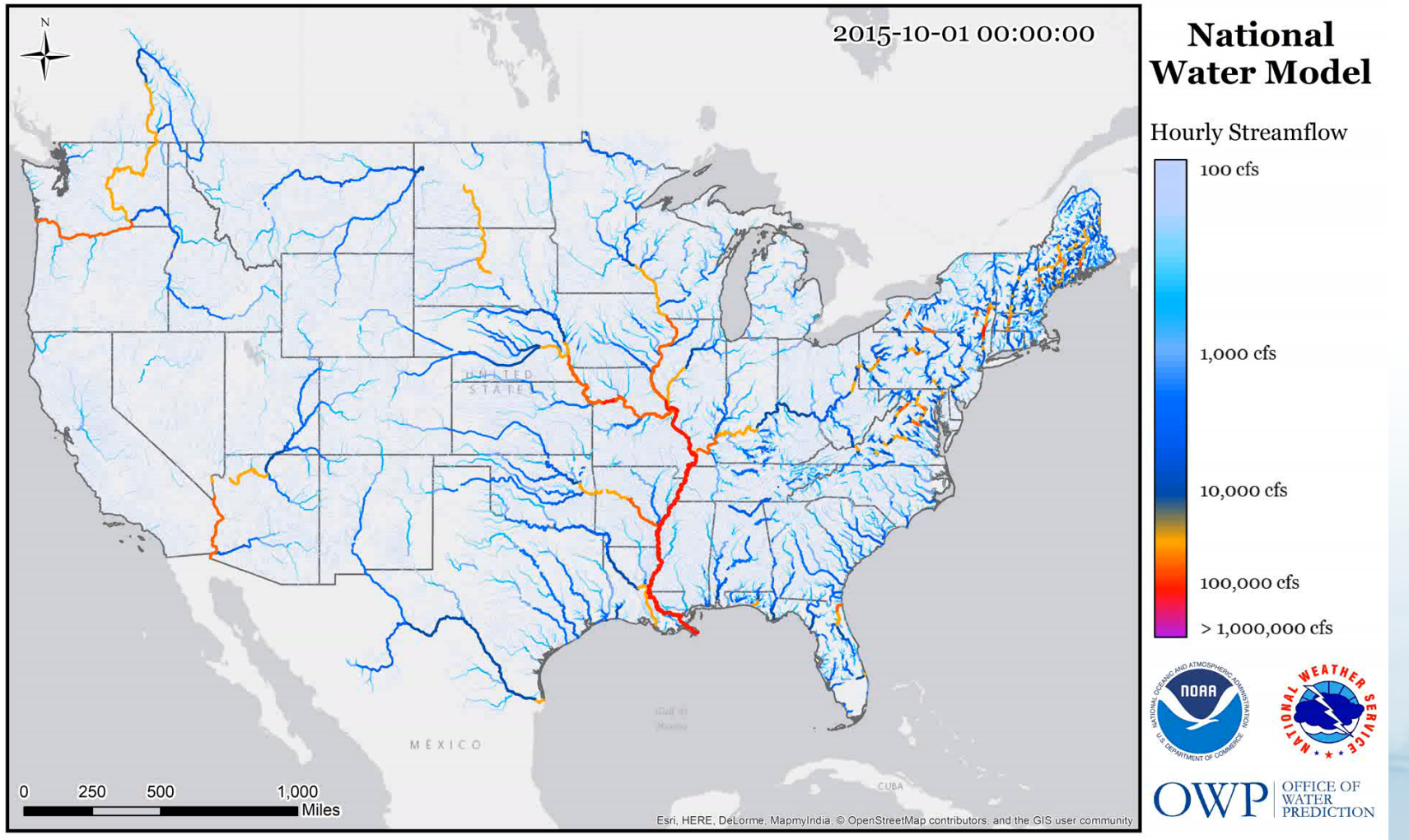
Application at each of these levels has been demonstrated

A fundamental step forward in mapping for flood emergency response

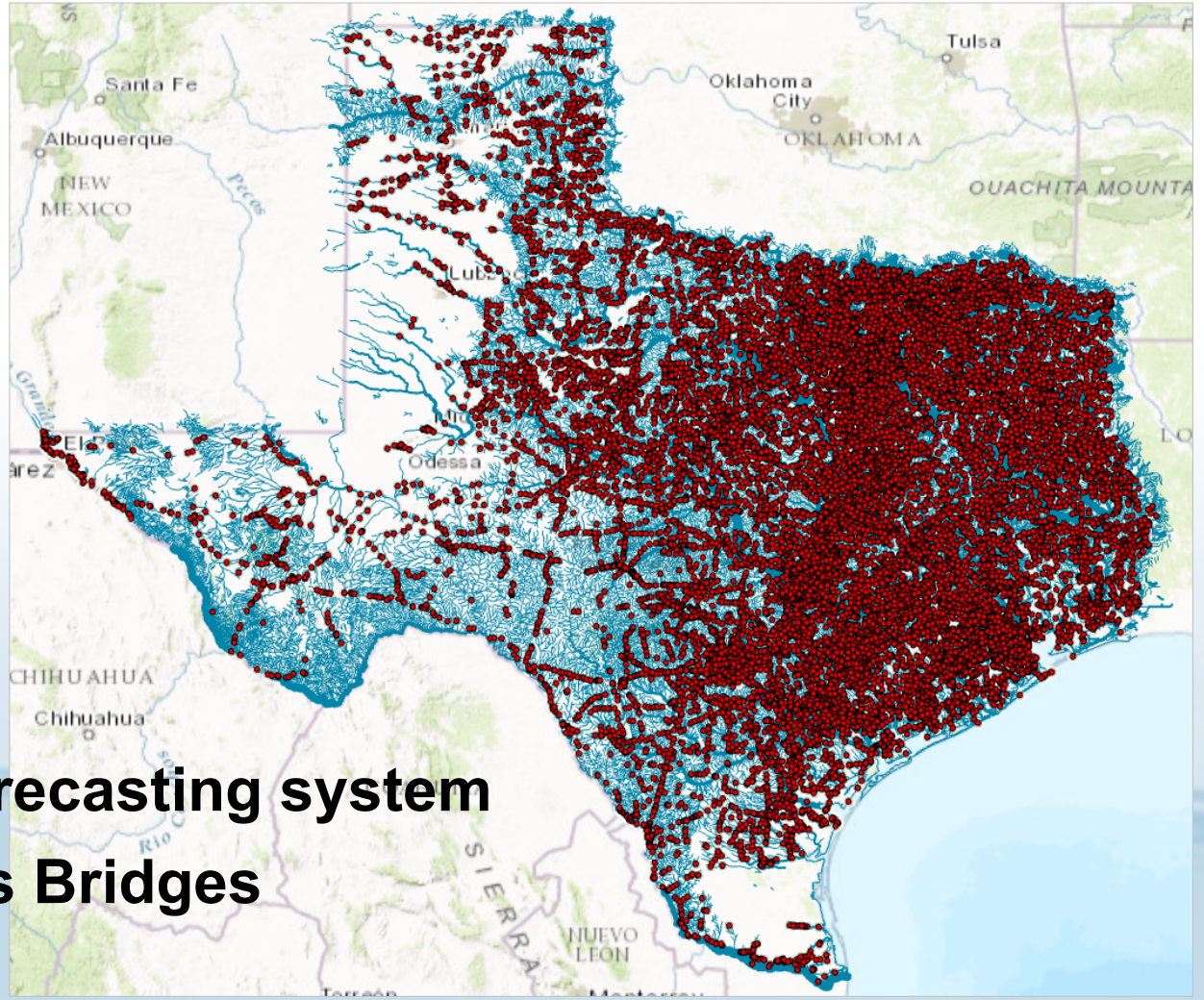
Densified Measurement

More forecasting requires more data

US National Water Model

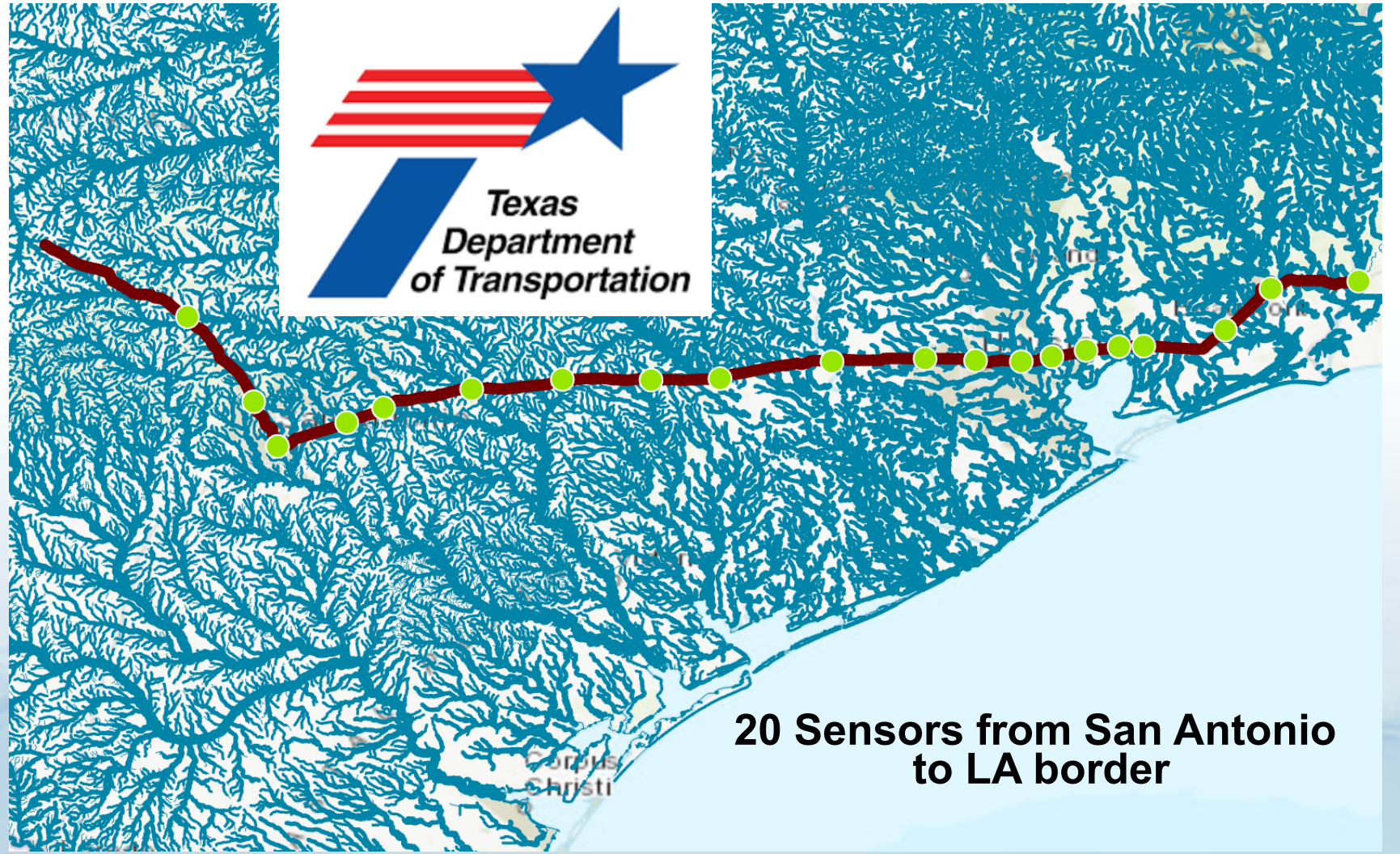


27,000 Texas bridges on 15,700 stream reaches forecast by the National Water Model

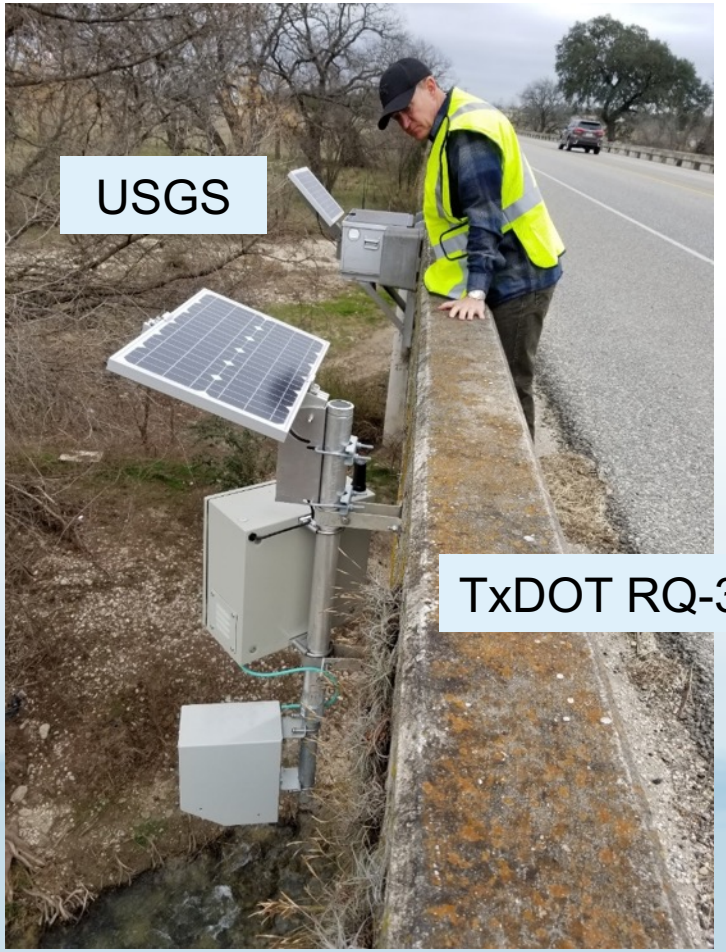


Flood forecasting system for Texas Bridges

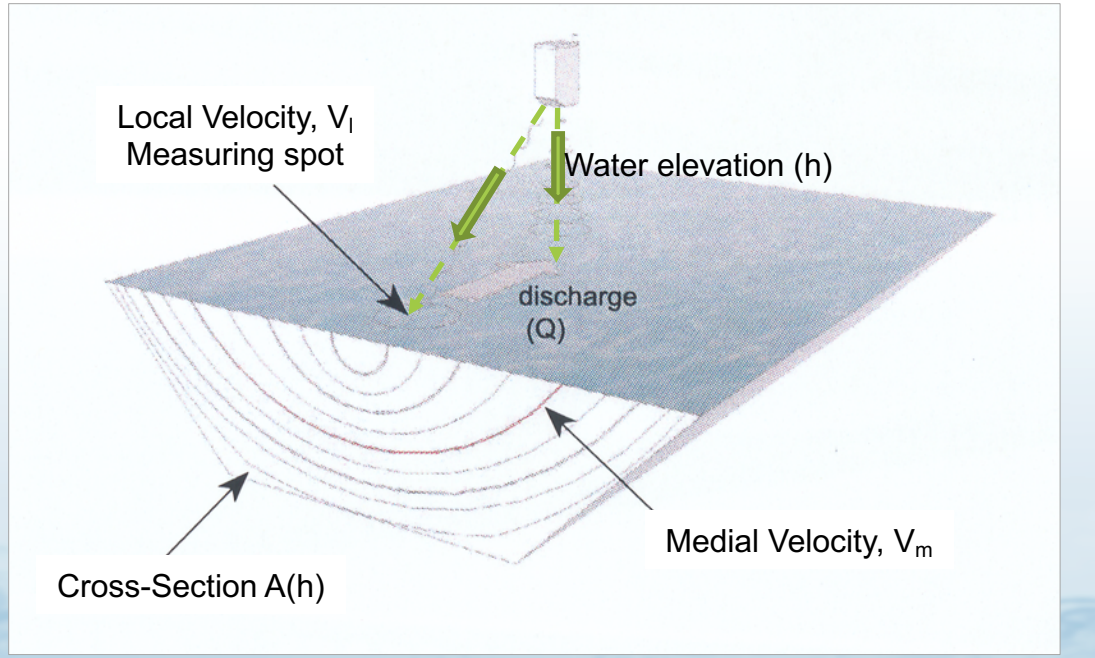
Radar Streamflow Measurement on I-10



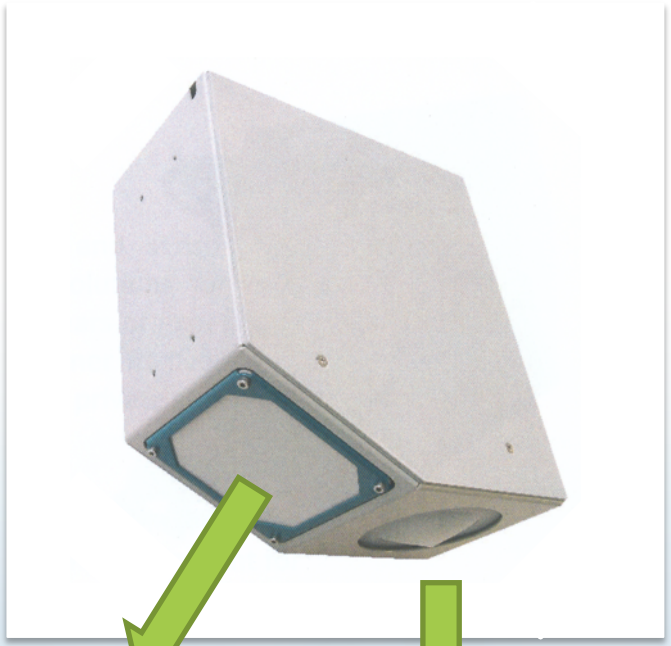
Sensors on Guadalupe River at Comfort



Radar Measurement of Water Elevation and Velocity



RQ-30



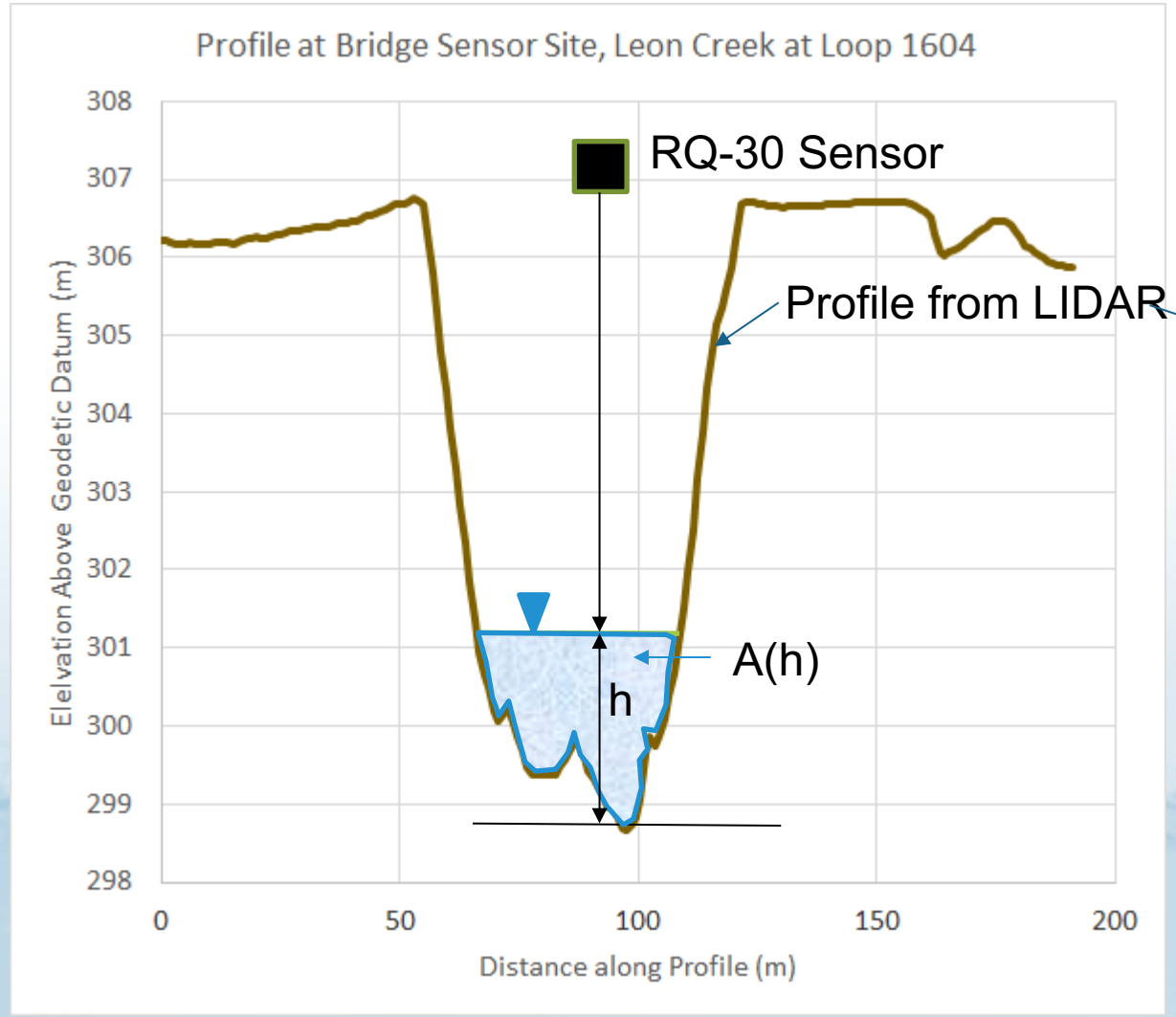
Velocity

Water elevation (h)

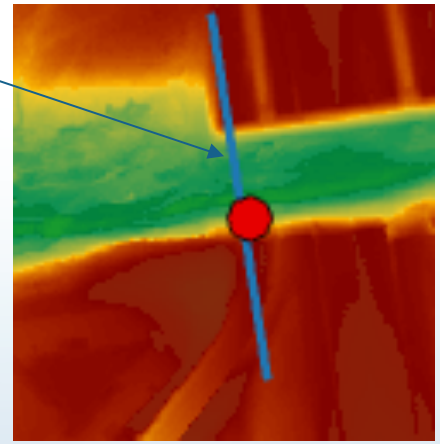
$V_m = V_l * k$

k = calibration factor at site

Cross-Section Profile from LIDAR

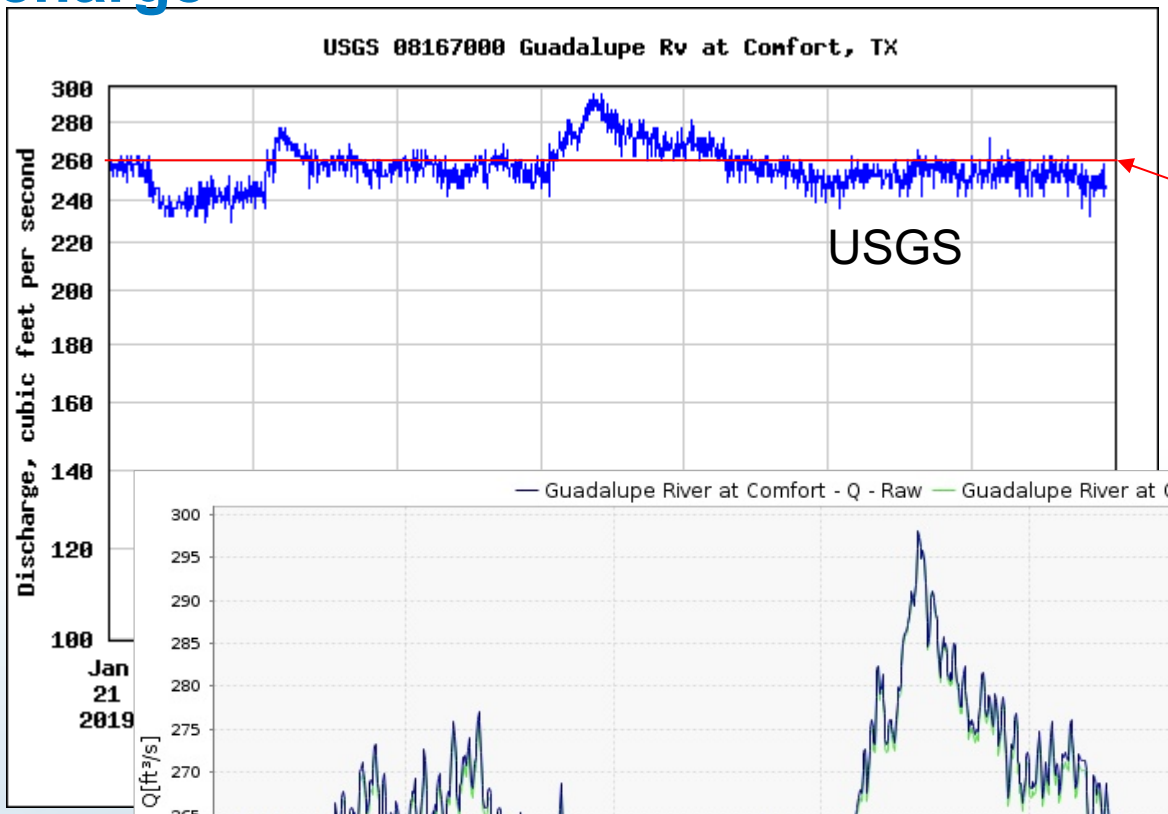


Referenced to geodetic datum



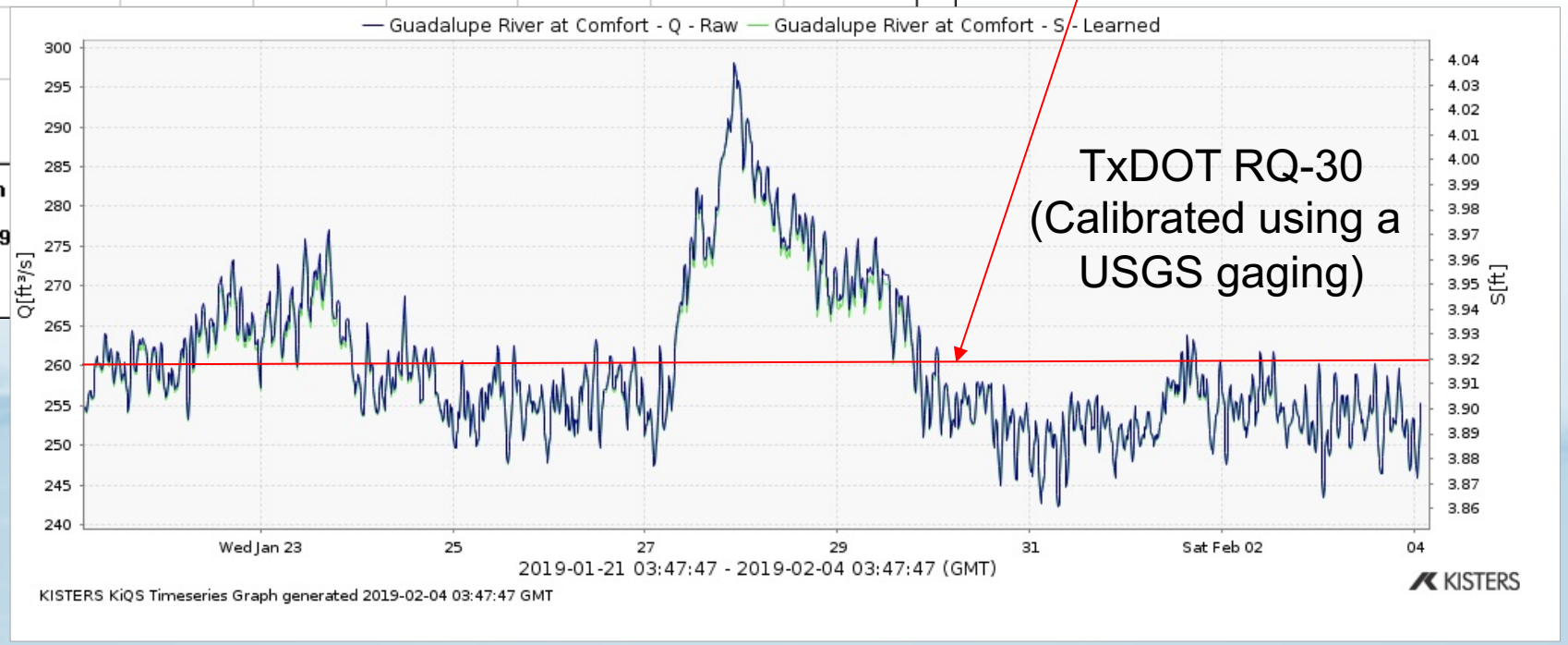
Local datum is the stream bed. If channel erodes or degrades, new profile is used and local datum changes

Guadalupe River at Comfort: Calibration using Local Measurement of Discharge



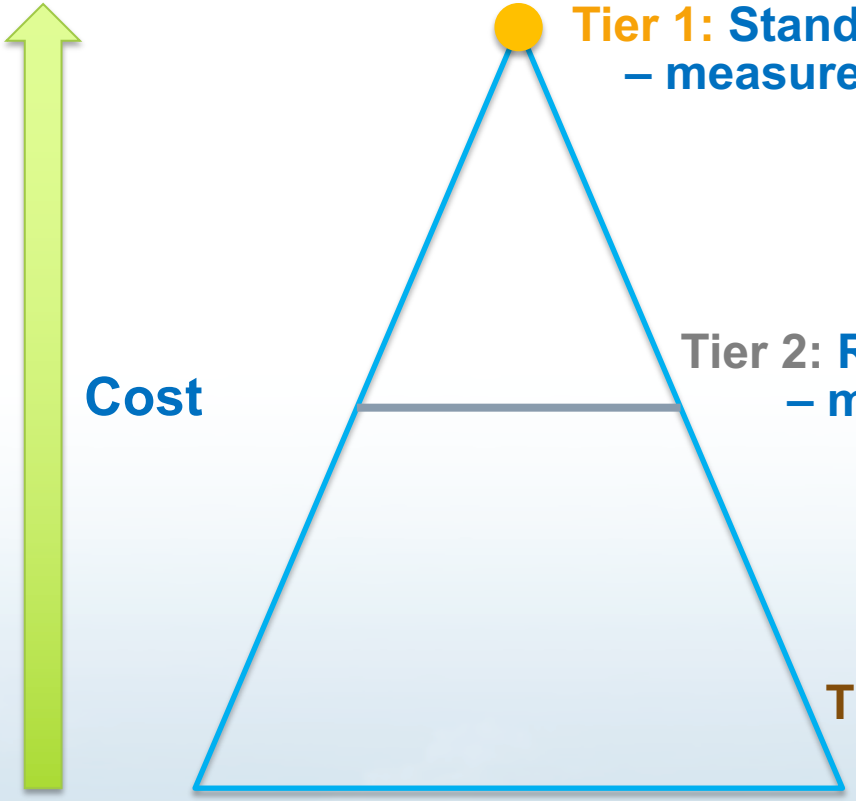
260 cfs

KISTERS



TxDOT RQ-30
(Calibrated using a
USGS gaging)

Three-Tier Flood Alert System



Tier 1: Standard USGS Gages
– measure everything

Tier 2: Radar Sensors on Bridges (TxDOT)
– medium and high flows

Tier 3: Water Level Sensors
– local flood alert systems

Interoperable flood warning systems

Working with LIDAR data

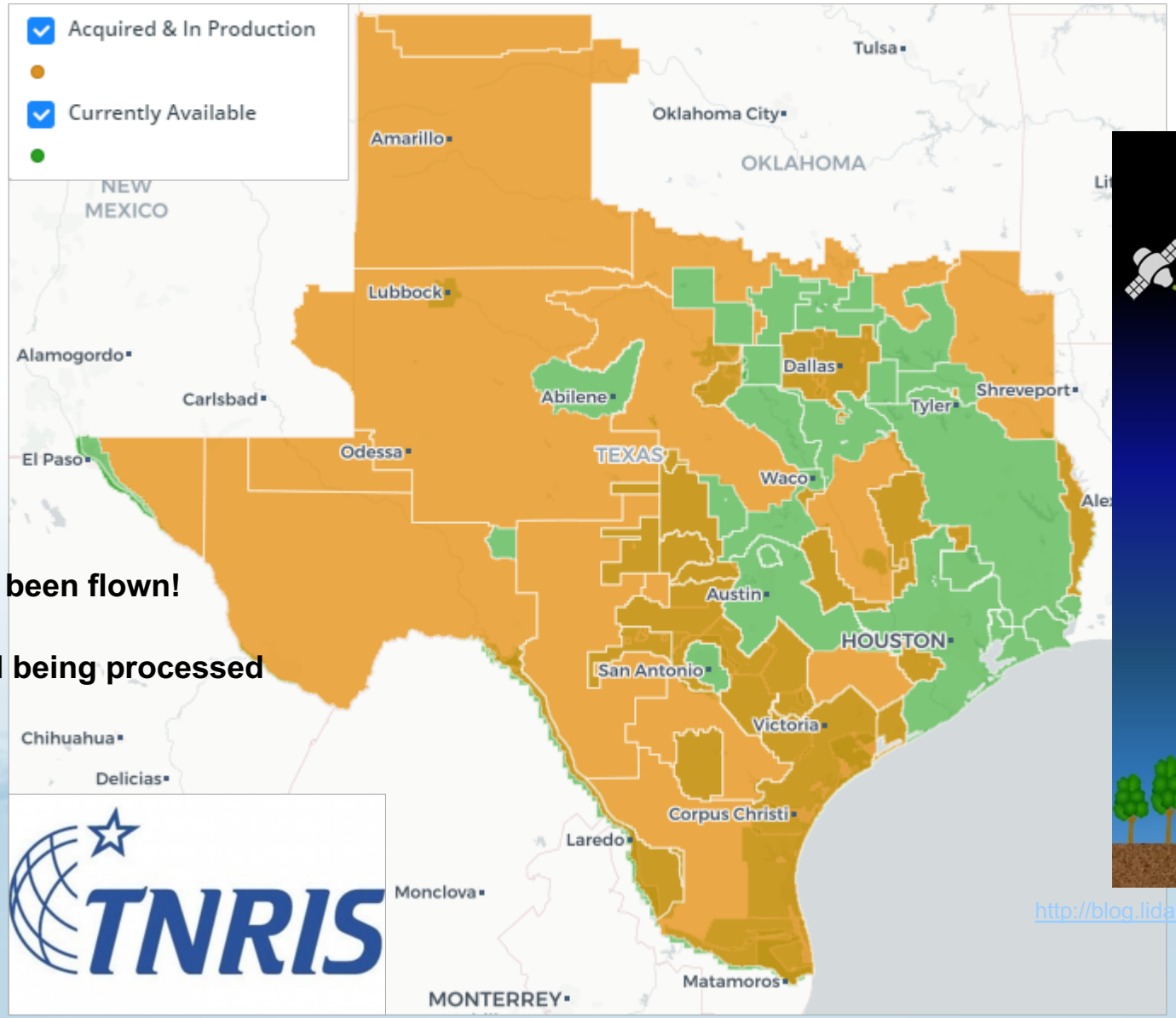
Denser data, better mapping, more issues

Texas 1m LIDAR Coverage

USGS

FEMA

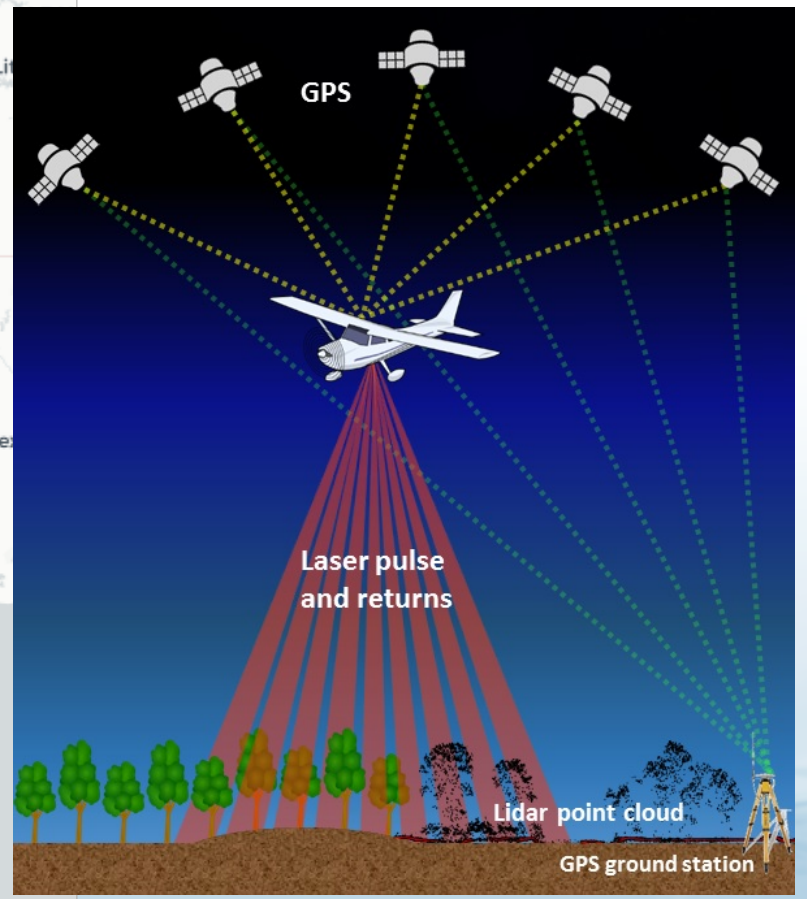
Thanks for your support!



All of Texas has been flown!

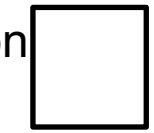
Some regions are still being processed

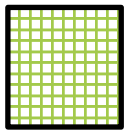
TNRIS

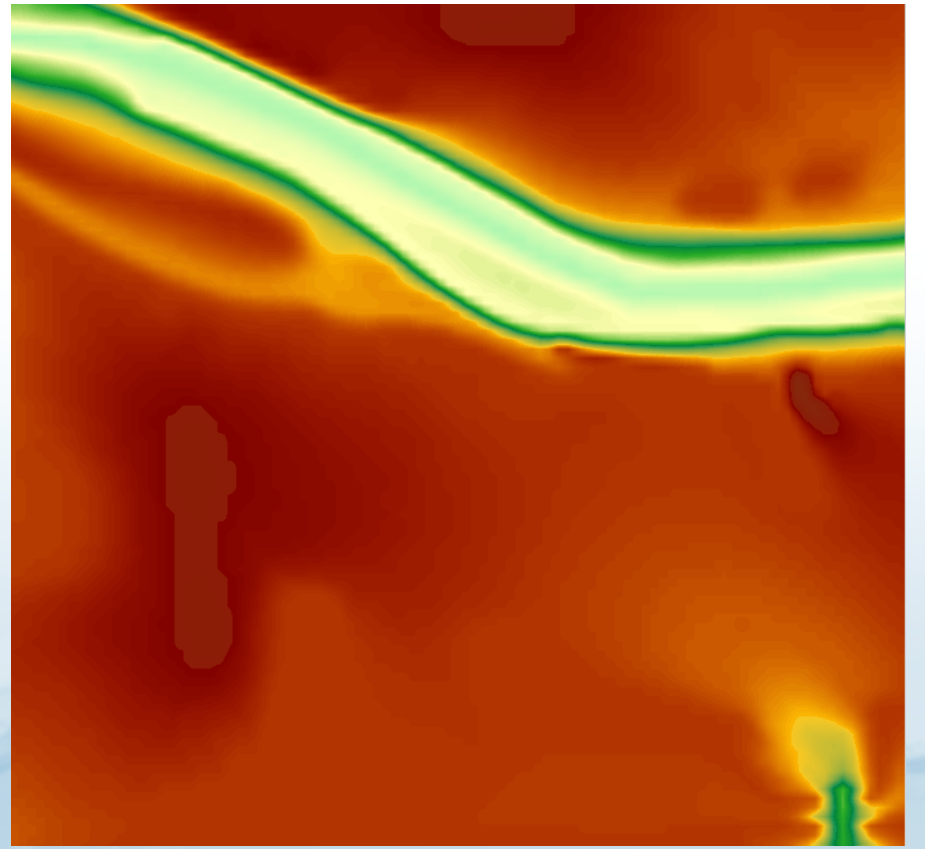


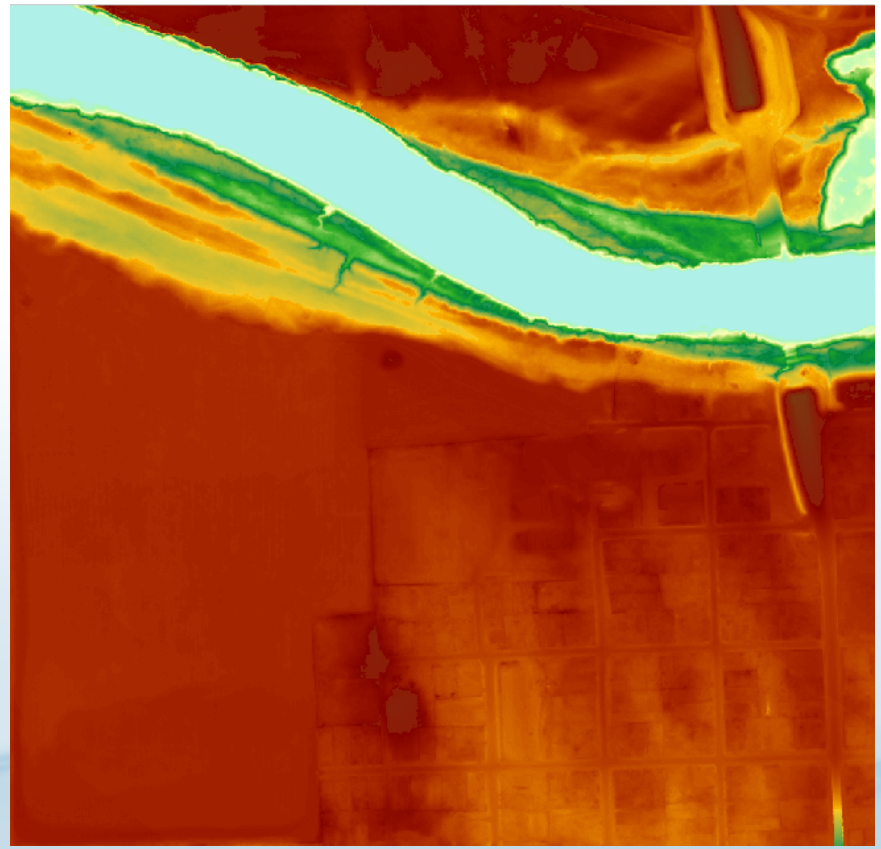
http://blog.lidarnews.com/wp-content/uploads/2016/03/Lidar-Graphic1.jpg

New LIDAR data is 100 times denser

National Elevation Dataset  1 cell
10m x 10m

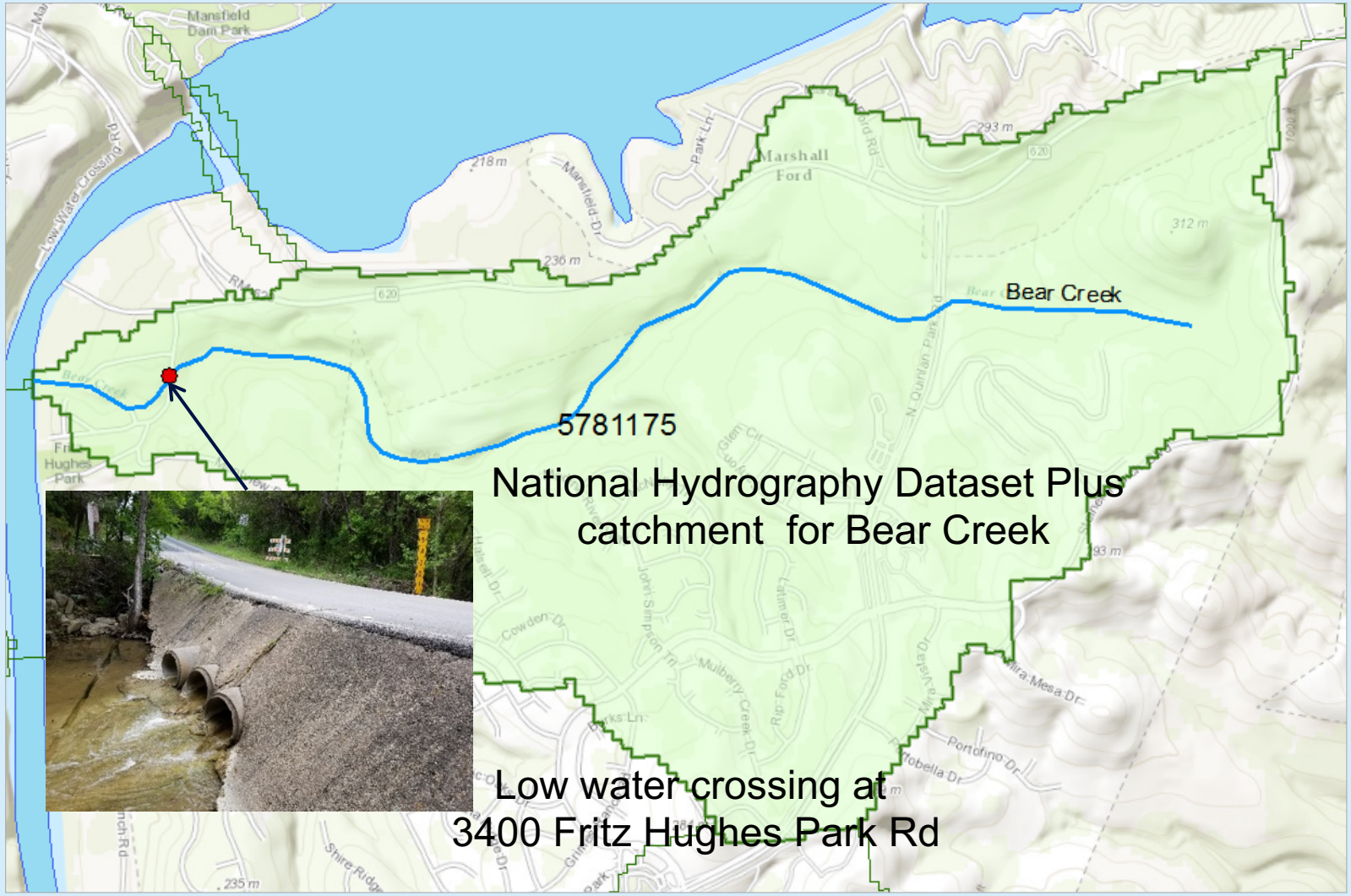
New LIDAR data  100 cells
1m x 1m





LIDAR is critical for accurate terrain description

Flood Information for Fritz Hughes Park Rd near Lake Travis



Road, Stream and Low Water Crossing Images

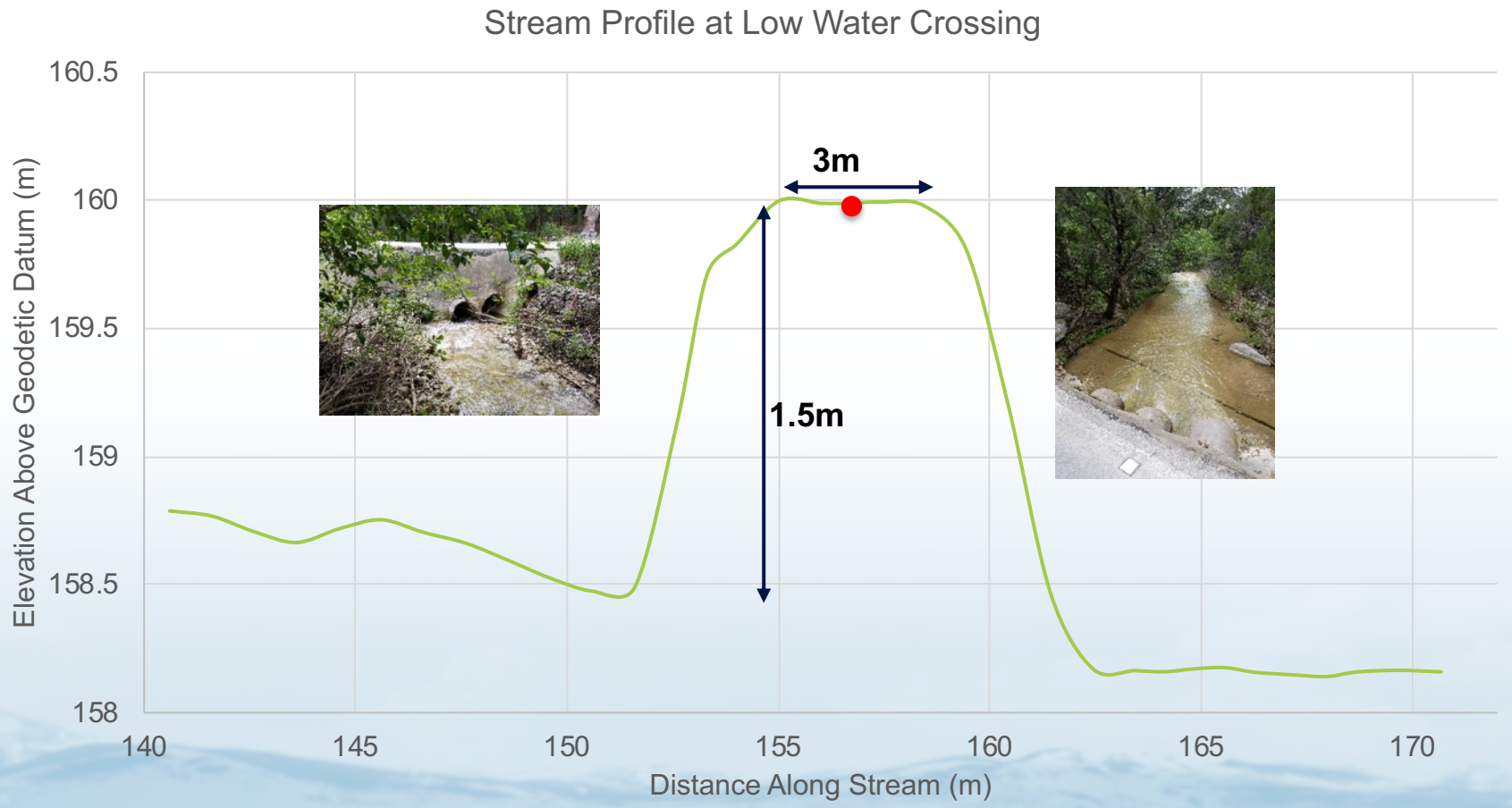
Road View

Downstream View

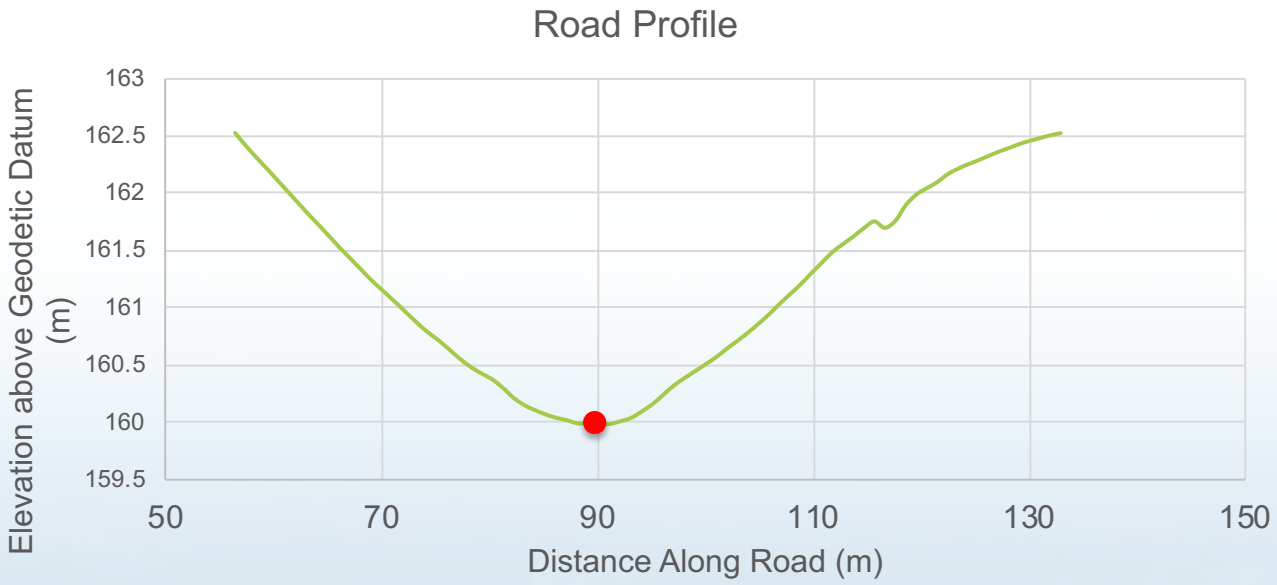
Upstream Pipes

Downstream Pipes

Stream Profile

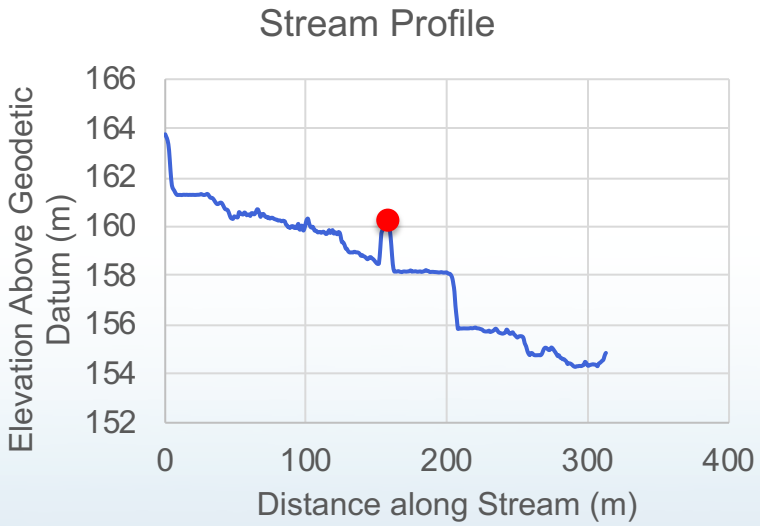


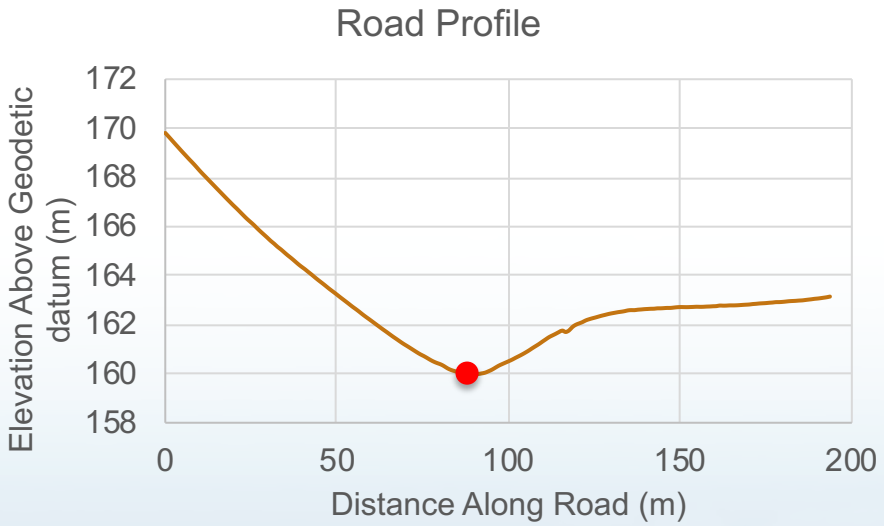
Road Profile

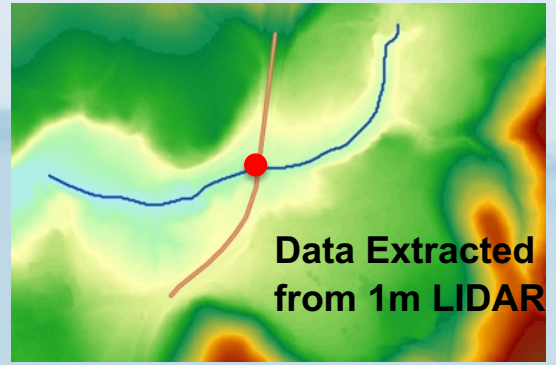


Low Water Crossing at Bear Creek on Fritz Hughes Park Rd

Road is at Elevation 160m where it crosses the stream

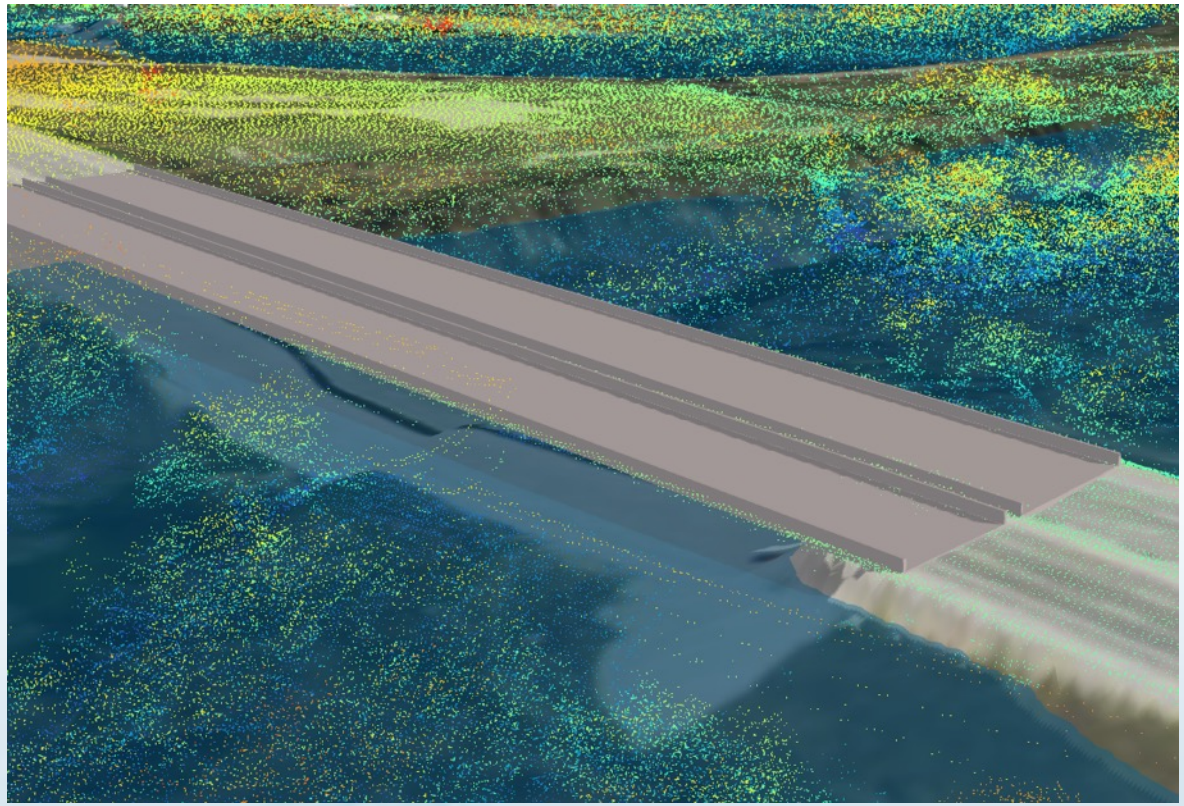


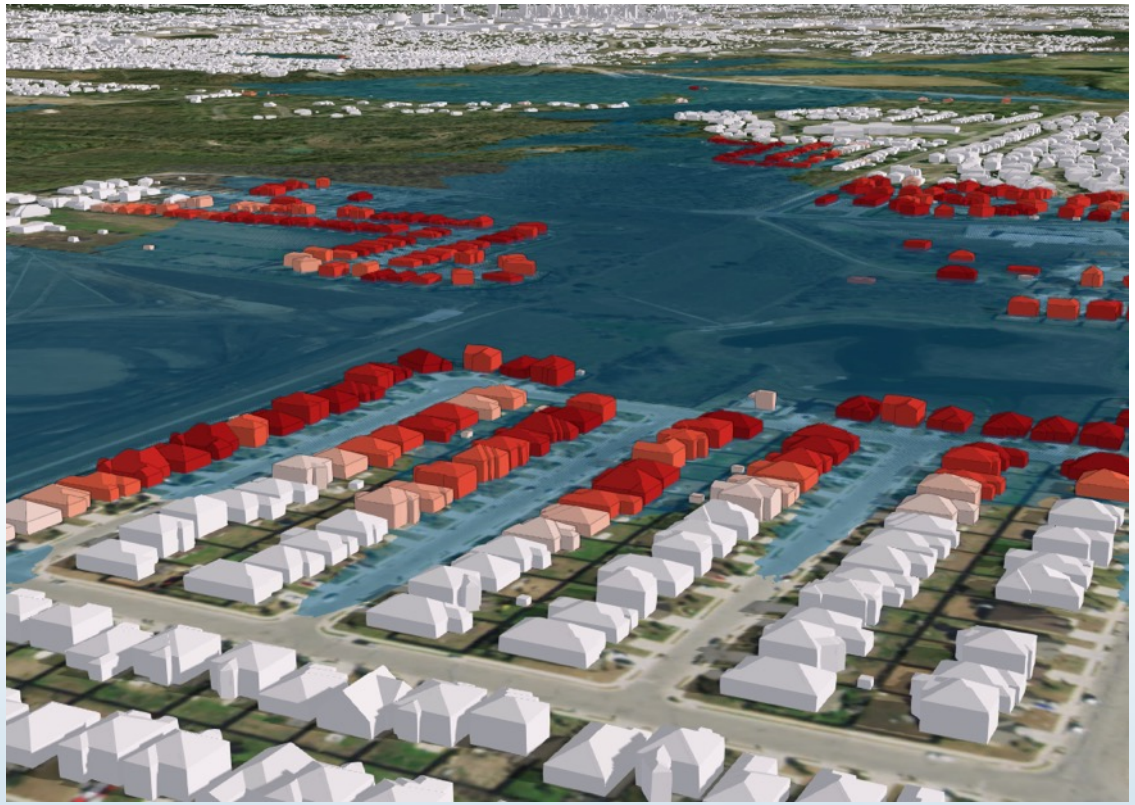




Flood Mapping in 3D using LIDAR

Source: Gert van Maren, ESRI





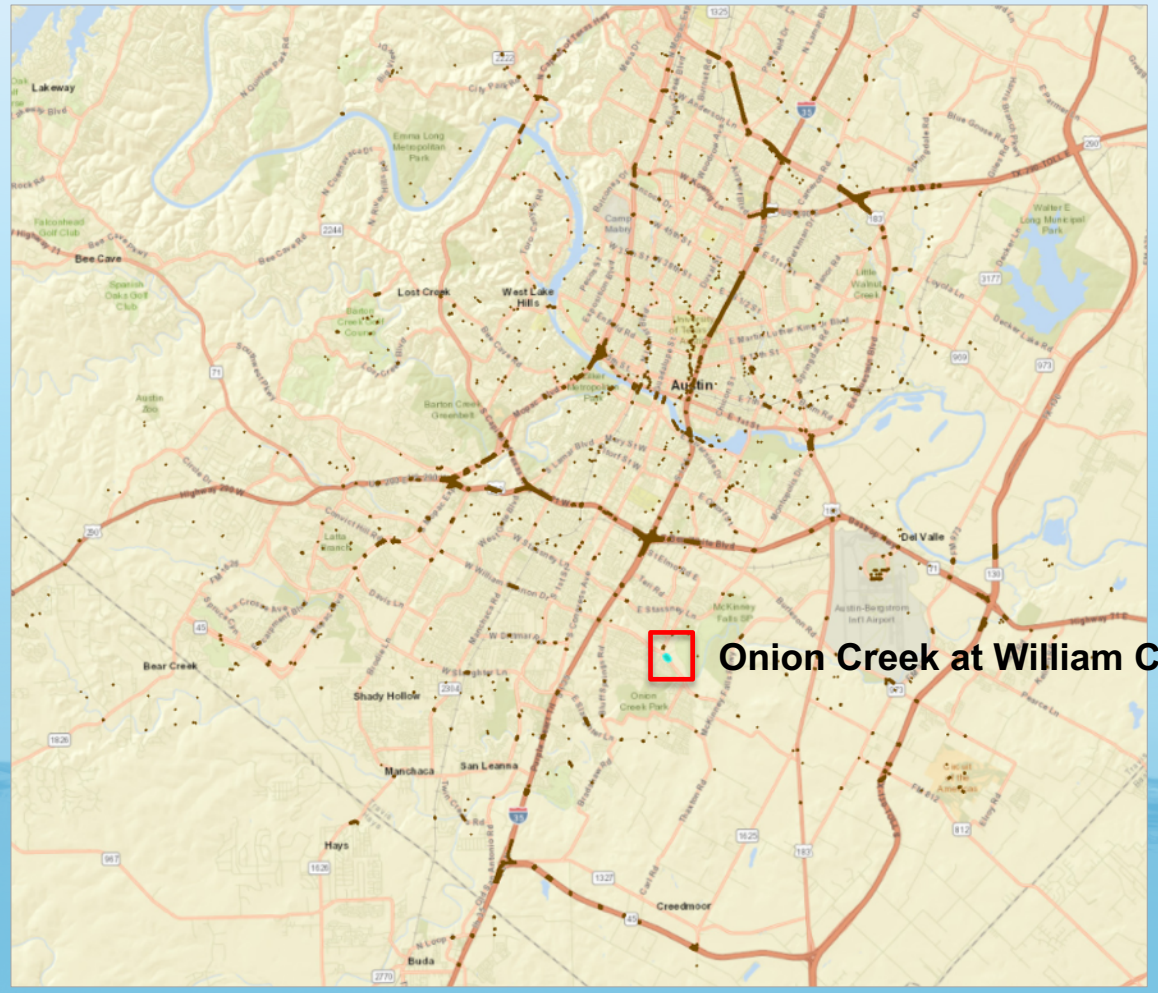
Transportation System

Building Infrastructure

http://www.arcgis.com/home/webscene/viewer.html?webscene=3455af9be32141569da41f42d880d022

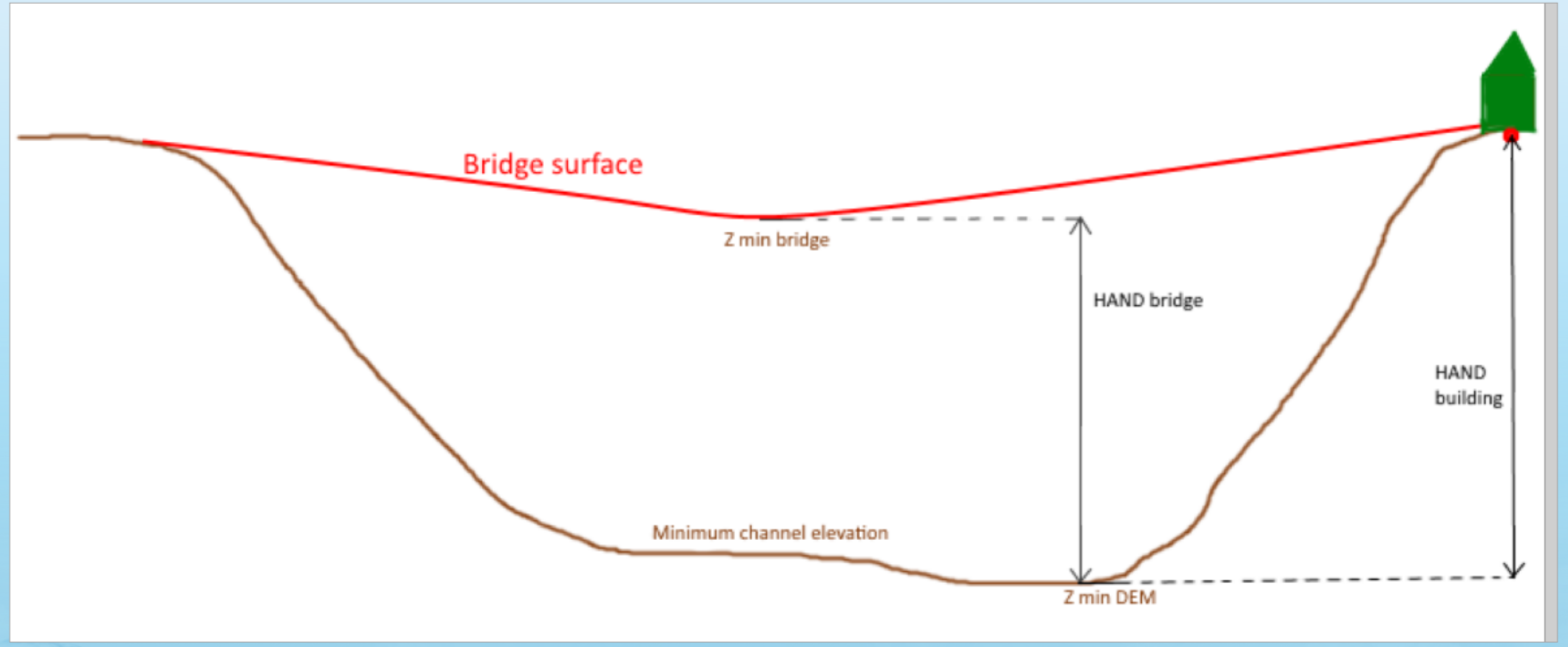
1057 Bridge Spans Extracted for Austin Area from 1m LIDAR Point Cloud Data

Gert Van Maren (ESRI)



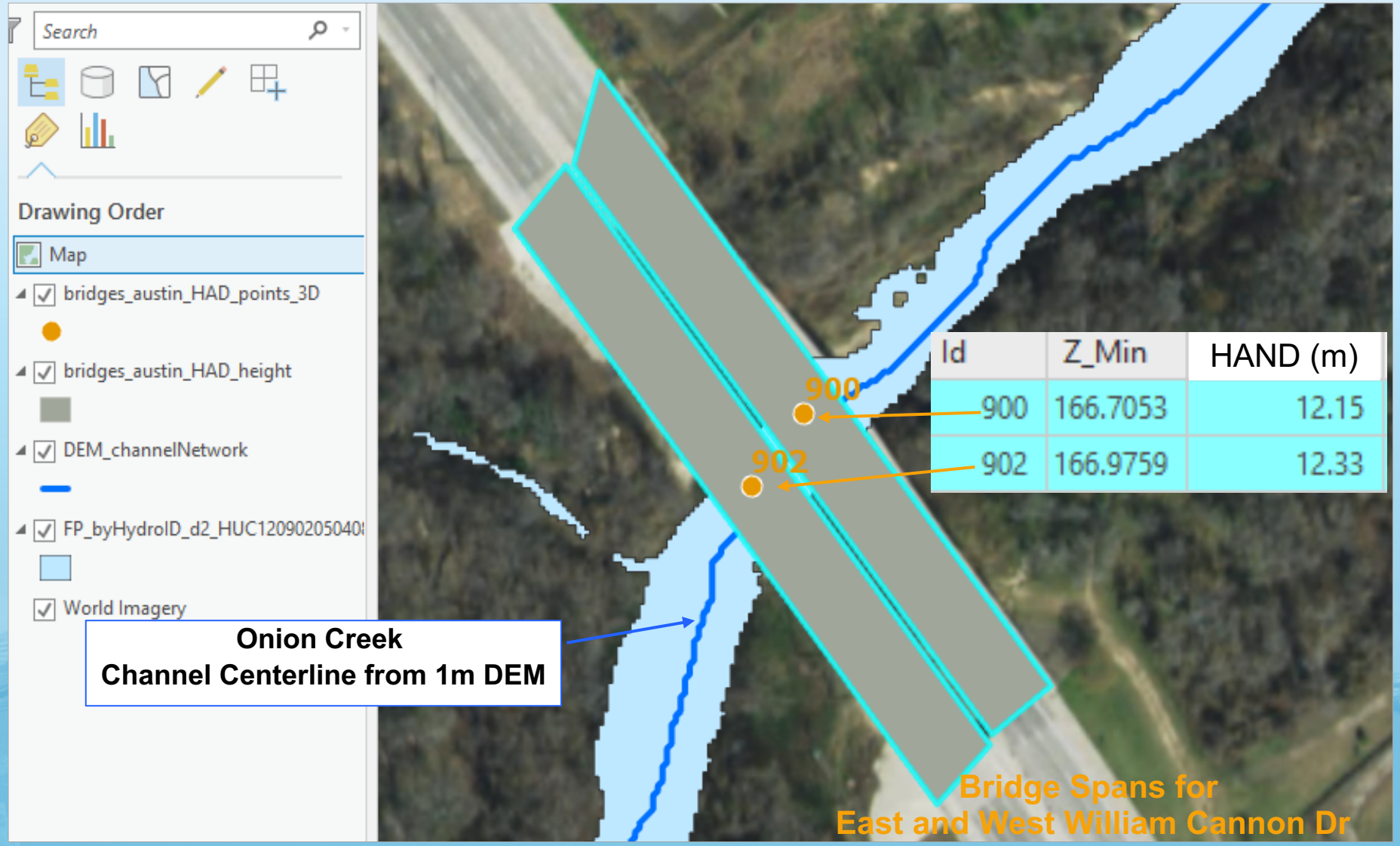
Automated Bridge Profile Extraction

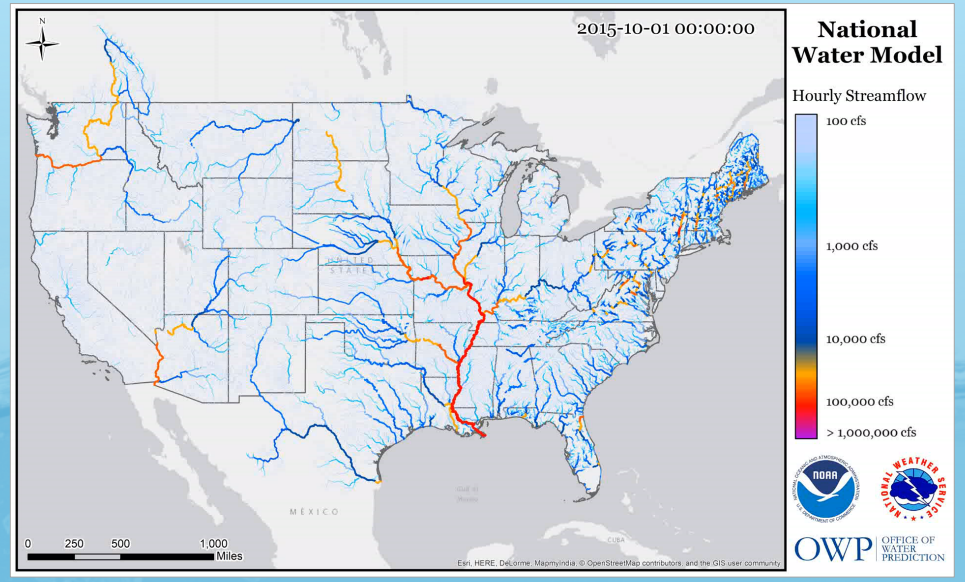
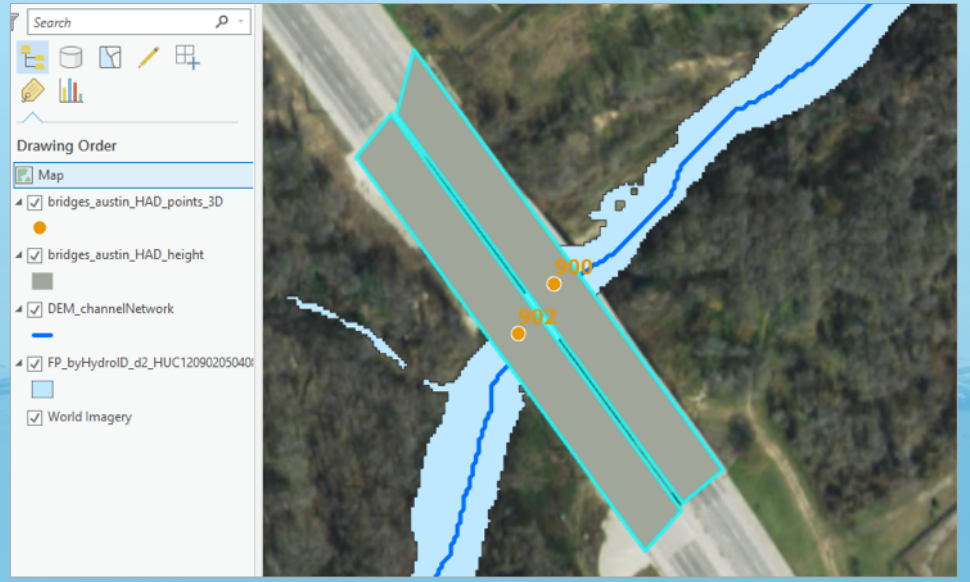
Gert Van Maren (ESRI)



Onion Creek at William Cannon Dr

Gert Van Maren (ESRI)



Conclusions

- Height Above Nearest Drainage (HAND) method is a fundamental innovation for local and regional flood inundation mapping
- Good results during Hurricane Harvey
- Useful for local inundation mapping, especially when used with LIDAR
- At local scale the road system and stream system need to be considered in 3D