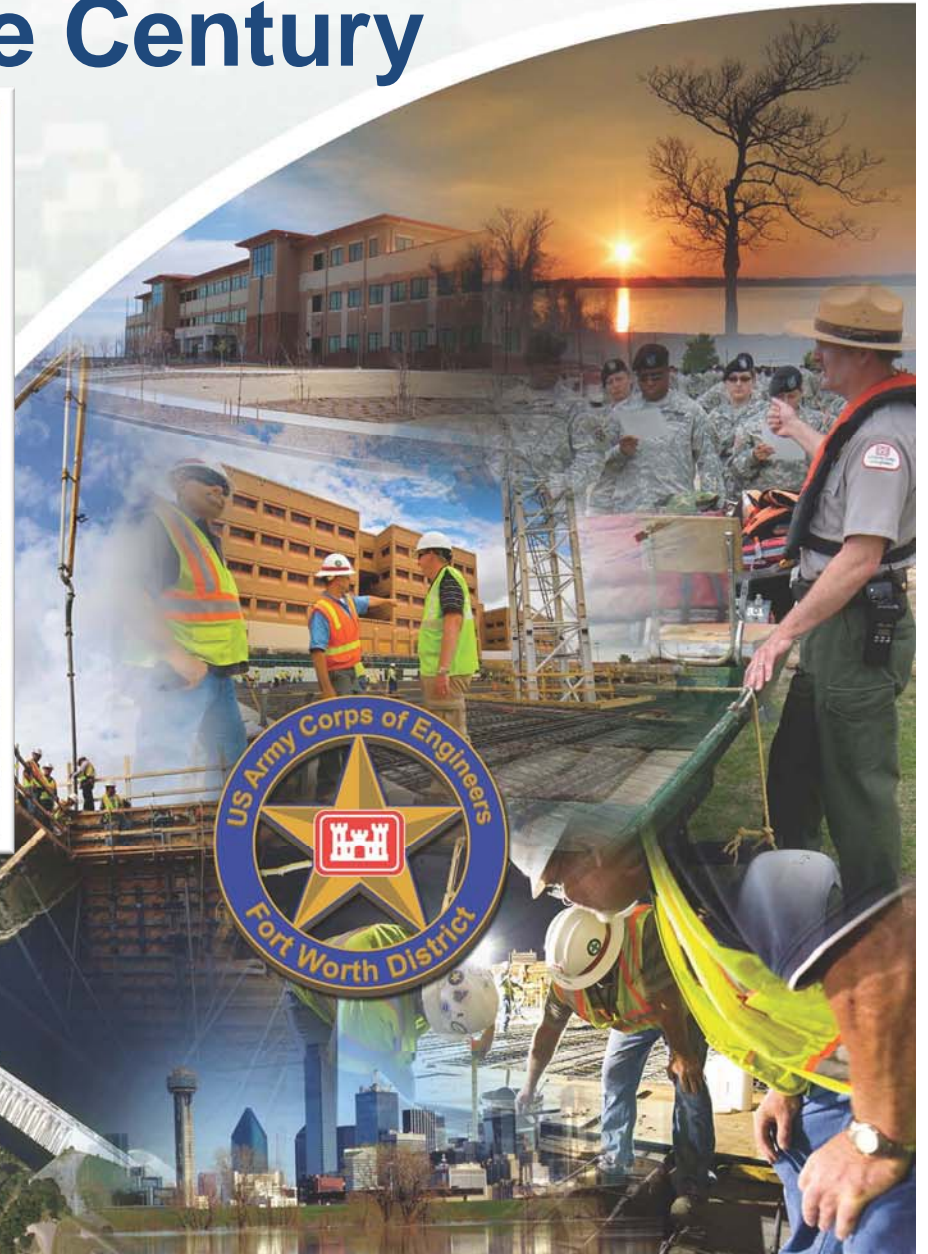
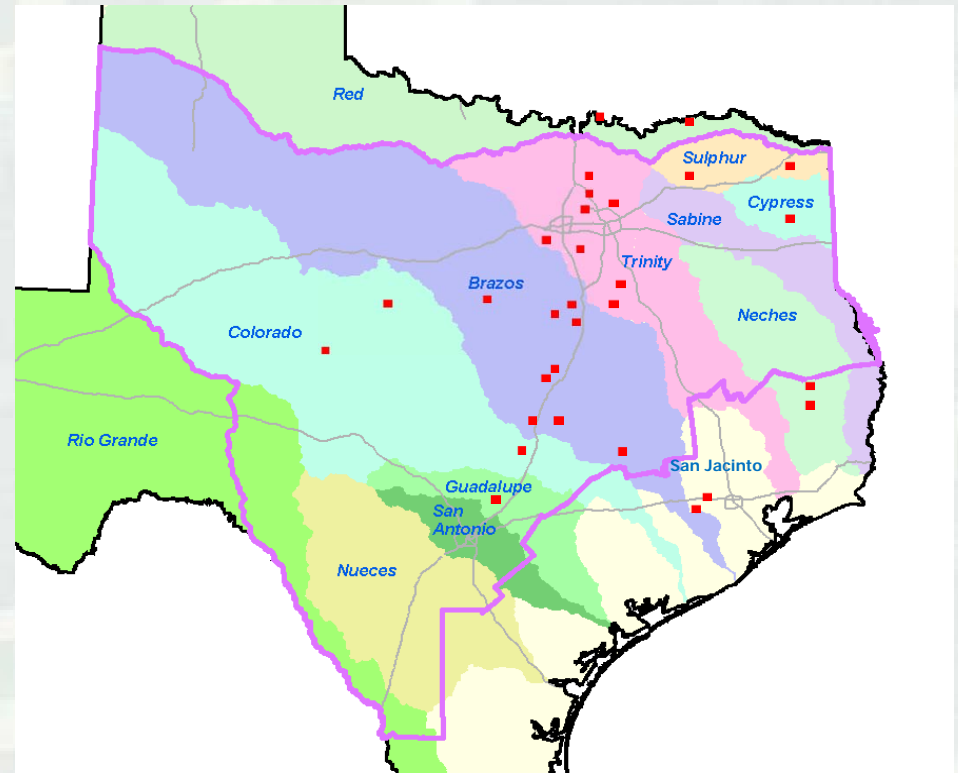


# From Drought of the Century to Flood of the Century



# Statewide Reservoir Development Background

- Multi-purpose
  - ▶ Flood control, water supply, hydropower, environmental, recreation, navigation
- Critical to the early development of Texas
- Significant federal economic contribution
- Planned/constructed dams 111/32
  - ▶ 1<sup>st</sup> - Marshall Ford Dam (Lake Travis) 1942
  - ▶ Last – Cooper (Jim Chapman Reservoir) 1991
- 8.8 M ac-ft conservation storage
  - ▶ 20% - 25% surface water supply
- 15.9 M ac-ft flood storage in 31 federal dams
- Costs (2013)
  - ▶ Construction - \$8.2 billion
  - ▶ Benefits - \$76 billion (flood only)
  - ▶ B/C ratio – 9.3
- Annual recreation visits – 22 M



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# Real-Time Operations and FRM

- Federal, state and local partnership
  - ▶ Real-time operations
    - USGS, NWS-RFC
    - City of Dallas, TRWD, state and local EM's
  - ▶ FRM
    - FEMA, state, local
    - NCTCOG, Steering Committee, FMTF
      - ▷ CDC Program
    - Local governments

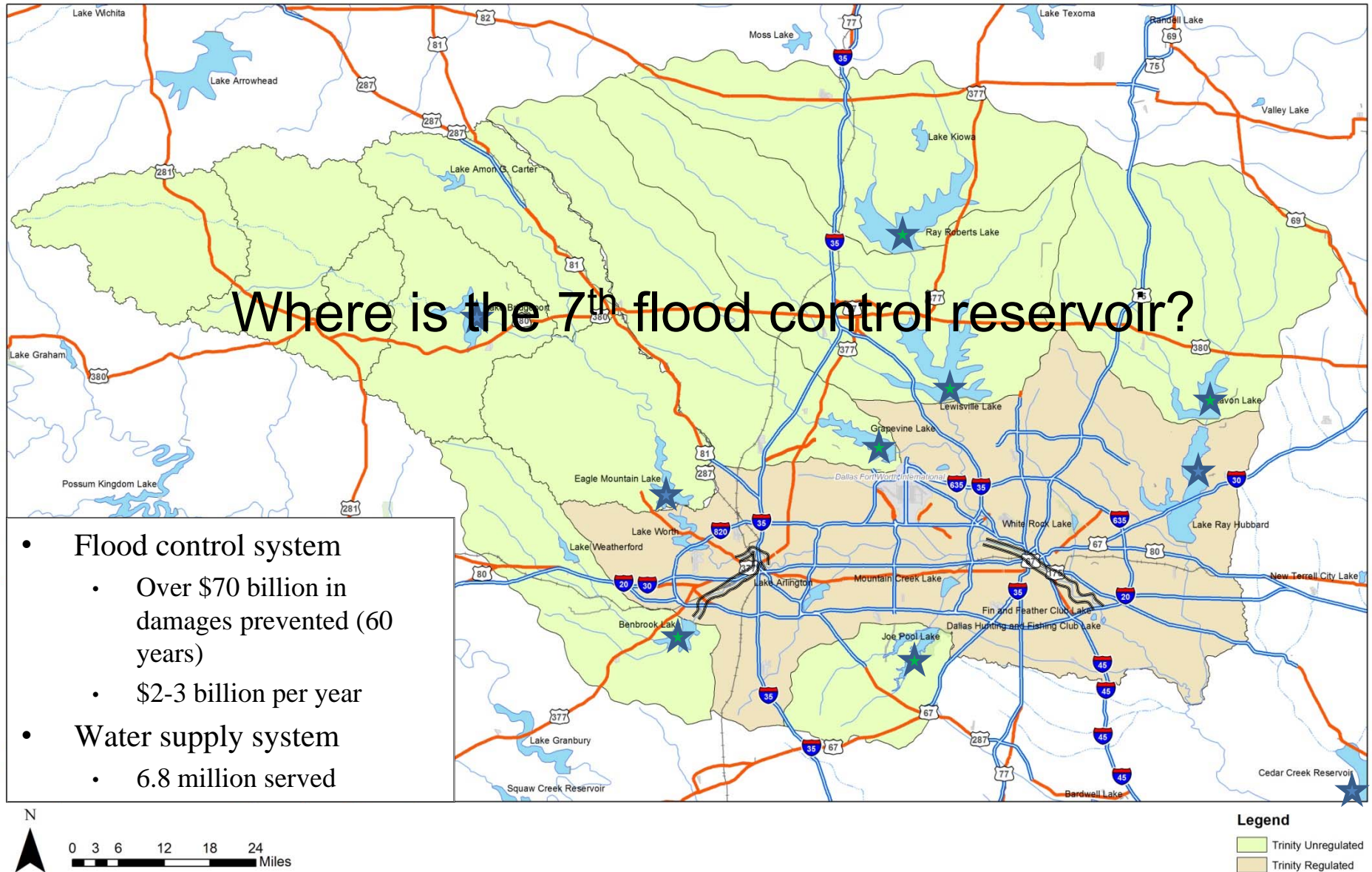


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# What Do You See?





# Seventh Flood Control Reservoir – CDC Regulatory Program

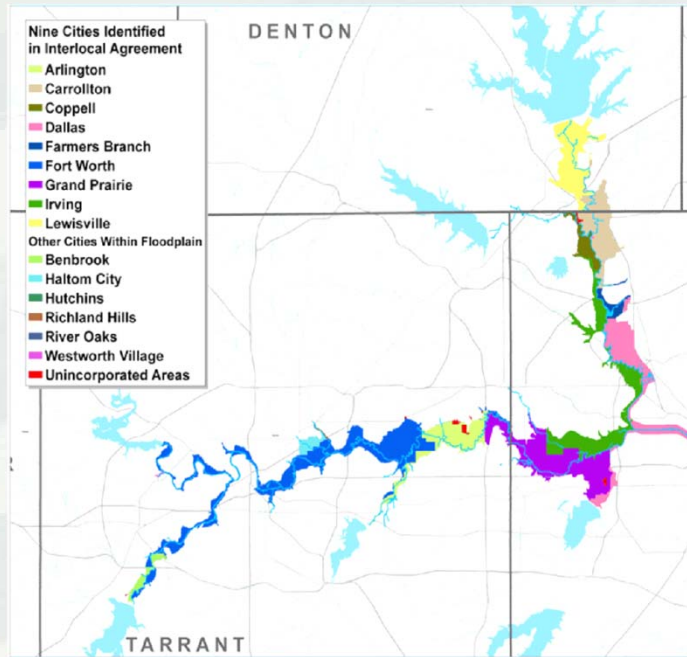
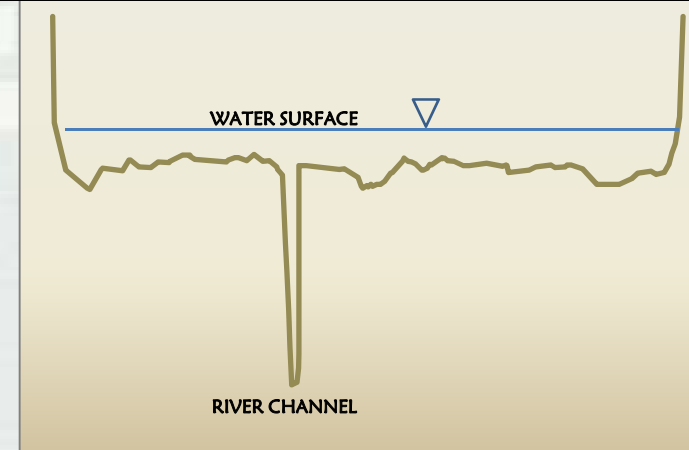
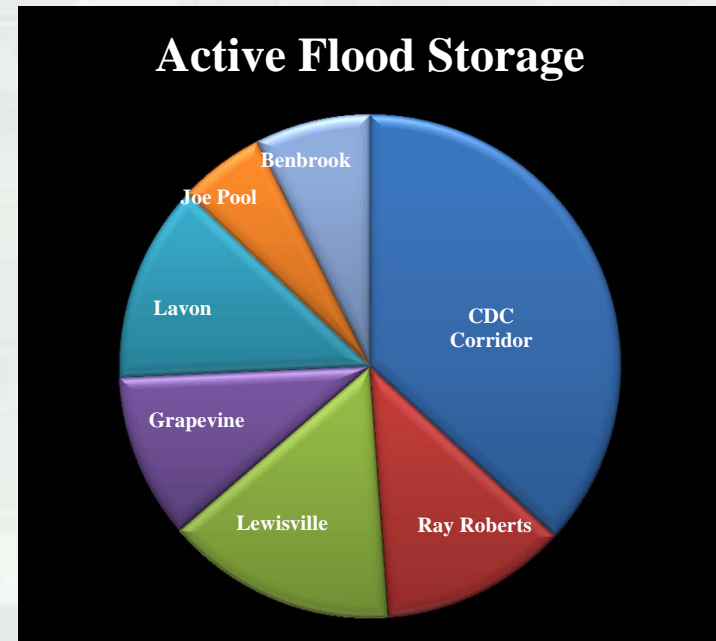
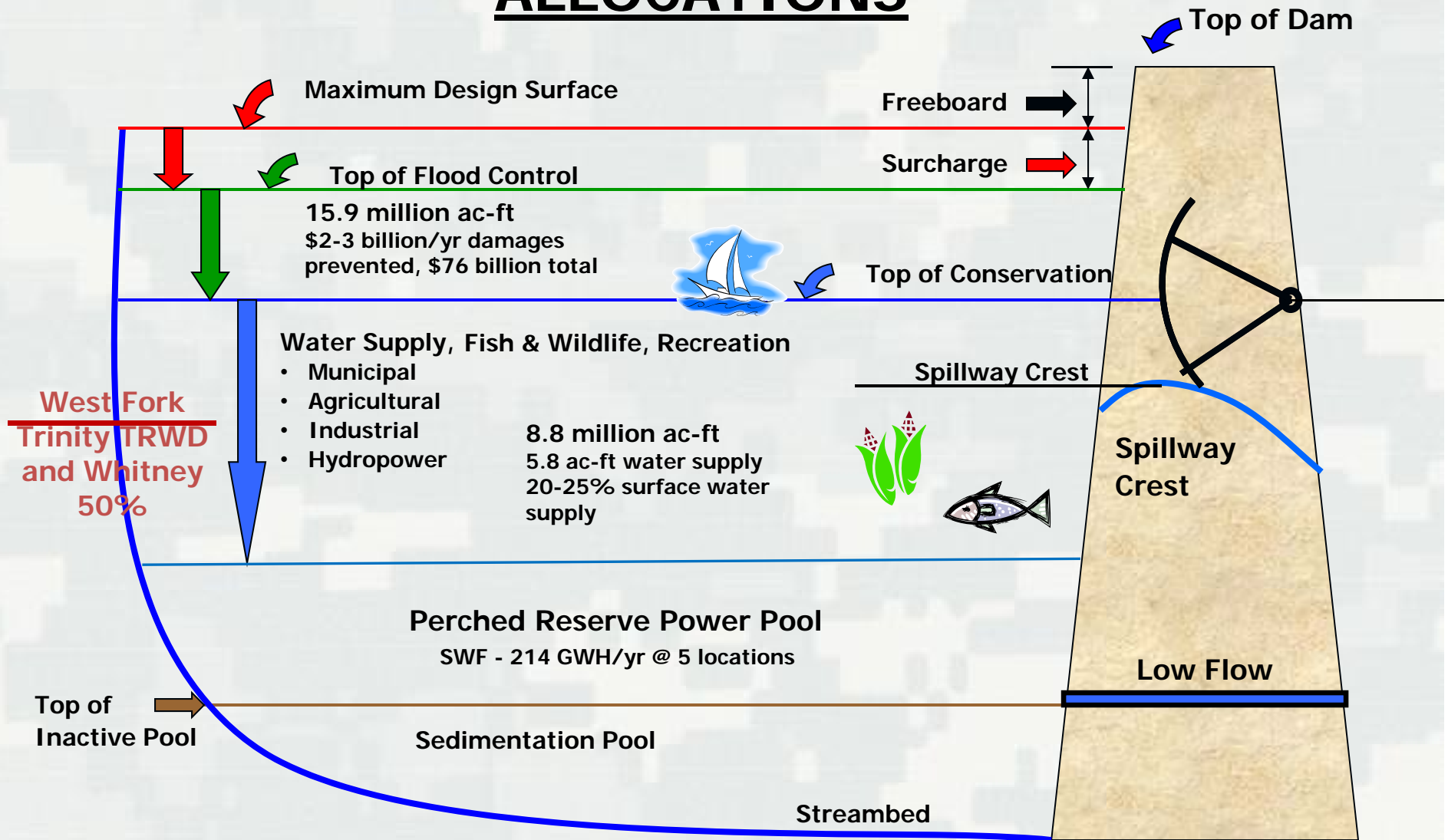


Figure is for demonstration purposes only and should not be used in determining exact cover



Full floodplain conveyance and storage

# RESERVOIR ALLOCATIONS





# Plans of Regulation

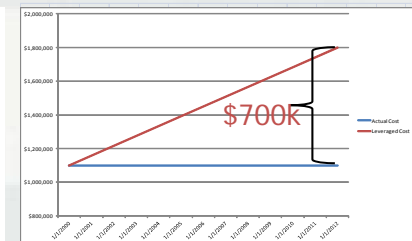
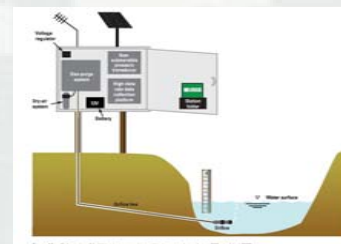
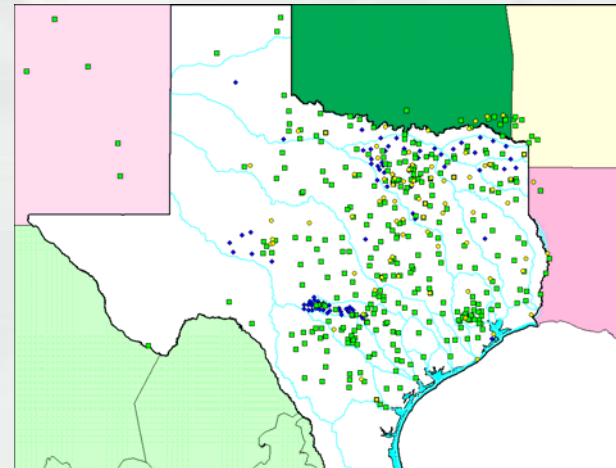
- Peak flow vs. volume
- Follow published plans of regulation for each project
- Store flood producing runoff to protect downstream areas
- Uncontrolled areas
- Project Safety – can we store it? Surcharge releases?
- Forecasts - reservoir managers, surcharge releases
- Evacuate flood water to prepare for subsequent flooding events
- Coordinate with other dam operators
- Retain full conservation pools and additional supplies on a temporary basis to support drought (deviation)
- Controls



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# Hydrologic Network

- Cooperative program – federal, state, local, academia, AE community
- Over 400 Remote Sensing Stations, approximately 2000 Observers
- Basic data for operation of the projects
- Calibration of NWS precipitation estimates
- Model calibrations, real-time forecasting and hydrologic investigations
- Jointly funded with USACE direct expenditures of close to \$18 million annually, SWF \$1 million annually
- Partnerships
  - ▶ USGS, NWS, River Authorities, Counties, Cities
  - ▶ Coordination and resource sharing to maximize network benefits
  - ▶ USACE-SWF has leveraged partnerships for \$700k





# Surcharge Operations

What was the largest historical dam failure catastrophe?



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# Maintaining Perspective On Water Management

- Historical Disasters

- ▶ S. Fork Dam, Johnstown, Pennsylvania (Operational Issues)
  - May 1889, 2209 dead, \$17 mil damages
- ▶ St Francis Dam, California (Operational & Design)
  - March 1928, 450 dead, several towns destroyed
- ▶ Buffalo Gap, Virginia Tailings Dams (Operational & Des.)
  - Feb 72, 125 dead (COE Involvement)
- ▶ Teton Dam, Idaho (Design Issues)
  - June 1976, 11 dead, \$.5 billion damages
- ▶ Banqiao & Shimantan Dams (Ru & Hong Rivers, China)(Design Issues)
  - August 75, 85,000 dead, 11 million affected



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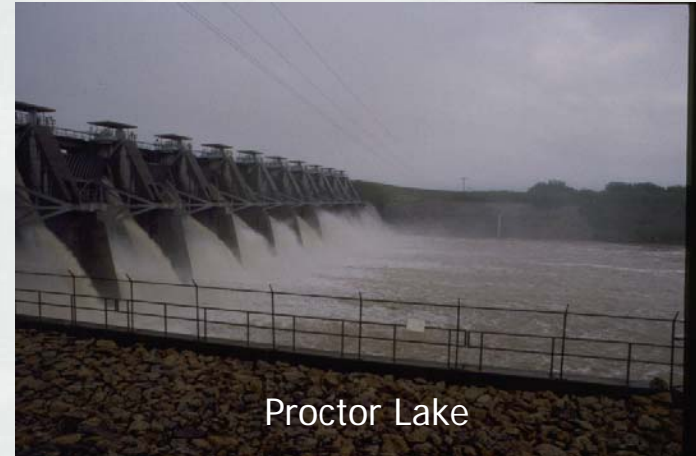
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# Surcharge Operations

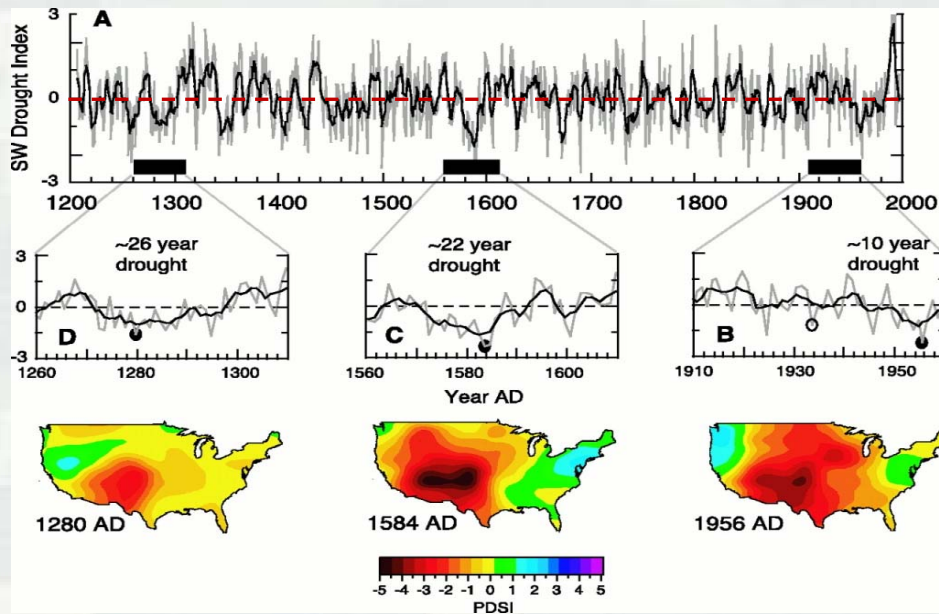
## Rare!

- Most likely from ensemble events
- Dams have limited capability to store runoff, 100-yr, SPF, PMF, ensemble
- Once full spillway activation likely
- Control point flows no longer applicable
- Dam safety
- Spillways
  - ▶ Uncontrolled
    - Rare
    - Damages
  - ▶ Tainter gates
    - Requires SWF internal decision

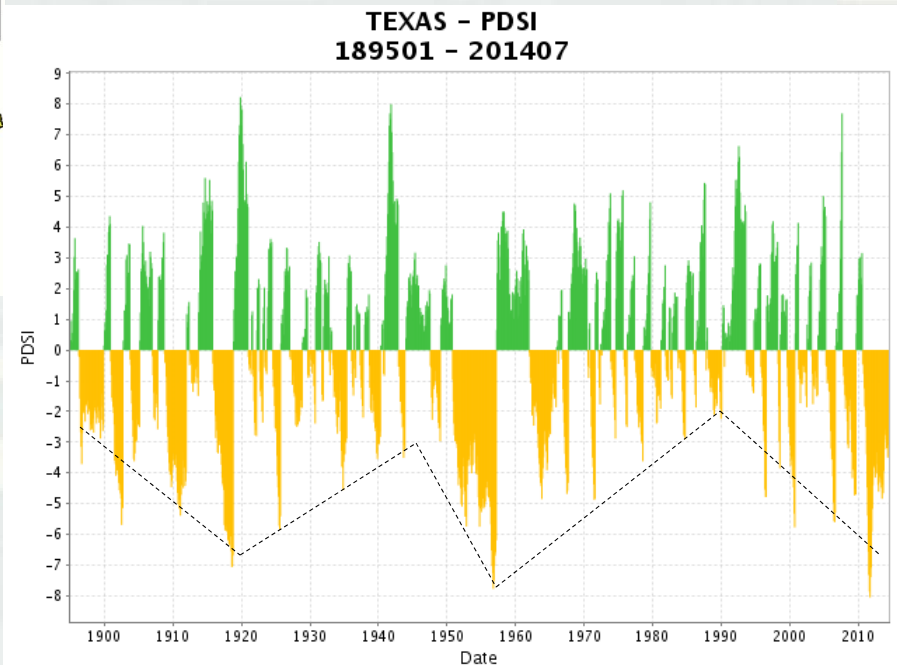


# PREVIEW: CLIMATE VARIABILITY

## UPPER TRINITY RIVER – DALLAS, FORT WORTH AREA



- Region of significant climate variability
- Observations show loss rates vary from 15% to 85%

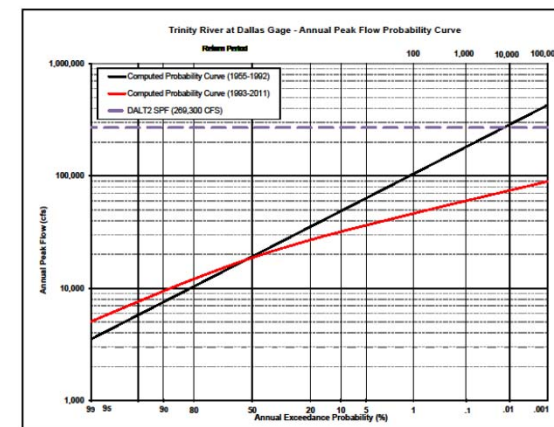
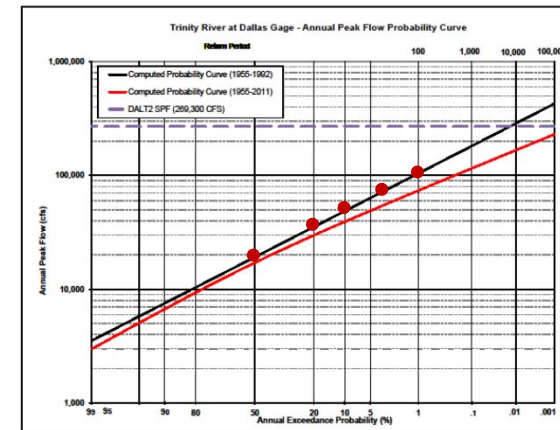




# Apparent Divergence in Statistical and Process-Based Flood Hydrology

## Upper Trinity River – Dallas, Fort Worth Area

- Apparent agreement between modeling and statistical hydrology up through early 1990's
- Divergence of modeling and statistical hydrology mid 1990's – current period
- Is modeling over estimating flood risk?
- Is statistical hydrology under estimating flood risk?



# Climatic Influence on Flood-Risk Potential

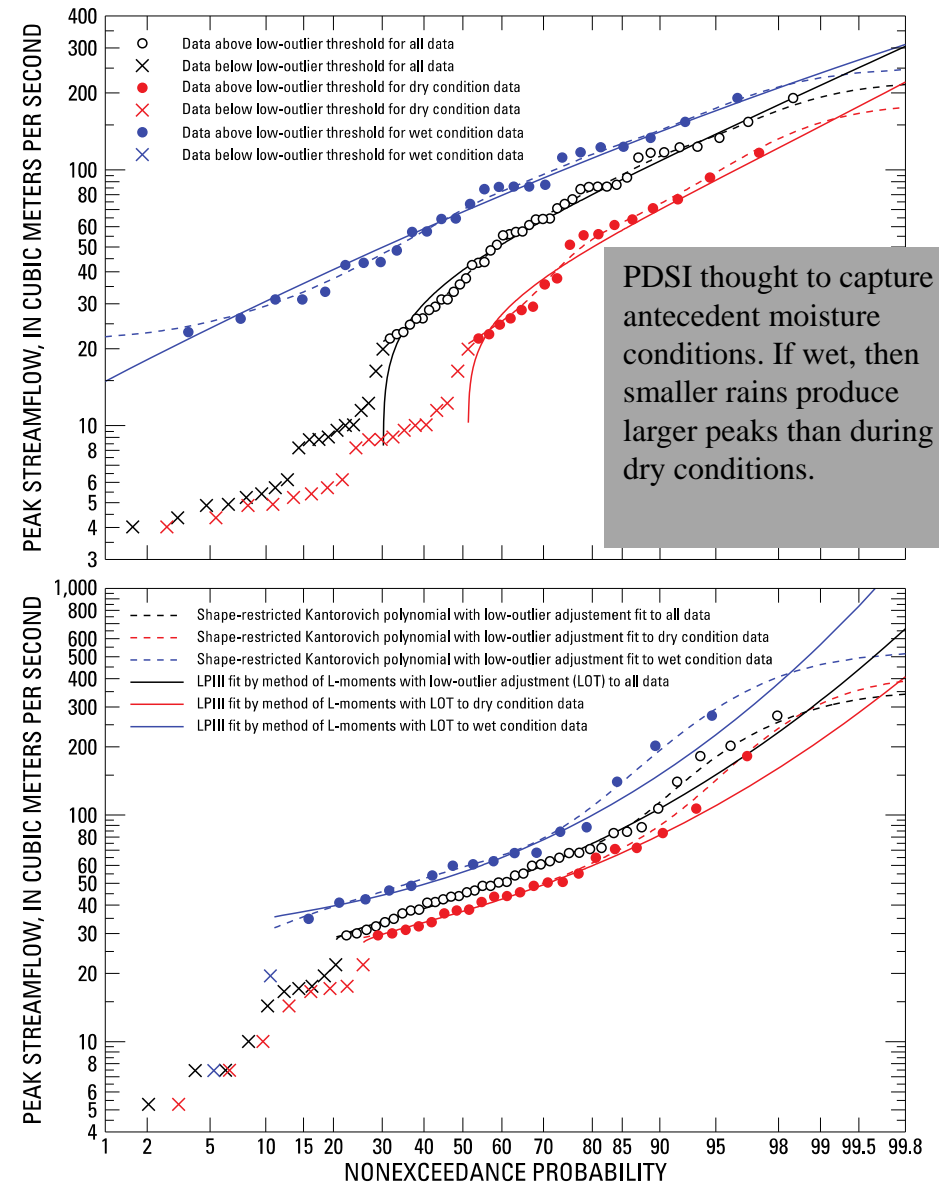
Courtesy of William Asquith

Investigation of population mixing by the Palmer Drought Severity Index (PDSI) for the month of the annual peak.

A threshold of  $PDSI = 1.75$  was heuristically determined to about split record into two classifications: dry and wet.

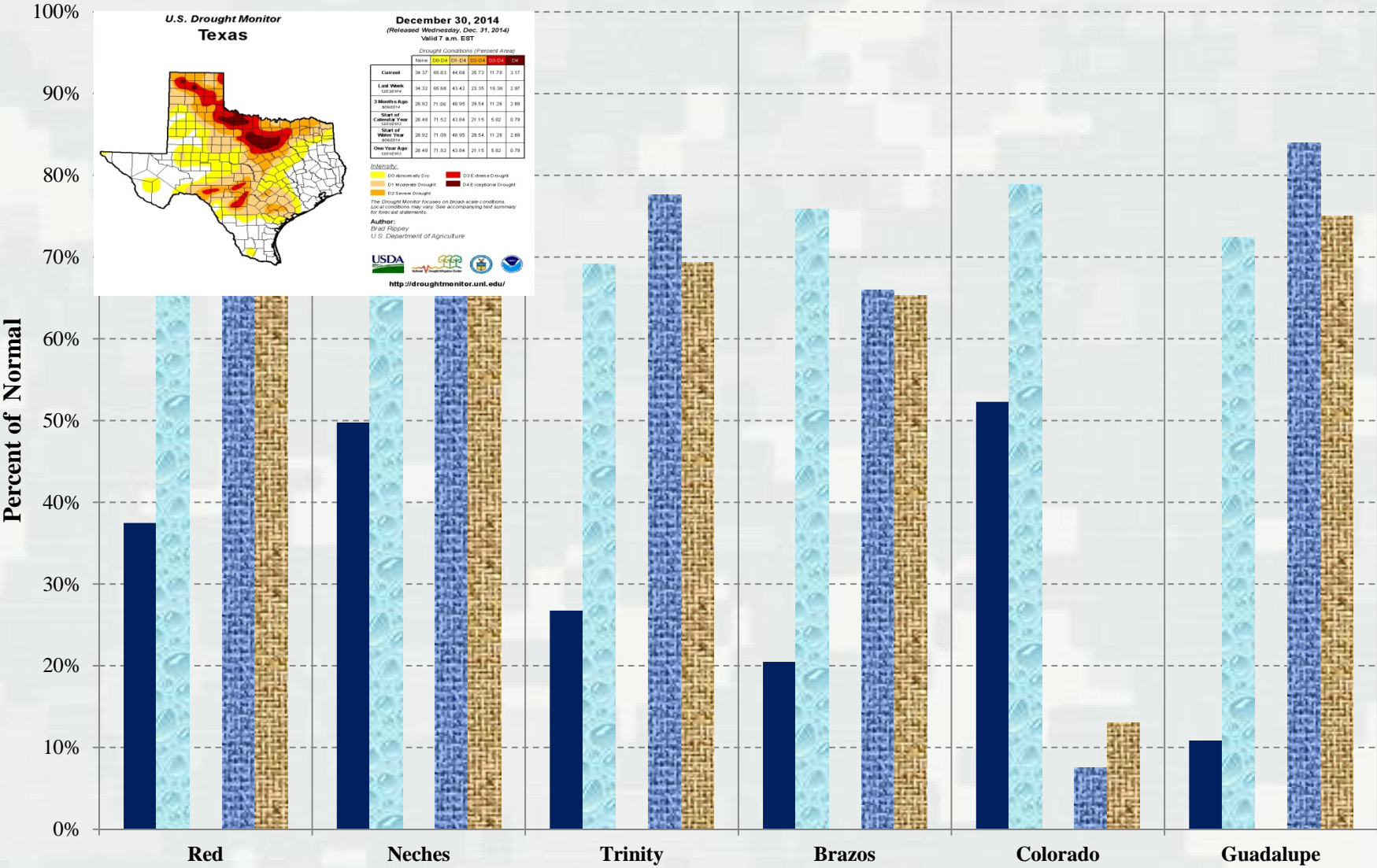
Many streamgages show substantial log-cycle offsets and hints of convergence base on dry/wet. Two examples shown.

Western 2/3 of study area perhaps more strongly impacted by climatic influences than eastern 1/3. Possible that developed (urbanized to substantial degree) watersheds do not show dry/wet impact.



# Summary of Projects Averages for CY2014 Reservoir Inflow & Basin Average Precip

■ Resv Inflow
 ■ Basin Avg Precip
 ■ 1 Jan 14 Cons Storage
 ■ 31 Dec 14 Cons Storage





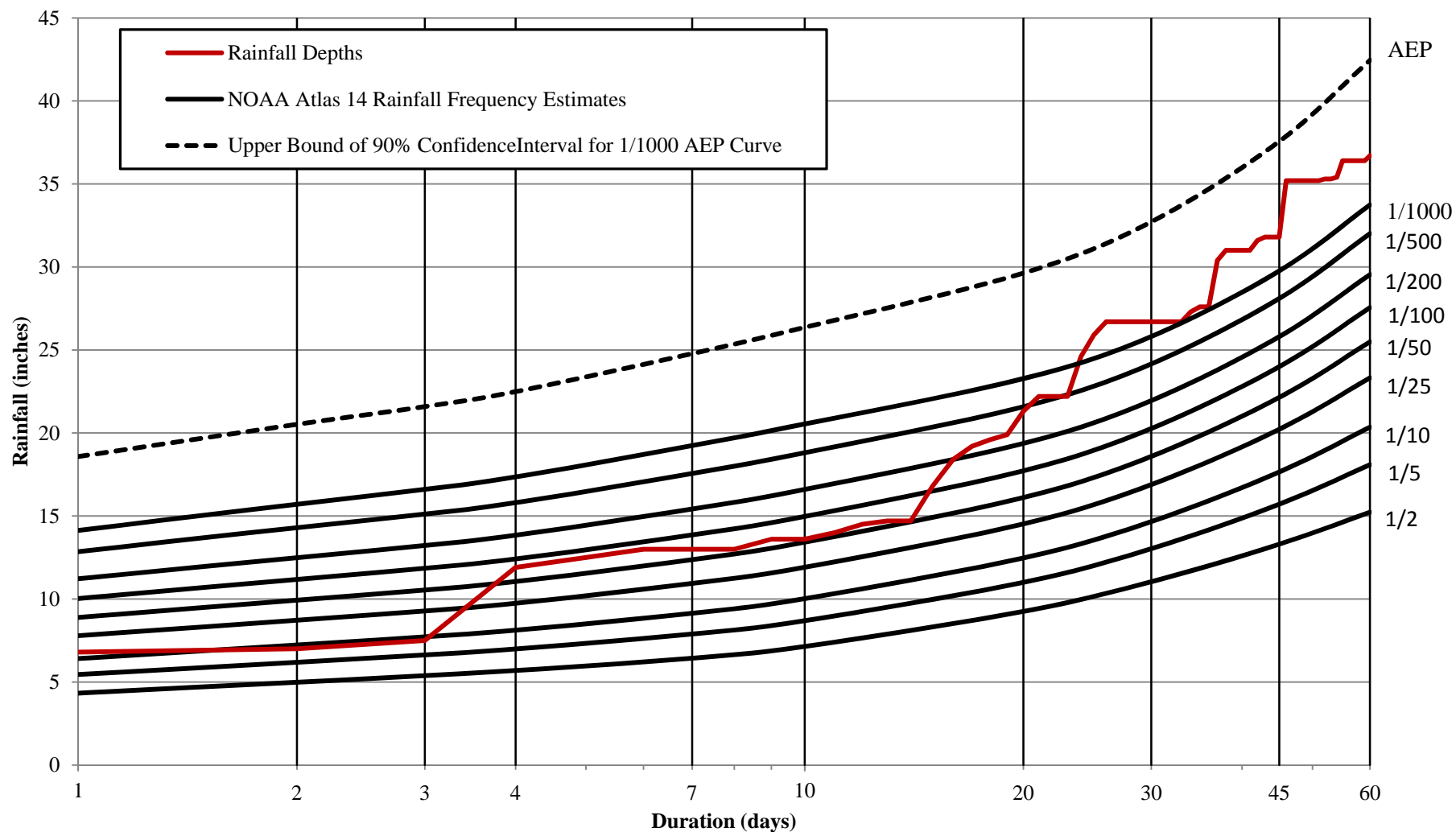
# May – June 2015 Event

- Ended 2014 in significant drought
- Whitney (48%C) and TRWD W. Fork Trinity projects well below conservation
- 20” – 30” rainfall across entire upper Trinity River
- 15” – 18” rainfall on Brazos Basin (Waco, Whitney, Aquilla)
- Sequential events with little opportunity to make releases
- Few significant single events (Exceptions - Blanco, Clear Creek, West Fork Trinity)

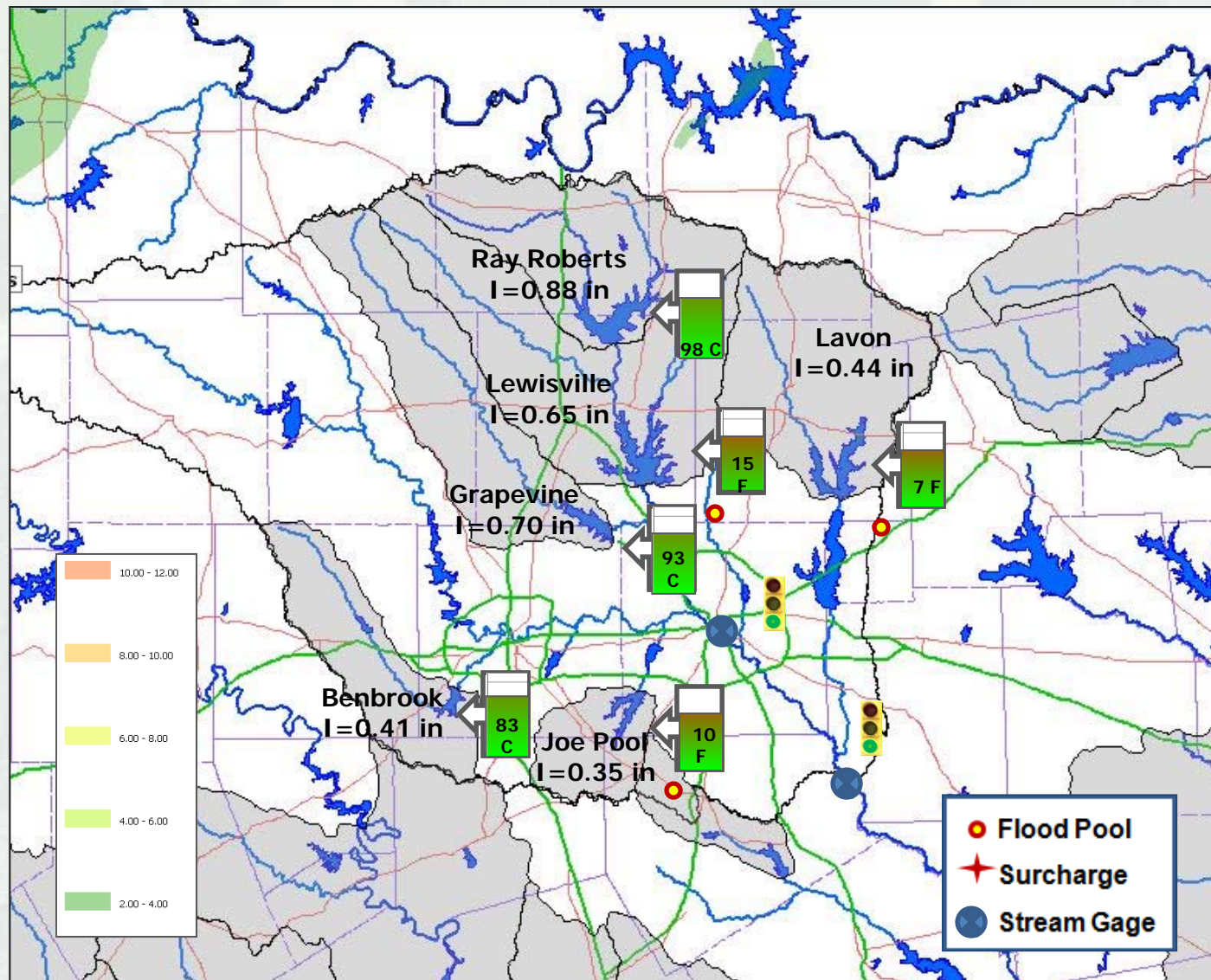


**Rainfall Frequency Data in Texas is limited to TP 40 and 49 (1960s era analysis) which only analyzed precipitation out to a 10-Day Duration**

**NOAA Atlas 14 update for Texas is in progress. Hendrix, OK is northwest of Lewisville Dam provides a reasonable estimate of what the NOAA Atlas 14 update may look like in North Texas.**



# May 1- 5

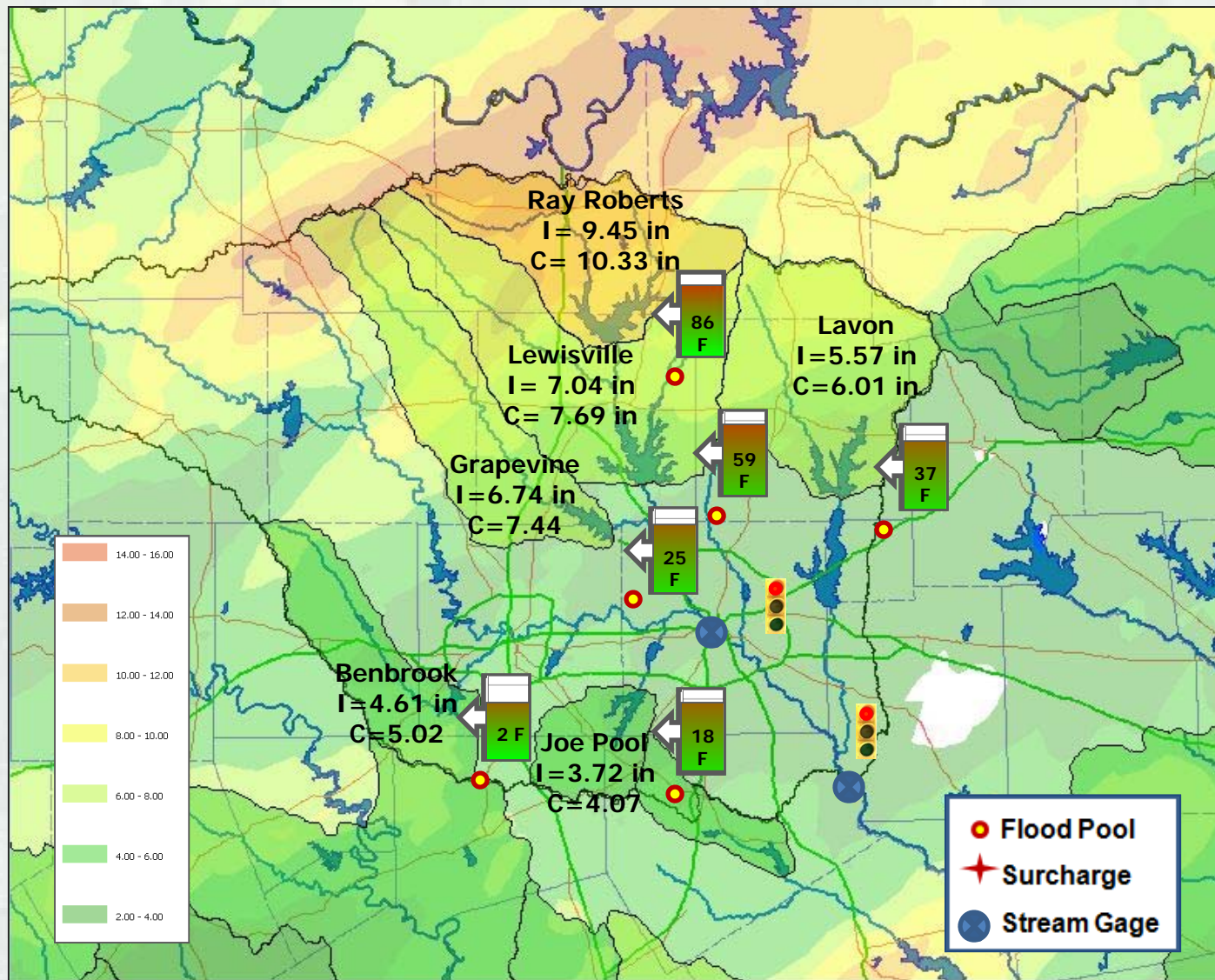


\*Pool percent taken on the last day

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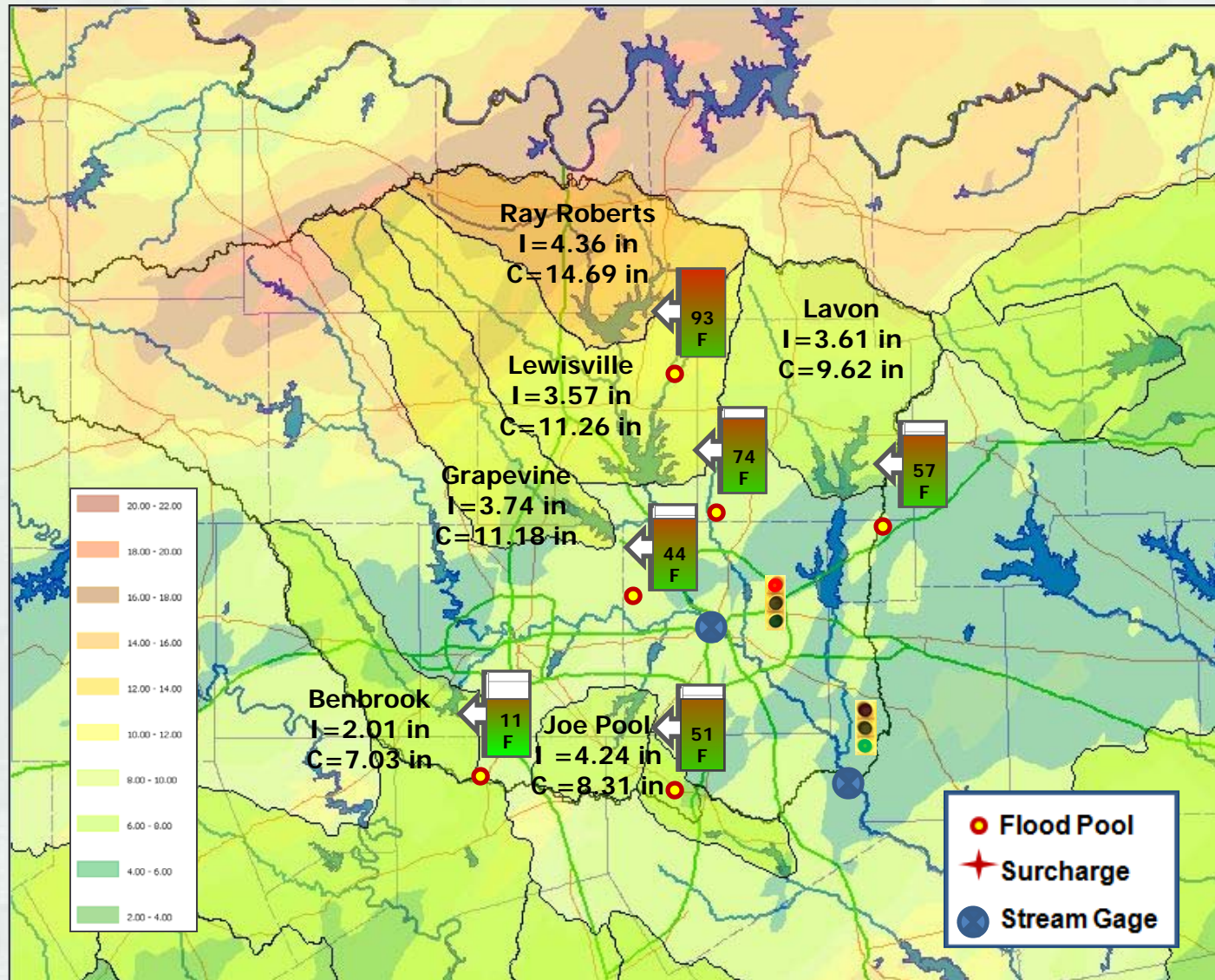
# Storm Event May 6-12



\*Pool percent taken on the last day

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# Storm Event May 13-19

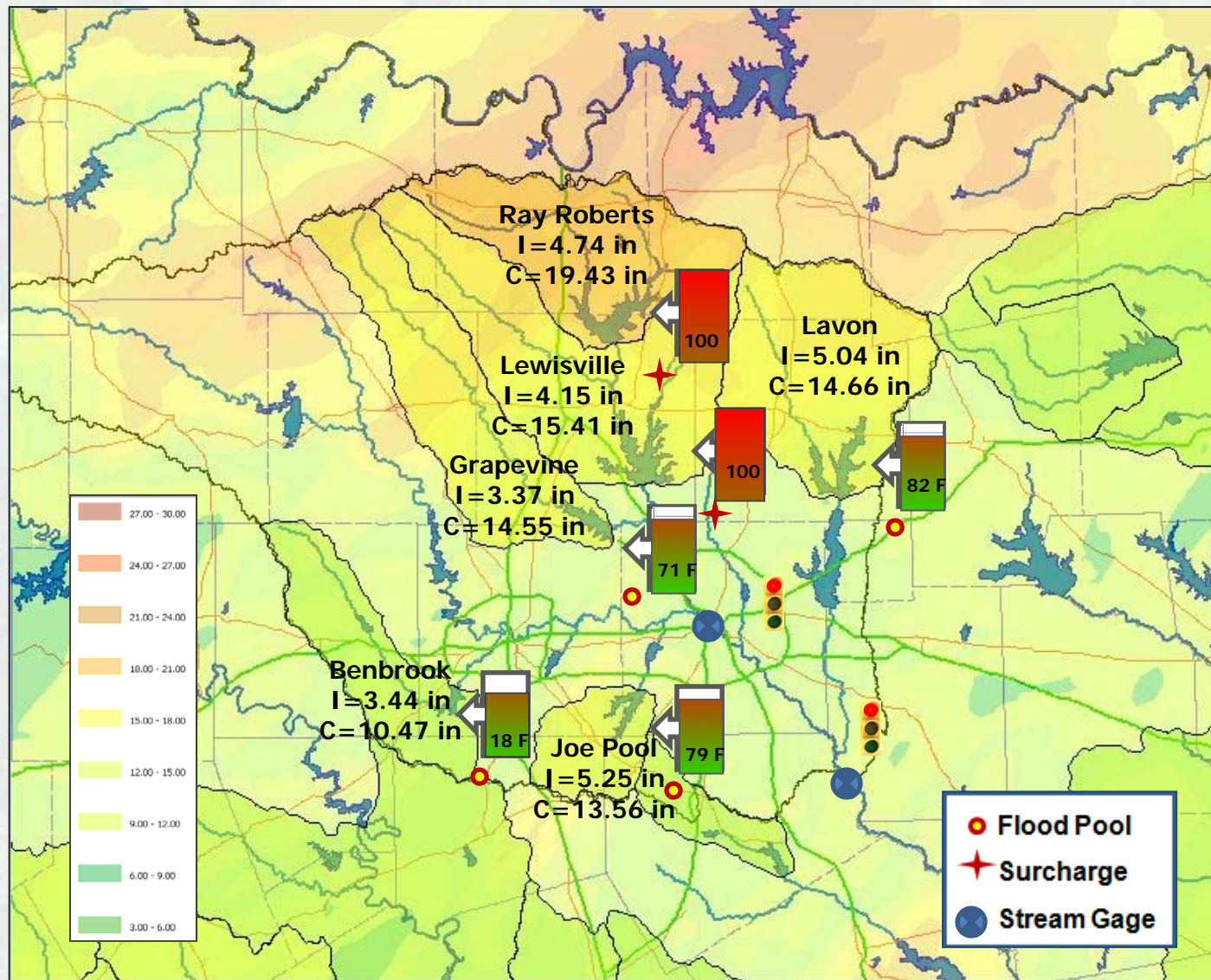


\*Pool percent taken on the last day

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# Storm Event May 20-25

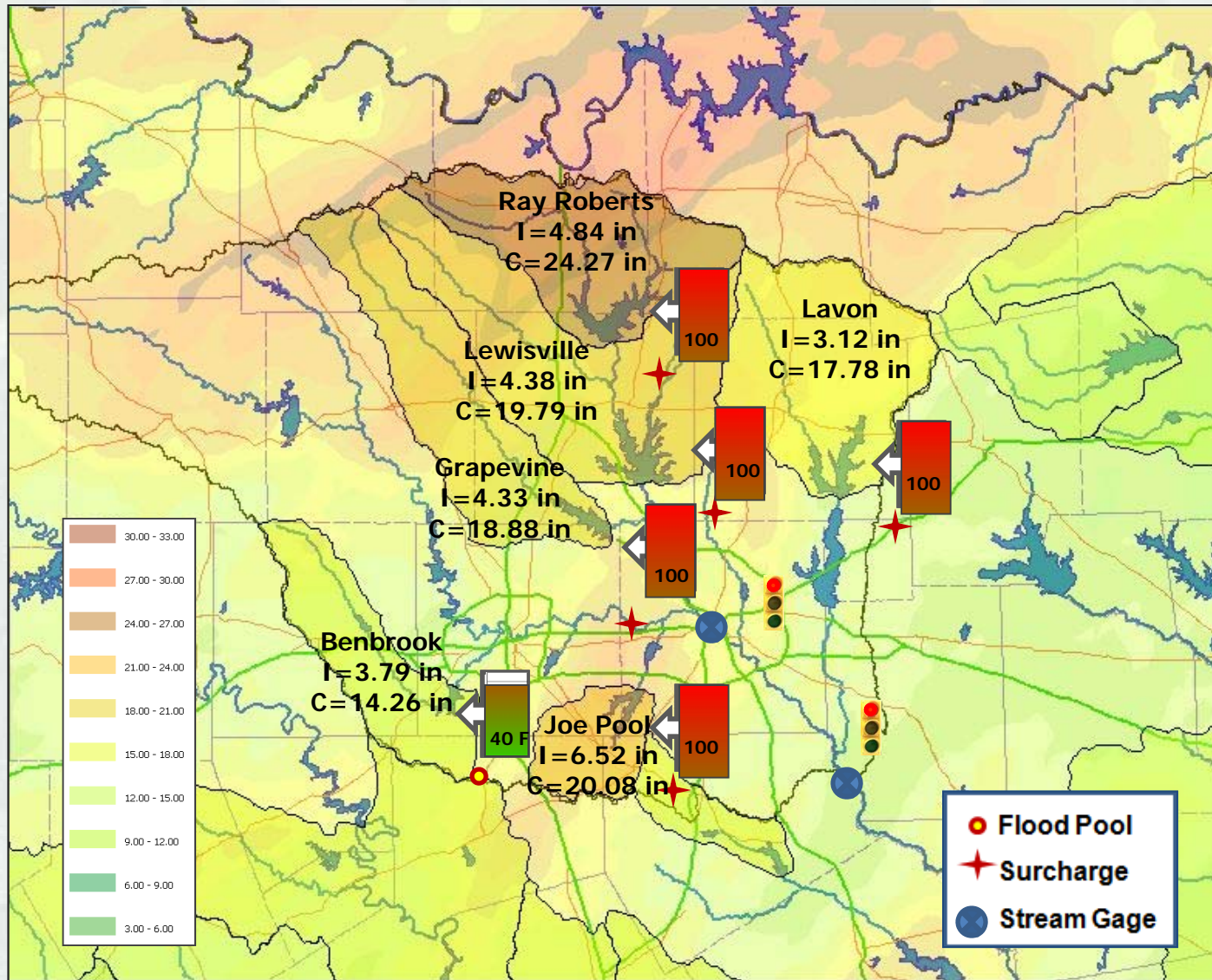


\*Pool percent taken on the last day

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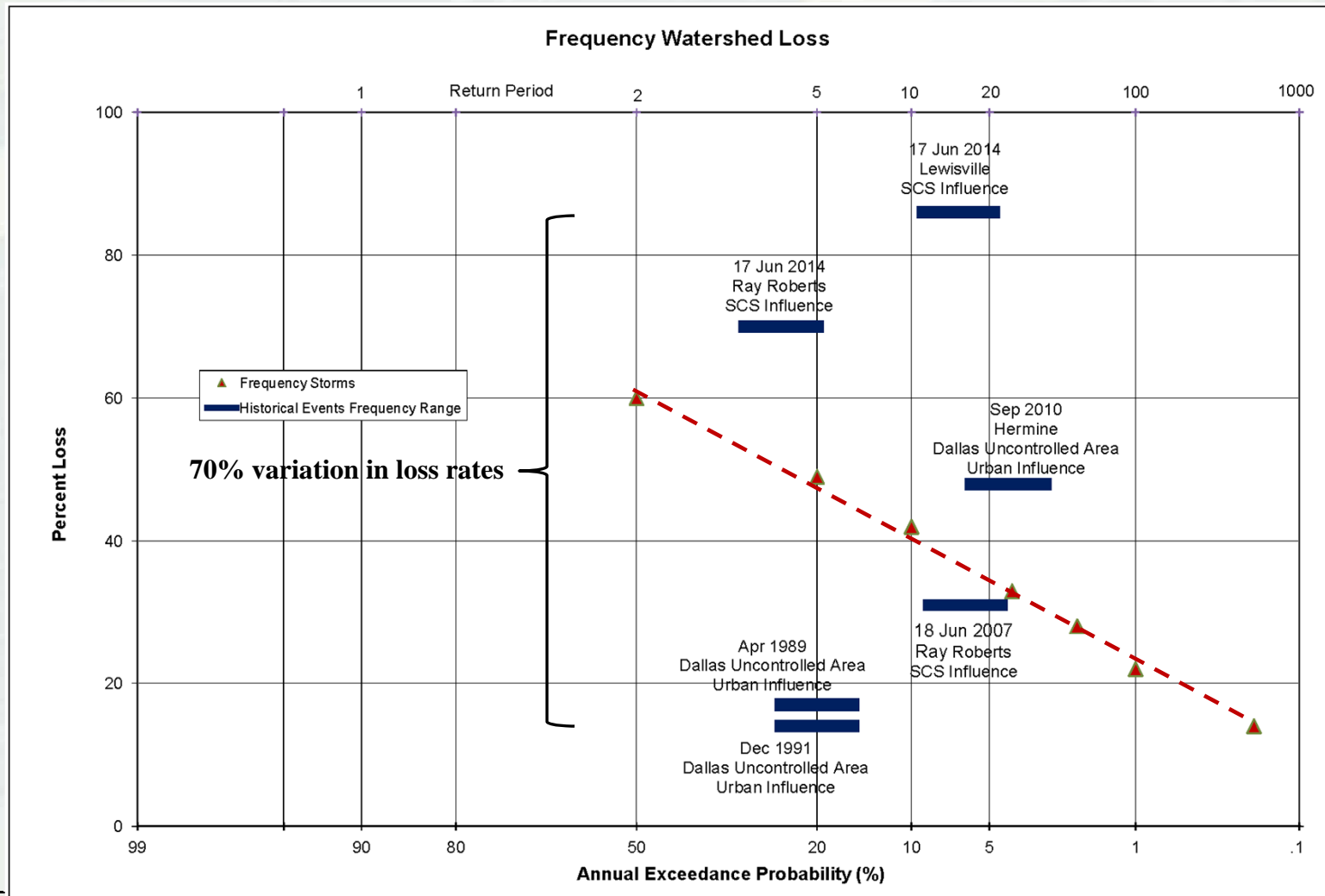
# Storm Event May 26-31



\*Pool percent taken on the last day

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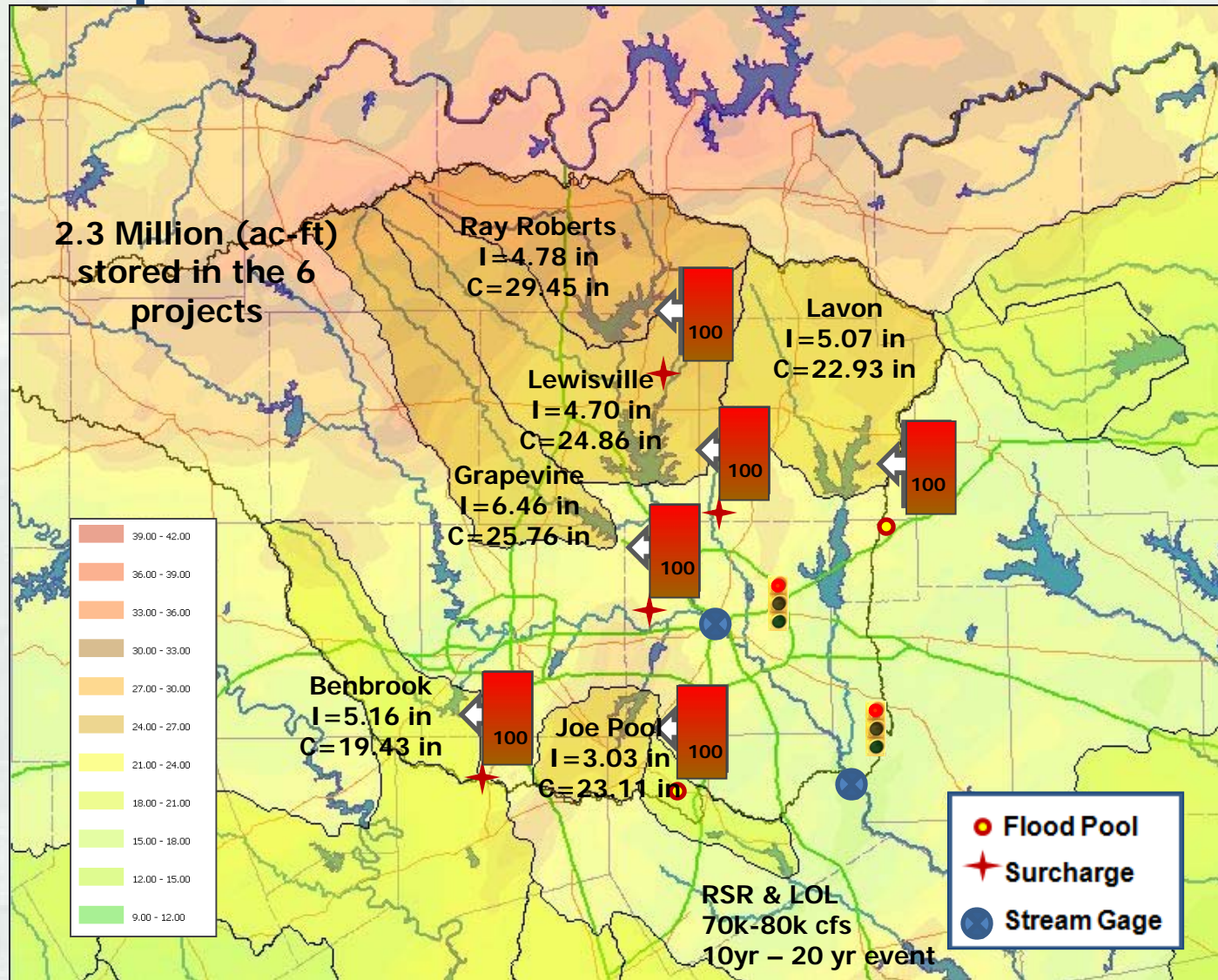
# Variations in Loss Rates for Forecast Modeling Upper Trinity River – Dallas, Fort Worth Area



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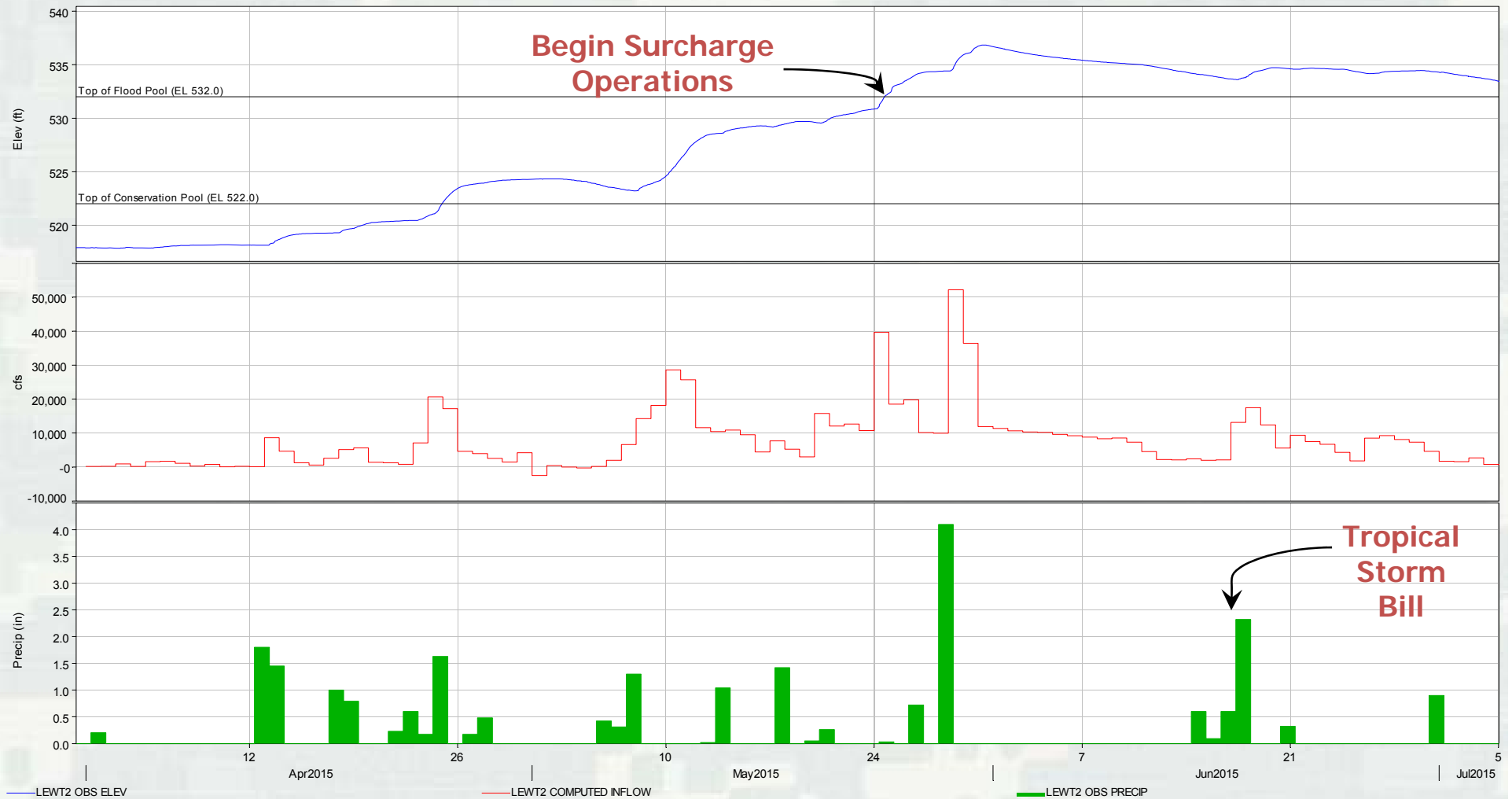


# Tropical Storm Bill June 13-23



\*Pool percent taken on the last day

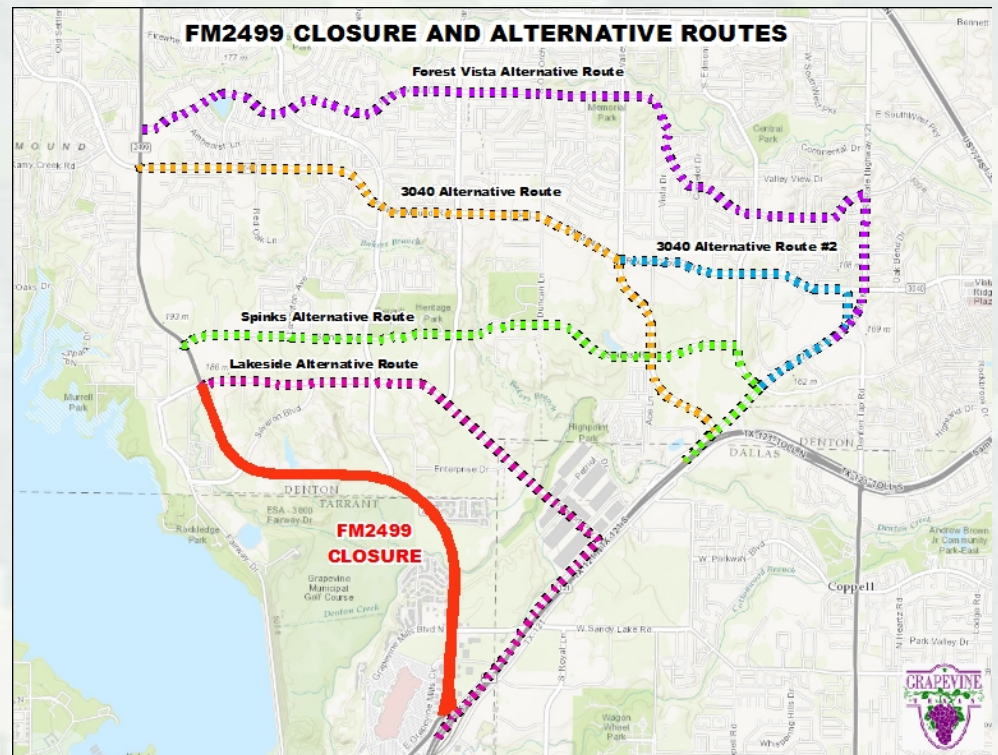
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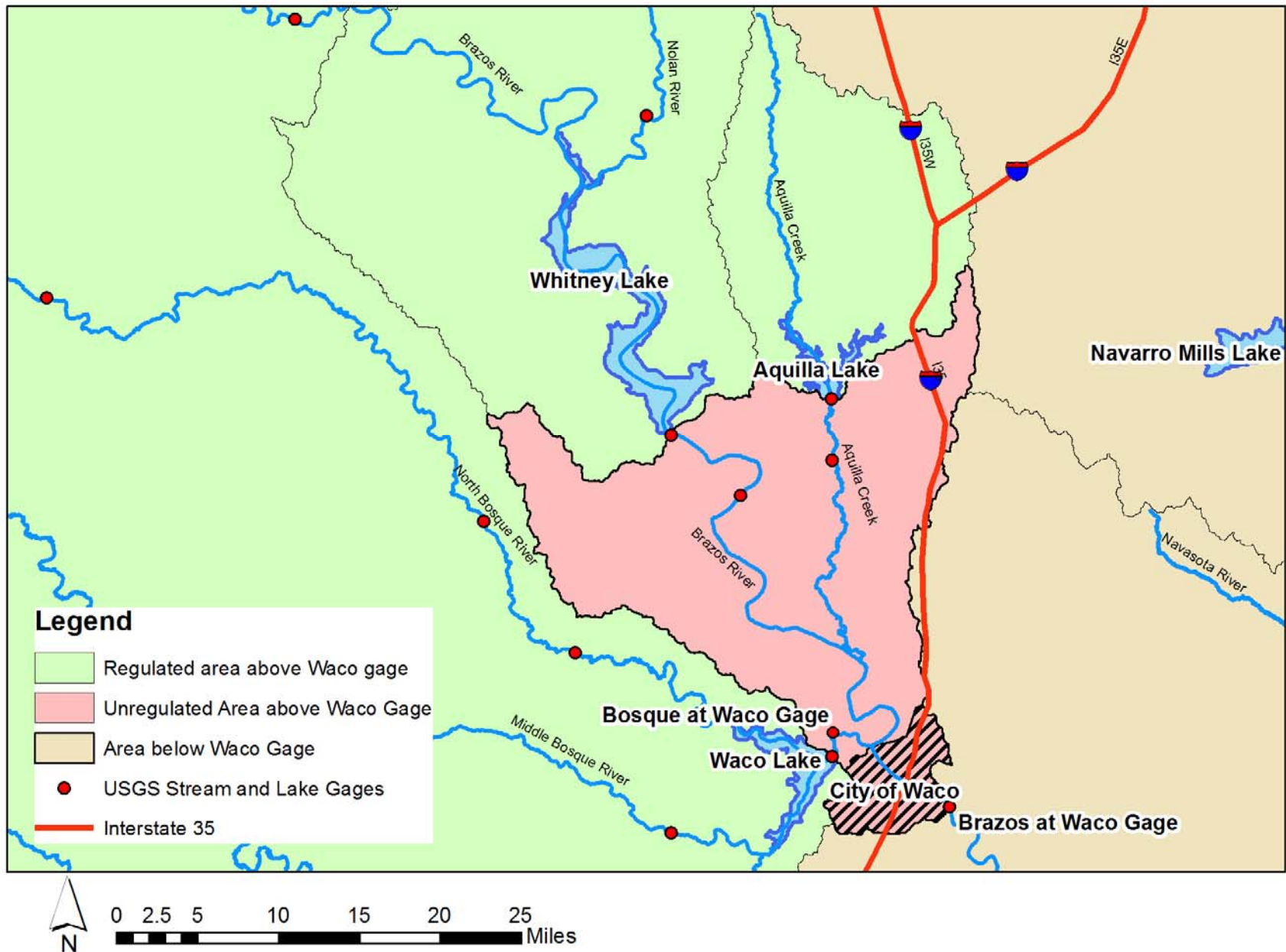


# FM 2499 Closure



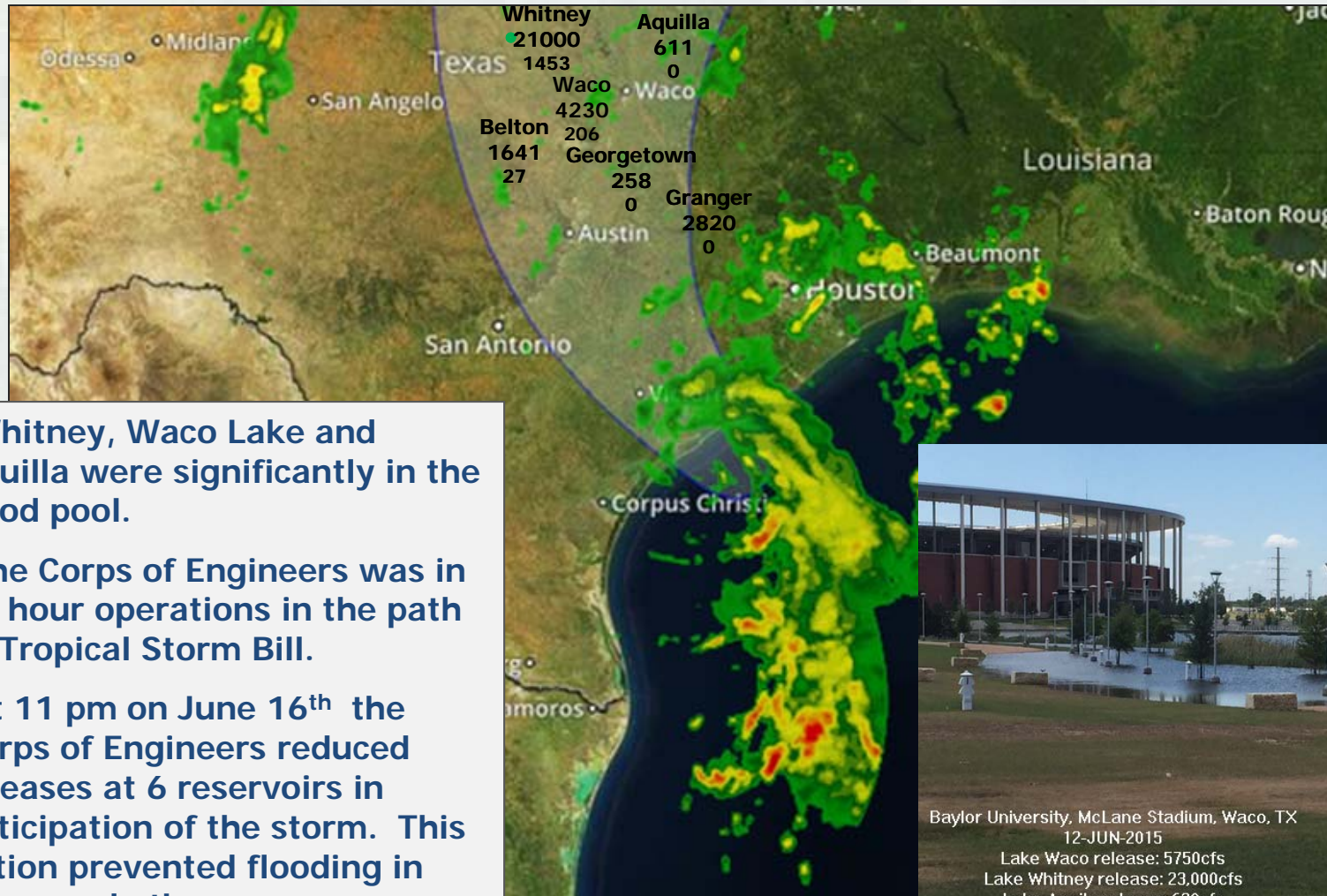
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## Regulated and Unregulated Areas above Waco Gage





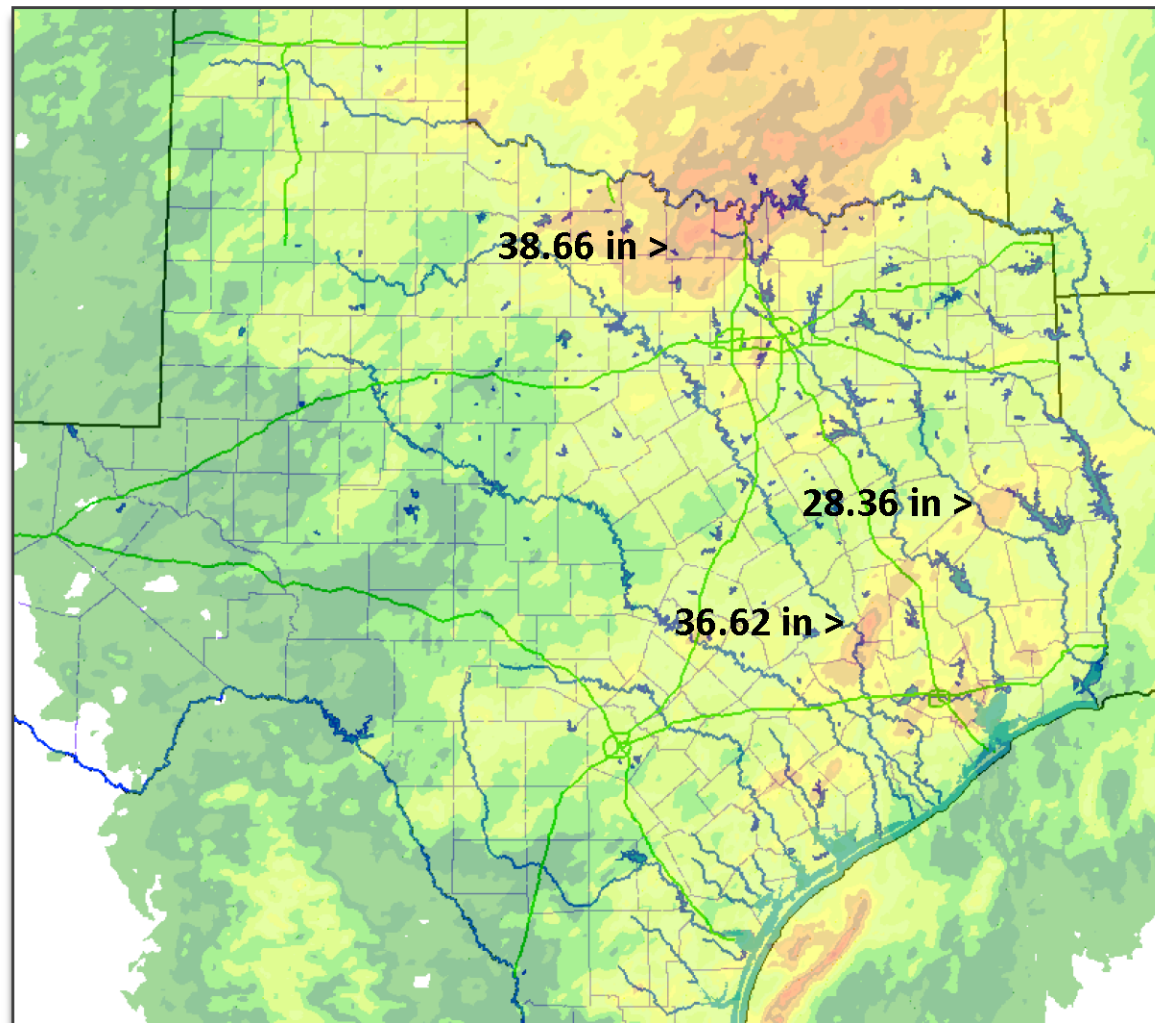
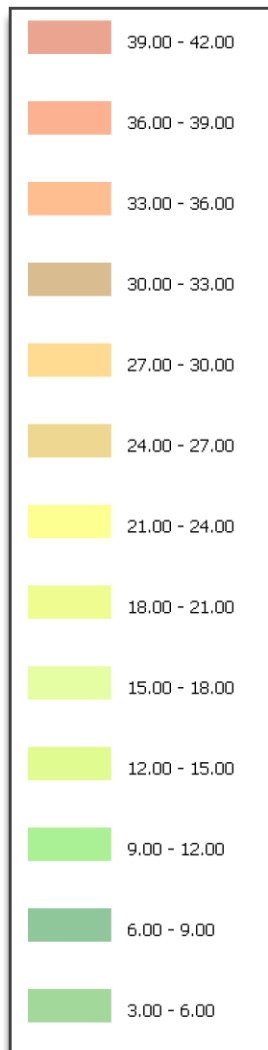
# Anticipating Bill, June 16



- Whitney, Waco Lake and Aquilla were significantly in the flood pool.
- The Corps of Engineers was in 24 hour operations in the path of Tropical Storm Bill.
- At 11 pm on June 16<sup>th</sup> the Corps of Engineers reduced releases at 6 reservoirs in anticipation of the storm. This action prevented flooding in Waco and other areas.



# Total Rainfall for May-June 2015



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# Pool-Elevation Frequencies

<u>Reservoir</u>	<u>Return Interval</u>
▪ Sam Rayburn	14
▪ Benbrook	7
▪ Joe Pool	125
▪ Ray Roberts	167
▪ Lewisville	100
▪ Grapevine	40
▪ Lavon	55
▪ Bardwell	125
▪ Navarro	40
▪ Somerville	70



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# Damages Prevented

■ Red River Basin	\$5.2 million
■ Neches River Basin	\$99.7 million
■ Trinity River Basin	\$6.7 billion
■ Brazos River Basin	\$173.5 million
■ Guadalupe River Basin	\$59.9 million
■ Colorado River Basin	\$23.7 million
■ <b>Total</b>	<b>\$7.1 billion</b>



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# Important Changes and Lessons

- Significant new technology
- Not enough gages (gages wash out in extreme events)
- Rainfall tipping buckets do not track extreme events
- Loss rate variations – 24 hour forecast time
- Surcharge operations at 11 SWF reservoirs
- Damage inducing surcharge releases at Lewisville, Grapevine and Lavon
- Plans of regulation do not address multiple simultaneous surcharge operations
- Forecast were frequently superseded
- Inundation mapping
- Staff performance – **AMAZING!**



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# Flood Inundation Mapping (Our Unforeseen Mission)



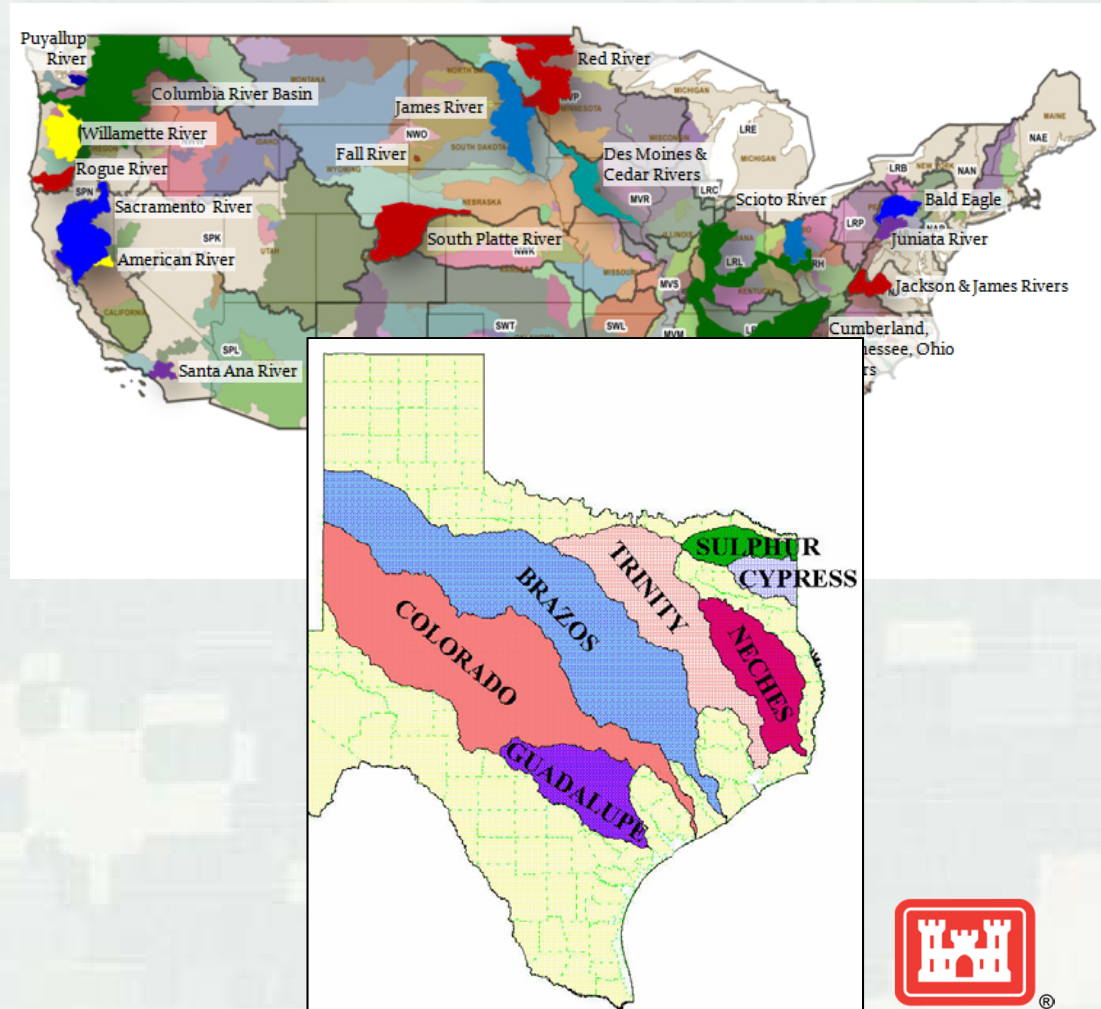
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# CWMS Implementation

- 200+ USACE watersheds
- \$150 M investment, nationally
- \$6 M for Texas
- 6+ year plan
- Supports
  - ▶ Dam safety, operations (forecasting), **can be leveraged (FEMA)**
- 2014
  - ▶ Colorado, Neches, Guadalupe, Trinity, San Jacinto (Buffalo Bayou)
- 2015
  - ▶ Brazos
- MetVue -> HMS-> RiverWare-> RAS-> FIA



May 2015 Flood - Inundation Requests					
River/Reach	Requested By:	Modeled By	Model Type:	Mapped by	Status
1 Gualadupe River downstream of Canyon	SWF	SWF	RAS	SWF	Complete
2 Elm Fork downstream of Lewisville Dam	SWF	SWF	RAS	MMC	Complete
3 East Fork downstream of Lavon Dam	SWF	SWF	RAS	MMC	Complete
4 Denton Creek downstream of Grapevine Dam	SWF	SWF	RAS	MMC	Complete
5 Trinity River - Dallas to Lake Livingston	SWF	MMC	FESM	MMC	Complete
6 Culp Branch downstream of Ray Roberts Spillway	SWF	N/A	N/A	SWF	Complete
7 Ray Roberts Pool at 645.5'	SWF	N/A	N/A	SWF	Complete
8 Brazos River - Simonton County to Coast	State of Texas	MMC	FESM	MMC	Complete
9 Colorado River - from Wharton TX to Coast	State of Texas	MMC	FESM	MMC	Complete
San Jacinto River - West Fork near Porter, Humboldt and Houston County through entrance to Galveston Bay	State of Texas	MMC	FESM	MMC	Complete
11 Neches- Below Sam Rayburn to Coast	State of Texas	MMC	FESM	MMC	Complete
12 Nueces River - Below Lake Corpus	State of Texas	MMC	FESM	MMC	Complete
13 Sabine River	State of Texas	MMC	FESM	MMC	Complete

### Scope of Inundation Requests:

**~ 1,500 River Miles**

- 13 River Basins/Reaches
- 7 Reaches (~500 river miles) requested by USACE's EOC [Impacted by USACE reservoir surcharge releases]
- 6 Reaches (~1,000 river miles) requested by the State of Texas

**Suspense Schedule? Right Now!**





# Final Map Products

- GIS Shapefiles
- Google Earth Files
- PDF Map Books in DFW

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- # Final Map Products
- 
- U.S. Army Corps of Engineers  
Fort Worth District
- Denton Creek downstream of Grapevine Lake estimated  
2,000 CFS from Grapevine with 5,000 CFS release from Lewisville -- and -- 7,000 CFS from G
- Apartment Complex  
on Sandy Lake Rd
- GIS Shapefiles
  - Google Earth Files
  - PDF Map Books in DFW
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# Final Map Products

U.S. Army Corps of Engineers  
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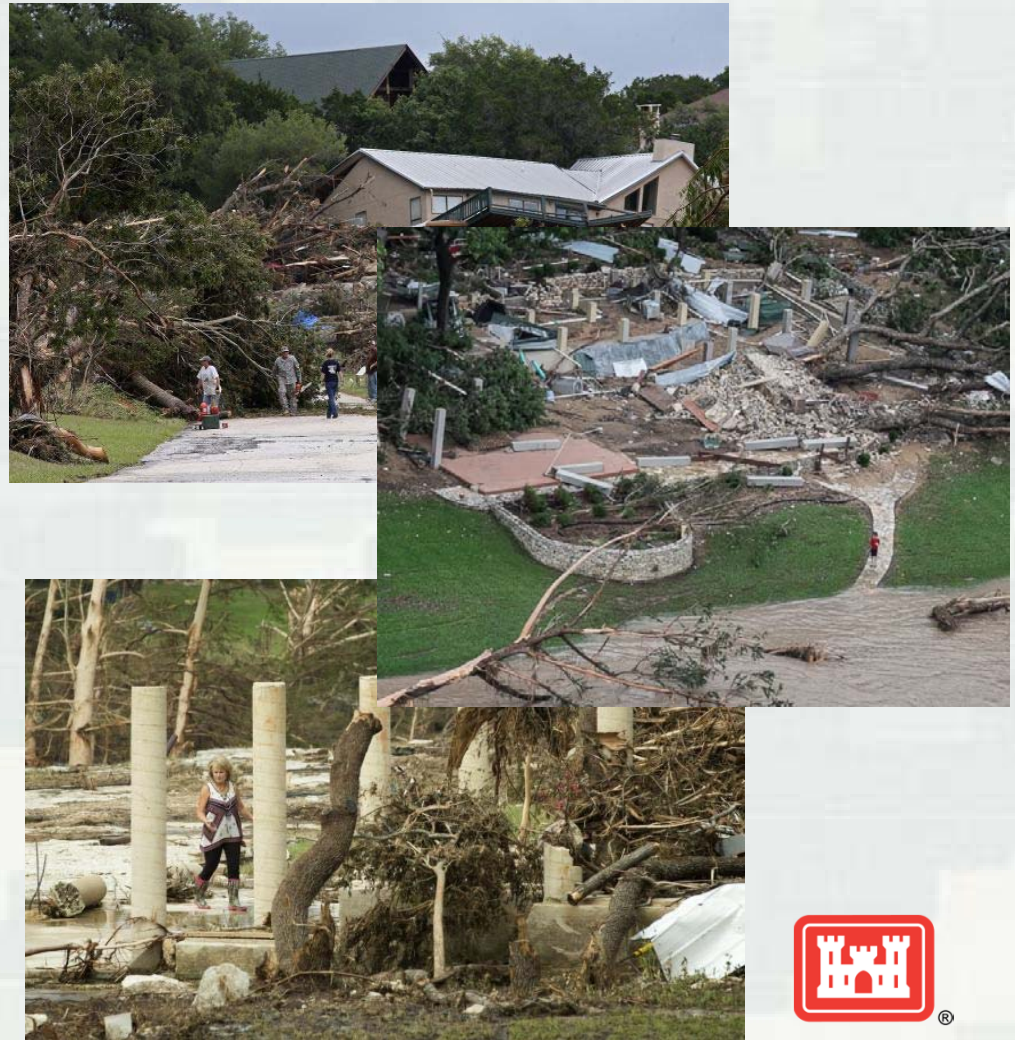
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# FEMA Support: Wimberley, TX

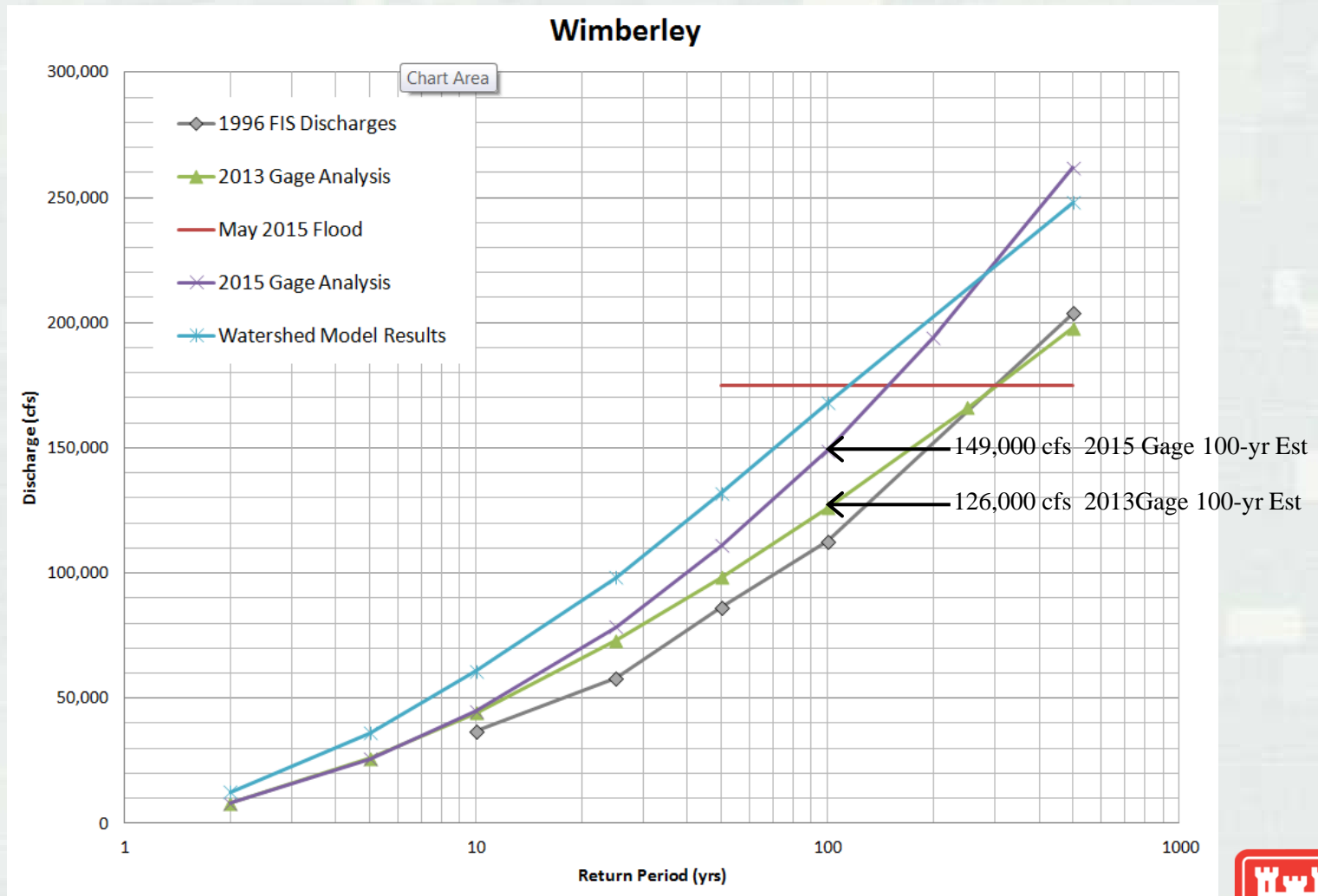
## May 2015 Flood

- 9 +- Deaths
- 100's homes damaged
- River rose 26 feet in 1 hour
- Estimated Peak Flow of 175,000 cfs > 100-yr
- HW mark 5-10 feet above current BFE
- *What is the true 100-yr (BFE) at Wimberley?*



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# Discharge-Frequency Curves: Blanco River at Wimberley

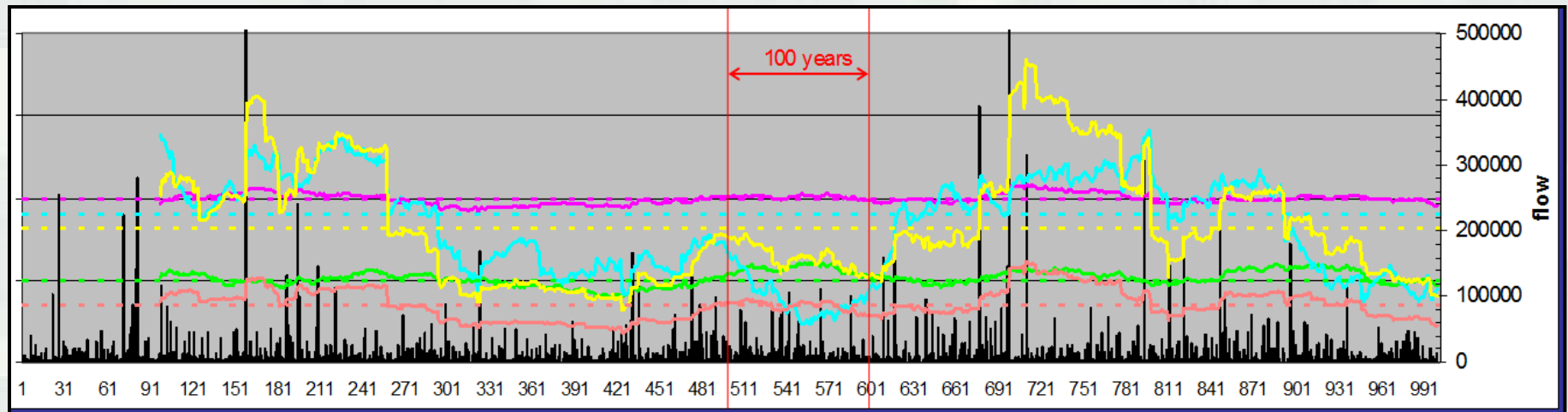


355 Square Miles, 88 years of record



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# How Much Uncertainty Do You Have with 100 years of Record?



Sliding Window = 100 years of Record

Solid Yellow Line = Estimate of 100-yr (1%) Discharge

**100-yr (1%) Estimate varies from 100,000 to 450,000 cfs  
with 100 years of Record**

Credit: Beth Faber at USACE-HEC

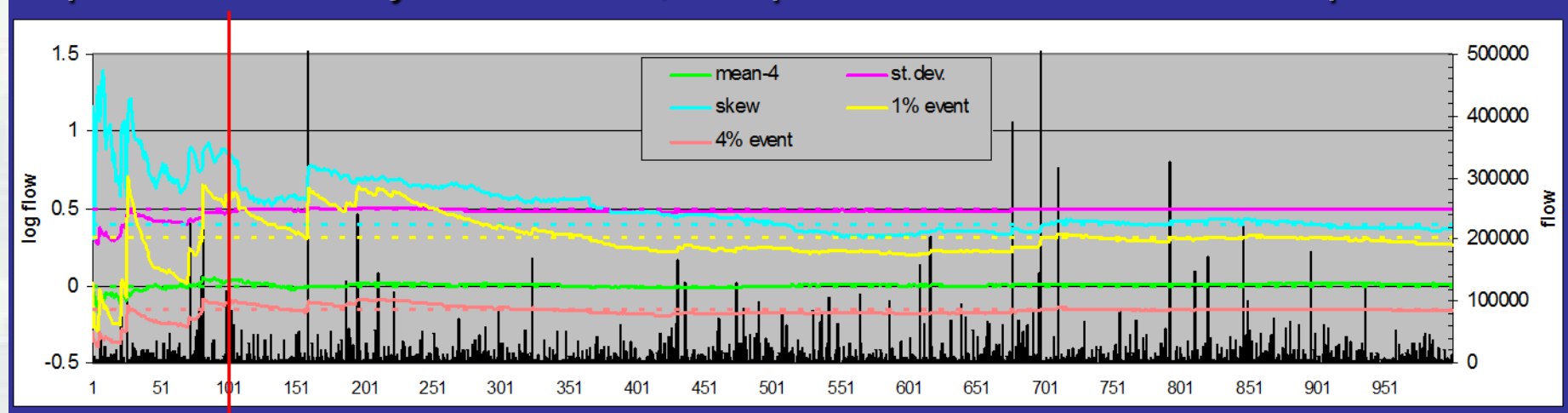


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# How Much Gage Record Do You Need to Estimate the 100-yr Discharge?

Experiment: 1000 years of data, sampled from LP III with known parameters



Dashed Yellow Line = Actual 100-yr (1%) Discharge

Solid Yellow Line = Estimate of 100-yr (1%) Discharge based on previous years of record

**300 to 400 years of Record before 100-yr Estimate Converges**

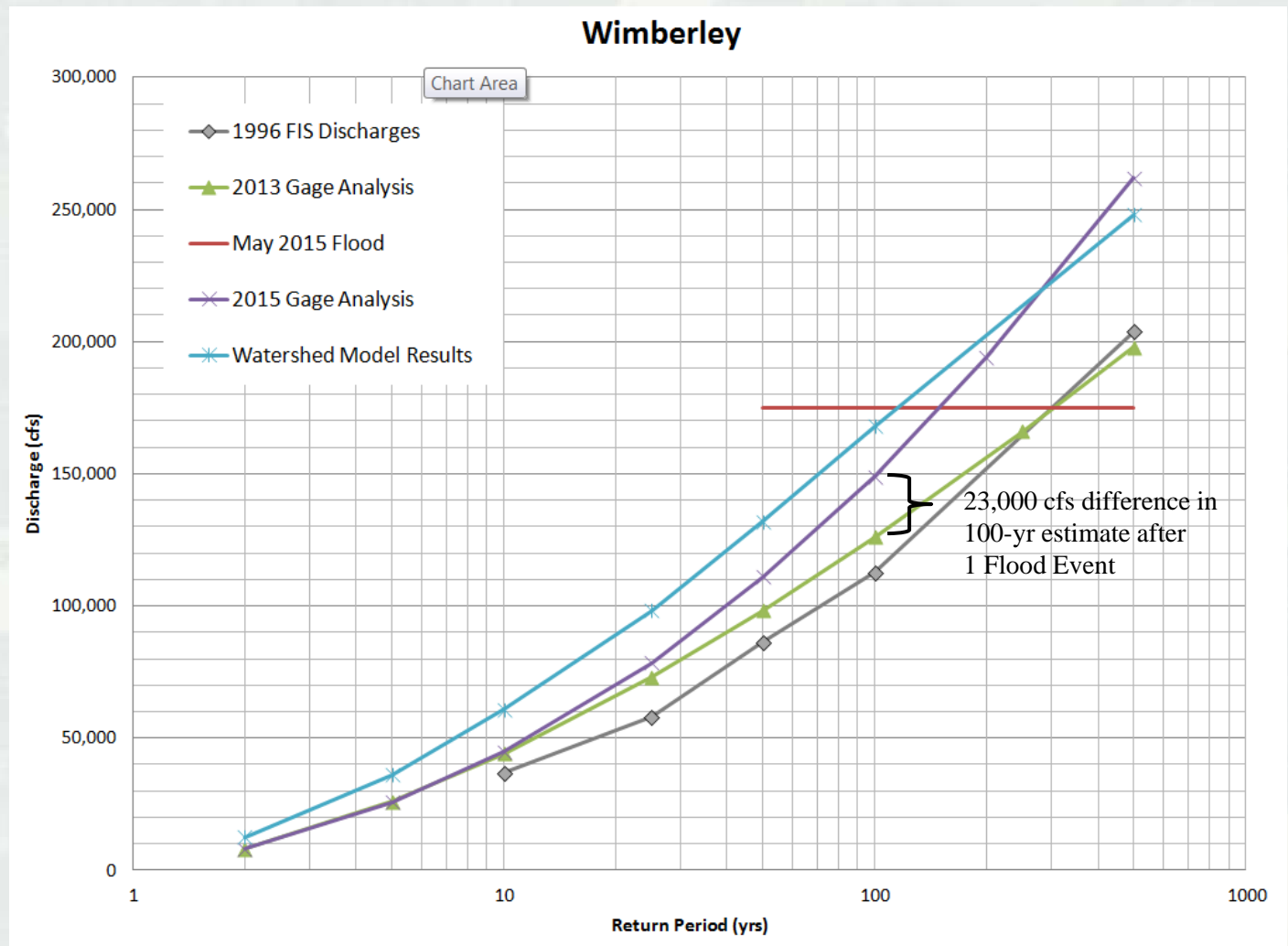


Credit: Beth Faber at USACE-HEC

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# Conclusions

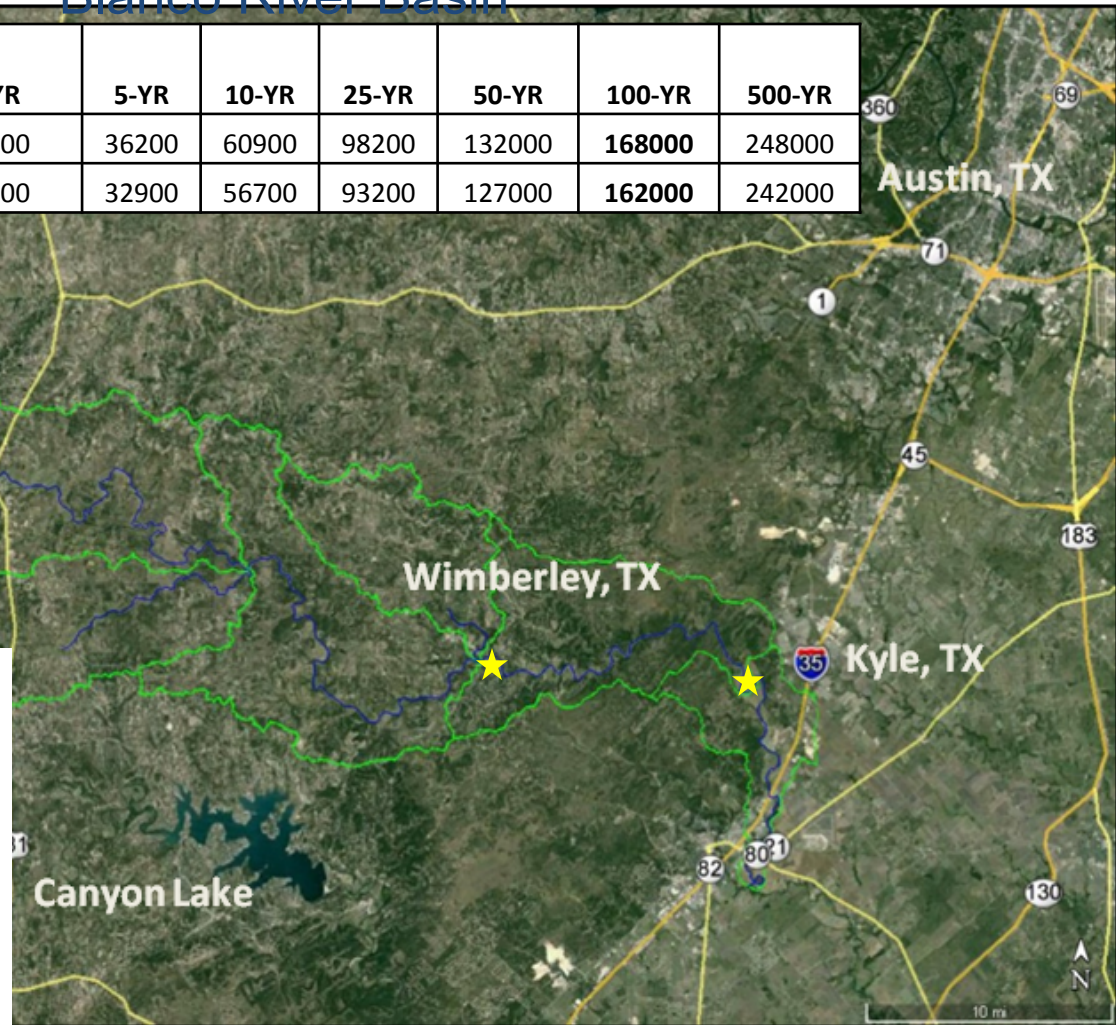
- 100 years of Record may not be enough!
- Watershed models can help compensate for non-representative samples in the gage record
- Need to use reasonable loss rates that consistent with extreme events



## Flood Frequency Estimates – HMS Modeling, Blanco River Basin

Description	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	500-YR
At Blanco River at Wimberley Gage	12500	36200	60900	98200	132000	<b>168000</b>	248000
At Blanco River near Kyle Gage	10500	32900	56700	93200	127000	<b>162000</b>	242000

- Model calibrated to observed events
- Statistical rainfall estimates (NOAA Atlas 14, focus)
- Loss rates
  - ▶ Antecedent conditions
  - ▶ Intensity
  - ▶ Regulation of WS



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# WEB Site

[www.swf-wc.usace.army.mil](http://www.swf-wc.usace.army.mil)

## Questions?



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