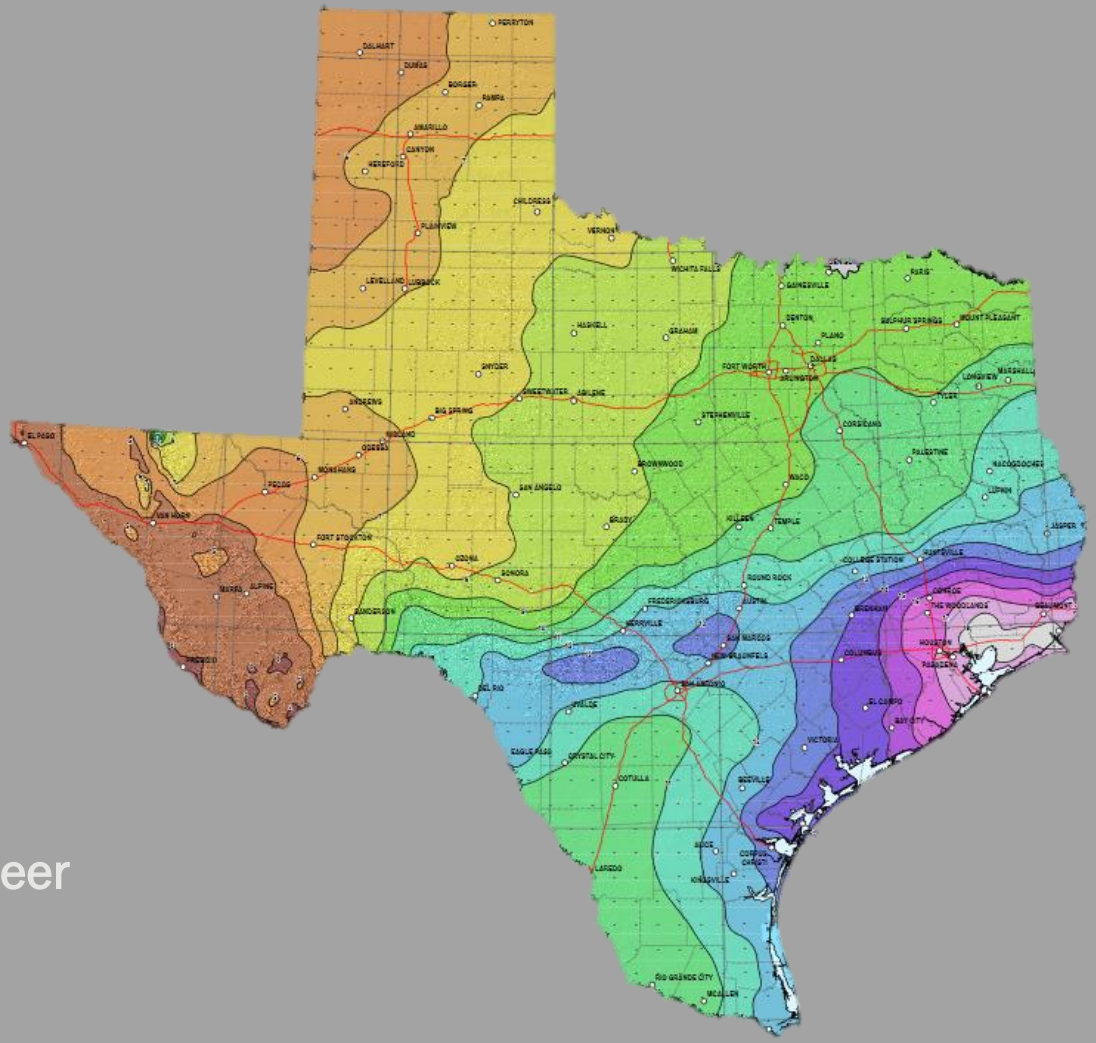
NOAA ATLAS 14 – VOLUME 11



November 28th, 2018
iSWM Subcommittee
Max Strickler, Hydrologist
Mikaela Mahoney, Hydraulic Engineer
U.S. Army Corps of Engineers
Fort Worth District

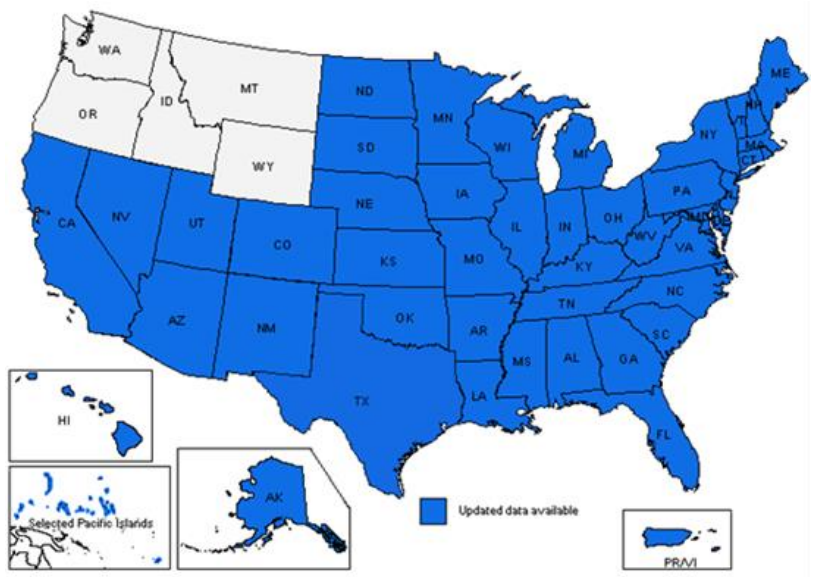
US Army Corps of Engineers ®

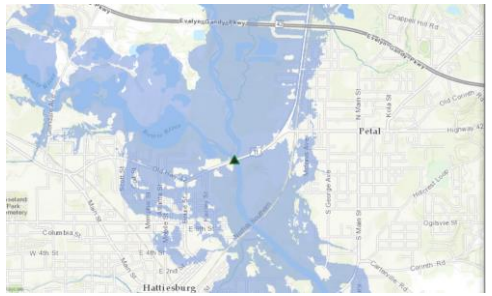
U.S.ARMY

NOAA ATLAS 14 METEOROLOGY RESEARCH INCENTIVE

- **What is it:**
  - Precipitation frequency estimates
  - How much rain in a 100-year storm event
  - Non-regulatory
- **Benefits:**
  - Better understanding of the risk from extreme precipitation events
  - Infrastructure design – parking lots to dams
  - Floodplain mapping (NFIP), where can we safely construct new neighborhoods
  - Preparedness or mitigation planning
- **Schedule:**
  - Volume 11 (Texas) released September 2018
  - Documentation: December 2018

NOAA Atlas 14





US Army Corps of Engineers ®

U.S.ARMY

WHAT IS NOAA ATLAS 14?

- NOAA's Office of Water Prediction, Hydro-meteorological Design Studies Center
- National initiative which begun around 2000
- Today's de facto national standard for precipitation frequency estimates
- 30 arc-second resolution, ~800 meter grid
  - Durations from 5 minutes to 60 days for
  - Average recurrence intervals (ARIs) from 1 to 1,000 years
- Electronically accessible
  - http://hdsc.nws.noaa.gov/hdsc/pfds/
- Funded locally

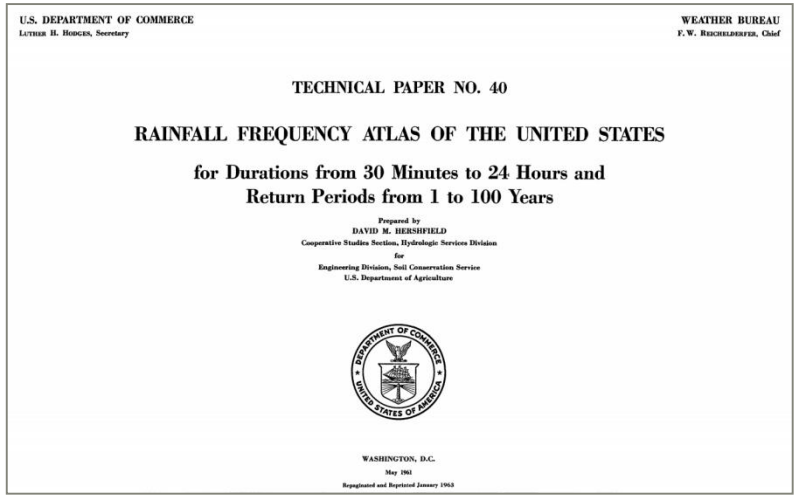
US Army Corps of Engineers ®

U.S.ARMY

PREVIOUS PRECIPITATION FREQUENCY PRODUCTS

NOAA/NWS

- NWS Technical Paper No. 40 (1961)
- NWS Technical Paper No. 49 (1964)
- NWS Hydro-35 (1977)



U.S. DEPARTMENT OF COMMERCE
LUTHER H. HODGES, Secretary

WEATHER BUREAU
F. W. REICHELDERFER, Chief

TECHNICAL PAPER NO. 40

RAINFALL FREQUENCY ATLAS OF THE UNITED STATES

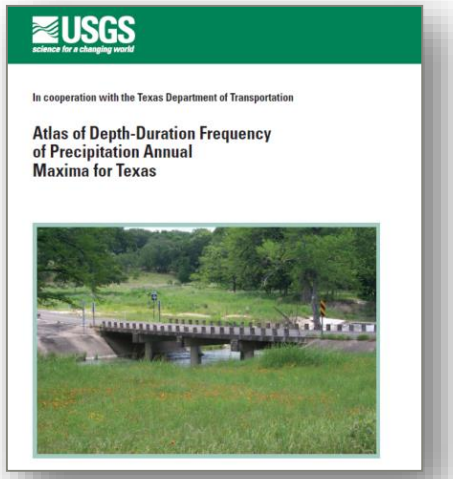
for Durations from 30 Minutes to 24 Hours and
Return Periods from 1 to 100 Years

Prepared by
DAVID M. HERSHFIELD
Cooperative Studies Section, Hydrologic Services Division
for
Engineering Division, Soil Conservation Service
U.S. Department of Agriculture

WASHINGTON, D.C.
May 1961
Reprinted and Reprinted January 1963

USGS

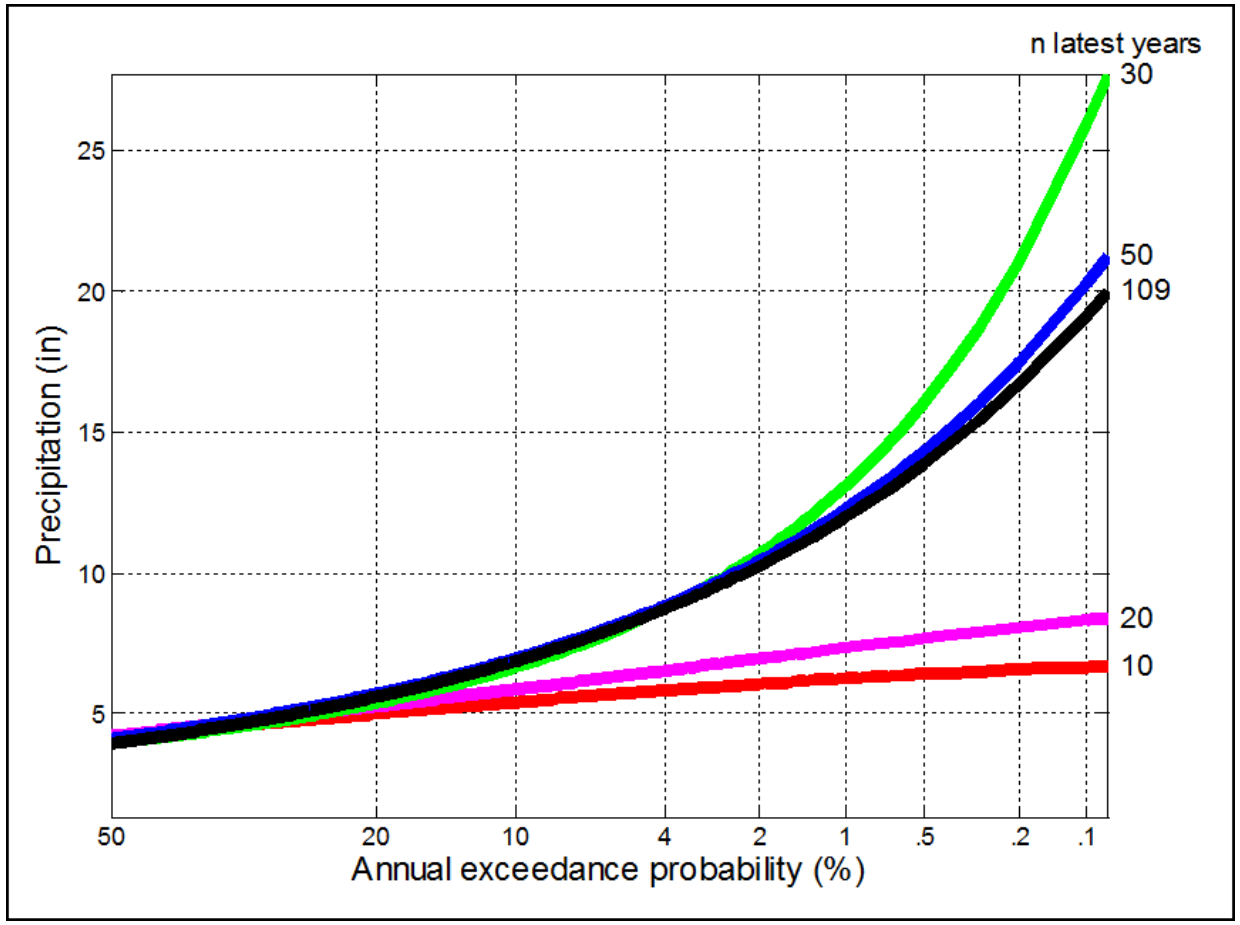
- Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas (2004)
  - Based on data from 1998 study (data from 1994)



US Army Corps of Engineers ®

U.S.ARMY

IMPORTANCE OF NEW DATA



- Hydro-35/TP 40 - ~20-years of record
- USGS - ~35-years of record
- NA14 - ~60-years of record

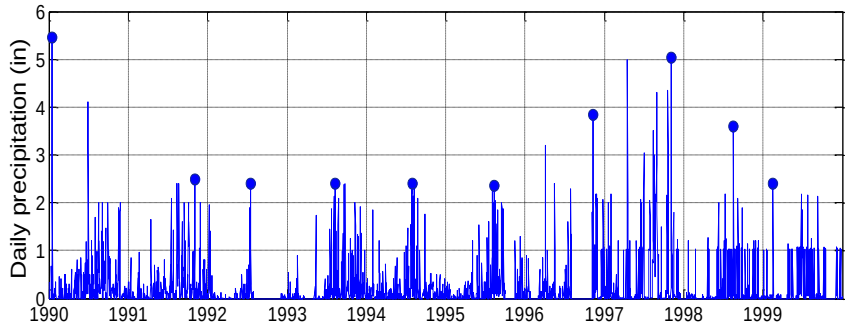
US Army Corps of Engineers ®

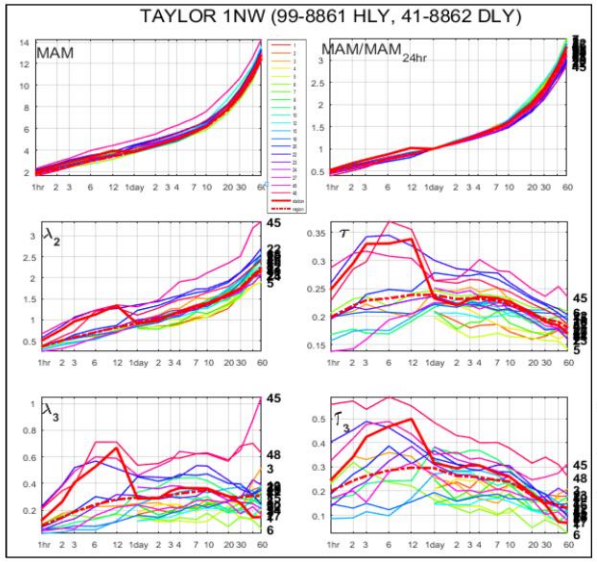
U.S.ARMY

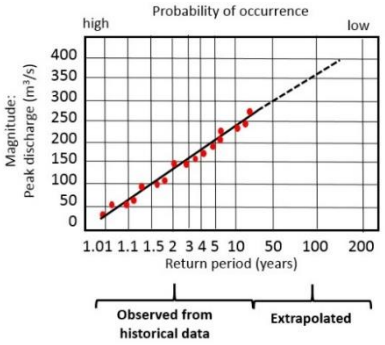
WHY IS NOAA ATLAS 14 RIGHT FOR TEXAS?

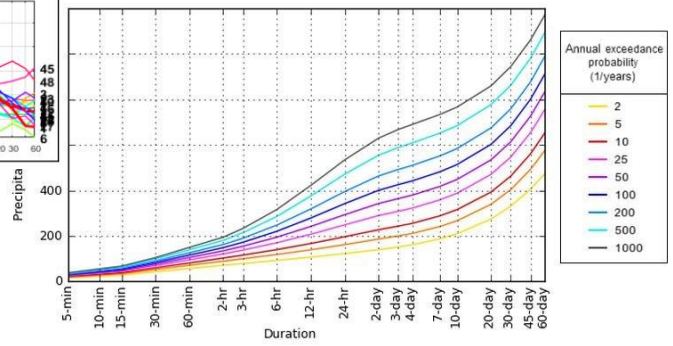
Approach: Regional frequency analysis approach based on GEV distribution with parameters calculated based on L-moment statistics from annual maximum series (AMS)

- Data Collection and formatting
  - Station cleanup and quality control of AMS extraction
  - Dense rain gage network with longer period of records
- Regionalization
  - All stations analyzed together as a set; multiple sets per station
- Statistical analysis of precipitation gage data
  - L-moment statistics calculated from annual maximum series (AMS)
- Derivation of AMS- and PDS-based DDF curves and upper and lower confidence bounds
- Spatial interpolation using PRISM
  - 30-arc-sec grids
  - Accounts for variations in terrain and coastal proximity
- Peer reviewed
- Web publication with detailed documentation



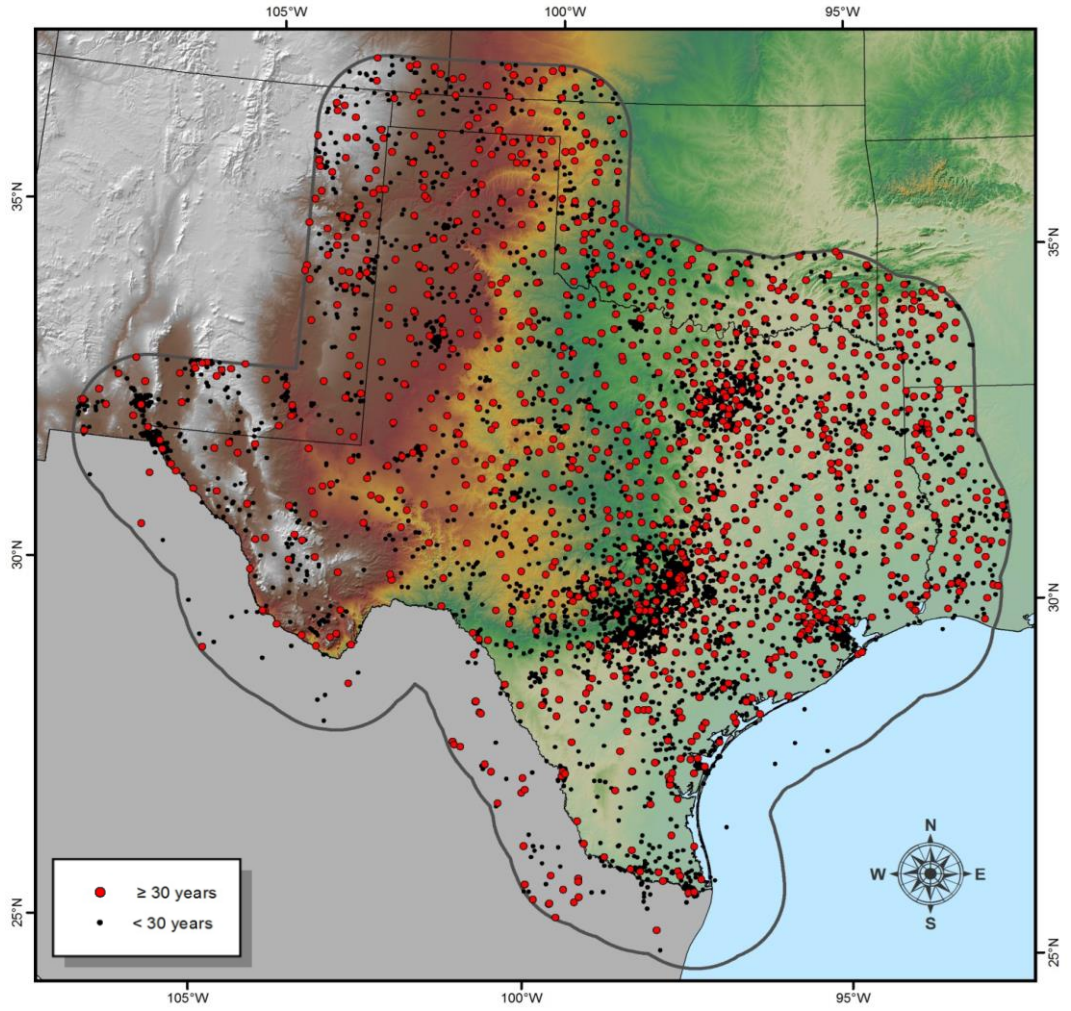






PRECIPITATION DATA

- Formatted 11,930 stations
  - ≤ 15-min
  - 1-hour
  - 1-day
- Retained 3,900 stations
  - Length of record
  - Reliability of record
- Average record length ~60 years
- Records through December 2017 (added 2018 data for stations – Hurricane Harvey)
- Digitized pre-1948 data from NCEI's Climate Database Modernization Program

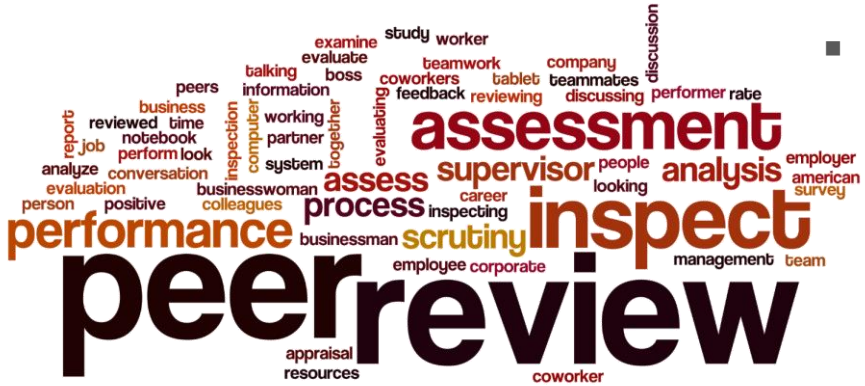


US Army Corps of Engineers ®

U.S.ARMY

NOAA ATLAS 14 – PEER REVIEW BOARD

- Dr. John Nielsen-Gammon – Texas A&M University/State Climatologist
- Dr. William Asquith – Texas Tech University/USGS
- Dr. Nick Fang – University of Texas at Arlington
- Dr. Dongjin Seo – University of Texas at Arlington
- Steve Fitzgerald – Harris County Flood Control District
- Daniel Huckaby – NWS
- Paul McKee – NWS
- Maureen O'Leary – NWS
- Jon Zeitler - NWS



- Alan Johnson – FEMA
- Saul Nuccitelli - TxDOT
- Jason Johnson – NWS
- Simeon Benson – USACE
- Jerry Cotter - USACE
- Craig Loftin – USACE
- Helena Mosser – USACE
- Steve Pilney – USACE
- Max Strickler – USACE

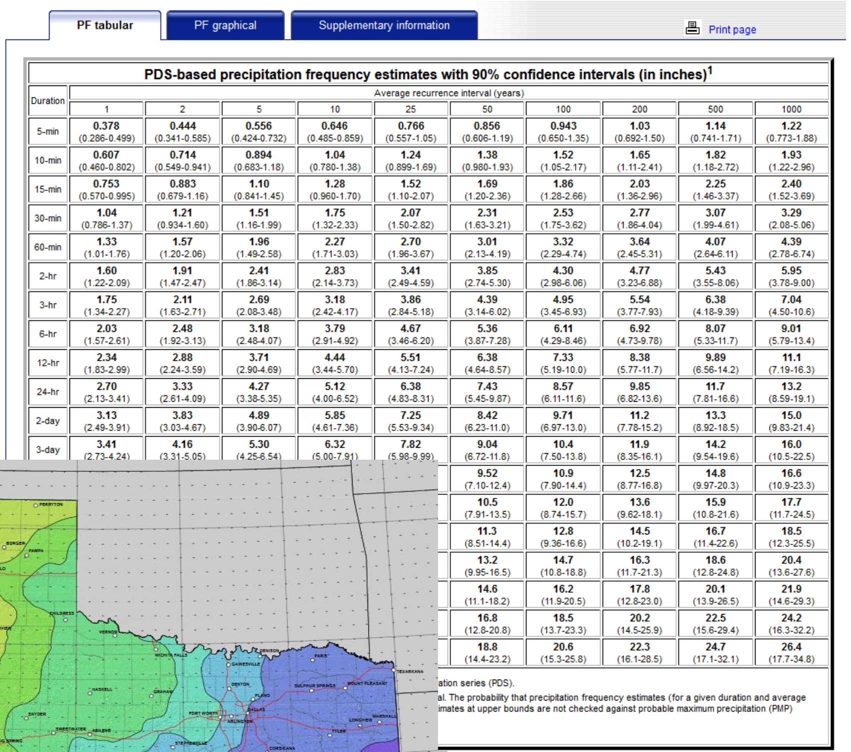
InFRM
INTERAGENCY FLOOD RISK MANAGEMENT

US Army Corps of Engineers ®

U.S.ARMY

NOAA ATLAS 14 - ACCESS

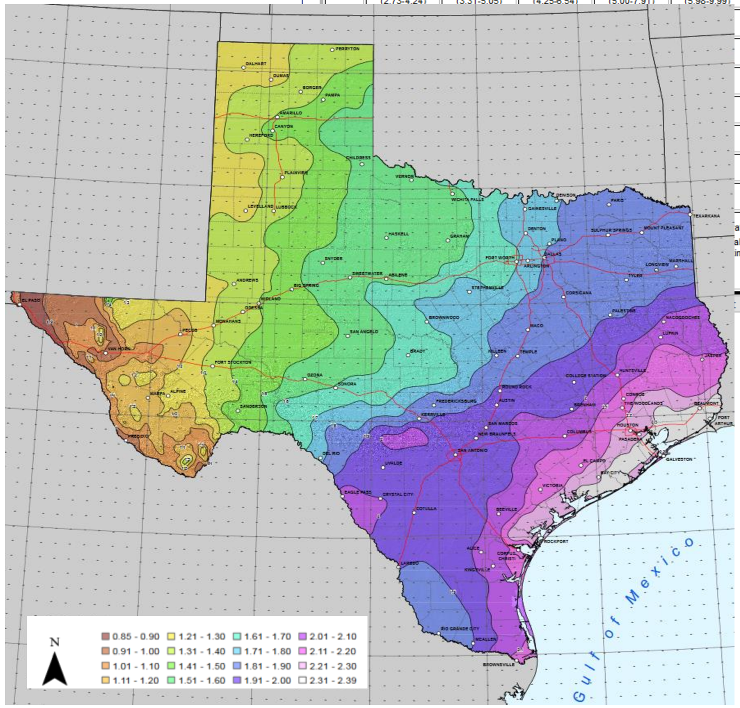
- To access NOAA Atlas 14 data
  - Navigate to: http://hdsc.nws.noaa.gov/hdsc/pfds/
    Or thru
    www.InFRM.US
  - Click on a study location
  - Access tables, and other forms of data in electronic format
- Utilize USACE applications that incorporate NOAA Atlas 14 data
- Use an updated NFIP map



PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.378 (0.286-0.499)	0.444 (0.341-0.585)	0.556 (0.424-0.732)	0.646 (0.485-0.859)	0.766 (0.557-1.05)	0.856 (0.606-1.19)	0.943 (0.650-1.35)	1.03 (0.692-1.50)	1.14 (0.741-1.71)	1.22 (0.773-1.88)
10-min	0.607 (0.460-0.802)	0.714 (0.549-0.941)	0.894 (0.683-1.18)	1.04 (0.780-1.38)	1.24 (0.899-1.69)	1.38 (0.980-1.93)	1.52 (1.05-2.17)	1.65 (1.11-2.41)	1.82 (1.18-2.72)	1.93 (1.22-2.96)
15-min	0.753 (0.570-0.995)	0.883 (0.679-1.16)	1.10 (0.841-1.45)	1.28 (0.960-1.70)	1.52 (1.10-2.07)	1.69 (1.20-2.36)	1.86 (1.28-2.66)	2.03 (1.36-2.96)	2.25 (1.46-3.37)	2.40 (1.52-3.69)
30-min	1.04 (0.786-1.37)	1.21 (0.934-1.60)	1.51 (1.16-1.99)	1.75 (1.32-2.33)	2.07 (1.50-2.82)	2.31 (1.63-3.21)	2.53 (1.75-3.62)	2.77 (1.86-4.04)	3.07 (1.99-4.61)	3.29 (2.08-5.06)
60-min	1.33 (1.01-1.76)	1.57 (1.20-2.06)	1.96 (1.49-2.58)	2.27 (1.71-3.03)	2.70 (1.96-3.67)	3.01 (2.13-4.19)	3.32 (2.29-4.74)	3.64 (2.45-5.31)	4.07 (2.64-6.11)	4.39 (2.78-6.74)
2-hr	1.60 (1.22-2.09)	1.91 (1.47-2.47)	2.41 (1.86-3.14)	2.83 (2.14-3.73)	3.41 (2.49-4.59)	3.85 (2.74-5.30)	4.30 (2.98-6.06)	4.77 (3.23-6.88)	5.43 (3.55-8.06)	5.95 (3.78-9.00)
3-hr	1.75 (1.34-2.27)	2.11 (1.63-2.71)	2.69 (2.08-3.48)	3.18 (2.42-4.17)	3.86 (2.84-5.18)	4.39 (3.14-6.02)	4.95 (3.45-6.93)	5.54 (3.77-7.93)	6.38 (4.18-9.39)	7.04 (4.50-10.6)
6-hr	2.03 (1.57-2.61)	2.48 (1.92-3.13)	3.18 (2.48-4.07)	3.79 (2.91-4.92)	4.67 (3.46-6.20)	5.36 (3.87-7.28)	6.11 (4.29-8.46)	6.92 (4.73-9.78)	8.07 (5.33-11.7)	9.01 (5.79-13.4)
12-hr	2.34 (1.83-2.99)	2.88 (2.24-3.59)	3.71 (2.90-4.69)	4.44 (3.44-5.70)	5.51 (4.13-7.24)	6.38 (4.64-8.57)	7.33 (5.19-10.0)	8.38 (5.77-11.7)	9.89 (6.56-14.2)	11.1 (7.19-16.3)
24-hr	2.70 (2.13-3.41)	3.33 (2.61-4.09)	4.27 (3.38-5.35)	5.12 (4.00-6.52)	6.38 (4.83-8.31)	7.43 (5.45-9.87)	8.57 (6.11-11.6)	9.85 (6.82-13.6)	11.7 (7.81-16.6)	13.2 (8.59-19.1)
2-day	3.13 (2.49-3.91)	3.83 (3.03-4.67)	4.89 (3.90-6.07)	5.85 (4.61-7.36)	7.25 (5.53-9.34)	8.42 (6.23-11.0)	9.71 (6.97-13.0)	11.2 (7.78-15.2)	13.3 (8.92-18.5)	15.0 (9.83-21.4)
3-day	3.41 (2.73-4.24)	4.16 (3.31-5.05)	5.30 (4.25-6.54)	6.32 (5.00-7.91)	7.82 (5.98-9.99)	9.04 (6.72-11.8)	10.4 (7.50-13.8)	11.9 (8.35-16.1)	14.2 (9.54-19.6)	16.0 (10.5-22.5)
						9.52 (7.10-12.4)	10.9 (7.90-14.4)	12.5 (8.77-16.8)	14.8 (9.97-20.3)	16.6 (10.9-23.3)
						10.5 (7.91-13.5)	12.0 (8.74-15.7)	13.6 (9.62-18.1)	15.9 (10.8-21.6)	17.7 (11.7-24.5)
						11.3 (8.51-14.4)	12.8 (9.36-16.6)	14.5 (10.2-19.1)	16.7 (11.4-22.6)	18.5 (12.3-25.5)
						13.2 (9.95-16.5)	14.7 (10.8-18.8)	16.3 (11.7-21.3)	18.6 (12.8-24.8)	20.4 (13.6-27.6)
						14.6 (11.1-18.2)	16.2 (11.9-20.5)	17.8 (12.8-23.0)	20.1 (13.9-26.5)	21.9 (14.6-29.3)
						16.8 (12.8-20.8)	18.5 (13.7-23.3)	20.2 (14.5-25.9)	22.5 (15.6-29.4)	24.2 (16.3-32.2)
						18.8 (14.4-23.2)	20.6 (15.3-25.8)	22.3 (16.1-28.5)	24.7 (17.1-32.1)	26.4 (17.7-34.8)

ation series (PDS).
al. The probability that precipitation frequency estimates (for a given duration and average
imates at upper bounds are not checked against probable maximum precipitation (PMP)



US Army Corps of Engineers ®

U.S.ARMY

RESULTS

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 11, Version 2

PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

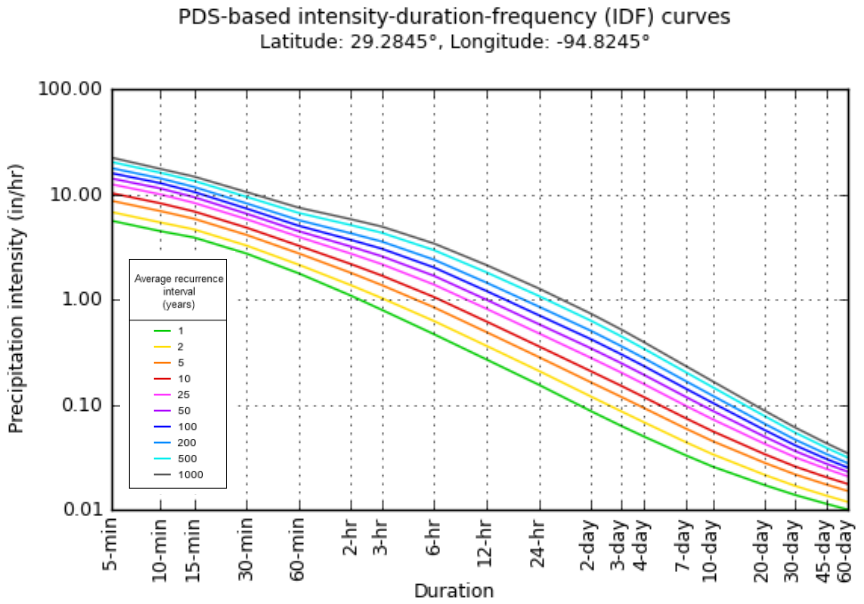
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**5.62** (4.25-7.42)	**6.79** (5.18-8.86)	**8.69** (6.62-11.4)	**10.3** (7.72-13.7)	**12.5** (9.06-17.1)	**14.2** (10.0-20.0)	**15.9** (11.0-23.1)	**17.8** (11.9-26.4)	**20.3** (13.2-31.3)	**22.4** (14.1-35.3)
10-min	**4.46** (3.37-5.89)	**5.39** (4.12-7.04)	**6.92** (5.27-9.08)	**8.20** (6.15-10.9)	**9.97** (7.25-13.7)	**11.3** (8.04-16.0)	**12.7** (8.78-18.5)	**14.1** (9.50-21.0)	**16.0** (10.4-24.6)	**17.4** (11.0-27.5)
15-min	**3.88** (2.94-5.13)	**4.63** (3.53-6.04)	**5.84** (4.45-7.67)	**6.86** (5.15-9.14)	**8.28** (6.02-11.4)	**9.38** (6.64-13.2)	**10.5** (7.25-15.2)	**11.7** (7.88-17.4)	**13.4** (8.70-20.6)	**14.7** (9.31-23.2)
30-min	**2.73** (2.07-3.61)	**3.26** (2.49-4.26)	**4.11** (3.13-5.40)	**4.82** (3.62-6.42)	**5.80** (4.20-7.94)	**6.54** (4.61-9.21)	**7.31** (5.04-10.6)	**8.19** (5.51-12.2)	**9.45** (6.14-14.6)	**10.5** (6.64-16.6)
60-min	**1.77** (1.34-2.34)	**2.14** (1.64-2.79)	**2.74** (2.09-3.60)	**3.24** (2.43-4.32)	**3.93** (2.85-5.38)	**4.46** (3.14-6.27)	**5.02** (3.46-7.27)	**5.67** (3.81-8.45)	**6.64** (4.31-10.3)	**7.45** (4.71-11.8)
2-hr	**1.09** (0.828-1.42)	**1.37** (1.03-1.74)	**1.79** (1.37-2.32)	**2.17** (1.64-2.87)	**2.72** (1.99-3.71)	**3.18** (2.26-4.46)	**3.68** (2.55-5.29)	**4.25** (2.87-6.27)	**5.08** (3.31-7.79)	**5.78** (3.67-9.07)
3-hr	**0.798** (0.611-1.04)	**1.03** (0.777-1.29)	**1.37** (1.05-1.77)	**1.69** (1.28-2.22)	**2.17** (1.60-2.96)	**2.58** (1.85-3.61)	**3.04** (2.11-4.35)	**3.55** (2.40-5.22)	**4.30** (2.81-6.56)	**4.93** (3.14-7.70)
6-hr	**0.468** (0.361-0.606)	**0.624** (0.467-0.761)	**0.842** (0.649-1.07)	**1.06** (0.806-1.38)	**1.39** (1.03-1.88)	**1.68** (1.21-2.34)	**2.01** (1.41-2.87)	**2.39** (1.62-3.48)	**2.94** (1.93-4.45)	**3.40** (2.17-5.27)
12-hr	**0.270** (0.210-0.347)	**0.363** (0.272-0.436)	**0.491** (0.381-0.621)	**0.618** (0.476-0.802)	**0.817** (0.612-1.10)	**0.996** (0.724-1.38)	**1.21** (0.847-1.70)	**1.45** (0.987-2.09)	**1.81** (1.19-2.72)	**2.13** (1.36-3.27)
24-hr	**0.155** (0.121-0.198)	**0.210** (0.158-0.250)	**0.284** (0.222-0.357)	**0.360** (0.279-0.463)	**0.477** (0.360-0.639)	**0.584** (0.427-0.804)	**0.710** (0.502-0.995)	**0.857** (0.587-1.23)	**1.08** (0.714-1.61)	**1.27** (0.820-1.95)
2-day	**0.087** (0.069-0.110)	**0.120** (0.090-0.140)	**0.163** (0.129-0.203)	**0.208** (0.162-0.266)	**0.278** (0.212-0.371)	**0.343** (0.254-0.470)	**0.419** (0.298-0.583)	**0.504** (0.346-0.717)	**0.628** (0.416-0.929)	**0.733** (0.473-1.11)
3-day	**0.063** (0.050-0.079)	**0.086** (0.066-0.101)	**0.118** (0.094-0.147)	**0.151** (0.118-0.192)	**0.201** (0.154-0.267)	**0.247** (0.183-0.337)	**0.300** (0.214-0.416)	**0.359** (0.248-0.509)	**0.445** (0.295-0.654)	**0.516** (0.334-0.778)
4-day	**0.050** (0.040-0.063)	**0.069** (0.053-0.080)	**0.094** (0.074-0.116)	**0.119** (0.094-0.151)	**0.158** (0.121-0.209)	**0.194** (0.144-0.263)	**0.234** (0.167-0.324)	**0.279** (0.193-0.394)	**0.343** (0.228-0.503)	**0.396** (0.257-0.596)
7-day	**0.033** (0.027-0.041)	**0.044** (0.034-0.052)	**0.060** (0.048-0.073)	**0.075** (0.059-0.094)	**0.098** (0.076-0.129)	**0.119** (0.089-0.161)	**0.143** (0.102-0.196)	**0.168** (0.117-0.236)	**0.204** (0.136-0.298)	**0.234** (0.152-0.349)
10-day	**0.026** (0.021-0.032)	**0.034** (0.027-0.040)	**0.045** (0.036-0.055)	**0.056** (0.045-0.070)	**0.073** (0.056-0.095)	**0.088** (0.066-0.118)	**0.104** (0.075-0.143)	**0.122** (0.085-0.171)	**0.147** (0.098-0.213)	**0.167** (0.109-0.249)
20-day	**0.017** (0.014-0.021)	**0.022** (0.017-0.026)	**0.028** (0.023-0.034)	**0.034** (0.027-0.042)	**0.042** (0.033-0.055)	**0.050** (0.037-0.066)	**0.057** (0.041-0.078)	**0.066** (0.046-0.092)	**0.078** (0.052-0.112)	**0.088** (0.057-0.129)
30-day	**0.014** (0.011-0.017)	**0.017** (0.014-0.020)	**0.022** (0.018-0.026)	**0.026** (0.021-0.032)	**0.032** (0.024-0.040)	**0.036** (0.027-0.048)	**0.041** (0.030-0.055)	**0.046** (0.033-0.064)	**0.054** (0.037-0.078)	**0.061** (0.040-0.089)
45-day	**0.011** (0.009-0.014)	**0.014** (0.011-0.017)	**0.017** (0.014-0.021)	**0.021** (0.017-0.025)	**0.025** (0.019-0.031)	**0.028** (0.021-0.036)	**0.031** (0.022-0.041)	**0.034** (0.024-0.047)	**0.039** (0.027-0.056)	**0.043** (0.028-0.063)
60-day	**0.010** (0.008-0.012)	**0.012** (0.010-0.015)	**0.015** (0.013-0.018)	**0.018** (0.014-0.022)	**0.021** (0.016-0.026)	**0.023** (0.017-0.030)	**0.025** (0.018-0.034)	**0.028** (0.020-0.038)	**0.032** (0.021-0.045)	**0.035** (0.023-0.050)

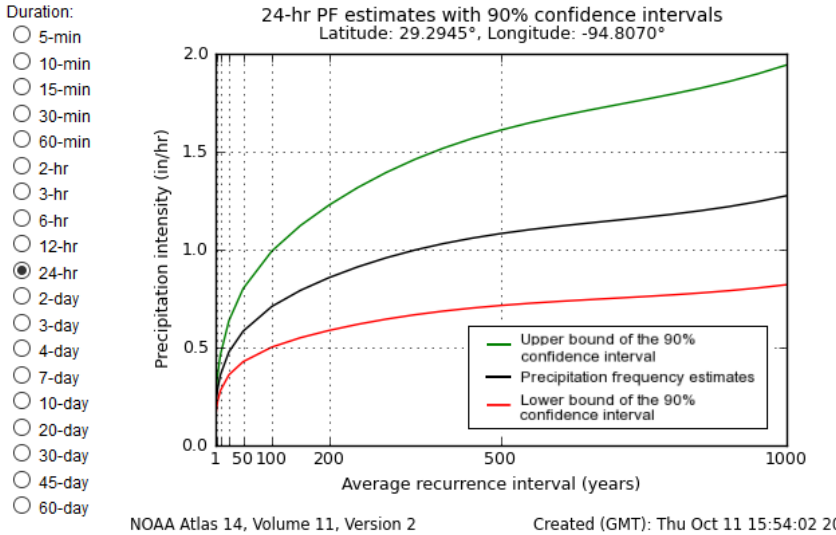
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Estimates from the table in CSV format: Precipitation frequency estimates | Submit

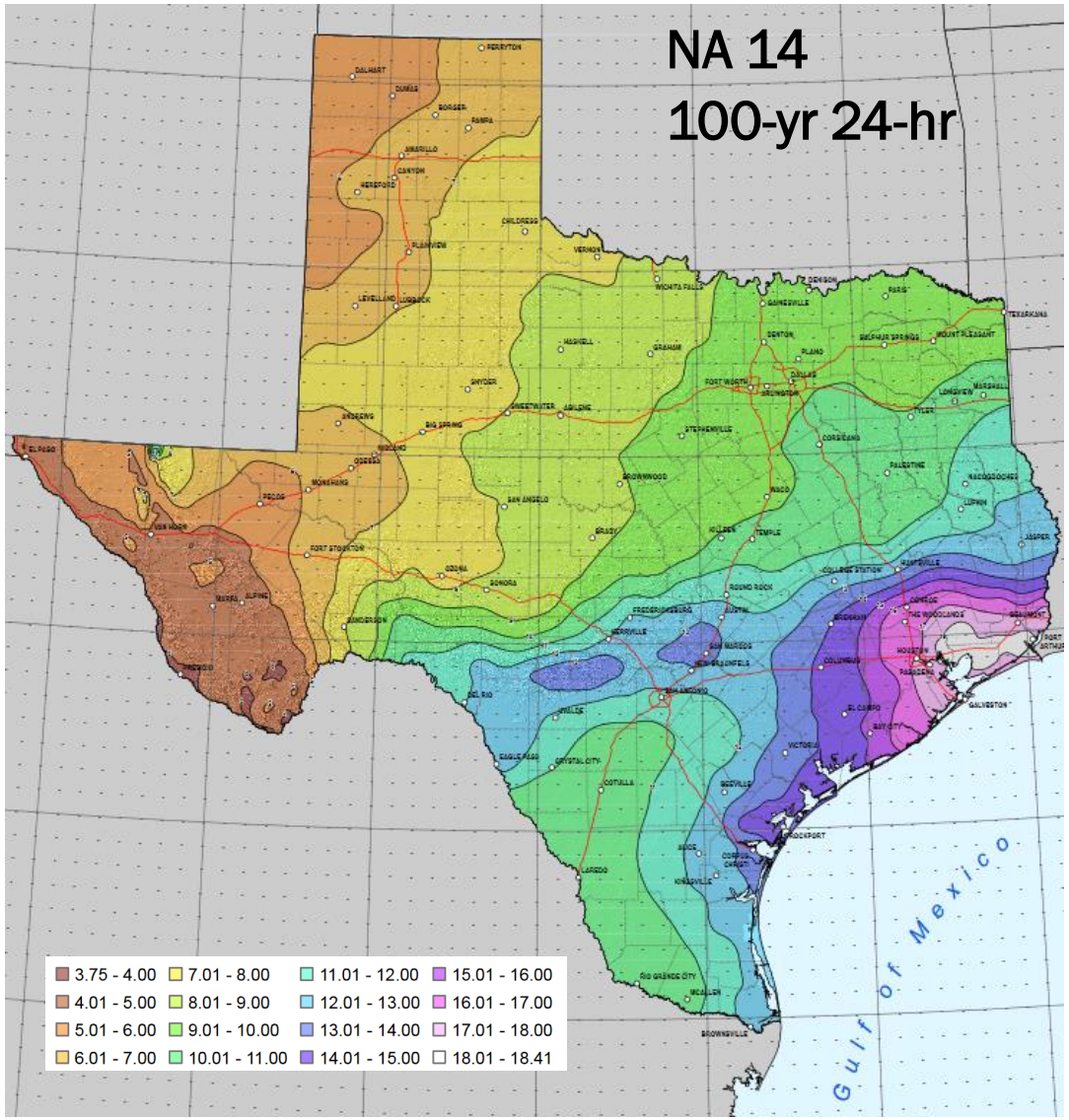


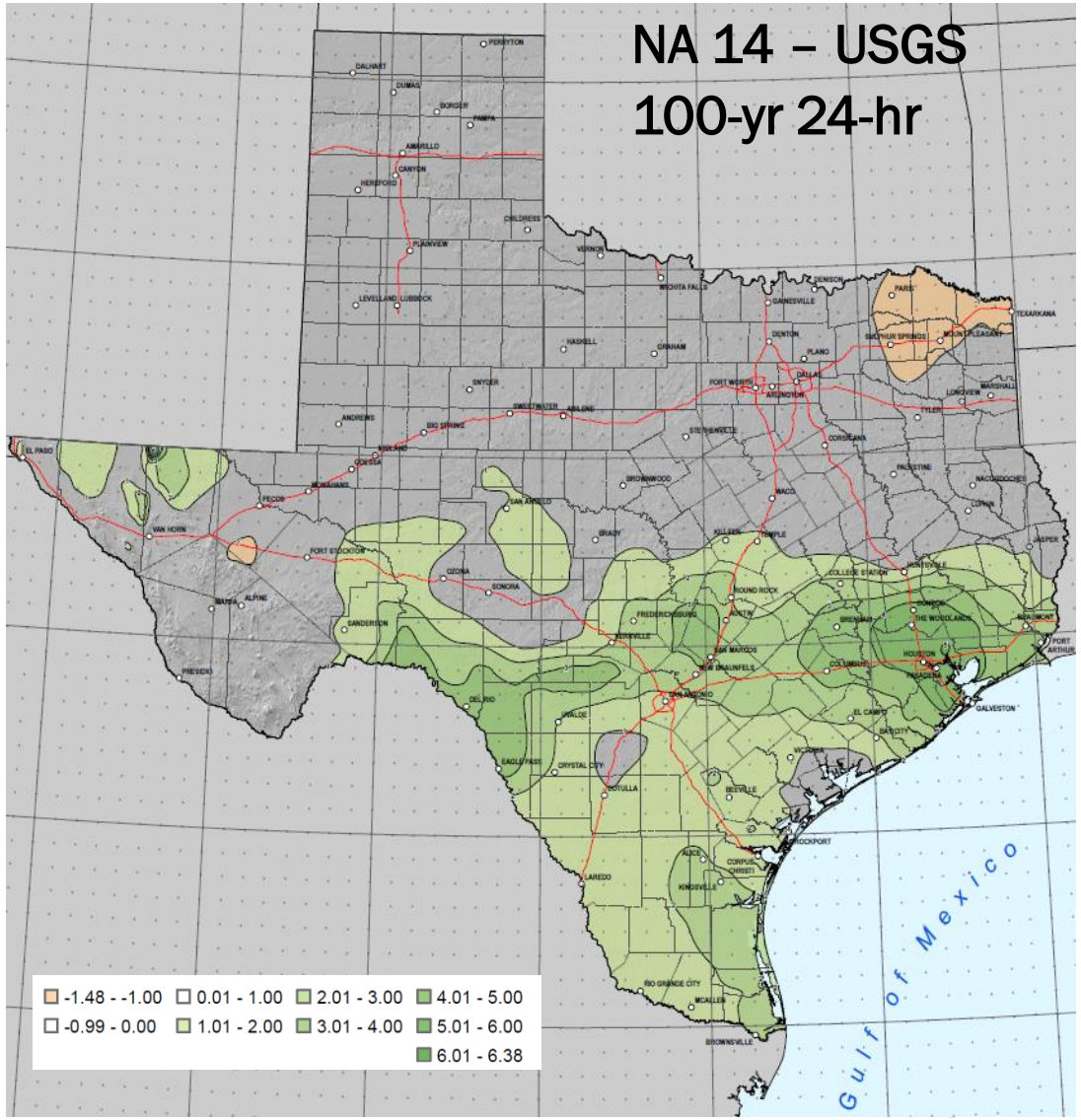


NOAA Atlas 14, Volume 11, Version 2 Created (GMT): Thu Oct 11 15:54:02 2018

U.S.ARMY

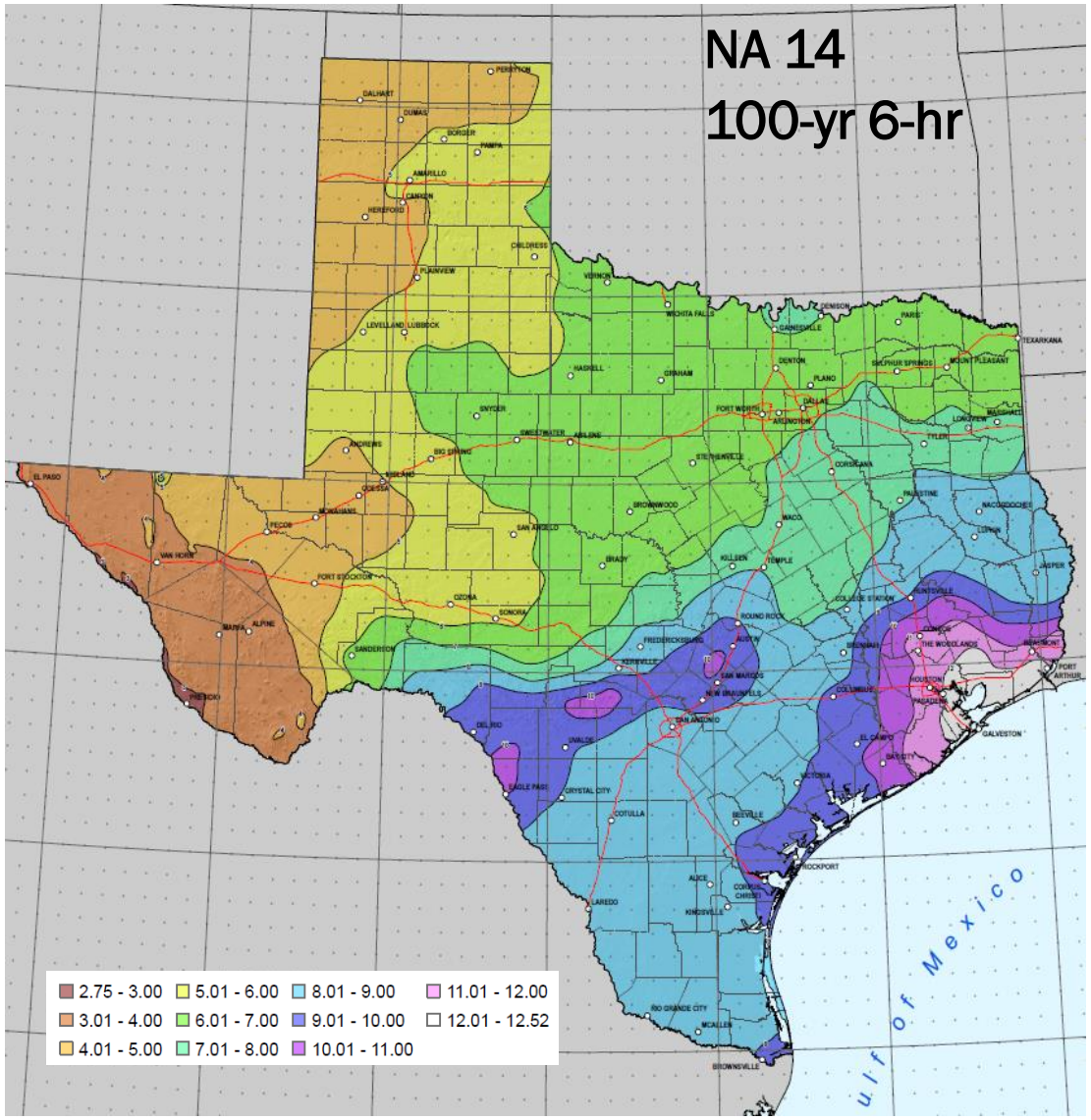
HOW DOES NOAA ATLAS COMPARE TO PREVIOUS STUDIES?

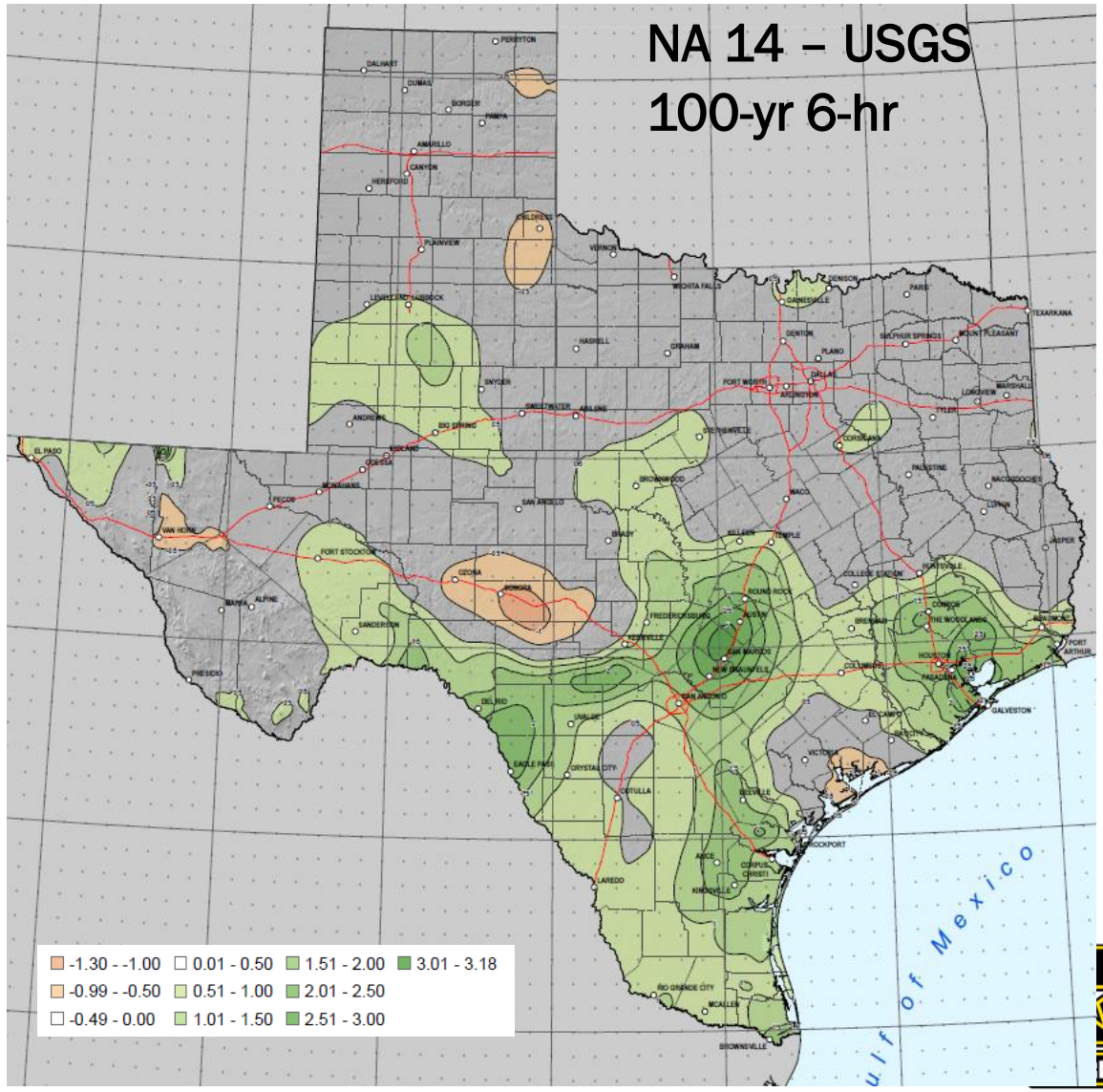




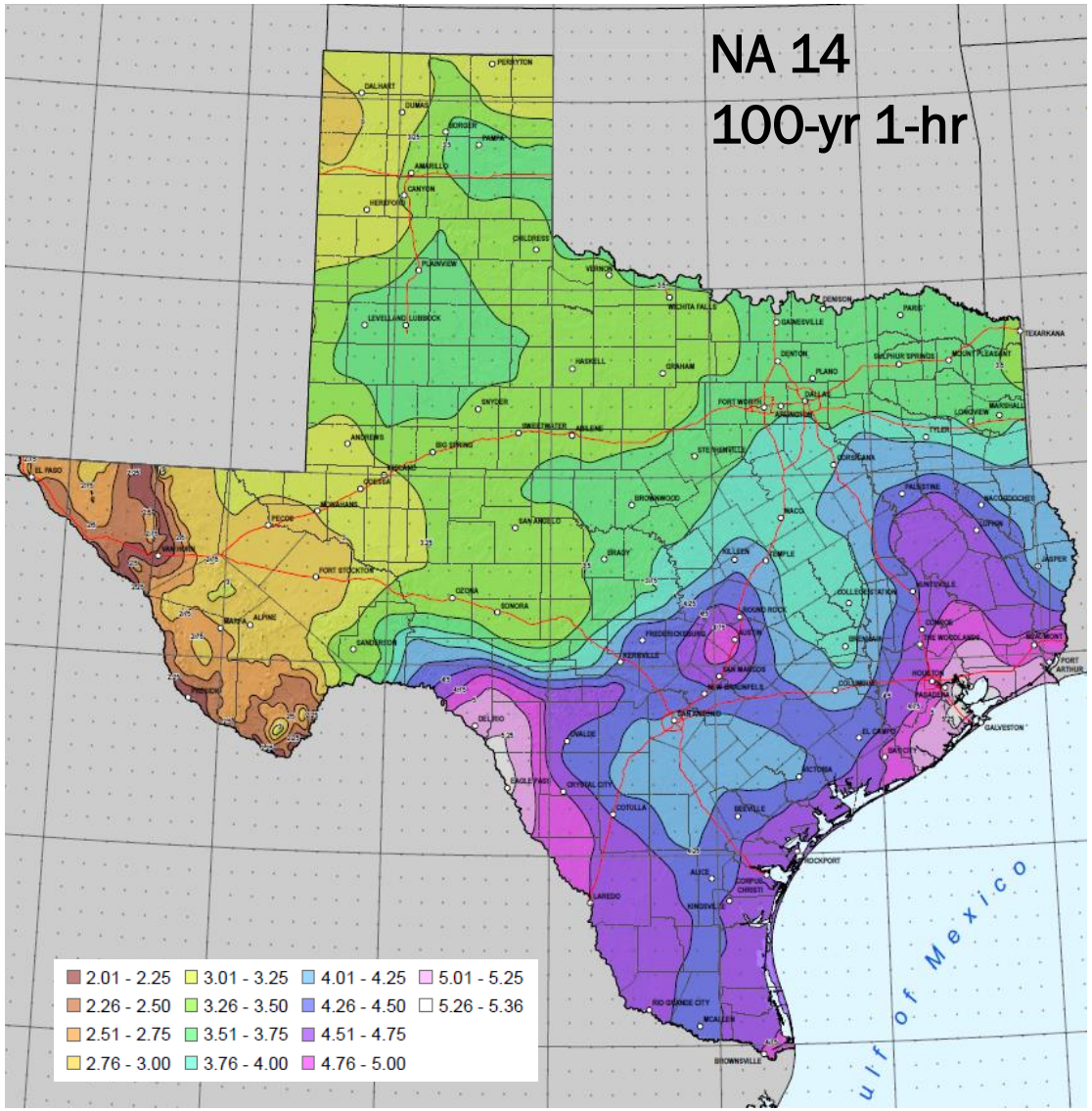
U.S.ARMY

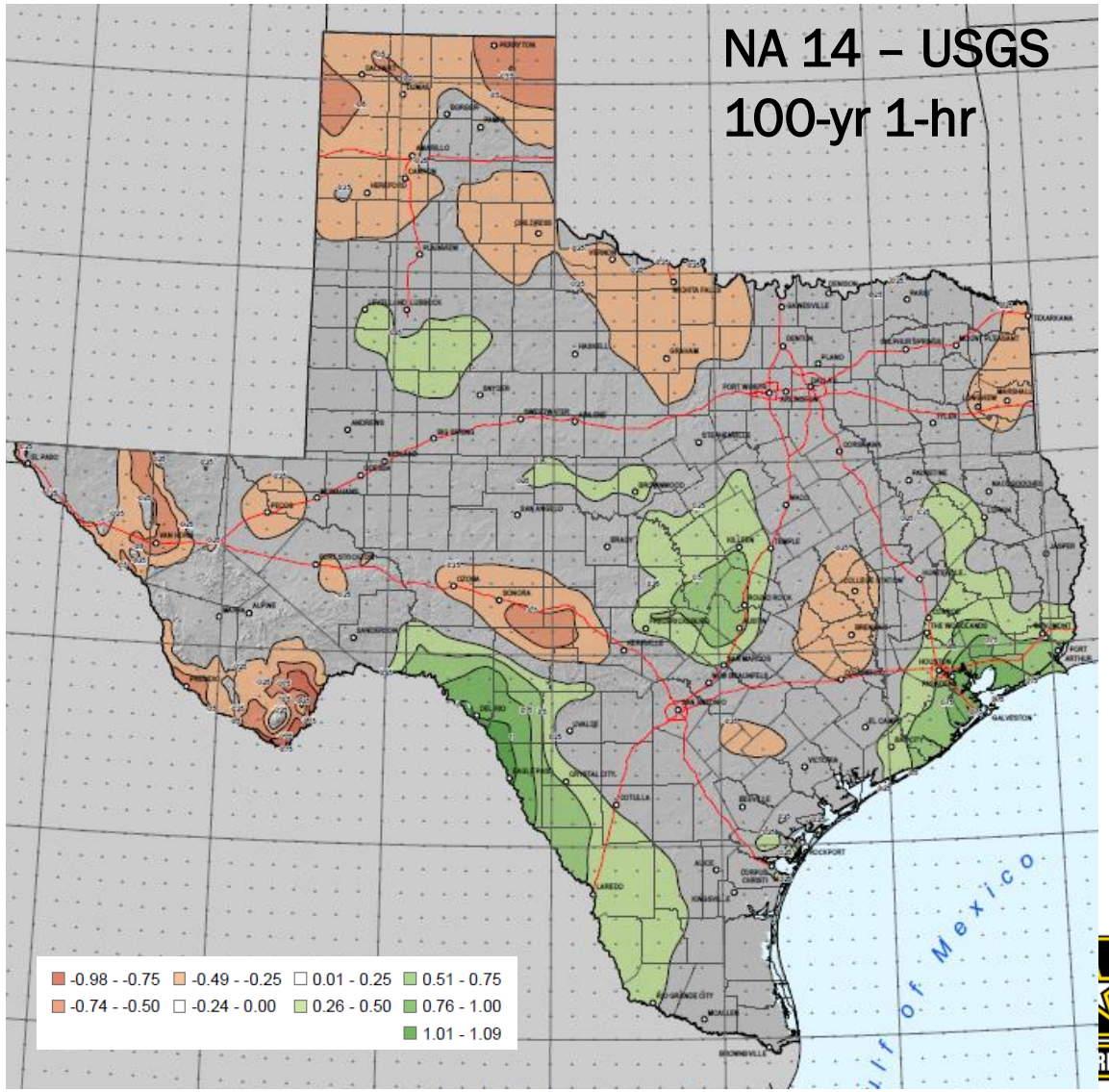
HOW DOES NOAA ATLAS COMPARE TO PREVIOUS STUDIES?





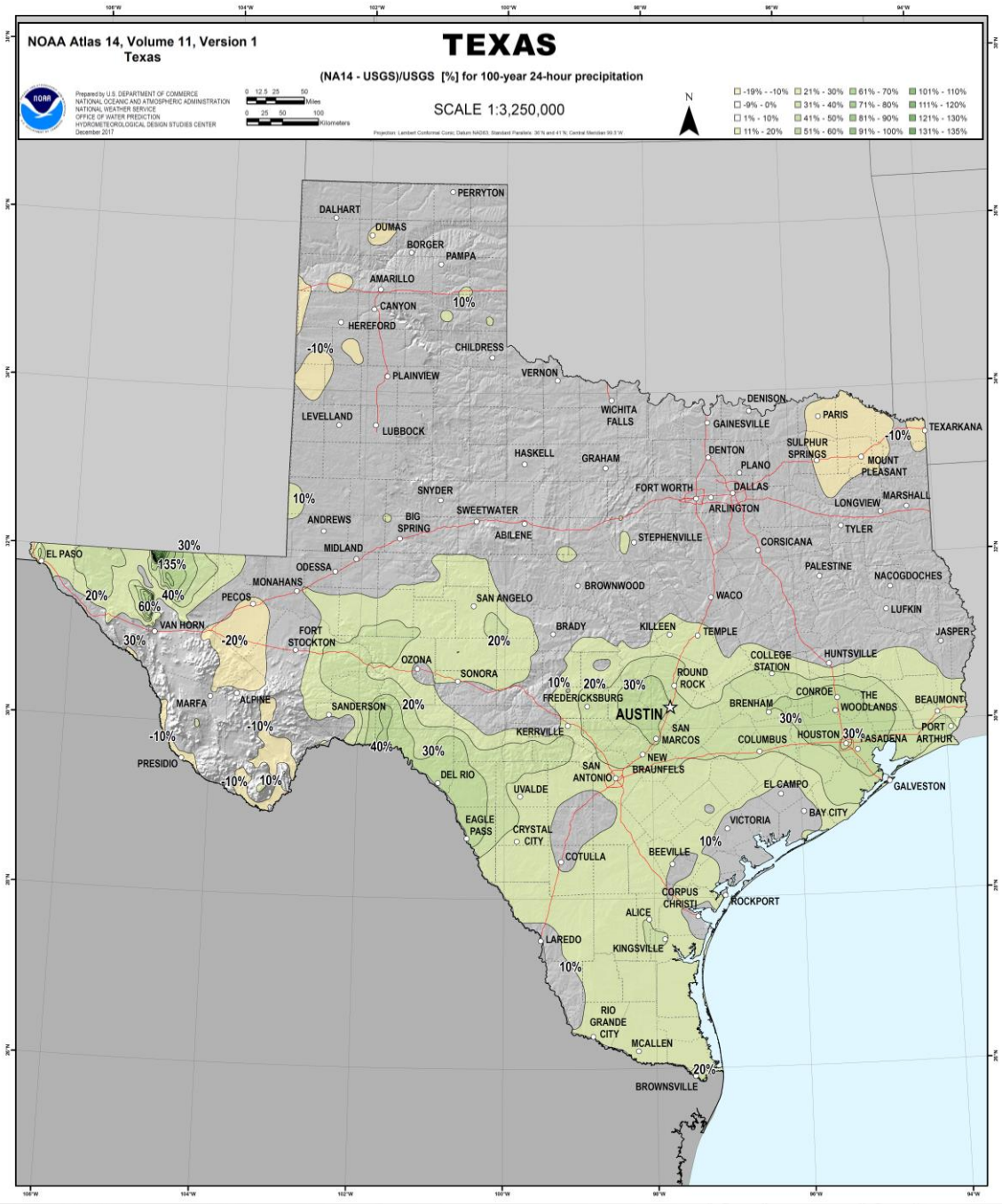
HOW DOES NOAA ATLAS COMPARE TO PREVIOUS STUDIES?





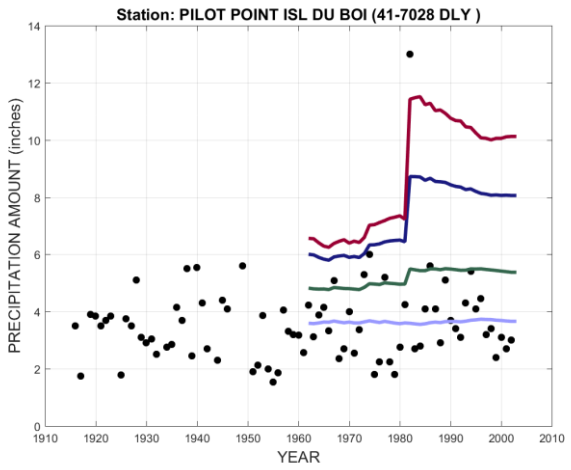
NOAA ATLAS 14 IMPACTS

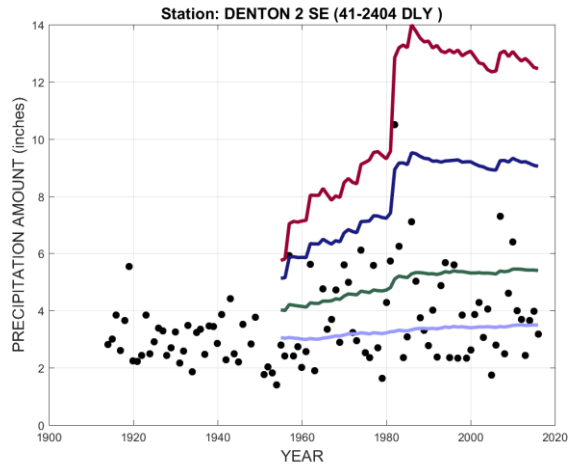
- Up to 30% increase for 100-year 24-hour precipitation
  - Houston and Austin Areas
  - Similar increase for other durations
- Up to 20% decrease for 100-year 24-hour precipitation
- Impacts
  - More accurate estimates spatially → better preparedness and response
  - New delineation of floodplain maps
    - Frequency of precipitation does not equate to frequency of flooding
  - Better planning/design of infrastructure
  - More resilient towards future storms

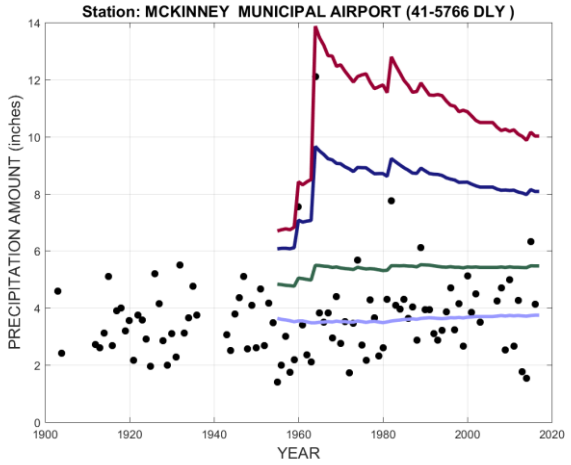


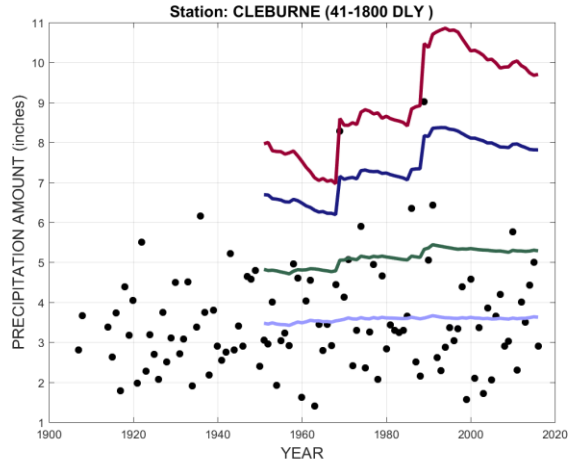
WE HAVE NOAA ATLAS 14, ARE WE DONE YET?

- Areas of concern
  - Short period of observations
  - Climate variability, extreme weather, drought and climate change
    - Evaluation of how non-stationarity may affect estimates
- Understanding what is happening with weather and climate change
- Point estimates – need updated Area Reduction Factors
- Identify geographic discontinuities
- Need for additional studies ($3 - $4 M)
  - Other methods to estimate precipitation frequency (check)
  - Trend analysis
  - Storm studies (design storms)
- Responsibility of Atlas 14
  - Who will update in 10-20 years?
  - How will it be funded?









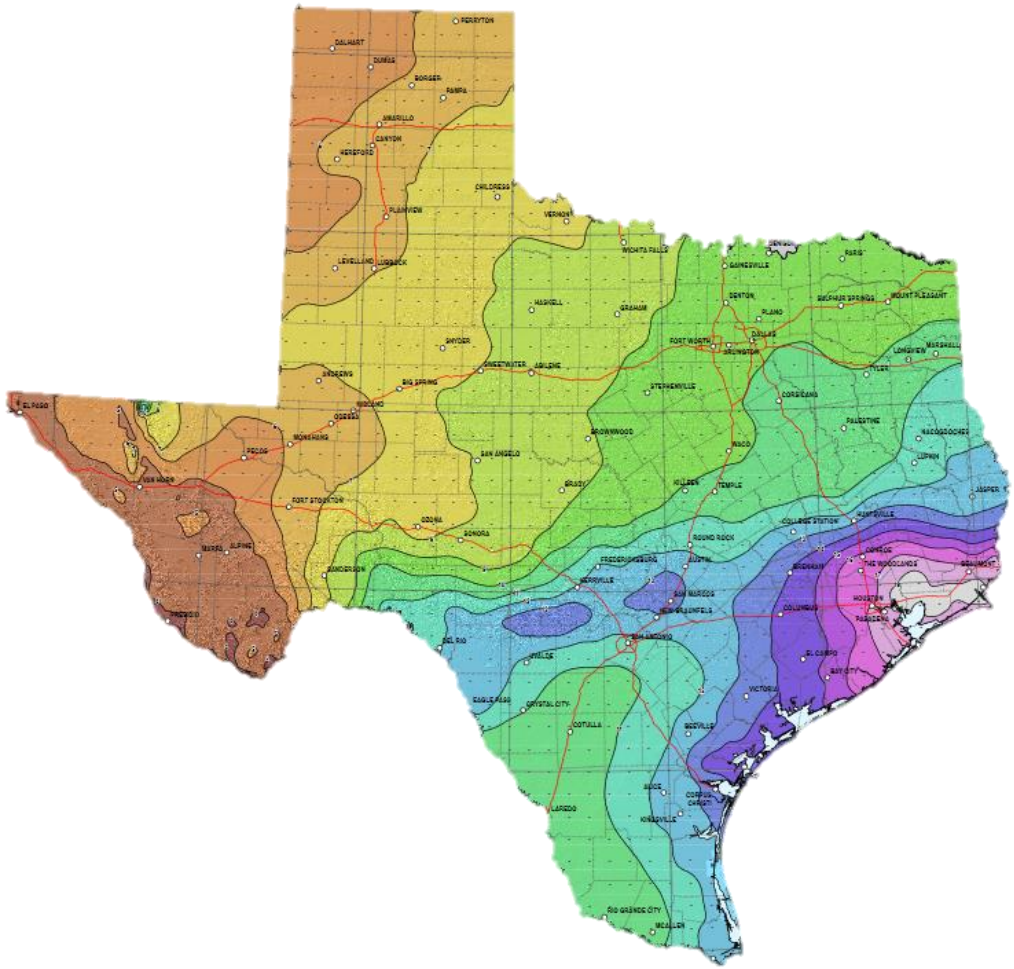
InFRM
INTERAGENCY FLOOD RISK MANAGEMENT

US Army Corps of Engineers ®

U.S.ARMY

NOAA ATLAS 14 – VOLUME 11

- Updated precipitation frequency estimates for Texas
  - Quantify the degree or risk of flooding at a location
  - Improved statistical techniques with longer record lengths – more reliable estimates
  - Easily accessible
- Non-Regulatory
  - No current requirement for communities or agencies to use Atlas 14
- Not done yet, still need more research
  - Area Reduction Factor
  - Non-stationarity of data
  - Climate change



US Army Corps of Engineers ®

U.S.ARMY

QUESTIONS?

Max Strickler

Maxwell.R.Strickler@usace.army.mil
817-886-1541

Mikaela Mahoney

Mikaela.Mahoney@usace.army.mil
817-886-1546

US Army Corps of Engineers ®

U.S.ARMY

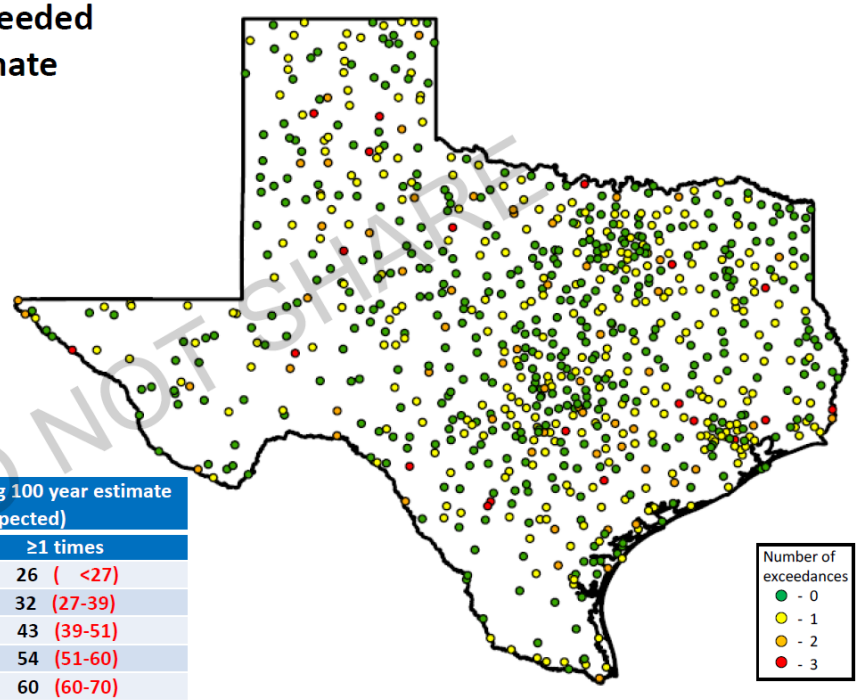
INFRM – NOAA ATLAS 14 PEER REVIEW BOARD

- Appropriateness of selected distribution
- How many data points equaled or exceeded estimate
- Variability of estimates over time

Number of times AM exceeded 24-hour 100-year estimate

Record length	# of stations	# of exceedances 0	1	2	3
≤ 30	129	96	30	2	1
31- 50	296	202	78	12	4
51 - 70	356	204	125	25	2
71 - 90	224	104	97	18	5
> 90	223	89	89	32	13

Record length	# of stations	% of stations exceeding 100 year estimate actual (expected) 0 times	≥1 times
≤ 30	129	74 (>73)	26 (<27)
31- 50	296	68 (61-73)	32 (27-39)
51 - 70	356	57 (49-61)	43 (39-51)
71 - 90	224	46 (40-49)	54 (51-60)
> 90	223	40 (30-40)	60 (60-70)



US Army Corps of Engineers ®

U.S.ARMY