New NOAA Precipitation-Frequency Atlas for Wisconsin

Presentation to the Milwaukee Metropolitan Sewerage District

Technical Advisory Team

January 16, 2014

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New NOAA Precipitation-Frequency Atlas for Wisconsin

NRCS Natural Resources Conservation Service

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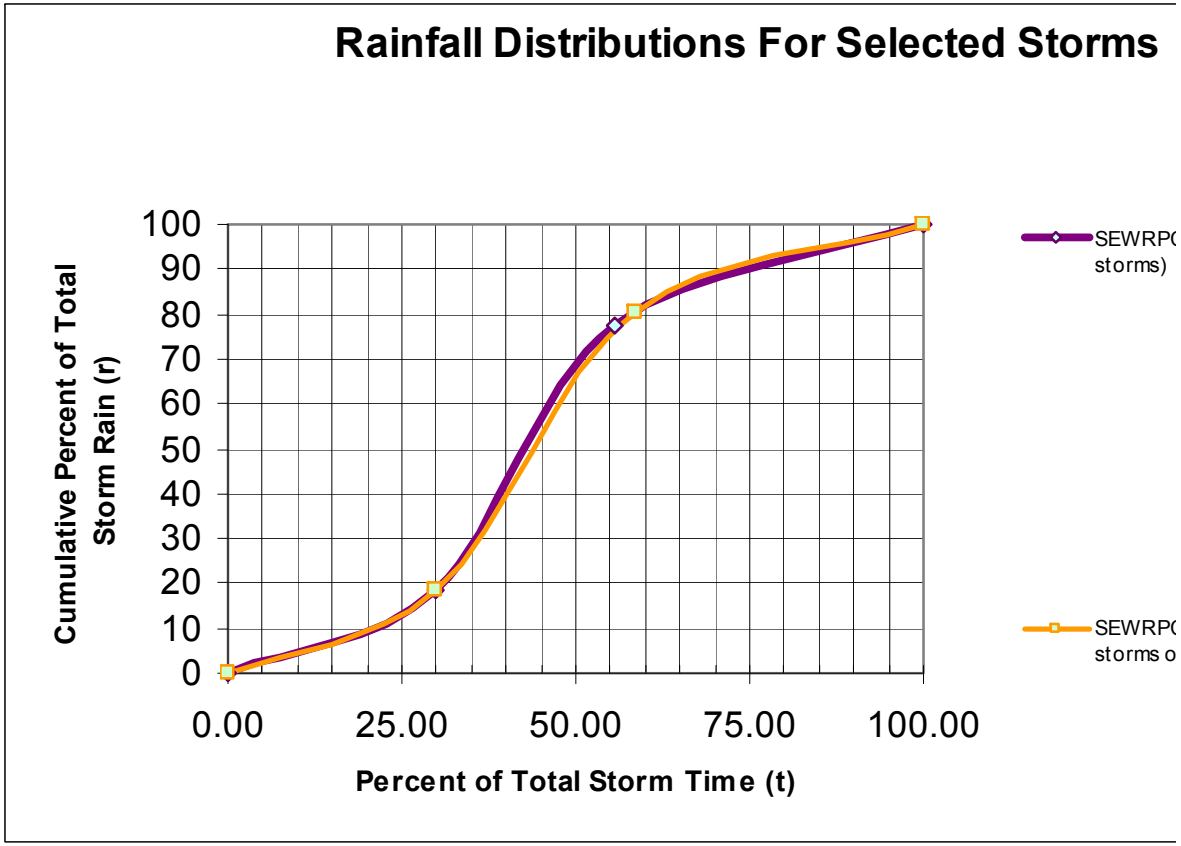
Overview

- Review past precipitation frequency studies
- Introduce NOAA Atlas 14, *Precipitation-Frequency Atlas of the United States*, Volume 8, Version 2.0: Midwestern States
  - Precipitation frequency information
  - Temporal storm distributions
- Compare precipitation frequency and temporal distribution information from various commonly-used sources with Atlas 14
- Proposed USDA Natural Resources Conservation Service approach to applying Atlas 14
- Status regarding use of Atlas 14 for regulatory projects in Wisconsin
- Interactive, online demonstration of Atlas 14

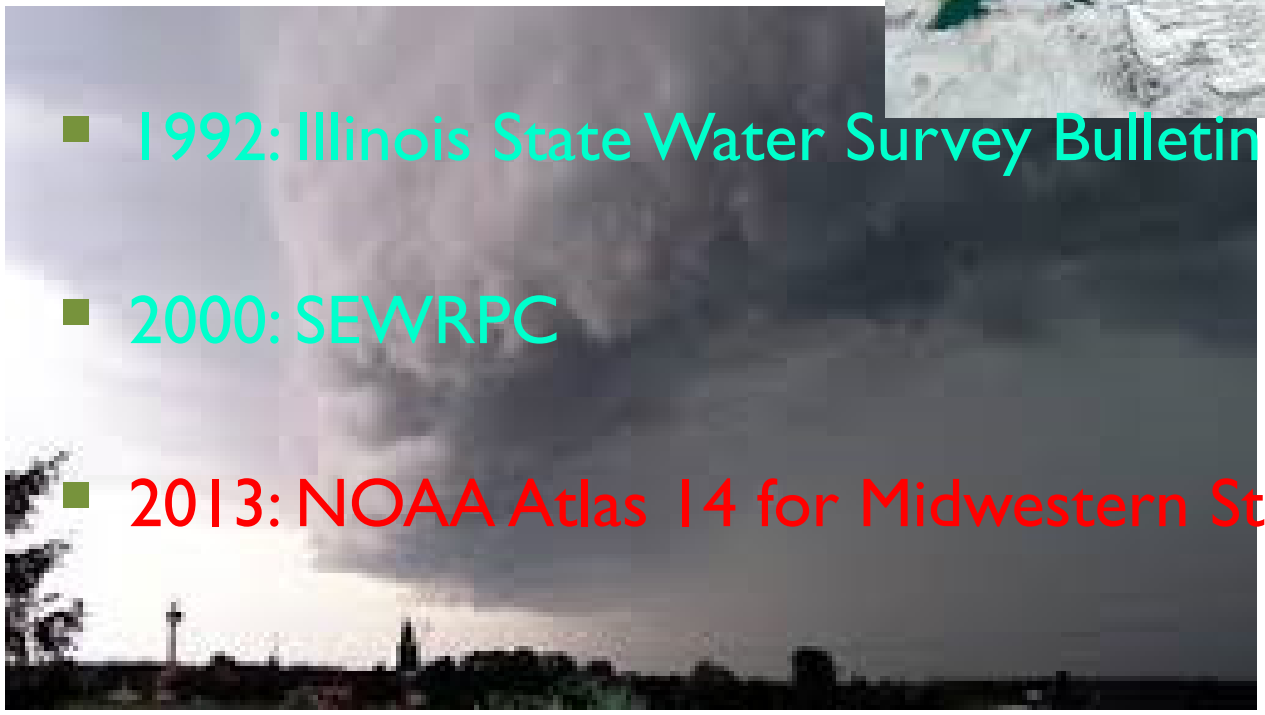
What Is a Design Storm ?

- Design storm is a hypothetical distribution of rainfall over time
- Individual design storms are developed for a given rainfall frequency and duration
  - Storm depth for a given frequency and duration is distributed over time
- Design storm is applied in a hydrologic model to estimate rates and volumes of runoff
  - Generally analyze storms of several durations for a given frequency
  - Results in "critical" (maximum) flow
- Hydrologic model results are used to size stormwater and floodland management facilities and for determining flood hazard areas



Sources of Design Rainfall Estimates

- 1961: U.S. Weather Bureau TP-40
- 1990: SEWRPC
- 1992: Illinois State Water Survey Bulletin 71
- 2000: SEWRPC
- 2013: NOAA Atlas 14 for Midwestern States



Sources of Design Rainfall Estimates

- U.S. Weather Bureau Technical Paper No. 40 (TP-40), *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*
  - Published in 1961 by U.S. Weather Bureau for the continental US
  - In Wisconsin, these rainfall depths were often applied with the SCS Type II time distribution

Sources of Design Rainfall Estimates

- Illinois State Water Survey Bulletin 71, *Rainfall Frequency Atlas of the Midwest*
  - Published in 1992
  - Developed for Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin
  - These rainfall depths are applied with a Huff time distribution

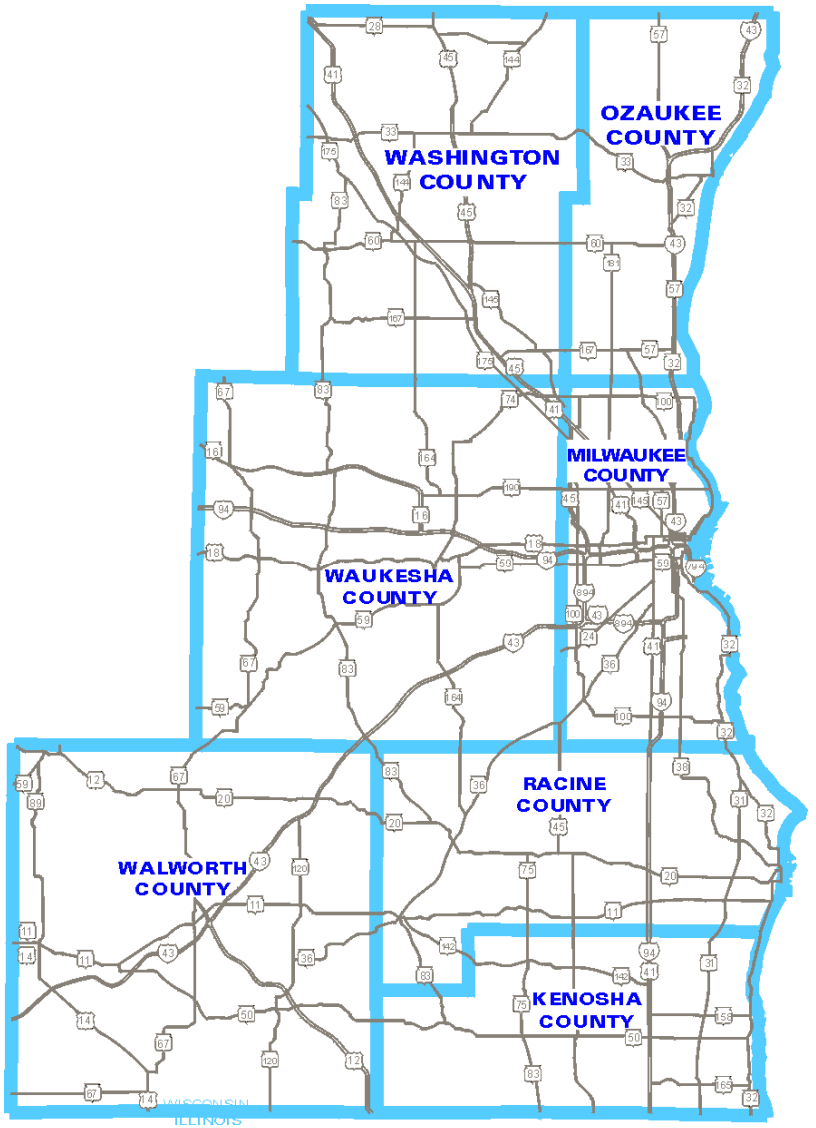
ILLINOIS STATE WATER SURVEY
PRAIRIE RESEARCH INSTITUTE

Sources of Design Rainfall Estimates

- SEWRPC 1990
  - Originally developed in 1969
  - Updated in 1990 (Data from 1903-1986)
  - Developed for Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties
  - Design storms were developed with either the SCS Type II or Huff distributions

Sources of Design Rainfall Estimates

- SEWRPC 2000
  - Developed for seven-county Southeastern Wisconsin Region using data from 1891-1998
  - Rainfall depths are applied with a new time distribution for the Region
- SEWRPC Technical Report No. 40, *Rainfall Frequency in Southeastern Wisconsin*, 2000
  - Camp, Dresser & McKee Engineers
  - University of Wisconsin-Madison
  - SEWRPC staff
- Developed rainfall depths for recurrence intervals of 2, 5, 10, 25, 50, and 100 years
- Durations of 5 minutes through 10 days



Sources of Design Rainfall Estimates

- NOAA Atlas 14, *Precipitation-Frequency Atlas of the United States*, Volume 8, Version 2.0: Midwestern States
  - NWS is currently revising throughout the country, applying a region-by-region approach
  - WDNR, WisDOT, and SEWRPC jointly funded the Wisconsin portion of the project
  - Completed in 2013

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE

NOAA Atlas 14

- 2013 NOAA Atlas 14 supersedes:
  - 1961 U.S. Weather Bureau TP No. 40, 30 minutes to 24 hour durations and RI from 1 to 100 years
  - 1964 U.S. W.B. TP No. 49, Two- to 10-day durations and RI from 2 to 100 years
  - 1977 National Weather Service Hydro 35, five- to 60-minute durations

NOAA Atlas 14 Midwestern States

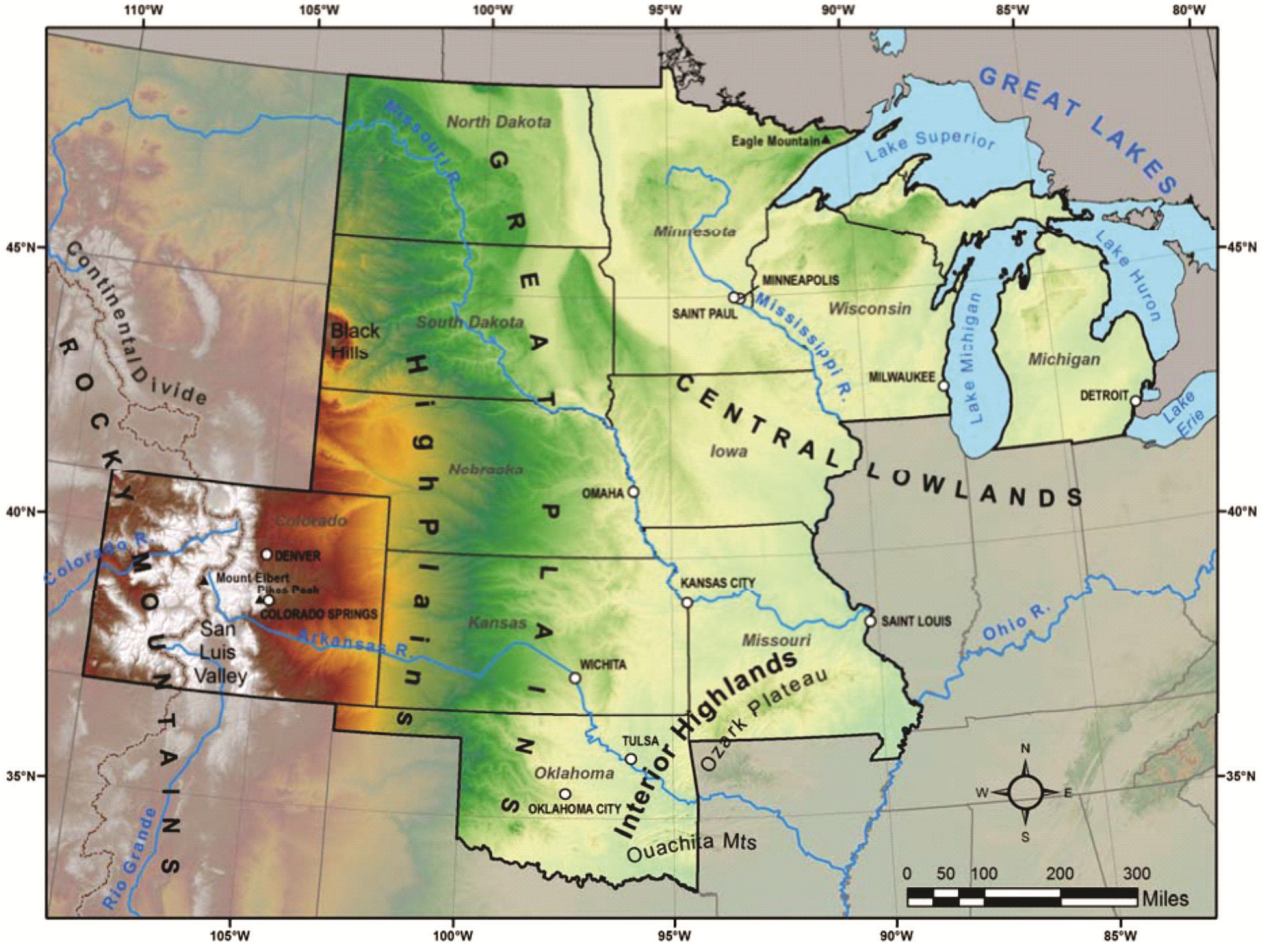


Figure 4.1.1. Project area for NOAA Atlas 14 Volume 8.
(The shaded relief was obtained from USGS EROS Data Center.)

NOAA Atlas 14

- Analyzed data from 16,227 U.S. Federal, Environment Canada, state, and local stations
  - One-day: 11,918
  - One-hour: 2,657
  - 15-minutes, or variable: 1,652
  - In general, only stations with >= 30 years of data were considered, but for hourly stations >= 20 years

NOAA Atlas 14

- Low outliers were typically removed
- High outliers: Compared with nearby concurrent depths, and also reviewed observation forms, monthly reports, and historical publications

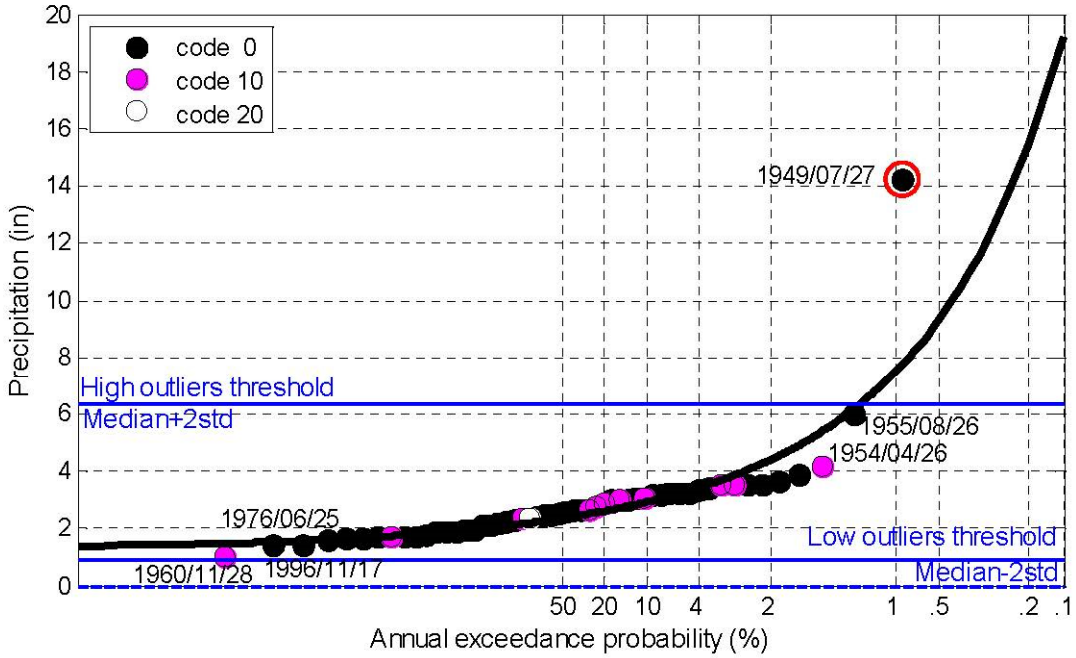


Figure 4.5.1. Outlier tests for 24-hour AMS at station 21-0826. Data quality codes were assigned to annual maxima during the extraction process (Section 4.3).

NOAA Atlas 14

- Parametric and non-parametric statistical tests were made on annual mean series to evaluate climate stationarity (Appendix 2)
- Conclusion: Accepted assumption of stationarity

NOAA Atlas 14

- Precipitation frequency relationships developed using annual maximum series
- Smoothed precipitation-frequency across durations
- Converted annual maximum series to partial duration series

NOAA Atlas 14

- Generalized extreme value (GEV) distribution adopted for all stations and durations

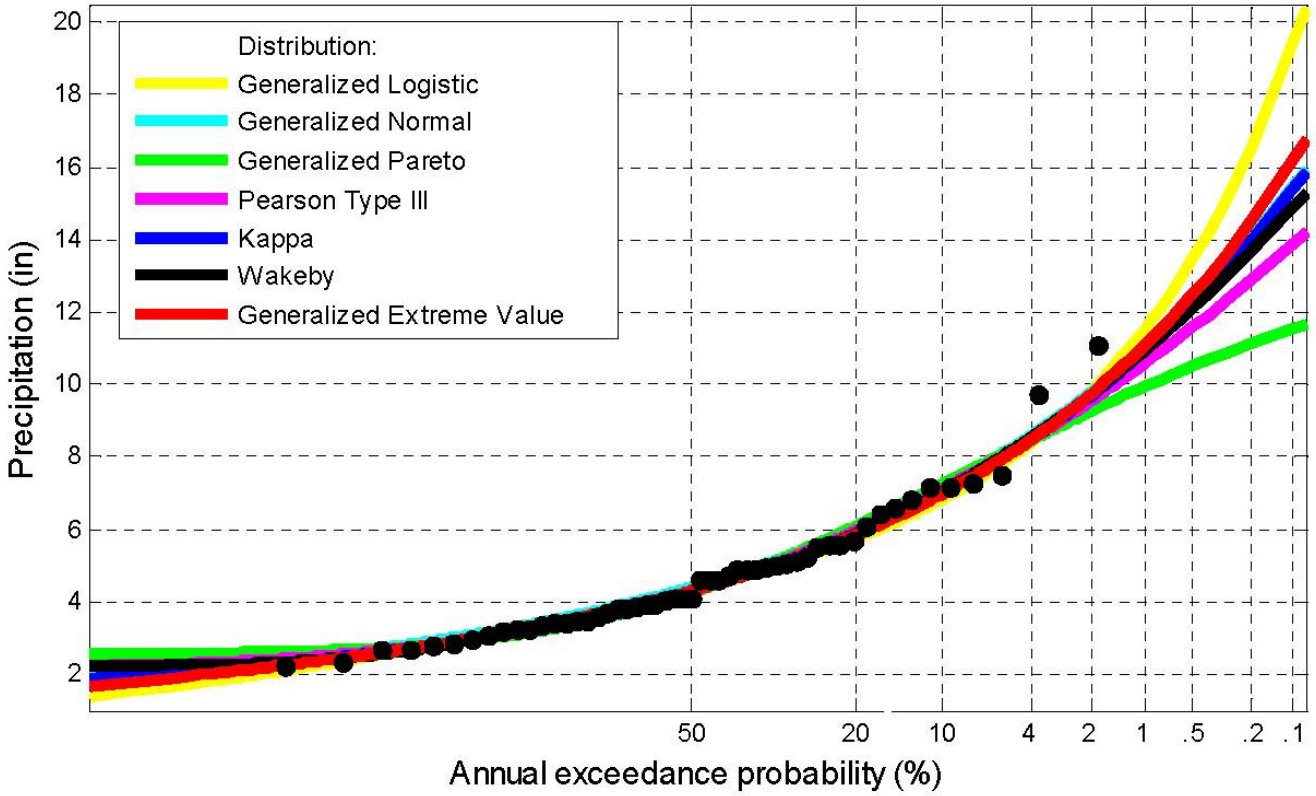


Figure 4.6.3. Probability plots for selected distributions for 1-day AMS at station Nowata (34-6485) in Oklahoma.

NOAA Atlas 14: Gridded Precipitation-Frequency

- Developed gridded precipitation-frequency estimates at 30 arc-seconds resolution
- Station mean annual maximum (MAM) precipitation for 17 durations from 15 minutes through 60 days was interpolated to produce grid

NOAA Atlas 14: Gridded Precipitation-Frequency

- Strong linear relationships between:
  - MAM and two-year precip and
  - Precip-freq relationships for consecutive frequencies

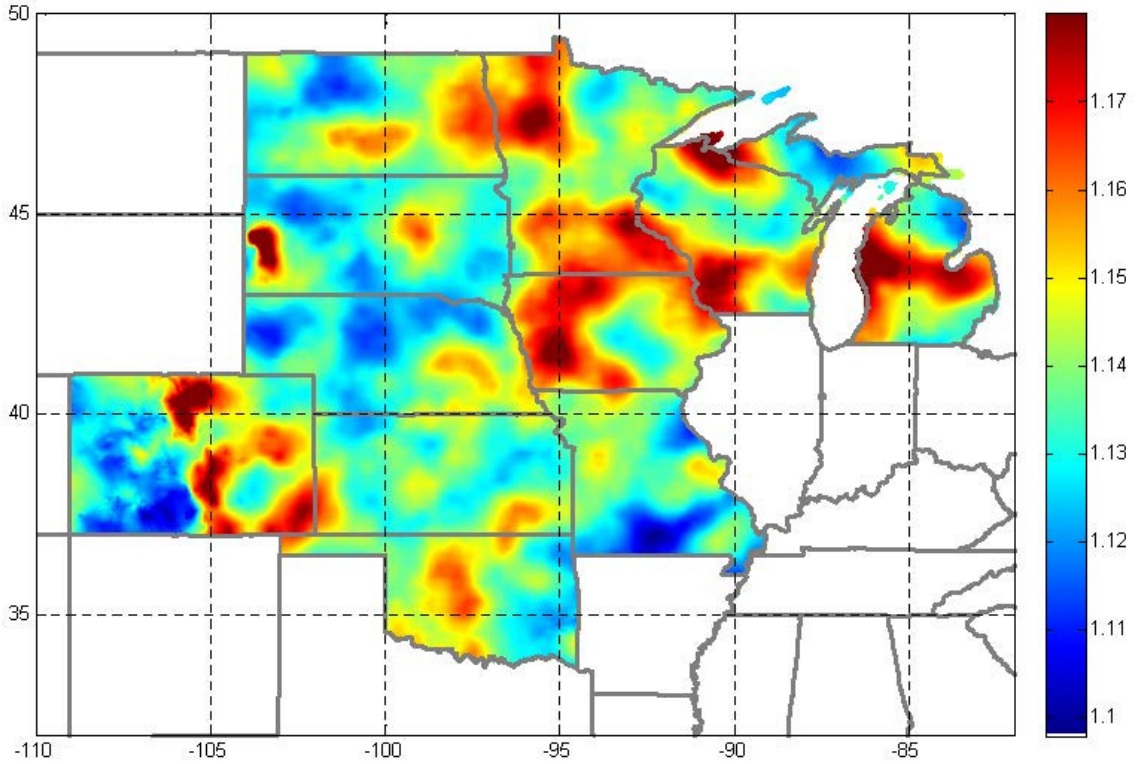
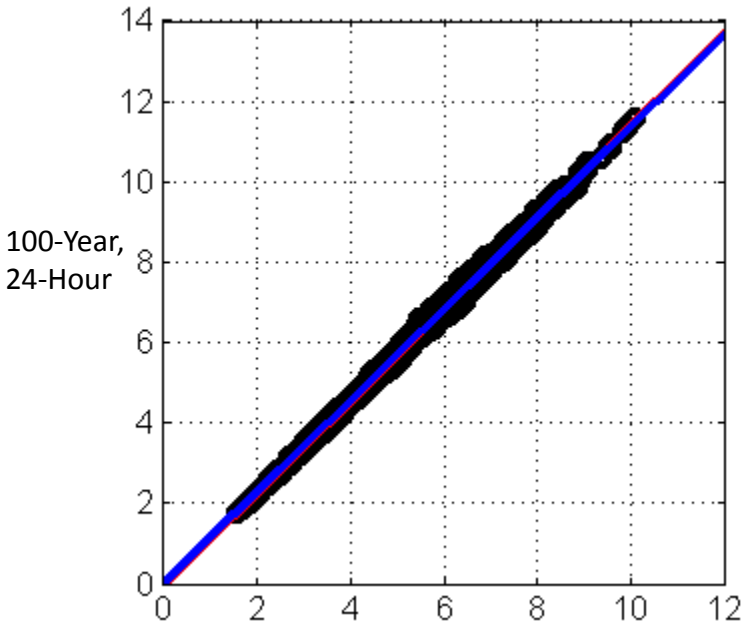
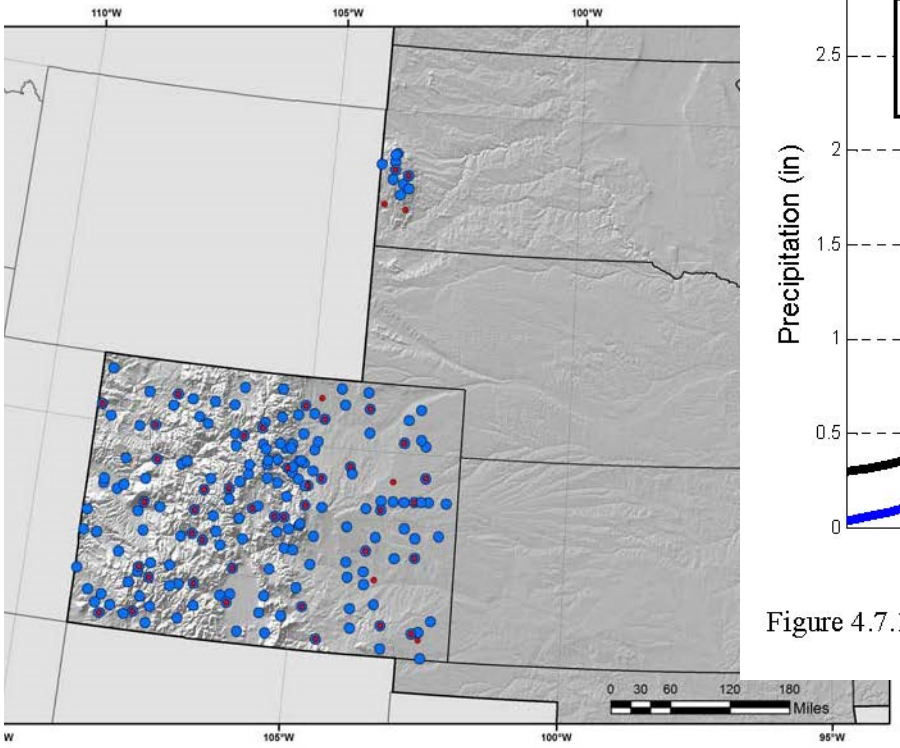


Figure 4.8.2. Spatially interpolated ratios used to calculate 24-hour 100-year precipitation frequency grid from the 24-hour 50-year grid.



NOAA Atlas 14: Rain vs. Total Precipitation

- Precipitation-frequency relationships were developed using both liquid and frozen precipitation (liquid equivalent)
- Trivial difference between using rain and using total precipitation except at high altitudes in Colorado and South Dakota



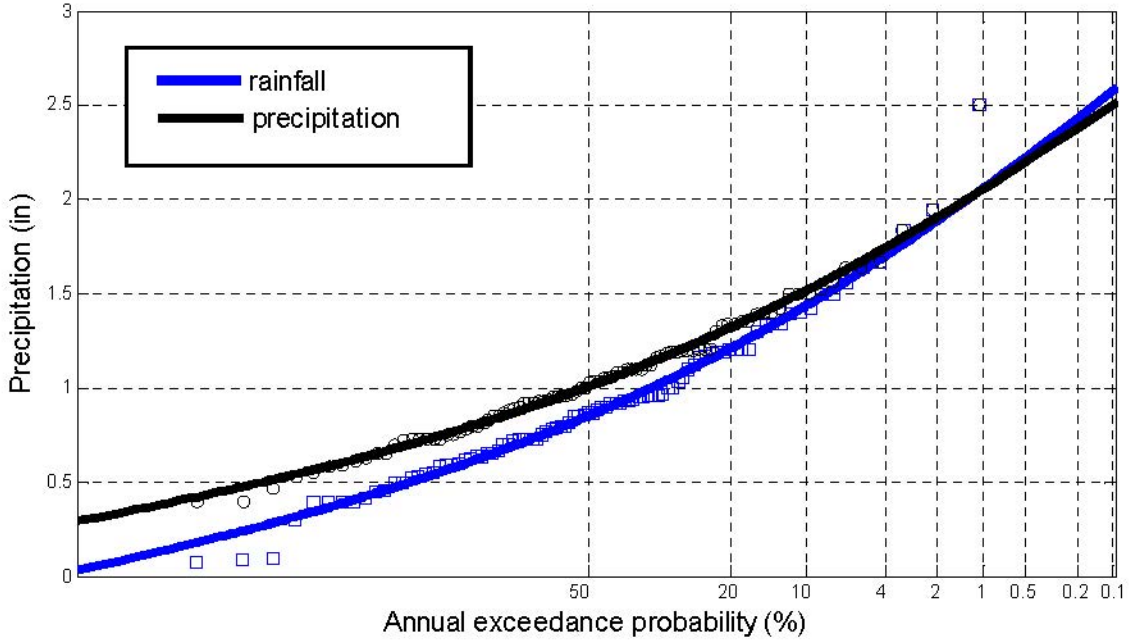
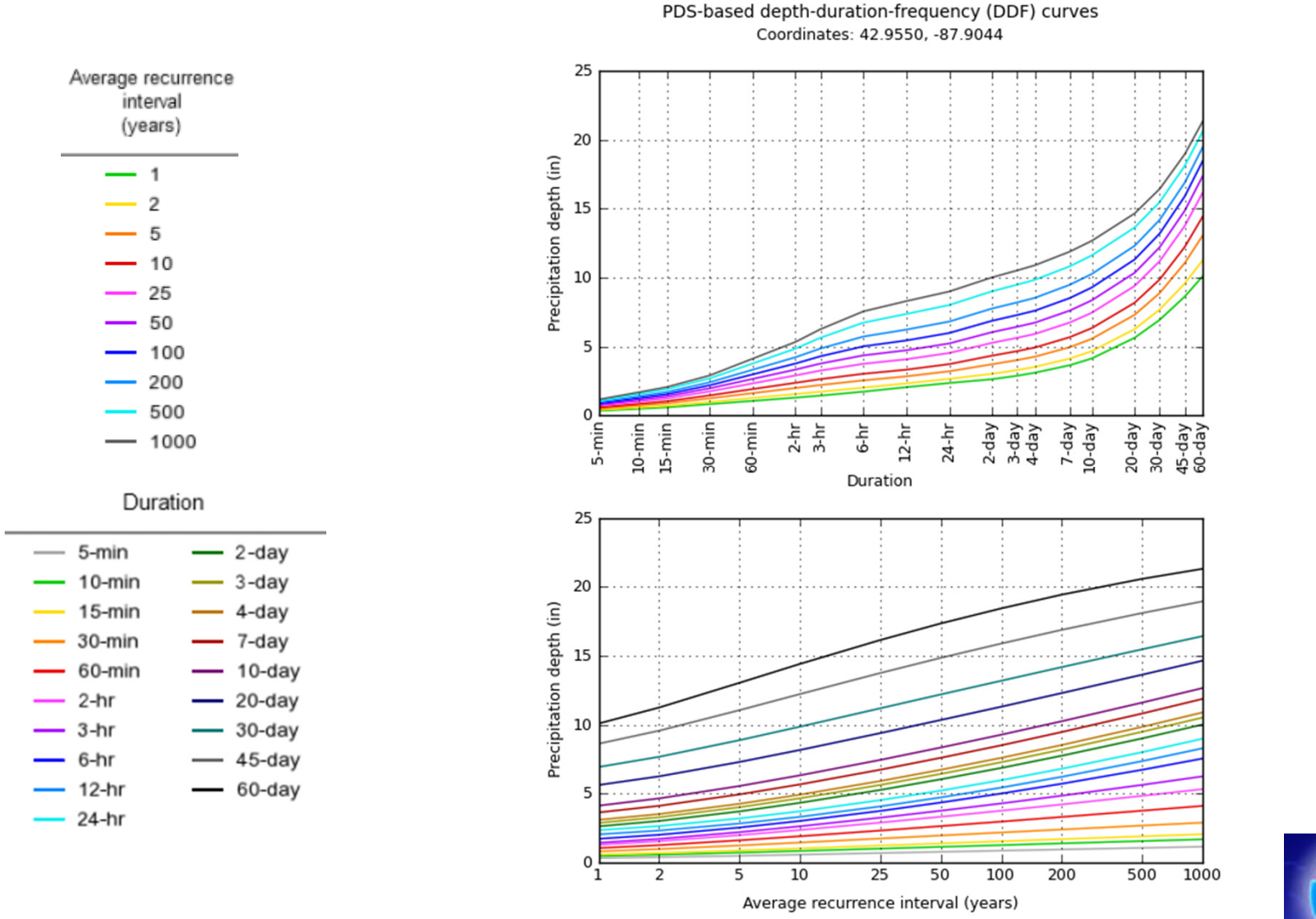
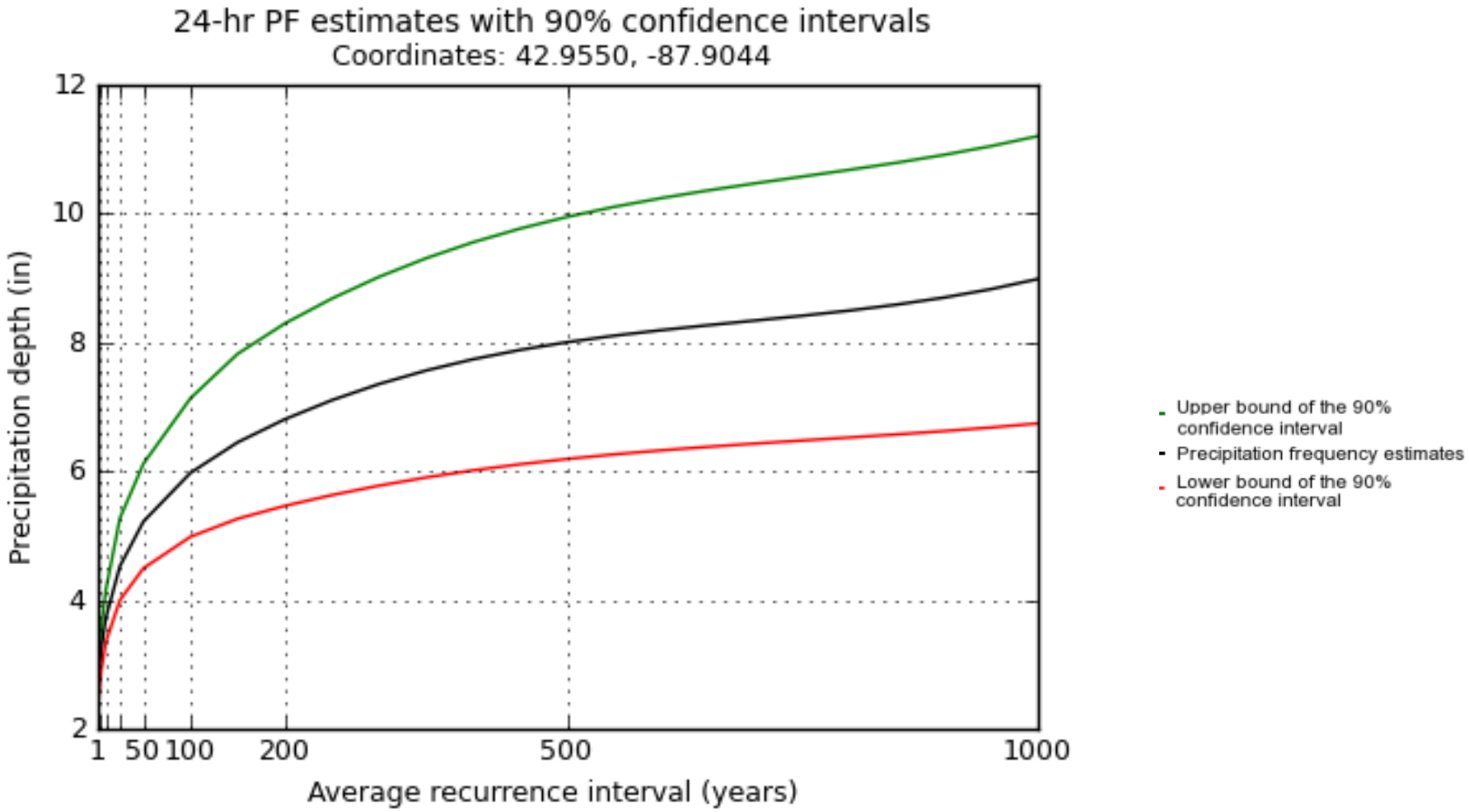


Figure 4.7.1. Probability distributions for the 24-hour rainfall and precipitation annual maximum series at station 05-1071 (elevation 7,946 ft).

Depth-duration frequency curves: Milwaukee, WI



90 % Confidence Intervals: Milwaukee, WI



NOAA/NWS/OHD/HDSC

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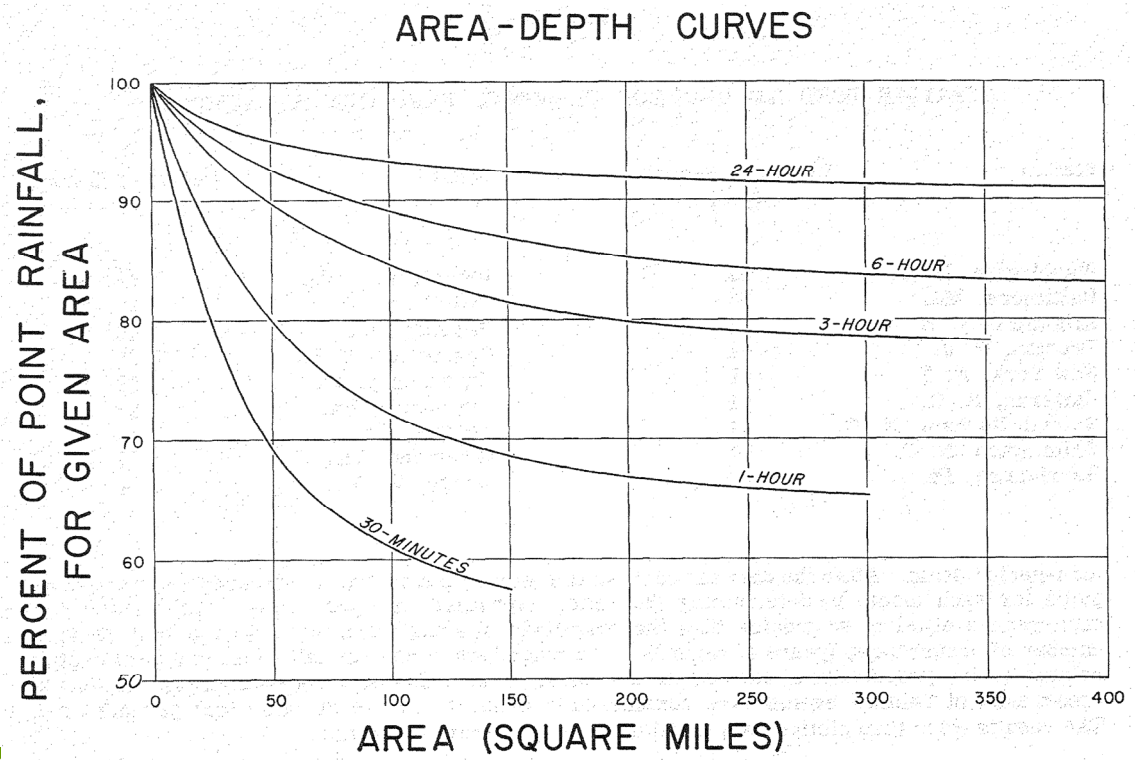
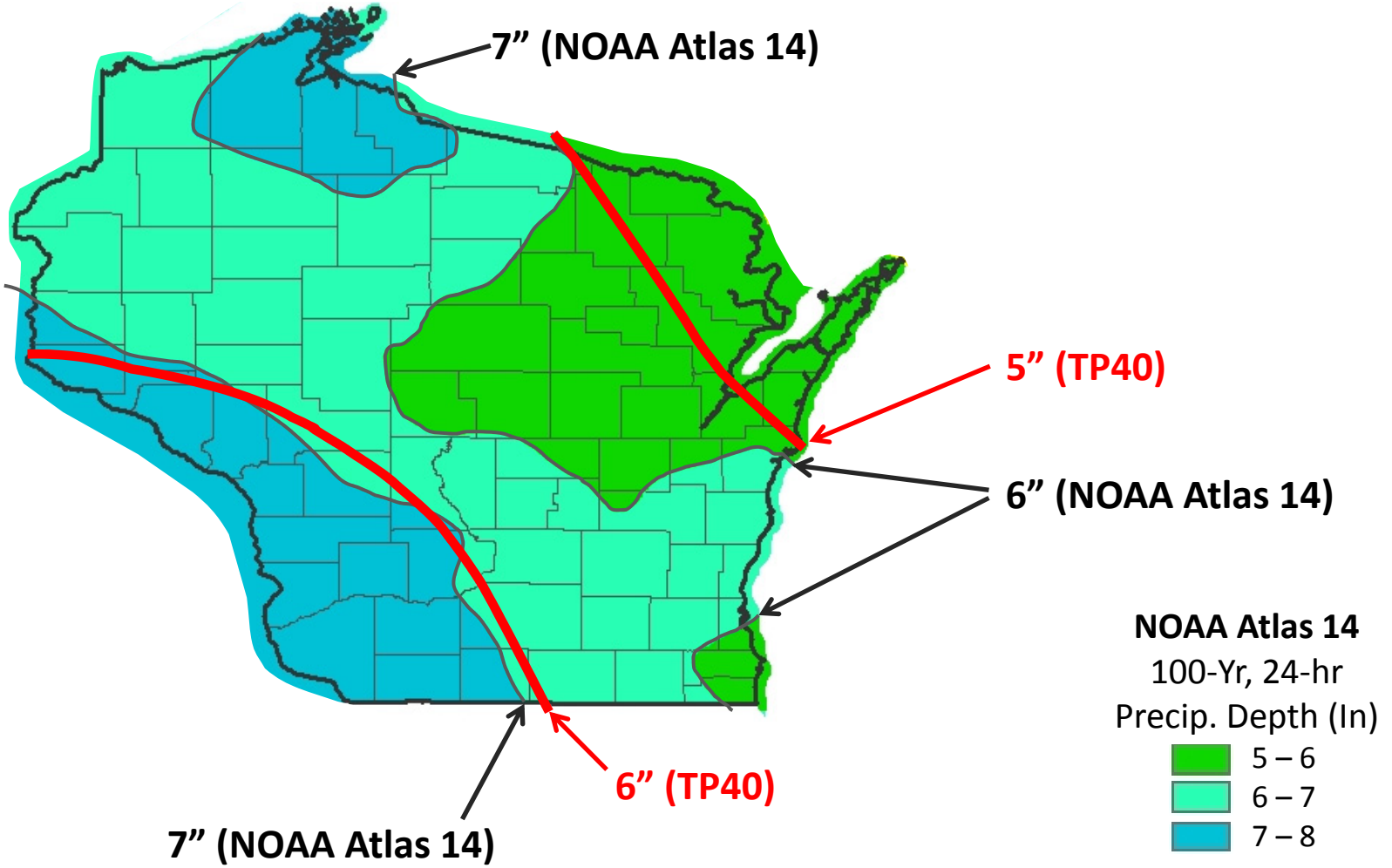
NOAA Atlas 14: Areal Reduction Factors (ARF)

- Point precipitation-frequency estimates
  - Areal reduction factors: Atlas 14 recommends using 1960 U.S. Weather Bureau TP 29
  - NOAA is working on development of new areal reduction factors
  - Possible approach: Use gridded precipitation to average over subwatershed, then apply ARF for entire watershed area studied



NOAA Atlas 14 Versus TP 40 Data

100-Yr, 24-Hr Precipitation Depths

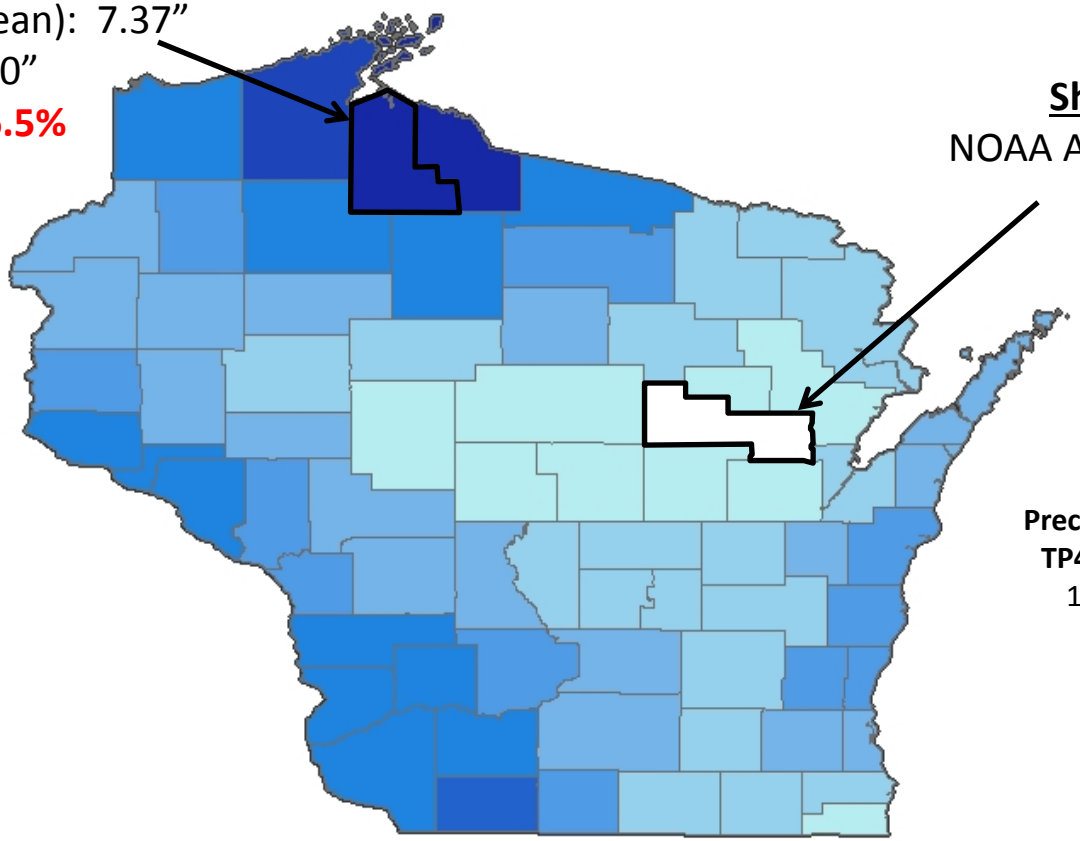


NOAA Atlas 14 Versus TP40 Precipitation Depths

100-Yr, 24-Hr Precipitation Depths
Percent Change From TP40 to NOAA Atlas 14 (Mean)

Ashland County:
NOAA Atlas 14 (Mean): 7.37”
TP40: 5.40”
Increase 36.5%

Shawano County:
NOAA Atlas 14 (Mean): 5.40”
TP40: 5.40”
No Change



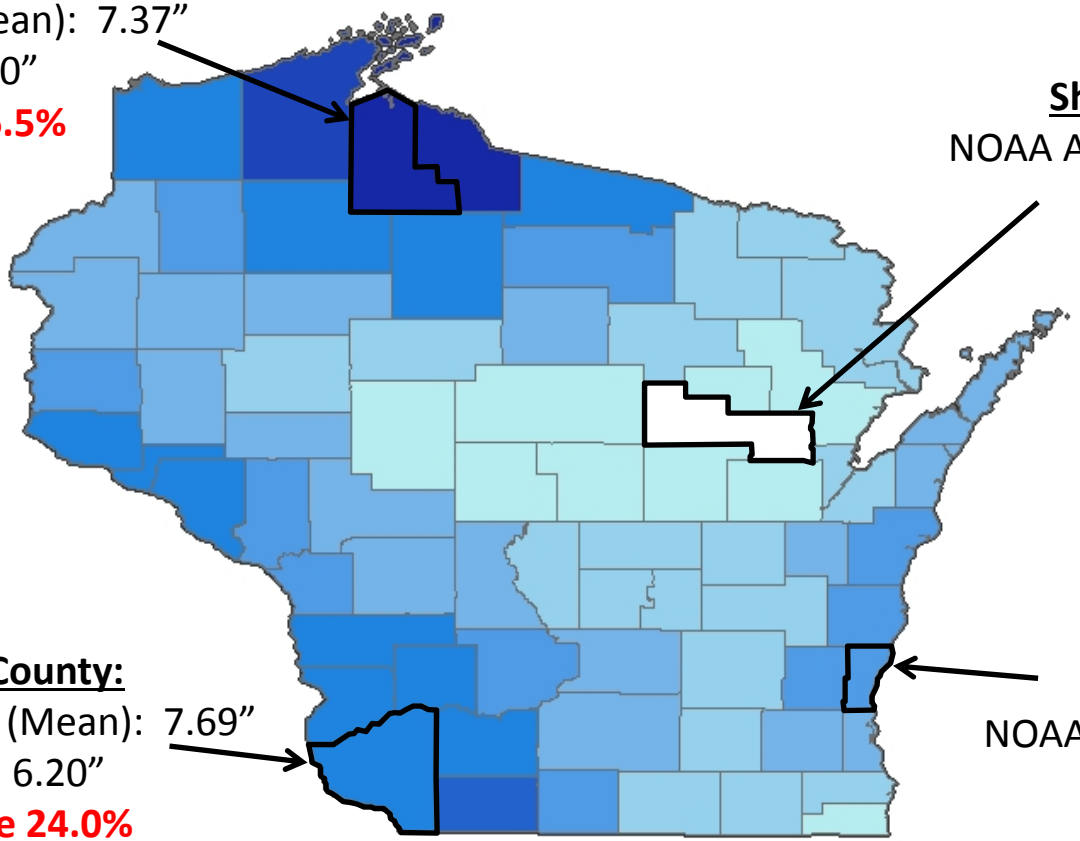
Precipitation Depth Change From TP40 to NOAA Atlas 14 (Mean)
100-Year, 24-hour (Percent)

- 0
- 0.01 - 5
- 5 – 10
- 10 – 15
- 15 – 20
- 20 – 25
- 25 – 30
- 30 – 35
- 35 – 40

NOAA Atlas 14 Versus TP40 Precipitation Depths

100-Yr, 24-Hr Precipitation Depths
Percent Change From TP40 to NOAA Atlas 14 (Mean)

Ashland County:
NOAA Atlas 14 (Mean): 7.37”
TP40: 5.40”
Increase 36.5%



Shawano County:
NOAA Atlas 14 (Mean): 5.40”
TP40: 5.40”
No Change

Grant County:
NOAA Atlas 14 (Mean): 7.69”
TP40: 6.20”
Increase 24.0%

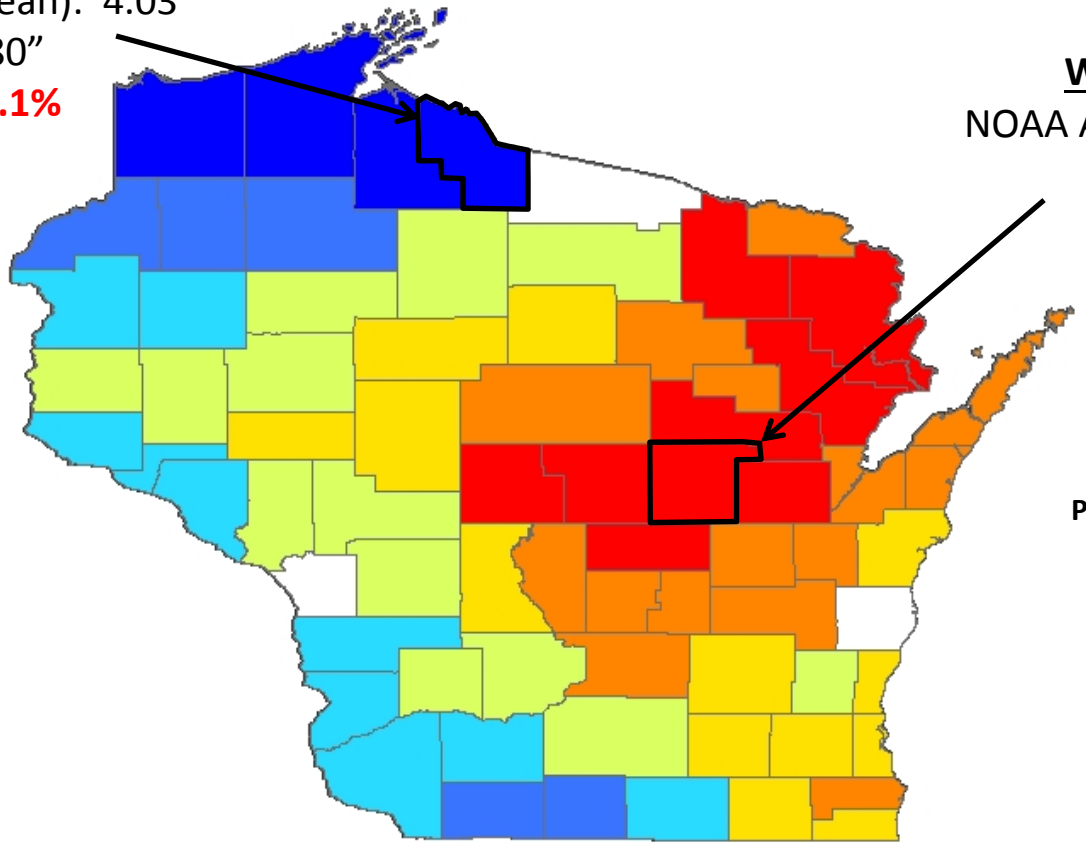
Ozaukee County:
NOAA Atlas 14 (Mean): 6.38”
TP40: 5.40”
Increase 18.1%

NOAA Atlas 14 Versus TP40 Precipitation Depths

10-Yr, 24-Hr Precipitation Depths
Percent Change From TP40 to NOAA Atlas 14 (Mean)

Iron County:
NOAA Atlas 14 (Mean): 4.03”
TP40: 3.80”
Increase 6.1%

Waupaca County:
NOAA Atlas 14 (Mean): 3.57”
TP40: 3.90”
Decrease 8.5%



Precipitation Depth Change From TP40 to NOAA Atlas 14 (Mean)
10-Year, 24-hour (Percent)

- -8.5 to -7.5
- -7.5 to -5.0
- -5.0 to -2.5
- -2.5 to -0.01
- 0.0
- 0.01 to 2.5
- 2.5 to 5.0
- 5.0 to 7.5

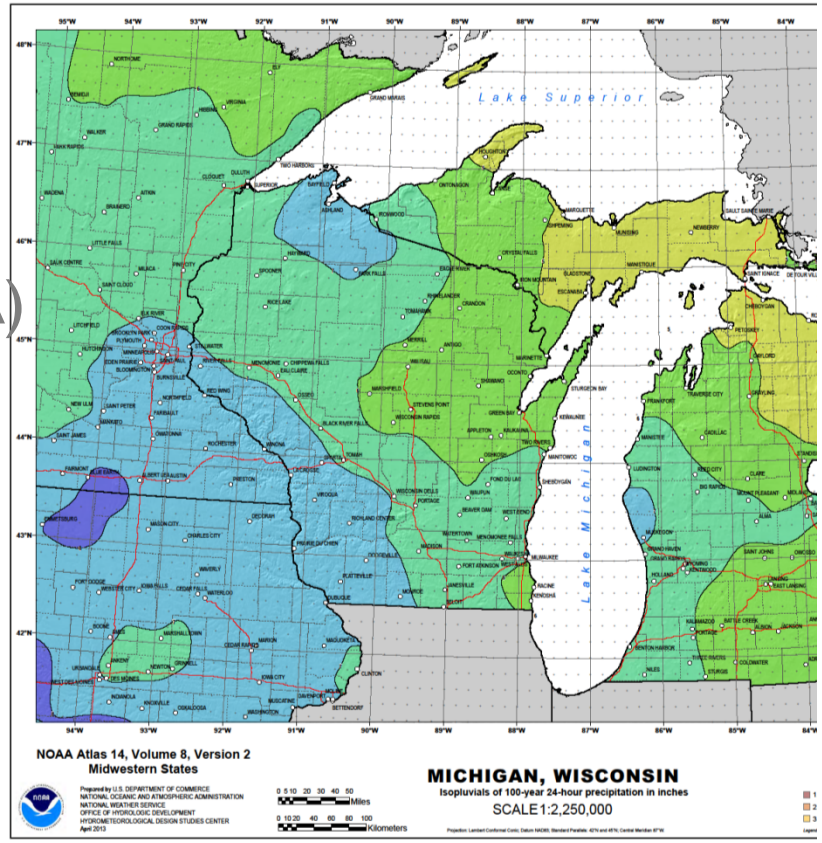
Rainfall Depths for MMSD Planning Area

- Comparison of 100-year, 24-hour rain depths:
  - Weather Bureau TP-40: 5.44 inches
  - ISWS Bulletin 71: 6.24 inches
  - SEWRPC 1990: 5.50 inches
  - SEWRPC 2000: 5.88 inches
  - NOAA Atlas 14: 5.98 inches (GMIA)

5 to 6 inches

6 to 7 inches

7 to 8 inches



Rainfall Depths for MMSD Planning Area

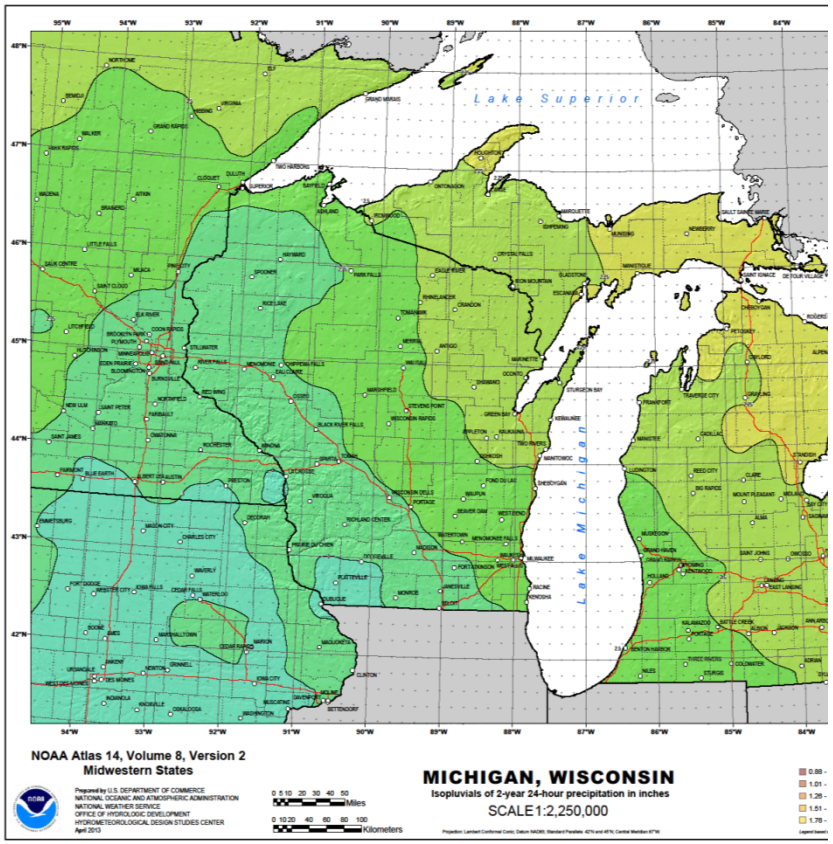
- Comparison of two-year, 24-hour rain depths:
  - Weather Bureau TP-40: 2.6 inches
  - ISWS Bulletin 71: 2.70 inches
  - SEWRPC 1990: 2.4 inches
  - SEWRPC 2000: 2.57 inches
  - NOAA Atlas 14: 2.65 inches

2.26 to 2.50 inches

2.51 to 2.75 inches

2.76 to 3.00 inches

3.01 to 3.25 inches



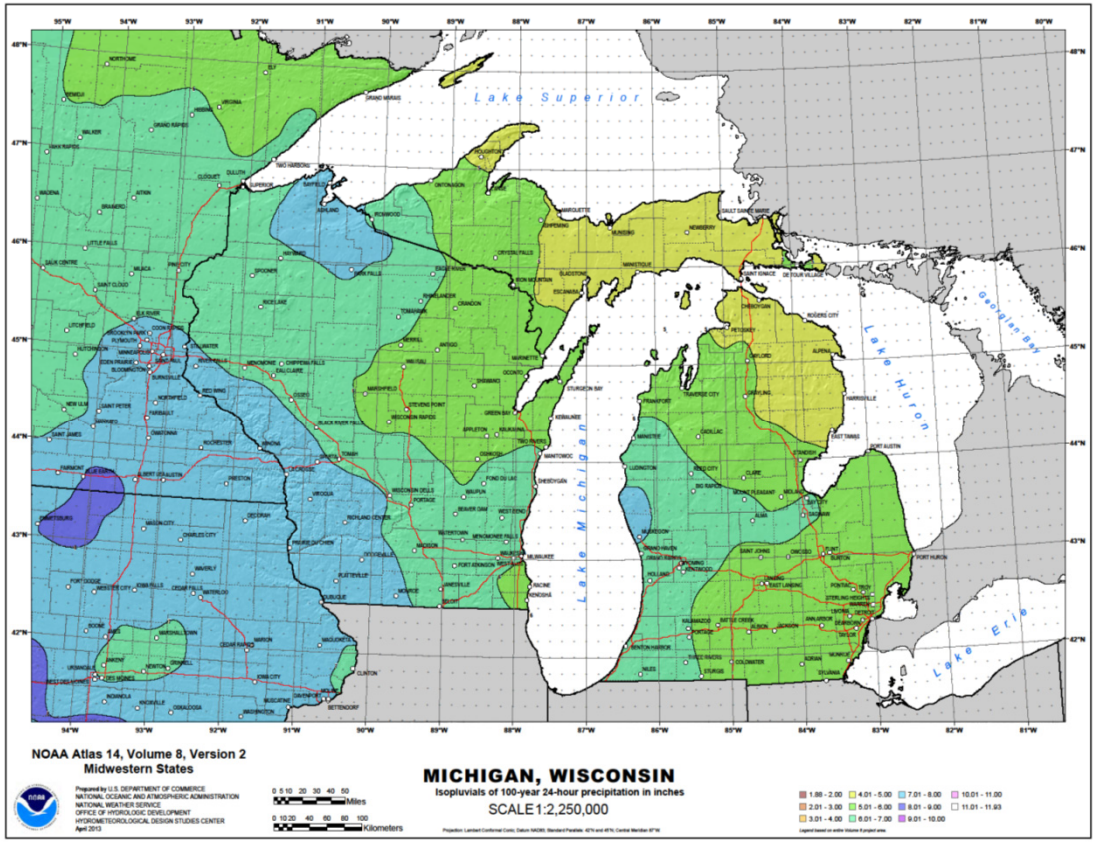
13.14 Rainfall Data

(1) When this chapter requires the calculation of runoff, governmental units shall use the most recent rainfall depths identified by the Southeastern Wisconsin Regional Planning Commission.

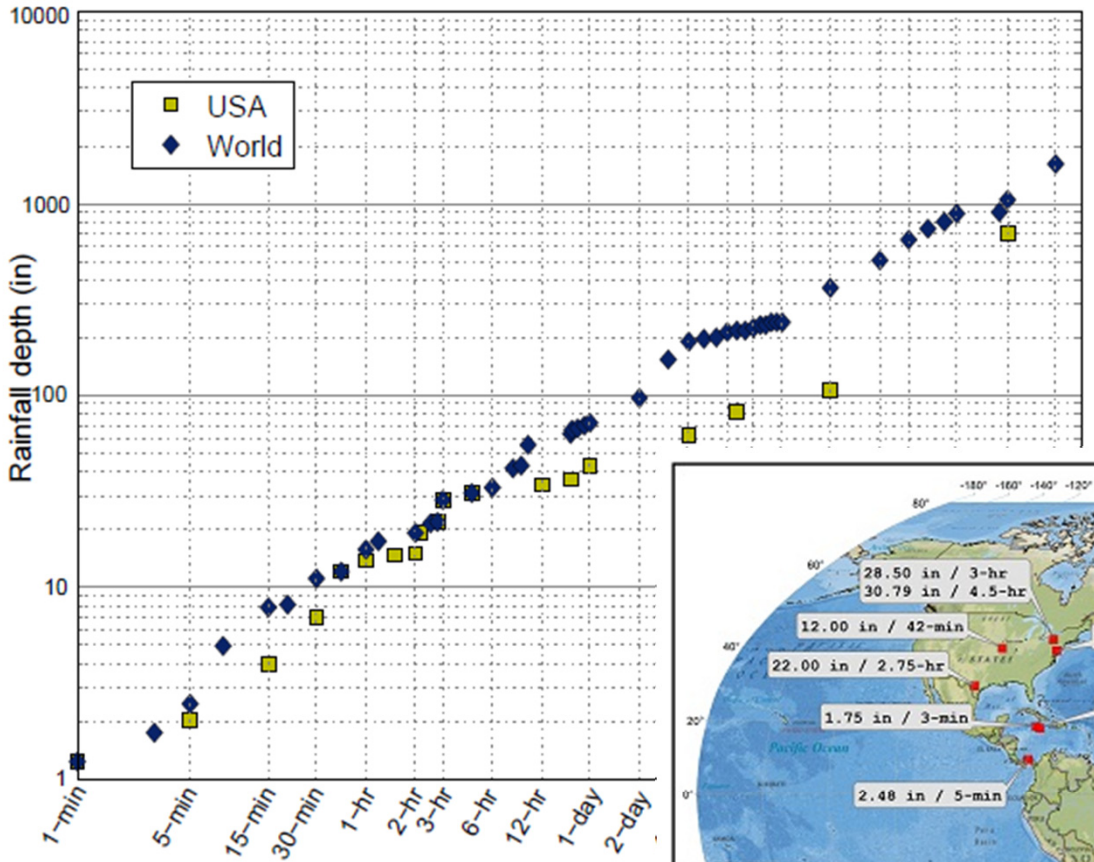
(2) The District may approve the use of proposed alternative depths if a governmental unit submits information showing that the proposed alternative depths are more protective than the depths obtained according to sub. (1) and the governmental unit has adopted the alternative depths in its storm water management ordinance.

Accessing Precipitation-Frequency Information

- NOAA recommends using Precipitation Frequency Data Server (PFDS), or ASCII grids, rather than cartographic maps



Record point precipitation measurements (1-minute to 2-year)

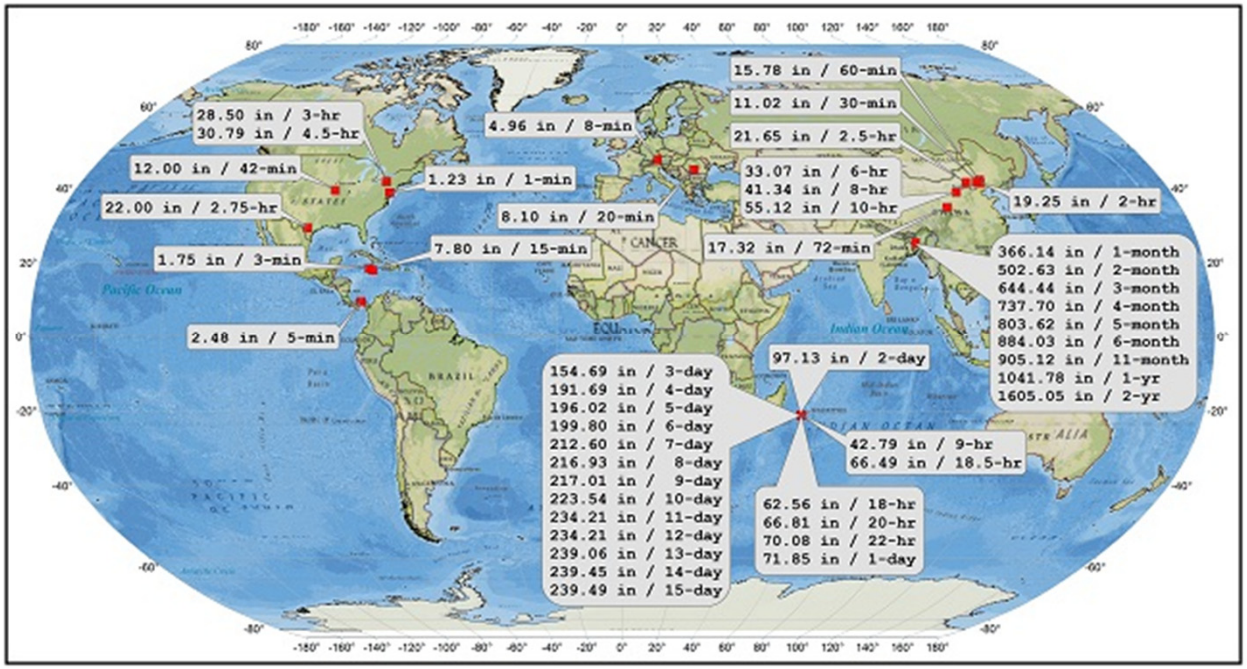


One-day Maximum Precipitation

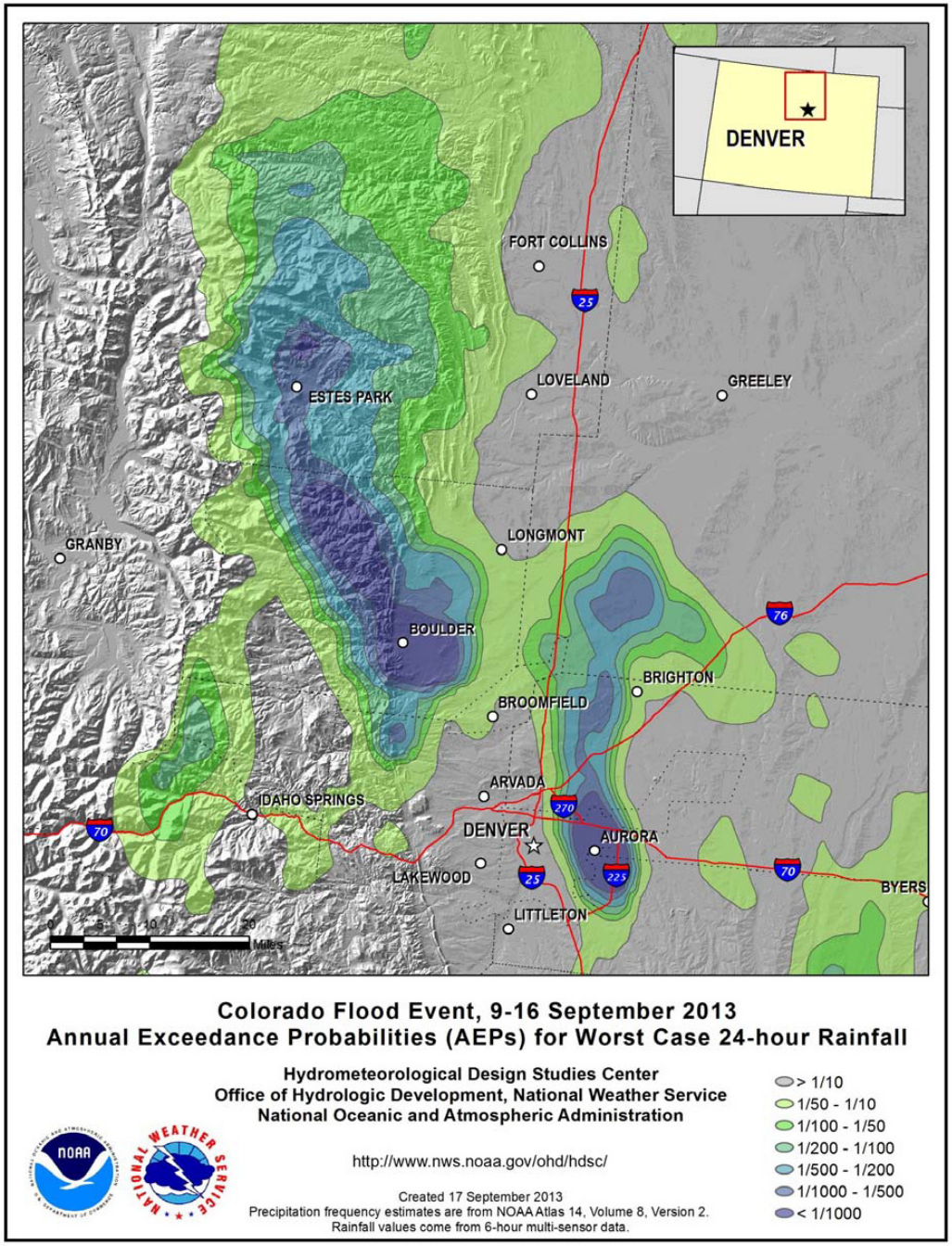
USA: 40 to 50 inches
World: 70 to 80 inches

One-day, 1000-year RI

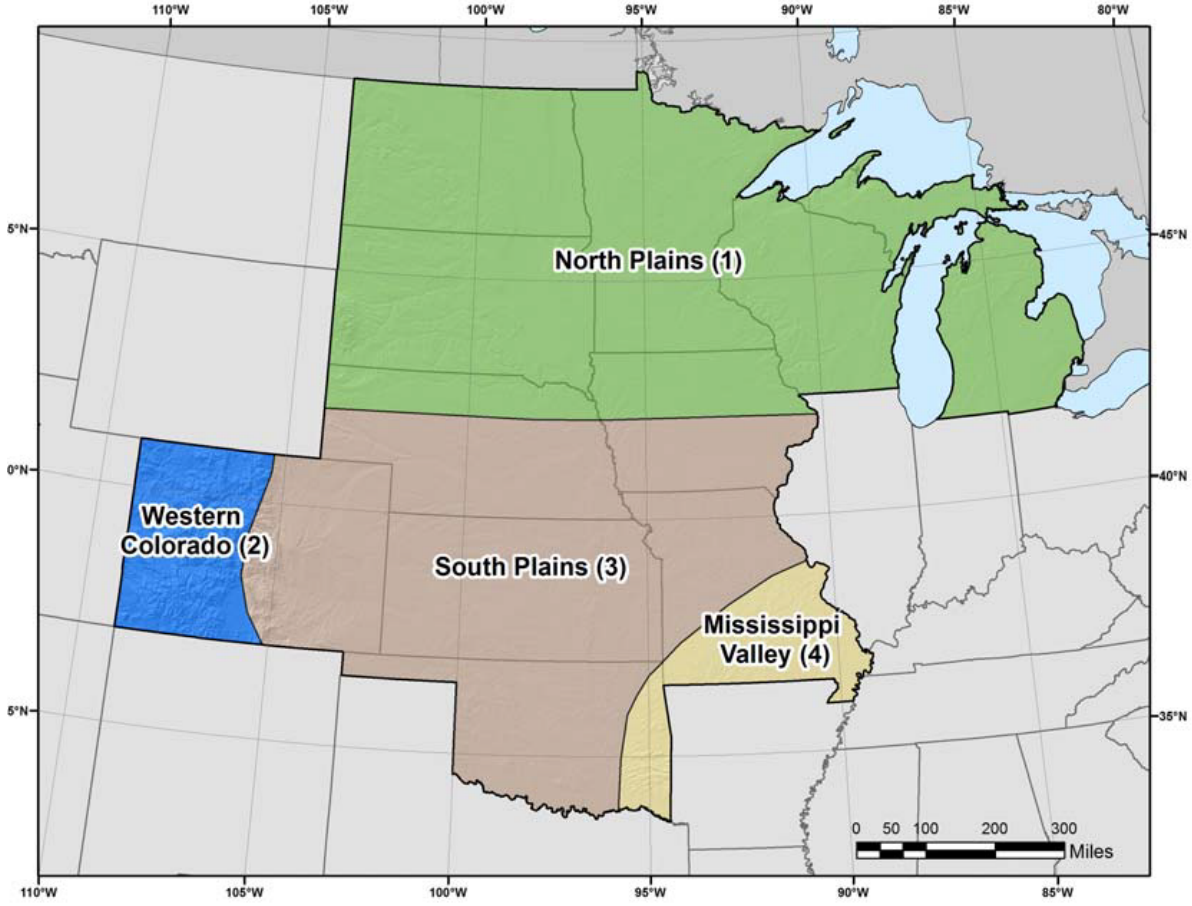
Milwaukee, WI: 8.99 inches



- NOAA Atlas 14 used to estimate probabilities of September 2013 Colorado rainfalls
  - 1000-year, 4-day rain is about 8 inches. Observed 4-day rain (13" to14") is at upper bound of 90% confidence interval for 1000-year R.I.



Atlas 14 Climate Regions for Temporal Distributions



Atlas 14 Temporal Distributions

- Methodology similar to Illinois State Water Survey "Huff distributions"
- Distributions for 1st, 2nd, 3rd, and 4th quartile storms (i.e., storms with most rain in first quarter, second quarter, etc.)
- 10th through 90th percentile distributions for each quartile
- "Event" was defined as the precipitation pattern over a specific duration
- Temporal distribution curves do not necessarily represent individual storms
- Events always start with precipitation, but do not necessarily end with precipitation, therefore, more "front–loaded" 1st quartile cases

Atlas 14 Temporal Distributions

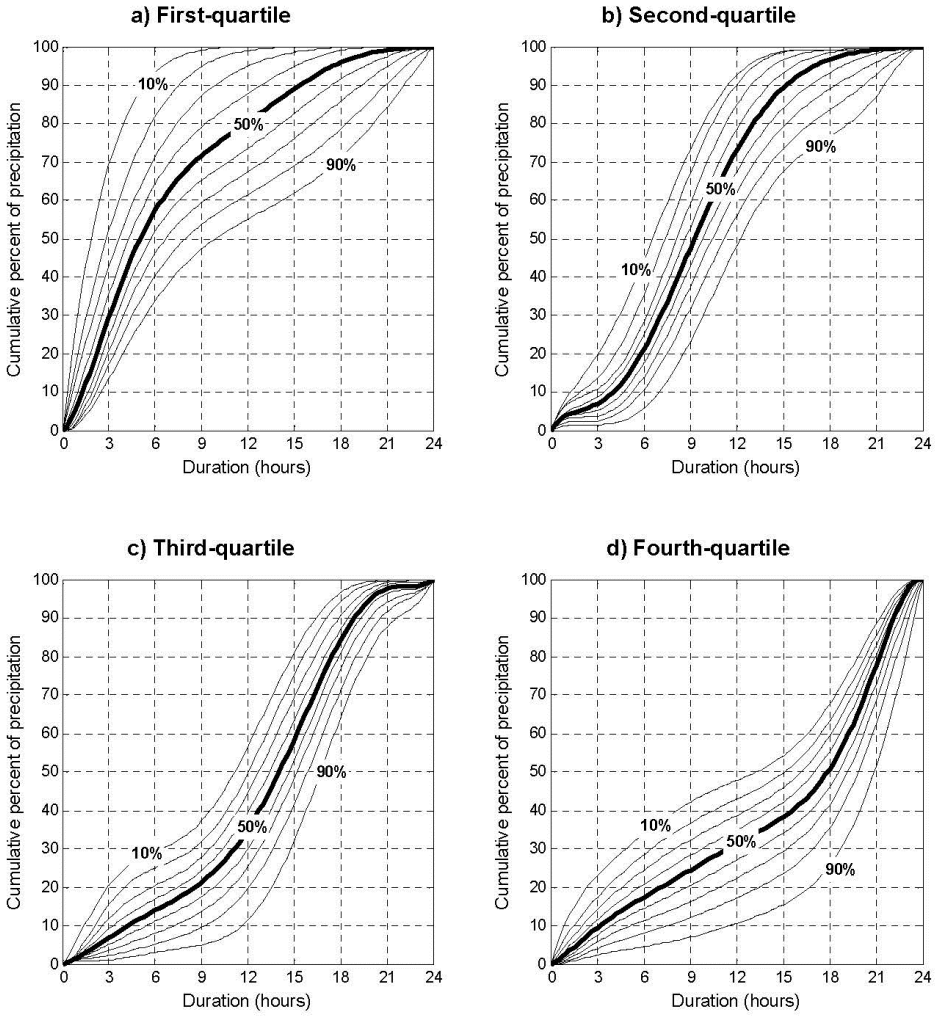
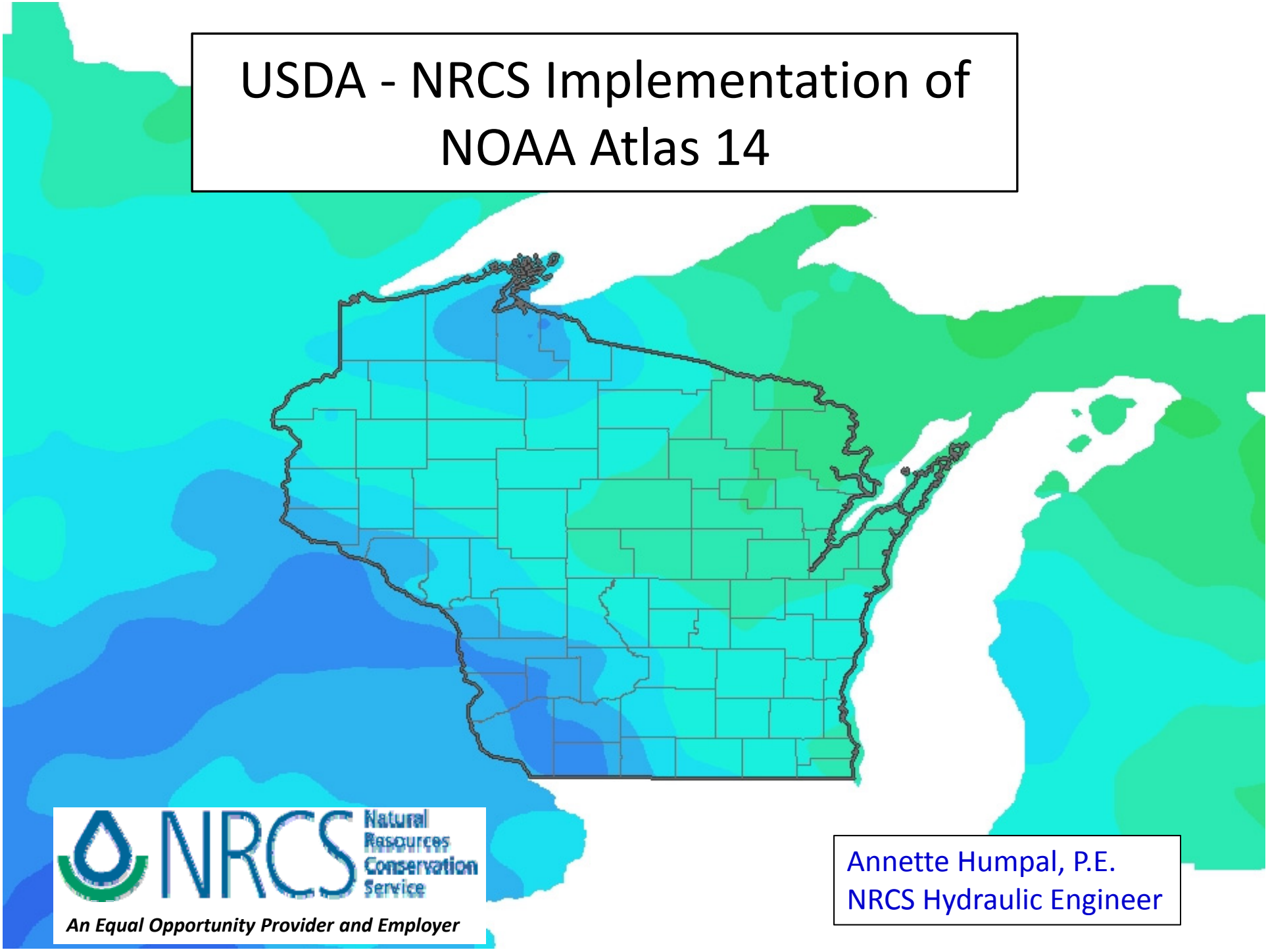


Figure A.5.4. 24-hour temporal distribution curves for the Mississippi Valley region (region 4): a) first-quartile, b) second-quartile, c) third-quartile, and d) fourth-quartile cases.

USDA - NRCS Implementation of NOAA Atlas 14



NRCS Natural Resources Conservation Service

An Equal Opportunity Provider and Employer

Annette Humpal, P.E.
NRCS Hydraulic Engineer

NRCS Work to Implement NOAA Atlas 14

General Overview:

- NRCS Work and Priorities at a National and State Level
- NRCS Development of Generalized Precipitation Depths (by County)
- NRCS Development of Temporal Storm Distributions based on NOAA Atlas 14 Data

NRCS Work to Implement NOAA Atlas 14

NRCS Priorities include:

- Working Nationwide to provide consistent methods for analyzing and using the Atlas 14 data.
- Developing precipitation data (depths and storm distributions) by County for use in the NRCS hydrology computer programs
- Coordination in WI with NRCS Partner Agencies

NRCS Work to Implement NOAA Atlas 14

The NRCS National Water Quality and Quantity Team is working with NRCS Hydraulic Engineers from the MW and SE States to Develop Generalized (not site specific):

- Precipitation Depths by County and Storm Frequency
- Rainfall Distributions by County

These will be made available in:

- NRCS Engineering Field Handbook, WI Supplements (Online)
- NRCS Hydrology (Computer) Programs

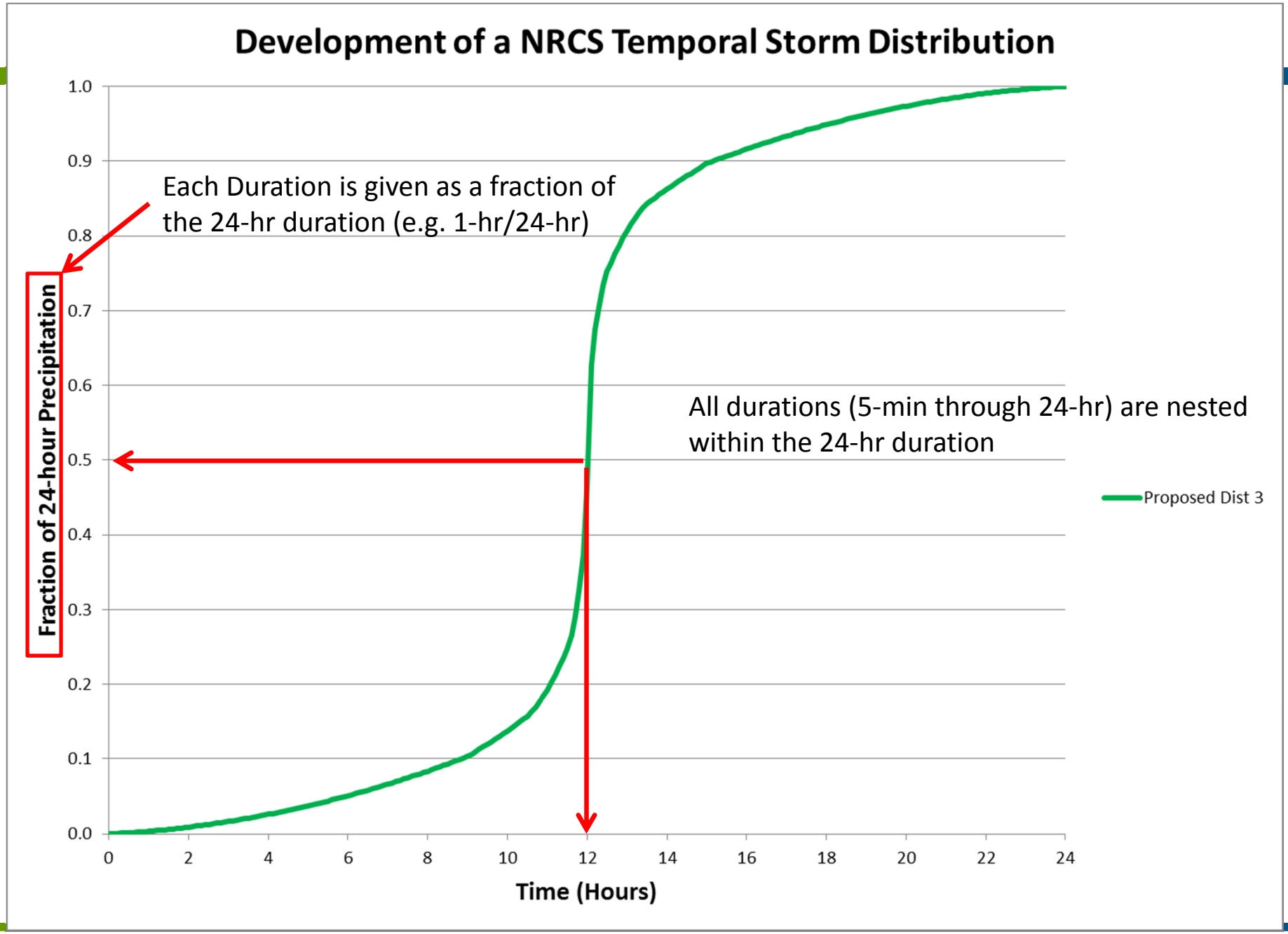
NRCS Work to Implement NOAA Atlas 14

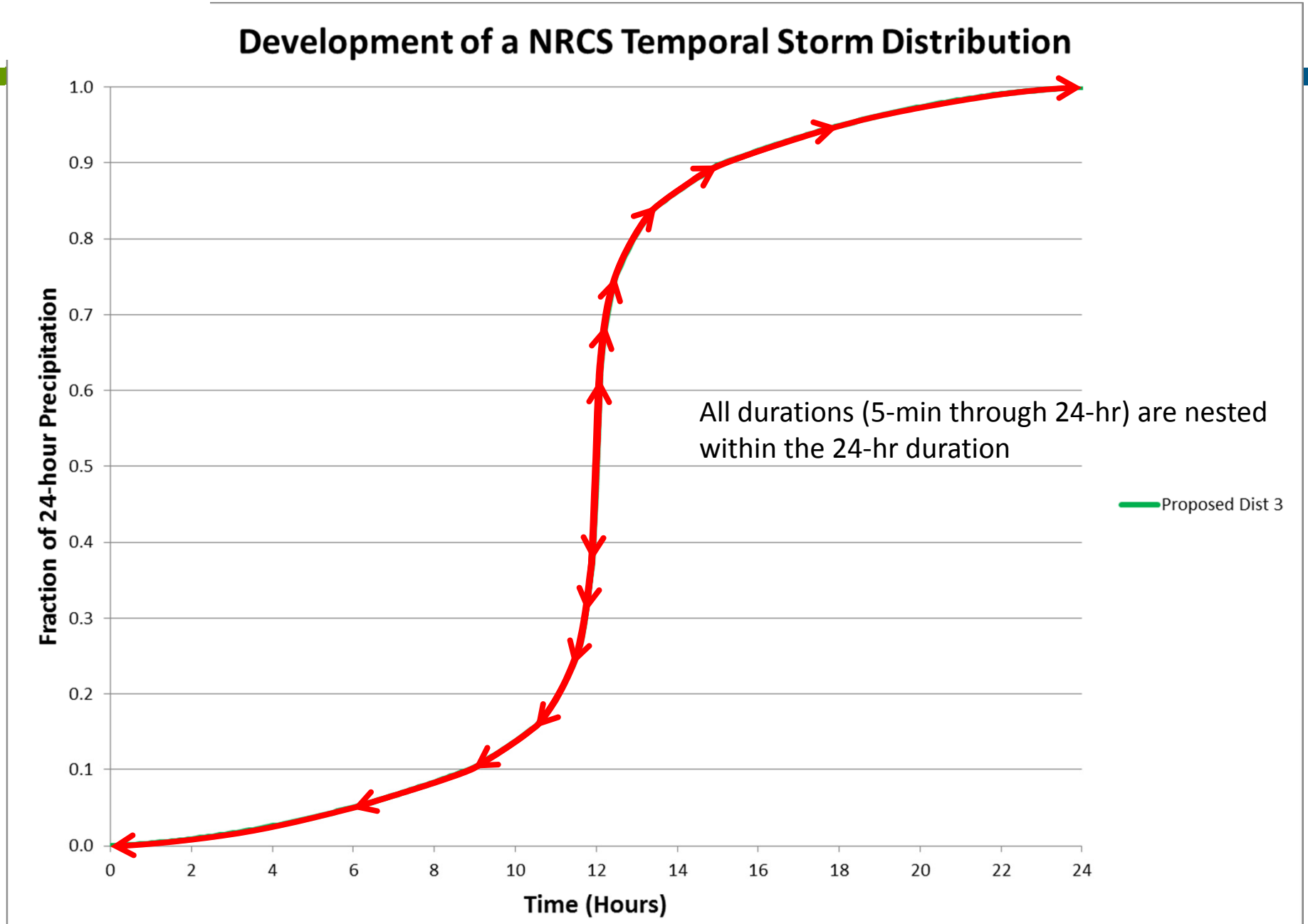
NRCS in Each State will select a Precipitation Depth for Each County and Storm Frequency

- For Current and Previous NOAA Atlas Updates, NRCS in Most States (other than PA) have selected a Mean Value for each County.
- NRCS Engineers in WI are proposing to Choose … Mean Values

NRCS Temporal Distributions:

- Are generally 24 hours in duration
- Assumes that the precipitation values for all durations (5-minute, through 24-hour) are imbedded within the same design storm for a given frequency (e.g. ,25-yr).
- Are centered around the 12-hour time period (conservative)
- Rainfall Distributions used by NRCS have historically been developed using ratios of the shorter duration storms (e.g. 1-hour) to the 24-hour rainfall for a given storm frequency.
- These rainfall distributions are meant to be conservative for design purposes, and not meant to duplicate actual storm events.

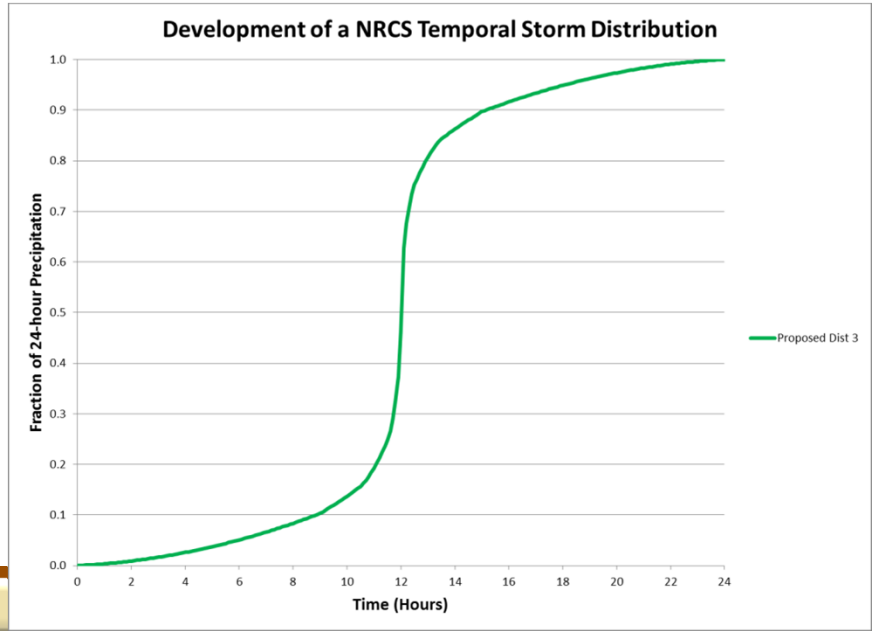

Development of a NRCS Temporal Storm Distribution
Each Duration is given as a fraction of the 24-hr duration (e.g. 1-hr/24-hr)
All durations (5-min through 24-hr) are nested within the 24-hr duration
Fraction of 24-hour Precipitation
Time (Hours)
Proposed Dist 3
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24


Development of a NRCS Temporal Storm Distribution
Fraction of 24-hour Precipitation
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
Time (Hours)
All durations (5-min through 24-hr) are nested within the 24-hr duration
Proposed Dist 3

NRCS Temporal Distributions

NRCS Purpose in Nesting All Durations within the 24-hr Temporal Distribution:

- The storm duration producing the largest peak discharge is generally approximately equal to the time of concentration of the watershed to the design point (NRCS NEH Ch 4)
- Thus, the NRCS 24-hour Temporal Distribution is applicable to any watershed with a Tc less than 24 hours



Water Quality and Quantity Team Findings

From their analysis of the data from the ***previously completed*** NOAA Atlas 14, Volume 1 (Desert Southwest) and Volume 2 (Ohio Valley and Neighboring States):

- NRCS Types I, IA, II and III Rainfall Distributions are **not consistent** with NOAA Atlas 14 precipitation values
- Use of rainfall distributions that cover large geographic regions (such as Type II), would lead to over-or under-estimation of peak discharge

Tentative NRCS Rainfall Distribution Regions

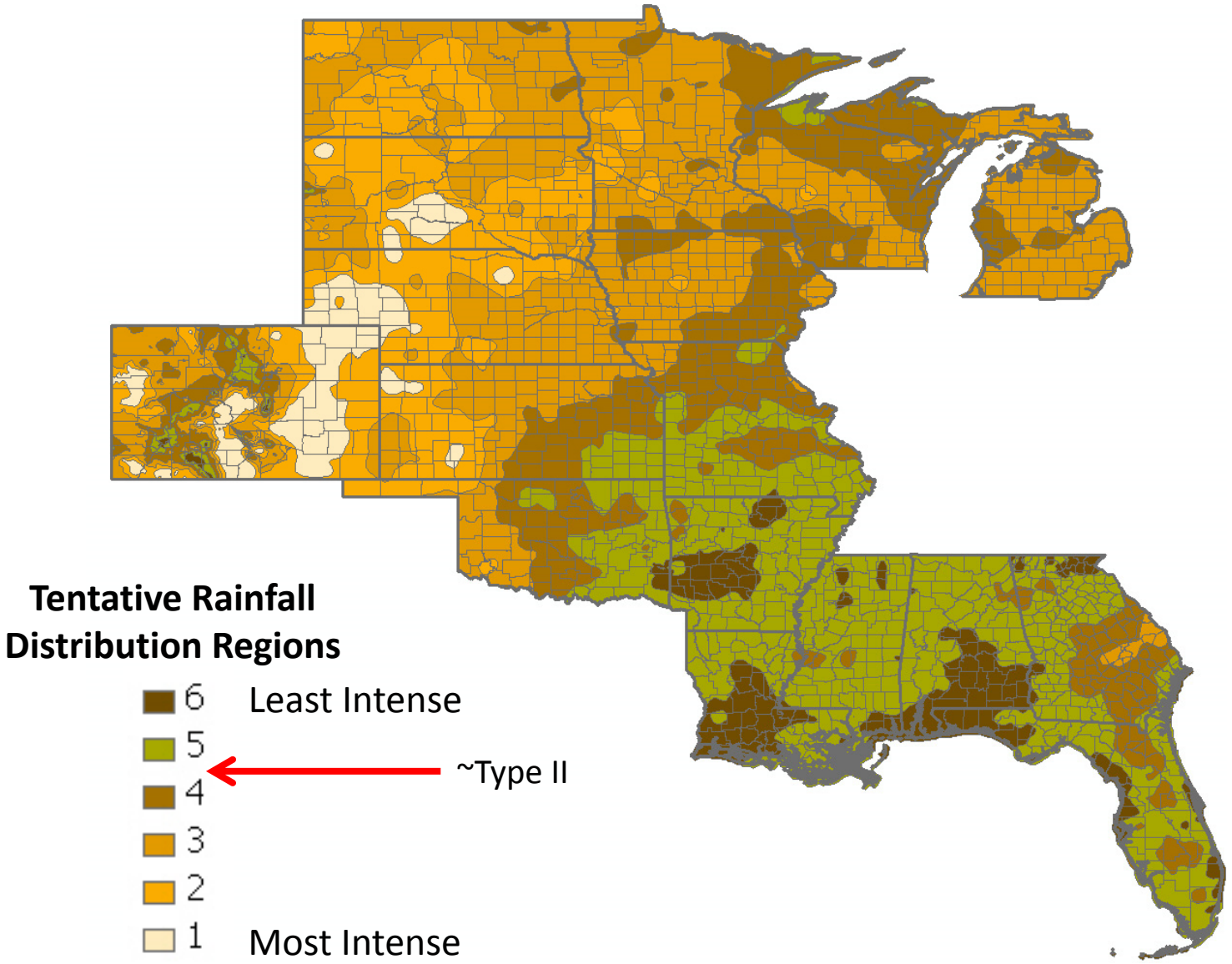
Midwest and Southeast States

Rainfall Distribution Region	Minimum Ratio: (25-yr, 1-hr) / (25-yr, 24-hr)	Maximum Ratio: (25-yr, 1-hr) / (25-yr, 24-hr)
Dist-1	0.58	
Dist-2	0.53	0.58
Dist-3	0.48	0.53
Dist-4	0.43	0.48
Dist-5	0.38	0.43
Dist-6		0.38

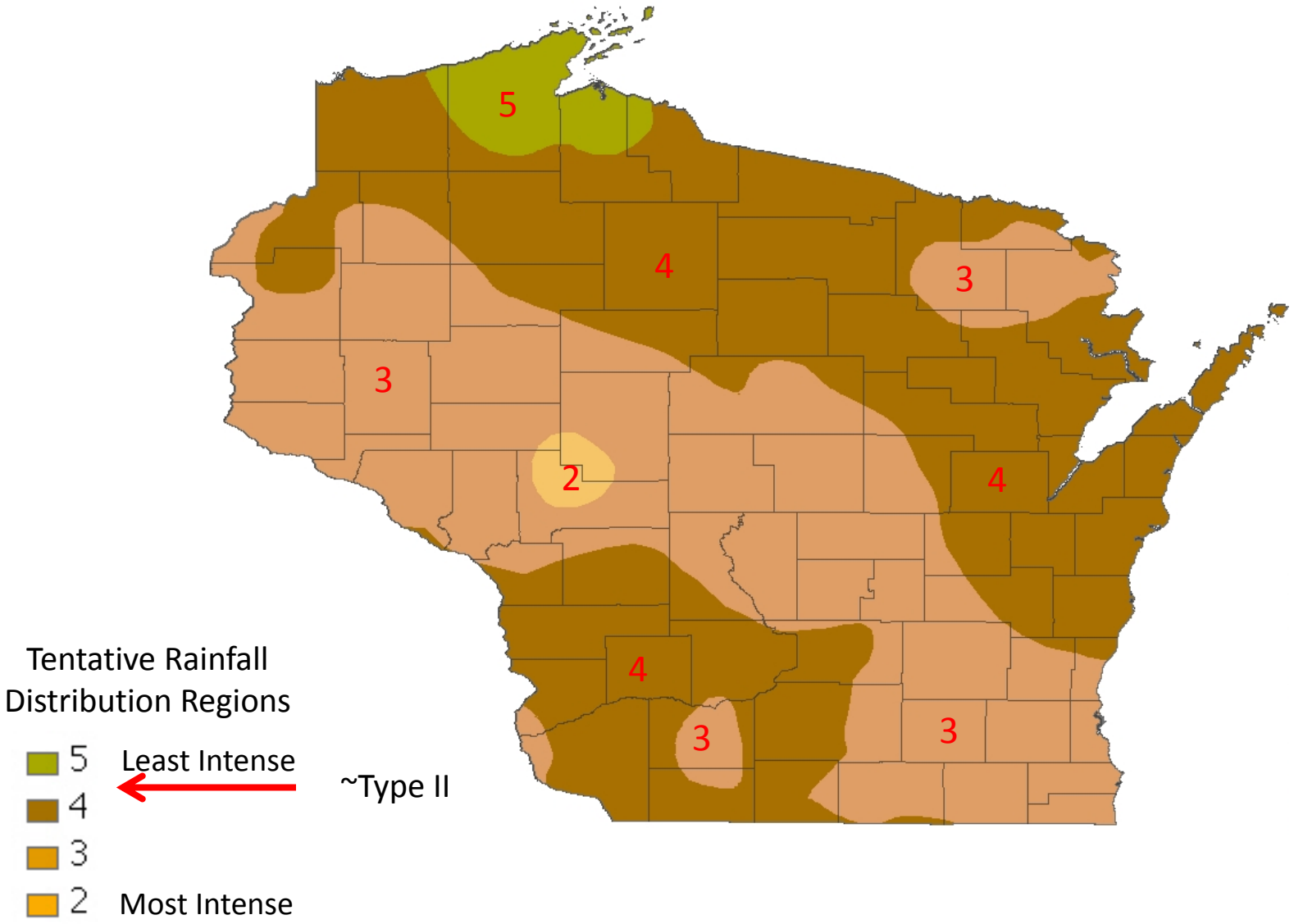
~ Type II

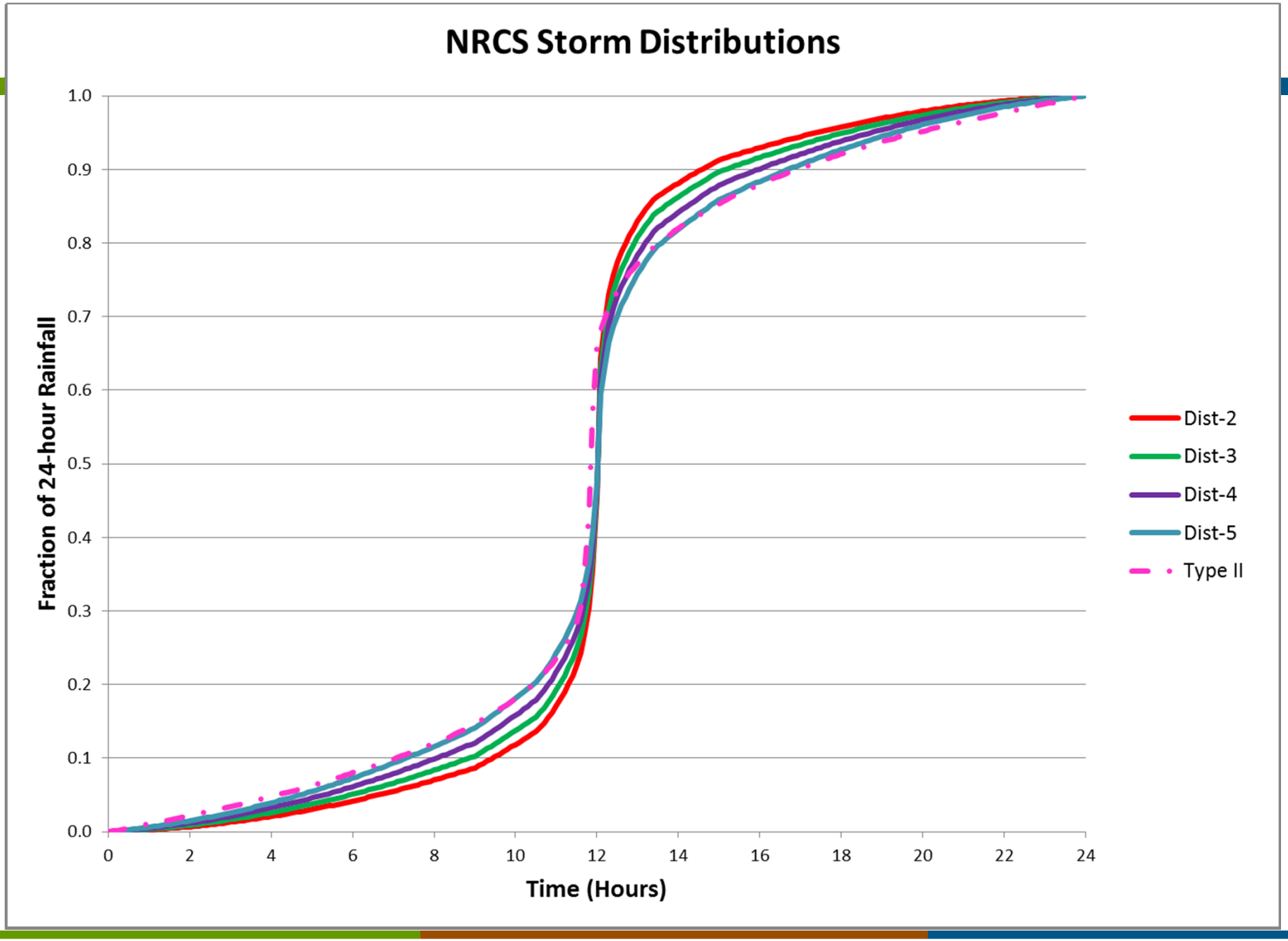
Type II Ratio ~ between Dist-4 and Dist-5

NRCS NWQQ Team Rainfall Distribution Regions



NRCS NWQQ Team Rainfall Distribution Regions - WI

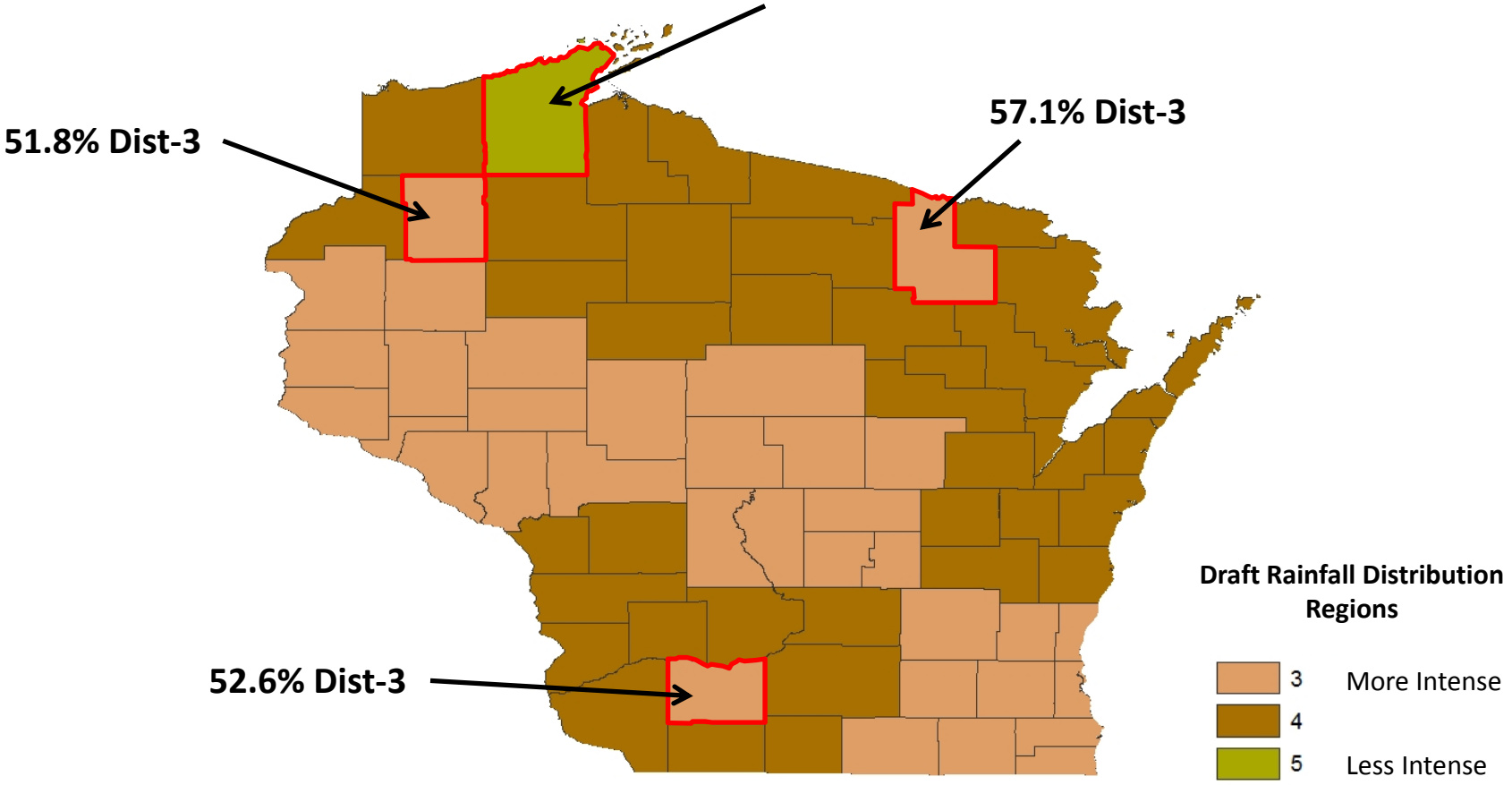



NRCS Storm Distributions
Fraction of 24-hour Rainfall
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
Time (Hours)
Dist-2
Dist-3
Dist-4
Dist-5
Type II

NRCS WI Proposed Rainfall Distributions

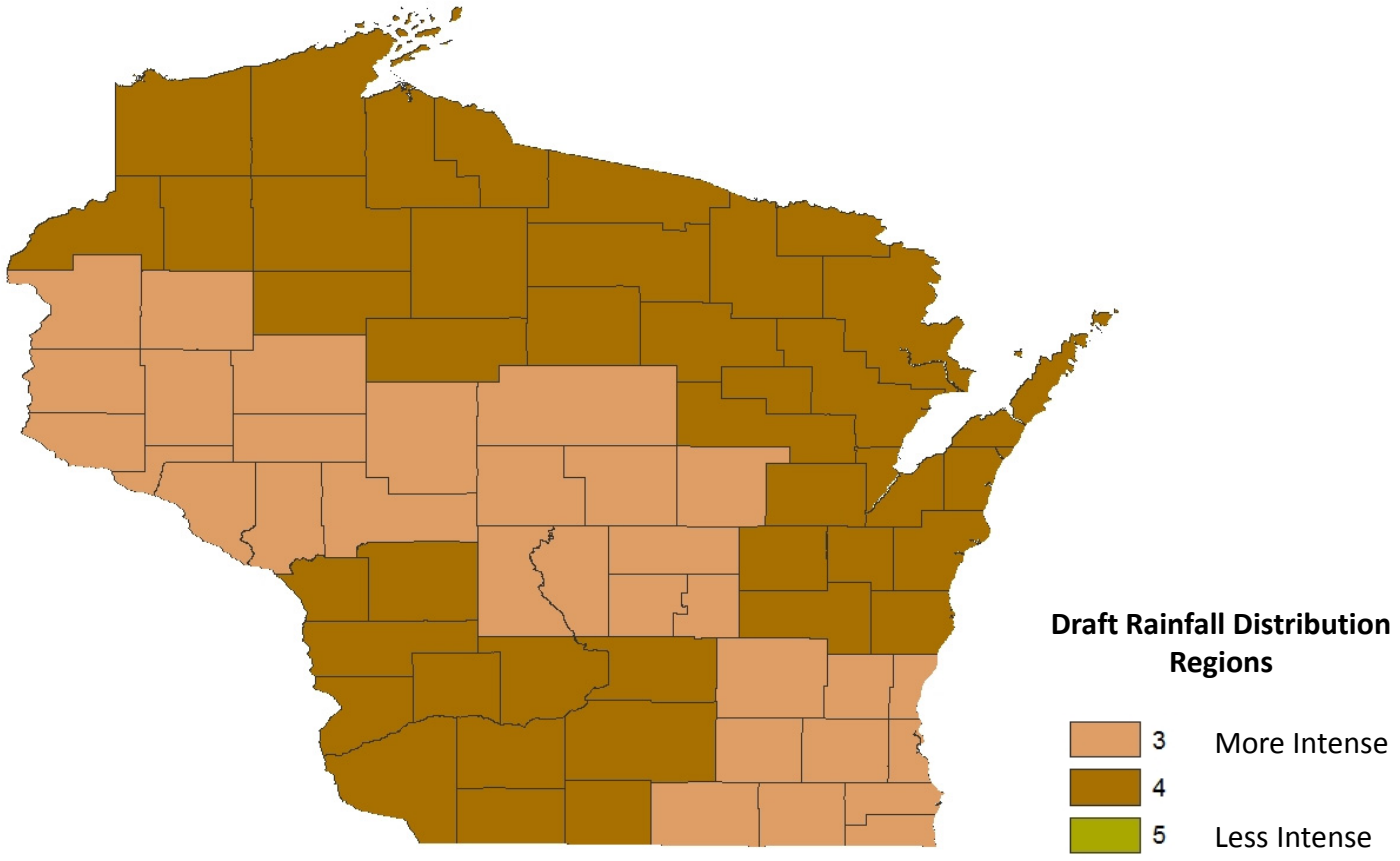
Initial Simplified Rainfall Distribution Regions

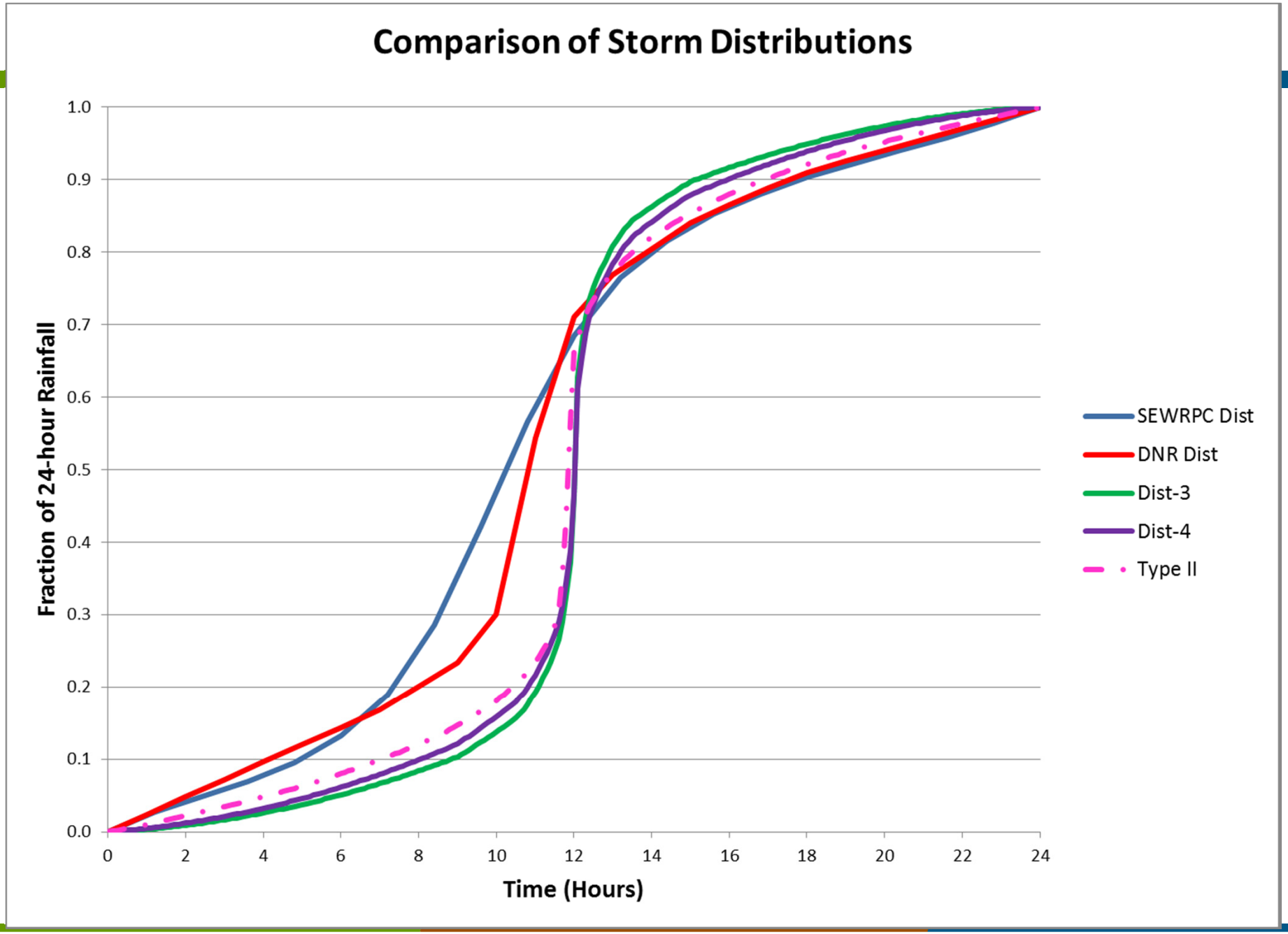
Based on Dominant (>50%) Distribution for Each County



NRCS WI Proposed Rainfall Distributions

DRAFT!!




Comparison of Storm Distributions
Fraction of 24-hour Rainfall
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
Time (Hours)
SEWRPC Dist
DNR Dist
Dist-3
Dist-4
Type II

Next Steps

NRCS Precipitation Data is to be Finalized and Databases Are to be Developed For WI for use in NRCS Hydrology Computer Programs

- Final Comments from Partners
- Finalize Precipitation Depths (by Storm Frequency) by County
- Finalize Rainfall Distributions by County

Temporal Distributions

- For studies to delineate regulatory floodplain limits, WDNR will accept critical duration analyses for peak flow determinations using Atlas 14 precipitation and:
  - The WDNR State distribution,
  - The SEWRPC 2006 distribution for the Southeastern Wisconsin Region, or
  - The new NRCS distributions.
- WDNR will not accept Atlas 14 precipitation with the NRCS Type II distribution

Accessing Precipitation-Frequency Information

- http://hdsc.nws.noaa.gov/hdsc/pfds/