Hydrometeorological Design Studies Center
Progress Report for Period
1 April to 30 June 2024

Office of Water Prediction
National Weather Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Silver Spring, Maryland

October 28, 2024

DISCLAIMER

The data and information presented in this report are provided only to demonstrate current progress on the various tasks associated with these projects. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any other purpose does so at their own risk.

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I. INTRODUCTION

The Hydrometeorological Design Studies Center (HDSC) within the Office of Water Prediction (OWP) of the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) updates precipitation frequency estimates for parts of the United States and affiliated territories, in coordination with stakeholder requests. Updated precipitation frequency estimates, accompanied by additional relevant information, are published as NOAA Atlas 14 and are available for download from the Precipitation Frequency Data Server (PFDS).

NOAA Atlas 14 is divided into volumes based on geographic sections of the country and affiliated territories. Figure 1 shows the states or territories associated with each of the volumes of the Atlas. To date, precipitation frequency estimates have been updated for AZ, NV, NM, UT (Volume 1, 2004), DC, DE, IL, IN, KY, MD, NC, NJ, OH, PA, SC, TN, VA, WV (Volume 2, 2004), PR and U.S. Virgin Islands (Volume 3, 2006), HI (Volume 4, 2009), Selected Pacific Islands (Volume 5, 2009), CA (Volume 6, 2011), AK (Volume 7, 2011), CO, IA, KS, MI, MN, MO, ND, NE, OK, SD, WI (Volume 8, 2013), AL, AR, FL, GA, LA, MS (Volume 9, 2013), CT, MA, ME, NH, NY, RI, VT (Volume 10, 2015), and TX (Volume 11, 2018).

HDSC is currently working on two NOAA Atlas 14 Volumes: Volume 12 and Volume 13, and initiated Atlas 15 development. The Volume 12 project area covers the states of Idaho, Montana and Wyoming, while the Volume 13 project area covers the states of Delaware, Maryland, North Carolina, Pennsylvania, South Carolina, Virginia and Washington D.C. and approximately a 1-degree buffer around these states.

Figure 1 shows the new and updated project areas included in NOAA Atlas 14, Volumes 1 to 13. The proposed schedules for the two projects are contingent on funding and a timely hiring process. For any inquiries regarding NOAA Atlas 14, please email hdsc.questions@noaa.gov.

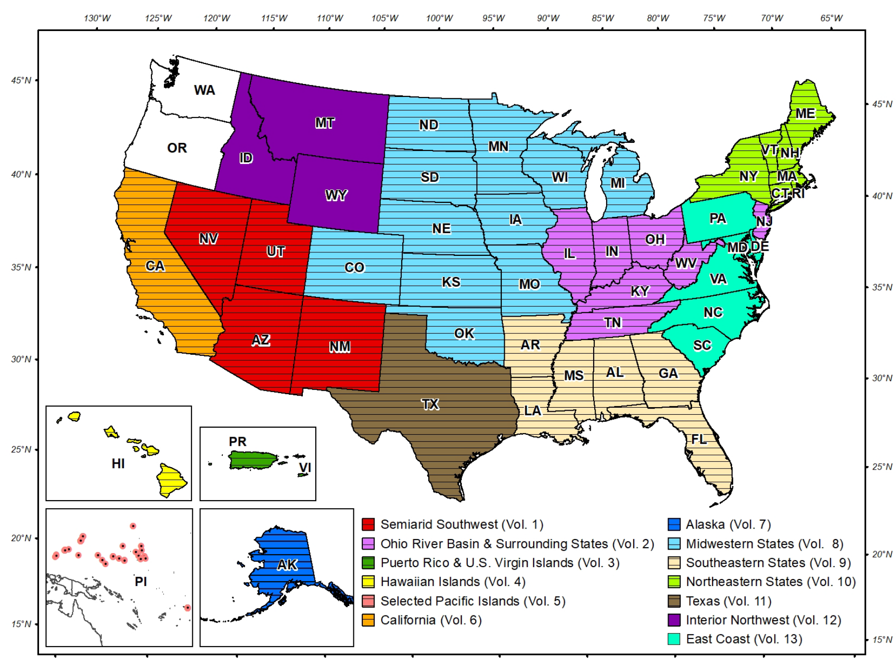

Figure 1. States or territories associated with each of the volumes of the Atlas.

II. CURRENT NOAA ATLAS 14 PROJECTS

1. VOLUME 12: INTERIOR NORTHWEST

On May 26, 2021, the HDSC commenced work on a NOAA Atlas 14 Volume 12. The precipitation frequency estimates for this volume include the states of Idaho, Montana, and Wyoming, with an approximately 1-degree buffer around these states (Figure 2). The expected project's completion date for this volume by the end of September, 2024.

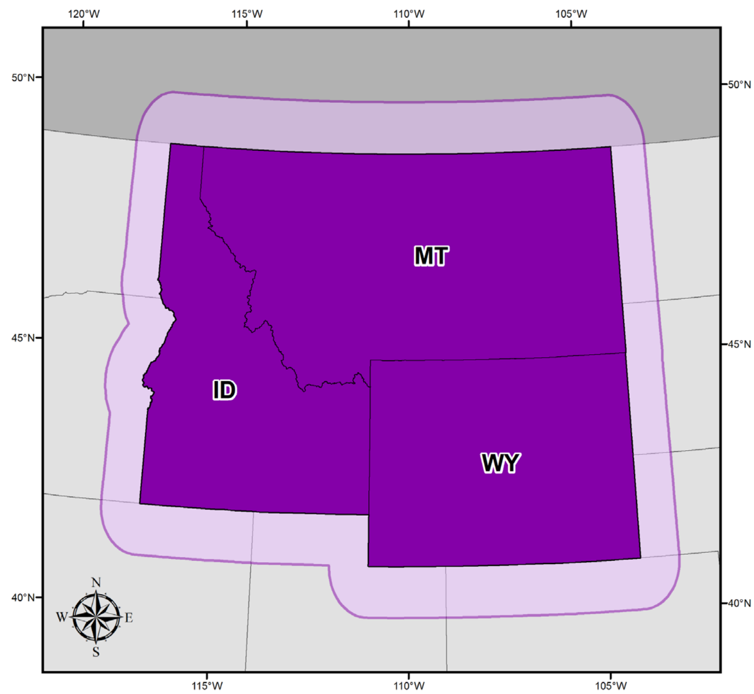

Figure 2. NOAA Atlas 14, Volume 12 extended project area (shown in purple).

In the reporting period of April 1 to June 30, 2024, we finalized mean annual maxima grids across all durations with the help of the Oregon State University, PRISM group. We updated estimates across all duration, 1-day through 60-day, and began reviewing the spatial patterns and final depth-duration-frequency (DDF) curves. We also finalized development of the supplementary information, such as trend analysis, temporal analysis and confidence intervals, and started drafting documentation. For more information on how the supplementary information tasks, please refer to January - March, 2024 Progress Report. We also addressed responses to the peer review.

1.1. PROGRESS IN THIS REPORTING PERIOD (April - June 2024)

For the sources of datasets considered, contacted, downloaded or formatted for the precipitation frequency analysis for NOAA Atlas 14 Volume 12, please see July - Sept, 2022 Progress Report.

1.1.1. Spatial interpolation and analysis of mean annual maximum (MAM) data

Spatial interpolation of MAM values estimated at gauged locations is done by the Oregon State University's PRISM Climate Group using their hybrid statistical-geographic approach for mapping climate data. During this reporting period, three additional iterations were done with the PRISM group to ensure realistic spatial patterns and consistency in gridded MAMs for 1-hour, 6-hour, 1-day, 4-day, 10-day, 30-day, and 60-day durations. In the process, we reviewed MAM data for each station for inconsistencies relative to MAMs at nearby stations in order to identify locations where MAMs are affected by short periods of record or missed extreme amounts. Flagged MAMs were investigated and either adjusted or removed from the analysis.

1.1.2. Revision of spatially interpolated precipitation frequency estimates

In NOAA Atlas 14, the grids of mean annual maxima (MAM) at 30 arc-sec resolution, together with at-station precipitation frequency estimates, are the basis for calculation of gridded annual maximum series (AMS)-based and partial duration series (PDS)-based precipitation frequency estimates and corresponding upper and lower bounds of the 90% confidence interval. Mean annual maximum grids serve as the basis for calculation of the precipitation frequency estimates for the 2-year average recurrence interval (ARI), which are then used to calculate gridded 5-year estimates and so on. More information on this method will be provided in the Volume 12 document, which will be available for download from the PFDS web page in September 2024.

During this reporting period we reviewed spatial patterns for the 2-year, 100-year and 1000-year grids across all durations, and revisited and improved at-station and regional estimates where needed. The resulting adjustments were then carried through to other recurrence intervals in an iterative process. Typically, several iterations are required to ensure realistic spatial patterns and consistency in gridded estimates for 13 selected durations from 1 hour to 60 days (1-hr, 2-hr, 3-hr, 6-hr, 12-hr, 24-hr, 2-day, 4-day, 7-day, 20-day, 30-day, 45-day and 60-day).

To ensure consistency in grid cell values across all durations and frequencies (e.g., a 24-hour estimate has to be at least equal to the corresponding 12-hour estimate), we also conducted duration-based internal consistency checks across durations and frequencies.

1.1.3. Confidence intervals

A Monte Carlo simulation procedure, similar to the methodology described in Hosking and Wallis (1997), is employed to construct 90% confidence intervals (i.e., 5% and 95% confidence limits) on both AMS-based and PDS-based precipitation frequency curves (see Section 4.6.1 for calculation of PDS-based precipitation frequency estimates). At each station, 1,000 simulated data sets per duration were used to generate precipitation quantiles, using the region L-moment algorithm (see Section 4.6.2 for spatial dependence analysis). Estimates were sorted from smallest to largest and the 50th value was selected as the lower confidence limit, while the 950th value was selected as the upper confidence limit. The region used for the simulation is designed to mirror the characteristics of the actual target station region, including the number of sites and the record length at each site. The L-moment ratios for individual sites within the simulated region are constructed by linearly varying the ratios across sites, with the mean value set to the regional average L-moment ratio and the range determined by the standard error. The simulation algorithm is designed to account for uncertainties such as sampling variability, model choice, and parameter uncertainty, but it does not include other sources of uncertainty, such as differences between model estimation methods (MLE vs. L-moments), that could significantly impact the total error, particularly at more rare frequencies.

For some stations, due to differences in record lengths across hourly and daily durations, confidence intervals for hourly durations were wider than corresponding intervals at daily durations; therefore, they were restricted by the corresponding values at 24-hour duration. Confidence limits for sub-hourly durations were calculated using similar approaches that were used to calculate frequency estimates at those durations. Since confidence limits were derived for each duration independently, like precipitation frequency estimates, they could fluctuate from duration to duration and were smoothed across durations using cubic spline functions.

1.1.4. Extraction of rainfall data

For some applications it may be important to differentiate frequency estimates from liquid precipitation only (i.e. rainfall). For example, rainfall is treated differently from snowfall in watershed modeling because of different runoff producing mechanisms: while rainfall generates runoff almost immediately, snowfall generally goes into storage until it melts at a later date. For high elevation areas in the Volume 12 project area, the contribution of snowfall to the annual precipitation is notable; however, high annual snowfall does not necessarily translate into a direct relationship to high snowfall AMS, especially for durations of 24-hour and less. To explore differences in total and liquid-only precipitation frequency estimates, concurrent rainfall and precipitation AMS were extracted at stations which had information useful for distinguishing the type of precipitation. Rainfall analysis is typically done for durations up to 24 hours, which are of the most interest to design projects relying on peak flows.

For the rain-precipitation analysis at 24-hour duration, two main data sources, Global Historical Climatology Network daily (GHCNd), and Snow Telemetry (SNOTEL) Network, were considered, and the concurrent daily precipitation and snowfall for each of these networks was calculated differently due to data availability.

For GHCNd, recorded snowfall amounts were first converted to snow water equivalent (SWE) using the 10 to 1 rule, which assumes the density of water is 10 times the density of snowfall. This ratio is on average higher (thus lower liquid equivalent) for many areas in the project area; however, historical observations of snowfall were often assumed to have a 10 to 1 ratio, and thus precipitation was recorded as 1/10th the actual snowfall observation (and no direct precipitation was melted/recorded) . The rainfall was then calculated by subtracting the SWE from the precipitation. Values less than 0 are truncated to 0 rainfall. Warm season (i.e. May – September) precipitation is assumed to be rainfall. Some stations report “missing” snowfall during warm season months, which would cause too many missing periods for annual maximum rainfall to be sufficiently extracted, even though these warm months are likely mostly 0 snowfall (with some exceptions). Precipitation and rainfall-only time series for the GHCNd dataset remain after these steps.

For SNOTEL, recorded SWE on the ground and mean daily temperatures were used to estimate snowfall days within the time series. Positive changes in SWE were subtracted from the precipitation to create a rainfall time series. Rain on deep snowpacks can often cause SWE to rise during rainfall events for some time. An upper bound of 34°F for mean daily temperature was used to distinguish rain on deep snowpack, where the precipitation was assumed to be rainfall if the daily mean temperature was over 34°F. A value of 34°F was chosen for this threshold due to the Critical Success Index (CSI) showing a 34.5°F (1.4°C) threshold as the most skillful for estimating rain versus snow, and rounding down to the nearest integer value of 34°F to account for some uncertainty in accumulation potential.

While daily snowfall and ground SWE estimates were readily available for daily durations, there is a very limited quantity of sub-daily snowfall data available. Temperature measurements at hourly time steps co-located with precipitation data could be used to distinguish liquid from solid precipitation, but these data are only available for a very limited number of stations. Instead of observational data, modeled daily mean temperature data, available from the PRISM AN81d and AN91d at 4-km resolution, were used at station locations to aid in distinguishing rainfall from precipitation. Similar to the 24-hour SNOTEL analysis threshold, 34°F daily mean temperature is used to determine if the station's precipitation is rain or snow. If the day's mean temperature is 34°F or less, then all hours that day are considered snow.

There is a large uncertainty associated with extracting rainfall using only extreme time series data, particularly in high terrain areas, where the contribution of snowfall events can be significant. This uncertainty is associated with available data, data measurement errors, assumptions associated with 10 to 1 snowfall-to-liquid ratios, or ground SWE not being a 1:1 indicator of snowfall (e.g. blowing snow, rainfall on deep snowpacks, avalanches).

1.1.5. Development of PFDS web pages for Volume 12

During this reporting period, we worked on the development of updated PFDS web pages for the new project area of Volume 12 and have prepared pertinent Federal Geographic Data Committee (FGDC) compliant metadata. We also developed templates for all PFDS cartographic maps.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (July - Sep 2024)

During the next reporting period, we will work on finalizing the data and supplementary information for the web publication. This includes completing the final gridded AMS-based and partial duration series (PDS)-based estimates, as well as gridded upper and lower confidence limits for 90% confidence interval for all durations and frequencies, creating cartographic maps, documentation, and other web documents. We will also develop final rainfall frequency estimates. We expect to publish estimates on the PFDS by the end of September.

1.3. PROJECT SCHEDULE

- Data collection, formatting, and initial quality control [Completed]
- Extraction of annual maximum series (AMS); additional quality control and data reliability tests (e.g., outliers, independence, consistency across durations, duplicate stations, candidates for merging)] [Completed]
- Regionalization and frequency analysis [Completed]
- Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [Completed]
- Peer review [Completed]
- Revision of PF estimates [FY Q4 2024; In progress]
- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [FY Q4 2024; In progress]
- Web publication [FY Q4 2024; In progress]

2. VOLUME 13: EAST COAST STATES UPDATE

On July 28, 2022, the NOAA Atlas 14 Volume 13 kickoff meeting was held to commence work on a new NOAA Atlas 14 Volume 13. The precipitation frequency estimates for this volume include the states of Delaware, Maryland, North Carolina, Pennsylvania, South Carolina, Virginia and Washington D.C. and approximately a 1-degree buffer around these states (Figure 7). This project's expected completion date is December 2025, subject to change based on the availability of funds and personnel to support the development of two volumes.

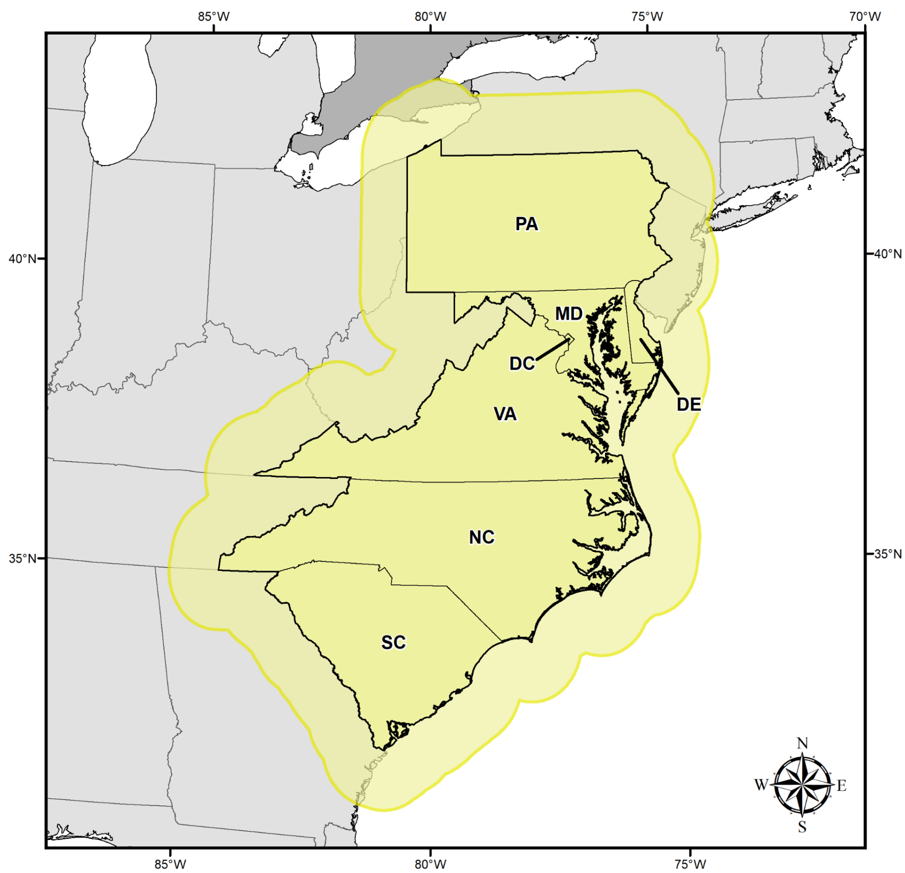

Figure 3. NOAA Atlas 14, Volume 13 extended project area (shown in yellow).

2.1. PROGRESS IN THIS REPORTING PERIOD (April - June 2024)

In the reporting period of April 1 to June 30, 2024, we continued to work on the cleanup software and initiated the manual station cleanup for the co-located NCEI networks. In addition, we continue quality controlling the station metadata and high outlier checks. Finally, we continue investigating the development of the mean annual maxima grids for this project area.

2.1.1. Data collection and data screening

We continue to format and quality control the identified precipitation networks (see Table 2) that are considered for the development of the Atlas 14 Volume 13 estimates. As with all NOAA Atlas 14 Volumes, the primary source of data is the NOAA's National Centers for Environmental Information

(NCEI). The NCEI is the most reliable data source network in the United States. The NCEI's precipitation data alone may not be sufficient to support the objectives of NOAA Atlas 14. Since the NOAA Atlas 14 estimates are based on the statistical analysis of the historical record of the observed precipitation data, denser spatial coverage may be needed to compute the robust and reliable precipitation frequency estimates. Therefore, for each project area, we also collect digitized data measured at 1-day or shorter reporting intervals from other Federal, State and local agencies. During this reporting period, NCEI datasets were updated through water year 2024.

Table 2. Sources of datasets considered, contacted, downloaded or formatted for the precipitation frequency analysis for NOAA Atlas 14 Volume 13.

FID	Data Provider	Dataset name	Abbr.	Status
1	National Centers for Environmental Information (NCEI)	Automated Surface Observing System	ASOS	Formatted
2		DSI 3240, DSI 3260	DSI 3240 DSI 3260	Formatted
3		Global Historical Climatology Network	GHCNd	Formatted
4		Environment Canada	GHCNd	Formatted
5		Integrated Surface Data (Lite)	ISD_LITE	Formatted
6		Local Climatological Data	LCD	Formatted
7		Coop Hourly	GHCNh	Formatted
8		United States CoCORAHS	GHCNd	Formatted
9		Canada CoCORAHS	GHCNd	Formatted
10		Weather Bureau Army Navy (WBAN)	GHCNd	Formatted
11		U.S. Climate Reference Network	USCM	Formatted
12	Aberdeen Proving Ground	Phillips Airfield Weather Station	PAWS	Formatted
13	Hampton Roads Sanitation District		HRSD	Received
14	Midwestern Regional Climate Center (MRCC)	CDMP 19th Century Forts and Voluntary Observers Database	FORTS	Formatted
15	National Weather Service (NWS) Mid-Atlantic River Forecast Center (MARFC)	Integrated Flood Observing and Warning System	IFLOWS	Formatted
16	National Oceanic and Atmospheric Administration (NOAA)	National Estuarine Research Reserve	NERRS	Formatted
17	National Atmospheric Deposition Program (NADP)	National Trends Network	NADP	Formatted
18	North Carolina State University, State Climate Office (NCSU)	North Carolina Environment & Climate Observing Network	ECONet	Formatted
19	Tennessee Valley Authority (TVA)	Rainfall Gauge Data	TVA	Formatted
21	U.S. Dept of Agriculture (USDA), Forest Service	Remote Automated Weather Station Network	RAWS	Formatted
22	U.S. Dept of Agriculture (USDA), Natural Resources Conservation Service (NRCS)	Soil Climate Analysis Network	SCAN	Formatted
24	University of Albany	New York State Mesonet	NYS	Formatted

FID	Data Provider	Dataset name	Abbr.	Status
25	University of Delaware, Center for Environmental Monitoring & Analysis	Delaware Environmental Observing System	DEOS	Formatted
26	University of Georgia	Georgia Weather Network	GWN	Formatted
27	Western Kentucky University	Kentucky Mesonet	KYM	Formatted

The following datasets were not used after investigation and review of periods of record and data quality: Automatic Position Reporting System WX NET/Citizen Weather Observer Program, Synoptic Weather, Maryland Department of Transportation Road Weather Network, Pennsylvania State University Environmental Monitoring Network, and WeatherSTEM.2.1.2.

2.1.2. Station metadata screening

In this reporting period, we continue to perform manual metadata inspection for datasets formatted (Table 2). See previous report on methodology here: October - December, 2023 QPR Report.

2.1.3. Station cleanup

In this reporting period, we finalized the first round of cleanup for the colocated NCEI datasets, using the station cleanup visualization dashboard software, documented in the previous October - December, 2023 QPR Report. For more information on station cleanup investigation, please refer to the previous January - March, 2024 QPR Report.

2.1.4. Mean Annual Maxima (MAM) grids for base durations

During this reporting period, we continued to explore in-house development of mean annual maxima (MAM) grids for this project area. Using stepwise multiple regression, we are attempting to determine the most critical covariates in this project area based on mean squared error and R^2 to derive the mean annual maxima grids that we can then use to interpolate at-station regional estimates to 30-arc-sec grids, following the NOAA Atlas 14 interpolation process.

For this analysis, we have identified several different spatial covariates, belonging to three different categories: static variables, taken directly from source datasets (e.g., elevation, slope, aspect, latitude, longitude, and distance to coast); derived variables, based on journal publications (e.g., southness, eastness, height above local terrain, and nearby surface water proportion, a.k.a. "lake effect index"); and model/climatology based variables (e.g., PRISM mean annual precipitation, MAM derived from NCAR's CONUS404).

Initial analysis selects 7 of 11 covariates, including MAM grids derived from NCAR'S CONUS404. Using stepwise multiple regression with background error correction via ordinary kriging, this initial analysis produced a cross-validation $R^2 \approx 0.90$. Error standard deviations are ±6-7% over the Volume 13 area for 1-day duration. In the next reporting period, we will continue evaluating spatial covariates selected and will extend the analysis to other base durations needed for development of preliminary estimates.

2.1.5 Extraction and quality control of annual maximum series outliers

The precipitation frequency analysis approach we used in this project is based on AMS analysis across a range of durations. AMS for each station whose data were formatted were obtained by extracting the highest precipitation amount for a particular duration in each successive calendar year. AMS at stations formatted during this period were extracted for all durations equal to or longer than the base duration (or reporting interval) up to 60 days. The criteria for extraction were designed to exclude maxima if there were too many missing or accumulated data during the year, especially during critical months when precipitation maxima were most likely to occur. All annual maxima that resulted from accumulated data were flagged and screened to ensure that the incomplete data did not result in erroneously low maxima. Since AMS data at both high and low extremities can considerably affect precipitation frequency estimates, they have to be carefully investigated and either corrected or removed from the AMS if due to measurement errors.

In this reporting period, we started the daily AMS quality control task. We use different statistical tests to identify high and low outliers in the distribution of at-station precipitation AMS. All identified outliers and other questionable maxima at base durations (1-hour and 1-day) are now being verified. First, they are mapped with concurrent measurements at nearby stations. If the values cannot be confirmed from similar measurements at nearby stations, they are investigated further using information from monthly climatological data publications, cooperative observation forms, historical storm reports, surface weather observations and monthly storm data reports obtained primarily from NCEI's Image and Publications Service/Common Access system and NERMS (NCEI Environmental Record Management System). Gridded precipitation products and other NEXRAD radar products are also used in some cases to verify and help disprove events for areas with good radar coverage.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (July - Sep 2024)

We will continue with data collection, reformatting, cleanup and data quality checks for NCEI stations. In parallel, we will continue to evaluate the spatial covariates, and will start investigating the regionalization approach for this project area.

2.3. PROJECT SCHEDULE

- Data collection, formatting, and initial quality control [Revised to FY Q2 2025; In Progress]
- Extraction of annual maximum series (AMS); additional quality control and data reliability tests (e.g., outliers, independence, consistency across durations, duplicate stations, candidates for merging)] [Revised to FY Q2 2025; In Progress]
- Regionalization and frequency analysis [Revised to FY Q2 2025; In Progress]
- Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [Revised to FY Q3 2025; In Progress]
- Peer review [Revised to FY Q3 2025; In Progress]
- Revision of PF estimates [FY Q3 2025]
- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [FY Q1 2026]
- Web publication [FY Q1 2026]

III. ATLAS 15: PRECIPITATION FREQUENCY STANDARD UPDATE

NOAA has received federal funding under the Bipartisan Infrastructure Law to revise and update precipitation frequency estimates nationwide to account for temporal nonstationarity and the integration of future climate projections. Once completed, this update will be known as NOAA Atlas 15 and will provide civil engineers and other design professionals with consistent, high-quality, authoritative rainfall estimates that have continuous spatial coverage across the U.S. and affiliated territories. For more information on the initiation of Atlas 15 development, please refer to July - Sept, 2023 Progress Report.

NOAA Atlas 15 will contain two volumes. Volume 1 will use the latest observed precipitation data and nonstationary statistical methods to generate spatially continuous precipitation frequency estimates that represent the most current conditions. Volume 2 will leverage climate model outputs (e.g., CMIP5/6 models) to develop the adjustment factors that extend Volume 1 estimates into the future. For more information on the timeline for the development and deployment of updated authoritative Atlas 15 precipitation frequency estimates nationwide, please refer to the Atlas 15 Flyer.

The first major milestone for this project is the development and publication of the NOAA Atlas 15 Pilot study. The NOAA Atlas 15 Pilot will provide a first look at the structure of the NOAA Atlas 15 dataset over the state of Montana to collect early feedback on development frameworks and Web dissemination strategies. With the Pilot release, the intention is to demonstrate the nature of the data and help ensure practitioners have the precipitation information they need upon final publication.

The NOAA Atlas 15 Pilot will cover a subset of storm durations (1 hour to 10 days) and average annual exceedance probabilities (50% to 1%), and will be presented as two volumes. The NOAA Atlas 15 Pilot Volume 1 estimates are based on historical observations and provide estimates for the year of 2023. The NOAA Atlas 15 Pilot Volume 2 estimates are developed by applying adjustment factors to the 2023 Volume 1 estimates (i.e. future relative changes obtained from downscaled climate model data). Currently, the plan for the NOAA Atlas 15 pilot release is by the end of FY 2024.

IV. OTHER

4.1. FREQUENCY ANALYSIS OF RECENT HISTORICAL STORM EVENTS

HDSC creates maps of annual exceedance probabilities (AEPs) for selected significant storm events for which observed precipitation amounts have AEP of 1/500 or less over a large area for at least one duration. AEP is the probability of exceeding a given amount of rainfall for a given duration at least once in any given year at a given location. It is an indicator of the rarity of rainfall amounts and is used as the basis of hydrologic design. For the AEP analysis, we look at a range of durations and select one or two critical durations to analyze which show the lowest exceedance probabilities for the largest area, i.e., the “worst case(s).” Since, for a given event, the beginning and end of the worst case period are not necessarily the same for all locations, the AEP maps represent isohyets within the whole event. The maps, occasionally accompanied with extra information about the storm, are available for download from the AEP Storm Analysis page. During this reporting period, we analyzed two rainfall events:

- 48-hour & 7-day rainfall for the Midwest in June 2024
- 6-hour, 12-hour, and 24-hour rainfall for Northern Minnesota in June 2024

4.1.1 MIDWEST

Catastrophic flooding occurred in the midwest due to the combination of a stalled frontal boundary and a moist air mass that settled over the region. Several rounds of training thunderstorms formed along this frontal boundary over several days. Several NWS weather forecasts offices had writeups about this event including: NWS Sioux Falls, NWS Des Moines, and NWS La Crosse

We analyzed AEPs for this event for several durations and decided to create AEP maps for 48-hour and 7-day periods. We chose multiple durations to show areas that were affected by the heavy shorter bursts of precipitation, as well as the cumulative effect of multiple days of bursts of rainfall. Areas that experienced the maximum rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%) are shown on the maps in Figures 4-6. Precipitation frequency estimates used in the analysis were from NOAA Atlas 14 Volume 8. The underlying observed data came from the NCEI's multi-sensor Stage IV QPE Product.

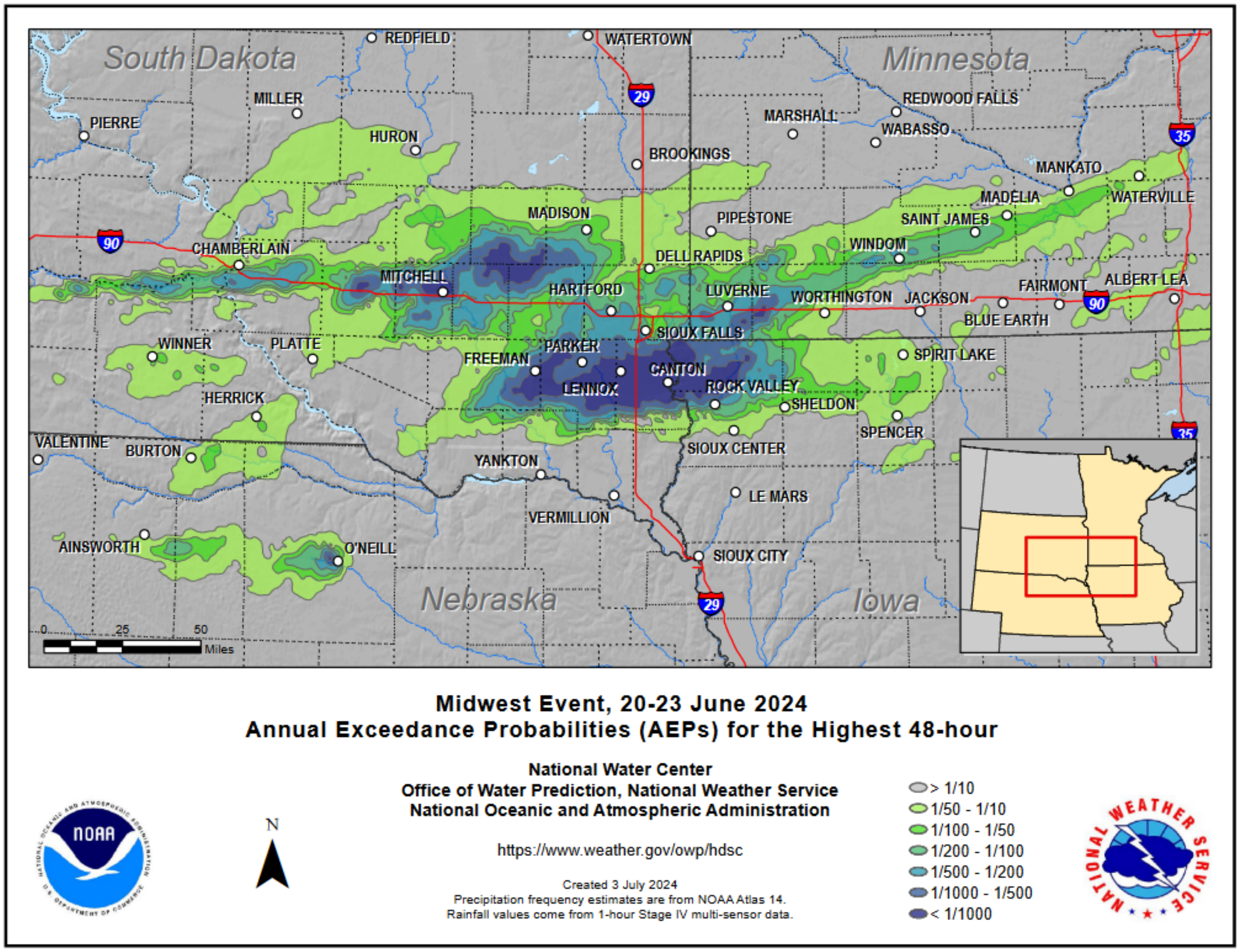

Figure 4. Annual exceedance probabilities for the worst case 48-hour rainfall during the Midwest event.

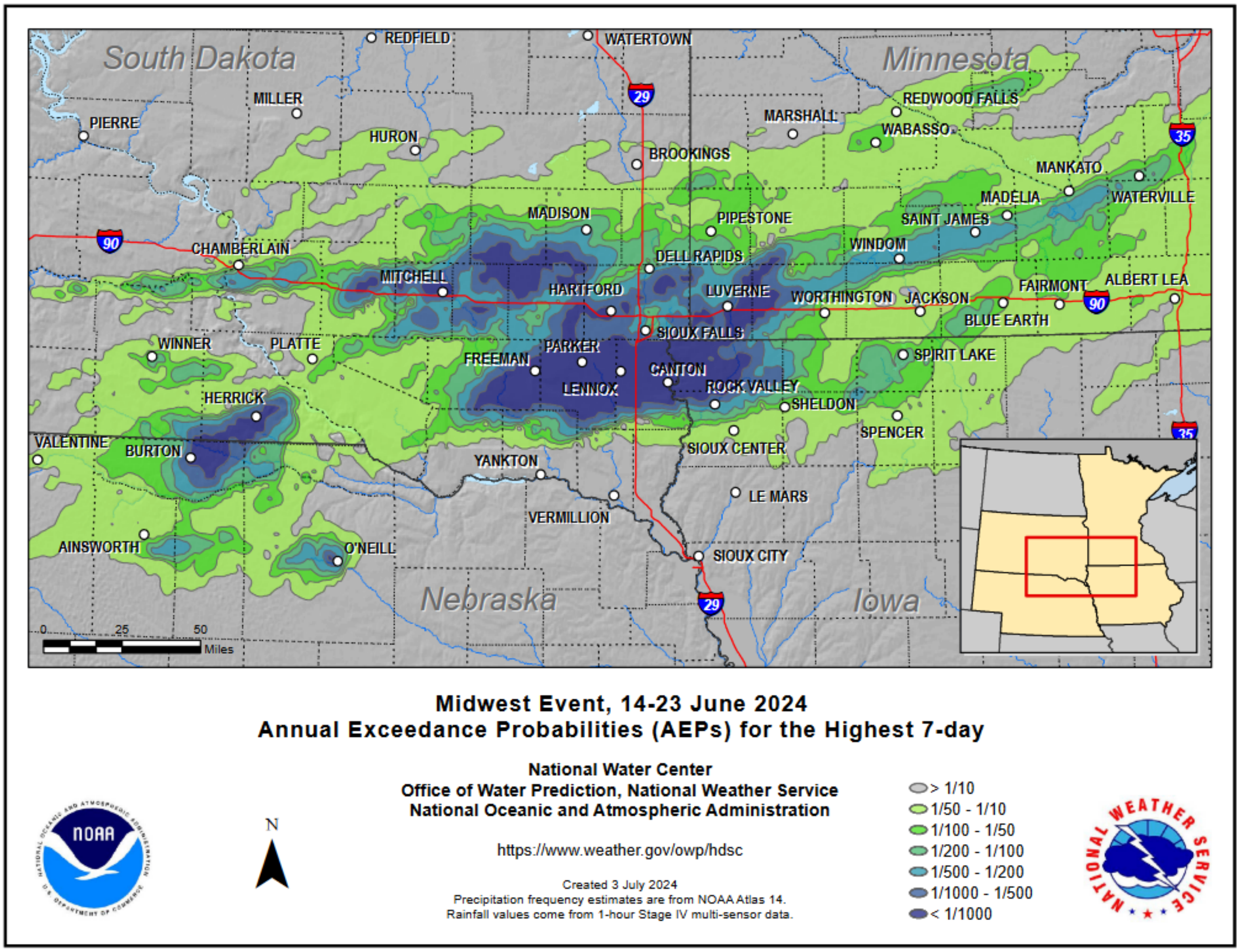

Figure 5. Annual exceedance probabilities for the worst case 7-day rainfall during the Midwest event.

4.1.2 NORTHERN MINNESOTA

Slow-moving training thunderstorms, associated with a stationary front, moved across northeastern Minnesota during the afternoon and into the evening of June 18, 2024. An in depth summary of this event can be found here: NWS Duluth.

We analyzed AEPs for this event for several durations and decided to create AEP maps for the 6-hour, 12-hour, and 24-hour periods. Areas that experienced the maximum rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%) are shown on the maps in Figures 4-6. Precipitation frequency estimates used in the analysis were from NOAA Atlas 14 Volume 8. The underlying observed data came from the NCEI's multi-sensor Stage IV QPE Product.

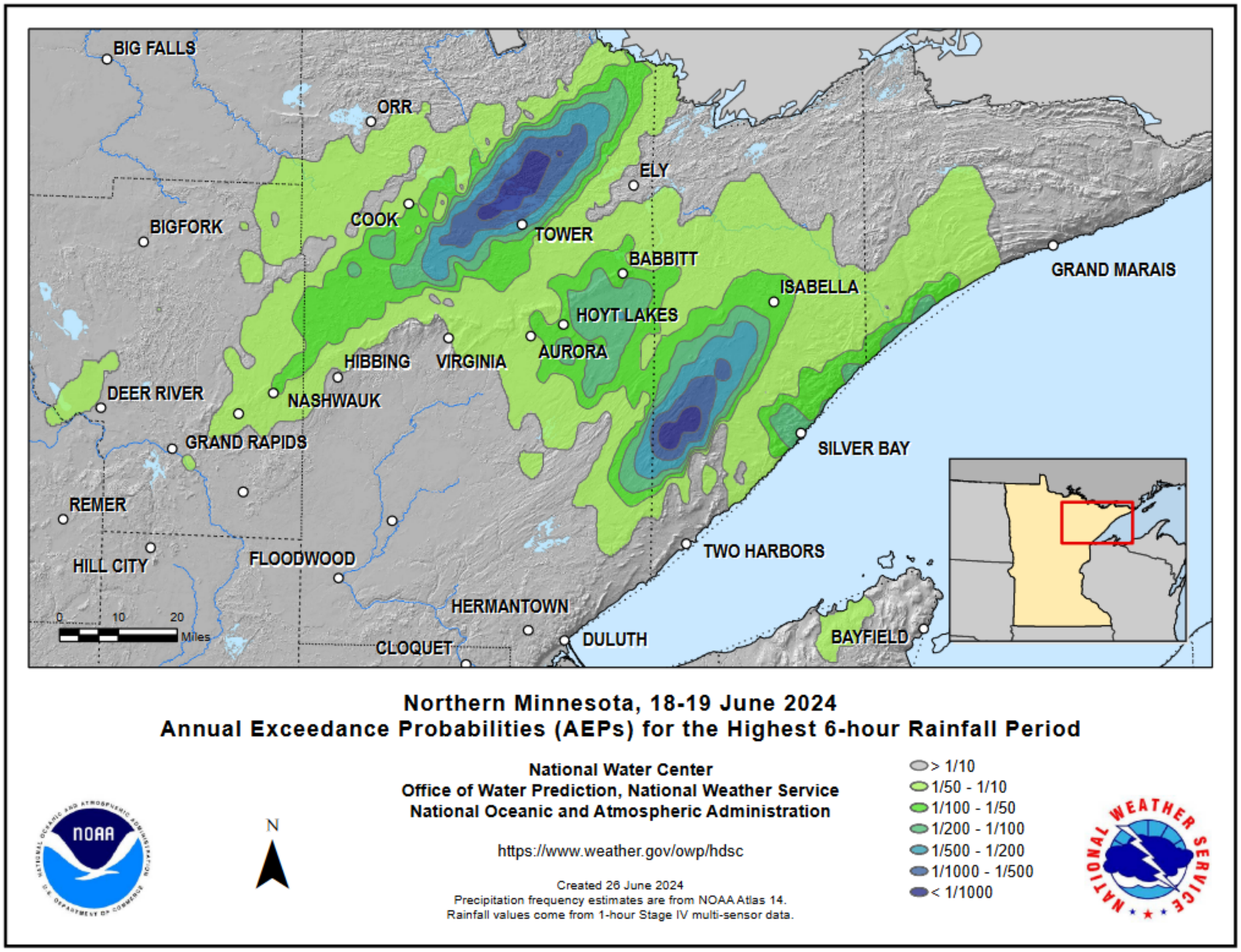

Figure 6. Annual exceedance probabilities for the worst case 6-hour rainfall during the Northern Minnesota event.

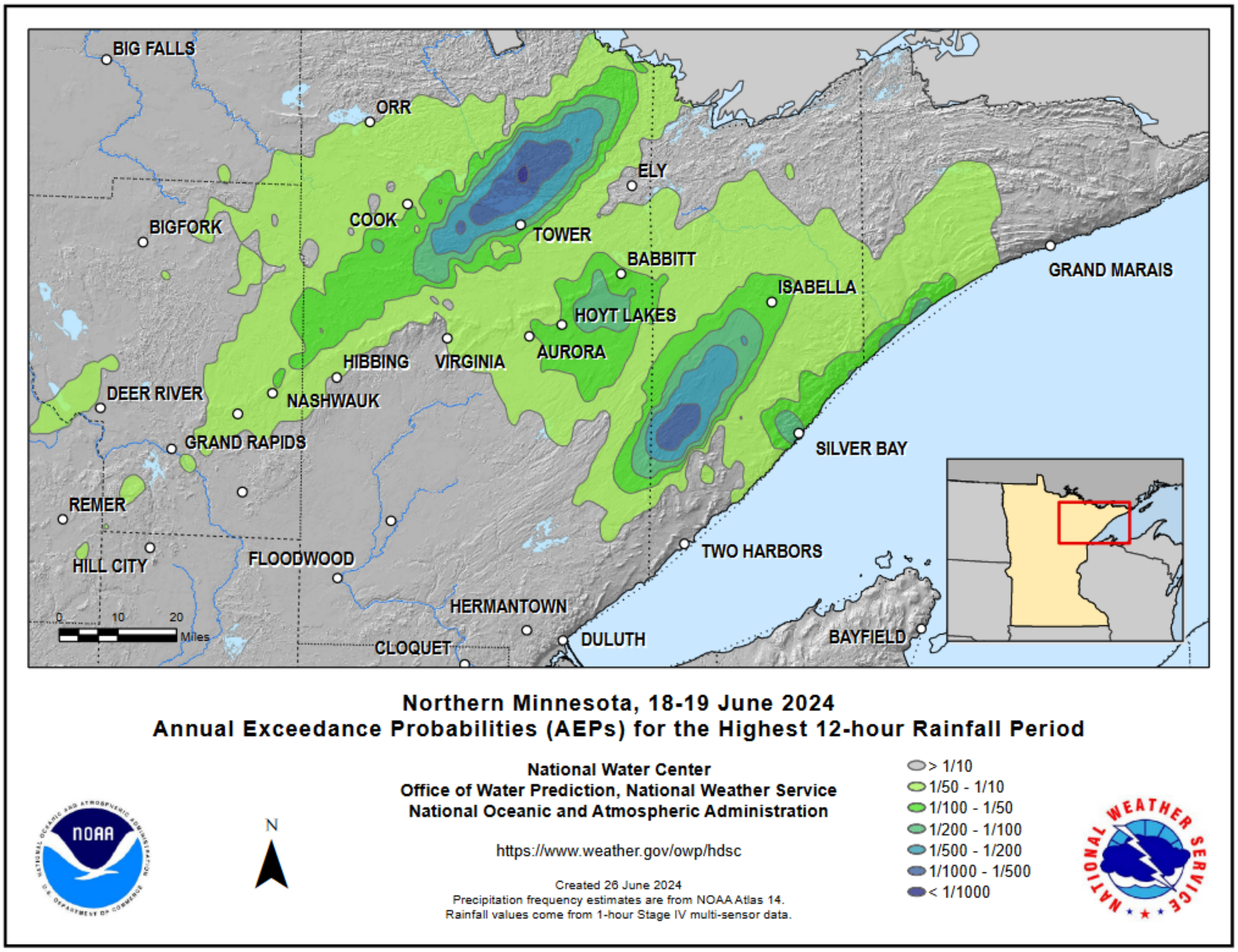

Figure 7. Annual exceedance probabilities for the worst case 12-hour rainfall during the Northern Minnesota event.

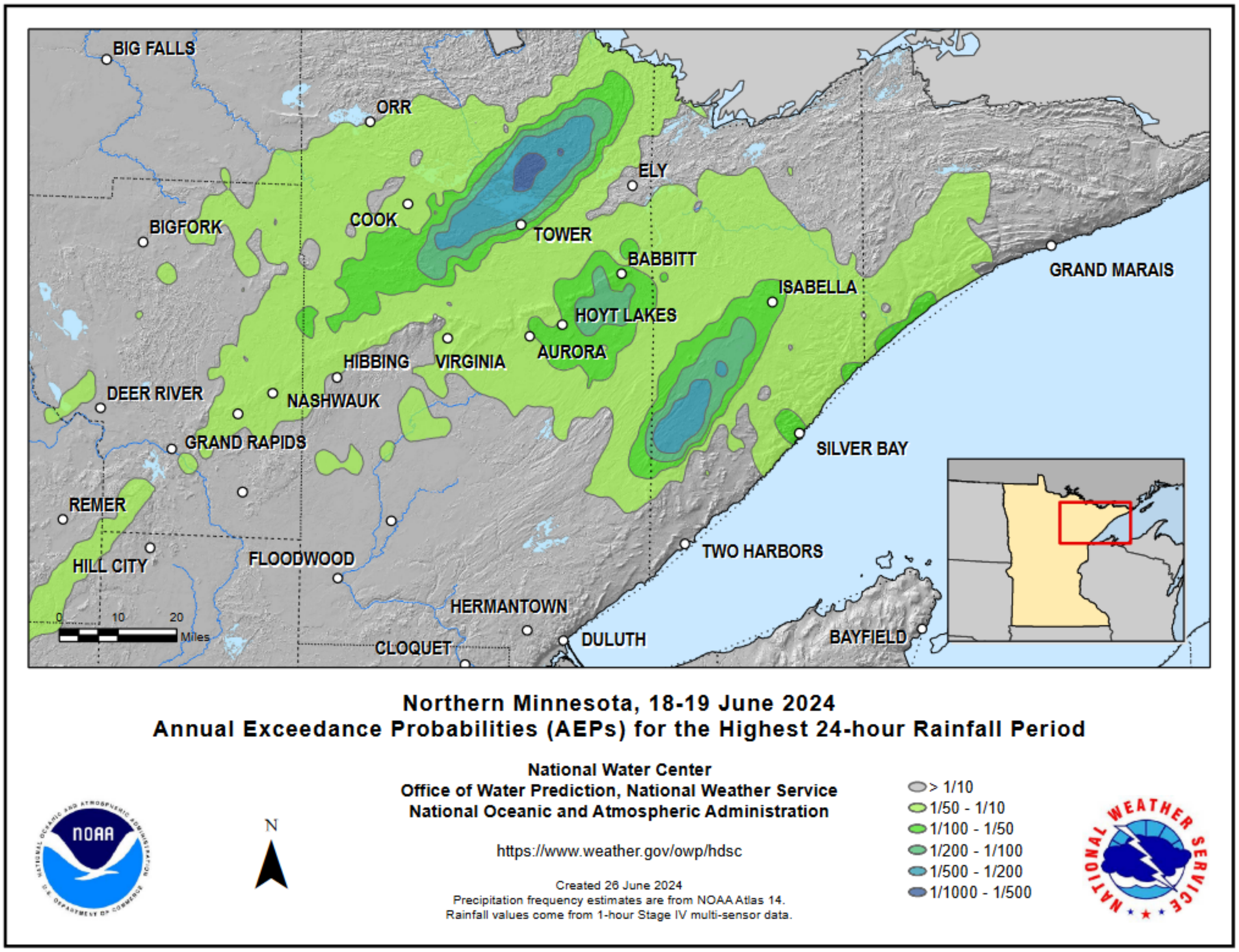

Figure 8. Annual exceedance probabilities for the worst case 24-hour rainfall during the Northern Minnesota event.

4.2. CONFERENCES

Dr. Fernando Salas, NOAA/National Weather Service, presented at the 2024 AWRA Spring Specialty Conference in Tuscaloosa, Alabama, on the topic of the NOAA Atlas 15 and the new National Water Prediction Service, on April 8, 2024.

Sandra Pavlovic, NOAA/National Weather Service, provided an update on the NOAA Atlas 15 during the NOAA-FHWA meeting on April 22, 2024.

Sandra Pavlovic, NOAA/National Weather Service, gave a presentation on the NOAA Atlas 15 at the 2024 ASFPM Annual Meeting in Salt Lake City, Utah, on June 26, 2024.

Janel Hanrahan and Michael St. Laurent participated in the June 25-26, 2024 Workshop of the ASCE-NOAA Task Force on Climate Resilience in Engineering Practice, in Reston, VA.