Hydrometeorological Design Studies Center
Progress Report for Period
1 April to 30 June 2023

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

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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.

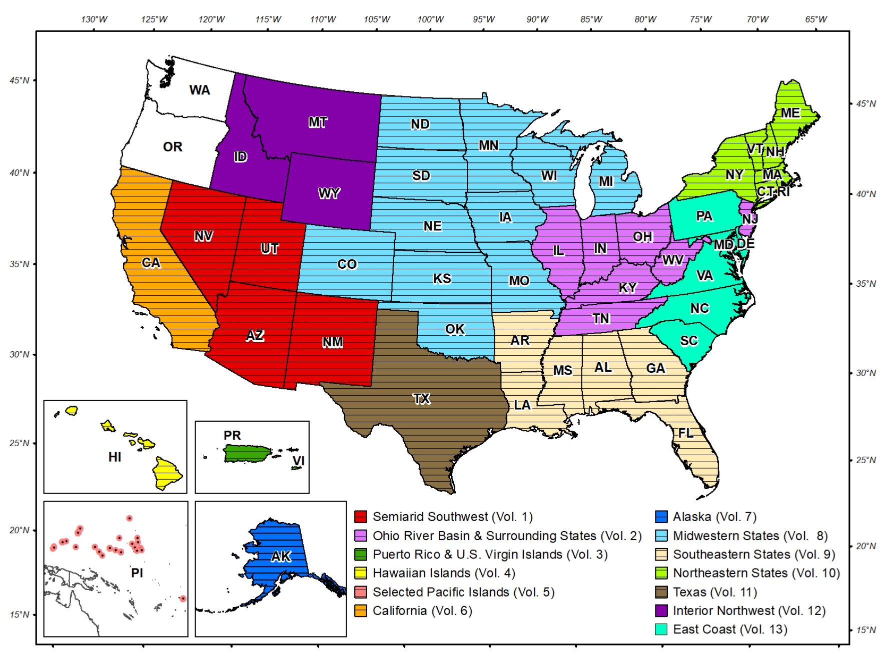

Figure 1. States or territories associated with each of the volumes of the Atlas.

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 has been revised to Q2 of 2024, due to delays with availability of personnel to support the development of two volumes.

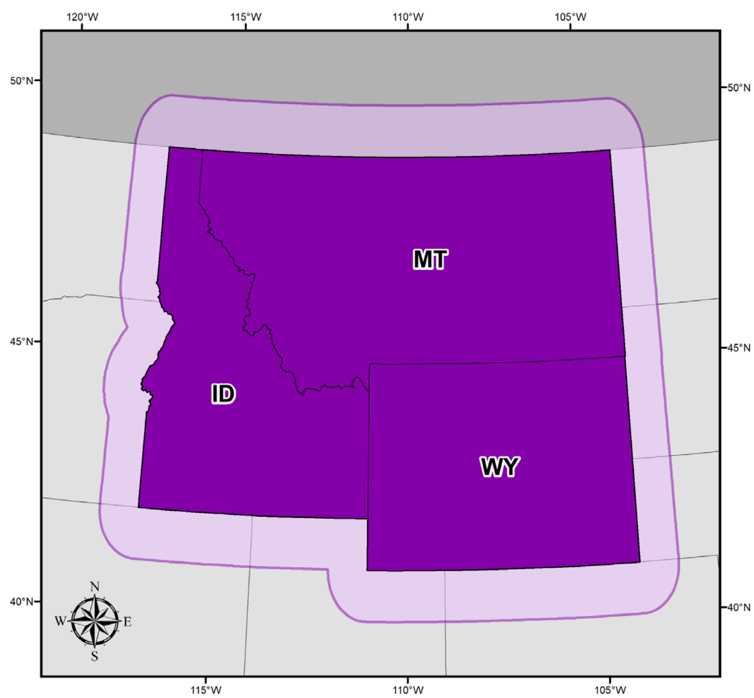

Figure 2. NOAA Atlas 14, Volume 12 extended project area (shown in purple).

In the reporting period of April 1 to June 30, 2023, we conducted quality control checks for 15-minute stations for all durations, spatial review of mean annual maximum grids, regionalization, and development of precipitation frequency estimates for 2-year and 100-year as well as the peer review webpage. The following sections provide a more detailed account of the significant tasks accomplished during this reporting period.

1.1. PROGRESS IN THIS REPORTING PERIOD (Apr - June 2023)

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. AMS quality control

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.

The 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. 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, and monthly storm data reports obtained primarily from the NCEI's Image and Publication System (IPS). Additional resources, such as historical storm reports and surface weather observations, are accessed through NCEI's Environmental Document Access and Display System, Version 2 (EV2). 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.

In this reporting period, we completed work on the 15-minute AMS quality control task for 15-min, 30-min, 45-min, 60-min, 90-min, and 120-m. Overall, all 15-minute with more than 15 years of data were reviewed, including 369 high outliers. A total of 475 data corrections were implemented.

1.1.2. Spatial 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, two 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 and 10-day durations. In the process, we reviewed MAM spatial patterns for each station looking for inconsistencies relative to MAMs at nearby stations in order to identify locations where MAMs are affected by short periods of record, missed winter events or missed several extreme events. We also investigate any inconsistent areas that are unduly influenced by the interpolation process or a lack of stations. Flagged MAMs were investigated and either adjusted or removed from the analysis. The development of final gridded MAM estimates will require several iterations with the PRISM group.

1.1.3. Regionalization

Regional approaches to frequency analysis use data from stations that are expected to have similar frequency distributions to yield more accurate estimates of extreme quantiles than approaches that use only data from a single station. In recent NOAA Atlas 14 Volumes, we used the region of influence regional frequency analysis approach where each station is assigned its own region with a potentially unique combination of nearby stations.

For this project area, initial regions were defined based on stations' distances from a target station, elevation differences, inspection of their locations with respect to mountain ridges, and assessment of similarities/dissimilarities in the progression of relevant L-moment statistics across durations for over 1500 stations. During this process, some inconsistent stations were removed from the analysis, particularly in dense network areas where nearby stations have much longer records.

Depth-duration-frequency curves were then computed for all gauged locations using a regional frequency analysis approach based on Generalized Extreme Value distribution parameterized via L-moment statistics.

1.1.4. Development of gridded PF estimates (2-year/100-year) and analysis of spatial patterns

In NOAA Atlas 14, the interpolated MAM grids together with at-station precipitation frequency estimates are the basis for calculation of gridded precipitation frequency estimates and corresponding upper and lower bounds of the 90% confidence interval. For a selected duration, development of precipitation frequency grids utilizes the inherently strong (zero-intercept) linear relationship that exists between consecutive precipitation frequency estimates, as well as between 2-year precipitation frequency estimates and MAM.

During this reporting period, we developed gridded precipitation frequency estimates for durations between 1-hour and 10-days and for up to 100-year average recurrence intervals (ARIs). Presently, we are reviewing maps of the resulting estimates for the 2-year and 100-year ARIs. Inconsistent estimates or unreasonable patterns are resolved on a case-by-case basis in various ways: by manually adjusting the value to reflect expected patterns, omitting the station from the analysis, or by adding anchoring estimates at critical ungauged locations.

1.1.5. Development of a web page for the peer review

All NOAA Atlas 14 Volumes are subject to peer review which provides critical feedback on the reasonableness of DDF curves and spatial patterns in interpolated precipitation frequency estimates across durations and frequencies, and accuracy of station metadata. In September, we will send out an invitation for a review of preliminary estimates to potential reviewers suggested by funding agencies as well as subscribers to our list server. All information needed for the review will be provided via a web page that is currently being constructed specifically for that purpose. The reviewers will be asked to provide feedback on the reasonableness of point precipitation frequency estimates, their spatial patterns, and station metadata.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (July - Sep 2023)

A large portion of the work in the next reporting period will plan on completing the regionalization task and completing the review of spatial patterns of precipitation frequency estimates for Peer Review. We will derive and investigate depth-duration-frequency curves at gauged locations and interpolate estimates at a high resolution grid. We will complete the analysis of spatial patterns in 2-year and 100-year precipitation frequency estimates in preparation for the peer review of initial estimates that is expected to take place in September.

The project milestone schedule has been revised to align with the availability of funds and personnel (current and projected).

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 [Revised to Q3 2023]
- Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [Revised to Q4 2023]
- Peer review [Q4 2023]
- Revision of PF estimates [Q2 2024]

- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [Q2 2024]
- Web publication [Q2 2024]

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 5). 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. During this reporting period, OWP worked to establish a NOAA Atlas 14 focused grant through the NOAA Cooperative Institute for Research to Operations in Hydrology (CIROH) to comprehensively support research and development activities across multiple Atlas 14 volumes. The grant award is pending as of this reporting period.

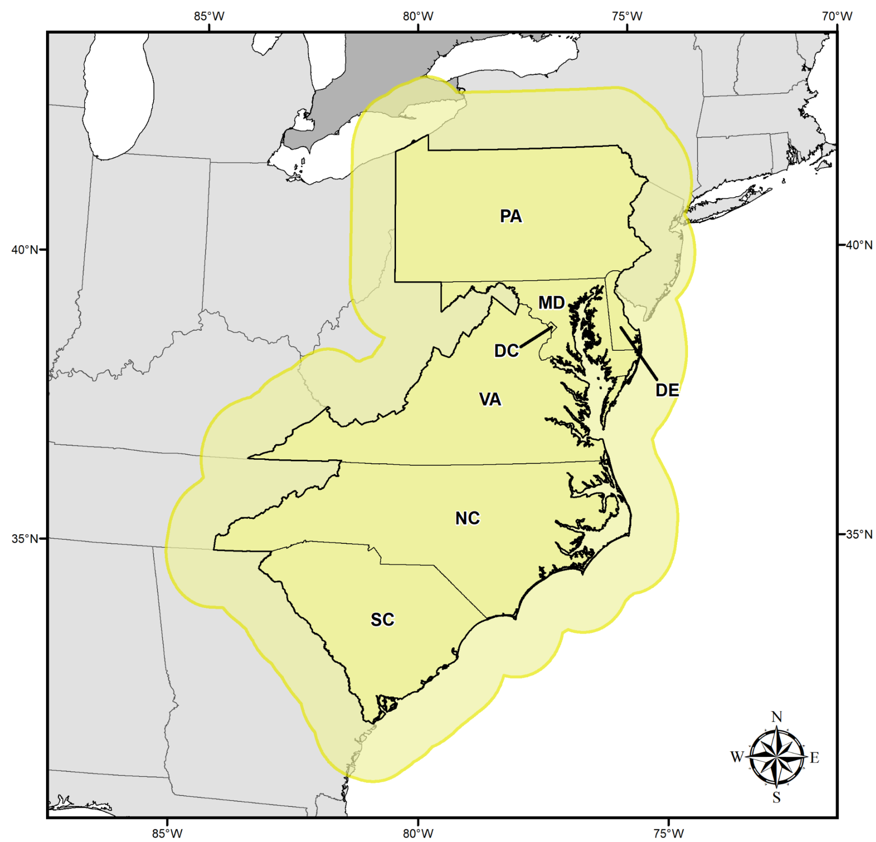

Figure 6. NOAA Atlas 14, Volume 13 extended project area (shown in yellow).

2.1. PROGRESS IN THIS REPORTING PERIOD (Apr - June 2023)

2.1.1. Data collection and data screening

During the April 1 to June 30, 2023 reporting period, we compiled a list of precipitation networks that will be considered for the development of the Atlas 14 Volume 13 estimates, and formatting the NCEI datasets for this project area. 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.

In support of this project, we are interested in collecting all available precipitation datasets (daily, hourly, 5-minute, etc.) for stations in Delaware, Maryland, North Carolina, Pennsylvania, South Carolina, Virginia, and Washington D.C. as well as in adjacent portions of neighboring states (Georgia, Kentucky, New York, New Jersey, Ohio, Tennessee, West Virginia) and also in Canada. We welcome any information on the data for this project area. If you have any relevant information, please contact us at hdsc.questions@noaa.gov.

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	GHCN-DAILY	Formatted
4		Environment Canada	GHCN-DAILY	Formatted
5		Integrated Surface Data (Lite)	ISD_LITE	Formatted
6		Local Climatological Data	LCD	Formatted
7		Hourly Precipitation Data (HPD) v1.0 Beta and v2.0 Beta	HPDv1, HPDv2	Formatted
8		United States CoCORAHS	GHCN-DAILY	Formatted
9		Canada CoCORAHS	GHCN-DAILY	Formatted
10		Weather Bureau Army Navy (WBAN)	GHCN-DAILY	Formatted
11		U.S. Climate Reference Network	USCRN	Formatted
12	Aberdeen Proving Ground	Phillips Airfield Weather Station	PAWS	Received

FID	Data Provider	Dataset name	Abbr.	Status
13	Hampton Roads Sanitation District		HRSD	Contacted
14	Midwestern Regional Climate Center (MRCC)	CDMP 19th Century Forts and Voluntary Observers Database	FORTS	Received
15	National Weather Service (NWS) Mid-Atlantic River Forecast Center (MARFC)	Integrated Flood Observing and Warning System	IFLOWS	Received
16	National Oceanic and Atmospheric Administration (NOAA)	National Estuarine Research Reserve	NERRS	Received
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	Partially Received
19	Tennessee Valley Authority (TVA)	Rainfall Gauge Data	TVA	Contacted
20	U.S. Department of Agriculture (USDA)	Agriculture Research Service	ARS	Received
21	U.S. Dept of Agriculture (USDA), Forest Service	Remote Automated Weather Station Network	RAWS	Received
22	U.S. Dept of Agriculture (USDA), Natural Resources Conservation Service (NRCS)	Soil Climate Analysis Network	SCAN	Received
23	U.S. Geological Survey (USGS)	National Water Information System	NWIS	Investigating
24	University of Albany	New York State Mesonet	NYS	Received
25	University of Delaware, Center for Environmental Monitoring & Analysis	Delaware Environmental Observing System	DEOS	Received
26	University of Georgia	Georgia Weather Network	GWN	Received
27	Western Kentucky University	Kentucky Mesonet	KYM	Contacted

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. Station metadata screening

Python-based software has been developed to modernize and automate our station metadata quality control system. To ensure accuracy in NCEI datasets, any discrepancies in the elevation, latitude, and longitude of individual stations are first rectified using the latest station metadata entry from the NCEI's Enhanced Master Station History Report (EMSHR). Furthermore (and for all other datasets), station location is marked for additional review by conducting two tests: elevation differences over 150m and locations outside of the 1-minute precision box. In the first test, DEM was derived for all stations, and then the extracted DEM was compared to the station metadata elevation to determine whether the station elevation was accurate. Next, a 150 m absolute difference threshold is applied to select all stations with an elevation difference relative to the DEM that exceeds 150 m. The minimum and maximum elevations from the DEM are extracted after constructing a one-minute square box around the center of all the stations from the preceding test. The station elevations that do not fall within the minimum and maximum DEM elevations are flagged for manual review. These tests are especially beneficial for stations whose precision is off by a few seconds, which can result in a location error of over a mile. 165 stations that could not be adjusted automatically based on the current data format were marked for manual review. The team began manually inspecting the station's metadata.

2.1.3. Investigating spatial covariates

In this reporting period, we explore the spatial covariates for this project area. We are exploring applying the stationary regional maximum likelihood approach for this volume. We are interested in identifying and incorporating spatial-varying covariates into the parameterization process, allowing parameters to vary in space at each grid point. For example, the spatial covariate, PRISM mean annual precipitation (MAP), is incorporated into the parameter optimization process, which allows for grid points to account for the effects of terrain.

For initial analysis, we have identified several different spatial covariates, including slope, latitude, effective terrain height, coastal proximity, PRISM MAP, elevation, etc. Using multiple regression, we are attempting to determine the most critical covariates in this project area based on mean squared error and R^2. After conducting an initial analysis, we have discovered that incorporating spatial-varying covariates into the parameterization process shows promise for achieving favorable results in this project area. As a result, we intend to continue with this analysis.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (July - Sep 2023)

We will continue with data collection, reformatting, and station metadata checks for NCEI stations. All collected data will be examined and formatted into a common format, where appropriate. In parallel, we will continue to

2.3. PROJECT SCHEDULE

- Data collection, formatting, and initial quality control [Q2 2023; 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)] [Q2 2024]
- Regionalization and frequency analysis [Q3 2024]

- Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [Q3 2024]
- Peer review [Q4 2024]
- Revision of PF estimates [Q3 2025]
- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [Q4 2025]
- Web publication [Q4 2025]

III. ATLAS 15: PRECIPITATION FREQUENCY STANDARD UPDATE

We are delighted to announce that 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. Moreover, NOAA Atlas 15 will leverage the most recently available precipitation observations, and will provide enhanced supplemental products that will enable the design of robust and resilient climate ready civil infrastructure based on a rigorous process vetted through significant stakeholders interactions. NOAA Atlas 15 will be presented in two volumes to account for a changing climate. Volume 1 will account for temporal trends in historical observations, and Volume 2 will use future climate model projections to generate adjustment factors that can be used with Volume 1 estimates to project future conditions.

NOAA has established contract vehicles and grants to support this effort as well as a detailed project schedule with key milestones for the duration of the entire project which is expected to last 4 years. Preliminary estimates over the contiguous U.S. will be released in 2025 ahead of the peer-reviewed publication in 2026. With contracts and grants in place, a technical meeting has been planned for July 10, 2023 to bring together the dedicated teams that will be working towards achieving project milestones, and we will provide regular updates to ensure transparency and collaboration.

IV. OTHER

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 data from the extreme rainfall event that took place in Fort Lauderdale Florida on 12 April 2023. For this event, we looked at a range of durations and selected the 12-hour duration to analyze. Areas that experienced the maximum 12-hour rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%) are shown on the map in Figure 4. Precipitation frequency estimates from NOAA Atlas 14 Volume 9 were used in the analysis. The underlying observed rainfall data came from 1-hour Stage IV multi-sensor precipitation estimates.

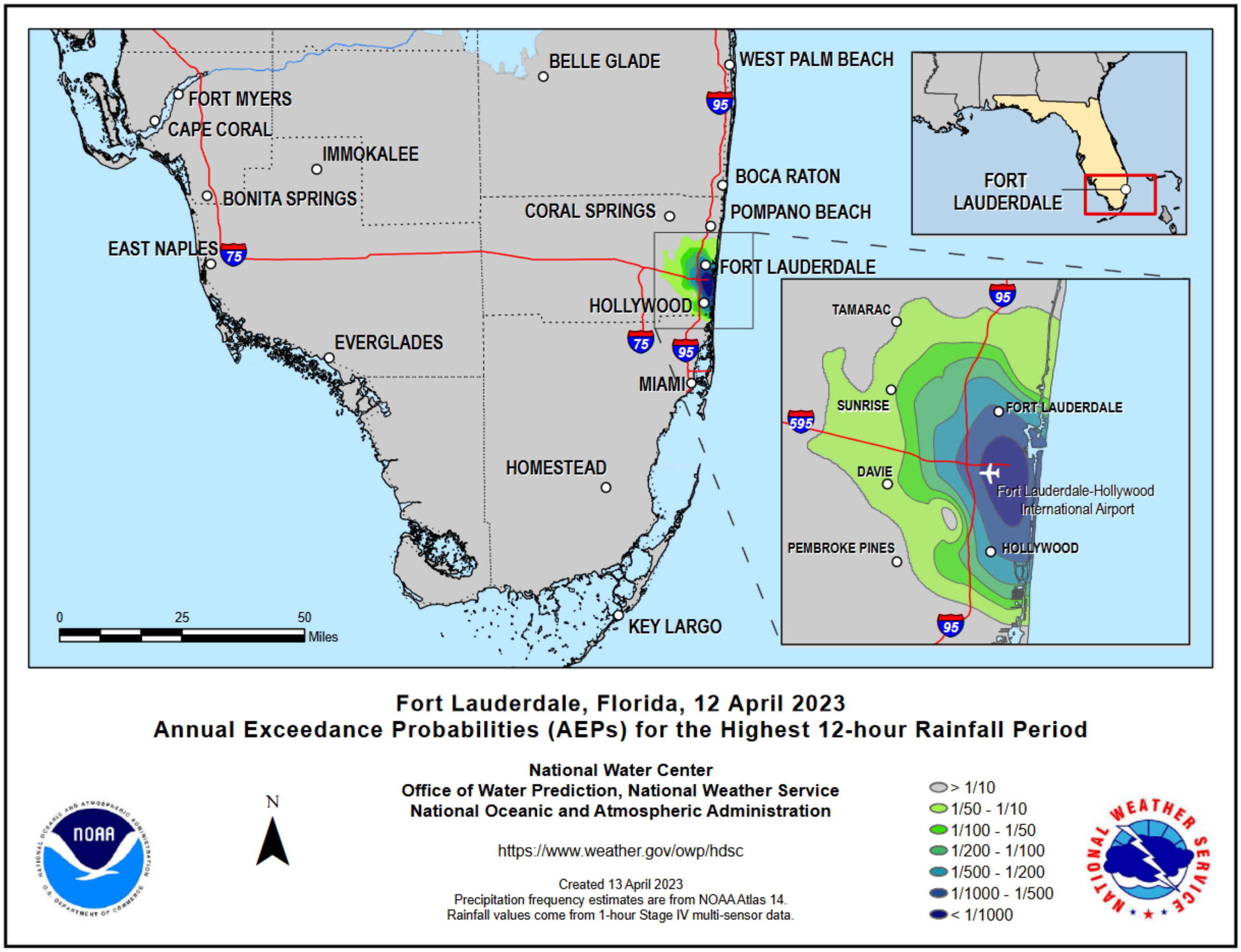

Figure 7. Annual exceedance probabilities for the worst case 12-hour rainfall during the Fort Lauderdale, FL event

2. CONFERENCES

The HDSC team has been keeping various stakeholders updated on the progress of the Atlas 15 project. Sandra Pavlovic recently provided a status update to the NOAA-DOT Partnership Team on April 3. On April 24, she also had the opportunity to brief the Stormwater Policy Forum organized by the National Municipal Stormwater Alliance and Water Environment Federation in Washington D.C. Additionally, Sandra attended and presented at the 2023 Association of State Floodplain Managers Annual Conference on May 10 and the 2023 Environmental & Water Resources Institute Annual Conference on May 25.