HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 April to 30 June 2016

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

July 2016

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; formerly, Office of Hydrologic Development and National Water Center)[1] of the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) has been updating precipitation frequency estimates for various parts of the United States and affiliated territories. Updated precipitation frequency estimates for durations from 5 minutes to 60 days and average recurrence intervals between 1- and 1,000-years, accompanied by additional relevant information (e.g., 95% confidence limits, temporal distributions, seasonality) are published in NOAA Atlas 14. All NOAA Atlas 14 products and documents 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, we have updated precipitation frequency estimates for Arizona, Nevada, New Mexico and Utah (Volume 1, 2004), Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia and West Virginia (Volume 2, 2004), Puerto Rico and U.S. Virgin Islands (Volume 3, 2006), Hawaiian Islands (Volume 4, 2009), Selected Pacific Islands (Volume 5, 2009), California (Volume 6, 2011), Alaska (Volume 7, 2011), Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin (Volume 8, 2013), Alabama, Arkansas, Florida, Georgia, Louisiana, and Mississippi (Volume 9, 2013), and Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (Volume 10, 2015). Since May 2015, HDSC has been working on updating precipitation frequency estimates for the state of Texas. We expect to publish them in mid-2018 in NOAA Atlas 14, Volume 11.

Funding for HDSC work comes from external sources. For recent volumes, most of the funds have come from the U.S. Army Corps of Engineers (USACE), Federal Highway Administration (FHWA) and State Departments of Transportation. These funds flow through the Transportation Pooled Fund (TPF) Program, which is set up to allow interested federal, state, and local agencies and other organizations to combine resources to support transportation relevant research studies. This requires only a single agreement between NWS and FHWA rather than many agreements with each entity providing funds. OWP has been working with FHWA and several Northwestern state agencies on securing funding to extend NOAA Atlas 14 coverage to the remaining five northwestern states: Idaho, Montana, Oregon, Washington, and Wyoming in Volume 12. An updated solicitation for this project will be listed on the TPF web page in the near future. For any inquiries regarding the status of this effort, please send an email to HDSC.questions@noaa.gov.

[1]*The Office of Hydrologic Development reorganized into the National Water Center in May 2015 which was recently renamed as the Office of Water Prediction (OWP) with locations in Silver Spring, MD, Tuscaloosa, AL, and Chanhassen, MN.*

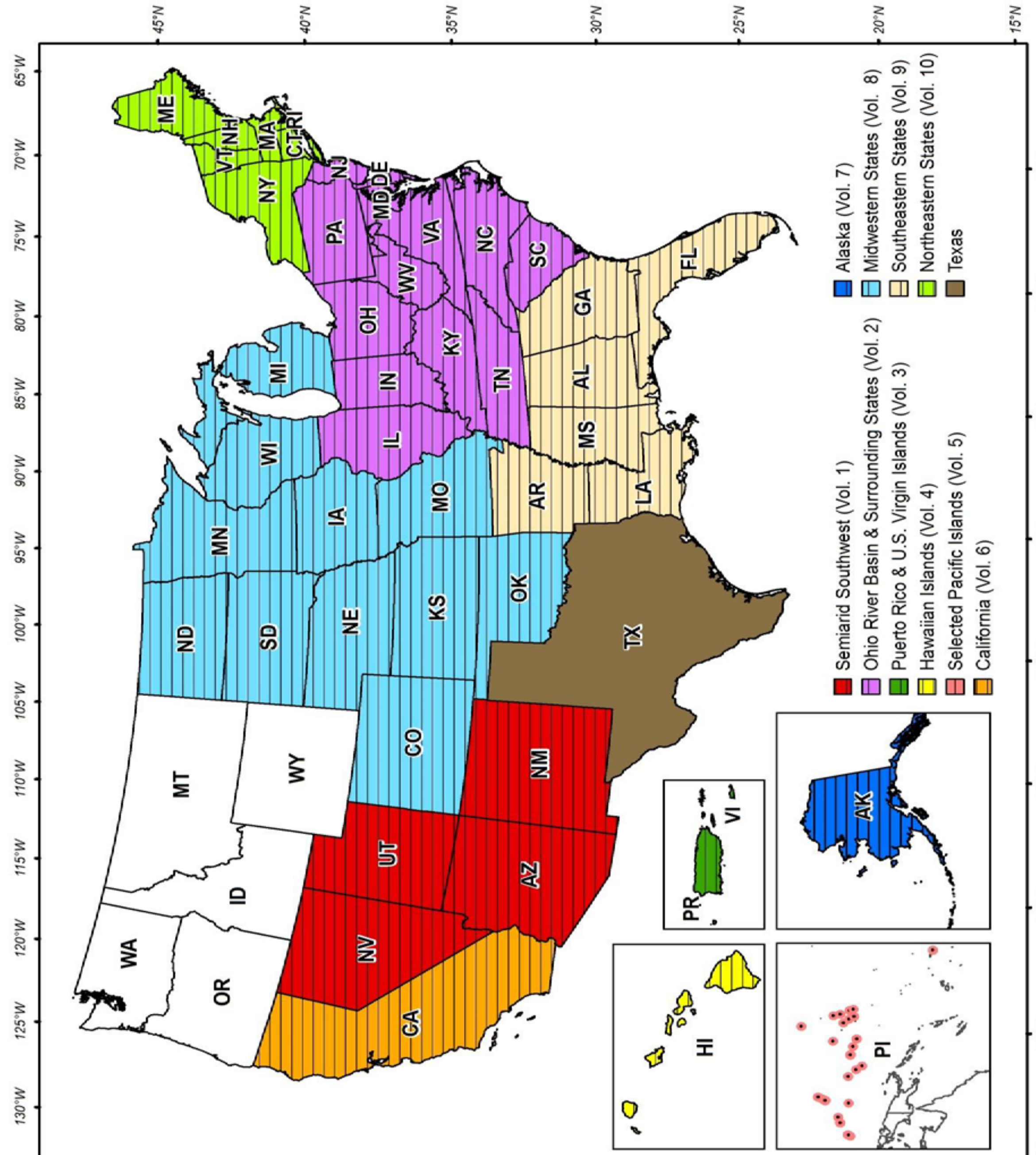

Figure 1. Current project area for Volume 11 (Texas) and project areas included in published Volumes 1 to 10.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1 PROGRESS IN THIS REPORTING PERIOD (Apr - Jun 2016)

Precipitation frequency estimates for the following seven northeastern states: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont were published on September 30, 2015, as NOAA Atlas 14, Volume 10. The estimates for any location in the project area, along with all related products except documentation, are available for download in a variety of formats through the Precipitation Frequency Data Server (PFDS).

Work on documentation describing the station metadata, data, and project methodology has been put on hold as of October 2015 until some funding issues are resolved.

1.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jul - Sep 2016)

We are hopeful that funding issues will be resolved soon, but we cannot anticipate the exact release date of the NOAA Atlas 14 Volume 10 document at this time. The document will be published here: http://www.nws.noaa.gov/oh/hdsc/currentpf.htm.

1.3 PROJECT SCHEDULE

Data collection, formatting, and initial quality control [Complete]

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) [Complete]

Regionalization and frequency analysis [Complete]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [Complete]

Peer review [Complete]

Revision of PF estimates [Complete]

Remaining tasks (e.g., development of gridded precipitation frequency estimates, confidence intervals, development of PFDS web pages) [Complete]

Web publication of estimates [Complete]

Web publication of Volume 10 document [TBD]

2. PRECIPITATION FREQUENCY PROJECT FOR TEXAS

2.1 PROGRESS IN THIS REPORTING PERIOD (Apr - Jun 2016)

The extended project area for the NOAA Atlas 14 Volume 11 precipitation frequency project includes the state of Texas and approximately a 1-degree buffer around the state (Figure 2). We began this project in May 2015 and expect to complete it in mid-2018.

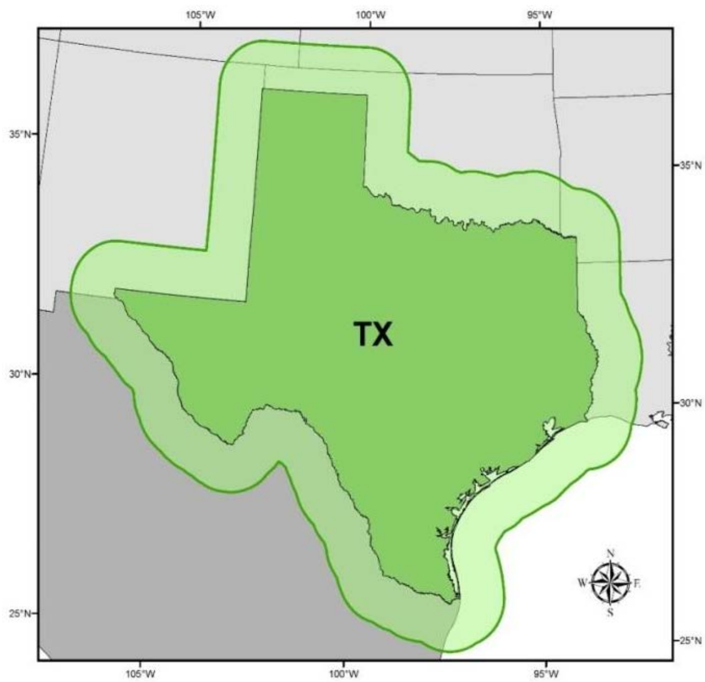

Figure 2. NOAA Atlas 14, Volume 11 extended project area (shown in green).

During this reporting period, we have made significant progress on data collection and formatting, annual maximum series extraction, station screening and quality control tasks. Below, we describe in more detail the major tasks performed during this reporting period.

2.1.1. Data collection and formatting

The primary source of data for NOAA Atlas 14 Volumes is the NOAA's National Centers for Environmental Information (NCEI), but we recognize that the NCEI's precipitation data may not be sufficient to accomplish the objectives of NOAA Atlas 14. Therefore, for each project area, we also collect the data from other Federal, State and local agencies.

For this project area we are trying to assemble all reliable precipitation data for stations in Texas, as well as in adjacent portions of neighboring states (Arkansas, Louisiana, New Mexico, and Oklahoma) and also in Mexico. Since we started this project, we have contacted numerous agencies for assistance with the data. During this reporting period, we continued reviewing the information provided to us and contacting other agencies which were indicated as additional sources of potentially useful data.

We format all data to a common format at one of three base durations (1-day, 1-hour, 15-minute) that correspond to the original reporting period. Data recorded at variable time steps are formatted at 15-minute increments. So far, we have formatted data for 7,541 stations from 16 datasets; they are listed in Table 1. Locations of daily stations formatted and processed as of this time are shown in Figure 3. Only stations with at least 30 years of AMS data (shown as red circles) will be considered for frequency analysis, although allowances may be made for isolated stations. Stations with less than 30 years of data, shown as black dots in the figure, will still be used in various quality control tasks; some of those stations may end up being used in the analysis through merging their data with data from nearby stations and from datasets not formatted yet. Similarly, Figures 4 and 5 show locations of stations recording at 1-hour and at sub-hourly durations, respectively, where stations with less than 20 years of AMS data are shown as black dots. Datasets grayed out in Table 1 are formatted but not processed yet, so stations from those datasets that pass minimum number of data-years requirement are not plotted on the maps.

Table 1. Datasets formatted as of this time. Datasets grayed out are formatted but not plotted in Fig. 3-5.

Source of data and dataset/network name (formatted and plotted on the map)	**Recording period**	**Number of stations**
NCEI - Automated Surface Observing System (ASOS)	1-min	81
NCEI - DSI 3260	15-min	352
NCEI - DSI 3240	1-hr	806
NCEI - Global Historical Climatology Network (GHCN)	1-day	5,302
NCEI - Unedited Local Climatological Data (ULCD)	1-hr	176
NCEI - Quality Controlled Local Climatological Data (QCLCD)	1-hr	266
City of Dallas ALERT Network	varying	62
Climate Database Modernization Program - 19th Century Forts and Voluntary Observers Database Build Project (FORTS)	1-day	26
Jefferson County Drainage District 6 ALERT Precipitation and Stream Level Network	varying	95
Servicio Meteorologico Nacional, Mexico	1-day	99
Tarrant Regional Water District (Greater Fort Worth area)/ Tarrant County Urban Flood Control Network	15-min	35
West Texas Mesonet	1-min, 15-min	95
National Atmospheric Deposition Program (NADP)	1-day	32
National Estuarine Research Reserve System (NERRS)	15-min, 1-hr	2
Remote Automatic Weather Stations (RAWS)	1-hr	108
Sabine River Authority Precipitation Data	1-day	4
TOTAL		**7,541**

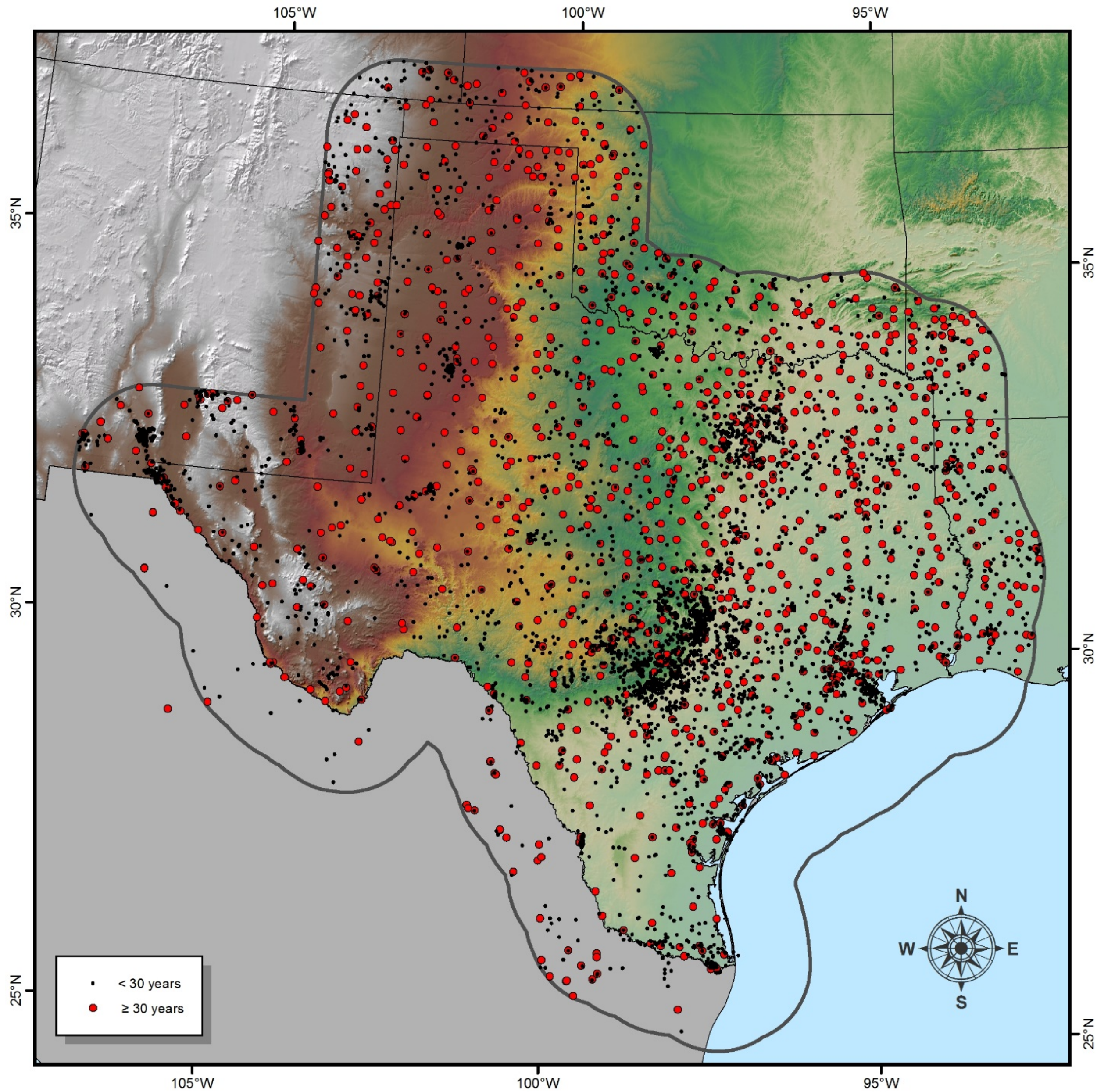

Figure 3. Map of stations recording at 1-day intervals formatted as of this time. Only stations shown as red circles (1048 of 5427 stations) will be considered in frequency analysis for durations between 1 day and 60 days.

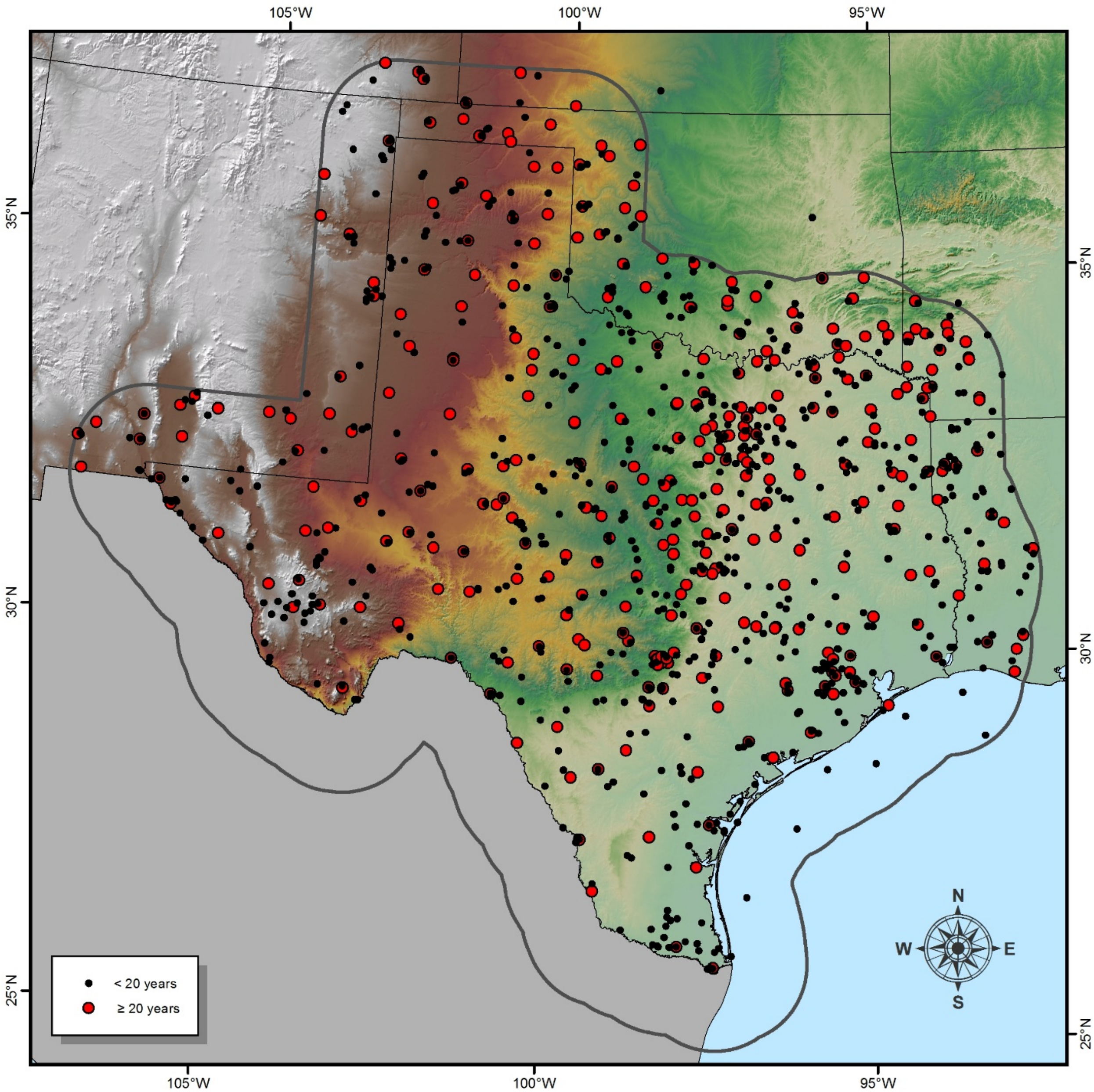

Figure 4. Map of stations recording at 1-hour interval formatted as if this time. Only stations shown as red circles (330 of 1248 stations) will be considered in frequency analysis for durations between 1 hour and 60 days.

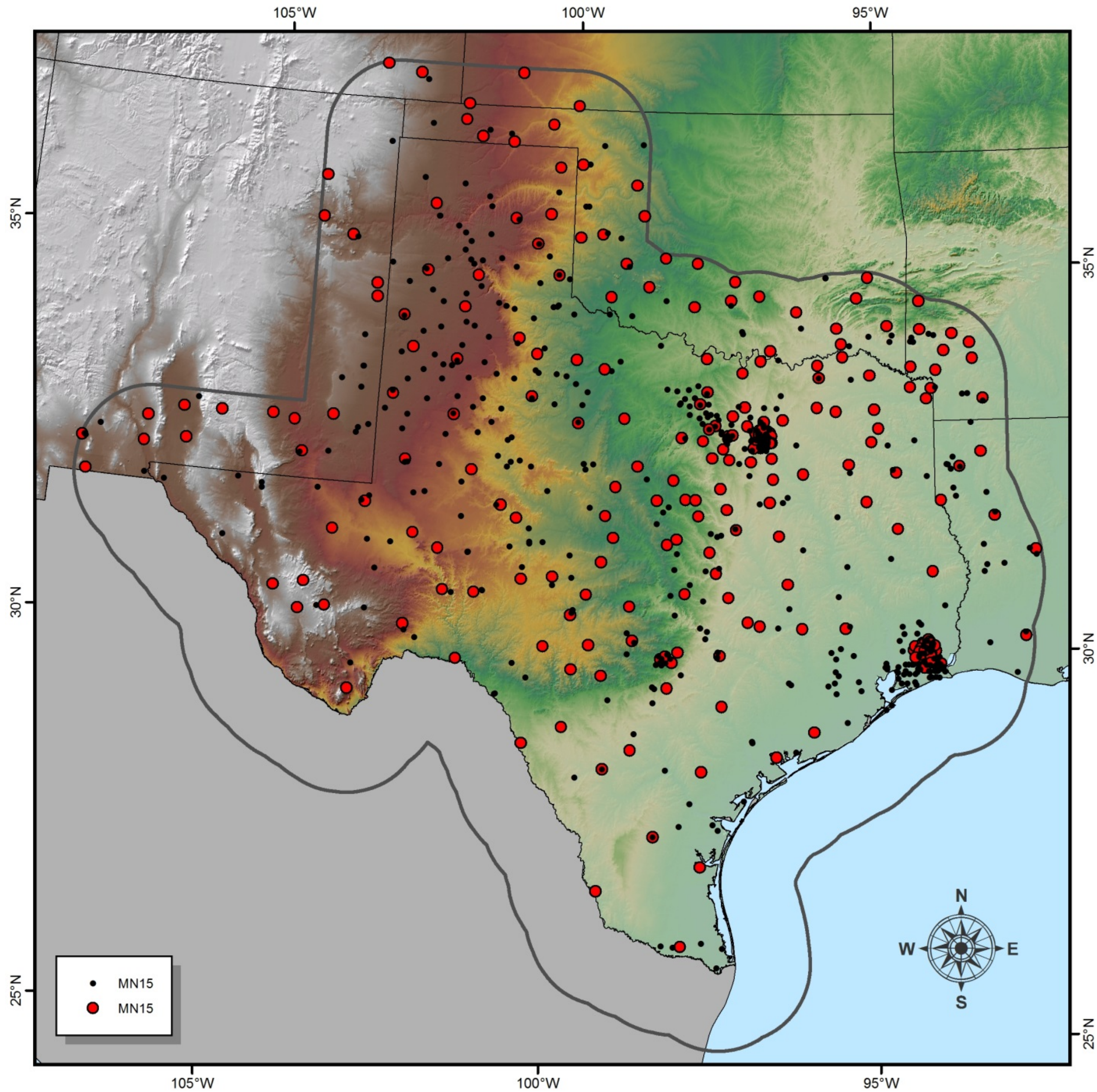

Figure 5. Map of stations recording at sub-hourly intervals formatted as of this time. Only stations shown as red circles (263 of 720 stations) will be considered in frequency analysis for durations between 15 minutes and 60 days.

Table 2 contains information on a status of collection and formatting tasks for additional datasets. Datasets indicated as "not used" generally contain information already included in other datasets, data assessed as not reliable for this specific purpose, or stations with very short periods of record deemed unsuitable for merging with any nearby station.

Table 2. Status of data collection and formatting for additional datasets.

Source of data and dataset/network name (when available)	Status
Harris County Flood Control District's Flood Warning System	formatting in progress
Mexico Hourly Data downloaded from Iowa IEM	
Oklahoma Mesonet Observation Network	
Texas Water Development Board	
Texas Commission on Environmental Quality (TCEQ) Air Quality Network	
Titus County Fresh Water Supply District No. 1	
USDA NRCS Soil Climate Analysis Network (SCAN)	
USGS Hydrologic Data for Urban Studies in Texas	
Edwards Aquifer Authority	waiting for data
Guadalupe-Blanco River Authority	
Lower Colorado River Authority Regional Met. Network (LCRA)	
International Boundary and Water Commission	contacted with data request
Lavaca/Navidad River Authority Gage Network	
Texas Evapotranspiration Network	
United States Bureau of Reclamation	
San Antonio River Authority	need contact information
Bexar County Urban Flood Control Network	not used
City of Austin ALERT Network	
Meteorological Assimilation Data Ingest System (MADIS)	
Northeast Texas Municipal Water District (NETMWD)	
PivoTrac Monitoring, LLC	
Road Weather Information System (RWIS)	
Union Pacific Railroad Weather Station Network	
USGS Water Data for the Nation	

We would like to thank all of those who responded to our inquiry and/or provided the data. We still welcome any information on the data for this project area and ask for help with collecting the data from datasets indicated as "need contact information". If you know about any datasets in addition to those listed in Tables 1 and 2, particularly in areas of low station density (see Figures 3 to 5), please contact us at HDSC.Questions@noaa.gov.

2.1.2. Annual maximum series (AMS) extraction

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. Calendar year was used in this project area, rather than a standard water year (October - September), based on the distribution of heavy precipitation events so that a year begins and ends during a relatively dry season. AMS at stations were extracted for all durations equal to and 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 screened to ensure that the incomplete data did not result in erroneously low maxima (see Section 2.1.5).

2.1.3. Data digitization

In this reporting period, we continued to digitize additional precipitation data from the NCEI's Climate Database Modernization Program (CDMP). The focus up until this point has been mostly on extending records for hourly stations in urban areas, but this work will also apply to stations in data scarce areas and stations with significant periods of record missing. A summary of the work completed and in progress thus far with the stations' names, recording intervals and periods of record digitized is shown in Table 3.

Table 3. Status of digitization work.

Station name	Recording interval	Period digitized
Brackettville/Fort Clark	1-day	1853-1899
Taylor	1-hour	1903-1932
Fort Worth	1-hour	1903-1940
San Antonio	1-hour	in progress
Galveston	1-hour	in progress

Figure 6 shows, as an example, the effect of newly digitized hourly data on 1-day AMS for NCEI's daily station Taylor (station ID 41-8861; also merged with nearby NCEI's station 41-8862). For this station, the daily record was extended for an additional 27 years (1903-1929). As is evident from the figure, several of the largest values in the AM series, including the AM from the September 7-11, 1921 extreme event, come from the newly digitized data.

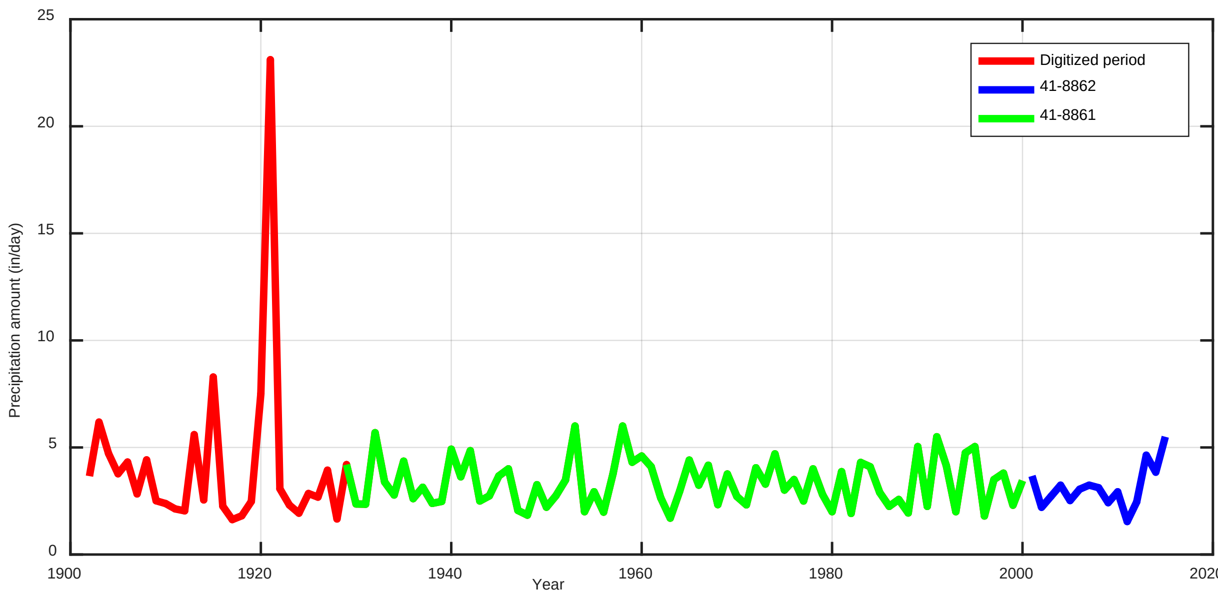

Figure 6. 1-day annual maximum series for Taylor station (41-8861 in green and 41-8862 in blue). AM from the newly digitized hourly data are shown in red.

2.1.4. Metadata quality control

We finished screening the basic metadata (latitude, longitude and elevation) for stations formatted so far and made corrections where appropriate. Specifically, we screened stations that plotted in the ocean or in the wrong state, or had no elevation recorded in the original dataset. Stations that had no elevation were assigned elevations from a 30-second resolution digital elevation model (DEM). We also checked station locations if their provided elevation was more than 100 feet different than the elevation extracted from the DEM. Such stations were re-located as necessary based on inspection of satellite images, maps and records of the station's history. We will provide original and revised coordinates for all stations used in the analysis in Appendix 1 of the NOAA Atlas 14, Volume 11 document.

2.1.5. Co-located station cleanup

In this reporting period we completed an investigation of NCEI's co-located stations. This task involved the comparison of AMS for locations where there is both an automated gauge and a cooperative observer recording daily precipitation.

Time series plots of annual maxima at co-located stations were reviewed at 1-hour and 1-day durations. If the station with a shorter reporting interval provided the same information as a longer reporting interval, then the station with the longer reporting interval was removed. If the station with the longer reporting interval had a longer period of record, then it was retained in the dataset in addition to the co-located station with the shorter reporting interval. Where appropriate, we used data from stations recording at shorter intervals to extend records or to fill in gaps in records for collocated stations recording at longer intervals. As a result of this analysis, we extended data at 161 hourly and daily stations and made 1,024 data corrections.

Figure 7 shows the AMS data for co-located stations 41-5048. For years where observations were only available for the automated hourly gauge, we aggregated 1-hour data to 1-day and added those data to the daily gauge record. One year in particular missing from the daily record is 1954, when a significant event of 22.13 inches during 24 hours occurred, which significantly exceeds the greatest daily rainfall value observed in the full record by the cooperative observer. For this event we also had to manually correct the hourly gauge record, which was missing about 7 hours of data during the height of the storm and only recorded a total of 12.97 inches.

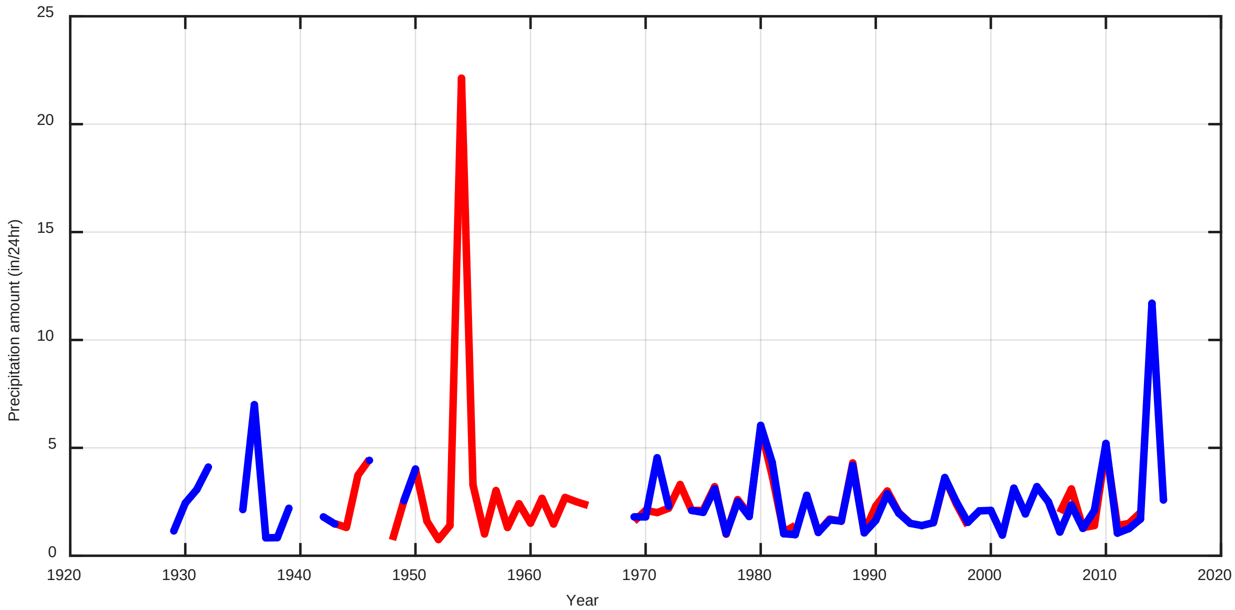

Figure 7. Co-location example. 24-hour AMS for daily station 41-5048 is shown in blue and for co-located hourly gauge is shown in red.

Co-located analysis also helps us with the AMS quality control task (Section 2.1.6), as large differences in corresponding AM time series at co-located stations usually indicate data quality issues, where hourly data is typically more prone to error and often goes missing during extreme rainfall events. Figure 8 shows a large discrepancy in 1981 AM for NCEI's co-located station 41-0738. In this case, the hourly AM value was underestimated due to two consecutive accumulation periods (both longer than 24-hour) in the hourly station record, since accumulation amounts are typically distributed equally across the whole period. Using information in storm data and in the cooperative observer forms, we found that the 1-day value of 10.40 inches measured by the observer fell in less than 12 hours and we adjusted the hourly distribution to more accurately represent the event.

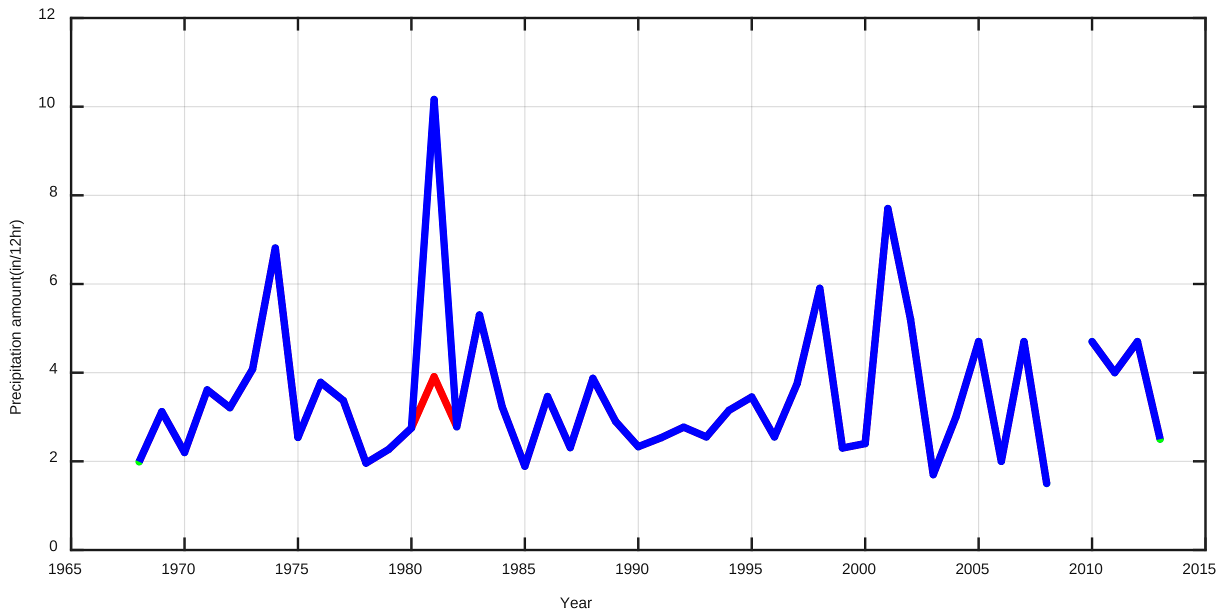

Figure 8.AMS quality control during co-located task. Original 12-hour AMS for station 41-0738 is shown in red and adjusted AMS is in blue.

2.1.6. AMS quality control

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.

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 (15-minute, 1-hour and 1-day) are now being verified. First, they are mapped with concurrent measurements at nearby stations. If they cannot be confirmed, they are investigated further using information from climatological observation forms, monthly storm data reports and other historical weather event publications obtained primarily from the NCEI's Environmental Document Access and Display System (EDADS).

Figure 9 shows the distribution of the daily AMS data for NCEI's 79-0049 station where statistical tests identified the 11/04/1978 amount of 20 inches/day as a high outlier. This event was flagged as suspicious after reviewing nearby stations that did not observe any rainfall within a few days of this event. After reviewing the original observer's form, the event was confirmed to be zero and is most likely a typo. We have corrected this value in our raw data files and extracted a new AM for that year.

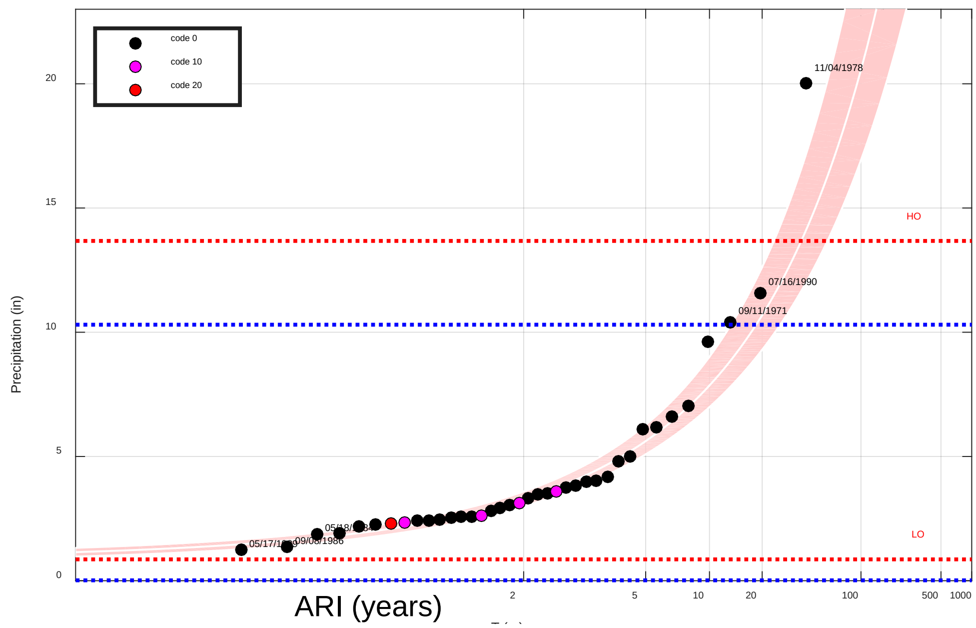

Figure 9. Quality control for 1-day AMS for station 79-0049. 1978 AM value of 20 inches was flagged as a high outlier by statistical tests. Further review established there was no rain on that day.

2.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jul - Sep 2016)

We will continue data collection, re-formatting and digitization tasks. We will also work on quality control of the identified high and low outliers in the annual maximum data series.

2.3 PROJECT SCHEDULE

Data collection, formatting, and initial quality control [In progress; still collecting additional datasets]

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) [In progress; due January 2017]

Regionalization and frequency analysis [March 2017]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [June 2017]

Peer review [August 2017]

Revision of PF estimates [January 2018]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [March 2018]

Web publication [April 2018]

III. OTHER

1. EXCEEDANCE PROBABILITY ANALYSIS FOR THE WEST VIRGINIA RAINFALL EVENT OF JUNE 23-24, 2016

During this reporting period we analyzed annual exceedance probabilities (AEPs) of the worst case rainfall for the West Virginia rainfall event that occurred during June 23-24, 2016. AEP is 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 which show the lowest exceedance probabilities for the largest area, i.e., the “worst case(s).” Since the beginning and end of the worst case period are not necessarily the same for all locations, the AEP maps do not represent isohyets at any particular point in time, but rather within the whole event.

The underlying data for the AEP analyses were rainfall observations and point rainfall frequency estimates for a range of durations and frequencies. The National Centers for Environmental Prediction (NCEP), Environmental Modeling Center’s (EMC) Stage IV analysis. Stage IV data is a mosaicked product of regional hourly and 6-hourly multi-sensor (radar and gauges) precipitation estimates (MPEs) produced by the 12 River Forecast Centers. Hourly rainfall grids for each event were aggregated to overlapping longer durations, such as 24-hour, and the maximum amount of rainfall was extracted for each selected duration for each grid cell inside the area of interest. Rainfall frequency estimates are from NOAA Atlas 14, Volume 2 (30 arc-sec ASCII grids; http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_gis.html).

We looked at several durations and created a map for 24-hour duration that showed the lowest AEPs for the largest area. The map in Figure 10 shows the areas that experienced rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%). The map is also available for download from the following page:
http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/

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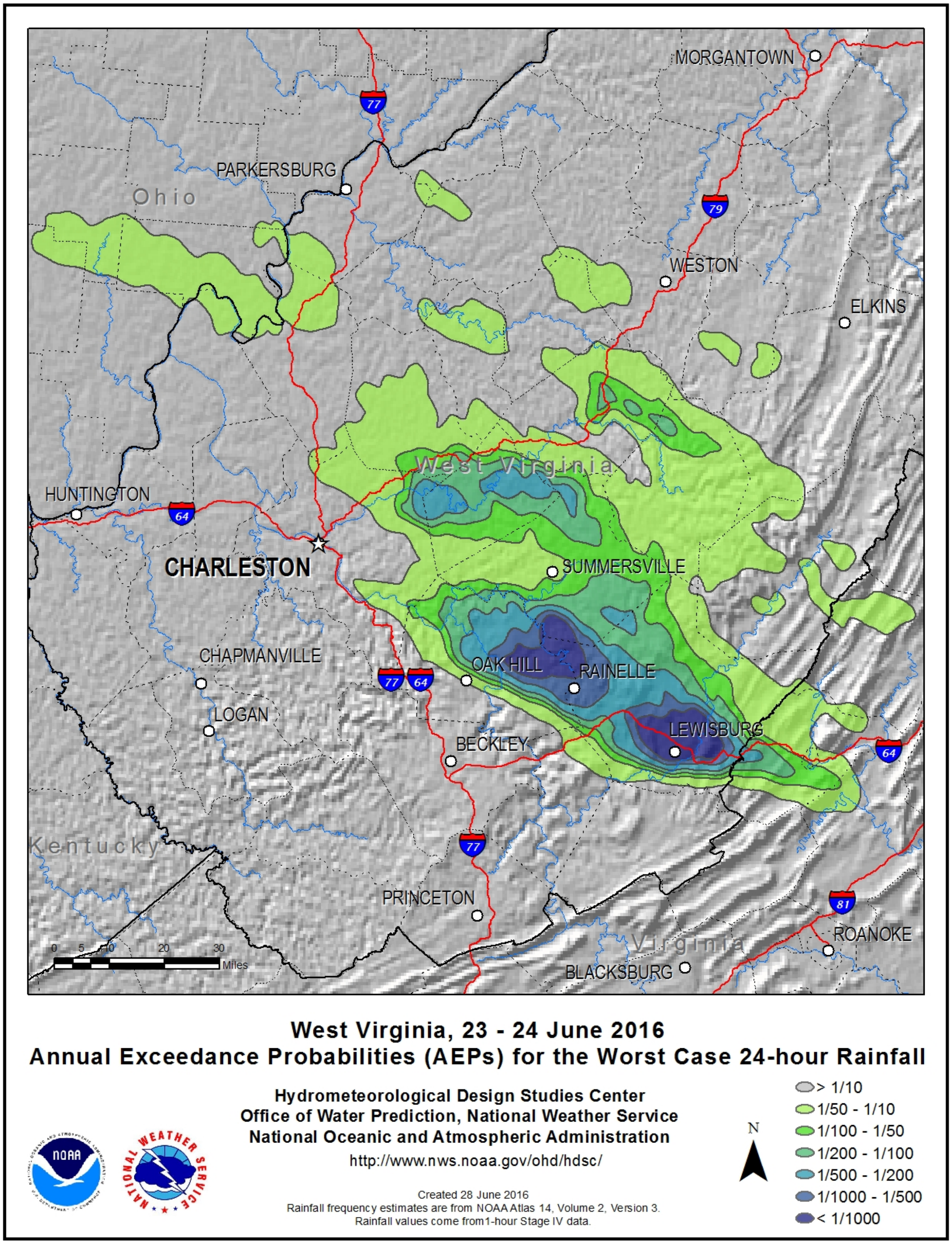

Figure 10. Annual exceedance probabilities for the worst case 24-hour rainfall for the West Virginia event of June 23-24, 2016.

2. PUBLICATIONS

HDSC (Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite) published two articles in the American Society of Civil Engineers/Environmental & Water Resources Institute's (ASCE/EWRI) quarterly newsletter *Currents*, 18/2, Spring/Summer 2016:

- NOAA's Likelihood Analysis of Historical Rainfall Events;
- NOAA Updated Precipitation Frequency Estimates for the Northeastern States.

3. CONFERENCES, MEETINGS

On April 8, HDSC group member Sandra Pavlovic, gave a presentation at the American Water Resources Association (AWRA) National Capital Region Section (NCR) Water Resources Symposium in District of Columbia on recently published NOAA Atlas 14 Volume 10 update for the Northeast.

On May 24, Sanja Perica, HDSC Chief, updated the Advisory Committee on Water Information's (ACWI) Water Resources and Climate Change Workgroup on HDSC plans for addressing non-stationarity in NOAA Atlas 14.

On June 13, Sanja Perica participated in the NOAA-Reinsurance Industry Workshop (insurance industry-federal agency data and information sharing workshop) held in Washington, D.C. She shared information on NOAA Atlas 14 products and discussed the planned updates.