HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 July to 30 September 2015

National Water Center
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National Oceanic and Atmospheric Administration
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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.

TABLE OF CONTENTS

I. INTRODUCTION 1

II. CURRENT PROJECTS 3

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES 3

1.1 PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2015) 3

1.1.1 Publication announcement 3

1.1.2 Data collection and data screening 4

1.1.3 Rainfall frequency analysis 4

1.1.4 Development of gridded precipitation freq. estimates and confidence limits 5

1.1.5 Consistency checks 5

1.1.6 Comparison with previous NWS studies 5

1.1.7 Development of PFDS web pages for Volume 10 6

1.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2015) .. 8

1.3 PROJECT SCHEDULE 8

2. PRECIPITATION FREQUENCY PROJECT FOR TEXAS 9

2.1 PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2015) 9

2.1.1 Data collection and data screening 9

2.1.2 Metadata quality control 10

2.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2015) 10

2.3 PROJECT SCHEDULE 11

II. OTHER 12

1. EXCEEDANCE PROBABILITY ANAYSIS FOR THE RECENT SOUTH CAROLINA STORM 12

2. RECENT MEETINGS AND CONFERENCES 13

I. INTRODUCTION

The Hydrometeorological Design Studies Center (HDSC) within the National Water Center (formerly, Office of Hydrologic Development)[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, precipitation frequency estimates have been updated 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), and 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). On September 30th, HDSC published updated estimates for the following seven northeastern states: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont in Volume 10. Since May 2015, HDSC has been working on updating precipitation frequency estimates for the state of Texas. They are expected to be published in mid-2018 in NOAA Atlas 14, Volume 11.

We have been working with the Federal Highway Administration (FHWA) and several 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 FHWA's Transportation Pooled Fund Program's web page in the near future. This program allows interested federal, state, and local agencies and other organizations to combine resources to support transportation relevant research studies. For any inquiries regarding the status of this effort, please send an email to HDSC.questions@noaa.gov.

Due to lack of funding, in FY15 HDSC suspended activities on the following two projects: "Analysis of potential impacts of climate change on precipitation frequency estimates" and "Development of regional areal reduction factors to accompany NOAA Atlas 14 point precipitation frequency estimates." Consequently, we omit related sections in the most current progress reports. For more details on the work accomplished so far on those two projects, please see Oct - Dec 2014 progress report.

[1]As of April 1, 2015, the Office of Hydrologic Development reorganized into the National Water Center (NWC) with locations in Chanhassen, MN; Silver Spring MD; and Tuscaloosa, AL.

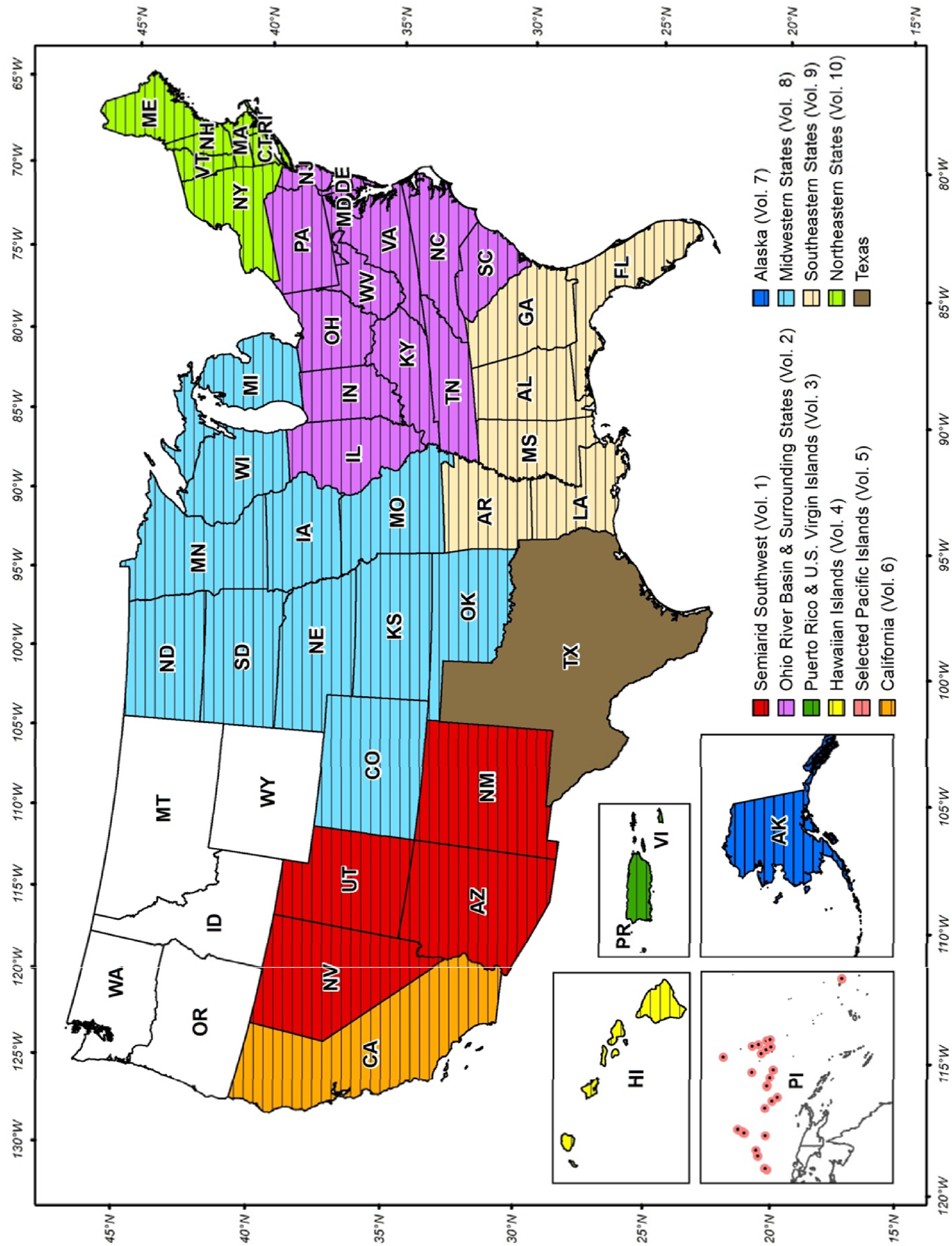

Figure 1. Current project area for Volume 11 (Texas) and project areas included in published Volumes 1 to 10.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1 PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2015)

The project area for the Northeastern precipitation frequency project includes the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont. Precipitation data from stations in approximately 1-degree buffer around these states was also collected to assist in regional frequency analysis (Figure 2).

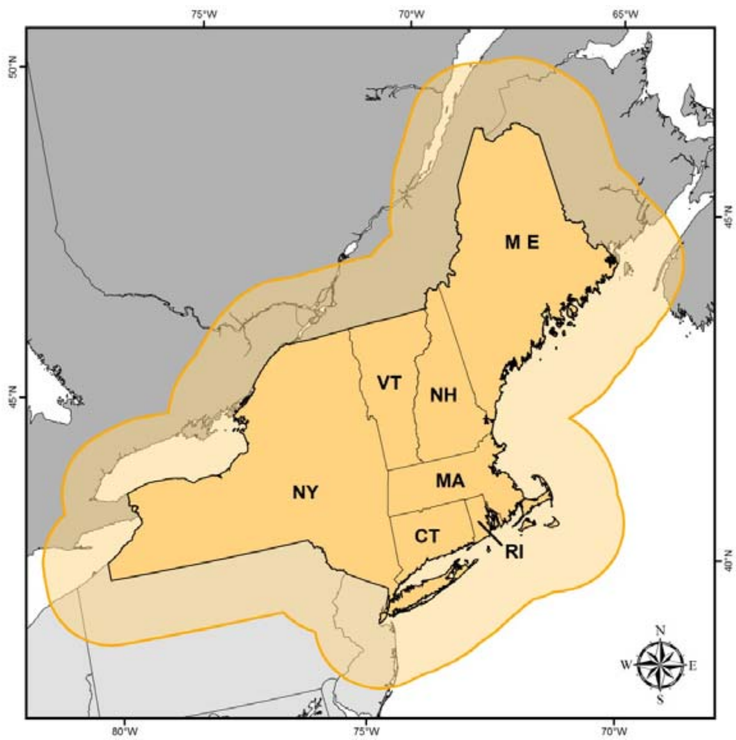

Figure 2. Extended project area for Volume 10 (shown in orange).

1.1.1 Publication announcement

Precipitation frequency estimates for the seven northeastern states listed above were published on September 30, as NOAA Atlas 14 Volume 10. They are available for any location in the project area in a variety of formats through the Precipitation Frequency Data Server (PFDS) at http://hdsc.nws.noaa.gov/hdsc/pfds (via a point-and-click interface). Additional results and information available there include:

- ASCII grids of partial duration series-based and annual maximum series-based precipitation frequency estimates and related confidence limits for a range of durations and frequencies with associated Federal Geographic Data Committee-compliant metadata;

- cartographic maps of partial duration series-based precipitation frequency estimates for selected frequencies and durations;
- quality controlled annual maximum series for all observing locations in the project area;
- temporal distributions;
- seasonality analysis.

Cartographic maps were created to serve as visual aids and are not recommended for estimating precipitation frequency estimates. Users are advised to take advantage of the PFDS interface or the downloadable underlying ASCII grids for obtaining precipitation frequency estimates.

Work on documentation describing the station metadata, data, and project methodology has ceased until we resolve some funding issues. We expect we'll release the accompanying document in early 2016.

1.1.2 Data collection and data screening

During the previous reporting period, we digitized and formatted an additional 40+ years of hourly precipitation data for stations from the NCEI's Climate Database Modernization Program (CDMP)***.*** In the Quarterly Progress Report for April-June 2015, we used the Ithaca station as an example to show the influence of the increase of the number of data years on precipitation frequency estimates. In this reporting period, we digitized hourly precipitation data for 1906-1948 for two more stations: Hartford Brainard Airport, CT and Canton, NY and thus extended their hourly records for 43 years.

1.1.3 Rainfall frequency analysis

Precipitation frequency estimates represent precipitation magnitudes regardless of the type of precipitation. For some applications it may be important to differentiate total precipitation (which may include snow) frequency estimates from rainfall (i.e., liquid precipitation) frequency estimates. We conducted the rainfall frequency analysis for durations up to 24 hours, which are of most interest to design projects relying on peak flows.

Concurrent daily precipitation and snowfall measurements were available from NCEI's daily dataset. Recorded snowfall amounts were first converted to snow water equivalent using the 10 to 1 rule, which assumes that the density of water is 10 times the density of snowfall. Rainfall amounts were then calculated as a difference between precipitation and snow water equivalent.

Since snow and temperature measurements were not available for hourly durations, we used daily maximum and minimum temperature measurements from co-located daily stations to classify precipitation amounts as solid or liquid. Precipitation that occurred when the daily maximum temperature was above 34 ^{0}F was considered rainfall. Precipitation that occurred when the temperature was equal to or below that threshold was considered snowfall.

Frequency analysis was done on at-station rainfall AMS and on total precipitation AMS. A comparison of two types of frequency estimates is underway to determine if and where there is a need to publish separate rainfall frequency estimates.

1.1.4 Development of gridded precipitation frequency estimates and confidence limits

In NOAA Atlas 14, the grids of mean annual maxima (MAM) at 30 arc-sec resolution, together with at-station precipitation frequency estimates, are basis for calculation of gridded precipitation frequency estimates and corresponding upper and lower bounds of the 90% confidence interval.

MAM grids were developed from at-station MAM values, provided by the HDSC, by Oregon State University's PRISM Climate Group using their hybrid statistical-geographic approach for mapping climate data named Parameter-elevation Regressions on Independent Slopes Model (PRISM). Two more iterations during this period were done to attain reasonable patterns in the MAM across all durations from 15 minutes to 60 days.

Mean annual maximum grids served as the basis for calculation of the precipitation frequency estimates for the 2-year average recurrence interval, which were then used to calculate gridded 5-year estimates and so on. To achieve smoother spatial results, HDSC applied a dynamic filter to precipitation frequency grids calculated from MAM grids. More information on this method will be provided in the Volume 10 document, which will be available for download from the PFDS web page in early 2016 (in the meantime, please check Volume 9 document for more information).

1.1.5 Consistency checks

To ensure consistency in grid cell values across all durations and frequencies (e.g., 24-hour estimate has to be at least equal to 12-hour estimate), duration-based internal consistency checks were conducted. For inconsistent cases, the longer duration grid cell value was adjusted by multiplying the shorter duration grid cell value by 1.01 to provide a 1% difference between the values. After grid cell consistency was ensured across durations, it was performed across frequencies to ensure that there were no frequency-based inconsistencies caused by the adjustment across durations.

1.1.6 Comparison with previous NWS studies

The information in NOAA Atlas 14 Volume 10 supersedes similar information for Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont contained in the following publications:

a. Weather Bureau's Technical Paper No. 40, *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years* (Hershfield, 1961);

b. Weather Bureau's Technical Paper No. 49*, Two- to Ten-Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States* (Miller, 1964);

c. NOAA Technical Memorandum NWS HYDRO-35*, Five- to 60-Minute Precipitation Frequency for the Eastern and Central United States* (Frederick et al., 1977).

With each volume of NOAA Atlas 14, we provide comparisons of the estimates against the previous NWS studies. We prepared and analyzed difference maps between NOAA Atlas 14 24-hour and 1-hour 100-year estimates and corresponding estimates from superseded publications. The map in Figure 3 illustrates the differences in 100-year 60-minute estimates (in inches) between NOAA Atlas 14 Volume 10 and HYDRO35. The contour lines superimposed on the map represent isopluvials from HYDRO35. 100-year 60-minute precipitation frequency estimates at specific locations across the project area changed between -0.63 and 0.5 inches, or from -25% to 19%. The maximum increase of 0.5 inches (18%) occurred in northern New York, while the largest decrease of 0.63 inches (-22%) occurred on the border between Vermont and Massachusetts. Increases in magnitudes between 0.1 and 0.5 inches were observed near the coast of Massachusetts and Rhode Island. Only small increases were observed on Long Island in New York.

The differences in estimates between the two publications are attributed to a number of factors. Firstly, differences in data quality control procedures and frequency analysis approaches (distribution selection, parameter estimation method, regional versus at-station methods) affect estimates, especially at higher average recurrence intervals (ARIs). Secondly, differences in spatial interpolation techniques impact estimates at ungauged locations. Isopluvials in HYDRO35 were based solely on station data without incorporating topographic features; NOAA Atlas 14 estimates were based on PRISM products that integrate topography. Finally, the increase in the amount of available data from HYDRO35 to NOAA Atlas 14, both in the number of stations and their record lengths, has a considerable effect on estimates. HYDRO35 was published in 1977, so potentially more than 35 additional years of data at existing stations were available for the NOAA Atlas 14 analyses. Also, many stations that were not suitable for frequency analysis in HYDRO35 due to short records could be included in NOAA Atlas 14. A detailed comparison of the numbers of stations and record lengths available to each of the two projects could not be provided since the HYDRO35 project covered a significantly larger area and the necessary information was not available in the HYDRO35 document.

1.1.7 Development of PFDS web pages for Volume 10

Web pages were updated for the new project area of Volume 10 and all related products. Federal Geographic Data Committee (FGDC) compliant metadata were prepared for Volume 10. A cartographic map template was developed and maps for selected durations and recurrence intervals were created.

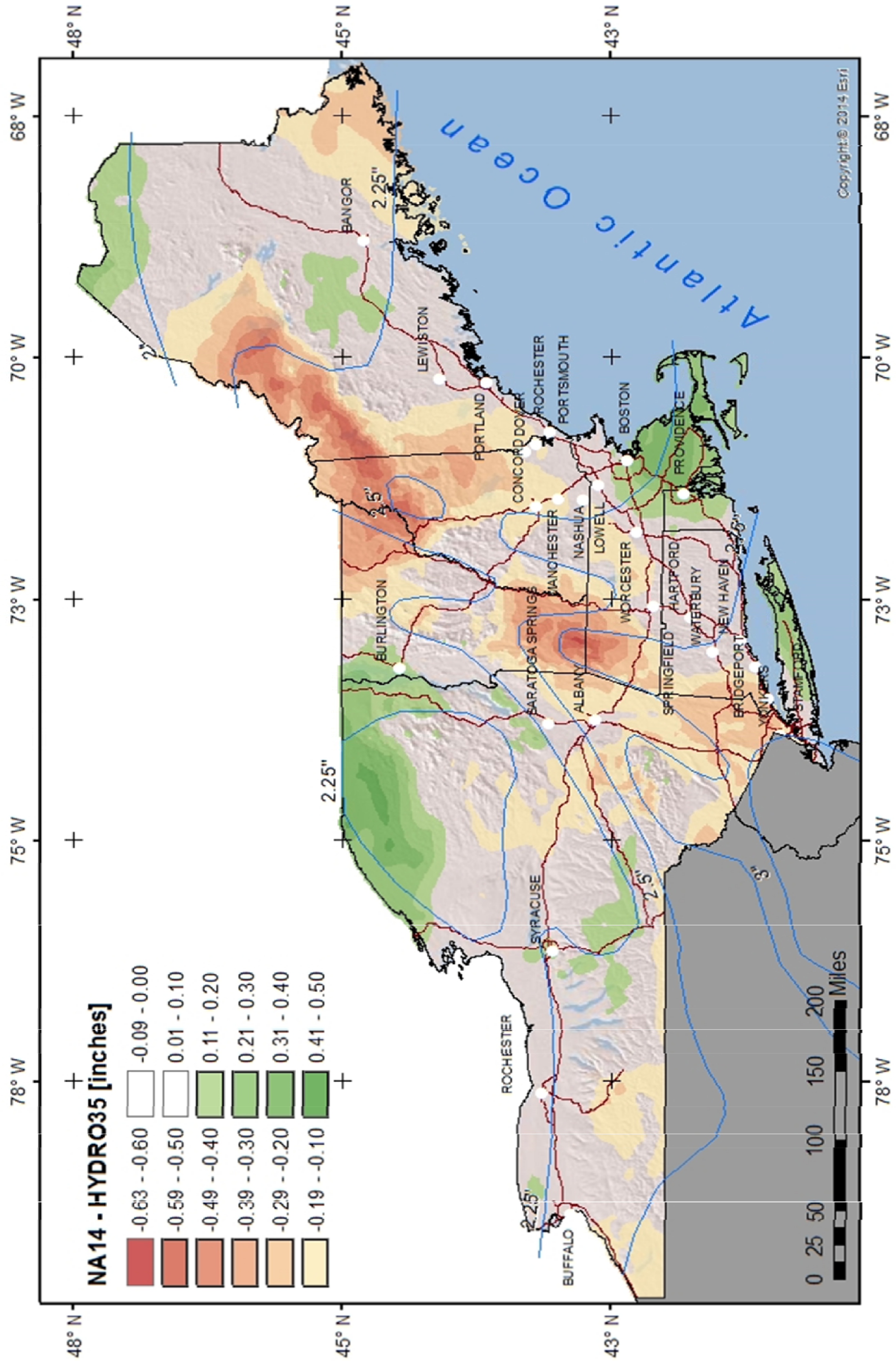

Figure 3. Map showing differences in 100-year 60-minute estimates (in inches) between NOAA Atlas 14 Volume 10 and HYDRO35. Superimposed on the map are isopluvials (blue lines) from HYDRO35.

1.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2015)

In the next reporting period, HDSC will work on the documentation to accompany Volume 10 precipitation frequency estimates. We will also finish rainfall frequency analysis.

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 documentation [Early 2016]

2. PRECIPITATION FREQUENCY PROJECT FOR TEXAS

2.1 PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2015)

NOAA Atlas 14, Volume 11 precipitation frequency project includes the state of Texas and approximately a 1-degree buffer around this state (Figure 4). This project started in May 2015 and is expected to be completed in mid-2018.

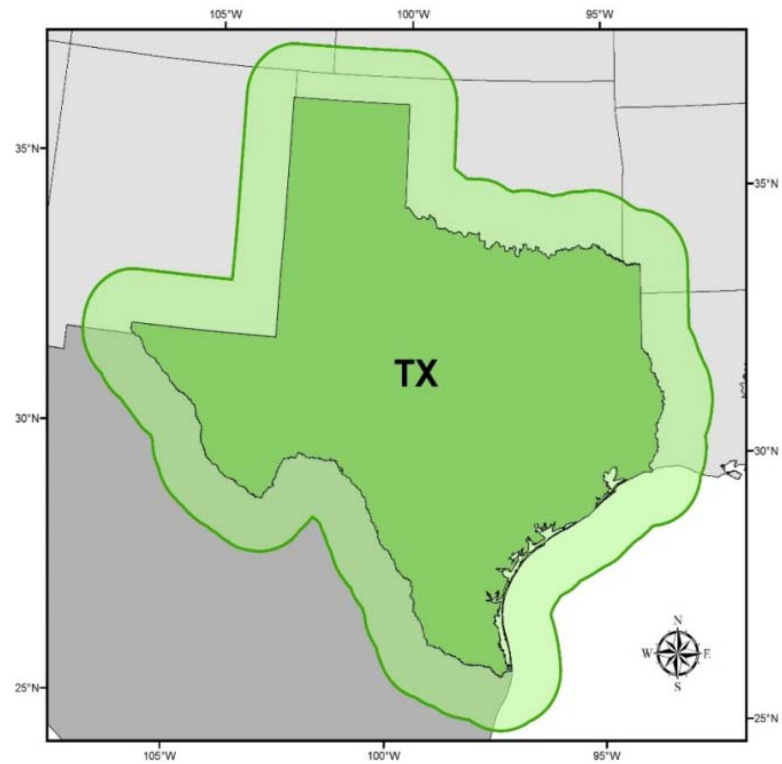

Figure 4. NOAA Atlas 14, Volume 11 extended project area (shown in green).

2.1.1 Data collection and data screening

The primary source of data for NOAA Atlas 14 Volumes is the NOAA's National Centers for Environmental Information – NCEI, but it is recognized 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 digitized data measured at 1-day or shorter reporting intervals from other Federal, State and local agencies. For this project area, we are interested in collecting all available precipitation datasets (daily, hourly, 5-minute, etc.) for stations in Texas, as well as in adjacent portions of neighboring USA states (Arkansas, Louisiana, New Mexico, and Oklahoma) and also in Mexico.

In early 2015, we asked our partners for assistance with the data. During this reporting period, we continued reviewing the information they provided and contacting other agencies which were indicated as additional sources of potentially useful data.

- We looked into data used in the following USGS studies; : ;http://pubs.usgs.gov/sir/2004/5041/pdf/sir2004-5041.pdf and http://pubs.usgs.gov/wri/wri98-4044/pdf/98-4044.pdf;
- Downloaded daily data from the Oklahoma Mesonet observation network: http://www.mesonet.org/index.php/weather/daily_data_retrieval;
- Researched the Harris County (Flood Warning System), City of Dallas (Trinity Watershed Management Flood Control), City of Austin and Jefferson County Drainage District 6 ALERT Precipitation Networks (http://www.harriscountyfws.org/; http://www.ci.dallas.tx.us/sts/html/fc.html; https://www.austintexas.gov/department/flood-early-warning-system; http://www.dd6.org/;
- Researched the Texas Commission on Environmental Quality (TCEQ) air quality network: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/daily_average.pl;
- Researched the Lower Colorado River Authority (LCRA) regional meteorological network: http://hydromet.lcra.org/full.aspx;
- Researched the Edwards Aquifer Authority data: http://www.edwardsaquifer.org/;
- Researched the Natural Resources Conservation Service (NRCS) Soil Climate Analysis Network (SCAN): http://www.wcc.nrcs.usda.gov/scan/.

We would like to thank all of those who responded to our inquiry and/or provided the data. 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.

2.1.2 Metadata quality control

We began screening NCEI's stations' metadata (which make up the majority of the data for the project) for errors. Stations with potential errors were identified by reviewing published coordinates and elevations for large changes over the course of the station's lifetime. Stations with assigned elevations that were more than 100 feet different from elevations extracted from an 10-m digital elevation model (DEM) are being investigated. Such stations may be re-located based on inspection of satellite images and maps.

2.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2015)

The main focus for the next period will continue to be data collection, reformatting, and station metadata checks. All collected data will be examined and formatted into a common format, where appropriate.

2.3 PROJECT SCHEDULE

Data collection, formatting, and initial quality control [February 2016]

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) [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]

II. OTHER

1. EXCEEDANCE PROBABILITY ANALYSIS FOR THE RECENT SOUTH CAROLINA STORM

HDSC analyzes annual exceedance probabilities (AEPs) for selected significant storm events that typically have observed amounts with AEPs of less than 0.2% (1/500) over extended areas for some durations. AEP is probability of exceeding a given amount of rainfall 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. The AEPs are estimates from the NOAA Atlas 14. We look at a range of durations and create maps for durations that show the lowest AEPs for the largest area. Maps do not represent isohyets at any particular point in time, but rather isolines of AEPs within the whole event. The maps are available for download from the following page: http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/.

During this reporting period, HDSC did the AEP analysis for the South Carolina rainfall event that occurred during 2 - 4 October 2015. The rainfall event delivered rainfall amounts that exceeded 20 inches in 48 hours in some locations and caused historic flooding throughout South Carolina. We compared maximum observed rainfall amounts to corresponding rainfall frequency estimates for durations from 1-day to 60-day for a rain gauge in South Carolina - US1SCCR0069, Mount Pleasant 6.4 NE (Figure 5). The rain gauge is part of the Community Collaborative Rain, Hail & Snow Network (CoCoRaHS). As can be seen from Figure 5, observed rainfall amounts have annual exceedance probabilities of significantly less than 1/1000 for all durations from 2-day to 60-day (ending on October 5).

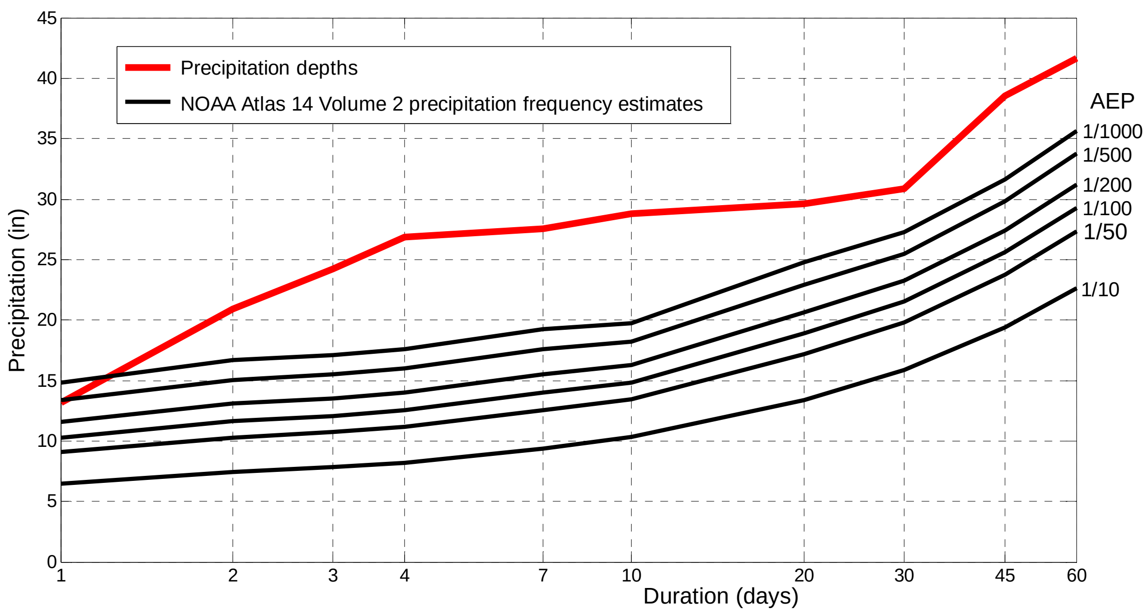

Figure 5. Maximum observed rainfall amounts in relationship to corresponding precipitation frequency estimates for the US1SCCR0069 *gauge*

We also created AEP maps for the areas that experienced rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%) for the 24-hour and 72-hour duration. Figure 6 shows the AEP map for 72 hours.

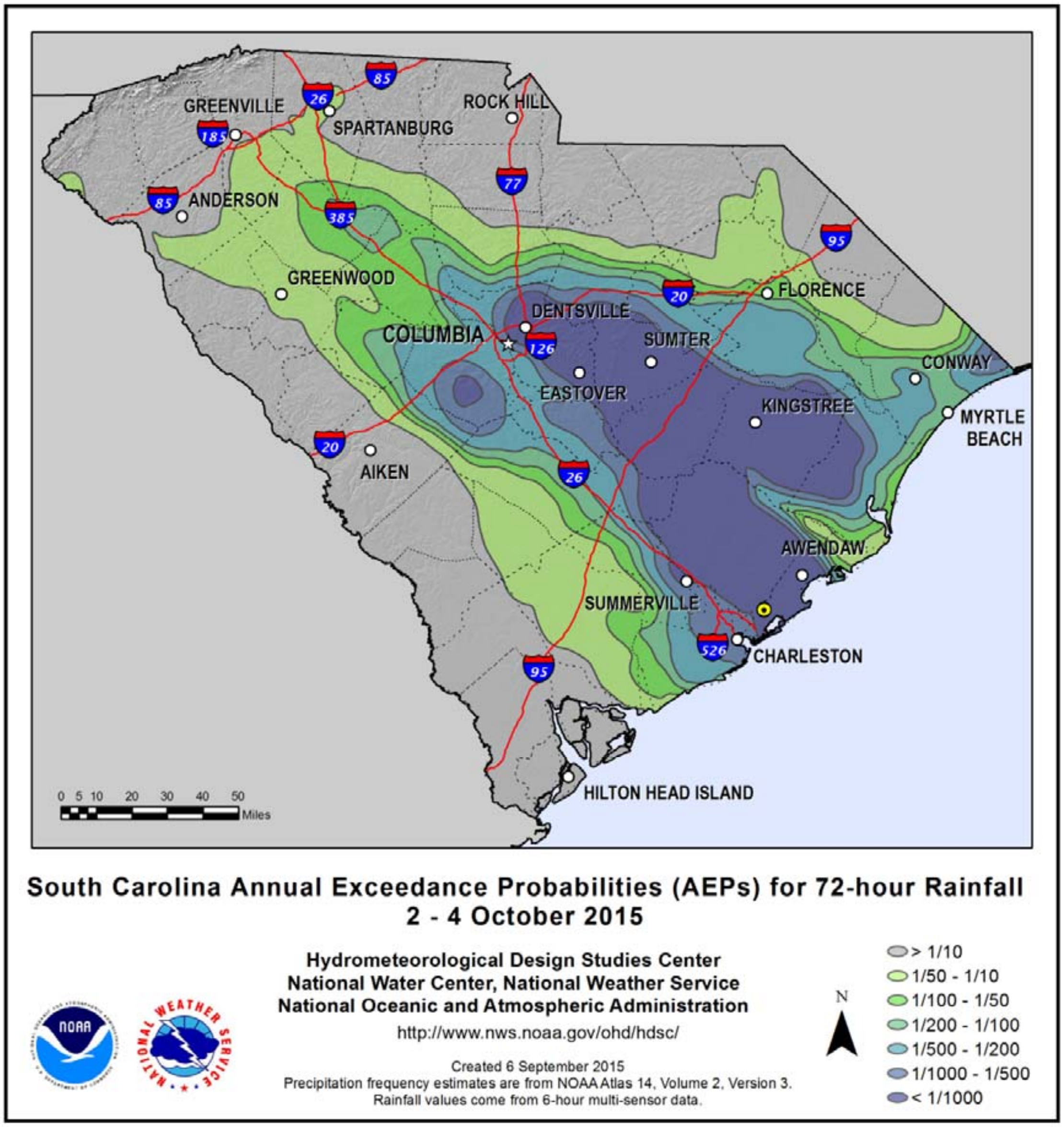

Figure 6. Annual exceedance probabilities for the worst case 72-hour rainfall from 2 to 4 October 2015. The yellow marker is the location of the US1SCCR0069 CoCoRaHS gauge.

2. RECENT MEETINGS AND CONFERENCES

On September 2, Sanja Perica made a presentation titled “Non-stationarity effects on NOAA Atlas 14 precipitation frequency estimates” at the Interagency Water and Climate Change Adaptation Workgroup meeting in Washington, D.C.