HYDROMETEOROLOGICAL DESIGN STUDIES CENTER QUARTERLY PROGRESS REPORT

1 July 2013 to 30 September 2013

Office of Hydrologic Development

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 Hydrologic Development of National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) is 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; http://hdsc.nws.noaa.gov/hdsc/pfds/index.html).

NOAA Atlas 14 is divided into volumes based on geographic sections of the country and affiliated territories. HDSC is currently updating estimates for the following northeastern states: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont that will be published in 2015 as Volume 10. Figure 1 shows the states or territories associated with each of the Volumes of the Atlas.

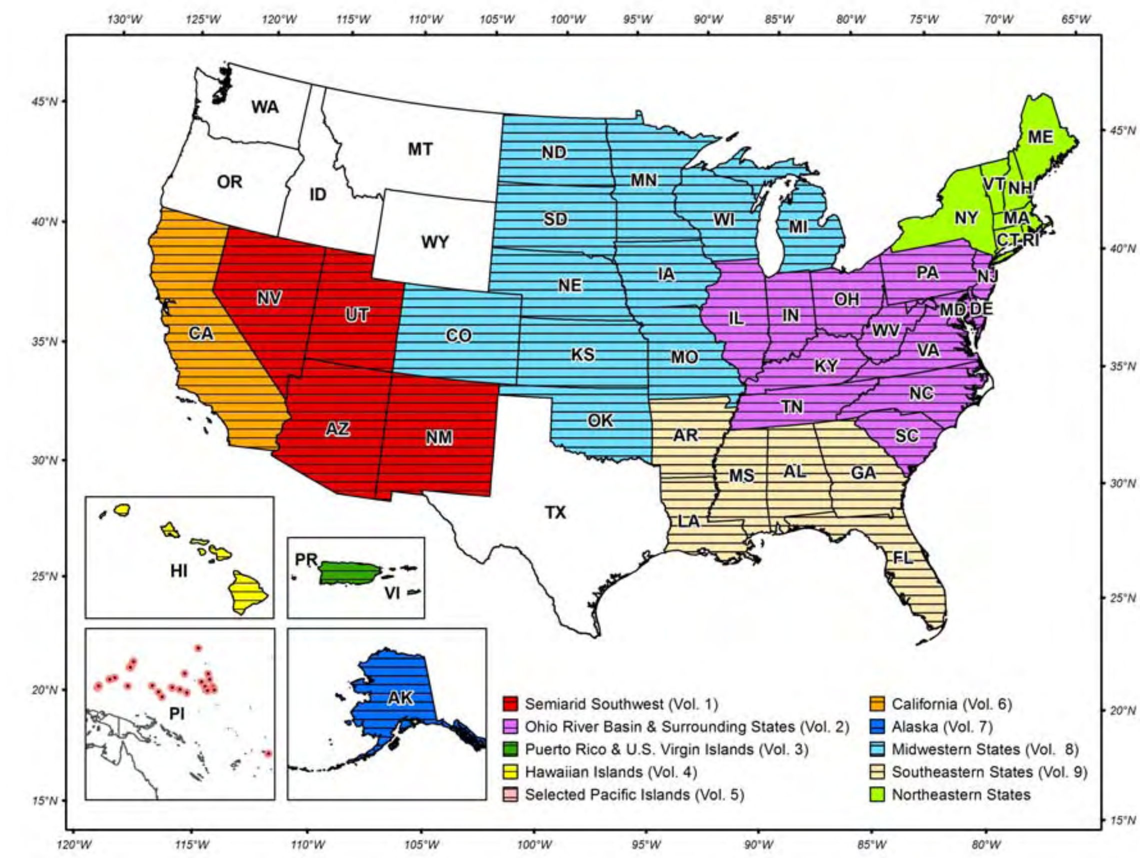

Figure 1. Current project area and project areas included in published NOAA Atlas 14, Volumes 1-9.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1. PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2013)

The project area includes the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont and an approximately 1-degree buffer around these states (Figure 2).

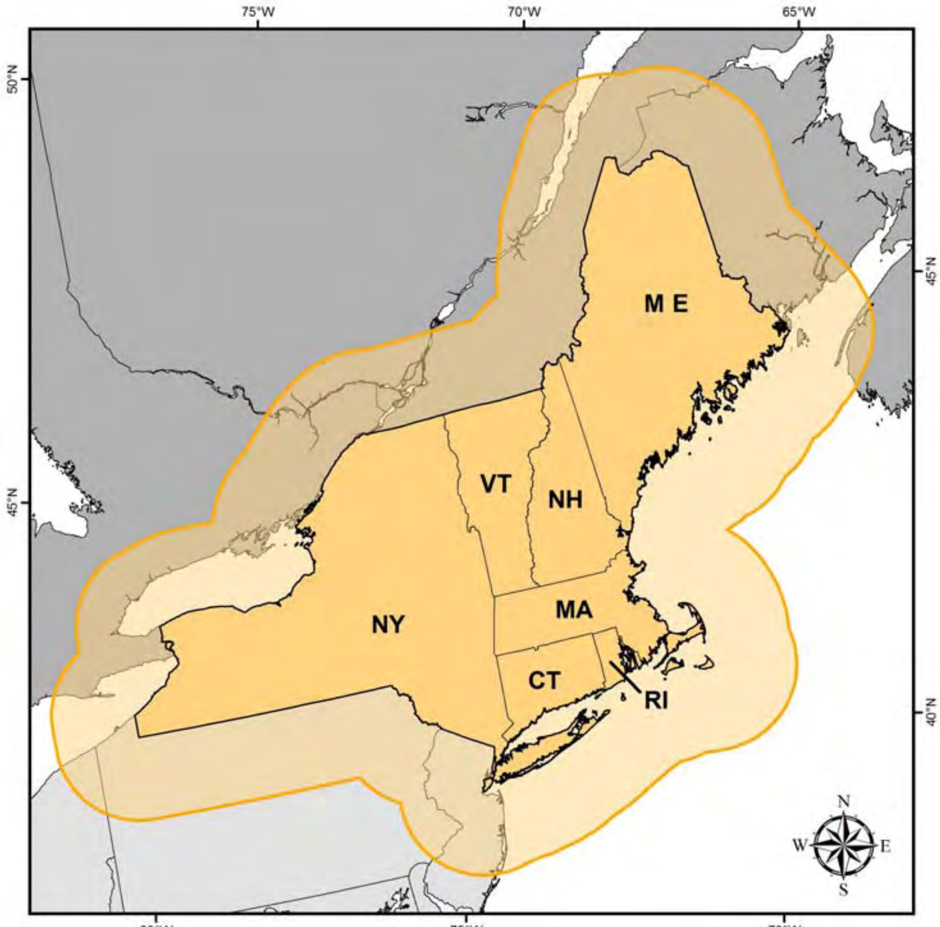

Figure 2. Northeastern precipitation frequency project area (shown in orange).

1.1.1. Data collection and formatting

During this reporting period we accomplished the following tasks:

- collected NJ Mesonet and SafetyNet datasets from the Office of the New Jersey State Climatologist at Rutgers University;
- requested data from the New Hampshire Department of Transportation and from the Earth Networks;

- digitized scanned observation forms for selected stations from the Massachusetts Department of Conservation and Recreation that have long records or are located in areas where data coverage is inadequate;
- formatted data from the following datasets: Boston Water and Sewer Commission, National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN), New Hampshire Department of Transportation, Office of the New Jersey State Climatologist at Rutgers University: NJ Mesonet and SafetyNet, and U.S. Department of Agriculture: Agricultural Research Service (ARS);
- re-formatted NCDC hourly data to accommodate changes in NCDC accumulation flags;
- updated NCDC daily, hourly, and 15-minute data to include the most recently released data.

Table 1 shows the current status of the data collection and formatting task.

Table 1. Sources of data for the precipitation frequency analysis for NOAA Atlas 14 Volume 10. Datasets in grey were investigated but will not be used for various reasons.

Source	**Reporting interval**	**Preliminary number of stations**	**Formatting status and comments**
Automated Surface Observing Systems (ASOS)	1-minute	42	formatted
Colorado Climate Center: Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)	1-day	2,637	formatted (however, many stations only have a few years of data)
Boston Water and Sewer Commission	5-minute 15-minute 1-hour	6	formatted
Earth Networks	n/a	n/a	sent inquiry; expect data in October
Environment Canada	1-day 1-hour	2,980 536	formatted
Illinois State Water Survey: National Atmospheric Deposition Program (NADP) dataset	1-day	62	formatted
Massachusetts Department of Conservation and Recreation (DCR)	1-day	176	received data on CD; digitized data for relevant stations
Mid-Atlantic River Forecast Center: Integrated Flood Observing and Warning System (IFLOWS) data	variable	336	formatted data to 1-hour and 1-day
Midwestern Region Climate Center (MRCC): 19th Century Forts and Voluntary Observers Database	1-day	63	formatted
Mount Washington Observatory	1-hour 1-day	1	sent inquiry
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	1-day 1-hour 15-minute n-minute	3,001 593 517 43	formatted
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC): U.S. Climate Reference Network (USCRN)	1-day 1-hour	11 11	formatted
National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN)	1-day	1	formatted

Source	Reporting interval	Preliminary number of stations	Formatting status and comments
New Hampshire Department of Transportation	15-minute	~15	received data for two stations so far; formatted
Office of the New Jersey State Climatologist at Rutgers University: NJ Mesonet	variable	7	received data via email; formatted
Office of the New Jersey State Climatologist at Rutgers University: NJ SafetyNet	variable	5	received data via email; formatted
U.S. Department of Agriculture: Agricultural Research Service (ARS)	variable	23	missing elevation in metadata; formatted
U.S. Forest Service: Remote Automated Weather Stations (RAWS) dataset	1-hour	40	formatted
USGS Maine Water Science Center	1-day 15-minute	16 n/a	formatted
USGS Massachusetts-Rhode Island Water Science Center	1-day hourly 15-minute	5 1 16	formatted
USGS New Hampshire-Vermont Water Science Center	1-day 15-minute	6 n/a	formatted
USGS New York Water Science Center	1-day	1	formatted
Citizen Weather Observers Program	n/a	n/a	data have short records
Connecticut ALERT Network/ Automated Flood Warning Systems (AFWS)	variable	n/a	network discontinued; no suitable archived dataset available
Cornell University: Network for Environment and Weather Applications (NEWA)	1-hour	n/a	data have short records and limited quality assurance
Global Summary of the Day (NCDC)	1-day	n/a	data are duplicate of NCDC and Environment Canada data
NOAA Earth Systems Research Laboratory - Meteorological Assimilation Data Ingest System (MADIS)	various	n/a	data are a collection from other sources, which we investigated individually
Northeast States for Coordinated Air Use Management (NESCAUM): CAMNET	15-minute	n/a	only one unique site with short record
Northeast Regional Climate Center (NRCC): CLimate Information for Management and Operational Decisions (CLIMOD)	1-day	n/a	data are duplicate of NCDC
Rhode Island Department of Environmental Management, Office of Water Resources	1-hour	1	record is too short for use in analysis
U.S. Army Corps of Engineers	1-hour	n/a	no suitable dataset available
U.S. Geological Survey (USGS) Connecticut Water Science Center	15-minute	n/a	downloaded but only three years of data available
Vermont Department of Transportation	n/a	n/a	data not suitable for precipitation frequency analysis

Table 2 shows the number of stations whose data were formatted so far to one of three base durations: 1-day, 1-hour, and 15-minute. For stations recording at variable intervals, data were formatted to all three base durations. Formatted data will be used to compile annual maximum series for all selected durations between a base duration and 60-day (see Section 1.1.2).

Table 2. The number of stations that have been formatted per duration.

Base duration	Number of stations
1-day	8,296
1-hour	1,535
15-minute	425

Locations of stations formatted at 1-day intervals are shown in Figure 3 and locations of stations formatted at 1-hour and 15-minute intervals are shown in Figure 4. These figures show the stations retained in the database based on station screening tasks (described in Section 1.1.3) accomplished so far.

If you know about other datasets we could use, particularly in areas not currently well covered, such as Maine, please contact us at HDSC.Questions@noaa.gov.

Lastly, we are reviewing data to ensure that historically documented extreme events are properly included in our dataset. For example, we are cross-referencing NCDC's statewide 24-hour record rainfall (http://www.ncdc.noaa.gov/extremes/scec/overview) against our data. So far, we have found that the NCDC data we have are missing both the Pennsylvania and Rhode Island official state 24-hour precipitation records, despite having official NWS weather gauges at those locations. We are investigating and trying to obtain these data to include in our analysis.

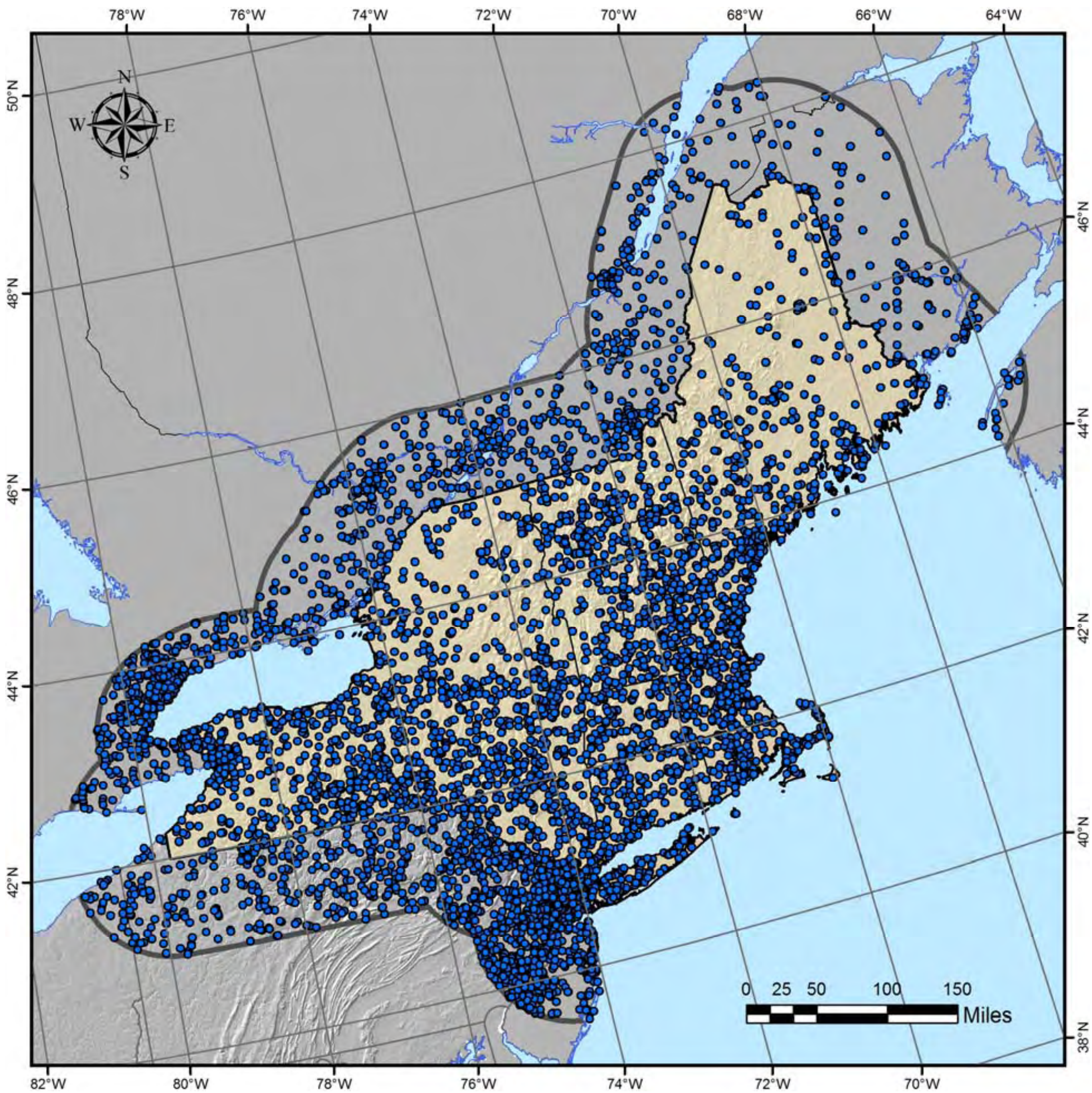

Figure 3. Map of stations whose data were formatted at 1-day interval.

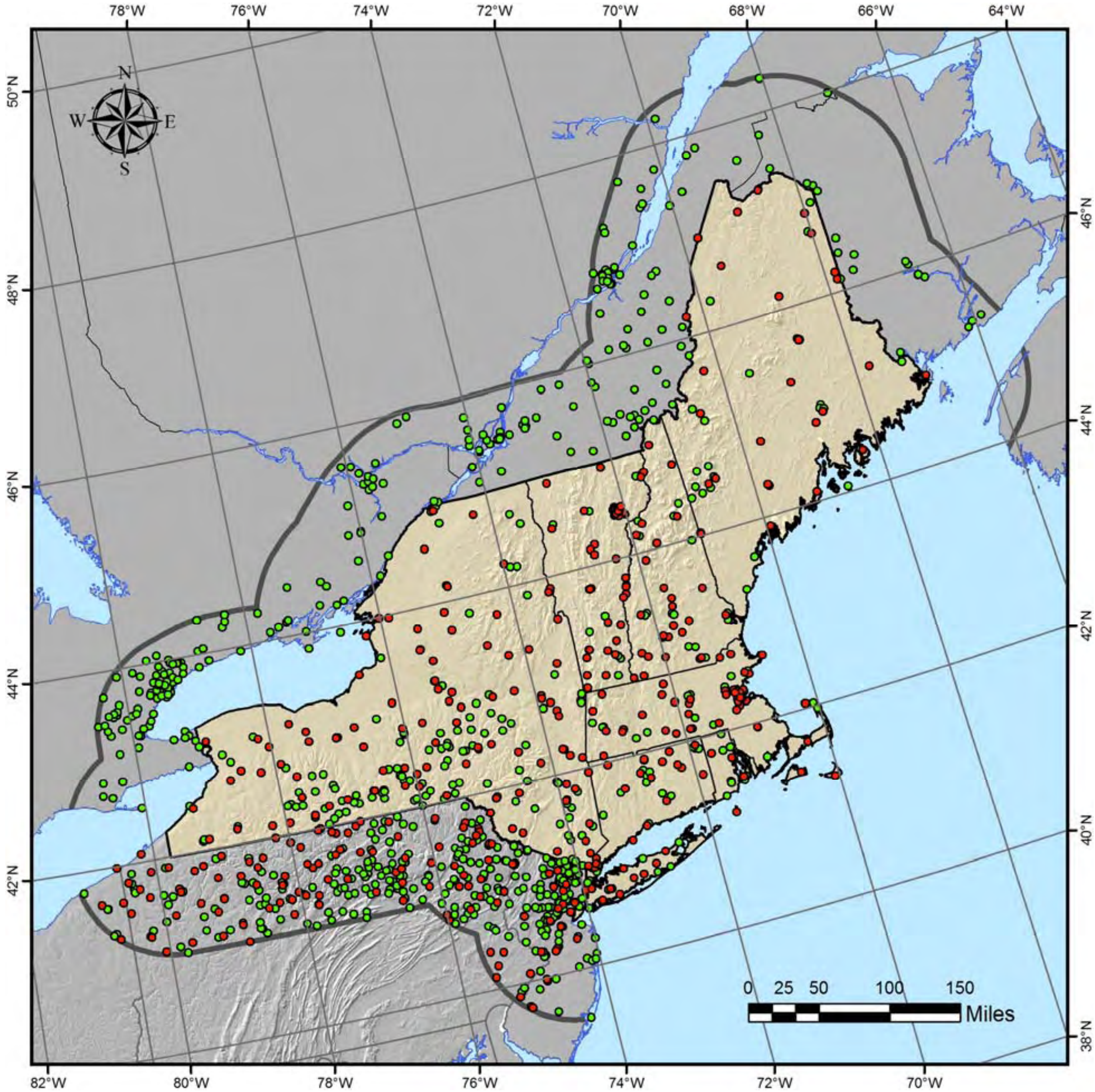

Figure 4. Map of stations whose data were formatted at 1-hour (green circles) and at 15-minute (red circles) intervals.

1.1.2. Annual maximum series extraction

We extracted annual maximum series (AMS) for all stations retained in the database for durations equal to and longer than the base duration up to 60 days. AMS for the 1-day through 60-day durations were compiled from daily, hourly, and 15-minute records. To accomplish this, 15-minute and 1-hour data were first aggregated to constrained 1-day (hours 0 to 24) values before extracting 1-day and longer duration annual maxima. Hourly and 15-minute data were used to compile AMS for 1-hour through 12-hour durations, where 15-minute data were first aggregated to constrained 1-hour (0 to 60 minutes) values before extracting AMS. 15-minute data were also used to compile AMS for 15-minute and 30-minute durations.

The criteria for AMS extraction are designed to exclude maxima if there are too many missing or accumulated data during the year and more specifically during critical months when precipitation maxima are most likely to occur ("wet season"). If you would like to read more about the criteria, see, for example, Section 4.3 on pages 9-11 in the NOAA Atlas 14 Volume 9 documentation.

We started work on delineating extreme precipitation climate regions by assessing the periods in which two-thirds of annual maxima occurred at each station for the 1-day and 1-hour durations. They will be used to assign a wet season for the AMS extraction, analysis of trends in AMS, analysis of temporal distributions, and in portraying the seasonality of annual maxima data.

1.1.3. Station screening

a. Quality control of metadata and location screening

We checked basic station metadata (latitude, longitude and elevation) 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 200 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. Misplacement was typically the result of latitude and longitude resolving location to the nearest minute rather than a finer resolution. We will provide original and revised coordinates for all stations used in the analysis in the final NOAA Atlas 14 documentation for the project.

In addition, we removed from the database 2,934 stations that were located outside the project area boundaries (as shown in Figure 2). Most of the deletes occurred because some agencies provided data for their entire boundary state (or province in Canada) beyond our immediate buffer area.

b. Co-located station cleanup

Co-located stations are defined here as stations that have the same, or very nearly the same, geospatial data, but report precipitation amounts at different time intervals (15-minute, 1-hour, or 1-day). Time series plots of the 1-hour and 1-day annual maximum series of co-located stations were reviewed, where 15-minute and 1-hour data were first aggregated to corresponding 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, stations were extended using data from the shorter reporting interval. 155 stations were removed because they were co-located with stations reporting the same data at shorter intervals and data at 77 hourly and/or daily stations were extended.

The consistency between the 1-hour and 1-day data reported at different time intervals was also inspected. Any disparate maxima were checked for errors. Questionable values were investigated using climatological observation forms, monthly storm data reports and other historical weather event publications and corrected as necessary.

c. Nearby station cleanup

Nearby stations are defined here as stations within five miles with consideration to elevation differences. We will evaluate all daily, hourly and 15-minute nearby stations and consider merging records to increase record lengths. So far, we have completed this nearby-station cleanup for the 15-minute data with 23 station pairs being merged.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2013)

We will format any additional data acquired in the next reporting period. We will finish all station screening tasks, including checking metadata quality, screening for duplicate stations from different datasets, screening nearby stations for potential merges, and removing any stations not meeting the minimum requirement for data years. We will also work on quality control of high and low outliers in the annual maximum series for all base durations.

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, trend analysis, independence, consistency across durations, duplicate stations, candidates for merging) [January 2014]

Regionalization and frequency analysis [July 2014]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [December 2014]

Peer review [December 2014]

Revision of PF estimates [June 2015]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [July 2015]

Web publication [September 2015]

2. AREAL REDUCTION FACTORS

2.1. PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2013)

Areal reduction factors (ARFs) are needed to convert average point precipitation frequency estimates to areal estimates with the same annual exceedance probability for an area of interest. This is a fixed-area definition which is different from the moving storm-based depth-area relationships used with probable maximum precipitation. HDSC performed an extensive literature review of ARF methods and their main advantages and disadvantages and selected three diverse fixed-area ARF methods for further evaluation. Selection was done primarily from the perspective of their potential application to NOAA Atlas 14 precipitation frequency estimates.

The first method uses spatial correlograms and extreme value theory to derive the ARFs (Sivapalan and Bloschl, 1998). It is based on assumptions that the areal-averaged parent rainfall is gamma distributed and that the link between the point parent and areal parent rainfall is only dependent on the spatial correlation of rainfall.

The second method combines the notion of dynamic scaling with that of statistical self-affinity to find a general functional form for the mean rainfall intensity as a function of both the duration and area (De Michele, Kottegoda and Rosso, 2001). One potential disadvantage of this method is that derived ARFs do not depend on annual exceedance probabilities.

For the third method, point and areal depth-duration-frequency curves are characterized using the Generalized Extreme Value (GEV) distribution. The parameters of the GEV distribution are a determined as a function of both the area and duration (Overeem et al., 2010).

In addition, HDSC developed a new copula-based ARF method. This method uses copulas along with spatial dependence structure to model the distribution of the rain field over a catchment area. Areal estimates are then obtained from the joint distribution and these estimates are used in turn to obtain areal reduction factors.

During this reporting period, we continued to evaluate the four methods. We applied all four methods to rainfall data in Oklahoma and assumed that the whole state is a single climate region. For the two methods that rely on spatial correlograms, we looked at several correlation models for 1-day AMS. Correlation coefficients were calculated only for station pairs that had a minimum of ten years of overlap. The generalized exponential function gave the most reasonable fit; however, there was too much scatter around the fitted curve to consider the correlogram reliable. This occurred in the AMS data as well as in the parent rainfall data. Based on this finding, we decided to focus on testing the methods which do not rely on spatial correlograms namely Overeem et al., 2010 and De Michele, Kottegoda and Rosso, 2001.

We also looked at the sensitivity of these two remaining methods to type of rainfall data used in analysis (radar versus interpolated raingauge data) and how different interpolation schemes applied to raingauge data affect ARF estimates. As expected, results were sensitive to the choice of dataset.

References:

De Michele, C., N. T. Kottegoda, and R. Rosso, 2001. The derivation of areal reduction factor of storm rainfall from its scaling properties. *Water Resources Research*, 37, 3247-3252.

Overeem, A, T. A. Buishand, I. Holleman, and R. Uijlenhoet, 2010. Extreme value modeling of areal rainfall from weather radar. *Water Resources Research, Vol. 46*.

Sivapalan M., and G. Bloschl, 1998. Transformation of point rainfall to areal rainfall: Intensity-duration-frequency curves. *Journal of Hydrology*, 204, 150-167.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2013)

We will extend this work to all states in the contiguous USA for which we have NOAA Atlas 14 coverage.

We will continue testing the sensitivity of areal reduction factors to the chosen data and approach. We recently became aware of a new product that may be useful for this project developed by the PRISM Climate Group (Oregon State University): a 4-km gridded daily precipitation dataset for the contiguous United States for the period from 1981 to 2010. During the next reporting period, we'll obtain the data and downscale it to hourly durations using approaches applied in the NWS Distributed Model Intercomparison Project, Phase 2 (http://www.nws.noaa.gov/oh/hrl/dmip/2/wb_precip.html).

2.3. PROJECT SCHEDULE

Due to limited resources and the departure of several group members, including the recent departure of the key group member working on this task (see Section III. Other, 3. Personnel) and higher priority precipitation frequency projects, the completion date of this project has to be postponed. Our new estimate for the completion date is September 2014.

III. OTHER

1. STORM ANALYSIS

HDSC creates maps of annual exceedance probabilities (AEPs) for selected significant storm events that typically have AEPs of less than 0.2%. We look at a range of durations and select the one that shows the lowest AEPs for the largest area, i.e., the worst case. In each analysis, the time period for the worst case shown in the maps is not necessarily the same for all locations; as a result, maps do not represent isohyets at any particular point in time, but rather isolines of AEPs within the whole event.

The underlying data for these analyses are rainfall observations (usually from Stage IV gridded data - http://www.emc.ncep.noaa.gov/mmb/ylin/pcpanl/stage4/) and point rainfall frequency estimates (usually from NOAA Atlas 14) for a range of durations and AEPs. 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 developed maps representing the annual exceedance probabilities of three recent events:

- 10-day rainfall from the 29 July - 8 August 2013 event in southern Missouri (Figure 5);
- 7-day rainfall from the 9-16 September 2013 event in New Mexico (Figure 6);
- 24-hour, 48-hour and 7-day rainfall from the 9-16 September 2013 event near Boulder, Colorado. This storm delivered total rainfall amounts that exceeded 17 inches in some locations as it slowly moved through the area and caused extensive river flooding. The map showing the AEPs for the worst case 7-day rainfall is shown in Figure 7. As can be seen in Figure 8, which shows the observations and precipitation frequency estimates for a rain gauge near Boulder, the annual exceedance probabilities for the event rapidly decreased with duration and reached 1/1,000 at 24-hour. The accumulated rainfall continued increasing through 7 days, and corresponding AEPs continued becoming more and more rare. In the figure, we also showed the upper bound of the 90% confidence interval for 1/1,000 AEP to illustrate uncertainty associated with the estimation of AEPs. As can be seen from the figure, the accumulated rainfall remained below the upper confidence limit for the 1/1,000 AEP for all durations up to 4 days.

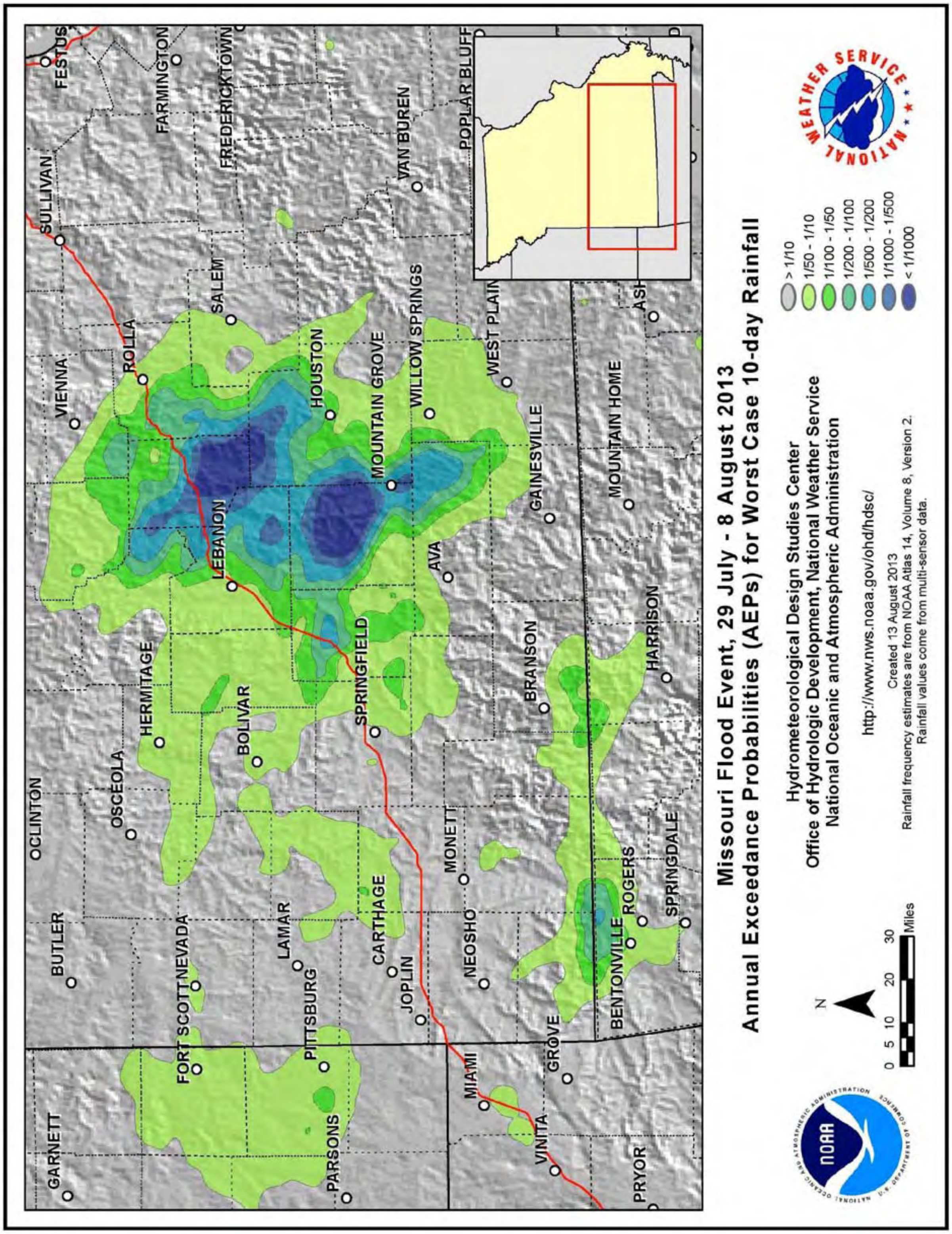

Figure 5. Annual exceedance probabilities for the worst case 10-day rainfall from the 29 July - 8 August 2013 event in southern Missouri.

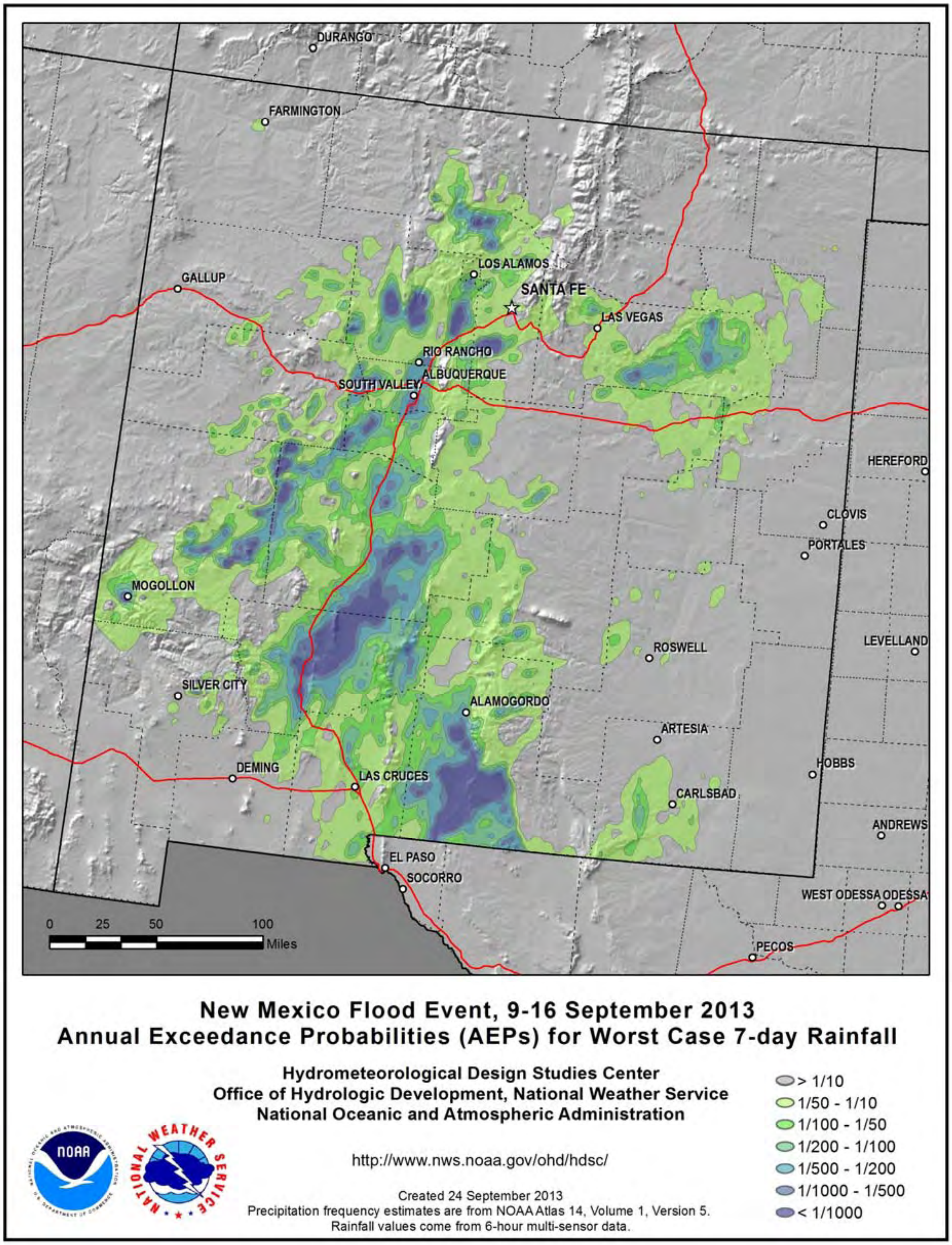

Figure 6. Annual exceedance probabilities for the worst case 7-day rainfall from the 9-16 September 2013 event in New Mexico.

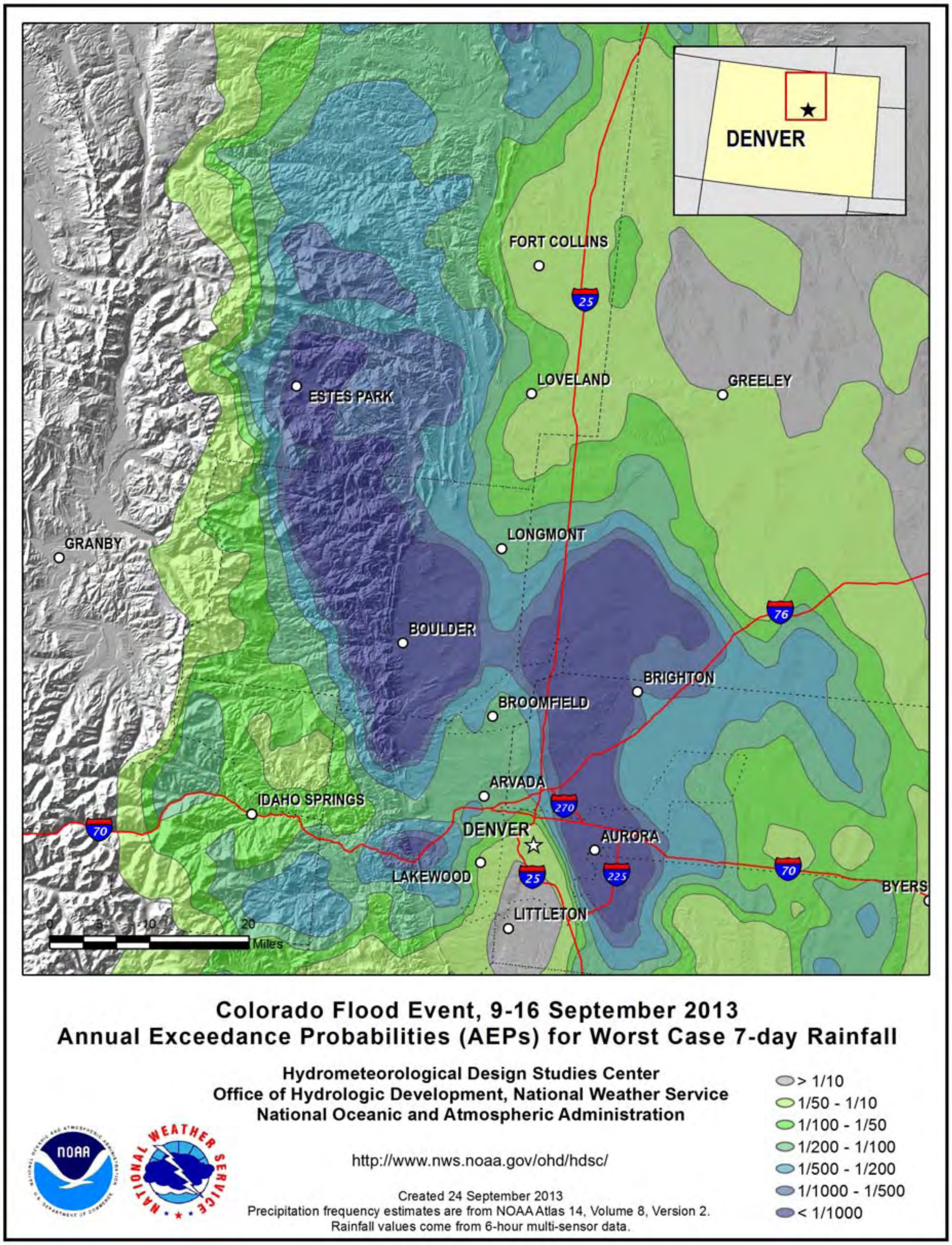

Figure 7. Annual exceedance probabilities for the worst case 7-day rainfall from the 9-16 September 2013 event near Boulder, Colorado.

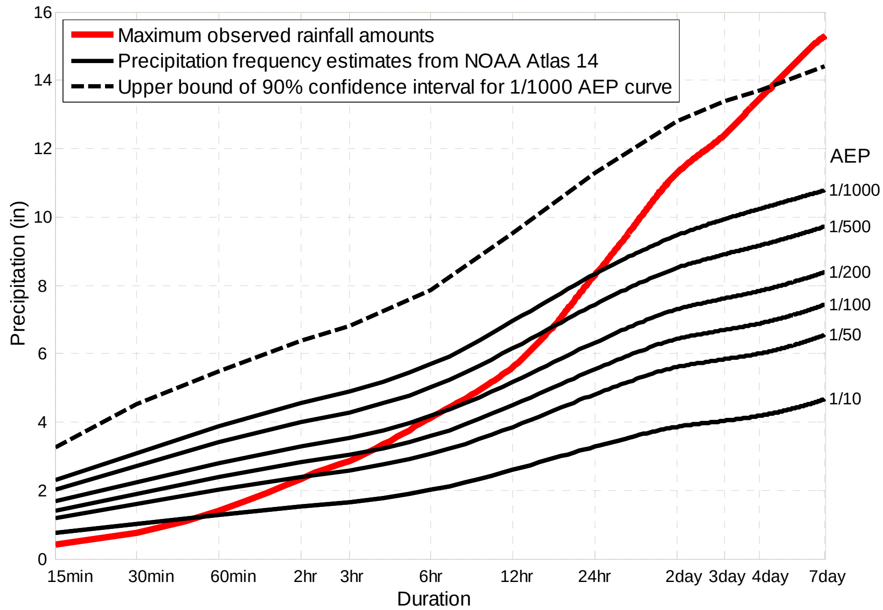

Figure 8. Maximum observed rainfall amounts in relationship to corresponding precipitation frequency estimates for the Justice Center gauge, an ALERT station maintained by the Urban Drainage and Flood Control District in Denver.

2. RECENT MEETINGS AND CONFERENCES

- On July 7th, Sanja Perica gave a presentation on NOAA Atlas 14 products and methods to the Advisory Committee on Water Information's (ACWI) Subcommittee on Hydrology's (SOH) Extreme Storms Work Group (ESWG) and other Federal agency personnel.
- Dr. Perica gave a similar webinar presentation for the U.S. Army Corps of Engineers personnel working on USACE standards in the wake of hurricane Sandy on September 10th.
- Geoff Bonnin gave presentations on trends in exceedances and important semantic problems in describing the frequency rainfall based on Bonnin et al, 2011 to:
  - a group of consulting engineers and others organized by Parsons Brinkerhoff (July 12th)
  - the ACWI Climate Adaptation Workgroup (September 11th).

3. PERSONNEL

There were two personnel departures from HDSC in September 2013. Ishani Roy, a UCAR employee who worked on statistical analyses for the precipitation frequency and areal reduction factor projects, departed on September 6th. Debbie Martin, a long-time contractor with HDSC, departed on September 30th but will continue to support various tasks on a part-time basis as we transition assignments to other staff.