HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 July 2011 to 30 September 2011

Office of Hydrologic Development

U.S. National Weather Service

National Oceanic and Atmospheric Administration

Silver Spring, Maryland

October 2011

DISCLAIMER

The data and information presented in this report are provided only to demonstrate current progress on the various technical 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. The Atlas is divided into volumes based on geographic sections of the country and affiliated territories. NOAA Atlas 14 is a web-based document available through the Precipitation Frequency Data Server (PFDS; http://hdsc.nws.noaa.gov/hdsc/pfds/index.html).

HDSC is currently updating estimates for Alaska, the following southeastern states: Alabama, Arkansas, Georgia, Florida, Louisiana and Mississippi, and the following midwestern states: Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin. The funding for the following northeastern states: Connecticut, Massachusetts, Maine, New Hampshire, New York, Rhode Island and Vermont has been secured. Once the contract documents have been finalized we will begin the three year task of updating precipitation frequency estimates for the northeastern states. Figure 1 shows new project areas as well as updated project areas included in NOAA Atlas 14, Volumes 1 to 6.

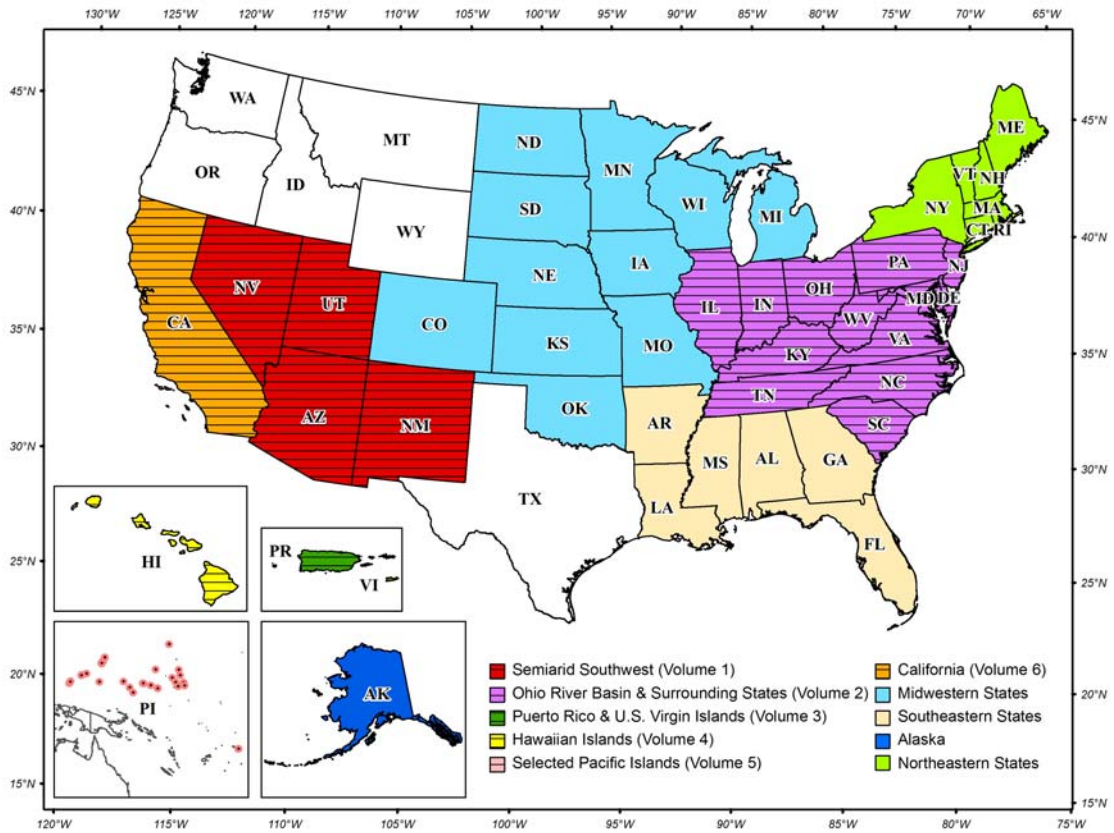

Figure 1. Current project areas and project areas included in published NOAA Atlas 14, Volumes 1-6.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE SOUTHEASTERN STATES

1.1. PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2011)

The project includes the states of Alabama, Arkansas, Florida, Georgia, Louisiana and Mississippi and an approximately 1-degree buffer around the core states (Figure 2). To facilitate a more efficient process, Southeastern and Midwestern (see Section 2) precipitation frequency projects are being done simultaneously. Because of that, some of the results shown in this report apply for the both projects.

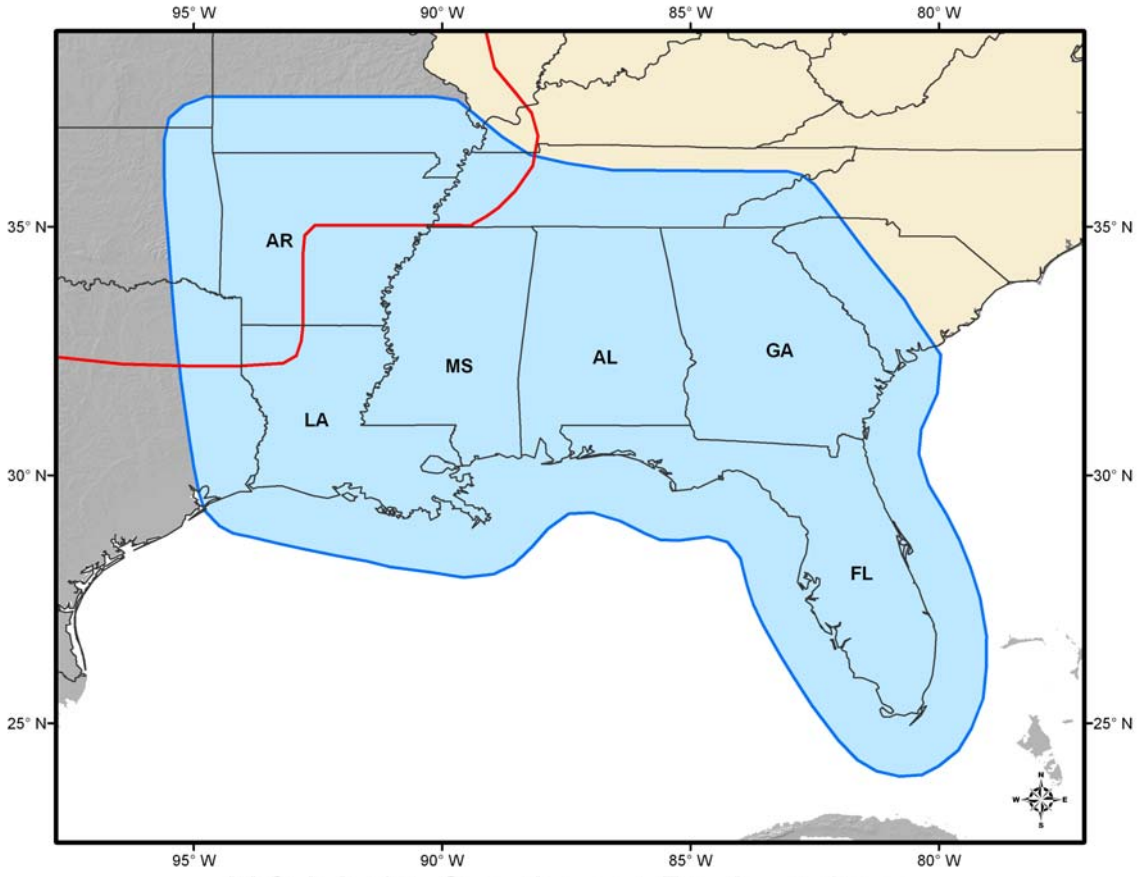

Figure 2. Southeastern precipitation frequency project area (shown in blue). Also shown is the border of the Midwestern precipitation frequency project area (red line).

1.1.1. Data collection and formatting

Daily data from the Midwestern Region Climate Center's (MRCC) 19th Century Forts and Voluntary Observers Database were downloaded and formatted. This extended data into the early 1800s for about 150 stations.

Daily data from the National Climatic Data Center (NCDC) were edited to correct a gross error where days with zero rainfall were incorrectly digitized as missing before 1947.

1.1.2. Station screening

HDSC completed screening all 15-minute, 1-hour and 1-day stations for (1) duplicate records from different data sources, (2) duplicate records at co-located daily, hourly, and/or 15-minute stations, (3) extending records using data from co-located stations, (4) merging records of nearby stations, and (5) removing shorter, less reliable records in station dense areas. This was a significant accomplishment, since, for instance, 5,792 1-day stations required review. A total of 1,553 pairs of stations were merged or extended during this process.

1.1.3. Quality control of AMS

All identified high outliers and other questionable maxima at stations were verified, corrected, or removed from the dataset for the 15-minute, 1-hour and 1-day durations. Values in question were mapped with concurrent measurements at nearby stations. Questionable values that could not be confirmed by measurements at nearby stations were further investigated using other resources, such as NCDC's database of storm data and observation forms to which they have recently restored access.

1.1.4. Correction for constrained observations

Concurrent constrained and unconstrained annual maxima at hourly stations were extracted to develop daily correction factors (e.g., aggregated 1-day amounts and moving window 24-hour amounts). Similarly, concurrent constrained and unconstrained annual maxima at 15-minute stations were extracted to develop hourly correction factors (e.g., 1-hour and 60-minutes). Ratios of the constrained and unconstrained maxima will be examined to develop correction factors for the following durations: 1-hour, 2-hour, 3-hour, 6-hour, 1-day, 2-day, 3-day, 4-day, and 7-day.

1.1.5. Temporal distribution analysis

Algorithms to develop temporal distributions of the data were refined and codes were de-bugged. Once the hourly data are finalized, the temporal distributions can easily be produced.

1.1.6. Mean annual maxima analysis

Spatial analysis of at-station mean annual maxima estimates (MAMs) for 1-hour and 1-day durations has started. Any remaining inconsistencies resulting from stations that may have had less reliable sampling (shorter record or missed several heavy events) relative to nearby stations are investigated and either adjusted or removed from the analysis. Resulting preliminary estimates will be sent to the PRISM Group at Oregon State University for spatial interpolation, once the contract is in place.

1.1.7. Regionalization for frequency analysis

The regionalization approach used for frequency analysis is described in more detail in NOAA Atlas 14 Volume 6, California. During this reporting period, regionalization codes were refined to allow for more detailed investigation of various statistical measures across durations within a station's region and to assure consistency in interpolated estimates across the whole range of frequencies.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2011)

In the next reporting period, the following tasks will be completed: investigation of outliers in the AMS for all remaining durations, trend analysis for 1-hour and 1-day durations, regionalization and preliminary frequency analysis. Spatial patterns in mean annual maxima will be investigated in preparation for spatial interpolation by the PRISM Group.

1.3. PROJECT SCHEDULE

Completion dates are revised for remaining tasks as a result of delays in contracting the Oregon State University's PRISM Group to spatially interpolate the mean annual maxima and the loss of four employees during this reporting period. As a result, the publication date is pushed to September 2012.

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) [Near completion]

Regionalization and frequency analysis [November 2010; revised to November 2011]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [August 2011, revised to February 2012]

Peer review [September 2011, revised to April 2012]

Revision of PF estimates [December 2011, revised to July 2012]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [April 2012, revised to July 2012]

Web publication [May 2012, revised to September 2012]

2. PRECIPITATION FREQUENCY PROJECT FOR THE MIDWESTERN STATES

2.1. PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2011)

The project area includes the states of Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin and an approximately 1-degree buffer around the core states (Figure 3). To facilitate a more efficient process, Southeastern (see Section 1) and Midwestern precipitation frequency projects are being done simultaneously. Because of that, some of the results shown in this report apply for the both projects.

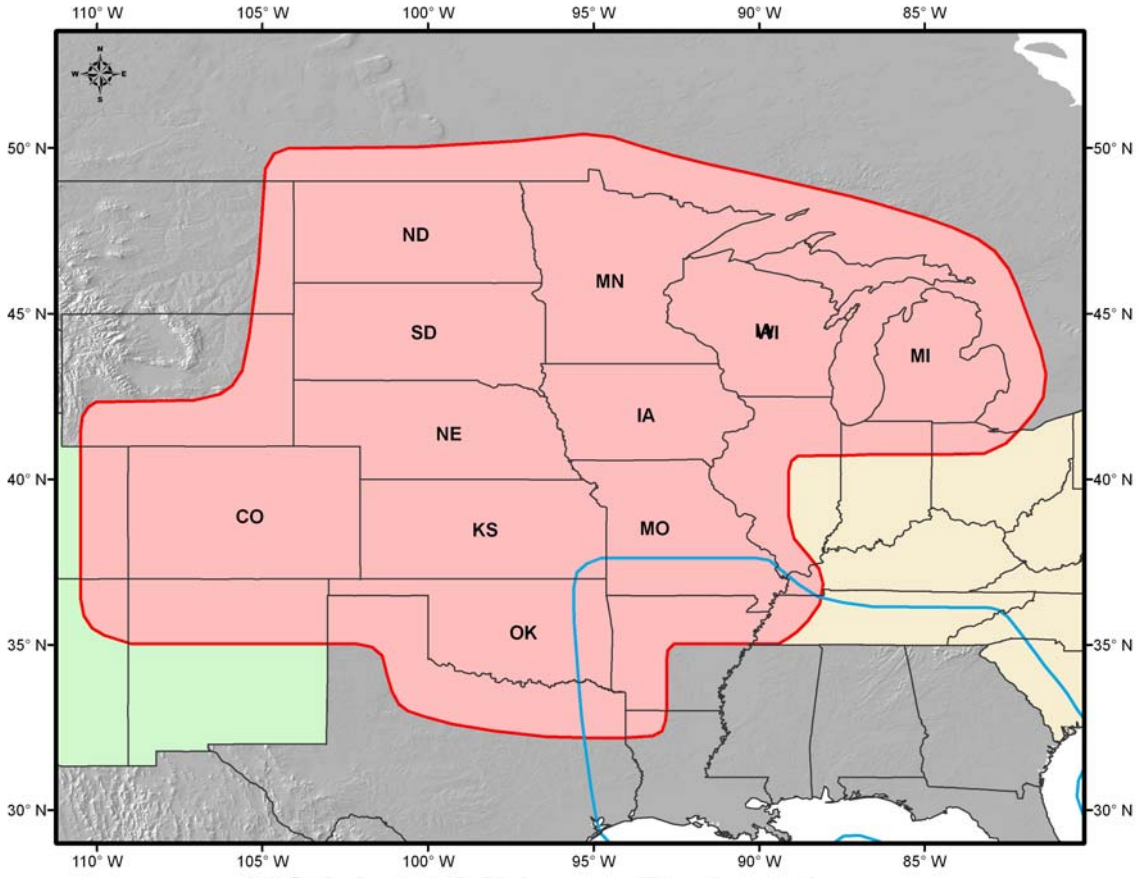

Figure 3. Midwestern precipitation frequency project area (shown in red). Also shown is the border of the Southeastern precipitation frequency project area (blue line).

2.1.1. Data collection and formatting

Daily data from the Midwestern Region Climate Center's (MRCC) 19th Century Forts and Voluntary Observers Database were downloaded and formatted. This extended data into the early 1800s for about 150 stations.

Daily data from the National Climatic Data Center (NCDC) were edited to correct a gross error where days with zero rainfall were incorrectly digitized as missing before 1947.

2.1.2. Station screening

HDSC completed screening all 15-minute, 1-hour and 1-day stations for (1) duplicate records from different data sources, (2) duplicate records at co-located daily, hourly, and/or 15-minute stations, (3) extending records using data from co-located stations, (4) merging records of nearby stations, and (5) removing shorter, less reliable records in station dense areas. This was a significant accomplishment, since, for instance, 5,792 1-day stations required review. A total of 1,553 pairs of stations were merged or extended during this process.

2.1.3. Extraction of AMS

Three datasets in Minnesota and North Dakota were identified for not collecting observations during the cold winter season - Minnesota Department of Natural Resources, State Climatology Office, North Dakota State Water Commission (NDSWC) Precipitation Network, and North Dakota State Climate Office: North Dakota Agricultural Weather Network (NDAWN). Since precipitation is limited and annual maxima are unlikely to have occurred during those months, allowable amounts of missing data were adjusted to allow the extraction of annual maxima from those data.

2.1.4. Quality control of AMS

All identified high outliers and other questionable maxima at stations were verified, corrected, or removed from the dataset for the 15-minute, 1-hour and 1-day durations. Values in question were mapped with concurrent measurements at nearby stations. Questionable values that could not be confirmed by measurements at nearby stations were further investigated using other resources, such as NCDC's database of storm data and observation forms to which they have recently restored access.

2.1.5. Correction for constrained observations

Concurrent constrained and unconstrained annual maxima at hourly stations were extracted to develop daily correction factors (e.g., aggregated 1-day amounts and moving window 24-hour amounts). Similarly, concurrent constrained and unconstrained annual maxima at 15-minute stations were extracted to develop hourly correction factors (e.g., 1-hour and 60-minutes). Ratios of the constrained and unconstrained maxima will be examined to develop correction factors for the following durations: 1-hour, 2-hour, 3-hour, 6-hour, 1-day, 2-day, 3-day, 4-day, and 7-day.

2.1.6. Temporal distribution analysis

Algorithms to develop temporal distributions of the data were refined and codes were de-bugged. Once the hourly data are finalized, the temporal distributions can easily be produced.

2.1.7. Mean annual maxima analysis

Spatial analysis of at-station mean annual maxima estimates (MAMs) for 1-hour and 1-day durations has started. Any remaining inconsistencies resulting from stations that may have had less reliable sampling (shorter record or missed several heavy events) relative to nearby stations are investigated and either adjusted or removed from the analysis. Resulting

preliminary estimates will be sent to the PRISM Group at Oregon State University for spatial interpolation, once the contract is in place.

2.1.8. Regionalization for frequency analysis

The regionalization approach used for frequency analysis is described in more detail in NOAA Atlas 14 Volume 6, California. During this reporting period, regionalization codes were refined to allow for more detailed investigation of various statistical measures across durations within a station's region and to assure consistency in interpolated estimates across the whole range of frequencies.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2011)

In the next reporting period, the following tasks will be completed: investigation of outliers in the AMS for all remaining durations, trend analysis for 1-hour and 1-day durations, regionalization and preliminary frequency analysis. Spatial patterns in mean annual maxima will be investigated in preparation for spatial interpolation by the PRISM Group.

2.3. PROJECT SCHEDULE

Completion dates are revised for remaining tasks as a result of delays in contracting the Oregon State University's PRISM Group to spatially interpolate the mean annual maxima and the loss of four employees during this reporting period. As a result, the publication date is pushed to September 2012.

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

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Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [April 2012, revised to July 2012]

Web publication [May 2010, revised to September 2012]

3. PRECIPITATION FREQUENCY PROJECT FOR ALASKA

3.1. PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2011)

The University of Alaska, Fairbanks (UAF) and HDSC are jointly working on this project.

3.1.1. Peer review

A peer review of precipitation frequency estimates was conducted from August 2nd through August 30th. The review included the following items:

a) a list of all stations used in the analysis. The list included information on station name, state, source of data, assigned station ID, latitude, longitude, elevation, and period of record. It also showed information if the station was merged with another station and if metadata at the station were changed;

b) a list of all stations that were received by HDSC, but not considered in analysis. This list contained stations that were not used, either because there was another station with a longer period of record nearby, or station data were not reliable, or the station period of record was not long enough and it was not a candidate for merging with any nearby station;

c) at-station depth-duration-frequency curves for a range of durations for which AMS data were available;

d) spatially-interpolated maps of mean annual maxima for 60-minute, 24-hour and 10-day durations;

e) spatially-interpolated AMS-based precipitation frequency estimates for 60-minute, 24-hour and 10-day durations and for 1/2 and 1/100 annual exceedance probabilities (AEPs).

HDSC received six responses from different individuals or groups. In particular, HDSC met with UAF to review and discuss their specific comments. All comments will be addressed; HDSC responses will be available in the final documentation.

All estimates are being re-visited based on the comments received during the review period.

3.1.2. Rainfall AMS extraction

For some applications it may be important to differentiate frequency estimates from liquid precipitation (i.e., rainfall) only. As discussed in previous Quarterly Progress Reports, rainfall-only observations are being segregated from existing datasets using co-located or nearby measurements of snow and/or temperature.

During this quarter, UAF completed rainfall extraction for the remaining datasets: USGS daily, NCDC hourly and LTER hourly. They reviewed differences between the numbers of years in the rainfall data versus the precipitation data.

HDSC extracted annual maximum series (AMS) for durations 24-hours and shorter. Frequency analysis was done on at-station rainfall-only AMS and on total precipitation AMS using the Generalized Extreme Value (GEV) distribution with parameters estimated from L-moment statistics. Various types of regression equations are being investigated to relate rainfall frequency estimates with precipitation frequency estimates.

3.1.3. Station screening

Although 1-hour SNOTEL data were previously excluded due to short periods of record and data quality concerns, HDSC reviewed the tipping bucket data, based on a comment received during the peer review, and added back two stations that had more than 15 years of data to the analysis.

Since the Automated Surface Observing Systems (ASOS) data from NCDC were added to the analysis in the last quarter, HDSC completed the final screening of stations within five miles for (1) duplicate records from different data sources, (2) duplicate records at co-located daily, hourly, and/or 15-minute stations, (3) extending records using data from co-located stations, (4) merging records of nearby stations, and (5) removing shorter, less reliable records.

Given the limited data available in the project area, stations with at least 10 years were considered for the analysis on a case by case basis. All stations with less than 10 years were removed from the analysis.

3.1.4. Quality control of AMS

NCDC restored access to their database of climate publications and forms in September. Therefore, HDSC re-checked high outliers and other questionable maxima for all durations that could not be confirmed by measurements at nearby stations. Unresolved cases were submitted to UAF for further review. Any corrections were implemented in the dataset.

3.1.5. Correction for constrained observations

Concurrent constrained and unconstrained annual maxima at hourly stations were extracted to develop daily correction factors (e.g., aggregated 1-day amounts and moving window 24-hour amounts). Co-located hourly and n-minute stations were used for hourly durations (e.g., 1-hour and 60-minutes). Slope coefficients of zero-intercept regression models of concurrent (occurring within +/- 1 day or +/- 1 hour) unconstrained and constrained annual maxima for a given duration were used to estimate the correction factors(Tables 1 and 2).

Table 1. Correction factors applied to constrained AMS data across daily durations.

Duration (days)	**1**	**2**	**3**	**4**	**7**	**>7**
Correction factor	1.12	1.05	1.04	1.03	1.02	1.00

Table 2. Correction factors applied to constrained AMS data across hourly durations.

Duration (hours)	**1**	**2**	**3**	**6**	**>6**
Correction factor	1.08	1.04	1.02	1.01	1.00

3.1.6. Spatial interpolation of mean annual maxima

HDSC re-evaluated spatial patterns in mean annual maxima (MAMs) and 2-year and 100-year frequency estimates for the 60-minute, 24-hour and 10-day durations across the project area, in particular, with respect to reviewer comments. Some estimates in areas of varied terrain and/or where the lack of stations or short records unduly influenced expected spatial patterns were adjusted to better anchor the spatial interpolation.

Revised at-station MAM estimates for the range of durations 60-minutes through 60-days will be sent to Oregon State University's PRISM Group for final spatial interpolation using their hybrid statistical-geographic approach for mapping climate data named Parameter-elevation Regressions on Independent Slopes Model (PRISM).

3.1.7. Regionalization for frequency analysis

Regionalization was revisited after the peer review. The approach being used for this project is the "region-of-influence" approach developed for the California project (described in previous reports). The region for each station was reassessed based on inspection of spatial maps with associated tables and by examination of similarities (or dissimilarities) in selected statistics across durations from 60-minues to 60-days at stations in the region. Precipitation frequency estimates produced using the final regions will be reviewed and compared to peer-reviewed results.

3.1.8. Spatial interpolation of precipitation frequency estimates

HDSC is revising the spatial interpolation technique for the precipitation frequency estimates, as was used in NOAA Atlas 14 Volume 6, to better address the scarcity of data in a significant portion of Alaska, especially at sub-daily durations. The technique used in previous Volumes of NOAA Atlas 14 used the closest nine stations during the interpolation process, which in Alaska could cover a very large area; and using an alternative approach with a fixed search radius may result in numerous regions with a single station. Therefore, a different interpolation approach, based on interpolated ratios of precipitation frequency estimates at consecutive frequencies, is currently under investigation.

3.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2011)

The project will be completed in the next reporting period.

3.3. PROJECT SCHEDULE

UAF and HDSC: data collection, formatting, and initial quality control [Complete]

UAF and HDSC: extraction of annual maximum series (AMS) for precipitation and rainfall; additional quality control and data reliability tests (e.g., outliers, trend analysis, independence, consistency across durations, duplicate stations, candidates for merging) [Complete]

HDSC: regionalization and frequency analysis [Complete]

HDSC: initial spatial interpolation of PF estimates and consistency checks across durations [Complete]

HDSC and UAF: peer review [Complete]

HDSC: revision of PF estimates [May 2011, revised to October 2011]

HDSC: remaining tasks (e.g., development of precipitation frequency estimates for PD series, seasonality, temporal distributions) [October 2011]

HDSC: web publication of estimates [November 2011]

HDSC and UAF: documentation [December 2011]

4. AREAL REDUCTION FACTORS

4.1. PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2011)

Areal reduction factors (ARFs) are needed to convert average point precipitation frequency estimates to areal estimates with the same recurrence interval for any area of interest. HDSC is testing two existing methods and developing a new method for calculating ARF. Please see the July – September 2010 Quarterly Report (http://www.nws.noaa.gov/ohd/hdsc/current-projects/pdfs/HDSC_PR_Oct10.pdf) for more information on the methods. This project was put on hold to minimize the impact of loss of personnel on precipitation frequency projects.

4.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2011)

In the next quarter, limited activity in radar data formatting is planned.

4.3. PROJECT SCHEDULE

This project began on April 1, 2010. It is expected to be completed by April 2013.

III. OTHER

1. UPDATES TO PREVIOUS VOLUMES OF NOAA ATLAS 14

On August 1st, HDSC released the following updated Volumes - NOAA Atlas 14 Volume 4 Version 3.0: Precipitation-Frequency Atlas of the United States, Hawaiian Islands and NOAA Atlas 14 Volume 5 Version 3.0: Precipitation-Frequency Atlas of the United States, Selected Pacific Islands.

The update to Version 3.0 for both volumes reflects minor adjustments made to precipitation frequency estimates for the sub-hourly (n-minute) durations and updated temporal distribution information. Minor changes to the text were also made, in particular to reflect the updated web pages and functionality of the Precipitation Frequency Data Server (PFDS, http://hdsc.nws.noaa.gov/hdsc/pfds/index.html). Appendix A.10 of the updated documentation provides additional information (http://www.nws.noaa.gov/oh/hdsc/currentpf.htm).

Volume 4 Version 3.0 and Volume 5 Version 3.0 information supersedes Volume 4 Version 2.1 and Volume 5 Version 2.0 information.

2. UPDATED WEBSITE

At the end of August, access to the older version of the PFDS web site FOR ALL PROJECT AREAS was deactivated in favor of the updated PFDS format. Users should update any existing bookmarks to the state specific pages or access the PFDS directly through http://hdsc.nws.noaa.gov/hdsc/pfds/index.html to reach the current pages.

3. UPCOMING PRESENTATIONS

Ishani Roy of HDSC will be presenting *A Copula Based Approach for Estimation of Areal Reduction Factors* at the American Geophysical Union Fall Meeting December 5th-9th in San Francisco.

4. UPDATE TO PRECIPITATION FREQUENCY ESTIMATES FOR THE NORTHEASTERN STATES

In anticipation of updating precipitation frequency estimates for the following Northeastern states: Connecticut, Rhode Island, Maine, Massachusetts, New Hampshire, New York and Vermont, HDSC began to collect all available precipitation datasets (daily, hourly, 5-minute, etc.) with at least 10 years of record. In addition, data will be collected in adjacent portions of neighboring states that border the project area. A data request was submitted to members of the HDSC listserver and to other potentially interested parties.

Please contact HDSC (HDSC.Questions@noaa.gov) regarding any available datasets (besides data available through the National Climatic Data Service) in the project area. In other projects we have found such local datasets extremely useful.

5. PERSONNEL

Four members of HDSC resigned to pursue other opportunities or retired in August and September. Their primary tasks have been absorbed by the remaining nine members of the group.