HYDROMETEOROLOGICAL DESIGN STUDIES CENTER QUARTERLY PROGRESS REPORT

1 April 2008 to 30 June 2008

Office of Hydrologic Development

U.S. National Weather Service

National Oceanic and Atmospheric Administration

Silver Spring, Maryland

July 2008

DISCLAIMER

Table of Contents

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. Updated precipitation frequency estimates for durations from 5 minutes to 60 days and selected average recurrence intervals accompanied by additional information (e.g., 90% confidence intervals, temporal distributions, seasonality) are published in NOAA Atlas 14. The Atlas is divided into volumes based on geographic sections of the country. NOAA Atlas 14 is a web-based document available through the Precipitation Frequency Data Server (http://www.nws.noaa.gov/ohd/hdsc). We are currently working on updating precipitation frequency estimates for Hawaii (NOAA Atlas 14, Volume IV) and the remainder of California (NOAA Atlas 14, Volume V). We are also finalizing agreements to update estimates for the southeastern states of Florida, Georgia, Alabama and Mississippi and for Alaska. There have also been discussions for updating estimates in Midwestern states. See Upcoming Projects for more detail.

In addition, HDSC is developing depth-area relationships (known also as Areal Reduction Factors - ARF) that will enable conversion of point rainfall frequency estimates to areal average frequency estimates for the same duration and same average recurrence interval. The results of this supplementary study will be applicable to all volumes of NOAA Atlas 14.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY FOR HAWAII

Unforeseen inconsistencies from duration to duration related to the data sampling and data quality have unfortunately delayed the peer review which was scheduled to begin in July 2008. We are currently investigating the causes/resolutions of these inconsistencies. More information is provided in Section 1.1.5. Preliminary review of precipitation frequency estimates. Once they are resolved, we will commence the peer review as soon as possible.

1.1. PROGRESS IN THIS REPORTING PERIOD

1.1.1. Data

a. Conversion factors for hourly durations

Conversion factors are used to convert from constrained to unconstrained (i.e., with no pre-defined start time) observations. Based on the most recent investigation of concurrent constrained and unconstrained annual maxima obtained from co-located hourly and n-minute stations, it was decided to use a conversion factor of 1.11 for the 1-hour duration, 1.06 for the 2-hour, and 1.00 for other hourly durations.

b. HaleNet data

Additional hourly and daily data were obtained from Haleakala National Park & Biological Resources Division for eleven stations located in high elevation areas of eastern Maui. Four of those stations were excluded because they had six or fewer years of data or data seemed to be inconsistent with nearby Halenet stations. Remaining seven HaleNet stations have 9 to 17 years of data with an average of 12.8 years. Annual maximum series (AMS) for those stations were quality controlled, and mean annual maxima (MAMs) were computed for all durations. These MAMs may be used to anchor the spatial interpolation that serves as the base map for deriving all precipitation frequency estimates. Since the records are less than 20 years, the data will not be used in the frequency analysis.

c. n-minute ratios

The 5-minute, 10-minute, 15-minute, 30-minute, and 60-minute durations are collectively referred to as “n-minute”. Because of the small number of stations with 5-minute data available to generate n-minute precipitation frequency quantiles for the whole study area, they will be estimated by applying linear scaling factors to 60-minute quantiles. Those factors were developed using ratios of n-minute quantiles to 60-minute quantiles from co-located 5-minute and hourly stations in the project area.

Table 1 shows the four 5-minute stations available in Hawaii. The three stations with more than 10 years of data were used in the computation of the ratios. n-minute quantiles were computed using regional L-moment approach with all three stations as one region. Ratios of the n-minute quantiles to the 60-minute quantile were computed for all frequencies at each station. Those ratios were then averaged for average recurrence intervals 2-year through 100-year to compute the final ratios. As can be seen from Table 2, the ratios are very similar to those computed in NOAA Atlas 14, Volume 3 for Puerto Rico and U.S. Virgin Islands which have a similar tropical climate.

Table 1. Available 5-minute stations in Hawaii.

Station	Island	Locale	Latitude	Longitude	Elevation (ft)	Years of data
51-1492	Hawaii	Windward	19.7222	-155.0558	38	8
51-1919	Oahu	Leeward	21.3219	-157.9253	7	18
51-2572	Maui	Leeward	20.8997	-156.4286	51	17
51-5580	Kauai	Windward	21.9839	-159.3406	100	25

Table 2. n-minute ratios (5-, 10-, 15- and 30-minute to 60-minute) for NOAA Atlas 14 Volume 3, Puerto Rico and U.S. Virgin Islands and Volume 4, Hawaiian Islands.

	5-min	10-min	15-min	30-min
NOAA Atlas 14 Volume 3 (Puerto Rico)	0.240	0.328	0.421	0.674
NOAA Atlas 14 Volume 4 (Hawaii)	**0.273**	**0.374**	**0.468**	**0.693**

1.1.2. Regionalization

a. Regions applicable for daily durations

HDSC met with local experts, Kevin Kodama, the Hydrologist in Charge at the National Weather Service Weather Forecast Office in Honolulu and Pao-Shin Chu, the Hawaiian State Climatologist on May 12, 2008 to review daily regions and preliminary results. After a careful review of the regional delineations during the meeting, several changes were made to the daily regions. Twenty-eight homogeneous regions, shown in Figure 1, were developed. The most noteworthy differences relative to the regionalization map with twenty-four regions, shown in previous progress report, are:

a. the coastal region and inland/upslope region on the windward side of the Big Island were divided into north and south sub-regions to reflect prevailing wind and precipitation directions/patterns;

b. the region on the north coast of western Maui was divided into east and west sub-regions. The western half was merged with stations to the south;

c. the leeward region on the west coasts of the islands was split by island to keep the numbers of stations per region more consistent among all regions with little impact on the overall quantiles;

d. two stations (51-3054 and 51-2880) on the southern tip of the Big Island were re-assigned from the region that includes the Kona coast into the region that encompasses the southeast coast.

All modifications were carefully examined with respect to extreme precipitation climatology, impact on statistical heterogeneity measures and impact on regional growth factors. Based on H1 statistical heterogeinity measure, homogeinity improved relative to numbers shown in previous report.

Each region was renumbered according to general climatic/geographic zones:

- regions 1-9: windward coastal regions;
- regions 10-14: windward uplands;
- regions 15-19: windward transitionary regions;
- regions 20-27: leeward lowlands and slopes;
- region 28: high elevation stations.

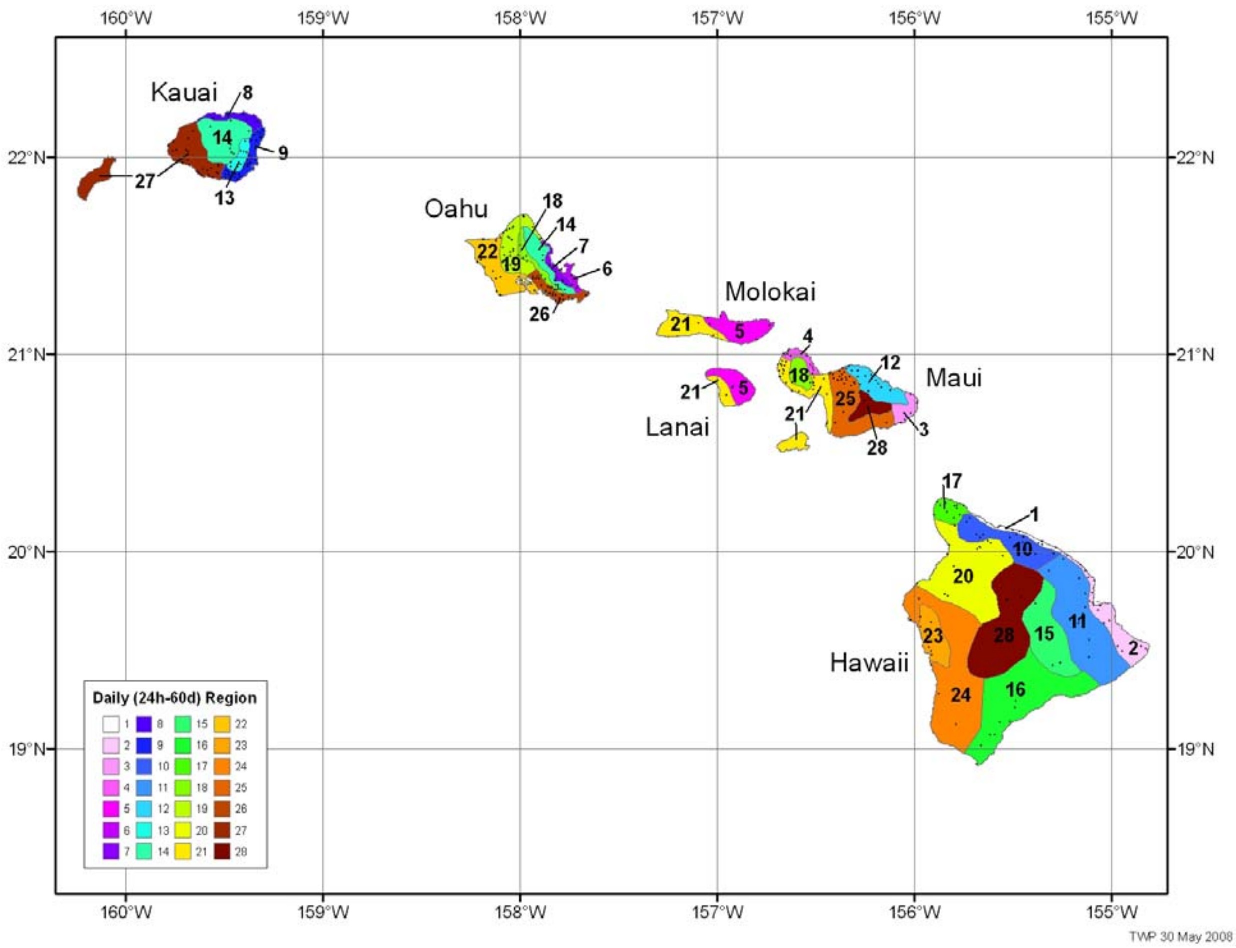

Figure 1. Twenty-eight daily regions (applicable for durations 24-hour through 60-day).

b. Regions applicable to hourly durations (durations < 24 hours)

Four hourly regions shown in previous progress reports were reexamined relative to newly delineated daily regions. Eleven homogeneous regions, shown in Figure 2, were developed. The most noteworthy differences relative to the previous regionalization map are:

a. the windward coast on Oahu was divided into a coastal region and a transitional region;
b. the transitional region on Oahu was expanded to include stations further west;
c. the windward region was subdivided into four separate regions by island;
d. the leeward coast of the Big Island was assigned as its own region;
e. a high elevation region was created on the Big Island – although it has only one station, it was deemed that local conditions justify a separate region.

All modifications were carefully considered with respect to extreme precipitation climatology, homogeneity, and impact on regional growth factors. Table 3 shows the number of stations and H1 measures for all hourly durations for the eleven regions. It is typically assumed that H1 > 2.0 indicates possible regional heterogeneity. A few durations with H1 slightly greater than 2.0 were accepted due to the limited number of stations and climatologically reasonable regional delineations. Note that since region 11 is comprised of a single station, a regionally-based H1 can not be computed. Investigation of hourly regions is still ongoing, and may result in additional site redistribution.

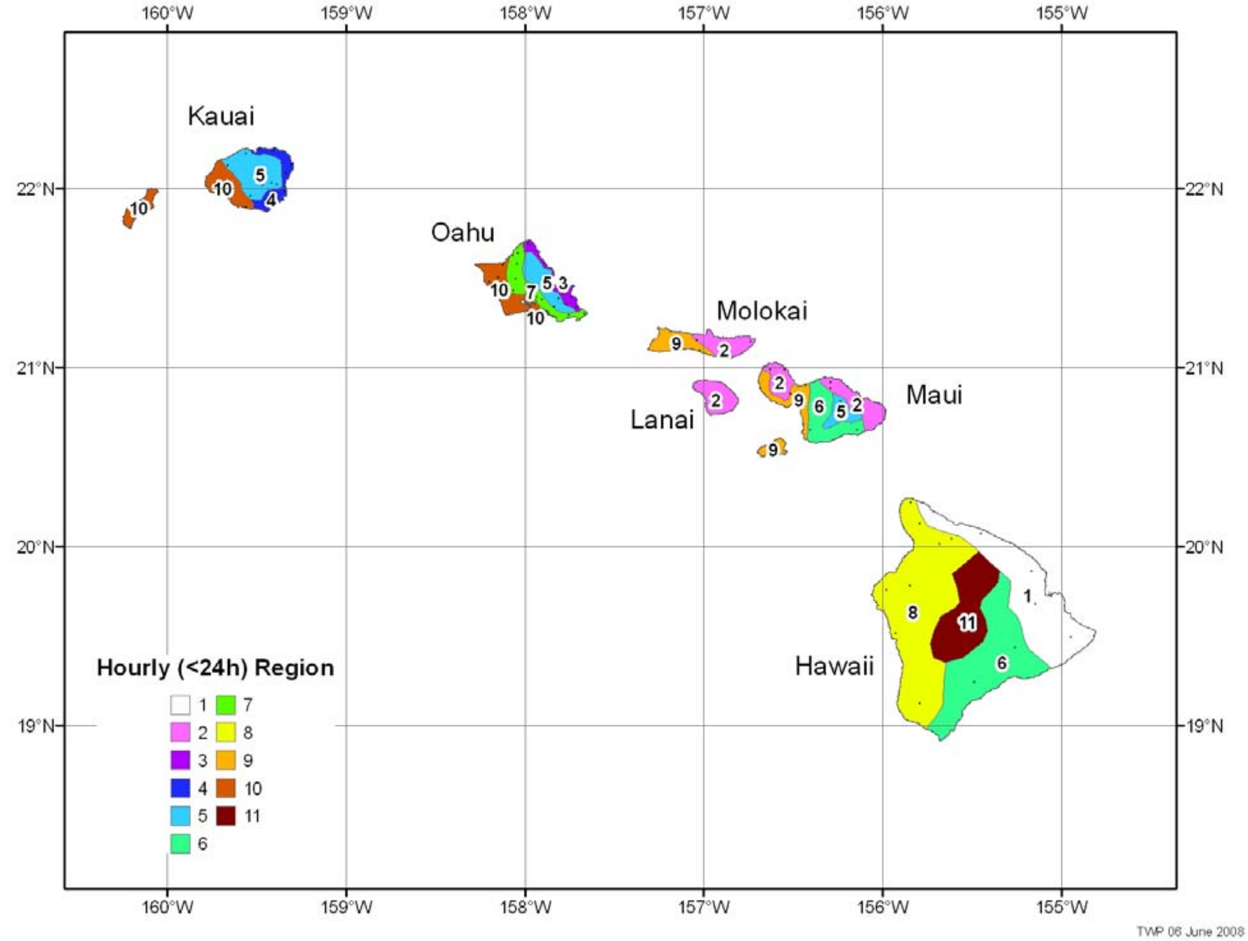

Figure 2. Eleven hourly regions (applicable for hourly durations less than 24-hour).

Table 3. Statistical heterogeneity measure (H1) for all hourly regions and durations.

Region	Number of stations	Duration				
		1-hour	2-hour	3-hour	6-hour	12-hour
1	6	-1.69	-0.52	-0.98	-0.59	0.23
2	9	0.24	1.23	1.81	2.26	2.47
3	6	-0.17	-1.56	-1.01	-0.78	-0.79
4	5	1.64	1.51	0.75	0.56	1.46
5	10	-0.46	1.05	0.90	-0.18	-0.63
6	5	0.01	-0.83	-0.61	-0.16	-0.09
7	9	-0.15	-0.25	-0.42	0.05	0.00
8	8	0.36	0.00	-0.89	-1.23	-0.91
9	5	-0.18	-0.82	-1.15	-1.06	-1.50
10	7	-0.19	-0.30	-0.55	0.47	-0.17
11	1	n/a	n/a	n/a	n/a	n/a

1.1.3. Distribution selection for AMS data

It is assumed that the stations within a region share the same shape but not scale (i.e., mean annual maximum value) of their precipitation frequency distribution curves. Five three-parameter distributions were tested for an appropriate fit to the AMS data: Generalized Extreme Value (GEV), Generalized Logistic (GLO), Generalized Normal (GNO), Generalized Pareto (GPA), and Pearson Type III (PE3). Based on the goodness-of-fit measure Z, described in Hosking and Wallis (1997), several distributions gave an acceptable fit for a number of regions and durations. GEV distribution was selected as a representative distribution for all regions and all durations. Sensitivity testing suggested there is little difference (< 5%) in 100-year estimates when using GEV versus other candidate distributions.

1.1.4. Spatial interpolation of at-site estimates of mean annual maxima (MAMs)

Mean annual maxima were computed for all sites. MAMs for selected durations (60-minute 12-hour, 24-hour and 10-day) were submitted to the PRISM Group at Oregon State University for interpolation. Preliminary grids of interpolated MAMs were reviewed. Subsequent correspondence with the PRISM Group regarding outliers and issues identified in the process led to:

- Inclusion of the HaleNet stations in eastern Maui (see 1.1.1.b. for information on HaleNet data).
- Development of pseudo MAMs for all daily durations at station 51-6565, Mount Waialeale to anchor interpolation in central Kauai. This station has Hawaii's highest mean annual total precipitation amount, but does not have sufficient non-accumulated data to extract at least 20 daily annual maxima necessary to compute precipitation frequencies. Therefore, "pseudo MAMs" were developed for all durations using an average of 2-year precipitation frequency estimates (which nearly equate the mean annual maxima) from previous precipitation frequency publications (Technical Papers 43 and 51), MAMs from available daily annual maximum series (<20 data years), and interpolated MAM values from a non-PRISM spatial

interpolation approach using nearby stations. The pseudo data MAMs will be used to anchor spatial interpolation.

- Justification of high MAM values at station 51-2227, Intake Wainiha, relative to lower mean annual total precipitation values compared to nearby stations by local anecdotal evidence that heavier rain typically falls on the slopes given the nature of the flooding and the lower precipitation readings at higher elevation stations.
- Deletion of stations 51-9261, Waiawa in central valley of Oahu, and 51-1665, Honaunau in southwest Hawaii, from the analysis. Those stations have relatively short periods of record with missing and accumulated data which may contribute to their inconsistent MAM and L-statistics, and there are nearby stations that can provide information in those areas.

1.1.5. Preliminary review of precipitation frequency estimates

During a comprehensive review of spatially interpolated station estimates and review of station estimates at all durations through the Precipitation Frequency Data Server, two issues were noted that require further analysis:

a) Spatial inconsistencies. They were observed at hourly supplemental data locations. Hourly supplemental data are data from stations with less than the required 15 years of data to be included in the computation of regional statistics, but could be used to anchor MAM estimates spatially. It was decided to exclude hourly supplemental stations from the analysis since many of their MAMs were low relative to MAMs at nearby stations. Some supplemental stations may be included later to fill in spatially gaps, as needed.

b) Inconsistencies among durations. Because data are not perfect and precipitation frequency estimates for different durations are computed independently at stations, inconsistencies (generally minor) among durations can occur. For the Hawaii project, significant inconsistencies (e.g., precipitation frequency estimates for 24-hour larger than corresponding 4-day estimates) were found, primarily at stations with accumulated data. Accumulated data are measurements of rainfall that fell over two or more days and so the distribution of the total amount among those days is unknown. At those stations, annual maxima were extracted only for durations for which the data passed our extraction criteria. This often precluded the extraction of annual maxima at shorter durations, notably 1-day and 2-day. An investigation into the cause and resolution of these inconsistencies is underway and has unfortunately delayed the peer review which was scheduled to begin in July 2008. Once concluded, new MAMs will be submitted to the PRISM Group for spatial interpolation. Then, after an internal review, the peer review will commence.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (FY08/Q4)

1.2.1. Resolve inconsistent precipitation frequency estimates

Because frequency estimates for different durations are computed independently, inconsistencies from duration to duration can occur. Accumulated data at some stations may also be contributing to observed inconsistencies. HDSC will resolve those inconsistencies during the next quarter.

1.2.2. Development of precipitation frequency estimates for partial duration series (PDS)

Precipitation frequency estimates for PDS will be computed for all durations.

1.2.3. Development of PRISM grids for mean annual maxima

Once inconsistencies noted in 1.2.1 are resolved, HDSC will submit updated 60-minute, 12-hour, 24-hour and 10-day at-site estimates of MAMs to Oregon State University's PRISM Group for spatial interpolation. The resulting grids will then be used to develop gridded precipitation frequency estimates. MAM grids and 100-year estimates for selected durations will be submitted for a peer review by the end of the next quarter.

1.2.4. Peer review

Once the PRISM Group has returned the updated MAMs and we have derived the grids of precipitation frequency estimates, we will commence the peer review.

1.3. PROJECTED SCHEDULE

Frequency analysis for all durations [August 2008]

Development of precipitation frequency grids for 1-hr, 12-hr, 24-hr, and 10-day durations based on PRISM deliverables [September 2008]

Peer review of estimates [September 2008]

Development of precipitation frequency estimates for PDS [September 2008]

Development of final precipitation frequency grids for all durations based on PRISM deliverables [November 2008]

Remaining tasks and web publication [January 2009]

2. PRECIPITATION FREQUENCY FOR REMAINDER OF CALIFORNIA

2.1. PROGRESS IN THIS REPORTING PERIOD

HDSC has made progress in compiling and formatting of the datasets collected for the California project.

- Additional daily and hourly data were obtained from the U.S. Army Corps of Engineers for the buffer area in Oregon.
- Additional daily and hourly data were obtained from the U.S. Geological Survey for California and Oregon.
- All daily datasets have been processed into a common format (seven datasets were completed in the past quarter) and are being prepared for quality control.
- Work has begun on processing the hourly datasets into a common format (one has been completed and three begun in the past quarter).
- The downloading of hourly data from the Remote Automated Weather Station (RAWS) Network was completed.
- Daily and hourly NCDC data were updated through 12/2007.

Table 4 provides basic information for each dataset: data type, data source, number of stations in each processed dataset, and current status of data formatting including some comments/notes about the task. The numbers of stations are subject to change as we review the data further and eliminate duplicate data, impose a minimum number of years of data, merge appropriate stations, etc.

Lastly, the metadata (latitude, longitude, elevation) for stations are being quality controlled for accuracy. A review of station elevation versus a high resolution (3-second) digital elevation model was used to identify potential metadata errors. Any potential errors are being resolved.

Table 4. List of data types, data sources, number of stations in each processed dataset, and current status of data formatting including some comments/notes about the task. (ALERT data are Automated Local Evaluation in Real Time gauges that measure precipitation using tipping buckets in increments of 0.04".)

Type of data	Data Sources	Number of Stations	Status of Formatting	Comments/Notes
Daily	NCDC	1225	Done	Obtained 2007 data.
	CA Department of Water Resources	411	Done	
	U.S. Army Corps of Engineers, Sacramento District	43	Done	
	U.S. Army Corps of Engineers, Oregon	61	On hold	Due to short records and difficulties in formatting these data, these stations will be pre-screened
	Santa Barbara County Flood Control District	62	Done	
	LA County Dept. of Public Works	591	Done	
	Jim Goodridge, Retired State Climatologist	1	Done	
	County of San Diego Flood Control	91	Done	
	California Nevada River Forecast Center	650	Done	6-hour ALERT data were accumulated to daily
	Ventura County Watershed Protection District	104	Done	
	U.S. Geological Survey	10	Done	
	SNOTEL	152	Done	
Hourly	NCDC	509	Done	Obtained 2007 data.
	CA Department of Water Resources	495	Done	
	U.S. Army Corps of Engineers, Sacramento District	43	Done	
	U.S. Army Corps of Engineers, Oregon			
	Metro Flood Control District, Fresno	8	In progress	
	Jim Goodridge, Retired State Climatologist		In progress	Metadata will be compiled as the data are formatted.
	RAWS	193 in CA; 72 in OR	Done	Only data with more than 10 years were processed.
	U.S. Geological Survey	11	In progress	
	SNOTEL	66	Done	
15-min	Metro Flood Control District, Fresno	8		
	County of San Diego Flood Control			
	USGS	12		3 from OR; 9 From CA

Type of data	Data Sources	Number of Stations	Status of Formatting	Comments/Notes
5-min	Ventura County Watershed Protection District	105		
	Santa Barbara County Flood Control District	49		
	LA County Dept. of Public Works	41	Done	
	Riverside County Flood Control District			
ALERT	California Dept. of Parks & Recreation (Orange Cnty)	45		
	County of San Diego Flood Control	70	50% done	

2.2. PROBLEMS/CONCERNS

We have not yet resolved problems with the contract between NWS and the California Department of Water Resources in order to obtain funding for this project. The initial contract was modified based on additional requirements of the State of California. The modified contract has been reviewed within the Department of Commerce who has found that some of the modifications do not conform with Federal requirements. We continue to work towards resolving this problem.

2.3. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (FY08/Q4)

HDSC will continue to format data and evaluate for any data overlap. We will begin the quality control of the daily data.

2.4. PROJECTED SCHEDULE

Data quality control [November 2008]

Regionalization and frequency analysis for 1-hr and 24-hr AMS [January 2009]

Development of precipitation frequency grids for 1-hr and 24-hr durations based on PRISM deliverables [February 2009]

Peer review of estimates [March 2009]

Regionalization and frequency analysis for other durations [May 2009]

Development of precipitation frequency grids for all durations based on PRISM deliverables [June 2009]

Remaining tasks and web publication [July 2009]

3. AREAL REDUCTION FACTORS (ARFs)

3.1. PROGRESS IN THIS REPORTING PERIOD

HDSC is developing geographically-fixed areal reduction factors that can be used to convert point precipitation frequency estimates into corresponding areal estimates in the United States. For a given average recurrence interval (ARI), rainfall duration and area size, the areal reduction factor (ARI) is defined as a ratio of average point depth and areal depth with same ARI. The HDSC ARF team will continue to investigate an approach that utilizes radar-estimated precipitation. A pilot study to evaluate the value of radar-estimated precipitation grids for the ARF in the Louisville, KY area provided encouraging results. Unfortunately, other project tasks and limited resources precluded any work on this task during this reporting period.

3.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (FY08/Q4)

Optimization, debugging and testing of the new ARF estimation procedure will resume during the next reporting period.

III. OTHER

1. Presentations and Meetings

On 30 April – 1 May 2008, Sanja Perica presented "Impact of Climate Change on Precipitation Frequency Estimates. HDSC Perspective" at the workshop, *Precipitation Intensity Estimates in a Changing Climate*, hosted by NOAA's National Climatic Data Center in Asheville, NC.

On May 12-16, 2008, Geoff Bonnin attended the American Society for Civil Engineer's World Environmental & Water Resources Congress 2008 in Honolulu, Hawaii. He presented "Updated NOAA Precipitation Frequency Estimates for Hawaii" in the *Water Resources Planning and Management* track, *Stochastic Modeling of Rainfall Processes* session.

On June 20, 2008, Geoff Bonnin made a presentation, *Updating California Precipitation Frequency Estimates,* at the American River Watershed Institute's California Extreme Precipitation 2008 Symposium in Davis, CA. Contacts during the conference resulted in additional sources of historical data that might be useful during the project.

2. Upcoming Projects

Final agreements between the Federal Highway Administration and NOAA/NWS to update the southeast states of Florida, Georgia, Alabama and Mississippi have been prepared jointly and have been submitted to FHWA for formal approval. Once approved at FHWA they will be submitted to the Department of Commerce for approval.

The University of Alaska, Fairbanks (UAF) has obtained funding for a joint effort with NWS to update precipitation frequency estimates for Alaska. With the funding obtained by NWS, from the NOAA Climate program, funding is now in place for this project. We intend to meet with UAF and to establish detailed joint procedures and begin the project during the next reporting period.

Funding has been identified for updating precipitation frequency estimates for the Midwestern states of North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, and Missouri. The funding will be transferred from the states to NWS through the FHWA's Transportation Pooled Fund Program. FHWA is currently arranging for transfer of funds from the States. We are working with FHWA to establish the contractual relationship between FHWA and NWS and expect to be able to begin a three-year update project in September. Discussions are underway for both Colorado and Wisconsin to join the project.

There have been preliminary discussions within NWS about beginning a marketing campaign to obtain funding to update precipitation frequency estimates for the northeastern states of New York, Maine, Vermont, New Hampshire, Massachussetts, Connecticut and Rhode Island. We expect to begin the campaign during the next reporting period.

3. Personnel

HDSC is in the process of acquiring two PhD-level scientists for the group through the University Corporation for Atmospheric Research (UCAR). They will assist in the research and development of state-of-the-science methods for our work. In addition, two junior level scientists will be hired to assist in data quality control and other technical tasks to facilitate the timely completion of projects.

Two interns are currently working with HDSC for the summer on administrative and technical tasks. Sarah Dietz, a college undergraduate in Computer Sciences, comes to us through the Oak Ridge Institute for Science and Education (ORISE) which is a U.S. Department of Energy institute focusing on scientific initiatives and research. John Yarchoan is a high school student who has returned for another summer after volunteering with HDSC in the summer of 2007.