HAWAII PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 43*

Seventh Progress Report
1 October through 31 December 2002

Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. 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 purpose other than for what it was intended does so at their own risk.

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1. Introduction

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency estimates for Hawaii. Current precipitation frequency estimates for Hawaii are contained in *Technical Paper No. 43,* "Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years" (U.S. Weather Bureau 1962). The update includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all available rainfall data for the study area and use accepted statistical methods. The study results will be published as a Volume of NOAA Atlas 14 on the internet using web pages with the ability to download digital files.

The study area covers the Hawaiian islands including Hawaii, Maui, Lanai, Molokai, Oahu, and Kauai. The study area including preliminary regions is shown in Figure 1.

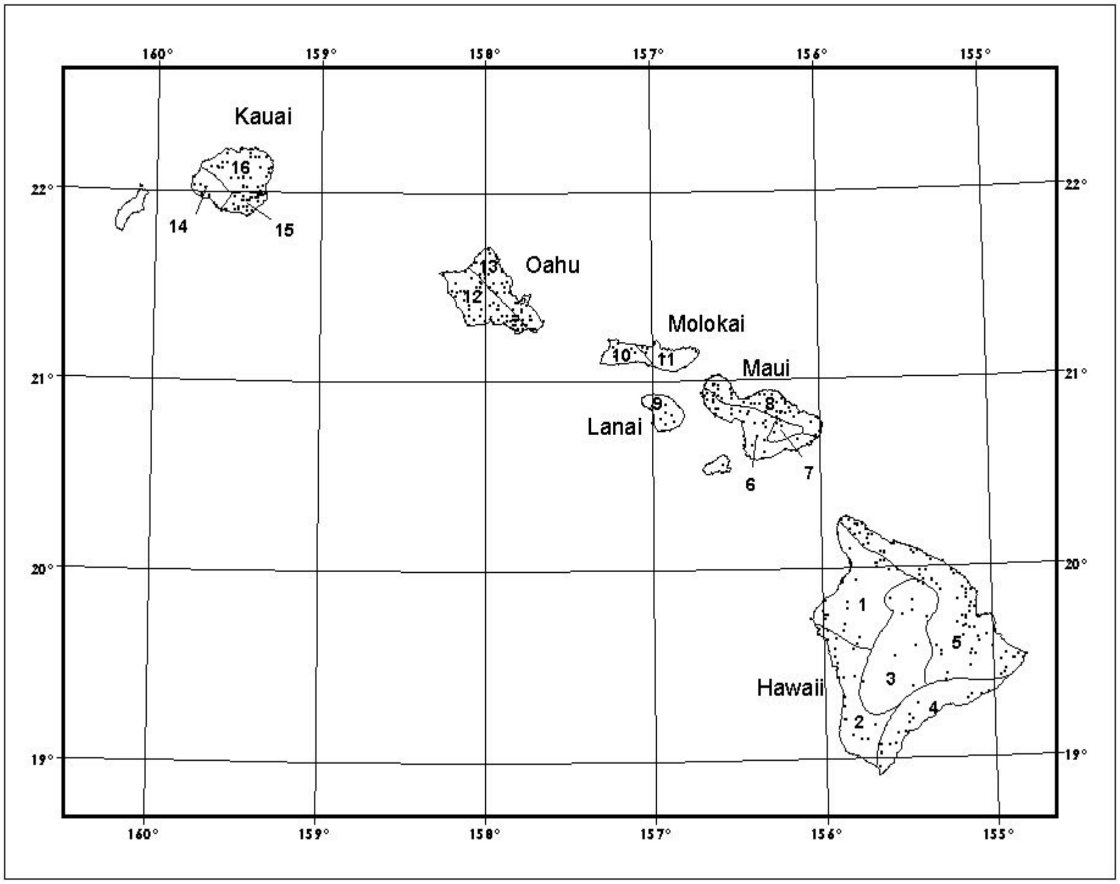

Figure 1. Hawaii Precipitation Frequency study area, regional divisions and daily station locations.

2. Highlights

Data entry of monthly maximums from daily gages maintained by the State continues by the University of Hawaii. HDSC received data from the University for Maui County during the reporting period. Entry continues by the University with Oahu County. Additional information on this subject is available in Section 4.1, Data Collection and Quality Control.

Software was refined and automated to adjust quantiles for co-located hourly and daily data across all durations and frequencies. Software to compute and adjust confidence limits for co-located stations was also written. Software to carry quantile estimates of hourly stations out to 48-hours was completed. Additional information is provided in Section 4.2, Software Updates.

The Oregon State University's Spatial Climate Analysis Service (SCAS) delivered a 14-page interim report to HDSC on December 24, 2002 describing the production of the draft 1-hour and 24-hour "index flood" rainfall grids using PRISM. A minor change was made to the Cascade, Residual Add-back (CRAB) precipitation frequency grid derivation procedure to prevent multiple filtering as longer return frequencies are generated. Additional information is provided in Section 4.3, Spatial Interpolation.

In addition to the 12-hour, 24-hour, and 4-day durations, it was decided that temporal distributions of extreme rainfall would be produced for the 6-hour duration. Additional information is provided in Section 4.4, Temporal Distribution.

Seasonal information will be presented graphically as percentages of "exceedences" that occur in each month for a given region for 2-year, 10-year, 25-year, 50-year, and 100-year return frequencies. The software for the 1-hour and 24-hour durations has been written. Additional information is provided in Section 4.5, Seasonal Graphs.

In order to accommodate all of the Precipitation Frequency Data Server and geospatial files, the allocated disk space for the PFDS was increased. The PFDS output was also modified to include "seasonal exceedence graphs." Additional information is provided in Section 4.6, Precipitation Frequency Data Server.

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for areas from 10 to 400 square miles continues. The initial computer programming to quantify the spatial variation of storms used in the D-A-D analysis has been completed and tested successfully on two study areas. The second phase of the programming to perform the actual D-A-D curve fitting is nearly complete. Additional information is provided in Section 4.7, Spatial Relations (Depth Area Duration Study).

3. Status

3.1 Project Task List.

The following checklist shows the components of each task and an estimate of the percentage completed per task. Past status reports should also be referenced for additional information.

Hawaii study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [25%]:
- Multi-Day
- Daily
- Hourly
- 15-minute
- N-minute

The University of Hawaii will continue digitizing daily data from a network of state operated gages. Once this data is added to our data set the number of daily stations will greatly increase. The University will enter monthly maximums of daily data.

L-Moment Analysis/Frequency Distribution for 5 minute to 60 days and 2 to 1000 years [0%]:
- Multi-Day
- Daily
- Hourly
- 15-minute
- N-minute

Spatial Interpolation [0%]
- Create mean annual maximum (a.k.a. "index flood") grids with PRISM for all durations from 60-minute to 60-days.
- Apply a precipitation frequency map derivation procedure, known as the cascade residual add-back (CRAB) procedure to create a total of 162 grids. The same procedure will be used to create 162 upper and 162 lower bound precipitation frequency grids.
- Apply study-wide conversion factor to the 1-hour precipitation frequency grids to calculate the n-minute (5-, 10-, 15-, and 30-minute) grids.

Peer Reviews [0%]:
- External peer review of point precipitation frequency estimates
- External peer review of spatial interpolation grids

Data Trend Analysis [0%]
- Analyze linear trends in annual maxima and variance over time
- Analyze shift in means of annual maxima between two time periods (i.e., test the equality of 2 population distribution means)

Temporal Distributions of Extreme Rainfall [0%]
- Assemble hourly data by quartile of greatest precipitation amount and convert to cumulative rainfall amounts for each region
- Sort, average and plot time distributions of hourly maximum events by storm area, quartile and duration

Deliverables [20%]
- Prepare data for web delivery
- Prepare documentation for web delivery
- Write hard copy of Final Report
- Publish hard copy of Final Report

Spatial Relations (Depth Area Duration Study) [60%]
- Obtain hourly data from dense-area reporting networks
- QC and format data from dense networks
- Compute maximum and average annual areal depth for each duration from stations for each network
- Compute maximum to average depth ratio for all durations and networks and plot
- Prepare curves of best fit (depth area curves) for each duration and network
- Combine all stations from all study areas to compute the ratio of maximum to average depth for all durations and networks and plot
- Examine differences in individual D-A-D curve plots for durations and study areas compared to those for combined study area data plots

Depth Area Duration (DAD) reductions for areas from 10 to 400 square miles are being updated for the entire United States and will be presented in separate volume of NOAA Atlas 14.

4. Progress in this Reporting Period

4.1 Data Collection and Quality Control.

HDSC received the hand entered digital rainfall data from the University of Hawaii for Maui County. The University began to hand enter state rainfall data for Oahu County as well.

4.2 Software Updates

Internal consistency software was refined to include all durations and all return frequencies. When internal consistency adjustments are made in the quantiles for one return frequency, it is necessary to adjust all frequencies to maintain realistic results (i.e., so that 50-year estimates are not greater than 100-year estimates). This is particularly true at shorter return frequencies because ratios of small values can be large, leading to large adjustments. Software to carry quantile estimates of hourly stations out to 48-hours was also completed.

Software was created to generate a complete list of co-located hourly and daily stations with their assigned regions and run existing adjustment software on all regions at once with minimal manual input. This provides a more efficient and less error-prone mechanism for completing the precipitation frequency analysis for a given study area. In addition, software to compute and adjust confidence limits for co-located stations was written.

4.3 Spatial Interpolation

The Spatial Climate Analysis Service (SCAS) at Oregon State University delivered a 14-page interim report to HDSC on December 24, 2002. The report describes the work performed to produce the draft 1-hour and 24-hour “index flood” rainfall grids for the Semiarid Southwest study using the PRISM model (Parameter-elevation Regressions on Independent Slopes Model). This production provides the foundation for the Hawaii “index flood” rainfall grids. Although the interim report deals with the Semiarid grids, the Hawaii grids will essentially be created using the same process. A few adjustments to the PRISM process will be made for the Hawaii project, namely to account for coastal effects that the Semiarid project did not have.

A minor change was made to the Cascade, Residual Add-back (CRAB) precipitation frequency grid derivation procedure. Instead of using a final, slightly filtered grid as the predictor for the subsequent grid, the CRAB procedure now maintains and uses unfiltered grids for its predictor grids throughout the process. The final grids for each precipitation frequency estimate are still slightly filtered, but because filtering is not done on the predictor grid, a greater level of spatial detail is maintained and portrayed in the resulting grids/maps.

Lastly, a final map/grid deliverable list was developed (see Table 1). All durations and return frequencies will have ArcInfo ASCII grids and ESRI shapefiles of isohyets. Initially, a subset of durations and return frequencies will have state-specific printable cartographic maps in PDF format with the remaining durations to be produced as time permits in the future (indicated in table by asterisks).

Table 1. List of all map/grid deliverables.

	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr	1000-yr
5-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
10-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
15-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
30-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
60-min	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
120-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
3-hr	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
6-hr	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
12-hr	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
24-hr	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
48-hr	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
4-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
7-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
10-day	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
20-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
30-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
45-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
60-day	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*

G = ArcInfo ASCII grid
S = ESRI shapefile of isohyets
SM = State-specific printable cartographic map (PDF format)
SM* = State-specific printable cartographic map (PDF format) as time permits

4.4 Temporal Distribution

In addition to the 12-hour, 24-hour, and 4-day durations, it was decided that temporal distributions of extreme rainfall would be produced for the 6-hour duration. Distributions are grouped according to the quartile of time in which the most rain fell. All quartiles from each duration, 6-hour, 12-hour, 24-hour and 96-hour will be presented in the final document. In addition, a single plot combining all four quartiles into a single distribution will be presented for each duration.

4.5 Seasonal Graphs

Seasonal information will be presented graphically as percentages of "exceedences" that occur in each month for a given region. "Exceedences" are events that exceed corresponding 2-year, 10-year, 25-year, 50-year, and 100-year precipitation frequency estimates at a given station and duration. The percentage is derived from the total number of cumulative years for all stations in a given region. Theoretically, 50% of the events should exceed the 2-year estimates, 4% should exceed the 25-year estimates, 2% should exceed the 50-year estimates and only 1% should exceed the 100-year estimates.

Exceedence graphs will be presented for the 1-hour, 24-hour, 48-hour and 10-day durations. The software for the 1-hour and 24-hour durations has been written and preliminary graphs have been incorporated into the Precipitation Frequency Data Server. Work is nearly complete for the 48-hour and 10-day duration software.

4.6 Precipitation Frequency Data Server

In order to accommodate all of the PFDS and GIS compatible files, the allocated disk space for the PFDS was increased to 30 gigabytes. Our calculations suggest that this will be ample disk space to accommodate all of our current precipitation frequency projects. The PFDS output was also modified to include links to regional "seasonal exceedence graphs".

4.7 Spatial Relations (Depth Area Duration Study)

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for area sizes of 10 to 400 square miles continues. The initial computer programming to quantify the spatial variation of storms used in the D-A-D analysis has been written, tested successfully, and performed on two study areas. The second phase of the programming to perform the actual D-A-D curve fitting is nearly complete and will be tested in January on two study areas. There has been no change in the D-A-D study areas that will be used to develop the final D-A-D curves (see previous progress report). Currently, there are 12 study areas scattered throughout the conterminous United States that have been quality controlled. Three other study areas may be added once the D-A-D curves are developed for the existing study areas. These three study areas will be used if it is determined that a single curve for the entire U.S. is insufficient and separate curves need to be developed.

Upon completion, the final D-A-D reduction relationships will be available for use in basins throughout the continental United States. We have not yet been able to find data networks in the Hawaiian Islands suitable for this type of analysis. As a consequence, we have no basis for recommending these relationships will be suitable for the Hawaiian Islands. We will discuss this issue further with local experts to ensure we have not overlooked possible sources of data.

5. Issues

5.1 Personnel Change

As of December 5, 2002, Eloisa Raynault resigned from HDSC. Eloisa was a civil engineer who was the project lead for the Ohio River Basin and Surrounding States Precipitation Frequency Study. A replacement will not be hired due to budget constraints. Unfortunately, Eloisa's departure has forced a delay in project schedules.

5.2 AMS Annual Meeting

HDSC is presenting four papers/posters at the 83rd American Meteorological Society Annual Meeting in February of 2003. The papers include *Updating NOAA/NWS Rainfall Frequency Atlases*, which will give an overview of our approach, *Updated Precipitation Frequencies for the Semiarid Southwest United States*, which will present selected results from the Semiarid study, *Updated Precipitation Frequencies for the Ohio River Basin and Surrounding States*, which will present selected results from the Ohio study, and *NOAA/NWS Precipitation Frequency Data Server*, which will present the PFDS in detail.

6. Projected Schedule.

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on next quarter are also included in this section. The University of Hawaii Digitizing completion date is indicated as Month Zero (M_0).

Data Collection and Quality Control [M_0 + 3 months]
Trend Analysis [M_0 + 4 months]
L-Moment Analysis/Frequency Distribution [M_0 + 5 months]
Peer Review of Point Estimates [M_0 + 7 months]
Temporal Distributions of Extreme Rainfall [M_0 + 8 months]
Spatial Interpolation [M_0 + 10 months]
Precipitation Frequency Maps [M_0 + 11 months]
Web Publication [M_0 + 11 months]
Spatial Relations (Depth Area Duration Studies) [January 2003]

We expect to be able to obtain NCDC data through 2002 and then start the quality control and testing of the regionalization on an island by island basis as complete data sets are assembled. The estimation of the appropriate probability distribution functions and the parameterization of these functions as well as the spatial interpolation steps will be done for all islands as a group to ensure consistency in this part of the process.

6.1 Data Collection and Quality Control.

During the next quarter the University of Hawaii will continue to hand enter data into a digital format for Oahu County and begin data entry for Kauai. The projected schedule is summarized in Table 2.

Table 2. Projected Schedule of Hand Entry of State Daily Gage Monthly Maximums.

Island	Projected Completion Date
Oahu	01/31/03
Kauai	05/15/03

6.2 Spatial Relations (Depth Area Duration Study)

Software development for the D-A-D computations will be completed in the next quarter and the computations will be performed for 12 study areas.

References

Frederick, R.H., V.A. Myers and E.P. Auciello, 1977: Five to 60-minute precipitation frequency for the Eastern and Central United States, NOAA Technical Memo. NWS HYDRO-35, Silver Spring, MD, 36 pp.

Hershfield, D.M., 1961: Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, *Weather Bureau Technical Paper No. 40*, U.S. Weather Bureau. Washington, D.C., 115 pp.

Hosking, J.R.M. and J.R. Wallis, 1997: *Regional frequency analysis, an approach based on L-moments*, Cambridge University Press, 224 pp.

Huff, F. A., 1990: Time Distributions of Heavy Rainstorms in Illinois. Illinois State Water Survey, Champaign, 173, 17pp.

Lin, B. and L.T. Julian, 2001: Trend and shift statistics on annual maximum precipitation in the Ohio River Basin over the last century. Symposium on Precipitation Extremes: Prediction, Impacts, and Responses, 81st AMS annual meeting. Albuquerque, New Mexico.

Miller, J.F., 1964: Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States, *Technical Paper No. 49*, U.S. Weather Bureau and U.S. Department of Agriculture, 29 pp.

Miller, J.F., R.H. Frederick and R.J. Tracy, 1973: Precipitation-frequency atlas of the western United States, *NOAA Atlas 2*, 11 vols., National Weather Service, Silver Spring, MD.

U.S. Weather Bureau, 1962: Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years, *Weather Bureau Technical Paper No. 43*, U.S. Weather Bureau. Washington, D.C., 60 pp.