REPORT DOCUMENTATION FORM
WATER RESOURCES RESEARCH CENTER
University of Hawaii at Manoa

[1] Report Number Special Report 9:23:83	[2] FCST Category 02-B, 07-C
[3] Title Rainfall Frequency Study for Oahu: Option 1—Preparation of Rainfall Frequency Maps	[4] Report Date September 1983 [5] No. of Pages v + 5 (12 unnumbered maps attached) [6] No. of Tables 0 [7] No. of Figures
[8] Author(s) Dr. Thomas W. Giambelluca Dr. L. Stephen Lau Dr. Yu-Si Fok Dr. Thomas A. Schroeder	[9] Grant Agency United States Department of the Army, Pacific Ocean Division, Corps of Engineers [10] Grant/Contract No. Option No. 1; Proposal No. DACW84-82-R-0014

[11] Descriptors: *Hydrologic maps, *frequency analysis, hydrometeorology, precipitation intensity, storms, topography, regional analysis
Identifiers: *Rainfall-frequency maps, 1:62,500 scale maps, Gumbel extreme value, log-Pearson Type III, Oahu, Hawaii

[12] Abstract (Purpose, method, results, conclusions)

Annual maximum rainfall series at 157 gages were used to evaluate extreme value rainfall. Daily fixed-interval data were adjusted by a factor of 1.143 to represent true maxima. Records of short-term stations were extrapolated by regional analysis. Gumbel extreme value, log-Pearson Type III, and log-normal distributions were tested for applicability and found to have approximately equal goodness-of-fit. The Gumbel distribution was used, fitted by the method of moments. A topographically based interstation interpolation model was developed as an aid in mapping maximum rainfall for durations of 1-, 6-, and 24-hr and return periods of 2-, 10-, 50-, and 100 years.

2540 Dole Street, Holmes Hall 283 • Honolulu, Hawaii • U.S.A.

RAINFALL FREQUENCY STUDY FOR O'AHU:
OPTION 1—PREPARATION OF RAINFALL FREQUENCY MAPS

Thomas W. Giambelluca
L. Stephen Lau
Yu-Si Fok
Thomas A. Schroeder

Special Report 9:23:83

September 1983

Option 1 Completion Report
for
Rainfall-Frequency Study for Oahu
Proposal No. DACW84-82-R-0014
Project Period: 27 November 1982-21 September 1983
Principal Investigator: L. Stephen Lau
Associate Investigators: Yu-Si Fok
Thomas A. Schroeder

PREPARED FOR
U.S. Department of the Army, Pacific Ocean Division, Corps of Engineers

WATER RESOURCES RESEARCH CENTER
University of Hawaii at Manoa
2540 Dole Street
Honolulu, Hawaii 96822

ABSTRACT

Annual maximum rainfall series at 157 gages were used to evaluate extreme value rainfall. Daily fixed-interval data were adjusted by a factor of 1.143 to represent true maxima. Records of short-term stations were extrapolated by regional analysis. Gumbel extreme value, log-Pearson Type III, and log-normal distributions were tested for applicability and found to have approximately equal goodness-of-fit. The Gumbel distribution was used, fitted by the method of moments. A topographically based interstation interpolation model was developed as an aid in mapping maximum rainfall for durations of 1-, 6-, and 24-hr and for return periods of 2-, 10-, 50-, and 100-years.

RAINFALL FREQUENCY STUDY FOR O'AHU

OPTION 1—PREPARATION OF RAINFALL FREQUENCY MAPS

The rainfall frequency maps for O'ahu, which this report accompanies, were developed as a result of the completion of the following tasks.

1. Data Assembly

The data base for this project was compiled in accordance with the stipulations of the U.S. Department of the Army, Pacific Ocean Division, Corps of Engineers' Basic Contract, and was reported on earlier by Dr. Thomas A. Schroeder. Annual maximum rainfall series were assembled for 99 standard (nonrecording) and 58 recording rain gages.

2. Adjustment of Fixed-Interval Daily Data

The data of the 99 standard rain gages, in the form of 24-hr fixed-interval totals, had to be adjusted to represent true annual maxima. Data were evaluated at 17 stations at which recording and nonrecording gages were operated simultaneously for a significant length of time. Each pair of annual maximum series was compared to test the validity of the theoretically derived factor, 1.143, suggested by Weiss (1964) for converting fixed-interval observations to true maxima. Ratios of maxima of recording to nonrecording gages at each site did not differ significantly from this value in most cases. Therefore, the annual maximum series at nonrecording gages were adjusted by the 1.143 factor.

3. Selection of a Station Network

Ideally, a network for rainfall frequency analysis should consist of stations having long records and providing an even spatial distribution over the island. Various criteria were considered for the selection of stations for the network, including various minimum record length requirements and restriction to a common base period. Using eight stations having at least 60 years of data, comparisons were made among computed extreme value rainfall based on six different 10-yr periods, four

15-yr periods, three 20-yr periods, and two 30-yr periods for frequencies of 2, 10, 50, and 100 years. It was concluded that, for 2- and 10-yr return periods, a set of 30 years of data would, in most cases, provide about the same result as a 60-yr data set. Also, one 30-yr period was found to give about the same result as any other 30-yr period. For longer return intervals, such as 50 and 100 years, a data set with more than 30-yr record is desirable.

4. Time-Extrapolation of Short-Term Station Records of 24-hr Rainfall

Because of the limited number of stations having 30 years or more of data, stations with 20 to 29 years of data were extended to at least 30 years by regional analysis. Regression techniques were used to relate short-term stations to nearly "predictor" stations. The predictor stations' records were then used to simulate annual maxima for years during which the short-term station did not operate.

5. Selection of Extreme Value Frequency Distribution

Graphical representations of the Gumbel extreme value, log-Pearson Type III, and log-normal distributions were constructed for several stations on O'ahu. No significant differences were found among the three in terms of straight line goodness-of-fit. The Gumbel distribution was selected for use because of its computational simplicity.

6. Analysis of Annual Maximum Series

The annual maximum series of each selected station were evaluated according to the Gumbel distribution by the method of moments. Values were computed for the 24-hr duration at all selected stations, and for durations of 1- and 6-hr at selected recording stations. Estimates were checked graphically. Computed values were then adjusted to represent partial duration series values.

7. Development of an Interstation Interpolation Model

To facilitate mapping of rainfall frequency patterns, a topographically based interstation interpolation model, similar mainland (Miller, Frederick, and Tracey 1973), was developed. Sixteen topographic variables were evaluated at each station and entered as independent variables in stepwise multiple regression analysis. Rainfall at each duration of interest (1-, 6-, 24 hr) and at the extreme return periods (2, 100-yr) served as the dependent variables. Variables were selected for maximum R^2 improvement. Equations were limited to six or less variables for 24-hr rainfall and to four or less variables for the shorter durations. The six selected equations include the following:

- 2-yr, 24-hr rainfall (TWO24)

$$\begin{aligned} \mathrm{TWO24} = &- 0.161 + 0.006\mathrm{ELEV} + 0.154\mathrm{DCREST} \\ &- 0.046\mathrm{DCOAST} + 0.203\mathrm{WVALLEY} \\ &+ 51.268\mathrm{INVDCR} - 0.055\mathrm{EFFELEV} \end{aligned}$$

$$R^2 = 0.832 \quad R = 0.912 \quad N = 62$$

- 100-yr, 24-hr rainfall (HUND24)

$$\begin{aligned} \mathrm{HUND24} = &\ 5.622 + 1.515\mathrm{TWO24} - 0.048\mathrm{DCOAST} \\ &+ 0.993\mathrm{NBARRIER} - 0.012\mathrm{SLOPE2} - 4.358\mathrm{CREST3} \end{aligned}$$

$$R^2 = 0.660 \quad R = 0.812 \quad N = 61$$

- 2-yr, 6-hr rainfall (TWO6)

$$\mathrm{TWO6} = 0.569 + 0.559\mathrm{TWO24}$$

$$R^2 = 0.944 \quad R = 0.971 \quad N = 25$$

- 100-yr, 6-hr rainfall (HUND6)

$$\begin{aligned} \mathrm{HUND6} = &\ 2.515 + 5.820\mathrm{TWO6} - 2.013\mathrm{TWO24} \\ &+ 1.883\mathrm{WVALLEY} - 11.626\mathrm{CREST3} \end{aligned}$$

$$R^2 = 0.749 \quad R = 0.865 \quad N = 25$$

- 2-yr, 1-hr rainfall (TWO1)

$$\begin{aligned} \mathrm{TWO1} = &\ 0.163 + 0.325\mathrm{TWO6} - 0.0006\mathrm{ELEV} \\ &+ 0.00195\mathrm{SLOPE2} + 3.584\mathrm{INVDCR} \end{aligned}$$

$$R^2 = 0.912 \quad R = 0.955 \quad N = 25$$

- 100-yr, 1-hr rainfall (HUND1)

$$\mathrm{HUND1} = 0.666 + 0.917\mathrm{TWO1} + 0.269\mathrm{HUND6} - 0.001\mathrm{HCREST}$$

$$R^2 = 0.850 \quad R = 0.922 \quad N = 25;$$

and their variables:

ELEV	Station elevation (meters)
MEDRF	Station median annual rainfall (millimeters)
DCREST	Distance from crest of nearest major airflow barrier (kilometers) measured along a 68.5-248.5° line (ENE-WSW)
DCOAST	Distance from windward coast (kilometers) measured in ENE direction
WRIDGE	Width of nearest major barrier (kilometers) measured along 68.5-248.5° line; barrier defined by smoothed line connecting ends of ridges at 1600-ft contour
WVALLEY	Width of nearest major barrier (kilometers) measured along 68.5-248.5° line; barrier defined by smoothed line connecting heads of valleys at 1600-ft contour
HCREST	Height of nearest major barrier to airflow along 68.5-248.5° line (meters)
NBARRIER	Number of major barriers in ENE direction
SLOPE1	Slope in ENE direction (meters/kilometer)
SLOPE2	Slope in WSW direction (meters/kilometer)
ROUGHNESS	Roughness parameter; difference in height between highest and lowest of a nine-point sample along a strip oriented ENE-WSW
INVDCR	Inverse distance from the crest = 1/(DCREST + 5)
CREST1	Height of crest over distance from crest = HCREST/(DCREST + 5)
CREST2	Width of barrier (ridges) over distance from crest = WRIDGE/(CREST + 5)
CREST3	Width of barrier (valleys) over distance from crest = WVALLEY/(DCREST + 5)
EFFELEV	Effective elevation = ELEV/(DCOAST + 1)
TWO24	2-year, 24-hour rainfall
TWO6	2-year, 6-hour rainfall
HUND6	100-year, 6-hour rainfall
TWO1	2-year, 1-hour rainfall.

8. Plotting of Rainfall Frequency Maps

Each topographic variable appearing in any of the six regression polynomials was evaluated at each intersection of a 1 min latitude by 1 min longitude grid covering the island of O'ahu. A total of more than 600 points was involved. Gridpoint rainfall values were computed for the 2- and 100-yr return periods for each of the three durations (1-, 6-, and 24-hr). For the intermediate return periods, 10 and 50 yr, gridpoint rainfall was computed from the Gumbel expression with the parameters derived from the 2- and 100-yr rainfall values.

A computer routine was developed to plot the computed values at each grid point for each of the 12 maps specified in the contract: 2-yr 24-hr, 10-yr 24-hr, 50-yr 24-hr, 100 yr 24 hr, 2-yr 6-hr, 10-yr 6-hr, 50-yr 6-hr, 100-yr 6-hr, 2 yr 1 hr, 10-yr 1-hr, 50-yr 1-hr, and 100-yr 1-hr. Station values were also plotted on each map for reference. Smoothed contour analysis was done by hand, giving most weight to long-term station values.

REFERENCES

Miller, J.F.; Frederick, R.H.; and Tracey, R.J. 1973. Precipitation-frequency atlas of the western United States, Vol. 2 — Wyoming. National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

Weiss, L.L. 1964. Ratio of true to fixed interval maximum rainfall. J. Hydraul. Div., Proc. Am. Soc. Civ. Eng. 90(HY1):77-82.