GENERALIZED SKEW COEFFICIENT FOR FLOOD FREQUENCY COMPUTATIONS FOR THE STATE OF HAWAII

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4027

Prepared in cooperation with the

DEPARTMENT OF THE ARMY

PACIFIC OCEAN DIVISION

CORPS OF ENGINEERS

Fort Shafter, Hawaii

Honolulu, Hawaii

July 1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

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CONVERSION TABLE

The following table may be used to convert measurements in the inch-pound system to the International System of Units (SI).

Multiply inch-pound units	By	To obtain SI units
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)

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ABSTRACT

The generalized skew coefficient used in the estimation of flood-flow frequencies for Hawaii streams was set at -0.05 by the Hydrology Committee of the Water Resources Council in 1976. This value was determined by averaging the skew coefficients from 30 gaging stations in Hawaii with at least 25 years of record through water year 1973. In 1980, there were 68 gaging stations which had records of 25 years or longer.

Using the Water Resources Council's recommended procedures, a detailed study of skew coefficients for stations in Hawaii was conducted with the following results:

There were no discernible geographic or topographic trends when station skew coefficients were plotted on topographic maps;

Prediction equations based on regression techniques using basin and climatic characteristics had high standard errors and were not considered reliable.

A mean of the skew coefficients for 68 stations was computed to be -0.14, which is not significantly different from the value of -0.05 recommended by the Water Resources Council (1976, 1977, and 1981). Therefore, the general skew coefficient of -0.05 is considered satisfactory for use in the State of Hawaii. Additional studies should be made when more records reach a length of 25 years.

INTRODUCTION

Background

For many years, agencies of the Federal government worked independently of each other when determining flood-flow frequencies. Because of the many methods available, it was not unusual for more than one agency to determine the flood-flow frequency for the same area with great disparity between the results. Because of these disparities, there was a need for Federal agencies to develop a uniform method of determining flood-flow frequencies that would give more consistent results with the same data.

The U.S. Water Resources Council (1967) Bulletin No. 15, "A Uniform Technique for Determining Flood Flow Frequencies," was the initial attempt to promote a uniform and consistent method to determine flood-flow frequencies. In that report, the Council recommended that all Federal agencies adopt the log-Pearson Type III distribution as the base method for determining flood-flow frequencies. The Council also recommended use of this base method by State and local agencies and private concerns. Bulletin No. 17, (Water Resources Council, 1976) "Guidelines for Determining Flood Flow Frequency," was an extension of Bulletin No. 15. It provided sufficient detail for uniform application of currently accepted methods for the analysis of peak-flow frequency data at gaging stations. Bulletin No. 17A, (Water Resources Council, 1977) "Guidelines for Determining Flood Flow Frequency," revised and expanded on some of the techniques and procedures. Additional revisions were made in Bulletin 17B (Water Resources Council, 1981).

Purpose and scope

The development of a uniform technique for determining flood-flow frequencies is a continuing process of improving on current practices. As part of this improvement process, the purpose of this report is to improve the estimate of the generalized skew coefficient, $\bar{G}$, for flood-frequency determinations in the State of Hawaii.

Bulletins No. 17, 17A, and 17B (Water Resources Council 1976, 1977, and 1981) recommend use of a generalized skew coefficient of -0.05 for the State of Hawaii. The value was based on the records for 30 stream-gaging stations with 25 or more years of record. Since development of the skew coefficient in Bulletin 17, at least 25 years of record have become available at 38 more stream-gaging stations.

LOG-PEARSON TYPE III DISTRIBUTION

The Pearson Type III distribution was introduced to the American engineering profession in 1924 by H. A. Foster (U.S. Water Resources Council, 1967). In Foster's method, the natural data were used to compute the mean, standard deviation, and skew coefficient of the distribution. Today, the practice is to transform the natural data to their logarithms before computing the statistical parameters. Because of the logarithmic transformation, the method is now referred to as the log-Pearson Type III method.

The following symbols are used in the log-Pearson Type III method as presented in Bulletin No. 17B:

X = logarithm of annual peak flow.

N = number of items in the data set.

$\bar{X}$ = mean logarithm.

S = standard deviation of logarithms.

G = skew coefficient of logarithms.

K = Pearson Type III coordinates expressed in number of standard deviations from the mean for various exceedance probabilities.

Q = computed flood flow for a selected exceedance probability.

The outline of work is as follows:

1. Transform the list of N annual flood magnitudes to a list of corresponding logarithmic magnitudes.
2. Compute the mean of the logarithms:

$$\bar{X} = \frac{\Sigma X}{N}$$

3. Compute the standard deviation of the logarithms:

$$S = \sqrt{\frac{\Sigma(X - \bar{X})^2}{N - 1}}$$

$$= \sqrt{\frac{(\Sigma X^2) - (\Sigma X)^2/N}{N - 1}}$$

4. Compute the coefficient of skewness:

$$G = \frac{N\Sigma(X - \bar{X})^3}{(N-1)(N-2)S^3}$$

$$= \frac{N^2(\Sigma X^3) - 3N(\Sigma X)(\Sigma X^2) + 2(\Sigma X)^3}{N(N-1)(N-2)S^3}$$

5. Compute the base 10 logarithms of discharge, Q, at selected exceedance probability, P, by the equation:

$$\log Q = \bar{X} + KS$$

K can be obtained from the Table in appendix 3 of Bulletin No. 17B for the computed value of G and the selected exceedance probability. Log Q is the logarithm of a flood discharge for that exceedance probability.

6. Find the antilog of log Q to obtain the flood discharge Q.

The frequency curve can be drawn by plotting each Q versus its respective probability or percent chance of occurrence on lognormal probability paper and drawing a continuous line through the plotted points.

DETERMINATION OF GENERALIZED SKEW COEFFICIENT

Sixty-eight stream-gaging stations in the State of Hawaii, with 25 or more years of record, were used for the present study. The procedures recommended by Water Resources Council (1981) for determining generalized skew coefficients were followed to determine a generalized skew coefficient for Hawaii. Figure 1 shows a schematic diagram of procedures used in the determination of generalized skew coefficients. Calculations were made using log-Pearson Type III distribution and a digital computer.

A list of the 68 stations with the years of record of annual peak discharges and skew coefficients is shown in tables 1-5. The tables also show the basin and climatic characteristics, i.e. drainage area, channel slope, channel length, mean basin elevation, forest cover, and mean annual precipitation. Figures 2 through 6 show the locations of the gaging stations. All stations have an eight digit number. However, the first two digits (16) and the last two (00) are common to all stations shown in figures 2 through 6. Therefore, the four middle digits are the only ones shown. For example, the eight digit number for station 0600 in figure 2 is 16060000.

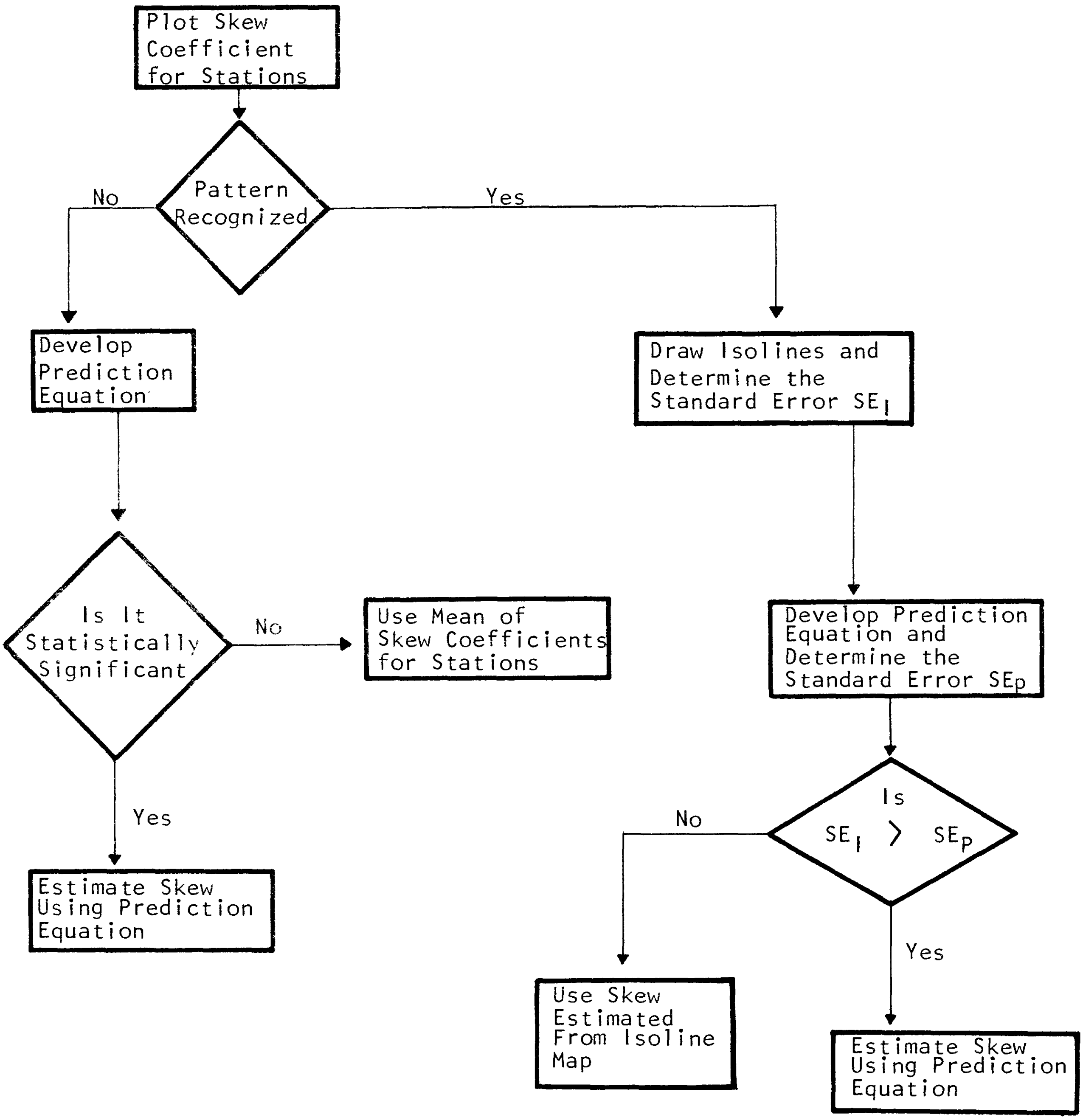

Figure 1. Schematic diagram of procedures for determination of generalized skew coefficients. (Guidelines for Determining Flood Flow Frequency, U.S. Water Resources Council, 1977.)

Table 1. Gaging stations and basin and climatic characteristics, Island of Kauai

Station No.	Years of record	Skew of logs	Drainage area (mi^2)	Channel slope (ft/mi)	Channel length (mi)	Ele-vation (ft)	Forest cover (percent)	Rainfall (in.)
0100	62	-0.325	3.95	90	6.41	3,930	57	146
0130	40	-0.289	1.68	145	4.42	3,840	72	135
0160	46	+0.412	20.0	534	6.92	3,100	45	62
0170	25	-1.633	1.68	190	4.69	4,250	18	148
0190	36	-0.541	1.79	245	4.35	4,360	31	157
0310	39	-0.218	57.8	247	19.70	2,820	60	68
0360	35	-0.013	26.0	184	13.40	2,460	73	100
0490	55	+0.291	18.5	288	9.14	2,050	95	162
0600	66	-0.109	22.4	116	12.20	1,210	83	163
0630	60	+0.201	5.29	379	4.55	2,270	100	300
0680	64	+0.081	6.27	285	4.30	1,390	100	151
0710	27	+1.247	17.9	154	10.70	1,260	82	162
0800	39	-0.411	3.86	919	3.70	1,620	98	130
0890	61	+0.295	4.27	494	6.78	1,360	91	134
1010	37	+0.010	7.4	827	4.55	3,150	98	271
1080	26	+0.863	10.2	674	6.95	3,210	73	247

Table 2. Gaging stations and basin and climatic characteristics, Island of Oahu

Station No.	Years of record	Skew of logs	Drainage area (mi^2)	Channel slope (ft/mi)	Channel length (mi)	Ele- vation (ft)	Forest cover (percent)	Rainfall (in.)
2000	55	-0.750	1.38	155	4.65	1,750	100	241
2130	27	-0.350	45.7	84	20.40	920	40	72
2160	27	-0.796	26.4	130	10.70	990	77	97
2245	26	-0.707	2.59	226	7.95	1,020	89	95
2260	30	-0.315	3.45	284	4.82	1,410	100	111
2280	53	-0.790	2.73	264	4.20	1,160	98	121
2290	63	-0.353	2.61	268	2.65	1,180	98	122
2385	58	+0.092	1.14	1,210	2.05	1,300	97	150
2405	61	+0.491	1.06	1,230	1.61	1,160	99	145
2440	53	-0.078	1.18	364	2.35	1,170	86	120
2460	45	-0.545	1.04	650	2.41	1,330	94	110
2470	27	-0.145	3.63	233	5.00	930	80	97
2750	43	-0.708	0.97	116	1.04	1,150	96	100
2780	26	+0.407	0.29	2,060	0.68	1,440	100	98
2830	33	+1.049	0.28	755	0.55	1,470	100	150
2840	41	+0.281	0.93	1,250	1.04	1,210	100	140
3030	26	-0.337	2.78	493	3.02	1,230	100	222

Table 3. Gaging stations and basin and climatic characteristics, Island of Molokai

Station No.	Years of record	Skew of logs	Drainage area (mi^2)	Channel slope (ft/mi)	Channel length (mi)	Elevation (ft)	Forest cover (percent)	Rainfall (in.)
4000	54	+0.403	4.62	548	4.60	2,270	100	92
4020	28	+0.529	4.38	506	3.32	2,250	100	194
4030	27	+0.532	1.41	2,250	1.39	1,820	100	179
4050	26	+0.198	1.09	2,285	1.54	2,150	100	145
4080	44	+0.620	3.68	1,135	4.06	1,000	100	77
4140	29	-1.800	6.57	436	9.33	2,310	39	47
4160	25	-1.065	0.24	128	1.00	2,320	100	125

Table 4. Gaging stations and basin and climatic characteristics, Island of Maui

Station No.	Years of record	Skew of logs	Drainage area (mi^2)	Channel slope (ft/mi)	Channel length (mi)	Elevation (ft)	Forest cover (percent)	Rainfall (in.)
5010	49	+0.257	6.29	920	6.14	4,310	99	140
5020	49	+0.448	0.43	1,510	2.40	2,790	82	140
5080	56	-0.616	3.49	1,135	6.00	4,430	88	190
5100	39	-0.778	0.69	877	5.30	3,320	100	235
5150	37	-1.123	0.32	488	3.85	2,490	100	285
5160	33	+0.525	4.31	1,270	6.30	4,600	75	165
5170	33	-0.793	3.11	1,030	5.80	4,340	83	225
5180	55	-0.554	3.66	1,070	6.33	4,360	81	190
5190	33	-0.295	1.93	1,020	6.13	4,650	83	200
5200	35	-0.447	0.51	565	2.45	2,120	100	340
5270	43	-0.696	3.17	920	6.70	4,810	100	150
5360	48	-0.079	1.16	786	5.75	3,610	100	280
5450	55	+0.353	2.35	643	4.54	2,740	100	290
5550	30	-0.677	3.93	705	9.90	5,420	91	110
5570	37	-0.225	0.47	724	1.93	1,900	100	275
5650	35	+1.137	0.64	558	3.01	2,120	100	350
5660	25	-1.430	0.20	610	1.40	1,670	100	285
5700	60	+0.063	3.58	630	4.03	2,340	94	300
5770	36	-0.542	2.41	444	7.50	3,930	100	260
5850	57	+0.207	1.34	502	4.18	2,340	100	215
5860	41	+0.186	0.55	500	2.40	1,840	100	215
5870	64	+0.299	0.64	415	2.90	1,790	100	175
6070	29	-1.294	8.24	425	6.10	1,050	96	220
6180	28	+0.174	3.47	717	4.61	2,190	100	220
6200	63	+0.447	4.11	900	5.25	3,140	100	150

Table 5. Gaging stations and basin and climatic characteristics, Island of Hawaii

Station No.	Years of record	Skew of logs	Drainage area (mi^2)	Channel slope (ft/mi)	Channel length (mi)	Elevation (ft)	Forest cover (percent)	Rainfall (in.)
7000	48	-0.115	17.4	355	17.90	4,960	93	125
7040	50	+0.161	149	438	26.10	5,500	79	105
7580	32	+0.241	1.18	291	2.55	3,770	100	114

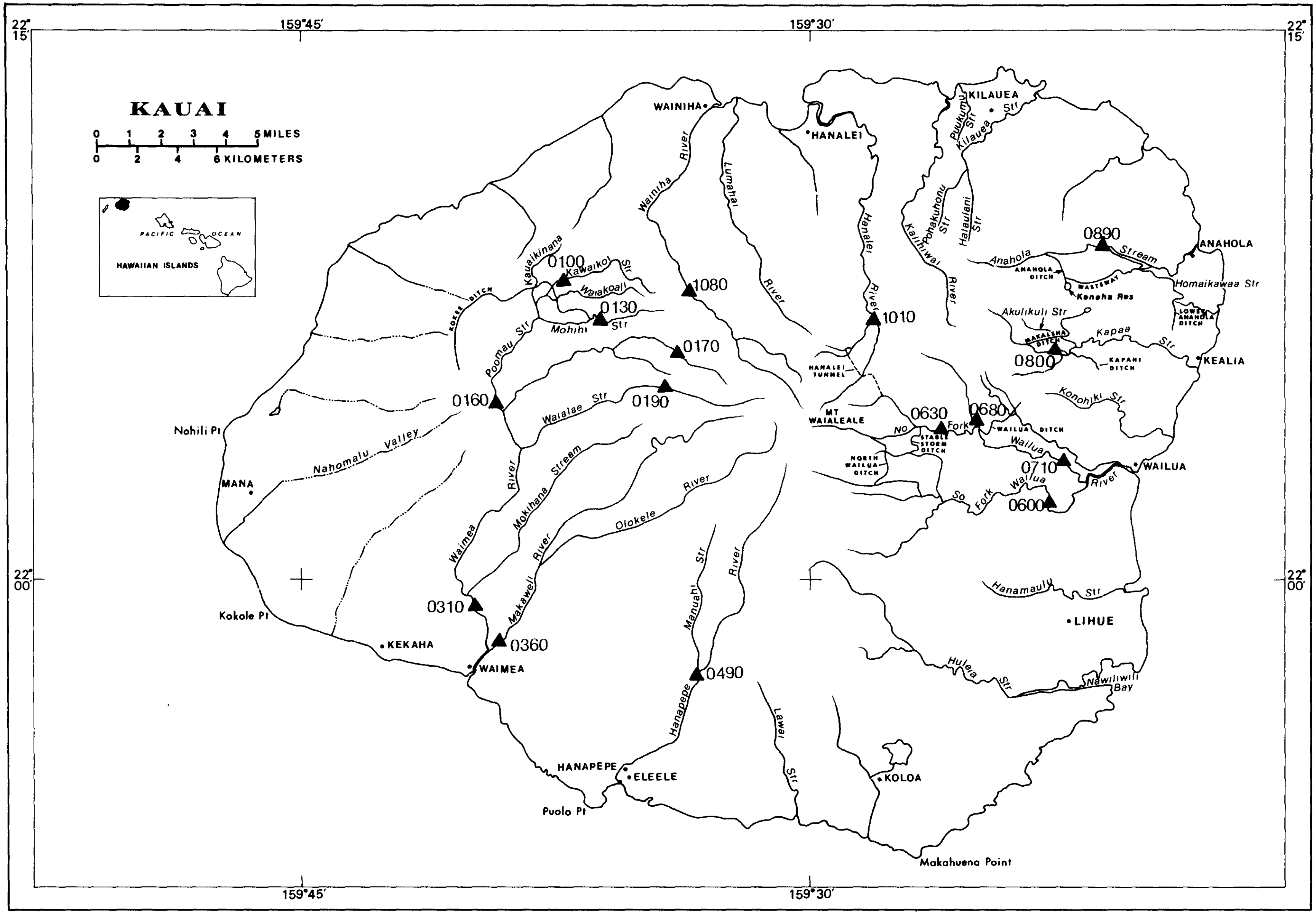

Figure 2. Location of gaging stations, Island of Kauai.

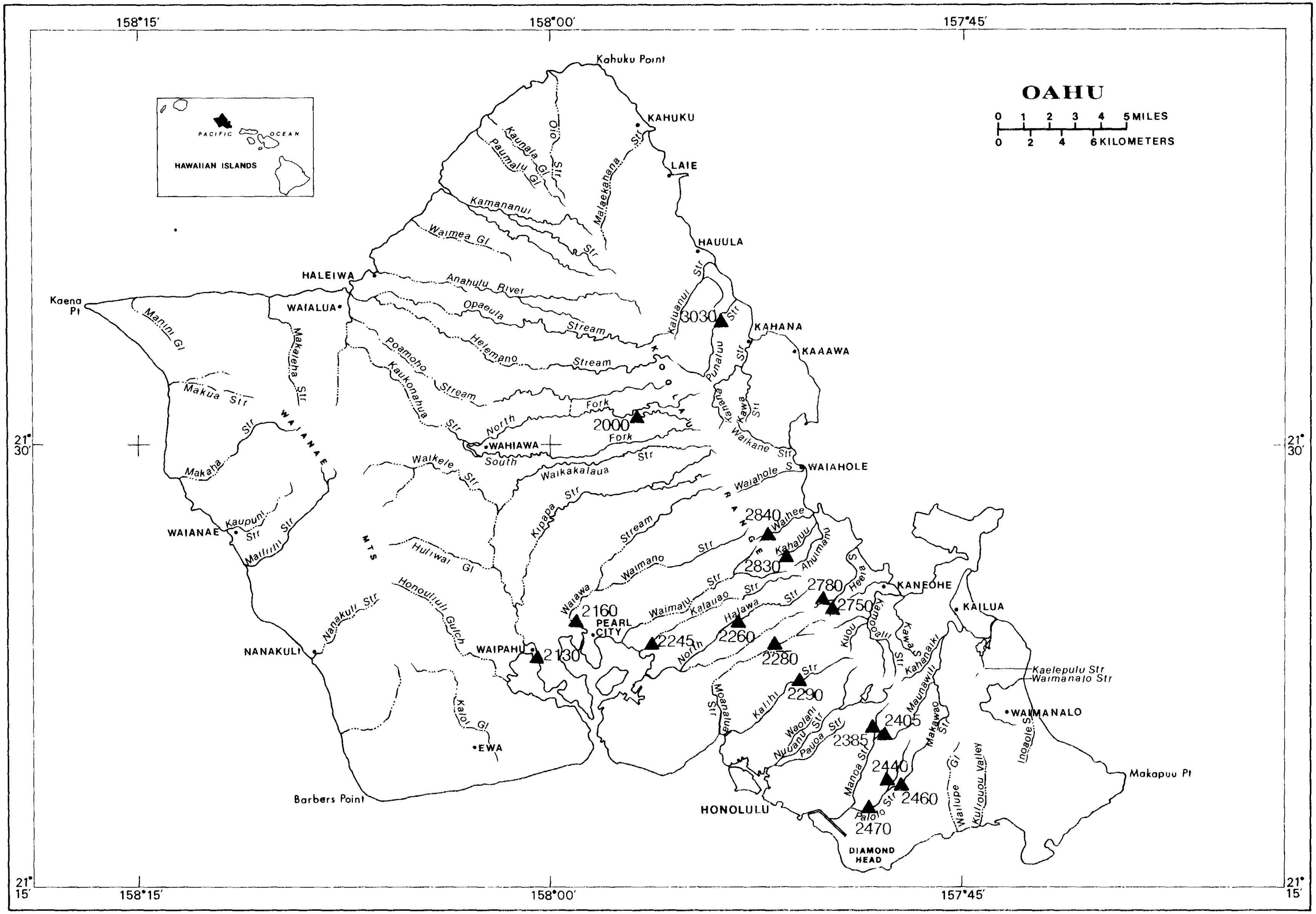

Figure 3. Location of gaging stations, Island of Oahu.

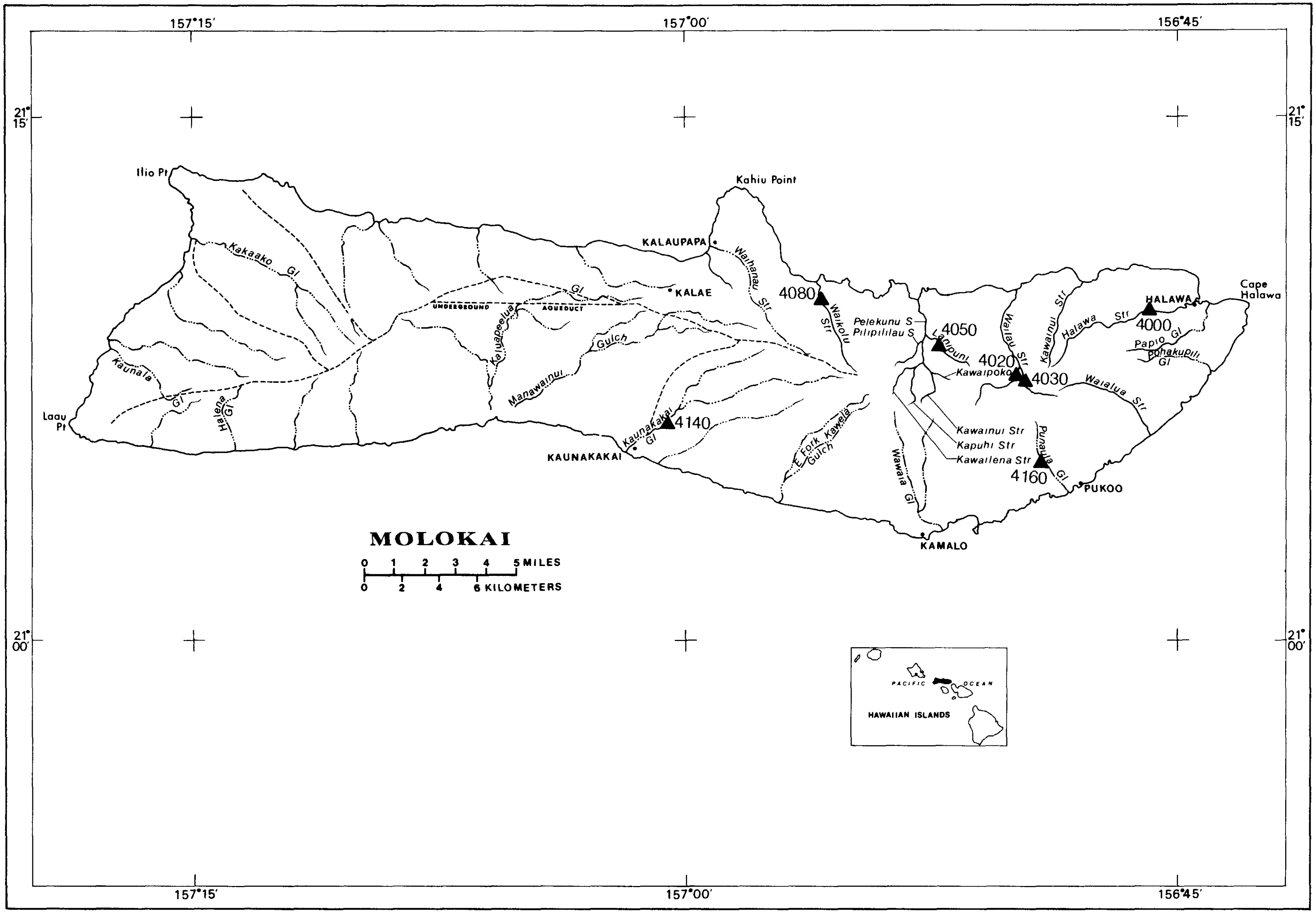

Figure 4. Location of gaging stations, Island of Molokai.

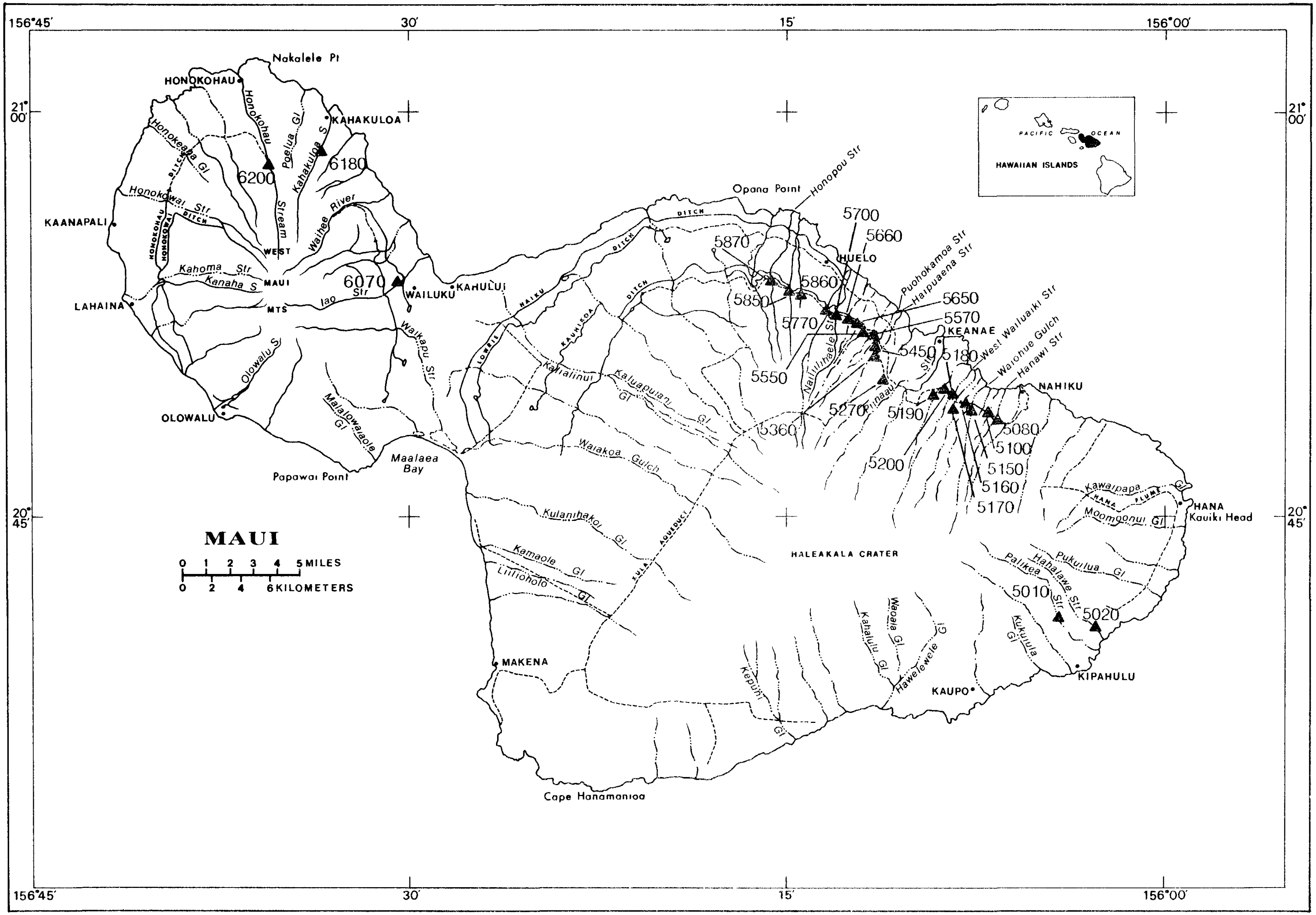

Figure 5. Location of gaging stations, Island of Maui.

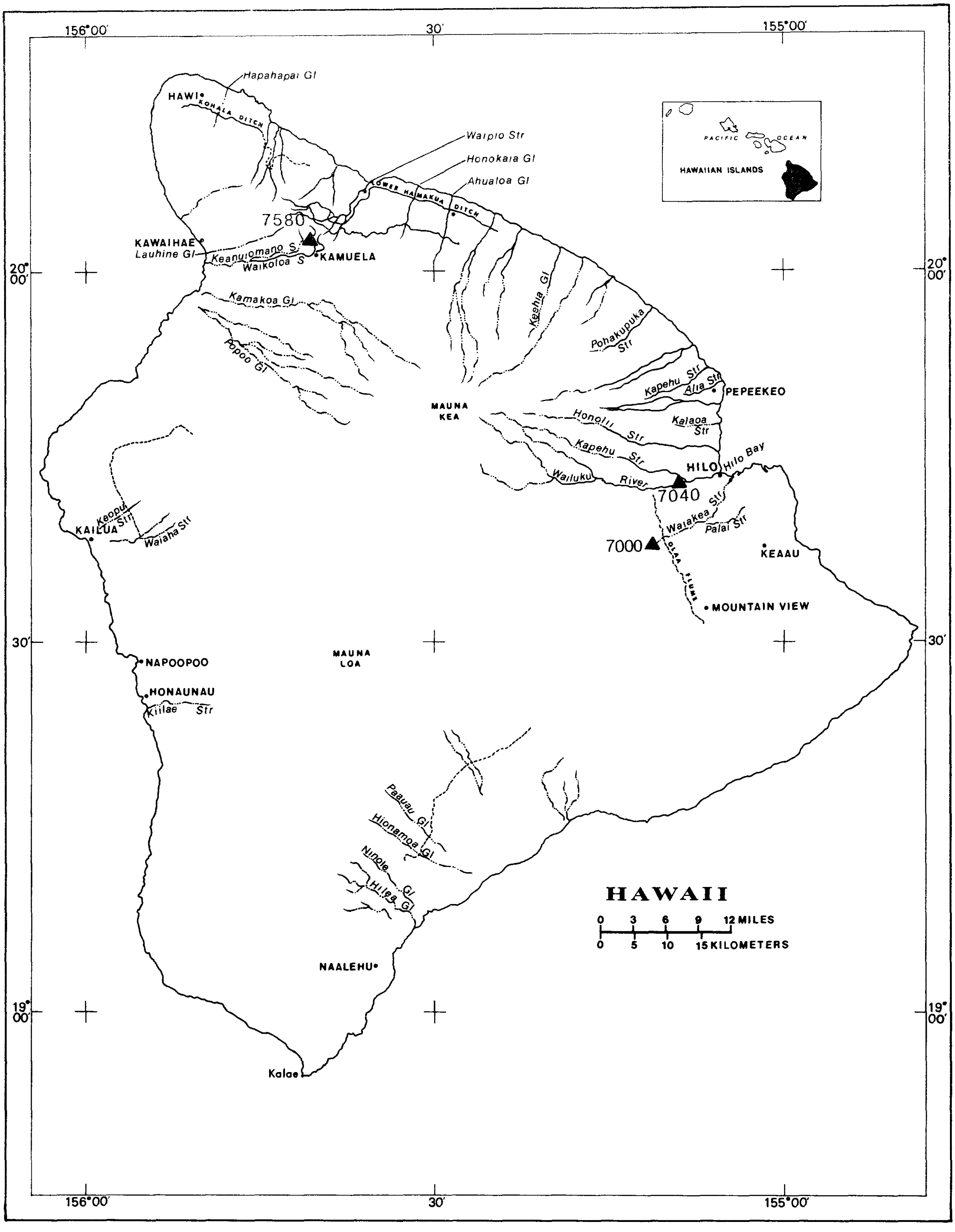

Figure 6. Location of gaging stations, Island of Hawaii.

After computing and compiling the statistical data for the annual flood series at each station, the computed skew value for each station was plotted on maps at the center of the drainage basin to see if there was a pattern from which isolines could be drawn. The plotted skew values showed no discernible pattern. Next, a multiple regression analysis relating computed station skew coefficients to the logarithms of the characteristics listed in tables 1-5 was made in order to develop a prediction equation. Values for channel slope, forest cover and precipitation were divided by 100 and elevation was divided by 1000 before the values were converted to logarithms.

The stepwise regression procedure was used for all multiple regression analyses, and the 95-percent significance level was used for all F-tests.

The first regression analysis was run for the State of Hawaii. All 68 stations listed in tables 1-5 were used for this analysis. The skew coefficient of the logarithms (the coefficient of skewness) was the dependent variable, and drainage area, channel slope, channel length, mean basin elevation, forest cover, and mean annual precipitation were the independent variables. The values for the independent variables were transformed to their natural logarithms prior to the regression analysis. The stepwise regression procedure, using the F-test for significance of regression at the 95-percent point, showed that the coefficients of drainage area, channel slope, channel length, and forest cover were the only ones statistically significant in the statewide analysis. This regression analysis resulted in the following equation:

$$G = 0.033 + 0.332Ln(DA) + 0.193Ln(CS) - 0.455Ln(CL) + 0.512Ln(FC);$$

where:

G = Coefficient of skewness;

Ln(DA) = Natural logarithm of drainage area in square miles;

Ln(CS) = Natural logarithm of channel slope in 100 feet per mile;

Ln(CL) = Natural logarithm of channel length in miles;

Ln(FC) = Natural logarithm of forest cover in ratio of area of forest cover to drainage area.

This regression analysis resulted in a coefficient of determination (square of the coefficient of correlation) of 0.290 and a standard error of estimate of 0.546 for the above regression equation. These results do not give much confidence for the use of a prediction equation. Multiple regression analyses were then run for the individual islands except for the Islands of Hawaii and Molokai. They have only three and seven stations respectively, with 25 or more years of record.

For the Island of Kauai, 16 stations were used in the multiple regression analysis. The stepwise regression procedure resulted in the following equation:

$$G = 0.323 + 0.844Ln(FC).$$

The coefficient of determination was 0.405 and the standard error of estimate was 0.508.

Seventeen stations were used in the multiple regression analysis for Oahu. The coefficient of determination was 0.542 and the standard error of estimate was 0.369. Only the coefficient for channel slope was found to be statistically significant, resulting in the following equation:

$$G = -0.757 + 0.411Ln(CS).$$

The regression analysis for Maui used data for 25 stations. None of the coefficients were statistically significant.

The results of the Kauai analysis were slightly better than those for the State, the results for Oahu were much better, and those for Maui were much poorer.

In view of the poor and inconsistent results obtained from the multiple regression analyses, the mean of the skew coefficients for all 68 gaging stations was computed. The computed mean skew coefficient is -0.14, which is not significantly different from the value of -0.05 recommended by the Water Resources Council (1976, 1977, and 1981). Most of the difference is accounted for by a few records that show very large values of skew. Therefore, the general skew coefficient of -0.05 is considered satisfactory for use in the State of Hawaii. Additional studies should be made when more records reach a length of 25 years.

BASIN AND CLIMATIC CHARACTERISTICS

Topographic and climatic characteristics of the drainage basins, listed in tables 1-5, were derived as follows:

DA, Drainage area -- Area of drainage basin, in square miles, as planimetered from 1:24,000 topographic maps.

CS, Channel slope -- The difference in elevation, in feet, at points 10 percent and 85 percent of the channel length (CL) divided by the distance between the two points in miles.

CL, Channel length -- Distance along a stream, in miles, from the gaging station to the basin divide.

E, Mean basin elevation -- Elevation, in feet above mean sea level, measured on 1:24,000 topographic maps by laying a grid over the map, determining the elevation at each grid intersection, and averaging these elevations. The grid spacing was selected to give at least 25 intersections within the basin.

FC, Forest cover -- The percent of the drainage area covered by the forests and/or vegetation as shown in green on 1:24,000 topographic maps.

R, Mean annual precipitation -- Rainfall, in inches, determined by placing a grid over an isohyetal map and locating 20-25 random points within the basin boundary and computing the arithmetic average of these points.

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