WORKING PAPER NO. 51

STANDARD

FOR

HYDROLOGIC ANALYSIS PROCEDURES

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Pacific Northwest
Region IX
Portland, Oregon

December 1964

Hydrology Committee
12/7/64

HYDROLOGIC COMPUTATIONS FOR RIVER BASIN STUDIES

INTRODUCTION

The purpose of this paper is to describe a procedure for the hydrologic computations necessary to river basin studies. For this paper "hydrology" is defined as the science dealing with water, its properties, phenomena and distribution, especially with reference to water on the surface of the land, in the soil and underlying rock, and in the atmosphere. This definition implies that quantity and quality are hydrologic factors that are inseparable for a complete analysis of existing data. However, it is proposed herein to separate the computations by obtaining and analyzing data on quantities of flow, and later superimposing quality data upon the quantity analysis to determine flow and storage needs for water quality control.

Because the river basins in the Pacific Northwest have climatic conditions ranging from coastal, through maritime and mountain to arid semi-desert in the space of a few hundred miles, it is necessary to describe for each basin a base system from which decisions may be made regarding pertinent data to be used in the analysis. It is the responsibility of the basin engineer for each basin to set up the base system and determine where data are needed and how much information is necessary for his particular basin or project.

RECOMMENDED PROCEDURE

A set of instructions giving procedures for determining flow regulation requirements for quality control[1/] was used as a basis for this paper and is considered an integral portion of this paper.

1/ F. H. Rainwater, "Hydrologic Aspects of Analysis of Flow Regulation Requirements for Quality Control", DHEW, PHS, February 1964.

It is recommended that the basin or project engineer for each area start the hydrologic analysis by defining the base system in the following steps:

1. Obtain a map(s) of the basin showing topography, streams, cities, roads and other data necessary for location of points on the base system.

2. Draw or obtain a "stick" diagram1/ (example Figure 1) showing the schematic layout of the basin with streams, cities, industries, gaging stations, dams and reservoirs, irrigation diversions and returns, quality data stations and any other data that appear to affect the quality of the waters in the basin.

3. Gather all available data from the files, consolidate information and put pertinent portions on "stick" diagram.

   a. Economics

   b. Water uses (irrigation, fisheries, recreation, power, navigation, etc.)

   c. Municipal and industrial water supplies

   d. Municipal and industries wastes

   e. Geology, meteorology, physiography

   f. Water quality

   g. Surface water hydrology

   h. Ground water hydrology

   i. Existing and proposed dam and reservoir data

4. Make a reconnaissance tour of the area to become familiar with areal problems.

1/ Some of these have been prepared by Mr. Fischman.

5. Outline the proposed plan for the basin and assemble a committee composed of the technical administrative group for the purpose of:

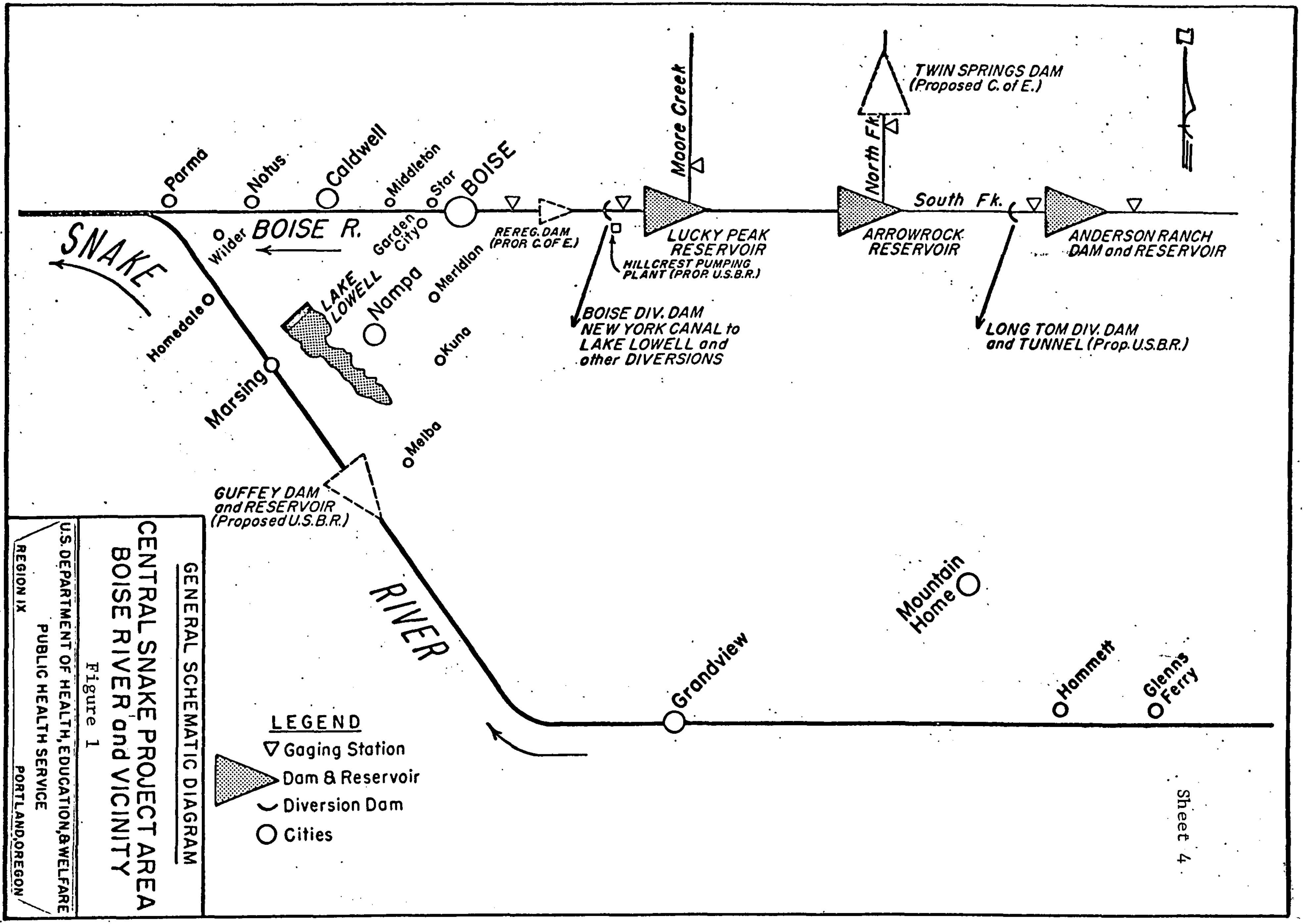
a. Dividing the area into reaches that can be analyzed efficiently and effectively.

b. Deciding on objectives and criteria that will be most useful for evaluating the flows needed for quality control in each reach.

After the base system has been established, low flow frequency graphs at selected points within each reach are needed. In the Pacific Northwest these are not available through other agencies and this office has to supply them. These are in general based on USGS surface water records. It is recommended that a base hydrologic period of time from 1931 through 1960 be used. At present there is no standard base period among the agencies in the Northwest; however, the selected time includes 1931 which is considered by the Corps of Engineers and the Bureau of Reclamation as the critical low flow year.

There are, of course, many exceptions such as the case in which only a few years data are available, or dams, reservoirs and irrigation diversions have changed the regimen of the stream during the period of record. Such cases are unique and the project engineer must decide the validity of data and resulting graphs. Correlations with other stations or different statistical procedures may be required for making the decisions. Several papers[1/,2/,3/,4/] are available as background information.

1/ USGS Water Supply Paper No. 1543A
2/ USGS Water Supply Paper No. 1541A and C
3/ Linsley, Kohler, Paulhus, Hydrology for Engineers
4/ Beard, Leo R., "Statistical Methods in Hydrology", Corps of Engineers, Sacramento, Calif., January 1962.



GENERAL SCHEMATIC DIAGRAM

CENTRAL SNAKE PROJECT AREA

BOISE RIVER and VICINITY

Figure 1

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE

PUBLIC HEALTH SERVICE

REGION IX

PORTLAND, OREGON

Sheet 4

The office procedure recommended for computing low flow frequency data is set forth in the following description and data sheets:

1. A description of each critical point is made by filling in the blanks of Sheet 1.

2. Flow data are tabulated for the chosen period of record on Sheet 2. Data sources are shown. Appropriate means are calculated for the water year, climatic year or calendar year. The June 11, 1964 memorandum from Frank H. Rainwater in Appendix I explains the differences involved in the use of each period of time.

3. The flow data are ranked in ascending order of magnitude (Sheet 3). Median monthly values for the period of record are added and divided by 12 to give a median-annual mean. Ratios of each monthly median to the median-annual mean are computed to give an expected monthly distribution of flows.

4. The ranked values of annual means for the water year, climatic year, or calendar year, whichever fit the particular climatic area involved in the basin, are plotted on the frequency diagram of Sheet 4 using plotting positions as determined by the recurrence interval $T=\frac{N+1}{M}$. These recurrence intervals have been computed for periods of record from 10 through 42 years in Sheet 7 for convenience in plotting.

5. Tabulate at the bottom of Sheet 5 the annual means from the frequency diagram at probabilities of exceedance of 0.9, 0.7, 0.5, 0.3, and 0.1, which correspond to recurrence intervals 1.1, 1.4, 2.0, 3.3 and 10 years respectively. Tabulate the ratios found in 3 above in the column headed % of annual mean. Multiply the annual mean at each recurrence interval by the monthly ratio to

obtain the expected flow for the month. These values can then be plotted on Sheet 6 to give monthly hydrographs for the various recurrence intervals.

Quality data are associated with the quantity data by the equation:

$$Q_b C_b = Q_{a-b} C_{a-b}$$

where: Q_b = flow in cfs or mgd at point B
C_b = concentration in mg/1 at point B

$Q_{a-b} C_{a-b}$ = The algebraic summation of the products of flow and concentration between points A and B

Mr. Rainwater's procedure[1/] is based on this equation. All withdrawals and additions of water are tabulated. Appropriate quality values are associated with the quantities by the detailed method shown. The end result is a presentation of streamflow regulation needs for quality control.

Use of this method depends on the quality data available in each basin. In general, it is preferable for each quality variant used to plot the changes in the variant with changes in flow in the stream. From such a graph it is possible to pick expected quality data that corresponds to the expected quantities computed above. It is probable in the Pacific Northwest that there are areas in which data are not available. In such cases it may be necessary to make spot measurements and attempt a correlation with adjacent or like areas. Problems of this type will have to be solved individually as they appear, but the majority of basins are expected to have adequate data for implementing these recommendations.

1/ F. H. Rainwater, "Hydrologic Aspects of Analysis of Flow Regulation Requirements for Quality Control", DHEW, PHS, February 1964.

HYDROLOGIC QUANTITY ANALYSIS

BASIN____________ STATE____________ COUNTY____________

River or stream____________ tributary to____________

Gaging station designation: Name____________

Data determined at station:	
Flow____________	No. ____________
Quality____________	Location ____________
Temperature____________	Elevation ____________
	Drainage Area ____________
	Length of record____________

Discharge Data:

Average discharge ____________ cfs____________ Acre-feet

Maximum day ____________ cfs____________ Date

Minimum day ____________ cfs____________ Date

Regulation above station ____________

Diversions above station ____________

Source Document(s):

Supplemental Data:

Nearest meteorological station(s)____________

Mean annual rainfall ____________ Length of record____________

Mean annual temperature____________ Length of record____________

Source Document(s):

Remarks:

By____________ Date____________

HYDROLOGIC QUANTITY ANALYSIS
Station Name and No.________ (All units in cfs)

Entries by _____________ Date _______
Analysis by _____________ Date _______

	WSP No.	Water Year	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	MEANS		
															Water Yr.	Climatic Yr.	Calendar Yr.
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3																	
4																	
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	M E A N																

HYDROLOGIC QUANTITY ANALYSIS
Station Name and No.________ (All units in cfs except %)

Entries by ______________ Date ______
Analysis by ______________ Date ______

Rank	NOTES	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	MEAN OF YEAR		
														Water	Climatic	Calendar
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
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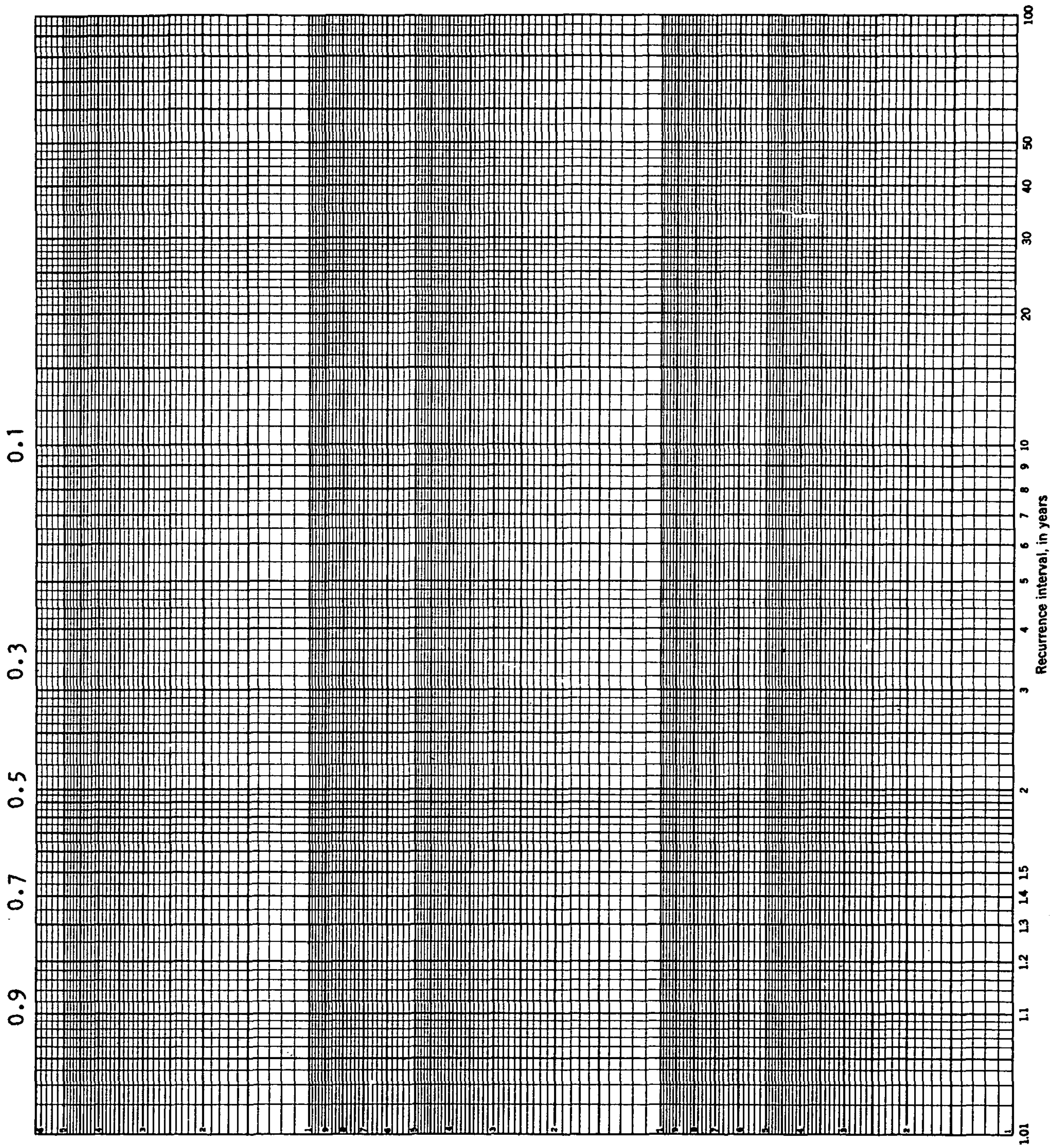
38																
39																
40																
41																
42																
MEDIAN																
Distribution Ratio (Σ medians/12)																

FREQUENCY DIAGRAM

PROBABILITY OF EXCEEDANCE



ANNUAL MEAN DISCHARGE IN CFS

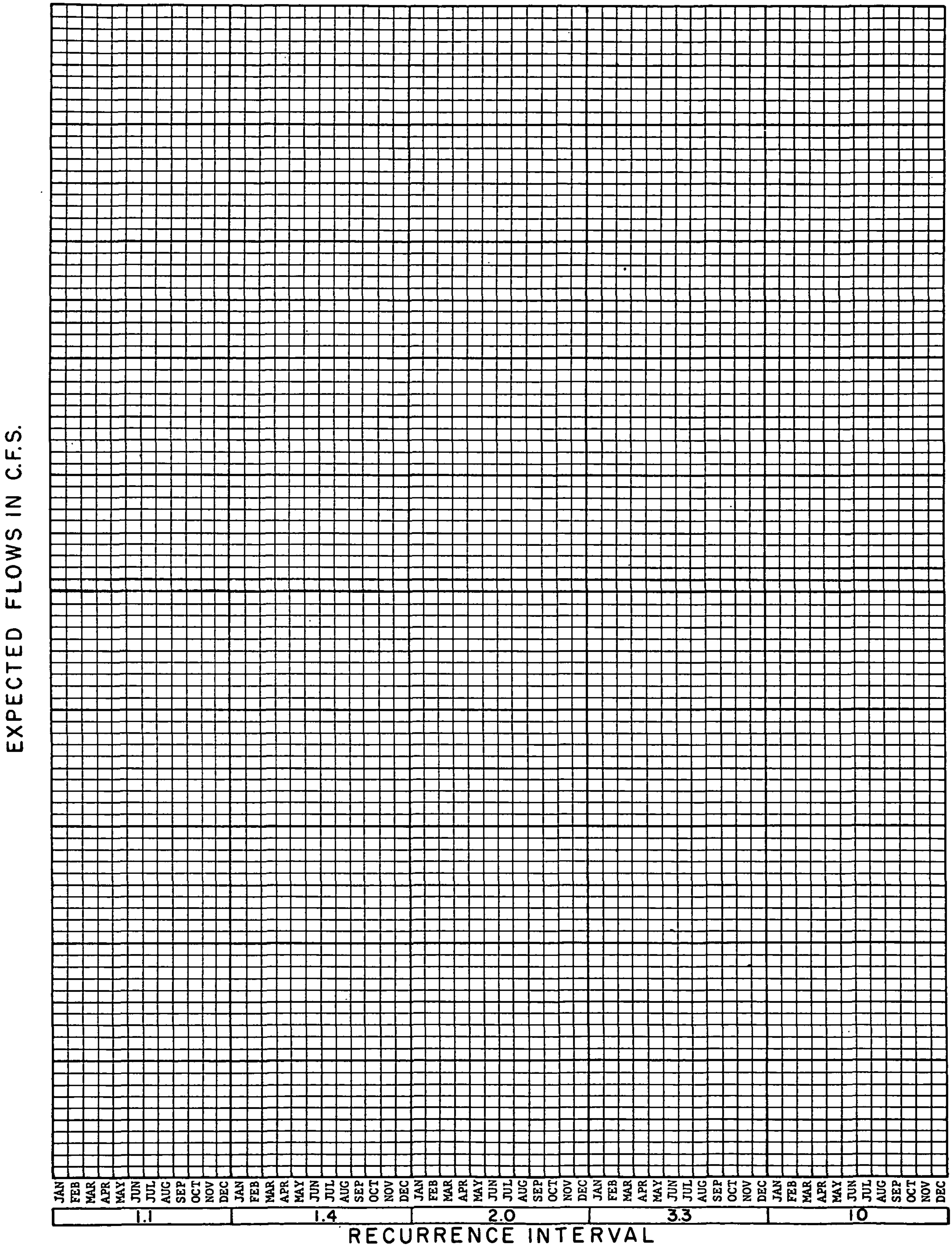
Plotted by__________ Date__________

EXPECTED FLOWS IN CFS AT STATION__________
FOR VARIOUS RECURRENCE INTERVALS

Month	% of Annual Mean	Recurrence Interval				
		1.1	1.4	2.0	3.3	10
January						
February						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						
Annual Mean						

Computed by______________Date__________

EXPECTED FLOWS in c.f.s. at Station ______ for various Recurrence Intervals



Plotted by ______________ Date __________

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MAY 1962 EDITION
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APPENDIX I

UNITED STATES GOVERNMENT

Memorandum

PUBLIC HEALTH SERVICE-BSS

Westgarth

TO : Project Director
Columbia River Basin Project

DATE: JUN 11 1964

File: Water Resources, Hydrology

FROM : Western Operations Officer (WPS)
Technical Services Branch
DWS&PC

SUBJECT: Hydrologic Procedures and Methods

Mr. Haywood and I have discussed the content of your June 9, 1964, memorandum on this subject; and he has asked me to reply.

It has not been our intent to dictate the use of the climatic year data in flow regulation studies. The technical essence of its recommendation is presented in paragraph 2 of your memorandum.

Enclosed are copies of illustrations showing normal periods of low flow and normal distribution of runoff by months. These are from USGS Water Resources Review Supplement No. 2 by Earl Harbeck and Walter Langbein. In reference to figure 10, the runoff characteristics within your Project area demonstrate the inadvisability of establishing a uniform nation-wide procedure. On the basis of these data describing natural runoff patterns, I would be a little sceptical of using the water year in Southern Washington and in Oregon because minimum flows normally occur in August or September and the droughts may often extend into October, as you pointed out. There certainly would be no objection to using the calendar year in this area however. Conversely the calendar year would not be appropriate in the Snake River Basin because the low flow periods commonly occur during the winter months. It is understood, of course, that irrigation practices may completely change these normal runoff patterns.

There is some merit in maintaining compatibility with work done by other State and Federal agencies with whom you coordinate your activities. However, we don't want to coordinate to the detriment of our own program. The needs of the agencies naturally differ. For example, the Corps is interested in controlling flood volumes and consequently would probably use the water year. The Bureau of Reclamation is concerned with irrigation; hence, the calendar years serves their purpose best. We are interested in low flow regulation, consequently, should pick periods to best serve our needs.

Frank H. Rainwater
Frank H. Rainwater

Enclosure

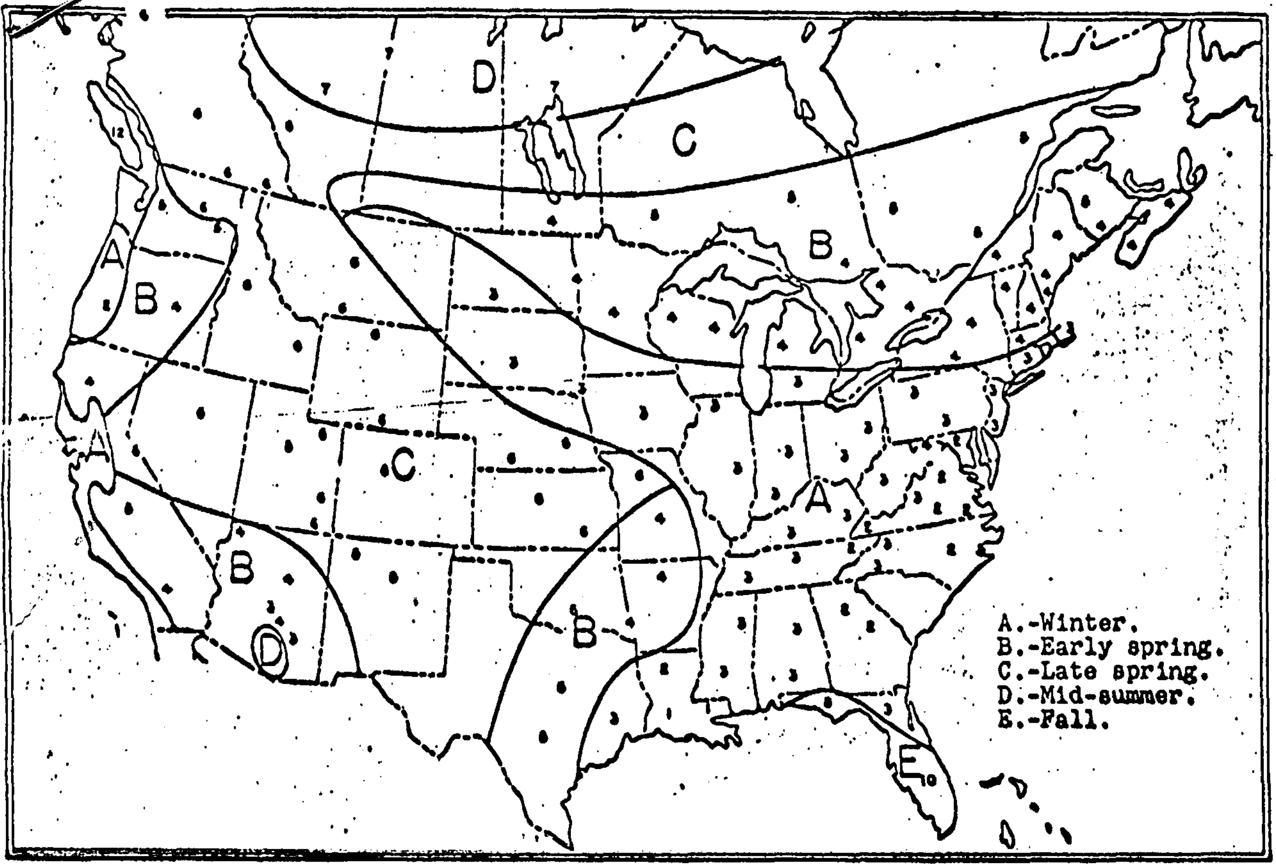

Figure 9.--Seasons of highest flows.

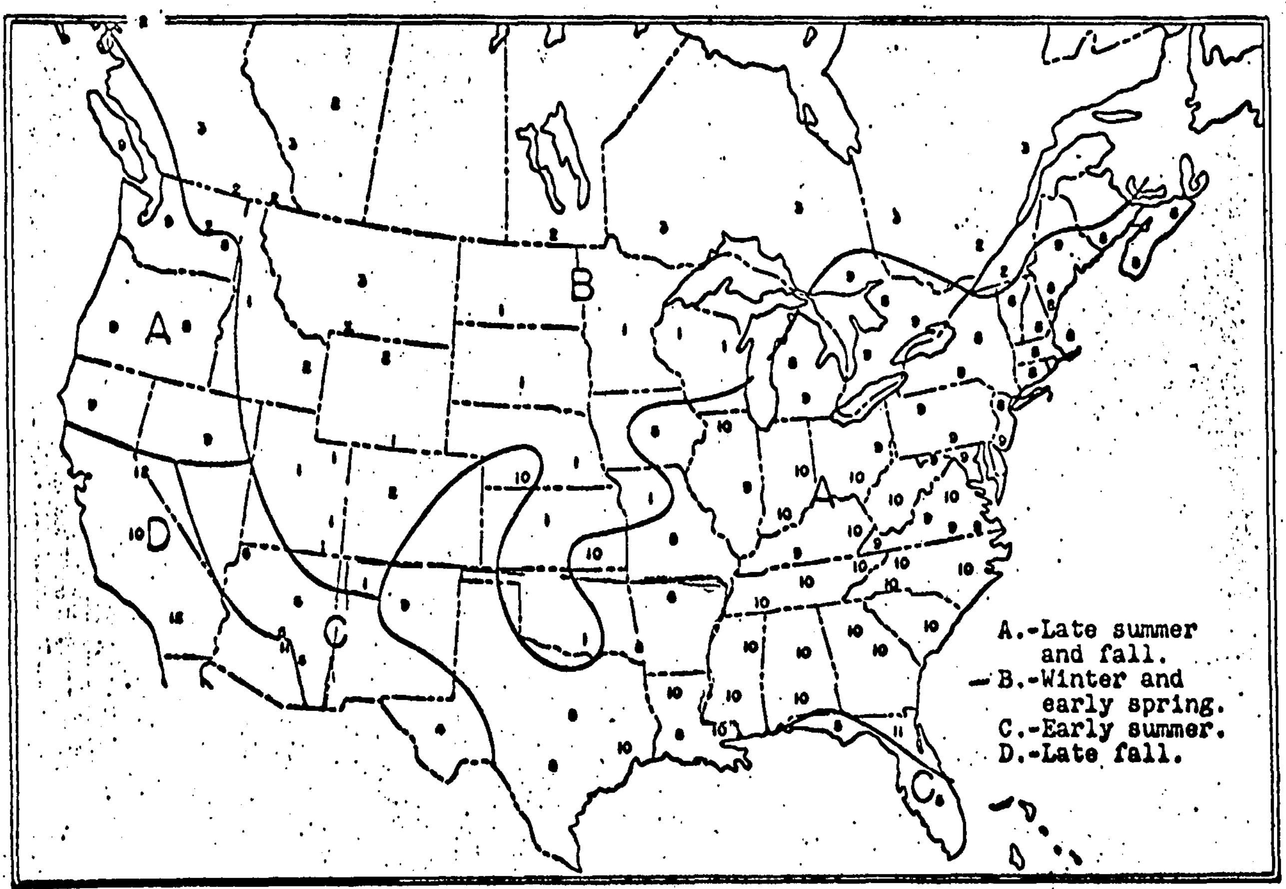

Figure 10.--Seasons of lowest flows.

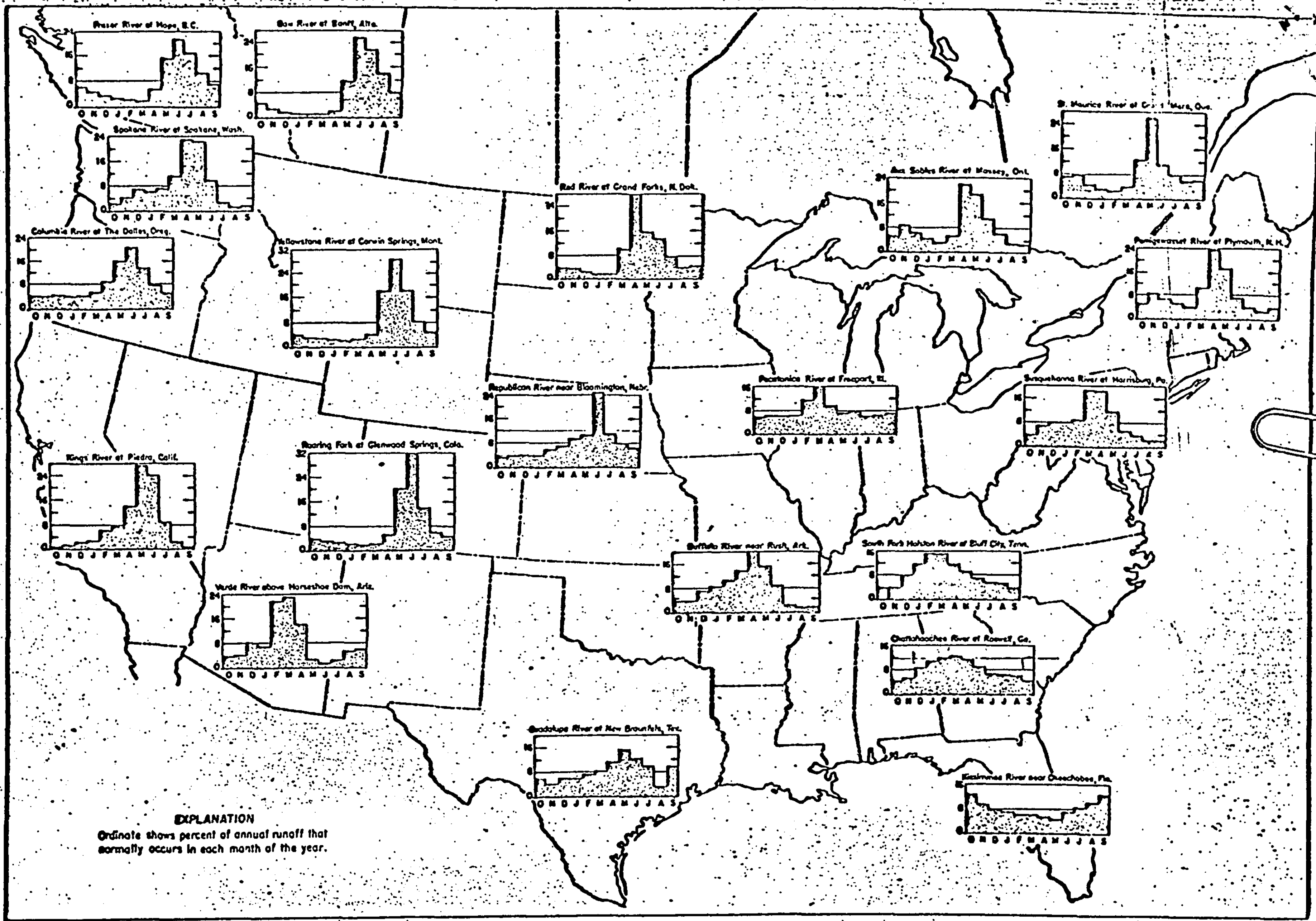

Figure 11.--Normal distribution of runoff, by months.