Magnitude and Frequency of Floods in Eastern Oregon

By D. D. Harris and Lawrence E. Hubbard

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Conversion factors for inch-pound system and International System Units (SI)

[For use of those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:]

Multiply inch-pound units	By	To obtain metric unit
	Length	
inch (in.)	25.40	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)
	Specific combinations	
cubic foot per second (ft^3/s)	0.0283	cubic meter per second (m^3/s)

MAGNITUDE AND FREQUENCY OF FLOODS IN EASTERN OREGON

By D. D. Harris and Lawrence E. Hubbard

ABSTRACT

A method for estimating the magnitude and frequency of floods at ungaged sites is presented for unregulated streams in eastern Oregon. Equations relating flood magnitude to basin characteristics were developed for exceedance probabilities of 0.5 to 0.01 (2- to 100-year recurrence intervals). Flood characteristics were found to be best defined by dividing eastern Oregon into four geographic regions: Southeast, Northeast, North Central, and Eastern Cascades. Separate equations are presented for each region.

Also presented are values of maximum discharges, of flood discharges for selected exceedance probabilities, and of basin characteristics for all gaging stations used in the analysis. Included are data for 148 stations in Oregon, 3 stations in northern California, 3 stations in western Idaho, 4 stations in northern Nevada, and 4 stations in southern Washington. Drainage areas used in the analysis range from 0.47 to 11,300 square miles.

INTRODUCTION

The increasing emphasis on flood plain zoning and the collection of new flood data in eastern Oregon provides a basis to update the flood frequency analysis for that area. Although some parts of the area are still deficient of data, this analysis makes use of the most recent data available. Little flood data for streams with drainage areas less than 10 mi^2 were available when flood frequency reports were last prepared (Thomas and others, 1963; Hulsing and Kallio, 1964; Butler and others, 1966; Young and Cruff, 1967). A small-stream flood data program for drainage areas generally less than 10 mi^2 was begun in 1952, in cooperation with the Oregon Department of Transportation, Highway Division, then the Oregon State Highway Commission. The small-stream program was expanded in 1965 through funds provided by the U.S. Forest Service, to include many previously ungaged streams in national forests. In 1969 six small-stream, peak- flow gaging stations were installed in cooperation with the U.S. Bureau of Land Management. Now, with at least 10 years of data collected at many new sites on small streams and with added data at the old sites, the data base can be used to re-evaluate magnitude and frequency statistics.

This analysis is limited to eastern Oregon. Another flood frequency report has been recently prepared for the western part of the State (Harris and others, 1979).

In describing flood frequency in this report, the term "exceedance probability" is used in preference to the term "recurrence interval." However, both terms are used in most tables, graphs, and illustrative problems. For example, a flood with a 0.01 exceedance probability is a flood that has one chance in a hundred of being exceeded in any one year. This is a 100-year flood under the "recurrence interval" terminology.

Purpose and Scope

This report describes methods for estimating the magnitude and frequency of floods at ungaged sites on streams with unregulated flow in eastern Oregon. The purpose is to provide a method to estimate flood magnitude and frequency and to present the supporting data. The report is based on data from nearly all unregulated streams (or data from regulated streams prior to their regulation) where gaging stations have been operated for at least 10 years.

Records at the gaging stations provided the basis for estimating flood-peak discharges and frequency of occurrence at ungaged sites. Stations used in this analysis have records ranging from 10 to 75 years. Data used to evaluate peak flows were for 162 gaging stations in eastern Oregon, and adjacent states. Of that total, 62 were crest-stage gaging stations. A crest-stage gage records only the peak stages of a stream. Drainage areas ranged in size from 0.47 mi^2 to 11,300 mi^2. Locations of gaging stations used are shown in figure 1.

The magnitude of a flood is influenced by physiographic characteristics of the drainage basin. These characteristics, which include basin size, climate, topography, geography, soils, and vegetation, are referred to as basin characteristics throughout this report.

Multiple-regression analysis was used to correlate flood discharges with selected basin characteristics and to develop appropriate regional relation equations shown in table 1. Although many basin characteristics were tried as independent variables in regression analysis, the number retained in the equations was reduced for practicality and simplicity, with little effect on the accuracy of the flow estimate.

Previous Studies

Previous flood frequency reports by Thomas and others (1963), Hulsing and Kallio (1964), Butler and others (1966), Young and Cruff (1967), and Kjelstrom (1981), covered parts of eastern Oregon. Those reports contained peak-flow data for 93 stations in eastern Oregon. For those reports, the smallest drainage basin sampled was about 9 mi^2.

Regression equations for flood-peak discharge are presented in a report "Evaluation of the streamflow data program in Oregon" (Lystrom, 1970), which are based on data through water year 1967 (October 1966 through September 1967) from all stations with 10 or more years of record of unregulated flow through the 1967 water year.

Because of the inclusion of data from many small drainage basins and the addition of data for long-term stations, the equations presented in this report are probably more reliable than those presented in previous Geological Survey reports for eastern Oregon.

GENERAL DESCRIPTION OF THE AREA

The area studied includes all that part of Oregon east of the crest of the Cascade Range. According to Dicken (1965), the principal geomorphic features in eastern Oregon include the east slope of the Cascade Range, the Deschutes-Umatilla Plateau, the Blue Mountains, the High Lava Plains, the Basin and Range, and the Owyhee Upland (fig. 1).

High flows on streams in eastern Oregon are caused by generalized rains, snowmelt, and cloudburst storms. The largest flows on most streams result from heavy winter rains accompanied by snowmelt on frozen ground.

The east slope of the Cascade Range is primarily comprised of Pliocene and Pleistocene flows of basalt and andesite along with volcanic tuff and ash deposits resting on older volcanic rocks. Much of this volcanic material in the eastern part of the Oregon cascades is highly permeable. Annual precipitation, most of which occurs as snow, ranges from less than 20 inches along the eastern edge of the area to more than 100 inches in the high elevations as shown in figure 2. Peak stream flows in this area most commonly result from snowmelt. The permeable volcanic materials tend to dampen the snowmelt runoff, and in many areas are the source of prominent springs. In some places, the flat terrain produced by recent lava flows that cover highly permeable pumice and ash beds make the contributing drainage area boundaries impractical to determine.

The Deschutes-Umatilla Plateau lies north and west of the Blue Mountains and is bounded by the Cascade Range on the west, and the Columbia River on the north. High stream flows in this area are caused by snowmelt runoff or rainstorms, including summer cloudburst storms. Winter flooding is greatest when the ground is frozen. Annual precipitation in this area ranges from less than 10 to more than 25 inches.

The Blue Mountains lie in the northeast part of Oregon. High stream flows result from snowmelt sometimes in combination with direct rainfall. Cloudburst storms are common. Average annual precipitation ranges from less than 10 inches along the perimeter to more than 80 inches in the Wallowa Mountain area.

The High Lava Plains, Basin-Range, and Owyhee Upland areas in the southeastern part of the state are mostly covered by sagebrush and scattered juniper trees, and include several local mountain ranges. Annual precipitation ranges from less than 10 to about 30 inches. High streamflows in these provinces result from the same causes as those in the Blue Mountains.

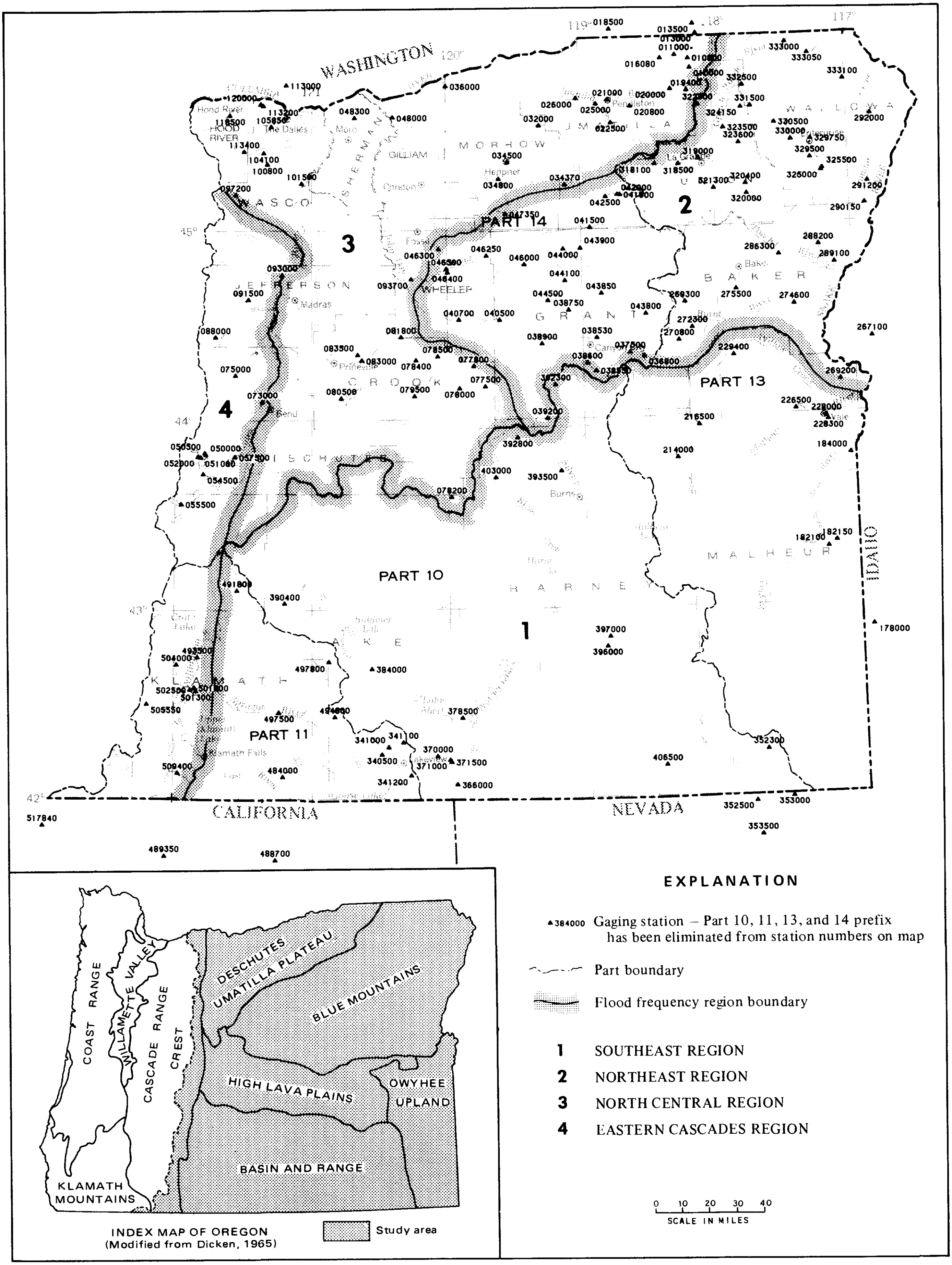

FIGURE 1. – Gaging stations, flood-frequency regions, and geomorphic provinces.

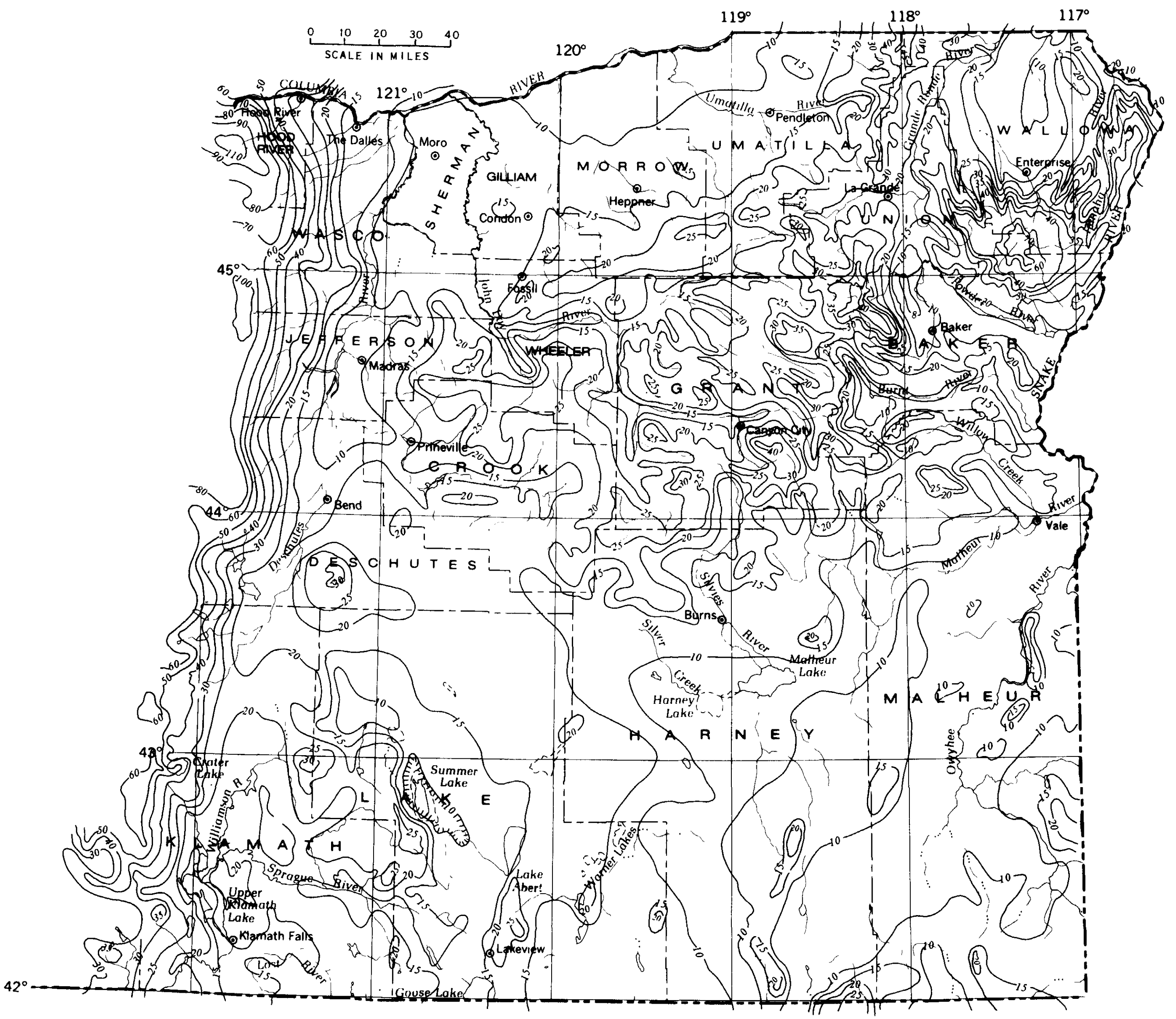

FIGURE 2. – Average precipitation, in inches, in eastern Oregon (modified from U.S. Weather Bureau, 1964)

ANALYTICAL TECHNIQUE

Discharges at selected exceedance probabilities were related to basin characteristics for gaged sites by the multiple- regression technique to define regional flood magnitude-frequency relations for use at ungaged sites.

Drainage Basin Characteristics

Drainage-basin characteristics computed for each gaging station used in the study are listed in table 2 at the back of the report and are defined as follows:

1. Drainage area (A), in square miles, the total contributing area upstream from the gaging-station site, as shown in the latest Geological Survey water-resources data reports.

2. Main-channel slope (S), in feet per mile, determined from elevations at points 10 and 85 percent of the distance along the channel from the gaging station to the basin divide (Benson, 1962b and 1964).

3. Main-channel length (L), in miles, from the gaging station to the basin divide, measured in accordance with guidelines given by the U.S. Water Resources Council (1968) or taken in part from the various River Mile Index publications prepared by the Columbia Basin Inter-Agency Committee (1963, 1965, 1966) and by the Pacific Northwest River Basins Commission (1976).

4. Mean basin elevation (E), in feet above mean sea level, determined by the grid method from quadrangle map of a practical scale by laying a grid over the map, recording the elevation at each grid intersection, and averaging those elevations. The grid spacing was selected to give at least 25 intersections within the basin boundary.

5. Area of lakes and ponds (ST), expressed as a percentage of the drainage area, determined from the most recent quadrangle maps available.

6. Forest cover (F), expressed as the percentage of the drainage area covered by forest, as shown on the most recent quadrangle maps available.

7. Soils index (SI), determined from a map compiled from computed values of soil indexes according to procedures described by the Soil Conservation Service (1959, 1964). Soils index values are a function of soil permeability. Data for these computations were derived from soils-association and land-use maps included in a Columbia North-Pacific Framework report (1970a, 1970b). Data were also furnished by the Soil Conservation Service staff, State office, Portland, OR.

8. Latitude at gage (LAT). Latitude of stream-gaging station in decimal degrees.

9. Longitude (LONG). Longitude of stream-gaging station in decimal degrees.

10. Mean annual precipitation (P), in inches, determined from an isohyetal map prepared by the National Weather Service, River Forecast Center, Portland, OR, (U.S. Weather Bureau, 1964), using adjusted climatological data (1930-57) and values derived by correlation with other physiographic factors (figure 2).

11. Precipitation intensity (I), defined as the maximum 24-hour rainfall having a recurrence interval of 2 years (2-year, 24-hour rainfall), expressed in inches. These values were determined using an isopluvial map of 2-year, 24-hour precipitation prepared by U.S. National Oceanic and Atmospheric Administration (1973).

12. Temperature index (TI), the mean minimum January air temperature, in degrees Fahrenheit, in the basin. This value was determined from the U.S. Weather Bureau map shown in figure 3 (Sternes, 1960). The mapped air temperature provides an available indicator of areas susceptible to snow and frozen ground.

Magnitude and Frequency of Floods at Gaged Sites

Methods for estimating flow frequencies at gaged sites, presented in "Guidelines for Determining Flood Flow Frequency," published by the U.S. Water Resources Council (1981) were used in this study. Data from 148 gaging stations in Oregon, 3 in California, 3 in Idaho, 4 in Nevada, and 4 in Washington, representing basins that have virtually no regulation of flow, and 10 years or more of record, provided the basic dependent variables (annual peak discharge). For each station, the logarithms of the annual peaks were used to compute the mean, standard deviation, and skew coefficient that describe a log-Pearson Type-III distribution. The log-Pearson Type III frequency distribution was used to determine discharges for selected exceedance probabilities. Adjustments to the frequency distributions were made using methods described in Water Resources Council Bulletin 17B (1981).

Data from the log-Pearson Type-III frequency curve for each station are presented in table 3 at the back of the report. It lists flows for selected exceedance probabilities between 0.5 and 0.01, ie:

$Q_{0.5}$(2 yr), $Q_{0.2}$(5 yr), $Q_{0.10}$(10 yr), $Q_{0.04}$(25 yr),

$Q_{0.02}$(50 yr), and $Q_{0.01}$(100 yr).

The figures in parentheses are the corresponding recurrence intervals. To explain exceedance probability the following example is used: A flow of 900 ft^3/s with an exceedance probability of 0.5 means that there is a 50 percent chance that the flow will exceed 900 ft^3/s in any one year. Another way of describing the same probability is that a 900-ft^3/s flow has a 2-year recurrence interval. A flow with an exceedance probability of 0.01 has a 1 percent chance of being exceeded in any one year. It could also be described as having a 100-year recurrence interval, on the average.

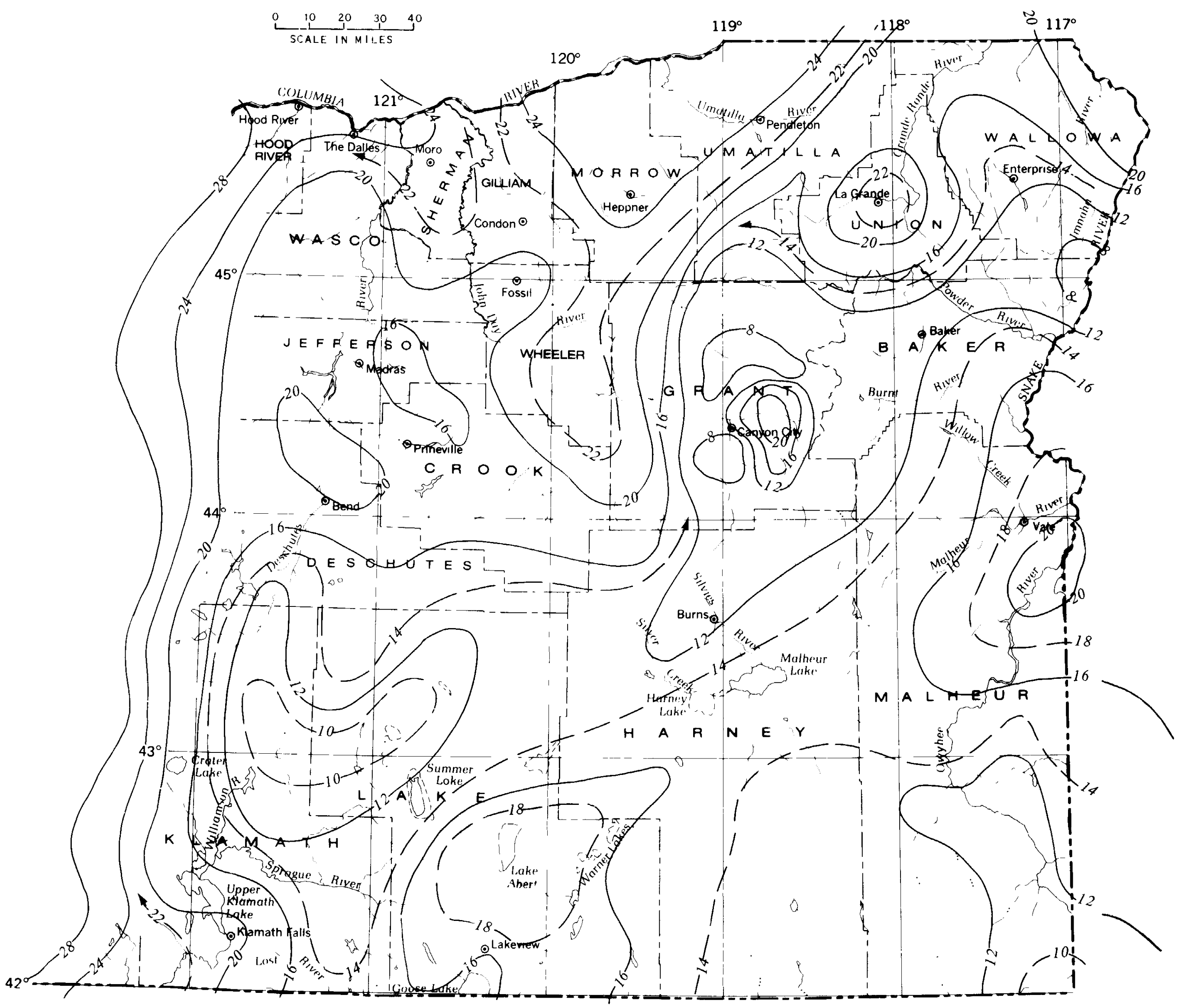

FIGURE 3. – Minimum January air temperature, in degrees Fahrenheit (modified from Sternes, 1960).

A few streams had no flow during some years. Gaged streams which have had such "zero" event years are identified in table 3. For these sites, adjustments have been made in the flood frequency relations by using methods described by the U.S. Water Resources Council (1981). Of the 162 gaging stations used in this analysis, 19 had some years with "zero" events.

Historic flood information was used, when available, to supplement the systematic gaging-station record.

Where two or more gaging stations have been operated on a stream and the drainage area of one is not more than 25 percent different from that at another, only the station with the longest record was used.

Discharges taken directly from a flood frequency distribution for a gaging station are generally considered to be applicable to any site on a stream within 5 percent drainage area of the gaged site (written communication, Hodges and others).

Reasonable discharge estimates can be made at nearby sites on the same stream by adjusting gaged discharge on basis of drainage basin characteristic ratios. The fundamental relation most often used in flood formulas is that discharge varies as a function of basin characteristics that significantly influence stream runoff (Jarvis and others, 1936). For this report "nearby sites" on the same stream are arbitrarily considered to be within 25 percent drainage area (or channel length) of that for the gaged site.

Regression Analysis

Multiple linear regression analyses were used to define equations expressing the logarithm of flood discharge for selected exceedance probabilities as a function of the logarithm of various basin characteristics. This relation may be expressed by the mathematical model:

$$\mathrm{Log}Q_T = \mathrm{Log}K + a\mathrm{Log}C_1 + b\mathrm{Log}C_2 + c\mathrm{Log}C_3 \ldots\ldots + z\mathrm{Log}C_n \qquad (1)$$

which transformed becomes:

$$Q_T = KC_1{}^a C_2{}^b C_3{}^c \ldots C_n{}^z$$

in which Q_T is the discharge for a selected exceedance probability, T; K is a regression constant; C_1, C_2, C_3, and C_n are basin characteristics; and a, b, c, and z are regression coefficients.

A stepwise regression analysis of the logarithm of variables was made using a SAS (Statistical Analysis System) data set. An evaluation of the various steps of the stepwise regression was made based on improvement of standard error and coefficient of determination to select the most suitable regional equation.

Data for the 148 gaging stations in eastern Oregon were used for the "first try" of regression equations. The residuals (the difference between the logarithms of the flood discharges estimated from the gaging station record and the logarithms of the flood discharges computed from the regression equations) were plotted on a map of eastern Oregon (not shown in report). The plotted residuals were examined for groupings of similiar magnitudes. Four general areas of similiar values became apparent. The boundaries of these areas of similiar residuals, along with the boundaries of the geomorphic provinces and drainage basins, were used as a guide in delineating the boundaries of the four flood-frequency regions. These four regions (Southeast, Northeast, North Central, and Eastern Cascades) are shown in figure 1. Using the same regression techniques as above, basins were assigned to the region in which the gaging station was located and flood-frequency equations were then developed for each region.

Oregon data were supplemented by using data from near-by gaging stations in California, Idaho, Nevada, and Washington. To determine the flood-frequency equations for the Southeast Region, data from 32 stations in Oregon, four in Nevada, two in California, and one in Idaho were used in the regression analysis. For the Northeast Region, data from two Idaho stations were used to supplement data for 58 stations in Oregon. Four Washington stations were used to supplement data from 39 Oregon stations for the North Central Region. Data from 19 Oregon stations were supplemented by data from one additional California station to develop the equations for the Eastern Cascade Region.

The final regression equations for each of the four regions are shown in table 1. These equations relate floods having exceedance probabilities of 0.5, 0.2, 0.10, 0.04, 0.02, and 0.01 to selected basin characteristics in each of the flood-frequency regions shown in figure 1. Standard errors of estimate are also shown in table 1.

APPLICATION OF RESULTS

Method Used

The design flow or peak discharge for selected exceedance probabilities (or recurrence intervals) can be estimated for sites on unregulated streams in eastern Oregon by using the method described below.

1. Determine the region in which the site is located and whether or not flood frequency data are available for a gaging station on the stream.

2. If the location is at one of the gaged sites used in this analysis or is on the same stream and has a drainage area or channel length (in the eastern Cascades region) within 5 percent of that at the gaged site, USE THE GAGING-STATION DATA DIRECTLY FROM TABLE 3. In using channel length, the drainage pattern needs to be examined to evaluate the effect of any major, intervening tributary between the ungaged and gaged sites. If in the user's judgement, the intervening tributary provides a large contribution to peak flow, then regional flood frequency equations need to be used (table 1).

Table 1. — Regional flood-frequency equations

General form of equation $Q_T=KA^aL^bTI^cP^d(1+F)^e$ where:

Q_T = discharge for selected exceedance probability,
K = regression constant,
A = drainage area, in square miles,
L = channel length, in miles,
TI = temperature index, the mean minimum January temperature, in degrees Fahrenheit, in the basin,
P = mean annual precipitation, in inches, in the basin,
F = forest cover in percent.

Exceedance Probability (Recurrence interval)		Equation	Standard error		
				Percent	
			Log units	plus	minus
		(1) SOUTHEAST REGION (39 stations)			
$Q_{0.5}(2)$	=	$0.105A^{0.79}TI^{1.67}$	0.317	107	52
$Q_{0.2}(5)$	=	$.328A^{0.77}TI^{1.52}$	.283	92	48
$Q_{0.1}(10)$	=	$.509A^{0.77}TI^{1.50}$	.283	92	48
$Q_{0.04}(25)$	=	$.723A^{0.75}TI^{1.52}$	.291	95	49
$Q_{0.02}(50)$	=	$.872A^{0.76}TI^{1.52}$	.313	106	52
$Q_{0.01}(100)$	=	$.960A^{0.75}TI^{1.57}$	.323	110	52
		(2) NORTHEAST REGION (60 stations)			
$Q_{0.5}(2)$	=	$0.508A^{0.82}P^{1.36}(1+F)^{-.27}$	0.259	82	45
$Q_{0.2}(5)$	=	$2.44A^{0.79}P^{1.09}(1+F)^{-.30}$	.254	79	44
$Q_{0.1}(10)$	=	$5.28A^{0.78}P^{0.96}(1+F)^{-.32}$	.262	83	45
*$Q_{0.04}(25)$	=	$11.8A^{0.77}P^{0.83}(1+F)^{-.35}$	.277	89	47
$Q_{0.02}(50)$	=	$19.8A^{0.76}P^{0.75}(1+F)^{-.36}$	.280	90	48
$Q_{0.01}(100)$	=	$30.7A^{0.76}P^{0.68}(1+F)^{-.38}$	.303	101	50

* Revised 1/26/84

Table 1. - Regional flood - frequency equations - continued

Exceedance Probability (Recurrence interval)		Equation	Standard error		
			Log units	Percent	
				plus	minus
(3) NORTH CENTRAL REGION (43 stations)					
$Q_{0.5}(2)$	=	$0.00013A^{0.80}P^{1.24}TI^{2.53}$	.342	120	55
$Q_{0.2}(5)$	=	$.00068A^{0.76}P^{0.90}TI^{2.64}$	.279	90	47
$Q_{0.1}(10)$	=	$.00134A^{0.74}P^{0.73}TI^{2.73}$	.281	91	48
$Q_{0.04}(25)$	=	$.00325A^{0.72}P^{0.55}TI^{2.78}$	.293	96	49
$Q_{0.02}(50)$	=	$.00533A^{0.70}P^{0.44}TI^{2.83}$	.315	107	52
$Q_{0.01}(100)$	=	$.00863A^{0.69}P^{0.35}TI^{2.86}$	.340	119	54
(4) EASTERN CASCADES REGION (20 stations)					
$Q_{0.5}(2)$	=	$0.017L^{1.72}P^{1.32}$	0.275	88	47
$Q_{0.2}(5)$	=	$.118L^{1.59}P^{1.01}$	.234	71	42
$Q_{0.1}(10)$	=	$.319L^{1.53}P^{0.85}$	.235	72	42
$Q_{0.04}(25)$	=	$.881L^{1.46}P^{0.68}$	.254	79	44
$Q_{0.02}(50)$	=	$1.67L^{1.42}P^{0.58}$	.276	89	47
$Q_{0.01}(100)$	=	$2.92L^{1.39}P^{0.49}$	.299	99	50

3. If the site is on a stream that has a gaging station listed in this report but has a drainage area or channel length estimated at 5 to 25 percent different from that at the gaging station, adjust the peak discharges of the gaged site (table 3) on the basis of drainage area (or channel length if intervening tributaries are not a factor) by using the following equation:

$$Q_u = Q_g(Au/Ag)^a, \text{ or } Q_u=Q_g(L_u/L_g)^b$$

where

Q_u and Q_g are the discharges at the ungaged and gaged sites,

Au and Ag are the drainage areas, L_u and L_g are channel lengths,

and

"a" and "b" are exponents. The values for "a" and "b" for a given region can be approximated from the exponents for drainage area (A) and channel length (L) given in the equation in table 1.

4. If the site is on an ungaged stream or if the site is on a gaged stream shown in table 3 but the drainage area (or channel length) at the site differs by more than an estimated 25 percent from that at the gaging station, then,

   a. Inspect the applicable regional equations in table 1 and identify which basin characteristics are needed to estimate discharge for selected exceedance probabilities.

   b. Determine the appropriate basin-characteristic values as follows:

      Drainage area (A) - Compute the drainage area, in square miles, within the surface-water divide upstream from the desired site on the stream, using the best available topographic map, generally U.S. Geological Survey 7 1/2- or 15-minute quadrangle maps. Determine the drainage area by use of accepted engineering equipment, eg: mechanical planimeter, electronic graphic calculator, digitizer, etc. Drainage areas for two stations used in this analysis (14079500 and 14080500) included areas identified as non-contributing. Such areas do not contribute to direct surface runoff and are measured separately and subtracted from the total area to obtain the contributing area.

      Channel Length (L) - Compute the channel length, in miles for the stream as determined from U.S. Geological Survey maps by use of accepted engineering equipment. If U.S. Geological Survey maps have not been prepared for an area, use the best maps available.

Forest-cover index (F) - Compute the percentage of the total drainage area covered by brush or trees, as indicated by the extent of green overprint (vegetation) shown on U.S. Geological Survey topographic maps. The value of 1+F is used in the equation for the Northeast Region to avoid having "zero" values.

Mean annual precipitation (P) - Determine the precipitation, in inches, for the basin from figure 2.

Temperature index (TI) - Determine the mean minimum January air temperature, in degrees Fahrenheit, for the basin from figure 3.

c. Compute the peak discharge for the desired exceedance probabilities, or recurrence intervals, directly through the use of the appropriate regional equations.

d. Compare, for reasonableness, the estimated peak discharge values particularly those for small probabilities (long recurrence intervals) with (1) maximum peak discharges for nearby streams, shown in table 4 at the back of the report, and (2) other maximum observed discharges (fig.6)

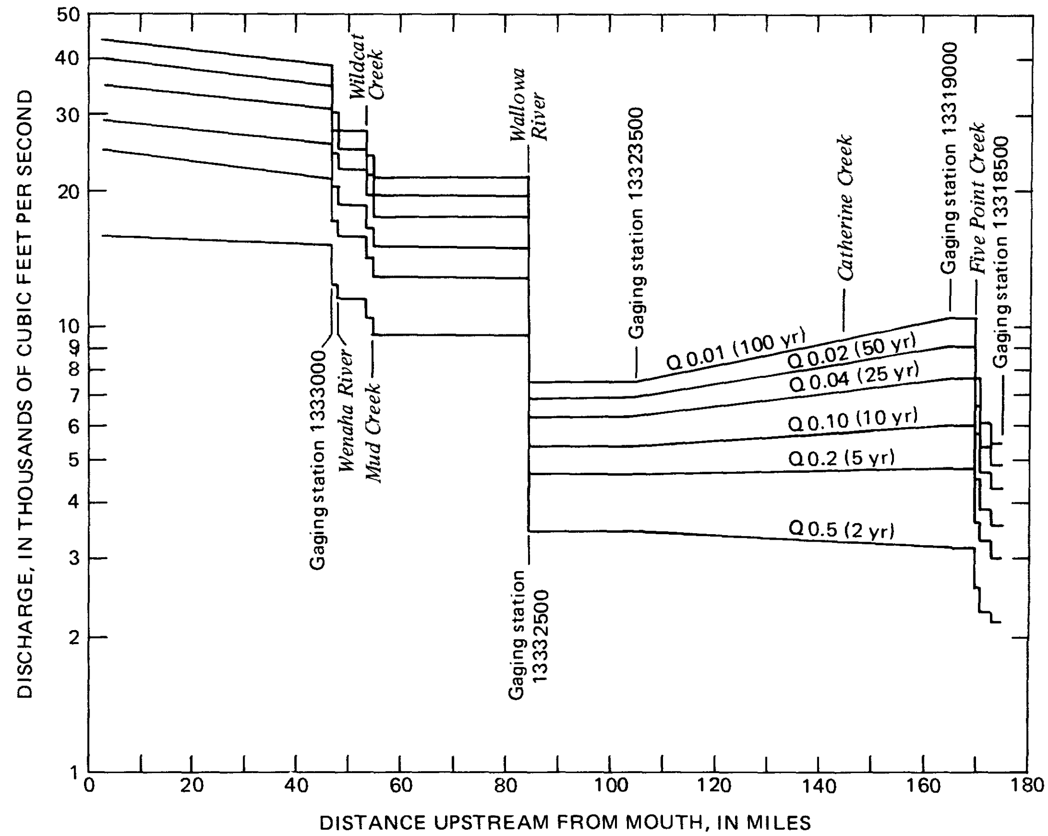

FIGURE 4. – Variation of flood discharge with channel distance upstream from mouth of Grande Ronde River.

Peak discharges for exceedance probabilities between 0.5 and 0.01, other than those shown in the equations, can be determined either by plotting station values from table 3 or by plotting computed values from the equations on probability paper and drawing a smooth curve through the points. Peak discharges for other exceedance probabilities can then be estimated from the curve.

Extrapolation of peak discharges for exceedance probabilities greater than 0.01 (the 100-year flood) exceeds the limits of this study. Extropolated values should be qualified and used judiciously.

For consistency, it may be necessary to deviate from the above methods when determining discharges for long reaches of streams.

Figures 4 and 5 show variation of flood discharge with channel distance for the Grande Ronde and John Day Rivers, respectively. Flood frequency relations on some reaches of both streams deviate from the relations depicted by the equations. Large peak flows on the Grande Ronde River attenuate through the wide flat Grande Ronde valley (river mile 160 to 100). On the John Day River, large peak flows attenuate slightly by normal flood wave deformation processes, where litte contributing inflow occurs from river mile 160 to the mouth.

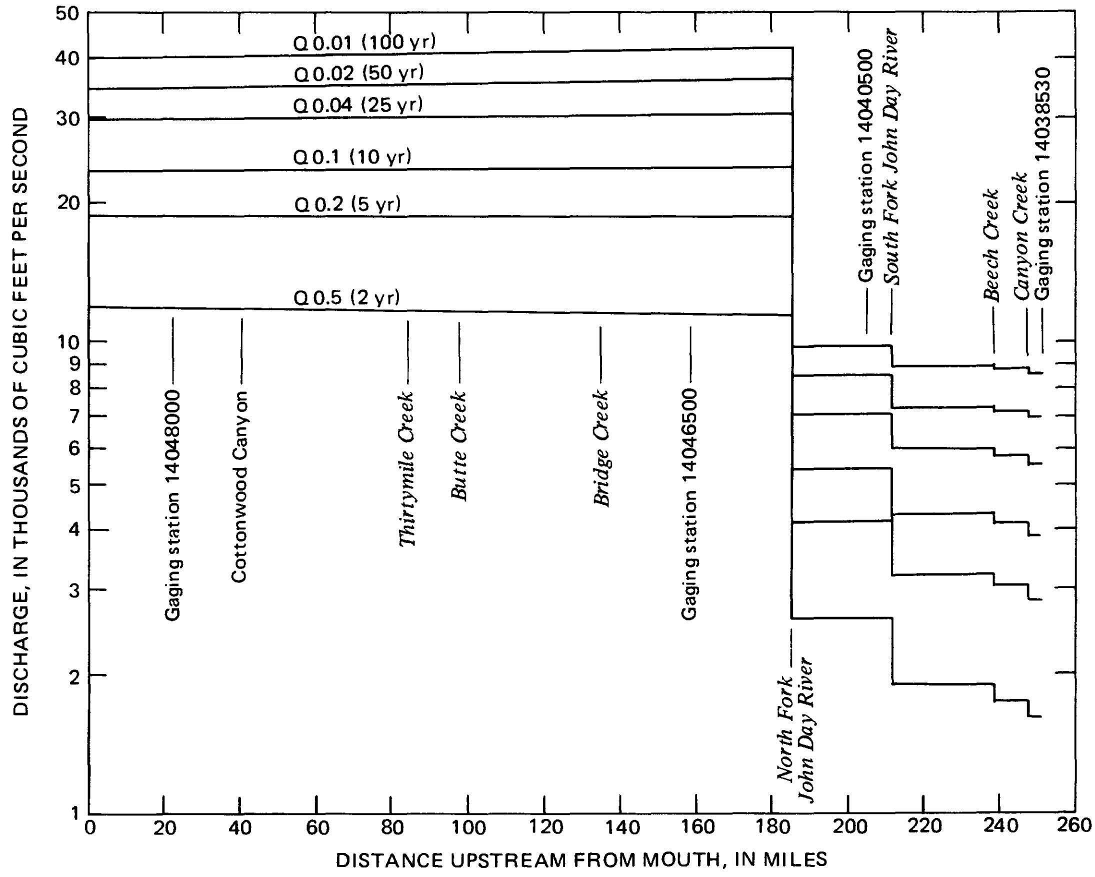

FIGURE 5. – Variation of flood discharge with channel distance upstream from mouth of John Day River.

Evaluation of Estimates

Peak discharges estimated from the regression equations can be evaluated for credibility by comparison to maximum observed peak discharges for streams with similar drainage areas in the same regions. Maximum observed peak discharges for all gaging stations used in the analysis are listed in table 4. Figure 6 shows the maximum observed peak discharges for long-term gaging stations in eastern Oregon in relation to drainage area. Figure 6 also shows a maximum envelope curve developed by Matthai (1969). For drainage areas between 1 and 200 mi^2, the equation for the Matthai curve is

$$Q = 11{,}000A^{0.61}.$$

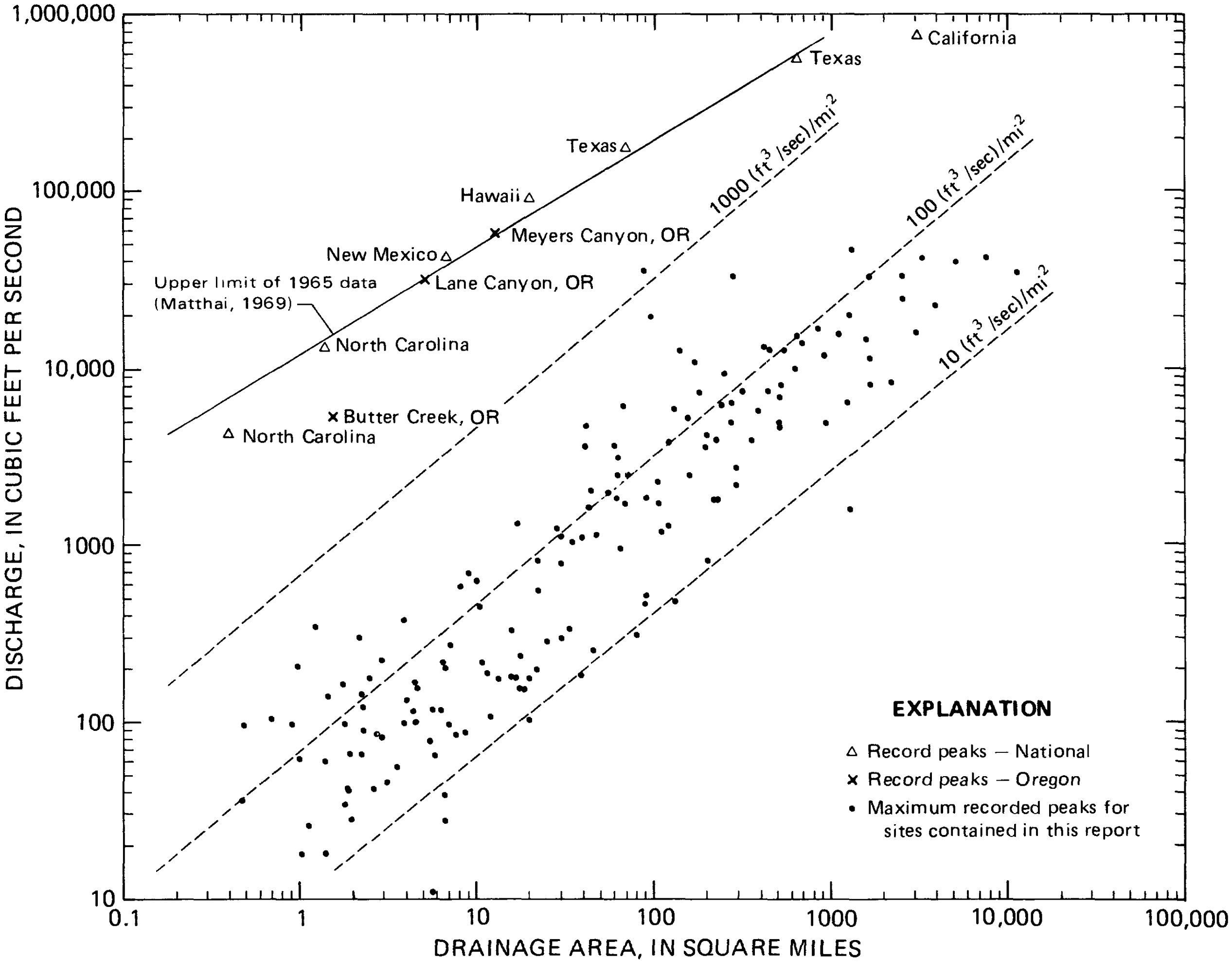

FIGURE 6. — Maximum observed peak discharges in relation to drainage areas.

Also shown are the observed discharges that have the highest unit runoff measured in Oregon and the highest peak discharges observed throughout the United States. Figure 6 can be used to judge the reasonableness or uniqueness of flood-peak discharges estimated from log Pearson Type III distributions. For example, if the 0.02 (50-year) flood discharge estimated from a log Pearson Type III distribution at a gaged site with a drainage area of 5 mi^2 was 13,000 ft^3/s, a comparison with figure 6 indicates the discharge could be too high. The user might then examine the distribution to determine if any extreme events have biased the computation.

The standard error (table 1) provides an assessment of accuracy of the regionalized estimates of peak flow. It is a measure of the departure of estimated flood magnitudes from those observed. About 70 percent of the observed discharge values can be expected to be within one standard error of the estimated value.

In the Eastern Cascade Region, "channel length" was found to be significant, whereas, "drainage area" was not. Possibly the high permeabilities of the recent volcanics and uncertain drainage boundaries could be reasons why "drainage area" was not significant. Many of the streams in this region are fed by large springs and have very little seasonal variation of flow. The areas of highly permeable ash and other volcanic materials as identified on the geologic map by Wells and Peck (1961) could help explain why specific flood peaks might differ markedly from those calculated by regional equations.

Annual flood peaks on streams are caused by either heavy winter rains (with or without frozen ground), cloudbursts, or snow melt. Cloudburst storms are common in parts of the North Central, Northeast, and Southeast Regions. All Regions can have snowmelt peaks. Data used in this analysis may represent a combination of any of the above events.

The Southeast and North Central Regions have large areas where little flood peak data are available (fig. 1). Consequently flood frequency relationships are poorly defined. These areas lack well defined stream channels or have stream channels where there is no flow for many years. Flood frequency estimates for these areas where flood data are lacking are to be used with particular caution.

Illustrative Problems

The method for estimating discharges of selected exceedance probabilities (recurrence intervals) is shown by the following examples:

Example 1. (Determining magnitude of flood for a given exceedance probability in an ungaged area)

Determine the discharge for an exceedance probability of 0.01 (100-year flood) for a site in the Northeast Region, where the drainage area is 25 mi^2. According to the precipitation map (fig. 3) the average annual precipitation in the drainage basin is 32 inches. The forest cover in the basin is found to be 65 percent.

From the Northeast Region equation (table 1), the 0.01 exceedance probability is:

$$\begin{aligned} Q_{0.01} &= 30.7A^{0.76}P^{0.68}(1 + F)^{-0.38} \\ &= (30.7)(25)^{0.76}(32)^{0.68}(1 + 65)^{-0.38} \\ &= \frac{(30.7)(11.5)(10.6)}{(4.91)} \\ &= 762\ \text{ft}^3/\text{s} \end{aligned}$$

Example 2. (Determining two floods in an ungaged area)

Determine the discharge for exceedance probabilities of 0.5 and 0.04 (2- and 25-year floods) for a site on a stream in the Eastern Cascades Region. The channel length is 12.6 miles, and average precipitation in the basin is 54 inches. From the Eastern Cascades Region equation, the 0.5 exceedance probability flood is:

$$\begin{aligned} Q_{0.5} &= 0.017L^{1.72}P^{1.32} \\ &= (0.017)(12.6)^{1.72}(54)^{1.32} \\ &= (0.017)(78.1)(194) \\ &= 258\ \text{ft}^3/\text{s} \end{aligned}$$

From the Eastern Cascade Region equation, the 0.04 exceedance probability flood is:

$$\begin{aligned} Q_{0.04} &= 0.881L^{1.46}P^{0.68} \\ &= (0.881)(12.6)^{1.46}(54)^{0.68} \\ &= (0.881)(40.4)(15.1) \\ &= 537\ \text{ft}^3/\text{s} \end{aligned}$$

Example 3. (Developing a flood frequency curve)

Develop a flood-frequency curve for a site in the Southeast Region. The drainage area is 35 mi^2 and the mean minimum air temperature in the basin for January is 15 degrees Fahrenheit.

Based on the above information, develop a flood-frequency curve by computing the flood discharges for

$Q_{0.5}$, $Q_{0.2}$, $Q_{0.1}$, $Q_{0.04}$, $Q_{0.02}$, and $Q_{0.01}$

exceedance probabilities, as shown below:

$$Q_{0.5} = 0.105A^{0.79}TI^{1.67}$$

$$= (0.105)(35)^{0.79}(15)^{1.67}$$

$$= (0.105)(16.6)(92.1)$$

$$= 161 \text{ ft}^3/\text{s}$$

$$Q_{0.2} = 0.328A^{0.77}TI^{1.52}$$

$$= (0.328)(35)^{0.77}(15)^{1.52}$$

$$= (0.328)(15.5)(61.3)$$

$$= 312 \text{ ft}^3/\text{s}$$

$$Q_{0.1} = 0.509A^{0.77}TI^{1.50}$$

$$= (0.509)(35)^{0.77}(15)^{1.50}$$

$$= (0.509)(15.5)(58.1)$$

$$= 458 \text{ ft}^3/\text{s}$$

$$Q_{0.04} = 0.723A^{0.75}TI^{1.52}$$

$$= (0.723)(35)^{0.75}(15)^{1.52}$$

$$= (0.723)(14.4)(61.3)$$

$$= 638 \text{ ft}^3/\text{s}$$

$$Q_{0.02} = 0.872A^{0.76}TI^{1.52}$$

$$= (0.872)(35)^{0.76}(15)^{1.52}$$

$$= (0.872)(14.9)(61.3)$$

$$= 796 \text{ ft}^3/\text{s}$$

$$Q_{0.01} = 0.960A^{0.75}TI^{1.57}$$

$$= (0.960)(35)^{0.75}(15)^{1.57}$$

$$= (0.960)(14.4)(70.2)$$

$$= 970 \text{ ft}^3/\text{s}$$

Plot the flood discharges on probability paper at the respective exceedance positions and draw a smooth curve through the points, as shown in figure 7.

Example 4. (Determining the exceedance probability or recurrence interval for a selected discharge)

Using the curve developed in Example 3 (fig. 7), determine exceedance probability and recurrence interval for a peak discharge of 700 ft^3/s. At the 700 ft^3/s discharge magnitude on the graph, project horizontally to the frequency curve. Project up vertically at the intersection with the curve and read an exceedance probability of 0.03 and project down vertically and read a recurrence interval of 33 years.

Example 5. (Determining a flood discharge on a stream near an existing gaging station)

a.) Determine the discharge for an exceedance probability of 0.02 (the 50-year flood) for a site downstream from the existing gaging station on Mosier Creek near Mosier (No. 14113200) in the North Central Region. The gaged site has a drainage area of 41.5 mi^2, and the selected site has a drainage area of 45 mi^2.

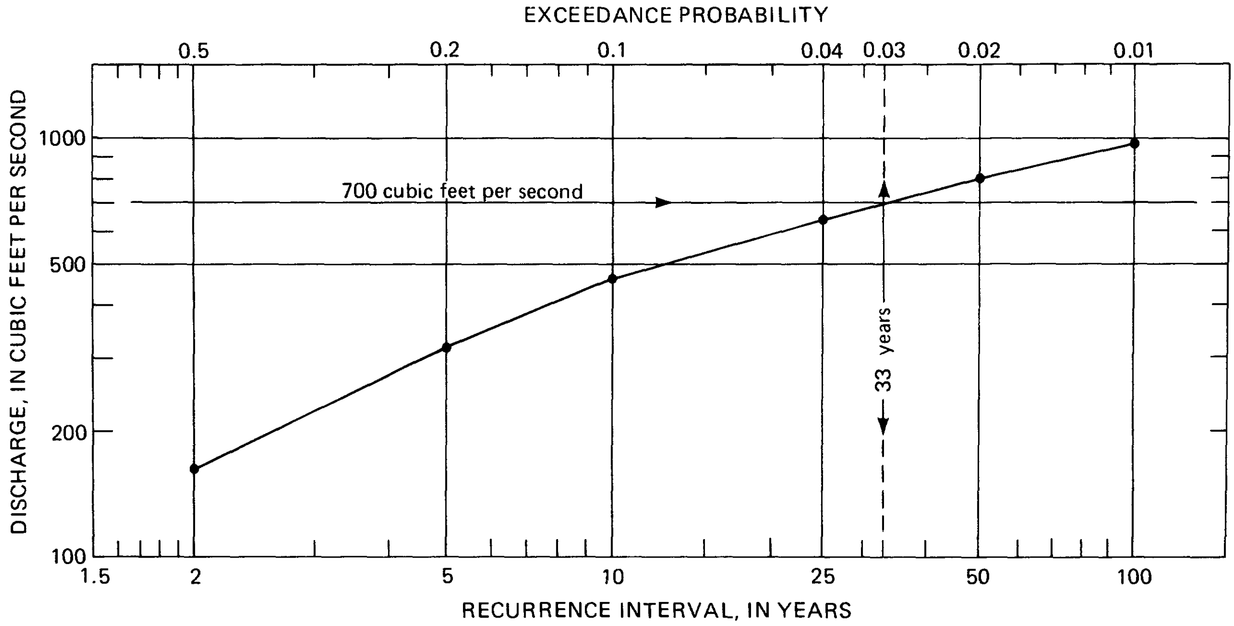

FIGURE 7. – Flood-frequency curve developed by regional analysis for an example computation at an ungaged site in the Southeast Region (example 3).

Therefore, the drainage areas differ by more than 5 percent but less than 25 percent. The flood for an exceedance probability of 0.02 at the gaged site (table 3) is 5,470 ft^3/s. Use the relationship

$$Q_u = Q_g(A_u/A_g)^a.$$

The exponent "a" (table 1) for an exceedance probability of 0.02 in the North Central Region is 0.70.

$$\begin{aligned} Q_u &= Q_g(A_u/A_g)^a \\ &= 5{,}470\ (45/41.5)^{0.70} \\ &= (5{,}470)(1.08)^{0.70} \\ &= (5{,}470)(1.06) \\ &= 5{,}800\ ft^3/s \end{aligned}$$

b.) Determine the discharge for an exceedance probability of 0.1 (10-year recurrance interval) for a site upstream from the existing gaging station on Brown Creek near La Pine (No. 14054500) in the Eastern Cascades Region. The gaged site has a channel length of 9.8 mi and the selected site has a channel length of 8.9 mi. The discharge for an exceedance probability of 0.1 at the gaged site (table 3) is 77.2 ft^3/s. The exponent "a" for an exceedance probability of 0.1 in the Eastern Cascades Region is 1.53.

$$\begin{aligned} Q_u &= Q_g(L_u/L_g)^{1.53} \\ &= (77.2)(8.9/9.8)^{1.53} \\ &= (77.2)(.91)^{1.53} \\ &= (77.2)(.87) \\ &= 67\ ft^3/s \end{aligned}$$

Example 6. (Determining a flood on the Grande Ronde River)

Determine the discharge for an exceedance probability of 0.01 (100-year flood) for a site at mile 130 on the Grande Ronde River.

From the profiles in fig. 4 the flood for an exceedance probability of 0.01 at mile 130 is found to be 8,500 ft^3/s.

Limitations

The procedures in this report developed through regional analysis, are usable, under certain limitations, for estimating flood magnitudes of selected exceedance probabilities or recurrence intervals at ungaged sites in eastern Oregon. The equations are based on data representing unregulated flood conditions and are not applicable to streams where storage or artifical structures have modified the flow appreciably such as sites downstream from large reservoirs. In general, the equations are not applicable at any site where flow from 10 percent or more of the runoff is regulated.

Ranges of basin characteristics used for defining equations for each region are:

Region	Drainage Area (A) (mi^2)	Mean Annual Precipitation (P) (in)	Forest Cover (F) (percent)	Temperature Index (TI) (°F)	Length (L) (mi)
1. Southeast	1.4-11,300	---	---	10-21	---
2. Northeast	0.47-5,090	10-50	0-100	---	---
3. North Central	0.68-7,580	11-100	---	13-27	---
4. Eastern Cascades	---	20-68	---	---	1.6-100.4

Extrapolation beyond the limits of the data used for defining relationships is not advisable. Such extrapolations could produce erroneous discharge values. However, if extrapolations are made, they should be used judiciously and qualified accordingly.

No weighting of regional equations is warranted, when a basin falls in more than one region. Basins are assigned to the region in which the site is located to be consistent with the method used in the regression analysis.

To accomodate drainage basins that originate in adjacent states, isolines in figure 3 have been extended.

For a few stations discharges determined from the flood-frequency equations will differ markedly from those values obtained from the station flood frequency relation. Such large differences could be caused by too short a period for sampling of flood peaks or by local physiographic anomalies.

EFFECT OF URBANIZATION

The regional analysis presented in this report is primarily based on peak flow data that is unaffected by urbanization. Urbanization can alter the hydrology of a basin. No specific studies have been made in eastern Oregon to evaluate the effects of urbanization on the hydrology. However, Sauer and others (1981) developed general equations that adjust the rural peak discharge to an equivalent urban condition. The equations are based on data collected across the entire United States, but only scattered data were available for the western part of the country. The following equations can be used for eastern Oregon:

$UQ2 = 13.2A^{.21}(13-BDF)^{-.43}RQ2^{.73}$ $SE = \pm 43$ percent

$UQ5 = 10.6A^{.17}(13-BDF)^{-.39}RQ5^{.78}$ $SE = \pm 40$ percent

$UQ10 = 9.51A^{.16}(13-BDF)^{-.36}RQ10^{.79}$ $SE = \pm 41$ percent

$UQ25 = 8.68A^{.15}(13-BDF)^{-.34}RQ25^{.80}$ $SE = \pm 43$ percent

$UQ50 = 8.04A^{.15}(13-BDF)^{-.32}RQ50^{.81}$ $SE = \pm 44$ percent

$UQ100 = 7.70A^{.15}(13-BDF)^{-.32}RQ100^{.82}$ $SE = \pm 46$ percent

where: A = Drainage area, in mi^2

BDF = Basin Development Factor. This is derived by subdividing the drainage basin into the upper, middle, and lower thirds. Values are then assigned to each third of the drainage basin by using a one (1) if more than 50 percent of the drainage channels have been improved, or a zero (0) if not; another one (1) if more than 50 percent of the drainage channels have been lined with impervious material, or a zero (0) if not; another one (1) if more than 50 percent of the secondary tributaries consist of enclosed storm drains or storm sewers, or a zero (0) if not; another one (1) if more than 50 percent of the streets and highways have curbs and gutters, or a zero (0) if not. The BDF value is a summation of values for all parts of the basin and can range from 0 to 12. For more details on BDF refer to the report by Sauer and others (1981).

RQ = The rural discharge in ft^3/s (or the flood discharge determined from the equations in Table 1). The number following these letters represent the recurrance interval ie: RQ2 = 2 year, RQ5 = 5 year, etc.

UQ = The equivalent urban discharge in ft^3/s.

SE = The average standard error, in percent.

An example of use of the equations would be to determine the equivalent urban peak runoff for a 10-year flood (UQ10) for a drainage basin of 10 mi^2, and a RQ10 of 500 ft^3/s. Assume that more than 50 percent of the drainage channels have been improved throughout the entire drainage basin; more than 50 percent of the drainage channels have been improved in the lower third of the drainage basin; more than 50 percent of the drainage channels have been lined with impervious material in the lower third of the drainage basin; and more then 50 percent of the streets and highways have curbs and gutters in the lower third of the drainage basin. The summation of values for these improvements gives a BDF of 6:

$$
\begin{aligned}
UQ10 &= 9.51A^{.16}(13\text{-}BDF)^{-.36}RQ10^{.79} \\
&= (9.51)(10)^{.16}(13\text{-}6)^{-.36}(500)^{.79} \\
&= (9.51)(1.4)(.5)(136) \\
&= 900\ ft^3/s
\end{aligned}
$$

This shows that a basin with an increase in urbanization of approximately 50 percent would have a corresponding peak flow increase of about 80 percent.

The average standard error shown for the urbanization adjustment equation needs to be considered in conjunction with the standard error of the flood frequency equation.

ALTERNATIVES FOR FUTURE STUDIES

Future studies to estimate magnitude and frequency of floods in eastern Oregon will involve revising the equations with additional peak flow data and basin characteristic information as they become available. New technological methods will be used to help reduce the standard error of estimates. Use of channel geometry measurements could be considered as a means of estimating flood magnitudes for streams lacking reliable peak flow data. This method is described in a report by Harenberg (1980). Periodically, the available data, revised flood frequency methods, and need for flood information will be evaluated to determine the feasibility for making a new analysis.

SUMMARY

The study describes a method for estimating the magnitude and frequency of floods on unregulated streams in eastern Oregon. Equations were developed by multiple-regression analysis using flood-frequency data for 162 gaging stations. An evaluation of the differences between the flood discharges determined from the gaging-station records and the discharges estimated from the general regression equation along with topographic and geologic information were used to delineate boundaries for four flood-frequency regions in eastern Oregon.

Drainage area size was the most significant basin characteristic in three of the four flood frequency regions. Channel length was found to be the most significant basin characteristic in the Eastern Cascades Region. Mean annual precipitation was a significant basin characteristic in all but the Southeast Region. The temperature index (mean minimum January temperature) was a significant basin characteristic in the Southeast and North Central Regions. Percent of forest cover was found to be a significant basin characteristic in the Northeast Region.

Standard errors ranged from the smallest of a plus 71 and a minus 42 percent in the Eastern Cascade Region to the largest of a plus 120 and a minus 55 percent in the North Central Region. Lowest standard errors were related to the

$Q_{0.2}$ (5-year) flood, and

the highest standard errors were generally related to the

$Q_{0.01}$ (100-year) flood in all regions.

Estimates of discharge determined through the use of the flood-frequency equations are accurate within the standard errors and within the limits of the data used in developing the equations.

Estimates of peak discharge can be adjusted for the effects of urbanization.

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Table 2. — Basin characteristics used in multiple regressions

Station number	Drainage area (mi^2) A	Main channel slope (ft/mi) S	Main channel length (mi) L	Mean basin elevation (ft) E	Area of lakes and ponds (percent) ST	Forest cover (percent) F	Soils index SI	Latitude (degrees) LAT	Longitude (degrees) LONG	Mean annual precipitation (in) P	Precipitation intensity (in) I	Temperature index (°F) TI
(1) SOUTHEAST REGION												
10352300	6.6	200.0	3.5	5400	0.0	0.0	3.50	42.23	117.74	10	1.2	12.0
10352500	225	68.0	27.3	5875	0.0	0.0		41.96	117.83	11	1.1	12.0
10353000	140	68.0	23.8	6081	0.0	12.0		41.98	117.57	9	1.3	12.0
10353500	1100	29.0	51.5	5498	0.0	9.3		41.78	117.80	9	1.0	12.0
10366000	194	120.0	20.0	5800	3.0	20.0	3.90	42.07	119.96	15	1.4	17.0
10370000	63.0	111.0	12.0	6210	0.0	68.0	7.00	42.22	120.10	20	1.4	17.0
10371000	67.0	76.2	14.0	5880	0.7	10.0	3.50	42.20	120.01	15	1.5	18.0
10371500	249	96.9	22.0	6110	1.7	44.9	5.60	42.19	120.00	17	1.4	17.0
10378500	170	93.3	20.0	5910	0.3	20.4	4.60	42.42	119.92	20	1.4	18.0
10384000	275	33.3	32.0	6050	0.1	82.9	9.50	42.68	120.57	18	1.5	17.0
10390400	10.6	288.0	9.5	6170	0.0	98.0	12.20	43.02	121.20	25	1.5	10.0
10392300	18.4	98.0	5.6	5530	0.0	95.0	7.90	44.17	119.21	30	1.4	14.0
10392800	8.50	210.0	4.5	5790	0.0	100.0	7.90	43.90	119.50	25	1.4	18.0
10393500	934	12.3	65.0	5200	0.0	63.6	5.80	43.72	119.18	19	1.3	11.0
10396000	200	97.8	22.5	6160	0.1	10.7	3.50	42.79	118.87	14	1.4	13.0
10397000	30.0	196.7	12.2	5890	0.2	18.5	3.50	42.84	118.85	12	1.2	14.0
10403000	228	41.7	25.6	5180	0.1	71.4	7.10	43.69	119.66	20	1.4	15.0
10406500	88.0	151.5	22.0	5920	0.0	8.3	3.30	42.16	118.46	14	1.2	13.0
11340500	32.9	246.4	6.5	6208	0.3	92.0	2.90	42.23	120.50	15	1.6	17.5
11341000	30.0	70.6	17.0	6033	0.0	90.3	3.10	42.27	120.45	15	1.5	17.5
11341100	5.62	212.0	5.4	5620	0.0	69.0	2.50	42.29	120.35	18	1.4	18.0
11341200	11.4	613.0	4.2	6340	0.1	76.0	7.90	42.12	120.29	18	1.6	16.0
11484000	270	39.0	30.8	5140	0.5	40.0	4.90	42.11	121.21	18	1.5	15.0
11488700	1.74	48.0	2.7	4300	0.0	5.0		41.67	121.26	17	1.1	16.0
11489350	9.98	56.0	5.8	5000	0.0	90.0		41.69	122.05	16	1.8	21.0
11491800	2.63	67.0	3.4	5090	0.7	99.3	17.30	43.09	121.55	20	1.6	10.0
11494800	2.20	468.0	4.3	6610	0.0	94.0	2.70	42.43	120.84	18	1.6	15.0
11497500	513	52.0	37.2	5490	0.6	65.2	9.60	42.45	121.24	17	1.5	14.0
11497800	2.46	179.0	4.7	6660	0.0	92.0	17.80	42.72	120.88	24	1.7	13.0
13178000	440	33.0	40.6	5780	0.0	30.0	4.30	42.87	116.95	15	1.3	15.0
13182100	3.09	675.0	3.1	4560	0.0	8.0	5.00	43.29	117.25	12	1.0	15.0
13182150	1.38	270.0	1.5	5030	0.0	0.0	5.20	43.32	117.19	12	1.0	16.0
13184000	11300	14.9	259.0	5120	0.4	3.5	4.40	43.73	117.07	11	1.0	13.0
13214000	910	44.7	49.2	4900	0.2	29.4	5.30	43.78	118.33	16	1.5	12.0
13216500	355	67.4	34.4	5360	0.0	49.8	4.90	43.95	118.17	19	1.6	12.0
13226500	539	43.0	43.7	4230	0.0	1.1	5.00	44.02	117.46	17	1.3	14.0
13228000	3880	14.6	154.8	3940	0.1	7.0	4.90	43.98	117.24	14	1.3	15.0
13228300	6.46	126.0	5.2	2700	0.0	0.0	2.50	43.96	117.23	10	1.0	18.0
13229400	1.86	188.0	2.8	4050	0.1	0.0	5.20	44.31	117.90	10	1.0	12.0

Table 2. — Basin characteristics used in multiple regressions — continued

Station number	Drainage area (mi^2) A	Main channel slope (ft/mi) S	Main channel length (mi) L	Mean basin elevation (ft) E	Area of lakes and ponds (percent) ST	Forest cover (percent) F	Soils index SI	Latitude (degrees) LAT	Longitude (degrees) LONG	Mean annual precipitation (in) P	Precipitation intensity (in) I	Temperature index (°F) TI
(2) NORTHEAST REGION												
13267100	4.60	242.0	3.9	3210	0.0	0.0		44.39	116.88	25	1.4	16.0
13269200	0.90	211.0	1.6	2830	0.0	0.0	5.20	44.17	117.13	10	1.2	18.0
13269300	110	69.2	19.3	4870	0.0	90.0	5.30	44.60	118.25	24	1.5	9.0
13270800	38.5	370.0	7.5	5820	0.0	92.0	6.90	44.40	118.30	23	1.7	11.0
13272300	0.48	108.0	1.0	3980	0.0	0.0	1.50	44.47	118.20	10	0.9	11.0
13274600	1.80	323.0	2.6	2960	0.0	0.0	2.00	44.58	117.45	10	1.2	15.0
13275500	219	56.9	28.6	5170	0.0	74.7	5.80	44.66	117.87	25	1.7	12.0
13286300	0.96	167.0	2.0	2950	0.0	0.0	2.00	44.83	117.55	15	0.9	12.0
13288200	156	142.9	26.4	5791	0.2	59.2	3.40	44.88	117.25	45	2.0	12.0
13289100	6.64	275.0	6.4	3600	0.0	0.7	2.50	44.79	117.14	15	1.1	14.0
13290150	2.89	513.0	1.9	5110	0.0	85.0	5.60	45.09	116.89	32	1.6	8.0
13291200	4.00	621.0	3.5	5250	0.0	88.0	2.20	45.20	116.87	31	1.5	10.0
13292000	622	72.6	56.0	5690	0.0	50.8	3.70	45.56	116.83	28	1.8	13.0
13318100	1.80	136.0	2.8	4480	0.0	92.0	5.60	45.33	118.45	25	1.9	17.0
13318500	505	70.1	35.2	4800	0.0	86.0	5.90	45.32	118.27	24	1.6	17.0
13319000	678	26.8	44.8	4640	0.0	84.5	5.60	45.35	118.12	24	1.7	19.0
13320000	105	113.6	26.4	5320	0.0	83.3	2.80	45.16	117.77	25	1.8	17.0
13320400	15.8	454.0	8.1	5160	0.0	93.0	1.40	45.21	117.73	25	1.4	20.0
13321300	15.5	134.0	6.6	4140	0.3	27.0	6.00	45.19	118.01	18	1.2	21.0
13322300	1.37	400.0	1.6	4460	0.0	83.0	5.60	45.64	118.11	28	2.3	19.0
13323500	1250	35.3	68.0	4193	0.1	62.5	4.20	45.51	117.93	23	1.6	19.0
13323600	22.0	231.0	11.6	5520	0.0	98.7	4.60	45.43	117.82	32	1.8	20.0
13324150	0.99	192.0	2.0	3550	0.0	27.0	1.80	45.62	117.80	25	1.5	17.0
13325000	10.3	422.0	6.0	7890	0.9	50.5	2.30	45.27	117.21	47	2.2	11.0
13325500	43.0	310.0	10.4	7520	1.9	56.5	2.30	45.28	117.20	50	2.2	11.0
13329500	29.6	296.0	10.8	7460	0.2	53.0	2.30	45.34	117.29	43	2.2	13.0
13329750	4.38	128.0	4.3	4140	0.0	0.0	1.50	45.44	117.28	15	1.2	13.0
13330000	70.9	139.0	20.1	6820	0.4	80.3	2.80	45.44	117.43	38	1.9	14.0
13330500	68.0	177.5	18.4	5810	0.0	84.8	2.50	45.53	117.55	38	1.7	15.0
13331500	240	69.0	45.5	5760	0.7	80.0	1.60	45.62	117.72	40	1.8	18.0
13332500	2555	25.1	87.6	4449	0.2	60.5	3.90	45.73	117.78	26	1.7	18.0
13333000	3275	22.6	120.4	4460	0.1	66.2	4.30	45.95	117.45	25	1.6	18.0
13333050	0.47	100.0	0.9	4440	0.0	36.0	2.50	45.89	117.28	12	1.2	16.0
13333100	5.49	197.0	5.6	4520	0.0	70.0	7.90	45.75	117.02	15	1.2	18.0
14036800	17.4	250.0	5.6	6320	0.0	96.0	4.00	44.32	118.56	28	1.7	16.0
14037500	7.00	523.1	5.2	6900	1.1	67.1	5.60	44.34	118.66	37	1.7	18.2
14038530	386	75.0	32.2	4900	0.0	55.0	1.50	44.42	118.90	25	1.6	14.0
14038550	24.8	216.0	9.1	5780	0.0	84.0	5.60	44.25	118.91	25	1.5	8.0
14038600	6.54	439.0	3.5	5060	0.0	90.0	2.20	44.29	118.98	20	1.4	8.0
14038750	1.94	409.0	2.7	5190	0.0	33.0	7.90	44.57	119.11	20	1.6	8.0
14038900	17.5	280.0	6.7	5310	0.0	76.0	7.90	44.39	119.31	22	1.5	14.0
14039200	11.9	283.0	5.3	5510	0.0	39.0	7.90	44.00	119.28	25	1.3	15.0
14040500	1680	27.3	78.1	4530	0.0	43.3	5.20	44.52	119.62	22	1.5	12.0
14040700	2.22	323.0	4.0	4270	0.0	35.0	2.50	44.52	119.92	24	1.4	22.0
14041500	525	73.0	46.0	5450	0.1	97.0	4.70	45.00	118.94	27	1.6	10.6
14041900	2.27	225.0	3.8	4580	0.0	97.0	2.20	44.17	118.71	20	1.4	14.0
14042000	60.7	66.6	10.4	4630	0.0	73.8	2.70	45.17	118.73	24	1.4	14.0
14042500	121	60.7	16.9	4630	0.0	77.7	2.90	45.16	118.82	24	1.4	13.0
14043300	6.93	249.0	3.8	5350	0.0	100.0	2.20	44.54	118.54	30	1.6	9.0
14043850	3.89	297.0	3.4	5130	0.0	95.0	7.90	44.65	118.86	22	1.5	8.0
14043900	1.90	161.0	1.8	4130	0.0	60.0	7.90	44.89	119.01	20	1.4	10.0
14044000	515	26.8	65.7	4800	0.0	80.5	4.60	44.89	119.14	23	1.4	8.0
14044100	3.50	4.5	3.6	4490	0.0	45.0	2.50	44.72	119.13	18	1.4	10.0
14044500	90.2	59.0	15.6	4830	0.0	40.0	3.50	44.62	119.26	21	1.6	10.0
14046000	2520	24.9	99.6	4580	0.0	70.1	4.90	44.81	119.43	22	1.5	14.3
14046250	2.73	590.0	3.5	3460	0.0	43.0	4.10	44.86	119.71	18	1.3	22.0
14046300	5.56	335.0	3.8	3380	0.0	93.0	7.90	44.89	120.07	18	1.4	20.0
14046400	1.35	419.0	2.5	2380	0.0	20.0	1.90	44.77	120.00	16	1.2	21.0
14046500	5090	20.0	143.0	4400	0.0	57.3	4.90	44.79	120.01	21	1.5	16.0
14047350	6.25	136.0	4.3	4100	0.0	94.0	2.20	45.03	119.57	20	1.4	22.0

Table 2. Basin characteristics used in multiple regressions — continued

Station number	Drainage area (mi^2) A	Main channel slope (ft/mi) S	Main channel length (mi) L	Mean basin elevation (ft) E	Area of lakes and ponds (percent) ST	Forest cover (percent) F	Soils index SI	Latitude (degrees) LAT	Longitude (degrees) LONG	Mean annual precipitation (in) P	Precipitation intensity (in) I	Temperature index (°F) TI
(3) NORTH CENTRAL REGION												
14010000	63.0	189.5	17.8	4260	0.0	86.3	5.60	45.83	118.17	33	2.0	19.8
14010800	34.4	207.0	13.3	4030	0.0	75.0	3.70	45.88	118.18	34	2.2	21.0
14011000	43.3	166.6	16.4	3590	0.0	67.1	3.40	45.90	118.28	31	2.2	20.9
14013000	59.6	160.0	13.3	3860	0.0	87.0		46.01	118.12	40	2.4	20.0
14013500	17.0	294.0	8.4	3140	0.0	33.0		46.06	118.14	36	2.4	21.0
14016030	1.22	239.0	2.2	1660	0.0	0.0	2.50	45.88	118.39	15	1.2	24.0
14018500	1657	60.0	59.4	1600	0.2	25.0		46.04	118.77	22	1.5	19.0
14019400	0.68	972.0	1.4	3410	0.0	54.0	5.60	45.71	118.20	15	1.8	20.0
14020000	131	137.8	17.8	3390	0.0	58.7	5.60	45.72	118.32	19	1.9	20.0
14020800	4.45	401.0	4.5	2820	0.0	13.0	1.70	45.63	118.62	15	1.3	23.0
14021000	637	47.1	45.3	3120	0.0	37.4	3.30	45.67	118.79	18	1.5	21.0
14022500	180	114.7	26.5	3210	0.0	39.3	2.30	45.55	118.77	19	1.7	19.4
14025000	291	64.2	35.3	3030	0.0	13.8	1.90	45.65	118.83	18	1.2	21.0
14026000	1280	32.1	62.3	2920	0.0	29.1	2.80	45.68	119.03	17	1.4	21.0
14032000	291	78.5	37.2	3150	0.0	10.7	2.30	45.54	119.31	15	1.2	23.2
14034370	1.11	508.0	1.8	4310	0.0	81.0	4.00	45.23	119.12	20	1.4	23.0
14034500	87.0	117.3	21.6	3520	0.0	24.8	2.50	45.35	119.55	16	1.2	24.0
14034800	120	106.0	17.0	3760	0.0	30.0	2.00	45.26	119.62	16	1.3	24.0
14036000	850	45.0	70.1	2300	0.0	6.3	2.30	45.75	120.01	14	1.1	24.0
14048000	7580	12.0	278.8	3380	0.0	41.3	4.20	45.59	120.41	19	1.4	20.0
14048300	8.05	65.0	5.8	1560	0.0	0.0	2.50	45.59	120.69	11	1.1	24.0
14077500	64.4	132.4	13.6	4670	0.0	42.9	8.40	44.17	119.73	20	1.4	22.0
14077800	2.15	260.0	5.2	5150	0.0	76.0	7.90	44.28	119.82	18	1.3	22.0
14078000	450	57.9	33.6	4600	0.4	21.2	2.50	44.16	119.92	20	1.4	21.0
14078200	19.6	290.0	5.5	5000	0.0	0.0	10.00	43.59	119.98	15	1.4	13.0
14078400	7.53	291.0	6.7	5670	0.0	92.0	7.50	44.31	120.24	25	1.5	20.0
14078500	159	41.7	19.2	5130	0.0	70.7	7.00	44.33	120.08	21	1.5	19.0
14079500	1660	34.2	56.2	4650	0.3	22.6	5.50	44.12	120.25	20	1.4	18.0
14080500	2200	4.2	120.2	4650	0.3	26.0	5.10	44.11	120.79	20	1.4	18.0
14081800	2.28	400.0	2.0	5130	0.0	97.0	7.90	44.43	120.35	25	1.5	20.0
14083000	200	92.6	21.6	4654	0.0	60.9	6.40	44.31	120.64	21	1.4	17.5
14083500	78.8	83.2	17.5	4440	0.0	35.0	7.40	44.34	120.67	22	1.5	16.0
14093700	1.42	409.0	3.4	3210	0.1	51.0	2.80	44.74	120.27	12	1.2	16.0
14097200	40.7	203.0	15.7	4110	0.0	82.0	1.90	45.18	121.58	81	4.2	20.0
14100800	9.01	316.0	8.7	3830	0.0	99.0	1.20	45.34	121.35	40	2.0	20.0
14101500	417	81.7	44.4	2940	0.2	69.7	2.20	45.24	121.09	45	2.9	20.0
14104100	3.87	281.0	6.3	3920	0.0	97.0	1.20	45.40	121.37	38	2.2	20.0
14105850	23.0	180.0	14.7	2830	0.0	95.0	1.30	45.54	121.32	34	2.5	24.0
14113000	1297	46.0	38.7	3140	0.1	77.0		45.76	121.21	36	2.5	21.0
14113200	41.5	261.8	13.8	2220	0.3	91.0	1.50	45.65	121.38	28	1.7	25.0
14113400	4.50	418.3	5.1	5150	0.0	95.0	1.20	41.41	121.52	45	4.0	22.0
14118500	95.6	137.7	18.4	3170	0.6	35.5	3.20	45.60	121.63	100	4.1	27.0
14120000	279	270.0	20.5	3340	0.2	89.0	3.30	45.66	121.40	79	3.5	26.0

Table 2. – Basin characteristics used in multiple regressions – continued

Station number	Drainage area (mi^2) A	Main channel slope (ft/mi) S	Main channel length (mi) L	Mean basin elevation (ft) E	Area of lakes and ponds (percent) ST	Forest cover (percent) F	Soils index SI	Latitude (degrees) LAT	Longitude (degrees) LONG	Mean annual precipitation (in) P	Precipitation intensity (in) I	Temperature index (°F) TI
(4) EASTERN CASCADES REGION												
11493500	1290	20.1	59.6	5020	6.1	74.3	13.80	42.74	121.83	24	2.0	12.0
11501000	1580	4.9	95.2	5318	1.5	64.8	10.90	42.58	121.85	20	1.6	13.0
11501300	5.77	328.0	5.2	5070	0.0	97.0	13.80	42.56	121.84	21	1.7	15.0
11502500	3000	2.0	100.4	5164	3.4	69.7	12.20	42.57	121.88	22	1.8	12.0
11504000	90.0	130.4	18.4	5684	0.0	84.2	11.30	42.70	121.98	28	2.6	16.0
11505550	13.2	158.0	4.9	6040	1.2	97.0	5.60	42.49	122.19	45	3.2	24.0
11509400	1.02	315.0	1.6	4500	0.0	99.0	5.60	42.13	121.96	20	1.8	21.0
11517340	2.9	520.0	4.5	3200	0.0	100.0		41.84	122.92	35	2.4	24.0
14050000	132	327.7	22.4	5850	1.4	74.0	11.90	43.81	121.78	49	2.5	20.0
14050500	16.5	120.4	11.3	5230	1.0	98.2	9.60	43.82	121.79	40	3.3	17.0
14051000	33.2	90.9	8.8	5270	7.2	92.2	13.80	43.82	121.82	45	2.8	18.0
14052000	21.5	187.5	6.4	5290	2.8	94.4	13.80	43.80	121.84	31	2.6	17.0
14054500	19.7	126.5	9.8	5150	0.2	99.2	13.80	43.71	121.80	35	2.5	16.0
14055500	39.0	185.9	10.4	5540	14.1	83.3	13.80	43.55	121.96	60	3.5	17.0
14057500	45.1	20.8	9.6	4695	0.0	98.2	13.10	43.80	121.57	36	1.9	13.5
14073000	47.3	200.0	17.8	5630	0.1	60.9	15.80	44.09	121.37	20	1.7	18.0
14075000	54.8	236.4	16.7	5840	0.2	77.8	7.00	44.23	121.57	48	2.1	20.0
14088000	22.2	250.0	6.4	4440	4.9	93.7	13.80	44.43	121.72	65	3.4	20.0
14091500	316	48.6	38.4	4320	0.7	91.4	4.70	44.63	121.48	68	3.5	19.0
14093000	104	105.9	29.6	3256	0.2	60.6	3.50	44.76	121.23	35	2.2	18.0

Table 3. — Discharges for selected flood-frequencies at gaging stations

Station number	Peak discharge, in cubic feet per second for selected exceedance probabilities					
	0.50 (2-yr)	0.20 (5-yr)	0.10 (10-yr)	0.04 (25-yr)	0.02 (50-yr)	0.01 (100-yr)
(1) SOUTHEAST REGION						
10352300	4.9	11.1	17.1	27.0	36.4	47.7
10352500	515	1230	1940	3130	4250	5600
10353000	412	723	937	1200	1400	1580
10353500	224	728	1260	2140	2930	3830
10366000	1300	2240	2890	3710	4310	4890
10370000	472	821	1130	1630	2100	2660
10371000	482	1270	2140	3780	5480	7700
10371500	1210	2440	3540	5280	6840	8650
10378500	437	1160	1950	3410	4910	6830
10384000	902	1540	2060	2820	3470	4200
10390400	71.0	119	159	221	276	338
10392300	68.3	118	153	198	232	266
10392800	49.5	72.1	87.2	106	120	134
10393500	1280	2130	2760	3620	4310	5030
10396000	1270	2030	2570	3270	3810	4350
10397000	85.0	174	251	369	471	587
10403000	552	1030	1430	2020	2530	3090
10406500	109	182	237	314	376	442
11340500	229	299	341	390	425	458
11341000	185	341	462	631	766	909
11341100	52.7	80.7	101	128	149	171
11341200	95.1	149	187	238	278	319
11484000	2300	3410	4210	5300	6160	7070
11488700	50.4	117	178	274	359	455
11489350	45.9	116	198	365	553	817
11491800 1/	14.6	27.8	37.8	51.5	62.1	72.8
11494800	30.5	41.3	49.0	59.3	67.5	76.1
11497500	1230	2290	3170	4490	5630	6900
11497800	54.2	130	196	296	378	467
13178000	1970	3120	3990	5200	6190	7240
13182100 1/	9.2	45.8	96.4	200	308	447
13182150 1/	4.1	9.9	15.3	31.0	24.0	39.0
13184000	11400	20000	26100	34200	40300	46500
13214000	1970	3830	5420	7850	9980	12400
13216500	859	1350	1730	2270	2710	3180
13226500	1560	4110	6570	10600	14200	18300
13228000	7730	14900	20900	29900	37600	46200
13228300	100	152	188	232	266	299
13229400 1/	9.2	30.2	52.5	90	125	164

Table 3. – Discharges for selected flood-frequencies at gaging stations – continued

Station number	Peak discharge, in cubic feet per second for selected exceedance probabilities					
	0.50 (2-yr)	0.20 (5-yr)	0.10 (10-yr)	0.04 (25-yr)	0.02 (50-yr)	0.01 (100-yr)
(2) NORTHEAST REGION						
13267100	67.1	106	135	174	204	236
13269200	17.3	41.0	63.0	98.0	130	167
13269300	664	985	1130	1420	1580	1740
13270800	76.2	115	142	175	200	226
13272300	12.3	24.6	36.2	55.5	73.3	96.0
13274600	18.5	49.5	80.0	132	181	240
13275500	725	1050	1250	1480	1640	1800
13286300 1/	36.0	148	304	631	1010	1520
13288200	2050	2790	3320	4030	4580	5170
13289100	98.2	139	167	205	233	263
13290150	70.3	136	189	266	331	401
13291200	72.1	103	123	148	167	186
13292000	2720	4150	5210	6690	7890	9180
13318100	13.4	21.2	26.9	34.7	41.0	47.7
13318500	2190	3010	3590	4340	4920	5510
13319000	3180	4800	6000	7670	9020	10500
13320000	764	1020	1170	1360	1490	1610
13320400	115	182	227	283	323	362
13321300	96.3	141	170	205	231	256
13322300	36.6	47.4	54.2	62.6	68.7	74.8
13323500	3430	4650	5390	6280	6890	7480
13323600	424	589	698	836	938	1040
13324150 1/	21.0	37.2	50.0	66.0	79.0	91.0
13325000	103	153	189	240	281	325
13325500	833	1190	1420	1720	1930	2150
13329500	541	736	858	1010	1110	1220
13329750 1/	26	54	78	115	146	180
13330000	1570	1940	2160	2420	2600	2780
13330500	907	1200	1390	1620	1790	1950
13331500	3300	4480	5250	6220	6930	7640
13332500	9570	12900	15000	17700	19500	21400
13333000	15100	21400	25500	30700	34600	38400
13333050	12.5	22.0	29.4	39.7	48.1	57.1
13333100	40.1	71.4	96.7	134	165	200
14036800	72.7	115	144	180	207	234
14037500	86.9	125	151	185	211	238
14038530	1630	2890	3960	5580	7000	8620
14038550	171	242	285	335	369	401
14038600	17.7	27.8	35.2	45.2	53.1	61.4
14038750	13.2	20.5	25.6	32.2	37.3	42.5
14038900 1/	65.0	118	155	204	246	282
14039200	53.8	76.0	89.8	106	117	128
14040500	2640	4280	5500	7170	8520	9930
14040700 1/	30.0	72.0	117	195	269	372
14041500	3080	4500	5410	6530	7330	8100
14041900	28.8	46.1	58.7	75.9	89.4	103
14042000	634	994	1280	1680	2020	2400
14042500	1050	1590	1990	2560	3010	3500
14043800	39.5	58.8	72.5	90.7	105	119
14043850	47.6	68.0	81.9	99.8	113	127
14043900	20.8	39.0	53.5	74.3	91.4	110
14044000	1590	2370	2900	3600	4140	4680
14044100	12.3	39.3	69.9	126	182	250
14044500	400	791	1150	1720	2240	2860
14046000	8580	13500	17300	22600	27100	31900
14046250 1/	17	47	76	123	165	214
14046300	4.1	6.8	3.9	11.9	14.4	17.0
14046400 1/	4.8	19	36	71	110	155
14046500	11700	18700	23800	30800	36300	42000
14047350	53.9	91.8	118	153	178	203

Table 3. — Discharges for selected flood-frequencies at gaging stations — continued

Station number	Peak discharge, in cubic feet per second for selected exceedance probabilities					
	0.50 (2-yr)	0.20 (5-yr)	0.10 (10-yr)	0.04 (25-yr)	0.02 (50-yr)	0.01 (100-yr)
(3) NORTH CENTRAL REGION						
14010000	800	1220	1550	2010	2410	2840
14010800	547	811	986	1210	1370	1530
14011000	492	814	1080	1470	1800	2180
14013000	918	1490	1930	2560	3070	3630
14013500	324	551	719	947	1130	1310
14016080 1/	22	73	133	254	382	550
14018500	6860	12100	16500	23000	28700	35100
14019400	57.6	76.6	89.5	106	119	132
14020000	1980	2860	3510	4400	5120	5880
14020800	53.7	97.2	126	166	197	230
14021000	5280	8470	10900	14400	17300	20400
14022500	1350	2410	3280	4570	5680	6920
14025000	549	1010	1380	1930	2390	2890
14026000	6400	9940	12600	16200	19000	22100
14032000	310	586	848	1290	1730	2270
14034370 1/	7.6	14.8	20.4	28.2	34.7	41.7
14034500 2/	190	533	997	2040	3340	5320
14034800	276	693	1090	1750	2350	3040
14036000	986	4510	9760	21900	36500	57500
14048000	12200	18900	23700	30100	35100	40200
14048300 1/	27	234	631	1620	2820	4470
14077500	612	781	885	1010	1100	1180
14077800	68.1	115	156	218	274	338
14078000	1370	2750	4060	6270	8390	11000
14078200 1/	14	66	138	295	467	724
14078400 1/	42	79	78	145	174	204
14078500	1390	1780	2040	2370	2620	2870
14079500	3910	6460	8350	10900	13000	15100
14080500	3530	5290	6630	8300	9580	10800
14081800 1/	33	59	85	120	148	178
14083000	337	575	742	958	1120	1280
14083500	138	248	331	443	531	621
14093700 1/	1.1	6.4	16	46	92	172
14097200	1460	2360	2980	3800	4430	5060
14100800	103	260	431	753	1090	1540
14101500	2980	5190	6960	9530	11700	14100
14104100	50	103	155	247	337	452
14105850	171	441	746	1340	1980	2850
14113000	8130	14500	19600	27000	33100	39800
14113200	776	1730	2630	4100	5470	7090
14113400	36.7	55.7	69.2	87.3	101	116
14118500	6520	9520	11600	14300	16300	18400
14120000	11400	18000	22700	28900	33600	38400

Table 3. —Discharges for selected flood-frequencies at gaging stations — continued

Station number	Peak discharge, in cubic feet per second for selected exceedance probabilities					
	0.50 (2-yr)	0.20 (5-yr)	0.10 (10-yr)	0.04 (25-yr)	0.02 (50-yr)	0.01 (100-yr)
(4) EASTERN CASCADES REGION						
11493500	683	956	1150	1400	1590	1800
11501000	2020	3830	5400	7850	10000	12500
11501300	24.2	39.5	51.5	69.1	83.9	100
11502500	2890	4820	6410	8800	10900	13200
11504000	371	435	475	522	555	538
11505550	86	132	164	204	234	264
11509400 1/	0.8	3.9	8.8	20.4	35	56
11517840	11.9	27.4	42.5	68.0	92.4	122
14050000	262	360	416	481	524	563
14050500	89.1	114	129	148	161	174
14051000	103	168	214	274	319	365
14052000	49.8	80.5	102	132	154	177
14054500	52.4	67.7	77.2	83.6	96.7	105
14055500	236	345	430	556	662	781
14057500	193	221	237	254	265	274
14073000	477	643	755	899	1010	1120
14075000	519	802	1030	1370	1670	2010
14088000	158	235	293	373	439	508
14091500	2540	3430	4100	5010	5750	6550
14093000	524	934	1280	1830	2310	2860

1/ Adjusted for "zero" events.

2/ Adjusted for historic peak.

Table 4. — Maximum discharges at gaging stations used in eastern Oregon flood-frequency analysis

Station number	Station name	Flood region 1/	Years of record	Drainage area (mi^2)	Discharge (cfs)	Date
10352300	JACKSON CREEK TRIBUTARY NEAR MCDERMITT, NV 2/	SE	10	6.6	28	09-01-79
10352500	MCDERMITT CREEK NEAR MCDERMITT, NV	SE	31	225	3970	02-01-63
10353000	EAST FORK QUINN RIVER NEAR MCDERMITT, NV	SE	31	140	12700	01-15-56
10353500	QUINN RIVER NEAR MCDERMITT, NV	SE	30	1100	15800	04-27-52
10366000	TWENTYMILE CREEK NEAR ADEL, OR	SE	49	194	3670	12-23-64
10370000	CAMAS CREEK NEAR LAKEVIEW, OR	SE	26	63.0	3190	12-23-64
10371000	DRAKE CREEK NEAR ADEL, OR	SE	26	67.0	6210	12-23-64
10371500	DEEP CREEK ABOVE ADEL, OR	SE	51	249	9420	12-23-64
10378500	HONEY CREEK NEAR PLUSH, OR	SE	57	170	11000	12-23-64
10384000	CHEWAUCAN RIVER NEAR PAISLEY, OR	SE	65	275	6490	12-22-64
10390400	BRIDGE CREEK NEAR THOMPSON RESERVIOR, OR 2/	SE	14	10.6	218	12-22-64
10392300	SILVIES RIVER NEAR SENECA, OR 2/	SE	13	18.4	152	05-15-75
10392800	CROWSFOOT CREEK NEAR BURNS, OR 2/	SE	14	8.50	88	05-15-75
10393500	SILVIES RIVER NEAR BURNS, OR	SE	73	934	4960	04-06-52
10396000	DONNER AND BLITZEN RIVER NEAR FRENCHGLEN, OR	SE	53	200	4270	04-26-78
10397000	BRIDGE CREEK NR FRENCHGLEN, OR	SE	39	30.0	301	05-19-53
10403000	SILVER CREEK NEAR RILEY, OR	SE	28	228	1810	12-22-64
10406500	TROUT CREEK NEAR DENIO, NV	SE	58	88.0	470	08-01-33
11340500	COTTONWOOD CREEK NEAR LAKEVIEW, OR	SE	10	32.9	337	03-30-11
11341000	THOMAS CREEK NR LAKEVIEW, OR	SE	25	30.0	790	12-22-55
11341100	SALT CREEK NEAR LAKEVIEW, OR 2/	SE	16	5.62	118	01-21-72
11341200	CRANE CREEK NEAR LAKEVIEW, OR 2/	SE	14	11.4	190	01-23-70
11484000	MILLER CREEK NEAR LORELLA, OR	SE	11	270	5000	03-01-10
11488700	DRY LAKE TRIBUTARY AT PEREZ, CA	SE	11	1.74	164	01-23-70
11489350	HORSETHIEF CREEK NR MACDOEL, CA 2/	SE	11	9.98	635	12-22-64
11491800	MOSQUITO CREEK NEAR SHEVLIN, OR 2/	SE	15	2.63	42	12-22-64
11493500	WILLIAMSON RIVER NEAR KLAMATH AGENCY, OR	EC	26	1290	1590	03-13-10
11494800	BROWNSWORTH CREEK NEAR BLY, OR 2/	SE	12	2.20	66	12-22-64
11497500	SPRAGUE RIVER NEAR BEATTY, OR	SE	34	513	6980	12-23-64
11497800	CURRIER CREEK NEAR PAISLEY, OR 2/	SE	14	2.46	178	05-10-67
11501000	SPRAGUE RIVER NEAR CHILOQUIN, OR	EC	59	1580	14900	12-26-64
11501300	CRYSTAL CREEK NEAR CHILOQUIN, OR 2/	EC	15	5.77	65	12-22-64
11502500	WILLIAMSON R BL SPRAGUE R NR CHILOQUIN, OR	EC	63	3000	16100	12-26-64
11504000	WOOD RIVER AT FT KLAMATH, OR	EC	24	90.0	520	11-17-20
11505550	LOST CREEK NEAR ROCKY POINT, OR 2/	EC	14	13.2	176	05-10-66
11509400	KLAMATH RIVER TRIBUTARY NEAR KENO, OR 2/	EC	16	1.02	18	12-23-64
11517840	DONA CREEK NEAR KLAMATH RIVER, CA 2/	EC	13	2.9	83	12-22-64
13178000	JORDAN C AB LN TREE C NR JORDAN VALLEY, OR	SE	24	440	7530	12-24-64
13182100	DAGO GULCH NEAR ROCKVILLE, OR 2/	SE	10	3.09	46	09-11-79
13182150	LONG GULCH NEAR ROCKVILLE, OR 2/	SE	10	1.38	18	09-01-79
13184000	OWYHEE RIVER NEAR OWYHEE, OR	SE	16	11300	35000	03-02-10
13214000	MALHEUR RIVER NEAR DREWSEY, OR	SE	54	910	12000	12-23-64
13216500	N FK MALHEUR R AB BEULAH RES NR BEULAH, OR	SE	43	355	3970	12-23-64
13226500	BULLY CREEK AT WARMSPRINGS NR VALE, OR	SE	35	539	12800	12-22-64
13228000	MALHEUR R AT VALE, OR	SE	12	3880	22800	03-02-10
13228300	LYTLE CREEK NEAR VALE, OR 2/	SE	11	6.46	220	01-17-71
13229400	LOST VALLEY CREEK TRIB. NEAR IRONSIDE, OR 2/	SE	12	1.86	41	03-31-69
13267100	DEER CREEK NEAR MIDVALE, ID 2/	NE	10	4.60	156	01-27-70
13269200	MOORES HOLLOW TRIBUTARY NR WEISER, ID 2/	NE	13	0.90	98	08-10-65
13269300	NORTH FORK BURNT RIVER NR WHITNEY, OR	NE	15	110	1190	04-06-71
13270800	SO FK BURNT RIVER NR UNITY, OR	NE	16	38.5	186	04-29-65
13272300	JOB CREEK TRIBUTARY NEAR UNITY, OR 2/	NE	13	0.48	96	04-15-75
13274600	BURNT RIVER TRIBUTARY AT DURKEE, OR 2/	NE	12	1.80	98	01-17-71
13275500	POWDER RIVER NEAR BAKER, OR	NE	15	219	1820	03-20-10
13286300	WATERSPOUT CREEK NEAR BAKER, OR 2/	NE	11	0.96	208	07-10-70

Table 4. — Maximum discharges at gaging stations used in eastern Oregon flood-frequency analysis — continued

Station number	Station name	Flood region 1/	Years of record	Drainage area (mi^2)	Discharge (cfs)	Date
13288200	EAGLE CR AB SKULL CR NR NEW BRIDGE, OR	NE	22	156	5310	07-12-75
13289100	IMMIGRANT GULCH NR RICHLAND, OR 2/	NE	15	6.64	205	02-20-68
13290150	NORTH PINE CREEK NR HOMESTEAD, OR 2/	NE	14	2.89	226	04-30-65
13291200	MAHOGANY CREEK NR HOMESTEAD, OR 2/	NE	11	4.00	134	05-07-71
13292000	IMNAHA RIVER AT IMNAHA, OR	NE	51	622	10100	01-17-74
13318100	MCINTYRE CREEK NEAR STARKEY, OR 2/	NE	14	1.80	34	05-07-79
13318500	GRANDE RONDE R NR HILGARD, OR	NE	19	505	5060	05-08-56
13319000	GRANDE RONDE R AT LA GRANDE, OR	NE	71	678	14100	01-30-65
13320000	CATHERINE CREEK NEAR UNION, OR	NE	58	105	1740	05-27-48
13320400	LITTLE CR AT HIGH VALLEY NR UNION, OR 2/	NE	26	15.8	330	05-27-48
13321300	LADD CANYON NR HOT LAKE, OR 2/	NE	16	15.5	182	03-12-72
13322300	DRY CREEK NEAR BINGHAM SPRINGS, OR 2/	NE	14	1.37	60	01-25-75
13323500	GRANDE RONDE RIVER NEAR ELGIN, OR	NE	24	1250	6480	02-02-65
13323600	INDIAN CREEK NEAR IMBLER, OR	NE	13	22.0	818	05-27-48
13324150	RYSDAM CANYON TRIBUTARY NEAR MINAM, OR 2/	NE	13	0.99	62	01-13-74
13325000	EAST FORK WALLOWA RIVER NR. JOSEPH, OR	NE	54	10.3	450	07-25-37
13325500	WALLOWA R AB WALLOWA LAKE NR JOSEPH, OR	NE	13	43.0	1630	06-26-27
13329500	HURRICANE CREEK NEAR JOSEPH, OR	NE	56	29.6	1110	06-09-48
13329750	TROUT CREEK TRIBUTARY AT ENTERPRISE, OR 2/	NE	11	4.38	116	06-15-67
13330000	LOSTINE RIVER NEAR LOSTINE, OR	NE	55	70.9	2550	06-16-74
13330500	BEAR CREEK NEAR WALLOWA, OR	NE	57	68.0	1730	06-15-74
13331500	MINAM RIVER AT MINAM, OR	NE	15	240	6260	06-16-74
13332500	GRANDE RONDE R AT RONDOWA, OR	NE	52	2555	24700	01-30-65
13333000	GRANDE RONDE RIVER AT TROY, OR	NE	35	3275	42200	12-23-64
13333050	BUFORD CREEK NEAR FLORA, OR 2/	NE	13	0.47	36	04-28-78
13333100	DOE CREEK NEAR IMNAHA, OR 2/	NE	15	5.49	78	04-30-65
14010000	SO FK WALLA WALLA R NR MILTON, OR	NC	58	63.0	2530	01-29-65
14010800	NF WALLA WALLA R NR MILTON FREEWATER, OR	NC	10	34.4	1040	01-25-75
14011000	NO FK WALLA WALLA RIVER NR MILTON, OR	NC	38	43.8	2050	01-30-65
14013000	MILL CREEK NEAR WALLA WALLA, WA	NC	44	59.6	3680	01-29-65
14013500	BLUE CREEK NEAR WALLA WALLA, WA	NC	31	17.0	1320	01-06-69
14016080	DRY CREEK TRIB. NEAR MILTON-FREEWATER, OR 2/	NC	13	1.22	348	05-26-71
14018500	WALLA WALLA RIVER NEAR TOUCHET, WA	NC	29	1657	33400	12-22-64
14019400	ELBOW CREEK NEAR BINGHAM SPRINGS, OR 2/	NC	14	0.68	105	01-25-75
14020000	UMATILLA R AB MEACHAM CR NR GIBBON, OR	NC	47	131	5930	01-25-75
14020800	MISSION CREEK AT ST. ANDREWS MISSION, OR 2/	NC	18	4.45	170	01-30-65
14021000	UMATILLA RIVER AT PENDLETON, OR	NC	47	637	15400	02-22-49
14022500	MCKAY CREEK NEAR PILOT ROCK, OR	NC	53	180	7400	01-30-65
14025000	BIRCH CREEK AT RIETH, OR	NC	49	291	2200	01-30-65
14026000	UMATILLA RIVER AT YOAKUM, OR	NC	22	1280	20000	05-30-06
14032000	BUTTER CREEK NEAR PINE CITY, OR	NC	50	291	2740	01-30-65
14034370	WILLOW CREEK TRIBUTARY NEAR HEPPNER, OR 2/	NC	20	1.11	26	01-30-65
14034500	WILLOW CR AT HEPPNER, OR	NC	30	87.0	36000	06-14-03
14034800	RHEA CREEK NEAR HEPPNER, OR	NC	19	120	1280	06-10-69
14036000	WILLOW CREEK NEAR ARLINGTON, OR	NC	19	850	16900	01-14-74
14036800	JOHN DAY RIVER NR PRAIRIE CITY, OR	NE	14	17.4	155	12-22-64
14037500	STRAWBERRY C AB SLIDE C NR PRAIRIE CITY, OR	NE	49	7.00	274	06-14-64
14038530	JOHN DAY RIVER NEAR JOHN DAY, OR	NE	11	386	5830	06-09-69
14038550	EAST FORK CANYON CREEK NR CANYON CITY, OR 2/	NE	15	24.8	285	12-21-64
14038600	VANCE CREEK NEAR CANYON CITY, OR 2/	NE	14	6.54	39	12-21-64

Table 4. — Maximum discharges at gaging stations used in eastern Oregon flood-frequency analysis — continued

Station number	Station name	Flood region 1/	Years of record	Drainage area (mi²)	Discharge (cfs)	Date
14038750	BEECH CREEK NEAR FOX, OR 2/	NE	12	1.94	23	01-03-66
14038900	FIELDS CREEK NEAR MOUNT VERNON, OR 2/	NE	13	17.5	240	01-22-70
14039200	VENATOR CREEK NEAR SILVIES, OR 2/	NE	13	11.9	108	05-10-74
14040500	JOHN DAY R AT PICTURE GORGE NR DAYVILLE, OR	NE	52	1680	8170	12-22-64
14040700	WHISKY CREEK NEAR MITCHELL, OR 2/	NE	11	2.22	143	01-17-74
14041500	NF JOHN DAY RIVER NR DALE, OR	NE	29	525	8170	05-26-48
14041900	LINE CREEK NEAR LEHMAN SPRINGS, OR 2/	NE	15	2.27	90	01-30-65
14042000	CAMAS CREEK NR. LEHMAN, OR	NE	20	60.7	1880	12-21-55
14042500	CAMAS CREEK NEAR UKIAH, OR	NE	55	121	3840	01-30-65
14043800	BRIDGE CREEK NEAR PRAIRIE CITY, OR 2/	NE	16	6.93	98	05-15-75
14043850	COTTONWOOD CREEK NEAR GALENA, OR 2/	NE	15	3.89	98	04-01-78
14043900	GRANITE CREEK NEAR DALE, OR 2/	NE	11	1.90	66	04-07-79
14044000	MF JOHN DAY R AT RITTER, OR	NE	50	515	4730	01-30-65
14044100	PAUL CREEK NEAR LONG CREEK, OR 2/	NE	11	3.50	56	01-23-70
14044500	FOX CREEK AT GORGE NR FOX, OR	NE	28	90.2	1860	03-25-52
14046000	MF JOHN DAY RIVER AT MONUMENT, OR	NE	55	2520	33400	01-30-65
14046250	IVES CANYON NEAR SPRAY, OR 2/	NE	12	2.73	86	06-30-78
14046300	BIG SERVICE CREEK NEAR SERVICE CREEK, OR 2/	NE	11	5.56	11	03-16-72
14046400	DONNELY CREEK TRIB. NEAR SERVICE CREEK, OR 2/	NE	16	1.85	42	07-02-78
14046500	JOHN DAY RIVER AT SERVICE CREEK, OR	NE	51	5090	40200	12-23-64
14047350	ROCK CREEK TRIBUTARY NEAR HARDMAN, OR 2/	NE	14	6.25	117	01-30-65
14048000	JOHN DAY R AT MCDONALD FERRY, OR	NC	75	7580	42800	12-24-64
14048300	SPANISH HOLLOW AT WASCO, OR 2/	NC	21	8.05	585	12-21-64
14050000	DESCHUTES RIVER BL SNOW CR NR LA PINE, OR	EC	42	132	480	08-19-74
14050500	CULTUS RIVER AB CULTUS CR NR LA PINE, OR	EC	45	16.5	178	05-31-56
14051000	CULTUS CR AB CRANE PRAIRIE RES NR LA PINE, OR	EC	43	33.2	336	12-25-64
14052000	DEER CR AB CRANE PRAIRIE RES NR LA PINE, OR	EC	43	21.5	200	12-25-64
14054500	BROWN CREEK NEAR LA PINE, OR	EC	44	19.7	104	08-04-56
14055500	ODELL CREEK NEAR CRESCENT, OR	EC	44	39.0	1100	12-25-64
14057500	FALL RIVER NEAR LA PINE, OR	EC	42	45.1	254	06-05-65
14073000	TUMALO CREEK NEAR BEND, OR	EC	66	47.3	1140	11-29-68
14075000	SQUAW CREEK NEAR SISTERS, OR	EC	64	54.8	1980	12-23-64
14077500	NF BEAVER CR NR PAULINA, OR	NC	13	64.4	955	03-25-52
14077800	WOLF CREEK TRIBUTARY NEAR PAULINA, OR 2/	NC	15	2.15	300	12-22-64
14078000	BEAVER CREEK NEAR PAULINA, OR	NC	33	450	12800	12-22-64
14078200	LIZARD GULCH TRIBUTARY NEAR HAMPTON, OR 2/	NC	15	19.6	177	12-21-64
14078400	LOOKOUT CREEK NEAR POST, OR 2/	NC	14	7.53	85	01-20-72
14078500	NF CROOKED R AB DEEP CREEK, OR	NC	11	159	2500	03-26-43
14079500	CROOKED RIVER AT POST, OR	NC	27	1660	11500	01-18-71
14080500	CROOKED R NR PRINEVILLE, OR	NC	26	2200	8410	03-26-52
14081800	AHALT CREEK NEAR MITCHELL, OR 2/	NC	23	2.28	122	12-21-64
14083000	OCHOCO CR AB MILL CREEK NR PRINEVILLE, OR	NC	13	200	821	03-19-32
14083500	MILL CREEK NEAR PRINEVILLE, OR	NC	12	78.8	314	02-04-25
14088000	LAKE CREEK NEAR SISTERS, OR	EC	61	22.2	556	12-15-77
14091500	METOLIUS R NR GRANDVIEW, OR	EC	59	316	7530	12-24-64
14093000	SHITIKE CREEK AT WARM SPRINGS, OR	EC	12	104	2300	01-15-74
14093700	WOODS HOLLOW AT ASHWOOD, OR 2/	NC	20	1.42	140	02-07-79
14097200	WHITE RIVER NR GOVERNMENT CAMP, OR	NC	10	40.7	3650	12-13-77
14100800	JORDAN CREEK NEAR TYGH VALLEY, OR 2/	NC	14	9.01	700	12-22-64
14101500	WHITE RIVER BELOW TYGH VALLEY, OR	NC	62	417	13300	01-06-23
14104100	RAMSEY CREEK NEAR DUFUR, OR 2/	NC	14	3.87	380	01-14-74
14105850	SOUTH FORK MILL CR NEAR THE DALLES, OR	NC	16	28.0	1250	01-15-74
14113000	KLICKITAT R NR PITT, WA	NC	54	1297	47400	01-15-74
14113200	MOSIER CREEK NEAR MOSIER, OR	NC	16	41.5	4790	12-23-64
14113400	DOG RIVER NEAR PARKDALE, OR	NC	12	4.50	100	05-29-69
14118500	WEST FORK HOOD RIVER NEAR DEE, OR	NC	49	95.6	20000	01-20-72
14120000	HOOD RIVER AT TUCKER BRIDGE, NR HOOD RIVER, OR	NC	20	279	33200	12-22-64

1/ SE: Southeast
NE: Northeast
NC: North Central
EC: Eastern Cascades

2/ Crest-stage gage