# Estimation of Peak Discharges for Rural, Unregulated Streams in Eastern Oregon

Open File Report SW 06-001

State of Oregon
Water Resources Department

# Estimation of Peak Discharges for Rural, Unregulated Streams in Eastern Oregon

*By* Richard M. Cooper, PE

---

State of Oregon
Water Resources Department

Open File Report SW 06-001

Salem, Oregon
March 2006

# Contents

# Figures

# Tables

# Estimation of Peak Discharges for Rural, Unregulated Streams in Eastern Oregon

*By* Richard M. Cooper, PE

## Abstract

Methods for estimating the magnitudes of peak discharges at various frequencies were developed for rural, unregulated streams in eastern Oregon. Development of these methods had two parts: (1) fitting observed peak discharges to a theoretical probability distribution and (2) the development of equations to predict the magnitude of peak discharges at various frequencies. In the first part, logarithms of annual peak discharges were fitted to the Pearson type III probability distribution for each of 276 gaging stations in the study area. For each gaging station, based on its fitted probability distribution, estimates were made of the magnitudes of the peak discharges for recurrence intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years. All annual series of peak discharges used in this analysis were from rural, unregulated streams.

In fitting the probability distributions, estimates of station skew were improved by adjustment with a "generalized" skew value based on the skews for long-term stations in the area. The areal distribution of the generalized logarithmic skew coefficients of annual peak discharges for Oregon was determined using geographic information systems (GIS) techniques. The actual areal distribution is a GIS grid but is represented in this report as an isoline map. In practice, generalized logarithmic skew coefficients are determined from the grid, not the isoline map.

Eastern Oregon was divided into six "flood regions." For each region, prediction equations were developed for estimating peak discharges at ungaged sites for the selected recurrence intervals. The equations relate peak discharge to physical and climatologic watershed characteristics such as drainage area and precipitation intensity. The equations were derived by generalized least-squares regression using data for the 276 gaged watersheds. Average standard error of prediction for the equations ranged from 37.7 to 104 percent. The accuracy of the equations and limitations on their use are discussed. Use of the prediction equations in various circumstances is illustrated with examples.

Use of the prediction equations requires estimates of watershed characteristics. Because of the reliance in this analysis on GIS techniques, making appropriate and reliable estimates of watershed characteristics may be inconvenient for many users. To make the prediction equations as widely available as possible, the Oregon Water Resources Department has developed an interactive Web site utility to facilitate the use of the equations:

www.oregon.gov/owrd/programs/streamslakessanddams/surfacewater/EstimationofPeakDischarges/

In preparation for doing the flood frequency analysis, the relative importance of the hydrologic processes contributing to peak discharges was determined. Annual peak discharges occurred most frequently in spring and were most likely the result of snowmelt. Rain falling on snow in the months from December to February was the second most frequent cause of annual peak discharges. Convective storms in late spring and summer were responsible for only a minor part of all annual discharges.

For peaks with the largest unit discharges (greater than 500 cfs per square mile), however, most occurred in mid-winter, most likely the result of rain on snow. The second largest number of large unit peak discharges occurred in late spring and summer. These peaks were due mostly to thunderstorms. The largest unit discharges (greater than 1,000 cfs per square mile) were all due to thunderstorms.

Thunderstorms were essentially unrepresented in the systematic record used to develop the prediction equations presented in this report. What impact this had on the estimation of peak discharges is unknown.

Severe thunderstorms were associated with watersheds of a particular type. The watersheds were small, mostly not forested, and relatively hot, dry, and low in elevation. A map showing areas of eastern Oregon most likely to be affected by a severe thunderstorm was developed.

# Introduction

A study of the magnitude and frequency of peak discharges in eastern Oregon has been completed by the Oregon Water Resources Department with financial assistance from the Federal Emergency Management Agency, the Oregon Department of Transportation, and the Association of Oregon Counties, and with the cooperation of the U.S. Geological Survey. The study was undertaken to provide engineers and land managers with the information needed to make informed decisions about development in or near watercourses in the study area.

Much development takes place near rivers and streams and usually involves a variety of engineered structures. Some structures such as bridges and culverts, dams, levees, and floodways are within the stream banks and generally are exposed to streamflow at all times. Other structures such as homes, businesses or agricultural buildings are exposed to streamflow only during times of flooding. Safe and economical design of these structures and correct assessment of the hazards of development in flood plains require knowledge of the magnitude and frequency of the peak discharges of nearby streams.

Peak discharges have the potential to extensively damage any structure exposed to them. The extent to which a structure is designed to withstand the impacts of peak discharges depends on the risk a failure of the structure poses to life and property. In some cases, failure of the structure is unacceptable. For example, a dam upstream of a populated area will be designed to withstand and function properly under the probable maximum flood.

Usually the failure of a structure is more likely to cause property damage than loss of life. In these cases, it may make economic sense to replace the structure periodically rather than build it to withstand any extreme flood. For example, a remote, rarely traveled road may be designed with the expectation that culverts under the road will wash out on average once in 10 to 25 years. As another example, homes on flood plains typically are required to be built above the elevation of the flood likely to occur on average once in 100 years. Because risk assessment is an important part of planning and design, the magnitude of peak discharges at various frequencies is needed.

This report provides techniques for estimating the magnitudes of peak discharges at a variety of frequencies or “return intervals”. A return interval is the number of years expected to pass “on average” between peak discharges of a given magnitude. For example, consider the gaging station on the John Day River at McDonald Ferry, Oregon (14048000). Annual peak discharges have been measured at this site for 98 years through 2003. A magnitude and frequency analysis, described later, estimates the 2-year peak discharge to be 12,400 cubic feet per second (cfs). The largest peak each year is expected to exceed this value half the time, that is, every two years on average. In fact, for the 98 years of record the annual peak discharge exceeded 12,400 cfs 45 times. Similarly, the 100-year peak discharge is 42,700 cfs and is expected to be exceeded one-percent of the time or once in a hundred years on average. For the 98 years of record, one annual peak discharge exceeded 42,700 cfs.

# Purpose and Scope

This report describes the results of an analysis of the peak discharges of *rural* streams in Oregon east of the crest of the Cascade Range (fig. 1). A previous report described a similar analysis for rural streams west of the crest of the Cascade Range (Cooper, 2005).

The results of this study include (1) the magnitude of annual peak discharges for selected frequencies at 276 gaging stations, (2) the areal distribution within eastern Oregon of generalized logarithmic skew coefficients for annual peak discharges, and (3) sets of prediction equations relating the magnitude of peak discharges at selected frequencies to physical and climatological watershed characteristics such as drainage area or mean January precipitation. A set of frequency specific prediction equations was developed for each of six hydrologically similar regions within eastern Oregon. The prediction equations may be used at ungaged sites to make estimates of peak discharges.

The selected peak discharge frequencies are described by the recurrence interval at which the peak discharge is likely to recur. The selected recurrence intervals are the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year peak discharge. A 10-year peak discharge has a probability of exceedance in any year of 0.10 or 10 percent, and a 100-year peak discharge, a probability of exceedance of 0.01 or 1 percent.

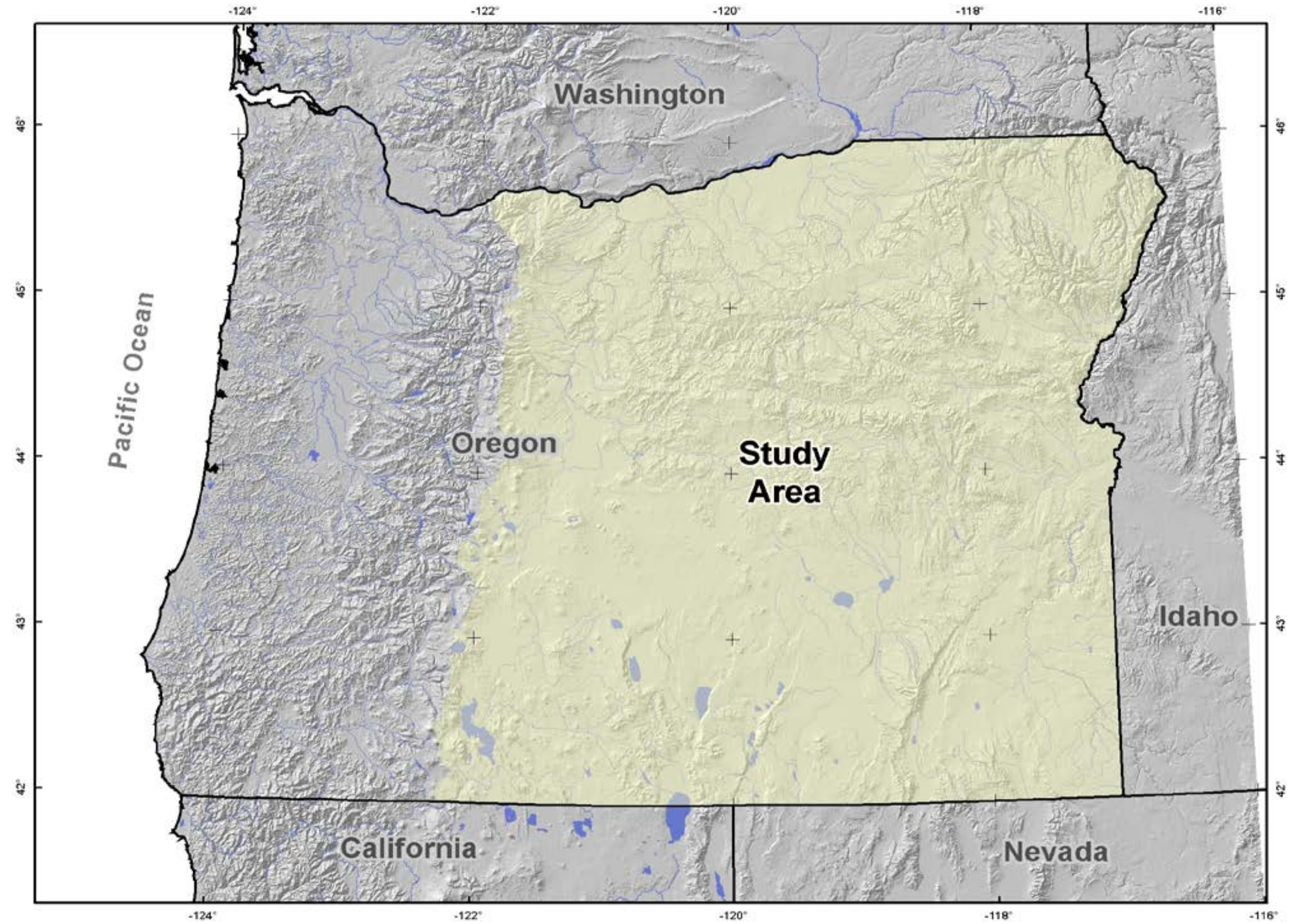



**Figure 1.** The study area in eastern Oregon.

The study described in this report is based on annual series of peak discharges for 276 gaging stations in eastern Oregon, southeastern Washington, western Idaho, northwestern Nevada, and northeastern California. The study had two parts: (1) a magnitude and frequency analysis, and (2) derivation of the prediction equations. In the magnitude and frequency analysis, a frequency distribution was fitted to the measured annual peak discharges of each gaging station. The fitted distribution was used to estimate the magnitude of annual peak discharges at selected frequencies. The prediction equations were derived using generalized least-squares regression analysis.

Although the analysis described in this report was based in part on gaging stations located in southeastern Washington, western Idaho, northwestern Nevada, and northeastern California, the resulting prediction equations are to be applied only to eastern Oregon. The out-of-State gaging stations were included to increase the information used in the derivation of the prediction equations, to reduce any edge effects in developing the generalized skew coefficients, and in some cases, because parts of the out-of-State gaging station watersheds lie in Oregon.

The prediction equations may be used to estimate peak flows for any stream. Be aware, however, that the prediction equations do not account for reservoir operations, diversion or urbanization. Many streams are affected by these factors. In these cases, the estimates of peak flow represent a hypothetical condition of the watershed, not the actual condition.

For peak discharges for urban watersheds, it is recommended that the prediction equations developed by Sauer and others (1983) be used. These prediction equations are applicable to urban areas anywhere in the United States. The equations are included in the National Flood Frequency Program (Sauer, 2002).

The prediction equations require estimates of several physical characteristics of the watershed of interest. Most of these characteristics are estimated from regionalized data. These data are described later in the report and only the versions of the regionalized data described there should be used with the prediction equations. Sources for these data sets are listed elsewhere in the report. The best estimates of watershed characteristics are achieved by analyzing the regionalized data with geographic information systems (GIS) techniques rather than making the estimates manually from plotted isoline maps.

For these reasons, making appropriate and reliable estimates of watershed characteristics may be inconvenient for many users. To make the prediction equations as widely available as possible, the Oregon Water Resources Department has developed an interactive Web site utility to facilitate the use of the equations. The Web site and the options available there are described in a later section of the report.

# Acknowledgements

This study was completed in part due to generous financial support from the Federal Emergency Management Agency (from both the National Dam Safety Program and the Federal Insurance and Mitigation Division), the Oregon Department of Transportation, and the Association of Oregon Counties. Their contributions are gratefully acknowledged.

Many thanks are due to Ken Stahr who made numerous contributions. He has done the bulk of the GIS work. He delineated and digitized most of the watersheds, he managed all the various coverages and grids used to calculate watershed characteristics and calculated those characteristics, and he created several of the figures in this report. He is also largely responsible for developing a method for auto-delineation of watersheds. This method is used in a Web utility available from the Oregon Water Resources Department's Web site for estimating peak discharges at ungaged sites.

Bob Harmon is lead worker for GIS work in the Oregon Water Resources Department. He acquired the watershed characteristic grids and coverages used for this analysis and wrote the computer programs that calculate watershed characteristics.

# Previous Studies

In the 1960s, the U.S. Geological Survey published a series of reports describing methods for determining the magnitude of floods at specified frequencies. These reports had the general title “Magnitude and Frequency of Floods in the United States”. The U.S. Geological Survey previously had divided the continental United States into 14 large regions or “parts” of relatively similar hydrology, and each report in the series referred to one of these parts. Of interest here were the reports for Parts 10, 11, 13, and 14 - the Great Basin (Butler and others, 1966), Pacific slope basins in California (Young and Cruff, 1967), the Snake River basin (Thomas, Broom and Cummans, 1963), and Pacific slope basins in Oregon and the Lower Columbia River basin (Hulsing and Kallio, 1964), respectively.

In all of the reports, methods were described for determining the probable magnitude of peak discharges of any frequency between 1.1 (1.2 for part 11) and 50 years. The methods differed somewhat from one another, but had common elements. First, each gaging station used had more than 5 years of record and was unaffected by significant reservoir operations, diversions, or urbanization. Second, a frequency curve for each suitable gage was fitted visually to the annual peak discharges plotted on log-probability paper. Third, a regionalization of peak discharges was done by correlating a variety of watershed characteristics to one or more flood characteristics. Fourth, the study areas were divided into a number of sub-regions, a separate regionalization being made for each sub-region. Finally, the use of the prediction methods was limited to the range of the parameters used to develop the methods.

In all cases, all of the annual peak discharges used in the analysis were included in the report. The reports for parts 10, 13, and 14 included the watershed characteristics used to develop the prediction equations. For part 11, only some of the characteristics were included. For the analysis for part 10, 113 gaging stations were used, for part 11, 147 gaging stations, for part 13, 179 gaging stations and for part 14, 304 gaging stations.

Lystrom (1970) evaluated the streamflow-data program in Oregon. As part of that analysis, he developed prediction equations for estimating peak discharge magnitudes for recurrence intervals of 2, 5, 10, 25, and 50 years. There were two sets of equations: one for western Oregon and one for eastern Oregon. Lystrom did not explicitly limit the use of the equations, but good practice would limit their application to the range of values exhibited by the characteristics of the watersheds used to develop the equations.

Lystrom's equations were derived by regressing peak discharges of a given frequency on watershed characteristics. Annual peak discharges were fitted to log-Pearson Type III distributions to obtain peak discharges of specified frequency. The regressions were done by ordinary least-squares. Standard errors of estimate ranged from 56 to 60 percent. The characteristics considered by Lystrom were drainage area, main-channel slope, percent area of lakes and ponds, mean watershed elevation, percent area of forest cover, mean annual precipitation, 2-year 24-hour precipitation intensity, mean minimum January temperature, and a soils index developed by the Soil Conservation Service. Of these, drainage area, percent area of lakes and ponds, mean annual precipitation, and the soils index appeared in the prediction equations Lystrom developed for eastern Oregon.

Lystrom's analysis was based on annual peak discharges for 222 gaging stations with more than 10 years of record and unaffected by significant reservoir operations, diversions, or urbanization. The watershed characteristics for each of the gaging stations used in the regressions were included in his report.

The Oregon Water Resources Department (1971) developed curves relating mean annual peak discharges to drainage area for 29 hydrologically similar regions in the State. Multipliers related the mean annual peak discharges to peak discharges for recurrence intervals of 1.01-, 1.05-, 1.25-, 2-, 5-, 20-, and 100-years. The analysis applied to all of western Oregon and parts of eastern Oregon. The curves were to be used for watersheds of less than 100 square miles.

The curves were developed from methods described by Hazen (1930). The only watershed characteristic required to use the curves was drainage area. The analysis was based on annual peak discharges for 120 gaging stations, most of which had more than 20 years of record.

Harris and Hubbard (1982) reported a method for estimating peak discharge magnitudes for unregulated streams in eastern Oregon for recurrence intervals of 2, 5, 10, 25, 50, and 100 years. Four sub-regions were defined: southeast, northeast, north central and eastern Cascades. A set of prediction equations was developed for each region. Harris and Hubbard did not explicitly limit the use of the equations, but, again, good practice would limit their application to the range of values exhibited by the characteristics of the watersheds used to develop the equations.

The equations were derived by regressing peak discharges of a given frequency on watershed characteristics. Annual peak discharges were fitted to log-Pearson Type III distributions to obtain peak discharges of a specified frequency. The regressions were done by ordinary least-squares. Standard errors of estimate ranged from 58 to 93 percent. The characteristics considered were drainage area, main-channel slope, main-channel length, mean watershed elevation, percent area of lakes, percent forest cover, a soils index developed by the Soil Conservation Service, latitude of the gaging station, longitude of the gaging station, mean annual precipitation, 2-year 24-hour precipitation intensity, and mean minimum January temperature. Of these, only drainage area, main-channel length, mean annual precipitation, percent forest cover, and mean minimum-January temperature were used in the equations.

The analysis was based on annual peak discharges for 162 gaging stations with more than 10 years of record and unaffected by significant reservoir operations, diversions, or urbanization. The watershed characteristics for each of the gaging stations used in the regressions are included in Harris and Hubbard's report.

Campbell and others (1982) developed a method for predicting peak discharges on small, unregulated watersheds in Oregon for recurrence intervals of 10, 25, 50 and 100 years. Six sub-regions were defined. The four sub-regions in western Oregon were the same as those used by Harris and others (1979). In eastern Oregon, one sub-region was defined by watersheds in or near the upper Klamath River basin. A second sub-region was defined by watersheds in or near the John Day, Umatilla, Grande Ronde and Powder River basins. Watersheds used in the study ranged in size from 0.21 to 10.6 square miles.

In each region, annual peak discharge data from gaging stations with more than 20 years of record were fitted to four frequency distributions: Gumbel, two-parameter log-normal, three-parameter log-normal, and log-Pearson Type III. The log-Pearson Type III distribution was determined to be best suited to all regions of the State.

Prediction equations were derived by regressing peak discharges of a given frequency (determined from fitting annual peak discharges to a log-Pearson Type III distribution) on watershed characteristics. The regressions were done using ordinary least-squares. Standard errors of estimate ranged from 60 to 89 percent for eastern Oregon. The characteristics considered were drainage area, mean watershed elevation, gage datum, main-channel slope, main-channel length, percent forest cover, latitude of the gaging station, longitude of the gaging station, mean annual precipitation, 2-year 24-hour precipitation intensity, and mean minimum January temperature. Of these, only drainage area was used in the equations for eastern Oregon.

The analysis was based on annual peak discharges for 80 gaging stations with more than 10 years of record and unaffected by significant reservoir operations, diversions, or urbanization. The watershed characteristics for each of the gaging stations used in the regressions were included in Campbell and others' report.

Thomas and others (1993) reported a method for estimating peak discharge magnitudes for unregulated streams in the southwestern United States for recurrence intervals of 2, 5, 10, 25, 50, and 100 years. Their study area included much of eastern Oregon. Eight sub-regions were defined and a set of prediction equations was developed for each region. Watersheds in Oregon that coincide with their study area were all included in their region 2. Use of the equations was limited to watersheds with characteristics within the limits of the characteristics of the watersheds used to develop the prediction equations.

The prediction equations were derived by regressing peak discharges of a given frequency on watershed characteristics. Annual peak discharges were fitted to log-Pearson Type III distributions to obtain peak discharges of a specified frequency. The regressions were done by generalized least-squares. Overall, standard errors of estimate ranged from 45 to 135 percent, but for region 2, they ranged from 61 to 72 percent. The characteristics considered were drainage area, main-channel slope, main-channel length, mean watershed elevation, elevation of the gage datum, percent forested area, latitude of the gage, longitude of the gage, mean annual precipitation, 100-year 24-hour precipitation intensity, mean annual free water-surface evaporation, distance from Gulf of Mexico, distance from Gulf of California, relation of gaged site to major orographic barriers, basin shape (length squared divided by area), potential vegetation at the gaged site, active channel width, channel slope of lower one-third of stream length, and an erodent factor. Of these, only drainage area, mean watershed elevation, mean annual precipitation, mean annual evaporation, and latitude and longitude of the gage had significant coefficients in the regressions. For region 2, only drainage area and mean watershed elevation had significant coefficients.

The analysis was based on annual peak discharges for 1,323 gaging stations with more than 10 years of record and unaffected by significant reservoir operations, diversions, or urbanization. The watershed characteristics for each of the gaging stations used in the regressions were included in the report.

# Current Study

The current study improves on previous work in several important ways. Because of these improvements, the prediction equations developed for this study are considered more reliable than prediction equations previously reported for use in eastern Oregon and should be used in lieu of equations from previously published reports for eastern Oregon.

First, more gaging stations were used in this study than in other studies. Most other studies have used only peak discharge record published by the U.S. Geological Survey. This study includes peak discharge record published by the U.S. Geological Survey and the Oregon Water Resources Department.

Second, more than 20 years of streamflow record has been collected since the last comprehensive study for eastern Oregon (Harris and Hubbard, 1982). This new record includes continuation of record at existing stations and addition of record at new stations by both the U.S. Geological Survey and the Oregon Water Resources Department.

Third, generalized logarithmic skew coefficients for Oregon have been developed specifically for this study. The most recent previous study (Harris and Hubbard, 1982) used the generalized logarithmic skew coefficients provided by the U.S. Water Resources Council in Bulletin 17A (1977). The new generalized skew coefficients are based on more peak discharge data than the previous analysis of generalized skew. In the 25 years since the previous analysis, new stations have been established and records at many previously existing stations have been extended.

Fourth, more watershed characteristics and better methods to estimate them are now available. Many physical and climatological characteristics of watersheds have been regionalized and put into digital formats in recent years. By using these regionalized characteristics in conjunction with GIS techniques, estimation of watershed characteristics is easier, more precise, more accurate, and more readily reproduced than previously possible.

Finally, other studies in Oregon have used ordinary least-squares regression to develop the prediction equations. This study uses a generalized least-squares analysis that accounts for unequal lengths and variances of streamflow records and cross-correlation between series of streamflow characteristics where ordinary least-squares regression does not.

# Description of the Study Area

The study area includes all of Oregon east of the crest of the Cascade Range (fig. 1). Some of the gaging stations used in the analysis lie outside of the study area. These stations are located adjacent to the study area in southeastern Washington, western Idaho, northwestern Nevada and northeastern California. By physiography and climate, these out-of-State areas are extensions of the adjacent regions of the study area.

Eastern Oregon comprises two-thirds of the state. It lies in the rain shadow of the Coast and Cascade Ranges and is much drier than western Oregon. Over large areas of eastern Oregon, annual precipitation is less than 20 inches (G.H. Taylor, Oregon State Climatologist, written commun., 2002). In the extreme, the Alvord Desert east of the Steens Mountains has a mean annual precipitation of less than 4 inches. Mountainous regions in eastern Oregon receive upwards of 30 inches annually with areas of the Wallowa Mountains receiving more than 80 inches.

Much of the northern and eastern parts of eastern Oregon drain to the Pacific Ocean by way of the Columbia and Snake Rivers. Major drainages include the Deschutes, John Day, Umatilla, Grande Ronde, Powder, Malheur and Owyhee Rivers. Southwestern eastern Oregon also drains to the Pacific, in this case, by way of the Klamath River. The remainder of eastern Oregon has no outlet to the sea and is part of the Great Basin of the western United States. Major drainages include the Chewaucan and Silvies Rivers. Regions of eastern Oregon receiving less than about 15-20 inches of rain annually are generally without trees except along watercourses. The dominant vegetation is sagebrush or grass. Wetter areas tend to be forested except at higher elevations above the tree line.

## Physiography

Principal physiographic features of the study area are the eastern Cascades, the Deschutes-Umatilla Plateau, the Blue Mountains, the High Lava Plains, the Owyhee Uplands, and the Basin and Range (fig. 2). With the exception of the High Lava Plains, these physiographic features are parts of larger features that extend into adjacent states.

Land surface elevations in eastern Oregon are generally over 3,000 feet. Only the Deschutes-Umatilla Plateau has lower elevations, with the land surface dropping below 500 feet along the Columbia and Deschutes Rivers. Most of Oregon’s high country occurs in the eastern part of the state. Extensive areas of the Wallowa, Elkhorn, Strawberry and Steens Mountains exceed 8,000 feet.

The Cascade Range parallels the Pacific coastline extending from British Columbia, across both Washington and Oregon, and into California to the Sierra Nevada. The elevation of the crest line of the Cascades is generally over 4,000 feet with several peaks exceeding 10,000 feet. In Oregon, the Cascade Range provides a continuous hydrologic divide along its length. Almost all watersheds draining the east side of the Cascades are tributary to just two streams: the Deschutes and Klamath Rivers.

The eastern Cascades are composed primarily of geologically recent andesite and basalt flows and volcanic tuff and ash deposits (Baldwin, 1981). Much of this rock is highly permeable and many streams are fed by large springs. In fact, some of the largest springs in the United States occur along the eastern side of the Cascades (Meinzer, 1927). This highly

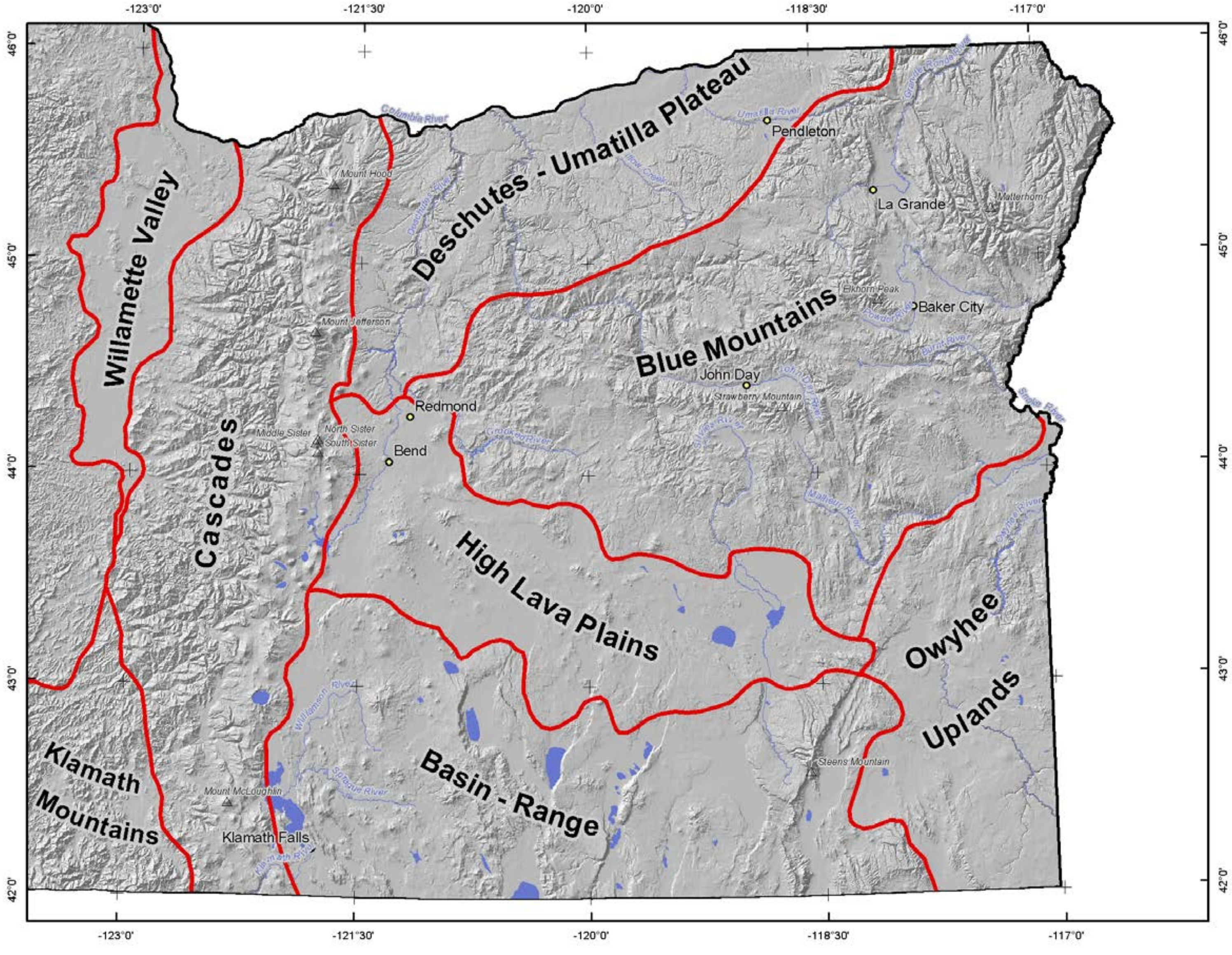



**Figure 2.** Physiographic features of Oregon. Physiographic regions are based on Dicken (1965) and Baldwin (1981).

permeable rock makes watershed boundaries uncertain in many areas (Gannet and others, 2000). In spite of relatively high precipitation, many areas show poor stream development because of the highly permeable rock.

The highest elevations in the eastern Cascades receive the most precipitation. Precipitation decreases rapidly with elevation from west to east. Vegetation also changes dramatically. The highest, wettest areas are heavily forested. As elevation and precipitation decrease, forest gives way to open stands of juniper and finally to sagebrush or grasslands. Much of the sagebrush and grassland areas are now in agricultural production.

The Deschutes-Umatilla Plateau in north-central Oregon is part of the much larger Columbia basin that also occupies much of eastern Washington. This region drains the northern side of the Blue Mountains. The land slopes gently to the north from elevations of 3,000 feet to a few hundred feet along the Columbia River.

Uplands of the Deschutes-Umatilla Plateau receive significant precipitation and stream networks are well developed. Lowlands are much drier, and few streams originate there. Streams crossing the lowland areas have cut deeply incised canyons. They include the Deschutes, John Day, and Umatilla Rivers and Willow and Butter Creeks. Upland areas, being the wettest, are the most heavily vegetated, and are forested. The lowlands, however, are sparsely vegetated, dominated by sagebrush and grasslands. Much of these dry lowland areas are now used for agriculture.

The Blue Mountains of northeastern Oregon are comprised of several mountain ranges separated by faulted valleys and synclinal basins (Baldwin, 1981). Ranges include the Ochoco, Aldrich, Strawberry, Elkhorn, and Wallowa Mountains. The ranges are separated by the John Day, Grande Ronde, and Powder Rivers and their tributaries.

The Blue Mountains are rugged and steep sloped with high relief in many areas. The Wallowa Mountains, for example, have several peaks over 9,000 feet and extensive alpine areas. The Blue Mountains are the wettest area of eastern Oregon and stream networks are well developed. Most of the Blue Mountains are wet enough to support forest. Lowland valleys generally are not, and the vegetation is dominated by sagebrush and scattered grasslands. Lowland areas with access to water are in agricultural production.

The High Lava Plains region is located in the center of eastern Oregon between the Blue Mountains to the north and the Basin and Range to the south. The region has low relief and is lower in elevation than surrounding regions, though elevations still exceed 3,000 feet. Large lakes occupied much of this region during the Pleistocene. These lakes are gone from the western portion of the region, Christmas Lake and Fort Rock Valleys, but in the Harney Basin to the east, Harney and Malheur Lakes persist. The large expanses of relatively flat terrain are occasionally broken by cinder cones and lava buttes. The west end of the region is dominated by Newberry Crater, the remnants of a large shield volcano.

The High Lava Plains are very dry. There is almost no stream development in the region. The only perennial streams are Silver Creek and the Silves and Donner und Blitzen Rivers. These streams cross the plains, emptying into Malheur Lake, but they originate in the Blue and Steens Mountains. The dominant vegetation is sagebrush and grasslands with occasional areas of scattered junipers. Areas with access to water are used for agriculture.

The Owyhee Upland is located in the extreme southeastern part of Oregon. It is part of a large basin extending into Idaho. The basin slopes to the north and is drained by the Owyhee River. Elevations within Oregon are generally above 4,000 feet, with a few areas above 6,000 feet. Precipitation in this region is very low, most areas receiving less than 12 inches. Vegetation is sparse and is dominated by sagebrush and grasslands. Because of the low precipitation, stream development is minimal, and there are few perennial streams. The Owyhee River is deeply incised through this region.

The Basin and Range occupies the southern part of eastern Oregon. It is part of a much larger physiographic province extending into the southwestern United States. It is characterized by north trending fault-block mountains interspersed with internally draining basins (Baldwin, 1981). Major ranges include Winter Rim, Abert Rim, the Warner Mountains, Hart Mountain, Steens Mountain, and the Pueblo Mountains. Major basins include the Klamath, Goose Lake, and Summer Lake basins; Warner, Guano, and Catlow Valleys; and the Alvord Desert. Klamath, Summer, Abert, Goose and Warner Lakes are remnants of much larger Pleistocene lakes that once filled these basins.

The western portion of the Basin and Range region is much wetter than the eastern portion and is mostly forested. The eastern portion is vegetated by sagebrush and grasslands even in higher, wetter areas. Stream networks are poorly developed and there are few perennial streams. In the western portion, highly permeable rock and soil inhibit stream development, and in the east, low rainfall. Important streams are the Sprague and Chewaucan Rivers, Deep, Thomas, Honey, and Trout Creeks, and the Donner und Blitzen River.

# Climate

Weather in Oregon is determined mostly by the behavior of the jet stream (Taylor and Hannan, 1999). In winter, the jet stream typically flows directly over the Pacific Northwest. This pattern pushes a series of air masses from the Pacific Ocean over Oregon. Air masses are large bodies of air of relatively uniform temperature and moisture. Where air masses with different temperatures collide, called a front, stormy weather usually results. Because these colliding air masses are moist, they bring cloudy skies and precipitation to the northwest.

Most of the time, these air masses move over the State from the west. They bring mild temperatures and showers or low intensity rain. This pattern may dominate Oregon weather for weeks at a time. Occasionally, the jet stream directs air masses over Oregon from the subtropics to the southwest. This pattern brings warm temperatures and very wet weather. Oregon's wettest weather results from this pattern. Another occasional winter pattern directs air masses from the Gulf of Alaska over Oregon. This pattern brings cold temperatures and snow to low elevations.

In summer, the jet stream moves to the north and Oregon is typically under a ridge of high pressure. As a result, summers are warm and dry. In this pattern, air masses from California and from the Great Basin may bring relatively moist air into Oregon resulting in thunderstorms in eastern Oregon and the Cascades.

Although both western and eastern Oregon are under the influence of the same large-scale weather patterns, climates in the two regions are markedly different. This difference is a result of the Coast and Cascade Ranges that lie perpendicular to the path of the air masses arriving over Oregon from the Pacific. These mountains remove most of the moisture from the air masses as they pass to the east. Consequently, eastern Oregon is much drier than western Oregon.

The mountains restrict air movement from both east to west and west to east. As a result, weather in eastern Oregon is influenced less by the Pacific Ocean, and western Oregon is influenced less by air from the continent. Eastern Oregon is then both colder in winter than western Oregon and warmer in summer. The warmer summer temperatures make eastern Oregon prone to many more thunderstorms than western Oregon as well as to thunderstorms of greater intensity.

Rainfall due to frontal storms from the Pacific shows a pronounced seasonality in both western and eastern Oregon with the most precipitation from these storms occurring in December and January and the least in summer months. Because there are few thunderstorms in western Oregon, almost all precipitation is from these frontal storms, and occurs from November to April or May. In eastern Oregon, however, thunderstorms provide significant summer precipitation being nearly equal to that arising from winter storms. Rainfall patterns in eastern Oregon do not show a strong seasonality with relatively uniform rainfall from month to month. Even with the thunderstorms, rainfall amounts in eastern Oregon, both winter and summer, are much less than for western Oregon.

# Characteristics of Peak Discharges

Peak discharges in the study area result primarily from three hydrological processes: (1) rainfall from frontal storms moving eastward from the Pacific Ocean, (2) snowmelt, and (3) rainfall from convective storms. Many peak discharges, including some of the largest peaks, result from a combination of processes, for example, warm rain falling on accumulated snow. For a few watersheds in the Cascade Range, annual peak discharges result from spring flow. Very rarely does a peak discharge results from a glacial outburst. The most recent of these occurred in September 1998 from the White River Glacier on Mt. Hood.

## Frontal Storms

Frontal storms occur mostly in winter and are regional in affect. Precipitation from these storms falls mostly as snow in eastern Oregon. Rain is most likely in October and November or in April and May.

Precipitation intensities for these storms tend to be low, but storms may last for several days. When the precipitation is in the form of rain, streamflow usually increases rapidly and then, after the front has passed, decreases gradually over several days. Maximum flows are sustained for only a short time – perhaps a few hours. When precipitation is in the form of snow, streamflow is likely to remain unchanged or decrease if temperatures are very low. Streamflows in eastern Oregon tend to be near annual minimums during the winter months. Annual peak discharges associated with rain only events are rare.

**Snowmelt**

Snowmelt usually occurs in spring and is responsible for most peak discharges in eastern Oregon though not the largest peaks. As the weather warms in the spring, as a general trend, streamflow from snowmelt increases gradually over several weeks. Eventually, as the snow pack diminishes, streamflow begins a gradual decline to base flow levels. The maximum streamflows associated with this general trend may be sustained for a week or more. Superimposed on this general trend are numerous short duration peaks due to diurnal temperature variation and to short periods of either rain or high temperatures. Maximum flows associated with these superimposed peaks are sustained only briefly. The overall peak discharge for the period will result from one of these superimposed peaks. The time of occurrence of maximum snowmelt depends on elevation - in March at lowest elevations and in June, or even July, at highest elevations

**Convective Storms**

Although convective storms may occur anytime, storms of greatest intensity occur in late spring or summer. Rainfall intensities for these storms may be high, but their durations are short. Streamflow hydrographs associated with convective storms rise and then decrease rapidly. Maximum flows are not sustained.

Floods from thunderstorms have other important characteristics. They are local, affecting only a small area, and although peak discharges may be very large, flow volumes are small and peak discharges attenuate quickly. The flash flood on Bridge Creek and its tributaries on July 13, 1956 (Hendricks, 1964) illustrates these points.

The flood flow resulted from brief, intense rainfall falling over a relatively small, un-forested area. These conditions resulted in a flood that concentrated quickly with high flow rates and unit runoff but small flood volume, only 2,700 acre-feet. The peak discharge was 54,500 cfs from Meyers Canyon and 14,400 cfs from Bridge Creek above Gable Creek (upstream of Meyers Canyon). However, the peak discharge in Bridge Creek 8.5 miles downstream from Meyers Canyon was only 16,300 cfs. The peak lasted only 10 to 15 minutes and the stage dropped 7 feet in around 2 hours.

This storm also generated an unknown amount of flow from Girds Creek, which is adjacent to Bridge Creek. Bridge and Girds Creeks are both tributaries of the John Day River. On July 14 between 3:30 and 4:00 PM, flow at McDonald Ferry on the John Day River increased from 1,400 cfs to 6,600 cfs, then receded slowly to 1,600 cfs by 10:00 am on July 15.

Sometimes convective storms in eastern Oregon produce no precipitation (G.H. Taylor, Oregon State Climatologist, written communication, 2004). These dry lightening storms result from air masses originating over the Gulfs of Mexico or California. As these air masses move north, they lose much of their moisture over the mountains of Arizona, New Mexico, Nevada and California. By the time they arrive here, they are relatively dry. They produce lightening over our mountains, but little rain.

## Mixed Processes

Occasionally, storms from the subtropical Pacific bring rain to eastern Oregon even in mid winter. In these cases, rain often falls on snow and frozen ground, producing among the largest peak events in eastern Oregon. The storms of December 1964 and February 1996 were of this type. Rain on snow events may occur anytime from about November through May.

## Spring Flow

A number of streams in eastern Oregon are strongly influenced by spring discharge. Generally, the watersheds of streams with significant springs have high groundwater recharge rates resulting in attenuated peak discharges and high base flows. A characteristic of streams influenced by spring flow is a low ratio of maximum to minimum discharges.

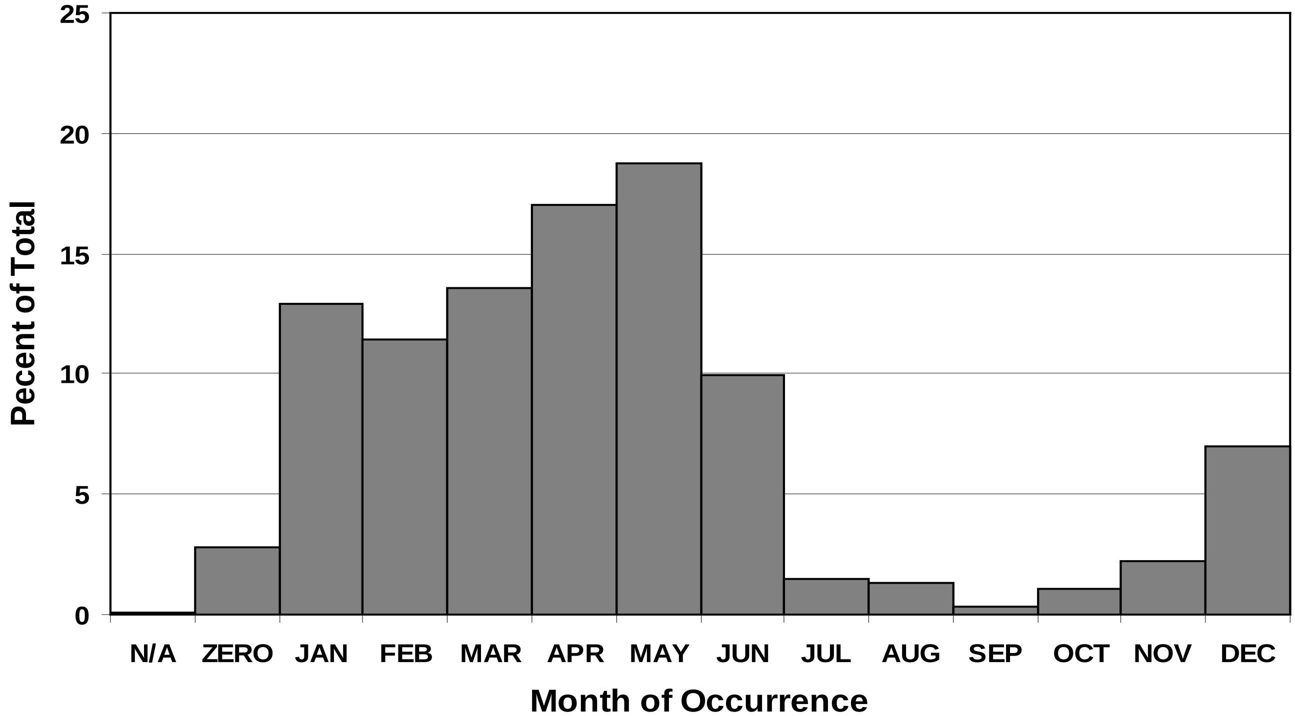



**Figure 3.** Distribution of monthly occurrence of 6,960 observed peak discharges. Zero is the percent of zero peaks (2.8 percent). N/A is the percent of peaks that are not zero, but for which the date of occurrence is unknown (0.1 percent).

Most of the larger, most strongly spring influenced streams are associated with the young, highly porous volcanic rock of the eastern slope of the Cascade Mountains and parts of the Klamath basin. For some of these watersheds, peak discharges are dominated by spring flow, with some peaks due entirely to spring flow. These peaks tend to occur in late summer and early fall. The timing and the magnitude of the peaks are related to the travel time of groundwater from time of recharge from snowmelt or rainfall to the time of discharge at the spring. The Deschutes River above Snow Creek near La Pine, OR (14050000) is an example of such a watershed.

Significant springs occurring in areas other than the Cascades are rare and tend not to dominate peak discharges, only contribute to it. Of the gaging stations considered for this study and located in these areas, only the South Fork Burnt River above Barney Creek near Unity, OR (13270800), the South Fork Walla Walla River (14010000 and 14010500), and Bridge Creek near Frenchglen, OR (10397000) have significant contributions from spring flow.

## Relative Importance of Underlying Processes

An analysis was done to determine the relative importance of the hydrologic processes contributing to peak discharges. Although it is difficult to classify an individual peak as to the types of hydrologic processes it resulted from, some general conclusions about all peaks can be made. First, assume that the hydrologic processes associated with a peak discharge are related to its season of occurrence. For example, rain and rain on snow events are most likely in winter, snowmelt in spring and thunderstorms in summer. Unfortunately, none of these classifications is definitive, only likely. Still, an analysis of this type indicates the relative importance of the hydrologic processes contributing to peak discharges.

In order to see how peak discharges in eastern Oregon are distributed in time, they were grouped by their month of occurrence (fig. 3). All east side peak discharges unaffected by regulation or urbanization were included even if the associated gaging station did not qualify for inclusion in the flood frequency analysis. (Gaging stations excluded from the flood frequency analysis but used here included those with fewer than 10 years of record or with too many zero peaks or peaks below the gage threshold.) In all, 6,960 peaks representing 340 watersheds were identified. Only peak discharges occurring on watersheds in eastern Oregon were included in this analysis; out-of-State peaks were not.

From the distribution of all peak discharges, it is clear that most annual peak discharges occurred in spring. These peaks were most likely due to snowmelt; though rain falling on already melting snow may have contributed. The second most number of peaks occurred in January and February. These mid-winter peaks were most likely due to warm rain falling on accumulated snow and frozen ground.

Fewer than 5 percent of all peak discharges occurred from July through October. These peaks were most likely due to thunderstorms, though some, like those in September of 1977, were due to frontal storms. Some of the peaks in May and June are known to be from thunderstorms, but what part is unknown.

## Peaks with Large Unit Runoff

A similar analysis was done for the 89 peak discharge events with unit runoffs[1] greater than 100 cfs per square mile (table 1 and fig. 4). These largest peak discharges show a very different distribution from the set of all peaks. The largest number of large peaks occurred in mid-winter. These peaks most likely were the result of warm rain falling on snow and frozen ground. The chart shows that these rain-on-snow events were responsible for a significant portion of the largest unit peak discharges in eastern Oregon. The second largest number of large peaks occurred in late spring and summer. These peaks were due mostly to thunderstorms. The largest events in terms of unit runoff occurred because of these summer thunderstorms. The 89 peak discharges are plotted against area on figure 5. Peak discharges that plot above the 1,000 cfs per square mile line were most likely all due to thunderstorms.

The 89 largest peaks were plotted against five selected watershed characteristics (fig. 6). The watersheds associated with the 13 unit peak discharges greater than about 500 cfs per square mile have some interesting similarities. All have areas less than 50 square miles, mean annual precipitations less than 20 inches, mean watershed elevations less than 4,000 feet, mean maximum July temperatures greater than 80 degrees Fahrenheit, and percent forest cover less than 35 percent. Of the 13, 10 had percent forest cover of less than 1 percent.

The relationships of the other 76 large unit peak discharges to watershed characteristics are less clear. To get a better picture, the watersheds associated with the 89 largest unit peak discharges were scored based on the same five watershed characteristics used in figure 6.

Each watershed received one point for any of the following that are true: 1) drainage area less than 50 square miles, b) mean annual precipitation less than 20 inches, c) mean watershed elevation less than 4,000 feet, d) maximum July temperature greater than 80 degrees Fahrenheit, and e) forest cover less than 35 percent. The scoring for at least one of the watersheds is misleading. The peak discharge for Willow Creek at Heppner, OR (14034500) arose entirely from one tributary, Balm Fork. While Willow Creek scores a one, Balm Fork scores a five.

Table 2 summarizes the results of the watershed scoring. Some interesting patterns have emerged. First, watersheds prone to peaks with large unit discharges are likely to have multiple large peaks. The 89 large unit peak discharges were from just 45 watersheds. In fact, 58 of the unit peaks came from just 15 watersheds (Table 3).

Second, more watersheds with high unit discharges had high scores than low scores. Of the 45 watersheds, 28 (62 percent) had scores of 4 or 5 and 14 had scores of 0 to 2 (31 percent). Summer[2] peaks tended to occur on watersheds with high scores – 24 of 28 peaks had scores of 4 or 5 (86 percent) while only 3 of 28 had scores of 0 to 2 (11 percent). Winter peak discharges were about evenly divided between watersheds with high and low scores – 13 of 27 watersheds (48 percent) had

[1] Unit runoff is calculated simply by dividing the peak discharge by the watershed area. It is reported in cubic feet per second per square mile.

[2] For this analysis, summer is defined as May 1 to October 31, and winter is defined as November 1 to April 30

**Table 1.** Maximum observed peak discharges in eastern Oregon – unit discharge greater than 100 cfs per square mile.

[**Area**, drainage area, in square miles; **MAP**, mean annual precipitation, in inches; **Elevation**, mean watershed elevation, in feet; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Forest**, forest cover, in percent; **M**, month; **D**, day; **Y**, year; **Peak**, maximum observed annual peak discharge, in cubic feet per second; **Unit Peak**, maximum observed annual peak discharge divided by drainage area, in cubic feet per second per square mile]

| Station Number | Station Name | Watershed Characteristics | | | | | Date of Occurrence | | | Peak | Unit Peak |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Area | MAP | Elevation | Mx Jul T | Forest | M | D | Y | | |
| n/a | Lane Canyon near Nolin, OR | 5.00 | 13.3 | 1320 | 88.6 | 0.1 | 7 | 26 | 1965 | 28500 | 5700 |
| 14045100 | East Fork Cottonwood Creek tributary near Hamilton, OR | 0.79 | 15.3 | 3620 | 81.1 | 33.6 | 5 | 15 | 1973 | 4140 | 5241 |
| n/a | Meyers Canyon near Mitchell, OR | 12.70 | 15.4 | 3400 | 84.0 | 21.1 | 7 | 13 | 1956 | 54500 | 4291 |
| n/a | Butter Creek tributary near Echo, OR | 0.33 | 10.2 | 1070 | 88.7 | 0.0 | 6 | 9 | 1948 | 1150 | 3485 |
| 14032100 | Butter Creek tributary near Pine City, OR | 1.50 | 10.5 | 1180 | 88.4 | 0.0 | 6 | 9 | 1948 | 5220 | 3480 |
| 13219300 | Malheur River tributary near Harper, OR | 0.10 | 9.6 | 2870 | 91.8 | 0.0 | 7 | 10 | 1970 | 238 | 2380 |
| 13219300 | Malheur River tributary near Harper, OR | 0.10 | 9.6 | 2870 | 91.8 | 0.0 | 6 | 8 | 1972 | 217 | 2170 |
| 14034480 | Balm Fork near Heppner, OR | 26.30 | 16.9 | 3170 | 80.9 | 0.4 | 6 | 14 | 1903 | 36000 | 1369 |
| 13219300 | Malheur River tributary near Harper, OR | 0.10 | 9.6 | 2870 | 91.8 | 0.0 | 7 | 4 | 1978 | 100 | 1000 |
| n/a | Bridge Creek above Gable Creek near Mitchell, OR | 15.00 | 17.2 | 3590 | 82.5 | 26.1 | 7 | 13 | 1956 | 14400 | 960 |
| 14032100 | Butter Creek tributary near Pine City, OR | 1.50 | 10.5 | 1180 | 88.4 | 0.0 | 8 | 14 | 1976 | 1240 | 827 |
| 14047470 | Juniper Canyon tributary near Mikkalo, OR | 1.90 | 11.4 | 1800 | 85.2 | 0.0 | 6 | 30 | 1978 | 1540 | 811 |
| 13219300 | Malheur River tributary near Harper, OR | 0.10 | 9.6 | 2870 | 91.8 | 0.0 | 1 | 19 | 1971 | 65 | 650 |
| 10395700 | Donner und Blitzen River tributary near Frenchglen, OR | 1.00 | 22.6 | 5480 | 78.5 | 12.4 | 1 | 15 | 1974 | 489 | 489 |
| 14095200 | Sagebrush Creek tributary near Gateway, OR | 10.70 | 11.1 | 2520 | 85.9 | 2.3 | 5 | 7 | 1957 | 5200 | 486 |
| 13219300 | Malheur River tributary near Harper, OR | 0.10 | 9.6 | 2870 | 91.8 | 0.0 | 12 | 23 | 1972 | 44 | 440 |
| n/a | Speare Canyon near Nolin, OR | 22.00 | 14.4 | 1680 | 87.9 | 0.0 | 7 | 26 | 1965 | 8500 | 386 |
| 14034500 | Willow Creek at Heppner, OR | 97.26 | 21.8 | 3560 | 77.8 | 25.7 | 6 | 14 | 1903 | 36000 | 370 |
| n/a | Bridge Creek below Bear Creek near Mitchell, OR | 45.00 | 15.0 | 3130 | 84.7 | 22.3 | 7 | 13 | 1956 | 16300 | 362 |
| 13219300 | Malheur River tributary near Harper, OR | 0.10 | 9.6 | 2870 | 91.8 | 0.0 | 7 | 12 | 1975 | 33 | 330 |
| 10395700 | Donner und Blitzen River tributary near Frenchglen, OR | 1.00 | 22.6 | 5480 | 78.5 | 12.4 | 3 | 2 | 1972 | 321 | 321 |
| 14048080 | Buck Canyon near Klondike, OR | 3.40 | 11.4 | 1750 | 83.4 | 0.0 | 8 | 26 | 1953 | 1030 | 303 |
| 10395700 | Donner und Blitzen River tributary near Frenchglen, OR | 1.00 | 22.6 | 5480 | 78.5 | 12.4 | 3 | 30 | 1969 | 300 | 300 |
| 14016080 | Dry Creek tributary near Milton-Freewater, OR | 1.20 | 18.9 | 1680 | 86.4 | 0.0 | 5 | 26 | 1971 | 348 | 290 |
| 14019120 | North Fork Cold Springs Canyon tributary near Holdman, OR | 2.90 | 14.7 | 1520 | 88.1 | 0.0 | 8 | 22 | 1978 | 820 | 283 |
| 14074600 | Three Creek below Snow Creek Canal near Sisters, OR | 3.04 | 53.3 | 6820 | 67.0 | 52.6 | 1 | 17 | 1971 | 836 | 275 |
| 14048080 | Buck Canyon near Klondike, OR | 3.40 | 11.4 | 1750 | 83.4 | 0.0 | 12 | 21 | 1964 | 904 | 266 |
| 14074900 | Snow Creek near Sisters, OR | 1.63 | 60.4 | 7190 | 65.6 | 32.4 | 1 | 18 | 1971 | 423 | 260 |
| 10395700 | Donner und Blitzen River tributary near Frenchglen, OR | 1.00 | 22.6 | 5480 | 78.5 | 12.4 | 3 | 30 | 1964 | 254 | 254 |
| n/a | Birch Creek tributary (Jack Canyon) at Pilot Rock, OR | 27.00 | 16.7 | 2500 | 85.3 | 0.0 | 6 | 22 | 1938 | 6300 | 233 |

**Table 1.** Maximum observed peak discharges in eastern Oregon – unit discharge greater than 100 cfs per square mile - continued.

[**Area**, drainage area, in square miles; **MAP**, mean annual precipitation, in inches; **Elevation**, mean watershed elevation, in feet; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Forest**, forest cover, in percent; **M**, month; **D**, day; **Y**, year; **Peak**, maximum observed annual peak discharge, in cubic feet per second; **Unit Peak**, maximum observed annual peak discharge divided by drainage area, in cubic feet per second per square mile]

| Station Number | Station Name | Watershed Characteristics | | | | | Date of Occurrence | | | Peak | Unit Peak |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Area | MAP | Elevation | Mx Jul T | Forest | M | D | Y | | |
| 14016200 | Pine Creek near Weston, OR | 15.46 | 29.8 | 3240 | 80.3 | 49.7 | 12 | 5 | 1971 | 3450 | 223 |
| 14016300 | Dry Creek above Little Dry Creek near Weston, OR | 19.64 | 28.9 | 3010 | 80.5 | 43.4 | 1 | 24 | 1970 | 4180 | 213 |
| 14074900 | Snow Creek near Sisters, OR | 1.63 | 60.4 | 7190 | 65.6 | 32.4 | 12 | 10 | 1987 | 341 | 209 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 1 | 20 | 1972 | 20000 | 209 |
| 13286300 | Waterspout Creek near Baker, OR | 1.00 | 10.8 | 2950 | 87.5 | 0.0 | 7 | 10 | 1970 | 208 | 208 |
| 14048020 | Grass Valley Canyon near Grass Valley, OR | 8.10 | 12.5 | 2370 | 82.9 | 0.0 | 12 | 21 | 1964 | 1570 | 194 |
| 13272300 | Job Creek tributary near Unity, OR | 0.50 | 10.1 | 3980 | 86.2 | 0.0 | 4 | 15 | 1975 | 96 | 192 |
| 14016300 | Dry Creek above Little Dry Creek near Weston, OR | 19.64 | 28.9 | 3010 | 80.5 | 43.4 | 12 | 7 | 1973 | 3600 | 183 |
| 14047470 | Juniper Canyon tributary near Mikkalo, OR | 1.90 | 11.4 | 1800 | 85.2 | 0.0 | 6 | 9 | 1972 | 346 | 182 |
| n/a | Alkali Canyon at Arlington, OR | 56.00 | 14.2 | 1810 | 87.1 | 0.1 | 6 | 26 | 1927 | 10000 | 179 |
| 14047450 | West Fork Dry Creek near Gooseberry, OR | 0.80 | 12.9 | 2530 | 84.4 | 0.0 | 12 | 22 | 1964 | 134 | 168 |
| 14016080 | Dry Creek tributary near Milton-Freewater, OR | 1.20 | 18.9 | 1680 | 86.4 | 0.0 | 3 | 27 | 1981 | 200 | 167 |
| 13286300 | Waterspout Creek near Baker, OR | 1.00 | 10.8 | 2950 | 87.5 | 0.0 | 7 | 6 | 1981 | 165 | 165 |
| 13286300 | Waterspout Creek near Baker, OR | 1.00 | 10.8 | 2950 | 87.5 | 0.0 | 8 | 3 | 1976 | 165 | 165 |
| 10395700 | Donner und Blitzen River tributary near Frenchglen, OR | 1.00 | 22.6 | 5480 | 78.5 | 12.4 | 3 | 10 | 1966 | 159 | 159 |
| 14090500 | Whitewater River near Grandview, OR | 31.80 | 58.6 | 4690 | 73.5 | 86.7 | 12 | 11 | 1992 | 4800 | 151 |
| 14019400 | Elbow Creek near Bingham Springs, OR | 0.70 | 32.1 | 3400 | 78.9 | 45.7 | 1 | 25 | 1975 | 105 | 150 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 12 | 13 | 1977 | 14300 | 149 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 2 | 7 | 1996 | 13900 | 145 |
| n/a | Warmsprings Creek near Mt Vernon, OR | 2.73 | 16.1 | 4200 | 84.1 | 48.4 | 7 | 10 | 1956 | 393 | 144 |
| 14047450 | West Fork Dry Creek near Gooseberry, OR | 0.80 | 12.9 | 2530 | 84.4 | 0.0 | 8 | 15 | 1979 | 115 | 144 |
| 14019400 | Elbow Creek near Bingham Springs, OR | 0.70 | 32.1 | 3400 | 78.9 | 45.7 | 1 | 30 | 1965 | 99 | 141 |
| 14016300 | Dry Creek above Little Dry Creek near Weston, OR | 19.64 | 28.9 | 3010 | 80.5 | 43.4 | 1 | 19 | 1971 | 2760 | 141 |
| 14077800 | Wolf Creek tributary near Paulina, OR | 2.20 | 22.6 | 5140 | 78.1 | 70.1 | 12 | 22 | 1964 | 300 | 136 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 1 | 15 | 1974 | 13000 | 136 |
| 13287200 | West Eagle Creek below Jim Creek near Baker, OR | 15.72 | 49.7 | 6760 | 67.8 | 56.0 | 6 | 15 | 1974 | 2130 | 135 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 12 | 22 | 1933 | 12900 | 135 |
| 13231700 | Canyon Creek tributary near Brogan, OR | 1.20 | 11.9 | 4020 | 87.2 | 0.0 | 7 | 12 | 1975 | 150 | 125 |
| 14019400 | Elbow Creek near Bingham Springs, OR | 0.70 | 32.1 | 3400 | 78.9 | 45.7 | 6 | 20 | 1974 | 86 | 123 |
| 14079750 | Crooked River tributary near Post, OR | 0.30 | 13.2 | 3810 | 82.9 | 51.0 | 6 | 10 | 1969 | 36 | 120 |

**Table 1.** Maximum observed peak discharges in eastern Oregon – unit discharge greater than 100 cfs per square mile - continued.

[**Area**, drainage area, in square miles; **MAP**, mean annual precipitation, in inches; **Elevation**, mean watershed elevation, in feet; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Forest**, forest cover, in percent; **M**, month; **D**, day; **Y**, year; **Peak**, maximum observed annual peak discharge, in cubic feet per second; **Unit Peak**, maximum observed annual peak discharge divided by drainage area, in cubic feet per second per square mile]

| Station Number | Station Name | Watershed Characteristics | | | | | Date of Occurrence | | | Peak | Unit Peak |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Area | MAP | Elevation | *Mx Jul T* | Forest | M | D | Y | | |
| 14120000 | Hood River at Tucker Bridge near Hood River, OR | 278.37 | 75.8 | 3350 | 71.3 | 77.1 | 12 | 22 | 1964 | 33200 | 119 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 12 | 12 | 1955 | 11300 | 118 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 2 | 23 | 1986 | 11200 | 117 |
| 14046650 | Carrol Creek near Mitchell, OR | 0.30 | 14.5 | 3820 | 82.8 | 42.5 | 6 | 10 | 1969 | 35 | 117 |
| 14113200 | Mosier Creek near Mosier, OR | 41.40 | 31.3 | 2190 | 79.7 | 85.9 | 12 | 23 | 1964 | 4790 | 116 |
| 14046650 | Carrol Creek near Mitchell, OR | 0.30 | 14.5 | 3820 | 82.8 | 42.5 | 2 | 6 | 1979 | 34 | 113 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 11 | 24 | 1960 | 10800 | 113 |
| 14016080 | Dry Creek tributary near Milton-Freewater, OR | 1.20 | 18.9 | 1680 | 86.4 | 0.0 | 3 | 2 | 1972 | 135 | 113 |
| 14021600 | Nelson Creek at Pendleton, OR | 2.60 | 13.6 | 1450 | 88.2 | 0.2 | 8 | 22 | 1978 | 290 | 112 |
| 14016300 | Dry Creek above Little Dry Creek near Weston, OR | 19.64 | 28.9 | 3010 | 80.5 | 43.4 | 1 | 6 | 1969 | 2190 | 112 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 11 | 23 | 1942 | 10600 | 111 |
| 14048040 | Gordon Hollow at De Moss Springs, OR | 8.90 | 11.3 | 1980 | 82.4 | 0.0 | 12 | 21 | 1964 | 984 | 111 |
| 14092750 | Shitike Creek at Peters Pasture near Warm Springs, OR | 22.21 | 66.0 | 4860 | 72.4 | 89.7 | 2 | 7 | 1996 | 2430 | 109 |
| 14047470 | Juniper Canyon tributary near Mikkalo, OR | 1.90 | 11.4 | 1800 | 85.2 | 0.0 | 1 | 12 | 1980 | 207 | 109 |
| 13269200 | Moores Hollow tributary near Weiser, Id | 0.90 | 11.0 | 2840 | 92.7 | 0.0 | 8 | 10 | 1965 | 98 | 109 |
| 14021600 | Nelson Creek at Pendleton, OR | 2.60 | 13.6 | 1450 | 88.2 | 0.2 | 1 | 30 | 1965 | 278 | 107 |
| 14016200 | Pine Creek near Weston, OR | 15.46 | 29.8 | 3240 | 80.3 | 49.7 | 2 | 14 | 1981 | 1640 | 106 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 12 | 12 | 1946 | 10100 | 105 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 12 | 27 | 1998 | 10100 | 105 |
| 13177885 | Pole Creek tributary near McDermitt, NV | 1.00 | 13.5 | 5500 | 85.0 | 0.0 | 1 | 21 | 1972 | 105 | 105 |
| 14021600 | Nelson Creek at Pendleton, OR | 2.60 | 13.6 | 1450 | 88.2 | 0.2 | 2 | 6 | 1979 | 270 | 104 |
| 14121000 | Hood River near Hood River, OR | 331.99 | 70.3 | 3090 | 72.3 | 73.6 | 1 | 6 | 1923 | 34000 | 102 |
| 14016200 | Pine Creek near Weston, OR | 15.46 | 29.8 | 3240 | 80.3 | 49.7 | 1 | 24 | 1970 | 1580 | 102 |
| 14090400 | Whitewater River near Camp Sherman, OR | 22.87 | 68.3 | 5140 | 71.4 | 82.2 | 2 | 7 | 1996 | 2320 | 101 |
| 14047450 | West Fork Dry Creek near Gooseberry, OR | 0.80 | 12.9 | 2530 | 84.4 | 0.0 | 9 | 18 | 1969 | 81 | 101 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 12 | 25 | 1980 | 9680 | 101 |
| 14118500 | West Fork Hood River near Dee, OR | 95.79 | 86.2 | 3140 | 71.9 | 84.2 | 12 | 28 | 1945 | 9660 | 101 |
| 14019400 | Elbow Creek near Bingham Springs, OR | 0.70 | 32.1 | 3400 | 78.9 | 45.7 | 3 | 19 | 1976 | 70 | 100 |
| 14093700 | Woods Hollow at Ashwood, OR | 1.40 | 13.6 | 3190 | 83.2 | 24.5 | 2 | 7 | 1979 | 140 | 100 |

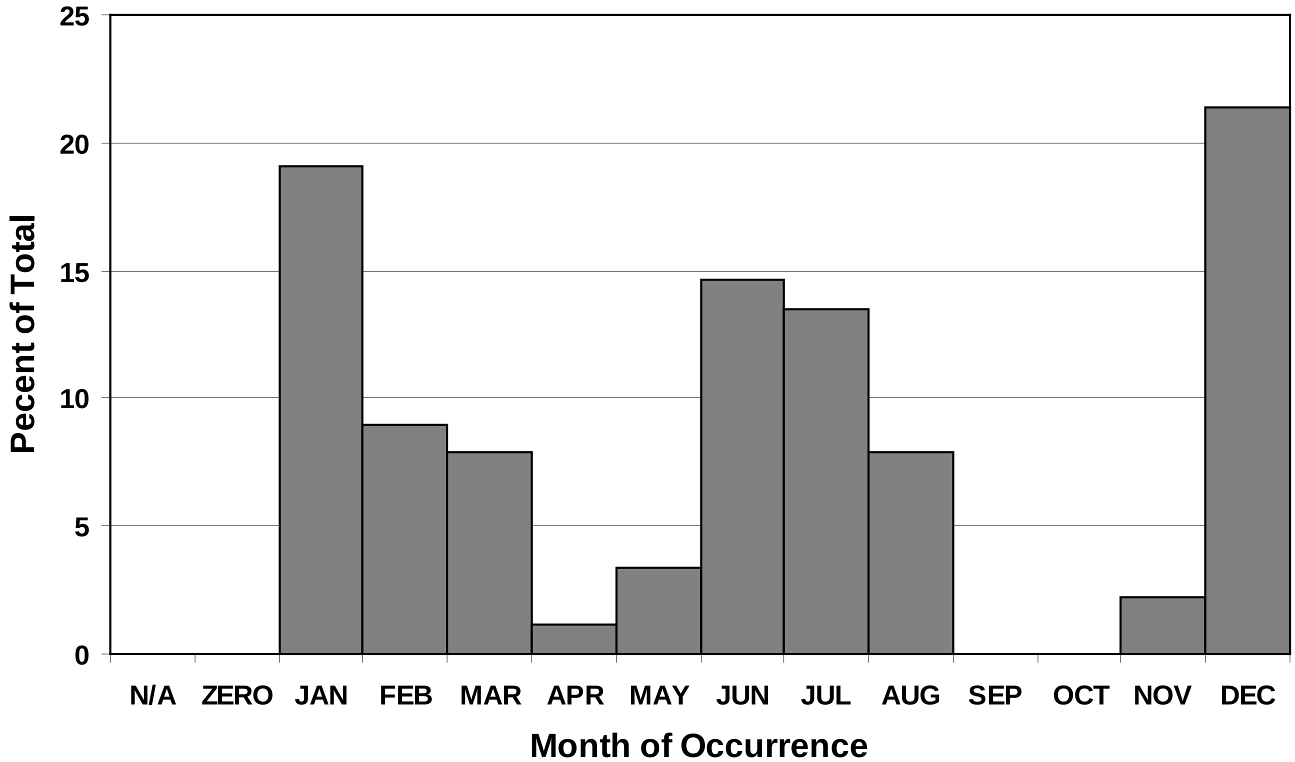



**Figure 4**. Monthly distribution of occurrence of the 89 observed peaks with unit discharges greater than 100 cfs per square mile. There are no zero peaks or peaks with an unknown date of occurrence.

**Table 2.** The watersheds associated with the 89 largest unit peak discharges were scored based on five watershed characteristics. Each watershed received one point for any of the following that are true: 1) drainage area less than 50 square miles, b) mean annual precipitation less than 20 inches, c) mean watershed elevation less than 4,000 feet, d) mean maximum July temperature greater than 80 degrees Fahrenheit, and e) forest cover less than 35 percent.

| Watershed Score | All Peaks | | Summer Peaks May 1 to October 31* | | Winter Peaks November 1 to April 30 | |
|---|---|---|---|---|---|---|
| | Number of Watersheds | Number of Peaks | Number of Watersheds | Number of Peaks | Number of Watersheds | Number of Peaks |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 9 | 21 | 1 | 1 | 8 | 20 |
| 2 | 5 | 13 | 2 | 2 | 5 | 11 |
| 3 | 3 | 8 | 1 | 1 | 2 | 7 |
| 4 | 5 | 6 | 4 | 4 | 2 | 2 |
| 5 | 23 | 41 | 20 | 28 | 10 | 13 |
| Totals | 45 | 89 | 28 | 36 | 27 | 53 |

* There are no peaks in October and only one in September.

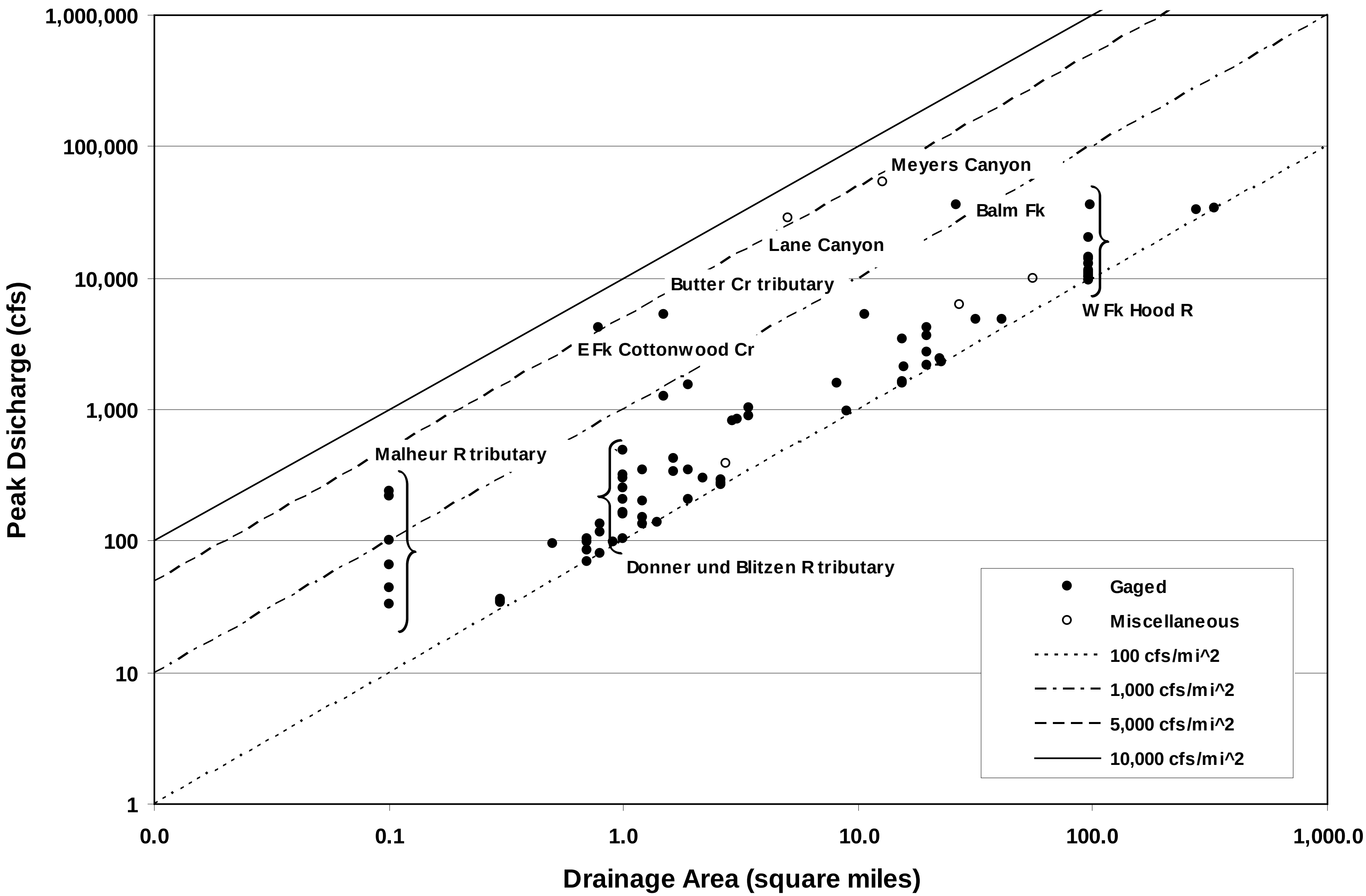



**Figure 5.** Observed annual peaks with unit discharges greater than 100 cfs/mi$^2$ plotted against area. Peak discharges above 1,000 cfs/mi$^2$ were most likely all due to thunderstorms.

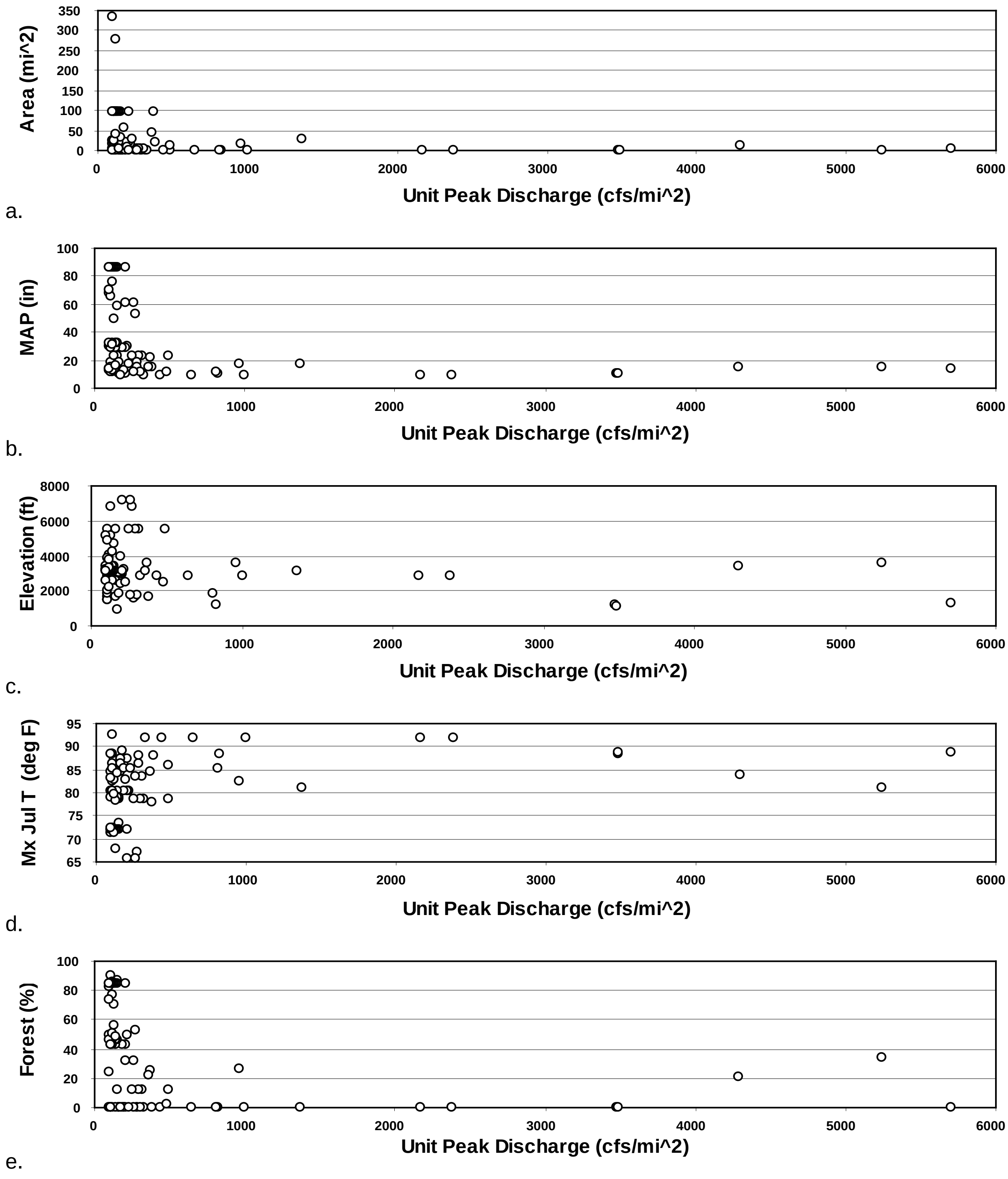



**Figure 6.** The 89 largest unit peak discharges for eastern Oregon plotted against selected watershed characteristics: a) drainage area, in square miles, b) mean annual precipitation (MAP), in inches, c) mean watershed elevation, in feet, d) mean maximum July temperature, in degrees Fahrenheit, and e) forest cover, in percent.

**Table 3.** Watersheds with multiple large unit peak discharges (greater than 100 cfs per square mile) from a total of 89 such peaks.

| Gage Number | Gaging Station Name | Number of Peaks | | |
|---|---|---|---|---|
| | | Summer May 1 to October 30* | Winter November 1 to April 30 | Total |
| 14118500 | West Fork Hood River near Dee, OR | 0 | 13 | 13 |
| 13219300 | Malheur River tributary near Harper, OR | 4 | 2 | 6 |
| 10395700 | Donner und Blitzen River tributary near Frenchglen, OR | 0 | 5 | 5 |
| 14019400 | Elbow Creek near Bingham Springs, OR | 1 | 3 | 4 |
| 14016300 | Dry Creek above Little Dry Creek near Weston, OR | 0 | 4 | 4 |
| 13286300 | Waterspout Creek near Baker, OR | 3 | 0 | 3 |
| 14047470 | Juniper Canyon tributary near Mikkalo, OR | 2 | 1 | 3 |
| 14021600 | Nelson Creek at Pendleton, OR | 1 | 2 | 3 |
| 14047450 | West Fork Dry Creek near Gooseberry, OR | 2 | 1 | 3 |
| 14016080 | Dry Creek tributary near Milton-Freewater, OR | 1 | 2 | 3 |
| 14016200 | Pine Creek near Weston, OR | 0 | 3 | 3 |
| 14032100 | Butter Creek tributary near Pine City, OR | 2 | 0 | 2 |
| 14046650 | Carrol Creek near Mitchell, OR | 1 | 1 | 2 |
| 14048080 | Buck Canyon near Klondike, OR | 1 | 1 | 2 |
| 14074900 | Snow Creek near Sisters, OR | 0 | 2 | 2 |
| Totals | 15 Watersheds | 18 | 40 | 58 |

* There are no peaks in October and only one in September.

scores of 0 to 2 while 12 of 27 watersheds (44percent) had scores of 4 or 5. In other words, watersheds with high scores are likely to have peaks either summer or winter, while watersheds with low scores are likely to have peaks only in winter. Of watersheds with multiple peaks, five had winter peaks only, two had summer peaks only, and eight had both winter and summer peaks.

Most of the 36 summer peak discharges resulted from thunderstorms. By delineating on a map of the State the watershed characteristics previously associated with these peaks, the areas prone to severe thunderstorms can be identified. On figure 7, areas of the State are delineated with mean annual precipitation less than 20 inches (horizontal blue hatching), mean maximum July temperatures greater than 80 degrees Fahrenheit (diagonal red hatching), and mean watershed elevations less than 4,000 feet (diagonal green hatching). Also delineated are areas of forest (solid light green).

Thunderstorm prone areas on figure 7 are those areas with little or no forest cover where all three hatched areas overlap. They are in north central and far eastern Oregon. Also shown on figure 7 are the locations of the 36 largest summer peaks, i.e., those peaks most likely to have resulted from a thunderstorm.

Note that on figure 7, the summer peak for West Eagle Creek below Jim Creek near Baker, OR (#2) falls well outside the thunderstorm prone area. The peak was mostly, if not entirely, the result of snowmelt. Temperatures were over 90 degrees Fahrenheit throughout much of northeastern Oregon at the time. The mean flow for both the day before and the day after was 1,220 cfs, and on the day of the peak, 1,600 cfs. The instantaneous peak was only 2,130 cfs. If a thunderstorm was involved with this peak, it contributed only part of the flow.

In terms of unit discharge, eastern Oregon has experienced only a few extreme events. Only 13 peak discharges, out of nearly 7,000, are known to have exceeded 500 cfs per square mile. The highest recorded unit peak discharge was 5,700 cfs per square mile from Lane Canyon near Nolin, OR on July 26, 1965. This unit peak discharge is among the largest recorded in the United States.

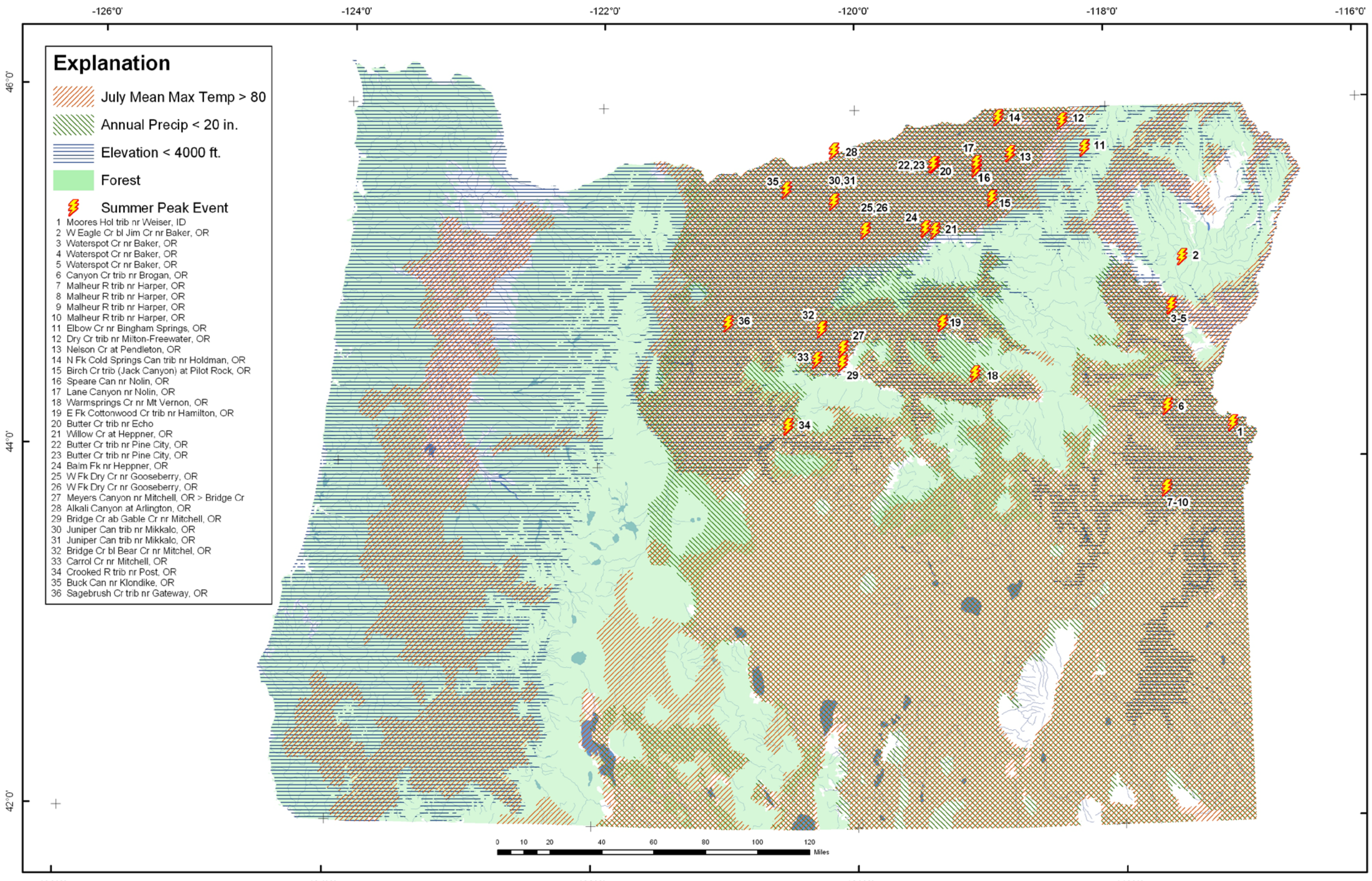



**Figure 7.** Thunderstorm prone areas of eastern Oregon. Thunderstorms are most likely to occur in areas with little or no forest cover where July mean maximum temperatures are above 80 degrees Fahrenheit, mean annual precipitation is below 20 inches and mean watershed elevation is below 4,000 feet.

Without exception, the 13 largest of the large unit peak discharges scored five based on their watershed characteristics. With one exception, these 13 largest of the large unit peaks occurred in summer. The 12 summer peaks are most likely the result of thunderstorms. The low elevations and small drainage areas of the watersheds and the very high discharges make it unlikely the peaks resulted from snow melt.

The one winter peak was from the watershed above the gaging station Malheur River tributary near Harper, OR (13219300). The other three peak discharges for this watershed occurred in summer. Remarkably, this watershed accounted for 4 of the 13 largest unit peak discharges and 6 of the largest 89 largest unit peak discharges. As will be discussed later, this watershed is not like other watersheds in the area. In forming the prediction equations, it was an extreme outlier at every return interval.

One other watershed had more than one peak in the top 13. Butter Creek tributary near Pine City, OR (14032100) contributed two peaks.

Two storms accounted for 4 of the largest 13 unit peak discharges. A thunderstorm on June 9, 1948 caused the peaks on Butter Creek tributary near Echo, OR and Butter Creek tributary near Pine City, OR. A thunderstorm on July 13, 1958 caused the peaks on Meyers Canyon near Mitchell, OR, and Bridge Creek above Gable Creek near Mitchell, OR. This second storm also caused a large unit peak discharge for Bridge Creek below Bear Creek near Mitchell. OR, but this peak did not make the top 13.

## Frequency of Thunderstorms

Large unit peak discharges due to thunderstorms are not well represented in the systematic record. In fact, among the gaging stations used in this study, they have almost no representation. Recall from the previous section that the analysis of the characteristics of peak discharges included more gaging stations and measurement sites than were used in the flood frequency analysis (340 vs. 194[3], respectively). If the analysis were restricted to just the peaks associated with the 194 gaging stations in eastern Oregon used in the flood frequency analysis there would be 6,074 peaks instead of 6,960. Although the reduction in the number of peaks is almost 13 percent, the distribution of peaks by month is similar (fig. 8).

What is not similar is the representation of the very largest unit peak discharges. Among the peak discharges associated with the 194 gaging stations, only 36 have unit discharges greater than 100 cfs per square mile. Of these, only one has a unit discharge in excess of 500 cfs per square mile. Large unit peak discharges due to thunderstorms are essentially unrepresented in the flood frequency analysis. What impact this has on the estimation of peak discharges is unknown.

There appears to be two reasons for this under representation: 1) extreme thunderstorms are infrequent, and 2) the watersheds where these extreme floods are most likely to occur are unlikely to be systematically measured or gaged. Extreme floods resulting from thunderstorms are associated with watersheds of a particular type (Figure 7 and Table 2). These watersheds do not generate much streamflow, being dry much of every year and often having years without any streamflow at all. Because they have little streamflow, these watersheds are seldom gaged. When measured, as with the crest stage gage program of the 1960s, 1970s, and 1980s, the resulting annual series often has too many zero peaks to be fitted to a log-Pearson Type III distribution. The fitting of the log-Pearson Type III distribution to an annual series of peak discharges is described later in the report.

# Historic Floods

The occurrence of regional and flash floods in eastern Oregon have been described in a number of reports. Particularly helpful was “The Oregon Weather Book, a State of Extremes” (Taylor and Hatton, 1999). Several USGS reports provided useful descriptions of floods, particularly those arising from thunderstorms. A report by the US Army Corps of Engineers (1978) described flash floods in the Willow Creek Basin in detail.

[3] In total, 276 gaging stations were included in the flood frequency analysis. Of these, 194 were actually in eastern Oregon. The rest were in California, Nevada, Idaho and Washington.

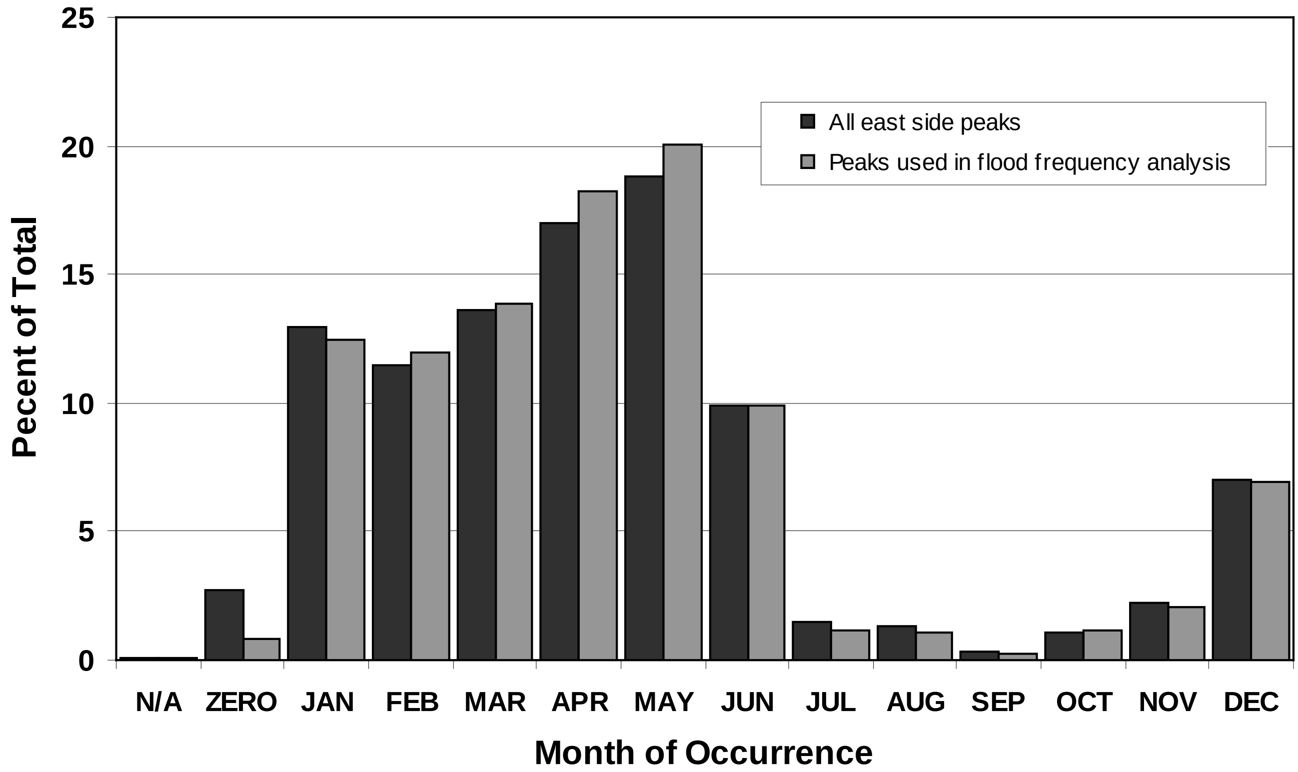



**Figure 8**. A comparison of the monthly distributions of occurrence of all east side peaks and the peaks used in the flood frequency analysis.

Not all significant high water events are found in these reports, however. To identify other periods of high water, each annual peak discharge for the 276 gaging stations was analyzed to determine its approximate recurrence interval. This analysis revealed a number of significant high streamflow events otherwise unreported. They are briefly described below. The underlying hydrologic processes of these events were not determined, however. Table 4 lists the 55 peak discharges greater than the 100-year event for their respective gaging station.

Little is known about floods in eastern Oregon prior to 1900. What little evidence of flooding is available suggests that flash floods, while not common, probably occurred regularly in some areas. No reports of regional flooding were found. The U.S. Army Corps of Engineers (1978) reported five flash floods occurring from 1881 to 1900 in the Willow Creek drainage in Morrow County, and Taylor and Hatton (1999) reported a flash flood on Bridge Creek near Mitchell on June 2, 1894. It is interesting to note that all five floods in the Willow Creek drainage also occurred in June. Neither report provides information about flow rates or flood volumes.

None of these flash floods was wide spread, each affecting only limited stream reaches. Given that the population in the region was sparse and streamflow records very few, and that the effects of these floods tended to be local, other flash floods probably occurred but went unreported because they caused little or no damage, or simply were unobserved.

Possibly the best-known flood in eastern Oregon occurred on June 14, 1903. This flash flood destroyed much of the town of Heppner and killed more than 200 people (U.S. Army Corps of Engineers, 1978; Hubbard, 1991; Taylor and Hatton, 1999). The flood originated from a thunderstorm centered over Balm Fork, a tributary of Willow Creek. Balm Fork enters Willow Creek just upstream of Heppner. The flow rate at Heppner was 36,000 cfs making the unit discharge from Balm Fork almost 1,400 cfs per square mile. While this flood is well known because of the number of deaths and the

**Table 4.** Observed peak discharges in eastern Oregon greater than a 100-year event.

[**Area**, drainage area, in square miles; **M**, month; **D**, day; **Y**, year; **Peak**, observed annual peak discharge, in cubic feet per second; **Unit Peak**, observed annual peak discharge divided by drainage area, in cubic feet per second per square mile; **X 100**, the ratio of the observed peak discharge to the estimated 100-year peak discharge]

| Station Number | Station Name | Area | Date of Occurrence | | | Peak | Unit Peak | X 100 |
|---|---|---|---|---|---|---|---|---|
| | | | M | D | Y | | | |
| 14034480 | Balm Fork near Heppner, OR | 26.3 | 6 | 14 | 1903 | 36,000 | 1370 | 20.4 |
| 14034500 | Willow Creek at Heppner, OR | 97.3 | 6 | 14 | 1903 | 36,000 | 370 | 10.7 |
| 10403500 | Silver Creek above Suntex, OR | 260 | 4 | 14 | 1904 | 1,760 | 6.8 | 1.03 |
| 13275500 | Powder River near Baker, OR | 216 | 3 | 20 | 1910 | 1,820 | 8.4 | 1.01 |
| 10406500 | Trout Creek near Denio, NV | 85.5 | 8 | 1 | 1933 | 470 | 5.5 | 1.07 |
| 13325000 | East Fork Wallowa River near Joseph, OR | 10.3 | 7 | 25 | 1937 | 450 | 43.7 | 1.40 |
| 13320000 | Catherine Creek near Union, OR | 103 | 5 | 27 | 1948 | 1,740 | 16.9 | 1.07 |
| 14032000 | Butter Creek near Pine City, OR | 287 | 2 | 21 | 1949 | 3,800 | 13.2 | 1.03 |
| 14050500 | Cultus River above Cultus Creek near La Pine, OR | 19.6 | 5 | 31 | 1956 | 178 | 9.1 | 1.03 |
| 14054500 | Brown Creek near La Pine, OR | 20.4 | 8 | 4 | 1956 | 104 | 5.1 | 1.04 |
| 14054500 | Brown Creek near La Pine, OR | 20.4 | 12 | 11 | 1956 | 101 | 5.0 | 1.01 |
| 14081800 | Ahalt Creek near Mitchell, OR | 2.3 | 12 | 21 | 1964 | 122 | 53.0 | 1.18 |
| 10384000 | Chewaucan River near Paisley, OR | 267 | 12 | 22 | 1964 | 6,490 | 24.3 | 1.24 |
| 11494800 | Brownsworth Creek near Bly, OR | 2.2 | 12 | 22 | 1964 | 66 | 30.0 | 1.09 |
| 14038500 | John Day River at Prairie City, OR | 230 | 12 | 22 | 1964 | 2,400 | 10.4 | 1.02 |
| 14077800 | Wolf Creek tributary near Paulina, OR | 2.2 | 12 | 22 | 1964 | 300 | 136 | 1.34 |
| 14078000 | Beaver Creek near Paulina, OR | 451 | 12 | 22 | 1964 | 12,800 | 28.4 | 1.71 |
| 10370000 | Camas Creek near Lakeview, OR | 66.1 | 12 | 23 | 1964 | 3,190 | 48.3 | 1.65 |
| 10378500 | Honey Creek near Plush, OR | 167 | 12 | 23 | 1964 | 11,000 | 65.8 | 1.65 |
| 13214000 | Malheur River near Drewsey, OR | 944 | 12 | 23 | 1964 | 12,000 | 12.7 | 1.09 |
| 13216500 | North Fork Malheur River above Beulah Reservoir near Beulah, OR | 342 | 12 | 23 | 1964 | 3,970 | 11.6 | 1.02 |
| 14048000 | John Day River at McDonald Ferry, OR | 7630 | 12 | 24 | 1964 | 42,800 | 5.6 | 1.00 |
| 14091500 | Metolius River near Grandview, OR | 318 | 12 | 24 | 1964 | 7,530 | 23.7 | 1.04 |
| 14052000 | Deer Creek above Crane Prairie Reservoir near La Pine, OR | 13.0 | 12 | 25 | 1964 | 200 | 15.4 | 1.24 |
| 14055500 | Odell Creek near Crescent, OR | 37.9 | 12 | 25 | 1964 | 1,100 | 29.1 | 1.61 |
| 11501000 | Sprague River near Chiloquin, OR | 1,600 | 12 | 26 | 1964 | 14,900 | 9.3 | 1.08 |

**Table 4.** Observed peak discharges in eastern Oregon greater than a 100-year event – continued.

[**Area**, drainage area, in square miles; **M**, month; **D**, day; **Y**, year; **Peak**, observed annual peak discharge, in cubic feet per second; **Unit Peak**, observed annual peak discharge divided by drainage area, in cubic feet per second per square mile; **X 100**, the ratio of the observed peak discharge to the estimated 100-year peak discharge]

| Station Number | Station Name | Area | Date of Occurrence | | | Peak | Unit Peak | X 100 |
|---|---|---|---|---|---|---|---|---|
| | | | M | D | Y | | | |
| 11502500 | Williamson River below Sprague River near Chiloquin, OR | 3,000 | 12 | 26 | 1964 | 16,100 | 5.4 | 1.08 |
| 13319000 | Grande Ronde River at La Grande, OR | 691 | 1 | 30 | 1965 | 14,100 | 20.4 | 1.33 |
| 14042500 | Camas Creek near Ukiah, OR | 121 | 1 | 30 | 1965 | 3,840 | 31.8 | 1.04 |
| 14118500 | West Fork Hood River near Dee, OR | 95.8 | 1 | 20 | 1972 | 20,000 | 209 | 1.10 |
| 13287200 | W Eagle Creek below Jim Creek near Baker, OR | 15.7 | 6 | 15 | 1974 | 2,130 | 136 | 1.00 |
| 13272300 | Job Creek tributary near Unity, OR | 0.5 | 4 | 15 | 1975 | 96 | 192 | 1.24 |
| 13288200 | Eagle Creek above Skull Creek near New Bridge, OR | 156 | 7 | 12 | 1975 | 5,310 | 34.0 | 1.14 |
| 14037500 | Strawberry Creek above Slide Creek near Prairie City, OR | 7.0 | 5 | 31 | 1983 | 354 | 50.9 | 1.14 |
| 13283600 | Wolf Creek above Wolf Creek reservoir near North Powder, OR | 30.9 | 5 | 13 | 1984 | 1,350 | 43.7 | 1.15 |
| 13275200 | Deer Creek above Phillips Lake near Sumpter, OR | 33.4 | 4 | 15 | 1989 | 1,240 | 37.2 | 1.05 |
| 14020740 | Moonshine Creek near Mission, OR | 4.6 | 2 | 7 | 1996 | 247 | 53.7 | 1.31 |
| 14090400 | Whitewater River near Camp Sherman, OR | 22.9 | 2 | 7 | 1996 | 2,320 | 101 | 1.61 |
| 14091500 | Metolius River near Grandview, OR | 318 | 2 | 7 | 1996 | 8,430 | 26.6 | 1.16 |
| 14095500 | Warm Springs River near Simnasho, OR | 106 | 2 | 7 | 1996 | 4,670 | 44.0 | 1.88 |
| 14097100 | Warm Springs River near Kahneeta Hot Springs, OR | 525 | 2 | 7 | 1996 | 22,600 | 43.0 | 1.00 |
| 13324300 | Lookingglass Creek near Looking Glass, OR | 77.1 | 2 | 9 | 1996 | 2,120 | 27.5 | 1.15 |
| 13332500 | Grande Ronde River at Rondowa, OR | 2,590 | 2 | 9 | 1996 | 28,400 | 11.0 | 1.10 |
| 13333000 | Grande Ronde River at Troy, OR | 3,310 | 2 | 9 | 1996 | 51,800 | 15.7 | 1.10 |
| 14088000 | Lake Creek near Sisters, OR | 20.9 | 2 | 10 | 1996 | 589 | 28.1 | 1.04 |
| 10384000 | Chewaucan River near Paisley, OR | 267 | 1 | 1 | 1997 | 7,010 | 26.3 | 1.34 |
| 13292000 | Imnaha River at Imnaha, OR | 621 | 1 | 1 | 1997 | 20,200 | 32.5 | 1.79 |
| 14051000 | Cultus Creek above Crane Prairie reservoir near La Pine, OR | 35.0 | 1 | 2 | 1997 | 386 | 11.0 | 1.01 |
| 14055600 | Odell Creek near La Pine, OR | 49.3 | 1 | 2 | 1997 | 778 | 15.8 | 1.13 |
| 11502500 | Williamson River below Sprague River near Chiloquin, OR | 3,000 | 1 | 5 | 1997 | 17,100 | 5.7 | 1.15 |
| 13330500 | Bear Creek near Wallowa, OR | 67.0 | 5 | 30 | 2003 | 2150 | 32.1 | 1.03 |

damage done, other flash floods in Oregon have had greater unit runoffs.

High streamflows occurred in the Cascade Range near Mount Jefferson and Mount Hood on January 6 and 7, 1923. Peak discharges in the White and Hood Rivers exceeded 50-year events and in the Metolius River, the peak discharge exceeded the 25-year event.

The earliest report of an eastern Oregon flood with regional effects was for an event that occurred March 31 to April 1, 1931 (Hubbard, 1991; Taylor and Hatton, 1999). This flood was a rain on snow event affecting most of the Cascade Range and the Blue Mountains. All of western Oregon was also affected. Hubbard estimated the recurrence intervals to be from 10 to 50 years.

High streamflows occurred throughout the Blue Mountains March 18 – 20, 1932. Return intervals for peak discharges were from 10 to 50 years.

Heavy warm rains falling on snow caused flooding in northwestern and north-central Oregon from December 21 – 24, 1933 (Taylor and Hatton, 1999). Affected areas in eastern Oregon were in the Hood River basin, the lower Deschutes and John Day Rivers and the Umatilla River. Recurrence intervals for affected steams were 10 to 25 years.

High peak discharges occurred in streams in northeast Oregon December 12 – 15, 1946. In the Umatilla River basins and parts of the North Fork John Day basin estimated recurrence intervals for affected streams were from 10 to 25 years. For the forks of the Walla Walla River, recurrence intervals exceeded 50 years.

On June 9, 1948, a thunderstorm near Echo Oregon caused very high discharges in two unnamed tributaries to Butter Creek (Hulsing and Kallio, 1964). The larger flow was 5,220 cfs from a drainage area of 1.4 square miles. The smaller flow was 1,150 cfs from 0.33 square miles. The unit discharges were 3,730 and 3,480 cfs per square mile, respectively.

A thunderstorm on June 17, 1950 over Balm Canyon, a tributary to Rhea Creek, caused a discharge of 2,700 cfs from the 28 square mile drainage (Wells, 1954; Hulsing and Kallio, 1964). The unit discharge was 96.4 cfs per square mile. Balm Canyon should not be confused with Balm Fork, the source of the 1903 Heppner flood.

Warm weather from March 25 – 28 and again in the first week of April 1952, led to melting of much of an above-normal snow pack in northeastern and north-central Oregon (Wells, 1959a). Maximum discharges exceeded previous highs for many streams. No recurrence intervals were reported, but the current analysis shows this event was no more than a 10- or 25-year event in most locations. However, for the Malheur River near Drewsey, OR (13214000) and the John Day River near Prairie City, OR (14036800), the recurrence interval was more than 50 years and for the Silvies River near Burns, OR (10393500), more than 100 years.

A thunderstorm on August 10, 1952 over the upper end of Eightmile Canyon near the town of Eightmile caused a flash flood with a unit discharge of over 200 cfs per square mile (Wells, 1959a). The contributing area of Eightmile Canyon above Eightmile is about 10 square miles. High flow lasted only 1 to 1.5 hours and then receded rapidly.

A thunderstorm on August 26, 1953 near Klondike Oregon resulted in a flash flood in Bull Run Canyon (Wells, 1959b). The discharge was 1,030 cfs from a contributing area of 3.9 square miles or 264 cfs per square mile.

A thunderstorm on August 28, 1953 near Lexington Oregon caused a peak discharge of 1,740 cfs in Black Horse Creek (Wells, 1959b; Hulsing and Kallio, 1964). The contributing area was 23.4 square miles and the unit discharge 74.4 cfs per square mile. This same storm generated discharges of 2,110 cfs in Eightmile Canyon 10 miles south of Ione and 3,240 cfs from Clark Canyon 0.7 mile downstream from Fuller Canyon near Lexington (Wells, 1959b). Neither drainage areas nor unit discharges are reported for these two watersheds.

A series of storms from December 1955 to January 1956 caused widespread flooding in most of California, western Nevada, western Oregon and parts of Idaho. In eastern Oregon, the Klamath River and its tributaries, the Chewaucan River, and Thomas and Deep Creeks were affected. Warm temperatures and rain at high elevation melted much of the accumulated snow pack, resulting in record-breaking streamflows for many streams (Wells, 1962; Hofmann and Rantz, 1963). Recurrence intervals varied from 10 to 50 years, depending on location (Hubbard, 1991).

High streamflows occurred in a number of streams in the Blue Mountains on May 8 and 9, 1956. Return intervals for peak discharges were from 10 to 50 years.

A thunderstorm centered near Mt. Vernon, Oregon, occurred on July 10, 1956 (Hendricks, 1964). Rainfall and hail from the storm generated high discharges in Beech Creek, and its tributary, Warm Springs Creek. The peak discharge on Warm springs Creek was 393 cfs from a contributing area of 2.73 square miles. The peak discharge on Beech Creek was 929 cfs from an estimated contributing area of 12.5 square miles (out of 113 squares miles total for Beech Creek). The unit discharges were 144 and 74.3 cfs per square mile, respectively.

One of the largest unit discharges ever measured in the United States resulted from a thunderstorm near Mitchell Oregon on July 13, 1956 (Hendricks, 1964). The storm generated runoff in parts of both the Bridge and Girds Creek watersheds. The most flow occurred from Meyers Canyon where the discharge was estimated to be 54,500 cfs from a drainage area of 12.7 square miles. The unit discharge was 4,290 cfs per square mile.

Rain falling on snow and frozen ground caused flooding in eastern Washington, eastern Oregon and southern Idaho from February 24 – 28, 1957 (Hendricks, 1963). In Oregon, flooding was confined to the Malheur and Powder River basins and Prairie Creek in the Grande Ronde basin. Flooding on the Malheur was most severe. The current analysis shows the recurrence interval for the Malheur River near Drewsey, OR (13214000) was about 100 years and for Bully Creek near Vale, OR (13227000), in excess of 50 years.

Flooding occurred in the Powder, Burnt, Malheur, and Owyhee basins and near Lakeview during the period of January 31 to February 5, 1963 as the result of a sudden thaw and moderate rain on snow (Rostvedt, 1968). Based on peak streamflow data available as of 1963, recurrence intervals for some streams near Lakeview were estimated to be in excess of 50 years (Rostvedt, 1968). The current analysis shows that the recurrence intervals were probably less than 50 years except for Honey Creek near Plush, OR (10378500), where the recurrence interval was well in excess of 50 years. In eastern Oregon, floods in 1964 and 1996 generally exceeded the 1963 flood.

The floods that occurred in December 1964 and January 1965 were extreme (Waananen, and others, 1971). All of Oregon, northern California, and parts of Idaho and southern Washington were affected. Many streams had peak discharges in excess of a 100-year event. Beaver Creek near Paulina, OR (14078000), Camas Creek near Lakeview, OR (1037000), and Odell Creek near Crescent, OR (14055500) had peak discharges in excess of the 500-year event.

The storms and resulting flooding are remarkable both because of the high discharges and because of the very large area affected. Discharges on many streams in Oregon were the highest recorded up to that time and on many of those streams the 1964 flood remains the highest on record. On many other streams, only the 1996 flood exceeds that of 1964.

The floods were caused by three major storms occurring between December 19 and January 31. The greatest of these occurred December 19 – 23. All of the storms were from the southwest bringing torrential warm rains. Peak discharges were substantially increased from snowmelt due to warm temperatures and strong winds.

The greatest recorded peak for any stream in eastern Oregon for this flood period was 42,800 cfs at the gaging station on the John Day River at McDonald Ferry, OR (14048000). By the current analysis, this flow corresponds to a 100-year event. It is interesting to note that for this event the discharge from the 7,630 square mile John Day watershed was less than the discharge from the 12.7 square mile Meyers Canyon watershed during the thunderstorm of July 13, 1956.

The highest known unit discharge in Oregon resulted from a thunderstorm that occurred July 26, 1965 near Nolin, Oregon (Hubbard, 1991; Taylor and Hatton 1999; Rostvedt, 1970). High flows occurred in several watersheds in the vicinity, but the highest discharge by far was in Lane Canyon. The flow at the mouth of the canyon (5.04 square miles) was estimated to be 28,500 cfs – a remarkable 5,650 cfs per square mile. Neighboring Speare Canyon generated 14,600 cfs from a total watershed area of 23.0 square miles. However, based on the degree and location of erosion in the watershed, only the upper watershed contributed.

Thunderstorms on the evening of June 9, 1969 brought heavy rain to areas east of John Day and near Heppner, Oregon (Reid, 1975). Peak discharge in the John Day River near John Day, OR (14038530) was 5,830 cfs. Based on peak flow records available at the time, the reported discharge had a recurrence interval greater than 50 years. The current analysis shows the recurrence interval was probably less than 50 years.

For the June 9 event, Shobe Canyon had the highest peak discharge of any tributary in the Willow Creek basin. The discharge was 2,660 cfs from a contributing area of 6.22 square miles. The unit discharge was 428 cfs per square mile. For Willow Creek, a peak discharge of 6,680 cfs occurred the next day, June 10.

Most of the annual peak discharges reported for eastern Oregon for 1970 occurred January 22 – 27. While a few peaks had recurrence intervals between 10 and 25 years, most were below 10 years. The peak discharge for Lone Rock Creek near Lone Rock, OR (140473800), however, was greater than a 50-year event.

High peak discharges occurred January 17 – 20, 1971, throughout eastern Oregon and accounted for most of the annual peaks that year. A few peaks had recurrence intervals between 10 and 50 years, but most were below 10 years.

Most of the annual peak discharges reported for eastern Oregon for 1974 occurred January 12 – 19. A few peaks had recurrence intervals between 10 and 25 years, but most were below 10 years. The peak discharge for Ramsey Creek near Dufer, OR (14104100) and the Imnaha River at Imnaha, OR (13292000) were greater than 50-year events.

Snowmelt in the Wallowa Mountains in mid June 1974 caused high peak discharges in most streams in the area. Peak discharges for several streams had recurrence intervals of 50 years. The annual peak for West Eagle Creek below Jim Creek near Baker, OR (13287200) had a recurrence interval in excess of 100 years.

High streamflows occurred throughout the Umatilla River basin on January 25, 1975. Recurrence intervals for affected streams ranged from 10 to 50 years.

A thunderstorm on August 14, 1976 near Echo Oregon resulted in a flash flood in a Butter Creek tributary – the same tributary that was the site of the flash flood on June 9, 1948 (see description above). For the 1976 event, the peak discharge was 1,240 cfs or 827 cfs per square mile.

High streamflows occurred over most of eastern Oregon December 13 – 15, 1977. In some locations, peak discharges had recurrence intervals of 10 – 25 years. The recurrence intervals for the White River near Government Camp, OR (14097200), West Fork Hood River near Dee, OR (14118500), and Lake Creek near Sisters, OR (14088000) were in excess of 25 years.

Heavy warm rain on December 25, 1980 brought high streamflows to the Hood River basin and Cascade tributaries to the lower Deschutes River. Recurrence intervals for peaks on affected streams were generally only 10 to 15 years. The peak on Squaw Creek near Sisters, however, had a recurrence interval of greater than 50 years. This storm also was responsible for a debris flow that flowed down Polallie Creek eventually blocking the East Fork of the Hood River at their confluence (Hubbard, 1991; Taylor and Hatton, 1999). The lake that formed behind the debris dam was breached within minutes causing flooding and extensive damage downstream on the East Fork.

Heavy rain on snow and warm temperatures brought flooding to the Klamath River and its tributaries February 21 – 22 1982 (Hubbard, 1991; Taylor and Hatton, 1999). The peak discharges on the Sprague and Williamson Rivers were 25- to 50-year events.

High streamflows occurred in the Wallowa Mountains May 30, 1984. Peak discharges on several streams were in excess of the 10-year event. The peak for Catherine Creek near Union, OR (14032000) was greater than a 25-year event.

Heavy rainfall and melting snow caused widespread flooding February 22 – 23, 1986 (Taylor and Hatton, 1999). In eastern Oregon, many streams had peak discharges with recurrence intervals of 10 to 25 years. The peak discharge for the Grande Ronde at Rondowa, OR (13332500) was nearly a 50-year event.

Heavy rain falling on snow from May 19 – 20, 1991 caused flooding in the John Day, Grande Ronde, and Umatilla basins (Taylor and Hatton, 1999). Recurrence intervals for peak discharges in the affected area were generally from 10 to 25 years.

Mild temperatures and heavy rain falling on an above average snow pack during March 1993 resulted in high peak discharges in the Malheur and Owyhee basins and parts of the John Day basin (Taylor and Hatton, 1999). Recurrence intervals for peak discharges in the affected area were from 10 to 50 years.

During the period of February 5 – 9, 1996, warm temperatures and intense rain falling on a deep snow pack combined to create severe flooding throughout the northern part of Oregon (Taylor and Hatton, 1999). In many areas, flood magnitudes were generally comparable to or greater than those of the 1964 flood. While flooding was not as widespread in eastern Oregon, some streams experienced very high streamflows. Recurrence intervals for peak discharges on the Whitewater, Warm Springs, Metolius, and Grande Ronde Rivers were greater than 100 years.

From December 30, 1996 to January 5, 1997, warm moist air from the subtropical Pacific passed over the entire northwest (Taylor and Hatton, 1999). Heavy rain, warm temperatures, and rapid snowmelt caused flooding over much of the region. Estimated recurrence intervals for peak discharges for several widely spaced streams in Oregon exceeded 50 years. Discharge in the Imnaha River at Imnaha, OR (13292000) exceeded the 100-year discharge by twice. For the Chewaucan River near Paisley, OR (10384000), the peak discharge was 1.3 times the 100-year discharge.

High streamflows occurred in a number of streams in the Cascade Range near Mount Jefferson and Mount Hood on November 25 and 26, 1999. Return intervals for peak discharges were from 10 to 50 years.

# Magnitude and Frequency Analysis

For a site where peak discharges have been systematically measured, the magnitude of peak discharges can be related to frequency by fitting the measured peaks to a theoretical probability distribution. From the probability distribution, the magnitude of the peak discharge at any frequency can be estimated. In practice, however, it is seldom reasonable to make estimates of flood magnitudes for return intervals greater than about 500 years.

For this study, the logarithms of annual series of peak discharges at 276 streamflow gaging stations in eastern Oregon, southeastern Washington, southwestern Idaho, northwestern Nevada, and northeastern California (Appendix A) were fitted to the Pearson Type III distribution following guidelines established by the Interagency Advisory Committee on Water Data (1982). These guidelines are commonly known as Bulletin 17B. Where the logarithms of the annual peak discharges are used, the fitted Pearson type III distribution is referred to as the log-Pearson type III distribution.

The log-Pearson Type III frequency distribution requires three parameters: the mean, standard deviation, and skew[4] of the logarithms of the annual series of peaks being fitted. The parameters define a smooth trend line through the observed peak discharges when plotted on a log-probability plot (i.e., the logarithm of the magnitude of each annual peak discharge plotted against its probability of occurrence). However, some peak discharges do not fit the general trend of observed peak discharges. Because the data are ranked, these outliers always occur at the high or low ends of the distribution. The log-Pearson type III distribution usually cannot fit both the general trend of the observed peak discharges and the outliers. This distorted fit typically does a poor job of representing the high end of the distribution and may significantly over- or under-estimate the largest peak discharges.

Following procedures recommended in Bulletin 17B, the parameters of the log-Pearson type III distribution are adjusted for the effects of high and low outliers as well as for historic peaks, for zero-flow peaks[5], and for peaks below the gage threshold. It is beyond the scope of this report to discuss these adjustments, but for those interested, they are treated in detail in Bulletin 17B.

Even after adjustment for outliers, the station skew value may be poorly defined for short record gaging stations. A better estimate of the skew coefficient is obtained by taking a weighted average of the adjusted station skew and a “generalized” skew

[4] The mean is a measure of the central tendency of the distribution, the standard deviation is a measure of the dispersion of the distribution about the mean, and the skew is a measure of the asymmetry of the distribution. A distribution with a skew of zero is symmetrical.

[5] For some watersheds, in some years, there is no streamflow. The annual peak discharge in those years is zero.

based on the skew coefficients for long-term stations in the area.

Although generalized logarithmic skew coefficients for the United States are provided with Bulletin 17B, Bulletin 17B recommends that generalized skew coefficients be developed for each area of concern. If the newly developed generalized skew coefficients have a mean squared error less than that of the generalized skew coefficients provided by Bulletin 17B, the newly developed skew coefficients should be used in lieu of those provided in Bulletin 17B.

Generalized skew coefficients for Oregon were developed as part of this study. These generalized skew coefficients were combined with station skew values to obtain weighted skew estimators for each station. The weighted skew values were used in fitting the Pearson type III distributions. These topics are discussed in detail later in the report.

In general, fitting the theoretical Pearson type III distribution to the logarithms of the observed peak discharges was straightforward and produced good results. Of the 276 gaging stations, 141 required adjustment for high or low outliers or historic or zero peak discharges. Peak discharge statistics for the gaging stations are listed in Appendix B. Statistics include length of record; number of historical peaks; user defined high and low outlier thresholds; number of high and low outliers; number of zero flow peaks and peaks below the gage threshold; the station, Bulletin 17B, generalized, and weighted skews used in fitting the distribution; and the statistics from the trend analysis. The meaning and significance of these statistics can be found in Bulletin 17B.

A visual check of the “goodness of fit” of the theoretical Pearson type III distribution to the logarithms of the annual peak discharges was made for each of the 276 gaging stations. Four gaging stations originally considered for inclusion in this analysis were rejected based on this visual check. The fitted distributions did not reasonably approximate the actual distribution of observed peak discharges.

To make the check, the theoretical distribution and the observed peak discharges were plotted on a log-probability plot. (Appendix C discusses how the plotting position was determined for the probability axis.) The log-Pearson type III distribution generally plots as a curved line. The sense and degree of curvature is determined by the skew coefficient. Curvature is concave upward when the skew coefficient is positive and concave downward when it is negative. When the skew coefficient is zero, the distribution plots as a straight line. An example plot for the gaging station on the Middle Fork John Day River at Ritter, OR (14044000) is shown in Figure 9.

Peak discharge magnitudes at selected frequencies are obtained from the log-Pearson type III distribution by this equation:

$$\log Q = \overline{X} + KS \qquad (1)$$

where

$\overline{X}$ = the mean of the logarithms of the peak discharges,

$K$ = a factor that is a function of the skew coefficient of the logarithms of the peak discharges and the selected frequency, and

$S$ = the standard deviation of the logarithms of the peak discharges.

Values of K can be obtained from Appendix 3 of Bulletin 17B. The table requires the skew coefficient and the frequency.

The 2-, 5-, 10-, 25-, 50-, 100-, and 500-year peak discharges for the 276 gaging stations are listed in Appendix D.

# Peak Discharge Data

The data used in this study are the annual series of peak discharges for the 276 gaging stations. An “annual series” of peak discharges represents the largest instantaneous peak for each year of record, reported in cubic feet per second (cfs). Peaks were measured at both continuous record sites and at crest-stage gage sites that record only the maximum peak discharge for each year. These measurement sites represent watersheds not significantly affected by reservoir operations, diversions, or urbanization. All sites have 10 or more years of measured peak discharges through water year 2003.

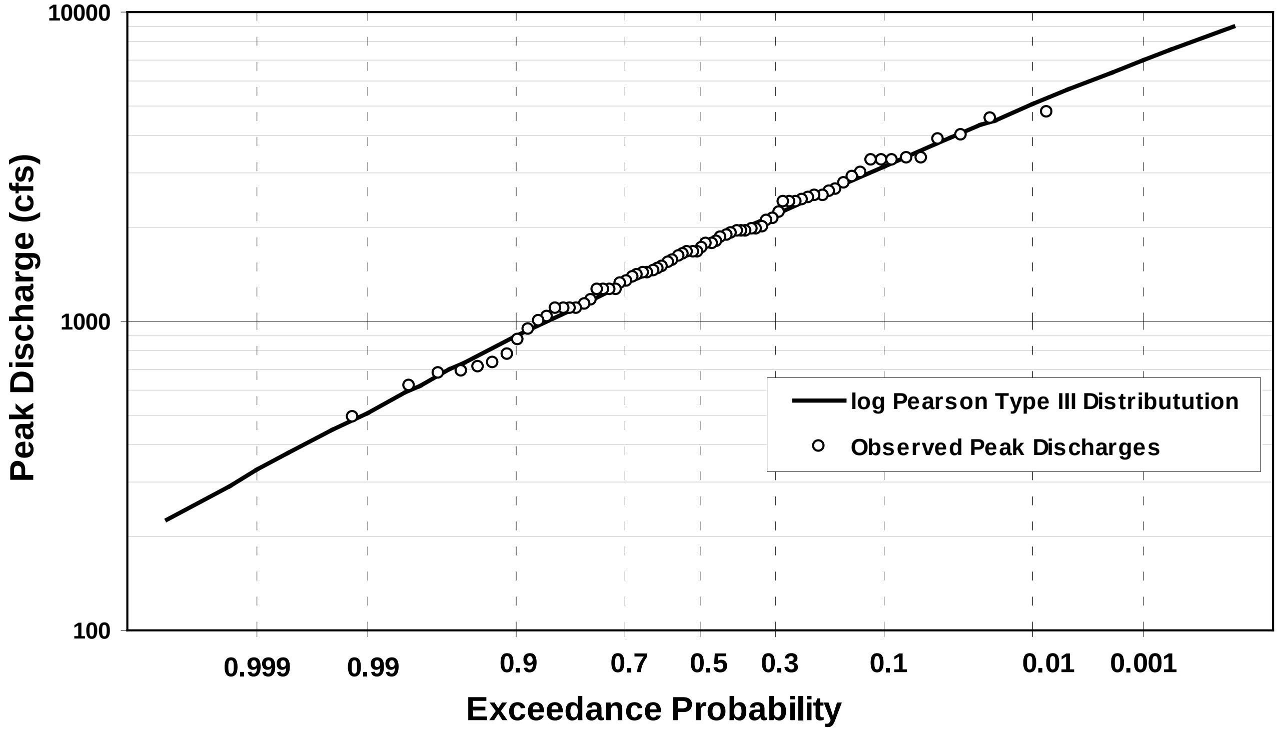



**Figure 9.** Log-Pearson Type III distribution fitted to measured peak discharges for the gaging station Middle Fork John Day River at Ritter, OR (14044000).

The peak discharges used in this study were measured and reported by the U.S. Geological Survey and the Oregon Water Resources Department. All peak discharge data used in the analysis are available from the Oregon Water Resources Department (webmaster@wrd.state.or.us), and all peaks except those originating with the Oregon Water Resources Department are available from the U.S. Geological Survey (info-or@usgs.gov).

## Quality Assurance

No effort was made to directly check the accuracy of peak discharges reported for the various gaging stations. It was assumed that adequate checks were made by the agency responsible for the peak estimates. However, a few scriveners' errors were discovered during the analysis. Unusual results in fitting the probability distributions or in doing the regression analysis were sometimes the result of erroneous peak values. In the first case, erroneous peaks caused the absolute value of the skew parameter of the distribution to be large. In the second case, erroneous peaks lead to large residuals in forming the prediction equations. In both cases, the observed peaks were examined for errors and corrected as necessary.

## Assumptions of the Magnitude and Frequency Analysis

Assumptions of the magnitude and frequency analysis are that the peaks in any systematic series are random and that they are all derived from the same population. These assumptions mean (1) that the value of one peak does not depend on the value of a preceding peak, and (2) that all peaks arise from the same processes, e.g., as the result of rain from a frontal-storm as opposed to rain from a convective storm or as the result of snowmelt. Implicit in the second assumption is that the processes are not changing in time. For example, it is assumed that weather may vary from year to year, but that climate is not steadily getting wetter or drier, or warmer or colder. Other factors are also assumed to remain constant; that land use, for example, does not change substantially over the period the measurements are made.

## Random Peak Discharges

A usual test for randomness is to check each series of annual peaks for a statistically significant linear correlation, i.e., a trend (Thomas and others, 1993; Wiley and others, 2000). A significant trend suggests that systematic, nonrandom changes in peak discharge characteristics are occurring in time. A trend test is not definitive; it is cause for investigation, not necessarily for the elimination of a gaging station from the analysis.

Peak discharges from the 276 gaging stations were tested for linear correlation. The resulting information was analyzed in two ways: 1) to check for regional, climate dependent trends, and 2) to check for local trends resulting from significant physical changes to a watershed. Local changes include human caused changes due to land use or water management as well as natural changes such as a volcanic eruption. Local trends that can be attributed to physical changes in the watershed may require all or part of a gaging station’s period of record to be removed from consideration.

In the regional analysis, no consistent long-term trend was found, although there is evidence of a regional fluctuation of peak discharges between wet and dry periods. This fluctuation led to a higher than expected number of significant trends in long-term gaging station records. The evidence is too weak, however, to support a strong conclusion as to whether the fluctuations are truly periodic or what the period might be. Locally, no significant trend could be linked to physical changes in the associated watershed.

No gaging stations were eliminated from consideration based on the trend analysis. The details of the trend analysis are found in Appendix E.

## Mixed Populations

For many watersheds in eastern Oregon, more than one hydrologic process may generate peak discharges. Most commonly, peaks result from snowmelt in spring or warm winter rain falling on accumulated snow. A few peaks result from rain from frontal storms in the summer or fall. More rarely, a peak results from a thunderstorm in late spring or summer. Finally, for a few watersheds in the Cascade Mountains where large springs dominate streamflow, annual peaks often occur in late summer and fall. While it is convenient to think of these processes as giving rise to distinct populations of peaks, the processes occur in unpredictable combinations and the populations overlap considerably. For example, rain-on-snow events probably form a continuum from pure rain to pure snowmelt.

For those watersheds where more than one hydrologic process generates peak discharges, the log-Pearson Type III distribution may poorly fit the distribution of annual peaks. When plotted on log-probability paper, a mixed population of peaks may show a sharp break in slope or a curve that reverses direction. The fitted distribution often has a large skew coefficient. If the peaks in these cases are separated into homogeneous populations, log-Pearson Type III distributions fitted to the separate populations may be significantly different from one another. In such cases, the distributions may be combined by the method described by Crippen (1978).

Often, however, the distribution of a mixed population of peaks does not exhibit a break in slope or a curve that reverses direction. If the distribution is well approximated by a log-Pearson Type III distribution, and if each of the separate populations is well represented in the mixed population, then there is no benefit to dividing the peaks into separate populations. The log-Pearson Type III distribution fitted to the mixed population will be close to the composite distribution calculated from the separate populations (Advisory Committee on Water Information, 2002).

The distributions of peak discharges for watersheds in eastern Oregon are generally well approximated by a log-Pearson Type III distribution, and there is no need to do a composite analysis based on separate populations. The exception is probably for peaks due to severe thunderstorms. While peaks from most thunderstorms appear to be distributed like peaks from snowmelt or rain-on-snow, very limited evidence suggests that peaks from severe thunderstorms are not. Unfortunately, there are so few of these peaks in the systematic record, it is not possible to determine the frequency characteristics of the population (see Relative Importance of Underlying Processes).

The peaks for all gaged watersheds used in the study were sorted into their months of occurrence in order to identify watersheds likely to have mixed populations.

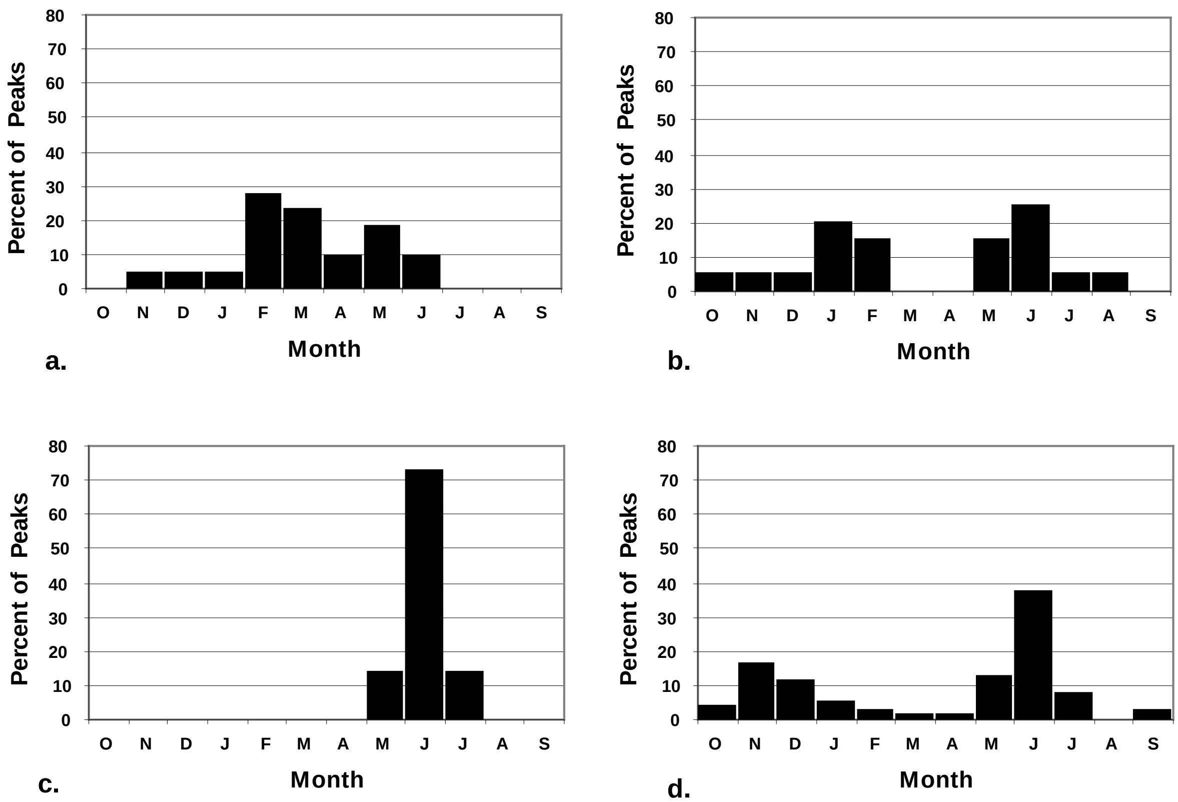


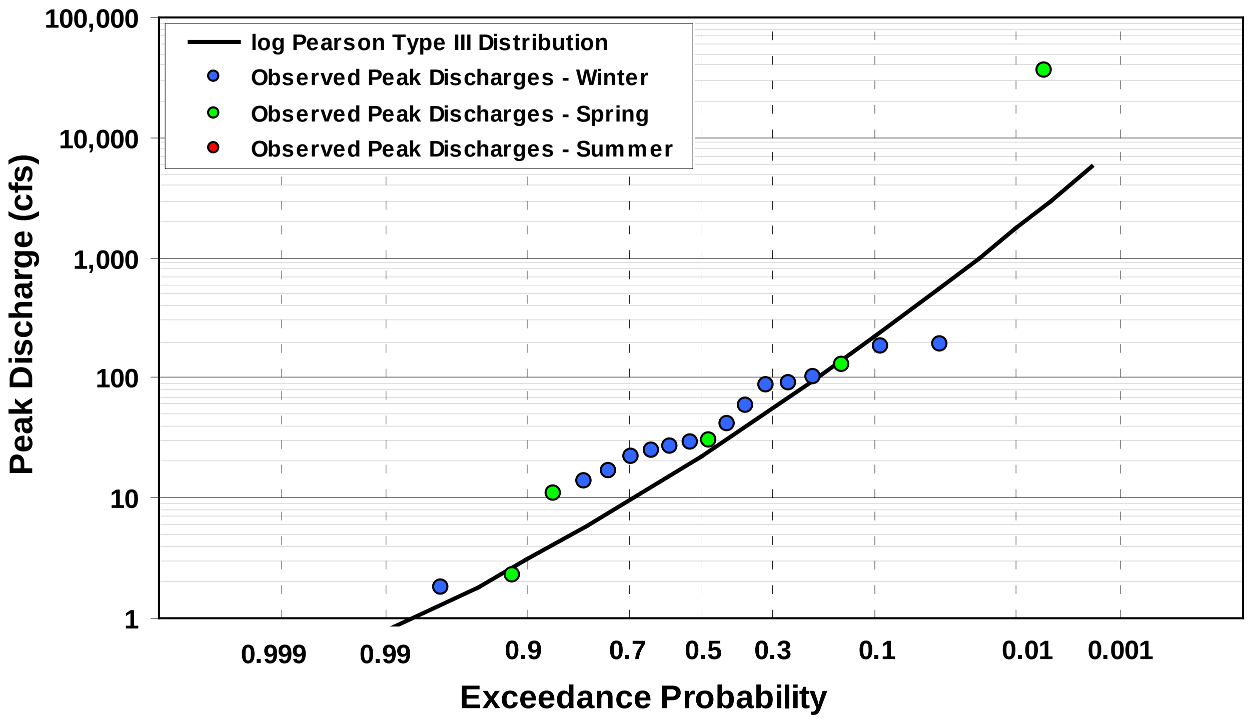

**Figure 10.** Distributions of the monthly occurrences of annual peak discharges for four gaging stations: a) Balm Fork near Heppner, OR (14034480), b) Willow Creek at Arlington, OR (14036000), c) East Fork Wallowa River near Joseph, OR (13325000), and d) Squaw Creek near Sisters, OR (14075000).

This analysis assumes that the type of peak is related to the season of occurrence. This assumption is not definitive, but it holds generally. Rain-on-snow events generally occur in winter (October to March), snowmelt generally occurs in spring (April to June), and thunderstorms generally occur in summer (July to September). Some spring-dominated watersheds in the Cascades do not hold to these generalities at all. Their peaks occur in late summer and early fall and are not directly related to any of these meteorologic processes.

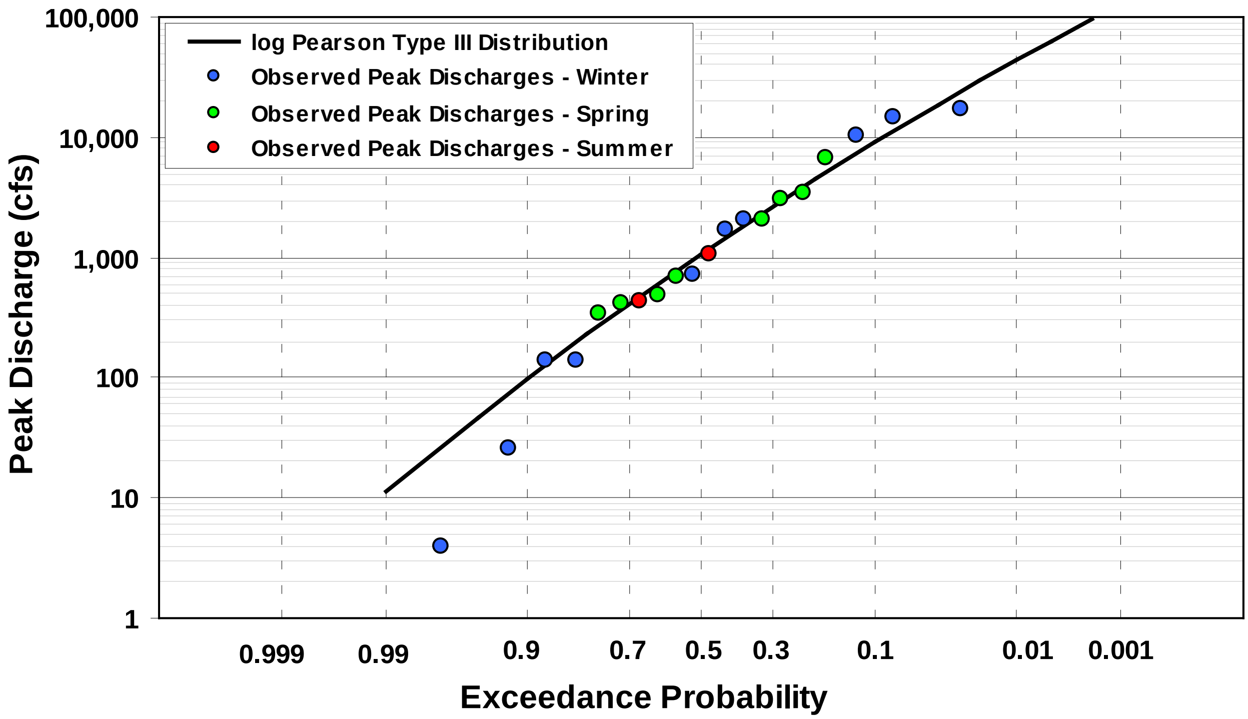
Figure 10 shows the monthly distributions for four watersheds. Three of the watersheds were selected because the monthly distributions were bimodal: Balm Fork near Heppner, OR (14034480), Willow Creek at Arlington, OR (14036000), and Squaw Creek near Sisters, OR (14075000). A bimodal monthly distribution is an indication of a mixed population of peaks. Balm Fork also includes a peak due to a severe thunderstorm. The fourth watershed, East Fork Wallowa River near Joseph, OR (13325000), was selected because it has several summer peaks and no winter peaks.

Log-probability plots of the peak discharges for the four gaged watersheds are shown in figure 11. The peaks are identified by their season of occurrence. Also shown is the log-Pearson Type III distribution fitted to the peak discharges. The distributions of the peak discharges for 3 of the 4 watersheds do not show breaks in slope or curves that reverse direction. The fitted log-Pearson Type III distributions for these watersheds are all reasonable. The remaining watershed, Balm Fork, may show a break in slope.

Balm Fork provides the single example of a peak due to a severe thunderstorm for any gaged watershed used in this study. The one high outlier represents the Heppner flood of June 1903. Its plotting position is based on a known historic period of 100 years. In fact, the frequency of an event of this magnitude on Balm Fork is unknown, and there is not sufficient information to determine the frequency.

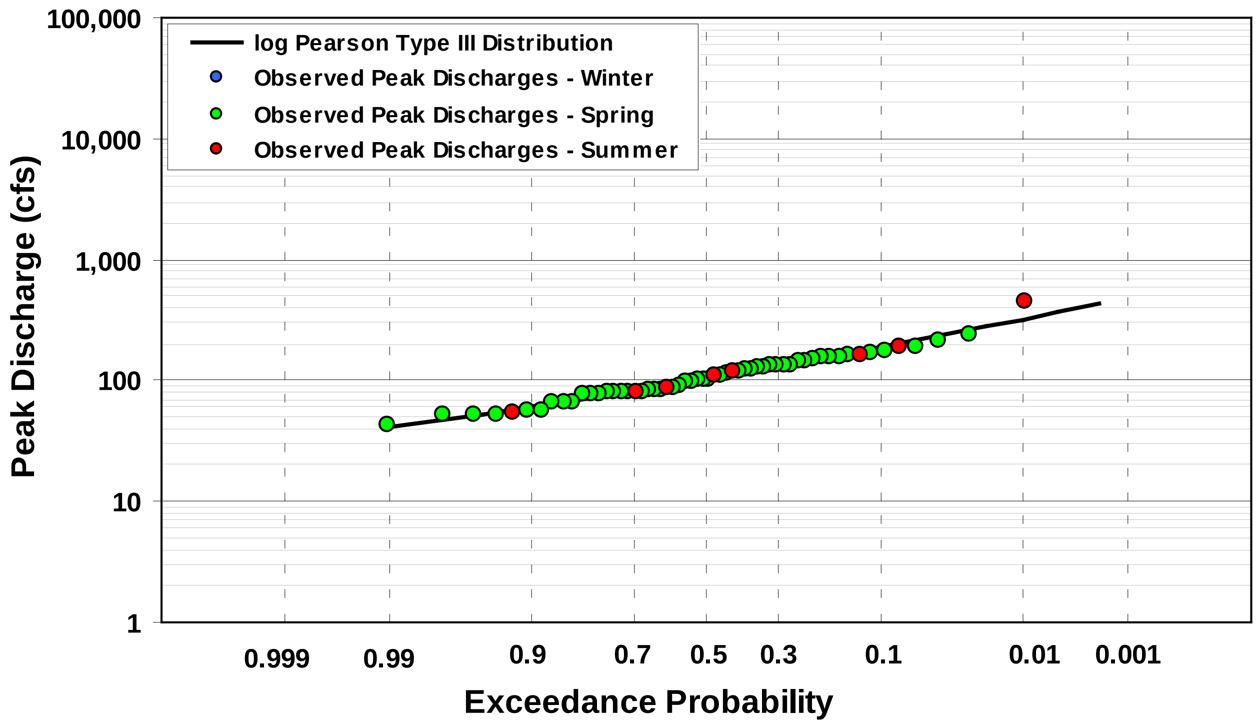



a.

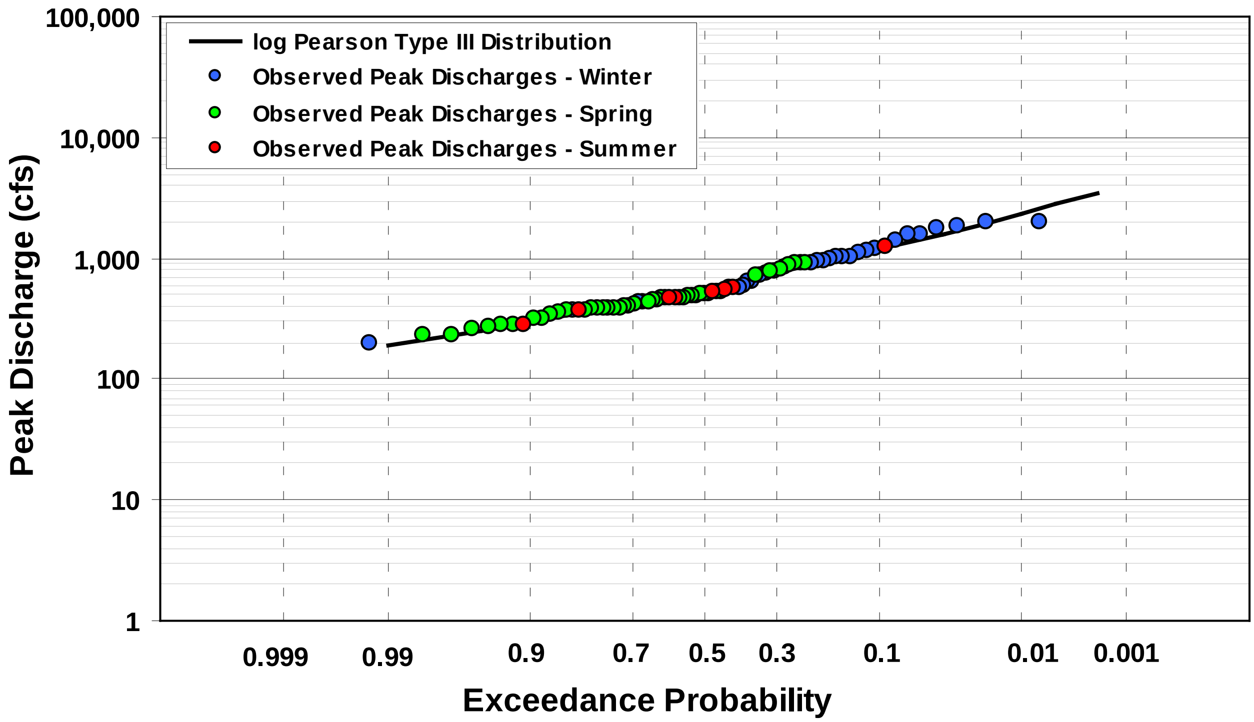



b.

**Figure 11.** Distributions of annual peak discharges for four gaging stations: a) Balm Fork near Heppner, OR (1403448), b) Willow Creek at Arlington, OR (14036000), c) East Fork Wallowa River, OR (1332500), and Squaw Creek near Sisters, OR (14075000). Peak discharges are identified




c.




d.

**Figure 11 - continued.** by their season of occurrence: winter is November to March, spring, is April to June, and summer is July to September. Also shown are the log-Pearson Type III distributions that were fitted to the peaks.

For the peak to fall on the fitted line, it would have to have a frequency on the order of once in 1,000 or so years. If a peak of this magnitude occurs more often than this, as seems likely, then the peak represents a break in slope and indicates a population of thunderstorms that should be considered separately.

Because there are not enough annual peak discharges representing severe thunderstorms, a typical frequency analysis cannot be performed. Unfortunately, there are not good alternatives. It is sometimes possible to obtain accounts of past floods through old newspapers, journals, histories, and interviews with local residents. While these accounts may accurately report the time of occurrence, information regarding peak stages or flow rates is often vague or missing. Flood peaks can also be synthesized based on assumed rainfall intensities and watershed runoff characteristics. The uncertainties associated with these methods are high and largely not quantifiable. For an example of how these methods were put to use in the Willow Creek basin in north central Oregon, see the report by the U.S. Army Corps of Engineers (1978).

## Correcting for Low Peak Discharges not identified as Low Outliers

In some cases, low peak discharges have a pronounced negative effect on the fit of the log-Pearson Type III distribution to an annual series of peaks. Where two or more low peak discharges occur, the test for low outliers from Bulletin 17B often sets the low outlier threshold too low to catch all the outliers. On a log-probability plot, these low peak discharges give the distribution a strong downward curve, and there is often a sharp break in slope (fig. 12). Unless these low outliers are censored, the fit of the log-Pearson Type III distribution is compromised with the upper end of the distribution poorly defined and often overestimated.

These low peak discharges may represent a separate population of peaks, but there is no benefit to treating them as such, as they do not provide any information about the *magnitude* of peak discharges at the upper end of the distribution. However, the low peaks do provide information about the *frequency* of the peak discharges at the upper end. The peaks below the low threshold are used with any zero peaks in a conditional probability adjustment as described in Bulletin 17B, Appendix 5.

Where low peak discharges caused a poor fit of the log-Pearson Type III distribution to a series of annual peaks, the low outlier threshold was increased to improve the fit to the upper end of the annual peaks. The Advisory Committee on Water Information (2002) offers suggestions on how to determine how many low peak discharges to eliminate. In general, low peaks are eliminated one at a time until the conditional probability distribution based on the remaining peaks stops changing significantly. Figure 12 shows examples of how the fit of the log-Pearson Type III distribution was improved for three gaging stations: Currier Creek near Paisley, OR (11497800), the Silvies River near Seneca, OR (10392300), and the East Fork Quinn River near McDermitt, NV (10353000).

## Generalized Skew

The skew coefficient of an annual series of peaks is sensitive to extreme values, especially when records are short. A more accurate estimate of the skew coefficient is obtained by weighting the station skew with a generalized skew value based on the skew coefficients of nearby long-term gaging stations. The weighting is based on the relative mean-square errors of the station and generalized skew and is given by this equation:

$$G_W = \frac{MSE_{\bar{G}}(G) + MSE_G(\bar{G})}{MSE_{\bar{G}} + MSE_G} \quad \text{......................(2)}$$

Where

$G_W$ = weighted skew coefficient,

$G$ = adjusted station skew,

$\bar{G}$ = generalized skew,

$MSE_{\bar{G}}$ = mean-square error of the generalized skew, and

$MSE_G$ = mean-square error of the station skew.

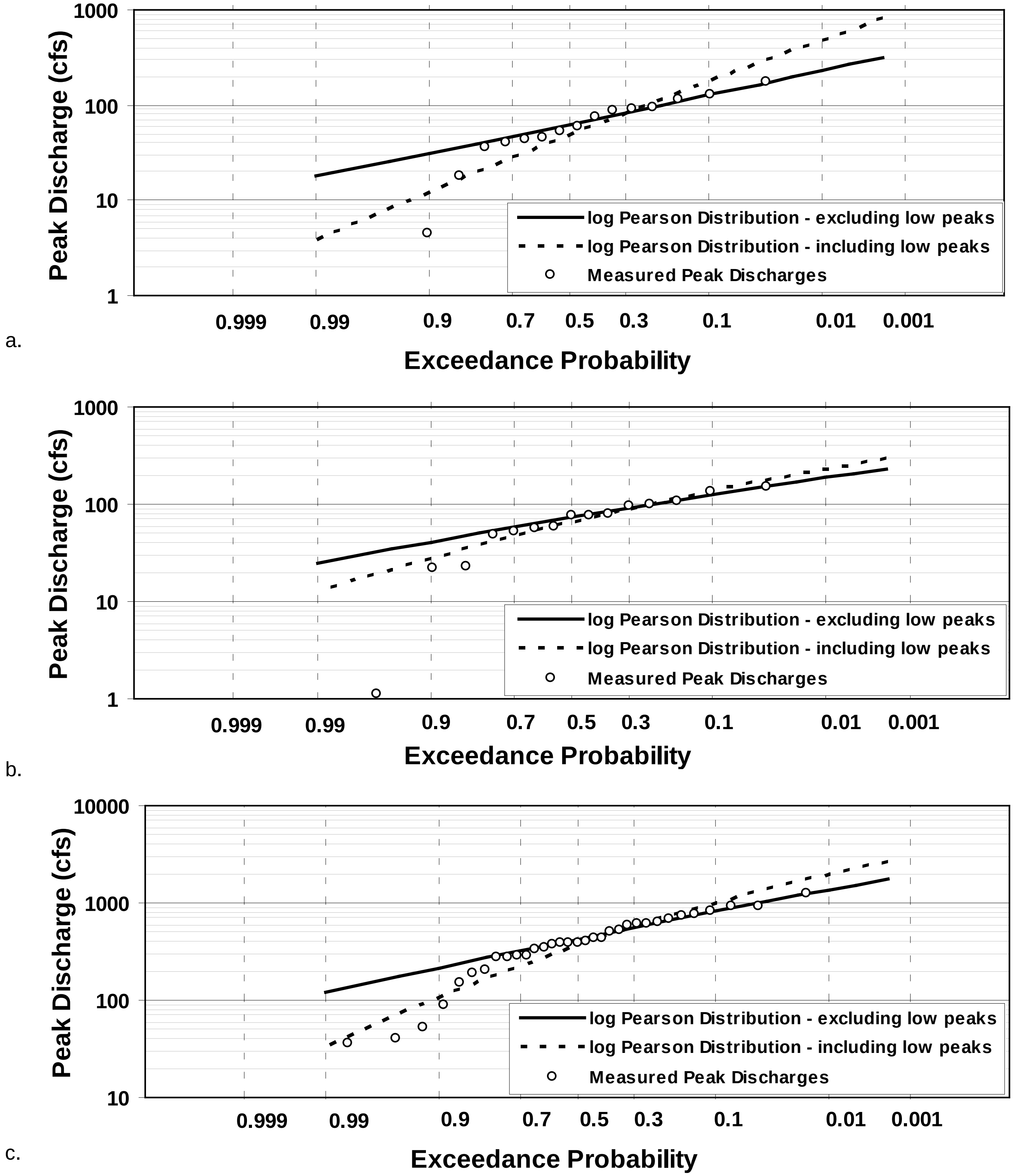



**Figure 12.** The effect of low peaks on the fit of the log-Pearson Type III distribution to the peak discharges for three gaging station: a) Currier Creek near Paisley, OR (11497800), b) Silvies River near Seneca, OR (10392300), and c) East Fork Quinn River near McDermitt, NV (10353000).

Included with Bulletin 17B is a map of the generalized logarithmic skew coefficients of annual maximum streamflows for the entire United States. Although many peak discharge frequency studies use this map to obtain generalized skew values, Bulletin 17B recommends that users of the guide develop their own generalized skew coefficients for their area of interest using the procedures outlined in the bulletin.

Bulletin 17B outlines three methods for developing generalized skew coefficients: (1) drawing skew isolines on a map, (2) developing skew prediction equations, and (3) using the mean of station skew values. These generalized skews are to be developed using at least 40 stations with 25 or more years of record. The isoline map is drawn by hand from station skews plotted at the centroid of their watersheds. The prediction equations are developed to relate station skews to predictor variables that include the physical or climatological characteristics of the watersheds.

For this analysis, all three methods were tried. For the isoline method, rather than drawing the map by hand as suggested by Bulletin 17B, the map was drawn using GIS techniques, by the method described by Lumia and Baevsky (2000). How this method was adapted for this analysis is described in the next section. For the skew prediction equation method, useful equations could not be developed. There is not a good linear correlation between station skew and any of the available watershed characteristics.

The analyses were done statewide and were based on 267 gaging stations with more than 25 years of record in Oregon, southern Washington, western Idaho, northwestern Nevada, and northern California. The skews used in each analysis were the station skews adjusted for the effects of high and low outliers, zero peak discharges, and peak discharges below the gage threshold (see Bulletin 17B).

The isoline and average skew methods were evaluated based on a comparison of their mean-square errors to that of the generalized skew map provided with Bulletin 17B, the method with the smallest mean-square error being preferred. Mean-square errors for the isoline method and for the generalized skew map of Bulletin 17B were calculated by estimating the skew at each of the long-term stations by each method, squaring the difference between the station skew and the generalized skew, and taking the mean of the squared differences:

$$MSE = \frac{\sum_{i=1}^{n}(G_i - \overline{G_i})^2}{n} \quad \text{....................................(3)}$$

where

$MSE$ = mean-square error,

$G_i$ = station skew for gaging station i,

$\overline{G_i}$ = generalized skew for gaging station i,

$n$ = number of stations.

For the method where the generalized skew is estimated as the mean of all station skews, the mean-square error was simply the variance of the station skews.

The mean-square error for the isoline method (MSE = 0.112) was significantly smaller than for either the mean of all stations skews (MSE = 0.222) or the generalized skew from Bulletin 17B (MSE = 0.302 for all of the United States or MSE = 0.227 for the area of the generalized skew analysis).

## Developing Generalized Skew Isolines

Lumia and Baevsky's (2000) method assigns skew values to cells of a grid overlaid on the area of interest. The isolines are drawn from this grid. The grid values are estimated by a weighted average of the skews of nearby long-term gaging stations. The station skews, plotted at the centroids of their watersheds, are weighted by their distance from the grid cell and by their length of record. The closer the centroid of the watershed and the longer the station record, the more weight the station skew is given in the calculation. Lumia and Baevsky used the ARC/Info (Environmental Systems Research Institute, Inc., Redlands, California) routine GRID IDW to determine the skew value at each cell (Y.H. Baevsky, U.S. Geological Survey, written commun., 2001), and used that routine's default values for grid spacing, 10,000 meters, and number of stations, 12 (R. Lumia, U.S. Geological Survey, written commun., 2001). LATTICECONTOUR was used to determine the isolines.

This study also used these routines; however, the grid spacing and number of stations were varied to see the effect on the resulting skew isoline map. As the grid spacing decreases, the isolines become increasingly angular and blocky. As the number of stations decreases, the number of isolines increases and peaks and valleys appear around some stations. The gradients near these stations become increasingly steep.

The generalized skew map selected for this study was based on a grid spacing of 20,000 meters and 12 stations. The part of the map for eastern Oregon is shown in figure 13. This map was selected because it had the smallest mean square error while having skew isolines that are smooth and with no peaks or valleys. This map offers considerable improvement in mean-square error over either the generalized skew map provided by Bulletin 17B or the average of the skews of the 267 stations.

Figure 13 is provided for illustration only. A GIS (ARC/INFO) grid of the generalized skew coefficients may be obtained from the Oregon Water Resources Department (webmaster@wrd.state.or.us). It is recommended that generalized skew for a watershed be determined from this grid (using a GIS overlay analysis) rather than from a plotted map of generalized skew isolines.

# Estimation of Magnitude and Frequency of Peak Streamflows at Ungaged Sites

Peak discharges for an ungaged watershed may be estimated from prediction equations that relate peak discharge to climatologic and physical characteristics of the watershed (Thomas, 1969; Riggs, 1973). The prediction equations are derived using multiple linear-regression techniques. This generalization or regionalization of peak discharges from measured to unmeasured watersheds is known as a “regional regression analysis”.

For this study, a combination of regression techniques was used to derive the prediction equations. A preliminary analysis using ordinary least-squares regression was conducted to define flood regions of homogeneous hydrology and to determine which climatological and physical characteristics of the watersheds would be most useful in the prediction equations. The final prediction equations were derived using generalized least-squares regression (Tasker and others, 1986; Tasker and Stedinger, 1989) using the computer model, GLSNET (version 2.5), developed by the U.S. Geological Survey (2000).

# Flood Regions

When using regression techniques to derive prediction equations, the accuracy of the equations may be improved by doing the derivations for regions of relatively uniform hydrology, called herein, flood regions. Six flood regions were defined for this study (fig. 14).

The first flood region defined for eastern Oregon was for the east slope of the Cascade Mountains – region 1. This region is unique in that its peak discharges have lower ratios of maximum to minimum peak discharges than do other regions[6] (Figure 15). Three characteristics of the region cause these low ratios: 1) it has much greater accumulations of snow than other areas, 2) it has numerous small lakes, and 3) its geology is characterized by young, highly porous, volcanic rock with large areas of cinder and pumice, and blocky lava flows. Because of the geology, peak discharges often are affected by spring flow and hydrologic boundaries are indeterminate.

Watersheds with springs, snow accumulation, and lakes have low ratios of maximum to minimum discharges because of short-term storage of precipitation with a gradual release to streamflow.

[6] It is often difficult to calculate the ratio of maximum to minimum discharge using the observed minimum discharge for a stream. Many streams in eastern Oregon naturally have entire years with no flow – the annual peak discharge is zero. In these cases, the ratio of maximum to minimum discharges is undefined. In other cases, the low discharge is affected by diversion. In these cases, the calculated ratio is larger than the actual ratio. Here, we use the 95 percent exceedance natural streamflow as the measure of minimum discharge. These values are calculated by the Department for many watersheds in Oregon for use in the Water Availability Program (Cooper, 2002). This flow characteristic has the advantages of seldom being zero and of having been corrected for diversion. The disadvantage is that the values are only available for gaging stations with continuous record.

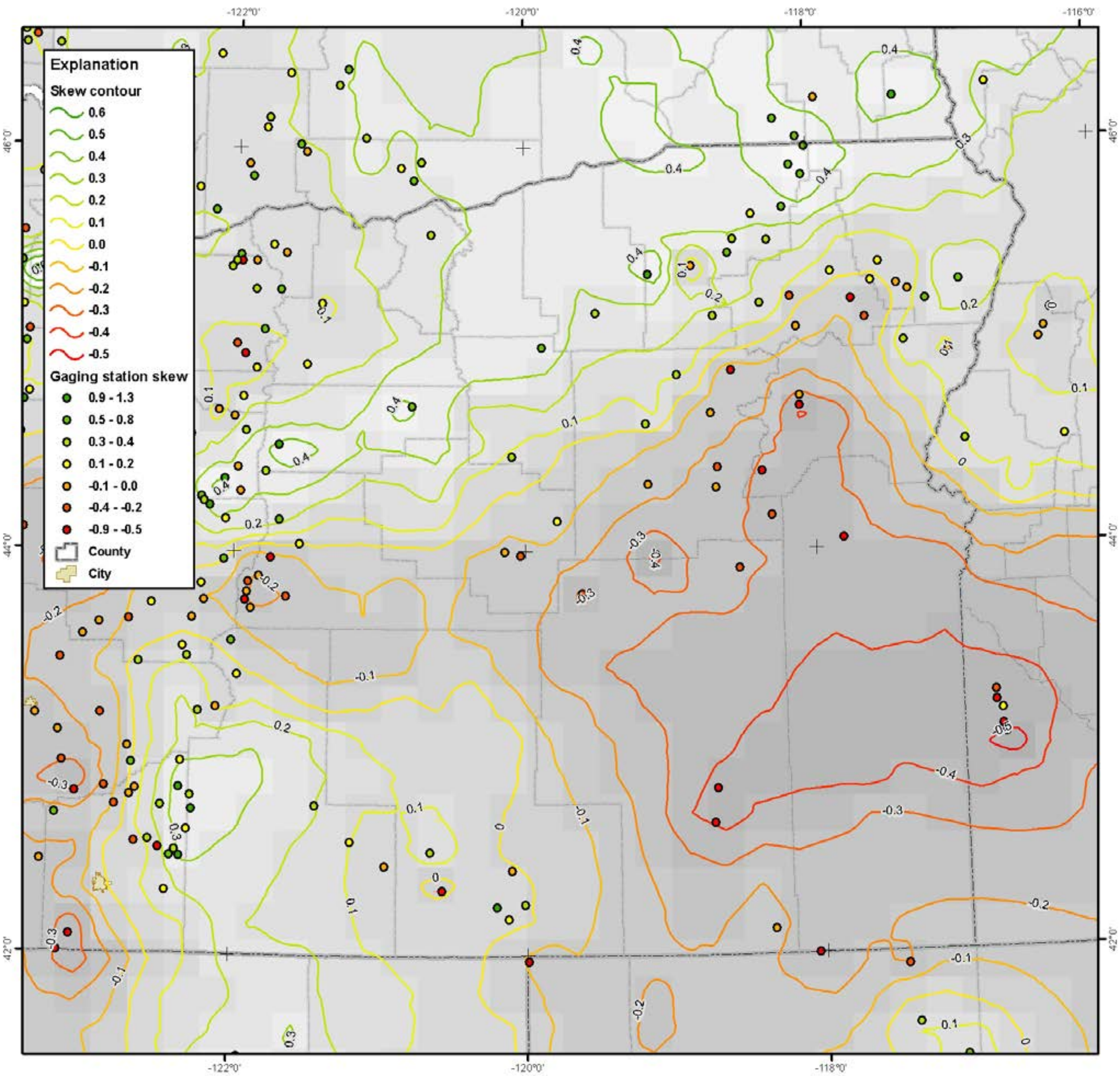



**Figure 13.** Generalized logarithmic skew coefficients for eastern Oregon. The isoline interval is 0.1. The colored circles represent skew coefficients of long-term gaging stations and are located at the centroids of their respective watersheds. The shaded background represents the GIS grid on which the isolines are based. Darker shades represent negative skews, and lighter shades, positive skews. The value of the skew coefficient for each grid cell was calculated as a weighted average of nearby gaging station skews.

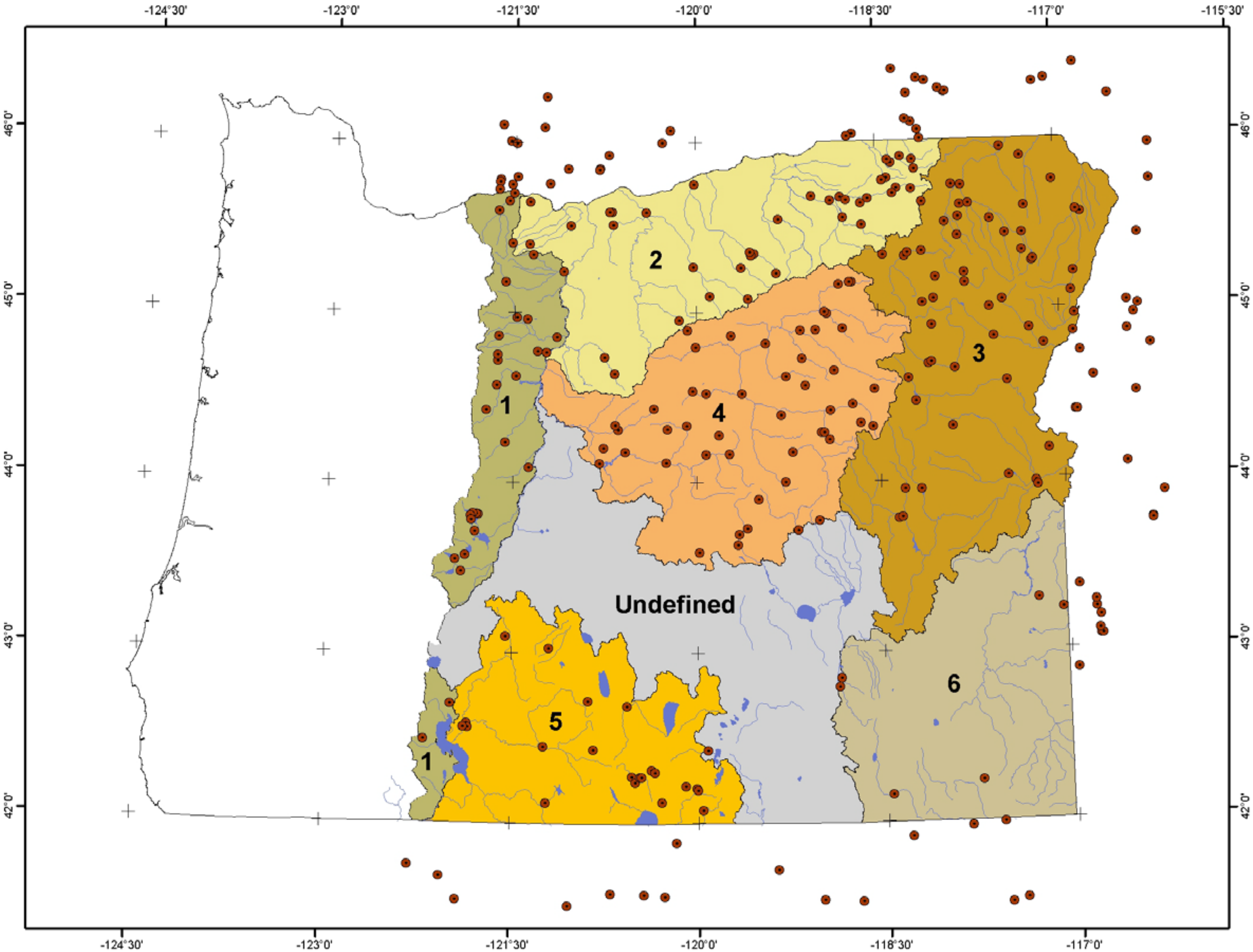



**Figure 14.** Flood regions of eastern Oregon. The dots represent gaging station locations. Note the poor stream development and lack of gaging stations in the undefined area.

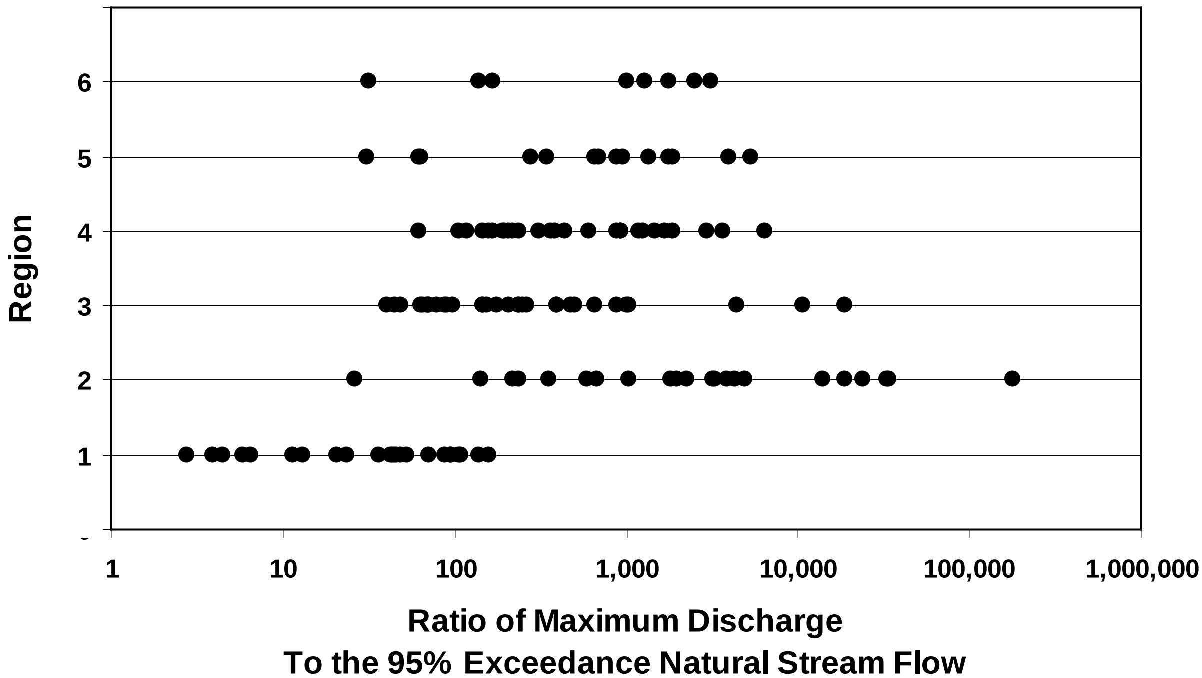



**Figure 15.** A plot of the ratio of maximum discharge to the 95 percent exceedance streamflow for selected gages from each region. Shown are gaging stations in Oregon with more than 10 years of continuous record and for which the 95 percent exceedance natural streamflow is greater than zero.

Streams with high ratios of maximum to minimum streamflows have limited capacity for storage, and peak discharges are dominated by direct runoff from rainfall.

The rest of eastern Oregon was divided into regions based on a simple cluster analysis (Wiley and others, 2000). First, an ordinary least-squares regression was done using 100-year peak discharges as the response variable and drainage area as the only predictor variable. Then, the residuals from the regression were plotted at the centroids of their respective watersheds on a map of the study area (Figure 16). Clusters of residuals of similar sign and magnitude were presumed to indicate areas of similar hydrology and were defined as flood regions. As much as possible, natural hydrologic boundaries were used to define regions to avoid splitting river basins into parts. In some cases, splitting basins was unavoidable, e.g., the Deschutes and John Day River basins.

These regions represent areas of similar hydrology. Separate sets of prediction equations were derived for each of these regions. Table 5 shows how gaging stations are distributed among the regions and how gaging stations are distributed by watershed area within each region.

Region 1 comprises the watersheds of all streams arising on the east side of the Cascade Mountains. These streams include the Hood, White, Warm Springs, Metolius, Little Deschutes, and upper Deschutes Rivers. The region includes all of the east side of the Cascade Mountains.

Region 2 occupies roughly the area previously defined as the Deschutes-Umatilla Plateau. It includes all of the Umatilla River, Willow Creek, tributaries of the John Day River below Bridge Creek, east side tributaries of the Deschutes River below the Crooked River, and tributaries of the Columbia River between the Deschutes and the Hood Rivers. These streams primarily drain the north slope of the Blue Mountains.

Region 3 comprises all Snake River tributaries in Oregon except the Owyhee River. Major streams are the Grande Ronde, Imnaha, Powder, Burnt, and Malheur River and numerous smaller watersheds. Region 3 occupies the eastern half of the Blue Mountains. The region includes all of the Wallowa

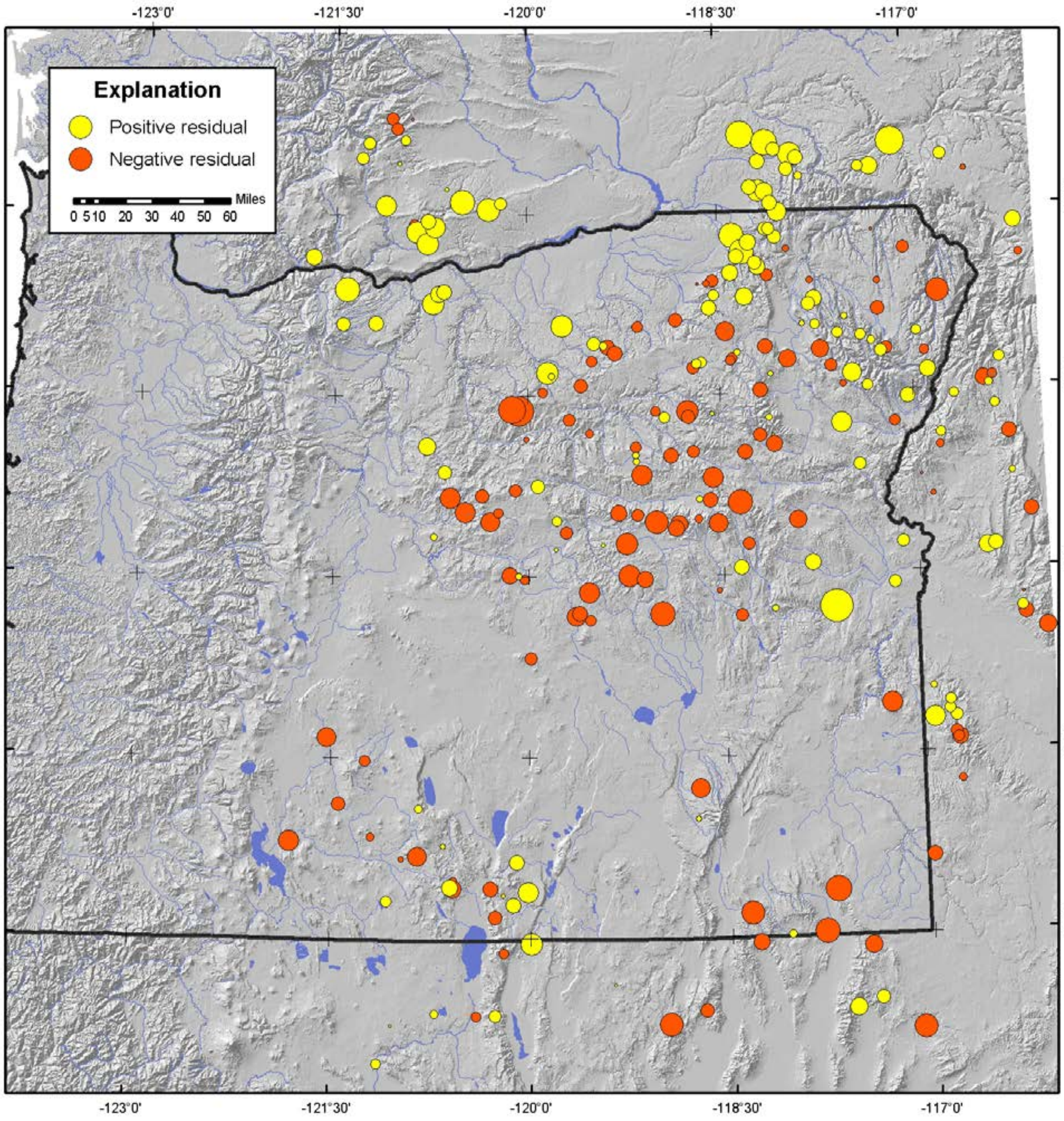



**Figure 16.** Residuals from a regression of 100-year peak discharges with drainage area for all gaging stations in eastern Oregon except those in the Cascade Range (flood region 1). The size of each circle is proportional to the absolute value of the residual. Negative residuals are shown in red and positive residuals, in yellow.

**Table 5.** Number of gages and their average record length by area and region.

| Area | Region 1 | | Region 2 | | Region 3 | | Region 4 | | Region 5 | | Region 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of gages | Average record length | Number of gages | Average record length | Number of gages | Average record length | Number of gages | Average record length | Number of gages | Average record length | Number of gages | Average record length |
| square miles | | years | | years | | years | | years | | years | | Years |
| **< 1** | 0 | N/A | 3 | 19.3 | 5 | 13.8 | 0 | N/A | 2 | 11.0 | 2 | 22.5 |
| **1 – 3** | 0 | N/A | 5 | 18.2 | 9 | 13.1 | 7 | 13.9 | 5 | 13.8 | 1 | 19.0 |
| **3 – 10** | 2 | 12.5 | 12 | 16.4 | 12 | 13.4 | 11 | 19.6 | 3 | 15.3 | 3 | 13.7 |
| **10 – 30** | 12 | 37.2 | 6 | 18.7 | 12 | 25.1 | 8 | 16.1 | 4 | 17.8 | 7 | 25.4 |
| **30 – 100** | 12 | 39.6 | 12 | 32.3 | 15 | 31.7 | 6 | 17.5 | 6 | 18.2 | 4 | 34.5 |
| **100 – 300** | 10 | 24.9 | 11 | 43.7 | 10 | 33.7 | 7 | 26.9 | 5 | 57.6 | 4 | 59.3 |
| **300 – 1000** | 5 | 63.2 | 6 | 38.2 | 9 | 48.8 | 5 | 53.0 | 1 | 56.0 | 1 | 24.0 |
| **1000 – 3000** | 0 | N/A | 3 | 48.3 | 2 | 46.5 | 5 | 44.2 | 2 | 85.0 | 0 | N/A |
| **> 3000** | 0 | N/A | 0 | N/A | 2 | 35.0 | 2 | 86.5 | 0 | N/A | 0 | N/A |
| **Total** | 41 | 36.9 | 58 | 29.3 | 76 | 27.1 | 51 | 27.3 | 28 | 29.7 | 22 | 31.0 |

Mountains and the eastern slopes of the Elkhorn and Greenhorn Mountains.

Region 4 occupies the western part of the Blue Mountains. Major streams include the John Day River and its tributaries above Bridge Creek, the Crooked and Silvies Rivers and Silver Creek. The region includes all of the Ochoco and Strawberry Mountains and the western slopes of the Elkhorn and Greenhorn Mountains.

Region 5 occupies the western third of the Basin and Range. Major streams include the Williamson, Sprague, Sycan and Chewaucan Rivers and Thomas, Bridge and Drews Creeks. The region includes Winter Rim, and Yamsay and Gearhart Mountains.

Region 6 occupies the southeastern corner of Oregon and includes the Owyhee Upland and the eastern third of the Basin and Range. Major streams are the Owyhee and Donner und Blitzen Rivers and Trout Creek. The region includes the Pueblo and Steens Mountains.

Note that the area occupied by the High Lava Plains and the middle third of the Basin and Range is not included in a flood region. This area is not represented by any gaging stations. Prediction equations developed for surrounding regions can be expected to perform poorly in this undefined area.

# Watershed Characteristics

Ninety-two watershed characteristics were available for this study (Appendix F). For each gaging station, the 92 watershed characteristics were estimated using the GIS computer program ARC/INFO 7.2.1 (Environmental Systems Research Institute, Inc., Redlands, California).

In a GIS analysis of watershed characteristics, each characteristic is associated with either a coverage (vector data) or a grid (raster data). For this study, the elevation grid (digital elevation model) came from the National Center for Earth Resources Observation & Science (1999). The precipitation and temperature grids came from the Oregon Climate Service (G.H. Taylor, Oregon State Climatologist, written commun., 2000, 2001). The soils coverage came from the National Cartography and Geospatial Center (1994). The climatologic characteristic grids from the Oregon Climate Service were generated using PRISM (Daly and others, 1997). PRISM stands for Parameter-elevation Regressions on Independent Slopes Model.

**Table 6.** Watershed characteristics used in the regression analysis.

[Units: $mi^2$, square miles; ft, feet; in, inches; in/hr, inches per hour; °, degrees; °F, degrees Fahrenheit]

| Characteristic | Units | Data type | Scale or resolution | Source |
|---|---|---|---|---|
| Drainage area | $mi^2$ | vector | 1:24,000 | Water Resources Department |
| Mean watershed slope | ° | grid | 30 m | U.S. Geological Survey |
| Maximum watershed aspect | ° | grid | 30 m | U.S. Geological Survey |
| Mean watershed elevation | ft | grid | 30 m | U.S. Geological Survey |
| Mean January precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean July precipitation | in | grid | 4,000 m | Oregon Climate Service |
| 2-year 24-hour precipitation intensity | in | grid | 3,000 m | Oregon Climate Service |
| Annual snowfall | in | grid | 4,000 m | Oregon Climate Service |
| Mean minimum January temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean minimum July temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean maximum January temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean maximum July temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Soil storage capacity | in | vector | 1:250,000 | Natural Resources Conservation Service |
| Soil permeability | in/hr | vector | 1:250,000 | Natural Resources Conservation Service |
| Soil depth | in | vector | 1:250,000 | Natural Resources Conservation Service |

To begin, each watershed was delineated from U.S. Geological Survey 1:24000 scale topographic maps and digitized into a coverage of all watersheds. The locations of the outlet and the centroid, the area, and the perimeter of each watershed were calculated directly from this coverage. For other characteristics, the watershed coverage was over-laid on the respective coverage or grid. Stream length and percent area of lakes and ponds were determined from an overlay of the hydrography coverage. For all others, the value of the characteristic was calculated as its average over the area of the watershed. The GIS analysis of watershed characteristics was implemented using an Arc Macro Language script. The script is available from the Oregon Water Resources Department on request (webmaster@wrd.state.or.us ).

Most of the 92 characteristics were not used in the regression analysis. Some of the characteristics, such as the location of the centroid of a watershed, perimeter length or minimum watershed elevation, are poorly (or not at all) related to streamflow. Others, such as percent of a watershed above 3,000 feet, tend to cluster at one or two values. For example, most eastern Oregon watersheds have 100 percent of their area above 3,000 feet. Many of the characteristics, including the various monthly precipitation or temperature characteristics, are highly correlated with each other and using combinations of these values in a regression analysis does not add information. Based on these considerations and some trial regressions using ordinary least-squares, 15 characteristics were selected for the regression analysis (Table 6). These 15 characteristics for each of the 276 gaged watersheds used in the regional regression analysis are given in Appendix G.

The selected 15 characteristics were checked for collinearity. Matrices of the correlation coefficients for the characteristics of the watersheds for each of the three flood regions are shown in Tables 7, 8, 9, 10, 11, and 12. High correlation coefficients (absolute values greater than about 0.80) were detected. None of these pairs of characteristics were allowed to appear together in a prediction equation. The largest correlation coefficient for any pair of

**Table 7.** Correlation matrix of explanatory variables for the 41 gaging stations of region 1, east slope of the Cascade Range.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mn Jul T | Mx Jan T | Mx Jul T | Soil C | Soil P | Soil D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | 1.00 | | | | | | | | | | | | | | |
| **Slope** | 0.16 | 1.00 | | | | | | | | | | | | | |
| **Aspect** | 0.18 | 0.35 | 1.00 | | | | | | | | | | | | |
| **Elev** | -0.69 | -0.29 | -0.10 | 1.00 | | | | | | | | | | | |
| **Jan P** | -0.03 | 0.38 | 0.33 | -0.15 | 1.00 | | | | | | | | | | |
| **Jul P** | -0.31 | 0.00 | -0.01 | 0.37 | 0.66 | 1.00 | | | | | | | | | |
| **I24-2** | -0.22 | 0.18 | 0.28 | 0.17 | **0.91** | **0.83** | 1.00 | | | | | | | | |
| **Snow** | -0.41 | -0.06 | 0.02 | 0.53 | 0.63 | **0.86** | **0.81** | 1.00 | | | | | | | |
| **Mn Jan T** | 0.24 | 0.53 | 0.29 | -0.65 | 0.30 | -0.28 | -0.04 | -0.44 | 1.00 | | | | | | |
| **Mn Jul T** | 0.31 | 0.44 | 0.41 | -0.69 | 0.24 | -0.37 | -0.07 | -0.51 | **0.94** | 1.00 | | | | | |
| **Mx Jan T** | 0.16 | -0.02 | -0.16 | -0.17 | -0.53 | -0.68 | -0.64 | -0.56 | 0.22 | 0.18 | 1.00 | | | | |
| **Mx Jul T** | 0.40 | -0.09 | -0.13 | -0.43 | -0.56 | **-0.86** | -0.74 | **-0.83** | 0.34 | 0.39 | **0.83** | 1.00 | | | |
| **Soil C** | 0.13 | -0.13 | 0.07 | -0.28 | 0.15 | 0.12 | 0.18 | 0.15 | -0.12 | 0.06 | -0.22 | -0.18 | 1.00 | | |
| **Soil P** | -0.38 | -0.34 | -0.46 | 0.56 | -0.17 | 0.24 | 0.04 | 0.42 | -0.73 | -0.78 | -0.08 | -0.27 | 0.00 | 1.00 | |
| **Soil D** | -0.13 | 0.09 | 0.30 | -0.14 | 0.51 | 0.17 | 0.45 | 0.26 | 0.19 | 0.28 | -0.30 | -0.22 | 0.51 | 0.10 | 1.00 |

**Table 8.** Correlation matrix of explanatory variables for the 58 gaging stations of region 2, north-central eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mn Jul T | Mx Jan T | Mx Jul T | Soil C | Soil P | Soil D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | 1.00 | | | | | | | | | | | | | | |
| **Slope** | 0.28 | 1.00 | | | | | | | | | | | | | |
| **Aspect** | -0.12 | -0.07 | 1.00 | | | | | | | | | | | | |
| **Elev** | 0.24 | 0.68 | -0.37 | 1.00 | | | | | | | | | | | |
| **Jan P** | 0.19 | 0.55 | -0.05 | 0.44 | 1.00 | | | | | | | | | | |
| **Jul P** | 0.25 | 0.79 | 0.15 | 0.61 | 0.43 | 1.00 | | | | | | | | | |
| **I24-2** | 0.21 | 0.65 | -0.05 | 0.51 | **0.97** | 0.58 | 1.00 | | | | | | | | |
| **Snow** | 0.33 | 0.64 | -0.22 | 0.75 | **0.86** | 0.55 | **0.87** | 1.00 | | | | | | | |
| **Mn Jan T** | -0.09 | -0.15 | 0.33 | -0.59 | -0.09 | 0.06 | -0.05 | -0.28 | 1.00 | | | | | | |
| **Mn Jul T** | -0.22 | -0.43 | 0.33 | -0.79 | -0.32 | -0.25 | -0.37 | -0.54 | 0.77 | 1.00 | | | | | |
| **Mx Jan T** | -0.12 | -0.47 | 0.20 | -0.71 | -0.69 | -0.38 | -0.69 | -0.79 | 0.56 | 0.62 | 1.00 | | | | |
| **Mx Jul T** | -0.20 | -0.42 | 0.44 | **-0.83** | -0.43 | -0.39 | -0.48 | -0.77 | 0.42 | 0.63 | 0.73 | 1.00 | | | |
| **Soil C** | -0.25 | -0.20 | 0.50 | -0.60 | -0.15 | -0.08 | -0.16 | -0.48 | 0.37 | 0.51 | 0.31 | 0.65 | 1.00 | | |
| **Soil P** | 0.19 | -0.14 | -0.10 | -0.09 | 0.48 | -0.05 | 0.38 | 0.32 | 0.12 | 0.19 | -0.27 | -0.18 | -0.09 | 1.00 | |
| **Soil D** | -0.15 | -0.35 | 0.11 | -0.43 | 0.09 | -0.23 | 0.07 | -0.24 | 0.16 | 0.19 | 0.12 | 0.31 | 0.51 | 0.39 | 1.00 |

**Table 9.** Correlation matrix of explanatory variables for the 76 gaging stations of region 3, northeast eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mn Jul T | Mx Jan T | Mx Jul T | Soil C | Soil P | Soil D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | 1.00 | | | | | | | | | | | | | | |
| **Slope** | 0.36 | 1.00 | | | | | | | | | | | | | |
| **Aspect** | -0.16 | 0.01 | 1.00 | | | | | | | | | | | | |
| **Elev** | 0.20 | 0.60 | -0.04 | 1.00 | | | | | | | | | | | |
| **Jan P** | 0.26 | 0.73 | 0.04 | 0.73 | 1.00 | | | | | | | | | | |
| **Jul P** | 0.17 | 0.49 | 0.16 | 0.72 | 0.62 | 1.00 | | | | | | | | | |
| **I24-2** | 0.20 | 0.63 | 0.18 | 0.71 | **0.92** | **0.80** | 1.00 | | | | | | | | |
| **Snow** | 0.29 | 0.65 | 0.06 | **0.86** | **0.89** | **0.82** | **0.92** | 1.00 | | | | | | | |
| **Mn Jan T** | 0.16 | -0.06 | 0.10 | -0.40 | -0.11 | -0.27 | -0.11 | -0.24 | 1.00 | | | | | | |
| **Mn Jul T** | -0.05 | -0.20 | -0.03 | -0.70 | -0.44 | -0.78 | -0.59 | -0.70 | 0.60 | 1.00 | | | | | |
| **Mx Jan T** | 0.01 | -0.50 | 0.11 | -0.72 | -0.67 | -0.55 | -0.65 | -0.72 | 0.44 | 0.52 | 1.00 | | | | |
| **Mx Jul T** | -0.21 | -0.52 | 0.00 | **-0.83** | -0.70 | **-0.86** | **-0.81** | **-0.88** | 0.14 | 0.77 | 0.66 | 1.00 | | | |
| **Soil C** | 0.01 | -0.37 | 0.02 | -0.22 | -0.20 | -0.15 | -0.13 | -0.08 | 0.46 | 0.08 | 0.20 | -0.03 | 1.00 | | |
| **Soil P** | 0.12 | 0.13 | -0.02 | 0.30 | 0.24 | 0.22 | 0.22 | 0.32 | -0.18 | -0.27 | -0.16 | -0.23 | -0.10 | 1.00 | |
| **Soil D** | -0.16 | -0.48 | -0.07 | -0.34 | -0.35 | -0.29 | -0.31 | -0.24 | 0.20 | 0.11 | 0.21 | 0.19 | 0.69 | 0.37 | 1.00 |

**Table 10.** Correlation matrix of explanatory variables for the 51 gaging stations of region 4, central eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mn Jul T | Mx Jan T | Mx Jul T | Soil C | Soil P | Soil D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | 1.00 | | | | | | | | | | | | | | |
| **Slope** | -0.09 | 1.00 | | | | | | | | | | | | | |
| **Aspect** | 0.11 | 0.07 | 1.00 | | | | | | | | | | | | |
| **Elev** | -0.14 | 0.13 | -0.18 | 1.00 | | | | | | | | | | | |
| **Jan P** | -0.13 | 0.42 | -0.01 | 0.58 | 1.00 | | | | | | | | | | |
| **Jul P** | -0.09 | 0.05 | -0.11 | 0.16 | 0.46 | 1.00 | | | | | | | | | |
| **I24-2** | -0.14 | 0.10 | 0.00 | 0.36 | 0.72 | 0.64 | 1.00 | | | | | | | | |
| **Snow** | 0.02 | 0.19 | -0.03 | **0.87** | 0.76 | 0.22 | 0.47 | 1.00 | | | | | | | |
| **Mn Jan T** | -0.33 | 0.05 | 0.00 | -0.63 | -0.19 | -0.01 | -0.06 | -0.62 | 1.00 | | | | | | |
| **Mn Jul T** | -0.04 | 0.14 | -0.07 | -0.31 | -0.13 | -0.16 | -0.28 | -0.25 | 0.59 | 1.00 | | | | | |
| **Mx Jan T** | 0.02 | -0.09 | 0.21 | -0.78 | -0.40 | 0.03 | -0.19 | -0.75 | 0.48 | 0.13 | 1.00 | | | | |
| **Mx Jul T** | 0.29 | -0.14 | 0.12 | -0.52 | -0.69 | -0.45 | -0.63 | -0.60 | -0.02 | 0.09 | 0.50 | 1.00 | | | |
| **Soil C** | -0.22 | 0.27 | -0.13 | 0.34 | 0.51 | 0.45 | 0.36 | 0.45 | 0.02 | -0.09 | -0.43 | -0.68 | 1.00 | | |
| **Soil P** | 0.26 | 0.23 | 0.05 | 0.50 | 0.47 | 0.19 | 0.11 | 0.53 | -0.46 | -0.06 | -0.29 | -0.25 | 0.24 | 1.00 | |
| **Soil D** | -0.01 | 0.14 | 0.03 | 0.32 | 0.32 | 0.24 | 0.37 | 0.32 | -0.05 | -0.24 | -0.37 | -0.45 | 0.74 | 0.17 | 1.00 |

**Table 11.** Correlation matrix of explanatory variables for the 28 gaging stations of region 5, southwest eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mn Jul T | Mx Jan T | Mx Jul T | Soil C | Soil P | Soil D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | 1.00 | | | | | | | | | | | | | | |
| **Slope** | 0.17 | 1.00 | | | | | | | | | | | | | |
| **Aspect** | -0.04 | 0.16 | 1.00 | | | | | | | | | | | | |
| **Elev** | -0.07 | 0.64 | 0.01 | 1.00 | | | | | | | | | | | |
| **Jan P** | -0.12 | 0.34 | 0.02 | 0.26 | 1.00 | | | | | | | | | | |
| **Jul P** | 0.16 | 0.47 | 0.26 | 0.56 | 0.25 | 1.00 | | | | | | | | | |
| **I24-2** | -0.11 | 0.33 | 0.10 | 0.39 | 0.78 | 0.71 | 1.00 | | | | | | | | |
| **Snow** | -0.03 | 0.46 | 0.08 | 0.59 | 0.79 | 0.64 | **0.88** | 1.00 | | | | | | | |
| **Mn Jan T** | -0.21 | -0.09 | -0.31 | 0.10 | -0.14 | -0.32 | -0.28 | -0.35 | 1.00 | | | | | | |
| **Mn Jul T** | -0.15 | 0.05 | -0.19 | 0.01 | -0.34 | -0.56 | -0.65 | -0.58 | 0.78 | 1.00 | | | | | |
| **Mx Jan T** | -0.03 | -0.43 | -0.49 | -0.61 | -0.52 | -0.56 | -0.58 | -0.68 | 0.17 | 0.26 | 1.00 | | | | |
| **Mx Jul T** | -0.04 | -0.58 | -0.33 | **-0.81** | -0.54 | -0.78 | -0.72 | **-0.81** | 0.09 | 0.34 | **0.85** | 1.00 | | | |
| **Soil C** | 0.28 | -0.15 | 0.42 | -0.09 | 0.34 | 0.48 | 0.57 | 0.44 | -0.53 | -0.74 | -0.55 | -0.39 | 1.00 | | |
| **Soil P** | 0.01 | 0.03 | 0.29 | 0.18 | 0.39 | 0.62 | 0.69 | 0.49 | -0.37 | -0.61 | -0.55 | -0.47 | 0.72 | 1.00 | |
| **Soil D** | 0.20 | 0.27 | 0.55 | 0.18 | 0.26 | 0.69 | 0.51 | 0.44 | -0.46 | -0.54 | -0.57 | -0.53 | 0.63 | 0.56 | 1.00 |

**Table 12.** Correlation matrix of explanatory variables for the 22 gaging stations of region 6, southeast eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mn Jul T | Mx Jan T | Mx Jul T | Soil C | Soil P | Soil D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | 1.00 | | | | | | | | | | | | | | |
| **Slope** | 0.25 | 1.00 | | | | | | | | | | | | | |
| **Aspect** | -0.03 | -0.31 | 1.00 | | | | | | | | | | | | |
| **Elev** | -0.04 | -0.01 | 0.22 | 1.00 | | | | | | | | | | | |
| **Jan P** | -0.13 | -0.02 | 0.01 | 0.48 | 1.00 | | | | | | | | | | |
| **Jul P** | -0.41 | -0.20 | 0.27 | 0.17 | 0.57 | 1.00 | | | | | | | | | |
| **I24-2** | -0.04 | -0.16 | 0.25 | 0.56 | **0.91** | 0.53 | 1.00 | | | | | | | | |
| **Snow** | 0.11 | -0.01 | 0.27 | 0.76 | 0.78 | 0.34 | **0.90** | 1.00 | | | | | | | |
| **Mn Jan T** | 0.50 | 0.10 | 0.27 | 0.32 | -0.03 | -0.39 | 0.24 | 0.42 | 1.00 | | | | | | |
| **Mn Jul T** | 0.62 | 0.41 | 0.09 | 0.23 | -0.24 | -0.46 | -0.08 | 0.16 | **0.84** | 1.00 | | | | | |
| **Mx Jan T** | 0.48 | 0.00 | 0.20 | -0.14 | -0.53 | -0.65 | -0.30 | -0.14 | 0.72 | 0.74 | 1.00 | | | | |
| **Mx Jul T** | 0.03 | 0.33 | -0.31 | -0.71 | -0.70 | -0.36 | **-0.84** | **-0.83** | -0.27 | 0.12 | 0.29 | 1.00 | | | |
| **Soil C** | 0.00 | 0.17 | -0.06 | -0.08 | 0.08 | 0.17 | 0.13 | 0.19 | 0.19 | 0.10 | -0.06 | 0.02 | 1.00 | | |
| **Soil P** | -0.48 | -0.41 | 0.04 | 0.11 | -0.01 | 0.34 | -0.10 | -0.14 | -0.51 | -0.45 | -0.33 | 0.01 | -0.45 | 1.00 | |
| **Soil D** | -0.49 | -0.08 | -0.14 | -0.03 | -0.24 | 0.16 | -0.39 | -0.26 | -0.42 | -0.34 | -0.29 | 0.25 | 0.03 | 0.56 | 1.00 |

characteristics used in the final prediction equations was -0.67.

The area determined for each gaged watershed from the spatial analysis was compared to the published value. Where significant differences occurred, the delineation of the watershed was checked. A number of errors were discovered in this way. The distribution of gaged watersheds by area and region is shown in Table 5.

## Description of the Watershed Characteristics

All characteristics represent the watershed upstream of the gaging station, or other point of interest, that contributes to peak discharges. The watershed is delineated based on topography as shown on U.S. Geological Survey 1:24,000-scale topographic maps.

**Drainage area** is the size of the watershed in square miles.

**Mean watershed slope** is calculated as the average of the slopes of all the cells of the digital elevation model found within the watershed boundaries. In this case, slope is given as a percent of vertical or 90 degrees. For example, a 0% percent slope is horizontal, a 50% slope is 45 degrees from horizontal, and a 100% percent slope is vertical.

**Mean watershed aspect** is calculated as the average of the aspects of all the cells of the digital elevation model found within the watershed boundaries. Aspect is given as a compass direction, for example, $0^{o}$ is north facing and $180^{o}$ is south facing.

**Mean elevation** is calculated as the average of the elevations of all the cells of the digital elevation model found within the watershed boundaries. It is reported in feet.

**Mean January precipitation, mean July precipitation, 24-hour 2-year precipitation intensity, and annual snowfall** are calculated as the average of the values of all the cells of their respective coverages found within the watershed boundary. All are reported in inches. Each of the coverages represents averages for water years 1961 to 1990.

**Mean January minimum temperature, mean July minimum temperature, mean January maximum temperature, and mean July maximum temperature** are calculated as the average of the values of all the cells of their respective coverages found within the watershed boundary. All are reported in degrees Fahrenheit. Each of the coverages represents averages for water years 1961 to 1990.

**Soil capacity** is the maximum volume of water the soil is expected to hold. It is calculated as the area weighted average of the soil capacity for all the soils found within the watershed boundary. Soil capacity for a given soil is its porosity times its depth. Soil capacity is reported in inches.

**Soils permeability** is the rate at which water is expected to infiltrate the soil. It is calculated as the area weighted average of the infiltration rate for all the soils found within the watershed boundary. It is reported in inches per hour.

**Soil depth** is the depth of soil to bedrock averaged over the watershed. It is reported in inches.

# Selection of Gaging Stations

Within the study area and adjacent parts of Washington, Idaho, Nevada and California there are around 450 to 500 gaging stations where peak discharges have been systematically recorded. Of these, 299 stations had more than 10 years of record and were in rural watersheds unaffected by significant diversion, regulation or urbanization. Twenty-three of these stations were eliminated for a variety of reasons.

Two gaging stations in northern Nevada considered for inclusion in flood region 6 were dropped because they so profoundly leveraged the fit of the regression line. Little Humboldt River near Paradise Valley, NV (10329000) and Quinn River near McDermitt, NV (10353500) have drainages areas much larger than other stations in the region and significantly lower yields. Including them in the regression resulted in underestimating peak discharges at stations with smaller drainage areas.

Four gaging stations were eliminated because reasonable fits to the log-Pearson Type III distribution could not be made. These stations were Dry Creek at the mouth near Clarkston, WA (13343450), South Fork John Day River near Dayville, OR (14039500), Donnely Creek tributary near Service Creek, Or (14046400), and Wildcat Creek near Prineville, OR (14082400).

The location of the gaging station Dry Lake tributary at Perez, CA (11487700) could not be determined. Published information about the station location (latitude and longitude, physical description, public land survey, and drainage area) could not be reconciled with any actual watershed on 1:24,000 scale topographic maps.

The Williamson River below Sheep Creek near Lenz, OR (11491400) was eliminated because it was an extreme low outlier in any regression trial in which it appeared. The watershed is extremely unproductive. All reported peaks have unit discharges of less than 1.0 cfs per square mile suggesting large losses to regional groundwater. The watershed is in an area of deep pumice deposits.

The Williamson River near Klamath Agency, OR (11493500), the Sycan River near Beatty, OR (11499000), and the Sycan River below Snake Creek near Beatty, OR (1199100) were eliminated because of natural streamflow regulation. The first gaging station is located at the outlet of Klamath Marsh and the other two are below Sycan Marsh. Also the Williamson River gaging station represents a watershed with unit peak discharges of less than 1.0 cfs per square mile. Much of the watershed has deep deposits of pumice from eruptions of Mount Mazama suggesting large losses to regional groundwater.

The South Fork Burnt River above Barney Creek near Unity, OR (13270800) was eliminated because it is unlike other streams in region 3. It has an unproductive watershed with unit peak discharges that are low in comparison to other streams in the region. The South Fork Burnt River is known to have significant contributions from spring flow. The ratio of maximum peak discharge to the 95 percent exceedance streamflow is low (12, compared to the next lowest ratio in the region, 41) suggesting that peak discharges are attenuated due to high groundwater recharge rates in the watershed.

The Malheur River tributary near Harper, OR (13219300) was also eliminated because it is unlike other stream in region 3. In this case, the watershed generates very high runoff. It has recorded 6 of the 89 largest unit peak discharges reported in eastern Oregon. When included in a regression analysis for the region, its residual is over 5 standard deviations from the mean. It has very high leverage and a pronounced effect on the fit of the regression line, causing the resulting predication equation to overestimate peak discharges for small watersheds.
.

Two gaging stations, the Deschutes River at Mecca, OR (14093500) and the Deschutes River at Moody near Biggs, OR (14103000), were eliminated because they could not be assigned to any one region. The upper Deschutes River and east flowing tributaries from the Cascades are in region 1. The rest of the Deschutes basin is divided between regions 2 and 4.

In several cases, gaging stations occur near each other on the same stream reach. In 9 of these cases, one of each pair was eliminated: Deep Creek at Adel, OR (10374500), Grande Ronde River at Elgin, OR (13324000), Asotin Creek near Asotin, OR (13334500), South Fork Walla Walla River near Milton, OR (14010500), Umatilla River at Gibbon, OR (14020500), Umatilla River above McKay Creek near Pendleton, OR (14022000), Butter Creek at Foleys Bridge near Echo, OR (14032050), Rock Creek above Cayuse Canyon near Condon, OR (14047400), and White River above Trout Creek near Trout Lake, WA (14121400). For each pair, estimated peak discharges at the upstream station are greater than at the downstream station. The apparent decrease in discharge occurs not because of stream losses, but because of uncertainty in estimating the peak discharges. For each pair, only the station considered the most reliable was retained. The stations were judged on their length and quality of record and their fit to the probability distribution.

# The Regression Analysis

A regional regression analysis is based on the assumption that streamflow is related to various watershed characteristics. For example, streamflow increases with watershed size, other factors like precipitation being equal. A 100-square mile watershed produces more runoff than a 25-square mile watershed.

As an example, the relationship between 100-year peak streamflows and watershed area for region 3 is shown in Figure 17. The line shown on the plot minimizes the sum of the squared differences between the line and the points.

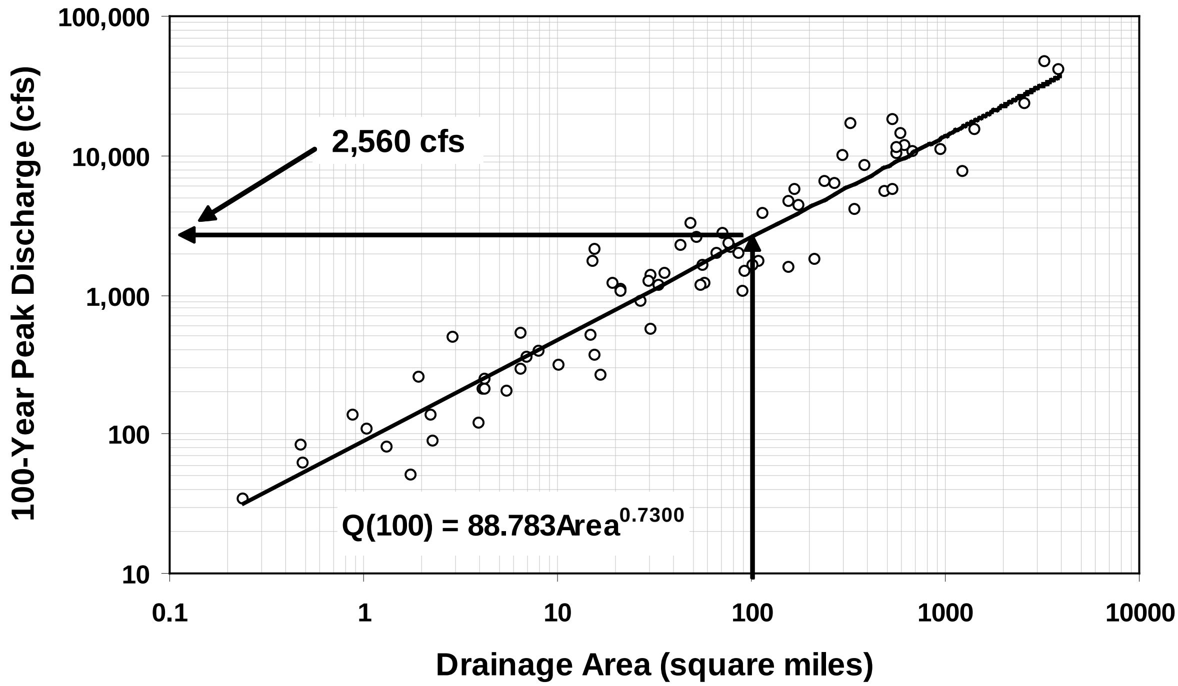



**Figure 17.** A simple regional regression model. 100-year peak discharges are plotted against watershed area for Region 3. The line (i.e., the model) through the data points was fitted by ordinary least squares regression analysis and is represented mathematically by the equation shown on the chart. Based on this model, a watershed of 100 square miles has a 100-year peak discharge of about 2,560 cfs.

The line "models" the relationship between streamflow and watershed area. It can be used to predict the streamflow for a watershed given its area. The variation about the line is due, in part, to other watershed characteristics not included in the model.

Similar relationships exist between peak discharge and other watershed characteristics (Table 6), each characteristic accounting for part of the variability in streamflow. These relationships can be quantified in a mathematical form. For this analysis, a linear relationship is assumed between streamflow and watershed characteristics. The linear mathematical model takes the form

$$y = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_m x_m \quad \text{.......................} (4)$$

where y represents streamflow and $x_1, x_2, \ldots, x_m$ represent the *m* watershed characteristics. The regression coefficients, $b_1, b_2, \ldots, b_m$, define the relationship among variables and are determined from the data.

The data consist of *n* observations of y and $x_m$, from which *n* equations of the type of Equation 4 can be written. The regression coefficients are determined by minimizing the sum of the squared differences between the actual values of y and the values of y estimated by the *n* equations. The equations resulting from this minimization are called the normal equations.

While regression analysis assumes a linear relationship between the response and predictor variables, the true relationship for peak streamflows is nonlinear. A log-transformation of peak discharges and watershed characteristics allows the nonlinear relationship to be modeled by a linear relationship (Riggs, 1968, 1973).

The nonlinear model of the relationship between streamflow and watershed characteristics looks like this

$$y = 10^{b_0} x_1^{b_1} x_2^{b_2} \cdots x_m^{b_m} \quad \text{......................................} (5)$$

A logarithmic transformation of Equation 5 yields the linear relationship

$$\log(y) = b_0 + b_1\log(x_1) + b_2\log(x_2) + \cdots + b_m\log(x_m) \qquad (6)$$

Previous studies in Oregon have used ordinary least-squares regression to derive the prediction equations. Ordinary least-squares regression assumes that peak discharge records are equally reliable, i.e., of the same length and variance, and that concurrent flows at any pair of stations are independent. These conditions are seldom met in practice.

Tasker and Stedinger (1989) proposed an operational generalized least-squares model for deriving prediction equations for streamflow characteristics such as peak discharge. This model accounts for the unequal lengths and variances of peak discharge records and cross-correlation between series of streamflow characteristics. Tasker and others (1986) showed that generalized least-squares, compared to ordinary least-squares, provides (1) estimates of regression parameters with smaller mean square errors, (2) relatively unbiased estimates of the variance of the regression parameters, and (3) a more accurate estimate of the model error.

## Defining the Prediction Equations

Only some of the 15 watershed characteristics are correlated with peak discharge. Since only correlated watershed characteristics can explain the observed variability in peak discharges, there is no benefit to including all characteristics in a prediction equation. The goal, then, is to find the prediction equation that explains as much of the observed variability in peak discharges as possible with the fewest number of watershed characteristics.

With 15 watershed characteristics, the number of possible prediction equations is $2^{15} - 1$ or 32,767. Rather than test all possible prediction equations, a backward-step analysis may be used to determine the best prediction equation. In a backward step analysis, a regression is done using all candidate watershed characteristics. The characteristic that has the least significant coefficient is eliminated and the regression is run again. This process is repeated until only one characteristic remains.

Each regression is associated with a set of watershed characteristics and their respective coefficients, and each set of characteristics and coefficients represents a candidate prediction equation. The best prediction equation generally is considered to be the combination of watershed characteristics that gives the smallest model error while its regression coefficients are all significantly different from zero. The significance of the regression coefficients is determined by a statistical test (Student’s t-test was used).

The null hypothesis, $H_o$, is that the coefficient in question is equal to zero. The statistical test determines the probability, P, that the coefficient is *not* different from zero. $H_o$ is rejected, and the coefficient retained, for small values of P. In this analysis, $H_o$ is rejected for P less than 0.05.

The computer program used to do the generalized least squares regressions (GLSNET, version 2.5), limits the number of predictor variables to 9, so the set of 15 watershed characteristics had to be reduced to 9 or fewer for each region. First, highly correlated pairs of watershed characteristics ($r \geq 0.8$) were identified for each region. A regression was done for each characteristic from each pair. Only the characteristic with the most significant regression coefficient was retained. Second, regressions were done using ordinary least squares analysis to determine the characteristics most likely to be significantly correlated to peak discharge from among the remaining characteristics.

To be certain that the selected set of characteristics did not exhibit significant collinearity, two tests were done. In the first test, a quantity called the *variance inflation factor* (VIF) was determined for each watershed characteristic used in a generalized least squares regression for each region (Chatterjee and others, 2000). If the predictor variable $X_j$ is regressed on all other predictor variables in the characteristic set, then

$$VIF_j = \frac{1}{1 - R_j^2} \qquad (7)$$

where

$R_j^2$ = the square of the multiple correlation coefficient that results from the regression of $X_j$ on the other predictor variables.

The further $VIF_j$ deviates from one, the stronger is the indication of collinearity between $X_j$ and the other predictor variables. Chatterjee and others (2000) suggest that a VIF in excess of 10 indicates that multicollinearity may interfere with estimation of the regression coefficients. The results of this test are shown in Table 13. None of the VIFs were greater than 10. The largest was 5.40.

In the second test, principal components were used to determine the presence of multicollinearity (Chatterjee and others, 2000). In determining the principal components, eigenvalues were calculated. Two quantities based on the eigenvalues are indicators of multicollinearity. The first is the condition number, which is simply the square root of the maximum eigenvalue divided by the minimum eigenvalue. The second quantity is the sum of the reciprocals of the eigenvalues. Chatterjee and others (2000) suggest that significant collinearity is indicated when the condition number exceeds 15 and when the sum of reciprocals of the eigenvalues exceeds five times the number of predictor variables, or 45 for all regions. The results of this test are shown in Table 14. None of the condition numbers exceeded 15, the largest being only 5.56. None of the sums of reciprocals exceeded 45, the largest being only 22.0.

When the set of nine or fewer characteristics was determined for each region, a backward step analysis was done using the 100-year peak discharges. The results of the backward-step analyses for regions 1, 2, 3, 4, 5, and 6 are shown in tables 15, 16, 17, 18, 19, and 20, respectively.

The set of characteristics determined for the 100-year peak discharges was used for all frequencies. If a backward step analysis is done independently at each frequency, the resulting prediction equations may incorporate different predictor variables. While this may lead to the smallest model errors for each equation, it may lead to undesirable results overall. Specifically, flood magnitude may not vary smoothly with frequency - a plot of magnitude versus frequency likely will show discontinuities. It is even possible that the magnitude of a high frequency event will exceed the magnitude of a low frequency event. For example, the 10-year event could be larger than the 25-year event.

The final prediction equations are shown by region, in Tables 21, 22, 23, 24, 25, and 26. Maps of all of the characteristics used in the prediction equations are shown in figures 18, 19, 20, 21, 22, 23, 24 and 25. These maps are for illustration only. It is strongly recommended that estimates of watershed characteristics be made from the digital grids and coverages described in Appendix F using GIS techniques.

# Accuracy of the Prediction Equations

Measures of the accuracy of the prediction equations are average prediction error (Wiley and others, 2000) and equivalent years of record (Hardison, 1971). These measures are reported in Tables 21, 22, 23, 24, 25, and 26 for all prediction equations developed in this analysis. The average prediction error ranged from 37.7 to 104 percent over the six flood regions. Equivalent years of record varied from 1.2 to 20.1 years. Flood region 6 had the highest average prediction error.

The average prediction error is the square root of the sum of the squared standard error of the model and the average squared standard error of sampling *in log units*. Model error is the uncertainty due to a model that does not account for all the variability in peak discharges. Sampling error is the uncertainty due to estimating model parameters from a sample, i.e., not from the whole population (Tasker and Stedinger, 1989). For all prediction equations, the model error is larger than the error due to sampling. The contribution of the sampling error to the total error, or average prediction error, ranges from about two percentage points for region 2 to about eight percentage points for region 6.

In practical terms, the small sampling error compared to the large model error means increasing the length of record available for estimating the peak discharges at gaged watersheds will not significantly decrease the average error of prediction. More benefit would result from improving the models by increasing the accuracy with which current watershed characteristics are estimated or by adding new characteristics to account for previously unaccounted for variability. The preceding comment does not mean that estimates of peak discharge at individual gaging stations could not be improved by additional years of record. Estimates at short record stations likely would be improved by additional record.

An equivalent number of years of record is the number of years of actual record required to give the same accuracy as a prediction equation. It is also used as a weighting factor in estimating peak

**Table 13.** Variance inflation factors (VIFs) for the characteristic sets used in the generalized least squares regressions for each region. A VIF in excess of 10 suggests that multicollinearity is significant enough to interfere with estimation of coefficients in the regression. All VIF calculated for these data sets are considerably less than 10.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Watershed Characteristic | Region 1 | Region 2 | Region 3 | Region 4 | Region 5 | Region 6 |
|---|---|---|---|---|---|---|
| **Area** | 2.57 | 1.22 | 1.35 | 1.39 | 1.30 | 1.62 |
| **Slope** | 1.42 | ----- | 2.69 | 1.44 | ----- | 2.64 |
| **Aspect** | 2.09 | 1.60 | 1.19 | 1.08 | 2.43 | 1.67 |
| **Elev** | 4.67 | ----- | 3.93 | ----- | 3.70 | 2.94 |
| **Jan P** | ----- | 1.96 | 3.43 | 2.96 | 1.77 | 3.73 |
| **Jul P** | ----- | 2.03 | 2.36 | ----- | 4.28 | 2.73 |
| **I24-2** | ----- | ----- | ----- | ----- | ----- | ----- |
| **Snow** | 2.37 | ----- | ----- | ----- | ----- | ----- |
| **Mn Jan T** | ----- | 1.50 | ----- | 1.45 | 1.49 | 2.68 |
| **Mn Jul T** | ----- | ----- | ----- | ----- | ----- | ----- |
| **Mx Jan T** | 1.59 | ----- | 2.74 | ----- | 5.40 | ----- |
| **Mx Jul T** | ----- | 3.01 | ----- | 3.24 | ----- | 5.90 |
| **Soil C** | 1.75 | 2.74 | ----- | 3.91 | ----- | ----- |
| **Soil P** | 2.56 | 2.09 | 1.62 | 1.73 | 2.52 | 2.73 |
| **Soil D** | 2.21 | 20.1 | 1.94 | 2.50 | 3.43 | ----- |

**Table 14.** A principal component analysis of possible multicollinearity among the characteristics sets used in the generalized least squares regressions for each region. A condition number greater than 15 is an indication that multicollinearity is significant enough to interfere with estimation of regression coefficients. Similarly, significant multicollinearity is indicated if the sum of reciprocals of the eigenvalues is larger than five times the number of predictor variables – in this case, 45. These results indicate that multicollinearity is not a factor in estimating regression coefficients for prediction equations in any region.

| Parameter | Region 1 | Region 2 | Region 3 | Region 4 | Region 5 | Region 6 |
|---|---|---|---|---|---|---|
| **Condition Number** | 4.16 | 3.68 | 4.33 | 3.95 | 5.56 | 4.90 |
| **Sum of Reciprocals** | 17.4 | 16.0 | 19.2 | 16.2 | 21.6 | 22.0 |

**Table 15.** Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 1, east slope of the Cascade Range.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Snow,** mean annual snowfall, in inches; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P** soil permeability, in inches per hour; **Soil D**, in soil depth, in inches; -----, variable removed. Selected model is indicated by the shaded area.]

| Predictor Variable | Step | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | d | e | f | g | h | i |
| | Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero. | | | | | | | | |
| **Area** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Slope** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | ----- |
| **Aspect** | 0.805 | 0.719 | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Elev** | 0.027 | 0.007 | 0.006 | 0.002 | 0.001 | 0.000 | 0.000 | ----- | ----- |
| **Snow** | 0.738 | 0.752 | 0.782 | ----- | ----- | ----- | ----- | ----- | ----- |
| **Mx Jan T** | 0.552 | 0.541 | 0.542 | 0.395 | ----- | ----- | ----- | ----- | ----- |
| **Soil C** | 0.328 | 0.312 | 0.332 | 0.271 | 0.210 | 0.132 | ----- | ----- | ----- |
| **Soil P** | 0.492 | 0.470 | 0.309 | 0.287 | 0.291 | ----- | ----- | ----- | ----- |
| **Soil D** | 0.891 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Model error - log units** | 0.033903 | 0.032650 | 0.031608 | 0.0305565 | 0.030289 | 0.030447 | 0.031886 | 0.048486 | 0.15765 |
| **Model error – percent** | 44.4 | 43.5 | 42.7 | 41.9 | 41.7 | 41.9 | 42.9 | 54.1 | 114 |
| **Sampling error - percent** | 26.0 | 24.3 | 22.9 | 21.1 | 19.4 | 18.0 | 16.4 | 16.6 | 22.3 |
| **Prediction error - percent** | 52.7 | 50.9 | 49.4 | 47.8 | 46.7 | 46.2 | 46.5 | 57.4 | 119 |
| **Equivalent years of record** | 4.6 | 4.9 | 5.1 | 5.5 | 5.7 | 5.9 | 5.8 | 4.0 | 1.3 |

**Table 16.** Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 2, north-central eastern Oregon.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches; -----, variable removed. Selected model is indicated by the shaded area.]

| Predictor Variable | Step | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | d | e | f | g | h | i |
| | Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero. | | | | | | | | |
| **Area** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Aspect** | 0.561 | 0.578 | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Jan P** | 0.007 | 0.005 | 0.005 | 0.005 | 0.006 | 0.001 | 0.009 | ----- | ----- |
| **Jul P** | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 | ----- |
| **Mn Jan T** | 0.510 | 0.522 | 0.537 | 0.407 | ----- | ----- | ----- | ----- | ----- |
| **Mx Jul T** | 0.582 | 0.538 | 0.576 | ----- | ----- | ----- | ----- | ----- | ----- |
| **Soil C** | 0.131 | 0.102 | 0.121 | 0.018 | 0.013 | 0.003 | ----- | ----- | ----- |
| **Soil P** | 0.845 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Soil D** | 0.406 | 0.372 | 0.339 | 0.393 | 0.395 | ----- | ----- | ----- | ----- |
| **Model error - log units** | 0.024631 | 0.023911 | 0.023914 | 0.022934 | 0.022729 | 0.022550 | 0.028716 | 0.041504 | 0.049299 |
| **Model error – percent** | 37.4 | 36.8 | 36.4 | 36.0 | 35.8 | 35.6 | 40.6 | 49.6 | 57.7 |
| **Sampling error - percent** | 27.6 | 25.9 | 24.8 | 23.4 | 22.0 | 20.6 | 20.0 | 19.0 | 16.8 |
| **Prediction error - percent** | 47.6 | 46.0 | 45.0 | 43.7 | 42.8 | 41.8 | 45.9 | 54.0 | 57.9 |
| **Equivalent years of record** | 16.1 | 17.0 | 17.6 | 18.5 | 19.2 | 20.1 | 17.1 | 12.9 | 11.5 |

**Table 17.** Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 3, northeast eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; inches; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Selected model is indicated by the shaded area.]

| Predictor Variable | Step | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | d | e | f | g | h | i |
| | Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero. | | | | | | | | |
| **Area** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Slope** | 0.938 | 0.939 | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Aspect** | 0.353 | 0.336 | 0.333 | 0.320 | 0.277 | 0.281 | 0.351 | 0.368 | ----- |
| **Elev** | 0.302 | 0.262 | 0.261 | 0.261 | 0.268 | 0.218 | 0.469 | ----- | ----- |
| **Jan P** | 0.846 | 0.843 | 0.799 | 0.773 | ----- | ----- | ----- | ----- | ----- |
| **Jul P** | 0.992 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Mx Jan T** | 0.427 | 0.421 | 0.417 | 0.426 | 0.322 | 0.301 | ----- | ----- | ----- |
| **Soil P** | 0.717 | 0.715 | 0.717 | 0.574 | 0.584 | ----- | ----- | ----- | ----- |
| **Soil D** | 0.859 | 0.857 | 0.830 | ----- | ----- | ----- | ----- | ----- | ----- |
| **Model error - log units** | 0.041158 | 0.040345 | 0.039563 | 0.038834 | 0.038160 | 0.037658 | 0.037719 | 0.037387 | 0.037262 |
| **Model error – percent** | 49.4 | 48.8 | 48.3 | 47.8 | 47.4 | 47.0 | 47.1 | 46.8 | 46.4 |
| **Sampling error - percent** | 23.0 | 21.8 | 20.5 | 19.4 | 17.9 | 16.8 | 15.7 | 13.6 | 11.8 |
| **Prediction error - percent** | 55.6 | 54.5 | 53.4 | 52.4 | 51.4 | 50.5 | 50.2 | 49.2 | 48.5 |
| **Equivalent years of record** | 5.2 | 5.4 | 5.7 | 5.8 | 6.1 | 6.3 | 6.3 | 6.6 | 6.8 |

**Table 18.** Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 4, central eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Jan P**, mean January precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Selected model is indicated by the shaded area.]

| Predictor Variable | Step | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | d | e | f | g | h | i |
| | Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero. | | | | | | | | |
| **Area** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Slope** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.034 | ----- |
| **Aspect** | 0.340 | 0.360 | 0.443 | ----- | ----- | ----- | ----- | ----- | ----- |
| **Jan P** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | ----- | ----- |
| **Mn Jan T** | 0.022 | 0.013 | 0.013 | 0.011 | 0.016 | ----- | ----- | ----- | ----- |
| **Mx Jul T** | 0.258 | 0.252 | 0.374 | 0.303 | ----- | ----- | ----- | ----- | ----- |
| **Soil C** | 0.388 | 0.389 | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Soil P** | 0.869 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Soil D** | 0.002 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | ----- | ----- | ----- |
| **Model error - log units** | 0.031101 | 0.030189 | 0.029969 | 0.029620 | 0.029693 | 0.034143 | 0.050593 | 0.061133 | 0.067009 |
| **Model error – percent** | 42.3 | 41.7 | 41.5 | 41.2 | 41.3 | 44.6 | 55.5 | 61.9 | 65.3 |
| **Sampling error - percent** | 24.8 | 23.5 | 22.3 | 21.1 | 20.1 | 19.5 | 20.0 | 18.8 | 16.8 |
| **Prediction error - percent** | 50.2 | 48.8 | 48.0 | 47.1 | 46.7 | 49.4 | 60.0 | 65.7 | 68.3 |
| **Equivalent years of record** | 5.2 | 5.5 | 5.7 | 5.9 | 6.0 | 5.4 | 3.8 | 3.3 | 3.1 |

**Table 19.** Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 5, southwest eastern Oregon.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T,** mean maximum July temperature, in degrees Fahrenheit; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Selected model is indicated by the shaded area.]

| Predictor Variable | Step | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | d | e | f | g | h | i |
| | Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero. | | | | | | | | |
| **Area** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Aspect** | 0.848 | 0.827 | 0.865 | ----- | ----- | ----- | ----- | ----- | ----- |
| **Elev** | 0.013 | 0.007 | 0.001 | 0.001 | 0.001 | 0.000 | 0.003 | ----- | ----- |
| **Jan P** | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | ----- |
| **Jul P** | 0.065 | 0.029 | 0.025 | 0.021 | 0.045 | 0.008 | ----- | ----- | ----- |
| **Mn Jan T** | 0.179 | 0.160 | 0.147 | 0.135 | 0.191 | ----- | ----- | ----- | ----- |
| **Mx Jan T** | 0.864 | 0.874 | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Soil P** | 0.278 | 0.264 | 0.231 | 0.214 | ----- | ----- | ----- | ----- | ----- |
| **Soil D** | 0.969 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Model error - log units** | 0.023054 | 0.021239 | 0.019644 | 0.018220 | 0.019070 | 0.020119 | 0.029643 | 0.044803 | 0.066105 |
| **Model error – percent** | 36.1 | 34.5 | 33.1 | 31.9 | 32.6 | 33.6 | 41.3 | 51.8 | 64.8 |
| **Sampling error - percent** | 29.8 | 28.1 | 26.0 | 24.4 | 23.2 | 22.1 | 22.5 | 23.0 | 22.7 |
| **Prediction error - percent** | 48.0 | 45.5 | 43.0 | 40.9 | 40.7 | 40.9 | 47.9 | 57.9 | 70.2 |
| **Equivalent years of record** | 8.5 | 9.3 | 10.3 | 11.2 | 11.1 | 11.0 | 8.2 | 5.8 | 4.2 |

**Table 20.** Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 6, southeast eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil P**, soil permeability, in inches per hour. Selected model is indicated by the shaded area.]

| Predictor Variable | Step | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | d | e | f | g | h | i |
| | Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero. | | | | | | | | |
| **Area** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Slope** | 0.554 | 0.532 | 0.325 | 0.310 | ----- | ----- | ----- | ----- | ----- |
| **Aspect** | 0.149 | 0.126 | 0.104 | 0.090 | 0.137 | 0.021 | 0.020 | 0.007 | ----- |
| **Elev** | 0.553 | 0.405 | 0.476 | ----- | ----- | ----- | ----- | ----- | ----- |
| **Jan P** | 0.196 | 0.139 | 0.147 | 0.191 | 0.158 | 0.485 | ----- | ----- | ----- |
| **Jul P** | 0.223 | 0.202 | 0.214 | 0.198 | 0.176 | ----- | ----- | ----- | ----- |
| **Mn Jan T** | 0.351 | 0.327 | 0.166 | 0.085 | 0.082 | 0.202 | 0.200 | ----- | ----- |
| **Mx Jul T** | 0.869 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Soil P** | 0.679 | 0.633 | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Model error - log units** | 0.077814 | 0.071058 | 0.066508 | 0.064061 | 0.064550 | 0.69177 | 0.066936 | 0.070277 | 0.10940 |
| **Model error – percent** | 71.5 | 67.6 | 65.0 | 63.6 | 63.9 | 66.6 | 65.3 | 67.2 | 88.7 |
| **Sampling error - percent** | 54.3 | 49.6 | 45.2 | 41.4 | 38.1 | 35.3 | 30.9 | 27.4 | 26.9 |
| **Prediction error - percent** | 97.8 | 90.3 | 84.5 | 80.3 | 78.3 | 78.9 | 75.0 | 74.9 | 95.7 |
| **Equivalent years of record** | 3.6 | 4.1 | 4.5 | 4.9 | 5.1 | 5.1 | 5.6 | 5.5 | 3.8 |

**Table 21**. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 1, eastern slope of the Cascade Range.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet.]

| Prediction equation | Percent standard error of the model, in percent | Average standard error of sampling, in percent | Average prediction error, in percent | Average equivalent years of record |
|---|---|---|---|---|
| $Q(2) = 0.7516\ Area^{0.8787}\ Slope^{1.984}\ (Elev/1{,}000)^{-1.069}$ | 46.3 | 14.9 | 49.1 | 1.2 |
| $Q(5) = 1.986\ Area^{0.8392}\ Slope^{1.981}\ (Elev/1{,}000)^{-1.315}$ | 38.6 | 13.3 | 41.1 | 2.4 |
| $Q(10) = 3.262\ Area^{0.8181}\ Slope^{1.992}\ (Elev/1{,}000)^{-1.454}$ | 37.4 | 13.5 | 40.1 | 3.5 |
| $Q(25) = 5.352\ Area^{0.7980}\ Slope^{2.011}\ (Elev/1{,}000)^{-1.599}$ | 38.5 | 14.4 | 41.5 | 4.7 |
| $Q(50) = 7.195\ Area^{0.7870}\ Slope^{2.027}\ (Elev/1{,}000)^{-1.688}$ | 40.4 | 15.4 | 43.7 | 5.4 |
| $Q(100) = 9.242\ Area^{0.7783}\ Slope^{2.045}\ (Elev/1{,}000)^{-1.765}$ | 42.9 | 16.4 | 46.5 | 5.8 |
| $Q(500) = 14.73\ Area^{0.7636}\ Slope^{2.088}\ (Elev/1{,}000)^{-1.912}$ | 50.2 | 19.2 | 54.6 | 6.1 |

**Table 22**. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 2, north-central eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **Soil C,** soil storage capacity, in inches.]

| Prediction equation | Percent standard error of the model, in percent | Average standard error of sampling, in percent | Average prediction error, in percent | Average equivalent years of record |
|---|---|---|---|---|
| $Q(2) = 31.63\ Area^{0.7947}\ Jan\ P^{1.335}\ Jul\ P^{-0.5420}\ Soil\ C^{1.337}$ | 58.9 | 19.7 | 63.2 | 2.1 |
| $Q(5) = 149.5\ Area^{0.7783}\ Jan\ P^{1.037}\ Jul\ P^{-0.7030}\ Soil\ C^{1.615}$ | 41.0 | 17.0 | 44.9 | 5.8 |
| $Q(10) = 252.6\ Area^{0.7706}\ Jan\ P^{0.8967}\ Jul\ P^{-0.8129}\ Soil\ C^{1.622}$ | 35.0 | 16.8 | 39.3 | 10.4 |
| $Q(25) = 367.6\ Area^{0.7617}\ Jan\ P^{0.7737}\ Jul\ P^{-0.9569}\ Soil\ C^{1.556}$ | 32.7 | 17.8 | 37.7 | 16.1 |
| $Q(50) = 444.9\ Area^{0.7559}\ Jan\ P^{0.7050}\ Jul\ P^{-1.059}\ Soil\ C^{1.499}$ | 33.5 | 19.1 | 39.1 | 18.9 |
| $Q(100) = 520.6\ Area^{0.7507}\ Jan\ P^{0.6468}\ Jul\ P^{-1.154}\ Soil\ C^{1.445}$ | 35.6 | 20.6 | 41.8 | 19.6 |
| $Q(500) = 702.7\ Area^{0.7407}\ Jan\ P^{0.5300}\ Jul\ P^{-1.348}\ Soil\ C^{1.330}$ | 44.2 | 24.6 | 51.7 | 20.1 |

**Table 23**. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 3, northeast eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles.]

| Prediction equation | Percent standard error of the model, in percent | Average standard error of sampling, in percent | Average prediction error, in percent | Average equivalent years of record |
|---|---|---|---|---|
| $Q(2) = 21.83\ Area^{0.7546}$ | 56.8 | 10.9 | 58.2 | 1.3 |
| $Q(5) = 36.80\ Area^{0.7459}$ | 47.3 | 10.1 | 48.6 | 2.5 |
| $Q(10) = 47.68\ Area^{0.7431}$ | 44.8 | 10.2 | 46.1 | 3.6 |
| $Q(25) = 61.90\ Area^{0.7415}$ | 44.3 | 10.7 | 45.8 | 5.2 |
| $Q(50) = 72.81\ Area^{0.7408}$ | 45.1 | 11.2 | 46.8 | 6.1 |
| $Q(100) = 84.03\ Area^{0.7402}$ | 46.7 | 11.8 | 48.5 | 6.8 |
| $Q(500) = 111.9\ Area^{0.7388}$ | 52.2 | 13.3 | 54.3 | 7.7 |

**Table 24**. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 4, central eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Jan P**, mean January precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Soil D**, soil depth, in inches.]

| Prediction equation | Percent standard error of the model, in percent | Average standard error of sampling, in percent | Average prediction error, in percent | Average equivalent years of record |
|---|---|---|---|---|
| $Q(2) = 1.051\ Area^{0.8723}\ Slope^{-0.8984}\ Jan\ P^{2.381}\ Mn\ Jan\ T^{2.169}\ Soil\ D^{-1.257}$ | 48.6 | 18.5 | 52.7 | 1.4 |
| $Q(5) = 11.54\ Area^{0.8576}\ Slope^{-0.8858}\ Jan\ P^{2.025}\ Mn\ Jan\ T^{1.983}\ Soil\ D^{-1.530}$ | 42.1 | 17.2 | 46.1 | 2.3 |
| $Q(10) = 28.15\ Area^{0.8509}\ Slope^{-0.8835}\ Jan\ P^{1.857}\ Mn\ Jan\ T^{1.981}\ Soil\ D^{-1.665}$ | 40.5 | 17.5 | 44.7 | 3.3 |
| $Q(25) = 58.27\ Area^{0.8445}\ Slope^{-0.8857}\ Jan\ P^{1.699}\ Mn\ Jan\ T^{2.043}\ Soil\ D^{-1.782}$ | 40.1 | 18.3 | 44.7 | 4.5 |
| $Q(50) = 83.98\ Area^{0.8407}\ Slope^{-0.8904}\ Jan\ P^{1.610}\ Mn\ Jan\ T^{2.117}\ Soil\ D^{-1.865}$ | 40.5 | 19.2 | 45.5 | 5.3 |
| $Q(100) = 109.2\ Area^{0.8375}\ Slope^{-0.8971}\ Jan\ P^{1.538}\ Mn\ Jan\ T^{2.205}\ Soil\ D^{-1.941}$ | 41.3 | 20.1 | 46.7 | 6.0 |
| $Q(500) = 152.8\ Area^{0.8316}\ Slope^{-0.9183}\ Jan\ P^{1.416}\ Mn\ Jan\ T^{2.449}\ Soil\ D^{-2.097}$ | 44.2 | 22.3 | 50.5 | 7.1 |

**Table 25.** Prediction equations for estimating peak discharges for ungaged watersheds in flood region 5, southwest eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit.]

| Prediction equation | Percent standard error of the model, in percent | Average standard error of sampling, in percent | Average prediction error, in percent | Average equivalent years of record |
|---|---|---|---|---|
| $Q(2) = 0.4165\ Area^{0.6647}\ (Elev/1{,}000)^{2.888}\ Jan\ P^{-1.375}\ Jul\ P^{-0.6152}$ | 48.7 | 22.0 | 54.5 | 1.7 |
| $Q(5) = 0.2788\ Area^{0.7052}\ (Elev/1{,}000)^{3.441}\ Jan\ P^{-1.542}\ Jul\ P^{-0.7073}$ | 40.0 | 18.9 | 42.1 | 3.7 |
| $Q(10) = 0.2226\ Area^{0.7254}\ (Elev/1{,}000)^{3.738}\ Jan\ P^{-1.612}\ Jul\ P^{-0.7485}$ | 33.3 | 18.7 | 38.7 | 5.9 |
| $Q(25) = 0.1694\ Area^{0.7468}\ (Elev/1{,}000)^{4.075}\ Jan\ P^{-1.687}\ Jul\ P^{-0.7908}$ | 31.7 | 19.6 | 37.8 | 8.6 |
| $Q(50) = 0.1397\ Area^{0.7608}\ (Elev/1{,}000)^{4.302}\ Jan\ P^{-1.736}\ Jul\ P^{-0.8185}$ | 32.2 | 20.7 | 38.8 | 10.1 |
| $Q(100) = 0.1174\ Area^{0.7737}\ (Elev/1{,}000)^{4.505}\ Jan\ P^{-1.781}\ Jul\ P^{-0.8428}$ | 33.6 | 22.1 | 40.9 | 11.0 |
| $Q(500) = 0.08444\ Area^{0.8011}\ (Elev/1{,}000)^{4.892}\ Jan\ P^{-1.863}\ Jul\ P^{-0.8859}$ | 39.3 | 25.9 | 48.1 | 11.4 |

**Table 26.** Prediction equations for estimating peak discharges for ungaged watersheds in flood region 6, southeast eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees.]

| Prediction equation | Percent standard error of the model, in percent | Average standard error of sampling, in percent | Average prediction error, in percent | Average equivalent years of record |
|---|---|---|---|---|
| $Q(2) = 29.38\ Area^{0.7718}\ (Aspect/100)^{-2.200}$ | 94.6 | 32.1 | 104 | 1.2 |
| $Q(5) = 75.05\ Area^{0.7796}\ (Aspect/100)^{-2.556}$ | 76.0 | 27.6 | 83.6 | 1.9 |
| $Q(10) = 112.5\ Area^{0.7873}\ (Aspect/100)^{-2.664}$ | 69.7 | 26.4 | 76.2 | 2.8 |
| $Q(25) = 164.7\ Area^{0.7977}\ (Aspect/100)^{-2.749}$ | 66.2 | 26.1 | 73.2 | 4.1 |
| $Q(50) = 207.8\ Area^{0.8051}\ (Aspect/100)^{-2.808}$ | 66.0 | 26.6 | 73.3 | 4.9 |
| $Q(100) = 255.6\ Area^{0.8120}\ (Aspect/100)^{-2.872}$ | 67.2 | 27.4 | 74.9 | 5.5 |
| $Q(500) = 389.6\ Area^{0.8267}\ (Aspect/100)^{-3.039}$ | 73.5 | 30.1 | 82.5 | 6.3 |

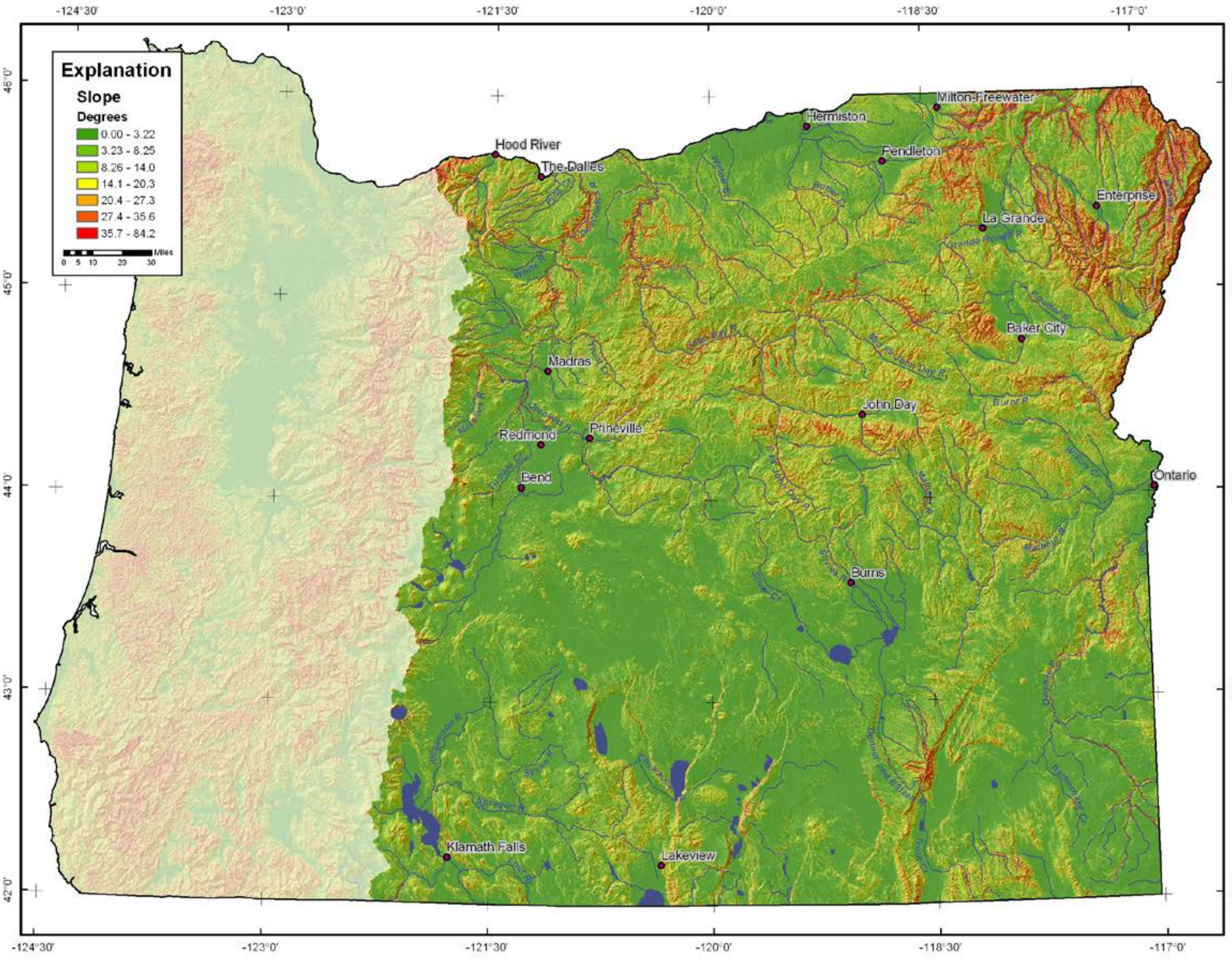



**Figure 18.** Areal distribution of slope.

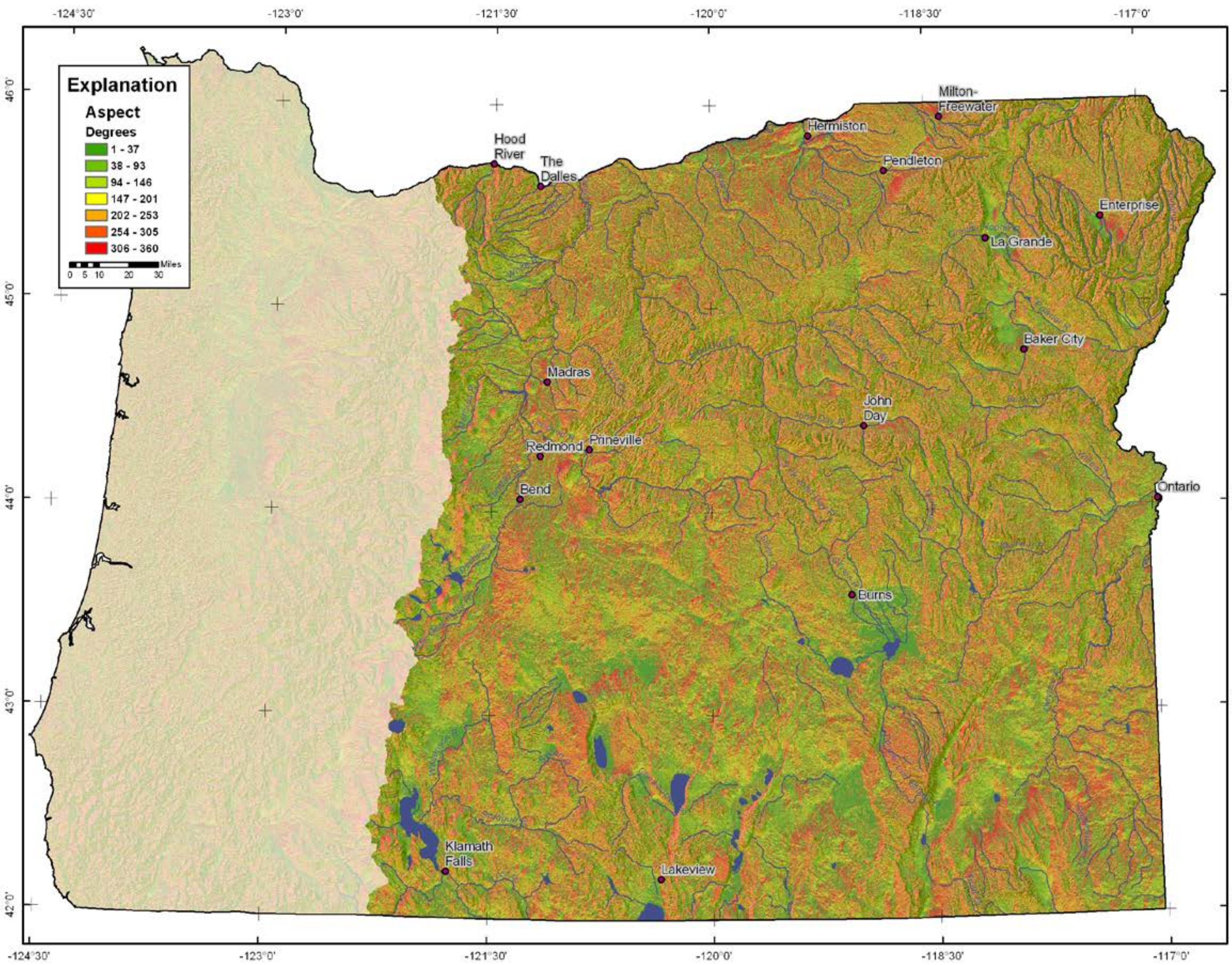



**Figure 19.** Areal distribution of aspect.

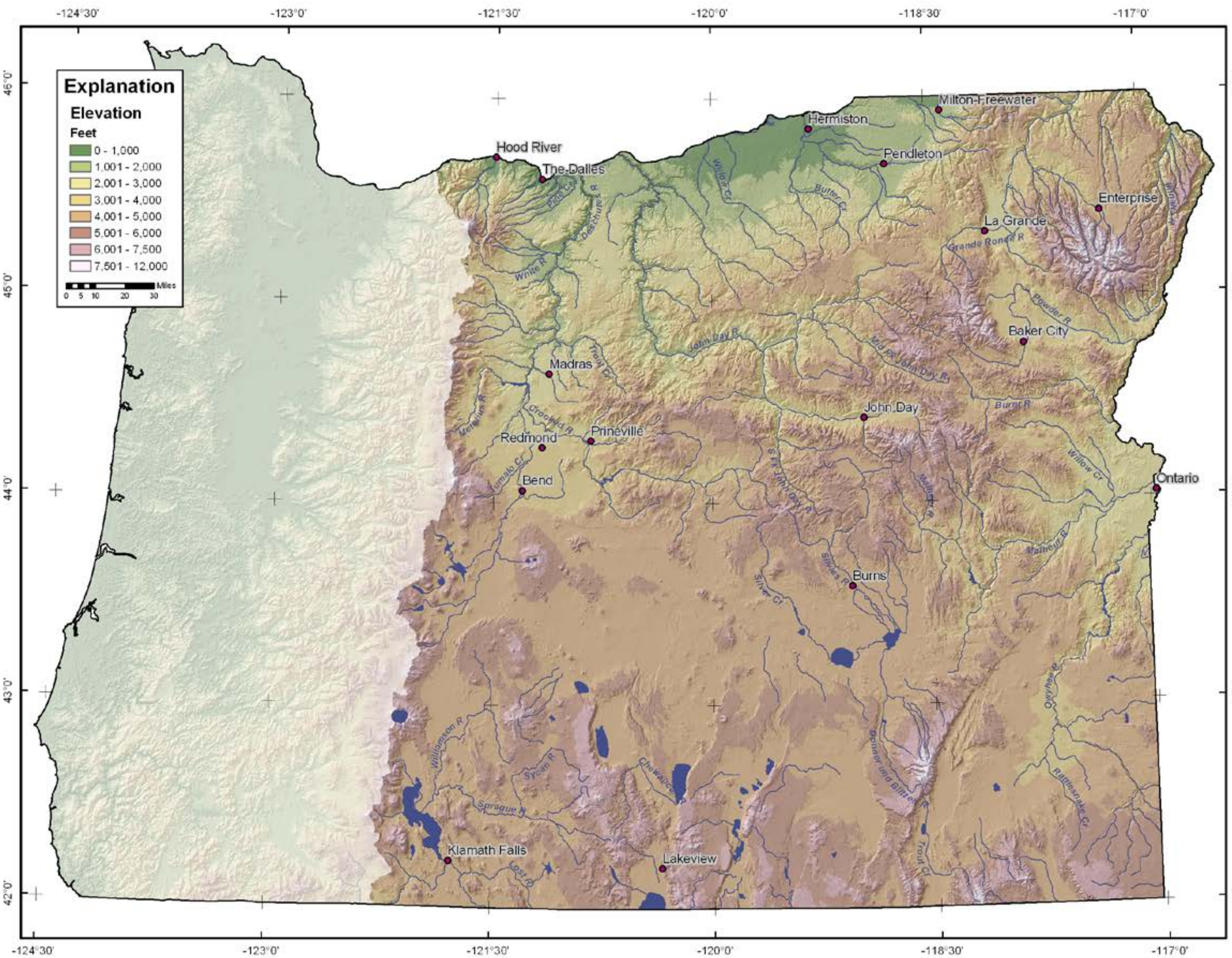



**Figure 20.** Elevation.

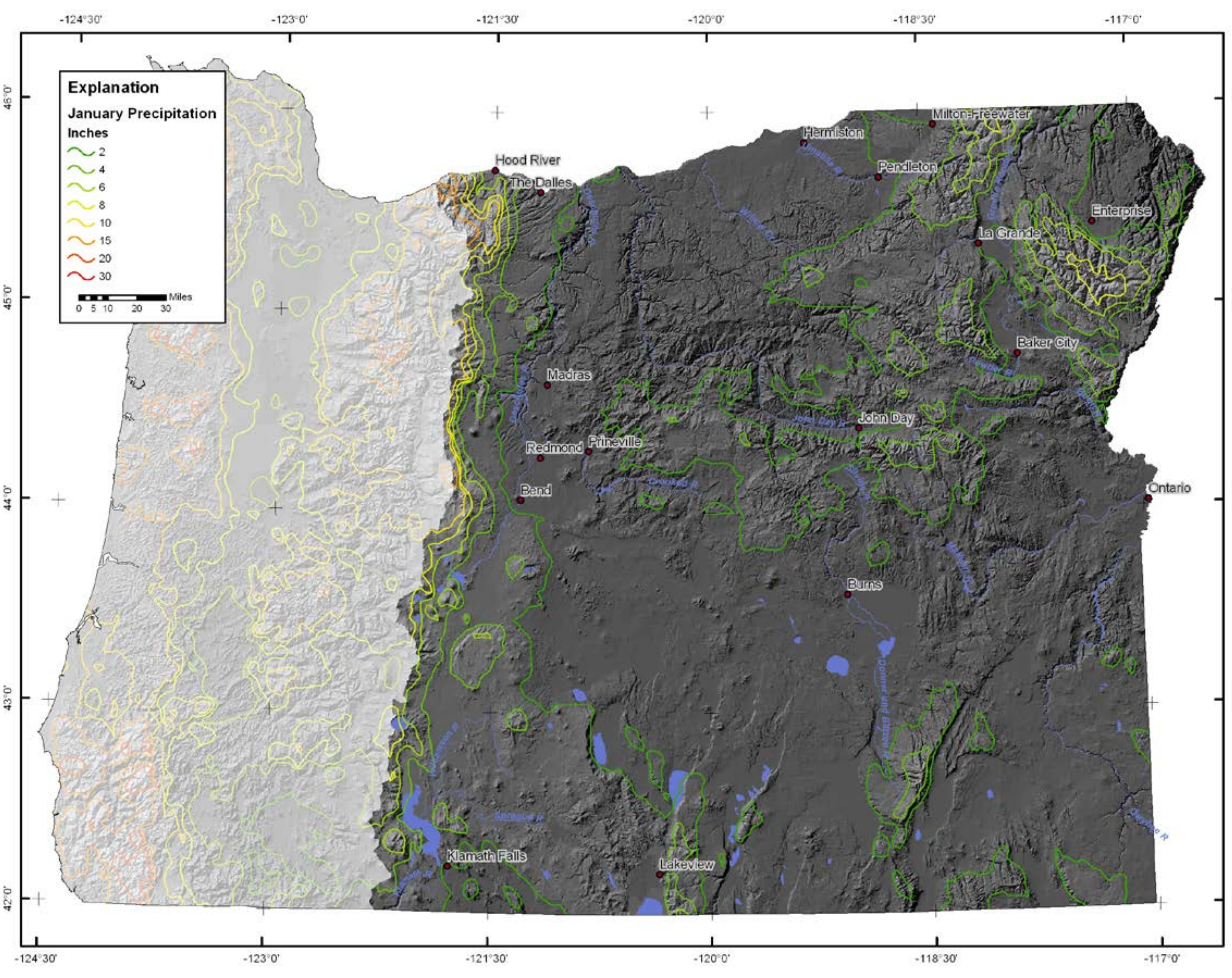



**Figure 21.** Mean January precipitation (1961-1990). The isolines are superimposed on both a shaded relief map of elevation and the GIS grid of the mean January precipitation on which the isolines are based. Darker areas represent lower precipitation amounts.

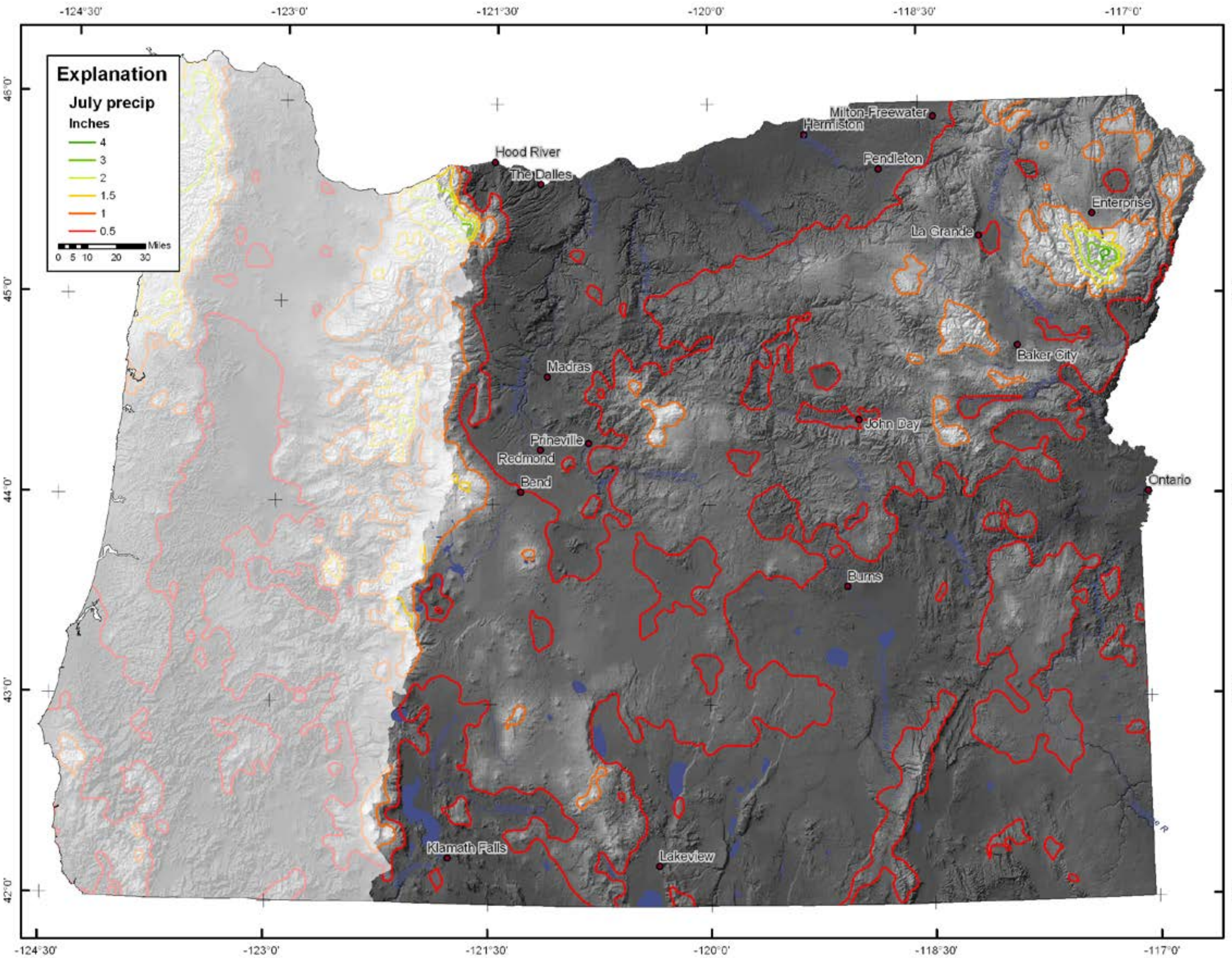



**Figure 22.** Mean July precipitation (1961-1990). The isolines are superimposed on both a shaded relief map of elevation and the GIS grid of the mean July precipitation on which the isolines are based. Darker areas represent lower precipitation amounts.

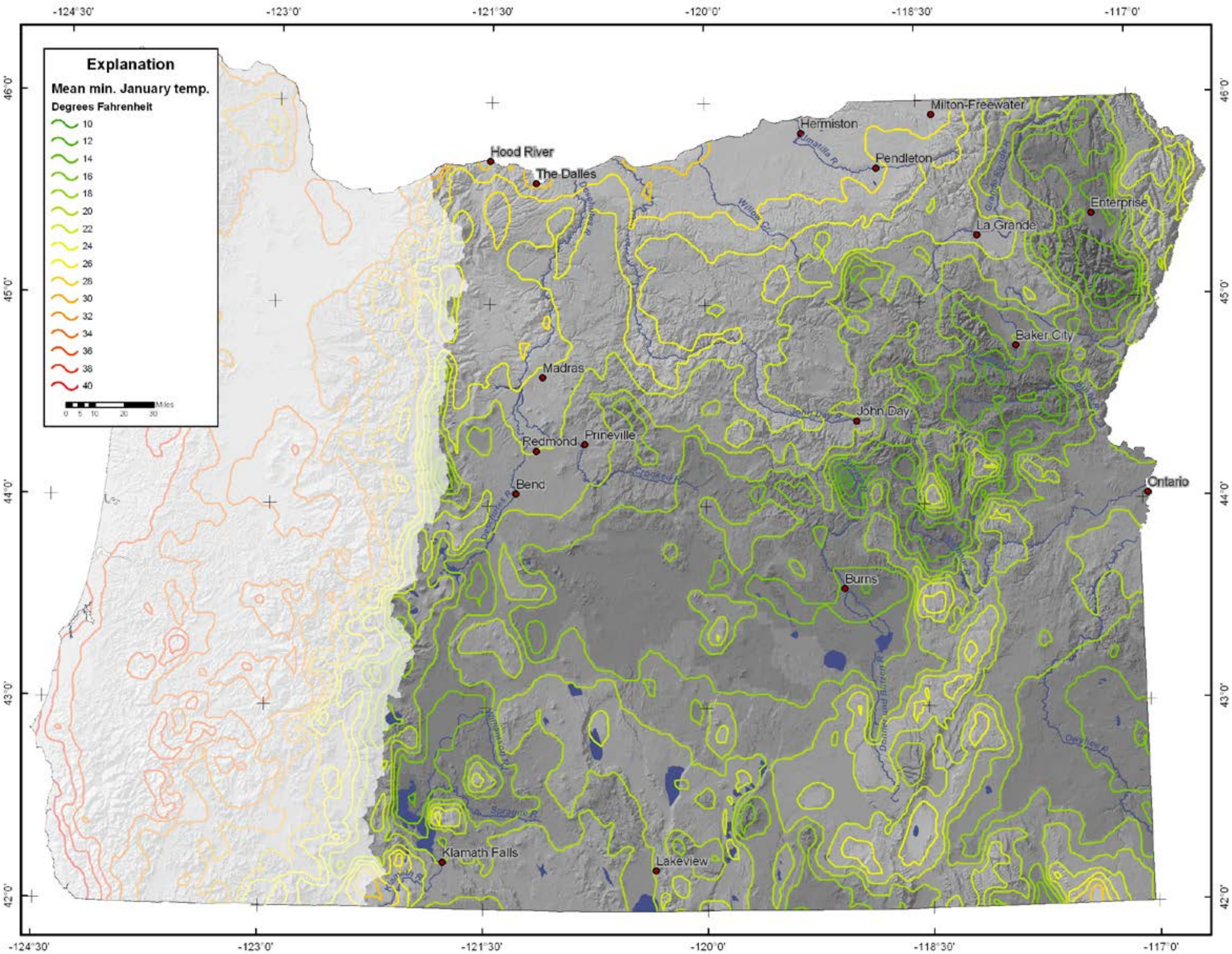



**Figure 23.** Mean minimum January temperature (1961-1990). The isolines are superimposed on both a shaded relief map of elevation and the GIS grid of the mean minimum January temperatures on which the isolines are based. Darker areas represent higher temperatures.

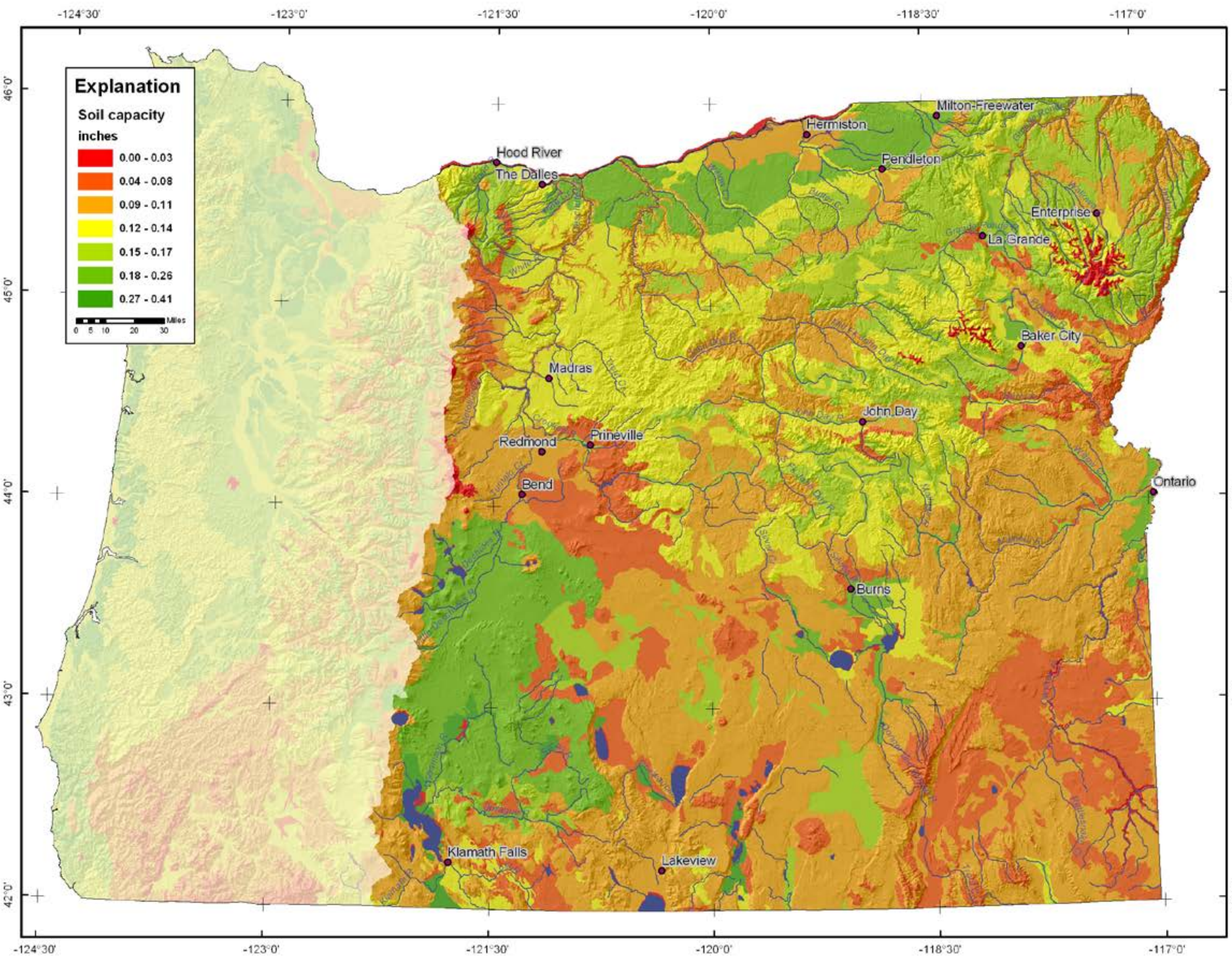



**Figure 24.** Areal distribution of soil storage capacity.

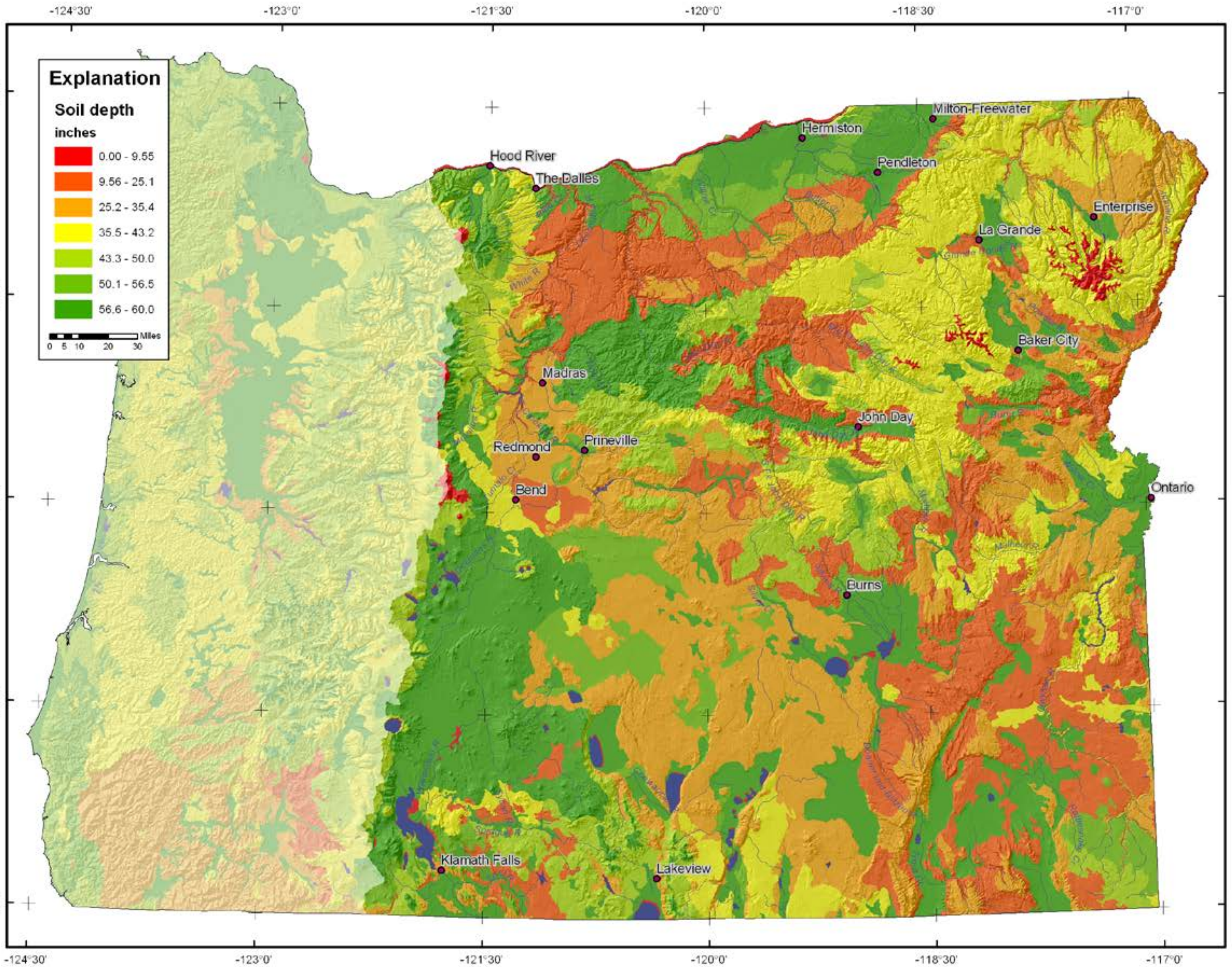



**Figure 25.** Areal distribution of soil depth.

discharges at gaging stations (Equation 8 – discussed in the next section). Hardison (1971) describes the calculation involved in estimating an equivalent number of years of record.

# Estimating Peak Discharges

The procedure for estimating peak streamflows depends on whether the location of interest is gaged or ungaged, and if ungaged, whether it is near a gaged location on the same stream.

## Gaged Locations

If the watershed of interest is one of the gaged watersheds listed in Appendix D, the frequency specific discharges may be read directly from the table. For Oregon gaging stations, the table gives three discharges at every frequency. The first discharge, designated S, is based on the systematic and historical streamflow record and is estimated by the guidelines of Bulletin 17B. The second, designated R, is estimated from the appropriate prediction equation given in Tables 21, 22, 23, 24, 25, or 26. The third discharge, designated W, is a weighted average of the first two discharges (Wiley and others, 2000):

$$Q_W = \frac{(Q_S N + Q_R E)}{(N + E)} \quad (8)$$

where

$Q_W$ = the weighted discharge,

$Q_S$ = the discharge from the log-Pearson Type III distribution fitted to annual series of peak discharges at the gaging station,

$Q_R$ = the discharge estimated from the regional regression analysis,

$N$ = the number of years of peak discharge record, and

$E$ = the equivalent years of record.

All discharges are at a selected frequency and are in cubic feet per second.

For example, the weighted 100-year peak discharge at the gaging station Strawberry Creek above Slide Creek near Prairie City, OR (14037500) is 305 cfs. The station (S) and prediction equation (R) estimated discharges are 311 cfs and 169 cfs, respectively.

Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) recommends using the weighted discharge (W) as the estimate of peak discharge at the gaging station because its variance is less than the variance of either estimate (S or R). The weighting is discussed in detail in Appendix 8 of Bulletin 17B.

### Limitations on the Use of Gaging Station Peak Discharges

Streamflows at some of the gaging stations used in this report are now regulated. The peak discharges estimated from the frequency analysis and reported in Appendix D are based on peak discharges observed before the streams were regulated. The peak discharge estimates for each station represent the stream in its unregulated state, not its current regulated condition. The currently regulated stations are identified in Appendix D.

## Ungaged Locations

If the watershed of interest is ungaged, the frequency specific discharge is calculated from the appropriate prediction equation given in Table 21, 22, 23, 24, 25, or 26. For example, for an ungaged watershed in region 2, the 100-year peak discharge is given by

$$Q_{100} = 520.6\, Area^{0.7507}\, JanP^{0.6468}\, JulP^{-1.154}\, SoilC^{1.445} \quad (9)$$

where

$Q_{100}$ = the 100-year peak discharge in cubic feet per, second,

$Area$ = the drainage area of the watershed in square miles,

$JanP$ = the January precipitation in inches,

$JulP$ = the July precipitation in inches, and

$SoilC$ = the mean soil storage capacity, inches.

West Birch Creek above Jack Canyon is an ungaged watershed in Region 2. The watershed above Jack Creek has a drainage area of 86.25 square miles, mean January precipitation of 2.85 inches, mean July precipitation of 0.647 inches, and a soil storage capacity of 0.128 inches. Substituting these values into Equation 9 yields

$$Q_{100} = 520.6x86.25^{0.7507}2.85^{0.6468}0.647^{-1.154}0.128^{1.445}$$

$Q_{100} = 2{,}470$ cfs.

## Limitations on the Use of the Prediction Equations

The prediction equations may be used to estimate peak flows for any stream. However, the prediction equations do not account for reservoir operations, diversion, urbanization, and in most cases, significant contributions from spring flow. (See the next section for a discussion on spring flow). Many streams are affected by these factors. In these cases, the estimates of peak flow represent a hypothetical condition of the watershed, not the actual condition.

Unless the user intends to predict peak discharges for the hypothetical condition of a watershed, the prediction equations should be used only on rural, unregulated streams and where streamflow arises primarily from storm runoff or snowmelt rather than spring flow. They should not be used where there are significant areas of impervious surface due to pavement or buildings, or where streams have been lined or diverted through culverts or artificial channels. They also should not be used for streams regulated by reservoirs, diversion, or large natural lakes. Also to be avoided are streams with large losses to ground water.

In all cases, hypothetical or not, the equations should not be used for watersheds that have characteristics that fall outside the range of characteristics of the watersheds used to develop the prediction equations. The ranges of characteristics for these watersheds are given in table 27.

## Use of the Prediction Equations for Streams with Significant Spring Flow

The regression analysis assumes that the processes underlying peak discharges can be generalized from stream to stream. For direct runoff and snowmelt, peak discharges are a function of factors like watershed area, elevation, and precipitation intensity. However, the physical properties of a watershed that result in significant spring-flow tend to be local and unique, and the affected stream tends to be unlike its neighbors. A spring, for example, may be the result of a fault or a lava flow.

Typically, prediction equations based on a regression analysis are not useful for estimating peak discharges for streams dominated by spring flow. In a regression analysis, such a stream is often an outlier and is eliminated from the regression as it increases the standard error without improving the prediction equation. The resulting equation is, of course, a poor predictor of peak discharge on any spring-dominated stream in the region.

For regions 2 to 6, the prediction equations should not be used for streams where springs make significant contributions to peak discharge. These occasions will be rare, however. Only one such gaged stream was eliminated from a regression analysis - the South Fork Burnt River above Barney Creek near Unity, OR (13270800) from region 3. This was the only gaged stream in region 3 with a significant contribution from spring flow and is unlike its neighbors. The prediction equations for region 3 significantly over-predict for this stream.

Springs are widespread in region 1, and peak discharges are significantly affected. Unlike other regions, however, spring dominated peaks do not appear as outliers in the regressions. In fact, the standard errors for prediction equations in the region are among the lowest of the six regions. The low standard errors and lack of outliers strongly suggest that the physical properties of the watersheds that contribute to springs are well distributed over the region and that the prediction equations may be used to predict peak discharges for ungaged watersheds.

Caution is advised, however. The prediction equations for region 1 relate peak discharge to watershed area, slope, and elevation. It is unclear how these characteristics relate to the underlying geology and the hydrogeologic processes determining spring flow. Characteristics such as slope and elevation are well integrated regionally, while the locations of lava flows and deposits of pumice and cinder are not likely to be so well integrated. Since watershed boundaries may be indeterminate in the region, area is also suspect as a predictor variable.

**Table 27.** Ranges of selected characteristics for gaged east side watersheds by region.

| Region | Number of stations | Drainage area, in square miles | Mean watershed slope, in degrees | Mean watershed aspect, in degrees | Mean watershed elevation, in feet | Mean January precipitation, in inches | Mean July precipitation, in inches | Mean minimum January temperature, in degrees Fahrenheit | Mean soil capacity, in inches | Mean soil depth, in inches |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 41 | 4.64 – 525 | 5.03 – 19.3 | ----- | 2770 – 6060 | ----- | ----- | ----- | ----- | ----- |
| **2** | 58 | 0.293 – 1630 | ----- | ----- | ----- | 1.52 – 7.97 | 0.234 – 1.28 | ----- | 0.102 – 0.196 | ----- |
| **3** | 76 | 0.240 – 3870 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **4** | 51 | 1.70 – 7630 | 5.35 – 22.6 | ----- | ----- | 1.37 – 5.28 | ----- | 16.4 – 23.1 | ----- | 21.3 – 50.7 |
| **5** | 28 | 0.609 – 2992 | ----- | ----- | 4850 – 7050 | 1.78 – 4.46 | 0.197 – 0.915 | ----- | ----- | ----- |
| **6** | 22 | 0.152 – 453 | ----- | 133 – 244 | ----- | ----- | ----- | ----- | ----- | ----- |

If the underlying geology is reasonably uniform and hydrologic boundaries do not differ greatly from watershed boundaries based on elevation, then area, slope and elevation may be reasonable predictor variables. Slope would work much the same for groundwater as for surface water - discharge is dependent on head gradient. Elevation may be related to rapidity of recharge. Snow melts more rapidly at low elevation and more slowly at high elevation. The correlation in this case would be negative. In the prediction equations for region 1, elevation is negatively correlated.

## Ungaged Location, near a Gaging Station on the Same Stream

If an ungaged watershed is on the same stream as a gaged watershed listed in this report, and the ungaged watershed has an area between 0.50 and 1.50 times the area of the gaged watershed, peak discharges at the ungaged site may be calculated from the peak discharges at the gaged site by this equation (Thomas and others, 1993; Sumioka, 1997):

$$Q_u = Q_g \left( \frac{A_u}{A_g} \right)^a \quad (10)$$

where

$Q_u$ = the estimated discharge for the ungaged watershed,

$Q_g$ = the discharge from the log-Pearson Type III distribution fitted to annual series of peak discharges at the gaging station,

$A_u$ = the area of the ungaged watershed,

$A_g$ = the area of the gaged watershed, and

$a$ = the exponent of area from one of the prediction equations in Table 21, 22, 23, 24, 25, or 26.

All discharges are at a selected frequency and are in cubic feet per second. The exponent is from the prediction equation for the selected region and frequency.

Equation 10 should be used only if the gaged and ungaged watersheds have similar characteristics. If the watersheds differ appreciably in topography, vegetative cover, or geology, the peak discharge estimates should be made by way of the appropriate prediction equations.

Consider the Middle Fork of the John Day River. This stream, at its mouth, is ungaged, and peak discharges could be estimated by the prediction equations for region 4. However, there is a gaging station, Middle Fork John Day River at Ritter (14044000), 14.9 miles upstream. Selected characteristics for the gaged and ungaged watersheds are given in Table 28. The watersheds are similar and use of Equation 10 is appropriate.

From Table 24 for the 100-year peak discharge for region 4, the area coefficient is 0.8375. Taking the areas from Table 28 and the 100-year peak discharge for the gaging station on the Middle Fork John Day River from Appendix D, then making the substitutions into Equation 10,

$$Q_u = 5{,}200 \left( \frac{791}{523} \right)^{0.8375}$$

$$Q_u = 7{,}350 \text{ cfs}$$

## Making Estimates of Peak Discharge at the Oregon Water Resources Department Web Site

At the Oregon Water Resources Department Web site (https://www.oregon.gov/owrd/), a user can make estimates of peak discharge magnitudes at the selected frequencies by one of four methods:

1. Selecting from among about 2,600 watersheds (both western and eastern Oregon) for which the physical characteristics are already known,
2. Manually entering the required watershed characteristics,
3. Submitting a user-delineated watershed, or
4. Using a utility on the Web site to auto-delineate the watershed.

Because of the inherent difficulties in independently estimating watershed characteristics, it is strongly recommended the user take advantage of options 1, 3, and 4 listed above rather than option 2. In all cases, a report

**Table 28.** Selected characteristics for the ungaged watershed Middle Fork John Day River at the mouth and for the gaged watershed Middle Fork John Day River at Ritter, OR (14044000).

| Watershed characteristic | Ungaged watershed | Gaged watershed |
|---|---|---|
| | Middle Fork John Day River at the mouth | Middle Fork John Day River at Ritter, OR (14044000) |
| Area, in square miles | 791 | 523 |
| Slope, in degrees | 11.9 | 12.9 |
| Mean January precipitation, in inches | 2.56 | 2.93 |
| Mean minimum January temperature, in degrees | 18.7 | 17.8 |
| Soils depth to bedrock, in inches | 33.0 | 38.4 |

detailing peak discharges and how they were determined for the specified watershed is returned to the user.

Selecting among already delineated watersheds (Option 1) is done onscreen using interactive maps. For manual input (Option 2), a form is provided. If the user supplies the watershed delineation (Option 3), it must be submitted as a "shape file" in Oregon Lambert coordinates. A shape file is an open specification for a GIS theme developed by Environmental Systems Research Institute, Inc.

For Option 4, the user need only select a point on a stream where the magnitude of a specified peak discharge is desired. Selection of the point is done interactively from topographic maps displayed onscreen. Nothing further is required from the user. Delineation of the watershed above the selected point, determination of the watershed characteristics, and calculation of the peak discharges are done automatically. The auto-delineation program, however, *does not* account for the effects of reservoir operations, diversion or urbanization.

Please refer to Oregon Water Resources Department's Web site for more information:

http://www.oregon.gov/owrd

The user may also obtain, online, the peak discharge characteristics for the 276 gaging stations used in this study. In addition to the discharge magnitudes given in Appendix D of this report, the online version includes the 95 percent confidence intervals.

# Summary

An analysis of the magnitude and frequency of peak discharges in eastern Oregon has been completed with financial assistance from the Federal Emergency Management Agency, the Oregon Department of Transportation, and the Association of Oregon Counties, and with the cooperation of the U.S. Geological Survey. The study was undertaken to provide engineers and land managers with the information needed to make informed decisions about development in or near watercourses in the study area.

This report describes the results of an analysis of the peak discharges of *rural* streams in Oregon east of the Cascade crest. The results of the analysis include (1) the magnitude of annual peak discharges for selected frequencies at 276 gaging stations, (2) generalized logarithmic skew coefficients for eastern Oregon, and (3) sets of equations relating the magnitude of peak discharges at selected frequencies to physical watershed characteristics such as drainage area or mean watershed elevation. There is a set of frequency specific prediction equations for each of six hydrologically homogeneous "flood regions" within eastern Oregon. The selected frequencies are described by the interval at which a peak discharge of given magnitude is likely to recur. The recurrence intervals are 2, 5, 10, 25, 50, 100, and 500 years.

The annual peak discharges at the 276 streamflow gaging stations in eastern Oregon, southwestern Washington, and northwestern California were fitted to the log-Pearson Type III distribution. The parameters of the log-Pearson type III distribution were adjusted for the effects of high and low outliers, for historic peaks, for zero peaks, and for peaks below the gage threshold based on guidelines in Interagency Advisory Committee on Water Data's Bulletin 17B. Station skew values also were adjusted by a "generalized" skew value based on the skews for long-term stations in the area.

The areal distribution of the generalized logarithmic skew coefficients of annual peak discharge for Oregon was determined using GIS techniques. Generalized skew coefficients derived from the distribution were used to improve estimates of skew for short record gaging stations. The areal distribution is a GIS grid but is represented in this report as an isoline map. In practice, generalized skew coefficients are determined from the grid, not the isoline map. The grid is available on request (webmaster@wrd.state.or.us).

In developing the prediction equations, an analysis was done to determine the relative importance of the hydrologic processes contributing to peak discharges. Annual peak discharges occur most frequently in spring and are most likely the result of snowmelt. Rain falling on snow in the months from December to February is the second most frequent cause of peak discharges. Convective storms in late spring and summer are responsible for only a minor part of all peak discharges.

For peaks with the largest unit discharges (greater than 500 cfs per square mile), however, most occur in mid-winter, the result of rain on snow. The second largest number of large peaks occurs in late spring and summer. These peaks are due mostly to thunderstorms. The largest unit discharges (greater than 1,000 cfs per square mile) are all due to thunderstorms.

Thunderstorms are essentially unrepresented in the systematic record used to develop the prediction equations presented in this report. What impact this has on the estimation of peak discharges is unknown.

Severe thunderstorms are associated with watersheds of a particular type. The watersheds are small, not forested, and relatively hot, dry, and low in elevation. A map showing areas of eastern Oregon most likely to be affected by a severe thunderstorm was developed.

A combination of regression techniques was used to derive the prediction equations. A preliminary analysis using ordinary least-squares regression was conducted to define flood regions of homogeneous hydrology and to determine which climatological and physical characteristics of the watersheds would be most useful in the prediction equations. The final prediction equations were derived using generalized least-squares regression. The computer model, GLSNET (version 2.5), developed by the U.S. Geological Survey was used to do the generalized least-squares regression analysis. Average standard error of prediction for the equations for the three flood regions ranged from 37.7 to 104 percent. Equivalent years of record varied from 1.2 to 20.1 years.

The prediction equation may be used to estimate peak flows for any stream. However, the prediction equations do not account for reservoir operations, diversion or urbanization. Many streams are affected by these factors. In these cases, the estimates of peak flow represent a hypothetical condition of the watershed, not the actual condition.

Use of the prediction equations requires estimates of several physical and climatological characteristics of the watershed in question. Because the watershed characteristics can be difficult to estimate, the Oregon Water Resources Department has developed an interactive utility, available on its Web site, to facilitate the use of the equations. The user need only select a site on a stream from an onscreen interactive map and the magnitude of floods at various frequencies will be reported for that location.

To use the interactive utility, go online to this Web address:

https://www.oregon.gov/owrd

# References


Advisory Committee on Water Information, 2002, Bulletin 17-B flood frequency guidelines, Frequently asked questions: U.S. Geological Survey, http://water.usgs.gov/wicp/acwi/hydrology/Frequency/B17bFAQ.html, accessed February 2003.

Baldwin, E.M., 1981, Oregon Geology, Third edition: Dubuque, Iowa, Kendall/Hunt Publishing Company, 170 p.

Butler, E., Reid, J.K., and Berwick, V.K., 1966, The Great Basin, part 10 of Magnitude and frequency of floods in the United States: U.S. Geological Survey Water-Supply Paper 1684, 256 p.

Campbell, A.J., Sidle, R.C., and Froehlich, H.A., 1982, Prediction of peak flows for culvert design on small watersheds in Oregon: Corvallis, OR, Oregon State University Water Resources Research Institute, 96p.

Chatterjee, S., Hadi, A. S., and Price, B., 2000, Regression analysis by example**,** Third Edition: New York, Wiley, 359 p.

Cooper, R.M., 2002, Determining Surface Water Availability in Oregon: Oregon Water Resources Department Open File Report SW 02 – 002, Salem, OR, 57 p.

Cooper, R.M., 2005, Estimation of Peak Discharges for Rural, Unregulated Streams in Western Oregon: U.S Geological Survey Scientific Investigations Report 2005 - 5116, 50 p.

Crippen, J.F., 1978, Composite log Pearson Type III frequency-magnitude curve of annual floods: U.S. Geological Survey Open-File Report 78-352, 5 p.

Daly, C., Taylor, G.H., and Gibson, W.P., 1997, The PRISM approach to mapping precipitation and temperature *in* Reprints of 10$^{th}$ Conference on Applied Climatology, Reno, Nevada: American Meteorological Society, p. 10-12.

Dicken, S.N., 1965, Oregon geography, fourth edition: Ann Arbor, Michigan, Edwards Brothers, Inc., 104 p.

Gannet, M.W., Lite, K.E., Morgan, D.S., and Collins, C.A., 2000, Ground-water hydrology of the upper Deschutes basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 00-4162, 77 p.

Hardison, C.H., 1971, Prediction error of regression estimates of streamflow characteristics at ungaged sites: U.S. Geological Survey Professional Paper 750-C, p. C228-C236.

Harris, D.D., Hubbard, L.L., and Hubbard, L.E., 1979, Magnitude and frequency of floods in western Oregon: U.S. Geological Survey Open-File Report 79-553, 29 p.

Harris, D.D., and Hubbard, L.E., 1982. Magnitude and frequency of floods in eastern Oregon: U.S. Geological Survey Water Resources Investigations Report 82-4078, 39 p.

Hazen, A., 1930, Flood Flows: John Wiley and Sons, Inc, New York.

Hendricks, E.L., 1963, Summary of floods in the United States during 1957: U.S Geological Survey Water-Supply Paper 1652-C, 98 p.

______1964, Summary of floods in the United States during 1956: U.S Geological Survey Water-Supply Paper 1530, 85 p.

Hofmann, W., and Rantz, S.E., 1963, Floods of December 1955 to January 1956 in the far western states, Part 1 - Description: U.S. Geological Survey Water-Supply Paper 1650-A, 156 p.

Hubbard, L.L., 1991, Oregon – floods and droughts *in* National water summary 1988-89: U.S. Geological Survey Water-Supply Paper 2375, p. 459-466.

Hulsing, H., and Kallio, N.A., 1964, Pacific slope basins in Oregon and lower Columbia River basin, part 14 of Magnitude and frequency of floods in the United States: U.S. Geological Survey Water-Supply Paper 1689, 320 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency – Bulletin 17B of the Hydrology Subcommittee: Reston, Virginia, U.S. Geological Survey, Office of Water Data Coordination, 28 p.

Lumina, R., and Baevsky, Y., 2000, Development of a contour map showing generalized skew coefficients of annual peak discharges of rural, unregulated streams in New York, excluding Long Island: U.S. Geological Survey Water Resources Investigations Report 00-4022, 11p.

Lystrom, D.J., 1970, Evaluation of the streamflow-data program in Oregon: U.S. Geological Survey Open-File Report, 28 p.

Meinzer, O.E., 1927, Large springs of the United States: U.S. Geological Survey Water-Supply Paper 557, 94 p.

National Cartography and Geospatial Center, 1994, State soil geographic (STATSGO) database (1:250,000 scale): U.S. Department of Agriculture, Natural Resources Conservation Service, http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/, accessed July 1995.

National Center for Earth Resources Observation & Science, 1999, National elevation dataset: - one arc-sec resolution: U.S. Geological Survey, http://edc.usgs.gov, accessed March 2005.

Oregon Water Resources Department, 1971, Regionalized flood frequency data for Oregon: Salem, OR, Oregon Water Resources Department, 33 p.

Reid, J.K., 1975, Summary of floods in the United States during 1969: U.S Geological Survey Water-Supply Paper 2030, 173 p.

Riggs, H.C., 1968, Some statistical tools in hydrology: U.S. Geological Survey Techniques of Water Resources Investigations, book 4, chapter A1, 39 p.

______1973, Regional analysis of streamflow characteristics: U.S. Geological Survey Techniques of Water Resources Investigations, book 4, chapter B3, 15 p.

Rostvedt, J.O., 1968, Summary of floods in the United States during 1963: U.S Geological Survey Water-Supply Paper 1830-B, 120 p.

______ 1970, Summary of floods in the United States during 1965: U.S Geological Survey Water-Supply Paper 1850-E, 120 p.

Sauer, V.B., Thomas, Jr., W.O., Stricker, V.A., and Wilson, K.V., 1983, Flood characteristics of urban watersheds in the United States: U.S. Geological Survey Water-Supply Paper 2207, 37 p.

Sauer, V.B, 2002, Urban flood frequency estimating techniques *in* The national flood frequency program, version 3: A computer program for estimating magnitude and frequency of floods at ungaged sites: U.S. Geological Survey Water-Resources Investigations Report 02-4168, p. 8-10.

Sumioka, D.L., Kresch, D.L., and Kasnick, K.D., 1997, Magnitude and frequency of floods in Washington: U.S. Geological Survey Water Resources Investigations Report 97-4277, 91p.

Tasker, G.D., Eychaner, J.H., and Stedinger, J.R., 1986, Application of generalized least-squares in regional hydrologic regression analysis: U.S. Geological Survey Water-Supply Paper 2310, p. 107-115.

Tasker, G.D., and Stedinger, J.R., 1989, An operational GLS model for hydrologic regression: Journal of Hydrology, v. 111, p. 361-375.

Taylor, G.H. and Hatton, R.R., 1999, The Oregon weather book, a state of extremes: Corvallis, Oregon, Oregon State University Press, 242 p.

Thomas, C.A., Broom, H.C., and Cummans, J.E., 1963, Snake River basin, part 13 of magnitude and frequency of floods in the United States: U.S. Geological Survey Water-Supply Paper 1688, 250 p.

Thomas, B.E., Hjalmerson, H.W., and Waltemeyer, S.D., 1993, Methods for estimating magnitude and frequency of floods in the southwestern United States: U.S. Geological Survey Open File Report 93-419, 211 p.

Thomas, D.M., and Benson, M.A., 1969, Generalization of streamflow characteristics from drainage watershed characteristics: U.S. Geological Survey Open-File Report, 45 p.

U.S. Army Corps of Engineers, 1978, Hydrologic report, streams of Morrow County, Oregon - Prepared as part of the Federal Insurance Administration flood insurance studies of Morrow County, Heppner, Ione, and Lexington, Oregon:

Preliminary Draft, Department of the Army, Corps of Engineers, Walla Walla District, Walla, Walla, Washington, 80p.

U.S. Geological Survey, 2000, GLSNET – Regional hydrologic regression and network analysis using generalized least squares (Version 2.5): http://water.usgs.gov/software/glsnet.html, last modified 9/29/1997, accessed August 2002.

U.S. Water Resources Council, 1977, Guidelines for determining flood flow frequency: Washington, D.C., U.S. Water Resources Council Bulletin 17A, 26 p.

Waananen, A.O., Harris, D.D, and Williams, R.C., 1971, Floods of December 1964 and January 1965 in the far western United States, Part1 -- Description: U.S. Geological Survey Water-Supply Paper 1866-A, 265 p.

Wells, J.V.B., 1954, Summary of floods in the United States during 1950: U.S Geological Survey Water-Supply Paper 1137-I, p. 957-991

______1959a, Summary of floods in the United States during 1952: U.S Geological Survey Water-Supply Paper 1260-F, p. 687-713

______1959b, Summary of floods in the United States during 1953: U.S Geological Survey Water-Supply Paper 1320-E, p. 341-364

______1962, Summary of floods in the United States during 1955: U.S Geological Survey Water-Supply Paper 1455-B, p. 69-143

Wiley, J.B., Atkins, Jr., J.T., and Tasker, G.D., 2000, Estimating magnitude and frequency of peak discharges for rural, unregulated streams in West Virginia: U.S. Geological Survey Water Resources Investigations Report 00-4080, 93 p.

Young, L.E., and Cruff, R.W., 1967, Pacific slope basins in California, part 11, Vol. 2, of Magnitude and frequency of floods in the United States: U.S. Geological Survey Water-Supply Paper 1685, 308 p.

**Appendix A.** Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis.

| Station Number | Station Name | Flood Region | Hydrologic Unit | Latitude Decimal Degrees | Longitude Decimal Degrees |
|---|---|---|---|---|---|
| 10329500 | Martin Creek near Paradise Valley, NV | 6 | 16040109 | 41.535 | 117.417 |
| 10330300 | Mullinex Creek near Paradise Valley, NV | 6 | 16040109 | 41.511 | 117.540 |
| 10352300 | Jackson Creek tributary near McDermitt, NV | 6 | 16040201 | 42.233 | 117.739 |
| 10352500 | McDermitt Creek near McDermitt, NV | 6 | 16040201 | 41.967 | 117.834 |
| 10353000 | East Fork Quinn River near McDermitt, NV | 6 | 16040201 | 41.983 | 117.583 |
| 10353600 | Kings River near Orovada, NV | 6 | 16040201 | 41.907 | 118.308 |
| 10353700 | Leonard Creek near Denio, NV | 6 | 16040202 | 41.528 | 118.712 |
| 10353750 | Mahogany Creek near Summit Lake, NV | 6 | 16040202 | 41.542 | 119.015 |
| 10360900 | Bidwell Creek below Mill Creek near Fort Bidwell, CA | 5 | 18080001 | 41.882 | 120.174 |
| 10361700 | Badger Creek tributary near Vya, NV | 6 | 17120008 | 41.722 | 119.372 |
| 10366000 | Twentymile Creek near Adel, OR | 5 | 17120007 | 42.072 | 119.962 |
| 10370000 | Camas Creek near Lakeview, OR | 5 | 17120007 | 42.216 | 120.101 |
| 10371000 | Drake Creek near Adel, OR | 5 | 17120007 | 42.200 | 120.011 |
| 10371500 | Deep Creek above Adel, OR | 5 | 17120007 | 42.189 | 120.001 |
| 10378500 | Honey Creek near Plush, OR | 5 | 17120007 | 42.425 | 119.922 |
| 10384000 | Chewaucan River near Paisley, OR | 5 | 17120006 | 42.685 | 120.569 |
| 10390400 | Bridge Creek near Thompson Reservoir, OR | 5 | 17120005 | 43.025 | 121.200 |
| 10392300 | Silvies River near Seneca, OR | 4 | 17120002 | 44.175 | 119.214 |
| 10392800 | Crowsfoot Creek near Burns, OR | 4 | 17120002 | 43.899 | 119.497 |
| 10393500 | Silvies River near Burns, OR | 4 | 17120002 | 43.715 | 119.176 |
| 10393900 | Devine Can near Burns, OR | 4 | 17120001 | 43.772 | 119.004 |
| 10396000 | Donner Und Blitzen River near Frenchglen, OR | 6 | 17120003 | 42.791 | 118.867 |
| 10397000 | Bridge Creek near Frenchglen, OR | 6 | 17120003 | 42.844 | 118.849 |
| 10402800 | Claw Creek near Riley, OR | 4 | 17120004 | 43.726 | 119.593 |
| 10403000 | Silver Creek near Riley, OR | 4 | 17120004 | 43.692 | 119.658 |
| 10403500 | Silver Creek above Suntex, OR | 4 | 17120004 | 43.633 | 119.667 |
| 10406500 | Trout Creek near Denio, NV | 6 | 17120009 | 42.156 | 118.458 |
| 11339995 | Cottonwood Creek above Cottonwood Reservoir near Lakeview, OR | 5 | 18020001 | 42.272 | 120.532 |
| 11340500 | Cottonwood Creek near Lakeview, OR | 5 | 18020001 | 42.235 | 120.501 |
| 11340950 | Thomas Creek above Barnes Spring near Lakeview, OR | 5 | 18020001 | 42.267 | 120.467 |
| 11341000 | Thomas Creek near Lakeview, OR | 5 | 18020001 | 42.267 | 120.450 |
| 11341050 | Cox Creek below Salt Creek near Lakeview, OR | 5 | 18020001 | 42.307 | 120.375 |
| 11341100 | Salt Creek near Lakeview, OR | 5 | 18020001 | 42.293 | 120.346 |
| 11341200 | Crane Creek near Lakeview, OR | 5 | 18020001 | 42.118 | 120.290 |
| 11342945 | Thomas Creek near Cedarville, CA | 5 | 18020002 | 41.564 | 120.268 |
| 11342960 | North Fork Pit River tributary near Alturas, CA | 5 | 18020002 | 41.576 | 120.435 |
| 11348080 | Big Sage Reservoir tributary near Alturas, CA | 5 | 18020002 | 41.583 | 120.699 |
| 11348560 | Turner Creek tributary near Canby, CA | 5 | 18020002 | 41.513 | 121.040 |
| 11484000 | Miller Creek near Lorella, OR | 5 | 18010204 | 42.117 | 121.217 |
| 11489350 | Horsethief Creek near McDoel, CA | 5 | 18010205 | 41.688 | 122.053 |
| 11489500 | Antelope Creek near Tennant, CA | 1 | 18010205 | 41.547 | 121.917 |
| 11491800 | Mosquito Creek near Shevlin, OR | 5 | 18010201 | 43.094 | 121.547 |
| 11494800 | Brownsworth Creek near Bly, OR | 5 | 18010202 | 42.428 | 120.839 |

**Appendix A.** Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

| Station Number | Station Name | Flood Region | Hydrologic Unit | Latitude Decimal Degrees | Longitude Decimal Degrees |
|---|---|---|---|---|---|
| 11497500 | Sprague River near Beatty, OR | 5 | 18010202 | 42.447 | 121.237 |
| 11497800 | Currier Creek near Paisley, OR | 5 | 18010202 | 42.715 | 120.881 |
| 11501000 | Sprague River near Chiloquin, OR | 5 | 18010202 | 42.585 | 121.849 |
| 11501300 | Crystal Creek near Chiloquin, OR | 5 | 18010202 | 42.563 | 121.839 |
| 11502500 | Williamson River below Sprague River near Chiloquin, OR | 5 | 18010201 | 42.565 | 121.878 |
| 11504000 | Wood River at Fort Klamath, OR | 1 | 18010203 | 42.700 | 121.983 |
| 11505550 | Lost Creek near Rocky Point, OR | 1 | 18010203 | 42.493 | 122.192 |
| 11516900 | Little Shasta River near Montague, CA | 1 | 18010207 | 41.753 | 122.299 |
| 13172666 | West Fork Reynolds Creek near Reynolds, ID | 6 | 17050103 | 43.070 | 116.760 |
| 13172668 | East Fork Reynolds Creek near Reynolds, ID | 6 | 17050103 | 43.070 | 116.750 |
| 13172680 | Reynolds Creek at Tollgate Weir near Reynolds, ID | 6 | 17050103 | 43.100 | 116.770 |
| 13172720 | Macks Creek near Reynolds, ID | 6 | 17050103 | 43.230 | 116.790 |
| 13172735 | Salmon Creek near Reynolds, ID | 6 | 17050103 | 43.270 | 116.790 |
| 13172740 | Reynolds Creek at Outlet Weir near Reynolds, ID | 6 | 17050103 | 43.180 | 116.760 |
| 13172800 | Little Squaw Creek tributary near Marsing, ID | 6 | 17050103 | 43.364 | 116.921 |
| 13172900 | Succor Creek near Jordan Valley, OR | 6 | 17050103 | 43.235 | 117.057 |
| 13178000 | Jordan Creek above Lone Tree Creek near Jordan Valley, OR | 6 | 17050108 | 42.874 | 116.953 |
| 13182100 | Drago G near Rockville, OR | 6 | 17050110 | 43.294 | 117.254 |
| 13207000 | Spring Valley Creek near Eagle, ID | 3 | 17050114 | 43.739 | 116.300 |
| 13207500 | Dry Creek near Eagle, ID | 3 | 17050114 | 43.732 | 116.304 |
| 13213800 | Cottonwood Creek near Drewsey, OR | 3 | 17050116 | 43.950 | 118.303 |
| 13213900 | Malheur River tributary near Drewsey, OR | 3 | 17050116 | 43.781 | 118.358 |
| 13214000 | Malheur River near Drewsey, OR | 3 | 17050116 | 43.785 | 118.331 |
| 13216500 | North Fork Malheur River above Beulah Reservoir near Beulah, OR | 3 | 17050116 | 43.948 | 118.173 |
| 13226500 | Bully Creek at Warmsprings near Vale, OR | 3 | 17050118 | 44.019 | 117.460 |
| 13228000 | Malheur River at Vale, OR | 3 | 17050117 | 43.981 | 117.239 |
| 13228300 | Lytle Creek near Vale, OR | 3 | 17050117 | 43.957 | 117.226 |
| 13229400 | Lost Valley Creek tributary near Ironside, OR | 3 | 17050119 | 44.314 | 117.903 |
| 13248900 | Cottonwood Creek near Horseshoe Bend, ID | 3 | 17050122 | 43.893 | 116.202 |
| 13250600 | Big Willow Creek near Emmett, ID | 3 | 17050122 | 44.074 | 116.486 |
| 13250650 | Fourmile Creek near Emmett, ID | 3 | 17050122 | 44.073 | 116.487 |
| 13251300 | West Branch Weiser River near Tamarack, ID | 3 | 17050124 | 45.021 | 116.435 |
| 13251500 | Weiser River at Tamarack, ID | 3 | 17050124 | 44.947 | 116.382 |
| 13252500 | East Fork Weiser River near Council, ID | 3 | 17050124 | 44.761 | 116.258 |
| 13253500 | Weiser River at Starkey, ID | 3 | 17050124 | 44.850 | 116.444 |
| 13260000 | Pine Creek near Cambridge, ID | 3 | 17050124 | 44.590 | 116.737 |
| 13261000 | Little Weiser River near Indian Valley, ID | 3 | 17050124 | 44.489 | 116.390 |
| 13267000 | Mann Creek near Weiser, ID | 3 | 17050124 | 44.392 | 116.894 |
| 13267100 | Deer Creek near Midvale, ID | 3 | 17050124 | 44.391 | 116.880 |
| 13269200 | Moores Hollow tributary near Weiser, ID | 3 | 17050201 | 44.169 | 117.125 |
| 13269300 | North Fork Burnt River near Whitney, OR | 3 | 17050202 | 44.601 | 118.256 |
| 13272300 | Job Creek tributary near Unity, OR | 3 | 17050202 | 44.464 | 118.200 |
| 13274600 | Burnt River tributary at Durkee, OR | 3 | 17050202 | 44.575 | 117.446 |

**Appendix A.** Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

| Station Number | Station Name | Flood Region | Hydrologic Unit | Latitude Decimal Degrees | Longitude Decimal Degrees |
|---|---|---|---|---|---|
| 13275105 | Powder River at Hudspeth Lane near Sumpter, OR | 3 | 17050203 | 44.685 | 118.091 |
| 13275200 | Deer Creek above Phillips Lake near Sumpter, OR | 3 | 17050203 | 44.692 | 118.063 |
| 13275500 | Powder River near Baker, OR | 3 | 17050203 | 44.656 | 117.875 |
| 13281200 | Rock Creek near Haines, OR | 3 | 17050203 | 44.910 | 118.056 |
| 13282400 | Anthony Creek below North Fork near North Powder, OR | 3 | 17050203 | 45.044 | 118.125 |
| 13283600 | Wolf Creek above Wolf Creek Reservoir near North Powder, OR | 3 | 17050203 | 45.066 | 118.032 |
| 13285900 | Big Creek below Burn Creek near Medical Springs, OR | 3 | 17050203 | 45.010 | 117.575 |
| 13286300 | Waterspout Creek near Baker, OR | 3 | 17050203 | 44.836 | 117.547 |
| 13287200 | West Eagle Creek below Jim Creek near Baker, OR | 3 | 17050203 | 45.050 | 117.467 |
| 13288200 | Eagle Creek above Sc near New Bridge, OR | 3 | 17050203 | 44.881 | 117.253 |
| 13289100 | Immigrant G near Richland, OR | 3 | 17050203 | 44.786 | 117.135 |
| 13289600 | East Brownlee Creek at Brownlee Ranger Station, ID | 3 | 17050201 | 44.736 | 116.838 |
| 13289960 | Wildhorse River at Brownlee Dam, ID | 3 | 17050201 | 44.852 | 116.890 |
| 13290150 | North Pine Creek near Homestead, OR | 3 | 17050201 | 45.090 | 116.896 |
| 13290190 | Pine Creek near Oxbow, OR | 3 | 17050201 | 44.954 | 116.873 |
| 13291200 | Mahogany Creek near Homestead, OR | 3 | 17060102 | 45.204 | 116.868 |
| 13291400 | Deer Creek near Imnaha, OR | 3 | 17060102 | 45.550 | 116.792 |
| 13292000 | Imnaha River at Imnaha, OR | 3 | 17060102 | 45.563 | 116.833 |
| 13315500 | Mud Creek near Tamarack, ID | 3 | 17060210 | 44.997 | 116.348 |
| 13316500 | Little Salmon River at Riggins, ID | 3 | 17060210 | 45.413 | 116.325 |
| 13316800 | North Fork Skookumchuck Creek near White Bird, ID | 3 | 17060209 | 45.726 | 116.205 |
| 13317200 | Johns Creek near Grangeville, ID | 3 | 17060209 | 45.938 | 116.201 |
| 13318100 | McIntyre Creek near Starkey, OR | 3 | 17060104 | 45.328 | 118.449 |
| 13318500 | Grande Ronde River near Hilgard, OR | 3 | 17060104 | 45.317 | 118.267 |
| 13318800 | Grande Ronde River at Hilgard, OR | 3 | 17060104 | 45.339 | 118.243 |
| 13319000 | Grande Ronde River at La Grande, OR | 3 | 17060104 | 45.346 | 118.124 |
| 13320000 | Catherine Creek near Union, OR | 3 | 17060104 | 45.156 | 117.774 |
| 13320400 | Little Creek at High Valley near Union, OR | 3 | 17060104 | 45.213 | 117.775 |
| 13321300 | Ladd Can near Hot Lake, OR | 3 | 17060104 | 45.193 | 118.013 |
| 13322300 | Dry Creek near Bingham Springs, OR | 3 | 17060104 | 45.636 | 118.115 |
| 13323500 | Grande Ronde River near Elgin, OR | 3 | 17060104 | 45.513 | 117.926 |
| 13323600 | Indian Creek near Imbler, OR | 3 | 17060104 | 45.433 | 117.822 |
| 13323700 | North Fork Clarks Creek near Elgin, OR | 3 | 17060104 | 45.541 | 117.811 |
| 13324150 | Rysdam Can tributary near Minam, OR | 3 | 17060104 | 45.615 | 117.796 |
| 13324300 | Lookingglass Creek near Looking Glass, OR | 3 | 17060104 | 45.732 | 117.864 |
| 13325000 | East Fork Wallowa River near Joseph, OR | 3 | 17060105 | 45.272 | 117.210 |
| 13325500 | Wallowa River above Wallowa Lake near Joseph, OR | 3 | 17060105 | 45.283 | 117.200 |
| 13329500 | Hurricane Creek near Joseph, OR | 3 | 17060105 | 45.337 | 117.292 |
| 13329700 | Trout Creek tributary near Chico, OR | 3 | 17060105 | 45.597 | 117.260 |
| 13329750 | Trout Creek tributary at Enterprise, OR | 3 | 17060105 | 45.439 | 117.283 |
| 13330000 | Lostine River near Lostine, OR | 3 | 17060105 | 45.439 | 117.426 |
| 13330500 | Bear Creek near Wallowa, OR | 3 | 17060105 | 45.527 | 117.551 |
| 13331500 | Minam River at Minam, OR | 3 | 17060105 | 45.620 | 117.726 |

**Appendix A.** Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

| Station Number | Station Name | Flood Region | Hydrologic Unit | Latitude Decimal Degrees | Longitude Decimal Degrees |
|---|---|---|---|---|---|
| 13332500 | Grande Ronde River at Rondowa, OR | 3 | 17060106 | 45.727 | 117.783 |
| 13333000 | Grande Ronde River at Troy, OR | 3 | 17060106 | 45.946 | 117.448 |
| 13333050 | Buford Creek near Flora, OR | 3 | 17060106 | 45.890 | 117.283 |
| 13333100 | Doe Creek near Imnaha, OR | 3 | 17060106 | 45.747 | 117.022 |
| 13334700 | Asotin Creek below Kearney G near Asotin, WA | 3 | 17060103 | 46.326 | 117.152 |
| 13335050 | Asotin Creek at Asotin, WA | 3 | 17060103 | 46.341 | 117.055 |
| 13341100 | Cold Springs Creek near Craigmont, ID | 3 | 17060306 | 46.236 | 116.518 |
| 13342450 | Lapwai Creek near Lapwai, ID | 3 | 17060306 | 46.427 | 116.804 |
| 14010000 | South Fork Walla Walla River near Milton, OR | 2 | 17070102 | 45.830 | 118.169 |
| 14010800 | North Fork Walla Walla River near Milton Freewater, OR | 2 | 17070102 | 45.885 | 118.185 |
| 14011000 | North Fork Walla Walla River near Milton, OR | 2 | 17070102 | 45.902 | 118.282 |
| 14011800 | Couse Creek near Milton-Freewater, OR | 2 | 17070102 | 45.869 | 118.366 |
| 14013000 | Mill Creek near Walla Walla, WA | 2 | 17070102 | 46.008 | 118.118 |
| 14013500 | Blue Creek near Walla Walla, WA | 2 | 17070102 | 46.058 | 118.136 |
| 14015900 | Spring Creek tributary near Walla Walla, WA | 2 | 17070102 | 46.104 | 118.189 |
| 14016000 | Dry Creek near Walla Walla, WA | 2 | 17070102 | 46.122 | 118.236 |
| 14016080 | Dry Creek tributary near Milton-Freewater, OR | 2 | 17070102 | 45.885 | 118.391 |
| 14016200 | Pine Creek near Weston, OR | 2 | 17070102 | 45.779 | 118.403 |
| 14016500 | East Fork Touchet River near Dayton, WA | 2 | 17070102 | 46.279 | 117.901 |
| 14016600 | Hatley Creek near Dayton, WA | 2 | 17070102 | 46.281 | 117.894 |
| 14016650 | Davis Hollow near Dayton, WA | 2 | 17070102 | 46.300 | 117.953 |
| 14017000 | Touchet River at Bolles, WA | 2 | 17070102 | 46.274 | 118.221 |
| 14017040 | Thorn Hollow near Dayton, WA | 2 | 17070102 | 46.347 | 118.065 |
| 14017070 | East Fork McKay Creek near Huntsville, WA | 2 | 17070102 | 46.363 | 118.132 |
| 14017200 | Badger Hollow near Clyde, WA | 2 | 17070102 | 46.416 | 118.338 |
| 14017500 | Touchet River near Touchet, WA | 2 | 17070102 | 46.042 | 118.683 |
| 14018500 | Walla Walla River near Touchet, WA | 2 | 17070102 | 46.028 | 118.729 |
| 14019400 | Elbow Creek near Bingham Springs, OR | 2 | 17070103 | 45.713 | 118.198 |
| 14020000 | Umatilla River above Meacham Creek near Gibbon, OR | 2 | 17070103 | 45.720 | 118.322 |
| 14020300 | Meacham Creek at Gibbon, OR | 2 | 17070103 | 45.689 | 118.356 |
| 14020740 | Moonshine Creek near Mission, OR | 2 | 17070103 | 45.661 | 118.564 |
| 14020800 | Mission Creek at St Andrews Mission, OR | 2 | 17070103 | 45.635 | 118.622 |
| 14020900 | Wildhorse Creek near Athena, OR | 2 | 17070103 | 45.766 | 118.443 |
| 14021000 | Umatilla River at Pendleton, OR | 2 | 17070103 | 45.672 | 118.792 |
| 14021980 | Patawa Creek at West Boundary near Pendleton, OR | 2 | 17070103 | 45.653 | 118.744 |
| 14022200 | North Fork McKay Creek near Pilot Rock, OR | 2 | 17070103 | 45.507 | 118.616 |
| 14022500 | McKay Creek near Pilot Rock, OR | 2 | 17070103 | 45.549 | 118.773 |
| 14025000 | Birch Creek at Rieth, OR | 2 | 17070103 | 45.653 | 118.879 |
| 14026000 | Umatilla River at Yoakum, OR | 2 | 17070103 | 45.678 | 119.033 |
| 14032000 | Butter Creek near Pine City, OR | 2 | 17070103 | 45.544 | 119.311 |
| 14034250 | Glade Creek tributary near Bickleton, WA | 2 | 17070101 | 46.069 | 120.206 |
| 14034325 | Alder Creek near Bickleton, WA | 2 | 17070101 | 45.997 | 120.275 |
| 14034370 | Willow Creek tributary near Heppner, OR | 2 | 17070104 | 45.228 | 119.333 |

**Appendix A.** Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

| Station Number | Station Name | Flood Region | Hydrologic Unit | Latitude Decimal Degrees | Longitude Decimal Degrees |
|---|---|---|---|---|---|
| 14034470 | Willow Creek above Willow Creek Lake, near Heppner, OR | 2 | 17070104 | 45.341 | 119.515 |
| 14034480 | Balm Fork near Heppner, OR | 2 | 17070104 | 45.332 | 119.540 |
| 14034500 | Willow Creek at Heppner, OR | 2 | 17070104 | 45.351 | 119.549 |
| 14034800 | Rhea Creek near Heppner, OR | 2 | 17070104 | 45.261 | 119.623 |
| 14036000 | Willow Creek near Arlington, OR | 2 | 17070104 | 45.753 | 120.010 |
| 14036800 | John Day River near Prairie City, OR | 4 | 17070201 | 44.319 | 118.557 |
| 14037500 | Strawberry Creek above Slide Creek near Prairie City, OR | 4 | 17070201 | 44.342 | 118.656 |
| 14038500 | John Day River at Prairie City, OR | 4 | 17070201 | 44.454 | 118.717 |
| 14038530 | John Day River near John Day, OR | 4 | 17070201 | 44.419 | 118.903 |
| 14038550 | East Fork Canyon Creek near Canyon City, OR | 4 | 17070201 | 44.246 | 118.911 |
| 14038600 | Vance Creek near Canyon City, OR | 4 | 17070201 | 44.289 | 118.978 |
| 14038602 | Canyon Creek near Canyon City, OR | 4 | 17070201 | 44.290 | 118.956 |
| 14038750 | Beech Creek near Fox, OR | 4 | 17070201 | 44.568 | 119.108 |
| 14038900 | Fields Creek near Mt Vernon, OR | 4 | 17070201 | 44.393 | 119.307 |
| 14039200 | Venator Creek near Silvies, OR | 4 | 17070201 | 43.999 | 119.275 |
| 14040500 | John Day River at Picture Gorge, near Dayville, OR | 4 | 17070201 | 44.521 | 119.625 |
| 14040600 | Mountain Creek near Mitchell, OR | 4 | 17070201 | 44.535 | 120.029 |
| 14040700 | Whisky Creek near Mitchell, OR | 4 | 17070201 | 44.522 | 119.922 |
| 14040900 | Bruin Creek near Dale, OR | 4 | 17070202 | 44.898 | 118.793 |
| 14041000 | Desolation Creek near Dale, OR | 4 | 17070202 | 44.989 | 118.919 |
| 14041500 | North Fork John Day River near Dale, OR | 4 | 17070202 | 44.999 | 118.940 |
| 14041900 | Line Creek near Lehman Springs, OR | 4 | 17070202 | 45.169 | 118.711 |
| 14042000 | Camas Creek near Lehman, OR | 4 | 17070202 | 45.171 | 118.731 |
| 14042500 | Camas Creek near Ukiah, OR | 4 | 17070202 | 45.157 | 118.819 |
| 14043800 | Bridge Creek near Prairie City, OR | 4 | 17070203 | 44.542 | 118.540 |
| 14043850 | Cottonwood Creek near Galena, OR | 4 | 17070203 | 44.653 | 118.865 |
| 14043900 | Granite Creek near Dale, OR | 4 | 17070203 | 44.894 | 119.014 |
| 14044000 | M Fork John Day River at Ritter, OR | 4 | 17070203 | 44.889 | 119.140 |
| 14044100 | Paul Creek near Long Creek, OR | 4 | 17070203 | 44.724 | 119.132 |
| 14044500 | Fox Creek at Gorge near Fox, OR | 4 | 17070202 | 44.619 | 119.262 |
| 14046000 | North Fork John Day River at Monument, OR | 4 | 17070202 | 44.814 | 119.431 |
| 14046250 | Ives Can near Spray, OR | 4 | 17070204 | 44.860 | 119.714 |
| 14046300 | Big Service Creek near Service Creek, OR | 4 | 17070204 | 44.894 | 120.070 |
| 14046500 | John Day River at Service Creek, OR | 4 | 17070204 | 44.794 | 120.006 |
| 14047100 | Butte Creek near Fossil, OR | 4 | 17070204 | 44.954 | 120.137 |
| 14047350 | Rock Creek tributary near Hardman, OR | 2 | 17070204 | 45.078 | 119.569 |
| 14047380 | Lone Rock Creek near Lonerock, OR | 2 | 17070204 | 45.092 | 119.886 |
| 14047390 | Rock Creek above Whyte Park near Condon, OR | 2 | 17070204 | 45.265 | 120.021 |
| 14048000 | John Day River at McDonald Ferry, OR | 4 | 17070204 | 45.588 | 120.408 |
| 14048040 | Gordon Hollow at De Moss Springs, OR | 2 | 17070204 | 45.514 | 120.682 |
| 14048300 | Spanish Hollow at Wasco, OR | 2 | 17070105 | 45.589 | 120.694 |
| 14048310 | Spanish Hollow tributary at Wasco, OR | 2 | 17070105 | 45.592 | 120.715 |
| 14050000 | Deschutes River below Snow Creek near La Pine, OR | 1 | 17070301 | 43.814 | 121.776 |

**Appendix A.** Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

| Station Number | Station Name | Flood Region | Hydrologic Unit | Latitude Decimal Degrees | Longitude Decimal Degrees |
|---|---|---|---|---|---|
| 14050500 | Cultus River above Cultus Creek near La Pine, OR | 1 | 17070301 | 43.818 | 121.794 |
| 14051000 | Cultus Creek above Crane Prairie Reservoir near La Pine, OR | 1 | 17070301 | 43.821 | 121.823 |
| 14052000 | Deer Creek above Crane Prairie Reservoir near La Pine, OR | 1 | 17070301 | 43.805 | 121.838 |
| 14053000 | Charlton Creek above Crane Prairie Reservoir near La Pine, OR | 1 | 17070301 | 43.781 | 121.835 |
| 14054500 | Brown Creek near La Pine, OR | 1 | 17070301 | 43.713 | 121.803 |
| 14055500 | Odell Creek near Crescent, OR | 1 | 17070301 | 43.548 | 121.961 |
| 14055600 | Odell Creek near La Pine, OR | 1 | 17070301 | 43.576 | 121.880 |
| 14061000 | Big Marsh Creek Hoey Ranch near Crescent, OR | 1 | 17070302 | 43.478 | 121.914 |
| 14073000 | Tumalo Creek near Bend, OR | 1 | 17070301 | 44.088 | 121.372 |
| 14075000 | Squaw Creek near Sisters, OR | 1 | 17070301 | 44.234 | 121.566 |
| 14077500 | North Fork Beaver Creek near Paulina, OR | 4 | 17070303 | 44.167 | 119.733 |
| 14077800 | Wolf Creek tributary near Paulina, OR | 4 | 17070303 | 44.278 | 119.817 |
| 14078000 | Beaver Creek near Paulina, OR | 4 | 17070303 | 44.164 | 119.922 |
| 14078200 | Lizard G tributary near Hampton, OR | 4 | 17070303 | 43.589 | 119.983 |
| 14078400 | Lookout Creek near Post, OR | 4 | 17070304 | 44.311 | 120.240 |
| 14078500 | North Fork Crooked River above Deep Creek, OR | 4 | 17070304 | 44.333 | 120.083 |
| 14079500 | Crooked River at Post, OR | 4 | 17070304 | 44.117 | 120.250 |
| 14079800 | Crooked River above Prineville Reservoir near Post, OR | 4 | 17070304 | 44.178 | 120.583 |
| 14080500 | Crooked River near Prineville, OR | 4 | 17070304 | 44.114 | 120.794 |
| 14080600 | Dry Creek near Prineville, OR | 4 | 17070305 | 44.203 | 120.760 |
| 14081800 | Ahalt Creek near Mitchell, OR | 4 | 17070305 | 44.433 | 120.351 |
| 14083000 | Ochoco Creek above Mill Creek near Prineville, OR | 4 | 17070305 | 44.308 | 120.644 |
| 14083500 | Mill Creek near Prineville, OR | 4 | 17070305 | 44.336 | 120.667 |
| 14088000 | Lake Creek near Sisters, OR | 1 | 17070301 | 44.426 | 121.725 |
| 14090350 | Jefferson Creek near Camp Sherman, OR | 1 | 17070301 | 44.572 | 121.638 |
| 14090400 | Whitewater River near Camp Sherman, OR | 1 | 17070306 | 44.718 | 121.635 |
| 14091500 | Metolius River near Grandview, OR | 1 | 17070301 | 44.626 | 121.482 |
| 14092750 | Shitike Creek at Peters Pasture near Warm Springs, OR | 1 | 17070306 | 44.751 | 121.632 |
| 14092885 | Shitike Creek below Wolford Can near Warm Springs, OR | 1 | 17070306 | 44.772 | 121.304 |
| 14093000 | Shitike Creek at Warm Springs, OR | 1 | 17070306 | 44.764 | 121.232 |
| 14093600 | Trout Creek below Amity Creek near Ashwood, OR | 2 | 17070307 | 44.639 | 120.674 |
| 14093700 | Woods Hollow at Ashwood, OR | 2 | 17070307 | 44.736 | 120.753 |
| 14095500 | Warm Springs River near Simnasho, OR | 1 | 17070306 | 44.969 | 121.476 |
| 14096300 | Mill Creek near Badger Butte near Warm Springs, OR | 1 | 17070306 | 44.862 | 121.626 |
| 14096850 | Beaver Creek below Quartz Creek near Simnasho, OR | 1 | 17070306 | 44.959 | 121.393 |
| 14097100 | Warm Springs River near Kahneeta Hot Springs, OR | 1 | 17070306 | 44.857 | 121.149 |
| 14097200 | White River near Government Camp, OR | 1 | 17070306 | 45.178 | 121.575 |
| 14100800 | Jordan Creek near Tygh Valley, OR | 1 | 17070306 | 45.341 | 121.346 |
| 14101500 | White River below Tygh Valley, OR | 1 | 17070306 | 45.242 | 121.094 |
| 14104100 | Ramsey Creek near Dufur, OR | 2 | 17070105 | 45.401 | 121.380 |
| 14104500 | Fifteenmile Creek near Rice, OR | 2 | 17070105 | 45.511 | 121.037 |
| 14107000 | Klickitat River above West Fork near Glenwood, WA | 2 | 17070106 | 46.265 | 121.244 |
| 14110000 | Klickitat River near Glenwood, WA | 2 | 17070106 | 46.089 | 121.258 |

**Appendix A.** Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

| Station Number | Station Name | Flood Region | Hydrologic Unit | Latitude Decimal Degrees | Longitude Decimal Degrees |
|---|---|---|---|---|---|
| 14111800 | West Prong Little Klickitat River near Goldendale, WA | 2 | 17070106 | 45.925 | 120.720 |
| 14112000 | Little Klickitat River near Goldendale, WA | 2 | 17070106 | 45.844 | 120.795 |
| 14112200 | Little Klickitat River tributary near Goldendale, WA | 2 | 17070106 | 45.837 | 120.797 |
| 14112500 | Little Klickitat River near Wahkiacus, WA | 2 | 17070106 | 45.844 | 121.059 |
| 14113000 | Klickitat River near Pitt, WA | 2 | 17070106 | 45.757 | 121.209 |
| 14113200 | Mosier Creek near Mosier, OR | 2 | 17070105 | 45.649 | 121.376 |
| 14113400 | Dog River near Parkdale, OR | 1 | 17070105 | 45.408 | 121.519 |
| 14118500 | West Fork Hood River near Dee, OR | 1 | 17070105 | 45.599 | 121.635 |
| 14120000 | Hood River at Tucker Bridge near Hood River, OR | 1 | 17070105 | 45.656 | 121.547 |
| 14121000 | Hood River near Hood River, OR | 1 | 17070105 | 45.700 | 121.511 |
| 14121300 | White Salmon River below Cascades Creek near Trout Lake, WA | 1 | 17070105 | 46.102 | 121.604 |
| 14121500 | Trout Lake Creek near Trout Lake, WA | 1 | 17070105 | 46.006 | 121.539 |
| 14122000 | White Salmon River near Trout Lake, WA | 1 | 17070105 | 45.992 | 121.492 |
| 14123000 | White Salmon River at Husum, WA | 1 | 17070105 | 45.797 | 121.483 |
| 14123500 | White Salmon River near Underwood, WA | 1 | 17070105 | 45.753 | 121.526 |
| 14124500 | Little White Salmon River at Willard, WA | 1 | 17070105 | 45.781 | 121.625 |
| 14125000 | Little White Salmon River above Lapham Creek Willard, WA | 1 | 17070105 | 45.767 | 121.628 |
| 14125500 | Little White Salmon River near Cook, WA | 1 | 17070105 | 45.724 | 121.633 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System-atic | Histor-ical | Histor-ical | User thresh-old | High outlier | User thresh-old | Low outlier | Zero peaks | Below thresh-old | Station | Bulletin 17B | General-ized | Weight-ed | Kendall's tau | Signifi-cance level |
| 10329500 | 1922-1999 | 76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.233 | 0.233 | 0.063 | 0.161 | 0.134 | 0.087 |
| 10330300 | 1962-1979 | 18 | 0 | 0 | 0 | 0 | 50 | 4 | 0 | 0 | -1.644 | -0.383 | 0.053 | -0.064 | -0.092 | 0.595 |
| 10352300 | 1969-1981 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.265 | -0.042 | -0.242 | -0.198 | -0.171 | 0.440 |
| 10352500 | 1949-1999 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.439 | -0.439 | -0.256 | -0.340 | -0.057 | 0.553 |
| 10353000 | 1949-1981 | 33 | 0 | 0 | 0 | 0 | 200 | 6 | 0 | 0 | -1.228 | 0.012 | -0.192 | -0.106 | -0.009 | 0.938 |
| 10353600 | 1963-1995 | 24 | 51 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.919 | 0.678 | -0.221 | 0.570 | -0.113 | 0.441 |
| 10353700 | 1961-1980 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.051 | 0.051 | -0.151 | -0.090 | -0.035 | 0.833 |
| 10353750 | 1988-1999 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.115 | -0.115 | -0.148 | -0.141 | 0.351 | 0.112 |
| 10360900 | 1961-1982 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.051 | 0.051 | -0.062 | -0.025 | -0.013 | 0.933 |
| 10361700 | 1962-1978 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.255 | 0.201 | -0.152 | -0.057 | -0.165 | 0.354 |
| 10366000 | 1963-1998 | 34 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.752 | -0.480 | -0.093 | -0.473 | -0.014 | 0.906 |
| 10370000 | 1913-1972 | 25 | 69 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1.182 | 0.857 | 0.033 | 0.404 | 0.220 | 0.123 |
| 10371000 | 1915-1973 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.228 | 0.228 | 0.011 | 0.086 | 0.277 | 0.047 |
| 10371500 | 1923-2000 | 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.015 | 0.015 | 0.013 | 0.014 | 0.179 | 0.026 |
| 10378500 | 1910-1998 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.095 | -0.095 | 0.006 | -0.055 | 0.053 | 0.495 |
| 10384000 | 1914-2000 | 83 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.012 | 0.257 | 0.110 | 0.197 | 0.179 | 0.017 |
| 10390400 | 1965-1982 | 17 | 0 | 0 | 0 | 0 | 50 | 7 | 0 | 0 | 1.046 | -0.077 | 0.152 | 0.088 | -0.498 | 0.005 |
| 10392300 | 1967-1981 | 15 | 0 | 0 | 0 | 0 | 25 | 3 | 0 | 0 | -2.641 | -0.036 | -0.225 | -0.176 | -0.019 | 0.921 |
| 10392800 | 1966-1979 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.389 | -0.389 | -0.190 | -0.235 | 0.354 | 0.078 |
| 10393500 | 1906-1997 | 86 | 0 | 0 | 0 | 0 | 200 | 3 | 0 | 0 | -0.938 | -0.444 | -0.281 | -0.373 | 0.009 | 0.899 |
| 10393900 | 1965-1981 | 13 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | -1.336 | -1.078 | -0.291 | -0.427 | -0.494 | 0.019 |
| 10396000 | 1911-2003 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.496 | -0.496 | -0.409 | -0.456 | 0.067 | 0.388 |
| 10397000 | 1911-1970 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.501 | -0.501 | -0.413 | -0.448 | -0.009 | 0.932 |
| 10402800 | 1967-1977 | 11 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.719 | -0.355 | -0.296 | -0.307 | -0.309 | 0.186 |
| 10403000 | 1952-1980 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.666 | -0.666 | -0.280 | -0.405 | 0.039 | 0.764 |
| 10403500 | 1904-1925 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.106 | -0.106 | -0.268 | -0.221 | 0.066 | 0.704 |
| 10406500 | 1911-1997 | 74 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.070 | -0.070 | -0.177 | -0.113 | 0.037 | 0.643 |
| 11339995 | 1981-2000 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.460 | 0.460 | -0.031 | 0.089 | 0.427 | 0.021 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System-atic | Histor-ical | Histor-ical | User thresh-old | High outlier | User thresh-old | Low outlier | Zero peaks | Below thresh-old | Station | Bulletin 17B | General-ized | Weight-ed | Kendall's tau | Signifi-cance level |
| 11340500 | 1909-1919 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.564 | -0.564 | -0.015 | -0.113 | -0.467 | 0.060 |
| 11340950 | 1946-1958 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.087 | -0.087 | -0.031 | -0.044 | 0.359 | 0.088 |
| 11341000 | 1912-1958 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.447 | -0.447 | -0.029 | -0.162 | 0.300 | 0.036 |
| 11341050 | 1977-1988 | 10 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.976 | -0.368 | 0.034 | -0.040 | -0.200 | 0.421 |
| 11341100 | 1964-1981 | 18 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | -1.871 | -0.047 | 0.034 | 0.010 | -0.367 | 0.033 |
| 11341200 | 1966-1981 | 16 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.858 | -0.343 | 0.046 | -0.052 | -0.326 | 0.078 |
| 11342945 | 1963-1973 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.332 | 0.332 | 0.041 | 0.098 | -0.278 | 0.234 |
| 11342960 | 1963-1973 | 11 | 0 | 0 | 0 | 0 | 50 | 4 | 0 | 0 | -1.208 | -0.409 | 0.041 | -0.046 | 0.127 | 0.586 |
| 11348080 | 1963-1973 | 11 | 0 | 0 | 0 | 0 | 60 | 3 | 0 | 0 | -1.810 | -0.751 | 0.074 | -0.077 | 0.018 | 0.938 |
| 11348560 | 1963-1973 | 11 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.488 | -0.007 | 0.165 | 0.129 | -0.315 | 0.178 |
| 11484000 | 1910-1920 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.169 | 0.169 | 0.076 | 0.095 | -0.257 | 0.271 |
| 11489350 | 1963-1973 | 11 | 21 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1.243 | 1.026 | 0.192 | 0.385 | -0.183 | 0.432 |
| 11489500 | 1953-1979 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.447 | 0.447 | 0.324 | 0.365 | -0.088 | 0.518 |
| 11491800 | 1965-1981 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | -0.606 | -0.606 | 0.248 | -0.428 | -0.377 | 0.042 |
| 11494800 | 1965-1981 | 14 | 83 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.942 | 0.621 | 0.074 | 0.575 | -0.181 | 0.368 |
| 11497500 | 1914-2001 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.105 | -0.105 | 0.059 | -0.028 | 0.091 | 0.322 |
| 11497800 | 1965-1982 | 17 | 0 | 0 | 0 | 0 | 20 | 3 | 0 | 0 | -1.408 | 0.053 | 0.099 | 0.086 | -0.273 | 0.126 |
| 11501000 | 1921-2003 | 83 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.048 | 0.048 | 0.127 | 0.077 | 0.093 | 0.215 |
| 11501300 | 1965-1981 | 17 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.111 | 0.209 | 0.267 | 0.251 | -0.081 | 0.649 |
| 11502500 | 1917-2003 | 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.270 | 0.270 | 0.175 | 0.232 | 0.053 | 0.468 |
| 11504000 | 1913-1936 | 22 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.434 | 0.185 | 0.350 | 0.298 | -0.382 | 0.013 |
| 11505550 | 1966-1982 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.576 | -0.576 | 0.316 | -0.487 | -0.221 | 0.217 |
| 11516900 | 1958-1978 | 21 | 83 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1.373 | 0.711 | 0.147 | 0.434 | -0.091 | 0.565 |
| 13172666 | 1965-1978 | 14 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.855 | -0.231 | -0.537 | -0.465 | -0.077 | 0.702 |
| 13172668 | 1963-1993 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.691 | -0.691 | -0.537 | -0.588 | 0.002 | 0.986 |
| 13172680 | 1966-1993 | 28 | 0 | 0 | 0 | 0 | 50 | 2 | 0 | 0 | -1.257 | -0.693 | -0.478 | -0.546 | -0.153 | 0.252 |
| 13172720 | 1964-1990 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.514 | -0.514 | -0.447 | -0.469 | -0.214 | 0.118 |
| 13172735 | 1964-1993 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.596 | -0.596 | -0.435 | -0.489 | -0.216 | 0.093 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System-atic | Histor-ical | Histor-ical | User thresh-old | High outlier | User thresh-old | Low outlier | Zero peaks | Below thresh-old | Station | Bulletin 17B | General-ized | Weight-ed | Kendall's tau | Signifi-cance level |
| 13172740 | 1963-1993 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.358 | -0.358 | -0.573 | -0.494 | -0.299 | 0.018 |
| 13172800 | 1961-1980 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | -0.369 | -0.582 | -0.422 | -0.464 | -0.018 | 0.914 |
| 13172900 | 1966-1979 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.046 | -0.046 | -0.452 | -0.353 | 0.033 | 0.870 |
| 13178000 | 1946-1971 | 24 | 48 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.223 | 0.012 | -0.416 | -0.198 | 0.105 | 0.471 |
| 13182100 | 1970-1981 | 12 | 0 | 0 | 0 | 0 | 10 | 2 | 1 | 0 | -1.751 | -1.102 | -0.459 | -0.564 | 0.198 | 0.369 |
| 13207000 | 1955-1982 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.023 | -0.023 | -0.270 | -0.198 | 0.163 | 0.344 |
| 13207500 | 1955-1982 | 15 | 0 | 0 | 0 | 0 | 50 | 5 | 0 | 0 | -0.408 | -0.634 | -0.273 | -0.355 | 0.124 | 0.520 |
| 13213800 | 1968-1991 | 24 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.335 | -0.723 | -0.311 | -0.430 | -0.341 | 0.020 |
| 13213900 | 1964-1982 | 19 | 0 | 0 | 0 | 0 | 10 | 2 | 2 | 0 | -0.742 | -0.027 | -0.322 | -0.233 | -0.211 | 0.207 |
| 13214000 | 1921-1998 | 73 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.520 | -0.229 | -0.293 | -0.257 | 0.072 | 0.368 |
| 13216500 | 1937-1998 | 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.349 | -0.349 | -0.335 | -0.342 | 0.150 | 0.094 |
| 13226500 | 1904-1985 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.584 | -0.584 | -0.345 | -0.439 | 0.177 | 0.103 |
| 13228000 | 1904-1919 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.184 | 0.184 | -0.345 | 0.033 | -0.382 | 0.102 |
| 13228300 | 1969-1982 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.378 | 0.378 | -0.362 | 0.096 | -0.177 | 0.378 |
| 13229400 | 1967-1978 | 12 | 0 | 0 | 0 | 0 | 10 | 2 | 2 | 0 | -1.274 | -0.508 | -0.307 | -0.348 | -0.321 | 0.147 |
| 13248900 | 1961-1980 | 19 | 0 | 0 | 0 | 0 | 51 | 6 | 0 | 1 | 0.549 | -0.322 | -0.229 | -0.255 | 0.024 | 0.888 |
| 13250600 | 1962-1997 | 22 | 24 | 1 | 2,100 | 1 | 0 | 1 | 0 | 0 | -2.471 | -0.196 | -0.129 | -0.151 | 0.229 | 0.135 |
| 13250650 | 1962-1971 | 10 | 0 | 0 | 0 | 0 | 50 | 2 | 0 | 0 | -0.785 | -0.143 | -0.172 | -0.167 | 0.156 | 0.531 |
| 13251300 | 1960-1977 | 18 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.827 | 0.209 | 0.089 | 0.122 | 0.126 | 0.466 |
| 13251500 | 1937-1997 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.033 | -0.033 | 0.061 | 0.019 | 0.185 | 0.102 |
| 13252500 | 1933-1943 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.637 | 0.637 | 0.093 | 0.586 | 0.180 | 0.469 |
| 13253500 | 1939-1949 | 11 | 37 | 1 | 2,800 | 0 | 0 | 0 | 0 | 0 | 0.021 | 0.072 | 0.076 | 0.074 | 0.055 | 0.815 |
| 13260000 | 1939-1997 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.672 | 0.672 | 0.133 | 0.645 | 0.033 | 0.823 |
| 13261000 | 1924-1971 | 38 | 42 | 1 | 2,230 | 0 | 0 | 0 | 0 | 0 | -0.016 | 0.150 | 0.115 | 0.131 | 0.098 | 0.385 |
| 13267000 | 1937-1965 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.229 | 0.229 | 0.166 | 0.189 | 0.058 | 0.664 |
| 13267100 | 1962-1971 | 10 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.772 | 0.180 | 0.134 | 0.143 | 0.135 | 0.587 |
| 13269200 | 1964-1979 | 14 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | -0.556 | 0.121 | -0.213 | -0.132 | -0.011 | 0.956 |
| 13269300 | 1965-1994 | 18 | 0 | 0 | 0 | 0 | 600 | 8 | 0 | 0 | -1.400 | -0.480 | -0.226 | -0.292 | -0.033 | 0.850 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System-atic | Histor-ical | Histor-ical | User thresh-old | High outlier | User thresh-old | Low outlier | Zero peaks | Below thresh-old | Station | Bulletin 17B | General-ized | Weight-ed | Kendall's tau | Signifi-cance level |
| 13272300 | 1967-1979 | 13 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.812 | -0.314 | -0.314 | -0.089 | -0.144 | 0.494 |
| 13274600 | 1967-1979 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | -0.309 | -0.371 | -0.074 | -0.139 | 0.282 | 0.180 |
| 13275105 | 1981-1999 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.747 | -0.747 | -0.275 | -0.390 | 0.124 | 0.472 |
| 13275200 | 1968-1999 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.106 | -0.106 | -0.282 | -0.212 | 0.105 | 0.405 |
| 13275500 | 1904-1967 | 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.581 | -0.581 | -0.322 | -0.436 | -0.042 | 0.658 |
| 13281200 | 1977-1999 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.427 | -0.427 | -0.228 | -0.289 | -0.214 | 0.153 |
| 13282400 | 1963-1978 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.431 | -0.431 | -0.060 | -0.148 | -0.029 | 0.882 |
| 13283600 | 1974-2000 | 27 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | -0.596 | -0.106 | -0.067 | -0.081 | -0.285 | 0.037 |
| 13285900 | 1963-1979 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.274 | -0.274 | -0.144 | -0.179 | 0.155 | 0.385 |
| 13286300 | 1969-1982 | 14 | 0 | 0 | 0 | 0 | 20 | 3 | 2 | 0 | -0.584 | -0.346 | -0.085 | -0.145 | -0.056 | 0.780 |
| 13287200 | 1968-1986 | 19 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.897 | 0.897 | -0.056 | 0.175 | 0.088 | 0.598 |
| 13288200 | 1958-1997 | 40 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.328 | 0.328 | 0.129 | 0.213 | 0.000 | 1.000 |
| 13289100 | 1964-1981 | 14 | 0 | 0 | 0 | 0 | 40 | 2 | 0 | 1 | -1.824 | 0.636 | 0.111 | 0.576 | -0.022 | 0.912 |
| 13289600 | 1962-1971 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.609 | 0.210 | 0.124 | 0.140 | 0.180 | 0.469 |
| 13289960 | 1979-1994 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.238 | 0.238 | 0.115 | 0.145 | -0.295 | 0.125 |
| 13290150 | 1965-1979 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.105 | -0.105 | 0.200 | 0.130 | -0.256 | 0.222 |
| 13290190 | 1967-1996 | 30 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.956 | -0.037 | 0.114 | 0.054 | -0.240 | 0.063 |
| 13291200 | 1965-1975 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.005 | 0.005 | 0.200 | 0.162 | -0.067 | 0.788 |
| 13291400 | 1965-1979 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0.202 | -0.023 | 0.180 | 0.141 | 0.045 | 0.856 |
| 13292000 | 1929-2003 | 75 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.703 | 0.703 | 0.216 | 0.456 | 0.109 | 0.165 |
| 13315500 | 1937-1971 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.096 | -0.096 | 0.025 | -0.018 | -0.065 | 0.642 |
| 13316500 | 1948-2000 | 47 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.416 | -0.066 | 0.076 | 0.005 | -0.105 | 0.300 |
| 13316800 | 1960-1971 | 12 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1.094 | 1.094 | 0.177 | 0.327 | 0.303 | 0.170 |
| 13317200 | 1961-1972 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.101 | -0.101 | 0.181 | 0.120 | -0.030 | 0.891 |
| 13318100 | 1966-1979 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.190 | 0.190 | 0.270 | 0.251 | 0.429 | 0.033 |
| 13318500 | 1938-1956 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.482 | 0.482 | 0.133 | 0.227 | 0.164 | 0.326 |
| 13318800 | 1967-1981 | 15 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.106 | 0.233 | 0.136 | 0.160 | 0.000 | 1.000 |
| 13319000 | 1904-1988 | 80 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.100 | 0.219 | 0.130 | 0.182 | 0.054 | 0.482 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System-atic | Histor-ical | Histor-ical | User thresh-old | High outlier | User thresh-old | Low outlier | Zero peaks | Below thresh-old | Station | Bulletin 17B | General-ized | Weight-ed | Kendall's tau | Signifi-cance level |
| 13320000 | 1912-1999 | 76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.258 | -0.258 | -0.092 | -0.187 | -0.055 | 0.478 |
| 13320400 | 1948-1979 | 26 | 76 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.788 | -0.562 | -0.087 | -0.334 | -0.296 | 0.034 |
| 13321300 | 1953-1972 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.421 | -0.421 | -0.023 | -0.121 | 0.092 | 0.619 |
| 13322300 | 1965-1979 | 14 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.487 | 0.223 | 0.265 | 0.255 | 0.110 | 0.582 |
| 13323500 | 1956-1981 | 26 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.720 | -0.280 | 0.082 | -0.042 | -0.068 | 0.627 |
| 13323600 | 1938-1950 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.103 | 0.103 | 0.028 | 0.045 | 0.103 | 0.625 |
| 13323700 | 1966-1983 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.293 | -0.293 | 0.111 | 0.004 | 0.162 | 0.365 |
| 13324150 | 1967-1979 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | -0.464 | -0.523 | 0.113 | -0.350 | -0.065 | 0.759 |
| 13324300 | 1983-2003 | 21 | 59 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.725 | 0.424 | 0.418 | 0.421 | 0.024 | 0.880 |
| 13325000 | 1925-1982 | 58 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.451 | 0.451 | 0.094 | 0.267 | 0.146 | 0.105 |
| 13325500 | 1924-1940 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.039 | -0.039 | 0.089 | 0.059 | 0.282 | 0.180 |
| 13329500 | 1915-1978 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.172 | -0.172 | 0.072 | -0.055 | 0.242 | 0.008 |
| 13329700 | 1967-1982 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | -0.101 | -0.253 | 0.118 | 0.035 | 0.130 | 0.537 |
| 13329750 | 1967-1977 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | -0.192 | -0.271 | 0.072 | 0.004 | -0.455 | 0.052 |
| 13330000 | 1913-2003 | 75 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.401 | -0.091 | 0.055 | -0.032 | 0.051 | 0.515 |
| 13330500 | 1915-2003 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.098 | 0.098 | 0.029 | 0.069 | 0.152 | 0.061 |
| 13331500 | 1913-2003 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.076 | 0.076 | -0.001 | 0.034 | -0.058 | 0.602 |
| 13332500 | 1927-1996 | 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.098 | 0.098 | 0.108 | 0.103 | 0.115 | 0.168 |
| 13333000 | 1945-2003 | 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.230 | 0.230 | 0.159 | 0.196 | -0.036 | 0.689 |
| 13333050 | 1967-1981 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.186 | 0.186 | 0.340 | 0.302 | 0.077 | 0.691 |
| 13333100 | 1965-1979 | 15 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.766 | 0.393 | 0.191 | 0.239 | -0.181 | 0.347 |
| 13334700 | 1960-1996 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.691 | 0.691 | 0.435 | 0.519 | -0.039 | 0.762 |
| 13335050 | 1990-1999 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.144 | 0.144 | 0.424 | 0.371 | 0.467 | 0.060 |
| 13341100 | 1961-1981 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.457 | -0.457 | 0.283 | -0.361 | -0.170 | 0.323 |
| 13342450 | 1975-2000 | 25 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.347 | 0.132 | 0.283 | 0.230 | -0.073 | 0.607 |
| 14010000 | 1903-1991 | 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.545 | 0.545 | 0.476 | 0.511 | 0.115 | 0.161 |
| 14010800 | 1970-1991 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.115 | -0.115 | 0.494 | 0.296 | -0.208 | 0.175 |
| 14011000 | 1930-1969 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.523 | 0.523 | 0.482 | 0.498 | -0.028 | 0.801 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System-atic | Histor-ical | Histor-ical | User thresh-old | High outlier | User thresh-old | Low outlier | Zero peaks | Below thresh-old | Station | Bulletin 17B | General-ized | Weight-ed | Kendall's tau | Signifi-cance level |
| 14011800 | 1966-1978 | 12 | 0 | 0 | 0 | 0 | 300 | 5 | 0 | 0 | -1.009 | 0.148 | 0.405 | 0.350 | 0.030 | 0.891 |
| 14013000 | 1914-1999 | 64 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.523 | 0.523 | 0.484 | 0.503 | 0.033 | 0.702 |
| 14013500 | 1940-1971 | 31 | 0 | 0 | 0 | 0 | 100 | 2 | 0 | 0 | -0.203 | 0.439 | 0.444 | 0.442 | -0.071 | 0.574 |
| 14015900 | 1955-1974 | 20 | 0 | 0 | 0 | 0 | 5 | 3 | 0 | 0 | 0.342 | 0.093 | 0.439 | 0.109 | 0.085 | 0.600 |
| 14016000 | 1949-1967 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.230 | -0.230 | 0.439 | -0.194 | -0.333 | 0.053 |
| 14016080 | 1967-1982 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0.211 | 0.002 | 0.432 | 0.026 | 0.076 | 0.682 |
| 14016200 | 1966-1985 | 20 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.153 | -0.771 | 0.373 | -0.735 | -0.069 | 0.672 |
| 14016500 | 1944-1968 | 21 | 71 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.779 | 0.166 | 0.362 | 0.250 | -0.229 | 0.147 |
| 14016600 | 1955-1974 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.721 | -0.721 | 0.334 | -0.659 | 0.196 | 0.226 |
| 14016650 | 1957-1975 | 19 | 21 | 1 | 305 | 0 | 0 | 0 | 0 | 0 | -0.137 | -0.027 | 0.323 | 0.210 | -0.041 | 0.804 |
| 14017000 | 1925-1989 | 43 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.692 | -0.098 | 0.359 | 0.143 | -0.081 | 0.445 |
| 14017040 | 1962-1976 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.670 | -0.670 | 0.318 | -0.601 | 0.029 | 0.882 |
| 14017070 | 1963-1977 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.253 | 0.253 | 0.357 | 0.331 | -0.057 | 0.765 |
| 14017200 | 1955-1974 | 20 | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | -1.115 | 0.654 | 0.405 | 0.471 | -0.026 | 0.871 |
| 14017500 | 1942-1965 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.106 | 0.106 | 0.380 | 0.307 | 0.209 | 0.258 |
| 14018500 | 1949-1999 | 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.151 | 0.151 | 0.404 | 0.279 | -0.122 | 0.215 |
| 14019400 | 1965-1979 | 13 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -2.063 | 0.788 | 0.373 | 0.456 | -0.013 | 0.951 |
| 14020000 | 1933-2003 | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.356 | 0.356 | 0.370 | 0.362 | 0.101 | 0.216 |
| 14020300 | 1976-2003 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.014 | 0.014 | 0.263 | 0.167 | -0.024 | 0.859 |
| 14020740 | 1992-2003 | 12 | 71 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.751 | 0.146 | 0.303 | 0.213 | -0.031 | 0.889 |
| 14020800 | 1958-1979 | 17 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.781 | -0.056 | 0.303 | 0.203 | -0.132 | 0.458 |
| 14020900 | 1967-1978 | 12 | 0 | 0 | 0 | 0 | 200 | 3 | 0 | 0 | -1.567 | 0.421 | 0.372 | 0.382 | -0.121 | 0.583 |
| 14021000 | 1904-2003 | 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.056 | 0.056 | 0.325 | 0.169 | 0.043 | 0.611 |
| 14021980 | 1992-2003 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.084 | 0.084 | 0.302 | 0.255 | -0.182 | 0.411 |
| 14022200 | 1974-2003 | 30 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.577 | -0.033 | 0.303 | 0.169 | -0.131 | 0.309 |
| 14022500 | 1927-2001 | 74 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.221 | 0.221 | 0.277 | 0.245 | 0.076 | 0.341 |
| 14025000 | 1928-2001 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.059 | -0.059 | 0.166 | 0.044 | 0.022 | 0.809 |
| 14026000 | 1905-1926 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.096 | 0.097 | 0.281 | 0.221 | -0.091 | 0.554 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System-atic | Histor-ical | Histor-ical | User thresh-old | High outlier | User thresh-old | Low outlier | Zero peaks | Below thresh-old | Station | Bulletin 17B | General-ized | Weight-ed | Kendall's tau | Signifi-cance level |
| 14032000 | 1929-2004 | 76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.727 | 0.727 | 0.385 | 0.553 | 0.059 | 0.454 |
| 14034250 | 1961-1976 | 16 | 0 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | -1.968 | 0.209 | 0.336 | 0.303 | -0.159 | 0.390 |
| 14034325 | 1963-1977 | 15 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -2.456 | 0.560 | 0.308 | 0.366 | -0.048 | 0.805 |
| 14034370 | 1960-1979 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | -0.472 | -0.522 | 0.299 | 0.109 | 0.077 | 0.691 |
| 14034470 | 1983-2003 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.087 | -0.087 | 0.311 | 0.185 | -0.205 | 0.193 |
| 14034480 | 1983-2003 | 21 | 100 | 1 | 36,000 | 0 | 0 | 0 | 0 | 0 | -0.594 | 0.343 | 0.297 | 0.325 | -0.257 | 0.103 |
| 14034500 | 1949-1982 | 32 | 100 | 1 | 36,000 | 0 | 50 | 3 | 0 | 0 | -0.069 | 1.815 | 0.308 | 0.719 | -0.121 | 0.331 |
| 14034800 | 1961-2001 | 38 | 0 | 0 | 0 | 0 | 60 | 4 | 0 | 0 | -0.476 | 0.183 | 0.281 | 0.239 | -0.165 | 0.144 |
| 14036000 | 1961-1979 | 19 | 21 | 1 | 17,000 | 0 | 0 | 1 | 0 | 0 | -0.761 | -0.292 | 0.331 | -0.262 | -0.006 | 0.972 |
| 14036800 | 1965-1979 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.693 | -0.693 | -0.220 | -0.321 | -0.313 | 0.119 |
| 14037500 | 1931-2002 | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.019 | -0.019 | -0.220 | -0.100 | 0.175 | 0.032 |
| 14038500 | 1940-1968 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.709 | 0.709 | -0.224 | 0.069 | -0.048 | 0.721 |
| 14038530 | 1969-2003 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.124 | -0.124 | -0.214 | -0.177 | -0.207 | 0.091 |
| 14038550 | 1965-1979 | 15 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.212 | -1.138 | -0.210 | -0.846 | -0.295 | 0.125 |
| 14038600 | 1964-1979 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.084 | 0.020 | -0.167 | -0.121 | -0.253 | 0.208 |
| 14038602 | 1981-2002 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.366 | -0.366 | -0.208 | -0.256 | -0.130 | 0.397 |
| 14038750 | 1965-1979 | 12 | 0 | 0 | 0 | 0 | 9 | 3 | 0 | 1 | -0.938 | -0.275 | -0.111 | -0.145 | -0.412 | 0.062 |
| 14038900 | 1967-1979 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | -0.566 | -0.623 | -0.129 | -0.231 | 0.000 | 1.000 |
| 14039200 | 1967-1979 | 13 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -2.779 | -0.925 | -0.370 | -0.476 | -0.179 | 0.393 |
| 14040500 | 1927-2002 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.103 | -0.103 | -0.161 | -0.127 | 0.071 | 0.367 |
| 14040600 | 1967-2001 | 32 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.439 | -0.031 | 0.107 | 0.050 | -0.347 | 0.005 |
| 14040700 | 1969-1979 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.022 | -0.061 | 0.011 | -0.004 | -0.491 | 0.036 |
| 14040900 | 1969-1981 | 12 | 0 | 0 | 0 | 0 | 20 | 2 | 0 | 0 | -2.641 | 0.456 | 0.079 | 0.156 | 0.326 | 0.141 |
| 14041000 | 1950-1961 | 12 | 14 | 1 | 930 | 1 | 0 | 0 | 0 | 0 | -0.094 | -0.261 | -0.001 | -0.062 | -0.030 | 0.891 |
| 14041500 | 1930-1958 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.512 | -0.512 | -0.069 | -0.220 | 0.341 | 0.009 |
| 14041900 | 1965-1979 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.075 | -0.075 | 0.216 | 0.142 | -0.039 | 0.841 |
| 14042000 | 1951-1969 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.557 | 0.557 | 0.194 | 0.290 | -0.345 | 0.039 |
| 14042500 | 1915-2002 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.279 | 0.279 | 0.185 | 0.238 | -0.022 | 0.784 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System-atic | Histor-ical | Histor-ical | User thresh-old | High outlier | User thresh-old | Low outlier | Zero peaks | Below thresh-old | Station | Bulletin 17B | General-ized | Weight-ed | Kendall's tau | Signifi-cance level |
| 14043800 | 1964-1979 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.107 | 0.107 | -0.212 | -0.131 | 0.320 | 0.096 |
| 14043850 | 1965-1979 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.016 | -0.016 | -0.112 | -0.087 | 0.038 | 0.842 |
| 14043900 | 1965-1979 | 10 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | -1.846 | -0.375 | 0.127 | 0.035 | -0.270 | 0.278 |
| 14044000 | 1930-2003 | 74 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.195 | -0.195 | -0.106 | -0.157 | 0.161 | 0.042 |
| 14044100 | 1969-1979 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | -0.553 | -0.623 | 0.100 | -0.560 | -0.636 | 0.006 |
| 14044500 | 1931-1958 | 28 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.268 | 0.306 | 0.062 | 0.148 | 0.236 | 0.078 |
| 14046000 | 1925-2003 | 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.243 | 0.243 | 0.057 | 0.166 | 0.128 | 0.096 |
| 14046250 | 1968-1979 | 11 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | -0.962 | -0.316 | 0.189 | -0.274 | 0.382 | 0.102 |
| 14046300 | 1969-1979 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.084 | -0.001 | 0.307 | 0.243 | -0.455 | 0.052 |
| 14046500 | 1926-2003 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.083 | -0.083 | 0.004 | -0.048 | 0.085 | 0.282 |
| 14047100 | 1974-2002 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.118 | -0.118 | 0.307 | 0.151 | 0.069 | 0.615 |
| 14047350 | 1965-1979 | 14 | 0 | 0 | 0 | 0 | 20 | 2 | 0 | 1 | -1.058 | -0.554 | 0.244 | 0.068 | -0.363 | 0.071 |
| 14047380 | 1966-2002 | 36 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.579 | 0.087 | 0.399 | 0.264 | -0.206 | 0.077 |
| 14047390 | 1976-1989 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.089 | -0.089 | 0.358 | 0.249 | 0.407 | 0.043 |
| 14048000 | 1894-2003 | 98 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.096 | -0.096 | 0.106 | -0.026 | 0.032 | 0.643 |
| 14048040 | 1959-1981 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | -0.149 | -0.417 | 0.250 | -0.392 | 0.029 | 0.853 |
| 14048300 | 1959-1979 | 21 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 0 | -1.572 | 0.201 | 0.263 | 0.244 | 0.029 | 0.853 |
| 14048310 | 1968-1979 | 12 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | -1.790 | -0.781 | 0.263 | -0.326 | 0.109 | 0.623 |
| 14050000 | 1938-1997 | 58 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.596 | -0.596 | -0.103 | -0.330 | -0.082 | 0.361 |
| 14050500 | 1923-1997 | 55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.146 | -0.146 | -0.194 | -0.169 | -0.048 | 0.603 |
| 14051000 | 1924-1997 | 61 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.239 | -0.239 | -0.214 | -0.227 | 0.104 | 0.237 |
| 14052000 | 1924-1997 | 60 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.454 | -0.188 | -0.230 | -0.208 | 0.011 | 0.903 |
| 14053000 | 1938-1991 | 49 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | -0.829 | -0.570 | -0.266 | -0.397 | -0.163 | 0.099 |
| 14054500 | 1923-1997 | 58 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.082 | -0.082 | -0.233 | -0.151 | -0.027 | 0.761 |
| 14055500 | 1933-1976 | 44 | 60 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.859 | 0.703 | -0.045 | 0.291 | 0.072 | 0.490 |
| 14055600 | 1970-2004 | 35 | 45 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.675 | 0.620 | -0.060 | 0.217 | -0.303 | 0.011 |
| 14061000 | 1912-1958 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.031 | 0.031 | 0.017 | 0.023 | 0.297 | 0.017 |
| 14073000 | 1914-1980 | 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.134 | 0.134 | -0.024 | 0.066 | 0.128 | 0.125 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System -atic | Histor- ical | Histor- ical | User thresh- old | High outlier | User thresh- old | Low outlier | Zero peaks | Below thresh- old | Station | Bulletin 17B | General -ized | Weight- ed | Kendall's tau | Signifi- cance level |
| 14075000 | 1916-2004 | 81 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.464 | 0.464 | 0.199 | 0.345 | 0.078 | 0.302 |
| 14077500 | 1942-1954 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.272 | -0.272 | -0.081 | -0.124 | 0.297 | 0.158 |
| 14077800 | 1965-1979 | 15 | 70 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.991 | 0.642 | -0.015 | 0.306 | -0.200 | 0.299 |
| 14078000 | 1943-1985 | 43 | 70 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.121 | -0.037 | -0.081 | -0.055 | -0.001 | 0.992 |
| 14078200 | 1965-1982 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | -0.237 | -0.342 | -0.177 | -0.220 | -0.066 | 0.710 |
| 14078400 | 1966-1979 | 14 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | -1.374 | -0.576 | 0.053 | -0.085 | 0.253 | 0.208 |
| 14078500 | 1942-1970 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.578 | 0.578 | 0.058 | 0.162 | 0.182 | 0.411 |
| 14079500 | 1909-1993 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.209 | -0.209 | -0.096 | -0.137 | 0.333 | 0.013 |
| 14079800 | 1961-1998 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.060 | -0.060 | -0.081 | -0.076 | 0.231 | 0.272 |
| 14080500 | 1909-1960 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.150 | -0.150 | -0.071 | -0.099 | 0.065 | 0.643 |
| 14080600 | 1969-1979 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0.381 | -0.004 | -0.004 | 0.025 | -0.180 | 0.469 |
| 14081800 | 1956-1979 | 23 | 70 | 0 | 0 | 1 | 20 | 3 | 4 | 0 | -3.141 | 0.690 | 0.236 | 0.454 | -0.008 | 0.957 |
| 14083000 | 1918-1933 | 13 | 0 | 0 | 0 | 0 | 100 | 2 | 0 | 0 | -1.159 | 0.036 | 0.180 | 0.146 | -0.116 | 0.581 |
| 14083500 | 1918-1932 | 12 | 0 | 0 | 0 | 0 | 100 | 3 | 0 | 0 | -0.768 | -0.264 | 0.301 | 0.182 | 0.091 | 0.681 |
| 14088000 | 1915-1997 | 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.249 | 0.249 | 0.337 | 0.286 | 0.078 | 0.309 |
| 14090350 | 1984-2003 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.430 | 0.430 | 0.246 | 0.298 | 0.227 | 0.162 |
| 14090400 | 1983-2003 | 20 | 79 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.743 | 0.149 | 0.233 | 0.182 | 0.211 | 0.194 |
| 14091500 | 1913-2003 | 83 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.832 | 0.832 | 0.333 | 0.576 | 0.099 | 0.187 |
| 14092750 | 1983-2003 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.273 | 0.273 | 0.231 | 0.243 | 0.168 | 0.299 |
| 14092885 | 1976-1996 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.252 | 0.252 | 0.225 | 0.233 | 0.114 | 0.469 |
| 14093000 | 1912-2003 | 17 | 0 | 0 | 0 | 0 | 200 | 1 | 0 | 0 | -0.243 | -0.243 | 0.233 | 0.224 | 0.353 | 0.048 |
| 14093600 | 1966-1990 | 22 | 0 | 0 | 0 | 0 | 500 | 8 | 0 | 0 | -0.634 | 0.252 | 0.342 | 0.314 | 0.091 | 0.554 |
| 14093700 | 1960-1979 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0.884 | 0.595 | 0.425 | 0.471 | -0.065 | 0.689 |
| 14095500 | 1984-2003 | 19 | 79 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1.395 | 1.045 | 0.110 | 0.501 | 0.029 | 0.861 |
| 14096300 | 1984-2003 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.186 | 0.186 | 0.127 | 0.145 | 0.427 | 0.008 |
| 14096850 | 1984-2003 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.126 | 0.126 | 0.116 | 0.119 | -0.069 | 0.672 |
| 14097100 | 1973-2003 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.145 | 0.145 | 0.145 | 0.145 | -0.140 | 0.269 |
| 14097200 | 1970-1981 | 12 | 0 | 0 | 0 | 0 | 1,000 | 4 | 0 | 0 | -0.955 | 0.462 | 0.183 | 0.240 | -0.030 | 0.891 |

**Appendix B.** Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

| Station number | Period of record | Length of record | | High Peaks | | | Low Peaks | | | | Skew | | | | Trend analysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System-atic | Histor-ical | Histor-ical | User thresh-old | High outlier | User thresh-old | Low outlier | Zero peaks | Below thresh-old | Station | Bulletin 17B | General-ized | Weight-ed | Kendall's tau | Signifi-cance level |
| 14100800 | 1965-1979 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.563 | 0.563 | 0.164 | 0.248 | -0.156 | 0.458 |
| 14101500 | 1918-1990 | 73 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.226 | 0.061 | 0.137 | 0.091 | -0.015 | 0.853 |
| 14104100 | 1965-1981 | 15 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1.003 | 1.003 | 0.164 | 0.329 | 0.211 | 0.274 |
| 14104500 | 1947-1983 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.186 | 0.186 | 0.196 | 0.193 | 0.147 | 0.410 |
| 14107000 | 1945-1999 | 42 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.337 | 0.480 | 0.294 | 0.371 | 0.043 | 0.688 |
| 14110000 | 1910-1979 | 69 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.065 | 0.314 | 0.284 | 0.300 | 0.118 | 0.152 |
| 14111800 | 1961-1975 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.467 | 0.467 | 0.291 | 0.332 | 0.219 | 0.255 |
| 14112000 | 1911-1978 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.261 | 0.228 | 0.305 | 0.278 | 0.171 | 0.210 |
| 14112200 | 1960-1988 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.627 | 0.593 | 0.295 | 0.394 | 0.010 | 0.940 |
| 14112500 | 1945-1981 | 36 | 0 | 0 | 0 | 0 | 500 | 2 | 0 | 0 | -1.292 | 0.140 | 0.298 | 0.231 | 0.072 | 0.539 |
| 14113000 | 1910-1999 | 74 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.194 | 0.194 | 0.286 | 0.233 | 0.007 | 0.926 |
| 14113200 | 1964-1981 | 18 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1.295 | 0.353 | 0.153 | 0.207 | -0.007 | 0.970 |
| 14113400 | 1960-1971 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.761 | 0.761 | 0.151 | 0.580 | 0.333 | 0.131 |
| 14118500 | 1914-1999 | 67 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.655 | -0.080 | 0.160 | 0.022 | 0.092 | 0.272 |
| 14120000 | 1898-2003 | 44 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -0.747 | -0.179 | 0.159 | 0.002 | -0.099 | 0.342 |
| 14121000 | 1914-1964 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.145 | 0.145 | 0.159 | 0.152 | -0.082 | 0.393 |
| 14121300 | 1958-1978 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.058 | 0.058 | 0.206 | 0.159 | 0.257 | 0.103 |
| 14121500 | 1910-1969 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.089 | 0.089 | 0.196 | 0.173 | 0.121 | 0.583 |
| 14122000 | 1929-1967 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.309 | 0.309 | 0.202 | 0.226 | 0.128 | 0.542 |
| 14123000 | 1910-1962 | 26 | 41 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.807 | 0.689 | 0.197 | 0.385 | -0.142 | 0.310 |
| 14123500 | 1916-1999 | 78 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.146 | -0.146 | 0.193 | -0.009 | 0.077 | 0.316 |
| 14124500 | 1945-1961 | 17 | 0 | 0 | 0 | 0 | 2,000 | 1 | 0 | 0 | -0.452 | 0.048 | 0.161 | 0.129 | -0.281 | 0.115 |
| 14125000 | 1950-1963 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.641 | 0.641 | 0.161 | 0.265 | -0.287 | 0.152 |
| 14125500 | 1957-1977 | 21 | 0 | 0 | 0 | 0 | 2,100 | 4 | 0 | 0 | -0.281 | 0.402 | 0.159 | 0.230 | 0.205 | 0.193 |

# Appendix C

## Plotting Position

For this study, plotting positions for the observed peak discharges were determined following the recommendations of Cunnane (1978).

Many plotting position formulae are special cases of the general formula:

$$F_i = \frac{i - \alpha}{N + 1 - 2\alpha} \quad \text{(C-1)}$$

where

$i$ = the rank of the peak discharge, the largest peak being number 1,

$F_i$ = the probability associated with peak i,

$N$ = the number of peak discharges, and

$\alpha$ = a constant greater than 0 and less than 1.

The value of $\alpha$ determines how well the calculated plotting positions fit a given theoretical distribution. For example, the Hazen formula, $\alpha$ equal to 0.5, gives a good approximation of the extreme value distribution. Plotting positions for the Weibell distribution, recommended by Bulletin 17B, are obtained from Equation C-1 setting $\alpha$ equal to 0.0.

Cunnane (1978) gives recommendations for unbiased plotting positions for a variety of theoretical probability distributions. For the Pearson Type-III distribution Cunnane recommends $\alpha$ be between 0.44 and 0.375. For this analysis, $\alpha$ has been given a value of 0.4075, the average of 0.44 and 0.375.

## Reference

Cunnane, C., 1978, Unbiased plotting-positions – A review: Journal of Hydrology, v. 37, p. 205-222.

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 10329500 [a] | S | 400 | 1060 | 1810 | 3220 | 4710 | 6670 | 13700 |
| 10330300 [a] | S | 244 | 574 | 892 | 1420 | 1910 | 2500 | 4260 |
| 10352300 | S | 3.9 | 9.6 | 15.0 | 23.8 | 31.8 | 41.1 | 68.1 |
| | R | 19.5 | 37.4 | 51.8 | 72.0 | 87.6 | 103 | 141 |
| | W | 4.6 | 11.8 | 19.6 | 32.6 | 44.1 | 56.8 | 89.8 |
| 10352500 [a] | S | 473 | 1220 | 1930 | 3070 | 4080 | 5220 | 8390 |
| 10353000 [a] | S | 427 | 656 | 818 | 1030 | 1190 | 1360 | 1770 |
| 10353600 [a] | S | 31.7 | 75.2 | 125 | 224 | 335 | 489 | 1110 |
| 10353700 [a] | S | 87.0 | 206 | 321 | 512 | 689 | 898 | 1530 |
| 10353750 [a] | S | 13.7 | 30.6 | 46.1 | 70.6 | 92.5 | 117 | 189 |
| 10360900 [a] | S | 153 | 267 | 358 | 488 | 595 | 712 | 1020 |
| 10361700 [a] | S | 16.9 | 55.1 | 102 | 194 | 293 | 425 | 893 |
| 10366000 | S | 2230 | 4970 | 7250 | 10500 | 13100 | 15900 | 22600 |
| | R | 1560 | 3330 | 4950 | 7560 | 9940 | 12700 | 20500 |
| | W | 2190 | 4750 | 6790 | 9720 | 12200 | 14900 | 22000 |
| 10370000 | S | 457 | 735 | 961 | 1300 | 1600 | 1940 | 2910 |
| | R | 360 | 680 | 960 | 1390 | 1770 | 2180 | 3330 |
| | W | 450 | 727 | 961 | 1330 | 1650 | 2010 | 3040 |
| 10371000 | S | 487 | 1270 | 2130 | 3710 | 5320 | 7390 | 14500 |
| | R | 947 | 1990 | 2920 | 4410 | 5770 | 7310 | 11700 |
| | W | 506 | 1350 | 2260 | 3870 | 5440 | 7370 | 13600 |
| 10371500 | S | 1350 | 2770 | 4030 | 6030 | 7830 | 9910 | 15900 |
| | R | 1120 | 2300 | 3360 | 5070 | 6600 | 8350 | 13400 |
| | W | 1340 | 2730 | 3960 | 5890 | 7620 | 9620 | 15500 |
| 10378500 | S | 453 | 1210 | 2020 | 3460 | 4890 | 6650 | 12400 |
| | R | 1040 | 2130 | 3110 | 4660 | 6060 | 7660 | 12200 |
| | W | 463 | 1250 | 2100 | 3590 | 5040 | 6800 | 12300 |
| 10384000 | S | 933 | 1690 | 2340 | 3340 | 4220 | 5230 | 8180 |
| | R | 853 | 1660 | 2380 | 3510 | 4500 | 5620 | 8780 |
| | W | 930 | 1690 | 2340 | 3360 | 4260 | 5300 | 8280 |
| 10390400 | S | 54.7 | 108 | 156 | 232 | 300 | 379 | 612 |
| | R | 64.4 | 105 | 137 | 185 | 224 | 265 | 370 |
| | W | 55.3 | 108 | 152 | 217 | 273 | 335 | 513 |
| 10392300 | S | 72.8 | 104 | 125 | 150 | 169 | 188 | 231 |
| | R | 61.4 | 103 | 135 | 180 | 215 | 252 | 346 |
| | W | 71.9 | 104 | 126 | 156 | 179 | 202 | 258 |
| 10392800 | S | 49.7 | 72.2 | 86.9 | 105 | 118 | 131 | 161 |
| | R | 78.8 | 119 | 147 | 185 | 215 | 247 | 324 |
| | W | 50.8 | 74.8 | 91.6 | 113 | 130 | 146 | 185 |
| 10393500 | S | 1260 | 2190 | 2860 | 3730 | 4390 | 5060 | 6610 |
| | R | 964 | 1670 | 2180 | 2860 | 3370 | 3890 | 5080 |
| | W | 1250 | 2170 | 2830 | 3680 | 4320 | 4970 | 6480 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 10393900 | S | 6.1 | 14.4 | 21.7 | 32.4 | 41.4 | 51.1 | 75.8 |
| | R | 13.7 | 26.4 | 36.6 | 51.1 | 62.8 | 75.2 | 106 |
| | W | 6.7 | 16.0 | 24.4 | 37.0 | 47.4 | 58.5 | 86.5 |
| 10396000 | S | 1360 | 2210 | 2770 | 3470 | 3980 | 4470 | 5550 |
| | R | 391 | 813 | 1180 | 1720 | 2170 | 2650 | 3890 |
| | W | 1350 | 2180 | 2730 | 3410 | 3910 | 4390 | 5470 |
| 10397000 | S | 89.4 | 175 | 241 | 329 | 398 | 469 | 636 |
| | R | 56.1 | 107 | 149 | 210 | 258 | 307 | 423 |
| | W | 88.7 | 173 | 236 | 321 | 387 | 454 | 614 |
| 10402800 | S | 226 | 467 | 667 | 957 | 1200 | 1450 | 2110 |
| | R | 160 | 308 | 427 | 595 | 732 | 877 | 1240 |
| | W | 215 | 427 | 589 | 812 | 990 | 1180 | 1660 |
| 10403000 | S | 592 | 1040 | 1360 | 1770 | 2090 | 2400 | 3130 |
| | R | 489 | 867 | 1160 | 1560 | 1880 | 2210 | 3040 |
| | W | 587 | 1020 | 1340 | 1740 | 2050 | 2370 | 3110 |
| 10403500 | S | 569 | 865 | 1070 | 1320 | 1510 | 1700 | 2140 |
| | R | 525 | 945 | 1270 | 1720 | 2090 | 2460 | 3410 |
| | W | 565 | 874 | 1100 | 1400 | 1630 | 1870 | 2460 |
| 10406500 | S | 111 | 186 | 241 | 317 | 378 | 441 | 601 |
| | R | 246 | 527 | 767 | 1120 | 1410 | 1720 | 2530 |
| | W | 113 | 193 | 257 | 350 | 426 | 507 | 710 |
| 11339995 | S | 141 | 364 | 603 | 1040 | 1490 | 2060 | 3990 |
| | R | 161 | 284 | 388 | 543 | 675 | 818 | 1200 |
| | W | 143 | 346 | 532 | 818 | 1080 | 1380 | 2350 |
| 11340500 [b] | S | 238 | 303 | 344 | 392 | 426 | 458 | 531 |
| | R | 210 | 375 | 514 | 723 | 899 | 1090 | 1610 |
| | W | 233 | 323 | 403 | 529 | 633 | 740 | 988 |
| 11340950 | S | 255 | 413 | 530 | 690 | 818 | 952 | 1290 |
| | R | 197 | 351 | 480 | 673 | 837 | 1020 | 1490 |
| | W | 247 | 397 | 513 | 683 | 826 | 982 | 1390 |
| 11341000 | S | 183 | 341 | 466 | 644 | 791 | 948 | 1360 |
| | R | 201 | 358 | 490 | 688 | 855 | 1040 | 1520 |
| | W | 185 | 343 | 471 | 656 | 810 | 977 | 1410 |
| 11341050 | S | 200 | 378 | 525 | 745 | 932 | 1140 | 1710 |
| | R | 261 | 474 | 651 | 914 | 1140 | 1380 | 2020 |
| | W | 209 | 403 | 572 | 824 | 1040 | 1270 | 1880 |
| 11341100 | S | 51.0 | 77.9 | 97.3 | 123 | 144 | 165 | 218 |
| | R | 57.5 | 94.3 | 124 | 165 | 199 | 234 | 323 |
| | W | 51.4 | 80.0 | 102 | 133 | 159 | 185 | 248 |
| 11341200 | S | 91.8 | 145 | 184 | 236 | 277 | 320 | 427 |
| | R | 86.6 | 147 | 198 | 272 | 334 | 400 | 572 |
| | W | 91.4 | 145 | 187 | 246 | 295 | 346 | 475 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 11342945 [a] | S | 58.9 | 84.2 | 102 | 125 | 144 | 162 | 209 |
| 11342960 [a] | S | 71.1 | 92.8 | 107 | 123 | 135 | 147 | 174 |
| 11348080 [a] | S | 110 | 146 | 169 | 196 | 217 | 236 | 281 |
| 11348560 [a] | S | 20.6 | 32.0 | 40.6 | 52.6 | 62.3 | 72.7 | 99.8 |
| 11484000 | S | 2300 | 3410 | 4200 | 5270 | 6110 | 6990 | 9210 |
| | R | 707 | 1320 | 1830 | 2600 | 3260 | 3980 | 5960 |
| | W | 1870 | 2500 | 2930 | 3620 | 4260 | 5010 | 7090 |
| 11489350 [a] | S | 42.0 | 89.6 | 138 | 223 | 309 | 419 | 796 |
| 11489500 [a] | S | 232 | 460 | 677 | 1040 | 1400 | 1830 | 3240 |
| 11491800 | S | 15.2 | 26.4 | 34.3 | 44.5 | 52.1 | 59.7 | 77 |
| | R | 21.3 | 31.1 | 38.4 | 48.2 | 55.6 | 63.1 | 80.8 |
| | W | 15.5 | 26.9 | 35.0 | 45.4 | 53.1 | 60.7 | 78.2 |
| 11494800 | S | 27.1 | 34.9 | 40.4 | 48.0 | 54.0 | 60.3 | 76.6 |
| | R | 41.8 | 69.7 | 92.4 | 126 | 153 | 183 | 257 |
| | W | 27.9 | 38.4 | 48 | 62.6 | 74.5 | 86.6 | 115 |
| 11497500 | S | 1280 | 2400 | 3340 | 4740 | 5940 | 7260 | 10900 |
| | R | 1250 | 2430 | 3450 | 5040 | 6420 | 7980 | 12300 |
| | W | 1270 | 2410 | 3360 | 4800 | 6040 | 7430 | 11200 |
| 11497800 | S | 62.1 | 98.8 | 127 | 165 | 197 | 230 | 319 |
| | R | 40.6 | 67.3 | 89.1 | 121 | 147 | 176 | 247 |
| | W | 60.6 | 94.3 | 119 | 153 | 182 | 213 | 295 |
| 11501000 | S | 2060 | 4040 | 5780 | 8510 | 11000 | 13800 | 21900 |
| | R | 2280 | 4540 | 6540 | 9670 | 12400 | 15500 | 24500 |
| | W | 2070 | 4080 | 5860 | 8680 | 11200 | 14100 | 22400 |
| 11501300 | S | 23.1 | 37.8 | 49.6 | 66.9 | 81.7 | 98.2 | 144 |
| | R | 35.0 | 52.6 | 66.0 | 84.1 | 98.0 | 112 | 146 |
| | W | 23.7 | 39.4 | 52.3 | 70.9 | 86.1 | 102 | 145 |
| 11502500 | S | 2910 | 5080 | 6900 | 9660 | 12100 | 14900 | 22800 |
| | R | 2760 | 5470 | 7880 | 11600 | 14900 | 18700 | 29400 |
| | W | 2900 | 5110 | 7000 | 9940 | 12500 | 15500 | 23900 |
| 11504000 | S | 370 | 434 | 475 | 525 | 561 | 597 | 679 |
| | R | 377 | 551 | 670 | 822 | 938 | 1060 | 1350 |
| | W | 370 | 439 | 486 | 546 | 591 | 634 | 734 |
| 11505550 | S | 84.7 | 127 | 153 | 184 | 206 | 226 | 270 |
| | R | 55.0 | 83.7 | 103 | 129 | 148 | 167 | 215 |
| | W | 82.8 | 121 | 145 | 173 | 193 | 212 | 256 |
| 11516900 [a] | S | 178 | 377 | 578 | 940 | 1310 | 1780 | 3420 |
| 13172666 [a] | S | 5.3 | 9.0 | 11.5 | 14.6 | 16.9 | 19.1 | 24 |
| 13172668 [a] | S | 4.3 | 6.6 | 8.1 | 9.9 | 11.1 | 12.2 | 14.5 |
| 13172680 [a] | S | 176 | 279 | 345 | 424 | 479 | 531 | 642 |
| 13172720 [a] | S | 87.6 | 218 | 336 | 512 | 661 | 821 | 1230 |
| 13172735 [a] | S | 66.6 | 192 | 316 | 514 | 688 | 882 | 1400 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 13172740 [a] | S | 341 | 914 | 1450 | 2270 | 2980 | 3750 | 5750 |
| 13172800 [a] | S | 10.6 | 33.2 | 56.8 | 96.4 | 133 | 174 | 289 |
| 13172900 | S | 743 | 1870 | 2920 | 4560 | 6010 | 7620 | 12000 |
| | R | 252 | 544 | 792 | 1160 | 1460 | 1780 | 2630 |
| | W | 685 | 1620 | 2350 | 3360 | 4180 | 5070 | 7510 |
| 13178000 [a] | S | 1960 | 2950 | 3630 | 4480 | 5120 | 5760 | 7250 |
| 13182100 | S | 25.0 | 36.2 | 43.0 | 50.7 | 55.8 | 60.6 | 70.4 |
| | R | 15.8 | 32.1 | 45.2 | 63.2 | 77.2 | 91.7 | 127 |
| | W | 24.7 | 36.0 | 43.1 | 51.8 | 58.1 | 64.1 | 77 |
| 13207000 [a] | S | 68.3 | 197 | 334 | 578 | 816 | 1100 | 2000 |
| 13207500 [a] | S | 173 | 335 | 460 | 634 | 771 | 914 | 1260 |
| 13213800 | S | 357 | 857 | 1300 | 1960 | 2510 | 3110 | 4660 |
| | R | 437 | 711 | 912 | 1180 | 1380 | 1590 | 2100 |
| | W | 362 | 840 | 1230 | 1770 | 2190 | 2640 | 3750 |
| 13213900 | S | 32.1 | 51.5 | 65.2 | 82.9 | 96.4 | 110 | 143 |
| | R | 40.0 | 67.0 | 86.6 | 112 | 132 | 152 | 203 |
| | W | 32.9 | 53.9 | 69.7 | 90.9 | 107 | 124 | 164 |
| 13214000 | S | 2070 | 3940 | 5410 | 7500 | 9190 | 11000 | 15500 |
| | R | 3840 | 6090 | 7750 | 9950 | 11600 | 13400 | 17600 |
| | W | 2090 | 4000 | 5520 | 7660 | 9390 | 11200 | 15700 |
| 13216500 | S | 938 | 1650 | 2160 | 2850 | 3370 | 3910 | 5170 |
| | R | 1780 | 2860 | 3640 | 4680 | 5490 | 6310 | 8330 |
| | W | 952 | 1690 | 2230 | 2970 | 3540 | 4110 | 5480 |
| 13226500 | S | 1830 | 4670 | 7280 | 11300 | 14800 | 18500 | 28400 |
| | R | 2490 | 3980 | 5070 | 6520 | 7630 | 8770 | 11600 |
| | W | 1860 | 4590 | 6910 | 10200 | 12700 | 15500 | 22400 |
| 13228000 [b] | S | 6970 | 13200 | 18500 | 26600 | 33600 | 41600 | 63900 |
| | R | 11100 | 17500 | 22100 | 28300 | 33100 | 38100 | 50000 |
| | W | 7520 | 14200 | 19700 | 27300 | 33400 | 39800 | 56200 |
| 13228300 | S | 97.2 | 182 | 253 | 364 | 460 | 570 | 884 |
| | R | 89.6 | 149 | 192 | 248 | 291 | 336 | 446 |
| | W | 95.7 | 171 | 227 | 304 | 364 | 428 | 597 |
| 13229400 | S | 16.8 | 28.5 | 36.9 | 47.8 | 56 | 64.2 | 83.6 |
| | R | 34.7 | 58.1 | 75.2 | 97.5 | 115 | 132 | 176 |
| | W | 19.2 | 35.3 | 48.6 | 66.9 | 80.8 | 94.9 | 128 |
| 13248900 [a] | S | 75.6 | 141 | 193 | 265 | 322 | 383 | 537 |
| 13250600 [a] | S | 973 | 1510 | 1890 | 2380 | 2750 | 3130 | 4050 |
| 13250650 [a] | S | 132 | 270 | 388 | 566 | 717 | 885 | 1340 |
| 13251300 [a] | S | 38.7 | 58.4 | 72.8 | 92.5 | 108 | 125 | 167 |
| 13251500 [a] | S | 483 | 719 | 886 | 1110 | 1280 | 1460 | 1900 |
| 13252500 [a] | S | 54.1 | 64.6 | 71.8 | 80.9 | 87.9 | 95.1 | 113 |
| 13253500 [a] | S | 1000 | 1570 | 2000 | 2590 | 3070 | 3580 | 4900 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 13260000 [a] | S | 252 | 419 | 567 | 804 | 1030 | 1290 | 2130 |
| 13261000 [a] | S | 741 | 1110 | 1380 | 1750 | 2040 | 2350 | 3140 |
| 13267000 [a] | S | 430 | 680 | 873 | 1150 | 1380 | 1620 | 2290 |
| 13267100 [a] | S | 66.2 | 105 | 135 | 178 | 213 | 251 | 351 |
| 13269200 | S | 18.8 | 38.9 | 56.3 | 82.7 | 106 | 131 | 202 |
| | R | 20.0 | 33.8 | 43.8 | 56.8 | 66.8 | 77.1 | 103 |
| | W | 19.1 | 37.1 | 50.7 | 68.5 | 82.4 | 96.9 | 134 |
| 13269300 | S | 649 | 995 | 1180 | 1370 | 1480 | 1570 | 1720 |
| | R | 760 | 1230 | 1570 | 2030 | 2370 | 2730 | 3610 |
| | W | 654 | 1010 | 1230 | 1470 | 1630 | 1780 | 2070 |
| 13272300 | S | 12.9 | 25.0 | 35.2 | 50.2 | 63.1 | 77.3 | 116 |
| | R | 12.4 | 21.1 | 27.4 | 35.6 | 41.9 | 48.4 | 64.5 |
| | W | 12.9 | 24.4 | 33.5 | 46 | 56.1 | 66.8 | 95 |
| 13274600 | S | 18.5 | 49.5 | 81.8 | 138 | 192 | 258 | 462 |
| | R | 35.9 | 60.2 | 77.9 | 101 | 119 | 137 | 182 |
| | W | 21.8 | 53.4 | 79.9 | 116 | 144 | 173 | 250 |
| 13275105 | S | 527 | 826 | 1020 | 1270 | 1450 | 1620 | 2010 |
| | R | 663 | 1070 | 1370 | 1770 | 2080 | 2390 | 3160 |
| | W | 532 | 844 | 1060 | 1340 | 1550 | 1750 | 2220 |
| 13275200 | S | 276 | 482 | 636 | 846 | 1010 | 1180 | 1610 |
| | R | 309 | 505 | 648 | 836 | 981 | 1130 | 1500 |
| | W | 277 | 483 | 637 | 845 | 1010 | 1180 | 1590 |
| 13275500 | S | 725 | 1050 | 1250 | 1480 | 1640 | 1790 | 2120 |
| | R | 1260 | 2030 | 2590 | 3330 | 3900 | 4490 | 5920 |
| | W | 733 | 1070 | 1290 | 1560 | 1760 | 1950 | 2350 |
| 13281200 | S | 332 | 507 | 624 | 771 | 879 | 986 | 1230 |
| | R | 220 | 361 | 463 | 598 | 702 | 809 | 1070 |
| | W | 328 | 498 | 610 | 751 | 856 | 961 | 1210 |
| 13282400 | S | 248 | 336 | 393 | 462 | 512 | 560 | 670 |
| | R | 290 | 474 | 608 | 785 | 922 | 1060 | 1410 |
| | W | 249 | 345 | 411 | 498 | 563 | 627 | 776 |
| 13283600 | S | 304 | 500 | 646 | 845 | 1000 | 1170 | 1590 |
| | R | 289 | 472 | 606 | 783 | 918 | 1060 | 1400 |
| | W | 304 | 499 | 642 | 838 | 992 | 1150 | 1560 |
| 13285900 | S | 204 | 355 | 468 | 625 | 750 | 880 | 1210 |
| | R | 265 | 433 | 556 | 718 | 843 | 971 | 1290 |
| | W | 207 | 362 | 480 | 641 | 769 | 900 | 1230 |
| 13286300 | S | 55.8 | 115 | 165 | 242 | 307 | 381 | 581 |
| | R | 20.7 | 35.0 | 45.4 | 58.9 | 69.3 | 79.9 | 106 |
| | W | 46.9 | 81.9 | 103 | 128 | 148 | 170 | 228 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 13287200 | S | 592 | 922 | 1170 | 1520 | 1810 | 2120 | 2940 |
| | R | 173 | 285 | 367 | 474 | 557 | 642 | 851 |
| | W | 573 | 870 | 1080 | 1360 | 1590 | 1830 | 2480 |
| 13288200 | S | 2020 | 2690 | 3150 | 3750 | 4200 | 4660 | 5800 |
| | R | 987 | 1590 | 2030 | 2620 | 3070 | 3530 | 4670 |
| | W | 2000 | 2660 | 3100 | 3680 | 4120 | 4570 | 5700 |
| 13289100 | S | 91.8 | 130 | 160 | 202 | 238 | 278 | 387 |
| | R | 89.4 | 148 | 191 | 247 | 291 | 335 | 445 |
| | W | 91.5 | 133 | 166 | 214 | 253 | 295 | 407 |
| 13289600 [a] | S | 87 | 165 | 232 | 338 | 432 | 540 | 857 |
| 13289960 [a] | S | 885 | 1590 | 2180 | 3070 | 3850 | 4720 | 7220 |
| 13290150 | S | 67.6 | 134 | 194 | 289 | 376 | 477 | 781 |
| | R | 48.9 | 81.6 | 105 | 137 | 161 | 185 | 246 |
| | W | 65.9 | 125 | 172 | 240 | 296 | 358 | 531 |
| 13290190 | S | 2550 | 4130 | 5330 | 7020 | 8390 | 9850 | 13700 |
| | R | 1610 | 2570 | 3280 | 4220 | 4950 | 5690 | 7510 |
| | W | 2520 | 4030 | 5150 | 6670 | 7890 | 9190 | 12600 |
| 13291200 | S | 70.6 | 102 | 125 | 155 | 179 | 204 | 267 |
| | R | 63.5 | 106 | 137 | 177 | 208 | 240 | 318 |
| | W | 70 | 103 | 127 | 160 | 186 | 214 | 283 |
| 13291400 | S | 5.2 | 9.8 | 13.8 | 20 | 25.5 | 31.7 | 50.1 |
| | R | 33.3 | 55.8 | 72.2 | 93.7 | 110 | 127 | 169 |
| | W | 7.6 | 17.2 | 27.4 | 43.1 | 56.1 | 69.6 | 104 |
| 13292000 | S | 2630 | 4220 | 5530 | 7530 | 9280 | 11300 | 17100 |
| | R | 2800 | 4460 | 5680 | 7300 | 8550 | 9820 | 13000 |
| | W | 2630 | 4220 | 5540 | 7510 | 9230 | 11200 | 16800 |
| 13315500 [a] | S | 199 | 280 | 334 | 404 | 456 | 508 | 633 |
| 13316500 [a] | S | 4860 | 6650 | 7840 | 9340 | 10500 | 11600 | 14200 |
| 13316800 [a] | S | 136 | 218 | 283 | 378 | 460 | 551 | 807 |
| 13317200 [a] | S | 95.7 | 207 | 313 | 490 | 657 | 859 | 1490 |
| 13318100 | S | 13.2 | 21 | 27.2 | 36.1 | 43.6 | 51.8 | 74.5 |
| | R | 33.7 | 56.5 | 73.1 | 94.8 | 111 | 129 | 171 |
| | W | 14.1 | 23.9 | 32.5 | 45.4 | 56.2 | 67.6 | 97.2 |
| 13318500 | S | 2190 | 3010 | 3590 | 4360 | 4950 | 5570 | 7130 |
| | R | 2360 | 3770 | 4790 | 6160 | 7220 | 8300 | 10900 |
| | W | 2190 | 3080 | 3740 | 4640 | 5360 | 6110 | 7940 |
| 13318800 | S | 2340 | 3200 | 3790 | 4560 | 5150 | 5750 | 7230 |
| | R | 2530 | 4040 | 5140 | 6610 | 7740 | 8890 | 11700 |
| | W | 2360 | 3290 | 3990 | 4950 | 5700 | 6480 | 8360 |
| 13319000 | S | 3230 | 4870 | 6080 | 7770 | 9130 | 10600 | 14400 |
| | R | 3010 | 4800 | 6110 | 7850 | 9190 | 10600 | 13900 |
| | W | 3230 | 4870 | 6090 | 7770 | 9130 | 10600 | 14300 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 13320000 | S | 751 | 1010 | 1170 | 1360 | 1500 | 1630 | 1930 |
| | R | 721 | 1170 | 1490 | 1920 | 2260 | 2600 | 3430 |
| | W | 750 | 1010 | 1180 | 1380 | 1530 | 1670 | 2000 |
| 13320400 | S | 115 | 182 | 227 | 284 | 326 | 368 | 463 |
| | R | 175 | 289 | 371 | 480 | 563 | 649 | 860 |
| | W | 117 | 187 | 238 | 304 | 353 | 403 | 517 |
| 13321300 | S | 95.2 | 140 | 171 | 210 | 240 | 270 | 340 |
| | R | 175 | 288 | 371 | 479 | 562 | 648 | 859 |
| | W | 101 | 158 | 204 | 269 | 319 | 369 | 488 |
| 13322300 | S | 36.2 | 47.1 | 54.4 | 63.8 | 71 | 78.3 | 96 |
| | R | 26.8 | 45.1 | 58.4 | 75.8 | 89.2 | 103 | 137 |
| | W | 35.7 | 46.9 | 54.9 | 65.6 | 74 | 82.7 | 104 |
| 13323500 | S | 3340 | 4530 | 5310 | 6280 | 6990 | 7700 | 9350 |
| | R | 4740 | 7520 | 9550 | 12300 | 14300 | 16500 | 21700 |
| | W | 3380 | 4700 | 5640 | 6900 | 7860 | 8820 | 11000 |
| 13323600 | S | 422 | 588 | 700 | 845 | 955 | 1070 | 1340 |
| | R | 221 | 362 | 465 | 601 | 705 | 812 | 1080 |
| | W | 406 | 559 | 660 | 791 | 893 | 999 | 1260 |
| 13323700 | S | 165 | 391 | 616 | 998 | 1360 | 1810 | 3190 |
| | R | 171 | 282 | 362 | 468 | 549 | 633 | 839 |
| | W | 165 | 378 | 570 | 862 | 1120 | 1400 | 2240 |
| 13324150 | S | 22.9 | 39.5 | 51.4 | 67.1 | 78.9 | 90.9 | 119 |
| | R | 22.4 | 37.8 | 49 | 63.6 | 74.8 | 86.3 | 115 |
| | W | 22.9 | 39.2 | 50.9 | 66 | 77.5 | 89.2 | 117 |
| 13324300 | S | 753 | 1010 | 1190 | 1440 | 1640 | 1850 | 2380 |
| | R | 579 | 940 | 1200 | 1550 | 1820 | 2100 | 2770 |
| | W | 747 | 1010 | 1190 | 1450 | 1660 | 1880 | 2440 |
| 13325000 | S | 103 | 152 | 188 | 238 | 279 | 322 | 437 |
| | R | 126 | 208 | 267 | 346 | 406 | 468 | 621 |
| | W | 103 | 153 | 189 | 241 | 282 | 327 | 443 |
| 13325500 | S | 822 | 1180 | 1430 | 1760 | 2020 | 2280 | 2920 |
| | R | 378 | 616 | 790 | 1020 | 1200 | 1380 | 1820 |
| | W | 805 | 1140 | 1370 | 1670 | 1900 | 2140 | 2730 |
| 13329500 | S | 537 | 734 | 863 | 1020 | 1140 | 1260 | 1530 |
| | R | 281 | 460 | 591 | 763 | 895 | 1030 | 1370 |
| | W | 535 | 730 | 857 | 1020 | 1130 | 1250 | 1530 |
| 13329700 | S | 8.3 | 13.5 | 17.4 | 22.8 | 27.2 | 31.9 | 44.1 |
| | R | 7.4 | 12.7 | 16.5 | 21.5 | 25.3 | 29.2 | 39 |
| | W | 8.2 | 13.2 | 17 | 22.2 | 26.3 | 30.5 | 41.3 |
| 13329750 | S | 28 | 58.3 | 85.5 | 129 | 168 | 213 | 345 |
| | R | 64.9 | 108 | 139 | 180 | 212 | 245 | 325 |
| | W | 33.5 | 71.8 | 106 | 153 | 191 | 231 | 332 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 13330000 | S | 1560 | 1930 | 2150 | 2420 | 2600 | 2780 | 3180 |
| | R | 547 | 889 | 1140 | 1470 | 1720 | 1980 | 2620 |
| | W | 1560 | 1910 | 2130 | 2390 | 2570 | 2750 | 3160 |
| 13330500 | S | 929 | 1240 | 1440 | 1700 | 1890 | 2090 | 2540 |
| | R | 521 | 847 | 1080 | 1400 | 1640 | 1890 | 2500 |
| | W | 925 | 1230 | 1430 | 1690 | 1880 | 2080 | 2540 |
| 13331500 | S | 3120 | 4080 | 4700 | 5470 | 6040 | 6600 | 7900 |
| | R | 1360 | 2190 | 2790 | 3590 | 4210 | 4840 | 6390 |
| | W | 3080 | 4010 | 4610 | 5350 | 5900 | 6450 | 7770 |
| 13332500 | S | 9640 | 13600 | 16400 | 20100 | 22900 | 25800 | 33000 |
| | R | 8230 | 12900 | 16400 | 21000 | 24600 | 28300 | 37200 |
| | W | 9620 | 13600 | 16400 | 20100 | 23000 | 26000 | 33300 |
| 13333000 | S | 14700 | 22000 | 27400 | 34700 | 40700 | 47000 | 63500 |
| | R | 9890 | 15500 | 19700 | 25200 | 29500 | 33900 | 44500 |
| | W | 14700 | 21800 | 27000 | 34100 | 39800 | 45900 | 61700 |
| 13333050 | S | 11.7 | 20.3 | 27.7 | 39 | 49.1 | 60.7 | 94.7 |
| | R | 12.8 | 21.7 | 28.2 | 36.6 | 43.1 | 49.8 | 66.3 |
| | W | 11.8 | 20.5 | 27.8 | 38.4 | 47.3 | 57.1 | 84.2 |
| 13333100 | S | 39.3 | 70.5 | 97.2 | 139 | 176 | 218 | 343 |
| | R | 79.8 | 133 | 171 | 221 | 260 | 300 | 398 |
| | W | 43 | 80.8 | 114 | 164 | 206 | 250 | 367 |
| 13334700 [a] | S | 398 | 909 | 1470 | 2550 | 3710 | 5280 | 11300 |
| 13335050 [a] | S | 801 | 2100 | 3630 | 6700 | 10100 | 14800 | 33400 |
| 13341100 [a] | S | 49.3 | 109 | 160 | 235 | 298 | 366 | 540 |
| 13342450 [a] | S | 817 | 1740 | 2630 | 4150 | 5620 | 7420 | 13200 |
| 14010000 | S | 777 | 1190 | 1520 | 2010 | 2440 | 2920 | 4310 |
| | R | 883 | 1310 | 1630 | 2080 | 2430 | 2790 | 3680 |
| | W | 778 | 1190 | 1520 | 2020 | 2440 | 2910 | 4240 |
| 14010800 | S | 465 | 739 | 956 | 1270 | 1540 | 1840 | 2670 |
| | R | 594 | 926 | 1180 | 1540 | 1820 | 2110 | 2840 |
| | W | 470 | 757 | 994 | 1340 | 1620 | 1920 | 2720 |
| 14011000 | S | 482 | 806 | 1080 | 1520 | 1920 | 2390 | 3800 |
| | R | 606 | 957 | 1240 | 1650 | 1980 | 2330 | 3230 |
| | W | 485 | 816 | 1100 | 1550 | 1930 | 2370 | 3660 |
| 14011800 | S | 365 | 613 | 821 | 1140 | 1420 | 1740 | 2670 |
| | R | 237 | 453 | 642 | 931 | 1180 | 1450 | 2210 |
| | W | 348 | 568 | 747 | 1030 | 1280 | 1570 | 2410 |
| 14013000 [a] | S | 868 | 1520 | 2090 | 3030 | 3890 | 4930 | 8180 |
| 14013500 [a] | S | 320 | 526 | 699 | 966 | 1200 | 1480 | 2280 |
| 14015900 [a] | S | 22.5 | 75.8 | 145 | 294 | 467 | 710 | 1680 |
| 14016000 [a] | S | 549 | 1140 | 1660 | 2420 | 3080 | 3810 | 5770 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 14016080 | S | 30.7 | 93.8 | 169 | 317 | 476 | 688 | 1450 |
| | R | 21.5 | 58.8 | 97.5 | 164 | 228 | 305 | 547 |
| | W | 28.6 | 77.9 | 126 | 208 | 290 | 394 | 745 |
| 14016200 | S | 669 | 1450 | 2040 | 2790 | 3350 | 3880 | 5030 |
| | R | 178 | 345 | 491 | 716 | 909 | 1120 | 1720 |
| | W | 615 | 1150 | 1400 | 1710 | 1990 | 2320 | 3240 |
| 14016500 [a] | S | 815 | 1300 | 1670 | 2220 | 2680 | 3180 | 4570 |
| 14016600 [a] | S | 79.6 | 179 | 258 | 364 | 445 | 525 | 706 |
| 14016650 [a] | S | 9.1 | 47.1 | 116 | 311 | 600 | 1090 | 3810 |
| 14017000 [a] | S | 2570 | 4220 | 5510 | 7370 | 8930 | 10600 | 15200 |
| 14017040 [a] | S | 37.1 | 107 | 174 | 277 | 363 | 456 | 690 |
| 14017070 [a] | S | 55.1 | 190 | 381 | 827 | 1390 | 2260 | 6230 |
| 14017200 [a] | S | 50.5 | 179 | 372 | 854 | 1500 | 2550 | 7910 |
| 14017500 [a] | S | 3660 | 6580 | 9130 | 13100 | 16800 | 21000 | 33800 |
| 14018500 [a] | S | 5990 | 11200 | 15800 | 23200 | 30000 | 37900 | 62300 |
| 14019400 | S | 57 | 76 | 89.6 | 108 | 123 | 138 | 178 |
| | R | 18.1 | 36 | 51.5 | 75.4 | 96 | 119 | 183 |
| | W | 52.1 | 65.7 | 75.7 | 93.4 | 110 | 129 | 180 |
| 14020000 | S | 2000 | 3030 | 3830 | 4980 | 5950 | 7010 | 9920 |
| | R | 1370 | 2170 | 2810 | 3710 | 4420 | 5170 | 7080 |
| | W | 1990 | 3000 | 3750 | 4840 | 5740 | 6750 | 9520 |
| 14020300 | S | 2300 | 3710 | 4800 | 6380 | 7690 | 9120 | 13000 |
| | R | 1600 | 2740 | 3660 | 4980 | 6050 | 7180 | 10100 |
| | W | 2260 | 3590 | 4580 | 5990 | 7170 | 8480 | 12100 |
| 14020740 | S | 68.2 | 96.7 | 117 | 144 | 166 | 188 | 246 |
| | R | 54.8 | 102 | 143 | 208 | 264 | 326 | 497 |
| | W | 66.1 | 98.2 | 129 | 179 | 221 | 267 | 382 |
| 14020800 | S | 57.2 | 96.1 | 127 | 174 | 213 | 258 | 381 |
| | R | 42.6 | 79.6 | 116 | 176 | 230 | 292 | 474 |
| | W | 55.9 | 92.6 | 124 | 175 | 221 | 273 | 420 |
| 14020900 | S | 377 | 566 | 712 | 921 | 1100 | 1290 | 1820 |
| | R | 165 | 327 | 475 | 708 | 913 | 1140 | 1800 |
| | W | 344 | 489 | 606 | 805 | 990 | 1200 | 1800 |
| 14021000 | S | 5270 | 8580 | 11200 | 14900 | 18100 | 21500 | 30800 |
| | R | 3790 | 6950 | 9600 | 13500 | 16700 | 20100 | 29400 |
| | W | 5230 | 8480 | 11000 | 14700 | 17800 | 21200 | 30600 |
| 14021980 | S | 130 | 268 | 399 | 619 | 831 | 1090 | 1910 |
| | R | 142 | 303 | 472 | 769 | 1050 | 1380 | 2420 |
| | W | 133 | 284 | 443 | 723 | 989 | 1310 | 2280 |
| 14022200 | S | 657 | 1010 | 1280 | 1650 | 1950 | 2270 | 3120 |
| | R | 489 | 893 | 1220 | 1670 | 2030 | 2410 | 3400 |
| | W | 649 | 997 | 1260 | 1650 | 1970 | 2310 | 3200 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 14022500 | S | 1370 | 2450 | 3380 | 4820 | 6100 | 7580 | 11900 |
| | R | 1010 | 1920 | 2710 | 3890 | 4880 | 5960 | 8920 |
| | W | 1360 | 2420 | 3310 | 4680 | 5880 | 7270 | 11400 |
| 14025000 | S | 564 | 1040 | 1430 | 2020 | 2520 | 3090 | 4660 |
| | R | 866 | 1780 | 2650 | 4060 | 5300 | 6710 | 10800 |
| | W | 573 | 1090 | 1570 | 2360 | 3050 | 3800 | 5810 |
| 14026000 [b] | S | 6360 | 10100 | 12900 | 17100 | 20500 | 24300 | 34400 |
| | R | 4770 | 9040 | 12800 | 18500 | 23300 | 28600 | 43300 |
| | W | 6240 | 9880 | 12900 | 17600 | 21600 | 26100 | 37900 |
| 14032000 | S | 329 | 709 | 1110 | 1860 | 2640 | 3680 | 7540 |
| | R | 727 | 1570 | 2410 | 3760 | 4970 | 6360 | 10500 |
| | W | 338 | 760 | 1240 | 2150 | 3070 | 4220 | 8170 |
| 14034250 [a] | S | 7.4 | 15.7 | 23.8 | 37.8 | 51.5 | 68.5 | 125 |
| 14034325 [a] | S | 204 | 448 | 698 | 1150 | 1610 | 2190 | 4230 |
| 14034370 | S | 8.1 | 15.6 | 22.1 | 32.3 | 41.4 | 51.9 | 82.4 |
| | R | 20.3 | 40.6 | 57.3 | 81.5 | 101 | 123 | 180 |
| | W | 8.6 | 18 | 27.7 | 43.7 | 57.2 | 71.8 | 110 |
| 14034470 | S | 166 | 299 | 412 | 584 | 736 | 909 | 1410 |
| | R | 279 | 560 | 824 | 1240 | 1600 | 2000 | 3140 |
| | W | 174 | 340 | 512 | 800 | 1050 | 1320 | 2050 |
| 14034480 | S | 22.3 | 96.3 | 218 | 544 | 1000 | 1770 | 5830 |
| | R | 82.5 | 195 | 314 | 519 | 711 | 940 | 1650 |
| | W | 26 | 116 | 252 | 531 | 835 | 1250 | 2930 |
| 14034500 [b] | S | 200 | 473 | 795 | 1460 | 2240 | 3350 | 8120 |
| | R | 331 | 690 | 1040 | 1590 | 2070 | 2630 | 4230 |
| | W | 204 | 495 | 837 | 1500 | 2190 | 3100 | 6610 |
| 14034800 | S | 272 | 521 | 746 | 1110 | 1440 | 1830 | 3030 |
| | R | 293 | 632 | 967 | 1510 | 1990 | 2540 | 4150 |
| | W | 273 | 534 | 787 | 1210 | 1600 | 2050 | 3360 |
| 14036000 | S | 1080 | 4520 | 9170 | 18900 | 29700 | 44100 | 94900 |
| | R | 1690 | 4280 | 7020 | 11700 | 16100 | 21400 | 37900 |
| | W | 1150 | 4440 | 8070 | 14300 | 20300 | 27700 | 53000 |
| 14036800 | S | 72.7 | 115 | 144 | 180 | 207 | 233 | 294 |
| | R | 195 | 255 | 293 | 340 | 375 | 409 | 489 |
| | W | 76.1 | 122 | 154 | 196 | 227 | 257 | 326 |
| 14037500 | S | 94.7 | 147 | 185 | 234 | 272 | 311 | 407 |
| | R | 79.8 | 106 | 121 | 141 | 155 | 169 | 200 |
| | W | 94.6 | 147 | 183 | 231 | 267 | 305 | 395 |
| 14038500 | S | 609 | 985 | 1270 | 1670 | 2000 | 2360 | 3280 |
| | R | 884 | 1270 | 1520 | 1840 | 2070 | 2290 | 2810 |
| | W | 616 | 997 | 1290 | 1690 | 2010 | 2350 | 3210 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 14038530 | S | 1340 | 2550 | 3540 | 4950 | 6120 | 7390 | 10700 |
| | R | 1310 | 1950 | 2390 | 2950 | 3370 | 3790 | 4790 |
| | W | 1340 | 2520 | 3430 | 4680 | 5680 | 6730 | 9370 |
| 14038550 | S | 176 | 241 | 275 | 310 | 332 | 350 | 384 |
| | R | 80.4 | 129 | 163 | 206 | 238 | 270 | 342 |
| | W | 170 | 231 | 262 | 295 | 316 | 336 | 376 |
| 14038600 | S | 18 | 27.8 | 34.7 | 43.8 | 50.8 | 57.9 | 75.3 |
| | R | 16.3 | 30.2 | 41.3 | 57.3 | 70.4 | 84.5 | 121 |
| | W | 17.8 | 28.1 | 35.9 | 46.7 | 55.5 | 64.8 | 88 |
| 14038602 | S | 287 | 468 | 596 | 763 | 890 | 1020 | 1320 |
| | R | 217 | 365 | 470 | 608 | 712 | 817 | 1060 |
| | W | 283 | 459 | 582 | 740 | 859 | 980 | 1270 |
| 14038750 | S | 11.8 | 18.7 | 23.6 | 30 | 35 | 40.1 | 52.5 |
| | R | 8.7 | 14.8 | 19.5 | 26.1 | 31.5 | 37.1 | 51.7 |
| | W | 11.5 | 18.1 | 22.7 | 29 | 34 | 39.2 | 52.2 |
| 14038900 | S | 67.1 | 124 | 168 | 230 | 279 | 331 | 464 |
| | R | 82.3 | 148 | 201 | 278 | 342 | 412 | 600 |
| | W | 68.3 | 127 | 173 | 239 | 293 | 351 | 499 |
| 14039200 | S | 54.4 | 75.9 | 88.7 | 103 | 113 | 123 | 142 |
| | R | 30.1 | 52 | 68.1 | 89.6 | 106 | 123 | 163 |
| | W | 52.6 | 73.4 | 85.9 | 101 | 112 | 123 | 147 |
| 14040500 | S | 2760 | 4630 | 6040 | 7960 | 9480 | 11100 | 15100 |
| | R | 2970 | 4790 | 6140 | 7960 | 9390 | 10900 | 14500 |
| | W | 2760 | 4640 | 6040 | 7960 | 9470 | 11100 | 15000 |
| 14040600 | S | 144 | 250 | 335 | 457 | 560 | 673 | 978 |
| | R | 249 | 369 | 457 | 578 | 674 | 775 | 1030 |
| | W | 147 | 255 | 342 | 467 | 571 | 684 | 985 |
| 14040700 | S | 33.5 | 74.7 | 114 | 177 | 237 | 307 | 518 |
| | R | 47.8 | 86.4 | 117 | 161 | 199 | 240 | 352 |
| | W | 34.9 | 76.6 | 114 | 173 | 224 | 282 | 448 |
| 14040900 | S | 33.9 | 44.1 | 50.8 | 59.3 | 65.7 | 72.1 | 87.3 |
| | R | 49.9 | 73.6 | 90.5 | 113 | 131 | 150 | 196 |
| | W | 34.8 | 46.5 | 55.1 | 66.8 | 76 | 85.4 | 108 |
| 14041000 | S | 699 | 911 | 1040 | 1210 | 1320 | 1440 | 1690 |
| | R | 869 | 1220 | 1460 | 1780 | 2020 | 2270 | 2880 |
| | W | 710 | 939 | 1100 | 1300 | 1450 | 1600 | 1960 |
| 14041500 | S | 3060 | 4490 | 5440 | 6630 | 7500 | 8360 | 10300 |
| | R | 2720 | 3770 | 4470 | 5390 | 6090 | 6800 | 8510 |
| | W | 3050 | 4460 | 5380 | 6530 | 7370 | 8200 | 10100 |
| 14041900 | S | 28.3 | 45.8 | 59.4 | 78.9 | 95.1 | 113 | 160 |
| | R | 23.9 | 37.8 | 48.2 | 62.6 | 74 | 86.2 | 117 |
| | W | 27.9 | 44.7 | 57.3 | 74.9 | 89.1 | 104 | 145 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 14042000 | S | 638 | 1010 | 1310 | 1740 | 2100 | 2510 | 3630 |
| | R | 449 | 686 | 864 | 1110 | 1310 | 1510 | 2050 |
| | W | 620 | 965 | 1220 | 1580 | 1870 | 2190 | 3060 |
| 14042500 | S | 1040 | 1600 | 2030 | 2630 | 3140 | 3680 | 5150 |
| | R | 721 | 1080 | 1340 | 1690 | 1970 | 2260 | 3010 |
| | W | 1030 | 1580 | 1990 | 2560 | 3030 | 3540 | 4890 |
| 14043800 | S | 40 | 59 | 71.9 | 88.3 | 101 | 113 | 142 |
| | R | 55.4 | 82.1 | 101 | 125 | 143 | 162 | 208 |
| | W | 40.8 | 60.9 | 75.1 | 93.7 | 108 | 122 | 157 |
| 14043850 | S | 47.8 | 68.1 | 81.6 | 98.8 | 112 | 124 | 155 |
| | R | 23.2 | 37.6 | 48.3 | 62.8 | 74.4 | 86.4 | 116 |
| | W | 45 | 63 | 74.5 | 89.2 | 101 | 112 | 141 |
| 14043900 | S | 20.5 | 38.4 | 53.4 | 76.2 | 96 | 118 | 180 |
| | R | 14.6 | 32.6 | 48.7 | 73.8 | 96.1 | 121 | 193 |
| | W | 19.4 | 36.9 | 52 | 75.3 | 96 | 120 | 186 |
| 14044000 | S | 1720 | 2570 | 3160 | 3910 | 4470 | 5040 | 6380 |
| | R | 1690 | 2570 | 3180 | 3980 | 4590 | 5210 | 6680 |
| | W | 1720 | 2570 | 3160 | 3910 | 4480 | 5050 | 6400 |
| 14044100 | S | 13.3 | 39.2 | 64.4 | 104 | 139 | 176 | 273 |
| | R | 19.5 | 38.8 | 55.1 | 79.7 | 101 | 124 | 188 |
| | W | 14.6 | 39 | 60.2 | 90.9 | 116 | 144 | 217 |
| 14044500 | S | 412 | 797 | 1140 | 1680 | 2160 | 2730 | 4410 |
| | R | 355 | 543 | 685 | 881 | 1040 | 1200 | 1620 |
| | W | 409 | 775 | 1080 | 1540 | 1940 | 2380 | 3640 |
| 14046000 | S | 9130 | 14400 | 18500 | 24200 | 29000 | 34100 | 47700 |
| | R | 7560 | 11600 | 14500 | 18500 | 21700 | 25000 | 33200 |
| | W | 9100 | 14300 | 18300 | 23900 | 28400 | 33300 | 46300 |
| 14046250 | S | 24.6 | 47.8 | 66.3 | 92.6 | 114 | 137 | 194 |
| | R | 9.1 | 17.1 | 23.9 | 34.1 | 42.7 | 52.3 | 78.4 |
| | W | 20.9 | 37.4 | 48.8 | 64.2 | 76.8 | 90.4 | 127 |
| 14046300 | S | 4 | 6.7 | 9 | 12.4 | 15.4 | 18.7 | 28.1 |
| | R | 9.3 | 16.6 | 22.6 | 31.2 | 38.3 | 45.9 | 65.7 |
| | W | 4.6 | 8.4 | 11.9 | 17.5 | 22.3 | 27.6 | 42 |
| 14046500 | S | 12200 | 19400 | 24700 | 31800 | 37400 | 43300 | 58000 |
| | R | 10700 | 16900 | 21400 | 27600 | 32600 | 37700 | 50800 |
| | W | 12200 | 19300 | 24500 | 31500 | 37000 | 42800 | 57200 |
| 14047100 | S | 6.3 | 12.6 | 18.3 | 27.5 | 36 | 45.9 | 75.8 |
| | R | 18 | 31.3 | 42 | 57.5 | 70.3 | 84 | 120 |
| | W | 7 | 14.3 | 21.3 | 32.6 | 42.8 | 54.4 | 87.6 |
| 14047350 | S | 55.6 | 87.6 | 112 | 145 | 171 | 200 | 273 |
| | R | 28 | 64 | 100 | 160 | 213 | 275 | 460 |
| | W | 51.4 | 80.7 | 107 | 152 | 192 | 238 | 362 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 14047380 | S | 312 | 522 | 694 | 951 | 1170 | 1420 | 2130 |
| | R | 187 | 431 | 672 | 1060 | 1400 | 1800 | 2950 |
| | W | 302 | 507 | 688 | 986 | 1250 | 1560 | 2420 |
| 14047390 | S | 879 | 1720 | 2490 | 3740 | 4910 | 6300 | 10600 |
| | R | 492 | 1100 | 1720 | 2750 | 3690 | 4770 | 8020 |
| | W | 805 | 1480 | 2090 | 3140 | 4120 | 5300 | 8940 |
| 14048000 | S | 12400 | 19500 | 24600 | 31500 | 37000 | 42700 | 57000 |
| | R | 12600 | 20200 | 26000 | 34200 | 40800 | 47800 | 65800 |
| | W | 12500 | 19500 | 24700 | 31700 | 37200 | 43100 | 57700 |
| 14048040 | S | 162 | 447 | 727 | 1180 | 1590 | 2050 | 3320 |
| | R | 63.4 | 195 | 348 | 635 | 928 | 1300 | 2550 |
| | W | 134 | 318 | 485 | 791 | 1100 | 1490 | 2770 |
| 14048300 | S | 83.7 | 184 | 284 | 460 | 632 | 847 | 1560 |
| | R | 66.2 | 199 | 352 | 636 | 925 | 1290 | 2510 |
| | W | 79 | 191 | 323 | 577 | 834 | 1160 | 2220 |
| 14048310 | S | 64.4 | 179 | 295 | 489 | 667 | 874 | 1470 |
| | R | 54.6 | 164 | 289 | 523 | 761 | 1060 | 2070 |
| | W | 60.7 | 170 | 291 | 516 | 743 | 1030 | 1950 |
| 14050000 | S | 245 | 345 | 408 | 483 | 537 | 587 | 699 |
| | R | 543 | 768 | 916 | 1100 | 1250 | 1400 | 1760 |
| | W | 246 | 350 | 416 | 496 | 553 | 607 | 726 |
| 14050500 | S | 88.5 | 114 | 130 | 148 | 161 | 173 | 200 |
| | R | 38.2 | 60.1 | 75.4 | 95 | 110 | 125 | 161 |
| | W | 87.6 | 112 | 127 | 145 | 158 | 170 | 198 |
| 14051000 | S | 106 | 173 | 220 | 283 | 331 | 380 | 498 |
| | R | 103 | 157 | 194 | 241 | 277 | 314 | 402 |
| | W | 106 | 172 | 219 | 281 | 328 | 376 | 492 |
| 14052000 | S | 48.7 | 76.9 | 96.5 | 122 | 141 | 161 | 208 |
| | R | 53.3 | 83.6 | 105 | 133 | 154 | 175 | 228 |
| | W | 48.8 | 77 | 96.8 | 123 | 142 | 162 | 209 |
| 14053000 | S | 18.9 | 32.5 | 42.2 | 54.7 | 64.1 | 73.5 | 95.1 |
| | R | 37.7 | 58.9 | 73.7 | 92.5 | 107 | 121 | 156 |
| | W | 19.1 | 33.2 | 43.3 | 56.5 | 66.4 | 76.2 | 98.8 |
| 14054500 | S | 51.5 | 66.1 | 74.9 | 85.4 | 92.8 | 99.9 | 115 |
| | R | 46.3 | 72.1 | 89.9 | 113 | 130 | 147 | 189 |
| | W | 51.5 | 66.2 | 75.5 | 86.7 | 94.7 | 102 | 119 |
| 14055500 | S | 238 | 340 | 414 | 515 | 595 | 681 | 904 |
| | R | 176 | 262 | 321 | 396 | 454 | 513 | 658 |
| | W | 237 | 337 | 408 | 505 | 583 | 666 | 879 |
| 14055600 | S | 300 | 399 | 466 | 554 | 621 | 689 | 856 |
| | R | 226 | 335 | 410 | 505 | 579 | 654 | 838 |
| | W | 298 | 395 | 462 | 549 | 616 | 685 | 854 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 14061000 | S | 276 | 398 | 481 | 590 | 674 | 759 | 967 |
| | R | 237 | 355 | 437 | 542 | 622 | 705 | 909 |
| | W | 276 | 396 | 478 | 586 | 669 | 753 | 961 |
| 14073000 | S | 474 | 641 | 753 | 894 | 1000 | 1110 | 1360 |
| | R | 272 | 399 | 486 | 597 | 682 | 770 | 986 |
| | W | 470 | 632 | 739 | 874 | 976 | 1080 | 1330 |
| 14075000 | S | 562 | 905 | 1180 | 1600 | 1950 | 2360 | 3490 |
| | R | 477 | 690 | 836 | 1020 | 1170 | 1320 | 1690 |
| | W | 561 | 902 | 1180 | 1580 | 1930 | 2310 | 3410 |
| 14077500 | S | 612 | 781 | 885 | 1010 | 1090 | 1180 | 1360 |
| | R | 557 | 915 | 1190 | 1570 | 1880 | 2210 | 3070 |
| | W | 607 | 799 | 935 | 1120 | 1270 | 1420 | 1790 |
| 14077800 | S | 63.7 | 97.2 | 123 | 160 | 190 | 224 | 314 |
| | R | 30.9 | 47.2 | 59.7 | 77.2 | 91.6 | 107 | 148 |
| | W | 61.4 | 91.7 | 114 | 144 | 169 | 196 | 269 |
| 14078000 | S | 1400 | 2590 | 3560 | 4970 | 6170 | 7480 | 11000 |
| | R | 1890 | 3320 | 4410 | 5940 | 7170 | 8480 | 11800 |
| | W | 1420 | 2620 | 3610 | 5060 | 6280 | 7600 | 11100 |
| 14078200 | S | 18.4 | 64.1 | 120 | 227 | 340 | 484 | 966 |
| | R | 44.5 | 100 | 150 | 225 | 291 | 364 | 561 |
| | W | 21 | 70.9 | 128 | 227 | 320 | 429 | 753 |
| 14078400 | S | 48.4 | 70.6 | 85.8 | 105 | 120 | 135 | 170 |
| | R | 50 | 77.4 | 97.1 | 123 | 144 | 165 | 217 |
| | W | 48.6 | 71.8 | 88.3 | 110 | 128 | 145 | 188 |
| 14078500 | S | 1390 | 1760 | 2000 | 2300 | 2520 | 2740 | 3260 |
| | R | 1000 | 1470 | 1810 | 2270 | 2630 | 3000 | 3940 |
| | W | 1350 | 1710 | 1960 | 2290 | 2550 | 2820 | 3490 |
| 14079500 | S | 4040 | 6700 | 8670 | 11300 | 13400 | 15600 | 21100 |
| | R | 4630 | 8410 | 11300 | 15500 | 18800 | 22400 | 31400 |
| | W | 4080 | 6870 | 9010 | 12000 | 14400 | 17000 | 23500 |
| 14079800 | S | 4150 | 8050 | 11300 | 16300 | 20500 | 25100 | 37900 |
| | R | 4690 | 8480 | 11400 | 15600 | 18900 | 22500 | 31500 |
| | W | 4220 | 8140 | 11400 | 16000 | 19900 | 24000 | 34900 |
| 14080500 [b] | S | 3530 | 5350 | 6620 | 8280 | 9550 | 10800 | 14000 |
| | R | 4800 | 8800 | 11900 | 16400 | 19900 | 23700 | 33400 |
| | W | 3620 | 5680 | 7280 | 9550 | 11400 | 13300 | 18100 |
| 14080600 | S | 192 | 311 | 401 | 526 | 627 | 734 | 1010 |
| | R | 127 | 252 | 358 | 519 | 658 | 815 | 1250 |
| | W | 177 | 293 | 385 | 523 | 641 | 773 | 1140 |
| 14081800 | S | 37.3 | 51.9 | 62.7 | 77.7 | 89.9 | 103 | 138 |
| | R | 37.6 | 55.4 | 68.5 | 86.4 | 101 | 116 | 156 |
| | W | 37.3 | 52.1 | 63.2 | 78.7 | 91.4 | 105 | 141 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 14083000 | S | 353 | 534 | 668 | 853 | 1000 | 1160 | 1570 |
| | R | 443 | 720 | 924 | 1200 | 1410 | 1640 | 2170 |
| | W | 361 | 561 | 717 | 937 | 1110 | 1300 | 1770 |
| 14083500 | S | 149 | 235 | 301 | 395 | 473 | 557 | 782 |
| | R | 112 | 189 | 246 | 324 | 384 | 445 | 594 |
| | W | 144 | 226 | 287 | 372 | 440 | 512 | 698 |
| 14088000 | S | 159 | 244 | 309 | 402 | 479 | 564 | 792 |
| | R | 143 | 231 | 297 | 384 | 452 | 523 | 701 |
| | W | 159 | 244 | 309 | 401 | 478 | 562 | 787 |
| 14090350 | S | 363 | 520 | 635 | 793 | 920 | 1050 | 1410 |
| | R | 619 | 953 | 1200 | 1530 | 1790 | 2070 | 2790 |
| | W | 374 | 556 | 700 | 901 | 1060 | 1230 | 1650 |
| 14090400 | S | 414 | 638 | 806 | 1040 | 1230 | 1440 | 1990 |
| | R | 728 | 1130 | 1430 | 1830 | 2160 | 2500 | 3400 |
| | W | 426 | 674 | 871 | 1150 | 1370 | 1610 | 2220 |
| 14091500 | S | 2590 | 3590 | 4350 | 5420 | 6310 | 7280 | 9900 |
| | R | 3410 | 5020 | 6160 | 7670 | 8860 | 10100 | 13400 |
| | W | 2610 | 3630 | 4420 | 5540 | 6460 | 7460 | 10100 |
| 14092750 | S | 652 | 1120 | 1510 | 2100 | 2620 | 3200 | 4870 |
| | R | 453 | 713 | 907 | 1170 | 1380 | 1600 | 2170 |
| | W | 637 | 1060 | 1380 | 1850 | 2250 | 2690 | 3940 |
| 14092885 | S | 661 | 1290 | 1870 | 2820 | 3690 | 4730 | 7940 |
| | R | 847 | 1370 | 1770 | 2310 | 2750 | 3210 | 4400 |
| | W | 677 | 1310 | 1850 | 2660 | 3350 | 4150 | 6440 |
| 14093000 | S | 568 | 861 | 1080 | 1390 | 1640 | 1910 | 2630 |
| | R | 1170 | 1930 | 2500 | 3300 | 3940 | 4630 | 6400 |
| | W | 643 | 1090 | 1480 | 2040 | 2490 | 2960 | 4140 |
| 14093600 | S | 598 | 1190 | 1750 | 2690 | 3590 | 4680 | 8190 |
| | R | 320 | 689 | 1040 | 1600 | 2090 | 2630 | 4210 |
| | W | 565 | 1060 | 1470 | 2140 | 2770 | 3530 | 5930 |
| 14093700 | S | 2.5 | 11.3 | 27.1 | 73 | 143 | 270 | 1040 |
| | R | 8.3 | 22.6 | 39 | 69.9 | 101 | 140 | 271 |
| | W | 3.3 | 15.5 | 33.5 | 70.9 | 112 | 168 | 397 |
| 14095500 | S | 394 | 711 | 1000 | 1480 | 1930 | 2490 | 4250 |
| | R | 629 | 995 | 1260 | 1620 | 1900 | 2190 | 2930 |
| | W | 411 | 754 | 1060 | 1520 | 1920 | 2380 | 3740 |
| 14096300 | S | 353 | 607 | 813 | 1120 | 1380 | 1670 | 2470 |
| | R | 338 | 532 | 675 | 867 | 1020 | 1180 | 1580 |
| | W | 352 | 598 | 789 | 1060 | 1280 | 1530 | 2200 |
| 14096850 | S | 587 | 1550 | 2600 | 4580 | 6620 | 9270 | 18500 |
| | R | 929 | 1520 | 1960 | 2570 | 3060 | 3570 | 4880 |
| | W | 627 | 1540 | 2370 | 3640 | 4760 | 6060 | 10000 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 14097100 | S | 2400 | 5250 | 8000 | 12700 | 17200 | 22600 | 39900 |
| | R | 2820 | 4320 | 5390 | 6810 | 7940 | 9120 | 12100 |
| | W | 2420 | 5110 | 7440 | 11000 | 14100 | 17700 | 28600 |
| 14097200 | S | 1650 | 2340 | 2830 | 3500 | 4030 | 4590 | 6010 |
| | R | 974 | 1550 | 1990 | 2590 | 3070 | 3590 | 4930 |
| | W | 1560 | 2170 | 2600 | 3190 | 3690 | 4210 | 5600 |
| 14100800 | S | 103 | 259 | 431 | 757 | 1100 | 1550 | 3180 |
| | R | 259 | 450 | 604 | 824 | 1000 | 1200 | 1700 |
| | W | 117 | 296 | 479 | 781 | 1060 | 1390 | 2430 |
| 14101500 | S | 2940 | 5110 | 6860 | 9420 | 11600 | 14000 | 20600 |
| | R | 4240 | 6740 | 8610 | 11200 | 13300 | 15500 | 21200 |
| | W | 2970 | 5190 | 6980 | 9590 | 11800 | 14200 | 20700 |
| 14104100 | S | 54.4 | 111 | 165 | 258 | 348 | 459 | 822 |
| | R | 85.2 | 130 | 172 | 240 | 300 | 365 | 545 |
| | W | 55.4 | 113 | 166 | 253 | 334 | 429 | 731 |
| 14104500 | S | 1610 | 2710 | 3600 | 4920 | 6050 | 7310 | 10800 |
| | R | 1170 | 2520 | 3930 | 6460 | 8910 | 11900 | 21300 |
| | W | 1560 | 2660 | 3720 | 5600 | 7390 | 9460 | 15400 |
| 14107000 [a] | S | 1880 | 2640 | 3210 | 3990 | 4620 | 5290 | 7060 |
| 14110000 [a] | S | 3170 | 4520 | 5510 | 6880 | 7970 | 9140 | 12200 |
| 14111800 [a] | S | 110 | 231 | 349 | 555 | 757 | 1010 | 1850 |
| 14112000 [a] | S | 1010 | 2050 | 3030 | 4670 | 6240 | 8150 | 14300 |
| 14112200 [a] | S | 25.5 | 58.8 | 94.6 | 162 | 232 | 325 | 662 |
| 14112500 [a] | S | 3190 | 6240 | 9020 | 13500 | 17700 | 22700 | 38000 |
| 14113000 [a] | S | 7860 | 14700 | 20700 | 30100 | 38700 | 48800 | 78800 |
| 14113200 | S | 668 | 1600 | 2580 | 4350 | 6160 | 8460 | 16400 |
| | R | 1000 | 1970 | 2900 | 4480 | 5970 | 7730 | 13000 |
| | W | 686 | 1660 | 2660 | 4400 | 6080 | 8160 | 15000 |
| 14113400 | S | 35 | 54.6 | 70.7 | 95.5 | 117 | 143 | 217 |
| | R | 49.1 | 81 | 105 | 138 | 163 | 190 | 256 |
| | W | 36 | 57.8 | 76.6 | 105 | 128 | 155 | 228 |
| 14118500 | S | 6520 | 9430 | 11500 | 14100 | 16100 | 18200 | 23300 |
| | R | 3810 | 6300 | 8280 | 11100 | 13400 | 16000 | 22800 |
| | W | 6470 | 9330 | 11300 | 13900 | 16000 | 18100 | 23300 |
| 14120000 | S | 10300 | 16100 | 20300 | 26000 | 30500 | 35200 | 47000 |
| | R | 6930 | 10800 | 13700 | 17800 | 21100 | 24700 | 34200 |
| | W | 10200 | 15800 | 19800 | 25100 | 29400 | 33900 | 45400 |
| 14121000 | S | 9620 | 15600 | 20200 | 26800 | 32300 | 38300 | 54400 |
| | R | 7920 | 12500 | 16000 | 20900 | 24900 | 29300 | 40800 |
| | W | 9580 | 15400 | 19900 | 26300 | 31600 | 37400 | 52900 |
| 14121300 [a] | S | 693 | 967 | 1160 | 1410 | 1610 | 1810 | 2310 |
| 14121500 [a] | S | 1570 | 2190 | 2620 | 3200 | 3640 | 4100 | 5240 |

**Appendix D.** Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

| Station number | Estimate type | Peak discharges in cubic feet per second for the indicated recurrence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 | 500 |
| 14122000 [a] | S | 1960 | 2790 | 3390 | 4200 | 4840 | 5510 | 7230 |
| 14123000 [a] | S | 2790 | 4150 | 5200 | 6690 | 7940 | 9300 | 13000 |
| 14123500 [a] | S | 4620 | 6950 | 8600 | 10800 | 12500 | 14200 | 18500 |
| 14124500 [a] | S | 2790 | 3360 | 3720 | 4150 | 4460 | 4760 | 5440 |
| 14125000 [a] | S | 2520 | 3170 | 3600 | 4140 | 4550 | 4960 | 5950 |
| 14125500 [a] | S | 3250 | 5280 | 6890 | 9240 | 11200 | 13400 | 19500 |

[a] Station is located outside the State of Oregon.

[b] Stream flow at this station site is now regulated.

# Appendix E

## Test for Random Peak

A usual test for randomness is to check each series of annual peaks for a statistically significant linear correlation, i.e., a trend (Thomas et al., 1994; Wiley et al., 2000). A significant trend suggests that systematic, non-random changes in peak discharge characteristics are occurring in time. A trend test is not definitive; it is cause for investigation, not necessarily for the elimination of a gaging station from the analysis.

All 276 gaging stations were tested for linear correlation. The resulting information was analyzed in two ways: 1) to check for regional, climate dependent trends, and 2) to check for local trends resulting from significant physical changes to a watershed. Local changes include human caused changes due to land use or water management as well as natural changes such as a volcanic eruption. Local trends that can be attributed to physical changes in the watershed may require all or part of a gaging station's period of record to be removed from consideration.

Almost all gaging station records exhibit some degree of linear correlation. Most of these trends result from natural random variation in peak flows, not from either long-term climate change or physical changes to the watershed. A statistical test determines which of the trends is significant, that is, the least likely to have occurred by chance. These unlikely trends represent the gaging station records to be investigated.

A significant trend does not necessarily mean a series of peaks is non-random. For any group of gaging stations, a few of the annual series will have significant trends by chance. The level of significance of the statistical test determines how many of these significant but chance trends are to be expected. For example, for a 0.05 level of significance, about five percent of stations should show a significant trend.

Although all significant trends should be investigated for physical changes to the gaging station's watersheds, regional trends require that a greater number of significant trends occur than are expected by chance.

In the regional analysis, no consistent long-term trend was found, although there is evidence of a regional fluctuation of peak discharges between wet and dry periods. This fluctuation led to a higher than expected number of significant trends in long-term gaging station records. The evidence is too weak, however, to support a strong conclusion as to whether the fluctuations are truly periodic or what the period might be. Locally, no significant trend could be linked to physical changes in the associated watershed[1].

**The Statistical Test -** Kendall's tau, a nonparametric measure of linear correlation, was used to determine the degree and direction of correlation, and the correlation's statistical significance, for each of the 276 annual series of peaks. A positive value of tau indicated a positive correlation, and a negative value, a negative correlation. Small values of the probability associated with tau indicated a significant correlation. Calculations of Kendall's tau and its associated probability for each series were made using the algorithm given by Press et al. (1986). Appendix B shows the value of tau and its associated probability for each gaging station.

**Test for Significance -** Statistical significance was determined by a two-sided test at the 0.05 level. For this test, the null hypothesis, $H_o$, states there is no trend. $H_o$ is accepted if the probability associated with tau is greater than 0.05 and is rejected otherwise. By chance, five percent of the gaging stations should show a significant trend. The significant, but chance, trends should be about half positive and half negative.

**Checking for Regional Trends –** In an initial check for regional trends, only the 86 gaging stations with more than 30 years of record were used. These long-term records were considered least likely to be

[1] No watersheds known to be significantly affected by regulation or diversions were included in the analysis.

**Table E-1.** The distribution of trends in annual peak data among watersheds in eastern Oregon by flood region. Trends were determined for watersheds with more than 30 years of record.

| Region | Watersheds with Positive Trends | | Watersheds with Negative Trends | | Watersheds with Trends | | Number of Watersheds |
|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | |
| **1** | 1 | 5.3 | 1 | 5.3 | 2 | 10.6 | 19 |
| **2** | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 19 |
| **3** | 1 | 11.0 | 0 | 0.0 | 1 | 11.0 | 21 |
| **4** | 2 | 18.0 | 1 | 9.1 | 3 | 27.3 | 11 |
| **5** | 2 | 28.6 | 0 | 0.0 | 2 | 28.6 | 7 |
| **6** | 0 | 0.0 | 1 | 11.1 | 1 | 11.1 | 9 |
| **All** | 6 | 7.0 | 3 | 3.5 | 9 | 10.5 | 86 |

affected by random variation in the annual series of peak discharges. By chance, five percent of the gaging stations (4 to 5 stations) should show a significant trend.

Table E-1 summarizes the results of the test for significance for the long-term stations. Nine stations (10.5) percent showed a significant trend. Of these, six showed a positive trend and three a negative trend. Region 5 had the highest percentage of significant trends (28.6 percent) and region 2, the fewest (0.0 percent).

More significant trends occurred than were expected by chance and most were positive. The six positive trends had periods of record beginning before 1940. The negative trends had periods of record beginning after 1960 (Table E-2). Figure E-1 shows the trend lines for representative gaging stations from each group. These results suggest that, for these gaging stations, peak discharges are not entirely random; that they exhibit long-term fluctuations between wet and dry periods – dry around 1930 and wet around 1960.

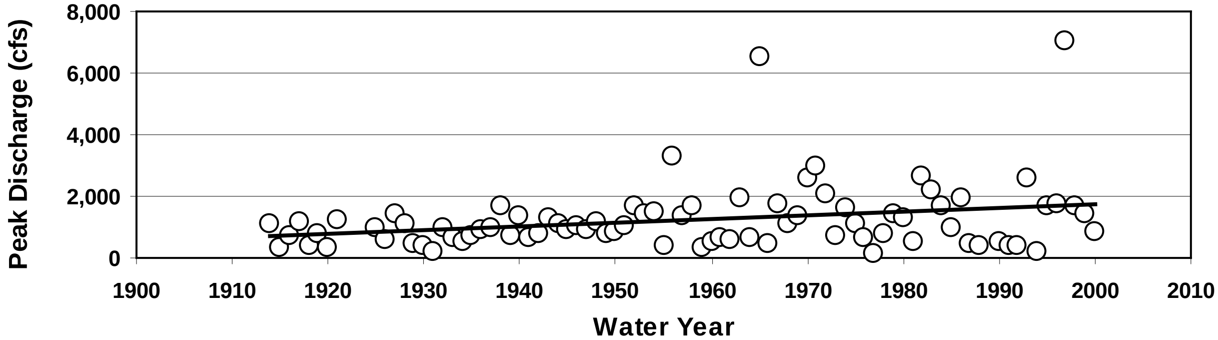
The pattern shown by these gaging stations is not as strong as that shown by gaging stations in western Oregon (Cooper, 2005), but being dry in 1930 and wet in 1960 is consistent with the pattern in western Oregon. The eastern Oregon pattern is also consistent with observations made about precipitation in Oregon by Taylor and Hannan (1999) who suggest alternating periods of relatively high and low rainfall. Based on long-term precipitation records from the coast and in Portland, weather was cool and wet from 1896 to 1916, warm and dry from 1916 to 1946, cool and wet from 1946 to 1976, and warm and dry from 1976 to 1995. After 1995 appears to be the beginning of another wet period.

If peak discharges are in fact subject to serial correlation due to long-term fluctuations in weather, it should be possible to demonstrate that the direction and the statistical significance of a trend are functions of the length of the record on which it is based and the record's location in time. In order to make this test, all record lengths must be the same. To that end, for all 276 gaging stations, all possible records of 10, 20, 30, 40, 50, 60, 70, and 80 years were identified and Kendal's tau determined[2]. A long-term gage contributes a number of records in this scheme. For example, a gaging station with 50 years of data yields 21 records 30 years in length. The total number of sampled records varies as a function of sample record length – the longer the sample, the fewer the possible records (Table E-3).

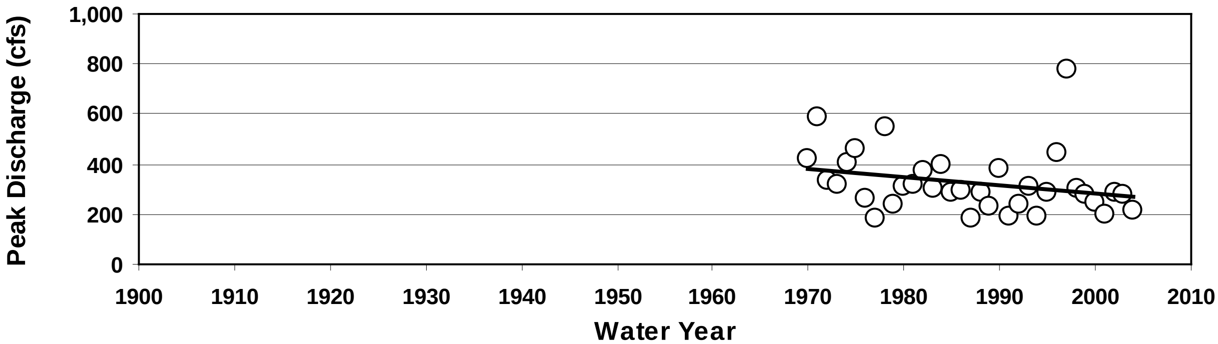
Table E-3 shows trend direction and number of significant trends as a function of record length for eastern Oregon. The same information for western Oregon is included for comparison. For both sides of the state, trend direction and statistical significance are functions of sample record length. For eastern Oregon, trends are about equally positive and negative for record lengths of 20 years or less, but the percentage of positive trends increases rapidly with increasingly longer records. Trends for gaging stations in western Oregon exhibit a similar pattern though the increase in the percentage of positive trends begins at 40 years of record, not 20 years.

---

[2] For this test, records with gaps longer than five years were not considered.




a.




b.

**Figure E-1.** Examples of gaging station peaks with significant trends (a) the Chewaucan River near Paisley, OR (10384000) and (b) Odell Creek near La Pine, OR (14055600).

**Table E-2.** The 9 gaging stations with significant trends and more than 30 years of record. The list is sorted on the beginning year of the period of record.

| Gage Number | Period of Record | Number of Peaks | Trend Direction | Region |
|---|---|---|---|---|
| 14061000 | 1912-1914, 1928-1930, 1932-1946, 1947-1958 | 32 | + | 1 |
| 10384000 | 1912-1921, 1925-2000 | 83 | + | 5 |
| 13329500 | 1915, 1924-1978 | 56 | + | 3 |
| 10371500 | 1923, 1930-2000 | 72 | + | 5 |
| 14044000 | 1930-2003 | 74 | + | 4 |
| 14037500 | 1931-1967, 1970-2002 | 70 | + | 4 |
| 13172740 | 1963-1993 | 31 | - | 3 |
| 14040600 | 1967-1972, 1974-1979,1981-1989, 1991-2001 | 32 | - | 4 |
| 14055600 | 1970-2004 | 31 | - | 1 |

**Table E-3.** Trend direction and number of significant trends as a function of record length.

| Eastern Oregon | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Record Length** | **Number of Observations** | **Trend Direction** | | | | **Significant Trends** | |
| | | **Positive** | **Negative** | **Zero** | **% Positive** | **Number** | **Percent** |
| **10** | 5294 | 2695 | 2559 | 40 | 50.9 | 376 | 7.1 |
| **20** | 3245 | 1692 | 1498 | 55 | 52.1 | 214 | 6.6 |
| **30** | 2195 | 1303 | 878 | 14 | 59.4 | 129 | 5.9 |
| **40** | 1515 | 1017 | 492 | 6 | 67.1 | 129 | 8.5 |
| **50** | 967 | 726 | 239 | 2 | 75.1 | 135 | 14.0 |
| **60** | 512 | 447 | 65 | 0 | 87.3 | 69 | 13.5 |
| **70** | 152 | 147 | 5 | 0 | 96.7 | 18 | 11.8 |
| **80** | 33 | 33 | 0 | 0 | 100 | 4 | 12.1 |
| **Western Oregon*** | | | | | | | |
| **Record Length** | **Number of Observations** | **Trend Direction** | | | | **Significant Trends** | |
| | | **Positive** | **Negative** | **Zero** | % Positive | **Number** | **Percent** |
| **10** | 6761 | 3332 | 3361 | 68 | 49.3 | 289 | 4.3 |
| **20** | 3794 | 1777 | 1936 | 81 | 46.8 | 161 | 4.2 |
| **30** | 2184 | 1083 | 1087 | 14 | 49.6 | 149 | 6.8 |
| **40** | 1214 | 614 | 592 | 8 | 50.6 | 161 | 13.3 |
| **50** | 641 | 375 | 265 | 1 | 58.5 | 109 | 17.0 |
| **60** | 285 | 186 | 98 | 1 | 65.3 | 59 | 20.7 |
| **70** | 96 | 71 | 25 | 0 | 74.0 | 35 | 36.5 |
| **80** | 30 | 28 | 2 | 0 | 93.3 | 13 | 43.3 |

* From Cooper, 2005

Again from Table E-3, for eastern Oregon for record lengths of 30 years or less, the percentage of significant trends is about what is expected by chance. For record lengths of more than 30 years, the percentage of significant trends increases with record length to about 50 or 60 years and then remains relatively constant at a little over 10 percent for longer records. This pattern is similar to the pattern shown by trends in western Oregon, except that for western Oregon the number of significant trends continues to increase with record length. Also the percentages of significant trends at longer record lengths are much greater for western Oregon than for eastern Oregon.

In Figure E-2, for each record length, the number of standard deviations Kendall's tau departs from the mean (i.e., its z score) is plotted against the beginning year of the period of record. Plotted in this way, tau gives the direction of the trend and is proportional to its statistical significance. All records of a given length are plotted on the same chart. The solid black line on each chart is a sixth order polynomial fitted to the plotted points. Each line represents the trend of its associated z scores.

Figure E-2 shows that the likelihood a trend will be in a certain direction or will be significant or both varies as both a function of length of record and the record's place in time. For example, for records 40 years in length (Figure E-2d) a record beginning between 1912 and 1947, or after 1959, is more likely to be positive than negative, and if beginning before 1912 or between 1947 and 1959, more likely to be negative. Significant trends (tau more than about two standard deviations from the mean) are most likely to occur near the maximum and minimum points of the fitted line: 1930 and 1955.

The longer the length of record, the more the record's place in time affects direction and significance. At

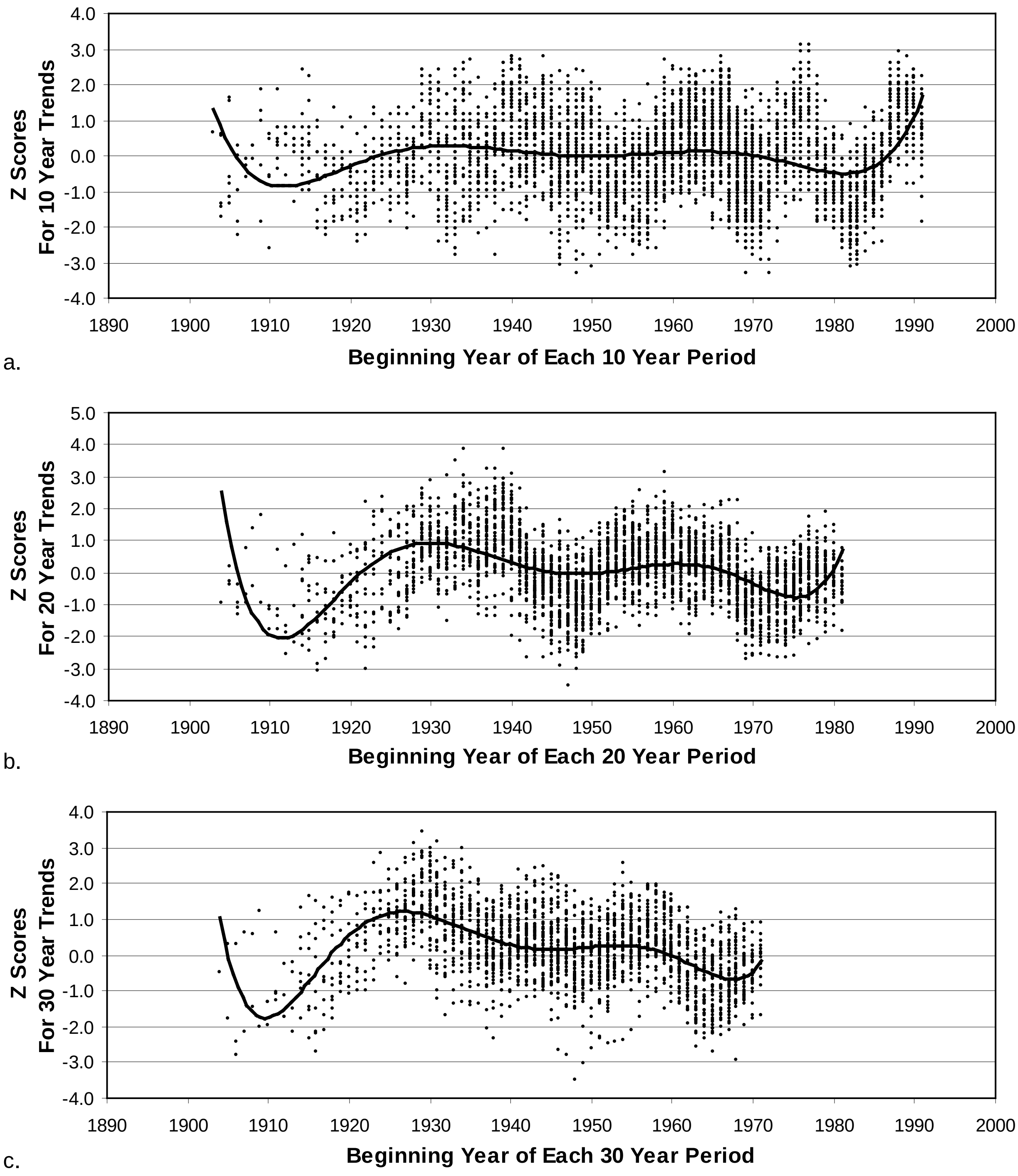
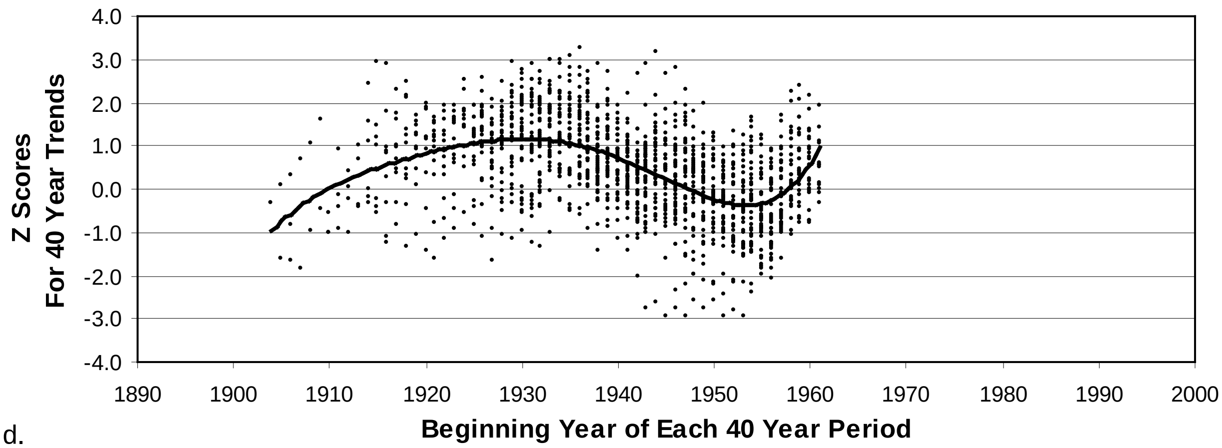
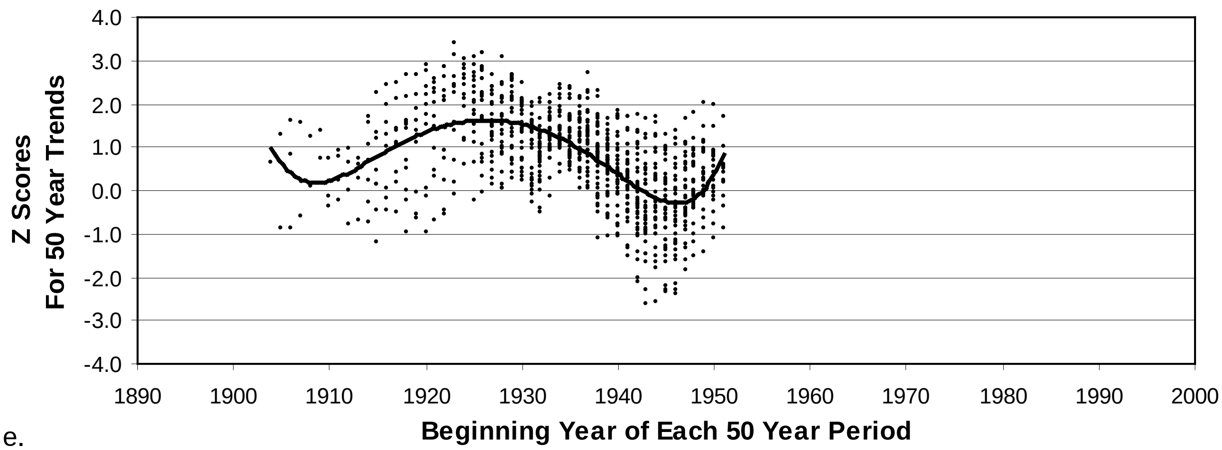


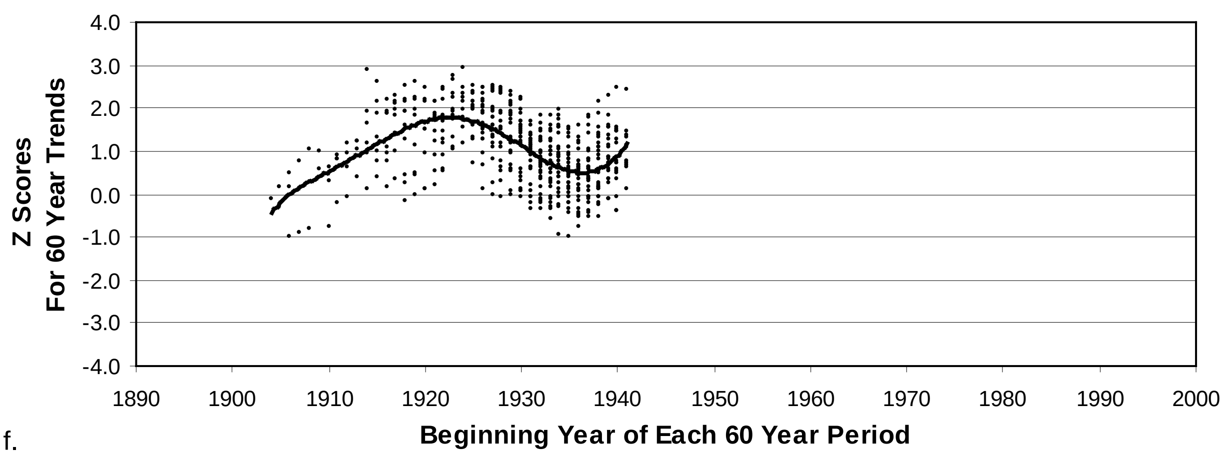

**Figure E-2.** These charts show how Kendal's tau varies in time and as a function of the length of the period of record. The number of standard deviations Kendall's tau departs from the mean (i.e., its z score) for the specified periods of record is plotted against the beginning year of each period. Plotted in this way, tau gives the direction of the trend, and is proportional to its statistical significance, for the period of record




d.




e.




f.

**Figure E-2 - continued.** that follows its plotted position. The solid line on each chart is a sixth order polynomial fitted to the plotted points. The charts are for uniform periods of record of a) 10 years, b) 20 Years, c) 30 years, d) 40 years, e) 50 years, and f) 60 years.

short record lengths, the trend line is relatively flat. At records lengths of about 30 or 40 years, the trend line begins to take on a roughly sinusoidal shape. The sinusoidal shape of the trend line is more pronounced for trends in western Oregon (see Figure E-2, Cooper, 2005).

The sinusoidal trend lines of the z scores in Figure E-2 suggest that the linear trends on which the z scores are based fluctuate between positive and negative. These region wide fluctuations explain the over abundance of significant trends in the long-term gages and the grouping of positive and negative trends shown in Table E-2. They also explain why the percentage of significant trends and the number of positive trends both increase with record length (Table E-3).

To understand how the z scores of the linear trends relate to the original time series of peak discharges, it is helpful to look at the behavior of z scores of linear trends sampled from a theoretical, perfectly sinusoidal population. A sine curve with a period of 60 years and beginning in 1880 was sampled for all possible periods of lengths of 10, 20, 30, 40, 50, and 60 years. Kendall's tau and the associated z score were calculated for each sample. The population curve and the z scores of the trend lines for each period of record are plotted in Figure E-3. The z scores based on the samples from the sine curve (Figure E-3) behave in a fashion similar to the z scores from the actual peak discharges (Figure E-2). The z scores are sinusoidal in both cases and their periods shorten as the length of sampled record increases. Also the most significant trends occur near the maximum and minimum points of the curves.

Note that when the length of the sampled record is half that of the period of the population curve, the z scores and the population curve are exactly 180 degrees out of phase. This means that for periods beginning in wet years trend lines will tend to be negative, and beginning in dry years, positive.

For the z scores for actual peak discharges, the z scores and the sine curve are 180 degrees out of phase for a period of 76 years and a period of record of about 35 years (Figure E-4). These results are identical to those found for western Oregon (Cooper, 2005). In Figure E-4, the time line is divided into wet and dry periods. The breaks occur where the two sinusoidal curves meet as they cross zero. Interestingly, these periods match reasonably well with those observed by Taylor and Hannan (1999).

Although this analysis suggests a periodicity to peak discharges, less than one complete period is represented in the record. Whether these observed fluctuations are truly periodic with a constant period remains to be seen. Further, the data points are scattered widely about the trend lines indicating that a trend line of the z scores for any single gaging station may vary considerably from the trend line for z scores from all gaging stations (Figure E-5). So, while the fluctuations appear to have a general, regional basis, locally there is considerable variation.

Based on this analysis, it is concluded that while the time series of peak discharges exhibit some serial correlation, the correlation is due to fluctuations between wet and dry periods and not to a continuous upward or downward trend. Over the long term, peak discharge characteristics remain constant. Further, it is concluded that the available peak discharge records represent long-term peak discharge characteristics; that they adequately represent the variability exhibited by peak discharges over the long-term.

**Checking for Local Trends –** Table E-4 summarizes the results of the tests for significance for all 276 stations. For these stations, 29 (10.5 percent) showed a significant trend. Of these, 15 showed a positive trend and 14, a negative trend. Region 5 had the highest percentage of significant trends (28.6 percent), and region 2, the fewest (1.7 percent). While the number of significant trends exceeds that expected by chance, the trends are not predominately either positive or negative. The excess of significant trends is attributed to the fluctuations discussed in the previous section. The 29 gaging stations with significant trends were examined to determine if the trends were the result of physical changes in the associated watersheds. Since no physical cause could be determined for any of the trends, the trends were assumed to be due to chance alone, and the 29 gaging stations were retained in the analysis.

# References

Cooper, R.M., 2005, Estimation of Peak Discharges for Rural, Unregulated Streams in Western Oregon: U.S Geological Survey Scientific Investigations Report 2005-5116, 50 p.

Press, W.H., Flannery, B.P., Teukolsky, S.A., and Vetterling, W.T., 1986, Numerical recipes. The art of scientific computing: Cambridge, Cambridge University Press, 818 p.

Taylor, G.H. and Hatton, R.R., 1999, The Oregon weather book, a state of extremes: Corvallis, Oregon, Oregon State University Press, 242 p.

Thomas, B.E., Hjalmerson, H.W., and Waltemeyer, S.D., 1993, Methods for estimating magnitude and frequency of floods in the southwestern United States: U.S. Geological Survey Open File Report 93-419, 211 p.

Wiley, J.B., Atkins, Jr., J.T., and Tasker, G.D., 2000, Estimating magnitude and frequency of peak discharges for rural, unregulated streams in West Virginia:  U.S. Geological Survey Water Resources Investigations Report 00-4080, 93 p.

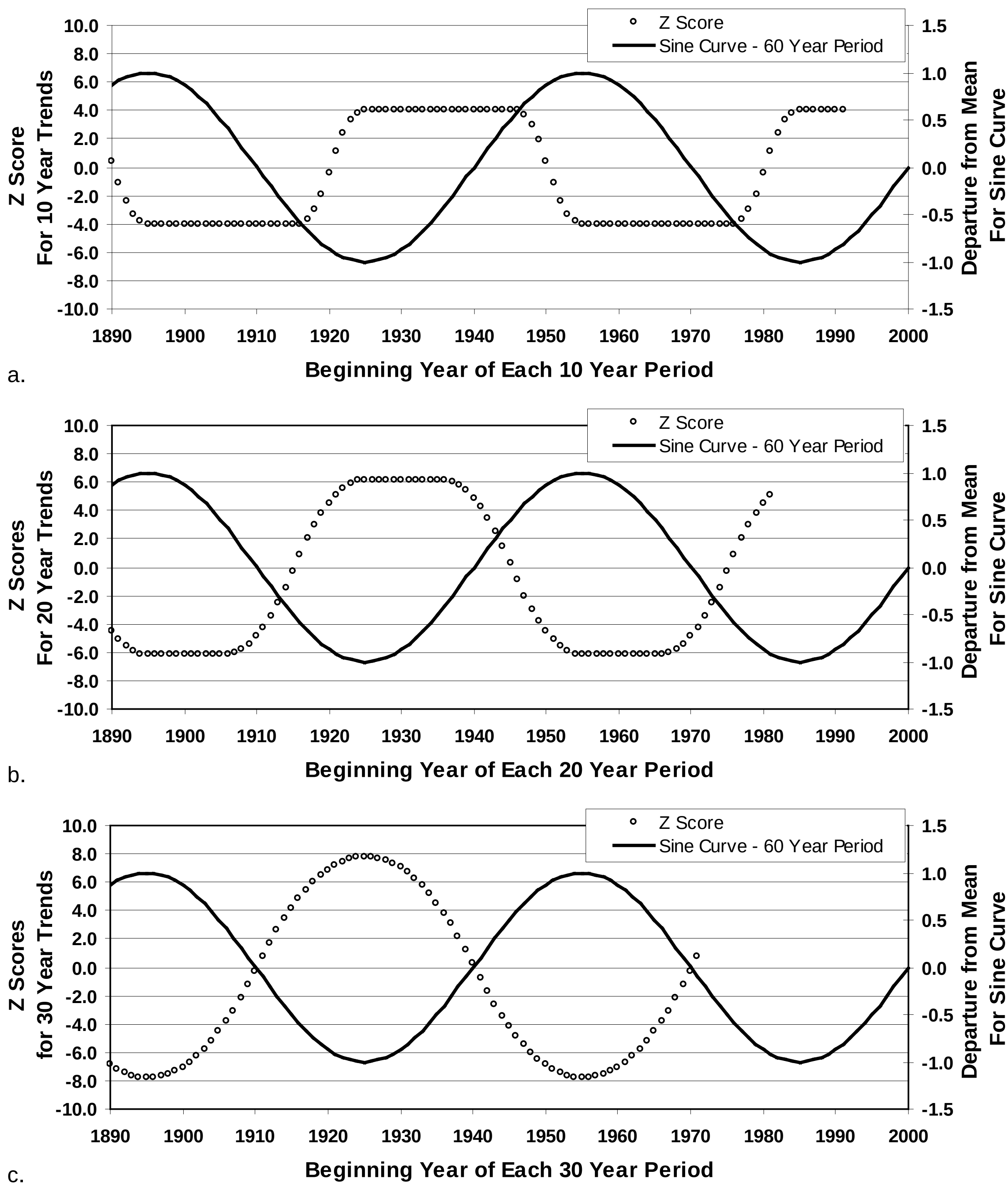
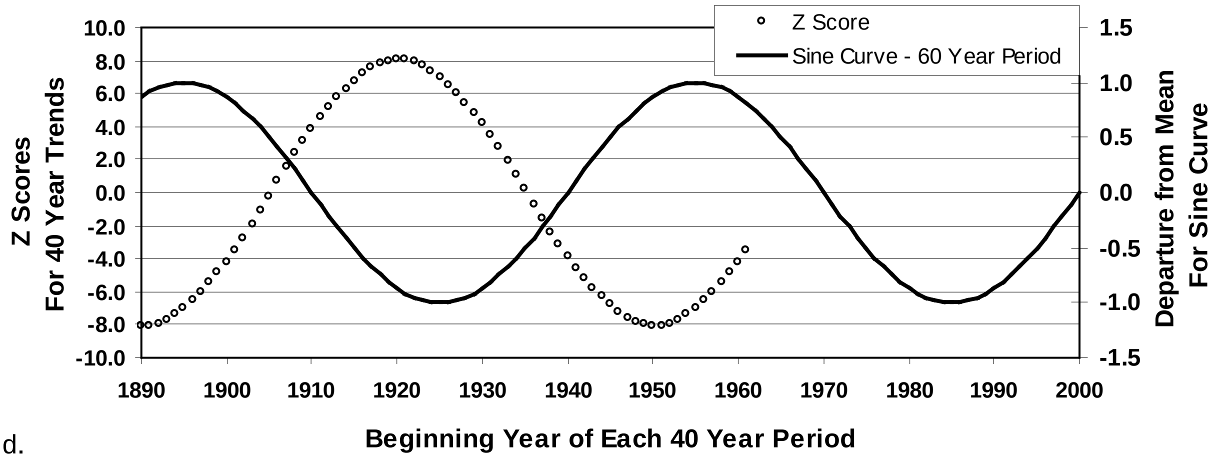
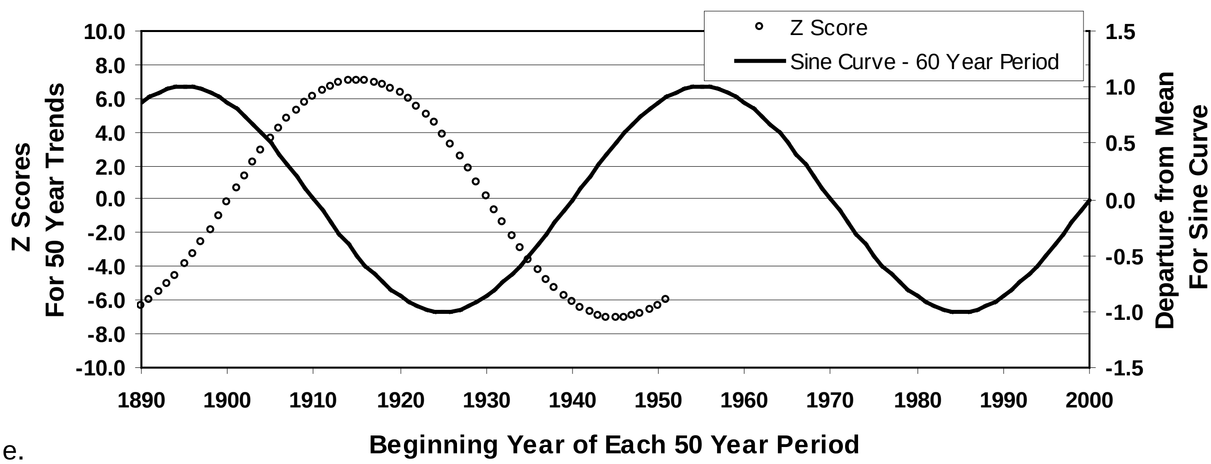


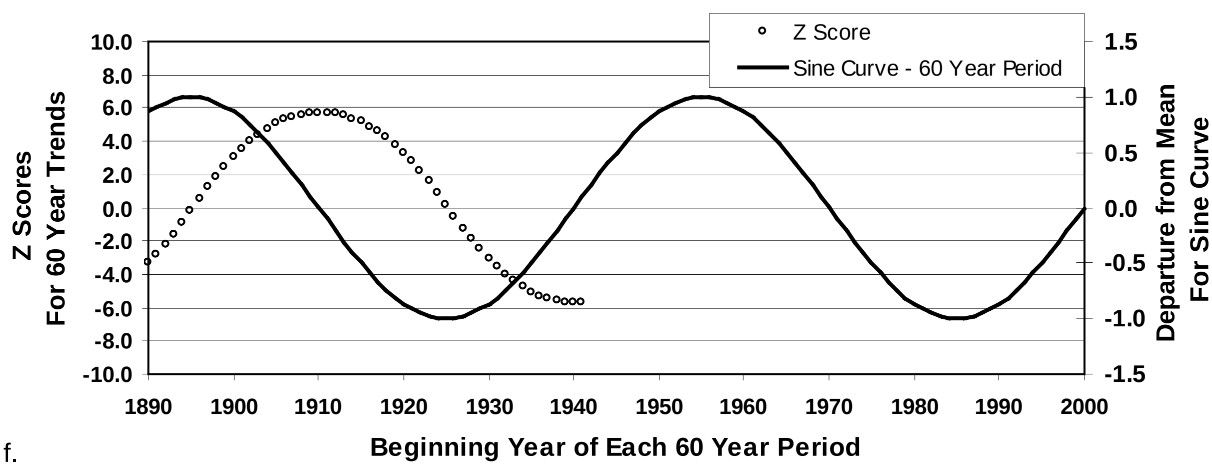

**Figure E-3.** Kendall's tau was calculated for samples of specified length taken from a population based on a sine curve with a period of 60 years and beginning in 1880 (blue line). The values of the population represent departures from a mean of zero. Z scores for the tau values are shown plotted against time. These z scores




d.




e.




f.

**Figure E-3 – continued.** exhibit behavior similar to the z scores in Figure E-2. Note that when the length of the sample is half the period of the sine curve, the two curves are 180 degrees out of phase.

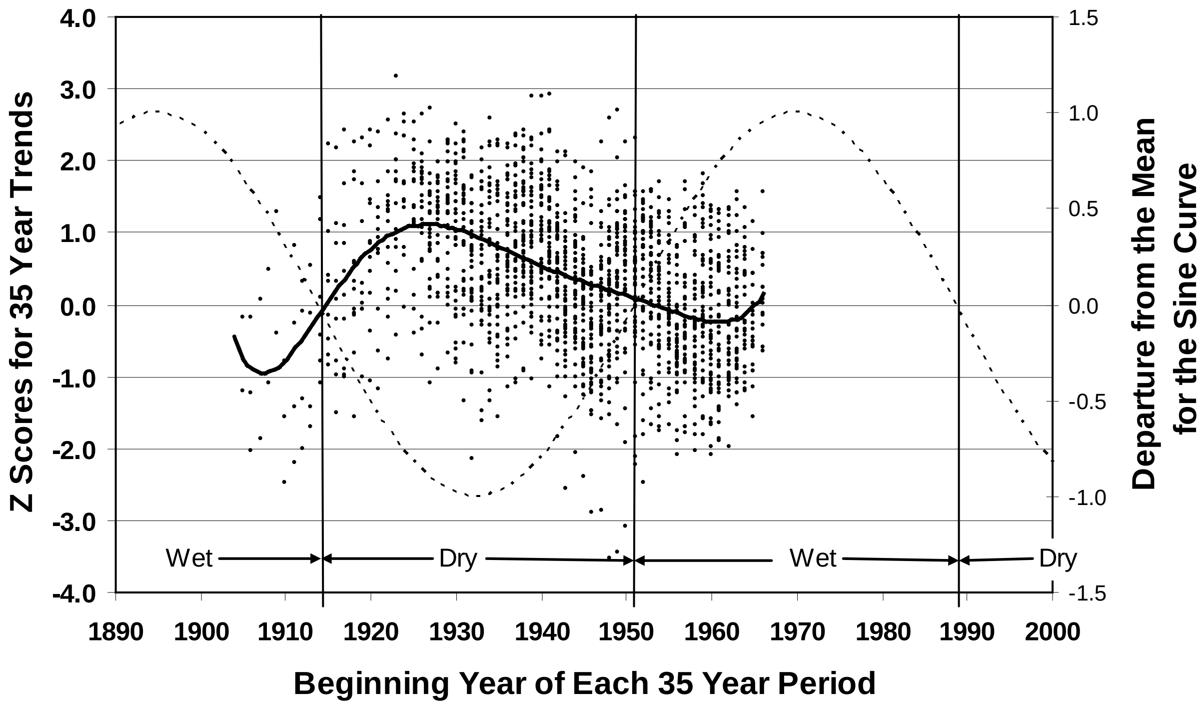



**Figure E-4.** Z scores for Kendall's tau calculated for all possible periods of 35 years are plotted against the beginning year of each period. The solid curved line is a fourth order polynomial fitted to the plotted points. The dashed line is a sine curve with a period of 75 years and beginning in 1876. The parameters of the sine curve and the length of record were selected so that the two curves were 180 degrees out of phase. The boundaries of the wet and dry periods are located where the two curves cross each other and zero.

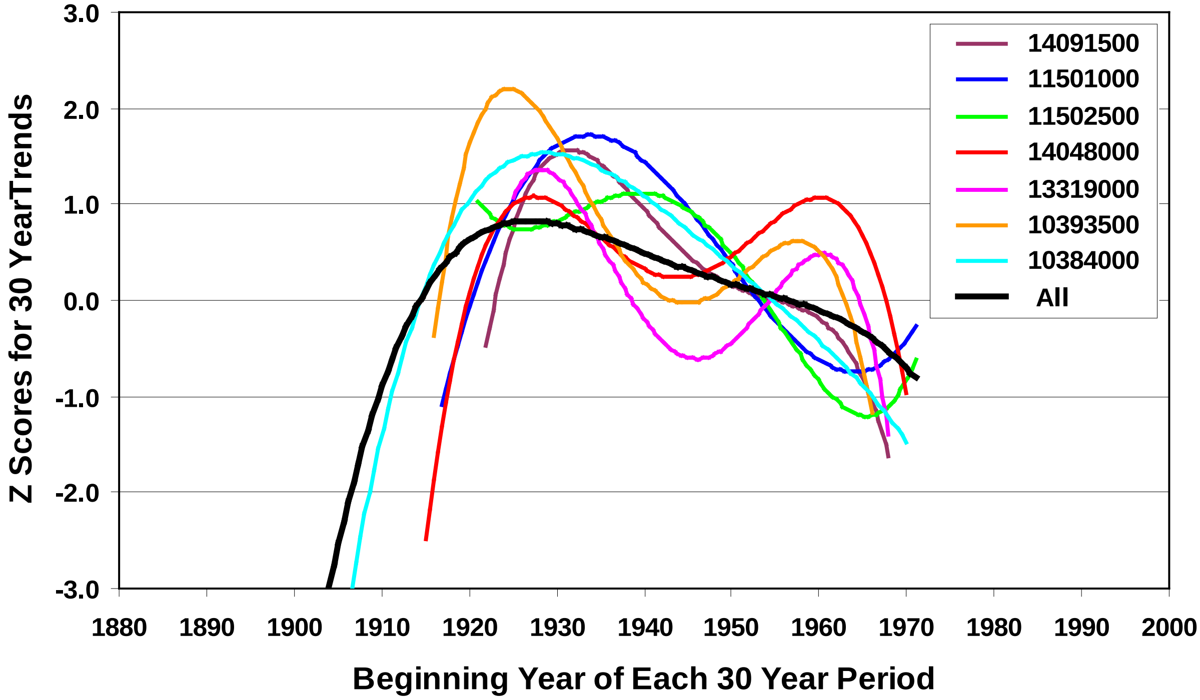



**Figure E-5.** Trend lines of z scores for the seven gaging stations with the longest periods of record compared to the trend line for z scores of all gaging stations.

**Table E-4.** The distribution of trends in annual peak data among watersheds in eastern Oregon by flood region. Trends were determined for watersheds with more than 10 years of record.

| Region | Watersheds with Positive Trends | | Watersheds with Negative Trends | | Watersheds with Trends | | Number of Watersheds |
|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | |
| **1** | 3 | 7.3 | 2 | 4.9 | 5 | 12.2 | 41 |
| **2** | 1 | 1.7 | 0 | 0.0 | 1 | 1.7 | 58 |
| **3** | 2 | 2.6 | 3 | 3.9 | 5 | 6.6 | 76 |
| **4** | 4 | 7.8 | 5 | 9.8 | 9 | 17.6 | 51 |
| **5** | 5 | 17.9 | 3 | 10.7 | 8 | 28.6 | 28 |
| **6** | 0 | 0.0 | 0 | 4.5 | 1 | 4.5 | 22 |
| **All** | 15 | 5.4 | 14 | 5.1 | 29 | 10.5 | 276 |

**Appendix F.** Available Watershed characteristics.

[Units: **mi²** = square miles, **ft** = feet, **in** = inches, **in/hr** = inches per hour, % = percent; ° = degrees, **°F** = degrees Fahrenheit]

| Characteristic | Units | Data type | Scale or resolution | Source |
|---|---|---|---|---|
| Latitude of the outlet | ° | vector | 1:24,000 | Oregon Water Resources Department |
| Longitude of the outlet | ° | vector | 1:24,000 | Oregon Water Resources Department |
| Latitude of the centroid | ° | vector | 1:24,000 | Oregon Water Resources Department |
| Longitude of the centroid | ° | vector | 1:24,000 | Oregon Water Resources Department |
| Drainage area | $mi^2$ | vector | 1:24,000 | Oregon Water Resources Department |
| Stream length | mi | vector | 1:24,000 | US Geological Survey |
| Perimeter | mi | vector | 1:24,000 | Oregon Water Resources Department |
| Area of lakes and ponds | % | vector | 1:24,000 | US Geological Survey |
| Minimum watershed elevation | ft | grid | 30 m | US Geological Survey |
| Maximum polygon elevation | ft | grid | 30 m | US Geological Survey |
| Maximum watershed elevation | ft | grid | 30 m | US Geological Survey |
| Maximum relief | ft | grid | 30 m | US Geological Survey |
| Mean watershed slope | ° | grid | 30 m | US Geological Survey |
| Mean watershed aspect | ° | grid | 30 m | US Geological Survey |
| Mean watershed elevation | ft | grid | 30 m | US Geological Survey |
| Area above 3000 feet | % | grid | 30 m | US Geological Survey |
| Area above 4000 feet | % | grid | 30 m | US Geological Survey |
| Area above 5000 feet | % | grid | 30 m | US Geological Survey |
| Area above 6000 feet | % | grid | 30 m | US Geological Survey |
| Mean soils storage capacity | in | vector | 1:250,000 | Natural Resource Conservation Service |
| Mean soils mean permeability | in/hr | vector | 1:250,000 | Natural Resource Conservation Service |
| Mean soils depth to bedrock | in | vector | 1:250,000 | Natural Resource Conservation Service |
| Mean annual precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean January precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean February precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean March precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean April precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean May precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean June precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean July precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean August precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean September precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean October precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean November precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Mean December precipitation | in | grid | 4,000 m | Oregon Climate Service |
| Precipitation intensity 2-year 1-day | in | grid | 3,000 m | Oregon Climate Service |
| Precipitation intensity 2-year 2-day | in | grid | 3,000 m | Oregon Climate Service |
| Precipitation intensity 2-year 3-day | in | grid | 3,000 m | Oregon Climate Service |
| Precipitation intensity 2-year 4-day | in | grid | 3,000 m | Oregon Climate Service |
| Precipitation intensity 2-year 5-day | in | grid | 3,000 m | Oregon Climate Service |
| Mean annual snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean January snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean February snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean March snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean April snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean May snow fall | in | grid | 4,000 m | Oregon Climate Service |

**Appendix F.** Available Watershed characteristics - continued.

[Units: **mi²** = square miles, **ft** = feet, **in** = inches, **in/hr** = inches per hour, % = percent; ° = degrees, **°F** = degrees Fahrenheit]

| Characteristic | Units | Data type | Scale or resolution | Source |
|---|---|---|---|---|
| Mean June snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean July snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean August snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean September snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean October snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean November snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean December snow fall | in | grid | 4,000 m | Oregon Climate Service |
| Mean annual minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean January minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean February minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean March minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean April minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean May minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean June minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean July minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean August minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean September minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean October minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean November minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean December minimum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean annual temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean January temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean February temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean March temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean April temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean May temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean June temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean July temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean August temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean September temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean October temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean November temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean December temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean annual maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean January maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean February maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean March maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean April maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean May maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean June maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean July maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean August maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean September maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean October maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean November maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |
| Mean December maximum temperature | °F | grid | 4,000 m | Oregon Climate Service |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 10329500 | 176.00 | 13.60 | 167 | 6220 | 2.87 | 0.429 | 1.20 | 93.2 | 21.5 | 36.6 | 51.8 | 80.6 | 0.095 | 1.12 | 40.0 |
| 10330300 | 26.90 | 18.40 | 133 | 6050 | 2.72 | 0.382 | 1.17 | 88.3 | 19.6 | 35.8 | 49.4 | 80.5 | 0.102 | 1.47 | 39.9 |
| 10352300 | 6.74 | 5.49 | 235 | 5460 | 1.51 | 0.511 | 1.00 | 46.0 | 20.4 | 37.9 | 49.6 | 82.3 | 0.092 | 2.83 | 54.1 |
| 10352500 | 225.00 | 10.20 | 164 | 5890 | 2.19 | 0.330 | 1.06 | 53.7 | 20.9 | 37.6 | 52.0 | 83.2 | 0.098 | 0.77 | 25.1 |
| 10353000 | 137.00 | 12.90 | 180 | 6120 | 2.97 | 0.478 | 1.26 | 90.7 | 25.4 | 38.2 | 54.3 | 80.0 | 0.093 | 0.78 | 33.7 |
| 10353600 | 20.10 | 24.80 | 194 | 6500 | 2.73 | 0.363 | 1.17 | 76.0 | 21.1 | 36.6 | 51.7 | 80.5 | 0.082 | 1.39 | 32.0 |
| 10353700 | 51.10 | 19.50 | 184 | 6180 | 1.61 | 0.417 | 0.93 | 46.3 | 18.4 | 38.3 | 53.5 | 86.0 | 0.085 | 2.09 | 32.6 |
| 10353750 | 14.00 | 17.50 | 199 | 7180 | 1.96 | 0.617 | 1.05 | 69.0 | 19.9 | 35.0 | 51.7 | 80.2 | 0.099 | 1.48 | 44.2 |
| 10360900 | 25.60 | 25.40 | 147 | 6690 | 4.46 | 0.442 | 1.54 | 139.0 | 19.5 | 37.5 | 46.4 | 77.2 | 0.089 | 3.36 | 39.1 |
| 10361700 | 7.68 | 6.79 | 178 | 6160 | 1.46 | 0.323 | 0.91 | 45.8 | 16.6 | 36.4 | 45.6 | 80.3 | 0.084 | 1.70 | 49.0 |
| 10366000 | 189.00 | 5.49 | 168 | 5820 | 2.01 | 0.369 | 1.01 | 54.4 | 22.2 | 38.6 | 49.3 | 80.6 | 0.099 | 1.37 | 38.8 |
| 10370000 | 66.20 | 8.68 | 166 | 6240 | 3.82 | 0.423 | 1.33 | 101.0 | 20.0 | 37.9 | 45.3 | 78.0 | 0.107 | 1.62 | 46.8 |
| 10371000 | 71.30 | 4.45 | 197 | 5930 | 1.78 | 0.414 | 0.98 | 48.0 | 19.1 | 39.6 | 46.6 | 81.4 | 0.106 | 0.90 | 37.8 |
| 10371500 | 254.00 | 6.96 | 168 | 6140 | 3.09 | 0.425 | 1.23 | 84.9 | 20.4 | 38.4 | 46.4 | 78.9 | 0.105 | 1.30 | 42.4 |
| 10378500 | 168.00 | 6.47 | 144 | 5950 | 2.53 | 0.416 | 1.14 | 70.1 | 20.6 | 38.8 | 46.1 | 80.3 | 0.096 | 1.27 | 35.2 |
| 10384000 | 267.00 | 10.80 | 167 | 6040 | 2.93 | 0.733 | 1.46 | 101.0 | 19.5 | 38.9 | 43.1 | 78.4 | 0.120 | 3.76 | 47.9 |
| 10390400 | 10.90 | 7.91 | 159 | 6210 | 3.92 | 0.915 | 1.83 | 138.0 | 20.6 | 36.3 | 44.7 | 76.2 | 0.182 | 15.00 | 60.0 |
| 10392300 | 18.30 | 10.90 | 159 | 5510 | 2.23 | 0.603 | 0.95 | 86.6 | 19.8 | 33.8 | 46.8 | 75.9 | 0.166 | 1.14 | 42.3 |
| 10392800 | 8.29 | 6.92 | 149 | 5780 | 3.00 | 0.377 | 1.26 | 140.0 | 18.9 | 32.3 | 43.8 | 71.3 | 0.140 | 0.85 | 45.2 |
| 10393500 | 913.00 | 8.09 | 173 | 5180 | 1.85 | 0.567 | 0.91 | 76.8 | 16.4 | 35.2 | 43.4 | 80.0 | 0.144 | 1.05 | 44.5 |
| 10393900 | 5.11 | 5.51 | 206 | 5380 | 1.64 | 0.616 | 0.93 | 78.0 | 17.7 | 36.9 | 41.9 | 81.1 | 0.135 | 0.86 | 42.9 |
| 10396000 | 206.00 | 9.00 | 200 | 6200 | 3.34 | 0.577 | 1.50 | 120.0 | 21.4 | 36.5 | 49.5 | 76.4 | 0.092 | 1.16 | 21.8 |
| 10397000 | 29.40 | 6.09 | 244 | 5890 | 2.73 | 0.504 | 1.34 | 82.8 | 21.1 | 36.8 | 48.5 | 77.2 | 0.092 | 1.16 | 22.0 |
| 10402800 | 72.70 | 5.85 | 185 | 5110 | 1.65 | 0.609 | 0.96 | 66.5 | 17.6 | 36.3 | 43.6 | 81.1 | 0.122 | 0.87 | 37.1 |
| 10403000 | 224.00 | 6.72 | 183 | 5160 | 1.87 | 0.548 | 1.01 | 77.5 | 18.0 | 34.9 | 45.8 | 79.4 | 0.128 | 0.87 | 39.9 |
| 10403500 | 269.00 | 6.78 | 178 | 5140 | 1.80 | 0.553 | 0.98 | 73.5 | 18.0 | 34.9 | 46.3 | 79.7 | 0.127 | 0.87 | 39.4 |
| 10406500 | 85.60 | 13.00 | 181 | 6040 | 2.24 | 0.368 | 1.12 | 62.6 | 21.1 | 37.0 | 51.6 | 80.8 | 0.086 | 1.26 | 30.6 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 11339995 | 22.60 | 13.40 | 146 | 6200 | 3.16 | 0.728 | 1.50 | 108.0 | 20.0 | 39.6 | 44.2 | 77.9 | 0.100 | 1.86 | 48.3 |
| 11340500 | 32.50 | 12.30 | 149 | 5960 | 3.00 | 0.655 | 1.41 | 96.8 | 20.0 | 39.7 | 45.0 | 78.9 | 0.100 | 1.78 | 47.0 |
| 11340950 | 30.10 | 12.00 | 166 | 6000 | 2.97 | 0.704 | 1.42 | 103.0 | 19.7 | 39.2 | 43.7 | 78.2 | 0.100 | 1.74 | 46.9 |
| 11341000 | 30.80 | 11.90 | 166 | 5980 | 2.96 | 0.696 | 1.41 | 102.0 | 19.7 | 39.2 | 43.8 | 78.4 | 0.100 | 1.72 | 46.9 |
| 11341050 | 34.40 | 9.95 | 172 | 5480 | 2.71 | 0.414 | 1.14 | 69.8 | 20.5 | 38.2 | 48.1 | 81.4 | 0.099 | 0.98 | 40.7 |
| 11341100 | 5.19 | 12.50 | 198 | 5620 | 3.46 | 0.407 | 1.24 | 88.3 | 20.7 | 37.4 | 48.3 | 79.2 | 0.097 | 1.28 | 40.3 |
| 11341200 | 11.30 | 15.90 | 192 | 6230 | 4.37 | 0.465 | 1.49 | 129.0 | 21.7 | 37.2 | 47.0 | 76.4 | 0.098 | 1.51 | 43.5 |
| 11342945 | 0.98 | 23.50 | 174 | 7050 | 2.79 | 0.681 | 1.37 | 84.7 | 21.4 | 38.4 | 47.6 | 77.7 | 0.072 | 10.20 | 34.0 |
| 11342960 | 2.43 | 5.40 | 231 | 4850 | 2.11 | 0.303 | 1.02 | 48.0 | 19.1 | 41.0 | 47.4 | 85.0 | 0.076 | 0.95 | 50.5 |
| 11348080 | 2.60 | 1.48 | 118 | 5070 | 2.35 | 0.315 | 1.13 | 54.6 | 20.2 | 41.7 | 46.6 | 85.0 | 0.080 | 1.17 | 27.8 |
| 11348560 | 0.61 | 0.44 | 120 | 4910 | 2.83 | 0.197 | 1.18 | 59.2 | 23.6 | 42.3 | 47.7 | 85.4 | 0.080 | 0.83 | 24.1 |
| 11484000 | 272.00 | 3.99 | 178 | 5180 | 2.88 | 0.511 | 1.18 | 62.4 | 21.4 | 40.4 | 47.6 | 81.0 | 0.095 | 1.37 | 38.1 |
| 11489350 | 9.76 | 5.80 | 176 | 5290 | 2.63 | 0.436 | 1.23 | 39.4 | 23.6 | 39.8 | 49.6 | 81.3 | 0.092 | 2.29 | 48.0 |
| 11489500 | 19.20 | 13.90 | 176 | 6010 | 8.88 | 0.454 | 2.19 | 139.0 | 28.4 | 40.4 | 53.9 | 81.9 | 0.050 | 1.93 | 49.4 |
| 11491800 | 2.34 | 1.35 | 196 | 5080 | 3.35 | 0.581 | 1.49 | 96.6 | 17.3 | 38.4 | 40.2 | 81.3 | 0.180 | 16.10 | 60.0 |
| 11494800 | 2.18 | 14.80 | 174 | 6600 | 2.88 | 0.858 | 1.60 | 120.0 | 20.2 | 38.0 | 44.1 | 76.0 | 0.100 | 1.61 | 44.2 |
| 11497500 | 529.00 | 6.33 | 188 | 5390 | 2.61 | 0.628 | 1.34 | 80.3 | 19.8 | 39.2 | 44.5 | 79.7 | 0.129 | 3.74 | 44.4 |
| 11497800 | 2.43 | 2.81 | 262 | 6660 | 3.12 | 0.885 | 1.60 | 127.0 | 20.2 | 35.0 | 43.3 | 72.8 | 0.187 | 11.00 | 59.5 |
| 11501000 | 1590.00 | 5.36 | 180 | 5250 | 2.76 | 0.607 | 1.38 | 76.8 | 19.3 | 38.7 | 43.6 | 80.0 | 0.154 | 5.46 | 46.5 |
| 11501300 | 5.77 | 9.21 | 217 | 5040 | 4.17 | 0.403 | 1.59 | 99.8 | 18.6 | 38.5 | 42.6 | 79.7 | 0.170 | 3.56 | 38.1 |
| 11502500 | 2990.00 | 4.78 | 168 | 5170 | 3.21 | 0.580 | 1.48 | 95.7 | 18.4 | 38.5 | 42.1 | 79.8 | 0.181 | 8.88 | 52.1 |
| 11504000 | 71.80 | 8.62 | 172 | 5440 | 6.34 | 0.556 | 2.26 | 253.0 | 18.8 | 37.2 | 41.7 | 74.8 | 0.205 | 9.15 | 56.7 |
| 11505550 | 13.60 | 7.24 | 199 | 6060 | 6.99 | 1.030 | 2.86 | 216.0 | 21.9 | 37.0 | 44.3 | 72.4 | 0.094 | 2.85 | 50.7 |
| 11516900 | 46.60 | 10.90 | 190 | 5750 | 3.41 | 0.437 | 1.48 | 61.3 | 22.6 | 35.7 | 46.5 | 76.3 | 0.081 | 4.70 | 48.1 |
| 13172666 | 0.19 | 7.95 | 140 | 6800 | 4.21 | 0.709 | 1.38 | 87.6 | 15.4 | 34.1 | 45.0 | 78.4 | 0.090 | 2.58 | 42.9 |
| 13172668 | 0.15 | 7.32 | 226 | 6830 | 4.17 | 0.709 | 1.36 | 87.3 | 15.4 | 34.1 | 45.0 | 78.3 | 0.090 | 2.58 | 42.9 |
| 13172680 | 21.10 | 13.30 | 174 | 6040 | 3.97 | 0.650 | 1.32 | 80.7 | 15.2 | 34.3 | 45.3 | 79.3 | 0.088 | 1.80 | 36.4 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 13172720 | 12.50 | 12.30 | 141 | 4880 | 1.81 | 0.433 | 0.92 | 27.8 | 16.5 | 35.8 | 47.8 | 83.6 | 0.090 | 1.57 | 37.0 |
| 13172735 | 13.90 | 14.90 | 153 | 4940 | 1.78 | 0.415 | 0.92 | 27.3 | 16.6 | 36.0 | 48.1 | 84.3 | 0.090 | 1.08 | 34.2 |
| 13172740 | 91.90 | 11.80 | 172 | 5010 | 2.35 | 0.483 | 1.01 | 39.5 | 16.4 | 35.6 | 47.6 | 82.8 | 0.088 | 1.97 | 36.9 |
| 13172800 | 1.80 | 8.54 | 160 | 4460 | 1.69 | 0.461 | 0.94 | 30.3 | 16.5 | 36.5 | 47.2 | 86.6 | 0.088 | 2.09 | 38.8 |
| 13172900 | 83.80 | 10.80 | 178 | 5280 | 2.23 | 0.520 | 1.02 | 49.5 | 16.0 | 35.7 | 47.6 | 84.1 | 0.093 | 2.06 | 43.7 |
| 13178000 | 453.00 | 11.30 | 174 | 5790 | 2.73 | 0.580 | 1.14 | 63.6 | 15.9 | 35.0 | 48.3 | 80.8 | 0.086 | 1.59 | 33.6 |
| 13182100 | 3.05 | 23.10 | 196 | 4690 | 2.23 | 0.574 | 1.07 | 50.3 | 16.2 | 35.6 | 46.8 | 84.7 | 0.104 | 0.71 | 37.5 |
| 13207000 | 19.20 | 14.80 | 204 | 4020 | 2.75 | 0.520 | 1.06 | 65.0 | 19.7 | 34.6 | 55.4 | 88.3 | 0.125 | 1.75 | 45.0 |
| 13207500 | 57.80 | 15.20 | 203 | 3990 | 2.77 | 0.522 | 1.06 | 68.3 | 19.5 | 34.4 | 55.1 | 87.9 | 0.120 | 2.92 | 47.8 |
| 13213800 | 53.00 | 9.20 | 156 | 5220 | 2.63 | 0.476 | 1.03 | 73.6 | 19.6 | 32.3 | 54.2 | 80.7 | 0.126 | 0.89 | 37.9 |
| 13213900 | 2.23 | 7.14 | 155 | 3850 | 1.38 | 0.354 | 0.71 | 20.7 | 13.4 | 34.6 | 49.1 | 89.0 | 0.110 | 0.63 | 42.9 |
| 13214000 | 944.00 | 8.98 | 168 | 4850 | 2.07 | 0.442 | 0.91 | 59.5 | 16.5 | 34.7 | 48.7 | 83.0 | 0.124 | 0.90 | 36.3 |
| 13216500 | 342.00 | 12.20 | 172 | 5360 | 2.80 | 0.628 | 1.03 | 84.0 | 17.4 | 33.6 | 49.6 | 79.7 | 0.122 | 1.05 | 33.4 |
| 13226500 | 534.00 | 10.30 | 165 | 4140 | 1.42 | 0.451 | 0.71 | 33.8 | 18.4 | 34.6 | 53.7 | 86.2 | 0.097 | 0.58 | 30.1 |
| 13228000 | 3870.00 | 9.30 | 170 | 4350 | 1.63 | 0.457 | 0.81 | 39.1 | 18.7 | 35.5 | 51.7 | 85.0 | 0.108 | 0.96 | 32.6 |
| 13228300 | 6.50 | 8.55 | 182 | 2710 | 1.33 | 0.354 | 0.71 | 15.0 | 20.1 | 37.5 | 54.6 | 93.1 | 0.090 | 0.40 | 25.8 |
| 13229400 | 1.85 | 7.73 | 165 | 4150 | 1.44 | 0.471 | 0.67 | 40.3 | 14.5 | 32.9 | 52.0 | 84.9 | 0.108 | 0.84 | 33.6 |
| 13248900 | 6.94 | 14.40 | 175 | 3890 | 2.75 | 0.505 | 1.04 | 52.4 | 19.1 | 34.8 | 54.3 | 88.8 | 0.130 | 0.60 | 41.7 |
| 13250600 | 48.90 | 13.40 | 192 | 4140 | 3.36 | 0.605 | 1.14 | 46.9 | 21.9 | 35.8 | 56.3 | 86.9 | 0.093 | 0.36 | 21.4 |
| 13250650 | 6.26 | 13.20 | 204 | 3800 | 3.06 | 0.569 | 1.11 | 41.3 | 21.9 | 36.1 | 56.7 | 88.0 | 0.090 | 0.30 | 18.2 |
| 13251300 | 3.93 | 15.60 | 133 | 4950 | 4.76 | 0.833 | 1.45 | 106.0 | 15.9 | 31.6 | 47.5 | 78.3 | 0.090 | 0.57 | 29.7 |
| 13251500 | 36.40 | 12.90 | 164 | 4660 | 4.29 | 0.790 | 1.36 | 99.9 | 13.6 | 31.2 | 46.0 | 79.7 | 0.097 | 1.20 | 34.1 |
| 13252500 | 2.24 | 15.50 | 160 | 6890 | 7.11 | 1.050 | 1.87 | 195.0 | 13.6 | 31.5 | 42.7 | 74.2 | 0.061 | 13.40 | 43.6 |
| 13253500 | 115.00 | 15.30 | 179 | 4910 | 4.82 | 0.842 | 1.45 | 117.0 | 13.1 | 31.4 | 44.8 | 79.0 | 0.091 | 1.22 | 31.2 |
| 13260000 | 55.20 | 14.80 | 175 | 4760 | 4.84 | 0.654 | 1.42 | 79.9 | 17.1 | 32.7 | 50.5 | 80.1 | 0.092 | 0.65 | 30.4 |
| 13261000 | 79.40 | 15.30 | 211 | 5320 | 4.41 | 0.792 | 1.38 | 121.0 | 16.4 | 33.0 | 46.5 | 79.0 | 0.062 | 9.96 | 36.7 |
| 13267000 | 56.00 | 18.00 | 164 | 4870 | 4.59 | 0.675 | 1.35 | 82.8 | 18.7 | 31.7 | 51.8 | 78.7 | 0.092 | 0.54 | 28.4 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 13267100 | 4.29 | 9.30 | 185 | 3260 | 3.16 | 0.404 | 1.03 | 43.8 | 17.2 | 33.5 | 56.9 | 90.4 | 0.148 | 0.61 | 44.0 |
| 13269200 | 0.89 | 9.55 | 166 | 2840 | 1.34 | 0.283 | 0.71 | 18.3 | 18.7 | 35.8 | 60.7 | 92.7 | 0.108 | 0.70 | 44.3 |
| 13269300 | 110.00 | 10.80 | 169 | 4900 | 3.15 | 0.843 | 1.06 | 95.4 | 16.9 | 32.0 | 45.6 | 77.7 | 0.167 | 1.12 | 47.6 |
| 13272300 | 0.48 | 4.24 | 120 | 3980 | 1.11 | 0.472 | 0.59 | 27.4 | 13.5 | 33.8 | 44.6 | 86.2 | 0.130 | 1.70 | 56.3 |
| 13274600 | 1.94 | 8.97 | 217 | 2980 | 1.14 | 0.396 | 0.71 | 20.8 | 18.0 | 34.9 | 51.5 | 87.1 | 0.127 | 1.21 | 58.9 |
| 13275105 | 92.20 | 15.00 | 156 | 5410 | 3.09 | 1.000 | 1.07 | 96.7 | 16.6 | 32.9 | 44.8 | 75.8 | 0.136 | 1.13 | 39.2 |
| 13275200 | 33.50 | 20.70 | 190 | 5820 | 3.37 | 1.010 | 1.12 | 98.0 | 15.5 | 33.9 | 44.2 | 75.8 | 0.128 | 1.03 | 34.8 |
| 13275500 | 216.00 | 14.90 | 167 | 5210 | 2.93 | 0.963 | 1.07 | 81.5 | 14.7 | 33.3 | 44.4 | 77.3 | 0.136 | 1.15 | 39.9 |
| 13281200 | 21.30 | 25.00 | 174 | 6930 | 4.37 | 1.230 | 1.14 | 172.0 | 15.4 | 35.8 | 41.8 | 73.3 | 0.085 | 1.28 | 26.8 |
| 13282400 | 30.80 | 16.60 | 159 | 6120 | 4.66 | 0.890 | 1.29 | 170.0 | 17.3 | 33.4 | 43.9 | 72.3 | 0.137 | 1.68 | 40.7 |
| 13283600 | 30.60 | 14.20 | 154 | 5090 | 3.45 | 0.789 | 1.18 | 107.0 | 19.5 | 31.1 | 47.1 | 72.1 | 0.154 | 1.32 | 41.7 |
| 13285900 | 27.30 | 14.40 | 192 | 5070 | 4.75 | 0.888 | 1.51 | 150.0 | 20.4 | 30.4 | 47.6 | 73.1 | 0.167 | 1.08 | 42.1 |
| 13286300 | 0.94 | 5.77 | 160 | 2950 | 1.05 | 0.472 | 0.71 | 20.0 | 18.2 | 35.2 | 50.5 | 87.5 | 0.120 | 1.17 | 58.8 |
| 13287200 | 15.60 | 20.70 | 184 | 6760 | 6.60 | 1.150 | 1.96 | 282.0 | 16.5 | 30.2 | 41.4 | 67.8 | 0.117 | 1.21 | 33.5 |
| 13288200 | 156.00 | 21.60 | 183 | 5750 | 6.52 | 0.984 | 1.86 | 239.0 | 15.4 | 31.2 | 43.0 | 72.6 | 0.116 | 0.86 | 30.2 |
| 13289100 | 6.48 | 14.50 | 187 | 3620 | 3.59 | 0.587 | 1.25 | 59.3 | 16.8 | 34.8 | 51.0 | 87.4 | 0.084 | 0.43 | 23.1 |
| 13289600 | 7.37 | 24.30 | 210 | 5920 | 5.69 | 0.759 | 1.61 | 108.0 | 16.3 | 31.4 | 46.5 | 74.8 | 0.090 | 0.57 | 29.7 |
| 13289960 | 177.00 | 16.30 | 195 | 5040 | 5.26 | 0.810 | 1.55 | 105.0 | 18.1 | 31.5 | 50.9 | 77.9 | 0.090 | 0.77 | 32.2 |
| 13290150 | 2.91 | 19.00 | 199 | 5070 | 5.88 | 0.702 | 1.68 | 121.0 | 20.8 | 32.2 | 53.4 | 78.9 | 0.170 | 1.07 | 42.5 |
| 13290190 | 297.00 | 15.30 | 165 | 4290 | 4.70 | 0.605 | 1.46 | 116.0 | 16.2 | 34.1 | 49.3 | 83.6 | 0.131 | 1.20 | 36.5 |
| 13291200 | 4.12 | 18.70 | 158 | 5190 | 4.94 | 0.742 | 1.57 | 122.0 | 21.0 | 31.1 | 51.5 | 74.6 | 0.170 | 1.07 | 42.5 |
| 13291400 | 1.75 | 21.40 | 206 | 5050 | 2.60 | 1.080 | 1.22 | 70.8 | 22.0 | 32.0 | 52.1 | 74.8 | 0.115 | 0.74 | 34.2 |
| 13292000 | 622.00 | 19.90 | 179 | 5140 | 3.91 | 1.120 | 1.50 | 132.0 | 19.1 | 31.6 | 48.2 | 73.4 | 0.129 | 0.90 | 34.1 |
| 13315500 | 15.10 | 15.70 | 162 | 4750 | 4.11 | 0.789 | 1.33 | 99.0 | 12.6 | 31.0 | 44.9 | 80.3 | 0.091 | 0.67 | 30.4 |
| 13316500 | 561.00 | 18.50 | 181 | 5440 | 5.23 | 0.997 | 1.58 | 149.0 | 13.4 | 30.7 | 44.8 | 76.8 | 0.079 | 3.59 | 30.1 |
| 13316800 | 15.30 | 17.20 | 210 | 5030 | 3.88 | 1.860 | 1.63 | 118.0 | 13.4 | 33.4 | 43.0 | 78.1 | 0.070 | 3.04 | 23.5 |
| 13317200 | 6.63 | 6.53 | 252 | 3920 | 2.43 | 1.670 | 1.51 | 87.1 | 17.8 | 35.3 | 46.7 | 79.8 | 0.148 | 1.26 | 54.6 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 13318100 | 1.78 | 7.22 | 176 | 4500 | 3.24 | 0.735 | 1.34 | 71.9 | 21.7 | 35.5 | 48.0 | 76.4 | 0.170 | 1.07 | 42.5 |
| 13318500 | 495.00 | 11.50 | 174 | 4750 | 3.16 | 0.843 | 1.30 | 85.7 | 20.3 | 36.2 | 46.6 | 75.0 | 0.154 | 1.25 | 41.0 |
| 13318800 | 543.00 | 11.40 | 173 | 4670 | 3.15 | 0.826 | 1.30 | 83.5 | 20.4 | 36.1 | 46.9 | 75.3 | 0.154 | 1.24 | 41.0 |
| 13319000 | 686.00 | 11.50 | 174 | 4580 | 3.17 | 0.790 | 1.31 | 80.5 | 20.7 | 35.9 | 47.4 | 75.7 | 0.153 | 1.23 | 40.6 |
| 13320000 | 103.00 | 15.80 | 194 | 5280 | 4.97 | 1.020 | 1.67 | 182.0 | 19.2 | 31.4 | 45.3 | 72.1 | 0.155 | 1.13 | 40.2 |
| 13320400 | 15.80 | 13.00 | 218 | 5150 | 4.99 | 1.070 | 1.80 | 170.0 | 18.7 | 33.7 | 43.9 | 73.5 | 0.159 | 1.16 | 41.3 |
| 13321300 | 15.80 | 8.63 | 190 | 4130 | 2.45 | 0.675 | 1.14 | 53.9 | 21.4 | 34.6 | 49.4 | 75.9 | 0.100 | 0.57 | 26.4 |
| 13322300 | 1.32 | 16.60 | 172 | 4450 | 6.07 | 0.850 | 1.94 | 117.0 | 22.6 | 32.8 | 48.7 | 73.5 | 0.127 | 2.02 | 41.3 |
| 13323500 | 1250.00 | 10.50 | 169 | 4220 | 3.11 | 0.776 | 1.31 | 78.9 | 20.9 | 35.5 | 47.6 | 77.4 | 0.152 | 1.29 | 42.5 |
| 13323600 | 21.40 | 12.10 | 198 | 5640 | 5.91 | 1.130 | 1.99 | 212.0 | 20.3 | 32.3 | 45.8 | 71.0 | 0.156 | 1.28 | 41.8 |
| 13323700 | 15.30 | 10.10 | 201 | 4390 | 3.97 | 0.796 | 1.42 | 114.0 | 18.9 | 33.3 | 44.6 | 77.7 | 0.164 | 0.97 | 42.7 |
| 13324150 | 1.04 | 5.16 | 216 | 3540 | 2.82 | 0.589 | 1.18 | 65.8 | 17.2 | 34.3 | 42.8 | 82.4 | 0.140 | 0.60 | 43.3 |
| 13324300 | 77.10 | 12.00 | 154 | 4380 | 5.87 | 0.855 | 1.84 | 111.0 | 21.2 | 32.9 | 46.7 | 75.8 | 0.139 | 1.38 | 39.8 |
| 13325000 | 10.20 | 25.50 | 197 | 7700 | 7.14 | 3.640 | 2.58 | 373.0 | 13.4 | 29.6 | 37.1 | 64.7 | 0.069 | 0.76 | 20.1 |
| 13325500 | 43.70 | 26.00 | 176 | 7530 | 7.07 | 3.280 | 2.54 | 369.0 | 13.5 | 29.7 | 37.2 | 64.6 | 0.082 | 0.90 | 24.0 |
| 13329500 | 29.60 | 29.00 | 169 | 7460 | 7.25 | 2.590 | 2.60 | 392.0 | 13.7 | 29.5 | 37.6 | 64.6 | 0.076 | 0.74 | 21.3 |
| 13329700 | 0.24 | 7.07 | 237 | 4520 | 1.47 | 0.699 | 1.02 | 51.8 | 14.2 | 34.8 | 42.2 | 79.0 | 0.164 | 1.02 | 41.5 |
| 13329750 | 4.23 | 6.54 | 206 | 4160 | 1.02 | 0.748 | 0.95 | 37.1 | 14.2 | 34.5 | 43.1 | 81.6 | 0.110 | 0.59 | 32.5 |
| 13330000 | 71.40 | 25.50 | 168 | 6900 | 6.54 | 1.740 | 2.27 | 331.0 | 14.8 | 30.2 | 39.2 | 65.9 | 0.120 | 1.14 | 33.3 |
| 13330500 | 67.00 | 24.30 | 174 | 5940 | 5.98 | 1.210 | 1.92 | 257.0 | 17.0 | 31.2 | 42.0 | 69.4 | 0.146 | 1.19 | 39.0 |
| 13331500 | 239.00 | 23.00 | 175 | 5700 | 5.97 | 1.130 | 1.92 | 250.0 | 16.9 | 31.3 | 41.7 | 70.5 | 0.134 | 1.08 | 36.0 |
| 13332500 | 2590.00 | 12.80 | 173 | 4510 | 3.72 | 0.929 | 1.45 | 117.0 | 18.8 | 34.1 | 45.1 | 76.5 | 0.145 | 1.30 | 40.7 |
| 13333000 | 3310.00 | 13.90 | 174 | 4410 | 3.78 | 0.936 | 1.44 | 112.0 | 18.8 | 34.0 | 45.1 | 77.0 | 0.145 | 1.25 | 40.4 |
| 13333050 | 0.49 | 1.61 | 188 | 4420 | 2.08 | 0.813 | 1.03 | 62.9 | 15.9 | 33.2 | 42.8 | 79.0 | 0.170 | 0.66 | 44.1 |
| 13333100 | 5.58 | 8.15 | 179 | 4510 | 1.52 | 0.839 | 0.97 | 45.0 | 20.3 | 33.3 | 49.0 | 75.4 | 0.170 | 1.07 | 42.5 |
| 13334700 | 171.00 | 19.30 | 170 | 3750 | 2.82 | 0.869 | 1.16 | 65.1 | 24.0 | 35.5 | 53.0 | 76.9 | 0.112 | 0.97 | 32.8 |
| 13335050 | 325.00 | 15.10 | 161 | 3360 | 2.47 | 0.827 | 1.08 | 55.4 | 23.3 | 35.7 | 52.7 | 79.7 | 0.116 | 0.93 | 32.5 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 13341100 | 8.03 | 5.28 | 167 | 4050 | 1.93 | 1.170 | 1.17 | 83.9 | 17.8 | 34.2 | 44.6 | 77.0 | 0.157 | 1.21 | 54.9 |
| 13342450 | 269.00 | 10.70 | 181 | 3150 | 1.93 | 1.050 | 1.10 | 69.1 | 20.5 | 35.7 | 48.6 | 80.5 | 0.143 | 0.87 | 51.2 |
| 14010000 | 61.80 | 24.40 | 186 | 4280 | 6.88 | 0.896 | 2.04 | 120.0 | 22.5 | 32.7 | 47.0 | 75.3 | 0.145 | 1.51 | 41.0 |
| 14010800 | 34.70 | 22.70 | 193 | 3930 | 6.59 | 0.819 | 1.96 | 95.3 | 23.3 | 34.1 | 47.1 | 78.5 | 0.153 | 1.22 | 39.9 |
| 14011000 | 42.90 | 22.50 | 193 | 3650 | 6.09 | 0.765 | 1.87 | 86.3 | 23.7 | 34.7 | 47.7 | 79.4 | 0.144 | 1.09 | 36.6 |
| 14011800 | 19.90 | 14.10 | 193 | 3060 | 4.04 | 0.605 | 1.49 | 63.6 | 25.0 | 36.2 | 50.1 | 80.8 | 0.154 | 0.94 | 38.4 |
| 14013000 | 58.60 | 26.60 | 186 | 3940 | 7.37 | 1.000 | 2.07 | 108.0 | 22.5 | 33.4 | 45.3 | 78.1 | 0.156 | 1.25 | 40.9 |
| 14013500 | 17.40 | 20.90 | 196 | 3130 | 5.88 | 0.698 | 1.79 | 54.8 | 24.4 | 36.2 | 47.7 | 83.2 | 0.163 | 1.18 | 43.0 |
| 14015900 | 1.87 | 6.79 | 225 | 1820 | 3.16 | 0.551 | 1.24 | 23.8 | 26.5 | 38.8 | 54.6 | 87.0 | 0.198 | 1.38 | 59.0 |
| 14016000 | 46.50 | 12.20 | 208 | 2380 | 4.45 | 0.634 | 1.51 | 39.6 | 25.6 | 37.8 | 51.8 | 85.4 | 0.183 | 1.49 | 53.5 |
| 14016080 | 1.18 | 3.13 | 217 | 1680 | 2.32 | 0.366 | 1.11 | 23.6 | 26.5 | 39.2 | 53.9 | 86.4 | 0.195 | 1.26 | 58.7 |
| 14016200 | 15.50 | 11.30 | 209 | 3240 | 3.86 | 0.619 | 1.47 | 67.2 | 24.8 | 36.0 | 49.6 | 80.3 | 0.153 | 0.77 | 37.8 |
| 14016500 | 107.00 | 21.00 | 194 | 3810 | 6.17 | 1.280 | 1.90 | 90.1 | 23.6 | 35.0 | 46.8 | 80.3 | 0.169 | 1.36 | 49.2 |
| 14016600 | 3.76 | 12.00 | 219 | 2950 | 3.71 | 0.779 | 1.31 | 33.3 | 24.6 | 37.9 | 51.1 | 84.5 | 0.196 | 1.17 | 55.0 |
| 14016650 | 2.97 | 10.10 | 226 | 2460 | 2.76 | 0.604 | 1.18 | 21.2 | 25.1 | 39.3 | 53.3 | 86.2 | 0.196 | 1.29 | 59.1 |
| 14017000 | 363.00 | 15.20 | 199 | 2930 | 4.40 | 0.890 | 1.50 | 52.4 | 24.6 | 37.1 | 50.5 | 83.5 | 0.182 | 1.33 | 53.4 |
| 14017040 | 3.51 | 9.65 | 208 | 2040 | 2.39 | 0.541 | 1.05 | 16.6 | 25.7 | 39.9 | 55.3 | 87.1 | 0.200 | 1.26 | 59.1 |
| 14017070 | 4.72 | 9.46 | 208 | 1920 | 2.34 | 0.539 | 1.02 | 16.5 | 25.7 | 39.7 | 55.5 | 87.3 | 0.196 | 1.27 | 59.2 |
| 14017200 | 4.21 | 11.40 | 204 | 1740 | 1.87 | 0.395 | 0.94 | 13.5 | 24.8 | 38.2 | 56.2 | 87.5 | 0.180 | 1.31 | 59.4 |
| 14017500 | 755.00 | 11.60 | 197 | 2120 | 3.08 | 0.644 | 1.20 | 32.2 | 25.3 | 38.4 | 53.7 | 85.9 | 0.183 | 1.45 | 55.1 |
| 14018500 | 1630.00 | 11.60 | 197 | 2080 | 3.31 | 0.602 | 1.27 | 37.0 | 25.5 | 38.2 | 53.4 | 85.4 | 0.172 | 1.49 | 52.5 |
| 14019400 | 0.69 | 27.80 | 146 | 3350 | 4.33 | 0.644 | 1.55 | 74.4 | 24.2 | 35.5 | 48.9 | 78.9 | 0.160 | 1.13 | 40.8 |
| 14020000 | 131.00 | 21.80 | 183 | 3970 | 5.67 | 0.789 | 1.85 | 106.0 | 23.4 | 33.8 | 49.1 | 75.4 | 0.148 | 1.45 | 41.0 |
| 14020300 | 176.00 | 19.40 | 183 | 3900 | 4.82 | 0.706 | 1.65 | 94.8 | 22.5 | 34.3 | 49.9 | 77.0 | 0.157 | 1.28 | 41.3 |
| 14020740 | 4.70 | 14.00 | 195 | 2910 | 3.92 | 0.713 | 1.40 | 64.5 | 25.0 | 37.8 | 52.3 | 81.3 | 0.134 | 0.94 | 33.0 |
| 14020800 | 4.55 | 14.60 | 187 | 2800 | 3.60 | 0.604 | 1.33 | 56.3 | 25.1 | 38.4 | 53.1 | 82.4 | 0.115 | 0.69 | 25.9 |
| 14020900 | 15.30 | 10.40 | 206 | 3010 | 3.62 | 0.566 | 1.43 | 59.2 | 24.9 | 36.7 | 50.1 | 81.7 | 0.149 | 0.72 | 36.8 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 14021000 | 638.00 | 13.90 | 189 | 2990 | 3.97 | 0.614 | 1.45 | 67.2 | 24.0 | 36.7 | 50.9 | 81.0 | 0.160 | 1.32 | 45.7 |
| 14021980 | 31.50 | 6.74 | 242 | 1980 | 2.47 | 0.456 | 1.07 | 31.8 | 25.4 | 39.7 | 53.8 | 85.6 | 0.117 | 2.53 | 47.2 |
| 14022200 | 50.80 | 14.50 | 191 | 3280 | 4.14 | 0.798 | 1.46 | 78.3 | 24.1 | 37.2 | 51.4 | 79.4 | 0.166 | 1.09 | 41.7 |
| 14022500 | 179.00 | 15.70 | 191 | 3270 | 3.45 | 0.658 | 1.32 | 64.5 | 23.6 | 37.5 | 50.8 | 79.8 | 0.150 | 1.22 | 39.7 |
| 14025000 | 285.00 | 11.30 | 175 | 3030 | 2.49 | 0.574 | 1.09 | 44.1 | 24.0 | 40.2 | 50.0 | 80.4 | 0.133 | 1.39 | 35.4 |
| 14026000 | 1270.00 | 12.60 | 187 | 2860 | 3.28 | 0.583 | 1.28 | 55.4 | 24.2 | 38.1 | 51.1 | 81.5 | 0.149 | 1.42 | 42.2 |
| 14032000 | 287.00 | 11.50 | 180 | 3140 | 2.12 | 0.564 | 0.95 | 35.2 | 23.8 | 38.9 | 49.4 | 80.9 | 0.135 | 0.92 | 27.8 |
| 14034250 | 0.29 | 5.55 | 187 | 2810 | 2.28 | 0.315 | 0.90 | 29.0 | 21.9 | 35.8 | 52.3 | 81.7 | 0.140 | 1.50 | 32.8 |
| 14034325 | 8.26 | 4.78 | 148 | 3270 | 2.47 | 0.321 | 0.94 | 31.8 | 21.3 | 35.2 | 51.7 | 80.4 | 0.140 | 1.50 | 32.8 |
| 14034370 | 1.10 | 16.20 | 229 | 4320 | 3.73 | 0.847 | 1.39 | 96.3 | 22.1 | 33.6 | 46.9 | 71.6 | 0.170 | 1.07 | 42.5 |
| 14034470 | 68.00 | 14.80 | 181 | 3770 | 2.64 | 0.676 | 1.12 | 58.3 | 23.1 | 36.2 | 47.9 | 76.4 | 0.134 | 0.91 | 31.0 |
| 14034480 | 26.30 | 12.50 | 181 | 3170 | 1.77 | 0.528 | 0.91 | 25.2 | 24.1 | 38.7 | 49.3 | 80.9 | 0.128 | 0.87 | 24.9 |
| 14034500 | 97.30 | 14.10 | 180 | 3560 | 2.37 | 0.627 | 1.05 | 48.1 | 23.4 | 37.0 | 48.4 | 77.8 | 0.133 | 0.93 | 29.6 |
| 14034800 | 114.00 | 13.30 | 187 | 3750 | 2.03 | 0.638 | 1.03 | 44.0 | 23.7 | 37.0 | 47.8 | 76.8 | 0.130 | 0.82 | 29.6 |
| 14036000 | 861.00 | 8.35 | 181 | 2310 | 1.60 | 0.402 | 0.88 | 21.9 | 25.2 | 39.5 | 52.5 | 83.9 | 0.153 | 1.28 | 38.2 |
| 14036800 | 17.50 | 18.50 | 174 | 6220 | 5.02 | 0.780 | 1.49 | 161.0 | 17.2 | 36.1 | 43.8 | 76.0 | 0.145 | 1.47 | 41.1 |
| 14037500 | 6.97 | 22.60 | 165 | 6920 | 5.28 | 0.660 | 1.48 | 187.0 | 16.8 | 35.3 | 43.4 | 75.1 | 0.139 | 1.52 | 40.3 |
| 14038500 | 230.00 | 15.30 | 188 | 5260 | 3.53 | 0.696 | 1.14 | 112.0 | 16.7 | 35.9 | 44.2 | 79.1 | 0.142 | 1.37 | 41.0 |
| 14038530 | 390.00 | 14.20 | 185 | 5000 | 3.13 | 0.654 | 1.04 | 94.2 | 17.5 | 36.1 | 44.8 | 79.9 | 0.134 | 1.25 | 39.5 |
| 14038550 | 24.70 | 20.00 | 205 | 5760 | 3.10 | 0.621 | 1.00 | 103.0 | 16.5 | 34.8 | 44.1 | 77.3 | 0.141 | 1.14 | 37.1 |
| 14038600 | 4.96 | 19.60 | 163 | 5050 | 2.20 | 0.618 | 0.85 | 61.8 | 20.2 | 35.9 | 48.3 | 79.5 | 0.119 | 1.18 | 32.8 |
| 14038602 | 86.20 | 18.60 | 191 | 5340 | 2.74 | 0.601 | 0.96 | 93.1 | 16.7 | 35.3 | 44.5 | 78.4 | 0.131 | 1.05 | 34.1 |
| 14038750 | 1.70 | 11.70 | 170 | 5110 | 2.34 | 0.590 | 0.82 | 55.8 | 20.4 | 35.4 | 45.9 | 77.8 | 0.170 | 1.07 | 42.5 |
| 14038900 | 17.70 | 21.90 | 177 | 4960 | 2.47 | 0.572 | 0.94 | 69.2 | 21.7 | 35.5 | 49.4 | 77.7 | 0.120 | 0.97 | 28.2 |
| 14039200 | 11.10 | 11.40 | 207 | 5520 | 2.29 | 0.621 | 1.03 | 104.0 | 17.2 | 33.8 | 43.1 | 77.0 | 0.167 | 1.07 | 42.0 |
| 14040500 | 1690.00 | 14.80 | 183 | 4640 | 2.34 | 0.569 | 0.93 | 66.6 | 19.3 | 36.8 | 46.1 | 80.8 | 0.131 | 1.00 | 37.5 |
| 14040600 | 27.40 | 10.30 | 184 | 5110 | 3.20 | 0.825 | 1.42 | 69.8 | 20.4 | 35.6 | 45.1 | 74.9 | 0.162 | 1.00 | 40.0 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 14040700 | 2.27 | 5.91 | 164 | 4300 | 2.73 | 0.663 | 1.18 | 58.6 | 19.7 | 36.9 | 45.9 | 78.4 | 0.131 | 0.70 | 27.3 |
| 14040900 | 4.57 | 10.90 | 217 | 5230 | 3.43 | 0.714 | 1.13 | 93.0 | 19.6 | 36.4 | 44.6 | 73.9 | 0.165 | 1.14 | 42.3 |
| 14041000 | 108.00 | 10.80 | 186 | 5270 | 3.64 | 0.737 | 1.15 | 102.0 | 18.7 | 35.7 | 43.9 | 74.4 | 0.152 | 1.27 | 40.8 |
| 14041500 | 534.00 | 14.50 | 182 | 5420 | 3.65 | 0.811 | 1.18 | 109.0 | 18.6 | 34.7 | 44.7 | 74.3 | 0.146 | 1.32 | 40.0 |
| 14041900 | 2.30 | 7.86 | 190 | 4560 | 2.83 | 0.886 | 1.23 | 71.7 | 19.9 | 37.5 | 45.2 | 74.2 | 0.170 | 1.07 | 42.5 |
| 14042000 | 60.80 | 6.70 | 179 | 4690 | 2.68 | 0.986 | 1.25 | 71.3 | 20.4 | 37.6 | 45.9 | 73.8 | 0.165 | 1.14 | 42.2 |
| 14042500 | 121.00 | 8.67 | 183 | 4730 | 2.84 | 0.948 | 1.25 | 74.1 | 20.1 | 37.5 | 45.4 | 73.6 | 0.162 | 1.16 | 42.3 |
| 14043800 | 6.97 | 12.90 | 157 | 5310 | 3.45 | 0.758 | 1.16 | 120.0 | 18.5 | 35.0 | 45.6 | 78.3 | 0.167 | 1.12 | 42.3 |
| 14043850 | 3.78 | 10.50 | 154 | 5110 | 2.66 | 0.668 | 0.91 | 64.6 | 19.3 | 35.6 | 44.4 | 78.8 | 0.167 | 1.12 | 42.3 |
| 14043900 | 1.80 | 9.28 | 183 | 4110 | 1.85 | 0.630 | 0.87 | 37.8 | 20.0 | 38.4 | 44.4 | 79.8 | 0.100 | 0.89 | 21.3 |
| 14044000 | 523.00 | 12.80 | 183 | 4780 | 2.93 | 0.719 | 1.02 | 87.2 | 17.8 | 35.6 | 44.0 | 79.0 | 0.144 | 0.99 | 38.4 |
| 14044100 | 3.52 | 9.48 | 101 | 4540 | 1.90 | 0.572 | 0.82 | 43.1 | 20.7 | 37.3 | 45.2 | 80.0 | 0.137 | 0.76 | 29.6 |
| 14044500 | 92.60 | 6.88 | 188 | 4820 | 2.27 | 0.456 | 0.80 | 52.4 | 20.8 | 36.2 | 46.0 | 78.2 | 0.154 | 1.22 | 50.7 |
| 14046000 | 2530.00 | 11.70 | 178 | 4540 | 2.65 | 0.699 | 1.03 | 69.1 | 19.7 | 36.5 | 45.1 | 77.9 | 0.140 | 1.03 | 36.7 |
| 14046250 | 2.87 | 14.30 | 237 | 3520 | 1.79 | 0.551 | 0.94 | 28.1 | 23.1 | 39.3 | 47.6 | 82.9 | 0.121 | 0.77 | 37.7 |
| 14046300 | 5.52 | 19.90 | 183 | 3970 | 1.81 | 0.560 | 1.04 | 25.7 | 22.6 | 38.5 | 45.6 | 80.2 | 0.140 | 0.85 | 45.2 |
| 14046500 | 5140.00 | 13.00 | 179 | 4440 | 2.41 | 0.633 | 0.99 | 62.1 | 20.0 | 37.1 | 45.9 | 79.7 | 0.133 | 0.96 | 36.3 |
| 14047100 | 8.34 | 16.10 | 169 | 3890 | 1.89 | 0.580 | 1.07 | 25.3 | 22.7 | 38.4 | 45.2 | 79.5 | 0.140 | 0.85 | 45.2 |
| 14047350 | 6.23 | 11.00 | 185 | 4120 | 1.97 | 0.667 | 1.05 | 45.0 | 24.0 | 36.7 | 47.4 | 75.7 | 0.133 | 0.86 | 41.0 |
| 14047380 | 68.80 | 10.20 | 176 | 4130 | 1.81 | 0.649 | 1.03 | 37.5 | 22.4 | 36.5 | 45.5 | 76.3 | 0.142 | 0.82 | 45.2 |
| 14047390 | 308.00 | 12.00 | 178 | 3640 | 1.70 | 0.601 | 0.99 | 31.8 | 23.0 | 37.3 | 46.9 | 78.2 | 0.124 | 0.80 | 33.0 |
| 14048000 | 7630.00 | 13.10 | 179 | 3920 | 2.14 | 0.585 | 0.98 | 48.7 | 21.2 | 37.7 | 47.2 | 80.7 | 0.132 | 0.89 | 36.9 |
| 14048040 | 8.83 | 4.21 | 153 | 1980 | 1.52 | 0.276 | 0.83 | 17.8 | 24.4 | 38.2 | 53.6 | 82.4 | 0.180 | 1.29 | 59.1 |
| 14048300 | 8.17 | 2.92 | 180 | 1540 | 1.64 | 0.276 | 0.87 | 14.0 | 25.2 | 39.1 | 54.3 | 83.8 | 0.180 | 1.29 | 59.1 |
| 14048310 | 6.18 | 3.47 | 179 | 1590 | 1.68 | 0.276 | 0.89 | 14.7 | 25.0 | 38.9 | 54.0 | 83.4 | 0.180 | 1.29 | 59.1 |
| 14050000 | 115.00 | 8.65 | 187 | 5760 | 10.10 | 1.220 | 3.12 | 333.0 | 20.6 | 35.2 | 41.2 | 69.6 | 0.092 | 4.43 | 41.3 |
| 14050500 | 16.80 | 5.03 | 162 | 5160 | 8.93 | 1.130 | 2.88 | 260.0 | 21.5 | 36.6 | 44.4 | 72.4 | 0.104 | 4.81 | 48.6 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 14051000 | 33.40 | 6.15 | 137 | 5240 | 8.59 | 1.270 | 2.92 | 273.0 | 22.0 | 35.8 | 43.4 | 71.1 | 0.118 | 6.28 | 48.4 |
| 14052000 | 14.50 | 6.44 | 134 | 5310 | 7.96 | 1.280 | 2.68 | 263.0 | 21.5 | 35.2 | 43.4 | 71.3 | 0.127 | 6.79 | 51.2 |
| 14053000 | 15.10 | 5.37 | 131 | 5400 | 7.88 | 1.230 | 2.63 | 263.0 | 21.7 | 34.9 | 43.0 | 71.3 | 0.108 | 5.18 | 48.9 |
| 14054500 | 20.40 | 5.10 | 121 | 5190 | 6.31 | 0.931 | 2.14 | 200.0 | 20.9 | 35.8 | 43.8 | 73.3 | 0.138 | 7.46 | 52.9 |
| 14055500 | 36.50 | 8.06 | 133 | 5630 | 7.76 | 1.020 | 2.64 | 252.0 | 21.5 | 35.6 | 40.8 | 71.9 | 0.079 | 3.31 | 40.7 |
| 14055600 | 46.80 | 8.10 | 144 | 5500 | 7.42 | 0.900 | 2.46 | 231.0 | 21.4 | 36.1 | 41.1 | 72.5 | 0.099 | 4.87 | 44.1 |
| 14061000 | 48.50 | 7.98 | 150 | 5270 | 6.18 | 0.785 | 2.23 | 211.0 | 20.0 | 38.3 | 40.4 | 74.7 | 0.142 | 8.59 | 53.3 |
| 14073000 | 48.30 | 8.94 | 142 | 5700 | 5.59 | 1.080 | 2.04 | 183.0 | 21.0 | 34.9 | 42.2 | 71.8 | 0.080 | 6.14 | 42.2 |
| 14075000 | 55.40 | 11.40 | 149 | 5920 | 8.31 | 1.220 | 2.64 | 288.0 | 19.7 | 35.1 | 39.7 | 69.8 | 0.065 | 6.61 | 39.3 |
| 14077500 | 65.20 | 6.87 | 196 | 4660 | 2.65 | 0.513 | 1.02 | 63.6 | 19.6 | 37.0 | 46.1 | 82.0 | 0.112 | 1.10 | 33.6 |
| 14077800 | 2.14 | 11.00 | 215 | 5140 | 3.19 | 0.581 | 1.16 | 78.7 | 22.2 | 36.1 | 47.2 | 78.1 | 0.124 | 0.81 | 39.2 |
| 14078000 | 451.00 | 6.97 | 187 | 4580 | 2.25 | 0.534 | 1.02 | 62.1 | 18.1 | 36.6 | 44.7 | 82.1 | 0.104 | 1.23 | 30.9 |
| 14078200 | 19.40 | 6.92 | 162 | 4900 | 1.37 | 0.572 | 0.80 | 42.4 | 18.6 | 37.1 | 46.1 | 82.6 | 0.092 | 1.12 | 28.0 |
| 14078400 | 7.20 | 8.36 | 117 | 5570 | 2.84 | 0.978 | 1.32 | 71.3 | 18.7 | 35.5 | 44.9 | 76.8 | 0.140 | 0.85 | 45.2 |
| 14078500 | 161.00 | 7.10 | 160 | 5130 | 2.86 | 0.961 | 1.32 | 66.7 | 19.5 | 35.8 | 45.0 | 77.3 | 0.137 | 0.88 | 44.0 |
| 14079500 | 1990.00 | 5.83 | 173 | 4660 | 1.86 | 0.602 | 0.96 | 50.1 | 17.9 | 36.9 | 44.9 | 81.9 | 0.107 | 1.29 | 32.8 |
| 14079800 | 2240.00 | 6.34 | 174 | 4630 | 1.85 | 0.605 | 0.96 | 49.3 | 18.0 | 37.0 | 44.9 | 81.8 | 0.109 | 1.25 | 33.1 |
| 14080500 | 2550.00 | 6.65 | 175 | 4600 | 1.79 | 0.597 | 0.95 | 47.3 | 18.1 | 37.1 | 44.8 | 81.8 | 0.106 | 1.24 | 32.7 |
| 14080600 | 14.50 | 5.35 | 216 | 4370 | 1.92 | 0.545 | 1.06 | 35.2 | 20.6 | 39.0 | 43.9 | 81.3 | 0.080 | 0.67 | 27.0 |
| 14081800 | 2.29 | 8.53 | 172 | 5160 | 3.40 | 1.300 | 1.51 | 77.8 | 20.7 | 35.2 | 44.5 | 75.1 | 0.170 | 1.07 | 42.5 |
| 14083000 | 200.00 | 12.70 | 191 | 4550 | 2.33 | 0.783 | 1.20 | 50.5 | 18.9 | 36.7 | 42.7 | 79.6 | 0.130 | 0.83 | 41.4 |
| 14083500 | 70.70 | 15.80 | 183 | 4560 | 2.14 | 0.668 | 1.14 | 44.5 | 18.7 | 36.9 | 41.9 | 80.0 | 0.134 | 0.83 | 43.4 |
| 14088000 | 21.10 | 8.14 | 151 | 4430 | 8.58 | 0.841 | 2.18 | 264.0 | 22.0 | 37.1 | 42.7 | 74.1 | 0.088 | 9.42 | 55.6 |
| 14090350 | 27.90 | 16.30 | 147 | 5120 | 8.26 | 1.060 | 2.45 | 211.0 | 23.0 | 37.2 | 43.6 | 72.0 | 0.075 | 5.94 | 45.5 |
| 14090400 | 22.90 | 19.30 | 148 | 5140 | 10.30 | 1.070 | 2.85 | 253.0 | 23.7 | 36.9 | 45.1 | 71.4 | 0.073 | 5.22 | 44.1 |
| 14091500 | 319.00 | 11.70 | 142 | 4170 | 6.22 | 0.747 | 1.85 | 151.0 | 23.3 | 38.0 | 44.2 | 76.5 | 0.092 | 6.09 | 51.2 |
| 14092750 | 22.20 | 15.00 | 148 | 4860 | 9.90 | 1.020 | 2.76 | 228.0 | 24.7 | 37.3 | 46.6 | 72.4 | 0.083 | 6.56 | 50.7 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 14092885 | 75.30 | 10.10 | 142 | 3560 | 5.61 | 0.571 | 1.71 | 106.0 | 25.2 | 39.4 | 48.2 | 80.1 | 0.093 | 3.19 | 40.5 |
| 14093000 | 105.00 | 9.72 | 145 | 3200 | 4.60 | 0.490 | 1.48 | 80.3 | 25.2 | 40.5 | 48.5 | 82.8 | 0.101 | 2.46 | 40.5 |
| 14093600 | 119.00 | 13.10 | 183 | 4360 | 2.07 | 0.686 | 1.12 | 38.2 | 20.2 | 37.7 | 43.2 | 79.9 | 0.137 | 0.71 | 48.5 |
| 14093700 | 1.43 | 11.50 | 149 | 3190 | 1.57 | 0.394 | 0.95 | 15.9 | 22.6 | 40.3 | 45.2 | 83.2 | 0.130 | 0.37 | 56.6 |
| 14095500 | 106.00 | 7.66 | 156 | 3730 | 7.22 | 0.709 | 1.99 | 155.0 | 24.6 | 37.2 | 47.3 | 75.2 | 0.083 | 4.67 | 48.2 |
| 14096300 | 25.80 | 12.00 | 163 | 4770 | 10.80 | 1.030 | 2.94 | 246.0 | 24.7 | 36.6 | 46.2 | 71.6 | 0.087 | 7.76 | 53.8 |
| 14096850 | 145.00 | 7.35 | 166 | 3090 | 4.43 | 0.377 | 1.39 | 70.1 | 25.3 | 39.0 | 49.8 | 79.8 | 0.088 | 2.28 | 41.3 |
| 14097100 | 525.00 | 7.53 | 160 | 3300 | 5.42 | 0.487 | 1.61 | 97.3 | 25.1 | 38.9 | 48.7 | 79.3 | 0.092 | 2.99 | 43.5 |
| 14097200 | 40.40 | 15.70 | 164 | 4220 | 8.11 | 0.934 | 2.16 | 199.0 | 24.5 | 34.8 | 46.9 | 68.7 | 0.095 | 3.20 | 46.8 |
| 14100800 | 8.97 | 14.70 | 143 | 3770 | 5.81 | 0.465 | 1.65 | 101.0 | 25.9 | 37.0 | 50.5 | 75.1 | 0.128 | 2.72 | 50.7 |
| 14101500 | 398.00 | 9.85 | 150 | 2960 | 4.77 | 0.419 | 1.45 | 84.3 | 24.5 | 37.8 | 50.0 | 78.5 | 0.119 | 2.10 | 42.4 |
| 14104100 | 3.92 | 10.40 | 134 | 3860 | 6.88 | 0.635 | 1.99 | 136.0 | 26.5 | 37.0 | 51.1 | 72.9 | 0.113 | 3.25 | 52.0 |
| 14104500 | 175.00 | 8.83 | 184 | 2350 | 3.13 | 0.295 | 1.13 | 41.1 | 24.5 | 38.8 | 50.2 | 81.5 | 0.135 | 1.33 | 35.0 |
| 14107000 | 152.00 | 14.00 | 175 | 4690 | 6.80 | 0.794 | 1.93 | 156.0 | 22.9 | 32.6 | 46.6 | 70.3 | 0.106 | 2.71 | 52.7 |
| 14110000 | 360.00 | 12.40 | 159 | 4520 | 7.97 | 0.833 | 2.10 | 176.0 | 23.8 | 33.2 | 46.8 | 70.7 | 0.102 | 2.89 | 52.9 |
| 14111800 | 10.30 | 10.90 | 134 | 4060 | 4.75 | 0.316 | 1.39 | 76.5 | 19.4 | 34.2 | 43.0 | 79.1 | 0.122 | 1.74 | 53.4 |
| 14112000 | 81.50 | 8.37 | 176 | 3090 | 4.31 | 0.276 | 1.30 | 54.9 | 20.7 | 35.1 | 45.3 | 81.0 | 0.144 | 1.42 | 54.7 |
| 14112200 | 0.73 | 4.67 | 250 | 1910 | 3.71 | 0.234 | 1.19 | 34.2 | 22.6 | 36.5 | 48.2 | 83.4 | 0.168 | 1.22 | 53.6 |
| 14112500 | 281.00 | 6.55 | 190 | 2540 | 4.41 | 0.254 | 1.31 | 52.5 | 22.1 | 36.0 | 46.8 | 81.9 | 0.153 | 1.36 | 51.9 |
| 14113000 | 1300.00 | 8.46 | 176 | 3050 | 6.11 | 0.441 | 1.66 | 98.8 | 23.6 | 35.5 | 47.4 | 78.2 | 0.134 | 1.99 | 53.2 |
| 14113200 | 41.40 | 12.90 | 168 | 2180 | 5.51 | 0.281 | 1.60 | 62.2 | 26.0 | 38.9 | 52.5 | 79.8 | 0.158 | 1.51 | 49.8 |
| 14113400 | 4.64 | 10.10 | 182 | 5180 | 11.80 | 1.110 | 3.20 | 308.0 | 25.7 | 35.0 | 48.8 | 68.2 | 0.150 | 3.74 | 60.0 |
| 14118500 | 95.80 | 18.10 | 177 | 3140 | 13.30 | 1.350 | 3.25 | 208.0 | 25.2 | 36.2 | 48.8 | 71.9 | 0.150 | 2.47 | 49.9 |
| 14120000 | 278.00 | 15.80 | 171 | 3350 | 11.70 | 1.070 | 2.99 | 223.0 | 25.0 | 36.0 | 49.0 | 71.3 | 0.147 | 2.57 | 51.8 |
| 14121000 | 332.00 | 15.00 | 175 | 3090 | 11.00 | 0.952 | 2.84 | 200.0 | 25.2 | 36.4 | 49.5 | 72.4 | 0.148 | 2.39 | 51.9 |
| 14121300 | 29.60 | 14.30 | 213 | 5190 | 14.80 | 1.620 | 3.52 | 353.0 | 24.6 | 33.5 | 49.5 | 66.9 | 0.108 | 1.92 | 52.0 |
| 14121500 | 67.00 | 9.92 | 151 | 3570 | 12.40 | 1.370 | 3.10 | 178.0 | 26.0 | 35.9 | 50.4 | 73.4 | 0.115 | 2.75 | 52.5 |

**Appendix G.** Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

| Station number | Watershed characteristics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Slope | Aspect | Elev | Jan P | Jul P | I24-2 | Snow | Mn Jan T | Mx Jan T | Mn Jul T | Mx Jul T | Soil C | Soil P | Soil D |
| 14122000 | 177.00 | 10.40 | 171 | 3930 | 11.90 | 1.150 | 2.93 | 212.0 | 25.3 | 35.1 | 49.6 | 72.3 | 0.110 | 2.66 | 52.5 |
| 14123000 | 296.00 | 10.20 | 173 | 3340 | 10.70 | 0.852 | 2.64 | 172.0 | 25.1 | 35.6 | 49.6 | 74.8 | 0.114 | 2.83 | 54.2 |
| 14123500 | 386.00 | 10.70 | 175 | 3000 | 9.89 | 0.729 | 2.47 | 149.0 | 25.0 | 35.8 | 49.8 | 76.0 | 0.121 | 2.51 | 54.2 |
| 14124500 | 114.00 | 12.30 | 166 | 2970 | 12.90 | 0.740 | 3.03 | 153.0 | 25.5 | 35.2 | 50.2 | 74.2 | 0.101 | 3.30 | 55.7 |
| 14125000 | 116.00 | 12.30 | 165 | 2940 | 12.90 | 0.733 | 3.02 | 152.0 | 25.5 | 35.2 | 50.2 | 74.3 | 0.102 | 3.26 | 55.7 |
| 14125500 | 134.00 | 12.60 | 166 | 2770 | 12.50 | 0.691 | 2.96 | 142.0 | 25.7 | 35.7 | 50.4 | 75.1 | 0.104 | 3.01 | 55.7 |