Hydroclimatology of flow events in the Gila River basin, central and southern Arizona

HYDROCLIMATOLOGY OF FLOW EVENTS
IN THE GILA RIVER BASIN, CENTRAL AND SOUTHERN ARIZONA

by

Katherine Kristin Hirschboeck

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF GEOSCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 8 5

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Katherine Kristin Hirschboeck

entitled Hydroclimatology of Flow Events in the Gila River Basin, Central and Southern Arizona

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Victor R. Baker	4/19/85 Date
Charles W. Stockton	4/19/85 Date
E. J. McCullough	4-19-85 Date
R. W. Reeves	4-18-85 Date
Anthony J. Brazel	4-18-85 Date

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Victor R. Baker
Dissertation Director

19 April 1985
Date

STATEMENT BY AUTHOR

This dissertation

is dedicated to my parents

for having first nurtured within me

a love for nature

and

an inquiring mind.

ACKNOWLEDGMENTS

This dissertation would not have been possible without the assistance of many people. I gratefully acknowledge the untiring support of my dissertation committee, especially the directors, Victor Baker and Charles Stockton. I thank them not only for their input and suggestions, but also for their constant encouragement during various stages of my graduate career. I am also especially grateful for the long-standing support of Edgar J. McCullough, Jr. during my years at Arizona. Richard Reeves and Anthony Brazel were always encouraging and were most helpful in providing suggestions and assistance during initial and completion stages of the dissertation.

It would be impossible to name all those others who, through their support and care, made the completion of this work possible. However, the following provided assistance beyond the call of duty: Patrick J. Bartlein offered much advice and encouragement in the early stages of this research. Brenda Keller was instrumental in helping me to develop my computer and programming skills and spent numerous hours writing and debugging programs for me and with me. The data analysis portion of this research would not have been possible without her. Richard Porter spent many tedious hours helping me collect portions of the daily precipitation data. Ellen White and Mary Lee Eggart drafted several of the figures, and Don Rome also helped with figure preparation. To all of them I give my sincere thanks.

I gratefully acknowledge the Geosciences Department at the University of Arizona for providing computer money for a significant amount of this research. The Graduate School Development Fund also assisted in data collection expenses. A large portion of the flood and climate data was provided without charge from the U. S. Geological Survey and the Laboratory of Tree-Ring Research, respectively.

Finally, I would like to thank, in a special way, all of my family and friends located throughout the country -- from New England, Wisconsin, Baton Rouge, Oklahoma, California, Oregon, and many other places -- for giving me the strength, encouragement, and moral support to persist in this effort and see it to completion.

TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

TABLE OF CONTENTS--Continued

TABLE OF CONTENTS--Continued

TABLE OF CONTENTS -- Continued

LIST OF ILLUSTRATIONS

Page

Figure

LIST OF ILLUSTRATIONS -- Continued

LIST OF ILLUSTRATIONS -- Continued

LIST OF TABLES

ABSTRACT

Traditional flood-frequency techniques are based on the assumption that the observed flood record represents a sample that has been drawn from a single climatically homogeneous population of floods. A hydroclimatic approach was used to evaluate this assumption by identifying the circulation patterns and atmospheric flood-generating mechanisms which control the temporal and spatial variability of flooding.

Mean monthly discharges and instantaneous peak flows of the partial duration series were analyzed for thirty gaging stations in the climatically sensitive, semiarid, Gila River basin for the period 1950 to 1980. Correlation fields and composite maps were constructed to define the relationship between 700 mb height circulation anomalies and mean monthly streamflow. Individual flood events were linked to climate by analyzing daily synoptic weather maps and classifying each flood event into one of eight hydroclimatic categories on the basis of the atmospheric mechanisms which generated each flow.

The analysis demonstrated that floods and anomalously high streamflow in the Gila River basin originate from a variety of atmospheric processes which vary spatially, seasonally, and from year-to-year. The mechanisms most important for generating floods included winter fronts, cutoff lows, tropical storms, snowmelt, and widespread and localized summer monsoon-related circulation patterns.

When flood discharges were grouped into hydroclimatically homogeneous categories, histogram plots of their frequency distributions exhibited means and variances that differed from those of the overall frequency distribution of the entire flood series. The means of the discharges generated by frontal precipitation and tropical storms tended to plot above the mean of the overall series, while the means of floods generated by snowmelt tended to plot below the overall mean. Flood estimates computed from a series containing mixed distributions were not the same as flood estimates computed from climatically homogeneous subsets of the same series.

These results have implications for traditional flood-frequency analysis and other stochastic methods of analyzing hydrologic time series. The hydroclimatically-defined subgroups in the flood series of the Gila River basin indicate that nonhomogeneity and nonstationarity can be imparted to a hydrologic time series by differing atmospheric mechanisms alone.

CHAPTER 1

INTRODUCTION

Extreme flow events in the normally dry stream channels of the Desert Southwest have been responsible for severe erosion, extensive property damage, road closures, bridge collapses, and loss of life. As rapid urbanization of the Southwest continues, there is an ever-growing need for a better understanding of the nature of flooding and the variability in flow regimes of arid and semi-arid streams.

Traditional methods of analyzing flow events were developed primarily for perennial streams in humid regions and are not always suitable for application to more arid environments. Extremely variable arid streamflow regimes tend to exhibit highly skewed or complex frequency distributions which impede the use of conventional techniques such as probabilistic flood-frequency analysis. New and sophisticated models and methodologies are continuously being proposed to provide better statistical fits for the observed data in streamflow series, yet nearly all are based on certain underlying assumptions that may be violated due to the inherent nature of streamflow in arid regions -- and perhaps in humid regions as well.

The importance of climate as a source of variability, non-stationarity, and nonhomogeneity in streamflow regimes has been both recognized and hotly debated in recent years. Nevertheless, the assumptions of stationarity and homogeneity form the basis for most of the current methods of hydrologic time series analysis. Arid streamflow regimes, which are especially sensitive to variations in climate, are by their very nature most susceptible to violations of these basic assumptions. It is therefore essential that climate fluctuations not be "filtered out" or removed, but thoroughly examined, when modeling flow variability in arid streams.

In a recent paper, Ronald F. Kilmartin (1980) called for the active development and growth of a much needed new cross-discipline -- hydroclimatology -- which he described as the "modeling of long-term climatic fluctuations in water resources systems analysis" (p. 166). Kilmartin cited the need to close some gaps between the closely related disciplines of hydrology, meteorology, climatology, oceanography, and statistics, and to expand and develop the approach to hydrologic problems that is already found in the cross-discipline of hydrometeorology. Although Kilmartin's emphasis was on long-period events in hydrology with specific reference to the consideration of past and future climatic changes, a cross-disciplinary approach is also needed for short-period hydrologic events, such as those in an annual or partial duration flood series. Even within a secular time framework, decadal-scale climatic variability and infrequent extreme events will have a major impact on a 30- or 40-year flood record, whether or not an actual "climatic change" is perceived to have transpired.

Until very recently, the status quo of flood-frequency analysis, and other areas of hydrology as well, has been to treat events in a hydrologic time series only as a set of varying time-dependent numerical values. The quantitative techniques which have been developed and refined through the years to manipulate series of flood values have reached a certain degree of sophistication. Yet somehow the obvious fact that these values represent a response to varying processes in the physical world, such as climate, has tended to become less important than the urge to statistically model flood values in search of the best fit of the observed data and therefore (ideally) the best predictive capability for future flows:

> ...the main emphasis in stochastic analysis of hydrological processes, which basically is the domain of pure hydrology, has been on the fitting of various preconceived mathematical models to empirical data rather than on arriving at a proper model from the physical nature of the process itself. The empirical data representing a hydrologic event are treated as a collection of abstract numbers that could pertain to anything or to nothing at all. Their hydrologic flavor, the physical substance that makes, for instance, a precipitation record an entity entirely distinct from, say, a record of stock market fluctuations, is not reflected in the analysis. Thus what we usually find is not, in fact, statistical or stochastic hydrology but merely an illustration of statistical and probabilistic concepts by means of hydrologic data. Such an approach can hardly contribute to the hydrological knowledge.
>
> In trying to improve this situation, the main problem is to find the ways in which the physical features of a phenomenon can be introduced into the analysis. (Klemes 1974a, p. 2)

The cross-discipline of hydroclimatology embodies within it just such a way to introduce the physical features of the hydrologic response to climate into various analyses and to integrate the physical sources of variability in a hydrologic time series with the statistical properties of the varying series itself.

Hydroclimatology also offers the possibility of bridging some of the gaps between the deterministic and stochastic schools in hydrology. Deterministic approaches, by their very nature, are heavily dependent on the input of climatic information to compute a hydrologic output. Criticisms often raised against deterministic methods are that modeling of the climatic-hydrologic relationship generally involves only the means of variables and that the models are based on constraining underlying assumptions about the environment that over-simplify the processes operating in the real world and neglect the large number of random factors which can affect the responses of natural hydrologic systems (Yevjevich 1974). Stochastic approaches, on the other hand, tend to constrain themselves at the opposite end of the spectrum by having as their basis the underlying assumption that all hydrologic processes should be viewed as "random numbers of random variables" or as "...a function of an infinite number of causative random variables, independent among themselves, each one having a very small additive effect on the phenomenon...." (Yevjevich 1974, p. 232). To a stochastic hydrologist such an assumption is, in effect, liberating (rather than constraining) because it allows hydrologic processes to be modeled statistically on the basis of the central limit theorem using probability density functions. At the same time this assumption, in practice, has tended to limit the scope of stochastic hydrology by focusing analysis on the hydrologic time series itself and appearing to eliminate the need to examine hydrologic events from any sort of deterministic viewpoint, especially in terms of the climatic origins of the events.

A hydroclimatic approach to the analysis of a time series of flows can interpret each hydrologic event in terms of its climatologic origins. Extreme events or exceedance events in hydrologic time series can be viewed not only as "random numbers of random variables," but as real-world physical events occurring within the context of a history of climatic variations in magnitude, frequency, and seasonality, and within a spatial framework of regional and global networks of changing combinations of meteorological features and circulation patterns.

The purpose of this dissertation is to apply a hydroclimatic approach to the analysis of flow events at 30 stream gaging stations located in the arid and semiarid Gila River Basin of central and southern Arizona. The study seeks to identify the climatic causes for the occurrence of individual flood flows and define the synoptic climatic patterns which are associated with the flows. The resulting physically-based understanding of the nature of floodflow variability is then used to reevaluate some statistical properties of the flood time series and explore some of the basic underlying assumptions in traditional probabilistic flood-frequency analysis. The goal of this research is to develop deeper insights into the contribution of climatic variability to hydrologic variability and to combine this information with common stochastic methods of analysis in order to draw closer to an understanding of real-world hydrologic processes.

Flood Analysis with a Climatic Perspective: An Overview

The interactions between climatic and hydrologic processes have been recognized since the advent of quantitative hydrologic analysis, yet the climatic factor has been incorporated into the mathematical modeling of hydrologic phenomena to varying degrees. Through the years, deterministic approaches have evolved primarily as rainfall-based methods and have commonly relied on the input of climatic information to their models, while stochastic approaches have been more likely to be runoff-based and applied to hydrologic data alone, without consideration of the climatic input. In recent years, some physically-based models of runoff have been combined with stochastic methods and have ushered in a new direction in hydrology which has served to advance the analysis of floods with a climatic perspective in a combined deterministic-stochastic approach.

Deterministic Approaches and Climate

The basis of a deterministic approach to flood analysis is that "floods are physical phenomena which result from an input of precipitation into a drainage basin, the flood magnitude varying with the nature of both the precipitation and the drainage basin" (Ward 1978, p. 71). Determinism has often been identified with causality, but Klemes (1978) points out that the two terms are not really synonymous. Causal relationships exist whenever one thing happens <u>because</u> of another, while the term deterministic involves a one-to-one relationship among events, i.e. one can be determined from the other whether or not one is caused by the other. Deterministic models, however, are often developed with causality in mind or used to explore the possibility of causal relationships. It is therefore within the deterministic approach that much effort has been placed on examining the relationship between climatic factors and runoff responses.

Comparative discussions of the many deterministic models that have been developed for runoff analysis have been presented in several recent review papers. An overview of rainfall-runoff models is given by Linsley (1982), deterministic surface water routing models are described by Dawdy (1982), physically based and process-oriented models are discussed by Woolhiser (1982) and Dunne (1982), and some deterministic models which specifically focus on the analysis of peak flows are reviewed by Feldman (1980). The common thread among most of these approaches -- from the earliest simple mathematical calculations of peak discharge using the "rational formula" to the sophisticated modeling of runoff by solving partial differential equations for three-dimensional, time-varying flow -- is the inclusion of climatic or meteorologic variables as important factors in the analysis.

A deterministic approach to flood analysis is designed to calculate or predict a hydrologic output, such as a flood hydrograph, from a given or predetermined climatic or meteorologic input, such as rainfall duration and intensity. The cross-discipline of hydrometeorology, which Bruce and Clark (1980) define as "an approach through meteorology to the solution of hydrologic problems" (p. 2), has evolved contemporaneously with the expansion of deterministic methods in the twentieth century, reflecting the importance of meteorology as a determinisitic factor in hydrologic analysis.

Hydrometeorology. One example of the use of the relationship between meteorology and hydrology for flood analysis is the "probable maximum precipitation" method to determine the design flood for a river basin (see Myers 1969 and Miller 1973). Probable maximum precipitation (PMP) is defined as "...the theoretically greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin at a particular time of year" (American Meteorological Society 1959). The methodology was developed in the United States in the mid-1930s and remains in use today, particularly as a guide for the design specifications of large dams. In the PMP approach, information obtained from extensive meteorological analyses of major storms and atmospheric conditions known to have produced flooding is used to develop regional maps depicting precipitation-depth estimates for storms of different duration. The PMP estimates are then converted to estimates of the probable maximum flood for a particular drainage basin through a deterministic model such as the unit hydrograph.

The PMP method is mentioned here because it has aroused a great deal of controversy between the deterministic and stochastic /probabilistic schools of thought and because it exemplifies a deterministic hydrometeorologic approach to flood analysis. The crux of the argument against PMP by stochastic hydrologists is that the method is not based on any concept of probability or statistics (despite its name) and that it implies that there are definable upper limits to the meteorological processes operating in an area (Yevjevich 1968, Benson 1973, and Schulz et al. 1973). PMP proponents have responded that the method provides a useful bench mark for determination of the design flood for a dam, especially when existing records are inadequate for using statistical flood-frequency methods to estimate extreme floods. E. M. Laurenson summed up the controversy with the following statement:

> The argument that has gone on over the past twenty years between determinists and probabilists on the question of PMP has been most destructive, because it has forced people into opposing camps and into positions they feel they must maintain....
>
> The only hope for advancement in the area of estimation of extreme floods is in a combination of the deterministic approach to those aspects of the precipitation and runoff processes where we have physical knowledge and the probabilistic approach to those aspects which cannot be described in terms of cause and effect. (Schulz et al. 1973, p. 105)

As Laurenson suggests, deterministic hydrometeorological studies of runoff phenomena have greatly increased our understanding of the physical processes that produce floods. In the arid, semiarid, and mountainous West, the complexities of the storm-flood relationship are especially difficult to analyze but several studies have contributed in this area, notably National Weather Service Hydrometeorological Report No. 50 by Hansen and Schwarz (1981) on the meteorology of important rainstorms in the Colorado River and Great Basin drainages, and the National Oceanic and Atmospheric Administration (NOAA) studies of R. A. Maddox and his colleagues (Maddox and Chappell 1978; Maddox, Chappell and Hoxit 1979; Maddox, Canova and Hoxit, 1980) on meteorological characteristics of flash floods in the western United States. Extensive and detailed work on semiarid rainfall-runoff relationships has also been done on small United States Agriculture Department (USDA) experimental watersheds in the Southwest (see for example, Renard and Keppel 1966; Drissel and Osborn 1968; Osborn 1971; Osborn and Laursen 1973).

These studies of flooding from a meteorological perspective have advanced our knowledge of the physical causes of individual flood events. However, the deterministic hydrometeorological approach is usually not directed toward synthesizing this information over spatial and temporal scales to present a picture of the variability of occurrence of the hydrometeorological phenomena. Here lies the strength of a hydroclimatic approach to flood analysis.

Hydroclimatology and Hydrometeorology. The subtle differences between a hydroclimatic and hydrometeorologic approach to the analysis of floods can be explained in part by a comparison of "climate" and "weather." Fairbridge (1967) presents the following definitions:

> Climatology is that branch of atmospheric science which deals with the climate, i.e. the statistical synthesis of all weather events taking place in a given area in a long interval of time. It is customary to describe the climate by the seasonal variation of various meteorological elements and their characteristic combinations. (p. 217-218)
>
> Weather is defined as a state or condition of the atmosphere at any particular place and time.... Weather is specifically distinguished from climate, which represents a regional or global synthesis of weather extended through time on the scale of years, rather than minutes or hours. (p. 1114)

The key phrases here are: "synthesis of events," "seasonal variation," "long interval of time," "characteristic combinations," "frequency of events," and "regional or global." A hydroclimatic approach to the analysis of a hydrologic event (as opposed to a hydrometeorologic approach) is one which places the hydrologic event in the context of its history of variation -- in magnitude, frequency, and seasonality -- over a long period of time and in the spatial framework of the regional and global network of changing combinations of meteorological elements such as precipitation, storm tracks, air masses, and other components of the broadscale atmospheric circulation. The time and frequency aspects inherent in a hydroclimatic approach necessitates the introduction of stochastic elements to the analysis. Hydroclimatology therefore provides a bridge between deterministic, physically-based hydrometeorological analyses of floods, and stochastic analyses of flood frequencies and variability.

Stochastic Approaches and Climate

The stochastic approach to hydrology has been defined as: "...the manipulation of statistical characteristics of hydrologic variables to solve hydrologic problems, on the basis of the stochastic properties of the variables. A stochastic variable is defined as a <u>chance</u> variable or one whose value is determined by a probability function." (Committee on Surface-Water Hydrology 1965, p. 77) Some hydrologists make a distinction between the terms "stochastic" and "probabilistic" by stating that in a probabilistic process, the sequence of occurrence of the variates involved is ignored and they are treated as time-independent, while in a stochastic process, the variates are analyzed at each moment of time in sequence and are treated as time--dependent (see Chow 1964). Others use the terms "stochastic", "probabilistic", and "random" interchangeably as synonyms for any process which is governed by the laws of chance (Yevjevich 1974). Unless otherwise stated, the more inclusive latter meaning for the term "stochastic" will be used in this text, meaning stochastic <u>or</u> probabilistic, and the term "probabilistic" will be reserved specifically for referring to the time-independent use of probability functions, as in traditional flood-frequency analysis.

Since the basis of a stochastic approach is the modeling of a process according to the laws of chance, climate -- when viewed as a deterministic component -- is generally not involved in most stochastic/probabilistic analyses of hydrologic processes. Furthermore, in some cases, when the effects of a climatic control may be influencing a hydrologic series by producing a trend or a jump in the record, this deterministic component of the series is often removed (see Yevjevich 1972). In general, climatic information enters into most stochastic analyses of hydrologic processes mainly by offering either support or reservations concerning the underlying assumptions of stationarity and homogeneity in the hydrologic data.

Flood-Frequency Analysis. Stochastic/probabilistic approaches to flood analysis were formally introduced in 1914 by Weston E. Fuller when he presented a discussion of flood frequencies and used the return period (T) as a measure of the probability of recurrence of floods of different magnitudes (Fuller 1914). This concept soon expanded into the use of theoretical probability distribution functions to describe the actual frequency distribution of the floods (Foster 1924, Hazen 1930, Gumbel 1941) and is still in active use today in what might be referrred to as traditional probabilistic flood-frequency analysis.

Numerous methods for calculating the best estimates of flood frequency have evolved over the past 70 years and are reviewed by Jarvis and others (1936), Benson (1962), and Reich (1976). In 1968 Benson reported on a study by a Federal interagency group which compared the most commonly used methods of flood-frequency analysis and recommended that all U.S. government agencies adopt the log-Pearson Type III distribution as their base method in order to achieve a uniform procedure for computing flood estimates (Benson 1968). Although the recommendation set off a major controversy, it did result in a standard procedure for flood analysis in the United States which was first outlined by the U. S. Water Resources Council in 1967, revised in 1976 and revised again as Bulletin #17B in 1981. The recommendation also set off a flurry of reactivated interest in methods of flood-frequency analysis which persists to the present day.

Despite the continued interest in improving flood-frequency estimates, climatic information has not often been utilized in this area except as a factor in the underlying assumptions of the analysis. Bulletin #17B addresses the role of climate and climatic variability in terms of the conditions necessary for a valid statistical procedure. These assumptions are "that the array of flood information is a reliable and representative time sample of random homogeneous events" (U. S. Water Resources Council 1981, p. 6). Possible violations of these conditions that are related to climate are subsequently elaborated in the bulletin:

> <u>Climatic Trends</u>
> There is much speculation about climatic changes. Available evidence indicates that major changes occur in time scales involving thousands of years. In hydrologic analysis it is conventional to assume flood flows are not affected by climatic trends or cycles. Climatic time invariance was assumed when developing this guide. (p. 6)
>
> <u>Mixed Populations</u>
> At some locations flooding is created by different types of events. For example, flooding in some watersheds is created by snowmelt, rainstorms, or by combinations of both snowmelt and rainstorms. Such a record may not be homogeneous and may require special treatment. (p. 7)

In addition to these factors, climate and climatic variability may also be involved in violations of the assumptions of randomness of events and representativeness of the time sample.

Given these assumptions and their possible violations, traditional flood-frequency analysis could be enhanced by a hydroclimatic understanding of the physical causes of flood events and the nature of climatic anomalies which produce unusual "outliers," mixed populations, or trends in a flood series. This possibility is explored in Chapter 6 of this dissertation.

Time-Dependent Stochastic Approaches. At the same time the pure probabilistic methods of flood-frequency analysis were being refined, compared, and promulgated in the 1960s, the techniques of time-dependent stochastic analysis of hydrologic processes were reaching a high degree of sophistication, due primarily to the work of Vujica Yevjevich and his students and associates at Colorado State University. For the most part, the view of this stochastic school of hydrologic thought concerning the role of climate in introducing variability to a hydrologic time series can be summed up by the following:

> In the analysis of the longest series of annual values of precipitation and runoff, no statistically significant climatic changes could be detected. There is, however, a possibility that some slow changes of yet unidentified characterisitcs may be taking place, mainly because of man-made factors....These new factors are bound to change the climate and also to affect some hydrologic phenomena along the water cycle. However, an overemphasis on these changes has given them a distorted importance. The consequence has been to retard investigation of the basic structure of hydrologic time series by proper techniques. The 'warming up' and 'cooling off' periods over some areas, or the advance or retreat of glaciers, may be only part of a random fluctuation in the time series of temperature and volume of ice in glaciers. The 'climatic change complex'... has diverted the efforts of hydrologic investigations to less productive scientific areas. (Yevjevich 1968, p. 228-229)

These comments are symbolic of a bias among some stochastic hydrologists against any approach to the analysis of a sequence of hydrologic data which is dominated by a "ruling hypothesis" that seeks to deterministically explain all hydrologic variability as a function of climatic changes and therefore essentially denies the basis of the stochastic approach: that a hydrologic process is a random process. Given the history of a rash of hydrologic determinists in search of hidden periodicities and cycles in the early 1900s, which culminated in what has been described as "the largest historic failure in the analysis of hydrologic processes" (Yevjevich 1974, p. 229), the wariness of some stochastic hydrologists toward climatic explanations for hydrologic phenomena is understandable and justified.

In recent years, others from the stochastic school have more responsibly explored the relationship between climatic and hydrologic series using various time series analysis techniques, and at least one new textbook in the field, Stochastic Water Resources Technology (Kottegoda 1980), has devoted its entire first chapter to certain aspects of climate and climatic change. Most of this work has been done in the realm of water resources systems analysis for the purpose of providing better estimates of long-term storage and water availability, given the possibility or reality of climatic changes or long-term climatic fluctuations. Of great interest in this area is the potential for modeling two types of phenomena that have been observed in hydrologic time series and have been linked to climate: the "Joseph" and "Noah" effects, so named by Mandelbrot and Wallis (1968).

Joseph Effects. The phenomenon described as a "Joseph Effect" is the occurrence, on occasion, of very long periods of low flows (or precipitation), or very long periods of high flows (or precipitation). The term was inspired by the biblical story of Joseph, whose Egyptian reign included seven years of plenty followed by seven years of famine. Models which can account for or describe the extended wet and dry episodes often seen in hydrologic series are considered to be in the Joseph realm and have been used to explore the relationship of droughts and long-term persistence to the statistical properties of time series.

Modeling of Joseph effects has often concentrated on reproducing, or properly describing, the "Hurst phenomenon," a property of many geophysical time series, observed in a statistic (the Hurst coefficient) computed from the adjusted range of cumulative departures from the mean, which seems to reflect the presence of a long-term storage effect in the data (Hurst 1951, 1957). Mandelbrot and Wallis's 1968 introduction of the Joseph and Noah effects was in fact an attempt to explain the empirical observations of Hurst. Those who have attempted physical interpretations of the phenomenon have tended to focus on either a climatic explanation, or an explanation based on cumulative processes occurring in nature, or both (Klemes 1974b). Although a definitive explanation still eludes researchers, the answer appears to lie in the continued study of Joseph effects in hydrologic time series.

In his paper on "a needed cross-discipline," Kilmartin (1980) saw a great need for the application of a hydroclimatological approach to the analysis of the Hurst phenomenon and Joseph effects because "...the 'Joseph event' is not merely a within-basin process, it is a basin response to a major anomaly in the atmospheric circulation, an anomaly that is often near hemispherical in areal magnitude" (p.161). Indeed, the most active current research on the relationship between climatic variability and hydrologic variability is largely concentrated in the "Joseph realm" of time series analysis of long-term climatic and hydrologic fluctuations and the consequences of these fluctuations for future water supplies.

Noah Effects. In contrast with the long-period Joseph effects, the term "Noah Effect" refers to the short-term rare occurrences in nature of extremely high flows (or precipitation) and, of course, was inspired by the biblical story of Noah and the great flood. Time series modeling of the Noah Effect has posed problems of a different nature than the Joseph effect.

Statistically, the phenomenon has usually been analyzed by using extreme value theory or other probabilistic methods for modeling "outlier" behavior in the tails of highly skewed distributions (see, for example, Kottegoda 1984). The huge recurrence interval that should, in theory, be attached to a true Noah event renders most time series techniques which use available hydrologic records useless for examining the phenomenon. Dendrochronologic reconstructions of annual or seasonal runoff -- particularly effective for studying Joseph events (Stockton 1975, Stockton and Boggess 1980) -- are generally not sufficiently sensitive to the extremes in a series to be of major use in the study of Noah events, however some success has been achieved in evaluating the recurrence intervals of extremely large floods by using geomorphic methods for estimating the discharges of paleofloods (Baker 1982; Costa 1978).

Kilmartin (1980) indicates that the study of extremely large flows has traditionally fallen within the (more deterministic) realm of hydrometeorology, especially in the probable maximum flood approach. However, a hydroclimatic approach to the analysis of Noah events, outliers, or the extremes of a flood probability distribution could contribute important information about the synoptic circulation anomalies and characteristic climatic patterns that affect the recurrence probabilities and variability of such unusual events.

Physically Based Approaches and Climate

Apart from some of the studies mentioned above, most stochastic hydrologists who analyze floods have not focused on incorporating climate or climatic variability into their models. Recently, however, a new outlook has emerged among some hydrologists who are calling for a more physically-based stochastic hydrologic analysis (Klemes 1978, 1982). The physically-based approach has proceeded along two closely related avenues of inquiry: detailed conceptual rainfall-runoff modeling of the dynamic hydrologic physical system, and attempts at arriving at a conceptual basis for the probability laws and distribution functions that emerge from the physical properties and interactions of hydrologic variables.

Hydrodynamical Models. An example of approaches that follow both avenues to analyze floods are the so-called "hydrodynamical models" (Eagleson 1972). The underlying purpose of such models is to derive the probability distribution of peak streamflows, not on the basis of extreme value theory (Gumbel 1941), but by conceptualizing the streamflow process as a sequence of kinematic waves which originate from a given joint probability distribution of rainfall intensity and duration, and are transformed into streamflow waves through a modeled catchment process. The model effectively integrates several of the deterministic and stochastic approaches previously discussed in this overview by aiming to describe the continuum from rainfall to flood with a set of differential equations; culminating in a derivation of the probability distribution of the resulting flood peaks. Another model with a similar physically-based, combined deterministic-stochastic approach can be found in the "geomorphoclimatic" model of Rodriguez-Iturbe (1982) which seeks to "couple" the geomorphic processes operating in a basin with the intensity and duration properties of climate to arrive at an instantaneous unit hydrograph that is conceived as a stochastic response function dependent on climate and geomorphology.

This kind of comprehensive modeling represents an exciting turn of events in hydrology and holds out the possibility of an ever-deepening understanding of hydrologic processes as they occur in nature:

> The hydrodynamical model, which aims at describing the prototype by a set of differential equations, is often viewed as an ideal of perfection and rigor, the final goal of conceptual hydrologic modeling. It is argued that such a model would have a general applicability since, by being able to describe the streamflow process in terms of the basic equations of mechanics, it would readily facilitate the derivation of all the commonly used coarser representations such as the series of mean daily, monthly, and annual flows, as well as any specific properties like those of maximum and minimum flows, drought periods, and flood volumes.
> (Klemes 1978, p. 302)

The difficulties in developing such models, however, often lead to simplification or lumping of input parameters, estimation of critical parameters for which no actual measurements are available, and assumptions for ease of analysis that may or may not hold up in the real world. Given these factors, and the complexity and expense of developing such rigorous models, their greatest value at the present time seems to be their immense contribution to the understanding of fundamental hydrologic processes, rather than their practical usefulness in providing computed end products, such as quick, physically-based flood frequency estimates.

Physically-based Distribution Functions. Another way in which stochastic hydrologists have attempted to incorporate more deterministic aspects of the physical world, such as climate, into their models is by probing the possibility of a physical basis for the particular shape of the various probability distribution functions (PDFs) which stochastically describe streamflow behavior. The more traditional stochastic analyses in this area have directed most of their attention to the timing of floods in relation to each other, and the resulting PDFs which represent this process (Todorovic and Zelenhasic 1970; Denny et al. 1974; Gupta et al. 1976; Todorovic 1978). This interest in the timing of large floods has nurtured an interest in the climatic factors that influence hydrologic variability, especially in terms of the seasonality of flows. A good example of this sensitivity toward climate in a stochastic analysis of flows can be found in Denny et al. (1974). By incorporating observations on the nature and timing of climatic inputs to streamflow in southern Arizona, the authors develop the underlying assumptions for a Markov analysis of stream behavior and impart a physical basis to their model. The Gupta et al. (1976) analysis shows a similar sensitivity to climatic effects in its development of a joint probability distribution function for the largest flood and its time of occurrence in a hydrologic series.

Mixed Distributions. One of the most frequently cited areas of potential research using physically-based distribution functions is the problem of mixed distributions or multiple populations in hydrologic time series. As previously mentioned in the discussion on traditional flood-frequency analysis, homogeneity in the flood series is a basic underlying assumption for the probabilistic determination of flood magnitudes and frequencies. It seems that wherever this assumption is stated in the literature, it is followed by a "disclaimer" (such as that in the citation from the U. S. Water Resources Council Bulletin #17B) which states that due to differences in the climatic processes involved in the generation of floods -- fronts, snowmelt, convectional showers, tropical storms, etc. -- multiple populations or mixed distributions may be present in the data.

Despite the almost universal recognition that observed flood samples may not be drawn from a single population, only a handful of researchers have seriously devoted their efforts to the analysis of this problem. Potter (1958) was one of the first to discuss the evidence for two or more distinct populations of peak runoff (as seen in "dogleg" flood frequency curves), but did not explore the possible causes for the multiple populations. Singh (1968, 1974) presented the first attempts at mathematically modeling mixed distributions, but although referring to climate as the probable cause of multiple populations in streamflow, his approach was entirely runoff-based: objectively searching the streamflow data alone to extract a mixture of distributions, rather than applying any sort of physically-based separation of populations on the basis of climate. Other studies have concentrated on mixed distributions in streamflow series by separating them into seasonal subpopulations (Guillot 1973; Browzin et al. 1973), hence hypothesizing a seasonalized climatic influence.

Waylen and Woo (1982) moved beyond the simple seasonal division of a flood series and looked at the differences between rainfall- and snowmelt-generated floods to examine the problem of mixed distributions in hydrologic data. With a physically-based perspective on the climatic processes responsible for generating floods in southwestern British Columbia, they were able to subdivide a flood series into separate rainfall and snowmelt "populations" and improve the fit of the flood-frequency curve by using a compounded Gumbel distribution developed from separate fits to each subset of data.

The use of climatic information to investigate mixed distributions and multiple populations in hydrologic time series has great potential for improving flood estimates and enhancing understanding of the flooding process. In this dissertation, the possibility of mixed distributions in the flood series of Arizona streams is explored extensively.

Summary

Many methodologies for flood analysis have evolved since the days of simple deterministic rainfall-runoff formulas and the first stochastic evaluations of the probability of flood recurrence. In general, deterministic approaches have been more likely to incorporate climate into their models, while stochastic approaches have tended to be more runoff-based. The emergence of a physically-based approach to the analysis of floods has served to unite the deterministic and stochastic methodologies to a certain degree. The cross-discipline of hydroclimatology holds the possibility of enhancing our understanding of the flooding process in both deterministic and stochastic ways, and is especially suited to the development of new physically-based approaches to the analysis of flood series.

Hydroclimatology of Flow Events

Many factors affect the variability of flow in arid and semiarid streams. Most major drainages are characterized by ephemeral or intermittent flows in alluvial channels which are developed in sparsely vegetated valley bottoms filled with hundreds of meters of silts, sands, and gravels. Stream channels entrenched into easily erodible unconsolidated sediments or braided channels composed of unvegetated gravel bars and sand can undergo change during flow events and over time, and in turn effect changes in the flow itself (Burkham 1976). Transmission losses into the stream bed and banks during flow can alter the flood hydrograph (Renard and Keppel 1966). In watersheds of the West, flow regimes can also be affected by land use changes such as irrigation, overgrazing, and rapid urbanization, as well as the historical entrenchment of many arid and semiarid streams from braided channels to arroyos. Complex responses due to natural adjustments within the basin itself may also affect the nature of arid streamflow. With all of these factors in mind, it is nevertheless obvious that the ultimate source of variability of flow in any stream is linked inextricably with the external climatic source of the water delivered to the basin system. The variability imparted by climate preceeds any subsequent variations that may be introduced to the system by other factors. Since the arid and semiarid streams of the West are subject to so many other non-climatic sources of variability in their flow regimes, it is imperative for the variability imparted by climate to be defined and examined. It is for this reason that a hydroclimatic understanding of the nature of streamflow variability is needed.

Flow Events and Floods

Webster's Seventh New Collegiate Dictionary (1967) defines a flood as "a rising and overflowing of a body of water especially onto normally dry land" (p. 320), yet there are numerous other interpretations of the exact meaning of the term "flood." In the United States, perhaps due to the role of the media in relating knowledge of floods to the public, the term is usually linked to whether or not damage has occurred as a result of the rising waters. Many limit the definition of a flood to instances when water actually overflows a stream channel as in the <u>Dictionary of Geological Terms</u> (American Geological Institute 1962) definition of a flood as "any relatively high streamflow which overtops the natural or artificial banks in any reach of a stream." However, in the entrenched alluvial channels of the Southwest, significant amounts of damage can result from flow events which remain confined within the steep-sided but easily eroded banks. In fact any flow of water in arid regions characterized by stream channels which are normally dry is often referred to as a flood.

Hydrologists define floods on the basis of the volume of discharge, identifying as a flood any event which exceeds a certain (often arbitrary) threshold discharge value or base level. The terms "peak discharge," "flood peak," or "instantaneous peak" are also used to describe floods, but these terms are defined on the basis of some designated period of time (hourly, daily, monthly, annual, etc.) over which the peak event is determined. A single definition for the term "flood" may perhaps never be agreed upon, hence the more general term "flow event" is preferred by some, especially in ephemeral streams where the occurrence of any flow at all is indeed an event.

In this study, the terms flood, flow event, and peak discharge are used more or less interchangeably. The flow events which were chosen for analysis are those compiled by the U.S. Geological Survey as the partial-duration series for a station. A partial-duration series is one in which all instantaneous peak discharges above a selected base are listed without regard to the number of floods occurring within any given time period. The base is usually selected for each gaged station such that it is equal to the lowest annual flood on record; thus at least one flood in each year is included (Dalrymple 1960). Use of the partial-duration series in statistical analyses of floods poses problems in ensuring that all events are independent and in interpreting the flood recurrence interval (e.g. "10-year flood") because the events in the analysis are not separated by a fixed interval, as in the annual flood series. However, the fixed interval of one year assumed by the annual series is, in itself, artificial because many cases can be cited where a high flow occurring in late September is designated as the annual flood for Water Year (t) and a subsequent high flow occurring a few weeks later in October is listed as the annual flood for Water Year (t+1). Despite difficulties in statistical interpretation, the partial duration series is very well suited to a hydroclimatic analysis of flows because it includes much more information than the annual series about the variability of peak flow events over time. Analysis of the partial duration series is addressed in more detail in Chapter 2.

Hydroclimatology

A hydroclimatic approach to the analysis of a time series of hydrologic events, such as floods, is one that interprets the events as occurring within the context of a history of climatic variations over time, and within a spatial framework of changing regional and global combinations of meteorological features and circulation patterns. The following example is presented as an illustration of how a partial duration flood series might be analyzed hydroclimatically. Three major hypotheses emerge from this analytical approach, and have formed the basis for the research described in subsequent chapters of this dissertation.

A Flood Series Example. Figure 1 is a plot of the partial duration flood series for the Santa Cruz River at Tucson for the period 1915 through 1980 as recorded at the U.S. Geological Survey's Congress Street gage. In the figure, X's denote the magnitude of the annual flood for each water year (October through September of the

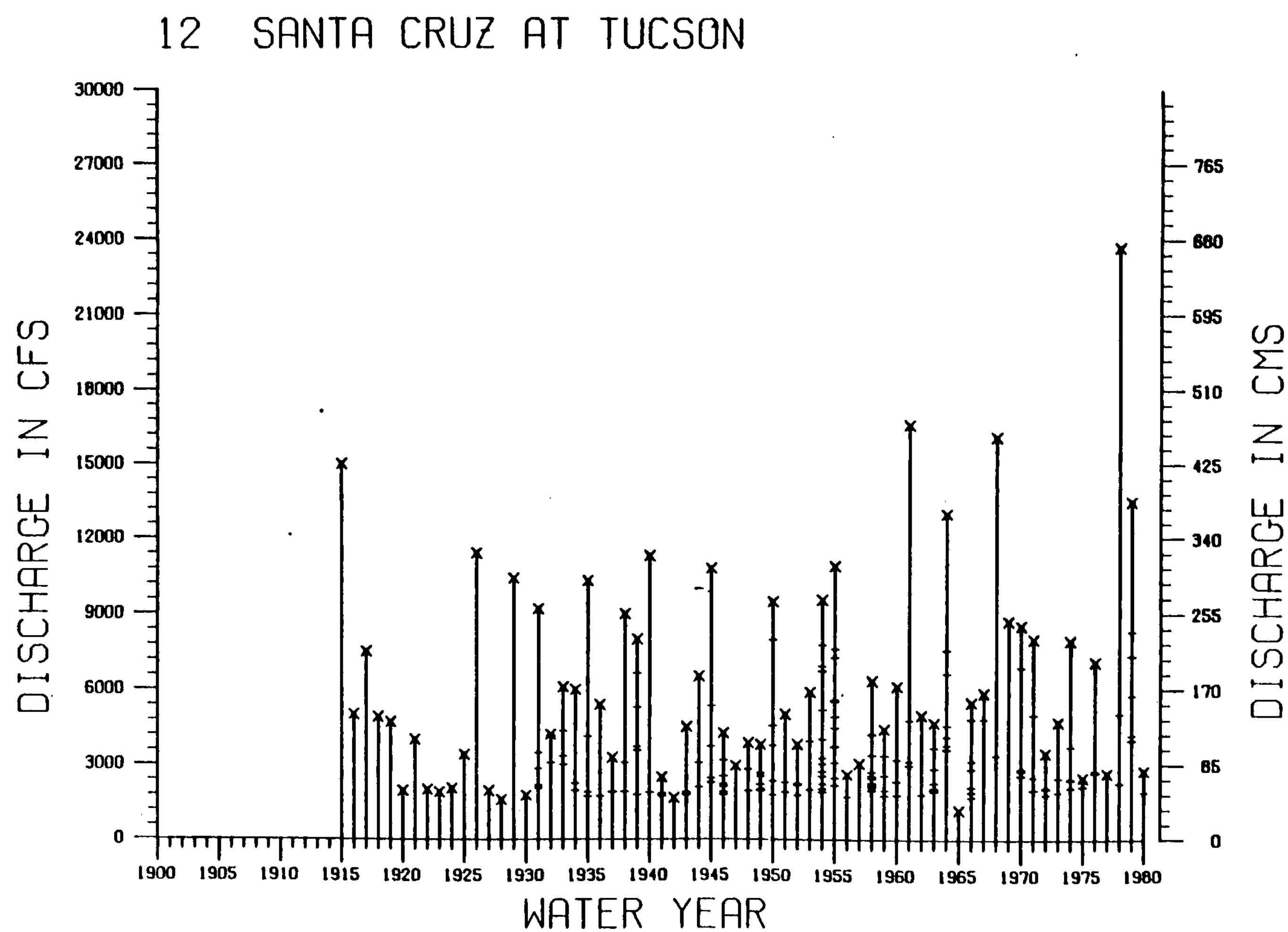


Fig. 1 Partial-Duration Flood Series for the Santa Cruz River at Tucson

corresponding calendar year) and the horizontal bars denote the magnitudes of the partial duration peaks within each water year. (Prior to 1931 only the annual flood was recorded, hence no partial series bars are plotted on the diagram for water years 1915-1930.) Although the Congress Street station's 67 years of record constitute one of the longest flood series available in Arizona, the gage was removed in late 1981.

Several features of this flood series plot deserve comment. Significant temporal variability can be observed in both the magnitudes of the annual peaks and the frequencies of the partial series peaks. Five of the six largest annual floods in the record occurred after 1960, while the number of partial series peaks occurring after 1960 in the 20 year period 1961-1980 is 56, compared to 78 partial peaks in the 20 year period 1941-1960. However, because this analysis of the Santa Cruz flood series up to this point has been entirely "runoff-based," i.e. concerned only with the variability of the flows themselves, there is no physical justification for splitting the time series at 1960 without a priori knowledge of circumstances that may have taken place at that time. A split down the middle of the time period at 1948 would be equally as valid.

Figure 2 displays standard flood frequency analyses of the Santa Cruz River annual discharges, for (a), the entire 1915-1980 record and (b), the same record truncated at 1960. Figure 3 shows frequency analyses of the Santa Cruz record split down the middle at 1948. Estimated values of the 10-, 100-, and 500-year floods which were derived from each analysis are listed in Table 1. As demonstrated

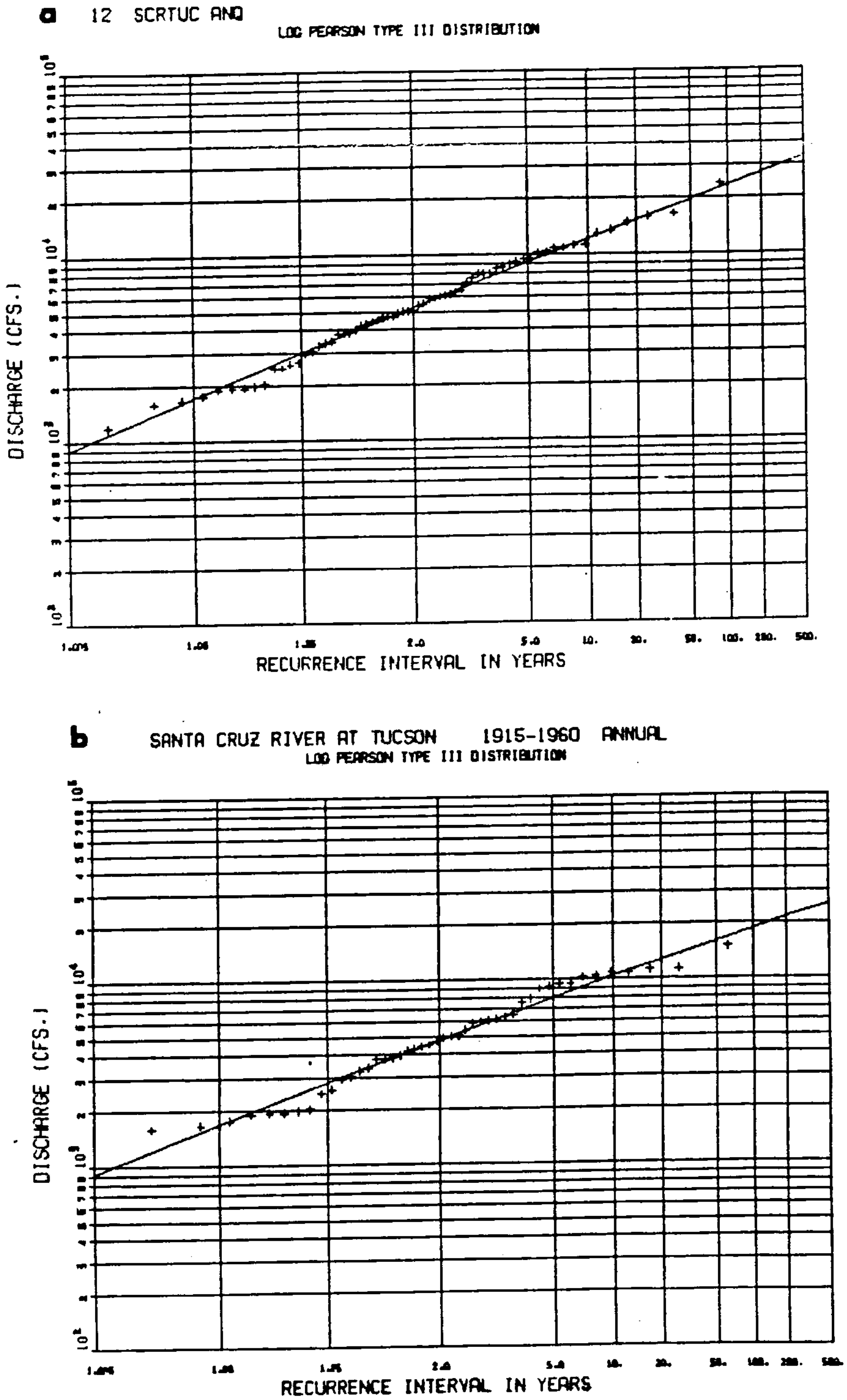
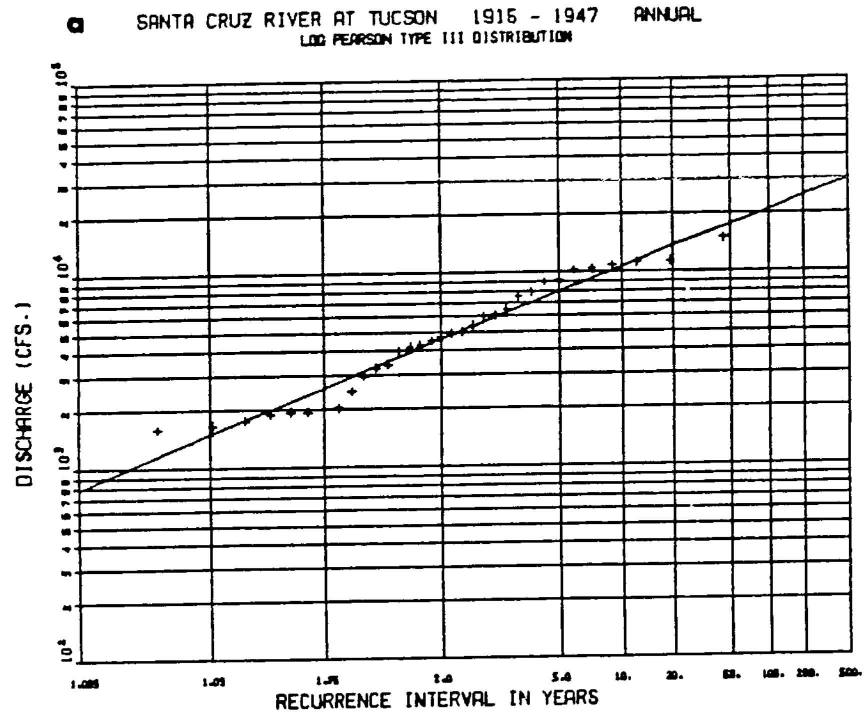


Fig. 2 Recurrence-Interval Curves for Annual Floods — Santa Cruz River at Tucson
a. Period 1915-1980 b. Period 1915-1960



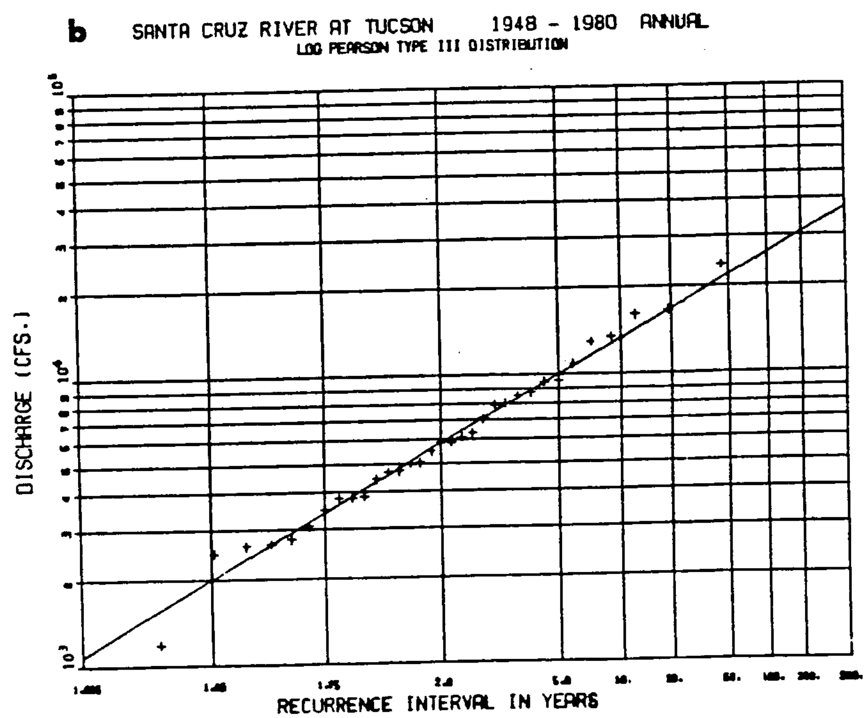


Fig. 3 Recurrence Interval Curves for Annual Floods -- Santa Cruz River at Tucson
a. Period 1915-1947 b. Period 1948-1980

Table 1 Flood Estimates based on Different Portions of the Record

		ENTIRE RECORD 1915-1980	PRE-1960 1915-1960	SPLIT RECORD 1915-1947	1948-1980
10-YR	CFS	(12,100)	(10,400)	(10,700)	(13,400)
	CMS	343	294	303	379
100-YR	CFS	(23,600)	(18,800)	(21,100)	(26,000)
	CMS	668	532	597	736
500-YR	CFS	(33,600)	(25,500)	(30,100)	(36,900)
	CMS	951	722	852	1,045

1983 FLOOD CFS (52,700)
CMS 1,490 ←-------- CLOSEST ESTIMATE -------- (1,045)

by these arbitrary splits or truncations of the record, it is clear that the computed estimates of flood frequency are time-dependent: changing and evolving along with variations in the flood series itself. Although one might view the information in Table 1 merely as an exercise in record-splitting and numerical manipulations, there are definite real world ramifications to differences in flood estimates that are obtained from the analysis of an incomplete record. In 1960, if floodplain limits along the Santa Cruz River had been determined on the basis of the 100-year flood, the following 20 years would have demonstrated that the 1960 estimates were inadequate and should be adjusted upwards.

Because the atmospheric and hydrologic conditions which produce floods are constantly changing and evolving, all flood series records should be viewed as "incomplete," and efforts to identify the minimum length of record from which reliable estimates can be made, as a possible justification for shutting down gages, should be discouraged. A case in point is the Santa Cruz River at Tucson. In October 1983, two years after the Congress Street gage was removed, the Santa Cruz experienced a flood that far exceeded any event recorded in the 20th century. The field estimate of peak discharge at the Congress Street bridge was 1,490 m^3/s (52,700 cfs) (Saarinen et al. 1984) -- significantly larger than any of the 500-year flood estimates given in Table 1.

In this case traditional flood-frequency techniques for estimating the likelihood of a very large flood had seemingly been inadequate -- or had they? Perhaps the 1983 flood was indeed so rare an event that the probability of another similar event occurring is actually less than .001 (1 in 1000) as might be suggested by plotting the 1983 event on Figure 2a and evaluating its recurrence interval as greater than 1000 years. Yet it is interesting to note that of all the values listed in Table 1, the period of record that produced an estimate closest to the 1983 event was the second half of the split record, 1948-1980. If these later years, or even the post-1960 years are more reliable estimators of the most recent flooding activity in the river, perhaps there is reason to separate the flood record into sub-periods representing different kinds of flow activity in the basin. Nevertheless, without additional information which would justify splitting of the record, all that remains is an arbitrary manipulation of the data to squeeze out the best fit, an activity which could result in even poorer estimates if the future flood record of the Santa Cruz were to return to a pattern like the pre-1960 years.

The example given here is not an isolated one. Numerous other similar examples of the inadequacy of traditional flood-frequency techniques can be cited for streams all over the world. The problem must lie somewhere in the failure to meet the basic underlying assumptions set forth by the technique. Hydroclimatology provides a means to critically evaluate the applicability of these assumptions in individual cases and to formulate a physical justification for splitting flood records into meaningful subgroups when necessary.

<u>Alternative Approaches</u>. How should one evaluate or analyze an event like the October 1983 Tucson flood, when traditional flood--frequency analysis appears to have limitations? With the previous

overview of various approaches to flood analysis in mind, several deterministic and time-dependent stochastic methods could be applied. However because of the pervasive use of the recurrence interval concept for practical application in floodplain zoning, flood hazard mapping, and flood insurance evaluation, an effort should also be made to improve flood-frequency techniques themselves.

A deterministic approach to the Tucson flood might evaluate it in terms of its comparability to probable maximum precipitation (PMP) and probable maximum flood (PMF) estimates for the region. In Saarinen et al. (1984) the storm which generated the October flood was appraised in terms of the PMP model storm for Colorado and Great Basin drainages (Hansen and Schwarz 1981). It was concluded that, although many of the features of the PMP model were present in the October 1983 storm, an even larger event could conceivably occur if a more direct surge of tropical moisture were to enter the region.

Using only a deterministic approach, this evaluation of the Tucson flood as an extreme event -- but not as extreme as some other that might transpire -- lacks a more definitive description of the actual probability of the event and its variability through time. To accomplish this, a stochastic-probabilistic approach could be combined with deterministic information about the physical genesis of the event. The Tucson flood could then be evaluated as one unique event in a physically-based stochastic process of time-dependent varying flows.

<u>Stochastic Process Models for Flood Series</u>. A process is a phenomenon which undergoes continuous changes, especially with respect

to time, hence Figure 1 is a representation of the hydrologic process of changing flood peaks over a specified time period, 1915-1980. This specified time period (symbolized by t) is, however, only one portion of the total time over which floods have been occurring or will occur in the Santa Cruz River. The undefinable length of total time, theoretically going to infinity, is symbolized by T. Any flood series, then, can be thought of as events occurring in t which are elements of the largest possible time period T, in symbols: ($t \in T$).

The flood peaks in Figure 1 are represented by vertical lines placed at specified intervals of time and thus have been plotted as if they were discrete events, even though the instantaneous peak is obviously one brief moment of discharge in a continuum of flow. Flood peaks are usually treated as discrete events because such events are easier to analyze both conceptually and mathematically and because there is, in fact, real world significance attached to the discrete magnitude of the instantaneous peak in terms of maximum amount of floodplain inundation that will occur. These discrete flood events occur at intervals (i's) within the specified period t and are symbolized by t_1, t_2,...t_i, etc., up to the last recorded event for a sample of N size (or a record of N years) t_n. This concept is illustrated in Figure 4a which can be viewed as a generalized version of the actual Santa Cruz flood series of Figure 1.

In Figure 4a, the magnitude of the peak discharge recorded during each flood event is represented by x for each t_i. Hence the flood peak occurring at t_1 is $x(t_1)$, (sometimes also referred to as x_1), and is indicated by a dot on top of the line drawn at time t_1.

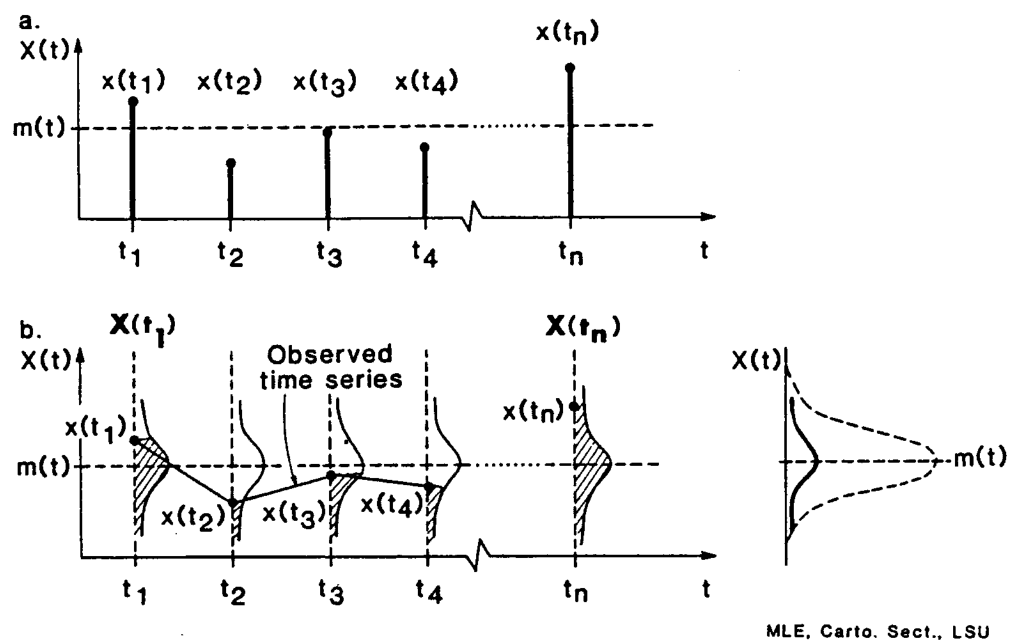


Fig. 4 Stationary Stochastic—Process Model for a Flood Series
a. Generalized version of an observed flood series
b. Stationary stochastic process

However, the measured value of any x_i at time t_i can be viewed as one sample from a whole population of possible events that could conceivably occur at time t_i. The set of all possible x's that could occur at t_1, in other words, the available population at time t_1, is symbolized by $X(t_1)$ and is represented by a continuous distribution of possible values along the t_1 axis in Figure 4b. The individual x_i's that together comprise each X(t) at time t_i are often referred to as variates, or variables that may take on any of the values of the specified $X(t_i)$ set, with a specified probability.

Of course it is assumed that any x_i sample drawn from $X(t_i)$ will be a good estimator of the whole $X(t_i)$ population; the best estimator being the population mean $m(t_i)$. In reality the sample x_i might fall anywhere within $X(t_i)$. The shaded areas in Figure 4b represent the probability that the observed sample x_i is less than or equal to the true value of x_i, given the shape of the population's theoretical distribution $X(t_i)$. Figure 4b suggests that at some times, t_n for example, the observed flood value represents an extremely rare event because it falls well within the uppermost tail of the theoretical distribution of all possible floods at time t_n. Other floods, such as x_2, are much smaller than would be expected on the basis of the theoretical distribution $X(t_2)$ and would be considered unusually low for peak events at time t_2.

The family of all $X(t_i)$'s over the t record can be collectively referred to as $\{X(t):t \in T\}$, which is a representation, in a single variable, of the entire flood series process. In fact, the underlying basis for all stochastic analyses of hydrologic processes, whether floods or some other phenomenon, is the process $\{X(t):t \in T\}$, a family of X(t) variables, assumed to be random, with t belonging to a larger set T:

> Mathematically speaking, a stochastic process is a family of random variables X(t) which is a function of time (or other parameters) and whose variate x_t is running along in time t within a range T. Quantitatively, the stochastic process, which may be discrete or continuous, can be sampled continuously or at discrete or uniform intervals of t=1, 2, ..., and the values of the sample form a sequence of x_1, x_2, ..., starting from a certain time and extending for a period of T. This sequence of sampled values is known as a time series, which may be discrete or continuous. (Chow 1964, p. 8-9)

Furthermore,

> The random variable X(t) has a certain probability distribution. If this distribution remains constant throughout the process, the process and the time series are said to be stationary. Otherwise they are nonstationary. For example, a virgin flow with no significant change in river-basin characteristics or climatic conditions for the period of record is considered as a stationary time series. If it is affected by man's activities in the river basin or nature's large accidental or slow modifications of the rainfall and runoff conditions, the recorded or historical flow is a nonstationary time series. Since a nonstationary process is very complicated mathematically, hydrologic processes are generally treated as stationary. (Chow 1964, p. 8-9)

Figure 4b depicts a stationary stochastic process for a flood series. The left part of the diagram displays each individual random variable X(t) at its specified time. The right side of the diagram displays the family of all X(t)'s combined into a single theoretical distribution which represents the entire flooding process over time t. In the strict sense, true stationarity is achieved when statistical properties computed from different parts of a time series do not change, except due to sampling variations. The stationarity of this time series is evident because there is no change over time in either the mean value m(t), or the variance about the mean, and the mean and variance of each $X(t_i)$ is equal to the mean and variance of $\{X(t): t \in T\}$, the theoretical distribution for the flooding process over the length of the time series. As Chow states in the above quotes, hydrologic processes are generally treated as stationary, hence Figure 4b is the model that is usually assumed for analyzing floods stochastically and/or probabilistically.

Figure 5 presents three alternative ways of looking at a flood series stochastically. Figure 5a depicts a nonstationary stochastic process with a time-varying mean. It is clear that the statistical properties of the random variable X(t) differ from one realization of X(t) in time to another. The theoretical distribution for the complete time series on the right side of the figure is a complex one which bears no resemblance to any one X(t) distribution. This is the classic representation of a flood series composed of multiple populations, each with a different mean. If this model is true, the flood event x_n which was interpreted as being so rare in Figure 4b because of its upper tail location, must now be interpreted as an event with a high likelihood of being equalled or exceeded, given the new position of the theoretical distribution $X(t_n)$ on the X(t) axis.

Figure 5b depicts a nonstationary stochastic process with a time-varying variance. Here the mean m(t) remains the same throughout all X(t)'s, but the variance, or spread about the mean, changes from one segment of the time series to another. The theoretical distribution for the entire series bears a resemblance in the mean to the individual random variables X(t), but has a much larger variance than

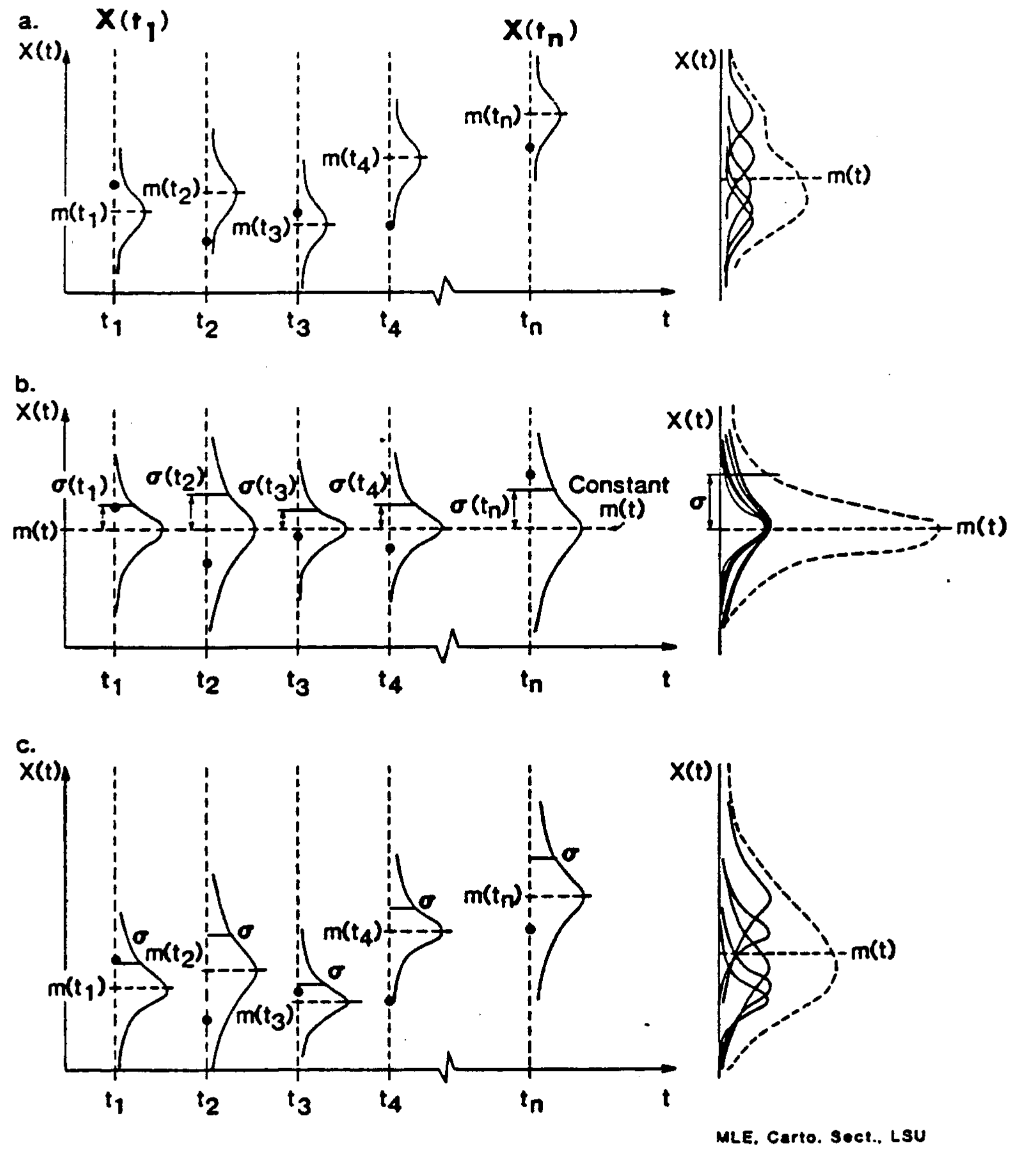


Fig. 5 Nonstationary Stochastic-Process Models for Flood Series
a. Time-varying mean
b. Time-varying variance
c. Time-varying mean and variance

any one X(t). This representation of the flooding process indicates that the large flood x_n and the small flood x_2 are not located in the extremes of the upper and lower tails of their respective populations as they were in Figure 4b. However floods x_3 and x_4 are now tending toward the lower extremes of their distributions, even though they are not far from the mean of the series.

Figure 5c depicts a stochastic process with a time-varying mean and variance. The resulting theoretical distribution for the entire time series is complex and reflects multiple populations as in Figure 5a. In this representation, floods x_2 and x_n would have a greater likelihood of being predicted accurately because they lie closer to the means of their respective populations. Conversely, flood x_4 would probably be over-estimated since it now reflects an extreme in the lower tail of its theoretical distribution.

<u>A Physically-Based Stochastic-Process Model for a Flood Series.</u> It is interesting to note that of all four possible models for a stochastic flood series process, Figures 5a and especially 5c depict theoretical distributions for the complete flood series that look most like the typical positively skewed flood-frequency distributions of many arid, semiarid, and humid streams. Although model 4a is the most easily analyzed, it may not be the best model for studying flood processes in the real world. In fact many stochastic hydrologists concede that, in the physical world, most hydrologic time series are nonstationary with a mean and variance that tend to vary with time. The crux of the problem is that the actual distributions of the X(t)'s over time are unknown, and without knowledge of their distributions,

stationarity is perhaps the safest and least arbitrary assumption to make, in addition to easing the mathematics involved in analyzing the series.

The stochastic school of hydrology has greatly developed the analysis of time series of hydrologic data in the past 20 years, yet according to Klemes:

> The main limitation of this school has been its failure to see that (like the deterministic features) the statistical and stochastic properties of hydrologic processes have definite physical causes and are amenable to explanation, as opposed to mere manipulation and approximate description by various mathematical constructs. (Klemes 1978, p. 287)

In the flood series example just presented, an understanding of the physical causes for the events or variates in the random variable X(t) at each t_i would greatly assist in choosing, evaluating, or developing the best stochastic model for the flooding process.

The purpose of the research presented in the following chapters is to use hydroclimatic techniques to explore the physical causes for the events in several observed flood series. This information is then applied toward an evaluation of which stochastic-process model (e.g. Figures 4b through 5c) best represents the flooding process as it occurs in nature.

Some Hypotheses. The Santa Cruz flood series example suggests some hypotheses which might be explored or tested in the development of a hydroclimatically-based stochastic-process model. Figure 6 is a first approximation for viewing the series hydroclimatically -- separating the series into seasonal groupings. The plot shows a tendency for annual floods to occur primarily in summer between 1930 and 1960; however, annual floods occurred much more frequently in fall

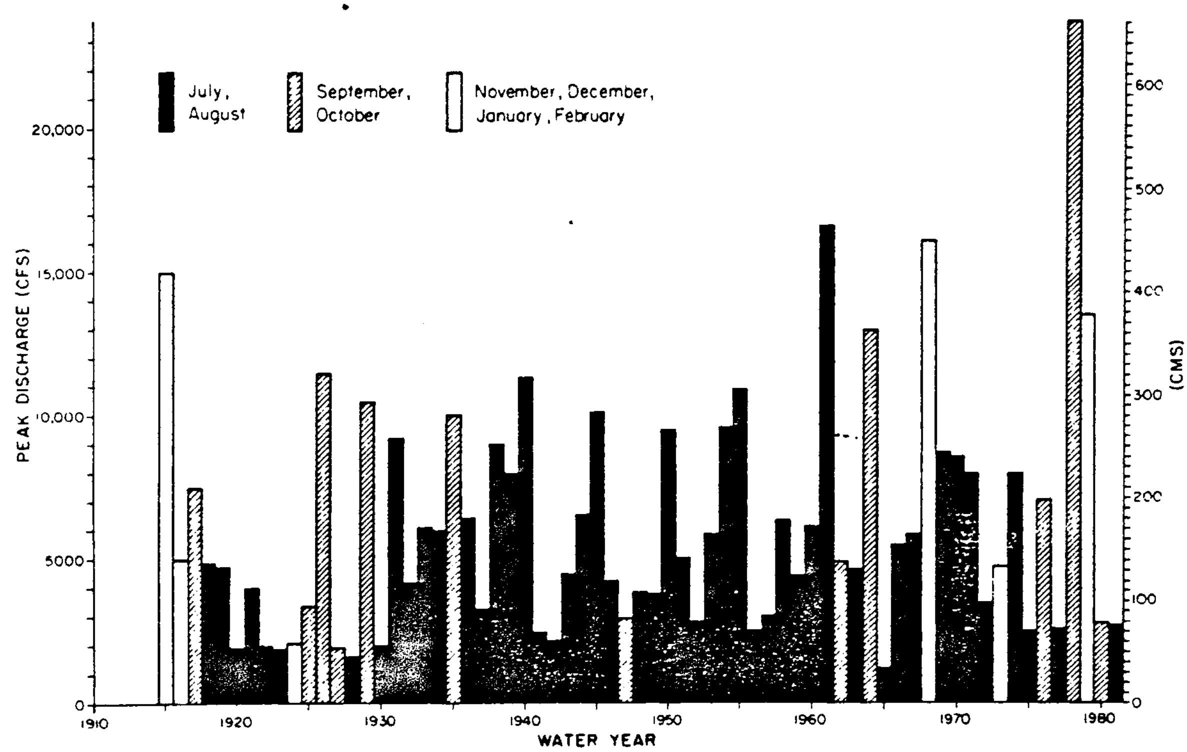


Fig. 6 Seasonal Variations in the Annual Flood Series of the Santa Cruz River 1915-1981 (from Betancourt and Turner, in press)

or winter, both prior to 1930, and after 1960. The plot also suggests that floods produced by fall or winter atmospheric processes may come from a different population than the summer floods. Finally, as observed first in Figure 1, there appears to be a time-dependent trend reflecting a different kind of flood activity occurring after 1960. To evaluate these observations, and those to be discussed in Chapters 3 and 4, within the framework of a physically-based stochastic-process model, the following general hypotheses have been formulated:

1) Floods occurring as a result of different atmospheric mechanisms belong to different populations. The dominance of these different populations at different times (t_i) will determine the shape of the overall frequency distribution of the flood series.

2) Differences among the populations described in (1) above are due to either varying means as in Figure 5a, changing variances as in Figure 5b, or both as in Figure 5c. The mean and variance associated with each theoretical distribution has a physical basis that is linked to the nature of the atmospheric mechanisms operating at t_i.

3) A shift in general atmospheric circulation patterns, or the anomalous persistence of certain patterns will be reflected in a flood series by a shift to a different theoretical distribution for the random variable X(t) in the series.

Summary

Observations from an actual flood series on the nature of flow variability suggest the need to reevaluate the popular representation of a flood series as a stationary time series. Alternatives to the stationary stochastic-process model can be envisioned which depict time-varying means, time-varying variance, or both. These alternative models result in theoretical distributions that are made up of multiple populations and whose shape may more accurately represent observed flood-frequency distributions. Hydroclimatic information about the generating mechanisms for each flood can provide a physical basis for identifying which stochastic-process model is actually in operation.

The following chapters describe the data, methods, and results of a hydroclimatic evaluation of flood events in the Gila River Basin. Chapter 2 describes the study area, the data sets used in the analysis, and the methodologies applied to these data. Chapter 3 discusses the climatology of the Gila River Basin in terms of the seasonal and spatial variability of synoptic circulation features and the atmospheric genesis of major flood-producing events. Chapter 4 describes the hydrology of streams in the Gila River Basin in terms of the seasonal and spatial variation of flow, the genesis of flow events, and hydrologic variability as seen in the annual and partial duration flood series of the 30 stream stations. Chapter 5 brings the climatic and hydrologic approaches together by describing the hydroclimatology of flow events in the Gila River Basin and Chapter 6 focuses on how the hydroclimatic approach can be integrated with traditional flood-frequency analysis. Chapter 7 summarizes, discusses results, and presents final conclusions of the research.

CHAPTER 2

DATA AND METHODS

The hydroclimatic study of flow events presented here is based on and three kinds of data: streamflow data, precipitation data, and 700 millibar (mb) atmospheric pressure data. These data were analyzed on an event basis by investigating the relationship between atmospheric phenomena and individual flood events, and on a monthly basis by averaging the data over monthly time scales to detect the broader climatic patterns from which the individual events evolved. The hydroclimatic information obtained from the event and monthly analyses was then used to evaluate the three hypotheses on flood time series which were presented at the end of Chapter 1.

The Gila River Basin

Flood time series from 30 gaging stations in the Gila River basin of central and southern Arizona were selected for the hydroclimatic analysis. The stations were chosen to provide a regional sampling of flooding activity in the basin's major drainages. A map of the study area is presented in Figure 7, giving locations of the 30 stream gaging stations as well as the 38 climatic stations used in the analysis.

GAGING STATIONS

	Code	Station	ID#
1.	GILCLF	Gila River near Clifton	94420
2.	SFRCLF	San Francisco River at Clifton	94445
3.	GILSOL	Gila River at head of Safford Valley, near Solomon	94485
4.	GILCAL	Gila River at Calva	94665
5.	SCLPER	San Carlos River near Peridot	94685
6.	SPDPAL	San Pedro River at Palominas	94705
7.	SPDCHA	San Pedro River at Charleston	94710
8.	SPDRED	San Pedro River near Redington	94720
9.	SCRLOC	Santa Cruz River near Lochiel	94800
10.	SCRNOG	Santa Cruz River near Nogales	94805
11.	SCRCON	Santa Cruz River at Continental	94820
12.	SCRTUC	Santa Cruz River at Tucson	94825
13.	RILTUC	Rillito Creek near Tucson	94860
14.	SRWVVO	Santa Rosa Wash near Vaiva Vo, near Sells	94885
15.	PCHMAV	Pacheta Creek at Maverick	94892
16.	BBNFAP	Big Bonito Creek near Fort Apache	94897
17.	NFWMCN	North Fork White River near McNary	94910
18.	CRDSHO	Corduroy Creek near mouth, near Show Low	94960
19.	SLTCHR	Salt River near Chrysotile	94975
20.	SLTROO	Salt River near Roosevelt	94985
21.	TONROO	Tonto Creek above Gun Creek, near Roosevelt	94990
22.	OAKCRN	Oak Creek near Cornville	95045
23.	RATRIM	Rattlesnake Canyon near Rimrock	95053
24.	WEBPIN	Webber Creek above West Fork Webber Creek, near Pine	95077
25.	VRDHSD	Verde River below Tangle Creek, above Horseshoe Dam	95085
26.	AFRMAY	Agua Fria River near Mayer	95125
27.	NEWNEW	New River at New River	95138
28.	HASWIK	Hassayampa River at Box Damsite, near Wickenburg	95155
29.	RIOAJO	Rio Cornez near Ajo	952017
30.	GILVIR	Gila River below Blue Creek, near Virden, N.M.	94320

CLIMATE STATIONS

AJ	Ajo
AL	Alpine
AP	Apache Powder Company
CH	Childs
CL	Clifton
CD	Cordes
CK	Crown King
DC	Duncan
FV	Fort Valley
GB	Gila Bend
HB	Holbrook
HD	Horseshoe Dam
MV	Maverick
MC	McNary
NG	Nogales
PA	Payson
PR	Prescott
RO	Roosevelt 1 WNW
SC	San Carlos
SCR	San Carlos Reservoir
SX	Santa Rita Experimental Range
SR	Santa Rosa School
SB	Sasabe 7 NW
SD	Sedona Ranger Station
SL	Sells
TM	Tempe
TB	Tombstone
TU	Tucson University of Arizona
WG	Walnut Grove
WR	Whiteriver
WK	Wickenburg
YL	Y Lightning Ranch
YC	Yuma Citrus Station

Supplementary Stations:

BH	Beaverhead Ranger Station, N.M.
CC	Chiricahua National Monument
CB	Cibecue
CF	Cliff 10 SE, N.M.
JP	Junipine

Fig. 7 Gila River Basin Base Map

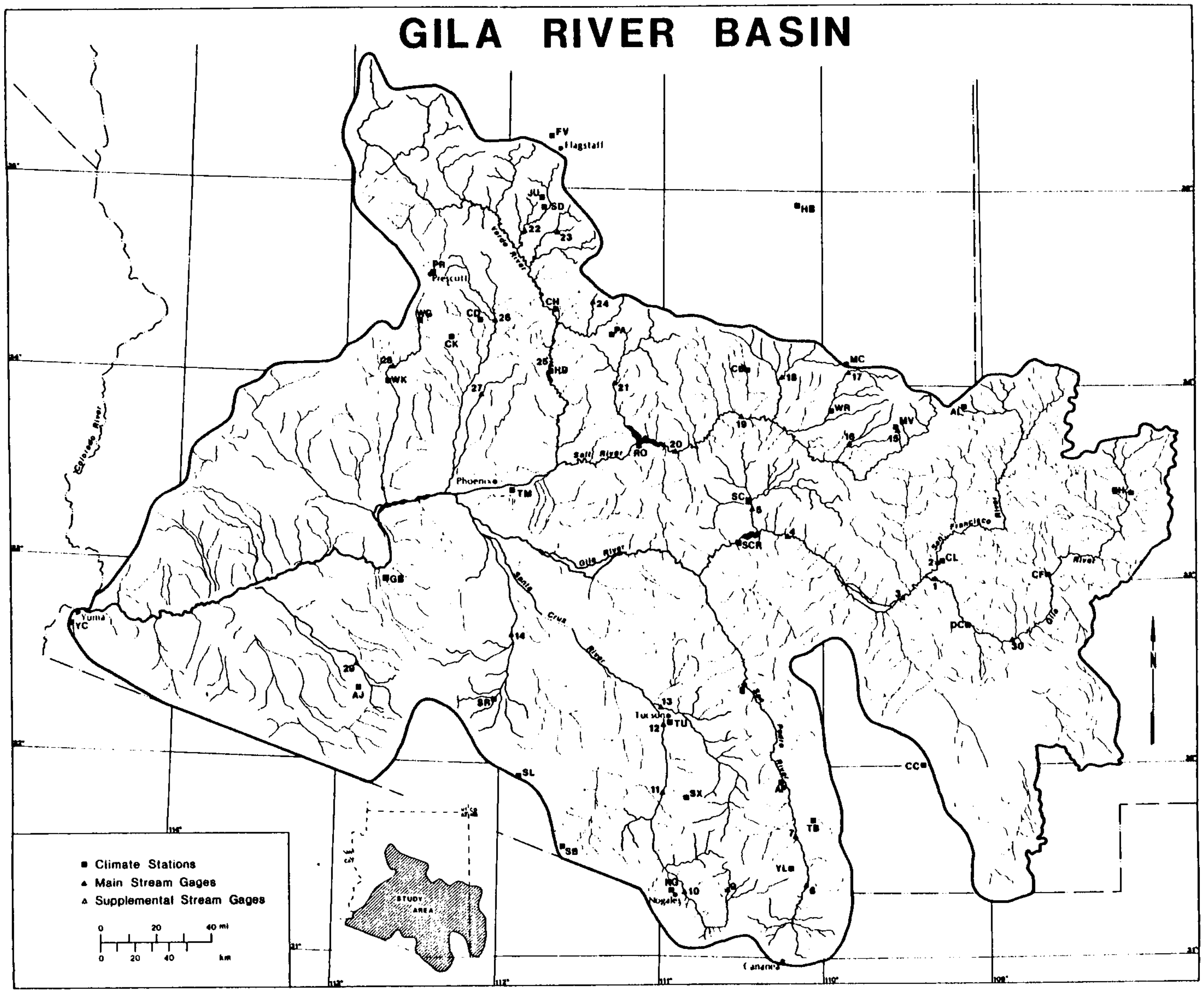


Fig. 7 Gila River Basin Base Map

The Gila River heads in the Sierra Mimbres and Mogollon Mountains of western New Mexico and flows westward across southern Arizona, joined by the Salt-Verde River system which drains the Mogollon Rim to the north, and the San Pedro and Santa Cruz Rivers which drain higher elevations in the border regions of Arizona and Mexico to the south. Much of the drainage is internal, especially in the most arid southwestern portion of the basin.

The location, physiography, and climate of the study area allow a variety of physical processes to produce flooding in different parts of the basin. Most of the western part of the basin lies within the Sonoran Desert and is characterized by extremely arid conditions, sparsely vegetated flat-floored alluvial valleys, and ephemeral stream systems which flow largely in response to local convectional showers. However, the Gulf of California and the Pacific Ocean are close enough to provide a source for large influxes of moisture which are occasionally steered into the region either by tropical storms or other kinds of atmospheric circulation patterns. In the range and basin topography in the central and southeastern portions of the basin, slightly higher elevations and frequent rainfall due to orographic effects result in increased intermittent streamflow with the added possibility of exceptionally large flows and flash floods when excess moisture enters the region. In the northern and northeastern parts of the basin, many streams draining the high elevations of the Mogollon Rim are able to maintain perennial flow due to an enhanced orographic effect and the accumulation of sufficient snowfall during winter storms to contribute to spring snowmelt flooding. Local convectional thunderstorms are a common source of flash flooding throughout the basin, especially during the humid summer months, and large frontal storms frequently sweep through the basin in winter.

A summary of basin characteristics for the 30 stations selected for this study is given in Appendix 1. The stations reflect a wide range of conditions in the Gila River basin and provide an adequate sample with which to examine multiple causes of flooding in an arid and semiarid environment.

Streamflow Data

The streamflow data for the 30 selected U.S. Geological Survey gaging stations were obtained directly from U.S.G.S.computer files. Two types of stream data were used, (1) a monthly data set composed of mean monthly discharges for each year of a station's record, and (2) a flood data set composed of the "peaks-above-base" partial duration series for each station.

Station Selection

The selection of gaging stations was made with the hydroclimatic goals of this study in mind. One of the most difficult tasks in any hydroclimatic study of streamflow variability is to be able to distinguish between the effects of natural climatic variability and the effects of land use alterations and basin characteristics on the hydrology of a stream system. When analyzing only a single gaging station this can be extremely difficult unless detailed information about the land-use history of the basin is available in addition to a good network of climatic stations located within the watershed.

However, when a group of stations within a region are studied together and climate plays a strong role in their hydrologic variability, a common climatic signal will be detectable in streams that are responding to the same large-scale atmospheric controls. Comparing records for different gages along the same river can also help to separate localized hydrologic responses due to basin factors, from the broader hydrologic response due to climate over the whole watershed.

The 30 Gila basin stations were chosen to represent different aspects of the basin's climate and physiography. Care was taken to select watersheds with as few diversions and upstream impoundments as possible, although nearly all streams but the very smallest drainages along the Mogollon Rim are used as sources of irrigation or municipal water supplies to varying degrees. No major reservoirs were located upstream from any of the selected gaging stations. The quality of the records ranged from "poor" to "good" in the U.S.G.S. rating system, with most being assigned "fair" ratings. Record lengths varied among the stations. The longest continuous record was 70 years for the period 1911-1980 (San Francisco River at Clifton), and the shortest record of 13 years covered the period 1967-1980 (Rio Cornez near Ajo).

Fourteen of the 30 stations were designated as the main stream gages for this analysis (see Figure 7), while the other 16 upstream gages and tributary stations were used primarily to provide supplemental information about the nature and development of flooding at the main gages. Since a common period of record is essential when comparing hydrologic variability from basin to basin, the 31-year period of 1950-1980 was chosen. All but two of the main stream gages shared this period of record. The records of Rio Cornez near Ajo and Santa Rosa Wash near Sells were shorter than the 1950-80 base period, but these two stations were retained as main gages because they are the only representatives from the most arid part of the basin.

Treatment of Data

Peak Flow Data. The flood events recorded at each of the selected stations over the period of record comprised the primary data base for the hydroclimatic research. The flow events studied were those from the U.S.G.S. peaks-above-base or partial-duration series data file and included the largest annual flood for each water year in addition to any other discharge extremes during the year that exceeded a given base discharge.

The means and standard deviations of the 30 flood series varied considerably across the basin due in part to differences in drainage basin area, thus in order to compare the relative magnitudes of the peak flows from basin to basin, the flood values were standardized to dimensionless "z-scores" in the following manner. First a logarithmic (base 10) transformation of the data was performed for each station. By taking the logarithms of each discharge value, the highly skewed distributions typical of most flood series took on a more normally distributed distribution, useful for later statistical analyses. More elaborate curve-fitting of various other distributions to the data was not desired at this stage of the analysis. The mean of the 1950-1980 series of discharge logarithms was then subtracted from each individual discharge logarithm, and this value was divided by the standard deviation of the series to arrive at a dimensionless set of discharge values which could be used to compare the relative magnitudes of flood events in different sized basins over time. The z-scores were computed separately for both the partial-duration series and the annual series for each station and are given in Appendix B for the 14 main gages and several other supplementary gages.

Mean Monthly Discharge. The other type of streamflow data analyzed during the course of this research was a set of mean monthly discharge values, by station, for each year in the 1950-1980 period of record. These data were also obtained directly from U.S.G.S. computer files. Although the main focus of the study was on peak flows, analysis of the monthly data provided a means to analyze hydrologic variations on a "long-period" basis by examining the relationship between monthly averaged upper air pressure patterns and the mean monthly discharge recorded at various gages throughout the Gila basin. The technique for doing this, called correlation field analysis, is described below.

The mean monthly discharge values were prepared for the analysis by standardizing the data in monthly units over the base period 1950-1980, on a station-by-station basis. Because monthly discharge values in semiarid regions also exhibit skewed distributions due to highly variable flow, the raw data were first transformed by taking logarithms (base 10). Months with no flow are frequent in arid regions, hence the problem of attempting to take the logarithm of zero was avoided by adding 1 to each discharge value before transformation, as suggested by Kilmartin and Peterson (1972). Z-scores were then computed from the logarithms of discharge in a manner similar to that described above for the peak flow data, except that data for each month were transformed and standardized separately so that the high and low scores would be reflecting variability over time within a given month rather than mirroring the natural annual cycle of seasonal variations that occurs across months in every year. These standardized values were then suitable for comparing relative discharge variability through time over different-sized basins, and served as the input data for the monthly streamflow-circulation correlation field analysis.

Precipitation Data

A network of climate stations was selected to study the spatial distribution of daily precipitation across the Gila River basin during the development of peak flow events at each of the streamflow gaging stations. Snow depth information was also included for some stations in the network in order to observe snow accumulations and snowmelt in the higher elevations of the study area during flooding episodes.

Station Selection

Locations of the 38 precipitation and supplementary snow depth stations are given by the two-letter codes in Figure 7. An effort was made to select one or two stations which were representative of the watershed above each of the 30 stream gages. Another criterion was that the stations have long enough records to encompass the 1950-1980 base period, although this was not possible for all the stations. Reliable, continuous records were hardest to find in the arid southwestern watersheds, hence the Gila Bend and Yuma Citrus stations were included to reflect precipitation activity in that part of the basin. The Holbrook and Fort Valley stations, although outside the Gila River drainage area, have lengthy records and were included because they would reflect the climate just to the north of the basin at the edge of the Mogollon Rim and on the Colorado Plateau.

Treatment of Data

The precipitation data were not used in any computations or statistical analyses, hence no special treatment of the data was necessary. Daily precipitation totals at each station were mapped and used as part of the event analysis described later in this chapter, and monthly totals of precipitation were used primarily as supplementary information for the streamflow correlation-field study. In the winter months, snow accumulations and snow left on the ground were recorded for selected high elevation stations. These observations were later used to evaluate the contribution of snowmelt to the development of flooding in the northern part of the basin.

700 Millibar Pressure Height Data

An important phase of the hydroclimatic analysis of flooding in the Gila basin was the attempt to place the individual peak flow events into a broader climatic context by investigating the relationship between monthly upper air circulation anomalies and higher than normal streamflow at various locations within the study area. A grid of mean monthly 700 mb pressure heights for the 1950-1980 base period was used for this purpose.

Figure 8 depicts the grid-point network of 700 mb pressure heights that was used to define broadscale circulation features in the atmosphere. The grid is a simplified version of the 212 point grid used by Bartlein (1978) and the original source of his data was a five degree by five degree diamond-shaped grid for the whole Northern Hemisphere obtained from the Center for Climatic Research at the University of Wisconsin-Madison. The pressure height data set was updated from 1976 through 1980 by extracting 700 mb heights from the published monthly 700 mb circulation maps in Monthly Weather Review. Maps constructed from the collected data were compared with published circulation maps to validate the accuracy of the collected grid point data and assure its homogeneity with the earlier grid data.

Bartlein (1978) showed these data to be approximately normally distributed, hence no logarithmic transformation was necessary. The monthly 700 mb pressure heights were, however, standardized in the same manner as the monthly streamflow data to produce a set of 1950-1980 pressure height anomalies for each month.

Flood Event Analysis

A major contribution of the hydroclimatic approach to flood analysis lies in the possibility of identifying physically-based sources of variability and/or multiple populations in hydrologic time series. A physically-based analysis of flood genesis in the Gila River basin was accomplished by constructing flood maps, plotting daily precipitation totals, and interpreting daily weather maps for every partial series flood event which occurred in the 30-station sample during the 1950-1980 period of record. This detailed hydroclimatic analysis

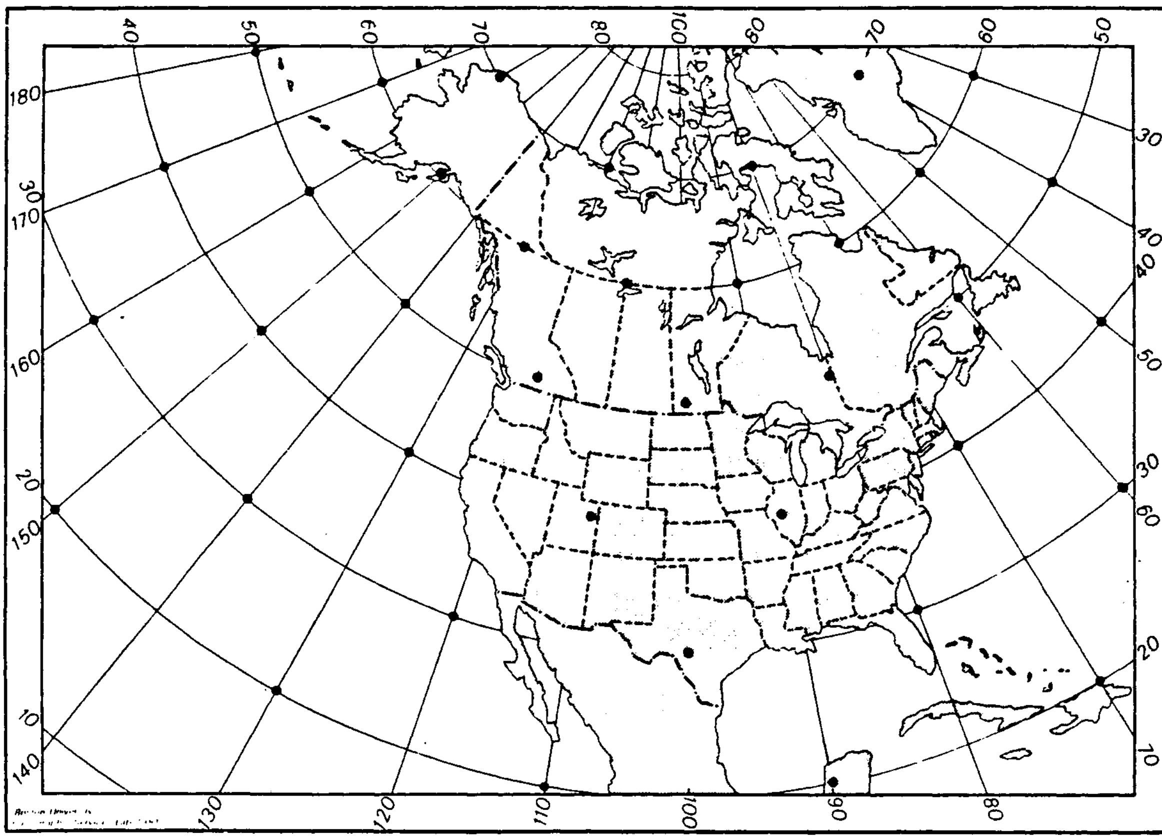


Fig. 8 Gridpoint Network for 700 mb Height Data

of individual flood events formed the basis for a hydroclimatic classification system that separated the flood series into climatically homogeneous subgroups in order to examine the possibility of mixed distributions and multiple populations in the data.

Individual Flood Maps

Simple basin flood maps were constructed from the peak flow data set and the daily precipitation station totals to visually display the spatial distribution and relative magnitude of flooding (using z-scores) and precipitation (in hundreths of an inch) for every peak-flow-event day in the 1950-1980 record. Figure 9 depicts a four-day flood sequence related to a major occluded front situated over the basin on March 1, 1978 and another cold front passing through the region between the 2nd and 3rd of March.

Several pieces of information can be easily observed with this simple method of data presentation. First of all, the maps show at a glance where flooding is taking place in the basin in response to the March 1-4 storm event. Secondly, the lines defining certain events as annual floods show that 17 of the 30 stations in the basin experienced their largest flow of 1978 during this four-day event, most of them in the northern part of the basin. The plotted z-scores indicate that the floods which occurred during the frontal storm were some of the largest in the entire 1950-1980 record for these stations. Finally, the day-to-day sequence of maps reveals an integrated response and a downstream progression of the flooding in the northern part of the basin, in contrast to the isolated single large flood occurring in the southern part of the basin. The construction and analysis

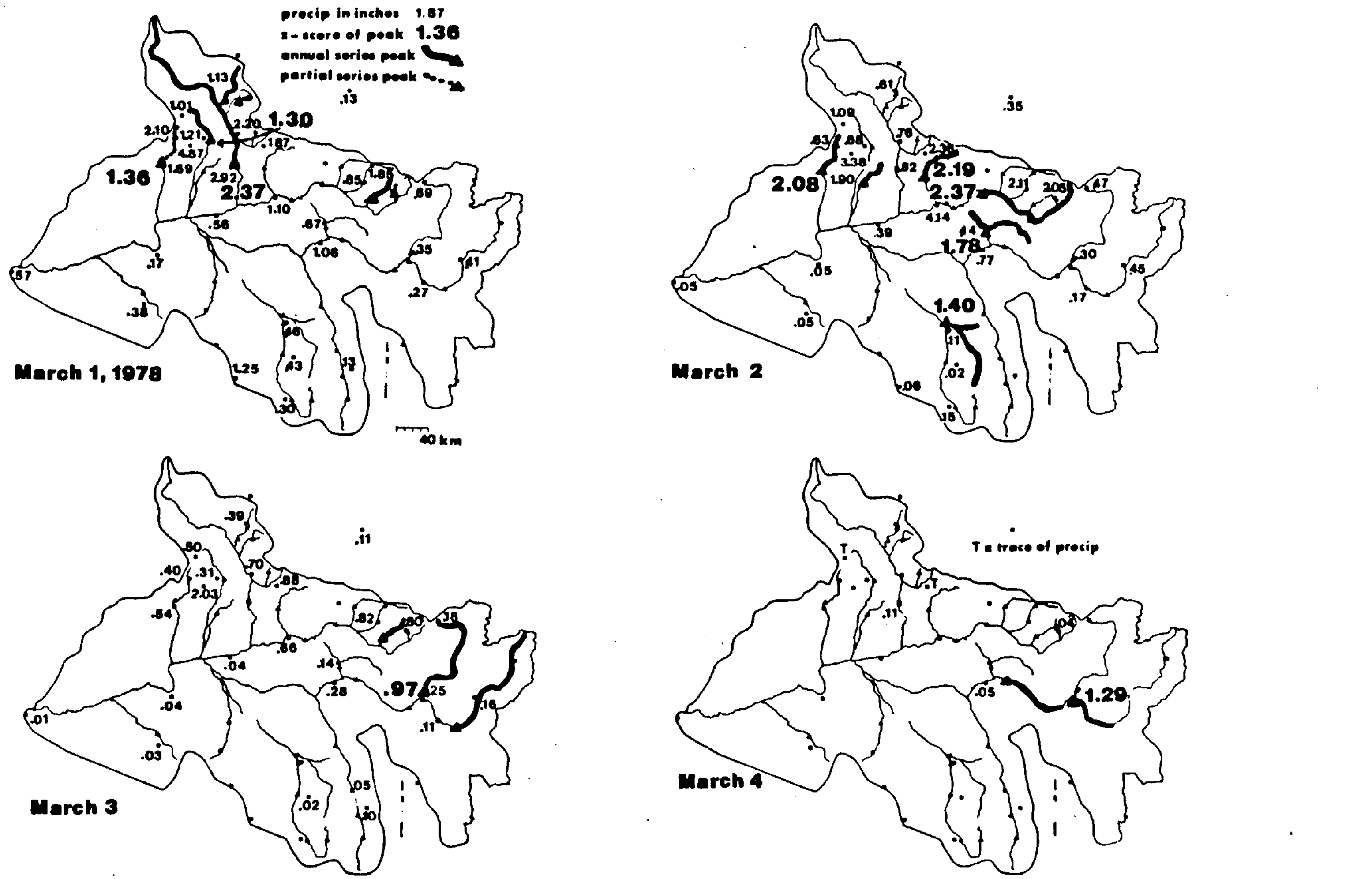


Fig. 9 Flood Map Sequence for a Frontal Storm Flood, March 1 - 4, 1978

of these basin flood maps, in conjunction with daily weather maps and any other available synoptic information, served as the basis for the development of a hydroclimatic classification of peak flow events in the Gila River basin.

Hydroclimatic Classification

Several synoptic-based classifications for exceptionally large floods and major flash flood events have been devised by hydrometeorologists for areas in the western United States (Maddox and Chappell 1978; Maddox et al. 1979, 1980; Hansen and Schwarz 1981). However, no one has yet attempted the classification of a complete flood series for one or several streams in a region in terms of the meteorological and climatological processes which produce each individual flow event in the series.

Such a classification was completed during the course of this research for the 30 gages in the Gila River basin for the period 1950-1980. The classification was based on observations made from the compiled individual flood event maps and associated weather maps as well as other information such as beginning and ending dates for the summer "monsoon" season. Subjectivity is usually put forth as the main criticism of climatic classification schemes, therefore, to be as objective as possible the hydroclimatic classification developed in this study was carefully structured in flow-chart format to arrive at a consistent evaluation for each of the 2,852 flow events recorded in the Gila River basin during the period of record. The classification scheme is described in more detail in Chapter 3 and in Appendix C.

Monthly Circulation-Streamflow Analysis

As previously stated, streamflow was also analyzed on a monthly basis in order to identify the large-scale and longer-period climatic patterns from which the individual flood events evolved. This circulation-streamflow analysis was accomplished through the construction of correlation fields and circulation anomaly maps using the standardized 700 mb height and mean monthly discharge data sets.

Correlation Fields

The correlation field technique is a way of displaying the spatial relationship between a series of observations at a single station and a corresponding spatial array of observations in a grid of several stations. By plotting the correlation coefficients in map form at each respective grid point location, a correlation pattern will emerge that displays geographically where a strong relationship exists between the grid point observations and the single station observations. The technique has been used successfully by meteorologists in relating precipitation at a station to the circulation features seen in a grid of 500, 700, or 850 mb pressure heights (Stidd 1954, Klein 1963, Lund 1971). These studies have demonstrated that there is a physical meaning to the correlation field such that the grid point pattern of correlations, when contoured, can be interpreted as a circulation composite map or a circulation anomaly map by revealing the dominant areas of mean upper air high and low pressure which affect precipitation variability at the station.

More recently the technique has been applied to observations of monthly streamflow at a station (Bartlein 1978). Like the precipitation correlation fields, the streamflow correlation fields display the relative positions of upper air highs and lows which control the air flow and meteorologic conditions that either enhance or suppress monthly discharge at a given station. It should be noted that in the correlation field technique as used here, the pattern of the positive and negative correlations over the gridpoint network is of greater interest than the relative significance of the correlation coefficients at any one gridpoint. Lund (1971) and Stidd (1977) attempted to assess the significance of the magnitudes of individual correlation coefficients, but did not address testing the significance of the correlation pattern itself. However, the correlation fields may be compared with actual 700 mb maps during periods of high and low monthly streamflow to check the validity of the constructed correlation fields as generalized representations of the actual circulation-streamflow relationship.

Figure 10 shows correlation fields constructed by Bartlein (1978 and written communication) for two Gila River basin stations and the Bright Angel Creek station in the Colorado River basin to the north. The upper air flow patterns which enhance streamflow are slightly different in each basin, but appear to have some common features suggesting that a more detailed study of correlation fields for other stations in the area would be fruitful.

Monthly correlation fields were constructed for 16 Gila River basin stations from the product-moment correlation coefficients between the time series of standardized monthly streamflow at a given station, and the time series of standardized 700 mb heights at each of 38 grid

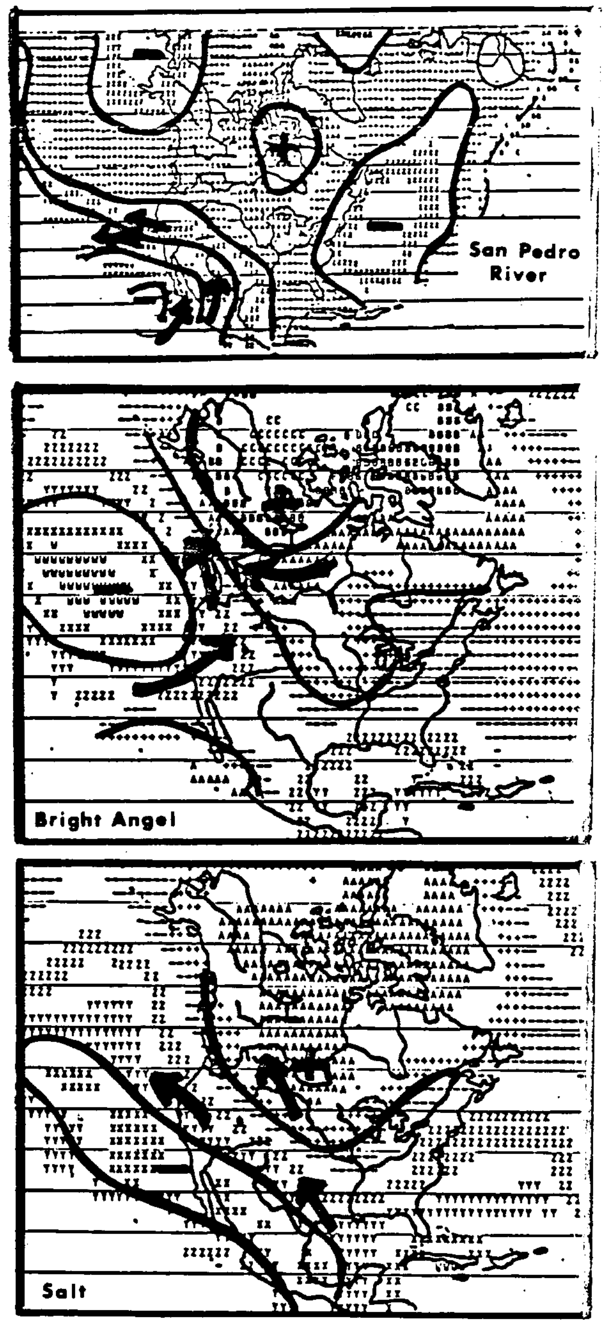


Fig. 10 Correlation Fields for Streamflow at Three Arizona Stations (from Bartlein, written communication)

points. The correlation coefficients were plotted at their respective gridpoints, and when contours were drawn, the resulting correlation field could then be interpreted as a an upper air circulation map with positive and negative areas on the map reflecting anomalous clockwise and counterclockwise flow, respectively.

Composite Circulation Maps

The maps of standardized values of monthly 700 mb heights for each month in the 1950-1980 record can also be interpreted as monthly circulation anomaly maps, representing areas of higher-than-normal and lower-than-normal 700 mb constant pressure surface. In order to examine the relationship between anomalous upper air flow and different types of flooding events in the Gila River basin, composite circulation maps were constructed by averaging together the standardized circulation maps for thôse months during which a certain type of flooding dominated. For example, months which experienced frequent flooding due to tropical storms were identified, and the corresponding monthly circulation maps were composited to obtain a generalized anomaly map describing the circulation pattern most strongly associated with flooding due to tropical storms in the Gila River basin. These composite maps were then compared with the actual 700 mb maps associated with the tropical storms to validate that the composite pattern correctly represented, in a generalized way, the true condition of the atmosphere.

Flow-Frequency Analysis

One of the goals of this research is to apply physically-based information about the nature of hydroclimatic flood variability to traditional, runoff-based flood-frequency analysis. Before any hydroclimatic assessment of the flood series was undertaken, standard flood-frequency analysis was performed in the usual manner on the annual flood series for all 30 stations over their entire periods of record to provide a basis for a later hydroclimatic reevaluation of the data.

The frequency analysis program used was obtained from the Inland Waters Directorate, Environment Canada. Program FDRPFFA (Flood Damage Reduction Program - Flood Frequency Analysis, Condie et al., 1981) was selected for use because it provides flood estimates for the same series of data using different theoretical distributions and curve-fitting techniques, including two procedures for fitting the log-Pearson Type III distribution to the data (method-of-moments and maximum likelihood). The greater flexibility in choice of distributions and curve-fitting provides more information about the nature of flood series variability and also relates information about the degree of disparity among 100-year (or other return-period) flood estimates, that can be introduced solely by the distribution chosen for the analysis.

An accompanying program, Program NONPARA (Statistical Tests for Independence, Trend, Homogeneity and Randomness, Shiau and Condie, 1980) was also run on the flood peak data to assess the amount of statistical persistence, trend, and nonstationarity that was evident in the flood series as a whole, before any physically-based separation of the series was attempted.

Discussions on the use of the annual vs. the partial duration series for frequency analysis and other aspects of this portion of the research are presented in Chapter 6.

Analysis of Hydroclimatic Groups

The hydroclimatic classification of flow events described above was accomplished by using the individual flood event maps and related climatic information to follow the classification flow chart for each event and assign that event to one of eight main categories of flood genesis for the Gila River basin (see Chapter 3). This classification of flood events into groups raises the question of whether or not these hydroclimatically homogeneous groups can be conceived as subpopulations, statistically distinct from each other and distinct from the overall population of the entire flood series.

The very small sizes of some of the group samples and the slightly skewed nature of the group distributions (even after logarithmic transformation) hindered attempts for robust testing of the difference between group means and group variances. Side-by-side plots of the histograms of each group were constructed using Program BMDP7D, "Description of Groups (Strata) with Histograms and Analysis of Variance" (BMDP Statistical Software, Dixon 1981) and proved to be very effective for a visual "first approximation" assessment of the differences among groups. Evaluation and discussion of this portion of the research is presented in Chapter 5.

Summary

Floods evolve from a variety of physical mechanisms in the Gila River basin. The hydroclimatic approach presented here for the analysis of floods was based on monthly and peak flow discharge data for 30 gages located throughout the study area. The pattern of daily precipitation totals at 38 climate stations in the basin was used, in conjunction with daily weather maps and other supplementary climatic information, to classify each partial duration series flood event according to the climatic generating mechanism associated with the event.

Monthly correlation fields were constructed from standardized monthly discharge totals and a grid of standardized 700 mb pressure heights to examine longer-period hydroclimatic relationships in the study area. Composite circulation maps were also constructed from the standardized 700 mb data to identify broadscale circulation patterns associated with different types of flood-generating mechanisms.

Traditional flood-frequency analysis was performed on each of the 30 flood series for a later hydroclimatic reevaluation of the technique. Events in the flood series were grouped into hydroclimatically homogeneous groups and differences among the groups were assessed by plotting histograms and performing statistical tests.

The following three chapters discuss different aspects of the results of the analyses described above in terms of climatology, hydrology, and hydroclimatology; and the final two chapters discuss some implications of these results.

CHAPTER 3

CLIMATOLOGY

In every year, the cycle of shifting circulation patterns in the midlatitudes proceeds from season to season and brings with it sequences of high and low pressure, warm and cold fronts, influxes of moist and dry air, and occasional unique events such as tropical storms. The spatial and temporal interplay of these various physical mechanisms in the atmosphere constitutes the climate for a particular region.

The Gila River basin is situated in a region that experiences a variety of circulation patterns with strong seasonal differences in the types of atmospheric processes that affect the basin. The climatic genesis of flood events at different times of the year is as seasonally and spatially variable as is the climate itself. These differences in the physical mechanisms that produce floods during different times of the year in different parts of the basin suggest that there is a strong possibility for the existence of mixed distributions or multiple populations in the Gila basin flood series. To examine this possibility, a climatically-based flow-event classification system has been developed and is described in this chapter.

Climate of the Gila River Basin

The observations of Sellers and Hill (1974) on the annual variation of mean monthly precipitation and precipitation intensity across the state of Arizona provide a general introduction to the climate of the study area. They noted the existence of a bimodal pattern, seen in two distinct seasons of precipitation, with the summer season experiencing slightly greater intensities of precipitation than the winter season.

Figure 11 shows this bimodal precipitation pattern throughout Arizona, even at the Yuma station in the most arid southwestern portion of the state. The seasonal plots show that the summer peak tends to be more dominant in the southeastern portion of the state and that winter precipitation takes on more importance in the northern part of the Gila River basin. The reasons for this spatial pattern are due primarily to the dominance of different types of precipitation generating mechanisms in different parts of the basin.

Summer Precipitation

The summer rainy period of higher intensity precipitation, the so-called "summer monsoon," begins in late June or early July and generally persists until late August or early September. The synoptic circulation pattern responsible for the influx of moisture that starts off the rainy season has been discussed and debated by a number of authors.

Bryson and Lowry (1955) linked the abrupt onset of raininess in Arizona to the marked adjustment, or "summer high jump" which occurs

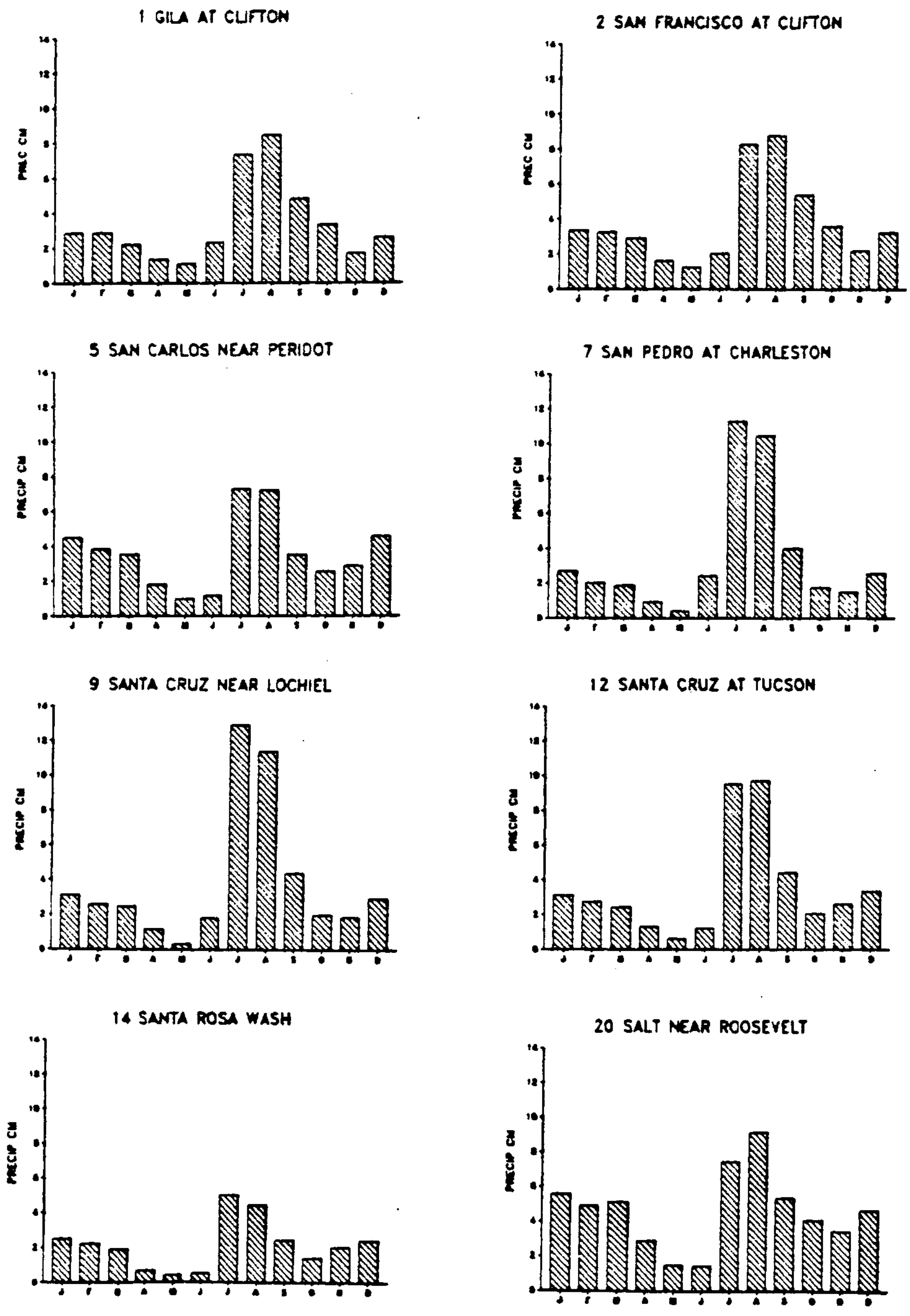


Fig. 11 Seasonal patterns of Monthly Precipitation in Arizona (source of data is U. S. G. S., see Appendix A)

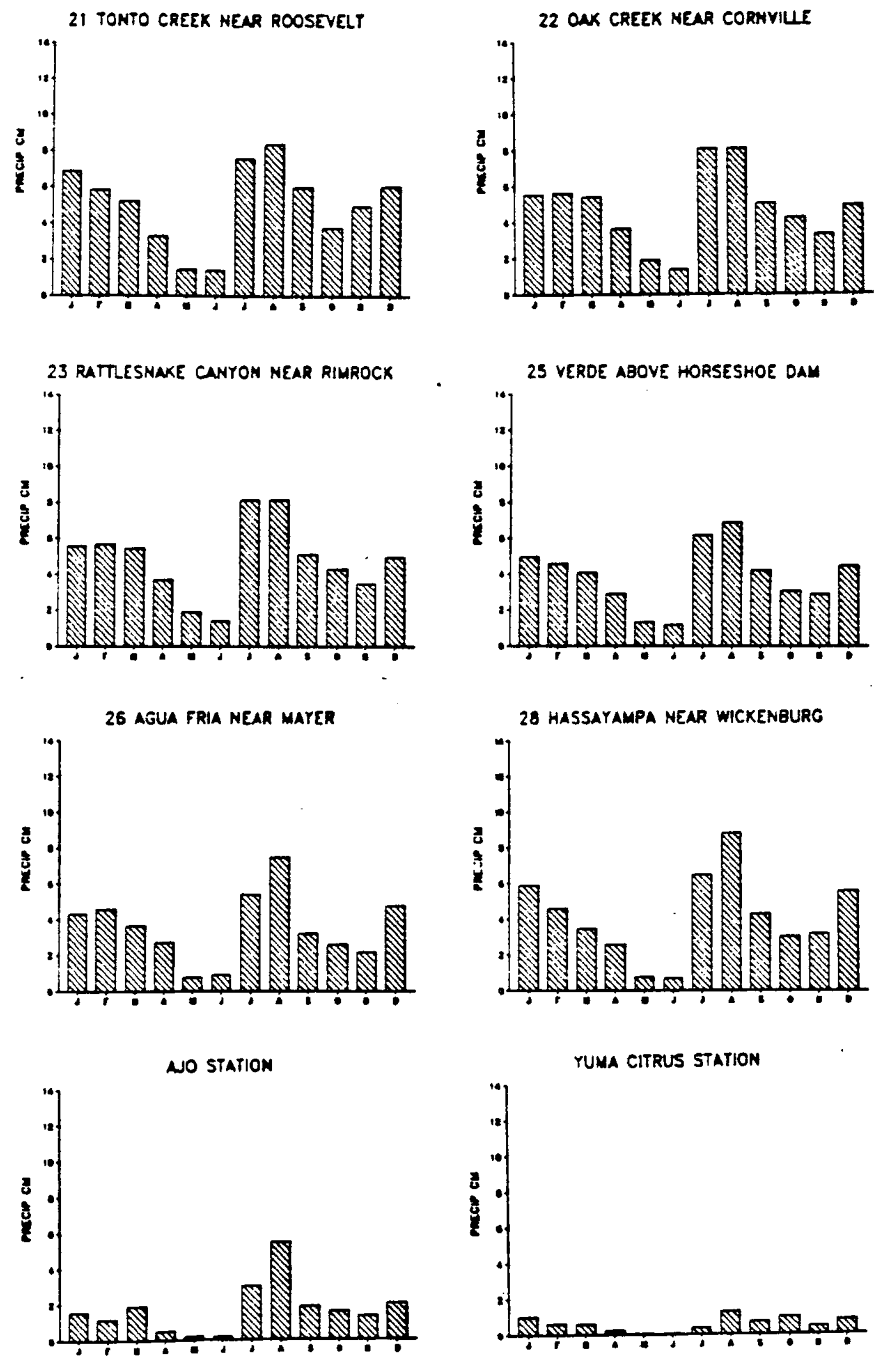


Fig. 11 --Continued

in the general circulation of the atmosphere sometime near the end of June. They observed that a semi-permanent trough aloft over Arizona shifts its orientation in response to this late June broadscale atmospheric adjustment. Once the summer pattern is established, the trough aloft shifts to a location off the California coast and a southeasterly flow around the western limb of the Bermuda High begins to entrain moist air from the Gulf of Mexico into Arizona to start off the summer widespread rains.

A contrasting view was presented by Hales (1974) who insisted on the Pacific Ocean or Gulf of California as the principal source of moisture for southern Arizona's rainy season. He argued that the terrain over central Mexico reached to high enough elevations to act as a barrier to the movement of low-level moisture westward and northwestward into Arizona.

Others have suggested that both the Gulf of Mexico and the Pacific Ocean may serve as sources of summer moisture at different times during the season, the Gulf of Mexico source being more important soon after the "summer high jump," and the Pacific Ocean source gaining importance later in the season, especially when other synoptic adjustments allow tropical storms from the eastern North Pacific to move inland or dissipate off of Baja, California (Douglas and Fritts 1973).

Whatever the source of the relatively sudden influx of moist air, its effect on the climatology of the Gila basin is to shift the region into a new mode of atmospheric operation characterized by widespread, but scattered, convectional thunderstorms which are triggered and enhanced by intense surface heating and orographic effects.

Winter Precipitation

The secondary winter precipitation maximum which dominates from November through April, especially in the northern part of the Gila basin, is mainly frontal in origin and is associated with large-scale low pressure systems traveling in the belt of upper air westerly wind flow. For the most part, the main winter storm track lies to the north of the study area and precipitation is usually related to trailing cold fronts moving across the northern part of the basin. Occasionally a very deep trough will develop over the western United States and steer major cyclonic centers into the area.

Summer vs. Winter Precipitation

McDonald (1956) was the first to demonstrate, using coefficients of variation, that summer precipitation in Arizona has great spatial variability in any one year from station to station, but shows less temporal variability because individual stations tend to receive summer rains fairly consistently from year to year. Conversely, precipitation occurring in winter months can have great variability from year to year, but tends to be spatially homogeneous in any one year. He attributed this to differences in the physical mechanisms which produce precipitation in the two seasons. Winter precipitation results primarily from the passage of frontal and cyclonic circulation systems, some of which are large enough to cover the entire state with one spatially homogeneous storm. In contrast, much of the summer precipitation results from isolated thunderstorms and intense, local convectional showers which are easily triggered by surface heating and orographic effects operating on the unstable, moist air entrained by the summer monsoon.

Winter frontal storms and summer local convectional storms are the two most common sources of precipitation in the Gila River basin, but Douglas and Fritts (1973) and Douglas (1974) reported on two other atmospheric mechanisms which contribute significantly to precipitation in the study area: tropical storms and cutoff lows.

Tropical Storms

The season of tropical storm influence on Southwest precipitation is generally August through October, and synoptic conditions in September tend to be the most favorable for the movement of storms into the Southwest (Douglas and Fritts 1973). Figure 12 shows the percentage of annual precipitation due to tropical storms for the periods 1921-1940 and 1947-1970 for five stations in Arizona. At the Yuma station, closest to the Pacific Ocean and Gulf of California moisture source, precipitation due to one or more tropical storms exceeded 70% of the annual total for some years. Tropical storm precipitation percentages were somewhat less, but still significantly large, at other stations in the Gila River basin. It is clear that variability in precipitation time series and flood series will be strongly affected by the temporal variability of tropical storms which track close enough to the coast to influence precipitation inland.

A series of maps have been compiled by Walter Kip Smith of the Laboratory of Tree-Ring Research at the University of Arizona (written communication) which depict the precipitation patterns in the Southwest that are associated with 74 Pacific tropical storms

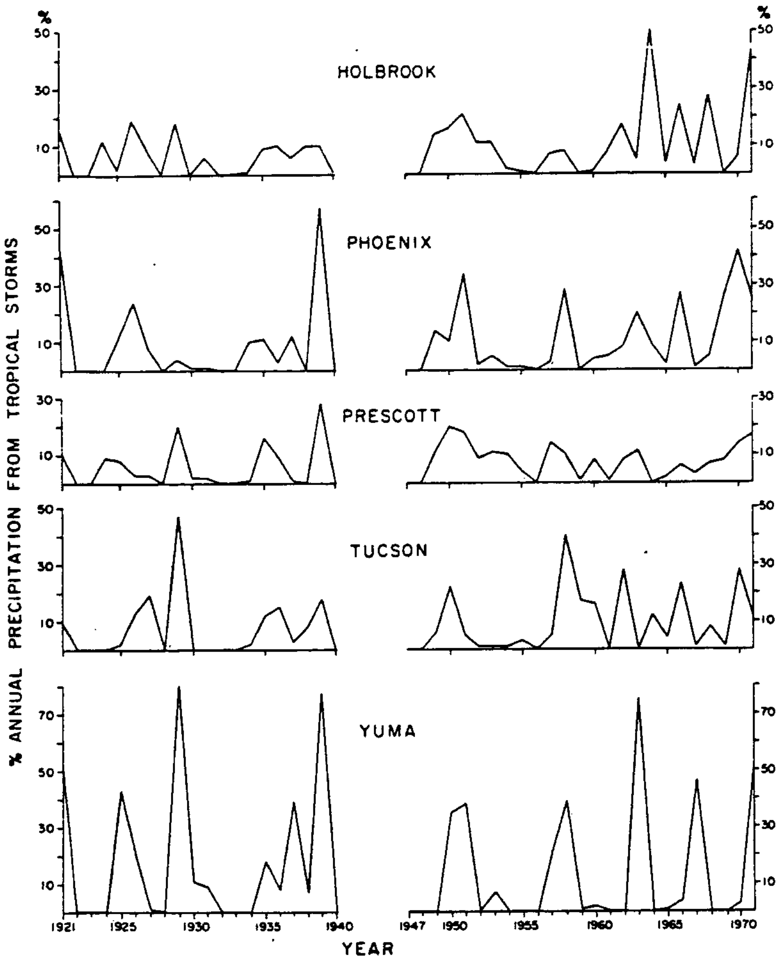


Fig. 12 Percentage of Annual Precipitation Due to Tropical Storms for Five Stations in Arizona (from Douglas and Fritts, 1971)

of the 1900s from 1901 to 1983. Over half (36 of 68) of the tropical storms listed produced flooding somewhere in the Gila River basin during the period 1901-1980 indicating the importance of the tropical storm generating mechanism as a source of flooding.

Cutoff Lows

Closely associated with tropical storms in a synoptic sense is the occurrence of cutoff lows in the upper atmosphere. Cutoff cyclones tend to develop off the west coast of the U.S. during the fall (September-November) transitional period when summer circulation patterns are adjusting to the more developed ridges and troughs of the winter pattern, and again during the spring (May-June) transitional period between winter and summer. These periods are normally dry in the study area, thus the occurrence of a cutoff low and the precipitation resulting from it are usually quite anomalous events.

During the course of examining weather maps for the hydroclimatic classification, it was observed that tropical storms at the surface were often associated with a trough aloft, or frequently, a cutoff low in the upper atmosphere. Douglas (1974) showed that, although the cutoff-low contribution to the total annual precipitation is somewhat less than is typically contributed by tropical storms, in certain instances cutoff lows can indeed be responsible for a significant percentage of the annual precipitation at some Arizona stations.

Easterly Waves

At times, weak middle-level, short-wave troughs move through the general westerly flow in an easterly direction and induce instability that results in significant localized precipitation and severe flash flooding. In their synoptic classification of meteorological features which produce flash floods, Maddox et al. (1980) included these short-wave trough events as one of four major synoptic types responsible for flash flood events in western United States. Because they are a smaller, short-wave phenomenon, detection of easterly waves over Arizona is not very accurate when based on a single daily 500 mb weather map, hence no attempt was made to classify easterly waves in the study presented here, although it is recommended that this potential source of flooding in the Gila basin be examined in more detail using the appropriate upper air maps.

Summary and Discussion

Precipitation occurs from a variety of atmospheric mechanisms at different times of the year in central and southern Arizona. The synoptically distinct nature of the different seasonal sources for precipitation and floods is a strong physically-based argument for hypothesizing the existence of multiple populations in the flood series of the Gila River basin. In fact, there may even be physically-based reasons for the actual shape of the probability distribution for different types of flood-generating mechanisms.

Tropical storms and cutoff lows are unique atmospheric events that may or may not occur in the study area in any given year. The probability of precipitation and flooding resulting from these events is based on the presence or absence of a specific atmospheric synoptic pattern. The probability of precipitation and flooding in response to the summer monsoon circulation is of a completely different nature than the probability of flooding due to tropical storms or cutoff lows. The "ingredients" for summer monsoon flooding are present at all times (subject to slight variations in moisture) once the monsoon circulation has been established, while flooding due to a tropical storm or cutoff low circulation is highly dependent on the occasional development of specific kinds of large-scale atmospheric circulation patterns. The probability of flooding due to winter frontal storms, although a regular seasonal feature of the Gila basin's climate, is also dependent on the development of particular configurations in the large-scale circulation, such as the position of a trough aloft.

These physical constraints on the occurrence of the different atmospheric processes which produce flooding may be reflected in the stochastic-process model of a flood series (Figures 4 and 5) by the position and shape of the individual theoretical distributions -- the $X(t_n)$'s -- which occur at different times over the period of record. The hydroclimatic classification of flow events was developed to examine this possibility.

Hydroclimatic Classification

Figure 13 presents the generalized flow chart procedure that was used with each partial-series flow event to assign it to one of several climatically-based classifications of flow genesis. Decisions were made at branching points in the chart on the basis of the individual flood event maps (Figure 9) and daily synoptic weather maps (NOAA Daily Weather Maps, Weekly Series).

The general pathway through the chart consisted of the following: After first deciding whether or not the monsoon summer

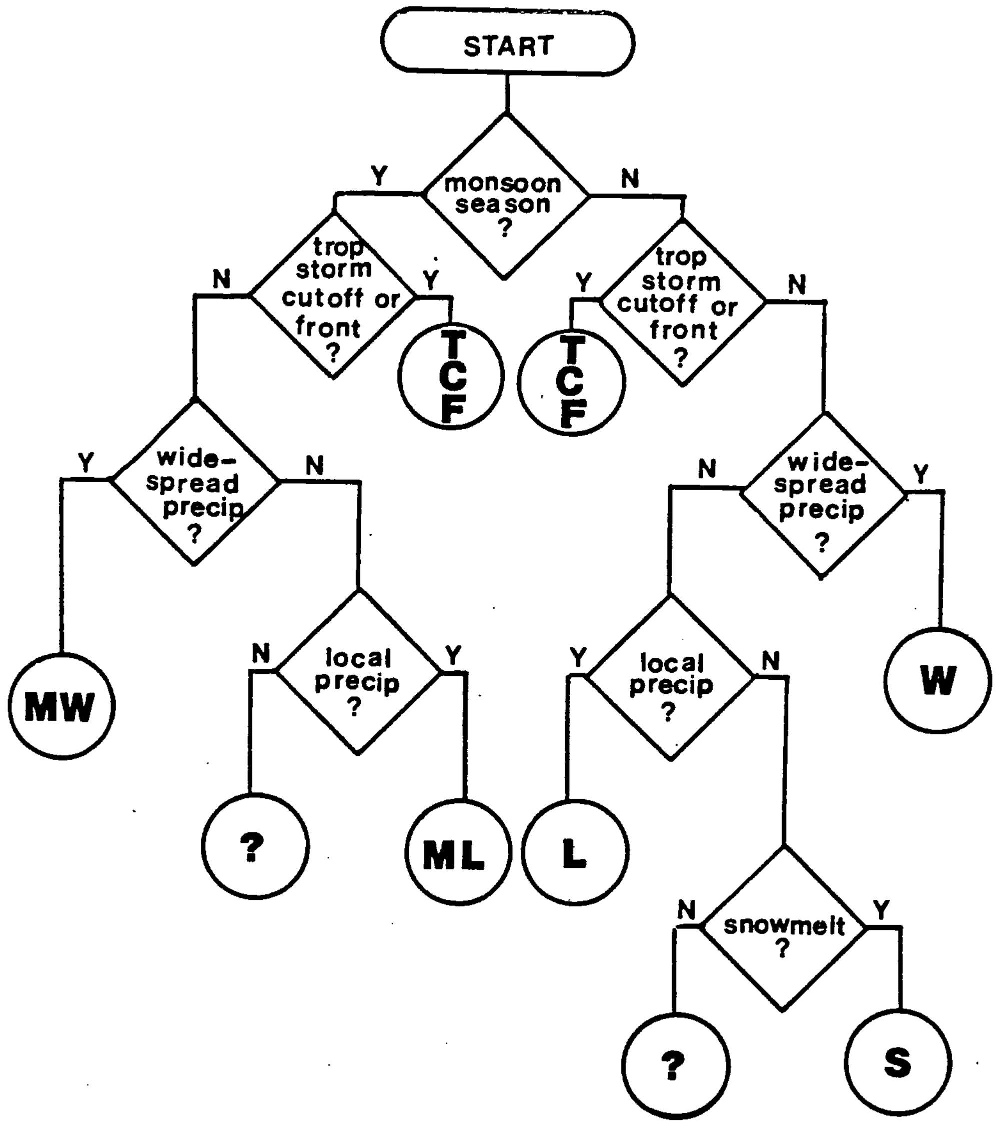


Fig. 13 Flow Chart for Assigning a Hydroclimatic Classification to Each Flow Event

circulation pattern had been established, weather maps were examined to determine if major synoptic features such as tropical storms, cutoff lows, or fronts were affecting the precipitation pattern of the developing flood. If no such features were observed, a determination was made of the "widespread-synoptic" vs. "local convectional" nature of the precipitation over the basin on the basis of the pattern of daily precipitation totals plotted on the flood event maps. During the non-monsoon season, evidence for snowmelt as a source of flooding was also examined. Combinations of classifications were possible, but an attempt was made to determine the dominating feature. If no classification or "probable" classification could be identified, the flood event was designated a "mystery flood," signified by " ?." (Fortunately, there were very few of these.)

A listing of the classification assigned to each flow event is presented in Appendix B. During the classification process the number of antecedant flows occurring at an individual station in the 30-day period prior to a given flood was also noted. The specific criteria used for the determination of the monsoon period, tropical storms, cutoff lows, and widespread vs. local precipitation are given in Appendix C.

Summary

The climate of central and southern Arizona is such that, during the course of a year, a variety of synoptic patterns and atmospheric processes will generate precipitation in the Gila River basin. These differing generating mechanisms may be the source of multiple populations in the flood series of stations in the Gila basin. A scheme is presented to classify flow events in the basin according to the atmospheric mechanism which generated the flow. This information is used in the following chapters to examine the general hypotheses presented at the end of Chapter 1.

CHAPTER 4

HYDROLOGY

Hydrologic activity in the Gila River basin shows considerable spatial and temporal variability. The annual distributions of peak flows at various stations in the study area reflect the spatial variability produced by different types of flood-generating mechanisms in different parts of the basin. The temporal variability of annual and partial series flow events at each station over the period of record is more difficult to assess in terms of flood-generating mechanisms. The hydroclimatic classification of the flow events sheds new light on the origins of temporal hydrologic variability in the study area.

The Nature of Hydrologic Activity in Arid Regions

Sensitivity to climatic variability is high in arid and semiarid streams. Ephemeral and intermittent flow is common in many streams of the Southwest, and these flow regimes tend to have a different kind of rainfall-runoff relationship than that of perennial flows in more humid regions. Because ephemeral streams flow only in response to precipitation events, they should exhibit a close relationship between the occurrence of a rainfall event and the corresponding runoff response. However, transmission losses and recharge into channel beds may obscure the actual magnitudes of discharge involved in the rainfall-runoff relationship and cause this relationship to vary considerably from flow event to flow event. Furthermore, the existence of antecedant rainfall may change the relationship altogether, yielding more runoff than might otherwise be expected (Chery 1972).

Runoff hydrographs of streamflow in arid regions like the Gila River basin can be strikingly different at different times of the year, due, in part, to some of the above-mentioned factors and in part, to the kinds of atmospheric generating mechanisms which produce the flows. For example, a flow event occurring in response to an intense summer convectional thunderstorm might exhibit a hydrograph similar to Figure 14a, while a flow event produced by a winter frontal storm would show a longer rise time, less of a peak, and a longer recession time (Figure 14b). Brown (1965) observed patterns similar to those in Figure 1 when comparing summer and winter recession flows in small semiarid watersheds in Arizona. He also noted the contribution of snowmelt to the longer recession times of winter flows.

Floods produced by rare extreme events, such as tropical storms, cutoff lows, or a combination of processes, exhibit complex hydrographs (Figure 14c) which reflect the great magnitude of moisture delivered to the watershed, the complex nature of the storm itself, and also the complicated nature of the catchment's response to a synoptic-scale delivery system. Figure 15 displays hydrographs for various gaging stations along the Santa Cruz River during a major flood in October 1977 that was generated by the combination of moisture from Tropical Storm Heather and a cold front with a trough aloft. The three crests seen in the flood wave at the downstream (highest discharge) stations

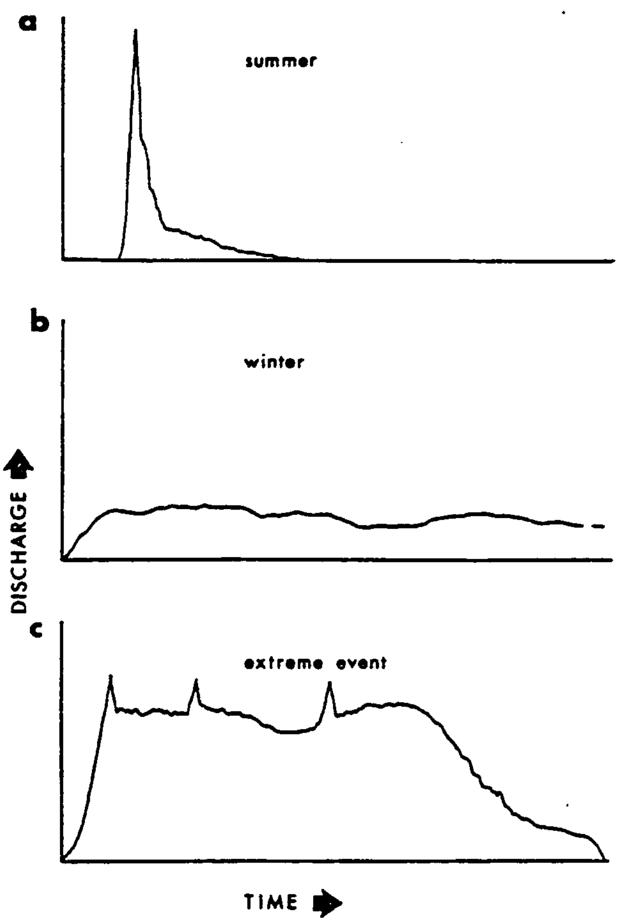


Fig. 14 Idealized Hydrographs for Different Atmospheric Generating Mechanisms
a. Summer Convectional Shower
b. Winter Frontal Storm
c. Tropical Storm/Cutoff Low Combination
(from Keith 1981)

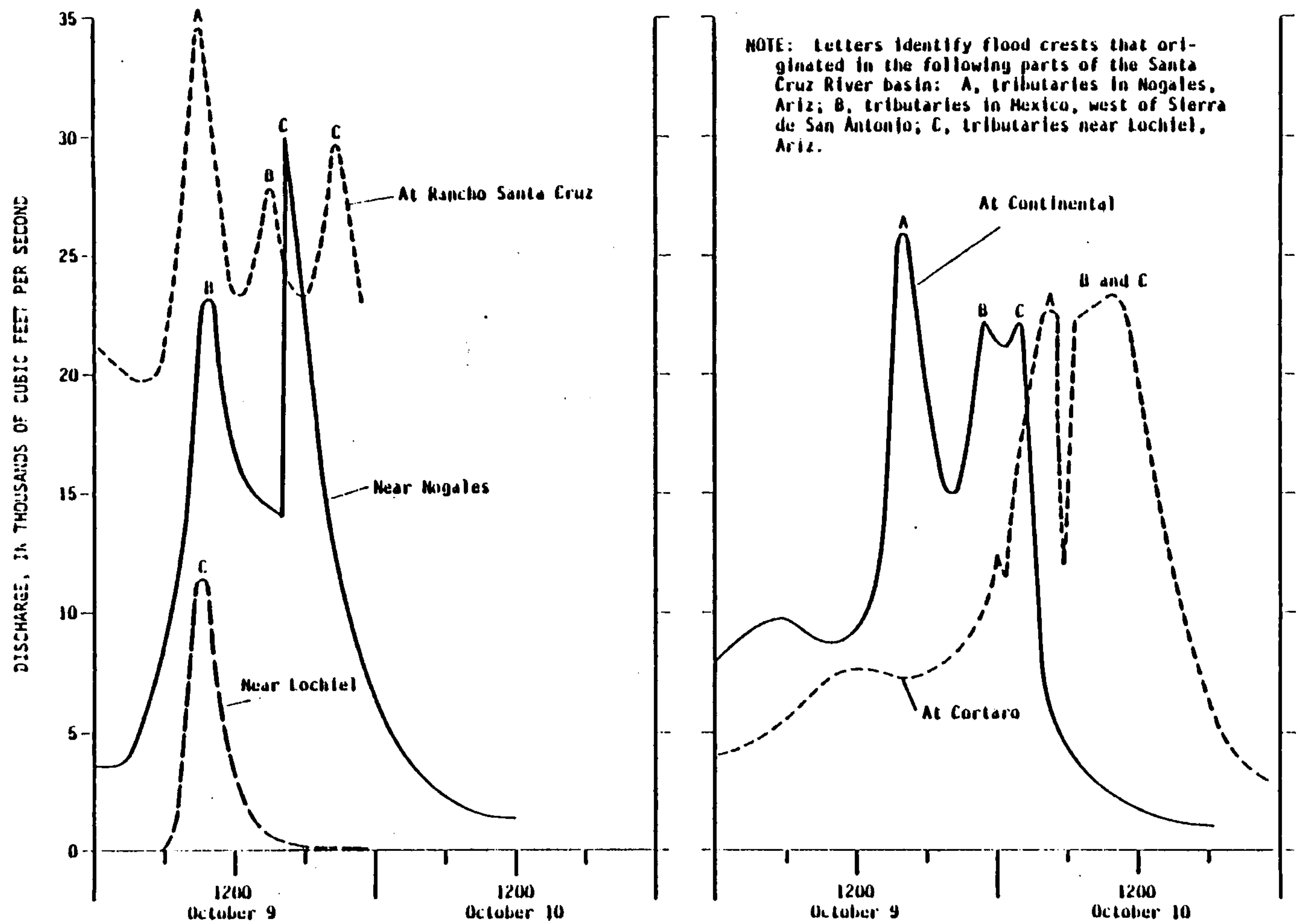


Fig. 15 Complex Hydrograph for October 1977 Flood Wave (from Aldridge and Eychaner 1982)

were produced, not by three pulses of a complex atmospheric process, but by differences in travel time from three separate tributaries, all of which experienced high discharges due to the extent and intensity of the combined atmospheric generating mechanisms (Aldridge and Eychaner 1982). If pulses in synoptic atmospheric activity were superimposed on the flow hydrograph, an even more complex pattern would probably have emerged.

The varying nature of the atmospheric processes affecting the Southwest, and the sensitivity of arid and semiarid hydrologic systems to climate, suggests that they may be particularly susceptible to violations of the homogeneity and stationarity assumptions in a time series of flows. The remainder of this chapter will describe hydrologic variability in the Gila River basin with this possibility in mind.

Hydrologic Variability in the Gila River Basin

Chapter 3 described the bimodal nature of summer and winter precipitation in the Gila River basin. The seasonal variability of monthly runoff shows a similar bimodality, but the seasonal distribution of annual flood peaks has a slightly different pattern, especially in the southern part of the basin.

Seasonal Variability of Monthly Runoff

Figure 16 displays plots of mean monthly discharge for selected gages in the Gila River basin. Means and standard deviations of discharge in cubic meters per second are presented for each month. The seasonal variability of monthly runoff across the Gila River basin

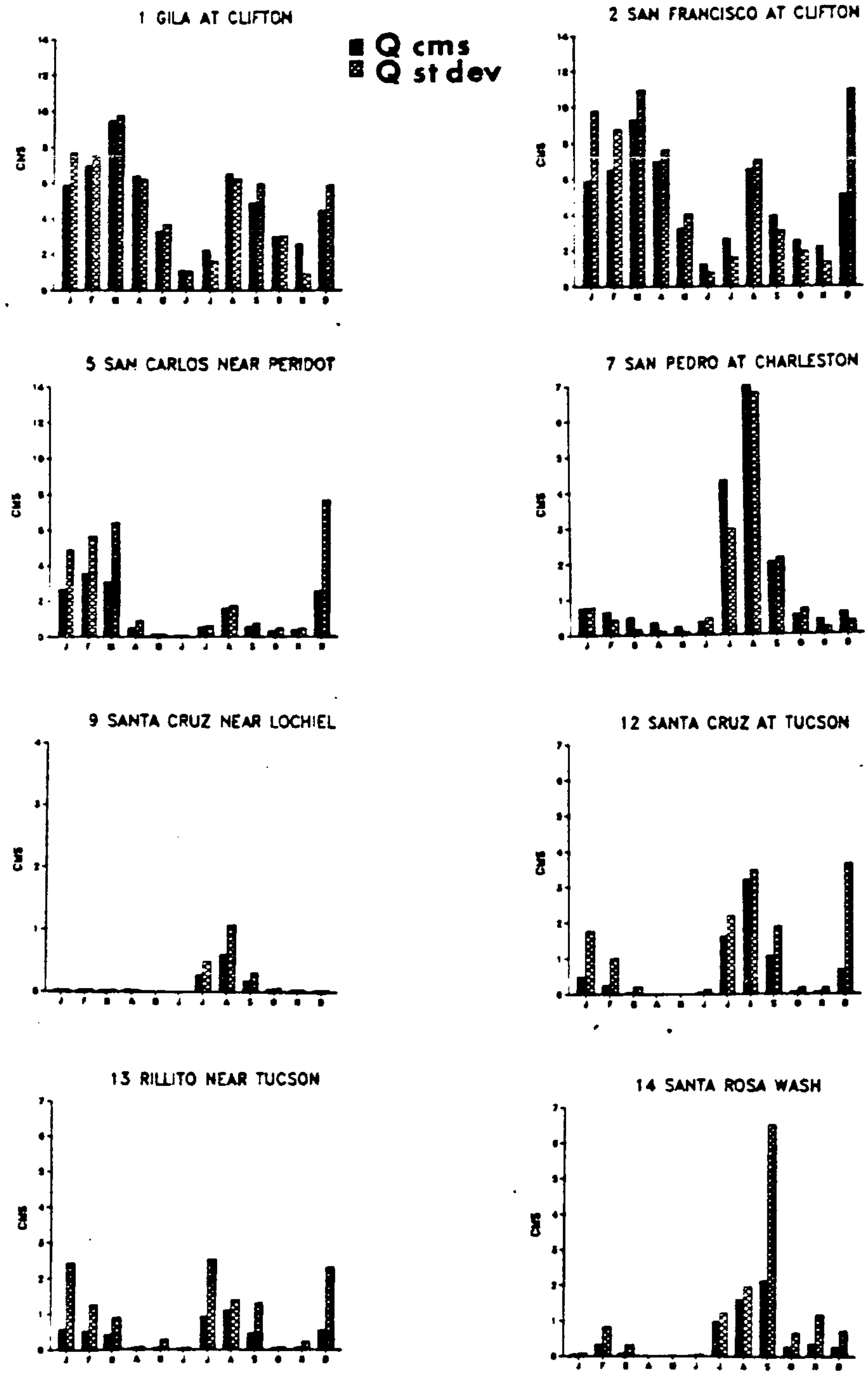


Fig. 16 Seasonal Patterns of Mean Monthly Discharge at Selected Gila River Basin Stations (st dev = standard deviation of Q)

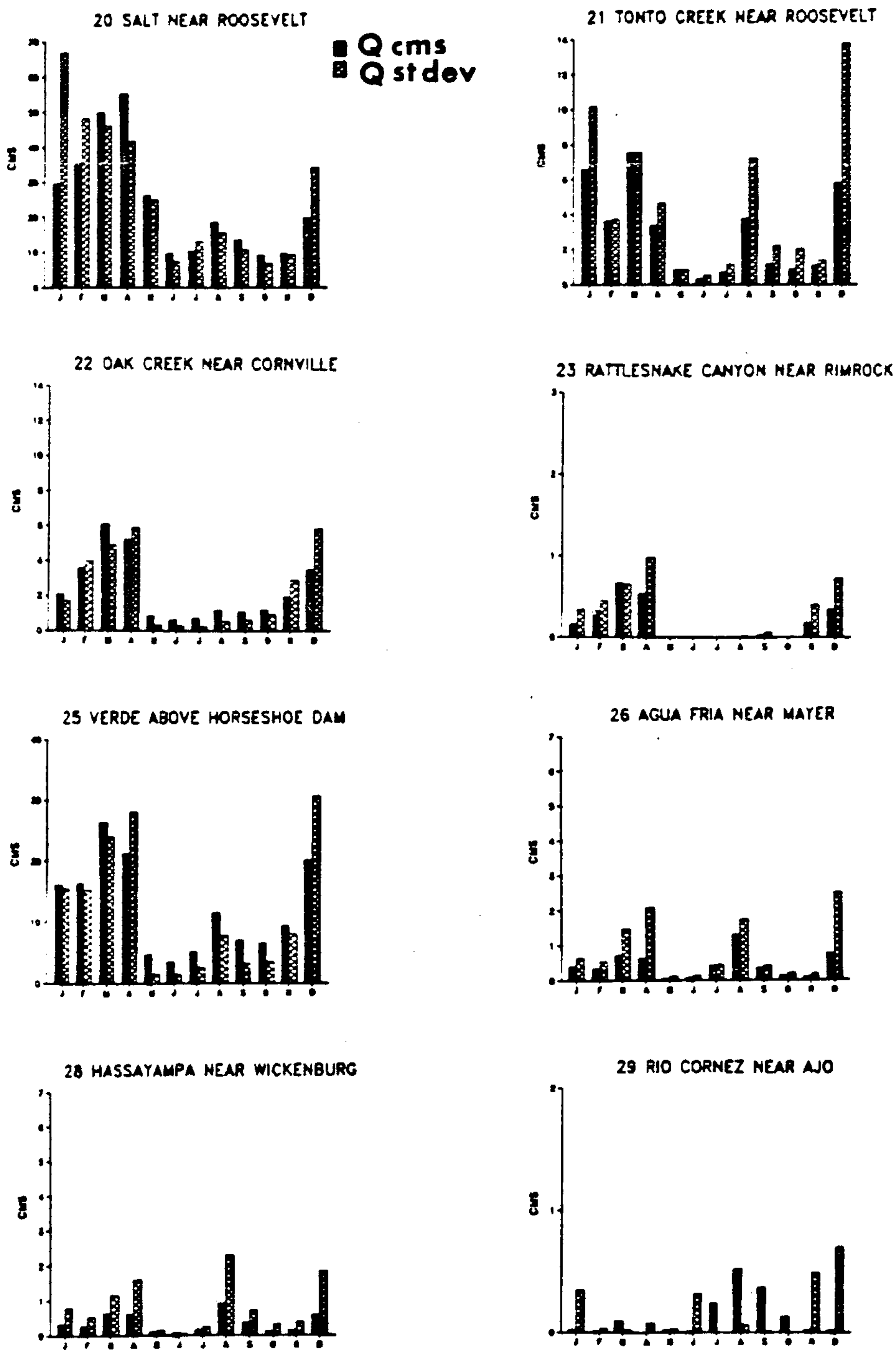


Fig. 16 --Continued

has a great similarity to the seasonal patterns of precipitation presented in Figure 11. The major differences between the monthly precipitation and monthly runoff patterns is in the winter months when proportionately larger discharges occur with relatively smaller amounts of monthly precipitation in some basins, such as in the Gila near Clifton and the San Francisco at Clifton. The saturated soil conditions and lower evapotranspiration rates of winter are primarily responsible for the larger winter discharges, but another factor could be the seasonal difference in flood-generating storm types.

The monthly standard deviations give a good indication of which stations experience the most variable runoff conditions. As would be expected, in the Gila River basin, the more arid stations in the southern and western part of the basin tend to have high monthly standard deviations in comparison to their mean monthly discharges.

Seasonality of Peak Flows

Figure 17 displays plots of the frequency of annual peaks which occurred in each month at selected stations over the period 1940 to 1975. Since record length varied somewhat from station to station, the shaded portion of the plots, (which represents the period of record common to all stations: 1955-1975), should be used to compare stations with each other.

The most notable feature of Figure 17 is the tendency toward a single mode of warm season flooding in the southern and western basins and a tendency toward a bimodal flooding regime in the northern and higher elevation drainages. This is partly due to the fact that the basins in the south and west drain lower elevations and are not

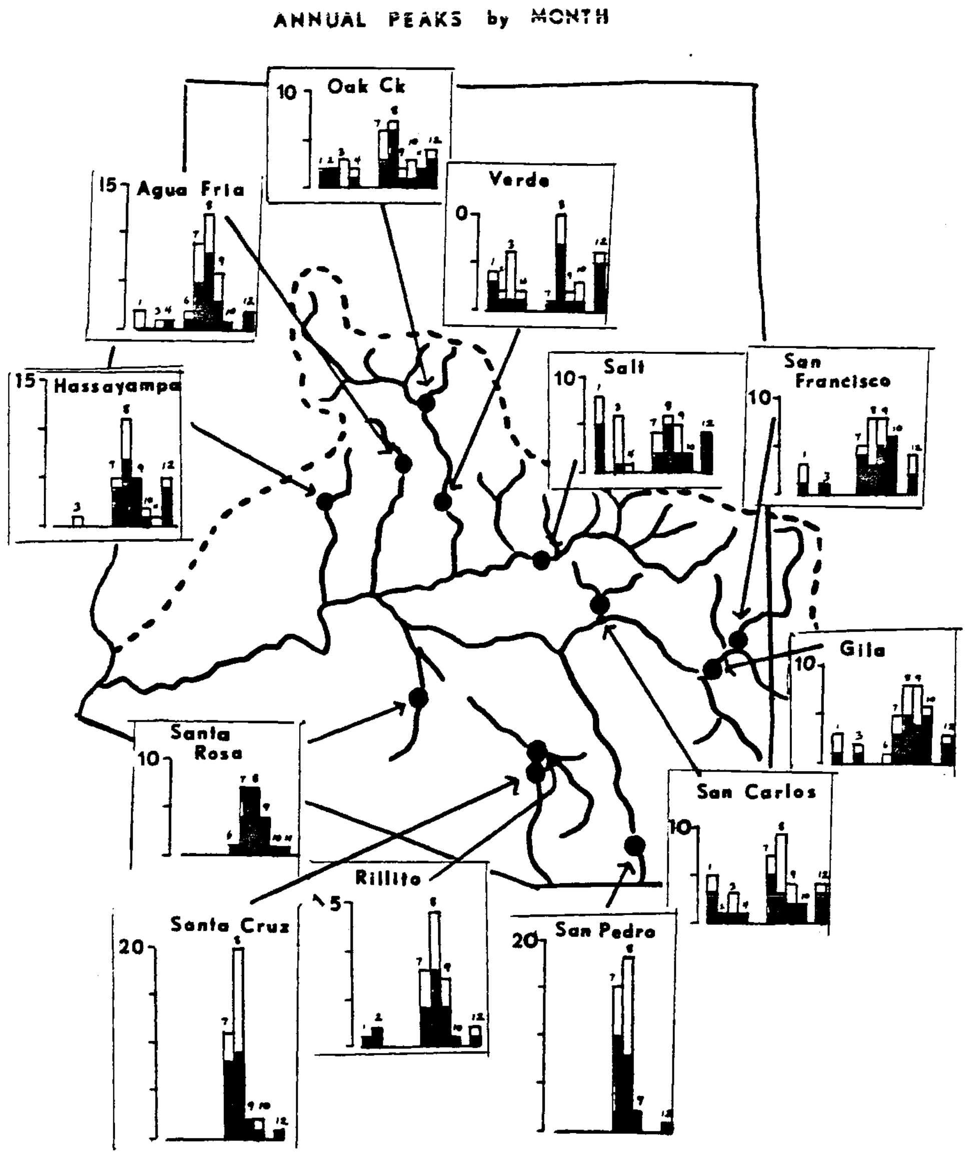


Fig. 17 Seasonal Distribution of Annual Peaks in the Gila Basin

affected by snowmelt to any significant degree. Another factor in the monthly distribution of annual peaks is the location of the basins in relation to the seasonal storm tracks and moisture sources. The more northerly basins are, of course, more likely to be affected by a trailing cold front or a trough aloft during the winter, while the southern and western basins lie closer to either the Gulf of Mexico or the Pacific Ocean - Gulf of California moisture sources for the summer monsoon.

The Fall Regime

Although the seasonal contrasts between summer and winter hydrologic regimes are most often described and analyzed, a third "fall" regime of flooding activity often operates in September and October and has been responsible for some of the study area's major floods. It is during this transitional season that adjustments in the upper atmosphere are most likely to shift into anomalous flow patterns, develop cutoff lows, or allow tropical storms to enter the region. The complex hydrograph of an extreme event (Figure 14c) would probably be more likely to develop during this season than any other.

Figure 17 reflects the importance of this third regime, to a certain degree, by the frequency of September and October floods occurring in all parts of the basin. In terms of precipitation seasons, this period should actually be relatively drier since it generally occurs after the monsoon circulation has broken up and before major winter storms begin to enter the region.

What appears to be happening is that the relative importance of the fall regime as a source of flooding varies through time, going for long periods of time without producing any floods, and then becoming more dominant at other times. This is very evident in the time series of annual floods for the Santa Cruz River at Tucson (Figure 6) and is also seen in other flood series in the basin, notably the San Carlos River near Peridot, the San Pedro River at Charleston, Rillito Creek near Tucson, and the Salt River near Roosevelt.

It should be emphasized that it is not really the months of September and October that define this regime. They have merely been chosen as useful months to "bracket" the occurrence of anomalous atmospheric configurations that can play a major role in the development of floods in the study area. Tropical storms and cutoff lows occur in months other than September and October and may produce "fall-regime" type flooding in August or even July. The grouping of annual flows into seasons should be viewed as a first approximation of the actual variability of atmospheric flood-generating mechanisms over time.

The Gila River Basin Flood Series: Some Observations

Time series plots of partial duration and annual flood peaks for all 30 of the study stations are presented in Appendix D. A detailed discussion of each flood series plot will not be presented here, but several observations can be noted about some of the series individually, and about the group of all flood series as a whole.

Figure 18 is a plot of the longest continuous flood series of all those studied, and it is perhaps the most intriguing. It shows a highly variable flow regime for the San Francisco River at Clifton with the appearance of a definite shift in the mean and/or variance

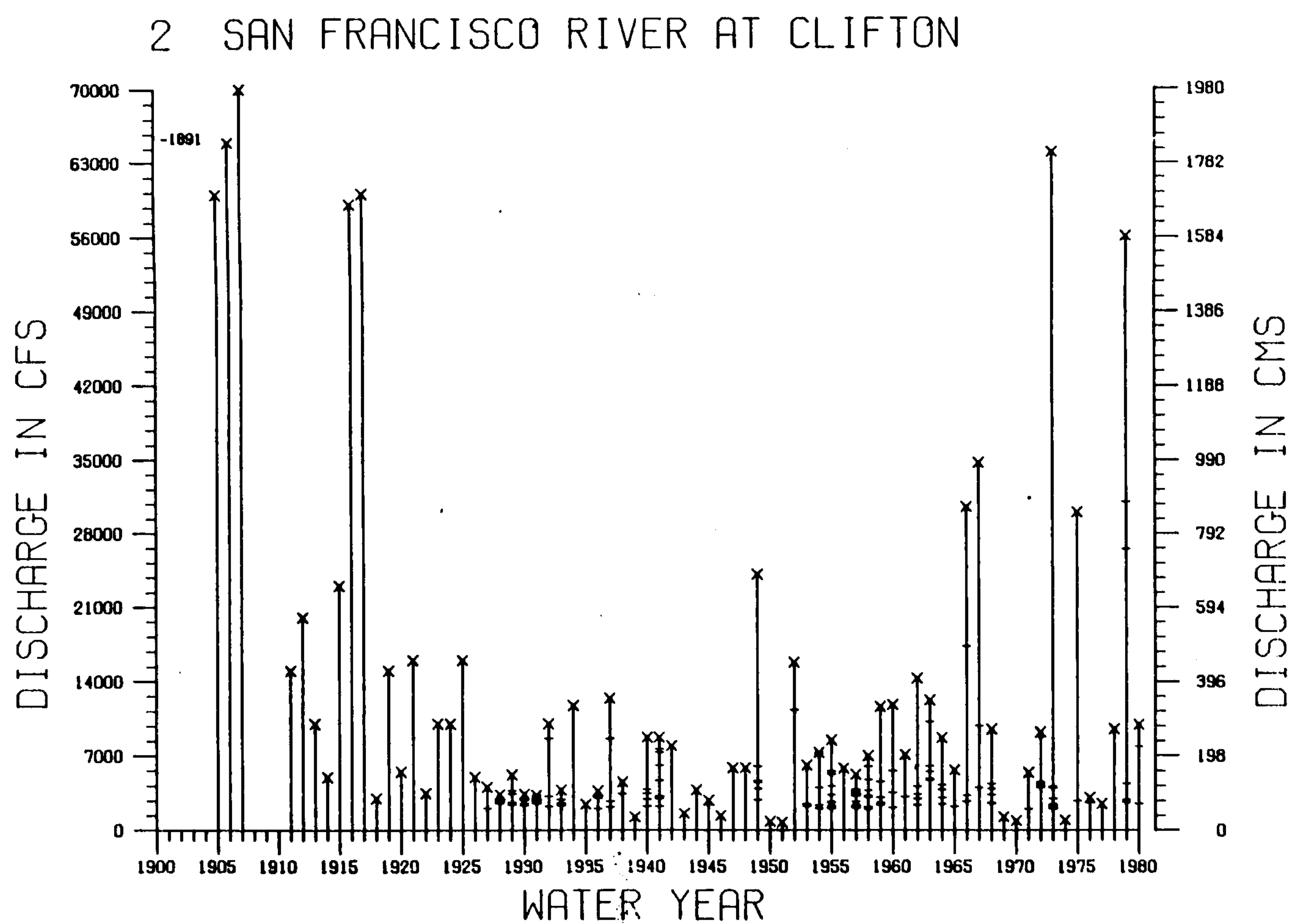


Fig. 18 Flood Series of San Francisco River at Clifton

of peak flows over time. The current regime of the river, beginning perhaps in 1965, seems to be more like that of the early 1900s than any other period in the last 50 years. A hint of this pattern is also seen in the nearby Gila River stations (see Appendix D), especially the Gila near Solomon and perhaps at Calva, although the record there is incomplete in the early years.

Other flood series such as those of the San Pedro River at several gages (Appendix D) show a tendency toward almost the inverse of the San Francisco - Gila River pattern with more variability in flood magnitudes occurring in the middle 1900s and not as many large floods taking place in recent years, except for three somewhat larger floods in the 1970s. The San Pedro record also includes a major outlier.

A certain tendency for increasing flood magnitudes in recent years is evident in some, but not all, of the basins along the Mogollon Rim such as Big Bonito Creek, Tonto Creek, Oak Creek, and Rattlesnake Canyon.

The group of flood series as a whole defies any simple description or explanation of their temporal patterns. Gages located on the same stream generally show similar patterns, but regional groupings of streams do not always covary in their flood histories. Table 2 presents a general summary of flooding variability for the entire Gila River basin over the 1950-1980 study period.

How should the flow variability in these streams be evaluated? One approach is to compile a detailed record of the events in the series along with information on channel changes, land use, and other

Table 2 Number of Flood Peaks per Year in the Gila River Basin

WYEAR	TOT #	# PER STA	# PARTIAL	#P PER STA	% 1950-80	% PER STA	RANK	# STA
1950	49	2.33	28	1.33	1.72	2.23	21	21
1951	37	1.76	16	.76	1.30	1.68	30	21
1952	90	3.91	67	2.91	3.16	3.74	9	23
1953	43	1.87	20	.87	1.51	1.79	29	23
1954	141	6.13	118	5.13	4.94	5.86	2	23
1955	183	7.63	159	6.63	6.42	7.29	1	24
1956	38	1.58	14	.58	1.33	1.51	31	24
1957	81	3.38	57	2.38	2.84	3.23	14	24
1958	153	5.67	126	4.67	5.36	5.42	3	27
1959	98	3.50	70	2.50	3.44	3.34	12	28
1960	84	3.00	56	2.00	2.95	2.87	16	28
1961	63	2.17	34	1.17	2.21	2.07	26	29
1962	64	2.21	35	1.21	2.24	2.11	22	29
1963	111	3.83	82	2.83	3.89	3.66	10	29
1964	118	4.07	89	3.07	4.14	3.89	8	29
1965	79	2.72	50	1.72	2.77	2.60	17	29
1966	156	5.38	127	4.38	5.47	5.14	5	29
1967	76	2.53	46	1.53	2.66	2.42	19	30
1968	102	3.40	72	2.40	3.58	3.25	13	30
1969	64	2.13	34	1.13	2.24	2.04	27	30
1970	65	2.17	35	1.17	2.28	2.07	24	30
1971	100	3.33	70	2.35	3.51	3.18	15	30
1972	78	2.60	48	1.60	2.73	2.48	18	30
1973	166	5.53	136	4.53	5.82	5.28	4	30
1974	66	2.20	36	1.20	2.31	2.10	23	30
1975	63	2.17	34	1.17	2.21	2.07	25	29
1976	69	2.46	41	1.46	2.42	2.35	20	28
1977	56	2.00	28	1.00	1.96	1.91	28	28
1978	106	3.79	78	2.79	3.72	3.62	11	28
1979	141	5.04	113	4.04	4.94	4.82	6	28
1980	112	4.15	86	3.19	3.93	3.97	7	27
TOTAL	2852	104.64	2005	73.70	100.00	99.99		

factors (Betancourt and Turner, in press). Such information is usually not easily obtained or even in existence, but even if it were available for all streams, there would still be a need and desire to assess these records in a stochastic-probabilistic manner.

Figure 18 calls to mind many of the questions that were raised in Chapter 1 about stochastic-process models, changing means and variances, and their relationship to physical processes in the real world. The following chapter will present the results of the hydroclimatic assessment of flow events and will begin to explore some answers to these questions.

CHAPTER 5

HYDROCLIMATOLOGY

The variations in hydrologic activity that occur both spatially and temporally in the Gila River basin can be analyzed in terms of the concomitant variability in atmospheric processes and associated large-scale circulation patterns. This hydroclimatic approach to the study of streamflow variability provides a physically-based background for understanding both climatic and non-climatic influences on flood behavior.

This chapter presents the results of the hydroclimatic methodologies that were employed to analyze flooding in the Gila River basin. First, monthly circulation-streamflow correlation fields will be discussed in terms of how the large-scale atmospheric circulation shifts seasonally to produce runoff-generating conditions from varying upper air patterns at different times during the year. The results of the hydroclimatic classification of flow events will then be summarized, linking individual events to specific kinds of atmospheric processes that vary both temporally and spatially across the study area. Finally, composite circulation anomaly maps will be presented to describe the large-scale upper air patterns associated with the various atmospheric mechanisms that produce individual flow events.

Monthly Circulation-Streamflow Correlation Fields

Correlation field analysis, as described in Chapter 2, is a useful technique for identifying the circulation anomalies that are associated with variations in monthly streamflow. The correlation field, which is simply a contoured map of correlation coefficients, can be interpreted as an upper-air pressure anomaly map: mapped areas of higher-than-normal and lower-than-normal 700 mb height. The map pattern emerges by correlating variations in mean monthly discharge at a gaging station with variations in 700 mb height at a single gridpoint location and plotting the value of the resulting correlation coefficient at that gridpoint. When this value is positive it means that high 700 mb heights at the gridpoint tend to covary with high monthly discharges at the gaging station over the period of record (or the inverse, low pressure heights covarying with low discharges). When the correlation coefficient is negative it means that low 700 mb heights at the gridpoint covary with high discharges at the station, (or that high 700 mb heights covary with low discharges). By plotting the entire grid of correlation coefficients, each computed by separate gridpoint-discharge correlations, a spatial pattern emerges that describes the general pressure height-discharge relationship for a given station over the period of record.

For the most part, correlation fields have been used to describe the broad scale circulation patterns associated with variability in either precipitation or streamflow at a single station or at several widely-spaced stations across areas as large as the whole North American continent. The correlation fields constructed for this study represent one of the first attempts to see if the technique is applicable for a network of several more closely spaced stream stations, all lying within the single hydrologic unit of the Gila River drainage basin. If the monthly correlation field pattern for any one station in the Gila River basin is similar or identical to the pattern of an adjacent station, it suggests that streamflow at both stations is responding in homogeneous fashion to the same general upper air circulation controls. Conversely, if nearby or adjacent stream stations have different correlation field patterns for the same period of record, two alternative explanations are possible: (1) non-climatic factors are controlling discharge variability in the streams, or (2) the flow occurring in the streams is sensitive to, and generated by, different aspects of the broad scale circulation and hence should not be grouped together in any sort of regional flood or streamflow analysis.

The correlation fields constructed by Bartlein for three stations in Arizona (Figure 10) show that high streamflow in the San Pedro and Salt Rivers is associated with a negative circulation anomaly off the coast of southern California. The lower-than-normal 700 mb heights indicated by the negative circulation anomaly allow the counter-clockwise flow of warm moist air into central and southern Arizona from either the eastern Pacific Ocean and Gulf of California, in the case of the San Pedro correlation field, or the Gulf of Mexico, in the case of the Salt River correlation pattern. High discharges in the more northern station of Bright Angel Creek appear to be responding to a slightly different circulation pattern -- anomalous low pressure located off the coast of northern California and Oregon reflecting a mean storm track and associated westerly air flow that are positioned further to the north and are particularly suited to steering flow-generating storm systems across northern Arizona.

These three previously constructed correlation fields suggest that the circulation-streamflow response varies spatially across the state of Arizona. Bartlein's analysis of the Arizona stations did not separate the observations by season or month, but other stations in the United States which were analyzed on a seasonal basis showed that the circulation-streamflow relationship can also vary temporally throughout the year (Bartlein 1978). The correlation fields which will be described below were constructed for a fairly dense network of gaging stations on a month-by-month basis to explore in detail the nature of the hydroclimatic relationship between large-scale upper air circulation anomalies and streamflow occurring at several stations located within the single hydrologic unit of the Gila River drainage basin.

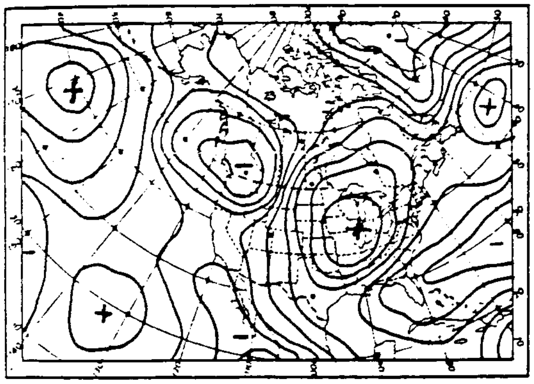
July Correlation Fields

As seen in Figure 16, the early summer months of May and June define a season of relatively low flow for most of the Gila River basin and in some years stream channels at certain stations remain completely dry for periods of two months or more. Because of the very small discharge volumes involved, correlation fields constructed for the months of May and June were not considered to be very accurate or reflective of any real circulation-streamflow relationship. However, with the onset of the monsoon rains in July, monthly streamflow volumes increase across the basin and the circulation patterns associated with this increase are depicted in Figure 19.

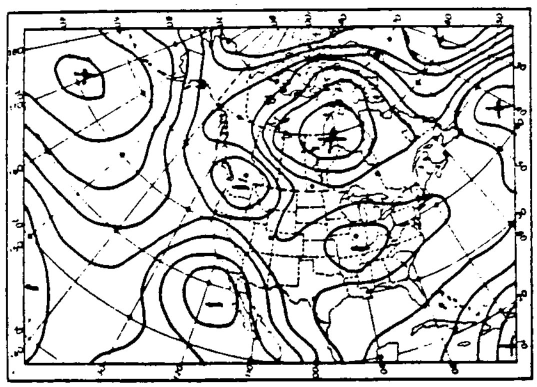
The figure shows July correlation fields for 10 stations selected to represent hydrologic activity in different geographic sectors of the basin. For the Santa Cruz River, correlation fields for both the upstream gage at Lochiel and the Congress Street gage in Tucson are depicted in order to observe any differences in the circulation-streamflow relationship that occur in the same stream system due to differences in drainage basin size and position in the drainage network.

A comparison of the 10 correlation fields reveals immediately that all streams in the Gila River basin do not respond in homogeneous fashion to the July broadscale circulation. However, there is a distinct geographic nature to the differing anomaly patterns across the basin and stations which share similar July circulation patterns can be grouped together as follows:

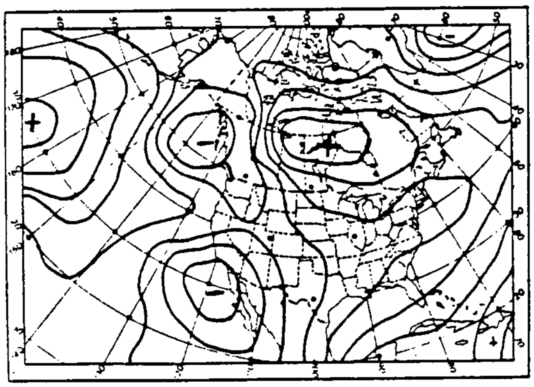
The Southeast Group. The easternmost and southernmost stations -- the Gila at Clifton, the San Pedro at Charleston, and the Santa Cruz at Lochiel and Tucson -- all share a negative circulation anomaly off Baja California that represents stronger than normal airflow from the south and southeast. In the case of the Gila, San Pedro, and Santa Cruz at Tucson, the stronger than normal southeasterly flow may represent the July onset of an especially intense monsoonal circulation from tropical latitudes in Mexico and the Gulf of Mexico. The Lochiel pattern suggests that higher streamflow is associated with a stronger than normal southerly component in the airflow bringing



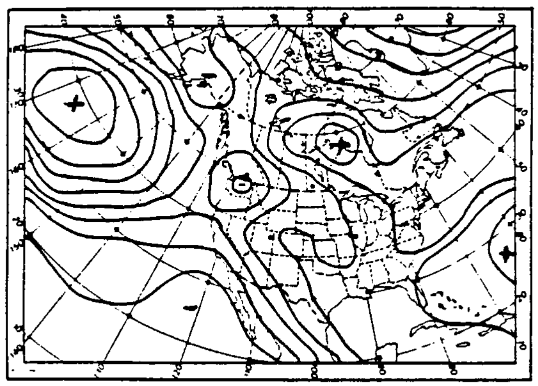
1. Gila River near Clifton



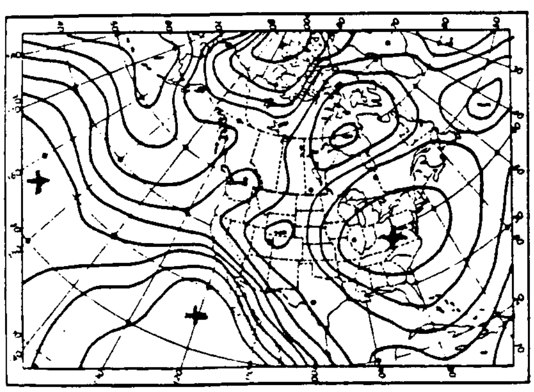
7. San Pedro River at Charleston



9. Santa Cruz River near Lochiel

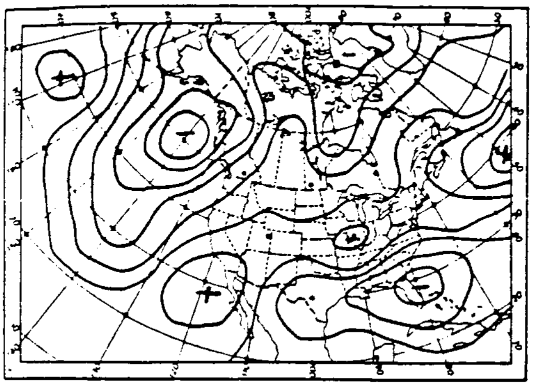


12. Santa Cruz River at Tucson

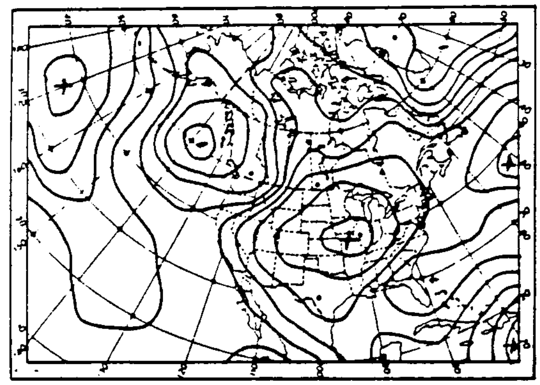


13. Rillito Creek near Tucson

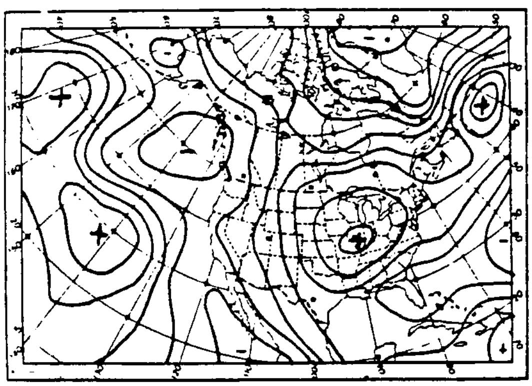
Fig. 19 July Correlation Fields



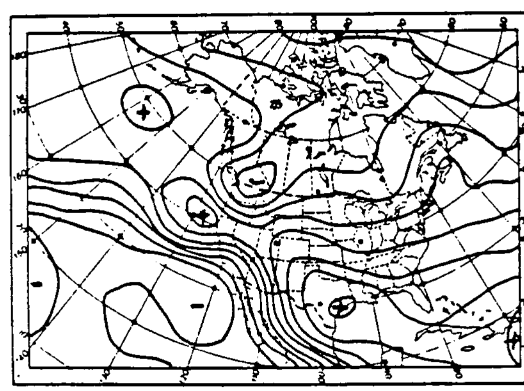
20. Salt River near Roosevelt



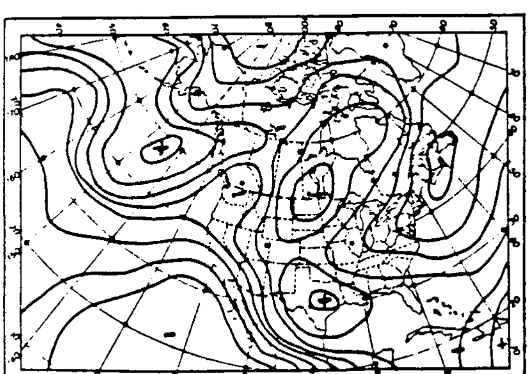
25. Verde River below Tangle Creek



28. Hassayampa River at Box Damsite



14. Santa Rosa Wash near Vaiva Vo



29. Rio Cornez near Ajo

Fig. 19 --<u>Continued</u>

moisture from the lower Gulf of California and the tropical eastern Pacific directly north into the headwaters of the Santa Cruz.

The Southwest Group. Rio Cornez and the Santa Rosa Wash, both located in the most arid southwestern portion of the basin, share a very similar July circulation-streamflow pattern. Their correlation fields indicate that they receive higher than normal runoff in association with higher than normal 700 mb pressure in the western Gulf of Mexico and south-central United States and lower than normal 700 mb pressure in the eastern Pacific Ocean at latitudes of around 20 N, slightly further west than the Southeast Group's negative anomaly. This configuration suggests that when subtropical high pressure is centered further west than the typical Atlantic Ocean Bermuda High position, anomalously strong Gulf airflow can be entrained as far as western Arizona and introduce monsoon moisture into this arid portion of the state. The negative circulation anomaly in the Pacific provides another possible moisture source, enhancing airflow up the Gulf of California into western Arizona.

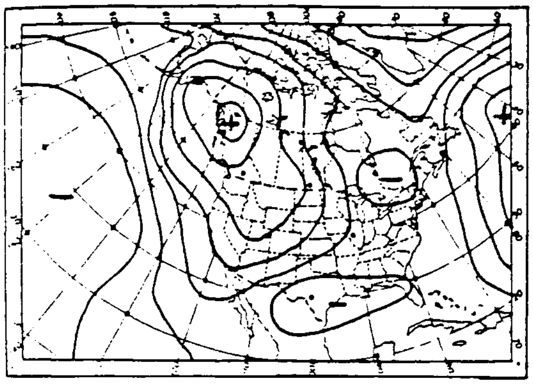
The Northwest Group. The Hassayampa and Verde Rivers experience enhanced July streamflow under a circulation regime similar to that of the Southwest Group, but with the anomalous high pressure area centered further north over eastern United States and the Pacific negative circulation anomaly positioned south of the Baja peninsula. The resulting anomalous airflow reaches these basins directly from the south or south-southeast and could be reflecting a stronger than normal northward penetration of the monsoon moisture early in the season. Another review of the 10 correlation fields might place the

Gila at Clifton with this group rather than the Southeast Group because of the presence of the strong positive anomaly in eastern United States in the Gila correlation field.

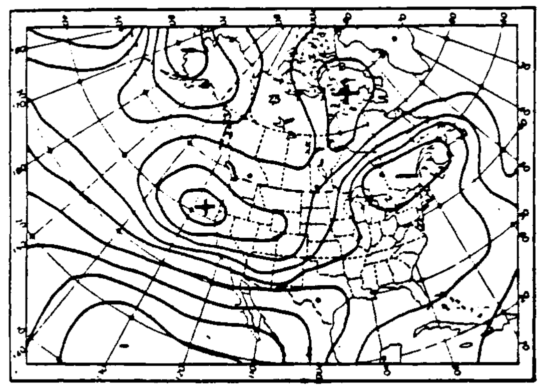
Remaining Stations. The remaining two stations, the Salt River at Roosevelt in the north central part of the basin, and the more southerly Rillito Creek near Tucson, show distinct differences in their correlation fields but share the tendency toward higher than normal 700 mb pressure off the Baja California coast in direct contrast to the other eight patterns. The anomalous flow resulting from this pattern would be westerly, bringing stronger than normal airflow into the region from the Pacific. It is not immediately evident why these two streams show a completely different relationship to the July 700 mb circulation than the other Gila basin stations. Rillito Creek, especially, seems to respond in unique ways to the broadscale circulation, as will be seen in the correlation fields for other months. There is a strong possibility that non-climatic factors may be overshadowing the circulation-streamflow relationship at these stations, nevertheless, stronger than normal Pacific airflow is also a reasonable physical explanation for higher than normal runoff at certain locations in the Gila River basin.

August Correlation Fields

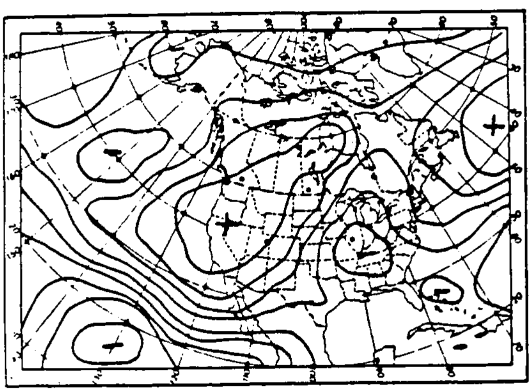
As the summer rainy season progresses into August, slight shifts are evident in the circulation patterns that tend to enhance streamflow in the Gila River basin. Figure 20 depicts August correlation fields for the same ten stations discussed above. On the basis



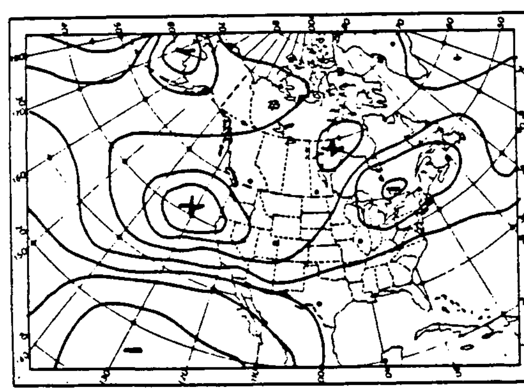
1. Gila River near Clifton



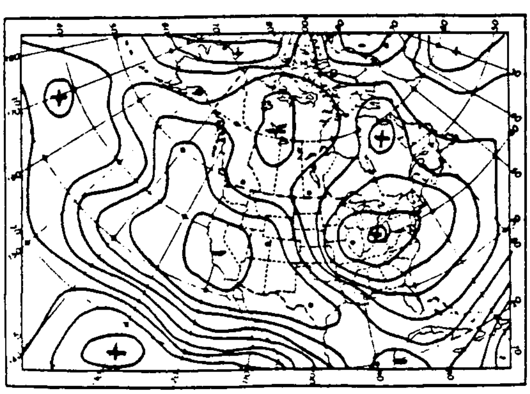
7. San Pedro River at Charleston



9. Santa Cruz River near Lochiel

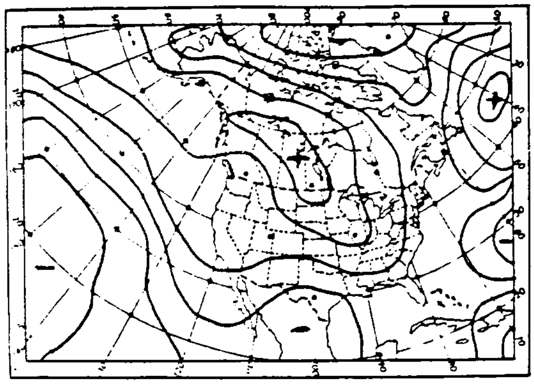


12. Santa Cruz River at Tucson

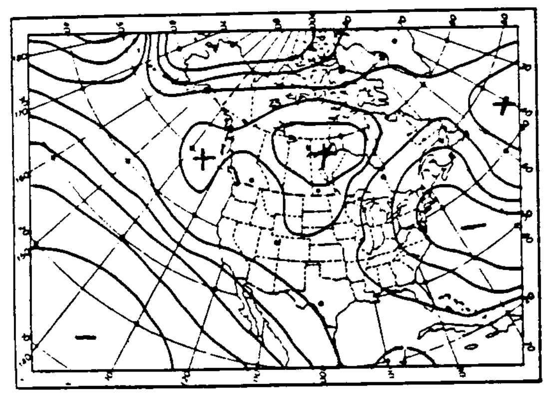


13. Rillito Creek near Tucson

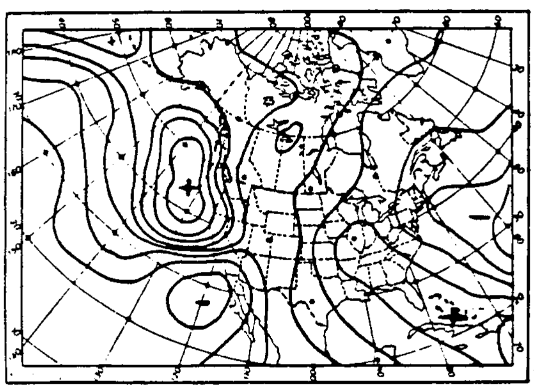
Fig. 20 August Correlation Fields



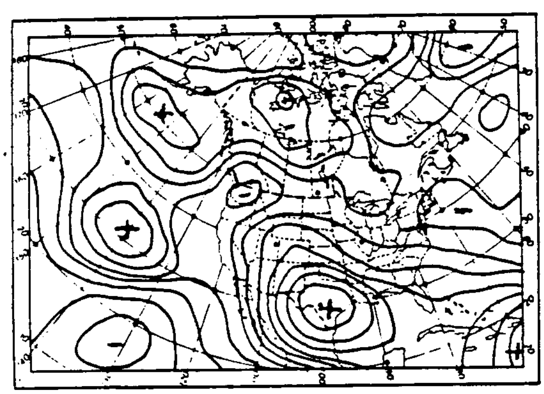
20. Salt River near Roosevelt



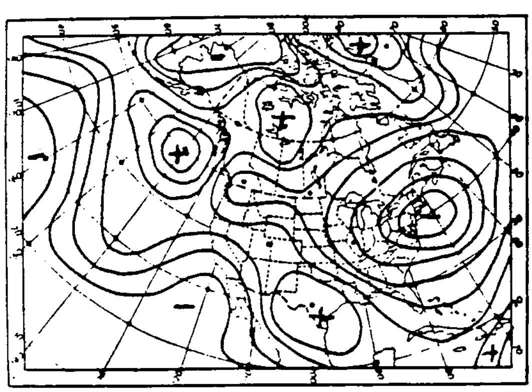
25. Verde River below Tangle Creek



28. Hassayampa River at Box Damsite



14. Santa Rosa Wash near Vaiva Vo



29. Rio Cornez near Ajo

Fig. 20 —<u>Continued</u>

of their August patterns, the grouping of those stations which respond in similar fashion is slightly different.

The Southeast Group. The San Pedro and Santa Cruz at Lochiel and Tucson emerge as a distinct group in their hydrologic response to the August circulation, while the Gila at Clifton no longer appears to be related to this group. The dominant circulation feature affecting the southeast basins in August is a zonally elongated negative circulation anomaly centered well off the coast in the eastern Pacific at around 15 N latitude. A positive anomaly is located to the north and the resulting stronger than normal airflow is from the east. The pattern reflects the continued importance of Gulf of Mexico moisture in enhancing streamflow in the southeastern part of the Gila River basin. The anomalous easterly flow may also be an indication of a greater frequency of easterly waves which can affect streamflow and flooding in the southern part of the basin. In fact, the one easterly wave event that could be specifically identified during the course of the hydroclimatic classification occurred in August 1969 in association with Tropical Storm Doreen and produced annual flood peaks in the San Pedro at Redington, and the Santa Cruz at Lochiel and Tucson.

The Western Group. The August circulation-streamflow relationship is very similar to that of July at the Rio Cornez and Santa Rosa Wash stations, reflecting stronger than normal airflow from the south and southeast into the western part of the basin. In August, the Hassayampa River also seems to be affected by this general circulation pattern and is now classified as part of the Western Group, although the Pacific Ocean negative anomaly and the Atlantic Ocean positive anomaly are shifted slightly to the east in the Hassayampa correlation field.

The North-Central and Eastern Group. In August, the Verde, Salt, and Gila Rivers all seem to share a somewhat similar response to the broadscale circulation. The correlation fields are characterized by a negative circulation anomaly far off the coast in the eastern Pacific. In the Verde this pattern results in stronger than normal southeasterly flow into the northern part of the basin, but in the Salt and Gila basins, an additional negative circulation anomaly centered over the western Gulf of Mexico shifts the airflow to a more easterly and northeasterly flow. The anomalous easterly component described above in conjunction with the Southeast Group, seems to be present in this area of the basin as well during August, but it is set up by a slightly different pressure height configuration.

The Rillito Pattern. As in July, the correlation field for the Rillito station is unique. It is characterized by a center of lower than normal pressure positioned over California and stronger than normal airflow from the Pacific Ocean into the study area. The sensitivity of Rillito runoff to the Pacific Ocean moisture source is an interesting phenomenon and warrants further investigation if it can be demonstrated to be a real aspect of the Rillito's hydroclimatology.

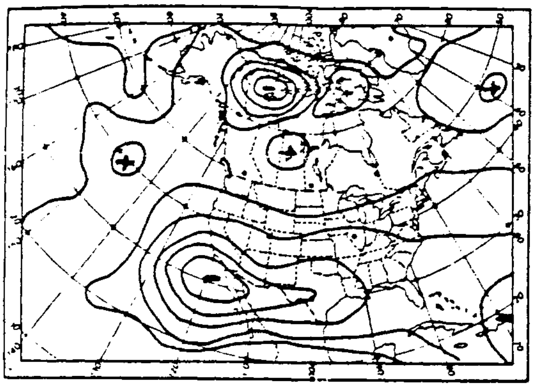
September Correlation Fields

September usually marks the beginning of the "fall regime" (see Chapter 4) and is characterized by a much greater likelihood of both cutoff lows and Pacific tropical storms affecting the Southwest

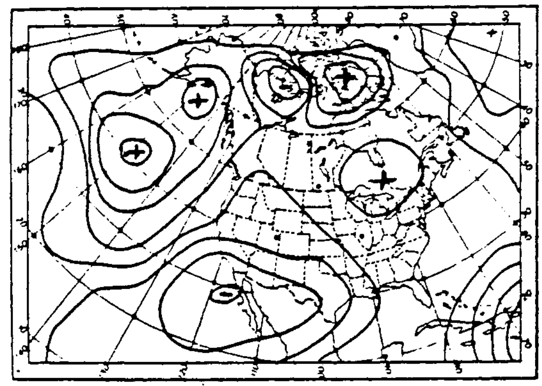
(Douglas and Fritts 1973, Douglas 1974). This tendency shows up in many of the September correlation fields displayed in Figure 21 as a strong negative circulation anomaly centered over Baja California, reflecting both the lower than normal 700 mb heights that would be associated with upper level cutoff lows, and the anomalous south and southwest airflow that would be associated with tropical storms tracking close enough to the coast to enhance Gila basin precipitation and streamflow, or perhaps even tracking directly into the study area from the eastern Pacific or up the Gulf of California.

The Southwest Group. The two southwest stations, Rio Cornez and Santa Rosa Wash, are the only locations in the Gila basin (other than the Rillito) that do not show the tendency toward a negative anomaly in the vicinity of Baja California in their September correlation fields. The anomaly pattern for these two stations therefore contrasts notably with their July and August patterns which do show a strong negative anomaly off the Baja coast. In place of the negative anomaly, the area of higher than normal 700 mb heights is centered further west than in July and August, over Texas, and brings stronger than normal airflow from the south along the Baja peninsula or up the Gulf of California into the western part of the Gila basin. Although the cutoff low influence does not seem as evident with this pattern of anomalous upper air flow, the pattern may be particularly suited to steering tropical storms into the area.

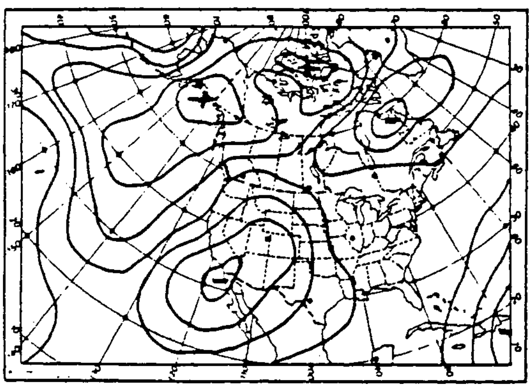
Other Stations. The Gila, San Pedro, and Santa Cruz at Lochiel all show a strong negative anomaly center off of Baja that steers airflow from the south and southwest into the Gila basin. The



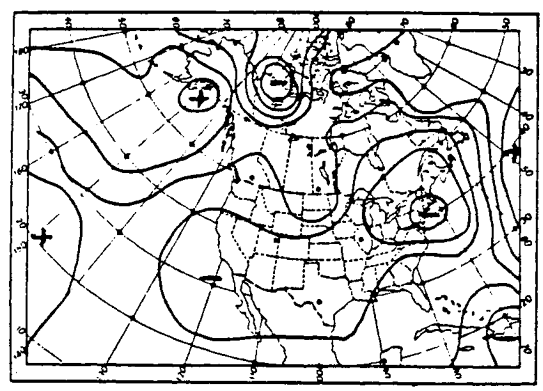
1. Gila River near Clifton



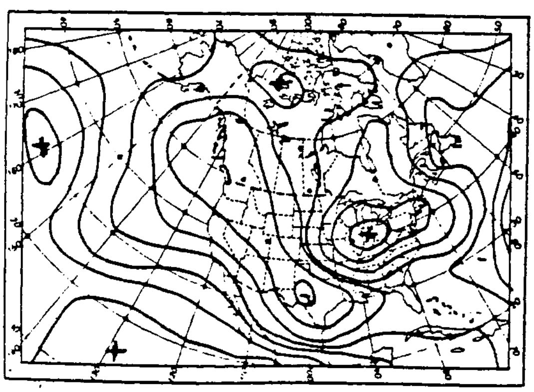
7. San Pedro River at Charleston



9. Santa Cruz River near Lochiel

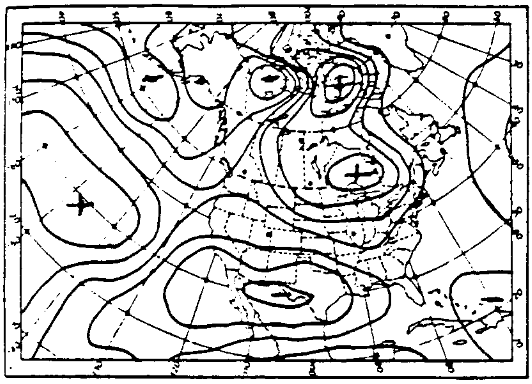


12. Santa Cruz River at Tucson

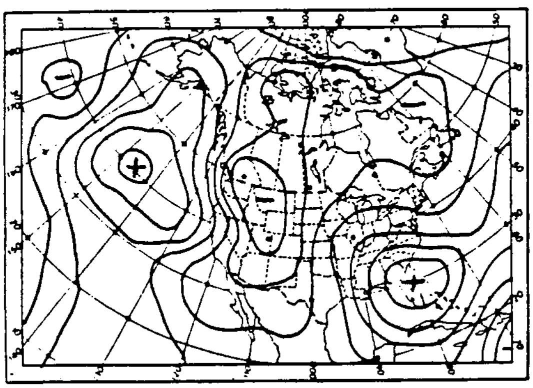


13. Rillito Creek near Tucson

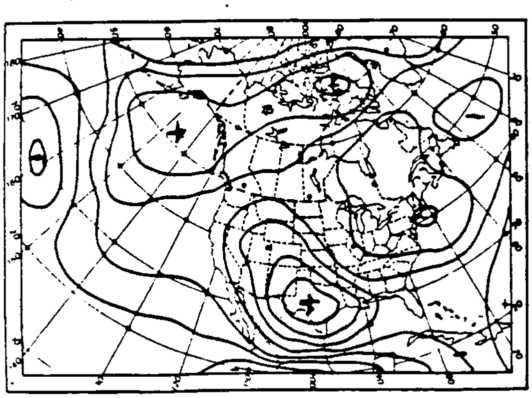
Fig. 21 September Correlation Fields



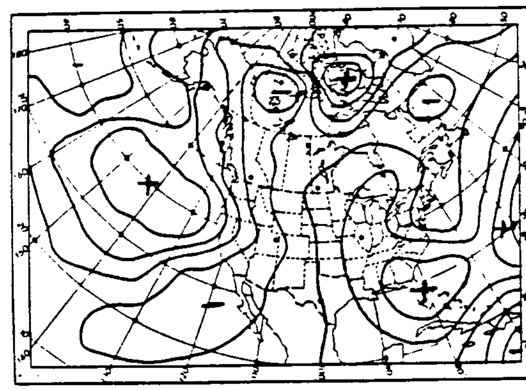
20 Salt River near Roosevelt



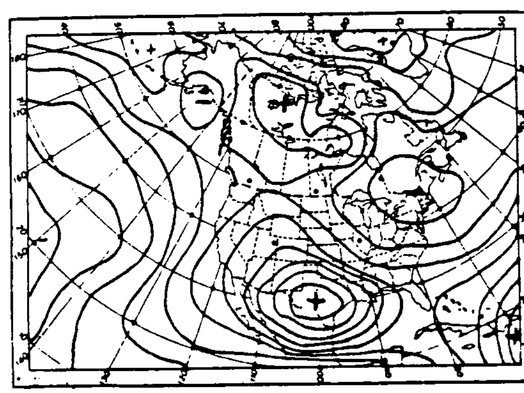
28. Hassayampa River at Box Damsite



29. Rio Cornez near Ajo



25. Verde River below Tangle Creek



14. Santa Rosa Wash near Vaiva Vo

Fig. 21 --Continued

Hassayampa and Verde Rivers show a slightly weaker tendency toward this same pattern. The more elongated pattern of the negative anomaly in the Salt River correlation field may be reflecting more frequent troughing and a southward shift in the storm track as a source of enhanced streamflow in the northeastern part of the basin or else a tendency to bring in anomalous airflow from the west and southwest, or even from the east and southeast, more like the early summer pattern.

One feature common to the northern basins -- the Hassayampa, the Verde, and the Salt -- is the more southerly position of the east Pacific positive anomaly in their September correlation fields. It is usually in September that a major readjustment of the general circulation takes place and pressure systems begin to move southward as the midlatitude winter storm track establishes itself. The effects of this readjustment on streamflow would be felt earliest in the northern part of the basin and may explain the sensitivity of these basins to the east Pacific positive anomaly.

September runoff in the Santa Cruz at Tucson does not appear to be sensitive to the same upper air configuration that enhances runoff in the headwaters of the Santa Cruz at Lochiel, but does show a tendency toward lower than normal 700 mb heights over the study area. The Rillito station once again has a correlation field that is unlike the others and shows a sensitivity toward anomalous airflow from the Pacific, in this case, northwesterly flow rather than direct westerly flow.

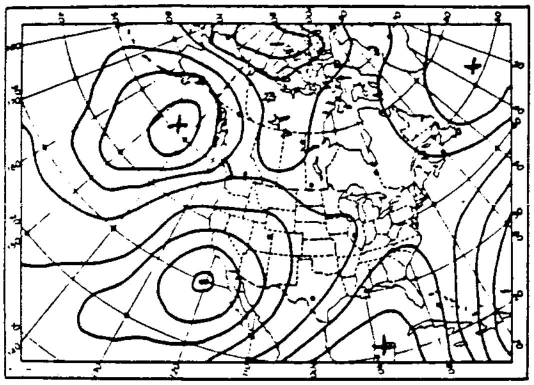
October Correlation Fields

The October correlation fields in Figure 22 depict circulation-streamflow relationships similar to those of September, reflecting the fall regime and the possibility of more frequent cutoff lows and tropical storms affecting Gila River basin runoff. Rio Cornez and Santa Rosa Wash are once again dominated by a strong positive anomaly situated over Texas, and the Santa Cruz at Lochiel also shares a similar tendency in its October pattern. All of the other stations, except the Rillito, show a negative circulation anomaly, either immediately off Baja, as seen in the correlation fields of the more northern basins, or further off the coast, as seen in the patterns of the San Pedro and the Santa Cruz at Tucson and Lochiel.

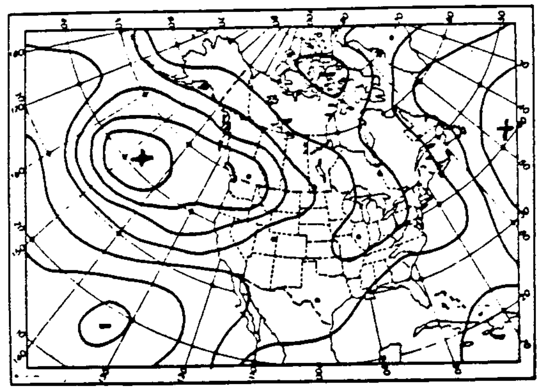
In October, especially in the northern basins of the Verde, Salt, and Hassayampa, the eastern Pacific positive anomaly and the Baja negative anomaly are both very intense, reflecting a highly meridional circulation regime with much troughing and ridging, another indication of adjustment in the general circulation during the transitional autumn season. The passing of upper air troughs and associated surface fronts in conjunction with this readjustment is another source of enhanced streamflow for the Gila River basin, and the simultaneous occurrence or rapid succession of a front, a tropical storm, and a cutoff low can be a major source of high runoff in the basin in October and also in September.

Summary of Summer and Fall Correlation Fields

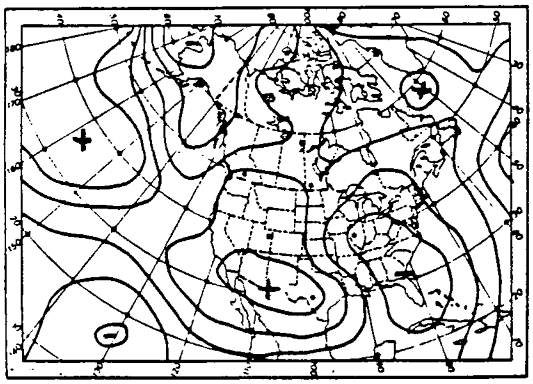
The patterns in Figures 19 through 22 can be summarized as follows. Summer streamflow in different parts of the Gila River basin



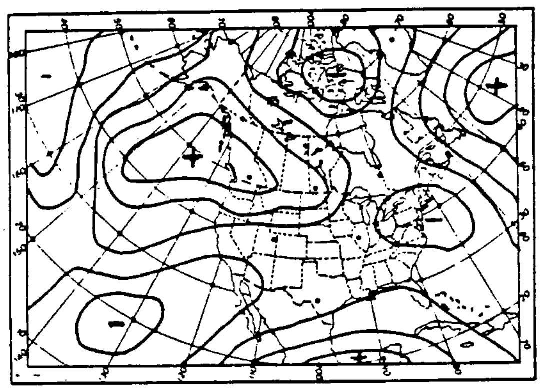
1. Gila River near Clifton



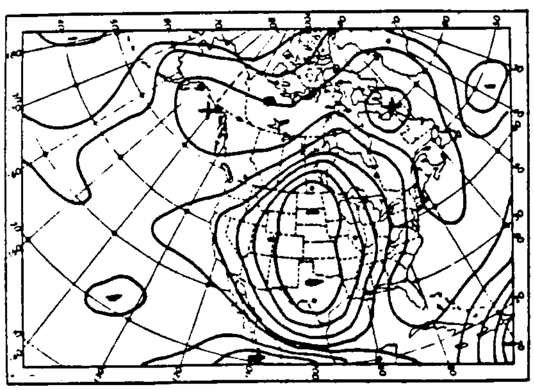
7. San Pedro River at Charleston



9. Santa Cruz River near Lochiel

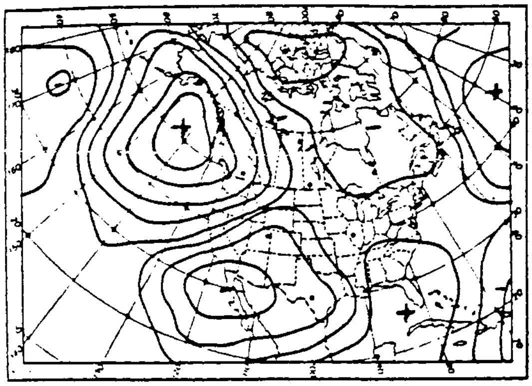


12. Santa Cruz River at Tucson

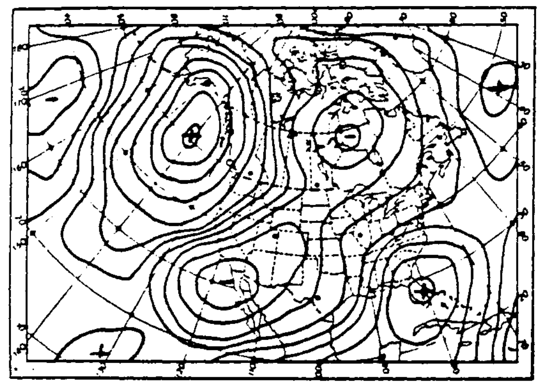


13. Rillito Creek near Tucson

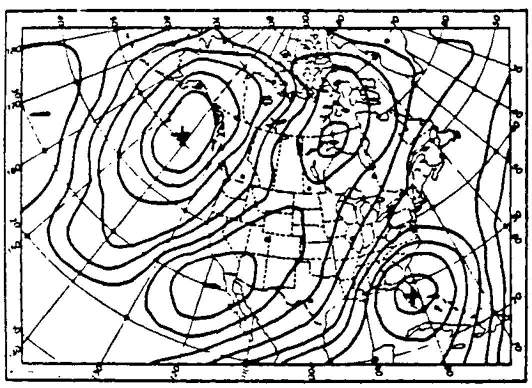
Fig. 22 October Correlation Fields



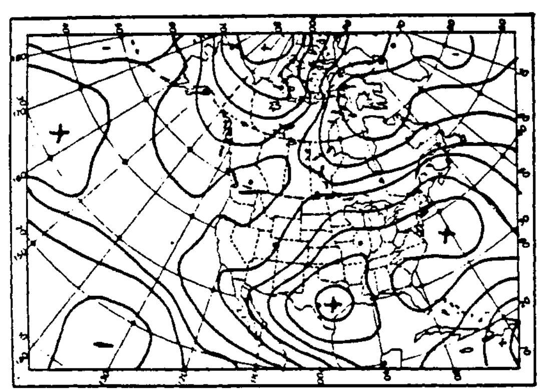
20. Salt River near Roosevelt



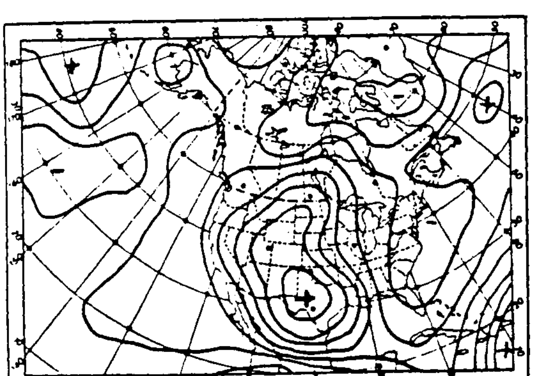
25. Verde River below Tangle Creek



28. Hassayampa River at Box Damsite



14. Santa Rosa Wash near Vaiva Vo



29. Rio Cornez near Ajo

Fig. 22 —Continued

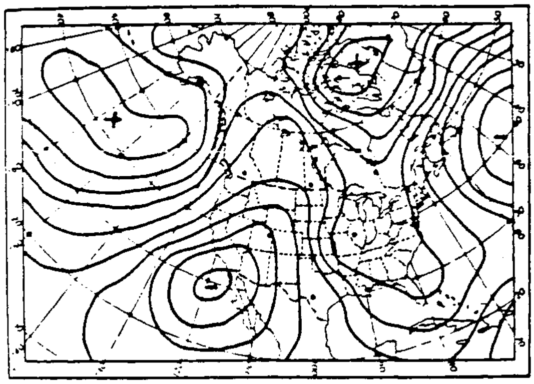
appears to be enhanced by slightly different configurations of anomalous upper air flow. The general streamflow-enhancing pattern for the whole basin is one of stronger than normal airflow from the south and southeast (Gulf of Mexico and tropical Mexico moisture sources) in the early part of the rainy season, shifting to stronger than normal airflow from the south and southwest (Gulf of California and eastern Pacific) moisture sources later in the rainy season. During the fall, correlation fields for different parts of the basin tend to be more similar, suggesting that fall streamflow throughout the basin is sensitive to the same general upper air pattern: a strong negative circulation anomaly off northern Baja California.

The two most arid stations in the southwestern part of the basin consistently display correlation fields that contrast significantly with the rest of the Gila River basin. The enhancement of streamflow at Rio Cornez and Santa Rosa Wash may indeed be due to a unique upper air pattern as described above, however it is also possible that the uniqueness of the correlation fields of these two stations could be due to the fact that their record lengths are shorter than the other stations analyzed. Another possibility is that the enhancement of streamflow in the southwestern Gila basin is more closely related to atmospheric processes that are not reflected at the 700 mb level. Gulf surges northward up the Gulf of California have been shown to be very important for introducing large amounts of moisture into western Arizona (Hales 1972), but this low level atmospheric phenomenon is difficult to observe on a daily or hourly 700 mb chart, and would be completely absent from a mean monthly 700 mb map. Hales indicates that gulf surges often operate in conjunction with tropical storms and "may also help to explain the hard-to-accept statement made quite often that circulation around a tropical disturbance several hundred miles out in the Pacific results in an increase of tropical moisture over Southern California and Arizona" (Hales 1972, p. 306). This explanation is quite applicable to the Southwest Group's correlation fields and may be a factor in other parts of the basin too.

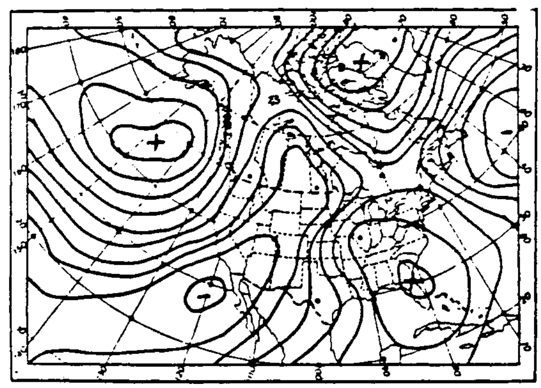
An physical explanation for the consistently unique correlation fields at the Rillito station is not immediately apparent. Urbanization in the drainage basin might very well be a streamflow-affecting factor that is overshadowing the effects of climate and hence distorting the correlation field pattern.

December Correlation Fields

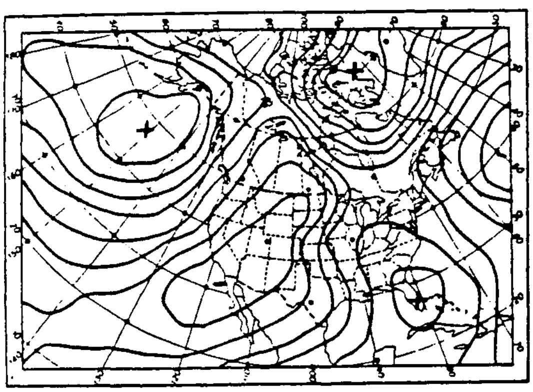
The months of December through March were chosen to describe winter circulation-streamflow relationships in the Gila River basin. Figure 23 displays December correlation fields and it is immediately apparent by the similarity of patterns that the winter streamflow response to circulation is more homogeneous across the whole basin than the summer response. The dominant features in all but the southwestern and Rillito stations are a greatly expanded and intensified positive anomaly center in the eastern Pacific Ocean with a strong negative anomaly positioned to the south and east of it. The negative anomaly is centered, once again, off the northwest coast of the Baja peninsula, but extends diagonally to the north and northeast to encompass most of western United States. The pattern indicates that enhanced December streamflow is associated with strong meridionality



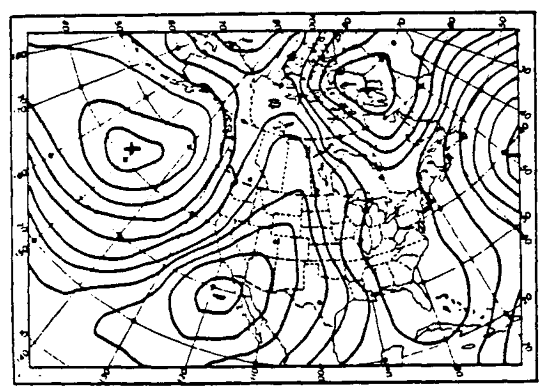
1. Gila River near Clifton



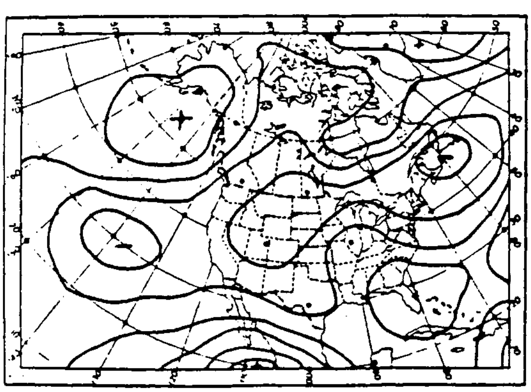
7. San Pedro River at Charleston



9. Santa Cruz River near Lochiel

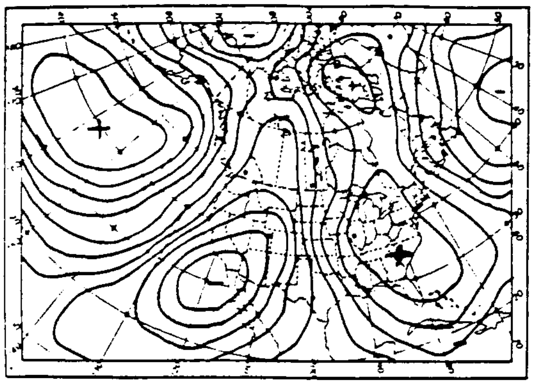


12. Santa Cruz River at Tucson

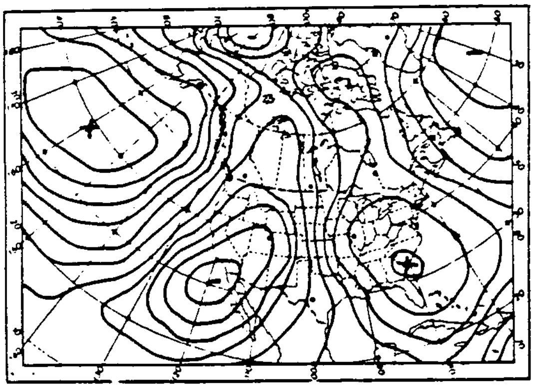


13. Rillito Creek near Tucson

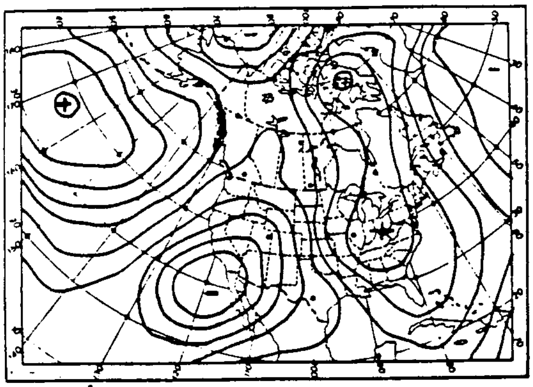
Fig. 23 December Correlation Fields



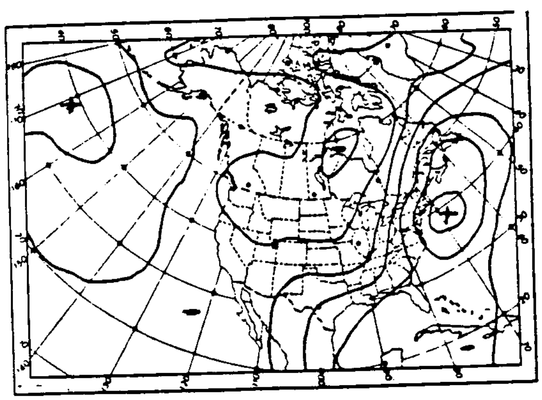
20. Salt River near Roosevelt



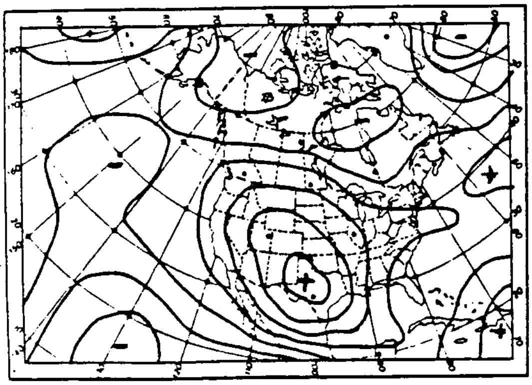
25. Verde River below Tangle Creek



28. Hassayampa River at Box Damsite



14. Santa Rosa Wash near Vaiva Vo



29. Rio Cornez near Ajo

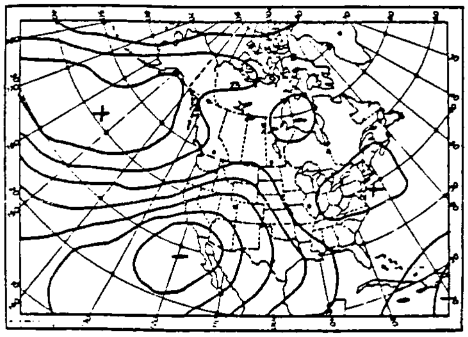
Fig. 23 —Continued

in the general circulation with the frequent development of a deep trough over the southwestern United States. Runoff produced by an occasional upper level cutoff low and the frequent passage of cold fronts across Arizona would result from this pattern.

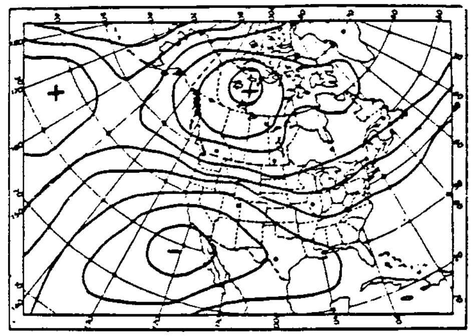
The two southwestern stations and Rillito Creek once again have patterns different than the rest of the basin. As seen in Figure 16, mean monthly discharge is low throughout most of the winter in Rio Cornez and Santa Rosa Wash and the low discharge magnitudes may invalidate any significance to their correlation fields. The Rillito, which does experience major winter runoff, has a pattern that steers Pacific airflow into the basin, and which bears somewhat more of a resemblance to the other station's patterns than has been seen in any of the other months.

January Correlation Fields

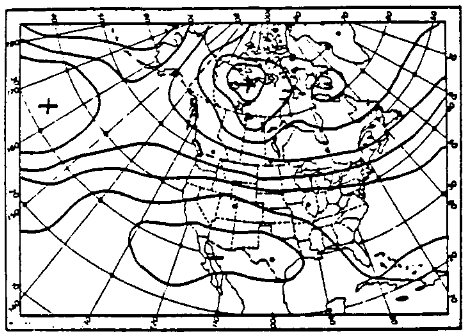
As in December, the January correlation fields in Figure 24 reflect a fairly homogeneous circulation-streamflow response throughout the Gila River basin. The January pattern bears some resemblance to the December pattern in the relative positions of positive and negative anomalies, but there is a distinct tendency toward zonality as opposed to meridionality in the upper air flow. The shape and positions of the anomaly centers, especially those of the three southeast stations, are indicative of a split zonal flow steering northwesterly flow anticyclonically around the positive anomaly and into the eastern United States, and southwesterly flow cyclonically around the negative anomaly and into southwestern and south central United States. The northern basins reflect the same general pattern,



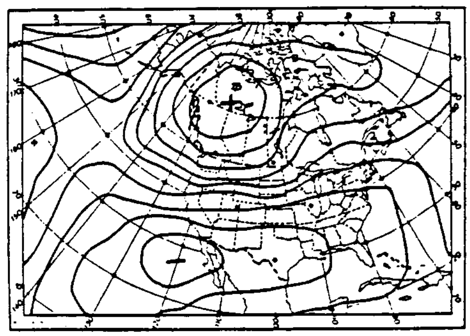
1. Gila River near Clifton



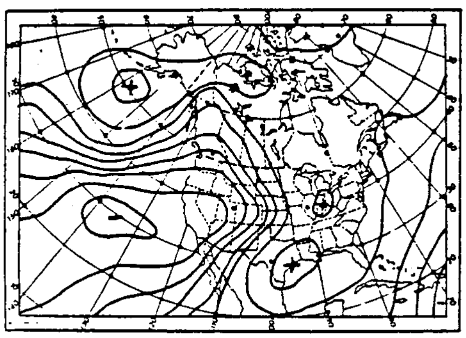
7. San Pedro River at Charleston



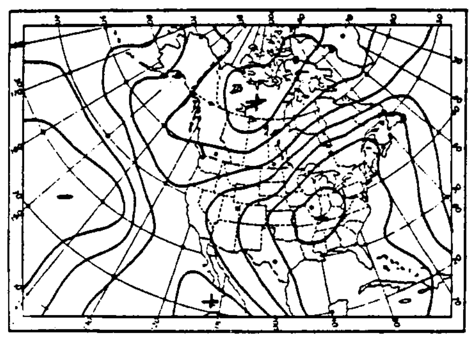
9. Santa Cruz River near Lochiel



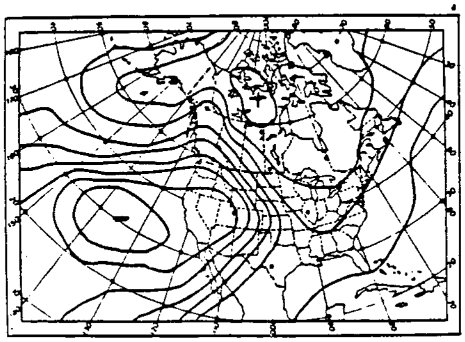
12. Santa Cruz River at Tucson



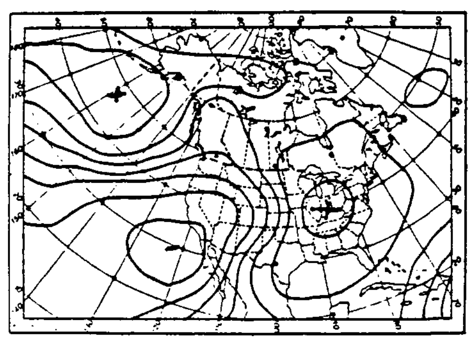
25. Verde River below Tangle Creek



13. Rillito Creek near Tucson



28. Hassayampa River at Box Damsite



20. Salt River near Roosevelt

Fig. 24 January Correlation Fields

but shifted to the west so that a stronger anomalous southwesterly airflow is steered directly into the Southwest.

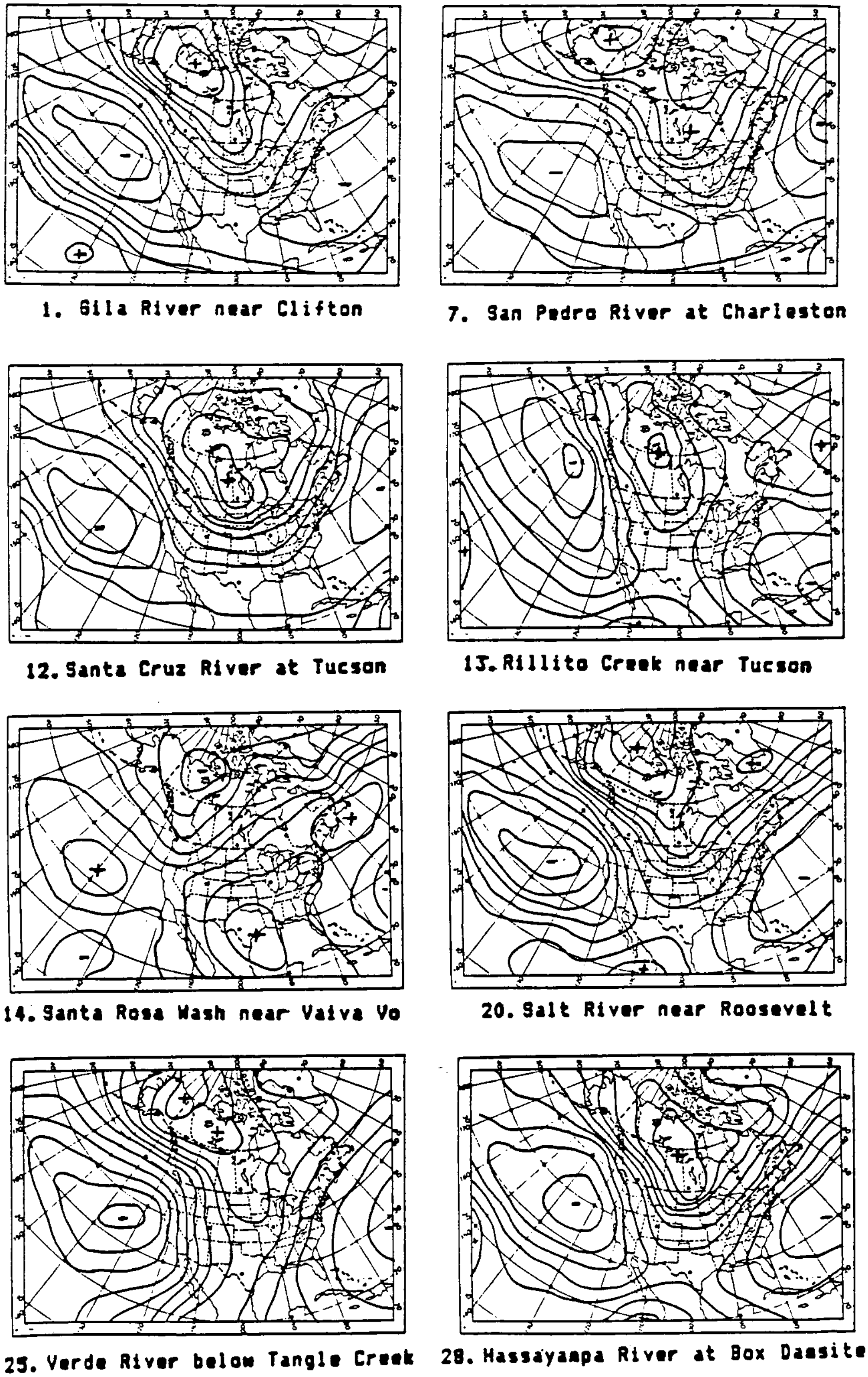
Lower than normal 700 mb heights over the study area and stronger westerly flow would enhance Gila River basin streamflow in January from an occasional upper level cutoff low and especially from the more frequent passage of fronts across the area.

The Rillito station has a correlation field reflecting streamflow enhancement due to stronger than normal southerly airflow. Snowmelt runoff from anomalously warm January temperatures is a plausible explanation for this circulation-streamflow pattern.

February Correlation Fields

The February pattern for enhanced streamflow (Figure 25), is also fairly homogeneous across the Gila basin, but is notably different from the general January anomaly pattern. The dominant feature is the negative circulation anomaly center in the eastern North Pacific, representing strong troughing over the ocean and stronger than normal southwesterly airflow into the Southwest. This pattern has been shown by Douglas (1981) to be associated with cold sea surface temperatures in the central North Pacific, warm waters in the eastern tropical Pacific, a strong subtropical jet stream, and above normal precipitation in southwestern United States. The pattern is also associated with El Nino years and was especially dominant during the winters of 1977-78, 1978-79, and 1979-80 (Douglas 1981).

The correlation field for Santa Rosa Wash is included in Figure 25 because the station did experience some streamflow during February,



1. Gila River near Clifton

7. San Pedro River at Charleston

12. Santa Cruz River at Tucson

13. Rillito Creek near Tucson

14. Santa Rosa Wash near Vaiva Vo

20. Salt River near Roosevelt

25. Verde River below Tangle Creek

28. Hassayampa River at Box Damsite

Fig. 25 February Correlation Fields

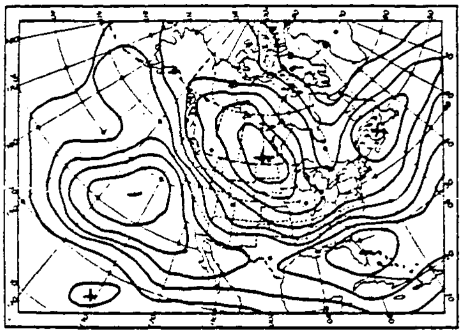
but the pattern is unrelated to the dominant February pattern and may not be significant.

March Correlation Fields

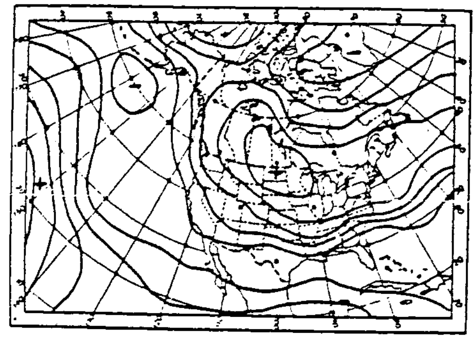
The dominant March correlation field anomalies in Figure 26 are essentially identical to those of February with the two southeast stations of the San Pedro and Santa Cruz showing a somewhat less defined version of the same pattern. Although Rio Cornez experienced a fair amount of March runoff, its correlation field is once again unlike those of the other stations. In February the Rillito shared the dominant basin-wide pattern to a certain degree, but in March the station's response differs from all the others in the usual manner.

Summary of Winter Correlation Fields

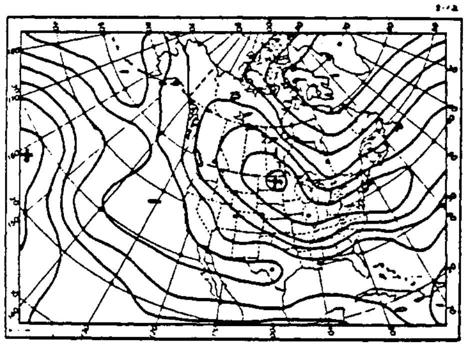
In contrast to summer, during the winter months stations in the Gila River basin tend to have a homogeneous basin-wide streamflow response to specific dominant upper air circulation anomaly patterns. The dominant streamflow-enhancing circulation shifts during the course of the winter from December's more meridional pattern with a negative anomaly off Baja reflecting the influence of frequent low latitude troughs and associated cold fronts, to January's more zonal split flow pattern that is indicative of a more southerly storm track and frequent frontal passages, and finally, to the dominant wet winter pattern of February and March characterized by frequent troughing in the North Pacific and stronger than normal southwesterly flow into the study area from the tropical eastern Pacific Ocean.



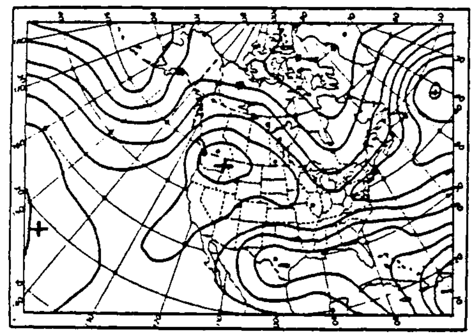
1. Gila River near Clifton



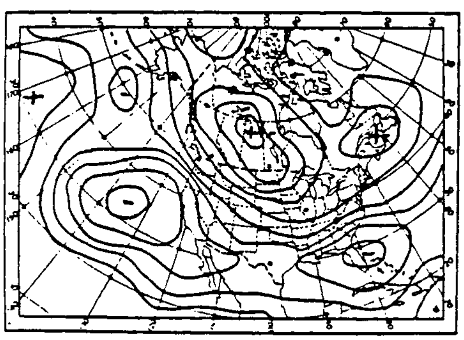
7. San Pedro River at Charleston



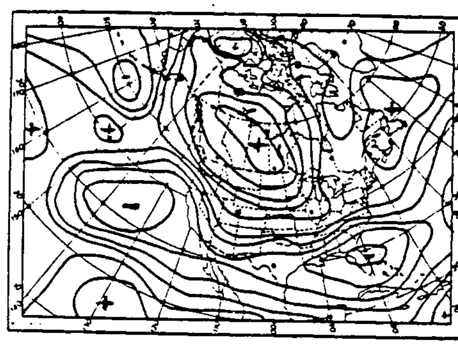
12. Santa Cruz River at Tucson



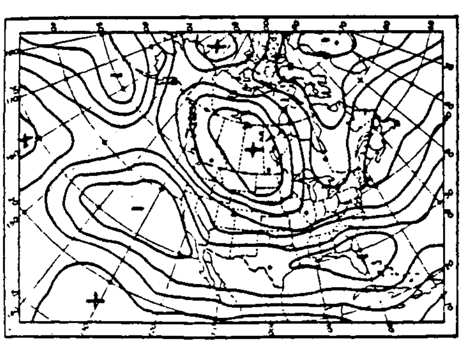
13. Rillito Creek near Tucson



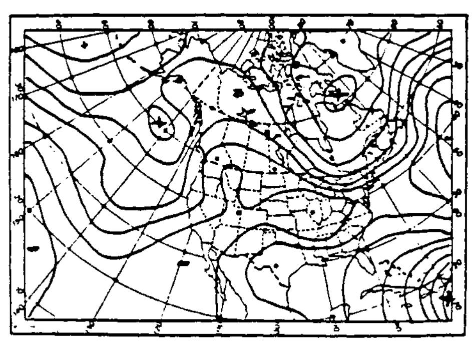
20. Salt River near Roosevelt



25. Verde River below Tangle Creek



28. Hassayampa River at Box Damsite



29. Rio Cornez near Ajo

Fig. 26 March Correlation Fields

Discussion of Correlation Field Analysis

The results of the correlation field analysis show that in the Gila River basin, higher than normal monthly streamflow in the summer, fall, and winter seasons can be linked to specific anomalous configurations of the 700 mb pressure surface. The differences between the summer and winter circulation-streamflow response reinforce the observations of McDonald (1956, 1960) on spatial variability in precipitation and runoff in Arizona during summer and winter. He found winter to be a time of greater spatial homogeneity than summer in both precipitation and runoff due to the widespread cyclonic and frontal systems that govern winter precipitation. The similar correlation fields for stations throughout the basin during winter, and to a certain degree, during fall, indicate that a single dominant anomaly pattern can affect all parts of the basin and hence will contribute to the homogeneous response.

The correlation fields of summer months reflect a more localized streamflow response to the broadscale circulation, with groups of stations in different parts of the basin showing a sensitivity to different 700 mb anomaly patterns. McDonald attributed summer's lack of spatial homogeneity to the isolated nature of orographic and convectional precipitation across the basin, however the correlation field analysis suggests that different upper air patterns are responsible for the movement of moist air into different parts of the basin during the summer and this may have an added affect on the larger spatial variability of rainfall and runoff during summer.

The correlation field analysis has important implications for the hydroclimatology of flow events in the Gila River basin. First of all, it clearly demonstrates that streamflow occurring in the basin at various times during the year results from different upper atmospheric patterns. These circulation patterns govern both the location of the moisture source for the runoff, the direction of moist airflow into the basin, and the type of mechanism -- front, tropical storm, cutoff low, etc. -- that will produce the runoff-generating precipitation.

Other studies have shown that specific types of circulation patterns and circulation anomalies, including those which govern streamflow and flooding, have varied significantly over time, even during the last 30 years (Hirschboeck 1975, Bartlein 1982). This holds important implications for one of the three major hypotheses formulated for this study and presented in Chapter 1.

The third hypothesis postulated that: "A shift in general atmospheric circulation patterns, or the anomalous persistence of certain patterns will be reflected in a flood series by a shift to a different theoretical distribution for the random variable X(t) in the series" (p. 37). The correlation field analysis suggests that the persistence, over a season or over several years, of one of the anomaly patterns defined by the analysis will result in prolonged enhanced streamflow and increase the probability of flooding during the period affected by the circulation anomaly. This actually happened during the winters of 1977-78, 1978-79, and 1970-80 in the Gila basin when the persistence of the correlation field pattern seen in Figures

25 and 26 produced major flooding throughout the study area and some stations, notably the Salt River near Roosevelt, Tonto Creek near Roosevelt, the Agua Fria River near Mayer, and the Verde below Horseshoe Dam, experienced three annual floods in a row which ranked among the largest floods in their entire records. Floods generated during periods dominated by the February-March circulation anomaly pattern depicted in Figures 25 and 26 therefore have a greater probability of being large floods than floods generated during periods dominated by the inverse of the February-March anomaly pattern, or by any other winter patterns that might occur.

An evaluation of the results of the correlation field analysis in terms of the stochastic process models presented in Figures 4 and 5 implies that the theoretical probability distributions for flood magnitudes will differ over the course of a time series for floods generated under different circulation patterns. Segments of the time series dominated by streamflow-enhancing circulation anomalies will have distributions like those at time t_n in Figure 5a or 5c. Segments of the time series dominated by streamflow-suppressing circulation anomalies (the inverse of the correlation field patterns depicted in Figures 20 through 26) will have theoretical probability distributions like those at times t_1 or t_3 in the same figures. Segments of the time series affected by circulations unlike those depicted in the correlation fields may have probability distributions which fall in between the two extremes, such as those at times t_2 and t_4 in Figure 5.

The analysis of runoff hydroclimatology on a monthly basis is effective for identifying broadscale climatic controls on streamflow variability, but the atmospheric mechanisms that actually combine together to produce a flood operate at time scales of hours and days within the broader patterns observed at the monthly scale. The following section will describe results of the hydroclimatic analysis of flooding in the Gila River basin on an individual event basis.

Hydroclimatic Classification of Flow Events

By following the procedure described in Chapter 2 and outlined in Appendix C, a hydroclimatic classification was assigned to each flow event occurring at selected Gila basin gaging stations during the period 1950 through 1980. The actual classification assigned to each flood in the record is given in Appendix D in station-by-station format for the main gages of this study. Table 3 summarizes the hydroclimatic classification for all stations in the Gila River basin on a monthly basis for each year over the period of record. The coded values in the table represent the number of partial series flood peaks generated in the study area by the indicated atmospheric mechanisms, in each month of each year.

A review of the table shows that there is a large degree of month-to-month and year-to-year temporal variability in both the classification types and the number of floods associated with each type. July and August are the only months which experience flooding in the Gila basin in almost every year of the record. This supports McDonald's conclusion that summer runoff in Arizona has greater spatial

Table 3 Hydroclimatic Classification Summary for the Gila River Basin, 1950–1980 (Values are number of floods occurring from each hydroclimatic mechanism in the given month)

T=TROPICAL STORM	L=LOCAL
C=CUTOFF LOW	CONVECTIONAL
F=FRONTAL	S=SNOWMELT
W=SYNOPTIC	MW=MONSOON
WIDESPREAD	WIDESPREAD
ML=MONSOON	(E=EASTERLY WAVE)
LOCAL	(G=GULFSURGE)

Table 3 Hydroclimatic Classification Summary for the Gila River Basin, 1950-1980

WYEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
1950	F3				S1 F2 W1	W1
51						
52	L1 W2	F1	F8	F24		F4 S3 SW1
53						SL1 SW1 L1
54						F14 W2 S2 SF1
55	L3					
56	T9			F3		
57				F10	S2 W1 F2	
58	L1 F1 C1 W1	W2 F2 CF2			F6 W5	F25 W3
59	T4 L3				F1	
1960	F8	C6	F16	F17	F1	F1 S13 W1
61	L1 C2					S1
62			W6 SW1	C9 SC2	F13	F1 S3
63	C4		W1	F1	F4	S1 L3
64	C1	F1				S1
65	C1			W3 F10	F3 S1	W3 L2 F1
66		F15 L1	F62 W6	F2 S1	F2 W1	S12
67			F8			
68			CF5 F20	F13	F12 W1 S3 L3	L1 F9
69	TC1	F1		F19	F1 SL1	S3 C1
1970	C1	F1				
71	C1 W3					
72	T4 F8 CF10		L1 F12			
73	TC21 C27 L1 W1	F5	F18	SL1	F5 W18	F16 S8 SL1
74				F2		F2 S1
75	CF5	F1				F5 S1
76					F21	L1
77						
78	T11			F10 W2	F12 W6 S1	F36 W8 L1
79	T3 L1	CF9 C16	F31	F20 W13	S8 F1	C6 F10 S5 SL1
1980				F26 C2	F37 W4 S1	F5 L1

Table 3 --Continued

WYEAR	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
1950			L1	ML7 MW30	ML1 MW2	F1
51				ML2 MW6	MW11 T16	L1
52			C1	ML1 MW4	ML8 MW15	T3 F2
53				ML9 MW26	ML3 MF1 MW1	
54	L1		ML1 MW1 MF1	ML13 MW5 T10 MF23	ML29 MW29	W4 L1 F5
55			C4	ML24 MW34	ML39 MW78	
56			L1	ML10 MW8	ML4 MW2	
57			F1	ML3 MW11	ML16 MW34	ML1
58	F3 W4 S5	C1 L1	L1 C2	ML9 MW7	ML23 MW20	ML6 MW1 T13 W3 C4
59			ML1	ML9 MW9	ML28 MW43	
1960	L1	L1		MW2	ML4 MW5 MF2	ML2 MF1 T2
61	S3			ML10 MW9	ML17 MW8	T4 TC1 C3 ML3
62	L5 S1	L1	W1	ML3 MW3	MW2	T2 TF8 F2
63				ML18	ML12 MW50	ML10 MW4 MF2 MFC1
64	SF1 L3			MF1 MW31	ML12 MW30 MF1	ML2 MW22 MF2 C10
65	C1 CF6 F6 S3 L4	L1		ML5 MW2	ML5 MW2 MF5	ML7 T6 F1
66	L2	L1		MW7	ML9 MW23 C1	C5 CT3 T2
67			L1	ML10 MW13	ML23 MW11	ML2 MW4 W3
68	L10	L1		ML1 MW8	ML6 MW6 T1	L1 C1
69	S1 L3	L1		ML4 MW1	ML5 MW4 T4 ET3	ML5 T6
1970	L3			ML4 MW7	ML14 MW9	ML2 T1 TF16 L2
71				C4 ML2 MW2	ML13 MW37 C7 CT8 T10	ML8 F2 T4
72			L1 W2	ML3 MW3 G2	ML4 MW6 MF8 T1	ML8 MW7
73	F1 S21	F10 L3	W1 ML1	MW4	GML1 MW1	
74	SF1			ML8 MW16	ML3 MW26	ML4 W1
75	F3 L2 W2 SL3 S2	L1		ML16 MW1	ML2	ML3 MW9 F7
76	F1 L3 S3	W3		ML5 MW18	ML2	ML1 MW3 C1 W6 L1
77	S4			ML5 MW5	ML15 MW7 T8	ML7 MW5
78	F3	L1	L1	ML5 HW1	ML5 MW1	
79	F1 L4	C1 L1 W2	L1	MW1	ML3 MW2	
1980	F1 L4 L4 C4	L4	L1 ML1		ML2 MW7	C4

variability but less temporal variability than winter runoff (McDonald 1960).

The table also shows that, on occasion, several different kinds of atmospheric processes, or combinations of simultaneously occurring processes, have generated floods within the same month. Of note are the months of: October 1958, 1972, and 1973; February 1968; March 1954 and 1979; April 1965 and 1975; July 1954; August 1969, 1971, and 1972; and September 1958, 1961, 1963, 1964, 1970, and 1976. September has the greatest variety of flood-generating mechanisms because it is a transition month, reflecting at times both summer- and winter-like circulation patterns in addition to a high likelihood of tropical storms and cutoff lows.

Table 4 summarizes the frequencies of each type of flood-generating mechanism by month. In order to simplify the numerous combinations of classifications associated with tropical storms and cutoff lows (which frequently occurred together and are synoptically related), a combined tropical storm/cutoff low class was formed. Similarly, the various snowmelt combinations were put together in a single snowmelt category when it was clear that snowmelt and not some other feature was primarily responsible for the flood. Monthly frequencies of the simplified eight-category classification are shown in Table 5, along with percentages reflecting the relative importance of each type of flood-generating mechanism in the study area. The most important categories for the Gila River basin as a whole are, in descending order, monsoon widespread (MW), frontal (F), monsoon local (ML), and tropical storm/cutoff low (TC). Table 5 also shows

Table 4 Monthly Frequencies of Classified Gila Basin Floods, 1950-1980

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
T	TROPICAL STORM	31									10	43	43	127
C	CUTOFF LOW	38	22		11		7	5	2	7	4	8	28	132
TC	TROPICAL/CUTOFF	22										8	4	34
CF	CUTOFF/FRONT	15	11	5				6					1	38
TF	TROPICAL/FRONT												24	24
F	FRONTAL	20	27	175	157	123	129	19	10	1			20	681
L	LOCAL	11	1	1		3	10	49	17	8			6	106
W	WIDESPREAD	7	2	13	18	37	18	6	5	4			17	127
MF	MONSOON FRONT									1	24	17	5	47
ML	MONSOON LOCAL									4	186	308	71	569
MW	MONSOON WIDESPREAD									1	274	472	55	802
S	SNOWMWELT				1	17	54	43						115
SW	SNOW/WIDESPREAD			1			2							3
SL	SNOW/LOCAL				1	1	3	3						8
SC	SNOW/CUTOFF				2									2
SF	SNOW/FRONT						1	2						3
G	GULF SURGE										2			2
	TOTAL	144	63	195	190	181	224	133	34	26	500	856	274	2820

Table 5 Monthly Frequencies of Floods in Main Hydroclimatic Categories

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	%
TC	TROP STORM/CUTOFF LOW	106	33	5	11		7	11	2	7	14	59	100	355	13
F	FRONTAL	20	27	175	157	123	129	19	10	1			20	681	24
L	LOCAL	11	1	1		3	10	49	17	8			6	106	4
W	WIDESPREAD SYNOPTIC	7	2	13	18	37	18	6	5	4			17	127	4
MF	MONSOON FRONTAL									1	24	17	5	47	2
ML	MONSOON LOCAL									4	186	310	71	571	20
MW	MONSOON WIDESPREAD									1	274	472	55	802	28
S	SNOWMELT			1	4	18	60	48						131	5
	TOTAL	144	63	195	190	181	224	133	34	26	498	858	274	2820	100

the clear dominance of some categories in certain months, such as the tropical storm/cutoff low type in September and October, and the frontal type in December through March.

Table 6 reveals the relative importance of each category for generating floods at specific stations in the Gila River basin. It is immediately apparent that different parts of the study area are affected to varying degrees by the eight categories of flood-generating mechanisms. As would be expected, the more northern stations are strongly dominated by frontal floods, while the more southern stations -- including the southeastern and southwestern stations -- are dominated by monsoon widespread floods. Tropical storms and cutoff lows are an important source of flooding at stations throughout the basin, but snowmelt as a flood-generating mechanism is limited to the northern, high elevation catchments that drain the Mogollon Rim.

Table 7 displays the same information as Table 6, but for annual floods at selected stations only. This table shows that snowmelt is not an important generator of annual floods in the study area, but tropical storms, cutoff lows, and monsoon widespread circulations emerge again as the major producers of annual floods in the basin.

Discussion of the Hydroclimatic Classification

The classification of flood events on the basis of the atmospheric mechanisms which generate them reveals much more information about the nature of flood variability than is obtainable from an analysis of the runoff values alone in a flood time series. Floods vary in both magnitude and frequency over time, and hydroclimatic information about flood events provides a physically-based understanding

Table 6 Classification Frequencies for Selected Stations -- Partial Duration Series, 1950-1980

	STATION		TC	F	L	W	MF	ML	MW	S
1	GILCLF	Gila near Clifton	14	18	2	2	2	24	27	1
2	SFRCLF	San Francisco at Clifton	23	28	2	4	1	21	34	5
5	SCLPER	San Carlos near Peridot	16	29	2	7		28	31	3
7	SPDCHA	San Pedro at Charleston	12	4		1	3	35	48	
9	SCRLOC	Santa Cruz near Lochiel	4	3		1	1	19	28	
10	SCRNOG	Santa Cruz near Nogales	8	10	1	3	2	40	55	
12	SCRTUC	Santa Cruz at Tucson	18	11	1	2	4	40	64	
13	RILTUC	Rillito near Tucson	14	19	1	6	2	28	32	
14	SRWVVO	Santa Rosa Wash near Vaiva Vo	8	2	2	7	1	8	24	
20	SLTROO	Salt near Roosevelt	15	50	3	6		7	17	12
21	TONROO	Tonto near Roosevelt	16	58	1	10		11	30	2
22	OAKCRN	Oak Creek near Cornville	10	41		9	2	8	16	13
25	VRDHSD	Verde above Horseshoe Dam	12	47		7	1	4	13	14
26	AFRMAY	Agua Fria near Mayer	13	20	4	4	2	30	40	
28	HASWIK	Hassayampa near Wickenburg	20	40		8	2	16	31	
29	RIOAJO	Rio Cornez near Ajo	8	6		3		15	20	

Table 7 Classification Frequencies for Selected Stations -- Annual Series, 1950 -1980

	STATION		TC	F	L	W	MF	ML	MW	S
1	GILCLF	Gila near Clifton	7	8				5	11	
2	SFRCLF	San Francisco at Clifton	10	8				8	5	
5	SCLPER	San Carlos near Peridot	5	14		2		4	6	
7	SPDCHA	San Pedro at Charleston	3	3			1	10	14	
12	SCRTUC	Santa Cruz at Tucson	5	2		1	1	5	17	
20	SLTROO	Salt near Roosevelt	6	15				1	8	1
21	TONROO	Tonto near Roosevelt	7	14		1		3	6	
22	OAKCRN	Oak Creek near Cornville	4	15				2	9	1
25	VRDHSD	Verde above Horseshoe Dam	3	17			1	3	6	1
26	AFRMAY	Agua Fria near Mayer	6	7	2			8	8	
28	HASWIK	Hassayampa near Wickenburg	6	11			2	5	7	

of why different portions of a record tend to be characterized by high or low flood volumes or frequencies.

Figure 27 depicts the variability over time of the average number of floods occurring per station in the Gila River basin. In the last 31 years, there have been episodes of both frequent and infrequent flooding in the basin. By referring to the hydroclimatic summary in Table 3, the reasons for the widespread, frequent flooding in certain years can be determined. The high frequency of flooding in the mid and late 1950s was due to a very active monsoon circulation that produced many July and August flows throughout the basin. Frequent flooding in 1963 and 1964 was also related to a strong monsoon, but one that persisted into September and produced many late summer flows. The numerous floods occurring in water year 1966 had an entirely different origin, resulting from intense frontal activity in the Gila River basin during November and December of 1965. The majority of the floods recorded during water year 1973 were a result of tropical storms and cutoff lows occurring in October 1972, while the high frequency of flooding in the late 1970s was due to intense late winter frontal activity, especially in the northern part of the basin.

These observations demonstrate clearly that variations in the seasonal timing and frequency of flooding are closely related to variations in atmospheric activity over time. An important related question, however, is whether or not variations in the magnitudes of floods are also related to the types of atmospheric processes which generate the floods. The answer to this question has implications for the first and second major hypotheses presented in Chapter 1.

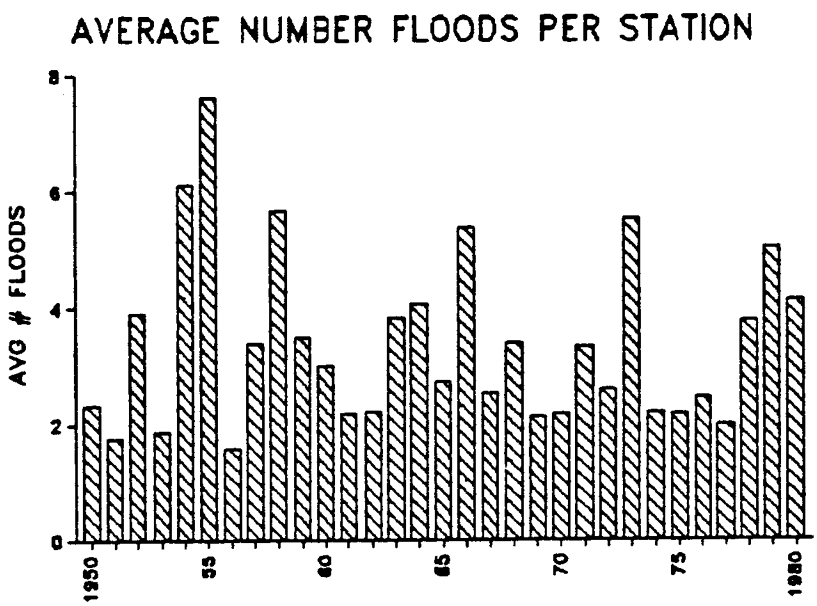


Fig. 27 Average Number of Gila Basin Flood Peaks Occurring per Station per Year

If floods generated by, say, tropical storms or frontal activity can be shown to have significantly greater discharge volumes on the average than floods generated by monsoon activity, the stationary stochastic model of Figure 4 will not be a valid theoretical framework in which to analyze the Gila River basin flood series because the different hydroclimatic categories of floods will represent different theoretical probability distributions in the time series. The possibility of hydroclimatically-controlled mixed distributions in the Gila basin flood series will be examined in the following chapter.

Composite Circulation Anomaly Maps

After the hydroclimatic origins of flooding in the study area were determined and summarized on a monthly basis (Table 3), those months which were dominated by a high frequency of flooding from one specific category were selected to link the event-based classification scheme to mean monthly circulation patterns similar to those depicted in the correlation fields. The standardized maps of monthly 700 mb heights for the months selected from Table 3 were averaged together to obtain composite circulation anomaly maps for the major flood-generating mechanisms in the Gila basin. The resulting patterns depict the anomalous circulations that are associated with the dominance of different hydroclimatic categories.

Tropical Storm Anomaly Patterns

Figure 28 shows the 700 mb monthly anomaly patterns associated with a high frequency of tropical storm flooding in the study area. Separate composite maps are given for August, September, and October

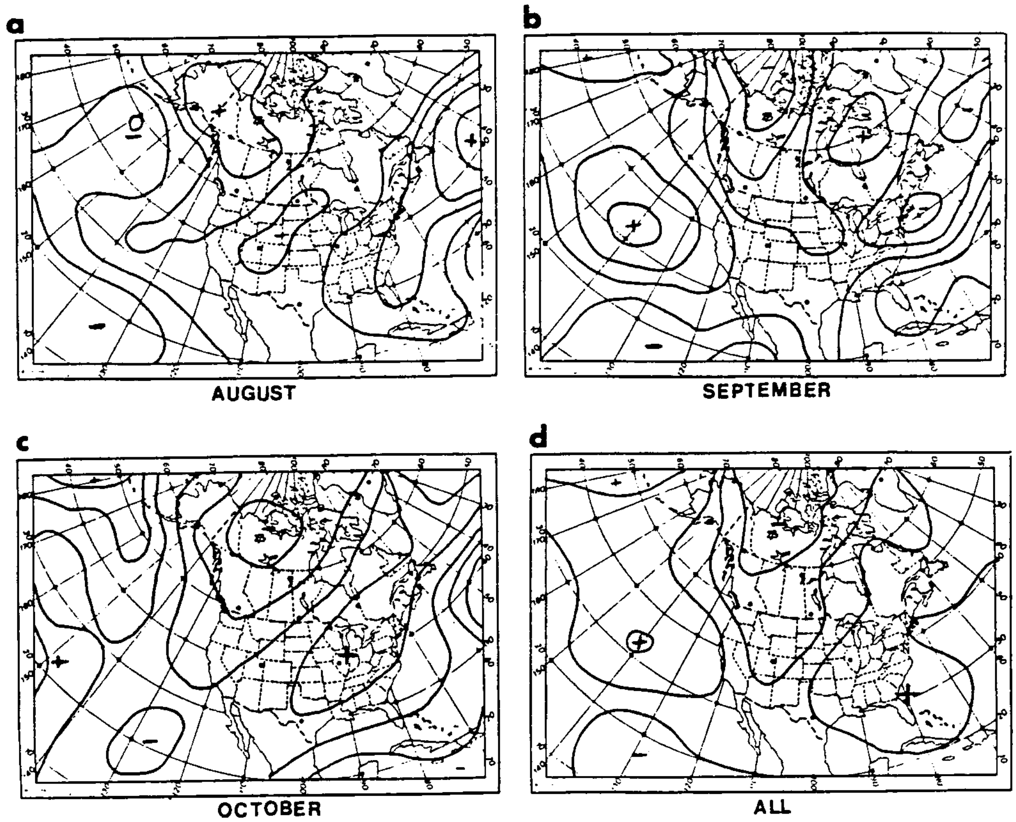


Fig. 28 Tropical Storm Anomaly Patterns

and Figure 28d is a composite map for August-through-October combined. All of the maps show lower-than-normal 700 mb heights in the eastern tropical North Pacific Ocean, combined with a positive subtropical high pressure anomaly in eastern United States. The anomalous air flow associated with this pattern would be stronger-than-normal southeasterly winds in the eastern tropical Pacific, a flow pattern that is favorable to the formation of tropical storms and very conducive to steering the storms northward along the coast of western Mexico and Baja California (Douglas and Fritts 1973).

A strong upper level trough is present over the west coast in the October composite, but is not evident on the other maps. Douglas and Fritts (1973) found tropical storm activity to be below normal in September with a broad west coast trough and attributed this to vertical shearing by the upper level winds in the trough. In October, tropical storms are frequently associated with upper level cutoff lows, and this tendency may be reflected in the October composite.

The tropical storm anomaly pattern is similar to many of the summer and fall correlation fields discussed earlier in this chapter, especially those of October in the southern basins of the study area. The pattern also bears some resemblance to the very persistent correlation field configurations of Rio Cornez and Santa Rosa Wash. These observations lead to the conclusion that the tropical storm circulation anomaly plays an important role in both enhancing monthly streamflow at stations in the Gila River basin, and in producing frequent individual flood events throughout the basin.

Cutoff Low Anomaly Patterns

The anomaly patterns for months experiencing frequent flooding due to cutoff lows are presented in Figure 29. Although the September and October composite maps differ somewhat in their overall patterns, the location of a strong negative anomaly center just off the coast of southern California is consistent in both maps. The configuration is ideal for steering moist air from the eastern tropical North Pacific into the Gila basin and also for positioning and directing fronts diagonally across the study area to produce widespread flooding.

The cutoff low anomaly pattern is not exactly like any of the correlation fields discussed earlier but its influence is probably present in those fall and winter correlation fields showing strong negative anomalies off western Baja California.

Front Anomaly Patterns

The winter anomaly patterns for months dominated by frequent flooding due to frontal rainfall and cyclonic storms are shown in Figure 30. All maps show lower than normal pressure in the eastern North Pacific and resulting stronger than normal westerly airflow into the study area. As in the winter correlation fields, the patterns of January and March have a definite zonal orientation, while those of November and February reflect more meridionality. The composite map for the four front-dominated months (Figure 30e) depicts the basics of the front anomaly pattern: a Pacific storm track (indicated by lower than normal Pacific pressure) at a low enough latitude to steer diagonally oriented cold fronts across central and southern Arizona. The east-west orientation of the negative anomaly reflects a tendency

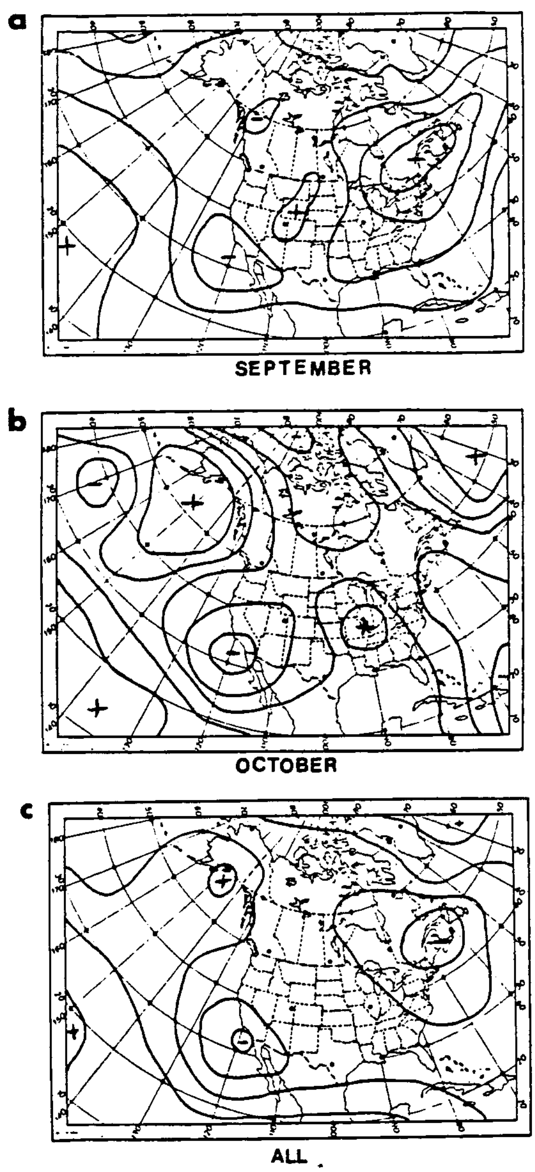


Fig. 29 Cutoff Low Anomaly Patterns

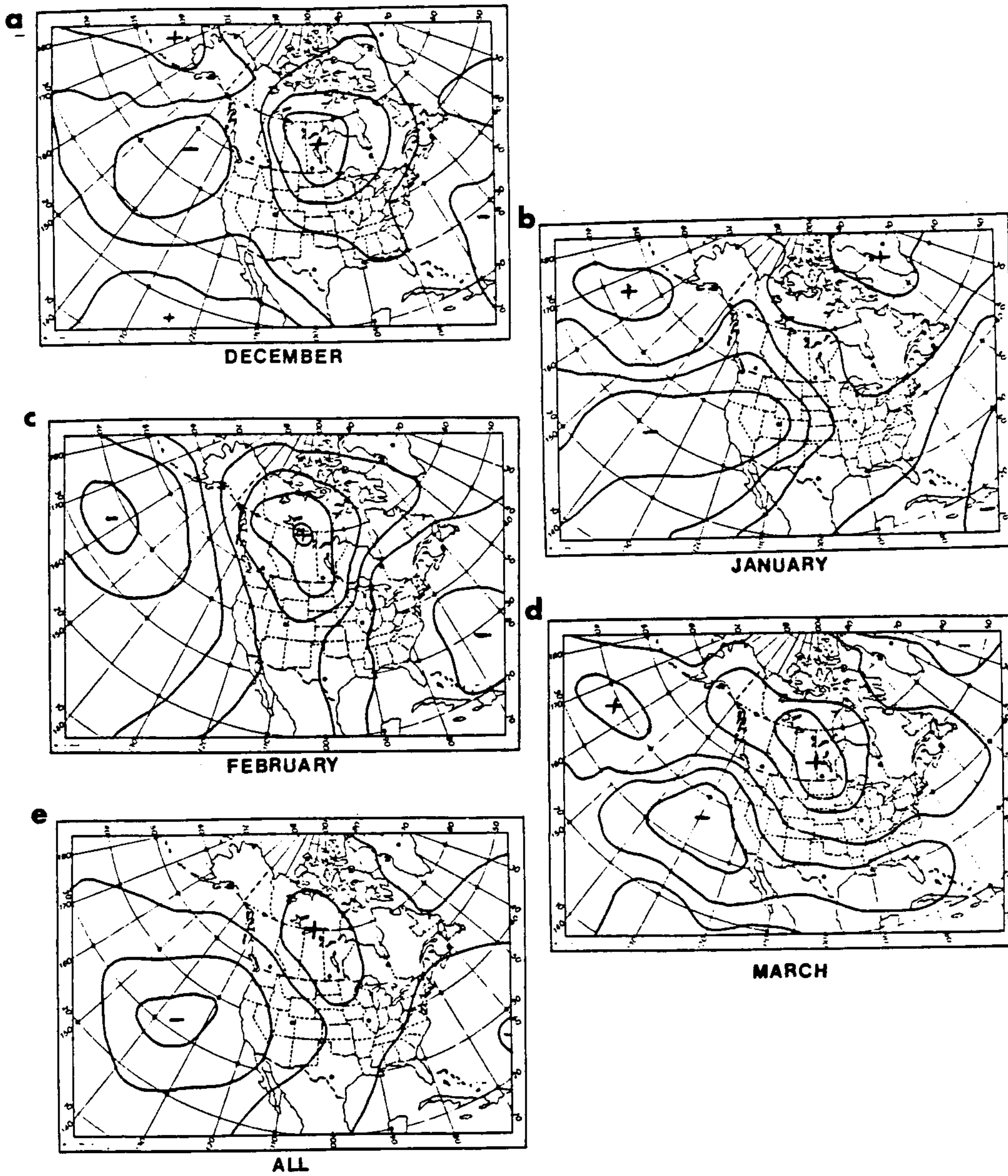


Fig. 30 Front Anomaly Patterns

toward stronger than normal westerly flow (zonality) which would direct many fronts across the region in rapid succession during the course of a winter.

The similarity of the front anomaly pattern to many of the winter correlation fields supports the conclusion that enhanced monthly streamflow and the frequency of occurrence of individual winter flooding events are closely related, and both are dependent on circulation configurations that promote frequent frontal passages.

Monsoon Widespread Anomaly Patterns

Figure 31 shows the composite anomaly patterns for those summer months which experienced exceptionally high frequencies of monsoon widespread flooding. The composite patterns are characterized by stronger than normal high pressure situated over eastern United States and lower than normal pressure in the eastern tropical North Pacific. This general configuration is seen in various forms in the summer correlation fields and indicates the occurrence of unusually strong southwesterly airflow from the Gulf of Mexico and tropical Mexico into central and southern Arizona.

Monsoon widespread flooding is very difficult to describe or explain by referring to specific synoptic circulation features because they are largely absent from daily weather maps of the summer circulation over the southwest. Nevertheless, the monsoon widespread classification was formulated because some unique aspect of the broad-scale circulation must be in operation for such widespread precipitation and flooding to occur at certain times, and not others, during the

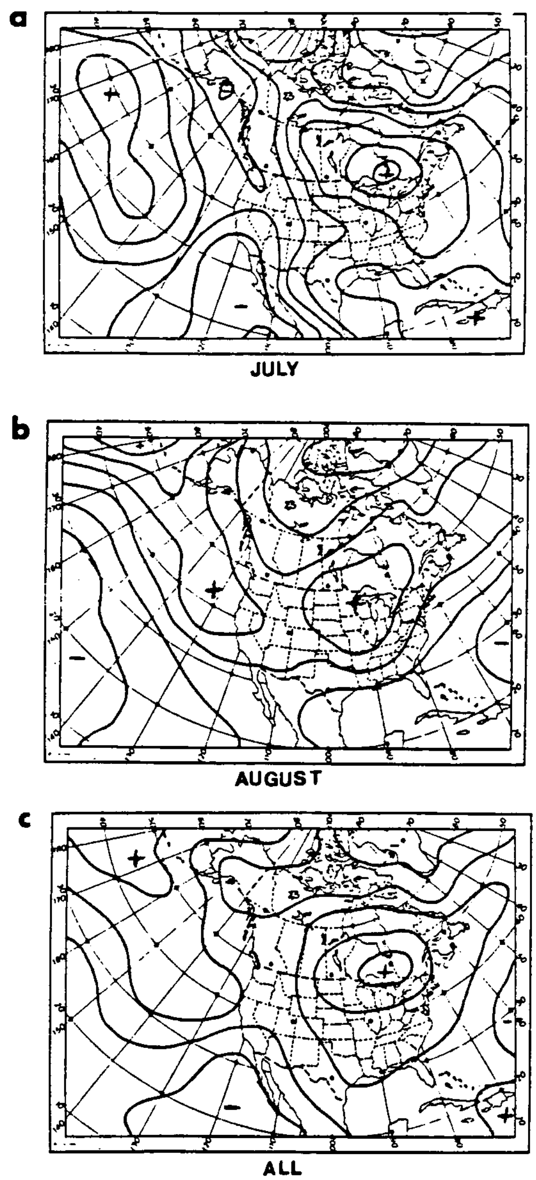


Fig. 31 Monsoon Widespread Anomaly Patterns

summer, even if the circulation mechanism responsible for the flooding is not detectable in the daily weather map series.

The summer correlation fields and the monsoon widespread composite anomaly maps depict a consistent and physically plausible synoptic pattern that introduces greater than normal amounts of moisture into the study area so that thermal convectional activity and orographic uplift can produce large amounts of rain and runoff. Due to weak summer circulation, this general pattern can be more easily observed on mean monthly maps than on the daily maps. The monthly circulation analysis is therefore particularly helpful for determining the source of summer flooding events.

Snowmelt Anomaly Patterns

Anomaly maps for months experiencing several floods due to snowmelt are displayed in Figure 32. Composite maps for March and April are presented in (a) and (b) of the figure, but Figure 32c is not a combined version of the individual monthly maps, as are the general composites for the other categories. Figure 32c is the composite anomaly pattern for two months which experienced unusually high frequencies of snowmelt flooding: March 1960 and April 1973 (see Table 3). Because snowmelt flooding was not very frequent during the study period, it was thought that the best way to define a circulation anomaly pattern related to snowmelt would be to composite only the most extreme months of snowmelt flooding.

March's pattern makes the most sense as a cause of frequent snowmelt flooding because it is characterized by higher than normal 700 mb heights over the study area, suggesting warmer than normal

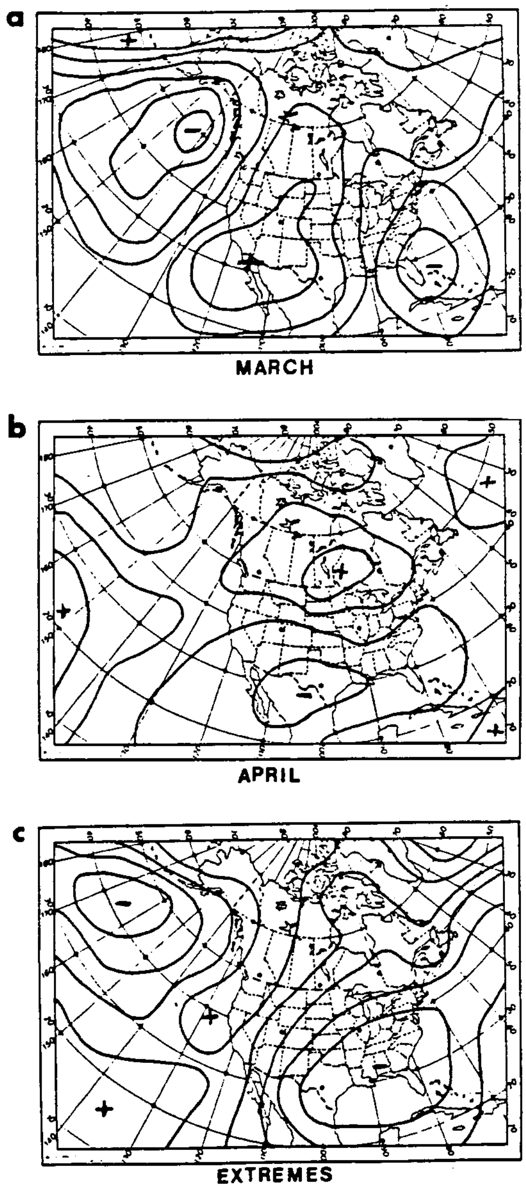


Fig. 32 Snowmelt Anomaly Patterns

March temperatures at the surface. April's anomaly pattern would steer relatively warm, and perhaps dry, air from south central United States into Arizona and hence would be another plausible circulation pattern for increasing snowmelt.

The composite pattern for the two extreme snowmelt months is puzzling. The pattern would steer stronger than normal cold airflow from the north or northeast directly into Arizona, a situation that is not very conducive to snowmelt. The only possible explanation for the pattern is that it reflects a circulation that promotes the buildup of large amounts of snow on the ground, which, when melted due to a sudden warming that is not represented in the mean monthly pattern, would produce much snowmelt flooding.

Low-Flooding Anomaly Patterns

In order to define circulation systems that might suppress flooding, composite maps were constructed for selected months of low flooding during the otherwise wet months of July, August, and September. These maps, shown in Figure 33, are interesting in that they represent almost the inverse of the monsoon widespread composite maps and also the inverse of many of the summer correlation fields. The anomalous airflow associated with these patterns is generally from the dry continental interior into the study area. The dominance of circulation patterns like those in Figure 33, or the dominance of the inverse of some of the correlation field patterns would greatly lower the probability of flooding in the study area.

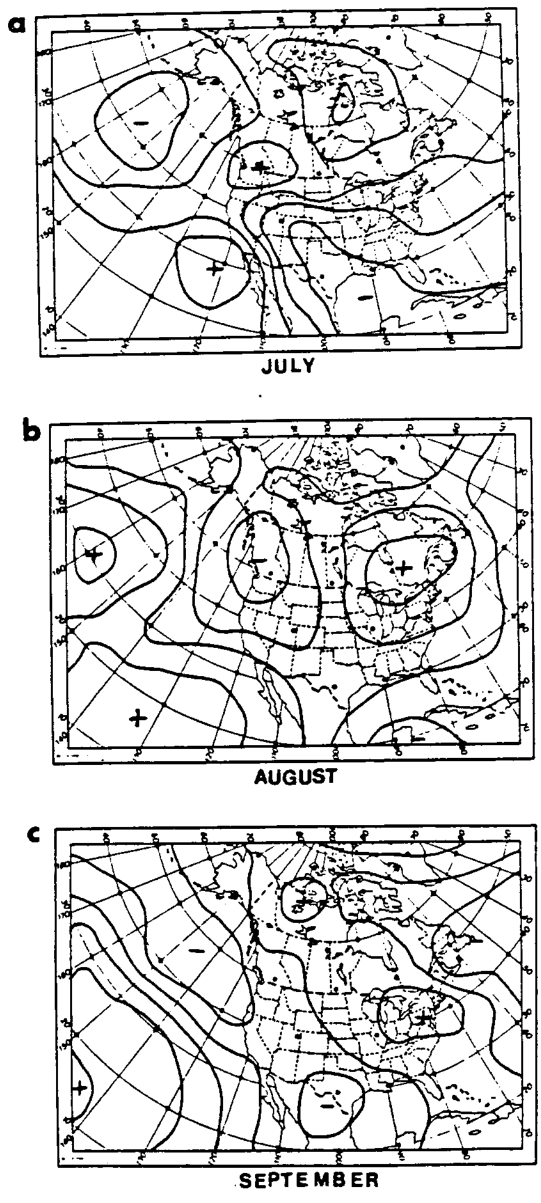


Fig. 33 Low-Flooding Anomaly Patterns

Discussion of the Composite Circulation Anomaly Maps

The composite anomaly map analysis demonstrates clearly that different flood-generating mechanisms are associated with specific upper air circulation configurations. The analysis also shows that many of the same patterns seen in the monthly streamflow correlation fields are present in the composite maps, indicating that mean monthly streamflow variability and flood event variability are related to similar anomalous circulation patterns.

Both of these conclusions have implications for the third major hypothesis formulated for this research (see Chapter 1). The first conclusion suggests that variability in the kinds of atmospheric processes that produce floods is related to variability in the broad-scale circulation of the atmosphere. If unique theoretical probability distributions are associated with floods generated by different atmospheric processes, the third hypothesis, which states that a shift in general atmospheric circulation patterns will be reflected in a flood series by a shift to a different theoretical distribution, is likely to be true.

The second conclusion, concerning the relationship between monthly streamflow-circulation anomalies and individual flood-event anomalies, is also important for the third hypothesis because it suggests that individual short-period flood events may develop from longer-period circulation anomalies, some of which may exhibit persistence over extended segments of the flood time series.

Summary

Three methods of hydroclimatic analysis were used to study the climatic origins of flooding variability in the Gila River basin. First, circulation-streamflow correlation fields were constructed for selected stations on a month-by-month basis. Then, each individual flood event was assigned a hydroclimatic classification and a basin-wide summary of the different flood-generating mechanisms was compiled. Finally, months dominated by the major flood-generating mechanisms were identified and their standardized monthly 700 mb maps were composited to reveal the circulation anomaly pattern most closely associated with each hydroclimatic category.

The correlation field analysis demonstrated that specific broadscale circulation anomaly patterns are associated with higher than normal streamflow in different parts of the study area and that winter streamflow responds to circulation in a more homogeneous manner than summer streamflow. The hydroclimatic classification of flood events revealed that there has been considerable variability in the frequencies of the various flood-generating mechanisms over time, and that different mechanisms are important at different times of the year and in different parts of the Gila basin. The composite anomaly map analysis defined the specific circulation patterns associated with each flood-generating mechanism and showed that individual flood events develop from long-period monthly circulation anomaly patterns.

The next chapter relates these conclusions to flood-frequency analysis and will specifically address the question of whether floods generated under different hydroclimatic regimes belong to different theoretical probability distributions.

CHAPTER 6

HYDROCLIMATOLOGY AND FLOOD-FREQUENCY ANALYSIS

Probabilistic flood-frequency analysis is used today throughout the world to assess the magnitude and frequency of floods. The technique, and the concept of a "100-year flood" that is basic to the technique, have been incorporated into zoning laws, bridge and culvert specifications, drainage designs, flood insurance maps, and many other aspects of the human environment.

The standardization of the technique in the United States by the Water Resources Council and the practicality and universality of its use as a basis for decision-making in city, county, state, and federal agencies, has at times led to an almost "cookbook" approach to the analysis of flood variability. Although the underlying assumptions which must be met for the technique to be valid are clearly stated in procedure manuals such as Bulletin #17B (U. S. Water Resources Council 1981), in practice these assumptions may not be explored to any great depth for each individual flood series analyzed. Part of the problem lies in the inadequacy of current techniques to assess accurately the validity of certain assumptions when only short time series are available for analysis. Another part of the problem is a lack of understanding about the physical sources of variability in a flood time series.

The hydroclimatic analysis of flow events presented here offers the opportunity to explore the underlying assumptions of traditional flood-frequency analysis from a physically-based perspective.

Basic Assumptions of Flood-Frequency Analysis

Bulletin #17B states that, in order for the statistical analysis of flood data to be valid, the array of flood information must be "a reliable and representative time sample of random homogeneous events" (U. S. Water Resources Council 1981, p. 6). Each of the assumptions implied by this statement may be violated due to possible climatic or nonclimatic influences on flood behavior and flood discharge estimates.

Reliability of Flow Estimates

The reliability of the data is an important factor to consider before any statistical manipulation of the data is undertaken. Flood discharge values that have been estimated from a previously determined stage-discharge rating curve and measured gage heights or high water marks, are often subject to large amounts of error. Furthermore, measurement error is far more likely during peak flow events than at other times because of the turbulent and pulselike nature of flood flow, and the damaging effects of torrential waters which have been known to destroy stream gages, often when they are most needed.

Unfortunately, unless researchers personally collect their own flood data, they have little control over this underlying assumption in flood analysis, other than carefully reviewing the data for apparent errors and investigating the general reliability of a station's records.

Representative Time Sample

Recorded flood series are only one portion of a stream's entire history of flood variability. When a flood record is analyzed statistically, it is assumed that the results of the analysis will be applicable to both future flows and past unrecorded events; in other words, that the time sample of flood values analyzed is representative of flood activity occurring at other times in the stream's history.

Of course this assumption is not meant to be applied at the geologic time scale, but, as seen in Chapter 1, stationarity is generally assumed for most hydrologic time series, whether they have short records of 30 years or less, or long records of 100 years or more.

Three factors can affect the validity of the representative sample assumption: the length of the record, watershed changes which take place during the course of the record or afterward, and climatic trends or variations.

Length of Record. Using data from the Minnesota River, Victorov (1971) effectively demonstrated that short record lengths can yield values for a 100-year flood that vary from +211% to -67% of the "true" value of the 100-year flood, (which was assumed to be that computed from a complete 68-year record). Short records are not able to represent the wide range of variability in flood magnitudes that might exist in a longer record, hence the use of a short record may invalidate the underlying assumption of a representative time sample. Attempts have been made to determine when a record is "long enough" (Baran et al. 1971; Knisel et al. 1979), yet Victorov found that even records of 40 or 50 years still yielded errors of 26% to 20% when compared to the 68-year record.

Victorov also concluded that the range of error in flood estimates from short samples is dependent on whether the sample was drawn from a period of wet or dry years. The results of the Gila basin hydroclimatic analysis indicate that his conclusion could be expanded to say that the range of error in flood estimates from short samples is dependent on whether or not the sample was drawn from a period dominated by a streamflow-enhancing upper air circulation pattern. Since certain types of circulation anomalies can be very persistent, such as the winter anomaly pattern associated with the El Nino phenomenon, a short record could conceivably be representative of only anomalous streamflow conditions, rather than reflecting the stream's overall flow variability.

Watershed Changes. The effects of watershed changes on flood time series, especially due to the increased urbanization of a drainage basin, have been studied extensively. Detailed observations of changing land use patterns such as increasing percentages of paved area and alterations in vegetation and surface cover have been analyzed to determine how flood discharges will be affected by the changes. Adjustments in channel dimensions and shape, such as arroyo formation in the Southwest, have also been analyzed in terms of their effect on flooding. In general, most researchers are attuned to the possibility that watershed changes may affect the validity of some flood records as representative samples of a stream's flooding variability.

Climatic Trends or Variations. Chapter 1 discussed at length the history of flood analysis with a climatic perspective. In general, hydrologists have been slow to include climatic variability as a factor that might affect the degree to which a certain segment of a record is representative of the whole record.

The discussion of the Santa Cruz flood series in Chapter 1 and the flood estimates computed from different portions of the record (Table 1) showed that the period of record that came closest to yielding a good estimate of the large 1983 flood was, not the complete record, but the more recent second half of the time series, especially the post-1960 segment. Since the 1983 event was generated in part by Tropical Storm Octave, it would be classified as a tropical storm/cutoff low type event in the classification scheme designed for this study. Table 8 presents information compiled from Appendix B on the number of tropical storm/cutoff low floods that occurred at the Santa Cruz River at Tucson during the three-decade period of 1951 to 1980. The table shows that, in recent years, tropical storms have increased in importance as a flood-generating mechanism for the Santa Cruz River. The hydroclimatic classification of the floods therefore provides a plausible climatically-based explanation for the fact that the most recent portion of the flood record produced estimates closest to the actual discharge of the 1983 flood. In terms of the climatic processes currently at work in the Santa Cruz, the sample of floods occurring in recent years may be a more representative time sample than a sample of floods from earlier in the record, and perhaps even more representative than the entire 66 year record of the Santa Cruz River.

Table 8 Number of Tropical Storm/Cutoff Low Floods Occurring at the Santa Cruz at Tucson by Decade, 1950 -1980

DECADE WYEAR	T ALONE	C ALONE	BOTH T+C	ALL TC	% TC PER DECADE
1951-60	4	0	0	4	22
1961-70	3	3	0	6	33
1971-80	3	2	3	8	44
TOTAL	10	5	3	18	

The representative time sample assumption can be viewed in terms of the stochastic process models presented in Chapter 1. The stationary model depicted in Figure 4b would yield representative estimates of the stochastic process from samples selected at any portion of the record. The nonstationary models in Figure 5 would yield different estimates in different parts of the record because the theoretical probability distributions from which the time sample would be drawn vary through time in relation to the overall population mean and variance of the stochastic process. In terms of the Santa Cruz example discussed above, the population of all tropical storm floods might have a theoretical distribution like that exhibited by the random variable $X(t_n)$. If several events like $X(t_n)$ were to occur more frequently in a certain portion of the record, a time sample from that portion of the record would yield the best estimate of any future tropical storm flooding.

Randomness of Events

The randomness of events is an important assumption in all stochastic analyses of hydrologic time series. The term "random" can have different connotations due to the philosophies of different researchers and the context in which the term is used. The basic dictionary meaning of the term is "being a member of a set whose members have an equal probability of occurring," (Webster's Seventh New Collegiate Dictionary, 1967). Kisiel (1969) discusses randomness in terms of the stochastic process models depicted in Figures 4 and 5:

> If the stochastic process $\{X(t): t \quad T\}$ is entirely random, the values $x(t_1)$, $x(t_2)$, ..., $x(t_n)$ from the populations $X(t_1)$, $X(t)$, ..., $X(t_n)$ in the time series are <u>internally independent</u> among themselves and, thus, constitute a <u>random sequence</u>.....If the process is nonpure random, the values x_1, x_2, ..., x_n are dependent and coupled among themselves. The resulting nonrandom time sequence does not fluctuate as rapidly as a random time sequence because of the regularity introduced by stochastic dependence (in a sense, deterministic behavior). (pp. 16-17)

Factors which can affect the randomness of a time series of flood values are: autocorrelation in the series, the use of the partial duration flood series instead of the annual flood series, and the occurrence of episodes within a time series that are dominated by persistent or anomalous hydroclimatic activity.

<u>Autocorrelation</u>. The tendency for sequential members of a time series to be correlated with each other is termed autocorrelation (or serial correlation). Sequential dependence of events in hydrologic time series is common, especially in daily and monthly streamflow data. The term "persistence" is often used to describe autocorrelation in hydrologic series characterized by sequences in which low flows tend to follow low flows, and high flows follow high flows. Persistence is a major source of nonrandomness in hydrologic data:

> Streamflow is by nature nonrandom. Each daily discharge is affected by flows for previous days and in turn, affects succeeding daily flows. Monthly discharge is also nonrandom but to a lesser degree than daily discharge. The primary cause of nonrandomness in streamflow data is the lag in rainfall-runoff relation (carryover effect). A secondary cause is the nonrandomness of precipitation and the tendency of wet and dry years to occur in groups rather than in random sequence. (Searcy 1960, p. 71)

If daily streamflow discharges are highly autocorrelated, but monthly discharges are autocorrelated to a lesser degree, it follows that discharges recorded or observed at longer time intervals, such as annual flood peaks, will tend to exhibit greater and greater tendencies toward randomness as the rainfall-runoff carryover effect between events becomes less and less important. Lower autocorrelation among annual peaks and their tendency toward randomness prompted the authors of Bulletin 17B to be slightly less concerned with meeting this assumption than the others:

> In general, an array of annual maximum peak flow rates may be considered a sample of random and independent events. Even when statistical tests of the serial correlation coefficients indicate a significant deviation from this assumption, the annual peak data may define an unbiased estimation of future flood activity if other assumptions are attained. The nonrandomness of the peak series will, however, increase the degree of uncertainty in the relation; that is, a relation based upon nonrandom data will have a degree of reliability attainable from a lesser sample of random data. (U. S. Water Resources Council 1981, pp. 6-7)

Annual vs. Partial Duration Flood Series. The partial duration flood series, (or all peaks above a given base), was chosen for use in this study because many more flow events could be analyzed and categorized into hydroclimatic types to better define the nature of hydroclimatic variability in the study area. The partial series, however, has a much greater likelihood of being autocorrelated because the time interval between subsequent flood peaks may at times be very short. The compilers of the peaks-above-base data sets at the U. S. Geological Survey follow certain criteria in order to assure the independence of the selected peaks:

> 1. Publish only the highest peak of two or more occurring within 48 hours of each other, unless it is probable that the peaks in that period are independent. The peaks are independent if the hydrograph recedes to a well-defined trough as defined in paragraph 2 below. List only the first, if two dependent peaks occurring within 48 hours of each other happen to be equal.

> 2. Do not publish a peak unless the discharge of the trough between it and the adjacent higher peak is 25 percent or more below the discharge of the lower peak.
> (U. S. Geological Survey 1976, p. 39)

These criteria do a fairly good job of reducing autocorrelation in the partial flood series. Program NONPARA (Shiau and Condie 1980) uses the Spearman rank order correlation coefficient to test for independence in flood series data, and when the program was run on the partial series records of the 30 Gila basin stations, only three of the basins: Santa Cruz near Lochiel, Santa Rosa Wash, and Big Bonito Creek, showed significant autocorrelation in their records.

Anomalous Hydroclimatic Episodes. It is conceivable that the tendency toward randomness and nonrandomness might vary over time within a single hydrologic series due to hydroclimatic factors. Flood peaks generated by certain atmospheric processes, or developing under certain anomalous circulation patterns, may contain more inherent persistence than other peaks.

For example, the winter anomaly pattern associated with the occurrence of El Niño is one that steers frequent cold fronts across the Gila River basin and has been responsible for extensive flooding in the northern part of the study area (see the discussions of Figures 26 and 30 in Chapter 5). Three sequential winters, 1977-78, 1978-79, and 1979-80, were affected by this pattern, due to the persistence of a strong cold sea surface temperature anomaly in the central Pacific Ocean and a warm sea surface temperature anomaly in the eastern tropical Pacific (Douglas 1981). At some stations these three winters had a higher frequency of winter flooding than any other three-year period during the 1950-1980 study period. Floods occurring under this anomalous regime therefore tended to have a different probability of occurring than floods in the rest of the time series, and the randomness assumption may be invalid for station records affected by this particular circulation anomaly.

Homogeneous Populations

As discussed in Chapter 1, the possibility that flood series may be composed of multiple populations, rather than a single homogeneous population is almost universally recognized, although attempts to separate out the multiple populations have only recently gained momentum. For many years, watershed and channel changes (e.g., urbanization, paving over a channel bed), and differences due to changing data collection techniques, (e.g., moving the location of the gage, recalibrating the stage-discharge rating curve), were considered to be the main sources of multiple populations in a flood series. Later, climate was recognized as an important factor, but actual analysis of climatically-induced multiple populations has been limited to the examination of the different frequency distributions that arise from flood series separated into seasonal groupings or rainfall- and snowmelt-generated events (e.g., Waylen and Woo 1982).

Theory of Mixed Distributions. The statistical theory behind multiple populations and mixed distributions has been discussed by various authors such as Hawkins (1974), who also gives a good summary of previous work in the area. According to Hawkins, a set of hydrologic observations, sampled blindly from a population as if they represented a single phenomenon, can also be thought of as a combined or mixed sample representing different phenomena. In other words, the overall population may, in actuality, be composed of two or more subpopulations, each with a distinct distribution. An example given frequently is that of annual floods arising from two sources: summer thunderstorms and hurricanes, each with its own characteristic theoretical distribution.

Figure 34 depicts a theoretical representation of the mixed distribution model. Events from two separate populations with different means, standard deviations, and skewness may, when combined together, form the top distribution in the figure, which is the distribution that is "seen" or represented by the observed mean, standard deviation, and skewness of the data sample. Many distributions of observed hydrologic data may be decomposed into simpler components as suggested by Anderson:

> Complicated frequency functions (double peaked, etc.) can easily be thought of as decomposed into a few simpler frequency functions, which when "added," give their final composite effect. Each of the simpler functions is taken to be more and more nearly a Gaussian frequency function as the decomposition proceeds to more elementary levels. Note however that even a basic effect may not behave according to a simple Gaussian frequency function. Nature does not follow a Gaussian law precisely. (Anderson 1967, p. 7)

Some reasons given by Hawkins (1974) for decomposing hydrologic data into component distributions are: to extend frequency curves for the prediction of rare events, to use in simulation studies, and to aid in understanding the basic underlying phenomena.

A primary reason for developing the hydroclimatic classification for flood events in the Gila River basin was to examine the mixed distribution problem from a physically-based perspective by decomposing the overall distribution of flood peaks into simpler components linked

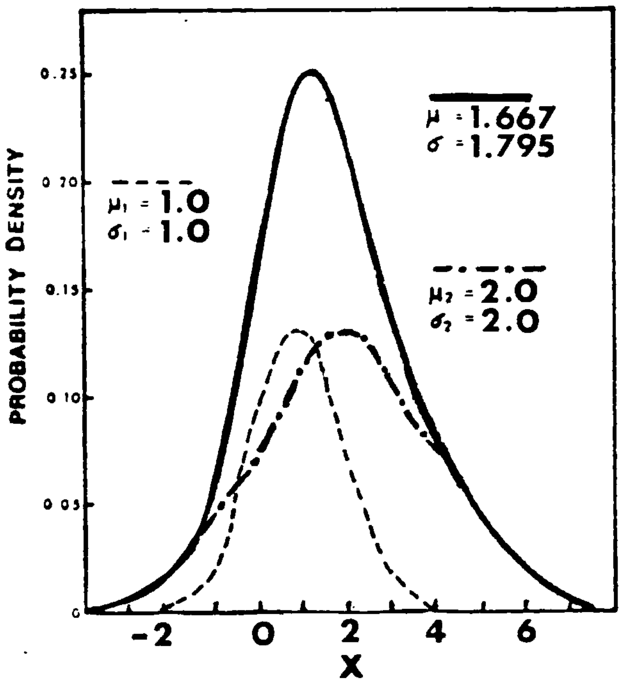


Fig. 34 The Mixed Distribution Model
(mean and standard deviation are given for each subgroup, and for the overall population)

to specific flood-generating mechanisms. Of particular interest was the hypothesis presented in Chapter 1 concerning the importance of subpopulations in determining the shape of the overall distribution curve for a flood series. This concept is visually portrayed in the stochastic process models of Figure 5. By attributing the varying shapes of the theoretical distributions at each t to be a function of the kind of flood-generating mechanism operating at time t, the overall flood peak distribution can be explained in terms of the dominance of different subpopulations at different times during the flood record.

Mixed Distributions in the Gila River Basin Flood Series

The true shape of the theoretical probability distribution of all possible floods occurring at a given station can never be completely defined. The same is true for the shapes of the theoretical distributions, or subpopulations, of all possible floods generated by specific kinds of atmospheric processes. The best approximation of the true distribution of a variable is a histogram of a large sample extracted from the population. If mixed distributions are present within the overall population of all possible values, the histogram of a single sample that has been "blindly" selected from the overall population may contain elements of several different smaller subpopulations. These subpopulations can likewise be approximated by individual sample histograms which, when combined, will form the sample histogram of the entire data series.

Histograms of the Flood Series

Histograms of peak discharges from several of the main stations in the study area were plotted to display an approximation of the general shape of the overall theoretical flood distribution at the stations. Figure 35 displays plotted histograms of the partial and annual series of flood peaks for selected stations in the Gila River basin. In the plots, the A's represent annual flood peaks and the B's represent the partial series peaks that were not annual extremes. In all parts of the Gila basin, the partial and annual flood series have strongly positively skewed distributions.

In order to "normalize" these skewed distributions so that statistical tests for the comparison of groups would be valid, the data were logarithmically transformed (base 10) and were also standardized over the base period of 1950-1980, as described in Chapter 2, so that comparisons among basins would be easier. Histograms of the standardized discharge data are presented in Figure 36 for the whole partial series, for the annual peaks only, and for the non-annual partial series peaks only. (Note that, due to differences in the plotting programs, the positive end of the histogram classes in these and subsequent plots is reversed from the format in Figure 35, with the largest values now appearing at the top of the class interval axis.) The transformation and standardization procedure was successful in normalizing the data to varying degrees, more so in the annual series data alone. The decomposition of the whole record into annual and non-annual subgroups demonstrates, as might be expected, that the subgroup of non-annual partial series peaks has a mean and standard

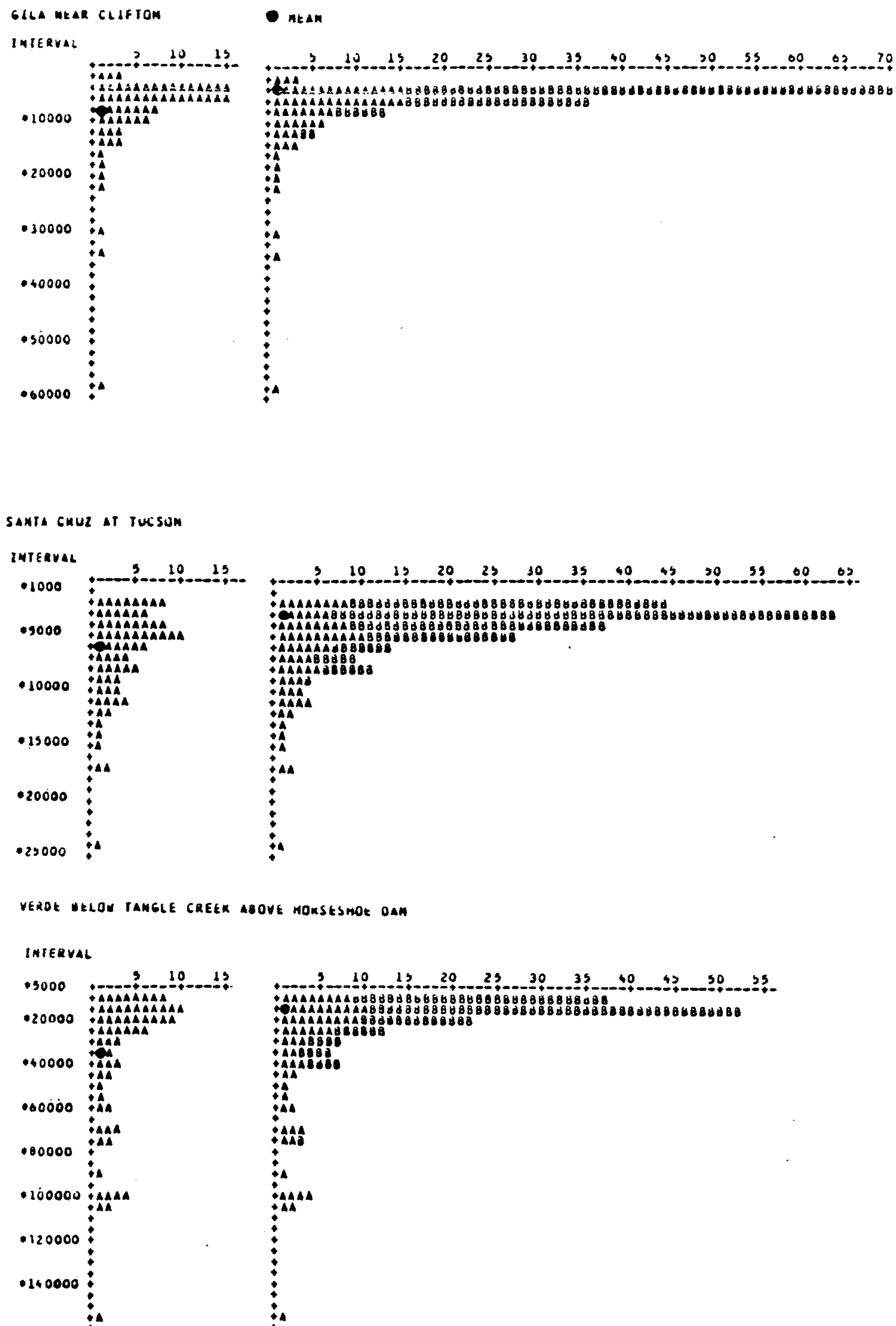


Fig. 35 Selected Histograms of Partial Series Flood Discharges (values are in cfs; note strong positive skew)

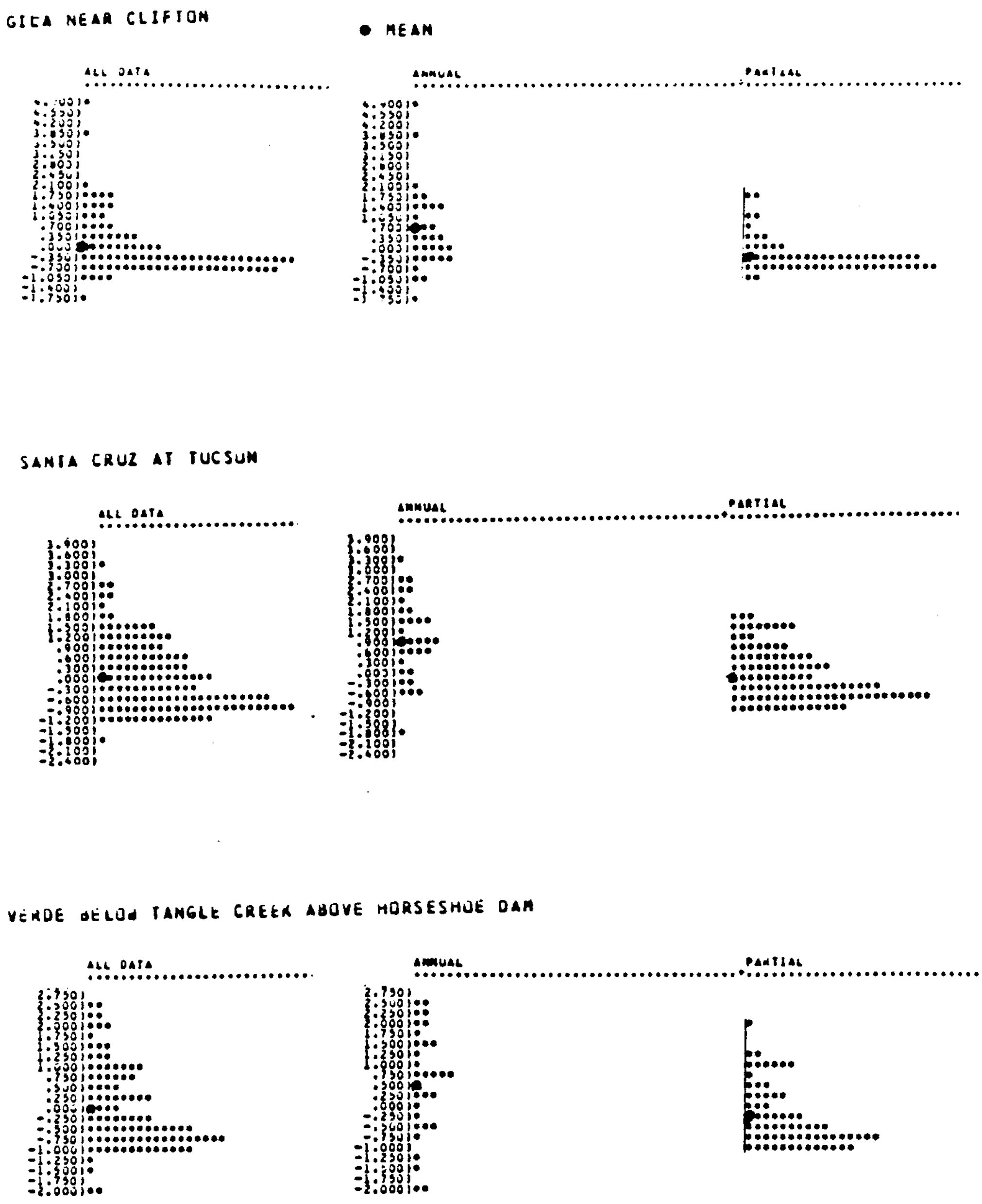


Fig. 36 Selected Histograms of Standardized Flood Discharges (values are z-scores of the base 10 logarithms of discharge; note tendancy toward normality, especially in annual series)

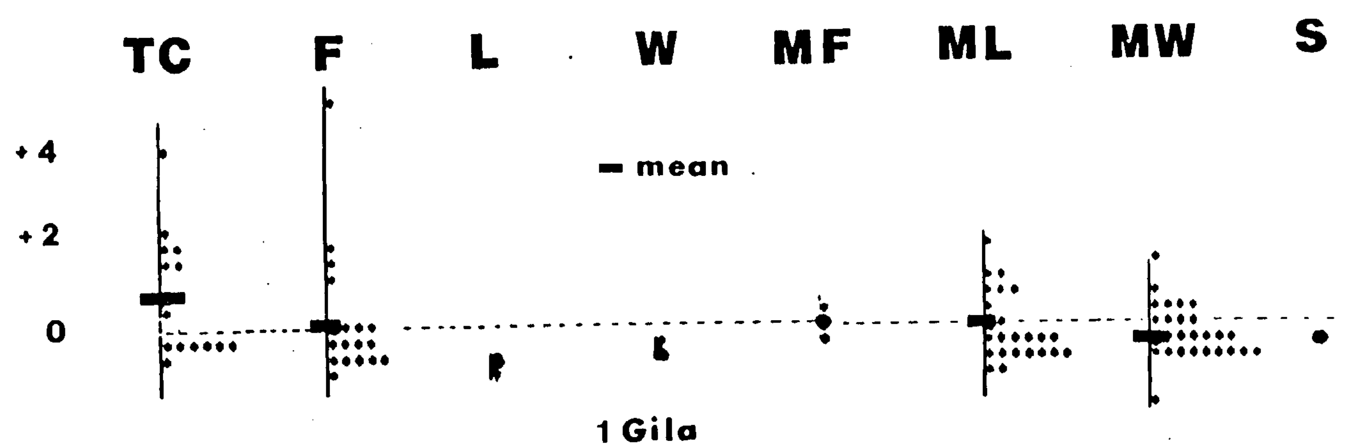
deviation that are lower than that of the annual series. The two subgroups, which could be thought of as a mixed distribution, are present in the data due to differences in sampling procedure (selecting the largest vs. selecting all non-annual peaks above a base) rather than being a function of any external controls on the flood discharges.

Histograms of Hydroclimatic Subgroups

To see if the external control of climate also produces distinct subgroups in the Gila basin data, 16 partial series records (standardized logarithms of discharge) were decomposed into subgroups on the basis of the eight general hydroclimatic categories, using BMDP Program P7D, "Description of Groups (Strata) with Histograms and Analysis of Variance." The results of this analysis are presented in Figure 37. The mean, standard deviation, and sample size are given for each subgroup as well as the results of the one-way analysis of variance tests performed by the BMDP program.

The array of histogram plots depicts varying hydroclimatic responses at the 16 stations and shows that there is a definite spatial pattern in these responses, with stations in similar geographical settings tending to share a like response.

Eastern Stations. The eastern stations of the Gila near Clifton and the San Francisco River at Clifton, and the more central station of the San Carlos near Peridot, which is located at about the same latitude, will be discussed together even though this grouping of stations does not share as clear a regional hydroclimatic response as some of the other sections of the Gila River basin.



	TC	F	L	W	MF	ML	MW	S
MEAN	.684	.151	-.866	-.594	-.002	-.092	-.265	-.244
STD.DEV.	1.326	1.373	.015	.350	.357	.745	.614	.000
MAXIMUM	3.761	4.755	-.856	-.347	.251	1.782	1.489	-.244
MINIMUM	-.728	-1.009	-.877	-.842	-.254	-1.001	-1.649	-.244
SAMPLE SIZE	14	18	2	2	2	24	27	1

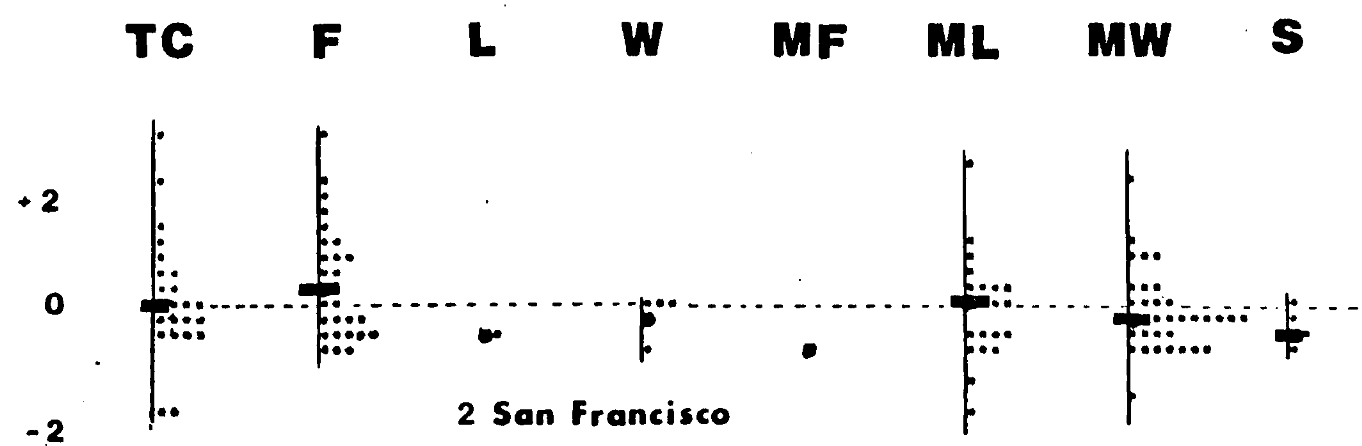
ALL GROUPS COMBINED

MEAN	.000
STD.DEV.	1.000
MAXIMUM	4.755
MINIMUM	-1.649
SAMPLE SIZE	90

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	11.2799	6	1.8800	2.01	.0737
WITHIN GROUPS	77.7201	83	.9364		
TOTAL	89.0000	89			
LEVENE'S TEST FOR EQUAL VARIANCES		6, 83		3.27	.0061
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		6, 7		10.60	.0032
BROWN-FORSYTHE		6, 45		2.89	.0182

Fig. 37 Histograms and Statistics of Hydroclimatic Subgroups (Output shown is from BMDP P7D; values are standardized discharges, hence mean of all subgroups combined is 0)



	TC	F	L	W	MF	ML	MW	S
MEAN	.130	.407	-.640	-.248	-.829	-.127	-.182	-.486
STD DEV	1.228	1.113	.013	.468	.000	1.007	.769	.337
MAXIMUM	3.337	3.171	-.630	.101	-.829	2.575	2.394	-.009
MINIMUM	-2.221	-.963	-.649	-.939	-.829	-2.078	-1.884	-.886
SAMPLE SIZE	23	28	2	4	1	21	34	5

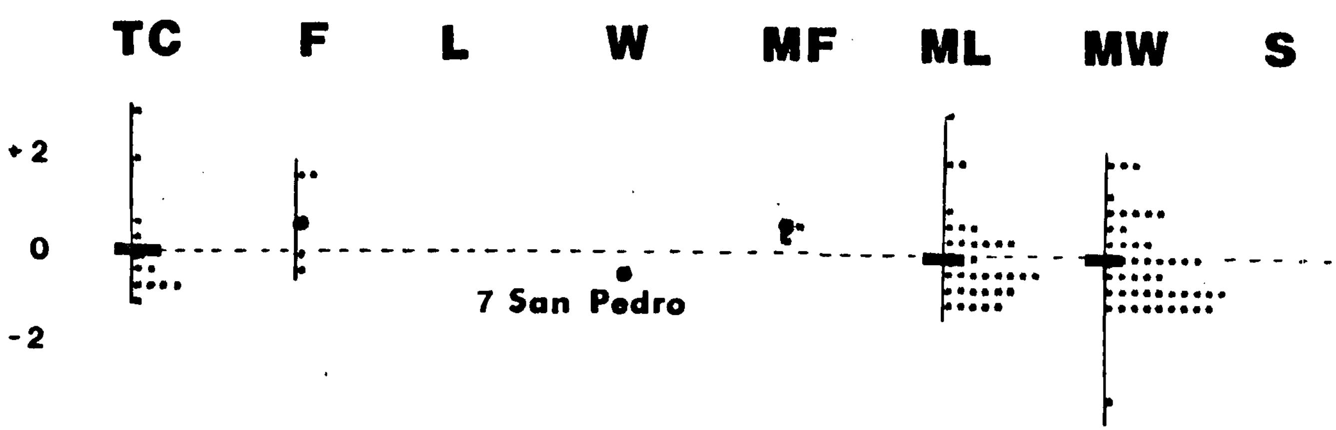
ALL GROUPS COMBINED

MEAN	.000
STD DEV	1.000
MAXIMUM	3.337
MINIMUM	-2.221
SAMPLE SIZE	118

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	9.4358	6	1.5726	1.62	.1474
WITHIN GROUPS	107.5642	111	.9690		
TOTAL	117.0000	117			
LEVENE'S TEST FOR EQUAL VARIANCES		6, 111		2.55	[illegible]
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		6, 22		7.86	.0001
BROWN-FORSYTHE		6, 88		2.53	.0265

Fig. 37 --Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	.109	.761	.000	-.275	.568	-.002	-.119	.000
STD DEV	1.307	1.125	.000	.000	.188	.946	.976	.000
MAXIMUM	3.142	1.739	.000	-.275	.725	3.134	2.125	.000
MINIMUM	-.978	-.429	.000	-.275	.360	-.998	-3.249	.000
SAMPLE SIZE	12	4	0	1	3	35	48	0

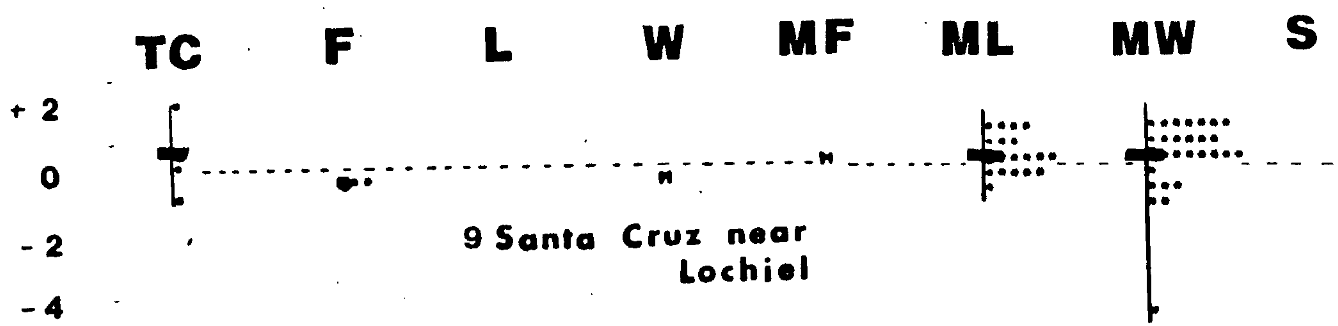
ALL GROUPS COMBINED

MEAN	.000
STD DEV	1.000
MAXIMUM	3.142
MINIMUM	-3.249
SAMPLE SIZE	103

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	4.1859	4	1.0465	1.05	.3653
WITHIN GROUPS	97.8141	98	.9981		
TOTAL	102.0000	102			
LEVENE'S TEST FOR EQUAL VARIANCES		4, 98		1.55	.1922
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		4, 14		4.14	.0203
BROWN-FORSYTHE		4, 21		1.09	.3892

Fig. 37 —Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	423	- 437	000	- 353	084	062	- 046	000
STD DEV	1 289	190	000	000	000	671	1 221	000
MAXIMUM	2.042	-. 294	. 000	- 353	. 084	1. 162	1 102	000
MINIMUM	-1.049	-. 654	. 000	-. 353	084	-1. 219	-5 050	000
SAMPLE SIZE	4	3	0	1	1	19	28	0

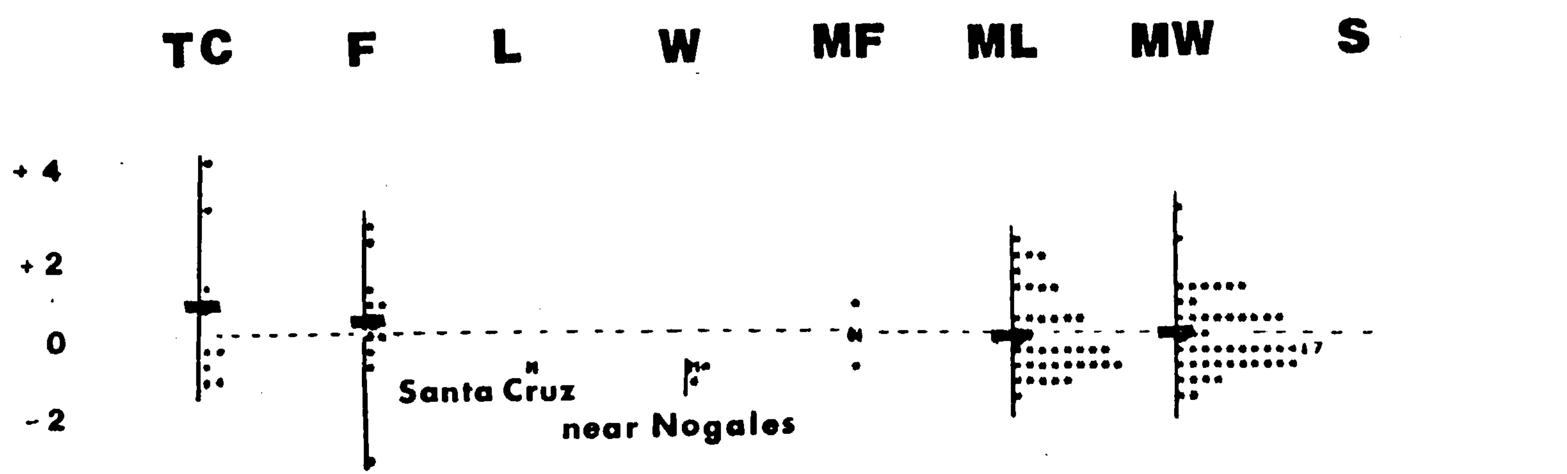
ALL GROUPS COMBINED

MEAN	000
STD. DEV.	1. 000
MAXIMUM	2. 042
MINIMUM	-5. 050
SAMPLE SIZE	56

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	1 5531	3	5177	. 50	6814
WITHIN GROUPS	53. 4469	52	1 0278		
TOTAL	55 0000	55			
LEVENE'S TEST FOR EQUAL VARIANCES		3, 52		1 66	1875
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		3, 11		2. 61	1040
BROWN-FORSYTHE		3, 8		59	. 6371

Fig. 37 —<u>Continued</u>



	TC	F	L	W	MF	ML	MW	S
MEAN	.559	.355	-.572	-.803	.002	-.022	-.076	.000
STD DEV	1.821	1.514	.000	.092	1.022	.920	.790	.000
MAXIMUM	3.734	2.509	-.572	-.736	.724	2.015	2.711	.000
MINIMUM	-.959	-2.689	-.572	-.909	-.721	-1.381	-1.338	.000
SAMPLE SIZE	8	10	1	3	2	40	55	0

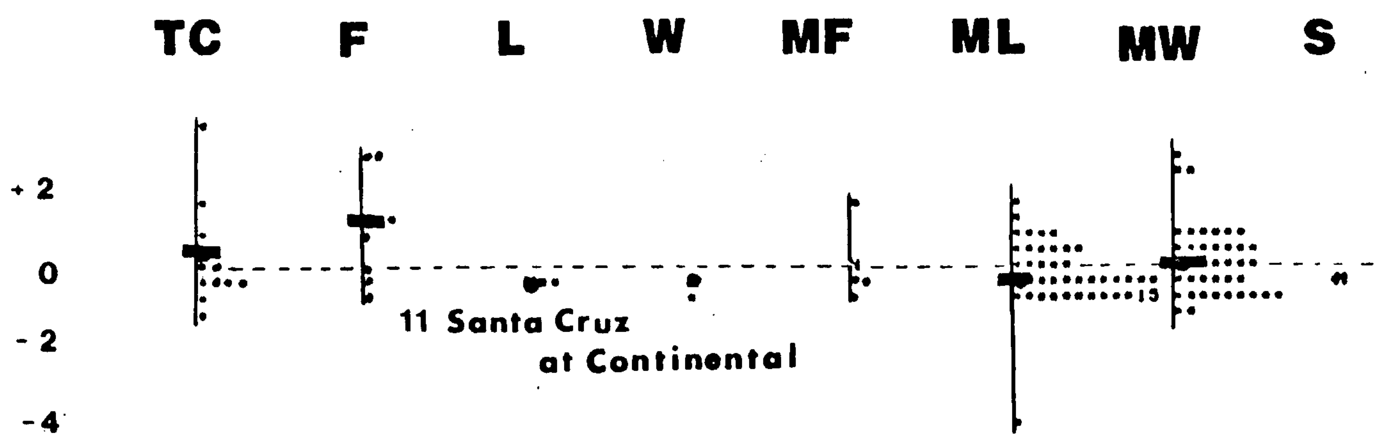
ALL GROUPS COMBINED

MEAN	.000
STD DEV	1.000
MAXIMUM	3.734
MINIMUM	-2.689
SAMPLE SIZE	119

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	6.3584	5	1.2717	1.29	.2744
WITHIN GROUPS	111.6416	113	.9880		
TOTAL	118.0000	118			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 113		5.41	.0002
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		5, 9		9.57	.0021
BROWN-FORSYTHE		5, 17		.89	.5060

Fig. 37--Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	208	1 013	- 349	- 502	- 048	- 294	115	- 512
STD DEV	1 384	1 249	062	220	1 089	816	936	000
MAXIMUM	3 626	2 944	- 278	- 346	1 581	1 741	2 895	- 512
MINIMUM	-1 234	- 816	- 391	- 657	- 711	-3 899	-1 223	- 512
SAMPLE SIZE	11	9	3	2	4	45	40	1

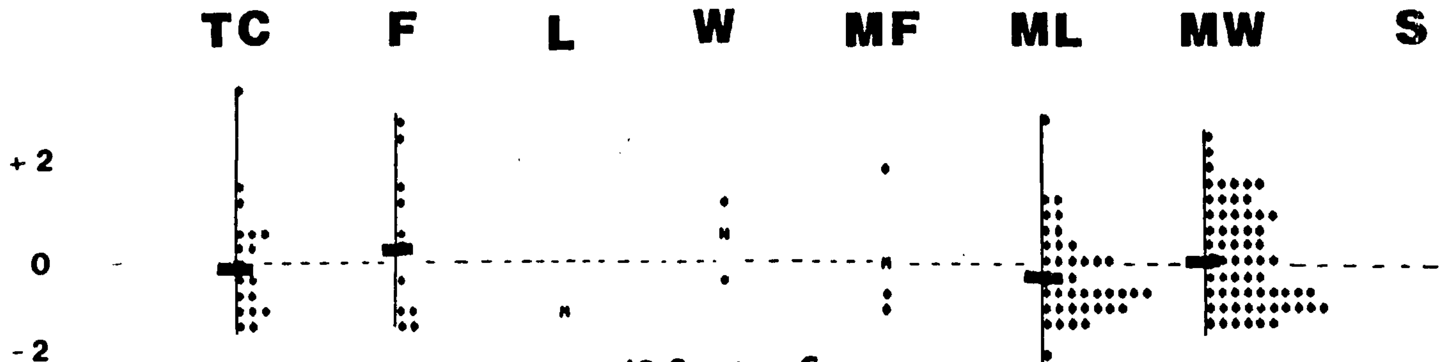
ALL GROUPS COMBINED

MEAN	000
STD DEV	1 000
MAXIMUM	3 626
MINIMUM	-3 899
SAMPLE SIZE	115

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	15 2785	6	2 5464	2 79	0147
WITHIN GROUPS	98 7215	108	9141		
TOTAL	114 0000	114			
LEVENE'S TEST FOR EQUAL VARIANCES		6, 108		1 90	0[illegible]76
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		6, 10		2 88	06[illegible]3
BROWN-FORSYTHE		6, 28		2 86	.02[illegible]7

Fig. 37 --Continued



12 Santa Cruz
Tucson

	TC	F	L	W	MF	ML	MW	S
MEAN	.066	.375	-.939	.503	.039	-.253	.072	.000
STD.DEV.	1.144	1.414	.000	1.015	1.190	.854	.952	.000
R.E.S.D.	1.104	1.546	.000	1.272	1.237	.828	1.033	.000
MAXIMUM	3.350	2.667	-.939	1.221	1.748	2.721	2.289	.000
MINIMUM	-1.223	-1.304	-.939	-.215	-.982	-1.934	-1.243	.000
SAMPLE SIZE	18	11	1	2	4	40	64	0

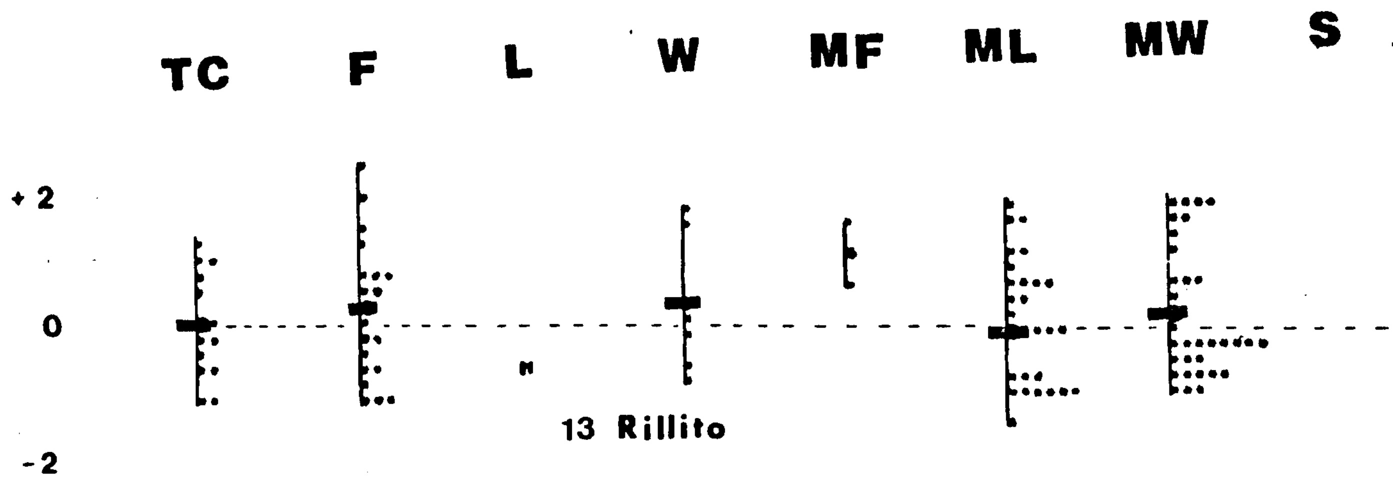
ALL GROUPS COMBINED

MEAN	.000
STD.DEV.	1.000
MAXIMUM	3.350
MINIMUM	-1.934
SAMPLE SIZE	140

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	5.9011	5	1.1802	1.19	.3183
WITHIN GROUPS	133.0989	134	.9933		
TOTAL	139.0000	139			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 134		2.08	.0721
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		5, 8		.76	.6045
BROWN-FORSYTHE		5, 20		.92	.4862

Fig. 37 --Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	- 021	169	- 782	203	918	- 128	- 050	000
STD DEV	829	1 126	000	1 125	720	972	1 036	000
R E S D	873	1 199	000	1 251	902	1 036	1 156	000
MAXIMUM	1 301	2 458	- 782	1 702	1 427	1 632	1 716	000
MINIMUM	-1 276	-1 342	- 782	- 905	409	-1 726	-1 276	000
SAMPLE SIZE	14	19	1	6	2	28	32	0

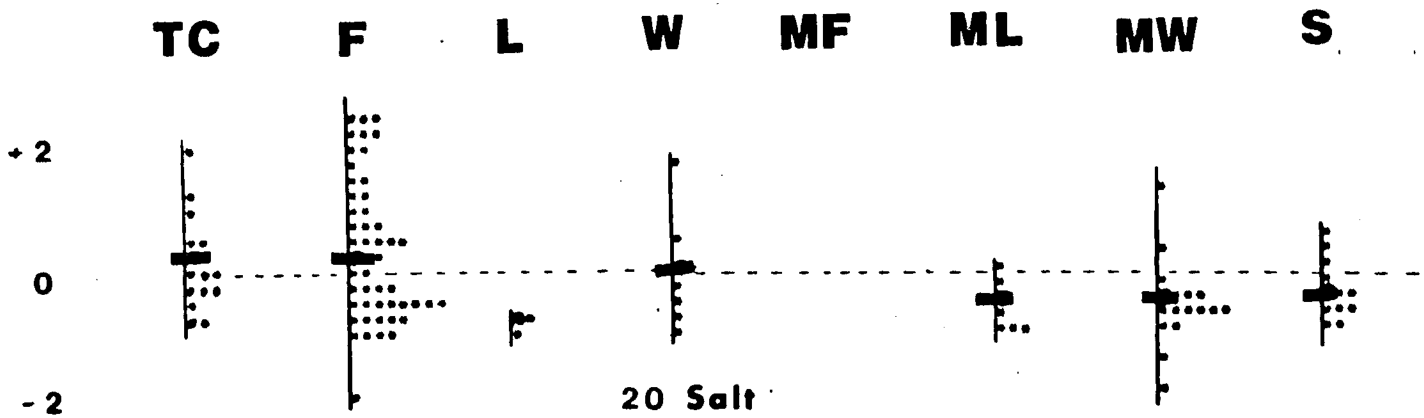
ALL GROUPS COMBINED

MEAN	000
STD DEV	1 000
MAXIMUM	2 458
MINIMUM	-1 726
SAMPLE SIZE	102

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	3 6323	5	7265	72	6127
WITHIN GROUPS	97 3677	96	1 0142		
TOTAL	101 0000	101			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 96		1 33	2582
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		5, 9		69	6420
BROWN-FORSYTHE		5, 34		77	5812

Fig. 37 — Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	227	373	- 768	- 031	000	- 591	- 610	- 423
STD DEV	778	1 144	120	1 002	000	376	689	472
MAXIMUM	2 098	2 595	- 661	1 711	000	020	1 229	532
MINIMUM	844	-2 078	- 897	- 928	000	- 930	-2 049	- 972
SAMPLE SIZE	15	50	3	6	0	7	17	12

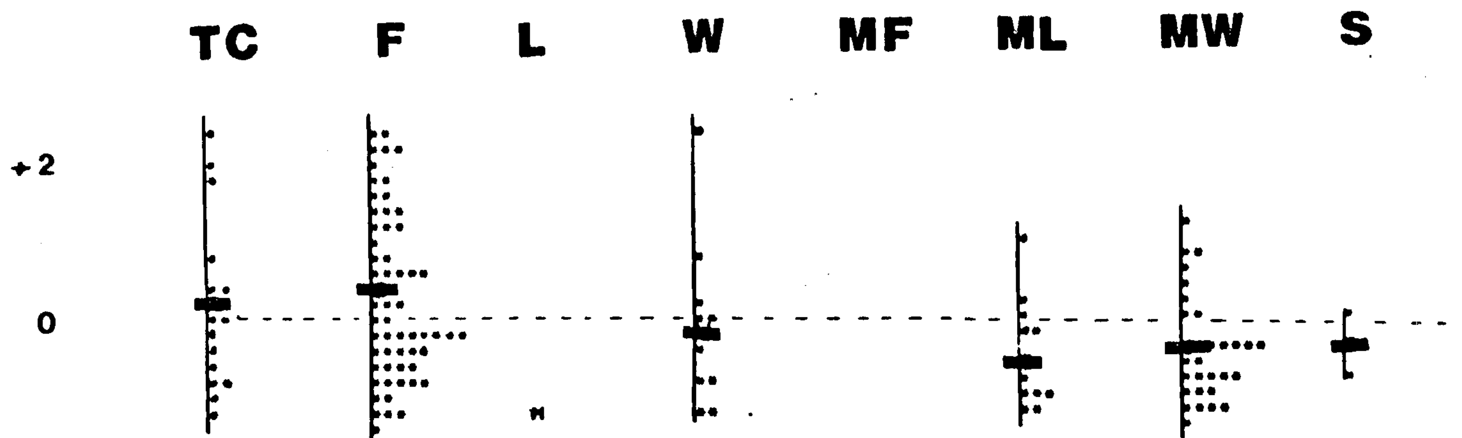
ALL GROUPS COMBINED

MEAN	000
STD DEV	1 000
MAXIMUM	2 595
MINIMUM	-2 078
SAMPLE SIZE	110

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	20 4349	6	3 4058	3 96	0013
WITHIN GROUPS	88 5651	103	8599		
TOTAL	109 0000	109			
LEVENE'S TEST FOR EQUAL VARIANCES		6. 103		5 03	0001
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		6, 25		8 74	0000
BROWN-FORSYTHE		6, 38		6 97	0000

Fig. 37 -- Continued



21 Tonto

	TC	F	L	W	MF	ML	MW	S
MEAN	.183	.314	-1.193	-.110	.000	-.510	-.414	-.393
STD DEV	1.074	1.064	.000	1.081	.000	.696	.681	.523
MAXIMUM	2.339	2.496	-1.193	2.394	.000	1.005	1.282	-.023
MINIMUM	-1.150	-1.321	-1.193	-1.160	.000	-1.129	-1.321	-.763
SAMPLE SIZE	16	58	1	10	0	11	30	2

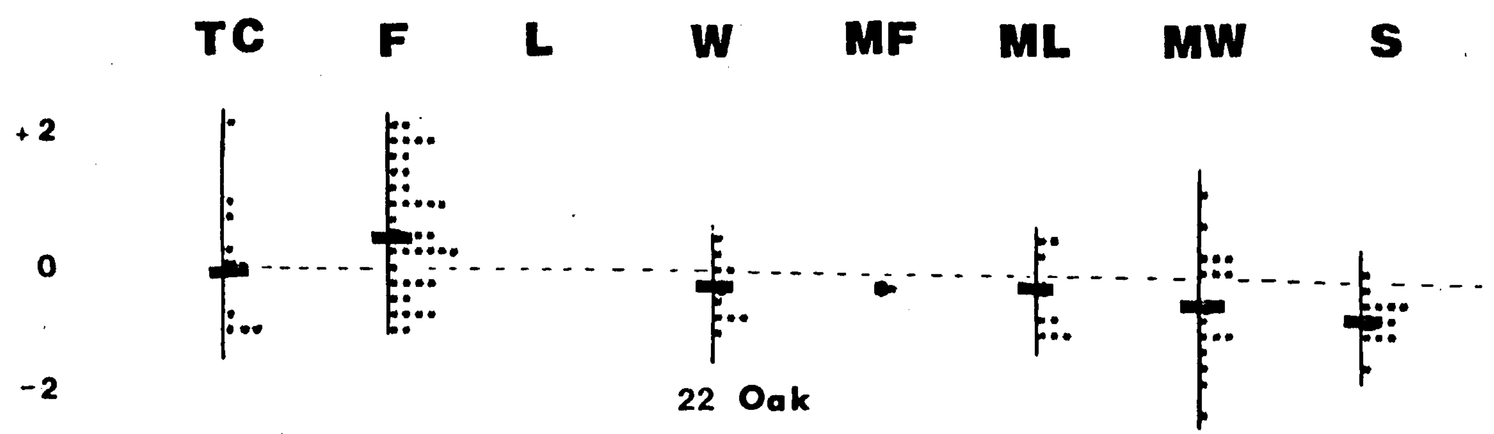
ALL GROUPS COMBINED

MEAN	.000
STD. DEV.	1.000
MAXIMUM	2.496
MINIMUM	-1.321
SAMPLE SIZE	128

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	16.1108	5	3.2222	3.55	.0050
WITHIN GROUPS	110.8892	122	.9089		
TOTAL	127.0000	127			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 122		3.13	.0108
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		5, 10		3.23	.0541
BROWN-FORSYTHE		5, 47		4.27	.0028

Fig. 37 — Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	.067	.566	.000	-.330	-.321	-.364	-.498	-.723
STD DEV	1.093	.987	.000	.510	.048	.658	1.009	.378
MAXIMUM	2.293	2.369	.000	.499	-.287	.564	1.296	-.012
MINIMUM	-1.047	-1.055	.000	-.988	-.355	-1.013	-2.366	-1.595
SAMPLE SIZE	10	41	0	9	2	8	16	13

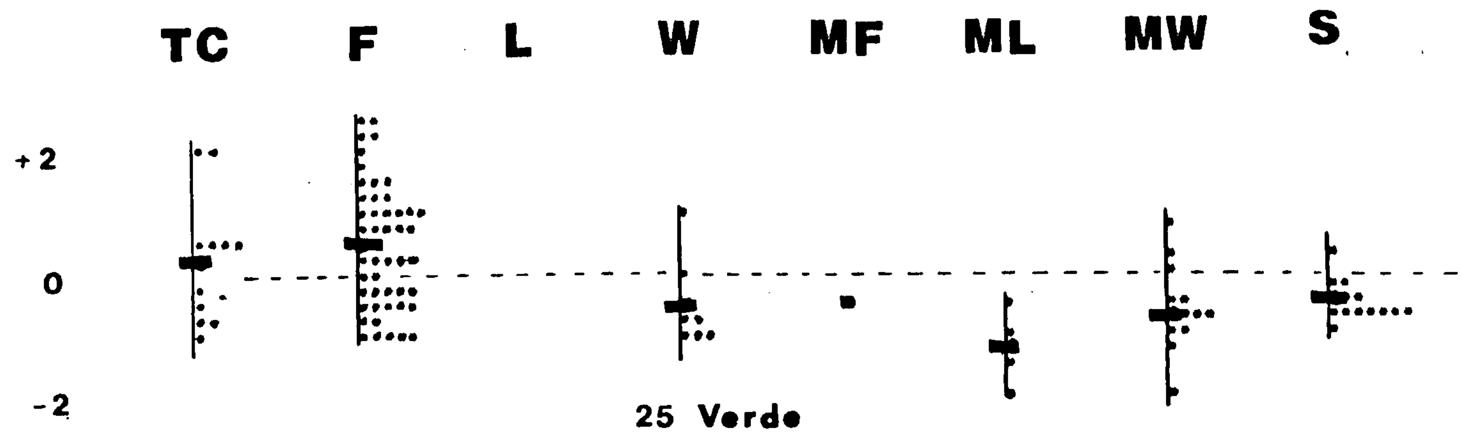
ALL GROUPS COMBINED

MEAN	.000
STD. DEV	1.000
MAXIMUM	2.369
MINIMUM	-2.366
SAMPLE SIZE	99

ANALYSIS OF VARIANCE TABLE.

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	26.1921	6	4.3654	5.59	.0001
WITHIN GROUPS	71.8079	92	.7805		
TOTAL	98.0000	98			
LEVENE'S TEST FOR EQUAL VARIANCES		6, 92		4.06	.0012
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		6, 29		7.41	.0001
BROWN-FORSYTHE		6, 49		8.04	.0000

Fig. 37 — Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	243	472	000	- 445	- 453	-1 241	- 648	- 579
STD DEV.	964	997	000	766	000	630	701	323
MAXIMUM	1 956	2 393	000	1 098	- 453	- 596	640	266
MINIMUM	- 964	-1 016	000	- 984	- 453	-2 030	-2 114	-1 040
SAMPLE SIZE	12	47	0	7	1	4	13	14

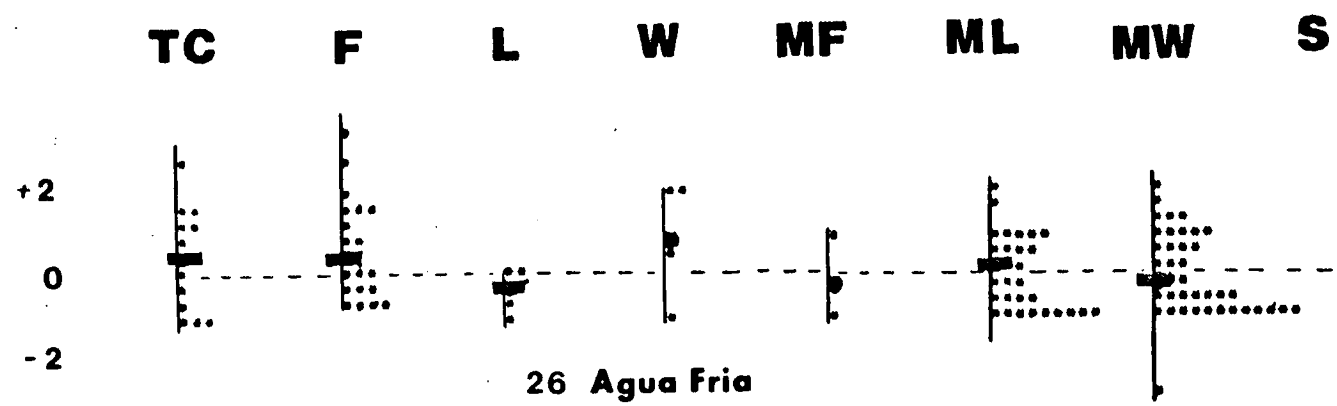
ALL GROUPS COMBINED

MEAN	000
STD DEV.	1 000
MAXIMUM	2 393
MINIMUM	-2 114
SAMPLE SIZE	98

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	29 0791	5	5 8158	7 88	0000
WITHIN GROUPS	67 9209	92	7383		
TOTAL	97 0000	97			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 92		4 85	0006
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		5, 18		9 43	0002
BROWN-FORSYTHE		5, 43		10 48	0000

Fig. 37 -- Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	346	.510	-.442	739	- 216	- 168	- 260	000
STD DEV	1 087	1. 102	.514	1 413	1 209	811	935	000
MAXIMUM	2. 433	3. 275	.032	1 889	639	1. 719	1 719	.000
MINIMUM	- 962	-. 817	-. 975	-1 050	-1. 071	-1 172	-2. 949	000
SAMPLE SIZE	13	20	4	4	2	30	40	0

ALL GROUPS COMBINED

MEAN	000
STD. DEV.	1. 000
MAXIMUM	3. 275
MINIMUM	-2 949
SAMPLE SIZE	113

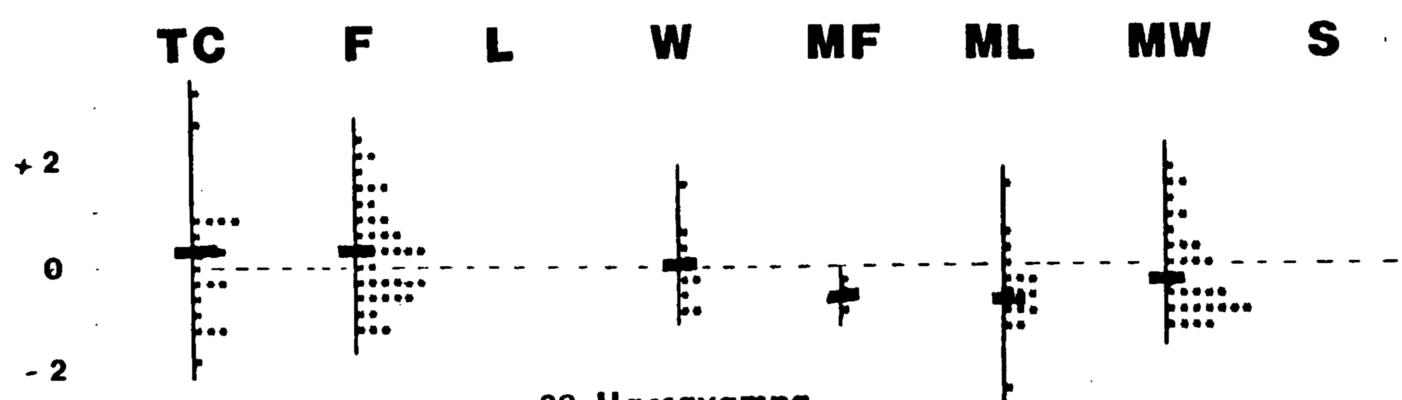
ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	13. 3636	6	2. 2273	2. 39	0329
WITHIN GROUPS	98. 6364	106	9305		
TOTAL	112. 0000	112			
LEVENE'S TEST FOR EQUAL VARIANCES		6, 106		1 12	[illegible]

ONE-WAY ANALYSIS OF VARIANCE
TEST STATISTICS FOR WITHIN-GROUP
VARIANCES NOT ASSUMED TO BE EQUAL

	DF	F VALUE	TAIL PROBABILITY
WELCH	6, 9	1 59	[illegible]
BROWN-FORSYTHE	6, 13	1 99	[illegible]

Fig. 37 -- <u>Continued</u>



28 Hassayampa

	TC	F	L	W	MF	ML	MW	S
MEAN	168	288	000	- 061	- 652	- 485	- 172	000
STD DEV	1 268	971	000	763	298	869	890	000
MAXIMUM	3 334	2 505	000	1 360	- 442	1 515	1 668	000
MINIMUM	-1 776	-1 324	000	- 883	- 863	-2 477	-1 289	000
SAMPLE SIZE	20	40	0	8	2	16	31	0

ALL GROUPS COMBINED

MEAN	.000
STD DEV	1.000
MAXIMUM	3.334
MINIMUM	-2.477
SAMPLE SIZE	117

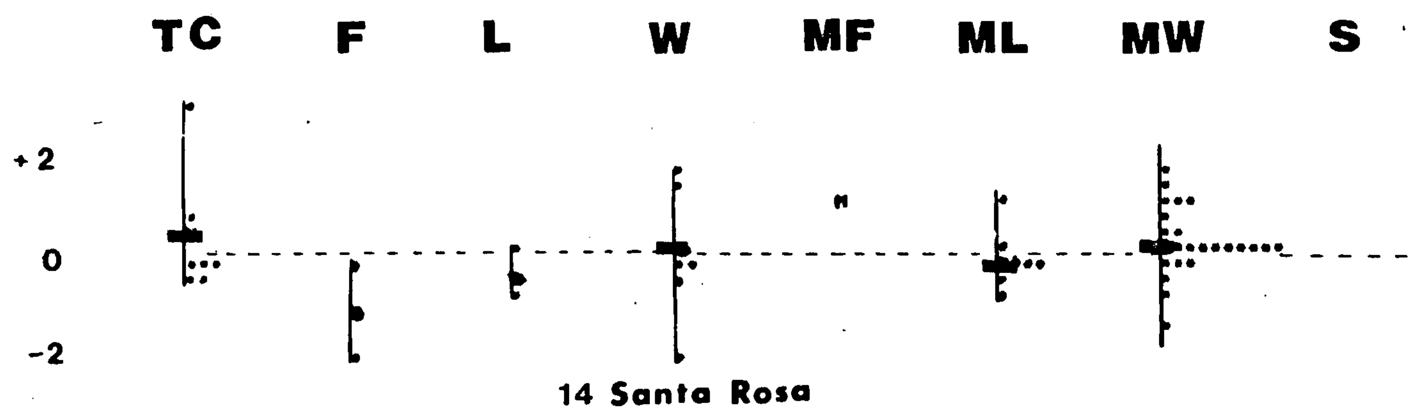
ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	9.4483	5	1 8897	1 97	.0888
WITHIN GROUPS	106.5517	111	9599		
TOTAL	116.0000	116			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 111		1 19	3196

ONE-WAY ANALYSIS OF VARIANCE
TEST STATISTICS FOR WITHIN-GROUP
VARIANCES NOT ASSUMED TO BE EQUAL

	DF	F VALUE	TAIL PROBABILITY
WELCH	5, 12	2 86	.0631
BROWN-FORSYTHE	5, 76	2 48	.0393

Fig. 37 —Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	308	-1. 268	-. 591	- 111	1 174	- 256	121	000
STD. DEV.	1. 324	1 474	625	1 433	000	655	776	000
MAXIMUM	3 309	- 225	-. 149	1 907	1 174	1. 162	1 578	000
MINIMUM	- 730	-2. 310	-1. 033	-2 527	1. 174	-1. 064	-1 920	000
SAMPLE SIZE	8	2	2	7	1	8	24	0

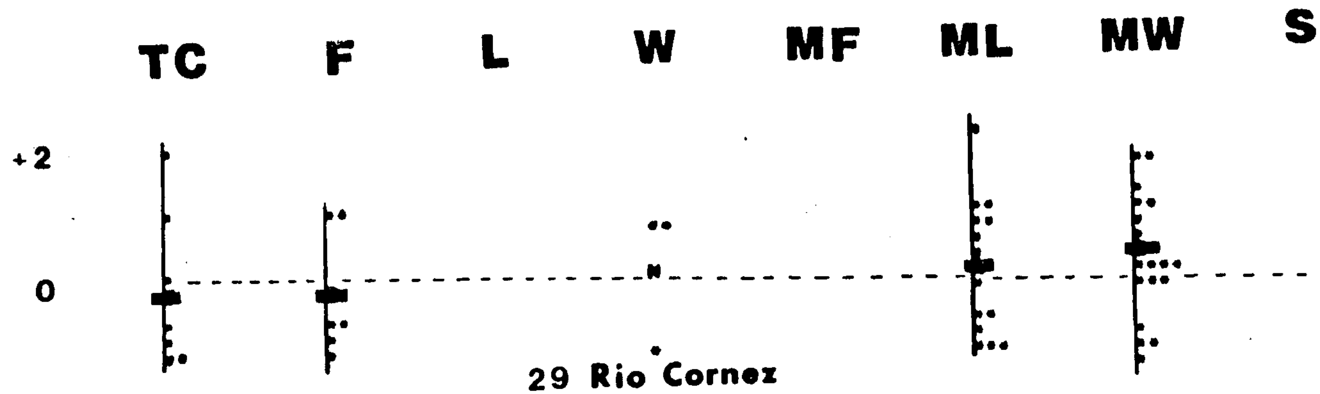
ALL GROUPS COMBINED

MEAN	000
STD. DEV	1. 000
MAXIMUM	3 309
MINIMUM	-2 527
SAMPLE SIZE	52

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	7. 0135	5	1 4027	1 47	.2190
WITHIN GROUPS	43. 9865	46	9562		
TOTAL	51 0000	51			
LEVENE'S TEST FOR EQUAL VARIANCES		5. 46		1 47	2176
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		5, 5		72	6358
BROWN-FORSYTHE		5, 8		1 09	4323

Fig. 37 — Continued



	TC	F	L	W	MF	ML	MW	S
MEAN	-.153	-.285	.000	.025	.000	-.008	.149	.000
STD DEV	1.192	1.009	.000	1.163	.000	1.059	.930	.000
MAXIMUM	2.092	1.022	.000	.754	.000	2.234	1.846	.000
MINIMUM	-1.298	-1.242	.000	-1.317	.000	-1.261	-1.395	.000
SAMPLE SIZE	8	6	0	3	0	15	20	0

ALL GROUPS COMBINED

MEAN	.000
STD. DEV.	1.000
MAXIMUM	2.234
MINIMUM	-1.395
SAMPLE SIZE	52

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	1.1211	4	.2803	.26	.8995
WITHIN GROUPS	49.8789	47	1.0613		
TOTAL	51.0000	51			
LEVENE'S TEST FOR EQUAL VARIANCES		4, 47		.28	.8899
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		4, 10		.23	.9138
BROWN-FORSYTHE		4, 18		.24	.9131

Fig. 37 -- Continued

In each basin the monsoon widespread category is responsible for the most floods, with the frontal category second in importance at the San Francisco and San Carlos, and third in importance at the Gila near Clifton. The shape of the monsoon widespread histogram differs slightly among the three basins, but in each case the mean discharge of the MW distribution is smaller than the mean of the entire series, even though this type produced the most floods.

Tropical storms and cutoff lows produced flooding in all three basins with the standard deviations of the TC discharges being fairly high in the San Francisco and Gila Rivers. Frontal floods had the highest mean discharge in the San Francisco and San Carlos, but the tropical storm/cutoff low category yielded the highest mean discharge in the Gila River. The San Francisco also has a small distribution of floods due to snowmelt that plots lower than the other distributions in the array.

The statistical tests for differences in the group means and variances resulted in relatively low tail probabilities, indicating that the observed differences among the subgroup histograms would probably not have emerged if the true means and variances of each subpopulation were, in fact, identical. In other words, it is fairly likely that the differences among the histograms are reflecting a tendency toward mixed distributions within the overall population of all floods at each station. The results of the one-way analysis of variance may or may not be valid, due to problems with meeting the underlying assumptions of the analysis when small samples of skewed partial series flood data are used. This is discussed at greater length below.

Southern Stations. The southern stations of the San Pedro, the Santa Cruz, and the Rillito all share a dominance by the monsoon widespread and monsoon local categories in producing floods. The means of the MW and ML distributions are close to the overall mean of the flood series at each station and there does not appear to be any significant difference between the two categories, with the exception of the Santa Cruz at Tucson record where the monsoon local distribution plots a certain distance below the mean.

The distributions of flood discharges produced by winter frontal storms plot consistently above the mean, but have larger standard deviations than the monsoon distributions. This is also true for the tropical storm/cutoff low distributions at all stations but the Rillito.

Two upstream stations on the Santa Cruz were included in the analysis to observe any changes in a single river's sensitivity to climate at different points in the drainage hierarchy. Although monsoon circulations produce the most flooding at all stations on the river, frontal storms, tropical storms, and cutoff lows are less important contributors to flooding at the small (2.7 km) upstream station near Lochiel on the Santa Cruz. The importance of the larger, well-integrated synoptic systems for producing floods increases as the drainage area increases downstream.

The one-way analysis of variance results indicate that there is very little difference among the means of the hydroclimatic subgroups in the Rillito and the Santa Cruz at Lochiel. At Lochiel this is no doubt due to the dominance of essentially one type of climatic flood-generating mechanism. The Rillito station's lack of sensitivity to different climate types may be a reflection of problems already encountered in attempts to interpret the Rillito's correlation fields (Chapter 5). It is probable that in this heavily urbanized drainage basin, land use factors override the importance of climate in producing variations in discharge.

In the other southern stations, the probabilities that the subgroup means are not different are lower, but not necessarily significant. This may be due to the dominance of the two mean-centered monsoon categories for producing floods in these basins. There do appear to be some differences in variance among the subgroups, especially at the Santa Cruz station at Tucson.

Northern Stations. The northern stations of the Salt River near Roosevelt, Tonto Creek, the Verde River, and Oak Creek show the most distinct differences in their hydroclimatic subgroups. Frontal floods dominate, and the means of the front-generated discharges plot above the overall series mean at each station.

The widespread synoptic category (which reflects widespread precipitation in the study area not related to either monsoon circulation or frontal passages) was responsible for a fair amount of flooding, but the means of the discharges in this category plot below the overall series mean at each station. The same is true for flooding due to the monsoon widespread and monsoon local categories, a striking contrast to the pattern seen in the southern basins.

Another feature unique to the northern basins is the small distribution of snowmelt-generated floods that consistently plots well below the mean.

In the northern basins, the distributions of tropical storm/ cutoff low floods do not appear to be any different, in mean or variance, than the distributions of frontal floods, but both groups combined are distinct from the other categories.

The statistics for the analysis of variance tests reflect highly significant differences among the group means and variances at each of the northern stations.

Western Stations. The western stations actually represent two modes of hydroclimatic response, one in the northwest and one in the southwest. In the northwest, the Hassayampa and Agua Fria stations are dominated by frontal storm flooding, hence in this respect they are similar to the northern group of stations. However, in comparison with the northern group, these western and more arid stations experience proportionately more monsoon-related flooding in their records. In the northwest, the tropical storm/cutoff low category has a mean and variance similar to the frontal category, and the means of both subgroups plot above the overall mean, while the means of the monsoon subgroups plot below the overall mean. The analysis of variance tests indicate that there are significant differences among the group means in the two northwest stations.

The two arid southwestern stations, Santa Rosa Wash and Rio Cornez, are dominated by monsoon flooding, but the much smaller sample sizes of these two stations do not allow the distributions of the other categories to be very well defined. It is evident that tropical storm/cutoff low floods play some role in the flooding at these stations, but only at Santa Rosa Wash is the mean of the tropical storm distribution larger than the means of the monsoon distributions. The analysis of variance tests show essentially no difference among groups at the Rio Cornez station, and only a slight possibility that the Santa Rosa subgroups are different.

Annual vs. Partial Series Hydroclimatic Subgroups. In order to see if some flood-generating mechanisms were more likely to produce annual floods than others, the above histogram analysis was rerun with the annual flood peaks separated from the non-annual partial series peaks. The results of these runs were inconclusive, primarily because there was too small of a sample of annual peaks (only 31 years) to effectively begin to define the shapes of the subgroup distributions. Selected annual vs. partial series histogram plots are included in Appendix E.

Significance of the Analysis of Variance Results

The visual display of the histogram arrays in Figure 37 may be a more valid indicator of differences among the hydroclimatic subgroups than the statistics of the one-way analysis of variance. Due to the nature of the discharge data used in the analyses, one or more of the underlying assumptions in one-way analysis of variance may have been violated and hence may have invalidated the results.

The assumptions in one-way analysis of variance are: (1) that the raw scores within each subgroup are normally distributed, (2) that the subgroups all have the same variance, and (3) that all the observations in all the subgroups are independent of each other (McCollough 1974).

Normal Distributions. The raw discharge data were logarithmically transformed and standardized in an attempt to normalize the positively skewed flood data, but it is evident by viewing Figure 37 that the distributions of some of the subgroup's standardized discharges are still quite skewed. This is especially evident in the tropical storm/cutoff low category. A reevaluation of the criteria for classifying floods into given categories might result in more normalized and coherent distributions, yet as Anderson (1967) suggests, Nature might not follow a Gaussian law, and hence normally distributed subgroups should not necessarily be expected.

Equal Variances. The second assumption for analysis of variance states that all subgroups must have the same variance. This is clearly not the case in Figure 37. In fact it is physically more plausible that flood discharges evolving from different types of atmospheric mechanisms will have different variances.

A case in point is the tropical storm/cutoff low subgroup. This category consistently shows a tendency toward high variances in stations throughout the Gila River basin. A physical explanation of this is that because tropical storms and cutoff lows are short term, isolated, but intense events the exact position of the synoptic feature in relation to the study area has an important bearing on how much precipitation and subsequent flooding might result form it. A tropical storm tracking well off the west coast of Mexico can play a major role in bringing extra moisture into the Gila River basin, and precipitation resulting from this excess moisture influx might induce flooding that would be considered to be related to the occurrence of the tropical storm, even though the flood discharges might be relatively low. Another tropical storm tracking directly up the Gulf of California and actually entering the study area might produce much higher discharges. If a trough aloft or a cutoff low occurred in tandem with the tropical storm, extremely high flood discharges could result. Hence the resulting distribution of TC-related discharges would have a high variance and possibly a tendency toward positive skewness.

Equal variances among subgroups is not a physically justified assumption for the hydroclimatic categories and it is far more likely that the real world of varying flood discharges operates like the model depicted in Figure 4b or 4c. The BMDP program computes two one-way analysis of variance statistics that do not assume the equality of variances in each group, the Welch and Brown-Forsythe statistics, but because the first assumption on normality may already be violated, the usefulness of these statistics is difficult to evaluate.

<u>Independent Observations</u>. The third assumption, that the observations in all the groups must be independent, is probably the most easily met by the flood discharge data. Nevertheless, the question of independence is always present when partial series flood data are used, and since sample sizes were too small to use only annual data, this assumption might also be a factor in the significance of the statistical results.

Since it appears that the assumptions necessary for a valid one-way analysis of variance cannot be met by the flood discharge data, the statistical results of the BMDP program should be evaluated less seriously than the actual plots of the histograms themselves. In either case, distinct differences are evident in the hydroclimatic groups and the differences are most significant in the northern group of stations. It is therefore concluded from the histogram analysis that climatically-controlled mixed distributions are present in many of the Gila River basin flood series, and this may affect the validity of traditional flood-frequency techniques when they are applied to these flood series.

Flood-Frequency Analysis and Hydroclimatology

The preceeding discussion on the basic assumptions of flood-frequency analysis, and the results of the correlation field analysis, the composite anomaly maps, and the hydroclimatic grouping of floods in the Gila River basin, all lead to the question of how hydroclimatology can be practically applied to the analysis of floods. The reevaluation of flood recurrence intervals on the basis of the hydroclimatic principles that have emerged from this study will be reserved for a follow-up project, but some preliminary discussion of the problem is in order here.

In current practice, even though a flood analyst might be aware that a given flood record may show a sensitivity to anomalous circulation patterns over time, or show strong evidence of being composed of mixed distributions due to different flood-generating mechanisms, the flood record would probably be analyzed in the usual manner for lack of the development of new methodologies to treat the time series in an appropriate, physically-based manner.

Mathematical models for fitting mixed distributions in hydrology have been developed on a theoretical basis (Singh 1968, 1974, Hawkins 1974) by mathematically decomposing hydrologic or simulated data into components, however these models now need to be practically applied to distributions that have been shown a priori to include real physically-based subpopulations.

A simple technique, which was first proposed by Potter (1958), is to fit a separate frequency curve to each previously defined sub-group. Waylen and Woo (1982) improved on this by fitting the Gumbel distribution separately to annual floods generated by two mixed processes and then compounding the two distributions.

Modeling and fitting the eight hydroclimatic subgroups of the Gila basin flood series will be a challenge because of the very small sample sizes of some groups, and because the classification is more clearly defined for partial series flood peaks than for annual peaks. Stochastically modeling the partial series itself is a challenge, let alone modeling subpopulations of the partial series.

The recent theoretical work on modeling floods as peaks-above-base and including the time between flood exceedances as a variable in the model holds much promise for evaluating the partial series (see Todorovic and Zelenhasic 1970; Gupta et al. 1976; Todorovic 1978; and Taesombut and Yevyevich 1978). However, this stochastic theory of the flooding process is based on the common underlying assumption of most stochastic analyses that flood exceedances and times between flood exceedances can be viewed as "random numbers of random variables." The physically-based information introduced by the hydroclimatic approach to flood analysis may force a reevaluation of this assumption, and further complicate the stochastic modeling of the partial series.

Hydroclimatic Reevaluation of the 1983 Santa Cruz Flood

With the above in mind, a very simple attempt at evaluating floods generated by different processes was undertaken for the Santa Cruz at Tucson to view the practical potential such an analysis might have. A log-Pearson Type III distribution was fit to the discharges of each of the four main hydroclimatic categories which produced floods in the Santa Cruz. No special allowance was made for the fact that the discharges are partial series peaks rather than annual peaks, but Langbein (1949) showed that the difference between recurrence intervals computed from the two types of series becomes inconsequential for floods greater than about a five-year recurrence interval. No compounding of the distributions was attempted.

The results for the four categories are presented in Table 9 and can be compared with the Santa Cruz flood estimates presented in Table 1 of Chapter 1. The table shows that floods generated by frontal precipitation and tropical storms or cutoff lows have a great likelihood of being quite large at any recurrence interval. A 50-year frontal or tropical storm flood, has a discharge magnitude that is in the range of the 100-year flood of the entire series. The tropical storm/cutoff low flood-generating mechanism has the potential for producing the largest discharges of all in the Santa Cruz, although

Table 9 Flood Estimates Based on Hydroclimatic Groups -- Santa Cruz River at Tucson, Partial Duration Series, 1950-1980

		ANNUAL 1948-80	ML N=40	MW N=64	F N=11	TC N=18
10-YR	cfs	(13,400)	(5720)	(7530)	(12,500)	(8700)
	cms	379	162	213	354	246
50-YR	cfs	(21,900)	(9380)	(12,500)	(27,200)	(21,600)
	cms	620	266	354	770	612
100-YR	cfs	(26,000)	(11,400)	(15,100)	(36,400)	(31,600)
	cms	736	323	428	1031	895
200-YR	cfs	(30,500)	(13,700)	(18,100)	(48,000)	(46,300)
	cms	864	388	513	1359	1311
500-YR	cfs	(36,900)	(17,300)	(22,700)	(68,100)	(76,800)
	cms	1045	490	643	1928	2175

1983 FLOOD = 1490 CMS (52,700 CFS)

only with recurrence intervals greater than about 200 years. It is also interesting to note that according to the table, the rare occurrence of a 500-year discharge produced by a monsoon circulation will actually not exceed the 100-yr flood discharge estimated on the basis of the entire Santa Cruz record.

Table 9 has some practical applications for risk-assessment for the Santa Cruz River. After the October 1983 flood, some discussion occurred over what recurrence interval should be assigned to the flood. Based on the entire record of the Santa Cruz (Figure 3a), the 1983 flood's recurrence interval turns out to be greater than 1000-years. Yet the 24-hour precipitation recurrence interval for the storm was calculated to be only 30 to 50 years (Saarinen et al. 1984). Since other large tropical storm/cutoff low floods had occurred in recent years, notably October 1977, there was some speculation that the 1983 flood was not as unusual an event as the computed flood recurrence interval indicated. Table 9 shows that, based on other tropical storm/cutoff low floods that have occurred in the Santa Cruz, the 1983 event should be assigned a recurrence interval of about 200 years, rather than 1000-years.

Summary

In this chapter, the basic underlying assumptions of flood--frequency analysis were discussed and evaluated in terms of the influences that climate and hydroclimatic responses might have on them. It was demonstrated that persistent circulation anomalies and the dominance of different types of flood-generating mechanisms may affect the assumptions of a representative time sample, the randomness of events, and the homogeneity of the overall flood distribution.

The homogeneity assumption was examined in detail by exploring the possibility of the occurrence of mixed distributions in the Gila basin flood series. A clear regional pattern emerged in histogram plots of the eight hydroclimatic categories, with the northern stations showing the greatest tendency for distinct hydroclimatic subpopulations in their flood series. In general, the distributions of discharges produced by frontal passages and tropical storms or cutoff lows tended to have high variances and plot above the overall mean of the series. The distributions of monsoon widespread and monsoon local discharges plotted near the overall mean in those southern stations that were dominated by the monsoon-type flooding, and slightly below the mean in the northern stations that were dominated by frontal floods. When snowmelt flooding occurred, its distribution always plotted well below the mean.

One-way analysis of variance statistics were computed to test the differences among the hydroclimatic group means and variances. Although the statistics for some stations showed significant differences, the results may not be valid due to the failure of the flood data to meet some of the basic assumptions for one-way analysis of variance. Nevertheless, a visual analysis of the histograms of the hydroclimatic subgroups showed that mixed distributions are present at several stations in the Gila River basin.

An example of a practical application of the hydroclimatic classification of floods was given for the October 1983 flood on the Santa Cruz River at Tucson. By separating the flood series into hydroclimatic groups and computing recurrence intervals for each group, the 1983 flood was reevaluated as a 200-year flood instead of a greater-than-1000-year flood.

CHAPTER 7

SUMMARY AND CONCLUSIONS

The purpose of this hydroclimatic study of flow events has been two-fold. Of primary importance has been the quest for a more physically-based understanding of the nature of flooding variability in the Gila River basin. In this study the focus has been on climate as a source of hydrologic variability, yet numerous other controls, both external and internal, are constantly at work in hydrologic systems. Climate is, nevertheless, the ultimate source of the water flowing in a stream channel, and it is therefore an appropriate place to begin the development of a physically-based model for the streamflow and flooding processes.

Of secondary importance to this study has been the desire to explore ways in which physically-based hydrologic models can be practically applied as tools for better interpretation of past events and improved prediction of events yet to come. However, there is no guarantee that a better understanding of the complexities of a hydrologic process will necessarily lead to better operational models or predictions. As Klemes (1974b) states:

> The history of stochastic hydrology... conveys a simple message: ...nature is complex, and our grasp of it is very sketchy. The more physically sound models we are able to develop, the more impenetrable the mathematical jungle we enter and the more inherent uncertainties we discover. The rather paradoxical result is that a better understanding of the physical nature of historic processes may lead to simpler and

> 'less accurate' operational models; the refinements and subtleties now considered important and beneficial may be found unfounded and superfluous in view of the clay feet of the basic hypotheses. (Klemes 1974b, p. 686)

The results of the study presented here have both theoretical and practical implications for flooding in the Gila River basin. Of theoretical interest is the reevaluation of the traditional stationary stochastic-process model for a hydrologic time series on the basis of hydroclimatic information about the events in the time series. Of practical interest is the reevaluation of traditional flood-frequency analysis techniques on the basis of a hydroclimatic understanding of how the floods are climatically generated.

Summary of Results

The hydroclimatic approach used in this analysis was based on monthly and peak flow discharge data for 30 gaging stations located throughout the Gila River basin in central and southern Arizona. The analysis proceeded along two lines: a monthly analysis and an event analysis. The monthly analysis utilized the correlation field technique to define the relationship between 700 mb height circulation anomalies and variations in mean monthly discharges at stations in the Gila basin. The event analysis used daily weather maps and precipitation patterns to classify over 2000 partial duration series flood events into one of eight hydroclimatic categories on the basis of the atmospheric mechanisms which generated each flood. The results of the event analysis were then linked back to the monthly analysis by constructing composite monthly circulation anomaly maps for the most dominant hydroclimatic categories. The findings from each of these hydroclimatic analyses are summarized below.

Monthly Correlation Fields

The correlation field analysis demonstrated that specific broadscale circulation anomaly patterns are associated with higher than normal streamflow in different parts of the study area and that these circulation-streamflow relationships change with the seasons. A regional grouping of the stations emerged from the analysis as streams in the eastern, southern, northern, and western parts of the basin each exhibited a unique sensitivity to different aspects of the circulation.

Correlation fields in fall and winter were more spatially homogeneous than correlation fields in summer, indicating that the fall and winter synoptic patterns had a broadly based influence over the whole basin, while the less synoptically-defined summer monsoonal circulations effected a more localized response of streamflow to the broadscale circulation.

The general streamflow-enhancing summer circulation pattern for the basin as a whole was one of stronger than normal airflow from the south and southeast (Gulf of Mexico and tropical Mexico moisture sources) in the early part of the rainy season, shifting to stronger than normal airflow from the south and southwest (Gulf of California and eastern Pacific moisture sources) later in the rainy season. The fall streamflow-enhancing pattern for the basin as a whole was characterized by a strong negative circulation anomaly off northern Baja California. In winter the dominant streamflow-enhancing circulation shifted during the course of the winter from December's more meridional pattern, with a negative anomaly off Baja reflecting the influence of frequent low latitude troughs, to a zonal split-flow pattern in January that represented a more southerly storm track and frequent frontal passages, and finally, to the February and March anomaly patterns characterized by frequent troughing in the North Pacific and stronger than normal southwesterly flow into the study area from the tropical eastern Pacific Ocean. This last pattern has been shown to be linked with long-lasting sea surface temperature anomalies in the Pacific Ocean, and with El Nino, indicating that persistence and nonstationarity may be introduced into streamflow records by the persistence and dominance of certain configurations of the upper level circulation.

Hydroclimatic Classification

The hydroclimatic classification of floods demonstrated that different types of atmospheric mechanisms generate flooding in different parts of the Gila River basin, and that there has been a certain amount of temporal variability in the frequencies of floods produced by different flood-generating mechanisms.

Of the eight hydroclimatic categories, the most important for producing flooding in the Gila River basin as a whole were, in descending order, monsoon widespread, frontal, monsoon local, and tropical storm/cutoff low. A definite regional and seasonal pattern was discovered in the flood-generating mechanisms, with frontal flooding dominating the northern basins and affecting all basins more often in the winter; monsoon widespread and monsoon local flooding dominating the southern and western basins, but affecting all of the stations to some degree during summer; and tropical storm/cutoff low flooding affecting the entire basin, but most often in late summer or fall. Snowmelt flooding was of less importance to the basin as a whole and was concentrated in the northern basins in late winter.

The relative magnitudes of the discharges associated with each hydroclimatic group at selected stations were displayed in histogram plots to evaluate the homogeneity assumption of flood-frequency analysis. The comparison of flood magnitudes generated by different atmospheric mechanisms indicated that mixed distributions or multiple populations were present in many of the flood records of the Gila River basin, with the northern stations showing the strongest evidence of this. One-way analysis of variance tests supported the histogram analysis, but due to the skewed nature of the standardized flood discharge data and the differences in variance from category to category, the statistical results may not be meaningful.

Composite Circulation Anomaly Maps

Composite monthly 700 mb height maps were constructed to define the anomalous circulations that were associated with the dominance of different types of flood events and flood-generating mechanisms. The resulting maps were similar to many of the monthly circulation-streamflow correlation fields, indicating that mean monthly streamflow variability and flood event variability are related to similar anomalous circulation patterns, and that the climatic factors that influence the generation of individual flooding events can be detected in the general circulation on a monthly time scale.

Reevaluation of Flood-Frequency Analysis

The results which emerged from the hydroclimatic study of flow events in the Gila River basin suggested that some of the basic assumptions of traditional flood-frequency analysis may not be valid and that information about the hydroclimatic sources of flooding may, when introduced into the analysis, provide a more sound, physically-based starting point from which to analyze a flood series. A pilot attempt at the reevaluation of flood recurrence intervals using additional hydroclimatic information was undertaken for the Santa Cruz River at Tucson. By decomposing the partial duration series of floods into hydroclimatic groups and by separately computing flood return periods from each group, new estimates were obtained for floods generated by different atmospheric mechanisms. The Santa Cruz estimates for tropical storm/cutoff low flooding resulted in the assignment of a return period in the range of 200 years for the large flood that occurred on the Santa Cruz in October of 1983.

Discussion

The results summarized above can now be applied toward an evaluation of the stochastic-process models presented in the introductory chapter and interpreted visually in Figures 4 and 5. Figure 4a depicts a generalized version of an observed flood series. If this series is classified according to the atmospheric mechanism which produced each event in the series, the result might be that of

Figure 38a which is based on hydroclimatic patterns actually observed in the flood series of the Gila River basin.

The Stationary Model

The traditional stochastic approach to the analysis of this flood series would assume the stationary model depicted in Figure 38b. The theoretical distribution functions for floods occurring at each time t would be assumed to be identical, with equal means and variances throughout the time series. In other words, no difference would be expected between the average size of a snowmelt flood as compared to the average size of a flood resulting from a winter frontal storm. Furthermore, no difference would be expected between the possible range of flood sizes that might be generated from each event; a snowmelt flood would have just as much of a chance as a frontal flood to be, say, two standard deviations greater than, or less than, the mean discharge of the entire series.

Kisiel (1969) states that stationarity in a time series indicates that the <u>generating mechanism</u> of the stochastic process is of the same nature at each point in time. Hence, in Figure 38b, the generating mechanism associated with rising floodwaters at time t_1 is assumed to be of the same nature as the generating mechanism associated with flooding at time t_2 or time t_n. However, the mechanism of a winter frontal storm system has a different nature than that of a tropical storm system and is especially different from the mechanism of snowmelt. Stationarity as expressed above is therefore not a characteristic of the flood series of the Gila River basin.

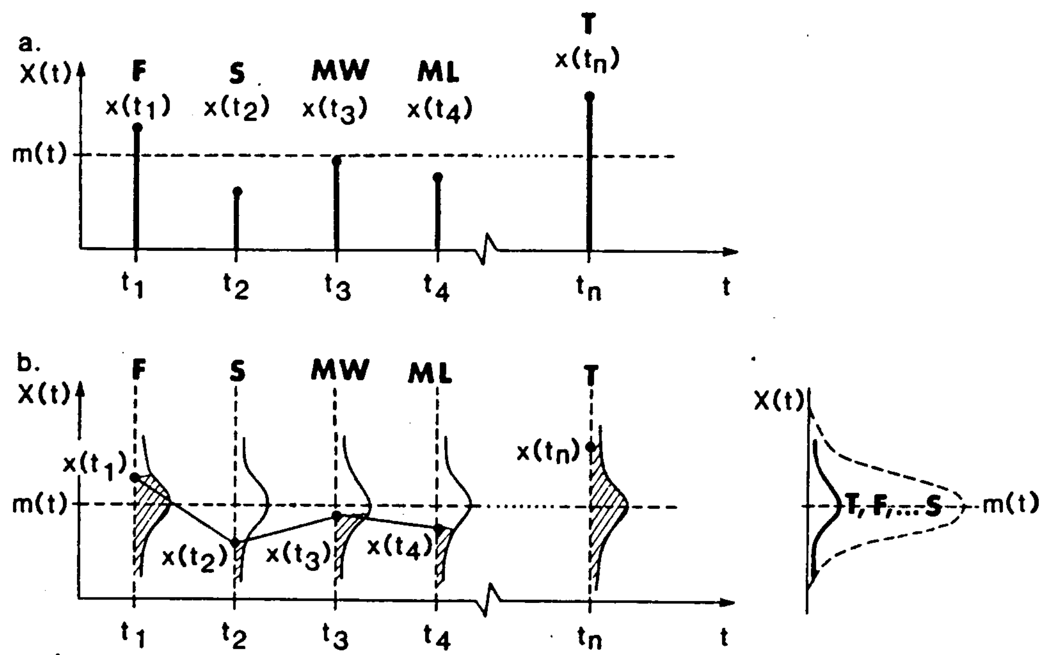


Fig. 38 Generalized Version of a Hydroclimaticaly Classified Flood Series
a. Observed flood series
b. Stationary Process with different hydroclimatic generating mechanisms, e.g. F = Front

Even if "generating mechanism" is taken in the very broad sense and assumed to be just the fact that precipitation is the mechanism that produces flooding, it can be shown that the nature of precipitation varies both seasonally and from year to year. If "generating mechanism" is interpreted in a more physically-based sense and taken to mean the actual synoptic system which generates a given storm with specific attributes, then it is clear from the results of this study that the stationary stochastic process model is not physically valid.

Alternative Models

The display of hydroclimatically grouped histograms in Figure 37 represents the decomposition of several flood series into component parts that are physically meaningful. Each histogram is an approximation of the theoretical probability distribution of the population of all floods generated at a given station by a given hydroclimatic mechanism. The shapes of these known distributions for different flood-generating mechanisms can be substituted into Figure 38b at the appropriate times to construct a physically-based stochastic model for the flooding process.

The results of the Gila basin study showed that any of the three alternative models presented in Chapter 1 and in Figure 5 may be valid. Figure 39 interprets the "nonstationary, time-varying mean process" hydroclimatically. With this interpretation, each of the events in the observed flooding process can be explained probabilistically, but not by stating that the process represents "a random number of random variables." Rather, Figure 39 suggests that the largest event in the series, $x(t_n)$, was large because it was one of

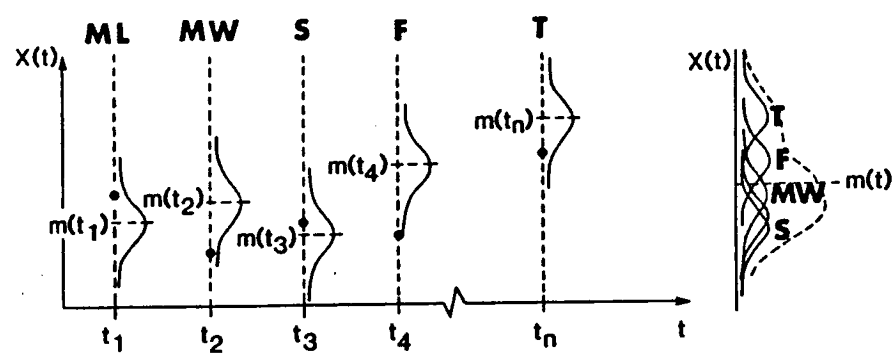


Fig. 39 Hydroclimatic Time-varying Mean Model

a whole population of floods that tend to have higher discharges.

Early in this study it was thought that the population of tropical storm floods would plot out as Figure 39 suggests. However histogram plots of the tropical storm/cutoff low (TC) category showed that its mean was not always greater than the overall mean of the series. Another possible explanation is found in Figure 40, the "time-varying variance" model. Here the theoretical probability distribution for TC floods has a very high variance, and the largest event in the series, $x(t_n)$ was large because it had a greater chance of being large, given the broad tails of the distribution.

The best model for hydroclimatically describing the flooding process in the Gila River basin is seen in Figure 41, the "time-varying mean and variance" model. Due to the physical properties of the flood-generating mechanisms, some of them will have distributions with high variance, like the tropical storm/cutoff low category, others may have low variance but will have means that are significantly higher or lower than the overall series mean. This is seen in the Snowmelt category that consistently plotted below the mean in a small, well-defined distribution. Finally some flood-generating mechanisms will have both high variance and a tendency to plot significantly above or below the mean. This is seen in the frontal group of floods, especially in the northern basins.

The histograms in Figure 37 show that the distributions of flood magnitudes generated by different processes tend to be skewed rather than normally distributed. Figure 42 depicts the stochastic-process model for floods with a series of skewed theoretical probability

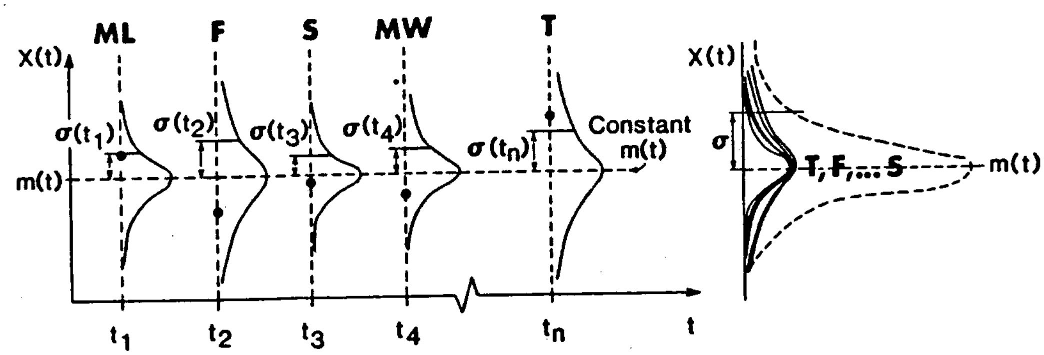


Fig. 40 Hydroclimatic Time-varying Variance Model

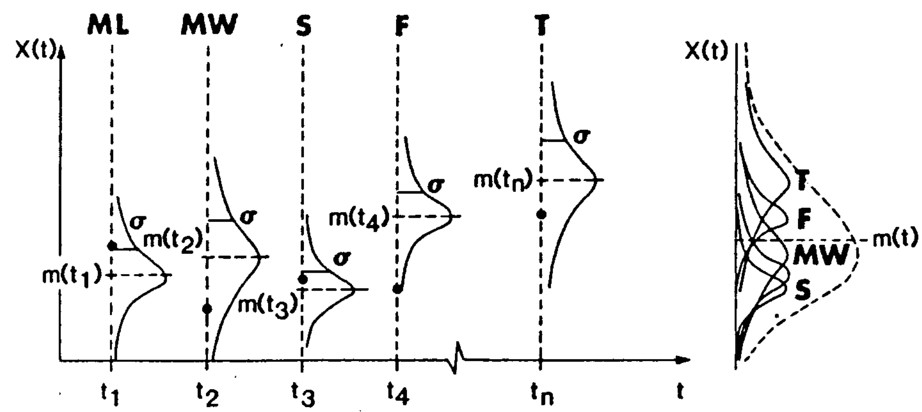


Fig. 41 Hydroclimatic Time-varying Mean and Variance Model

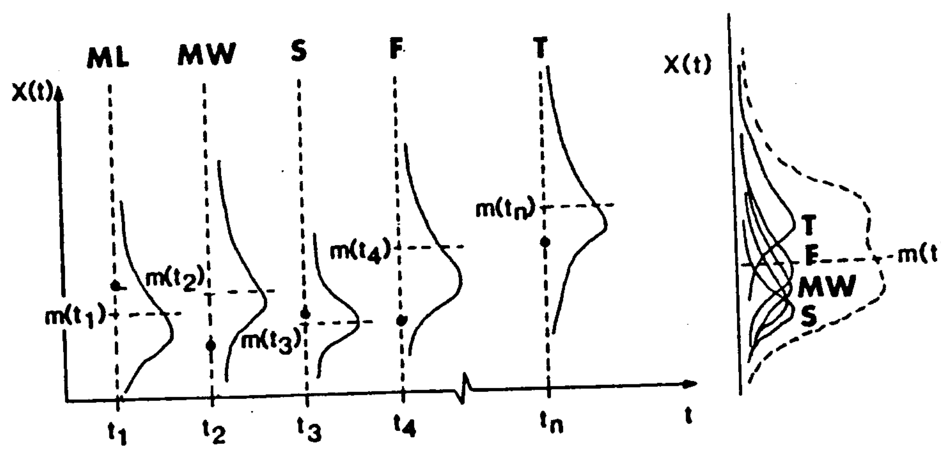


Fig. 42 Hydroclimatic Time-varying Mean and Variance Model with Skewed Distributions

distributions and this representation is probably the closest to actual conditions in the Gila River basin.

Superimposed on this pattern of changing probabilities of different-sized floods due to the occurrence of various flood-generating mechanisms, is another source of hydroclimatic variability: anomalous or persistent patterns of broadscale atmospheric circulation. It would conceivably be possible to categorize flood discharges on the basis of the upper air circulation and plot histograms for each circulation category in a manner similar to the hydroclimatic classification described above. The models in Figures 41 or 42 could then be interpreted once again in terms of the combined effects of the frequency and persistence of specific large-scale circulation patterns and the frequency and persistence of both the flood-generating mechanisms and the floods which evolved from them. The results of this analysis would apply to the third hypothesis presented in Chapter 1, which stated that a shift in general atmospheric circulation patterns, or the anomalous persistence of certain patterns will be reflected in a flood series by a shift to a different theoretical distribution for the variable X(t) in the series.

It should be noted before closing this discussion that describing the operation of a stochastic process model in physically-based terms is far easier than trying to mathematically define or solve such a model, and that it is primarily the relative ease of mathematical manipulation that has promoted the stationary stochastic model to the state of its present dominance in the field of hydrology.

A pilot attempt was made to make practical use of the results of this study by reevaluating the return period of the 1983 flood on the Santa Cruz River. One approach would have been an elaborate mathematical solution of the equations for the eight distributions. The alternative that was taken reevaluated the 1983 flood within the homogeneous set of floods generated by the tropical storm/cutoff low mechanism. The 200-year return period that resulted is really a return period for points in time during which tropical storms or cutoff lows are likely to generate floods. The task of determining the probability that a tropical storm or cutoff low will occur and will generate a flood was not attempted here, other than showing that in recent years there has been a slightly greater frequency of occurrence of these features. An assessment of this probability and the mathematical modeling of an eight-distribution stochastic process are the next stages of analysis that must be undertaken to fully implement the proposed physically-based model in the practical realm of flood risk determination.

Conclusions

This study has shown that a physically-based approach to the analysis of floods, particularly with respect to climate, will provide a much deeper understanding of the nature of floodflow variability than any analysis that is limited to the mathematical manipulation of runoff-based data alone.

The major conclusions which have emerged from the hydroclimatic analysis of flow events in the Gila River basin are the following:

1) Floods occur in the Gila River basin as a result of different kinds of atmospheric processes. These flood-generating processes vary spatially across the basin, and temporally throughout the year, and from year to year.

2) Discharge magnitudes, whether in the form of mean monthly runoff or instantaneous peak flows, are closely linked to specific configurations of the broadscale circulation. The development of certain synoptic patterns, such as fronts or tropical storms, within the broadscale pattern, provides a link between individual flood events and longer term climatic variability.

3) The frequency distributions of flood discharges generated from various atmospheric mechanisms are significantly different for selected stations in the Gila basin, indicating that floods generated by different mechanisms belong to different populations.

4) Differences among the frequency distributions at a station are due to either varying means, varying variances, or both. The best model for a physically-based description of the stochastic process of flooding in the Gila River basin is that of a nonstationary process with time-varying mean and variance.

5) The mean, variance, and shape of the frequency distributions of different hydroclimatic categories of flooding have a physical basis that is linked to the nature of the flood- generating process.

6) When multiple populations are present due to mixed processes, the shape of the overall frequency distribution of a flood series can be thought of as the combination of separate frequency distributions each resulting from a specific type of flood-generating mechanism.

7) Flood estimates computed from a flood series containing mixed distributions are not the same as flood estimates computed from homogeneous subsets of the series. To better predict return periods for specific types of flood events, time series of floods should be separated into homogeneous hydroclimatic groups and analyzed separately.

Suggestions for Further Work

This research has focused primarily on theoretical aspects of flood variability, but one of the desired end products of a study such as this is the practical application of the developed theory to the areas of flood estimation and risk assessment. An assessment of the October 1983 flood on the Santa Cruz was attempted on the basis of the physically-based theory of flood variability developed in this study. Continued applications along these lines should yield more definitive results, especially for flood estimates in the northern part of the study area where the hydroclimatic subpopulations emerged as being very distinct.

Most mathematical modeling of hydrologic time series done today is based on the assumption of a stationary stochastic process. Even if physically-based studies of hydrologic time series demonstrate that the stationary model is not appropriate for a given flood series, the scarcity of available mathematical and statistical models with which to analyze nonstationary processes will probably lead the researcher to assume a stationary stochastic process during analysis, despite the physical evidence to the contrary. More work is needed in the area of nonstationary stochastic models and their mathematical description.

Some models and simulations of mixed distributions in hydrology have been developed in a theoretical sense, and the results of the Gila basin study are ready to be applied to these theoretical models to see how well they explain the mixed distributions defined for the region.

Numerous other studies are possible with a set of hydroclimatically defined flood data. The study of the geomorphic effectiveness of different types of flood events is an area of great potential. Flood hazard maps could be drawn up for floods generated by different atmospheric processes as potential guides for floodplain zoning or flood warning systems. Sea surface temperature anomalies could be linked with the circulation patterns that produce different flood types to develop a possible long-range prediction or warning capability for future flood episodes of a given type.

All of these possible studies will be enhanced by an improvement and refinement of the hydroclimatic classification procedure itself. Even though upper air data are not available, the classification could be extended back in time to include events in the first half of the twentieth century. A reevaluation of the current classification system is also a possibility, especially if a more synoptic categorization of the monsoon circulations could be achieved.

The hydroclimatic approach presented here holds promise for the continued development of the new trend in hydrology toward physically-based models of hydrologic processes. With the further development and refinement of techniques for mathematically and statistically describing these physically-based models, practical operational models based on sound physical principles may soon emerge.

APPENDIX A

BASIN CHARACTERISTICS FOR GILA RIVER BASIN STATIONS

Source: U. S. Geological Survey, Tucson District Office

MASTER LIST OF VARIABLES FOR STREAMFLOW/BASIN CHARACTERISTICS FILE

VARIABLE NUMBER	FILE CODE	DESCRIPTION
1	AREA	Total drainage area, in square miles, including non-contributing areas.
2	CONTDA	Drainage area, in square miles, that contributes to surface runoff.
3	SLOPE	Main channel slope, in feet per mile, measured by grid sampling method.
4	BSLOPE	Average basin slope, in feet per mile, measured by grid sampling method.
5	LENGTH	Stream length, in miles, measured along channel from gage to basin divide.
6	BLENGTH	Stream length, in miles, measured from gage to end of defined channel (blue line on topographic map).
7	VALLGH	Valley length, in miles, measured along general path of flood plain from gage to basin divide.
8	ELEV	Mean basin elevation, in feet above mean sea level, measured from topographic maps by transparent grid sampling method (20 to 80 points in basin were sampled).
9	ELV10,85	Average of channel elevations, in feet above mean sea level, at points 10- and 85-percent of stream length upstream from gage.
10	EL5000	Percent of basin above elevation 5000 feet, mean sea level.
11	EL6000	Percent of basin above elevation 6000 feet, mean sea level.
12	STORAGE	Area of lakes, ponds, and swamps in percent of contributing drainage area, measured by the grid sampling method.
13	LAKEAREA	Area of lakes and ponds, in percent of contributing drainage area, measured by the grid sampling method
14	FOREST	Forested area, in percent of contributing drainage area, measured by the grid sampling methods.
15	GLACIER	Area of glaciers, in percent of contributing drainage area.
16	SOIL INF	Soils index, in inches, a relative measure of potential infiltration (soil water storage), from Soil Conservation Service.
17	LOESS	Depth of surficial loess, in feet, from Soil Conservation Service.
18	AZIMUTH	Azimuth, in decimal degrees from north, of a straight line connecting points 85- and 10-percent of distance from gage to divide.
19	LAT	Latitude of center of basin, in decimal degrees.
20	LONG	Longitude of center of basin, in decimal degrees.
21	TIMETOPK	Time, in hours, measured as time difference between center of mass of total rainfall and peak discharge.
22	LAT GAGE	Latitude of stream-gaging station in decimal degrees.
23	LNG GAGE	Longitude of stream-gaging station in decimal degrees.
24	--	
25	--	
26	--	
27	--	
28	--	
29	--	
30	--	
31	--	
32	PRECIP	Mean annual precipitation, in inches, from U.S. Weather Bureau series, "Climates of States;" grid sampling methods used if isohyetal map is available, otherwise anomaly map constructed (WSP 1580-D).

VARIABLE NUMBER	FILE CODE	DESCRIPTION
33	I24,2	Precipitation intensity; 24-hour rainfall, in inches, expected on the average of once each d years. (Estimated from U.S. Weather Bureau Technical Paper 40 except for western States where NOAA Atlas 2 exists). d = 2.
34	I24,10	Do. d = 10.
35	I24,25	Do. d = 25.
36	I24,50	Do. d = 50.
37	I24,100	Do. d = 100.
38	—	
39	--	
40	--	
41	PRC10	Mean monthly precipitation, in inches, for "M" calendar month. M = October = 10.
42	PRC11	Do. M = November.
43	PRC12	Do. M = December.
44	PRC1	Do. M = January.
45	PRC2	Do. M = February.
46	PRC3	Do. M = March.
47	PRC4	Do. M = April.
48	PRC5	Do. M = May.
49	PRC6	Do. M = June.
50	PRC7	Do. M = July.
51	PRC8	Do. M = August.
52	PRC9	Do. M = September.

VARIABLE NUMBER	FILE CODE	DESCRIPTION
53	SNOFALL	Mean annual snowfall, in inches, from U.S. Weather Bureau, "Climates of States."
54	SNOMAR	Mean water equivalent, in inches, of snow cover as of March 1 from U.S. Weather Bureau, Technical Paper 50.
55	SNOAPR	Mean water equivalent, in inches, of snow cover as of April 30, from U.S. Weather Bureau, Technical Paper 50.
56	SN2	Maximum water equivalent, in inches, of snow cover as of March 15, T-year recurrence interval, from U.S. Weather Bureau, Technical Paper 50. T = 2.
57	SN10	Do. T = 10.
58	SN25	Do. T = 25.
59	SN100	Do. T = 100.
60	JANMIN	Mean minimum January temperature, in degrees F, from U.S. Weather Bureau, "Climates of States."
61	JANAV	Mean monthly temperature for January in degrees F, from U.S. Weather Bureau, "Climates of States."
62	MARMAX	Mean maximum March temperature, in degrees F, from U.S. Weather Bureau, "Climates of States."
63	JULYMAX	Mean maximum July temperature, in degrees F, from U.S. Weather Bureau, "Climates of States."
64	JULYAV	Mean monthly temperature for July, in degrees F, from U.S. Weather Bureau, "Climates of States."
65	WE MAR2	Water equivalent, in inches, of snow cover as of the first week in March, 2-year recurrence interval. Data compiled by New York District USGS.
66	--	
67	--	
68	--	
69	--	

VARIABLE NUMBER	FILE CODE	DESCRIPTION
70	EVAP	Mean annual lake evaporation, in inches, from U.S. Weather Bureau, Technical Paper 37.
71	EVAPAN	Mean annual Class A pan evaporation, in inches, from U.S. Weather Bureau, Technical Paper 37.
72	FROST	Mean frost depth on February 28, in inches, from U.S. Weather Bureau, "Climates of States."
73	--	
74	--	
75	P1,25	Annual flood peak, in cfs, of T-year recurrence interval, defined by log-Pearson Type III fitting, computer program no. J407. T = 1.25.
76	P2	Do. T = 2.
77	P5	Do. T = 5.
78	P10	Do. T = 10.
79	P25	Do. T = 25.
80	P50	Do. T = 50.
81	P100	Do. T = 100.
82	P200	Do. T = 200.
83	MEANPK	Mean of logarithms, base 10, of systematic annual peak discharges, from computer program no. J407.
84	SDPK	Standard deviation of logarithms, base 10, of systematic annual peak discharges, from computer program no. J407.
85	SKEWPK	Skew of logarithms, base 10, of systematic annual peak discharges, from computer program no. J407.
86	QA	Mean annual discharge, in cfs, from flow variability computer program no. W4422.
87	SDQA	Standard deviation of mean annual discharge, in cfs, from flow variability computer program no. W4422.

VARIABLE NUMBER	FILE CODE	DESCRIPTION
88	Q10	Mean discharge, in cfs, for "M" calendar month, from flow variability computer program no. W4422. M = October = 10.
89	Q11	Do. M = November.
90	Q12	Do. M = December.
91	Q1	Do. M = January.
92	Q2	Do. M = February.
93	Q3	Do. M = March.
94	Q4	Do. M = April.
95	Q5	Do. M = May.
96	Q6	Do. M = June.
97	Q7	Do. M = July.
98	Q8	Do. M = August.
99	Q9	Do. M = September.
100	SDQ10	Standard deviation, in cfs, of mean discharge for "M" calendar month, from flow variability computer program no. W4422. M = October = 10.
101	SDQ11	Do. M = November.
102	SDQ12	Do. M = December.
103	SDQ1	Do. M = January.
104	SDQ2	Do. M = February.
105	SDQ3	Do. M = March.
106	SDQ4	Do. M = April.
107	SDQ5	Do. M = May.
108	SDQ6	Do. M = June.
109	SDQ7	Do. M = July.

VARIABLE NUMBER	FILE CODE	DESCRIPTION
110	SDQ8	Do. M = August.
111	SDQ9	Do. M = September.
112	M1,2	Low-flow characteristics: Annual minimum "D"-day mean discharge, in cfs, for "T"-year recurrence interval, defined by log-Pearson Type III fitting, computer program no. A969. D = 1; T = 2.
	⋮	
131	V1,100	Flood volume characteristic: Annual maximum "D"-day mean discharge, in cfs, for "T"-year recurrence interval, defined by log-Pearson Type III fitting, computer program no. A969. D = 1; T = 100.
	⋮	
169	DEPH25	Flow depth, in feet, corresponding to difference between the 25% flow duration gage height and point of zero flow.
170	—	
171	D95	Flow-duration characteristic: Discharge, in cfs, exceeded "P" percent of time, defined by daily flow duration, computer program no. A969. P = 95.
	⋮	
178	P500	Annual flood peak, in cfs, of T-year recurrence interval, defined by log-Pearson Type III fitting, computer program J407. T = 500.
179	WRC SKEW	WRC skew of logarithms, base 10, of annual peak discharge after outlier and historic-peak adjustments and generalized skew weighting, from computer program J407.
180	WRC MEAN	WRC mean of logarithms, base 10, of annual peak discharges after outlier and historic-peak adjustments, from computer program J407.
181	WRC SD	WRD standard deviation of logarithms, base 10, of annual peak discharges after outlier and historic-peak adjustments, from computer program J407.
	⋮	
196	YRSPK	Number of years of systematic peak flow record.
197	YRSHISPK	Number of consecutive years used for historic-peak adjustment to flood-frequency data used in computer program J407.
198	YRSDAY	Number of years of daily-flow record.
199	YRSLOW	Number of years of low-flow record.
200	--	

STATION ID	STATION NAME (PLUS DATA TYPE IF STORED)	STATE CODE	DIST. CODE	LAST UPDATE	NO. OF CHAR. STORED IN FILE
09442000	1 GILA RIVER NEAR CLIFTON, ARIZ.	4	4	800610	88

AREA=	4010.000-SQ MI	CONTDA=	4010.000-SQ MI	SLOPE=	29.000-FT/MI	LENGTH=	158.800-MI
ELEV=	6250.000-FT	EL6000=	55.000-%	STORAGE=	0.100-%	FOREST=	44.000-%
SOIL INF=	2.870-IN	AZIMUTH=	240.000-DEC. DEG	LAT=	33.000-DEC. DEG	LONG=	108.600-DEC. DEG
LAT GAGE=	32.966-DEC. DEG	LNG GAGE=	109.310-DEC. DEG	PRECIP=	15.400-IN	I24,2=	1.600-IN
I24,10=	2.470-IN	I24,50=	3.350-IN	PRC10=	1.180-IN	PRC11=	0.690-IN
PRC12=	1.110-IN	PRC1=	1.110-IN	PRC2=	1.140-IN	PRC3=	0.890-IN
PRC4=	0.490-IN	PRC5=	0.400-IN	PRC6=	0.710-IN	PRC7=	2.740-IN
PRC8=	3.030-IN	PRC9=	1.880-IN	SNOFALL=	33.300-IN	JANMIN=	22.000-FAHR
P1,25=	3130.000-CFS	P2=	5600.000-CFS	P5=	10500.000-CFS	P10=	15000.000-CFS
P25=	22100.000-CFS	P50=	28700.000-CFS	P100=	36400.000-CFS	P200=	45600.000-CFS
MEANPK=	3.778-LOG10	SDPK=	0.331-LOG10	SKEWPK=	0.465-LOG10	QA=	194.000-CFS
SDQA=	164.000-CFS	Q10=	159.000-CFS	Q11=	94.900-CFS	Q12=	199.000-CFS
Q1=	264.000-CFS	Q2=	284.000-CFS	Q3=	373.000-CFS	Q4=	235.000-CFS
Q5=	103.000-CFS	Q6=	36.800-CFS	Q7=	143.000-CFS	Q8=	260.000-CFS
Q9=	177.000-CFS	SDQ10=	250.000-CFS	SDQ11=	70.300-CFS	SDQ12=	395.000-CFS
SDQ1=	339.000-CFS	SDQ2=	347.000-CFS	SDQ3=	418.000-CFS	SDQ4=	302.000-CFS
SDQ5=	133.000-CFS	SDQ6=	30.700-CFS	SDQ7=	200.000-CFS	SDQ8=	231.000-CFS
SDQ9=	166.000-CFS	M7,2=	15.100-CFS	M7,10=	8.120-CFS	M7,20=	6.810-CFS
V1,2=	2760.000-CFS	V1,10=	8430.000-CFS	V1,50=	17100.000-CFS	V3,2=	1780.000-CFS
V3,10=	5370.000-CFS	V3,50=	10700.000-CFS	V7,2=	1160.000-CFS	V7,10=	3350.000-CFS
V7,50=	6530.000-CFS	D10=	421.000-CFS	P500=	60300.000-CFS	WRC SKEW=	0.291-LOG10
WRC MEAN=	3.764-LOG10	WRC SD=	0.314-LOG10	YRSPK=	58.000-YEARS	YRSHISPK=	88.000-YEARS

STATION ID	STATION NAME	STATE CODE	DIST. CODE	LAST UPDATE	NO. OF CHAR. STORED IN FILE
09444500	2 SAN FRANCISCO RIVER AT CLIFTON, ARIZ.	4	4	801010	88

AREA=	2766.000-SQ MI	CONTDA=	2766.000-SQ MI	SLOPE=	48.900-FT/MI	LENGTH=	93.200-MI
ELEV=	6880.000-FT	EL6000=	68.000-%	STORAGE=	0.000E+00-%	FOREST=	87.000-%
SOIL INF=	2.900-IN	AZIMUTH=	200.000-DEC. DEG	LAT=	33.500-DEC. DEG	LONG=	109.000-DEC. DEG
LAT GAGE=	33.049-DEC. DEG	LNG GAGE=	109.295-DEC. DEG	PRECIP=	18.100-IN	I24,2=	1.600-IN
I24,10=	2.580-IN	I24,50=	3.270-IN	PRC10=	1.410-IN	PRC11=	0.870-IN
PRC12=	1.280-IN	PRC1=	1.320-IN	PRC2=	1.280-IN	PRC3=	1.140-IN
PRC4=	0.650-IN	PRC5=	0.490-IN	PRC6=	0.800-IN	PRC7=	3.260-IN
PRC8=	3.460-IN	PRC9=	2.120-IN	SNOFALL=	47.800-IN	JANMIN=	19.000-FAHR
P1,25=	2950.000-CFS	P2=	7280.000-CFS	P5=	16200.000-CFS	P10=	29600.000-CFS
P25=	50000.000-CFS	P50=	70300.000-CFS	P100=	95700.000-CFS	P200=	127000.000-CFS
MEANPK=	3.841-LOG10	SDPK=	0.449-LOG10	SKEWPK=	-0.019-LOG10	QA=	166.000-CFS
SDQA=	120.000-CFS	Q10=	90.100-CFS	Q11=	77.100-CFS	Q12=	180.000-CFS
Q1=	210.000-CFS	Q2=	231.000-CFS	Q3=	329.000-CFS	Q4=	247.000-CFS
Q5=	115.000-CFS	Q6=	44.400-CFS	Q7=	94.200-CFS	Q8=	231.000-CFS
Q9=	139.000-CFS	SDQ10=	68.600-CFS	SDQ11=	47.300-CFS	SDQ12=	387.000-CFS
SDQ1=	346.000-CFS	SDQ2=	310.000-CFS	SDQ3=	387.000-CFS	SDQ4=	270.000-CFS
SDQ5=	142.000-CFS	SDQ6=	27.800-CFS	SDQ7=	57.100-CFS	SDQ8=	250.000-CFS
SDQ9=	110.000-CFS	M7,2=	21.300-CFS	M7,10=	13.200-CFS	M7,20=	11.700-CFS
V1,2=	2300.000-CFS	V1,10=	9480.000-CFS	V1,50=	23500.000-CFS	V3,2=	1460.000-CFS
V3,10=	5470.000-CFS	V3,50=	12600.000-CFS	V7,2=	920.000-CFS	V7,10=	3120.000-CFS
V7,50=	6930.000-CFS	D10=	325.000-CFS	P500=	180000.000-CFS	WRC SKEW=	0.063-LOG10
WRC MEAN=	3.867-LOG10	WRC SD=	0.469-LOG10	YRSPK=	69.000-YEARS	YRSHISPK=	109.000-YEARS

09448500 **3** GILA R AT HEAD OF SAFFORD VALLEY NR SOLOMON ARIZ 4 4 820128 88

AREA=	7896.000-SQ MI	CONTDA=	7896.000-SQ MI	SLOPE=	26.400-FT/MI	LENGTH=	177.000-MI
ELEV=	6360.000-FT	EL6000=	57.000-%	STORAGE=	0.100-%	FOREST=	58.000-%
SOIL INF=	2.770-IN	AZIMUTH=	230.000-DEC. DEG	LAT=	33.300-DEC. DEG	LONG=	108.900-DEC. DEG
LAT GAGE=	32.868-DEC. DEG	LNG GAGE=	109.511-DEC. DEG	PRECIP=	16.700-IN	I24,2=	1.700-IN
I24,10=	2.480-IN	I24,50=	3.430-IN	PRC10=	1.290-IN	PRC11=	0.750-IN
PRC12=	1.200-IN	PRC1=	1.200-IN	PRC2=	1.230-IN	PRC3=	0.970-IN
PRC4=	0.530-IN	PRC5=	0.430-IN	PRC6=	0.770-IN	PRC7=	2.970-IN
PRC8=	3.290-IN	PRC9=	2.030-IN	SNOFALL=	38.600-IN	JANMIN=	21.000-FAHR
P1,25=	4470.000-CFS	P2=	9620.000-CFS	P5=	21800.000-CFS	P10=	34000.000-CFS
P25=	55400.000-CFS	P50=	76700.000-CFS	P100=	103000.000-CFS	P200=	136000.000-CFS
MEANPK=	4.002-LOG10	SDPK=	0.414-LOG10	SKEWPK=	0.434-LOG10	QA=	348.000-CFS
SDQA=	252.000-CFS	Q10=	204.000-CFS	Q11=	167.000-CFS	Q12=	372.000-CFS
Q1=	496.000-CFS	Q2=	507.000-CFS	Q3=	698.000-CFS	Q4=	458.000-CFS
Q5=	214.000-CFS	Q6=	82.200-CFS	Q7=	179.000-CFS	Q8=	468.000-CFS
Q9=	332.000-CFS	SDQ10=	210.000-CFS	SDQ11=	90.100-CFS	SDQ12=	666.000-CFS
SDQ1=	704.000-CFS	SDQ2=	622.000-CFS	SDQ3=	802.000-CFS	SDQ4=	503.000-CFS
SDQ5=	298.000-CFS	SDQ6=	65.400-CFS	SDQ7=	138.000-CFS	SDQ8=	452.000-CFS
SDQ9=	259.000-CFS	M7,2=	35.600-CFS	M7,10=	20.500-CFS	M7,20=	17.800-CFS
V1,2=	4330.000-CFS	V1,10=	15000.000-CFS	V1,50=	32900.000-CFS	V3,2=	2970.000-CFS
V3,10=	9450.000-CFS	V3,50=	19400.000-CFS	V7,2=	1910.000-CFS	V7,10=	5700.000-CFS
V7,50=	11300.000-CFS	Q10=	728.000-CFS	P500=	192000.000-CFS	WRC SKEW=	0.214-LOG10
WRC MEAN=	3.998-LOG10	WRC SD=	0.409-LOG10	YRSPK=	66.000-YEARS	YRSHISPK=	73.000-YEARS

09466500 **4** GILA RIVER AT CALVA, ARIZ. 4 4 770819 66

AREA=	11470.000-SQ MI	CONTDA=	11470.000-SQ MI	SLOPE=	20.400-FT/MI	LENGTH=	225.200-MI
ELEV=	5650.000-FT	EL6000=	41.000-%	STORAGE=	0.100-%	FOREST=	44.000-%
SOIL INF=	2.560-IN	AZIMUTH=	260.000-DEC. DEG	LAT=	33.000-DEC. DEG	LONG=	109.100-DEC. DEG
LAT GAGE=	33.185-DEC. DEG	LNG GAGE=	110.220-DEC. DEG	PRECIP=	15.500-IN	I24,2=	1.700-IN
I24,10=	2.580-IN	I24,50=	3.460-IN	PRC10=	1.150-IN	PRC11=	0.810-IN
PRC12=	1.110-IN	PRC1=	1.110-IN	PRC2=	1.150-IN	PRC3=	0.970-IN
PRC4=	0.530-IN	PRC5=	0.340-IN	PRC6=	0.680-IN	PRC7=	2.900-IN
PRC8=	3.020-IN	PRC9=	1.770-IN	SNOFALL=	30.200-IN	JANMIN=	23.000-FAHR
QA=	250.000-CFS	SDQA=	219.000-CFS	Q10=	146.000-CFS	Q11=	99.700-CFS
Q12=	245.000-CFS	Q1=	434.000-CFS	Q2=	482.000-CFS	Q3=	507.000-CFS
Q4=	241.000-CFS	Q5=	106.000-CFS	Q6=	15.400-CFS	Q7=	106.000-CFS
Q8=	399.000-CFS	Q9=	230.000-CFS	SDQ10=	307.000-CFS	SDQ11=	92.400-CFS
SDQ12=	484.000-CFS	SDQ1=	678.000-CFS	SDQ2=	653.000-CFS	SDQ3=	715.000-CFS
SDQ4=	354.000-CFS	SDQ5=	261.000-CFS	SDQ6=	26.400-CFS	SDQ7=	177.000-CFS
SDQ8=	448.000-CFS	SDQ9=	213.000-CFS	V1,2=	4160.000-CFS	V1,10=	12600.000-CFS
V1,50=	24800.000-CFS	V3,2=	2980.000-CFS	V3,10=	9090.000-CFS	V3,50=	17800.000-CFS
V7,2=	1990.000-CFS	V7,10=	5820.000-CFS	V7,50=	10600.000-CFS	Q10=	569.000-CFS

09468500 **5** SAN CARLOS RIVER NEAR PERIDOT, ARIZ. 4 4 811216 85

AREA=	1027.000-SQ MI	CONTDA=	1027.000-SQ MI	SLOPE=	29.400-FT/MI	LENGTH=	56.700-MI
ELEV=	4460.000-FT	EL6000=	4.900-%	STORAGE=	0.100-%	FOREST=	9.900-%
SOIL INF=	2.030-IN	AZIMUTH=	270.000-DEC. DEG	LAT=	33.400-DEC. DEG	LONG=	110.500-DEC. DEG
LAT GAGE=	33.321-DEC. DEG	LNG GAGE=	110.448-DEC. DEG	PRECIP=	17.200-IN	I24,2=	2.100-IN
I24,10=	3.090-IN	I24,50=	4.050-IN	PRC10=	1.000-IN	PRC11=	1.130-IN
PRC12=	1.800-IN	PRC1=	1.770-IN	PRC2=	1.510-IN	PRC3=	1.390-IN
PRC4=	0.710-IN	PRC5=	0.380-IN	PRC6=	0.450-IN	PRC7=	2.860-IN
PRC8=	2.840-IN	PRC9=	1.380-IN	SNOFALL=	15.200-IN	JANMIN=	24.000-FAHR
P1,25=	3410.000-CFS	P2=	7520.000-CFS	P5=	15900.000-CFS	P10=	23100.000-CFS
P25=	33900.000-CFS	P50=	43200.000-CFS	P100=	53500.000-CFS	P200=	64800.000-CFS
MEANPK=	3.876-LOG10	SDPK=	0.407-LOG10	SKEWPK=	-0.250-LOG10	QA=	46.800-CFS
SDQA=	51.800-CFS	Q10=	11.800-CFS	Q11=	14.000-CFS	Q12=	91.000-CFS
Q1=	93.500-CFS	Q2=	126.000-CFS	Q3=	108.000-CFS	Q4=	18.000-CFS
Q5=	4.000-CFS	Q6=	1.510-CFS	Q7=	19.500-CFS	Q8=	55.500-CFS
Q9=	20.400-CFS	SDQ10=	17.300-CFS	SDQ11=	17.000-CFS	SDQ12=	271.000-CFS
SDQ1=	172.000-CFS	SDQ2=	199.000-CFS	SDQ3=	226.000-CFS	SDQ4=	31.800-CFS
SDQ5=	3.110-CFS	SDQ6=	2.010-CFS	SDQ7=	21.400-CFS	SDQ8=	61.600-CFS
SDQ9=	26.000-CFS	V1,2=	1670.000-CFS	V1,10=	8170.000-CFS	V1,50=	23000.000-CFS
V3,2=	890.000-CFS	V3,10=	4510.000-CFS	V3,50=	13200.000-CFS	V7,2=	496.000-CFS
V7,10=	2330.000-CFS	V7,50=	6420.000-CFS	D10=	50.100-CFS	P500=	81300.000-CFS
WRC SKEW=	-0.202-LOG10	WRC MEAN=	3.865-LOG10	WRC SD=	0.347-LOG10	YRSPK=	50.000-YEARS
YRSHISPK=	67.000-YEARS						

09470500 **6** SAN PEDRO RIVER AT PALOMINAS, ARIZ. 4 4 781007 86

AREA=	741.000-SQ MI	CONTDA=	741.000-SQ MI	SLOPE=	23.500-FT/MI	LENGTH=	35.400-MI
ELEV=	4950.000-FT	EL6000=	2.400-%	STORAGE=	0.200-%	FOREST=	12.000-%
SOIL INF=	2.270-IN	AZIMUTH=	20.000-DEC. DEG	LAT=	31.200-DEC. DEG	LONG=	110.200-DEC. DEG
LAT GAGE=	31.380-DEC. DEG	LNG GAGE=	110.111-DEC. DEG	PRECIP=	17.900-IN	I24,2=	1.900-IN
I24,10=	2.910-IN	I24,50=	3.960-IN	PRC10=	0.770-IN	PRC11=	0.480-IN
PRC12=	1.200-IN	PRC1=	1.290-IN	PRC2=	0.770-IN	PRC3=	0.970-IN
PRC4=	0.390-IN	PRC5=	0.140-IN	PRC6=	1.160-IN	PRC7=	4.220-IN
PRC8=	4.940-IN	PRC9=	1.590-IN	SNOFALL=	13.700-IN	JANMIN=	26.000-FAHR
P1,25=	5930.000-CFS	P2=	6570.000-CFS	P5=	10200.000-CFS	P10=	12900.000-CFS
P25=	16500.000-CFS	P50=	19300.000-CFS	P100=	22200.000-CFS	P200=	25200.000-CFS
MEANPK=	3.799-LOG10	SDPK=	0.245-LOG10	SKEWPK=	0.197-LOG10	QA=	33.000-CFS
SDQA=	19.600-CFS	Q10=	6.780-CFS	Q11=	4.640-CFS	Q12=	10.000-CFS
Q1=	13.000-CFS	Q2=	9.450-CFS	Q3=	5.130-CFS	Q4=	2.580-CFS
Q5=	1.230-CFS	Q6=	5.000-CFS	Q7=	99.800-CFS	Q8=	191.000-CFS
Q9=	43.300-CFS	SDQ10=	12.400-CFS	SDQ11=	4.960-CFS	SDQ12=	14.200-CFS
SDQ1=	25.700-CFS	SDQ2=	12.000-CFS	SDQ3=	3.960-CFS	SDQ4=	2.390-CFS
SDQ5=	1.650-CFS	SDQ6=	7.380-CFS	SDQ7=	74.800-CFS	SDQ8=	184.000-CFS
SDQ9=	61.700-CFS	V1,2=	1660.000-CFS	V1,10=	4430.000-CFS	V1,50=	8120.000-CFS
V3,2=	877.000-CFS	V3,10=	2270.000-CFS	V3,50=	4080.000-CFS	V7,2=	493.000-CFS
V7,10=	1300.000-CFS	V7,50=	2350.000-CFS	D10=	37.000-CFS	P500=	29300.000-CFS
WRC SKEW=	-0.126-LOG10	WRC MEAN=	3.799-LOG10	WRC SD=	0.245-LOG10	YRSPK=	39.000-YEARS
YRSHISPK=	39.000-YEARS	(? 200?)=	92578.000-				

09471000 **7** SAN PEDRO RIVER AT CHARLESTON, ARIZ. 4 4 811026 89

AREA=	1219.000-SQ MI	CONTDA=	1219.000-SQ MI	SLOPE=	18.400-FT/MI	LENGTH=	56.200-MI
ELEV=	4840.000-FT	EL6000=	3.900-%	STORAGE=	0.100-%	FOREST=	12.000-%
SOIL INF=	2.010-IN	AZIMUTH=	360.000-DEC. DEG	LAT=	31.300-DEC. DEG	LONG=	110.200-DEC. DEG
LAT GAGE=	31.626-DEC. DEG	LNG GAGE=	110.174-DEC. DEG	PRECIP=	16.500-IN	I24,2=	1.900-IN
I24,10=	2.820-IN	I24,50=	3.810-IN	PRC10=	0.690-IN	PRC11=	0.590-IN
PRC12=	1.010-IN	PRC1=	1.060-IN	PRC2=	0.790-IN	PRC3=	0.730-IN
PRC4=	0.360-IN	PRC5=	0.160-IN	PRC6=	0.960-IN	PRC7=	4.450-IN
PRC8=	4.120-IN	PRC9=	1.580-IN	SNOFALL=	10.200-IN	JANMIN=	27.000-FAHR
P1,25=	4200.000-CFS	P2=	6920.000-CFS	P5=	12500.000-CFS	P10=	17800.000-CFS
P25=	26700.000-CFS	P50=	35300.000-CFS	P100=	45900.000-CFS	P200=	59000.000-CFS
MEANPK=	3.872-LOG10	SDPK=	0.291-LOG10	SKEWPK=	1.133-LOG10	QA=	55.100-CFS
SDQA=	25.400-CFS	Q10=	19.500-CFS	Q11=	14.800-CFS	Q12=	21.400-CFS
Q1=	26.800-CFS	Q2=	22.300-CFS	Q3=	17.200-CFS	Q4=	12.000-CFS
Q5=	8.210-CFS	Q6=	12.500-CFS	Q7=	153.000-CFS	Q8=	274.000-CFS
Q9=	72.100-CFS	SDQ10=	24.800-CFS	SDQ11=	6.780-CFS	SDQ12=	12.700-CFS
SDQ1=	27.100-CFS	SDQ2=	14.600-CFS	SDQ3=	4.940-CFS	SDQ4=	3.390-CFS
SDQ5=	2.720-CFS	SDQ6=	16.400-CFS	SDQ7=	105.000-CFS	SDQ8=	240.000-CFS
SDQ9=	76.000-CFS	M7,2=	2.680-CFS	M7,10=	1.610-CFS	M7,20=	1.360-CFS
V1,2=	2290.000-CFS	V1,10=	4950.000-CFS	V1,50=	7630.000-CFS	V3,2=	1210.000-CFS
V3,10=	2730.000-CFS	V3,50=	4530.000-CFS	V7,2=	706.000-CFS	V7,10=	1620.000-CFS
V7,50=	2670.000-CFS	D10=	69.900-CFS	P500=	81100.000-CFS	WRC SKEW=	-0.617-LOG10
WRC MEAN=	3.869-LOG10	WRC SD=	0.286-LOG10	YRSPK=	63.000-YEARS	YRSHISPK=	73.000-YEARS
(? 200?)=	92578.000-						

09472000 **8** SAN PEDRO RIVER NEAR REDINGTON, ARIZ. 4 4 781007 86

AREA=	2939.000-SQ MI	CONTDA=	2939.000-SQ MI	SLOPE=	15.300-FT/MI	LENGTH=	124.200-MI
ELEV=	4660.000-FT	EL6000=	3.400-%	STORAGE=	0.100-%	FOREST=	13.000-%
SOIL INF=	1.790-IN	AZIMUTH=	350.000-DEC. DEG	LAT=	31.700-DEC. DEG	LONG=	110.300-DEC. DEG
LAT GAGE=	32.381-DEC. DEG	LNG GAGE=	110.446-DEC. DEG	PRECIP=	15.500-IN	I24,2=	1.900-IN
I24,10=	2.780-IN	I24,50=	3.740-IN	PRC10=	0.650-IN	PRC11=	0.560-IN
PRC12=	0.940-IN	PRC1=	0.990-IN	PRC2=	0.740-IN	PRC3=	0.680-IN
PRC4=	0.340-IN	PRC5=	0.160-IN	PRC6=	0.900-IN	PRC7=	4.180-IN
PRC8=	3.870-IN	PRC9=	1.490-IN	SNOFALL=	12.600-IN	JANMIN=	28.000-FAHR
P1,25=	4430.000-CFS	P2=	8710.000-CFS	P5=	16800.000-CFS	P10=	23400.000-CFS
P25=	33100.000-CFS	P50=	41400.000-CFS	P100=	50400.000-CFS	P200=	60200.000-CFS
MEANPK=	3.908-LOG10	SDPK=	3131.000-LOG10	SKEWPK=	-0.588-LOG10	QA=	48.100-CFS
SDQA=	42.200-CFS	Q10=	6.690-CFS	Q11=	1.220-CFS	Q12=	14.100-CFS
Q1=	10.000-CFS	Q2=	4.380-CFS	Q3=	4.460-CFS	Q4=	1.380-CFS
Q5=	0.490-CFS	Q6=	1.140-CFS	Q7=	138.000-CFS	Q8=	326.000-CFS
Q9=	61.800-CFS	SDQ10=	9.900-CFS	SDQ11=	1.240-CFS	SDQ12=	53.100-CFS
SDQ1=	30.500-CFS	SDQ2=	8.650-CFS	SDQ3=	7.330-CFS	SDQ4=	3.080-CFS
SDQ5=	1.360-CFS	SDQ6=	2.940-CFS	SDQ7=	141.000-CFS	SDQ8=	367.000-CFS
SDQ9=	96.200-CFS	V1,2=	2000.000-CFS	V1,10=	5380.000-CFS	V1,50=	9870.000-CFS
V3,2=	1100.000-CFS	V3,10=	2870.000-CFS	V3,50=	5270.000-CFS	V7,2=	621.000-CFS
V7,10=	1780.000-CFS	V7,50=	3480.000-CFS	D10=	45.300-CFS	P500=	74600.000-CFS
WRC SKEW=	-0.117-LOG10	WRC MEAN=	3.933-LOG10	WRC SD=	0.343-LOG10	YRSPK=	0.000E+00-YEARS
YRSHISPK=	73.000-YEARS	(? 200?)=	92578.000-				

09480000 **9** SANTA CRUZ RIVER NEAR LOCHIEL, ARIZ. 4 4 781007 86

AREA=	82.200-SQ MI	CONTDA=	82.200-SQ MI	SLOPE=	42.200-FT/MI	LENGTH=	12.000-MI
ELEV=	5150.000-FT	EL6000=	0.200-%	STORAGE=	0.200-%	FOREST=	31.000-%
SOIL INF=	2.290-IN	AZIMUTH=	180.000-DEC. DEG	LAT=	31.400-DEC. DEG	LONG=	110.600-DEC. DEG
LAT GAGE=	31.355-DEC. DEG	LNG GAGE=	110.589-DEC. DEG	PRECIP=	18.200-IN	I24,2=	1.900-IN
I24,10=	3.180-IN	I24,50=	4.290-IN	PRC10=	0.780-IN	PRC11=	0.730-IN
PRC12=	1.160-IN	PRC1=	1.220-IN	PRC2=	1.020-IN	PRC3=	0.970-IN
PRC4=	0.460-IN	PRC5=	0.130-IN	PRC6=	0.710-IN	PRC7=	5.100-IN
PRC8=	4.490-IN	PRC9=	1.730-IN	SNOFALL=	13.800-IN	JANMIN=	27.000-FAHR
P1,25=	788.000-CFS	P2=	1700.000-CFS	P5=	3510.000-CFS	P10=	5040.000-CFS
P25=	7330.000-CFS	P50=	9270.000-CFS	P100=	11400.000-CFS	P200=	13700.000-CFS
MEANPK=	3.155-LOG10	SDPK=	0.567-LOG10	SKEWPK=	-2.185-LOG10	QA=	3.590-CFS
SDQA=	4.080-CFS	Q10=	1.560-CFS	Q11=	0.696-CFS	Q12=	0.708-CFS
Q1=	0.707-CFS	Q2=	0.664-CFS	Q3=	0.526-CFS	Q4=	0.315-CFS
Q5=	0.097-CFS	Q6=	0.030-CFS	Q7=	9.810-CFS	Q8=	21.100-CFS
Q9=	6.330-CFS	SDQ10=	2.170-CFS	SDQ11=	0.846-CFS	SDQ12=	0.777-CFS
SDQ1=	0.840-CFS	SDQ2=	1.050-CFS	SDQ3=	0.912-CFS	SDQ4=	0.565-CFS
SDQ5=	0.170-CFS	SDQ6=	0.075-CFS	SDQ7=	17.300-CFS	SDQ8=	38.000-CFS
SDQ9=	10.800-CFS	V1,2=	168.000-CFS	V1,10=	540.000-CFS	V1,50=	738.000-CFS
V3,2=	81.700-CFS	V3,10=	301.000-CFS	V3,50=	469.000-CFS	V7,2=	43.700-CFS
V7,10=	176.000-CFS	V7,50=	309.000-CFS	D10=	3.700-CFS	P500=	17100.000-CFS
WRC SKEW=	-0.202-LOG10	WRC MEAN=	3.217-LOG10	WRC SD=	0.386-LOG10	YRSPK=	30.000-YEARS
YRSHISPK=	30.000-YEARS	(? 200?)=	92578.000-				

09480500 **10** SANTA CRUZ RIVER NEAR NOGALES, ARIZ. 4 4 781007 86

AREA=	533.000-SQ MI	CONTDA=	533.000-SQ MI	SLOPE=	26.000-FT/MI	LENGTH=	51.200-MI
ELEV=	4850.000-FT	EL6000=	1.500-%	STORAGE=	0.000E+00-%	FOREST=	28.000-%
SOIL INF=	2.060-IN	AZIMUTH=	240.000-DEC. DEG	LAT=	31.300-DEC. DEG	LONG=	110.700-DEC. DEG
LAT GAGE=	31.344-DEC. DEG	LNG GAGE=	110.851-DEC. DEG	PRECIP=	18.700-IN	I24,2=	2.000-IN
I24,10=	3.170-IN	I24,50=	4.260-IN	PRC10=	0.790-IN	PRC11=	0.790-IN
PRC12=	1.250-IN	PRC1=	1.250-IN	PRC2=	1.050-IN	PRC3=	0.940-IN
PRC4=	0.430-IN	PRC5=	0.130-IN	PRC6=	0.640-IN	PRC7=	4.980-IN
PRC8=	4.560-IN	PRC9=	1.830-IN	SNOFALL=	13.700-IN	JANMIN=	27.000-FAHR
P1,25=	2340.000-CFS	P2=	4320.000-CFS	P5=	7930.000-CFS	P10=	10900.000-CFS
P25=	15200.000-CFS	P50=	18800.000-CFS	P100=	22900.000-CFS	P200=	27300.000-CFS
MEANPK=	3.634-LOG10	SDPK=	0.314-LOG10	SKEWPK=	0.346-LOG10	QA=	22.300-CFS
SDQA=	20.200-CFS	Q10=	6.350-CFS	Q11=	5.560-CFS	Q12=	19.600-CFS
Q1=	23.200-CFS	Q2=	20.000-CFS	Q3=	9.070-CFS	Q4=	3.600-CFS
Q5=	1.080-CFS	Q6=	1.220-CFS	Q7=	42.600-CFS	Q8=	108.000-CFS
Q9=	25.700-CFS	SDQ10=	9.170-CFS	SDQ11=	6.550-CFS	SDQ12=	59.100-CFS
SDQ1=	51.500-CFS	SDQ2=	39.200-CFS	SDQ3=	8.870-CFS	SDQ4=	2.710-CFS
SDQ5=	0.822-CFS	SDQ6=	3.100-CFS	SDQ7=	48.300-CFS	SDQ8=	144.000-CFS
SDQ9=	36.700-CFS	V1,2=	626.000-CFS	V1,10=	1950.000-CFS	V1,50=	3910.000-CFS
V3,2=	354.000-CFS	V3,10=	1130.000-CFS	V3,50=	2360.000-CFS	V7,2=	219.000-CFS
V7,10=	703.000-CFS	V7,50=	1470.000-CFS	D10=	34.600-CFS	P500=	33800.000-CFS
WRC SKEW=	-0.025-LOG10	WRC MEAN=	3.634-LOG10	WRC SD=	0.314-LOG10	YRSPK=	49.000-YEARS
YRSHISPK=	49.000-YEARS	(? 200?)=	92578.000-				

09482000 **11** SANTA CRUZ RIVER AT CONTINENTAL, ARIZ. 4 4 811216 84

AREA=	1662.000-SQ MI	CONTDA=	1662.000-SQ MI	SLOPE=	21.000-FT/MI	LENGTH=	99.200-MI
ELEV=	4350.000-FT	FL6000=	2.100-%	STORAGE=	0.000E+00-%	FOREST=	22.000-%
SOIL INF=	2.040-IN	AZIMUTH=	310.000-DEC. DEG	LAT=	31.500-DEC. DEG	LONG=	110.800-DEC. DEG
LAT GAGE=	31.853-DEC. DEG	LNG GAGE=	110.978-DEC. DEG	PRECIP=	18.100-IN	I24,2=	2.100-IN
I24,10=	3.180-IN	I24,50=	4.270-IN	PRC10=	0.870-IN	PRC11=	1.100-IN
PRC12=	1.410-IN	PRC1=	1.500-IN	PRC2=	1.160-IN	PRC3=	1.010-IN
PRC4=	0.540-IN	PRC5=	0.250-IN	PRC6=	0.510-IN	PRC7=	4.010-IN
PRC8=	4.090-IN	PRC9=	1.860-IN	SNOFALL=	9.700-IN	JANMIN=	30.000-FAHR
P1,25=	2270.000-CFS	P2=	4620.000-CFS	P5=	9050.000-CFS	P10=	12700.000-CFS
P25=	18000.000-CFS	P50=	22400.000-CFS	P100=	27100.000-CFS	P200=	32300.000-CFS
MEANPK=	3.653-LOG10	SDPK=	0.357-LOG10	SKEWPK=	-0.119-LOG10	QA=	19.300-CFS
SDQA=	23.200-CFS	Q10=	2.280-CFS	Q11=	0.202-CFS	Q12=	21.200-CFS
Q1=	12.000-CFS	Q2=	9.410-CFS	Q3=	0.328-CFS	Q4=	0.000-CFS
Q6=	0.408-CFS	Q7=	40.500-CFS	Q8=	119.000-CFS	Q9=	23.600-CFS
SDQ10=	5.270-CFS	SDQ11=	0.930-CFS	SDQ12=	89.900-CFS	SDQ1=	41.600-CFS
SDQ2=	44.000-CFS	SDQ3=	1.540-CFS	SDQ4=	0.001-CFS	SDQ6=	1.060-CFS
SDQ7=	51.300-CFS	SDQ8=	176.000-CFS	SDQ9=	59.600-CFS	V1,2=	999.000-CFS
V1,10=	3760.000-CFS	V1,50=	6770.000-CFS	V3,2=	494.000-CFS	V3,10=	1950.000-CFS
V3,50=	3620.000-CFS	V7,2=	261.000-CFS	V7,10=	1110.000-CFS	V7,50=	2190.000-CFS
D10=	0.300-CFS	P500=	39700.000-CFS	WRC SKEW=	-0.190-LOG10	WRC MEAN=	3.653-LOG10
WRC SD=	0.357-LOG10	YRSPK=	36.000-YEARS	YRSHISPK=	36.000-YEARS	(? 200?)=	92578.000-

09482500 **12** SANTA CRUZ RIVER AT TUCSON, ARIZ 4 4 781007 86

AREA=	2222.000-SQ MI	CONTDA=	2222.000-SQ MI	SLOPE=	20.100-FT/MI	LENGTH=	127.700-MI
ELEV=	4050.000-FT	EL6000=	1.800-%	STORAGE=	0.100-%	FOREST=	17.000-%
SOIL INF=	1.950-IN	AZIMUTH=	330.000-DEC. DEG	LAT=	31.600-DEC. DEG	LONG=	110.900-DEC. DEG
LAT GAGE=	32.221-DEC. DEG	LNG GAGE=	110.981-DEC. DEG	PRECIP=	16.900-IN	I24,2=	2.100-IN
I24,10=	3.120-IN	I24,50=	4.200-IN	PRC10=	0.810-IN	PRC11=	1.030-IN
PRC12=	1.320-IN	PRC1=	1.220-IN	PRC2=	1.080-IN	PRC3=	0.950-IN
PRC4=	0.510-IN	PRC5=	0.240-IN	PRC6=	0.470-IN	PRC7=	3.750-IN
PRC8=	3.820-IN	PRC9=	1.740-IN	SNOFALL=	8.600-IN	JANMIN=	32.000-FAHR
P1,25=	2950.000-CFS	P2=	5140.000-CFS	P5=	8820.000-CFS	P10=	11600.000-CFS
P25=	15600.000-CFS	P50=	18800.000-CFS	P100=	22100.000-CFS	P200=	25700.000-CFS
MEANPK=	3.712-LOG10	SDPK=	0.286-LOG10	SKEWPK=	-0.072-LOG10	QA=	22.500-CFS
SDQA=	20.700-CFS	Q10=	2.320-CFS	Q11=	2.400-CFS	Q12=	24.100-CFS
Q1=	17.100-CFS	Q2=	8.750-CFS	Q3=	1.570-CFS	Q4=	0.105-CFS
Q5=	0.081-CFS	Q6=	1.430-CFS	Q7=	57.600-CFS	Q8=	114.000-CFS
Q9=	37.700-CFS	SDQ10=	6.210-CFS	SDQ11=	6.550-CFS	SDQ12=	129.000-CFS
SDQ1=	62.100-CFS	SDQ2=	35.200-CFS	SDQ3=	7.420-CFS	SDQ4=	0.308-CFS
SDQ5=	0.356-CFS	SDQ6=	4.790-CFS	SDQ7=	78.000-CFS	SDQ8=	123.000-CFS
SDQ9=	57.000-CFS	V1,2=	1490.000-CFS	V1,10=	4470.000-CFS	V1,50=	8030.000-CFS
V3,2=	718.000-CFS	V3,10=	2280.000-CFS	V3,50=	4350.000-CFS	V7,2=	385.000-CFS
V7,10=	1220.000-CFS	V7,50=	2260.000-CFS	D10=	4.100-CFS	P500=	30800.000-CFS
WRC SKEW=	-0.127-LOG10	WRC MEAN=	3.707-LOG10	WRC SD=	0.282-LOG10	YRSPK=	64.000-YEARS
YRSHISPK=	75.000-YEARS	(? 200?)=	92578.000-				

09486000 **13** RILLITO CREEK NEAR TUCSON, ARIZ. 4 4 811216 85

AREA=	892.000-SQ MI	CONTDA=	692.000-SQ MI	SLOPE=	40.100-FT/MI	LENGTH=	72.500-MI
ELEV=	4400.000-FT	EL6000=	8.000-%	STORAGE=	0.000E+00-%	FOREST=	22.000-%
SOIL INF=	1.460-IN	AZIMUTH=	350.000-DEC. DEG	LAT=	32.100-DEC. DEG	LONG=	110.700-DEC. DEG
LAT GAGE=	32.295-DEC. DEG	LNG GAGE=	110.984-DEC. DEG	PRECIP=	15.500-IN	I24,2=	1.900-IN
I24,10=	2.920-IN	I24,50=	3.960-IN	PRC10=	0.770-IN	PRC11=	0.960-IN
PRC12=	1.180-IN	PRC1=	1.150-IN	PRC2=	1.050-IN	PRC3=	0.820-IN
PRC4=	0.470-IN	PRC5=	0.220-IN	PRC6=	0.560-IN	PRC7=	3.460-IN
PRC8=	3.220-IN	PRC9=	1.580-IN	SNOFALL=	11.100-IN	JANMIN=	31.600-FAHR
P1,25=	2590.000-CFS	P2=	5070.000-CFS	P5=	9420.000-CFS	P10=	12700.000-CFS
P25=	17300.000-CFS	P50=	20900.000-CFS	P100=	24700.000-CFS	P200=	28600.000-CFS
MEANPK=	3.689-LOG10	SDPK=	0.335-LOG10	SKEWPK=	-0.378-LOG10	QA=	14.000-CFS
SDQA=	17.100-CFS	Q10=	0.710-CFS	Q11=	2.200-CFS	Q12=	19.200-CFS
Q1=	20.400-CFS	Q2=	16.800-CFS	Q3=	15.100-CFS	Q4=	0.785-CFS
Q5=	1.310-CFS	Q6=	0.613-CFS	Q7=	33.000-CFS	Q8=	39.200-CFS
Q9=	16.600-CFS	SDQ10=	1.710-CFS	SDQ11=	8.060-CFS	SDQ12=	81.500-CFS
SDQ1=	65.400-CFS	SDQ2=	44.000-CFS	SDQ3=	31.400-CFS	SDQ4=	2.440-CFS
SDQ5=	9.460-CFS	SDQ6=	2.000-CFS	SDQ7=	89.000-CFS	SDQ8=	48.800-CFS
SDQ9=	46.000-CFS	V1,2=	908.000-CFS	V1,10=	3000.000-CFS	V1,50=	5560.000-CFS
V3,2=	399.000-CFS	V3,10=	1640.000-CFS	V3,50=	3740.000-CFS	V7,2=	195.000-CFS
V7,10=	816.000-CFS	V7,50=	1940.000-CFS	D10=	0.200-CFS	P500=	34000.000-CFS
WRC SKEW=	-0.300-LOG10	WRC MEAN=	3.689-LOG10	WRC SD=	0.335-LOG10	YRSPK=	65.000-YEARS
YRSHISPK=	65.000-YEARS						

09486500 **14** SANTA ROSA WASH NR VAIVA VO, ARIZ. 4 4 770822 83

AREA=	1782.000-SQ MI	CONTDA=	1782.000-SQ MI	SLOPE=	25.500-FT/MI	LENGTH=	55.000-MI
ELEV=	2340.000-FT	EL6000=	0.000E+00-%	STORAGE=	0.000E+00-%	FOREST=	0.300-%
SOIL INF=	1.980-IN	AZIMUTH=	20.000-DEC. DEG	LAT=	32.300-DEC. DEG	LONG=	111.900-DEC. DEG
LAT GAGE=	32.667-DEC. DEG	LNG GAGE=	111.927-DEC. DEG	PRECIP=	10.200-IN	I24,2=	1.900-IN
I24,10=	3.110-IN	I24,50=	4.280-IN	PRC10=	0.550-IN	PRC11=	0.800-IN
PRC12=	0.960-IN	PRC1=	0.980-IN	PRC2=	0.870-IN	PRC3=	0.740-IN
PRC4=	0.270-IN	PRC5=	0.160-IN	PRC6=	0.200-IN	PRC7=	1.980-IN
PRC8=	1.760-IN	PRC9=	0.960-IN	SNOFALL=	0.700-IN	JANMIN=	34.000-FAHR
P1,25=	456.000-CFS	P2=	1450.000-CFS	P5=	4490.000-CFS	P10=	8000.000-CFS
P25=	14700.000-CFS	P50=	21600.000-CFS	P100=	30400.000-CFS	P200=	41500.000-CFS
MEANPK=	3.153-LOG10	SDPK=	0.591-LOG10	SKEWPK=	1.187-LOG10	QA=	18.000-CFS
SDQA=	19.300-CFS	Q10=	10.200-CFS	Q11=	12.800-CFS	Q12=	9.640-CFS
Q1=	1.460-CFS	Q2=	11.800-CFS	Q3=	3.060-CFS	Q4=	0.144-CFS
Q5=	0.000-CFS	Q6=	0.851-CFS	Q7=	34.400-CFS	Q8=	56.400-CFS
Q9=	75.300-CFS	SDQ10=	25.400-CFS	SDQ11=	41.400-CFS	SDQ12=	25.600-CFS
SDQ1=	3.140-CFS	SDQ2=	26.700-CFS	SDQ3=	10.900-CFS	SDQ4=	0.518-CFS
SDQ5=	0.002-CFS	SDQ6=	1.780-CFS	SDQ7=	42.900-CFS	SDQ8=	69.300-CFS
SDQ9=	230.000-CFS	V1,2=	688.000-CFS	V1,10=	5380.000-CFS	V1,50=	28600.000-CFS
V3,2=	410.000-CFS	V3,10=	2620.000-CFS	V3,50=	10900.000-CFS	V7,2=	205.000-CFS
V7,10=	1270.000-CFS	V7,50=	4830.000-CFS	D10=	0.260-CFS	P500=	60400.000-CFS
WRC SKEW=	-0.100-LOG10	WRC MEAN=	3.153-LOG10	WRC SD=	0.591-LOG10		

09489200 **15** PACHETA CREEK NEAR MAVERICK, ARIZ. 4 4 811216 88

AREA=	14.800-SQ MI	CONTDA=	14.600-SQ MI	SLOPE=	160.400-FT/MI	LENGTH=	14.200-MI
ELEV=	8810.000-FT	FL6000=	100.000-%	STORAGE=	0.000E+00-%	FOREST=	88.000-%
SOIL INF=	3.000-IN	AZIMUTH=	180.000-DEC. DEG	LAT=	33.800-DEC. DEG	LONG=	109.500-DEC. DEG
LAT GAGE=	33.740-DEC. DEG	LNG GAGE=	109.540-DEC. DEG	PRECIP=	30.300-IN	I24,2=	2.200-IN
I24,10=	3.850-IN	I24,50=	5.180-IN	PRC10=	2.460-IN	PRC11=	1.610-IN
PRC12=	2.090-IN	PRC1=	2.280-IN	PRC2=	2.000-IN	PRC3=	2.210-IN
PRC4=	1.270-IN	PRC5=	0.910-IN	PRC6=	1.180-IN	PRC7=	5.550-IN
PRC8=	5.460-IN	PRC9=	3.150-IN	SNOFALL=	80.000-IN	JANMIN=	9.000-FAHR
P1,25=	54.000-CFS	P2=	100.000-CFS	P5=	181.000-CFS	P10=	243.000-CFS
P25=	329.000-CFS	P50=	399.000-CFS	P100=	472.000-CFS	P200=	548.000-CFS
MEANPK=	1.992-LOG10	SDPK=	0.313-LOG10	SKEWPK=	-0.449-LOG10	QA=	7.850-CFS
SDQA=	5.490-CFS	Q10=	2.650-CFS	Q11=	1.890-CFS	Q12=	2.520-CFS
Q1=	3.630-CFS	Q2=	4.530-CFS	Q3=	17.500-CFS	Q4=	38.900-CFS
Q5=	11.600-CFS	Q6=	1.500-CFS	Q7=	1.750-CFS	Q8=	3.290-CFS
Q9=	4.670-CFS	SDQ10=	3.670-CFS	SDQ11=	1.220-CFS	SDQ12=	3.400-CFS
SDQ1=	5.060-CFS	SDQ2=	4.270-CFS	SDQ3=	19.400-CFS	SDQ4=	36.100-CFS
SDQ5=	13.800-CFS	SDQ6=	1.410-CFS	SDQ7=	1.960-CFS	SDQ8=	3.320-CFS
SDQ9=	5.120-CFS	M7,2=	0.600-CFS	M7,10=	0.200-CFS	M7,20=	0.150-CFS
V1,2=	80.600-CFS	V1,10=	189.000-CFS	V1,50=	255.000-CFS	V3,2=	70.700-CFS
V3,10=	178.000-CFS	V3,50=	254.000-CFS	V7,2=	59.700-CFS	V7,10=	163.000-CFS
V7,50=	248.000-CFS	D10=	18.500-CFS	P500=	656.000-CFS	WRC SKEW=	-0.200-LOG10
WRC MEAN=	1.992-LOG10	WRC SD=	0.313-LOG10	YRSPK=	22.000-YEARS	YRSHTSPK=	22.000-YEARS

09489700 **16** BIG BONITO CREEK NR FORT APACHE, ARIZ. 4 4 820128 86

AREA=	119.000-SQ MI	CONTDA=	119.000-SQ MI	SLOPE=	105.600-FT/MI	LENGTH=	33.500-MI
ELEV=	7920.000-FT	FL6000=	100.000-%	STORAGE=	0.000E+00-%	FOREST=	95.000-%
SOIL INF=	3.000-IN	AZIMUTH=	230.000-DEC. DEG	LAT=	33.800-DEC. DEG	LONG=	109.700-DEC. DEG
LAT GAGE=	33.667-DEC. DEG	LNG GAGE=	109.846-DEC. DEG	PRECIP=	27.900-IN	I24,2=	2.500-IN
I24,10=	3.750-IN	I24,50=	4.840-IN	PRC10=	2.030-IN	PRC11=	1.450-IN
PRC12=	2.700-IN	PRC1=	2.930-IN	PRC2=	2.450-IN	PRC3=	2.790-IN
PRC4=	1.480-IN	PRC5=	0.780-IN	PRC6=	0.640-IN	PRC7=	3.540-IN
PRC8=	4.520-IN	PRC9=	2.560-IN	SNOFALL=	77.500-IN	JANMIN=	11.000-FAHR
P1,25=	299.000-CFS	P2=	683.000-CFS	P5=	1500.000-CFS	P10=	2220.000-CFS
P25=	3330.000-CFS	P50=	4300.000-CFS	P100=	5400.000-CFS	P200=	6600.000-CFS
MEANPK=	2.838-LOG10	SDPK=	0.427-LOG10	SKEWPK=	-0.003-LOG10	QA=	59.200-CFS
SDQA=	31.800-CFS	Q10=	22.100-CFS	Q11=	25.300-CFS	Q12=	35.600-CFS
Q1=	41.100-CFS	Q2=	52.400-CFS	Q3=	117.000-CFS	Q4=	206.000-CFS
Q5=	85.700-CFS	Q6=	20.400-CFS	Q7=	17.600-CFS	Q8=	49.700-CFS
Q9=	39.000-CFS	SDQ10=	21.300-CFS	SDQ11=	13.400-CFS	SDQ12=	45.200-CFS
SDQ1=	41.700-CFS	SDQ2=	40.500-CFS	SDQ3=	106.000-CFS	SDQ4=	169.000-CFS
SDQ5=	77.200-CFS	SDQ6=	15.900-CFS	SDQ7=	11.000-CFS	SDQ8=	40.100-CFS
SDQ9=	34.400-CFS	M7,2=	5.000-CFS	M7,10=	4.600-CFS	M7,20=	4.400-CFS
V1,2=	446.000-CFS	V1,10=	1010.000-CFS	V1,50=	1430.000-CFS	V3,2=	388.000-CFS
V3,10=	820.000-CFS	V3,50=	1120.000-CFS	V7,2=	311.000-CFS	V7,10=	743.000-CFS
V7,50=	1150.000-CFS	D10=	151.000-CFS	P500=	8400.000-CFS	WRC SKEW=	-0.190-LOG10
WRC MEAN=	2.822-LOG10	WRC SD=	0.416-LOG10	YRSPK=	23.000-YEARS	YRSHTSPK=	27.000-YEARS

09491000 17 NORTH FORK WHITE RIVER NEAR MCNARY, ARIZ. 4 4 820128 88

AREA=	66.000-SQ MI	CONTDA=	66.000-SQ MI	SLOPE=	116.600-FT/MI	LENGTH=	21.700-MI
ELEV=	9190.000-FT	EL6000=	100.000-%	STORAGE=	0.100-%	FOREST=	83.000-%
SOIL INF=	3.000-IN	AZIMUTH=	310.000-DEC. DEG	LAT=	34.000-DEC. DEG	LONG=	109.600-DEC. DEG
LAT GAGE=	34.046-DEC. DEG	LNG GAGE=	109.737-DEC. DEG	PRECIP=	32.200-IN	I24,2=	2.900-IN
I24,10=	4.160-IN	I24,50=	5.470-IN	PRC10=	2.350-IN	PRC11=	1.670-IN
PRC12=	3.120-IN	PRC1=	3.380-IN	PRC2=	2.830-IN	PRC3=	3.220-IN
PRC4=	1.700-IN	PRC5=	0.900-IN	PRC6=	0.740-IN	PRC7=	4.090-IN
PRC8=	5.210-IN	PRC9=	2.960-IN	SNOFALL=	80.000-IN	JANMIN=	8.000-FAHR
P1,25=	219.000-CFS	P2=	393.000-CFS	P5=	667.000-CFS	P10=	911.000-CFS
P25=	1220.000-CFS	P50=	1470.000-CFS	P100=	1730.000-CFS	P200=	2010.000-CFS
MEANPK=	2.586-LOG10	SDPK=	0.296-LOG10	SKEWPK=	0.202-LOG10	QA=	41.500-CFS
SDQA=	20.200-CFS	Q10=	17.600-CFS	Q11=	18.300-CFS	Q12=	17.400-CFS
Q1=	20.900-CFS	Q2=	19.600-CFS	Q3=	41.100-CFS	Q4=	122.000-CFS
Q5=	97.700-CFS	Q6=	49.300-CFS	Q7=	22.700-CFS	Q8=	33.700-CFS
Q9=	37.300-CFS	SDQ10=	7.940-CFS	SDQ11=	8.090-CFS	SDQ12=	10.500-CFS
SDQ1=	18.100-CFS	SDQ2=	8.080-CFS	SDQ3=	31.100-CFS	SDQ4=	92.000-CFS
SDQ5=	74.400-CFS	SDQ6=	46.300-CFS	SDQ7=	15.500-CFS	SDQ8=	18.800-CFS
SDQ9=	31.400-CFS	M7,2=	9.380-CFS	M7,10=	6.380-CFS	M7,20=	5.780-CFS
V1,2=	280.000-CFS	V1,10=	678.000-CFS	V1,50=	1190.000-CFS	V3,2=	242.000-CFS
V3,10=	436.000-CFS	V3,50=	1010.000-CFS	V7,2=	194.000-CFS	V7,10=	482.000-CFS
V7,50=	816.000-CFS	D10=	94.000-CFS	P500=	2400.000-CFS	WRC SKEW=	-0.160-LOG10
WRC MEAN=	2.586-LOG10	WRC SD=	0.296-LOG10	YRSPK=	33.000-YEARS	YRSHISPK=	33.000-YEARS

09496000 18 CORDUROY CREEK NEAR MOUTH, NEAR, SHOW LOW, ARIZ. 4 4 770920 86

AREA=	203.000-SQ MI	CONTDA=	203.000-SQ MI	SLOPE=	71.200-FT/MI	LENGTH=	31.500-MI
ELEV=	6370.000-FT	EL6000=	85.000-%	STORAGE=	0.100-%	FOREST=	93.000-%
SOIL INF=	3.000-IN	AZIMUTH=	260.000-DEC. DEG	LAT=	34.100-DEC. DEG	LONG=	110.100-DEC. DEG
LAT GAGE=	34.018-DEC. DEG	LNG GAGE=	110.242-DEC. DEG	PRECIP=	21.700-IN	I24,2=	2.100-IN
I24,10=	3.230-IN	I24,50=	4.480-IN	PRC10=	1.490-IN	PRC11=	1.280-IN
PRC12=	1.910-IN	PRC1=	2.130-IN	PRC2=	1.760-IN	PRC3=	2.040-IN
PRC4=	1.170-IN	PRC5=	0.590-IN	PRC6=	0.520-IN	PRC7=	3.080-IN
PRC8=	3.600-IN	PRC9=	2.080-IN	SNOFALL=	66.400-IN	JANMIN=	17.000-FAHR
P1,25=	255.000-CFS	P2=	1020.000-CFS	P5=	3810.000-CFS	P10=	7350.000-CFS
P25=	14500.000-CFS	P50=	22200.000-CFS	P100=	32300.000-CFS	P200=	45300.000-CFS
MEANPK=	2.987-LOG10	SDPK=	0.699-LOG10	SKEWPK=	-0.137-LOG10	QA=	18.800-CFS
SDQA=	20.500-CFS	Q10=	2.660-CFS	Q11=	8.190-CFS	Q12=	35.200-CFS
Q1=	52.700-CFS	Q2=	23.800-CFS	Q3=	50.400-CFS	Q4=	18.500-CFS
Q5=	8.540-CFS	Q6=	6.560-CFS	Q7=	6.330-CFS	Q8=	7.740-CFS
Q9=	4.270-CFS	SDQ10=	1.760-CFS	SDQ11=	22.900-CFS	SDQ12=	88.800-CFS
SDQ1=	114.000-CFS	SDQ2=	40.600-CFS	SDQ3=	52.000-CFS	SDQ4=	23.100-CFS
SDQ5=	9.480-CFS	SDQ6=	7.730-CFS	SDQ7=	6.790-CFS	SDQ8=	5.750-CFS
SDQ9=	4.190-CFS	M7,2=	1.390-CFS	M7,10=	1.020-CFS	M7,20=	0.927-CFS
V1,2=	306.000-CFS	V1,10=	3220.000-CFS	V1,50=	13500.000-CFS	V3,2=	175.000-CFS
V3,10=	1580.000-CFS	V3,50=	5790.000-CFS	V7,2=	103.000-CFS	V7,10=	921.000-CFS
V7,50=	3450.000-CFS	D10=	29.100-CFS	P500=	67600.000-CFS	WRC SKEW=	-0.200-LOG10
WRC MEAN=	2.987-LOG10	WRC SD=	0.699-LOG10				

09497500 **19** SALT RIVER NEAR CHRYSOTILE, ARIZ. 4 4 811216 88

AREA=	2849.000-SQ MI	CONTDA=	2849.000-SQ MI	SLOPE=	31.900-FT/MI	LENGTH=	154.600-MI
ELEV=	6730.000-FT	EL6000=	67.000-%	STORAGE=	0.100-%	FOREST=	81.000-%
SOIL INF=	2.980-IN	AZIMUTH=	260.000-DEC. DEG	LAT=	33.900-DEC. DEG	LONG=	109.900-DEC. DEG
LAT GAGE=	33.798-DEC. DEG	LNG GAGE=	110.499-DEC. DEG	PRECIP=	22.800-IN	I24,2=	2.200-IN
I24,10=	3.250-IN	I24,50=	4.360-IN	PRC10=	1.570-IN	PRC11=	1.340-IN
PRC12=	2.000-IN	PRC1=	2.230-IN	PRC2=	1.870-IN	PRC3=	2.140-IN
PRC4=	1.230-IN	PRC5=	0.620-IN	PRC6=	0.550-IN	PRC7=	3.240-IN
PRC8=	3.780-IN	PRC9=	2.190-IN	SNOFALL=	54.100-IN	JANMIN=	15.000-FAHR
P1,25=	3880.000-CFS	P2=	8530.000-CFS	P5=	19700.000-CFS	P10=	31100.000-CFS
P25=	51500.000-CFS	P50=	71900.000-CFS	P100=	97600.000-CFS	P200=	130000.000-CFS
MEANPK=	3.963-LOG10	SDPK=	0.428-LOG10	SKEWPK=	0.268-LOG10	QA=	590.000-CFS
SDQA=	366.000-CFS	Q10=	238.000-CFS	Q11=	225.000-CFS	Q12=	396.000-CFS
Q1=	515.000-CFS	Q2=	729.000-CFS	Q3=	1280.000-CFS	Q4=	1640.000-CFS
Q5=	790.000-CFS	Q6=	273.000-CFS	Q7=	218.000-CFS	Q8=	438.000-CFS
Q9=	358.000-CFS	SDQ10=	167.000-CFS	SDQ11=	119.000-CFS	SDQ12=	663.000-CFS
SDQ1=	765.000-CFS	SDQ2=	617.000-CFS	SDQ3=	991.000-CFS	SDQ4=	1240.000-CFS
SDQ5=	775.000-CFS	SDQ6=	206.000-CFS	SDQ7=	106.000-CFS	SDQ8=	264.000-CFS
SDQ9=	272.000-CFS	M7,2=	107.000-CFS	M7,10=	69.000-CFS	M7,20=	61.000-CFS
V1,2=	5230.000-CFS	V1,10=	18900.000-CFS	V1,50=	41100.000-CFS	V3,2=	4020.000-CFS
V3,10=	12700.000-CFS	V3,50=	25800.000-CFS	V7,2=	2890.000-CFS	V7,10=	7690.000-CFS
V7,50=	14100.000-CFS	D10=	1350.000-CFS	P500=	184000.000-CFS	WRC SKEW=	0.214-LOG10
WRC MEAN=	3.946-LOG10	WRC SD=	0.420-LOG10	YRSPK=	56.000-YEARS	YRSHISPK=	75.000-YEARS

09498500 **20** SALT RIVER NEAR ROOSEVELT, ARIZ. 4 4 820430 94

AREA=	4306.000-SQ MI	CONTDA=	4306.000-SQ MI	SLOPE=	23.300-FT/MI	LENGTH=	205.600-MI
ELEV=	6190.000-FT	EL6000=	51.000-%	STORAGE=	0.100-%	FOREST=	71.000-%
SOIL INF=	2.810-IN	AZIMUTH=	250.000-DEC. DEG	LAT=	33.900-DEC. DEG	LONG=	110.200-DEC. DEG
LAT GAGE=	33.619-DEC. DEG	LNG GAGE=	110.921-DEC. DEG	PRECIP=	22.000-IN	I24,2=	2.300-IN
I24,10=	3.270-IN	I24,50=	4.420-IN	PRC10=	1.610-IN	PRC11=	1.360-IN
PRC12=	1.850-IN	PRC1=	2.200-IN	PRC2=	1.940-IN	PRC3=	2.030-IN
PRC4=	1.140-IN	PRC5=	0.590-IN	PRC6=	0.570-IN	PRC7=	2.950-IN
PRC8=	3.610-IN	PRC9=	2.110-IN	SNOFALL=	44.500-IN	JANMIN=	17.000-FAHR
P1,25=	5360.000-CFS	P2=	13000.000-CFS	P5=	32600.000-CFS	P10=	53400.000-CFS
P25=	91300.000-CFS	P50=	130000.000-CFS	P100=	179000.000-CFS	P200=	241000.000-CFS
MEANPK=	4.189-LOG10	SDPK=	0.504-LOG10	SKEWPK=	0.150-LOG10	QA=	841.000-CFS
SDQA=	623.000-CFS	Q10=	319.000-CFS	Q11=	340.000-CFS	Q12=	698.000-CFS
Q1=	1050.000-CFS	Q2=	1250.000-CFS	Q3=	1760.000-CFS	Q4=	1950.000-CFS
Q5=	925.000-CFS	Q6=	336.000-CFS	Q7=	362.000-CFS	Q8=	648.000-CFS
Q9=	476.000-CFS	SDQ10=	244.000-CFS	SDQ11=	324.000-CFS	SDQ12=	1200.000-CFS
SDQ1=	2360.000-CFS	SDQ2=	1700.000-CFS	SDQ3=	1630.000-CFS	SDQ4=	1470.000-CFS
SDQ5=	874.000-CFS	SDQ6=	257.000-CFS	SDQ7=	460.000-CFS	SDQ8=	545.000-CFS
SDQ9=	371.000-CFS	M7,2=	135.000-CFS	M7,10=	80.400-CFS	M7,20=	69.200-CFS
V1,2=	9410.000-CFS	V1,10=	38900.000-CFS	V1,50=	89100.000-CFS	V3,2=	6700.000-CFS
V3,10=	25800.000-CFS	V3,50=	59300.000-CFS	V7,2=	4470.000-CFS	V7,10=	14900.000-CFS
V7,50=	32000.000-CFS	D95=	180.000-CFS	D90=	230.000-CFS	D75=	260.000-CFS
D70=	280.000-CFS	D50=	350.000-CFS	D25=	910.000-CFS	D10=	2600.000-CFS
P500=	347000.000-CFS	WRC SKEW=	0.133-LOG10	WRC MEAN=	4.124-LOG10	WRC SD=	0.466-LOG10
YRSPK=	59.000-YEARS	YRSHISPK=	110.000-YEARS				

09499000 **21** TONTO CREEK ABOVE GUN CR, NR ROOSEVELT, ARIZ. 4 4 820128 86

AREA=	675.000-SQ MI	CONTDA=	675.000-SQ MI	SLOPE=	88.400-FT/MI	LENGTH=	48.300-MI
ELEV=	5020.000-FT	EL6000=	17.000-%	STORAGE=	0.100-%	FOREST=	65.000-%
SOIL INF=	2.970-IN	AZIMUTH=	200.000-DEC. DEG	LAT=	34.200-DEC. DEG	LONG=	111.100-DEC. DEG
LAT GAGE=	33.980-DEC. DEG	LNG GAGE=	111.303-DEC. DEG	PRECIP=	23.900-IN	I24,2=	2.800-IN
I24,10=	4.020-IN	I24,50=	5.360-IN	PRC10=	1.480-IN	PRC11=	1.960-IN
PRC12=	2.390-IN	PRC1=	2.700-IN	PRC2=	2.290-IN	PRC3=	2.050-IN
PRC4=	1.290-IN	PRC5=	0.570-IN	PRC6=	0.550-IN	PRC7=	2.990-IN
PRC8=	3.300-IN	PRC9=	2.360-IN	SNOFALL=	27.800-IN	JANMIN=	26.000-FAHR
P1,25=	4230.000-CFS	P2=	10200.000-CFS	P5=	24300.000-CFS	P10=	37800.000-CFS
P25=	60300.000-CFS	P50=	81300.000-CFS	P100=	106000.000-CFS	P200=	135000.000-CFS
MEANPK=	4.032-LOG10	SDPK=	0.468-LOG10	SKEWPK=	-0.075-LOG10	QA=	105.000-CFS
SDQA=	86300.000-CFS	Q10=	31.200-CFS	Q11=	38.900-CFS	Q12=	204.000-CFS
Q1=	232.000-CFS	Q2=	126.000-CFS	Q3=	266.000-CFS	Q4=	119.000-CFS
Q5=	29.500-CFS	Q6=	10.900-CFS	Q7=	24.900-CFS	Q8=	133.000-CFS
Q9=	41.500-CFS	SDQ10=	71.400-CFS	SDQ11=	49.000-CFS	SDQ12=	484.000-CFS
SDQ1=	359.000-CFS	SDQ2=	132.000-CFS	SDQ3=	267.000-CFS	SDQ4=	164.000-CFS
SDQ5=	29.600-CFS	SDQ6=	18.300-CFS	SDQ7=	40.200-CFS	SDQ8=	254.000-CFS
SDQ9=	77.200-CFS	M7,2=	0.600-CFS	V1,2=	3080.000-CFS	V1,10=	12600.000-CFS
V1,50=	29000.000-CFS	V3,2=	1870.000-CFS	V3,10=	7240.000-CFS	V3,50=	16200.000-CFS
V7,2=	1170.000-CFS	V7,10=	3650.000-CFS	V7,50=	6790.000-CFS	D10=	183.000-CFS
P500=	181000.000-CFS	WRC SKEW=	-0.083-LOG10	WRC MEAN=	4.004-LOG10	WRC SD=	0.451-LOG10
YRSPK=	40.000-YEARS	YRSHTSPK=	75.000-YEARS				

09504500 **22** OAK CREEK NEAR CORNVILLE, ARIZ. 4 4 790919 88

AREA=	357.000-SQ MI	CONTDA=	357.000-SQ MI	SLOPE=	85.000-FT/MI	LENGTH=	40.800-MI
ELEV=	6200.000-FT	EL6000=	64.000-%	STORAGE=	0.300-%	FOREST=	66.000-%
SOIL INF=	2.670-IN	AZIMUTH=	190.000-DEC. DEG	LAT=	35.000-DEC. DEG	LONG=	111.700-DEC. DEG
LAT GAGE=	34.766-DEC. DEG	LNG GAGE=	111.890-DEC. DEG	PRECIP=	22.600-IN	I24,2=	2.400-IN
I24,10=	3.530-IN	I24,50=	4.660-IN	PRC10=	1.670-IN	PRC11=	1.310-IN
PRC12=	1.940-IN	PRC1=	2.170-IN	PRC2=	2.220-IN	PRC3=	2.130-IN
PRC4=	1.440-IN	PRC5=	0.750-IN	PRC6=	0.540-IN	PRC7=	3.190-IN
PRC8=	3.190-IN	PRC9=	1.990-IN	SNOFALL=	53.800-IN	JANMIN=	22.000-FAHR
P1,25=	1800.000-CFS	P2=	4590.000-CFS	P5=	11200.000-CFS	P10=	17600.000-CFS
P25=	28200.000-CFS	P50=	37900.000-CFS	P100=	49400.000-CFS	P200=	62600.000-CFS
MEANPK=	3.650-LOG10	SDPK=	0.471-LOG10	SKEWPK=	-0.401-LOG10	QA=	82.300-CFS
SDQA=	43.200-CFS	Q10=	42.100-CFS	Q11=	69.000-CFS	Q12=	124.000-CFS
Q1=	73.100-CFS	Q2=	127.000-CFS	Q3=	215.000-CFS	Q4=	184.000-CFS
Q5=	30.200-CFS	Q6=	21.600-CFS	Q7=	24.900-CFS	Q8=	40.800-CFS
Q9=	37.900-CFS	SDQ10=	33.200-CFS	SDQ11=	102.000-CFS	SDQ12=	206.000-CFS
SDQ1=	59.800-CFS	SDQ2=	141.000-CFS	SDQ3=	173.000-CFS	SDQ4=	208.000-CFS
SDQ5=	11.800-CFS	SDQ6=	8.900-CFS	SDQ7=	8.060-CFS	SDQ8=	18.600-CFS
SDQ9=	21.300-CFS	M7,2=	15.100-CFS	M7,10=	11.600-CFS	M7,20=	10.600-CFS
V1,2=	1420.000-CFS	V1,10=	6250.000-CFS	V1,50=	14200.000-CFS	V3,2=	994.000-CFS
V3,10=	3750.000-CFS	V3,50=	7060.000-CFS	V7,2=	667.000-CFS	V7,10=	2140.000-CFS
V7,50=	5570.000-CFS	D10=	123.000-CFS	P500=	83100.000-CFS	WRC SKEW=	-0.152-LOG10
WRC MEAN=	3.650-LOG10	WRC SD=	0.471-LOG10	YRSPK=	38.000-YEARS	YRSHTSPK=	38.000-YEARS

09505300 **23** RATTLESNAKE CANYON NEAR RIMROCK, ARIZ. 4 4 790904 85

AREA=	24.600-SQ MI	CONTDA=	24.600-SQ MI	SLOPE=	174.100-FT/MI	LENGTH=	15.500-MI
ELEV=	6560.000-FT	EL6000=	84.000-%	STORAGE=	0.000E+00-%	FOREST=	33.000-%
SOIL INF=	3.000-IN	AZIMUTH=	260.000-DEC. DEG	LAT=	34.800-DEC. DEG	LONG=	111.600-DEC. DEG
LAT GAGE=	34.767-DEC. DEG	LNG GAGE=	111.673-DEC. DEG	PRECIP=	22.800-IN	I24,2=	2.500-IN
I24,10=	3.820-IN	I24,50=	5.120-IN	PRC10=	1.690-IN	PRC11=	1.370-IN
PRC12=	1.960-IN	PRC1=	2.190-IN	PRC2=	2.230-IN	PRC3=	2.140-IN
PRC4=	1.460-IN	PRC5=	0.750-IN	PRC6=	0.550-IN	PRC7=	3.210-IN
PRC8=	3.210-IN	PRC9=	2.010-IN	SNOFALL=	59.200-IN	JANMIN=	22.000-FAHR
P1,25=	180.000-CFS	P2=	586.000-CFS	P5=	1840.000-CFS	P10=	3310.000-CFS
P25=	6130.000-CFS	P50=	9080.000-CFS	P100=	12900.000-CFS	P200=	17700.000-CFS
MEANPK=	2.758-LOG10	SDPK=	0.600-LOG10	SKEWPK=	-0.996-LOG10	QA=	6.540-CFS
SDQA=	6.500-CFS	Q10=	0.122-CFS	Q11=	6.230-CFS	Q12=	12.100-CFS
Q1=	5.660-CFS	Q2=	11.200-CFS	Q3=	23.500-CFS	Q4=	18.900-CFS
Q5=	0.053-CFS	Q6=	0.001-CFS	Q7=	0.029-CFS	Q8=	0.208-CFS
Q9=	0.809-CFS	SDQ10=	0.366-CFS	SDQ11=	14.100-CFS	SDQ12=	25.600-CFS
SDQ1=	12.000-CFS	SDQ2=	15.700-CFS	SDQ3=	22.900-CFS	SDQ4=	34.500-CFS
SDQ5=	0.165-CFS	SDQ6=	0.004-CFS	SDQ7=	0.089-CFS	SDQ8=	0.336-CFS
SDQ9=	2.080-CFS	V1,2=	207.000-CFS	V1,10=	742.000-CFS	V1,50=	1200.000-CFS
V3,2=	127.000-CFS	V3,10=	405.000-CFS	V3,50=	632.000-CFS	V7,2=	82.800-CFS
V7,10=	236.000-CFS	V7,50=	333.000-CFS	D10=	10.700-CFS	P500=	25800.000-CFS
WRC SKEW=	-0.100-LOG10	WRC MEAN=	2.758-LOG10	WRC SD=	0.600-LOG10	YRSPK=	22.000-YEARS
YRSHISPK=	22.000-YEARS						

09507700 **24** WEBBER CR ABV W FK WEBBER CR NR PINE, AZ 4 4 770920 86

AREA=	4.920-SQ MI	CONTDA=	4.920-SQ MI	SLOPE=	634.000-FT/MI	LENGTH=	3.800-MI
ELEV=	6980.000-FT	EL6000=	91.000-%	STORAGE=	0.000E+00-%	FOREST=	100.000-%
SOIL INF=	3.000-IN	AZIMUTH=	180.000-DEC. DEG	LAT=	34.400-DEC. DEG	LONG=	111.400-DEC. DEG
LAT GAGE=	34.411-DEC. DEG	LNG GAGE=	111.372-DEC. DEG	PRECIP=	27.500-IN	I24,2=	2.800-IN
I24,10=	4.000-IN	I24,50=	5.250-IN	PRC10=	1.790-IN	PRC11=	2.030-IN
PRC12=	2.810-IN	PRC1=	2.940-IN	PRC2=	3.030-IN	PRC3=	2.670-IN
PRC4=	1.590-IN	PRC5=	0.630-IN	PRC6=	0.520-IN	PRC7=	3.190-IN
PRC8=	3.930-IN	PRC9=	2.340-IN	SNOFALL=	70.000-IN	JANMIN=	24.000-FAHR
P1,25=	29.000-CFS	P2=	94.000-CFS	P5=	295.000-CFS	P10=	529.000-CFS
P25=	977.000-CFS	P50=	1450.000-CFS	P100=	2050.000-CFS	P200=	2810.000-CFS
MEANPK=	1.962-LOG10	SDPK=	0.599-LOG10	SKEWPK=	0.336-LOG10	QA=	2.240-CFS
SDQA=	1.600-CFS	Q10=	0.424-CFS	Q11=	1.170-CFS	Q12=	3.640-CFS
Q1=	2.790-CFS	Q2=	2.240-CFS	Q3=	5.470-CFS	Q4=	7.400-CFS
Q5=	1.430-CFS	Q6=	0.516-CFS	Q7=	0.333-CFS	Q8=	0.662-CFS
Q9=	0.802-CFS	SDQ10=	0.116-CFS	SDQ11=	1.400-CFS	SDQ12=	5.380-CFS
SDQ1=	3.430-CFS	SDQ2=	2.060-CFS	SDQ3=	6.020-CFS	SDQ4=	8.690-CFS
SDQ5=	1.390-CFS	SDQ6=	0.327-CFS	SDQ7=	0.118-CFS	SDQ8=	0.381-CFS
SDQ9=	0.699-CFS	M7,2=	0.200-CFS	M7,10=	0.110-CFS	M7,20=	0.090-CFS
V1,2=	38.000-CFS	V1,10=	195.000-CFS	V1,50=	540.000-CFS	V3,2=	26.000-CFS
V3,10=	110.000-CFS	V3,50=	280.000-CFS	V7,2=	16.000-CFS	V7,10=	67.000-CFS
V7,50=	160.000-CFS	D10=	4.100-CFS	P500=	4110.000-CFS	WRC SKEW=	-0.100-LOG10
WRC MEAN=	1.962-LOG10	WRC SD=	0.599-LOG10				

09508500 **25** VERDE RIVER BLW TANGLE CR ABV HORSESHOE DAM, AZ 4 4 820128 88

AREA=	5872.000-SQ MI	CONTDA=	5499.000-SQ MI	SLOPE=	16.200-FT/MI	LENGTH=	209.200-MI
ELEV=	5470.000-FT	EL6000=	30.000-%	STORAGE=	0.200-%	FOREST=	67.000-%
SOIL INF=	2.450-IN	AZIMUTH=	160.000-DEC. DEG	LAT=	34.800-DEC. DEG	LONG=	112.000-DEC. DEG
LAT GAGE=	34.073-DEC. DEG	LNG GAGE=	111.716-DEC. DEG	PRECIP=	18.400-IN	I24,2=	2.100-IN
I24,10=	3.180-IN	I24,50=	4.210-IN	PRC10=	1.210-IN	PRC11=	1.140-IN
PRC12=	1.770-IN	PRC1=	1.950-IN	PRC2=	1.800-IN	PRC3=	1.610-IN
PRC4=	1.140-IN	PRC5=	0.520-IN	PRC6=	0.460-IN	PRC7=	2.430-IN
PRC8=	2.720-IN	PRC9=	1.660-IN	SNOFALL=	31.600-IN	JANMIN=	21.000-FAHR
P1,25=	5940.000-CFS	P2=	15300.000-CFS	P5=	37900.000-CFS	P10=	60000.000-CFS
P25=	96800.000-CFS	P50=	131000.000-CFS	P100=	172000.000-CFS	P200=	219000.000-CFS
MEANPK=	4.204-LOG10	SDPK=	0.489-LOG10	SKEWPK=	-0.273-LOG10	QA=	435.000-CFS
SDQA=	217.000-CFS	Q10=	229.000-CFS	Q11=	332.000-CFS	Q12=	712.000-CFS
Q1=	570.000-CFS	Q2=	578.000-CFS	Q3=	932.000-CFS	Q4=	754.000-CFS
Q5=	164.000-CFS	Q6=	121.000-CFS	Q7=	180.000-CFS	Q8=	406.000-CFS
Q9=	248.000-CFS	SDQ10=	123.000-CFS	SDQ11=	286.000-CFS	SDQ12=	1080.000-CFS
SDQ1=	547.000-CFS	SDQ2=	541.000-CFS	SDQ3=	848.000-CFS	SDQ4=	992.000-CFS
SDQ5=	53.100-CFS	SDQ6=	51.300-CFS	SDQ7=	91.100-CFS	SDQ8=	277.000-CFS
SDQ9=	114.000-CFS	M7,2=	83.000-CFS	M7,10=	69.400-CFS	M7,20=	65.400-CFS
V1,2=	6510.000-CFS	V1,10=	25600.000-CFS	V1,50=	58900.000-CFS	V3,2=	4540.000-CFS
V3,10=	15100.000-CFS	V3,50=	30200.000-CFS	V7,2=	2970.000-CFS	V7,10=	8350.000-CFS
V7,50=	14600.000-CFS	D10=	660.000-CFS	P500=	293000.000-CFS	WRC SKEW=	-0.142-LOG10
WRC MEAN=	4.173-LOG10	WRC SD=	0.478-LOG10	YRSPK=	56.000-YEARS	YRSHTSPK=	110.000-YEARS

09512500 **26** AGUA FRIA RIVER NEAR MAYER, ARIZ. 4 4 820128 88

AREA=	588.000-SQ MI	CONTDA=	588.000-SQ MI	SLOPE=	56.900-FT/MI	LENGTH=	37.500-MI
ELEV=	5000.000-FT	EL6000=	9.900-%	STORAGE=	0.100-%	FOREST=	3.400-%
SOIL INF=	1.260-IN	AZIMUTH=	160.000-DEC. DEG	LAT=	34.500-DEC. DEG	LONG=	112.100-DEC. DEG
LAT GAGE=	34.315-DEC. DEG	LNG GAGE=	112.063-DEC. DEG	PRECIP=	16.700-IN	I24,2=	2.100-IN
I24,10=	3.170-IN	I24,50=	4.260-IN	PRC10=	1.030-IN	PRC11=	0.850-IN
PRC12=	1.870-IN	PRC1=	1.700-IN	PRC2=	1.800-IN	PRC3=	1.440-IN
PRC4=	1.070-IN	PRC5=	0.300-IN	PRC6=	0.350-IN	PRC7=	2.120-IN
PRC8=	2.940-IN	PRC9=	1.270-IN	SNOFALL=	21.200-IN	JANMIN=	24.000-FAHR
P1,25=	3350.000-CFS	P2=	6060.000-CFS	P5=	11100.000-CFS	P10=	15300.000-CFS
P25=	21500.000-CFS	P50=	27000.000-CFS	P100=	33100.000-CFS	P200=	39900.000-CFS
MEANPK=	3.774-LOG10	SDPK=	0.332-LOG10	SKEWPK=	-0.224-LOG10	QA=	15.600-CFS
SDQA=	15.000-CFS	Q10=	4.540-CFS	Q11=	3.550-CFS	Q12=	27.200-CFS
Q1=	13.900-CFS	Q2=	11.800-CFS	Q3=	25.400-CFS	Q4=	22.100-CFS
Q5=	1.510-CFS	Q6=	2.320-CFS	Q7=	15.100-CFS	Q8=	46.200-CFS
Q9=	12.300-CFS	SDQ10=	7.460-CFS	SDQ11=	6.680-CFS	SDQ12=	88.200-CFS
SDQ1=	22.200-CFS	SDQ2=	19.000-CFS	SDQ3=	51.800-CFS	SDQ4=	73.500-CFS
SDQ5=	3.710-CFS	SDQ6=	4.730-CFS	SDQ7=	15.400-CFS	SDQ8=	61.000-CFS
SDQ9=	14.500-CFS	M7,2=	0.130-CFS	M7,10=	0.065-CFS	M7,20=	0.053-CFS
V1,2=	660.000-CFS	V1,10=	2290.000-CFS	V1,50=	4880.000-CFS	V3,2=	335.000-CFS
V3,10=	1140.000-CFS	V3,50=	2390.000-CFS	V7,2=	186.000-CFS	V7,10=	613.000-CFS
V7,50=	1210.000-CFS	D10=	12.500-CFS	P500=	50100.000-CFS	WRC SKEW=	0.069-LOG10
WRC MEAN=	3.786-LOG10	WRC SD=	0.308-LOG10	YRSPK=	41.000-YEARS	YRSHTSPK=	41.000-YEARS

09513800 **27** NEW RIVER AT NEW RIVER, ARIZ. 4 4 820128 85

AREA=	85.700-SQ MI	CONTDA=	85.700-SQ MI	SLOPE=	105.200-FT/MI	LENGTH=	25.900-MI
ELEV=	3600.000-FT	EL6000=	0.000E+00-%	STORAGE=	0.000E+00-%	FOREST=	0.200-%
SOIL INF=	1.000-IN	AZIMUTH=	230.000-DEC. DEG	LAT=	34.000-DEC. DEG	LONG=	112.000-DEC. DEG
LAT GAGE=	33.908-DEC. DEG	LNG GAGE=	112.144-DEC. DEG	PRECIP=	19.500-IN	I24,2=	2.300-IN
I24,10=	3.370-IN	I24,50=	4.560-IN	PRC10=	1.150-IN	PRC11=	1.030-IN
PRC12=	2.320-IN	PRC1=	2.300-IN	PRC2=	1.930-IN	PRC3=	1.640-IN
PRC4=	1.290-IN	PRC5=	0.410-IN	PRC6=	0.330-IN	PRC7=	2.520-IN
PRC8=	3.250-IN	PRC9=	1.330-IN	SNOFALL=	8.000-IN	JANMIN=	32.000-FAHR
P1,25=	1090.000-CFS	P2=	3160.000-CFS	P5=	8630.000-CFS	P10=	14200.000-CFS
P25=	23800.000-CFS	P50=	32900.000-CFS	P100=	43700.000-CFS	P200=	56400.000-CFS
MEANPK=	3.429-LOG10	SDPK=	0.644-LOG10	SKEWPK=	-0.993-LOG10	QA=	5.630-CFS
SDQA=	7.070-CFS	Q10=	0.297-CFS	Q11=	2.270-CFS	Q12=	26.100-CFS
Q1=	8.650-CFS	Q2=	6.850-CFS	Q3=	4.300-CFS	Q4=	10.700-CFS
Q5=	0.128-CFS	Q6=	0.066-CFS	Q7=	0.482-CFS	Q8=	5.670-CFS
Q9=	2.010-CFS	SDQ10=	0.512-CFS	SDQ11=	4.810-CFS	SDQ12=	64.500-CFS
SDQ1=	12.000-CFS	SDQ2=	10.000-CFS	SDQ3=	4.680-CFS	SDQ4=	27.800-CFS
SDQ5=	0.228-CFS	SDQ6=	0.125-CFS	SDQ7=	0.714-CFS	SDQ8=	7.880-CFS
SDQ9=	3.400-CFS	V1,2=	360.000-CFS	V1,10=	3500.000-CFS	V1,50=	15000.000-CFS
V3,2=	180.000-CFS	V3,10=	1700.000-CFS	V3,50=	7400.000-CFS	V7,2=	96.000-CFS
V7,10=	870.000-CFS	V7,50=	3500.000-CFS	D10=	2.800-CFS	P500=	76300.000-CFS
WRC SKEW=	-0.214-LOG10	WRC MEAN=	3.481-LOG10	WRC SD=	0.535-LOG10	YRSPK=	20.000-YEARS
YRSHISPK=	0.000E+00-YEARS						

09515500 **28** HASSAYAMPA R. AT BOX DAMSITE, NR. WICKENBURG,AZ 4 4 811216 88

AREA=	417.000-SQ MI	CONTDA=	417.000-SQ MI	SLOPE=	71.000-FT/MI	LENGTH=	45.000-MI
ELEV=	4750.000-FT	EL6000=	12.000-%	STORAGE=	0.000E+00-%	FOREST=	9.600-%
SOIL INF=	1.050-IN	AZIMUTH=	210.000-DEC. DEG	LAT=	34.300-DEC. DEG	LONG=	112.500-DEC. DEG
LAT GAGE=	34.045-DEC. DEG	LNG GAGE=	112.709-DEC. DEG	PRECIP=	19.300-IN	I24,2=	2.400-IN
I24,10=	3.490-IN	I24,50=	4.670-IN	PRC10=	1.180-IN	PRC11=	1.240-IN
PRC12=	2.180-IN	PRC1=	2.310-IN	PRC2=	1.800-IN	PRC3=	1.350-IN
PRC4=	1.000-IN	PRC5=	0.290-IN	PRC6=	0.270-IN	PRC7=	2.540-IN
PRC8=	3.460-IN	PRC9=	1.680-IN	SNOFALL=	22.200-IN	JANMIN=	29.000-FAHR
P1,25=	1180.000-CFS	P2=	3340.000-CFS	P5=	8860.000-CFS	P10=	14400.000-CFS
P25=	23700.000-CFS	P50=	32400.000-CFS	P100=	42600.000-CFS	P200=	54500.000-CFS
MEANPK=	3.528-LOG10	SDPK=	0.547-LOG10	SKEWPK=	-0.109-LOG10	QA=	12.600-CFS
SDQA=	14.000-CFS	Q10=	4.110-CFS	Q11=	5.220-CFS	Q12=	20.500-CFS
Q1=	11.400-CFS	Q2=	9.700-CFS	Q3=	22.700-CFS	Q4=	21.800-CFS
Q5=	3.170-CFS	Q6=	1.820-CFS	Q7=	5.740-CFS	Q8=	32.200-CFS
Q9=	12.700-CFS	SDQ10=	10.700-CFS	SDQ11=	13.400-CFS	SDQ12=	65.000-CFS
SDQ1=	27.500-CFS	SDQ2=	18.400-CFS	SDQ3=	40.700-CFS	SDQ4=	55.900-CFS
SDQ5=	4.450-CFS	SDQ6=	1.540-CFS	SDQ7=	8.850-CFS	SDQ8=	80.800-CFS
SDQ9=	25.200-CFS	M7,2=	0.600-CFS	M7,10=	0.140-CFS	M7,20=	0.050-CFS
V1,2=	514.000-CFS	V1,10=	2360.000-CFS	V1,50=	6730.000-CFS	V3,2=	234.000-CFS
V3,10=	1120.000-CFS	V3,50=	3140.000-CFS	V7,2=	116.000-CFS	V7,10=	580.000-CFS
V7,50=	1640.000-CFS	D10=	10.200-CFS	P500=	72800.000-CFS	WRC SKEW=	-0.226-LOG10
WRC MEAN=	3.505-LOG10	WRC SD=	0.520-LOG10	YRSPK=	36.000-YEARS	YRSHISPK=	90.000-YEARS

09520170 **29** RIO CORNEZ NEAR AJO, ARIZ. 4 4 800610 36

AREA=	243.000-SQ MI	CONTDA=	243.000-SQ MI	SLOPE=	26.800-FT/MI	LENGTH=	33.600-MI
ELEV=	1950.000-FT	EL6000=	0.000E+00-%	STORAGE=	0.000E+00-%	FOREST=	0.000E+00-%
SOIL INF=	2.000-IN	AZIMUTH=	0.000E+00-DEC. DEG	LAT=	32.400-DEC. DEG	LONG=	112.700-DEC. DEG
LAT GAGE=	32.499-DEC. DEG	LNG GAGE=	112.881-DEC. DEG	PRECIP=	8.400-IN	I24,2=	1.700-IN
I24,50=	4.200-IN	SNOFALL=	1.000-IN	JANMIN=	38.000-FAHR	P1,25=	2010.000-CFS
P2=	3200.000-CFS	P5=	5100.000-CFS	P10=	6520.000-CFS	P25=	8470.000-CFS
P50=	10000.000-CFS	P100=	11700.000-CFS	P200=	13400.000-CFS	MEANPK=	3.506-LOG10
SDPK=	0.240-LOG10	SKEWPK=	0.374-LOG10	P500=	15900.000-CFS	WRC SKEW=	0.017-LOG10
WRC MEAN=	3.506-LOG10	WRC SD=	0.240-LOG10	YRSPK=	12.000-YEARS	YRSHISPK=	12.000-YEARS

09432000 **30** GILA R. BL. BLUE CR. NR. VIRDEN, N. MEX. 35 4 800610 89

AREA=	3203.000-SQ MI	CONTDA=	3203.000-SQ MI	SLOPE=	35.800-FT/MI	LENGTH=	115.300-MI
ELEV=	6690.000-FT	EL6000=	69.000-%	STORAGE=	0.000E+00-%	FOREST=	54.000-%
SOIL INF=	3.000-IN	AZIMUTH=	220.000-DEC. DEG	LAT=	33.100-DEC. DEG	LONG=	108.400-DEC. DEG
LAT GAGE=	32.648-DEC. DEG	LNG GAGE=	108.645-DEC. DEG	PRECIP=	16.200-IN	I24,2=	1.600-IN
I24,10=	2.460-IN	I24,50=	3.320-IN	PRC10=	1.310-IN	PRC11=	0.660-IN
PRC12=	1.030-IN	PRC1=	1.130-IN	PRC2=	1.130-IN	PRC3=	0.860-IN
PRC4=	0.530-IN	PRC5=	0.440-IN	PRC6=	0.910-IN	PRC7=	2.910-IN
PRC8=	3.350-IN	PRC9=	1.910-IN	SNOFALL=	39.000-IN	JANMIN=	21.000-FAHR
P1,25=	2460.000-CFS	P2=	4940.000-CFS	P5=	9890.000-CFS	P10=	14200.000-CFS
P25=	20800.000-CFS	P50=	26700.000-CFS	P100=	33300.000-CFS	P200=	40800.000-CFS
MEANPK=	3.708-LOG10	SDPK=	0.378-LOG10	SKEWPK=	0.179-LOG10	QA=	167.000-CFS
SDQA=	111.000-CFS	Q10=	106.000-CFS	Q11=	91.300-CFS	Q12=	158.000-CFS
Q1=	208.000-CFS	Q2=	247.000-CFS	Q3=	335.000-CFS	Q4=	227.000-CFS
Q5=	116.000-CFS	Q6=	39.700-CFS	Q7=	79.300-CFS	Q8=	231.000-CFS
Q9=	173.000-CFS	SDQ10=	107.000-CFS	SDQ11=	32.000-CFS	SDQ12=	207.000-CFS
SDQ1=	271.000-CFS	SDQ2=	265.000-CFS	SDQ3=	346.000-CFS	SDQ4=	220.000-CFS
SDQ5=	130.000-CFS	SDQ6=	37.600-CFS	SDQ7=	57.700-CFS	SDQ8=	220.000-CFS
SDQ9=	211.000-CFS	M7,2=	5.570-CFS	M7,10=	2.320-CFS	M7,20=	1.900-CFS
V1,2=	1820.000-CFS	V1,10=	6690.000-CFS	V1,50=	15100.000-CFS	V3,2=	1300.000-CFS
V3,10=	4260.000-CFS	V3,50=	8830.000-CFS	V7,2=	919.000-CFS	V7,10=	2560.000-CFS
V7,50=	4650.000-CFS	D10=	354.000-CFS	P500=	52200.000-CFS	WRC SKEW=	-0.017-LOG10
WRC MEAN=	3.693-LOG10	WRC SD=	0.359-LOG10	YRSPK=	53.000-YEARS	YRSHISPK=	88.000-YEARS
(? 2002)=	100176.000-						

SUMMARY OF SELECTED STREAMFLOW/BASIN CHARACTERISTICS FOR RETRIEVED STATIONS

ELEMENT	CHARACTERISTIC NAME	UNITS	MAX. VALUE	MIN. VALUE
1	AREA	SQ MI	11470.00	4.92
2	CONTDA	SQ MI	11470.00	4.92
3	SLOPE	FT/MI	634.00	15.30
0			---	---
5	LENGTH	MI	225.20	3.80
0			---	---
0			---	---
8	ELEV	FT	9190.00	1950.00
0			---	---
0			---	---
11	EL6000	%	100.00	0.00
12	STORAGE	%	0.30	0.00
0			---	---
14	FOREST	%	100.00	0.00
0			---	---
16	SOIL INF	IN	3.00	1.00
0			---	---
18	AZIMUTH	DEC. DEG	360.00	0.00
19	LAT	DEC. DEG	35.00	31.20
20	LONG	DEC. DEG	112.70	108.40
0			---	---
22	LAT GAGE	DEC. DEG	34.77	31.34
23	LNG GAGE	DEC. DEG	112.88	108.84
0			---	---
0			---	---
0			---	---
0			---	---
0			---	---
0			---	---
0			---	---
0			---	---
32	PRECIP	IN	32.20	8.40
33	I24,2	IN	2.90	1.60
34	I24,10	IN	4.16	2.46
0			---	---
36	I24,50	IN	5.47	3.27
0			---	---
0			---	---
0			---	---
0			---	---
41	PRC10	IN	2.46	0.55
42	PRC11	IN	2.03	0.48
43	PRC12	IN	3.12	0.94
44	PRC1	IN	3.36	0.98
45	PRC2	IN	3.03	0.74
46	PRC3	IN	3.22	0.68
47	PRC4	IN	1.70	0.27
48	PRC5	IN	0.91	0.13
49	PRC6	IN	1.18	0.20
50	PRC7	IN	5.55	1.98
51	PRC8	IN	5.46	1.76
52	PRC9	IN	3.15	0.96
53	SNOFALL	IN	80.00	0.70

APPENDIX B

PEAK DISCHARGE DATA AND HYDROCLIMATIC CLASSIFICATION

FOR MAIN GILA RIVER BASIN GAGING STATIONS

Key to Classification

WYEAR = Water year of flood

YEAR = Calendar year of flood

SERIES 3 = Annual Series 4 = Partial Duration Series

PKQ = Peak discharge in cubic feet per second

CLASSIF = Hydroclimatic Classification as follows:

1 - Tropical Storm (T)
2 - Cutoff Low (C)
3 - Front (F)
4 - Local Convectional (L)
5 - Widespread Synoptic (W)
6 - Monsoon Frontal (MF)
7 - Monsoon Local (ML)
8 - Monsoon Widespread (MW)
9 - Snowmelt (S)
0 - Mystery Flood (?)

ANTFLOOD = Antecedant floods; the value indicates how many times this station flooded in the previous 30 days

LOGQ = Logarithm (base 10) of PKQ

Z-PKQ = Z-scores (standardized scores) of LOGQ, partial duration series

Z-ANQ = Z-scores (standardized scores) of LOGQ, annual series
99.99 = missing data, i.e. non-annual flood peaks

1. GILCLF Gila River near Clifton

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z- Q
1950	1950	7	30	3	1680	8	0	3.23	-1.65	-1.67
1951	1951	9	3	3	4600	8	0	3.66	0.18	-0.30
1952	1952	1	20	3	4280	3	0	3.63	0.05	-0.40
1952	1952	9	24	4	2900	3	0	3.46	-0.66	99.99
1953	1953	7	30	3	3700	8	0	3.57	-0.21	-0.59
1954	1954	8	23	3	6000	7	2	3.78	0.66	0.07
1954	1954	7	2	4	2720	7	0	3.43	-0.77	99.99
1954	1954	7	20	4	3370	1	1	3.53	-0.38	99.99
1954	1954	7	22	4	4780	6	2	3.68	0.25	99.99
1954	1954	8	11	4	4280	8	2	3.63	0.05	99.99
1954	1954	8	21	4	3050	7	2	3.48	-0.57	99.99
1954	1954	8	24	4	2670	7	3	3.43	-0.81	99.99
1955	1955	7	23	3	9450	8	1	3.98	1.49	0.69
1955	1955	7	11	4	6280	7	0	3.80	0.75	99.99
1955	1955	7	29	4	3600	7	2	3.56	-0.26	99.99
1955	1955	8	12	4	3440	7	2	3.54	-0.35	99.99
1955	1955	8	20	4	4140	8	3	3.62	-0.01	99.99
1955	1955	8	26	4	4560	7	3	3.66	0.17	99.99
1955	1954	10	9	4	2570	4	0	3.41	-0.88	99.99
1956	1955	10	4	3	12700	1	1	4.10	2.03	1.09
1956	1955	10	3	4	10800	1	0	4.03	1.73	99.99
1957	1957	8	29	3	8070	7	2	3.91	1.20	0.47
1957	1957	7	27	4	2710	8	0	3.43	-0.78	99.99
1957	1957	8	7	4	3560	8	1	3.55	-0.28	99.99
1957	1957	8	23	4	3420	7	2	3.53	-0.36	99.99
1957	1957	8	31	4	3320	7	3	3.52	-0.41	99.99
1958	1958	3	24	3	3980	3	0	3.60	-0.08	-0.50
1958	1958	7	19	4	3070	7	0	3.49	-0.55	99.99
1958	1958	8	22	4	3370	7	0	3.53	-0.38	99.99
1958	1958	9	13	4	3190	1	1	3.50	-0.48	99.99
1959	1959	8	26	3	5610	7	6	3.75	0.54	-0.03
1959	1959	8	4	4	3350	8	0	3.53	-0.40	99.99
1959	1959	8	7	4	3070	8	1	3.49	-0.55	99.99
1959	1959	8	14	4	3560	8	2	3.55	-0.28	99.99
1959	1959	8	17	4	5130	7	3	3.71	0.38	99.99
1959	1959	8	20	4	2630	8	4	3.42	-0.83	99.99
1959	1959	8	25	4	5290	8	5	3.72	0.43	99.99
1959	1959	8	28	4	3630	7	7	3.56	-0.25	99.99
1960	1960	1	13	3	4000	3	0	3.60	-0.07	-0.49
1961	1961	8	13	3	2400	7	0	3.38	-1.00	-1.19
1962	1962	9	26	3	8980	1.3	0	3.95	1.40	0.62
1963	1963	8	31	3	3580	8	0	3.55	-0.27	-0.64
1963	1963	9	4	4	2640	8	1	3.42	-0.83	99.99
1964	1964	7	15	3	5070	8	0	3.71	0.36	-0.16
1964	1964	8	2	4	3320	8	1	3.52	-0.41	99.99
1964	1964	8	12	4	2680	8	2	3.43	-0.80	99.99

1964	1964	9	25	4	2790	2	0	3.45	-0.73	99.99
1965	1965	9	3	3	3310	1	0	3.52	-0.42	-0.75
1965	1965	8	2	4	2510	7	0	3.40	-0.92	99.99
1966	1965	12	24	3	10700	3	1	4.03	1.72	0.86
1966	1965	12	11	4	2890	3	0	3.46	-0.66	99.99
1966	1966	1	1	4	3340	3	2	3.52	-0.40	99.99
1966	1966	9	15	4	3540	1	0	3.55	-0.29	99.99
1967	1967	8	12	3	11100	7	0	4.05	1.78	0.91
1967	1967	8	14	4	7730	7	1	3.89	1.12	99.99
1967	1967	9	25	4	2620	5	0	3.42	-0.84	99.99
1968	1968	3	11	3	4380	3	1	3.64	0.09	-0.36
1968	1968	1	30	4	2590	3	0	3.41	-0.86	99.99
1968	1968	2	14	4	3710	3	1	3.57	-0.21	99.99
1969	1969	9	11	3	3610	1	1	3.56	-0.26	-0.63
1969	1969	9	2	4	2780	7	0	3.44	-0.73	99.99
1970	1970	8	5	3	4220	8	0	3.63	0.02	-0.41
1970	1970	9	18	4	2600	4	0	3.41	-0.86	99.99
1971	1970	10	2	3	5010	2.5	1	3.70	0.34	-0.18
1971	1971	7	15	4	3020	7	0	3.48	-0.58	99.99
1971	1971	9	23	4	3610	3	0	3.56	-0.26	99.99
1972	1972	9	3	3	6160	8	1	3.79	0.71	0.10
1972	1971	10	27	4	3780	2.3	0	3.58	-0.18	99.99
1972	1972	8	27	4	3620	6	0	3.56	-0.25	99.99
1972	1972	9	13	4	3990	7	2	3.60	-0.08	99.99
1973	1972	10	21	3	33000	2	0	4.52	3.76	2.40
1973	1973	2	24	4	3440	5	0	3.54	-0.35	99.99
1974	1974	7	19	3	3460	8	0	3.54	-0.34	-0.69
1974	1974	8	5	4	2780	8	1	3.44	-0.73	99.99
1974	1974	8	16	4	3100	7	2	3.49	-0.54	99.99
1975	1975	9	8	3	4660	8	0	3.67	0.20	-0.28
1975	1975	9	11	4	4200	8	1	3.62	0.02	99.99
1976	1976	2	11	3	2390	3	0	3.38	-1.01	-1.19
1977	1977	8	13	3	2820	8	1	3.45	-0.71	-0.97
1977	1977	8	12	4	2710	8	0	3.43	-0.78	99.99
1978	1978	3	4	3	8420	3	0	3.93	1.28	0.53
1979	1978	12	19	3	57000	3	1	4.76	4.75	3.15
1979	1978	11	26	4	11000	2	0	4.04	1.77	99.99
1979	1979	1	1	4	2760	3	1	3.44	-0.75	99.99
1979	1979	1	19	4	7200	3	1	3.86	1.00	99.99
1979	1979	2	18	4	3640	9	1	3.56	-0.24	99.99
1980	1980	9	10	3	8500	2	1	3.93	1.30	0.54
1980	1980	2	16	4	3300	3	0	3.52	-0.42	99.99
1980	1980	2	21	4	2710	3	1	3.43	-0.78	99.99
1980	1980	8	14	4	2760	8	0	3.44	-0.75	99.99

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	27	3	825	7	0	2.92	-2.08	-1.84
1951	1951	8	29	3	735	7	0	2.87	-2.22	-1.94
1952	1952	1	19	3	15800	3	1	4.20	1.60	0.68
1952	1952	1	14	4	11300	3	0	4.05	1.18	99.99
1953	1953	8	18	3	6090	7	1	3.78	0.41	-0.13
1953	1953	7	15	4	2510	7	0	3.40	-0.69	99.99
1953	1953	8	1	4	2290	7	1	3.36	-0.81	99.99
1954	1954	8	7	3	7280	7	2	3.86	0.63	0.02
1954	1954	3	24	4	7240	3	0	3.86	0.63	99.99
1954	1954	8	2	4	3990	7	0	3.60	-0.12	99.99
1954	1954	8	4	4	2370	8	1	3.37	-0.76	99.99
1954	1954	9	2	4	2060	5	2	3.31	-0.94	99.99
1955	1955	7	23	3	8450	8	1	3.93	0.82	0.15
1955	1954	10	8	4	2640	4	0	3.42	-0.63	99.99
1955	1955	7	22	4	4180	7	0	3.62	-0.06	99.99
1955	1955	7	25	4	2690	8	2	3.43	-0.61	99.99
1955	1955	8	5	4	2080	7	3	3.32	-0.93	99.99
1955	1955	8	6	4	5550	7	4	3.74	0.29	99.99
1955	1955	8	13	4	2110	8	5	3.32	-0.91	99.99
1955	1955	8	19	4	3340	8	6	3.52	-0.34	99.99
1955	1955	8	23	4	2280	8	4	3.36	-0.81	99.99
1955	1955	8	28	4	5290	7	4	3.72	0.23	99.99
1956	1955	10	4	3	5820	1	0	3.76	0.35	-0.17
1957	1957	7	26	3	5230	8	1	3.72	0.22	-0.26
1957	1957	7	17	4	2130	8	0	3.33	-0.90	99.99
1957	1957	8	5	4	3540	8	2	3.55	-0.27	99.99
1957	1957	8	7	4	2700	8	3	3.43	-0.60	99.99
1957	1957	8	17	4	3360	8	3	3.53	-0.33	99.99
1957	1957	8	19	4	3660	8	4	3.56	-0.22	99.99
1957	1957	8	20	4	2360	8	5	3.37	-0.77	99.99
1957	1957	8	21	4	2260	8	6	3.35	-0.82	99.99
1957	1957	8	24	4	3860	8	7	3.59	-0.16	99.99
1957	1957	8	25	4	3240	8	7	3.51	-0.38	99.99
1957	1957	8	26	4	3860	8	8	3.59	-0.16	99.99
1958	1958	9	12	3	7000	1	1	3.85	0.58	-0.02
1958	1958	3	7	4	2020	3	0	3.31	-0.96	99.99
1958	1958	3	18	4	3150	3	1	3.50	-0.41	99.99
1958	1958	3	23	4	6010	3	2	3.78	0.39	99.99
1958	1958	4	17	4	4750	5	2	3.68	0.10	99.99
1958	1958	7	30	4	2230	8	0	3.35	-0.84	99.99
1958	1958	8	21	4	3280	8	1	3.52	-0.36	99.99
1958	1958	9	27	4	3770	2	1	3.58	-0.19	99.99
1959	1959	8	28	3	11600	7	3	4.06	1.21	0.42
1959	1958	10	6	4	2430	1	2	3.39	-0.73	99.99
1959	1959	8	20	4	4590	8	0	3.66	0.06	99.99
1959	1959	8	25	4	3080	8	1	3.49	-0.44	99.99

1959	1959	8	26	4	2600	7	2	3.41	-0.65	99.99
1960	1960	1	12	3	11800	3	1	4.07	1.23	0.43
1960	1959	10	31	4	3560	3	0	3.55	-0.26	99.99
1960	1959	12	26	4	5590	3	0	3.75	0.30	99.99
1960	1960	3	9	4	2150	9	0	3.33	-0.89	99.99
1961	1961	9	10	3	7100	1	0	3.85	0.60	0.00
1961	1961	9	12	4	3180	1	1	3.50	-0.40	99.99
1962	1962	9	26	3	14300	1.3	0	4.16	1.47	0.59
1962	1961	12	16	4	4140	5	0	3.62	-0.07	99.99
1962	1962	1	25	4	3380	2	0	3.53	-0.32	99.99
1962	1962	2	13	4	2960	3	1	3.47	-0.49	99.99
1962	1962	7	30	4	2400	8	0	3.38	-0.75	99.99
1963	1962	10	18	3	12200	2	1	4.09	1.27	0.46
1963	1963	7	30	4	4740	7	0	3.68	0.10	99.99
1963	1963	8	2	4	6020	8	1	3.78	0.40	99.99
1963	1963	8	16	4	4840	8	2	3.68	0.12	99.99
1963	1963	8	22	4	10200	8	3	4.01	1.05	99.99
1963	1963	8	31	4	5510	8	3	3.74	0.29	99.99
1964	1964	7	31	3	8670	8	2	3.94	0.85	0.17
1964	1963	10	18	4	4280	2	0	3.63	-0.03	99.99
1964	1964	7	15	4	3820	8	0	3.58	-0.17	99.99
1964	1964	7	26	4	2470	8	1	3.39	-0.71	99.99
1964	1964	9	24	4	3090	2	0	3.49	-0.43	99.99
1965	1965	8	2	3	5640	7	0	3.75	0.31	-0.20
1965	1965	8	15	4	2250	6	0	3.35	-0.83	99.99
1966	1965	12	23	3	30500	3	1	4.48	2.41	1.24
1966	1965	12	30	4	17300	3	2	4.24	1.71	99.99
1966	1966	3	15	4	3290	9	0	3.52	-0.36	99.99
1966	1966	9	21	4	2710	2	0	3.43	-0.60	99.99
1966	1965	12	10	4	2740	3	0	3.44	-0.58	99.99
1967	1967	8	12	3	34700	7	2	4.54	2.58	1.35
1967	1967	7	28	4	9800	8	0	3.99	1.00	99.99
1967	1967	8	3	4	4000	8	1	3.60	-0.11	99.99
1968	1967	12	20	3	9480	3	0	3.98	0.96	0.24
1968	1968	1	29	4	4400	3	0	3.64	0.01	99.99
1968	1968	2	14	4	3350	3	1	3.53	-0.33	99.99
1968	1968	2	28	4	2600	4	2	3.41	-0.65	99.99
1968	1968	3	10	4	2550	3	2	3.41	-0.67	99.99
1968	1968	8	9	4	3920	7	0	3.59	-0.14	99.99
1969	1969	9	1	3	1270	7	0	3.10	-1.54	-1.47
1970	1969	10	21	3	902	2	0	2.96	-1.97	-1.76
1971	1970	10	4	3	5420	2.5	0	3.73	0.26	-0.23
1971	1971	8	22	4	2020	7	0	3.31	-0.96	99.99
1972	1971	10	25	3	9200	2.3	1	3.96	0.92	0.22
1972	1971	12	27	4	4300	3	0	3.63	-0.02	99.99
1972	1972	7	22	4	8810	7	0	3.94	0.87	99.99

1972	1972	9	3	4	4060	8	0	3.61	-0.09	99.99
1972	1971	10	1	4	4570	1	0	3.66	0.05	99.99
1973	1972	10	20	3	64000	2	2	4.81	3.34	1.87
1973	1972	12	29	4	2060	3	0	3.31	-0.94	99.99
1973	1973	2	22	4	4100	5	0	3.61	-0.08	99.99
1973	1973	4	14	4	3000	9	0	3.48	-0.47	99.99
1973	1973	4	29	4	2480	9	1	3.39	-0.71	99.99
1973	1973	5	15	4	2260	3	1	3.35	-0.82	99.99
1973	1972	10	5	4	4100	2.1	0	3.61	-0.08	99.99
1973	1972	10	6	4	4010	1.2	1	3.60	-0.11	99.99
1974	1974	7	21	3	964	8	0	2.98	-1.88	-1.71
1975	1975	9	9	3	30000	8	0	4.48	2.39	1.23
1975	1975	9	12	4	2800	3	0	3.45	-0.56	99.99
1976	1976	2	10	3	3100	3	0	3.49	-0.43	-0.71
1976	1976	7	11	4	2600	7	0	3.41	-0.65	99.99
1977	1977	9	5	3	2520	7	0	3.40	-0.69	-0.89
1978	1978	3	3	3	9500	3	0	3.98	0.96	0.25
1979	1978	12	19	3	56000	3	1	4.75	3.17	1.76
1976	1978	10	21	4	2900	1	0	3.46	-0.51	99.99
1979	1978	11	25	4	31000	2	0	4.49	2.43	99.99
1979	1978	12	31	4	2600	3	1	3.41	-0.65	99.99
1979	1979	1	18	4	26500	3	2	4.42	2.24	99.99
1979	1979	2	17	4	4350	9	1	3.64	-0.01	99.99
1980	1980	2	16	3	9900	3	0	4.00	1.01	0.28
1980	1980	2	20	4	7850	3	1	3.89	0.73	99.99
1980	1980	9	11	4	2500	2	0	3.40	-0.70	99.99

3. GILSOL Gila River at head of Safford Valley, near Solomon

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	30	3	1240	8	0	3.09	-2.20	-1.90
1951	1951	8	3	3	4240	8	0	3.63	-0.65	-0.75
1952	1952	1	19	3	19700	3	1	4.29	1.30	0.68
1952	1952	1	14	4	18600	3	0	4.27	1.23	99.99
1953	1953	7	30	3	3040	8	0	3.48	-1.07	-1.06
1954	1954	3	24	3	9850	3	0	3.99	0.42	0.04
1954	1954	7	22	4	4820	6	0	3.68	-0.48	99.99
1954	1954	8	3	4	4600	8	1	3.66	-0.54	99.99
1954	1954	8	5	4	4270	8	2	3.63	-0.64	99.99
1954	1954	8	8	4	7000	7	3	3.85	-0.01	99.99
1954	1954	8	11	4	4200	8	4	3.62	-0.66	99.99
1955	1955	7	24	3	11700	8	2	4.07	0.64	0.20
1955	1955	7	12	4	5030	7	0	3.70	-0.43	99.99
1955	1955	7	20	4	4020	7	1	3.60	-0.71	99.99
1955	1955	7	25	4	6450	8	2	3.81	-0.11	99.99
1955	1955	8	8	4	4380	8	3	3.64	-0.60	99.99
1956	1955	10	4	3	13300	1	1	4.12	0.80	0.32
1956	1955	10	3	4	6380	1	0	3.80	-0.13	99.99

1957	1957	7	26	3	5980	8	0	3.78	-0.21	-0.43
1957	1957	8	5	4	4050	8	1	3.61	-0.70	99.99
1957	1957	8	7	4	5160	8	2	3.71	-0.40	99.99
1957	1957	8	18	4	4040	8	3	3.61	-0.71	99.99
1957	1957	8	23	4	4340	7	4	3.64	-0.62	99.99
1957	1957	8	26	4	4060	8	4	3.61	-0.70	99.99
1957	1957	8	29	4	5040	7	5	3.70	-0.43	99.99
1958	1958	3	23	3	9060	3	1	3.96	0.32	-0.04
1958	1958	3	18	4	5820	3	0	3.76	-0.24	99.99
1958	1958	4	18	4	5210	5	1	3.72	-0.38	99.99
1958	1958	9	13	4	7310	1	0	3.86	0.04	99.99
1959	1959	8	28	3	7860	7	3	3.90	0.14	-0.17
1959	1959	8	18	4	4130	8	0	3.62	-0.68	99.99
1959	1959	8	25	4	5330	8	1	3.73	-0.36	99.99
1959	1959	8	27	4	5100	7	2	3.71	-0.41	99.99
1960	1960	1	12	3	16700	3	1	4.22	1.09	0.53
1960	1959	12	26	4	6460	3	0	3.81	-0.11	99.99
1961	1961	6	10	3	4800	1	0	3.68	-0.49	-0.63
1962	1962	9	26	3	16100	1.3	0	4.21	1.04	0.50
1962	1961	12	16	4	4930	5	0	3.69	-0.45	99.99
1962	1962	1	26	4	4260	9.2	0	3.63	-0.64	99.99
1962	1962	2	14	4	4450	3	1	3.65	-0.58	99.99
1963	1962	10	19	3	9350	2	1	3.97	0.36	-0.01
1963	1963	8	23	4	6080	8	0	3.78	-0.19	99.99
1963	1963	8	31	4	5260	8	1	3.72	-0.37	99.99
1964	1964	7	15	3	9880	8	0	3.99	0.43	0.04
1964	1964	8	1	4	4410	8	1	3.64	-0.60	99.99
1964	1964	9	24	4	4700	2	0	3.67	-0.51	99.99
1965	1965	8	2	3	4800	7	0	3.68	-0.49	-0.63
1966	1965	12	22	3	43000	3	1	4.63	2.29	1.41
1966	1965	12	30	4	22300	3	2	4.35	1.46	99.99
1966	1966	3	17	4	5640	9	0	3.75	-0.28	99.99
1966	1966	9	15	4	4220	1	0	3.63	-0.65	99.99
1966	1965	12	11	4	7950	3	0	3.90	0.15	99.99
1967	1967	8	12	3	34800	7	1	4.54	2.02	1.21
1967	1967	7	16	4	5100	8	0	3.71	-0.41	99.99
1968	1967	12	20	3	9280	3	0	3.97	0.35	-0.02
1968	1968	1	29	4	5700	3	0	3.76	-0.27	99.99
1968	1968	2	15	4	6750	3	1	3.83	-0.06	99.99
1968	1968	2	29	4	4220	4	1	3.63	-0.65	99.99
1968	1968	3	11	4	4500	3	1	3.65	-0.57	99.99
1969	1969	9	11	3	2460	1	0	3.39	-1.33	-1.26
1970	1970	8	6	3	2250	8	0	3.35	-1.45	-1.34
1971	1970	10	3	3	4510	2.5	0	3.65	-0.57	-0.69
1971	1971	8	21	4	4400	8	0	3.64	-0.60	99.99
1972	1971	10	25	3	10200	2.3	1	4.01	0.47	0.07
1972	1971	10	1	4	4560	1	0	3.66	-0.55	99.99
1972	1972	8	27	4	4620	6	0	3.66	-0.54	99.99
1972	1972	9	3	4	6720	8	1	3.83	-0.06	99.99

1973	1972	10	20	3	82400	2	1	4.92	3.11	2.02
1973	1972	12	29	4	6250	3	0	3.80	-0.15	99.99
1973	1973	2	22	4	8900	5	0	3.95	0.29	99.99
1973	1973	3	3	4	4160	10	1	3.62	-0.67	99.99
1973	1973	4	15	4	5400	9	0	3.73	-0.34	99.99
1973	1973	5	16	4	4320	3	0	3.64	-0.62	99.99
1973	1972	10	7	4	5130	1.2	0	3.71	-0.40	99.99
1974	1974	8	16	3	3280	7	0	3.52	-0.97	-0.99
1975	1975	9	9	3	35000	8	0	4.54	2.03	1.22
1976	1976	2	11	3	3400	3	0	3.53	-0.93	-0.96
1977	1977	8	13	3	2540	8	0	3.40	-1.29	-1.23
1978	1978	3	2	3	21600	3	0	4.33	1.42	0.77
1979	1978	12	19	3	100000	3	1	5.00	3.36	2.20
1979	1978	11	12	4	4500	2.3	0	3.65	-0.57	99.99
1979	1978	11	25	4	41000	2	1	4.61	2.23	99.99
1979	1979	1	18	4	39200	3	1	4.59	2.17	99.99
1979	1979	2	17	4	8100	9	1	3.91	0.17	99.99
1980	1980	2	16	3	25300	3	0	4.40	1.62	0.92
1980	1980	2	20	4	19200	3	1	4.28	1.27	99.99
1980	1980	9	10	4	8570	2	0	3.93	0.25	99.99

4. GILCAL Gila River at Calva

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	30	3	3210	8	0	3.51	-0.59	-0.62
1951	1951	8	4	3	2970	8	0	3.47	-0.68	-0.69
1952	1952	1	20	3	13200	3	2	4.12	1.17	0.60
1952	1952	1	16	4	7880	3	0	3.90	0.53	99.99
1952	1952	8	17	4	3350	8	0	3.53	-0.53	99.99
1953	1953	7	30	3	2040	8	0	3.31	-1.15	-1.02
1954	1954	3	25	3	4260	3	0	3.63	-0.23	-0.38
1954	1954	8	4	4	3320	8	0	3.52	-0.54	99.99
1954	1954	8	5	4	3170	8	1	3.50	-0.60	99.99
1954	1954	8	8	4	3100	7	2	3.49	-0.63	99.99
1954	1954	8	12	4	3990	7	3	3.60	-0.31	99.99
1954	1954	8	23	4	3550	7	4	3.55	-0.46	99.99
1954	1954	8	24	4	3080	7	5	3.49	-0.64	99.99
1954	1954	8	25	4	3530	7	6	3.55	-0.47	99.99
1955	1955	8	4	3	4950	8	3	3.69	-0.05	-0.25
1955	1955	7	12	4	3140	7	0	3.50	-0.61	99.99
1955	1955	7	26	4	4920	8	1	3.69	-0.05	99.99
1955	1955	7	31	4	4750	8	2	3.68	-0.10	99.99
1955	1955	8	7	4	3710	8	4	3.57	-0.41	99.99
1955	1955	8	20	4	3500	8	4	3.54	-0.48	99.99
1955	1955	8	28	4	3490	7	4	3.54	-0.48	99.99
1956	1955	10	5	3	4240	1	1	3.63	-0.24	-0.38

1956	1955	10	3	4	3720	1	0	3.57	-0.40	99.99
1956	1956	7	29	4	3000	7	0	3.48	-0.67	99.99
1957	1957	9	1	3	4220	7	5	3.63	-0.25	-0.39
1957	1957	7	28	4	3200	8	0	3.51	-0.59	99.99
1957	1957	8	8	4	3520	8	1	3.55	-0.47	99.99
1957	1957	8	19	4	3400	8	2	3.53	-0.51	99.99
1957	1957	8	23	4	3560	7	3	3.55	-0.46	99.99
1957	1957	8	27	4	3620	8	3	3.56	-0.44	99.99
1957	1957	8	30	4	3200	7	4	3.51	-0.59	99.99
1958	1958	3	26	3	6700	3	1	3.83	0.33	0.02
1958	1957	10	12	4	5150	3	0	3.71	0.00	99.99
1958	1958	3	19	4	4560	3	0	3.66	-0.15	99.99
1958	1958	4	19	4	3850	5	1	3.59	-0.36	99.99
1958	1958	9	15	4	4310	1	0	3.63	-0.22	99.99
1958	1958	9	28	4	3460	2	1	3.54	-0.49	99.99
1959	1959	8	26	3	3920	7	1	3.59	-0.34	-0.45
1959	1959	8	18	4	3040	8	0	3.48	-0.65	99.99
1959	1959	8	27	4	3460	7	2	3.54	-0.49	99.99
1959	1959	8	29	4	3760	7	2	3.58	-0.39	99.99
1960	1960	1	14	3	9090	3	1	3.96	0.71	0.28
1960	1959	12	27	4	4190	3	0	3.62	-0.25	99.99
1961	1961	8	23	3	3080	7	0	3.49	-0.64	-0.66
1962	1962	9	29	3	9000	3	0	3.95	0.70	0.27
1962	1961	12	18	4	4490	9.5	0	3.65	-0.17	99.99
1962	1962	1	17	4	4040	9.2	0	3.61	-0.30	99.99
1962	1962	2	15	4	3150	3	1	3.50	-0.61	99.99
1963	1962	10	20	3	3240	2	1	3.51	-0.57	-0.61
1964	1964	9	26	3	3060	2	0	3.49	-0.65	-0.66
1965	1965	8	14	3	4700	6	0	3.67	-0.11	-0.29
1965	1965	9	4	4	3010	1	1	3.48	-0.67	99.99
1966	1965	12	24	3	39000	3	1	4.59	2.52	1.54
1966	1965	12	13	4	3460	3	0	3.54	-0.49	99.99
1966	1966	1	1	4	20000	3	2	4.30	1.69	99.99
1966	1966	3	19	4	5200	9	0	3.72	0.01	99.99
1967	1967	8	13	3	40000	7	1	4.60	2.56	1.57
1967	1967	8	6	4	5500	8	0	3.74	0.08	99.99
1968	1967	12	21	3	8960	3	0	3.95	0.69	0.27
1968	1968	1	30	4	5960	3	0	3.78	0.18	99.99
1968	1968	2	16	4	6800	3	1	3.83	0.35	99.99
1968	1968	2	24	4	3830	9	2	3.58	-0.37	99.99
1968	1968	3	1	4	4070	4	2	3.61	-0.29	99.99
1968	1968	3	12	4	4520	3	3	3.66	-0.16	99.99
1969	1969	9	14	3	1160	1	0	3.06	-1.85	-1.51
1970	1970	3	3	3	982	3	0	2.99	-2.06	-1.65
1971	1971	8	22	3	7470	8	0	3.87	0.47	0.11
1972	1971	10	28	3	7160	2.3	0	3.85	0.41	0.07
1972	1972	8	28	4	4660	6	0	3.67	-0.12	99.99
1972	1972	9	4	4	3400	8	1	3.53	-0.51	99.99

1972	1972	9	10	4	5790	7	2	3.76	0.15	99.99
1973	1972	10	20	3	80000	2	1	4.90	3.42	2.17
1973	1972	10	8	4	3370	1.2	1	3.53	-0.53	99.99
1973	1972	12	30	4	3240	3	0	3.51	-0.57	99.99
1973	1973	2	24	4	9000	5	0	3.95	0.70	99.99
1973	1973	3	22	4	3430	3	1	3.54	-0.50	99.99
1973	1973	4	30	4	3360	9	0	3.53	-0.53	99.99
1974	1974	7	20	3	1160	8	0	3.06	-1.85	-1.51
1975	1975	9	10	3	15800	8	0	4.20	1.40	0.76
1976	1976	2	12	3	2600	3	0	3.41	-0.85	-0.81
1977	1977	8	15	3	6090	1	0	3.78	0.21	-0.07
1978	1978	3	4	3	19000	3	0	4.28	1.63	0.92
1979	1978	12	19	3	100000	3	1	5.00	3.70	2.36
1979	1978	11	26	4	22400	2	0	4.35	1.83	99.99
1979	1979	1	1	4	6360	3	1	3.80	0.27	99.99
1979	1979	1	18	4	27900	3	2	4.45	2.11	99.99
1979	1979	2	18	4	4520	9	0	3.66	-0.16	99.99
1980	1980	2	16	3	20600	3	0	4.31	1.73	0.99
1980	1980	2	21	4	20400	3	1	4.31	1.72	99.99
1980	1980	9	11	4	6300	2	0	3.80	0.25	99.99

5. SCLPER San Carlos River near Peridot

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	21	3	2150	8	0	3.33	-1.22	-1.36
1951	1951	8	29	3	2940	1	1	3.47	-0.78	-1.03
1951	1951	7	27	4	2420	8	0	3.38	-1.05	99.99
1951	1951	8	27	4	2280	1	0	3.36	-1.13	99.99
1952	1952	1	13	3	39200	3	1	4.59	2.80	1.67
1952	1951	12	31	4	9390	3	0	3.97	0.82	99.99
1952	1952	1	18	4	23900	3	1	4.38	2.11	99.99
1952	1952	8	5	4	3040	7	0	3.48	-0.74	99.99
1952	1952	8	11	4	6400	7	1	3.81	0.29	99.99
1952	1952	8	15	4	3300	8	2	3.52	-0.62	99.99
1952	1952	8	19	4	2720	8	3	3.43	-0.89	99.99
1953	1953	8	27	3	860	7	0	2.93	-2.48	-2.31
1954	1954	3	23	3	23500	3	0	4.37	2.09	1.13
1954	1954	7	12	4	11400	8	0	4.06	1.09	99.99
1954	1954	7	26	4	4100	7	1	3.61	-0.32	99.99
1954	1954	8	3	4	9900	8	2	4.00	0.90	99.99
1954	1954	8	5	4	3970	8	3	3.60	-0.37	99.99
1954	1954	8	22	4	2810	7	3	3.45	-0.84	99.99
1955	1955	8	6	3	14600	7	4	4.16	1.43	0.64
1955	1955	7	24	4	2510	8	1	3.40	-1.00	99.99
1955	1955	7	29	4	3240	7	2	3.51	-0.65	99.99
1955	1955	8	3	4	9840	8	3	3.99	0.89	99.99

1955	1955	8	18	4	4740	8	5	3.68	-0.12	99.99
1955	1955	8	19	4	6600	8	6	3.82	0.34	99.99
1955	1955	8	20	4	9250	8	7	3.97	0.80	99.99
1955	1955	7	22	4	2670	7	0	3.43	-0.92	99.99
1955	1955	8	23	4	4520	8	7	3.66	-0.19	99.99
1956	1956	1	29	3	9300	3	0	3.97	0.81	0.17
1957	1957	7	26	3	7310	8	0	3.86	0.48	-0.08
1958	1958	3	22	3	7670	3	2	3.88	0.54	-0.03
1958	1958	3	14	4	2540	5	0	3.40	-0.98	99.99
1958	1958	3	17	4	4550	3	1	3.66	-0.18	99.99
1958	1958	8	16	4	2900	7	0	3.46	-0.80	99.99
1959	1959	8	18	3	2280	8	0	3.36	-1.13	-1.30
1959	1958	10	12	4	2260	4	0	3.35	-1.15	99.99
1960	1959	12	26	3	14300	3	0	4.16	1.40	0.62
1960	1959	10	30	4	4100	3	0	3.61	-0.32	99.99
1960	1959	11	2	4	4750	2	1	3.68	-0.12	99.99
1960	1960	1	11	4	8910	3	1	3.95	0.75	99.99
1961	1961	7	22	3	5510	7	0	3.74	0.09	-0.38
1961	1961	7	28	4	3860	8	1	3.59	-0.41	99.99
1961	1961	8	22	4	4920	7	1	3.69	-0.07	99.99
1962	1962	9	26	3	4400	1.3	0	3.64	-0.23	-0.61
1962	1961	12	16	4	3800	5	0	3.58	-0.43	99.99
1962	1962	1	25	4	3930	2	0	3.59	-0.38	99.99
1963	1963	2	11	3	9740	3	0	3.99	0.87	0.22
1963	1962	10	18	4	3580	2	1	3.55	-0.51	99.99
1963	1963	1	11	4	3500	3	0	3.54	-0.54	99.99
1963	1963	8	6	4	2260	8	0	3.35	-1.15	99.99
1963	1963	8	13	4	2700	8	1	3.43	-0.90	99.99
1963	1963	8	31	4	3250	8	2	3.51	-0.64	99.99
1964	1964	7	25	3	6610	8	0	3.82	0.34	-0.19
1964	1964	8	8	4	2500	7	1	3.40	-1.01	99.99
1964	1964	8	17	4	3720	7	2	3.57	-0.46	99.99
1964	1964	9	9	4	3860	8	1	3.59	-0.41	99.99
1965	1965	1	8	3	1710	3	0	3.23	-1.53	-1.60
1966	1965	12	22	3	36300	3	1	4.56	2.69	1.59
1966	1965	11	30	4	8720	4	0	3.94	0.72	99.99
1966	1965	12	30	4	16500	3	2	4.22	1.60	99.99
1966	1966	8	12	4	8200	8	0	3.91	0.64	99.99
1966	1966	9	13	4	3100	2	0	3.49	-0.71	99.99
1967	1967	7	29	3	16100	7	1	4.21	1.57	0.74
1967	1967	7	24	4	5040	7	0	3.70	-0.04	99.99
1967	1967	8	18	4	6900	7	2	3.84	0.40	99.99
1968	1967	12	20	3	32000	3	0	4.51	2.52	1.45
1968	1968	1	28	4	3000	3	0	3.48	-0.75	99.99
1968	1968	2	14	4	6280	3	1	3.80	0.27	99.99
1968	1968	8	4	4	6050	8	0	3.78	0.22	99.99
1968	1968	8	9	4	4920	7	1	3.69	-0.07	99.99
1969	1969	1	22	3	4580	3	0	3.66	-0.17	-0.57

1970	1970	9	6	3	5080	1.3	0	3.71	-0.03	-0.46
1971	1971	8	14	3	7930	1	1	3.90	0.59	0.00
1971	1971	8	12	4	4560	1.2	0	3.66	-0.18	99.99
1971	1971	8	18	4	4460	8	2	3.65	-0.21	99.99
1971	1971	8	19	4	2610	8	3	3.42	-0.95	99.99
1971	1971	8	22	4	3370	7	4	3.53	-0.59	99.99
1971	1971	8	24	4	2250	7	5	3.35	-1.15	99.99
1971	1971	8	31	4	4210	7	6	3.62	-0.29	99.99
1971	1971	9	30	4	3440	1	1	3.54	-0.57	99.99
1972	1971	10	17	3	4970	3.2	1	3.70	-0.06	-0.49
1972	1971	12	26	4	3860	3	0	3.59	-0.41	99.99
1972	1972	9	13	4	2850	7	0	3.45	-0.83	99.99
1973	1972	10	19	3	25000	2	2	4.40	2.18	1.20
1973	1972	10	5	4	7610	2.1	1	3.88	0.53	99.99
1973	1972	10	7	4	4860	1.2	2	3.69	-0.09	99.99
1973	1972	12	29	4	7060	3	0	3.85	0.43	99.99
1973	1973	1	12	4	3130	9.41	1	3.50	-0.70	99.99
1973	1973	2	12	4	3130	3	0	3.50	-0.70	99.99
1973	1973	2	22	4	5200	5	1	3.72	0.01	99.99
1973	1973	3	16	4	6480	9	1	3.81	0.31	99.99
1973	1973	3	30	4	3500	3	1	3.54	-0.54	99.99
1973	1973	7	14	4	3980	8	0	3.60	-0.36	99.99
1974	1974	7	20	3	7800	8	0	3.89	0.57	-0.02
1974	1974	7	31	4	3900	7	1	3.59	-0.39	99.99
1974	1974	8	2	4	2780	8	2	3.44	-0.86	99.99
1975	1975	4	11	3	1960	5	0	3.29	-1.34	-1.45
1976	1976	9	25	3	12000	5	0	4.08	1.16	0.43
1976	1976	7	18	4	4320	7	0	3.64	-0.25	99.99
1977	1977	9	11	3	5400	8	3	3.73	0.06	-0.40
1977	1977	8	1	4	2240	7	0	3.35	-1.16	99.99
1977	1977	8	3	4	3980	7	1	3.60	-0.36	99.99
1977	1977	8	13	4	3660	8	2	3.56	-0.48	99.99
1977	1977	8	16	4	3580	1	3	3.55	-0.51	99.99
1977	1977	9	9	4	3790	7	2	3.58	-0.43	99.99
1978	1978	3	2	3	18600	3	2	4.27	1.77	0.89
1978	1978	1	31	4	2210	5	0	3.34	-1.18	99.99
1978	1978	2	11	4	5700	3	1	3.76	0.13	99.99
1978	1978	7	22	4	2780	7	0	3.44	-0.86	99.99
1978	1978	7	29	4	2540	7	1	3.40	-0.98	99.99
1978	1978	8	1	4	9650	8	2	3.98	0.86	99.99
1979	1978	12	18	3	22500	3	1	4.35	2.03	1.09
1979	1978	11	25	4	22400	2	0	4.35	2.02	99.99
1979	1979	1	17	4	16400	5	1	4.21	1.59	99.99
1980	1980	2	15	3	12300	3	0	4.09	1.20	0.46
1980	1980	2	20	4	11200	3	1	4.05	1.07	99.99
1980	1980	8	24	4	2300	8	0	3.36	-1.12	99.99

6. SPDPAL San Pedro River at Palominas

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	5	3	6270	8	0	3.80	0.88	0.13
1950	1950	7	21	4	5150	8	1	3.71	0.47	99.99
1950	1950	7	30	4	3610	8	2	3.56	-0.28	99.99
1951	1951	7	2	3	5710	7	0	3.76	0.69	-0.02
1951	1951	8	26	4	2760	1	0	3.44	-0.84	99.99
1952	1952	8	16	3	7400	8	2	3.87	1.23	0.42
1952	1952	8	5	4	3000	7	0	3.48	-0.66	99.99
1952	1952	8	8	4	4890	7	1	3.69	0.36	99.99
1953	1953	7	7	3	11900	8	1	4.08	2.23	1.22
1953	1953	7	6	4	3990	7	0	3.60	-0.07	99.99
1953	1953	7	13	4	4500	8	2	3.65	0.19	99.99
1953	1953	7	17	4	4380	8	3	3.64	0.13	99.99
1953	1953	7	18	4	3740	7	4	3.57	-0.20	99.99
1954	1954	7	31	3	17300	7	4	4.24	3.01	1.86
1954	1954	7	20	4	5020	1	0	3.70	0.42	99.99
1954	1954	7	22	4	3360	6	1	3.53	-0.43	99.99
1954	1954	7	23	4	3840	6	2	3.58	-0.15	99.99
1954	1954	7	24	4	2900	6	3	3.46	-0.74	99.99
1955	1955	7	31	3	6250	8	3	3.80	0.88	0.13
1955	1955	7	22	4	3110	7	0	3.49	-0.59	99.99
1955	1955	7	26	4	3370	8	1	3.53	-0.42	99.99
1955	1955	7	29	4	2800	7	2	3.45	-0.81	99.99
1955	1955	8	3	4	3140	8	4	3.50	-0.57	99.99
1955	1955	8	7	4	3780	8	5	3.58	-0.18	99.99
1955	1955	8	9	4	3430	7	6	3.54	-0.38	99.99
1955	1955	8	10	4	2860	7	7	3.46	-0.76	99.99
1955	1955	8	19	4	4580	8	8	3.66	0.22	99.99
1955	1955	8	21	4	5730	8	9	3.76	0.69	99.99
1955	1955	8	26	4	4520	7	8	3.66	0.20	99.99
1956	1956	7	17	3	4640	8	0	3.67	0.25	-0.38
1956	1956	7	26	4	2660	8	1	3.42	-0.92	99.99
1956	1956	8	26	4	4450	7	0	3.65	0.16	99.99
1957	1957	8	20	3	2540	8	0	3.40	-1.01	-1.40
1958	1958	8	5	3	16500	8	0	4.22	2.91	1.78
1958	1958	7	5	4	2560	7	0	3.41	-1.00	99.99
1958	1958	8	6	4	9560	8	1	3.98	1.77	99.99
1958	1958	8	14	4	4450	7	2	3.65	0.16	99.99
1958	1958	8	24	4	3500	7	3	3.54	-0.34	99.99
1958	1958	9	1	4	5910	7	4	3.77	0.76	99.99
1958	1958	9	12	4	2590	1	3	3.41	-0.97	99.99
1958	1958	9	23	4	5690	5	3	3.76	0.68	99.99
1959	1959	7	27	3	13000	8	1	4.11	2.41	1.37
1959	1959	6	29	4	2480	7	0	3.39	-1.06	99.99
1959	1959	7	28	4	2860	8	2	3.46	-0.76	99.99
1959	1959	7	29	4	2670	8	3	3.43	-0.91	99.99
1959	1959	8	13	4	3120	8	3	3.49	-0.58	99.99
1960	1960	8	16	3	3410	7	0	3.53	-0.40	-0.90

1961	1961	7	29	3	3820	8	2	3.58	-0.16	-0.71
1961	1961	7	16	4	2430	7	0	3.39	-1.11	99.99
1961	1961	7	28	4	3500	8	1	3.54	-0.34	99.99
1961	1961	8	11	4	3530	8	3	3.55	-0.32	99.99
1961	1961	8	13	4	3020	7	4	3.48	-0.65	99.99
1961	1961	8	29	4	2930	8	2	3.47	-0.71	99.99
1962	1962	7	26	3	4130	7	0	3.62	0.01	-0.57
1963	1963	7	27	3	6340	7	0	3.80	0.91	0.15
1963	1963	7	30	4	6180	7	1	3.79	0.85	99.99
1964	1964	8	14	3	11000	8	2	4.04	2.06	1.09
1964	1964	7	22	4	3460	8	0	3.54	-0.36	99.99
1964	1964	8	5	44	5570	7	1	3.75	0.63	0.00
1964	1964	9	10	4	2640	8	1	3.42	-0.93	99.99
1965	1965	7	28	3	4530	7	0	3.66	0.20	-0.42
1966	1966	7	28	3	3610	8	0	3.56	-0.28	-0.80
1966	1966	8	6	4	2990	7	1	3.48	-0.67	99.99
1966	1966	8	19	4	2530	8	2	3.40	-1.02	99.99
1966	1966	8	29	4	2490	7	2	3.40	-1.05	99.99
1967	1967	7	26	3	5560	7	0	3.75	0.63	-0.07
1968	1967	12	20	3	6500	3	0	3.81	0.96	0.20
1969	1969	7	28	3	4000	7	0	3.60	-0.06	-0.63
1969	1969	8	29	4	2610	8	0	3.42	-0.96	99.99
1970	1970	8	9	3	5870	8	2	3.77	0.74	0.02
1970	1970	7	28	4	2530	7	0	3.40	-1.02	99.99
1970	1970	8	3	4	4500	7	1	3.65	0.19	99.99
1971	1971	8	11	3	6380	2.1	4	3.80	0.92	0.16
1971	1971	7	24	4	2720	8	0	3.43	-0.87	99.99
1971	1971	7	29	4	2700	2	1	3.43	-0.88	99.99
1971	1971	7	30	4	4240	2	2	3.63	0.06	99.99
1971	1971	8	10	4	3090	2	3	3.49	-0.60	99.99
1971	1971	8	13	4	3290	1	5	3.52	-0.47	99.99
1971	1971	8	15	4	4460	8	6	3.65	0.17	99.99
1971	1971	8	20	4	3140	8	7	3.50	-0.57	99.99
1972	1972	8	26	3	1830	6	0	3.26	-1.70	-1.95
1973	1972	10	18	3	2900	2	0	3.46	-0.74	-1.17
1974	1974	7	30	3	7360	7	2	3.87	1.22	0.41
1974	1974	7	19	4	2670	8	0	3.43	-0.91	99.99
1974	1974	7	20	4	7020	8	1	3.85	1.12	99.99
1974	1974	8	4	4	6220	8	3	3.79	0.87	99.99
1974	1974	8	6	4	2900	8	4	3.46	-0.74	99.99
1975	1975	9	14	3	6840	3	0	3.84	1.06	0.28
1975	1975	7	13	4	2400	7	0	3.38	-1.13	99.99
1975	1975	7	18	4	2560	7	1	3.41	-1.00	99.99
1975	1975	7	22	4	2910	7	2	3.46	-0.73	99.99
1976	1976	7	27	3	5000	8	2	3.70	0.41	-0.25
1976	1976	7	22	4	3300	8	0	3.52	-0.46	99.99
1976	1976	7	24	4	3320	8	1	3.52	-0.45	99.99

1977	1977	7	31	3	3310	7	1	3.52	-0.46	-0.95
1977	1977	7	14	4	2640	7	0	3.42	-0.93	99.99
1977	1977	8	10	4	2840	7	2	3.45	-0.78	99.99
1977	1977	8	21	4	3190	7	2	3.50	-0.54	99.99
1978	1977	10	9	3	14500	1	0	4.16	2.64	1.56
1979	1979	1	18	3	12000	3	1	4.08	2.24	1.24
1979	1978	11	25	4	3110	2	0	3.49	-0.59	99.99
1979	1978	12	19	4	11500	3	1	4.06	2.15	99.99
1980	1980	8	4	3	2000	7	0	3.30	-1.51	-1.80

7. SPDCHA San Pedro River at Charleston

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANG
1950	1950	7	6	3	6070	8	0	3.78	0.40	0.01
1950	1950	7	21	4	4920	8	1	3.69	-0.02	99.99
1950	1950	7	30	4	3630	8	2	3.56	-0.63	99.99
1951	1951	7	2	3	5730	7	0	3.76	0.28	-0.08
1951	1951	8	26	4	4180	1	0	3.62	-0.35	99.99
1952	1952	8	17	3	7850	8	2	3.89	0.92	0.43
1952	1952	8	9	4	3120	7	0	3.49	-0.94	99.99
1952	1952	8	10	4	6770	7	1	3.83	0.62	99.99
1952	1952	8	19	4	4680	8	3	3.67	-0.12	99.99
1953	1953	7	7	3	8590	8	0	3.93	1.10	0.58
1953	1953	7	13	4	3120	8	1	3.49	-0.94	99.99
1953	1953	7	17	4	3720	8	2	3.57	-0.58	99.99
1953	1953	7	25	4	3230	7	3	3.51	-0.87	99.99
1954	1954	8	15	3	23600	7	9	4.37	3.13	2.23
1954	1954	7	18	4	14500	1	0	4.16	2.15	99.99
1954	1954	7	20	4	6770	1	1	3.83	0.62	99.99
1954	1954	7	21	4	3350	8	2	3.53	-0.80	99.99
1954	1954	7	22	4	6770	6	3	3.83	0.62	99.99
1954	1954	7	24	4	7130	6	4	3.85	0.72	99.99
1954	1954	8	1	4	14300	8	5	4.16	2.13	99.99
1954	1954	8	3	4	14100	8	6	4.15	2.10	99.99
1954	1954	8	5	4	8190	8	7	3.91	1.00	99.99
1954	1954	8	12	4	8340	7	8	3.92	1.04	99.99
1954	1954	8	23	4	5860	7	6	3.77	0.33	99.99
1955	1955	8	6	3	14400	7	6	4.16	2.14	1.42
1955	1955	7	20	4	3120	7	0	3.49	-0.94	99.99
1955	1955	7	22	4	7350	7	1	3.87	0.79	99.99
1955	1955	7	26	4	3180	8	2	3.50	-0.90	99.99
1955	1955	8	1	4	5780	8	3	3.76	0.30	99.99
1955	1955	8	2	4	4740	8	4	3.68	-0.10	99.99
1955	1955	8	3	4	3940	8	5	3.60	-0.47	99.99
1955	1955	8	9	4	13000	7	7	4.11	1.93	99.99
1955	1955	8	11	4	3840	7	8	3.58	-0.52	99.99
1955	1955	8	20	4	9990	8	8	4.00	1.40	99.99
1955	1955	8	26	4	5860	7	7	3.77	0.33	99.99

1956	1956	7	18	3	6550	8	0	3.82	0.55	0.14
1956	1956	8	27	4	3340	7	0	3.52	-0.80	99.99
1957	1957	7	25	3	6000	8	0	3.78	0.38	-0.01
1957	1957	8	18	4	4550	8	1	3.66	-0.18	99.99
1958	1958	8	5	3	8400	8	2	3.92	1.05	0.54
1958	1958	7	18	4	3490	7	0	3.54	-0.71	99.99
1958	1958	7	29	4	3100	8	1	3.49	-0.95	99.99
1958	1958	8	6	4	6280	8	3	3.80	0.47	99.99
1958	1958	8	15	4	3650	8	4	3.56	-0.62	99.99
1958	1958	8	16	4	4270	7	5	3.63	-0.31	99.99
1958	1958	8	24	4	4490	7	5	3.65	-0.21	99.99
1958	1958	9	1	4	4820	7	5	3.68	-0.06	99.99
1958	1958	9	23	4	4340	5	2	3.64	-0.27	99.99
1959	1959	7	27	3	7480	8	0	3.87	0.82	0.35
1959	1959	8	13	4	4880	8	0	3.69	-0.04	99.99
1959	1959	8	15	4	3030	7	2	3.48	-1.00	99.99
1960	1960	8	11	3	3900	7	0	3.59	-0.49	-0.71
1961	1961	7	30	3	3620	8	0	3.56	-0.64	-0.83
1961	1961	8	10	4	3220	7	1	3.51	-0.88	99.99
1962	1962	7	28	3	3580	7	0	3.55	-0.66	-0.85
1963	1963	7	27	3	6460	7	0	3.81	0.53	0.11
1963	1963	7	29	4	3510	7	1	3.55	-0.70	99.99
1963	1963	7	30	4	6260	7	1	3.80	0.46	99.99
1963	1963	9	3	4	4280	7	0	3.63	-0.30	99.99
1964	1964	8	14	3	7690	8	3	3.89	0.88	0.40
1964	1964	7	23	4	3120	8	0	3.49	-0.94	99.99
1964	1964	7	31	4	3000	8	1	3.48	-1.02	99.99
1964	1964	8	58	4	3120	7	2	3.49	-0.94	99.99
1964	1964	9	9	4	4680	8	1	3.67	-0.12	99.99
1964	1964	9	10	4	3840	8	2	3.58	-0.52	99.99
1965	1965	9	4	3	4180	1	0	3.62	-0.35	-0.60
1965	1965	7	28	4	3260	7	0	3.51	-0.85	99.99
1966	1966	8	3	3	4400	7	1	3.64	-0.25	-0.51
1966	1966	7	29	4	3360	8	0	3.53	-0.79	99.99
1966	1966	8	18	4	3600	8	2	3.56	-0.65	99.99
1967	1967	7	26	3	6010	7	0	3.78	0.38	0.00
1967	1967	8	11	4	4200	8	1	3.62	-0.34	99.99
1968	1967	12	20	3	5050	3	0	3.70	0.03	-0.29
1968	1968	9	31	4	3060	2	0	3.49	-0.98	99.99
1969	1969	7	28	3	3920	7	0	3.59	-0.48	-0.70
1969	1969	8	30	4	3220	8	0	3.51	-0.88	99.99
1970	1970	8	9	3	4600	8	1	3.66	-0.16	-0.44
1970	1970	8	3	4	3950	7	0	3.60	-0.46	99.99
1971	1971	8	10	3	5920	2	2	3.77	0.35	-0.03
1971	1971	7	29	4	3340	2	0	3.52	-0.80	99.99
1971	1971	7	31	4	3300	2	1	3.52	-0.83	99.99
1971	1971	8	11	4	4990	2.1	3	3.70	0.01	99.99
1971	1971	8	13	4	3260	1	4	3.51	-0.85	99.99
1971	1971	8	15	4	4580	8	5	3.66	-0.17	99.99

1971	1971	8	18	4	3140	8	6	3.50	-0.93	99.99
1971	1971	8	20	4	3220	8	7	3.51	-0.88	99.99
1971	1971	9	2	4	5170	7	6	3.71	0.08	99.99
1972	1972	8	26	3	5950	6	0	3.77	0.36	-0.02
1973	1973	7	15	3	3340	8	0	3.52	-0.80	-0.96
1974	1974	7	20	3	13100	8	0	4.12	1.95	1.27
1974	1974	7	30	4	5440	7	1	3.74	0.18	99.99
1974	1974	8	4	4	4900	8	2	3.69	-0.03	99.99
1974	1974	8	5	4	4400	8	3	3.64	-0.25	99.99
1974	1974	8	6	4	3080	8	4	3.49	-0.96	99.99
1975	1975	9	14	3	4020	3	0	3.60	-0.43	-0.66
1976	1976	9	5	3	3620	8	0	3.56	-0.64	-0.83
1976	1976	7	27	4	3240	8	0	3.51	-0.86	99.99
1977	1977	8	23	3	5200	7	0	3.72	0.09	-0.24
1978	1977	10	8	3	23700	1	0	4.37	3.14	2.23
1979	1979	1	18	3	11800	3	1	4.07	1.74	1.10
1979	1978	11	25	4	3320	2	0	3.52	-0.81	99.99
1979	1978	12	19	4	11600	3	1	4.06	1.70	99.99
1980	1980	8	15	3	990	8	0	3.00	-3.25	-2.95

9. SCRLOC Santa Cruz River near Lochiel

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	30	3	4520	8	3	3.66	1.10	0.97
1950	1950	7	8	4	4300	8	0	3.63	1.05	99.99
1950	1950	7	20	4	2240	7	1	3.35	0.43	99.99
1950	1950	7	22	4	3790	8	2	3.58	0.93	99.99
1950	1950	8	5	4	4490	7	4	3.65	1.10	99.99
1951	1951	8	2	3	2560	8	0	3.41	0.55	0.53
1952	1952	8	16	3	550	8	0	2.74	-0.93	-0.66
1953	1953	7	14	3	3320	8	2	3.52	0.80	0.73
1953	1953	7	7	4	1730	8	0	3.24	0.18	99.99
1953	1953	7	13	4	2180	8	1	3.34	0.40	99.99
1953	1953	7	15	4	1500	7	3	3.18	0.04	99.99
1953	1953	7	30	4	1480	8	4	3.17	0.03	99.99
1954	1954	7	22	3	1570	6	0	3.20	0.08	0.15
1954	1954	7	20	4	1510	1	0	3.18	0.05	99.99
1954	1954	7	31	4	1560	7	1	3.19	0.08	99.99
1955	1955	8	6	3	4300	7	2	3.63	1.05	0.94
1955	1955	7	22	4	2240	7	0	3.35	0.43	99.99
1955	1955	8	3	4	2860	8	1	3.46	0.66	99.99
1955	1955	8	9	4	1520	7	3	3.18	0.05	99.99
1955	1955	8	19	4	3950	8	4	3.60	0.97	99.99
1955	1955	8	20	4	4020	8	5	3.60	0.99	99.99
1955	1955	8	23	4	1180	8	5	3.07	-0.19	99.99
1955	1955	8	24	4	1560	8	6	3.19	0.08	99.99
1955	1955	8	27	4	1020	7	7	3.01	-0.33	99.99
1956	1956	7	17	3	1360	8	0	3.13	-0.05	0.04

1957	1957	8	9	3	688	7	0	2.84	-0.71	-0.49
1958	1958	8	7	3	380	8	0	2.58	-1.28	-0.95
1959	1959	8	14	3	243	8	0	2.39	-1.71	-1.29
1960	1960	7	30	3	625	8	0	2.80	-0.80	-0.56
1961	1961	8	8	3	1120	7	0	3.05	-0.24	-0.11
1962	1962	7	29	3	7.6	8	0	0.88	-5.05	-3.98
1963	1963	8	25	3	2390	7	0	3.38	0.49	0.48
1964	1964	9	9	3	2330	8	0	3.37	0.46	0.46
1965	1965	9	12	3	4810	7	0	3.68	1.16	1.02
1966	1966	8	18	3	1780	8	1	3.25	0.20	0.25
1966	1966	8	17	4	1150	8	0	3.06	-0.22	99.99
1966	1966	8	20	4	1020	8	2	3.01	-0.33	99.99
1967	1967	8	3	3	1870	8	1	3.27	0.25	0.29
1967	1967	7	29	4	790	7	0	2.90	-0.58	99.99
1968	1967	12	20	3	986	3	0	2.99	-0.36	-0.21
1969	1969	8	5	3	484	1	0	2.68	-1.05	-0.76
1970	1970	8	3	3	880	7	0	2.94	-0.47	-0.30
1971	1971	8	10	3	2830	2	0	3.45	0.65	0.61
1972	1972	7	16	3	2070	8	0	3.32	0.35	0.37
1973	1973	6	30	3	1490	7	0	3.17	0.03	0.11
1974	1974	8	4	3	1730	8	0	3.24	0.18	0.23
1975	1975	7	22	3	3330	7	0	3.52	0.81	0.74
1976	1976	7	22	3	3540	8	0	3.55	0.87	0.78
1977	1977	9	5	3	1130	7	0	3.05	-0.23	-0.10
1978	1977	10	9	3	12000	1	0	4.08	2.04	1.73
1978	1978	7	22	4	700	7	0	2.85	-0.69	99.99
1978	1978	8	3	4	632	8	1	2.80	-0.79	99.99
1979	1979	1	25	3	1060	3	1	3.03	-0.29	-0.15
1979	1978	12	18	4	730	3	0	2.86	-0.65	99.99
1979	1979	1	17	4	998	5	1	3.00	-0.35	99.99
1980	1980	6	30	3	406	7	0	2.61	-1.22	-0.90

10. SCRNOG Santa Cruz River near Nogales

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	20	3	7210	7	2	3.86	1.23	0.59
1950	1950	7	7	4	2210	8	0	3.34	-0.80	99.99
1950	1950	7	17	4	5890	8	1	3.77	0.88	99.99
1950	1950	7	22	4	4670	8	3	3.67	0.48	99.99
1950	1950	7	31	4	4060	8	4	3.61	0.24	99.99
1951	1951	8	3	3	3040	8	1	3.48	-0.26	-0.45
1951	1951	7	28	4	2840	8	0	3.45	-0.37	99.99
1952	1952	7	29	3	2330	8	0	3.37	-0.71	-0.77
1952	1952	8	16	4	2000	8	1	3.30	-0.98	99.99
1953	1953	7	14	3	3500	8	0	3.54	-0.01	-0.28
1954	1954	7	10	3	10600	7	1	4.03	1.89	1.05
1954	1954	7	9	4	2110	7	0	3.32	-0.88	99.99
1954	1954	7	12	4	2860	8	2	3.46	-0.36	99.99
1954	1954	7	23	4	2320	6	3	3.37	-0.72	99.99

1954	1954	7	24	4	5380	6	4	3.73	0.72	99.99
1954	1954	7	31	4	9840	7	5	3.99	1.76	99.99
1954	1954	8	5	4	2400	8	6	3.38	-0.66	99.99
1954	1954	8	23	4	4150	7	3	3.62	0.28	99.99
1955	1955	8	20	3	11100	8	6	4.05	1.97	1.10
1955	1955	7	17	4	2900	8	0	3.46	-0.34	99.99
1955	1955	7	21	4	3040	7	1	3.48	-0.26	99.99
1955	1955	7	22	4	3250	7	2	3.51	-0.14	99.99
1955	1955	8	4	4	6680	8	3	3.82	1.10	99.99
1955	1955	8	6	4	9830	7	4	3.99	1.76	99.99
1955	1955	8	9	4	2760	7	5	3.44	-0.42	99.99
1955	1955	8	13	4	2810	8	6	3.45	-0.39	99.99
1955	1955	8	22	4	6580	8	5	3.82	1.07	99.99
1956	1956	6	28	3	2530	4	0	3.40	-0.57	-0.67
1957	1957	8	18	3	1620	8	0	3.21	-1.34	-1.20
1958	1958	8	13	3	4000	7	2	3.60	0.22	-0.12
1958	1958	8	5	4	3000	8	0	3.48	-0.28	99.99
1958	1958	8	11	4	2920	8	1	3.47	-0.33	99.99
1958	1958	9	4	4	2080	7	3	3.32	-0.91	99.99
1959	1959	8	6	3	2640	8	1	3.42	-0.50	-0.62
1959	1959	7	21	4	2290	7	0	3.36	-0.74	99.99
1959	1959	8	21	4	2010	7	1	3.30	-0.97	99.99
1960	1960	1	11	3	2760	3	0	3.44	-0.42	-0.56
1961	1961	8	15	3	1640	8	0	3.21	-1.32	-1.19
1962	1962	8	19	3	2390	8	0	3.38	-0.67	-0.74
1962	1961	12	15	4	2080	5	0	3.32	-0.91	99.99
1962	1962	1	24	4	2020	2	0	3.31	-0.96	99.99
1963	1963	7	10	3	4510	7	0	3.65	0.42	0.02
1963	1963	7	29	4	2720	7	1	3.43	-0.45	99.99
1963	1963	7	30	4	2790	7	2	3.45	-0.40	99.99
1963	1963	7	31	4	2180	7	3	3.34	-0.83	99.99
1963	1963	8	3	4	3070	8	4	3.49	-0.24	99.99
1963	1963	8	5	4	2580	8	5	3.41	-0.54	99.99
1963	1963	8	26	4	2600	8	5	3.41	-0.53	99.99
1964	1964	8	14	3	5630	8	3	3.75	0.80	0.29
1964	1964	7	23	4	2980	8	0	3.47	-0.29	99.99
1964	1964	7	30	4	2220	8	1	3.35	-0.80	99.99
1964	1964	8	2	4	2650	8	2	3.42	-0.49	99.99
1964	1964	9	10	4	2070	8	1	3.32	-0.92	99.99
1964	1964	9	11	4	2260	8	2	3.35	-0.77	99.99
1965	1965	9	13	3	1580	7	0	3.20	-1.38	-1.23
1966	1966	8	20	3	4400	8	6	3.64	0.38	-0.01
1966	1965	12	17	4	2260	5	0	3.35	-0.77	99.99
1966	1965	12	22	4	3390	3	1	3.53	-0.07	99.99
1966	1965	12	23	4	3840	3	2	3.58	0.14	99.99
1966	1966	7	28	4	2920	8	0	3.47	-0.33	99.99
1966	1966	7	29	4	4110	8	1	3.61	0.26	99.99

1966	1966	8	5	4	2900	7	2	3.46	-0.34	99.99
1966	1966	8	17	4	3970	8	3	3.60	0.20	99.99
1966	1966	8	18	4	3010	8	4	3.48	-0.27	99.99
1966	1966	8	19	4	3620	8	5	3.56	0.04	99.99
1966	1966	8	24	4	2100	2	7	3.32	-0.89	99.99
1966	1966	8	27	4	2060	7	8	3.31	-0.93	99.99
1967	1967	7	27	3	6310	8	1	3.80	1.00	0.43
1967	1967	7	25	4	2370	7	0	3.37	-0.68	99.99
1968	1967	12	20	3	15200	3	1	4.18	2.51	1.48
1968	1967	12	15	4	3070	2.3	0	3.49	-0.24	99.99
1968	1968	7	18	4	2140	7	0	3.33	-0.86	99.99
1968	1968	7	22	4	3950	8	1	3.60	0.19	99.99
1969	1969	8	2	3	4460	7	1	3.65	0.40	0.01
1969	1969	7	31	4	2960	7	0	3.47	-0.30	99.99
1969	1969	8	26	4	2930	7	2	3.47	-0.32	99.99
1970	1970	8	16	3	4100	7	2	3.61	0.26	-0.09
1970	1970	8	3	4	2240	7	0	3.35	-0.78	99.99
1970	1970	8	9	4	2710	8	1	3.43	-0.45	99.99
1971	1971	8	20	3	2930	8	3	3.47	-0.32	-0.49
1971	1971	7	24	4	2140	8	0	3.33	-0.86	99.99
1971	1971	8	3	4	2050	8	1	3.31	-0.93	99.99
1971	1971	8	13	4	2370	1	2	3.37	-0.68	99.99
1971	1971	8	30	4	2420	7	3	3.38	-0.65	99.99
1972	1971	10	24	3	738	3	0	2.87	-2.69	-2.15
1973	1973	2	22	3	2300	5	0	3.36	-0.74	-0.78
1974	1974	8	1	3	17100	8	2	4.23	2.71	1.62
1974	1974	7	13	4	6910	7	0	3.84	1.15	99.99
1974	1974	7	19	4	4120	8	1	3.61	0.27	99.99
1974	1974	9	1	4	2180	7	0	3.34	-0.83	99.99
1975	1975	7	22	3	11400	7	0	4.06	2.01	1.14
1975	1975	7	24	4	2730	7	1	3.44	-0.44	99.99
1975	1975	7	27	4	5910	7	2	3.77	0.89	99.99
1975	1975	8	8	4	2580	7	3	3.41	-0.54	99.99
1975	1975	8	11	4	4540	7	4	3.66	0.43	99.99
1975	1975	9	1	4	6700	7	2	3.83	1.10	99.99
1975	1975	9	13	4	5400	3	3	3.73	0.73	99.99
1976	1976	7	22	3	6700	8	0	3.83	1.10	0.50
1976	1976	7	23	4	4580	8	1	3.66	0.45	99.99
1976	1976	7	25	4	5720	8	2	3.76	0.83	99.99
1976	1976	7	27	4	3600	8	3	3.56	0.03	99.99
1976	1976	7	28	4	5910	8	4	3.77	0.89	99.99
1976	1976	8	8	4	2360	7	5	3.37	-0.69	99.99
1977	1977	8	18	3	6700	7	2	3.83	1.10	0.50
1977	1977	7	18	4	2010	8	0	3.30	-0.97	99.99
1977	1977	8	14	4	2430	8	1	3.39	-0.64	99.99
1977	1977	8	16	4	2880	1	2	3.46	-0.35	99.99
1977	1977	9	4	4	3520	7	3	3.55	0.00	99.99
1977	1977	9	11	4	2730	8	4	3.44	-0.44	99.99

1978	1977	10	9	3	31000	1	2	4.49	3.73	2.34
1978	1977	10	8	4	19300	1	1	4.29	2.92	99.99
1978	1978	8	1	4	4480	8	0	3.65	0.41	99.99
1978	1978	8	2	4	2830	8	1	3.45	-0.38	99.99
1979	1978	12	18	3	12700	3	1	4.10	2.20	1.27
1979	1978	11	24	4	6100	2	0	3.79	0.94	99.99
1979	1978	12	31	4	2160	3	1	3.33	-0.84	99.99
1979	1979	1	18	4	7180	3	1	3.86	1.22	99.99
1979	1979	1	25	4	5530	3	2	3.74	0.77	99.99
1980	1980	8	9	3	1950	7	0	3.29	-1.02	-0.98

11. SCRCON Santa Cruz River at Continental

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1952	1952	8	15	3	1820	8	0	3.26	-1.09	-0.94
1953	1953	7	14	3	4910	8	0	3.69	0.66	0.15
1953	1953	7	15	4	2920	7	1	3.47	-0.26	99.99
1953	1953	7	16	4	4910	7	2	3.69	0.66	99.99
1954	1954	8	5	3	14600	8	8	4.16	2.58	1.35
1954	1954	7	16	4	2400	7	0	3.38	-0.61	99.99
1954	1954	7	20	4	8900	1	1	3.95	1.70	99.99
1954	1954	7	22	4	2540	6	2	3.40	-0.51	99.99
1954	1954	7	23	4	8300	6	3	3.92	1.58	99.99
1954	1954	7	25	4	2260	6	4	3.35	-0.71	99.99
1954	1954	7	30	4	2190	7	5	3.34	-0.77	99.99
1954	1954	7	31	4	4800	7	6	3.68	0.62	99.99
1954	1954	8	3	4	3320	8	7	3.52	-0.03	99.99
1954	1954	8	12	4	4320	7	9	3.64	0.43	99.99
1954	1954	8	24	4	2320	7	6	3.37	-0.67	99.99
1954	1954	9	24	4	5610	3	0	3.75	0.89	99.99
1955	1955	8	19	3	17500	8	8	4.24	2.89	1.55
1955	1955	7	22	4	2990	7	0	3.48	-0.22	99.99
1955	1955	7	31	4	2300	8	1	3.36	-0.68	99.99
1955	1955	8	2	4	2800	8	2	3.45	-0.33	99.99
1955	1955	8	3	4	4000	8	3	3.60	0.29	99.99
1955	1955	8	6	4	5990	7	4	3.78	1.01	99.99
1955	1955	8	9	4	2700	7	5	3.43	-0.40	99.99
1955	1955	8	12	4	2320	7	6	3.37	-0.67	99.99
1955	1955	8	14	4	3150	8	7	3.50	-0.13	99.99
1955	1955	8	21	4	4590	8	9	3.66	0.54	99.99
1955	1955	8	23	4	4110	8	9	3.61	0.34	99.99
1956	1956	7	29	3	3090	7	1	3.49	-0.16	-0.35
1956	1956	7	13	4	2010	7	0	3.30	-0.92	99.99
1957	1957	8	21	3	1690	8	0	3.23	-1.22	-1.02
1958	1958	8	5	3	5620	8	2	3.75	0.89	0.30
1958	1958	7	16	4	2870	7	0	3.46	-0.29	99.99
1958	1958	7	29	4	2990	8	1	3.48	-0.22	99.99
1958	1958	8	7	4	5100	8	3	3.71	0.72	99.99
1958	1958	8	12	4	2080	8	4	3.32	-0.86	99.99

1958	1958	8	13	4	2810	7	5	3.45	-0.33	99.99
1958	1958	8	14	4	2870	7	6	3.46	-0.29	99.99
1958	1958	8	23	4	2200	7	6	3.34	-0.76	99.99
1959	1959	8	17	3	3900	7	1	3.59	0.25	-0.10
1959	1959	8	13	4	2280	8	0	3.36	-0.70	99.99
1960	1960	1	12	3	3740	3	0	3.57	0.18	-0.15
1960	1960	8	14	4	2250	7	0	3.35	-0.72	99.99
1960	1960	9	10	4	2580	1	1	3.41	-0.48	99.99
1961	1961	8	23	4	4820	7	0	3.68	0.62	99.99
1961	1960	10	8	4	2890	4	1	3.46	-0.28	99.99
1961	1961	7	23	4	2520	7	0	3.40	-0.52	99.99
1961	1961	9	11	4	3190	1	1	3.50	-0.10	99.99
1961	1961	9	16	4	2100	7	2	3.32	-0.84	99.99
1962	1962	1	25	3	2480	2	0	3.39	-0.55	-0.60
1963	1963	8	6	3	4220	8	2	3.63	0.39	-0.01
1963	1963	7	29	4	2610	7	0	3.42	-0.46	99.99
1963	1963	7	31	4	3820	7	1	3.58	0.21	99.99
1963	1963	8	16	4	2370	8	3	3.37	-0.63	99.99
1963	1963	8	23	4	2490	8	4	3.40	-0.54	99.99
1963	1963	8	27	4	2320	8	5	3.37	-0.67	99.99
1963	1963	9	1	4	3920	7	4	3.59	0.26	99.99
1963	1963	9	2	4	2110	7	5	3.32	-0.83	99.99
1964	1964	9	10	3	14000	8	2	4.15	2.50	1.31
1964	1964	7	31	4	2100	8	0	3.32	-0.84	99.99
1964	1964	8	14	4	5290	8	1	3.72	0.79	99.99
1964	1964	8	28	4	2810	7	2	3.45	-0.33	99.99
1964	1964	9	11	4	2320	8	3	3.37	-0.67	99.99
1964	1964	9	13	4	2470	6	4	3.39	-0.55	99.99
1965	1965	9	12	3	370	7	0	2.57	-3.90	-2.69
1966	1965	12	23	3	5990	3	1	3.78	1.01	0.37
1966	1965	12	17	4	2780	5	0	3.44	-0.35	99.99
1966	1966	8	18	4	4980	8	0	3.70	0.68	99.99
1966	1966	8	20	4	3910	8	1	3.59	0.25	99.99
1966	1966	8	21	4	4490	8	2	3.65	0.50	99.99
1967	1967	7	27	3	3730	8	0	3.57	0.17	-0.15
1968	1967	12	20	3	18000	3	1	4.26	2.94	1.58
1968	1967	12	15	4	2870	2.3	0	3.46	-0.29	99.99
1969	1969	8	5	3	1680	1	0	3.23	-1.23	-1.03
1970	1970	7	20	3	3720	8	0	3.57	0.17	-0.15
1970	1970	9	4	4	2680	1	0	3.43	-0.41	99.99
1971	1971	8	20	3	3270	8	2	3.51	-0.06	-0.29
1971	1971	8	7	4	2550	7	0	3.41	-0.50	99.99
1971	1971	8	11	4	3110	2.1	1	3.49	-0.15	99.99
1971	1971	9	1	4	2040	7	3	3.31	-0.89	99.99
1972	1972	7	14	3	3290	7	0	3.52	-0.05	-0.29
1973	1973	3	14	3	2130	3	0	3.33	-0.82	-0.76
1974	1974	9	3	3	3450	7	1	3.54	0.03	-0.23
1974	1974	7	22	4	2860	8	0	3.46	-0.30	99.99

1974	1974	8	2	4	3130	8	1	3.50	-0.14	99.99
1974	1974	8	4	4	2680	8	2	3.43	-0.41	99.99
1975	1975	9	1	3	3350	7	0	3.53	-0.02	-0.27
1975	1975	7	16	4	2560	7	0	3.41	-0.49	99.99
1975	1975	7	23	4	2500	7	1	3.40	-0.53	99.99
1976	1976	7	12	3	3800	7	0	3.58	0.20	-0.13
1976	1976	7	22	4	2130	8	1	3.33	-0.82	99.99
1976	1976	9	25	4	2330	5	0	3.37	-0.66	99.99
1977	1977	7	18	3	3290	8	0	3.52	-0.05	-0.29
1977	1977	7	26	4	2050	7	1	3.31	-0.88	99.99
1977	1977	8	1	4	2350	7	2	3.37	-0.64	99.99
1977	1977	8	22	4	2000	7	2	3.30	-0.93	99.99
1977	1977	9	4	4	2060	7	1	3.31	-0.87	99.99
1977	1977	9	11	4	2530	8	2	3.40	-0.51	99.99
1978	1977	10	9	3	26500	1	1	4.42	3.63	2.01
1978	1978	6	28	4	2730	4	0	3.44	-0.38	99.99
1978	1978	7	25	4	4700	8	1	3.67	0.58	99.99
1978	1978	7	27	4	3900	7	2	3.59	0.25	99.99
1978	1978	8	1	4	5900	8	2	3.77	0.98	99.99
1978	1978	8	11	4	9090	7	3	3.96	1.74	99.99
1979	1978	12	18	3	16000	3	1	4.20	2.74	1.45
1979	1978	10	6	4	2710	4	0	3.43	-0.39	99.99
1979	1978	10	21	4	2280	1	1	3.36	-0.70	99.99
1979	1978	11	25	4	5540	2	0	3.74	0.87	99.99
1979	1978	12	31	4	2930	3	1	3.47	-0.25	99.99
1979	1979	1	18	4	6250	3	1	3.80	1.08	99.99
1979	1979	1	25	4	7300	3	2	3.86	1.35	99.99
1979	1979	7	30	4	2800	8	0	3.45	-0.33	99.99
1979	1979	8	15	4	3400	7	1	3.53	0.01	99.99
1979	1979	8	16	4	5900	7	2	3.77	0.98	99.99
1980	1980	8	25	3	2360	8	0	3.37	-0.63	-0.65
1980	1980	4	12	4	2170	99.99	0	3.34	-0.78	99.99

12. SCRTUC Santa Cruz River at Tucson

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	30	3	9490	8	3	3.98	1.74	0.69
1950	1950	7	8	4	1800	8	0	3.26	-1.21	99.99
1950	1950	7	18	4	4570	7	1	3.66	0.44	99.99
1950	1950	7	22	4	7990	8	2	3.90	1.43	99.99
1950	1950	8	11	4	3770	8	3	3.58	0.10	99.99
1950	1950	8	12	4	2340	8	4	3.37	-0.74	99.99
1951	1951	8	2	3	5020	8	2	3.70	0.61	-0.28
1951	1951	7	16	4	2300	8	0	3.36	-0.77	99.99
1951	1951	7	27	4	1900	8	1	3.28	-1.11	99.99
1952	1952	8	16	3	3820	8	1	3.58	0.13	-0.69
1952	1952	8	12	4	1780	7	0	3.25	-1.23	99.99
1952	1952	9	20	4	2260	1	0	3.35	-0.80	99.99
1952	1952	9	21	4	2180	1	1	3.34	-0.87	99.99

1953	1953	7	15	3	5900	8	0	3.77	0.90	-0.03
1953	1953	7	16	4	3950	7	1	3.60	0.19	99.99
1953	1953	7	29	4	2000	8	2	3.30	-1.02	99.99
1954	1954	7	24	3	9570	6	5	3.98	1.75	0.70
1954	1954	6	25	4	2240	8	0	3.35	-0.82	99.99
1954	1954	6	26	4	2740	6	1	3.44	-0.46	99.99
1954	1954	7	11	4	1910	7	1	3.28	-1.10	99.99
1954	1954	7	16	4	6940	7	2	3.84	1.18	99.99
1954	1954	7	20	4	6730	1	3	3.83	1.13	99.99
1954	1954	7	22	4	2040	6	4	3.31	-0.99	99.99
1954	1954	7	25	4	3270	6	6	3.51	-0.15	99.99
1954	1954	8	1	4	2530	8	6	3.40	-0.60	99.99
1954	1954	8	3	4	3030	8	7	3.48	-0.28	99.99
1954	1954	8	5	4	7770	8	8	3.89	1.38	99.99
1954	1954	8	12	4	5190	7	8	3.72	0.67	99.99
1954	1954	9	24	4	4010	3	0	3.60	0.21	99.99
1955	1955	8	3	3	10900	8	4	4.04	1.98	0.90
1955	1955	7	17	4	3090	8	0	3.49	-0.25	99.99
1955	1955	7	22	4	5590	7	1	3.75	0.80	99.99
1955	1955	7	23	4	7610	8	2	3.88	1.35	99.99
1955	1955	7	31	4	2460	8	3	3.39	-0.65	99.99
1955	1955	8	7	4	7290	8	5	3.86	1.27	99.99
1955	1955	8	10	4	4460	7	6	3.65	0.40	99.99
1955	1955	8	14	4	2180	8	7	3.34	-0.87	99.99
1955	1955	8	17	4	3750	7	7	3.57	0.09	99.99
1955	1955	8	19	4	5530	8	8	3.74	0.78	99.99
1955	1955	8	21	4	4920	8	9	3.69	0.57	99.99
1955	1955	8	23	4	3720	8	8	3.57	0.08	99.99
1956	1956	7	29	3	2610	7	1	3.42	-0.55	-1.27
1956	1956	7	13	4	1730	7	0	3.24	-1.28	99.99
1957	1957	8	31	3	3050	7	0	3.48	-0.27	-1.03
1958	1958	7	29	3	6350	8	2	3.80	1.03	0.08
1958	1958	7	3	4	2710	7	0	3.43	-0.48	99.99
1958	1958	7	16	4	2250	7	1	3.35	-0.81	99.99
1958	1958	7	29	4	3600	8	3	3.56	0.02	99.99
1958	1958	7	30	4	2090	8	4	3.32	-0.94	99.99
1958	1958	8	5	4	4240	8	4	3.63	0.31	99.99
1958	1958	8	6	4	1970	8	5	3.29	-1.05	99.99
1958	1958	8	8	4	4210	8	6	3.62	0.30	99.99
1958	1958	8	13	4	2140	7	7	3.33	-0.90	99.99
1958	1958	8	14	4	3390	7	8	3.53	-0.09	99.99
1958	1958	8	15	4	2550	8	8	3.41	-0.59	99.99
1958	1958	8	23	4	2450	7	9	3.39	-0.66	99.99
1959	1959	8	20	3	4420	8	3	3.65	0.38	-0.47
1959	1959	7	19	4	2570	7	0	3.41	-0.58	99.99
1959	1959	8	14	4	1760	8	1	3.25	-1.25	99.99
1959	1959	8	17	4	3370	7	2	3.53	-0.10	99.99
1959	1959	8	18	4	1980	8	3	3.30	-1.04	99.99

1960	1960	8	10	3	6140	8	1	3.79	0.97	0.03
1960	1960	1	12	4	3220	3	0	3.51	-0.18	99.99
1960	1960	8	9	4	2330	8	0	3.37	-0.75	99.99
1960	1960	9	10	4	1780	1	0	3.25	-1.23	99.99
1961	1961	8	23	3	16600	7	1	4.22	2.73	1.54
1961	1960	10	9	4	2980	2	1	3.47	-0.31	99.99
1961	1961	7	22	4	4780	7	0	3.68	0.52	99.99
1961	1961	8	17	4	3130	7	1	3.50	-0.23	99.99
1962	1962	9	26	3	4980	1.3	0	3.70	0.60	-0.29
1962	1962	1	25	4	1820	2	0	3.26	-1.19	99.99
1963	1963	8	26	3	4670	8	4	3.67	0.48	-0.39
1963	1963	7	29	4	2060	7	0	3.31	-0.97	99.99
1963	1963	7	31	4	3690	7	1	3.57	0.07	99.99
1963	1963	8	4	4	2040	8	2	3.31	-0.99	99.99
1963	1963	8	6	4	2860	8	3	3.46	-0.39	99.99
1963	1963	8	27	4	1940	8	5	3.29	-1.07	99.99
1963	1963	9	1	4	2270	7	4	3.36	-0.80	99.99
1964	1964	9	10	3	13000	8	1	4.11	2.30	1.17
1964	1964	7	24	4	7570	8	0	3.88	1.34	99.99
1964	1964	7	30	4	6630	8	1	3.82	1.10	99.99
1964	1964	7	31	4	4560	8	1	3.66	0.44	99.99
1964	1964	8	1	4	3620	8	3	3.56	0.03	99.99
1964	1964	8	9	4	3620	8	4	3.56	0.03	99.99
1964	1964	8	10	4	3780	7	5	3.58	0.11	99.99
1964	1964	8	15	4	4120	8	6	3.61	0.26	99.99
1965	1965	7	16	3	1190	7	0	3.08	-1.94	-2.46
1966	1966	8	19	3	5500	8	2	3.74	0.77	-0.14
1966	1965	12	23	4	4830	3	2	3.68	0.54	99.99
1966	1966	2	7	4	2110	3	0	3.32	-0.93	99.99
1966	1966	7	20	4	1900	8	0	3.28	-1.11	99.99
1966	1966	8	12	4	2830	8	1	3.45	-0.41	99.99
1966	1965	12	11	4	1700	3	0	3.23	-1.31	99.99
1966	1965	12	17	4	3150	5	1	3.50	-0.22	99.99
1967	1967	7	17	3	5860	8	2	3.77	0.88	-0.04
1967	1967	7	11	4	4830	8	0	3.68	0.54	99.99
1968	1967	12	20	3	16100	3	1	4.21	2.68	1.49
1968	1967	12	15	4	3380	2.3	0	3.53	-0.09	99.99
1969	1969	8	6	3	8710	1	0	3.94	1.59	0.56
1970	1970	7	20	3	8530	8	1	3.93	1.55	0.53
1970	1970	7	19	4	6880	7	0	3.84	1.17	99.99
1970	1970	8	14	4	2570	7	2	3.41	-0.58	99.99
1970	1970	8	18	4	2750	7	3	3.44	-0.46	99.99
1970	1970	9	5	4	2850	1.3	2	3.45	-0.39	99.99
1970	1970	9	12	4	2550	7	3	3.41	-0.59	99.99
1971	1971	8	17	3	8000	8	3	3.90	1.44	0.43
1971	1971	7	16	4	2000	7	0	3.30	-1.02	99.99
1971	1971	8	3	4	2000	8	1	3.30	-1.02	99.99
1971	1971	8	11	4	2000	2.1	2	3.30	-1.02	99.99
1971	1971	8	12	4	5000	1.2	3	3.70	0.60	99.99

1971	1971	8	20	4	2500	8	4	3.40	-0.63	99.99
1972	1972	7	15	3	3470	7	1	3.54	-0.04	-0.84
1972	1972	6	21	4	2090	4	0	3.32	-0.94	99.99
1972	1972	7	17	4	2030	8	2	3.31	-0.99	99.99
1972	1972	8	12	4	1800	8	2	3.26	-1.21	99.99
1973	1972	10	19	3	4710	2	1	3.67	0.50	-0.37
1973	1972	10	6	4	2460	1.2	0	3.39	-0.65	99.99
1973	1973	3	14	4	1890	3	0	3.28	-1.12	99.99
1974	1974	7	8	3	7930	8	2	3.90	1.42	0.42
1974	1974	7	1	4	2080	7	0	3.32	-0.95	99.99
1974	1974	7	7	4	3730	8	1	3.57	0.08	99.99
1974	1974	8	2	4	2430	8	2	3.39	-0.68	99.99
1974	1974	9	4	4	2390	7	0	3.38	-0.70	99.99
1975	1975	7	12	3	2480	8	0	3.39	-0.64	-1.35
1975	1975	9	1	4	2380	7	0	3.38	-0.71	99.99
1975	1975	9	13	4	2120	3	1	3.33	-0.92	99.99
1976	1976	9	25	3	7100	5	0	3.85	1.23	0.25
1976	1976	7	12	4	2760	7	0	3.44	-0.45	99.99
1976	1976	7	30	4	2670	8	1	3.43	-0.51	99.99
1977	1977	8	15	3	2660	1	0	3.42	-0.52	-1.24
1978	1977	10	10	3	23700	1	0	4.37	3.36	2.08
1978	1978	8	2	4	5030	8	0	3.70	0.61	99.99
1978	1978	8	12	4	2260	7	1	3.35	-0.80	99.99
1979	1978	12	19	3	13500	3	1	4.13	2.36	1.23
1979	1978	10	21	4	4180	1	0	3.62	0.29	99.99
1979	1978	11	25	4	3980	2	0	3.60	0.20	99.99
1979	1979	1	18	4	7350	3	1	3.87	1.29	99.99
1979	1979	1	25	4	8310	3	1	3.92	1.50	99.99
1979	1979	8	15	4	5760	7	0	3.76	0.85	99.99
1980	1980	8	13	3	2760	8	0	3.44	-0.45	-1.19
1980	1980	9	17	4	1910	7	1	3.28	-1.10	99.99

13. RILTUC Rillito Creek near Tucson

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	30	3	9490	8	3	3.98	1.84	0.93
1950	1950	6	23	4	1510	4	0	3.18	-0.75	99.99
1950	1950	7	19	4	1110	7	1	3.05	-1.18	99.99
1950	1950	7	21	4	1710	8	2	3.23	-0.57	99.99
1950	1950	7	23	4	3480	8	3	3.54	0.43	99.99
1951	1951	7	25	3	9500	8	0	3.98	1.84	0.93
1951	1951	8	2	4	4200	8	1	3.62	0.69	99.99
1951	1951	8	13	4	2280	7	2	3.36	-0.17	99.99
1952	1951	11	11	3	1630	3	0	3.21	-0.64	-1.31
195 3	1953	7	16	3	5470	7	1	3.74	99.99	0.23
1953	1953	7	14	4	1300	8	0	3.11	-0.96	99.99
1954	1954	7	24	3	7680	6	3	3.89	1.54	0.66
1954	1954	3	23	4	4610	3	0	3.66	0.82	99.99

1954	1954	7	16	4	1060	7	0	3.03	-1.25	99.99
1954	1954	7	20	4	6140	1	1	3.79	1.23	99.99
1954	1954	7	22	4	3630	6	2	3.56	0.49	99.99
1954	1954	9	23	4	2360	3	0	3.37	-0.12	99.99
1954	1954	9	24	4	2740	3	1	3.44	0.09	99.99
1955	1955	7	21	3	8070	7	0	3.91	1.61	0.72
1955	1955	7	22	4	4840	7	1	3.68	0.89	99.99
1955	1955	7	31	4	5320	8	2	3.73	1.02	99.99
1955	1955	8	2	4	1070	8	3	3.03	-1.23	99.99
1955	1955	8	3	4	7010	8	4	3.85	1.41	99.99
1955	1955	8	6	4	3100	7	5	3.49	0.26	99.99
1955	1955	8	7	4	1590	8	6	3.20	-0.68	99.99
1955	1955	8	14	4	1980	8	7	3.30	-0.37	99.99
1955	1955	8	20	4	7530	8	8	3.88	1.51	99.99
1955	1955	8	28	4	3700	7	7	3.57	0.51	99.99
1956	1956	7	29	3	2050	7	0	3.31	-0.32	-1.02
1957	1957	1	9	3	4500	3	0	3.65	0.79	-0.02
1958	1958	8	12	3	8930	7	1	3.95	1.75	0.85
1958	1958	3	22	4	1940	3	0	3.29	-0.40	99.99
1958	1958	7	1	4	1060	7	0	3.03	-1.25	99.99
1958	1958	7	18	4	3650	7	1	3.56	0.49	99.99
1959	1959	8	17	3	7710	7	3	3.89	1.55	0.67
1959	1959	7	19	4	1130	7	0	3.05	-1.16	99.99
1959	1959	7	26	4	2820	7	1	3.45	0.13	99.99
1959	1959	7	29	4	1050	8	2	3.02	-1.26	99.99
1959	1959	8	20	4	1980	8	3	3.30	-0.37	99.99
1960	1960	1	12	3	3610	3	1	3.56	0.48	-0.30
1960	1959	10	28	4	2150	3	0	3.33	-0.25	99.99
1960	1959	12	25	4	1110	3	0	3.05	-1.18	99.99
1960	1960	8	9	4	1470	8	0	3.17	-0.79	99.99
1961	1961	7	22	3	4140	7	0	3.62	0.67	-0.13
1961	1961	8	15	4	1280	8	2	3.11	-0.98	99.99
1961	1961	8	22	4	2350	7	1	3.37	-0.13	99.99
1961	1961	8	23	4	2290	7	2	3.36	-0.16	99.99
1962	1962	9	26	3	2690	1.3	0	3.43	0.06	-0.68
1962	1961	12	16	4	1420	5	0	3.15	-0.84	99.99
1962	1962	1	25	4	1050	2	0	3.02	-1.26	99.99
1963	1963	8	26	3	7640	8	0	3.88	1.53	0.65
1963	1963	2	12	4	3760	3	0	3.58	0.54	99.99
1964	1964	9	10	3	9420	8	1	3.97	1.83	0.92
1964	1964	7	22	4	1320	8	0	3.12	-0.94	99.99
1964	1964	8	1	4	1200	8	1	3.08	-1.07	99.99
1964	1964	9	6	4	1370	7	0	3.14	-0.89	99.99
1964	1964	9	15	4	1710	8	2	3.23	-0.57	99.99
1965	1965	9	12	3	754	7	0	2.88	-1.73	-2.30
1966	1965	12	22	3	12400	3	2	4.09	2.22	1.27
1966	1965	12	11	4	4910	3	0	3.69	0.91	99.99
1966	1965	12	17	4	1380	5	1	3.14	-0.88	99.99

1966	1965	12	31	4	1200	5	3	3.08	-1.07	99.99
1966	1966	2	8	4	1000	3	0	3.00	-1.33	99.99
1966	1966	8	10	4	1200	8	0	3.08	-1.07	99.99
1966	1966	9	13	4	3800	2	0	3.58	0.55	99.99
1967	1967	8	19	3	3100	7	0	3.49	0.26	-0.50
1967	1967	7	12	4	1100	8	0	3.04	-1.20	99.99
1967	1967	7	17	4	1700	8	1	3.23	-0.58	99.99
1968	1968	2	12	3	7740	5	0	3.89	1.55	0.67
1968	1967	12	20	4	7100	3	0	3.85	1.43	99.99
1968	1968	8	6	4	1350	7	0	3.13	-0.91	99.99
1968	1968	8	20	4	1670	1	1	3.22	-0.61	99.99
1969	1969	8	5	3	2220	1	0	3.35	-0.21	-0.92
1970	1970	9	6	3	7000	1.3	1	3.85	1.41	0.54
1970	1970	7	19	4	1110	7	0	3.05	-1.18	99.99
1970	1970	7	21	4	4180	8	1	3.62	0.68	99.99
1970	1970	8	11	4	1920	8	2	3.28	-0.41	99.99
1971	1971	8	20	3	9290	8	7	3.97	1.81	0.90
1971	1971	8	3	4	2400	8	0	3.38	-0.10	99.99
1971	1971	8	8	4	4800	2	1	3.68	0.88	99.99
1971	1971	8	9	4	2580	2	2	3.41	0.01	99.99
1971	1971	8	10	4	2200	2	3	3.34	-0.22	99.99
1971	1971	8	11	4	1490	2.1	4	3.17	-0.77	99.99
1971	1971	8	17	4	3840	8	5	3.58	0.57	99.99
1971	1971	8	18	4	1930	8	6	3.29	-0.40	99.99
1971	1971	9	1	4	5850	7	8	3.77	1.16	99.99
1972	1972	8	12	3	1820	8	0	3.26	-0.49	-1.17
1973	1972	10	20	3	5160	2	2	3.71	0.98	0.15
1973	1972	10	7	4	2030	1.2	0	3.31	-0.33	99.99
1973	1972	10	18	4	1130	2	1	3.05	-1.16	99.99
1973	1972	12	28	4	1090	3	0	3.04	-1.21	99.99
1973	1973	2	22	4	2810	5	0	3.45	0.13	99.99
1973	1973	3	14	4	1570	3	1	3.20	-0.69	99.99
1974	1974	8	2	3	1440	8	0	3.16	-0.82	-1.47
1974	1974	9	6	4	1030	7	0	3.01	-1.29	99.99
1975	1975	7	16	3	2270	7	0	3.36	-0.18	-0.89
1976	1976	9	25	3	9400	5	0	3.97	99.99	0.92
1977	1977	9	5	3	1200	7	0	3.08	99.99	-1.70
1978	1978	3	2	3	7500	3	0	3.88	99.99	0.63
1979	1978	12	18	3	16400	3	0	4.21	99.99	1.63
1980	1980	2	14	3	2300	5	0	3.36	99.99	-0.88

14. SRWVVO Santa Rosa Wash near Vaiva Vo, near Sells

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1955	1955	8	8	3	1150	8	5	3.06	-0.15	-0.19
1955	1955	7	21	4	830	7	0	2.92	-0.48	99.99
1955	1955	7	23	4	926	8	1	2.97	-0.37	99.99
1955	1955	7	24	4	1070	8	2	3.03	-0.22	99.99
1955	1955	8	2	4	824	8	3	2.92	-0.49	99.99
1955	1955	8	4	4	976	8	4	2.99	-0.31	99.99
1955	1955	8	14	4	948	8	6	2.98	-0.34	99.99
1956	1956	7	24	3	740	7	0	2.87	-0.59	-0.52
1957	1957	8	12	3	492	8	0	2.69	-1.01	-0.83
1958	1957	11	1	3	10000	5	0	4.00	2.05	1.44
1958	1958	2	6	4	4500	5	0	3.65	1.24	99.99
1958	1958	3	13	4	737	5	0	2.87	-0.60	99.99
1958	1958	7	30	4	4380	8	0	3.64	1.21	99.99
1959	1959	7	13	3	4120	7	0	3.61	1.15	0.77
1959	1959	7	27	4	746	8	1	2.87	-0.59	99.99
1959	1959	8	11	4	2540	8	2	3.40	0.66	99.99
1959	1958	10	15	4	865	4	0	2.94	-0.44	99.99
1960	1960	7	30	3	805	8	0	2.91	-0.51	-0.46
1960	1959	10	31	4	790	3	0	2.90	-0.53	99.99
1961	1961	7	27	3	892	8	1	2.95	-0.40	-0.38
1961	1961	7	23	4	734	7	0	2.87	-0.60	99.99
1962	1962	9	27	3	53100	1.3	0	4.73	3.74	2.69
1962	1962	6	28	4	702	5	0	2.85	-0.65	99.99
1963	1963	9	14	3	4180	6	1	3.62	1.16	0.78
1963	1963	8	14	4	1500	8	0	3.18	0.12	99.99
1963	1963	8	27	4	875	7	1	2.94	-0.42	99.99
1964	1964	7	25	3	6760	8	0	3.83	1.65	1.14
1964	1964	8	2	4	3580	8	1	3.55	1.01	99.99
1964	1964	8	13	4	3540	8	2	3.55	0.99	99.99
1964	1964	8	15	4	860	8	3	2.93	-0.44	99.99
1965	1965	9	4	3	433	1	0	2.64	-1.14	-0.92
1966	1966	9	14	3	1820	2.1	1	3.26	0.32	0.16
1966	1966	2	12	4	1070	5	0	3.03	-0.22	99.99
1966	1966	8	18	4	1070	8	0	3.03	-0.22	99.99
1967	1967	6	26	3	302	4	0	2.48	-1.50	-1.19
1968	1968	7	28	3	840	8	0	2.92	-0.47	-0.42
1968	1967	12	15	4	700	2.3	0	2.85	-0.65	99.99
1968	1968	9	3	4	744	1.4	0	2.87	-0.59	99.99
1969	1969	8	8	3	514	1	0	2.71	-0.96	-0.79
1970	1970	8	10	3	865	8	0	2.94	-0.44	-0.40
1971	1971	8	4	3	6110	8	0	3.79	1.55	1.07
1971	1971	8	13	4	2840	1	1	3.45	0.77	99.99
1971	1971	8	18	4	1360	8	2	3.13	0.02	99.99
1972	1972	8	14	3	410	7	0	2.61	-1.19	-0.96
1973	1972	10	21	3	762	2	0	2.88	-0.56	-0.50
1974	1974	8	2	3	762	8	0	2.88	-0.56	-0.50

20. SLTROO Salt River near Roosevelt

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	21	3	5930	8	0	3.77	-0.57	-0.79
1951	1951	8	28	3	27600	1	1	4.44	1.09	0.45
1951	1951	8	2	4	7070	8	0	3.85	-0.39	99.99
1952	1952	1	18	3	111000	3	2	5.05	2.60	1.58
1952	1951	12	31	4	42300	3	0	4.63	1.55	99.99
1952	1952	1	14	4	74100	3	1	4.87	2.16	99.99
1952	1952	3	16	4	4790	9	0	3.68	-0.80	99.99
1952	1952	4	9	4	6980	9.3	1	3.84	-0.39	99.99
1952	1952	4	21	4	6370	3	1	3.80	-0.49	99.99
1952	1952	4	28	4	9050	3	2	3.96	-0.11	99.99
1953	1953	3	9	3	4320	9.5	0	3.64	-0.91	-1.04
1954	1954	3	23	3	40800	3	0	4.61	1.52	0.77
1955	1955	8	24	3	8640	8	3	3.94	-0.16	-0.48
1955	1955	8	7	4	4690	8	0	3.67	-0.82	99.99
1955	1955	8	19	4	6350	8	1	3.80	-0.49	99.99
1955	1955	8	22	4	6840	8	2	3.84	-0.41	99.99
1956	1956	1	29	3	1460	3	0	3.16	-2.08	-1.92
1957	1957	1	10	3	6720	3	0	3.83	-0.43	-0.69
1957	1957	7	16	4	4340	7	0	3.64	-0.90	99.99
1957	1957	8	20	4	4100	8	0	3.61	-0.96	99.99
1958	1958	3	23	3	24000	3	2	4.38	0.94	0.34
1958	1958	2	26	4	5880	3	0	3.77	-0.57	99.99
1958	1958	3	17	4	8200	3	1	3.91	-0.22	99.99
1958	1958	4	24	4	7920	9	0	3.90	-0.25	99.99
1959	1959	8	20	3	12100	8	0	4.08	0.20	-0.21
1959	1959	8	27	4	4230	7	1	3.63	-0.93	99.99
1960	1959	12	26	3	78200	3	0	4.89	2.22	1.30
1960	1959	11	3	4	17200	2	1	4.24	0.58	99.99
1960	1960	1	12	4	32600	3	1	4.51	1.27	99.99
1960	1960	3	15	4	4070	9	0	3.61	-0.97	99.99
1960	1960	3	24	4	4240	5	1	3.63	-0.93	99.99
1960	1959	10	30	4	13900	3	0	4.14	0.35	99.99
1961	1961	7	28	3	2590	8	0	3.41	-1.46	-1.46
1962	1962	1	25	3	8540	2	0	3.93	-0.17	-0.49
1962	1962	2	14	4	4440	3	1	3.65	-0.88	99.99
1962	1962	4	12	4	5440	9	0	3.74	-0.66	99.99
1963	1963	8	31	3	31300	8	2	4.50	1.23	0.56
1963	1963	2	11	4	7160	3	0	3.85	-0.36	99.99
1963	1963	8	20	4	6680	7	0	3.82	-0.44	99.99
1963	1963	8	22	4	5400	8	1	3.73	-0.67	99.99
1963	1963	9	1	4	4700	8	3	3.67	-0.82	99.99
1964	1964	9	15	3	3620	8	0	3.56	-1.10	-1.19
1965	1965	1	8	3	20400	3	0	4.31	0.77	0.21
1965	1965	2	11	4	17300	3	0	4.24	0.59	99.99
1965	1965	3	12	4	4650	5	1	3.67	-0.83	99.99
1965	1965	4	11	4	4080	3	1	3.61	-0.97	99.99
1965	1965	4	23	4	5430	4	1	3.73	-0.66	99.99

1966	1965	12	23	3	68800	3	1	4.84	2.08	1.19
1966	1965	12	11	4	17300	3	0	4.24	0.59	99.99
1966	1965	12	30	4	59900	3	2	4.78	1.93	99.99
1966	1966	3	18	4	6130	9	0	3.79	-0.53	99.99
1967	1967	8	6	3	5600	8	0	3.75	-0.63	-0.83
1967	1966	12	7	4	5010	3	0	3.70	-0.75	99.99
1967	1967	8	12	4	4920	7	1	3.69	-0.77	99.99
1967	1967	8	18	4	4420	7	2	3.65	-0.88	99.99
1968	1967	12	20	3	17200	3	0	4.24	0.58	0.07
1968	1968	1	28	4	13500	3	0	4.13	0.32	99.99
1968	1968	2	14	4	8350	3	1	3.92	-0.20	99.99
1968	1968	3	11	4	9800	3	1	3.99	-0.02	99.99
1968	1968	4	17	4	4360	4	0	3.64	-0.90	99.99
1968	1968	8	3	4	5480	8	0	3.74	-0.65	99.99
1969	1969	1	26	3	6100	3	1	3.79	-0.54	-0.77
1969	1969	1	22	4	5200	3	0	3.72	-0.71	99.99
1970	1970	9	6	3	17300	1.3	0	4.24	0.59	0.08
1971	1971	8	13	3	12800	1	0	4.11	0.26	-0.17
1971	1971	8	15	4	5500	8	1	3.74	-0.65	99.99
1971	1971	9	2	4	8040	7	2	3.91	-0.24	99.99
1971	1971	9	30	4	6600	1	1	3.82	-0.45	99.99
1972	1971	12	27	3	30200	3	0	4.48	1.19	0.53
1972	1971	10	18	4	8800	3.2	1	3.94	-0.14	99.99
1972	1971	10	25	4	9620	2.3	2	3.98	-0.04	99.99
1973	1972	10	20	3	70000	2	1	4.85	2.10	1.21
1973	1972	11	18	4	4010	3	1	3.60	-0.99	99.99
1973	1972	12	29	4	22400	3	0	4.35	0.87	99.99
1973	1973	2	13	4	4360	3	0	3.64	-0.90	99.99
1973	1973	2	22	4	16600	5	1	4.22	0.55	99.99
1973	1973	3	18	4	16400	9	1	4.21	0.53	99.99
1973	1973	3	31	4	11600	3	1	4.06	0.16	99.99
1973	1973	4	14	4	9750	9	2	3.99	-0.03	99.99
1973	1973	4	30	4	12400	9	2	4.09	0.23	99.99
1973	1973	5	6	4	16200	3	2	4.21	0.52	99.99
1973	1972	10	7	4	11100	1.2	0	4.05	0.11	99.99
1974	1974	7	20	3	1500	8	0	3.18	-2.05	-1.90
1975	1974	10	29	3	10100	2.3	0	4.00	0.01	-0.36
1975	1975	3	10	4	6950	3	0	3.84	-0.39	99.99
1975	1975	4	11	4	4540	9.5	0	3.66	-0.85	99.99
1975	1975	4	27	4	4700	3	1	3.67	-0.82	99.99
1976	1976	2	10	3	16000	3	0	4.20	0.51	0.01
1977	1977	9	3	3	10200	7	0	4.01	0.02	-0.35
1978	1978	3	2	3	89400	3	2	4.95	2.36	1.40
1978	1978	2	1	4	8050	5	0	3.91	-0.24	99.99
1978	1978	2	12	4	4780	3	1	3.68	-0.80	99.99
1978	1978	3	13	4	5820	3	2	3.76	-0.59	99.99
1978	1978	3	24	4	6600	5	2	3.82	-0.45	99.99
1978	1978	4	2	4	6620	3	2	3.82	-0.45	99.99
1979	1978	12	19	3	95800	3	1	4.98	2.44	1.46

1979	1978	11	12	4	8900	2.3	0	3.95	-0.13	99.99
1979	1978	11	25	4	29600	2	1	4.47	1.17	99.99
1979	1978	12	31	4	5120	3	1	3.71	-0.72	99.99
1979	1979	1	7	4	48900	5	2	4.69	1.71	99.99
1979	1979	2	15	4	6570	9	0	3.82	-0.45	99.99
1979	1979	3	29	4	25600	3	0	4.41	1.01	99.99
1980	1980	2	15	3	99000	3	2	5.00	2.47	1.49
1980	1980	1	20	4	4580	2	0	3.66	-0.84	99.99
1980	1980	1	30	4	20500	3	1	4.31	0.77	99.99
1980	1980	2	20	4	46100	3	2	4.66	1.65	99.99
1980	1980	3	12	4	7190	3	2	3.86	-0.36	99.99
1980	1980	4	12	4	5020	4	0	3.70	-0.75	99.99
1980	1980	4	23	4	6720	3.4	1	3.83	-0.43	99.99
1980	1980	4	30	4	5090	2	2	3.71	-0.73	99.99

21. TONROO Tonto Creek above Gun Creek, near Roosevelt

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	16	3	5500	7	1	3.74	-0.08	-0.75
1950	1950	7	7	4	2500	8	0	3.40	-0.92	99.99
1951	1951	8	28	3	31100	1	0	4.49	1.77	0.86
1952	1952	1	18	3	45400	3	2	4.66	2.17	1.21
1952	1951	12	31	4	33900	3	0	4.53	1.86	99.99
1952	1952	1	14	4	3560	3	1	3.55	-0.54	99.99
1952	1952	3	2	4	3360	3	0	3.53	-0.61	99.99
1952	1952	3	15	4	2900	9	1	3.46	-0.76	99.99
1952	1952	4	20	4	2540	3	0	3.40	-0.90	99.99
1952	1952	4	29	4	2100	3	1	3.32	-1.11	99.99
1953	1953	7	30	3	2620	8	0	3.42	-0.87	-1.44
1954	1954	3	23	3	8100	3	0	3.91	0.33	-0.39
1954	1954	3	25	4	2770	5	1	3.44	-0.81	99.99
1955	1955	8	6	3	15200	7	1	4.18	1.01	0.19
1955	1955	6	13	4	8850	2	0	3.95	0.43	99.99
1955	1955	7	25	4	12000	8	0	4.08	0.75	99.99
1955	1955	8	10	4	2240	7	2	3.35	-1.04	99.99
1955	1955	8	12	4	2150	7	3	3.33	-1.08	99.99
1955	1955	8	21	4	7550	8	4	3.88	0.26	99.99
1955	1955	8	22	4	2110	8	5	3.32	-1.10	99.99
1955	1955	8	23	4	6470	8	6	3.81	0.09	99.99
1955	1955	8	24	4	6470	8	7	3.81	0.09	99.99
1956	1956	7	18	3	2330	8	0	3.37	-1.00	-1.55
1957	1957	1	9	3	15000	3	0	4.18	0.99	0.18
1957	1957	1	27	4	11200	3	1	4.05	0.68	99.99
1957	1957	8	16	4	6630	7	0	3.82	0.12	99.99
1958	1958	3	22	3	10600	3	2	4.03	0.62	-0.14
1958	1957	10	31	4	2000	5	0	3.30	-1.16	99.99
1958	1958	2	26	4	4300	3	0	3.63	-0.34	99.99
1958	1958	3	16	4	5920	5	1	3.77	0.00	99.99
1958	1958	4	4	4	2600	3	2	3.41	-0.88	99.99

1959	1959	8	19	3	11100	8	2	4.05	0.67	-0.10
1959	1959	7	29	4	2730	8	0	3.44	-0.83	99.99
1959	1959	8	1	4	2140	7	1	3.33	-1.09	99.99
1960	1979	12	26	3	25200	3	0	4.40	1.55	0.66
1960	1959	11	2	4	3270	2	1	3.51	-0.64	99.99
1960	1960	1	11	4	13100	3	1	4.12	0.85	99.99
1960	1960	3	2	4	4990	3	0	3.70	-0.18	99.99
1960	1959	10	30	4	10500	3	0	4.02	0.61	99.99
1961	1961	9	8	3	12900	1.2	0	4.11	0.83	0.04
1962	1962	9	6	3	3000	1	0	3.48	-0.73	-1.32
1962	1962	3	8	4	1720	3	0	3.24	-1.32	99.99
1963	1963	8	22	3	19700	8	3	4.29	1.28	0.43
1963	1963	8	15	4	4060	8	0	3.61	-0.40	99.99
1963	1963	8	17	4	2110	8	1	3.32	-1.10	99.99
1963	1963	8	19	4	4520	7	2	3.66	-0.29	99.99
1963	1963	8	31	4	8900	8	4	3.95	0.43	99.99
1964	1964	7	30	3	12000	8	1	4.08	0.75	-0.03
1964	1964	7	21	4	3600	8	0	3.56	-0.53	99.99
1964	1964	8	1	4	3060	8	2	3.49	-0.71	99.99
1964	1964	8	14	4	4200	8	3	3.62	-0.37	99.99
1964	1964	9	9	4	2780	8	1	3.44	-0.81	99.99
1964	1964	9	15	4	4450	8	1	3.65	-0.31	99.99
1964	1964	9	25	4	4960	2	2	3.70	-0.19	99.99
1965	1965	1	7	3	12900	3	1	4.11	0.83	0.04
1965	1965	1	6	4	12200	5	0	4.09	0.77	99.99
1965	1965	3	13	4	2670	5	0	3.43	-0.85	99.99
1965	1965	4	10	4	3980	3	1	3.60	-0.43	99.99
1965	1965	8	17	4	1720	8	0	3.24	-1.32	99.99
1965	1965	9	2	4	2060	7	1	3.31	-1.13	99.99
1966	1965	12	22	3	44700	3	2	4.65	2.16	1.19
1966	1965	11	25	4	4060	3	0	3.61	-0.40	99.99
1966	1965	12	10	4	18200	3	1	4.26	1.20	99.99
1966	1965	12	30	4	22100	3	2	4.34	1.41	99.99
1967	1966	12	7	3	7550	3	0	3.88	0.26	-0.46
1967	1967	8	6	4	1840	8	0	3.26	-1.25	99.99
1968	1967	12	19	3	19700	3	0	4.29	1.28	0.43
1968	1968	1	28	4	10200	3	0	4.01	0.58	99.99
1968	1968	2	14	4	4530	3	1	3.66	-0.29	99.99
1968	1968	3	10	4	3340	3	1	3.52	-0.61	99.99
1968	1968	7	25	4	3460	8	0	3.54	-0.57	99.99
1968	1968	8	4	4	1760	8	1	3.25	-1.30	99.99
1968	1968	8	12	4	2320	8	2	3.37	-1.00	99.99
1969	1969	1	26	3	10600	3	1	4.03	0.62	-0.14
1969	1969	1	22	4	4940	3	0	3.69	-0.19	99.99
1969	1969	7	25	4	3990	8	0	3.60	-0.42	99.99
1970	1970	9	5	3	53000	1.3	0	4.72	2.34	1.35
1970	1970	7	25	4	2990	8	0	3.48	-0.73	99.99
1971	1971	9	9	3	5280	7	0	3.72	-0.12	-0.79

1972	1971	12	26	3	2600	3	0	3.41	-0.88	-1.45
1972	1971	10	25	4	2440	2.3	1	3.39	-0.95	99.99
1972	1972	6	22	4	2020	5	0	3.31	-1.15	99.99
1972	1972	9	2	4	2100	7	0	3.32	-1.11	99.99
1972	1971	10	17	4	2070	3.2	0	3.32	-1.12	99.99
1973	1972	10	19	3	39800	2	1	4.60	2.03	1.09
1973	1972	11	17	4	6390	3	1	3.81	0.08	99.99
1973	1972	12	28	4	16800	3	0	4.23	1.11	99.99
1973	1973	2	12	4	4680	3	0	3.67	-0.25	99.99
1973	1973	2	22	4	6300	5	1	3.80	0.06	99.99
1973	1973	6	16	4	5800	9	1	3.76	-0.02	99.99
1973	1973	3	30	4	7270	3	1	3.86	0.22	99.99
1973	1973	5	5	4	5400	3	0	3.73	-0.10	99.99
1973	1972	10	7	4	8580	1.2	0	3.93	0.39	99.99
1974	1974	8	6	3	3800	8	0	3.58	-0.47	-1.10
1974	1974	1	21	4	2940	3	0	3.47	-0.75	99.99
1975	1974	10	29	3	2020	2.3	0	3.31	-1.15	-1.69
1976	1976	2	9	3	34900	3	2	4.54	1.89	0.96
1976	1976	2	5	4	5120	3	0	3.71	-0.16	99.99
1976	1976	2	6	4	3440	3	1	3.54	-0.58	99.99
1976	1976	9	26	4	1940	4	0	3.29	-1.19	99.99
1977	1977	8	15	3	2820	1	0	3.45	-0.79	-1.38
1978	1978	3	2	3	45800	3	3	4.66	2.18	1.22
1978	1978	1	15	4	2070	3	0	3.32	-1.12	99.99
1978	1978	1	17	4	3900	3	1	3.59	-0.45	99.99
1978	1978	2	1	4	3740	5	2	3.57	-0.49	99.99
1978	1978	2	11	4	6600	3	3	3.82	0.11	99.99
1978	1978	2	15	4	2300	3	3	3.36	-1.01	99.99
1978	1978	3	5	4	21400	3	3	4.33	1.37	99.99
1978	1978	3	12	4	4410	3	4	3.64	-0.32	99.99
1978	1978	3	22	4	6760	5	3	3.83	0.14	99.99
1978	1978	7	26	4	2810	7	0	3.45	-0.80	99.99
1979	1979	1	17	3	55800	5	1	4.75	2.39	1.40
1979	1978	11	12	4	6670	2.3	0	3.82	0.13	99.99
1979	1978	11	25	4	3780	2	1	3.58	-0.48	99.99
1979	1978	12	18	4	38700	3	1	4.59	2.00	99.99
1979	1979	3	21	4	5590	2	0	3.75	-0.06	99.99
1979	1979	3	22	4	5890	2	1	3.77	-0.01	99.99
1979	1979	3	29	4	20900	3	2	4.32	1.35	99.99
1980	1980	2	15	3	61400	3	2	4.79	2.50	1.49
1980	1980	1	11	4	3020	3	0	3.48	-0.72	99.99
1980	1980	1	15	4	4530	3	1	3.66	-0.29	99.99
1980	1980	1	18	4	5140	3	2	3.71	-0.15	99.99
1980	1980	1	30	4	28000	3	3	4.45	1.66	99.99
1980	1980	2	20	4	57200	3	2	4.76	2.42	99.99
1980	1980	3	7	4	2610	3	2	3.42	-0.88	99.99
1980	1980	3	11	4	5390	3	3	3.73	-0.10	99.99
1980	1980	8	13	4	4100	8	0	3.61	-0.39	99.99
1980	1980	8	24	4	4260	8	1	3.63	-0.35	99.99

22. OAKCRN Oak Creek near Cornville

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1949	10	19	3	6400	3	0	3.81	0.75	0.12
1950	1950	2	7	4	1670	9.3	0	3.22	-0.78	99.99
1950	1950	2	27	4	1390	5	1	3.14	-0.99	99.99
1951	1951	8	29	3	3440	1	0	3.54	0.05	-0.43
1952	1951	12	30	3	17200	3	0	4.24	1.88	1.00
1952	1952	1	18	4	7240	3	1	3.86	0.89	99.99
1952	1952	4	7	4	1920	9	0	3.28	-0.62	99.99
1952	1952	8	20	4	1360	7	0	3.13	-1.01	99.99
1953	1953	7	14	3	858	8	0	2.93	-1.54	-1.66
1954	1954	3	23	3	7850	3	0	3.89	0.99	0.31
1954	1954	3	29	4	1920	9	1	3.28	-0.62	99.99
1954	1954	7	22	4	2570	6	0	3.41	-0.29	99.99
1954	1954	8	4	4	1320	8	1	3.12	-1.05	99.99
1954	1954	9	11	4	1800	5	0	3.26	-0.69	99.99
1955	1955	8	23	3	6400	8	0	3.81	0.75	0.12
1956	1956	8	17	3	675	8	0	2.83	-1.81	-1.88
1957	1957	1	10	3	5150	3	1	3.71	0.51	-0.07
1957	1957	1	9	4	2670	3	0	3.43	-0.24	99.99
1957	1957	2	13	4	1430	9	0	3.16	-0.96	99.99
1957	1957	2	23	4	4200	3	1	3.62	0.27	99.99
1957	1957	6	11	4	2410	3	0	3.38	-0.36	99.99
1958	1957	11	3	3	9620	3	0	3.98	1.22	0.49
1958	1958	2	4	4	5120	5	0	3.71	0.50	99.99
1958	1958	2	25	4	5250	3	1	3.72	0.53	99.99
1958	1958	3	17	4	2660	3	1	3.42	-0.25	99.99
1958	1958	3	22	4	7450	3	2	3.87	0.93	99.99
1958	1958	8	3	4	5420	7	0	3.73	0.56	99.99
1958	1958	9	12	4	6820	1	0	3.83	0.83	99.99
1959	1959	8	5	3	3750	8	0	3.57	0.14	-0.35
1960	1959	12	25	3	4340	3	0	3.64	0.31	-0.22
1960	1960	8	31	4	1450	8	0	3.16	-0.94	99.99
1961	1961	7	31	3	4340	8	1	3.64	0.31	-0.22
1961	1961	4	1	4	1690	9	0	3.23	-0.76	99.99
1961	1961	7	15	4	1910	7	0	3.28	-0.63	99.99
1961	1961	8	9	4	1830	7	2	3.26	-0.67	99.99
1962	1962	2	12	3	7280	3	0	3.86	0.90	0.24
1962	1962	3	28	4	2100	9	0	3.32	-0.52	99.99
1963	1963	8	17	3	990	8	0	3.00	-1.37	-1.53
1964	1964	8	14	3	10300	8	1	4.01	1.30	0.55
1964	1964	8	3	4	1780	8	0	3.25	-0.71	99.99
1965	1965	4	4	3	3090	2.3	0	3.49	-0.08	-0.52
1965	1965	1	6	4	3060	5	0	3.49	-0.09	99.99
1965	1965	8	14	4	2420	6	0	3.38	-0.36	99.99
1965	1965	9	3	4	1320	1	1	3.12	-1.05	99.99
1965	1965	9	18	4	1310	3	2	3.12	-1.06	99.99
1966	1965	11	25	3	17600	3	1	4.25	1.91	1.02
1966	1965	12	23	4	1930	3	3	3.29	-0.61	99.99
1966	1965	12	30	4	13000	3	2	4.11	1.56	99.99

1966	1966	3	15	4	1530	9	0	3.18	-0.88	99.99
1966	1966	7	30	4	3530	8	0	3.55	0.08	99.99
1966	1966	8	6	4	1490	7	1	3.17	-0.91	99.99
1966	1965	12	10	4	5200	3	2	3.72	0.52	99.99
1966	1965	11	23	4	8760	3	0	3.94	1.11	99.99
1966	1966	8	10	4	4540	8	2	3.66	0.36	99.99
1966	1966	9	14	4	1400	2.1	0	3.15	-0.98	99.99
1967	1966	12	6	3	19200	3	0	4.28	2.01	1.10
1967	1967	8	10	4	1480	7	0	3.17	-0.92	99.99
1967	1967	9	25	4	2130	5	0	3.33	-0.50	99.99
1968	1968	2	26	3	816	9	0	2.91	-1.60	-1.71
1969	1969	1	25	3	15800	3	1	4.20	1.78	0.93
1969	1969	1	21	4	3370	3	0	3.53	0.02	99.99
1969	1969	3	31	4	1630	9	0	3.21	-0.81	99.99
1970	1970	9	5	3	24700	1.3	0	4.39	2.29	1.33
1970	1970	3	1	4	3550	5	0	3.55	0.08	99.99
1971	1971	8	27	3	4050	7	0	3.61	0.23	-0.28
1972	1971	12	26	3	4020	3	0	3.60	0.22	-0.29
1972	1972	8	12	4	3190	8	0	3.50	-0.04	99.99
1973	1972	10	19	3	8790	2	1	3.94	1.12	0.41
1973	1972	10	7	4	1480	1.2	0	3.17	-0.92	99.99
1973	1972	11	17	4	1670	3	1	3.22	-0.78	99.99
1973	1972	12	5	4	1870	3	1	3.27	-0.65	99.99
1973	1972	12	28	4	4160	3	1	3.62	0.26	99.99
1973	1973	4	13	4	3270	9	0	3.51	-0.01	99.99
1973	1973	4	26	4	2570	9	1	3.41	-0.29	99.99
1974	1974	7	7	3	3220	8	0	3.51	-0.03	-0.49
1974	1974	8	2	4	1310	8	1	3.12	-1.06	99.99
1975	1975	7	14	3	4820	7	0	3.68	0.43	-0.13
1975	1975	4	15	4	1370	9	0	3.14	-1.00	99.99
1976	1976	2	9	3	12500	3	0	4.10	1.52	0.72
1976	1976	4	20	4	2020	9	0	3.31	-0.56	99.99
1977	1977	7	18	3	415	8	0	2.62	-2.37	-2.31
1978	1978	3	1	3	17400	3	2	4.24	1.89	1.01
1978	1977	10	6	4	1620	1	0	3.21	-0.81	99.99
1978	1978	2	1	4	1610	5	0	3.21	-0.82	99.99
1978	1978	2	11	4	1700	3	1	3.23	-0.76	99.99
1978	1978	3	5	4	5400	3	2	3.73	0.56	99.99
1978	1978	3	22	4	3830	5	2	3.58	0.17	99.99
1979	1978	12	19	3	25100	3	0	4.40	2.31	1.34
1979	1978	11	12	4	4020	2.3	0	3.60	0.22	99.99
1979	1979	1	17	4	1910	5	1	3.28	-0.63	99.99
1979	1979	3	29	4	3720	3	0	3.57	0.13	99.99
1980	1980	2	19	3	26400	3	3	4.42	2.37	1.38
1980	1980	1	11	4	1980	3	0	3.30	-0.58	99.99
1980	1980	1	14	4	1590	3	1	3.20	-0.83	99.99
1980	1980	1	18	4	1470	3	2	3.17	-0.92	99.99
1980	1980	1	30	4	2390	3	3	3.38	-0.37	99.99
1980	1980	2	15	4	16700	3	2	4.22	1.85	99.99
1980	1980	2	18	4	9520	3	2	3.98	1.21	99.99
1980	1980	2	21	4	4010	3	4	3.60	0.22	99.99

25. VRDHSD Verde River below Tangle Creek, above Horseshoe Dam

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1949	10	19	3	9330	3	0	3.97	-0.13	-0.54
1950	1950	2	8	4	5620	9.3	0	3.75	-0.68	99.99
1951	1951	8	30	3	16400	1	0	4.21	0.49	-0.06
1952	1951	12	31	3	81600	3	0	4.91	2.23	1.30
1952	1952	1	18	4	27800	3	1	4.44	1.06	99.99
1952	1952	4	1	4	7960	9	0	3.90	-0.30	99.99
1952	1952	8	15	4	5550	8	0	3.74	-0.69	99.99
1953	1953	8	29	3	6390	8	0	3.81	-0.54	-0.86
1954	1954	3	23	3	19700	3	0	4.29	0.69	0.09
1954	1954	3	30	4	6310	9.3	1	3.80	-0.55	99.99
1954	1954	8	5	4	5080	8	0	3.71	-0.79	99.99
1955	1955	8	23	3	11600	8	2	4.06	0.11	-0.36
1955	1955	6	14	4	5000	2	0	3.70	-0.81	99.99
1955	1955	7	23	4	4010	8	0	3.60	-1.04	99.99
1955	1955	7	26	4	4610	8	1	3.66	-0.89	99.99
1955	1955	8	19	4	5720	8	2	3.76	-0.66	99.99
1956	1956	7	31	3	12800	8	0	4.11	0.22	-0.27
1957	1957	1	10	3	14500	3	0	4.16	0.35	-0.17
1957	1957	1	27	4	12400	3	1	4.09	0.18	99.99
1957	1957	2	14	4	4990	9	1	3.70	-0.81	99.99
1957	1957	2	20	4	4500	5	2	3.65	-0.92	99.99
1957	1957	2	25	4	10300	3	3	4.01	-0.02	99.99
1958	1958	3	23	3	21100	3	2	4.32	0.76	0.15
1958	1957	11	4	4	13000	2.3	0	4.11	0.23	99.99
1958	1958	2	5	4	4600	5	0	3.66	-0.90	99.99
1958	1958	2	26	4	5750	3	1	3.76	-0.65	99.99
1958	1958	3	18	4	8080	3	1	3.91	-0.28	99.99
1958	1958	6	21	4	4320	2	0	3.64	-0.96	99.99
1958	1958	9	13	4	9160	1	0	3.96	-0.15	99.99
1959	1959	8	17	3	6060	7	1	3.78	-0.60	-0.91
1959	1959	8	5	4	5210	8	0	3.72	-0.76	99.99
1960	1959	12	26	3	23400	3	0	4.37	0.87	0.24
1960	1959	10	29	4	19200	3	0	4.28	0.66	99.99
1960	1960	1	12	4	6420	3	1	3.81	-0.53	99.99
1960	1960	3	10	4	4880	9	0	3.69	-0.83	99.99
1961	1961	8	23	3	2800	7	0	3.45	-1.44	-1.56
1962	1962	2	13	3	13300	3	0	4.12	0.26	-0.24
1962	1962	3	29	4	4870	9	0	3.69	-0.83	99.99
1963	1963	8	22	3	18900	8	1	4.28	0.64	0.06
1963	1963	7	31	4	4570	7	0	3.66	-0.90	99.99
1963	1963	8	26	4	6300	8	2	3.80	-0.55	99.99
1964	1964	8	27	3	6910	6	0	3.84	-0.45	-0.80
1965	1965	1	7	3	25700	3	0	4.41	0.97	0.32
1965	1965	3	19	4	4300	3.4	0	3.63	-0.97	99.99
1965	1965	4	4	4	15700	2.3	1	4.20	0.44	99.99
1966	1965	12	22	3	39300	3	2	4.59	1.44	0.68
1966	1965	12	11	4	25600	3	1	4.41	0.97	99.99
1966	1965	12	31	4	31600	3	2	4.50	1.20	99.99

1966	1966	3	15	4	5870	9	0	3.77	-0.63	99.99
1966	1965	11	26	4	31400	3	0	4.50	1.19	99.99
1967	1966	12	7	3	53000	3	0	4.72	1.76	0.94
1968	1967	12	19	3	32600	3	0	4.51	1.23	0.52
1968	1968	1	28	4	12900	3	0	4.11	0.23	99.99
1968	1968	2	14	4	5320	3	1	3.73	-0.74	99.99
1968	1968	2	25	4	4030	9	2	3.61	-1.04	99.99
1969	1969	1	26	3	45800	3	1	4.66	1.60	0.81
1969	1969	1	22	4	7060	3	0	3.85	-0.43	99.99
1969	1969	3	22	4	5620	2	0	3.75	-0.68	99.99
1970	1970	9	6	3	61900	1.3	0	4.79	1.93	1.07
1970	1970	3	2	4	4400	3	0	3.64	-0.94	99.99
1971	1971	8	3	3	3030	8	0	3.48	-1.35	-1.50
1972	1971	12	27	3	21100	3	0	4.32	0.76	0.15
1973	1972	10	20	3	63400	2	1	4.80	1.96	1.09
1973	1972	10	26	4	5600	5	2	3.75	-0.68	99.99
1973	1972	11	18	4	6400	3	1	3.81	-0.54	99.99
1973	1972	12	28	4	27100	3	0	4.43	1.03	99.99
1973	1973	2	22	4	5090	5	0	3.71	-0.79	99.99
1973	1973	3	18	4	8500	9	1	3.93	-0.23	99.99
1973	1973	4	1	4	8250	3	1	3.92	-0.26	99.99
1973	1973	4	14	4	13400	9	2	4.13	0.27	99.99
1973	1973	4	26	4	6200	9	2	3.79	-0.57	99.99
1973	1972	10	7	4	16700	1.2	0	4.22	0.51	99.99
1974	1974	8	2	3	1500	8	0	3.18	-2.11	-2.09
1975	1975	4	15	3	5420	9	0	3.73	-0.72	-1.00
1976	1976	2	10	3	39900	3	1	4.60	1.45	0.69
1976	1976	2	5	4	10400	3	0	4.02	-0.01	99.99
1976	1976	4	21	4	6520	9	0	3.81	-0.52	99.99
1977	1977	8	24	3	1620	7	0	3.21	-2.03	-2.03
1978	1978	3	1	3	91400	3	2	4.96	2.35	1.40
1978	1978	1	15	4	4120	3	0	3.61	-1.02	99.99
1978	1978	1	17	4	4480	3	1	3.65	-0.92	99.99
1978	1978	2	1	4	4240	5	2	3.63	-0.98	99.99
1978	1978	2	11	4	8230	3	3	3.92	-0.26	99.99
1978	1978	3	6	4	24300	3	2	4.39	0.91	99.99
1978	1978	3	13	4	6390	3	3	3.81	-0.54	99.99
1978	1978	3	23	4	11000	5	3	4.04	0.05	99.99
1979	1978	12	19	3	94000	3	0	4.97	2.38	1.42
1979	1978	11	12	4	16900	2.3	0	4.23	0.52	99.99
1979	1979	1	17	4	28800	5	1	4.46	1.10	99.99
1979	1979	3	9	4	5650	9	0	3.75	-0.67	99.99
1979	1979	3	29	4	12700	3	1	4.10	0.21	99.99
1980	1980	2	15	3	94800	3	2	4.98	2.39	1.43
1980	1980	1	12	4	7260	3	0	3.86	-0.40	99.99
1980	1980	1	15	4	8580	3	1	3.93	-0.22	99.99
1980	1980	1	19	4	6250	2	2	3.80	-0.56	99.99
1980	1980	1	30	4	24000	3	3	4.38	0.90	99.99
1980	1980	2	20	4	65800	3	2	4.82	2.00	99.99
1980	1980	3	11	4	4130	3	2	3.62	-1.01	99.99

26. AFRMAY Agua Fria River near Mayer

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1950	7	17	3	2170	8	0	3.34	-1.19	-1.42
1951	1951	8	28	3	8180	1	1	3.91	0.99	0.30
1951	1951	7	31	4	3040	8	0	3.48	-0.64	99.99
1951	1951	8	29	4	8010	1	2	3.90	0.95	99.99
1951	1951	9	7	4	4380	4	2	3.64	-0.04	99.99
1952	1952	1	18	3	7500	3	0	3.88	0.84	0.18
1952	1951	10	30	4	5260	5	1	3.72	0.26	99.99
1952	1952	3	11	4	2900	3	0	3.46	-0.71	99.99
1952	1952	8	16	4	2320	8	0	3.37	-1.08	99.99
1952	1952	8	24	4	2510	8	1	3.40	-0.95	99.99
1952	1951	10	1	4	2770	4	1	3.44	-0.79	99.99
1953	1953	7	8	3	5510	8	0	3.74	0.34	-0.22
1953	1953	7	26	4	2510	8	1	3.40	-0.95	99.99
1954	1954	9	3	3	4570	4	2	3.66	0.03	-0.46
1954	1954	8	4	4	2380	8	0	3.38	-1.04	99.99
1954	1954	8	5	4	2910	8	1	3.46	-0.71	99.99
1955	1955	8	3	3	12800	8	3	4.11	1.72	0.88
1955	1955	6	13	4	2620	2	0	3.42	-0.88	99.99
1955	1955	7	17	4	2850	8	0	3.45	-0.74	99.99
1955	1955	7	23	4	7820	8	1	3.89	0.91	99.99
1955	1955	7	31	4	5480	8	2	3.74	0.33	99.99
1955	1955	8	7	4	5230	8	4	3.72	0.25	99.99
1955	1955	8	8	4	3920	7	5	3.59	-0.22	99.99
1955	1955	8	9	4	2520	7	6	3.40	-0.94	99.99
1955	1955	8	16	4	2310	7	7	3.36	-1.08	99.99
1955	1955	8	21	4	6780	8	7	3.83	0.68	99.99
1955	1955	8	22	4	3650	8	7	3.56	-0.34	99.99
1955	1955	8	23	4	7340	8	8	3.87	0.81	99.99
1955	1955	8	25	4	5820	7	9	3.76	0.43	99.99
1956	1956	7	25	3	6880	7	1	3.84	0.70	0.07
1956	1956	7	11	4	2840	7	0	3.45	-0.75	99.99
1956	1956	7	30	4	2370	8	2	3.37	-1.04	99.99
1957	1957	8	13	3	2710	8	1	3.43	-0.82	-1.14
1957	1957	7	26	4	2310	8	0	3.36	-1.08	99.99
1957	1957	8	11	4	2410	7	0	3.38	-1.02	99.99
1958	1958	6	21	3	4620	2	0	3.66	0.05	-0.44
1958	1958	9	12	4	3490	1	0	3.54	-0.41	99.99
1958	1958	9	28	4	2530	2	1	3.40	-0.94	99.99
1959	1959	8	4	3	9700	8	3	3.99	1.26	0.52
1959	1959	7	12	4	2880	7	0	3.46	-0.72	99.99
1959	1959	7	26	4	5910	7	1	3.77	0.45	99.99
1959	1959	8	1	4	4890	7	2	3.69	0.14	99.99
1959	1959	8	11	4	8170	8	4	3.91	0.98	99.99
1959	1959	8	13	4	7470	8	4	3.87	0.84	99.99
1959	1959	8	24	4	2350	8	5	3.37	-1.06	99.99
1960	1960	8	8	3	4820	7	0	3.68	0.12	-0.39
1960	1959	12	25	4	3400	3	0	3.53	-0.45	99.99

1961	1961	7	22	3	10200	7	1	4.01	1.35	0.58
1961	1960	10	9	4	2880	2	0	3.46	-0.72	99.99
1961	1961	7	16	4	2660	7	0	3.42	-0.85	99.99
1961	1961	7	28	4	2560	8	2	3.41	-0.92	99.99
1961	1961	9	13	4	2620	7	0	3.42	-0.88	99.99
1961	1961	9	17	4	10100	2	1	4.00	1.33	99.99
1962	1962	9	13	3	2470	4	0	3.39	-0.98	-1.26
1963	1963	8	19	3	12800	7	1	4.11	1.72	0.88
1963	1963	7	31	4	6450	7	0	3.81	0.60	99.99
1963	1963	8	21	4	6620	7	2	3.82	0.64	99.99
1963	1963	8	26	4	7480	8	3	3.87	0.84	99.99
1963	1963	9	10	4	3470	7	3	3.54	-0.42	99.99
1964	1964	7	24	3	9000	8	0	3.95	1.14	0.42
1964	1964	7	31	4	4140	8	1	3.62	-0.13	99.99
1964	1964	8	11	4	3850	7	2	3.59	-0.25	99.99
1964	1964	8	19	4	4440	7	3	3.65	-0.01	99.99
1964	1964	9	13	4	6620	6	1	3.82	0.64	99.99
1965	1965	4	4	3	7470	2.3	0	3.87	0.84	0.18
1965	1965	4	10	4	5830	3	1	3.77	0.43	99.99
1965	1965	8	17	4	2650	8	0	3.42	-0.86	99.99
1965	1965	9	2	4	2320	7	1	3.37	-1.08	99.99
1966	1965	12	10	3	12100	3	1	4.08	1.63	0.80
1966	1965	12	22	4	10200	3	2	4.01	1.35	99.99
1966	1965	12	30	4	3150	3	2	3.50	-0.58	99.99
1966	1966	8	17	4	2650	8	0	3.42	-0.86	99.99
1966	1965	11	25	4	3010	3	0	3.48	-0.65	99.99
1967	1967	8	19	3	6960	7	2	3.84	0.72	0.09
1967	1967	7	27	4	3570	8	0	3.55	-0.37	99.99
1967	1967	8	9	4	2650	7	1	3.42	-0.86	99.99
1968	1967	12	19	3	3850	3	0	3.59	-0.25	-0.68
1969	1969	8	7	3	2490	1	0	3.40	-0.96	-1.25
1970	1970	9	5	3	19800	1.3	1	4.30	2.43	1.44
1970	1970	8	18	4	2370	7	0	3.37	-1.04	99.99
1971	1971	8	25	3	7280	7	4	3.86	0.79	0.15
1971	1971	8	3	4	2570	8	0	3.41	-0.91	99.99
1971	1971	8	15	4	5680	8	1	3.75	0.39	99.99
1971	1971	8	23	4	2610	7	3	3.42	-0.88	99.99
1971	1971	8	17	4	4920	8	2	3.69	0.15	99.99
1972	1972	8	12	3	6800	8	2	3.83	0.68	0.06
1972	1972	7	17	4	4010	8	0	3.60	-0.18	99.99
1972	1972	8	7	4	4990	7	1	3.70	0.18	99.99
1972	1972	8	26	4	2330	6	2	3.37	-1.07	99.99
1972	1972	9	1	4	2400	8	3	3.38	-1.02	99.99
1973	1972	10	7	3	10700	1.2	0	4.03	1.43	0.65
1973	1972	10	19	4	5710	2	1	3.76	0.40	99.99
1973	1972	12	28	4	3770	3	0	3.58	-0.28	99.99
1973	1973	2	22	4	2360	5	0	3.37	-1.05	99.99
1973	1973	7	30	4	4070	8	0	3.61	-0.16	99.99
1974	1974	7	20	3	740	8	0	2.87	-2.95	-2.82

1975	1975	7	27	3	2190	7	0	3.34	-1.17	-1.41
1976	1976	2	9	3	9700	3	1	3.99	1.26	0.52
1976	1976	2	5	4	2720	3	0	3.43	-0.82	99.99
1976	1976	7	9	4	2400	7	0	3.38	-1.02	99.99
1976	1976	9	6	4	2640	8	0	3.42	-0.87	99.99
1977	1977	8	23	3	5480	7	0	3.74	0.33	-0.22
1977	1977	9	12	4	2600	8	1	3.41	-0.89	99.99
1978	1978	3	1	3	9900	3	1	4.00	1.30	0.54
1978	1978	2	11	4	4740	3	0	3.68	0.09	99.99
1978	1978	3	5	4	4160	3	2	3.62	-0.12	99.99
1979	1978	12	18	3	18300	3	0	4.26	2.30	1.34
1979	1979	1	17	4	14200	5	1	4.15	1.89	99.99
1979	1979	1	18	4	4510	3	1	3.65	0.01	99.99
1979	1979	3	28	4	6490	3	0	3.81	0.61	99.99
1980	1980	2	19	3	33100	3	2	4.52	3.27	2.11
1980	1980	1	30	4	8020	3	0	3.90	0.95	99.99
1980	1980	2	14	4	13900	5	1	4.14	1.85	99.99

28. HASWIK Hassayampa River at Box Damsite, near Wickenburg

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1950	1949	10	18	3	5500	3	1	3.74	1.03	0.38
1951	1951	8	29	3	27000	1	2	4.43	2.58	1.57
1951	1951	8	3	4	2130	8	0	3.33	0.10	99.99
1951	1951	8	20	4	750	8	1	2.88	-0.93	99.99
1951	1951	8	26	4	4910	1	1	3.69	0.91	99.99
1952	1951	12	30	3	1590	3	0	3.20	-0.19	-0.55
1952	1951	10	30	4	885	5	0	2.95	-0.76	99.99
1952	1952	1	18	4	590	3	1	2.77	-1.16	99.99
1952	1952	3	11	4	1410	3	0	3.15	-0.31	99.99
1952	1952	3	17	4	910	3	1	2.96	-0.74	99.99
1952	1952	8	14	4	775	8	0	2.89	-0.89	99.99
1952	1952	9	20	4	580	1	0	2.76	-1.18	99.99
1953	1953	7	18	3	865	8	0	2.94	-0.79	-1.01
1954	1954	3	23	3	3090	3	0	3.49	0.46	-0.06
1954	1954	3	25	4	1120	5	1	3.05	-0.53	99.99
1954	1954	9	2	4	2760	5	0	3.44	0.35	99.99
1955	1955	7	23	3	8840	8	1	3.95	1.49	0.73
1955	1955	6	13	4	1340	2	0	3.13	-0.36	99.99
1955	1955	7	21	4	2380	7	0	3.38	0.20	99.99
1955	1955	7	24	4	643	8	2	2.81	-1.08	99.99
1955	1955	7	31	4	2310	8	3	3.36	0.18	99.99
1955	1955	8	2	4	518	8	4	2.71	-1.29	99.99
1955	1955	8	10	4	3350	7	5	3.53	0.54	99.99
1955	1955	8	14	4	1070	8	6	3.03	-0.58	99.99
1955	1955	8	21	4	6710	8	6	3.83	1.22	99.99

1955	1955	8	23	4	8820	8	6	3.95	1.49	99.99
1955	1955	8	25	4	615	7	6	2.79	-1.12	99.99
1956	1956	8	18	3	1210	7	1	3.08	-0.46	-0.76
1956	1955	10	4	4	792	1	0	2.90	-0.87	99.99
1956	1956	7	25	4	685	7	0	2.84	-1.02	99.99
1957	1957	8	10	3	1980	7	0	3.30	0.02	-0.39
1957	1957	1	27	4	1300	3	0	3.11	-0.39	99.99
1957	1957	8	12	4	947	8	1	2.98	-0.70	99.99
1958	1958	9	5	3	10600	8	4	4.03	1.67	0.87
1958	1957	11	1	4	1320	5	1	3.12	-0.37	99.99
1958	1957	11	3	4	935	3	2	2.97	-0.71	99.99
1958	1958	2	4	4	1580	5	0	3.20	-0.20	99.99
1958	1958	8	14	4	1420	7	0	3.15	-0.30	99.99
1958	1958	8	15	4	800	8	1	2.90	-0.86	99.99
1958	1958	8	20	4	768	8	2	2.89	-0.90	99.99
1958	1958	8	28	4	1560	7	3	3.19	-0.21	99.99
1958	1958	9	12	4	3450	1	5	3.54	0.57	99.99
1958	1957	10	21	4	556	2	0	2.75	-1.22	99.99
1959	1959	8	24	3	5110	8	3	3.71	0.95	0.32
1959	1959	8	2	4	1240	8	0	3.09	-0.43	99.99
1959	1959	8	11	4	2030	8	1	3.31	0.05	99.99
1959	1959	8	21	4	1100	7	2	3.04	-0.55	99.99
1960	1959	12	26	3	3210	3	0	3.51	0.50	-0.03
1960	1960	8	10	4	1120	8	0	3.05	-0.53	99.99
1960	1960	8	23	4	2780	1.6	1	3.44	0.36	99.99
1960	1960	9	2	4	926	7	2	2.97	-0.72	99.99
1961	1961	8	19	3	1150	8	1	3.06	-0.51	-0.80
1961	1961	8	15	4	528	8	0	2.72	-1.27	99.99
1961	1961	8	30	4	845	7	2	2.93	-0.81	99.99
1961	1961	9	17	4	514	2	2	2.71	-1.30	99.99
1962	1962	9	21	3	1510	1	0	3.18	-0.24	-0.59
1963	1963	8	17	3	2150	8	0	3.33	0.11	-0.33
1963	1963	8	20	4	1270	7	1	3.10	-0.41	99.99
1963	1963	8	26	4	1130	8	2	3.05	-0.52	99.99
1964	1964	7	14	3	1230	6	0	3.09	-0.44	-0.75
1964	1964	7	30	4	760	8	1	2.88	-0.91	99.99
1964	1964	8	2	4	696	8	2	2.84	-1.00	99.99
1964	1964	9	14	4	535	8	0	2.73	-1.26	99.99
1965	1965	9	2	3	9060	7	0	3.96	1.51	0.75
1965	1965	4	4	4	1370	2.3	0	3.14	-0.34	99.99
1965	1965	4	10	4	2850	3	1	3.45	0.38	99.99
1965	1965	9	4	4	5240	1	1	3.72	0.98	99.99
1966	1965	12	10	3	5560	3	2	3.75	1.04	0.38
1966	1965	11	23	4	1400	3	0	3.15	-0.31	99.99
1966	1965	11	25	4	2650	3	1	3.42	0.31	99.99
1966	1965	12	30	4	2540	3	1	3.40	0.27	99.99
1967	1966	12	7	3	1740	3	0	3.24	-0.10	-0.49
1968	1967	12	19	3	11200	3	0	4.05	1.72	0.91
1968	1968	7	27	4	1690	8	0	3.23	-0.13	99.99

1969	1969	9	13	3	4630	1	1	3.67	0.86	0.25
1969	1969	1	26	4	1020	3	0	3.01	-0.63	99.99
1969	1969	9	3	4	890	7	0	2.95	-0.76	99.99
1970	1970	9	5	3	58000	1.3	0	4.76	3.33	2.14
1970	1970	3	2	4	1930	3	0	3.29	0.00	99.99
1971	1971	8	25	3	556	7	0	2.75	-1.22	-1.34
1972	1972	8	27	3	800	6	0	2.90	-0.86	-1.07
1973	1972	10	7	3	2600	1.2	0	3.41	0.29	-0.18
1973	1972	10	18	4	980	2	1	2.99	-0.66	99.99
1973	1973	2	22	4	784	5	0	2.89	-0.88	99.99
1973	1973	3	13	4	1130	3	1	3.05	-0.52	99.99
1973	1973	3	29	4	1180	3	1	3.07	-0.48	99.99
1974	1974	7	20	3	5560	8	0	3.75	1.04	0.38
1974	1974	8	5	4	2480	8	1	3.39	0.25	99.99
1975	1975	7	28	3	154	7	0	2.19	-2.48	-2.30
1976	1976	2	9	3	4560	3	1	3.66	0.84	0.24
1976	1976	2	5	4	2740	3	0	3.44	0.34	99.99
1976	1976	4	16	4	752	3	0	2.88	-0.92	99.99
1976	1976	9	6	4	3350	8	0	3.53	0.54	99.99
1977	1977	8	15	3	315	1	0	2.50	-1.78	-1.77
1978	1978	3	2	3	16000	3	3	4.20	2.07	1.18
1978	1978	1	15	4	863	3	0	2.94	-0.79	99.99
1978	1978	1	17	4	1320	3	1	3.12	-0.37	99.99
1978	1978	2	11	4	3550	3	2	3.55	0.60	99.99
1978	1978	2	13	4	584	3	3	2.77	-1.17	99.99
1978	1978	3	1	4	7710	3	2	3.89	1.36	99.99
1978	1978	3	5	4	2780	3	4	3.44	0.36	99.99
1979	1979	3	28	3	9640	3	2	3.98	1.58	0.80
1979	1978	11	11	4	4940	2.3	0	3.69	0.92	99.99
1979	1978	12	18	4	9200	3	0	3.96	1.53	99.99
1979	1979	1	17	4	3390	5	1	3.53	0.55	99.99
1979	1979	1	18	4	1380	3	1	3.14	-0.33	99.99
1979	1979	3	20	4	3000	2	0	3.48	0.43	99.99
1979	1979	3	21	4	2050	2	1	3.31	0.06	99.99
1979	1979	8	12	4	2360	8	0	3.37	0.20	99.99
1980	1980	2	19	3	24900	3	4	4.40	2.51	1.51
1980	1980	1	11	4	2340	3	0	3.37	0.19	99.99
1980	1980	1	15	4	500	3	1	2.70	-1.32	99.99
1980	1980	1	30	4	14600	3	2	4.16	1.98	99.99
1980	1980	2	14	4	7740	5	2	3.89	1.36	99.99
1980	1980	2	15	4	5690	3	2	3.76	1.06	99.99
1980	1980	2	17	4	3380	3	3	3.53	0.55	99.99
1980	1980	2	21	4	7440	3	5	3.87	1.32	99.99

29. RIOAJO Rio Cornez near Ajo

WYEAR	YEAR	MONTH	DAY	SERIES	PKQ	CLASSIF	ANTFLOOD	LOGQ	Z-PKQ	Z-ANQ
1967	1967	7	9	3	3460	8	0	3.54	1.11	0.14
1967	1967	7	11	4	1390	8	1	3.14	-0.10	99.99
1967	1967	8	18	4	3350	7	0	3.53	1.07	99.99
1967	1967	9	6	4	704	7	1	2.85	-1.01	99.99

1968	1968	8	5	3	3750	8	1	3.57	1.22	0.29
1968	1967	12	19	4	589	3	0	2.77	-1.24	99.99
1968	1968	7	5	4	623	8	0	2.79	-1.17	99.99
1968	1968	7	23	4	1550	8	1	3.19	0.05	99.99
1969	1969	8	29	3	1610	8	0	3.21	0.10	-1.31
1969	1968	11	14	4	895	3	0	2.95	-0.69	99.99
1969	1969	9	3	4	605	7	1	2.78	-1.21	99.99
1970	1970	8	16	3	2300	7	2	3.36	0.57	-0.63
1970	1970	7	4	4	1150	7	0	3.06	-0.35	99.99
1970	1970	8	2	4	800	7	1	2.90	-0.83	99.99
1970	1970	8	15	4	790	7	1	2.90	-0.85	99.99
1970	1970	8	26	4	581	7	3	2.76	-1.26	99.99
1970	1970	9	5	4	632	1.3	3	2.80	-1.15	99.99
1971	1971	8	20	3	3000	8	3	3.48	0.92	-0.13
1971	1971	8	4	4	1240	8	0	3.09	-0.25	99.99
1971	1971	8	13	4	1250	1	1	3.10	-0.24	99.99
1971	1971	8	19	4	1210	8	2	3.08	-0.28	99.99
1972	1972	8	9	3	2510	7	0	3.40	0.69	-0.47
1972	1972	6	7	4	557	5	0	2.75	-1.32	99.99
1972	1972	8	10	4	1840	7	1	3.26	0.27	99.99
1972	1972	8	31	4	565	1	2	2.75	-1.30	99.99
1973	1973	8	19	3	2620	7	1	3.42	0.74	-0.39
1973	1972	10	6	4	1550	1.2	0	3.19	0.05	99.99
1973	1973	8	16	4	525	8	0	2.72	-1.40	99.99
1974	1974	8	2	3	6000	8	1	3.78	1.85	1.18
1974	1974	7	6	4	3230	7	0	3.51	1.02	99.99
1974	1974	8	4	4	1980	8	2	3.30	0.37	99.99
1975	1975	9	7	3	2570	8	1	3.41	0.72	-0.42
1975	1974	10	29	4	811	2.3	0	2.91	-0.82	99.99
1975	1975	9	6	4	1920	8	0	3.28	0.33	99.99
1976	1976	9	4	3	8030	7	1	3.90	2.23	1.73
1976	1976	8	4	4	2420	5	0	3.38	0.64	99.99
1976	1976	7	24	4	5120	8	0	3.71	1.63	99.99
1976	1976	7	25	4	2160	8	1	3.33	0.49	99.99
1976	1976	7	29	4	659	8	2	2.82	-1.09	99.99
1976	1976	8	8	4	1520	7	3	3.18	0.02	99.99
1976	1976	9	24	4	2640	5	1	3.42	0.75	99.99
1977	1977	9	10	3	1390	8	1	3.14	-0.10	-1.58
1977	1977	7	18	4	1300	8	0	3.11	-0.19	99.99
1977	1977	8	2	4	597	7	1	2.78	-1.22	99.99
1977	1977	8	13	4	597	8	2	2.78	-1.22	99.99
1978	1977	10	6	3	7220	1	2	3.86	2.09	1.53
1978	1977	10	4	4	742	1	1	2.87	-0.94	99.99
1978	1978	1	10	4	659	3	0	2.82	-1.09	99.99
1978	1978	1	15	4	916	3	1	2.96	-0.65	99.99
1978	1978	3	6	4	3050	3	0	3.48	0.95	99.99
1978	1978	3	12	4	3230	3	1	3.51	1.02	99.99
1979	1978	11	11	3	3360	2.3	0	3.53	1.07	0.08

APPENDIX C

SPECIFIC CRITERIA FOR THE HYDROCLIMATIC CLASSIFICATION

Tropical Storm (T)

a) Tropical storm/hurricane symbol on daily weather map series in eastern North Pacific Ocean within 2 to 3 days of the flood event, or

b) Tropical storm mentioned as having an effect on the Southwest at the time (within about 2 to 3 days) of the flood event somewhere in the literature.

Cutoff Low (C) (criteria from Douglas 1974)

a) On daily weather map series, location of at least 2 closed isobars between 25° to 45° N and 105° to 145° W with at least a 200 ft lowering of pressure

b) A central temperature in the low of greater than, or equal to -25° C

c) Association with a migratory upper level "parent" anticyclone with the 500 mb level of the high no greater then 500 ft above the outer fringes of the low

d) Persistence of the low within the region for at least 2 days

(The criteria of two closed isobars and 2 days persistence were relaxed on rare occasions.)

Front (F or MF)

a) Cold, warm, stationary, or occluded front on daily weather map with at least some portion of the front reaching into the Gila River basin or northern Arizona within 1 to 2 days of widespread precipitation in the Gila basin, or

b) evidence that a front passed across basin rapidly between the time of two consecutive daily weather maps

<u>Local Convectional</u> (L or ML)

a) No evidence of any major synoptic features such as fronts, cutoff lows, etc. within 2 - 3 days of flooding event

b) Precipitation at only a few stations in the vicinity of the flooding station on the individual flood maps, or

c) No precipitation in the vicinity of the flooding station and no evidence of snowmelt or any other flood-generating feature, but evidence of convectional activity in other parts of the basin

<u>Widespread</u> (W or MW)

a) no evidence of any major synoptic features such as fronts, cutoff lows, etc within 2 - 3 days of flooding event

b) Widespread precipitation in Gila basin. Widespread defined as at least 2 stations recording precipitation in at least 6 of the 7 sectors of the basin (see sector map, next page), or precipitation in <u>all</u> sectors, with no more than one or two sectors recording precipitation at only one station.

<u>Snowmelt</u> (S, SF, SL, SW, SC, etc.)

a) Snow on ground available to melt, (as indicated by the snow recording stations), and a temperature rise during the time of the flood event, or

b) Evidence that snow at recording stations melted during or prior to the flood event

<u>Mystery Flood</u> (?)

a) No recorded daily precipitation occurring anywhere in the basin many days prior to and after the flood event

b) No direct or indirect evidence of snowmelt

<u>Monsoon Period</u> (M classification) (Criteria from A. V. Douglas, written communication, 1982)

Beginning date:

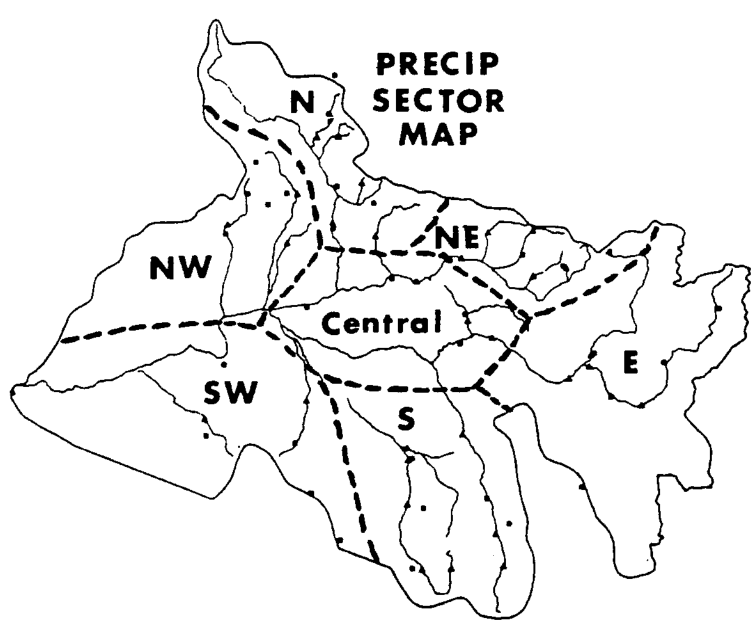
The date when rains start and are not broken for more than 3 days in southeastern Arizona. If no station in all of southeastern Arizona reports rainfall for 4 days, the monsoon is not considered to have started. Any earlier showers are "premonsoon."

Ending date:

The date of the last rainfall of the summer determined by either:

a) no more rains occur 7 days or sooner after this date,

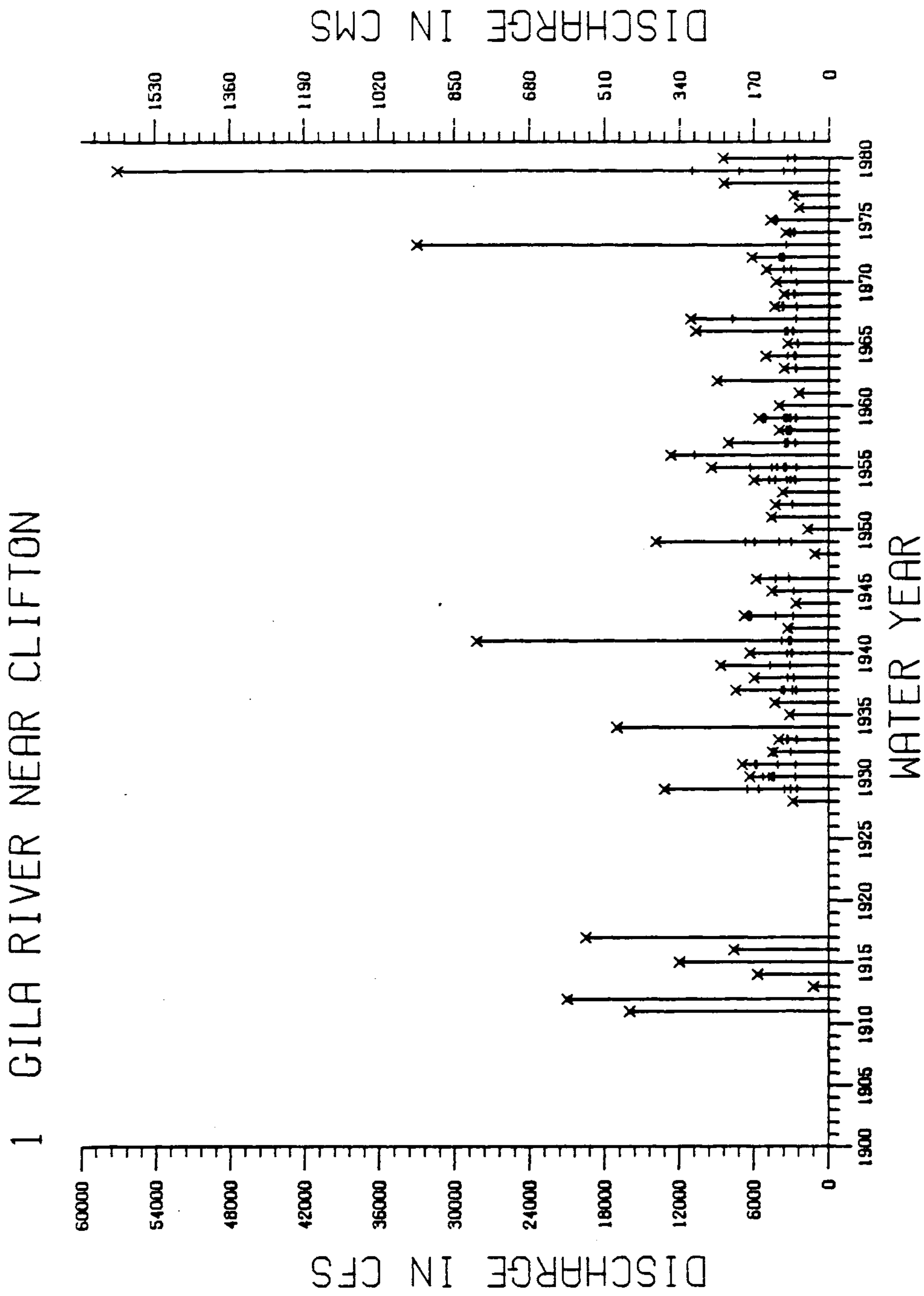
b) rains occur in 7 days after this last date but nighttime minimums indicate cool temperatures associated with a trough and cold temperatures aloft, ending the monsoonal circulation.

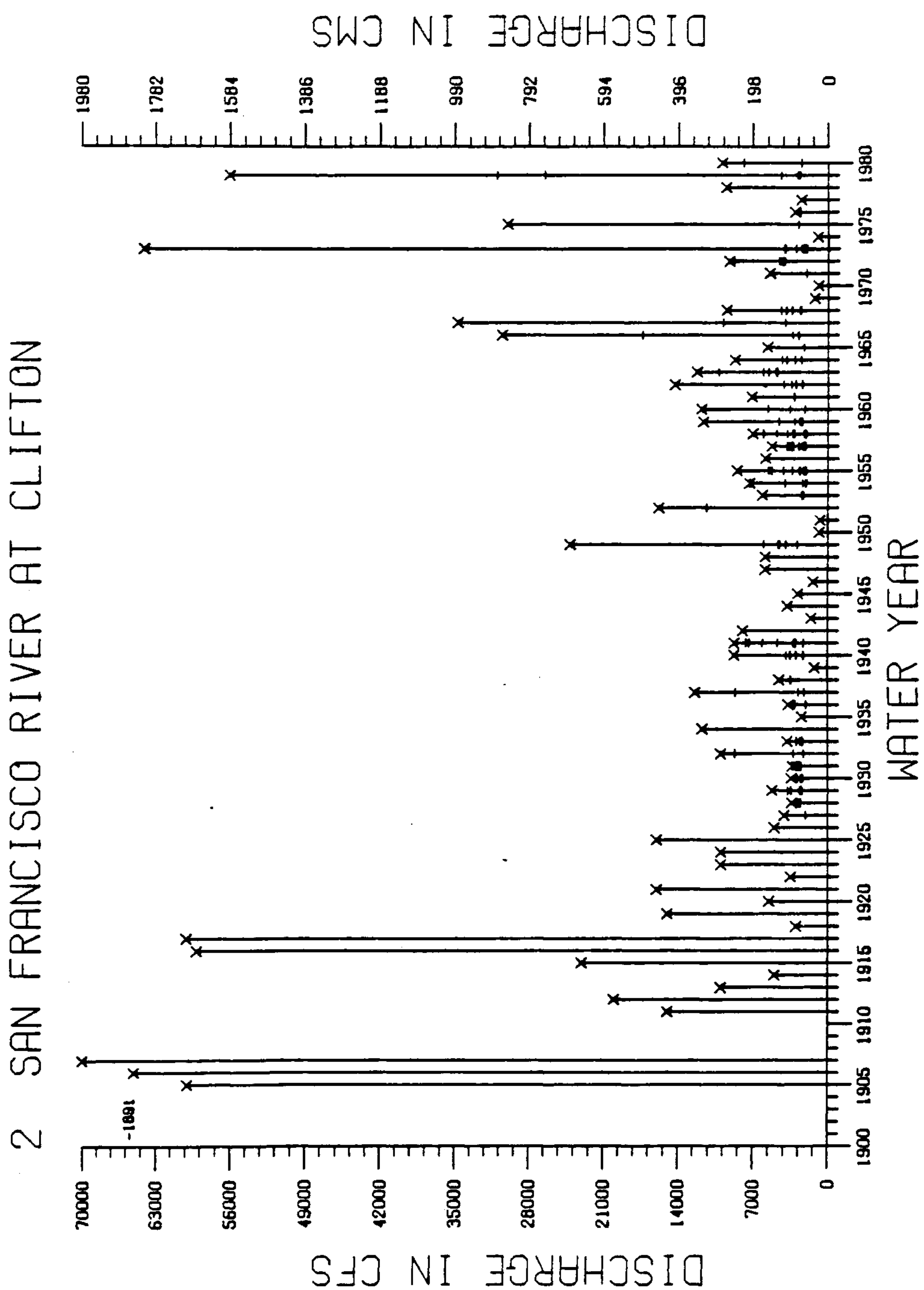


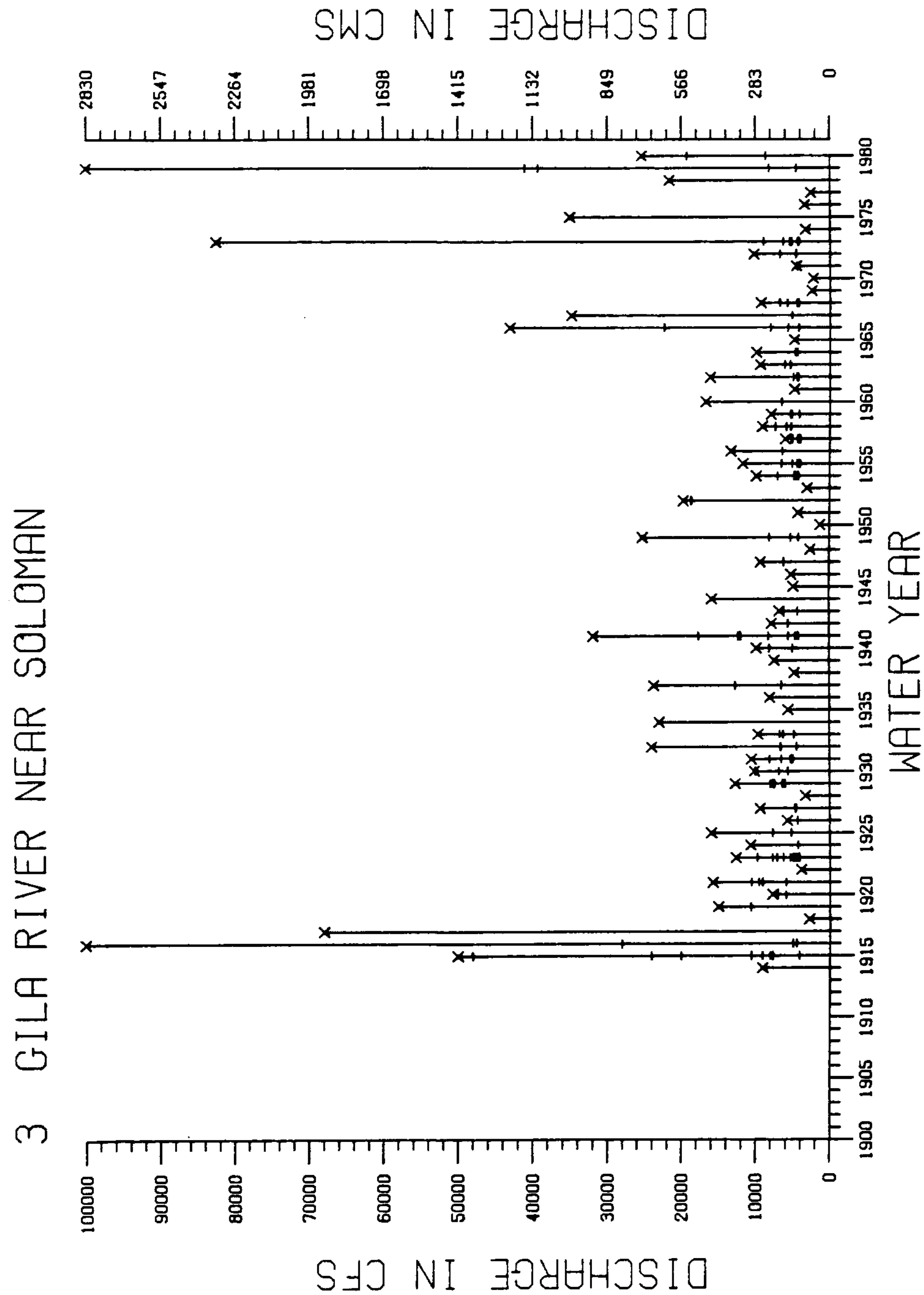
APPENDIX D

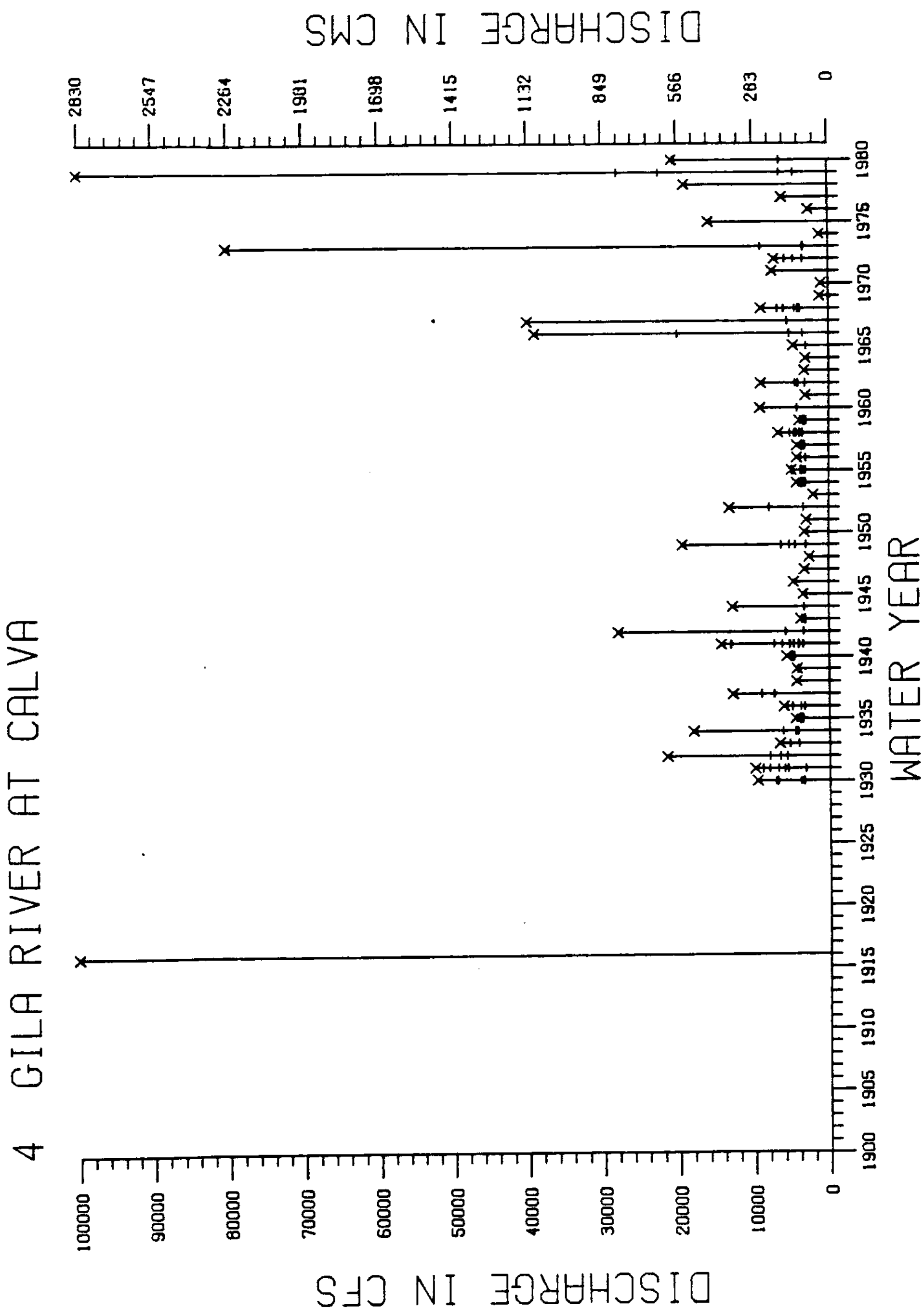
TIME SERIES PLOTS OF THE GILA RIVER BASIN

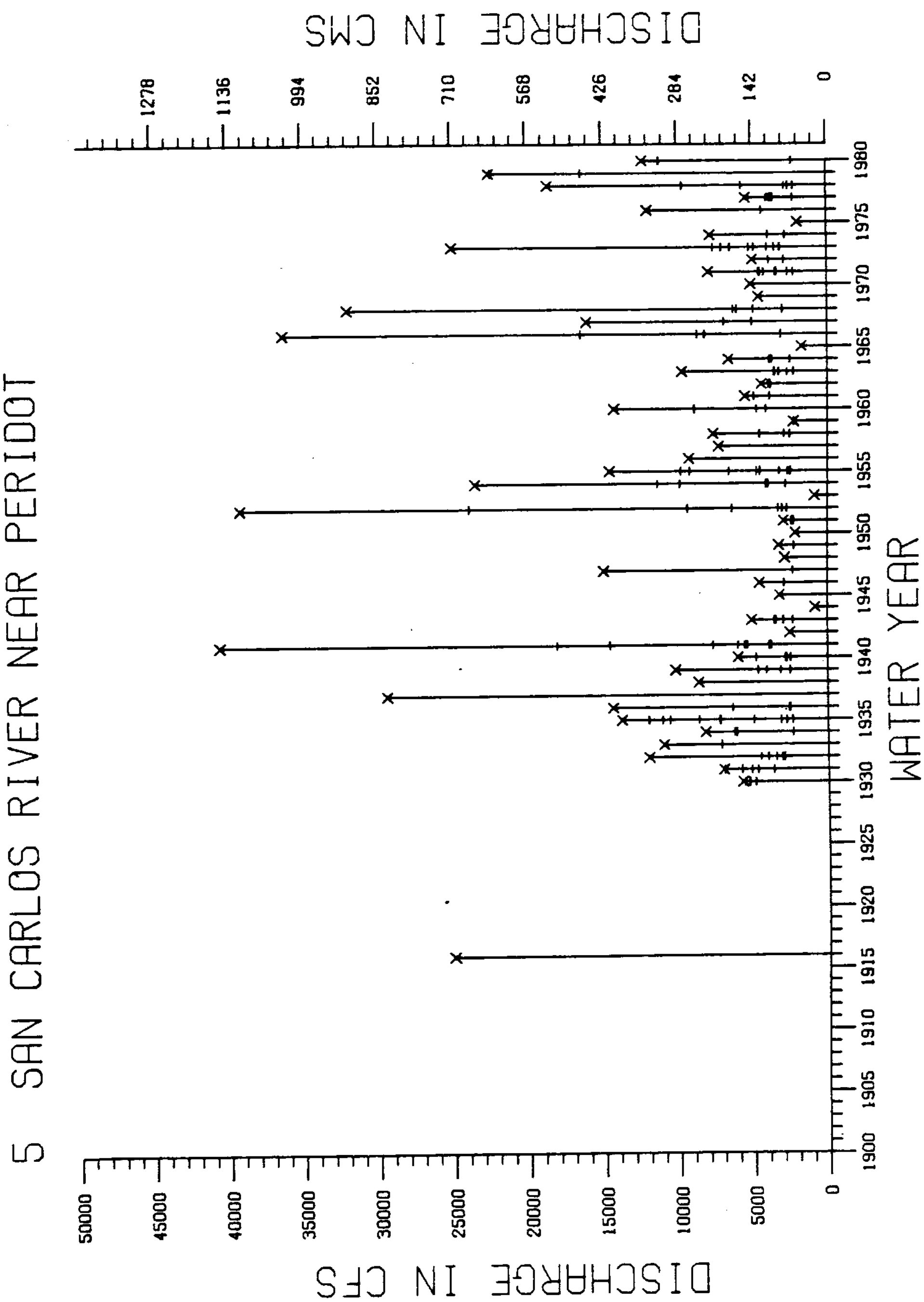
ANNUAL AND PARTIAL DURATION FLOOD PEAKS

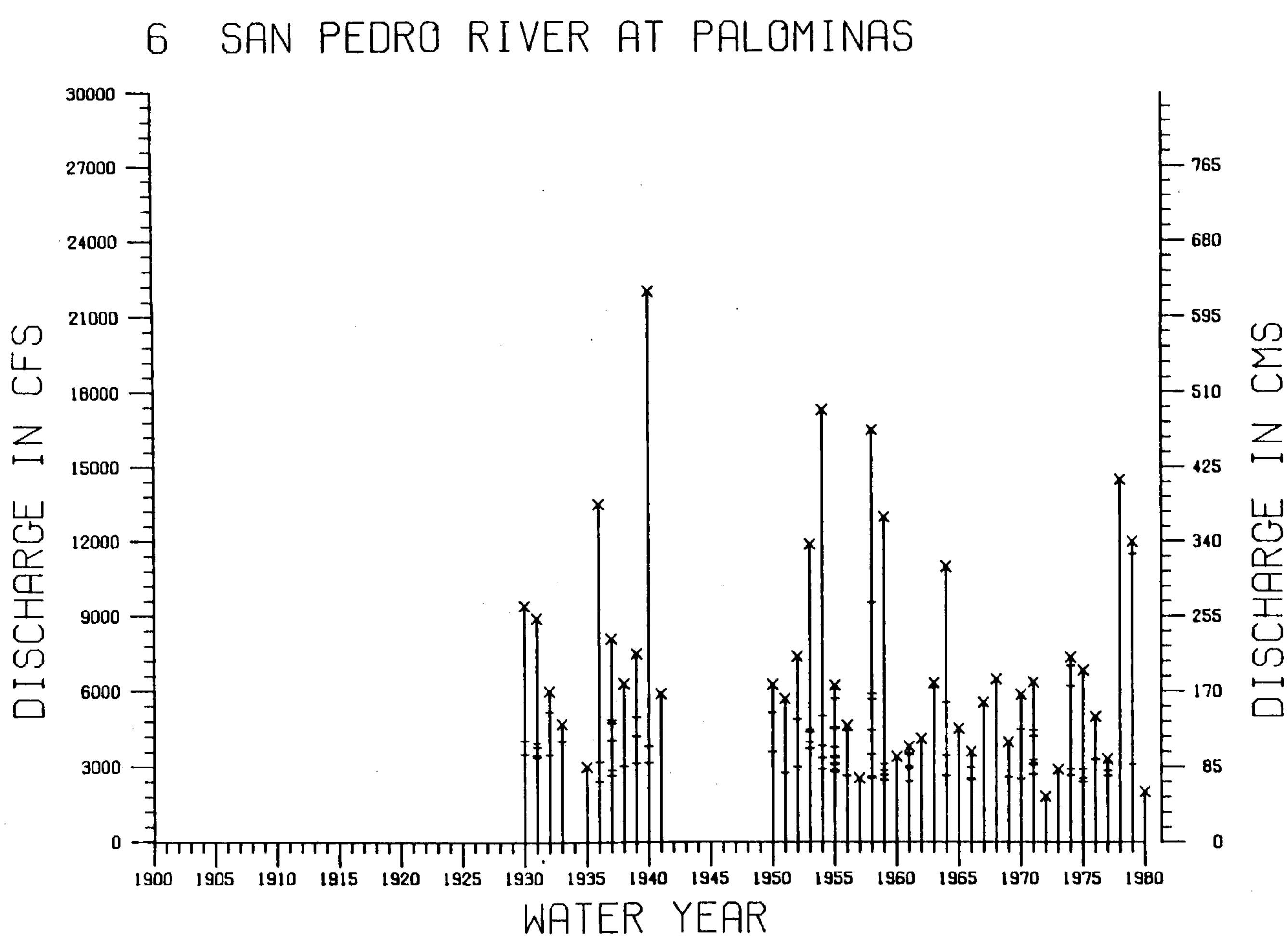

1 GILA RIVER NEAR CLIFTON
DISCHARGE IN CMS
0
170
340
510
680
850
1020
1190
1360
1530
DISCHARGE IN CFS
0
6000
12000
18000
24000
30000
36000
42000
48000
54000
60000
WATER YEAR
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

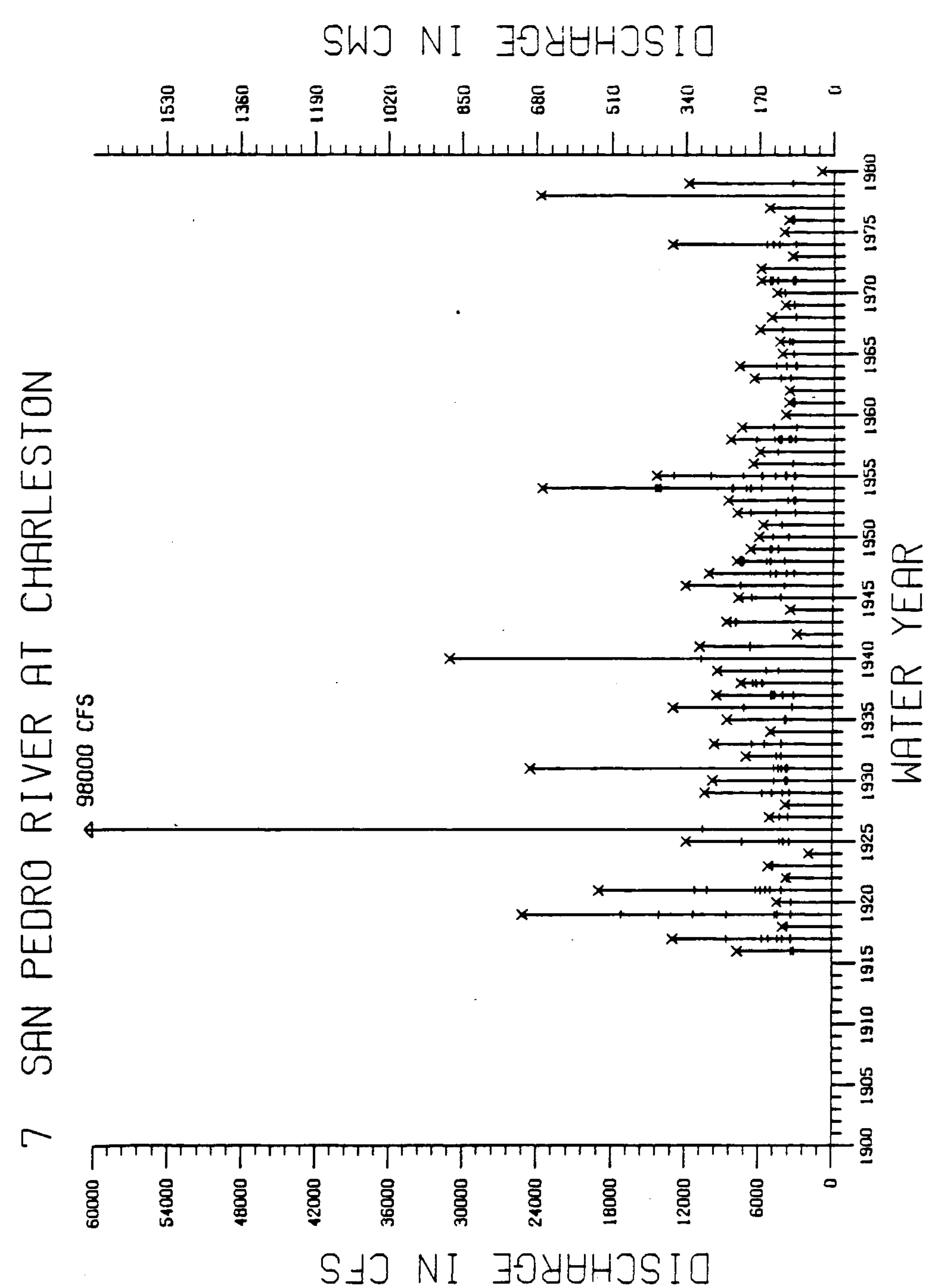

2 SAN FRANCISCO RIVER AT CLIFTON
DISCHARGE IN CFS
DISCHARGE IN CMS
WATER YEAR
-1891
0
7000
14000
21000
28000
35000
42000
49000
56000
63000
70000
0
198
396
594
792
990
1188
1386
1584
1782
1980
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

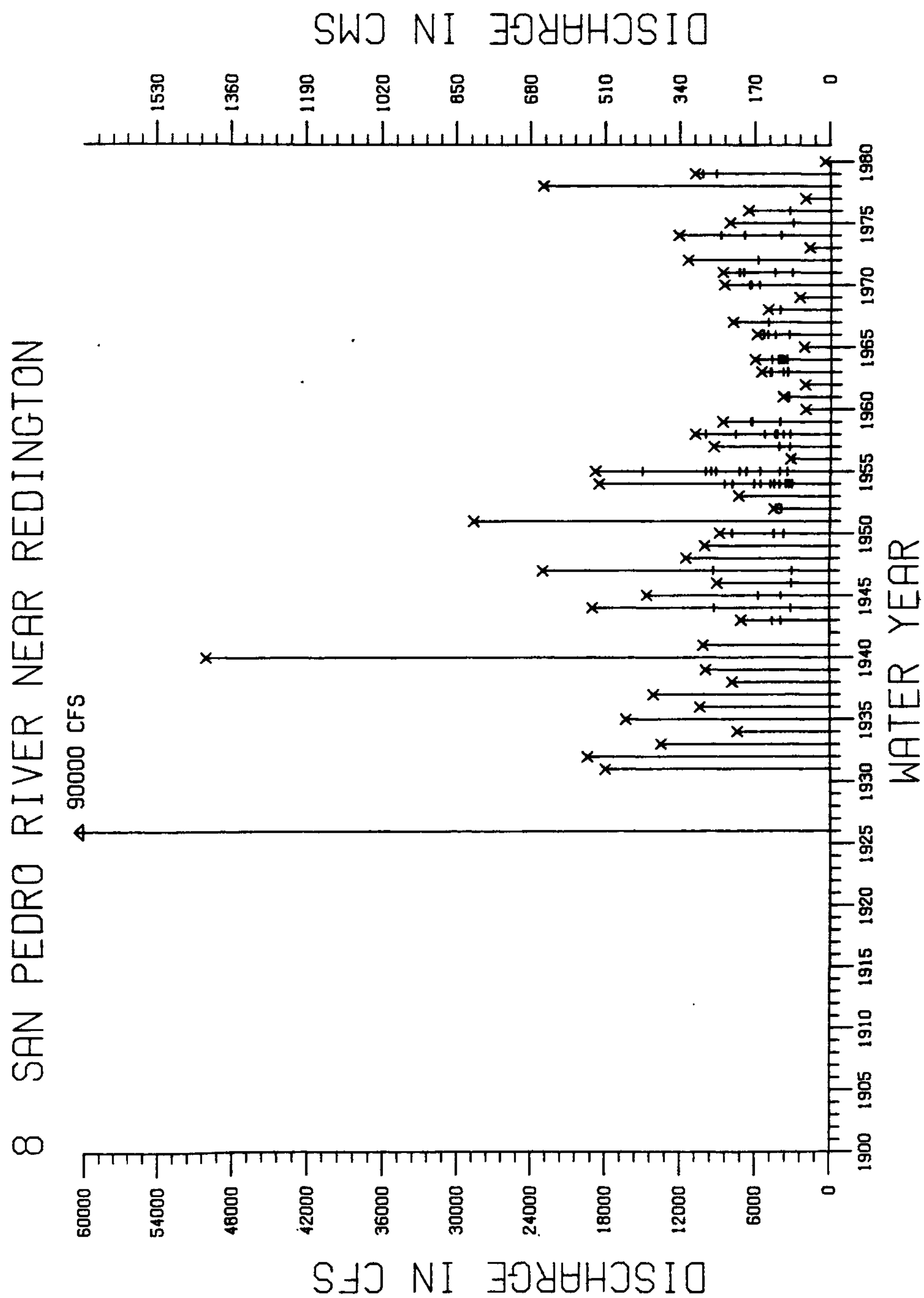

3 GILA RIVER NEAR SOLOMAN
DISCHARGE IN CFS
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
DISCHARGE IN CMS
0
283
566
849
1132
1415
1698
1981
2264
2547
2830
WATER YEAR
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980


4 GILA RIVER AT CALVA
DISCHARGE IN CFS
0 10000 20000 30000 40000 50000 60000 70000 80000 90000 100000
DISCHARGE IN CMS
0 283 566 849 1132 1415 1698 1981 2264 2547 2830
WATER YEAR
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980

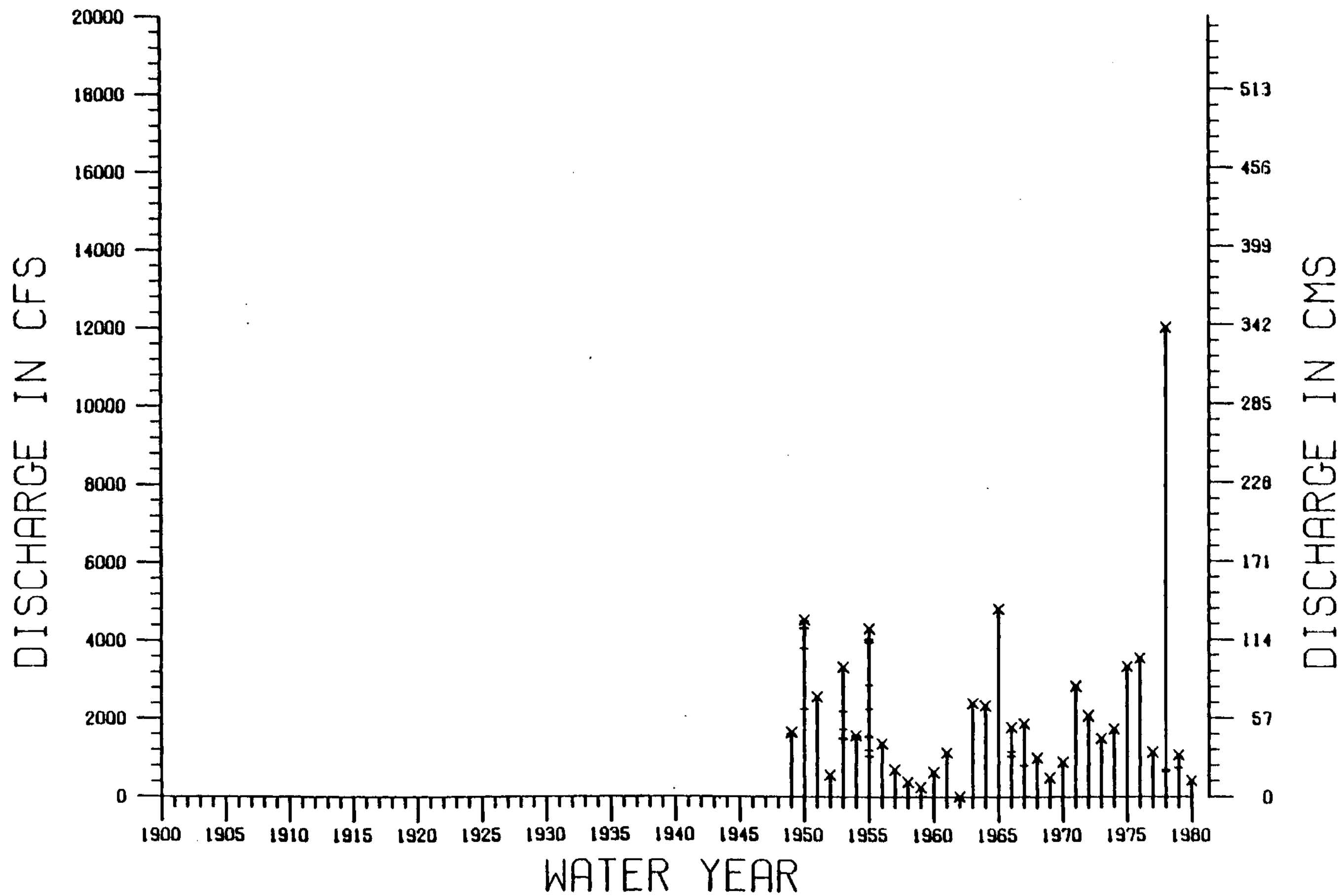

5 SAN CARLOS RIVER NEAR PERIDOT
DISCHARGE IN CMS
0
142
284
426
568
710
852
994
1136
1278
DISCHARGE IN CFS
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
WATER YEAR
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

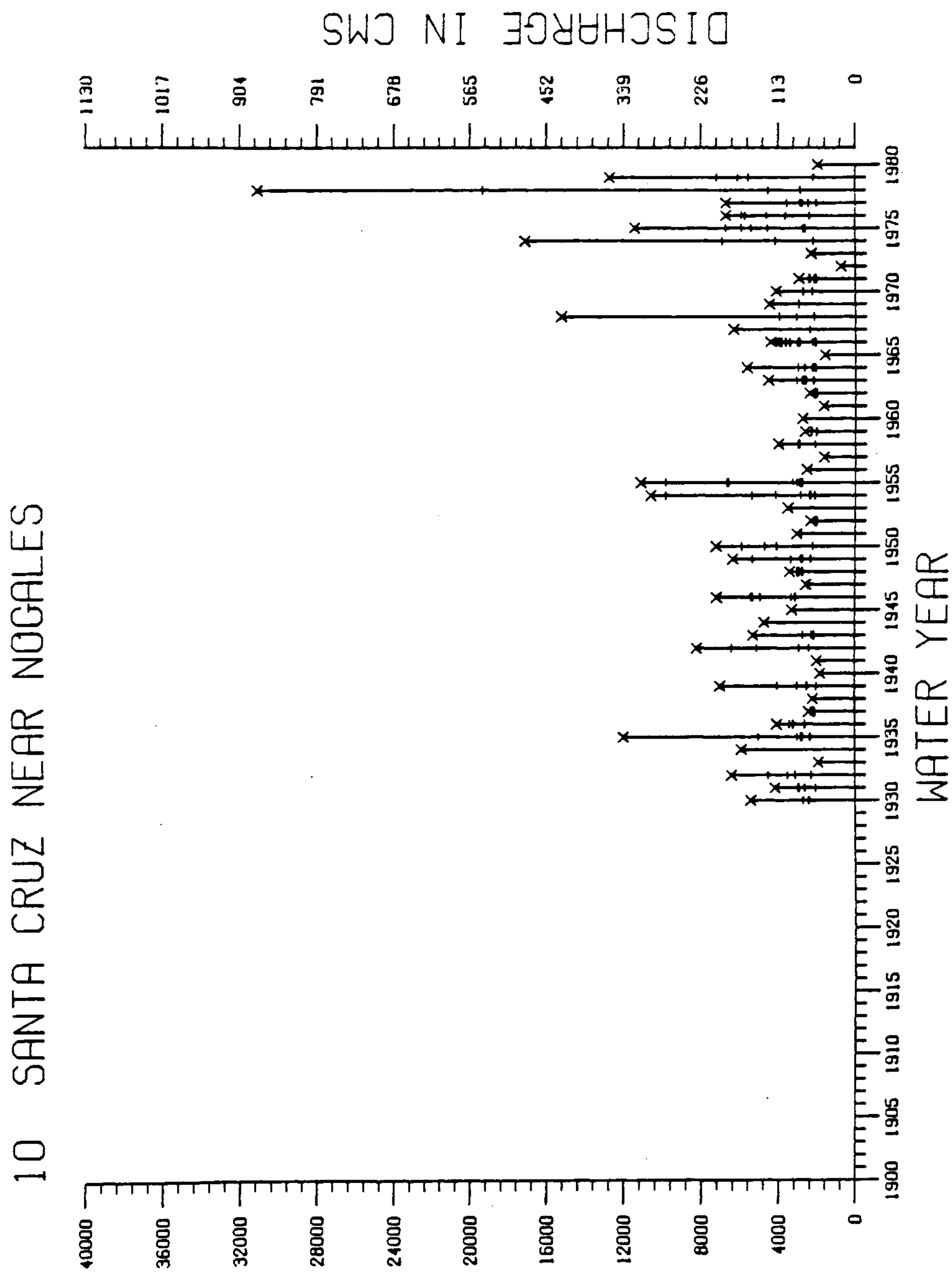

6 SAN PEDRO RIVER AT PALOMINAS
DISCHARGE IN CFS
30000
27000
24000
21000
18000
15000
12000
9000
6000
3000
0
DISCHARGE IN CMS
765
680
595
510
425
340
255
170
85
0
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR


7 SAN PEDRO RIVER AT CHARLESTON
98000 CFS
DISCHARGE IN CFS
60000
54000
48000
42000
36000
30000
24000
18000
12000
6000
0
DISCHARGE IN CMS
1530
1360
1190
1020
850
680
510
340
170
0
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

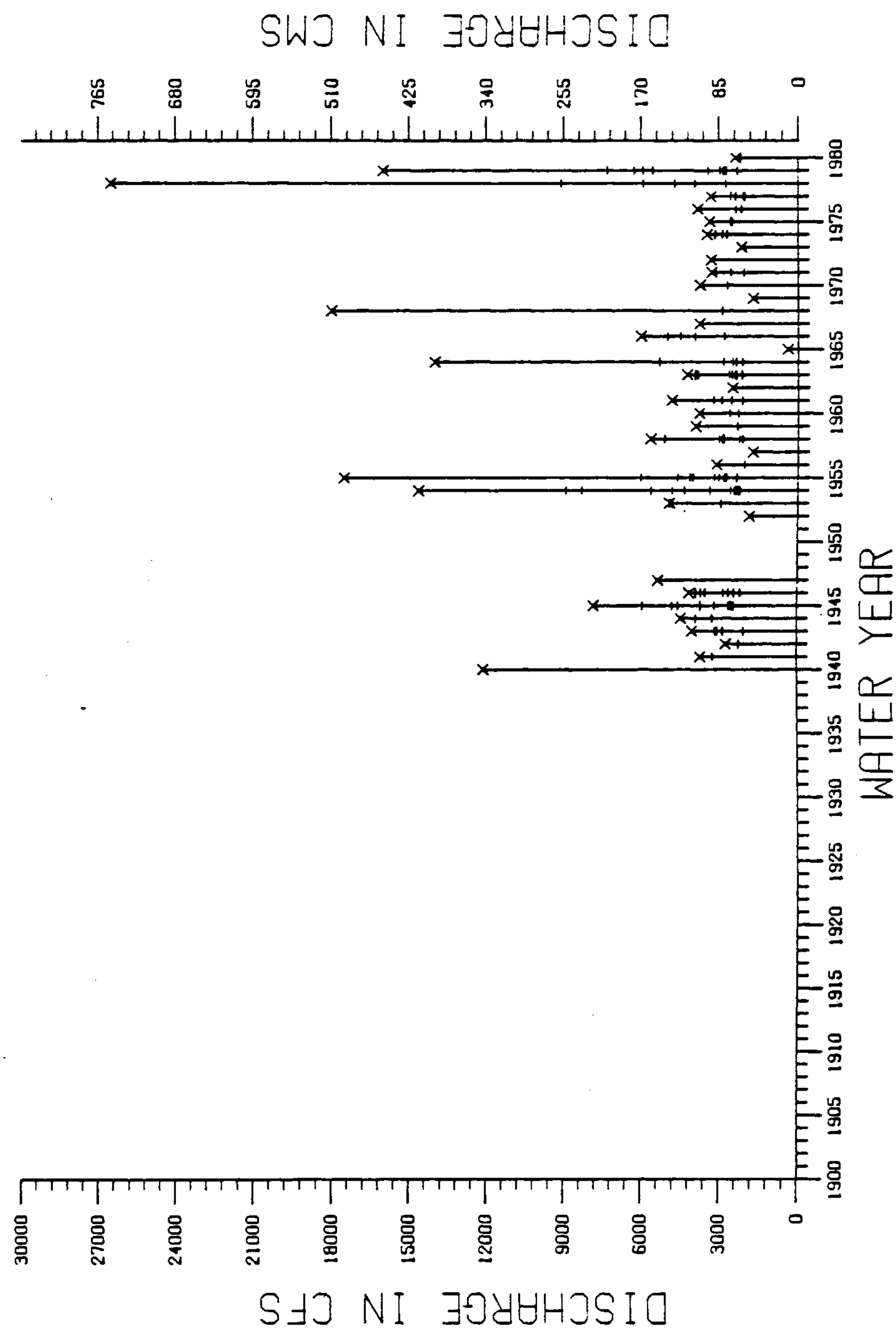

8 SAN PEDRO RIVER NEAR REDINGTON
90000 CFS
DISCHARGE IN CFS
0
6000
12000
18000
24000
30000
36000
42000
48000
54000
60000
DISCHARGE IN CMS
0
170
340
510
680
850
1020
1190
1360
1530
WATER YEAR
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

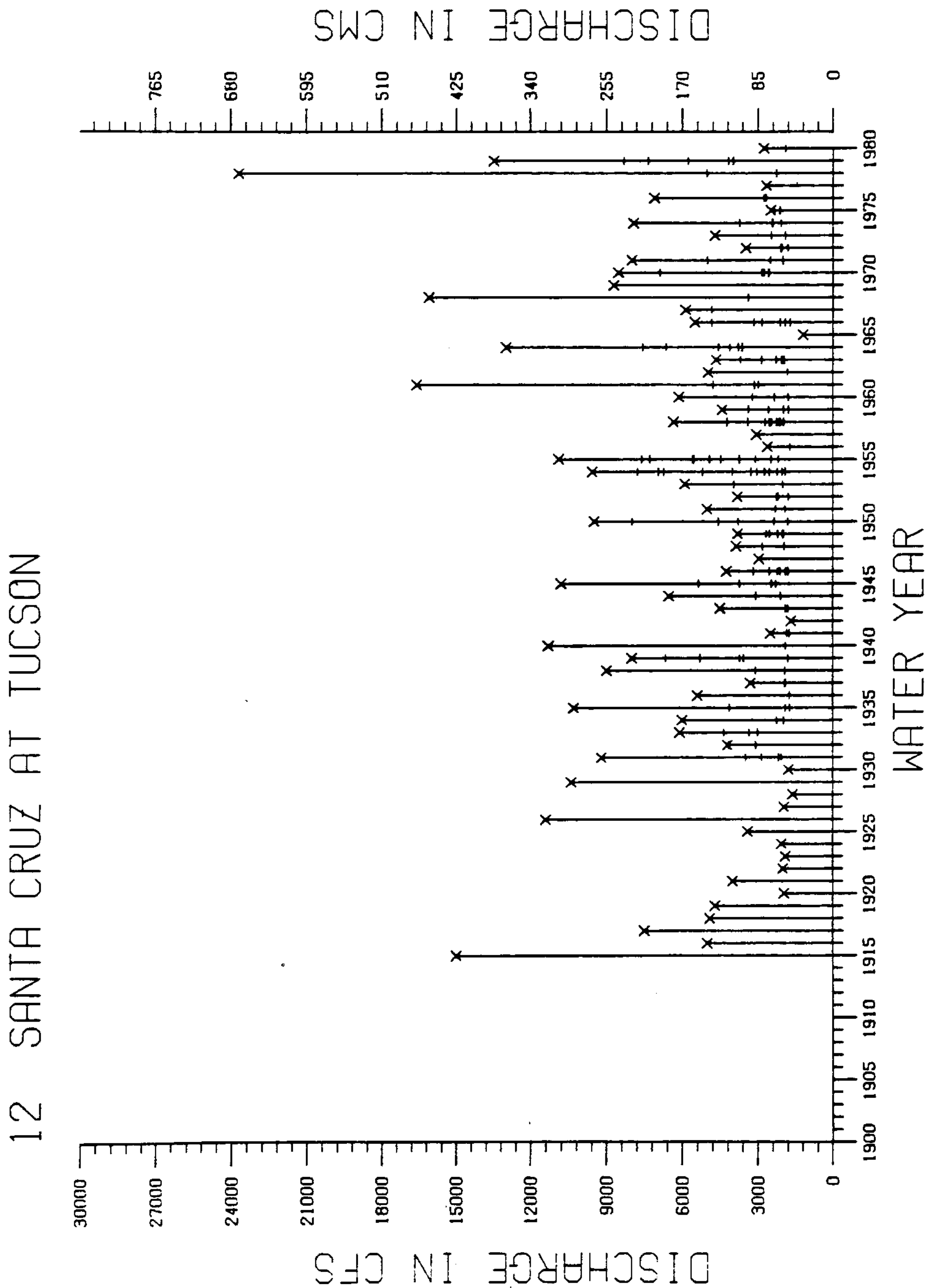
9 SANTA CRUZ NEAR LOCHIEL

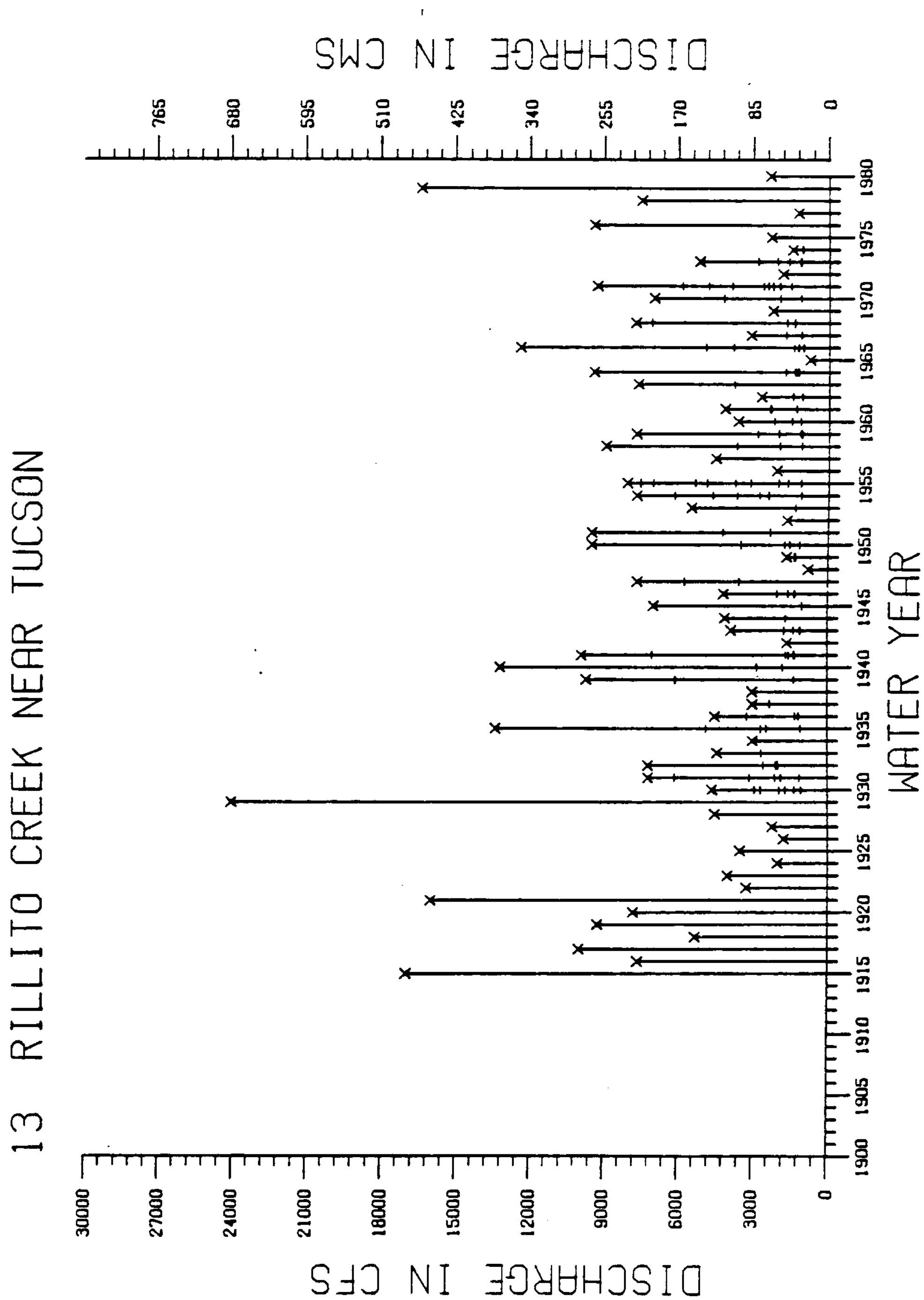


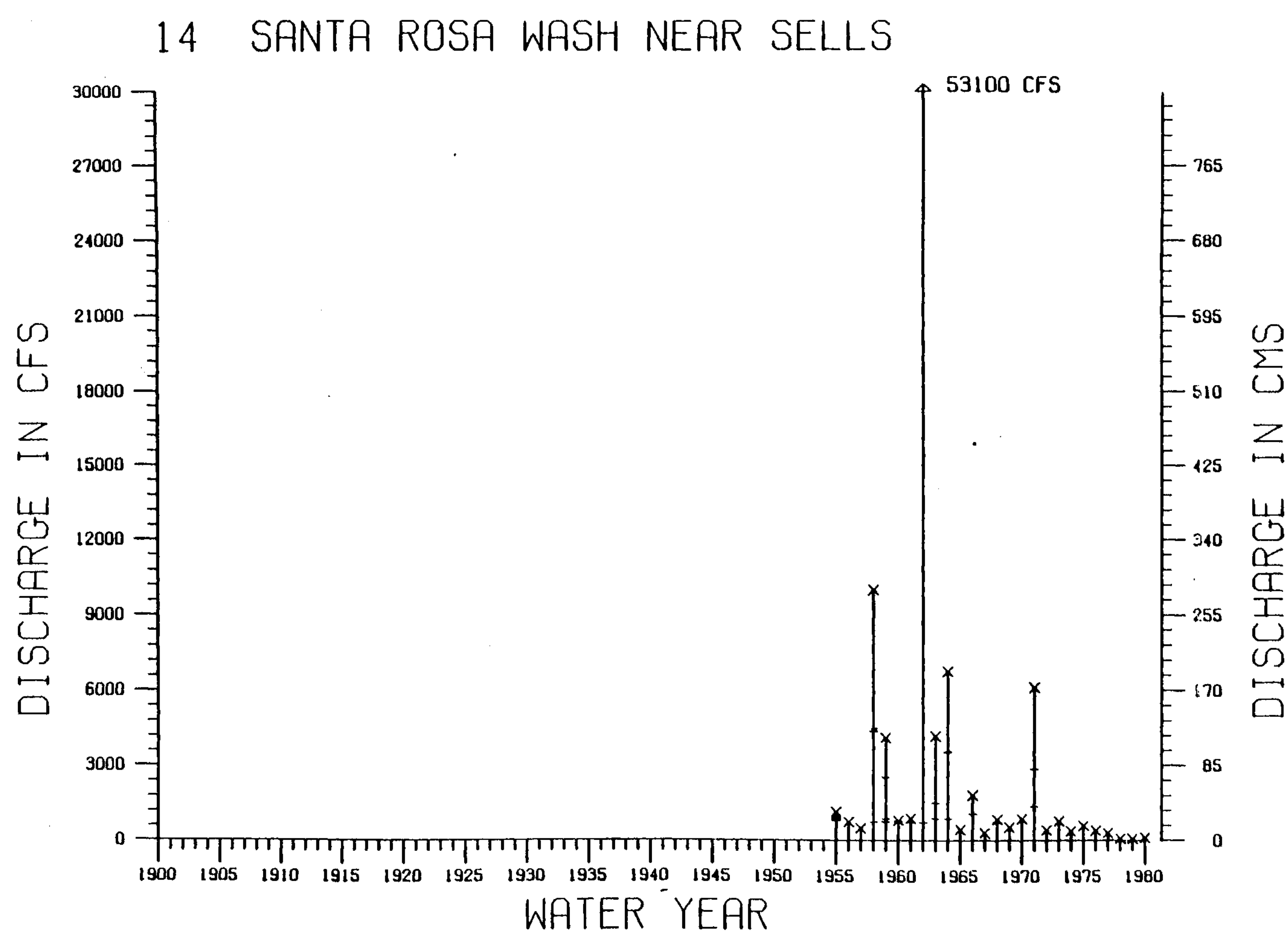

10 SANTA CRUZ NEAR NOGALES
DISCHARGE IN CMS
1130 1017 904 791 678 565 452 339 226 113 0
WATER YEAR
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980
DISCHARGE IN CFS
40000 36000 32000 28000 24000 20000 16000 12000 8000 4000 0

11 SANTA CRUZ AT CONTINENTAL

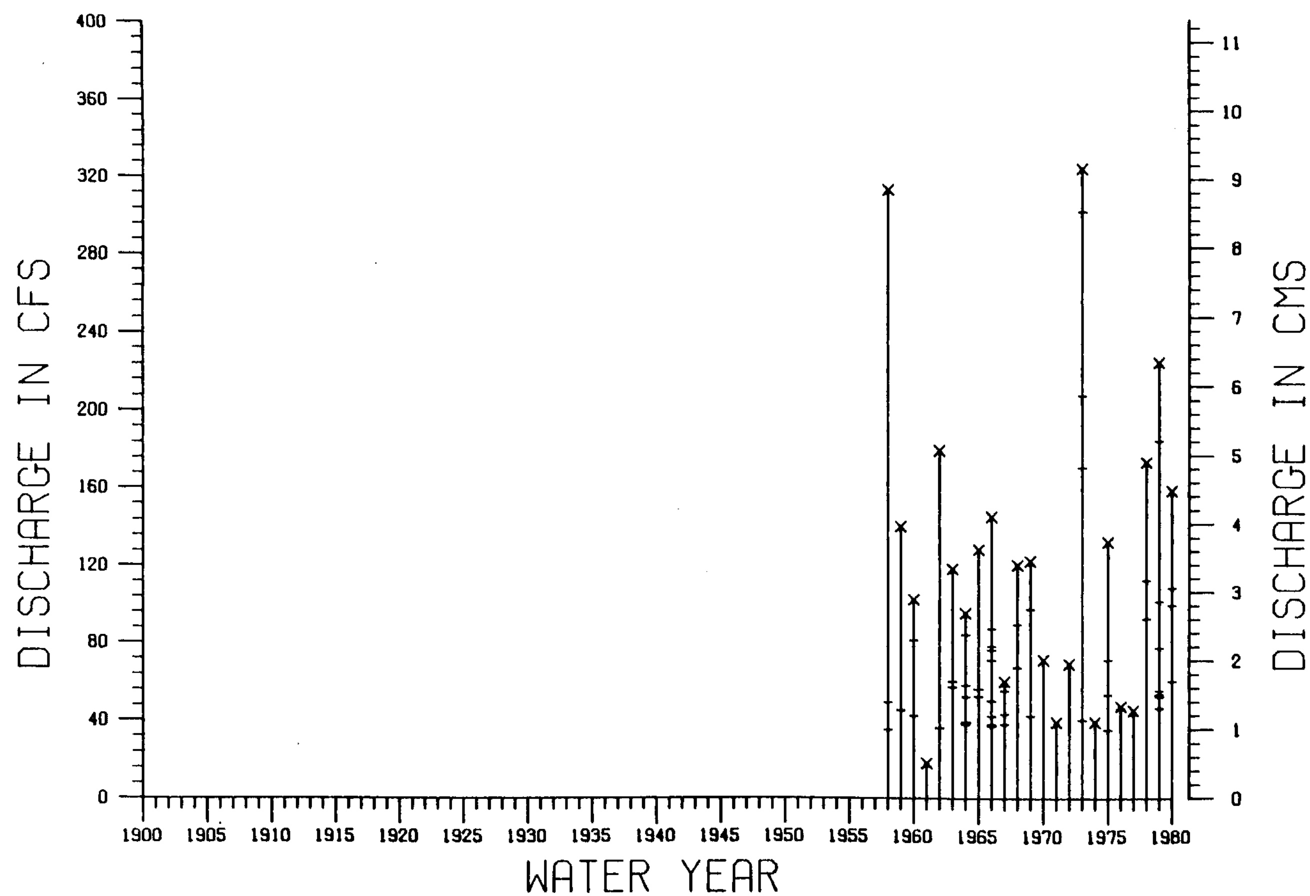


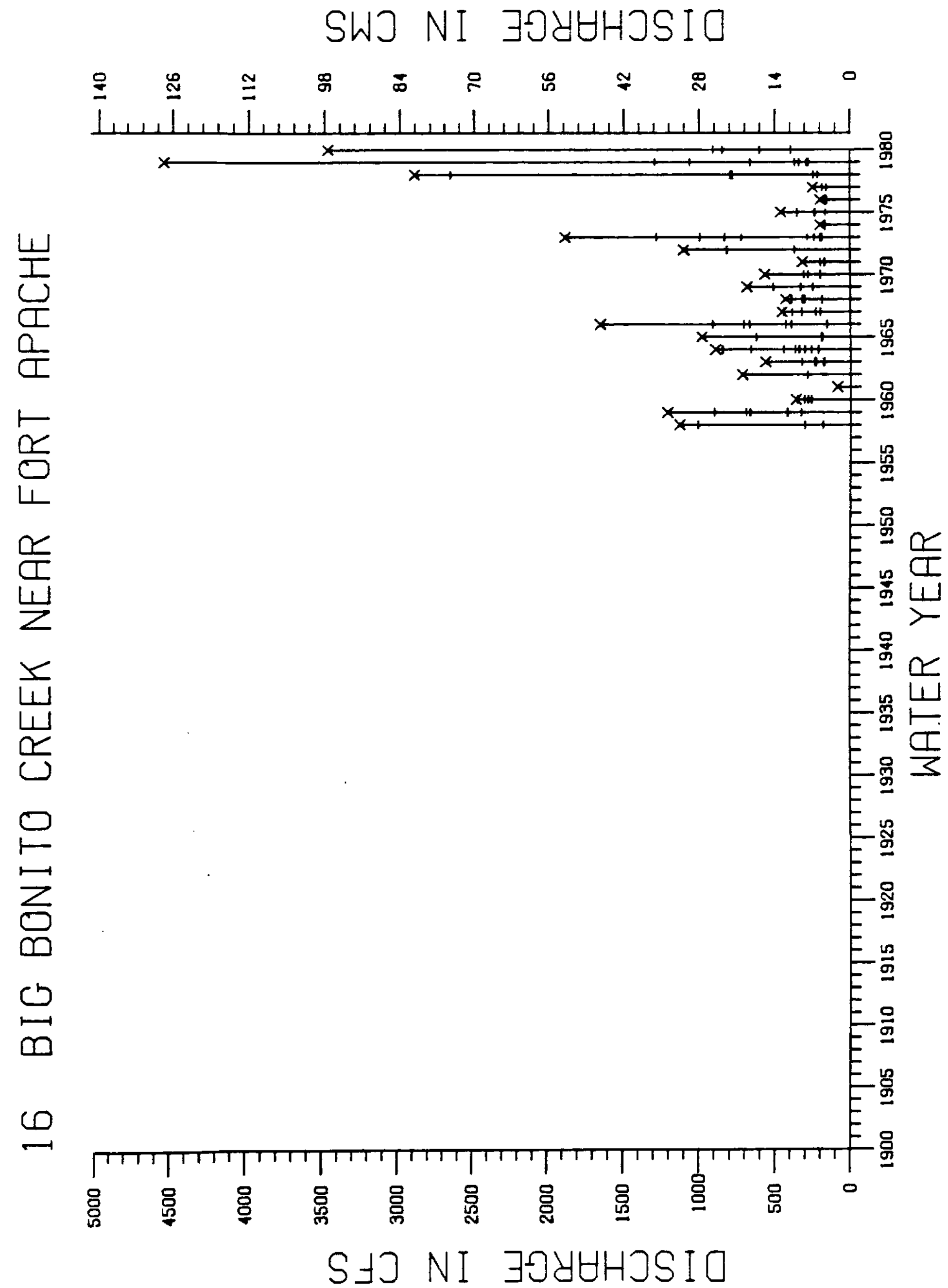

12 SANTA CRUZ AT TUCSON
DISCHARGE IN CFS
30000
27000
24000
21000
18000
15000
12000
9000
6000
3000
0
DISCHARGE IN CMS
765
680
595
510
425
340
255
170
85
0
WATER YEAR
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

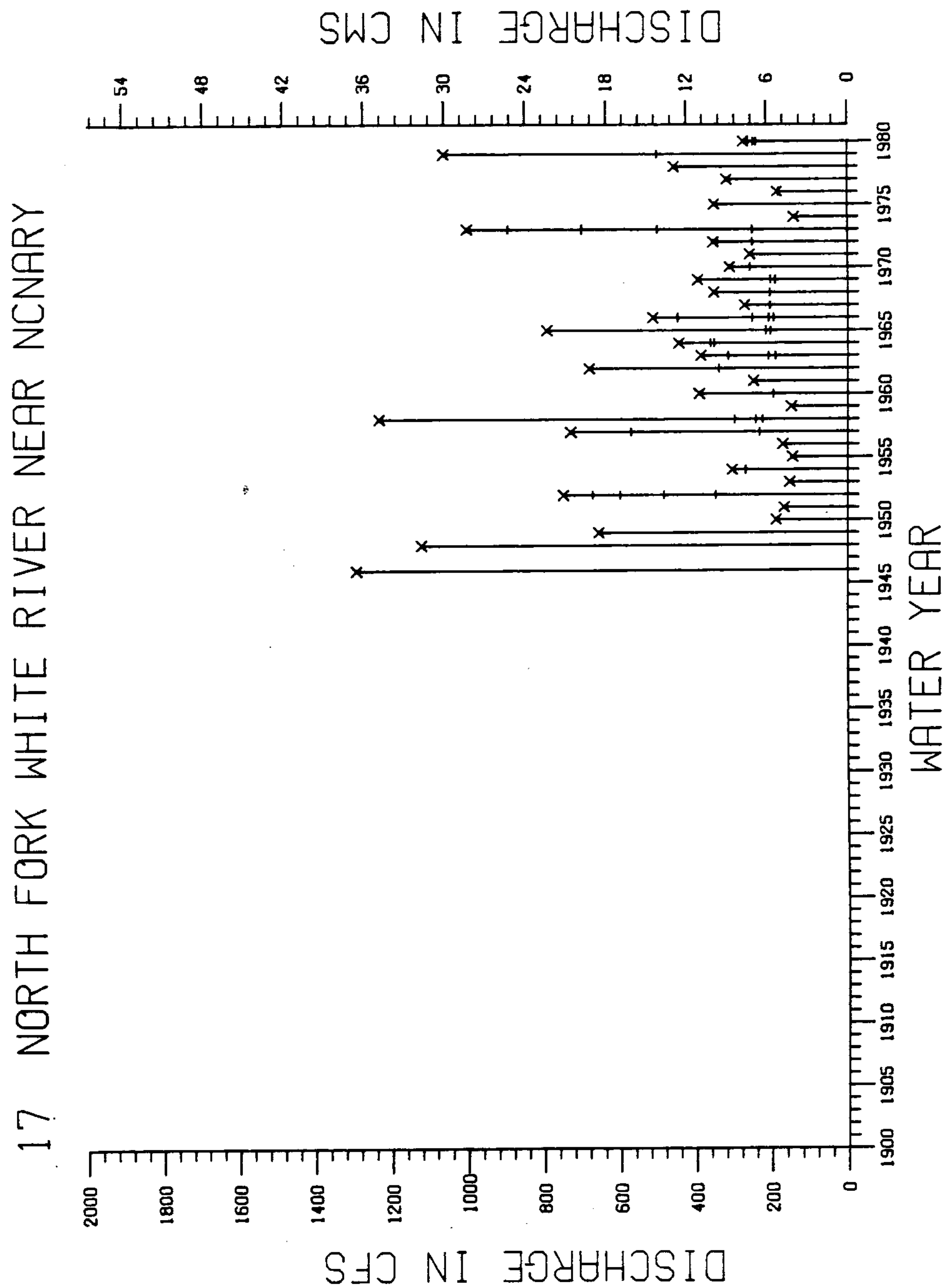

13 RILLITO CREEK NEAR TUCSON
DISCHARGE IN CMS
0 85 170 255 340 425 510 595 680 765
DISCHARGE IN CFS
0 3000 6000 9000 12000 15000 18000 21000 24000 27000 30000
WATER YEAR
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980

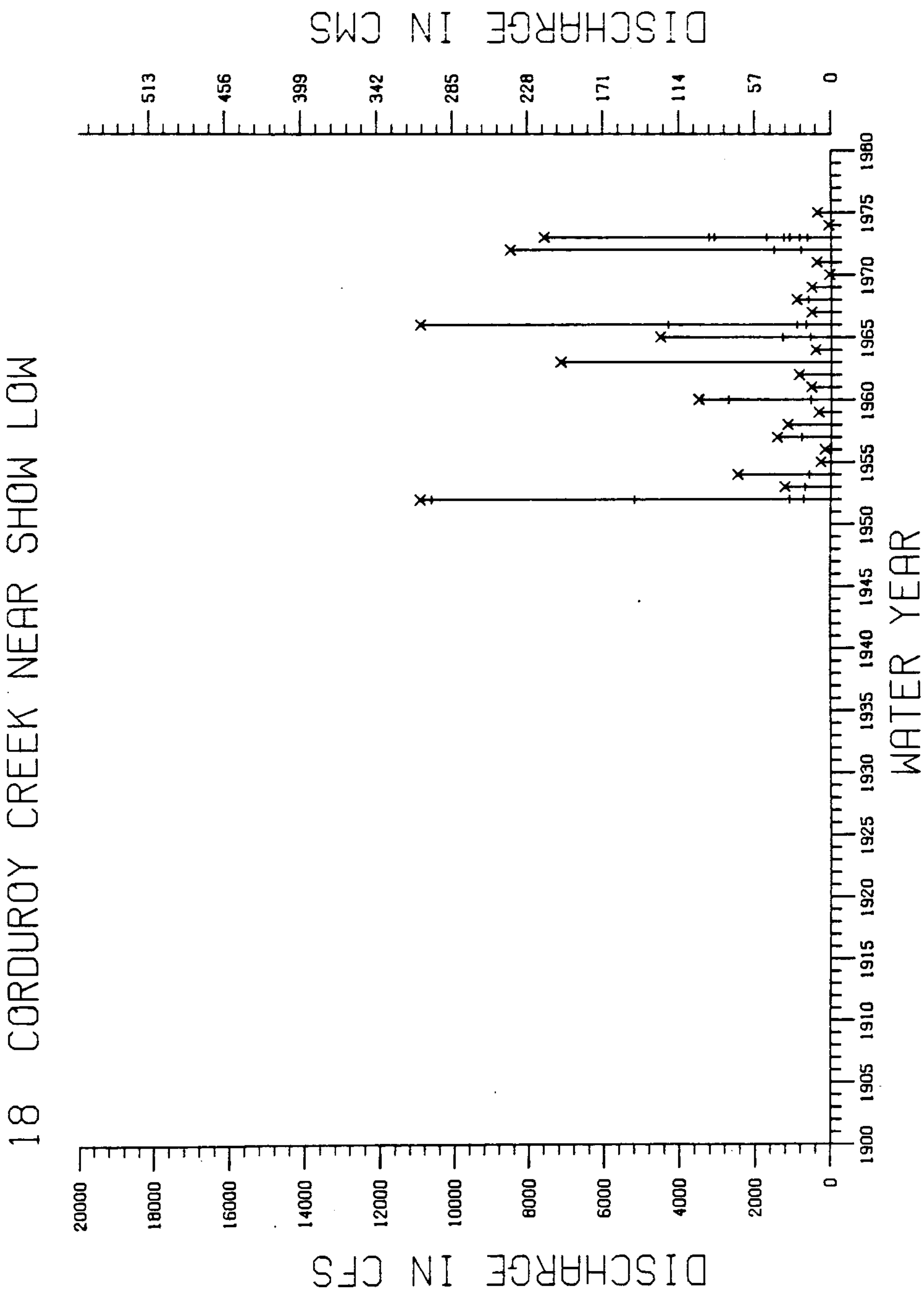

14 SANTA ROSA WASH NEAR SELLS
53100 CFS
DISCHARGE IN CFS
DISCHARGE IN CMS
WATER YEAR
30000
27000
24000
21000
18000
15000
12000
9000
6000
3000
0
765
680
595
510
425
340
255
170
85
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

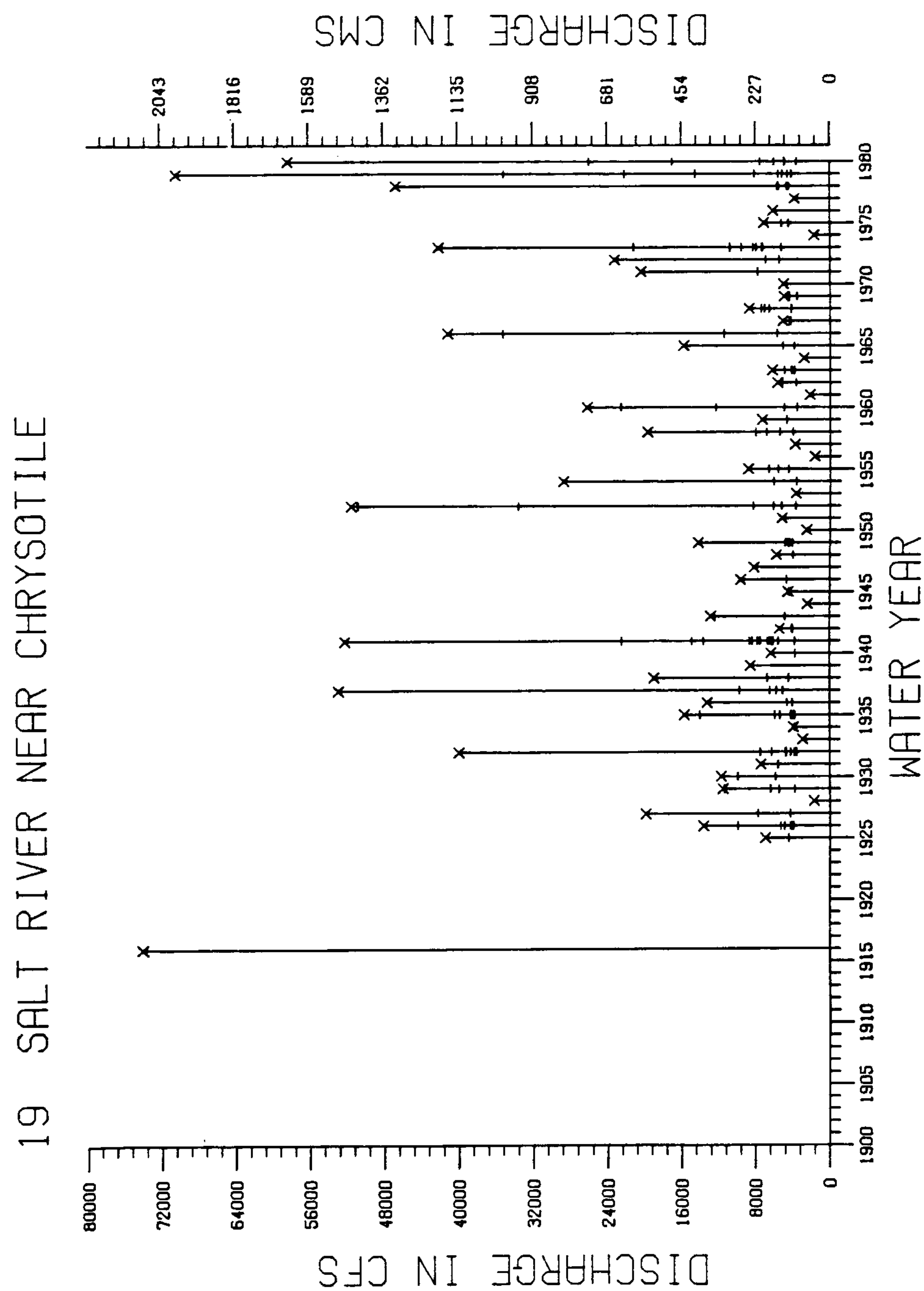
15 PACHETA CREEK NEAR MAVERICK

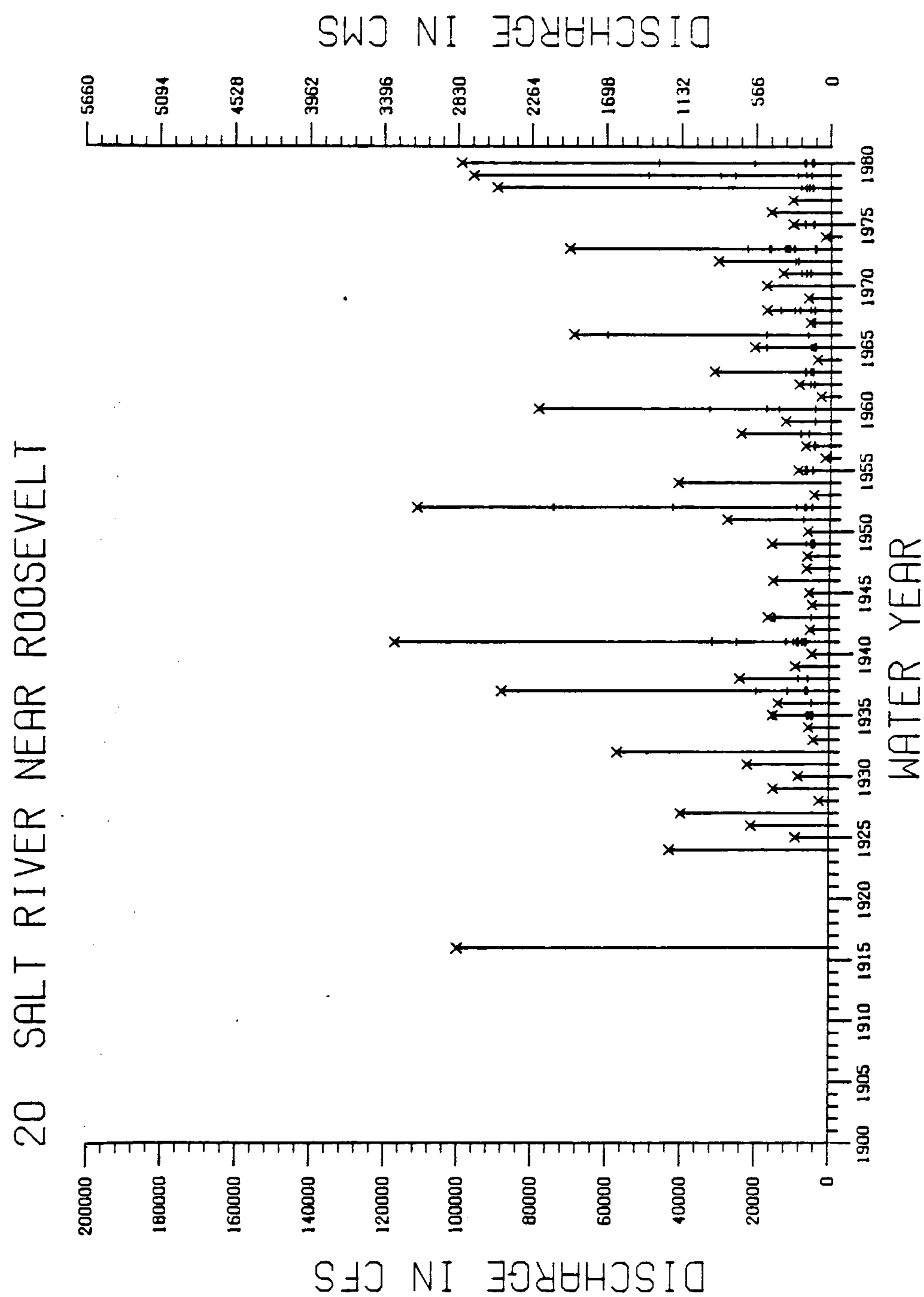


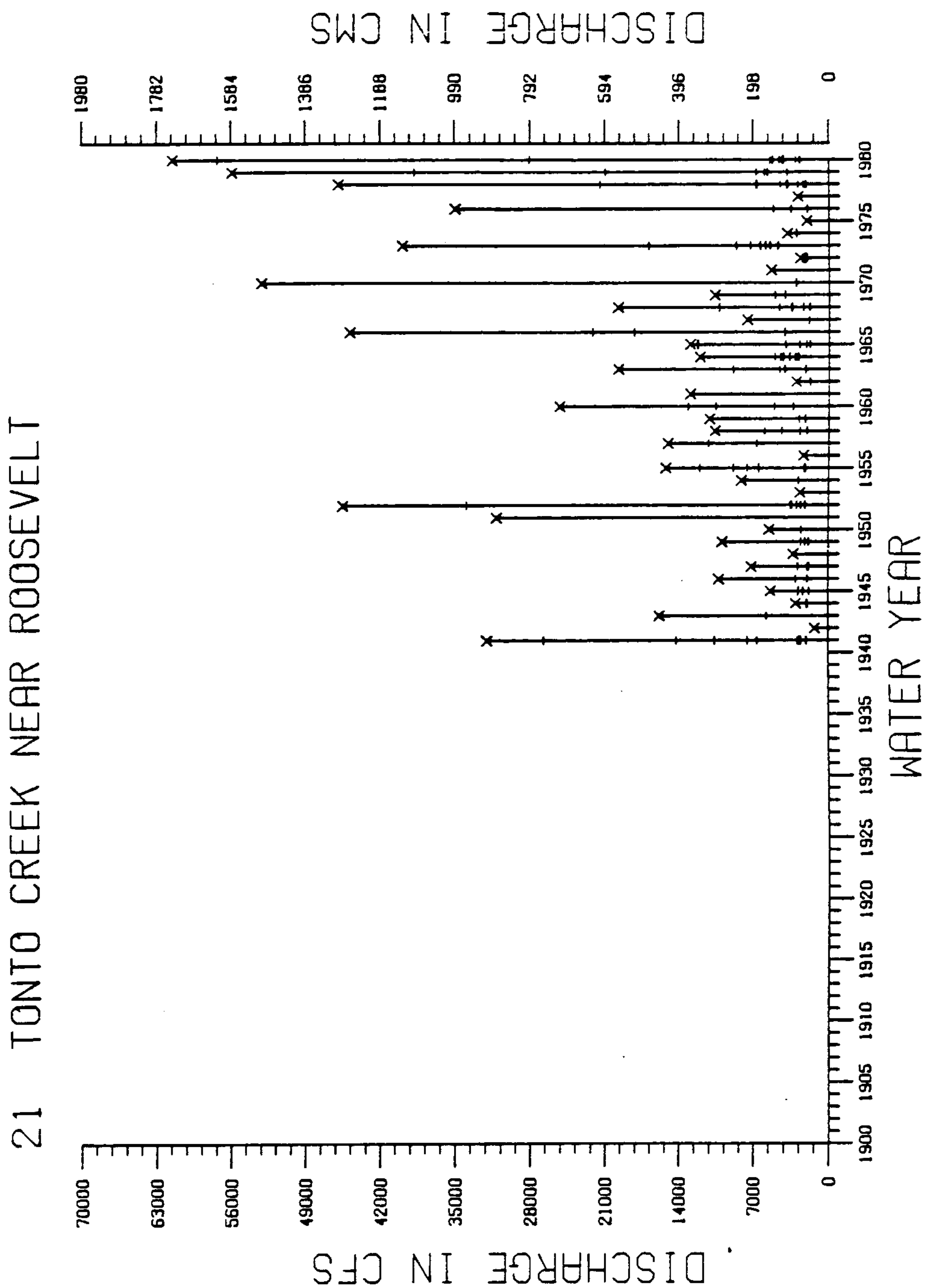

16 BIG BONITO CREEK NEAR FORT APACHE
DISCHARGE IN CMS
140 126 112 98 84 70 56 42 28 14 0
DISCHARGE IN CFS
5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
WATER YEAR
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980

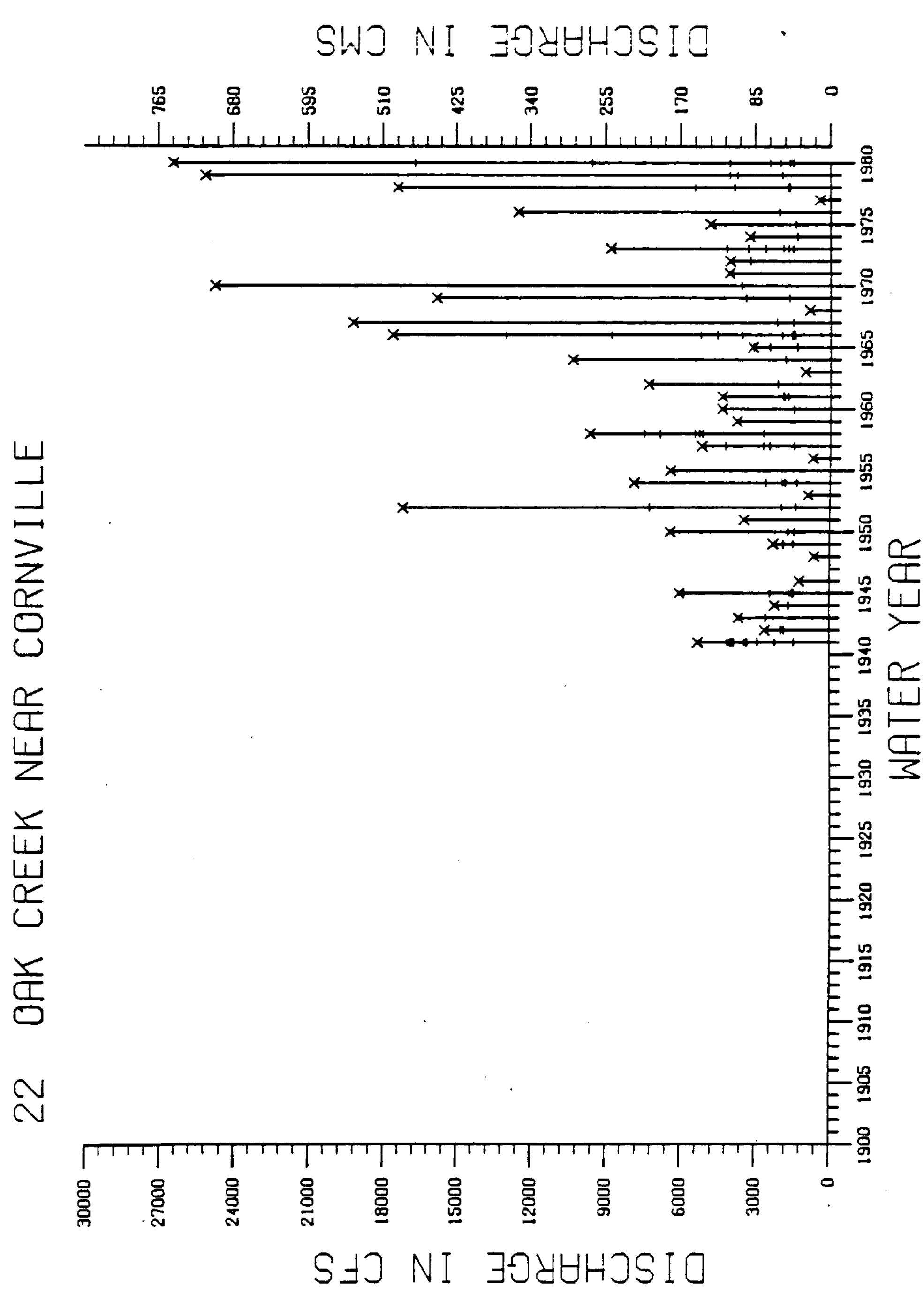

17 NORTH FORK WHITE RIVER NEAR NCNARY
DISCHARGE IN CMS
0 6 12 18 24 30 36 42 48 54
DISCHARGE IN CFS
0 200 400 600 800 1000 1200 1400 1600 1800 2000
WATER YEAR
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980

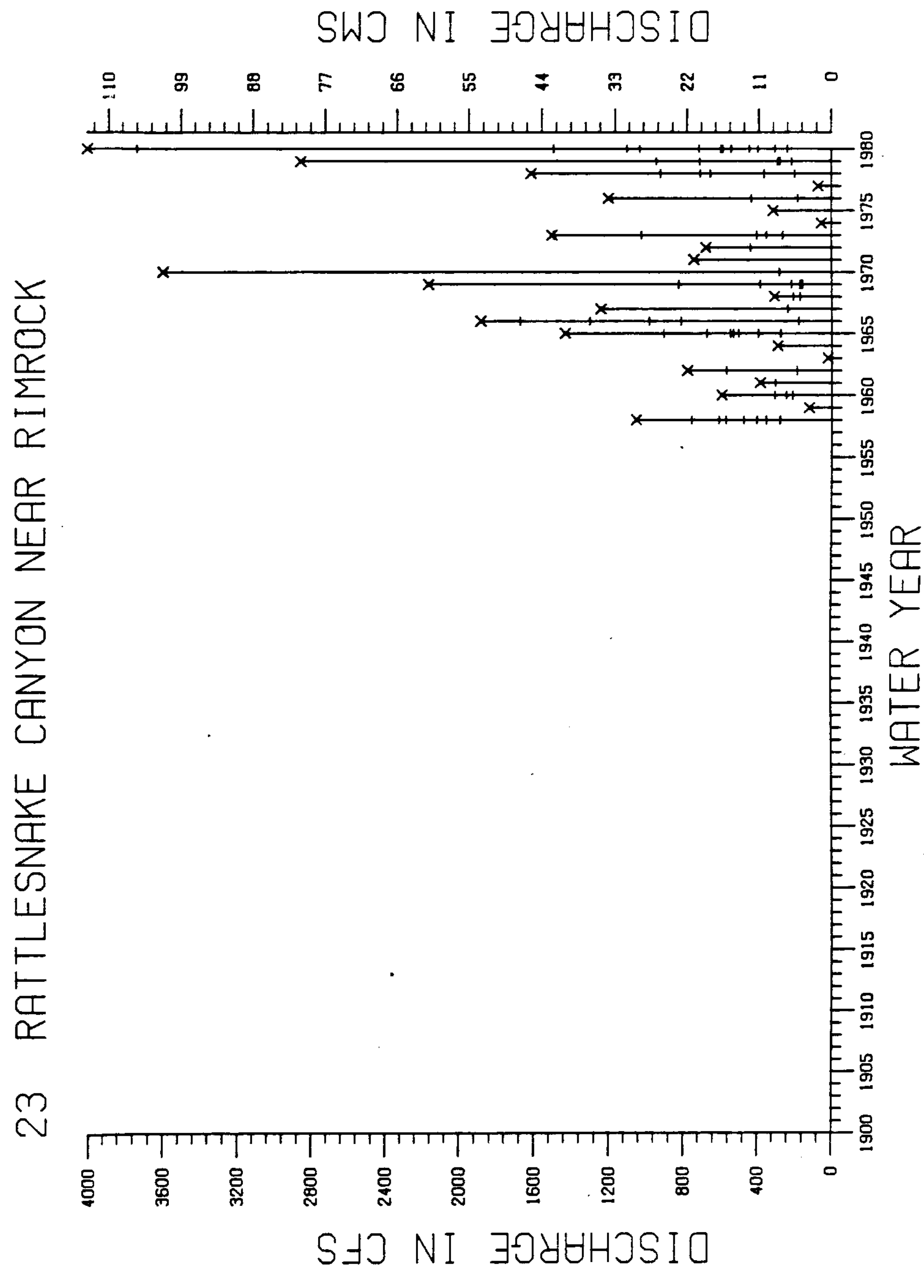

18 CORDUROY CREEK NEAR SHOW LOW
DISCHARGE IN CFS
DISCHARGE IN CMS
WATER YEAR
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
0
57
114
171
228
285
342
399
456
513
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

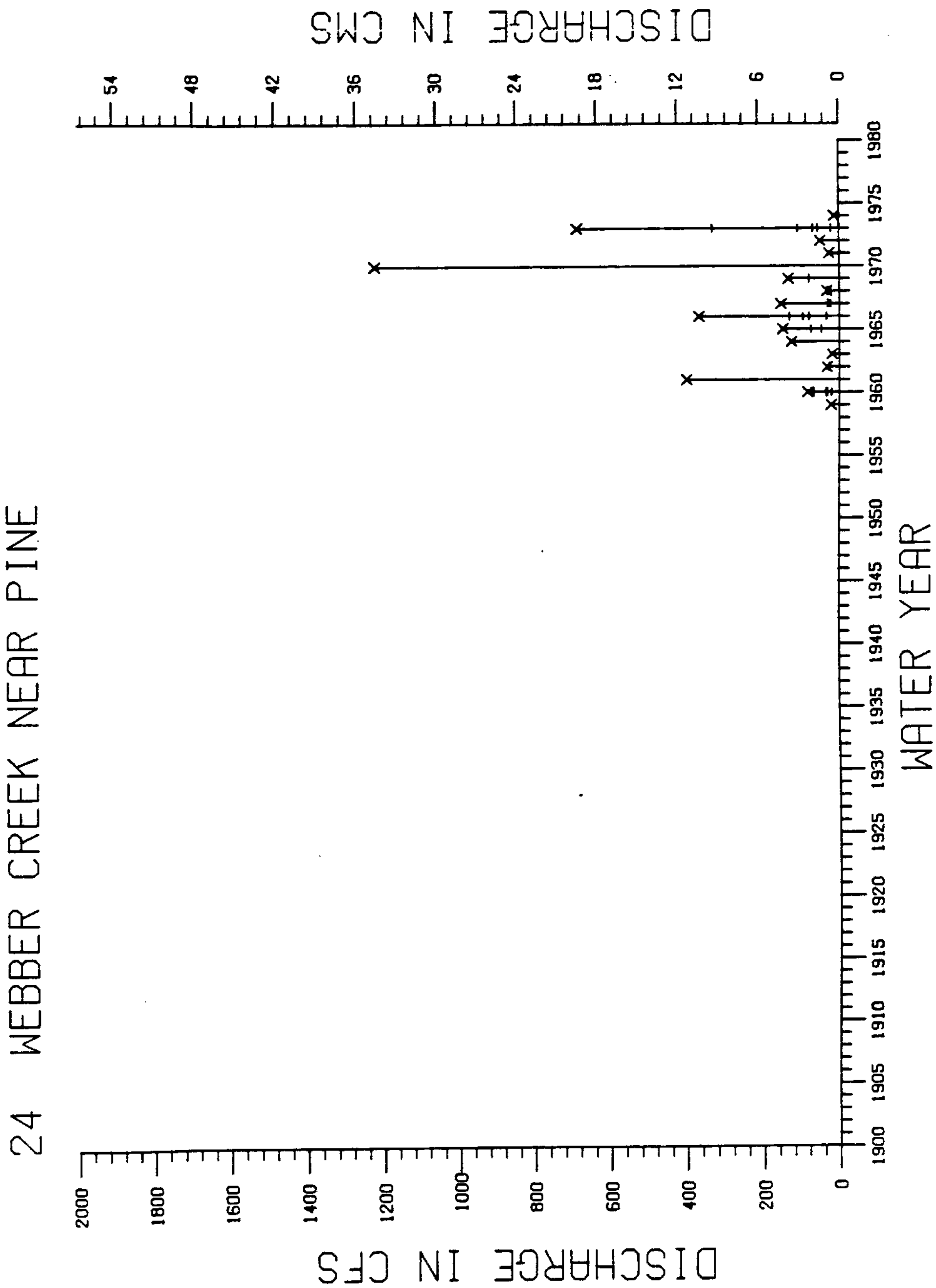

19 SALT RIVER NEAR CHRYSOTILE
DISCHARGE IN CMS
2043
1816
1589
1362
1135
908
681
454
227
0
DISCHARGE IN CFS
80000
72000
64000
56000
48000
40000
32000
24000
16000
8000
0
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

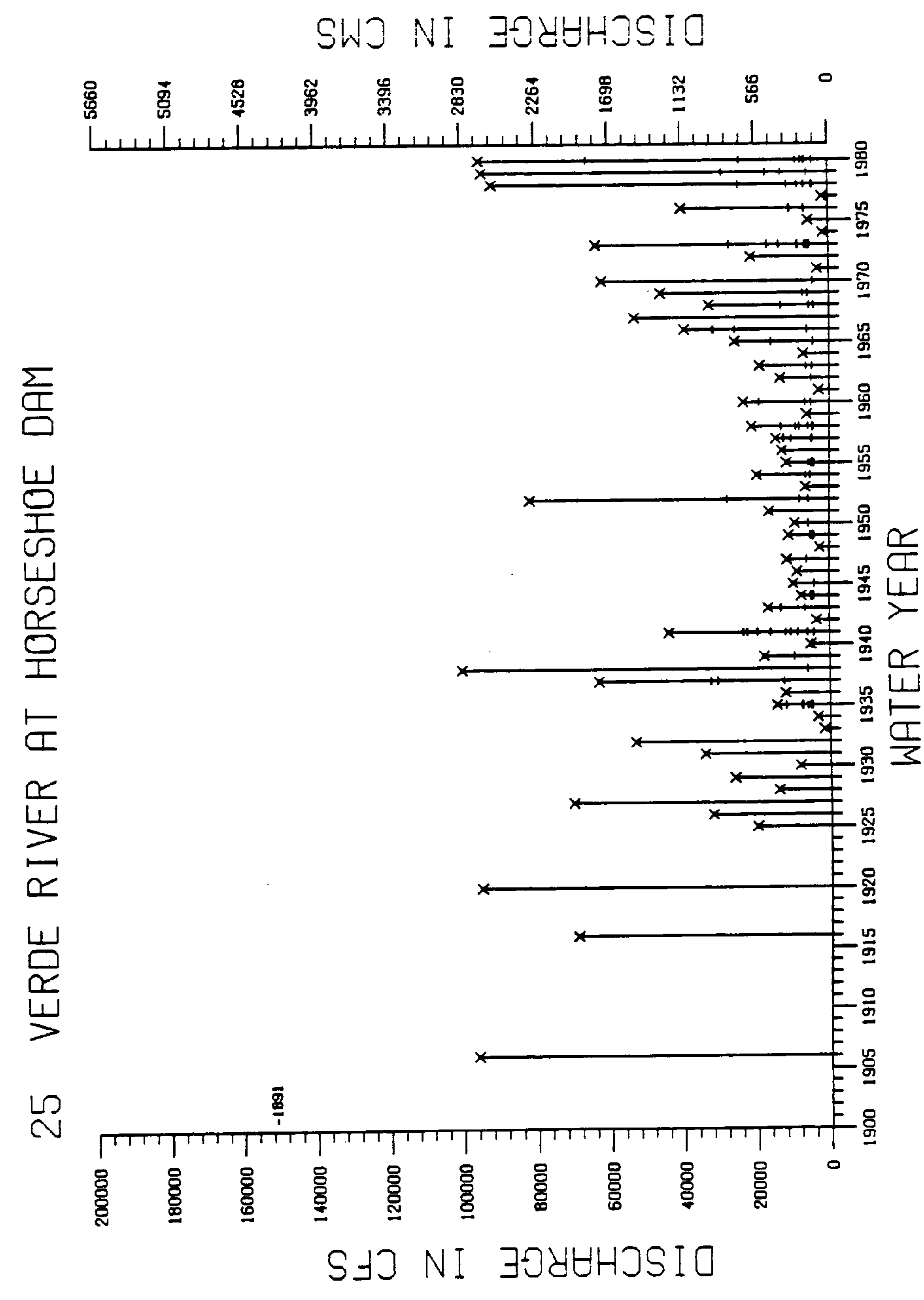

20 SALT RIVER NEAR ROOSEVELT
DISCHARGE IN CMS
5660
5094
4528
3962
3396
2830
2264
1698
1132
566
0
DISCHARGE IN CFS
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

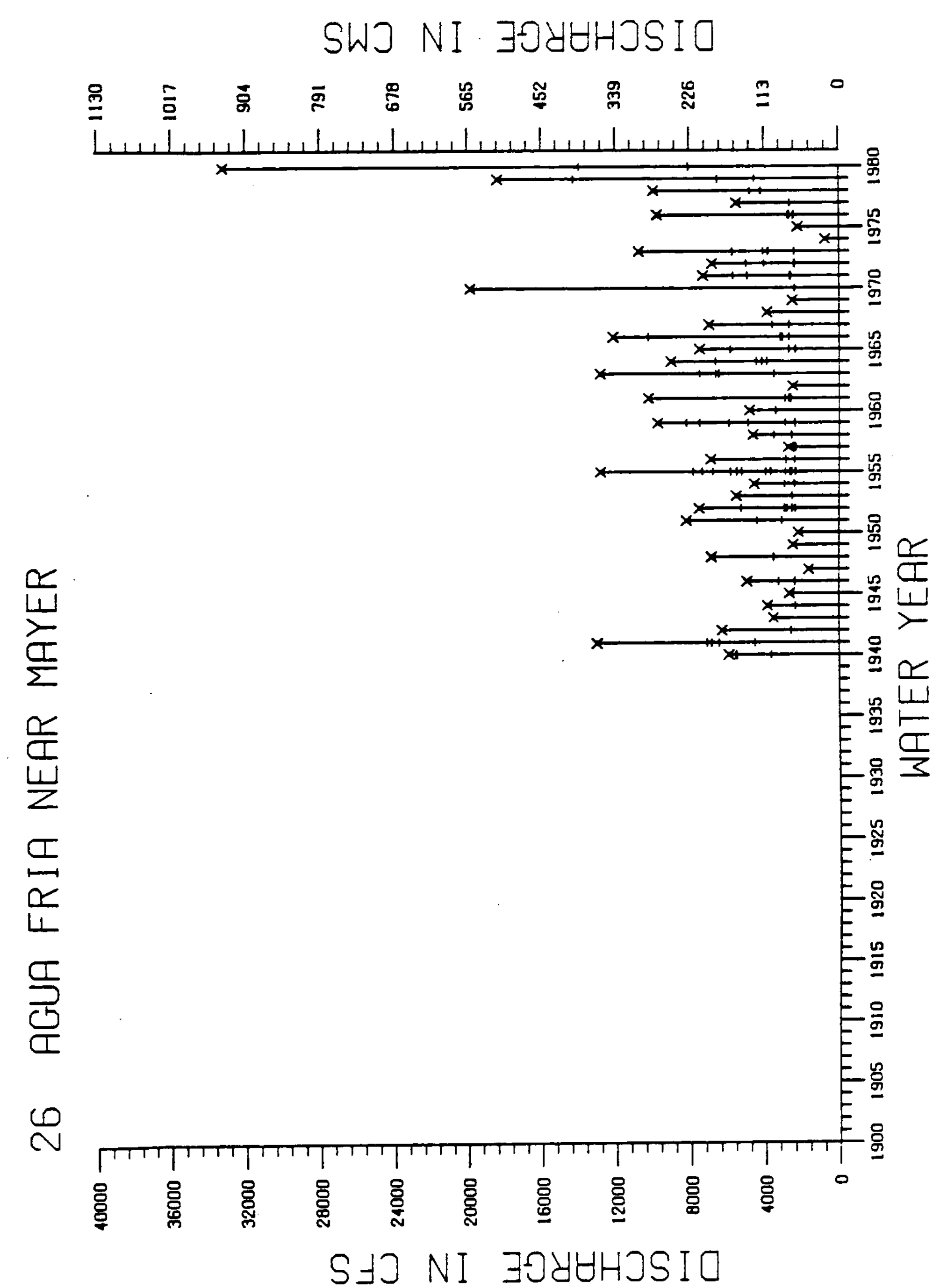

21 TONTO CREEK NEAR ROOSEVELT
DISCHARGE IN CFS
DISCHARGE IN CMS
WATER YEAR
0
7000
14000
21000
28000
35000
42000
49000
56000
63000
70000
198
396
594
792
990
1188
1386
1584
1782
1980
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

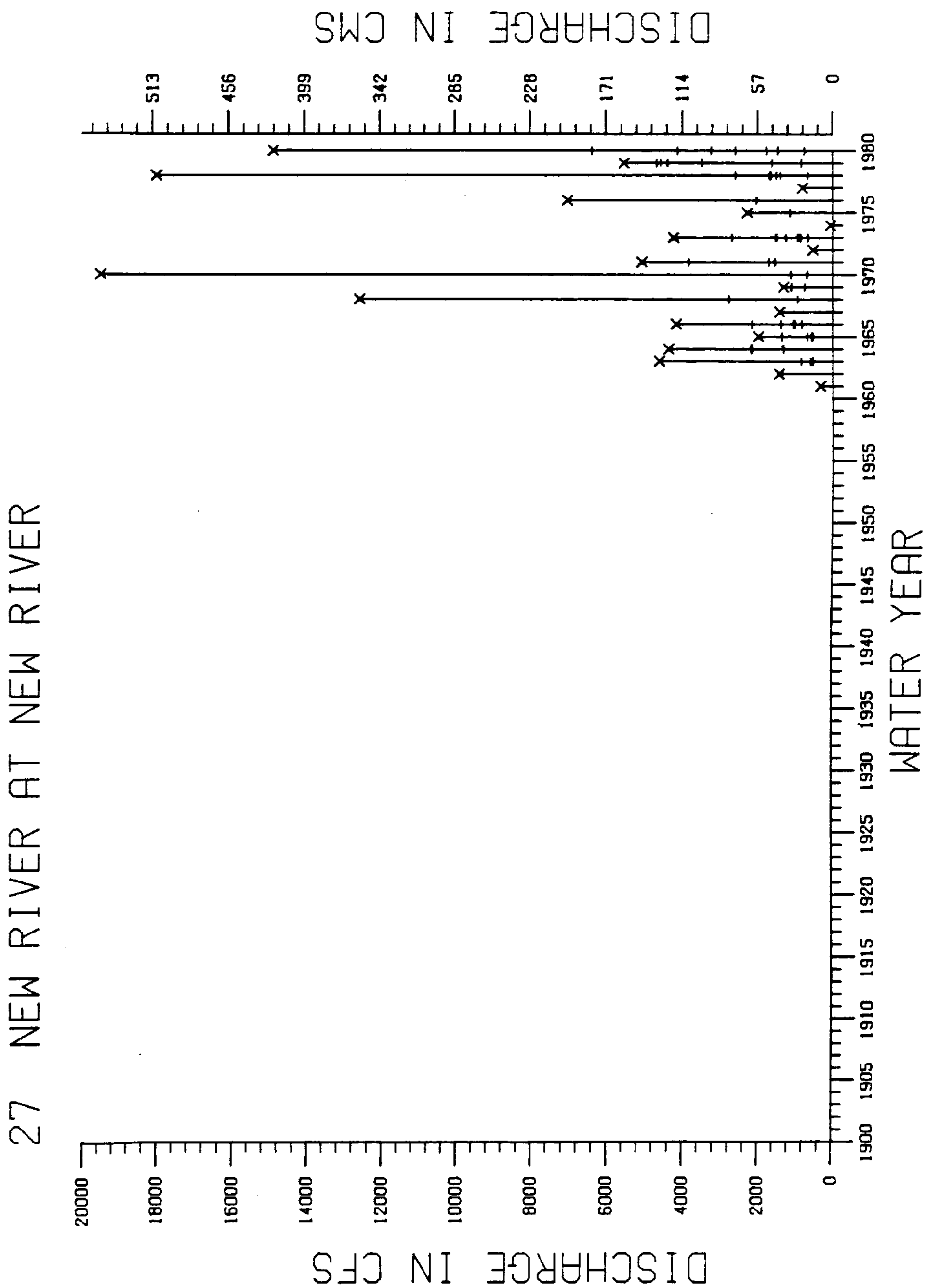

22 OAK CREEK NEAR CORNVILLE
DISCHARGE IN CMS
0 85 170 255 340 425 510 595 680 765
DISCHARGE IN CFS
0 3000 6000 9000 12000 15000 18000 21000 24000 27000 30000
WATER YEAR
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980

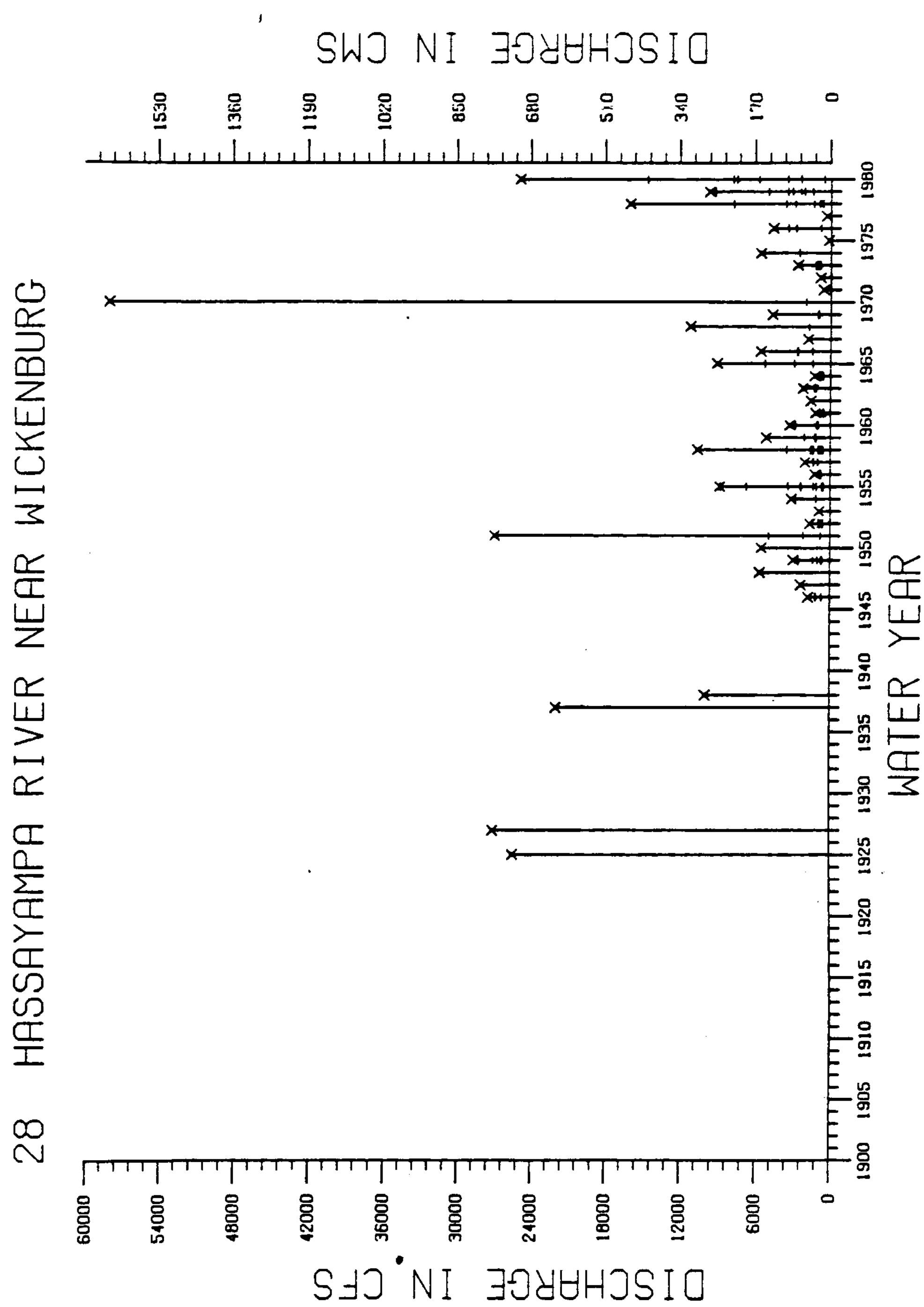

23 RATTLESNAKE CANYON NEAR RIMROCK
DISCHARGE IN CMS
110
99
88
77
66
55
44
33
22
11
0
DISCHARGE IN CFS
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
WATER YEAR
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980


24 WEBBER CREEK NEAR PINE
DISCHARGE IN CFS
0
200
400
600
800
1000
1200
1400
1600
1800
2000
DISCHARGE IN CMS
0
6
12
18
24
30
36
42
48
54
WATER YEAR
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

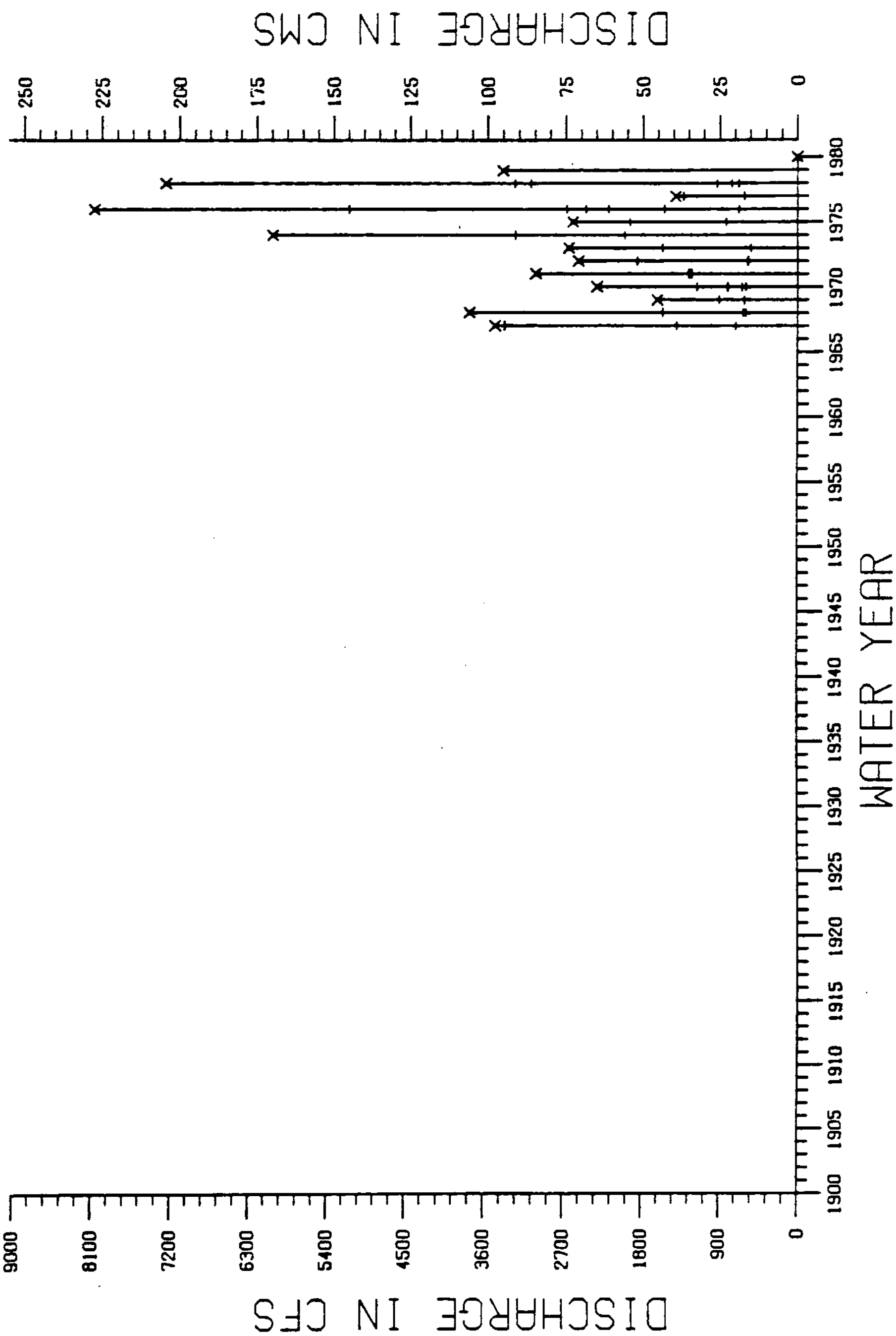

25 VERDE RIVER AT HORSESHOE DAM
DISCHARGE IN CMS
5660
5094
4528
3962
3396
2830
2264
1698
1132
566
0
DISCHARGE IN CFS
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
-1891
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

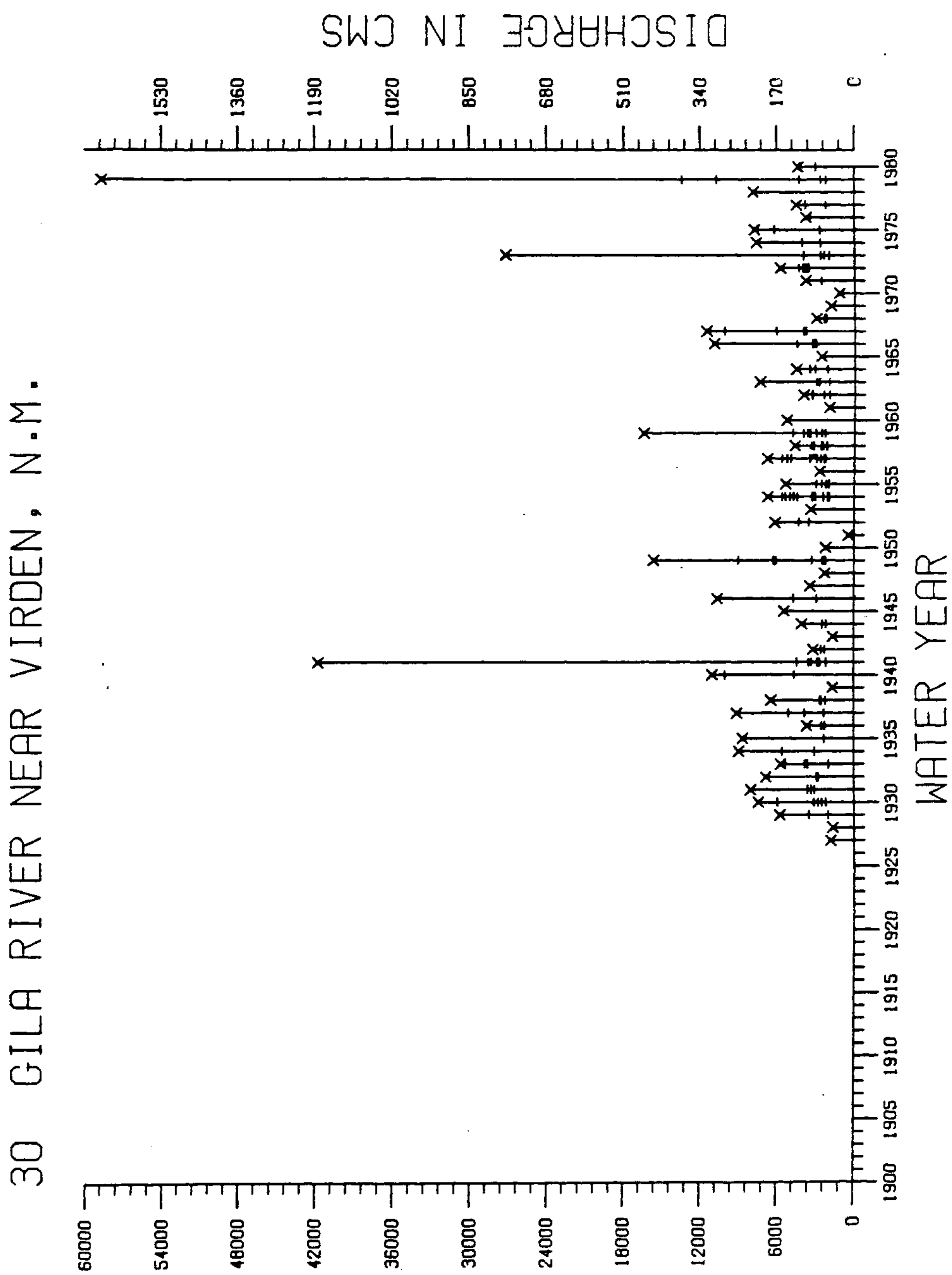

26 AGUA FRIA NEAR MAYER
DISCHARGE IN CMS
1130
1017
904
791
678
565
452
339
226
113
0
DISCHARGE IN CFS
40000
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR


27 NEW RIVER AT NEW RIVER
DISCHARGE IN CMS
513
456
399
342
285
228
171
114
57
0
DISCHARGE IN CFS
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
WATER YEAR
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980


28 HASSAYAMPA RIVER NEAR WICKENBURG
DISCHARGE IN CMS
1530
1360
1190
1020
850
680
510
340
170
0
DISCHARGE IN CFS
60000
54000
48000
42000
36000
30000
24000
18000
12000
6000
0
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

29 RIO CORNEZ NEAR AJO

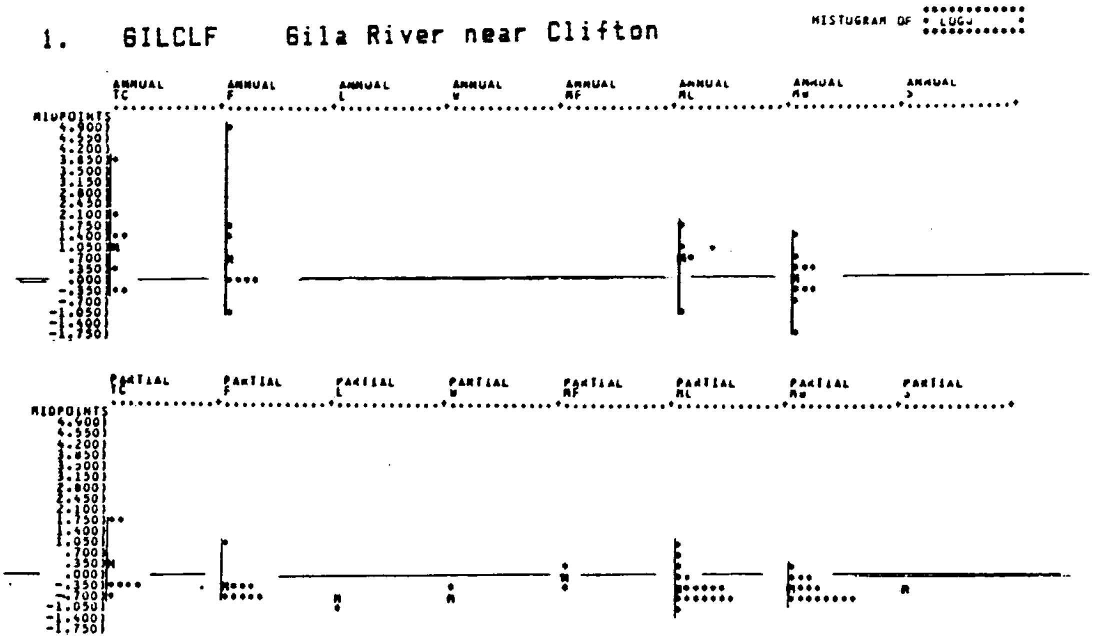



30 GILA RIVER NEAR VIRDEN, N.M.
DISCHARGE IN CMS
DISCHARGE IN CFS
WATER YEAR
0 6000 12000 18000 24000 30000 36000 42000 48000 54000 60000
0 170 340 510 680 850 1020 1190 1360 1530
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980

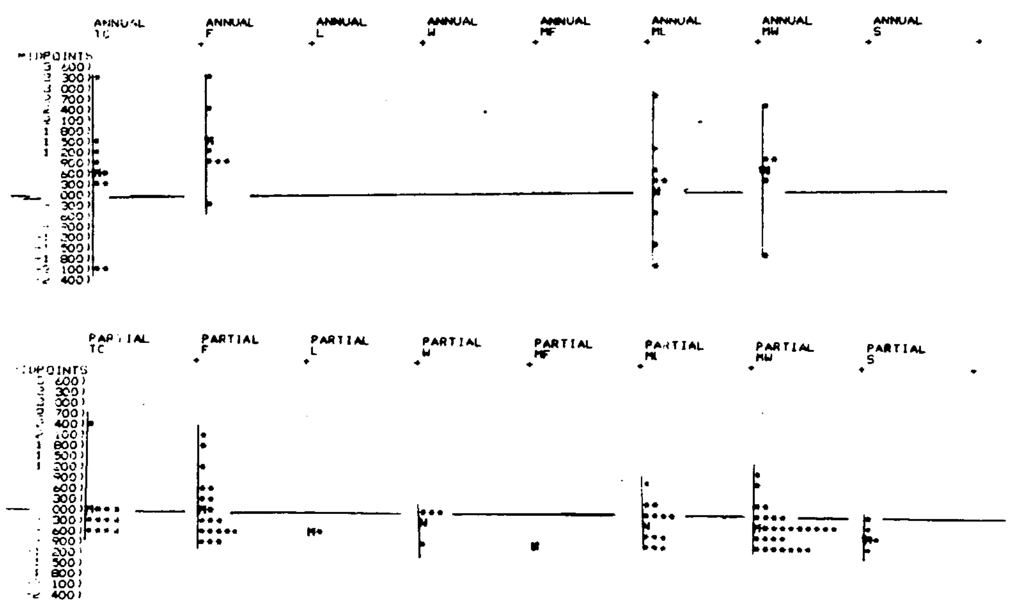
APPENDIX E

ADDITIONAL HISTOGRAMS OF GROUPED FLOOD DATA

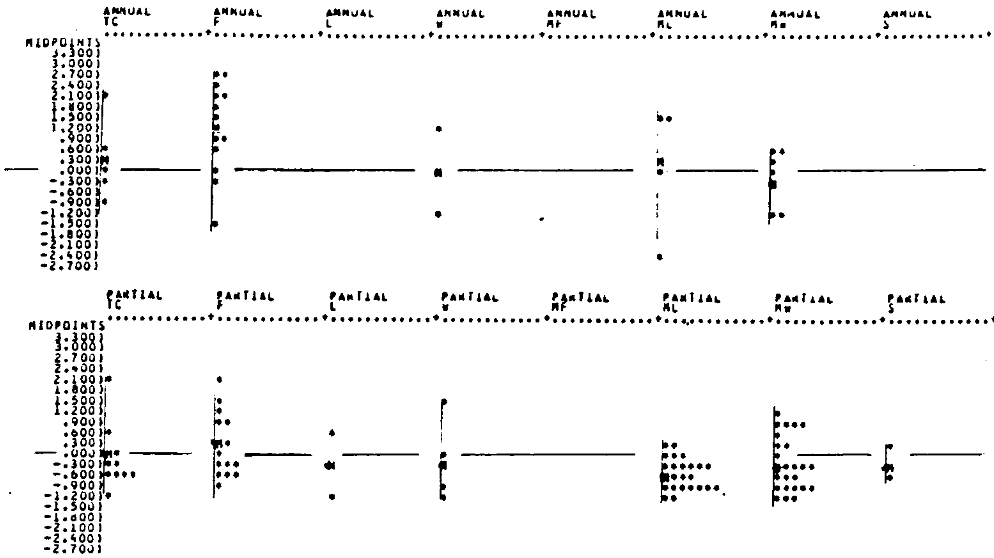
1. GILCLF Gila River near Clifton



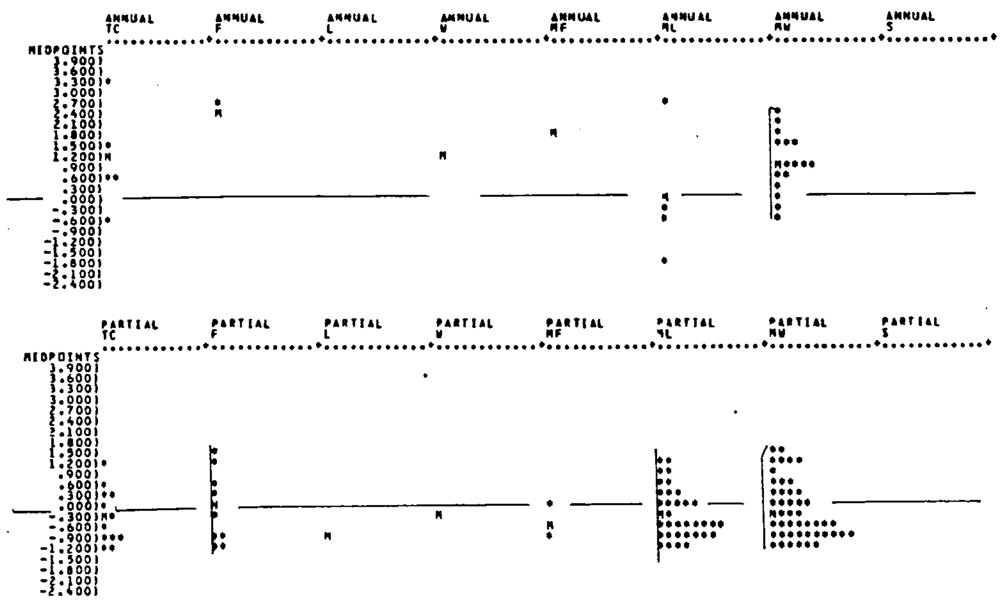
2. SFRCLF San Francisco River at Clifton



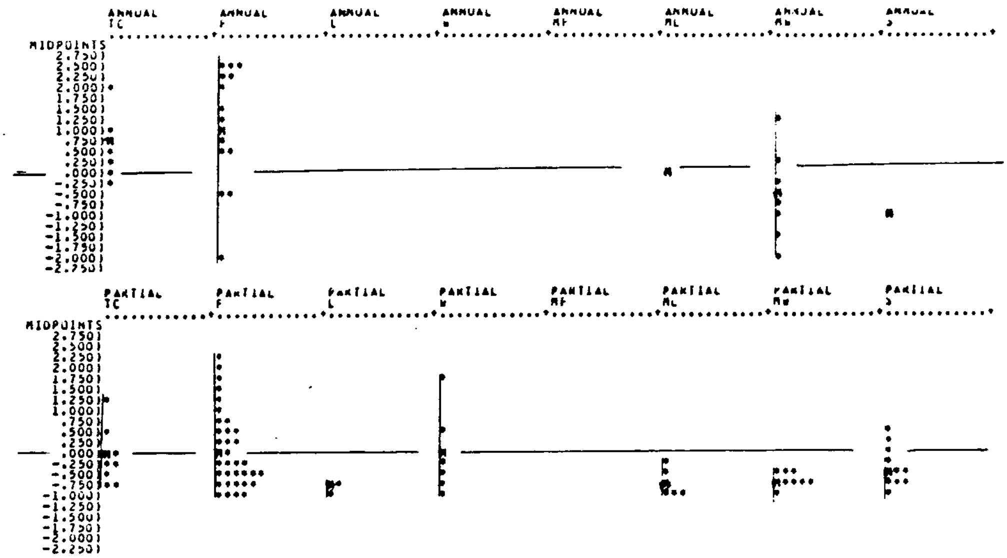
5. SCLPER San Carlos River near Peridot



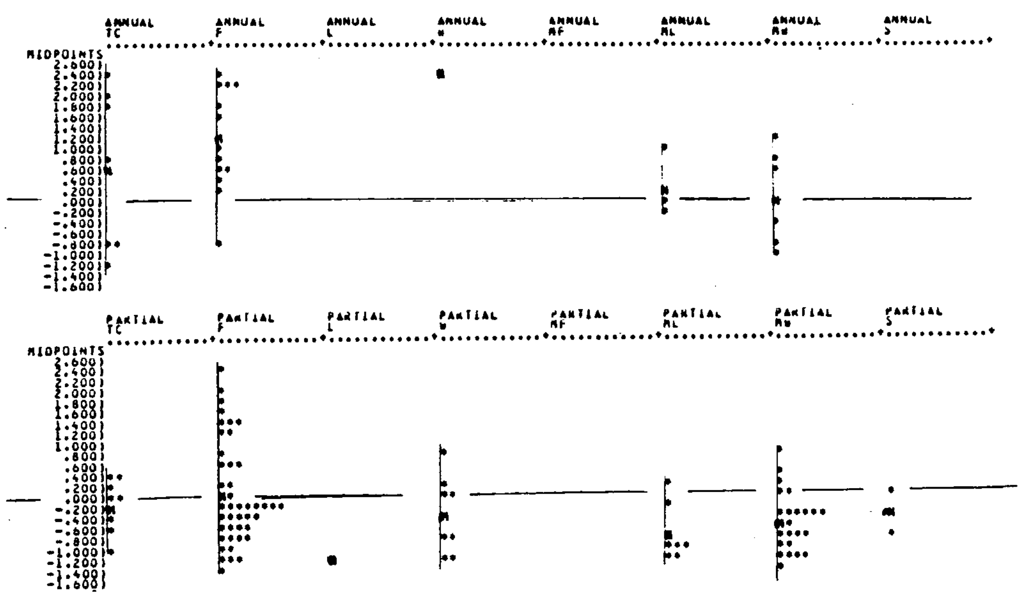
12. SCRTUC Santa Cruz River at Tucson



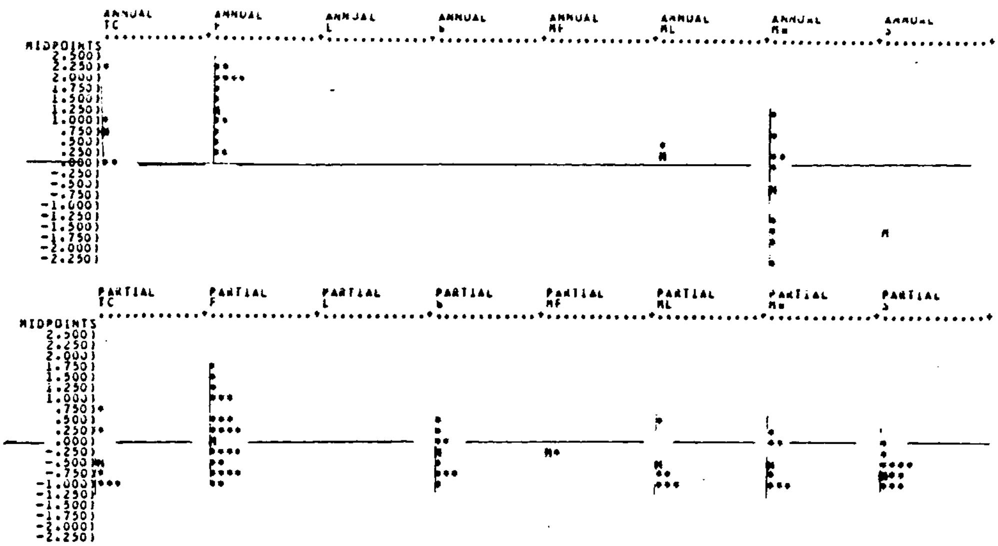
20. SLTROO Salt River near Roosevelt



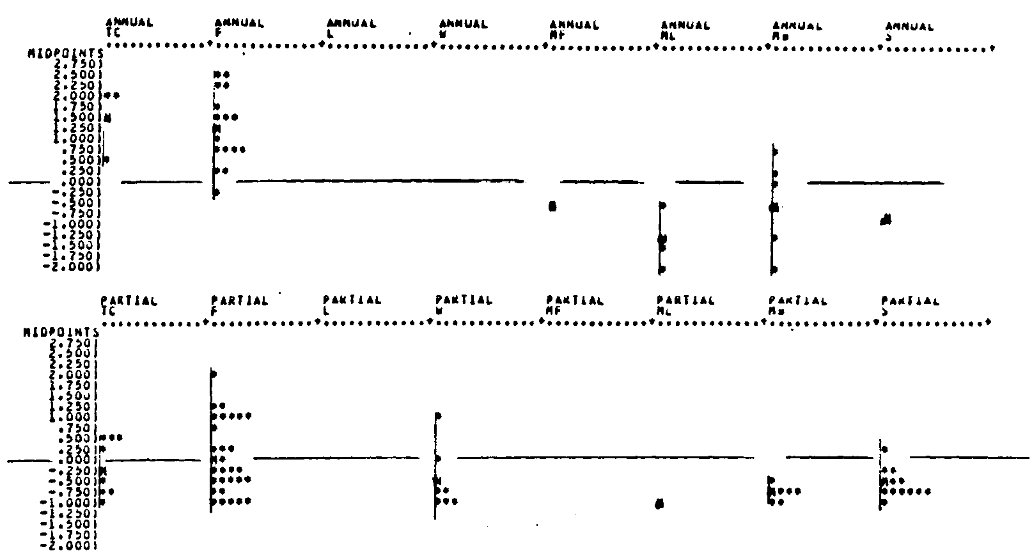
21. TONROO Tonto Creek above Gun Creek, near Roosevelt



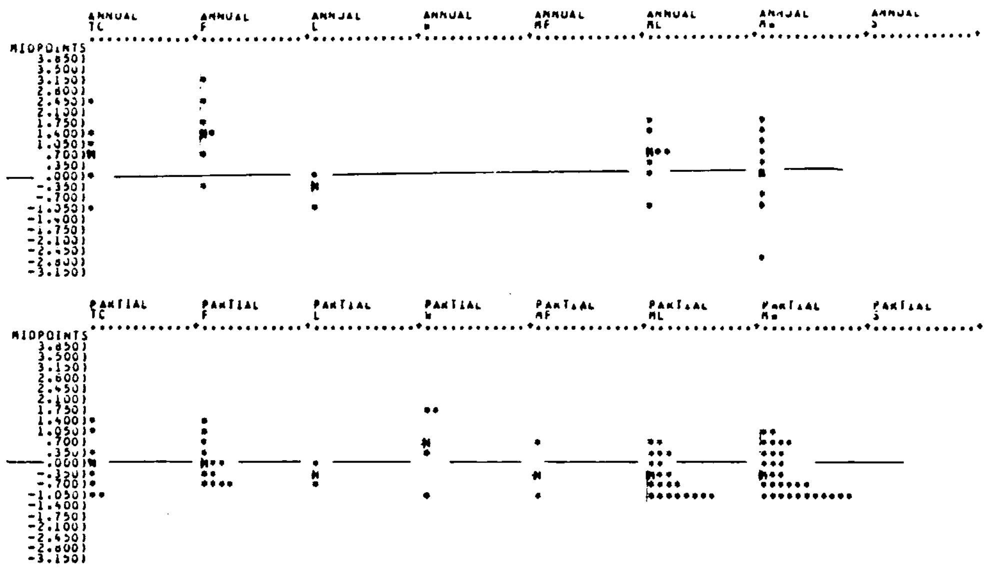
22. OAKCRN Oak Creek near Cornville



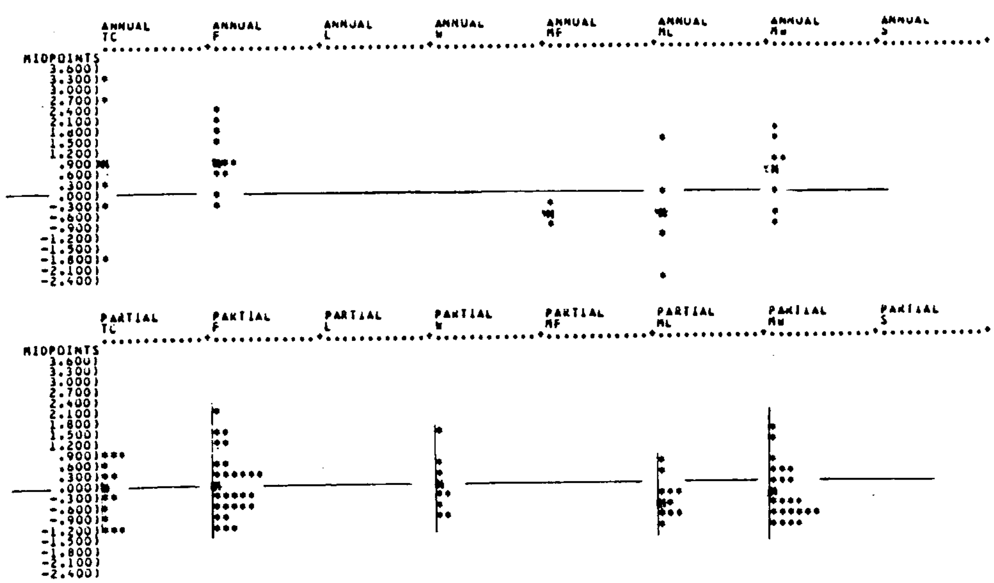
25. VRDHSD Verde River below Tangle Creek



26. AFRMAY Agua Fria River near Mayer



28. HASWIK Hassayampa River at Box Damsite, near Wickenburg



REFERENCES CITED

Aldridge, B. N. and Eychaner, J. H., 1982, Floods of October 1977 in southern Arizona and March 1978 in central Arizona: U. S. Geological Survey Open File Report 82-687, Tucson, Arizona.

American Geological Institute, 1962, Dictionary of geological terms: Doubleday, Garden City, New York, 545 p.

American Meteorological Society, 1959, Glossary of meteorology, ed. by Ralph E. Huschke, Boston, Mass.

Anderson, D. V., 1967, Review of basic statistical concepts in hydrology, in Statistical Methods in Hydrology, proceedings of Hydrology Symposium No. 5, held at McGill Univ., Montreal, Canada, 24-25 Feb, 1966: National Research Council of Canada and Dept. of Energy and Resources, Inland Waters Branch, p. 3-35.

Baker, V. R., 1982, Geology, determinism, and risk assessment, in Scientific Basis of Water-Resource Management, Studies in Geophysics: National Academy Press, p. 109-117.

Baran, N. E., Kisiel, C. C., and Duckstein, Lucien, 1971, A stochastic analysis of flows on Rillito Creek in Hydrology and Water Resources in Arizona and the Southwest, v. 1, p. 171-210.

Bartlein, P. J., 1978, The influence of short-period climatic variations on streamflow in the United States and Southern Canada, 1951-1970: Ph. D. dissertation, unpublished, Dept. of Geography, University of Wisconsin - Madison, 272 p.

__________, 1982, Streamflow anomaly patterns in the U. S. A. and southern Canada, 1951-1970: Jour. of Hydrology, v.57, p. 49-63.

Benson, M. A., 1962, Evolution of methods for evaluating the occurrence of floods: U. S. Geol. Survey WSP 1580-A, 30 p.

_________, 1968, Uniform flood-frequency estimating methods for federal agencies: Water Resources Research, v. 4, p. 891-908.

_________, 1973, Thoughts on the design of design floods, in Schulz, E. F., Koelzer, V. A., and Mahmood, Khalid, (eds.), Floods and Droughts, proceedings of the Second International Symposium in Hydrology, September 11-13, 1972, Fort Collins: Water Resources Publications, p. 27-33.

Betancourt, J. L., and Turner, R. M., (in press), Historic arroyo-cutting and subsequent channel changes at the Congress Street crossing, Santa Cruz River, Tucson, Arizona: U. S. Geol. Survey Water Supply Series.

Brown, H. E., 1965, Characteristics of recession flows from small watersheds in a semiarid region of Arizona: Water Resources Res., v. 1, p. 517-522.

Browzin, B. S., Baumbusch, C. A. and Pavlides, M. G., 1973, Significance of the genesis of floods on probability analysis, in Schulz, E. F., Koelzer, V. A., and Mahmood, Khalid, (eds.), Floods and Droughts, proceedings of the Second International Symposium in Hydrology, September 11-13, 1972, Fort Collins: Water Resources Publications, p. 450-461.

Bruce, J. P. and Clark, R. H., 1980, Introduction to hydrometeorology: Pergamon Press, Oxford, 324 p.

Bryson, R. A. and Lowry, W. P., 1955, Synoptic climatology of the Arizona summer precipitation singularity: Amer. Meteorol. Soc. Bull., v. 36, p. 329-339.

Burkham, D. E., 1976, Hydraulic effects of changes in bottom-land vegetation on three major floods, Gila River in southeastern Arizona: U. S. Geological Survey Professional Paper 655-J.

Chery, D. L., Jr., 1972, Significance of antecedent soil moisture to a semiarid watershed rainfall-runoff relation, in Hydrology and Water Resources in Arizona and the Southwest, v. 2, p. 385-405.

Chow, V. T., 1964, Handbook of applied hydrology: McGraw-Hill, New York.

Committee on Surface-Water Hydrology, 1965, Research needs in surface-water hydrology: Jour. Hydraulics Div., Amer. Soc. Civil Engr., v. 91, no. HY1, p. 75-83.

Condie, R., Nix, G. A., and Boone, L. G., 1981, Flood damage reduction program, flood frequency analysis, Program FDRPFFA: Hydrologic Applications Division, Water Resources Branch, Inland Waters Directorate, Environment Canada, Ottawa, Ontario.

Costa, J. E., 1978, Holocene stratigraphy in flood frequency analysis: Water Resources Res., v. 14, p. 626-632.

Dalrymple, Tate, 1960, Flood-frequency analysis, in Manual of Hydrology, part 3, flood-flow techniques: U. S. Geol. Survey WSP 1543-A, 80 p.

Dawdy, D. R., 1982, A review of deterministic surface water routing in rainfall-runoff models, in Singh, V. P. (ed.), Rainfall-runoff relationship, proceedings of the International Symposium on Rainfall-runoff Modeling, May 18-21, 1981, Mississippi State University: Water Resources Publications, p. 23-36.

Denny, J. L., Kisiel C. C., and Yakowitz, S. J., 1974, Procedures for determining the order of dependence in stream flow records: Water Resources Res., v. 10, p. 947-954.

Dixon, W. J., ed., 1981, BMDP statistical software: Univ. of California Press, Berkeley, 726 p.

Douglas, A. V., 1974, Cutoff lows in the southwestern United States and their effects on the precipitation of this region: Final Report on project entitled Dendroclimatic History of the United States, Laboratory of Tree-Ring Research, University of Arizona, Tucson, 40 p.

__________, 1981, On the influence of warm equatorial conditions in the central Pacific on climatic patterns in the United States: 1977-1980: Proceedings of the Fifth Annual Climate Diagnostics Workshop, October 22-24, 1980, Seattle, Wash.: U. S. Dept. of Commerce, NOAA, p. 239-250.

Douglas, A. V., and Fritts, H. C., 1973, Tropical cyclones of the eastern North Pacific and their effects on the climate of the western United States: Final Report, NOAA Contract 1-35241, Laboratory of Tree-Ring Research, University of Arizona, Tucson, 43 p.

Drissel, J. C. and Osborn, H. B., 1968, Variability in rainfall producing runoff from a semiarid rangeland watershed, Alamagordo Creek, New Mexico: Jour. of Hydrol., v. 6, p. 194-201.

Dunne, Thomas, 1982, Models of runoff processes and their significance, in Scientific Basis of Water-Resource Management, Studies in Geophysics: National Academy Press, p. 17-30.

Eagleson, P. S., 1972, Dynamics of flood frequency: Water Resources Res., v. 8, p. 878-898.

Fairbridge, R. W., ed., 1967, The encyclopedia of atmospheric sciences and astrogeology: Reinhold Publ. Corp., New York, 1200 p.

Feldman, A. D., 1980, Flood hydrograph and peak flow frequency analysis, in Improved Hydrologic Forecasting - Why and How, proceedings of Engineering Foundation Conference, March 25-30, 1979, Pacific Grove, Calif.: Amer. Soc. Civil Engr., p. 1-19.

Foster, H. A., 1924, Theoretical frequency curves: Transactions, Amer. Soc. Civil Engr., v. 87, p. 142.

Freeze, R. A., 1978, Mathematical models of hillslope hydrology, in Hillslope hydrology, M. J. Kirkby, ed., Wiley-Interscience, New York, p. 177-26.

Fuller, W. E., 1914, Flood flows: Transactions, Amer. Soc. Civil Engrs., v. 77, p. 564.

Guillot, Pierre, 1973, Application of the method of Gradex, in Schulz, E.F. Koelzer, V. A., and Mahmood, Khalid, (eds.), Floods and Droughts, proceedings of the Second International Symposium in Hydrology, September 11-13, 1972, Fort Collins: Water Resources Publications, p. 44-49.

Gumbel, E. F., 1941, The return period of flood flows: Annals of Mathematical Statistics, v. 12, p. 163-190.

Gupta, V. K., Duckstein, Lucien, and Peebles, R. W., 1976, On the joint distribution of the largest flood and its time of occurrence: Water Resources Res., v. 12, p.295-308.

Hales, J. E., Jr., 1972, Surges of maritime tropical air northward over the Gulf of California: Monthly Weather Rev., v. 100, p. 298-306.

__________, 1974, Southwestern United States summer monsoon source -- Gulf of Mexico or Pacific Ocean?: Jour. Applied Meteor., v. 13, p. 331-342.

Hansen, E. M. and Schwarz, F. K., 1981, Meteorology of important rainstorms in the Colorado River and Great Basin drainages: Hydrometeorological Report No. 50, NOAA, U. S. Dept. of Commerce, 167 p.

Hawkins, R. H., 1974, A note on mixed distributions in hydrology, in Proceedings of a Symposium on Statistical Hydrology: U. S. Dept. of Agriculture, Agric. Res. Service, Misc. Publ. No. 1275, p. 336-344.

Hazen, Allen., 1930, Flood flows, a study of frequencies and magnitudes: Wiley, New York.

Hirschboeck, K. K., 1975, The response of flooding in the upper Mississippi Valley to twentieth century climatic fluctuations, 1925-1969: M. S. thesis, Dept. of Geography, Univ. of Wisconsin-Madison, 216 p.

Hurst, H. E., 1951, Long term storage capacity of reservoirs: Transactions, Amer. Soc. Civil Engr., v. 116, p. 770.

___________, 1957, A suggested statistical model of some time series which occur in nature: Nature, v. 180, p. 494.

Jarvis, C. S. and others, 1936, Floods in the United States: U. S. Geological Survey Water Supply Paper 771.

Keith, S. J., 1981, Stream channel recharge in the Tucson basin and its implications for ground-water management: M. S. thesis, Dept. of Hydrology and Water Resources Administration, Univ. of Arizona, Tucson.

Kilmartin, R. F., 1980, Hydroclimatology -- a needed cross-discipline, in Improved Hydrologic Forecasting - Why and How, proceedings of Engineering Foundation Conference, March 25-30, 1979, Pacific Grove, Calif.: Amer. Soc. Civil Engineers, p. 160-198.

Kilmartin, R. F. and Peterson, J. R., 1972, Rainfall-runoff regression with logarithmic transforms and zeros in the data: Water Resources Res., v. 8, p. 1096-1099.

Kisiel, C.C., 1969, Time series analysis of hydrologic data: Advances in Hydroscience, v. 5 p. 1-119.

Klein, W. H., 1963, Specification of precipitation from the 700-millibar circulation: Monthly Weather Rev., v.91, p. 527-536.

Klemes, V., 1974a, Some problems in pure and applied stochastic hydrology, in Proceedings of a Symposium on Statistical Hydrology: U. S. Dept. of Agriculture, Agric. Res. Service, Misc. Publ. No. 1275, p. 2-15.

___________, 1974b, The Hurst phenomenon -- a puzzle?: Water Resources Res., v. 10, p. 675-688.

___________, 1978, Physically based stochastic hydrologic analysis: in Chow, V. T., ed., Advances in Hydroscience, v. 11, Academic Press, New York, p. 285-356.

___________, 1982, Empirical and causal models in hydrology: in Scientific Basis of Water-Resource Management, Studies in Geophysics: National Academy Press, p. 95-104.

Knisel, W. G., Renard, K. G., and Lane, L. J., 1979, Hydrologic data collection: how long is long enough?, in Specialty Conference on Irrigation and Drainage in the Nineteen-Eighties, Albuquerque, New Mexico, July 17-20, 1979: Amer. Soc. Civil Engrs., p. 238-254.

Kottegoda, N. T., 1980, Stochastic water resources technology: Wiley, New York, 384 p.

Langbein, W. B., 1949, Annual floods and the partial-duration flood series: Transactions Amer. Geophys. Union, v. 30, p. 879-881.

Linsley, R. K., 1982, Rainfall-runoff models -- an overview, in rainfall-runoff models, in Singh, V. P. (ed.), Rainfall-runoff relationship, proceedings of the International Symposium on Rainfall-runoff Modeling, May 18-21, 1981, Mississippi State University: Water Resources Publications, p. 23-36.

Lund, I. A., 1971, Correlations between areal precipitation and 850-millibar geopotential height: Monthly Weather Rev., v. 99, p. 691-697.

Maddox, R. A., Canova, Faye, and Hoxit, L. R., 1980, Meteorological characteristics of flash flood events over the western United States: Monthly Weather Rev., v. 108, p. 1866-1877.

Maddox, R. A. and Chappell, C. F., 1978, Meteorological aspects of twenty significant flash flood events: Preprints, Conference on Flash Floods: Hydrometeorological Aspects and Human Aspects, Los Angeles, Amer. Meteor. Soc., Boston, p. 1-9.

Maddox, R. A., Chappell, C. F., and Hoxit, L. R., 1979, Synoptic and mesoscale aspects of flash flood events: Amer. Meteor. Soc. Bulletin, v. 60, p. 115-123.

Mandlebrot, B., and Wallis, J. R., 1968, Noah, Joseph and operational hydrology: Water Resources Res., v. 7, p. 543-553.

McCollough, C., 1974, Introduction to statistical analysis: McGraw-Hill, New York, 380 p.

McDonald, J. E., 1956, Variability of precipitation in an arid region: a survey of characteristics for Arizona: Univ. of Arizona Institute of Atmospheric Physics Tech. Report No. 1, 88 p.

________, 1960, Variability factors in mountain-watershed hydrometeorology in an arid region: Jour. of Arizona Academy of Science, v. 1, p. 89-98.

Miller, J. F., 1973, Probable maximum precipitation -- the concept, current procedures and outlook, in Schulz, E. F., Koelzer, V. A., and Mahmood, Khalid, (eds.), Floods and Droughts, proceedings of the Second International Symposium in Hydrology, September 11-13, 1972, Fort Collins: Water Resources Publications, p. 50-61.

Myers, V. A., 1969, The estimation of extreme precipitation as the basis for design floods, resume of practice in the United States, in Floods and Their Computation, proceedings of the Leningrad Symposium, volume 1: International Assoc. of Scientific Hydrology, UNESCO, World Meteorological Organization, p. 84-104.

Osborn, H. B., 1971, Some regional differences in runoff-producing thunderstorm rainfall in the Southwest, in Hydrology and Water Resources in Arizona and the Southwest, v. 1, p. 13-27.

Osborn, H. B., and Laursen, E. M., 1973, Thunderstorm runoff in southeastern Arizona: Proceedings Amer. Soc. Civil Engr., Jour. Hydraulics Div., v. 99, p. 1129-1145.

Potter, W. D., 1958, Upper and lower frequency curves for peak rates of runoff: Transactions Amer. Geophys. Union, v. 39, p. 100-105.

Reich, B. M., 1976, Magnitude and frequency of floods: C. R. C. Critical Reviews in Environmental Control, v. 6, p. 297-348.

Renard, K. G. and Keppel, R. V., 1966, Hydrographs of ephemeral streams in the southwest: Proceedings Amer. Soc. Civil Engr., Jour. Hydraul. Div. v. 92, p. 33-52.

Rodriguez-Iturbe, Ignacio, 1982, The coupling of climate and geomorphology in rainfall-runoff analysis, in Singh, V. P. (ed.), Rainfall-runoff relationship, proceedings of the International Symposium on Rainfall-runoff Modeling, May 18-21, 1981, Mississippi State University: Water Resources Publications, p. 431-448.

Saarinen, T. F., Baker, V. R., Durrenberger, Robert, and Maddock, Thomas, Jr., 1984, The Tucson, Arizona, flood of October 1983: Committee on Natural Disasters, National Research Council, National Academy Press, Washington, D. C., 112 p.

Schulz, E. F., Koelzer, V. A., and Mahmood, Khalid, eds., 1973, Floods and Droughts, proceedings of the Second International Symposium in Hydrology, September 11-13, 1972, Fort Collins: Water Resources Publications, 679 p.

Searcy, J. K., 1960, Graphical correlation of gaging-station records, in Manual of Hydrology, part 1: U. S. Geol. Survey WSP 1541-C, p. 67-100.

Sellers, W. D. and Hill, R. H., 1974, Arizona climate, 1931-1972: Univ. of Arizona Press, Tucson, 616 p.

Shiau, Shin-Yong and Condie, R., 1980, Statistical tests for independence, trend, homogeneity and randomness, Program NONPARA: Hydrologic Applications Division, Water Resources Branch, Inland Waters Directorate, Environment Canada, Ottawa, Ontario.

Singh, K. P., 1968, Hydrologic distributions resulting from mixed populations and their computer simulation, in The use of analog and digital computers in hydrology, v. 2: Symposium organized by the International Assoc. of Scientific Hydrologists, Tucson, Ariz., 1968, publ. no. 81, p. 671-681.

Singh, K. P., 1974, A two-distribution method for fitting mixed distributions in hydrology, in Proceedings of a Symposium on Statistical Hydrology: U. S. Dept. of Agriculture, Agric. Res. Service, Misc. Publ. No. 1275, p. 371-382.

Stidd, C. K., 1954, The use of correlation fields in relating precipitation to circulation: Jour. Meteorology, v. 11, p. 202-213.

_________, 1977, A significance test for correlation fields: Fifth Conference on Probability and Statistics in Atmospheric Sciences, Amer. Meteor. Soc., p. 167-168.

Stockton, C. W., 1975, Long-term streamflow records reconstructed from tree rings: Papers of the Laboratory of Tree-Ring Research, 5, Univ. of Arizona Press, Tucson, Ariz.

Stockton, C. W. and Boggess, W. R., 1980, Tree rings: a proxy data source for hydrologic forecasting, in North, R. M., Dworsky, L. B., and Allee, D. J., (eds.), Unified Basin Management, symposium proceedings, May 4-7, 1980, Gatlinburg, Tennessee: American Water Resources Association, p. 609-624.

Taesombut, V. and Yevjevich, V., 1978, Use of partial flood series for estimating distribution of maximum annual flood peak: Hydrology Papers, No. 97, Colorado State University, Fort Collins, 71 p.

Todorovic, P., 1978, Stochastic models of floods: Water Resources Res., v. 14, p. 345-356.

Todorovic, P. and Zelenhasic, E.. 1970, A stochastic model for flood analysis: Water Resources Res., v. 6, p. 1641-1648.

U. S. Geological Survey, 1976, Preparation of water-resources data reports: U. S. Geol. Survey publ. for administrative use.

U. S. Water Resources Council, 1981, Guidelines for determining flood flow frequency, Bulletin #17B, U. S. Water Resources Council, Washington D.C.

Victorov, P., 1971, Effect of period of record on flood prediction: Proceedings, Amer. Soc. Civil Engr., Jour. Hydraulics Div., v. 97, no. HY11, p. 1853-1866.

Ward, Roy, 1978, Floods, a geographical perspective: Wiley, New York, 244 p.

Waylen, Peter and Woo, Ming-ko, 1982, Prediction of annual floods generated by mixed processes: Water Resources Res., v. 18, p. 1283-1286.

Webster's Seventh New Collegiate Dictionary, 1967: G. & C. Merriam Company, Springfield, Mass., 1221 p.

Woolhiser, D. A., 1982, Physically based models of watershed runoff, in Singh, V. P. (ed.), Rainfall-runoff relationship, proceedings of the International Symposium on Rainfall-runoff Modeling, May 18-21, 1981, Mississippi State University: Water Resources Publications, p. 189-202.

Yevjevich, V. M., 1968, Misconceptions in hydrology and their consequences: Water Resources Res., v. 4, p. 225-232.

Yevjevich, V. M., 1972, Stochastic processes in hydrology: Water Resources Publications, Fort Collins, Colorado.

_______________, 1974, Determinism and stochasticity in hydrology: Jour. Hydrology, v. 22, p. 225-238.