TEXAS WATER DEVELOPMENT BOARD

REPORT 96

# A STATISTICAL STUDY OF THE DEPTH OF PRECIPITABLE WATER IN WESTERN TEXAS AND EASTERN NEW MEXICO

By

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# FOREWORD

Recent experiments in the field of weather modification indicate that it may be possible under favorable conditions to increase precipitation in arid areas by 10 to 20 percent over that which is normally expected. In addition to increasing the available water supply, weather modification may eventually make possible the amelioration of the effects of severe weather such as hail storms and tornados.

An important consideration in planning a weather modification operation is the distribution, both in space and time, of precipitable water. The depth of water which would result if all the water vapor in the air column above a given point could be converted to liquid is defined as precipitable water.

This study was contracted for by the Texas Water Development Board in order to provide information on the available moisture in the atmosphere over western Texas and eastern New Mexico. We believe that the information contained in this report will be of value and interest, not only to prospective weather modifiers, but to all citizens concerned with increasing the supply of water available from the atmosphere in the more arid regions of Texas.

Texas Water Development Board

C. R. Baskin
Chief Engineer

## PREFACE

The search for sources of water for western Texas and eastern New Mexico has led to a study of the water that is available in the atmosphere. Any program designed to make use of this water must start with a thorough knowledge of the amount of precipitable water in the atmosphere. This study is an attempt to find a frequency distribution which will describe the depth of precipitable water in the atmosphere at a given time and from this to compute the probability that a given depth of precipitable water will exist at any time during the year.

The financial support for this project was provided by the Texas Water Development Board through an interagency contract with Texas A&M University, Project 02-55-143.

This study was conducted under the guidance of Dr. Robert A. Clark and Professor John F. Griffiths of Texas A&M University. The final manuscript was reviewed by Dr. Vance E. Moyer, Dr. Robert C. Runnels, and Dr. Edward A. Hiler, all from Texas A&M University.

Samuel Erick Baker

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# ABSTRACT

A Statistical Study of the Depth of Precipitable Water in Western Texas and Eastern New Mexico

Total depth of precipitable water for five stations in western Texas and eastern New Mexico is studied to determine a frequency distribution which will describe this climatic element. A conclusion evolving from the study is that a normal distribution adjusted for skewness and kurtosis may be used to describe adequately the frequency distribution presented by the observed depths of precipitable water grouped by pentads. An annual series of the yearly maximum depth of precipitable water from each of the five stations is plotted vs the recurrence interval. A Gumbel distribution is fitted to each annual series providing a means of determining the return periods of extreme depths of precipitable water.

## CHAPTER I

## INTRODUCTION

In recent years, the problem of adequate water supplies in western Texas and eastern New Mexico has become one of primary concern. The low water table of the High Plains region and the dwindling ground-water resources elsewhere in the area have brought about the realization that other water sources must be found and utilized. One possible source of the needed water is the atmosphere.

The total amount of water vapor in the atmosphere at a given time is known as the precipitable water. By definition, precipitable water is the depth of water that would be accumulated on a flat, level surface of unit area if all of the water vapor in a column of the atmosphere were condensed and precipitated. The importance of this atmospheric element is indicated by Solot (1939), viz., "one of the most significant quantities in hydrometeorological studies is Wp, the depth of precipitable water in a column of air."

It can be shown that the months of greatest rainfall are also months of greatest precipitable water (see Fig. 1). Fig. 1 is a plot of long-term, mean precipitation and mean depth of precipitable water at El Paso vs the time of year. The mean monthly amounts of

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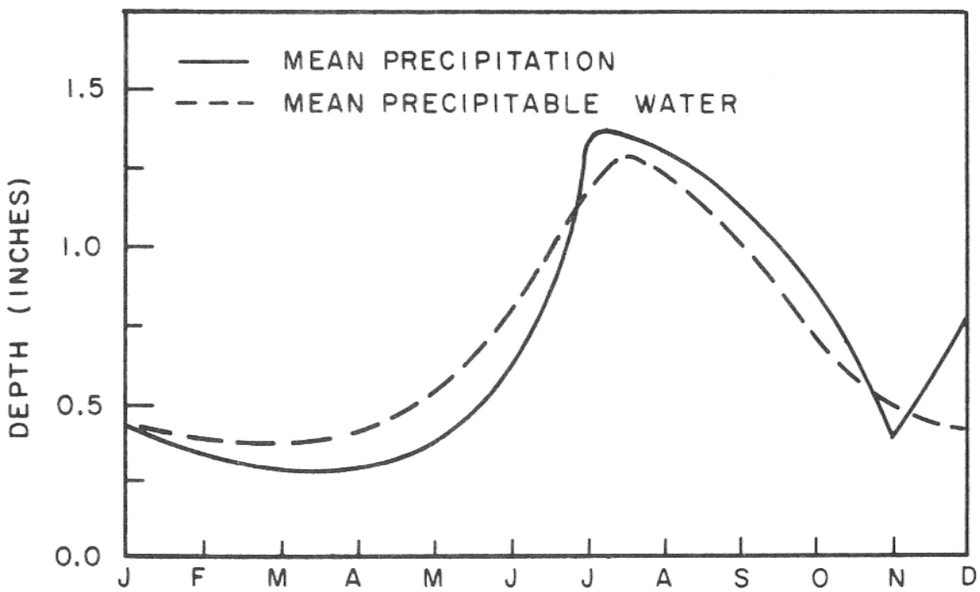


FIG. I. PRECIPITABLE WATER AND PRECIPITATION VS TIME OF YEAR (EL PASO).

precipitable water shown in this figure were taken from Shands (1949), who computed the seasonal distribution of the mean precipitable water for selected stations in the United States. The monthly values of the long-term, mean precipitation were obtained from the "Texas Climatological Annual Summary."

In a study by Huff (1963) of precipitation in central Illinois, it was shown that about 17% of the available precipitable water is precipitated by summer storms and 15% by winter storms. The highest percentage of available moisture (precipitable water) is precipitated in the spring, and the lowest in late summer and winter.

Compared to other areas of meteorology, relatively little has been written with regard to precipitable water. Shands (1949) and Reitan (1960a, 1960b) have discussed the mean monthly values of precipitable water at various stations in the United States. Benwell (1965) and Ananthakrishnan *et al.* (1964) discussed the estimation and variation of precipitable water over the North Atlantic and India, respectively. The importance of mass transfer to the depth of precipitable water over a given place was discussed by Benton *et al.* (1950). Several recent articles have been written describing studies of the transfer of water vapor (Meyers, 1965; Benton and Estoque, 1954; Rasmusson, 1967; Bannon, 1961; Starr and Peixoto, 1958; Starr *et al.*, 1965).. Penn and Kunkle (1963) have investigated the interlevel relationships of the mixing ratio at various levels in the atmosphere.

A review of the literature reveals a dearth of information and research pertaining to the frequency distribution of precipitable water. Frequency distributions have been suggested for other climatic elements such as rainfall, wind speed, temperature, cloud amount, atmospheric pressure, and humidity. A more complete knowledge of the frequency distribution of the depth of precipitable water would contribute to a better understanding of the available moisture in the atmosphere.

In this study the depth of precipitable water, as measured twice daily by radiosonde soundings, was investigated with the intent of finding a frequency distribution which would describe the magnitude of this variable in the atmosphere. A knowledge of this distribution will be of benefit in future attempts to obtain water from the atmosphere by weather modification.

In most hydrological research, extreme values of the climatic elements and their return periods are considered. This is necessary because extreme values of the elements involved dictate the safe limits on structure and system design. However, when considering precipitable water, a knowledge of the most probable depth that will be encountered at a given time is more pertinent than the extreme value that may occur in any given number of years. The extreme values of precipitable water are of interest, nevertheless, from the standpoint of knowing how much moisture has been available in the past and may be available in the future. A knowledge of the distribution of these extreme values and of their return periods, however, gives no clue as to when they might occur. In order for the depth of precipitable water to be used in a program designed to utilize this moisture as a water source (such as a cloud seeding program), the most probable depth available at any given time should be known. It is with this purpose in mind that this research has been conducted.

## CHAPTER II

## REDUCTION OF THE DATA

In order to study the depth of precipitable water in the area of interest (western Texas and eastern New Mexico), precipitable water data from five stations were selected. The five stations and their periods of record are:

1. Amarillo, Texas; July 1952-May 1965
2. Big Spring-Midland, Texas; July 1949-May 1965
3. El Paso, Texas; January 1946-March 1965
4. San Antonio, Texas; January 1946-December 1964
5. Albuquerque, New Mexico; January 1946-December 1964

Fig. 2 is a sectional map showing the location of the five stations. It can be seen from Fig. 2 that these stations are so located as to afford good coverage in the area of interest. The data consist of tabulations of twice-daily computations of the total precipitable water in the atmosphere. These tabulations were procured from the National Weather Records Center, Asheville, North Carolina.

The tabulations are copies of computer-output pages from a program owned by the National Weather Records Center that converts pressure and specific humidity in 50-mb layers into depth of precipitable water in inches. The depth of precipitable water (Wp) in a layer from n-1 to n is given by

$$Wp = 0.0002\ (P_{n-1} - P_n)\ (q_{n-1} + q_n),$$

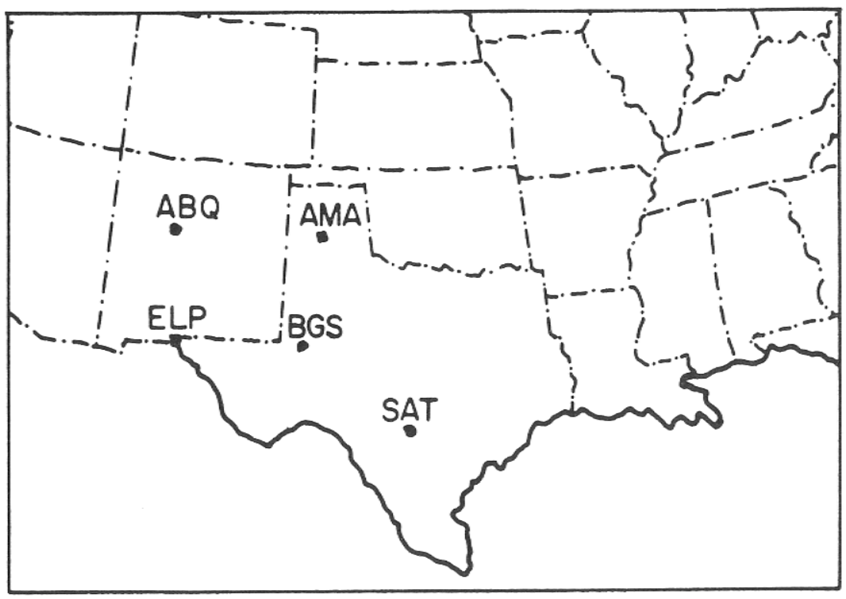


FIG. 2. LOCATION OF STATIONS.

where

$$q = 622\,\frac{e}{p}\,,$$

$$e = e_s RH\,,$$

P = pressure in millibars,

e = actual vapor pressure in millibars,

RH = relative humidity,

$e_s$ = saturation vapor pressure in millibars,

q = specific humidity in gm/kg.

Values of Wp from individual 50-mb layers are added to give the depth of precipitable water for thicker layers, e.g., surface to 850 mb.

The input parameters were obtained from twice-daily radiosonde soundings at each station. Times of the soundings prior to June 1957 were 0300Z and 1500Z (Z denotes Greenwich mean time). After June 1957, the soundings were made at 0000Z and 1200Z. All data at each station were considered to come from the same population with no differentiation being made between those prior to and after June of 1957. The data from each month are contained on two sheets, one sheet for each sounding time. Listed on each sheet are the surface pressure in millibars, the actual surface vapor pressure in millibars, and Wp for five layers. The five layers are: surface to 850 mb, surface to 700 mb, surface to 500 mb, surface to 400 mb, and the layer from the surface to 150 mb above the surface.

Huff (1963) states that 78% of the precipitable water is concentrated below 10,000 ft. Solot (1939), in his computations of the precipitable water in a column of air, assumed no precipitable water above 5 km. On the basis of these conclusions and for purposes of this study, the depth of precipitable water from the surface to 400 mb (approximately 24,000 ft or 7.3 km) was considered representative of the total precipitable water in a column of air. No consideration was given to the vertical distribution of the precipitable water.

In past studies of precipitable water (Reitan, 1960a, 1960b; Meyers, 1965; Shands, 1949), the monthly mean values were considered. A monthly mean value frequently has little meaning in terms of the depth that might be encountered on a specific day, as the depth of precipitable water can vary greatly over a 24-hour period (Benwell, 1965). Therefore a shorter time interval was needed for computations of statistical measures when the depth of precipitable water is used for weather modification or assessment of the moisture field at a given time.

For this reason as well as for convenience in handling the data, it was decided to treat the data by pentads (5-day groups). The data for February 29 were neglected so that the data from one year could be grouped in 73 pentads. The pentads were chosen so that pentad one represents the period from 1 January through 5 January, pentad two represents from 6 January through 10 January, *etc.* Appendix A lists the dates represented by the individual pentads.

# CHAPTER III

## COMPUTATION OF BASIC STATISTICS

Initially two programs were written to process the data and to yield basic statistics for preliminary analysis. A third program was written later to generate a theoretical distribution; it is discussed in Chapter IV. All programs were written in Fortran IV language for use with the Watfor compiler on the IBM 360-65 computer located at Texas A&M University. The programs handle the data from one station during each run.

The first program, named Basic, consisted of three parts: Basic I, Basic II, and Basic III. Basic I yielded the primary statistics of the number in the sample (N), the arthmetic mean ($\overline{X}$), the sum of the absolute values of deviations from the mean $\left(\sum_{i=1}^{n} |x_i - \overline{X}|\right)$, and the numerators of the second, third, and fourth moments $\left[\sum_{i=1}^{n} (x_i - \overline{X})^2, \sum_{i=1}^{n} (x_i - \overline{X})^3, \sum_{i=1}^{n} (x_i - \overline{X})^4\right]$. The method of computation of the Basic I statistics was as follows. Individual values of Wp ($x_i$) were read into a three-dimensional array. These individual values then were added and counted to yield a value of N and $\Sigma x_i$ for each pentad. The value of the arithmetic mean ($\overline{X}$) was obtained by dividing $\Sigma x_i$ by N, i.e.,

$$\overline{X} = \frac{\Sigma x_i}{N} . \tag{1}$$

The other Basic I statistics were computed by subtracting $\overline{X}$ from the individual values of Wp, i.e.,

$$dx_i = x_i - \overline{X} , \tag{2}$$

where $dx_i$ is the deviation from the mean for a value of Wp. The absolute values of $dx_i$ then were added to obtain $\Sigma \; |x_i - \overline{X}|$. The numerators of the second, third, and fourth moments are given by expressions (3), (4), and (5), respectively, viz.,

$$\Sigma \; (x_i - \overline{X})^2, \tag{3}$$

$$\Sigma \; (x_i - \overline{X})^3, \tag{4}$$

and

$$\Sigma \; (x_i - \overline{X})^4. \tag{5}$$

Basic II yielded the secondary statistics of the square root of N ($\sqrt{N}$), the variance ($s^2$), the standard deviation (s), the mean deviation ($|e|$), the coefficient of variation ($C_v$), the standard error of the mean (s.e.$\overline{X}$), the Cornu ratio, the skewness ($\gamma_1$), and the kurtosis ($\gamma_2$). These secondary statistics were computed from the primary statistics by the following relationships:

$$s^2 = \frac{\Sigma \; (x_i - \overline{X})^2}{N - 1} , \tag{6}$$

$$s = \sqrt{s^2} , \tag{7}$$

$$|e| = \frac{\Sigma\ |x_i - \overline{X}|}{N}, \tag{8}$$

$$C_v = \frac{s}{\overline{X}} 100 \quad \text{(expressed in percent)}, \tag{9}$$

$$s.e.\overline{X} = \frac{s}{\sqrt{N}}, \tag{10}$$

$$\text{Cornu ratio} = \frac{|e|}{s}, \tag{11}$$

$$\gamma_1 = \frac{\dfrac{\Sigma\ (x_i - \overline{X})^2}{N}}{s^3}, \tag{12}$$

and

$$\gamma_2 = \left( \frac{\dfrac{\Sigma\ (x_i - \overline{X})^4}{N}}{s^4} \right) - 3. \tag{13}$$

The Basic program yielded 73 sets of statistics, one set for each of the 73 pentads in a year. Basic III was written to yield statistics needed in a check for the suitability of the log-normal distribution and will be described in Chapter IV.

The second program, named Freq, yielded the maximum value of Wp, the minimum value of Wp, the range of Wp, and the observed frequency distribution. In Freq, as in Basic, the data were read into a three-dimensional array. The maximum and minimum values were found by setting a maximum register and a minimum register equal to the first value of Wp in each pentad. A comparison of all values in each pentad with the value in the register then was made. If a value of Wp was found to be greater than the value in the maximum register, it replaced the value in the maximum register, and the comparison continued until all values representing that pentad were considered. This procedure leaves the largest value of Wp for that pentad in the maximum register. The minimum was found in a similar manner by replacing the register value with a smaller value when one was encountered. The range of values of Wp for the pentad then was found by subtracting the minimum from the maximum.

The frequency distribution presented by the data of each pentad was computed by the second part of the Freq program. A class interval of 0.05 in. was used in grouping the data. The Freq program, using the 0.05-in. class interval, counted the number of values of Wp which fell in each interval from 0 to 3 in. This was accomplished by comparing each value of Wp in a pentad with the top limit of each interval starting at 0.05 in. and continuing to 3.00 in., if necessary, by increments of 0.05 in. The first case in which the observed value was less than or equal to the value of the top of the class interval thus defined the top of the class interval in which the observed value belonged. Each time a value of Wp was placed in an interval by this procedure the frequency of that interval was increased by one, thus defining the observed frequency distribution of the values of Wp from the pentad under consideration. As in the Basic program, Freq computed the frequency distribution, maximum Wp, minimum Wp, and the range of the data from each pentad, and printed out 73 sets of results for each station.

The two programs, Basic and Freq, were capable of treating the data from several pentads grouped together as a single population. This was done so that pentads with similar means and standard deviations could be treated as a single population thus describing a longer period of time than 5 days with a single set of statistics in the event that such treatment should prove feasible.

# CHAPTER IV

## TESTING THE DATA FOR NORMALITY

This study was based on the hypothesis that the data fit some form of the normal frequency distribution. In order to test this hypothesis, it was decided to check the data for normality.

There are two distinct types of error that are possible in statistical decision:

Type I: rejecting the hypothesis when it is true.

Type II: accepting the hypothesis when it is false.

The significance level indicates the probability of making a Type I error (Guilford, 1965). This means that with a significance level of 0.05 (5%) there is one chance in twenty of rejecting the hypothesis when it is true. With a significance level of 0.01 (1%) there is one chance in a hundred of making a Type I error. As the chances for a Type I error are reduced, however, the chances for a Type II error are increased (Guilford, 1965). The inverse relationship of the probabilities of making a Type I or Type II error is not a simple one, and a choice must be made as to the significance level which will give an acceptable value to each probability. In statistical work with meteorological data, the generally adopted significance levels are the 5% and 1% levels (Brooks and Carruthers, 1953). These levels give a small chance of making a Type I error while still giving a statistically acceptable chance of making a Type II error. The 5% significance level is obviously preferable in terms of not accepting a false hypothesis (making the Type II error).

The basic form of the normal distribution is referred to as the Gaussian distribution. In order to test the data for normality, with respect to the Gaussian distribution, three criteria were chosen at the 5% level of significance. The first criterion was that the value of the Cornu ratio be between 0.77 and 0.83. The second criterion required that the value of the skewness ($\gamma_1$) be

$$\pm 1.96 \times \text{s.e.}\gamma_1 \ ,$$

where

$$\text{s.e.}\gamma_1 = \sqrt{\frac{6}{N}} \ . \qquad (14)$$

The third criterion for normality at the 5% significance level required that the value of kurtosis ($\gamma_2$) fall between the limits shown in Table 1.

Table 1. Range of values within which the value of kurtosis will be found 95 times out of 100 for a sample drawn from a normal population (Brooks and Carruthers, 1953).

| | | Sample size (N) | | |
|---|---|---|---|---|
| 100 | 125 | 150 | 175 | 200 |
| -0.73 | -0.67 | -0.62 | -0.59 | -0.55 |
| +1.06 | +0.95 | +0.88 | +0.81 | +0.81 |

The 73 Cornu ratio values for each station were checked against the first criterion. If the first criterion was met, checks of the skewness and kurtosis against the second and the third criteria were made. Table 2 shows the results of the three tests for Gaussian normality. The data were not examined further for Gaussian normality unless all three criteria were met.

Table 2. The results of tests for normality on the Cornu ratio, skewness, and kurtosis.

| Station | Number of pentads passing: | | |
|---|---|---|---|
| | Cornu | Cornu, skewness, and kurtosis | Cornu, skewness, and positive kurtosis |
| AMA | 47 | 14 | 2 |
| BGS | 51 | 17 | 2 |
| ELP | 35 | 12 | 1 |
| SAT | 30 | 19 | 3 |
| ABQ | 44 | 5 | 0 |
| Total | 207 | 67 | 8 |

In order for statistical tests to be meaningful, they should be independent. The three tests (Cornu, skewness, and kurtosis) that were run on the data are independent unless the kurtosis is negative. In this case, the Cornu and kurtosis are not independent and the data cannot be considered to have come from a normal population.

It can be seen from Table 2 that only eight out of a possible 365 pentads meet the three criteria for normality with a positive value of kurtosis. The 83 pentads not accounted for in Table 2 did not pass any of the three tests. With only eight pentads passing the three independent tests it was decided not to test the data further for normality. In the event that the data from eight pentads were indeed drawn from normally distributed populations, this would not be significant in view of the possibility that data from the other 358 pentads were not drawn from normal populations.

An attempt was made to determine if data for a given station could be grouped into consecutive pentads (those having similar means and standard deviations) and then treated as if they were all drawn from a single population. The statistics (Basic I & II) computed from these combined data were found to be more divergent from a normal distribution than the statistics from the individual pentads. It was concluded that grouping was not feasible and that the data should be treated by individual pentads.

Since the values of precipitable water were shown not to fit the Gaussian or normal distribution, the next step was to check for suitability of the "log-normal" distribution. Basic III was written to perform this check by a method outlined by Brooks and Carruthers (1953, p. 102). This method requires that the kurtosis obtained from the data be compared to a theoretical kurtosis computed from

$$\gamma_{2t} = w^2 \left[\gamma_1{}^2 + 2(3w^2 + 8)\right], \qquad (15)$$

where

$$w = \left[\tfrac{1}{2}\gamma_1 + \sqrt{\tfrac{1}{4}\gamma_1^{\,2} + 1}\right]^{1/3} + \left[\tfrac{1}{2}\gamma_1 - \sqrt{\tfrac{1}{4}\gamma_1^{\,2} + 1}\right]^{1/3} \qquad (16)$$

and $\gamma_1$ equals the observed skewness.

A further check of w was made by computing a theoretical value of skewness ($\gamma_{1t}$) from

$$\gamma_{1t} = w^3 + 3w \ . \qquad (17)$$

If the value of $\gamma_{1t}$ , from Eq. (17), was not equal to the observed skewness ($\gamma_1$) (both values rounded to the second decimal point), the value of w was incorrect. The values of $\gamma_{2t}$ computed by Basic III were listed with the observed values of kurtosis ($\gamma_2$).

In order for the log-normal to be a suitable distribution for describing the data, the two values of kurtosis (observed and theoretical) should be approximately equal. Table 3 shows the results of the check for log-normal suitability.

Only 13 of a possible 365 pentads passed the test for log-normal suitability and there was no evident grouping as to time of year. It was concluded that the log-normal distribution could not be considered suitable for describing the frequency distribution of precipitable water.

After rejection of the log-normal distribution it was decided to test the data for suitability of the adjusted normal distribution. The adjusted normal distribution (Brooks & Carruthers, 1953) is a

Table 3. The number of pentads for which the log-normal distribution was considered suitable.

| Station | Number of pentads | Pentad numbers |
|---|---|---|
| AMA | 3 | 3, 40, 52 |
| BGS | 3 | 15, 70, 72 |
| ELP | 3 | 37, 40, 43 |
| SAT | 1 | 37 |
| ABQ | 3 | 15, 19, 64 |
| Total | 13 | |

derivation of the normal distribution in which adjustment is made for skewness and kurtosis that are out of range for the normal distribution. For the adjusted normal distribution to be able to describe a frequency distribution presented from sample data, the observed distribution cannot vary greatly from normal. The criteria used in checking for adjusted normality were a Cornu ratio value between 0.75 and 0.85 (the 1% significance level) and a "t" value of less than three for skewness and kurtosis.

The "t" values for the skewness and kurtosis were computed using the following relationship:

$$t = \frac{\text{sample statistic - population statistic}}{\text{standard error of the numerator}} .$$

Since the skewness and kurtosis of a normal population are both equal to zero, the separate relationships can be expressed by

$$t \text{ (for skewness)} = \frac{\gamma_1}{\sqrt{\frac{6}{N}}} \tag{18}$$

and

$$t \text{ (for kurtosis)} = \frac{\gamma_2}{2\sqrt{\frac{6}{N}}} . \tag{19}$$

Results of checking the data against the adjusted normal criteria are shown in Table 4.

Table 4. Results of tests for adjusted normality.

| Station | Number of pentads meeting criteria<br>All year | <br>22 to 59 |
|---|---|---|
| AMA | 31 | 27 |
| BGS | 37 | 34 |
| ELP | 26 | 26 |
| SAT | 45 | 30 |
| ABQ | 24 | 24 |

Of the 365 possible, 163 pentads met the criteria for adjusted normality. It is interesting to note that 141 of these 163 are between pentads 22 and 59. These pentads represent the period between the 16th of April and the 22nd of October.

On the basis of the above results, a decision was made to attempt to fit the observed frequency distribution for each pentad to a theoretically generated normal distribution, adjusted for the observed skewness and kurtosis. This theoretical distribution was determined by the observed mean and standard deviation for each pentad. This method of adjustment consists of computing the area (A) under the normal curve to the left of an ordinate x distance from the mean. The area A is found by entering Appendix II of the text by Brooks and Carruthers (1953, hereafter referred to as B & C) with the ratio $\frac{x}{s}$ , where s is the standard deviation. The adjustment for skewness is accomplished by entering Appendix III of B & C with the value of $\frac{x}{s}$ and obtaining a correction factor B. Multiplying B times the skewness yields an adjustment which then is added to A. An adjustment for kurtosis is found in a similar manner by obtaining a correction factor C from Appendix IV of B & C that is multiplied by the kurtosis. This adjustment then is added to the sum of A and the adjustment for skewness. For the purposes of fitting the theoretical distribution to the observed distribution, the ordinates were chosen at the limits of the class intervals used in Freq. Thus an adjusted area ($A_L$) to the left of each class limit was obtained by

$$A_L = (A + B\gamma_1 + C\gamma_2) \frac{N}{1000} . \qquad (20)$$

Since Appendices I, II, and III of B&C are based on a total frequency of 1000, the adjusted area ($A_L$) must be multiplied by $\frac{N}{1000}$ to give an area proportional to the observed sample size. The difference between $A_L$ for the upper limit of the class interval and $A_L$ for the lower limit is the theoretical frequency for that class interval.

A third computer program, named Ajnor, was written to generate the theoretical normal distribution adjusted for skewness and kurtosis. Ajnor computed the theoretical distribution according to the method outlined above. Appendix I of B & C was placed on punched cards and read into the computer as a table. Values of A were computed by "table lookup" for corresponding values of $\frac{x}{s}$. The values of B and C were computed by

$$B = \frac{sy}{6}\left[1 - \left(\frac{x}{s}\right)^2\right] \tag{21}$$

and

$$C = \frac{sy}{24} \cdot \frac{x}{s}\left[3 - \left(\frac{x}{s}\right)^2\right], \tag{22}$$

where y equals the vertical coordinate of the normal curve at $\frac{x}{s}$ expressed by

$$y = \frac{N}{s\sqrt{2\pi}} \cdot e^{-\frac{x^2}{2s^2}} . \tag{23}$$

The values of A, B, and C were then combined by Eq. (20). Each successive value of $A_L$ was subtracted from the previous one to find the theoretical frequency in the interval between. The theoretical frequencies were generated for intervals bounded by successive 0.05-in. increments from 0 to 3 in. The theoretical and observed distributions for each pentad then were listed together for easy comparison.

The goodness of fit of the observed distribution then was tested using a chi-square ($\chi^2$) test. The chi-square test is the significance test generally used for meteorological data (B & C, 1953). Values of chi-square are calculated by

$$\chi^2 = \Sigma \frac{(O - E)^2}{E} , \tag{24}$$

where O is the observed frequency for an interval and E is the theoretical frequency. A value of chi-square computed from Eq. (24) was compared with a value of chi-square for the desired significance level taken from Appendix V of B & C for the appropriate number of degrees of freedom. The number of degrees of freedom is found by subtracting four from the number of class intervals in which the theoretical frequency is five or more. Four is subtracted because there are four statistics used in generating the theoretical distribution, i.e., the mean, standard deviation, skewness, and kurtosis.

A null hypothesis was used in determining the results of the chi-square test. The null hypothesis was the assumption that the differences between the expected (theoretical) and observed values of frequency were small enough to be the result of chance (sampling error). If the null hypothesis was supported, the theoretical distribution was considered descriptive of the population from which the sample was drawn. In interpreting the test, the null hypothesis was supported if the chi-square value computed from Eq. (24) was less than or equal to the tabulated value of chi-square at the 5% significance level. If the computed value of chi-square was between the 5% and 1% significance values in Appendix V of B & C, the test was considered inconclusive. In the event that the computed value was greater than the tabulated value at the 1% significance level, the null hypothesis was not supported. Results of the chi-square test for the goodness of fit of the precipitable water data to an adjusted normal distribution are given in Table 5.

The results of the chi-square test show that out of 365 possible cases, 198 (52.2%) support the null hypothesis, 97 (26.6%) do not support the null hypothesis, and 70 (19.2%) are inconclusive. When the period from 16 April to 22 October is considered, 190 cases, 130 (68.4%) support the null hypothesis, 29 (15.3%) do not support the null hypothesis, and 31 (16.3%) are inconclusive. With so many inconclusive cases, it was decided to make another test for goodness of fit to supplement the chi-square test.

The Kolmogorov-Smirnow (K-S) test was used to test further the

Table 5. Results of the chi-square test for goodness of fit of a normal distribution adjusted for skewness and kurtosis to the observed distribution.

| Station | Number of pentads supporting or not supporting the null hypothesis, for the entire year | | |
|---|---|---|---|
| | Supporting | Inconclusive | Not supporting |
| AMA | 46 | 11 | 16 |
| BGS | 42 | 8 | 23 |
| ELP | 34 | 14 | 25 |
| SAT | 38 | 15 | 20 |
| ABQ | 38 | 22 | 13 |
| Total | 198 | 70 | 97 |
| | ..., for the period between pentads 22 and 59 (16 April to 22 October) | | |
| AMA | 24 | 7 | 7 |
| BGS | 31 | 2 | 5 |
| ELP | 23 | 9 | 6 |
| SAT | 28 | 6 | 4 |
| ABQ | 24 | 7 | 7 |
| Total | 130 | 31 | 29 |

goodness of fit of the normal distribution adjusted for skewness and kurtosis. According to Lilliefors (1967) and Guilford (1965), the K-S test is a more powerful test than the chi-square. In order to check for goodness of fit by the K-S test, the difference (D) between the cumulative theoretical frequency and the cumulative observed frequency in each interval is found. The largest of these differences ($D_{max}$) then is compared to a critical value in order to determine whether the null hypothesis is supported. If $D_{max}$ is smaller than the critical value, the null hypothesis is supported; if larger, the null hypothesis is rejected. Lilliefors (1967) states that the conventional method of computing the critical value of D, for a case where the mean and variance are estimated from the sample, results in the K-S test being much too conservative, i.e., the chance for a Type II error is too great to be acceptable. A new equation for computing the critical value for various significance levels was given by Lilliefors (1967). The critical value at the 5% significance level ($D_{.05}$) is found by

$$D_{.05} = \frac{0.886}{\sqrt{N}} \quad . \tag{25}$$

A routine was written and added to Ajnor to compute $D_{.05}$ from Eq. (25). The value of $D_{max}$ was found by computing a value of D for each interval and by comparing them to find the largest. The individual values of D were computed from (Guilford, 1965)

$$D = (Cp_o - Cp_e), \qquad (26)$$

where $Cp_o$ is the cumulative probability for the observed distribution and $Cp_e$ is the cumulative probability for the theoretical distribution. The cumulative probabilities are found by dividing the cumulative frequencies (Cf) by the sample size (N).

Table 6 presents the results of the K-S test as applied to the data. From Table 6, it can be seen that 310 out of 365 cases (85%) support the null hypothesis. When the period from 16 April to 22 October is considered, 172 cases out of 190 cases (90.5%) support the null hypothesis.

Table 7 is presented as a comparison between the chi-square and K-S tests. It can be seen that of the 97 pentads that failed the chi-square test, 57 (59%) passed the K-S test. Of the 70 pentads resulting in an inconclusive chi-square test, 57 (81%) passed the K-S test and 13 (19%) failed the K-S test. Out of 198 pentads passing the chi-square test, only two failed the K-S test. Thus it appears that the K-S test, even with Lilliefors' criteria (Eq. 25), is more conservative than the chi-square test.

A third test developed by Riedwyl (Speed and Smith, 1968) was investigated to see if it might be used to test the goodness of fit. The Riedwyl test consists of computing values of D (Eq. 26), summing the values of $D^2$, and multiplying this sum by the square of the number in the sample ($N^2$). The number so computed is checked

Table 6. Results of the Kolmogorov-Smirnov test for goodness of fit of a normal distribution adjusted for skewness and kurtosis to the observed distribution.

| Station | Number of pentads supporting the null hypothesis, entire year considered |
|---|---|
| AMA | 64 |
| BGS | 58 |
| ELP | 60 |
| SAT | 59 |
| ABQ | 69 |
| Total | 310 |
| | ..., for the period between pentads 22 and 59 |
| AMA | 34 |
| BGS | 35 |
| ELP | 33 |
| SAT | 35 |
| ABQ | 35 |
| Total | 172 |

Table 7. Comparison of the chi-square and K-S tests.

| Station | chi-square / K-S | Pass / Fail | Fail / Pass | Inc. / Pass | Inc. / Fail | Pass / Pass | Fail / Fail |
|---|---|---|---|---|---|---|---|
| AMA | | 0 | 9 | 9 | 2 | 46 | 7 |
| BGS | | 0 | 10 | 6 | 2 | 42 | 13 |
| ELP | | 0 | 15 | 11 | 3 | 34 | 10 |
| SAT | | 1 | 11 | 11 | 4 | 37 | 9 |
| ABQ | | 1 | 12 | 20 | 2 | 37 | 1 |
| Total | | 2 | 57 | 57 | 13 | 196 | 40 |

against a critical value, at the 5% level of significance, which is obtained from Table 4 of Speed and Smith (1968). As the critical values are computed only for sample sizes up to 45, it was necessary to extrapolate a plot of the critical values vs sample size in order to apply the test to the data. It was found that all pentads would pass the Reidwyl test using the critical values from the extrapolated curve. The Riedwyl test was therefore not used to test the data for goodness of fit because it was not possible to get meaningful results for large sample sizes using presently available tabulations of critical values.

Before reaching a definite conclusion about the suitability of the adjusted normal distribution to describe the frequency distribution of the depth of precipitable water, it was decided to investigate the binomial and Poisson distributions to see if they might be suitable.

The binomial distribution was not suitable as it is most applicable for describing the probability of occurrence or non-occurrence of discrete events, i.e., rain days and frost days. The Poisson distribution is a special case of the binomial distribution which may be modified to describe the distribution of a continuous variable such as depth of precipitable water. For the Poisson distribution to be useful in describing the distribution of a variable, the variance of the sample must be approximately equal to the mean. A check of the data revealed that in almost all cases the mean was an order of magnitude larger than the variance and in no case was the difference less than a factor of five. The Poisson distribution, therefore, was not suitable for describing the distribution of the depth of precipitable water.

In view of the results of the chi-square (Table 5) and Kolmogorov-Smirnov (Table 6) tests, it was concluded that the normal distribution adjusted for skewness and kurtosis is suitable for describing the distribution of the depth of precipitable water in western Texas and eastern New Mexico. Although the test results were good enough to use the adjusted normal distribution to describe precipitable water for the entire year, the results were particularly good for the period from 16 April to 22 October.

In Chapter V, a method is presented whereby the adjusted normal distribution may be used to determine the probability of having a given depth of precipitable water in the atmosphere.

# CHAPTER V

## PROBABLE DEPTH OF PRECIPITABLE WATER

It was shown in Chapter IV that the depth of precipitable water, grouped by pentads, may be described by a normal distribution adjusted for skewness and kurtosis. From the normal distribution adjusted for skewness and kurtosis, the probability of a given depth of precipitable water in the atmosphere may be determined.

A probability routine was written to be used with Ajnor that would yield the probability of the depth of precipitable water being equal to or greater than any value from 0.05 to 3.00 in. The Ajnor probability routine computes the cumulative probability in each interval by dividing the theoretical frequencies for each interval by the sum of the theoretical frequencies for all intervals and adding this probability to the cumulative probability of the preceding interval. The probability that the depth of precipitable water, as represented by the interval, will be equaled or exceeded is then computed by subtracting the cumulative probability for the interval from one. This yields the integer percent probability that a given depth of precipitable water will be equaled or exceeded during the pentad. Presenting the data in this manner thus affords an idea of the minimum depth of precipitable water that may be encountered during a given pentad.

Appendix B is a tabulation of the percent probability that a given depth or greater depth of precipitable water will be present in the atmosphere during any of the 73 pentads throughout the year.

One example of the use of Appendix B is shown in Fig. 3. This figure was constructed by plotting the probability that a given depth of precipitable water would be equaled or exceeded vs the pentad. This type of plot is prepared easily from Appendix B and affords a method of determining quickly the exceedance probability of a given depth of precipitable water throughout the year.

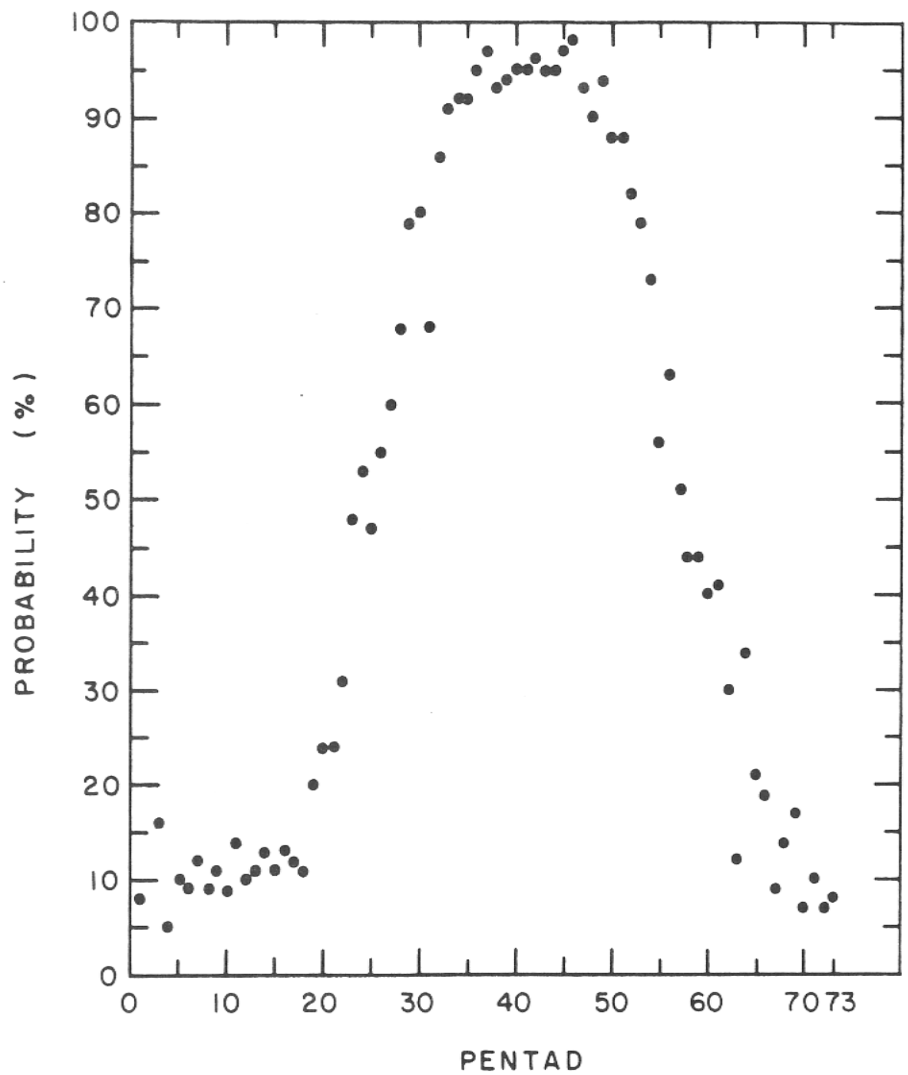


FIG. 3. PROBABILITY THAT A DEPTH OF ONE IN. OF PRECIPITABLE WATER WILL BE EQUALED OR EXCEEDED vs TIME OF YEAR (SAN ANTONIO).

# CHAPTER VI

## DISTRIBUTION OF THE ANNUAL SERIES

An investigation of the distribution of the annual extreme values of depth of precipitable water was conducted in order to determine the maximum annual values and the probable return periods of these extremes. A knowledge of these extreme values and their return periods is useful for storm adjustment in the preparation of inflow design flood analyses. The return period, according to Linsley *et al.* (1958), is used to signify the average number of years within which a given depth of precipitable water will be equaled or exceeded.

A program was written to determine the maximum depth of precipitable water for each year. The largest value was found by placing the first value of depth of precipitable water in a register and comparing every other value during the year with the register value. If a value was encountered which was larger than the register value, it replaced the register value and the comparison continued until the largest value for the year was in the register.

The annual series thus obtained was analyzed by a method used by Gumbel (1954) and described by Linsley *et al.* (1958). This method consists of arranging the annual series in descending order from largest to smallest. Each value in the annual series is given a rank value (m). The largest value has a rank value of one, the next largest a rank value of two and so on to the smallest value in the series which has a rank value equal to n (the number of years in the series). The return period ($T_r$) of each value in the annual series is computed from

$$T_r = \frac{n + 1}{m} . \tag{27}$$

The values of $T_r$ then are plotted vs the depth of precipitable water on extremal probability paper developed by Gumbel (1954).

A plot of the annual series vs return period is shown for El Paso in Fig. 4. The annual series plot revealed that a straight line could be fitted to the data. This indicated that it is possible to describe the return period of a given depth by the Gumbel distribution.

The Gumbel distribution was fitted to the data by calculating a theoretical value of the return period ($Tr_t$) for two values of depth of precipitable water ($X_1$ and $X_2$). The theoretical value of the return period was given by

$$Tr_t = \frac{1}{1 - P} , \tag{28}$$

where

$$P = e^{-e^{-y}} , \tag{29}$$

and e is the base of natural logarithms. The reduced variate was found from

$$y = a(X_i - X_f) , \tag{30}$$

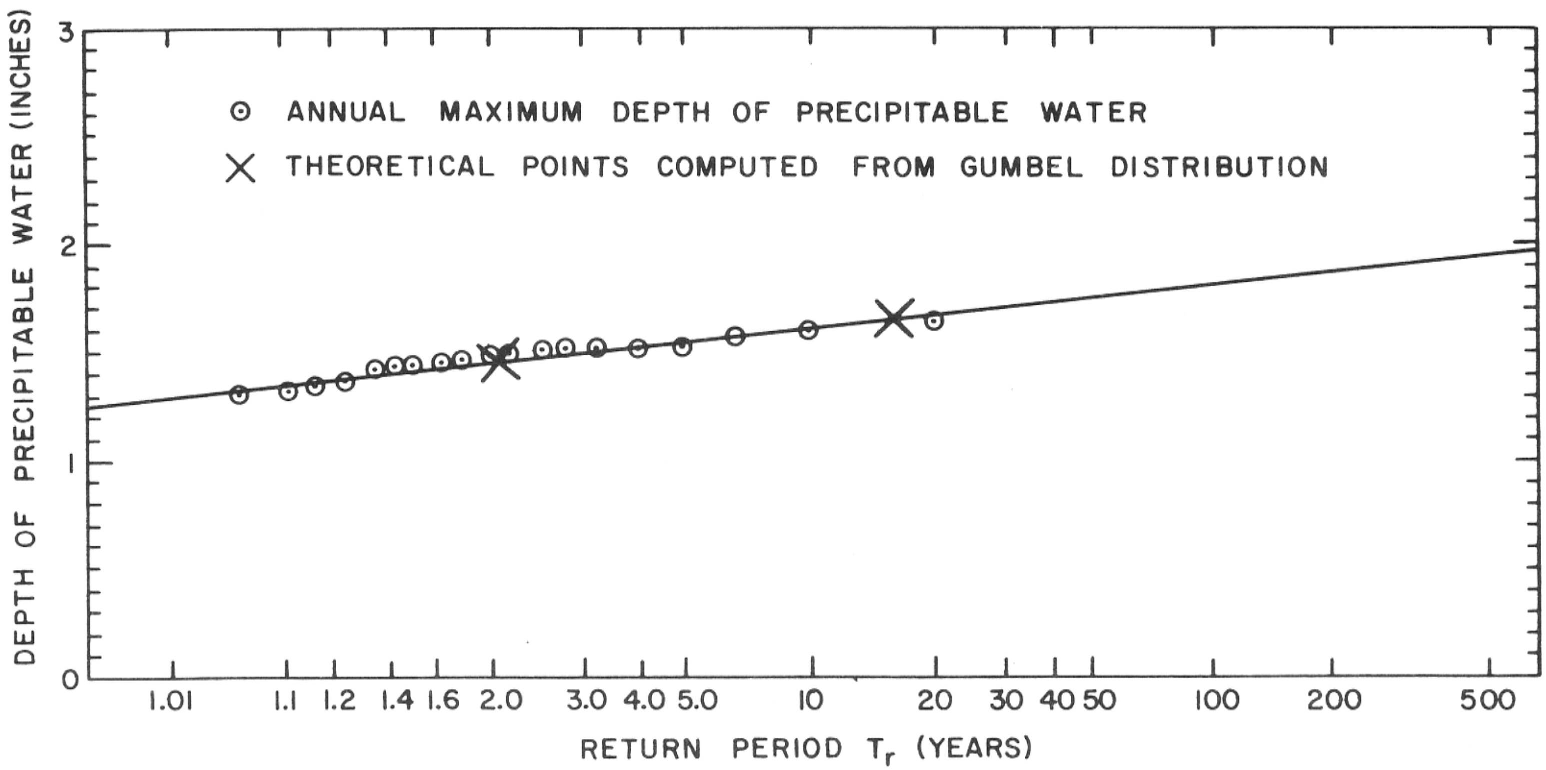


FIG. 4. A PLOT OF DEPTH OF PRECIPITABLE WATER vs RETURN PERIOD FOR EL PASO, TEXAS.

where

$$a = \frac{\sigma_n}{\sigma_x} \tag{31}$$

and

$$X_f = \overline{X} - \sigma_x \frac{\overline{Y}_n}{\sigma_n} \; . \tag{32}$$

The theoretical quantities $\sigma_n$ and $\overline{Y}_n$ are functions of n only. For the annual series considered in this study, these quantities are:

$$\sigma_n = 1.06 \tag{33}$$

and

$$\overline{y}_n = 0.52 \; . \tag{34}$$

The observed quantities $\sigma_x$ and $\overline{X}$ are the standard deviation and arithmetic mean of the annual series, respectively.

The two values of $Tr_t$ calculated using Eq. (28) were plotted vs the corresponding values of $X_1$ and $X_2$, and a straight line was drawn through these points. This line represents the return period vs depth of precipitable water according to the Gumbel distribution.

It can be seen (Fig. 4) that the Gumbel distribution line is a very good fit to the data. It is apparent that the annual maximum values of depth of precipitable water are distributed according to the Gumbel distribution. Appendix C is a plot of the return period vs depth of precipitable water for each of the five stations in the study. In each case, the line was fitted by a Gumbel distribution to the observed annual series.

# CHAPTER VII

## SUMMARY AND CONCLUSIONS

The total depth of precipitable water in the atmosphere was studied for five stations in the western Texas and eastern New Mexico area. The purpose of the study was to determine if the frequency distribution of the depth of precipitable water in this area could be described by some form of the normal distribution.

It was found that the basic form of the normal distribution and the log-normal form did not adequately describe the distribution of the data. The chi-square and Kolmogorov-Smirnov tests were used to determine goodness of fit of the observed distribution to a frequency distribution theoretically generated by adjusting the normal distribution for skewness and kurtosis. It was found that the observed distribution could be described by the normal distribution adjusted for skewness and kurtosis within statistically acceptable limits.

A study was made of the maximum value of depth of precipitable water from each year. This annual series was plotted on extremal probability paper. A line was fitted to this plot of the annual series using the Gumbel distribution. The results revealed that the return periods of extreme values of the depth of precipitable water may be determined using the Gumbel distribution.

Appendix B may be used to determine the probability of a given depth of precipitable water in the atmosphere at a station for any 5-day period during the year. The dates corresponding to any pentad may be found in Appendix A.

Appendix C may be used to determine the return period of an extreme value of the depth of precipitable water for any of the five stations.

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# APPENDICES

## APPENDIX A
### Dates Represented by Pentads

| Pentad | Dates |
|---|---|
| 1 | 1 January - 5 January |
| 2 | 6 January - 10 January |
| 3 | 11 January - 15 January |
| 4 | 16 January - 20 January |
| 5 | 21 January - 25 January |
| 6 | 26 January - 30 January |
| 7 | 31 January - 4 February |
| 8 | 5 February - 9 February |
| 9 | 10 February - 14 February |
| 10 | 15 February - 19 February |
| 11 | 20 February - 24 February |
| 12 | 25 February - 1 March |
| 13 | 2 March - 6 March |
| 14 | 7 March - 11 March |
| 15 | 12 March - 16 March |
| 16 | 17 March - 21 March |
| 17 | 22 March - 26 March |
| 18 | 27 March - 31 March |
| 19 | 1 April - 5 April |
| 20 | 6 April - 10 April |
| 21 | 11 April - 15 April |

| | | |
|---|---|---|
| 22 | 16 April | - 20 April |
| 23 | 21 April | - 25 April |
| 24 | 26 April | - 30 April |
| 25 | 1 May | - 5 May |
| 26 | 6 May | - 10 May |
| 27 | 11 May | - 15 May |
| 28 | 16 May | - 21 May |
| 29 | 21 May | - 25 May |
| 30 | 26 May | - 30 May |
| 31 | 31 May | - 4 June |
| 32 | 5 June | - 9 June |
| 33 | 10 June | - 14 June |
| 34 | 15 June | - 19 June |
| 35 | 20 June | - 24 June |
| 36 | 25 June | - 29 June |
| 37 | 30 June | - 4 July |
| 38 | 5 July | - 9 July |
| 39 | 10 July | - 14 July |
| 40 | 15 July | - 19 July |
| 41 | 20 July | - 24 July |
| 42 | 25 July | - 29 July |
| 43 | 30 July | - 3 August |
| 44 | 4 August | - 8 August |
| 45 | 9 August | - 13 August |

| | |
|---|---|
| 46 | 14 August - 18 August |
| 47 | 19 August - 23 August |
| 48 | 24 August - 28 August |
| 49 | 29 August - 2 September |
| 50 | 3 September - 7 September |
| 51 | 8 September - 12 September |
| 52 | 13 September - 17 September |
| 53 | 18 September - 22 September |
| 54 | 23 September - 27 September |
| 55 | 28 September - 2 October |
| 56 | 3 October - 7 October |
| 57 | 8 October - 12 October |
| 58 | 13 October - 17 October |
| 59 | 18 October - 22 October |
| 60 | 23 October - 27 October |
| 61 | 28 October - 1 November |
| 62 | 2 November - 6 November |
| 63 | 7 November - 11 November |
| 64 | 12 November - 16 November |
| 65 | 17 November - 21 November |
| 66 | 22 November - 26 November |
| 67 | 27 November - 1 December |
| 68 | 2 December - 6 December |
| 69 | 7 December - 11 December |

| | |
|---|---|
| 70 | 12 December - 16 December |
| 71 | 17 December - 21 December |
| 72 | 22 December - 26 December |
| 73 | 27 December - 31 December |

APPENDIX B

Probable Depth of Precipitable Water

The probability (in percent), based on a normal distribution adjusted for skewness and kurtosis, that the depth of precipitable water will be equaled or exceeded during the pentad.

| | Depth of Precipitable Water (in.) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
| Pentad 1 | | | | | | | | | | |
| AMA | 84 | 22 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 87 | 55 | 14 | 7 | 1 | 0 | 0 | 0 | 0 | 0 |
| ELP | 91 | 38 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 94 | 82 | 49 | 22 | 8 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 71 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 2 | | | | | | | | | | |
| AMA | 82 | 30 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 90 | 50 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 87 | 45 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 94 | 83 | 56 | 30 | 10 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 75 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 3 | | | | | | | | | | |
| AMA | 82 | 29 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 87 | 56 | 15 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 85 | 50 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 92 | 82 | 59 | 35 | 16 | 4 | 0 | 0 | 0 | 0 |
| ABQ | 75 | 28 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 4 | | | | | | | | | | |
| AMA | 80 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 93 | 45 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 91 | 31 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 95 | 82 | 50 | 21 | 5 | 0 | 0 | 0 | 0 | 0 |
| ABQ | 79 | 14 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 5 | | | | | | | | | | |
| AMA | 83 | 22 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 95 | 50 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 90 | 37 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 94 | 83 | 55 | 27 | 10 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 84 | 18 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 6 | | | | | | | | | | |
| AMA | 87 | 33 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 93 | 52 | 9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 89 | 32 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 88 | 60 | 30 | 9 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 79 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 7 | | | | | | | | | | |
| AMA | 94 | 42 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 93 | 58 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 91 | 33 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 94 | 84 | 57 | 30 | 12 | 2 | 0 | 0 | 0 | 0 |
| ABQ | 77 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 8 | | | | | | | | | | |
| AMA | 94 | 44 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 94 | 57 | 9 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 91 | 35 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 93 | 81 | 51 | 25 | 9 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 83 | 19 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 9 | | | | | | | | | | |
| AMA | 86 | 37 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 89 | 56 | 12 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 84 | 37 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 94 | 84 | 56 | 29 | 11 | 2 | 0 | 0 | 0 | 0 |
| ABQ | 79 | 24 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 10 | | | | | | | | | | |
| AMA | 90 | 38 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 90 | 55 | 11 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 85 | 27 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 96 | 87 | 60 | 31 | 9 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 78 | 13 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 11 | | | | | | | | | | |
| AMA | 83 | 39 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 85 | 55 | 14 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 79 | 35 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 90 | 67 | 38 | 14 | 2 | 0 | 0 | 0 | 0 |
| ABQ | 77 | 25 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 12 | | | | | | | | | | |
| AMA | 87 | 20 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 89 | 46 | 9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 83 | 26 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 95 | 86 | 58 | 29 | 10 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 76 | 21 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 13 | | | | | | | | | | |
| AMA | 82 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 99 | 42 | 7 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 86 | 30 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 96 | 88 | 62 | 32 | 11 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 76 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 14 | | | | | | | | | | |
| AMA | 87 | 32 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 89 | 59 | 16 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 82 | 42 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 90 | 65 | 35 | 13 | 3 | 0 | 0 | 0 | 0 |
| ABQ | 76 | 19 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 15 | | | | | | | | | | |
| AMA | 88 | 29 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 92 | 52 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 88 | 21 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 96 | 86 | 59 | 32 | 11 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 75 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 16 | | | | | | | | | | |
| AMA | 93 | 51 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 94 | 58 | 9 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 87 | 38 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 96 | 88 | 61 | 33 | 13 | 3 | 0 | 0 | 0 | 0 |
| ABQ | 80 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 17 | | | | | | | | | | |
| AMA | 95 | 54 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 93 | 59 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 86 | 34 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 89 | 62 | 31 | 12 | 2 | 0 | 0 | 0 | 0 |
| ABQ | 85 | 22 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 18 | | | | | | | | | | |
| AMA | 91 | 52 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 94 | 64 | 12 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 93 | 39 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 98 | 94 | 71 | 37 | 11 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 85 | 22 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 19 | | | | | | | | | | |
| AMA | 93 | 61 | 11 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 96 | 67 | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 95 | 38 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 98 | 93 | 74 | 46 | 20 | 4 | 0 | 0 | 0 | 0 |
| ABQ | 88 | 26 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 20 | | | | | | | | | | |
| AMA | 97 | 68 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 75 | 15 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 94 | 47 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 98 | 96 | 79 | 51 | 24 | 6 | 0 | 0 | 0 | 0 |
| ABQ | 91 | 43 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 21 | | | | | | | | | | |
| AMA | 94 | 64 | 13 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 93 | 74 | 27 | 6 | 1 | 0 | 0 | 0 | 0 | 0 |
| ELP | 88 | 48 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 98 | 93 | 75 | 49 | 24 | 6 | 0 | 0 | 0 | 0 |
| ABQ | 85 | 28 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 22 | | | | | | | | | | |
| AMA | 94 | 64 | 13 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 97 | 83 | 42 | 11 | 1 | 0 | 0 | 0 | 0 | 0 |
| ELP | 95 | 59 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 99 | 97 | 86 | 61 | 31 | 9 | 1 | 0 | 0 | 0 |
| ABQ | 87 | 35 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 23 | | | | | | | | | | |
| AMA | 95 | 67 | 16 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 89 | 38 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 92 | 60 | 12 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 100 | 99 | 95 | 80 | 48 | 17 | 2 | 0 | 0 | 0 |
| ABQ | 90 | 48 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 24 | | | | | | | | | | |
| AMA | 96 | 76 | 26 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 96 | 84 | 45 | 14 | 1 | 0 | 0 | 0 | 0 | 0 |
| ELP | 93 | 58 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 99 | 98 | 92 | 78 | 53 | 25 | 6 | 0 | 0 | 0 |
| ABQ | 95 | 54 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 25 | | | | | | | | | | |
| AMA | 98 | 86 | 43 | 13 | 2 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 87 | 49 | 15 | 1 | 0 | 0 | 0 | 0 | 0 |
| ELP | 95 | 61 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 99 | 98 | 92 | 75 | 47 | 19 | 3 | 0 | 0 | 0 |
| ABQ | 95 | 55 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 26 | | | | | | | | | | |
| AMA | 97 | 87 | 46 | 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 93 | 62 | 25 | 5 | 0 | 0 | 0 | 0 | 0 |
| ELP | 97 | 75 | 16 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 100 | 99 | 94 | 80 | 55 | 27 | 6 | 0 | 0 | 0 |
| ABQ | 94 | 64 | 11 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 27 | | | | | | | | | | |
| AMA | 98 | 89 | 54 | 16 | 1 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 95 | 71 | 33 | 6 | 0 | 0 | 0 | 0 | 0 |
| ELP | 97 | 74 | 18 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 100 | 99 | 96 | 84 | 60 | 30 | 8 | 1 | 0 | 0 |
| ABQ | 97 | 68 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 28 | | | | | | | | | | |
| AMA | 99 | 95 | 69 | 26 | 1 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 94 | 74 | 40 | 10 | 0 | 0 | 0 | 0 | 0 |
| ELP | 96 | 74 | 25 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 100 | 99 | 97 | 89 | 68 | 36 | 9 | 1 | 0 | 0 |
| ABQ | 97 | 74 | 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 29 | | | | | | | | | | |
| AMA | 97 | 91 | 66 | 30 | 5 | 0 | 0 | 0 | 0 | 0 |
| BGS | 99 | 96 | 77 | 41 | 10 | 0 | 0 | 0 | 0 | 0 |
| ELP | 97 | 80 | 33 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 100 | 99 | 98 | 94 | 79 | 39 | 8 | 1 | 0 | 0 |
| ABQ | 97 | 79 | 24 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 30 | | | | | | | | | | |
| AMA | 98 | 92 | 64 | 29 | 6 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 96 | 81 | 47 | 14 | 2 | 0 | 0 | 0 | 0 |
| ELP | 96 | 79 | 35 | 8 | 1 | 0 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 99 | 96 | 80 | 44 | 10 | 0 | 0 | 0 |
| ABQ | 95 | 74 | 24 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 31 | | | | | | | | | | |
| AMA | 100 | 99 | 87 | 50 | 10 | 0 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 95 | 69 | 26 | 2 | 0 | 0 | 0 | 0 |
| ELP | 97 | 85 | 46 | 16 | 2 | 0 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 99 | 92 | 68 | 34 | 9 | 1 | 0 | 0 |
| ABQ | 97 | 80 | 27 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 32 | | | | | | | | | | |
| AMA | 99 | 97 | 85 | 51 | 9 | 0 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 96 | 72 | 25 | 2 | 0 | 0 | 0 | 0 |
| ELP | 97 | 82 | 38 | 11 | 2 | 0 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 99 | 98 | 86 | 48 | 10 | 0 | 0 | 0 |
| ABQ | 96 | 78 | 28 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 33 | | | | | | | | | | |
| AMA | 99 | 97 | 84 | 53 | 18 | 1 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 98 | 80 | 40 | 10 | 1 | 0 | 0 | 0 |
| ELP | 98 | 94 | 70 | 33 | 9 | 1 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 99 | 98 | 91 | 60 | 22 | 4 | 0 | 0 |
| ABQ | 98 | 86 | 45 | 12 | 1 | 0 | 0 | 0 | 0 | 0 |
| Pentad 34 | | | | | | | | | | |
| AMA | 100 | 99 | 92 | 66 | 27 | 3 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 97 | 75 | 34 | 10 | 1 | 0 | 0 | 0 |
| ELP | 98 | 92 | 67 | 35 | 11 | 1 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 92 | 66 | 32 | 10 | 1 | 0 |
| ABQ | 98 | 89 | 52 | 17 | 1 | 0 | 0 | 0 | 0 | 0 |
| Pentad 35 | | | | | | | | | | |
| AMA | 100 | 99 | 92 | 62 | 24 | 2 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 97 | 81 | 41 | 10 | 1 | 0 | 0 | 0 |
| ELP | 99 | 97 | 75 | 35 | 8 | 1 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 99 | 98 | 92 | 72 | 41 | 13 | 1 | 0 |
| ABQ | 97 | 87 | 50 | 15 | 1 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pentad 36** | | | | | | | | | | |
| AMA | 100 | 99 | 95 | 67 | 25 | 3 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 98 | 83 | 45 | 13 | 1 | 0 | 0 | 0 |
| ELP | 99 | 98 | 87 | 48 | 12 | 1 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 95 | 73 | 36 | 10 | 1 | 0 |
| ABQ | 99 | 93 | 47 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Pentad 37** | | | | | | | | | | |
| AMA | 100 | 99 | 97 | 81 | 43 | 7 | 0 | 0 | 0 | 0 |
| BGS | 100 | 100 | 99 | 91 | 56 | 18 | 1 | 0 | 0 | 0 |
| ELP | 100 | 99 | 95 | 75 | 26 | 1 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 97 | 80 | 42 | 9 | 1 | 0 |
| ABQ | 99 | 97 | 78 | 36 | 4 | 0 | 0 | 0 | 0 | 0 |
| **Pentad 38** | | | | | | | | | | |
| AMA | 100 | 99 | 97 | 85 | 54 | 17 | 1 | 0 | 0 | 0 |
| BGS | 100 | 99 | 98 | 90 | 63 | 25 | 3 | 0 | 0 | 0 |
| ELP | 100 | 99 | 97 | 84 | 49 | 13 | 1 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 93 | 71 | 32 | 5 | 0 | 0 |
| ABQ | 100 | 99 | 92 | 62 | 15 | 0 | 0 | 0 | 0 | 0 |
| **Pentad 39** | | | | | | | | | | |
| AMA | 100 | 99 | 98 | 81 | 41 | 9 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 98 | 88 | 58 | 25 | 4 | 0 | 0 | 0 |
| ELP | 100 | 99 | 98 | 85 | 45 | 8 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 94 | 76 | 44 | 14 | 1 | 0 |
| ABQ | 99 | 98 | 89 | 56 | 16 | 1 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 40 | | | | | | | | | | |
| AMA | 100 | 99 | 96 | 85 | 47 | 9 | 0 | 0 | 0 | 0 |
| BGS | 100 | 100 | 99 | 93 | 66 | 25 | 3 | 0 | 0 | 0 |
| ELP | 100 | 99 | 98 | 86 | 44 | 5 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 95 | 79 | 45 | 12 | 1 | 0 |
| ABQ | 100 | 99 | 95 | 63 | 13 | 0 | 0 | 0 | 0 | 0 |
| Pentad 41 | | | | | | | | | | |
| AMA | 100 | 100 | 99 | 90 | 52 | 13 | 1 | 0 | 0 | 0 |
| BGS | 100 | 100 | 99 | 96 | 70 | 29 | 3 | 0 | 0 | 0 |
| ELP | 100 | 99 | 97 | 82 | 49 | 13 | 1 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 95 | 77 | 42 | 11 | 1 | 0 |
| ABQ | 100 | 99 | 94 | 65 | 15 | 0 | 0 | 0 | 0 | 0 |
| Pentad 42 | | | | | | | | | | |
| AMA | 100 | 100 | 99 | 88 | 44 | 8 | 0 | 0 | 0 | 0 |
| BGS | 100 | 100 | 99 | 93 | 66 | 31 | 7 | 0 | 0 | 0 |
| ELP | 100 | 99 | 98 | 87 | 55 | 15 | 1 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 96 | 76 | 35 | 7 | 0 | 0 |
| ABQ | 100 | 99 | 98 | 73 | 16 | 0 | 0 | 0 | 0 | 0 |
| Pentad 43 | | | | | | | | | | |
| AMA | 100 | 99 | 97 | 93 | 66 | 10 | 0 | 0 | 0 | 0 |
| BGS | 100 | 100 | 99 | 97 | 76 | 27 | 1 | 0 | 0 | 0 |
| ELP | 100 | 99 | 98 | 91 | 59 | 9 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 95 | 75 | 40 | 11 | 1 | 0 |
| ABQ | 100 | 99 | 98 | 79 | 24 | 1 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 44 | | | | | | | | | | |
| AMA | 100 | 99 | 97 | 87 | 55 | 17 | 1 | 0 | 0 | 0 |
| BGS | 100 | 100 | 99 | 93 | 63 | 19 | 1 | 0 | 0 | 0 |
| ELP | 100 | 99 | 97 | 85 | 46 | 9 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 95 | 71 | 30 | 5 | 0 | 0 |
| ABQ | 100 | 99 | 94 | 71 | 26 | 1 | 0 | 0 | 0 | 0 |
| Pentad 45 | | | | | | | | | | |
| AMA | 100 | 99 | 98 | 87 | 52 | 11 | 0 | 0 | 0 | 0 |
| BGS | 100 | 100 | 99 | 92 | 61 | 23 | 3 | 0 | 0 | 0 |
| ELP | 100 | 99 | 98 | 88 | 44 | 5 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 97 | 76 | 36 | 6 | 0 | 0 |
| ABQ | 100 | 99 | 96 | 73 | 19 | 0 | 0 | 0 | 0 | 0 |
| Pentad 46 | | | | | | | | | | |
| AMA | 100 | 100 | 99 | 90 | 54 | 15 | 1 | 0 | 0 | 0 |
| BGS | 100 | 100 | 99 | 96 | 68 | 27 | 3 | 0 | 0 | 0 |
| ELP | 100 | 99 | 98 | 88 | 49 | 7 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 98 | 80 | 42 | 10 | 1 | 0 |
| ABQ | 100 | 99 | 96 | 75 | 19 | 0 | 0 | 0 | 0 | 0 |
| Pentad 47 | | | | | | | | | | |
| AMA | 100 | 99 | 98 | 82 | 49 | 17 | 1 | 0 | 0 | 0 |
| BGS | 100 | 100 | 99 | 92 | 67 | 32 | 7 | 0 | 0 | 0 |
| ELP | 100 | 99 | 97 | 86 | 54 | 15 | 1 | 0 | 0 | 0 |
| SAT | 100 | 100 | 100 | 99 | 93 | 76 | 50 | 20 | 2 | 0 |
| ABQ | 99 | 98 | 91 | 66 | 22 | 1 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 48 | | | | | | | | | | |
| AMA | 100 | 99 | 97 | 78 | 36 | 6 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 98 | 84 | 53 | 18 | 2 | 0 | 0 | 0 |
| ELP | 100 | 99 | 96 | 76 | 37 | 8 | 1 | 0 | 0 | 0 |
| SAT | 100 | 100 | 99 | 97 | 90 | 72 | 47 | 20 | 4 | 0 |
| ABQ | 99 | 98 | 88 | 54 | 14 | 1 | 0 | 0 | 0 | 0 |
| Pentad 49 | | | | | | | | | | |
| AMA | 100 | 99 | 90 | 65 | 33 | 9 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 97 | 84 | 56 | 22 | 3 | 0 | 0 | 0 |
| ELP | 99 | 98 | 92 | 71 | 36 | 7 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 99 | 98 | 94 | 78 | 42 | 10 | 1 | 0 |
| ABQ | 99 | 97 | 81 | 39 | 6 | 0 | 0 | 0 | 0 | 0 |
| Pentad 50 | | | | | | | | | | |
| AMA | 100 | 99 | 92 | 58 | 20 | 3 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 96 | 80 | 47 | 14 | 1 | 0 | 0 | 0 |
| ELP | 99 | 98 | 88 | 58 | 24 | 3 | 0 | 0 | 0 | 0 |
| SAT | 100 | 100 | 99 | 96 | 88 | 69 | 38 | 11 | 1 | 0 |
| ABQ | 99 | 96 | 73 | 33 | 5 | 0 | 0 | 0 | 0 | 0 |
| Pentad 51 | | | | | | | | | | |
| AMA | 99 | 97 | 85 | 27 | 6 | 0 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 92 | 74 | 49 | 23 | 5 | 0 | 0 | 0 |
| ELP | 99 | 98 | 86 | 62 | 32 | 9 | 1 | 0 | 0 | 0 |
| SAT | 100 | 99 | 98 | 95 | 88 | 73 | 50 | 23 | 5 | 0 |
| ABQ | 98 | 94 | 71 | 35 | 7 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 52 | | | | | | | | | | |
| AMA | 99 | 98 | 81 | 42 | 12 | 2 | 0 | 0 | 0 | 0 |
| BGS | 99 | 98 | 88 | 62 | 33 | 11 | 1 | 0 | 0 | 0 |
| ELP | 98 | 96 | 75 | 42 | 16 | 4 | 0 | 0 | 0 | 0 |
| SAT | 100 | 99 | 98 | 94 | 82 | 60 | 35 | 13 | 2 | 0 |
| ABQ | 98 | 89 | 54 | 18 | 3 | 0 | 0 | 0 | 0 | 0 |
| Pentad 53 | | | | | | | | | | |
| AMA | 100 | 99 | 85 | 42 | 10 | 1 | 0 | 0 | 0 | 0 |
| BGS | 100 | 99 | 91 | 67 | 34 | 11 | 1 | 0 | 0 | 0 |
| ELP | 99 | 98 | 79 | 44 | 14 | 1 | 0 | 0 | 0 | 0 |
| SAT | 100 | 99 | 98 | 94 | 79 | 58 | 34 | 15 | 3 | 0 |
| ABQ | 98 | 89 | 54 | 20 | 3 | 0 | 0 | 0 | 0 | 0 |
| Pentad 54 | | | | | | | | | | |
| AMA | 99 | 95 | 75 | 41 | 14 | 1 | 0 | 0 | 0 | 0 |
| BGS | 99 | 98 | 88 | 63 | 32 | 11 | 1 | 0 | 0 | 0 |
| ELP | 99 | 95 | 72 | 39 | 13 | 2 | 0 | 0 | 0 | 0 |
| SAT | 100 | 99 | 96 | 87 | 73 | 54 | 32 | 14 | 4 | 0 |
| ABQ | 98 | 88 | 48 | 14 | 1 | 0 | 0 | 0 | 0 | 0 |
| Pentad 55 | | | | | | | | | | |
| AMA | 99 | 97 | 63 | 17 | 5 | 1 | 0 | 0 | 0 | 0 |
| BGS | 99 | 96 | 77 | 44 | 19 | 6 | 1 | 0 | 0 | 0 |
| ELP | 99 | 96 | 70 | 30 | 8 | 1 | 0 | 0 | 0 | 0 |
| SAT | 99 | 97 | 90 | 75 | 56 | 36 | 19 | 8 | 1 | 0 |
| ABQ | 99 | 92 | 45 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 56 | | | | | | | | | | |
| AMA | 95 | 82 | 48 | 20 | 8 | 4 | 0 | 0 | 0 | 0 |
| BGS | 98 | 92 | 73 | 47 | 25 | 9 | 1 | 0 | 0 | 0 |
| ELP | 97 | 88 | 59 | 28 | 11 | 2 | 0 | 0 | 0 | 0 |
| SAT | 99 | 98 | 93 | 81 | 63 | 41 | 22 | 7 | 1 | 0 |
| ABQ | 97 | 82 | 34 | 7 | 1 | 0 | 0 | 0 | 0 | 0 |
| Pentad 57 | | | | | | | | | | |
| AMA | 98 | 84 | 35 | 9 | 2 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 88 | 57 | 26 | 10 | 2 | 0 | 0 | 0 | 0 |
| ELP | 98 | 86 | 40 | 11 | 1 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 96 | 87 | 70 | 51 | 31 | 15 | 4 | 1 | 0 |
| ABQ | 97 | 76 | 14 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 58 | | | | | | | | | | |
| AMA | 99 | 89 | 47 | 13 | 1 | 0 | 0 | 0 | 0 | 0 |
| BGS | 99 | 94 | 64 | 26 | 6 | 0 | 0 | 0 | 0 | 0 |
| ELP | 98 | 89 | 49 | 13 | 1 | 0 | 0 | 0 | 0 | 0 |
| SAT | 98 | 97 | 87 | 68 | 44 | 24 | 9 | 1 | 0 | 0 |
| ABQ | 97 | 74 | 16 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 59 | | | | | | | | | | |
| AMA | 95 | 80 | 36 | 11 | 2 | 0 | 0 | 0 | 0 | 0 |
| BGS | 99 | 91 | 61 | 28 | 9 | 1 | 0 | 0 | 0 | 0 |
| ELP | 98 | 86 | 41 | 9 | 1 | 0 | 0 | 0 | 0 | 0 |
| SAT | 98 | 97 | 86 | 66 | 44 | 24 | 9 | 2 | 0 | 0 |
| ABQ | 96 | 72 | 17 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 60 | | | | | | | | | | |
| AMA | 99 | 84 | 22 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 99 | 90 | 52 | 18 | 4 | 0 | 0 | 0 | 0 | 0 |
| ELP | 98 | 83 | 24 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 98 | 96 | 84 | 63 | 40 | 21 | 8 | 1 | 0 | 0 |
| ABQ | 96 | 61 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 61 | | | | | | | | | | |
| AMA | 98 | 81 | 25 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 88 | 47 | 14 | 2 | 0 | 0 | 0 | 0 | 0 |
| ELP | 98 | 84 | 24 | 6 | 1 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 95 | 83 | 63 | 41 | 20 | 6 | 1 | 0 | 0 |
| ABQ | 95 | 63 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 62 | | | | | | | | | | |
| AMA | 96 | 75 | 16 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 97 | 81 | 30 | 9 | 2 | 0 | 0 | 0 | 0 | 0 |
| ELP | 96 | 64 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 93 | 76 | 52 | 30 | 14 | 4 | 1 | 0 | 0 |
| ABQ | 93 | 45 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 63 | | | | | | | | | | |
| AMA | 95 | 60 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 97 | 76 | 20 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 96 | 55 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 91 | 65 | 32 | 12 | 3 | 0 | 0 | 0 | 0 |
| ABQ | 91 | 23 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

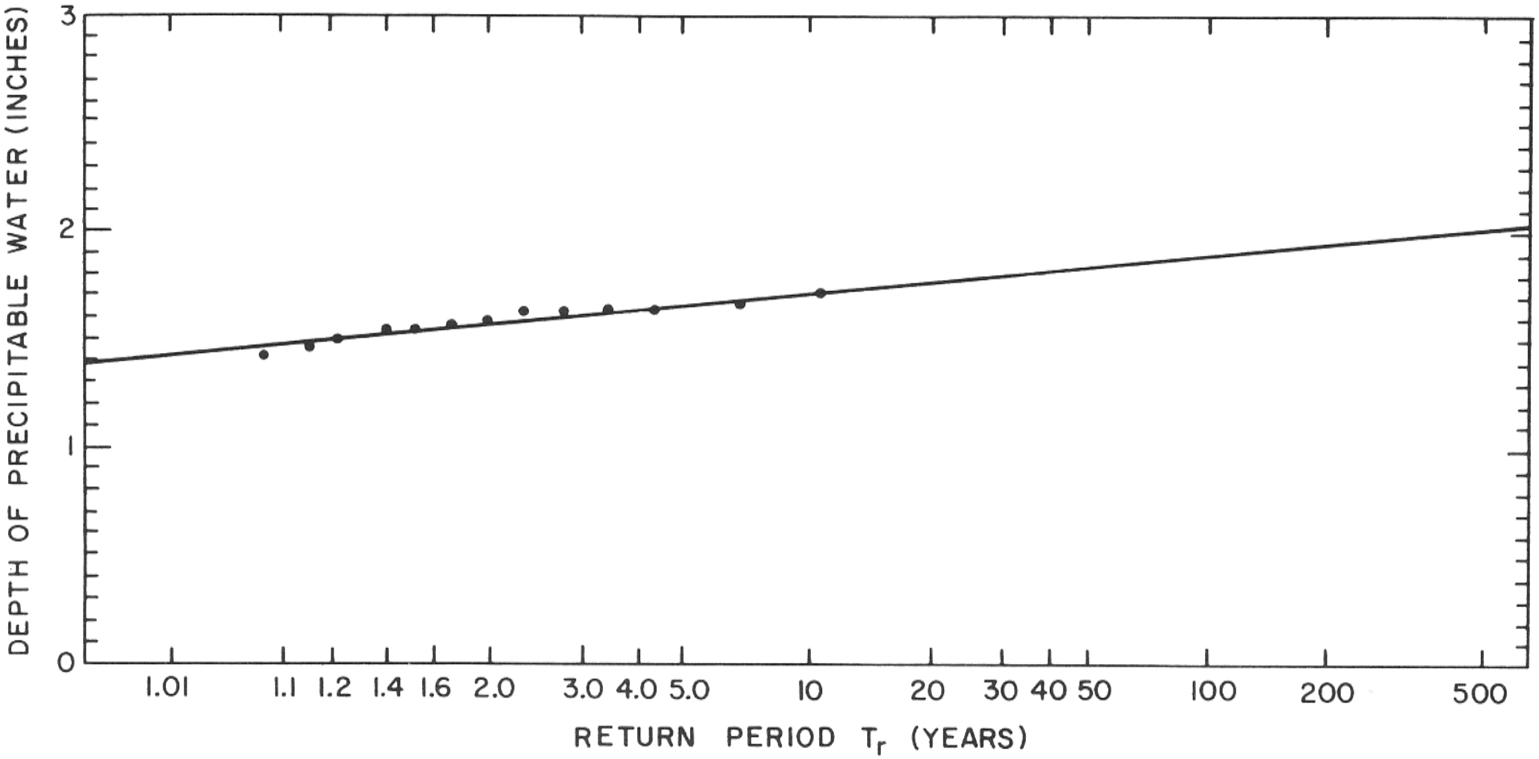
| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 64 | | | | | | | | | | |
| AMA | 96 | 62 | 8 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 97 | 77 | 17 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 96 | 63 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 98 | 94 | 79 | 57 | 34 | 14 | 3 | 0 | 0 | 0 |
| ABQ | 93 | 39 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 65 | | | | | | | | | | |
| AMA | 90 | 41 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 95 | 68 | 15 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 90 | 46 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 92 | 72 | 44 | 21 | 6 | 1 | 0 | 0 | 0 |
| ABQ | 90 | 19 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 66 | | | | | | | | | | |
| AMA | 93 | 43 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 97 | 65 | 11 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 95 | 54 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 96 | 87 | 64 | 39 | 19 | 6 | 1 | 0 | 0 | 0 |
| ABQ | 94 | 19 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 67 | | | | | | | | | | |
| AMA | 88 | 44 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 94 | 60 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 92 | 47 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 96 | 86 | 57 | 28 | 9 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 84 | 21 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 68 | | | | | | | | | | |
| AMA | 88 | 41 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 93 | 60 | 11 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 92 | 51 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 95 | 86 | 60 | 33 | 14 | 3 | 0 | 0 | 0 | 0 |
| ABQ | 80 | 26 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 69 | | | | | | | | | | |
| AMA | 88 | 42 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 91 | 61 | 14 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 91 | 51 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 94 | 86 | 62 | 36 | 17 | 6 | 1 | 0 | 0 | 0 |
| ABQ | 81 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 70 | | | | | | | | | | |
| AMA | 87 | 31 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 98 | 50 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 97 | 43 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 97 | 87 | 49 | 16 | 7 | 4 | 1 | 0 | 0 | 0 |
| ABQ | 77 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 71 | | | | | | | | | | |
| AMA | 94 | 34 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 95 | 60 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 90 | 40 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 96 | 87 | 59 | 28 | 10 | 2 | 0 | 0 | 0 | 0 |
| ABQ | 93 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

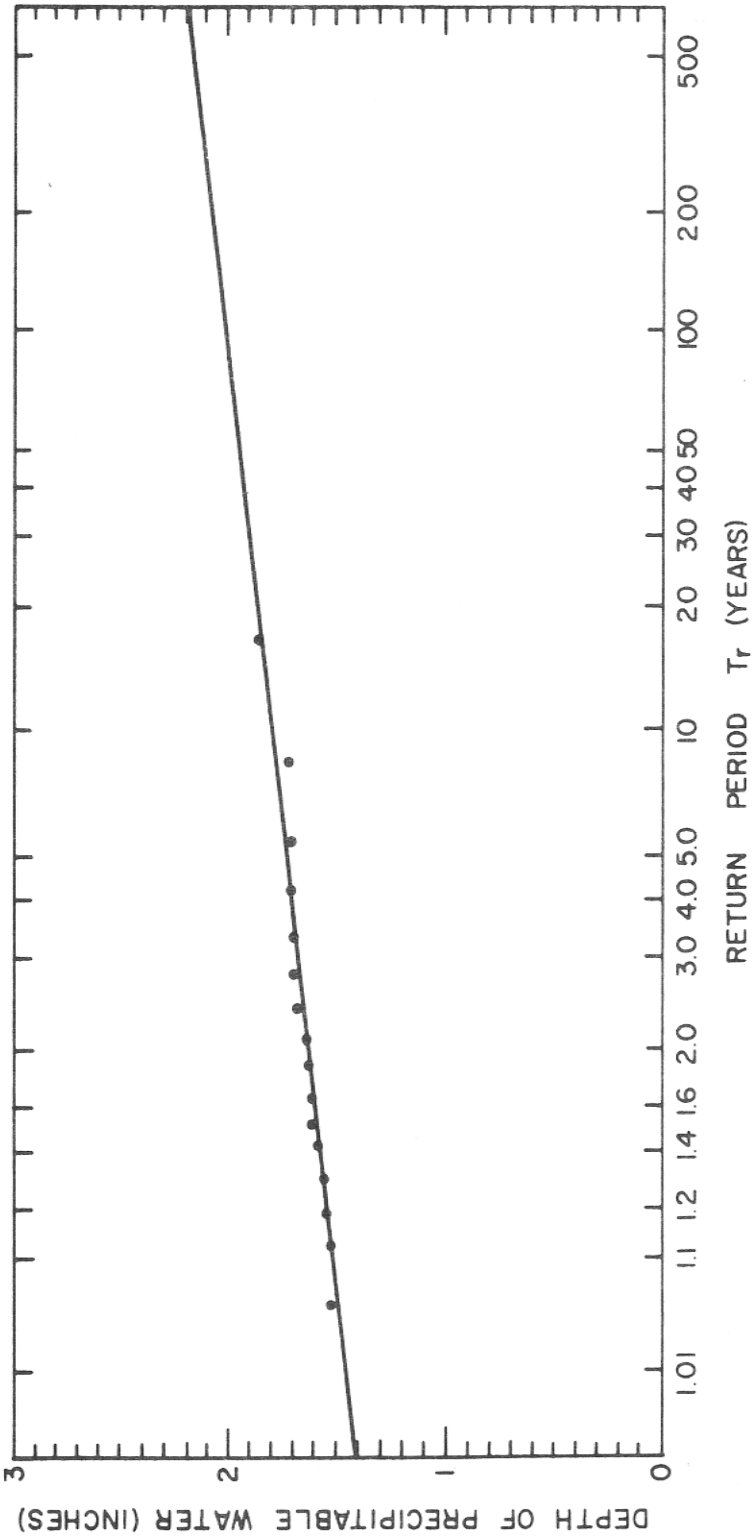
| | 0.10 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentad 72 | | | | | | | | | | |
| AMA | 89 | 26 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 95 | 48 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 90 | 35 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 96 | 86 | 51 | 21 | 7 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 79 | 21 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pentad 73 | | | | | | | | | | |
| AMA | 85 | 25 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BGS | 93 | 48 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ELP | 90 | 27 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SAT | 94 | 82 | 52 | 25 | 8 | 1 | 0 | 0 | 0 | 0 |
| ABQ | 79 | 14 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## APPENDIX C
## Plot of Annual Series

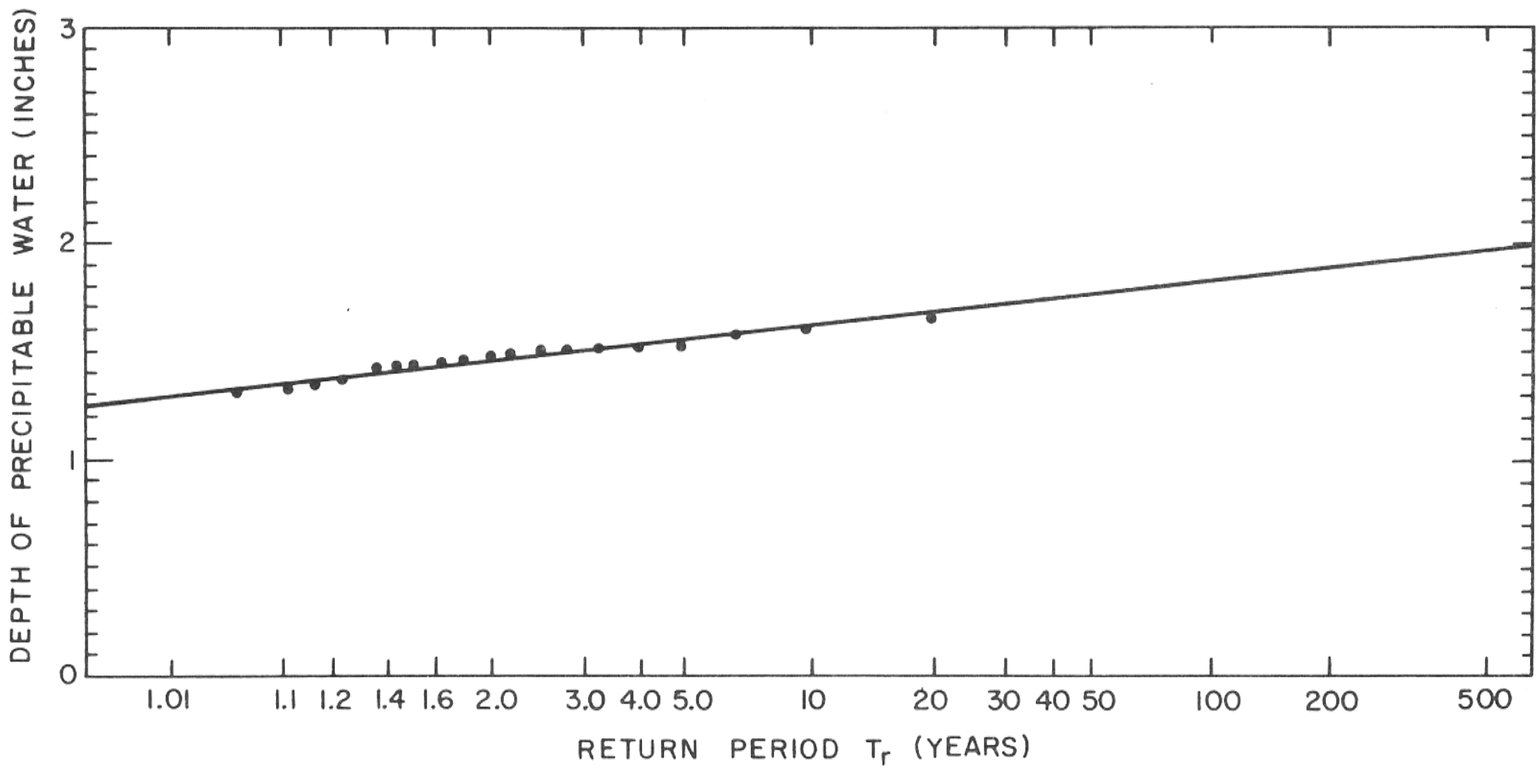
The five graphs that follow represent the Gumbel distribution applied to the annual series of each station. The return period for a given amount of depth of precipitable water may be found at the intersection of the Gumbel distribution line with the value of the depth.



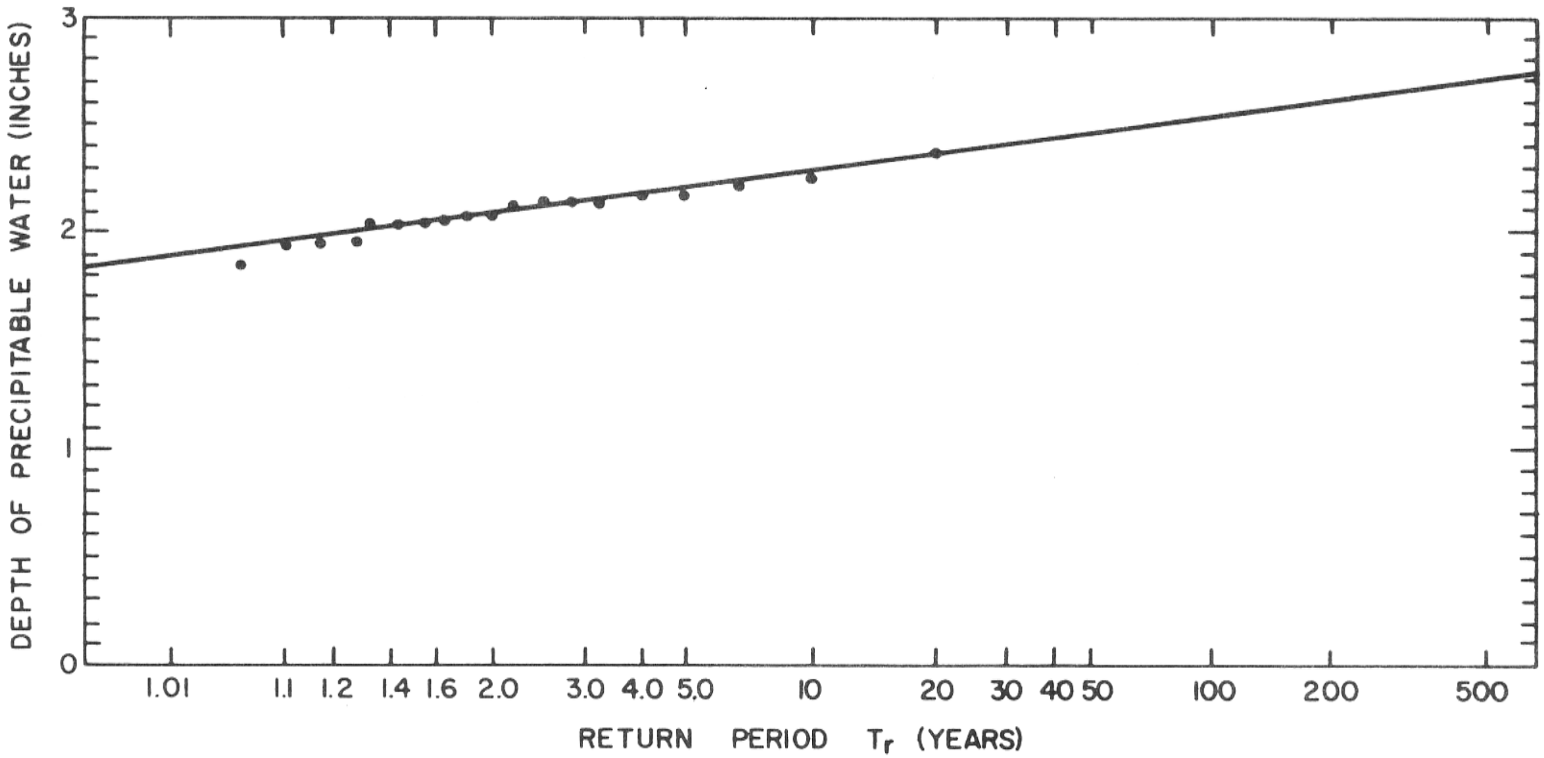

**AMA ANNUAL SERIES**



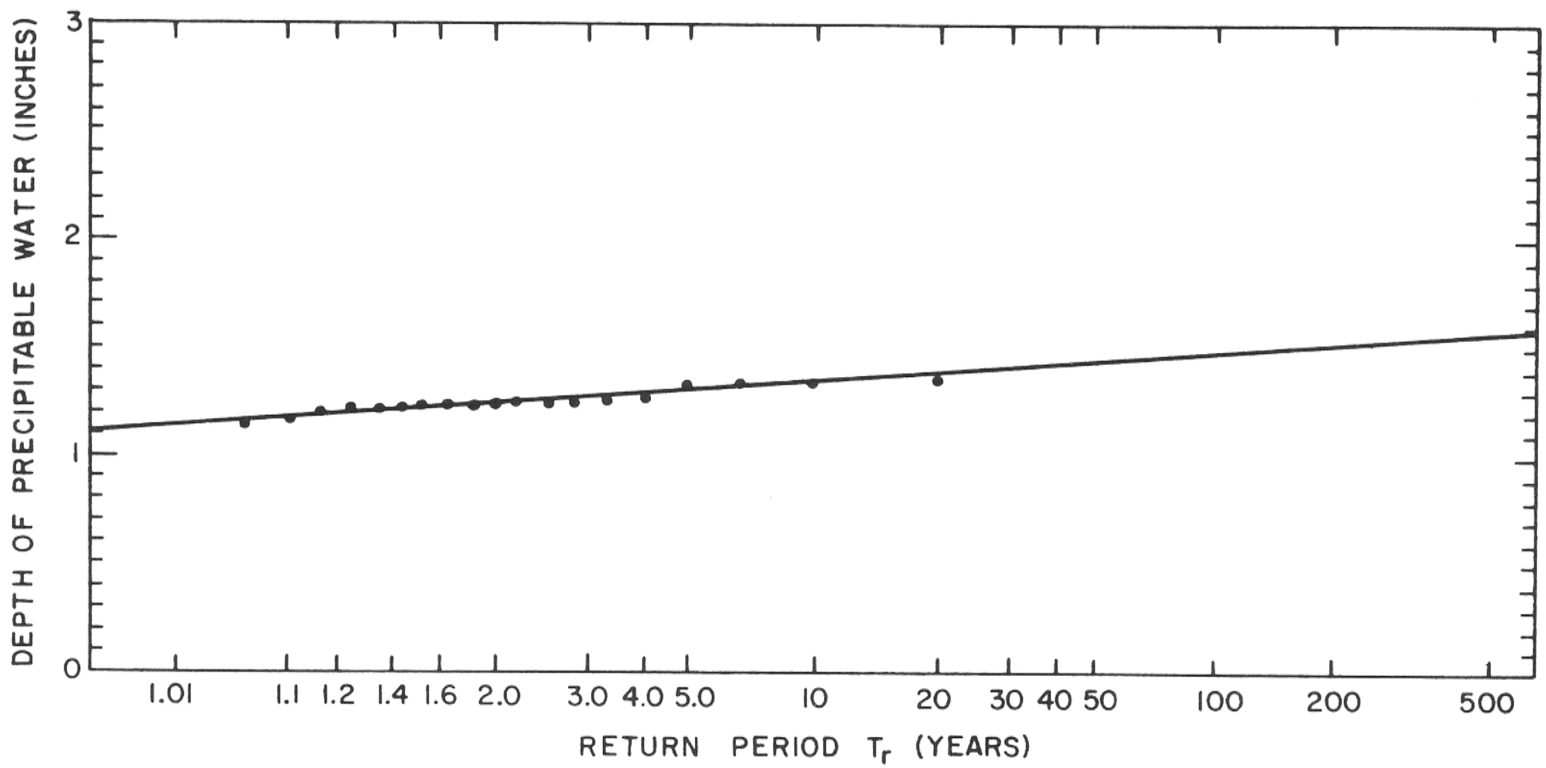

BGS ANNUAL SERIES




ELP ANNUAL SERIES




SAT ANNUAL SERIES




ABQ ANNUAL SERIES