PROBABILITY OF EXTREME 24-HOUR PRECIPITATION EVENTS IN FORT COLLINS

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In Fort Collins

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I. Introduction

Current practices for the design of small dams include protection against severe short term precipitation events from approximately six hours to 24 hours in duration. The basic guide used in establishing criteria used in Colorado is a publication prepared by the Bureau of Reclamation (1973). The precipitation material in this guide are derived from studies published by Riedel et. al. (1956) and Riedel et. al. (1969) in which probable maximum precipitation (PMP) maps were prepared. The PMP concept is then the basis for design of small dams. Inherent in the techniques used to arrive at PMP values is the intent to obtain values representative of the limit of natural events. Thus, the PMP values are a theoretical limit which are not expected to occur or whose probability of occurrence are near zero. The use of PMP is consistent with a design philosophy which intends to assume no risk where loss of human life is at stake.

The feature excluded by use of PMP is any information about the probability of various extreme precipitation events. The purpose of the present discussion is to illustrate the probability of 24-hour precipitation amounts using Ft. Collins data or variations from it. A discussion of the statistical basis precedes the discussion of the results and the basis is very important, since the results depend on the basis.

For reference later, the PMP for Ft. Collins has been obtained from the Bureau of Reclamation (1973). For six-hour 10 square mile event, a PMP of 21.5 inches is given. Extension to a 24-hour period adds 18% to the six-hour value to bring the 24-hour 10 square mile PMP to 25.4 inches, which will be used as 25 inches. The PMP decreases as the area increases and for 100 square miles is 20.4 inches and for 1000 square miles is 16.5 inches.

II. Statistical Approach

The approach used in describing precipitation events statistically begins with the assumption that the observed precipitation events are members of a much larger population which specifies the probability of events. A function is chosen to represent the total population and is fitted to the observed data. Once the function is fitted to the observed data, then probabilities of events not contained in the observed set can be derived from the function. Two questions which remain are whether or not the function correctly describes the population and is the sample data an adequate set to describe the function? These questions are not completely answered in the present discussion but are explored by examining the sensitivity to including a low probability event in the record.

The observed precipitation used in this study was the 24-hour maximum precipitation event for each year from 1900 through 1972 which yields a sample size of 73 values. A distribution of these events is shown in Figure 1. The most frequent event lies in the range of 1.0 inches to 1.5 inches, and the maximum 24-hour precipitation on record is 4.34 inches in 1902.

A function used to describe precipitation data has been reported by Mielke (1973). The function is a kappa function, and it provides a rather conservative estimate (higher probabilities) for large precipitation events compared with other frequently used functions, such as the Fisher-Tippet type I (1928). The results of fitting Ft. Collins' data to a three-parameter kappa is described in the next section.

III. Statistical Results

Two cases have been examined with the three-parameter kappa distribution. Case I used 73 years of observed 24-hour maximum precipitation. Case II used 73 years of observed data plus one extra year in which a rare event of 10 inches occurred.

Case I results are shown in Fig. 2 and Fig. 3. The two figures contain identical information presented in two different formats. Probability of an event is plotted as a function of the 24-hour precipitation. One line on the graph is for a specified time period and time periods of 1, 10, 50 and 100 years are shown.

All of the lines in Fig. 2 show the basic structure of the probability of precipitation. The lines drop from near 100% to near 20% rapidly and then below 10% the lines change slope dramatically and small changes in probability are associated with large changes in precipitation amount. Of course a probability of zero would occur with infinite precipitation. The presentation in Fig. 3 on semilog graph paper has probability changing from 100% to 0.001% and provides a large spread in the various lines at low probability and also allows better accuracy in reading low values of probability.

One term often used in describing 24-hour precipitation or river flow is the return period. The return period in years is the reciprocal of the probability of an event in one year. Thus the curve for one year gives a probability of 2% for a precipitation of 4.3 inches which is the 50 year return period. At 1% the precipitation is 5.2, which is the 100 year return period. Values published by Miller et. al.(1973) using a different technique and data set are 4.2 and 4.8 respectively. Other return periods can be read from the graph. For example, a 200 year return period with probability of 0.5% is 6.3 inches.

For design purposes, the return period has a very limited use because of its definition. The data in Fig. 3 gives a much more complete picture than return period. Consider an example using the 100 year return period at 5.2 inches. The definition states that there is a 1% chance of having a 24-hour precipitation at 5.2 inches in one (1) year. No consideration is given and no information conveyed about how the probability of such an event changes with time. Time is a key variable. How does the probability of getting a 5.2 inch event change with time? From the graph in Fig. 3, the probability is 1% in one year, 9.5% in ten years, 36% in 50 years and 63% in 100 years. If the problem is to consider precipitation possibities for 100 years, then a 5.2 inch event is quite likely with a 63% change of occurrence.

Another approach might be to determine the precipitation which has a probability of 1% in 100 years which is about 18.4 inches. This is a more rare event and has a chance of only 0.0033% in one year.

The PMP described earlier was 25 inches. From Fig. 3 the probability of a 25 inch event in 100 years is 0.33%. Recall that all this is based on the 73 year period of record for Fort Collins.

Case II results are shown in Fig. 4. Only the one year and 100 year curves are presented. The same curves from Case I are included for comparison. The 100 year return period would change from 5.3 inches to 6.3 inches. For more rare events, the results change markedly. A 10 inch event for Case I had a probability of 9% in 100 years. With the addition of a 10 inch event in the record, the probability jumped from 9% up to 21% in 100 years. The conclusion is that the occurrence of one really rare event would strongly effect the predicted probabilities of other rare events.

IV. Discussion

The two cases described above provide a description of the probabilities of large 24-hour precipitation events. The graphs extend predictions to very small probabilities and thus large 24-hour precipitation which are far removed from the observed data. Notice in Fig. 4 that the Case I and II curves are quite close for precipitation amounts within the observed record of 4.34 inches. The large differences in Fig. 4 for large precipitation amounts occur near the bottom of Fig. 2 after the curve has changed slope and entered the tail region.

The basic shape of the probability curves in Fig. 2 give a valid picture of how large changes in precipitation occur at small probabilities. The relative positions of the lines for 1, 10, 50 and 100 years are also correct. However, the precise shape of the curves, particularly below 10% probability, is dependent on the function assumed at the beginning. No attempt has been made to prove that the kappa distribution is the best choice to use with precipitation data. Kappa was chosen because it appears to fit precipitation well and it provides a conservative estimate at large events.

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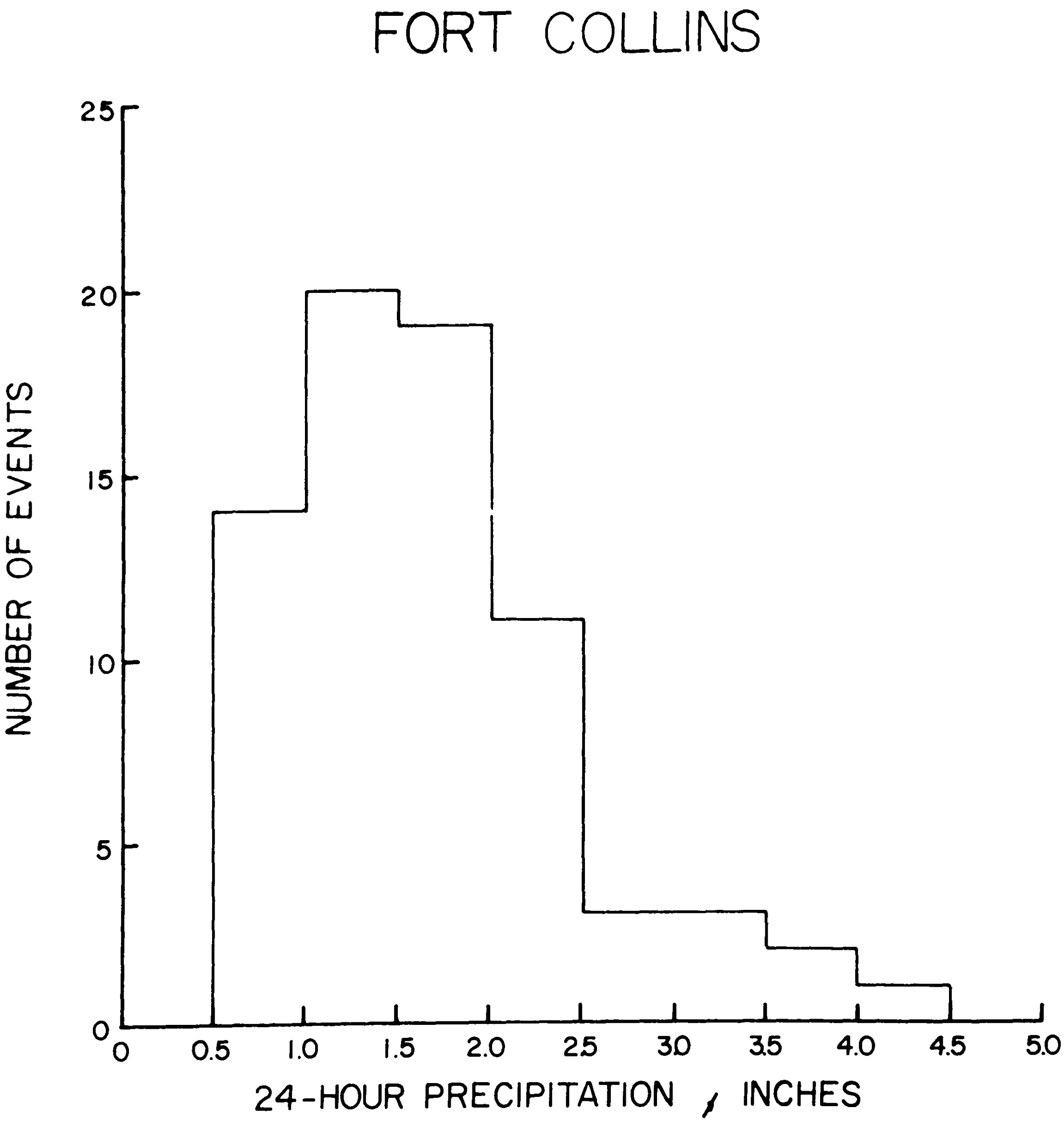

Figure 1. Observed 24-hour maximum precipitation for period 1900 to 1972.

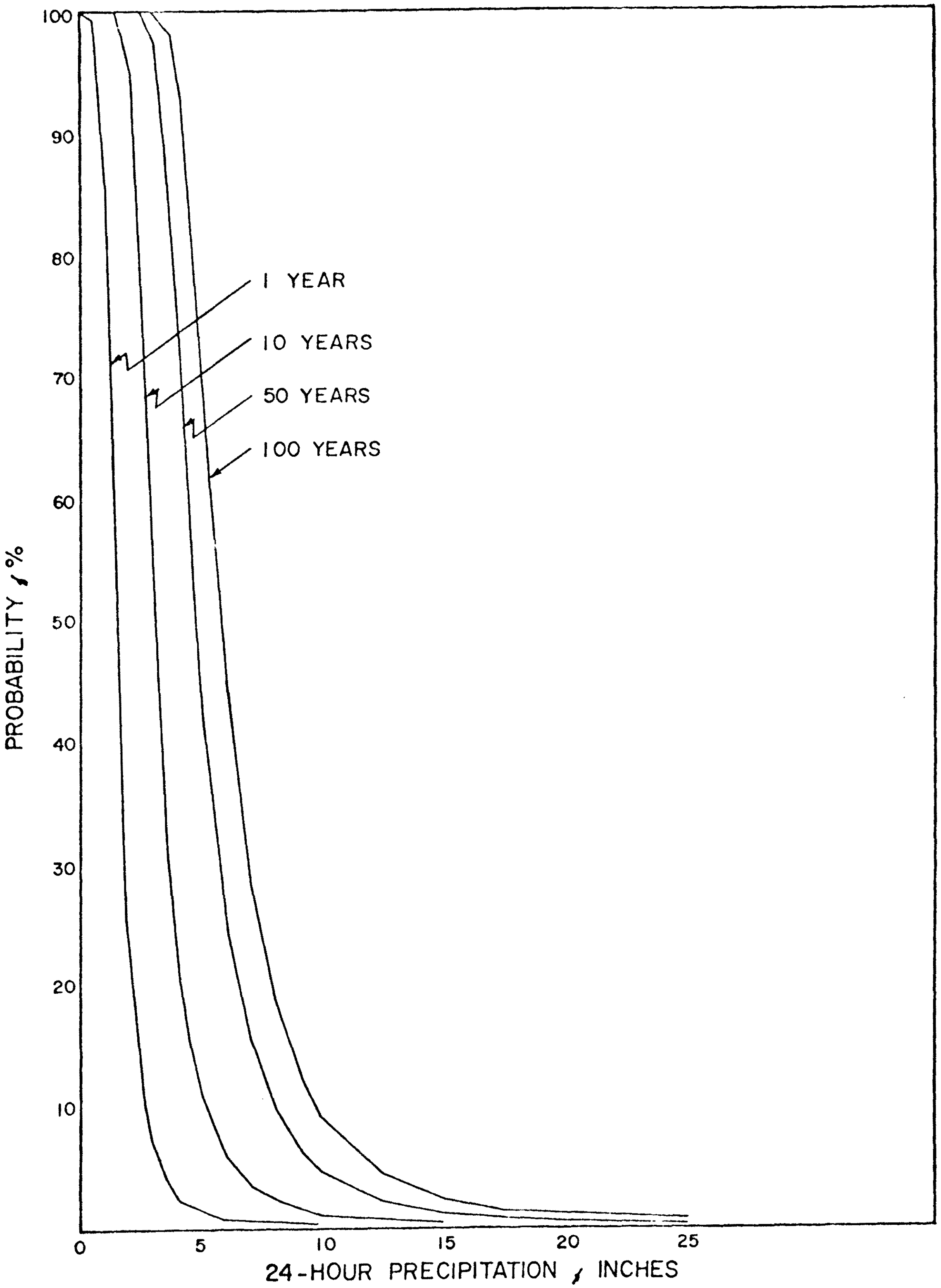

Figure 2. Precipitation probability.

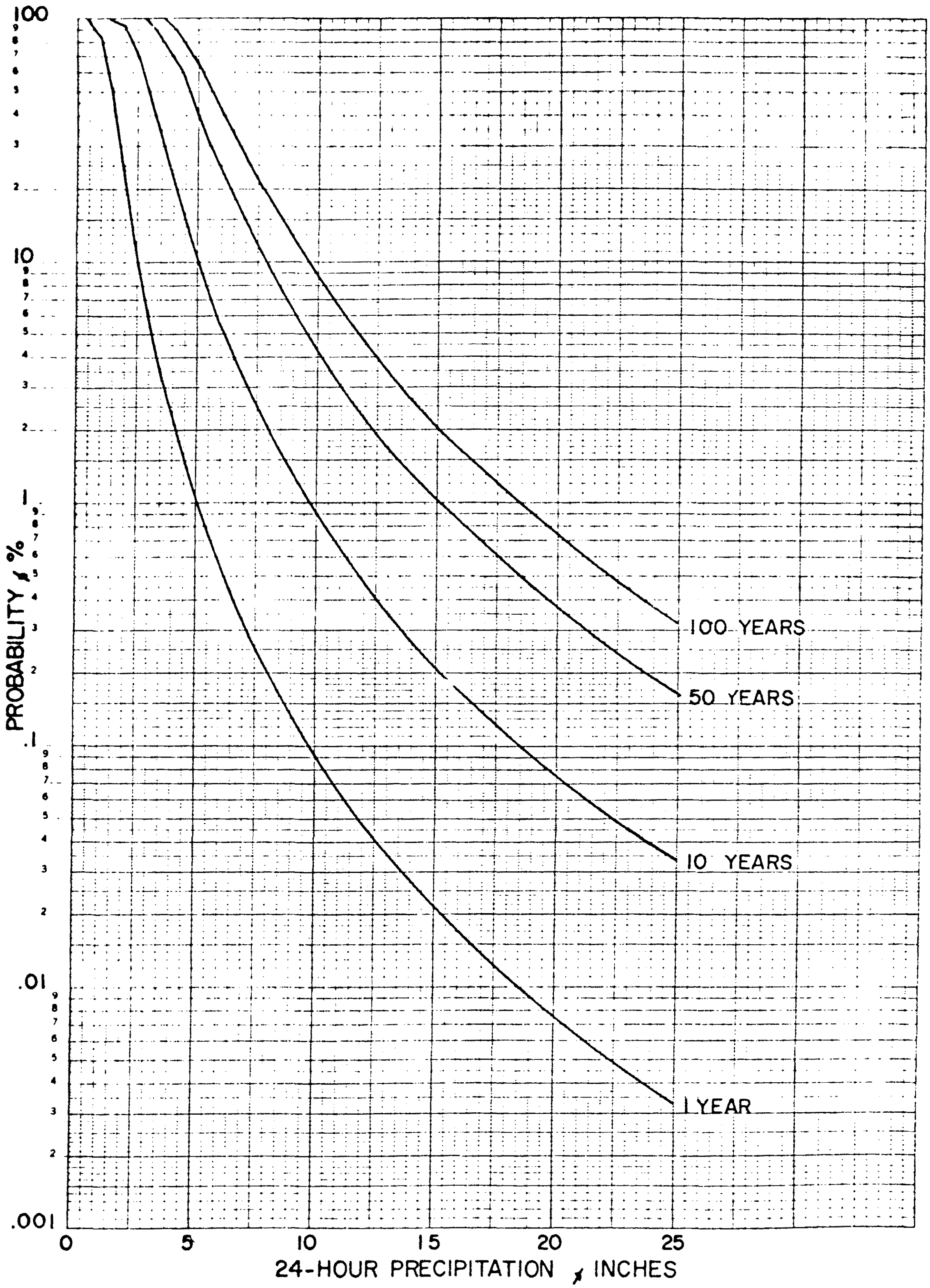

Figure 3. Precipitation probability

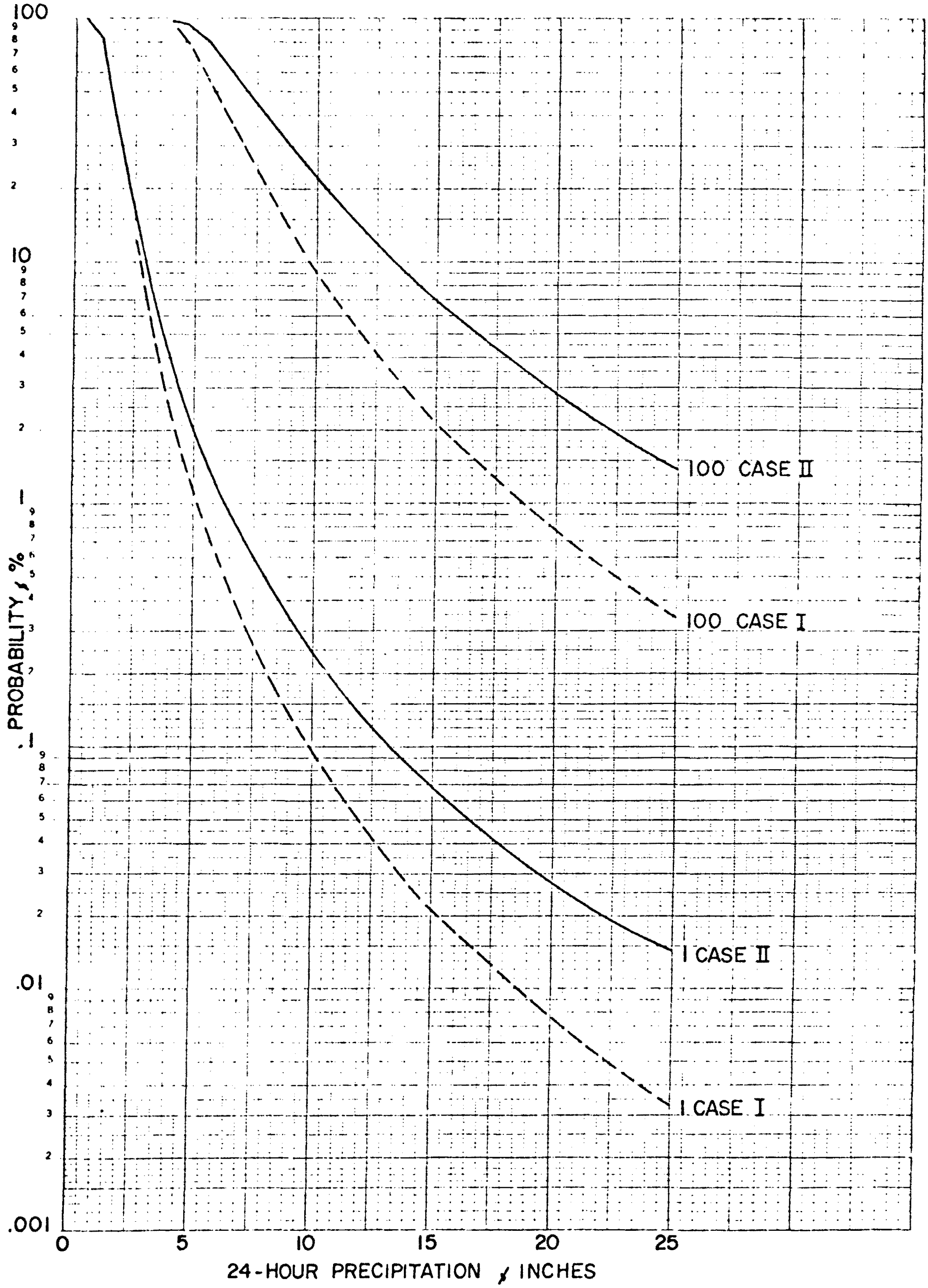

Figure 4. Precipitation probability with 10 inch event added to record.