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Estimating return period of intense rainfall using Alexander's technique

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ABSTRACT. After briefly describing the Alexander's technique an attempt has been made to determine the return period of the highest one-day point rainfall in east Uttar Pradesh (U.P.) by using this technique. This study has shown that a point rainfall of 20 inches or more in one-day has a return period of about 2,000 years.

1. Introduction

The design engineer is often confronted with the problem of estimating the return period or probability of occurrence of heavy rainfall equalling or exceeding a specified amount during a certain duration for the design of hydraulic structures. In recent years Alexander (1963, 1965, 1967) has developed a method, based upon probability considerations, which does not require any extrapolation of the frequency curve. In this paper this technique has been applied to a homogeneous area in east Uttar Pradesh for working out the return period of the highest one-day point rainfall experienced in that region during the last 70 years (1891 to 1960).

2. Alexander's method of determining retrun period of intense rainfall

In recent years Alexander (*loc. cit.*) has approached the problem based on the concept of joint probability in space and time. He believes that the probability of a major rain storm occurring over a particular catchment could be regarded as the joint probability of the storm occurring anywhere within a large homogeneous region containing the catchment and the probability of its actually occurring over the catchment in question. He tried several models in this connection. His earlier model (Karoly and Alexander 1960, Alexander 1963), known as the transposition model, gave the probability of transposition (P_t) as equal to the ratio of the area of the catchment to which the storm centre is transposed to the area of the homogeneous region within which the catchment located. In other words, if the size of a catchment within the homogeneous region of size A is B, then the probability of transposition (P_t) is B/A. It was however, found that this model is inapplicable for estimating the probability of point rainfall in which case B approaches zero and therefore, P_t also approaches zero. To meet this objection, 'coverage' model of Kendall and Moran (1963) was used. By this model this probability (called spatial probability P_s) is equal to C/A where C is the area of the rainstorm with rainfall exceeding a specific magnitude. This model takes into account all the storms that have occurred over the homogeneous region of size A during the period of N years. Apart from spatial probability, an estimate of probability of occurrence P_r of a storm above rank r in any year is required. If the length of record is N years, then this probability is equal to r/N. A practical method of working out the joint probability in space and time by the above method will be clear from the following hypothetical examples.

Consider a meteorologically homogeneous area of about 30,000 sq. miles. Within this area, during the past 70 years, there have been five separate areas (represented by Thiessen polygons) where rainfall of 15 inches and over in a day were recorded. The total area covered by 15 inches and more depth of rain within the homogeneous area was of the order of 500 sq. miles. The spatial probability P_s of 15 inches or more of rainfall occurring at any point within the homogeneous region is 1/60. In this example the daily rainfall data of 70-year period was considered. As the rainfall of 15 inches and more occured only once over these areas during the 70-year period (*i.e.*, r=1), the probability of occurrence (P_r), therefore, is 1/70. Since the two probabilities in space and

Fig. 1

time are independent, the joint probability for the occurrence of 15 inches or more of rainfall is equal to the product of P_s ans P_r which is equal to 1/4200. In other words, the return period for the occurrence of rainfall of the order of 15 inches or more in one-day is about 4,200 years or so.

3. Merits and demerits of this method

The above method has the advantage that no extrapolation of the frequency curve is required beyond the period of available data. The extrapolation techniques used in different frequency methods were criticised in the final report of the American Society of Civil Engineers' Sub-Committee (1953) set up to review the flood frequency methods. The other advantage of this method is that the return period need not be restricted to point rainfall only. According to Alexander (1967), it can be applied to a representative area which can be the average of the separate areas enclosing the storm rainfall of the specific magnitude in the homogeneous region. In the hypothetical example mentioned earlier, the representative area is of the order of 100 sq. miles which is the average of the five separate areas which received 15 inches or more of rainfall in one-day during the 70-year period.

Recently, Lockwood (1968) has applied Alexander's techniques for determining the return period of heavy rainfall in a homogeneous region in Malaya. He found that by this method one-day rainfall of 8 inches has a return period of about 200 years. Lockwood (1969) has, however, pointed out that this method is strictly applicable to a meteorologically homogeneous area with a dense network of raingauges whose records extend backward to atleast 40 or 50 years. He has also stated that this method is applicable to rain amounts which occur very rarely at individual stations in a homogeneous region.

4. Return period determination for the heaviest rainfall in east Uttar Pradesh

Mazumdar and Rangarajan (1966) while studying the regional storm analysis have found that the area bound by Lat. 24° to 29°N and Long. 79° to 85°E, which comprises the eastern half of Uttar Pradesh (U.P.) is a meteorologically homogeneous region as rainstorms of different intensities are randomly spread out in the whole area and there is no concentration of rain storms in any particular area. In this region an area roughly of the size of 34,000 sq. miles, having 78 rainfall stations whose data are continuously available for the last 70 years from 1891, was selected for this study (Fig. 1). While selecting the area it was seen that none of the submontane areas in the north of east U.P. were included in this region. Its homogeneity was further tested by applying the χ^2-test which showed that the distribution of extreme rainfall amounts in this area can be considered normal within 5 per cent chance of error for this hypothesis. Thiessen polygons were then constructed round each rainfall station in order to obtain the areas of influence for each of the rainfall stations. Highest one-day rainfall recorded at each individual station during the 70-year period have been marked against each station in Fig. 1. From this figure it can be seen that the highest rainfall of 20 inches or more was recorded only at two stations, *viz.*, Khajwa (Dist. Fatehpur) and Meja (Dist. Allahabad) on 22 June 1916 and 31 August 1915 respectively. Using Alexander's procedure mentioned earlier, return period was worked out for the highest one-day rainfall of 20 inches or more in the following manner —

Total area of the homogeneous region (A) } = 33585 sq. miles.

Total area of the Thiessen Polygons which received 1-day rainfall of 20 inches or more (B) } = 1212 sq. miles.

Spatial probability (P_s) = B/A } = 0·036.

Period of rainfall data used (N) } = 70 yr.

Probability of occurrence for 20 inches or more (P_r) } = 1/70.

The joint probability for the occurrence of rainfall of 20 inches or more in the homogeneous region in one-day } $= P_s \times P_r = 1/1940$

Return period (T)* = 1940 yrs (or about 2000 yrs).

5. Conclusion

Alexander's method takes into consideration both spatial and temporal distribution of rainfall and no extrapolation of the frequency curve is required to obtain return periods of extreme rainfall. Return periods thus obtained are applicable to point values as well as to average areas while Gumbel method (Linsley and Franzini 1964) gives return periods for point values only. The disadvantages of the Alexander's method are that it holds good only in regions which are meteorologically homogeneous and which have a dense network of raingauges having a fairly long period of rainfall data. In actual practice it is rather difficult to obtain such areas in nature. Using this technique it has been found that the highest one-day rainfall of 20 inches or more in east Uttar Pradesh (U.P.) has a return period of about 2000 years.

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*This return period according to Alexander, is applicable to an area of about 600 sq. miles

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