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Development of rainfall intensity-duration-frequency constants, curves and nomographs for selected station Arni, dist. Yeotmal

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■ **ABSTRACT :** Rainfall intensity-duration-frequency relationship and nomographs are required for design of soil and water conservation structures. Rainfall IDF relation depends on the physical characteristics of rainfall occurring in a particular place. The rainfall IDF relationship can be expressed as, $I= (KT^a) / (t+b)^d$ in which, I is maximum rainfall intensity (cm/h), T is return period (years), t is duration (h) and K, a, b and d are location specific constants. These specific constants in above relationship vary location to location and calculated by evaluating the rainfall IDF relationship. The study was undertaken to develop the rainfall IDF relationship and nomograph for Arni tehsil of Yeotmal district of Vidharbha region. The required automatic rainguage charts were collected from Arni station of hydrology project. These rainfall charts were analyzed for maximum annual rainfall intensity of selected duration's *viz.*, 0.08, 0.16, 0.25, 0.5, 1, 2, 3, 6, 12 and 24 hours. The plotting positions were obtained by using the 'computed method' for development of frequency lines. Value of constants a and b were determined by using graphical method and the values of K and d were determined by using least square method. The values of constants K, a, b and d were found to be 3.148, 0.2074, 0.12 and 0.5574 for Arni station of Yeotmal district. The nomograph was developed for the IDF relationship for the same station.

■ **KEY WORDS :** Nomographs, Rainfall intensity-duration-frequency

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Rainfall is the result of complex atmospheric phenomena and it is a complicated temporal and spatial structure. A wide range of frequency-content features and extreme variability over time intervals from a few seconds to years make rainfall an interesting and challenging process to study. It is important component of hydrological cycle, which causes the complex interaction between land and precipitation; it is source of water for infiltration into the soil, runoff, stream flow, floods and the basic cause of erosion. Out of all rainfall characteristics, rainfall intensity is by far the most important one. The rainfall intensity is inversely proportional to its duration of occurrence and directly proportional to the return period. Intense storms generally last for very short durations. With an increase in duration, there is a decrease in the maximum average intensity of the storm. In a specified return period (frequency) and for given duration of occurrence, a storm of higher intensity is less likely to occur than a storm of lower intensity. Thus, analysis of rainfall intensities, duration and frequency at any location provides very valuable information for the use of design engineers or hydrologists,

who are engaged in designing water control structures, for controlling floods from small watersheds.

Relationship between rainfall intensity-duration-frequency is location specific and mainly depends upon physical characteristics of rainfall occurring at a particular place. Hence, such relationship developed for particular station cannot be superimposed for other stations owing to different pattern of rainfall characteristics. So, it becomes necessary to develop such relationships for small units so that, their reliability and applicability will have greater practical importance.

Many researcher developed IDF relationship for different stations for Maharshtra state. Gore and Mal (1998) developed the IDF constants and station nomograph for Parbhani by analysing 14 years data and the constants were K = 7.454, a = 0.1551, b = 0.05 and d = 0.8524. Barai and Shinde (2002) developed the IDF relationship for Rahuri and the constants were K = 8.50, a = 0.1885, b = 1.00 and d = 1.011. Chunale *et al.* (2007) analysed rainfall data of Kolhapur and developed IDF constants as K = 3.995, a = 0.2235, b = 0.2, and d = 0.8047. Bhamre (2010) developed the IDF constants for three stations of Amravati division and the constants were developed for Akola, Buldhana and Amravati as K = 6.615, 4.573, 3.981, a = 0.1985, 0.1764, 0.2524, b = 0.05, 0.20, 0.30 and d = 0.8591, 0.6412, 0.7564, respectively. Thus, there is need of development of IDF relationship for location specific constants.

It is therefore, need to obtain a simplified methodology to readily find out the intensity of rainfall for different durations and recurrence intervals. In a view of above, it was thought to establish rainfall intensity-duration-frequency relationship and to prepare nomographs for selected gauging station in Yeotmal district.

METHODOLOGY

Location of study area:

The study was carried out for development of rainfall IDF relationship for station of Yeotmal district of Maharashtra state. The required data for the analysis were collected from station namely Arni of Yeotmal district. Geographical and climetological data of study area is given in Table A.

Data analysis:

In the present study autographic rainfall records were analyzed in the form of annual maximum series of various durations *viz.*, 5, 10, 15, 30 min, 1, 2, 3, 6, 12 and 24 h, as the aim was to obtain the annual maximum rainfall intensity or rainfall values, the rain storms which gave peak intensities were considered for analysis.The maximum depth of rainfall for various durations was worked out by using 'original trace method' (Ram Babu *et al.*, 1979).

Plotting positions for development of frequency line :

The rainfall intensities were plotted on log – normal probability paper, with rainfall intensities on log scale and per cent chance of occurrence on probability scale. A straight line passing through all the three points was extended so that, it intersect with ordinate. This line is called as frequency line of rainfall intensity. In the study, plotting positions were obtained by using the 'computing method' suggested by Ogrosky and Mockus (1957)

The ten frequency lines were drawn for ten durations and are designated as $I_{0.08}$, $I_{0.16}$, $I_{0.25}$, $I_{0.50}$, I_1, I_2, I_3, I_6, I_{12} and I_{24} for 0.08, 0.16. 0.25, 0.50, 1, 2, 3, 6, 12 and 24 h durations, respectively. The rainfall intensities for each duration against selected per cent frequencies (1%, 2%, 4%, 10%, 25% and 50%) were obtained. Return period in years was obtained by equation given as

$$T = \frac{100}{PC}$$

where, T is return period, PC is per cent chance of occurrence.

The developed graph which showing per cent chance of occurrence of rainfall intensity for various durations as shown in Fig. A.

Rainfall intensity-duration-return period equation:

The rainfall intensity-duration-frequency equation can be expressed as

Table A : Geographical and climatological data for selected stations

Sr. No.	Station	District	Altitude	Latitude	Longitude	Avg. annual rainfall
1.	Arni	Yeotmal	451 m	20°23'N	78°59'E	1029.0 mm

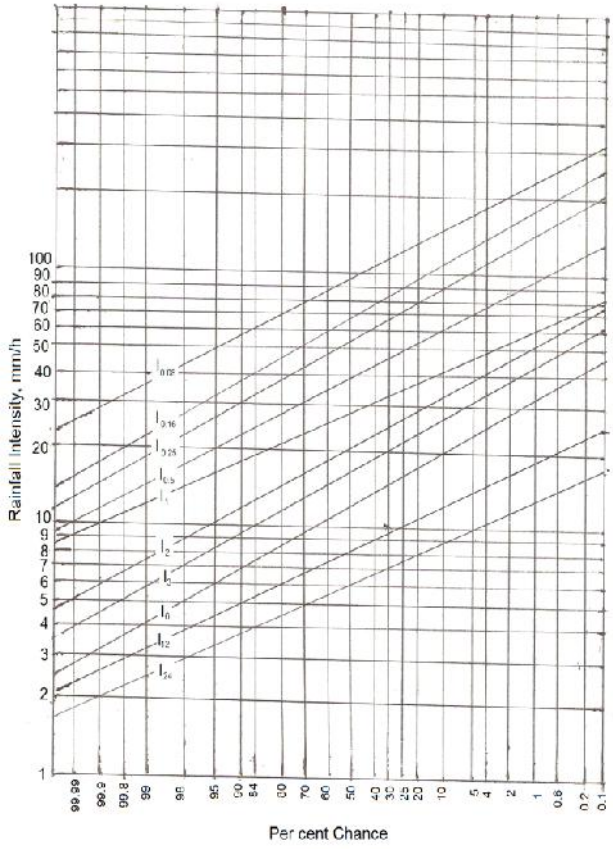

Fig. A : Frequency distribution of rainfall

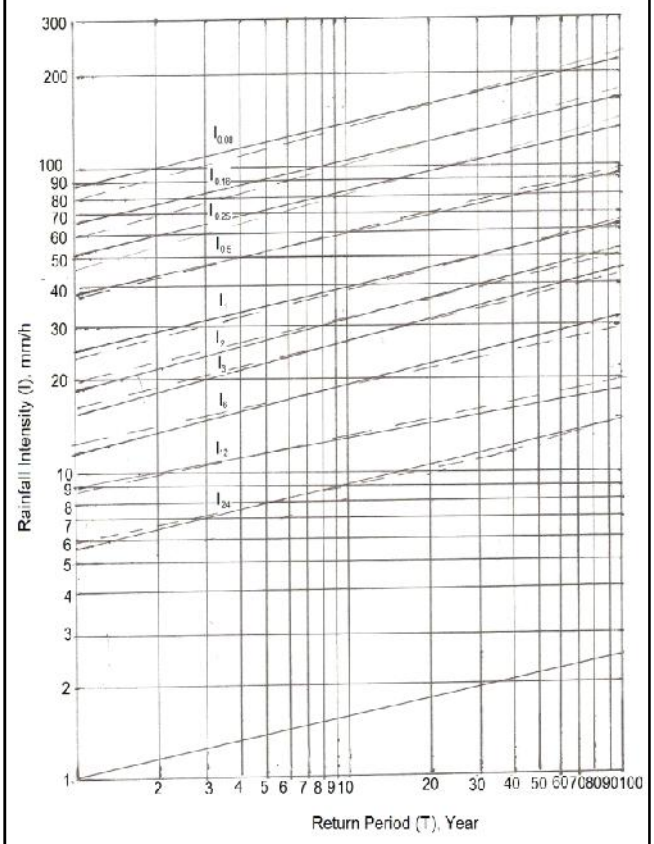

Fig. B : Rainfall Intensities for selected duration

$$I = \frac{KT^a}{(t+b)^d} \qquad (1)$$

where, I is maximum intensity of rainfall (cm/h), T is return period (years), t is duration at least equal to time of concentration of watershed (h) and K, a, b and d are location specific constants. In order to evaluate the co-efficients a, b, d, and K from general expression for frequency curves, the following steps are involved (Ram Babu *et al.,* 1979).

Geometric mean slope :

The values of rainfall intensities for all durations were plotted on Y- axis and values of return period on X- axis on log- log paper. All these points were connected by a thin dotted line giving more weightage to points from 10 year to 100 years return period. The dotted line was extended to cut the Y axis against 1-year return period. The slope of the individual dotted lines for each duration was determined. The geometric mean slope $(\bar{m})$ for the entire set of lines was determined. The geometric mean slope of the lines represents the exponent 'a' in the equation and it is shown in Fig. B.

Rainfall intensity of one-year return period :

A line representing the geometric mean slope was drawn at the base of graph of frequency distribution lines passing through origin. The solid lines parallel to this geometric mean slope line were drawn against the dotted lines for different durations; the values at Y-axis represent rainfall intensities for different durations and for 1-year return period.

The values of rainfall intensities for different durations were plotted on Y axis against selected duration on X-axis plotted on log-log paper. The points plotted in

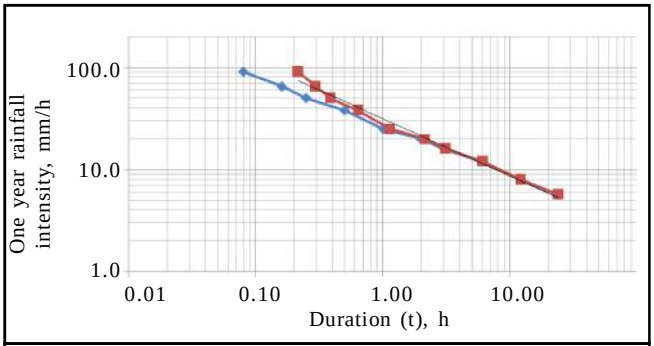

Fig. C : Fitting of constants 'b' in the IDF equation for Arni station

such that they do not fall in a straight line. Marked all these points which, fall in one straight line and suitable constant 'b' is to be added to all the values of durations by trial and error method. After adding this constant in the values of durations the points were aligned into a straight line for Arni station it is shown in Fig. C.

Estimation of constants 'K' and 'd' :

The constants 'K' and 'd' were solved by least square method. In this method the values of one year rainfall intensities for selected durations and the values of 'K' and 'd' were determined by solving the following equations.

$$\text{Log } K = \frac{\Sigma \text{Log } I \, \Sigma[\text{Log}(t+b)]^2 - \Sigma[\text{Log } I \times \text{Log}(t+b)] \times \Sigma \text{Log}(t+b)}{N\,\Sigma[\text{Log}(t+b)]^2 - [\Sigma \text{Log}(t+b)]^2} \quad (2)$$

$$d = \frac{\Sigma \text{Log } I \, \Sigma[\text{Log}(t+b)] - N\,\Sigma \text{Log } I \times \text{Log}(t+b)}{N\,\Sigma[\text{Log}(t+b)]^2 - [\Sigma \text{Log}(t+b)]^2} \quad (3)$$

where, K, b and d are location specific constants, I is one year rainfall intensity (mm/h), t is duration (h) and N is number of selected durations.

Development of nomograph :

A nomograph is an alignment chart consisting of a set of suitably graduated parallel scales. In the study there were three variables (rainfall intensity, duration and return period) and the alignment chart has three parallel scales, so graduated that a line which joins values on any two scales intersects the third scale at a point which satisfies the given equation. The procedure suggested by Luzzadar (1964) was adopted for development of nomograph.

The developed nomograph for Arni Station of Yeotmal district is shown in the figures, Fig. D.

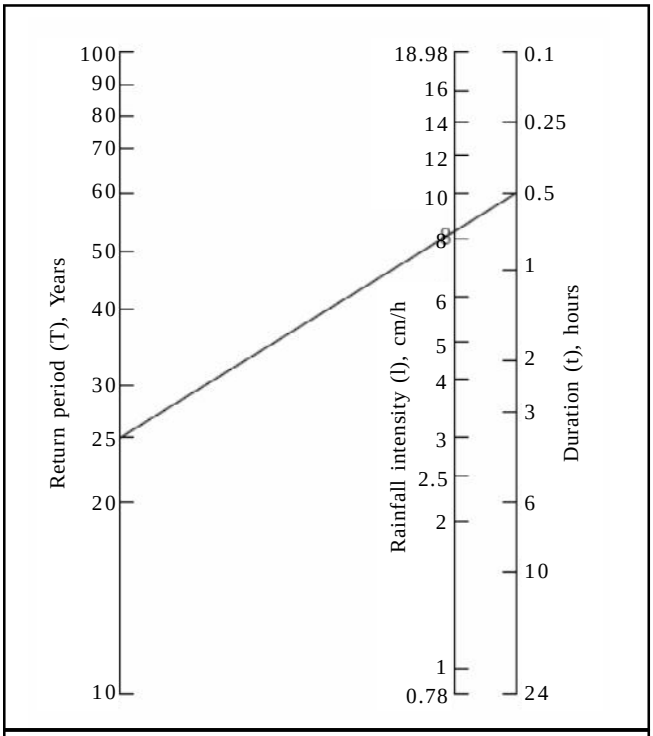

Fig. D : Nomograph for Arni station of Yeotmal district

RESULTS AND DISCUSSION

The stepwise procedures adopted for development of IDF relationship for Arni station of Yeotmal district, which gave results as follows :

The rainfall intensity-duration-frequency relationship was developed for Arni station of Yeotmal district is given as follows.

$$I_Y = \frac{3.148\,T^{0.2074}}{(t+0.12)^{0.5574}}$$

where, I_Y is rainfall intensity for Arni station of Yeotmal (cm/h),

T is return period (years)

t is duration (h).

The nomograph for obtaining quick solution of rainfall intensity-duration-frequency relationship was developed for Arni station of Yeotmal district. The maximum deviation in the values of intensity obtained from mathematical relationship of IDF and corresponding nomograph was in the range of – 5.54 to 2.98 per cent, which was well within accepted range. The integral square error was tested for goodness of fit between observed and computed values. ISE values for Arni of

10, 25 and 50 years duration are (0.004, 0.001, 0.010), respectively. Which are nearly to zero and it is satisfactory. Thus the nomograph developed in the study can be used satisfactorily for obtaining the solution of rainfall intensity-duration-frequency relationship.

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