Development of Rainfall Intensity-Duration-Return Period Equations and Nomographs of India

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Abstract

Rainfall intensity-duration-return period equations and nomographs are required for design of soil conservation and runoff disposal structures and for planning flood control projects. Rainfall intensity-duration-return period equations and nomographs have been developed for 141 stations (including 37 earlier developed) situated in the northern, central, eastern, western and southern rainfall zones of India. With the help of either the equations or nomographs, the intensity for any desired duration and return period (or frequency) may be determined. The zonal equations and nomographs for various rainfall zones of India were also developed. The deviation in the rainfall intensity obtained by the two methods (equations and nomographs) has been observed nearly 20 percent. Looking into simplicity in use, quickness and precision in results obtained, the nomographs appear to be the most handy tool for field workers.

Resume (French version may kindly be translated at your end)

Introduction

Rainfall intensity-duration-return period equations and nomographs for individual stations and on regional basis are required in the country for design of soil conservation, runoff disposal structures and for planning flood control projects. Such relationships and nomographs have been developed at a few stations scattered over one or other part of the country by various workers. Further, zonal equations and nomographs of different rainfall zones of India (northern, central, eastern, western and southern) were developed based on limited number (37 stations) of recording rain-gauge data in India by Ram Babu, *et al* (1980).

It is felt necessary to develop relationships and nomographs for more number of stations and also to develop zonal relationships and nomographs more precisely based on large number of stations.

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Material and Methods

To derive prediction equations for intensity-duration-frequency (return period) and also for development of nomographs, an effort has been made to process and analyse the recording rain-gauge data of 104 stations spread in different rainfall zones available with the Indian Meteorological Department, New Delhi.

Development of equations

Various formulae have been advanced connecting the three parameters – rainfall intensity, duration and return period (Frevert *et al*., 1955; Skurlow, 1960; Gupta *et al*., 1968; Senapati *et al*., 1976 and Ram Babu *et al*., 1980). The formula is of the general form:

$$I = KT^a / (t+b)^d \quad \text{---------- (1)}$$

Where, I = Intensity of rainfall (cm/hr), T = Return period (years), t = Duration (hours); K, a, b and d are constants.

Equation (1) was used for developing intensity-duration-frequency relationships.

Development of Nomograph

A nomograph is an alignment chart consists of a set of parallel scales, which are suitably graduated. In the present study, there were only three variables and thus the alignment chart had three parallel scales so graduated that a line which joins values on two scales will intersect the third scale at a value which satisfies the given equation. In order to design alignment charts for equation of the form:

$$f_1(u) + f_2(v) = f_3(w), \quad \text{---------- (2)}$$

the following are required:

(a) the graduation of scales, which are marked with the values of the variable and on which the distances to the graduations are laid off the proportion to the corresponding values of the function of the variables, and

(b) the determination of spacing of the parallel scale. The scale equation for determining functional modulus (m), commonly defined as a proportionality multiplier used to bring a range of values of particular function with a selected length for a scale, which is given as:

$$m = L/\{f(u_2) – f(u_{1)}\} \quad \text{---------- (3)}$$

where, m=calculated functional modulus, L=length of the scale chosen, $f(u_1)$ and $f(u_2)$=lower and upper limit respectively of the function.

The unknown functional modulus m_w was calculated by

$$m_w = m_u .m_v /(m_u - m_v) \quad \text{---------- (4)}$$

where, m_u and m_v are the calculated functional moduli

$$\text{Scale spacing ratio} = m_u / m_v \quad \text{---------- (5)}$$

was determined with the help of the equation (1). The limiting values of intensity were determined on the basis of conditions laid down on t and T.

Results and Discussion

Based on observed data for 141 stations, including 37 earlier developed (Ram Babu et. al. 1980), the intensity-duration-return period relationships and nomographs for individual station (northern – 12, central – 35, eastern – 15, western – 14 and southern – 65 stations) were developed. Zonal equations and nomographs for northern, western, central, eastern and southern rainfall zones of India (table 1) were also prepared. Zonal boundaries of different rainfall zones of India are shown in Fig. 1. A nomograph of one zone (Southern zone) has been shown in Fig. 2. With the help of either the equations and nomographs of individual station, the intensity for any desired duration and frequency (or return period) may be determined for that locations and the zonal equation may be used for any location falling in that zone.

Table 1: Intensity-Duration-Return period relationships of various rainfall zones of India

Zone	Equation	Zone	Equation
Northern	$I = \frac{4.4008\ T^{0.2239}}{(t+0.40)^{0.9323}}$	Western	$I = \frac{5.7557\ T^{0.2131}}{(t+0.60)^{0.9676}}$
Central	$I = \frac{7.1320\ T^{0.1993}}{(t+0.80)^{1.0237}}$	Southern	$I = \frac{8.0787\ T^{0.1838}}{(t+0.80)^{1.0771}}$
Eastern	$I = \frac{7.1320\ T^{0.1993}}{(t+0.80)^{1.0237}}$		

I = intensity (cm hr^{-1}); T = return period (year); and t = duration (hour).

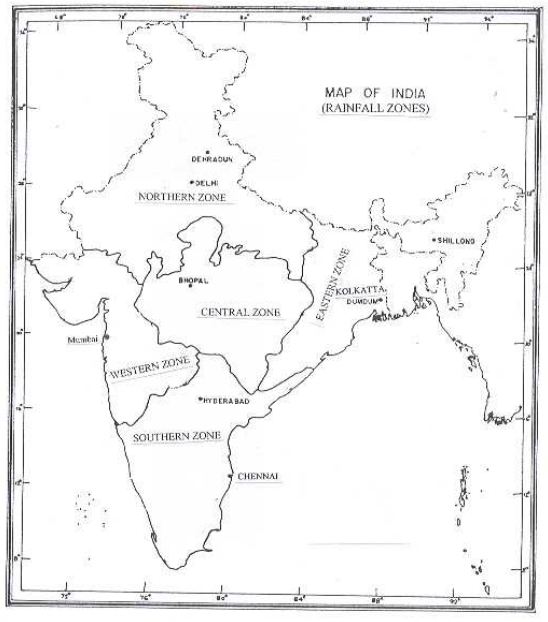

Fig.1 : Map showing the boundaries of different rainfall zones of India

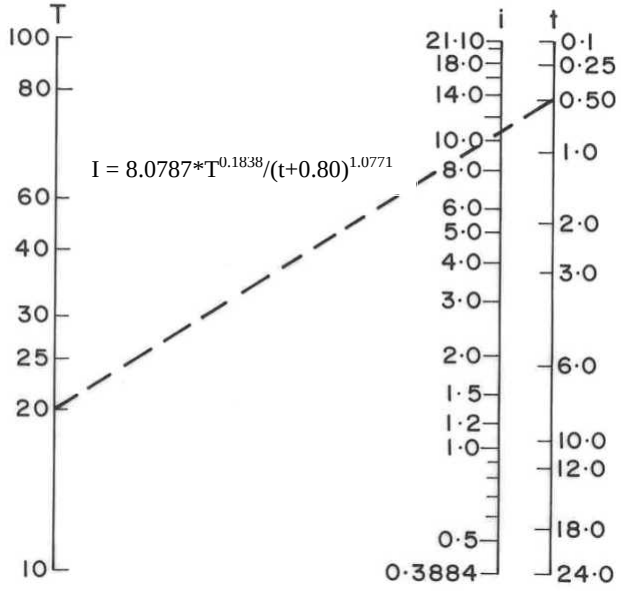

Fig.2 : Nomograph for solving intensity-duration-return period for recurrence interval – Southern rainfall zone, India

Percent deviation of rainfall intensity values observed from nomographs and those calculated from corresponding mathematical equations for various durations and 10, 25 and

50 years frequencies revealed that maximum deviations between the nomographic solutions and mathematical equations ($_{nomo}$) ranges from to -14.6 to 5.8 percent in case of Dharmsala (northern zone); -4.3 to 29.2 percent in case of Bhuj (western zone); -3.7 to 12.5 in case of Bramhpuri (central zone); -2.0 to 26.9 percent in case of Chitradurga (southern zone) and -16.0 to 4.5 percent in case of Gauhati (eastern zone). The deviations of other 136 stations are still less. On further scrutiny, it is observed that the nomographic solutions are more precise for predicting intensity of rainfall of various durations and frequencies. Looking into simplicity in use, quickness and precision in results obtained, the nomographs appear to be the most handy tool for field workers.

Further, the zonal equations and nomographs developed for various zones of India (northern, western, central, southern and eastern) compared fairly well with the equation and nomograph for individual station falling in that zone. In general, the variations in estimated rainfall intensities by the use of the station equation and zonal equation were between ±20 to 30 percent, suggesting the usefulness of zonal equations and nomographs.

Conclusions

Rainfall intensity-duration-return periods equations and nomographs of 141 stations situated in the northern, central, eastern, western and southern rainfall zones of India were developed. The zonal equations and nomographs for northern, central, eastern, western and southern zones of India were also developed. With the help of either the equation or nomograph, the intensity of rainfall of various durations and frequencies can be determined. Looking into simplicity in use, quickness and precision in results obtained nomographs are the most handy tool for field workers.

Literature cited

Frevert, R.K., Schwab, G.P., Edminster, T.W. and Barnes, K.K. (1955). Soil and Water Conservation Engineering. John Wiley and Sons, New York.

Gupta, S.K., Dalal, S.S. and Ram Babu (1968). Analysis of point rainfall data of Dehradun. *Irrig. Power J*. 25(3) : 291-330.

Ram Babu; Tejwani, K.G.; Agarwal, M.C. and Bhusan, L.S. (1980). Rainfall intensity – duration – return period equations and nomographs of India. Proc. 1st International Conference on Statistical Climatology, held in Tokyo, Nov. 29 – Dec. 1, 1979. Published in Statistical Climatology, Development in Atmosphere Science, 13 (Editors: S. Ikeda *et al*), Elsevier Scientific Publishing Company, New York, 1980 : 359 – 374.

Senapati, P.C., Shakya, S.K., and Nema, J.P. (1976). Nomograph of intensity, duration and recurrence interval of rainfall at Bombay (Colaba). *Irrig. Power J*. 33(4) : 525-528.

Skurlow, J. (1960). A nomograph for estimation of rainfall intensity and runoff. *J. Soil Cons. Serv*. New South Wales 16(2) : 126-136.