TECHNICAL NOTE

PRECIPITATION INTENSITY-DURATION-FREQUENCY FUNCTIONS FOR THE BANNU REGION NWFP PAKISTAN

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Abstract The function of precipitation intensity-duration-frequency is needed for the planning and design of water resource projects. Short duration precipitation data are hardly available. However the total hourly-recorded available precipitation data for different parts of NWFP from different departments have been collected and analyzed for the present study. The data from WAPDA is found to be more authentic. Making use of the data, functions of intensity-duration-frequency for precipitation are developed for the Bannu region, representing the lower hilly and plane areas in NWFP. The IDF curves are plotted for 2, 5, 10, 25, 50 and 100-year return periods. The theoretical intensities of precipitation calculated by the developed functions are in close agreement with those recorded at the stations through automatic gages. Only 7 % variation is observed for most of the time. The values of the constants k, b and exponents n, m in the IDF function $I = KT^n / (t+b)^m$ are calculated from the observed precipitation data. The correctness of the developed function is ascertained through its comparison with existing equations for depth duration developed for the world's largest rainfall events. The function developed is found to produce more realistic results for regions in NWFP. The developed function may be used in the same region in a radius of about 100 km. For design practices regarding the prediction of precipitation in the future, instead of consulting 26 years of data available for the same region on hourly basis.

Keywords Water Resource, Intensity-Duration-Frequency, Rainfall, Precipitation Data

چکیده برنامه ریزی و طراحی منابع آب به تابع فرکانس–شدت–مدت رسوب گذاری نیاز دارد. داده های رسوب گذاری کوتاه مدت بسختی قابل دسترسی است. اما همه اطلاعات ثبت شده ساعتی موجود در باره رسوب گذاری برای قسمتهای مختلف NWFP بدست آمده از ادارات مختلف در این تحقیق جمع آوری و تحلیل شده است. داده های WAPDA در این بین از بقیه معتبر تر است. با بهره گیری از این داده ها، تابع فرکانس–شدت–مدت رسوب گذاری برای منطقه بانو توسعه یافته و حاکی از این است که در مناطق NWFP دارای تپه و جلگه کمتر، رسوبات کوچکتر است. تغییرات فرکانس–شدت–مدت برای مدت بازگشت ۲، ۵، ۱۰، ۲۵، ۵۰ و ۱۰۰ سال رسم شده است. شدت رسوب گذاری تئوری که از این طریق محاسبه شده با مقادیر اندازه گیری شده بطور خودکار مطابقت نزدیکی داشته است. در اکثر مواقع فقط ۷ ٪ تفاوت وجود داشته است. مقادیر ثوابت k، b و توان های n ، m در تابع $I = KT^n / (t+b)^m$ با استفاده از داده های رسوب گیری تجربی تعیین شده اند. صحت تلبع بدست آمده از طریق مقایسه با معادله مورد استفاده برای تعیین بزرگترین موارد بارندگی در جهان احراز شده است. معلوم شده است که تابع بدست آمده می‌تواند نتایج واقعی تری در باره نواحی NWFP ارائه دهد. از تابع بدست آمده ممکن است تا شعاع ۱۰۰ کیلومتر بتوان استفاده کرد.

1. INTRODUCTION

The Intensity-Duration-Frequency functions are a classical precipitation analysis tool, which relates the probability of occurrence of storms of given duration and intensity. Such functions are developed for use in urban storm drainage design, calculation of maximum expected floods at various locations in the natural drain to ensure safe designing of various structures on the river etc. and to estimate probable maximum precipitation for a given geographic location, range of duration and time of the year [1]. The main objective of this study is to develop precipitation intensity-duration-frequency function for the Bannu region, based on previously recorded years of precipitation data to ease the prediction of rainfall for the future because the areas within the region are strongly affected by this precipitation.

From the review of relevant literature, it is clear that the flow of water in the channels, natural drains and rivers and occurrence of floods depends on various factors such as catchment areas, rainfall intensity and duration, slope of the catchment areas, length of the channel or drain, permeability of soil, storage area, vegetative cover and snowmelt [2].

Keeping all these factors in view, various methods have been developed for determination of relationships between intensity, duration and return period of precipitation to calculate the discharge/flood at various parts of natural rivers/drains at different times of the year.

The hydrologic data can be observed only once from a natural hydrological phenomena which may not occur again. The most important issue in hydrology deals with the interpreting of a past record of hydrologic events in terms of future probabilities of occurrence. This issue arises in the estimate of frequencies of rainfall, floods, droughts etc. The procedure of estimating the frequency of occurrence of different hydrologic events is called the frequency analysis. Information which concerns the probable maximums for proposed structure may be required to withstand and in many other hydrologic design problems can be analyzed by frequency analysis using past records. The design of hydraulic structures must rest on some form of frequency analysis. After the frequency of occurrence of certain maximum rainfall for flood for which the hydrologic structure should be designed, the proper design criteria can be worked out [2,3].

The distribution of frequency of hydrologic data may be calculated as an annual series or partial duration series. In the annual series, only the largest single event for each year is selected for analysis. When the design of the structure is controlled by the most critical condition, such as the design of a spillway and drainage channel, the annual series should be used. Such a series ignores the second and lower order events of each year, which may be even greater to annual maximum of other years [4,5].

The partial duration series should be used if the second largest value (or lowest) of the year would affect the design of structures. For example, the damage caused by flooding sometimes results from repetition of flood occurrences rather than from a single peak flow [1,6]. The annual and partial duration series give identical results for return periods greater than 10 years. With either of the data series, the return period or recurrence interval may be defined as the average number of years within which a given event will be equaled or exceeded. The general formula for the IDF function is $I=\frac{KT^n}{(t+b)^m}$ where ‘I’ is the intensity (in/hour), ‘T’ is the return period (years) and ‘t’ is the duration of precipitation (minutes) whereas k, b are constants and n, m are exponents to be determined for various locations as these are having different values for different regions of the world [1]. Thus it can be concluded that there is a need to develop such functions that would produce a realistic estimation of precipitation intensity for a region in the future.

The present research is directed towards developing Precipitation Intensity-Duration-frequency function for the Bannu region in NWFP which will enable the designers of water resource projects in finding the storm of any intensity and duration corresponding to any return period or frequency which can be used to estimate the flood of any frequency. The IDF function involves three parameters namely precipitation storm intensity, its duration and corresponding frequency of occurrence. Using the statistical approach the constants k, b and exponents m, n of mathematical relation mentioned can be found.

This regional IDF function can be applied to find the intensity of precipitation corresponding to any duration of storm and its frequency, which can further be used to determine the flood magnitude corresponding to any frequency in that region [1].

Besides its uses in the design of hydraulic structures, it may also be used as a basis for soil conservation and erosion control in agriculture and forestry. The type of protection may be recommended according to the precipitation intensity.

Environmental pollution decreases with precipitation. Therefore it will become easy to predict the effect of precipitation of any intensity on environmental pollution. Moreover the effect of precipitation on water logging and salinity of land may be predicted.

2. LITERATURE REVIEW

The rainfall intensity-duration-frequency formula for India was developed [7].

It describes that rainfall intensity duration frequency (IDF) is a relationship needed for planning and designing of water resources projects. The empirical formula used for the purpose is

$$I = \frac{a_\circ T^{a_1}}{t^{a_2}}$$

Where

I = Intensity of rainfall,

t = Duration,

T = Return period $a_\circ$, a_1, a_2, are constants

The above formula was applicable to rainfall intensity of a short duration (less than 24 hours) in order to avoid greater variation of the exponent of T (0.12 to 0.26) and of t (0.70 to 0.85).

There is a lack of long term self-recording rainfall data in India. In the absence of detailed data, use of regional relationship is made for hydrologic design using the data from 39 stations in India, Ram Babu Tajwani et al. [8] developed the IDF function and proposed different equations for different geographical locations in India [8]. These relationships produced results with an error of less than 50 %.

Another attempt was made to develop the same relationship. Data for 50 stations were compiled and 20 among these were selected for the purpose, which are scattered in various parts of India [9]. The data was compared with the data from other countries [10]. Gumbel's distribution was applied to the data to determine the rainfall intensity of different return periods.

The results obtained showed the error of about ± 50 % considered unsatisfactory.

Another approach was made for short-duration rainfall [11,12] in Sicily.

The Canadian atmospheric environment service uses annual extreme series to produce rainfall intensity duration frequency statistics for all recording rain gauge stations with more than 10 years of records.

Statistics for duration from 5 minutes to 24 hours are computed separately for each gauge. The results in rainfall rate units (mm/hr) are plotted on graph paper, scaled logarithmically in both directions. To aid interpolation, curves are fit to the data points for each of six return periods [1,4].

The discussion concludes that:

1. Depth duration relationships are not independent of geography.

2. For each recording rain gauge, B_T is not independent of return period T. Bell [12], Hershfield [3], recognized that short rainfall events ($t \leq$ 2hours) and long rainfall events (t greater than 2 hours) follow different depth-duration relationships i.e. $(1 + B_T)$ values are generally different in the ranges 5 minutes $\leq t \leq$ 2 hours and 2 hours $< t <$ 24 hours.

W. D. Hogg [12] has discussed and discovered the IDF function for Sicily. He has used data of more than 10 years. He has calculated the intensity of rainfall from the rainfall recorded continuously from 5 minutes to 24 hours for each gage. The IDF function is plotted on log-log paper, for 2, 5, 10, 25, 50 and 100 years, return periods. He has used the method of least square to define the best-fit line, and has used a depth-duration function as a basis for the study [12].

The Depth-duration function is for the world's largest events of rainfall [1]. An equation relating storm depth and duration is $h = Ct^n$.

Where

h = Storm depth in cm

t = Storm duration in hours

C = A co-efficient

And n = an exponent (a particular real number less than 1). Typically 'n' varies between 0.2 and 0.5.

The applicability of this equation is more accurate for regional or local conditions. This equation can also be used to study the characteristics of extreme rainfall events. Data of the world's greatest observed rainfall events were collected and equation $h = 39\ t^{0.5}$ was developed for the same purpose.

3. RESULTS AND DISCUSSIONS

It is often advisable to determine several intensity-duration-frequency functions, each for a different frequency or return period. A set of intensity-duration-frequency curves is referred to as IDF curves, with duration plotted in the abscissas, intensity in the ordinates and frequency (or return period) as curve parameter 7. Scales are used in the construction of IDF curves. These curves are developed for use in urban storm drainage designs and other applications. In equation,

$$I = \frac{KT^n}{(t+b)^m}$$

Where

I = Intensity of rainfall in in/hr,

t = duration of rainfall in minutes

T = return period in years

The values of k, b, m and n as evaluated from measured data of precipitation [1,3] are 42.266, -0.851, 0.821, and 0.178 respectively.

The IDF function developed may be used for the prediction of future rainfall intensities for any return period. The IDF curves are also plotted as shown in graph for 2, 5, 10, 25, 50 and 100 years return periods, which may be used for the same purpose but for the plotted return periods. However the inner values can be found out by interpolation from the curves. These curves may also be developed for any return periods. Design frequencies (and return periods) vary with the type of the project and degree of protection required. Commonly used return periods are [1]:

- 2 years for storm sewers in less important rural areas.
- 5 to 10 years for storm sewers in residential areas.
- 10 to 50 years for storm sewers in commercial areas.
- 50 to 100 years for flood protection works. However, keeping in view the importance of the project, the desired IDF function may be plotted [9].

The shape of the IDF function plotted is asymptotic in nature. Intensity of precipitation increases as duration decreases and vice versa. The separation between the IDF curves plotted for different return periods depends upon the value of n. When it is less, the IDF curves are closer [13,14].

The function obtained is applicable till the time there are no sudden changes in the environment due to pollution and deforestation.

For the world's largest rainfall events, the value of exponent n and coefficient 'C' were computed by the methodology of the current study. These values obtained are 0.493 and 35.15 against 0.50 and 39 respectively. The value of n obtained for the region is 0.178 showing less rainfall [3,15]. Moreover the value of n for India is 0.20 [7].

However, the statistical errors between the observed and computed intensities of precipitation are 7%.

4. CONCLUSIONS

1. The intensity for maximum rainfall events

can be predicted for any return period from the IDF function.

2. The intensity can directly be predicted for two years, five years, ten years, twenty-five years, fifty years and one hundred years and can be interpolated for the return periods in between. Whereas the intensity can be extrapolated for higher return periods.
3. If the value of two variables among intensity, duration and frequency are known, the third can be found out.

5. RECOMMENDATIONS

1. Lengthy data will give good results. Therefore a long data series should try to be collect.
2. It should be ensured that when recording the actual depth of precipitation it should take place through automatic precipitation recording gauges for most accurate study/results.
3. Increase the number of gauge stations in the region to get the variation in rainfall intensity and find out more specific results for each portion of the region.
4. Installation of automatic rainfall gauges recording on an hourly basis should be encouraged. If possible gauges recording in inches minute should be put to operation.
5. Data from other stations should be collected and the model should be verified by other researchers.
6. The IDF curves should be extended up to 24 hours and beyond by other researchers.

5. REFERENCES

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