Diyala Journal of Engineering Sciences, Vol. 11, No. 2, June 2018, pages 49-54 ISSN 1999-8716
DOI: 10.24237/djes.2018.11206 eISSN 2616-6909

Generation of Rainfall Intensity Duration Curves Using Disaggregation Technique

Qassem H. Jalut
Department of Civil Engineering, Engineering College, University of Daiyla

Abstract

The rainfall intensity-duration-frequency (IDF) relationship is a relationship between rainfall duration, rainfall intensity and storm return period generally required for outlining of various hydraulic structures such as dams, Culverts, Siphons etc. Evaluation of rainfall extreme expected values, as used in intensity-duration-frequency (IDF) relationship, has long been a major interest of both theoretical and applied studies in surface hydrology. The IDF relationship is resolved through factual investigation of tests of records from a given meteorological stations cover the study region. For the present study, information from the verifiable arrangement of most extreme month to month precipitation acquired from a pluviometric Kirkuk station were utilized. They were made accessible by the Ministry of Water Resources. Thirty seven outrageous occasions were gotten from the record from years of 1971 to 2010. Considering that the sample is representative of the genesis of the intense rainfalls of the studied region and that the probability of the events follows distribution of extremes Type I (Gumbel distribution). Many stations do not have long information records for lengths shorter than 1 day and in this way the character of short precipitation lengths must be evaluated from different sources. The fundamental focus point of this paper is to build IDF curves for the area utilizing precipitation recurrence investigation procedures utilizing new disaggregation strategy method. Different durations ranging from 5 minutes to 24 hours for return periods of 5, 10, 50, and 100 years were analyzed.

Keywords: Rainfall intensity; Disaggregation ;intensity-duration frequency curves .

Paper History: (22/11/2016), Accepted: (20/2/2017)

1. Introduction

Rainfall Intensity-Duration-Frequency (IDF) curves received considerable attention over the past decade. Many stations do not have long information records for lengths shorter than 1 day and in this way the character of short precipitation lengths must be evaluated from different sources. Koutsoyiannis et al. (1998) [1] proposed another summing up way to deal with the definition of IDF curves utilizing productive parameterization. Nhat et al. (2006) [2] have established IDF curves for the Monsoon area of Vietnam with two main procedures by which empirical functions were used to produce a set of IDF curves at 7 stations. He also produced a generalized IDF equation for location areas. Cecilia S. et al. (2007) [3] represents an experimental comparison of different methods for estimating rainfall intensity-duration-frequency relations from fragmentary records. Kim et al. (2008) [4] improved the accuracy of IDF Curves by using long and short duration separation technique. Application results showed that the developed IDF curve is more accurate than the previously suggested IDF curves. Ben-Zvi (2009) [5] proposed a procedure for basing intensity–duration–frequency (IDF) curves on partial duration series which are substantially larger than those commonly used for this purpose. El-Sayed (2011) [6] fitted the maximum annual precipitation series to one of the statistical distributions; Type I Extreme value (Gumbel), General Extreme value (GEV), Weibull, Normal, Log-normal, Pearson Type III and Log- Pearson Type III distributions. This distribution is used to find depth-duration-frequency values at 2, 10, 25, 50, 100 and 200 years. The fundamental focus point of this paper is to build IDF curves for the area utilizing precipitation recurrence investigation procedures utilizing new disaggregation strategy method. Different durations ranging from 5 minutes to 24 hours for return periods of 5, 10, 50, and 100 years were analyzed.

3. Data Base

For hydrological studies, data from the historical series of maximum monthly rainfall obtained from a pluviometric Kirkuk station were used. They were made available by the ministry of water resources. In the hydrological evaluation, only the extreme event series of the years without omissions were considered. For our study, the years considered without omissions were those that presented a complete record sequence of the period between October and April. In the end, a sample of rainfalls with 37 extreme events was obtained from the record presented in Table 1 from years of 1971 to 2010.

Considering that the sample is representative of the genesis of the intense rainfalls of the studied region and that the probability of the events follows distribution of extremes Type I (Gumbel distribution).

4. Frequency Analysis

For the analysis of the maximum annual rainfall, the asymptotic extreme distribution type I (Gumbel distribution) was adopted as theoretical model. Equation 1 and 2 show the mathematical relation and characteristic parameters of the adopted model (TUCCI, 1993) [7]. This model based on the extreme distribution type I . The following relations is used:

$$P(x_o \geq x) = 1 - e^{-e^{-y}} \qquad (1)$$

$$y = \frac{(x - \mu)}{\alpha} \qquad (2)$$

In which: $P(x_o \geq x)$ = probability that rainfall x is under or equal to a generic xo; and α and μ = characteristic parameters of the distribution. The parameters of the distribution are estimated by the Moment method using the mean $\bar{x}$ and the standard deviations s of the maximum annual rainfall sample values obtain from Table 1. Values of maximum daily rainfall that correspond to different recurrence times- calculated using the adjusted probability theoretical distribution (Gumbel distribution) are shown in Figure 1 using semi-log plot . Using Figure 1 and for different return periods (5,10,50,100 and 1000 years) the corresponding rainfall depths in mm were obtained and listed in Table 2.

Table 1 Monthly rainfall recorded at Kirkuk metrological station in mm for period (1971 – 2010)

Year	Jan.	Feb.	Mar.	Apr	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	TOTAL
1970	74.4	3.3	79.9	17.8	0.6	0	0.001	0	0	2.4	15	21	214.410
1971	1.3	42.3	100.1	144.4	0.7	0.0	0.0	0.0	0.0	0.001	13.5	58.8	361.101
1972	87.8	84.7	87.9	59.6	48.7	0.001	0.001	0.0	0.001	0.001	30.1	56.6	455.404
1973	66.3	64.1	33.4	39.8	9.1	0.0	0.0	0.0	0.0	0.001	5.6	42.6	260.901
1974	142.7	98.5	286.6	73.5	0.001	0.0	0.0	0.0	0.0	0.001	26.2	68.4	695.902
1975	37.0	155.8	13.9	56.6	16.6	0.001	0.0	0.0	0.0	0.001	23.0	117.9	420.802
1976	54.6	72.9	72.2	59.9	29.2	0.001	0.0	0.0	0.001	14.5	2.2	48.5	351.002
1977	82.5	40.4	33.9	67.1	13.2	0.3	0.0	0.0	0.0	2.7	22.6	83.3	346.000
1978	47.4	48.2	54.5	12.2	0.5	0.001	0.0	0.0	0.0	5.2	11.4	63.6	243.001
1979	84	22.3	42.3	2.6	23.1	0.001	0.0	0.0	0.001	37.5	28.3	51.9	292.002
1980	20.4	88.7	49.8	47.5	12.7	0.0	0.0	0.0	0.0	8.5	71.7	61.3	360.600
1981	86.3	92.5	87.6	21.6	13.9	1.2	0.001	0.001	0.0	11	70.9	104.4	489.402
1982	125.1	42.6	40	120.4	37	0.0	0.0	0.0	8.2	76.9	58.1	23.7	532.001
1983	36.7	38.7	26.7	37	28.5	0.0	0.0	0.0	0.0	0.001	13.5	20.6	201.701
1984	8.9	12.3	41	25.9	0.6	0.0	0.0	0.0	0.0	21.6	136	25.3	271.600
1985	63.9	101.1	36.8	29.4	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.3	343.600
1986	15.2	117.4	12.3	65.8	13.7	0.0	0.0	0.0	1.6	6.9	59.7	20.6	313.200
1987	17.2	57.7	70.8	6.1	3	0.0	0.0	0.0	0.0	22.4	5.3	123.5	306.000
1988	100.9	81.4	103.7	57.8	0.001	0.0	0.0	0.0	0.0	4.5	10.1	99.7	458.101
1989	20	41.5	116.8	0.001	1.2	0.0	0.0	1.6	0.0	10.8	116	83.9	346.801
1990	26.7	107.7	41	39.6	0.001	0.0	0.0	0.0	0.0	3.2	6.8	19.4	244.401
1991	68.3	106.4	M*	M	M	M	0.0	0.0	0.0	35.1	75.3	110.4	395.400
1992	130.8	147.6	55	21.5	32.8	1	0.0	0.0	0.001	0.0	157.9	122.8	669.402
1993	68.2	53.4	83	122.5	86.3	0.0	0.0	0.0	0.0	66	54.2	61.1	594.700
1994	94	33	47.2	29.3	11.1	0.0	0.0	0.0	0.001	13.8	75.7	61.2	365.301
1995	38.8	115.7	38.1	58.6	5.7	1.1	0.0	0.0	8.2	0.0	4	15.3	285.500
1996	148.8	14.2	95.4	24.9	6.2	0.0	0.001	0.0	0.8	4.8	38.5	64.9	398.501
1997	72.9	45.6	78.4	42	12.8	0.2	0.0	0.0	0.0	33.5	119.7	90.2	495.300
1998	119	41	49.5	60.7	5.4	1.6	8.1	0.0	0.0	0.0	0.0	2.4	287.700
1999	93.3	72.9	4	5.9	0.1	0.0	0.0	0.0	0.0	4.5	7.5	41.6	229.800

2000	85.4	14.7	11.4	6.4	5.6	0.0	0.0	0.0	0.001	10.3	28.8	71.6	234.201
2001	48.8	26.7	66.4	12.3	6.3	0	0	0.000	2.2	4.7	28.8	80.8	275.000
2002	104.7	17.2	81.1	31.3	9.2	0	0	0.000	0	14.7	22.9	180.5	461.600
2003	40	0	0	0	3.1	0	0	0.000	0	1.9	52.7	85.9	183.600
2004	125	52.7	8.6	49.9	4.9	0	0	0.000	0	1.0	43	27	312.100
2005	83.3	63.5	54.1	27.7	7.5	0.001	0	0.000	6.4	0.1	2.6	4.2	249.401
2006	65.3	191.9	0.2	98.3	37.7	0	0	0.001	0	38.4	14.7	11.9	458.401
2007	34.3	65.7	25.2	34.3	8.3	0.001	0	0.000	0	0.8	0.001	4.5	173.102
2008	49	27.5	26.1	0.1	4.6	0.001	0	0.001	0.2	17.2	5.8	4.4	134.902
2009	6.2	6.2	49.6	34.6	0.001	0	0	0.000	0.2	36.9	54.5	37.6	225.601
2010	22.5	56.9	64.4	29.2	56.7	M	M	M	M	M	M	M	229.700
AVG.	65.8	64.2	58.2	42.9	13.8	0.1	0.2	0.0	0.7	12.8	38.2	57.5	345.540
Max.	148.8	191.9	286.6	144.4	86.3	1.6	8.1	1.6	8.2	76.9	157.9	180.5	695.920
Min.	1.3	3.3	0.2	0.001	0	0	0	0	0	0	0	0	134.902
* M = Missing data													

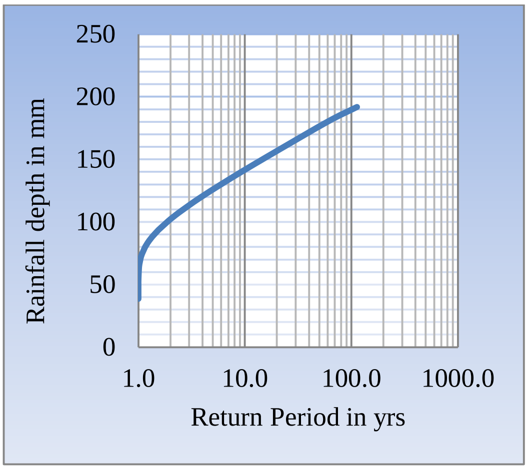

Figure 1: Rainfall depth versus different return periods

Table 2 Maximum rainfall (mm) that last 1(one) day estimated using Gumbel Distribution (from Figure 1)

Storm Recurrence (Return Period) Years	Exceedance Probability	Rainfall Depth (mm)
5	0.2	125
10	0.1	141
50	0.02	175
100	0.01	190
1000	0.001	238

4. Disaggregation Coefficients

The study area is situated in a semiarid region, where rainfall regimen is characterized by low frequency short term heavy storms**.** These characteristics indicate the adoption of ($\frac{P_{24hrs}}{P_{1\,day}}$ =1) where p24 hrs represents the maximum 24-hours rainfall and P1 day represents the maximum one day rainfall. For conservative estimation the relation between maximum 24-hours rainfall and maximum one day rainfall was taken to be 1.1 according to the recommendation cited in (Matos, 2006) [8]. A number of publications about studies performed in regions with different climate features have shown that the relations between different rainfalls do not show significant variations as shown in Table 3. Table 3 represents disaggregation coefficients obtained from different sources such as(U.S. Weather Bureau, Denver (North America), Bahia(South America)). CETESB method used Equation 4 and 5 to calculate the rainfall disaggregation coefficients. The evaluation of rainfalls with durations not listed in Table 3 was performed using rainfall disaggregation coefficients calculated from relation presented in Equation 4 and 5.

$$\frac{P_{24hrs}}{P_{1\,day}} = 1.0 \qquad (4)$$

$$C_{24}(d) = \frac{P_{24hrs}}{P_{1\,day}} \exp\left\{1.5 \ln\left[\frac{\ln(d)}{7.3}\right]\right\} \qquad (5)$$

Where :

$C_{24}(d)$ = 24- hour rainfall disaggregation coefficient

d= rainfall duration in minutes.

For semiarid region use ($\frac{P_{24hrs}}{P_{1\ day}}$ =1) and Equation 5 one can calculate the disaggregation coefficient:

Table 3 Relation between different rainfall durations(Matos, 2006)

Relation between rainfall durations	Values			
	Bahia	Adopted in Denver	U.S. Weather Bureau	CETESB Equations (5,6)
5 min/ 30 min	0.3	0.42	0.37	0.34
10 min/ 30 min	0.5	0.63	0.57	0.54
15 min/ 30 min	0.67	0.75	0.72	0.7
20 min/ 30 min	0.8	0.84		0.81
25 min/ 30 min		0.92		0.91
30 min/1 hr	0.73		0.79	0.74
1 hr/ 24 hr	0.57			0.42
6hr/24hr	0.85			0.72
8hr/24hr				0.78
10hr/24hr	0.89			0.82
12hr/24hr	0.91			0.85

5. Generation of IDF curves

Rainfall depths of different duration rainfalls based on maximum one day rainfall, resulting from the extreme event frequency analysis and the use of one day disaggregation coefficients C(d) determined by Equation 4 and 5 is given in Table 4. Graphical representation of intensity duration frequency curves to be used in the hydrologic study is shown in Figure 2.

Table 4 Rainfall depth and intensities corresponding to different durations and return periods

Duration		Rainfall Depth (mm)						Rainfall Intensity (cm/hr)			
	c(d)	05-year	10-year	50-year	100-year	1000-year	05-year	10-year	50-year	100-year	1000-year
05 minutes	0.11	13	15	18	20	25	16	18	22	24	30
15 minutes	0.22	27	31	38	41	52	11	12	15	17	21
30 minutes	0.31	39	44	54	59	74	8	9	11	12	15
60 minutes	0.42	53	59	74	80	100	5	6	7	8	10
02 hours	0.53	66	75	93	101	126	3	4	5	5	6
03 hours	0.60	75	85	105	114	143	2	3	3	4	5
06 hours	0.72	90	102	126	137	171	2	2	2	2	3
12 hours	0.85	106	120	149	162	202	1	1	1	1	2
24 hours	1.09	137	154	191	208	260	1	1	1	1	1
01 days	1	125	141	175	190						

Diyala Journal of Engineering Sciences, Vol. 11, No. 2, June 2018, pages 49-54 ISSN 1999-8716
DOI: 10.24237/djes.2018.11206 eISSN 2616-6909

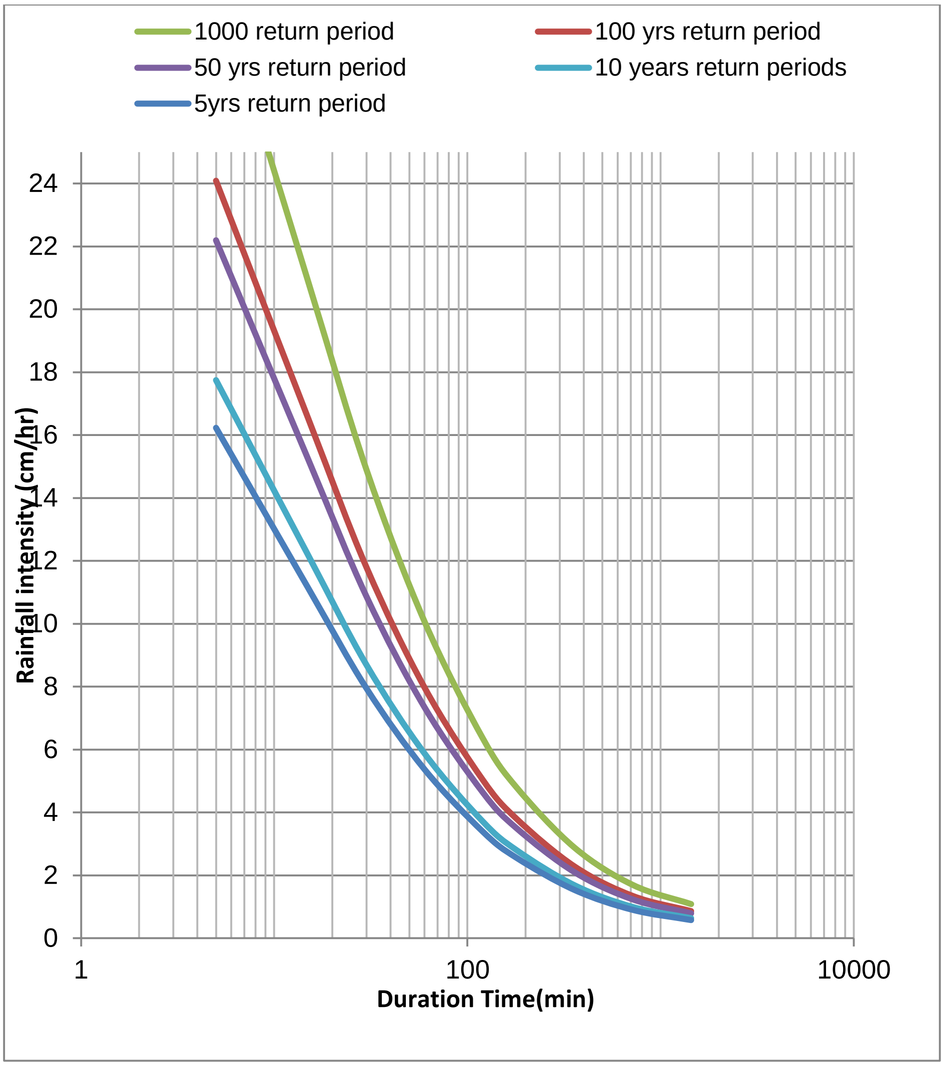

Figure 2: Rainfall duration intensity curve for different return period based on disaggregated data for years 1971 – 2010

6. Conclusion

The historical series of maximum monthly rainfall obtained from a pluviometric Kirkuk station were used. the asymptotic extreme distribution type I (Gumbel distribution) was adopted as theoretical model. this distribution is used to find depth-duration-frequency(DDF) values at 5, 10, 50,100 and 1000 years. These DDF values are used along with the rainfall disaggregation coefficients calculated from relation presented in Equation 4 and 5 the rainfall depth and intensities corresponding to different durations and return periods were obtained .The IDF curves are constructed to estimate rainfall intensity for various return periods and rainfall durations. Due to the need for short precipitation lengths, intensities corresponding to short durations. must be evaluated. The use of the disaggregation coefficients prove to be reliable and easy to achieve this task , which based on vast accumulated experience of a well known hydrological consulting firms.

References :

[1] Koutsoyiannis, D., Kozonis, D., and Manetas, A., (1998), A mathematical framework for studying rainfall intensity-duration-frequency relationships, Journal of Hydrology, 206(1-2), pp 118-135.
[2] Nhat L., Y. Tachikawa and K. Takara, (2006), Establishment of Intensity-Duration-Frequency Curves for Preceipitation in the Monsoon Area of Vietnam, Annuals of Disas. Prev.Res.Inst., Kyoto Univ., No. 49 B.
[3] Cecilia S. , R. T. Clarkeb and D. A. Jones, (2007), An experimental comparison of methods for estimating rainfall intensity-duration-frequency relations from

DOI: 10.24237/djes.2018.11206 eISSN 2616-6909

fragmentary records. Journal of Hydrology Vol. 341.pp 79-89.

[4] Kim T., J. Shin, K. Kim and J. Heo, (2008), Improving Accuracy of IDF Curves Using Long- and Short-duration Separation and Multi-Objective Genetic Algorithm, World Environmental and Water Resources Congress 2008 Ahupua'a, ASCE.

[5] Ben-Zvi A., (2009), Rainfall intensity–duration–frequency relationships derived from large partial duration series, Journal of Hydrology 367: pp 104-114.

[6] El-Sayed., E.A, (2011), Generation of Rainfall Intensity Duration Frequency Curves For Ungauged Sites, Nile Basin Water Science & Engineering Journal, Vol.4, Issue 1, 2011.

[7] TUCCI , C.E.M. (1993), Hydrology science and application Porto Alegre publisher . p 95

[8] MATOS,J. E. R. (2006), Heavy rains in Bahia: Regionalization equations and Methodologies. Salvador :Edufba p 296.