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ARID AND SEMI-ARID REGIONS IDF CURVE GENERATION: CASE STUDY AL QUSIR, EGYPT

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ABSTRACT

Intensity-Duration-Frequency curve is a graphical representation of the likelihood of a specific average rainfall intensity occurring. It is calculated using a mathematical function that links rainfall intensity to duration and frequency. These curves are extensively used in hydrology and civil engineering for flood forecasts and urban drainage design. In water resources projects and hydrological assessments, intensity-duration-frequency (IDF) curves are often utilized. The actual distribution of rainfall intensity over the period of rainfall is one of the most critical prerequisites for producing IDF curves, yet short-duration rainfall records are rare in arid places where daily rainfall data is available. Hydrologists can use the Natural Resources Conservation Service's (NRCS) standard synthetic rainfall distributions to generate short-duration rainfall data from daily rainfall data. The main purpose of this research is to demonstrate the technique for creating the IDF curve using daily rainfall data collected from the Al Qusir weather station. Where 36 years were used in this study in 1934 and from 1985 to 2020, where the highest value was recorded at 34 mm and was in 1934 The HyfranPlus program was used to perform frequency analysis on the observed rainfall records. The results of the comparison indicate that the Gamma distribution (maximum likelihood) is best suited to represent the rainfall data for the Al Qusir weather station in this. The results of the corresponding rainfall data for 2, 5, 10, 25, 50 and 100 years were used and the corresponding rain intensity was inferred for every 6 minutes over a 24 hour period. for each of the previous years.

Keywords: IDF, NRCS rainfall distributions, Rainfall intensity, arid regions, semi- arid regions

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1. INTRODUCTION

Al Qusir, Red Sea Governorate, Egypt, It is one of the semi-arid locations along the Red Sea's shore. The Red Sea coast has a dry environment with little precipitation. Rainfall has increased in frequency in recent years, resulting in severe flash floods in some areas. For example, on November 1, 1994, the Eastern Desert received 60mm of rain [1]. On November 16th, 17th, and 18th, 1996, a heavy downpour with a total rainfall of 40 mm occurred [2]. More recently, on 2020 and on 1997, at a density of 20 mm / day. It caused flash floods in the El Qusir city As a result, the tourist villages have been damaged, and many people have died and The international coastal road from Marsa Alam to Safaga stopped, and the Qena short road stopped [3]. Most water resource assessment studies require high-resolution rainfall data, but they are not available in many regions of the world, particularly in arid and semi-arid areas, due to the high expense of installing recording rain gauges. Daily or annual rainfall records are frequently available.

Hydrologists can solve this challenge by converting daily rainfall data into shorter-duration series. The development of intensity–duration–frequency curves (IDF Curves) is a graphic representation of the relationship between rainfall intensity and storm length over a certain return time. It is one of the most important hydrological analyses. [4]. Since 1935, engineers in the United States have used IDF curves. David Yarnell developed the first "Intensity Frequency Maps" for the United States in 1935. Rainfall intensity assessments, particularly IDF curves for varied return periods, are required for most water resource planning and management projects [5]. The IDF curve, for example, was designed by Saudi Arabian hydrology and engineering academics (Al-Wagdany 2021[6]; Al-Amri and Subyani 2017 [7]; Elsebaie 2012[8]). Researchers have also offered several ways based on statistical data analysis for generating the IDF curve for arid and non-arid environments. For example, Bell (1969) [9] and Chen (1983) [10] developed IDF formulas for certain United States locations. The IDF curves can be calculated using frequency analysis of short-duration precipitation data or a variety of empirical formulae. Chowdhury et al. (2007) used the Indian Meteorological Department's empirical reduction formula to derive short-duration rainfall from daily rainfall in Sylhet city. Al-Wagdany et al. (2021) in Saudi Arabia created IDF curves using NRCS synthetic rainfall hyetographs and daily rainfall records. The most frequent method for separating total rainfall into shorter-duration segments is synthetic rainfall hyetographs (Bonta 2004). The four synthetic NRCS distributions (Types I, IA, II, and III; (SCS, 1986)) created by the National Resource Conservation Service are the most prevalent rainfall temporal distributions (NRCS). For the West Coast of the United States, Type I and IA hyetographs are recommended, Type III for the East Coast of the United States and the Gulf of Mexico area prone to severe tropical storms, and a Type II hyetograph for the rest of the United States. Due to the lack of short-duration rainfall records, the temporal distribution of rainfall in Egypt has not been well researched. The only rainfall records available are daily data. The main objective of this research is the possibility of using the daily rainfall data available in Al qusir station, coupled with NRCS temporal dimensionless rainfall distributions to generate short-duration rainfall data for the Al qusir a region in Egypt. The IDF curves are created using the generated short-duration rainfall series. IDF curves were created for durations ranging from 10 minutes to 1440 minutes, as well as five distinct return periods of 5, 10, 25, 50, and 100 years in this study. Using daily data from the Al qusir rain gauge, the research presents a method for constructing IDF curves.

2. STUDY AREA

Al Qusir city in the Red Sea Governorate in the eastern desert and it is bounded by latitude 25º 50' N to 26º 10' N, and longitude 33º 40' E to 34º 20' E. Al Qusir city is located in the outlet of the Ambagi. One of the largest wadis in the eastern desert of Egypt. This makes it vulnerable to flash flooding. The presence of some homes in Al Qusir in the course of the wadi exposes it to flooding and is a source of concern for the city. The city of Al Quseir has historical importance and is a home many artifacts, old Buildings and the old port are considered an important tourist destination and a destination for diving in Egypt. It is considered the fourth city in size among the cities of the Red Sea Governorate, after the cities of Ras Ghareb, Safaga and The Hurghada. (See Figure 1).

Figure 1 Geographical location of the study area

3. AVAILABLE HISTORICAL DATA OF RAINFALL

The precipitation data of Al Qusir Weather Station is analyzed to predict the magnitude of runoff and discharge in its sub-basins for different return periods. It is recommended that a data set of at least thirty years is required to estimate the return period of 100 years with acceptable accuracy. This analysis is performed as described in the following steps. Figure (2) shows the recorded rainfall data for the weather station in Al-Qusir, which was established in 1925, and since the rain data from 1925 to 1984 is not available, there is no data for the highest value that occurred during this period, which was in 1934 and its value was 34 mm, and during the period from 1985 to 2020 and the maximum data value of 20 mm recorded in 1997 and 2020.

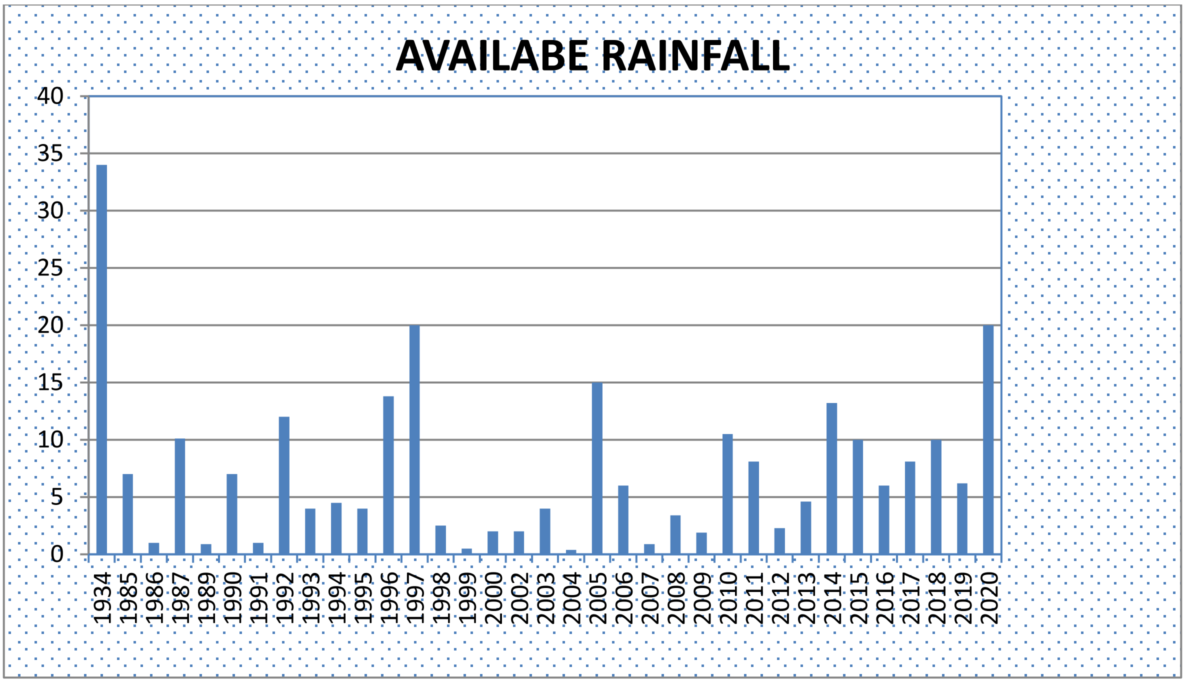


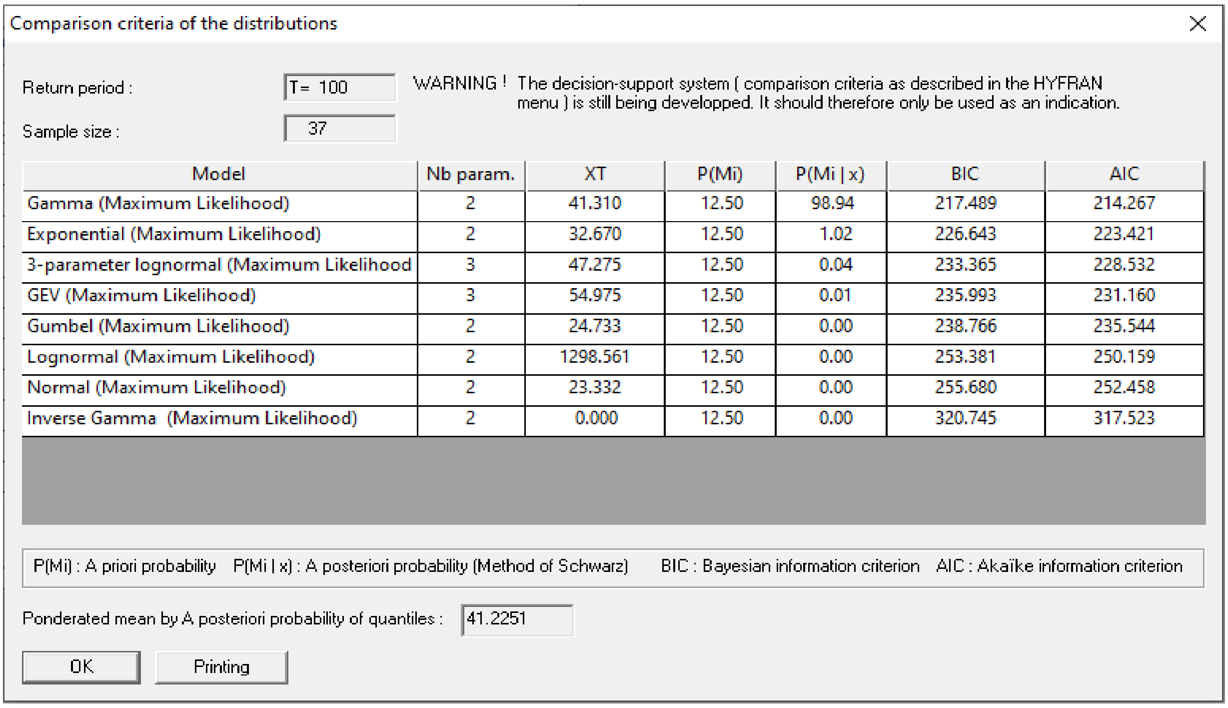
Figure 2 recorded rainfall data for Al-Qusir weather station

4. CONSTRUCTING OF IDF CURVES

Future rainfall depths in dry and semi-arid areas cannot be predicted with total certainty. As a result, using probability concepts, the magnitude and frequency of rainfall should be explored and appraised. Rainfall data are typically short or absent in locations where there is no reliable measurement, making it impossible to estimate intensity – time duration – frequency [11]. The IDF curves are created using the following steps: The first step is: Analysis of daily rainfall data taken at the Al Qusir station 1934 and from 1985 to 2020 and Using the proper statistical distribution, estimate the maximum depth of rainfall for 2year, 5 years, 10 years, 25 years, 50 years, and 100 years. The second stage is to generate short-duration rainfall data using typical NRCS Type II temporal rainfall distributions. The third step is to calculate the intensity of rainfall each period (from 10 minutes to 1440 minutes) for the different return periods; 2, 5, 10, 25, 50, and 100. For the same rainfall station, the generated data is utilized to create IDF curves.

5. PROBABILITY DISTRIBUTION

The HYFRAN-PLUS application was used to apply frequency analysis to rainfall data for the Al Qusir station in order to forecast the maximum depth of rainfall in Al Qusir for different return periods. The goal of frequency analysis is to use statistical probability distributions to calculate the size of severe occurrences (in this case, rainfall) and their frequency of occurrence [12]. The HYFRAN-PLUS application includes 14 statistical distributions that perform hydrological frequency analysis (HFA) for maximum yearly rainfall values of floods to a random sample if it is independent and identically distributed [13]. The frequency of available distributions was chosen and compared in order to determine the best acceptable model for data representation. The statistical distribution that best fits the observed sample data is then identified using statistical criteria. By selecting the lowest value for the Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of the comparison indicate that the Gamma distribution (maximum likelihood) is best suited to represent the rainfall data for the Al-Qusir weather station (see Figure 3, 4, 5, 6 and 7).


Comparison criteria of the distributions

Return period : T= 100

Sample size : 37

WARNING ! The decision-support system (comparison criteria as described in the HYFRAN menu) is still being developped. It should therefore only be used as an indication.

Model	Nb param.	XT	P(Mi)	P(Mi | x)	BIC	AIC
Gamma (Maximum Likelihood)	2	41.310	12.50	98.94	217.489	214.267
Exponential (Maximum Likelihood)	2	32.670	12.50	1.02	226.643	223.421
3-parameter lognormal (Maximum Likelihood	3	47.275	12.50	0.04	233.365	228.532
GEV (Maximum Likelihood)	3	54.975	12.50	0.01	235.993	231.160
Gumbel (Maximum Likelihood)	2	24.733	12.50	0.00	238.766	235.544
Lognormal (Maximum Likelihood)	2	1298.561	12.50	0.00	253.381	250.159
Normal (Maximum Likelihood)	2	23.332	12.50	0.00	255.680	252.458
Inverse Gamma (Maximum Likelihood)	2	0.000	12.50	0.00	320.745	317.523

P(Mi) : A priori probability P(Mi | x) : A posteriori probability (Method of Schwarz) BIC : Bayesian information criterion AIC : Akaïke information criterion

Ponderated mean by A posteriori probability of quantiles : 41.2251

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Figure 3 Comparison Criteria of the Distributions for Station "maximum likelihood"

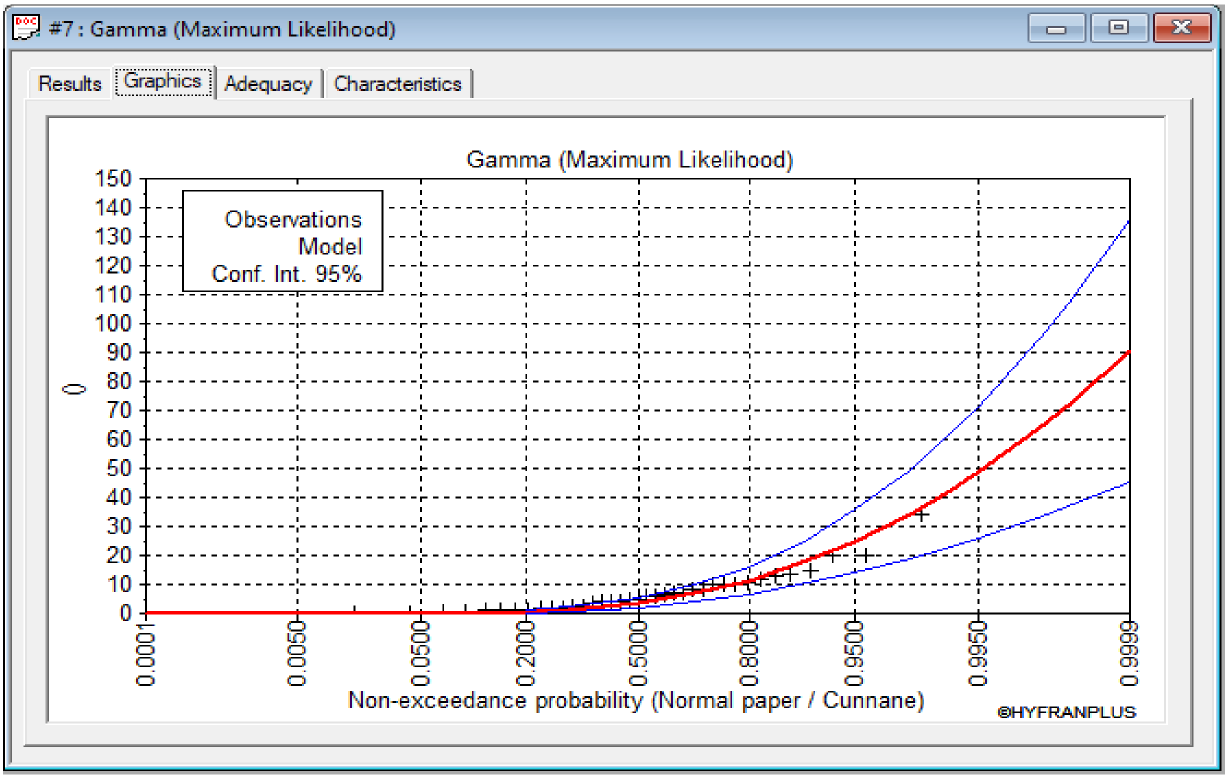
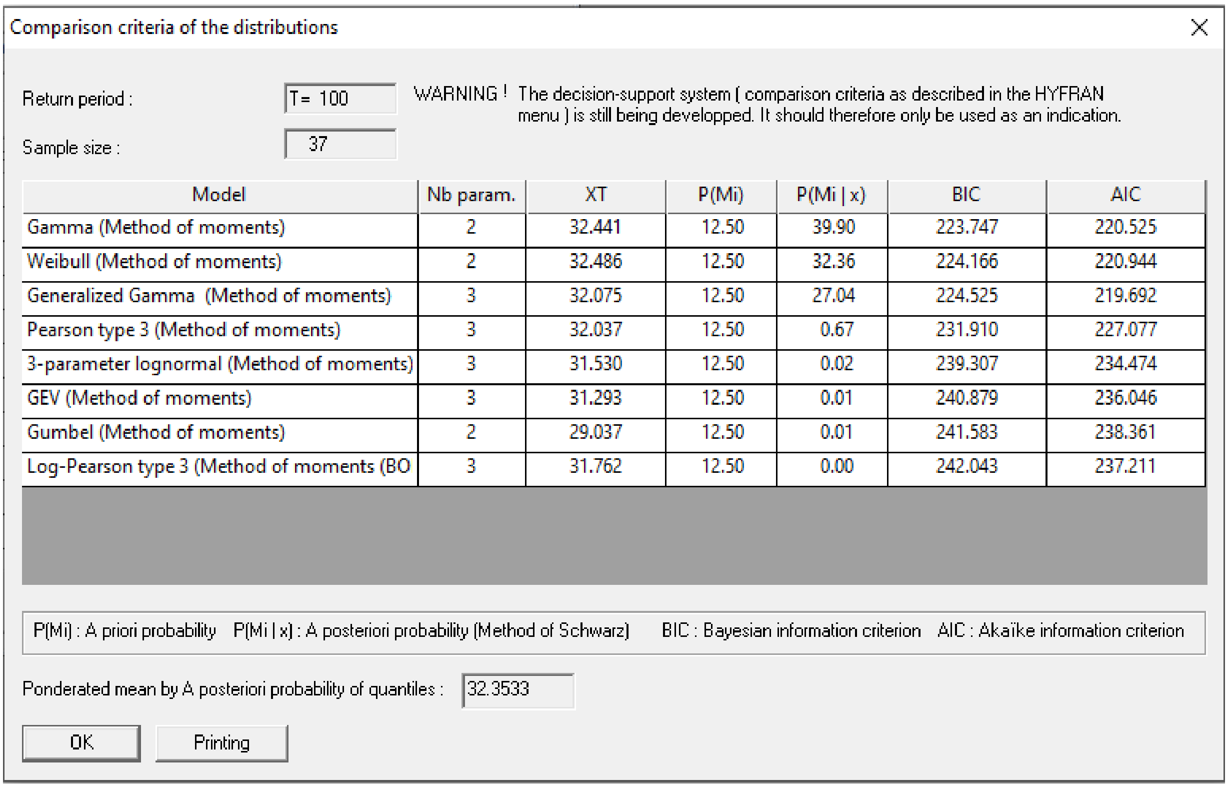


Figure 4 Distribution graph for Gamma "maximum likelihood"



Comparison criteria of the distributions

Return period : T= 100

Sample size : 37

WARNING ! The decision-support system (comparison criteria as described in the HYFRAN menu) is still being developped. It should therefore only be used as an indication.

Model	Nb param.	XT	P(Mi)	P(Mi | x)	BIC	AIC
Gamma (Method of moments)	2	32.441	12.50	39.90	223.747	220.525
Weibull (Method of moments)	2	32.486	12.50	32.36	224.166	220.944
Generalized Gamma (Method of moments)	3	32.075	12.50	27.04	224.525	219.692
Pearson type 3 (Method of moments)	3	32.037	12.50	0.67	231.910	227.077
3-parameter lognormal (Method of moments)	3	31.530	12.50	0.02	239.307	234.474
GEV (Method of moments)	3	31.293	12.50	0.01	240.879	236.046
Gumbel (Method of moments)	2	29.037	12.50	0.01	241.583	238.361
Log-Pearson type 3 (Method of moments (BO	3	31.762	12.50	0.00	242.043	237.211

P(Mi) : A priori probability P(Mi | x) : A posteriori probability (Method of Schwarz) BIC : Bayesian information criterion AIC : Akaïke information criterion

Ponderated mean by A posteriori probability of quantiles : 32.3533

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Figure 5 Comparison Criteria of the Distributions for Station “method of moments”

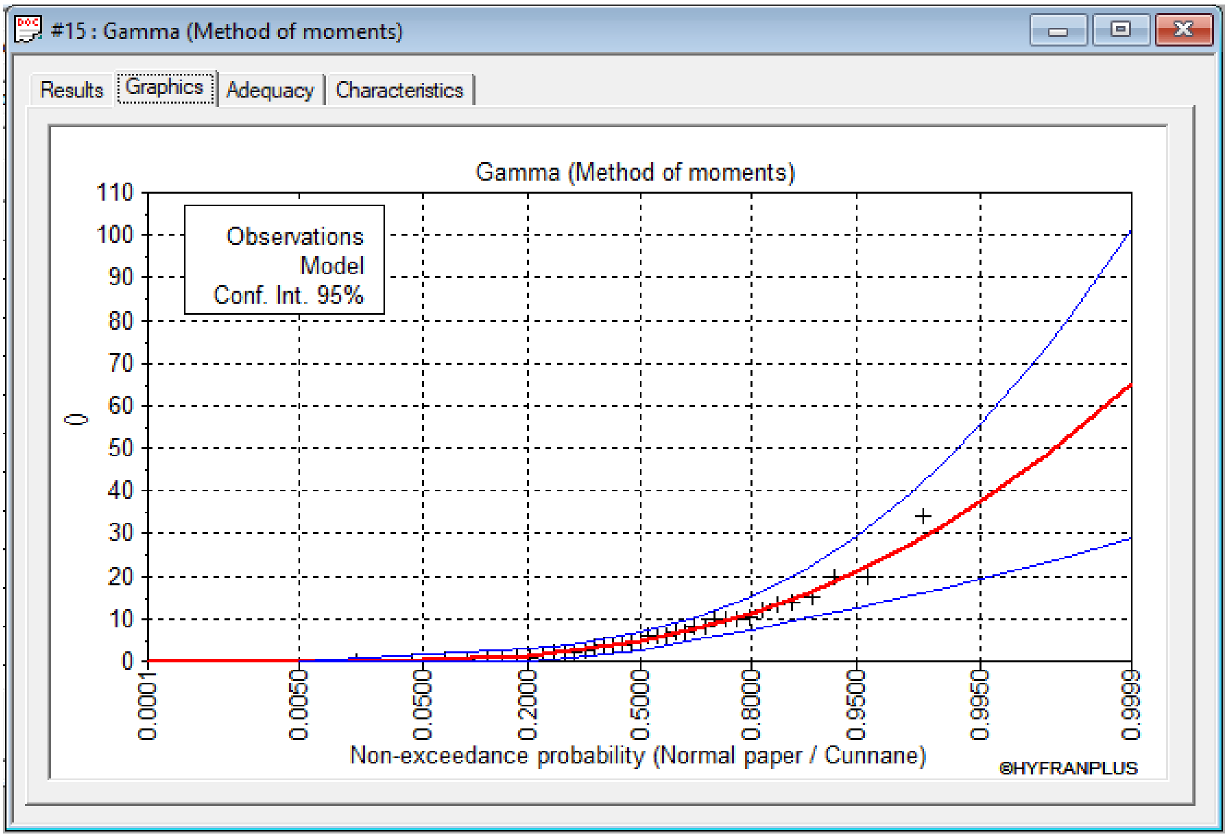
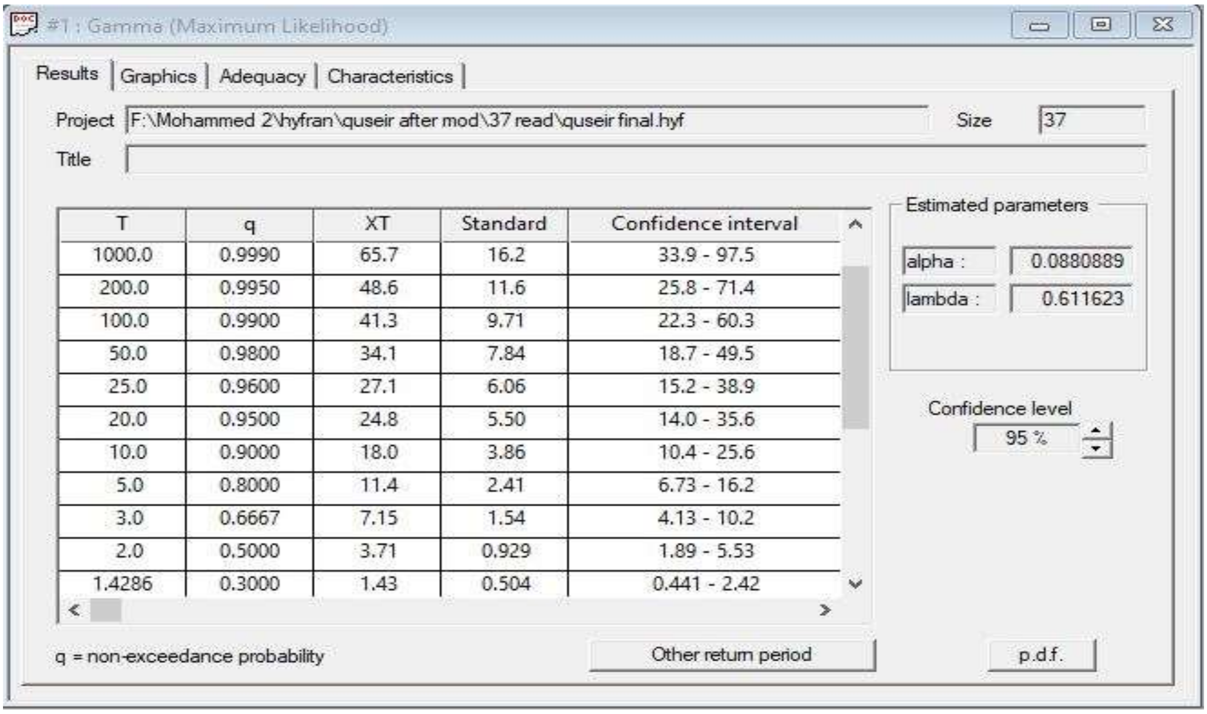


Figure 6 Distribution graph for Gamma “method of moment”


#1 : Gamma (Maximum Likelihood)

Results | Graphics | Adequacy | Characteristics

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T	q	XT	Standard	Confidence interval
1000.0	0.9990	65.7	16.2	33.9 - 97.5
200.0	0.9950	48.6	11.6	25.8 - 71.4
100.0	0.9900	41.3	9.71	22.3 - 60.3
50.0	0.9800	34.1	7.84	18.7 - 49.5
25.0	0.9600	27.1	6.06	15.2 - 38.9
20.0	0.9500	24.8	5.50	14.0 - 35.6
10.0	0.9000	18.0	3.86	10.4 - 25.6
5.0	0.8000	11.4	2.41	6.73 - 16.2
3.0	0.6667	7.15	1.54	4.13 - 10.2
2.0	0.5000	3.71	0.929	1.89 - 5.53
1.4286	0.3000	1.43	0.504	0.441 - 2.42

Estimated parameters

alpha : 0.0880889

lambda : 0.611623

Confidence level 95 %

q = non-exceedance probability

Other return period

p.d.f.

Figure 7 Gamma distributions (maximum likelihood)

Table 1 forecasted rainfall values at the Al-Qusir weather station

Rain gauge	Rainfall values for different Return Periods (mm/day)					
	2 years	5 years	10 years	25 years	50 years	100 years
Al-Qusir	3.71	11.40	18	27.1	34.1	41.30

6. RESULTS AND DISCUSSION

The rainfall depths corresponding to specific return periods were computed in this work utilizing statistical distribution functions to create IDF curves from rainfall data in the study area, and these functions are gamma. Engineers and hydrologists utilize synthetic rainfall distributions to convert daily observed rainfall data into shorter duration data in the United States and other parts of the world to construct and maintain hydraulic structures, and they have the advantage of being simple to use. [14]. The NRCS type II temporal rainfall distribution was utilized in this study to generate short-duration rainfall depths (from 10 minutes to 24 hours), as reported in [15]. (See Table 2). The resulting information is utilized to create IDF curves for the research region (Al Qusir city).

Table 2 Rainfall intensity (mm/ hr) at different rainfall duration using the 24-h type II NRCS distribution

Return Period	**2**	**5**	**10**	**25**	**50**	**100**
T(min)	**I(mm/hr)**	**I(mm/hr)**	**I(mm/hr)**	**I(mm/hr)**	**I(mm/hr)**	**I(mm/hr)**
6	5.09	15.63	24.67	37.15	46.74	56.61
12	4.31	13.24	20.90	31.46	39.59	47.95
18	3.82	11.73	18.52	27.88	35.08	42.49
24	3.30	10.15	16.03	24.13	30.36	36.77
30	2.82	8.66	13.68	20.60	25.92	31.39
36	2.47	7.58	11.97	18.02	22.67	27.46

42	2.20	6.77	10.69	16.09	20.25	24.52
48	1.99	6.13	9.68	14.57	18.33	22.20
54	1.82	5.60	8.84	13.31	16.75	20.29
60	1.68	5.17	8.17	12.29	15.47	18.74
120	1.00	3.06	4.84	7.29	9.17	11.10
240	0.59	1.82	2.88	4.33	5.45	6.60
360	0.44	1.34	2.12	3.19	4.02	4.86
420	0.39	1.20	1.89	2.85	3.58	4.34
480	0.35	1.08	1.71	2.57	3.24	3.92
600	0.30	0.92	1.45	2.18	2.74	3.32
720	0.26	0.80	1.26	1.90	2.39	2.89
840	0.23	0.71	1.12	1.69	2.13	2.58
960	0.21	0.64	1.02	1.53	1.93	2.33
1080	0.19	0.59	0.93	1.40	1.76	2.13
1200	0.18	0.54	0.86	1.29	1.63	1.97
1320	0.16	0.51	0.80	1.21	1.52	1.84
1440	0.15	0.48	0.75	1.13	1.42	1.72

The intensity duration frequency curve is plotted for various durations using the above rainfall intensity (see Table 2). The intensity duration frequency curve (see Figures (8.A), (8.B) and (8.C)) is depicted.

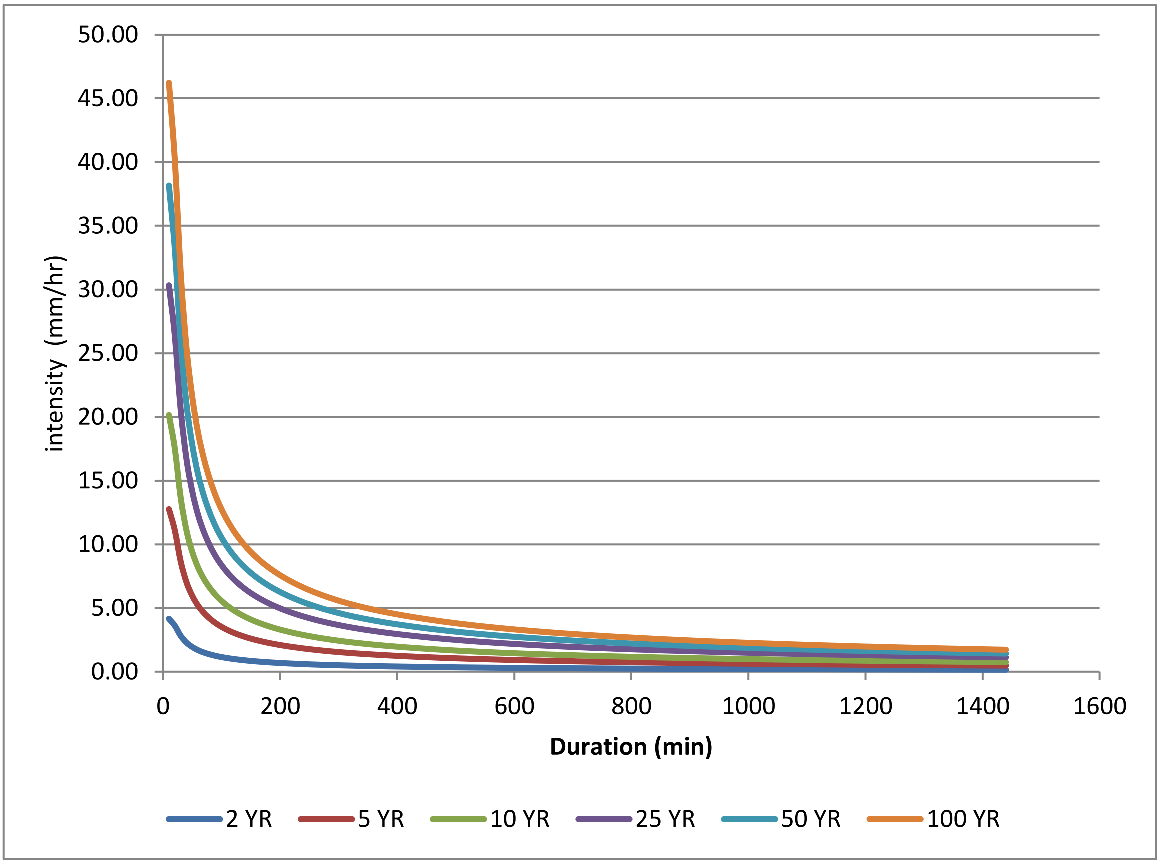

Figure 8 A

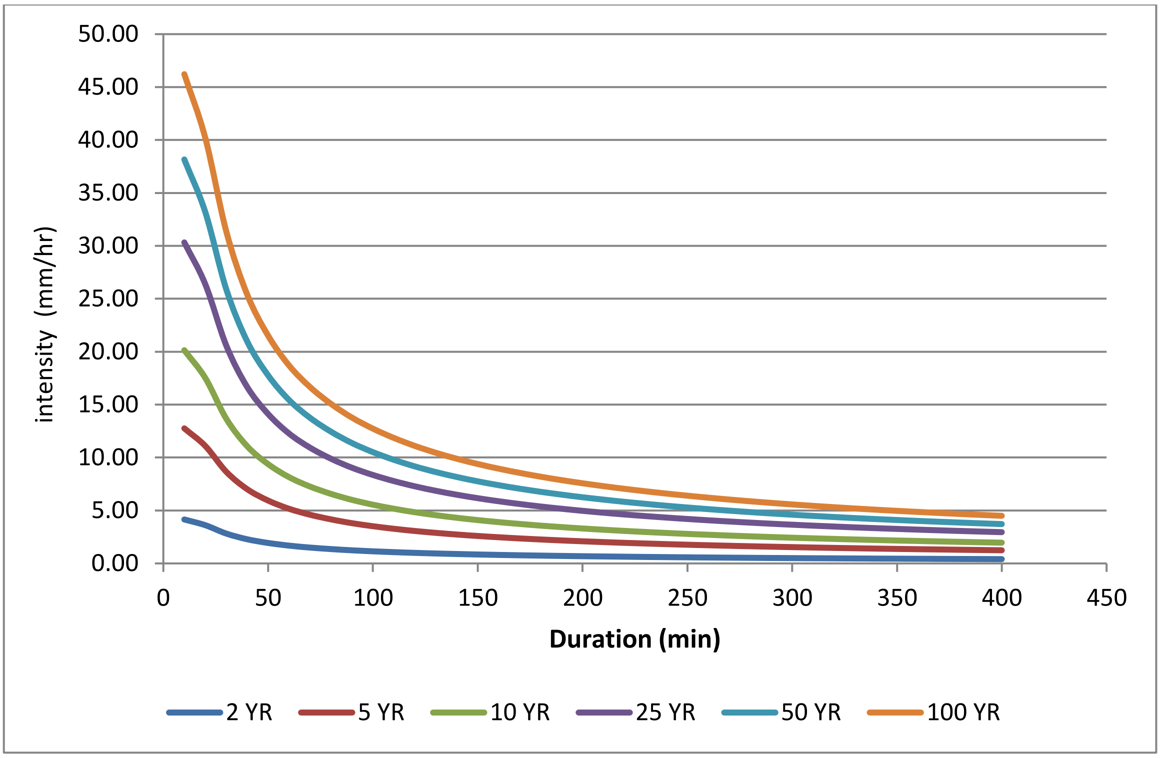

Figure 8 B

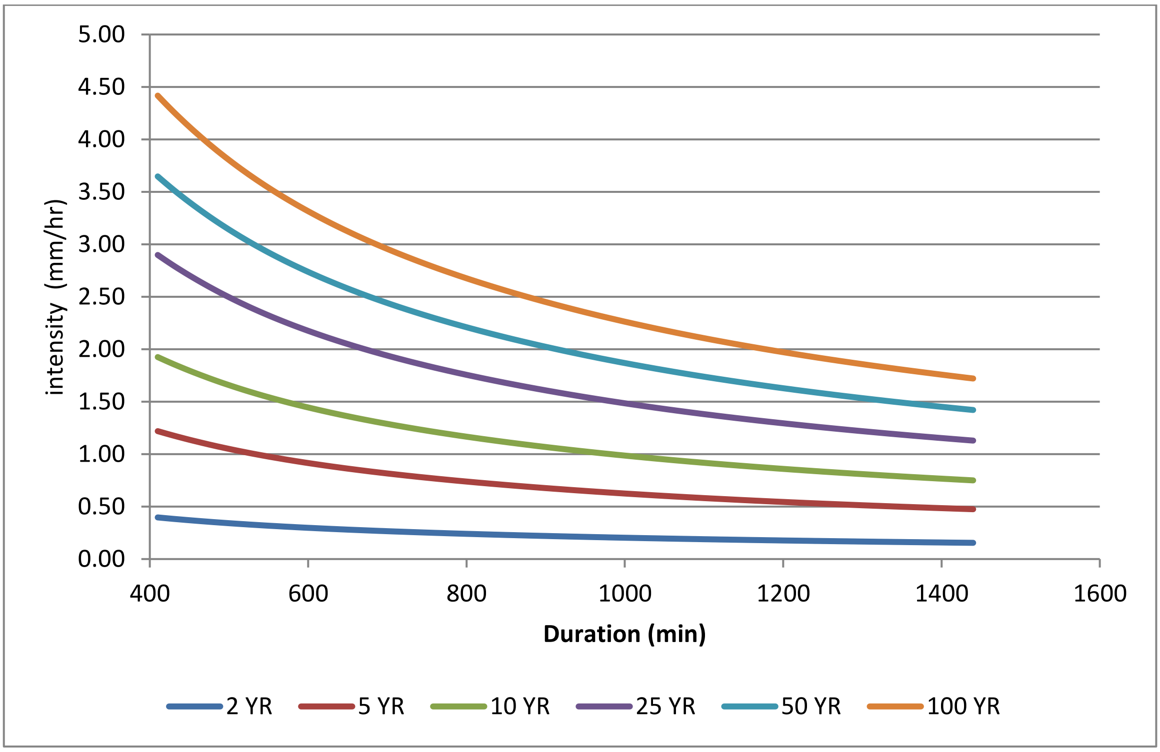

Figure 8 C

Figure 8 duration of intensity The Gamma method was used to generate frequency curves for the research area

7. CONCLUSION

Short-duration rainfall data is always scarce in arid regions, although daily rainfall data is frequently available. The maximum precipitation depth was determined in this study for varied return periods of 2, 5, 10, 25, 50, and 100 years, assuming that the data follows a gamma distribution. The goal of this paper is to create IDF curves for the Red Sea coast region of Al Qusir using NRCS temporal dimensionless rainfall distributions. Rainfall intensity-duration-frequency curves help engineers plan and develop water resource projects. Engineers and hydrologists will utilise frequency analysis as a general guide to prevent floods and droughts, and it will be applied to the planning and design of water resources connected to engineering, such as reservoir design and flood control work. Rainfall analysis and determining the yearly maximum daily rainfall would improve the management of water resource applications and the effective exploitation of water resources. The findings of this study will be valuable for agricultural scientists, decision makers, policy planners, and researchers in identifying areas of agricultural development and drainage system building.

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