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Generation of IDF Equation Case Study AL- SHUWAIJA Watersheds/(IRAQ-IRAN)

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Abstract

One of the most useful tools in water resources engineering is the Intensity-Duration-Frequency (IDF) relationship, which may be used in the planning, design, and operation of water resource projects and a wide range of engineering initiatives to mitigate the effects of flooding and torrents Al- Shuwaija in addition to the designs of rain networks within Cities nearby.

This research aims to find the curves of intensity, duration and frequency (IDF), determine the intensity of rainfall in Shuwaija, and derive an experimental method for estimating rainfall intensity. Rainfall records dating back 20 years were relied on as well as the processing of missing data for five plants. A set of tests was used for probability distributions using programs (ESY FIT, HYFRAN-PLUS), and Log-person type 3 was found to be the appropriate option for the probability distribution. For the AL-Shuwaija area, any return time with a given storm length may be predicted using a median empirical formula. The research found that the highest intensities occur over the shortest periods of time and that these intensities vary greatly with the return period, but that over longer periods, there is no fluctuation in intensities.

Keywords: Al- Shuwaija, Rainfall, Frequency, Duration, Intensities

الخلاصة

واحدة من أكثر الأدوات المفيدة في هندسة الموارد المائية هي علاقة الكثافة والمدة والتردد (IDF) ، والتي يمكن استخدامها في تخطيط وتصميم وتشغيل مشاريع الموارد المائية ومجموعة واسعة من المبادرات الهندسية للتخفيف من آثار الفيضانات والسيول بالإضافة إلى تصاميم شبكات الأمطار داخل المدن القريبة.

يهدف هذا البحث إلى إيجاد منحنيات الكثافة والمدة والتواتر (IDF) وتحديد كثافة هطول الأمطار في الشويجة واشتقاق طريقة تجريبية لتقدير كثافة هطول الأمطار. تم الاعتماد على سجلات هطول الأمطار لعشرون عاما وكذلك معالجة البيانات المفقودة لخمسة محطات . تم استخدام مجموعة من الاختبارات للتوزيعات الاحتمالية باستخدام البرامج (ESY FIT) , (HYFRAN-PLUS) وجد أن نوع (Log-person 3)هو الخيار المناسب للتوزيع الاحتمالي بالنسبة لاحواض الشويجة ، يمكن التنبؤ بأي وقت عودة بطول عاصفة معين باستخدام صيغة تجريبية متوسطة. وجد البحث أن أعلى الشدة تحدث خلال أقصر فترات زمنية ، هذه الشدة تختلف اختلافا كبيرا مع فترة العودة ، ولكن على مدى فترات زمنية أطول لا يوجد تقلب في الشدة.

1. INTRODUCTION

Surface runoff from rainfall in water basins is very important to accurately predict water resource management [1]. The lack of water sources during droughts, in addition to climate change, has a clear impact on the marshes. Therefore, it is necessary to evaluate hydraulic and hydrological behavior by estimating the amount of water revenue through rainfall [2]. In order to make full use of rainwater during flood and flood seasons, it was necessary to conduct a hydrological study by finding equations and values for rain prediction and the relationship of rain intensity and rain depth, through which it is possible to know the water discharges and revenues in addition to the rainfall of cities The Intensity-Duration-Frequency (IDF) connection between rainfall is one of the most often utilized techniques in many flood-prevention engineering projects. The relationship between rainfall intensity, duration, and return period is shown by an IDF curve. A greater temporal resolution (with a one-minute interval) history dataset of the greatest rainfall intensities is necessary for the construction of IDF curves [3]. Only a few stations record such

rainfall data, with 1-day totals from a more dense network of non-recording rain gauges being the most easily accessible [4].
Hydrological designs and hydrological impact assessments rely heavily on IDF curves for accurate predictions of design rainfall in terms of its intensity, duration, and frequency [5]. Water resources management relies heavily on accurate predictions of surface runoff caused by rainfall across water basins. Watershed runoff management and conservation procedures may be described using hydrological models [6].

Establishing a short-duration rainfall depth using an experimental method, is essential in order to conduct hydrological analysis, build an effective urban drainage system, and propose and develop a variety of hydraulic structures [7].

While it is essential to have access to historical rainfall data in order to do the IDF analysis, this information is not always readily available. The most well-known of these empirical equations was created by [8]. By adjusting the parameters, the Sherman intensity equation may be used to predict the rainfall intensities at a given location. Intensity-Duration-Frequency (IDF) is an acronym for these three terms. The intensity of a rainfall event is measured by how much rain fell in a certain time period relative to how long that time event lasted. It is often written in millimetres per hour (mm/h) [10].

[11] proposed a generalized IDF formula using the rainfall depth for one- hour storm with a10-year recurrence interval (P110) as an index. He provided ratios of the 24-hr rainfall depth to different other durations for the same return period, these rainfall durations are (5-min, 10-min, 20-min, 30-min, 120-min, 180-min, 360-min, and 720-min) and the ratios are (0.13, 0.2, 0.28, 0.34, 0.44, 0.57, 0.63, 0.75 and 0.88) of the 24-hr rainfall depth respectively.

[12] developed a generalized IDF formula for any location in the United States using three base rainfall depths:

- 1-hour with 10- a year return period (P110).
- 24- hours with 10-years return period (P2410).
- 1-hours with 100-years return period (P1100).

The intensity–duration–frequency (IDF) connection is a mathematical relationship between the intensity I the duration ‘d,' and the return period ‘T' (or equivalently, the yearly frequency of exceedance, commonly referred to as ‘frequency' solely) [14].

Using data from the National Climatic Data Center's (NCDC) synthetic rainfall photographs and daily rainfall records created IDF curves [15]. Most often, synthetic rainfall hyetographs are used to break down monthly totals into more manageable daily totals [16]. In this study, return periods of 5, 10, 25, 50 and 100 years from 10 minutes to 1440 minutes were used to calculate the IDF curves for this study for previous precipitation data. The commonly used return periods such as for United States Isohyet maps are (2, 5, 10, 25, 50 and 100) years. It is generally recommended that 2 to 100 years is the sufficient return period for soil and water conservation measures, construction of hydraulic structures, irrigation and drainage works [4]. Through hydrological modelling, it is possible to know the future flood discharges of rivers For periods of return period of 100 years [17]. Constructing Intensity-Duration-Frequency (IDF) curves for all of the rainfall stations in the research region using one of three methods (Bell, 1969) to determine the design storm parameters. By knowing the expected amount of rainfall, it is possible to find the best storage methods and monitoring stations for water quality to save water and ways to use it [18]. The expectation of rainfall amounts paralyzes them significantly in the scheduling of irrigation and thus the use of irrigation methods and methods of conservation, as the conservation of water increases the efficiency of water use when rain occurs and the application of irrigation operations through the study of the surface layers of the soil [19]. Climate change and lack of management of water resources inside Iraq through hydrological assessment represented by rain and rain predictions and failure to evaluate the efficiency of irrigation systems caused a shortage in the quantities of water in addition to the water facilities built by neighbouring countries [20]. Rain predictions for different return periods have a clear impact on the quantities of water received, which may cause flooding of high drains covering the marshes and thus regulating the capacity of the marshes and finding outlets for discharge and use [21].

2. STUDY AREA

The watersheds of Al - Shuwaija marsh are within Iraq and Iran, Al- Shuwaija marsh is located on the right bank of Tigers River at Kut city, It is around 5 kilometres long and 25 kilometres wide, with the Tigris River to the west and the Iranian highlands and the island to the north forming its eastern and southern borders, respectively[22]. Fig. 1 shows the study area location.

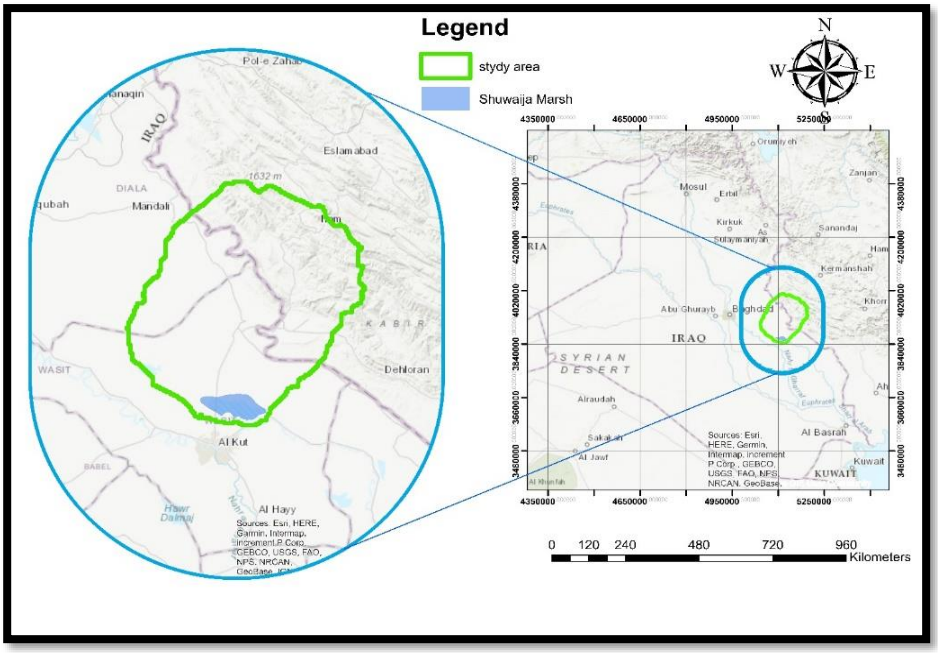

Figure 1 Site of the Study Area

3. AVAILABLE HISTORICAL DATA ON RAINFALL

The historical rainfall data was used for twenty years (2001-2020). Including daily rainfall, which was provided for both sites by the Iraqi metrological and Iranian metrological. Rainfall occurs during the autumn, winter and spring seasons. The maximum annual precipitation has reached (200 mm) for the year 2018. There are five precipitation measurement sites for Al- Shuwaija Marshes catchment valleys, these stations are designated (Badra, Ilam, Kut, Sumar and Mahran). The Iraq meteorological organization and Seismology (IMOS) operates the Badra and Kut stations, while the rest of the stations are affiliated with Iran Meteorological Organization (IMO). Since 2001, yearly precipitation totals have been recorded. Table 1 shows the maximum of depth water during 24 hours of rainfall stations in the study area. Table 2 shows the characteristics of rainfall stations in the study area. Thiessen polygons for the five rainfall stations in the watershed of the study area are shown in Fig 2

Table 1 Rainfall records for stations (IMOS), (IMO)

Station	Badra	Ilam	Mehran	Sumar	Kut
Year	Precipitation Maximum Storm in the year (mm)	Precipitation Maximum Storm in the year (mm)	Precipitation Maximum Storm in the year (mm)	Precipitation Maximum Storm in the year (mm)	Precipitation Maximum Storm in the year (mm)
2001	51	58.0	58.5	62.2	37.80
2002	78.1	85.5	77.2	105.8	62.5
2003	85.6	129.0	103.2	118.3	61.5
2004	70.9	76.2	75.1	71.8	63
2005	48.4	57.6	55.2	42.7	42
2006	70.8	87.0	77.3	83.5	54.4
2007	59.5	74.1	62.6	57.9	43
2008	71.4	75.3	71.0	83.6	59
2009	21.3	26.9	22.4	20.8	18.5
2010	35.6	55.1	38.3	36.9	28
2011	46.7	41.6	43.8	44.0	41
2012	85.3	135.2	91.8	149.1	69
2013	175.3	167.5	180.0	165.7	145
2014	82.9	101.7	88.9	98.5	65.6
2015	106.8	125.9	104.7	130.5	87
2016	69.4	84.4	70.1	78.0	52

Station	Badra	Ilam	Mehran	Sumar	Kut
Year	Precipitation Maximum Storm in the year (mm)	Precipitation Maximum Storm in the year (mm)	Precipitation Maximum Storm in the year (mm)	Precipitation Maximum Storm in the year (mm)	Precipitation Maximum Storm in the year (mm)
2017	120	161.9	126.2	161.7	86
2018	213.7	245.2	207.1	236.1	185
2019	85.7	102.7	96.8	92.6	82
2020	126	151.0	127.3	121.2	113.5

Table 2 Rainfall stations' characteristics

Station type	**Station name**	**Coordinates**		**Elevation(m)**	**Average accumulated rainfall (mm) (2001-2020)**
		North	**East**		
Rainfall	BADRH	3664983.36	587693.42	69	185
	MEHRAN	3664101.01	610096.86	150	195
	ILAM	3717575.69	629909.85	1337	223
	KUT	3600509.15	565728.99	14	175
	SUMAR	3748963.22	546238.97	297	207

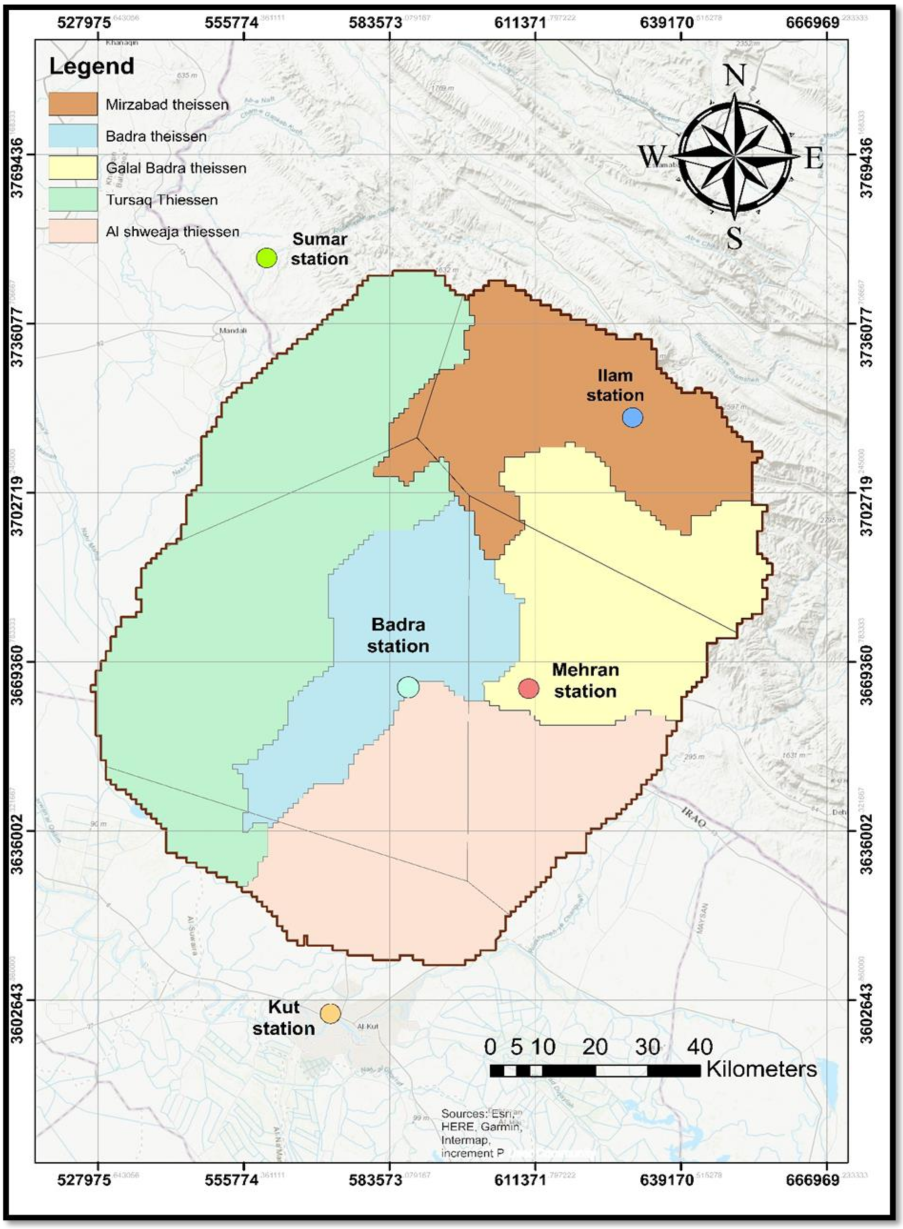

Figure 2 Generated Thiessen polygons for all rainfall station

4. CONSTRUCTING OF IDF CURVES

Intensity-Duration-Frequency (IDF) formulae are empirical equations depicting a link between the maximum intensity of rainfall (the dependent variable) and other factors of relevance, such as the duration and frequency of rainfall (as independent variables). Functions that are often used in hydrological applications may be found in the literature[23].

It is impossible to know with certainty how much rain will fall in the future. This calls for a probabilistic study and evaluation of rain's intensity and frequency. Rainfall statistics are typically inadequate or nonexistent in regions without reliable monitoring, making it difficult to make reliable estimates of intensity, duration, and frequency[24]. To derive an equation for calculating the rainfall intensity (I) for the region of interest, there are some required parameters to estimate, for establishing an equation to suit the calculation of rainfall intensity for a certain recurrence interval and specific storm period. These parameters depend mainly on the results obtained from the IDF curves[16].

Here are the building blocks for the IDF curves: To begin: The maximum depth of rainfall for the next two years, five years, ten years, twenty five years, forty five years, and one hundred years were estimated by analyzing daily rainfall data from the stations between 2001 and 2020 and using the proper statistical distribution. The second stage, for each of the return periods (2, 5, 10, 25, 50, and 100), calculate Intensity-Duration-Frequency (IDF) curves for all of the rainfall stations in the research region using the method Bell (1969) which provided a general IDF formula that takes into account the depth of rainfall during a one-hour storm with a 10-year repetition interval (P110). For the same return period, he provided ratios of the 24-hour rainfall depth to shorter durations, such as 5 minutes, 10 minutes, 20 minutes, 30 minutes, 120 minutes, 240 minutes, and 720 minutes; these shorter durations' ratios are 0.13, 0.28, 0.34, 0.57, 0.63, 0.75, and 0.88 of the 24-hour rainfall depth.

The main steps of the Bell method are:

- Obtaining daily precipitation records for the five rainfall stations in the area of study.
- Computing the annual maximum 24-hour precipitation at each of the three rainfall stations.
- Using Bell ratios to determine the precipitation for storm durations of 5, 10, 20, 30, 60, 120, 180, 360, 720, and 1440 minutes.
- The 24-hour rainfall data from the five sites was analyzed statistically using the Normal distribution, the Gumbel Max distribution, and the Log Pearson III distribution by using (Easy-Fit 5.6) software.
- Using the three tests (Kolmogorov-Smirnov, Anderson-Darling, and Chi-Square) to determine the distribution that best fits the data.
- The quantiles of rainfall (2, 5, 10, 25, 50, and 100 mm) for each storm duration at each of the five.
- Calculating the rainfall intensities (mm/hr.)
- IDF Curves plotted on log-log paper.

5. IDF PROGRAM

Maximum rainfall was predicted using frequency analysis applied to rainfall data from the stations with the help of the HYFRAN-PLUS tool. Log-person type3 statistical distribution functions were used to create IDF curves from rainfall data in the study region, allowing for the calculation of rainfall depths corresponding to various return times Software (Easy-Fit 5.6, 2012) was used to check the rain data from each weather station against the Normal, Gumbel, and Log Pearson Type III distributions. Fig. (3,4,5,6 and 7) shows extreme rainfall quantiles (XT) for the five stations. Using the Log Pearson Type III distribution, we can calculate the intensities of rainfall (I) for the specified times and return periods for the five stations (Badra, Kut, Sumar, Mehran and Ilam). This is done so that the optimal distribution function may be selected. Ranking the distributions by how well they hold to the 0.05 confidence interval that is often used to test the null hypothesis. The distribution ranks first; when the 5% confidence interval was reached. This is based on the results of the three statistical analyses (The Kolmogorov-Smirnov, The Anderson-Darling, and The Chi-Squared). Because of this, we conclude that the probability distribution function best suited to this data is the Log Pearson Type III distribution. All of the selected stations' data series are described. Tables (2,3,4,5and 6) display the statistical rankings for the five stations (Badra, Kut, Sumar, Mehran and Ilam). Third, the Log-person type 3 Distribution Function is used to analyze the hourly depth of precipitation for different return times. Using a curve-fitting technique to estimate the values of the unknowns in the equation.

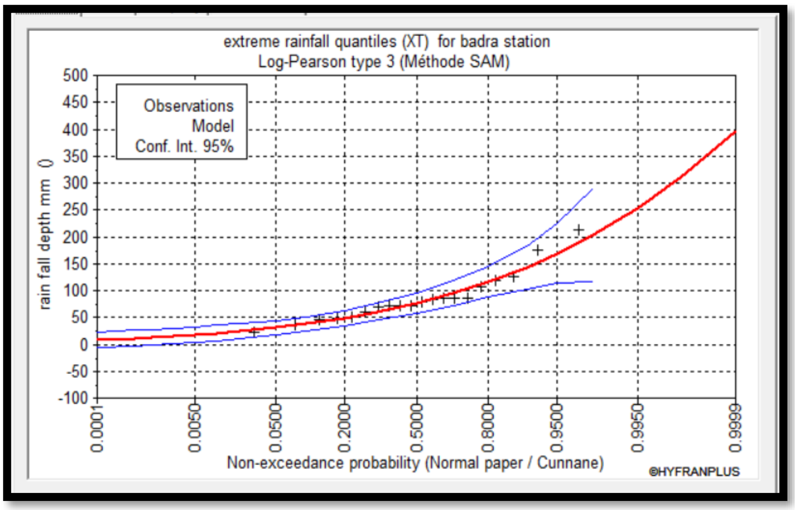

Figure 3 Extreme rainfall quantiles for BADRA

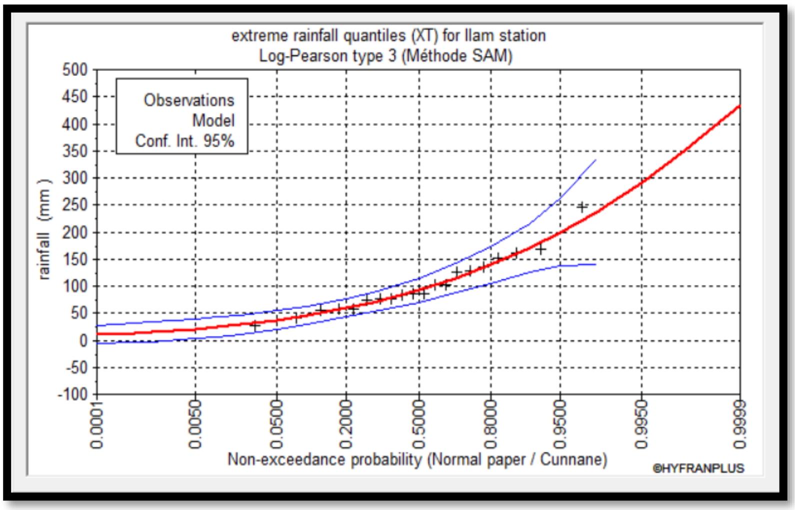

Figure 4 Extreme rainfall quantiles for ILAM

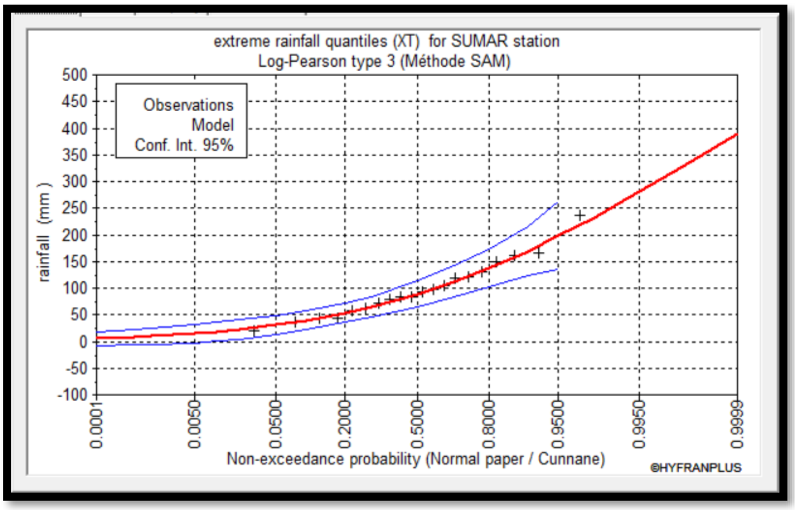

Figure 5 Extreme rainfall quantiles for SUMAR

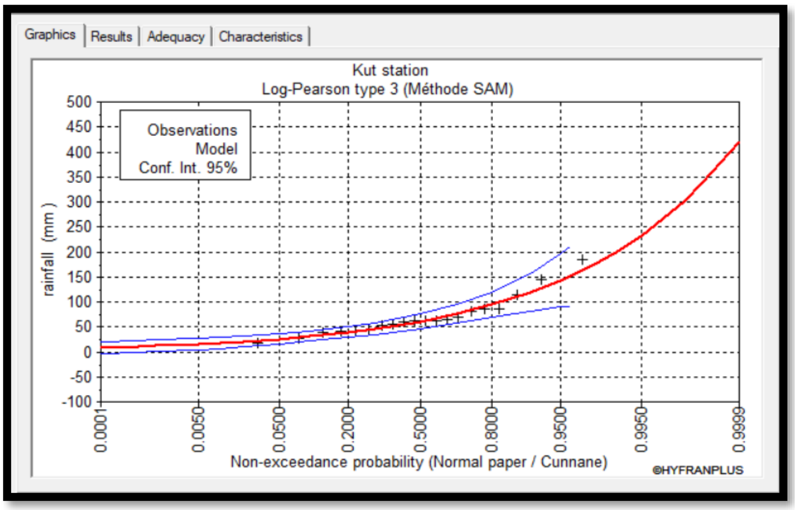

Figure 6 Extreme rainfall quantiles for KUT

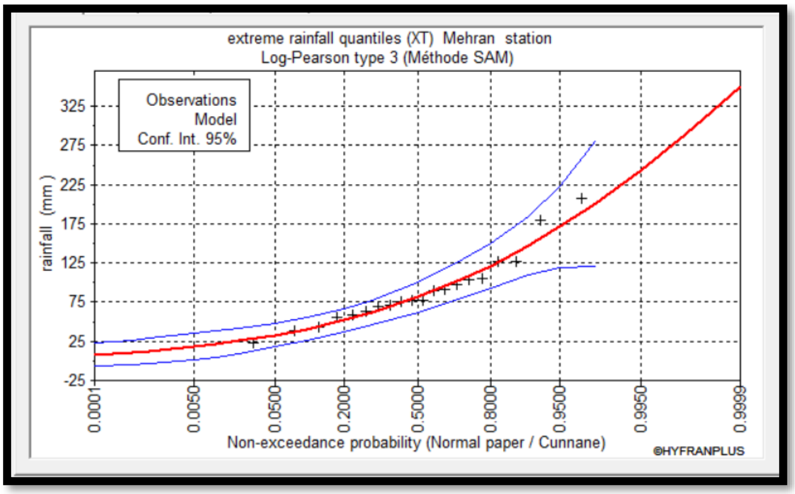

Figure 7 Extreme rainfall quantiles for MEHRAN

Table 2 Probability distributions test results for BADRA rainfall station

Goodness of Fit - Summary

#	Distribution	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Gumbel Max	0.17252135823684	2	0.528472425890653	2	3.16756724100549	2
2	Log-Pearson 3	0.162044477001326	1	0.453736236650993	1	4.02448396641749	3
3	Normal	0.24306742005803	3	1.3375284213209	3	2.76306498176331	1

Table 3 Probability distributions test results for ILAM rainfall station

Goodness of Fit - Summary

#	Distribution	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Gumbel Max	0.142607625529934	2	0.379216846805613	2	3.42718860545709	2
2	Log-Pearson 3	0.133457061005447	1	0.350661533713321	1	5.05881226953871	3
3	Normal	0.213019860327261	3	1.06327380309708	3	2.81526337008694	1

Table 4 Probability distributions test results for MEHRAN rainfall station

Goodness of Fit - Summary

#	Distribution	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Gumbel Max	0.114867554360128	2	0.351720154375982	2	3.47505487284941	2
2	Log-Pearson 3	0.112719760746466	1	0.330474129384624	1	0.928953698733902	1
3	Normal	0.184166966786153	3	1.00315084744415	3	4.52824808549645	3

Table 5 Probability distributions test results for SUMAR rainfall station

Goodness of Fit - Summary

#	Distribution	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Gumbel Max	0.077472150415556	2	0.10229091330213	2	0.004301854129642	1
2	Log-Pearson 3	0.064961953910799	1	0.102075263444459	1	0.487838779100493	3
3	Normal	0.108283232232624	3	0.297301129323751	3	0.205794893309437	2

Table 6 Probability distributions test results for KUT rainfall station

Goodness of Fit - Summary

#	Distribution	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Gumbel Max	0.135518539457911	2	0.450640096852231	2	1.81816079029745	2
2	Log-Pearson 3	0.101139743315211	1	0.25472402215382	1	1.43983299257671	1
3	Normal	0.205702405780701	3	1.10156167767495	3	4.60990574133376	3

6. RESULTS

In this study**,** Sherman Intensity Equation 1 is adopted and used to predict rainfall intensity for any return period given storm duration and calibrated IDF curve parameters. Precipitation At five stations, a gauge was selected to construct IDF curves for the study area. Daily rainfall records for the years (2001-2020) were taken into account Build the IDF curves. HyfranPlus was used to predict extreme rainfall quantiles for 5, 2, 10, 25, 50 and 100 return periods based on Log-person distribution.

Using the Log Pearson Type III distribution, we can calculate the intensities of rainfall (I) for the specified times and return periods. To do this, we divide the previously computed values for extremely heavy rainfall by their corresponding periods.

$$I = \frac{a}{(T_D + b)^c} \quad \text{......................................} \quad (1)$$

I = Intensity at specific duration (t) and return period (T) (mm/hr.)
a, b, c = Intensity parameters constants (Unit-less)
T_D = duration of the period (hrs)

Using a Log-Log scale, the IDF curves are displayed. Rainfall intensity forecasts are used to plot IDF curves for the (Badra, Kut, Sumar, Mehran and Ilam) stations over varying time and return period ranges. Fig. (8,9,10,11, and 12) illustrate the station's IDF curves calculated using the Bell method.

To estimate the IDF parameters, the values of the rainfall intensities are used as input data. The estimation of IDF parameters (a, b and c) of the Sherman equation were done using the Solver tool (Microsoft Excel, 2016). This is performed for 2, 5, 10, 25, 50, and 100-year return periods, as well as shorter intervals of 5 mins, 10 mins, 20 mins, 30 mins, 1, 2, 3, 6, 12 and 24 hours. The results of all return periods are summarized in Table 7.

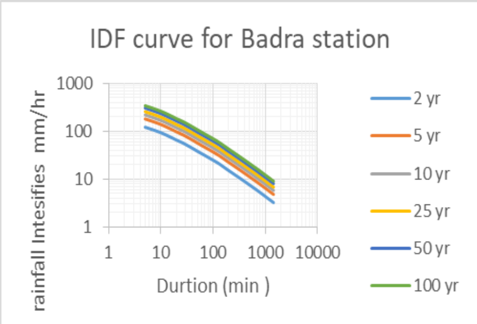

Figure 8 IDF BADRA Station

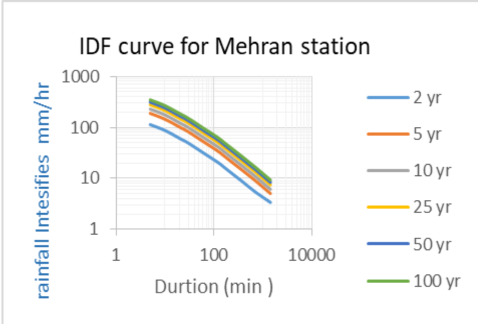

Figure 9 IDF MEHRAN Station

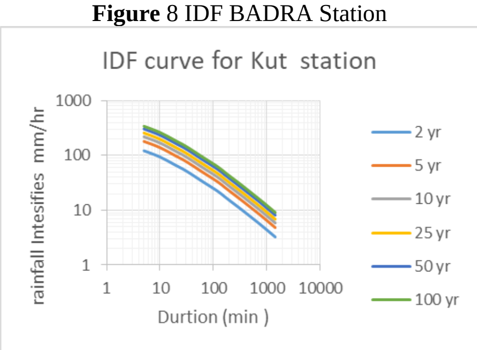

Figure 10 IDF KUT Station

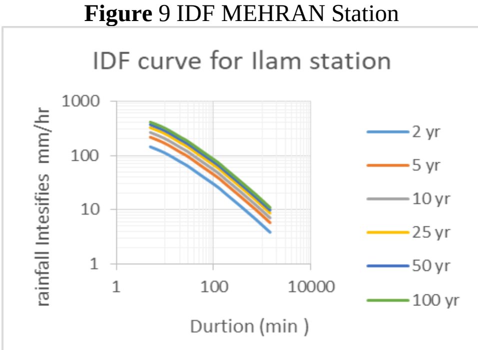

Figure 11 IDF ILAM Station

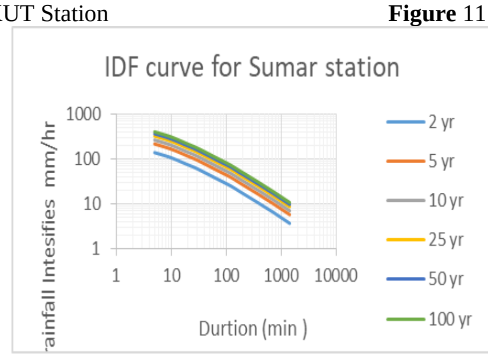

Figure 12 IDF ILAM Station

Table 7 IDF curves/Intensity equation parameters at return periods for the five stations using Bell method

	parameters	2 year	5 year	10 year	25 year	50 year	100 year
Mehrin	a	629.77	1057.30	1282.88	1560.38	1751.44	1948.74
	b	6.13	6.18	6.17	6.16	6.17	6.19
	c	0.71	0.71	0.71	0.71	0.71	0.71
Badra	a	683.33	1016.40	1235.04	1444.76	1716.51	1914.22
	b	6.18	6.20	6.20	6.20	6.20	6.19
	c	0.71	0.71	0.71	0.71	0.71	0.71
Kut	a	534.95	824.70	1041.94	1317.52	1539.97	1785.92
	b	6.20	6.16	6.20	6.17	6.15	6.19
	c	0.71	0.71	0.71	0.71	0.71	0.71
Ilam	a	807.14	1213.15	1487.37	1831.08	2074.77	2311.08
	b	6.17	6.17	6.19	6.20	6.19	6.19
	c	0.71	0.71	0.71	0.71	0.71	0.71
Sumar	a	776.10	1208.75	1469.95	1793.48	2041.33	2238.62
	b	6.20	6.20	6.15	6.12	6.21	6.17
	c	0.71	0.71	0.71	0.71	0.71	0.71

Table 8 compiles the results of five stations' worth of data from (Bell method) on the intensity of rainfall for varying return periods.

Table 8 Sherman rainfall intensity equation at the three stations using the Bell method

Name station	Retune period	Equation
Mehrin	2 year	$I = \frac{629.8}{(Td + 6.1)^{0.7}}$
	5 year	$I = \frac{1057.3}{(Td + 6.2)^{0.7}}$
	10 year	$I = \frac{1282.9}{(Td + 6.2)^{0.7}}$
	25 year	$I = \frac{1560.4}{(Td + 6.2)^{0.7}}$
	50 year	$I = \frac{1751.4}{(Td + 6.2)^{0.7}}$
	100 year	$I = \frac{1948.7}{(Td + 6.2)^{0.7}}$
Badra	2 year	$I = \frac{683.3}{(Td + 6.2)^{0.7}}$
	5 year	$I = \frac{1016.4}{(Td + 6.2)^{0.7}}$
	10 year	$I = \frac{1016.4}{(Td + 6.2)^{0.7}}$
	25 year	$I = \frac{1444.8}{(Td + 6.2)^{0.7}}$
	50 year	$I = \frac{1716.5}{(Td + 6.2)^{0.7}}$
	100 year	$I = \frac{1914.2}{(Td + 6.2)^{0.7}}$
Kut	2 year	$I = \frac{535.0}{(Td + 6.2)^{0.7}}$
	5 year	$I = \frac{824.7}{(Td + 6.2)^{0.7}}$
	10 year	$I = \frac{1041.9}{(Td + 6.2)^{0.7}}$
	25 year	$I = \frac{1317.5}{(Td + 6.1)^{0.7}}$
	50 year	$I = \frac{1540.0}{(Td + 6.1)^{0.7}}$
	100 year	$I = \frac{1785.9}{(Td + 6.2)^{0.7}}$
Ilam	2 year	$I = \frac{807.1}{(Td + 6.2)^{0.7}}$
	5 year	$I = \frac{1213.2}{(Td + 6.2)^{0.7}}$
	10 year	$I = \frac{1487.4}{(Td + 6.2)^{0.7}}$
	25 year	$I = \frac{1831.1}{(Td + 6.2)^{0.7}}$
	50 year	$I = \frac{2074.8}{(Td + 6.2)^{0.7}}$
	100 year	$I = \frac{2311.1}{(Td + 6.2)^{0.7}}$
Sumar	2 year	$I = \frac{776.1}{(Td + 6.2)^{0.7}}$
	5 year	$I = \frac{1208.8}{(Td + 6.2)^{0.7}}$
	10 year	$I = \frac{1470.0}{(Td + 6.2)^{0.7}}$

Name station	Retune period	Equation
	25 year	$I = \frac{1793.5}{(Td + 6.1)^{0.7}}$
	50 year	$I = \frac{2041.3}{(Td + 6.2)^{0.7}}$
	100 year	$I = \frac{2238.6}{(Td + 6.2)^{0.7}}$

7. CONCLUSIONS

The Intensity-Duration-Frequency analysis of rain at a location in Al- shuwaija Watershed was provided in this research. The IDF curves were created using the rain-gauge data that was gathered during 20 years. The maximum precipitation depth for various return periods of 2, 5, 10, 25, 50, and 100 years was computed here using the best data distribution approach. Maximum intensity 341.64 mm/hr occurs at a return period of 100 years with a duration of 5 minutes. The return period of 2 years and the length of 120 minutes represent the minimum intensity. This research will be useful in water resources projects and in designing rain networks for nearby cities. The calculated results can be used to estimate the revenues of the Shuwaija marsh for different return periods in addition to Groundwater recharge.

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