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STATISTICAL ANALYSIS OF EXTREME MONTHLY RAINFALL IN BASRAH CITY, SOUTH OF IRAQ

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ABSTRACT

The data set of highest monthly rainfall for Basrah station, south of Iraq, for 75-given years for period (1900-2000) with missing data for (1959-1979) provided the required data to identify the proper theoretical statistical distribution. A demonstration version of HYFRAN for windows software is used to fit the available data set. Six distributions are selected to carry this study including: Normal, Lognormal, 3-parameters lognormal, Pearson type III, Log Pearson type III, and Gumbal. Maximum likelihood method is selected to estimate theoretical distribution parameters. Adequacy test is conducted using Chi-square test. Results indicate that Pearson type III and Gumbal distributions are the proper for describe maximum monthly rainfall in the area being examined.

INTRODUCTION

Frequency estimates of hydrologic, climatic, and economic data are required for the planning, design and evaluation of water management plans. The data to be analyzed could be stream flow, precipitation amounts, sediments loads, river stages, lake stages, storm surge levels, flood damage, water demands, etc.

There are multiple forms of precipitation data used in frequency analysis, including annual maximum series (AMS). Due to its simplicity, the AMS-based method is the one used most often (Nguyen *et al.*, 1998) and (Nguyen *et al.*, 2002). An alternative to the AMS method is the partial duration series (PDS) method, used in extreme value analysis by climatologists (Fowler and Kilsby, 2003; Faiers *et al.*, 1994b; and Faiers *et al.*, 1997).

Many climatological and hydrological studies debate the proper statistical distributions to use when analyzing extreme events and suggest that no distribution can be used everywhere (Keim and Faiers, 2000;

Rohli *et al.*, 2002; and Huff and Angel, 1992). The Gumbal distribution is the most commonly used distribution in the analysis of extreme events (Wilks, 1993) and (Rohli *et al.*, 2002). Another distribution used in the analysis of return periods is the Log-Pearson Type III distribution (Naghavi *et al.*, 1993a) and (Naghavi *et al.*, 1993b). Still other studies have found that no specific distribution is best for their data (Keim and Faiers, 2000) and (Huff and Angel, 1992).

The aims of this research is to use the maximum recorded data of monthly rainfall in Basrah station, south of Iraq to identify the proper statistical distribution in order to use when analyzing extreme events in the area being examine.

PHYSICAL SETTING

Basrah is the largest city in southern Iraq, located on the west bank of Shatt Al-Arab, 55 km from the Arabian Gulf and 545 km form Baghdad. The investigation area subjected to the present study is focal point of Basrah city and is a part of the Shatt Al-Arab area which is situated within the so-Called delta plain. This delta plain again is a part of a large morphological unit, the Mesopotamian plain (Fig. 1). The area being examined is very flat and slightly declining along the course of the Tigris and Shatt Al-Arab rivers. The elevation of the highest part in the north of the area is about (3-4 m) above sea level.

The area is situated within the reach of a wide accumulation basin the sinking process of which has not yet come to an end (Buday and Jassim, 1987). The upper part of the basin is formed by the Dibdibba Formation (Pliocene-Pliestocene) which is partially covered with a series of clays and silts of alluvial origin (Al-Hammar Formation). The Dibdibba Formation is mainly composed of sandy-gravel sediments. Its floor declines coastward. The total thickness of the Dibdibba Formation is (300-400m) (Buday,1980).

Below the Dibdibba Formation the Nfayil Formation (Middle Miocene) is located, containing anhydrites, gypsum, marl and limestone. It is underlain by the Ghar Formation (Middle and Lower Miocene) which is built of sands with gravels and occasionally supplemented by clays. It lies discordantly on the Dammam Formation (Eocene) which is represented by limestones of numulitic facies.

CLIMATIC CONDITIONS

The climate of the most part of Iraq, as well the Basrah region is semi-arid, characterized by dry, hot and high wind velocity in summer, and cold, humid and little to moderate rainfall in winter. Metrological data related to

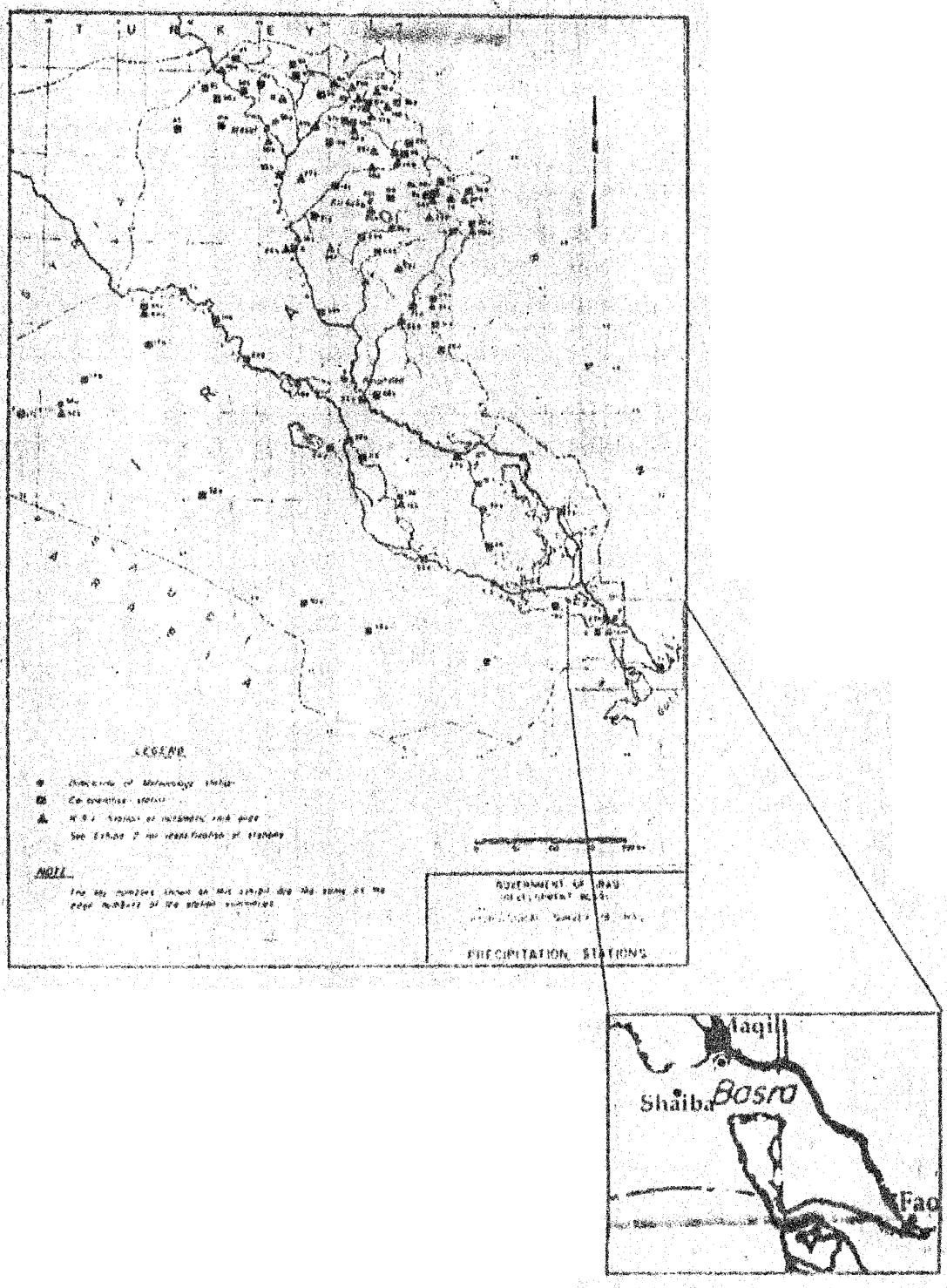

Fig.1: Map of Study area and location of metrological station used in present study

the area being examined are shortly presented in Table (1) below based on the meteorological records in Basrah station for period (1980-2000). Figures (2 and 3) show the comparison between monthly average rainfall and evaporation and monthly average temperature and relative humidity, respectively.

DATA COLLECTION AND PROCEDURE

An "extreme event" is the largest or smallest value of meteorological variable that occurs among a gives number of observation (Wilks, 1995). For this study, the highest monthly rainfall during a given year provided the data.

Data were acquired from records compiled by the metrological records stations in Basrah city. There are four metrological stations in Basrah city, these are: Basrah, Shuaiba, Maqil and Fao Stations. Data Base of monthly rainfall is presented for Basrah station for the period (1900-1958). It is provided by Development board and ministry of development (1959) (Summary of monthly precipitation at stations in Iraq for period (1887-1958), 1946). For the period (1980-2000) data are compiled from Iraq weather institute (The meteorological records station in Basrah City, 2000). missing Data for main station, i.e., Basrah is derived from the adjacent stations like Al-Maqil. Finally, 75 years of monthly rainfall are ready to use in the analysis.

A demonstration version of HYFRAN (hydrological frequency analysis) for windows software is used herein. HYFRAN for windows is software that allows fitting several statistical distributions to a data sample. The software has been developed by INRS-Eau with collaboration of hydro-Québec hydraulic service.

First, data entered into spreadsheet of the program manually or via windows clipboard. The program automatically calculates the empirical probability via several options, basic statistics of the entered data set, and allows drawing several plots like observations on probability paper, histograms, and chronological curves.

Second, a theoretical distribution is selected form the Fitting menu. The program calculates the non-exceeding probability (q), Return period (T) and estimates distribution parameters via several options like Maximum [illegible] square or empirical moments test (n>49). A plot of non-exceeding probability versus maximum rainfall is also presented.

Table 1: Monthly average meteorological data of Basrah station for period (1980-2000)

	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	Wind speed (m/s)	Sunshine Duration (h/d)	Evaporation (mm)
	Highest value	Lowest value					
October	36.20	20.50	07.42	38.10	2.70	09.40	230
November	27.20	15.00	13.30	52.45	3.05	07.70	127
December	20.40	09.60	21.90	63.90	2.85	06.90	84
January	18.10	08.50	30.25	69.00	3.12	07.00	72
February	20.60	09.50	20.56	58.36	3.40	07.70	102
March	24.80	13.30	28.58	51.60	3.73	08.00	203
April	32.50	19.60	14.89	38.74	4.12	08.70	287
May	39.70	25.25	03.46	27.18	3.85	10.00	421
June	44.80	28.60	00.00	22.00	5.00	11.30	538
July	45.90	30.60	00.00	23.00	5.76	11.00	501
August	46.10	29.00	00.00	22.45	4.85	10.30	501
September	43.00	25.60	00.02	25.10	3.55	10.20	401
Annual average	33.30	19.60		41.00	3.83		
Total annual average			140.00			105.50	3524

Six distributions are selected to carry this study including: Normal, Lognormal, 3-parameters lognormal, Pearson type III, Log Pearson type III, and Gumbal. Table (2) shows the basic statistics of the data set, and Figures (4 and 5) show the plots of observation on probability paper and histogram, respectively.

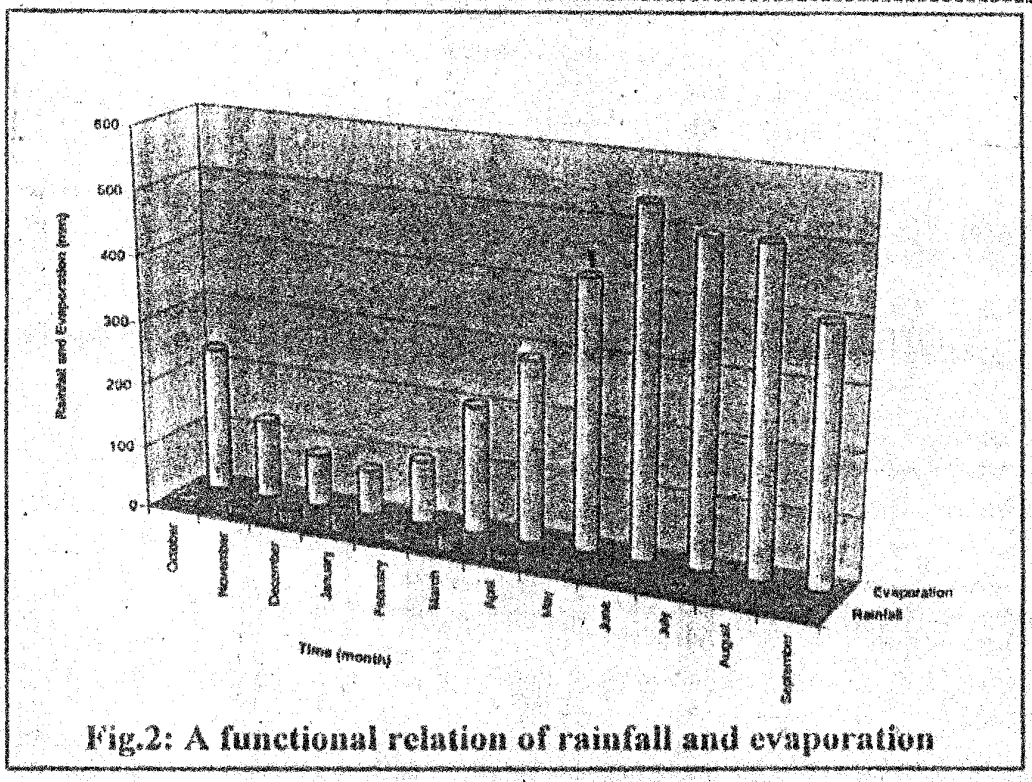

Fig.2: A functional relation of rainfall and evaporation

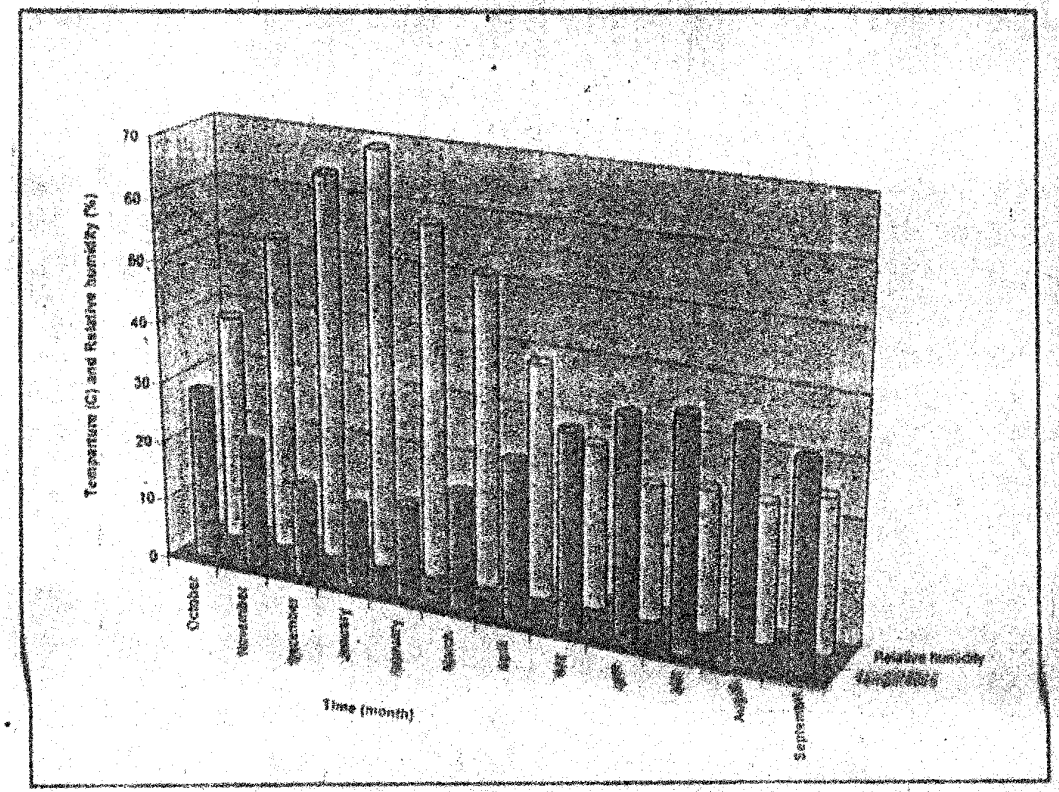

Fig. 3: A functional relation of temperature and relative humidity

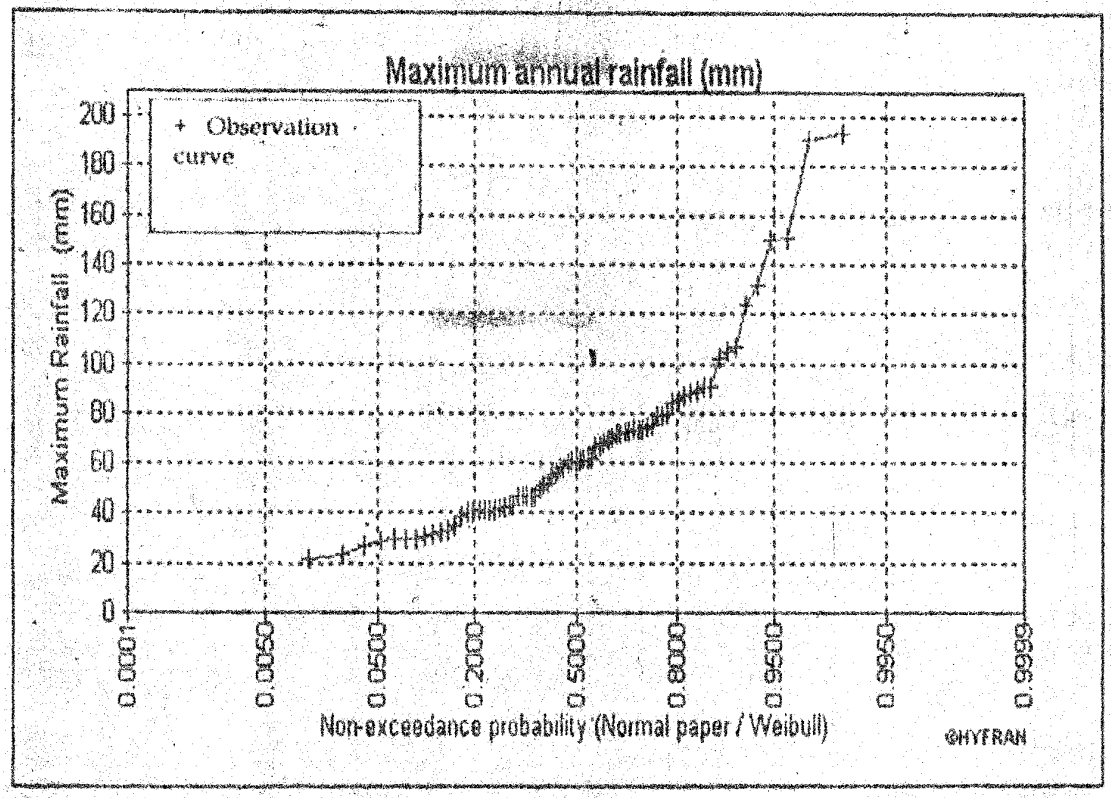

Fig.4: Observation of data set on Probability Paper

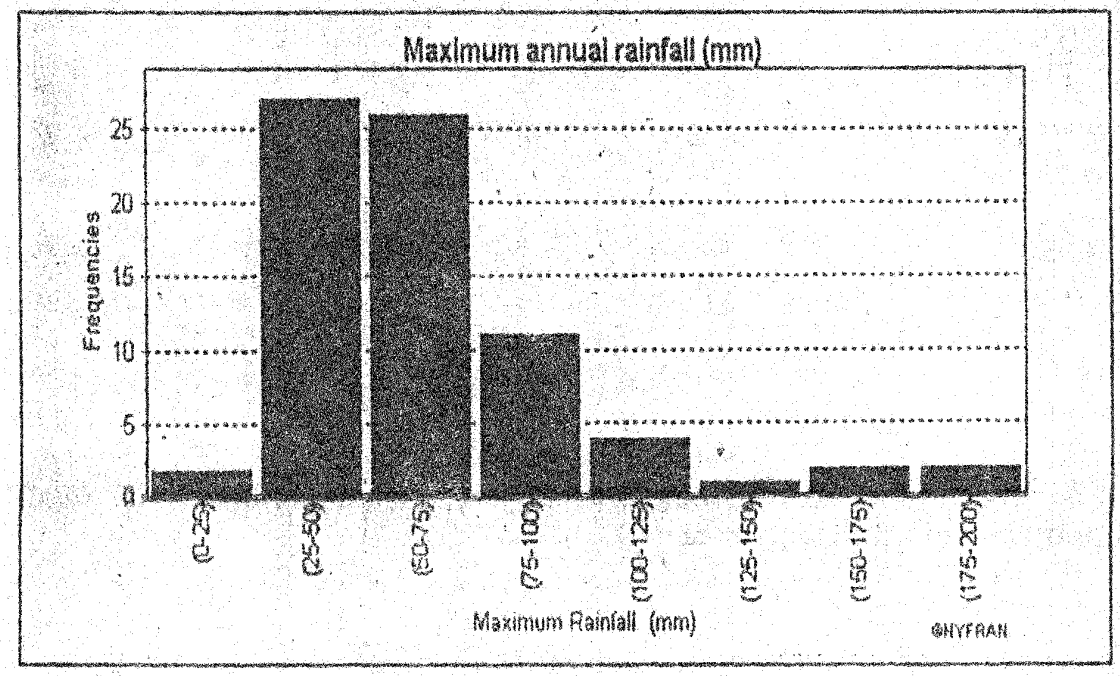

Fig.5: Histogram of observation data set.

Table 2: Basic statistics of data set

Basic statistics	Number of observations	75
Minimum	21.3	
Maximum	194	
Mean	66.1	
Standard deviation	34.7	
Median	61.2	
Coefficient of variation (Cv)	0.525	
Skewness coefficient (Cs)	1.71	
Kurtosis coefficient (Ck)	6.27	

Empirical non-exceeding probability is calculated using Weibul formula:

$$F[x[k]] = [k - a]/[n - 2a + 1] \qquad 0 < a \leq 0.5 \qquad (1)$$

Where, k=rank and n= number of observations, and for Weibul a=0, therefore

$$F[x[k]] = P_a = k/n + 1 \qquad (2)$$

The return period T (in years) is the reciprocal of P_a, or in mathematical notation

$$T = 1/P_a \qquad (3)$$

Maximum likelihood method is used to estimate theoretical distribution parameters. Adequacy test is conducted using Chi-Square test. Table (3) shows the theoretical distributions used herein and the mathematical formula for each one, with estimated distribution parameters, while Table (4) demonstrated the adequacy test via Chi-square method. Figures (6-12) show theoretical non-exceeding probability calculated by fitting model with empirical probability and using (99%) confidence interval.

It is obvious from Table (3) and Figures (6-11) that Pearson Type III and Gumbal distributions are the proper for describe the data set, especially Gumbal. Results of this study are partially agreed with the studies described earlier.

Table 3: Fitting models with estimated parameters

No.	Distribution	Mathematical formula	Estimated parameters
1.	Normal	$f(x)=\frac{1}{\sigma\sqrt{2\pi}}\exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\}$	$\mu=66.11333$ $\sigma=34.69971$
2.	Lognormal	$f(x)=\frac{1}{x\sigma\sqrt{2\pi}}\exp\left\{-\frac{[\ln x-\mu]^2}{2\sigma^2}\right\}$	$\mu=4.076722$ $\sigma=0.47432$
3.	3-parameters lognormal	$f(x)=\frac{1}{(x-m)\sigma}\exp\left\{-\frac{[\ln(x-m)-\mu]^2}{2\sigma^2}\right\}$	$\mu=3.878262$ $\sigma=0.570963$ $m=0.303968$
4.	Pearson type III	$f(x)=\frac{\alpha^\lambda}{\Gamma(\alpha)}(x-m)^{\lambda-1}e^{-\alpha(x-m)}$	$\alpha=0.04144$ $\lambda=1.928595$ $m=19.54477$
5.	Log Pearson type III	$f(x)=\frac{\alpha^\lambda}{x\Gamma(\alpha)}(\ln x-m)^{\lambda-1}e^{-\alpha(\ln x-m)}$	$\alpha=44.01571$ $\lambda=80.8526$ $m=-0.06641$
6.	Gumbal	$f(x)=\frac{1}{\alpha}\exp\left\{-\frac{x-u}{\alpha}\exp\left(-\frac{x-u}{\alpha}\right)\right\}$	$\alpha=23.50957$ $u=51.56874$

Table 4: Adequacy test using Chi-square

No.	Distribution	Chi-Square test	
		Tabulated value (0.01) significant level	Calculated value
1.	Normal	13.277	20.770
2.	Lognormal	13.277	14.030
3.	3-parameters lognormal	11.344	14.030
4.	Pearson type III	11.344	11.090
5.	Log Pearson type III	11.344	11.970
6.	Gumbal	13.277	6.69

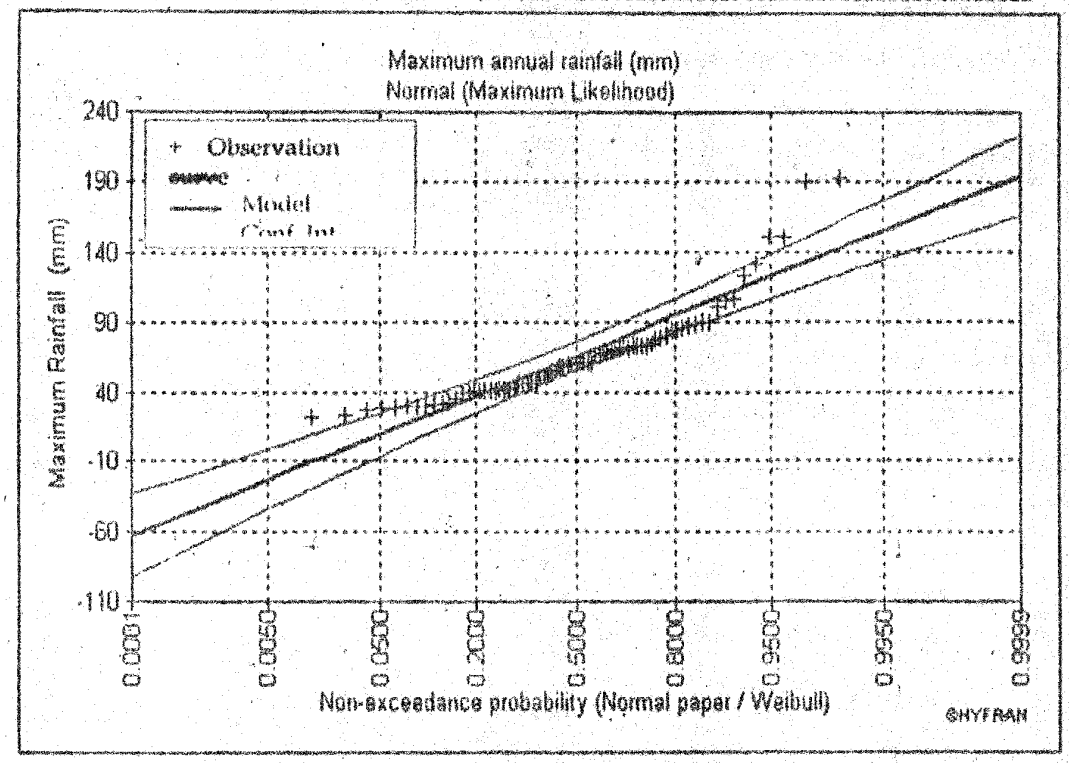

Fig. 6: Empirical, theoretical probabilities and confidence interval against maximum rainfall (Normal distribution)

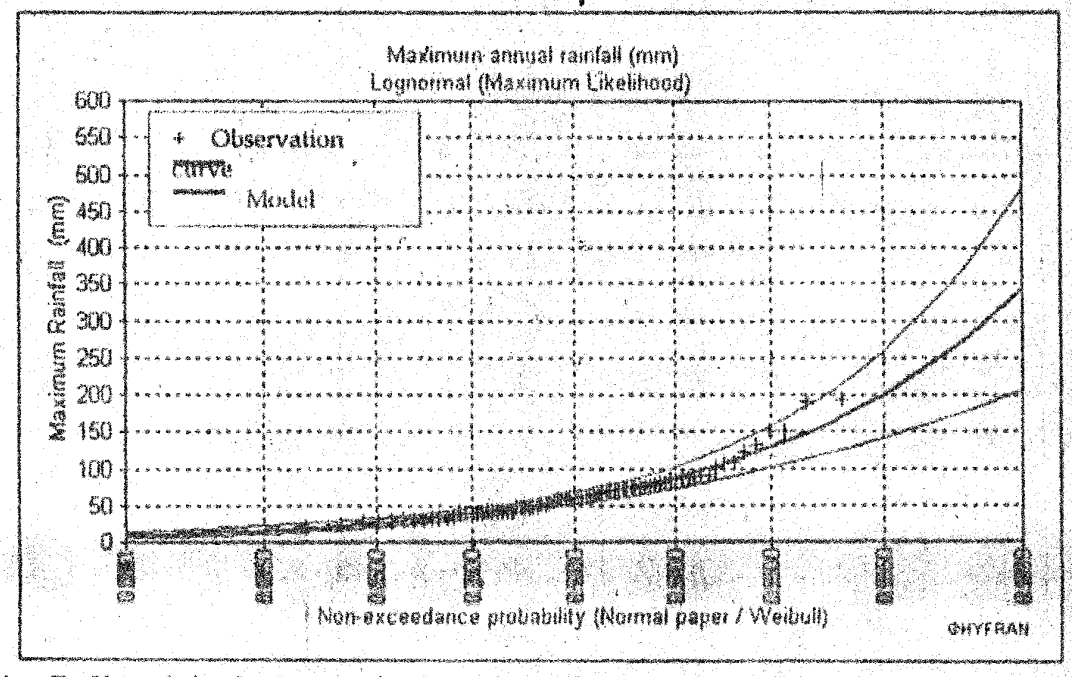

Fig. 7: Empirical, theoretical probabilities and confidence interval against maximum rainfall (log normal distribution)

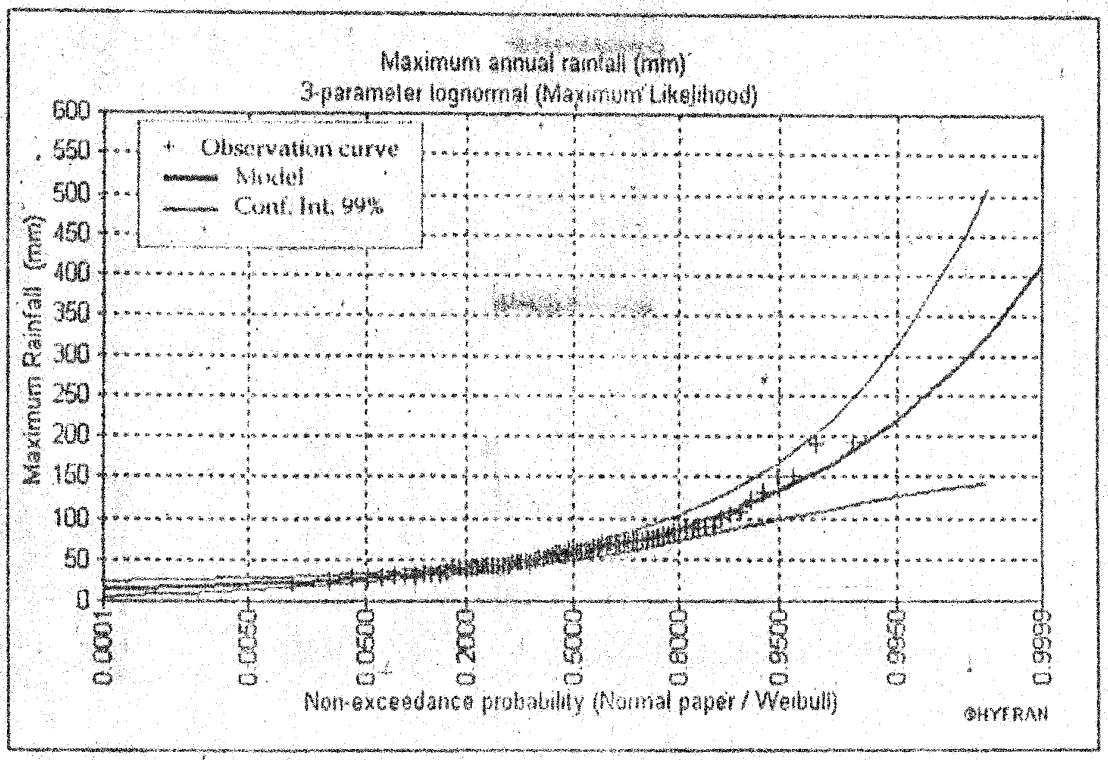

Fig. 8: Empirical, theoretical probabilities and confidence interval against maximum rainfall (3-parameters lognormal distribution)

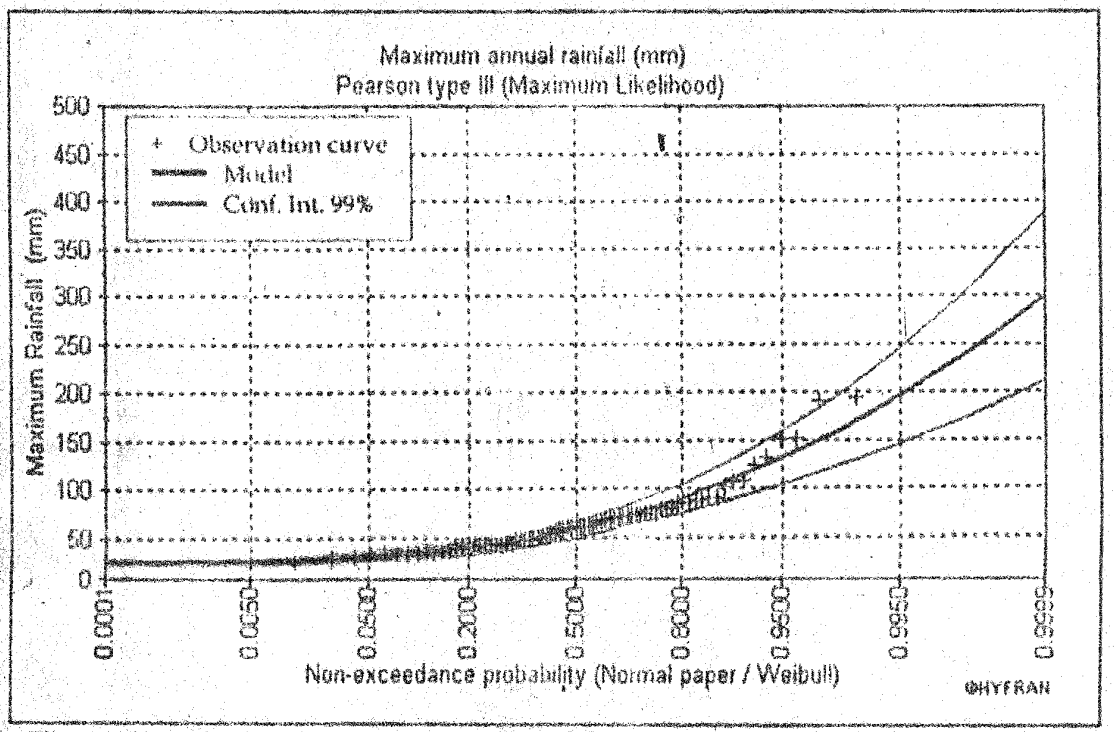

Fig.9: Empirical, theoretical probabilities and confidence interval against maximum rainfall (Pearson type III distribution)

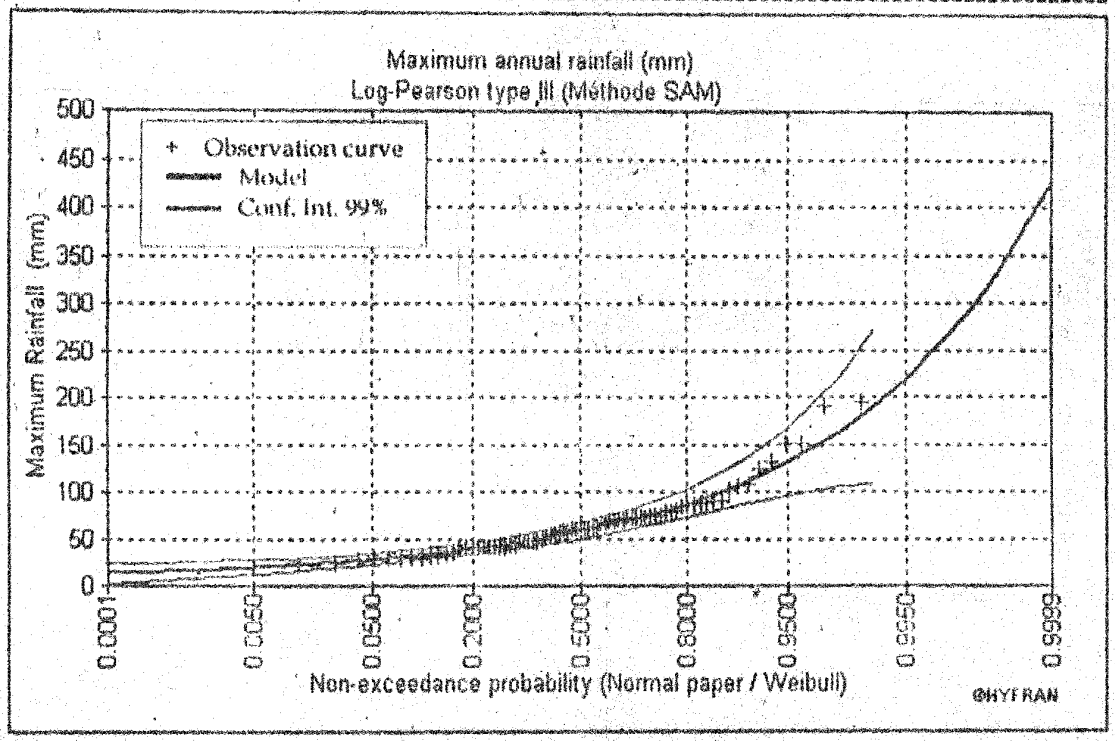

Fig.10: Empirical, theoretical probabilities and confidence interval against maximum rainfall (Log-Pearson type III distribution)

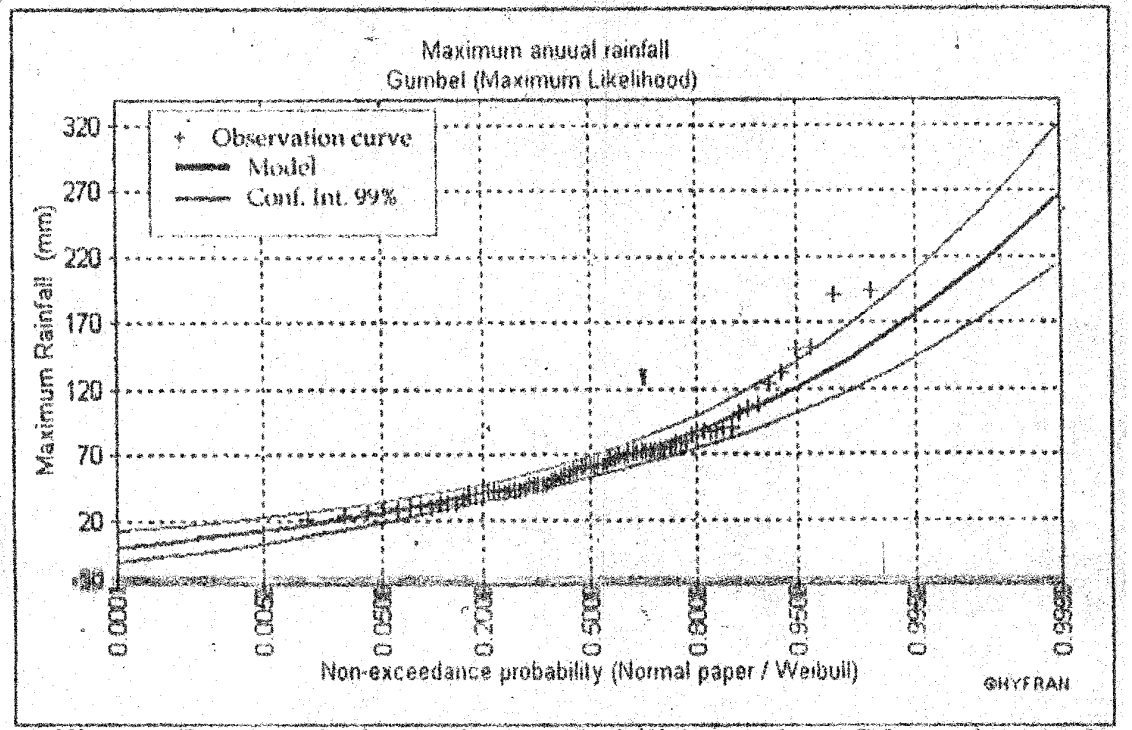

Fig.11: Empirical, theoretical probabilities and confidence interval against maximum rainfall (Gumbal distribution)

CONCLUSIONS

Frequency estimate of maximum monthly rainfall is helpful for the planning, design and evaluation of water management plants of Basrah, one of the largest cities in Iraq. Gumbal distribution is the best distribution in the analysis of extreme monthly rainfall in Basrah city.

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التحليل الاحتمالي لقيم الأمطار الشهرية القصوى في منطقة البصرة، جنوب العراق

حسين بدر غالب المنصوري

كلية العلوم، جامعة البصرة، العراق

الخلاصة

تم الاعتماد على البيانات المطرية الشهرية المسجلة لـ (75) سنة للفترة من (1900-2000) مع فقدان بالمعلومات المسجلة للفترة من (1959-1979) لمحطة البصرة المناخية، جنوب العراق لتحديد التوزيع الاحتمالي النظري الموائم. استخدمت النسخة التجارية لبرنامج HYFRAN لتحليل البيانات. اختبرت ستة توزيعات احتمالية لإجراء الدراسة هي: الطبيعي واللوغارتيمي الطبيعي واللوغارتيمي الطبيعي ذي الثلاث معاملات وبيرسون نوع الثالث وبيرسون اللوغارتيمي النوع الثالث وكامبل. استخدمت طريقة الإمكان الأكبر لتحديد معاملات التوزيع واختبار مربعات كاي لتحديد جودة الموائمة. بينت النتائج بان توزيع بيرسون النوع الثالث وكامبل هما احسن التوزيعات لتخمين احتمالية الأمطار الشهرية القصوى لمنطقة الدراسة.