Selection of suitable PDF model and build of IDF curves for rainfall in Najaf city, Iraq

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Abstract. The models of the Intensity-Duration-Frequency (IDF) curves relationship is considered a significant represents of the rainfall intensities used in the water resources structures, in the planning, designing and projects operation. This paper aims to estimate the Intensity-Duration-Frequency (IDF) curves and find the equations of these curves for AL-Najaf city, Iraq. Also, to identify the distribution that gives the highest rainfall intensities from the three commonly distributions used in this field. The (IDF) curves explain the relationship between the rainfall intensity and different return intervals. The study investigates the maximum daily rainfall data of 30 years using the Indian Meteorological Department (IMD) empirical formula to calculate the short durations rainfall intensity for 5, 10, 20, 30, 60 and 120 minutes, and with return periods of 2, 5, 10 and 25 years. The frequency analysis, which involves various statistical distributions, have been used to developing the relationship between rainfall intensities, durations, and return periods. The frequency analysis build based on the maximum daily rainfall data of the choosing interval (1989-2018), which had collected from the Meteorology and Seismic Monitoring Authority of Iraq. The used distributions are Gumbel, Lognormal and Log Pearson Type III distribution. The technique of the non-linear analysis has used to get the (IDF) curves equations. Also, Easy-fit software 5.5 involve the Kolmogorov-Smirnov test, which used to test the goodness of fit. The results showed that Gumbel distribution gave the best rainfall intensities for different return periods and different durations, where calculated rainfall intensities by Gumbel distribution had the highest values between the three applied distributions in this paper. The high values are more reliable to avoid the higher risks caused by sewer systems floods due to higher rainfall intensities due to climate change.

1. Introduction

Freshwater is already a limit resource in many parts of the world. The next century will be even more restrictive due to population growth, urbanization, and climate change, which will lead to a water crisis and dangerous environmental consequences [1]. So, must be taken care of with the water resources facilities and projects in the planning, design and operation. Most of the water resources facilities and infrastructures are require hydrological data such as rainfall intensity, temperature, humidity, filtration etc., for the planning, design and operation of these projects. The accurate analysis of the rainfall existing data is essential to specialists in hydrological engineering or the water resources field. It may show hazards of natural calamities. An incomplete and unprovided rainfall data make the design of structures of the water resources and infrastructure projects hardly task. For expected parameters probabilities, the analysis of rainfall frequency should be utilized [2].
Prediction of rainfall intensity is difficult since it subject to non-continuous daily functions such as temperature. Also, it depends on the rainfall periods and seasons [3]. Due to the increase in the population, urbanization and climate change, the sewer systems and infrastructures in urban areas become under increasing pressure, which is one of the big problems that face the municipalities in the control and management of urban flooding [4-6]. The heavy rainfall intensity causes the sewers to critical overflows where roads inundate and degrade the environment due to the polluted sewer [7] where the pollutants especially the BOD5 and TSS increased significantly after rain [8]. There is an increase in the precipitation rate in certain areas due to climate change [9]. Climate changes caused by global warming showed an increased rainfall intensity to higher values than the design intensity of the existing sewer systems, which causes flooding [10].

It is necessary to look at all aspects when comparing the results of the impacts of rainfall intensities and the urban area pavement to forecast the potential success of combined sewage systems [11]. The historical hydrology data have used to examine the different scenarios in the stormwater systems. The study and upgrade of the rainfall characteristics are significant to build water systems within the possible climate scenarios [12]. The analysis of rainfall intensities, particularly intensity-duration-frequency (IDF) curves to different return periods, are extremely necessary. The obtain better IDF curves are achieving by selecting proper statistical distributions applications based on the available rainfall data. Also, the accurate estimation of rainfall depth and intensity achieve through the long-term data of rainfall [13].

The researchers in many regions of the world took care in the development of the IDF curves for the design purposes of the water resources structures and the infrastructures with many return periods and different durations. The estimation of the rainfall intensities has concerned many researchers in hydrology fields and engineering. This worry appears in their literature, where they took care of select the methods used in IDF curves generation. Most researchers have chosen the methods and statistical techniques that have provided the maximum rainfall intensities to avoid risks of human lives lost, property damage and the uncomfortable psychological effects of sewers floods [14].

The estimation of IDF curves allows framing the rainfall development, considering the initially historical data, climate projections, and evaluating the probable maximum precipitation (PMP) to check the changes in rainfall patterns [15].

Many frequency analysis methods used to develop relationships between the intensity of rainfall, the storms duration, and the return periods from rainfall data for different zones in the world [16]. Where distributions of Gumbel, Log Pearson Type III, Normal and Lognormal used to obtain IDF curves, Non-linear regression analysis also has been used in the parameters finding of the (IDF) equations for the different return periods. The obtained results showed no substantial variation between the methods used, and priority tends to the purpose of result uses where all distributions have located at an appropriate significance level. Also, the results showed the rainfall intensity of a given durations frequency becomes high if the return period high [17-22].

2. Study Area
Geographically, the study conducted in AL-Najaf governorate, which located 160 km to the south-east of the capital of Baghdad, Iraq. It was study between coordinates of latitudes 32°21’ N and 29°50’ N, coordinates of longitudes 44°44’ E and 42°50’ E with a sum area of 28,824 km² (about 6.6% of Iraq area). Regional elevations were ranged between 26-61m above sea level with slight slopes and sandy clay soil, as shown in figure 1.
3. Methodology

3.1. Rainfall data collection
The metrological data collected from the Meteorology and Seismic Monitoring Authority of Iraq, from AL-Najaf station for the duration extended from 1989 to 2018, where these data used in the present paper. These data included daily rainfall (mm), as presented in figure 2.

3.2. Rainfall data analysis
For the delicate analysis of IDF curves of precipitation amounts of constant duration, it is needful to get the best fit probability between the theoretical distributions. There are required steps that implemented to the development of any IDF curve, and as follows:
1) Evaluation of the rainfall data and chose the maximum daily rainfall in the year.
2) Development of the Probability Density Function (PDF) distributions and choose the best fit for the available data series.
3) Distribution of best fit, which gives a mean to determine rainfall intensity for selected return periods and the specific duration.

3.3. Estimation of the short duration rainfall
The rainfall intensities of the various durations derive from the daily maximum rainfall data using the Indian Meteorological Department (IMD) formula, also called the reduction formula. IMD used to estimate the short durations rainfall intensities according to the following equation [23]:

\[ P_t = P_{24} * \left( \frac{t}{24} \right)^{\frac{1}{3}} \]  

(1)

Where \( P_t \) is the required rainfall depth in mm for the duration \( t \) in hours. \( P_{24} \) is the maximum depth of daily rainfall in mm, \( t \) is the duration in hours for the required rainfall depth and the constant value of 24 represents day hours.

3.4. Theory of distributions

3.4.1. Gumbel distribution theory. Gumbel distribution (EV-1, Generalized Extreme Values Distribution Type-I), used to model the distribution of maximum (or the minimum) samples numbers of various distributions. It is the most widely used distribution for IDF analysis, where it has suitability for maximum modelling. Gumbel distribution is relatively simple and uses only the extreme events (the maximum values or the peak rainfalls) [24]. For any duration, the maximum intensity and the statistical variables, which are the average and standard deviation, should be computed. Gumbel extreme values distribution given by the following equation [25]:

\[ P_T = P_{avg} + KS \]  

(2)

Where \( P_T \) is the precipitation frequency (mm) for each duration with a specified return period \( T \) (year), and \( P_{avg} \) is the average of the maximum precipitation corresponding to specific durations and obtained by the following equation:

\[ P_{avg} = \frac{1}{n} \sum_{i=1}^{n} P_i \]  

(3)

Where \( P_i \) is the individual rainfall extreme value, and \( n \) is the events number or record years. \( K \) is Gumbel frequency factor, and it is a function of the sample size and the return period. It computes with the following equation:

\[ K = -\frac{\sqrt{6}}{\pi} \left[ 0.5772 + \ln \left( \frac{T}{T-1} \right) \right] \]  

(4)

\( S \) is the \( P \) data standard deviation and computes with the following equation:

\[ S = \left[ \frac{1}{n-1} \sum_{i=1}^{n} (P_i - P_{avg})^2 \right]^{\frac{1}{2}} \]  

(5)

Multiplied the frequency factor \( K \) by the standard deviation \( S \) provide the rainfall of the desirable return period from the data average.

After the above steps, the rainfall intensity \( I \) (mm/hour) for the return period \( T \) can obtain from the following equation:

\[ I_T = \frac{P_T}{T_d} \]  

(6)

Where \( T_d \) is the duration (hours).

3.4.2. Log Pearson type III distribution theory. The Log Pearson type III distribution (LPT III) one of the Pearson distributions types III. It is reviewed by USA Weather Resources Council in the year 1967, this type of log distribution transforming the volume of the water and thereafter it analyzing the hydrologic frequency by the LPT III. Because it’s fast in the calculation, it used in computers with the frequency factors systematically in an analysis of the frequency. So, LPT III is significant and useful [24].

This probability model used for calculated the rainfall intensity for different return periods and rainfall durations to each station form the historical IDF curves. It involves logarithms of the measured
values. The standard deviation and the mean are determined using the logarithmically transformed data. A simple definition for LPT III distribution is provided by the following equations [16]:

\[ P = \log(P_i) \]  
\[ P_T = P_{avg} + K_T S \]  
\[ P_{avg} = \frac{1}{n} \sum_{i=1}^{n} P \]  
\[ S = \left[ \frac{1}{n-1} \sum_{i=1}^{n} (P - P_{avg})^2 \right]^{\frac{1}{2}} \]

\[ P_T, S \text{ and } P_{avg} \text{ are defined before in Gumbel theory barring that they determine according to the logarithmically transformed values of } P, \text{ not values of } P_i. \text{ The symbol } K_T \text{ represents Pearson frequency factor that build on the return period (T) and the skewness coefficient (C_s).} \]

\[ C_s = \frac{n \sum_{i=1}^{n} (P_i - P_{avg})^3}{(n-1)(n-2)(S)^3} \]

Many hydrology references have tables of \( K_T \) values, such as Chow (1988). Through knowing \( C_s \) and \( T \), \( K_T \) for LPT III distribution can determine. The solution in equation (8) will be given the estimated maximum value for the specific return period.

### 3.4.3. Lognormal distribution theory

The Lognormal distribution assumes that the hydrologic quantity distribution forms a lognormal distribution. In the 1962, the Board of the Corps of Engineers in the U.S Army used this distribution. It had applied this method to California frequency analysis, and this method evaluated to a high degree. This method transforms the peak flow data with a logarithm. Then uses the normal distribution to examine the flood frequency of the transformed data. This method presents considerably good results [24].

Sometimes, variables obey an exponential relationship as \( x = \exp(V) \). If the exponent is a random variable, such as \( V \), the equation will be \( X = \exp(V) \) which means a random variable equation. When \( V \) has a normal distribution, a particular case occurs, and the distribution of \( X \) is described as a lognormal distribution. For the transformation to \( \ln(X) = W \) or in our paper \( \ln(P_i) = P \), the natural logarithm of \( P_i \) will be normally distributed, and the random variable \( P_i \) will lognormally distributed random variable [26]:

\[ P = \ln(P_i) \]  
\[ Z = \frac{P - a}{b} \]

The Lognormal distribution will be a standard normal distribution. The factor of frequency for the lognormal distribution is equivalent to the factor of frequency for the normal distribution, but it will be applicable for the variable logarithms. The arithmetic mean and the standard deviation of variables will use in the following equation:

\[ P_T = P_{avg} + K_T S_P \]  
\[ P_{avg} = \frac{1}{n} \sum_{i=1}^{n} P \]

### 3.5. The goodness of fit test

The goodness of fit test aims to compare goodness fit between the expected frequencies obtained from the hypothesized distribution and the frequency of occurrence observed in a sample. The Easy Fit (v5.5) software program is used to transform goodness tests using the Kolmogorov-Smirnov test. The minimum value gained from the test of Kolmogorov-Smirnov considered the best fit of the chosen distributions.
3.6. Chi-square test.
The Chi-Square test commonly used to identify the best fit of the theoretical distribution for the available data, so it is powerful to do this test. The purpose of the Chi-Square test to obtains a good fit between the predicted and the observed data. The following equation considers the best representation of the Chi-Square Test:

\[ X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \]  

(16)

Where \( O_i \) represents the observed frequencies, and \( E_i \) represents the predictable frequencies. If \( O_i \) is close to the corresponding \( E_i \), the \( x^2 \) value will be small, indicate a good fit. Otherwise, it will be not [27].

3.7. Derivation of IDF equations
The IDF application builds on commonly empirical equations that correlate a maximum rainfall intensity, frequency and duration of occurrence based on available rainfall data. These empirical equations represent the relationship between the parameters of rainfall duration. The frequencies consider as independent variables and the max rainfall as a dependent variable. There are several commonly used equations of hydrology applications found in the literature. The general forms of the four commonly equations that used to describe the relationship between rainfall intensity the duration is summarized as follows [28]:

1) Sherman's equation:

\[ i = \frac{a}{(T+b)^c} \]  

(17)

2) Bernard's equation:

\[ i = \frac{c}{d^e} T^m \]  

(18)

3) Talbot's equation:

\[ i = \frac{c}{d+b} T^m \]  

(19)

4) Kimijima's equation:

\[ i = \frac{c}{d^e+b} T^m \]  

(20)

Where \( i \) is the rainfall intensity (mm/hour), \( d \) is the duration (minutes), \( T \) is the return period (year), and \( a, c, b, e \) and \( m \) are constant parameters associate with the metrological conditions.

The above empirical equations proved that the rainfall intensity reduces with an increase of the rainfall duration during the given return period. In hydrology practical applications, these empirical equations have been widely using. In the present paper, The Sherman equation selected to determine the rainfall intensity for the specific return periods.

4. Data analysis and results

4.1. Generation steps of the Intensity-Duration-Frequency (IDF) Curves
The steps of generating the intensity-duration-frequency (IDF) curves by the three used distributions which are Gumbel, Log-Pearson Type III, and Lognormal, will narrative as follow:

**Step 1:** Selecting the maximum daily rainfall from the collected daily rainfall data throughout the year. The maximum of the daily rainfalls data throughout the 30 years (1989-2018) from AL-Najaf city station shown in Table 1.
Table 1. The maximum of daily rainfalls data (mm) of 30 years (1989-2018) of AL-Najaf city station.

| Year | Maximum daily rainfall (mm) | Year | Maximum daily rainfall (mm) | Year | Maximum daily rainfall (mm) | Year | Maximum daily rainfall (mm) |
|------|-----------------------------|------|-----------------------------|------|-----------------------------|------|-----------------------------|
| 1989 | 5                           | 1997 | 21.1                        | 2005 | 27.7                        | 2013 | 64.5                        |
| 1990 | 12                          | 1998 | 12.4                        | 2006 | 22.6                        | 2014 | 22.2                        |
| 1991 | 8.8                         | 1999 | 8.2                         | 2007 | 12.8                        | 2015 | 32.9                        |
| 1992 | 16.2                        | 2000 | 10.7                        | 2008 | 26.8                        | 2016 | 26.6                        |
| 1993 | 34.4                        | 2001 | 17.3                        | 2009 | 12.6                        | 2017 | 8.6                         |
| 1994 | 42                          | 2002 | 15.2                        | 2010 | 10.9                        | 2018 | 19.3                        |
| 1995 | 11.5                        | 2003 | 19                          | 2011 | 13.8                        |      |                             |
| 1996 | 17.9                        | 2004 | 8.7                         | 2012 | 18.2                        |      |                             |

Step 2: Calculating the daily rainfall depth in (mm) from the maximum daily rainfall for the duration of t minutes (5, 10, 20, 30, 60, and 120 minutes) using the Indian Meteorological Department (IMD) reduction formula (1). The following example shows the calculating of the maximum daily rainfall depth with a 5-minutes duration for the year 1989:

\[ P_t = P_{24} \left( \frac{t}{24} \right)^{\frac{1}{3}} \]

\[ = 5 \text{ mm (Table 1)} \times \left( \frac{5 \text{ minutes}}{60 \text{ minutes/hour}} \right)^{\frac{1}{3}} \left( \frac{24 \text{ hour}}{24 \text{ hour}} \right) \]

\[ = 0.76 \text{ mm} \]

The calculation result of the maximum daily rainfall depth (mm) for each duration shown in Table 2 below.

Table 2. Maximum daily rainfall depth (mm) with different duration t-minutes.

| Year | Duration (minutes) |
|------|--------------------|
|      | 5 | 10 | 20 | 30 | 60 | 120 |
| 1989 | 0.76 | 0.95 | 1.20 | 1.38 | 1.73 | 2.18 |
| 1990 | 1.82 | 2.29 | 2.88 | 3.30 | 4.16 | 5.24 |
| 1991 | 1.33 | 1.68 | 2.12 | 2.42 | 3.05 | 3.84 |
| 1992 | 2.45 | 3.09 | 3.89 | 4.46 | 5.62 | 7.08 |
| 1993 | 5.21 | 6.56 | 8.27 | 9.47 | 11.93 | 15.03 |
| 1994 | 6.36 | 8.01 | 10.10 | 11.56 | 14.56 | 18.35 |
| 1995 | 1.74 | 2.19 | 2.76 | 3.16 | 3.99 | 5.02 |
| 1996 | 2.71 | 3.42 | 4.30 | 4.93 | 6.21 | 7.82 |
| 1997 | 3.20 | 4.03 | 5.07 | 5.81 | 7.32 | 9.22 |
| 1998 | 1.88 | 2.37 | 2.98 | 3.41 | 4.30 | 5.42 |
| 1999 | 1.24 | 1.56 | 1.97 | 2.26 | 2.84 | 3.58 |
| 2000 | 1.62 | 2.04 | 2.57 | 2.94 | 3.71 | 4.67 |
| 2001 | 2.62 | 3.30 | 4.16 | 4.76 | 6.00 | 7.56 |
| 2002 | 2.30 | 2.90 | 3.65 | 4.18 | 5.27 | 6.64 |
| 2003 | 2.88 | 3.62 | 4.57 | 5.23 | 6.59 | 8.30 |
Step 3: Using the Easy-Fit 5.5 software program to estimate the probability of rainfall depth for each return period and duration based on the durations data from Table 2. Rank the program by Chi-Square test and chose one of the selected distributions, Gumbel max, Log Pearson Type III, and Lognormal. The rainfall probability calculations based on the follows equation:

$$P(x) = 1 - \frac{1}{x}$$  \hspace{1cm} (21)

Where x the return period, 2, 5, 10 and 25 years. The results for each distribution shown in Tables 3.

Table 3. Rainfall depth (mm) for a specific duration in minutes using Easy-fit v5.5 and the three selected distributions.

| Distribution type | Return period (year) | Duration (minutes) |
|-------------------|----------------------|--------------------|
|                   |                      | 5  | 10  | 20  | 30  | 60  | 120 |
| Gumbel distribution| 2                    | 2.62 | 3.31 | 4.17 | 4.77 | 6.01 | 7.57 |
|                   | 5                    | 4.25 | 5.36 | 6.75 | 7.73 | 9.74 | 12.27 |
|                   | 10                   | 5.33 | 6.72 | 8.46 | 9.69 | 12.21 | 15.38 |
|                   | 25                   | 6.96 | 8.43 | 10.63 | 12.17 | 29.75 | 19.31 |
| Log Pearson Type III distribution | 2 | 2.45 | 3.08 | 3.89 | 4.45 | 5.61 | 7.06 |
|                   | 5                    | 3.96 | 4.98 | 6.28 | 7.19 | 9.06 | 11.41 |
|                   | 10                   | 5.16 | 6.50 | 8.19 | 9.37 | 11.81 | 14.88 |
|                   | 25                   | 6.92 | 8.72 | 10.99 | 12.58 | 15.85 | 19.97 |
| Lognormal distribution | 2 | 2.51 | 3.16 | 3.99 | 4.56 | 5.75 | 7.24 |
|                   | 5                    | 3.96 | 4.99 | 6.29 | 7.20 | 9.07 | 11.43 |
|                   | 10                   | 5.02 | 6.33 | 7.98 | 9.13 | 11.51 | 14.50 |
|                   | 25                   | 6.47 | 8.16 | 10.28 | 11.77 | 14.83 | 18.69 |

Step 4: Converting of the rainfall depth data (mm) in Table 5 to rainfall intensity, i (mm/hr.), via dividing the values of rainfall depth on the duration in hours. The following example explains the converting process of the rainfall depth from Table 2 to rainfall intensity, for 5 minutes and a 2-year return period:

$$i = \frac{60 \text{ minutes}}{5 \text{ minute}} * 2.6245 \text{mm}$$
The actual value in Microsoft Excel is 2.6245 mm. Values rounding has used in the presentation of tables, but not in the Microsoft Excel software, wherein the calculations took eight digits after the decimal point. The rainfall intensities data in a specific duration (minutes) for each distribution are shown in Table 4.

**Table 4. Rainfall intensity (mm/hr.) in a specific duration (minutes) for each distribution.**

| Distribution type          | Return period (year) | Duration (minutes) |
|----------------------------|----------------------|--------------------|
| Gumbel distribution        |                      |                    |
| 2                          | 31.49                | 19.83              |
| 5                          | 51.04                | 20.25              |
| 10                         | 63.98                | 25.39              |
| 25                         | 83.58                | 24.33              |
| Log Pearson Type III       |                      |                    |
| 2                          | 30.14                | 18.98              |
| 5                          | 47.52                | 18.86              |
| 10                         | 60.29                | 23.93              |
| 25                         | 77.70                | 24.33              |
| Lognormal distribution     |                      |                    |
| 2                          | 29.38                | 18.51              |
| 5                          | 47.46                | 18.84              |
| 10                         | 61.89                | 24.56              |
| 25                         | 83.09                | 32.96              |

**Step 5:** The rainfall intensities equations for the different return periods and the different durations in the present paper are estimating based on Sherman's equation and the Kolmogorov-Smirnov test, where the minimum value test considers the best fit of the chosen distributions. This test provided in the Solver tool in Microsoft Excel software.

Table 5 represents the estimated equations from the three distribution of the rainfall intensities for the return periods of 2, 5, 10, and 25 years and the duration of 5, 10, 20, 30, 60 and 120 minutes.

**Table 5. The estimated rainfall intensities equations using the three selected distributions.**

| Return period (year) | Estimated rainfall intensities equations using the selected distributions. |
|----------------------|---------------------------------------------------------------------------|
|                      | Gumbel Distribution | Log Pearson Type III Distribution | Lognormal Distribution |
| 2                    | \( i = \frac{92.27}{(T_c)^{0.667}} \) | \( i = \frac{86.31}{(T_c + 0.018)^{0.668}} \) | \( i = \frac{88.3}{(T_c)^{0.667}} \) |
| 5                    | \( i = \frac{149.942}{(T_c + 0.017)^{0.668}} \) | \( i = \frac{139.537}{(T_c + 0.022)^{0.668}} \) | \( i = \frac{139.633}{(T_c + 0.019)^{0.668}} \) |
| 10                   | \( i = \frac{187.1}{(T_c)^{0.667}} \) | \( i = \frac{181.899}{(T_c + 0.019)^{0.668}} \) | \( i = \frac{177.291}{(T_c + 0.023)^{0.668}} \) |
| 25                   | \( i = \frac{214.627}{(T_c)^{0.603}} \) | \( i = \frac{243.458}{(T_c)^{0.668}} \) | \( i = \frac{228.714}{(T_c + 0.028)^{0.669}} \) |
Where \( i \) represents rainfall intensity (mm/hour), and \( T_c \) is desirable time (or duration in minutes) for calculating rainfall intensity, \( i \).

**Step 6:** The paper assumed an intensity duration of 5 - 120 minutes with a time interval of 5 minutes and calculated the rainfall intensities data from the equations in Table 5 for the return periods of 2, 5, 10 and 25 years, based on the selected distributions, the results of the rainfall intensities shown in Table 6.

**Table 6.** The rainfall intensities for the selected distributions for the return periods of 2, 5, 10 and 25 years and duration of 5 - 120 minutes with a time interval of 5 minutes.

| \( T_c \) (min.) | Rainfall intensity from Gumbel distribution equations | Rainfall intensity from Pearson type III distribution equations | Rainfall intensity from Lognormal distribution equations |
|------------------|------------------------------------------------------|----------------------------------------------------------|--------------------------------------------------------|
|                  | years | years | years | years | years | years | years | years | years | years | years | years | years | years | years | years | years | years | years |
| 5                | 31.54 | 51.05 | 63.95 | 81.32 | 29.38 | 47.48 | 61.92 | 83.08 | 30.18 | 47.53 | 60.32 | 77.93 |
| 10               | 19.86 | 32.17 | 40.28 | 53.54 | 18.52 | 29.93 | 39.02 | 52.29 | 19.01 | 29.95 | 38.02 | 49.01 |
| 15               | 15.16 | 24.55 | 30.73 | 41.93 | 14.13 | 22.84 | 29.77 | 39.88 | 14.50 | 22.86 | 29.01 | 37.37 |
| 20               | 12.51 | 20.26 | 25.37 | 35.25 | 11.66 | 18.85 | 24.57 | 32.91 | 11.97 | 18.86 | 23.95 | 30.83 |
| 25               | 10.78 | 17.45 | 21.86 | 30.81 | 10.05 | 16.24 | 21.17 | 28.35 | 10.32 | 16.25 | 20.63 | 26.55 |
| 30               | 9.55  | 15.45 | 19.36 | 27.60 | 8.90  | 14.38 | 18.75 | 25.10 | 9.14  | 14.39 | 18.27 | 23.50 |
| 35               | 8.61  | 13.94 | 17.47 | 25.15 | 8.03  | 12.97 | 16.91 | 22.65 | 8.24  | 12.98 | 16.48 | 21.20 |
| 40               | 7.88  | 12.75 | 15.98 | 23.21 | 7.34  | 11.87 | 15.47 | 20.71 | 7.54  | 11.88 | 15.08 | 19.39 |
| 45               | 7.28  | 11.79 | 14.77 | 21.62 | 6.79  | 10.97 | 14.30 | 19.15 | 6.97  | 10.98 | 13.94 | 17.92 |
| 50               | 6.79  | 10.99 | 13.77 | 20.29 | 6.32  | 10.22 | 13.33 | 17.84 | 6.50  | 10.23 | 12.99 | 16.70 |
| 55               | 6.37  | 10.31 | 12.92 | 19.15 | 5.93  | 9.59  | 12.51 | 16.74 | 6.10  | 9.60  | 12.19 | 15.67 |
| 60               | 6.01  | 9.73  | 12.19 | 18.17 | 5.60  | 9.05  | 11.80 | 15.80 | 5.75  | 9.06  | 11.50 | 14.78 |
| 65               | 5.70  | 9.22  | 11.56 | 17.32 | 5.31  | 8.58  | 11.19 | 14.98 | 5.45  | 8.59  | 10.90 | 14.01 |
| 70               | 5.42  | 8.78  | 11.00 | 16.56 | 5.05  | 8.17  | 10.65 | 14.25 | 5.19  | 8.17  | 10.38 | 13.33 |
| 75               | 5.18  | 8.38  | 10.51 | 15.89 | 4.82  | 7.80  | 10.17 | 13.61 | 4.96  | 7.81  | 9.91  | 12.73 |
| 80               | 4.96  | 8.03  | 10.06 | 15.28 | 4.62  | 7.47  | 9.74  | 13.04 | 4.75  | 7.48  | 9.49  | 12.19 |
| 85               | 4.77  | 7.71  | 9.66  | 14.73 | 4.44  | 7.17  | 9.35  | 12.52 | 4.56  | 7.18  | 9.11  | 11.71 |
| 90               | 4.59  | 7.42  | 9.30  | 14.23 | 4.27  | 6.91  | 9.00  | 12.05 | 4.39  | 6.91  | 8.77  | 11.27 |
| 95               | 4.43  | 7.16  | 8.97  | 13.78 | 4.12  | 6.66  | 8.68  | 11.62 | 4.23  | 6.67  | 8.46  | 10.87 |
| 100              | 4.28  | 6.92  | 8.67  | 13.36 | 3.98  | 6.44  | 8.39  | 11.23 | 4.09  | 6.44  | 8.18  | 10.50 |
| 105              | 4.14  | 6.69  | 8.39  | 12.97 | 3.85  | 6.23  | 8.12  | 10.87 | 3.96  | 6.23  | 7.92  | 10.17 |
| 110              | 4.01  | 6.49  | 8.14  | 12.61 | 3.74  | 6.04  | 7.87  | 10.54 | 3.84  | 6.04  | 7.67  | 9.85 |
| 115              | 3.90  | 6.30  | 7.90  | 12.28 | 3.63  | 5.86  | 7.64  | 10.23 | 3.73  | 5.87  | 7.45  | 9.57 |
| 120              | 3.79  | 6.12  | 7.68  | 11.97 | 3.52  | 5.70  | 7.43  | 9.94  | 3.62  | 5.70  | 7.24  | 9.30 |

**Step 7:** Step 7: Drawing the intensity duration frequency (IDF) curves for the selected distributions using the calculated rainfall intensities data in Table 6 for the specific return periods of 2, 5, 10 and 25
years and for the assumed durations, which are 5 - 120 minutes with a time interval of 5 minutes, as shown in figures 3, 4 and 5.

Figure 3. Intensity duration frequency (IDF) curves using Gumbel distribution.

Figure 4. Intensity duration frequency (IDF) curves using Log Pearson type III distribution.

Figure 5. Intensity duration frequency (IDF) curves using Lognormal distribution.
5. Conclusion
The present paper showed a methodology for generating the Intensity-Duration-Frequency IDF curves and their equations for different return periods and different durations of the daily rainfall data to choose the method that gives the higher intensity rainfall result. These rainfall intensities usually utilized for design and analysis purposes in water resources projects, and in particular, for getting rainfall intensity with durations shorter than 24 hours, where durations used to estimate the rainfall intensities were from 5 to 120 minutes with a time interval of 5 minutes for return periods of 2, 5, 10 and 25 years. Three distributions methods have used in this paper are Gumbel, Log Pearson Type III and Lognormal distribution. The available collected data from the Meteorology and Seismic Monitoring Authority of Iraq - rain gauge station of AL-Najaf governorate, has analyzed using the three distributions.

Among the three applied distributions, Gumbel distribution had a higher rainfall intensity for the different return periods, which provide a higher standard for safety in the analysis and design of water resources projects. The IDF curves estimated equations help to calculate the rainfall intensity for any desired duration and for any return period in a short time. Calculated rainfall intensities can utilize for overflow analysis of the combined sewage and stormwater drainage systems and other water resources projects in AL-Najaf governorate.

6. References
[1] Al-Baidhani J H, and Al-Salihy S T 2016 Removal of heavy metals from aqueous solution by using low-cost rice husk in batch and continuous fluidized experiments International Journal of Chemical Engineering and Applications 7(1) 6.
[2] Al-Awadi A T 2016 Assessment of intensity duration frequency (IDF) models for Baghdad city, Iraq Journal of Applied Sciences Research 12(2) 7-11.
[3] Nile B K, Hassan W H, and Alshama G A 2019 Analysis of the effect of climate change on rainfall intensity and expected flooding by using ANN and SWMM programs ARPN Journal of Engineering and Applied Sciences 14(5) 974-984.
[4] Hassan W H, Nile B K, and Al-Masody B A 2017 Climate change effect on storm drainage networks by storm water management model Environmental Engineering Research 22(4) 393-400.
[5] Nile B K, Mohammed H A, and Htif K A 2021 February Analysis and evaluation of a sewage network during heavy rains using the SSOAP toolbox IOP Conf. Ser.: Mater. Sci. Eng. 1067(1) 012053.
[6] Al-Busaltan S, Kadhim, M A, Nile B K and Alshama G A 2021 February Evaluating Porous Pavement for the Mitigation of Stormwater Impacts IOP Conf. Ser.: Mater. Sci. Eng. 1067(1) 012052.
[7] Obaid H A, Shamsuddin S, Basim K N, and Shreeshivadasan C 2014 Modeling sewer overflow of a city with a large floating population Hydrology: Current Research 5(2) 1.
[8] Hussein A O, Shahid S, Basim K N, and Chelliapan S 2015 Modelling stormwater quality of an arid urban catchment Applied Mechanics and Materials 735(p) 215-219.
[9] Westra S, Alexander L V, and Zwiers F W 2013 Global increasing trends in annual maximum daily precipitation Journal of climate 26(11) 3904-3918.
[10] Nile B K, Hassan W H, and Esmaeel B A 2018 An evaluation of flood mitigation using a storm water management model [SWMM] in a residential area in Kerbala, Iraq MS&E 433(1) 012001.
[11] Kleidorfer M, Mikovits C, Jasper-Tönnies A, Huttonlau M, Einfalt T, and Rauch W 2014 Impact of a changing environment on drainage system performance Procedia Engineering 70 943-950.
[12] Parvez M B, and Inayathulla M 2019 Statical analysis of rainfall for development of intensity-duration-frequency curves for Upper Cauvery Karnataka by log-normal distribution Mathematical and Statistical Sciences 6 5.
[13] Al-Amri N S, and Subyani A M 2017 Generation of rainfall intensity duration frequency (IDF) curves for ungauged sites in arid region Earth Systems and Environment 1(1) 1-12.
[14] Balmforth D 2006 Designing for exceedance in urban drainage: good practice London: CIRIA.
[15] De Paola F, Giugni M, Topa M E, and Bucchignani E 2014 Intensity-Duration-Frequency (IDF) rainfall curves, for data series and climate projection in African cities SpringerPlus 3(1) 133.
[16] Elsebaie I H 2012 Developing rainfall intensity–duration–frequency relationship for two regions in Saudi Arabia Journal of King Saud University-Engineering Sciences 24(2) 131-140.
[17] AlHassoun S A 2011 Developing an empirical formulae to estimate rainfall intensity in Riyadh region Journal of King Saud University-Engineering Sciences 23(2) 81-88.
[18] El-Sayed E A H 2011 Generation of rainfall intensity duration frequency curves for ungauged sites. Nile Basin Water Sci Eng. J 4(1) 112-124.
[19] Dakheel A A 2017 Drawing Curves of The Rainfall Intensity Duration Frequency (IDF) and Assessment equation Intensity Rainfall for Nasiriyah City, Iraq University of Thi-Qar Journal 12(2) 63-82.
[20] Basumatary V, and Sil B S 2018 Generation of rainfall intensity-duration-frequency curves for the Barak River Basin Meteorology Hydrology and Water Management 6.
[21] Al-Sudani H I Z 2019 Rainfall returns periods in Iraq Journal of University of Babylon 27(2) 1-9.
[22] Mahdi E S, and Mohamedmeki M Z 2020 July Analysis of rainfall intensity-duration-frequency (IDF) curves of Baghdad city IOP Conf. Ser. Mater. Sci. Eng. 888(1) 012066.
[23] Jaleel L A, and Farawn M A 2013 Developing Rainfall Intensity-Duration-Frequency Relationship For Basrah City Kufa Journal of Engineering 5(1).
[24] Lee C 2005 Application of rainfall frequency analysis on studying rainfall distribution characteristics of Chia-Nan plain area in Southern Taiwan Crop Environ. Bioinf. 2(1) 31-38.
[25] Ahmed Z, Rao D R, Reddy K R M, and Raj E 2012 Rainfall Intensity Variation For Observed Data And Derived Data-A Case Study Of Imphal Arpn Journal Of Engineering And Applied Sciences 7(11).
[26] Parvez M B, and Inayathulla M 2019 Rainfall Analysis for Modelling of IDF Curves for Bangalore Rural, Karnataka Int. J. Sci. Res. in Multidisciplinary Studies 5 8.
[27] Stemmler M 2020 Person-centered methods: Configural frequency analysis (CFA) and other methods for the analysis of contingency tables Springer Nature.
[28] Chow V T, Maidment D R, and Mays L W 1988 Applied Hydrology McGraw-Hill Book Company. New York.