



## GENERATION OF RAINFALL INTENSITY-DURATION FREQUENCY MODELS FOR PORT HARCOURT CITY IN SOUTH- SOUTH NGERIA

C. C. Emeka-Chris

Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture,  
Umudike, Nigeria

\*Corresponding author's email address: [cemekachris1@gmail.com](mailto:cemekachris1@gmail.com)

### ARTICLE INFORMATION ABSTRACT

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Inadequate meteorological data poses a significant challenge for engineers in accurately designing, operating, and planning water resources, particularly against extreme rainfall events. This study focuses on Generating Intensity Duration Frequency (IDF) Models for Port Harcourt City in South Nigeria. Daily rainfall data spanning thirty-two years (1983-2014) were collected from the Nigeria Meteorological Agency (NIMET) Oshodi, Lagos State. The annual maximum series method was employed to select datasets for rainfall analysis.

Two statistical distributions, Gumbel and Log Pearson Type III, were utilized to calculate observed rainfall intensity values at durations of 10, 15, 20, 30, 60, 120, 180, 240, 300, and 360 minutes, considering return periods of 2, 5, 10, 20, 50, and 100 years. Non-linear regression analysis using Microsoft Excel's Optimization Technique Solver wizard was performed to derive parameters for the IDF models for each duration and return period. Metrics such as chi-square ( $\chi^2$ ), coefficient of determination ( $R^2$ ), and Root Mean Square Error (RMSE) were analyzed in order to assess the performance of the models. For the Gumbel distribution,  $R^2$  values ranged from 0.76 to 1.00, with RMSE from 0.20 to 11.73. The Log Pearson Type III distribution showed perfect  $R^2$  of 1 and RMSE ranging from 0.23 to 9.68, indicating superior performance in terms of  $R^2$  and RMSE.

While there were no significant differences among the predicted intensities of various IDF models, the Log Pearson Type III Model is recommended for predicting rainfall intensities in Port Harcourt due to its superior performance metrics. These IDF Models serve as valuable tools for engineers and hydrologists in estimating stormwater runoff, designing drainage systems, managing reservoirs, and planning water resources development to mitigate flooding and its impacts. Moreover, they can enhance the teaching of land drainage courses for engineering students, providing practical demonstrations and improving their understanding of the subject matter.

### 1.0 Introduction

Precipitation is an important component in the hydrologic cycle. Brian et al. (2006) posited that rainfall frequency analyses are desirable in the development plus designing of different water resources schemes, this includes storm sewers, culverts, and other hydraulic structures. A life-threatening precipitation happening endangers the quality of water, annihilation of assets, loss of lives due to flooding and pollution (Brian et al., 2006). According to Panel et al. (2016) the valuation of dangerous precipitation is a vital issue in hydrologic risk investigation and design. Additionally, they noted that the assessment of rainfall excesses as embodied in the intensity-duration-frequency (IDF) relationship has been the main objective of applied and theoretical hydrology. Similarly, Elsebaie (2012) noted that rainfall intensity-duration-frequency curves are

graphical demonstrations of the quantity of rainwater that falls within a specified period of time in catchment areas.

Prodanovic and Simonovic, (2007) suggested, that to design flood protection structures involving hydrologic flows, rainfall events statistics (that is, in relations to intensity, duration, and period of return) are required. Additionally, Elsebaie (2012) noted that, graphically the measure of precipitation that falls within a catchment range in a specified period of time are denoted by Rainfall – Intensity - Duration-Frequency (IDF) curves. He added that, IDF curves are an important tool for the engineers when designing urban drainage works.

According to (Koutsoyiannis, 2003) the IDF relationship is a mathematical connection between the precipitation intensity  $I$ , the duration  $d$ , and the return period  $T$ . In addition, Al-Dokhayel (1986) accomplished a research on the estimation of rainfall depth duration frequency (DDF) relationships intended for Qasim region in Kingdom of Saudi Arabia (KSA) on different return periods, by the use of two continuous probability distributions, namely, Gumbel distribution and Log Pearson Type III (LPT III) distributions. He found that, between the two distributions under study, the LPT III distribution technique provided greater precipitation estimations with lesser standard errors. Similarly, David et al. (2019) noted that the institution of IDF relationships commenced in the nineteen thirties, subsequently many sets of connections have been lumped together globally. Consequently, Elsebaie (2012) posited that the establishment of the IDF was formally on the basis of frequency investigation of precipitation at a particular station observed throughout a long period, normally the annual maximum of the series (AMS) or adequately high values greater than threshold. According to Akpan and Okoro (2013), Nwaogazie and Duru (2002) and Nwoke and Okoro (2012) developed Rainfall Intensity Frequency Models based on statistical method of least squares. In Nigeria, current studies on rainfall IDF development have been done in Southern Nigeria, with little information made available about rainfall intensities in particular for short durations.

The insufficient accessible IDF curves for selected parts of the country are very costly and plotting of the curves was done manually. Hence, this method of developing IDF curves manually is prone to error. The broad objective of this research was to generate Intensity-Duration – Frequency (IDF) curves and models for estimating the precipitation intensities for Port Harcourt city, using two statistical methods, that is Gumbel distribution and Log Pearson Type III distribution.

## **2. Materials and Method**

### **2.1 Description of the Study Area**

The area studied is Port Harcourt city. The city is the capital and largest city of Rivers State, in Nigeria. It is the fifth most populous city in Nigeria after Lagos, Kano, Ibadan and Benin (Statista, 2021 and world population review.com, 2021). It lies along the Bonny River and is located in the oil rich Niger Delta at latitude  $04^{\circ}45'$  to  $04^{\circ}60'N$  and Longitude  $06^{\circ}50'E$  to  $08^{\circ}0'07'E$  (Figure 1). It is located 64 kilometres from the Atlantic Ocean and situated 15.0 metres above sea level. Port Harcourt experiences rainy season from March to October and receives 2293.6mm of rainfall per year (Abah et al., 2019). Only the months of November to February truly qualify as dry season months in the city and the so-called dry season are not free from occasional rainfall. Port Harcourt has three hydro- vegetation zones such as beach ridge, salt water and fresh water.



**Figure 1:** Map of Port Harcourt City Local Government Area and its environs  
Source: Abah *et al.* (2019)

## 2.2 Data Collection

The required data in this research are the precipitation depths for smaller durations namely, 5, 10, 15, 20, 30, 60, 120, 180, 240, 300 and 360 minutes. Precipitation data were collected from Nigeria Meteorological Agency Lagos, Nigeria. Thirty-two years span of records was used for the studied location between 1983-2014.

## 2.3 Development of IDF curves

Two common frequency analysis techniques were used in the development of the relationship between rainfall intensity, storm duration, and return periods from rainfall data for the region under study. These techniques are the Gumbel distribution and the LPT III distribution.

### 2.3.1 Gumbel theory of distribution

Gumbel assumption methodology was adopted to perform the flood probability studies. In addition, Elsebaie (2012) noted that this is because the method of the analysis is widely accepted for IDF analysis owing to its appropriateness for modeling maxima. The Gumbel methodology determines the 2, 5, 10, 25, 50 and 100 year return intervals for each duration period and hence requires several calculations. The frequency precipitation for duration with a definite return period is expressed by the following formula

$$P_T = P_{ave} + KS \tag{1}$$

Where,

K =Gumbel frequency factor given by:

$$K = \frac{\sqrt{6}}{\pi} [0.5772 + \ln[\ln \left[ \frac{T}{T-1} (8) \right]]] \tag{2}$$

Where,

$P_{ave}$  = the average of the maximum precipitation corresponding to a specific duration.

In utilizing Gumbel's distribution, the arithmetic average ( $P_{ave}$ ) in Equation (3) was used:

$$P_{ave} = \frac{1}{n} \sum_{i=1}^n P_i \tag{3}$$

Where,

$P_i$  = the individual extreme value of rainfall and n is the number of events or years of record.

The standard deviation, S of P data was calculated using Equation (4)

$$S = \left[ \frac{1}{n-1} \sum_{i=1}^n (P_i - P_{ave})^2 \right] \quad (4)$$

The frequency factor (K), which is a function of the return period and sample size, was multiplied by the standard deviation to give the departure of a desired return period rainfall from the average.

Then the rainfall intensities, I (mm/h) for return period T were obtained from:

$$I_T = \frac{P_T}{T_d} \quad (5)$$

Where,

T<sub>d</sub> is duration in hours, P<sub>T</sub> is frequency precipitation values and I<sub>T</sub> is intensities for different durations.

From the raw data, the maximum precipitation (P) and the statistical variables (average and standard deviation) for each of the duration 0.25hr, 0.5hr, 1hr, 2hr, 4hr, and 6hr) were computed.

### 2.3.2 Log Pearson type III

The Log Pearson Type III probability model was utilized in the calculation of the precipitation intensity at different precipitation durations and return periods to form the historic IDF curves for the designated localities. Logarithmically transformed data was used in determination of the mean and the standard deviation. The simplified expression for this latter distribution is given as:

$$P^* = \log (P_i) \quad (6)$$

$$P^*_{T} = P^*_{ave} + K_T S \quad (7)$$

$$P^*_{ave} = \frac{1}{n} \sum_{i=1}^n P^* \quad (8)$$

$$S^* = \left[ \frac{1}{n-1} \sum_{i=1}^n (P^* - P^*_{ave})^2 \right]^{1/2} \quad (9)$$

Where, P<sup>\*</sup><sub>T</sub> is frequency precipitation and P<sup>\*</sup><sub>ave</sub> is the average of the maximum precipitation corresponding to a specific duration based on the logarithmically transformed P<sub>i</sub> values; i.e. P<sup>\*</sup> of Equation (6). K<sub>T</sub> is the Pearson frequency factor which depends on return period

(T) and skewness coefficient (C<sub>s</sub>).

The skewness coefficient (C<sub>s</sub>) is required to compute the frequency factor for this distribution. The skewness coefficients were computed using Equation (1) as suggested by (Burke and Burke, 2008).

$$C_s = \frac{n \sum_{i=1}^n (P^*_i - P^*_{ave})^3}{(n-1)(n-2)(S^*)^3} \quad (10)$$

The computed frequency precipitation P<sup>\*</sup><sub>T</sub> values and intensities (I<sub>T</sub>) for six different durations and six return periods using LPT III methodology.

### 2.4 Intensity-Duration –Frequency (IDF) Model Development

The Intensity-Duration-Frequency (IDF) formulae are the empirical equations demonstrating a correlation between the variables. Several commonly used IDF equations relating the

rainfall intensities, the frequencies, and durations are available in literature (Burke and Burke, 2008; Nhat et al., 2006 and Mohammad, 2016). The commonly used IDF equations is Sherman equation, which is given as:

$$i = \frac{aT^b}{(t+d)^c} \tag{11}$$

Where, i = intensity of rainfall in mm/hr; t = duration of rainfall in minutes; T = return period of rainfall in years; a, b, c, and d, are the regional IDF parameters to be determined. Equation (11) which is the most general form of IDF equation has been used to develop the IDF equations by optimization method.

#### 2.4.1 Application of Excel Solver Optimization Technique to estimate IDF Parameters

The excel solver methods are mainly the Generalized Reduced Gradient (GRG Solver) for optimization of nonlinear equations and the linear programming Solver (LP Solver) for linear equations. Due to the fact that IDF equations are nonlinear, the GRG Solver was used in this work to get the optimum of the parameters for the models.

#### 2.4.2 Calibration of the Sherman (1932) Model

Sherman (1932) model as given in equation (14) was calibrated using GRG Solver optimization method to obtain optimum values for the regional parameters namely a, b, c, and d for the models.

Thus, the objective function becomes:

$$\text{Min SSE} = \sum_{i=1}^n (i_{\text{obs}} - i_{\text{est}})^2 \tag{12}$$

Where,  $i_{\text{obs}}$  is observed intensity corresponding to any duration and  $i_{\text{est}}$  is estimated intensity corresponding to any duration. Solving equation (12) produces the optimum values for the parameters a, b, c, and d achieved through an iterative process that produces the least squared error.

### 2.5 Model Performance Analysis

The performance of the Intensity Duration Frequency (IDF) models given by Gumbel distribution and Log Pearson Type III Distribution (LPT III) were evaluated by obtaining empirical data from the models and then goodness of Fit test, Correlation Coefficient, and Root Mean Square Error (RMSE) analysis were carried out. To determine the best-fit distribution, the observed distributions were fitted to the theoretical distribution by comparing the frequencies observed in the data to the expected frequencies of the theoretical distribution. A Goodness-of-fit test between observed and expected frequencies is based on the chi-square quantity, which is expressed as:

$$\chi^2 = \sum_{i=1}^k \frac{(O_i - E_i)^2}{E_i} \tag{13}$$

Where,

$\chi^2$  = random variable whose sampling distribution is approximated very closely by the chi-square distribution.

$O_i$  and  $E_i$  = observed and expected frequencies for the  $i$ th class interval in the histogram.

K = the number of class intervals.

Mohammad (2016) provided programmable formulae to obtain the coefficient of

determination ( $R^2$ ) and Root Mean Square Error (RMSE) as follows:

$$R^2 = \frac{\sum_{i=1}^n (I_{obs} - I_{avg})^2 - \sum_{i=1}^n (I_{obs} - I_{pred})^2}{\sum_{i=1}^n (I_{obs} - I_{avg})^2} \quad (14)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (I_i - I_*)^2} \quad (15)$$

The theoretical description of Correlation Coefficient (CC) is as given in equation (16)

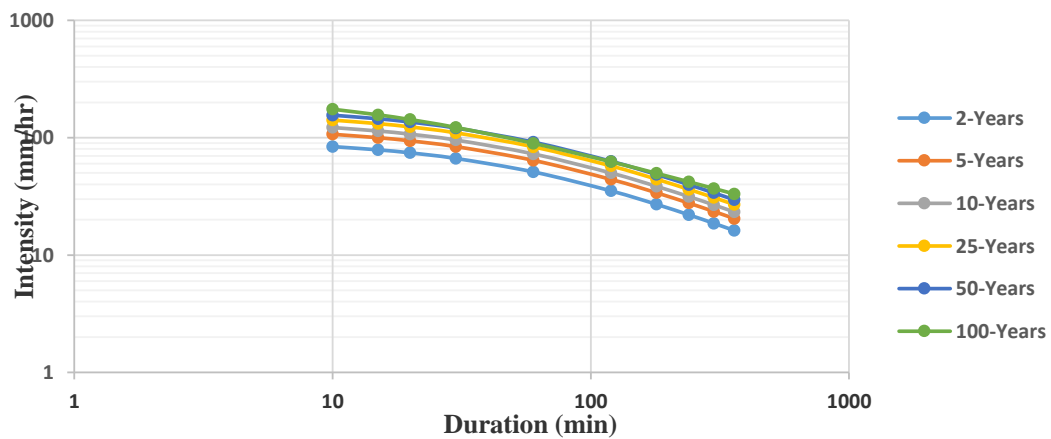
$$CC = \frac{\sum_{i=1}^N \left( \frac{(I_{obs} - I_{avg\ obs})(I_{pred} - I_{avg\ pred})}{\sqrt{\sum_{i=1}^N (I_{obs} - I_{avg\ obs})^2 + \sum_{i=1}^N (I_{pred} - I_{avg\ pred})^2}} \right)}{\sum_{i=1}^N} \quad (16)$$

Where,  $I_{obs}$  is the observed precipitation intensity of  $i$ th event,  $I_{pred}$  is the predicted precipitation intensity of the  $i$ th event,  $I_{avg\ obs}$  is the average observed precipitation intensity and  $I_{avg\ pred}$  is the average of predicted precipitation intensity.

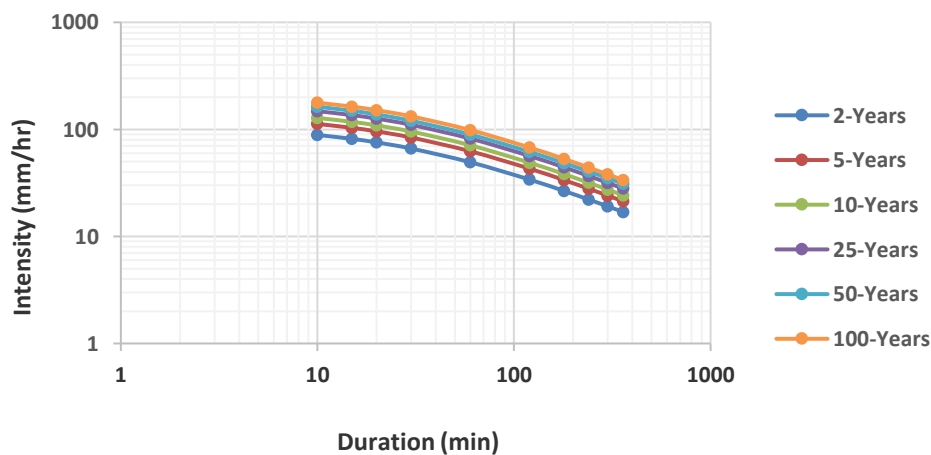
### 3. Results and discussion

#### 3.1 Intensity Duration Frequency IDF Curves by Gumbel and Log Pearson Type (LPT) III Methods for Port Harcourt.

The results of the Intensity Duration- Frequency curves by Gumbel and Log Pearson Type methods for Port Harcourt city are shown in Figures 2 and 3, respectively.



**Figure 2:** IDF curves by Gumbel method at Port-Harcourt



**Figure 3.1b:** IDF curves by LPT III method at Port-Harcourt

Figures 2 and 3 show results of the IDF curves obtained by Gumbel and LPT III methods for the region. According to the IDF curves rainfall estimates are increasing with increase in the return period and the rainfall intensities decrease with rainfall durations in all return periods. The trends of the results from the two methods have good consistency. The IDF curves proved the basic principle in hydrology that high intensity rainfalls had shorter durations. It also showed that rainfall intensities increase with return periods. This is in line with findings of similar research carried out by Ogbozige (2021), Mohammed et al. (2021), Majeed et al. (2021), Agarwal et al. (2021), Al-wagdany (2020) and Gratein et al. (2019).

### 3.2 Rainfall Intensity Duration Frequency Models and their Parameter Values

The parameter values used in deriving the Gumbel and Log Pearson Type III models, including the models for Port Harcourt region is shown in Table I.

**Table I:** Parameters values used in deriving models for rainfall intensity at Port Harcourt City.

S/No.	Location	Distribution	Parameters				Models
			a	b	c	d	
I.	Port Harcourt	Gumbel	135	1.72	0.83	46.35	$I = \frac{135T_r^{1.72}}{(t + 46.35)^{0.83}}$
		Log Pearson Type III	140	1.23	0.73	30.33	$I = \frac{140T_r^{1.23}}{(t + 30.33)^{0.73}}$

The Gumbel and Log Pearson Type III models, including the parameter values used in deriving the models for the region studied are shown in Table I. The parameter values used in deriving the models are a, b, c and d. Parameters b (1.72), c (0.83), and d (46.35) values using Gumbel distribution are higher than values obtained using Log Pearson Type III method for Port Harcourt region.

### 3.3 Model Performance/Validation for Port Harcourt IDF Models

The results of the computed indicators of goodness of fit between Gumbel and Log Pearson Type III Models, namely Chi Square ( $\chi^2$ ), Root Mean Square Error (RMSE), Correlation Coefficient (R) and Coefficient of Determination ( $R^2$ ) are given in Tables 2a and 3, respectively. Tables 2 and 3 show the model performance / validation of IDF Model obtained for Port Harcourt region using Gumbel and Log Pearson Type III distributions respectively.

**Table 2:** Model Performance/ Validation for Port Harcourt IDF Model Obtained by Gumbel method

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
Port-Harcourt	Gumbel	$\chi^2$	0.98	2.69	0.96	7.49	4.10	1.05	0.27	0.25	0.01	0.50
		RMSE	4.68	7.59	4.28	11.73	7.82	3.00	1.34	1.20	0.20	1.43
		R	1.00	1.00	1.00	0.99	0.87	0.98	0.99	1.00	1.00	1.00
		$R^2$	1.00	1.00	1.00	0.98	0.76	0.97	0.99	1.00	1.00	1.00
		Pvalue	0.96	0.75	0.97	0.19	0.54	0.96	1.00	1.00	1.00	0.99

**Table 3:** Model Performance/Validation for Port Harcourt IDF Model Obtained by Log Pearson Type III Method

Location	Distribution	Model validation	Duration (min)										
			10	15	20	30	60	120	180	240	300	360	
Port-Harcourt	Log Pearson Type III	$\chi^2$	2.60	4.29	2.23	4.17	0.42	0.39	0.03	0.10	0.01	0.10	
		RMSE	7.86	9.68	6.70	8.58	2.35	1.86	0.45	0.78	0.23	0.67	
		R	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		R <sup>2</sup>	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P-value	0.76	0.51	0.82	0.52	0.99	1.00	1.00	1.00	1.00	1.00	1.00

Tables 2 and 3 show the model performance / validation of IDF Model obtained for Port Harcourt region using Gumbel and Log Pearson Type III distributions respectively. Goodness of fit tests was used to choose the best statistical distribution among those techniques. As can be seen in Tables 2 and 3, most of the data fit both Gumbel and Log Pearson Type III distributions at 5% level of significance. However, the data at 30minutes and 60minutes durations do not give good fit using Gumbel distribution for Port Harcourt region. Also, the data for 15 minutes and 30 minutes durations do not give good fit using Log Pearson Type III distribution for Port Harcourt.

The correlation coefficient (R) and coefficient of determination (R<sup>2</sup>) obtained from the fitted IDF Models adopting Gumbel distribution are high and ranged from 0.97 to 1.00 except at 60 minutes duration with R as 0.87 and R<sup>2</sup> as 0.76, respectively. However, the correlation coefficient and coefficient of determination obtained from the fitted IDF Model adopting Log Pearson Type III distribution have perfect value of 1.

The values of root mean square errors (RMSE) obtained are lower for durations from 30minutes to 360 minutes using Log Pearson Type III, except for durations of 300minutes when compared to Gumbel distribution. The results show the goodness of fit of the formulae to estimate the rainfall intensities of the region of study, especially for higher durations and frequencies of 2 to 100 years.

### 3.4 Comparison of Observed and Predicted Rainfall Intensities

The results of the predicted rainfall intensities for different durations and return

Periods are shown in Table 4 and 5. Also some selected index values of predicted intensities for comparison of short, medium and higher durations are shown in Table 6.



**Table 4: Predicted Intensity-Duration frequencies for different return periods by Gumbel method at Port-Harcourt**

Return Period (Years)	2		5		10		25		50		100	
Duration (min)	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted
10	86.382	83.96554981	110.701	106.8743	126.84	122.0707	147.192	141.1825201	162.282	155.5011	177.294	174.8547
15	74.664	78.78027513	94.128	99.97962	107.044	114.0438	123.328	131.7165551	135.408	144.9406	147.42	156.6058
20	71.565	74.22266278	90.215	93.96795	102.591	107.0701	118.02	123.5249021	129.774	135.8244	141.282	142.618
30	72.624	66.57923988	91.556	83.98306	104.12	95.53717	119.964	110.0404577	131.712	120.8618	143.398	122.3677
60	50.865	51.07672082	64.083	64.07358	72.856	72.71203	83.919	83.56395718	92.122	91.6294	70.341	89.48134
120	32.678	35.17853278	41.195	44.05725	46.847	49.96015	53.975	57.40454873	59.26	62.90963	64.517	62.30258
180	25.935	27.01030311	32.693	33.89063	37.178	38.46038	42.833	44.24513759	47.027	48.50819	51.199	49.64461
240	22.938	22.00838133	28.616	27.689	32.384	31.45697	37.136	36.24202741	40.659	39.75916	44.164	42.05611
300	18.895	18.61875859	23.734	23.49087	26.945	26.71826	30.995	30.82797277	33.998	33.84244	36.985	36.90138
360	17.29	16.16426144	21.795	20.45039	24.784	23.28608	28.555	26.90547973	31.35	29.55577	34.131	33.12582

**Table 5: Predicted Intensity-Duration frequencies for different return periods by LPT III method at Port-Harcourt**

Return period (years)	2		5		10		25		50		100	
Duration (min)	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted
10	93.82	88.7856	118.928	112.5219	135.293	128.0203	156.419	148.055	171.905	162.92524	187.623	177.5798
15	75.344	81.5423	95.512	103.3653	108.656	117.5917	125.62	135.944	138.052	149.13244	150.68	163.0634
20	71.213	75.5563	90.273	95.78784	102.697	108.9643	118.73	125.936	130.483	137.84965	142.414	151.0655
30	71.784	66.2023	90.998	83.93016	103.522	95.46815	119.682	110.3	129.428	120.41026	143.558	132.3153
60	50.816	49.3025	64.269	62.46537	73.114	71.04943	84.333	82.0608	92.683	89.409988	101.158	98.44184
120	32.657	33.9709	41.397	42.96677	47.095	48.8773	54.447	56.4645	59.837	61.708828	65.309	67.7292
180	26.175	26.568	33.18	33.55299	37.747	38.17439	43.639	44.1175	47.96	48.416597	52.345	52.9129
240	21.525	22.1083	27.286	27.88576	31.041	31.73105	35.887	36.6852	39.44	40.416534	43.047	43.99422
300	19.321	19.0897	23.935	24.05273	27.229	27.37287	31.48	31.6576	34.596	34.998441	37.76	37.96152
360	17.252	16.893	21.87	21.26524	24.88	24.20328	28.764	28.0007	31.612	31.050985	34.502	33.57369

The rainfall intensity of any duration and return period is predicted by the aid of the developed IDF models. The factors that enhance the distribution of the observed and predicted rainfall intensities are duration and return period. Observed and predicted rainfall intensities were compared as way of verification of the developed models. For the studied location in Tables 4 and 5, it was noted that rainfall intensity decreases with increasing durations and for a given duration the higher return period yielded corresponding higher intensity values. From Table 5, the highest predicted intensity values were given by Log Pearson Type III.

**Table 6: Comparison of selected index values of predicted intensities (mm/hr) for short, medium and higher durations**

Method	Station	10min duration 100-year return period	60min duration 100-year return period	300 min duration 100-year return period
Gumbel	Port Harcourt	174.85	89.48	36.9
Log Pearson Type III	Port Harcourt	177.58	98.44	37.96

Table 6 shows the comparative predicted intensities by Gumbel and Log Pearson Type III Models for short, medium and higher durations. In Table 4 at 10 minutes duration and 100-year return period, the predicted intensities by Gumbel model was 174.85mm/hr. The predicted intensities at the same 10minutes duration and 100-year return period by Log Pearson Type III was 177.58mm/hr. Also, for 60minutes duration and 100-year return period, the predicted intensities by Gumbel was 89.48mm/hr. While at the same 60minutes duration and 100-year return period, the predicted intensities by Log Pearson Type III was 98.44mm/hr. Finally, at 300minutes duration and 100 years return period, the predicted intensities by Gumbel was 36.90mm/hr. While at the same 300minutes duration and 100-year return period, the predicted intensities by Log Pearson Type III was 37.96mm/hr. The predicted intensities values given in tables 3.4 establishes the consistent superiority of Log Pearson Type III model over Gumbel model in predicting higher intensity values at short, medium and higher durations in the studied location. This observation was also established in the works for Port Harcourt, Ikeja and Lahore city IDF models by Nwaogazie *et al.* (2019); David and Nwaogazie (2020) and Ahmed and Ali (2016) respectively.

### 3.5: Comparison of IDF Curves obtained with Published IDF Curves

The comparison of IDF curves obtained with published IDF curves by Mbajjorgu and Okonkwo (2010) is shown in Table 7.

**Table 7: Comparison of Mbajjorgu and Okonkwo (2010) estimated intensities with Intensities predicted by Gumbel distribution.**

Method	Station	10-yr 15min	2-yr, 30mins	5-yr, 1hr	25-yr, 1hr	100yr,6hr
Mbajjorgu and Okonkwo	Port Harcourt	122.4	71.6	62.8	82.5	34.4
Gumbel Distribution	Port Harcourt	114.0	66.6	64.1	83.6	33.1

Mbajjorgu and Okonkwo (2010) used the Gumbel method to develop IDF curves for some selected locations in Nigeria. Port Harcourt is common to his work, so comparison was made using results of predicted intensities developed by Gumbel distribution models for Port Harcourt. Table 7 shows the intensities estimated by Mbajjorgu and Okonkwo (2010) using Gumbel method and predicted intensities from this work by Gumbel distribution model. From the table, the intensities predicted by Gumbel distribution models for the selected location of study are lower than those of Mbajjorgu and Okonkwo (2010) at both shorter and higher rainfall durations. This could be as a result of differences in number of years of records of data

collected. Mbajjorgu and Okonkwo (2010) did not exactly specify the number of years of rainfall data used; rather the work stated that the length of available records used varies from 22 to 30 years. In this study, 33 years of daily rainfall data was used. Also, according to David and Nwaogazie (2020)) at times values of rainfall recorded at some stations may be incorrectly observed. However, the differences are not statistically significant at 5% level of significance. It was also noted that for a given return period, intensities decrease as duration increases. This is in line with what Mbajjorgu and Okonkwo (2010) obtained as shown in Table 7. Storms of 10-years return period and 15minutes duration gave the highest intensities than storms of 100-years return period and 6 hours duration. Therefore, models developed by Gumbel and Log Pearson Type III distributions are in agreement with Probability Distribution Function (PDF) theory which shows higher intensities occurring at shorter duration and lower intensities at longer duration.

#### **4. Conclusion**

This work shows the procedure for the development of rainfall intensity duration frequency models for Port Harcourt in South -South Nigeria. In this study, IDF models were developed for studied location. These models are guides for estimating the rainfall intensities for any specific return period at different durations. The highest intensity occurs at return periods of 100 years with durations of 10minutes (0.15hr), while the lowest intensity occurs at return period of 2 years with durations of 360minutes (6.0hr).

#### **5. Engineering implications of Findings**

The IDF Models developed will serve as tools for the Engineers and Hydrologists in estimating storm water runoff from a watershed for the design of drainage systems, reservoir management and planning of water resources development. This will mitigate flooding and its consequences.

Also, the findings when applied as demonstration tools in teaching land drainage courses to Engineering students, will enhance their understanding and appreciation of the course.

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