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AN INTEGRATED APPROACH TO THE DEVELOPMENT OF INTENSITY DURATION FREQUENCY CURVE FOR SOUTHERN CROSS RIVER CATCHMENT, NIGERIA

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ABSTRACT

Intensity-Duration-Frequency (IDF) curve is one of the most commonly used tools in Water Resources Engineering projects. These curves are useful in the design of urban drainage works such as storm sewers, culverts and other hydraulic structures. There are two common frequency analysis techniques that can be used to develop the IDF curve from rainfall data of the region. These techniques are Gumbel Approach and Log Pearson Distribution (LPT). For this research work, the Gumbel Distribution technique was used. An equation for estimating rainfall intensity for the region was derived. Rainfall intensities obtained showed good agreement with results from previous studies on some parts of the study area. The parameters of the IDF equation and coefficient of correlation for different return periods (10, 15, 30, 60, 120, 180, 360 and 420mins) were calculated using regression analysis. The results obtained showed that in all the cases, the correlation coefficient was very high, indicating the goodness of fit of the formula to generate IDF curves in the region of interest.

KEYWORDS: IDF, LPT.

1.0 INTRODUCTION

Rainfall Intensity Duration curves are graphical representation of the amount of water that falls within a given point in time in a given catchment area (Dupont and Allen, 2000). The establishment of Intensity Duration curve is a frequently used tool in water resources projects and management, sewer design, culverts and other hydraulic structures in urban areas as well as for geomorphologic researches. The connection between the rainfall intensity and duration is determined through statistical segmentation of data normally obtained from meteorological stations (Meyer, 1928; Kousioyiaus and Wheater, 2003).

Dilapidation of water quality, property damage and possible loss of life due to flooding is caused by severe rainfall event. Development of Intensity Duration curves had been intensified in advanced countries in order to control rainstorm estimations so as to take care of such circumstances. Oftentimes, urban environments are exposed to the danger of extreme hydrological events. Urban water systems (including culverts, storm water ponds, creeks, drainage systems, and storm sewer systems) along with infrastructure design and management are critical to lessen the risk of flooding. Historic rainfall event statistics (in terms of intensity, duration and return period) are used to design flood protection structures, and many other Civil Engineering structures involving hydrologic flows based on the return period of heavy rainfall event (Mc Cuen 1998; AlHousen, 2011; Hershfield, 1961).

The operation of quantifying rainfall is done using aerial maps and intensity duration frequency curves (Chow et al, 1988). The IDF formulae are the empirical equations representing a relationship among maximum rainfall intensity (as dependent variable) and other parameters of interest such as rainfall duration and frequency (Antigha and Ogarekpe 2013; Majudar, 2004; Okonkwo and Mbajoigu, 2010).

There are several commonly used functions found in the literature of hydrology applications (Chow et al, 1988; Oyedande, 1982; Paola, 2014) which have been widely applied in hydrology. The IDF relation is mathematically stated as follows:

$$i = f(T, d) \quad \text{eqn. 1}$$

Where **T** is the return period in years and d is the duration in minutes. The typical generalized Intensity Duration relationship is as given in equation (2). The maximum intensity varies inversely with the duration and generally an equation of the form is assumed between **i** and **t**.

$$i = \frac{C}{(t+a)^b} \quad \text{eqn. 2}$$

Where **C, a** and **b** are non-negative coefficient constants which are obtained through regression analysis and are related to the meteorological conditions.

The Intensity Duration curve is a graph with rainfall intensity (I) as ordinate (mm/hr), storm duration (D) plotted as absicca (minutes). The amounts of maximum daily precipitation values, similar to those represented by IDF curves, have shown increasing trends in many locations of the world (Arnbjerg-Nielsen, 2012; Mohymount, et al., 2004; Waters et al., 2003). It has been generally observed that the most intense storms last for very short durations. As the duration of storm increases, the maximum average intensity of the storm decreases. Once established, these curves are used to characterize rainfall pattern for a given area and to predict when a specific volume of flow or more will re-occur in the future (Sherman, 1932; Kousioyiaus et al, 1998).

The objectives of this research included, amongst others, to obtain an intensity duration data for design purposes from the area; extract extreme values of intensities from the data; subject these extreme value intensities to regression analysis using Microsoft Excel software; apply different plots approaches to determine which plot yielded the highest value of r^2; subject the chosen plotted values to the MATLAB programme to extract the hydrological constants of **C**, **a** and **b** for the catchment and use the constants obtained to generate the rainfall intensity-duration model for the catchment for different storm events.

2.0 Description of the Area of Study

Cross River South South lies between latitudes 04˚ 45‟ 30‟‟ North and 05˚ 47‟ 55‟‟ North of the Equator and longitudes 08˚ 05‟ 45‟‟ East and 08˚ 53‟ 42‟‟ East of the Meridian. The Local Government areas in Cross River South South include; Akamkpa, Akpabuyo, Bakassi, Biase, Calabar South, Calabar Municipality and Odukpani.

The population of the South South settlement is estimated at one million, one hundred and eighty-seven thousand, two hundred and fifty (1,187,250) (Census, 2006). Akpabuyo Local Government area has the highest population estimated at two hundred and seventy-one thousand, three hundred and ninety-five (271,395) and the lowest being Bakassi Local Government area which has an average population of thirty-one thousand, six hundred and forty-one (31,641) (Census, 2006). Cross River South South has an approximate land area of nine thousand, eight hundred square kilometers (9,800km^2).

Generally, there are two lying ridges which trend from North to West of the catchment. These ridges have been dissected by streams. The sandstones form ridge and dome structures. Other positive relief features are due to igneous intrusions at various locations. The mapped area has been described as an inter–fluvial settlement (Ugbong, 2000).

The major winds which significantly affect the climate of Cross River South South blow across the West African coast bringing about two major seasons in the area, namely, wet and dry seasons named after the pattern at which rain falls. While the wet season lasts between April and October, the dry season is normally from November to March of the following year. The dry season is also marked by a short period of dusty and foggy weather popularly called the harmattan which generally occurs between the months of December and January. The harmattan is characterized by poor visibility, sometimes with light drizzles during the morning hours. The intense heat from the sun at this time of the year encourages high evaporation which quickly condenses on the high concentration of aerosol particles at the lower atmosphere at night when the earth"s heat radiates away uninterrupted by a cloudless atmosphere. It is not surprising therefore to see foggy weather in the early hours of the morning before the sun rises again (Ewona and Udo 2008).

The average rainfall is about 1830mm with some variations within the metropolis (NAA Weather Report, 1995). In some wet years (1976, 1978, 1980, 1995, 1996, 1997, 2001, 2005, 2007 and 2008), rainfall readings have been observed to go up to over 3000mm (NIMET 2010, Antigha 2012). On the average, over 80% of the total annual rainfall falls over a period of seven months from April to October, June has an average rainfall of 530mm (Antigha, 2015).

2.1. Empirical Intensity Duration Formulae

There are several commonly used functions found in the literature of hydrology applications (Chow et al., 1988), four basic forms of equations used to describe the rainfall intensity duration relationship are summarized as follows:

Talbot equation:

$$i = \frac{a}{d+b} \text{ . . . . eqn. 3}$$

Bernard equation:

$$i = \frac{a}{d^e} \text{ . . . . eqn. 4}$$

Kimijima equation:

$$i = \frac{a}{d^e + b} \quad \text{eqn. 5}$$

Sherman equation:

$$i = \frac{a}{(d+b)^e} \quad \text{eqn. 6}$$

Where i is the rainfall intensity (mm/hour); d is the duration (minutes); a, b and e are the constant parameters related to the metrological conditions. These empirical equations show rainfall intensity decreased with increasing rainfall duration for a given return period. All functions have been widely used for hydrologic practical applications. The least-square method was applied to determine the parameters of the four empirical IDF equations that are used to represent intensity-duration relationships.

2.2. Stages of Developing Intensity Duration Curves

According to Abubakari (2013), the process of developing IDF curves are as follows; Obtaining Raw Data - here, a hyetograph of any duration from the storm record is plotted, this is done from a cumulative depth of rainfall with time. From the hyetograph plotted, one can then pick the maximum of each duration for the year to constitute the maximum intensity.

Classification of Extreme Events- the next process after obtaining the raw data, the most extreme events are selected. There is a creation of a ranked list of extreme events from each year for each selected storm duration. A substitute is to identify partial duration series which are ranked lists of the n maximum rainfall amounts within a period of n year of record.

Performing of Regression Analysis- regression analysis was used to generate maximum rainfall intensities for durations of interest which included 10, 15, 30, 60, 120, 150, 180, 240, 360 and 420 minutes. Microsoft Excel tool was used in organizing the voluminous data obtained for this research work and performing the analysis. In performing the analysis for each of the years obtained, maximum rainfall intensities were plotted against duration to obtain series of equations based on a couple of trendline options which included; exponential, linear, logarithmic, polynomial and power. These trend lines produced varying coefficient of variance values with the power model providing the highest intensities for every year regardless of the value of the coefficient of variance. The power model was utilized solely for generating Intensity Duration curve using an empirical approach, this was in order to get optimized values of intensity. In deriving the rainfall constants in the Sherman model, the model that produced the highest coefficient of variance was used, this made the constant values generated accurate and realistic.

Generation of Rainfall Intensity Duration Constants- the Intensity Duration regional constants considered in the earlier discussion were derived by following a set procedure of finding required variables and inputted in eqns. (5) and (6). A simultaneous equation was obtained and MATLAB was used as the tool for solving the equations. This process was continually done for 15 values of a, an optimal value of these constants was taken at a point where the data skewed.

Gumbel Distribution - Gumbel distribution is a statistical method often used for predicting extreme hydrological events such as floods. The extreme value distribution is used in the UK and in many parts of the world for flood studies. A random variable (x) is said to follow a Gumbel distribution of its cumulative distribution function and probability density function and is derived as follows,

$$f(x) = exp\left(-exp\left(-\frac{x-x_0}{s}\right)\right) \quad s \neq 0 \quad \text{. eqn. 7}$$

$$f(x) = \frac{1}{s} exp\left\{-\frac{x-x_0}{s} - exp\left[-\frac{x-x_0}{s}\right]\right\} \quad \text{. . . . . eqn. 8}$$

Frequency Factor - When the Gumbel statistic had been fitted to the sample, any extreme value related to a return period greater than or equal to two years ($T \geq 2$ years), is found by the formula,

$X_T = \bar{X} + K_T S$ . . . . eqn. 9

Where, X_T is the rainfall intensity for a given return period $\bar{X}$ is the mean rainfall intensity

K_T is the rainfall intensity for each return period, and

S is the standard deviation of rainfall intensities

$K_T = -\frac{\sqrt{6}}{\pi} * \left[0.5772 + \ln T\left(\frac{T}{T-1}\right)\right]$. eqn.10

Where, T is the return period

Statistical Test of Hypothesis - A statistical hypothesis test is a method of making statistical decisions using experimental data. The decisions are made using null hypothesis tests. There are two types of tests; parametric test and Non parametric test.

Parametric statistical procedures (t-test, least-squares etc.) depend on distributional assumptions about hydrological events. This is because hydrological events do not always need the assumptions for parametric tests.

3.0. MATERIALS AND METHODS

The major data required for this study was rainfall intensities for durations which ranged from 10minutes to 420minutes but was only available for daily rainfall intensity and was provided by the meteorological station at the Margaret Ekpo International Airport, Cross River State. For this project, a 23year rainfall data was employed.

Test of Goodness of Fit - To account for the validity of the fitting of the probability distribution and to determine whether the fitted distributions were consistent with the given set of observations, a test of goodness of fit is required and in this study, the Pearson's Chi-square test method which is generally preferred to the Kolmogorov-Smirnov method was employed. The steps included;

The observed data (O) and expected data (E) were put into intervals so as to determine the frequency of both variables in each class. The classification was rearranged such that the minimum expected frequency in each class became 5 or greater. The classes with low frequency were merged to this end. The chi-square value for all intervals were computed for all intervals.

For each observed number in the table, the expected data (E) was subtracted from the observed data (O) Their differences was squared i.e. $(O-E)^2$

The result from (ii) on each cell in the table was divided by the expected number for that cell i.e. $\frac{(O-E)^2}{E}$

The values of (iii) above was summed and this gives the chi-square value

$x^2(v) = \sum_i^n \frac{(O_i-E_i)^2}{E_i}$ . . . . eqn. 11

v = n-k-1. . . . . eqn. 12

Where, v is the degree of freedom n is the number of intervals.

k is the number of distribution parameter obtained from the statistics

the value obtained was compared to the chi-square value from tables and the null hypothesis was accepted since $x^2 < x^2_{0.95}$

Procedure of Data Analysis - There are two (2) procedures used in the analysis of rainfall data (a) graphical method, and (b) statistical method. The latter was used during the course of this research. Rainfall durations were abstracted from the data source and the following operations applied;

(i) Maximum intensities computed from

$I = \frac{R}{t}$ . . . . eqn. 13

Where, I is the rainfall intensity in mm/hr. R is the depth of rainfall in mm, and t is the duration of rainfall in hr.

4.0. Development of Intensity Duration Curve

The maximum intensities for each month in the 23years were selected and these intensities obtained were plotted against their corresponding duration. After the graph was plotted, the coefficient of variation for the linear, exponential, logarithmic, power and polynomial model was compared to each other and the model with the highest coefficient of variation (r^2) was selected. Each model generated a relationship between the intensity and duration. The graph was regressed for durations of 10minutes, 15minutes, 30minutes, 60minutes, 120minutes, 150minutes, 180minutes, 240minutes, 360minutes and 420minutes. The maximum value of each duration regressed was selected. This maximum value served as the representative intensity of a particular duration for the 23years available data. After the representative values for all the durations was obtained, a trial method was employed in the generation of rainfall constants **C, a** and **b**. The table below shows a typical example of how this could be done.

Table 1: Computation for Regression Analysis for a trial value of a.

Duration	Maximum Intensity	Log I	Log (t + a)	Log I. Log(t + a)	(Log(t + a))^2	Î	ΔI=(I- î)	ΔI^2

Where;

I – maximum intensity for a specific duration (mm/hr) t - specific duration (minutes) a – trial value

ΔI^2 – Squared deviation

VI. This table is repeated for different trial values of **a**. It is observed that as the trial value increases, the squared deviation (ΔI^2) reduces. A point is reached where there is an increment in the squared deviation due to a higher trial value, this is the point where the graph skews and the corresponding digits at that trial value is taken as the rainfall constants **C, a** and **b.**

Table 2: Trial values and its corresponding constants and sum of squared deviation.

Trial	**a**	**C**	**B**	$\sum\Delta I2$

At the point where it skewed, the values for the constants a, C and b were used to generate the general intensity duration equation of the form,

$$i = \frac{C}{(t+a)^b} \quad \text{eqn 14}$$

The equation generated was used to determine rainfall intensity for a particular duration.
A graph of intensity against varying durations was plotted.

The extraction of data of rainfall depth was immediately followed by the evaluation of rainfall intensities (mm/hr) obtained on a daily basis. Rainfall intensity is the ratio of depth and duration.

Thus, intensity $i = \frac{depth(mm)}{duration(hr)}$

This process was applied in deriving all the rainfall intensities for all days of the month for the 23 years of available data.

For the purpose of the research work, required data is maximum rainfall intensities for each year at rainfall durations of 10mins, 15mins, 30mins, 60mins, 120mins, 180mins, 360mins and 420mins. This was not available as the rainfall data obtained was only available for daily rainfall recordings. An alternative which was employed was getting the maximum rainfall intensities for each month of the year for the 23 years of available data and subjecting the data to regression analysis to obtain the required rainfall intensities at the durations.

Using Microsoft excel, a regression analysis was carried out on the yearly rainfall data and two approaches were used to determine the maximum intensities.

As discussed earlier, there are various regression models available for determining specific values of intensities for different durations. The power model being one of it was solely used at first in determining the maximum intensities for 10mins, 15mins, 30mins, 60mins, 120mins, 180mins, 360mins and 420mins. This was done in order to optimize the intensity values obtained from the equation derived. Previous work on Intensity duration relationship has proven to be unreliable for design of water resources and hydraulic structures in the region because it has generated very low values for intensity. The approach of using only power model was discarded because the optimized values for intensities were over-estimated, which could lead to over-designing and waste of materials.

A second approach which is detailed below was used. This involved using any model (i.e. logarithmic, linear, exponential, polynomial or power) that had the highest coefficient of variation ($\mathbf{r^2}$) value in each year. Exponential model yielded the best r^2 for 2004, 2005, 2010, 1995, 1992 and 2008. Logarithmic model yielded the best r^2 for 2003, 2001, 2000, 1990 and 2007. Polynomial model yielded the best r^2 for 1991 and 2002. Lastly, power model yielded the best r^2 for 1983, 1985, 1986, 1988, 1994, 1989, 1997 and 2009. After this was done, the maximum intensities for 10mins, 15mins, 30mins, 60mins, 120mins, 180mins, 360mins and 420mins was selected. These maximum values were used as a representative value for its respective duration.

The relationship between the maximum intensity and duration is of the form;

$$I = \frac{C}{(t+a)^b} \qquad \text{eqn. 15}$$

Every trial value of **a** produced one **C** and **b** value. The target was the point where the sum of the squared deviation skewed for a trial value of **a**. The values of **a** used for trial were 2 to 30.

Table 3: Computation for Regression Analysis (trial with a = 20).

			when a=20					
Duration in minutes	**Maximum Intensity**	**Log I**	**Log (t+ a)**	**Log I. Log (t+ a)**	**(Log (t +a))^2**	**î**	**ΔI=(I-î)**	**2 ΔI**
10	129.1439373	2.111074	1.477121255	3.11831231	2.181887201	129.8092	-0.665277332	0.442593928
15	116.4002318	2.065954	1.544068044	3.189973313	2.384146126	117.9173	-1.517085028	2.301546983
30	94.61461588	1.975958	1.698970004	3.357093764	2.886499076	94.412	0.202616093	0.041053281
60	72.829	1.862304	1.903089987	3.544132755	3.621751499	70.43673	2.392265824	5.722935774
120	51.04338412	1.707939	2.146128036	3.665456758	4.605865546	49.6951	1.348281037	1.817861755
150	44.0299823	1.643749	2.230448921	3.666297093	4.974902391	44.03078	-0.000798586	6.3774E-07
180	38.29961577	1.583194	2.301029996	3.642977843	5.294739041	39.78902	-1.489400702	2.218314452
240	32.41683281	1.510771	2.414973348	3.648470688	5.832096271	33.78643	-1.369597783	1.875798086
360	27.0768148	1.432598	2.579783597	3.695791723	6.655283405	26.66957	0.40724043	0.165844768
420	24.74634544	1.393511	2.643452676	3.68368057	6.987842053	24.34059	0.405752854	0.164635378
	SUM	17.28705	20.93906586	35.21218682	45.42501261	630.8868	-0.286003192	14.75058504

Log I = n log C – b log (t + a) . . . . . . eqn. 16

$\sum(\log I.(\log(t+a)) = \log C \sum \log(t+a) - b\sum(\log(t+a))^2$ . . . . eqn. 17

17.28705 = 10 log C – b (20.93906586) . . . . . eqn. 18

35.21218682 = log C (20.93906586) – b (45.42501261) . . . eqn. 19

Using MATLAB to solve equations (19) and (20) simultaneously, we have:

log C = 3.0339952 C = $10^{3.0339952}$ = 1081.422 b = 0.6233

$$I = \frac{C}{(t+a)^b} = \frac{1081.422}{(t+20)^{0.6233}}$$

Table 4: Duration and maximum intensities for the trial value of a = 20.

Duration	10	15	30	60	120	150	180	240	360	420
Intensity	129.8092	117.9173	94.412	70.43673	49.6951	44.03078	39.78643	33.78643	26.66957	24.34059

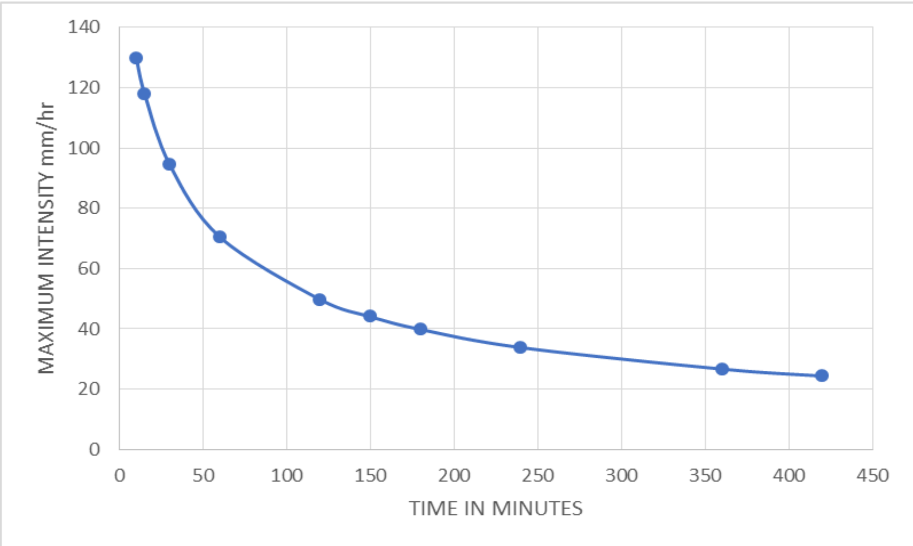

Fig. 1: Intensity- duration graph (a=20).

Table 5: Computation for Regression Analysis (trial with a = 22).

			when a=22					
Duration in minutes	**Maximum Intensity**	**Log I**	**Log (t+ a)**	**Log I. Log (t + a)**	**$(\text{Log}(t + a))^2$**	**Î**	**ΔI=(I-î)**	**2 ΔI**
10	129.1439373	2.111074	1.505149978	3.17748302	2.265476457	128.9436647	0.200273	0.040109
15	116.4002318	2.065954	1.568201724	3.239832382	2.459256647	117.5512414	-1.15101	1.324823
30	94.61461588	1.975958	1.716003344	3.39075093	2.944667475	94.63611336	-0.0215	0.000462
60	72.829	1.862304	1.913813852	3.564103856	3.662683462	70.79847585	2.030524	4.123028
120	51.04338412	1.707939	2.152288344	3.675978192	4.632345117	49.89790025	1.145484	1.312133
150	44.0299823	1.643749	2.235528447	3.674646556	4.997587437	44.16179033	-0.13181	0.017373
180	38.29961577	1.583194	2.305351369	3.649819417	5.314644937	39.86205598	-1.56244	2.441219
240	32.41683281	1.510771	2.418301291	3.653498447	5.848181136	33.77495519	-1.35812	1.844496
360	27.0768148	1.432598	2.582063363	3.699057711	6.66705121	26.56167235	0.515142	0.265372
420	24.74634544	1.393511	2.645422269	3.68642522	6.998258983	24.20398759	0.542358	0.294152
	SUM	17.28705	21.04212398	35.41159573	45.79015286	630.3918569	0.208903	11.66317

17.28705 = 10 log C – b (21.04212398) . . . . . . eqn. 20

35.41159573 = log C (21.04212398) – b (45.79015286) . . . . eqn. 21

Using MATLAB to solve equations (20) and (21) simultaneously, we have: log C = 3.069409071 C = $10^{3.069409071}$ = 1173.3 b = 0.63714

$$I = \frac{C}{(t+a)^b} = \frac{1173.3}{(t+22)^{0.63714}}$$

Table 6: Duration and maximum intensities for the trial value of a = 22.

Duration	10	15	30	60	120	150	180	240	360	420
Intensity	128.943665	117.5512	94.6361134	70.7984759	49.8979	44.1617903	39.86206	33.774955	26.2039876	24.20399

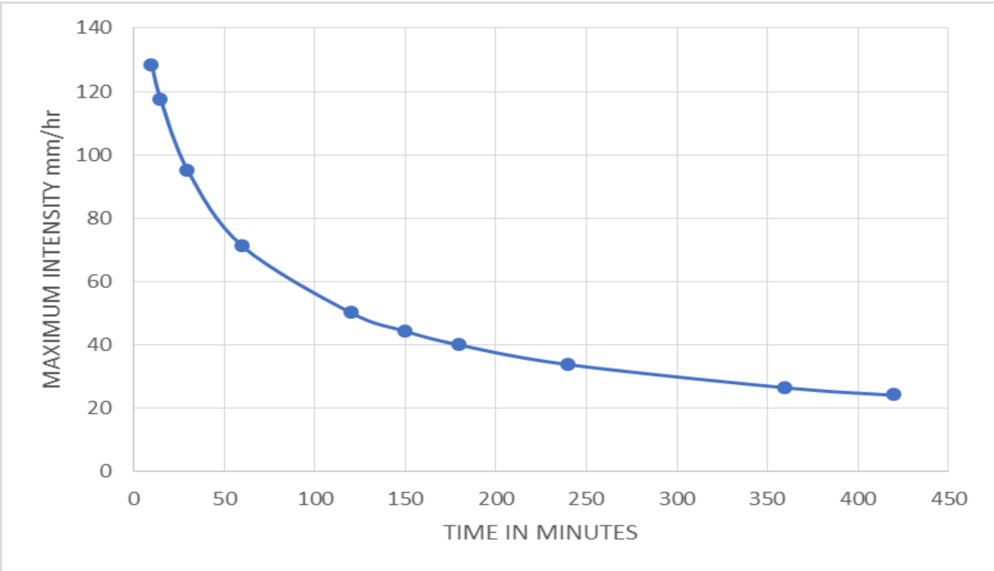

Fig. 2: Intensity- duration graph (a=22).

Table 7: Computation for Regression Analysis (trial with a = 24).

			when **a**=24					
Duration in minutes	**Maximum Intensity**	**Log I**	**Log (t + a)**	**Log I. Log (t+ a)**	**(Log(t + a))^2**	**Î**	**ΔI=(I-î)**	**ΔI^2**
10	129.1439373	2.111074023	1.531479	3.233065358	2.34542767	128.1689	0.975047525	0.950717675
15	116.4002318	2.065953845	1.591065	3.287066043	2.53148658	117.2239	-0.823669918	0.678432134
30	94.61461588	1.975958231	1.732394	3.423137708	3.00118814	94.85657	-0.241956108	0.058542758
60	72.829	1.862304347	1.924279	3.583593679	3.70285077	71.15849	1.670513502	2.790615362
120	51.04338412	1.70793946	2.158362	3.686352469	4.65852865	50.1109	0.932488084	0.869534027
150	44.0299823	1.643748511	2.240549	3.68289949	5.02006093	44.30589	-0.275907696	0.076125057
180	38.29961577	1.583194417	2.30963	3.656593587	5.33439151	39.95006	-1.650442664	2.723960988
240	32.41683281	1.510770581	2.421604	3.658487972	5.86416558	33.78059	-1.363761892	1.859846499
360	27.0768148	1.432597574	2.584331	3.702306644	6.67876788	26.47262	0.604195677	0.365052416
420	24.74634544	1.393511071	2.647383	3.689157478	7.00863659	24.0866	0.659748492	0.435268072
	SUM	17.28705206	21.14108	35.60266043	46.1455043	630.1145	0.486255002	10.80809499

17.28705 = 10 log C – b (21.14108) . . . . eqn. 22
35.60266043 = log C (21.14108) – b (46.1455043) . . . . . eqn. 23

Using MATLAB to solve equations (22) and (23) simultaneously, we have: log C = 3.104179719 C = $10^{3.104179719}$= 1271.1 b = 0.6506

$$I = \frac{C}{(t+a)^b} = \frac{1271.1}{(t+24)^{0.6506}}$$

Table 8: Showing the duration and maximum intensities for the trial value of a = 24.

Duration	10	15	30	60	120	150	180	240	360	420
Intensity	128.1689	117.2239	94.85657	71.15849	50.1109	44.30589	39.95006	33.78059	26.47262	24.0866

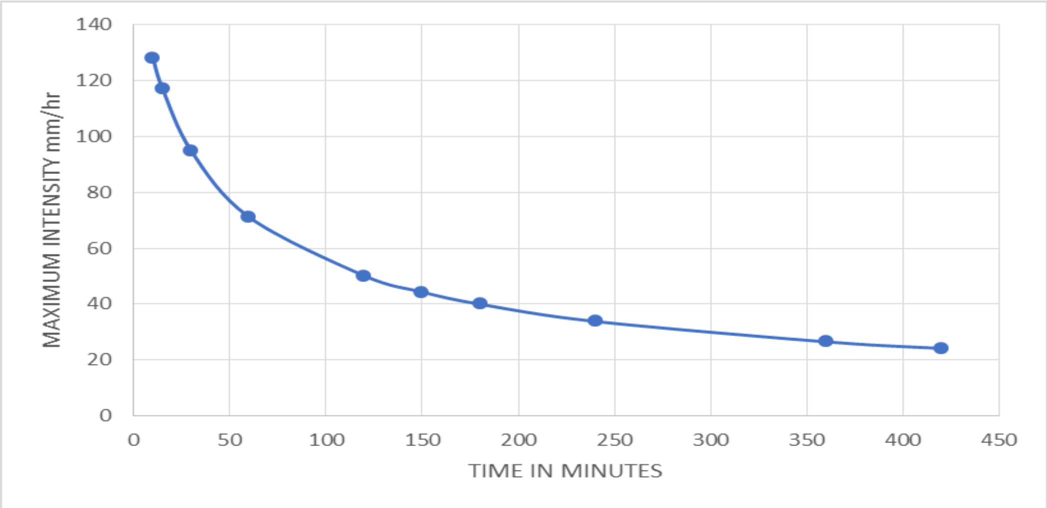

Fig. 3: Intensity- duration graph (a=24).

Using equation (13), the intensities for various durations are determined and entered in column î. The sum of the squared deviations for this case is 10.80809. The procedure is repeated for other values of **a** and the results are given in table 9.

Table 9: Trial values and its corresponding constants and sum of squared deviation.

A	C	b	$\sum \Delta I^2$
2	464.685	0.4763	302.7964694
4	518.322	0.4959	221.0187573
6	575.417	0.5144	162.6850222
8	635.412	0.5318	118.6346073
10	698.956	0.5485	85.40576536
12	766.377	0.5645	60.68631496
14	837.9997	0.5799	42.52263477
16	914.1544	0.5948	29.46262509
18	995.1784	0.6092	20.51736802

20	1081.422	0.6233	14.75058504
22	1173.2519	0.63714	11.66316885
24	1271.1000	0.6506	10.80809499
26	1375.221	0.6638	11.79053557
28	1486.1896	0.6767	14.23134143
30	1604.404	0.6895	18.149117

It was observed that the squared deviation is least when **a = 24.** Therefore, the desired regression equation for the data under consideration is;

$$I = \frac{1271.1}{(t + 24)^{0.6506}}$$

5.0. CONCLUSION AND RECOMMENDATION

The processes of data collection and analysis for the purpose of developing rainfall Intensity Duration models for Cross River State South South have been presented. For this research, a 23year rainfall data was employed ranging from 1983 to 2010. This was obtained from the Nigerian Meteorological Agency (NIMET) at the Margaret Ekpo International Airport, Calabar. Historical rainfall records are needed to obtain design estimates for both small and large projects. A model that relates rainfall intensity for various rainfall duration has been generated through regression analysis using analytical method and this was by defining regionalized parameters **C, a** and **b.** An intensity duration curve was further established to give a graphical representation of the research work. With the catchment empirical models and the constants generated, infrastructure in Cross River South South region could be designed to accommodate future precipitation extremes augmented by further urbanization.

It is recommended that the self-recording type of rain gauges should be installed at all pluviometric regions in the study area to aid in the collection and collation of the input data required for development of rainfall Intensity Duration models particularly in the face of climatic change. The number of gauging stations should also be increased to cover more locations. The data acquisition scheme should be taken seriously by employing capable hands with the skill and expertise as this will eradicate overdesigning such projects or under designing which could lead to flooding. It is equally recommended that the developed model be applied to the catchment for rainfall- intensity duration analysis as this will in no small measure assist in the correct qualification and quantification of rainfall- runoff processes in the catchment.

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