American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Rainfall Intensity – Duration Frequency Curves for Maxima Duration Series for Ondo Town, Ondo State, Nigeria

Philips Moses Otuaga*

Department of Civil Engineering and Technology,

Rufus Giwa Polytechnic, P.M.B. 1019, Owo, Ondo State, Nigeria.

E-mail: otuagamp@yahoo.com

Abstract

Rainfall intensity is defined as the ratio of the total amount of rain (rainfall depth) falling during a given period to the duration of the period It is expressed in depth units per unit time, usually as mm per hour (mm/h). The statistical characteristics of high-intensity, short-duration, convective rainfall are essentially independent of locations within a region and are similar in many parts of the world. Analysis of short-term rainfall data suggests that there is a reasonably stable relationship governing the intensity characteristics of this type of rainfall [1]. Point rainfall average intensities and return periods for specified durations were calculated for annual maxima series. Plots of these were made to give the intensity – duration frequency curves. The amount of rain expected in 12 hours on the 50 – years curve is about 17.5mm per hour. Also, at the 10 – year curve, the average intensity corresponding to 12 hours is about 12.4mm per hour. This study is used for various water resources engineering designs and planning.

Keywords: Rainfall Intensity; Total Amount; Rain; Maxima Series; and Duration Frequency Curves.

1. Introduction

The source of all water on land is the rainfall. The origin of the rainfall itself is found in the water vapour transportation from over the oceans on to the land.

----

* Corresponding author.

E-mail address: otuagamp@gmail.com.

It is the most important component of the hydrologic cycle and has a dominating influence on several hydrologic phenomena occurring as a result of complex interaction. It is the primary source of water for infiltration and percolation into the soil, runoff, stream flow, and floods as well as the basic cause of erosion [3].

For a considerable long time, series of rainfall amounts are recorded worldwide. Such amounts, expressed in mm or $kg \cdot m^{-2}$ and collected during a day or an hour are not only useful for general meteorological and climatological practices, but are of special interest for hydrology and agricultural meteorology [5].

While the total amounts of distribution of rainfall are important parameters affecting plant growth, rainfall intensity frequency data are required for design of engineering structures, analysis of erosion and flood problems. Since rainfall varies from year to year to the extent that even the average perceived in a year is either lower or higher than the average and not of the average value, therefore, frequency analysis has been found to be helpful.

It is essential that collected rainfall data should be analyzed using hydrologic techniques so that they can be converted into usable forms especially in connections with drainage works (sewers, road culverts, bridges), and agriculture. But as in many parts of the world reliable information on rainfall intensity frequency duration is impossible because of inadequate network of rain gauges.

The amount, seasonal distribution and type of rainfall as well as the length of wet season at a place depends largely on its locations with respect to the fluctuating ITD and its associated weather zones [2]. Other factors that influenced are the proximity of the land area to the source of water vapour, the orograph of the land itself and the weather systems, which help as trigger for rainfall. In this research project work emphasis is laid on the intensity and frequency of rainfall rather than its total amount.

2. Materials and Method

2.1 Study Area

Ondo town is situated in the Southwestern high forest vegetation belt of Nigeria. It lies between latitude $7^0 4^1$N and longitude $4^0 47^1$E. It has an annual rainfall of between 1300mm to 1500mm, which is concentrated almost entirely between March and October. Average humidity is about 80% with up to 90% occurring during the rainy season. The mean daily maximum air temperatures range from 28^0C to 35^0C, while the mean daily minimum ranges from 16^0C to 23^0C.

In this area of study, wet season is long, the harmattan season short and forest cover dense. The vegetation of the area plays the double role of supplying humus to the soil and protecting it from erosion.

2.2 Data Collection

Rainfall amount for durations of 0.2hrs, 0.4hr, 0.7hr, 1hr, 2.0hr, 3.0hr, 6.0hr, 12hr, and 24hr were collected for year 1996 to year 2012 from autographic records kept at Ondo station.

The rainfall data used for this study is 7^{th} years data extracted from records. (See table 1)

2.3 Data Analysis

The intense falls from point recording rainfall stations above threshold values of 12.7mm, 15.2mm, 20.3mm, 25.4mm, 25.4, 30.5mm, 38.1mm and 38.1mm for duration 0.2hr, 0.4hr, 0.7hr, 1.0hr, 2.0hr, 3.0hr, 6.0hr, 12.0hr, and 24.0hr, were extracted respectively from recording and converted to the corresponding average intensities (mm/hr).

$$Intensity, \mathrm{I} = \frac{\text{Rainfall Amount}}{\text{Time}}$$

The average intensities were then ranked in descending order of magnitudes, where the highest was accorded the value of order $M = 1$, the second to the highest of the order $M = 2$, and so on (see table 2).

The annual maxima series data set was obtained by choosing only the maximum intensity for each calendar year such that the number of intensities for each duration is equal to the number of water years N on record. This of course neglects the second and lower maxima, which might be higher than the annual maxima of other years. Then, the return period is calculated for each of the ranked intensity [4].

Return period

$$Tr = \frac{N + I}{M} \text{ (in years)}$$

Where $Tr =$ return period (years)

$N =$ Number of events on record

$M =$ rank in order of each entry.

The values of intensities, I versus periods, Tr were plotted for each duration and extrapolated for desired return periods are 2, 5, 10, 25 and 50 years. The intensities extracted are plotted against duration in hours as a function of return period to form the intensity – duration frequency curves for each station.

2.4 Results of Analysis

The results of this study are shown on the following tables and figures.

Table 1 shows the maximum rainfall for each calendar year.

Table 2 shows the maximum rainfall intensity for each calendar year and the return period.

Table 3 shows rainfall intensity – duration frequency curves data extracted from Figure 1.

Table 1: Rainfall Data (1998 – 2014) Ondo – Town

Duration of period	0.2hr	0.4hr	0.7hr	1hr	2hrs	3hrs	6hrs	12hrs	24hrs
Lower limit of falls entered	12.7mm	15.2mm	20.3mm	25.4mm	25.4mm	25.4mm	30.5mm	38.1mm	38.1mm
1998	22.1	29.5	30.0	34.5	34.8	35.6	36.1	-	-
1999	25.7	41.7	46.5	47.5	48.5	50.8	51.6	55.1	55.1
2000	20.3	29.2	36.8	38.1	57.9	60.5	68.1	68.6	101.1
2001	22.9	30.5	45.2	69.6	82.6	85.6	86.6	86.6	96.3
2002	21.1	52.1	71.9	75.7	97.5	100.6	111.3	127.8	151.6
2003	25.4	41.9	45.7	47.0	47.2	47.2	47.2	47.2	47.2
2004	25.4	61.0	82.6	87.4	94.7	104.6	108.5	108.5	118.7
2005	25.4	34.0	45.7	63.5	69.9	72.4	72.4	72.4	72.4
2006	26.1	34.0	34.0	34.0	34.0	34.3	36.3	41.7	49.0
2007	23.1	36.8	54.1	62.7	73.9	79.8	98.3	114.8	115.6
2008	23.4	30.2	51.3	54.1	55.4	65.3	70.6	70.6	92.7
2009	-	17.3	-	-	-	-	-	-	-
2010	19.1	23.4	24.9	-	27.7	-	37.3	-	53.6
2011	25.5	27.9	33.0	44.5	44.7	49.8	58.7	58.7	58.7
2012	45.4	45.2	32.3	31.5	48.6	54.6	62.8	74.2	74.2
2013	30.0	47.5	47.5	47.5	54.0	84.3	84.3	107.7	127.7
2014	23.9	41.1	52.6	65.3	107.1	107.9	110.5	110.5	110.5

Table 2: Rainfall Intensity Data (1998 – 2014) Ondo Town

Rank m	0.2HR			0.4HR			0.7HR			1HR			2HRS		
	Rainfall (mm)	I (mm /hr)	Tr (yrs)	rainfall	I (mm /hr)	Tr (yrs)	Rainfall (mm)	I (mm /hr)	Tr (yrs)	Rainfall (mm)	I (mm /hr)	Tr (yrs)	Rainfall (mm)	I (mm /hr)	Tr (yrs)
1	45.2	226.0	17.0	61.0	152.5	18.0	82.6	118.0	17.0	87.4	87.4	16.0	107.1	53.6	17.0
2.	30.0	150.0	8.5	52.1	130.3	9.0	71.9	102.7	8.5	75.7	75.7	8.0	92.5	48.8	8.5
3.	26.1	130.5	5.7	47.5	118.8	6.0	54.1	77.3	5.7	69.6	69.6	5.3	94.7	47.4	5.7
4.	25.7	128.5	4.3	45.2	113.0	4.5	52.6	75.1	4.3	65.3	653.	4.0	52.6	41.3	4.3
5.	25.4	127.0	3.4	41.9	104.8	3.6	51.3	73.3	3.4	63.5	63.5	3.2	73.9	36.9	3.4
6.	25.4	127.0	22.8	41.7	104.3	3.0	47.5	67.9	2.8	62.7	62.7	2.7	69.9	34.9	2.8
7.	25.4	127.0	2.4	41.1	102.8	2.6	46.5	66.4	2.4	54.1	54.1	2.3	57.9	28.9	2.4
8.	25.4	127.0	2.1	36.8	92.0	2.3	45.7	65.3	1.9	47.5	47.5	1.8	54.0	27.0	2.1
9.	23.9	119.5	1.9	34.0	85.0	2.0	45.7	65.3	1.9	47.5	47.5	1.8	54.0	27.	1.9
10.	23.4	117.0	1.7	34.0	85.0	1.8	45.2	64.6	1.7	47.0	47.0	1.6	48.6	24.3	1.7
11.	23.1	115.5	1.5	30.5	76.3	1.6	36.8	52.6	1.5	44.5	44.5	1.5	48.5	24.3	1.5
12.	22.9	114.5	1.4	30.2	75.5	1.5	34.0	48.6	1.4	38.1	38.1	1.3	47.2	23.6	1.4
13.	22.1	110.5	1.3	29.5	73.8	1.4	33.0	47.1	1.3	34.5	34.5	1.2	44.7	22.4	1.3
14.	22.1	110.5	1.2	29.2	73.0	1.3	33.0	47.1	1.2	34.0	34.0	1.1	34.8	17.4	1.2
15.	20.3	101.5	1.1	27.9	69.8	1.2	32.3	46.1	1.1	31.5	31.5	1.1	34.0	17.0	1.1
16.	19.1	95.5	1.1	23.4	58.5	1.1	24.9	35.6	1.1	-	-	-	27.7	13.9	1.1
17.	-	-	-	17.3	43.3	1.1	-	-	-	-	-	-	-	-	-
18.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2: Rainfall Intensity Data (1998 – 2014) Ondo Town

Rank m	3HRS			6HRS			12HRS			24HRS		
	Rainfall (mm)	I (mm/hr)	Tr (yrs)	Rainfall	I (mm/hr)	Tr (yrs)	Rainfall (mm)	I (mm/hr)	Tr (yrs)	Rainfall (mm)	I (mm/hr)	Tr (yrs)
1.	107.9	35.9	16.7	111.3	18.6	17.0	127.8	10.7	15.0	151.6	6.3	16.0
2.	104.6	34.9	8.0	110.5	18.4	8.5	114.8	9.6	7.5	127.7	5.3	8.0
3.	100.6	33.5	5.3	108.5	18.1	5.7	110.5	9.2	5.0	118.7	4.9	5.3
4.	85.6	28.5	4.0	98.3	16.4	4.3	108.5	9.0	3.8	115.6	4.8	4.0
5.	84.3	28.1	3.2	86.6	14.4	3.4	107.7	8.9	3.1	110.5	4.6	3.2
6.	79.8	26.6	2.7	84.3	14.1	2.8	86.6	7.2	2.5	101.1	4.2	2.7
7.	72.4	24.1	2.3	72.4	12.1	2.4	74.2	6.2	2.1	96.3	4.0	2.3
8.	65.3	21.8	2.0	70.6	11.8	2.1	72.4	6.0	1.9	92.7	3.9	2.0
9.	60..5	20.2	1.8	68.1	11.4	1.9	70.6	5.9	1.7	74.2	3.1	1.8
10	54.6	18.2	1.6	62.8	10.5	1.7	68.6	5.7	1.5	72.4	3.0	1.6
11.	50.8	16.9	1.5	58.7	9.8	1.5	58.7	4.9	1.4	58.7	2.4	1.5
12.	49.8	16.6	1.3	51.6	8.6	1.4	55.1	4.6	1.3	51.1	2.3	1.3
13.	47.2	15.7	1.2	47.2	7.9	1.3	47.2	3.9	1.2	53.6	2.2	1.2
14.	35.6	11.9	1.1	37.3	6.2	1.2	41.7	3.5	1.1	49.0	2.0	1.1
15.	34.3	11.4	1.1	36.3	6.1	1.1	-	-	-	-	-	-
16.	-	-	-	36.1	6.0	1.1	-	-	-	-	-	-
17.	-	-	-	-	-	-	-	-	-	-	-	-
18.	-	-	-	-	-	-	-	-	-	-	-	-

Table 3: Ondo - Town

Duration	.2hrs	0.4hrs	0.7hrs	1hr	2hrs	3hrs	6hrs	12hrs	24hrs
Year	I (mm/hr)	I (mm/hr)	I (mm/hr)	I (mm/hr)	I (mm/hr)	I (mm/hr)	I (mm/hr)	I (mm/hr)	I (mm/hr)
2	122.0	90.0	63.0	52.0	30.0	32.0	12.0	7.0	4.0
5.	141.0	108.0	80.0	70.0	44.0	32.0	17.0	10.0	5.0
10.	153.0	120.0	92.0	82.0	53.0	38.0	20.0	12.0	6.0
25.	169.0	136.0	106.0	97.0	63.0	47.0	24.0	15.0	7.0
50.	182.0	148.0	116.0	108.0	72.0	53.0	27.0	18.0	8.0

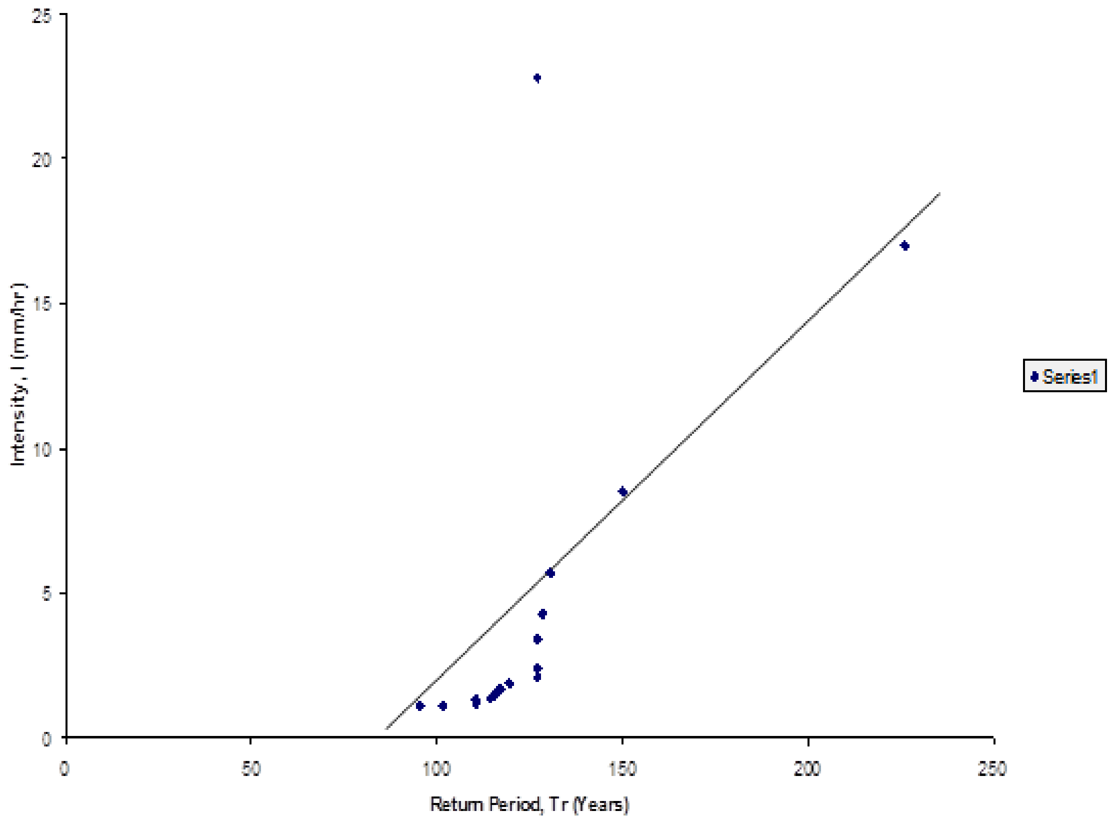

Figure 1: annual maxima series – intensity versus return period

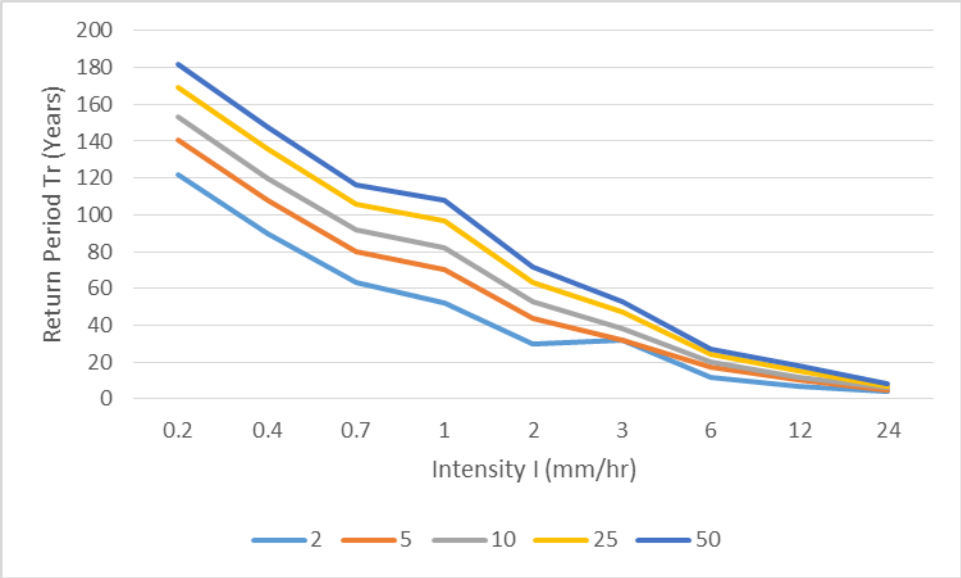

Figure 2: The probabilities of recurrence intervals (return period) of various intensities of given duration

Figure 1 shows the probabilities of the recurrence intervals (return period) versus intensity.

Figure 2 shows the probabilities of recurrence intervals (return period) of various intensities of given duration.

It can be seen from figure 2 that the probability of the recurrence interval varies directly with rainfall intensity with a given duration. The variation tends to be higher for short duration than for longer ones.

The plots of intensity/duration curves show an inverse variation of intensity with time (duration), very high intensity for short duration and low intensity for long duration. The amount of rain expected to be equaled or exceeded in 12 hours on the 56-years curve is about 17.5mm per hour in this area of study. Therefore, 210mm of rain or more may be expected to fall in 12 hours once in every 50 years.

Also, at the 10-year curve, the average intensity corresponding to 12 hours is about 12.4mm per hour. Thus, 14.8mm of rain or more may be expected to fall in 12 hours once in every 10 years, but on, at least, one of these occasions the rainfall may be expected to reach or exceed 210mm.

3. Recommendation

The design of dams and other water resources structures depend to a large extent on availability of rainfall, river stage and discharge data.

Therefore, it is recommended that the analysis of rainfall intensity duration frequency curve should be carried out before embarking on the following water resources projects.

(i) Construction of dams

(ii) Construction of culverts and drainage ditches

(iii) Construction of spillway for farm ponds.

(iv) Construction of water reservoir for Urban development

(v) The design of flood control.

4. Conclusion

The investigation carried out from this study his shown that for design of works, it is not satisfactory to equate return periods to the "desired life time of structure" and the "probability of not failing" within that life time. The higher the percentage probability of "not failing" the higher the required period for which the structure must be designed. Thus, a 50-years return period should be used for the design during a desired lifetime of 10 years so that the probability of not failing may be as high as 80% during the period. Hence, return period exceeding the lifetime of structure, ought to be considered essential for constructions.

References

[1]. Will Critchley, Klaus Siegert, C. Chapman, M. Finkel and Yoqneam: A Manual for the design and construction of water harvesting schemes for plant production. Food and Agriculture Organization (FAO) of The United Nations - Rome, (1991). Available online at http://www.fao.org/docrep/u3160e/u3160e05.htm#TopOfPage

[2]. Garnier, B.J., Weather conditions in Nigeria, (1967). Climate Res. Ser. (McGill University), No.2, 163 pp.

[3]. Greenland, D. J., and Lal, R., Soil conservation and management in the humid tropics, (Editors), 1977. Wiley, New York, NY, 283 pp.

[4]. Koutsoyiannis D., Kozonis D., & Manetas A., A mathematical framework for studying rainfall intensity-duration-frequency relationships, 1998. J. of Hydrology, Vol. 206, Pp. 118–135.

[5]. World Meteorological Organization (WMO) Laboratory Intercomparison of Rainfall Intensity Gauges, September 2004 – September 2005 Available online at http://www.wmo.int/pages/prog/www/IMOP/publications/IOM-84_Lab_RI/IOM-84_RIgauges_Sept2004-2005.pdf