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# Development of Intensity Duration Frequency Curves for Wolkite Town

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**Abstract:** One of the major challenges faced by engineer and hydrologist is insufficient or non-availability of hydrological and meteorological data to appropriately design, operate and plan water resources against extreme rainfall event. Such data would be needed for the development of Rainfall _Intensity _Duration-Frequency (IDF) curves for design of culverts, ditches, storm drainage and different hydraulic structures in urban area systems. The main objectives of this paper is to compare and contrast the existed IDF Curve for the study area which is prepared by Ethiopian Road Authority and the one which is calculated and organized specifically for the town by this researchers, and to derive the IDF curve relationship of the rainfall data which is found in Wolkite metrological station of Ethiopia. This study analyzed the daily rainfall data collected from Ethiopian Meteorological Agency (EMA) Addis Ababa, for five (5) stations in the southern nation, nationalities and peoples of Ethiopia. But only one of the stations which founds in Wolkite towns has adequate daily rainfall recorded for about 33 years (1987-2019). The data was processed and analyzed using Microsoft Excel spread sheet to generate series of peak annual rainfall. The rainfall intensity values were calculated for different duration of (10-200) minutes to estimate returns period of (2, 5, 10, 20, 50, and 100 years) using Gumbel Distribution Methods and Log Pearsons III Distribution Methods. The R2 test was used to confirm the appropriateness of the fitted distributions for the locations the two distribution methods. The result shows that Gumbels distribution methods has larger R2 values and the best fit from the two distributions, and the two distribution methods deliver almost all similar results, however the Log Pearsons method has greater results than Gumbles distribution methods. The developed IDF curve delivers larger amount of intensity than that of IDF curve developed by ERA for similar time of duration in minutes. Finally IDF curves were developed for the towns and recommended for the design of storm drainage system.

**Keywords:** Rainfall Intensity, Rainfall Duration, Time of Duration, IDF

## 1. Introduction

Extremely induced atmospheric water vapor content as result of raising universal temperature resulted in increased maximum rainfall. The increasing precipitation intensity and magnitude is recognized to have a substantial impact on disaster management efforts and pose challenging threat towards the determinations to meet the growing needs of the most susceptible population in sub-Saharan parts of Africa [6].

Rainfall Intensity-Duration-Frequency (IDF) relationship is one among the awkwardness of tools used for planning, scheming and operating water resource development structures [6]. It gives an idea on return period of rainfall intensity which can be expected within a defined period [3]. It also provides concise information between the maximum intensity of rain that falls within a given period of time [6]. Annual maxima and magnitudes above certain threshold or partial duration series of rainfall data are commonly applied as input for IDF analysis [4].

Hydrological information like IDF relationship being the major input of design of sewer systems and other hydraulic structures is not yet readily available in systematically organized relationships to the end operators in Ethiopia rather they grouped the total areas of the country in to 8 rainfalls regions by using monthly rainfall data and prepared IDF curve. The lack of systematic associations between events leads the design of many water resources infrastructures to be based on inadequate and fly-by-night data and information. Therefore, drainage system and highways fail to accommodate the unprecedented flood magnitude and easily get ruined [9].

Rainfall intensity–duration–frequency IDF curves are graphical representations of the amount of water that falls within a given period of time in catchment areas [8].

The rainfall intensity (I) is the average rainfall rate in mm/hr for duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of attentiveness calculated for the catchment area, the rainfall intensity can be determined from Rainfall-Intensity-Duration curves [9].

Many commendations for depth-duration-frequency curves in the practical literature suggest a "broken-leg" approach such that the depth duration frequency equation for dumpier duration precipitation, less than one hour, is different from that derived for longer duration rainfalls. Because of the scarcity of data, this approach was not taken and one curve was developed [7]. The amount of rainfall data gotten for peak rainfall intensities of periods shorter than a one-half hour was too limited to be useful. The curvatures presented are acceptable for rainfall durations of one-half hour or more. Intensities for periods shorter than 15 minutes appear to be overestimated by the curves presented by [9]. But most of the urban drainage structures designed by the rational method and those formulae require the time of concentration less than 30 minutes, so it needs an updated for the current status [5].

For drainage areas in Ethiopia, you may calculate the rainfall concentration at any mandatory time using the 24hr rainfall depth, which is recognized as a rainfall intensity-duration-frequency (IDF) relationship [14].

The IDF relationships, which were reasoned from daily rainfall, showed satisfactory consequences in comparison with the IDF curves obtained from at-site short duration rainfall data [9].

Now a day Wolkite town faces a difficulty of drainage problems which creates flooding on the road and nearby communities. On this paper the researcher tries to investigate is there any difference on the one which is used now a day which is prepared by ERA 2013 and the one which is constructed to specifically for the research area (Wolkite Town) IDF Curve which is the key factor in the design of drainage system.

## 2. Data Collection

Data from different meteorological stations in and around Wolkite Town were collected from the ministry of water, electricity, and irrigation office for five stations however, only one of these stations had a good record (1987-2019) and the recorded time is only 24 hours with some missing data found in Wolkite Town station. According to Ethiopian rainfall regions classification Wolkite town is found in rainfall regions under category B1, this rainfall station has been shown in figure 1 below and the accessible rainfall is used for predicting the maximum rainfall depth for the town.

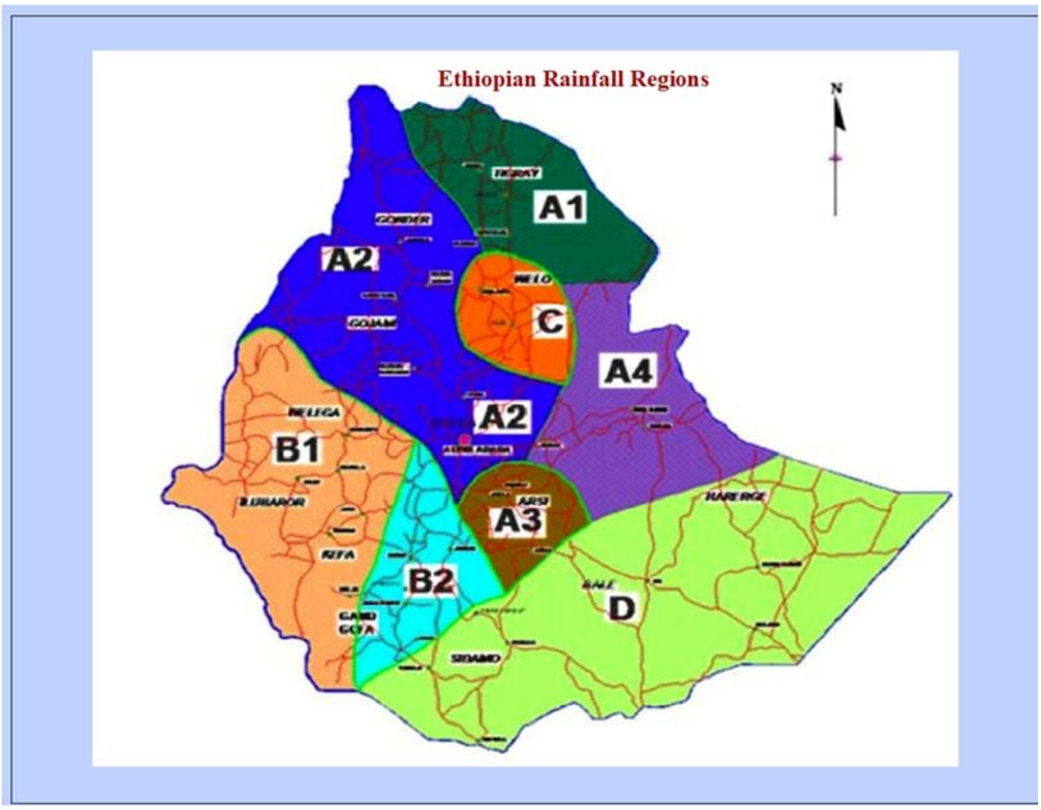


***Figure 1.*** *Ethiopian rainfall regions and there classification (source ERA_2013 DDM).*

# 3. Methodology Used for IDF Curve Development for Wolkite Town

### *3.1. Development of IDF Curves*

For accurate hydrologic analyses, reliable rainfall intensity estimates are necessary. The IDF relationship comprises the estimates of rainfall intensities of different durations and recurrence intervals. There are commonly used theoretical distribution functions that were applied in different regions all over the world; (e.g. Generalized Extreme Value Distribution (GEV), Gumbel, Pearson type III distributions) [1, 2, 10, 13, 15].

According to [9] the flood frequency analyses for drainage structures has been done using the following three basic flood frequency analysis methods and select the one which fits the best.

#### *3.1.1. Gumbles Distribution Methods (Extereme Value Type I)*

Gumbeles methods is one of the most widly used probablity – distribution functions for extreme values in hydrologic and meteorological studies for prediction of flood peakes, maximum ranifalls, and maximam wind speed, etc.

By considering the general hydrologic equations for frequancy analysis

$$X_T=\bar{X} + K_T * \sigma_{n-1} \quad (1)$$

Where $X_T$=value of the variate X of a random hydrologic series with a return period T,

$\bar{X}$=mean of the variate, σn-1=standard deviation of the variate,

$K_T$=frequency factor which depends upon the return period T and the assumed frequency distribution.

For the gumbles methods of distribution giving the variete X with the return period T is used as

$$X_T=\bar{X}+K\,\sigma_{n-1} \quad (2)$$

$$\sigma_{n-1}=\sqrt{\sum\frac{(X-\bar{X})^2}{N-1}} \quad (3)$$

K=Gumbels Frequancy factor expressed by $K=-\frac{\sqrt{6}}{\pi}\left[0.5772+ln\left[ln\left[\frac{T}{T-1}\right]\right]\right]$ (4)

#### *3.1.2. Log-Pearson Type III Distribution*

In this distribution the variants is first transformed into logarithmic form (base 10) and the transformed data is then analyzed. If X is the variants of a random hydrologic series, then the series of Z varieties where

$$Z=\ln x \quad (5)$$

For this Z series, for any recurrence interval T, equation (5) gives

$$Z_T = \bar{Z} + K_T * \sigma_{z-1} \quad (6)$$

Where Kz=a frequency factor which is a function of recurrence interval T and the coefficient of skew Cs,

$$\sigma_{z-1} = \text{standard deviation of the Z varite sample} = \sqrt{\sum\frac{(z-\bar{z})^2}{N-1}} \quad (7)$$

$$C_s = \text{coefficient of skew of variate Z} = \frac{N\sum(z-\bar{z})^2}{(N-1)(N-2)\sigma_{z-1}{}^3} \quad (8)$$

$\bar{z}$ = mean of the z values , N=sample size=number of years

When the skew is zero, i.e. Cs=0, the Log-Pearson Type III distribution reduces to Log-Normal Distribution. The Log-Normal Distribution plots as a straight line on logarithmic probability paper [15].

#### *3.1.3. Log-Norman Distribution Method*

$$Y_T=\bar{Z} + K_T\, \sigma^*{}_{z-1} \quad (9)$$

Where: $\bar{Z}$ is the mean of the logarthmic function , $K_T$=Read from a table by using $C_S$ and return period T and $\sigma^*{}_{z-1}$ is standard deviation of the logarthmic function [12].

Since the statistical parameter test shows that the data for 33 years sample data the skewness coefficent $C_s \neq 0$, no need of using Log-normal distribution methods rather it is recommeneded to use Log-Pearsons Mthods.

### *3.2. Goodness of Fit Test*

The aim of the test is to decide how good is a fit between the observed frequency of occurrence in a sample and the expected occurrences obtained from the conjectured deliveries [3].

### *3.3. Estimation of Short Duration Rainfall*

The basic equation in the expansion of the IDF curve, which is suggested by the ERA, 2013 is the subsequent one and the researcher adopts directly the ERA, 2013 IDF curve preparations guidebooks for the sake of examining the difference between the ERA IDF curve for the grouped regions and for the one developed to directly for the study areas.

The following stages are monitored to derive an IDF curve designed for Wolkite Towns by using Gumbels Distribution Methods from the time when it has the best $R^2$.

1) Transform the original equation in the arrangement of power-law family member [15, 2] as per the following:

$$I = \frac{CT^m}{T^e{}_d} \quad (10)$$

Where by spread over the logarithmic task to acquire

$$\text{Log } I=\log K - e \log T_d \quad (11)$$

Where $K = CT_r{}^m$ and e symbolizes the gradient of the straight line.

2) Compute the natural logarithm intended for (K) value

originate from Gumbel technique or from LPT III method as thriving as the natural logarithmic for rainfall period $T_d$.

3) Scheme the values of (log I) on the y-axis and the value of (log $T_d$) on the x axis for all the reappearance interims for the two methods.

4) Beginning the graphs (or mathematically) we bargain the value of (e) for all reappearance intervals where, at that moment we find out the average e value, $e_{ave}$, by consuming the subsequent equation:

$$e_{ave} = \frac{\sum e}{n} \tag{12}$$

Where n characterizes return intervals (years) value distinguished as Tr.

5) From the graph, we find (log K) values for each return interval where (log K) symbolizes the Y-intercept values as per Gumbel technique or LPT III method. Then we change Equa. (11) in to a linear equation by put on the natural logarithm to develope:

$$\text{Log K=log c + m log Tr} \tag{13}$$

6) Scheme the values of (log K) on they-axis and the values of (log Tr) on the X-axis to find out the values of parameters c and m as per Gumbel method or LPT III where (m) symbolizes the slope of the straight line and (c) characterizes the (anti log) for the y intercept [11]

## 4. Result and Discussion

### 4.1. Gumbles Distribution Methods (Extreme Value Type I)

*Table 1. Frequency analysis using Gumbels Distribution Methods.*

| T (years) | $\bar{X}$ | $K_T$ | $\sigma_{n-1}$ | $X_T$ |
|---|---|---|---|---|
| 2 | | -0.164 | | 43.60104 |
| 5 | | 0.719 | | 58.29416 |
| 10 | | 1.305 | | 68.0452 |
| 15 | 46.33 | 1.466 | 16.64 | 70.72424 |
| 25 | | 1.788 | | 76.08232 |
| 50 | | 2.592 | | 89.46088 |
| 100 | | 3.137 | | 98.52968 |

Based on the 33 years of daily maximum rainfall data the statistical parametres of mean value=46.33 and the standard deviation of the variate=16.64 the Daily maximum rainfall depth for different return periods ($X_T$) has been calculated and tabulated in the above table 1. The other important parameter of the factor of frequancy has been calculated for different return periods using equation 4 in table 2.

*Table 2. Factor of frequency ($K_T$) values for different return periods by Gumbels Distribution Methods.*

| $T_r$ (years) | 2 | 5 | 10 | 15 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|---|
| KT | -0.164 | 0.719 | 1.305 | 1.466 | 1.788 | 2.592 | 3.137 |

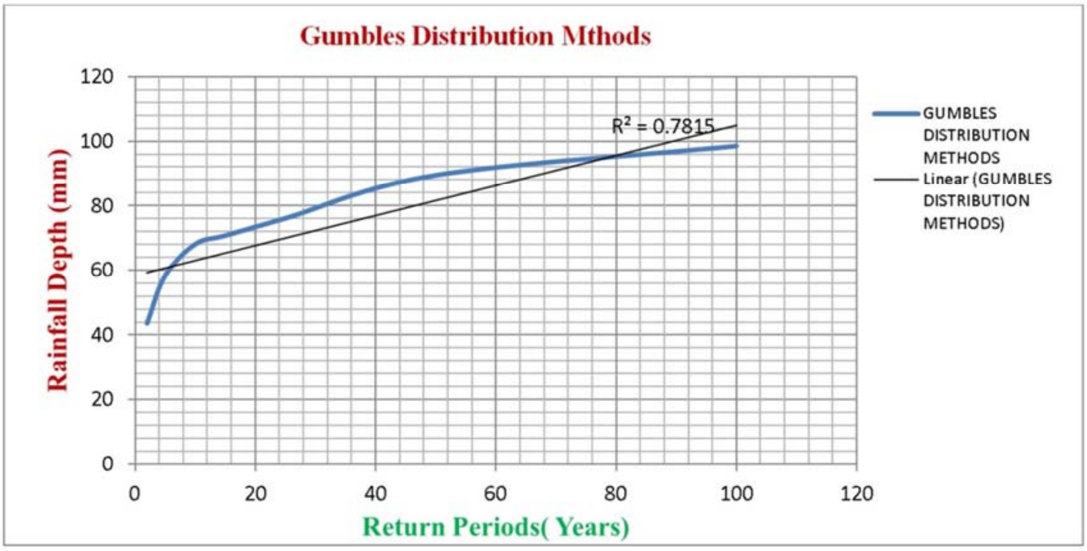


*Figure 2. Fitting Data's by Gumbels Distribution Method.*

The intensity aimed at different return periods (Tr) in addition time of duration (Td)) has been premeditated and tabulated in the following table 3 as below.

*Table 3. Calculated Rainfall for Wolkite Town Intensity (mm/hr).*

| Time | | Return Period ($T_r$) | | | | | |
|---|---|---|---|---|---|---|---|
| Time ($T_d$) | 2 Yr | 5 Yr | 10 Yr | 15 Yr | 25 Yr | 50 Yr | 100 Yr |
| 10 | 90.0775 | 108.244 | 124.383 | 134.917 | 149.467 | 171.753 | 197.36 |
| 20 | 69.7971 | 83.8734 | 96.3786 | 104.541 | 115.816 | 133.083 | 152.926 |
| 30 | 60.1223 | 72.2475 | 83.0193 | 90.0503 | 99.7622 | 114.636 | 131.728 |
| 40 | 54.0827 | 64.9898 | 74.6795 | 81.0043 | 89.7405 | 103.121 | 118.495 |
| 50 | 49.819 | 59.8663 | 68.7921 | 74.6182 | 82.6658 | 94.9909 | 109.154 |
| 60 | 46.5861 | 55.9814 | 64.328 | 69.776 | 77.3013 | 88.8267 | 102.07 |

| **Time** | | **Return Period ($T_r$)** | | | | | |
|---|---|---|---|---|---|---|---|
| **Time ($T_d$)** | **2 Yr** | **5 Yr** | **10 Yr** | **15 Yr** | **25 Yr** | **50 Yr** | **100 Yr** |
| 70 | 44.017 | 52.8941 | 60.7804 | 65.928 | 73.0383 | 83.928 | 96.4414 |
| 80 | 41.9063 | 50.3577 | 57.8659 | 62.7666 | 69.536 | 79.9035 | 91.8169 |
| 90 | 40.1287 | 48.2216 | 55.4113 | 60.1042 | 66.5864 | 76.5142 | 87.9222 |
| 100 | 38.6026 | 46.3877 | 53.304 | 57.8184 | 64.0541 | 73.6043 | 84.5784 |
| 110 | 37.2721 | 44.7889 | 51.4668 | 55.8256 | 61.8464 | 71.0674 | 81.6633 |
| 120 | 36.0975 | 43.3775 | 49.8449 | 54.0664 | 59.8974 | 68.8279 | 79.0899 |
| 130 | 35.0498 | 42.1184 | 48.3981 | 52.497 | 58.1588 | 66.8301 | 76.7942 |
| 140 | 34.1068 | 40.9853 | 47.0961 | 51.0847 | 56.5942 | 65.0321 | 74.7282 |
| 150 | 33.2518 | 39.9578 | 45.9154 | 49.804 | 55.1753 | 63.4018 | 72.8548 |
| 160 | 32.4713 | 39.02 | 44.8377 | 48.6351 | 53.8804 | 61.9137 | 71.1449 |
| 170 | 31.7549 | 38.1591 | 43.8485 | 47.5621 | 52.6916 | 60.5477 | 69.5752 |
| 180 | 31.094 | 37.3648 | 42.9358 | 46.5721 | 51.5949 | 59.2875 | 68.127 |
| 190 | 30.4814 | 36.6287 | 42.0899 | 45.6546 | 50.5784 | 58.1195 | 66.7849 |
| 200 | 29.9114 | 35.9438 | 41.3029 | 44.8009 | 49.6327 | 57.0327 | 65.5361 |

Where Yr stands for years for different return periods

### *4.2. Log-Pearson Type III Distribution*

***Table 4.*** *Frequency analysis using Log Pearson Methods.*

| **T (years)** | $\bar{Z}$ | $K_T$ | $\sigma_{z-1}$ | $Z_T$ | $X_T$=anti-log $Z_T$ |
|---|---|---|---|---|---|
| 2 | | -0.0029 | | 1.67452 | 47.2629 |
| 5 | | 0.84092 | | 1.814563 | 65.2474 |
| 10 | | 1.2837 | | 1.888049 | 77.2768 |
| 15 | 1.675 | 1.44136 | 0.16596 | 1.914215 | 82.0758 |
| 25 | | 1.75678 | | 1.966564 | 92.59 |
| 50 | | 2.06301 | | 2.017387 | 104.085 |
| 100 | | 2.33858 | | 2.063122 | 115.644 |

Since the statistical parameters has been calculated and the mean of Z values=1.675, the standard deviation of the Z variants=0.16596 and the Skew coefficient $C_s$=0.01665 has been calculated from the 33 sample size population, finally the $K_T$ values has been read from a table using the skewness coefficient for different reoccurrence times as presented in the above table 4. The tables that used for reading $K_T$ values using skewness and return periods have been shown in the appendix part. The extreme precipitation intended for different return periods $X_T$ has been calculated and presented in the above table 4.

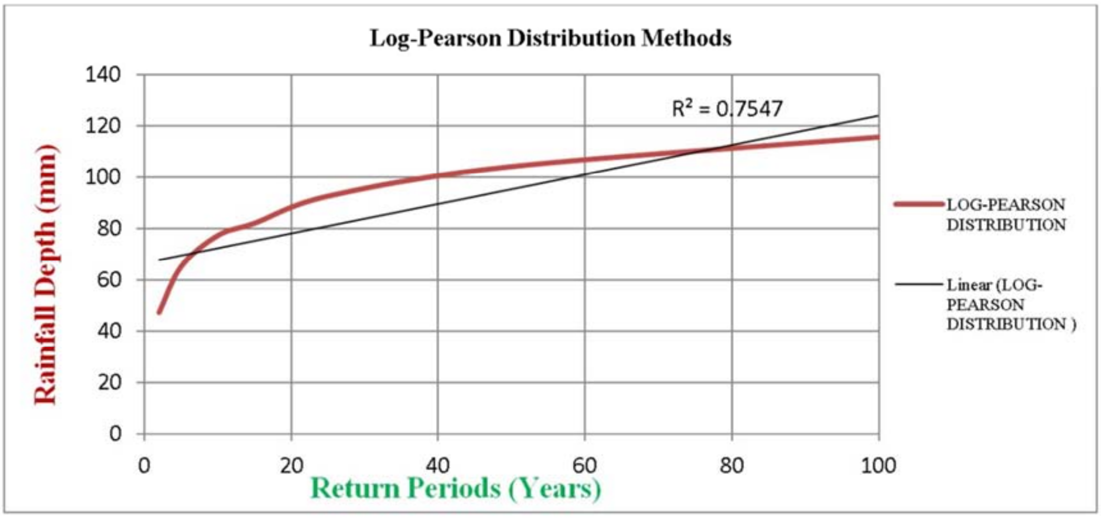


***Figure 3.*** *Fitting of Data's by Log-Pearson Distribution Methods.*

From the above two distribution methods one can seen that when the time of duration aproches to 10 minutes the generated intensity is rapidly increasing for all return periods in similar way. This indicates for smaller catchemts areas which has small time of concentration should give high empasize for the detrminations of the intensity for that site.

From the above graph of graph 2 and graph 3, the Godness ofFit test (GOF) by using non leaner regresion values $R^2$ method indicates that Gumbels Distribution Methods has best $R^2$ value=0.7815 than Log Pearson Distribution Methods $R^2$ vaules=0.7547. There for the finalized IDF curve for this study has been developed by gumblis distribution methods.

### 4.3. Comparasion of the Two Distribution Methods

The rainfall depth by mm and the intensity by mm/hr for the study area have been calculated for both Gumbel and Log Pearsons III distribution methods. The result shows that there is a slight difference in the generated intensity. Log Pearsons III distribution method has greater result both in the results of rainfall depth and rainfall intensity than Gumbels distribution method.

The Estimation of Short Duration Rainfall for the study area by both distribution methods shows that Log Pearsons III distribution methods have greater result than that of Gumbles Distribution Methods. The detail comparison of each parameter has been tabulated in table 5 below.

Centered on the above six steps aimed at valuation of short duration precipitation indicated in the methodology part the last intended and produced graph appearances like the subsequent figure 5 which provides the value of m=0.2005 and C=anti-log 1.6079=40.54152 for Gumbels Distribution approaches.

Centered on the above six steps aimed at valuation of short duration precipitation indicated in the methodology part the last intended and produced graph appearances like the subsequent figure 5 which provides the value of m=0.2224 and C=43.9137 for for Log Pearson Distribution approaches.

### 4.4. Comparison of Developed IDF Curve with That of ERA IDF Curve

Meanwhile the research area (Wolkite Town) be situated in the rainfall group B1 as per indicated in figure 1, according to Ethiopian Road Authority Drainage Design manual 2013 and the developed IDF curves for the RR-B1 has been taken for this paper and the comparison was done as following with the one that developed for the study area of Wolkite Town IDF curve by Gumbels Distribution approaches.

***Table 5.*** *Parameters that used for deriving the models equation for Wolkite Town.*

| Region | Parameter | Gumbel | Log Pearson III |
|---|---|---|---|
| Wolkite Town | C | 40.54 | 43.9137 |
| | M | 0.2005 | 0.2224 |
| | E | 0.368 | 0.368 |

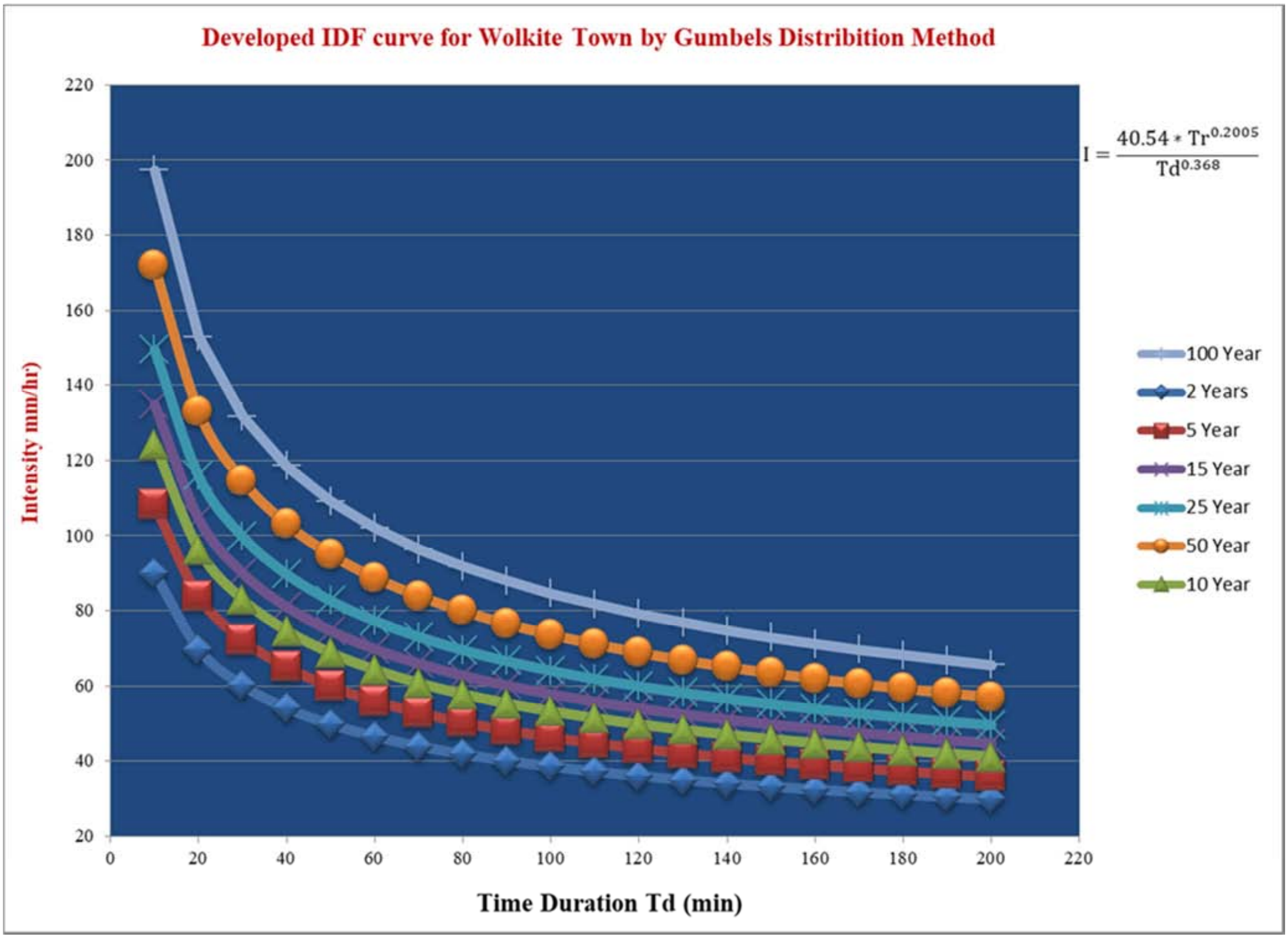


***Figure 4.*** *Developed IDF curve by Gumbles Distribution Method.*

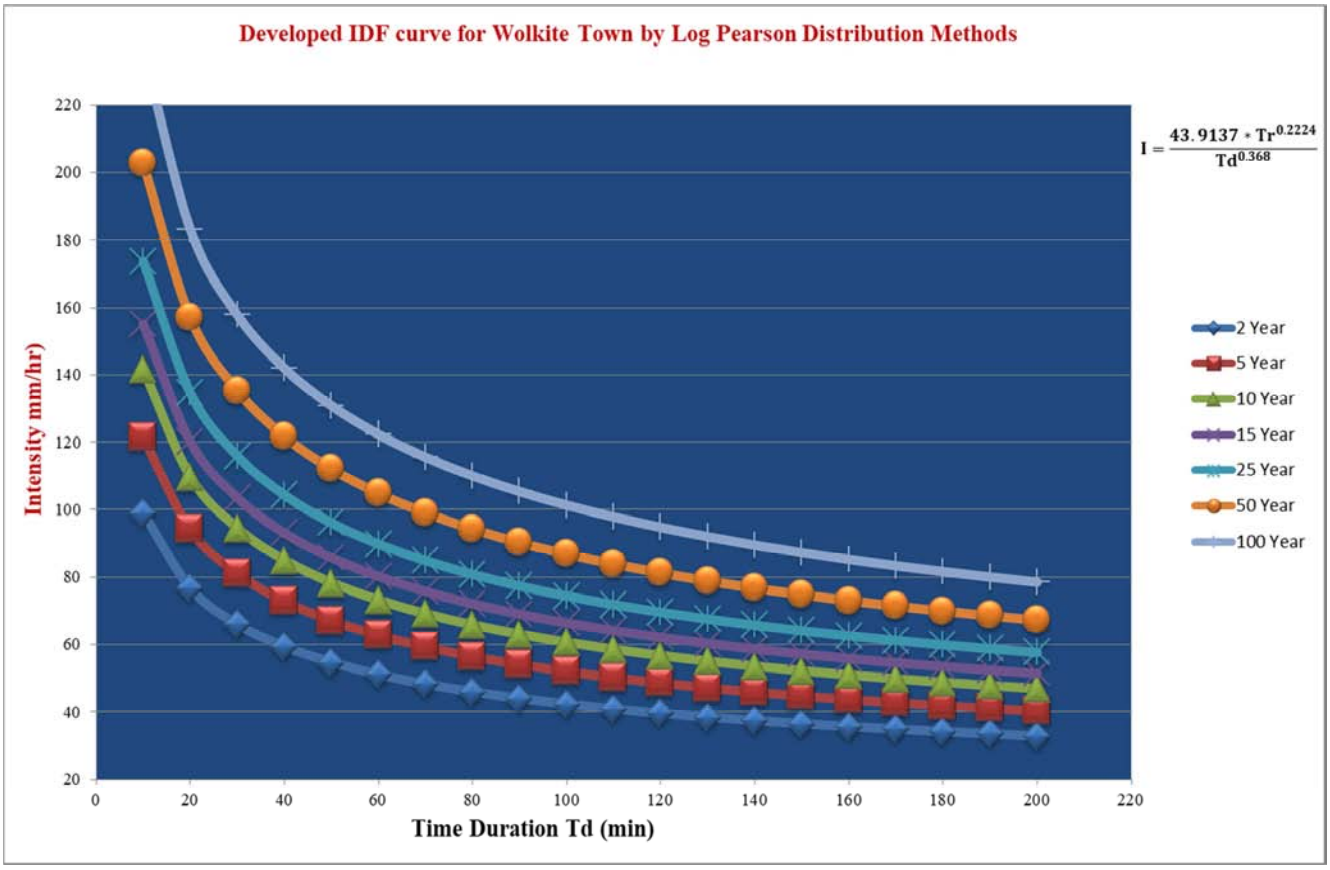


***Figure 5.*** *Developed IDF Curve by Log Pearsons Methods.*

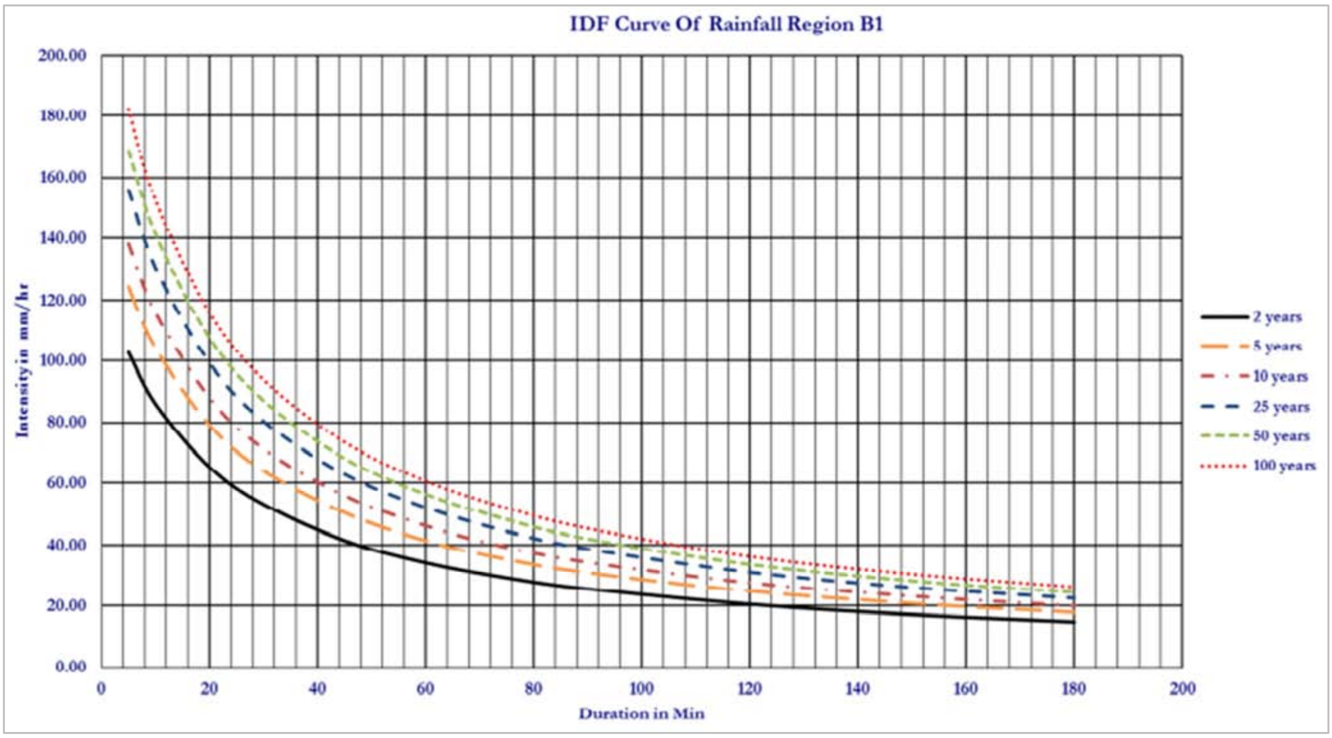


***Figure 6.*** *Developed IDF curve for RR-B1 by ERA_2013.*

From the above figure 4 IDF Curves developed for wolkite town by this researchers and the one that of figure 6 developed by ERA IDF curves, the result shows that different amounts of intensity (mm/hr) have been observed. The one which is prepared for this study IDF curve gives a high amount of intensity than the one which prepared by the [9] for the region

B1. The reasons behind that for the difference result observed from the above IDF curves are listed as follows.

1. The ERA developed IDF curve for the RR-B1 is a representative of large rainfall areas and prepared by taking the average different areas rainfall data, by grouping the regions which lead to the less accuracy of the intensity result compared to the one which is prepared by using specific rainfall data for a specific area which yields the best result.
2. The worlds climatic change variation also affects the rainfall amount, the rain falling duration, and, seasons of rainfall occurrences that have been affected [16], so this also creates the variation of the two IDF curve intensity values.
3. The rapid urbanizations development affects the hydrological water cycle of the area and this leads to the creation of variation in the amount of intensity, duration, and, the season of the rainfall.

***Table 6.*** *Comparison of 24 hr rainfall depth for the study area which is developed by ERA and that of the one developed this researcher.*

| 24 hour Rainfall Depth (mm) Vs Frequency (Year) | | | | | | |
|---|---|---|---|---|---|---|
| **Reoccurrence Period (Years)** | **2** | **5** | **10** | **25** | **50** | **100** |
| ERA (Rainfall Region-B1) | 58.87 | 71.26 | 79.29 | 89.35 | 96.84 | 104.37 |
| Self-Calculated (Rainfall Depth) | 43.60104 | 58.29416 | 68.0452 | 76.08232 | 89.46088 | 98.52968 |

***Table 7.*** *Comparison of IDF Curve Result Prepared by this Researcher and ERA IDF Curve.*

| Time (min) | Rainfall intensity for different return periods in mm/hr | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T=2 Yr | | T=5 Yr | | T=10 Yr | | T=25 Yr | | T=50 Yr | | T=100 Yr | |
| | P. I W.T | ERA | P. I W.T | ERA | P. I W.T | ERA | P. I W.T | ERA | P. I W.T | ERA | P. IW.T | ERA |
| 20 | 69.8 | 70.3 | 83.9 | 85.1 | 96.4 | 94.7 | 115.8 | 115.6 | 133.1 | 124.6 | 152.9 | 133.8 |
| 40 | 54.1 | 47.6 | 65.0 | 57.7 | 74.7 | 64.2 | 89.7 | 78.4 | 103.1 | 84.5 | 118.5 | 90.7 |
| 60 | 46.6 | 36.3 | 56.0 | 43.9 | 64.3 | 48.9 | 77.3 | 59.7 | 88.8 | 64.3 | 102.1 | 69.0 |
| 80 | 41.9 | 29.4 | 50.4 | 35.6 | 57.9 | 39.6 | 69.5 | 48.4 | 79.9 | 52.1 | 91.8 | 56.0 |
| 100 | 38.6 | 24.8 | 46.4 | 30.0 | 53.3 | 33.4 | 64.1 | 40.8 | 73.6 | 43.9 | 84.6 | 47.2 |
| 120 | 36.1 | 21.5 | 43.4 | 26.0 | 49.8 | 28.9 | 59.9 | 35.3 | 68.8 | 38.0 | 79.1 | 40.8 |
| 140 | 34.1 | 18.9 | 41.0 | 22.9 | 47.1 | 25.5 | 56.6 | 31.2 | 65.0 | 33.6 | 74.7 | 36.1 |
| 160 | 32.5 | 17.0 | 39.0 | 20.6 | 44.8 | 22.9 | 53.9 | 27.9 | 61.9 | 30.1 | 71.1 | 32.3 |
| 180 | 31.1 | 15.4 | 37.4 | 18.6 | 42.9 | 20.7 | 51.6 | 25.3 | 59.3 | 27.3 | 68.1 | 29.3 |

Where P.I W.T=Proposed intensity for Wolkite Town, and Yr stands for Years

# 5. Conclusion

The main tasks of this paper is developing of IDF curve for Wolkite town by the two distribution methods and select the one which best fit for the distributions, according to the basic task Gumbels distribution method is the best fit for this study.

There is a slight difference in the generated rainfall intensity between Gumbles distribution and Log Pearsond distribution method in the preparation of IDF curve for the research region.

ERA IDF curve for the study region delivers less amounts of intensity than that of IDF Curve developed by this researcher when the return period exceeds and equals 10 years, there for return period increase for larger structures and should give a precise consideration for each detail activates.

# 6. Recommendations

I would like to recommend for the Wolkite town sewerage and road authority to use the IDF Curve which is constructed for the town rather than using ERA IDF curve to get the most accurate value.

This researcher only addresses for the hydrological data based on 24 hr rainfall data, if possible the one can use short duration rainfall for the future and also should incorporate the climate change effects too.

# Acknowledgements

I would like to express my gratitude towards for Wolkite University, Research and Community Service Directors and Engineering and Technology College for supporting this work by ideas funding this paper to be accomplished in a well manner. I personally would also attempt to extend my indebtedness and appreciativeness for the Department of Water, Electricity and Irrigation Office which supports by delivering all the necessary raw materials.

# Appendix

***Table 8.*** *Coefficient of Skewness for both Positive and Negative Skew with different Return Periods.*

| Skew coefficient (g) | Recurrence interval (T-Yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 25 | 50 | 100 | 200 |
| | Percent chance (annual probability of occurrence p (%) | | | | | | |
| | 50 | 20 | 10 | 4 | 2 | 1 | 0.5 |
| 3.5 | -0.396 | 0.420 | 1.180 | 2.278 | 3.152 | 4.051 | 4.970 |
| 2.5 | -0.360 | 0.518 | 1.250 | 2.162 | 3.048 | 3.845 | 4.652 |
| 2.0 | -0.307 | 0.609 | 1.302 | 2.219 | 2.912 | 3.605 | 4.298 |
| 1.8 | -0.282 | 0.643 | 1.318 | 2.193 | 2.848 | 3.499 | 4.147 |
| 1.6 | -0.254 | 0.675 | 1.329 | 2.163 | 2.780 | 3.388 | 3.990 |
| 1.4 | -0.225 | 0.705 | 1.337 | 2.128 | 2.706 | 3.271 | 3.828 |
| 1.2 | -0.195 | 0.732 | 1.340 | 2.087 | 2.626 | 3.149 | 3.661 |
| 1.0 | -0.164 | 0.758 | 1.340 | 2.043 | 2.542 | 3.022 | 3.489 |
| 0.9 | -0.148 | 0.769 | 1.339 | 2.018 | 2.498 | 2.957 | 3.401 |

| Skew coefficient (g) | Recurrence interval (T-Yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2** | **5** | **10** | **25** | **50** | **100** | **200** |
| | **Percent chance (annual probability of occurrence p (%)** | | | | | | |
| | **50** | **20** | **10** | **4** | **2** | **1** | **0.5** |
| 0.8 | -0.132 | 0.780 | 1.336 | 1.993 | 2.453 | 2.891 | 3.312 |
| 0.7 | -0.116 | 0.790 | 1.333 | 1.967 | 2.407 | 2.824 | 3.223 |
| 0.6 | -0.099 | 0.800 | 1.328 | 1.939 | 2.359 | 2.755 | 3.132 |
| 0.5 | -0.083 | 0.808 | 1.323 | 1.910 | 2.311 | 2.686 | 3.041 |
| 0.4 | -0.066 | 0.816 | 1.317 | 1.880 | 2.261 | 2.615 | 2.949 |
| 0.3 | -0.050 | 0.823 | 1.309 | 1.849 | 2.211 | 2.544 | 2.856 |
| 0.2 | -0.033 | 0.830 | 1.301 | 1.818 | 2.159 | 2.472 | 2.763 |
| 0.1 | -0.033 | 0.836 | 1.292 | 1.785 | 2.107 | 2.400 | 2.670 |
| 0.0 | 0.000 | 0.841 | 1.282 | 1.751 | 2.054 | 2.326 | 2.576 |
| -0.1 | 0.017 | 0.846 | 1.270 | 1.716 | 2.000 | 2.252 | 2.482 |
| -0.2 | 0.033 | 0.850 | 1.258 | 1.680 | 1.945 | 2.178 | 2.388 |
| -0.3 | 0.050 | 0.853 | 1.245 | 1.643 | 1.890 | 2.104 | 2.294 |
| -0.4 | 0.066 | 0.855 | 1.231 | 1.606 | 1.834 | 2.029 | 2.201 |
| -0.5 | 0.083 | 0.860 | 1.216 | 1.567 | 1.777 | 1.955 | 2.108 |
| -0.6 | 0.099 | 0.857 | 1.200 | 1.528 | 1.720 | 1.880 | 2.016 |
| -0.7 | 0.115 | 0.857 | 1.183 | 1.488 | 1.663 | 1.806 | 1.926 |
| -0.8 | 0.132 | 0.856 | 1.166 | 1.448 | 1.606 | 1.733 | 1.837 |
| -0.9 | 0.148 | 0.854 | 1.147 | 1.407 | 1.549 | 1.660 | 1.749 |
| -1.0 | 0.164 | 0.852 | 1.128 | 1.366 | 1.492 | 1.588 | 1.664 |
| -1.2 | 0.195 | 0.843 | 1.086 | 1.282 | 1.379 | 1.449 | 1.501 |
| -1.4 | 0.225 | 0.832 | 1.041 | 1.198 | 1.270 | 1.318 | 1.351 |
| -1.6 | 0.254 | 0.817 | 0.994 | 1.116 | 1.166 | 1.197 | 1.216 |
| -1.8 | 0.282 | 0.799 | 0.945 | 1.035 | 1.069 | 1.087 | 1.097 |
| -2.0 | 0.307 | 0.777 | 0.895 | 0.959 | 0.980 | 0.990 | 0.995 |
| -2.5 | 0.360 | 0.710 | 0.771 | 0.793 | 0.798 | 0.799 | 0.800 |
| -3.0 | 0.396 | 0.636 | 0.660 | 0.666 | 0.666 | 0.667 | 0.667 |

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