Derivation of Intensity Duration Frequency Curves Using Short Duration Rainfall for Yermarus Raingauge Station Raichur District Karnataka

Mohammed Badiuddin Parvez[1], M .Inayathulla[2]
[1]*Research Scholar, Department of Civil Engineering, UVCE, Bangalore University, Bangalore, Karnataka, India*
[2]*Professor, Department of Civil Engineering, UVCE, Bangalore University, Bangalore, Karnataka, India*

***Abstract*- The estimation of rainfall intensity is commonly required for the design of hydraulic and water resources engineering control structures. The intensity-duration-frequency (IDF) relationship is a mathematical relationship between the rainfall intensity, the duration and the return period. The present study aimed the derivation of IDF curves of Yermarus Raingauge Station of Raichur District with 19 years of rainfall data (1998 to 2016). The Normal Distribution, Log Normal Distribution, Gumbel distribution, Pearson Type III Distribution and Log Pearsons Type III Distribution techniques are used to Find the rainfall intensity values of 2, 5, 10, 15, 30, 60, 120, 720, 1440 minutes of rainfall duration with different return period. Chi Square test was conducted to find the goodness of fit the short duration IDF using daily rainfall data are presented, which is input for water resources projects.**

Index terms- Gumbel Distribution, Intensity Duration Frequency (IDF), Log Normal Distribution, Normal Distribution, Pearson Type III Distribution, Log Pearson Type III Distribution Rainfall Duration, Return Period, Rainfall Intensity

I. INTRODUCTION

IDF stands for Intensity-Duration-Frequency. 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. The period of time over which rainfall is measured is called duration. The number of times, during a specified period of years, that precipitation of a certain magnitude or greater occurs or will occur at a station is called frequency (FAO, 2012).

The IDF-relationships give an idea about the frequency or return period of a mean rainfall intensity or rainfall volume that can be expected within a certain period, i.e. the storm duration. In this sense the storm duration is an artificial parameter that can comprise any part of a rainfall event. Runoff occurs when precipitation moves across the land surface, some of which eventually reaches natural or artificial streams and lakes. Runoff often transports contaminants to these water bodies, reducing their usefulness as a source of water (National Association of RC and D Councils, 2001). The relation between rainfall and runoff is influenced by various storm and basin characteristics. Because of these complexities and the frequent paucity of adequate runoff data, many approximate formulae have been developed to relate rainfall and runoff. The earliest of these formulae were usually empirical statements.

The scope of this study was to predict rainfall depth and intensity for Yermarus station using the data from 1998 to 2016 by using Normal, Log Normal, Pearson Type III, Log Pearson Type III and Gumbel distribution. For the distribution giving the best results, short duration IDF curves and equations were derived for the station having maximum rainfall depth for various short durations and standard return periods,

II MATERIALS AND METHODS

A Study Area

The Study area Yermarus Station of Raichur District, Karnataka is located It is located 7 Km towards North from District headquarters Raichur Karnataka. The average mean daily temperature varies from 24 to 410C respectively.

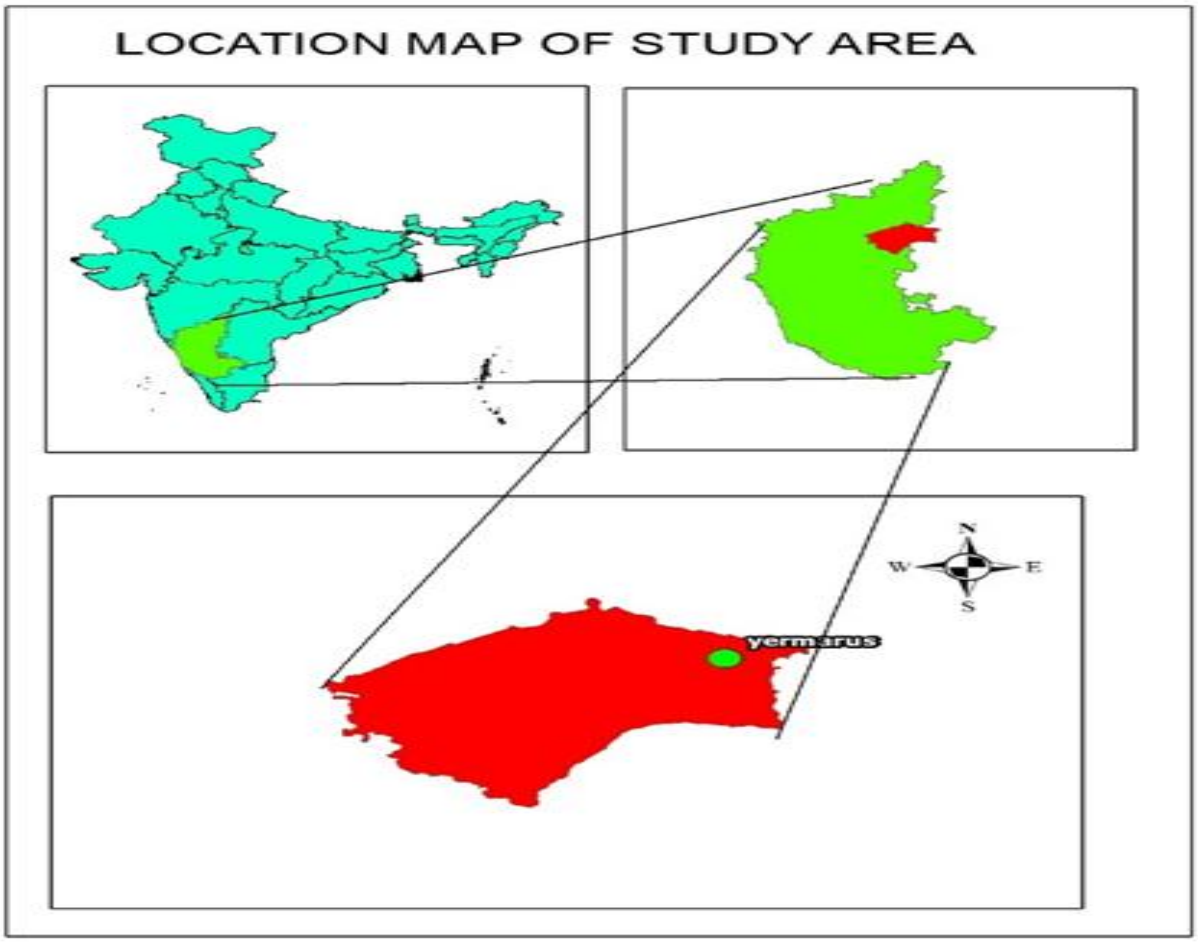


Fig 1 Location Map of Study Area

B Methodology

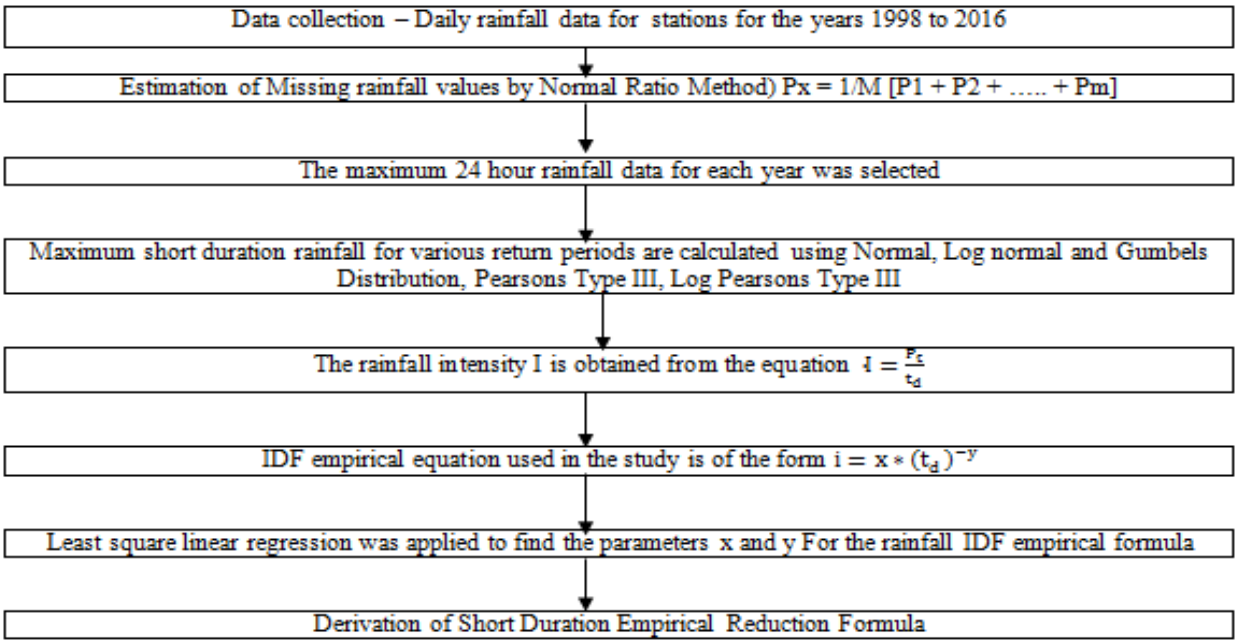


Fig 2 Methodology adopted for IDF curves

III RESULTS AND DISCUSSIONS

A Estimation of Short Duration Rainfall

Indian Meteorological Department (IMD) use an empirical reduction formula (Equation 3.1) for estimation of various duration like 1-hr, 2-hr, 3-hr, 5-hr, 8-hr rainfall values from annual maximum values. Chowdhury et al. (2007), used IMD empirical reduction formula to estimate the short duration rainfall from daily rainfall data in Sylhet city and found that this formula give the best estimation of short duration rainfall. (Rashid et al, 2012)

P_t=P_24 (t/24)^(1/3) (3.1)

where, Pt is the required rainfall depth in mm at t-hr duration,

P24 is the daily rainfall in mm and t is the duration of rainfall for which the rainfall depth is required in hr.

Short duration rainfall by using IMD empirical formula for Yermarus station is tabulated in Table 1.

Year	Rainfall (mm)	$P_t = P_{24}\left(\frac{t}{24}\right)^{\frac{1}{3}}$ in mm where, time t is in hours							
Duration in Minutes		5	10	15	30	60	120	720	1440
1998	113.4	17.17177	21.635114	24.766006	31.203213	39.313584	49.532012	90.00564	113.4
1999	84.1	12.73497	16.045089	18.367029	23.141007	29.155842	36.734059	66.75021	84.1
2000	63.8	9.661012	12.172136	13.933608	17.555247	22.118225	27.867217	50.63809	63.8
2001	75.9	11.49327	14.480645	16.576189	20.88469	26.31306	33.152379	60.24187	75.9
2002	60.9	9.221875	11.618857	13.300263	16.757281	21.112851	26.600525	48.33636	60.9
2003	57	8.631311	10.874793	12.448522	15.684154	19.760796	24.897043	45.24093	57
2004	98.8	14.96094	18.84964	21.577437	27.185868	34.252047	43.154875	78.41761	98.8
2005	63.4	9.600441	12.095822	13.84625	17.445182	21.979552	27.692501	50.32061	63.4
2006	116	17.56548	22.131157	25.333833	31.91863	40.214954	50.667667	92.06926	116
2007	101.9	15.43036	19.441077	22.254462	28.038866	35.326757	44.508925	80.87808	101.9
2008	80.4	12.17469	15.339181	17.558967	22.122913	27.873123	35.117935	63.81352	80.4
2009	265.5	40.20374	50.653639	57.983903	73.05514	92.043709	115.96781	210.7275	265.5
2010	65.8	9.963865	12.553708	14.370399	18.105568	22.811586	28.740797	52.22549	65.8
2011	103	15.59693	19.650941	22.494697	28.341542	35.708106	44.989394	81.75115	103
2012	29.5	4.467082	5.6281821	6.4426559	8.1172378	10.227079	12.885312	23.41417	29.5
2013	64.7	9.797295	12.343843	14.130164	17.802891	22.430237	28.260328	51.35242	64.7
2014	85.5	12.94697	16.312189	18.672782	23.526232	29.641194	37.345565	67.86139	85.5
2015	74.1	11.2207	14.13723	16.183078	20.389401	25.689035	32.366156	58.81321	74.1
2016	68.3	10.34243	13.030672	14.916386	18.793469	23.678288	29.832773	54.20975	68.3

Table1 Short duration rainfall for Yermarus

B Normal Distribution

Table 2 Estimation of maximum rainfall intensity for various return period by Normal Distribution For Yermarus Raingauge Station

Duration in minutes	Return period 2 yrs		Return period 5 yrs		Return period 10 yrs		Return period 25 yrs		Return period 50 yrs		Return period 75 yrs		Return period 100 yrs	
	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)
5	13.3255	7.2816	17.04113	204.4936	17.27425	207.2909	17.40586	208.8703	17.44836	209.3803	17.462348	209.5482	17.46926	209.6311
10	16.7892	9.1742	21.47052	128.8231	21.76423	130.5854	21.93005	131.5803	21.9836	131.9016	22.001224	132.0073	22.00994	132.0596
15	19.2188	10.5018	24.5776	98.31039	24.91381	99.65523	25.10362	100.4145	25.16492	100.6597	25.185098	100.7404	25.19507	100.7803
30	24.2141	13.2315	30.96583	61.93166	31.38943	62.77886	31.62858	63.25716	31.70581	63.41162	31.731235	63.46247	31.7438	63.4876
60	30.5079	16.6706	39.0145	39.0145	39.5482	39.5482	39.84952	39.84952	39.94682	39.94682	39.97885	39.97885	39.99468	39.99468
120	38.4375	21.0037	49.15519	24.5776	49.82761	24.91381	50.20724	25.10362	50.32984	25.16492	50.370195	25.1851	50.39014	25.19507
720	69.8456	38.1662	89.32092	7.44341	90.54278	7.545232	91.23262	7.602718	91.45539	7.621282	91.528719	7.627393	91.56496	7.630413
1440	88.0000	48.0864	112.5373	4.689054	114.0768	4.753198	114.9459	4.789412	115.2266	4.801107	115.31896	4.804957	115.3646	4.806859

C Log Normal Distribution

Table 3 Estimation of maximum rainfall intensity for various return period by Log Normal Distribution For Yermarus Raingauge Station

Duration in minutes	Return period 2 yrs.		Return period 5 yrs.		Return period 10 yrs.		Return period 25 yrs.		Return period 50 yrs.		Return period 75 yrs.		Return period 100 yrs.	
	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)
5	13.3255	7.2816	16.99618	203.9542	17.30654	207.6785	17.48238	209.7886	17.53926	210.4711	17.557994	210.6959	17.56725	210.8071
10	16.7892	9.1742	21.41389	128.4834	21.80492	130.8295	22.02647	132.1588	22.09813	132.5888	22.121731	132.7304	22.1334	132.8004
15	19.2188	10.5018	24.51277	98.05109	24.96039	99.84156	25.21399	100.856	25.29602	101.1841	25.323044	101.2922	25.3364	101.3456
30	24.2141	13.2315	30.88416	61.76831	31.44812	62.89624	31.76764	63.53528	31.87099	63.74199	31.905036	63.81007	31.92186	63.84372
60	30.5079	16.6706	38.9116	38.9116	39.62215	39.62215	40.02472	40.02472	40.15494	40.15494	40.197826	40.19783	40.21903	40.21903
120	38.4375	21.0037	49.02554	24.51277	49.92078	24.96039	50.42799	25.21399	50.59205	25.29602	50.646087	25.32304	50.6728	25.3364
720	69.8456	38.1662	89.08533	7.423777	90.71208	7.559341	91.63373	7.636144	91.93186	7.660988	92.030048	7.669171	92.07858	7.673215
1440	88.0000	48.0864	112.2405	4.676687	114.2901	4.762086	115.4513	4.810469	115.8269	4.826123	115.95059	4.831275	116.0117	4.833823

D Gumbel's Distribution

Table 4 Estimation of maximum rainfall intensity for various return period by Gumbel's Distribution For Yermarus Raingauge Station

Duration in minutes	Return period 2 yrs.		Return period 5 yrs.		Return period 10 yrs.		Return period 25 yrs.		Return period 50 yrs.		Return period 75 yrs.		Return period 100 yrs.	
	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)
5	13.3255	7.2816	11.99513	143.9416	12.10822	145.2986	12.17185	146.062	12.19237	146.3084	12.199118	146.3894	12.20245	146.4294
10	16.7892	9.1742	15.11295	90.67771	15.25543	91.53255	15.3356	92.0136	15.36145	92.1687	15.369956	92.21973	15.37416	92.24495
15	19.2188	10.5018	17.3	69.2	17.46309	69.85236	17.55487	70.2194	17.58446	70.33784	17.594196	70.37678	17.59901	70.39603
30	24.2141	13.2315	21.79663	43.59327	22.00212	44.00423	22.11775	44.2355	22.15503	44.31006	22.167297	44.33459	22.17336	44.34672
60	30.5079	16.6706	27.46204	27.46204	27.72093	27.72093	27.86662	27.86662	27.91359	27.91359	27.929045	27.92904	27.93668	27.93668
120	38.4375	21.0037	34.6	17.3	34.92618	17.46309	35.10974	17.55487	35.16892	17.58446	35.188391	17.59419	35.19801	17.59901
720	69.8456	38.1662	62.87237	5.239364	63.46509	5.288757	63.79862	5.316552	63.90617	5.325514	63.94155	5.328463	63.95903	5.329919
1440	88.0000	48.0864	79.21422	3.300593	79.961	3.331708	80.38123	3.349218	80.51672	3.354863	80.561305	3.356721	80.58333	3.357639

E Pearson Type III Distribution

Table 5 Estimation of maximum rainfall intensity for various return period by Pearson Type III Distribution For Yermarus Raingauge Station

Duration in minutes	Return period 2 yrs.		Return period 5 yrs.		Return period 10 yrs.		Return period 25 yrs.		Return period 50 yrs.		Return period 75 yrs.		Return period 100 yrs.	
	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)
5	13.3255	7.2816	15.36912	184.4294	15.58923	187.0707	15.71356	188.5627	15.75372	189.0446	15.766939	189.2033	15.77347	189.2817
10	16.7892	9.1742	19.66744	118.0047	19.98437	119.9062	20.16363	120.9818	20.22158	121.3295	20.240654	121.4439	20.25008	121.5005
15	19.2188	10.5018	22.71982	90.87928	23.11692	92.46769	23.34177	93.36708	23.41448	93.65792	23.438427	93.75371	23.45026	93.80105
30	24.2141	13.2315	28.12502	56.25004	28.54905	57.09809	28.7887	57.5774	28.86613	57.73226	28.891622	57.78324	28.90422	57.80844
60	30.5079	16.6706	35.18654	35.18654	35.69047	35.69047	35.97512	35.97512	36.06706	36.06706	36.097328	36.09733	36.11229	36.11229
120	38.4375	21.0037	44.33226	22.16613	44.96718	22.48359	45.32581	22.6629	45.44165	22.72082	45.479783	22.73989	45.49863	22.74932
720	69.8456	38.1662	80.55707	6.713089	81.71078	6.809232	82.36246	6.863538	82.57295	6.881079	82.642251	6.886854	82.6765	6.889708
1440	88.0000	48.0864	101.4955	4.228981	102.9491	4.289547	103.7702	4.323758	104.0354	4.334808	104.12271	4.338446	104.1659	4.340244

F Log Pearsons Type III Distribution

Table 6 Estimation of maximum rainfall intensity for various return period by Log Pearson Type III Distribution For Yermarus Raingauge Station

Duration in minutes	Return period 2 yrs.		Return period 5 yrs.		Return period 10 yrs.		Return period 25 yrs.		Return period 50 yrs.		Return period 75 yrs.		Return period 100 yrs.	
	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)	Rainfall Depth(mm)	Rainfall Intensity (mm/hr)
5	11.94884	143.3861	17.97517	215.7021	21.92114	263.0537	26.94032	323.2838	30.66383	367.966	32.82808	393.937	34.35985	412.3183
10	15.05462	90.32774	22.64734	135.8841	27.61896	165.7138	33.94274	203.6565	38.63409	231.8045	41.36087	248.1652	43.29079	259.7447
15	17.23323	68.93292	25.92472	103.6989	31.61579	126.4632	38.85471	155.4189	44.22496	176.8998	47.34635	189.3854	49.55555	198.2222
30	21.71251	43.42502	32.6631	65.3262	39.8334	79.66681	48.95387	97.90775	55.71996	111.4399	59.65266	119.3053	62.43608	124.8722
60	27.35605	27.35605	41.15293	41.15293	50.18695	50.18695	61.67802	61.67802	70.20275	70.20275	75.15765	75.15765	78.66453	78.66453
120	34.46646	17.23323	51.84944	25.92472	63.23159	31.61579	77.70943	38.85471	88.44992	44.22496	94.6927	47.34635	99.1111	49.55555
720	62.62971	5.219143	94.21668	7.851390	114.8994	9.574952	141.2074	11.76728	160.7242	13.39368	172.0681	14.339	180.0968	15.00807
1440	78.90849	3.287854	118.7056	4.946066	144.7642	6.031842	177.9102	7.412924	202.4998	8.43749	216.7922	9.033007	226.9078	9.454491

G Chi-Square Test

To identify a specific theoretical distribution for the available data it is important to do a test. The aim of the test is to find how good a fit is between the observed and the predicted data. Chi-square is one of the most widely used tests to find the best fit theoretical distribution of any specific dataset which is represented by Equation 3.2.

$\chi 2=\sum_{i=1}^{n}(O_i-E_i)^2/E_i$ (3.2)

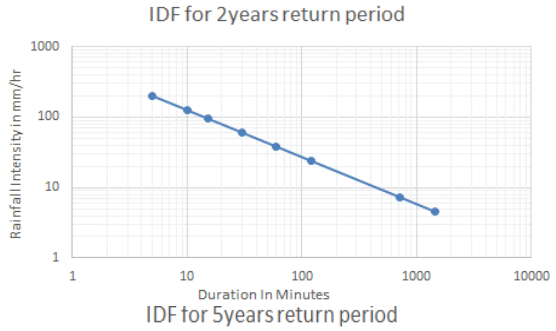
where, Oi and Ei represent the observed and expected frequencies respectively. If the observed frequencies are close to the corresponding expected frequencies, the $\chi 2$ value will be small, indicating a good fit; otherwise it will be a poor fit. (Rashid et al, 2012)

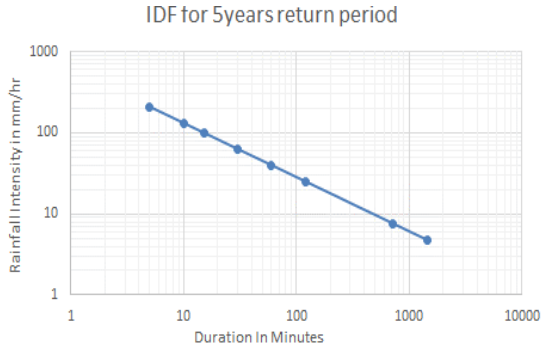
Table 7 : Chi –Square Test

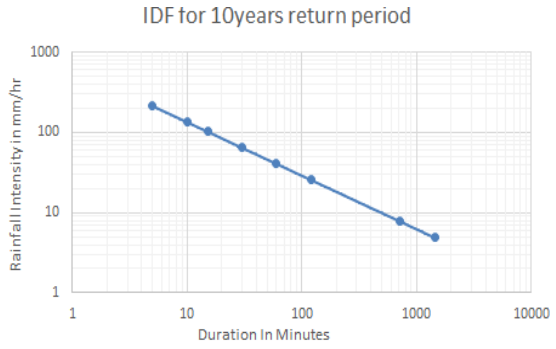
Duration in minutes	Observed values	NORMAL DISTRIBUTION		LOG-NORMAL DISTRIBUTION		GUMBELS DISTRIBUTION	
		Expected values	Chi-square values	Expected values	Chi-square values	Expected values	Chi-square values
5	13.32553325	19.19288241	1.793674629	17.65889708	1.063375703	26.38436048	6.463411112
10	16.78915342	24.18156492	2.259892942	22.24886064	1.339772111	33.24227764	8.143404001
15	19.21877022	27.68096332	2.586929912	25.46857068	1.533655195	38.0528833	9.321864328
30	24.21413316	34.87582837	3.259327451	32.08838831	1.932284463	47.94362868	11.74481309
60	30.50789607	43.9407903	4.106495264	40.42883589	2.43452587	60.40518698	14.79753724
120	38.43754045	55.36192664	5.173859824	50.93714136	3.06731039	76.1057666	18.64372866
720	69.84564629	100.599297	9.401527231	92.5589285	5.573672874	138.2933557	33.87790327
1440	88	126.7471718	11.84518206	116.6169424	7.022387779	174.2387099	42.68348345

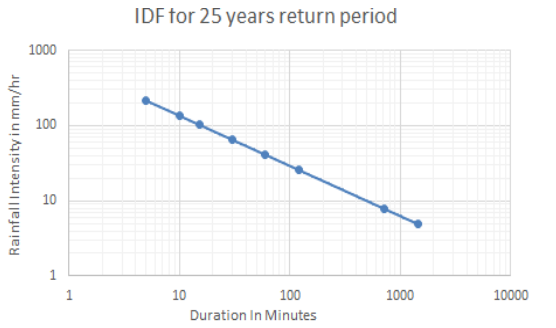
Table 7 Contd….

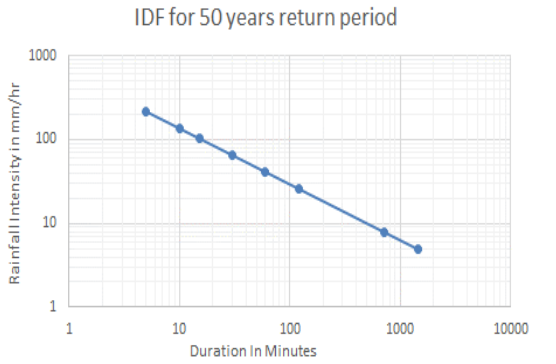
Duration in minutes	Observed values	PEARSON TYPE III		LOG PEARSON TYPE III	
		Expected values	Chi-square values	Expected values	Chi-square values
5	13.32553325	24.59217347	5.161690243	25.2391913	5.62360523
10	16.78915342	30.98425898	6.503335197	31.79945201	7.08531278
15	19.21877022	35.4680989	7.444455461	36.40126135	8.11065305
30	24.21413316	44.68700441	9.37942614	45.86271542	10.2187825
60	30.50789607	56.30209751	11.81733643	57.78340056	12.8748592
120	38.43754045	70.93619781	14.88891092	72.8025227	16.2213061
720	69.84564629	128.8996258	27.05494664	132.2909632	29.4760693
1440	88	162.4033519	34.08709678	166.6761693	37.1375202

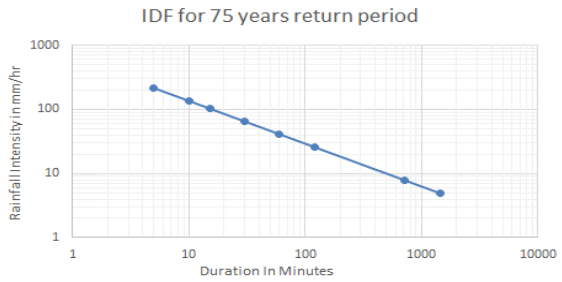












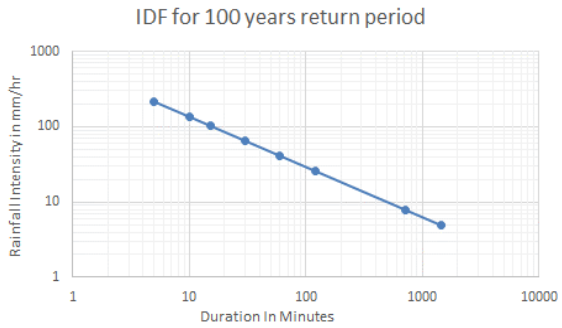


Fig 3: IDF for Yermarus Raingauge Station by Log Normal Distribution

Table 8 : Rainfall IDF Empirical Equation For Respective Return Period Using Log Normal Distribution		
Return Period (T) years	$i = x * (t_d)^{-y}$	
	X	Y
2	584.26	0.667
5	613.86	0.667
10	622.65	0.667
25	627.61	0.667
50	629.21	0.667
75	629.74	0.667
100	630.00	0.667

IV CONCLUSIONS

Among the various available probability distribution functions Log_ Normal distribution had the best approximation of rainfall intensity for various return periods. Study showed that i = x * (td)-y was the best form of IDF empirical equation for Yermarus Raingauge Station Raichur It has been tabulated in Table 8. These IDF equations will help to estimate the rainfall intensity for any specific return period in Yermarus Raingauge Station Raichur in a short time and more easily. The results computed can be utilized for developing surface drain network for recharging ground water.

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