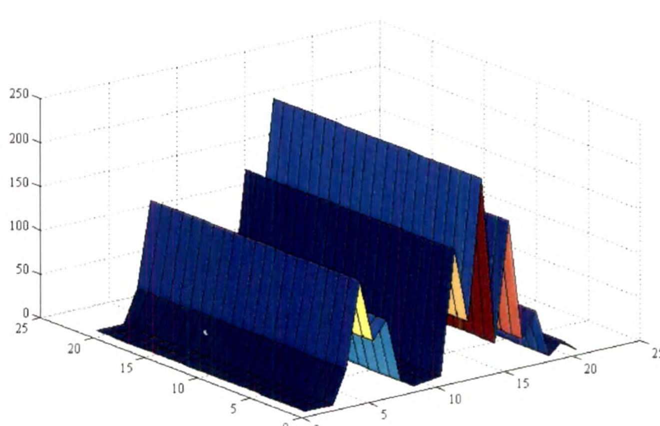
Chapter 4

RAINFALL PROBABILITY ANALYSIS BY GAMMA, GUMBEL AND FISHER TIPETT TYPE-II DISTRIBUTIONS AND ARTIFICIAL NEURAL NETWORKS



4.1 INTRODUCTION

In this chapter we investigate the following two prediction problems,

(i) Return Period Analysis (RPA) of Highest One day Maximum Rainfall.

(ii) Prediction of Weekly rainfall (WRF)

In Return period analysis we make estimation of return periods (T) of Highest One day Maximum Rainfall (HOMRF). Han [57] has made elaborative study on EVD distribution to predict the return period T. Singh *et al.* [145, 146] have used Extreme Value Distribution (EVD) to estimate the extreme rainfall for Bombay. Rao *et al.* [125]) has used extreme value distribution (EVD) (see Chow [18]) to predict the flood and drought situations. Gumbel distribution is applied by Mukherjee *et al.* [109] to estimate return period (T) of reoccurrence of Highest One day Maximum Rainfall (HOMRF). Statistical distribution is being used in Agarwal [3] and Bhatt [10] to obtain extremes with given return periods (T).

Cunnane *et al.*[24] and Gringorten [50] have used plotting rule for extremely probability paper to study the extreme value analysis. Fowler *et al.*[32]) have used two methods to assess rainfall extremes and its probabilities. One is percentile approach (Karl *et al.* [81]). The second method is the use of statistical distributions (Hennesey *et al.* [62]). In this method, estimation of T involves fitting an extreme value distribution (EVD) to the annual maximal series.

Estimated T is helpful to know the rainfall pattern for the erosion studies of agricultural fields and maximum utilization of natural resources and their withstands against heavy rain. Based on the consecutive day's HOMRF, period of crop tolerance, storage and irrigation can be planned to maximize the crop yield .

Kar [80] has predicted the extreme rainfall for mid central table zone of Orissa using Extreme value Type - I distribution and concluded that extreme-value Type-I distribution is a good fit for predicting the one day maximum rainfall.

We make Extreme value analysis of seven stations of Krishna Godavari agro-climatic zone and 14 stations of Gujarat was performed to find out the most suitable type of distribution (Kulshrestha *et al* [90, 91]).

Many agricultural operations like crop sowing, crop harvesting, and pest control required daily or weekly probabilities rather than the information on average of rainfall. Gupta *et al.* [54] and Sharma *et al.* [139] have found the rainfall probabilities for agricultural planning. Suitable model is required to know the daily (Coe *et al.* [21]) or weekly rainfall probabilities (see Biswas *et al.* [11]; (Gabriel *et al.* [35]; Sitangshu Sarkar [148] ; Victor, *et al.* [163]).

Annual rainfall data series has normal distribution, which gives a good fit to seasonal and annual rainfall over major portions of India but not the same for monthly or weekly rainfall. Mooley *et al.* [108] and Khambete *et al.* [84] showed that rainfall period less than four pentads (sum of five days rainfall) do not follow normal distribution and so used the Incomplete Gamma Distribution to pentad rainfall of two stations in Rajasthan.

Hargreaves [58] and Sarker *et al.*[135] have calculated the rainfall amount by Gamma distribution to obtain decade (sum of ten days rainfall) probabilities. To evaluate agricultural potential in Sudano-Sahelian zone of West Africa, Davy [28] has used Gamma Distribution Model (GDM). Biswas *et al.* [12] have used the same method for separating the agro climatic zones.

Many (Biswas *et al.* [13] ; Kulshrestha *et al.*[94] ; Mooley [107]) have studied and confirmed that Gamma Distribution Model (GDM) fits well to the Weekly Rainfall (WRF).

4.2 PROBLEM FORMULATION

4.2.1 PROBLEM 1: RETURN PERIOD ANALYSIS (RTPA)

4.2.1.1 METHOD I: EXTREME VALUE DISTRIBUTION (EVD)

Months of July and August have more rainy days in comparison with other months of summer monsoon (sum of rainfall during 15th June to 15th September) in Gujarat (Government of India [46]). Since last three years, due to global warming there is a change in environmental phenomenon (Fernando *et al.* [31] ; Gadgil [36] ; Hundal *et al.* [69, 70]) and daily rainfall increases in most of the days. Figure 4.1 and 4.2 show the daily rainfall at Anand station for the year 2000 to 2002 and 2002 to 2004, respectively. Also, in Gujarat the year 2005 and 2006 are the years of heavy rainfalls, therefore in these rainy days, daily rainfall increased.

High one-day rainfall creates the situation of flood. However, extreme event due to Highest One day Maximum Rainfall (HOMRF) like flood is nonperiodic. The knowledge of variations or occurrence of HOMRF in weather cycle is needed and is a must for the society and needed for Agricultural Engineers, Civil Engineers, Marketing Managers, Agriculturists, Fishermen, Tourists, Transporters, Public living below poverty lines.

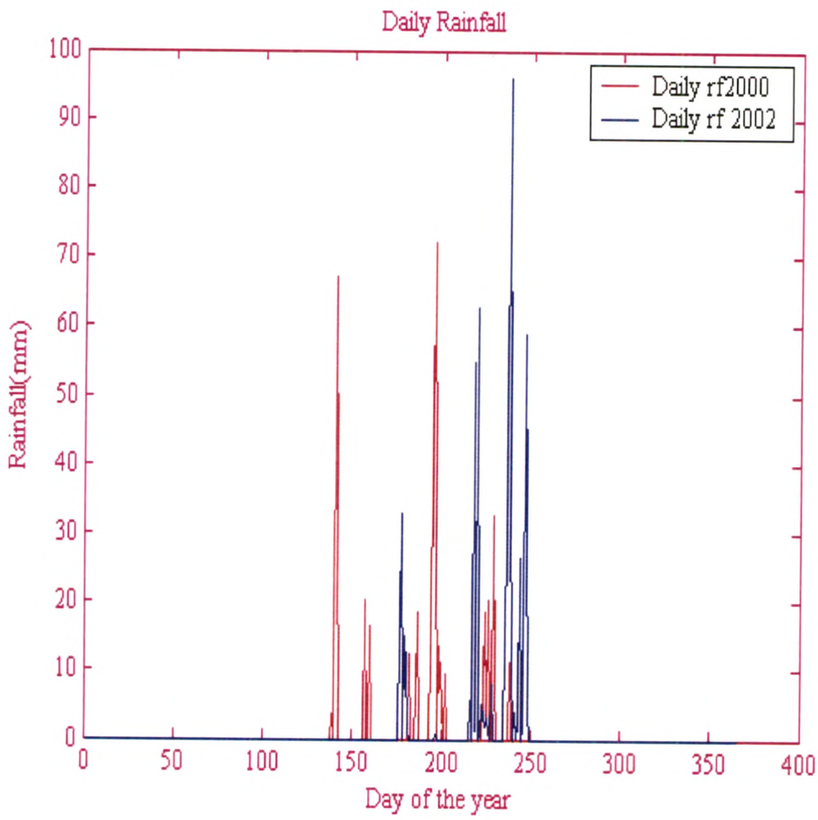


Fig: 4.1

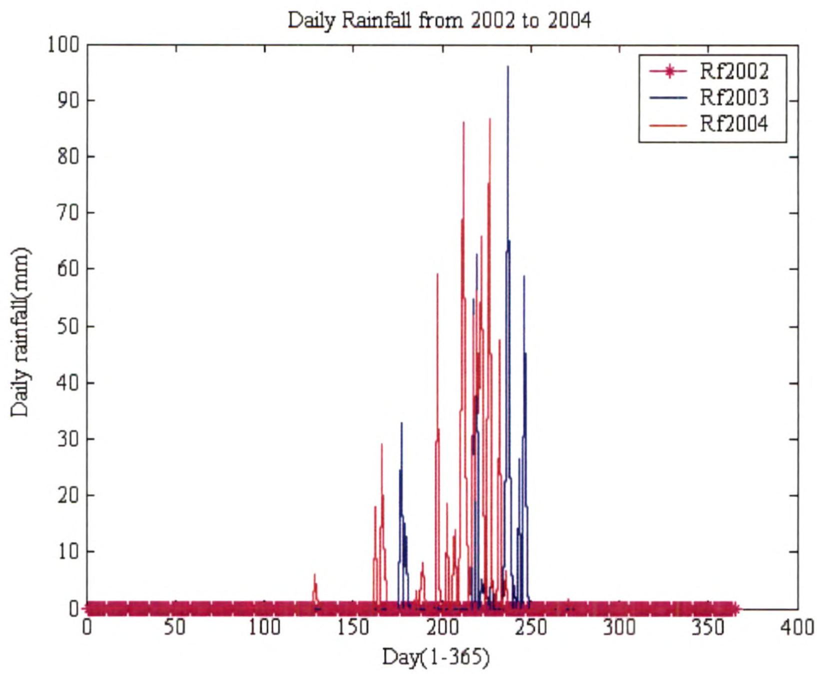


Fig: 4.2

An attempt has been made here for Return Period Analysis (RTPA) of 58 stations of adjacent covering eight agro climatic zones for 14 districts of Gujarat. The rainfall data of Highest One day Maximum Rainfall (HOMRF) of 58 stations from 1901-1992 were subjected to Gumbel [53] and Fisher and Tipett Type-II distributions. The results of selected stations on return periods are presented and discussed here. During the analysis Standard Error is computed.

4.2.1.2 METHOD II: ARTIFICIAL NEURAL NETWORK (ANN)

To predict the return period T, ANN method is applied with backpropagation algorithm with three layers. Some results (values of T) of the extreme value distribution (Fisher and Tipett Type-II) are used for training. Results of ANN are compared by the results of extreme value distribution (Fisher and Tipett Type-II).

4.2.2 SECOND PROBLEM: WEEKLY RAINFALL PROBABILITIES

Rainfall observations like average or normal are convenient for calculations by examining the trend for long-range data series. Rainfall averages might be suitable for some parts of India where rainfall follows normal distribution. But in the arid and semi-arid (like Gujarat) mean rainfall, pattern does not follow normal distribution as the tropical rainfall inherent uncertainties.

Also, certain specific purpose likes crop sowing, crop cultivation, and use of pesticides require, daily (Jackson [72]) or weekly rainfall probabilities. The probability of rainfall can be used for various purpose like, concrete work, marketing of goods, production of different commodities, land use planning etc.

An attempt has been made here to compute the probabilities of the rainfall of the Anand station for the standard week from 22 to 42 by two methods, namely, Gamma Distribution Method and ANN method.

4.2.2.1 METHOD I: GAMMA DISTRIBUTION MODEL (GDM)

Gamma Distribution Model is used to predict the Weekly Rainfall (WRF) probabilities (PBs) from the data series (DS) 1958 to 2005.

4.2.2.2 METHOD II: ARTIFICIAL NEURAL NETWORK

Results of return period obtained by Fisher and Tipett Type-II distribution for 20 stations are used for training purpose. With the help of this trained networks weekly rainfall probabilities of other 20 stations are predicted and compared with Gamma Distribution Model (GDM) probabilities (PBs) as Gamma Distribution Model (GDM) is a standard method for computation of daily or weekly rainfall probabilities.

4.3 DETAILS OF THE FIRST PROBLEM: RTPA

4.3.1 METHOD I: EXTREME VALUE DISTRIBUTION (EVD):

4.3.1.1 DATA

To predict the return period T, DS from 1901-1992 for daily rainfall is used. From the data Highest One day Maximum Rainfall is noted in each year and a Highest One day Maximum Rainfall (HOMRF) data series (DS) (Table 4.1) is prepared to apply extreme value distribution. Natural Logarithm series of these rainfalls is prepared.

Table 4.1 shows the names of the station for which analysis has to be done.

Mean of the one-day maximum rainfall (X_N) is showed in the Table 4.1. These means are to be used to find out the value of parameter u in equation in the section 4.3.1.2 (4.2), during the application of Extreme Value Distributions namely Gumbel and Fisher and Tipett Type-II distributions.

Relationship of Highest One day Maximum Rainfall (HOMRF) with normal rainfall (Table 4.1) is shown in the Figure 4.3 and relation of normal rainfall with percentage of coefficient of variation (CV%) of Highest One day Maximum Rainfall (HOMRF) is plotted in the figure 4.4. Figure 4.3 shows the increasing trend of Highest One day Maximum Rainfall (HOMRF) with normal rainfall. As normal rainfall increases, Highest One day Maximum Rainfall (HOMRF) increases. There is a linear trend found in the figure 4.4 with negative slope. Therefore, as normal rainfall increases percentage of Coefficient of variation (CV %) are decreases.

TABLE 4.1: DATA SERIES OF HIGHEST ONE DAY MAXIMUM RAINFALL

Sr. No	Station (Area Sq.K.M)	Number of data N	Mean of HOMRF (mm)	Normal Rainfall X_N (mm)	Coefficient of Variation with X_N C.V.%	Sr. No	Station (Area Sq.K.M)	Number of data N	Mean of HOMRF (mm)	Normal Rainfall X_N (mm)	Coefficient of Variation with X_N C.V.%
I	**SURAT (7657)**										
1	Surat	84	144	1102.7	40.5	**V**	**Baroda(7794)**				
2	Bardoli	87	151	1335.9	36	20	Chotaudaipur	85	133	1090	37.4
3	Mandvi	83	155	1318	41.9		**Sabarkantha(7390)**				
4	Olpad	87	132	867	42.2	21	**Himatnagar**	82	114	745.9	48.7
5	Valod	86	156	1397.9	38.7	22	Idar	83	131	949.9	44.7
II	**BHARUCH(9038)**					**VI**	Modasa	74	177	940.9	58.1
6	Bharuch	84	127	868.1	36.6	23	Prantij	83	126	740	45.2
7	Ankleshwar	87	127	904.3	37.7	24	**Ahmadabad(8707)**				
8	Amod	87	104	776.6	38.6	25	**Ahmadabad**	66	113	688.1	53.7
9	Hansot	86	128	839.4	40.3	26	Dholka	85	110	679.1	44.9
10	Jambusar	87	143	767.9	39.5	**VII**	Dholera	80	107	597.7	51.2
11	Vagara	87	111	773.6	38.8	27	Sanad	84	114	665.1	40.9
12	Ilav	86	118	838.7	42.4	28	**Kheda(7194)**				
III	**PANCHMAHAL(8866)**					29	**Kheda**	33	122	833.3	43.1
13	Lunavada	72	115	792.4	36.5	30	Anand	23	125	850.5	40.1
14	Bariya	86	150	1040.8	37.7	31	Mahudha	21	108	776.9	44
15	Godhara	85	125	942.3	38.6	32	Petlad	52	114	705.5	45.5
16	Halol	82	136	1025.5	42.6	33	Thasra	34	104	699.9	47.8
17	Zalod	84	130	834.9	36	**VIII**	**Banaskantha(12,703)**				
18	Jambugodha	85	143	1172.8	41.7	34	**Deesa**	73	110	594.2	55.1
19	Kalol	80	134	960.4	41.8	35	Palanpur	83	126	682	51.5
						36	Radhanpur	83	110	495.8	59.2
						37	Tharad	85	107	455	61.9

Sr. No	Station (Area Sq.K.M)	Number of data N	Mean of HOMRF (mm)	Normal Rainfall X_N (mm)	Coefficient of Variation with X_N C.V.%
X	**KACHHACH(45, 652)**				
38	Anjar	88	975	65	67.0
39	Rapar	84	76	359.2	59.9
40	Abdasa	72	81	318.4	70.3
X	**RAJKOT(**)**				
41	Rajkot	79	111	597.7	50.2
42	Dhoraji	83	105	595.4	51.6
43	Vankaner	82	110	563.6	45
44	Morbi	86	111	552.7	48.7
45	Jasdan	70	87	525.6	48
46	Gondal	81	110	637.3	53.2
XI	**SURENDRANAGAR(10,489)**				
47	Dhanghandhra	85	105	517.6	52.9
48	Wadhavan	89	117	485.3	51.6
49	Bajana	86	102	451.2	52.4
XII	**JAMNAGAR (14,125)**				
50	Jamnagar	76	104	490	53.7
51	Jamnagar-AM	77	109	415.1	69
52	Dwarka	79	105	407.6	72.1
XIII	**JUNAGADH(10,607)**				
53	Junagadh	78	130	851.2	56.5
54	Veraval	78	137	636.8	55
XIV	**BHAVNAGAR(11,155)**				
55	Bhavnagar	74	129	600.4	44.1
56	Mahuva	77	95	588.8	41.2
57	Palitana	84	112	617.8	49.7
58	Gogha	41	106	595.8	40.9

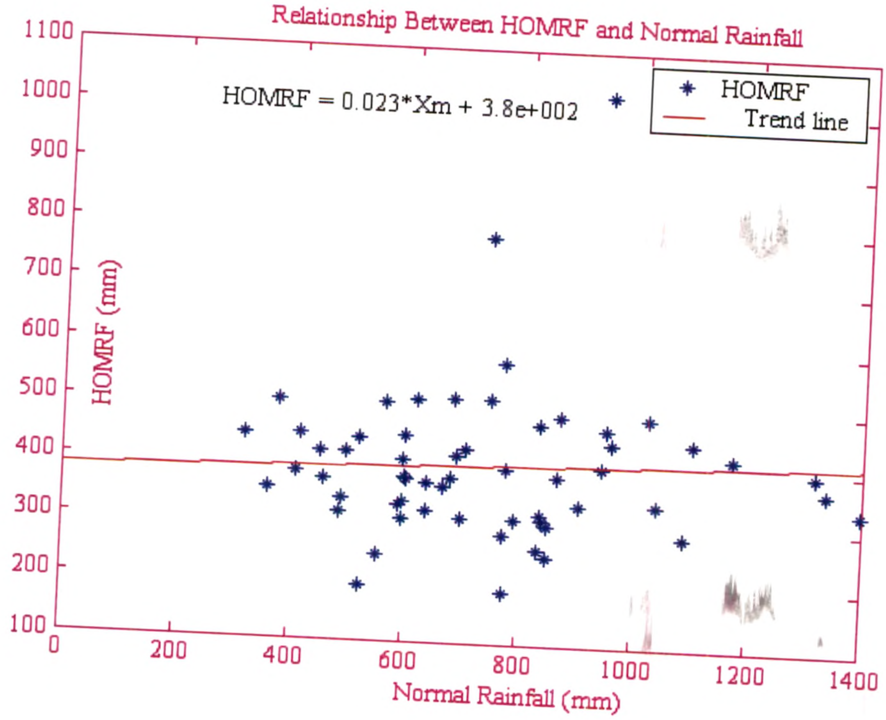

Relationship Between HOMRF and Normal Rainfall
HOMRF = 0.023*Xm + 3.8e+002
HOMRF
Trend line
HOMRF (mm)
Normal Rainfall (mm)
1100
1000
900
800
700
600
500
400
300
200
100
0
200
400
600
800
1000
1200
1400

Fig: 4.3

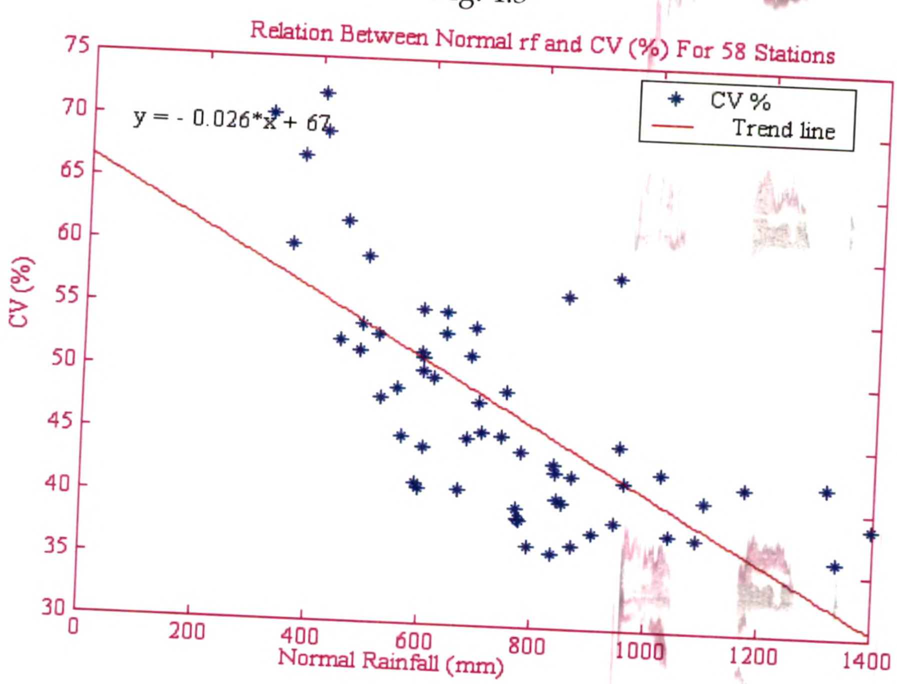

Relation Between Normal rf and CV (%) For 58 Stations
y = - 0.026*x + 67
CV %
Trend line
CV (%)
Normal Rainfall (mm)
75
70
65
60
55
50
45
40
35
30
0
200
400
600
800
1000
1200
1400

Fig: 4.4

4.3.1.2 DETAILS OF THE MODEL

Here, two DS are prepared one is Highest One day Maximum Rainfall (HOMRF) and another is $\log_e$(HOMRF). To apply EVD value of the parameters,

Take

$$\alpha = \frac{s_x}{1.283} \,.$$
$$and$$
$$u = Mean(x) - 0.45 s_x$$

(4.1)

$$\alpha_{II} = \frac{s_z}{1.283} \,.$$
$$and$$
$$u_{II} = Mean(z) - 0.45 s_z$$

(4.2)

where , s_x is the variance in the DS x of highest one day maximum rainfall. α *and* u are found by the method of moments (4.1) (Han [57]) . With the help of

Equation 4.2 α_{II} and u_{II} can be found by using z data series of log of highest one day maximum rainfall. s_z is the variance in the z data series.

Cumulative distribution functions (c.d.f) of Gumbel [53] and Fisher and Tippett Type-II distributions are given by,

$$p_G(X \leq x) = \exp(-\exp(-\alpha\,(x-u))) \tag{4.3}$$

and

$$p_F(Z \leq z) = \exp(-\exp(-\alpha_{II}\,(z - u_{II})))\ , \tag{4.4}$$

respectively.

After finding probabilities by both the distributions, return period (T_G and T_F) for actual HOMRF found by the formulas

$$T_G = \frac{1}{1 - p_G(x)} \tag{4.5}$$

$$T_F = \frac{1}{1 - p_F(x)} \tag{4.6}$$

T_G and T_F denotes the return period for Gumbel and Fisher Tipett Type-II (F.T. Type-II) distributions, respectively.

$$x_G = u - (\ln(\ln(\frac{T_G}{T_G - 1}))) \tag{4.7}$$

$$x_F = u_{II} - (\ln(\ln(\frac{T_F}{T_F - 1}))) . \tag{4.8}$$

Formulas (4.7) and (4.8) are used to find one day maximum rainfall X_G by Gumbel distribution and X_F by F.T. Type-II distributions at given T. The values of are T = 5, 10, 15, 20, 25, 50 and 100 years.

After finding T, for both the distributions, Standard Errors (Han [57]) are found by the formula

$$S.E_G. = \left(\frac{1}{\alpha}\right)\sqrt{\frac{\left(1.17 + 0.196\,Y_{T_G} + 1.099\left(Y_{T_G}\right)^2\right)}{N}} \tag{4.9}$$

$$S.E_F. = \left(\frac{1}{\alpha_{II}}\right)\sqrt{\frac{\left(1.17 + 0.196\,Y_{T_F} + 1.099\left(Y_{T_F}\right)^2\right)}{N}} \tag{4.10}$$

where, $Y_{T_G} = (\ln(\ln(\frac{T_G}{T_G - 1})))$, $Y_{T_F} = (\ln(\ln(\frac{T_F}{T_F - 1})))$ and N is total number of observations.

Required programmes are developed in MATLAB.

4.3.1.3 RESULTS AND DISCUSSION

Figure 4.5 is the map of the Gujarat showing 58 stations with their drawn isohyets of the one day maximum rainfall. Isohyets are the line joining same mean of one day maximum rainfall. This map includes 14 districts namely, Surat, Bharuch, Panchmahal, Baroda, Sabarkantha, Ahmedabad, Kheda, Banaskantha, Kachchh, Rajkot, Surendranagar, Jamnagar, Junagadh, and Bhavnagar. Here lines near Mahudha and Thasara show very less Highest One day Maximum Rainfall (HOMRF) that is 180mm in comparison to others. Surat district has highest HOMRF of 360mm (Table 4.2). This covers the area surrounding Surat, Mandvi and Bardoli. Longest isohyets is passing from Banaskantha to Vagra via Kheda, Anand and near by area having Highest One day Maximum Rainfall (HOMRF) of 260mm. On the record of DS of HOMRF during 1901 to 1992, Dhangadhra and surrounding it has highest HOMRF of 400mm. Figure 4.5 shows the HOMRF of 230mm through out Junagadh - Mahuva-Palitana- Bhavnagar- Dholka- Morbi, that is in Saurastra region. Isohyets with 300mm HOMRF is passing through Baroda via Modasa- Zalod- Godhara- Kalol- Bharuch and Ankleshwar.

These isohyets may change as Highest One day Maximum Rainfall (HOMRF) changes.

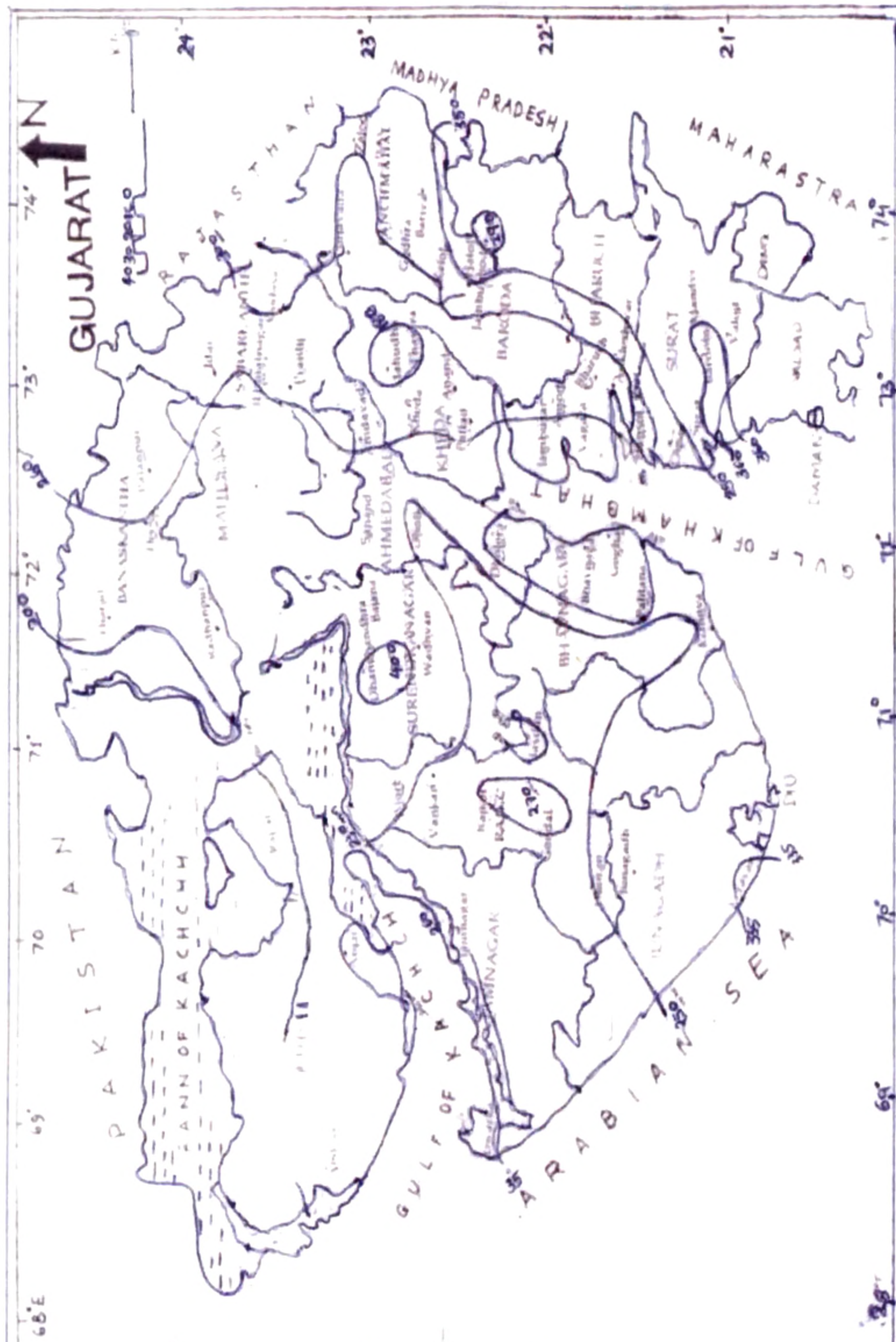


FIG 4.5 : Showing Isohyets of mean of one day maximum rainfall

Fig: 4.5

Return period T_G and T_F computed by the formulas 4.5 and 4.6 using values of α *and* u. Results are given in the Table 4.2.

Computed standard deviations (SD) from the data series used for Gumbel distribution are high (Table 4.2). Therefore, predicted return periods for highest one day maximum rainfall (HOMRF) by Gumbel distribution are very high.

While, applying Fisher and Tipett Type-II distribution Standard deviations (SD) are decreased and that values are ranging from 0.4 to 1.2 mm (Table 4.2). T_F varies between 3 and 122 years (Figure 4.7). It's three dimensional figure is shown in Fig : 4.8. Here highest one-day maximum rainfall Highest One day Maximum Rainfall (HOMRF) is scaled. This figure shows that T_F varies in proportion to Highest One day Maximum Rainfall (HOMRF). Correlation coefficient of T_F with Highest One day Maximum Rainfall (HOMRF) is 47.18 %

Inverse of T gives probability of getting highest one-day maximum rainfall (HOMRF). These computed probabilities by Gumbel and Fisher and Tipett Type-II distribution are depicted in the Figures 4.9 and 4.10. These figures show linear relationships with negative slops, that is, as the rainfall increases probabilities are decreasing.

Standard Error by Gumbel distribution $(S.E.)_G$ and Standard Error by F.T. Type-II distribution $(S.E.)_F$ are found by the formulas (4.9) and (4.10) and plotted in the Figure 4.11 with subplot graphs. $(S.E.)_G$ ranges between 0 to 7mm and $(S.E.)_F$ Ranges between 0 to 0.2mm. Small value of the computed $(S.E.)_F$ shows that predicted T_F by Fisher Tipett Type-II distribution are more accurate than T_G.

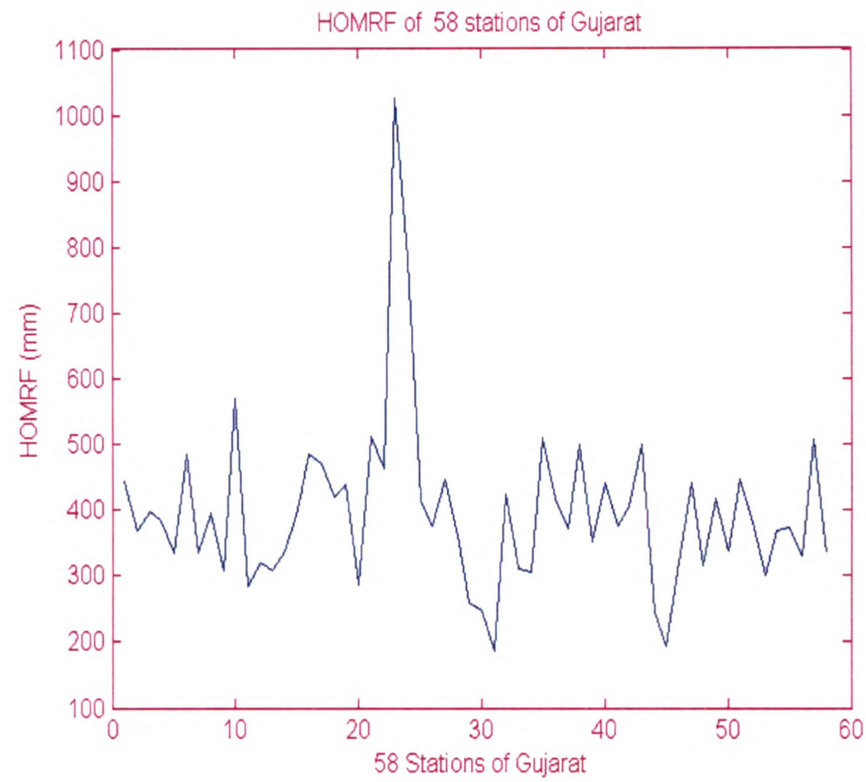

HOMRF of 58 stations of Gujarat
HOMRF (mm)
58 Stations of Gujarat

Fig: 4.6

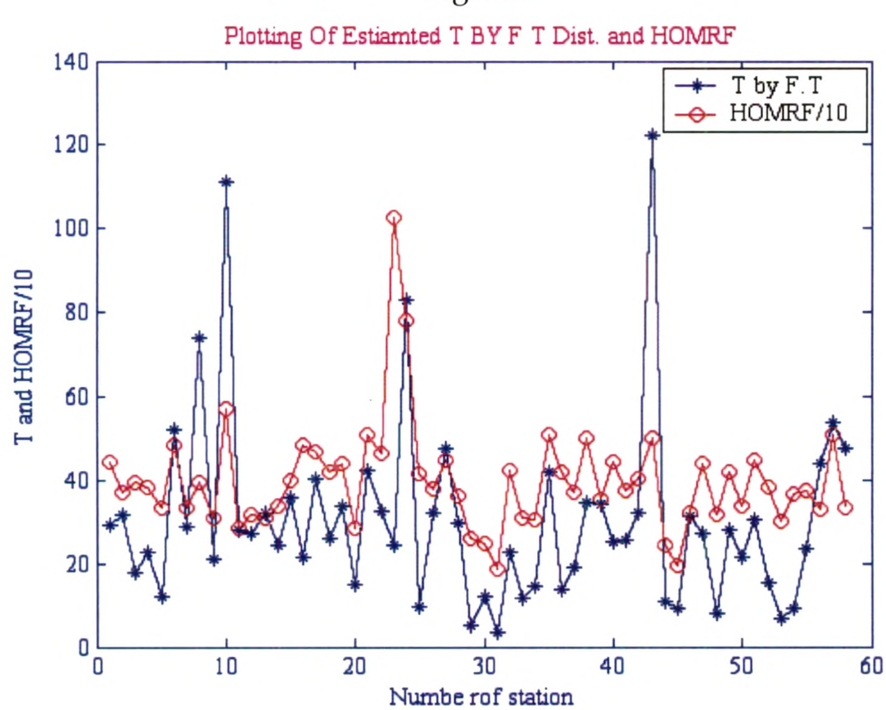

Plotting Of Estiamted T BY F T Dist. and HOMRF
T by F.T
HOMRF/10
T and HOMRF/10
Numbe rof station

Fig: 4.7

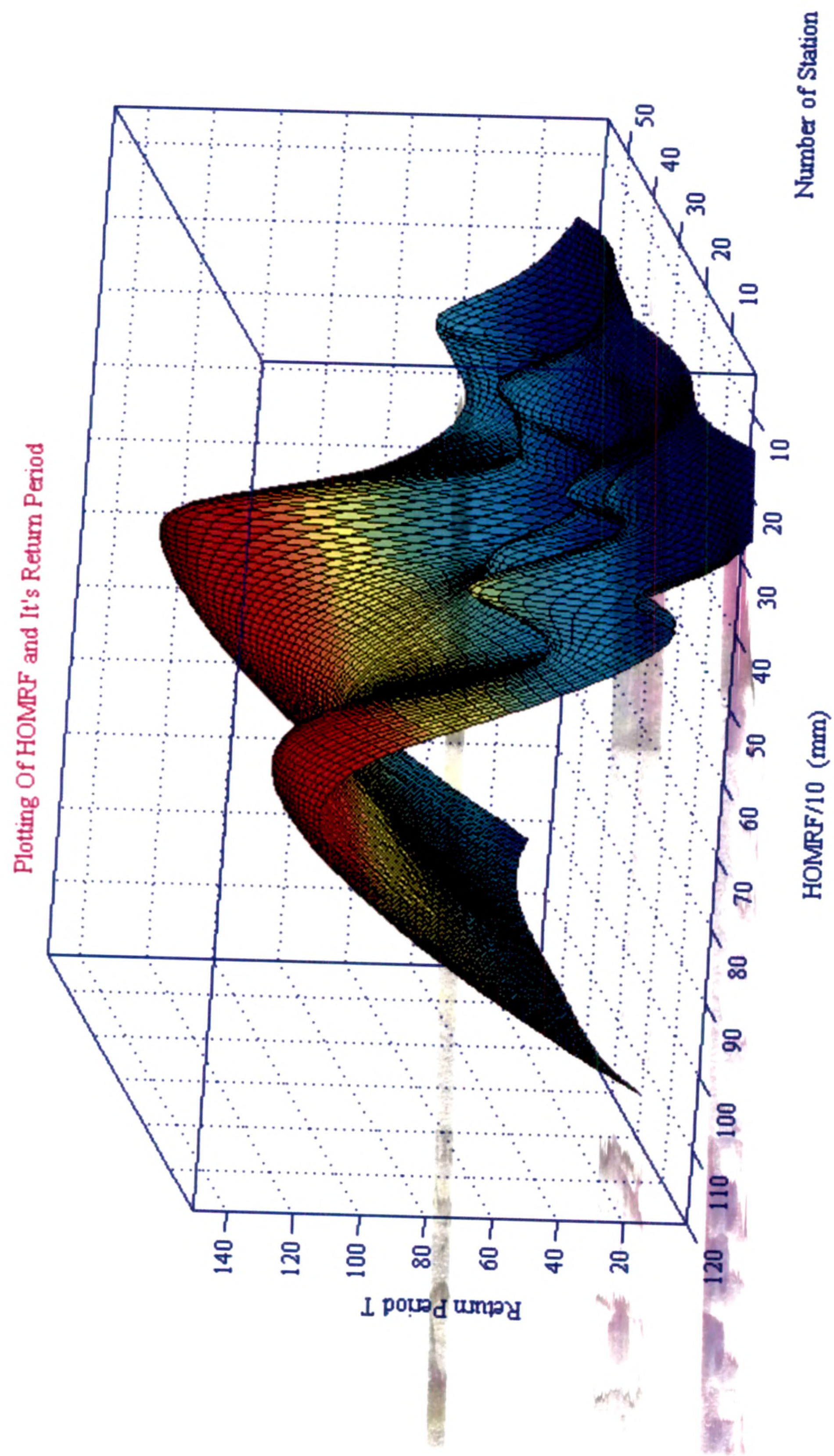

Plotting Of HOMRF and It's Return Period
Return Period T
140
120
100
80
60
40
20
HOMRF/10 (mm)
10
20
30
40
50
60
70
80
90
100
110
120
Number of Station
10
20
30
40
50

Fig: 4.8

TABLE 4.2

RETURN PERIOD BY GUMBEL (T_G) AND FISHER TIPETT TYPE-II (T_F) DISTRIBUTION

Sr. No	Station(Area)	HOMRF (mm)	T_G (yrs)	S.D. (G)	T_F (yrs)	S.D. (F)	Sr. No	Station (Area)	HOMRF (mm)	T_G (yrs)	S.D. (G)	T_F (yrs)	S.D. (F)
I	**SURAT (7657)**												
1	Surat	445.0	240	79	29	0.52	**V**	**Baroda(7794)**					
2	Bardoli	368.8	172	61	32	0.4	20	Chotaudaipur	286.0	52	58	15	0.47
3	Mandvi	397.0	89	79	18	0.53		**Sabarkantha(7390)**					
4	Olpad	383.0	191	69	23	0.54	21	Himatnagar	511.3	894	82	42	0.61
5	Valod	334.0	71	62	12	0.52	22	Idar	463.3	518	75	33	0.56
II	**BHARUCH(9038)**						**VI**	Modasa	1026.2	1101	169	24	0.87
6	Bharuch	485.1	1171	71	52	0.51	23	Prantij	781.6	5174	105	83	0.61
7	Ankleshwar	335.3	182	58	29	0.45	24	**Ahmadabad(8707)**					
8	Amod	395.0	97	59	73	0.46	25	**Ahmadabad**	414.8	317	75	10	1.01
9	Hansot	307.8	82	60	21	0.46	26	Dholka	377.0	176	75	32	0.55
10	Jambusar	571.5	9,989	64	111	0.43	**VII**	Dholera	447.6	741	72	48	0.56
11	Vagara	283.7	136	51	28	0.44	27	Sanad	361.4	261	64	30	0.53
12	Ilav	319.0	160	57	27	0.47	28	**Kheda(7194)**					
III	**PANCHMAHAL(8866)**						29	**Kheda**	258.4	52	52	5	1.01
13	Lunavada	308.4	237	51	32	0.44	30	Anand	247.4	27	58	12	0.47
14	Bariya	337.0	92	61	24	0.4	31	Mahudha	186.6	13	50	4	1.24
15	Godhara	400.8	475	63	36	0.5	32	Petlad	425.0	2932	78	23	0.67
16	Halol	484.6	409	82	22	0.66	33	Thasra	309.9	24	102	12	0.77
17	Zalod	470.0	492	78	40	0.53	**VIII**	**Banaskantha(12,703)**					
18	Jambugodha	420.4	205	75	26	0.52	34	**Deesa**	306.1	73	68	14	0.64
19	Kalol	440.0	318	76	34	0.52	35	Palanpur	509.8	1272	75	41	0.57
							36	Radhanpur	418.1	280	78	14	0.85
							37	Tharad	370.3	130	79	19	0.68

TABLE 4.2 (cont..)

Sr. No	Station (Area)	HOMRF (mm)	T_G (yrs)	S.D. (G)	T_F (yrs)	S.D. (F)
IX	**KACHCHH(45,652)**					
38	Anjar	501.2	750	79	34	0.71
39	Rapar	353.0	1048	86	34.	0.67
40	Abdasa	443.0	1065	56	25	0.83
X	**RAJKOT**					
41	Rajkot	375.2	261	73	26	0.59
42	Dhoraji	404.6	645	68	32	0.6
43	Vankaner	500.8	3764	65	122	0.46
44	Morbi	243.8	385	65	11	0.58
45	Jasdan	193.0	35	56	9	0.64
46	Gondal	320.0	189		31	0.48
XI	**SURENDRANAGAR(10,489)**					
47	Dhanghandhra	440.9	225	46	27	0.68
48	Wadhavan	316.0	37	58	8	0.89
49	Bajana	418.1	328	89	28	0.66
XII	**JAMNAGAR**					
50	Jamnagar	337.8	204	84	22	0.61
51	Jamnagar-AM	447.0	470	78	31	0.64
52	Dwarka	382.0	276	63	15	0.78
XII I	**JUNAGADHA(10,607)**					
53	Junaghar	301.0	41	78	7	0.88
54	Veraval	368.3	71	70	9	0.79
XI V	**BHAVNAGAR(11,155)**					
55	Bhavnagar	372.9	125	74	23	0.53
56	Mahuva	330.2	381	56	44	0.5
57	Palitana	508.0	1049	80	54	0.57
	Gogha	335.3	302	57	48	0.45

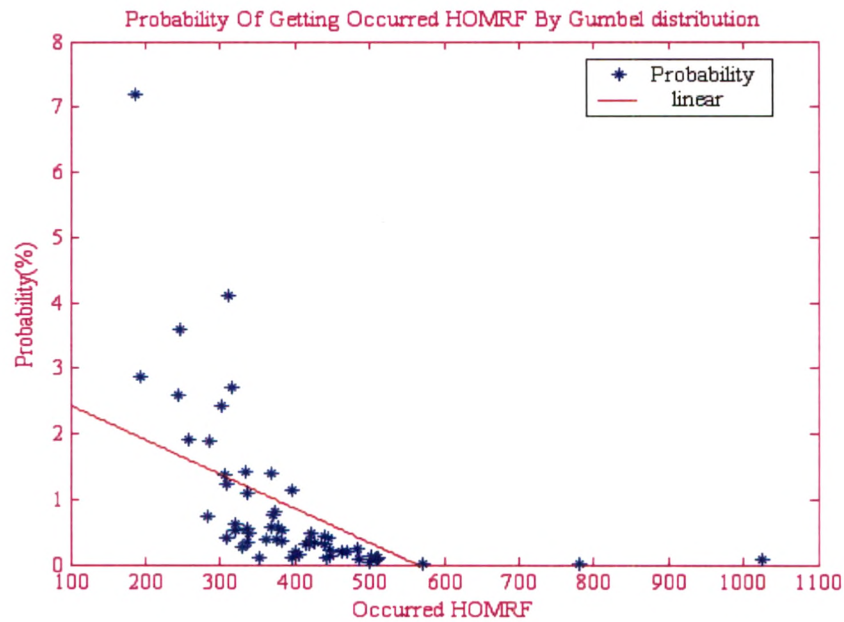


Fig: 4.9

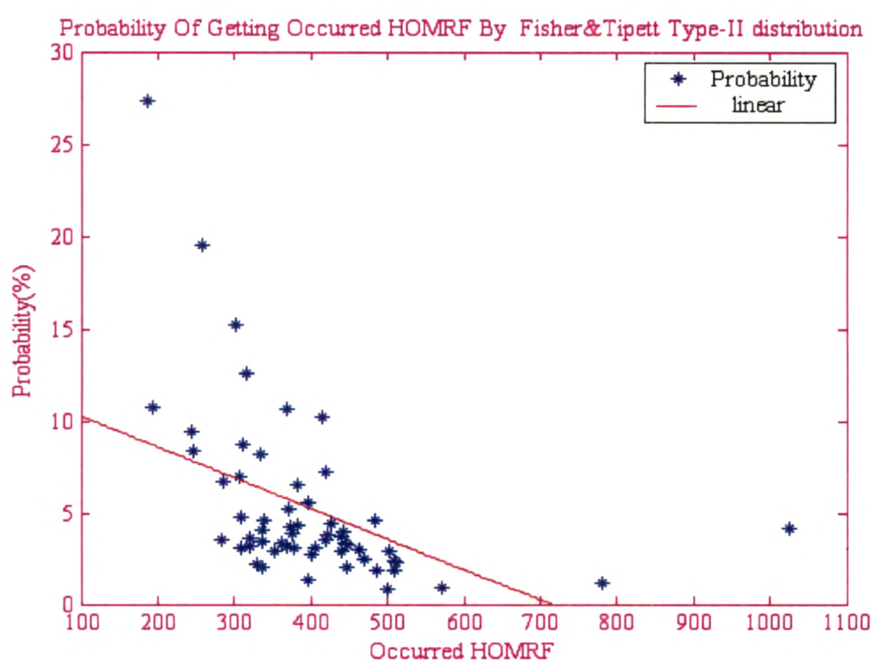


Fig: 4.10

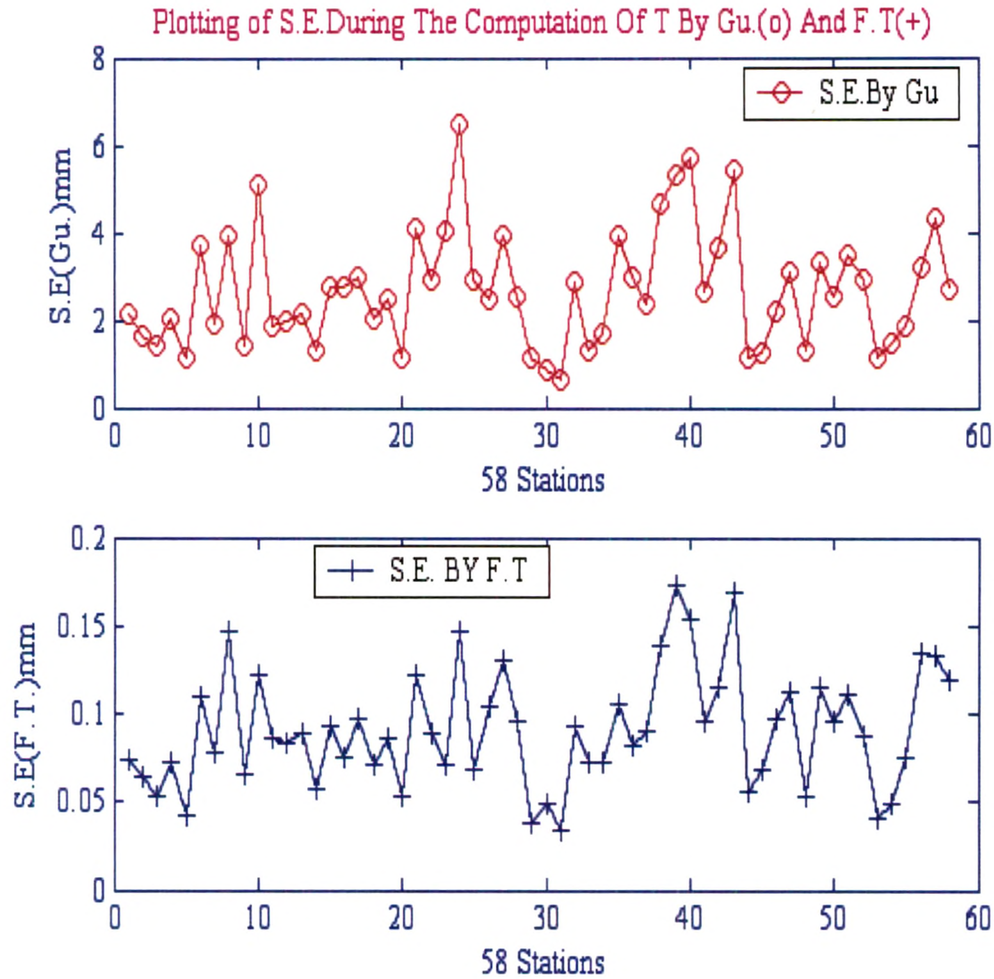


Fig: 4.11

Predicted Highest One day Maximum Rainfall (HOMRF) for the selected T by formulas (4.7) and (4.8) that are by Gumbel and Fisher and Tipett Type-II distribution are given in the Table 4.3. Selected T = 5 yrs, 10 yrs, 15 yrs, 20yrs , 25 yrs ,50yrs and 100 yrs. These HOMRF are plotted in the Figure 4.12 with number of stations for the selected T. These figures show that as T increases HOMRF also increases in both the distributions.

TABLE 4.3

PREDICTED HOMRF (mm)AMOUNT BY GUMBEL DIS. FOR SELECTED RETURN PERIOD T

Sr. No	T=5 (mm)	Sr. No	T=5 (mm)	Sr. No	T=5 (mm)	Sr. No	T=10 (mm)	Sr .No	T=10 (mm)	Sr .No	T=10 (mm)	Sr. No	T=15 (mm)	Sr. No	T=15 (mm)	Sr. No	T=15 (mm)
1	**201**	26	**164**	51	**165**	1	**247**	26	**207**	51	**210**	1	**273**	26	**232**	51	**236**
2	**195**	27	**159**	52	**156**	2	**231**	27	**202**	52	**197**	2	**251**	27	**225**	52	**220**
3	**212**	28	**160**	53	**180**	3	**259**	28	**197**	53	**221**	3	**285**	28	**218**	53	**245**
4	**182**	29	**159**	54	**195**	4	**222**	29	**190**	54	**242**	4	**245**	29	**207**	54	**269**
5	**201**	30	**166**	55	**182**	5	**237**	30	**200**	55	**225**	5	**257**	30	**219**	55	**249**
6	**178**	31	**144**	56	**135**	6	**219**	31	**173**	56	**168**	6	**243**	31	**190**	56	**187**
7	**169**	32	**170**	57	**169**	7	**202**	32	**216**	57	**216**	7	**221**	32	**242**	57	**242**
8	**147**	33	**177**	58	**147**	8	**181**	33	**237**	58	**181**	8	**201**	33	**270**	58	**200**
9	**171**	34	**159**			9	**207**	34	**198**			9	**227**	34	**221**		
10	**189**	35	**180**			10	**226**	35	**224**			10	**247**	35	**248**		
11	**148**	36	**166**			11	**178**	36	**212**			11	**194**	36	**238**		
12	**159**	37	**164**			12	**193**	37	**210**			12	**212**	37	**236**		
13	**151**	38	**160**			13	**181**	38	**210**			13	**198**	38	**238**		
14	**194**	39	**116**			14	**229**	39	**149**			14	**249**	39	**167**		
15	**171**	40	**133**			15	**208**	40	**176**			15	**229**	40	**200**		
16	**195**	41	**160**			16	**243**	41	**200**			16	**270**	41	**222**		
17	**186**	42	**152**			17	**231**	42	**190**			17	**257**	42	**212**		
18	**197**	43	**157**			18	**241**	43	**195**			18	**266**	43	**217**		
19	**188**	44	**151**			19	**233**	44	**184**			19	**258**	44	**202**		
20	**175**	45	**120**			20	**209**	45	**147**			20	**228**	45	**162**		
21	**173**	46	**152**			21	**221**	46	**185**			21	**248**	46	**204**		
22	**185**	47	**169**			21	**229**	47	**221**			21	**254**	47	**251**		
23	**299**	48	**178**			23	**398**	48	**227**			23	**454**	48	**255**		
24	**202**	49	**158**			24	**264**	49	**203**			24	**298**	49	**229**		
25	**167**	50	**150**			25	**210**	50	**187**			25	**235**	50	**207**		

(cont..)

TABLE 4.3 (cont..)

Sr. No	T=20 (mm)	Sr. No	T=20 (mm)	Sr. No	T=20 (mm)	Sr. No	T=25 (mm)	Sr. No	T=25 (mm)	Sr. No	T=25 (mm)	Sr. No	T=50 (mm)	Sr. No	T=50 (mm)	Sr. No	T=50 (mm)
1	**291**	26	**249**	51	**254**	1	**305**	26	**262**	51	**268**	1	**348**	26	**303**	51	**311**
2	**265**	27	**242**	52	**236**	2	**276**	27	**255**	52	**249**	2	**310**	27	**295**	52	**288**
3	**303**	28	**233**	53	**261**	3	**317**	28	**244**	53	**273**	3	**361**	28	**279**	53	**312**
4	**260**	29	**219**	54	**287**	4	**273**	29	**228**	54	**301**	4	**310**	29	**256**	54	**346**
5	**272**	30	**232**	55	**266**	5	**283**	30	**243**	55	**279**	5	**317**	30	**274**	55	**320**
6	**259**	31	**201**	56	**200**	6	**272**	31	**210**	56	**210**	6	**311**	31	**238**	56	**241**
7	**235**	32	**260**	57	**261**	7	**245**	32	**274**	57	**275**	7	**277**	32	**317**	57	**318**
8	**214**	33	**294**	58	**213**	8	**225**	33	**312**	58	**223**	8	**257**	33	**368**	58	**255**
9	**241**	34	**236**			9	**251**	34	**248**			9	**285**	34	**286**		
10	**262**	35	**266**			10	**273**	35	**279**			10	**308**	35	**320**		
11	**206**	36	**256**			11	**215**	36	**270**			11	**243**	36	**313**		
12	**225**	37	**254**			12	**235**	37	**268**			12	**267**	37	**311**		
13	**210**	38	**258**			13	**219**	38	**273**			13	**246**	38	**320**		
14	**263**	39	**180**			14	**274**	39	**190**			14	**307**	39	**220**		
15	**243**	40	**217**			15	**254**	40	**229**			15	**289**	40	**269**		
16	**289**	41	**238**			16	**304**	41	**250**			16	**349**	41	**287**		
17	**275**	42	**227**			17	**289**	42	**238**			17	**331**	42	**274**		
18	**283**	43	**232**			18	**296**	43	**244**			18	**337**	43	**280**		
19	**275**	44	**215**			19	**289**	44	**225**			19	**330**	44	**255**		
20	**241**	45	**173**			20	**252**	45	**181**			20	**283**	45	**206**		
21	**267**	46	**218**			21	**281**	46	**228**			21	**326**	46	**260**		
21	**271**	47	**271**			21	**285**	47	**287**			21	**326**	47	**336**		
23	**493**	48	**275**			23	**523**	48	**290**			23	**616**	48	**336**		
24	**323**	49	**247**			24	**342**	49	**261**			24	**399**	49	**304**		
25	**252**	50	**222**			25	**266**	50	**233**			25	**307**	50	**268**		

(cont..)

TABLE 4.3 (cont..)

Sr .No	T=100 (mm)	Sr. No	T=100 (mm)	Sr .No	T=100 (mm)
1	**391**	26	**344**	51	**353**
2	**343**	27	**334**	52	**326**
3	**404**	28	**314**	53	**350**
4	**348**	29	**285**	54	**389**
5	**351**	30	**305**	55	**360**
6	**349**	31	**265**	56	**271**
7	**308**	32	**359**	57	**362**
8	**290**	33	**423**	58	**286**
9	**317**	34	**323**		
10	**343**	35	**361**		
11	**271**	36	**355**		
12	**298**	37	**354**		
13	**274**	38	**366**		
14	**341**	39	**250**		
15	**324**	40	**309**		
16	**394**	41	**324**		
17	**373**	42	**310**		
18	**378**	43	**315**		
19	**371**	44	**286**		
20	**315**	45	**231**		
21	**371**	46	**291**		
21	**367**	47	**384**		
23	**709**	48	**382**		
24	**457**	49	**346**		
25	**347**	50	**303**		

Table 4.4

PREDICTED HOMRF (mm) AMOUNT BY F.T TYPE-II DIS. FOR SELECTED RETURN PERIOD T

Sr. No	T=5 (mm)	Sr. No	T=5 (mm)	Sr. No	T=5 (mm)	Sr. No	T=10 (mm)	Sr .No	T=10 (mm)	Sr .No	T=10 (mm)	Sr. No	T=15 (mm)	Sr. No	T=15 (mm)	Sr. No	T=15 (mm)
1	209	26	163	51	173	1	284	26	226	51	251	1	337	26	270	51	310
2	201	27	160	52	184	2	255	27	222	52	291	2	290	27	267	52	376
3	227	28	167	53	245	3	310	28	228	53	410	3	369	28	271	53	548
4	195	29	252	54	242	4	267	29	456	54	384	4	319	29	636	54	499
5	227	30	175	55	189	5	308	30	231	55	258	5	365	30	270	55	307
6	183	31	264	56	136	6	247	31	545	56	182	6	292	31	821	56	215
7	176	32	185	57	169	7	229	32	273	57	236	7	265	32	341	57	285
8	145	33	181	58	147	8	190	33	284	58	191	8	221	33	366	58	221
9	178	34	174			9	233	34	254			9	272	34	313		
10	195	35	190			10	251	35	265			10	289	35	320		
11	152	36	203			11	197	36	334			11	228	36	442		
12	166	37	175			12	218	37	260			12	255	37	325		
13	158	38	163			13	204	38	248			13	236	38	313		
14	200	39	123			14	253	39	182			14	289	39	227		
15	179	40	147			15	240	40	239			15	283	40	315		
16	219	41	170			16	322	41	240			16	400	41	291		
17	190	42	162			17	260	42	230			17	309	42	280		
18	208	43	153			18	282	43	201			18	335	43	233		
19	195	44	169			19	264	44	237			19	314	44	287		
20	187	45	138			20	246	45	201			20	287	45	248		
21	177	46	155			21	253	46	206			21	309	46	241		
22	196	47	171			21	272	47	255			21	327	47	319		
23	331	48	222			23	551	48	374			23	734	48	502		
24	195	49	164			24	279	49	241			24	342	49	300		
25	234	50	161			25	422	50	231			25	589	50	282		

cont..)

Table 4.4 (cont..)

Sr. No	T=20 (mm)	Sr. No	T=20 (mm)	Sr. No	T=20 (mm)	Sr. No	T=25 (mm)	Sr. No	T=25 (mm)	Sr. No	T=25 (mm)	Sr. No	T=50 (mm)	Sr. No	T=50 (mm)	Sr. No	T=50 (mm)
1	380	26	307	51	360	1	417	26	339	51	403	1	555	26	458	51	573
2	319	27	304	52	450	2	342	27	336	52	517	2	426	27	457	52	794
3	417	28	307	53	672	3	458	28	337	53	786	3	613	28	451	53	1274
4	362	29	804	54	599	4	398	29	962	54	689	4	536	29	1675	54	1063
5	412	30	301	55	347	5	452	30	327	55	381	5	601	30	423	55	510
6	329	31	1093	56	242	6	360	31	1363	56	264	6	477	31	2692	56	347
7	294	32	398	57	325	7	319	32	449	57	359	7	408	32	648	57	491
8	245	33	438	58	246	8	266	33	502	58	266	8	343	33	766	58	341
9	302	34	363			9	328	34	407			9	422	34	578		
10	319	35	365			10	345	35	404			10	436	35	553		
11	252	36	538			11	273	36	626			11	347	36	997		
12	284	37	381			12	309	37	430			12	399	37	624		
13	261	38	369			13	283	38	419			13	360	38	618		
14	317	39	265			14	340	39	299			14	423	39	432		
15	318	40	381			15	347	40	442			15	457	40	697		
16	466	41	334			16	524	41	371			16	753	41	513		
17	350	42	322			17	384	42	358			17	514	42	498		
18	377	43	260			18	414	43	282			18	551	43	363		
19	354	44	328			19	388	44	363			19	516	44	500		
20	320	45	287			20	348	45	322			20	450	45	457		
21	356	46	269			21	397	46	294			21	555	46	382		
21	373	47	374			21	412	47	422			21	560	47	612		
23	898	48	616			23	1049	48	722			23	1690	48	1177		
24	393	49	350			24	439	49	393			24	613	49	565		
25	745	50	325			25	891	50	362			25	1551	50	506		

(cont..)

Table 4.4 (cont..)

Sr .No	T=100 (mm)	Sr. No	T=100 (mm)	Sr .No	T=100 (mm)
1	**736**	26	**736**	51	**812**
2	**530**	27	**530**	52	**1214**
3	**818**	28	**818**	53	**2057**
4	**719**	29	**719**	54	**1635**
5	**798**	30	**798**	55	**681**
6	**629**	31	**629**	56	**456**
7	**521**	32	**521**	57	**670**
8	**441**	33	**441**	58	**435**
9	**542**	34	**542**		
10	**551**	35	**551**		
11	**442**	36	**442**		
12	**516**	37	**516**		
13	**457**	38	**457**		
14	**526**	39	**526**		
15	**600**	40	**600**		
16	**1079**	41	**1079**		
17	**686**	42	**686**		
18	**731**	43	**731**		
19	**685**	44	**685**		
20	**581**	45	**581**		
21	**773**	46	**773**		
21	**759**	47	**759**		
23	**2714**	48	**2714**		
24	**855**	49	**855**		
25	**2689**	50	**2689**		

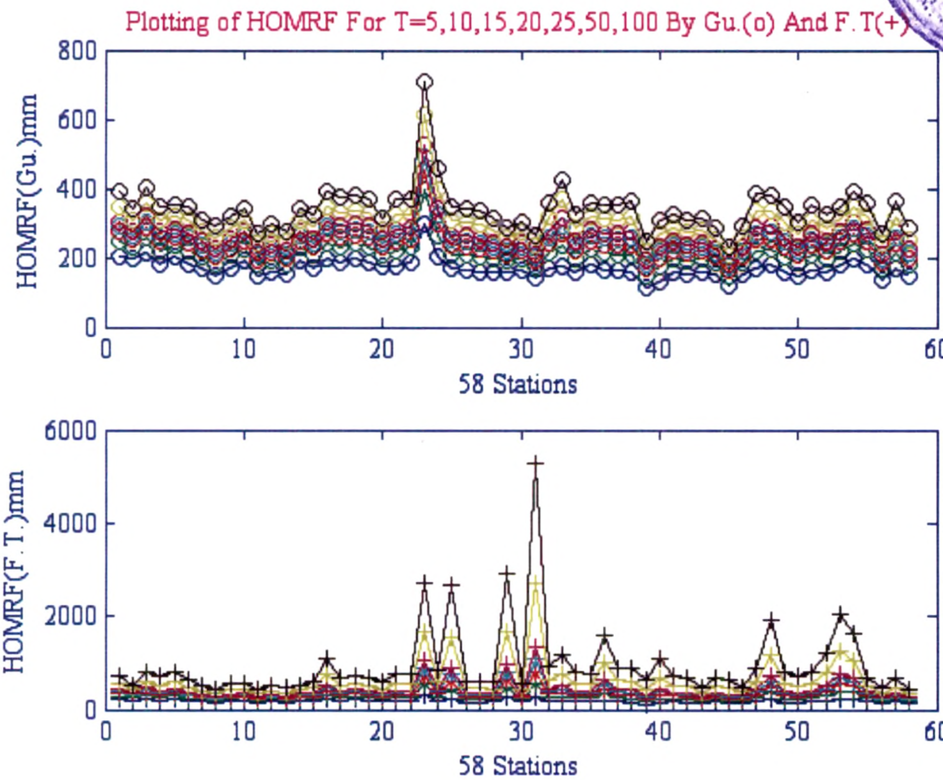


Fig: 4.12

4.3.1.4 CONCLUSION

From the above RTPA it is concluded that T obtained by Fisher and Tipett Type –II distribution is significant by computed Standard Error.

Fisher and Tipett Type-II distribution is preferred for prediction of return period T in place of Gumbel distribution.

4.3.2 ARTIFICIAL NEURAL NETWORK (ANN)

4.3.2.1 DATA

We now apply ANN method to predict return periods. To train the NN, input data series is highest one-day maximum rainfall (HOMRF) of first 20 stations out of 58 stations. Output data series is return period (T_F) by Fisher and Tipett Type -II distribution of these 20 stations. From this trained NN, return period T is predicted for next 20 stations and compared with T_F.

4.3.2.2 ANN IN DETAILS

Here, NN architecture is constructed by three layers namely input, layer hidden layer and output layer. Input and output layers have one node. Number of nodes of the hidden layer (NH) depends on the data size. Figure 4.13 shows the structure of this network. Input layer has a single neuron of HOMRF and output layer has a single neuron of return period T_F. Selected ANN parameters are given in the Table 4.5.

❖ STRUCTURE OF NN :

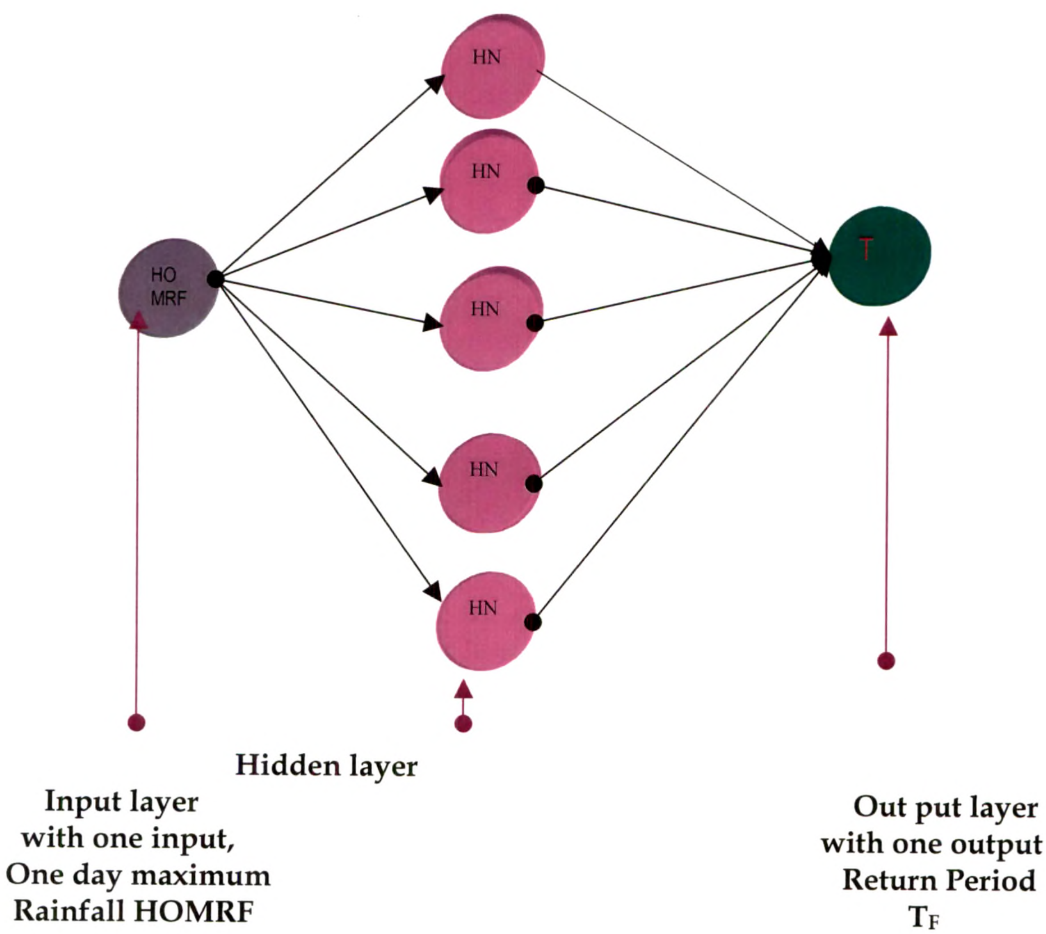


Fig: 4.13

4.3.2.3 RESULT AND DISCUSSION

Return period T obtained by artificial neural network is depicted in the Figure 4.14. Predicted return period T by ANN, at some places, namely, Modasa and Prantij stations of Sabarkantha etc. district have very high (210 yrs and 200 yrs) T. This is because of very highest one day maximum rainfall (HOMRF) values that are 1026.2 mm, 781.6mm. Here found S.Es. during the analysis are high in comparison to S.Es. of F.T. These S.Es. are showed in the figure 4.15.

TABLE 4.5
DETAILS OF THE PARAMETER VALUES USED IN ANN TRAINING

Sr. No.	Number of Station	Number of Epochs Used	Learn ing rate	Momen tum	No. of Neurons	Error Goal
1	21 to 40	80076	0.001	0.3	147	0.0001

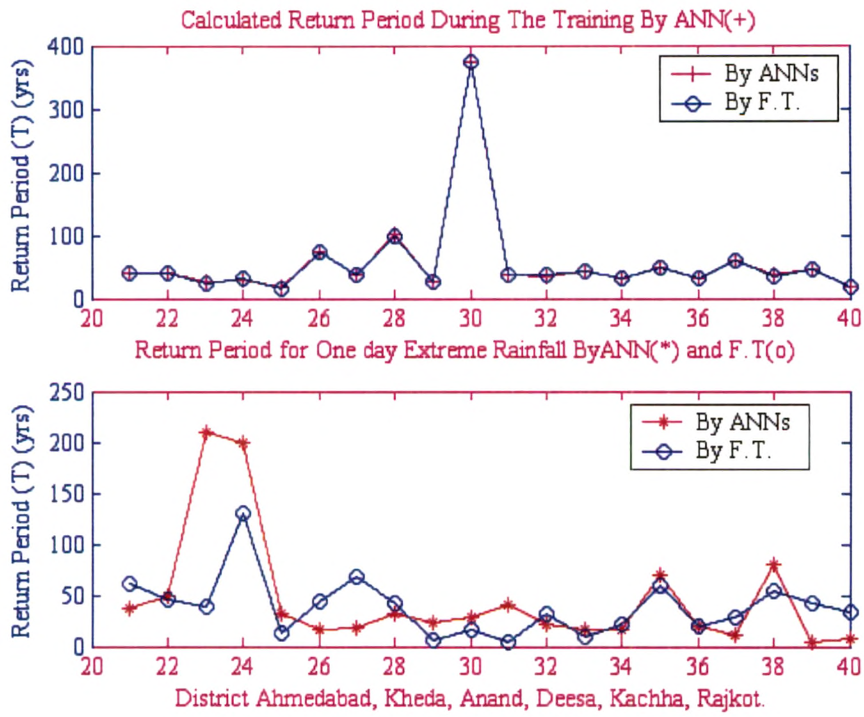


Fig: 4. 14

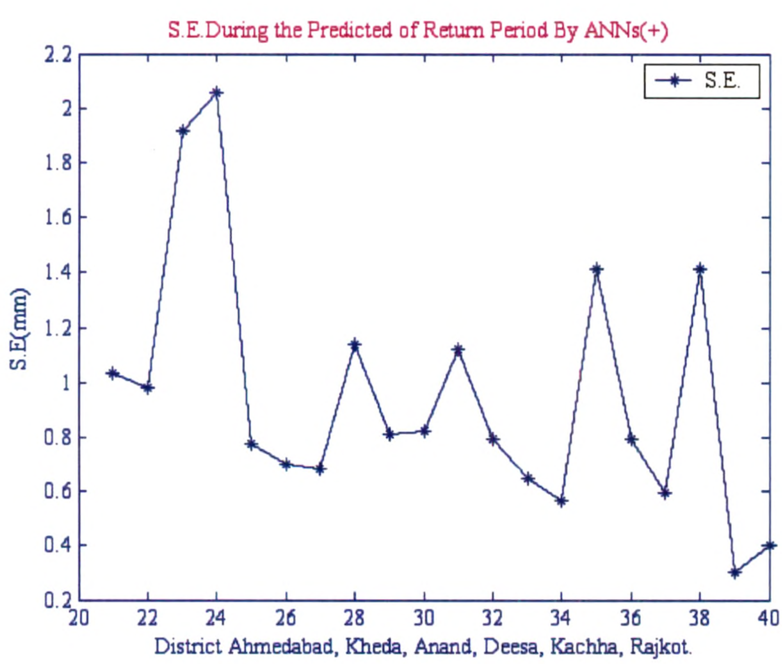


Fig: 4.15

4.3.2.4 CONCLUSION

Return period T obtained by ANN with supervised networks is significant to return period obtained by Fisher and Tipett Type-II (T_F) except at Modasa Prantij , Dholaka and Sanand (Fig. 4.14 ; Station no. 21 , 22, 25 and 26). Here, computed values of S.Es. are found less that is varying from 0.2 to 2.2.

4.4 SECOND PROBLEM

4.4.1. METHOD I

GAMMA DISTRIBUTION MODEL (GDM)

4.4.1.1 DATA

Standard Weekly [(Table A-3.3) from 22nd to 42nd data series (DS)] rainfall (WRF) observed at Anand station from 1958 -2005 have been averaged for the 48 years. These Weekly Mean Rainfall (WMRF) are shown in the Table 4.6 and Figure 4.16. These standard weeks from 22nd(28th May-3rd June) to 42nd(15th -21st October) are period of monsoon. From 24th(11-17 June) week monsoon advances and after 30th(23rd - 29th August) SW it's starting to decrease (Figure 4.16).

Data is noted from the Agro-meteorological Observatory of the department of Agricultural Meteorology, B A College of Agriculture, Anand Agricultural University, Anand.

TABLE 4.6
MEAN (1958-2005) STANDARD WEEKLY RAINFALL DS

Sr. No	Standard Week No.	**Mean Rainfall (Inches)**	Sr. No	Standard Week No.	**Mean Rainfall (Inches)**
1	22	**0.19**	11	32	**2.60**
2	23	**0.81**	12	33	**2.82**
3	24	**0.77**	13	34	**2.59**
4	25	**1.60**	14	35	**2.68**
5	26	**3.12**	15	36	**2.48**
6	27	**3.31**	16	37	**1.70**
7	28	**2.88**	17	38	**1.34**
8	29	**3.59**	18	39	**0.80**
9	30	**3.06**	19	40	**0.23**
10	31	**3.02**	20	41	**0.38**
			21	42	**0.22**

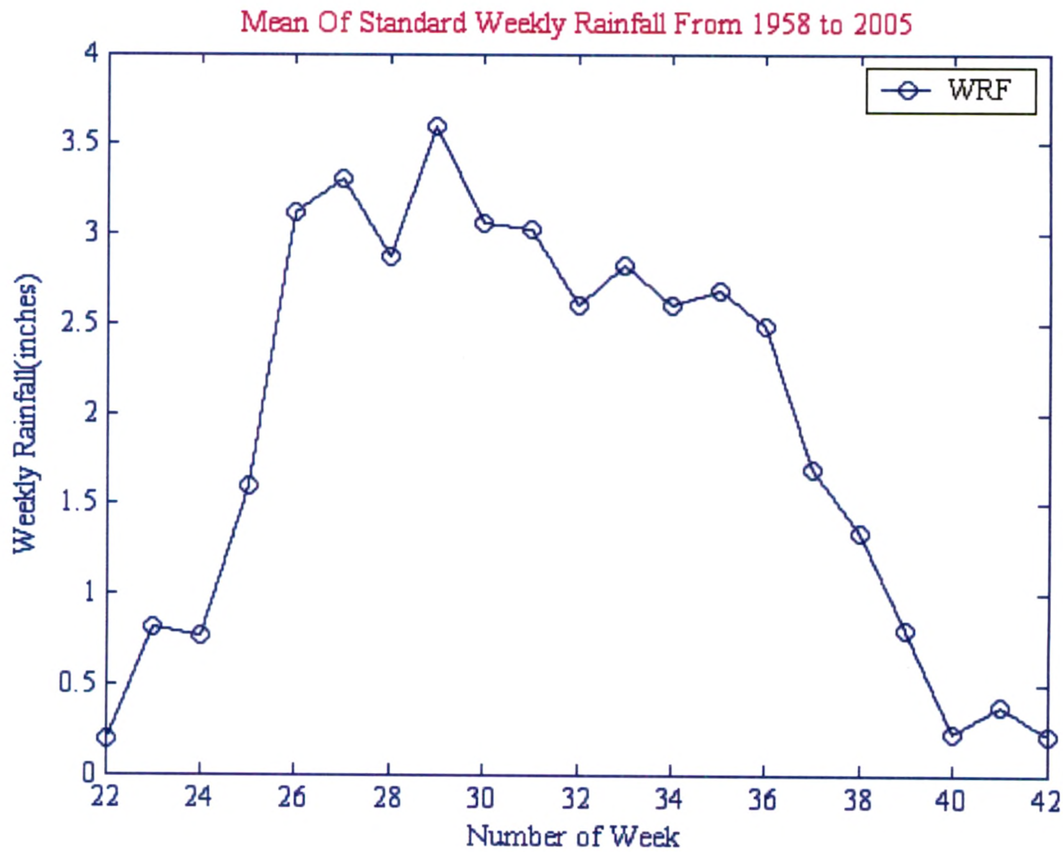


Fig: 4.16

4.4.1.2 METHOD II

GAMMA DISTRIBUTION MODEL (GDM) IN DETAILS

WMRF is always non-zero and positive in the summer monsoon period. Therefore GDM is applicable as its cumulative distribution function is given by

$$P_X(x) = \int_0^x \frac{\lambda^\eta \, x^{\eta-1} e^{-\lambda x}}{\Gamma \eta} \, dt \qquad (4.11)$$

where, scale (λ) and shape (η) parameters obtained by WMRF data from 22^{nd} - 42^{th} SW, from the method of Maximum Likely Hood(Han [57]) . Details are as under :

$$MRF = x \ (Mean \quad of \quad one \ day \quad \max imum \quad ra\inf all)$$

$$mx = mean(x);$$

$$m\ln x = mean(l_n x);$$

$$y = l_n x - m\ln x;$$

$$\eta = \frac{(1+\sqrt{1+\frac{4y}{3}})}{4y}; \ shape \quad parameter$$

$$\lambda = \frac{\eta}{mx} .scale \quad parameter$$

Figure 4.17 and 4.18 are showing the relation of Scale and Shape parameters, respectively, with Weekly Mean Rainfall (WMRF). Scale parameter is showing decreasing trend while shape parameter shows increasing trend.

Probability (PB) of getting zero mm rainfall 'p' is computed by actual occurred SW RF during the 48 years (1958-2005) of period. These probabilities in percentages are shown in the Figure 4.19 for the standard week from 22nd to 42nd . This figure shows the probability of getting zero rainfall is decreasing as the monsoon advances. At the time of withdrawal of monsoon (36th to 42nd SW) it starts increasing.

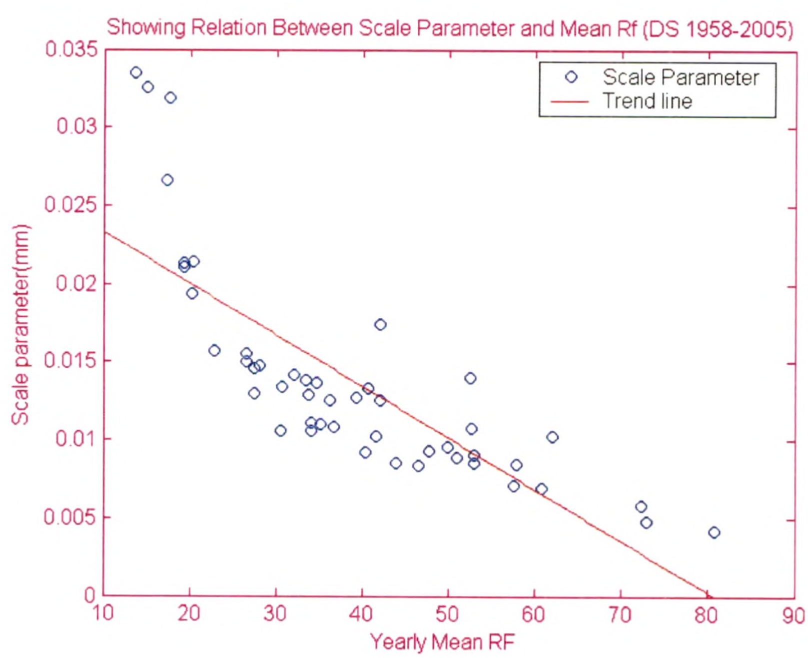


Fig: 4.17

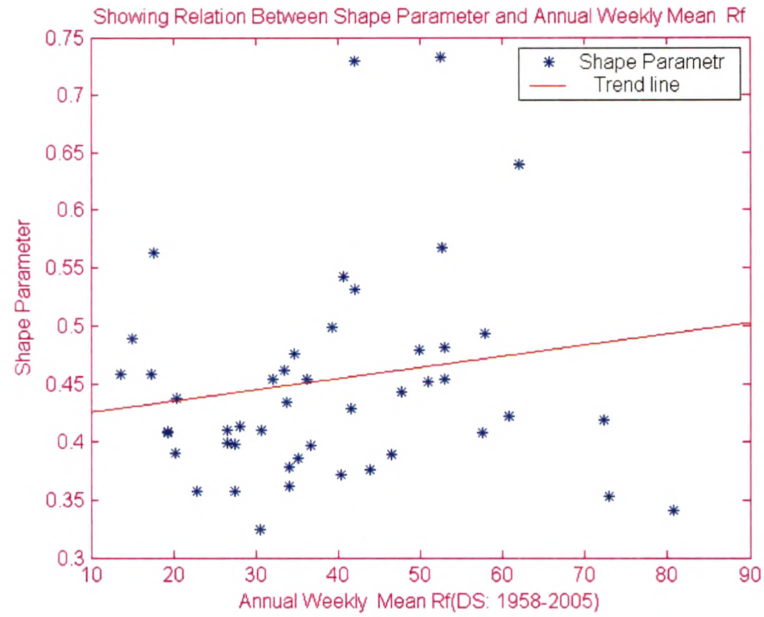


Fig: 4.18

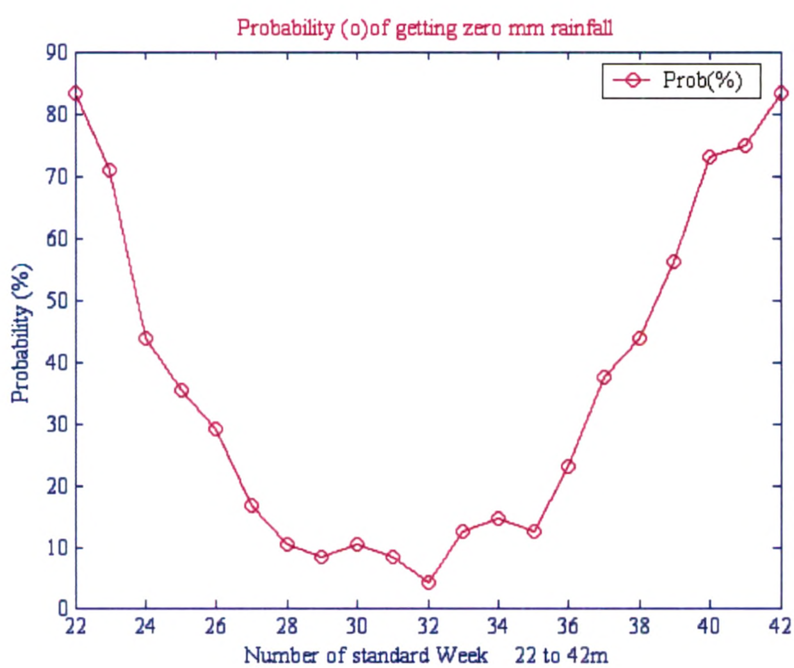


Fig: 4.19

To get the probabilities of getting x amount of RF, MATLAB function namely *'gammainc'* is used and these probabilities are modified by the formula used by Kulshrestha *et al.* [94] . That is

$$P_X(x) = p + (1-p)P_X(x) \qquad (4.12)$$

Here probabilities (PBs) of getting zero RF are also taken in to account during the computation of probabilities. $P_X(x)$ is the PB of getting x RF. These probabilities are converted in to the percentages.

4.4.1.3 RESULT AND DISCUSSION

Probabilities of getting weekly Rainfall (WRF) for the amount of 0.1", 0.5", 1.27" and 15" are computed by Gamma distribution and depicted in the Figures 4.20 to 4.23. These PB are compared with actual probabilities.

Figure 4.20 and 4.21 show the probabilities by Gamma Distribution Model (GDM) of getting Weekly Rainfall (WRF) of 0.1" and 0.5 from standard week (SW) of 22 to 42. As the monsoon advances probabilities are increased. Theses probabilities are compared with actual probabilities computed from 48 years DS. Differences of actual and computed probabilities by Gamma Distribution Model (GDM) are plotted in the same figure as subplot. These figure shows the highest difference is found 12% in the standard week (SW) of 33. Rests of the differences are less than 7%.

Computed probabilities for Weekly Rainfall of 1.27″ and 15″ are plotted in the Figures 4.21 and 4.22. Their differences with actual probabilities are plotted in the same figures as subplots. These differences are less than 1 %. In the case of WRF of 15″, computed probabilities are nearly almost zero at everywhere but actual probabilities at 15″ have more than zero that are 2% in the SW of 23rd, 27th and 31st. This happening due to heavy rainfall in the year of 2005 and 2006.

Computed probabilities are tested with student t-test for two tails and found significant with actual probabilities.

Figure 4.24 shows the predicted weekly Rainfall (WRF) from standard week of 22nd to 42nd at different probabilities (PBs) level. These levels are 10% to 100 % with the increment of 10. As the probabilities (PBs) are increases WRF are decreasing. In the month of August in each case WRF are increasing. For the 100% PB, weekly Rainfall (WRF) is non-zero but it is a very small amount.

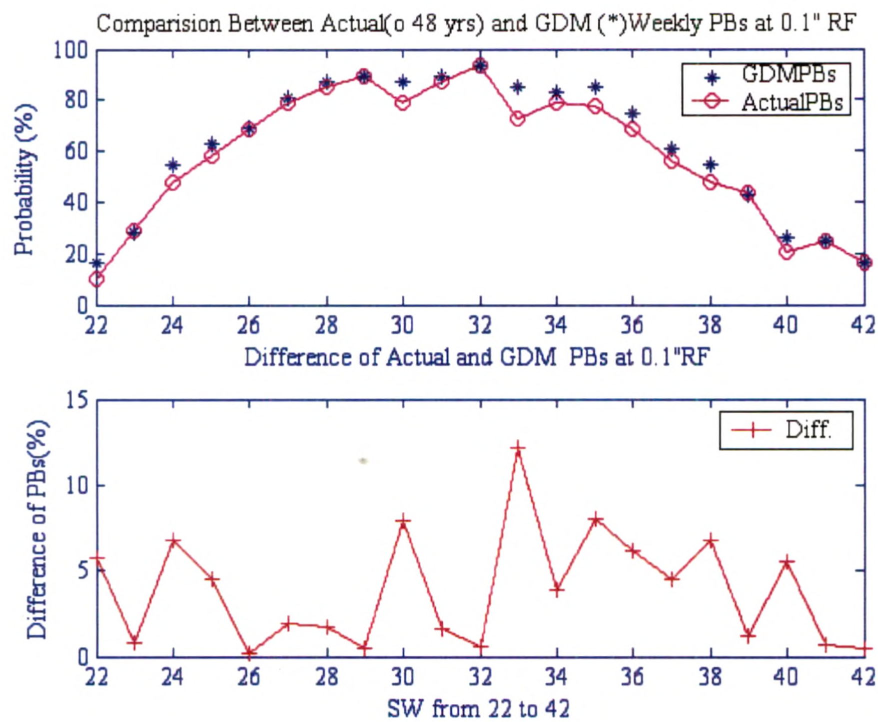


Fig: 4.20

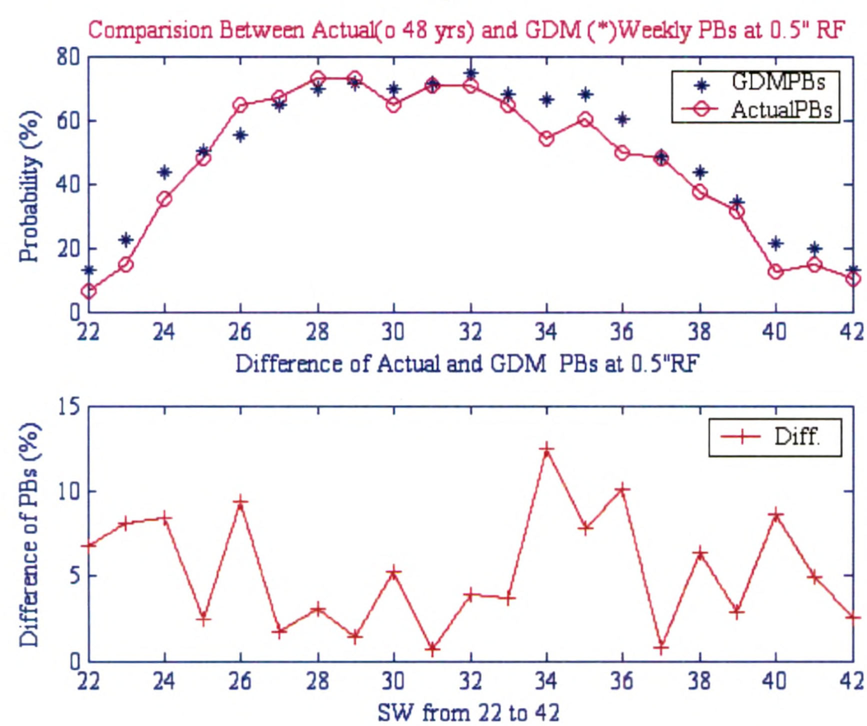


Fig: 4.21

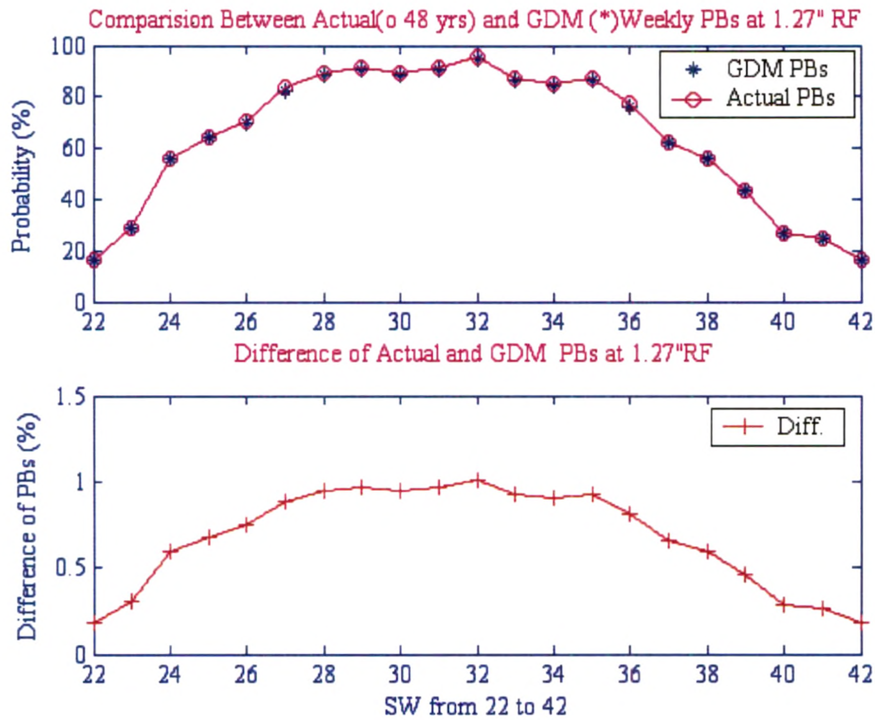


Fig: 4.22

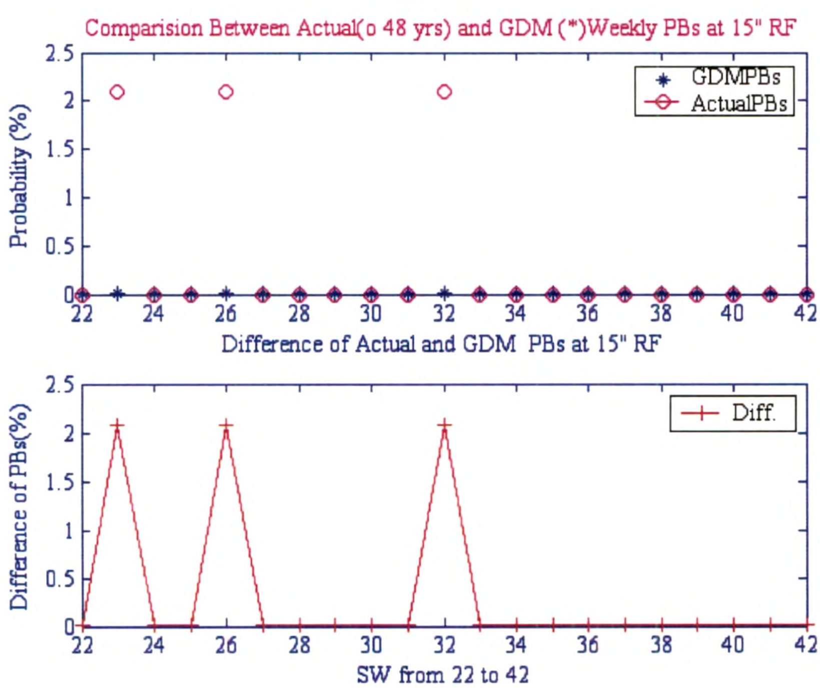


Fig: 4.23

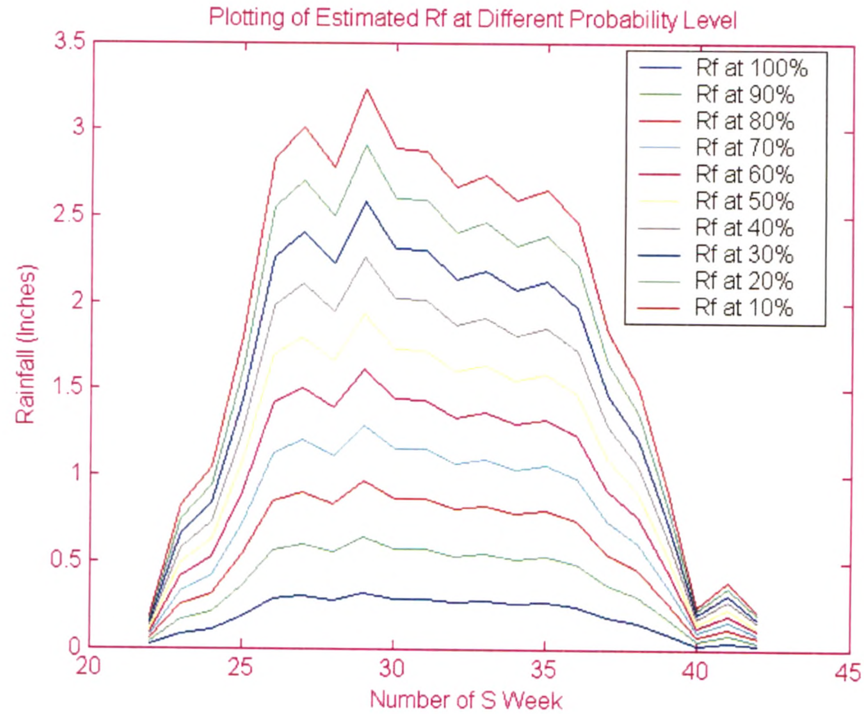


Fig: 4.24

4.4.2 ARTIFICIAL NEURAL NETWORK APPROACH

ANN is used with Back Propagation algorithm. Here NN is trained with the probabilities (PBs) (%) of WRF of 0.1″ and 0.2″ obtained by GDM. The NN consists of three layers. Those are Input layer, hidden layer and output layer. Input layer and output layer has one neuron. Here input is WRF and output is probabilities (PBs) for the Standard Week (SW) of 22^{nd} to 42^{nd}. Table 4.7 shows the used parameters to train the NN. Number of hidden neurons are 140 with momentum 0.5 and the error goal taken is 10^{-22}.

Probabilities (PBs) are obtained for the rest of the amount 2″, 3″ 5″ 7″ 10″ and 15″ of WRF and compared with probabilities (PBs) obtained by Gamma Distribution Model (GDM).

All the related programmes are developed in MATLAB.

- **STRUCTURE OF ANN**

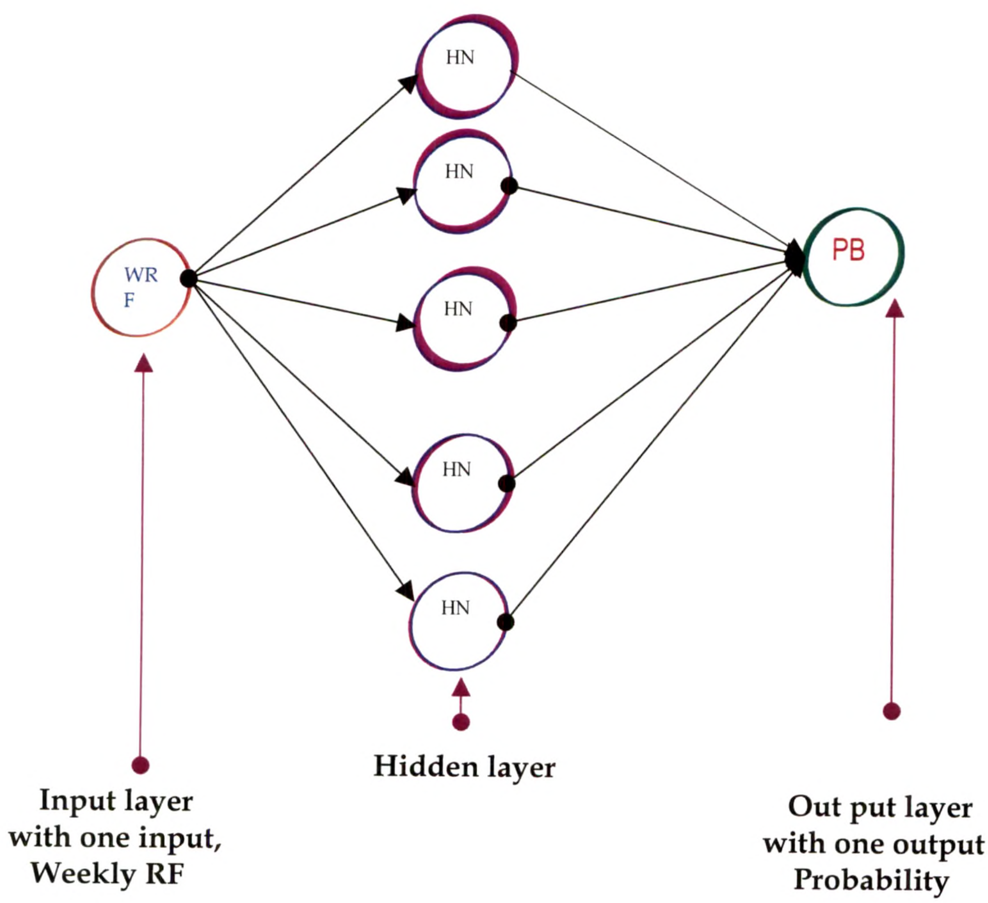


Fig: 4.25

TABLE 4.5
DETAILS OF THE PARAMETER VALUES USED IN ANN TRAINING

Sr. No.	WRF (Inches)	Number of epochs used	Learn ing rate	Momen tum	No. of neurons	Error goal	RMSE Related By GDM	PAE(%) Related By GDM
1	0.5	14772	0 001	0.5	140	10^{-22}	4.035	8.57
2	1.0	14772	0.001	0 5	140	10^{-22}	2.82	8.56

4.6.1 RESULT AND DISCUSSION

Computed probabilities for the Weekly Rainfall of 0.5″ and 1.0″ are shown in the Figure 4.23. These computed probabilities by ANN is compared with GDM and found significant by student t test. Figure 4.26 shows the computed probabilities by ANN and its comparison with obtained probabilities by Gamma Distribution Model.

Probabilities (PBs) of getting Weekly Rainfall of 2″, 3″ 5″ 7″ 10″ and 15″ are predicted by ANN and are found significant to probabilities by GDM. These probabilities are shown in the Figure 4.27 to 4.29.

Root Mean Square Error (RMSE) and Percentage of average error (PAE) during the use of ANN are found less than 10% (Table: 4.5).

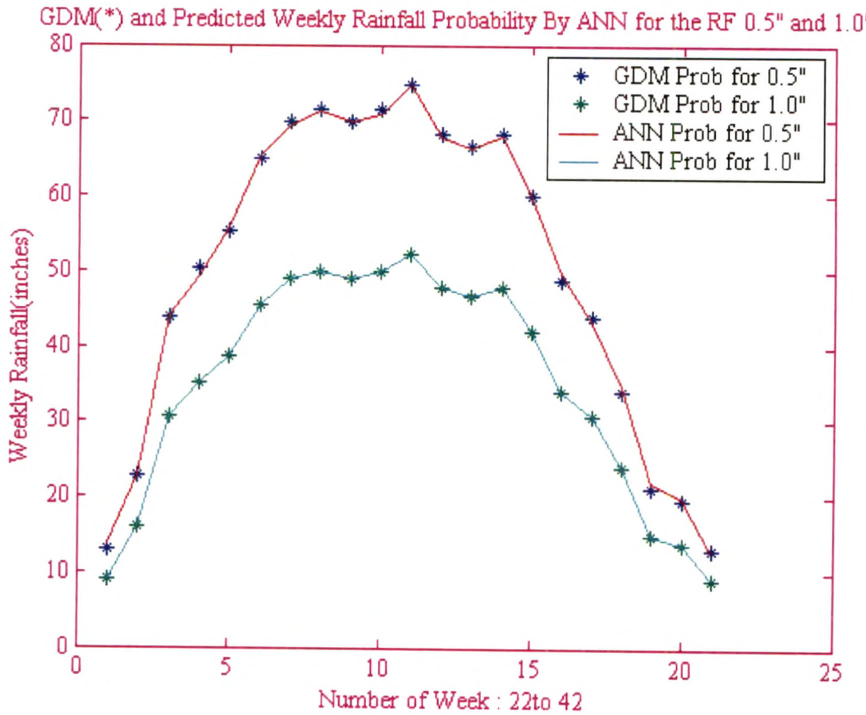


Fig: 4.26

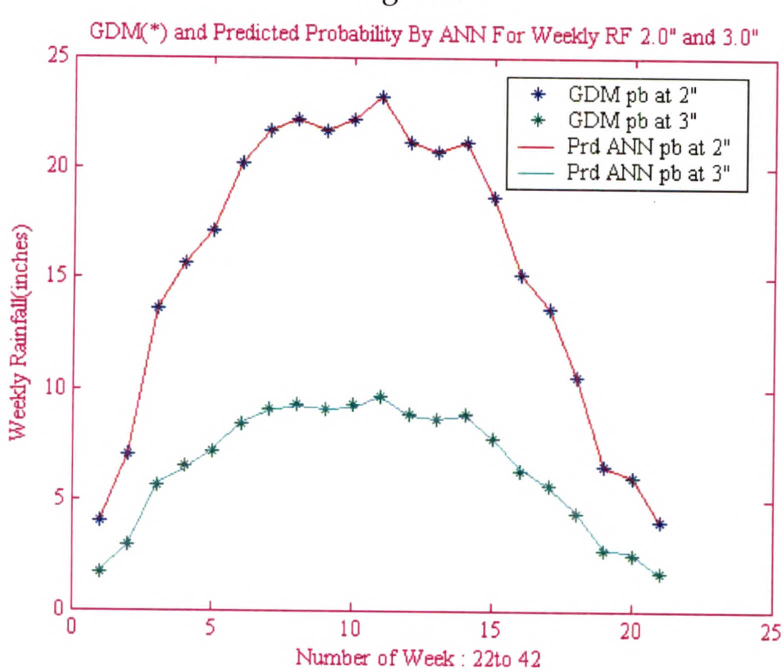


Fig: 4.27

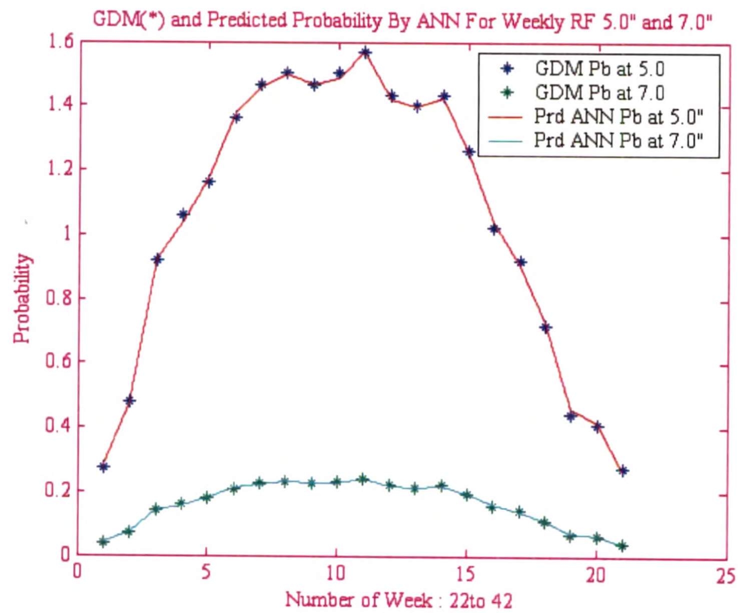


Fig: 4.28

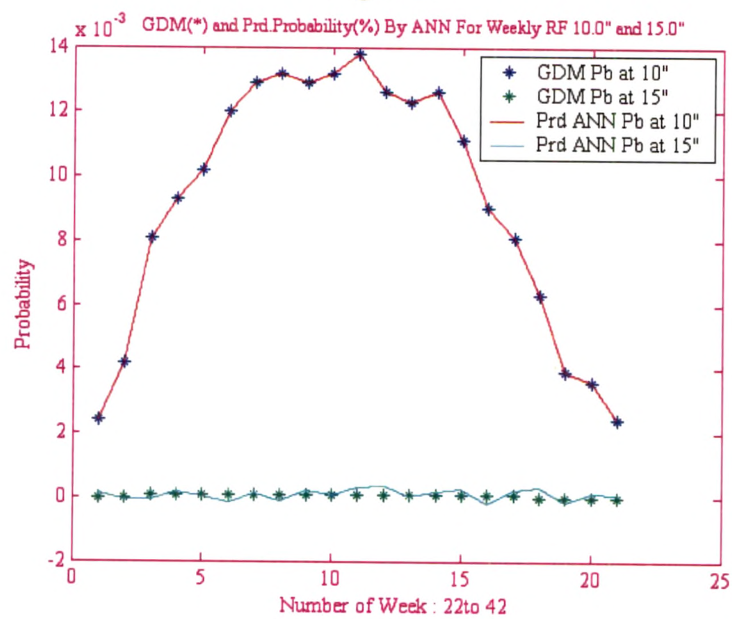


Fig: 4.29

4.4.2.3 CONCLUSION

Computation of the probabilities (PBs) by ANN is significant to PBs found by GDM. GDM PBs is significant to the actual probabilities (PBs). Therefore, probabilities (PBs) by ANN are also significant to actual probabilities (PBs).

4.5 CONCLUSION FOR USED TWO METHODS.

The Gamma Distribution Model and Artificial Neural Network Model used to predict the probabilities of getting certain fixed amount of weekly rainfall are found significant to actual probabilites.