CHAPTER IV

EXPERIMENTAL CONSIDERATIONS

Twelve gaging stations on the Mae Klong basin are selected for this investigation, three stations are on the Kwae Yai river, three on the Kwae Noi river, one on the Lam Taphoen river, one on the Lam Pachee river, and four on the Mae Klong river as shown in Fig 2. Number of years of records, catchment area, and location of each station are shown in Table 1.

Table 1 Detail of Available Data in the Mae Klong Basin

Station	River	Location	Years of record	Catchment area (sq.km.)
K1	Mae Klong	Ban Tha Pha	1965-1967,	-
K2	Mae Klong	Ratchaburi	1964-1967	-
K4	Mae Klong	Tha Muang	1939-1970	27,220
K6	Kwae Yai	Kaeng Riang	1952-1973	11,789
K9	Kwae Noi	Wang Pho	1962-1973	6,902
K10	Kwae Noi	Ban Lum Sum	1965-1973	7,008
K11	Mae Klong	Wang Khanai	1965-1973	27,228
K12	Lam Taphoen	Ban Thung Na Nang Rok	1965-1969	2,340
K13	Kwae Noi	Ban Tha Khanun	1965-1973	4,047
K17	Lam Pachee	Frontier Police Station	1966-1972	1,355
K19	Kwae Yai	Ban Ong Kha	1966-1973	9,216
K20	Kwae Yai	Kwae Wang Masang	1966-1973	11,963

ANALYSIS OF RECORDED DATA

4.1 Relationship between Runoff (flow) and Catchment area.

Eight gaging stations, K6, K9, K10, K12, K13, K17, K19 and K20 are used in the analysis. Stations K1, K2, K4 and K11 are not included in the investigation because these stations are located on the main stream (Mae Klong river), but the other eight's are located on the tributaries.

From Table 1, the length of concurrent records available for investigation from these gaging stations is six years (1966-1972) but station K12 has 3 years record (1966-1969) only.

$$\overline{Q}_a = \frac{\sum_{i=1}^{6} Q_a}{6}$$

and

$$\overline{Q}_m = \frac{\sum_{i=1}^{6} Q_m}{6} \qquad \text{etc.}$$

From equation (1) $Q = K_1 A^{n_1}$

where Q = Average maximum and minimum monthly flow, average maximum and minimum annual flow and average annual and monthly flow in cms. as shown in Appendix IV, A = catchment area in sq.km.

K_1, n_1 are constants obtained by fitting a least square regression line to the available data on a log-log paper.

$$\text{From} \quad Q = K_1 A^{n_1}$$

$$\log Q = \log K_1 + n_1 \log A$$

which is an equation of a straight line.

By the least square method

$$\log K_1 = \frac{\sum_{i=1}^{N} \log Q_i \sum_{i=1}^{N} (\log A_i)^2 - \sum_{i=1}^{N} \log A_i \sum_{i=1}^{N} \log A_i . \log Q_i}{N \sum_{i=1}^{N} (\log A_i)^2 - (\sum_{i=1}^{N} \log A_i)^2} \qquad \ldots(34)$$

$$n_1 = \frac{N \sum_{i=1}^{N} \log A_i \log Q_i - \sum_{i=1}^{N} \log A_i \sum_{i=1}^{N} \log Q_i}{N \sum_{i=1}^{N} (\log A_i)^2 - (\sum_{i=1}^{N} \log A_i)^2} \qquad \ldots(35)$$

where N is number of stations which are used in the analysis.

The values of K_1 and n_1 are obtained from equations (34) and (35) and a computer programming can be used to calculate K_1 and n_1. The Fortran IV program is shown in the Appendix III, the results are shown in Table 2, 3 and 4 and graph of results are shown in Appendix II.

The runoff - catchment area relation of maximum annual flow, minimum annual flow and minimum monthly flow of return period 2.33-yr, 10-yr, 20-yr, 50-yr, and 100-yr are also found and the results are shown in Table 5 and 6.

Table 2. The values of K_1 and n_1 of Average Annual and Monthly Flows

	Set (1)*		Set (2)*		Set (3)***	
	K_1	n_1	K_1	n_1	K_1	n_1
April	$.21595 \times 10^{-6}$	2.0131	$.80730 \times 10^{-7}$	2.1225	$.19540 \times 10^{-8}$	2.5171
May	$.67007 \times 10^{-5}$	1.6859	$.82142 \times 10^{-6}$	1.9192	$.60462 \times 10^{-7}$	2.1969
June	$.99936 \times 10^{-7}$	2.2508	$.81937 \times 10^{-8}$	2.5287	$.51813 \times 10^{-11}$	3.3170
July	$.85949 \times 10^{-8}$	2.6176	$.73847 \times 10^{-9}$	2.8904	$.12107 \times 10^{-12}$	3.8224
August	$.39465 \times 10^{-8}$	2.7698	$.13840 \times 10^{-9}$	3.1422	$.14187 \times 10^{-13}$	4.1257
Sept.	$.13924 \times 10^{-6}$	2.3797	$.10295 \times 10^{-7}$	2.6692	$.60158 \times 10^{-11}$	3.4682
Oct.	$.14888 \times 10^{-3}$	1.5600	$.52145 \times 10^{-5}$	1.9325	$.61041 \times 10^{-7}$	2.4077
Nov.	$.61754 \times 10^{-5}$	1.8173	$.55903 \times 10^{-7}$	2.3402	$.47220 \times 10^{-9}$	2.8468
Dec.	$.10671 \times 10^{-4}$	1.6875	$.25951 \times 10^{-8}$	2.6124	$.14142 \times 10^{-10}$	3.1645
Jan.	$.17165 \times 10^{-6}$	2.0991	$.13367 \times 10^{-8}$	2.6388	$.74930 \times 10^{-11}$	3.1883
Feb.	$.44079 \times 10^{-7}$	2.2153	$.20439 \times 10^{-8}$	2.5567	$.16188 \times 10^{-10}$	3.0695
March	$.24969 \times 10^{-6}$	2.0020	$.21353 \times 10^{-6}$	2.0194	$.62312 \times 10^{-8}$	2.3941
Annual	$.24294 \times 10^{-5}$	1.9526	$.61804 \times 10^{-7}$	2.3605	$.10241 \times 10^{-9}$	3.0457

* Set (1) All 8 gaging stations (K6, K9, K10, K12, K13, K17, K19, K20) are used.

** Set (2) 7 gaging stations (K6, K9, K10, K12, K13, K19, K20) are used.

*** Set (3) 5 gaging stations (K6, K9, K10, K12, K20) are used.

Table 3. The values of K_1 and n_1 of Average Maximum Annual and Monthly Flows

	Set (1)		Set (2)		Set (3)	
	K_1	n_1	K_1	n_1	K_1	n_1
April	$.28500 \times 10^{-4}$	1.5247	$.11831 \times 10^{-3}$	1.3665	$.16184 \times 10^{-4}$	1.5796
May	$.46693 \times 10^{-3}$	1.3185	$.95714 \times 10^{-3}$	1.2387	$.18731 \times 10^{-4}$	1.6622
June	$.14868 \times 10^{-4}$	1.7808	$.14155 \times 10^{-5}$	2.0421	$.17391 \times 10^{-8}$	2.7619
July	$.94434 \times 10^{-7}$	2.4729	$.50780 \times 10^{-9}$	3.0537	$.43154 \times 10^{-13}$	4.0569
Aug.	$.68364 \times 10^{-7}$	2.5325	$.3510 \times 10^{-9}$	3.1184	$.37736 \times 10^{-13}$	4.0964
Sept.	$.17366 \times 10^{-5}$	2.1712	$.36180 \times 10^{-7}$	2.6014	$.10137 \times 10^{-10}$	3.4767
Oct.	$.28770 \times 10^{-1}$	1.0459	$.12905 \times 10^{-3}$	1.6569	$.22282 \times 10^{-5}$	2.0807
Nov.	$.69763 \times 10^{-3}$	1.3595	$.12088 \times 10^{-6}$	2.3220	$.21093 \times 10^{-8}$	2.7486
Dec.	$.88405 \times 10^{-3}$	1.2298	$.41054 \times 10^{-8}$	2.5947	$.29675 \times 10^{-10}$	3.1152
Jan.	$.45817 \times 10^{-6}$	2.0107	$.15819 \times 10^{-8}$	2.6407	$.87248 \times 10^{-11}$	3.1911
Feb.	$.12221 \times 10^{-6}$	2.1198	$.19862 \times 10^{-8}$	2.5776	$.13268 \times 10^{-10}$	3.1096
Mar.	$.95493 \times 10^{-4}$	1.3765	$.37078 \times 10^{-3}$	1.2258	$.44059 \times 10^{-4}$	1.4527
Annual	$.11472 \times 10^{-1}$	1.2385	$.20196 \times 10^{-3}$	1.6875	$.35101 \times 10^{-6}$	2.3769

Table 4. The valuesof K_1 and n_1 of Average Minimum Annual and Monthly Flows

	Set (1)		Set (2)		Set (3)	
	K_1	n_1	K_1	n_1	K_1	n_1
Apr.	$.21235 \times 10^{-8}$	2.4942	$.54947 \times 10^{-9}$	2.6444	$.48171 \times 10^{-11}$	3.145
May	$.95654 \times 10^{-7}$	2.0873	$.67275 \times 10^{-8}$	2.3824	$.12563 \times 10^{-9}$	2.802
Jun.	$.38568 \times 10^{-8}$	2.5282	$.66526 \times 10^{-9}$	2.7234	$.13040 \times 10^{-11}$	3.387
Jul.	$.80969 \times 10^{-9}$	2.7823	$.97070 \times 10^{-9}$	2.7621	$.46658 \times 10^{-12}$	3.576
Aug.	$.52236 \times 10^{-9}$	2.9347	$.11240 \times 10^{-9}$	3.1055	$.20137 \times 10^{-13}$	4.026
Sept.	$.43434 \times 10^{-9}$	2.9612	$.31619 \times 10^{-10}$	3.2524	$.88472 \times 10^{-14}$	4.125
Oct.	$.29304 \times 16^{-6}$	2.1849	$.38953 \times 10^{-8}$	2.6651	$.99432 \times 10^{-11}$	3.300
Nov.	$.41815 \times 10^{-6}$	2.0695	$.12069 \times 10^{-7}$	2.4635	$.70870 \times 10^{-10}$	3.008
Dec.	$.44213 \times 10^{-6}$	2.0139	$.14414 \times 10^{-8}$	2.6502	$.69840 \times 10^{-11}$	3.215
Jan.	$.73246 \times 10^{-7}$	2.1744	$.14659 \times 10^{-8}$	2.6091	$.96998 \times 10^{-11}$	3.141
Feb.	$.13578 \times 10^{-7}$	2.3305	$.11955 \times 10^{-8}$	2.6005	$.92519 \times 10^{-11}$	3.115
Mar.	$.54553 \times 10^{-8}$	2.4013	$.11088 \times 10^{-8}$	2.5784	$.10842 \times 10^{-10}$	3.068
Annual	$.15515 \times 10^{-10}$	3.0313	$.20658 \times 10^{-9}$	2.7436	$.14566 \times 10^{-11}$	3.267

Table 5. The Values of K_1 and n_1 of Maximum Annual Flow at Any Return Period

Return Periods, T years	Set (1)		Set (2)		Set (3)	
	K_1	n_1	K_1	n_1	K_1	n_1
2.33	$.73660 \times 10^{-2}$	1.3108	$.22043 \times 10^{-3}$	1.7009	$.69270 \times 10^{-6}$	2.3225
10	$.22245 \times 10^{-1}$	1.2381	$.69241 \times 10^{-3}$	1.6238	$.24864 \times 10^{-5}$	2.2300
20	$.29669 \times 10^{-1}$	1.2222	$.92627 \times 10^{-3}$	1.6075	$.34154 \times 10^{-5}$	2.2106
50	$.39799 \times 10^{-1}$	1.2073	$.12440 \times 10^{-2}$	1.5925	$.46949 \times 10^{-5}$	2.1929
100	$.47668 \times 10^{-1}$	1.1990	$.14902 \times 10^{-2}$	1.5841	$.56930 \times 10^{-5}$	2.1830

Table 6. The Values of K_1 and n_1 of Minimum Annual and Monthly Flows of Return Period of 2.33-Year

	Set (1)		Set (2)		Set (3)	
	K_1	n_1	K_1	n_1	K_1	n_1
Apr.	$.83805 \times 10^{-12}$	3.3407	$.25050 \times 10^{-11}$	3.2190	$.49808 \times 10^{-14}$	3.8757
Dec.	$.11554 \times 10^{-8}$	2.6516	$.14527 \times 10^{-10}$	3.1380	$.17514 \times 10^{-13}$	3.8517
Annual	-	-	$.35813 \times 10^{-16}$	4.4326	$.55223 \times 10^{-20}$	5.3590

N.B. April and December only

4.2 Flood and Drought Magnitudes at Any Return Period

Flood Magnitude

Maximum annual flow data of station K4, K6, K9, K11, K12, K13, K17, K19, K10 and K20 as shown in Appendix IV are used in this investigation to find the flood magnitude at any return period range from 1 to 1000 years.

1. Plotting Positions formulas: Equation (4), (5), (6), (8), (9), (10), and (11) are used.

2. Gumbel's formula ($P_X = e^{-e^{-y}}$): Equations (12), (13), (14), (15), (16) and (18) are used. Equation (16) gives the exact value of the flood magnitude at any return period T_X but the equation (18) is a simplified formula to find the flood at any return period, T_X. For T_X more than 20 years, an error is less than 0.7 percent.

Fortran IV program used to calculate the return period and the flood magnitude is shown in Appendix III.

The results are shown in Table 7 and Appendix I.

The results from Gumbel's formula equation (16) and from Weibull formula equation (6) are plotted on Gumbel's paper as shown in Appendix II.

Drought Magnitude

Minimum annual flows and Minimum monthly flows of April, December and February of stations K4, K6, K9, K10, K11, K12, K13, K17, K19 and K20, are used in the calculation to find the relationship between the drought magnitude and the return period ranging from 1 to 1000 years.

1. Plotting Positions formulas: Equation (4), (5), (6), (8), (9), (10) and (11) are used.

2. Gumbel's formula ($P_{X_1} = e^{-e^{y}}$) : Equation (21), (22), (23), (24) and (25) are used.

Fortran IV program for these calculations is shown in Appendix III. The results are shown in Table 8 and Appendix I.

The results obtained from the use of Gumbel's formula (equation (25)) and of Weibull formula (equation (6)) are plotted on Gumbel's paper as shown in Appendix II.

4.3 Correlation

Equation (33) is used to find the correlation between data from two gaging stations in the Mae Klong basin. To simplify the calculation, the monthly flow data as shown in Appendix IV, are used instead of the daily flow data.

Fortran IV program used in calculating the result is shown in Appendix III.

The results are shown in Table 9.

Table 7 Estimated flood maginitude at any return period T_x by Gumbel's formula

Station K_4

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	2420.7970	2626.9760
5	3131.5310	3215.9970
10	3710.4130	3750.6940
20	4265.6910	4285.3900
50	4984.4400	4992.2200
100	5523.0430	5526.9170
200	6059.6810	6061.6140
500	6767.6710	6768.4440
1,000	7302.7540	7303.1410

Station K_6

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	1159.6260	1280.9740
5	1577.9320	1627.6440
10	1918.6360	1942.3430
20	2245.4460	2257.0410
50	2668.4690	2673.0480
100	2985.4660	2987.7460
200	3301.3070	3302.4440
500	3717.9970	3718.4520
1,000	4032.9220	4033.1500

Station K_9

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	1818.6160	1937.9410
5	2229.9490	2278.8330
10	2564.9730	2588.2850
20	2886.3370	2897.7380
50	3302.3090	3306.8110
100	3614.0220	3616.2640
200	3924.5970	3925.7160

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
500	4334.3430	4334.7900
1,000	4644.0180	4644.2420

Station K_{10}

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	1897.4350	2030.3100
5	2355.4750	2409.9100
10	2728.5410	2754.5010
20	3086.3950	3099.0910
50	3549.6010	3554.6140
100	3896.7090	3899.2050
200	4242.5500	4243.7950
500	4698.8210	4699.3190
1,000	5043.6600	5043.9100

Station K_{11}

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	2119.0060	2241.1420
5	2540.0300	2590.0660
10	2882.9480	2906.8090
20	3211.8830	3223.5520
50	3637.6550	3642.2640
100	3956.7130	3959.0070
200	4274.6050	4275.7510
500	4694.0050	4694.4620
1,000	5010.9760	5011.2060

Station K_{12}

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	21.5156	24.5331
5	31.9175	33.1537
10	40.3898	40.9793
20	48.5165	48.8048
50	59.0358	59.1496
100	66.9185	66.9752
200	74.7725	74.8008

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
500	85.1343	85.1456
1,000	92.9655	92.9711

<u>Station K_{13}</u>

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	1800.6570	1976.4970
5	2406.8060	2478.8430
10	2900.5060	2934.8590
20	3374.0740	3390.8740
50	3987.0590	3993.6940
100	4446.4060	4449.7100
200	4904.0770	4905.7250
500	5507.8860	5508.5450
1,000	5964.2310	5964.5610

Station K_{17}

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	157.7677	177.3705
5	225.3418	233.3725
10	280.3798	284.2095
20	333.1736	335.0466
50	401.5097	402.2494
100	452.7182	453.0865
200	503.7397	503.9235
500	571.0529	571.1263
1,000	621.9266	621.9634

Station K_{19}

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	767.8229	844.2653
5	1031.3320	1062.6480
10	1245.9560	1260.8900
20	1451.8290	1459.1330
50	1718.3100	1721.1940
100	1918.0000	1919.4370
200	2116.9620	2117.6790

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
500	2379.4540	2379.7410
1,000	2577.8400	2577.9830

Station K_{20}

T_x (year)	Estimated flood magnitude (cms.)	
	Equation (16)	Equation (18)
2.33	739.6403	808.3762
5	976.5840	1004.7430
10	1169.5710	1182.9990
20	1354.6890	1361.2560
50	1594.3040	1596.8980
100	1773.8630	1775.1540
200	1952.7660	1953.4110
500	2188.7960	2189.0530
1,000	2367.1810	2367.3100

Table 8 Estimated Drought Magnitude at any return period, T_{X_1} by Gumbel's formula

T_{X_1} year	K4	K6	K9	K10	K11	K12	K13	K17	K19	K20
Annual										
2.33	29.6186	13.1742	9.7322	10.0399	29.7553	0.0023	6.9848	0	12.5245	14.1065
5	19.7211	9.9727	7.5403	7.3813	19.3966	0	5.4781		10.7788	11.0028
10	11.6599	7.3651	5.7551	5.2159	10.9595		4.2509		9.3571	8.4748
20	3.9273	4.8638	4.0426	3.1388	2.8665		3.0737		7.9932	6.0500
30	0	3.4248	3.0574	1.9438	0		2.3965		7.2087	4.6550
40		2.4104	2.3629	1.1014			1.9190		6.6555	3.6715
50		1.6261	1.8260	0.4502			1.5499		6.2279	2.9112
100		0	0.1650	0			0.4081		4.9051	0.5592

*Drought in cms.

T_{X_1} year	K4	K6	K9	K10	K11	K12	K13	K17	K19	K20
<u>April</u>										
2.33	38.8125	14.9182	11.1724	11.4081	30.7757	0.0282	8.5211	0.0207	13.6693	15.2945
5	27.4305	10.8671	9.5003	9.0430	18.0418	0	7.7863	0	11.9442	11.6764
10	18.1599	7.5676	8.1384	7.1166	7.6701		7.1879		10.5391	8.7295
20	9.2674	4.4027	6.8320	5.2688	0		6.6138		9.1913	5.9028
30	4.1517	2.5819	6.0805	4.2058			6.2835		8.4160	4.2766
40	0.5451	1.2983	5.5506	3.4564			6.0507		7.8694	3.1301
50	0	0.3060	5.1410	2.8770			5.8707		7.4468	2.2439
100		0	3.8739	1.0847			5.3139		6.1395	0

T X_1 year	K4	K6	K9	K10	K11	K12	K13	K17	K19	K20
December										
2.33	111.8241	41.3331	31.0464	36.9742	91.7554	0.0794	28.3470	0.4449	33.2156	40.3539
5	87.3880	29.0720	23.6917	29.8789	64.7560	0	26.2322	0	23.8217	32.5317
10	67.4851	19.0854	17.7013	24.0998	42.7655		24.5097		16.1704	26.1606
20	48.3939	9.5061	11.9552	18.5564	21.6716		22.8574		8.8312	20.0493
30	37.4109	3.9952	8.6496	15.3674	9.5365		21.9069		4.6090	16.5335
40	29.6679	0.1101	6.3191	13.1191	0.9814		21.2368		1.6324	14.0549
50	23.6822	0	4.5175	11.3811	0		20.7187		0	12.1388
100	5.1643		0	6.0042			19.1161			6.2110

T_{X_1} year	K4	K6	K9	K10	K11	K12	K13	K17	K19	K20
<u>February</u>										
2.33	57.1781	21.3442	17.5469	17.7501	49.3965	0	12.5192	0.1534	18.7759	21.7171
5	42.1048	15.8392	14.5551	14.0206	35.9332		10.4277	0	16.2057	17.3732
10	29.8278	11.3555	12.1184	10.9830	24.9676		8.7243		14.1124	13.8351
20	18.0515	7.0545	9.7810	8.0692	14.4491		7.0902		12.1044	10.4412
30	11.2767	4.5803	8.4363	6.3930	8.3978		6.1502		10.9493	8.4887
40	6.5005	2.8359	7.4883	5.2112	4.1318		5.4875		10.1349	7.1122
50	2.8082	1.4875	6.7554	4.2977	0.8339		4.9752		9.5053	6.0482
100	0	0	4.4882	1.4714	0		3.3903		7.5576	2.7562

Table 9. Correlation coefficient of Monthly flow for Various Stations

Stations X	Stations Y	Period of Correlation	Correlation Coefficient (r)
K4	K1	1965-1967	.9967
	K2	1964-1967	.9836
	K6	1952-1957, 1963-1969	.9605
	K9	1963-1969	.9542
	K11	1965-1969	.9985
	K12	1965-1969	.3596
K6	K9	1962-1972	.8344
	K12	1965-1969	.3978
	K17	1966-1972	.2638
	K19	1966-1972	.9767
	K20	1966-1972	.9805
K9	K10	1965-1972	.9962
	K11	1965-1972	.9604
	K12	1965-1969	.2336
	K13	1965-1972	.9896
	K17	1966-1972	.1173
K12	K17	1966-1969	.6415
K13	K19	1966-1972	.8525