CHAPTER I

1.1 Introduction

The lower part of the Mae Klong basin from Karnchanaburi to the Gulf coast suffers not only from too much water but also from too little water at a certain time of the year. The former is due to the capacity of the lower part of the river being less than the combined flow of the Kwai Yai and Kwai Noi rivers causes flooding.. Lack of sufficient precipitation leads to the latter and drought occurs. This leads to many problems as follows:-

1. Flooding can cause enormous damages on crops, buildings, properties and human lives in the area below Karnchanaburi, especially in Rajburi.

2. Droughts may cause irrigation projects to fail, because in the period of drought the quantity of water is not enough for irrigation purposes.

3. The Mae Klong river at Rajburi and its downstream may be polluted due to many factories, such as sugar factories, paper factories, etc. from Karnchanaburi to Samuthsongkram. These factories drain a large volume of waste water into the river, so that in the dry season, the flow of river is in-sufficient for diluting the waste. River pollution causes more damages on crops, fish-farms, oyster-farms, etc.

In order to solve these problems, some hydrologic characteristics of the Mae Klong basin must be studied. The purpose of this study is to obtain basic characteristics of basin, namely,

1. the relation of the run-off to the drainage area,
2. the maximum annual and monthly flows of any return period at each gaging station in the basin,

3. the minimum annual and monthly flows of any return period at each gaging station in basin, and

4. the correlation of the flows at the various gaging stations.

1.2 Literature Review

There are many past investigations which relate the run off to the catchment characteristics. Some of them are reviewed here as follows:-

LEOPOLD and MILLER (1956) found relationship between the flood discharge and the catchment area of 12 streams of Central New Mexico as shown below

$$Q_{2.33} = 12A^{0.79}$$

where $Q_{2.33}$ = flood discharge with return period of 2.33 years in cfs.

A = drainage area in square miles

HACK (1957) studied the relationship between the catchment area in sq.mi. and the average discharge in cfs. of the Potomac River basin and found that

$$Q_{ave} = KA$$

where Q_{ave} = average discharge in cfs.

A = drainage area in sq.mi.

K = constant depending on the catchment characteristics

FANNING showed that an extreme discharge can be estimated by

$$Q_{max} = 2.56\ A^{5/6}$$

where Q_{max} = extreme flood discharge in cms.

A = catchment area in sq.km.

Other formulas for the extreme discharge in relation with the catchment area are

$$Q\ (\text{cms.}) = 10.11\ A^{2/3}(\text{sq.km.}) \quad \text{by RAVES}$$

$$= 31.6\ A^{1/2}(\text{sq.km.}) \quad \text{by DICKENS}$$

$$= 176\ A^{1/2}(\text{sq.km.}) \quad \text{by MYER}$$

CARTER (1961) developed an empirical equation relating the mean annual flood to the lag time, drainage area, and percentage of impervious cover, to determine the effect urbanization on the mean annual flood ($Q_{2.33}$) in the vicinity of Washington D.C. This equation is

$$Q_{2.33} = 223\ KA^{0.85}\quad T_3^{-0.45}$$

where $Q_{2.33}$ = mean annual flood in cfs which is equivalent to the flood having a recurrence interval of 2.33-yr.

A = drainage area in sq.mi.

T_3 = lag time expressed in hours

K = an adjustment factor based upon the degree of imperviousness of the area

The factor K was expressed as

$$K = \frac{0.30 + 0.0045I}{0.30}$$

where I = percentage of impervious cover

AHMAD (1962) studied the maximum observed flood of 25 stations of rivers in Thailand and found that

$$Q_{obs} = K_1 A^{1/2}$$

where Q_{obs} = maximum observed flood in cms.

A = catchment area in sq.km.

K_1 = a factor varying from 3.2 to 39.0

and

$$Q_{25} = K_1 A^{1/2}$$

where Q_{25} = flood of 25-yr. return period

K_1 = a factor varying from 7.0 to 40.0

From the results obtained, he concluded that for the same river, the value of K_1 decreased from its source to its mouth and this was due to the effects of the tributaries or the variations in channel profile, the absorptive capacity and the precipitation. He compared his results with the K_1 values of the great rivers of the world which varies from 2 to 70. Finally he found the relationship between the flood magnitude, the return period, and the catchment area and this is shown below

$$Q_T = 90\ (1 + 0.37\ \ln T)\ A^{0.3}$$

where Q_T = flood of return period T years in cms.

A = catchment area in sq.km.

BENSON (1962) studied the relationship between the flood peaks, the physiographic factors and the hydrographic factors of the basin in the Western Gulf of Mexico. Multiple regression analysis was used to develop the relationship between the peak discharges for various recurrence intervals and topographic and climatic factors. The equations are as follows:-

$$Q_{2.33} = 22.9\, A^{1.20}\, P^{1.57}\, L^{-1.10}$$

$$Q_{2.33} = 19.7\, A^{1.24}\, S_t^{-1.42}\, P^{1.62}\, L^{-1.10}$$

$$Q_{5} = 51.5\, A^{1.05}\, S_t^{-1.81}\, P^{1.49}\, L^{-0.83}$$

$$Q_{10} = 2.08\, A^{.71}\, S^{.43}\, S_t^{-1.45}\, P^{2.36}$$

$$Q_{10} = 4.05\, A^{1.05}\, S^{.38}\, S_t^{-1.53}\, P^{2.28}\, L^{-0.63}$$

$$Q_{25} = 1.11\, A^{.97}\, S^{.63}\, P^{2.68}\, L^{-0.43}$$

$$Q_{50} = 4.49\, A^{.95}\, S^{.61}\, P^{2.28}\, L^{-0.49}$$

$$Q_{100} = 0.257\, A^{1.07}\, S^{1.01}\, P^{3.17}\, L^{-0.47}$$

where

A	=	drainage area, sq.mi.
P	=	rainfall intensity for given duration, in./hr.
S	=	main-channel slope
L	=	basin length, miles
S_t	=	surface area of lakes and ponds, sq.mi.

CHOW (1964) found that

$$Q_{obs} = K_1 A^{n_1}$$

where Q_{obs} = some measured discharge in cfs. or cms. such as average annual flood or average annual run-off

A = catchment area in sq.mi. or sq.km.

n_1 = an index varying from 0.5 to 1.0

K_1 = a constant

NEMEC (1964) suggested that for the small basins without stream gaging records of any kinds, the flood peak flow can be estimated by the rational formula

$$Q_{max} = iKA$$

where Q_{max} = peak flow

i = given maximum value of rainfall intensity

K = runoff coefficient

A = basin area

However, the formula was suitable for storm sewer computation. For small catchments with relatively unimportant projects, the following exponential formula was used

$$Q_{max} = BA^{1-B_1} \varepsilon_0$$

where Q_{max} = peak flow in cms.

A = catchment area in sq.km.

B and B_1	=	regional parameters
ε_0	=	correction of a local nature for forested areas, slopes, etc.

For a minimum flow he suggested the use of the M.E. Shevelev's equation

$$\overline{Q}_{m_{min}} = KA^{0.034} \quad \overline{Q}_a^{\;0.94}$$

where	$\overline{Q}_{m_{min}}$	=	the average minimum monthly discharge in litre/sec
	$\overline{Q}_a$	=	average annual runoff in litre/sec
	A	=	catchment area in sq.km.
	K	=	regional coefficient (its average value is 0.115)

COLE (1965) showed that the relationship between the mean annual flood ($Q_{2.33}$) and the catchment area in England and Wales was

$$Q_{2.33}(\text{cfs}) = K_1 A^{0.85} \text{ (sq.mi.)}$$

He compared the value of the exponent with that obtained elsewhere. For instance, Cross and Webber (1959) found the value of the exponent to be 0.8 for Ohio, Carter (1951) obtained 0.8 for all. of Georgia except the rivers draining the swamp area to the south, Cragwall (1952) obtained a value of about 0.65 for Louisiana. In general, the regions with climates and topographics more similar to those of England and Wales seem to have the higher values, probably not exceeding about 0.9.

MORGAN (1965) proposed the formulas for Scotland and Wales as shown below

$$q = 3000\,A^{-1/2}$$

$$Q_{max} = 3000\,A^{1/2}$$

where q = flood discharge in cfs/sq.mi.

Q_{max} = flood or peak discharge in cfs

A = catchment area in sq.mi.

The formulas used in various countries were

$$Q_{max} = K_1 A^{3/4} \quad \text{for India,}$$

$$= K_1 A^{1/2} \quad \text{for Quebec, Greece,}$$

$$= K_1 A^{1/3} \quad \text{for Italy,}$$

$$= K_1 A^{1/2} \quad \text{for U.S.A. (Mayer's Formula),}$$

$$= K_1 A^{(0.894A)^{-0.048}} \quad \text{(Creager's formula)}$$

BISWAS (1965) proposed the formulas in these forms

$$Q_{max} = K_1 A^{n_1}$$

where K_1 = a constant for a particular area

A = catchment area in sq.mi.

n_1 = an index, varying from 0.13 to 1.75 but the majority of such formula use values between 0.5 to 0.75

He also showed that in India, in general, the following Ryve's formula can be used.

$$Q_{max} = K_1 A^{0.67}$$

The values of K_1 depended on soil, rainfall intensity, slope, etc. and, in general, were

450 - within 15 miles of coast
560 - 15 to 100 miles inland
675 - limited area near hills

BALAYO (1967) studied the Ping River in the Thailand and obtained the following results,

1) The average monthly runoff, $\bar{Q}_m$ varied with the exponential function of the area in the form

$$\bar{Q}_m (\text{cms.}) = K_1 A^{n_1} (\text{sq. km.})$$

The exponential n_1 ranged from 0.923 to 1.225 in all the month of the year and the average is 1.07.

2) The average annual runoff, $\bar{Q}_a$ varied with the exponential function of the area in the form

$$\bar{Q}_a = 0.00448 A^{1.105}$$

PINKAYAN and SAHAGUN (1973) did a hydrologic study of the Thung Ma Hiu Project in Thailand and found that,

$$\bar{Q}_a = 0.029 A^{0.870}$$

$$\bar{Q}_a = 2.467 \times 10^{-5} A^{1.033} R^{3.954}$$

where $\overline{Q}_a$ = average annual stream flow in cms.,

A = drainage area in sq.km.

R = catchment annual rainfall in m.m.

ESPEY and WINSLOW (1974) used data from 60 watersheds in Texas and East Coast to develop empirical equations which predict the peak flow for a specified recurrence interval.

First step was the generation of flood frequency curves for all watersheds by using the Log-Pearson Type III method. From the flood frequency analysis, the 2.33-yr, 5-yr, 10-yr, 20-yr and 50-yr recurrence interval peak flow for each watershed were determined.

By a multiple regression analysis of the 27 Texas watersheds the following equations were formed.

$$Q_{2.33} = 116\, A^{0.75}\, I^{0.28}\, \phi^{-1.09}$$

$$Q_{5} = 159\, A^{0.77}\, I^{0.27}\, \phi^{-1.23}$$

$$Q_{10} = 193\, A^{0.78}\, I^{0.27}\, \phi^{-1.40}$$

$$Q_{20} = 226\, A^{0.79}\, I^{0.27}\, \phi^{-1.58}$$

$$Q_{50} = 268\, A^{0.79}\, I^{0.26}\, \phi^{-1.83}$$

$$Q_{5} = 1.07\, Q_{2.33}^{1.04},$$

$$Q_{10} = 1.110\, Q_{2.33}^{1.07},$$

$$Q_{20} = 1.14\, Q_{2.33}^{1.09},$$

$$Q_{50} = 1.19\, Q_{2.33}^{1.11}$$

And for the 26 East Coast watersheds, the derived equations are as shown below

$$Q_{2.33} = 11700\ A^{0.73}\ S^{0.75}$$

$$Q_{5} = 16800\ A^{0.75}\ S^{0.76}$$

$$Q_{10} = 19800\ A^{0.67}\ S^{0.75}$$

$$Q_{20} = 21000\ A^{0.77}\ S^{0.72}$$

$$Q_{50} = 21200\ A^{0.78}\ S^{0.68}$$

$$Q_{5} = 1.11\ Q_{2.33}^{1.04}$$

$$Q_{10} = 1.20\ Q_{2.33}^{1.06}$$

$$Q_{20} = 1.30_{2.33}^{1.08}$$

$$Q_{50} = 1.40\ Q_{2.33}^{1.10}$$

Finally, a total of 60 watersheds, including all the Texas and East Coast watersheds, as well as four other watersheds from Missisippi, two from Michigan,, and one from Illinois, were used in the regression analysis. The equations obtained are shown below

$$Q_{2.33} = 169\ A^{0.77}\ I^{0.29}\ S^{0.42}\ R_{2.33}^{1.80}\ \emptyset^{-1.17}$$

$$Q_{5} = 172\ A^{0.80}\ I^{0.27}\ S^{0.43}\ R_{5}^{1.73}\ \emptyset^{-1.21}$$

$$Q_{10} = 178\ A^{0.82}\ I^{0.26}\ S^{0.44}\ R_{10}^{1.71}\ \phi^{-1.32}$$

$$Q_{20} = 243\ A^{0.84}\ I^{0.24}\ S^{0.48}\ R_{20}^{1.62}\ \phi^{-1.38}$$

$$Q_{50} = 297\ A^{0.85}\ I^{0.22}\ S^{0.50}\ R_{50}^{1.57}\ \phi^{-1.61}$$

$$Q_{5} = 1.13\ Q_{2.33}^{1.03},$$

$$Q_{10} = 1.24\ Q_{2.33}^{1.05},$$

$$Q_{20} = 1.34\ Q_{2.33}^{1.06},$$

$$Q_{50} = 1.47\ Q_{2.33}^{1.03}$$

where $Q_{2.33}$, Q_5, ... = peak flows, in cfs. of recurrence interval 2.33, 5, ...yr.,

A = drainage area, in sq.mi.

S = slope of the channel in ft./ft.

I = percentage of impervious cover,

ϕ = channel urbanization factor which is dimensionless,

R = rainfall, in inches for 6-hr duration.

AHMAD (1962) studied the flood magnitude in Thailand in relation to the return period by using Gumbel's formula and the results are shown below

River	Gaging Station	Period of Record years	Catchment Area, sq.km	100-yr Flood cms.	1,000-yr Flood cms.	Max. Observed Flood. cms.	Specific Flood lit/S/sq.km.	
							100-yr	1,000-yr
Mae Wang	Rashdabhisek	29	3,432	2,360	3,340	1,860	688	977
Mae Nan	Nai Wieng	26	4,558	3,222	4,266	2,628	706	932
Mae Ping	Nawarath Bridge	40	6,304	673	839	602	107	133
Mae Klong	Ban Tham	19	8,120	4,238	5,336	3,430	522	656
Mae Nan	Tha It	15	16,500	4,422	5,743	3,300	268	348
Pasak	Kang Koy	25	17,100	1,166	1,545	941	68	94
Mae Ping	Tha Kae	25	39,163	6,002	7,930	4,770	153	203
Chao Phaya	Wad Tha Hard	51	118,193	5,961	7,350	6,500	51	62

NUTASARA (1961) studied the drought in the Upper Chao Phaya river and its tributaries and the results are shown below

Minimum Specific Discharge (lit/sec/sq.km.)
For the Months of December, February and April.

Station	Chiengmai (1921 - 57) A = 6304 (sq.km.)			Lampang (1928 - 59) A = 3432 (sq.km.)			Nakonsawan (1917 - 58) A = 106,480 (sq.km.)		
Return Period, years	10	30	50	10	30	50	10	30	50
December	2.80	2.00	1.75	0.28	0.11	0.07	1.43	0.93	0.75
February	1.70	1.30	1.20	0.17	0.06	0.04	0.48	0.30	0.24
April	1.20	0.93	0.83	0.09	0.03	0.02	0.26	0.16	0.13

All results were based on the formula

$$P(x) = e^{-\left(\frac{x - \epsilon}{x_f - \epsilon}\right)^a}$$ and it was assumed that $\epsilon = 0$

CHUN (1965) studied the Chao Phaya river and its tributaries and found that the correlation coefficients between the flows at stations of the same river were high and the inter-river correlation was relatively high but different rivers have weak correlation because of the difference in basin characteristics and slight difference in climate.

1.3 Scope of the Research

The purpose of this study is to find the relationship between the flow and the catchment area, the maximum and minimum flows at any return period and the correlation of flows of twelve gaging stations in the Mae Klong basin. The catchment area under the investigation covers 32,610 square kilometers, - including the flood plain. The locations of the gaging stations are shown in Fig 2.

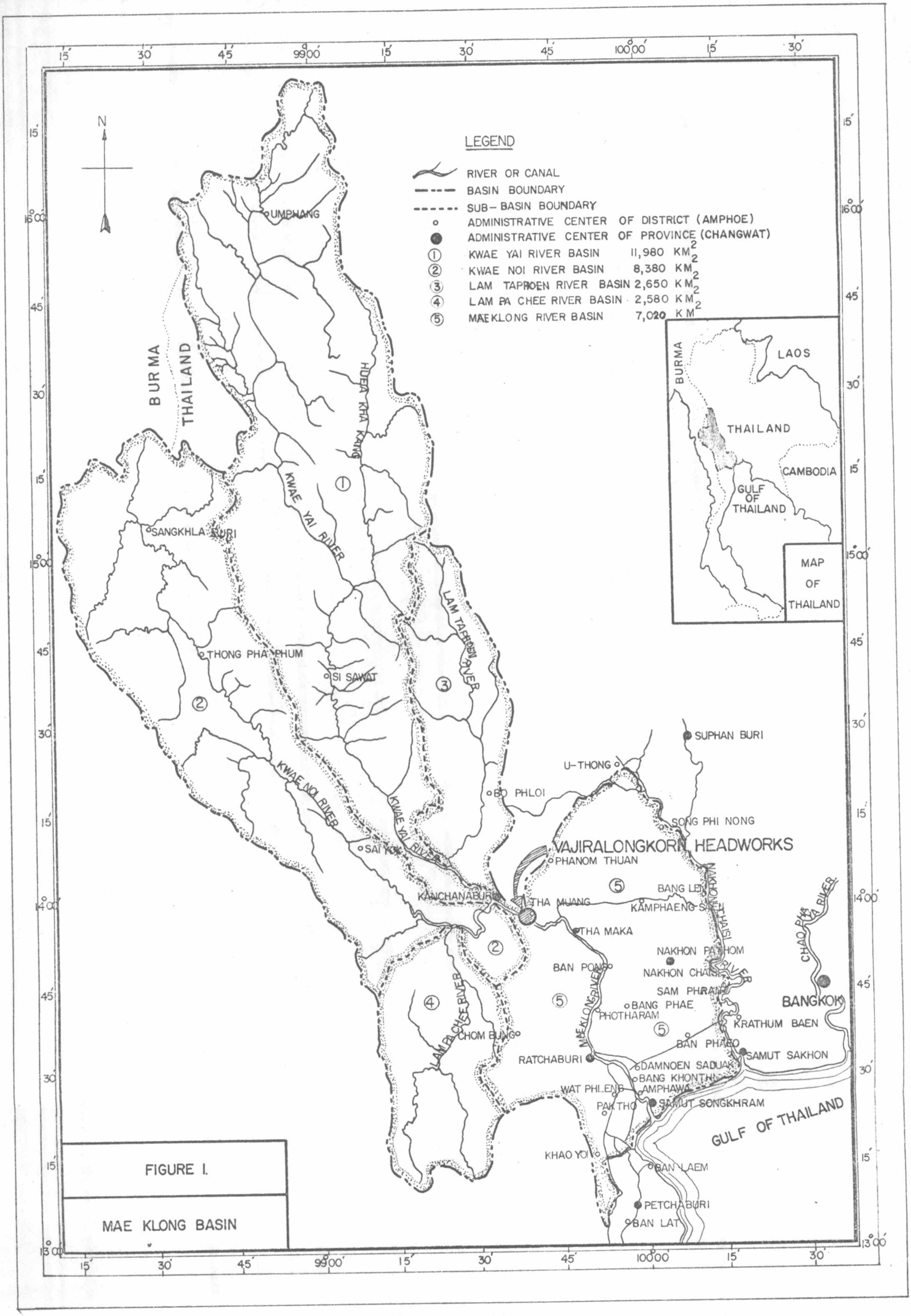

FIGURE I.

MAE KLONG BASIN

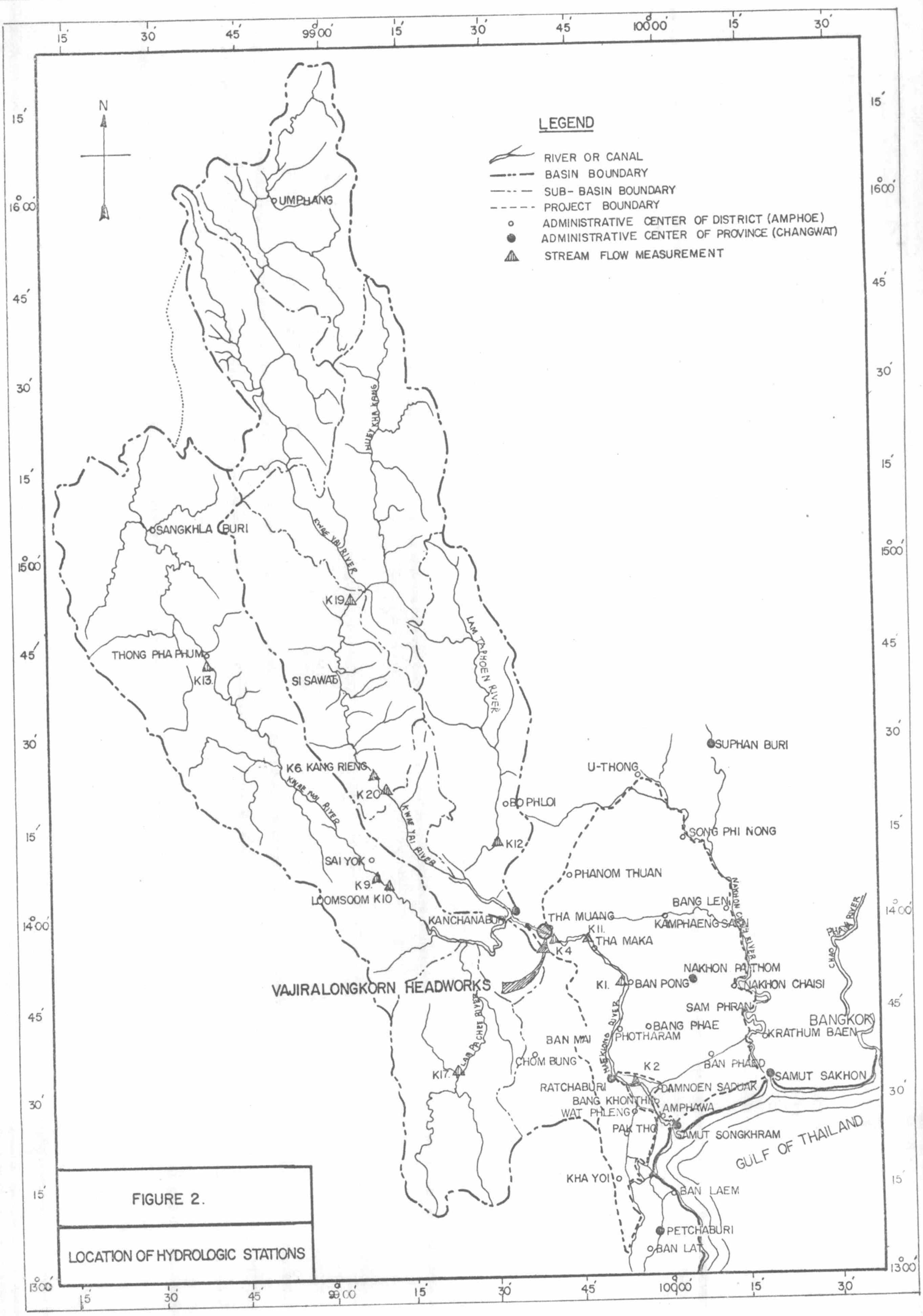

FIGURE 2.

LOCATION OF HYDROLOGIC STATIONS

1.4 Application

The knowledge of the basic characteristics of the Mae Klong basin in this investigation can be used

1. in solving stream pollution problem which occurs, during the dry season, in the lower part of the river,

2. for flood and drought protection,

3. in improving the water distribution system in the basin, and water quality management

4. in selecting a good location with more benefit of dam, and

5. in salinity control and navigation improvement

1.5 Plan of Investigation

In order to pursue the objective, the following steps were planned.

1. Obtain the stream records from several sources such as Royal Irrigation Department (R.I.D.), Electricity Generating Authority of Thailand (E.G.A.T.), National Energy Administration (N.E.A.). However, all data which were used in this investigation were taken only from R.I.D. and E.G.A.T.

2. Find the appropriate methods and formulas for analysis and investigation.

3. Compare the results from different methods and formulas.

4. Finally, discuss and conclude the results and recommend for further investigation.

1.6 Definition of Technical Terms

The definition of terms which are used in this analysis are as follows:-

1. Daily flow (Q_d) is the average flow in one day.

2. Monthly flow (Q_m) is the average of the daily flows for all the days of the month.

3. Average monthly flow ($\overline{Q}_m$) is the average of monthly flows of the same month but different years, so

$$\overline{Q}_m = \frac{\sum_{i=1}^{n} Q_m}{n}$$

where Q_m = monthly flow in cms.,
n = number of years of record.

4. Annual flow (Q_a) is the average of the daily flows for all the days of the year, or the average of the monthly flows for all the months of the year.

5. Average annual flow ($\overline{Q}_a$) is the average of the annual flows, so

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

where Q_a = annual flow in cms.,
n = number of years of record.

6. Minimum monthly flow ($Q_{m_{min}}$) is the smallest daily flow of the month.

7. Average minimum monthly flow ($\bar{Q}_{m_{min}}$) is the average of the minimum monthly flows of the same month but different years.

$$\bar{Q}_{m_{min}} = \frac{\sum_{i=1}^{n} Q_{m_{min}}}{n}$$

where n = number of years of record

8. Minimum annual flow ($Q_{a_{min}}$) is the smallest daily flow of the year.

9. Average minimum annual flow ($\bar{Q}_{a_{min}}$) is the average of the minimum annual flows.

$$\bar{Q}_{a_{min}} = \frac{\sum_{i=1}^{n} Q_{a_{min}}}{n}$$

where n = number of years of record

10. Maximum monthly flow ($Q_{m_{max}}$) is the largest daily flow of the month.

11. Ave. maximum monthly flow ($\bar{Q}_{m_{max}}$) is the average of the maximum monthly flows of the same month but different years.

$$\bar{Q}_{m_{max}} = \frac{\sum_{i=1}^{n} Q_{m_{max}}}{n}$$

where n = number of years of record

12. Maximum annual flow ($Q_{a_{max}}$) is the largest daily flow of the year.

13. Average maximum annual flow ($\bar{Q}_{a_{max}}$) is the average of the maximum annual flows.

$$\bar{Q}_{a_{max}} = \frac{\sum_{i=1}^{n} Q_{a_{max}}}{n}$$

where n = number of years of record

14. Return Period or Recurrence Interval (T) is the average number of years within which a given event (flow) will be equalled or exceeded for flood and equalled or less for drought.

15. Specific Runoff is the runoff per unit catchment area.

16. Water shed or Catchment Area or Drainage Area (A) is total area from which the surface runoff concentrates to a certain point of concentration.