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REPORT ON TECHNICAL FEASIBILITY STUDY
FOR
MAE KLONG RIVER BASIN FLOOD FORECASTING SYSTEM
THAILAND

March 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

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P R E F A C E

In response to a request by the Government of Thailand, the Government of Japan decided to take up a study on the Flood Forecasting and Warning Project in the Mae Klong River Basin and the Japan International Cooperation Agency carried out the study.

Noting that the project has a vital bearing on the development and livelihood of the inhabitants in the Mae Klong River Basin which is densely populated and the granary of the country, the Agency dispatched a study team consisted of 7 experts and headed by Mr. Shigeo Nakanishi, Water Management Officer, River Planning Division, River Bureau, Ministry of Construction, from November 8 to December 17, 1977.

The study team held discussions on the project with the Thai authorities concerned and collected information and data and conducted field surveys for the planning of the flood forecasting and warning system. Based on these surveys, and taking account of advice and views rendered by competent authorities of various Thai Government departments, the team conducted related studies after teturning to Japan and has compiled this report.

I sincerely hope that this report will contribute to the socio-enonomic development in the Mae Klong River Basin and to the enhancement of the friendly relations between the two countries.

I would like to take this opportunity to express my hearfelt appreciation to all the authorities concerned in Thailand of their wholehearted assistance rendered to the study team.

August 1978

Shinsaku Hogen
President

JAPAN INTERNATIONAL COOPERATION AGENCY

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CHAPTER 1. GENERAL

1-1 Introduction

The upper reaches of the Macklong river are covered densely with tropical rain forests, with cultivated land hardly found except along its banks. On the other hand, its lower basin area downstream of Kanchanaburi is an extensive plain bearing a high population density and known as one of Thailand's granary zones. However, this area has been frequently afflicted with heavy flood damages in the past on account of copious rain falling throughout the basin.

The Macklong River Basin Flood Forecasting and Warning Project, for which the present survey was conducted, is one of the pilot flood forecasting projects selected at the first meeting of ECAFE/WMO Typhoon Committee held in Bangkok in December 1968, and analysis of past flood data has been conducted for the project jointly by Royal Irrigation Department and Meteorological Department of Thai government.

To cooperate in the implementation of this project, the Japanese government sent a preliminary survey team comprising the following three members to Thailand from February 6 to 19, 1975.

Kazunori NAKAO	Leader, river engineer
Tomonami FUJII	Hydrologist
Kazuhiko TAKAYAMA	Telecommunication expert

With an all-out cooperation offered by Thai government, the preliminary survey team conducted a reconnaissance survey of the Macklong river and its two tributaries, the Khwae Yai and the Khwae Noi, and also collected past records of meteorological, hydrologic and hydraulic observations, analytical flood forecasting data, and information on the existing state of telecommunication systems. After careful examination of these data and the findings of its reconnaissance survey, the team presented the following comments and recommendations.

Comments and Recommendations of Japanese Preliminary Survey Team for Maeklong River Basin Flood Forecasting Project (Feb 6 ∿ 19, 1975)

Comments:

Surveys for the flood forecasting scheme of the Maeklong river basin have been actively conducted for more than ten years by the Thai government agencies and TCS, and there have been proposed more than four different forecasting systems in the past. Observation stations are not sufficiently installed, but considering the fact that their installation and maintenance entails substantial difficuly because of the basin's geographical condition and sparse population, it may be said that they are fairly well consolidated. Data collection and arrangement at these stations is conducted smoothly, and application of software techniques for run-off analysis and flood routing using the collected data has already entered the stage of practical operation. The team was informed that even trial flood forecasting was actually undertaken using the data of a number of observation stations to which communication means were available.

It appears, however, that this trial forecasting did not produce very good result for want of a well organized observation system and satisfactory communication means and the resultant lack of smooth data transmission. (For these reasons, the Thai government evinced great enthusiasm for the consolidation and improvement of observation equipment and communication facilities. The present survey was therefore conducted with stress placed on the study of the observation network and communication facilities which are indispensable for flood forecasting and warning)

Recommendations:
On the strength of the findings of the survey, the following recommendations are made.

(1) Responsibility for each stage of flood forecasting and warning should be made clear.

(2) There are many districts where observation stations are found close to each other. Determination should be made as to which organiza-

tion's stations are to be used in such districts.

(3) Decision should be made as to which organization is to exercise control over master station and monitor stations.

(4) An adequate observation network should be planned. For this purpose, basic analysis of the data so far collected should be prompted.

(5) For those stations where observers cannot be promptly assigned at time of a flood, it is advisable that self-recording equipment be installed so that data can be collected by telemetering.

(6) Adequacy of the communication system should be carefully checked by propagation test and other means since the Macklong basin is mountainous.

(7) Flood forecasting based on run-off calculation and flood routing is made by calculations worked out on a daily basis at present. When recording gauges are installed at most stations, calculations can be made on an hourly basis. In this case, however, the augmented volume of calculation will call for the introduction of a high-speed calculation system.

On the basis of the above comments and recommendations, Thai government planed to promote the proposed improvements pertaining to the forecasting system and method of data analysis, and subsequently requested, in January 1977, for the dispatch of a second Japanese survey team for the preparation of a draft design of the forecasting system and for related radio propagation test, to which Japanese government acceeded.

The second survey team stayed in Thailand from November 18 to December 17, 1977 and carried out various survey activities with the thorough cooperation of the pertinent Thai authorities including Meteorological Department, Royal Irrigation Department, and The Electricity Generating Authority of Thailand.

1-2 Terms of Reference

The terms of reference to the survey team as listed in the official request for the dispatch of flood forecasting experts dated January 1977 which Thai government forwarded to Japanese government are as follows.

(1) Hydrological analysis and survey for telecommunication system including radio propagation test.

(2) Preparation of a final draft plan of the flood forecasting system based on hydrological and telecommunications survey and

(3) Design of the telecommunication network.

1-3 Formation of Survey Team

The survey team was organized with a total of seven experts comprising three hydrologists and four telecommunication experts whose names are listed below together with their assignment and affiliation.

Table 1 Formation of Survey Team

(Name)	(Assignment)	(Affiliation)
Shigeo Nakanishi	Leader, Senior Hydrologist	Water Management Officer, River Planning Division, River Bureau, Ministry of Construction
Kazuhiko Takayama	Acting leader, Senior telecommunication expert	Senior Engineer, Electricity and Telecommunication Division, Minister's Secretariat, Ministry of Construction
Kazunori Yoshioka	Hydrologist	Chief, Survey Section, Numazu Work Office, Chubu Regional Construction Bureau, Ministry of Construction

(Name)	(Assignment)	(Affiliation)
Kenichi Shirai	Hydrologist	Chief, Water Management Section, Yodo River Dam Control Office, Kinki Regional Construction Bureau, Ministry of Construction
Kunio Ichimiya	Telecommunication expert	Deputy Head of Telecommunication Section, Chubu Regional Construction Bureau, Ministry of Construction
Etsuo Minamitake	Telecommunication expert	Engineer, Telecommunication Section, Kanto Regional Construction Bureau, Ministry of Construction
Kaname Murakami	Telecommunication expert	Engineer, Water Resources Development Public Corporation

1-4 Plan of Operation and Itinerary

The survey was conducted by dividing the team into two parties, the hydrologic party and the telecommunications party. The former arrived at Bangkok on November 8 and the latter on November 11. Both parties left Thailand on December 17, but the leader Nakanishi returned to Japan on November 22 in advance of other team members.

The plan of operation was formulated as follows on November 16 in accordance with the aforementioned terms of reference at a meeting of all team members and the representatives of Thai authorities including Meteorological Department, Royal Irrigation Department and the Electricity Generating Authority of Thailand. The itinerary of the team showing the progress of survey activities is given in Table 1-2.

I. Scope of Work

(1) Study of hydrological network and locations and number of observation stations, from hydrological consideration.

(2) Evaluation of the existing flood forecasting method by using data obtained recently as well as old data, and study of the possibility of other forecasting methods.

(3) Study of the adequate equipment to be used for the operation of flood forecasting based on the method studied in Item (2) above, with consideration given to the system of hydrological data collection and utilization.

(4) Decision of location of each telemetering station (including repeater stations).

(5) Radio propagation test of spans between respective telemetering stations.

(6) Preparation of the list of equipment for the system and their specifications in outline (including frequency zone).

(7) Cost estimation of the system.

II. Reports

The interim report will be submitted during the team's stay in Thailand. The final report will be completed within four months after the team's return to Japan.

Table 1-2 Itinerary of Survey Team

Date	Day	Hydro. Party	Telecom. Party	Remarks
Nov 8	Tue	Departure from Tokyo and arrival at Bangkok.		Team leader (Nakanishi), party members (Yoshioka and Shirai), and coordinator (Aiba).
9	Wed	Courtesy call on ESCAP, with consultations and preparations for survey.		ESCAP : Mr. Manalac.
10	Thu	Courtesy call on Japanese Embassy in Bangkok, JICA Office, and MD. AM: Pre- survey consultation meeting at MD. PM: Consolidation of survey equipment.		Pre-survey consultation meeting at MD was participated in by the following persons. From MD - Mr. Twee Montrivade. Mr. Sumeth Hinsheranan. Mr. Tawatchai Brikshavana. From RID - Mr. Damrong Jaraswathana. From EGAT - Mr. Naraongsak Vichetpan. From Japanese Embassy - Mr. Hideki Aramaki. From JICA - Mr. Kenji Iwaguchi.
11	Fri	Collection of hydrological data at MD.		An assembly room of MD was offered to the team as its office.
12 13	Sat) Sun	Holiday.		

Date	Day	Hydro. Party	Telecom. Party	Remarks
14	Mon	Field trip.		Departure (9:00) → Maeklong river estuary → arrival at Ratcha Buri (12:00) → Vajiralongkorn dam. Overnight stay at Vajiralongkorn dam guest house.
15	Tue	Field trip.		Departure (8:00) → Kanchanaburi Weather Observation Station → K20 → arrival at Ban Chao Nen dam (10:30) → departure for Bangkok (13:40) Field trip was participated in by the following non-team members. From MD – Mr. Tawatchai Brikshavana and one other. From RID – Mr. Damrong Jaraswathana and three others. From Typhoon Committee – Mr. Oi.
			Departure from Tokyo and arrival at Bangkok.	Acting team leader (Takayama) and party members (Ichimiya, Murakami and Minamitake).
16	Wed	AM: Consultation meeting at MD.	Courtesy calls on Japanese Embassy. JICA Office, RID, MD, and ESCAP; and consultations at MD.	Joint meeting of two parties with participation of Mr. Oi of Typhoon Committee.
		PM: Preparations for field trip.	Same as Hydro. Party.	

Date	Day	Hydro. Party	Telecom. Party	Remarks
17	Thu	Field trip (Nakanishi, Yoshioka and Shirai).	Field trip (Ichimiya and Minamitake). Field test preparations at MD (Takayama and Murakami).	Departure (8:00) → Sai Yok (12:00) → Thong Pha Phum (16:00); overnight stay at Thong Pha Phum.
18	Fri	- do -	Field trip (2 members). Field test preparation at MD (2 (2 members).	Team divided into three groups. 1) Arrival at Sangkhla Buri at 11:00. 2) Reconnaissance in the neighbourhood of Thong Pha Phum 3) Pilok.
19	Sat	- do -	Field test (2 members); Holiday for 2 others members.	Departure from Thong Pha Phum (7:40) → K-10 → K-11 → Bangkok. Field trip was participated in by the following non-team members. From MD - Mr. Twee, Montrivade, and two others. From RID - Mr. Damrong Jaraswathana and three others. From EGAT - Mr. N. Vichetpan. From Typhoon Committee - Mr. Oi.

Date	Day	Hydro. Party	Telecom. Party	Remarks
20	Sun	Holiday.	Holiday.	
21	Mon	Collection and analysis of hydrological data.	Reporting on survey of R2 site, and intra-party arrangements for radio propagation test	
22	Tue	Departure of Leader Nakanishi for Japan;	Checking of test equipment.	
		Consolidation and analysis of hydrological data;	Field test.	Telecom. party's field test Departure from Bangkok (13:00) → Kanchanaburi.
		Discussion with officials of MD and RID and Mr. Oi concerning forecasting system.		
23	Wed	Analysis of hydrological data;		
		Discussion with MD and RID officials to obtain information on existing forecasting and hydrologic observation system.	- do -	Reconnaissance of R1 site near Kanchanaburi, and radio propagation test between R1 and Ban Chao Nen dam.
24	Thu	- do -	- do -	Radio propagation test between R1 and K10 (Ban Lum Sum);

Date	Day	Hydro. Party	Telecom. Party	Remarks
				2 party members returned to Bangkok.
25	Fri	Discussion with MD and RID officials to obtain information on existing forecasting and hydrologic observation system	Field test.	Radio propagation test between R1 and Bangkok; Remaining 2 members returned to Bangkok. Field test was participated in by Mr. S. Chang-Iam and 3 others officials of MD.
26	Sat)	Holiday.	Holiday.	
27	Sun			
28	Mon	Analysis of hydrological and flood forecasting data.	Review of previous week's field test data; Arrangements for this week's survey plan.	
29	Tue	Data consolidation, and analysis of flood forecasting data.	Field test.	Bangkok → Kanchanaburi: Survey of R1 (second proposed repeater station site) by 2-member Kanchanaburi party; Other two members → Thong Pha Phum.
30	Wed	Analysis of hydrological and flood forecating data.	- do -	Radio propagation tests covering the following sections -

Date	Day	Hydro. Party	Telecom. Party	Remarks
				R1 - R2, R1' - K 10, K2 - K 10, R2 - Ban Sai Yok.
				Kanchanaburi party Thong Pha Phum.
Dec 1	Thu	- do -	Field test.	Radio propagation tests covering the following sections - R2 - Sangkhla Buri, R2 - Ban Pa Tho R2 - Pilok.
2	Fri	- do -	- do -	Thong Pha Phum → Bangkok.
				Field test was participated in by the following non-team members.
				From MD - Mr. Taweechai Chalayonnawin, and 3 others.
				From RID - Mr. Chalerm Tangtrongchit and 2 others.
3	Sat)			
4	Sun)	Holiday.	Holiday.	December 5 - King's birthday.
5	Mon			
6	Tue	Data consolidation, and analysis of hydrological and flood forecasting data.	Consolidation and reviewal of test data.	

Date	Day	Hydro. Party	Telecom. Party	Remarks
7	Wed	AM: - do -	- do - (2 members)	
		PM: Discussion at RID concerning flood forecasting system.	Same as hydro. party (Acting leader Takayama)	RID Officials - Mr. Damrong Jaraswathana Mr. Prasong Jitseri
8	Thu	Analysis of hydrological and flood forecasing data.	Consolidation and reviewal of test data.	
9	Fri	AM: Discussion at MD with Mr. Tawatchai Brikshavana on flood forecasting system.	Field trip (Takayama and Ichimiya); Preparation of interim report (2 members).	Field reconnais-sance of third proposed site of Kanchanaburi repeater station with participation of Mr. Sumeth Hinsheranan, of MD.
10 11	Sat) Sun	Holiday.	Holiday.	
12	Mon	Preparation of interim report, and explanation of H-H correlation method.	Final examination of data transmission system, and prepara-tion of interim report.	
13	Tue	Preparation of interim report, and consultation Japanese Embassy and JICA (P.M.).	Same as Hydro. Party.	
14	Wed	Discussion meeting with Thai offi-cials to	Same as Hydro. Party.	Discussions were held with the following Thai officials.

Date	Day	Hydro. Party	Telecom. Party	Remarks
		attain an accord of opinions and approaches to the establis-ment of data transmission system and flood fore-casting centers, and final intra-team arrange-ments.		From MD - Mr. Sumoth Hinsheram From RID - Mr. Damrong Jaraswathana Mr. Prasong Jitseri
15	Thu	AM: Arrange-ment of survey equip-ment, checking of equip-ment to be offered to Thai government, and their packing and ship-ment. PM: Interim report meeting.	Same as Hydro. Party	Interim report meeting was held with the partici-pation of the following officials. From MD - Mr. Twee Montrivade, and 2 others From RID - Mr. Damrong Jaraswathana and 1 other From Japanese Embassy - Mr. Hideki Aramaki.
16	Fri	Courtesy calls on MD, Japanese Embassy, JICA, RID and ESCAP.	Same as Hydro. Party.	
17	Sat	Departure for Tokyo.	Same as Hydro. Party.	

1-5 Acknowledgement

The survey was conducted smoothly as scheduled with the fullest and unlimited cooperation of the competent Thai authorities. All members of the team feel deeply indebted to the following officials of Thai government and ESCAP whose helpful assistance enabled them to discharge their duties successfuly during their stay in Thailand.

(1) Meteorological Department (MD)

Mr. Twee Montrivade, Deputy Director-General

Mr. Sumeth Hinsheranan, Director of Hydrometeorology Division

Mr. Tawatchai Brikshavana, Chief of Hydrological Forecast Section

Mr. Taweechai Chalayomnawin, Meteorologist

Mr. Sompong Chang-Iam, Hydrometeorologist

Mr. Prasit Chamlongrat, Hydrometeorologist

Mr. Charoen Chootirak, Electrician

Mr. Surin Nakanong, Electrician

Mr. Samarn Prasomsook, Electrician

(2) Royal Irrigation Department (RID)

Mr. Damrong Jaraswathana, Director of Hydrology Division

Mr. Chalerm Tangtrongchit, Hydrologist

Mr. Prasong Jitseri, Hydrologist

Mr. Santhan Somwong, Hydrologist

(3) The Electricity Generating Authority of Thailand (EGAT)

Mr. Narongsak Vichetpan, Head of Project Planning Section

(4) Economic and Social Commission for Asia and the Pacific (ESCAP)

Mr. A.I. McCutchan, Chief, Natural Resources Division

Mr. A.S. Manalac, Chief, Water Resources Section, Natural Resources Division

(5) The team wishes to express its deep gratitude to Dr. Kajit Buajitti, Director general of Meteorological Department, for his helpful assistance and accommodation to it.

The team's appreciation also goes to Mr. Hideomi Oi of ESCAP/WMO Typhoon Committee and Mr. Manabu Aiba of Japan International Cooperation Agency, who joined the team and offered valuable assistance in the adjustment of survey itinerary, interpreting service, liaison and coordination.

CHAPTER 2. CONCLUSION AND RECOMMENDATIONS

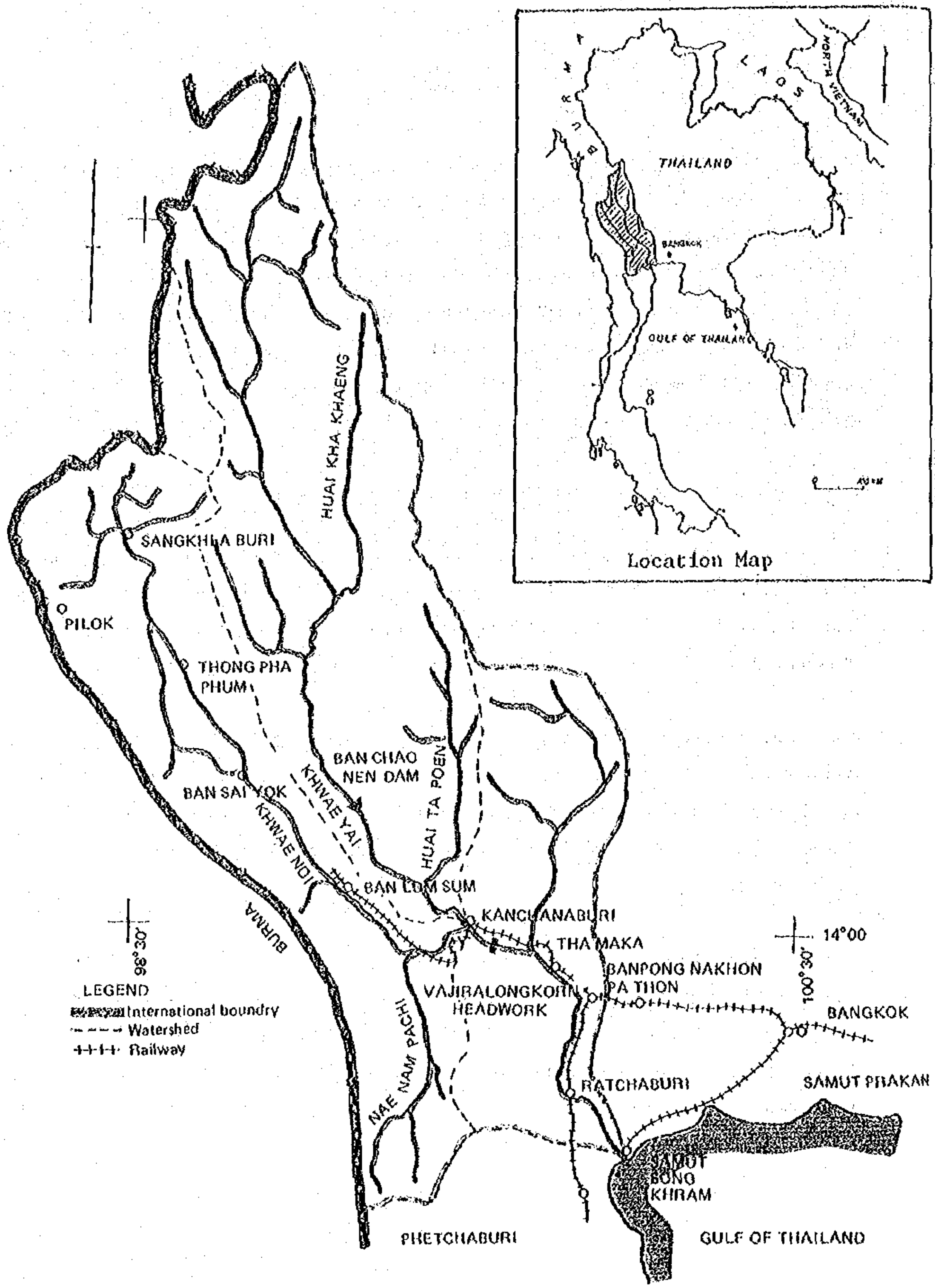
As a result of the study of the flood forecasting system of the Mae Klong River basin, the following conclusion was obtained. The study, particularly the hydraulic and hydrological analysis, was carried out mainly for the Khwae Noi River. Therefore, the conclusion regarding the flood forecasting system does not cover the entire basin. This is due to the facts that hydraulic and hydrological analysis following the completion of the Ban Chao Nen Dam being constructed on the Khwae Yai River has not been made and that operational rules have not been established.

2-1. Target area for flood forecasting and warning

The Mae Klong River combines its two major tributaries, Khwae Yai and Khwae Noi, at Kanchanaburi to form a large river flowing south. Kanchanaburi is situated between a mountain area and a plain which extends down stream with the town as its top.

Flooding has been occurring in the downstream section below Vajiralongkorn headwork situated downstream from Kanchanaburi. The flooding area may be divided roughly into two parts: 1) the left bank area between Tha Muang and Tha Maka; and 2) the area between Ban Pong and Ratchaburi on both banks.

Accordingly, the area downstream of Kanchanaburi is to be designated as the target area for flood forecasting and Wang Khanai (K-11) as the target point because of the hydraulic and hydrological observation made in the past and also because it is most upperstream point in the flooding area. (See Fig. 2-1.)


THAILAND
LAOS
BANGKOK
GULF OF THAILAND
Location Map
SANGKHLA BURI
PILOK
THONG PHA
PHUM
HUAI KHA KHAENG
BAN CHAO
NEN DAM
HUAI TA POEN
KHWAE YAI
BAN SAI YOK
KHWAE NOI
KANCHANABURI
THA MAKA
14°00
98°30'
100°30'
BURMA
LEGEND
International boundry
Watershed
Railway
VAJIRALONGKORN
HEADWORK
BANPONG NAKHON
PA THON
BANGKOK
NAE NAM PACHI
RATCHABURI
SAMUT PRAKAN
KHRAM
PHETCHABURI
GULF OF THAILAND

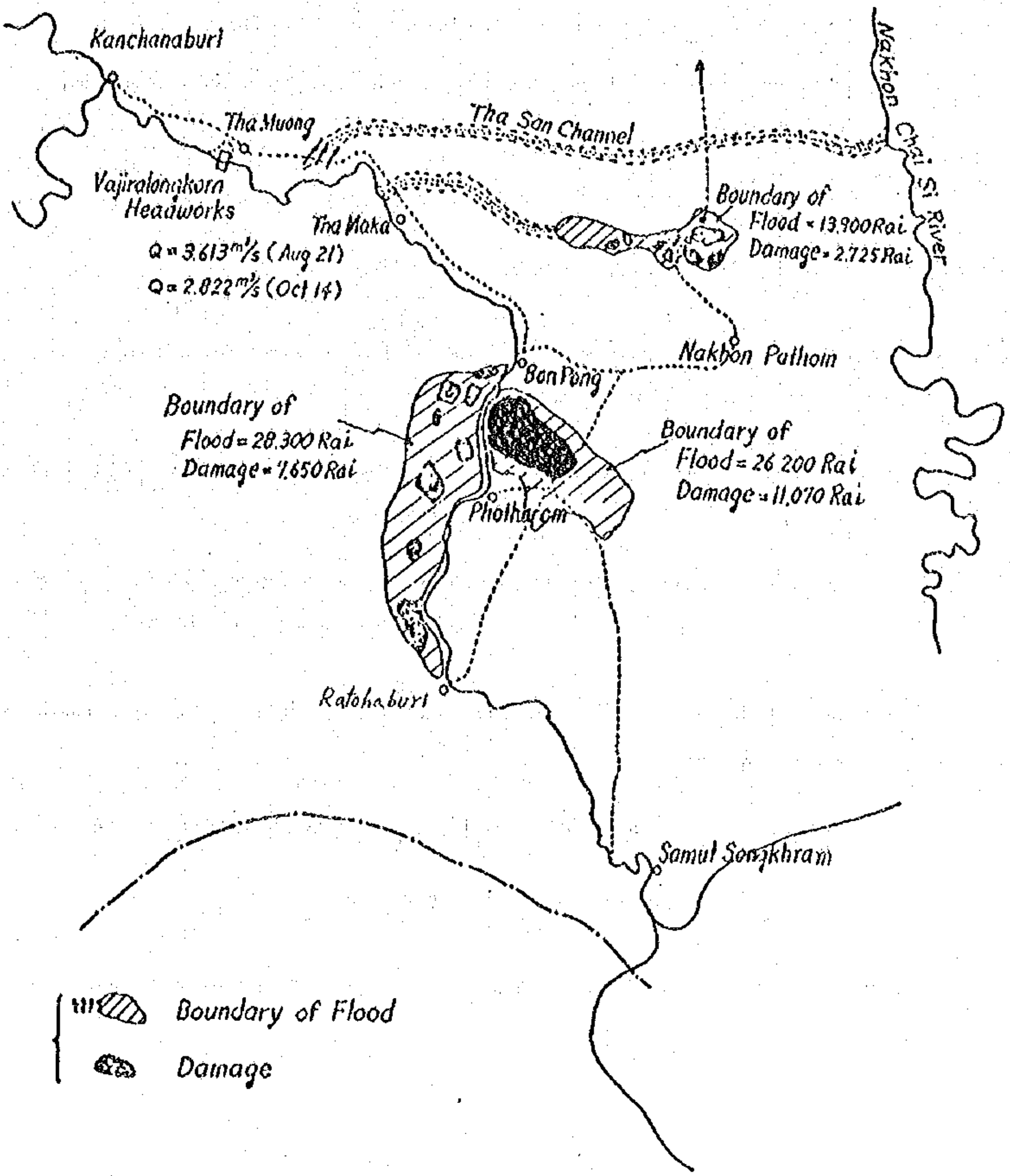


Fig. 2-1-2 Target Area and Flooded Area (1974)

2-2. Observation networks

In order to achieve the purpose of this project, the following observation and communication networks are to be established.

- o Gauging and raingauging stations: at 6 points

  (Sangkhla Buri, Thong Pha Phum, Ban Sai Yok, Ban Lum Sum, , Ban Chao Nen, Wang Khanai).

- o Raingauging stations: at 3 points

  (Ban Pa Tho, Pilok, Ban Lin Thin).

To connect these observation stations with a telemeter network, two relay stations will be necessary.

- o Repeater station (R-1): Near Kanchanaburi, connecting Bangkok and R-2.

- o Repeater station (R-2): Near Thong Pha Phum, connecting the upperstream section and R-1.

Monitoring and control stations for collecting data from each station are to be as follows:

- o Master control station: Meteorological Department (Bangkok)

- o Monitoring station: RID (Bangkok)

The above are to be connected with the telemeter network as shown on Fig. 2-2, 2-3.

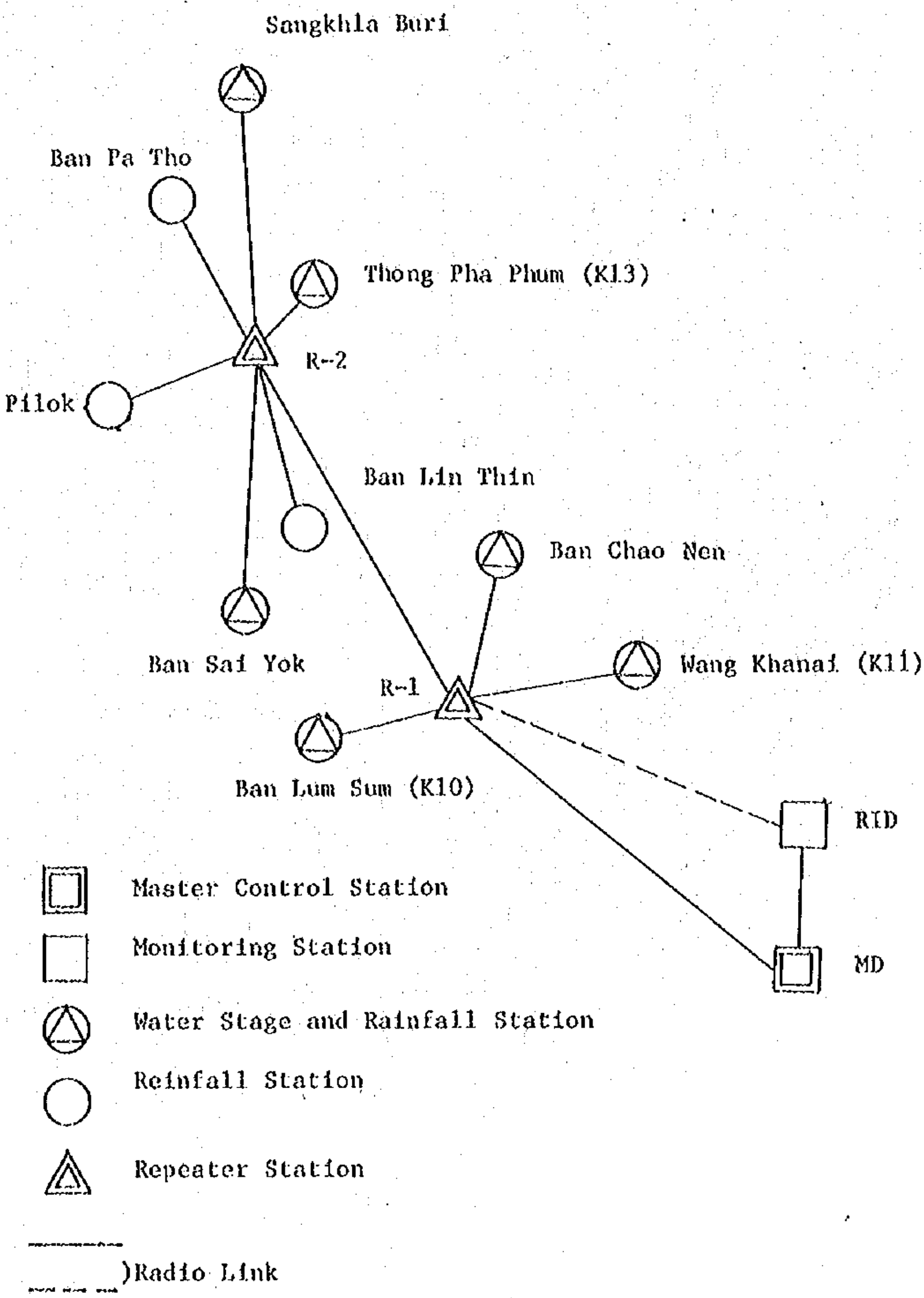


Fig. 2-2 Telemetering Network - (1)

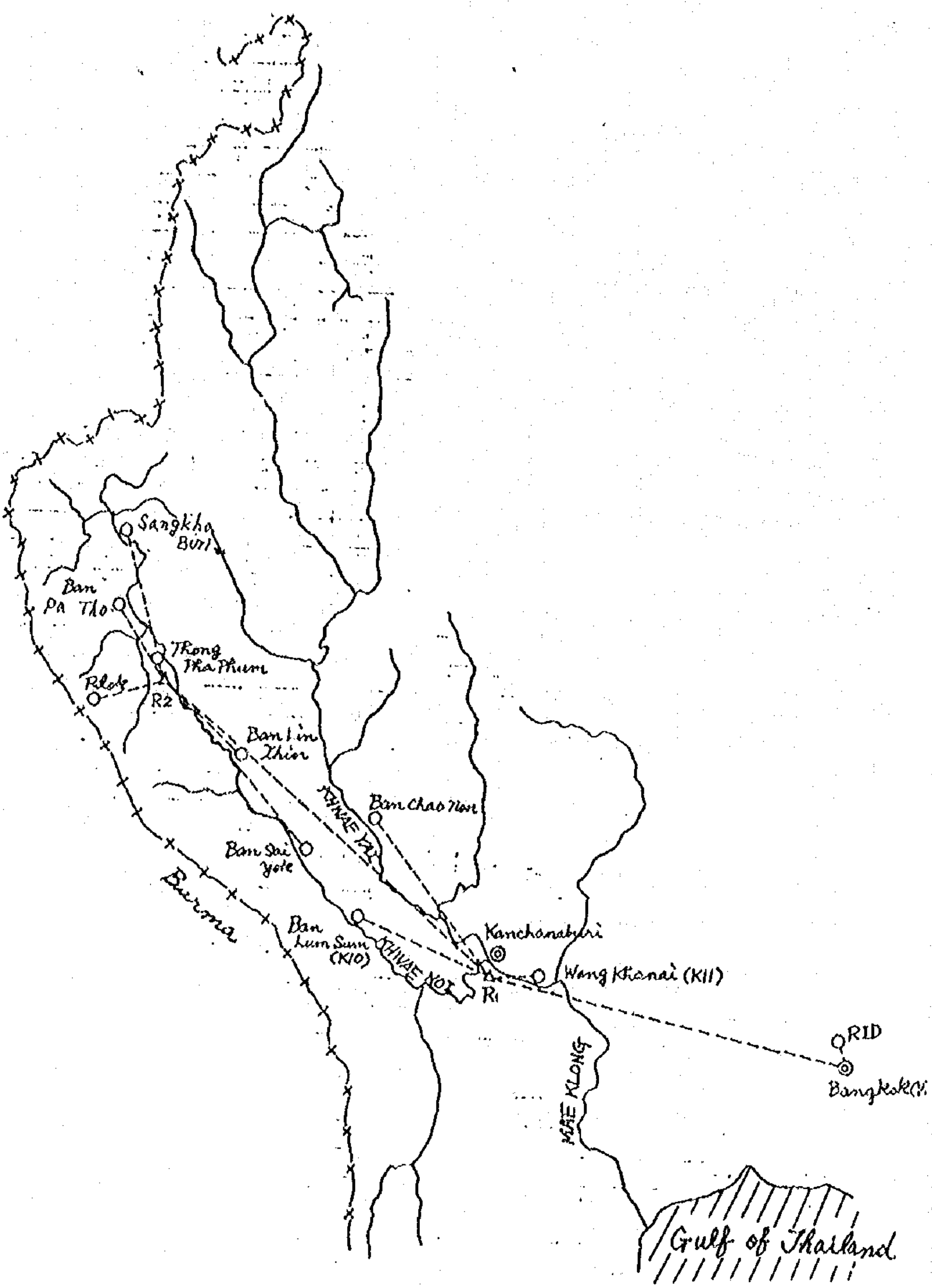


Fig. 2-3 Telemetering network (II)

2-3 Flood forecasting and warning method

With regard to the proposed flood forecasting and warning method the stage at Wang Khanai (K-11) is obtained by two stepswork. First, by means of two methods the stage (H) and the discharge (Q) at Ban Lun Sum (K-10) may be forecast. One method is the stage correlation method (H-H correlation) which uses water stage data at Thong Pha Phum (K-13) and another is the flood run-off analysis (R-Q, H analysis) which uses rain fall data of upstream basin. Then by combining these and data at the Ban Chao Nen Dam the stage at Wang Khanai (K-11) which is the final target point may be obtained. But it is advisable to make up the system for basin-wide coverage by means of R-Q, H analysis from upstream station to final station K-11.

With regard to R-Q, H analysis of the area upperstream of K-10, considering the situations such as the size of the basin, geographical features, number of raingauging stations and as well as the shortage of data for dividing the basin in the case of using a different method, it seems appropriate to conduct run-off simulation taking the area upstream of K-10 as one basin as it has been suggested. For that method it is necessary to alter the existing forecasting model for practical use in such a way that forecasting can begin on a given day and input the actual discharge data. In this case longterm rain forecasting is necessary but even without rain forecasting it is possible to give two-day forecasting.

However, in order to increase accuracy in forecasting for the area upstream of K-10, it is necessary to add to the run-off simulation model another model by which flooding effects may be calculated. Further, with regard to Wang Khanai (K-11) which is to be a flood forecasting point, flood routing calculation from K-10 and Ban Chao Nen Dam, study of H-H correation with allowance for side-afflux and the necessary survey or arrangement of hydrological material.

2-4 Function and organization

The function and organization of this system are as follows:

(1) The master control station is to be set up at the Meteorological Department to control telemeter observation stations. The data obtained at the telemeter stations are collected by the Meteorological Department and are sent, at the same time, to the RID through a radio circuit.

(2) The data are processed and analysed at the Meteorological Department.

2-4-1. Organization

For this flood forecasting and warning system to function fully, it is necessary to clarify the role played by the agency concerned as a flood forecasting center. Since it is to become the nerve center for the operation of flood forecasting and warning in Thailand, it should be able to perform the function which is expected of it.

For that purpose attention should be paid to the following points in forming the organization.

1) For hydrological analysis coordination with agencies concerned and requests for cooperation can be made satisfactorily.

2) In preparing the forecasting statement coordination with agencies concerned can be carried out promptly, if it is necessary.

3) It is possible to transmit the forecasting promptly to the residents or the agencies concerned through an established communication network.

2-4-2. Function and role

The function of the flood forecasting center is as follows:

1) The center can obtain the necessary data concerning rainfall, stage and discharge at a given time promptly and accurately.

2) The center can forecast, based on the data collected:

(1) the expected discharge and stage at the target point;
(2) whether flooding will occur causing damage; (3) if so, when it will occur, and the expected stage at its peak and the duration.

In order to perform the above function, the following role is to be played by the center:

1) To prepare the forecasting statement and promptly issue a flood forecasting if necessary.

2) To issue a flood forecasting to prevent a loss of life and property.

3) To provide information on flooding in response to changing circumstances.

4) In the case of flooding, to grasp the situation promptly so that information may be given to the public when necessary.

5) To sort out hydrological data and other information on flooding which may be used as material for further study.

The following points should be studied so that the center can perform the above function and the role.

1) The system of transmitting the flood forecasting should be made clear so that the forecasting can be effective.

2) When flooding is over, the flooding situation should be grasped accurately to improve the accuracy of flood forecasting. Coordination should be maintained, therefore, so that information and data can be made readily available.

3) The target area of flood forecasting corresponding to the size of flooded area should be clarified based on the data on inundation.

2-5. Costs

The costs of installing this system are estimated as follows:

Unit : US$

Item	Domestic currency	Foreign currency	Total
Installation	133,000	1,325,000	1,458,000
Road construction	455,000		455,000
Technical guidance		253,000	253,000
Reserve funds	88,000	199,000	287,000
Total	676,000	1,777,000	2,453,000

(1) Calculation of the cost:

1) The costs are calculated as of Mar. 1978, at the exchange rate of ¥220 to the US dollar.

2) The installation costs cover observation instruments, communication and other equipments and their installation and adjustment, construction of antenna posts, and station buildings.

3) Road construction costs cover the construction of roads to the relay stations Rep 1 and Rep 2.

4) Costs of technical guidance cover the training of Thai engineers in foreign countries and guidance by foreign engineers in Thailand.

5) Costs of civil engineering work are an estimate; they may have to be amended when detailed plans are available.

(2) Note

This project can be installed by several stages.
The detail is described in the annex.

2-6. Recommendations and suggestions for future

2-6-1. Future telemetering system

1) Under the present conditions

The system which has so far been studied is a minimum system necessary under the present conditions. The system is mainly based on the Khwae Noi River, because the river has the main catchment area which influences flood forecasting and warning for the Mae Klong River, and the discharge of Khwae Yai River is equivalent to those from the Ban Chao Nen Dam. The new system also gives some extra allowance in the information capacity at repeater stations or at the flood forecasting center. It will be necessary to install a closer observation network to obtain higher precision in flood forecasting by means of acquiring data on rainfall or hydrological data on the stage at each point simultaneously. With regard to the installation of hydrological observation stations, rainfall stations should be set up, one for every 500 Km^2 in the K-10 upperstream area which is the main target area of flood forecasting. Further, in other areas, major tributaries should have at least one stage and rainfall station each. With regard to the Mae Klong River itself, mainly stage observation stations should be set up at the Kanchanaburi confluence (or Vajiralongkorn Headwork), towns of Bang Pong and Ratchaburi which have been damaged by floods and Samut Songkhram, the rivermouth. Fig. 2-4 is a map of the entire basin (excluding the upperstream section of the Ban Chao Nen Dam), giving the locations of the various stations, and Fig. 2-5 is a partitioned map showing the locations in the K-10 upperstream area as a suggestion. Actual installation has to be carried out in the light of the past observation records, maintenance and control, and topographical conditions in the vicinities.

With regard to the method of flood forecasting, it should be changed when there is a satisfactory observation network in future, and further study will be necessary on a flood forecasting system of higher precision.

2) Connection with the Khwae Noi Dam project

On completion of the Khwae Noi River Dam project which is under study at present, operational rules should be decided after taking into consideration that the discharge from the dam should minimize the damage of the downstream area in case of flooding in connection with the Ban Chao Nen Dam on the Khwae Yai River.

Until the completion of the Khwae Noi River dam, the telemetering system described above is a necessary facility for flood forecasting and warning. Even after the completion of the dam, the raingauge will provide important information for determining rainfall in the wet area of the North-West.

2-6-2. Flood control

Judging from the flooding situation of the Mae Klong River, if flood control measures such as river improvement are carried out in the present flooding area, they will bring about very favorable economic results. Among the recent floods, both banks were inundated between Ban Pong and Ratchaburi in the 1972 flood (1,100∿1,400 m^2/sec.). In the 1974 flood (2,800∼3,600 m^2/sec.), inundation occurred not only in the above section but also at two sections of the left bank between Tha Muang and Tha Maka in the upperstream area. Under the present conditions, if the standard rate of flow is fixed after examining the discharge carefully at K-11, and if effective river control facilities are provided in the area which needs protection in the light of the discharge, it will be possible to reduce further the expected damage in conjunction with flood forecasting and warning. For the determination of the standard rate of flow at K-11, it is necessary to grasp the hydrological conditions of both Khwae Noi and Khwae Yai. In the case of Khwae Noi, it is natural flow until the completion of the dam which is being planned, whereas in the case of Khwae Yai it is possible to control the flow with the completion of the Ban Chao Nen Dam. Therefore, they have different forms of flood run-off. Further, by combining the discharge at K-10 on Khwae Noi and the discharge from the Ban Chao Nen Dam on Khwae Yai, the discharge at K-11 may be obtained. Thus, it is desirable to have the discharge from the dam in such a way that it will affect the downstream area most favorably.

With regard to the planned size of high-water discharge for flood control, it should be decided in the light of flood frequency, distribution of population and property in the flooding area, present situation regarding land utilization and its future changes. As for suggestions for flood control facilities, they should provide complete protection against small and medium scale floods; but they should be constructed in such a way that in the case of a large scale flood, spilling flood should be allowed (as in the case of the section between Tha Muang and Tha Maka). Decision should be made, therefore, after detailed survey of the site has been carried out.

2-6-3. Future technical cooperation

There are various soft factors regarding the flood forecasting and warning system such as the H-Q curve at major observation stations, the H-H curve between observation stations, characteristics of flooding in the basin concerned and the flood forecasting model. It is necessary to amend them with the latest data whenever flooding occurs and maintain them in good order.

The telemetering system has to be maintained always in good order after completion. For that purpose, the establishment of a maintenance system and the provision of funds will be necessary.

In other countries where flood forecasting and warning systems have been installed with Japan's technical cooperation, they have been given Japan's assistance for a few years after completion in maintenance and control. It is desirable for Thailand to obtain technical cooperation from overseas for a considerable period of time regarding the flood forecasting and warning system, the telemetering system, flood control measures for the downstream flooding area, and comprehensive flood control measures including the Khwae Noi River dam project.

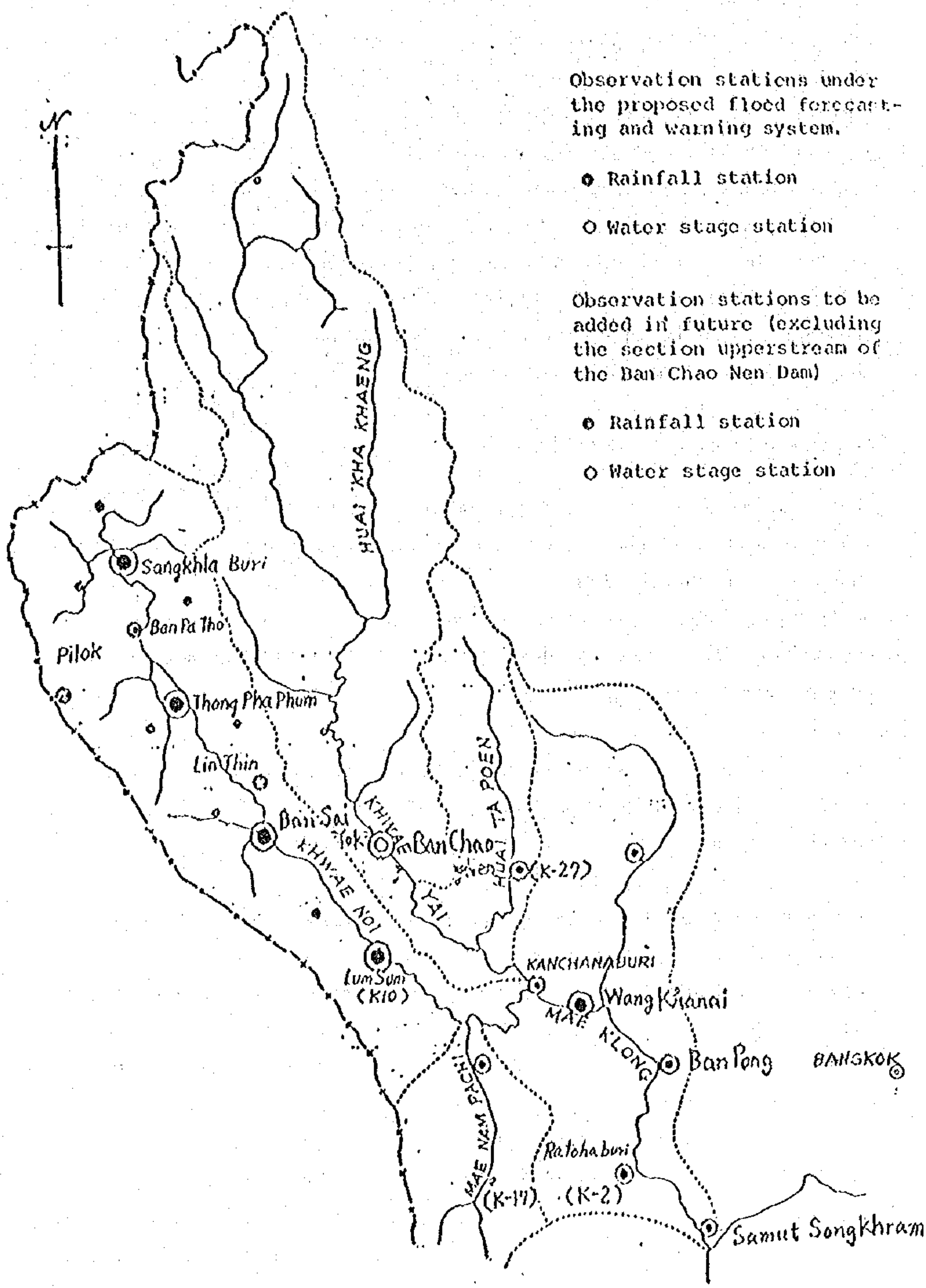


Fig. 2-4 Locations of Stations

area	1	=	645	km^2
"	2	=	899	"
"	3	=	344	"
"	4	=	526	"
"	5	=	330	"
"	6	=	943	"
"	7	=	261	"
"	8'	=	94	"
"	8	=	585	"
"	9	=	131	"
"	10	=	164	"
"	11	=	128	"
"	12	=	816	"
"	13	=	557	"
"	14	=	585	"
Total			7008	km^2

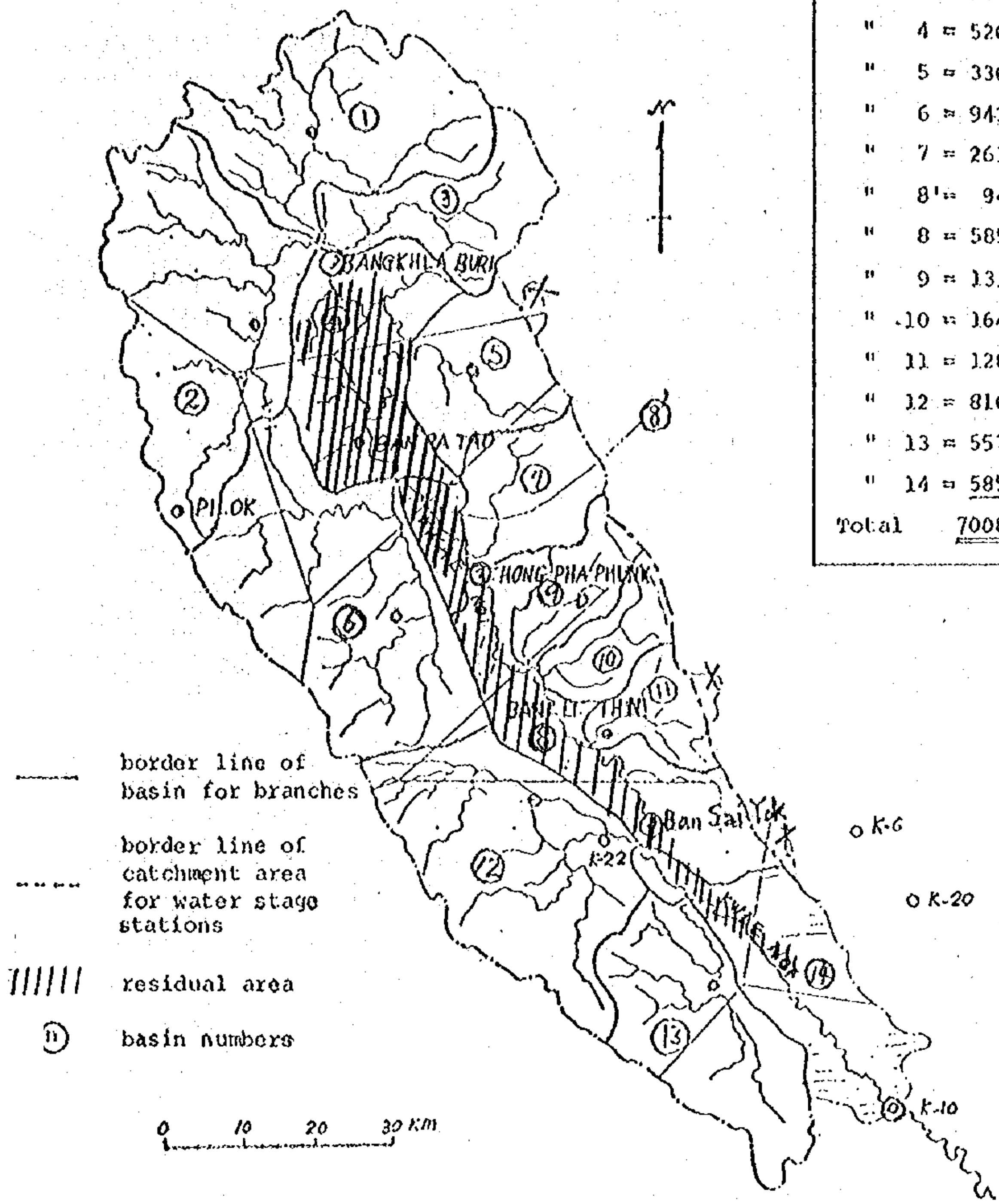


Fig. 2-5 Network of Rain Gauge Stations above K_{10}.

CHAPTER 3. EXISTING CONDITION OF THE MAE KLONG RIVER

3-1 Outline of the Mae Klong Basin

The Mae Klong is the third largest river in Thailand which flows in the western part of the country and its basin is a steep mountainous area. It flows through deep or narrow valleys and forms a basin of 1 to 1.5 mile diameter in some parts.

The Khwae Yai and the Khwae Noi, the two major tributaries of the north and east, by the mountain range on the Burmese border on the west, and by the Ratchaburi river and Gulf of Thailand on the south.

The Khwaei Yai and the Khwae Noi, the two major tributaries of the Mae Klong, rise in the mountainous district boarding on Burma, flow down southeast almost in parallel with each other, and join to form the Mae Klong at Kanchanaburi.

Kanchanaburi is situated 120 Km to the west of Bangkok, and the whole basin is divided into the mountainous upstream area and the flat downstream plain at this confluence.

The Khwae Yai, the eastern tributary, flows through valleys generally wider than those through which the Khwae Noi, the western tributary, flows. Hence, the Khwae Noi flows much more rapidly than the Khwae Yai. Because of their sharp bed slope and abundant water volume, tributaries of the Khwae Noi are concentrated near the water source and flow through places where the elevation is very close to the highest. As a consequence, new geological configuration can be observed along their uppermost reached, with a steep and long ridge extending along the Thailand-Burma borders.

The catchment area of the Mae Klong is far smaller than those of the other two major rivers in Thailand, the Chao Phraya and the Mun, but the mean discharge almost equals that of the Mun and accounts for 50% of the mean discharge of the Chao Phraya.

Table 3-1 Comparison of Annual Run-off

Basin	Catchment Area Km^2	Mean Discharge m^3/S	Specific Discharge $m^3/S/Km^2$
Chao Phraya (at Wat Tha Hat)	118,000	920	7.8×10^{-3}
Mun (at Ubon Ratchathani)	107,000	540	5.0×10^{-3}
Mae Klong (at Kanchanaburi)	27,000	410	15.0×10^{-3}

The upper part of the Mae Klong basin is covered by tropical rain forests, and farmland can be found only along river banks. However, the downstream area of the basin embraces an extensive and well developed plain which is densely populated. The southern part of the basin, which is covered predominantly by cultivated land, has many important cities such as Ratchaburi and Samut Songkhram, and is known as an important granary of Thailand together with the Chao Phraya river basin. This area is also known for the frequent occurrence of flood damage.

Table 3-2 Statistical Data of Basins

in 2503B.E.

Basin	Total Area Km^2	Total Population	Agricultural Population		Acreage of Agricultural Land Holdings		
			Person	%	Total Acreage	Number of Holding	Average of Holding
Khwae Yai River	14,630	104,300	83,700	80.2	325,100	14,452	22.49
Khwae Noi River	10,960	63,400	48,800	76.9	154,825	7,851	19.72
Mae Klong River plain	7,019	1,298,400	901,600	69.4	2,829,275	138,065	20.49
Total	32,609	1,466,100	1,034,100	70.5	3,309,200	160,368	20.63

(1) The Khwae Yai river has a catchment area of 14,630 Km^2. The whole basin, excepting that of the lower tributary, Huai Tapoen, is a steep and rough mountainous area covered with thick jungles and bamboo forests. It has a total length of about 450 Km (about 600 Km from the Mae Klong estuary), and its bed slope in the upstream sectie is very sharp, registering 1/40 near the headwaters and 1/700 near the confluence with the Huai Kha Khaeng river. In the neighboughhood of this confluence, the steep river valley disappears and the bed slope becomes milder toward downstream (approx. 1/2,000), recording as low a value as about 1/3,000 at Kanchanaburi, the lowermost end of the river. The average annual total discharge is $4,600 \times 10^6 m^3$.

(2) The Khwae Noi river has a catchment area of 10,960 Km^2. As a whole, its basin is a heavily undulating mountainous area covered with thick jungles and bamboo forests. It has a total length of about 400 Km (about 550 Km from the Mae Klong estuary) and a very sharp bed slope which is as large as 1/10 near the headwaters and 1/700 at Sangkhla Buri 70 Km downstream of the headwaters.

At Sangkhla Buri, it is joined by the Huai Pilok, one of its largest tributaries, and flows downwards passing by Thong Pha Phum at a point about 88 Km from Sangkhla Buri. The bed slope between these two cities averages about 1/1,500. From Thong Pha Phum, it flows further down a distance of 240 Km until it reaches Kanchanaburi, the lowermost point. The Lam Pa Chee, the largest tributary, joins it immediatly upstream of this point. The average annual total discharge is $6,700 \times 10^6 m^3$.

(3) The plain extending along both banks of the Mae Klong river occupies the western part of the so-called Central Plain of Thailand. It covers an area of 7,019 Km^2 and contains about 90% of the basin's total population. Along the left bank, the plain stretches from Kanchanaburi in a fan shape extending widely from northeast to south. Along the right bank, on the other hand, there extends a relatively wide plain up to the billy area which constitutes the water shed of the Lam Pa Chee basin.

The Mae Klong river has a total length of 143 Km (the total length of the Mae Klong river system from the estuary to the uppermost section of the Khwae Yai is about 600 Km), and an average bed slope of about 1/5,000. Its banks are steep and rise high, and its channel is gaining depth year after year. It has an average annual total discharge of $12,700 \times 10^6 m^3$.

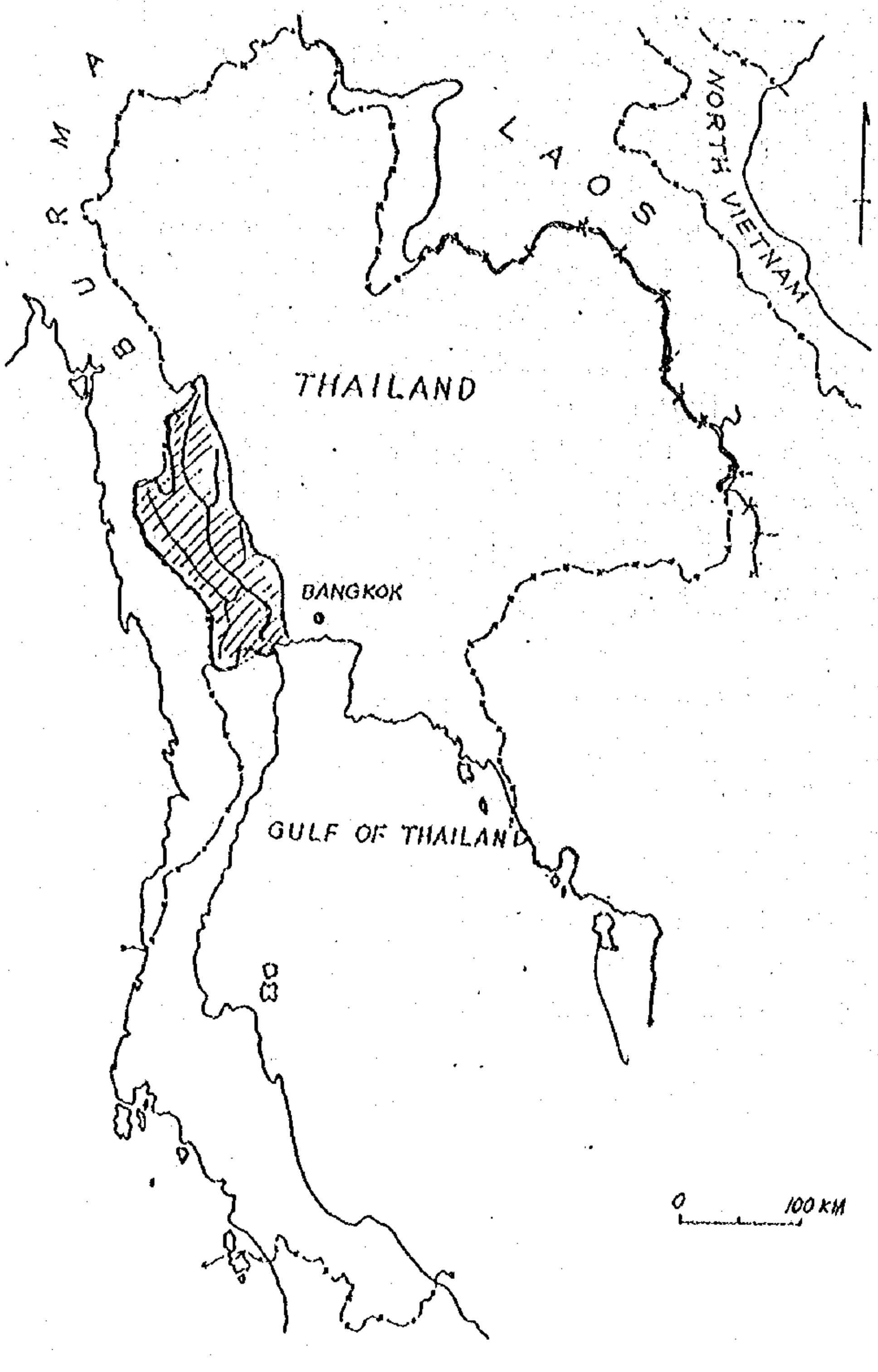


Fig. 3-1 Location Map of Mae Klong River Basin

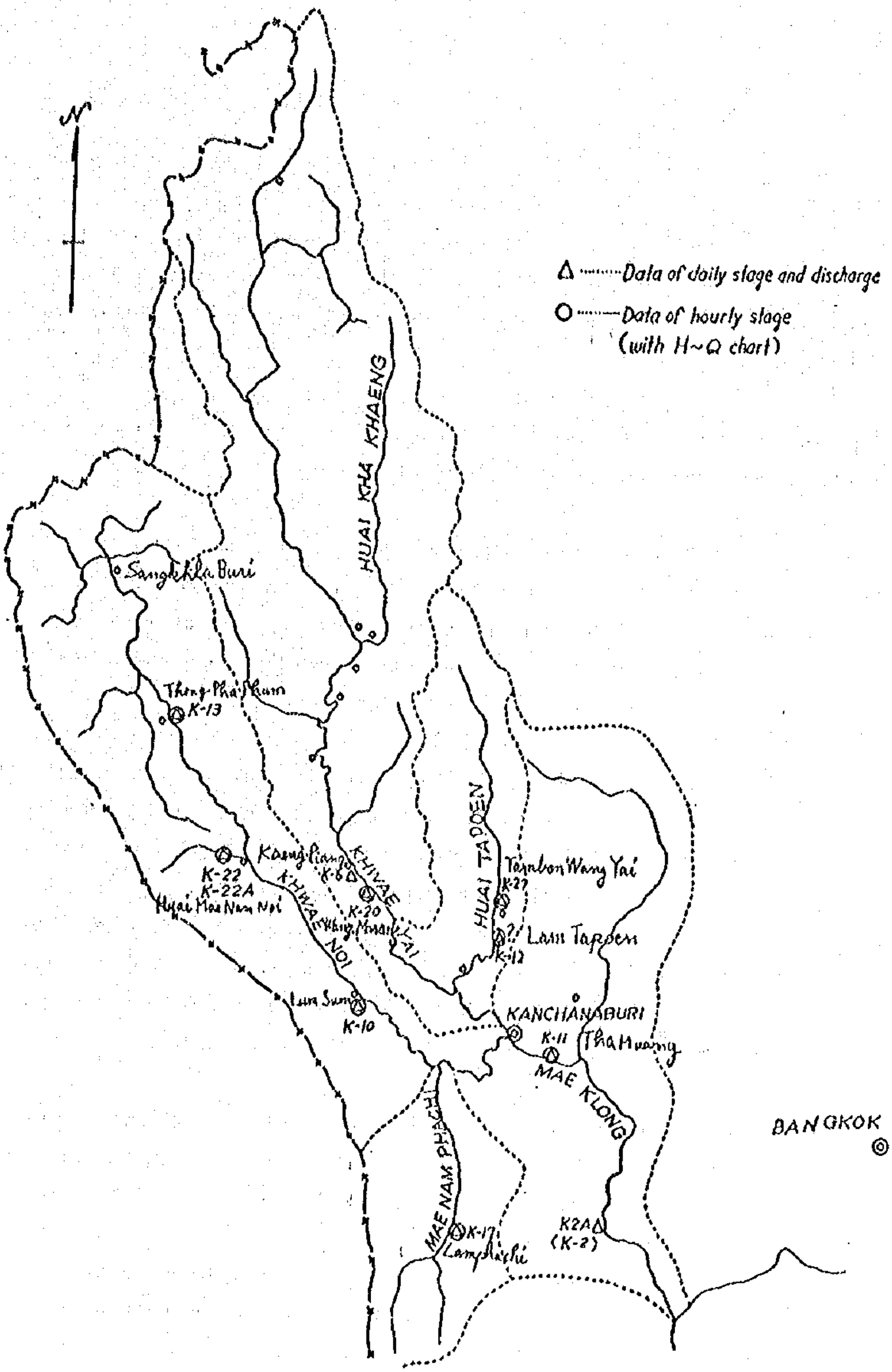


Fig. 3-2 Map of Mae Klong River Basin

3-2 Outline of the Mae Klong and its Tributaries

In the section downstream of Kanchanaburi, the Maeklong has a number of irrigation facilities including Vajiralongkorn dam and river improvement is in fair progress. The team was informed, however, that the expansion of river width involves extreme difficulty in urban areas such as Ratchaburi and Samut Songkhram because houses are built side by side along both banks.

Upstream of Kanchanaburi, the Mae Klong is divided into two major tributaries, the Khwae Yai and the Khwae Noi.

The Khwae Yai has two tributies, the Huai Kha Khaeng which joins the Khwae Yai in the upstream section and the Huai Tapoen which flows into the Khwae Yai in the downstream section. Channel improvement is hardly undertaken except that the construction of Ban Chao Nen dam is under way at a point about 90 Km upstream of Kanchanaburi.

The dam will have a height of 135m upon completion, and has so far been constructed to a height of about 100m, with storage of water already started. Ban Chao Nen dam is a multipurpose dam intended for power generation, irrigation water supply, and flood control. It is extremely large in size and expected to have a total storage capacity of about 17.7 billion tons and an effective storage capacity of about 7.5 billion tons. It is anticipated that the flood of the Khwae Yai can be almost perfectly controlled after completion of this giant dam.

The Khwae Noi also has two tributaries, the upstream tributary being the Huai Mae Nam Noi and the downstream tributary the Mae Nam Phachi. The team did not observe river improvement work in any part of this river. The Khwae Noi maintains a width of 50-70m as far as Thong Pha Phum which is about 200 Km upstream of Kanchanaburi, and abounds in water volume which is far larger than that of the Khwae Yai, and permits navigation by boat even in early February in the dry season. This is due partly to the copious rainfall in the western mountainous district through which the river flows and partly to the geology of the basin which is composed of limestone and therefore provides an extremely large subsurface percolation.

However, the prevelance of limestone is seriously impeding the progress of dam construction at Khao Kwang, Kaeng Puan, Ben Chan De and Khao Laem. Since early dam construction cannot be hoped for, there is great need for establishing a flood forecasting system for the Khwae Noi basin.

Table 3-3 Catchment Area and Length of Major Rivers

River Name	Primary Tributary	Secondary Tributary	Catchment Area	Length of River Channel	Remarks
Mae Klong R.			Km^2 32,609	Km^2	
	Khwae Yai		14,630	450	
		Upstream Section of the Khwae Yai	5,530		
		Huai Kha Khaeng	2,350	130	
		Huai Tapoen	2,650	140	
		The Khwae Yai downstream of confluence of the Huai Tapoen	4,100	-	
	Khwae Noi		10,960	400	
		Khwae Noi	8,380	400	
		Mae Nam Phachi	2,580	120	
	Mae Klong downstream of Kanchanaburi		7,019		Length o of River Channel from the estuary is 143 Km

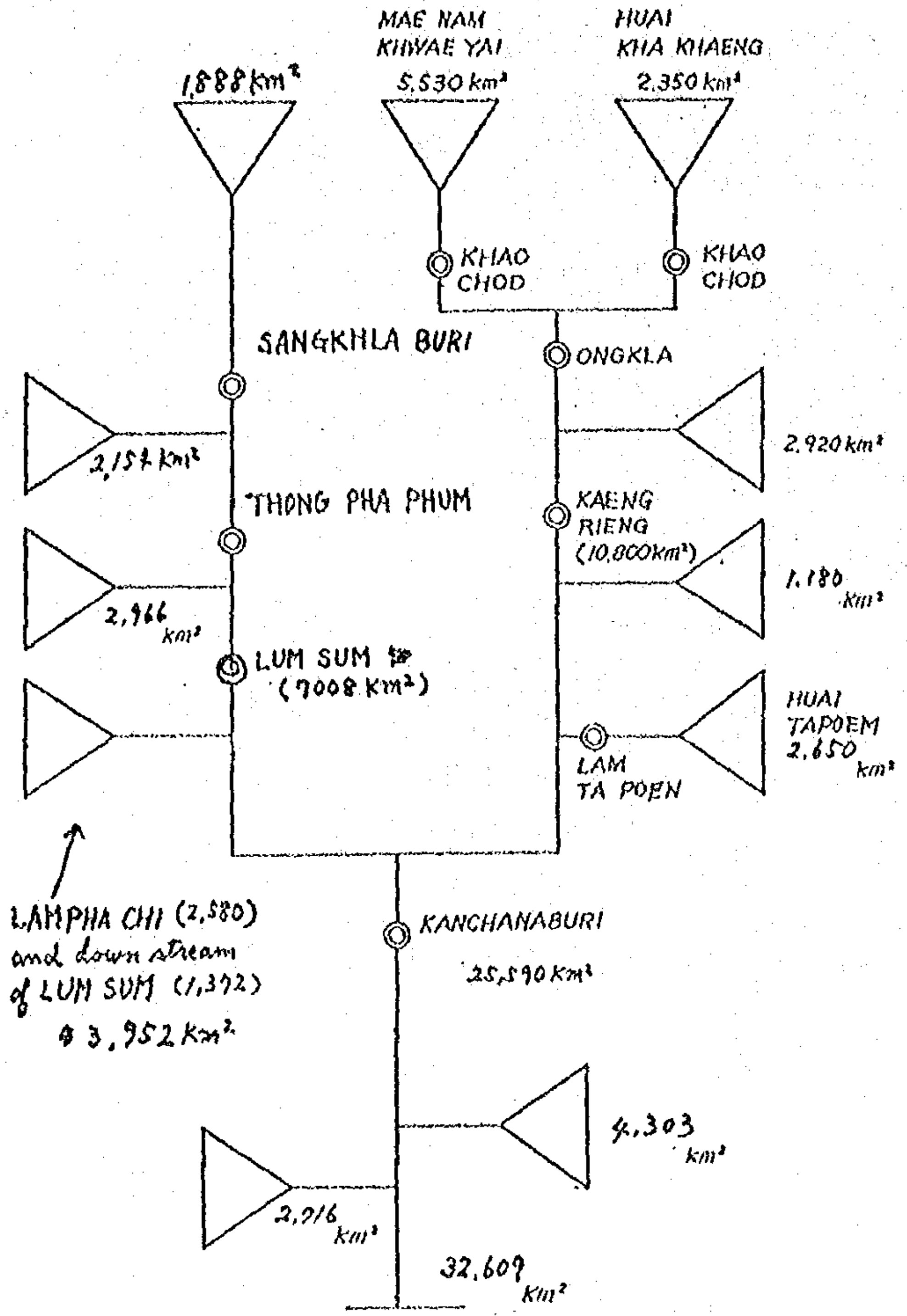


Fig. 3-3 Basin Model of Mae Nam Mae Klong

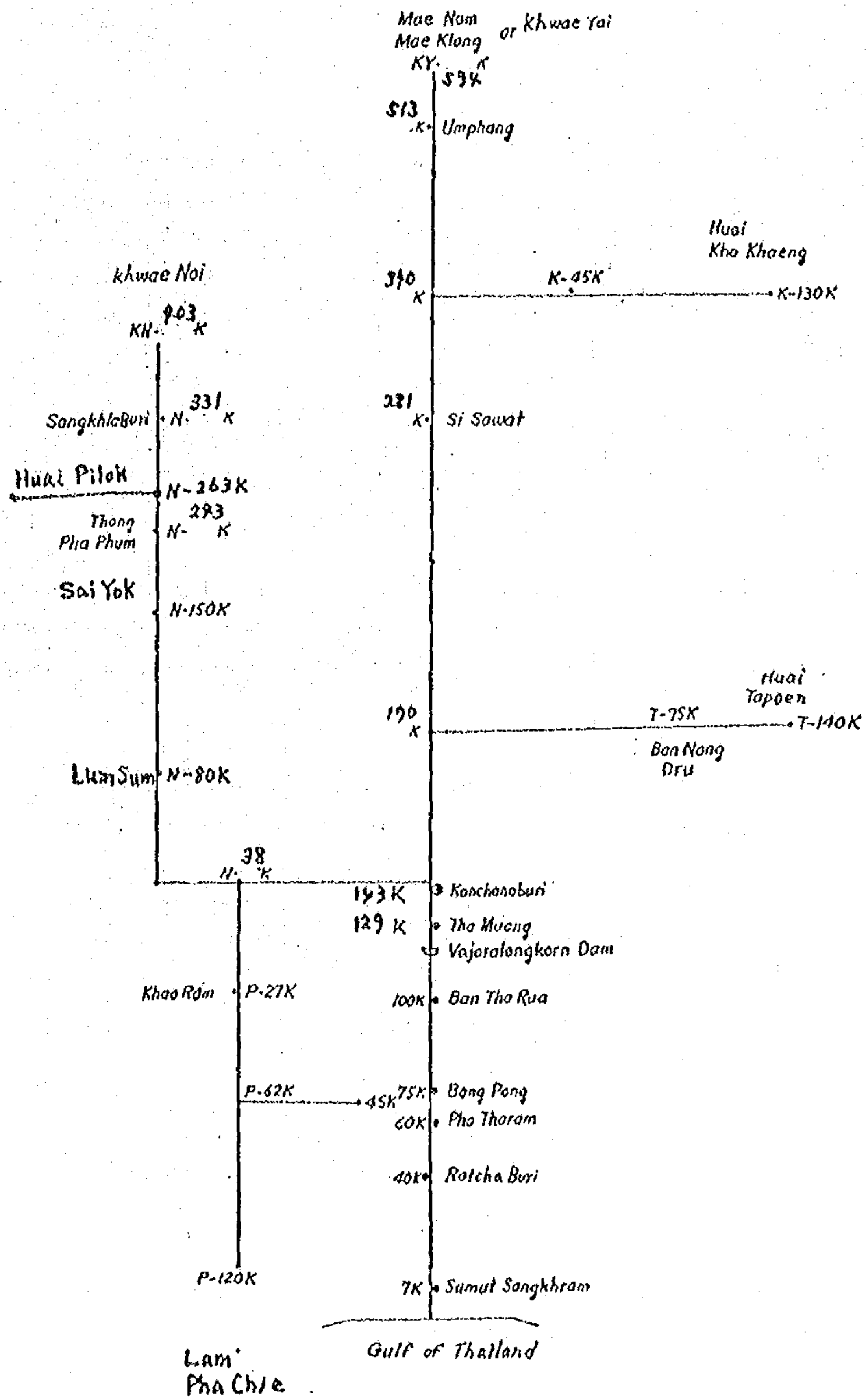


Fig. 3-4 River Channel Model of Mae Nam Mae Klong

3-3 Meteorological Features

The climate in Thailand is under the influence of seasonal monsoons. During the period from November to February, the cold and dry air called northeasterly monsoon is carried into Thailand from Mainland China. This period is the most comfortable season of the year, with the temperature ranging from 13 to 20°C, and may as well be called winter in Thailand.

From May to September, the warm and wet air masses called southwesterly monsoon move into Thailand from the Indian Ocean. This period is most humid of the year, and called the wet season.

March and April is the transitional period from northeasterly to southwesterly monsoon when the maximum atmospheric temperature stays within a range of 33~38°C. This period is called the early monsoon season or summer.

October is the reverse transitional period from southwesterly to northeasterly monsoon, and is called the later monsoon season.

Towards the end of the southwesterly monsoon season, tropical cyclones occasionally make an invasion into Thailand, but they lose energy before reaching the border line as they hit the mountains in the boundary area. These cyclonic depression are observed about 2.2 times a year, mostly in September and October.

The characteristics of rainfall in the Mae Klong basin divide themselves into three areas; the two areas into which the upstream basin is divided by the two tributaries and the downstream basin are (lower plain area).

In the high mountainous basins of the Khwae Yai and the Khwae Noi, no uniformity is observed in the generation of storm rains or in the distribution of rainfall and the annual total rainfall presents a wide range of variation from more than 2,000 mm recorded in the upper reaches (4,300 mm at Pilok) to 1,100 mm at Kanchanaburi. In this upstream basin of the Mae Klong, light rains start falling in February, and the rainfall intensity increases towards April by the influence of the southerly wind blowing from the Gulf of Thailand during the early monsoon season (summer), followed by the advent of the wet season brought about by the southwesterly monsoon during the period from May to September. Generally, September records the largest amount of rainfall, October and November register light rainfalls only, and virtually no rain is observed in December and January.

Lack of uniformity in rainfall distribution is also observed in the flat lower basin area extending from Kanchanaburi to the coasts of the Gulf of Thailand, the maximum rainfall being 1,500 mm and the minimum 900 mm. Seasonal rainfall pattern in this area is quite opposite to that observed in the upper reaches. Specifically, the rainfall which starts in March declines by degrees until May. In the southwesterly monsoon season (June and July), the basin is afflicted with a series of drought especially in its northern part near Kanchanaburi. After July, however, rainfall starts increasing, reaching its peak in September and October. November registers some rainfall, but virtually no rain falls from December to February.

By reason of the meterological characteristics described above, the water stage of the Mae Klong usually starts rising sometime during the period from mid-April to early May, becoming higher and higher with the increase in the intensity and frequency of rainfall. It records its peak values in August and September, and starts declining in October or November.

As a whole, the frequency of flood discharge is the highest in August, and deluges are recorded mostly during the three-month period from July to October. These deluges are caused by heavy rains yielded by the aforementioned strong monsoons, tropical cyclones, tropical depressions and other meteorological phenomena in mountainous regions.

Monthly rainfall data recorded in the Khwae Noi basin and other areas for the last three years are shown in Table 3-3, and monthly evaporation data at Thong Pha Phum are shown in Table 3-4.

Reference is to be made to the Report of Preliminary Survey for the Mae Klong River Floor Forecasting Project for the rainfall data for 1965~1973, evaporation data at Thong Pha Phum in 1972 and 1974, and sunshine duration data at Suphan Buri (1968~1974) and at Nakhon Pathom (1972~1974).

Table 3-3 Monthly Rainfall Data (1974~1976)

Station \ Month	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
	248	351	400	428	518	138	*	24	2	57	14	9	(2,188)
Sangkhla Buri	12	273	613	301	541	305	190	105	5	0	0	39	(2,383)
	119	349	197	414	416	411	252	46	0	-	-	-	(2,204)
	179	638	814	632	1,234	334	396	40	0	99	35	17	4,420
Pilok	29	315	1,080	698	1,156	376	231	40	3	0	0	5	3,932
	111	755	589	915	688	656	366	10	0	17	0	41	4,148
	92	427	495	379	904	60	31	63	0	44	11	70	2,576
Ban Pa Tho	13	238	488	370	357	188	63	13	0	0	3	26	1,760
	78	306	19	94	123	125	127	2	0	0	0	36	910
	172	390	347	244	449	212	318	35	0	29	33	92	2,319
Thong Pha Phum	35	246	270	175	316	248	304	8	14	0	0	43	1,658
	99	269	102	270	312	269	206	42	0	0	0	154	1,723
	99	474	283	284	334	182	286	35	0	30	112	164	2,284
Lin Thin	39	220	304	219	285	227	202	9	3	0	0	106	1,614
	53	374	123	257	224	321	257	40	0	0	0	100	1,749
	164	315	204	243	365	378	326	44	0	25	5	3	2,072
Huai Mae Nam	18	160	283	159	275	218	184	18	2	0	7	74	1,399
Noi	18	370	88	222	212	179	156	35	0	0	0	74	1,354
	117	228	229	138	139	338	355	32	21	23	0	161	1,781
Lum Sum	30	210	178	156	119	296	206	25	26	0	1	55	1,301
	69	179	11	94	283	217	258	91	3	18	0	4	1,227
	78	230	66	72	165	334	468	95	0	16	10	129	1,663
	0	176	159	*	100	323	208	30	32	0	13	159	1,200
Wang Masang	66	171	31	67	226	145	342	52	0	0	0	29	1,129

Notes: 1. Upper line Data of 1974

middle line " 1975

lower line " 1976

2. Data for 1965~1973 are described in report of Preliminary, survey for Mae Klong River Basin Flood Forecasting Project.

3. * means no observation

4. At Sangkhla Buri, no data was get in Jan. Feb and Mar.

Table 3-4 Monthly Evaporation Data (1965~1977)

Thong Pha Phum (K-10)

Year	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual	Remarks
1965											87.3			
1966				49.1	140.2	109.7	105.7	30.9	72.1	82.4	91.5	126.6		
1967	127.1	96.7	70.9	77.4	85.6	64.8	82.7	72.6	72.6	75.1	92.7	109.1	1,026.7	
1968	128.9	94.0	68.0	63.1	48.7	72.9	86.9	77.2	76.3	83.9	106.5	133.4	1,039.6	
1969	119.3	108.3	56.5	50.4	81.8	80.2	97.2	77.4	77.0	84.6	128.7	140.6	1,214.1	
1970	110.5	124.4	100.0	86.4	78.0	96.1	105.4	72.9	-	119.9	129.6	156.4		
1971	157.8	158.6	80.9	57.3	63.5	77.3	81.4	76.4	83.4	86.5	107.8	113.3	1,143.9	
1972	103.5	109.3	64.3	54.7	55.1	-	94.6	69.0	68.2	83.0	-	118.3		
1973	137.9	99.3	68.7	70.7	68.3	71.7	88.4	67.5	-	84.3	92.3	104.9		
1974	-	94.3	57.2	69.8	66.8	-	88.7	-	75.8	77.5	92.4	110.7		
1975	114.6	99.9	59.6	77.3	53.9	76.7	80.2	70.6	79.6	78.2	93.4	119.6	1,004.0	
1976	116.2	75.3	64.8	53.1	59.4	57.4	78.8	75.9	68.4	80.1	83.2	102.1	915.2	
1977	116.3	90.0	83.4											

3-4 Flood Occurrence

The flood occurrence condition in the Mae Klong river basin, described at length in the Preliminary Survey Report presented in March 1975, is reproduced below in outline.

(1) Outline

Rainfall in the Mae Klong river basin is copious in the May~October period due to the effect of the southwesterly monsoon. The rain brought about by the cyclone from the Bay of Bengal in and around May falls in the Lam Phachi river basin, and in June it falls in the basins of the Khwae Yai and the Khwae Noi.

The strong rain brought about by the typhoon falls in the basins of the Khwae Yai and the Khwae Noi in September, and in the Lam Phachi basin through October and November.

The water level of the Mae Klong river rises three times a year. The first rise occurs in the May-July period when the level becomes 3~4 m higher than in the dry season, with July recording a temporary decline of about 2 m. This is followed by the sharp rise which starts in the beginning of August. The annual highest water level is usually recorded in the August~September period. This second rise is followed by the third rise in some years, and this lasts from October to November but the increment of level is not so large as in the August~September period.

When the discharge of the Khwai Noi or Khwae Yai increases, the Mae Klong rises almost to the top of its banks. In certain cases where the discharge of both tributaries increases, the Mae Klong overflows its banks. Accordingly, there always is fear of flooding in August and September. On the left bank side of the Mae Klong, there extends a huge lowlying area which forms the natural retarding basin of the Mae Klong. The ground elevation of this retarding basin is 3~4 m lower than the crown height of banks. Even when the water level does not go beyond the free-board, the river water often flows into the retarding basin through the irrigation canal. If the flood occurs at the beginning or end of the irrigation season, a heavy damage is inflicted upon crops.

In Ratchaburi province, a railway line and a highway runs on the left bank side of the Mae Klong, and a stretch of hills extends on the rig bank side. Thus, the flat land on either side of the river is sandwiched in between the river bank and the hilly area. Therefore, the river water overflows into the lowlying land on the left bank side and intrudes into the town area. This part of the basin is known as Thung Khao Ngu where farming is not feasible when the river stage is high. Cultivation in this area is possible only in the non-irrigation season after the river water recedes.

Table 3-5 shows the annual maximum discharges recorded in the last ten years and the time of their occurrence. Station K11 in this table is located at Kanchanaburi, K20, K6 and K27 on the Khwae Yai and its tributaries, and K10, K13, K22 (or K22A), and K17 on the Khwae Noi and its tributatries.
(See Fig. 3-9 for the location of each station).

Table 3-6 shows the same date recorded up to 1964.

Table 3-5 Annual Maximum Discharge and Time of Occurrence (1)

Station / Year	K11	K20	K6	K27	K10	K13	K22 or K22A	K17
65	2,038		791		1,811			
	18^h 30 July		9^h 27 July		24^h 29 July			
66	2,209	766	780		2,263	3,146	143	190
	6^h 14 Sep.	21^h 11 Sep.	18^h 11 Sep.		18^h 12 Sep.	18^h 10 Sep.	28 July	2^h 20 Nov.
67	1,852	615	597		1,680	2,099	119	73
	6^h 22 Aug.	18^h 21 Aug.	15^h 21 Aug.		15^h 20 Aug.	18^h 18 Aug.	3^h 7 Aug.	21^h 8 Oct.
68	1,492	627	618	10	1,106	1,088	K22 54	954
	12^h 18 Aug.	7^h 17 Aug.	7^h 17 Aug.	12^h 19 Mar.	6^h 17 Aug.	11^h 15 Aug.	10^h 16 Aug.	21^h 22 Oct.
69	2,841	1,084	1,079	42	2,375	2,211	207	?
	9^h 14 Aug.	1^h 11 Aug.	22^h 10 Aug.	21^h 4 Nov.	24^h 11 Aug.	7^h 10 Aug.	K22A 24^h 9 Aug.	?
70	1,362	492	481	19	1,182	1,168	167	442
	15^h 19 July	24^h 26 Aug.	21^h 26 Aug.	24^h 5 Nov.	16^h 18 July	21^h 16 July	17^h 16 July	18^h 1 Dec.
71	2,367	876	832	13	1,896	1,887	123	186
	18^h 29 July	19^h 26 July	18^h 26 July	16^h 3 Nov.	19^h 28 July	21^h 26 July	13^h 26 July	23^h 11 Oct.
72	2,990	2,251	2,658	75	3,067	2,860	386	165
	18^h 19 July	19^h 20 Sep.	3^h 20 Sep.	6^h 28 Sep.	1^h 17 July	6^h 14 July	18^h 18 July	22^h 28 Oct.
73	1,982	920		56	1,762	1,846	135	598
	18^h 21 June	6^h 25 Sep.		6^h 10 Oct.	15^h 20 June	24^h 18 June	18 June	24^h 19 Nov.
74	3,561	1,784		380	3,294	3,058	321	355
	21 Aug.	13 Oct.		13 Oct.	6^h 21 Aug.	6^h 19 Aug.	18 Aug.	21^h 16 Oct.

Table 3-6 Annual Maximum Discharge and Time of Occurrence (2)

	K-11	K-6	K-10		K-11	K-6	K-10
51				58	1,609 25 July	880 6^h 1 Sep.	
52		1,738 6^h 25 Oct.		59	2,853 4 Oct.	1,792 6^h 3 Oct.	
53		2,164 15^h 18 Aug.		60	1,434 24 Aug.	816 18^h 8 Oct.	
54		869 9^h 27 Sep.		61	4,330 28 Aug.	1,628 18^h 3 Sep.	
55		629 12^h 26 Sep.		62	3,416 22 Sep.	2,746 20 Sep.	1,982 21 Sep.
56		855 6^h 18 Oct.		63	2,939 5 Oct.	2,114 6^h 4 Oct.	2,157 12 Aug.
57	2,799 24 Aug.	1,373 6^h 4 Oct.		64	2,251 27 Sep.	1,409 15^h 26 Sep.	1,354 27 Sep.

(2) Condition of Flooding

Inundation of the Mae Klong river basin usually occurs in areas downstream of Vajiralongkorn headwork.

Flooded area can be broadly divided into two. One is the area extend-on both banks of the Mae Klong between Ban Pong and Ratchaburi. This area is vulnerable to flood damage even by a relatively small increase of discharge. The other is the left bank area between Tha Muang and Tha Maka which is inundated by flood water overflowing the reservoir when the discharge at Vajiralongkorn headwork increases to more than about 2,300 m^3/s.

During the flood which lasted from September to October, 1972, the discharge was about 1,100~1,400 m^3/s at K11 and an estimated area of about 5,000 ha on both sides of the Mae Klong upstream of Ratchaburi was flooded. At this time, no flooding was observed in areas further upstream.

During the floods in August and October of 1974, the discharge at Vajiralongkorn ranged from 2,800~3,600 m^3/s, which far exceeded the overflow condition of the reservoir. Two areas between Tha Muang and Tha Maka were therefore flooded, producing a flood periphery of about 3,500 ha and in addition, flood water flowed into the Nakhon Chai Si river through Tha San channel. In these two floods, an immense inundation occurred in the downstream area, forming a flood periphery of about 13,600 ha on both banks of the river between Ban Pong and Ratchaburi.

These floods are illustrated in Figs. 3-5 and 3-6

Flooded and damaged areas in the period from 1969 to 1974 are shown in Table 3-8.

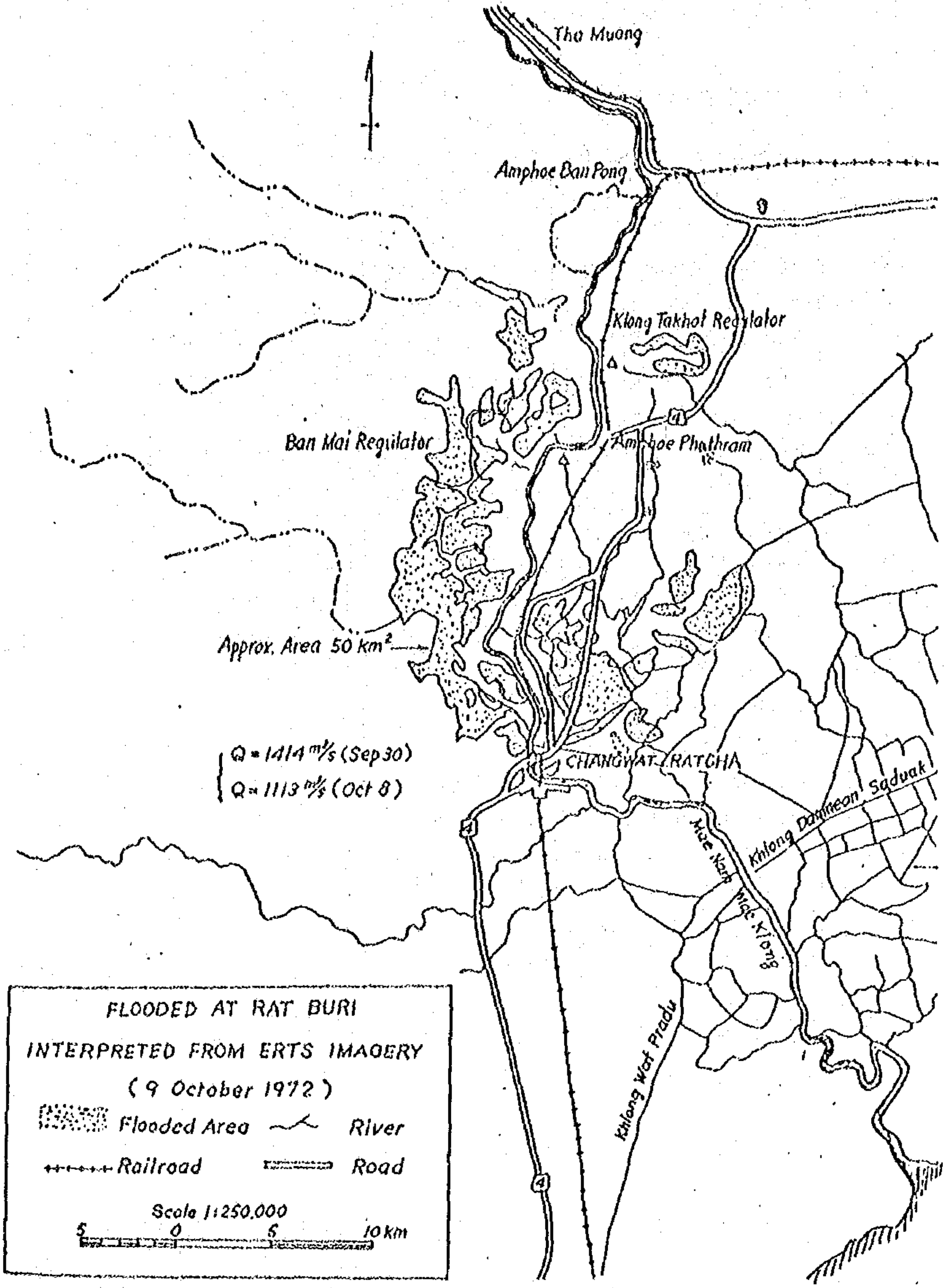


Fig. 3-5 Flooded Area (1972)

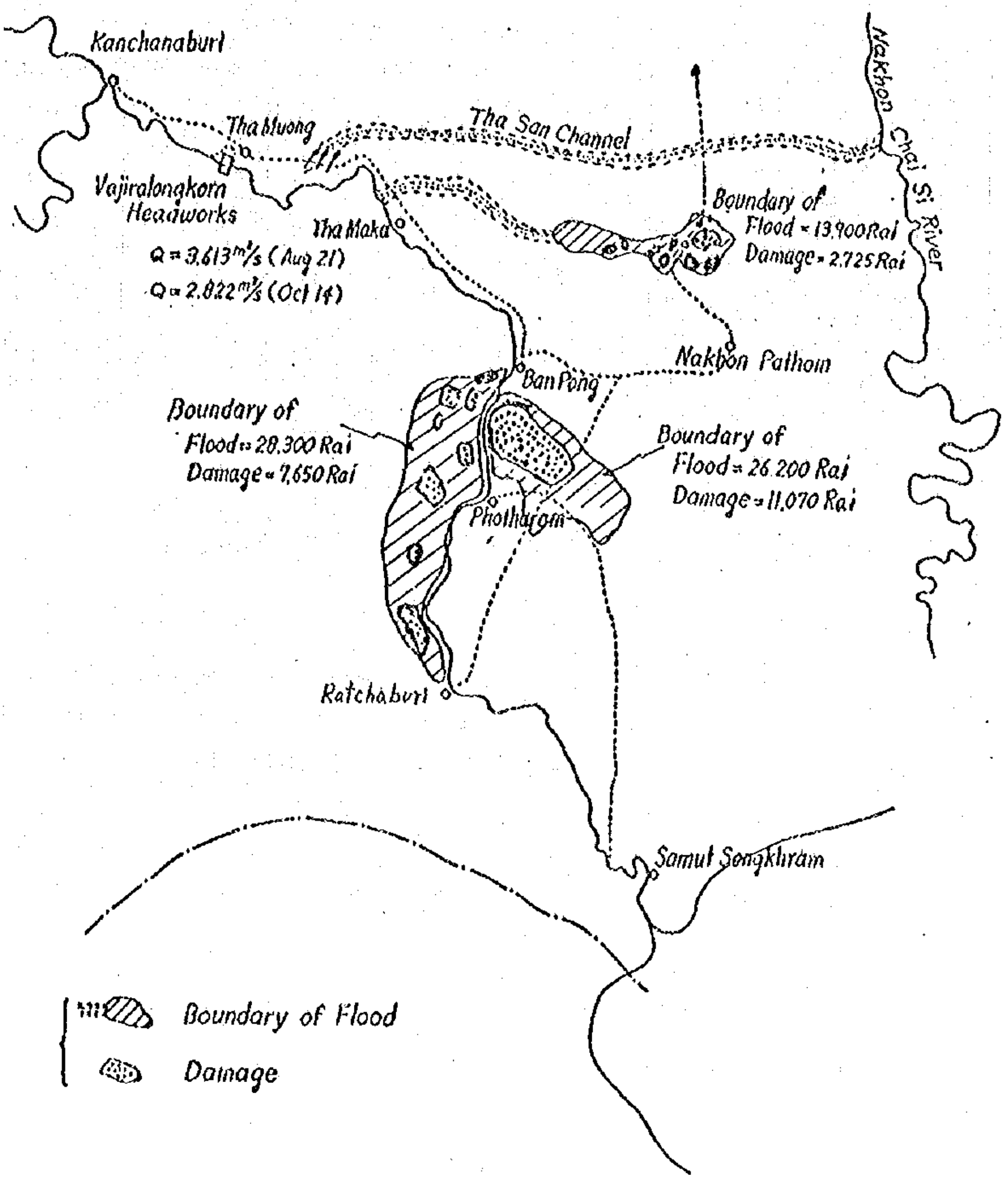


Fig. 3-6 Flooded Area (1974)

Table 3-8 Flood of Mae Klong Project Area

YEAR	PEAK DISCHARGE M^3/SEC	RETURN PERIOD YEAR	BOUNDARY OF FLOOD RAI	DAMAGE RAI
1969	2,841 (12 Aug.)	3	350,000	NO RECORD
1971	2,367 (29 Jul.)	2	1,500	1,500
1972	2,990 (19 Jul.) 2,370 (2 Aug.)	4 2	173,750	12,520
1974	3,613 (21 Aug.) 2,822 (14 Oct.)	8 3	68,744	21,819

3-5 Ban Chao Nen Hydropower Generation Programme

(1) Outline (Fig. 3-7, 3-8)

Under the Ban Chao Nen Hydropower Generation Programme, it is planned that a dam and power plant will be constructed on the Khwae Yai at a point about 150 Km to the northwest of Bangkok.

The dam is planned to be of the rockfill type with an impermeable core, having a height of 135 above the foundation rock, a total storage capacity of 17,745 million m^3 and an effective storage capacity of 7,470 million m^3. It will have a catchment area of 10,880 Km^2, and be used for year-round storage of flood water and supply of irrigation water in the dry season.

Five generators to be installed at Ban Chao Nen power plant are expected to exhibit a total installed capacity of 720,000 kW. The generators are planned to be installed in two stages. In the first stage, three generators will be installed to provide an installed capacity of 360,000 kW, which is to be augmented by another 360,000 kW by the second stage installation of two additional genertors. The two generators to be installed in the second stage are planned to be provided with a reversible turbine to pump up water.

Completion of this power plant will make it possible to generate an annual average of 1,160 million KWH of electric energy whiches to be transmitted to the substation in Bangkok by the transmission line having a total length of about 165 Km.

The dam is intended to be used for multipuporse operation such as supply of irrigation water and flood control besides power generation.

It is also planed that a regulating reservoir of 30 MCM will be built at a 30 Km downstream point from the dam site for pumping-up generation and for dissipation of hydraulic bore resulting from simultaneous discharge from Ban Chao Nen reservoir.

(2) Basic Data of Ban Chao Nen Power Generation Programme

1) Location — Ban Chao Nen on the Khwae Yai river.

2) Catchment area — 10,880 Km^2.

3) Annual inflow — 4,600 MCM.

4) Maximum possible discharge — 7,100 m^3/s.

5) Basic data of reservoir

a. Normal water surface level — El 180.0 m.

b. Ponding area — 419 Km^2

c. Total storage capacity — 17,745 MCM.

d. Effective storage capacity — 7,470 MCM.

e. Maximum level of ponding area — 182.4 m

(3) Basic Data of the Dam

1) Type — Rockfill dam with an impermeable core.

2) Dam site geology — Quartzite, sandstone, and limestone.

3) Crest height — 185.0 m.

4) Dam height — 135.0 m.

5) Crest length — 610.0 m.

6) Dam volume — 12,300,000 m^3.

(4) Basic Data of Spillway

1) Type — Open chute type.

2) Gate — Radial gate, 10 m × 9.5 m × 3.

3) Maximum discharge — 2,420 m^3/s.

(5) Power Generation

1) Maximum turbine discharge

First stage	133 m^3/s×3 generators = 399 m^3/s.
Second stage	199.5 m^3/s×2 generators = 399 m^3/s.
Total	798 m^3/s.

2) Maximum output

360,000 kW in both the first and second stages, totalling 720,000 kW.

3) Annual generated electric energy

1,160 × 10^6 KWH.

3-6 Existing State of Observation Stations and Availability of Data

There are many organizations engaged in observation activities along the Mae Klong river and in its basin in order to collect meteorological data as well as data for flood control and water utilization. Accordingly, the existing observation networks, belonging mostly to the following four organizations, present an extreme complexity.

1) Meteorological Department (MD), Ministry of Communications.

2) The Electricity Generating Authority of Thailand (EGAT).

3) National Energy Authority (NEA).

4) Royal Irrigation Department (RID).

A detailed list showing the distribution of the stations belonging to the four organizations and the availability of observation data is included in the Preliminary Survey Report pressented in March 1975.
In this report, therefore, the locations and other particulars of main stations covered by the present survey for the purpose of data analysis are shown in Tables 3-9 and 3-10, 3-11 and Fig 3-9, 3-10.

Table 3-9 List of Water Stage Stations

Name of Station		Name of Station	Code	Observation Period	Rating Curve	Drainge Area
1	Mae Klong	Wang Khanai (Tha Muang)	K11	1965~	1965~	26,449 Km^2
2	Khwae Noi	Thong Pha Phum	K13	1965~	1965~ 1971	4,047 Km^2
3	(Huai Mae Nam Noi)	Tambon Thung Na	K22A	1966~	1966~	321 Km^2
4	Khwae Noi	Ban Lum Sum	K10	1965~	1965~	7,008 Km^2
5	(Lam Phachi)	Lamphachi (Chom Bung)	K17	1967~	1966~	1,355 Km^2
6	Khwae Yai	Kaeng Riang	K6	1952~ 1972	1952~ 1971	11,010 Km^2
7	Khwae Yai	Wang Masang	K20	1966~	1966~	11,184 Km^2
8	(Huai Tapoen)	Ban Wang Yai	K27	1968~	1968~	1,921 Km^2

Fig. 3-7 Location of Ban Chao Nen Dam

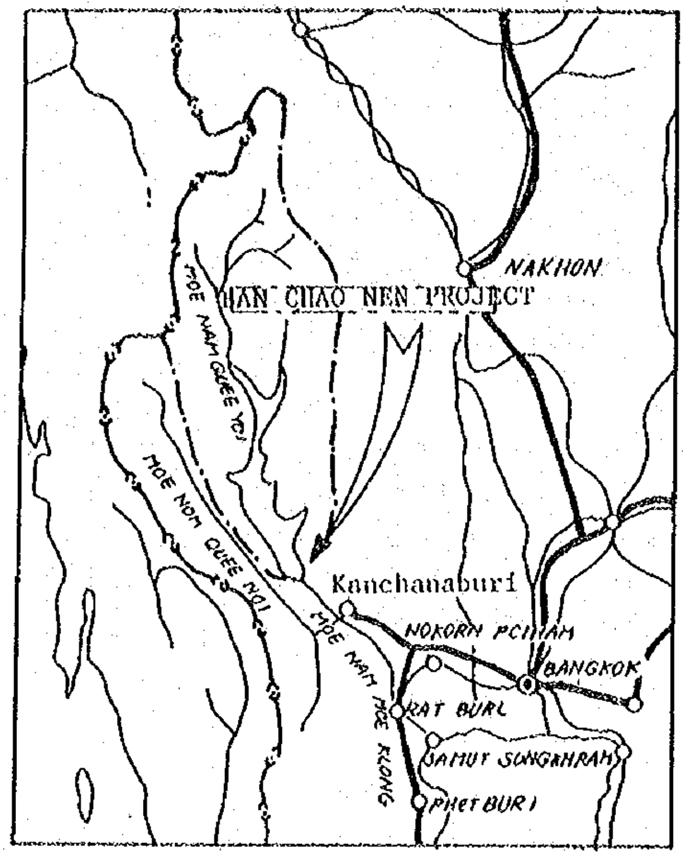
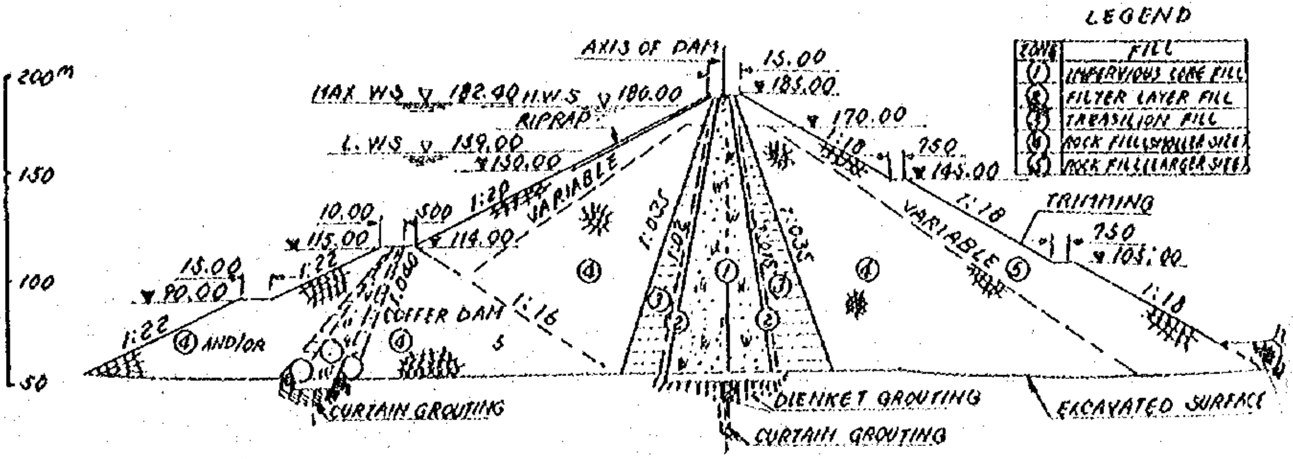


Fig. 3-8 Typical Cross Section of Dam



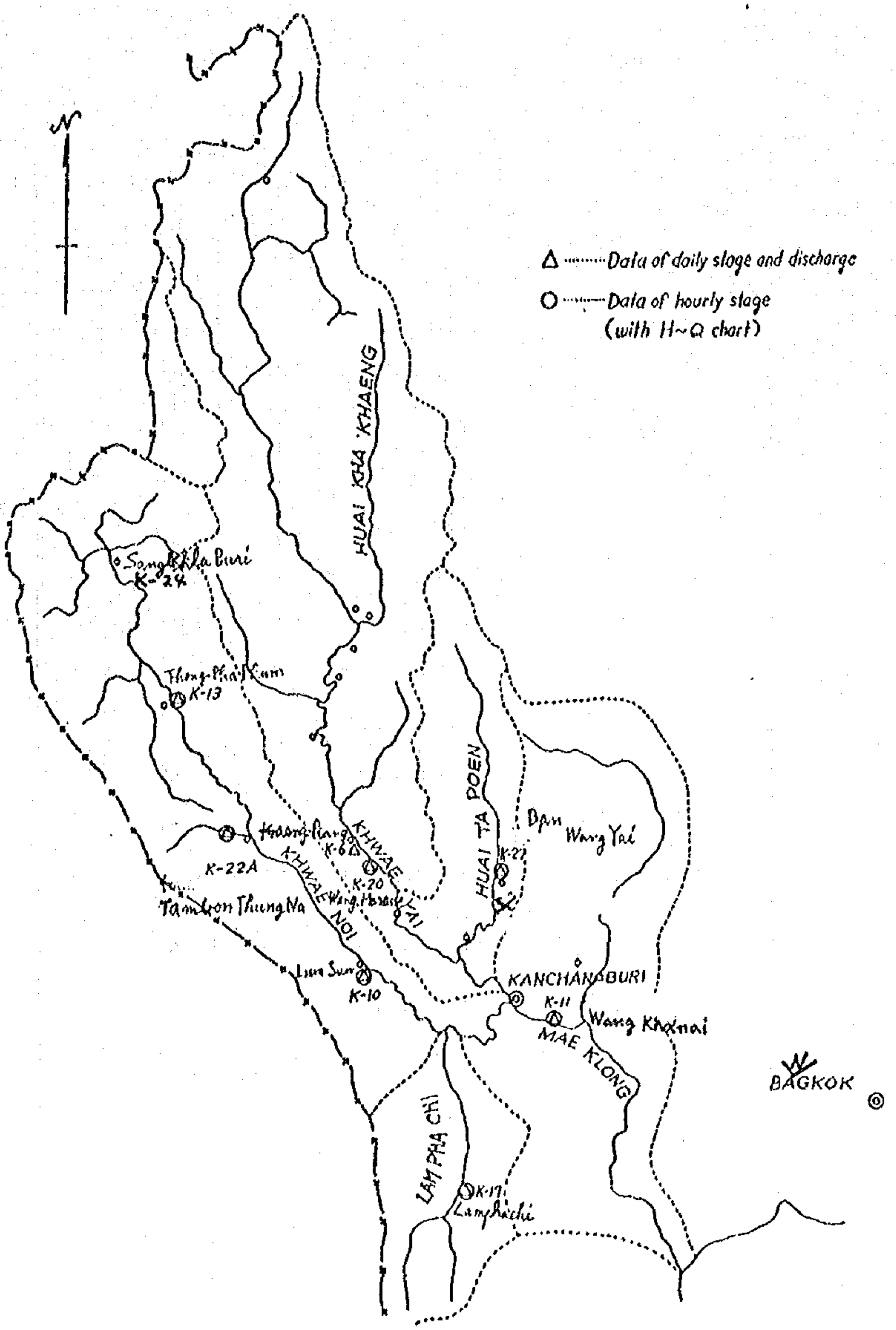


Fig. 3-9 Location of Water Stage Stations

Table 3-10 List of Rainfall Stations

Name of River Basin	Name of Station	Observation period
Khwae Noi	Sangkhla Buri	1952 ~
	Pilok	1956 ~
	Ban Pa Tho	1966 ~
	Thong Pha Phum	1952 ~
	Ban Lin Thin	1966 ~
	Huai Mae Nam Noi	1966 ~
	Ban Lum Sum	1965 ~
Khwae Yai	Umphang	1952 ~
	Ban Nasuan	1957 ~
	Si Sawat	1954 ~
	Kang Riang	1952 ~
	Wang Masung	1968 ~
	Bophloi	1954 ~
Mae Klong	Kanchanaburi (A. Muang)	1952 ~
	Tha Rua	1957 ~
	Tha Muang	1952 ~
	Tha Maka	1952 ~

Table 3-11

Cross Sections and Rating Curves of
Water Stage Station

Name of Station	Used Cross Section	Used Rating Curve
Sangkhla Buri K-24		1977
Thong Pha Phum K-13	1975 ∿ 76	1969
Ban Lum Sum K-10	1975 ∿ 76	1974
Wang Khanai K-11	1975 ∿ 76	1974

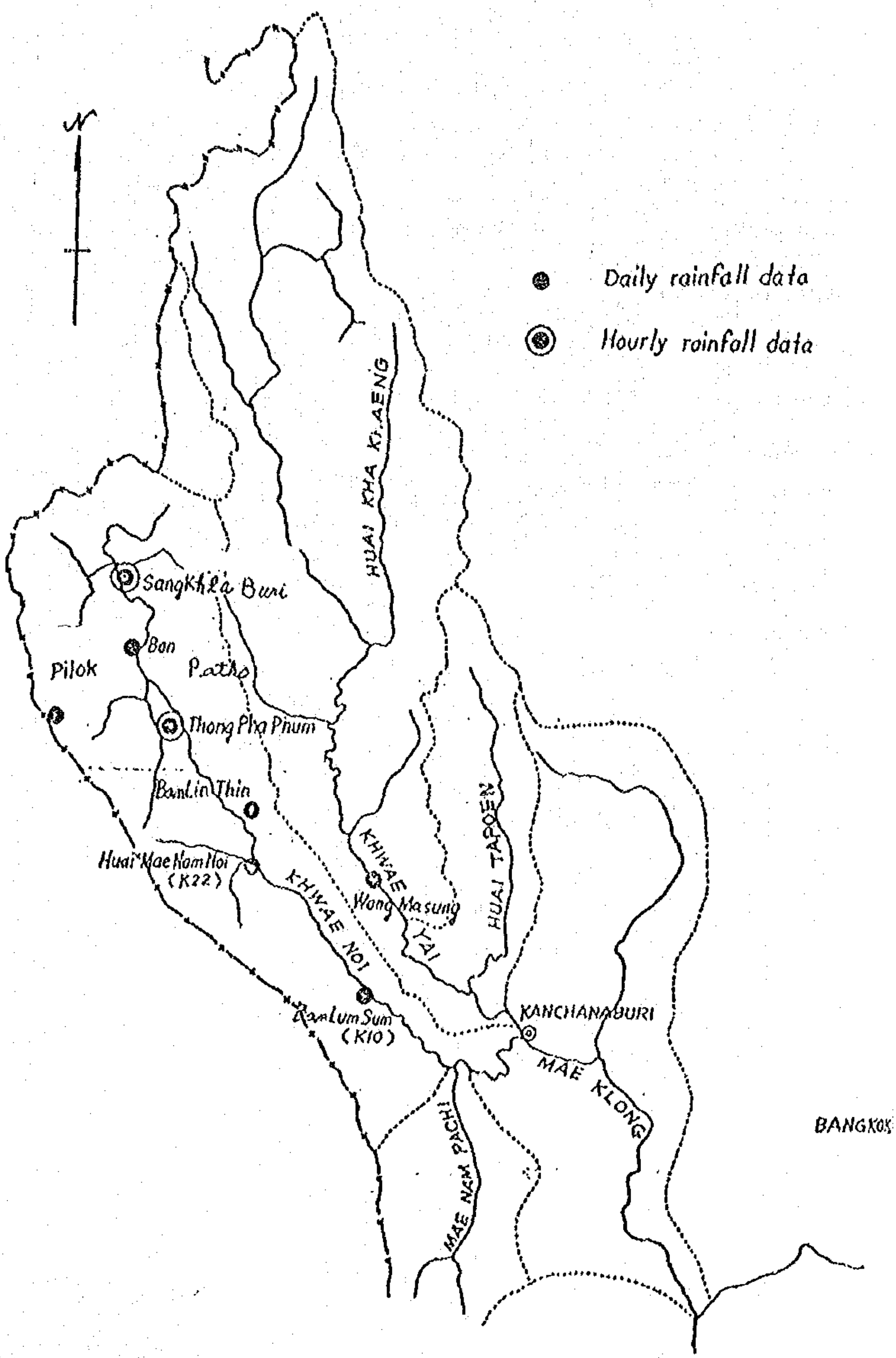


Fig. 3-10 Locations of Stations Providing Rainfall Data

3-7 Existing Telecommunication Network

High frequency SSB is used most widely in Thailand as a means of tele-communications. MD in Bangkok and its observation stations in local areas are connected by an SSB network, and so are RID Bangkok office and the greater part of its local branches.

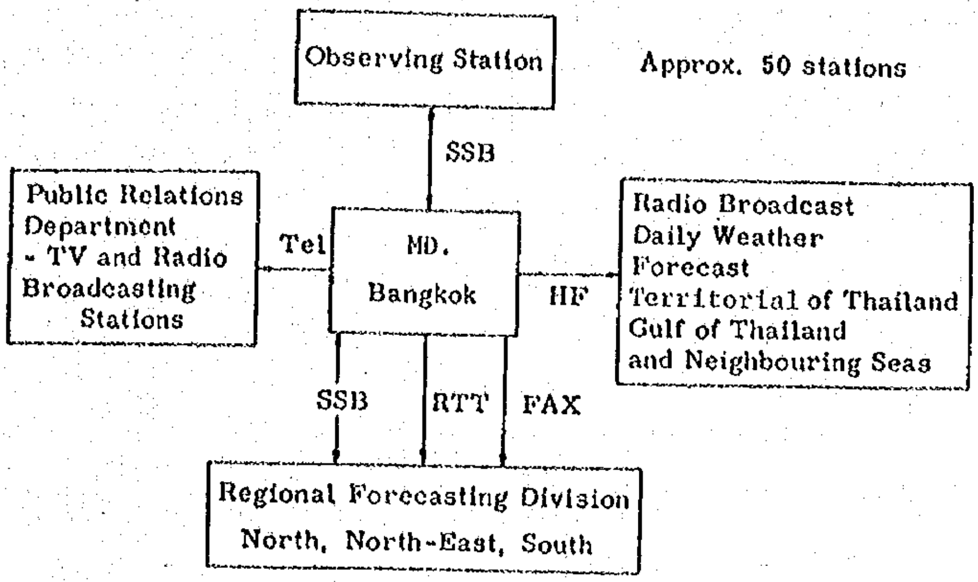


Fig. 3-11 Existing Telecommunication Network

In general, commercial power supply is not sufficient in mountainous areas. In other local areas, too, electricity is not supplied constantly and there are quite a few localities where power is supplied only for the night by diesel engine generators.

CHAPTER 4. ANALYSIS OF FLOOD DATA

4-1 Rainfall Characteristics in Mae Klong River Basin

4-1-1 Average Basin Rainfall by Isohyet Method

In order to grasp the rainfall characteristics in the Khwae Noi river basin and to examine if Thiessen method can be employed in the calculation of average basin rainfall using the data of the existing seven stations, the average basin rainfall was calculated by the isohyet method using the 15 rainfall data shown in Table 4-1. The duration of rainfall shown in the table was counted for each flood so that it varies by floods.

Table 4-1 Floods and Average Basin Rainfall

Flood Occurrence Time	Isohyet Method	Thiessen Method (7)	Thiessen Method (6)	Duration of Rainfall (day)
1. 1974 $15^{Aug} \sim 28$	416.04^{mm}	420.7^{mm}	377.9^{mm}	20
2. 1973 $15^{Aug} \sim 10^{Sep}$	434.19	405.30	355.20	27
3. 1973 $11^{Jun} \sim 30^{Jun}$	421.72	411.80	360.90	20
4. 1972 $19^{Jul} \sim 10^{Aug}$	447.28	391.10	351.70	22
5. 1972 $30^{Jun} \sim 18^{Jul}$	493.82	502.10	455.90	19
6. 1971 $17^{Jul} \sim 29^{Jul}$	313.65	299.00	273.10	13
7. 1970 $11^{Jul} \sim 19^{Jul}$	245.41	206,70	163.80	9
8. 1969 $22^{Jul} \sim 29^{Jul}$	165.48	156.30	140.90	8
9. 1969 $30^{Jul} \sim 26^{Aug}$	488.78	482.70	435.20	28
10. 1968 $5^{Aug} \sim 18^{Aug}$	280.39	234.30	185.90	14

Flood Occurrence Time	Isohyet Method	Thiessen Method (7)	Thiessen Method (6)	Duration of Rainfall (day)
11. 1967 9^{Aug}~26^{Aug}	359.18^{mm}	301.20^{mm}	233.70^{mm}	18
12 1967 27^{Aug}~15^{Sep}	279.60	254.80	219.20	20
13 1967 31^{Jul}~ 8^{Aug}	227.19	202.20	165.60	9
14 1966 21^{Jul}~ 2^{Aug}	300.96	-	-	-
15 1966 2^{Sep}~15^{Sep}	324.09	-	-	-

The isohyetal maps shown in Figs. 4-1-1~4-1-15 indicate that the rainfall in the Mae Klong basin has the following regional characteristics. (Appenddices referred to in the following pages are abbreviated to Ap. 1, Ap. 2, ...)

1) Irrespective of the differences in the duration of rainfall, amount of rainfall, and occurrence period of floods reviewed (which were recorded during the period from June to September), there is a general tendency that rainfall in the northwestern part of the basin is greater than that in the southeastern part.

2) The maximum rainfall is about as large as 10 times the minimum rainfall. Where the differences are relatively small, the maximum rainfall is also as large as 5 6 times the minimum rainfall.

3) However, a basin-wise review indicates that any heavy rainfall on the northwestern moutain slopes covers only those slopes and surrounding areas, and does not usually account much for the average rainfall in the basin.

Fig. 4-1-1 Isohyetal Map

1966 21 Jul~2 Aug

No.	Station	Rainfoll (mm)
10	Sangkhla Buri	356.0
10-1	Ban Pa Tho	238.8
11	Pilok	506.4
12	Thong Pha Phum	
12-1	Lin Thin	
19	Huai Mae Nam Noi	
14	Lum Sum	55.2
1	Umphang	199.4
3	Ban Nasuan	0
4	Si Sawat	40.3
5	Kaeng Riang	53.5
5-1	Wang Masang	-
8	Bo Phloi	23.1
7	Tha Rua	13.6

Rave = 300.96

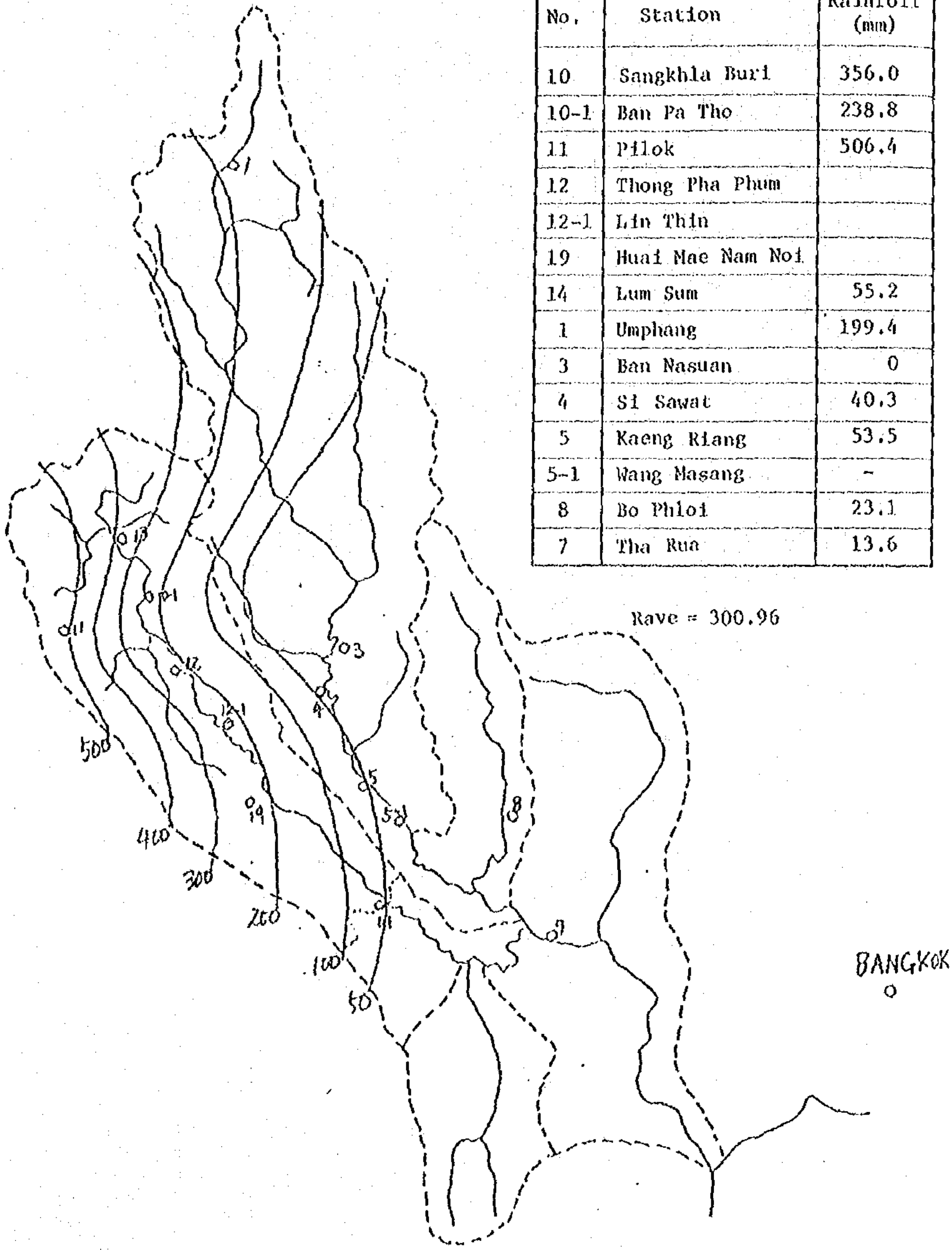


Fig. 4-1-2 Isohyetal Map

1966 2 Sep~15 Sep

No.	Station	Rainfoll (mm)
10	Sangkhla Buri	302.2
10-1	Ban Pa Tho	236.3
11	Pilok	824.0
12	Thong Pha Phum	
12-1	Lin Thin	
19	Huai Mae Nam Noi	199.1
14	Lum Sum	53.8
1	Umphang	188.1
3	Ban Nasuan	61.8
4	Si Swat	79.0
5	Kaeng Riang	48.5
5-1	Wang Masang	-
8	Bo Phloi	31.5
7	Tha Rua	19.3

Rave = 324.09

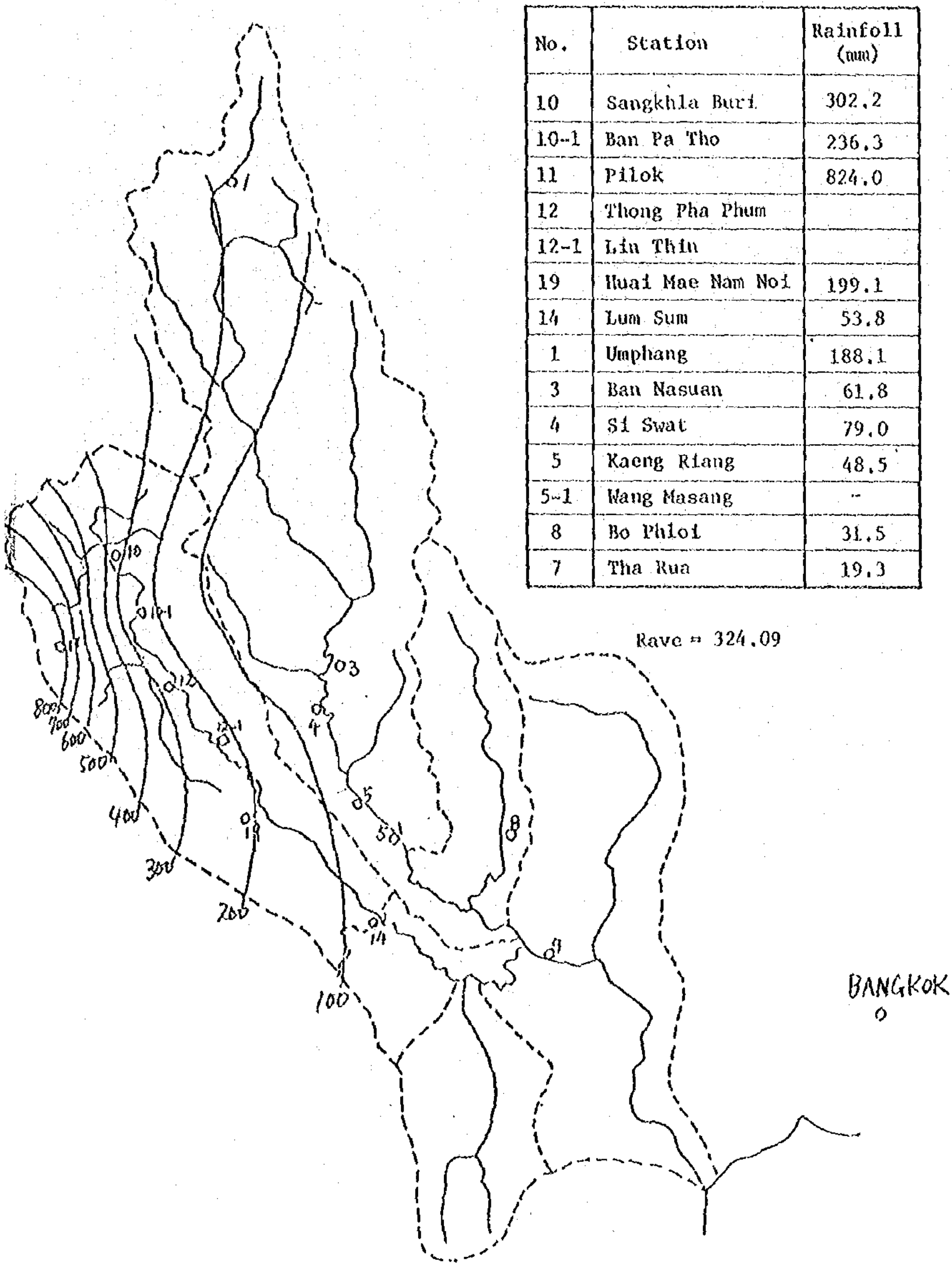
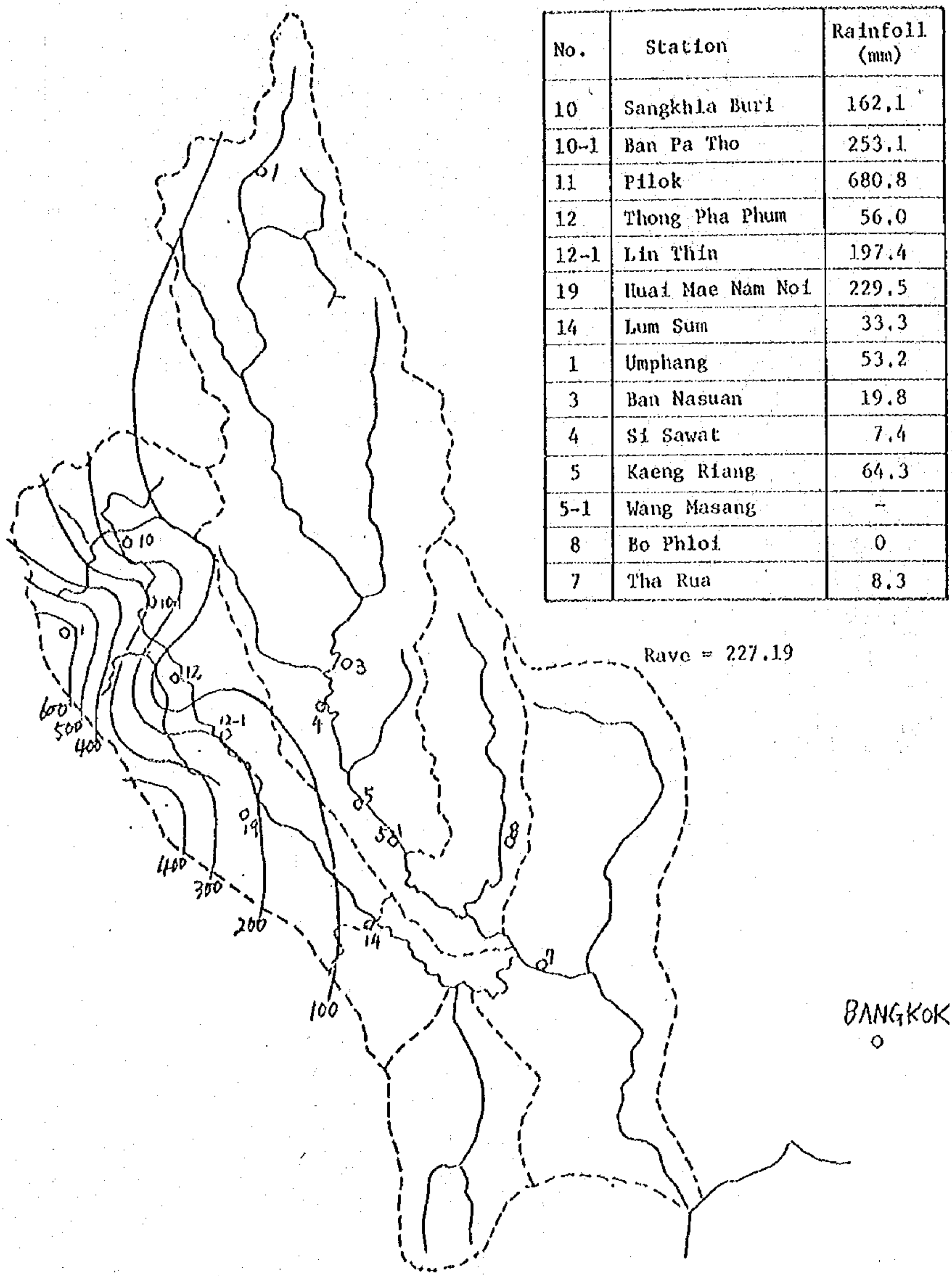


Fig. 4-1-3 Isohyetal Map

1967 31 Jul~8 Aug



No.	Station	Rainfoll (mm)
10	Sangkhla Buri	162.1
10-1	Ban Pa Tho	253.1
11	Pilok	680.8
12	Thong Pha Phum	56.0
12-1	Lin Thin	197.4
19	Huai Mae Nam Noi	229.5
14	Lum Sum	33.3
1	Umphang	53.2
3	Ban Nasuan	19.8
4	Si Sawat	7.4
5	Kaeng Riang	64.3
5-1	Wang Masang	-
8	Bo Phloi	0
7	Tha Rua	8.3

Rave = 227.19

Fig. 4-1-4 Isohyetal Map

1967 9 Aug~26 Aug

No.	Station	Rainfoll (mm)
10	Sangkhla Buri	255.5
10-1	Ban Pa Tho	324.1
11	Pilok	1071.4
12	Thong Pha Phum	80.1
12-1	Lin Thin	513.8
19	Huai Mae Nam Noi	238.8
14	Lum Sum	36.4
1	Umphang	233.9
3	Ban Nasuan	34.9
4	Si Sawat	32.6
5	Kaeng Riang	33.8
5-1	Wang Masang	-
8	Bo Phloi	39.7
7	Tha Rua	19.5

Rave = 359.18

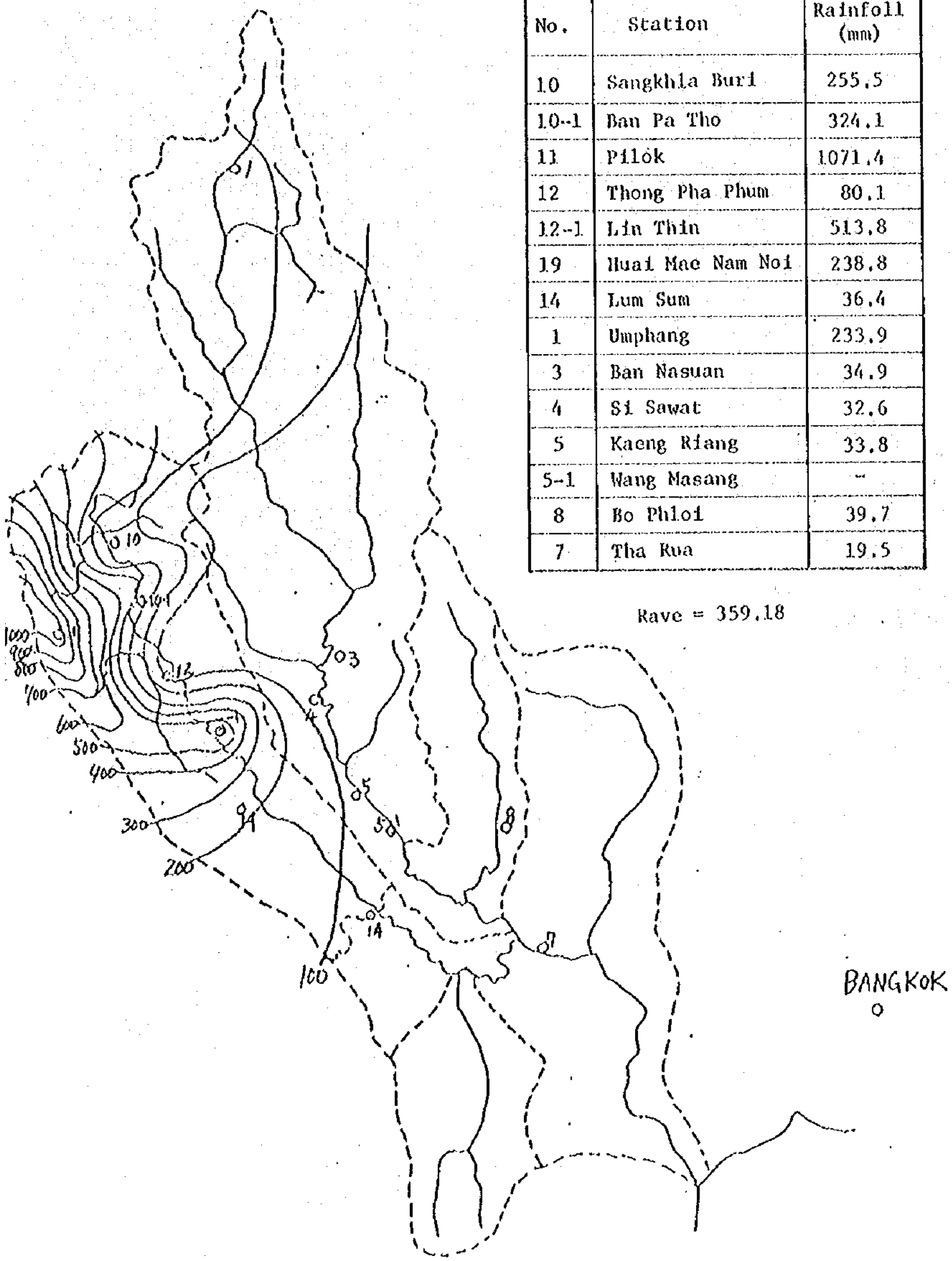


Fig. 4-1-5 Isohyetal Map

1967 27 Aug~15 Sep

No.	Station	Rainfall (mm)
10	Sangkhla Buri	264.6
10-1	Ban Pa Tho	280.3
11	Pilok	712.0
12	Thong Pha Phum	112.0
12-1	Lin Thin	273.6
19	Huai Mae Nam Noi	240.3
14	Lum Sum	71.6
1	Umphang	99.5
3	Ban Nasuan	50.3
4	Si Sawat	24.9
5	Kaeng Riang	38.6
5-1	Wang Masang	-
8	Bo Phloi	26.9
7	Tha Rua	10.9

Rave = 279.60

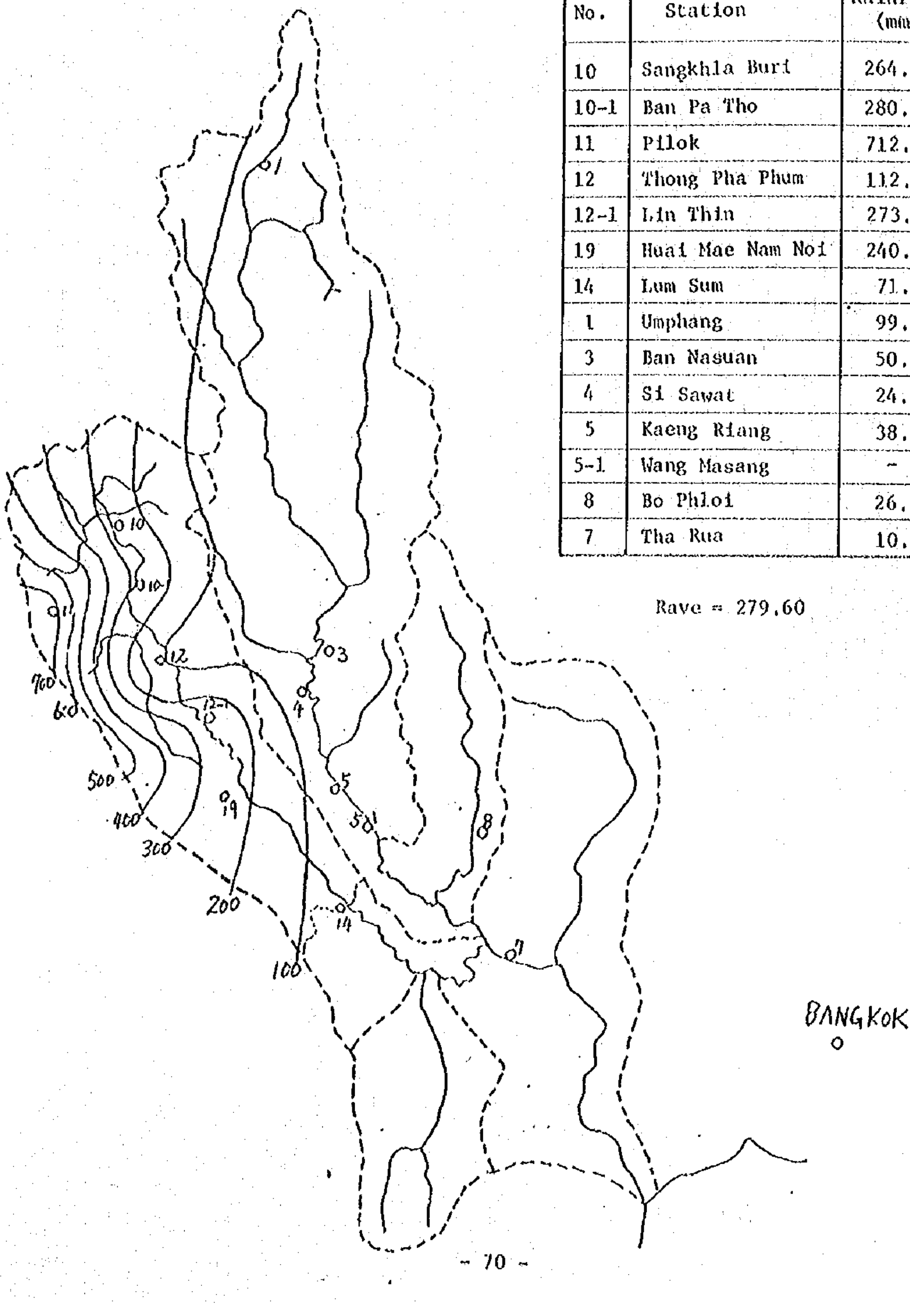
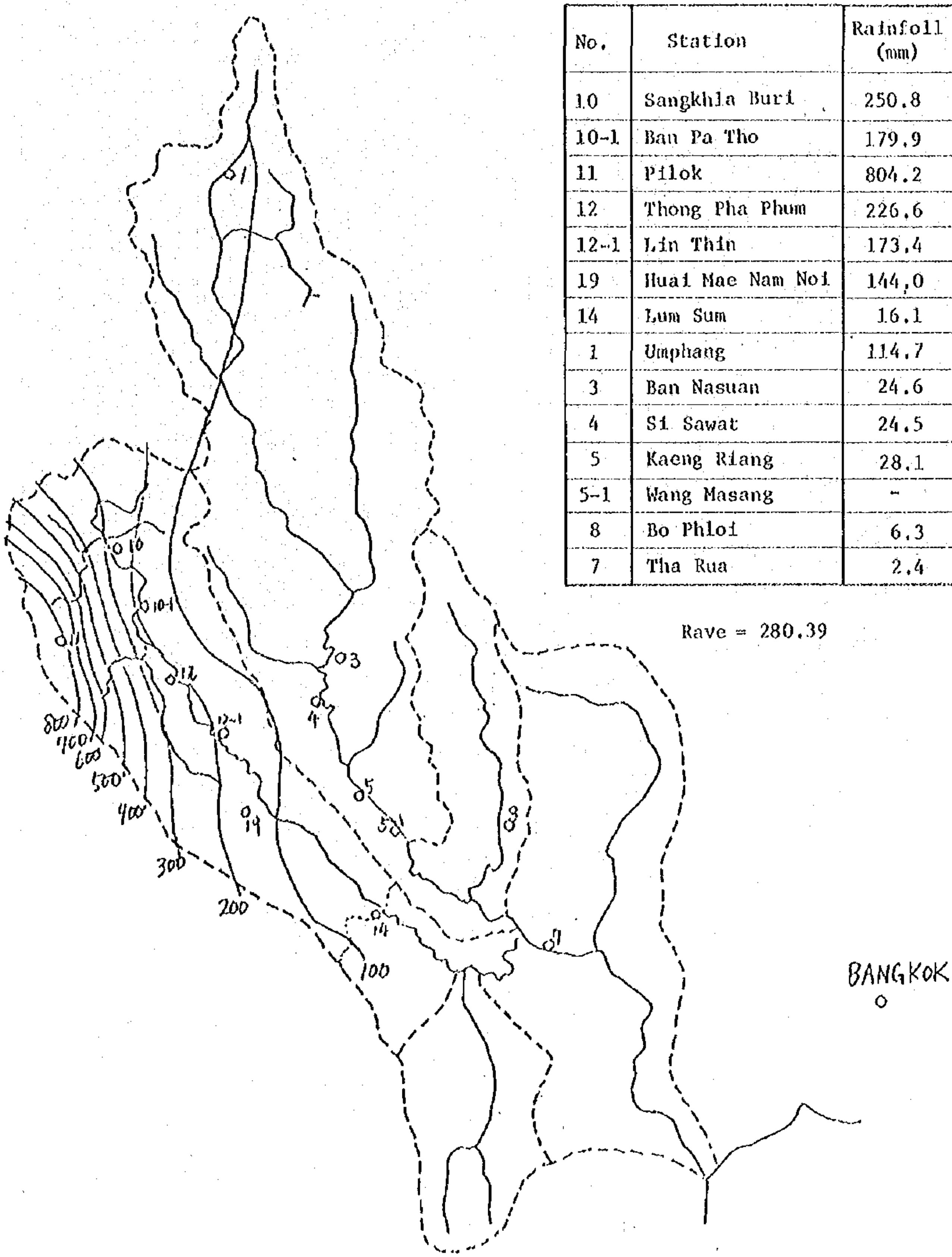


Fig. 4-1-6 Isohyetal Map

1968 5 Aug~18 Aug



No.	Station	Rainfoll (mm)
10	Sangkhla Buri	250.8
10-1	Ban Pa Tho	179.9
11	Pilok	804.2
12	Thong Pha Phum	226.6
12-1	Lin Thin	173.4
19	Huai Mae Nam Noi	144.0
14	Lum Sum	16.1
1	Umphang	114.7
3	Ban Nasuan	24.6
4	Si Sawat	24.5
5	Kaeng Riang	28.1
5-1	Wang Masang	-
8	Bo Phloi	6.3
7	Tha Rua	2.4

Rave = 280.39

Fig. 4-1-7 Isohyetal Map

1969 30 Jul~26 Aug

No.	Station	Rainfall (mm)
10	Sangkhla Buri	583.6
10-1	Ban Pa Tho	357.1
11	Pilok	1025.4
12	Thong Pha Phum	445.3
12-1	Lin Thin	429.5
19	Huai Mae Nam Noi	454.7
14	Lum Sum	58.1
1	Umphang	284.2
3	Ban Nasuan	160.7
4	Si Sawat	160.0
5	Kaeng Riang	-
5-1	Wang Masang	154.7
8	Bo Phloi	17.6
7	Tha Rua	80.9

Rave = 488.78

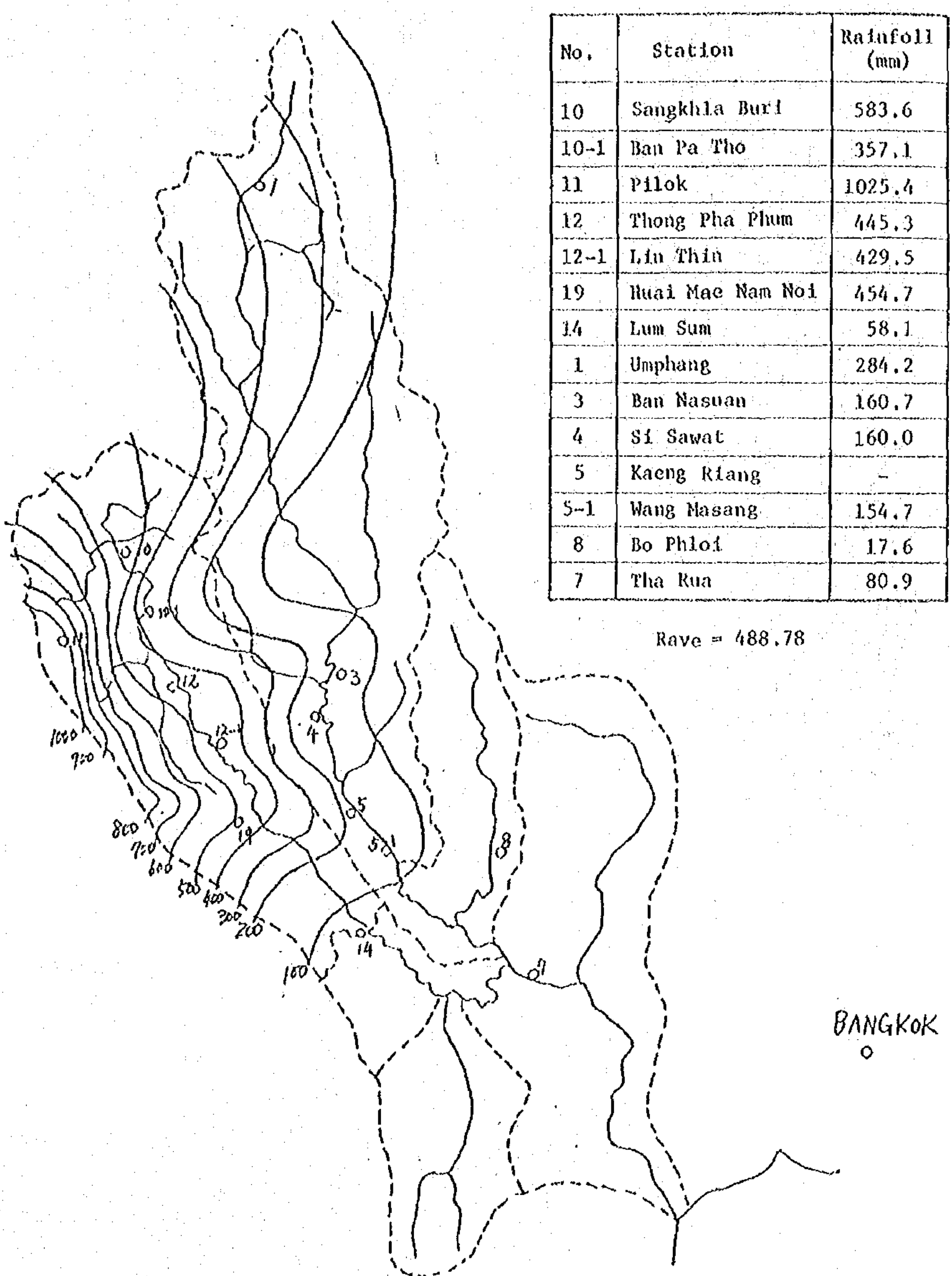


Fig. 4-1-8 Isohyetal Map

1969 22 Jul~29 Jul

No.	Station	Rainfall (mm)
10	Sangkhla Buri	173.4
10-1	Ban Pa Tho	170.9
11	Pilok	359.8
12	Thong Pha Phum	109.5
12-1	Lin Thin	98.7
19	Huai Mae Nam Noi	168.3
14	Lum Sum	19.0
1	Umphang	16.1
3	Ban Nasuan	38.4
4	Si Sawat	19.9
5	Kaeng Riang	-
5-1	Wang Masang	24.4
8	Bo Phloi	9.8
7	Tha Rua	10.5

Rave = 165.48

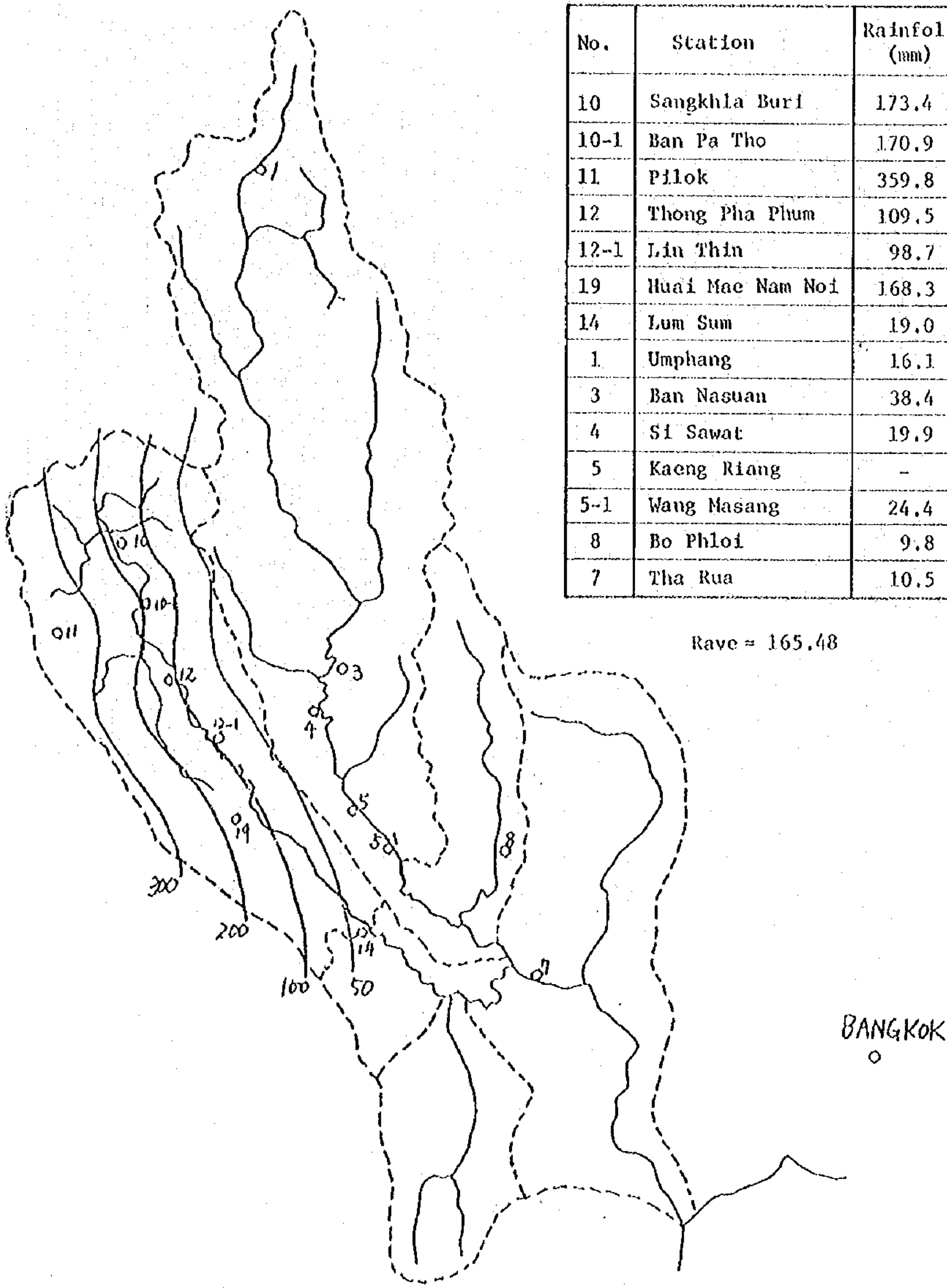
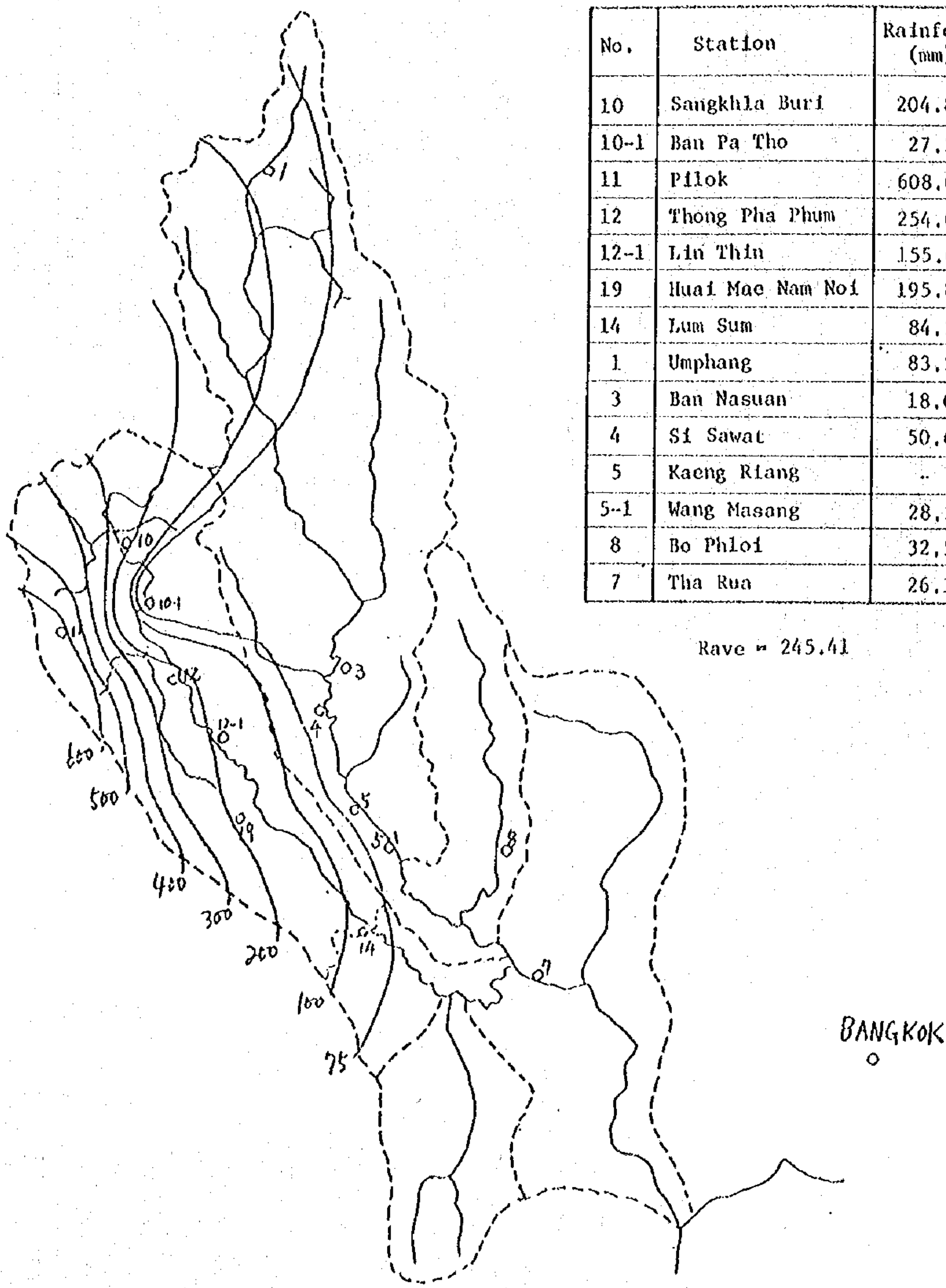


Fig. 4-1-9 Isohyetal Map

1970 11 Jul~19 Jul



No.	Station	Rainfoll (mm)
10	Sangkhla Buri	204.8
10-1	Ban Pa Tho	27.3
11	Pilok	608.0
12	Thong Pha Phum	254.0
12-1	Lin Thin	155.6
19	Huai Mae Nam Noi	195.8
14	Lum Sum	84.3
1	Umphang	83.3
3	Ban Nasuan	18.0
4	Si Sawat	50.6
5	Kaeng Riang	..
5-1	Wang Masang	28.3
8	Bo Phloi	32.5
7	Tha Rua	26.1

Rave = 245.41

Fig. 4-1-10 Isohyetal Map

1971 17 Jul~29 Jul

No.	Station	Rainfall (mm)
10	Sangkhla Buri	356.1
10-1	Ban Pa Tho	398.7
11	Pilok	705.0
12	Thong Pha Phum	224.2
12-1	Lin Thin	179.6
19	Huai Mae Nam Noi	207.6
14	Lum Sum	90.1
1	Umphang	125.4
3	Ban Nasuan	11.5
4	Si Sawat	47.9
5	Kaeng Riang	-
5-1	Wang Masang	43.2
8	Bo Phloi	23.6
7	Tha Rua	34.9

Rave = 313.65

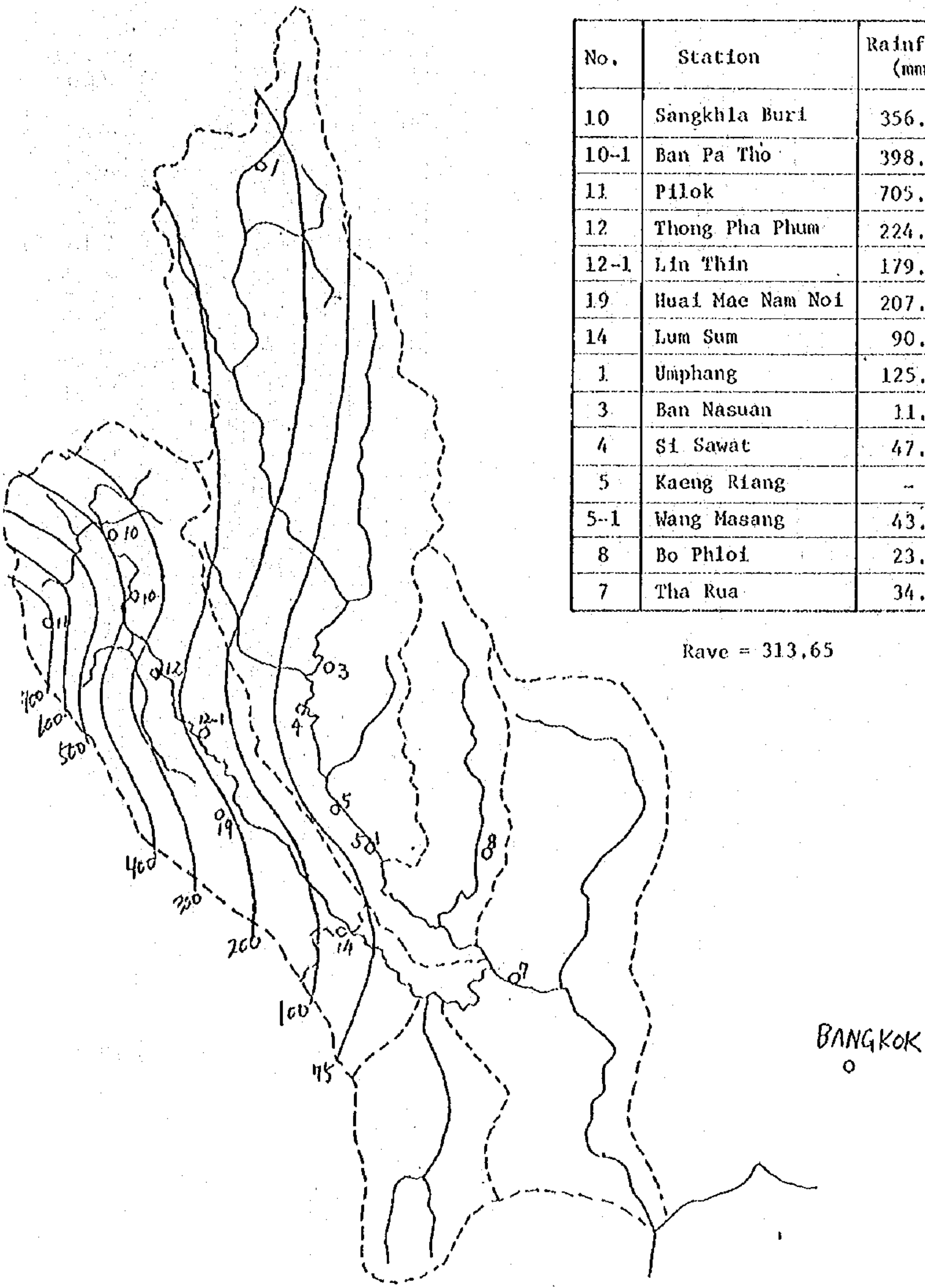
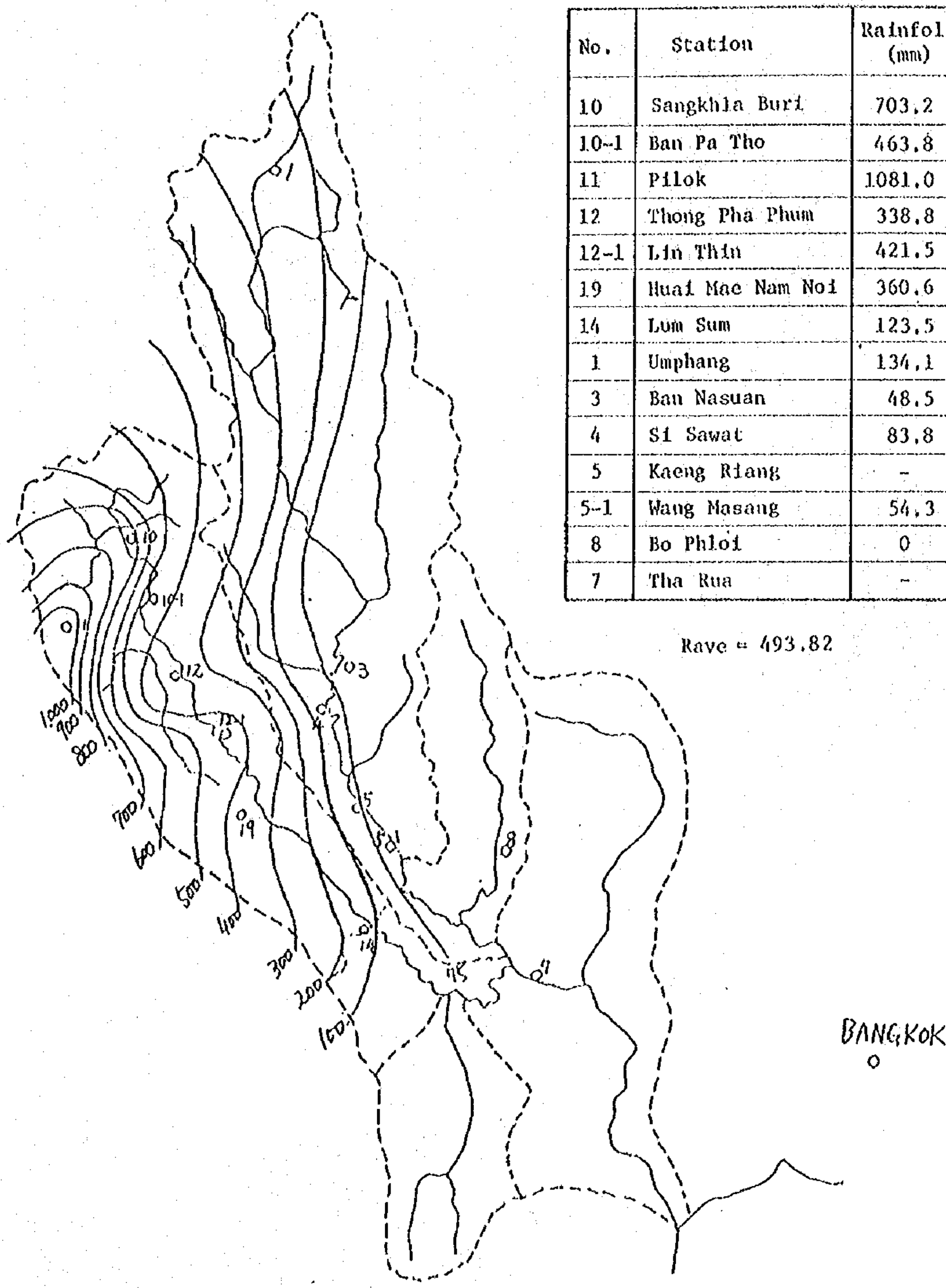


Fig. 4-1-11 Isohyetal Map

1972 30 Jun~18 Jul

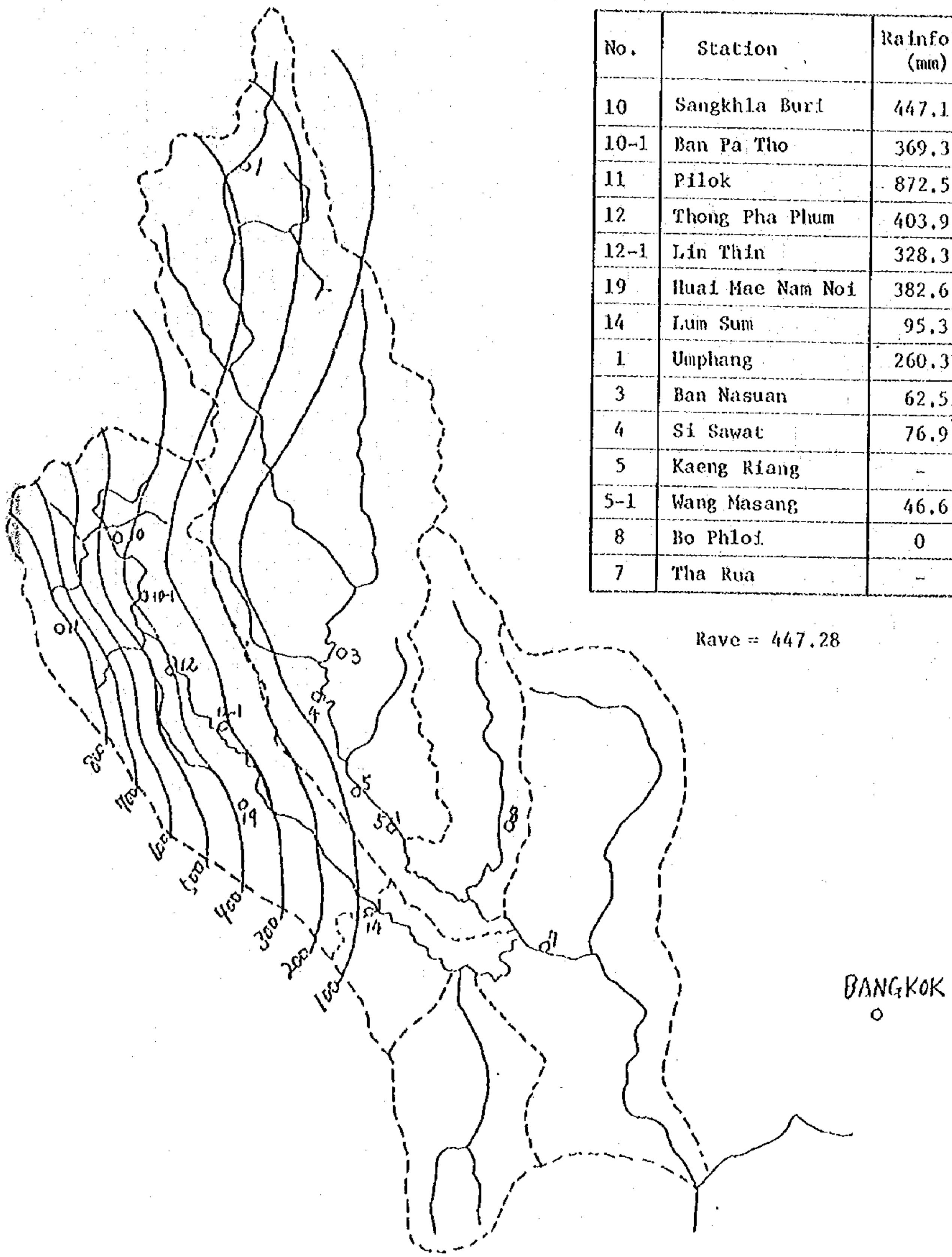


No.	Station	Rainfoll (mm)
10	Sangkhla Buri	703.2
10-1	Ban Pa Tho	463.8
11	Pilok	1081.0
12	Thong Pha Phum	338.8
12-1	Lin Thin	421.5
19	Huai Mae Nam Noi	360.6
14	Lum Sum	123.5
1	Umphang	134.1
3	Ban Nasuan	48.5
4	Si Sawat	83.8
5	Kaeng Riang	-
5-1	Wang Masang	54.3
8	Bo Phloi	0
7	Tha Rua	-

Rave = 493.82

Fig. 4-1-12 Isohyetal Map

1972 19 Jul~10 Aug

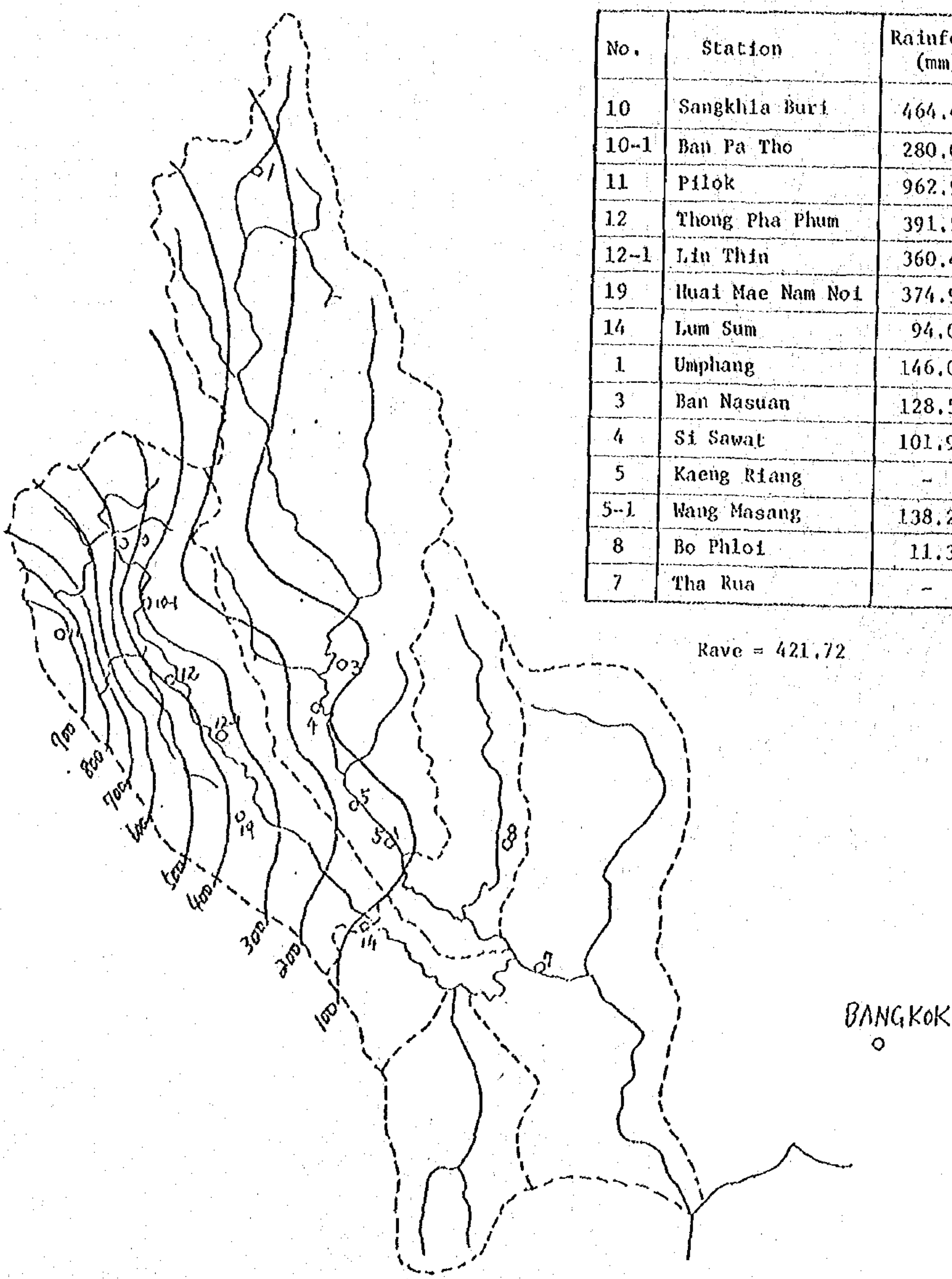


No.	Station	Rainfoll (mm)
10	Sangkhla Buri	447.1
10-1	Ban Pa Tho	369.3
11	Pilok	872.5
12	Thong Pha Phum	403.9
12-1	Lin Thin	328.3
19	Huai Mae Nam Noi	382.6
14	Lum Sum	95.3
1	Umphang	260.3
3	Ban Nasuan	62.5
4	Si Sawat	76.9
5	Kaeng Riang	-
5-1	Wang Masang	46.6
8	Bo Phloi	0
7	Tha Rua	-

Rave = 447.28

Fig. 4-1-13 Isohyetal Map

1973 11 Jun~30 Jun



No.	Station	Rainfall (mm)
10	Sangkhla Buri	464.4
10-1	Ban Pa Tho	280.0
11	Pilok	962.9
12	Thong Pha Phum	391.5
12-1	Lin Thin	360.4
19	Huai Mae Nam Noi	374.9
14	Lum Sum	94.0
1	Umphang	146.0
3	Ban Nasuan	128.5
4	Si Sawat	101.9
5	Kaeng Riang	-
5-1	Wang Masang	138.2
8	Bo Phloi	11.3
7	Tha Rua	-

Rave = 421.72

Fig. 4-1-14 Isohyetal Map

1973 15 Aug~10 Sep

No.	Station	Rainfoll (mm)
10	Sangkhla Buri	449.7
10-1	Ban Pa Tho	479.5
11	Pilok	1114.9
12	Thong Pha Phum	307.2
12-1	Lin Thin	296.0
19	Huai Mae Nam Noi	230.0
14	Lum Sum	129.3
1	Umphang	207.6
3	Ban Nasuan	163.2
4	Si Sawat	70.2
5	Kaeng Riang	-
5-1	Wang Masang	78.3
8	Bo Phloi	60.3
7	Tha Rua	-

Rave = 434.19

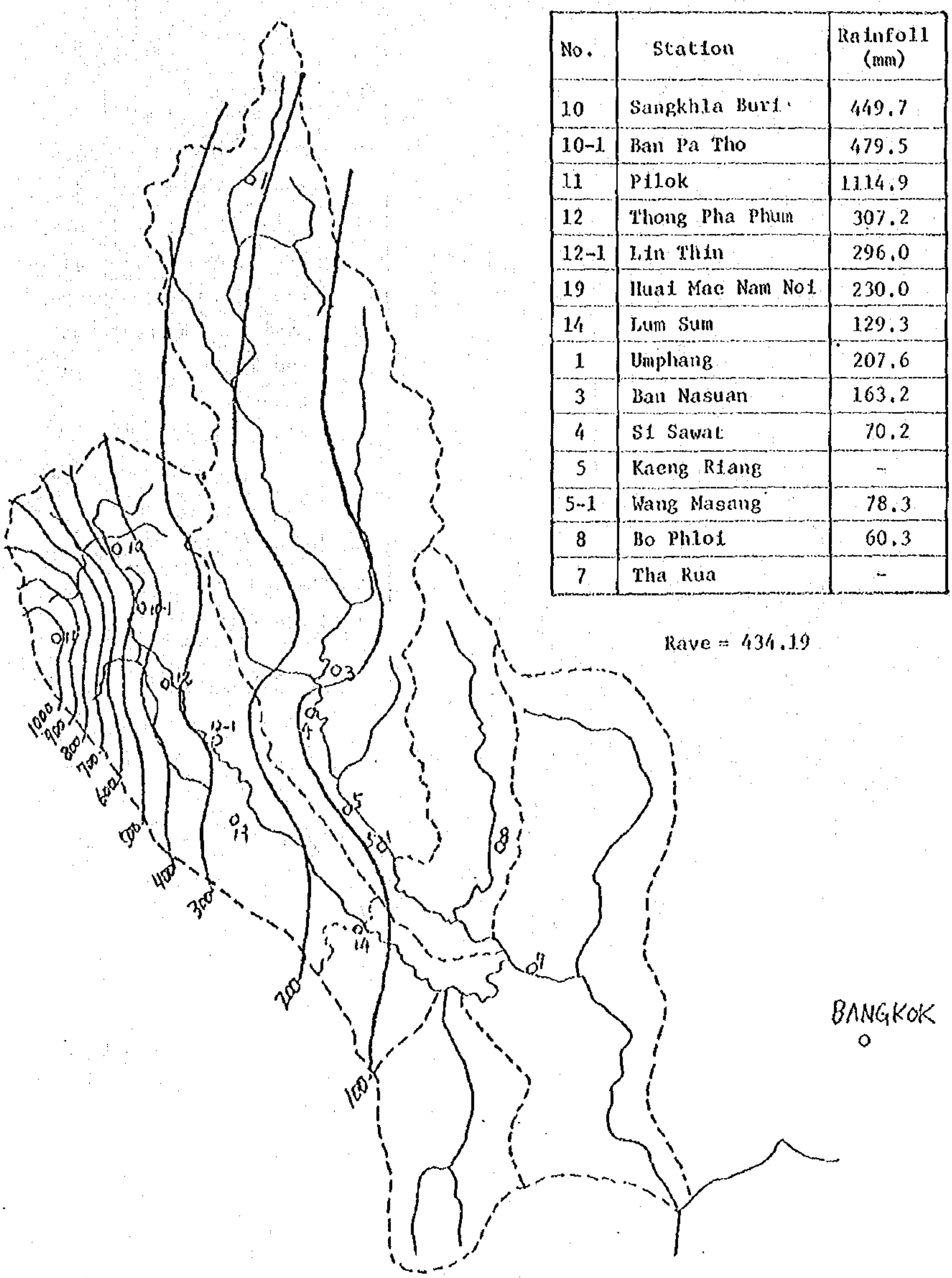
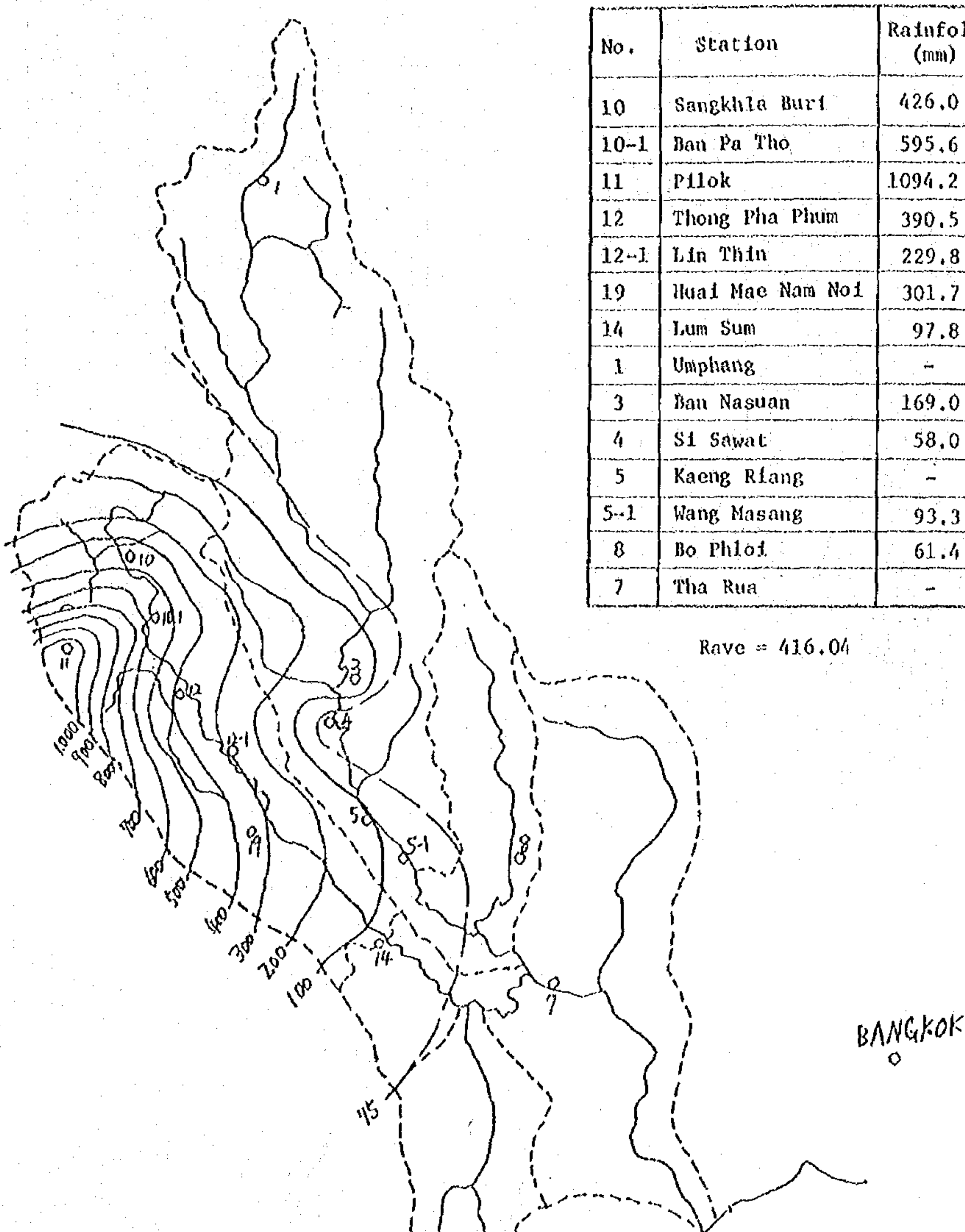


Fig. 4-1-15 Isohyetal Map

1974 9 Aug~28 Aug.

No.	Station	Rainfoll (mm)
10	Sangkhla Buri	426.0
10-1	Ban Pa Tho	595.6
11	Pilok	1094.2
12	Thong Pha Phum	390.5
12-1	Lin Thin	229.8
19	Huai Mae Nam Noi	301.7
14	Lum Sum	97.8
1	Umphang	-
3	Ban Nasuan	169.0
4	Si Sawat	58.0
5	Kaeng Riang	-
5-1	Wang Masang	93.3
8	Bo Phloi	61.4
7	Tha Rua	-

Rave = 416.04



4-1-2 Validity of Thiessen Polygon Method

Table 4-1 in the preceding section also shows the average rainfall data as obtained by Thiessen method using the data of seven stations listed in Table 4-2. The correlation coefficient as disclosed by comparison of these data to those by the isohyet method is as high as 0.983 although the small sample size (N=13), which indicates that the validity of Thiessen method is fairly high and its application in the calculation of average rainfall involves no serious problems. This can be ascribed to the fact that rainfall stations are located approximately at intermediate points in the semblance of progression from large to small rainfall in the basin (See Fig. 4-2 and Ap. 2).

Table 4-2 Thiessen's Weight

Station	7 Stations	6 Stations
Sangkhla Buri	0,2650	0,2768
Thong Pha Phum	0,1627	0,1697
Ban Pa Tho	0,1170	0,1784
Pi Lok	0,0797	-
Ban Lin Thin	0,0913	0,0913
Huai Nae Nam Noi (K22)	0,1976	0,01976
Lum Sum (K10)	0,0867	0,0867
	1,0000	1,000

4-1-3 Weight of Pilok Station in Average Basin Rainfall

As Pilok station is the only rainfall station located in the northwestern slope area where the rainfall is the heaviest in the whole basin, Rave of the six stations excluding Pilok was obtained by Thiessen method and compared with that of all the seven stations in order to find out if the average rainfall in the basin presents any variation due to the absence of Pilok station's data (See Ap. 2 and 3). As a consequence, the correlation between R_7 and R_6 turned out to be as follows.

Monthly rainfall	(1967 ~ 1975, N = 108)	γ = 0.99668
7 days rainfall	(1967 ~ 1974, N = 51)	γ = 0.98390
1 flood	(July 1971, N = 13)	γ = 0.99453

As seen above, the correlation coefficient is very high for all cases, and presents virtually no fluctuation even if Pilok stations' data is excluded in the calculation of average basin rainfall. This means, as clearly indicated by the aforementioned isohyets, that heavy rainfall regions do not occupy so large a portion of the whole basin area.

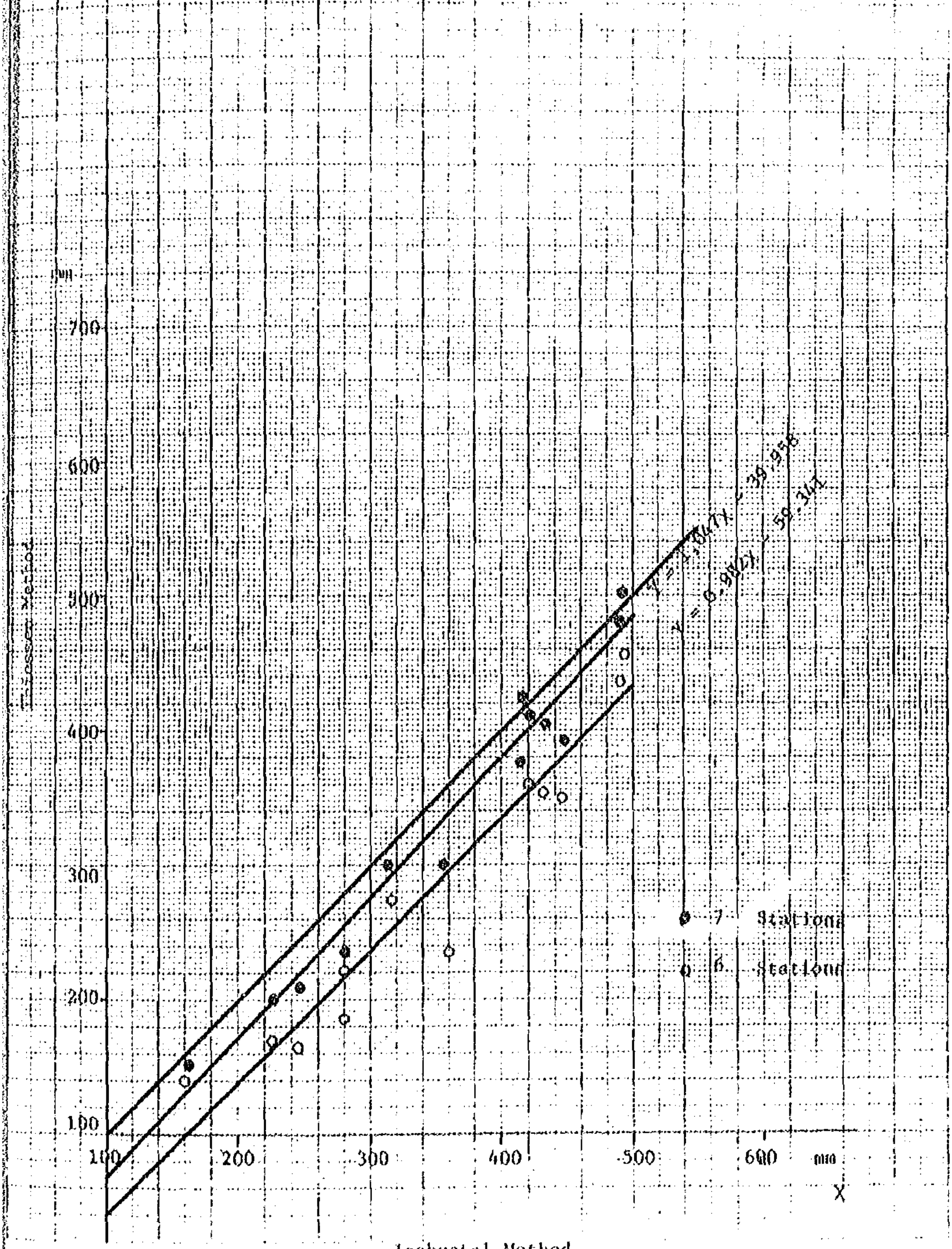
Nevertheless, it is quite probable that any heavy rainfall at Pilok causes the overall rainfall in the basin to become larger.

o Correlation between Pilok and R (Ap. 3)

7 days rainfall	(1967 ~ 1974, N = 51)	γ = 0.80921
1 flood	(July 1971, N = 13)	γ = 0.8480

The presence of such a high correlation between the rainfall at Pilok and the average rainfall in the basin makes it justifiable to pass judgement on the former as to whether it is heavy enough to cause a great flood in downstream areas.

Fig. 4-2 Correlation between $\bar{R}$ (Thiessen) and $\bar{R}$ (Isohyet Line)

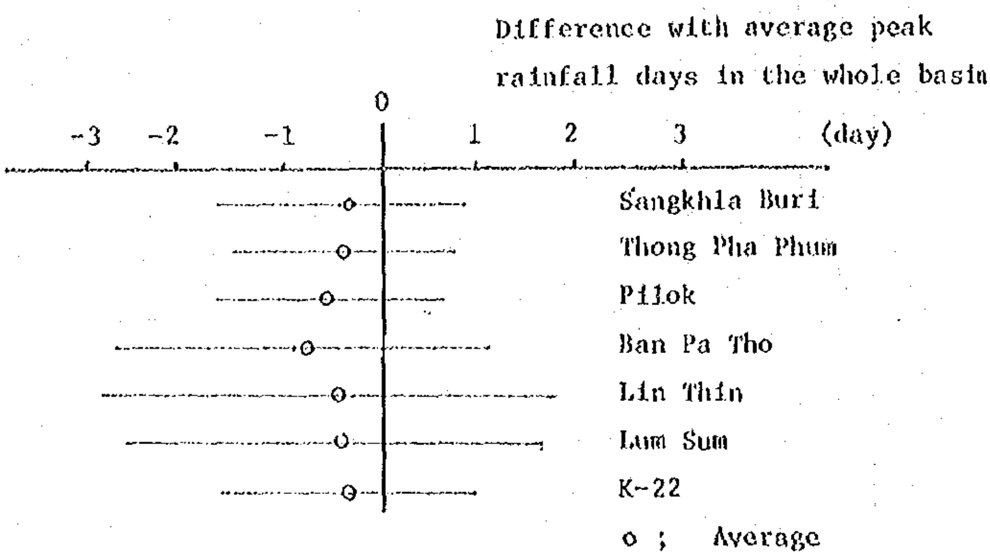


4-1-4 Rainfall Condition at Each Station

The rainfall characteristics discussed in the foregoing sections relate to regional differences. In this section, they are examined in specific relation to time distribution, and the differences in the peak rainfall occurrence are studied in order to gain a firm grasp of it.

To be more specific, the time distribution is expressed in terms of the time gap between the occurrence day of peak average rainfall in the basin (which is based on the rainfall data of all the seven stations in the basin) and the occurrence day of peak rainfall recorded at each of the seven stations (53 rainfall data between 1967 and 1974 were used for this purpose) (See Ap-4 and Figs. 4-3 and 4-4).

Fig. 4-3 Average Time Difference in Peak Rainfall Days and Their Dispersion



The above figure indicates that the peak rainfall days recorded at each station are free from any large variation on the whole, and if a peak rainfall occurs on any day at Thong Pha Phum or K-22, the average rainfall in the basin also reaches its peak almost on the same day. However, the mean deviation of all the seven stations from the peak occurrence day of the average basin rainfall is on the minus side, and Lin Thin, Lum Sum and Ban Pa Tho present a flat distribution profile of peak rainfall days than the other stations. This is an evidence to show that the occurrence of peak rainfall in the downstream area is subject to greater variation than in the upstream area, being earlier or later depending on the rainfall condition but usually taking place quicker than in the upstream area.

It is worthy of notice that among the stations located in the upstream area, Ban Pa Tho presents a tendency divergent from those of other stations, but the cause of this divergence is not known yet.

Fig. 4-4 Time Lag of Peak Rainfall Days between Seven Stations and Whole Basin

```
-5 |
-4 | X
-3 | XX
-2 | XXXXXXXX
-1 | XXXXXXX
 0 | XXXXXXXXXXXXXXXXXXXXXXXXXXX
 1 | XXXXX
 2 | XX
 3 | X                              [0.712]
 4 |
 5 |
```

```
-5 |
-4 | X
-3 | XXXX
-2 | XXXX
-1 | XXXX
 0 | XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 1 | XXXXXXX
 2 |
 3 |                                [0.830]
 4 |
 5 |
```

```
-5 |
-4 | X
-3 | XXX
-2 | XXXXXX
-1 | XXXXXXXXX
 0 | XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 1 | XXX
 2 | XX
 3 |
 4 |                                [0.774]
 5 |
```

```
-5 | X
-4 | XXX
-3 | XXX
-2 | XXXXXXXX
-1 | XXXXXXXXXX
 0 | XXXXXXXXXXXXXX
 1 | XXXXXXXX
 2 | XXX
 3 | XX                             [0.577]
 4 |
 5 |
```

```
-5 | X
-4 | XX
-3 | XXXXXX
-2 | XXXXXXX
-1 | XXXXX
 0 | XXXXXXXXXXXXXXXXXXX
 1 | XXXXXXX
 2 | XXXX
 3 | X                              [0.547]
 4 |
 5 | XX
```

```
-5 | X
-4 | XX
-3 | XXXXX
-2 | XXXX
-1 | XXXXXXX
 0 | XXXXXXXXXXXXXXXXXXXX
 1 | XXXXXXX
 2 | XXXXXX
 3 | X                              [0.642]
 4 |
 5 |
```

```
-5 | X
-4 | XX
-3 | X
-2 | XXX
-1 | XXX
 0 | XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 1 | XXXXXXXX
 2 | XX
 3 |
 4 |                                [0.849]
 5 |
```

4-1-5 Overall Rainfall Characteristics

The following are the major characteristics of rainfall in the Mae Klong river basin as summarized from the discussion advanced in the foregoing pages.

(1) Throughout the wet season, there is a tendency that the amount of rainfall is greater in the northwestern part of the basin than in the southeastern part.

(2) However, the rainfall area in the northwestern part is not so large relative to the whole basin area.

(3) Peak rainfall days throughout the basin area show no appreciable fluctuation, and the occurrence of average peak rainfall in the whole basin can be generally judged from the rainfall data at Thong Pha Phum or K-22.

(4) As a general tendency, peak rainfall days in the downstream area come earlier (by 2~3 days) than in the upstream area, though the time gap varies according to the rainfall intensity in each locality.

(5) In so far as can be judged from the average rainfall in the area upstream of K-10, it can be said that the existing seven stations are located suitably for the purpose of grasping the average rainfall in the whole Mae Klong basin. $\ddot{R}$ave of the seven stations obtained by Thiessen method can be considered generally applicable in the area upstream of K-10.

(6) It is not likely that the absence of Pilok station's data will incur any serious error in the calculation of the average rainfall in the basin. However, the rainfall data at this station serves as a criterion for forecasting the occurrence of a great flood in the downstream area. Specifically, it is possible to judge as to whether the rainfall at Pilok is large enough to a deluge in lower reaches.

4-2 Run-Off Characteristics of Mae Klong River

4-2-1 Time Lag of Average Basin Rainfall and K-10 Peak Discharge

The time lag between the occurrence day of peak daily rainfall and that of peak discharge, (Refer to the Preliminary Survey Report) as disclosed by the study of the aforementioned 53 flood data recorded between 1967 and 1974, is 3.4 days on the average, the standard deviation being 0.87 days. The lag ranges from 2.5 to 4.3 days for almost all floods studied, showing no fluctuation according to the magnitude of rainfall or discharge (See Ap-5). In other words, the peak discharge at K-10 was observed in three days after the peak daily rainfall was observed, and this fact will prove useful in the operation of the flood forecasting system.

4-2-2 Correlation between Rave and Qp

The correlation between the peak discharge and 1, 3, 5, 7 and 9 days rainfalls at K-10 was studied in order to determine the duration of rainfall which is most conductive to the occurrence of peak discharge. As shown in Table 4-3, this study disclesed that the 7-days rainfall is most dominant over the peak discharge, with the highest correlation of $\gamma = 0.8531$.

It was also discovered that this correlation between Rave and Qp can be divided, as hown in Fig. 4-5, by the discharge immediately before flood rising.

Regression formula:

$$Q \geqslant 200 \qquad Qp = 10.069\ R_7 - 326.06$$

$$Q < 200 \qquad Qp = 5.148\ R_7 - 104.40$$

For the purpose of actual flood forecasting, however, it is more expedient to use 7-days rainfall data easier to obtain than the 7-days maximum rainfall. For this reason, a case study was made for each of the four

7-days rainfalls shown in Fig. 4-6 in order to examine the possibility of using any of them in place of 7-days maximum rainfall (See Ap. 6).

Table 4-3 Correlation between Qp and R

Year	Occurrence Day of Actual Peak Discharge	Q $m^3/s.d$	R_1 1 day	R_3 3 days	R_5 5 days	R_7 7 days	R_9 9 days	R_{12} 12 days	Discharge at Time of Flood Rising (K-10)
1967	28 Jul	558	40.5	72.5	107	134.2	153.2	184.2	105
	10 Aug	1,239	38.5	85.0	132.2	170.2	202.2	237.8	355
	20 Aug	1,668	47.9	120.5	164.9	192.1	221.1	258.5	580
	4 Sep	1,257	36.4	68.2	103.8	134.9	154.2	192.8	494
	4 Oct	737	32.9	52.7	78.4	96.2	127.0	146.8	456
1968	1 Aug	425	19.3	39.9	81.0	110.2	131.9	173.6	106
	5 Aug	468	21.7	44.6	62.6	90.6	111.2	169.9	334
	17 Aug	1,094	34.7	88.7	133.6	164.5	189.2	220.7	317
	25 Aug	839	20.2	46.7	79.3	97.7	153.5	227.2	609
	15 Sep	879	28.2	71.6	98.7	120.0	148.2	193.9	439
1969	22 Jul	560	28.1	64.1	99.8	127.1	142.5	187.0	215
	31	1,094	46.6	97.0	125.6	140.4	197.9	296.8	316
	11 Aug	2,354	65.2	133.7	201.3	260.5	369.0	370.2	858
	10 Sep	581	32.5	55.3	83.6	106.9	122.3	150.2	290
	24	964	46.2	88.9	108.8	135.5	153.4	165.6	355
	5 Oct	635	39.8	54.8	80.2	93.0	96.7	102.5	382
1970	18 Jul	1,165	64.0	139.9	187.6	201.9	218.4	241.1	144
	22 Aug	709	30.5	54.7	104.5	123.8	142.9	192.3	191
	27	648	21.6	45.8	74.0	96.4	137.1	177.3	558
	9 Sep	604	28.8	58.9	73.4	76.5	107.4	147.7	389
1971	12 Jun	708	56.7	144.6	186.8	222.3	238.3	259.8	35
	21	451	30.6	71.6	112.1	132.9	148.7	288.5	142
	17 Jul	672	27.4	56.2	82.6	117.2	151.9	191.0	292
	28 Jul	1,859	52.8	142.2	188.3	218.0	242.1	296.6	416
1972	11 Jun	1,077	75.9	118.3	194.3	222.2	247.8	279.9	35
	1 Jul	352	26.6	48.3	67.6	150.6	133.4	165.5	159
	8	503	24.6	57.4	84.7	107.2	292.5	405.7	248
	17	3,026	101.4	249.1	319.9	352.7	385.5	423.0	406

Year	Occurrence Day of Actual Peak Discharge	Q $m^3/s.d$	R_1 1 day	R_3 3 days	R_5 5 days	R_7 7 days	R_9 9 days	R_{12} 12 days	Discharge at Time of Flood Rising (K-10)
1972	2 Aug	1,709	26.5	55.1	107.1	141.6	220.7	292.8	753
	22	887	18.3	64.0	76.7	98.9	130.4	151.3	553
	28	705	15.1	38.6	53.7	70.6	103.9	130.6	655
	31	687	22.7	46.0	65.3	88.8	106.7	130.6	680
	9 Sep	1,041	50.4	94.7	114.4	138.8	158.2	197.0	511
	21 Sep	850	50.7	73.4	90.8	105.0	147.6	167.4	488
	9 Oct	552	15.0	35.8	53.1	79.3	91.7	141.7	508
	27 Jul	1,846	57.4	113.3	153.1	188.6	237.7	292.8	753
1973	20 Jur	1,728	85.4	203.2	289.6	329.6	354.3	383.6	43
	12 Jul	767	17.7	44.2	81.7	105.7	157.0	199.4	142
	15	761	32.5	56.5	71.4	122.7	157	199.4	680
	21	835	43.5	74.9	96.1	122.6	146.4	189.8	583
	17 Aug	435	19.8	52.0	71.3	93.6	125.1	190.8	213
	27	1,465	44.4	102.5	140.9	177.1	212.4	261.3	418
	14 Sep	549	31.7	46.7	69.6	76.6	88.2	155.9	435
	25	872	26.5	59.0	89.3	125.6	136	162.8	448
1974	2 Jun	400	29.2	79.5	127.2	159.7	236.5	278.8	145
	12	493	19.1	52.9	82.8	106.6	141.3	174.3	213
	17	640	23.0	46.0	68.5	98.4	132.2	171.1	419
	1 Aug	374	27.0	46.8	65.7	95.1	121.9	156.2	298
	21	3,250	61.9	169.6	238.7	335.2	361.3	386.3	239
	14 Oct	696	24.5	56.4	73.3	91.1	118.7	127.5	244
	5 Sep	543	18.9	45.1	70.2	79.7	87.1	107.3	512

1 $Q \sim R_1$ (N=51)

$\gamma = 0,73271$ $Q = 24,7018\ R_1 + 54,2946$

2 $Q \sim R_3$ (N=51)

$\gamma = 0,80984$ $Q = 11,5416\ R_3 + 53,3042$

3 $Q \sim R_5$ (N=51)

$Y = 0{,}81583$ $Q = 8{,}8108\ R_5 - 31{,}6079$

4 $Q \sim R_7$ (N=51)

$Y = 0{,}85306$ $Q = 8{,}14147\ R_7 - 184{,}1164$

5 $Q \sim R_9$ (N=51)

$Y = 0{,}80380$ $Q = 7{,}09756\ R_9 - 264{,}3768$

$Q \sim R$ pilok (N=51)

$Y = 0{,}60796$ $Q = 2{,}11114\ R$ pilok $+ 181{,}4204$

Fig. 4 - 5 Correlation between Qp and R7

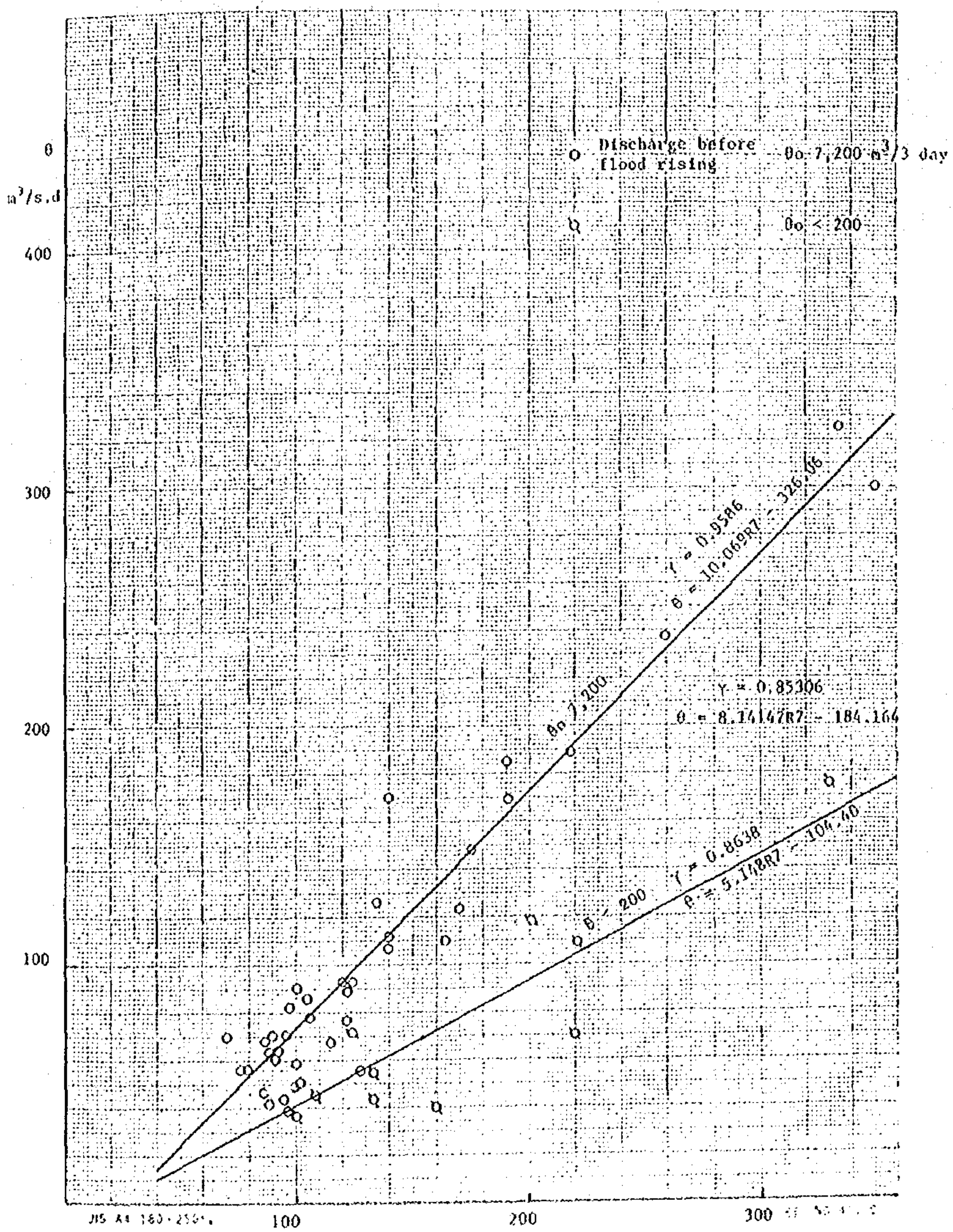
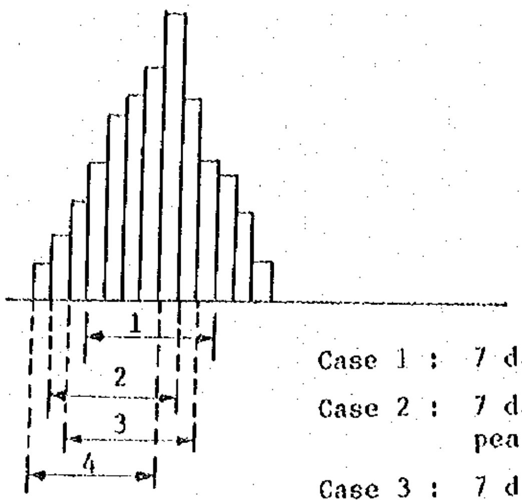


Fig. 4-6 Selection of 7-Days Rainfall Data



Case 1 : 7 days maximum rainfall

Case 2 : 7 days counting back from peak rainfall day

Case 3 : 7 days counting back from day after peak rainfall day

Case 4 : 7 days counting back from day before peak rainfall day

Correlation Coefficient of Rainfall:

Case 1 ~ 2	γ = 0,91582
Case 1 ~ 2	γ = 0.97773
Case 1 ~ 4	γ = 0.77384

Thus, it is clear that the rainfall for 7 days counting back from the day of peak occurrence can be used. It is to be noted that R^7 at which has a close bearing on the judgement of flood occurrence, show a rather poor correlation with Qp, the correlation coefficient being 0.6080 (N - 51).

4-2-3 Overall Run-Off Characteristics

From the data given above, the run-off characteristics at K-10 can be summarized as follows.

(1) Peak discharge is recorded in about three days after peak daily rainfall.

(2) Peak discharge can be generally grasped from the maximum 7-days rainfall.

(3) It can also be generally grasped from the rainfall on seven days counting back from the day of peak rainfall, in place of the maximum 7-days rainfall.

(4) Correlation between rainfall at Pilok and discharge at K-10 is not very high.

CHAPTER 5 FLOOD FORECASTING SYSTEM

5-1 Objectives and Methods of Flood Forecasting

The term "flood forecasting" means to forecast the occurrence of a flood, whenever it is considered certain or highly probable from meteorological and other condition, by indicating its condition in terms of river stage, discharge and other data, and issue necessary warnings to the relevant administrative organizations or to the residents in the basin.
The objectives of flood forecasting can be considered in two major categories. One is to furnish levee protection organizations with necessary information and guidance where inundation can be prevented by their activities, and the other is to provide information necessary for evacuation of residents and protection of their properties where the inundation is acutely impending or where no levee protection organizations are present. In order to fulfill these objectives, it is necessary to convey concrete and sufficient information to the pertinent administrative organs and residents with an ample allowance of time, and to select the most effective forecasting method according to the scale and characteristics of the river in question, topography, basin configuration, etc.

The main flood forecasting methods currently adopt in Japan are enumerated below for reference.

(1) Forecasting by water stage estimation at a downstream point from the rainfall in the upstream basin.

(2) Forecasting by water stage correlation between two points located in upstream and downstream areas.

(3) Forecasting based on the upstream area run-off calculated by unit hydrograph which is routed by simplified equation of unsteady flow and continuity equation.

In addition to the above, the following two methods are under study, though not yet yielding sufficient forecasting data.

(4) Flood routing by strict equation of unsteady flow and continuity equation.

(5) Flood forecasting by the so-called coaxial correlation chart.

In the actual operation of the flood forecasting system, it is usually the case to employ two or more methods, ranging from simple to complex ones, according to the forecasting stage.

The following are the main facilities required for flood forecasting services.

(1) Rain gauge

(2) Water stage gauge

(3) Data transmitting facilities

(4) Data processing facilities

While these equipments and facilities are available in many different types compatible with varying observation conditions, recent years have seen an increasing tendency towards developing automatic equipments designed to cut down the maintenance requirements to the minimum possible extent. To cite an example, the data transmission system in Japan used to be operated by the combination of ordinary rain gauge with telephone or telegram for rainfall data transmission to the flood forecasting center, but it has now been replaced almost completely by the telemetering network in which data of recording rain gauges are transmitted by radio wave in VHF or UHF band. The water stage observation system has likewise given place to the telemetering network, and the maintenance requirements have been largely reduced by the installation of the gauges which call for the replacement of recording paper at very long intervals.

It is of great importance to adopt the most suitable forecasting method or methods from among a number of methods introduced above, and select the most efficient equipments and integrate them into the flood forecasting system. In the design of the forecasting system, the objective of its establishment and operation should be recognized fully and clearly, and special consideration should be given to the items shown in the following table.

Item	Example	Mae Klong Basin Future Plan	Present Condition
1. Actions taken by flood forecasting	o Flood control by dam o Gates operation o Levee protection activities o Evacuation of residents	Evacuation of residents from expected flood area	RID makes flood forecasts on TV on the basis of information from the stations of MD and RID.
2. Information to be supplied	o Maximum stage and its occurrence time o Flood duration o Hydrograph	o Time of near-overflow stage o Maximum stage (discharge) o Flood duration	Forecast is made based on water stage at K-10 with reference to past stage data.
3. Required accuracy (allowable error) in forecasting		o 10~15% for water stage and 3~4 hours for time	
4. Maximum allowable time before forecasting	o Less than an hour o Less than half a day	o Less than 2 days	Approximately equivalent to the time of concentration from K-10 to K-11 (1 day)

Item	Example	Mae Klong Basin Future Plan	Mae Klong Basin Present Condition
	o Less than a day		
5. Maximum allowable operational cost			
6. Others			

The accuracy requirements and other data, to be determined for respective items in the above table, cannot be obtained quantitatively for the Mae Klong river basin, so that they are based on the judgement of the existing forecasting system in the basin. In the following sections, a detailed study is made on the method of flood forecasting and design of facilities, with account taken of the objectives of system operation.

5-2 Method of Flood Forecasting

During the survey period, studies on flood forecasting method were made mainly for the upper basin area extending upstream of Ban Lum Sum (K-10) on the Khwae Noi, and did not cover the whole Mae Klong basin. This is due to the fact that the necessary analysis of hydraulic and hydrologic data has not yet been undertaken for the following reasons.

(1) Operational rules of Ban Chao Nen dam now under construction on the Khwae Yai river have not yet been established.

(2) Completion of the said dam is expected to bring about a drastic change in the existing hydrological condition in the basin, making it nearly meaningless to use the hydrological data so far collected.

(3) Surveying data including river sections which are essential to flood routing from K-10 and Ban Chao Nen dam are not available.

5-2-1 Flood Forecasting Area

The target flood forecasting area in the Mae Klong river basin is quite clear as can be deduced from the description in Section 3-1 (General Basin Configuration) and Section 3-2 (River Channel).

Specifically, the upper reaches extending upstream of Kanchanaburi is a mountainous and very sparsely populated area not having a single locality where river inundation could become any serious problem, whereas the lower basin area downstream of Kanchanaburi is not only an important granary of the country but embraces many densely populated cities such as Ban Pong, Ratchaburi and Samut Songkhram along the river channel, and has actually been afflicted with frequent and heavy flood damages which pose a serious social problem. Hence, it is most reasonable to select the flood area in the downstream basin as the target area to be covered in the design of the planned flood forecasting network.

As for the target point at which flood forecast is to be made, it would be most reasonable to select K-11 (Wang Khanai) as it is a discharge observation station located close to the uppermost section which inundates by great floods.

5-2-2 Forecasting by Stage Correlation between Two Points in Upstream and Downstream Places (H-H Correlation)

Although this is the simplest of all flood forecasting methods, nevertheless it can be employed in making flood forecast with fairly high accuracy using charts and other data, provided that upstream stage data is transmitted to the downstream forecasting point within the specified time lag.

The validity of this H-H correlation method in the Mae Klong river basin flood forecasting may be evaluated as follows. (It is to be noted that the comments given below apply not to all rivers but mainly to Khwae Noi river because they are derived from the past activities of Japanese survey team and from the observations and analyses by Thai government which were both concentrated in the area upstream of K-10 (Ban Lum Sum).

i) H-H correlation is the only reasonable forecasting method pending the consolidation of rainfall observation network in the upstream area, i.e., until completion of the telemetering system.

ii) It will also be used as a principal means of data transmission from K-10 (Ban Lum Sum) to K-11 (proposed final forecasting point at Wang Khanai), until completion of river course cross-sectional surveying and establishment of a flood propagation simulation method.

iii) Even after a suitable other forecasting method has been established and computerized data processing has been set well afoot, H-H correlation method will still be used, by reason of its simplicity and fairly high accuracy, for the purpose of checking the newly introduced method.

On the strength of the above evaluation, analysis was made on H-H correlation between two selected stations, K-13 at Thong Pha Phum and K-10 at Ban Lum Sum, as both provide fairly well consolidated data and also allow for a flood travel period of more than one day.

o Analysis of H-H Correlation

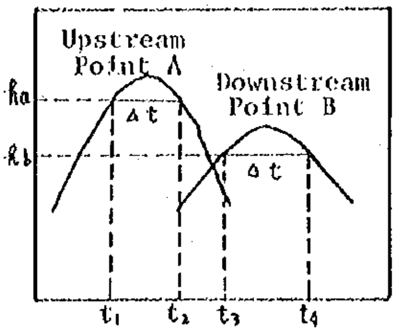
1) Peak-to-Peak Method

Peak-to-peak method is one of the flood forecasting method based on stage correlation, and is intended to obtain the peak stage correlation between two points, one in the upstream section and the other in the downstream section. To put in more detail, the correlation between the peak stage at an upstream point and that at a downstream point is obtained using a graph prepared from the past flood record, with parameter taken at the downstream stage recorded when the peak stage occurs at the upstream point. Fig. 5-1 is a graph prepared by plotting 60 floods with a maximum discharge of more than 300 m^3/s which were recorded at K-10 in the 9-year period from 1966 to 1974 (See Tables 5-1 and 5-2). As can be seen in this figure, the results show a considerably large variation and in addition, there cannot be observed any notable parameter variation due to downstream stage, suggesting that the accuracy of peak-to-peak method is rather poor. Applicability of this method for flood forecasting between the said two points cannot be justified either for the following reasons.

i. It takes a substantially long time to obtain the peak value at K-13.

ii. Peak-to-peak correlation does not necessarily conform to the correlation of all components of flood hydrograph

2) Hydrograph Correlation



In this method, the water stages h_a and h_b, recorded within the same time interval of Δt on the hydrographs at upstream point A and downstream point B as shown at the left, are assumed to correspond to each other, and the correlation between the two is obtained by varying Δt.

In this case, the time-lag is given as $t_3 - t_1$ (or $t_4 - t_2$). Fig. 5-2 shows the water stage correlation of September 1966 flood as an operational example of this method. Fig. 5-3 also shows the data of analysis made by this method for ten floods recorded in the past including the four great ones (August 1969 flood was omitted because its hydrograph has too many peaks).

Fig. 5-1 Correlation of Water Stage (Peak to Peak)

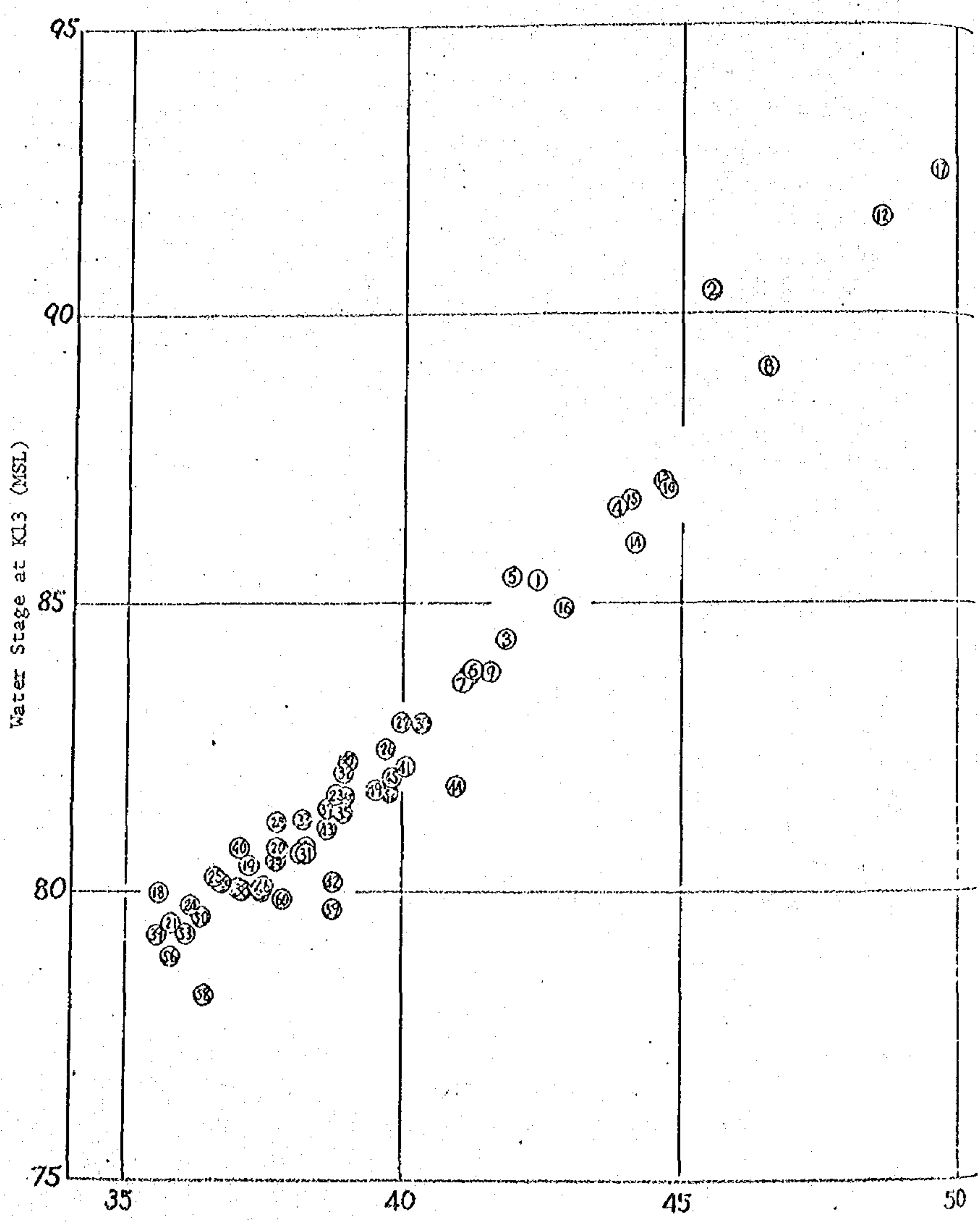


Table 5-1 Big Floods in the Past ($Q_{K-10} \geq ,000\ m^3/s$)

No.	Year	Thong Pha Phum (K-13)			Lum Sun (K-10)			Lag-time	K-10 (When K_{13} has peak)		Note
		H peak	Q peak	Day	H peak	Q peak	Day	K_{10}-K_{13}	H peak	Q peak	
1	1966	85. 38	1.566	Jul. 28	42. 37	1,352	Jul. 30	2	39. 92	877	
2		90. 38	2.983	Sep. 10	45. 51	2,233	Sep. 12	2	42. 08	1,291	
3	1967	84. 37	1,262	Aug. 9	41. 81	1,239	Aug. 10	1	41. 67	1,211	
4		86. 65	1,877	18	43. 80	1,668	20	2	41. 02	1,177	
5		85. 46	1,534	Sep. 3	41, 90	1,257	Sep. 4	1	40. 40	972	
6	1968	83. 82	1,073	Aug. 15	41. 22	1,094	Aug. 17	2	40. 51	963	
7	1969	83. 61	1,058	Jul. 29	41. 06	1,094	Jul. 31	2	39. 04	750	
8		89. 06	2,177	Aug. 10	46. 56	2,354	Aug. 11	1	45. 92	2,188	
9	1970	83. 80	1,096	Jul. 17	41. 52	1,165	Jul. 18	1	40. 39	1,867	

No.	Year	Thong Pha Phum (K-13)			Lum Sum (K-10)			Lag-time	K-10(When K_{13} has peak)		Note
		H peak	Q peak	Day	H peak	Q peak	Day	K_{10}-K_{13}	H peak	Q peak	
10	1971	86. 97	1,765	Jul. 26	44. 74	1,859	Jul. 28	2	42. 33	1,404	
11	1972	83. 73	1,080	Jun. 10	41. 16	1,077	Jun. 11	1	39. 32	783	
12		91. 64	2,808	Jul. 14	48. 57	3,026	Jul. 17	3	45. 74	2,143	
13		87. 10	1,758	25	44. 67	1,846	27	2	41. 14	1,073	
14		86. 02	1,536	31	44. 12	1,709	Aug. 2	2	43. 60	1,584	
15	1973	86. 78	1,690	Jun. 18	44. 05	1,728	Jun. 20	2	39. 71	864	
16		84. 89	1,310	Aug. 25	42. 87	1,465	Aug. 27	2	40. 75	1,050	
17	1974	92. 49	3,029	Aug. 19	49. 61	3,250	Aug. 21	2	48. 36	2,270	
Table 5-2 Floods in the Past (Q_{K-10} : 300 $100m^3/s$)											
18	1966	79. 98	448	Jul. 6	35. 61	339	Jul. 8	2	33. 97	195	
19		80. 46	522	Aug. 6	37. 23	510	Aug. 7	1	36. 75	457	

Table 5-2 Floods in the Past (Q_{K-10}: 300~100m^3/s)

No.	Year	Thong Pha Phum (K-13)			Lum Sum (K-10)			Lag-time	K-10 (When K_{13} has peak)		Note
		H peak	Q peak	Day	H peak	Q peak	Day	$K_{10}-K_{13}$	H peak	Q peak	
20		80. 76	570	Aug. 31	37. 72	569	Sep. 1	1	37. 30	518	
21		79. 44	371	Oct. 3	35. 82	360	Oct. 4	1	34. 87	269	
22	1967	80. 73	538	Jul. 27	37. 76	558	Jul. 28	1	37. 45	520	
23		81. 68	717	Oct. 3	38. 80	727	Oct. 4	1	38. 01	626	
24	1968	79. 76	405	Jul. 31	36. 20	425	Aug. 1	1	35. 67	372	
25		80. 23	469	Aug. 4	36. 63	468	5	1	35. 48	353	
26		82. 45	822	24	39. 70	839	25	1	39. 26	773	
27		82. 91	904	Sep. 14	39. 97	879	Sep. 15	1	39. 04	742	
28	1969	81. 20	642	Jul. 20	37. 72	560	Jul. 22	2	35. 57	345	
29		80. 52	539	Sep. 8	37. 70	581	Sep. 10	2	36. 26	408	
30		82. 90	930	23	40. 33	964	24	1	39. 77	888	
31		80. 64	551	Oct. 4	38. 24	635	Oct. 5	1	38. 11	617	

No.	Year	Thong Pha Phum (K-13)			Lum Sum (K-10)			Leg-time	K-10 (When K_{13} has peak)		Note
		H peak	Q peak	Day	H peak	Q peak	Day	K_{10}-K_{13}	H peak	Q peak	
32	1970	82. 06	763	Aug. 21	38. 95	709	Aug. 22	1	37. 38	514	
33		81. 23	619	25	38. 20	648	27	2	37. 77	560	
34		80. 65	526	Sep. 8	38. 14	604	Sep. 9	1	38. 14	604	
35	1971	81. 34	629	Jun. 11	38. 92	708	Jun. 12	1	36. 98	472	
36		80. 14	451	19	36. 77	451	21	2	33. 39	147	
37		81. 43	644	Jul. 16	38. 66	672	Jul. 17	1	38. 17	612	
38		80. 00	433	Sep. 1	37. 12	488	Sep. 2	1	36. 95	469	
39	1972	79. 26	348	Jun. 30	35. 60	352	Jul. 1	1	34. 63	263	
40		80. 73	559	Jul. 5	37. 07	503	8	3	34. 82	279	
41		82. 15	793	Aug. 20	40. 05	887	Aug. 22	2	39. 52	811	
42		80. 16	628	28	38. 76	705	28	0	38. 76	705	
43		81. 08	615	30	38. 62	687	31	1	38. 56	680	
44		81. 81	732	Sep. 8	40. 96	1,041	Sep. 9	1	39. 91	866	

No.	Year	Thong Pha Phum (K-13)			Lum Sum (K-10)			Lag-time	K-10 (When K_{13} has peak)		Note
		H peak	Q peak	Day	H peak	Q peak	Day	$K_{10}-K_{13}$	H peak	Q peak	
45		81. 96	759	Sep. 20	39. 80	850	Sep. 21	1	39. 03	742	
46		80. 08	461	Oct. 8	37. 49	552	Oct. 9	1	37. 30	529	
47	1973	82. 2[illegible]	811	Jul. 11	39. 02	767	Jul. 12	1	36. 59	456	
48		81. 64	704	15	38. 98	761	15	0	38. 98	761	
49		81. 74	720	20	39. 51	835	21	1	39. 45	827	
50		79. 57	390	Aug. 16	36 40	435	Aug. 17	1	36. 28	422	
51		80. 02	453	Sep. 13	37. 42	549	Sep. 14	1	36. 40	435	
52		81. 71	716	25	39. 76	872	25	0	39. 76	872	
53	1974	79. 27	349	May. 31	36. 11	400	Jun. 2	2	35. 16	305	
54		80. 05	457	Jun. 10	37. 04	493	12	2	35. 12	301	
55		80. 77	565	16	38. 27	640	17	1	37. 60	560	
56		78. 89	303	Jul. 31	35. 85	374	Aug. 1	1	35. 63	352	
57		79. 99	449	Sep. 4	37. 46	543	Sep. 5	1	37. 45	542	
58		78. 19	339	11	36. 43	432	12	1	36. 23	412	

No.	Year	Thong Pha Phum (K-13)			Lum Sum (K-10)			Lag-time	K-10 (When K_{13} has peak)		Note
		H peak	Q peak	Day	H peak	Q peak	Day	K_{10}-K_{13}	H peak	Q peak	
59		79. 69	407	Oct. 13	38. 73	696	Oct. 14	1	38. 65	686	
60		79. 87	432	19	37. 83	588	21	2	37. 13	504	

Fig. 5-2 Water Stage Correlation Curve (1946 Sep. Flood)

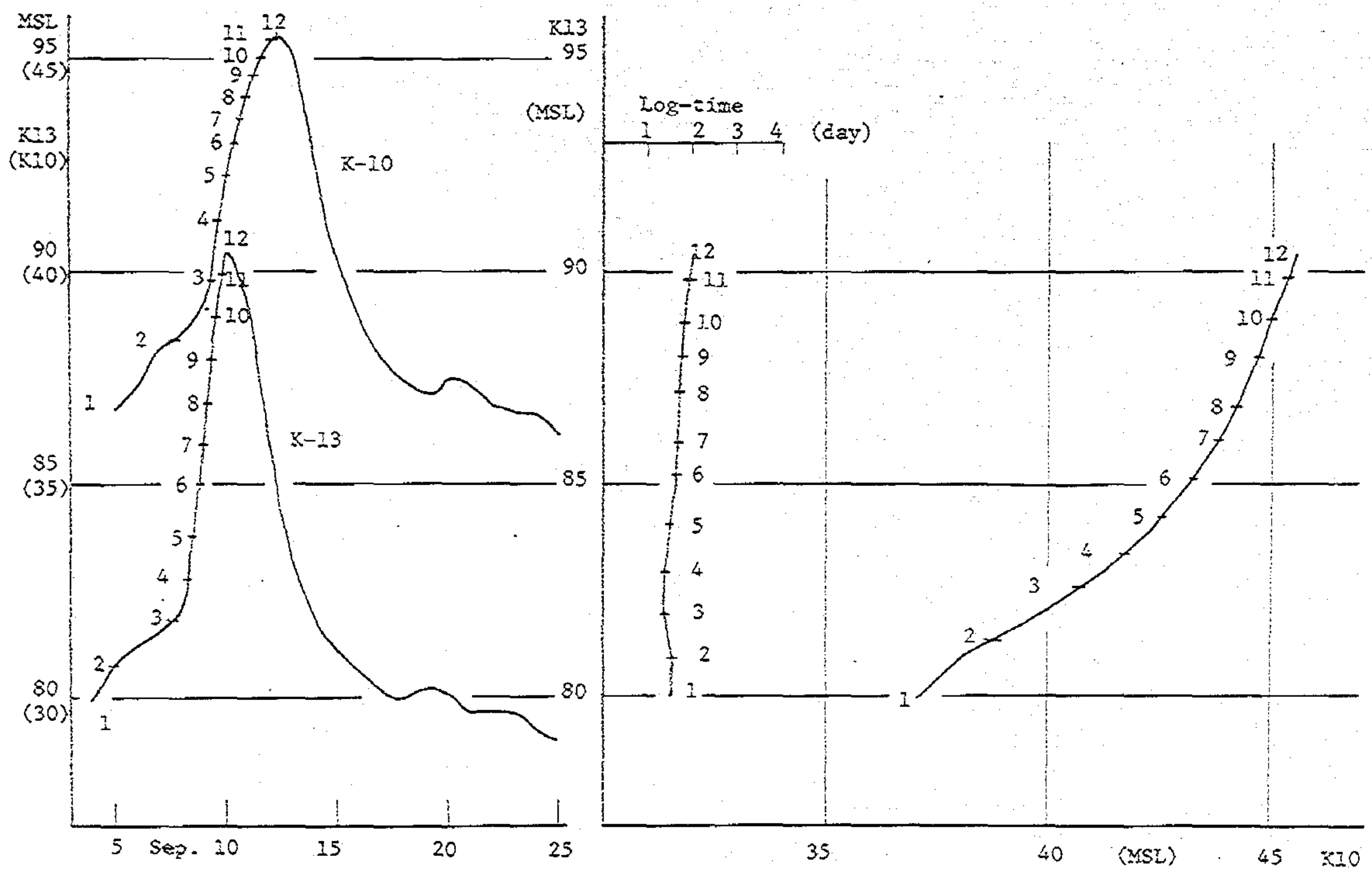
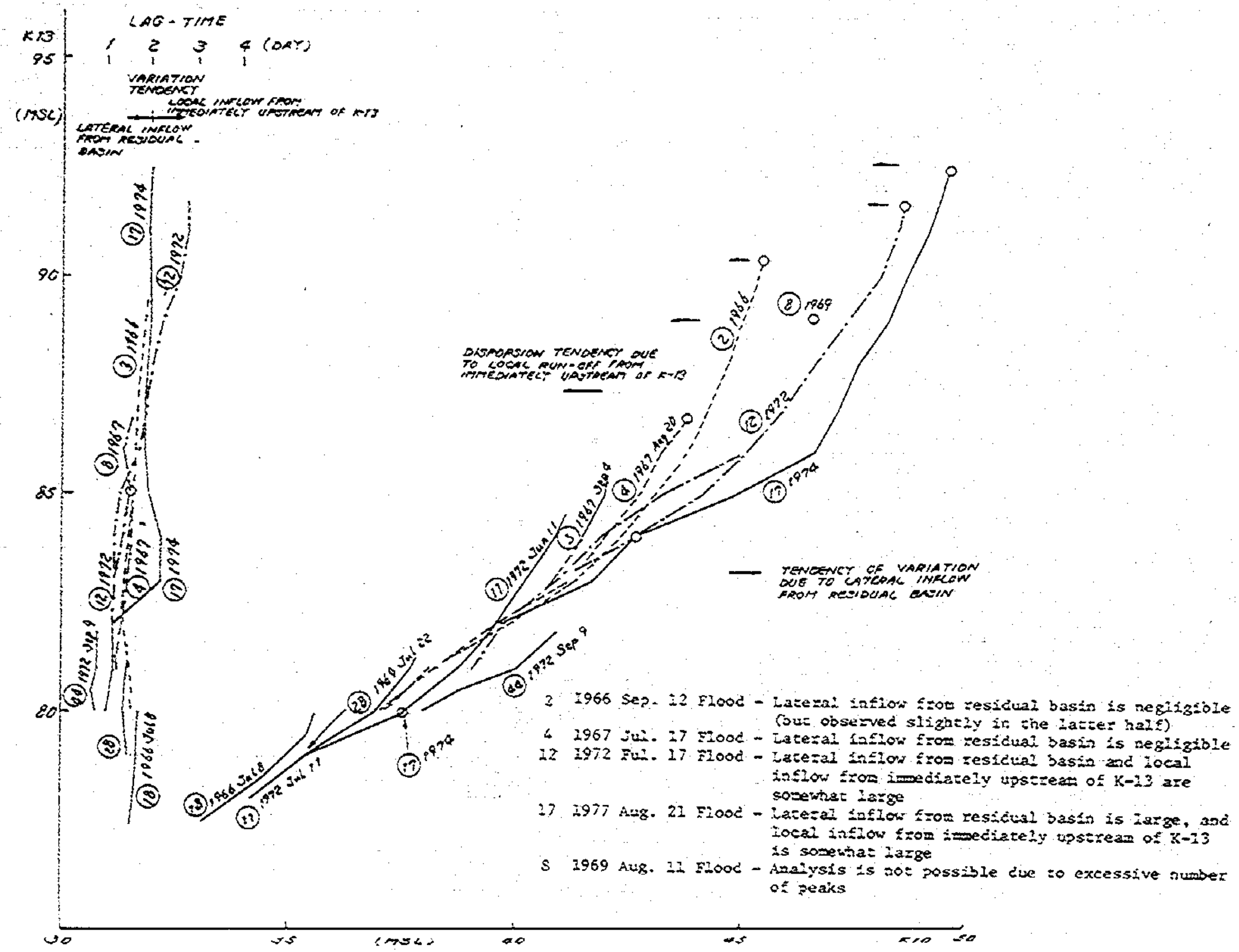


Fig. 5-3 Water Stage Correlation Curve



The above results indicate that the hydrograph correlation method is not any more reliable in terms of accuracy than the peak-to-peak method because the correlation curve presents a wide variation for each flood and this tendency becomes more and more pronounced with the magnitude of flood.

Study of each flood in respect of its hydrograph and correlation curve disclosed that there are two main causes of variation. One is the lateral inflow from the basin area between the two points, i.e., run-off from residual basin, and the other is the variation of hydrograph caused by local rainfall in the area immediately upstream of K-13, and it was also discovered that the stage correlation would depict approximately uniform curves curling upward in a similar pattern. Since the variation can be escribed mainly to the former cause (lateral inflow from residual basin), correction was effected by the method shown in the following table.

(1) Date of Flood Occurrence	(2) Total Run-Off Volume		(3) Daily Average Effective Depth of Run-Off	(4) Corrected State at K-10
	K-13	K-10		
1 Sep 12, 1966	935.7×10^{6}m^3	901.3×10^{6}m^3	Δ0.5(0.6) mm/day	0.3 m
4 Aug 20, 1967	577.9 "	529.8 "	Δ1.1(0.0) "	0 "
8 Aug 11, 1969	1,830.1 "	2,263.5 "	4.3(5.4) "	2.7 "
12 Jul 17, 1972	1,038.9 "	1,045.8 "	0.2(1.3) "	0.7 "
44 Sep 9, 1972	123.2 "	207.7 "	2.4(3.5) "	1.8 "
17 Aug 21, 1974	1,493.0 "	1,623.7 "	2.0(3.1) "	1.6 "

(1) : Peak occurrence day at K-10.

(2) : Total run-off volume between throughs in flood hydrograph.

(3) : Daily average of the value obtained by dividing the difference in the total run-off volume (2) by the residual basin area (2,961 Km^2) between K-10 and K-13. Figures in parentheses are the values calculated with the inflow from residual basin taken at zero for August 20, 1967 flood.

(4) : Correction was effected by the following equation which was established by deriving coefficient = 0.5 from Fig. 5, with the corrected water stage at K-10 taken at zero for the daily average effective height of run-off (Δ1.1 mm/day) of August 20, 1967 flood.

$$(4) = 0.5 \times [(3) + 1.1] \; ..... \; m$$

The peak stage of each flood corrected by the above method is indicated by an arrow mark in Fig. 5-3.

The water stage curves obtained from the above study for flood forecasting between K-10 and K-13 are shown in Fig. 5-4. The parallel lines in the figure indicate the accumulated rainfall height in the residual basin. Where there is any lateral inflow from the residual basin, the correlation curves are to be moved to the right to the corresponding line of rainfall height. (Peaks on the hydrograph are generally rounded or during the downflow travel from K-13 to K-10. Therefore lateral inflow decreases and usually assumes a minus value as shown in Column (3) of the above table, so that the inflow is taken at zero for the flood on August 20, 1967).

In the actual operation of flood forecasting work, however, it is difficult to obtain the effective depth of run-off in the residual area. During the flood, therefore, it is advisable to obtain correlation curves successively from the flood observation data of both K-13 and K-10 and assume the residual basin run-off of the flood in question to be the stage difference from zero inflow, and then shift the curves by that stage difference in order to make flood forecast in each subsequent stage.

o Example of Flood Forecasting Operation

Stage correlation curves between K-13 and K-10 are shown in Fig. 5-4. Examples of forecasting operation using these curves are shown in Table 5-3 and Figs. 5-5 and 5-6 for the following two floods.

i. Flood on September 12, 1966 as an example of the case where the inflow from residual basin is negligible.

ii. Flood on August 21, 1974 as an example of the case influenced by the inflow from residual basin.

In this exemplary forecasting operation, the water stage at K-10 was forecasted in the following way. For the September 1966 flood, the observation data up to September 11 were used as known data, and the water stage at K-10 after that day (or after the lapse of lag-time) was forecasted. For the August 1974 flood, the observation data up to August 18 were also used as known data, and the stage at K-10 on the following day (after the lapse of lag-time) was forecasted. As for the method of forecasting, the values recorded in the past were plotted on the H-H correlation chart shown in Fig. 5-4 with the aid of the hydrograph shown in Fig. 5-5, and estimation was made by extending the tendency curve so far depicted with the newest measured values at K-13. (See Fig. 5-6).

Table 5-3 Actual Stage Data Used for Exemplary Operation

September 1966 Flood			August 1974 Flood		
Date	Stage		Date	Stage	
	K-13	K-10		K-13	K-10
4	79.89	37.16	12	78.13	34.45
5	80.70	36.70	13	80.76	34.90
6	81.18	37.23	14	83.95	38.26
7	81.47	38.11	15	84.78	41.10
8	81.98	38.45	16	85.13	42.33
9	85.64	39.15	17	88.99	43.62
10	90.38	42.08	18	91.57	46.15
11	89.13	44.40	19	92.49	48.36
12	85.64	45.51	20	89.68	49.38
13	83.20	44.92	21	85.42	49.61
14	81.75	42.68	22	83.30	48.53
15	81.04	40.09	23	82.49	45.30
16	80.52	38.65	24	82.33	42.10
17	80.11	37.86	25	81.18	40.30
18	79.98	37.33	26	81.04	39.30
19	80.21	37.10	27	80.97	38.87
			28	80.86	38.76
			29	80.32	38.25
			30	80.01	37.86
			31	79.82	37.56

o September 1966 Flood

Figs. 5-5 and 5-6 were prepared by plotting the stage measured at K-13 and that measured at K-10 and shifted by lag-time (numbered 1 ∿ 6), and by plotting the measured stage at K-10 after shifting backward by lag-time (numbered 6' and 7').

By this plotting, the influence of lateral inflow from residual basin almost disappeared and it was found that the tendency curve between 6' and 7' was apparently within the region where the correlation curve was near the peak stage and curled upward, so that it was extended in the direction shown by the broken line. Here, the peak stage at K-13 reached 90.5 MSL on September 10.2, whereby the peak stage at K-10 was estimated from the correlation curve to reach 45.6 MSL after 2.4 days lag time, on September 12.6. The results of this operation showed an extremely good conformity to the actual observation data.

o August 1974 Flood

Plotting conducted in the same way suggested that the lateral inflow from residual basin was about 2.4 mm/day (3.1 mm/day in the actual record). The tendency curve after 6' (i.e.,after the assumed non-availability of observation data from August 19) could not be estimated because it was not possible to judge whether the stage at K-13 was also close to its peak by the hydrograph alone (Actually, the curve can be estimated by rainfall and other data after completion of telemetering network). Hence, the tendency curve was estimated in two ways. In one way, the correlation curves were shifted rightward to 6', based on the measured data, and then extended to 7' (curve 6'~7') assuming that the stage was close to its peak at K-10 and K-13.
In the other, it was estimated that the stage at K-13 was still much lower than its peak, whereby the straight line 6' ∿ 7" was drawn.

As a consequence, the stage at K-10 on August 19, 1974 was forecasted to range from 48.5 to 50.0 MSL.

In the above exemplary operation, the forecasting accuracy would have increased markedly if the said stage at K-10 had been estimated at 48.5 MSL assuming that the K-13 stage in near its peak, because the difference with the actually recorded value (48.36 MSL) is only 14 cm.

From the above example, it can be readily seen that flood forecasting in the Mae Klong basin by near-peak stage estimation calls for hourly stage observation just as in other river basins.

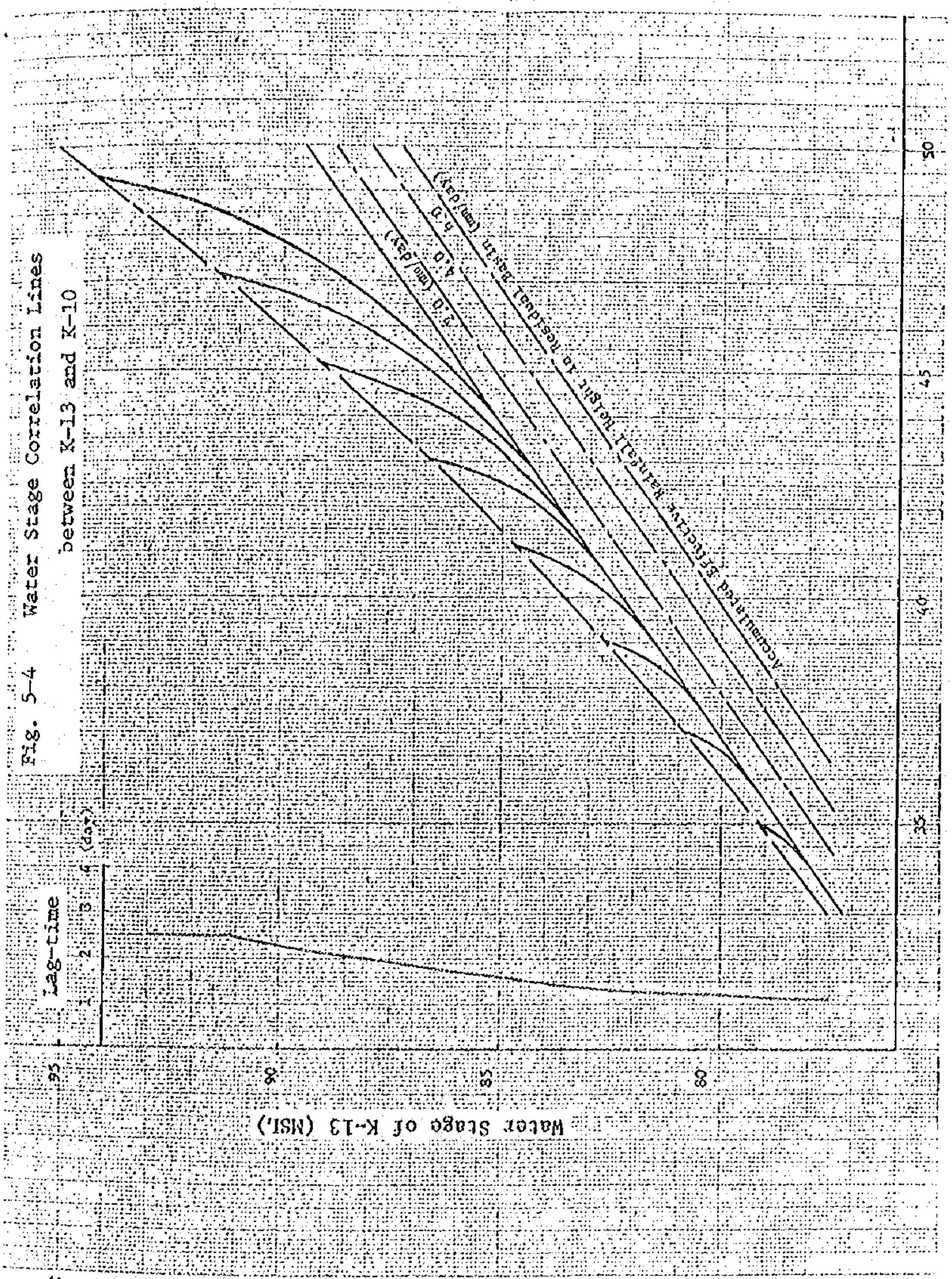
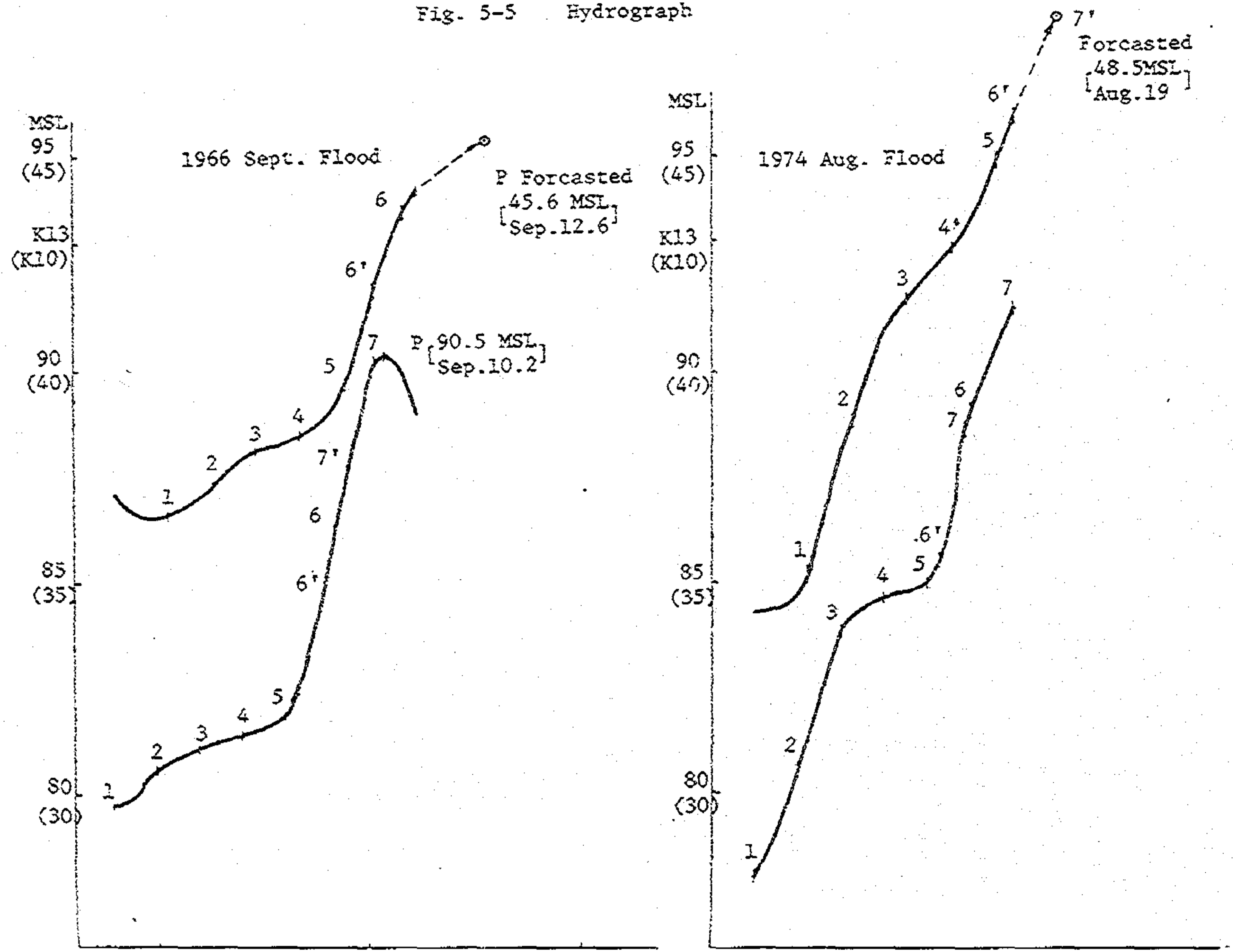
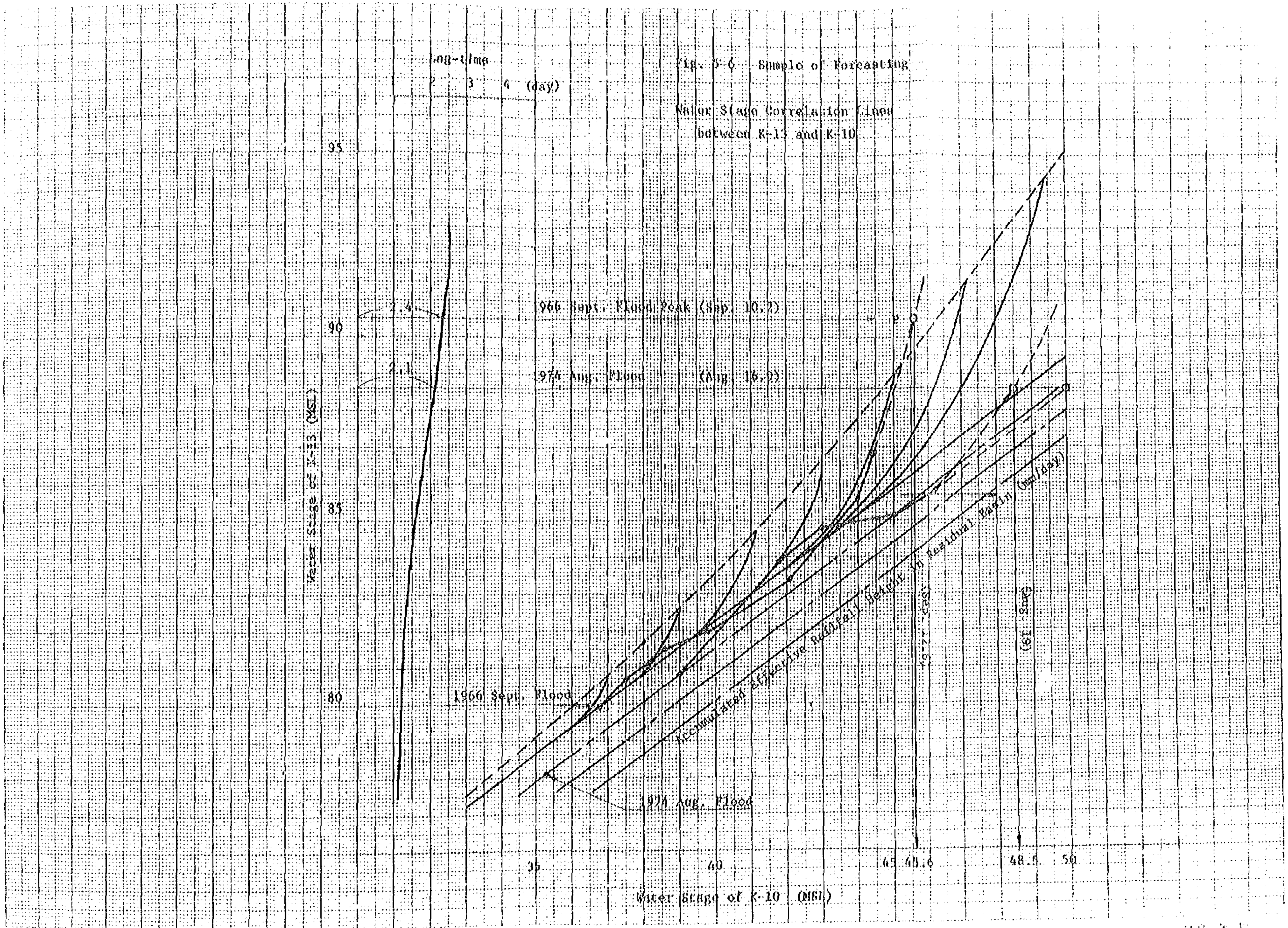


Fig. 5-4 Water Stage Correlation Lines between K-13 and K-10

Fig. 5-5 Hydrograph





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5-2-3 Simulation Model for Run-off Calculation

(1) Outline

The run-off calculation method so far employed for the Mae Klong river flood forecasting is generally justifiable for reasons enumerated below.

1) The average rainfall in the area upstream of K-10 can be generally grasped by the observation at the existing seven stations.

2) If any other method is introduced, the whole basin must be divided into a number of areas, which is liable to make it impossible to grasp rainfall in each divided area.

3) The target area for flood forecasting extends downstream of K-10.

Hence, effort was made to devise a method by which to bring solution for the following major problems involved in the presently employed method.

1) Calculations for flood forecasting start on a fixed day, i.e., April 1 of each year.

2) Adjustment or correction of computed discharges against measured values cannot be made in the course of calculation.

With these problems in mind, the simulation model was so designed as would permit the operations to be started on any given day and to correct computed discharge to measured value.

(2) Case Selection and Flow Chart

Studies were made on four different cases for selection of the most suitable one compatible with the following basic operational conditions.

1) Q_S is to be obtained from the newest rainfall data for the preceding 1~5 days, and discharge obtained from Q_S and assumed Q_B is to be compared to observed discharge in order to correct R_S and R_I for the preceding 5 days and 3 days, respectively.

2) β or α is to be obtained by reverse operation from the corrected R_S and R_I and used in the subsequent calculations.

3) Values of basic constants should be the same as in the presently employed method.

(2)-1 Outline of Each Case

The definitions of symbols given on page 136 also apply in the following explanation, and the symbols suffixed by "O" and "M" indicate the values "before correction" and those "after correction," respectively.

1) Rainfall Correction to Bring Computed Discharge in Conformity to Observed Value

Where $Q_c < Q_o$ in Cases 1 and 2, RS_O and RI_O are enlarged to RS_M and RI_M by Q_o/Q_c, but if $RE_M = RS_M + RI_M$ is larger than R, RE_M is taken at R, and if RS_M is larger than RE_M, then $RS_M = RE_M$ and $RI_M = 0$.

Where $Q_c > Q_o$, both RS_O and RI_O are reduced by the ratio Q_o/Q_c in Case 1, but only RS_O is reduced in Case 2. Once RI = 0, RI = 0 constantly in Case 1 but this relationship is not in Case 2 after reduction. At time of enlargement, therefore, RE changes in both cases. But at time of reduction, it changes in Case 1 and but not in Case 2.

In Case 3, only RS_O is enlarged or reduced according to Q_o/Q_c. If RS_M becomes larger than RE_O by the enlargement, $RS_M = RE_O$ and $RI_M = 0$. RE is not changed.

In Case 4, RS_O, RI_O and RE_O are all enlarged or reduced according to the ratio Q_o/Q_c. If RE_M becomes larger than R at time of enlargement, $RE_M = R$, and both RS_M and RI_M are simultaneously reduced by R/RE_M.

2) Calculation of α and β

α or β is obtained by reverse operation using RS_M, RI_M and RE_M.

In Case 1, β remains the same ($\beta_M = \beta_O$) while $RE_M < R$, and increases while $RE_M \geqslant R$ and $RS_M < RE_M$. After $RS_M \geqslant RE_M$, $\beta = 1.0$ and this relation does not change.

Case 2 is identical to Caae 1 up to the step where $\beta = 1.0$, but β becomes smaller thereafter if RS is reduced.

In Case 3, β presents the same behaiviours as in Case 2.

In Case 4, it assumes the same value constantly.

As for the value of α, $\alpha_O \neq \alpha_M$ at all times in Cases 1 and 4 and $\alpha_O = \alpha_M$ constantly in Case 3. In Case 2, α assumes the same value as in Case 1 at time of enlarging rainfall, and the same value as in Case 3 at time of its reduction.

3) Calculation after (T + 1) Days

In Cases 1, 2 and 3, the values of α obtained from 7~9 days rainfall are used directly. In Case 4, the value of β obtained from $\phi(Q_B)$ is employed directly.

In Cases 1, 2 and 3, β_M is derived from $\beta S_M/RE_M$; if it exceeds 0.55, the value obtained by reverse operation is used in the subsequent calculations. If the computation on the preceding three days indicates an increasing tendency of β, the maximum value is used. If this computation presents an opposite tendency of β, then the minimum value is adopted.

In Case 4, α_M is obtained from RE_M/R, and the average of computed values of the three preceding days is used in the subsequent calculations.

Table 5-4 shows the outline of each of the four cases.

Table 5-4 Outline of Each Case

		Case 1	Case 2	Case 3	Case 4
Correction of Counted Discharge	$Q_c < Q_o$	o RS and RI are enlarged RE is also enlarged o RE = R if enlarged RE is larger than R o RS = RE, RI = 0 if enlarged RS is larger than RE	Same as Case 1	o Only RS is enlarged o RS = RE, RI = 0 if enlarged RS is larger than RE o RE is not changed	o RS, RI and RE are enlarged or reduced. o RE = R if enlarged RE is larger than R, and enlarged RS is reduced by the ratio (R.RE)
	$Q_c > Q_o$	o RS and RI are reduced RE is also reduced	o RE is not changed but RS is reduced	o RE is not changed but RS is reduced	
Calculation after (T+1)	β	o If the value of β obtained from RE_M and RS_M is larger than 0.55 that value is used o Otherwise, β_m is o obtained from $\phi(Q_3)_{T-1}$	Same as Case 1 Same as Case 1	Same as Case 1 Same as Case 1	o β_T is obtained from $\phi(Q_3)_{T-1}$
Calculation after (T + 1) (Cont'd)	β (Cont'd)	o Once RI = 0, this relation (RI = 0, β = 1.0) holds itself thereafter	o Even after RI = 0. this relation does not necessarily hold thereafter, and β varies with 1.0 as maximum value	Same as Case 2	
	α	o Value of α given is advance is not changed	Same as Case 1	Same as Case 1	o α is obtained from R and RE_M and used in the subsequent calculations

(2)-1-1 Computation Steps and Flow Chart of Each Case

1) Case 1 (See Table 5-5 and Fig. 5-7)

(Step) (Operation)

1. Value of QB_{TO} is assumed.

2. $\phi(Q_B)_{T-1}$ is obtained from QB_{TO}.

3. β_{T-1} is obtained from $\phi(Q_B)_{T-1}$ (abbreviated to ϕ_{T-1} in the following steps).

4. The following relation is adopted for computation

$$\beta_{T-5} = \beta_{T-4} = \beta_{T-3} = \beta_{T-2} = \beta_{T-1}$$

5. For the period i (= T-5~T-1), the following calculations are worked out.

$$RE_{io} = \alpha_i \cdot R_{io}$$

$$RS_{io} = \beta_i \cdot RE_{io}$$

$$RI_{io} = RE_{io} - RS_{io}$$

6. QS_{To} is obtained from RS_{io}.

7. QC_{To} (= QB_{To} + QS_{To}) is obtained and compared with QO_T.

8. If any difference arises between QC_{To} and QO_T, correction is effected to make them equivalent to each othr other.

9. 1) Where $QC_{To} < QO_T$.

a. Initial values of RS, RI and RE are enlarged by the following equations for period i (= T-5~T-1).

$$RS_i = P \cdot RS_{io}$$

$$RI_i = P \cdot RI_{io}$$

$$RE_i = RS_i + RI_i$$

$$(P = QO_T / QC_{To})$$

b. If $RE_i \geqslant R_i$ in this case, adjustment is made to obtain the following relation.

$$RE_i = R_i$$

c. If $RS_i \geqslant RE_i$, adjustment is also made to establish the following relations.

$$RS_i = RE_i, \quad RI_i = 0$$

2) Where $QC_{To} > QO_T$.

RS_i, RI_i and RE_i are reduced with P.

10. Correction is effected to $QB_T = P \cdot QB_{To}$.

11. QS_T is obtained from RS_i to confirm $QC_T = QS_t + QB_T$.

12. ϕ_{T-1} is obtained from QB_T.

Operations after (T+1)

13. For period i (=T-3~T-1).

$\beta_i = RS_i/RE_i$ is obtained.

14. 1) Where $\beta_i > 0.55$ (irrespective of T), the following adjustment is made.

$$\beta K = \max(\beta_{T-2}, \beta_{T-1}) \text{ if } \beta_{T-3} < \beta_{T-1}$$

$$\beta K = \min(\beta_{T-2}, \beta_{T-1}) \text{ if } \beta_{T-3} > \beta_{T-1}$$

β after (T + 1) is given as βK in all cases.

2) Where $\beta_i \leq 0.55$, β_T is obtained from ϕ_{T-1}.

15. RE, RS and RI at T are obtained by the following equations.

$$RE_T = \alpha_T \cdot R_T$$

$$RS_T = \beta_T \cdot RE_T$$

$$RI_T = RE_T - RS_T$$

16. QS_{T+1} is obtained from the following surface components which are already known.

$$RS_{T-4},\ RS_{T-3},\ RS_{T-2},\ RS_{T-1} \text{ and } RS_T$$

17. ϕ_T is obtained from ϕ_{T-1}, QB_T, RI_{T-3}, RI_{T-2} and RI_{T-1}.

18. QB_{T+1} is obtained from Q_T.

19. QC_{T+1} $(=QB_{T+1} + QS_{T+1})$ is obtained.

20. QC after T+1 is obtained by the same step-wise procedure.

21. Step 8 and subsequent steps are followed in order to obtain the relation $QC_{T+1} = QO_{T+1}$ at T+1.

Table 5-5 Computation Steps in Case 1

DATE	R	Re	α	R_I	T.D.(I)			q_I	$\phi(Q_B)$	Q_B	q_B	β	R_S	T.D. (S)					q_s	Q_s	Q_c	Q_o
	mm/d	mm/d		mm/d				mm	mm	$m^3/s.d$	mm		$mm^3/s.d$						mm	$m^3/s.d$	$m^3/s.d$	$m^3/s.d$
T-5	*	⑨	*									(4)	(5) ⑨									
T-4	*	⑨	*									(4)	(5) ⑨									
T-3	*	⑨	*	⑨								(4) ⑬	(5) ⑨									
T-2	*	⑨	*	⑨								(4) ⑬	(5) ⑨									
T-1	*	⑨	*	⑨					(2) ⑫			(3) ⑬	(5) ⑨									
T	*		*		⑰	⑰	⑰	⑰	⑰	(1) ⑩	⑰	⑭	⑮	(6)	(6)	(6)	(6)	(6)	(6)	(6) ⑪	(7) → ⑧	
T+1	*		*							⑱				⑯	⑯	⑯	⑯	⑯	⑯	⑯	⑲	
T+2																						

T: Starting day of computation. Figures in parenthese: Initial values. Figures in circles: Determined (corrected) values. *: Known values. Q_B: Baseflow ($m^3/s.d$). q_B: Baseflow (mm). $\phi(Q_B)$: Basin potential. R: Total rainfall. Re: Effective rainfall. R_I: Infiltration compo. Rs: Surface compo. q_I: Infiltration (mm). QS, q_s: Surface runoff ($m^3/s.d$, mm). Q_c: Computed discharge ($m^3/s.d$). Q_o: Observed discharge ($m^3/s.d$). T.D.(I), T.D.(S): Time distribution. α: Coefficient of effective rainfall. β: Coefficient of surface runoff.

2) Case 2

(Step) (Operation)

1.
2 Same as Case 1.
7.

8. Correction is effected to $QC_{To} = QO_T$.

9. 1) Where $QC_{To} < QO_T$ (RS_{io}, RE_{io} and RI_{io} are changed), the following relations are obtained for period i (= T - 5∾T - 1)

$$RS_i = P \cdot RS_{io}$$

$$RE_i = P \cdot RE_{io}$$

$$RI_i = RE_i - RS_i$$

2) Where $QC_{To} > QO_T$ (RE_{io} is not changed), the following relations are obtained.

$$RS_i = P \cdot RS_{io}$$

$$RE_i = RE_{io}$$

$$RI_i = RE_i - RS_i$$

10. and subsequent steps - Same as in Case 1.

3) Case 3

(Step) (Operation)

1.
~ Same as in Case 1.
7.

8. Correction is effected to $QC_{To} = QO_T$.

9. 1) Where $QC_{To} < QO_T$ (RE_{io} is not changed), the following corrections are effected for period i ($= T - 5 \sim T - 1$).

a. Only RS_{io} is enlarged.

$$RS_i = P \cdot RS_{io}$$

$$RE_i = RE_{io}$$

$$RI_i = RE_i - RS_i$$

b. If $RS_i \geq RE_i$ in this case, corrections are made to obtain the following relations.

$$RS_i = RE_i$$

$$RI_i = 0$$

2) Where $QC_{To} > QO_T$ (RE_{io} is not changed),

$$RS_i = P \cdot RS_{io} \text{ (reduction)}$$

$$RI_i = RE_i - RS_i$$

10. and subsequent steps - Same as in Case 1.

4) Case 4

(Step) (Operation)

1.
⁓ Same as in Case 1.
7.

8. Correction is effected to $QC_{To} = QO_T$.

9. 1) For period i (= T - 5 ~ T - 1),

$$RS_i = P \cdot PS_{io}$$

$$RI_i = P \cdot RI_{io}$$

$$RE_i = RS_i + RI_i$$

2) If $RE_i \geqslant R_i$, the following relations are obtained.

$$RE_i = R_i$$

$$RS_i = (R_i/RE_i) \cdot RS_i$$

$$RI_i = RE_i - RS_i$$

10.
Same as in Case 1.
12.

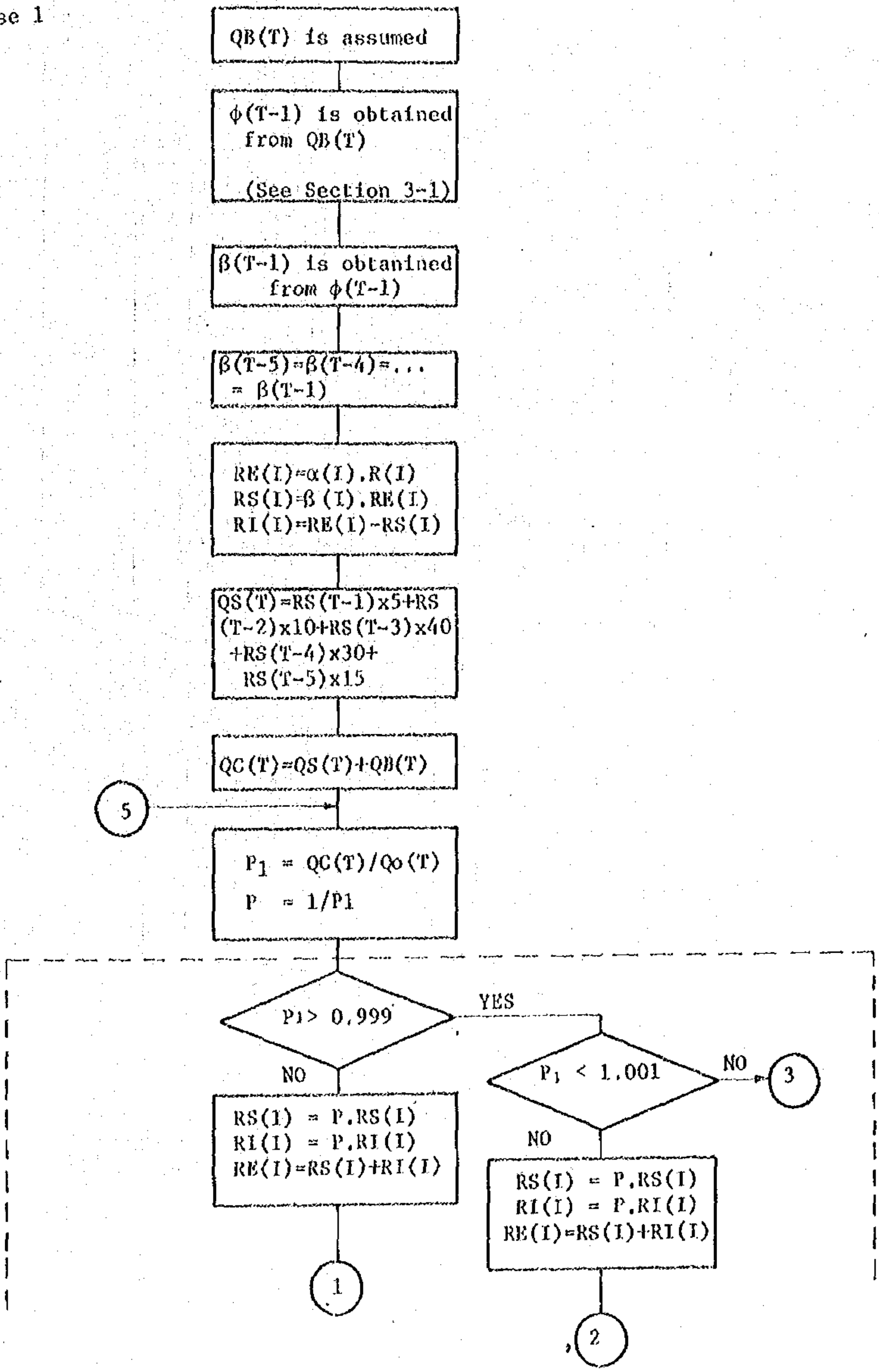
13. For period i (= T - 3 ~ T - 1),
⁓ $\alpha_i = RE_i/R_i$ is obtained.
14. Taking αK at $(\alpha_{T-3} + \alpha_{T-2} + \alpha_{T-1})/3$, α subsequent to T is given as αK.

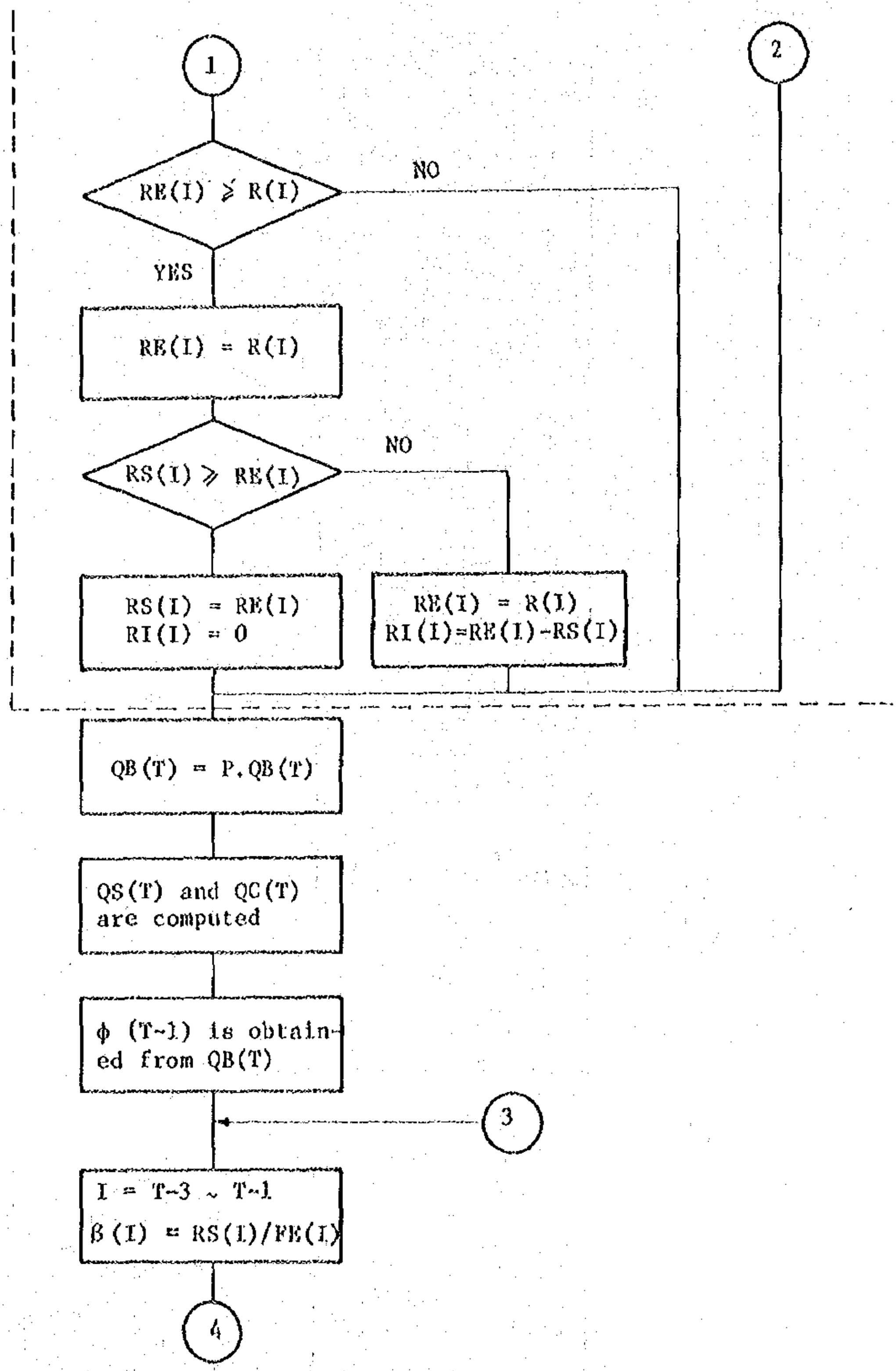
βT is obtained from ϕ_{T-1}.

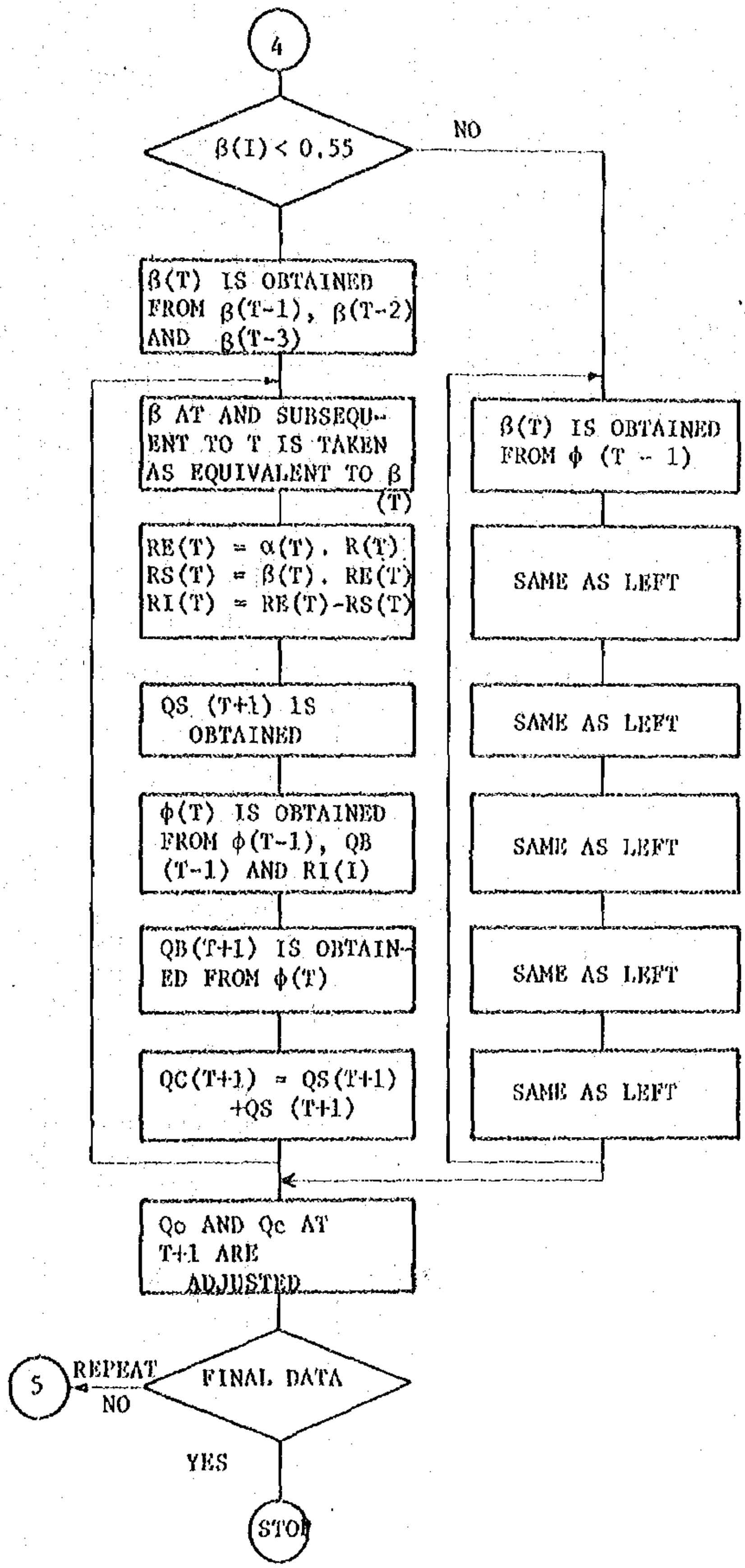
15. and subsequent steps - Same as in Case 1.

Fig. 5-7 Flow Chart of Run-Off Computation

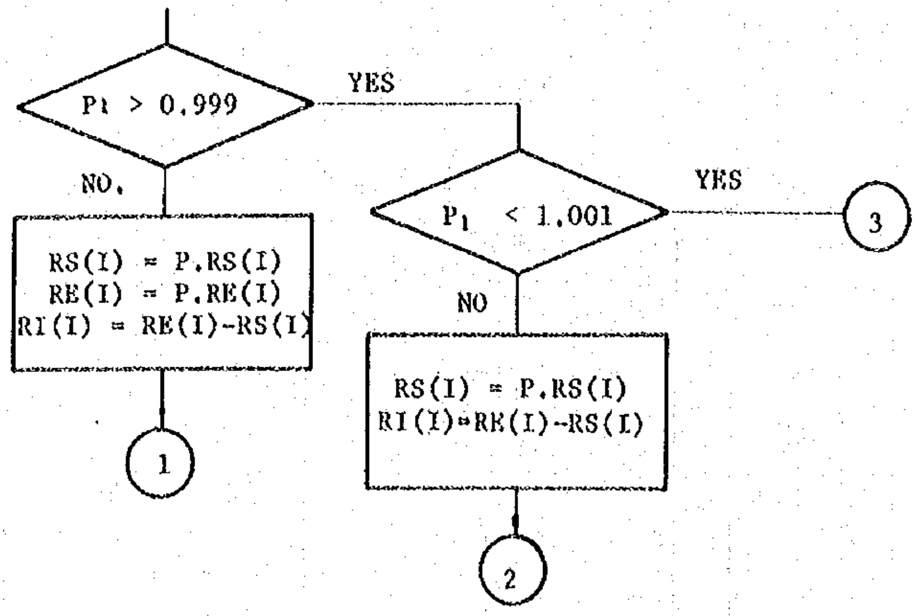
1. Case 1



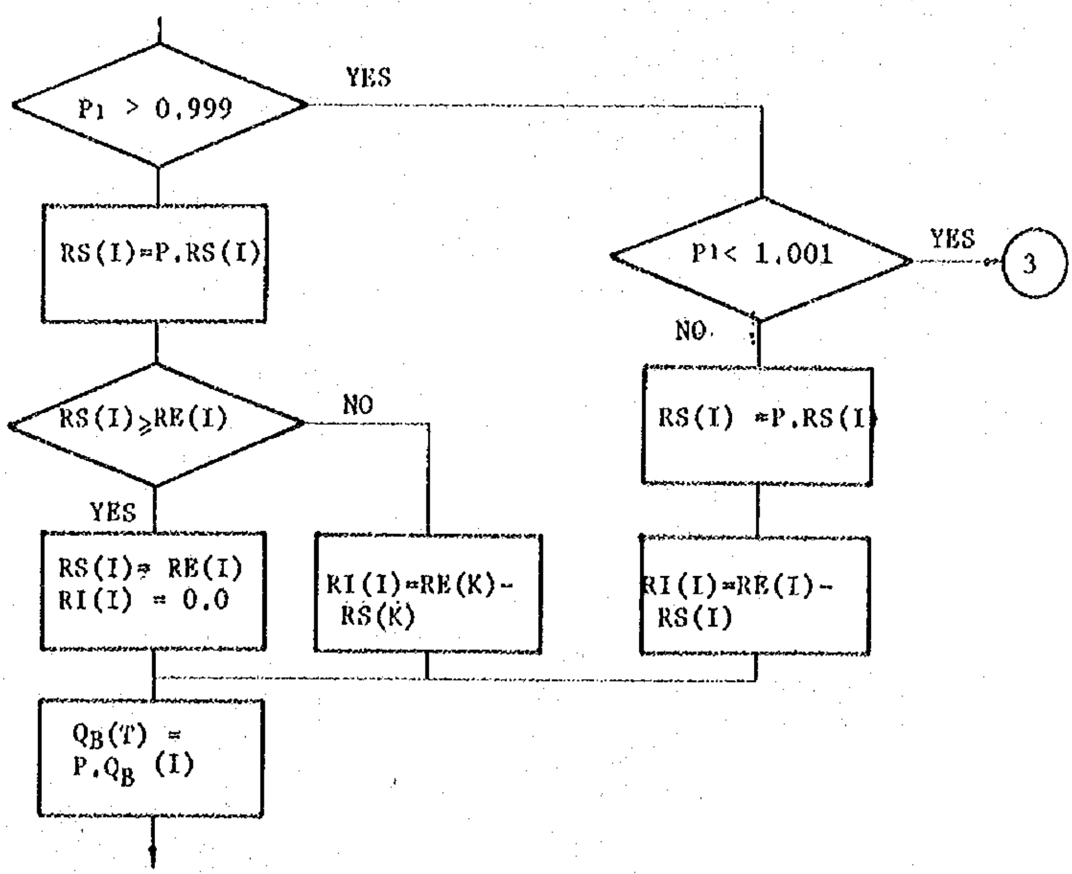

1
2
RE(I) ≷ R(I)
NO
YES
RE(I) = R(I)
RS(I) ≥ RE(I)
NO
RS(I) = RE(I)
RI(I) = 0
RE(I) = R(I)
RI(I)=RE(I)-RS(I)
QB(T) = P.QB(T)
QS(T) and QC(T)
are computed
ϕ (T-1) is obtained from QB(T)
3
I = T-3 ~ T-1
β(I) = RS(I)/FE(I)
4


4
β(I) < 0.55
NO
β(T) IS OBTAINED FROM β(T-1), β(T-2) AND β(T-3)
β AT AND SUBSEQUENT TO T IS TAKEN AS EQUIVALENT TO β (T)
RE(T) = α(T). R(T)
RS(T) = β(T). RE(T)
RI(T) = RE(T)-RS(T)
QS (T+1) IS OBTAINED
φ(T) IS OBTAINED FROM φ(T-1), QB (T-1) AND RI(I)
QB(T+1) IS OBTAINED FROM φ(T)
QC(T+1) = QS(T+1) +QS (T+1)
β(T) IS OBTAINED FROM φ (T - 1)
SAME AS LEFT
SAME AS LEFT
SAME AS LEFT
SAME AS LEFT
SAME AS LEFT
Qo AND Qc AT T+1 ARE ADJUSTED
FINAL DATA
REPEAT
NO
5
YES
STOP

Case 2 (Section boxed in broken line in Case 1 flow chart)

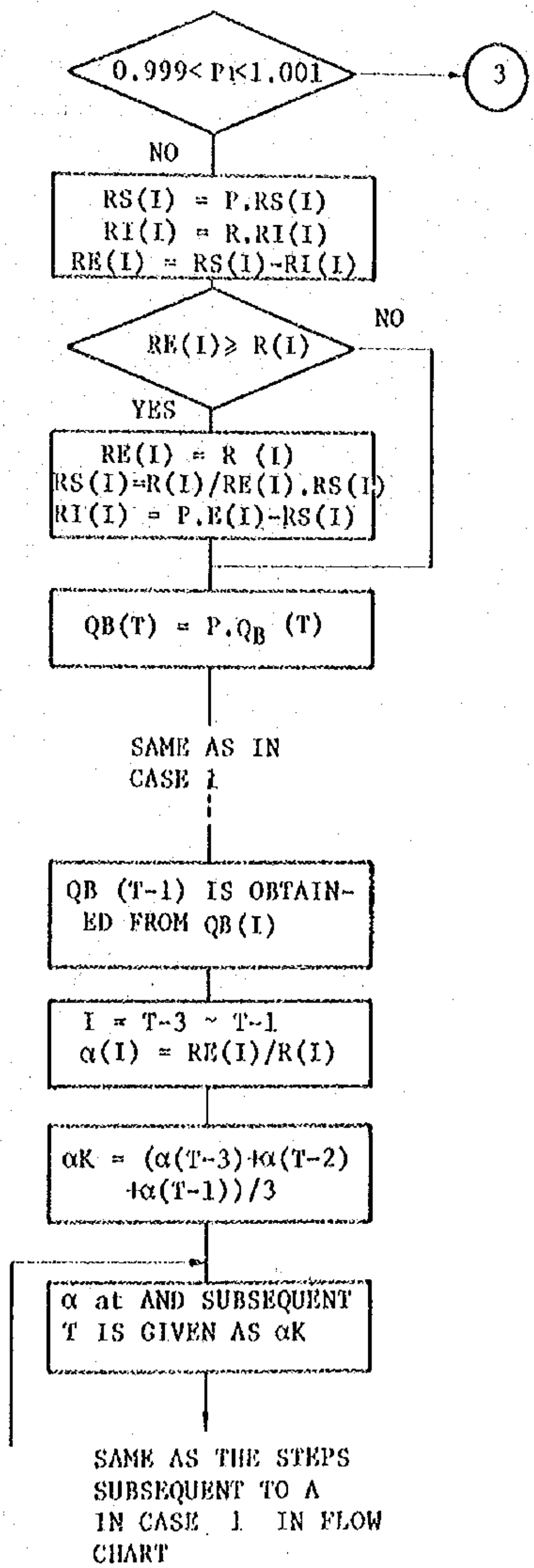


Case 3 (Section boxed in broken line in Case 1 flow chart)



Same as in Case 1

Case 4 (Steps subsequent to the section boxed in broken line in Case 1 flow chart)



(3) Constants and Their Calculation

(3)-1 Relationship between $\phi(QB)$ and QB (See Figs. 5-8-1 and 5-8-2)

The values adopted in the past were used, but approximation was effected using polygonal lines as shown below for the convenience of calculation.

1) $Q_B \geqslant 540\ m^3/s \quad (\phi(Q_B) \geqslant 68)$

$Q_B = EXP\ (0.0077231\phi + 5.76639)$

$\phi(Q_B) = (Ln\ Q_B - 5.76639)/0.0077231$

2) $300 \leq Q_B < 540 \quad (22 \leq \phi < 68)$

$Q_B = EXP\ (0.01306\phi + 5.41637)$

$\phi = (Ln\ Q_B - 5.41637)/0.01306$

3) $60 \leq Q_B < 300 \quad (-66 \leq \phi < 22)$

$Q_B = EXP\ (0.01829\phi + 5.3014)$

$\phi = (Ln\ Q_B - 5.3014)/0.01829$

4) $23 \leq Q_B < 60 \quad (-100 \leq \phi < -66)$

$Q_B = EXP\ (0.02817\phi + 5.95353)$

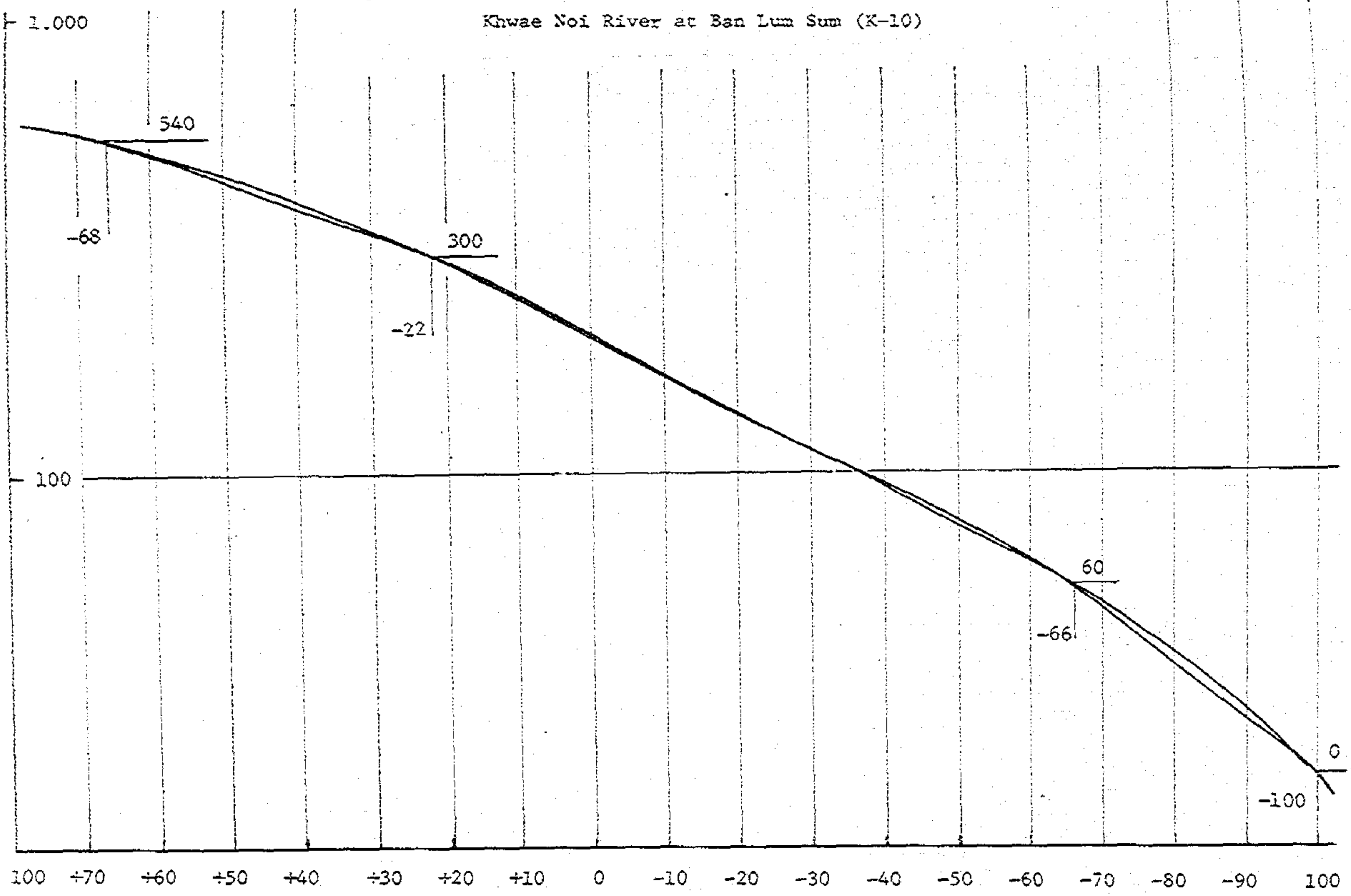
$\phi = (Ln\ Q_B - 5.95353)/0.02817$

5) $Q_B < 23 \quad (\qquad \phi < -100)$

$Q_B = EXP\ (0.04964\phi + 8.09986)$

$\phi = (Ln\ Q_B - 8.09986)/0.04964$

Fig. 5-8-1 Relationship between Basin Potential and Base Flow of Khwae Noi River at Ban Lum Sum (K-10)



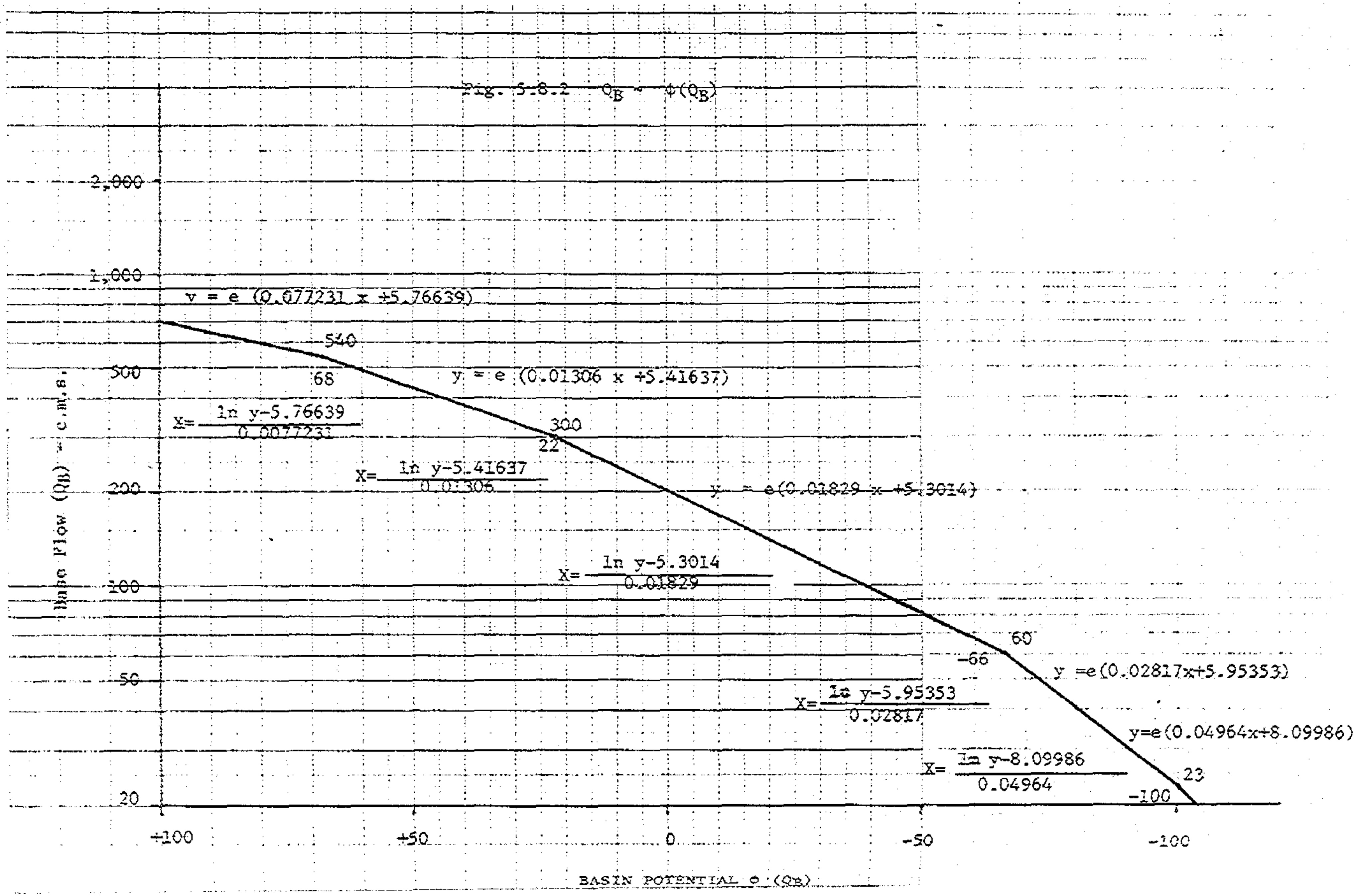
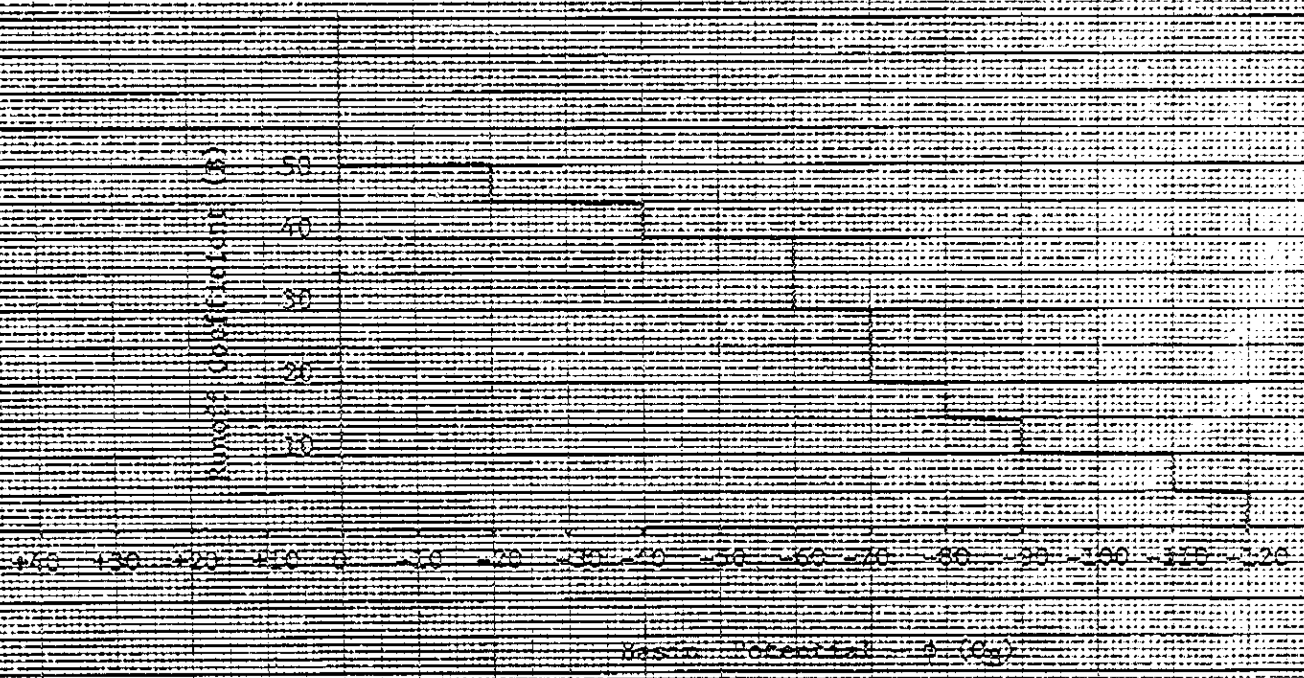


Fig. 5.8.2 Q_B ~ $\phi(Q_B)$
2,000
1,000
500
200
100
50
20
$y = e^{(0.077231\,x + 5.76639)}$
540
68
$y = e^{(0.01306\,x + 5.41637)}$
$X = \frac{\ln y - 5.76639}{0.0077231}$
300
22
$X = \frac{\ln y - 5.41637}{0.01306}$
$y = e^{(0.01829\,x + 5.3014)}$
$X = \frac{\ln y - 5.3014}{0.01829}$
60
-66
$y = e^{(0.02817x + 5.95353)}$
$X = \frac{\ln y - 5.95353}{0.02817}$
$y = e^{(0.04964x + 8.09986)}$
$X = \frac{\ln y - 8.09986}{0.04964}$
23
-100
+100
+50
0
-50
-100
BASIN POTENTIAL ϕ (Q_B)
Base Flow (Q_B) - c.m.s.

Fig. 3-9 Relationship between Surface Runoff Coefficient and Basin Potential of Khwae Noi River Basin at Ban Lum Sum (K.10)



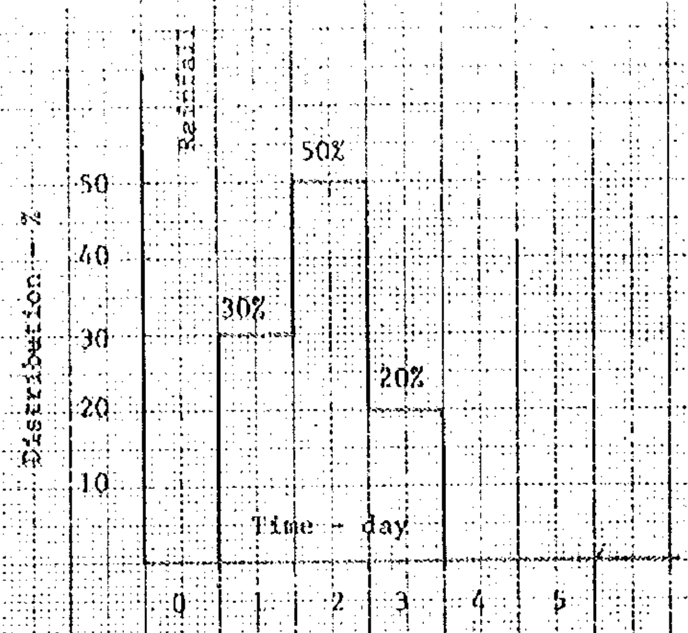


Fig. 5-10 Time Distribution of Infiltration Component

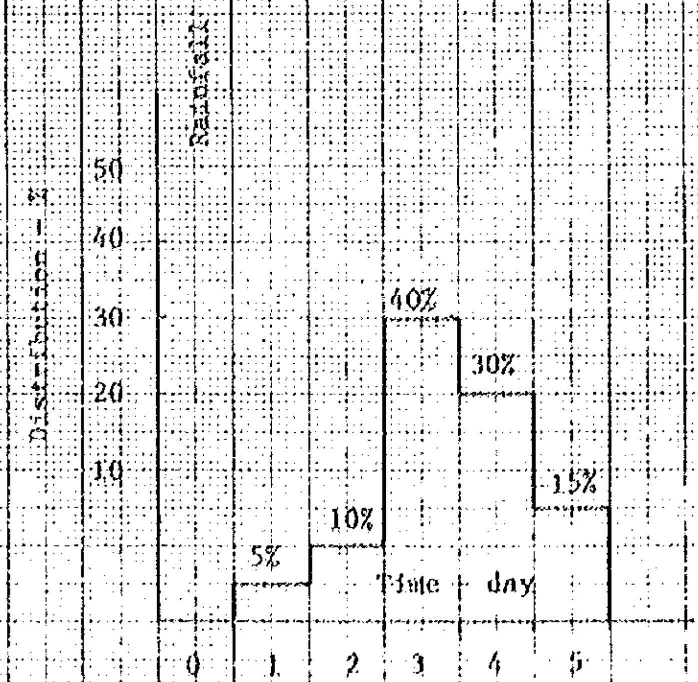


Fig. 5-11 Time Distribution of Surface Runoff Component

(3)-2 Relationship between β and ϕ(QB) (See Fig. 5-9)

The values adopted in the past were used.

(3)-3 Time Distribution of Infiltration Component (See Fig. 5-10)

(3)-4 Time Distribution of Surface Run-off Coefficient (See Fig. 5-11)

(3)-5 Initial Value of QB

Fig. 5-12 is a chart showing the relationship between rainfall during 1-month preceding T-1 (ΣR) and base flow at T (QB). As the chart indicates the existence of a fairly clear correlation between the two, the initial value of QB was obtained from it. Needless to say, if the initial value thus obtained exceeds Q_o, Q_o is to be taken at that value. This initial value of QB can be used only on starting calculations on a given day, and computed QB is to be employed once the calculations are put in progress. (The said chart was prepared from the data contained in "The Development of Pilot Flood Forecasting in the Mae Klong River Basin, 3rd Revision," See Ap-7)

(3)-6 α

1) Apr. 1 ~ 15 .... α = 1%

2) Apr. 16 ~ 30 10

3) May ~ Jun

$\sum_{1}^{8} R_i$ < 140 mm 15

140 ≤ " < 220 40

220 ≤ " 80

4) Jul.

$\sum_{1}^{9} R_i$	≤ 140 mm	....	$\alpha = 40\%$
140 < "	≤ 250	....	70
250 < "		....	100

5) Aug

$\sum_{1}^{9} R_i$	≤ 100 mm	....	60
100 < "	≤ 215	....	70
215 < "		....	100

6) Sep

$\sum_{1}^{7} R_i$	≤ 100 mm	....	50
100 < "	≤ 150	....	60
150 < "		....	100

7) Oct

$\sum_{1}^{7} R_i$	≤ 50 mm	....	30
50 < "		....	50

8) Nov 30

9) Dec 10

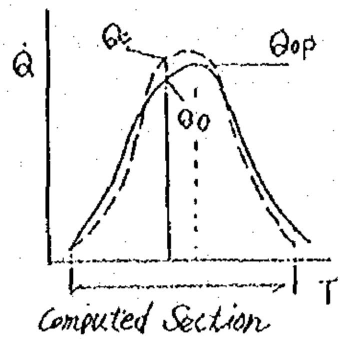
(4) Results and Problems

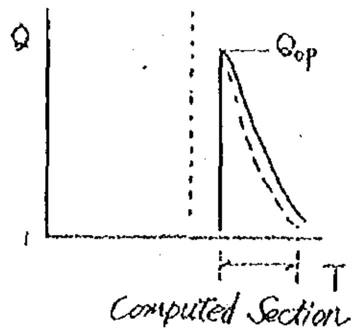
Computations were worked out on the eight floods shown in Table 5-6 for each of the four cases, and the error involved therein was obtained by the following equation.

$$E = \frac{1}{N} \left(\frac{Qc - Qo}{Qop}\right)^2$$

where, Q_{op} : Peak discharge observed in the computed section

Q_o : Discharge observed in the same section





Notes: Q_{op} is the observed peak discharge in the computed section. After peak discharge, therefore, it represents Q_o on each day of starting computation.

Table 5-6 Floods Used for Error Detection

No.	Year	Month	Observed Peak Discharge (m^3/s.d)	Discharge Observed on Starting Computation (m^3/s.d)	Starting Day of Computation	Rainfall in preceding 1 Month	Initial Value of QB	Verification Period
1.	1967	Aug.	1,668	580	14	569	430	
2.	1969	Jul.~Aug.	2,354	316	26	362	120	
3.	1970	Jul.	1,165	144	14	295	100	
4.	1971	Jul.~Aug.	1,859	416	20	382	140	
5.	1972	Jul.	3,026	406	11	362	120	

No.	Year	Month	Observed Peak Discharge (m^3/s.d)	Discharge Observed on Starting Computation (m^3/s.d)	Starting Day of Computation	Rainfall in preceding 1 Mongh	Initial Value of QB	Verification Period
6.	1972	Jul.~Aug.	1,846	753	23	625	440	
7.	1973	Jul.	1,728	43	15	344	43	
8.	1974	Aug.	3,250	239	12	312	150	

As is clear in Table 5-7 showing the results of this error detection computation, Case 1 shows the best conformity on the whole to all the eight floods in terms of average value and variation coefficient of error, so that it was determined to adopt Case 1 for run-off calculation.

Hydrographs of Case 1 are shown in Figs. 5-13-1 ~ 5-13-8. Result of Case 1 verification are shown in Tables 5-8-1 ~ 5-8-2, and an example of simulation of each case in Ap-12.

Fig. 5-12 QB ~ ΣR (1 Month Railfall)

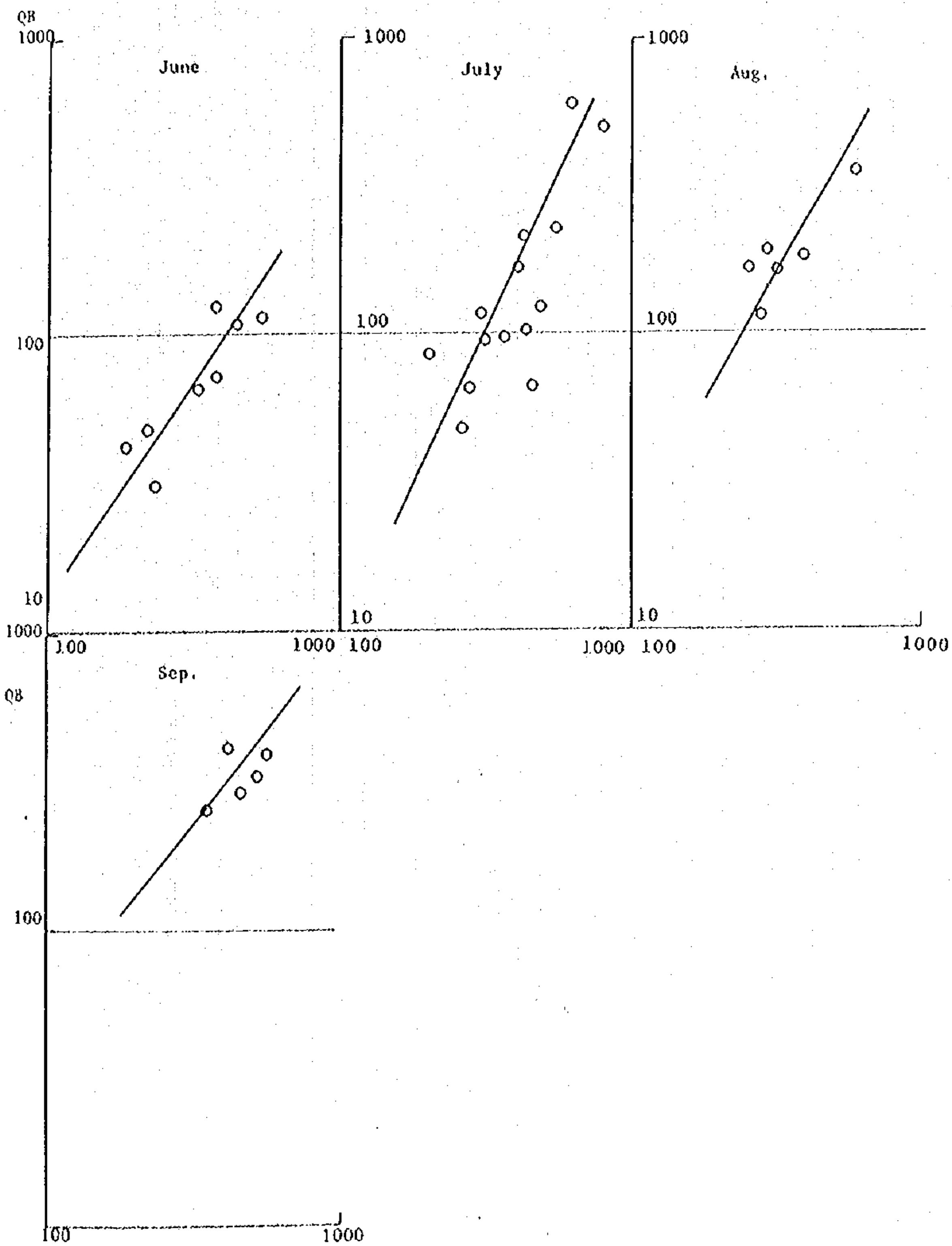


Table 5-7 Data of Error Computations (from Ap-8)

Year	Average Value				Coefficient of Variance				Remarks
	Case 1	2	3	4	Case 1	2	3	4	
1967	0.237	Δ 0.235	o 0.219	1.172	0.355	Δ 0.269	o 0.226	0.742	
1969	Δ 1.040	o 1.035	1.493	2.923	Δ 0.234	o 0.204	0.999	0.457	
1970	Δ 3.607	3.988	o 2.084	6.073	0.858	o 0.762	Δ 0.768	0.726	
1971	Δ 0.582	o 0.542	0.849	2.683	0.284	Δ 0.263	o 0.213	0.849	
1972 (1)	o 2.712	Δ 2.813	2.863	3.754	o 0.521	0.564	Δ 0.541	0.453	
1972 (2)	2.480	Δ 2.476	o 2.415	3.169	o 0.421	Δ 0.435	0.548	0.401	
1973	Δ 3.12	3.900	o 1.817	5.373	Δ 0.488	o 0.316	0.673	0.966	
1974	o 0.971	Δ 0.990	1.007	3.041	0.520	o 0.337	Δ 0.401	0.690	
Average	Δ 1.845	1.997	o 1.593	3.524	Δ 0.460	o 0.394	0.548	0.661	

o First in four cases

Δ Second in four cases

Table 5-8-1 Date of Case 1 Computation (I)

DATE	R	Re	α	RI	Time Distribution			qI	B.P.	QB	-qB	β	RS	T.D. x10⁻²					qs x10⁻²	Qs	Qc	Qo
	mm	mm		mm	0.3	0.5	0.2	mm	mm	$m^3/s.d$	mm		mm	5	10	40	30	15	mm	$m^3/s.d$	$m^3/s.d$	$m^3/s.d$
9	11.9	8.23	0.70	3.75								0.55	4.58									
10	9.1	6.37	0.70	2.87								0.55	3.50									
11	14.6	10.22	0.70	4.60								0.55 (4)	5.62 (5)									
12	14.4	10.08	0.70	4.54								0.55	5.54									
13	12.5	8.75	0.70	3.94					(2) 49.57			(3) 0.55	4.81									
14					1.18	2.26	0.92	4.37		(1) 430.0	-5.30			24.06	(6) 55.44	234.84	105.10	68.72	478.17	387.85	817.85	580.0

Table 5-8-1 Date of Case 1 Computation (II)

DATE	R	Re	α	RI	Time Distribution			qI	B.P.	QB	-qQ	β	RS	T.D. $x10^{-2}$					qs $x10^{-2}$	Qs	Qc	Qo
	mm	mm		mm	0.3	0.5	0.2	mm	mm	$m^3/s.d$	mm		mm	5	10	40	30	15	mm	$m^3/s.d$	$m^3/s.d$	$m^3/s.d$
9	11.9	5.91		2,66								0.55	3,25									
10	9.1	4.52		2,03								0.55	2,48									
11	14.6	7,25 (9)		3,26								0.55 (13)	3.99 (9)									
12	14.4	7,15		3,22 (9)								0,55	3.93									
13	12.5	6,21		2,79					(12) 23,26			0.55	3.41									
14	31.7	22.19 (15)	0.7	9.99 (15)	0,84	1.61	0.65	3,10	(17) 22.60	(17) 354.95	-3.76	(14) 0.55	12.20 (15)	17.06	39.32	(11) 159.45	114.54	48.74	339.11	(11) 275.05	(8) 580.0	580
15	28.7	20,09	0.7	9.04	3,00	1,40	0.64	5.04	23.91	303.32	-3,74	0.55	11.05	61,02	34.13	157.27	119.59	37.27	409.27	(16) 331.97	(17) 634.29	675
16	43.9	30.73	0.7	13.83	2.71	5,00	0.56	8,27	28.38	307.53	-3.79	0.55	16.90	55.25	122.05	136.52	117.95	57.79	491.55	378.70	706.24	740
17	47.9	33.53	0.7	15,09	4.15	4.52	1.99	10.67	35,02	326.03	-4.02	0.55	18.44	84.51	110.50	187.18	102.39	58.98	844.55	685,02	1011.05	889
18	12.7	12.70	1.0	5,72	4,53	6,92	1.81	13,25	43.89	355.59	-4.38	0.55	6.98	92.21	169.02	441.98	311.14	51.19	1120.53	708.87	1264.47	1177
19	14.7	14.70	1.0	6.61	1.72	7.55	2.77	12,03	50.99	399.24	-4.92	0.55	8.09	34.93	184.42	676.06	331.49	183.07	1409.95	1143.63	1542.86	1576
20	9.0	5.40	0.6	3.43	1.98	2.86	3.02	7.86	53.45	438.04	-5.40	0.55	2.97	40.43	69.85	737.16	507.05	165.74	1520.72	1333.47	1671.51	1668
21	15.0	10.50	0.7	4.73	0.73	3.31	1.14	5.18	53.05	452.34	-5.58	0.55	5.77	14.85	80.85	279.40	553.25	253.25	1181.87	1758.62	1410.96	1493
22	13.4	13.40	1.0	6,03	1,42	1.22	1.32	3.96	51.46	450.00	-5.55	0.55	7.37	28.88	29.70	323.40	309.55	276.62	368.15	704.16	1154.16	1160

Fig. 5-13-1 Observed and Computed Hydrograph for Case 1 Verification 1967 Aug.

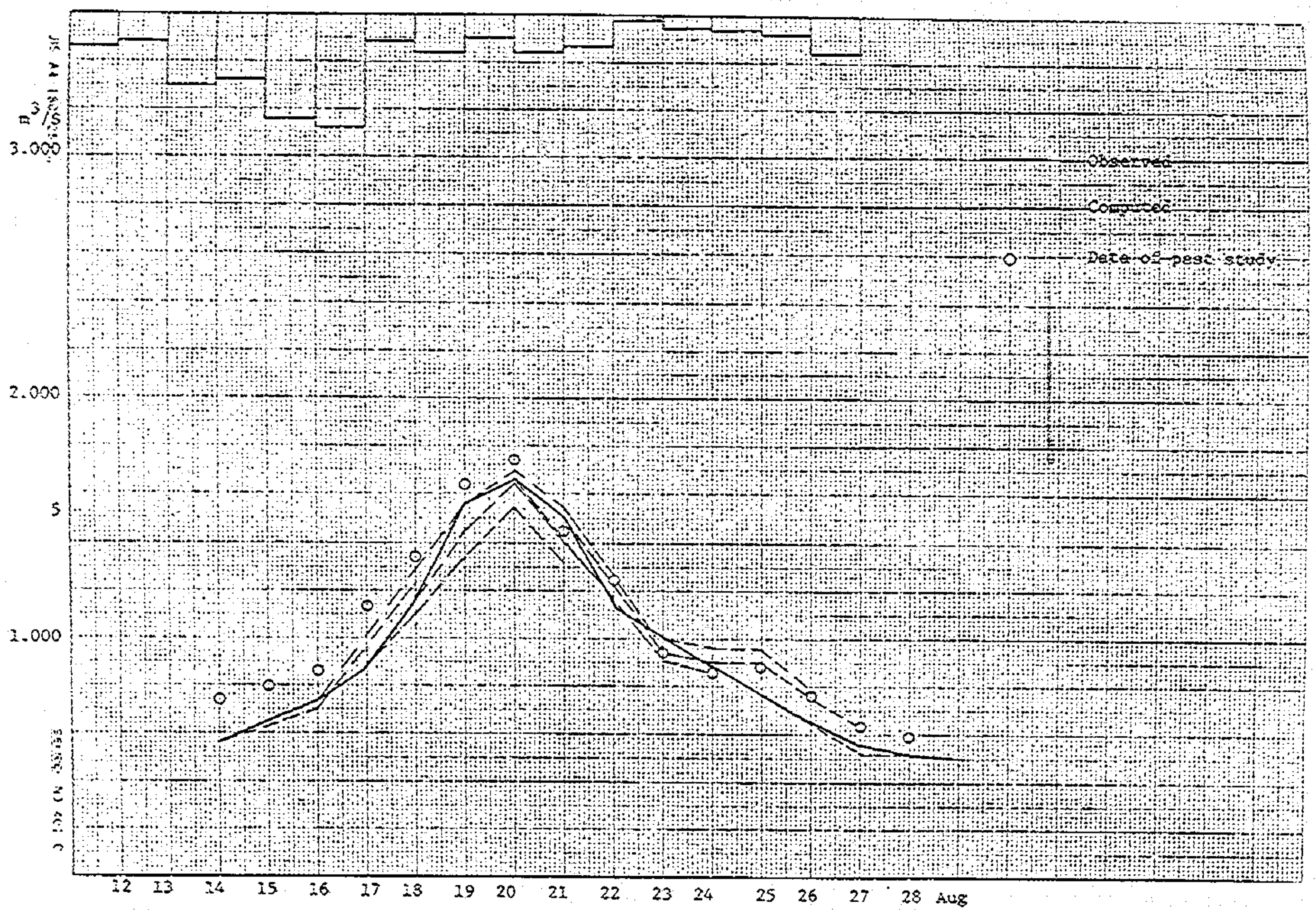


Fig. 5-13-2 Observed and Computed Hydrograph for Case 1 Vertification 1969 Jul. ~ Aug.

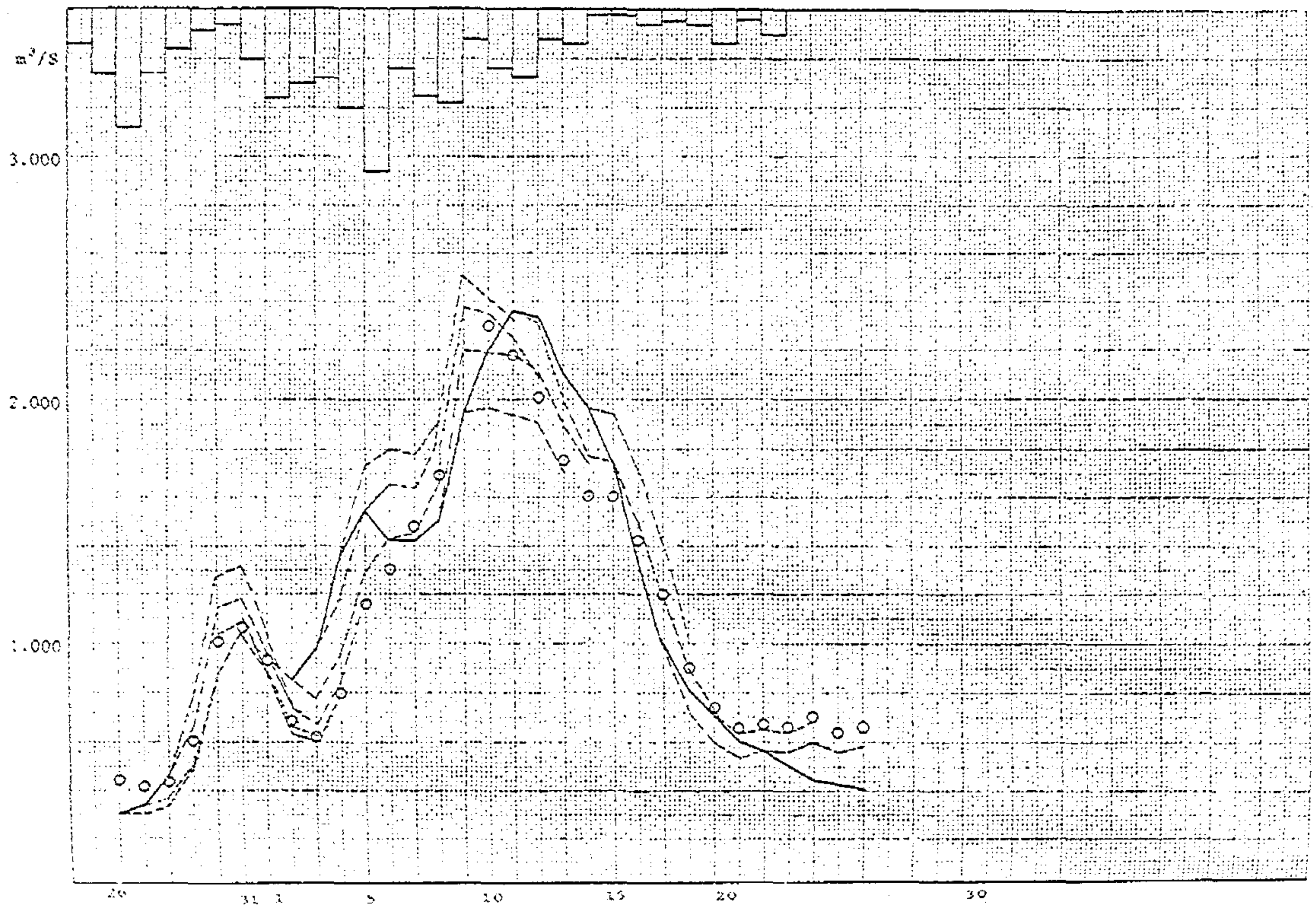


Fig. 5-13-3 Observed and Computed Hydrograph for Case 1 Vertification 1970 Jul.

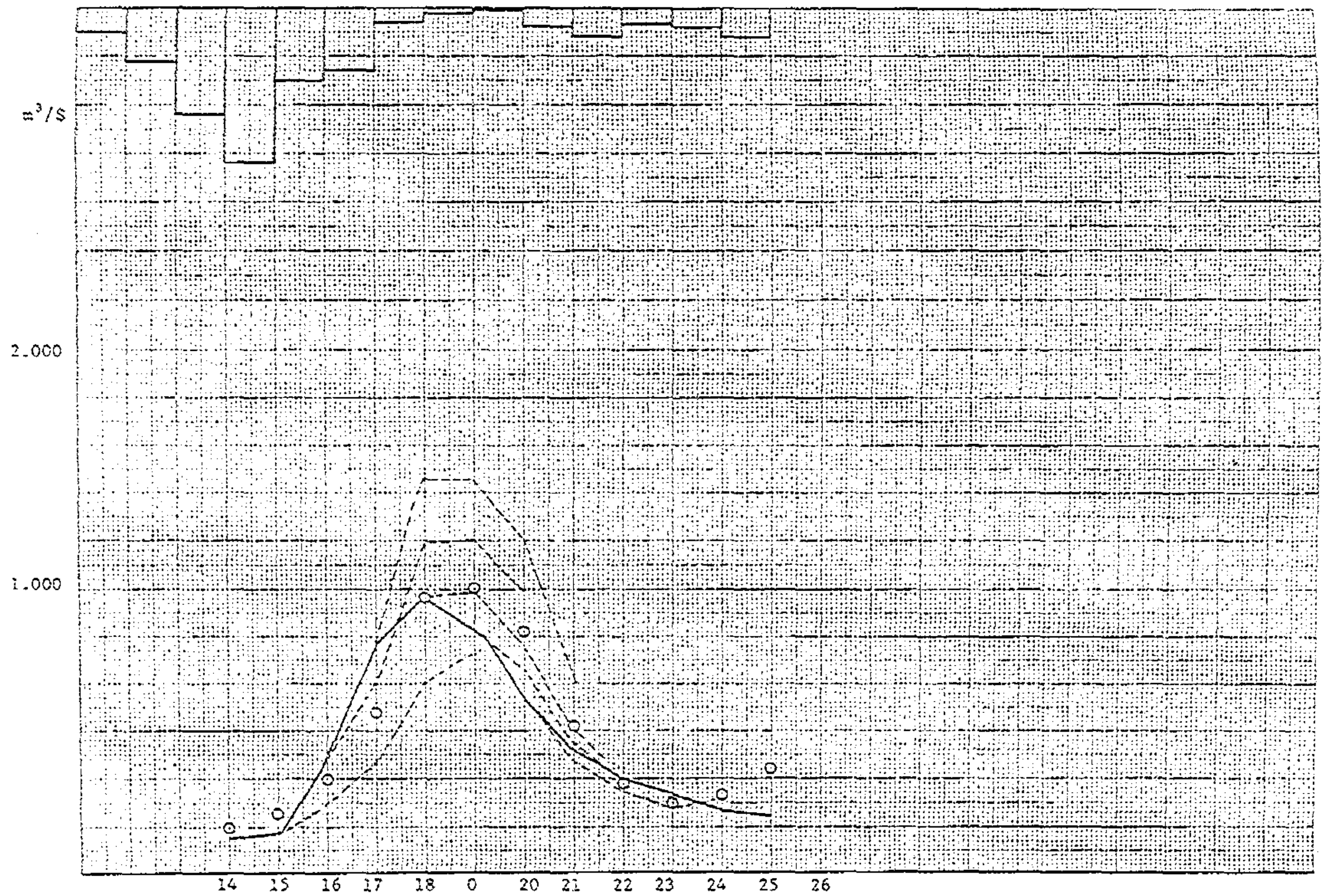


Fig. 5-13-4 Observed and Computed Hydrograph for Case I Vertification 1971 Jul. ~ Aug.

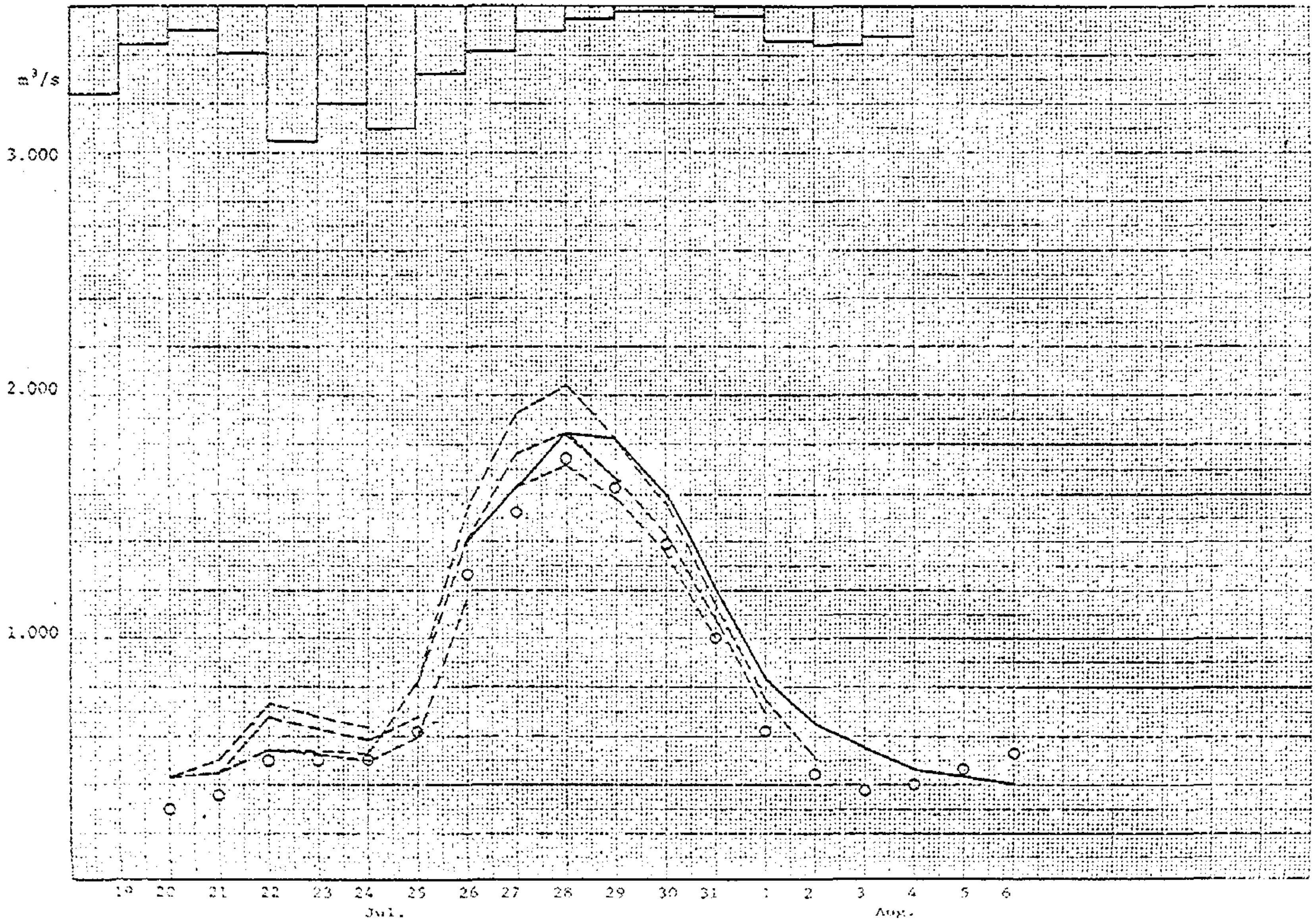


Fig. 5-13-5 Observed and Computed Hudrograph for Case 1 Verification

1972 Jul.

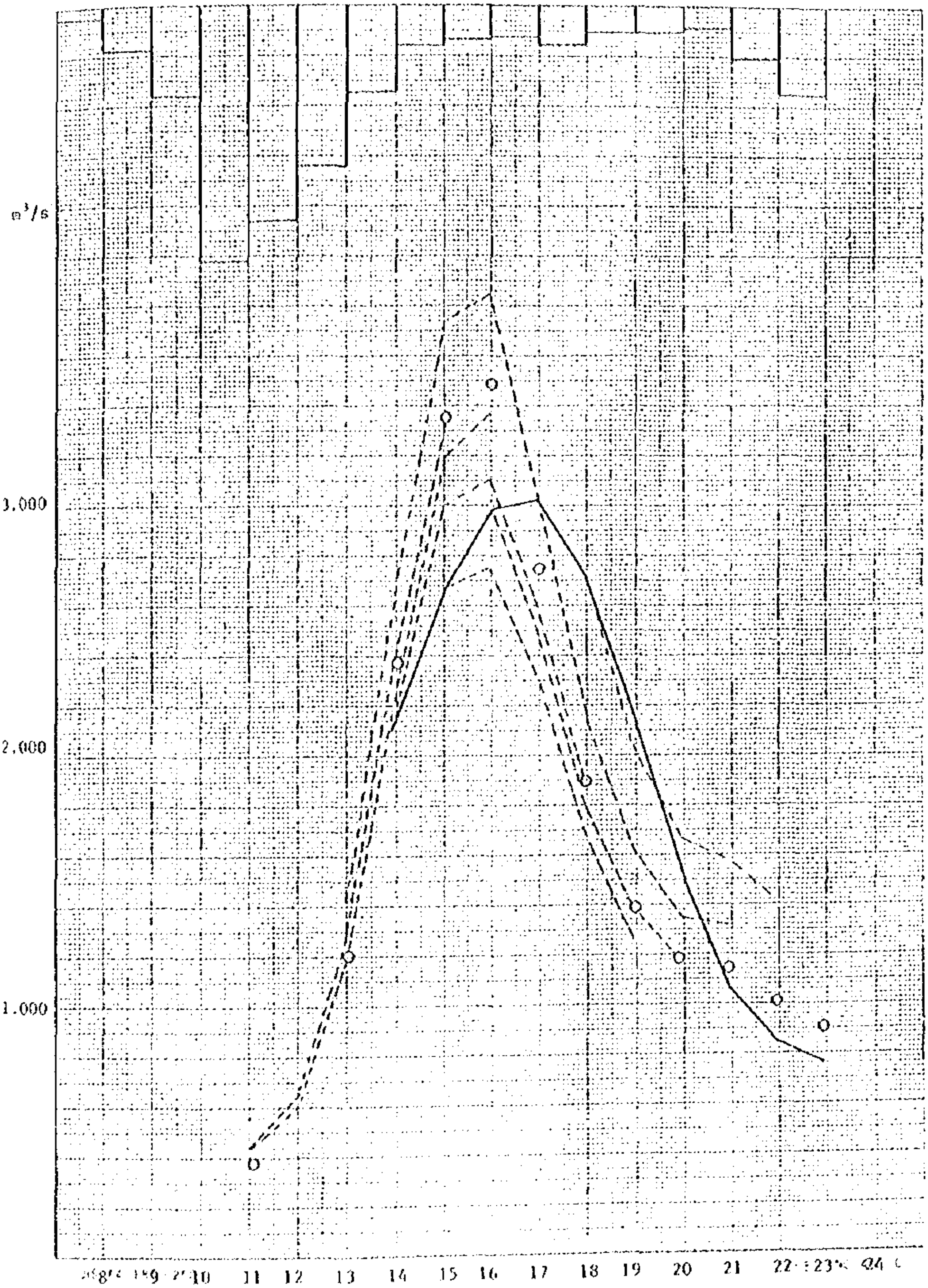


Fig. 5-13-6 Observed and Computed Hydrograph for Case 1 Verification 1972 Jul. ~ Aug.

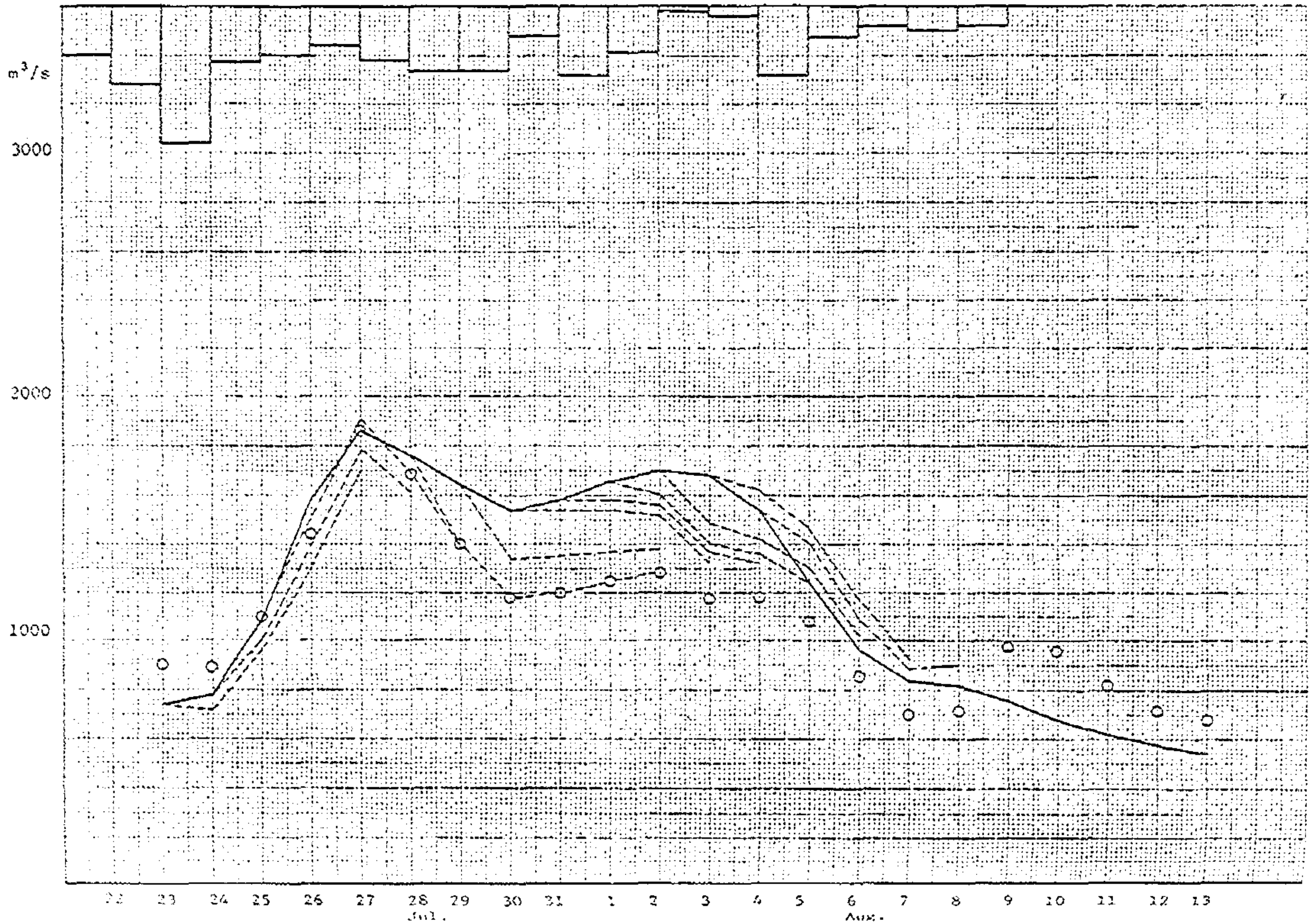


Fig. 5-13-7 Observed and Computed Hydrograph for Case 1 Verification 1973 Jun.

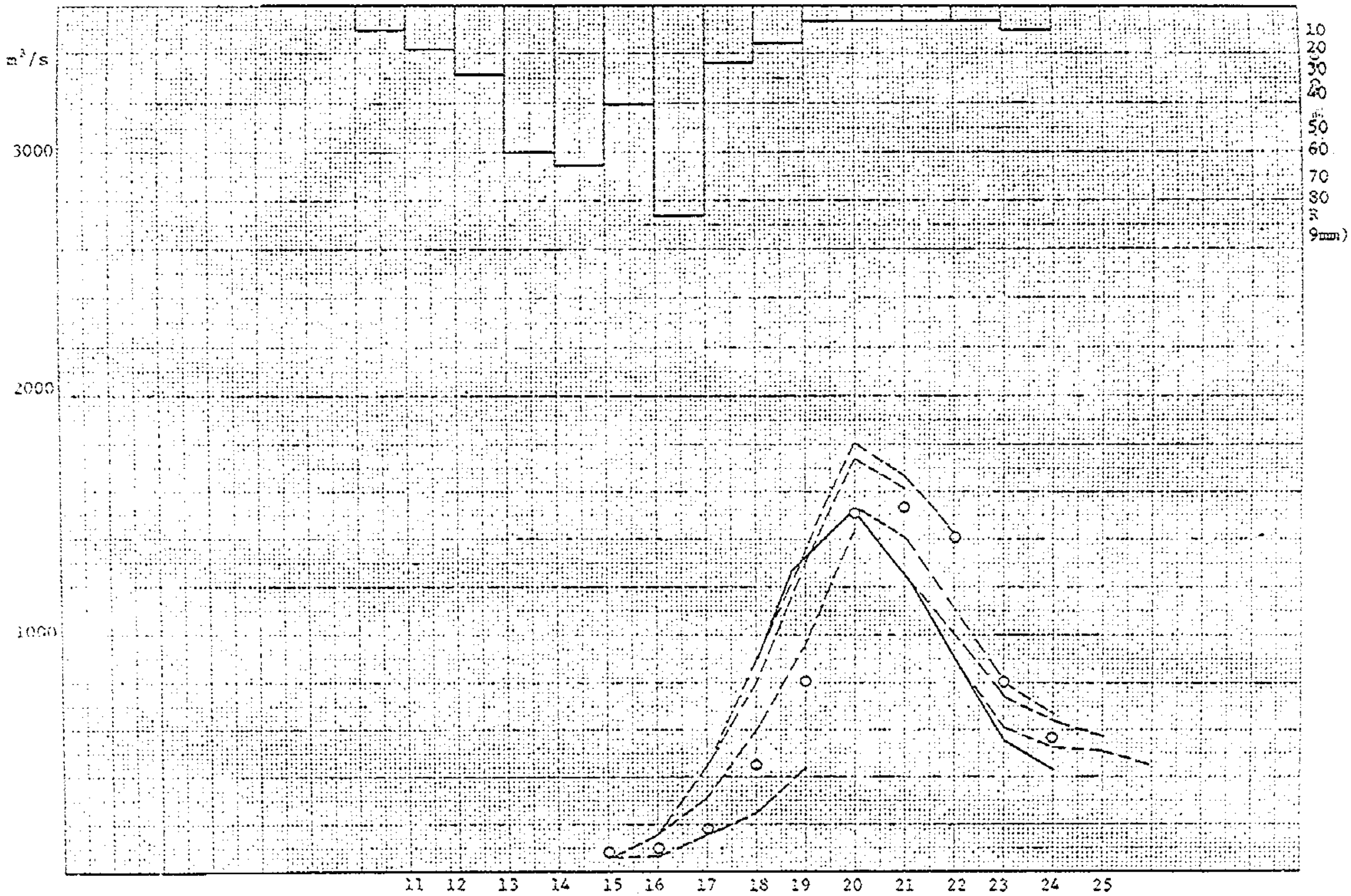
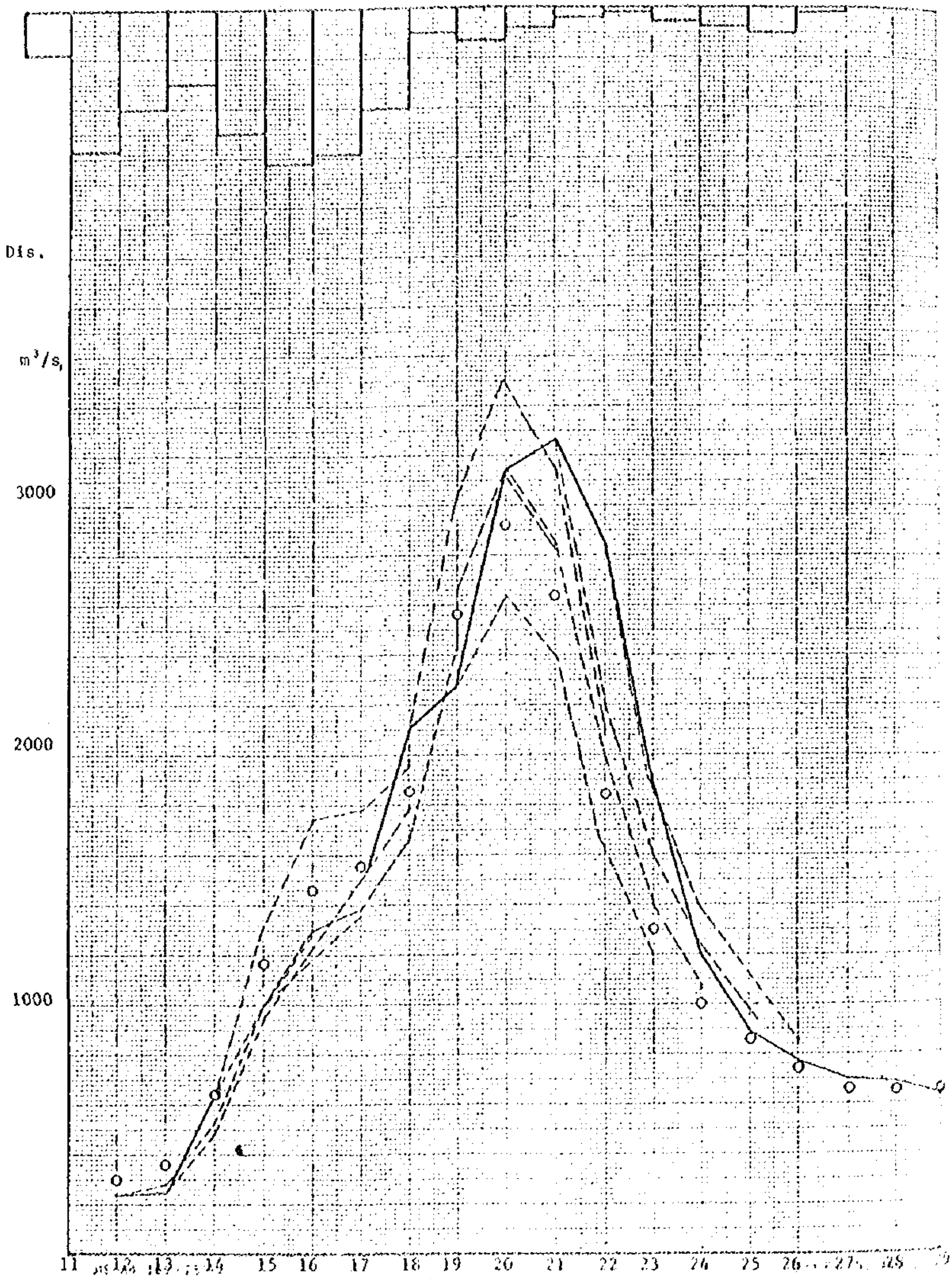


Fig. 5-13-8 Observed and Computed Hydrograph for Case 1 Verification

1974 Aug.



The computations worked out for the three floods in 1967, 1969 and 1971 produced generally satisfactory results. As for floods in 1970 and 1973, however, the computed value obtained immediately after starting computations was rather small so that correction had to be effected to make it conform to the observed value, and this resulted in a large peak discharge. The computations of May 1972 flood produced fairly good results for the flood rising stage, but the computed value turned out to be large at the peak and small thereafter. For floods in June 1972 and 1974, the computed value was small after peak.

The volume comparison between computed and observed hydrographs for the flood duration beginning on the day of starting computations and on the following day disclosed that, as shown in Table 5-9, the computed discharge was smaller by 5~10% than the observed values for almost all floods.

Table 5-9 Volume Comparison between Observed and Computed Hydrographs

(m^3/sec-day)

Year	Observed Discharge	Computed Discharge	Difference (%)
1967	14,344.0	14462.4	0.825
	13,764.0	14264.7	3.638
1969	35,444.0	32638.47	-7.915
	35,128.0	32609.21	-7.170
1970	6,481.0	5499.07	-15.151
	6,337.0	5283.14	-16.630
1971	16,255.0	15413.61	-5.176
	15,839.0	14663.81	-7.420
1972	22,305.0	21872.29	-1.940
	21,899.0	20768.01	-5.165
1972	26,205.0	22119.43	-15.591
	25,452.0	21923.58	-13.863
1973	9,475.0	6992.63	-26.199
	9,432.0	10798.93	14.492
1974	26,404.0	23101.21	-12.509
	26,165.0	22403.16	-14.377

The following are the conceivable causes and problems which gave rise to this difference between computed and observed values.

(1) Possibility of poor grasp of the average daily rainfall in the the basin.

(2) Validity of effective rainfall data.

(3) Suitability of time distribution of QB and QS.

(4) Justfiability of the selected correction method in which only observed data on the starting day is used for discharge conformity with no regard to discharge fluctuation before that day.

(5) Influences of inundation due to large discharge not considered in the design of runoff model.

(6) Validity of observed discharge data, especially during flooding.

As for Item (1) above, conclusion has already reached that the method employed in the present study is generally sufficient to grasp 7-days rainfall, but it may be necessary to make further studies on daily rainfall in future. The values of constants including the effective rainfall mentioned in Item (2) need to be verified by further examination. The validity of initial value of QB, mentioned in Items (3) and (4), were subjected to some reviewal which will be described later. As regards Items (5) and (6), it is considered necessary to design a model incorporating the decline of discharge due to inundation, and this will for redoubled effort to obtain accurate information on the inundation condition.

It may as well be added that care must be taken of the following point in applying the computation method discussed in this section.

- Both RS and RI are enlarged or reduced according to the ratio of observed discharge to computed discharge. After RI = 0, therefore, RI = 0 constantly without variation in the subsequent computations and consequently $\beta = 1.0$ as shown in the flow chart. Accordingly, if a flood routing needs to be followed by the routing of another flood, the initial value of QB should be obtained once again before starting computations.

5-2-4 Flood Forecasting Simulation Model

(1) Outline

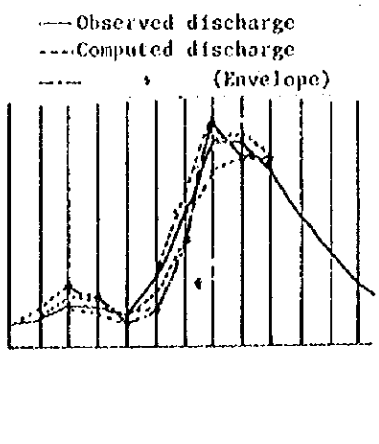
Flood forecasting at K-10 using the method studied in this report calls for the input of rainfall data forecasted for the period subsequent to the newest day of observation. In this section, however, the need for such input is set aside for future scrutiny, and studies are made as to whether it is possible to forecast flood occurrence by comparison of observed discharge data with the hydrograph prepared on the assumption that there would be no rain after the newest day of observation.

(2) Constants and Their Calculation

The constants and their calculations in this study are identical to those given in foregoing pages for verification of simulation data, etc.

(3) Results and Problems

Figs. 5-14-1 ~ 5-14-3 show part of the hydrograph prepared by effecting corrections every day, and Figs. 5-15-1 ~ 5-15-8 show enveloped values forecasted for T + 2 days and, T + 3 days (See Ap-9).



The former figures indicate that the values forecasted for T + 2 ~ 3 days present no large discrepancy compared to the results of verification computations. From the latter figures, on the other hand, it can be said that the discharge at T + 2 days can be generally forecasted, and even the forecasted discharge at T + 3 days can be used as fairly helpful data.

In the coming years, it is necessary to make further scrutiny into the validity of constants and into the inundation condition in order to improve the accuracy of simulation model. As for the initial value of QB and the time distribution of QS which also has a close bearing on the accuracy of model, some study was made as briefed below.

1) Initial Value of QB

A comparative study was made on the following four cases, with QBo taken at QB obtained from the rainfall during the preceding one month and with Qo taken at the discharge observed on starting computations (See Figs. 5-16-1 ~ 5-16-3 and Ap. 10).

1. QBo 2. QBo/2 3. QBo/4 4. Qo/2

This comparison produced no remarkable differences between the four cases, but it was noted that a notable difference could occur near the peak discharge if the rainfall is extremely heavy and concentrated as in May 1972 flood.

2) Time Distribution of QS

Figs. 5-17-1 ~ 5-17-3 show observed and computed hydrographs, of which two were selected from a number of cases studied by varying the time distribution, and one represents the values obtained from the prevailing method. These figures indicate that any minor changes in time distribution does not invite appreciably large differences in QC, unless a drastic change is effected to the fundamental pattern, i.e., sharp rising and gradual decline.

Fig. 5-14-1 Observed and Computed Hydrographs

(R = 0 after T + 1 day for forecasting) 1971 Jul~ Aug.

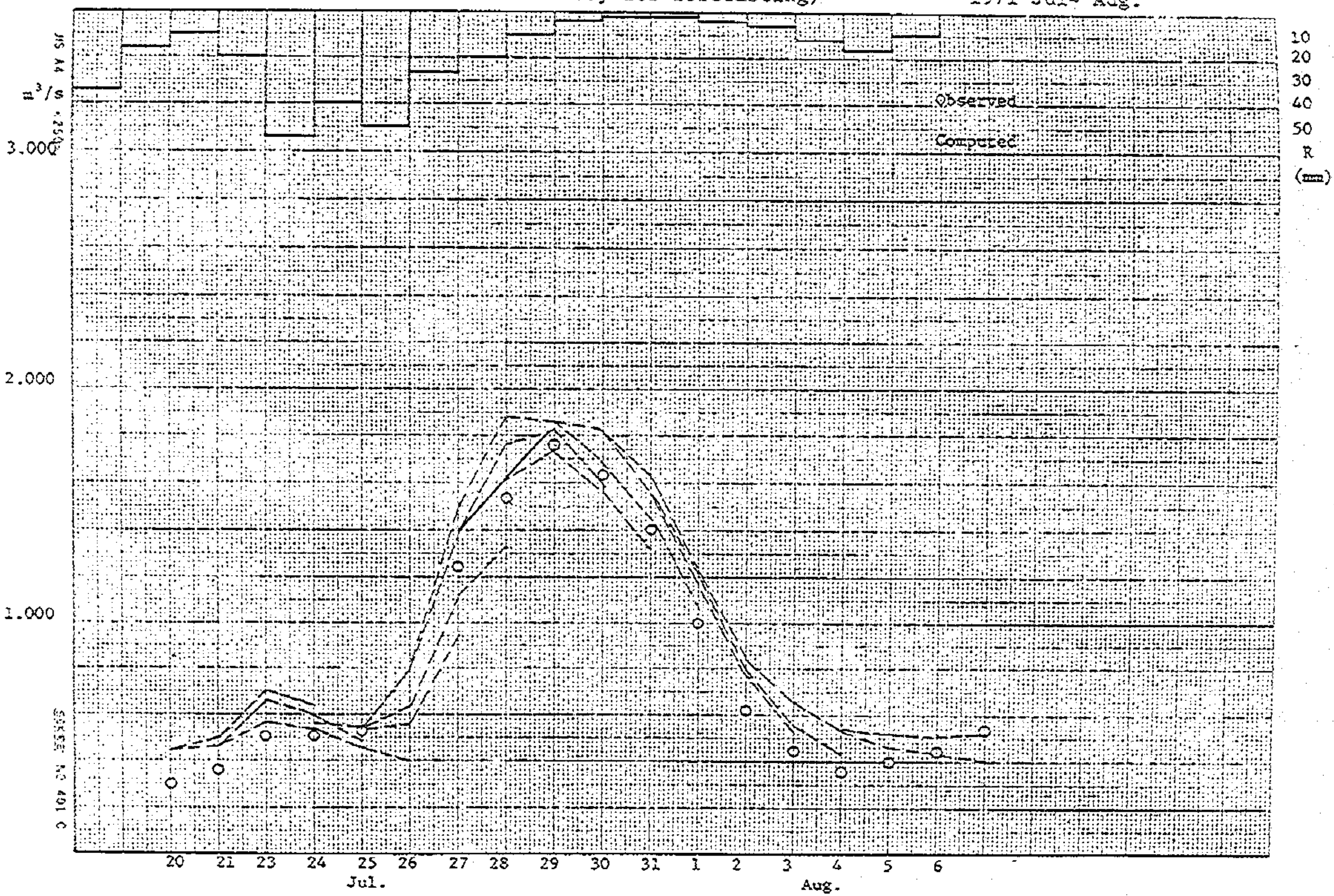


Fig. 5-14-2 Observed and Computed Hydrographs

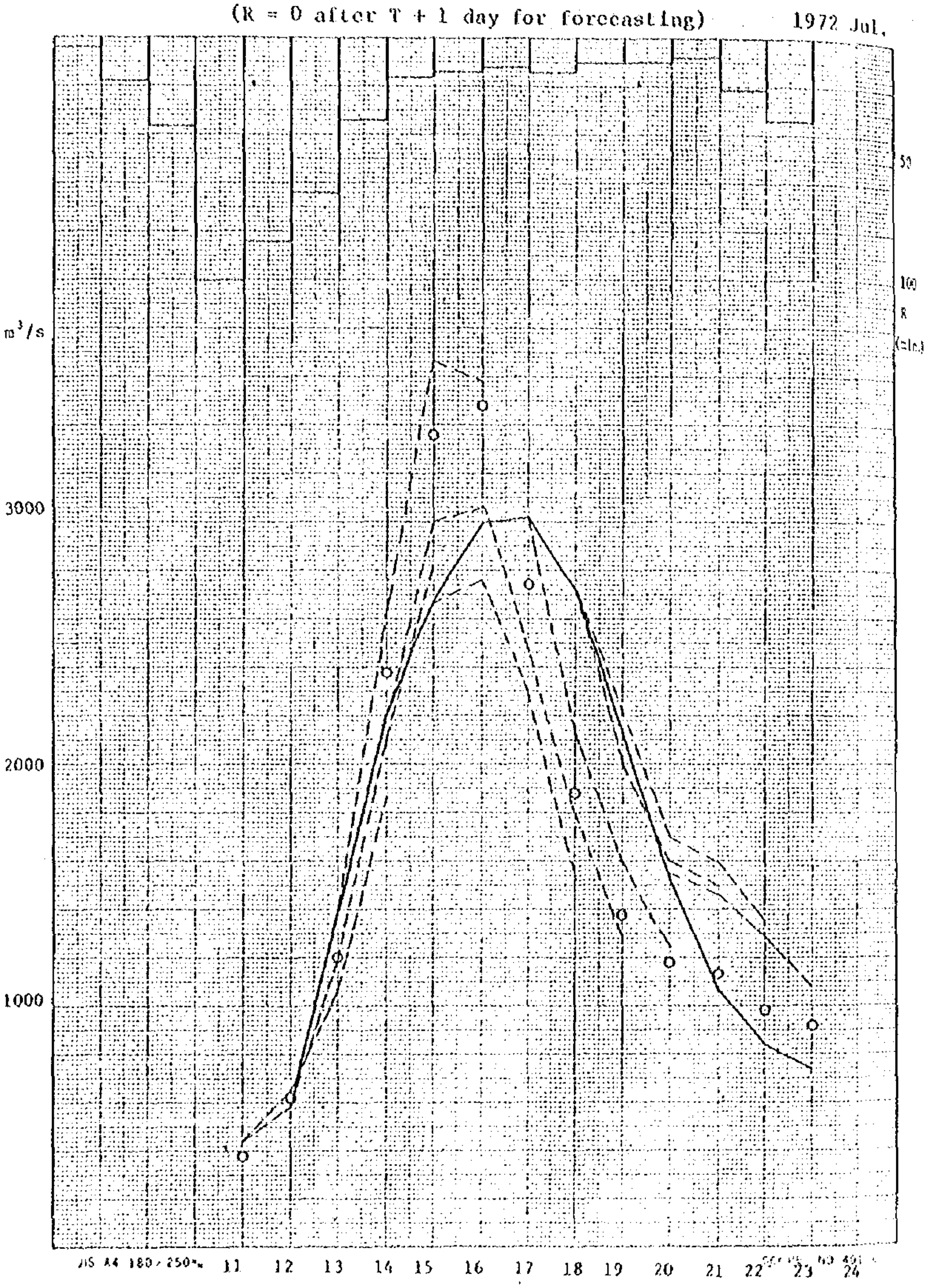


Fig. 5-14-3 Observed and Computed Hydrographs

(R = 0 after T + 1 day for forecasting) 1974 Aug.

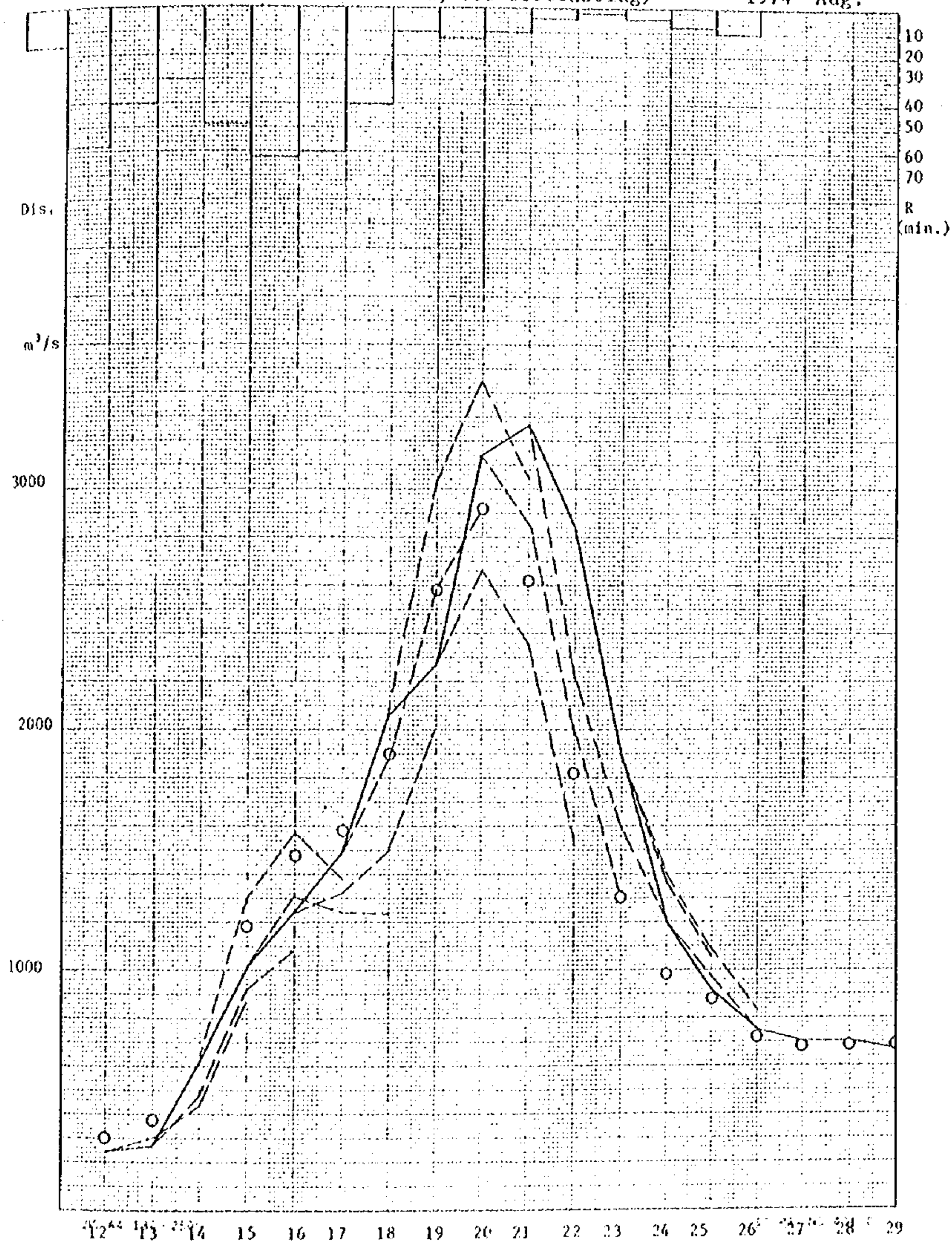


Fig. 5-15-1 Observed and Computed Hydrographs

(Forecasted values expressed by envelope) 1967 Aug.

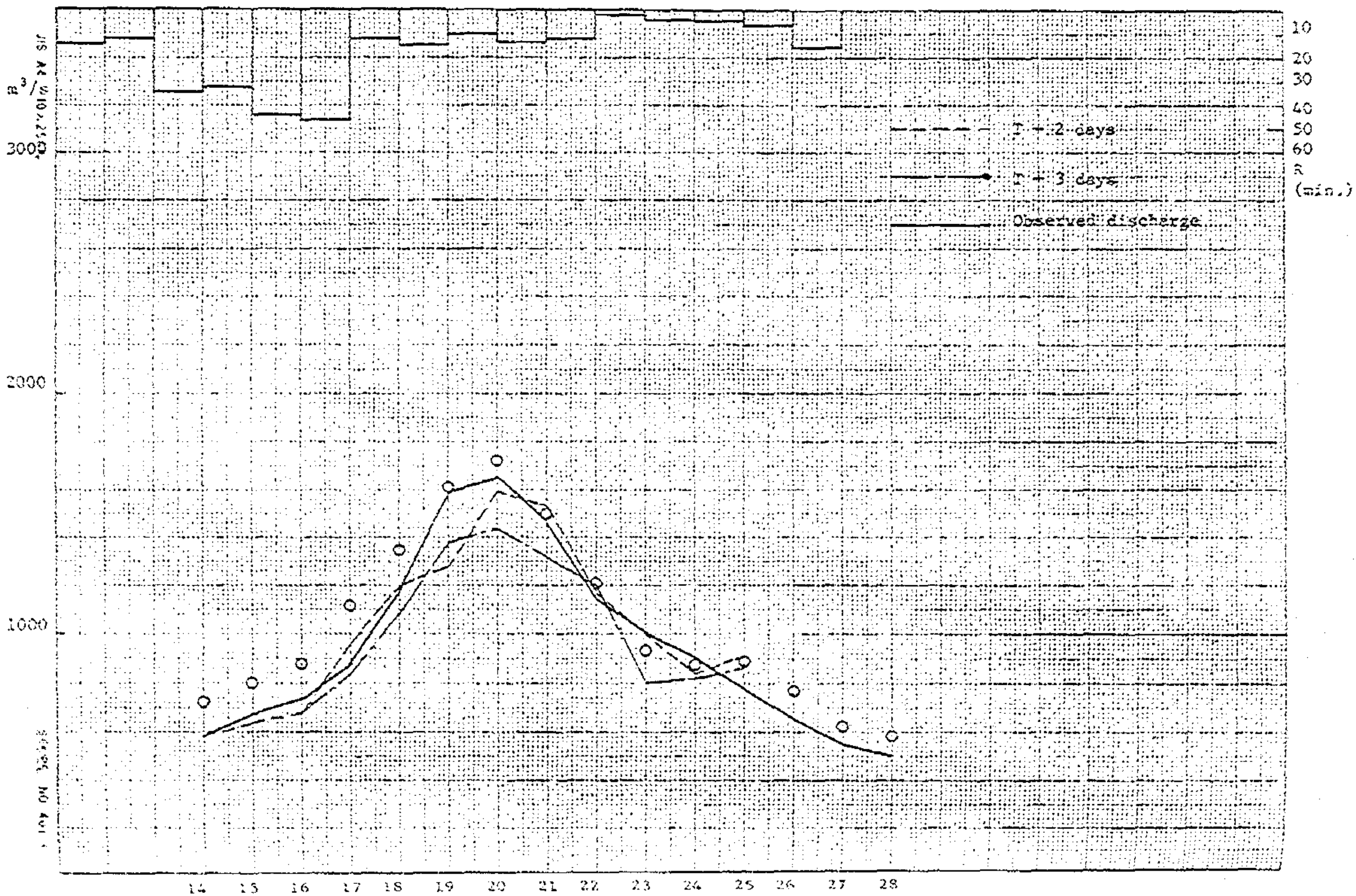


Fig. 5-15-2 Observed and Computed Hydrographs
(Forecasted values expressed by envelope)

1969 Jul.~ Aug.

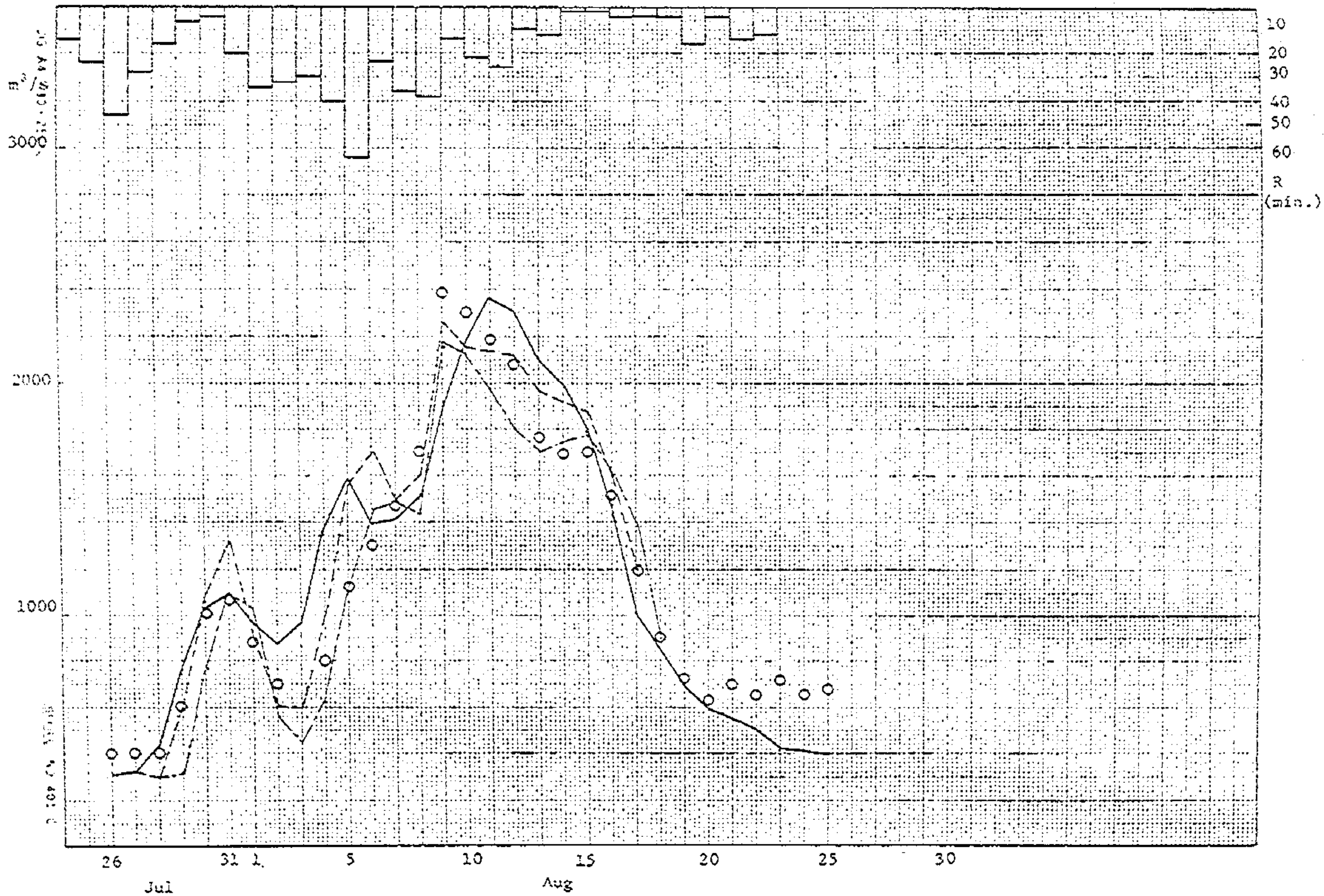


Fig. 5-15-3 Observed and Computed Hydrographs
(Forecasted values expressed by envelope)

1970 Jul.

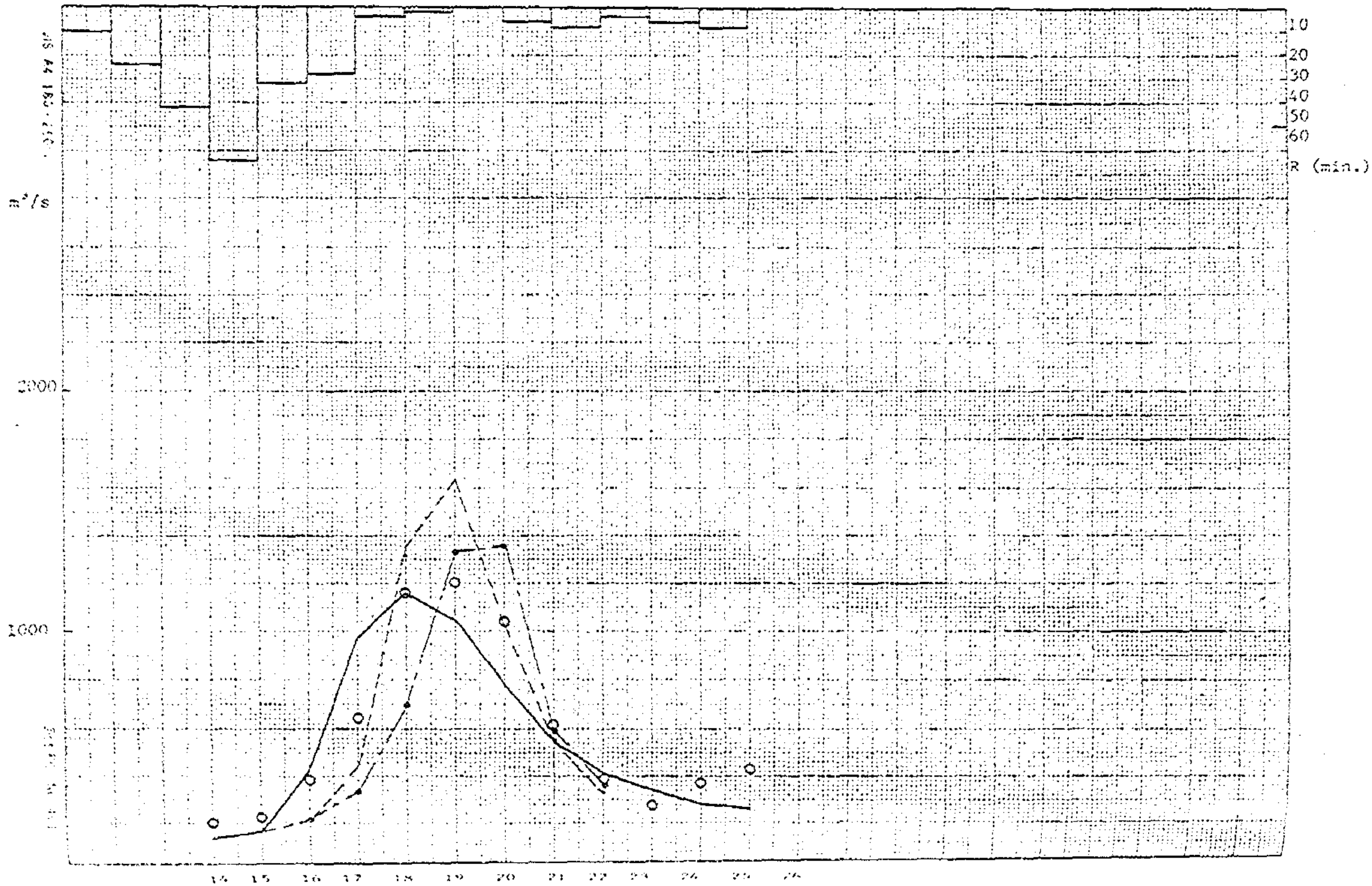


Fig. 5-15-4 Observed and Computed Hydrographs

(Forecasted values expressed by envelope)

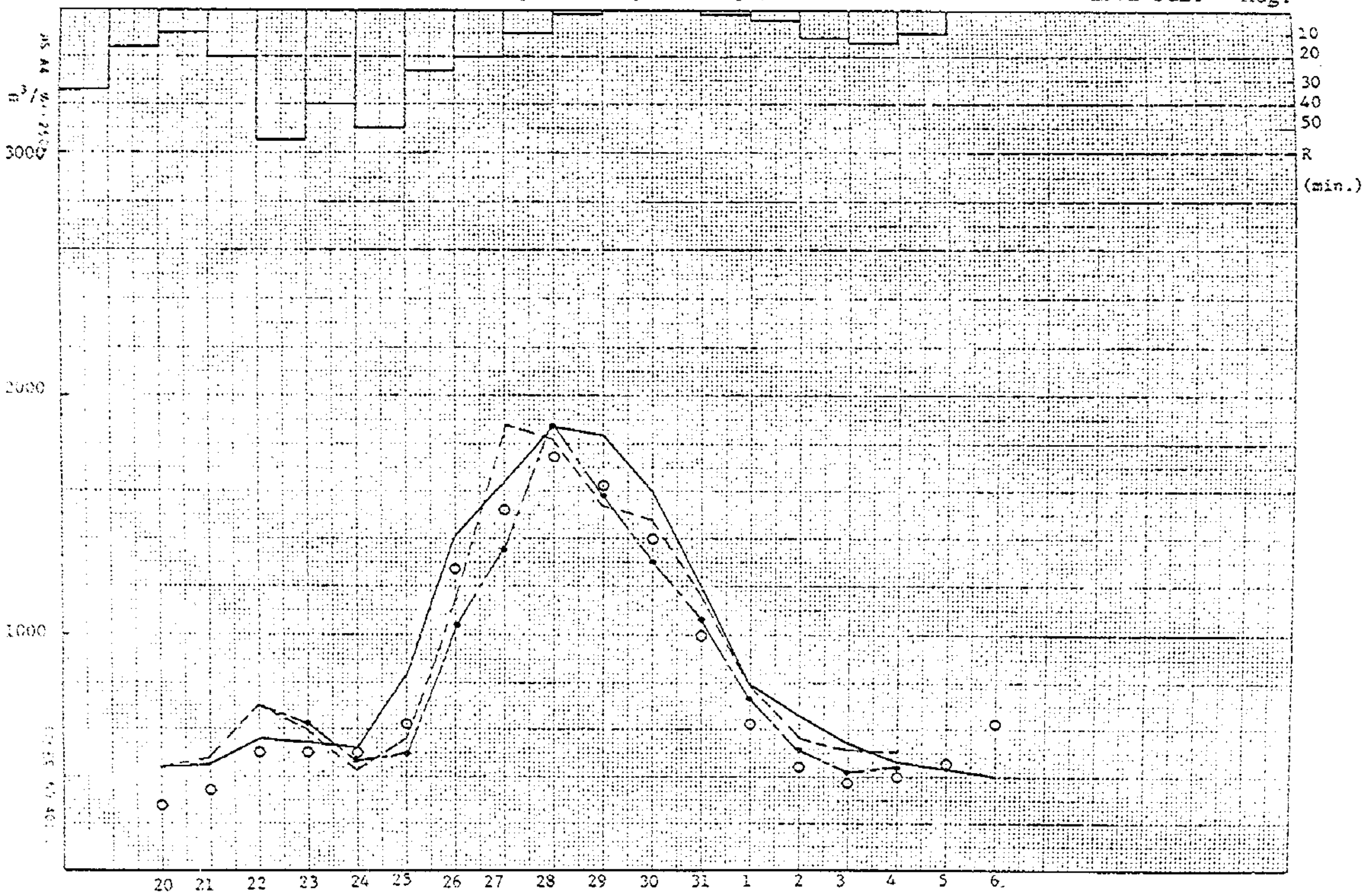


Fig. 5-15-5 Observed and Computed Hydrographs

(Forecasted values expressed by envelope) 1972 Jul.

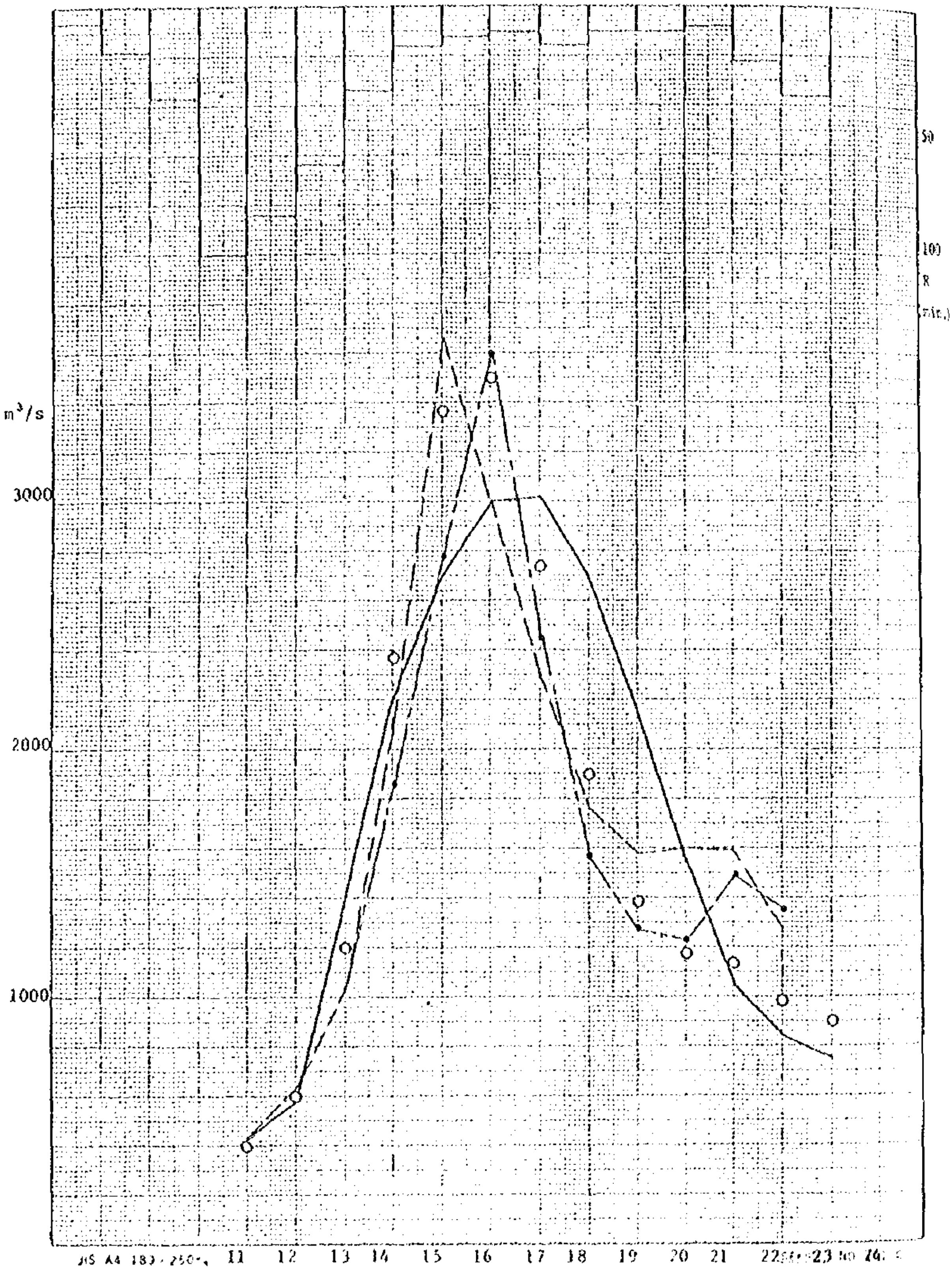


Fig. 5-15-6 Observed and Computed Hydrographs
(Forecasted values expressed by envelope)

1972 Jul.~ Aug.

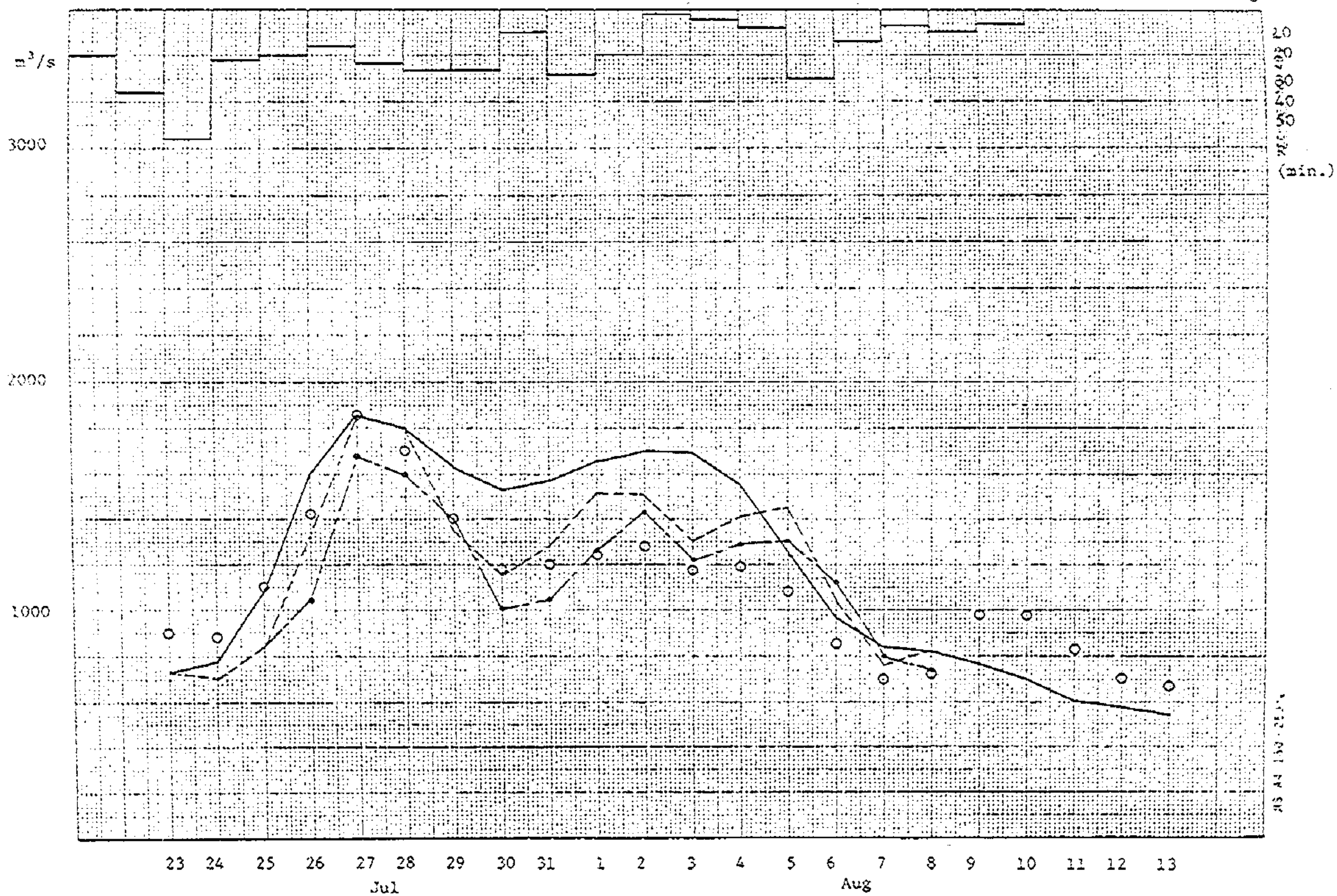


Fig. 5-15-7 Observed and Computed Hydrographs
(Forecasted values expressed by envelope)

1973 Jun.

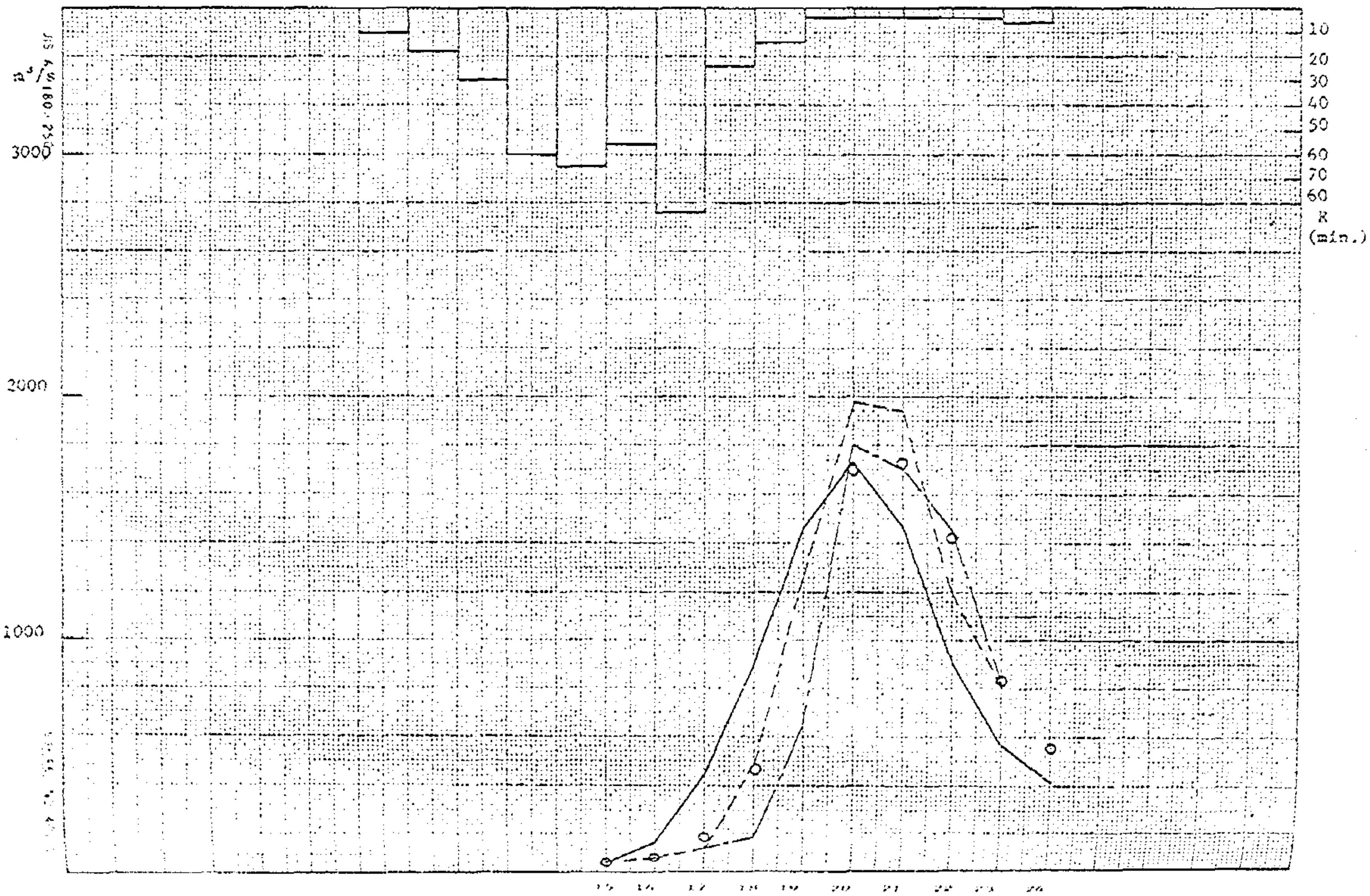


Fig. 5-15-8 Observed and Computed Hydrographs

(Forecasted values expressed by envelope) 1974 Aug.

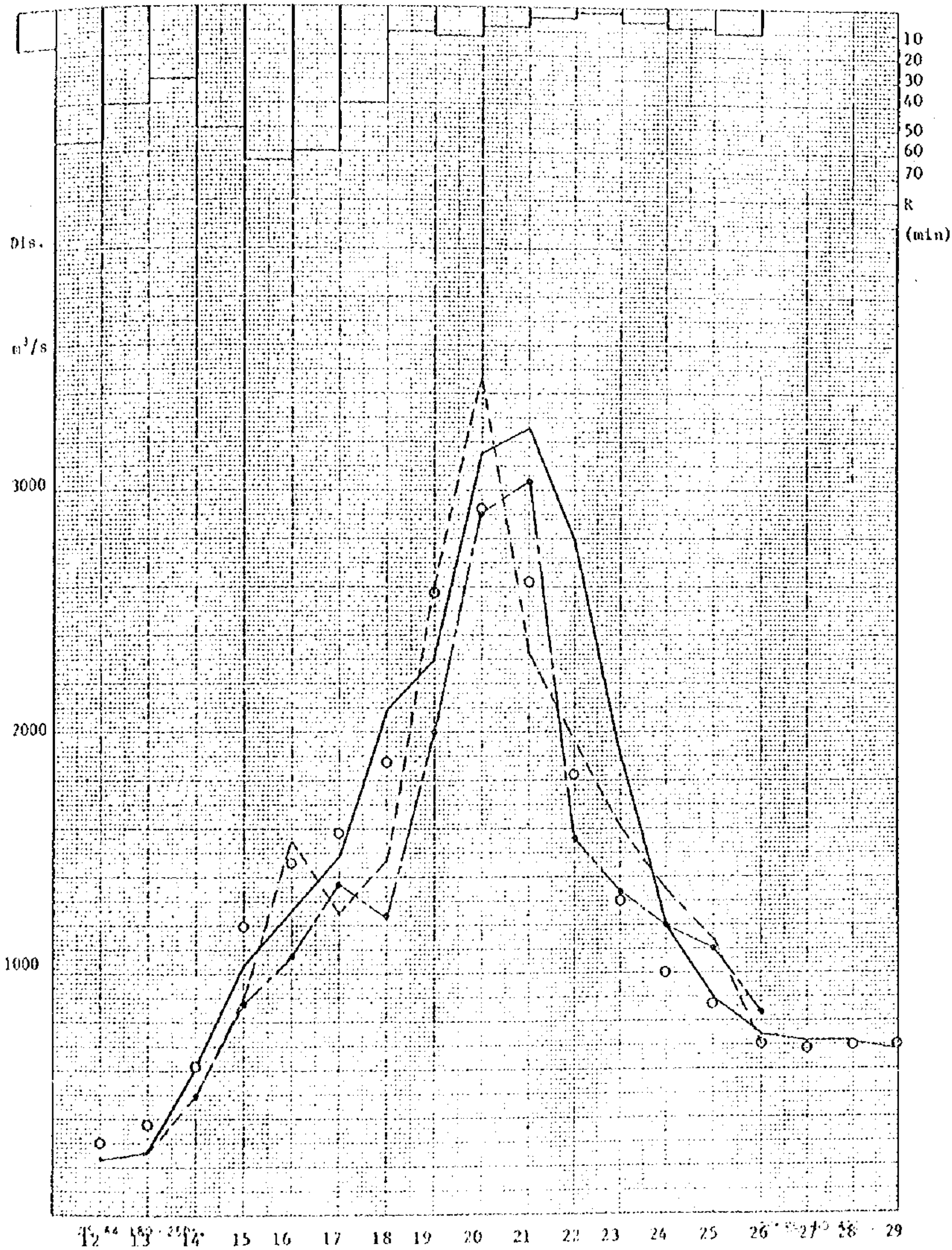


Fig. 5-16-1 Observed and Computed Hydrographs

(T + 2 days value enveloped; initial QB value changed) 1971 Jul. Aug.

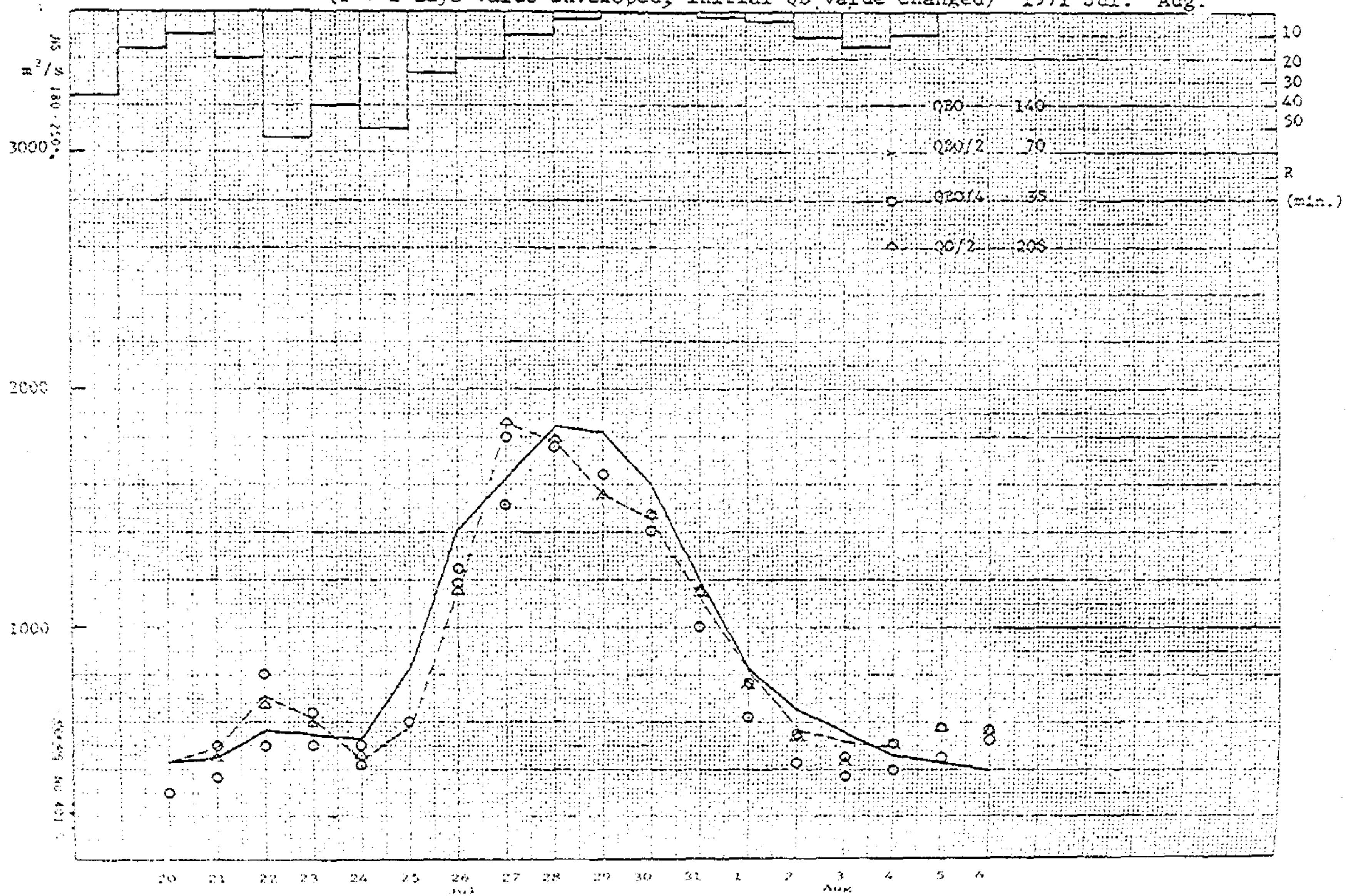


Fig. 5-16-2 Observed and Computed Hydrographs

(T + 2 days value enveloped; initial QB value changed) 1972 Jul.

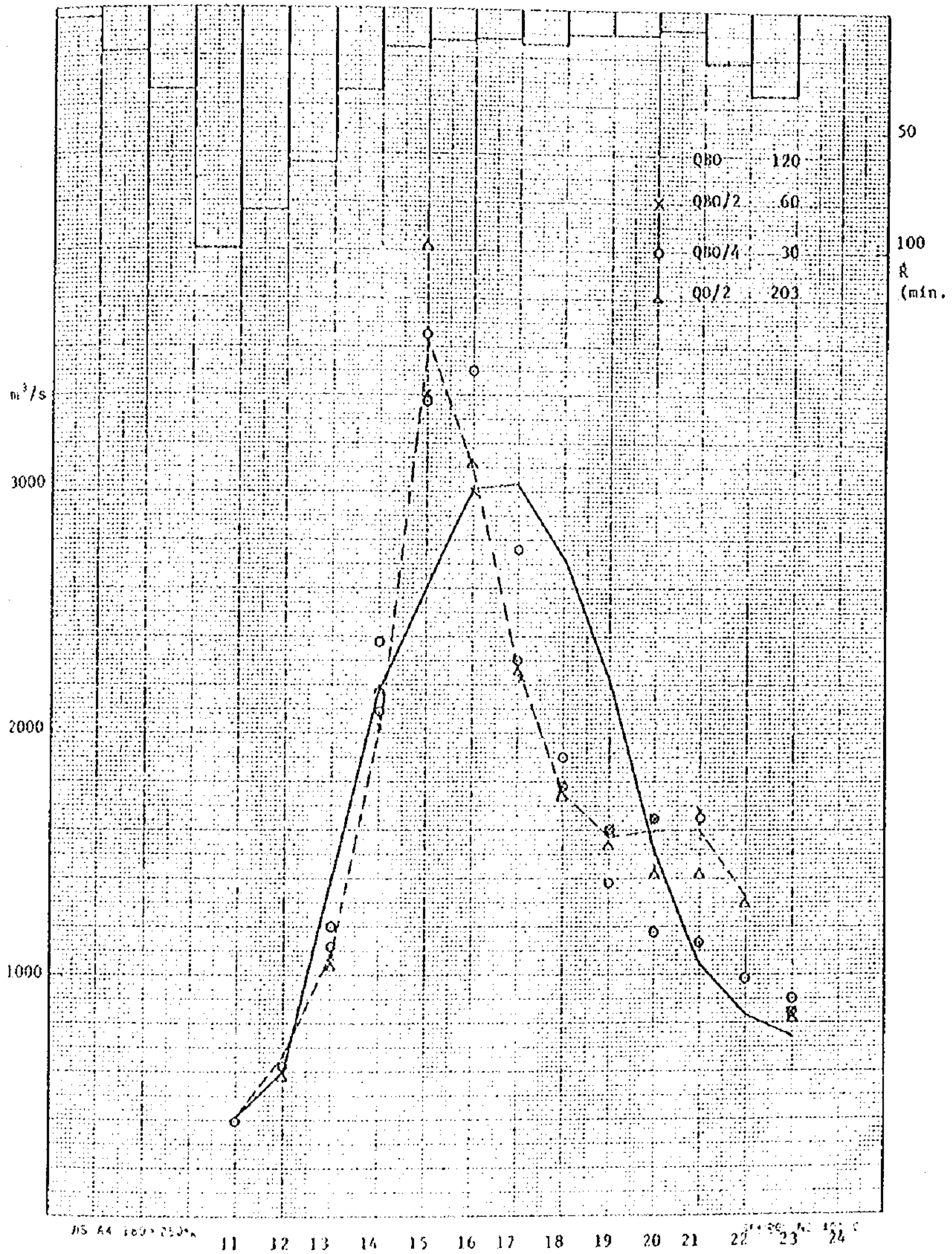


Fig. 5-16-3 Observed and Computed Hydrographs

(T + 2 days value enveloped; initial QB value changed) 1974 Aug.

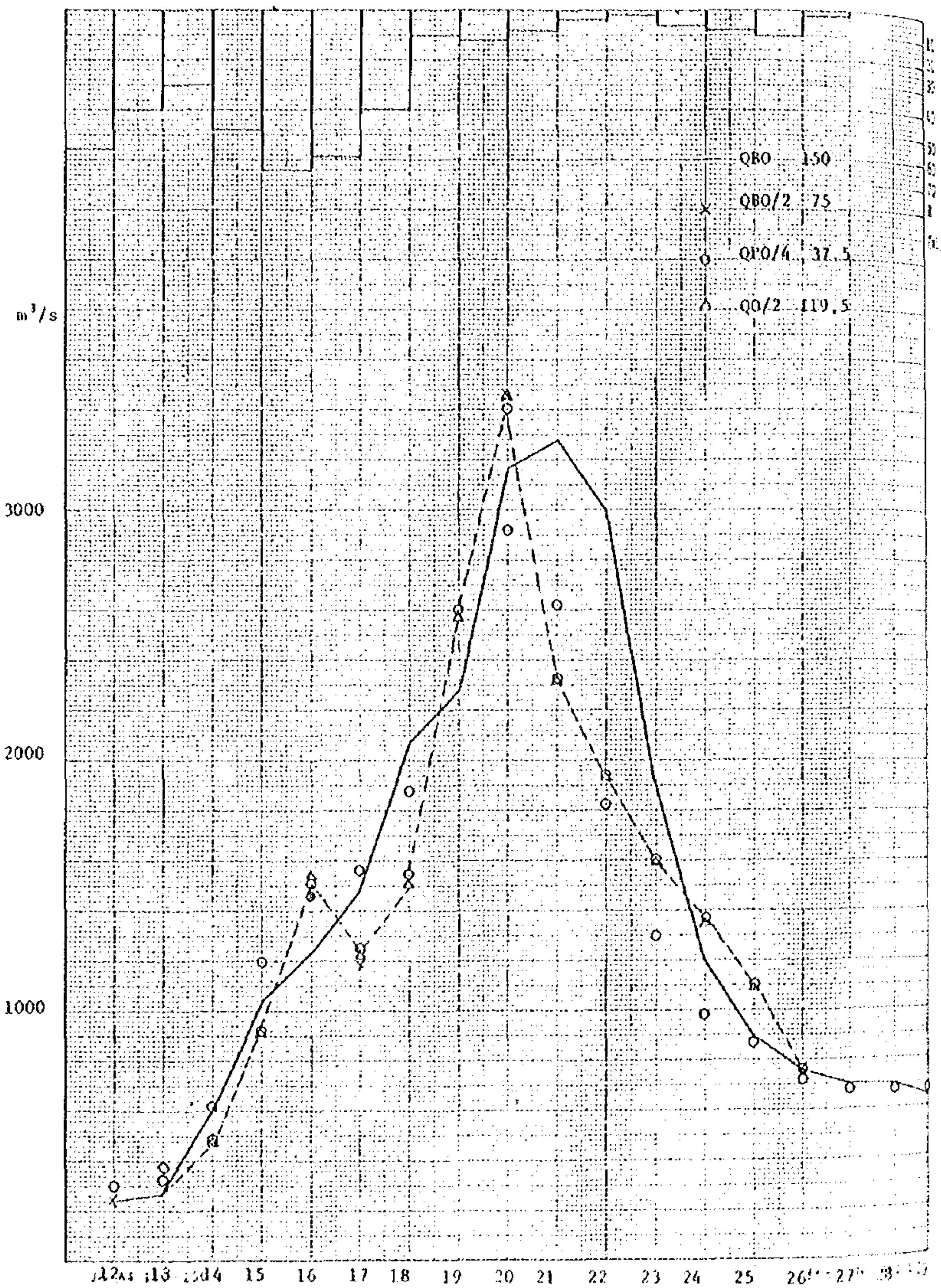


Fig. 5-17-1 Observed and Computed Hydrographs
(T ÷ 2 days values enveloped: time distribution changed)

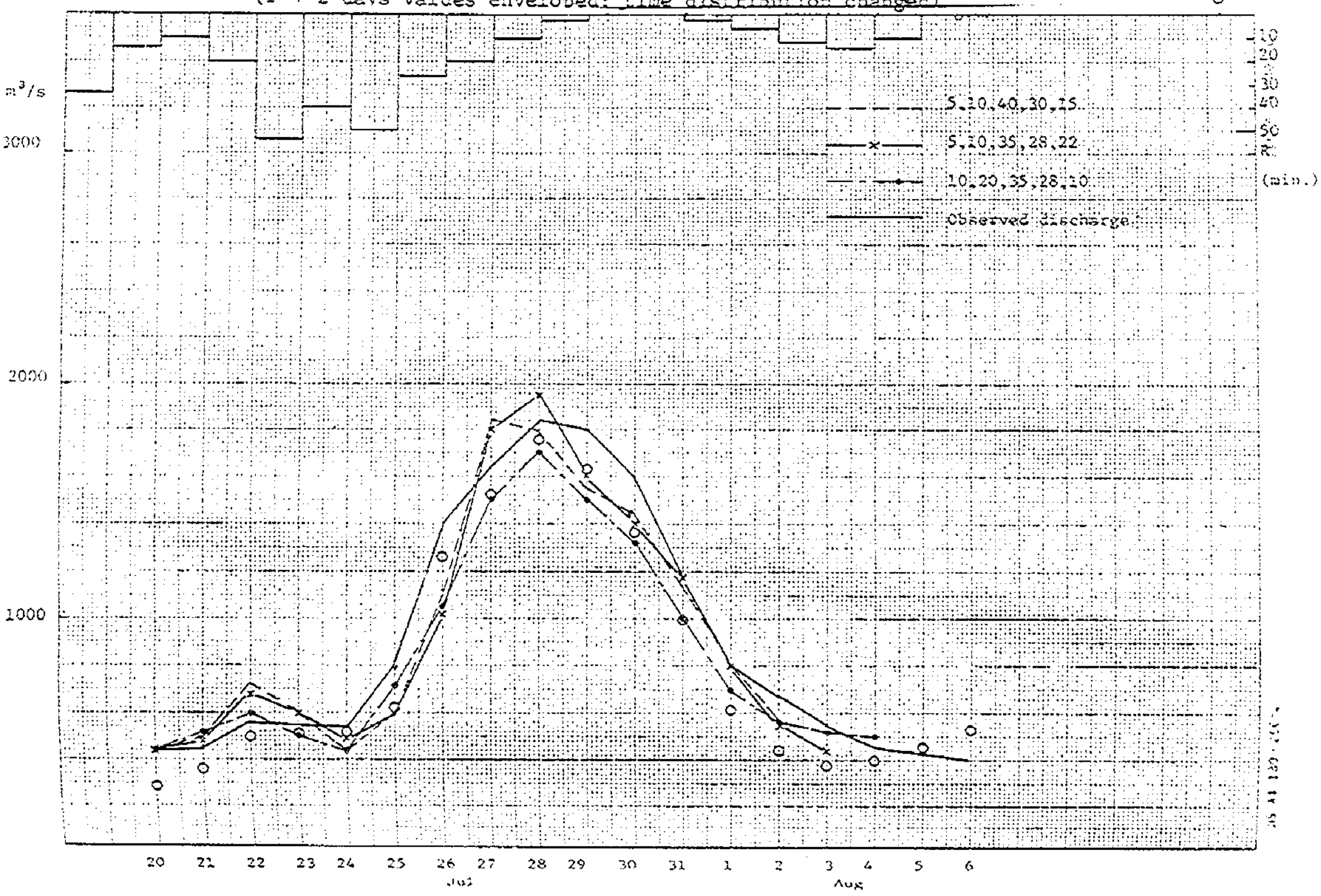


Fig. 5-17-2 Observed and Computed Hydrographs

(T + 2 days values enveloped; time distribution changed) 1972 Jul.

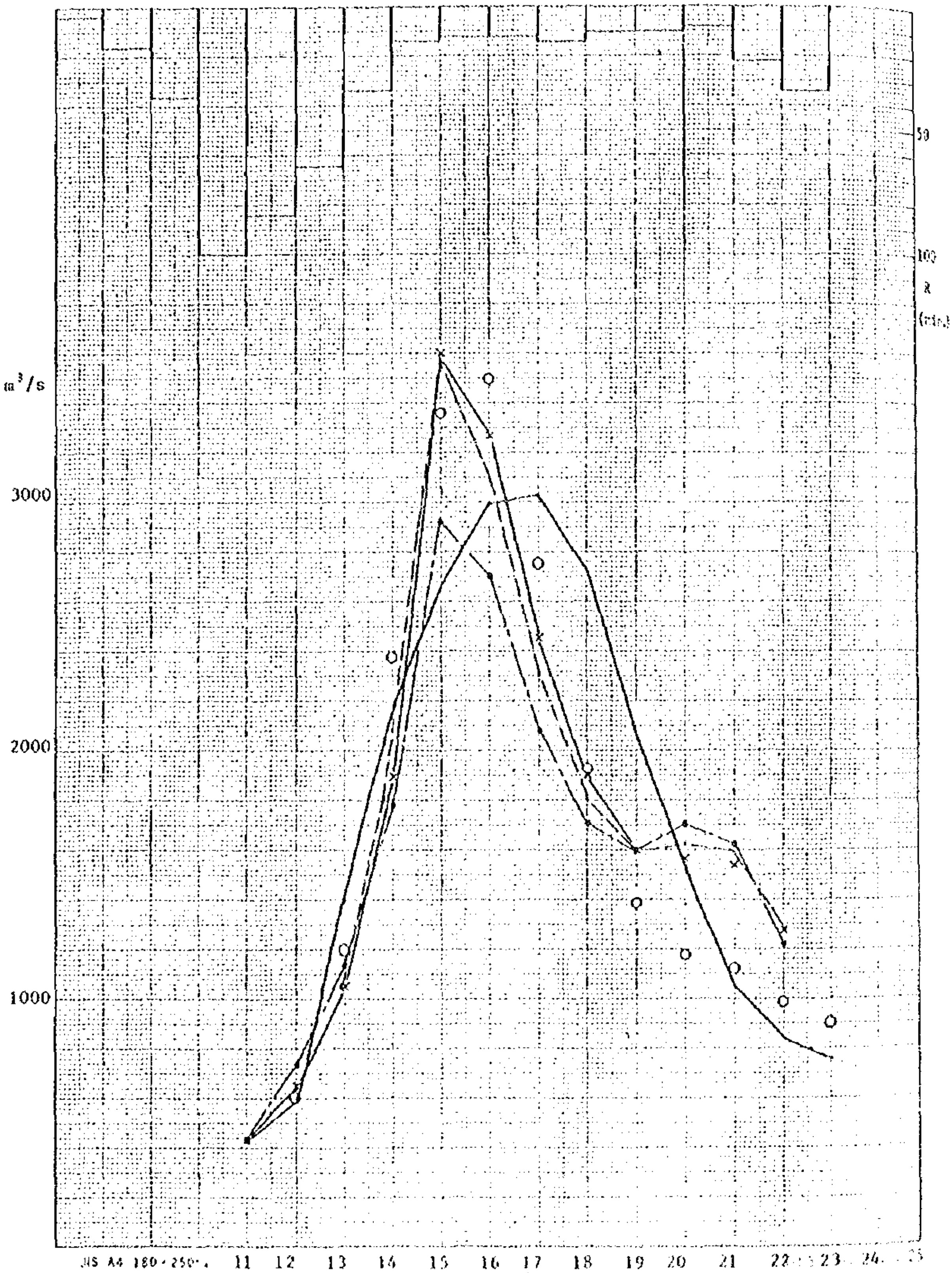
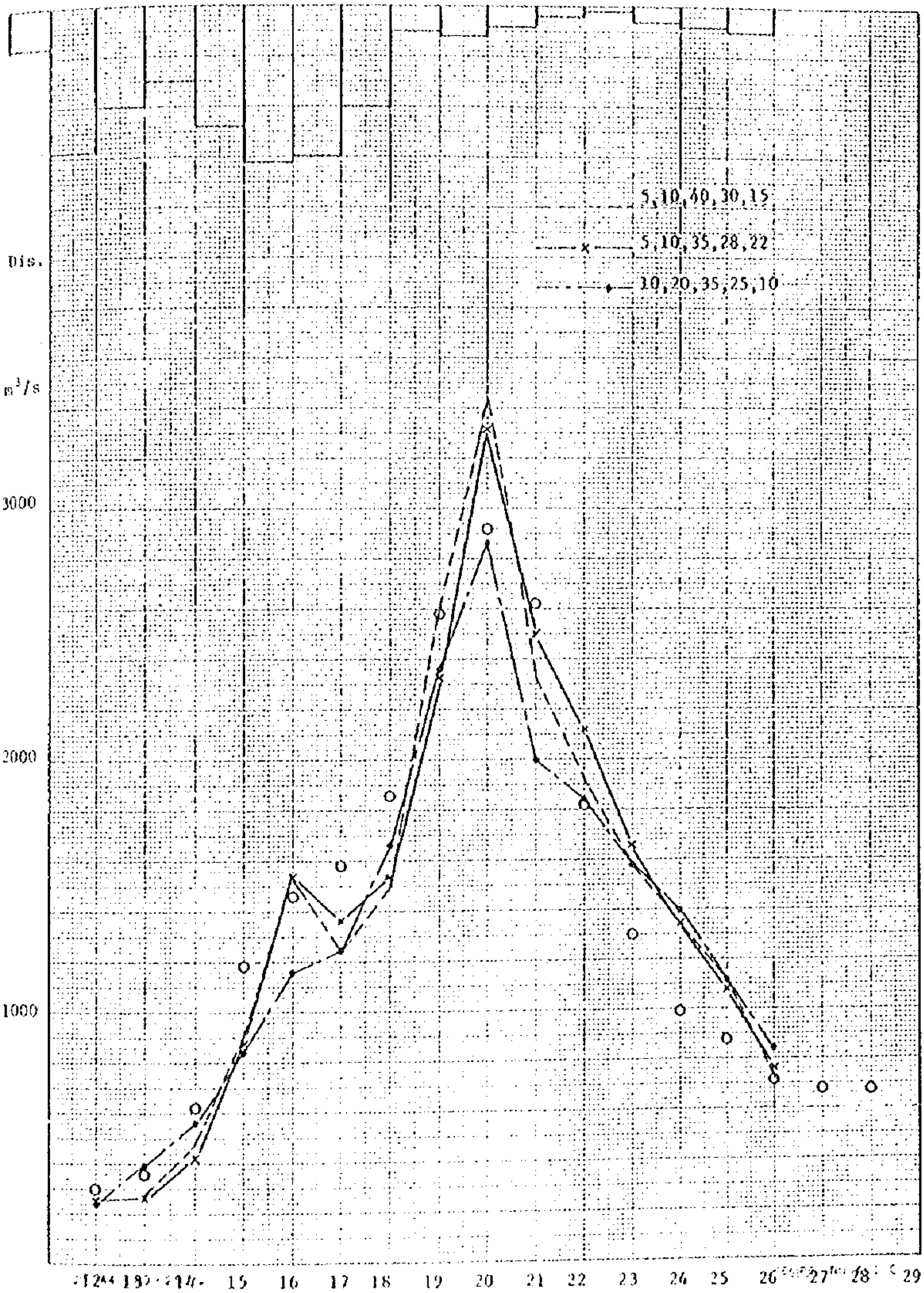


Fig. 5-17-3 Observed and Computed Hydrographs

(T + 2 days values enveloped; time distribution changed) 1974 Aug.



Sumulation Data for Runoff Calculation

1967

DATE	R (MM)	Qo (CMS-DAY)	ALPHA
Aug. 9	11.9	1211.0	0.70
10	9.1	1239.0	0.70
11	14.6	1060.0	0.70
12	14.4	740.0	0.70
13	12.5	596.0	0.70
**14	31.7	580.0	0.70
15	28.7	675.0	0.70
16	43.9	740.0	0.70
17	47.9	889.0	0.70
18	12.7	1177.0	1.00
19	14.7	1576.0	1.00
20	9.0	1668.0	0.60
21	15.0	1493.0	0.70
22	13.4	1160.0	1.00
23	2.1	992.0	0.70
24	5.2	902.0	0.70
25	6.7	757.0	0.70
26	7.7	649.0	0.60
27	14.8	570.0	0.60
28	16.3	516.0	0.60

1969

DATE	R (MM)	Qo (CMS-DAY)	ALPHA
Jul. 21	11.4	545.0	0.40
22	15.9	560.0	0.70
23	7.2	456.0	0.70
24	7.6	387.0	0.70
25	12.9	343.0	0.40
**26	24.0	316.0	0.40
27	46.6	320.0	0.70
28	26.4	466.0	0.70
29	15.7	750.0	0.70
30	8.3	1029.0	0.70
31	6.5	1094.0	0.70
Aug. 1	20.3	962.0	0.70
2	37.2	858.0	0.70
3	30.4	977.0	0.70
4	28.1	1350.0	0.70
5	40.4	1577.0	0.70
6	65.2	1420.0	1.00
7	23.8	1422.0	1.00
8	35.4	1514.0	1.00
9	36.0	1941.0	1.00
10	12.5	2188.0	1.00
11	23.2	2354.0	1.00
12	27.2	2313.0	1.00
13	10.8	2098.0	1.00
14	13.9	1967.0	1.00
15	2.1	1725.0	0.70
16	2.1	1376.0	0.70
17	5.3	1018.0	0.70
18	4.4	824.0	0.70
19	5.4	702.0	0.70
20	13.2	595.0	0.60
21	2.8	545.0	0.60
22	10.3	493.0	0.60
23	9.1	438.0	0.60

1969

DATE	R (MM)	Qo (CMS-DAY)	ALPHA
Aug. 24	4.8	414.0	0.60
25	1.6	398.0	0.60

1970

DATE	R (MM)	Qo (CMS-DAY)	ALPHA
Jul. 9	8.1	231.0	0.40
10	11.5	200.0	0.40
11	5.0	182.0	0.40
12	9.3	166.0	0.40
13	21.9	152.0	0.40
**14	44.4	144.0	0.40
15	64.0	167.0	0.70
16	31.5	463.0	0.70
17	25.8	967.0	0.70
18	3.6	1165.0	0.70
19	1.2	1041.0	0.70
20	0.4	746.0	0.70
21	7.0	526.0	0.70
22	10.9	403.0	0.70
23	4.7	330.0	0.70
24	8.0	283.0	0.40
25	10.8	246.0	0.40

1971

DATE	R (MM)	Qo (CMS-DAY)	ALPHA
Jul. 15	7.3	367.0	0.40
16	1.7	612.0	0.40
17	10.2	672.0	0.40
18	9.9	561.0	0.40
19	34.4	456.0	0.40
**20	14.7	416.0	0.40
21	9.4	462.0	0.40
22	19.1	567.0	0.40
23	52.8	554.0	0.70
24	39.7	548.0	0.70
25	49.7	835.0	0.70
26	26.7	1404.0	1.00
27	19.4	1632.0	1.00
28	10.6	1859.0	0.70
29	2.4	1827.0	0.70
30	0.1	1601.0	0.70
31	0.3	1210.0	0.70
Aug. 1	3.0	842.0	0.70
2	4.3	650.0	0.70
3	11.3	547.0	0.60
4	12.7	474.0	0.60
5	9.3	429.0	0.60
6	9.7	398.0	0.60

1972

DATE	R (MM)	Qo (CMS-DAY)	ALPHA
Jul. 6	2.4	392.0	0.40
7	24.9	461.0	0.40
8	4.8	503.0	0.40
9	17.7	477.0	0.40
10	36.5	448.0	0.70
**11	101.4	406.0	0.70
12	83.9	584.0	1.00
13	63.8	1392.0	1.00
14	34.3	2143.0	1.00
15	15.1	2669.0	1.00
16	13.0	2993.0	1.00
17	10.6	3026.0	1.00
18	13.9	2723.0	1.00
19	8.6	2171.0	1.00
20	8.8	1538.0	0.70
21	7.9	1068.0	0.70
22	20.2	839.0	0.70
23	34.2	753.0	0.70

1972

DATE	R (MM)	Qo (CMS-DAY)	ALPHA
Jul. 18	13.9	2723.0	1.00
19	8.6	2171.0	1.00
20	8.8	1538.0	0.70
21	7.9	1068.0	0.70
22	20.2	839.0	0.70
**23	34.2	753.0	0.70
24	57.4	783.0	0.70
25	21.7	1073.0	0.70
26	19.6	1579.0	0.70
27	14.9	1846.0	0.70
28	20.6	1757.0	0.70
29	24.5	1630.0	0.70
30	24.6	1536.0	0.70
31	10.9	1584.0	0.70
Aug. 1	26.5	1650.0	0.70
2	17.7	1700.0	0.70
3	0.6	1690.0	0.70
4	1.8	1530.0	0.70
5	7.4	1240.0	0.70
6	28.9	972.0	0.70
7	11.6	832.0	0.70
8	7.0	814.0	0.70
9	8.5	774.0	0.70
10	7.2	687.0	0.60
11	5.2	633.0	0.60
12	26.7	589.0	0.70
13	4.8	553.0	0.70

1973

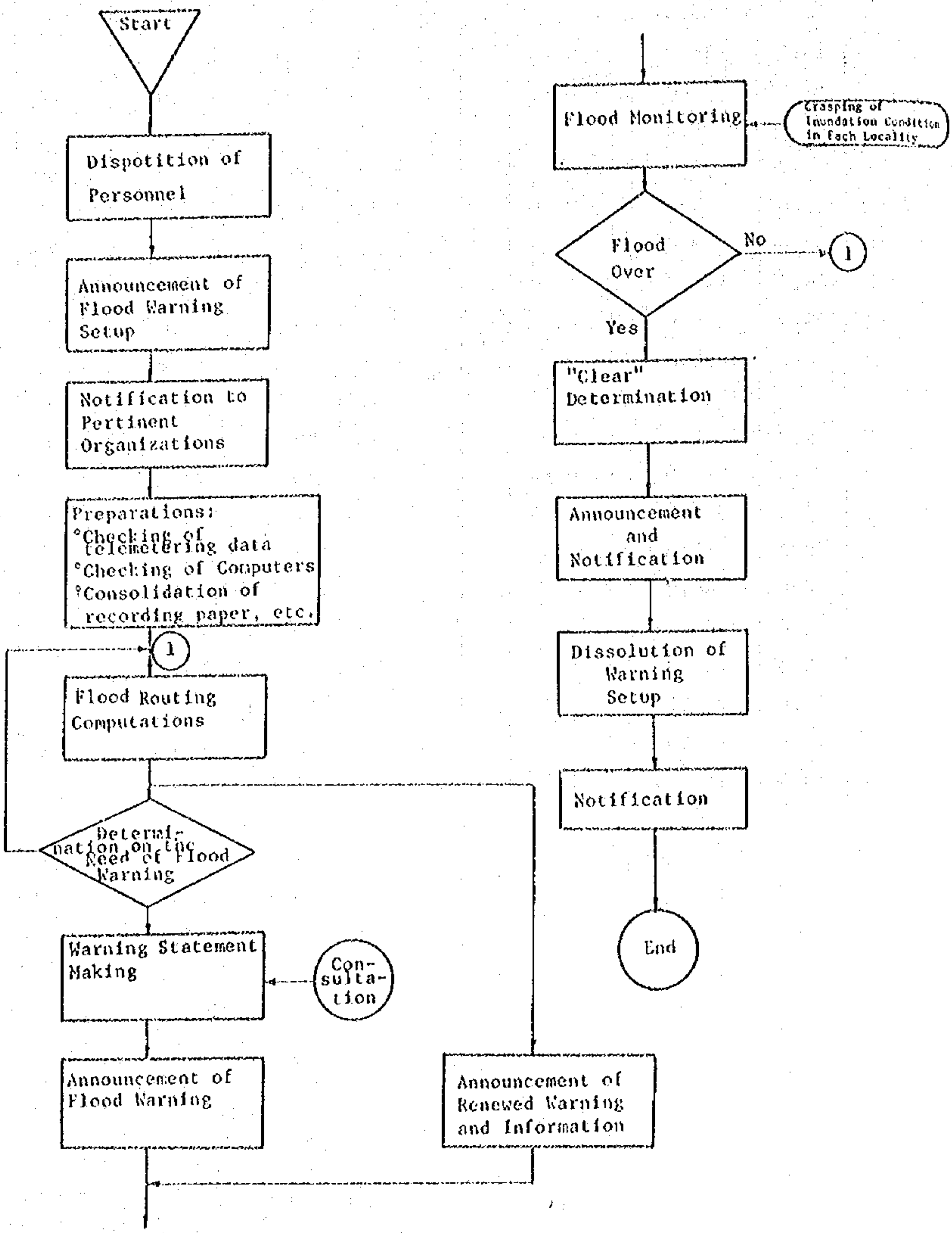
DATE	R (MM)	Qo (CMS-DAY)	ALPHA
Jun. 10	8.5	59.0	0.15
11	10.7	58.0	0.15
12	17.0	56.0	0.15
13	27.2	51.0	0.15
14	59.2	46.0	0.40
**15	65.0	43.0	0.40
16	52.8	142.0	0.80
17	85.4	440.0	0.80
18	23.0	864.0	0.80
19	14.0	1460.0	0.80
20	5.6	1728.0	0.80
21	5.0	1471.0	0.80
22	5.5	910.0	0.80
23	5.3	557.0	0.40
24	8.2	417.0	0.40
25	0.7	344.0	0.15
26	4.6	285.0	0.15
27	0.2	244.0	0.15
28	3.6	214.0	0.15
29	6.3	188.0	0.15
30	12.5	168.0	0.15

1974

DATE	R (MM)	Qo (CMS-DAY)	ALPHA
Aug. 7	12.4	289.0	0.60
8	3.6	274.0	0.60
9	3.5	282.0	0.60
10	4.3	263.0	0.60
11	16.0	243.0	0.60
**12	56.9	239.0	0.70
13	39.8	279.0	0.70
14	29.3	639.0	0.70
15	48.7	1025.0	0.70
16	61.9	1235.0	1.00
17	59.0	1479.0	1.00
18	39.6	2085.0	1.00
19	10.1	2270.0	1.00
20	12.6	3156.0	1.00
21	8.1	3250.0	1.00
22	3.7	2829.0	1.00
23	2.4	1860.0	1.00
24	5.2	1194.0	1.00
25	6.8	905.0	0.70
26	10.1	764.0	0.60
27	1.1	712.0	0.60
28	1.7	699.0	0.60
29	11.2	638.0	0.60
30	15.0	591.0	0.60
31	18.9	555.0	0.60

5-3 Sequence of Flood Warning

The following chart is a sequential illustration of flood warning work.



5-4 Observation and Arithmetic Processing Equipments

5-4-1 Rain Gauge

There are a diversity of gauges developed for rainfall observation. In Japan, the following gauges are used most widely.

(1) Ordinary rain gauge

(2) Direct-reading rain gauge

(3) Self-recording rain gauge

(4) Tipping bucket distance recording Rain Gauge (available in single and double tipping types)

The first gauge is used mainly for observation of daily rainfall at a fixed time, and the second and third ones are designed for observation at any desired time, but all three are giving place to the fourth one, the tipping bucket rain recorder by reason of its supremacy in terms of ease in observation and maintenance as well as in accuracy.

In a telemetering system, it is the common practice to adopt the method in which the said tipping bucket rain recorder is combined with an A/D converter for transmission of hourly cumulative rainfall data. In such a telemetering system, most of rainfall stations are not attended, so that it is advisable to install a gauge with a long self-recording span of three months or so and a large bucket for observation of total rainfall in order to provide against failures in the electric system.

5-4-2 Water Stage Gauge

Water stage gauges are also available in a great diversity of types. However, recording water stage gauges can be classified into the following five types according to the operating principle.

(1) Float type

(2) Bubble (pressure) type

(3) Electrode (needle sensor) type

(4) Digital (lead switch) type

(5) Ultrasonic wave type

The last type, ultrasonic current meter, is designed to measure and convert flow velocity directly into discharge.

The following table shows the specifications of the former four types for adoption of most suitable one in the Mae Klong basin telemetering network.

Type / Item	1 Float Type	2 Bubble (Pressure) Type	3 Electrode (Needle Sensor) Type	4 Digital (Lead Switch) Type	Remarks
Measuring Mechanism	Vertical float movement caused by the changes in water stage is converted to pulley rotation for stage measurement	Water stage is detected from the relationship between depth and changes in water pressure, and recorded by a motor-driven recorder	Water stage is detected by tracing an electrode on the water surface and recorded by a motor-driven recorder	Water stage is detected directly and recorded digitally by means of a lead switch fitted on the staff gauge and a permanent magnat float	
Required Facilities (Cost)	Observation well (Hight)	Pressure transmission pipe (Low)	Guide pipe incl. steel pipe (Medium)	Staff post (Medium)	Excl. observation house
Power Equipment	Not required	DC (cell)/AC	DC (cell)/AC	DC (cell)/AC	Excl. recorder

Type / Item	1 Float Type	2 Bubble (Pressure) Type	3 Electrode (Needle Sensor) Type	4 Digital (Lead Switch) Type	Remarks
Measure-ring Range	$10^m/20^m$	$10^m/(20,30,50^m)$	$10^m/20^m/50^m$		Type 2 has two different mechanisms, one designed for a measuring range of 10m and larger and the other for less than 10m range.
Mainte-nance Re-quire-ments	Small	Normal	Normal	Large	Manual mainte-nance
Total Cost	Large	Small	Medium	Medium	
Past Use in Thai-land	Unknown	Used	Not used	Not used	

The following table shows the estimated measuring range at each of the main water stage stations on the Maeklong river.

Station	Sangkhla Buri (K24)	Thong Pha Phum (K13)	Ban Lum Sum (K10)	Wang Khanai (K11)	Remarks
Highest High Water Stage	135.41 MSL	92.64^{m} MSL	49.62^{m} MSL	21.02^{m} MSL	
Dry Season Stage (River Bed Height)	124 "	73 "	31 "	11 "	Zero point on the staff gauge or river bed
Measuring Range	15 m	23 m	22 m	13 m	Up to H_{max} + extra height or up to bank height

As seen in the above table, all the four stations have a measuring range of more than 10 m. Considering the cost, therefore, it is likely that either the bubble type (2) or the electrode type (3) will have to be installed. Of these two, type (2) is more suitable than type (3) because the former has already been used at a number of stations along the Mae Klong, whereas the installation of the latter (guide pipe in particular) is difficult at some stations. However, in order for this bubble type gauge to be incorporated in the planned telemetering system, it is necessary to install an A/D converter and secure a torque large enough to turn the recorder. During its field trip, the team noted that torque was insufficient for the bubble type gauge installed at K-11. It may as well be added that some modifications will have to be effected to recorders with a measuring range of more than 10 m such as Model Z-905 Pressure Type Stage Recorder of Nakaasa Sokki Co., Ltd., Japan, which uses AC power equipment.

5-4-3 Arithmetic Processing Equipment

The system design for flood forecasting at K-11 being still at the stage of survey, selection of computing equipment cannot be made at present.

The functions to be performed by computing equipment are enumerated below in order to facilitate the planning of the forecasting operation scheme.

(1) Recording of hydrological data.

(2) Processing of hydrological data (e.g., average rainfall in the basin).

(3) Computation of storm run-off.

(4) Computations for integrated operation of dam and for satisfactory weir operation and maintenance.

(5) Integration of Items (1) ~ (4) by on-line system.

In order to fulfill these objectives and functions, not only the processing system but also the processing equipment must be suitably designed and selected according to the number of observation stations and presence of dams and other facilities. Accordingly, selection of computing equipment to be installed at the Mae Klong river basin flood forecasting center depends largely upon how the above-mentioned five functions are to be fulfilled and whether such functions need to be expanded in future to cover other river basins. It can be said, however, that the functions in Items (1) ~ (3) can be filled sufficiently by recently developed desktop electronic calculator having a high programming capacity.

CHAPTER 6 STUDY ON TELEMETERING SYSTEM

6-1 Outline

As stated in the Preliminary Survey Report, there have already been proposed a number of plans for the Maeklong river basin flood forecasting system, studied by MD, RID, or TCS.

During the present survey, field survey were conducted under the telemetering network plan proposed in the said preliminary survey report, with specific emphasis placed on the study of the following three points to which importance was attached in the same report.

(1) Selection of VHF band for stability of the whole telecommunication network.

(2) Ease in the maintenance and inspection of equipment and facilities after installation.

(3) Special care in the selection of the number and locations of repeater stations.

The following are the hydrological observation stations to be incorporated in the telemetering network.

o Stage and Rainfall Stations

Sangkhla Buri

Thong Pha Phum

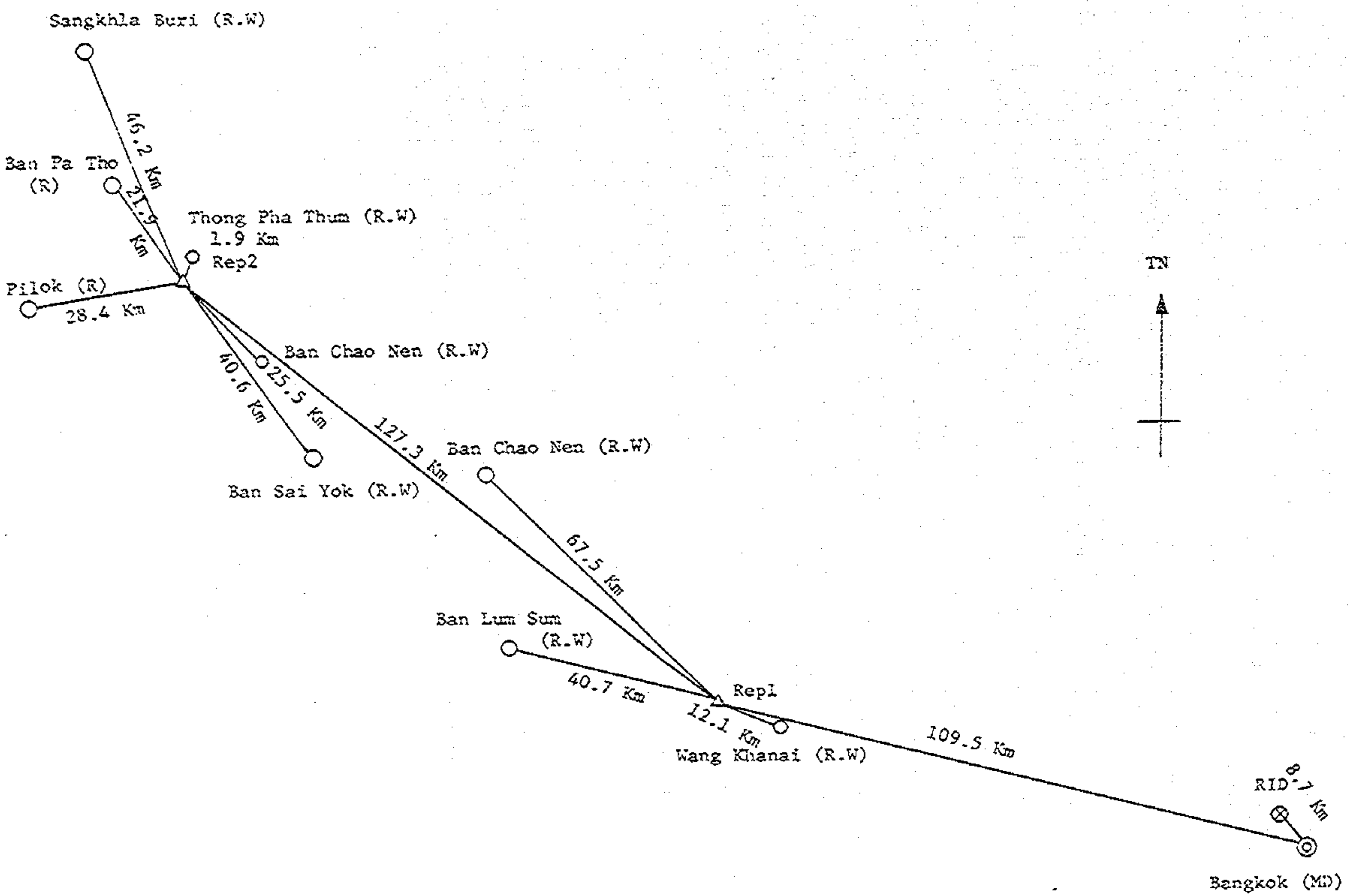
Ban Sai Yok

Ban Lum Sum

Ban Chao Nen

Wang Khanai (Total : 6 stations)

Fig. 6-1 Telemetering Network



o Rainfall Stations

Ban Pa Tho

Pilok

Ban Lin Thin (Total : 3 stations)

In order to connect these stations, two repeater stations are required.

o Repeater Station 1 - To be located near Kanchanaburi to link Bangkok and R2

o Repeater Station 2 - To be located near Thong Pha Phum to link upstream area and R1

Data transmitted from the above-mentioned stations are to be collected and processed at master statin and monitoring station belonging to Meterological Department and Royal Irrigation Department, respectively.

o Master Station MD (Bangkok)

o Monitoring Station RID (Bangkok)

Fig. 6-1 shows the telemetering network incorporating all these stations. To study the feasibility of this network plan, which was one of the objectives of the present survey, radio propagation test and circuit design were performed as detailed in the following sections.

6-2 Outline of Radio Propagation Test

6-2-1 Test Frequency

It was planned that the test would be conducted using VHF-band radio equipment and two frequencies, i.e., 57.11 MHz and 57.26 MHz, but only the former frequency was used. As this frequency is within the bandwidth allocated for TV channels, the competent Thai authorities requested that it be used temporarily only for the test from 8:00 to 16:00 hrs. on weekdays.

6-2-2 Test Items

The test covered the items listed below. Thong Pha Phum, Ban Lin Thin, RID, and Wang Khanai were excluded as it was considered that the topography at these stations was good enough to dispense with the test.

(1) Measurement of Receiving Radio Field Intensity in Each Radio Link

Field intensity measurement is generally conducted by receiving test wave at the receiving point by means of field intensity meter and recorder. In the present test, however, measurement was performed only by field intensity meter and no recorder was used for continous intensity measurement. Accordingly, the antenna was shifted in all horizontal and vertical directions in order to study the stability of field intensity.

(2) Measurement of S/N Ratio in Each Radio Link

Modulation at the specified level of 800 Hz was effected at the transmitting point by means of audio-frequency generator and S level was measured at the receiving end by means of level meter, then N level was measured without modulation. The values obtained were converted to S/N ratio for the purpose of qualitative circuit test.

(3) Voice Communication Test in Each Radio Link

The condition of actual voice communication was checked by radiotelephone.

(4) Survey of Site Conditions of Observation and Repeater Stations

The conditions at installation sites of observation and repeater stations were surveyed, and maps and sketches showing the survey data were prepared.

(5) Measurement of Noise Level in Bangkok

The external noise field intensity was measured by means of field intensity meter and quasi-peak meater, and recorded continuously for about 30 minutes by recorder.

6-2-3 Formation of Radio Propagation Test Groups

The test was conducted by dividing the team's telecommunication party into three groups, each composed of one Japanese expert and two or three local counterpart technicians, with two or three labourers recruited for transportation of equipment required in the repeater station test.

6-3 Test Equipment

Table 6-1 shows the equipment used in the test, and Fig. 6-1 shows the equipment composition for each test item.

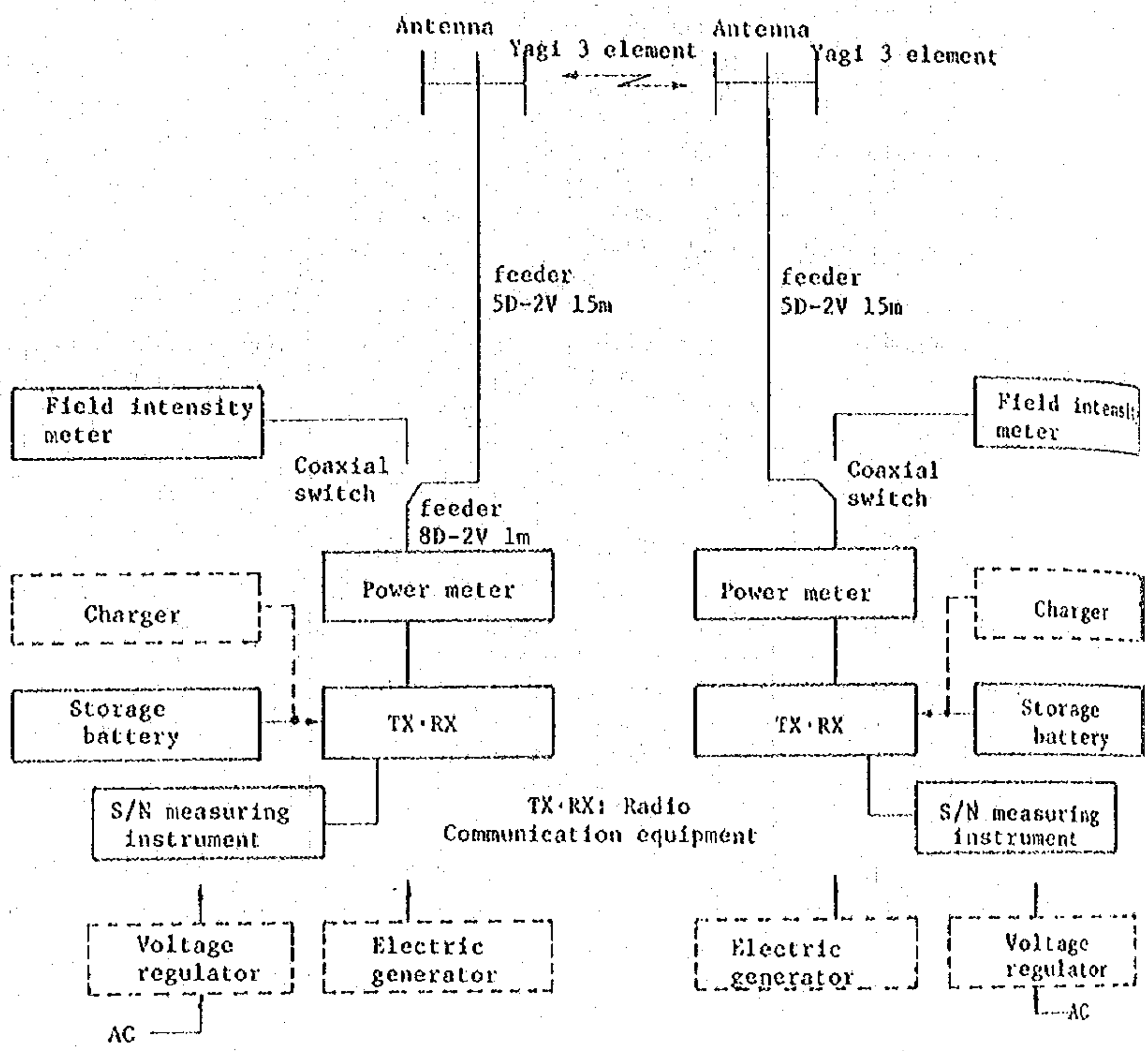
Table 6-1 Equipment for Radio Propagation Test

Article	Description	Quantity	Remarks
Radio Communication equipment	Antenna power 10W 60MHz Band CRI-06	4 sets	Includ frequency; 57.11 MHz, 57.26 MHz
Antenna	Yagi 3 element V3C-0625	3 "	
Antenna Pole	Joint type 10m MS-10A	3 "	
Feeder	5D-2V 15m	5 "	

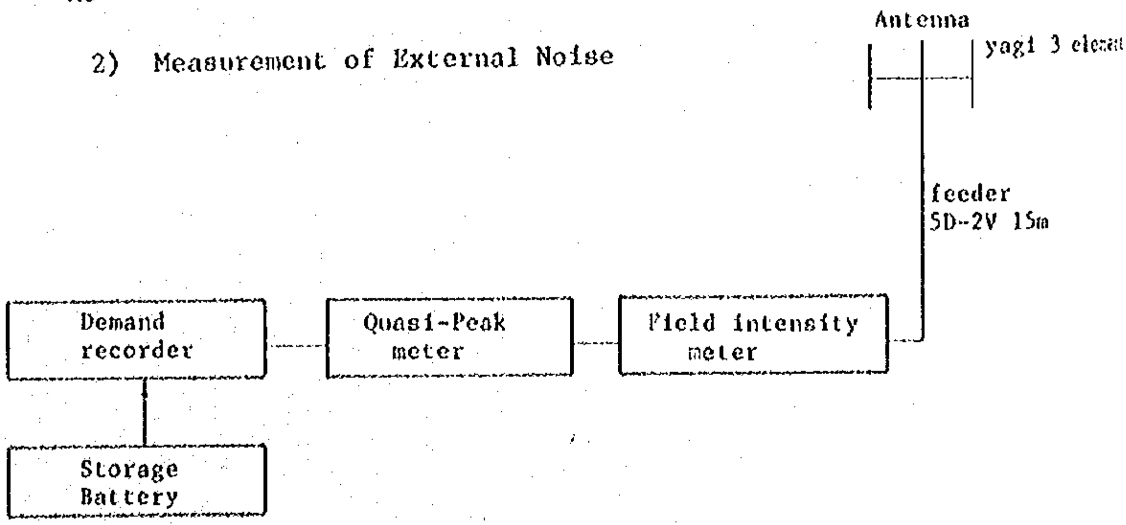
Article	Description	Quantity	Remarks
Storage Battery	12V40AH	3 sets	
Charger	AC100/200V DC 0~16V 9A 418-16	3 "	
Voltage regulator	200V/0~260V 5A SD-205	3 "	
Electric generator	100V 300W E-300	3 "	
Field intensity meter	25~230 MHz M-321C	2 "	Attashment: doublet antenna and legs
Power meter	50~400 MHz 15W TLP-52A	3 "	
S/N measuring instrument	KCD-1	3 "	
Circuit tester	TL-700	3 "	
Quasi-Peak meter	MH-33B	1 "	
Demand recorder	EPR-100A	1 "	
Tool set	S-10	3 "	
Coaxial switch		3	

Fig. 6-2 Equipment Composition for Each Test Item

1) Measurement of Receiving Field Intensity and S/N Ratio



2) Measurement of External Noise



6-4 Test Results

In the radio propagation test, a frequency of 57.11 MHz in VHF band was used to measure receiving input voltage (dB μV) by field intensity meter, and propagation loss was obtained from this input voltage by the application of the following equation. Table 6-2 shows the test results.

External noise level was calculated on the basis of the measured S/N ratio, and it proved to be in nearly conformity to the noise level in Bangkok at the said frequency which is shown in Fig. 6-3.

(1) Propagation Loss (Additional Loss Excluding Free Space Loss)

$$L_{pa} = X + r + L_{pf} + L_{ft} + L_{fr} - G_{At} - G_{Ar} - P$$

where, L_{pa} : Propagation loss (additional loss excluding free space loss) .... dB

* Spherical ground loss, ground reflection loss, diffraction loss or shielding loss

X : Conversion coefficient of receiving power and receiving open terminal voltage .... 111 dB

r : Measured value of field intensity meter (receiving input voltage) .... dB μV

L_{ft} : Transmitting feeder loss .... dB

L_{fr} : Receiving feeder loss .... dB

G_{At} : Transmitting antenna gain .... dB

G_{Ar} : Receiving antenna gain .... dB

P : Indication of transmitting power meter ..... dBm

L_{pf} : Free space loss .... dB

$$* L_{pf} = 32.4 + 20 \log f + 20 \log D$$

where, F : Frequency (MHz)

D : Span length (km)

(2) Signal-to-Noise Ratio

S/N ratio per section under normal channel condition, to be obtained by the following equation, should be larger than 30 dB.

$$S/N = P_t - (L_{pf} + L_{ft} + L_{fr}) + G_{At} + G_{Ar} - P_{rn} + I$$

where, S/N : Signal-to-noise ratio of channel .... dB

P_t : Transmitting antenna power .... dBm

P_{rn} : Received noise power .... dBm

* Received noise power is the sum total of internal noise power of receiver (P_{rni}) and external noise power (P_{rne}).

I : S/N improvement factor .... dB

* S/N improvement factor should be the value obtained by the following formula.

$$I = 10 \log \left(\frac{3fd^2 \cdot B}{2fm^3}\right)$$

where, fd : Maximum frequency deviation (±), KHz (±5 KHz for simplex radio links in VHF band)

fm : Maximum modulation frequency, KHz (3 KHz for simplex radio links in VHF band)

B : Equivalent noise bandwidth of receiver, KHz

(3) The test results indicate that the planned telemetering system is fully satisfactory in every respect.

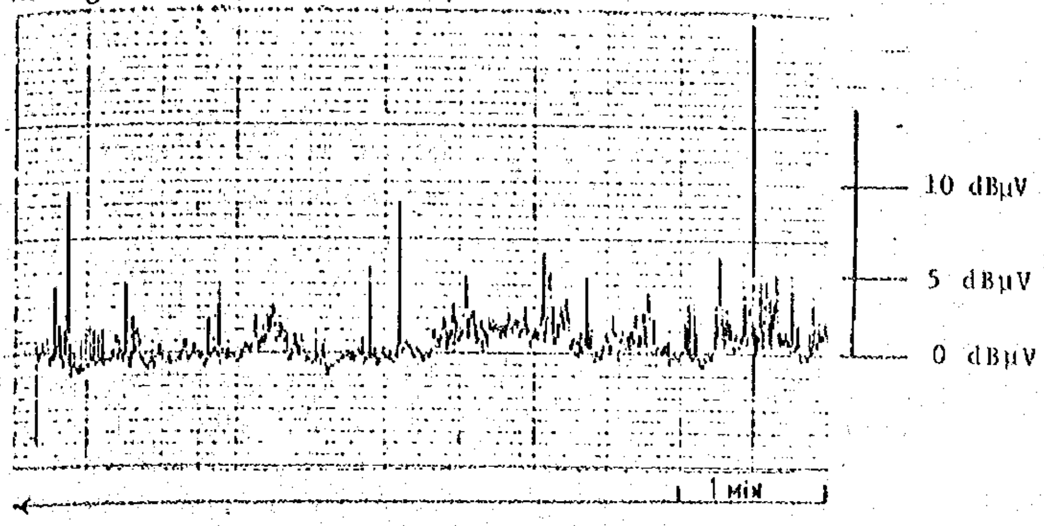
Table 6-2 Results of Radio Propagation Test

Item \ Name of station	Unit	Bangkok - Rep I 109.5Km	Rep I - Rep 2 127.3Km	Rep I - Ban Chao Nen 67.5Km	Rep 1 - Ban Lum Sum 40.7Km	Rep 2 - Pilok 28.4Km	Rep 2 - Ban Pha-Tho 21.9Km	Rep 2 - Ban Sai Yok 40.6Km	Rep 2 - Sangkhla Buri 46.2Km	Remark
Above sea level	m	1 | 252	220 | 520	252 | 420	220 | 50	520 | 950	520 | 105	520 | 85	520 | 140	
Antenna height above the ground	m	36.3 | 8.3	8.3 | 8.3	8.3 | 8.3	8.3 | 8.3	6.3 | 6.3	6.3 | 8.3	6.3 | 8.3	6.3 | 9.3	
Transmitting and receiving feeder loss (L_{ft}, L_{fr})	dB	-2.38	-2.38	-2.38	-23.8	-2.38	-2.38	-2.38	-2.38	T:5D-2V 15m R:5D-2V 15m
Combined antenna gain (G_{At}, G_{Ar})	dB	16	16	16	16	16	16	16	16	T:Yagi 3EL R:Yagi 3EL
Free space loss (L_{pf})	dB	-108.32	-109.63	-104.12	-99.73	-96.6	-94.34	-99.71	-100.82	
Additional loss (L_{pa})	dB	-30.5	-42.59	-40.95	-53.34	-49.62	-42.78	-50.91	-39.3	
Span loss	dB	-125.2	-138.6	-131.45	-139.45	-132.6	-123.5	-137	-126.5	
Transmitting power (P)	W	6.6	7.2	7	7	7.2	8	8	8	
	dBm	38.2	38.6	38.45	38.45	38.6	39	39	39	
Receiving power	dBm	-87	-100	-93	-101	-94	-84.5	-98	-87.5	
Receiving input voltage (r)	dBμV	26	13	20	12	19	28.5	15	25.5	0dBμV =-113dBm
Received noise power (P_{rn})	dBm	-104	-118	-118	-118	-112	-112	-122	-122	
High frequency S/N, C/N	dBm	17	18	25	17	28	37.5	24	34.5	
S/N improvement factor (I)	dBm	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	
Standard S/N ratio	dB	30.5	31.5	38.5	30.5	41.5	51	37.5	48	

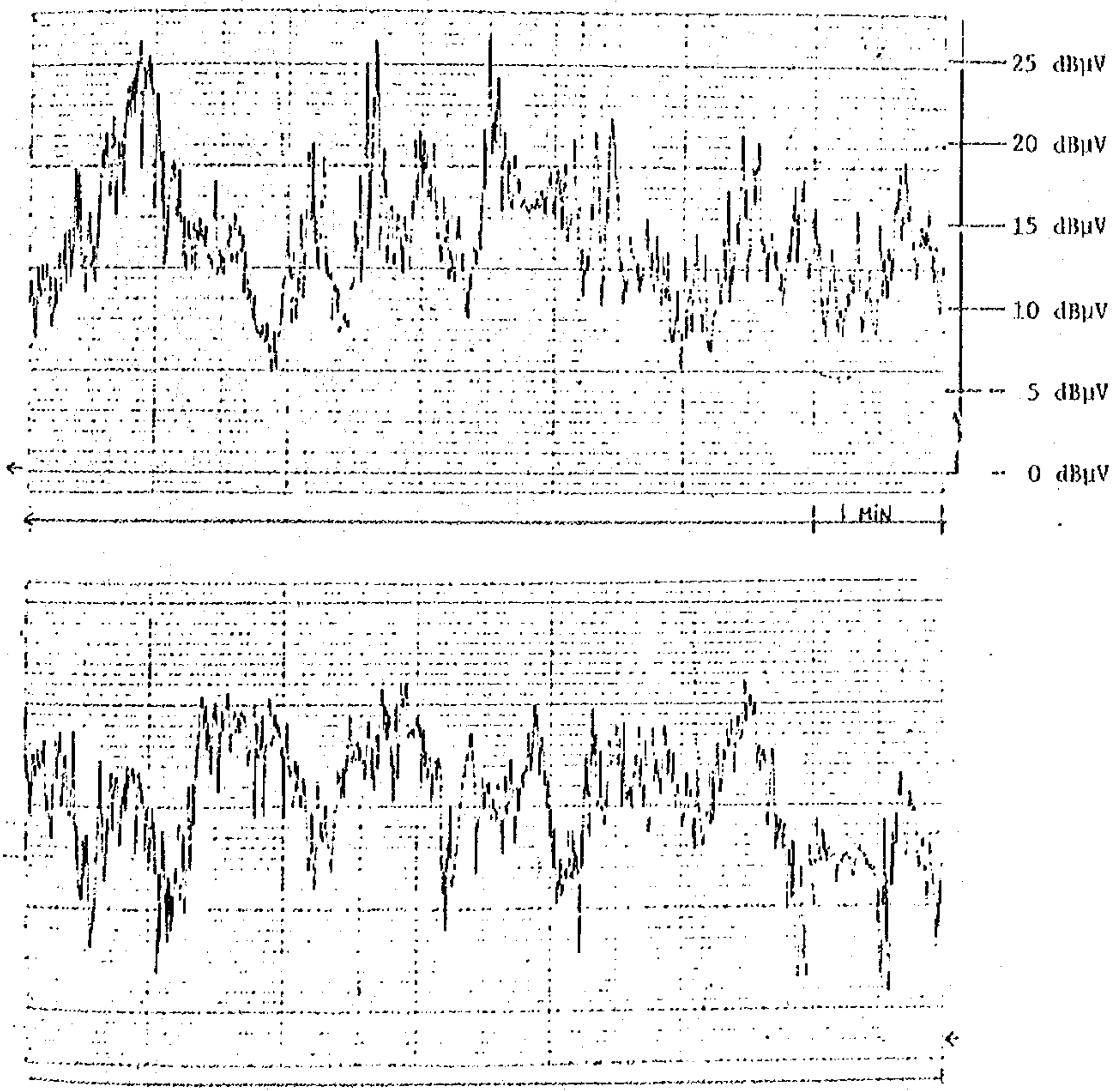
Fig. 6-3 City Noise in Bangkok

25, Dec, 1977

(1) Average Value (11:24 ~ 11:29)



(2) Peak Value (11:05 ~ 11:19)



CHAPTER 7 DESIGN OF TELEMETERING SYSTEM

7-1 Circuit Design

(1) Since the frequency used in the radio porpagation test (60 MHz band) is currently used for TV broadcasting, 80 MHz was adopted in the design of working circuit. Fig. 7-1 shows particulars of the circuit design.

(2) The antenna directions and directivity, which were taken into consideration in the circuit design, are shown in Figs. 7-1 and 7-2.

(3) The circuit reliability based on the present design can be judged by whether antenna power (P_t) satisfies the following relation.

$$Pt > A$$

$$A\ (dBm) = (L_{pa} + L_{pf} + L_{ft} + L_{fr} + L_F) - G_{At} - G_{Ar} + P_{th}$$

where, L_F : Fading loss dB (0.1 dB/km + 3 dB)

Pth : Threshold level (dBm)

* Thresholld level is the sum total of internal noise power of receiver (P_{rni}) and C_f = 9 dB. However, if external noise level is larger than threshold level, it should be added to the said sum total.

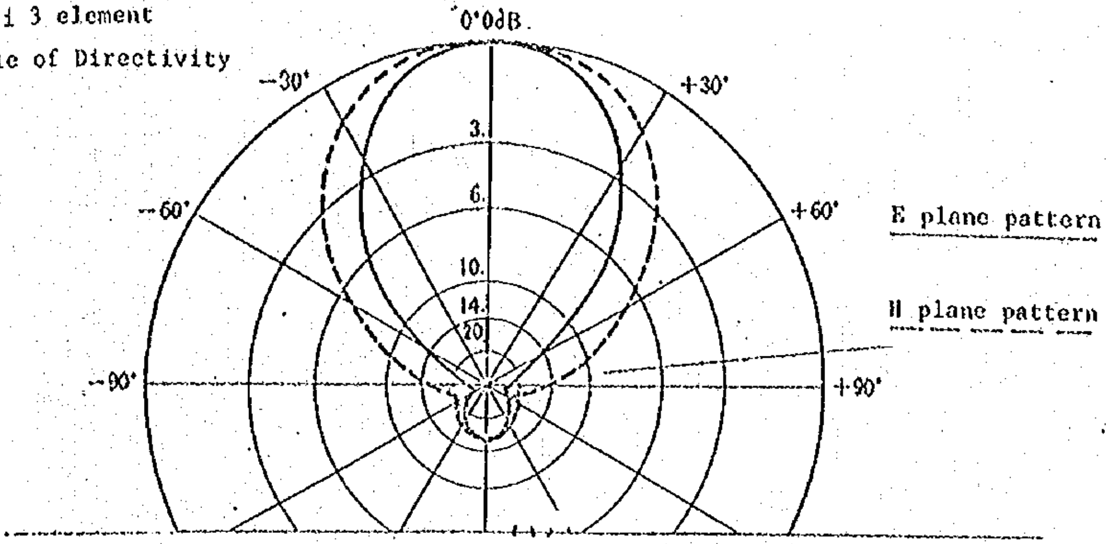
Table7-1 Circuit Design

Item \ Name of Station	Unit	Bangkok (MO) - Rep 1 109.5Km		Rep 1 - Rep 2 127.3Km		Rep 1 - Ban Chao Nen 67.5Km		Rep 1 - Ban Lum Sum 40.7Km		Rep 2 - Pilok 28.4Km		Rep 2 - Ban Pa-Tho 21.9Km	
Above sea level	m	1	220	220	520	220	420	220	50	520	950	520	105
Antenna height above the ground	m	38	10	10	10	10	20	10	30	10	20	10	20
Antenna		Yagi 5ELx2	Yagi 5ELx2	Yagi 5ELx2	Yagi 5ELx2	Yagi 5ELx2	Yagi 5EL	Yagi 5ELx2	Yagi 5ELx2	Yagi 3EL	Yagi 5EL	Yagi 3EL	Yagi 3EL
Antenna gain	dB	12.5	12.5	12.5	12.5	12.5	10	12.5	12.5	8	10	8	8
Antenna inclination loss	dB			-0.5 (10°)		-1.2 (17°30')		-1 (13°15')		-4 (36°30')		-3 (30°30')	
Feeder		10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V
Feeder loss	dB	-1.25	-0.75	-0.75	-0.75	-0.75	-1.25	-0.75	-1.25	-0.75	-1.25	-0.75	-1.25
Free space loss	dB	-111.3		-112.6		-107		-102.7		-99.53		-97.3	
Additional loss	dB	-33.5		-45.6		-44		-56.3		-52.6		-45.6	
Span loss	dB	-121.8		-135.2		-131.7		-137.5		-140.1		-131.9	
Transmitting power	W	10	10	10	10	10	10	10	10	10	5	10	5
	dBm	40	40	40	40	40	40	40	40	40	36.5	40	36.5
Receiving power	dBm	-81.8	-81.8	-95.2	-95.2	-91.7	-91.7	-97.5	-97.5	-100.1	-103.6	-91.9	-95.4
Received noise power	dBm	-104	-118	-118	-122	-118	-122	-118	-122	-122	-122	-122	-122
High frequency S/N, C/N	dB	22.7	36.2	22.8	26.8	26.3	30.3	20.5	24.5	21.9	18.4	30.1	26.6
S/N improvement factor	dB	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Standard S/N ratio	dB	35.7	49.7	36.3	40.3	39.8	43.8	34	38	35.4	31.9	43.6	40.1
Threshold level	dBm	-103.5	-114	-114	-114	-114	-114	-114	-114	-114	-114	-114	-114
Threshold margin	dB	21.7	32.2	18.8	18.8	22.3	22.3	16.5	16.5	13.9	10.4	22.1	18.6
Threshold S/N ratio	dB	35.2	45.7	32.3	32.3	35.8	35.8	30	30	27.4	23.9	35.6	32.1
Fading loss	dB	-14		-15.8		-9.8		-7.1		-5.9		-5.2	
S/N in during fading	dB	21.7	35.7	20.5	24.5	30	34	26.9	30.9	29.5	26	38.4	34.9
Remark													

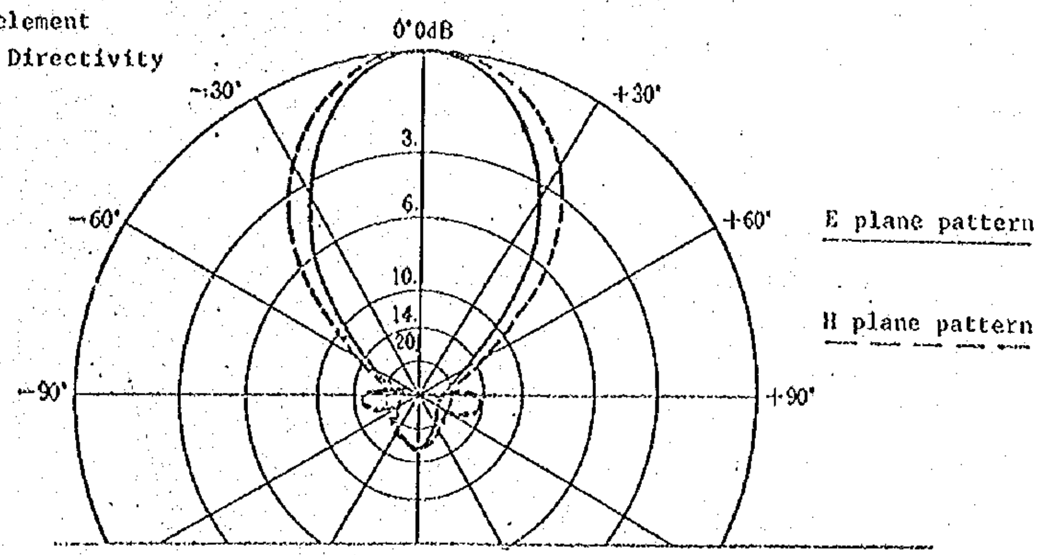
Item \ Name of Station	Unit	Rep 2 - Ban Sai Yok 40.6Km		Rep 2 - Saub-Khla Buri 46.2Km		Rep 1 - Wang Khanal 12.1Km		Rep 2 - Thong Pha Phum 1.9Km		Rep 2 - Ban Lin Thin 25.5Km		MO - RID (Bangkok) 8.7Km	
Above sea level	m	520	85	520	150	220	90	520	90	620	80	1	1
Antenna height above the ground	m	10	30	10	10	10	10	10	10	10	20	38	30
Antenna		Yagi 5EL	Yagi 5EL	Yagi 3EL	Yagi 3EL	Yagi 5ELx2	Yagi 3EL	Yagi 3EL	Yagi 3EL	Yagi 5EL	Yagi 3EL	Yagi 3EL	Yagi 3EL
Antenna gain	dB	10	10	8	8	12.5	8	8	8	10	8	8	8
Antenna inclination loss	dB			-5.8 (42°)		-18 (170°)		-30 (84°)		-0.7 (8°45')			
Feeder		10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V	10D-2V
Feeder loss	dB	-0.75	-1.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-1.25	-0.75	-2.25
Free space loss	dB	-102.6		-103.8		-97.1		-91.2		-98.6		-89.3	
Additional loss	dB	-53.9		-42.3		-7		-7		-18		-7	
Span loss	dB	-139		-137.4		-103.1		-113.7		-101.3		-83.3	
Transmitting power	W	10	5	10	5	1	10	1	5	1	5	1	1
	dBm	40	36.5	40	36.5	30	40	30	36.5	30	36.5	30	30
Receiving power	dBm	-99	-102.5	-97.4	-100.9	-73.1	-63.1	-83.7	-77.2	-71.3	-64.8	-53.3	-53.3
Received noise power	dBm	-122	-122	-122	-122	-118	-118	-122	-122	-122	-122	-104	-104
High frequency S/N, C/N	dB	23	19.5	24.6	21.1	44.9	54.9	38.3	44.8	50.7	57.2	50.7	50.7
S/N improvement factor	dB	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Standard S/N ratio	dB	36.5	33	38.1	34.6	58.4	68.4	51.8	58.3	64.2	70.7	64.2	64.2
Threshold level	dBm	-114	-114	-114	-114	-114	-114	-114	-114	-114	-114	-103.5	-103.5
Threshold margin	dB	15	11.5	16.6	13.1	40.9	50.9	30.3	36.8	42.7	49.2	50.2	50.2
Threshold S/N ratio	dB	28.5	25	30.1	26.6	54.4	64.4	43.8	50.3	56.2	62.7	63.7	63.7
Fading loss	dB	-7.1		-7.7		-4.2		-3.2		-5.6		-3.9	
S/N in during fading	dB	29.4	25.9	30.4	26.9	54.2	64.2	48.6	55.1	58.6	65.1	60.3	60.3
Remark													

Fig. 7-2 Antenna Directivity

Yagi 3 element
Example of Directivity



Yagi 5 element
Example of Directivity



Yagi 5 element×2
Example of Directivity

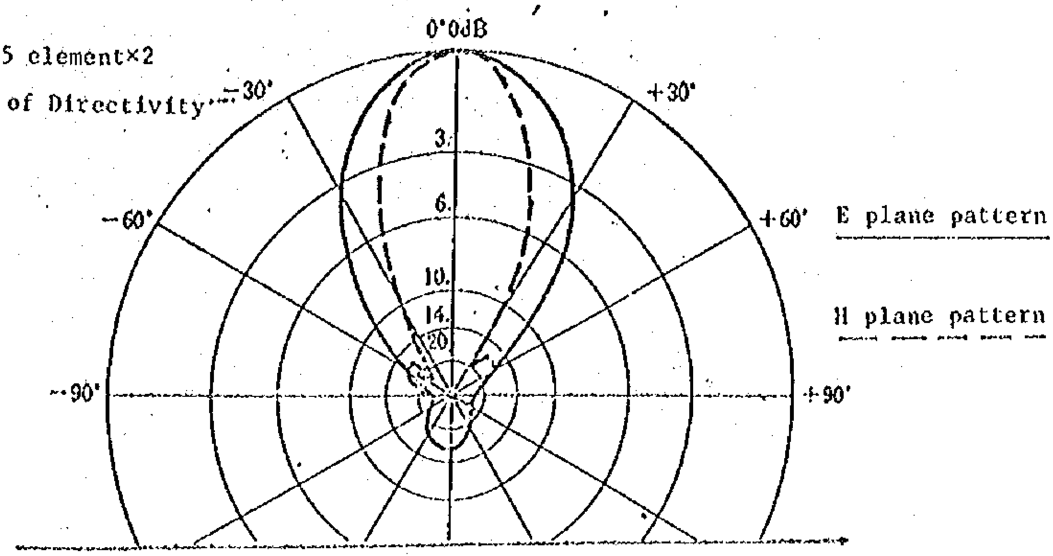
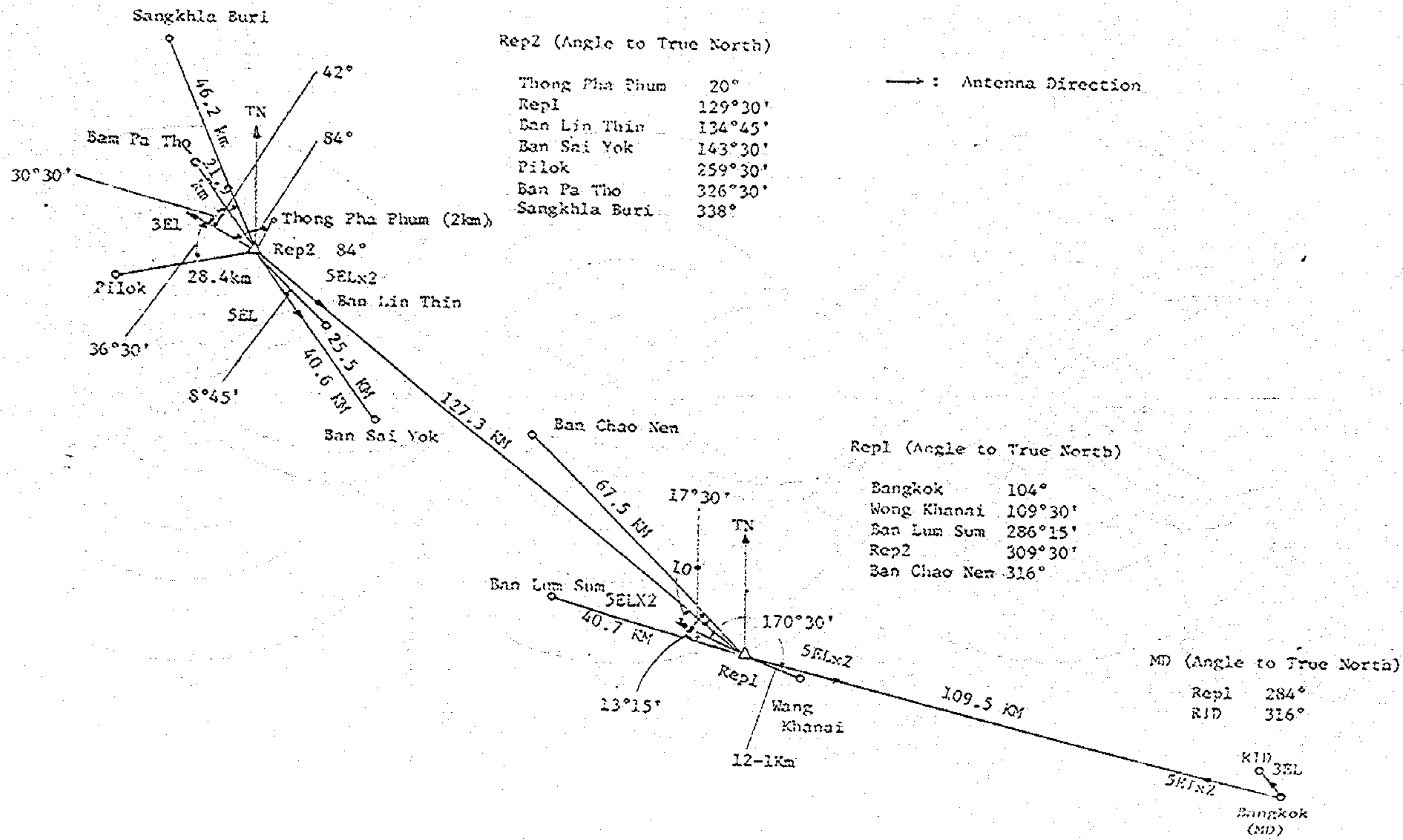


Fig. 7-1 Antenna Direction



7-2 Site Conditions

o MD (Master Station)

The building of master station is now under reconstruction. It is advisable that the space for the operating room and the flood forecasting center be secured on the seventh floor of the new building, with antenna masts erected on the roof. MD's location is subjected to a high level of city noise.

o RID (Monitoring Station)

For the purpose of satisfactory of circuit configuration, it is desirable that antenna masts of more than 30 m height be erected near the station building.

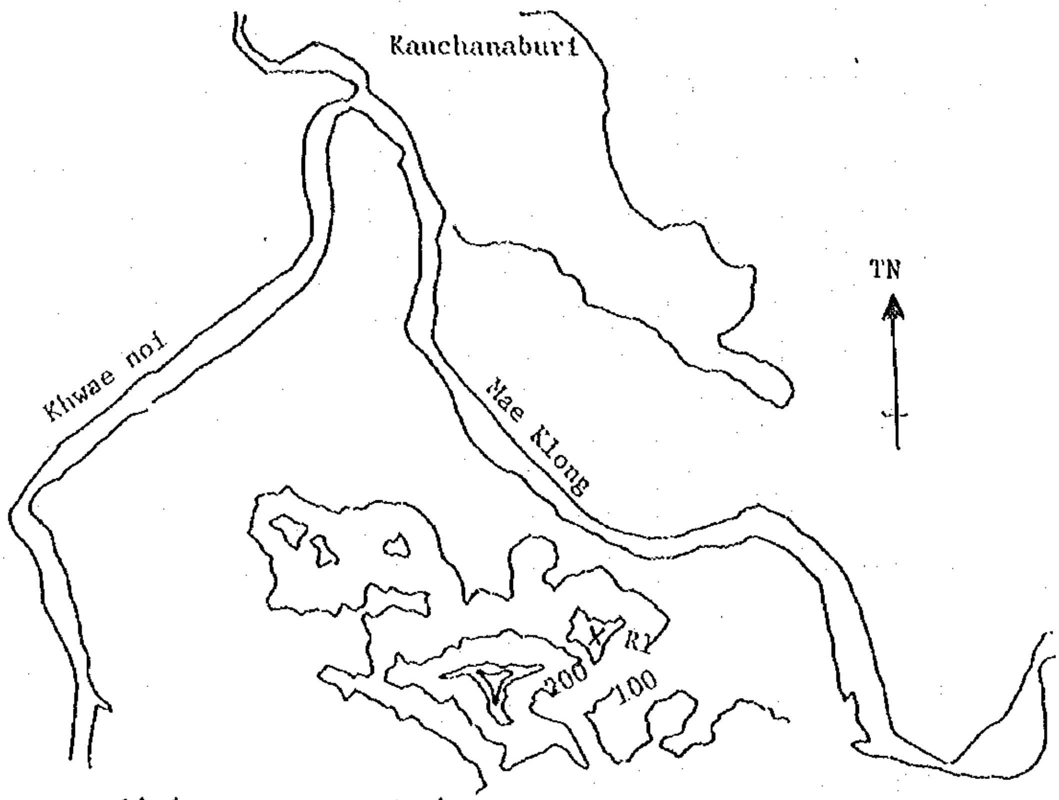
o R1 (Repeater Station)

The proposed construction site is situated at an elevation of about 220 m in one of the hilly areas, the highest of which having an elevation of 481 m, which extends about 3 Km to the south-south-east to Kanchanaburi (See Fig. 7-3).

The hill summit is covered with limestone, but spacious enough to build the station house after levelling.

Access to the site calls for an about 40-minute drive from Kanchanaburi and an about 30-minute climbing. Considering the future maintenance requirements, however, it is the best conceivable site of the station. Since the uphill road is steep and rugged, it is advisable to provide a well-consolidated route up to the summit.

Fig. 7-3 Location Map of R1 Station



o R1' (Repeater Station)

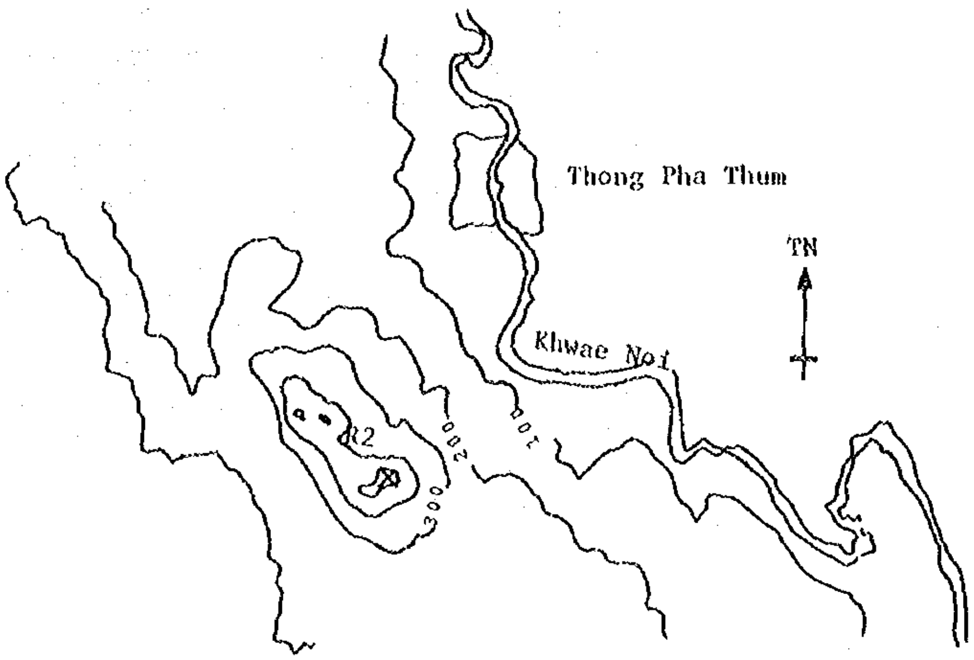
As an alternative of the above-mentioned site, the summit of Mt. Khao Luang was selected. It rises to an elevation of 423 m in the hilly area extending near Chom Bung which is located 32 Km to the south of Kanchanaburi and 36 Km to the northwest of Ratchaburi. In so far as can be judged from the desk design, this site can be connected with R2, Bangkok, Ban Chao Nen, and Ban Lum Sum, but it is not suited for construction of the station house because maintenance service will entail difficulty due to the tropical virgin forests enveloping the whole mountain and the long distance from the maintenance base.

o R2 (Repeater Station)

The site of this station is the summit of a mountain with an elevation of 520 m which is located about 2 Km to the southwest of Thong Pha Phum (See Fig. 7-4). The summit is covered with limestone but relatively flat, so that the construction of the station house is feasible after levelling work is conducted.

It takes about two hours on foot to get to the mountain from Thong Pha Phum. Ascent can be made with relative ease up to an elevation of 400 m, beyond which steepness becomes too sharp for climbing. Provision of a suitable route up to the summit is therefore necessary. However, the site is ideally located for circuit design and maintenance.

Fig. 7-4 Location Map of R2



o Ban Lum Sum (Rainfall and Water Stage Station)

This station is on the left bank of the Khwae Noi at a point about 40 Km to the west-north-west of Kanchanaburi, and can make use of MD's observation facilities. Its environs are a flat plain except that a low hill is found nearby, but the site is considerably shadowed in the whole circuit configuration. It is therefore desirable to erect an antenna mast having a height of about 30 m.

The station has a water stage gauging shed, but it was submerged beneath flood stage in the past and is not in service condition. The shed accommodating the signalling equipment is about 50 m apart from levee inside, so that it is necessary to devise a suitable method of installing water stage gauges.

o Wang Khanai (Rainfall and Water Stage Station)

This station is on the left bank of the Mae Klong river at a point about 13 Km to the southeast of Kanchanaburi, and is equipped with RID's observation facilities. Being situated in a flat plain, it is connected with R1 by a line of sight and consequently presents no problems in circuit design. The presently installed stage gauge is a French-made equipment of bubble type, but it cannot used for telemetering purpose due to the insufficient space for installing A/D converter and shortage of torque.

o Sangkhla Buri (Rainfall and Water Stage Station)

This site is located on the right bank of the upstream section of the Khwae Noi river, at a point near the wharf of Sangkhla Buri river port. MD's observation facilities are established nearby. The site presents no problems in circuit design.

o Ban Pa Tho (Rainfall Station)

The site of this station is in Ban Patho village about 80 m west of the Khwae Noi river right bank which is about 22 km to the north-north-west of Thong Pha Phum. The forest land surrounding the proposed site is cleared so that no specific problems are involved in the design of circuit configuration.

o Pilok (Rainfall Station)

Pilok is a mining town near the Burmese border. Although its environs present a basin-line topography, the test site has a relatively high elevation and poses no serious problems for circuit design. The site area is sufficiently wide, and no problems are entailed in rainfall gauging service or in the construction of the station house.

o Thong Pha Phum (Rainfall and Water Stage Station)

This is the location of an MD's observatory situated on the right bank of the Khwae Noi, not far from R2. It is suited to construction of a maintenance service base covering the stations connected with R2. The Khwae Noi right bank has no rivetment so that a suitable method must be devised for installation of water stage gauges.

o Ban Chao Nen (Rainfall and Water Stage Station ... Transmitting and Receiving Station)

The site of this station is on a hill where EGAT's radio relay station is built, and is about 1.5 Km apart from the construction site of Ban Chao Nen Dam. It poses no specific problems in circuit design. For the purpose of satisfactory data receiving and transmission, it is desirable to lay a wire line between the dam and the transmitting/receiving station. In this case, the existing poles are to be used for wire stringing.

o Ban Sai Yok (Rainfall and Water Stage Station)

This is the location of an MD's rainfall station which is built in a cleared area of 30 × 50 m in a teak forest extending at an elevation of about 15 m near the Sai Yok Falls, not far from Sai Yok boat embarkation platform on the right bank of the Khwae Noi river. Though easy of access, the site has a hollow like topography and is surrounded by a teak forest and consequently calls for an antenna height of about 30 m.

o Ban Lin Thin (Rainfall Station)

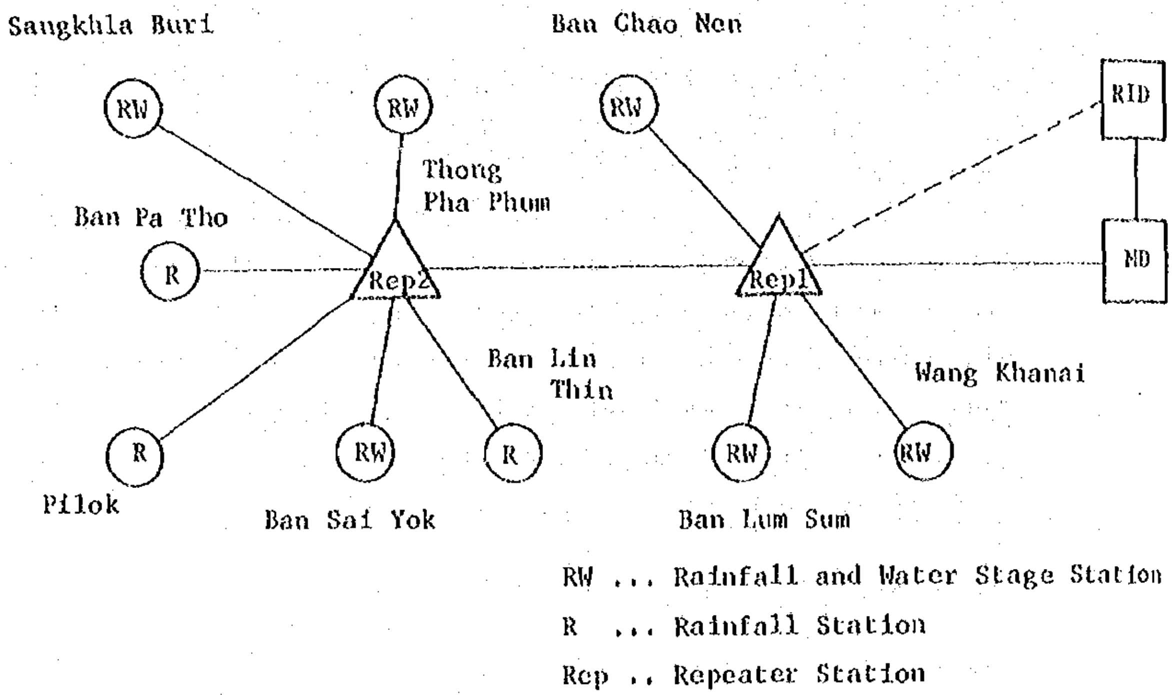
The site presents no problem in circuit design.

7-3 Outline of Proposed Telemetering System

As described above, the proposed telemetering system makes it possible to connect the observation stations in the Mae Klong river basin for automatic transmission of hydrological data to MD or RID.

The telemotering network is shown again in Fig. 7-5 for reference.

Fig. 7-5 Telemetering Network



Each telemetering station will have the equipments and facilities described in Section 2, Chapter 8, and a repeater station will be established in two places.

The master station is set up within MD for control of each telemetering station and collection of hydrological data and, if RID's monitoring station is provided with radio transmitter/receiver and master control equipment, then it will be possible to collect all data directly from R1 and not via MD.

Fig. 7-6 is a graphical illustration of such direct data reception from R1, showing also the equipment composition of the master station (MD) and monitoring station (RID).

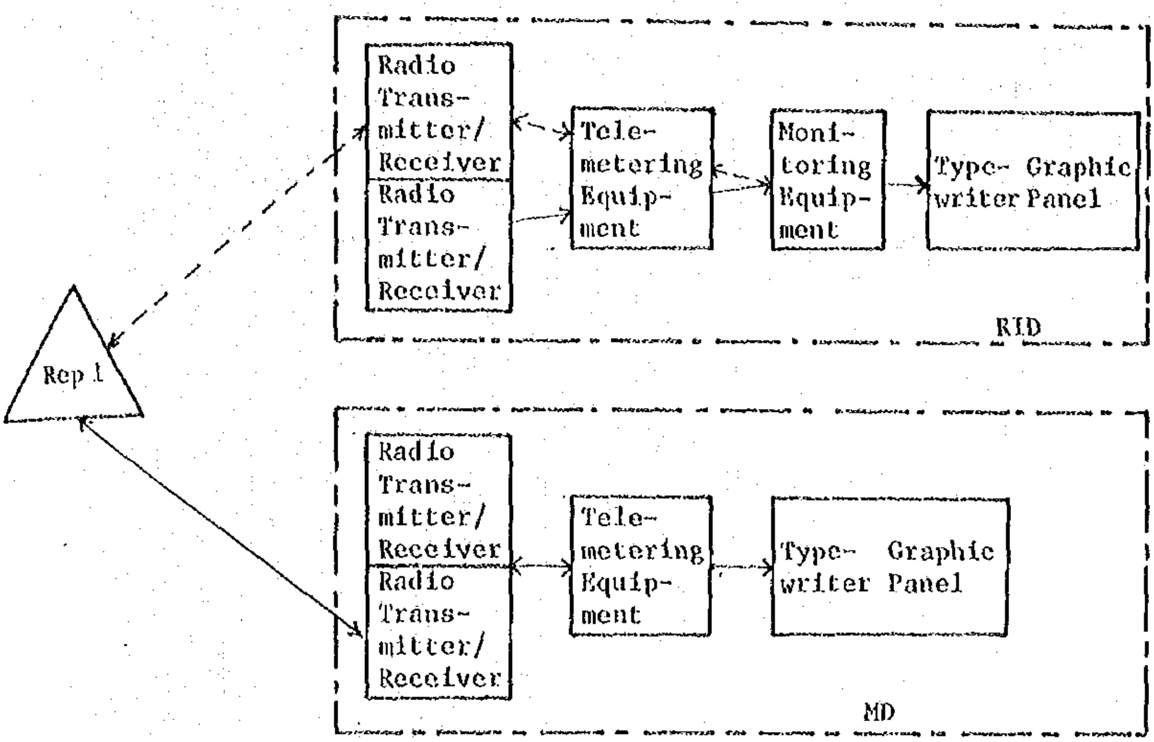


Fig. 7-6 Equipment Composition of MD and RID

The functions and main equipment of each station are shown in Table 7-2 and Fig. 7-7.

As shown in Fig. 7-8, three working frequencies within the band designated by Thai radiowave regulatory authorities are required for the operation of the telemetering system. At present, 80 MHz band (80 ~ 82 MHz, 83.15 ~ 86 MHz) is recommended.

The system is so designed that the master station will have a capacity for accommodating a total of 30 telemetry stations, which is large enough for future installation of additional stations. For the purpose of successful system operation including, among others, smooth station-to-station communication for integrated operation and satisfactory maintenance services, it is advisable that a mobile radio telephone having VHF br radio equipment (same frequency as telemeter, e.g., f1) be set up at the weather station at Kanchanaburi and Thong Pha Phum.

Fig. 7-7 System Configuration

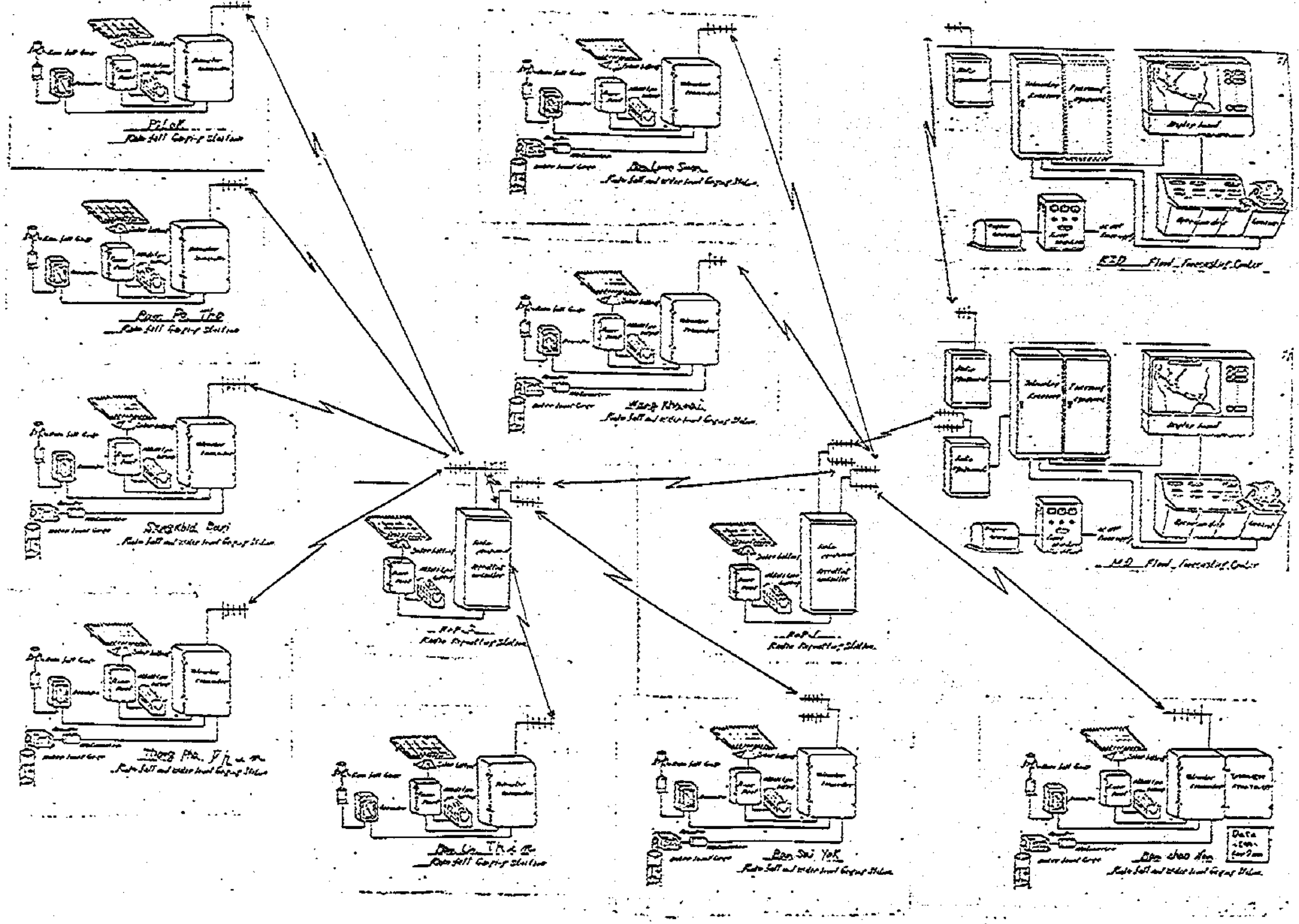
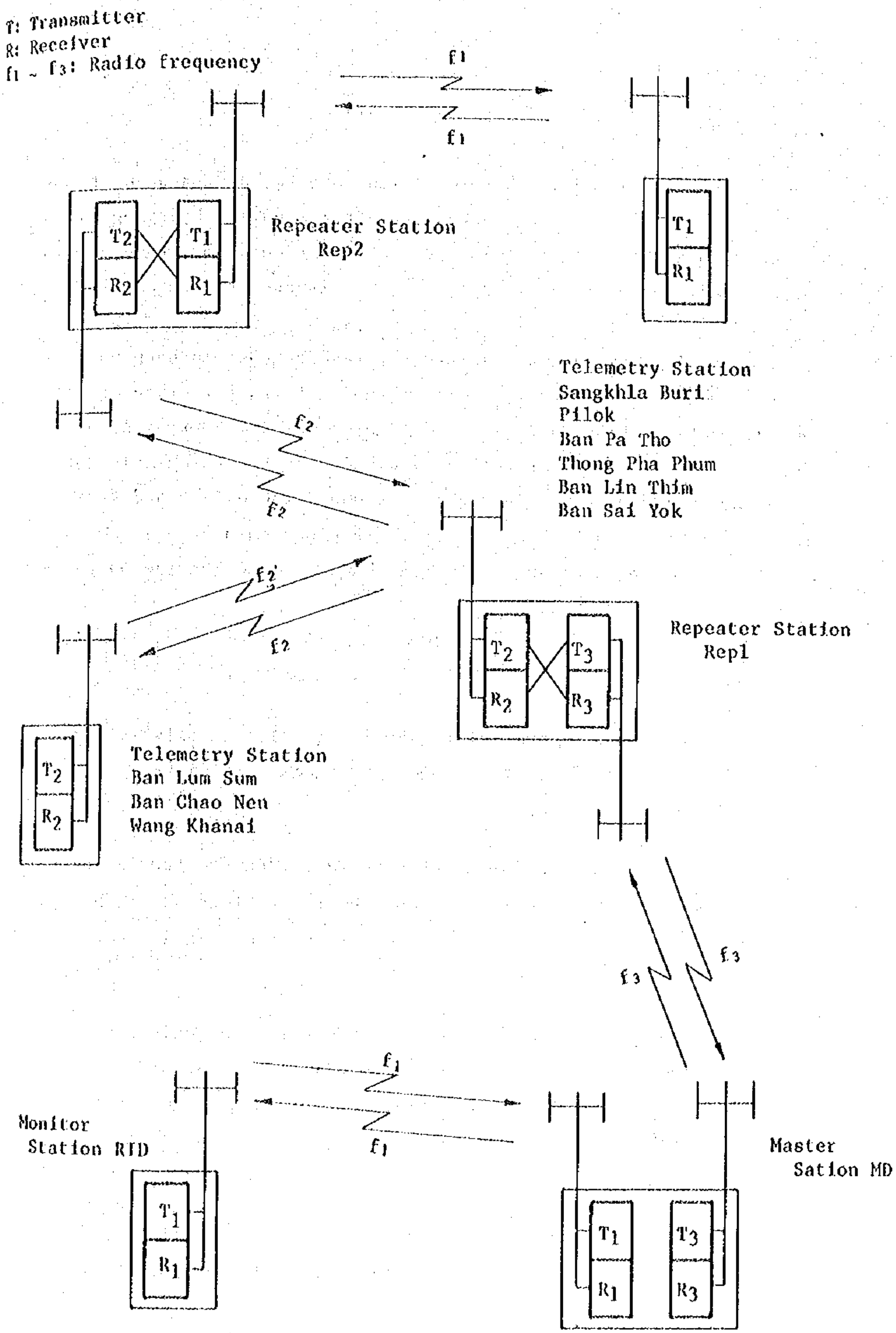


Table 7-2 Functions and Main Equipment of Each Station

Station	Functions	Main Equipment
M D	Master station	• Telemetering Equipment • Graphic panel, etc. • Emergency power supply equipment
RID	Monitoring station	• Telemetry monitoring equipment • Data display panel, etc. • Emergency power supply equipment
Sang Khla Buri	Rainfall and water gauge station	• Rain gauge and water stage gauge • Telemetering equipment • Power supply equipment
Thong Pha Phum	"	"
Ban Sai Yok	"	"
Ban Lum Sum	"	"
Ban Chao Nen	"	"
Wang Khanai	"	"
Ban Phatho	Rainfall station	• Rain gauge • Telemetering equipment • Power supply equipment
Pilok	"	"
Ban Lin Thin	"	"
Rep 1	Repeater station	• Repeater control unit • Power supply equipment
Rep 2	"	"

Fig. 7-8 Radio Repeating System



7-4 Cautions in System Designing

7-4-1 General

Prior to the introduction of telemetering system, a desk plan of the system should be formulated on the map after studying hydrological condition such as observation points and observation items, then a field survey, radio propagation test and other relevant studies should be made.

As telemetering system must satisfy the requirements in both hydrological and telecommunications aspects, its planning calls for close coordination and cooperation of hydrologists and telecommunication experts. It is also necessary to give careful consideration in the formulation of various plans including the maintenance personnel recruiting and training plan, maintenance equipment and materials procurement plan, and consumables supply plan because all these have a close bearing on the successful system operation.

7-4-2 Desk Design

(1) Validity of the circuit configuration (radio transmission route, working frequencies, etc.) should be checked by plotting the whole system plan on the map.

(2) Where a repeater station or stations are required for the design of a workable circuit configuration, their locations should be selected in careful consideration of the entire system plan and ease in maintenance services.

(3) In the subsequent design of telecommunication circuits, all pertinent conditions should be so set as will ensure an S/N ratio of more than 30 dB. Where the attainment of this target is not practicable, the circuit should be so designed that the S/N ratio will be more than 25 dB at least.

(4) Where the design of a stabilized circuit configuration is difficult, originally selected sites of observation stations should be reexam-

ined in collaboration with hydrologists for their relocation in other suitable places satisfying the above S/N requirement.

7-4-3 Field Survey

In the field survey on site conditions, the following items should be covered and confirmed.

1) Site area (to be large enough for construction of station house, erection of antennas, etc.)

2) Freedom from natural disasters such as flood and landslide.

3) Ease in obtaining the landowner's consent.

4) Availability of commercial power source; and cost and stability of power supply from lead-in wire.

5) Annual number of thunderstorm days, and lightning data covering the nerighbouring areas.

6) Meteorological data required for solar battery stations, such as annual average sunshine duration, maximum and minimum atmospheric temperatures, etc.

7) Presence of maintenance road and surrounding conditions.

8) Preparation of sketches of station sites; and photo taking if necessary.

9) Presence of noise sources in the neighbouring areas.

7-4-4 Radio Propagation Test

For the purpose of radio propagation test, radio telephone circuit should be established between respective test points, with antenna radiation direction adjusted suitably. The test should be started with the checking of the actual voice communication condition.

The arrival bearing should be checked against that studied in advance on the map in order to find out if it is the true bearing or represents the bearing of reflected wave. If the devistion from the true bearing is too large, further examination should be made.

7-4-5 Installation of Telemetry Facilities

A brief elucidation is given below on the special cautions to be exercised in in-site installation work of telemetry facilities as well as on the various equipment to be installed at each station.

(1) General Cautions

1) The equipment should be installed in such places that will not be submerged during flood.

2) In order to protect each equipment against lightning damage, due consideration should be given to the installation of lightning arester, connection of ground rods, and connection of grounding terminals. The overall grounding resistance should not be larger than 50Ω.

(2) Master Station (Monitoring Station)

Although the master station is generally designed for attended operation, due account must be taken of the following points for long lasting and fault-free operation of each component equipment.

1) The equipment should preferably be installed in rooms provided with moisture and dust-proof facilities and maintained at a constant temperature.

2) An emergency power supply equipment should be installed to provide against service interruption and encure stabilized equipment operation.

3) If the station is situated in a place liable to inundation, the emergency power supply equipment and all other equipment should be set up on the second or higher floors.

(3) Repeater Station

The repeater station constitutes the nucleus of the radio circuit and is usually built on a mountain summit or other high places for unattended operation. For its long-lasting and fault-free operation, therefore, careful prior study should be made to fill the following requirements.

1) The structure of station hause is designed after studying the climatic condition in the surrounding areas and can amply withstand storms and heavy local rains.

2) A maintenance road (preferably permitting passage of motorcars) is constructed as far as the station.

3) The station site is free from hydraulic jump, landslide, or other adverse influences of rainfall.

4) Sufficient care is taken of lightning prevention and earth quak-proof structure.

5) The lightning conductor is large enough in diameter, and ground rods are connected with each other by grounding bus bar.

(4) Observation (Signalling) Station

Since the observation station is usually designed for unattended operation, the following cautions should be exercised in the construction of station house and in the installation of each equipment.

1) The structure of the station house should be designed after studying the climatic condition in the surrounding area, and should be capable of withstanding storms and local heavy rains.

2) The station site should be free from landslide resulting from poor drainage of rainwater.

3) In order to minimize errors in rainfall gauging, the rain gauge should be set up in a place completely clear of any obstacles

such as trees and buildings in the air above it within an angle of 45° apart from the perpendiular rising therefrom. In case the gauge is to be installed on a mountain side, it is also necessary to pay attention to the wind direction.

4) Ventilating holes or other suitable ventilating devices should be provided to prevent moisture intrusion in order to protect the equipment from rust development due to droplets collecting on the ceiling and walls.

5) If the water stage gauge is set up in a place far from the station house and a wire line is required to connect them, adequate measures should be taken against lightning damage.

7-4-6 Protection against Lightning

As telemetering equipment are one of those electronic devices operating at low voltages, they are highly vulnerable to failures due to abnormal voltages. It is therefore important to minimize the occurrence of induced lightning. Damage due to induced lightning can be mitigated to a substantial degree if proper attention is exercised in fitting the lightning arrester and in grounding.

(1) Lightning Arrester

The following are the main intrusion paths of lightning current into telemetering equipment.

1) Antenna system

2) Commercial power lead-in wire

3) Signal line connecting gauge and sensor if they are separated.

The following measures should be taken for these three paths.

1) Insertion of a coaxial lightning arrester against intrusion through antenna system (preferably for D.C. by direct grounding).

2) Insertion of a combination of anti-lightning transformer and arrester against intrusion through commercial power lead-in wire.

3) Insertion of a cable protector against intrusion through signal line. If the line is excessively long or laid in places subjected to frequent lightning, it is commendable to transmit the data signal by A.C. method. In this case, too, the use of high lightning-resistant transformer and cable protector is necessary.

(2) Grounding

For protection of telemetering stations against lightning damage, it is necessary to install a lightning arrester and carry out the grounding work perfectly to ensure its effective functioning (See Fig. 7-9).

The following are the cautions to be observed in the grounding work.

1) Ground rods should be buried under ground in a number of places within the station compound. Then, the buried ground rods should be interconnected securely by the grounding bus line which is a stranded annealed copper cable having a size of more than 22 mm^2.

2) Grounding resistance should be made as low as possible. The number and burying depth of ground rods should be so determined as will make the resistance lower than 50Ω.

3) It should be noted that no grounding effect can be yielded unless the distance between adjoining rods is greater than the buried depth of the rods.

4) A ring grounding conductor should be laid within the station and connected with the grounding bus line in a number of places. The earth terminal of each equipment in the station should be connected securely with the ring conductor with a shortest possible distance.

Connection of grounding lines should preferably be performed by Thermit welding.

5) The equipment installed outside the station building should be grounded in their respective places, and should also be connected with the ring conductor by a connecting cable (not the signal line connecting the equipment and the station).

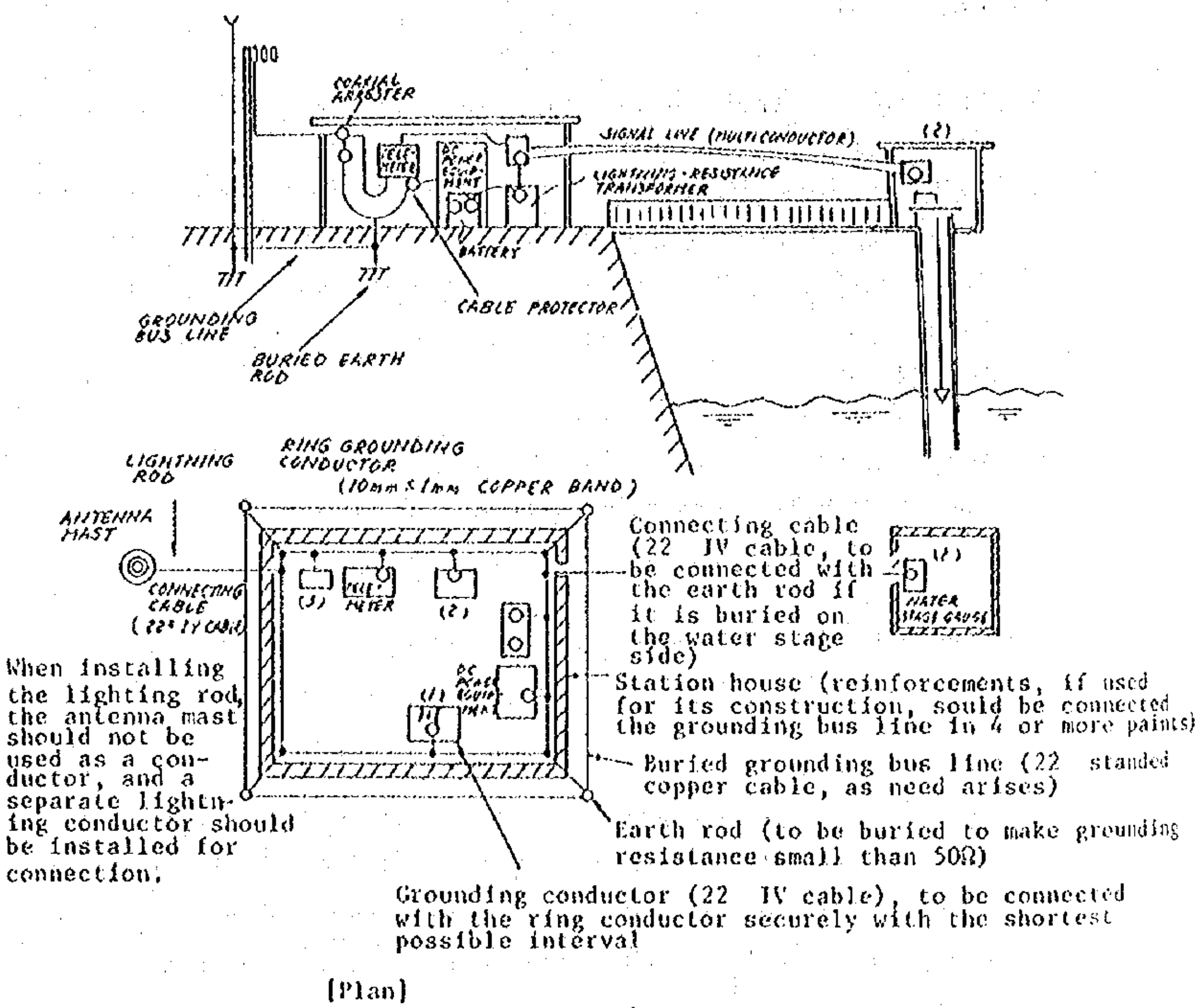


Fig. 7-9 Example of Grounding Work

CHAPTER 8 EQUIPMENT CONFIGURATION AND SPECIFICATIONS

8-1 Observation (Gauging) Facilities

8-1-1 Rain Gauge

The rain gauge will be tipping bucket type and installed on the roof. As to where the gauge is to be installed in Ban Chao Nen Dam area will be determined later at a discussion meeting with Thai authorities. If a rain gauge is to be installed as part of the dam construction project, it is advisable to use it concurrenly for telemetering purpose.

8-1-2 Water Stage Gauge

It is advisable to use the bubble type gauge which has already been in use at Ban Lum Sum station, as it calls for no auxiliary facilities. As regards Ban Chao Nen station, if a water stage gauge is to be installed as part of the dam construction project, it is advisable to use it for telemetering purpose as well.

8-1-3 Discharge from Dam

It is considered possible to obtain the discharge data of Ban Chao Nen Dam (preferably the discharge from the regulating reservoir to be constructed downstream of the dam) for transmission by the telemetry equipment at Ban Chao Nen station.

8-2 Station Building

8-2-1 Observation Station

Type B house with a space of 2.5 × 2.5 m shown in Fig. 8-1 is recommended for rainfall and water stage stations, and type A house with a space of 1.8 × 1.8 m shown also in Fig. 8-1 for rainfall stations.

8-2-2 Repeater Station

The repeater station should have an accommodation space for maintenance personnel. Fig. 8-2 shows an example of repeater station house. Special care must be taken of ventilation and insect control by fly screen.

8-2-3 Master Station

The master station should preferably have a flood forecasting room in addition to a machinery room where telemetering and other equipment are to be installed. Fig. 8-3 shows an example of master station house.

The station should also have a space shown in Fig. 8-4 for installation of an engine generator.

8-2-4 Monitoring Station

Same as master station.

Fig. 8-1 Station House

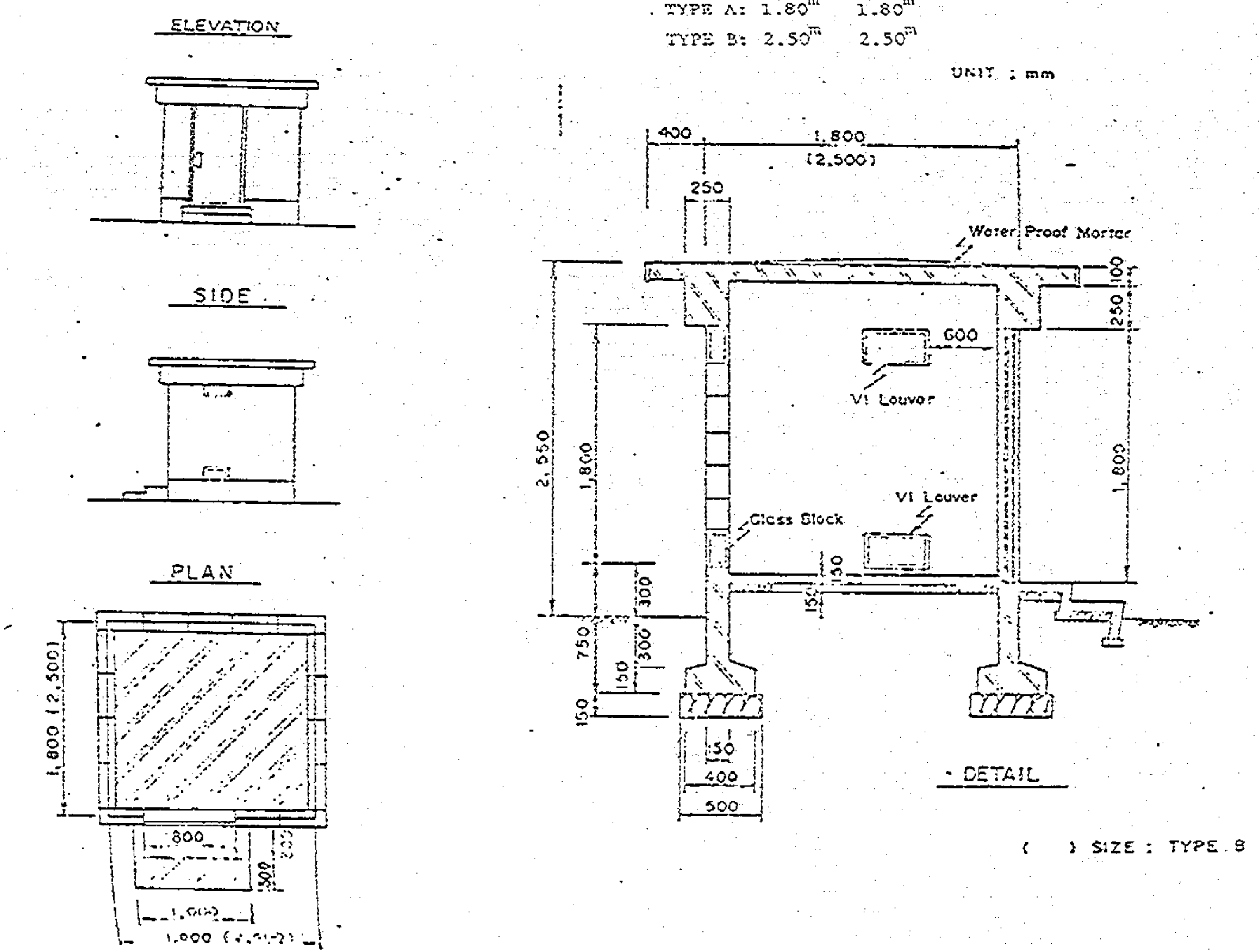


Fig. 8-2 Repeater Station House

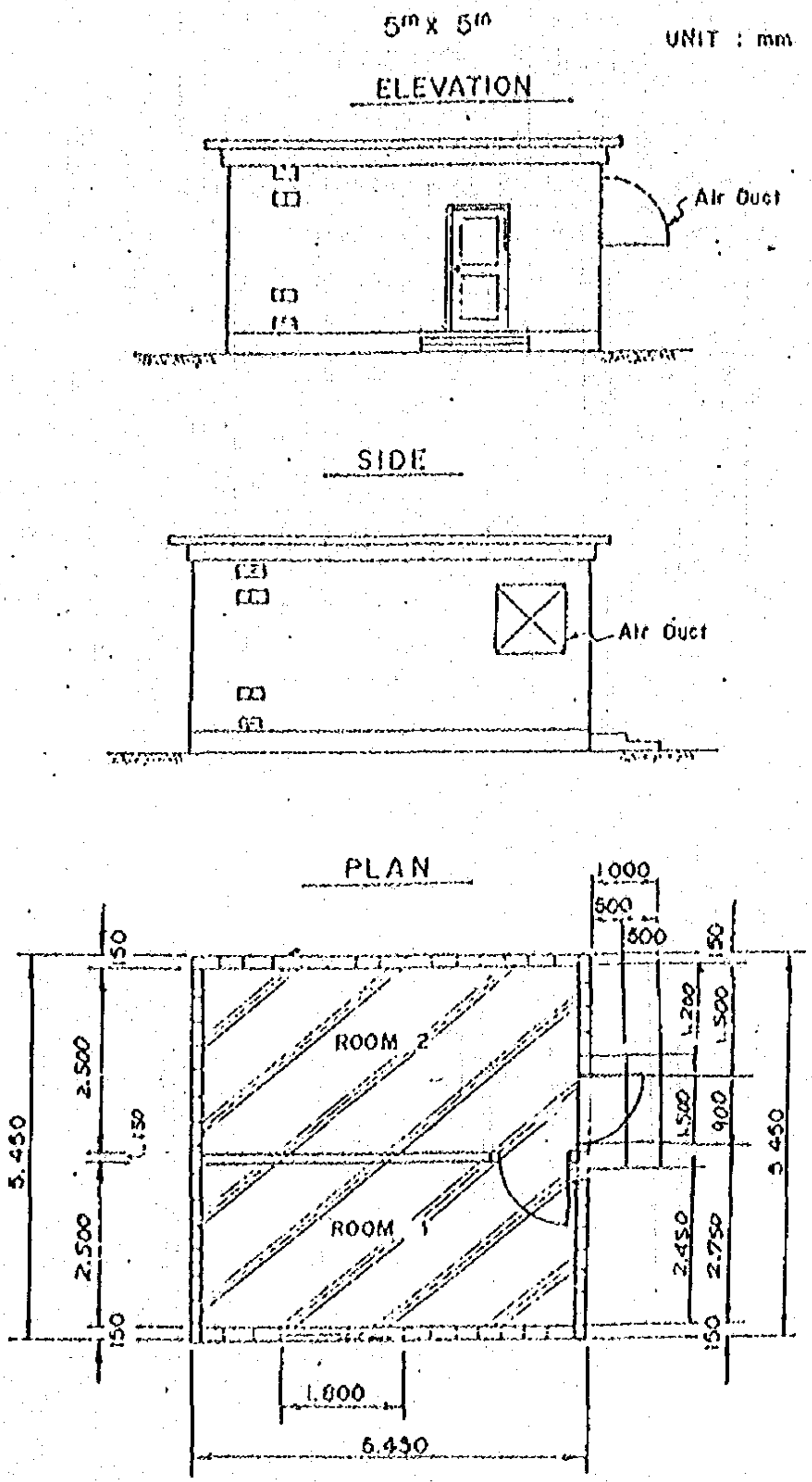
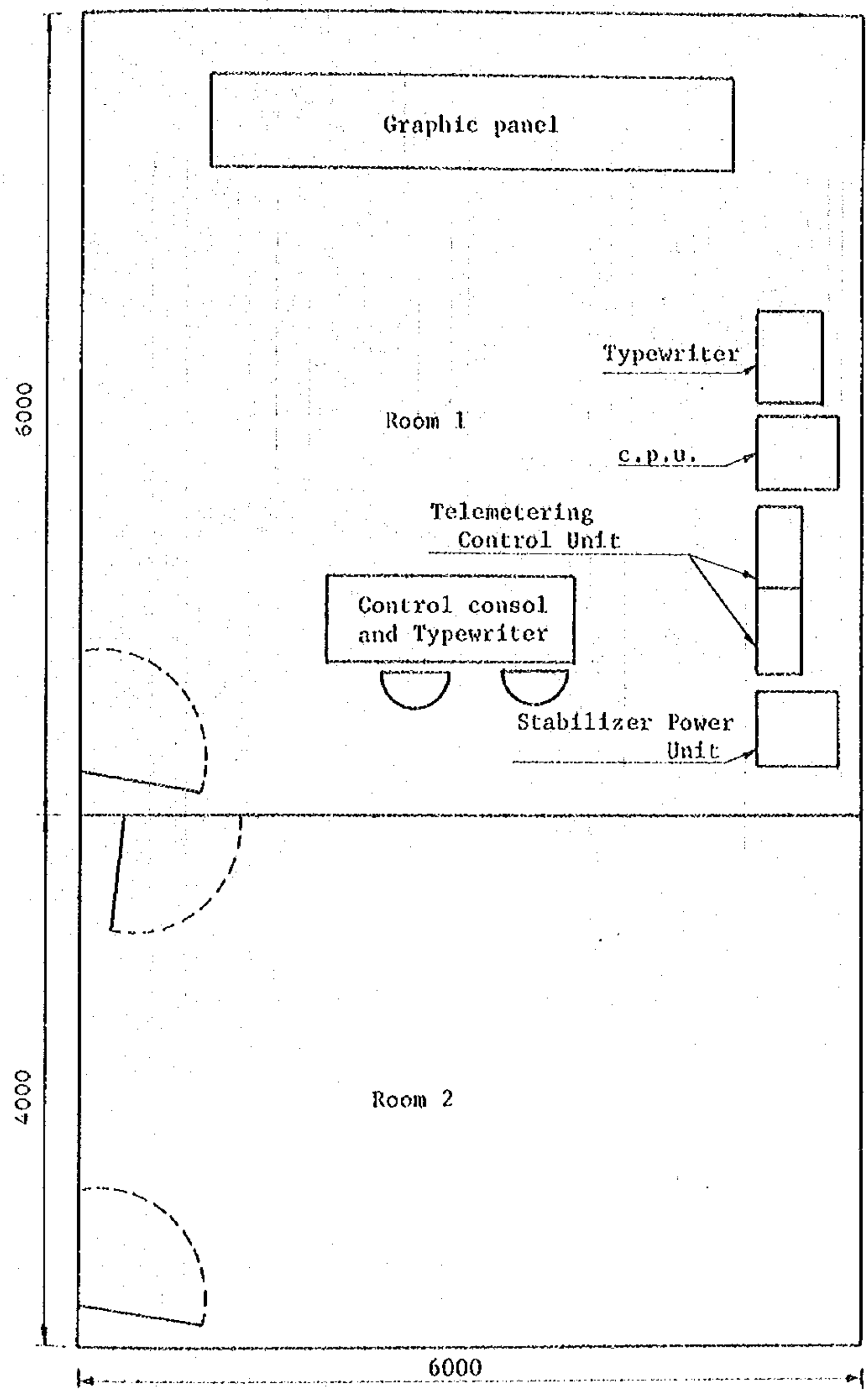


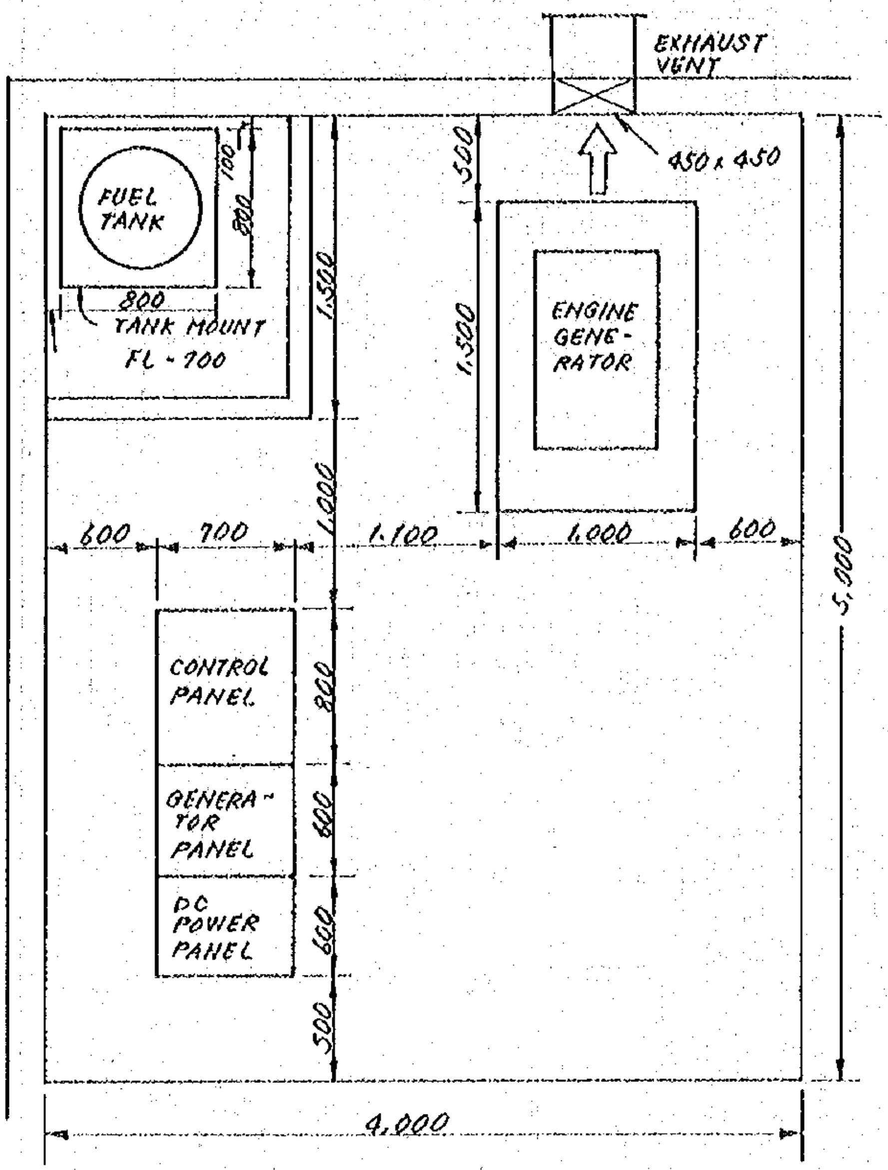
Fig. 8-3 Flood Forecasting Room of Master Station

Unit : mm



1. The floor of room 1 will be of free access type of 15 cm height.
2. A glazed partition will be provided between the two rooms.

Fig. 8-4 Emergency Power Supply Equipment Room



8-3 Antenna Mast

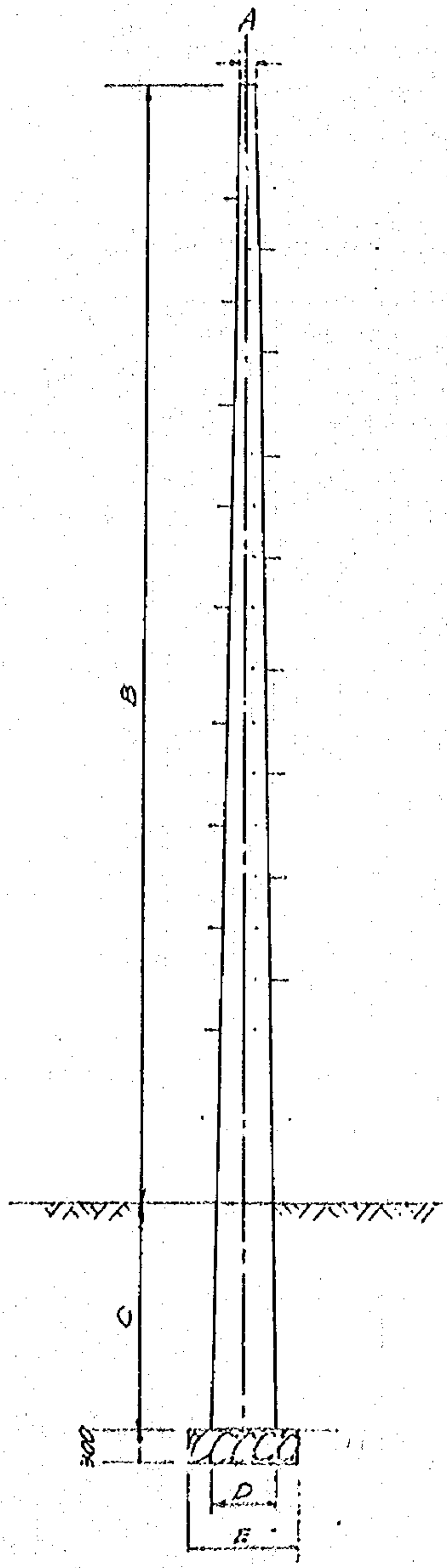
Either taper steel pole (panzer mast) or triangular tower (tripole) will be used. Table 8-1 shows the type of mast for each station, and Figs. 8-5 ∿ 8-7 illustrate the two types of mast.

Table 8-1 Type of Antenna Mast by Station

Station	Taper Steel Pole 10m	Taper Steel Pole 20m	Triangular Tower 30m	Triangular Tower 10m	Remarks
MD				1	To be erected on the roof of station house
RID			1		
Ban Chao Nen		1			
Ban Lum Sum			1		
Pilok		1			
Ban Patho		1			
Ban Sai Yok			1		
Sang Khla Buri	1				
Wang Khanai	1				
Thong Pha Phum	1				
Ban Lin Thin		1			
Kanchana Buri office	1				
Thong Pha Phum, office	1				
Rep 1	2				
Rep 2	2				
Total	9	4	3	1	

Fig. 8-5 Taper Steel Pole

Unit : mm



Height / Section	10M	20M
A	171	171
B	9,860	19,100
C	1,980	2,500
D	427	683
E	600	800

Fig. 8-6 Triangular Tower, H = 30 M

Unit : mm

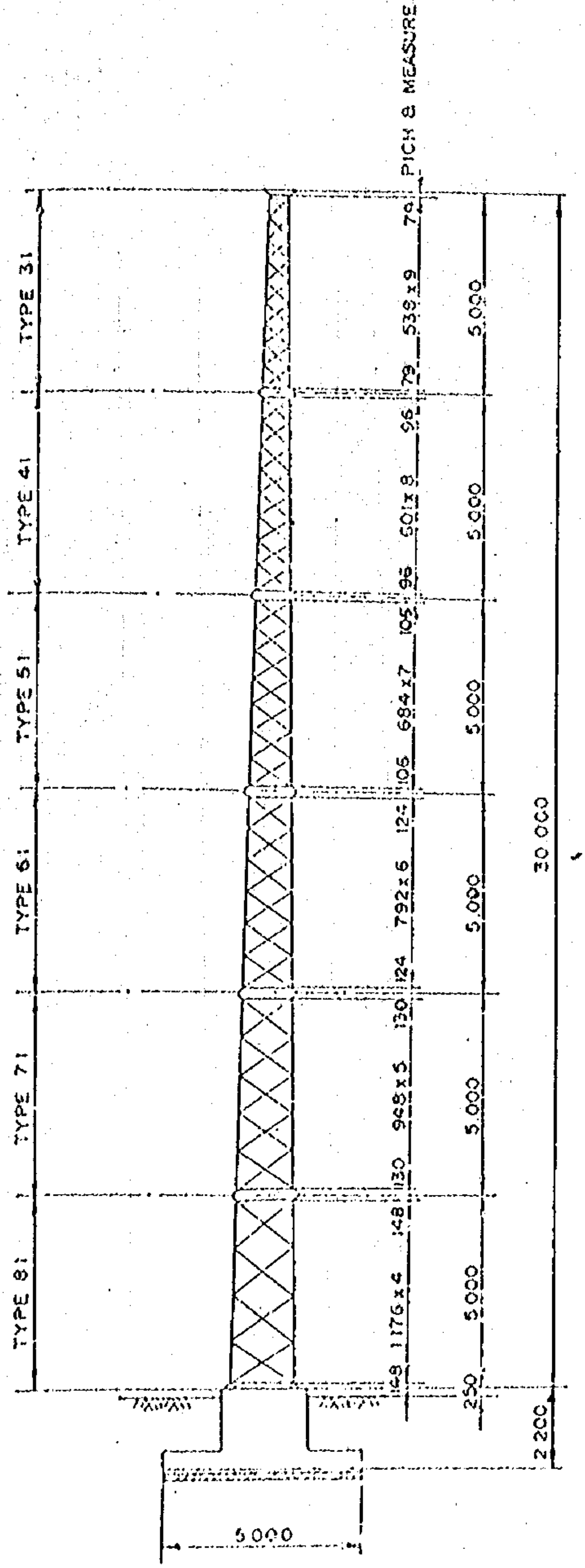
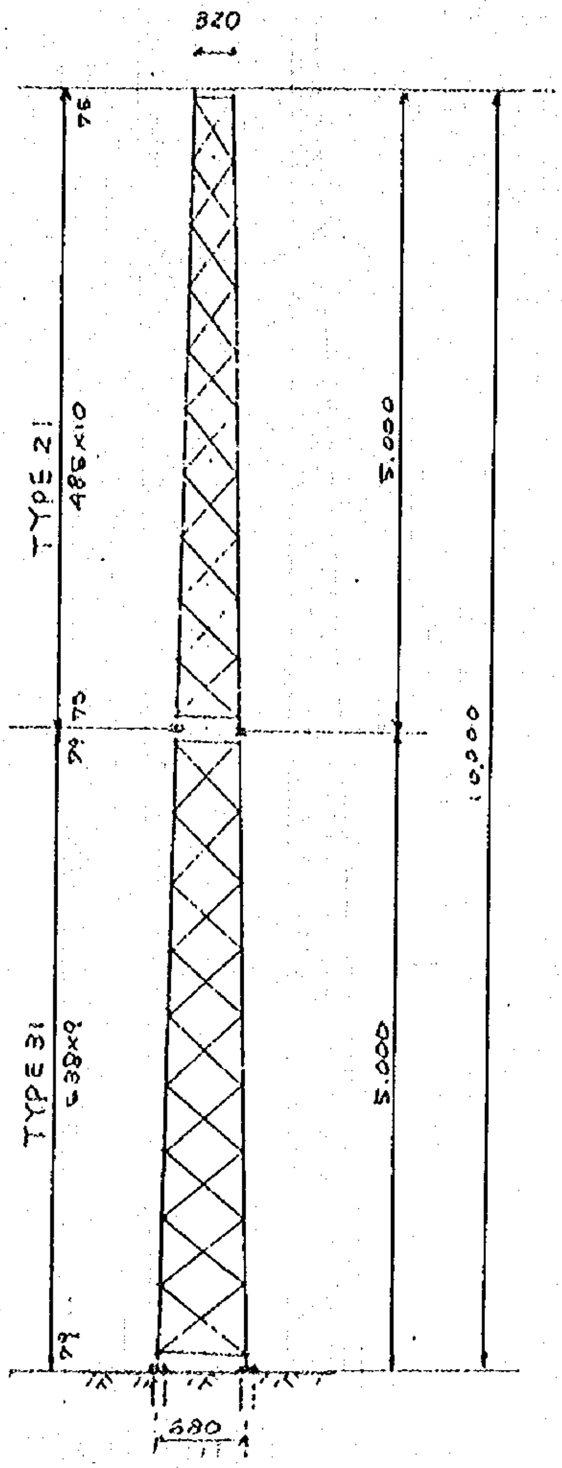


Fig. 8-7 Triangular Tower, H = 10 M

Unit : mm



8-4 Telecommunication Equipment

The telecommunication equipment to be installed at each station are shown in Table 8-2.

Table 8-2 Specifications and Quantities of Telecommunication Equipment

No.	Equipment	Specification	Master Station	Monitoring Station	Rep 1	Rep 2	Sangkhla Buri(WR)	Ban Pa Tho (R)	Pilok (R)	Thong Pha Phum (WR)	Ban Lin Thin(R)	Ban Sai Yok(WR)	Ban Lum Sum(WR)	Ban Chao Nen(WRQ)	Wang Khanai(WR)	Thong Pha Phum	Kanchana Buri	Total
1	Telemetry Control Unit, Type A	Standard Type, 16/30	1															1
2	" " , Type B	Standard type + Monitor		1														1
3	Control Desk	Console type	1															1
4	Typewriter		1	1														2
5	Data Processor		1															1
6	Forecasting Calculator	Desk-top type	1															1
7	Graphic Panel	Self-supporting type	1															1
8	Data Display Panel	Wall-mount type		1														1
9	Signalling Equipment	Single value type						1	1		1			1				4
10	" "	Multi-value type					1			1		1	1	1	1			6
11	Rain Gauge	Rain gauge, w/automatic recorder and A/D convertor					1	1	1	1	1	1	1	1	1			9
12	Water Stage Gauge	Water stage gauge, w/ " " " " "					1			1		1	1	1	1			6
13	Repeating Equipment				1	1												
14	Radio Equipment	80 MHz band, 10 W, for telemetering	1	1	4	4	1	1	1			1	1	1				16
15	" "	" " " , 1 W, "	1	1						1	1				1			5
16	Radio Telephone Equipment	80 MHz band, 10 W, fixed type														1	1	2
17	Portable Radio Equipment	80 MHz, 10 W, w/power equipment, antenna, battery, etc.	1	1												1	1	4
18	Antenna	80 MHz, Yagi 3-element, w/ coaxial lightning arrester	1	1			1	1		1	1				1	1	1	9
19	"	" , Yagi 3-element bi-directional, "				1												1
20	Antenna	80 MHz, Yagi 5-element, w/ coaxial lightning arrester										1		1				2
21	"	" , Yagi 5-element, stack, " " "	1	1	2	1							1					7
22	Engine Generator	10 kVA, automatic	1	1														2
23	Automatic Voltage Regulator	5 kVA	1	1														2
24	DC Power Equipment	Rectifier unit - 12 V, 10 A; alkali rebattery - 50 AH												1		1	1	3
25	Solar Cell Power Equipment	Solar cell - 12 V, 63 W; alkali rebattery - 600 AH			1	1												2
26	" "	" - 12 V, 7 W; " - 50 AH					1	1	1	1	1	1	1	1	1			9
27	Accessories and Spare Parts		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
28	Communication Cable	Self-supporting type, 0.9 mm², 12 cores, 1,000 m												1				1

8-5 Special Conditions at Ban Chao Nen Dam

8-5-1 Location of Transmitting and Receiving Station

Due to the difficulty in setting up a radio circuit between the dam site and R1, it planned that gauging and signalling equipment alone will be installed at the dam site. As for the installation site of radio equipment, a point near the existing radio station of EGAT covered by the propagation test was selected as it makes it feasible to include Ban Chao Nen station in the circuit configuration.

The gauging and signalling equipment and the radio equipment will be connected by wire line. The block diagram of Ban Chao Nen Dam station is as shown below.

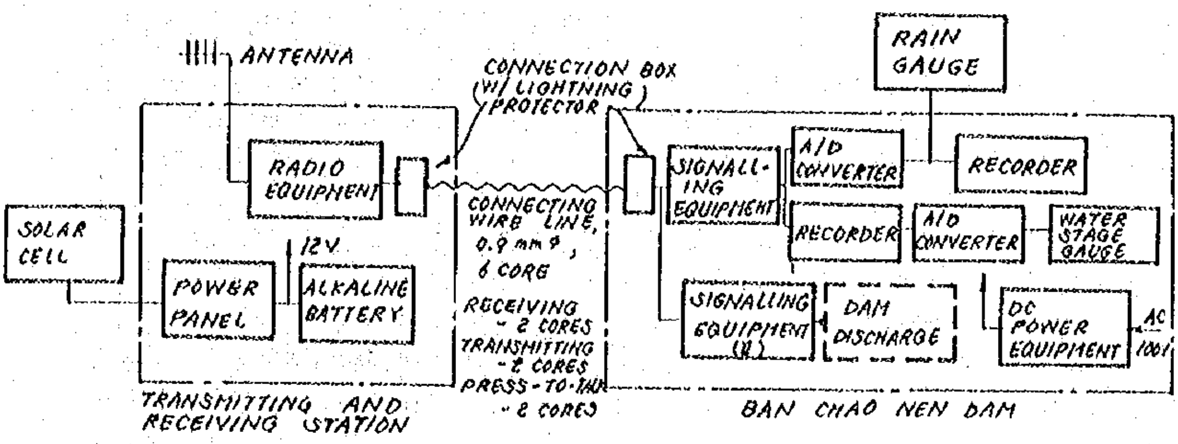


Fig 8-8 Block diagram of Ban Chao Nen Dam Station

8-5-2 Dam Discharge Data

The following are the particulars of the discharge data of Ban Chao Nen dam mentioned in Section 8-1-3 and the electric conditions for their transfer to the signalling equipment.

(1) Discharge Data

1) Discharge

Newest discharge data computed by the discharge computer which is expected to be installed at the dam.

2) Range and Minimum Unit

0 ~ 9999 m^3/s (4 digits), 1 m^3/s

(2) Electric Conditions

1) Output : No-voltage make contact

2) Code format : BCD code (4-digit) with odd number parity bit for each digit

3) Response time : Less than 1 sec (from reception of command to data transfer to signalling equipment)

4) Data holding time : Continuous until gauging command is cleared

8-6 Specifications of Telecommunication Equipment

The explanation given in the following sub-sections (8-6-1 ~ 8-6-22) cover the telecommunication equipment to be incorporated in the proposed telemetering system which are listed in Specifications of Japanese Ministry of Construction (See Appendix; hereafter called the "Standard Specification") as well as those equipment which are to be listed in the Special Specifications according to the annotations given in the Standard Specifications.

8-6-1 Telemetry Control Equipment Type A

(1) Outline

1) This equipment will be installed at MD for control of telemetering stations and repeater stations. It is required to exhibit the functions and performance stipulated in Section 3-1-2-1) of Standard Specifications.

2) Capacity and Coverage

The equipment will have a control capacity of 30 values which will be distributed as follows.

Telemetering stations

Rainfall stations	3 values	(3 stations)	}	16 values (9 stations)
Rainfall and water stage stations	10 "	(5 ")	}	
Rainfall, water stage and discharge station (Ban Chao Nen)	3 "	(1 ")	}	
Repeater stations				2 " (2 stations)

3) Additional Functions

The equipment will have the following additional functions which are stipulated in Section 3-1-3 of the Standard Specifications.

a. Data output to data processer.

b. Branching of received signal output to telemetry control equipment type B installed at RID.

c. Repeater control.

8-6-2 Telemetry Control Equipment Type B

(1) Outline

This equipment will be installed at RID. It is designed to exhibit the monitoring function (data recording by reception of signals transmitted from these stations which are under the control of other control station) in addition to the functions of type A control unit.

Besides exhibiting this monitoring function which is stipulated in Section 3-4 of the Standard Specifications, it can be changed over to perform the functions of type A control unit.

(2) Capacity and Coverage

Same as type A control unit.

(3) Operational Relationship with Type A Telemetering Equipment.

Under normal service condition, the equipment will be used for monitoring signals transmitted from telemetering stations through and under the control of type A telemetering equipment at MD. Where necessary, however, it may be changed over to exhibit the control functions (of type A unit) after making prior arrangements between RID and MD.

8-6-3 Data Processing Equipment

(1) Outline

This equipment is designed for diverse processing of output data from type A telemetering equipment. The processed data are printed for recording, and part of them are displayed on the graphic panel.

(2) Contents of Data Processing

1) Rainfall Data

a.	Computation of	hourly rainfall	9/15	values
b.	"	daily rainfall	"	"
c.	"	accumulated rainfall	"	"
d.	"	preceding 7 days rainfall	"	"
e.	"	preceding 8 days rainfall	"	"
f.	"	preceding 9 days rainfall	"	"

g.	Computation of	preceding 15 days rainfall	9/15 values
h.	"	preceding 1 month rainfall	" "
i.	"	average hourly rainfall in the basin	1 value
j.	"	average daily rainfall in the basin	"
k.	"	average 1 week rainfall in the basin	"
l.	"	average 15 days rainfall in the basin	"
m.	"	average 1 month rainfall in the basin	"

2) Water Stage Data

a.	Computation of average daily water stage	6/10 values
b.	Judgement of water level rising to specified stage	"
c.	Judgement of water level rising to warning stage	"

3) Discharge Data

Computation of discharge by H-Q method (quadratic equation) — 2/10 values

4) Information output to the graphic display

The data processor will be capable of processing and furnishing the following data for the graphic display.

Information listed in Items (2)-1)-a. ~ c., i. ~ k., m, (2)-2)-a. ~ c., and (2)-3), water stage at each gauging station, and discharge from Ban Chao Nen Dam.

(3) Equipment Specifications

The data processing equipment will be composed of processor and typewriter and have the following main specifications.

1) Data Processor

a. Type	:	Stored program digital computer
b. Memory elements	:	Magnetic core memory and semiconductor memory
c. Cycle time	:	Magnetic core 650 ns
d. Maximum memory capacity	:	65 K byte
e. Operation elements	:	TTL/MSI
f. Operation time	:	Addition and subtraction - 3.15 μs Multiplication and division - 14.7 μs
g. Addressing system	:	Direct, relative and indexing
h. Number of registors	:	8
i. Interrupting level	:	Internal and external
j. Additional functions	:	Memory protection, and power source abnormality interrupting and restarting
k. Power ratings	:	AC 100 V, 1 P, 50 Hz, 0.8 KVA

2) Typewriter

(Printing Unit)

a. Character	:	Alphabet, numerals, and general symbols
b. Printing speed	:	600 characters/min
c. Number of characters per line	:	136
d. Printing pitch	:	10 characters/25.4 mm
e. Code	:	ISO code

(Paper Tape Read-out Unit)

f. Read-out speed	:	600 characters/min

g. Number of units : 8

(Paper Tape Punch Unit)

h. Punching speed : 600 characters/min

i. Number of units : 8

j. Power ratings : AC, 220 V, 1 P, 50 Hz, 0.3 KVA

8-6-4 Flood Forecasting Calculator

(1) Outline

This will be a single purpose calculator designed for calculation of forecasted discharge by manual input of necessary data of the basin in question. It will be composed of calculator and printer-plotter.

(2) Calculator Proper

The calculator proper will consist of keyboard, arithmetic unit, cassettee storage unit, input/output unit, and extended memory unit, and will have the following main specifications.

1) Memory capacity : 12 kW

2) Number of digits : Mantissa 12 digits + exponent 2 digits (floating point arithmetic)

(3) Printer-Plotter

The printer-plotter will be designed for recording the output data from the calculater proper and will be capable of printing and plotting numerals, characters and symbols. It will have the following main specifications.

1) Printing format : Impact type printing

2) Number of characters : Max. 132 characters/line

3) Recording paper : Max. width - 381 mm

4) Plotting range : Y-axis optional, X-axis 335.3 mm

(4) Power Ratings

AC, 220 V, 1ϕ, 50 Hz

8-6-5 Control Desk

(1) Outline

The control desk will be designed for operation and data display of type A telemetry control equipment, and have the functions stipulated in Section 3-1-2-2) of the Standard Specifications.

(2) Structure

The control desk will be steel plate console type having a refined appearance as well as an easy-to-handle structure designed from a viewpoint of human engineering. In order to prevent it from any inadvertent and errorneous operation, its pushbuttons and switches will have covers.

8-6-6 Typewriter

The typewriter will be used for printing and recording observation data and power information as stipulated in Section 3-1-2-3) of the Standard Specifications. It will have a carriage length of 24 inches, a case and a stand.

8-6-7 Radio Equipment

The radio equipment will be used at the master station, monitoring station, repeater stations and gauging stations, and satisfy the requirements stipulated in Section 3-1-2-4) of the Standard Specifications.

The following two items are designated for its operation.

1) Frequency : 1 in 80 MHz band (same frequency for both transmitting and receiving)

2) Antenna power : 10 W or 1 W (Refer to Table 8-2 for antenna power of each station)

8-6-8 Antenna System

The antenna system will comprise antenna and coaxial lightning arrester, and satisfy the functional requirements stipulated in Section 3-1-2-5) of the Standard Specifications.

The following two items are designated for its operation.

1) Frequency : Same as preceding section.

2) Type and configuration : See Table 8-2.

8-6-9 Clock

The clock will be used for control of the telemetry control equipment (types A and B), and will satisfy the functional requirements stipulated in Section 3-1-2-6) of the Standard Specifications.

8-6-10 Graphic Display Panel

(1) Outline

The graphic display panel will be used for displaying, in numerical values and by indicator lamps, the various data and information received from the data processor.

(2) Composition

The panel will be composed of map unit and data display unit.

(3) Structure

The panel will be a steel cabinet of stand-alone type capable of being divided according to need.

(4) Map Unit

1) The map unit will be an acryl resin or other resin acreen on which the Macklong river basin is drawn in colour on the specified scale.

2) The map will bear main roads, main geographic names, dams and basin borders as well as rivers, all drawn in colour. Each station will be indicated by a lamp on the map, with its name also entered.

3) The unit will have a square electric clock which will receive drive signals from the telemetry control equipment.

(5) Data Display Unit

1) The data display unit will consist of station display part (illumination type) and data display part (incl. reference information).

2) The contents of display will be as follows.

a. Gauging time — Month, day, hour and minutes (6 digits)

b. Display data by station

(Rainfall)

Station name		15 values
Data	- Hourly rainfall and accumulated rainfall	

(Water stage)

Station name		10 values
Data	- Ovserved stage, and time of reaching designated stage and warning stage	

(Discharge)

Station name	- (Ban Chao Nen Dam)	1 value
Data	- Discharge at Ban Chao Nen	
Station name		4 values
Data	- Discharge obtained by H-Q calculation method	

c. Data of whole basin

o "Average daily rainfall in the basin" and its data	1 value
o "Average rainfall in the basin in the preceding 1 week" and its data	1 value
o "Average rainfall in the basin in the preceding 1 month" and its data	1 value

8-6-11 Data Display Panel

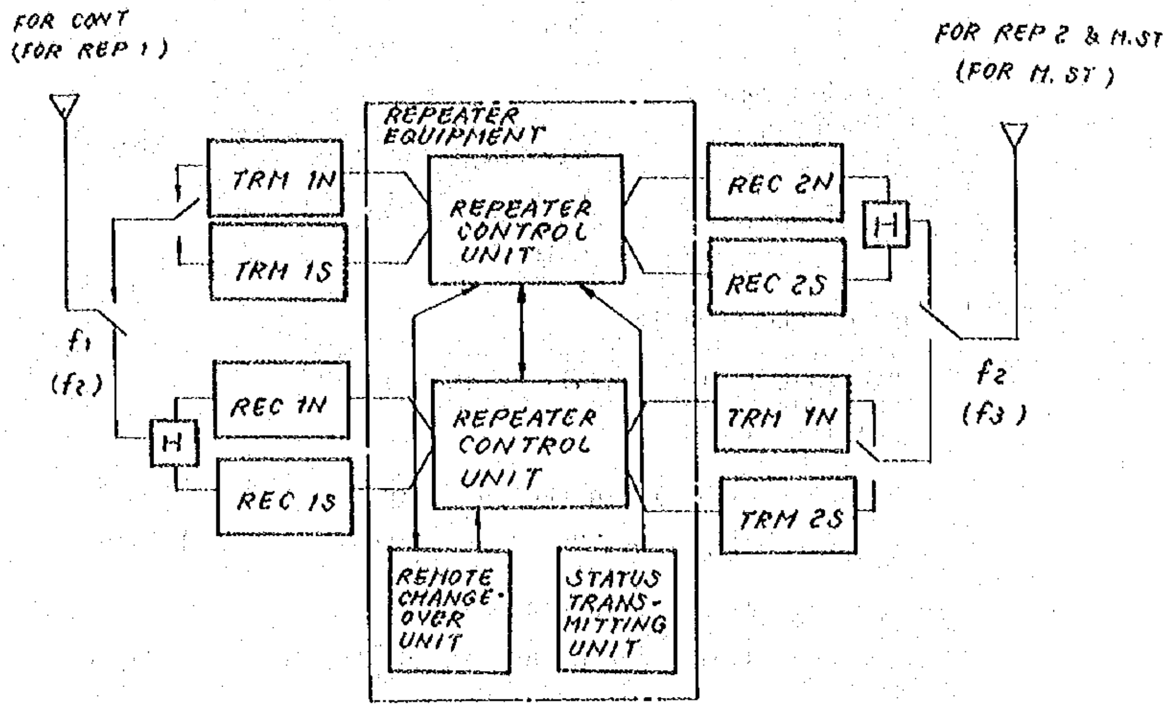
(1) The data display panel will display the data received from type B telemetry control equipment, and will consist of station display unit (illumination type) which indicates each station and data display unit which indicates each data. It will be a steel plate-made panel of wall-mount type.

(2) The content of display will be as follows.

Gauging time	Month, day, hour and minutes (6 digits)	1 value
Station name	(15 rainfall stations, 10 water stage stations, and 5 discharge stations)	30 values
Data	Rainfall -3 digits, 15 values Water stage - 4 digits, 10 values Discharge-4 digits, 5 values	30 values

8-6-12 Repeater Equipment

(1) The repeater equipment will have a configuration shown below.



(2) Repeater Control Unit

The repeater control unit will repeat received output data and will also have the function of detecting failures in receivers and transmitters for their automatic changeover. Receivers on both sides will be capable of receiving repeating-start and repeating-stop signals.

(3) Remote-Changeover Unit

The remote-changeover unit will perform the function of changing over transmitters by control signal received from the master station.

(4) Status Transmitting Unit

The status transmitting unit will transmit the repeater operational status (failure development in receivers and transmitters, and service condition of working transmitters and power supply equipment) to the master station.

(5) The repeater equipment will satisfy the functional requirements stipulated in Section 3-3 of the Standard Specifications.

8-6-13 Telemetering Equipment

(1) Outline

The telemetering equipment will, upon reception of calling signal from the master station, send out the data and information measured by the gauging equipment, and will satisfy the functional requirements stipulated in Section 3-2-2 of the Standard Specifications.

(2) Additional Functions

The following additional functions will be provided.

1) Those installed at rainfall and water stage stations will be of multi-value type.

2) Power information will be transmitted as special information.

3) Ban Chao Nen station will use two sets of equipment, the single-value type and the multi-value type. The multi-type equipment will be used for transmission of water stage and rainfall data, and the single-value type for transmission of dam discharge.

8-6-14 Rainfall Gauging Equipment

(1) Outline

The rainfall gauging equipment will gauge rainfall, transmit it to the telemetering equipment in digital code, and record it for itself.

It will consist of rain gauge, automatic recorder, and A/D converter.

(2) Rain Gauge

The rain gauge will be composed of receiver and gauging mechanism, and will have the following main specifications.

1) The receiver will have a diameter of 200 mm.

2) The gauging mechanism will transmit make signal at each 1 mm of rainfall, and will be accommodated in the receiver.

(3) A/D Converter

The A/D Converter will convert the rainfall depth to digital value in hundreds by the make signal received from the rain gauge, and will be accommodated in the telemetering equipment.

(4) Automatic Recorder

The automatic recorder will be a contact type recorder operating by the make contact of rain gauge, and will have the following main specifications.

Recording period	:	3 months
Drive system	:	Spring-clock drive
Recording system	:	Automatic zero point resetting after each 100 contacts, 1 mm per division, 100 mm per line
Power ratings	:	DC 12 V (dry battery)

(5) Accessories and Spare Parts

Recording paper	:	10 rolls
Ink, dropper, spare pen	:	2 each

8-6-15 Water Stage Gauging Equipment

(1) Outline

The water stage gauging equipment will gauge water stage, transmit the measured value to the telemetering equipment in digital code, and record it for itself. It will consist of water stage gauge, automatic recorder, and A/D converter.

(2) Water Stage Gauge

The water stage gauge will be of bubble type designed to gauge water stage by the changes in water pressure, and will have the following main specifications.

Measuring range	:	0 ~ 30 m
Sensitivity	:	1 cm
Error	:	±1%
Power ratings	:	DC 12V (dry battery)
Gas	:	Propane gas

(3) Automatic Recorder

The automatic recorder will be mechanically linked with the water stage gauge for automatic recording of water stage, and will have the following main specifications.

Maximum recording period	:	3 months
Drive system	:	Spring-clock drive
Recording system	:	Endless (automatic return) recording, 2-pen system - red pen in "m" green pen in "cm"
Power equipment	:	Not required

(4) A/D Converter

The A/D converter will convert the measured water stage to digital signal in thousands and transmit it to the telemetering equipment. It will be interlocked with the automatic recorder and housed therein.

(5) Accessories and Spare Parts

1) Propane gas cylinder, 10 kg : 1

2) Recording paper : 10 rolls

3) Ink (red and green), dropper, and spare pen : 2 sets each

8-6-16 Solar Cell Power Supply Equipment

(1) Outline

This equipment will convert the energy of sunlight directly to electric energy by silicon solar cell and charge it in alkaline battery for power supply to telemetering equipment, repeater equipment and gauging equipment. It will be composed of solar cell system, power panel, and storage battery.

(2) Solar Cell System

1) Structure

This system will have a group of necessary number of solar cell elements arranged in rows on a flat plane which is fitted in a stainless steel frame, and will have metal fixtures and fittings for adjusting light reception angle and for preventing bird damage.

2) Main Specifications

a. Output voltage : Nominal 12 V

b. Rated output : more than 7W or 63W (See Table 8-2 for output at each station) at 25°C and incident energy 100 mW/cm^2.

(3) Power Panel

1) Cabinet Structure

The cabinet of power panel will be of wall-mount type having a drip-proof construction of steel plate.

2) Instruments and Apparatuses

a. Overcharge protector (Charge controller), with a working voltage of $14.7\ ^{+0.2\ V}_{-0\ V}$	: 1 set
b. Switch of above	: 1 pce
c. DC voltammeter	: 1 set
d. Blocking diode	: 1 pce
e. Switch	: 1 set
f. Connector	: 1 set

(4) Storage Battery

The storage battery will be accommodated in a steel plate-made accessory box with a side-opening door (double-deck type for repeater stations), and will have the following main specifications.

Type	: Pocket type alkaline battery with transparent cell, Model AM
Quantity	: 10 cells
Capacity	: 50 AH or 600 AH (repeater station)

(5) Accessories

1) Maintenance tools : 1 set

8-6-17 Radio Telephone Equipment

(1) This is a fixed type radio telephone equipment to be installed at repeater maintenance bases for communication with the master station.

(2) The equipment will have the following specifications.

1) General Specifications

a.	Frequency band	:	80 MHz band
b.	Communication system	:	Simplex radio links
c.	Type of emission	:	F_3
d.	Power supply	:	DC 12 V (nominal)

2) Transmitter Unit

a.	Transmitting power	:	10 W
b.	Allowable frequency error	:	Within $\pm 10 \times 5^{-6}$
c.	Modulation	:	Phase modulation
d.	Maximum frequency deviation	:	±5 KHz
e.	S/N ratio	:	More than 40 dB (1 KHz 70% modulation)

3) Receiver Unit

a.	Receiving system	:	Superheterodyne
b.	Allowable frequency error	:	Within $\pm 10 \times 10^{-6}$
c.	Sensitivity	:	Less than 3 dB (20 dB noise quieting)
d.	Rated receiving output	:	More than 0.5 W
e.	Squelch sensitivity	:	Open at 10 dB noise quieting input voltage or lower, and not suppressing signals of 40 dB or higher

(3) The equipment will be provided with a controller for its operation, and will house repeater controlling signal unit.

8-6-18 Portable Radio Telephone Equipment

(1) This is a portable radio telephone equipment to be used for local liaison and communications.

(2) Structural Design and Components

The portable radio telephone equipment will consist of radio equipment, antenna and power supply unit, and will have a structure convenient to carry.

(3) Radio Equipment

The radio equipment will be the same in design and structure as that specified in the preceding section, and the two will be interchangeable.

(4) Antenna

The antenna will be whip type ($\lambda/4$).

(5) Power Supply Unit

Power rating will be DC 12 V (nominal), and alkaline battery will be used.

(6) Accessories

1)	Carrying case	1
2)	Earphone	"
3)	Alkaline battery power supply unit	"
4)	Charger (for battery)	"

8-6-19 DC Power Supply Unit

(1) Outline

This will be a power supply unit housing storage battery and will be used for power supply to the fixed type radio telephone equipment. Where necessary, however, it will also be used for charging batteries of telemetering stations.

(2) Structure

The DC power supply unit will have rectifier and battery accommodated in the same cabinet, and will have control instruments on the front.

(3) Rectifier

The rectifier will have an automatic voltage regulator and be used for floating charge. It will have the following main specifications.

1) Input : AC 220 V ±10%, 50 Hz ±5 Hz, 1ϕ

2) Output : Floating - DC 13.7 ~ 15.3 V ±2% (semi-fixed), 10 A
Equalizing - DC 15 ~ 17 V ±2%, 10 A

3) Load rating : 12 V ±10%

4) Instruments : Voltage and amperage measuring instruments, and indicator lamps

(4) Storage Battery

Same as specified in Section 8-6-16-(4).

(5) Accessories

Same as specified in Section 8-6-16-(5).

8-6-20 Automatic Voltage Regulating Equipment

This equipment will be installed at MD and RID for the purpose of stabilizing power supplied to respective equipment, and will have the following main specifications.

1) Input : AC 220 V $^{+10\%}_{-15\%}$, 1ϕ, 50 Hz ±2 Hz

2) Output : AC 220 V ±1%,
Response time - Less than 0.2 sec
Wave-form distortion - Less than 5%

3) Capacity : 5 KVA

8-6-21 Engine Generating Equipment

(1) Outline

This is a self-start stationary engine generator to be installed at MD and RID to supply power to each equipment and for lighting during service interruption.

(2) Component Equipment

The engine generator equipment will be composed of diesel engine, AC generator, and automatic control panel, and will have various control and protective functions necessary for its automatic operation.

(3) Diesel Engine

1) Type : 4-cycle, water-cooled engine

2) Output : 15 HP, 1,500 rpm

3) Starting system : Electric starting (DC 24 V)

4) Cooling system : Forced air-cooled system using radiator

5) Speed fluctuation : Instantaneous - Less than 10%
Setting time - Less than 5%

6) Overload and over-speed capacity : Overload - 110% for 30 minutes

Overspeed - 110% for 1 minute

8) Accessories : Exhaust damper (motor-driven), outdoor hood, silencer, fuel tank (200 ℓ), vibration-proof common bed, etc.

9) Storege battery for starting : Sintered electrode type alkaline battery (AHH), 24 V, 50 AH

(4) Generator

1) Voltage : 220 V, single phase

2) Cutput : 10 KVA, 50 Hz

3) Pole : 4

4) Excitation : Static

5) Voltage fluctuation : Instantaneous - ±10%

Setting - ±5%

(5) Automatic Control Panel

The automatic control panel will perform functions essential for automatic running of the engine generator, such as control, operation and indication, and will have voltammeter, frequency meter, integrating hour meters, indicator, and operating switches.

(6) Charger

This will be used for charging the starting battery, and its main specification will be the same as those of the rectifier of DC power supply equipment stipulated in Section 8-6-19.

(7) Spare Parts

1) Spare brush, 100% : 1 set

2) Fan belt : 1 pce

3) Battery maintenance tools : 1 set

8-6-22 Accessories and Spare Parts

(1) Each station will be furnished with the accessories and spare parts listed in the following items in addition to those expressly stipulated in the present specifications.

(2) Common Accessories and Spare Parts

1) Accessories

a. Maintenance and inspection tools : 1 set

b. Accessories and spare parts box : "

2) Spare Parts

a. Lamp and fuse (300% each) : "

(3) Master Station

1) Accessories

a. Mobile radio tester : 1 set

b. Telemeter checker : 1 unit

c. Through-type powermeter : 1 "

d. Terminated powermeter : 1 "

e. Frequency counter : 1 "

f. Circuit tester : 1 unit

g. Repeater controller : 1 "

h. Stabilizing rectifier (AC 220 V - DC 12 V, 10 A) : 1 "

i. Data recording paper : 2,000 sheets

2) Spare Parts

a. Telemetering equipment (multi-value type) : 1 unit

b. Radio equipment, 10 W : 2 sets

c. Water stage gauge : 1 unit

d. Rain gauge : 1 "

e. Solar cell power supply equipment (for telemetering stations) : 1 set

f. Spare sheet, 1 of each type : 1 "

g. Relay, 1 of each type : 1 "

h. Digital display unit, 10% : 1 "

i. Typewriter, 27" : 1 unit

(4) Monitoring Station

1) Accessories

a. Through-type powermeter : 1 unit

b. Terminated powermeter : 1 unit

c. Circuit tester : 1 unit

d. Data recording paper : 2,000 sheets

2) Spare Parts

a. Digital display unit, 10% : 1 set

(5) Repeater Station (Per Station Requirements)

1) Accessories

a. Through-type powermeter : 1 unit

b. Terminated powermeter : 1 "

c. Circuit tester : 1 "

d. Portable engine generator, gasoline, 1 KVA, 220 V : 1 "

e. Rectifier, AC 220 V - DC 12 V, 30 A : 1 "

2) Spare Parts

a. Spare sheet for repeater equipment, 1 for each type : 1 set

(6) Kanchanaburi and Thong Pha Phum Offices (Per Office Requirements)

1) Accessories

a. Through-type powermeter : 1 unit

b. Terminated powermeter : 1 "

c. Circuit tester : 1 "

d. Mobile radio tester : 1 set

e. Repeater controller : 1 unit

f. Portable engine generator, gasoline, 300 W : 1 "

g. Rectifier, AC 220 V - DC 12 V, 10 A : 1 "

2) Spare Parts

a. Telemetering equipment (multi-value type) : 1 unit

b. Radio equipment, 10W : 2 units

CHAPTER 9 COST ESTIMATION

9-1 Conditions for Cost Estimation

Calculations for project cost estimation were worked out on the basis of the following conditions.

(1) March 1978 is taken as base period.

(2) It is assumed that all observation equipment, communication facilities, station houses, antenna masts, etc. will be newly constructed with the exception of the following.

1) Poles for stringing wire line at Ban Chao Chen Station

Only the cables for connecting gauging shed (at dam site) and transmitting and receiving shed are covered, assuming that the poles for stringing them would be available at site.

2) Building space of Master Station and Monitoring Station

It is assumed that the necessary space would be secured within the existing office building. Hence, a small amount is appropriated for remodeling necessary for new facilities.

(3) The equipment and materials costs are the costs on delivery at site, calculated on condition that they would be supplied by Japanese manufacturers.

(4) The installation and adjustment costs cover the expenses to be disbursed in order for Japanese engineers to complete installation and adjustment services at site.

(5) The road construction cost cover the maintenance roads to repeater stations (R1 and R2) which will permit the passage of jeeps and have a total length of about 6 km (2km - R_1, 4 km - R_2)

(6) The construction costs of station houses, antenna masts, roads, etc. are based on the costs generally appropriated in Japan for construction of such facilities.

(7) The technical guidance costs comprise the overseas training cost and the local training cost. The former is appropriated for training six Thai engineers for 2 months in overseas countries, and the latter for inviting three foreign engineers to Thailand for one year for local guidance service.

(8) The reserve fund accounts for 15% each of the facilities cost and the construction cost.

(9) Breakdown of local and foreign currency requirements for project implementation is as shown below.

Table 9-1

Breakdown of Local and Foreign Exchange Requirements for Maeklong River Basin Flood Forecasting System

Cost Item	Foreign Currency	Local Currency	Remarks
1. Facilities Cost			
1-1 Equipment Cost	Equipment cost (incl. installation and adjustment costs)		
1-2 Station House		Materials cost, labor cost, and all other costs associated with station house construction	3 for rainfall stations, 5 for rainfall and water stage stations, 1 for transmitting/receiving station, and 2 for repeater stations.
1-3 Antenna Mast	Cost of superstructural materials	Substructural materials cost and construction cost	Panzer mast 20 m × 4 10 m × 9 Tripole 30 m × 3 10 m × 1
2. Road Construction Cost		Road construction cost	Maintenance roads to R1 and R2
3. Technical Guidance Cost	Local and overseas training costs		
4. Reserve Fund	15% of local currency portion of 1. (facilities cost)	15% of local currency portion of 1. and 2 (facilities cost and road construction cost)	

9-2 Total Project Cost

The total cost required for implementation of the Maeklong River Basin Flood Forecasting Project is as tabulated below.

Table 9-2 Total Project Cost

Item	Local Currency	Foreign Currency	Total
Facilities Cost	133,000	1,325,000	1,458,000
Road Construction Cost	455,000	-	455,000
Technical Guidance Cost	-	253,000	253,000
Reserve Fund	88,000	199,000	287,000
Total	676,000	1,777,000	2,453,000

In U.S.$ = ¥220

9-3 Facilities Cost

9-3-1 Breakdown of Facilities Cost

Breakdown of facilities cost is as shown below in Table 9-3

Table 9-3 Breakdown of Facilities Cost

In US$

Station	Equipment		Station House		Antenna Mast		Total		
	Local Currency	Foreign Currency	Local Currency	Foreign Currency	Local Currency	Foreign Currency	Local Currency	Foreign Currency	Total
Master Station	-	520,000	2,600	-	1,900	2,100	4,500	522,100	526,600
Monitoring Station	-	186,300	2,500	-	8,800	13,200	11,300	199,500	210,800
Rep 1	-	88,300	13,800	-	1,500	1,700	15,300	90,000	105,300
Rep 2	-	88,300	13,800	-	1,500	1,700	15,300	90,000	105,300
Sangkhla Buri	-	39,000	6,800	-	800	1,000	7,600	40,000	47,600
Ban Pa Tho	-	23,000	5,300	-	1,400	2,100	6,700	25,100	31,800
Pilok	-	23,600	5,300	-	1,400	2,100	6,700	25,700	32,400
Thong Pha Phum	-	37,700	6,800	-	800	800	7,600	38,500	46,100
Band Lin Thin	-	21,800	5,300	-	1,400	2,100	6,700	23,900	30,600
Ban Sai Yok	-	39,000	6,800	-	8,800	13,200	15,600	52,200	67,800
Ban Lum Sum	-	39,500	6,800	-	8,800	13,200	15,600	52,700	68,300
Ban Chao Nen	-	51,800	6,800	-	4,100*	2,100	10,900	53,900	64,800
Wang Khanai	-	37,700	6,800	-	800	2,100	7,600	39,800	47,400
Thong Pha Phum Office	-	35,000	0	-	800	800	800	35,800	36,600
Kanchanaburi Office	-	35,000	0	-	800	800	800	35,800	36,600
Sub-total	-	1,266,000	89,400	-	43,600	59,000	133,000	1,325,000	1,458,000
Total	1,266,000		89,400		102,600		1,458,000		

1$= ¥220

9-3-2 Breakdown of Equipment Cost

Breakdown of the equipment cost, which constitute part of the facilities cost, is shown below in detail in Table 9-4.

Table 9-4 Breakdown of Equipment Cost

Unit: US$

Article	Specification	Master Station		Monitoring Station		Rep 1		Rep 2		Sangkhla Buri		Ban Pa Tho		Pilok		Thong Pha Phum		Ban Lin Thin		Ban Sai Yok		Ban Lum Sum		Ban Chao Nen		Wang Khanai		Tong Pha Phum Office		Kanchana Buri Office		Total	
		Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount
Telemetry Control Unit, Type A	16/30	1	29,681																													1	29,681
" , Type B	W/monitoring function, 16/30			1	31,091																											1	31,091
Control Desk	Console type	1	27,273																													1	27,273
Typewriter	27", w/case and stand	1	6,819	1	6,819																											2	9,638
Data Processing Equipment		1	90,909																													1	90,909
Flood Forecasting Calculater		1	31,819																													1	31,819
Graphic Display Panel	Stand-alone type	1	90,909																													1	90,909
Data Display Panel	Wall-mount type			1	40,909																											1	40,909
Telemetering Equipment	Single-value type											1	4,850	1	4,850			1	4,850					1	4,850							4	19,400
" "	Multi-value type									1	5,259					1	5,259			1	5,259	1	5,259	1	5,259	1	5,259					6	31,554
Rainfall Gauging Equipment	Rain gauge w/automatic recorder and A/D converter									1	4,145	1	4,145	1	4,145	1	4,145	1	4,145	1	4,145	1	4,145	1	4,145	1	4,145					9	37,305
Water Stage Gauging Equipment	Water stage gauge, w/automatic recordor and A/D converter									1	11,818					1	11,818			1	11,818	1	11,818	1	11,818	1	11,818					6	70,908
Repeater Equipment						1	19,091	1	19,091																							2	38,182
Radio Equipment	80 MHz band, 10 W, for telemetering	1	3,436	1	3,436	4	13,744	4	13,744	1	3,436	1	3,436	1	3,436					1	3,436	1	3,436	1	3,436							16	54,976
" "	80 MHz band, 1 W, for telemetering	1	2,700	1	2,700											1	2,700	1	2,700							1	2,700					5	13,500
Radio Telephone Equipment	80 MHz band, 10 W, for telemetering																											1	3,382	1	3,382	2	6,764
Portable Radio Telephone Equipment	80 MHz band, 10 W, w/antenna, power supply unit, charger, etc.	1	3,109	1	3,109																							1	3,109	1	3,109	4	12,436
Antenna Equipment	Yagi 3-element, w/coaxial lightning arrester	1	755	1	755					1	755	1	755			1	755	1	755							1	755	1	755	1	755	9	6,795
" "	Yagi 3-element, bi-directional w/coaxial lightning arrester							1	1,300																							1	1,300
" "	Yagi 5-element, w/coaxial lightning arrester																			1	633			1	633							2	1,266
" "	Yagi 5-element, stack w/ coaxial lightning arrester	1	1,309	1	1,309	2	2,618	1	1,309					1	1,309							1	1,309									7	9,163
Engine Generator	10 kVA, automatic	1	43,636	1	43,636																											2	87,272
Automatic Voltage Regulator	5 kVA	1	6,545	1	6,545																											2	13,090
DC Power Supply Equipment	Rectifier unit - 12 V, 10 A; alkaline battery - 50 AH																							1	3,545			1	3,545	1	3,545	3	10,635
Solar Cell Power Supply Equipment	12 V, 50 W, alkaline battery - 600 AH					1	26,727	1	26,727																							2	53,454
Solar Cell Power Supply Equipment	12 V, 50 W, alkaline battery - 50 AH									1	4,091	1	4,091	1	4,091	1	4,091	1	4,091	1	4,091	1	4,091	1	4,091	1	4,091					9	36,819
Accessories and Spare Parts		1	62,180	1	4,871	1	5,560	1	5,569	1	446	1	353	1	359	1	332	1	279	1	618	1	402	1	918	1	332	1	16,009	1	16,009		114,237
Communication Cable	1000 m CQEV-SS 0.9 m/m 6P																							1	1,305							1	1,305
(Total Equipment Cost)			399,080		143,180		67,740		67,740		29,950		17,630		18,190		29,100		16,820		30,000		30,460		40,000		29,100		26,800		26,800		972,590
Installation and Adjustment Cost		1	120,920	1	43,120	1	20,560	1	20,560	1	9,050	1	5,370	1	5,410	1	8,600	1	4,980	1	9,000	1	9,040	1	11,800	1	8,600	1	8,200	1	8,200		293,410
Total			520,000		186,300		88,300		88,300		39,000		23,000		23,600		37,700		21,800		39,000		39,500		51,800		37,700		35,000		35,000		1,266,000

9-4 Technical Guidance Costs

(1) Overseas Training Cost

The overseas training cost covers the expenses for two-month overseas training of Thai engineers. Breakdown of this cost is as shown below.

Tuter		2 personsx2 monthsx5,000 = US$20,000
Trainee		
	Hydrologist	2 personsx2 monthsx800 = US$3,200
	Telecommunication engineer	4 personsx2 monthsx800 = US$4,800
Travelling expenses		6 personsx750 = US$4,500
	Total :	= 32,500 US$

(2) Local Guidance Cost

After completion of the telemetering system, one hydrologist and two telecommunication experts will be invited from abroad in order to ensure proper operation and management of the system. They will be staying in Thailand for one year and provide technical guidance in the system operation and management. Breakdown of this cost which covers their salaries, overhead fees, living expenses, etc. is shown below.

Hydrologist	1 personx12 monthsx6,000 = US$72,000
Telecommunication expert	2 personsx12 monthsx6,000 = US$144,000
Travelling expenses	6 persons 750 = US$4,500
Total :	US$220,500

Notes: Calculation of travelling expenses was worked out on the assumption that each expert would return to his country on vacation once in six months if his stay in Thailand is longer than that.

(3) Total Technical Guidance Costs

Overseas training cost	US$ 32,500
Local guidance cost	US$220,500
Total:	US$253,000

9-5 Management and Maintenance Cost

It is usually the case that 2 ~ 3% of the equipment cost is appropriated for management and maintenance of communication equipment and flood forecasting facilities. In the case of the proposed telemetering system, 2% of the total equipment cost is appropriated for this purpose.

1,266,000 (Total equipment cost) × 0.02 ≒ US$25,300

CHAPTER 10 MANAGEMENT AND MAINTENANCE

10-1 Maintenance and Managemant of Hydrological Stations and Flood Forecasting Center.

Accurate flood forecasting and warning in the rainy season presupposes satisfactory maintenance services conducted constantly to keep all hydrological observation equipment and data processing units in perfect service condition. Further, in order for Flood Forecasting Center to fulfull its functions successfully, it is necessary to establish an adequate organizational setup and devise a workable operational system.

Maintenance services for hydrological stations can be considered in two broad categories. One covers periodic and temporary inspections which call for the services of hydrologists, and the other is routine inspection not requiring such services.

The primary duty of Flood Forecasting Center is not only to issue accurate flood forecasting and warning during flood duration, but in order to fill that duty, the Center is required to exert ceaseless effort in the following services.

(1) Consolidation of telemeter data.

(2) Maintenance of processors.

(3) Preparation of a maintenance plan, and control of maintenance personnel based thereon.

(4) Studies for improving accuracy of simulation model.

(5) Formulation and execution of a development plan designed for upgrading the system reliability.

(6) Formulation and execution of a training programme for maintenance personnel.

Operation of these services calls not only for the availability of a sufficient number of maintenance personnel but also for frequent training of such personnel to acquaint them with maintenance technology as well as system's hardware and software technology.

10-1-1 Grouping of Maintenance and Technical Personnel

For the purpose of satisfactory operation of periodic and temporary maintenance services, the maintenance personnel should be grouped by block with at least one hydrologist assigned to each group, so that any block can be covered instantly in an emergency. For routine inspection and maintenance services, it is desirable that at least one maintenance staff be assinged to each station.

Flood Forecasting Center should have at least two hydrologists and a number of assistant hydrologists who will be given in-service training at the Center.

10-1-2 Outline of Maintenance Services

(1) Hydrological Stations

Maintenance and inspection services of hydrological stations should be conducted using the check lists shown in Figs. 10-1 and 10-2. Routine inspection should be performed once a day, and periodic and temporary inspections should be conducted at least once a month. This inspection frequency may be reduced to an extent in the dry season, but should be ovserved strictly with the approach of the wet season. Inspection should be carried out without fail after each flood or heavy rain.

At Flood Forecasting Center, on the other hand, telemetered hydrologic data should be checked for abnormality every day, and adequate instructions should be issued to field maintenance personnel if any abnormality is detected.

(2) Flood Forecasting Center

In addition to the above-mentioned error detection in telemetered data, computers should be checked from time to time using a programe prepared specifically for their functional check.

Results of error detection in telemetered data and computer functional check should be put on record by noting them down in check lists.

Table 10-1 Check List for Rain Gauge Inspection Service

a. Routine Inspection
1. Equipment Service Condition Clogging up of funnel in receiver Siltation of storage tank and tipping bucket Breakage or failure of equipment Residual quantities of recording paper, space parts, etc. Adjustment of clock 2. Checking of telemetered data against self-recorded data
b. Periodic and Temporary Inspection
1. } Same as for routine inspection 2. } 3. Checking recorded data by filling of specified quantity of clear water

Table 10-2 Check List for Stage Gauge Inspection Service

Check items are the same irrospective of the kind of inspection
1. Equipment Service Condition Breakage of staff gauge, adhesion of dirts and other foreign objects, and residual quantities of recording paper, spare parts, etc. Adjustment of clock 2. Checking of staff gauge reading against self-recorded and telemetered data.

10-2 Maintenance of Telecommunication Equipment

Stabilized and fault-free operation of the flood forecasting system calls for perfect maintenance and inspection services of all equipment including telemetering equipment as well as for incessant effort to improve them so as to best meet the purpose of their installation. It is therefore very important to secure a sufficient number of qualified maintenance personnel and conduct training frequently to improve their technical capabilities. At the same time the necessary budget should be secured for maintenance and management. Annual budgetary appropriation for maintenance services should be at least 2 ∿ 3% of total equipment cost (initial year value), although this percentage varies according the number of years elapsed after installation.

10-2-1 Grouping of Maintenance Personnel

Considering the configuration of the forecasting system, the whole basin area can be divided into three blocks for the purpose of maintenance services, i.e., the upstream area, mid-stream area, and Flood Forecasting Center.

(1) In the upstream area, at least two telecommunication experts should be stationed at Thong Pha Phum for maintenance of R2 and telemetering stations linked with it.

(2) In the mid-stream area, at least two telecommunication experts should also be stationed either at Kanchanaburi or Vajiralongkorn Dam for maintenance of R1 and telemetering stations linked with it.

(3) At Flood Forecasting Center, one senior expert assuming overall responsibilities for the system operation and three telecommunication experts should be stationed. These experts will be assigned to the task of maintaining perfect control of the entire telemetering system, not to speak of maintenance of master station and monitoring station (RID), so as to be able to formulate and execute various plans indispensable for smooth system operation, such as maintenance plan, equipment improvement and modification plan, training plan, spare parts and materials supply plan, gauging equipment consolidation plan, and so forth.

The staffs for the hydrologic and telecommunication maintenance on the whole system are shown in table 10-3.

10-2-2 Outline of Maintenance Services

Maintenance and inspection services should be conducted daily, monthly or temporarily as occasion demands, and the results of inspection should be put on record by noting them down in check lists. If a measured value shows any deviation from the standard value, it should be corrected by effecting suitable adjustment or repair to the gauging equipment.

Outline of maintenance and inspection services is given below.

(1) Telemetering Equipment

1) Daily Inspection

The master station should transmit calling signal to each station to confirm the performance of each equipment by checking the service condition of printer and other component parts.

Table 10-3 Staffs for Maintenance

	Center (MD, RID) Bangkok	Up-stream Area Thong Pha Phum	Midstream Area Kanchanaburi	Total
Hydrologist	2	1	1	4
Hydro-maintenance Staff		(6)	(3)	(9)
Senior Telecommunication Expert	1			1
Telecommunication Expert	3	2	2	7

2) Monthly Inspection

The monthly inspection should cover radio equipment, telemetering equipment, power supply equipment, and gauging equipment installed at master station, monitoring station and each observation station. During the monthly inspection, the level of radio circuit should also be checked.

(2) Repeater Station

1) Monthly Inspection

Radio equipment, repeater equipment and power supply equipment should be covered by the monthly inspection of repeater stations. The level of radio circuit should also be checked.

10-3 Technical Guidance

10-3-1 Invitation of Foreign Experts for Technology Transfer

Proper system operation presupposes the availability of engineers with accurate technical knowledge and capabilities. In order to secure the services of flood forecasting engineers satisfying such requirements, it is necessary to invite relevant experts from abroad for technolgy transfer.

At least one hydrologist and two telecommunication experts should be invited from abroad for one-year on-the-job training in order for local engineers to acquire the technical knowledge and skill required for satisfactory system operation and maintenance.

10-3-2 Overseas Training of Thai Engineers

In order to assure that the system will be operated smoothly for accurate flood forecasting in the coming years, overseas training of Thai engineers should be conducted as briefed below.

(1) Prior to the system commissioning, at least two hydrologists and four telecommunication engineers should be trained abroad for about two months.

(2) Another two hydrologists and four telecommunication engineers should be given on-the-job training in Thailand.

The above training plan will make it possible to secure expert services of at least four hydrologists and eight telecommunication engineers for the system operation.

10-4 Liaison and Communication System for Flood Forecasting

Flood forecasting system involves a number of operational stages from meteorological observation to flood data transmission to terminal organs as well as levee protection activities, so that its objective can never be achieved unless the operation at each stage is conducted quickly and accurately, ensuring smooth flow of information from stage to stage.

Establishment of a network and system of such stage-to-stage liaison and communication is an essential prerequisite to the prevention of flood disasters. For this reason, the following measures should be taken to acquire a clear-cut picture of liaison system.

(1) Establishment and consolidation of disaster preventive organizations

(2) Public enlightenment and training in disaster prevention

(3) Storage and consolidation of emergency goods and disaster preventive equipment and materials

(4) Consolidation of facilities and equipment for disaster prevention

(5) Designation of danger zones and anti-disaster improvement works in such zones.

ANNEX

Annex

Stage Construction

1. Stage Construction

The installation of the whole telemetering system are desirable to be set up at the same time, but construction can be carried out in the following phases.

(1) First phase:

3 observation stations are to be set up at Ban Lum Su, Wang Khanai and Ban Chao Nen. A relay station Rep 1 is also to be set up. The master control and monitoring stations are to have the minimum facilities necessary to receive data from the observation stations.

(2) Second phase:

2 observation stations at Thong Pha Phum and Sangkhla Buri and the relay station Rep 2 are to be added to those set up during the first phase.

(3) Third phase:

Remaining installations to be set up.

Costs broken down by phases are as follows:

Table A-1

Unit : US$

Item	Currency	1st phase	2nd phase	3rd phase	Total
Installation	Domestic currency	65,000	31,000	37,000	133,000
	Foreign currency	397,000	392,000	536,000	1,325,000
	Sub-total	462,000	423,000	573,000	1,458,000
Road construction	Domestic currency	0	227,000	228,000	455,000
	Foreign currency	0	0	0	0
	Sub-total	0	227,000	228,000	455,000
Technical guidance	Domestic currency	0	0	0	0
	Foreign currency	32,500	220,500	0	253,000
	Sub-total	32,500	220,500	0	253,000
Reserve funds	Domestic currency	10,000	39,000	39,000	88,000
	Foreign currency	60,000	59,000	80,000	199,000
	Sub-total	70,000	98,000	119,000	287,000
Total	Domestic currency	75,000	297,000	304,000	676,000
	Foreign currency	489,500	671,500	616,000	1,777,000
	Sub-total	564,500	968,500	920,000	2,453,000

Note 1: Costs of road construction regarding Rep 1 are allocated to the 2nd phase and those regarding Rep 2 are allocated to the 3rd phase.

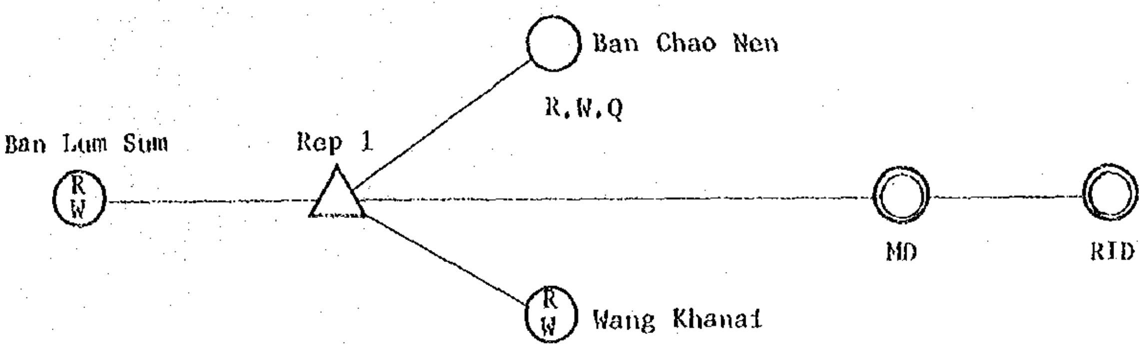
Note 2: Costs of technical guidance are for training in the 1st phase and for technical guidance at the sites in the 2nd phase.

2. Forecasting and warning effects by phased construction

When the system is complete, it will be possible to forecast flood hydrograph at K-10 as soon as data on rainfall and stage are obtained. Thus, by forecasting the stage at K-10 and K-11, it will be possible to give a three-day flood forecasting with a good degrees of precision. When the telemetering system is installed in phases, forecasting and warning effects may be as follows.

(1) On completion of the first phase construction

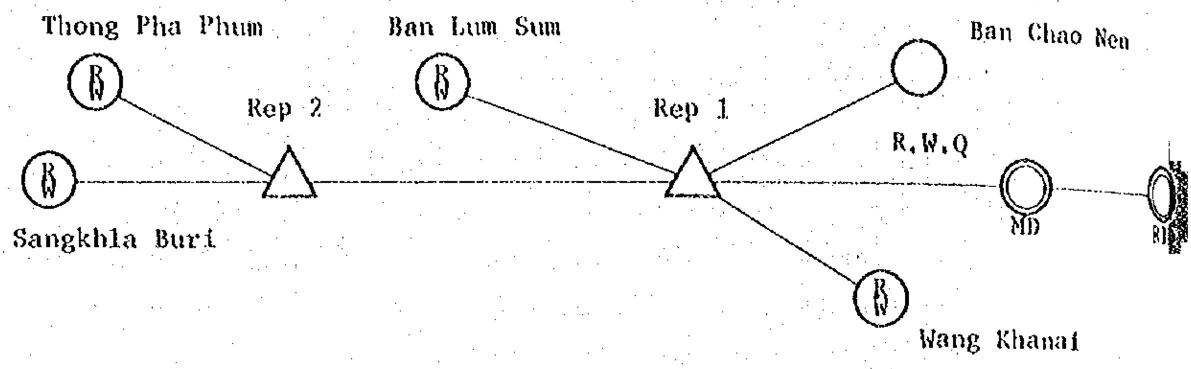
With three observation stations installed at Ban Lum Sum, Wang Khanai and Ban Chao Nen, forecasting will be limited to Wang Khanai (K-11) judging from the stage at Ban Lum Sum (K-10) and the discharge at Ban Chao Nen. Accordingly, the warning period corresponds to the travelling time of the flood from K-10 to K-11 (one day). Since data are obtainable continuously and instantly, however, forecasting may have a better degree of precision.



R: Rainfall St.
W: Water Stage St.
Q: Discharge Measurement St.

(2) On completion of the second phase construction

With two relay stations and five telemetered observation stations at Ban Lum Sum, Wang Khanai, Ban Chao Nen, Thong Pha Phum and Sangkhla Buri installed, it will be possible to discover the occurrence of flooding from the stage rise Sangkhla Buri (K-24); this will make it possible to forecast the stage at Thong Pha :phum (K-13) and Ban Lum Sum (K-10). Thus, it will be possible to obtain flood hydrograph at K-11 two to three days ahead, gaining the forecasting period by one to two days in advance as compared with the first phase.



3. Facilities Cost Broken down under Phased Construction Plan

Table A-2 Breakdown of Facilities Cost under 3-phased Construction Plan

Unit : US$ 1$=¥240

Year / Station	1st phase		2nd phase		3rd phase		Total		
	Local Currency	Foreign Currency	Local Currency	Foreign Currency	Local Currency	Foreign Currency	Local Currency	Foreign Currency	Total
Master Station *	4,500	93,300	–	147,800	–	281,000	4,500	522,100	526,600
Monitoring *	11,300	67,400	–	75,300	–	56,800	11,300	199,500	210,800
Rep 1	15,300	90,000	–	–	–	–	15,300	90,000	105,300
Rep 2	–	–	15,300	90,000	–	–	15,300	90,000	105,300
Sangkhla Buri	–	–	7,600	40,000	–	–	7,600	40,000	47,600
Ban Pa Tho	–	–	–	–	6,700	25,100	6,700	25,100	31,800
Pilok	–	–	–	–	6,700	25,700	6,700	25,700	32,400
Thong Pha Phum	–	–	7,600	38,500	–	–	7,600	38,500	46,100
Ban Lin Thin	–	–	–	–	6,700	23,900	6,700	23,900	30,600
Ban Sai Yok	–	–	–	–	15,600	52,200	15,600	52,200	67,800
Ban Lum Sum	15,600	52,700	–	–	–	–	15,600	52,700	68,300
Ban Chao Nen	10,900	53,900	–	–	–	–	10,900	53,900	64,800
Wang Khanai	7,600	39,800	–	–	–	–	7,600	39,800	47,400
Thong Pha Phum Office	–	–	–	–	800	35,800	800	35,800	36,600
Kanchanaburi Office	–	–	–	–	800	35,800	800	35,800	36,600
Total	65,200 ≒65,000	397,100 ≒397,000	30,500 ≒31,000	391,600 ≒392,000	37,300 ≒37,000	536,300 ≒536,000	133,000	1,325,000	1,458,000
	462,000		423,000		573,000		1,458,000		

* Breakdown of equipment cost of the two stations under the 3-phased construction plan is shown in Table A-3.

Table A-3 Breakdown of Equipment Cost of Master Station and Monitoring Station under 3-phased Construction Plan (Breakdown of foreign currency portions in Table A-2)

Unit : US$

Article	Speci-fication	Master Station				Monitoring Station				Remarks
		1st Phase	2nd Phase	3rd Phase	Total	1st Phase	2nd Phase	3rd Phase	Total	
Telemetry Control Unit, Type A		29,681			29,681					
" Type B					-	31,091			31,091	
Control Console			27,273		27,273					
Typewriter		4,819			4,819	4,819			4,819	
Data Processing Equipment				90,909	90,909					
Flood Forecasting culculator				31,819	31,819					
Graphic Display				90,909	90,909					
Data Display Panel								40,409	40,409	
Radio Equipment	80MHz band 10W, for tele-metering	3,436			3,436		3,436		3,436	
"	" 1W	2,700			2,700	2,700			2,700	
Portable Radio Equipment				3,109	3,109			3,109	3,109	
Antenna Equip.	Yagi 3-element	755			755	755			755	
"	Yagi 5-element	1,309			1,309		1,309		1,309	
Engine Generator			43,636		43,636		43,636		43,636	
Automatic Voltage Regulator			6,545		6,545		6,545		6,545	
Accessories and Spare Parts		27,445	34,737		62,180	2,315	2,556		4,871	
(Total Equipment Cost)		(70,145)	(112,293)	(216,746)	(399,084)	(41,680)	(57,482)	(44,018)	(143,180)	
Installation and Adjustment Cost		21,055	35,607	64,254	120,916	12,520	17,818	12,782	43,120	
Total		91,200	147,800	281,000	520,000	54,200	75,300	56,800	186,300	
Antenna Mast		2,100			2,100	13,200			13,200	
Grand Total		93,300	147,800	281,000	522,100	67,400	75,300	56,800	199,500	

Interim Report
on
the Flood-Forecasting and Warning System in the Mae Klong River Basin in Thailand

The Japanese Government has sent the Second Survey Team consisting of 3 Hydrologists and 4 Telecommunication experts for the conduction of a Survey of the Flood-forecasting and Warning system in the Mae Klong River Basin in Thailand, subsequent to the Preliminary Survey Team sent in 1975.

The survey has been conducted from 8th of November to 17th of December 1977 with the cooperation of the Thai authorities concerned such as the Meteorological Department, the Royal Irrigation Department and the Electric Generating Authority of Thailand. This is the interim report summarizing the results of the survey and study covering the period of the team's stay in Thailand.

It is understood that the final report will be completed within four months of the team's return to Japan.

1. Study on network, location and number of hydrological observation stations.

   The location and number of the existing observation stations, especially rainfall stations, are far from ideal as mentioned already in the Report of Preliminary Survey. For example, it is said in Japan that each rainfall observation station should be located in every 50 km^2 area, if possible. But considering the situation such as geographical features, rainfall characteristics and the maintenance difficulty of the stations in the Mae Klong River basin, it could be said that the existing observation stations are relatively well located for obtaining useful data or flood forecasting.

2. Study on existing flood forecasting method.

The flood forecasting method should be studied from the two points in mind. One is accuracy and the other is the availability for practical use of the method. Supposing the data collection on rainfall and water level in the real time after introduction of the telemeter system in future, the team arrived at the following conclusions, considering the above-mentioned two points;

(1) The simulation method developed by the MD and the RID for flood routing now applied for upper reach of K-10 is generally suitable in the Mae Klong River basin. But there may be room for further on study some coefficient such as L, B, time distribution and so on.

(2) According to this method, it is obligatory to start the calculation from 1st April in any case. But it's not necessary to calculate starting from the fixed date, so that it is better to modify the method in order to calculate from the date when the data on daily rainfall and water level are obtained.

(3) It is preferable that the computed discharge would be adjusted with the actually observed one on a daily basis. Once the adjustment of these two kinds of discharge is made, the calculation can be started again at that time.

(4) On the other hand, the introduction of the telemetering system makes the water stage correlation method useful for flood forecasting through easily obtaining accurate data required. Assuming such a situation, the team studied the said method chosing K-13 and K-10 as model stations. As a result of this study, it is made clear that the water stage of K-10 station can be forecast with required accuracy from that of K-13 station by using correlation curves which are obtained from a multitude of past flood hydrographs instead of using simple correlation lines like the peak to peak correlation.

But this method requires further studies taking into consideratin that it's application becomes problematic when the residual basin between K-13 and K-10 has a heavy rainfall.

(5) Although the forecasting method for the final target point K-11 was not studied in this work because of the time limit, it can be said that the water stage or discharge of K-11 station will be forecasted by using water stage correlation curves or calculating the flood routing from K-10 and Ban Chao Nen Dam site, taking into consideration the discharge from the Dam and the rainfall in the residual basin. This is the most important subject in future.

3. Equipment for the operation of flood forecasting.

The equipment should be selected from such points of view as evaluation of collected data and simulation method for flood routing to K-11. At present, as these problems have not been clearly defined it is difficult to mention here the definite equipment required. It can be said, however, that the introduction of a mini-computer is further required.

4. Decision of location of each telemetering station.

(1) According to the hydrological study, observation stations which should be set up for the telemetering network are as follows;

Sangkhla Buri	(Rainfall, Water stage)
Ban Pha Tho	(Rainfall)
Pilok	(Rainfall)
Thong Pha Phum	(Rainfall, Water stage)
Ban Lin Thin	(Rainfall)
Ban Sai Yok	(Rainfall, Water stage)
Ban Lum Sum	(Rainfall, Water stage)
Ban Chao Nen	(Rainfall, Water stage, discharge)
Wang Khanai	(Rainfall, Water stage)

(2) Repeater station

To make up the network, 2 repeater stations are required.
It is considered that there are 2 alternative plans for Repeater station R1.
One is on the mountains near Kanchanaburi, and a radio propagation test has taken place at 2 places on the mountains. The general condition of above points is good, because it is located near Kanchanaburi and there is a good road to the foot of the mountains. But the condition of radio propagation to connect with Repeater station R2 is not so good, because there is a mountain range between R1 and R2.
Another one is situated on a hill (Khao Luang) near Chom Bung, about 400 m high.
Although the test on this point has not taken place at this time because of the time limit, it could be said that there are few obstacle from the mountain.
But because of the inconvenience of accesibility and the difficulty of maintenance foreseen, the team consider that this point is not suitable for the repeater station.
Regarding the Repeater station R2, it is considered that the mountain (520m high) near Thong Pha Phum is good for the repeater station.

(3) Telemetering Network

The Master-control station in Bangkok should be located at the Meteorological Department as the Flood-forecasting center. The Monitor station should be located at the RID.
Total system is shown as Fig. 2.

5. Test for Telemetering System

(1) Measurement Item

a) Radio transmission test between the M.D. in Bangkok, the observation stations and the Repeater stations for measurement of electric field strength and checking of S/N (Signal to noise ratio)

b) Measurement of city noise level at the M.D. office in Bangkok.

Fig. 1. Location Map of Repeater Stations

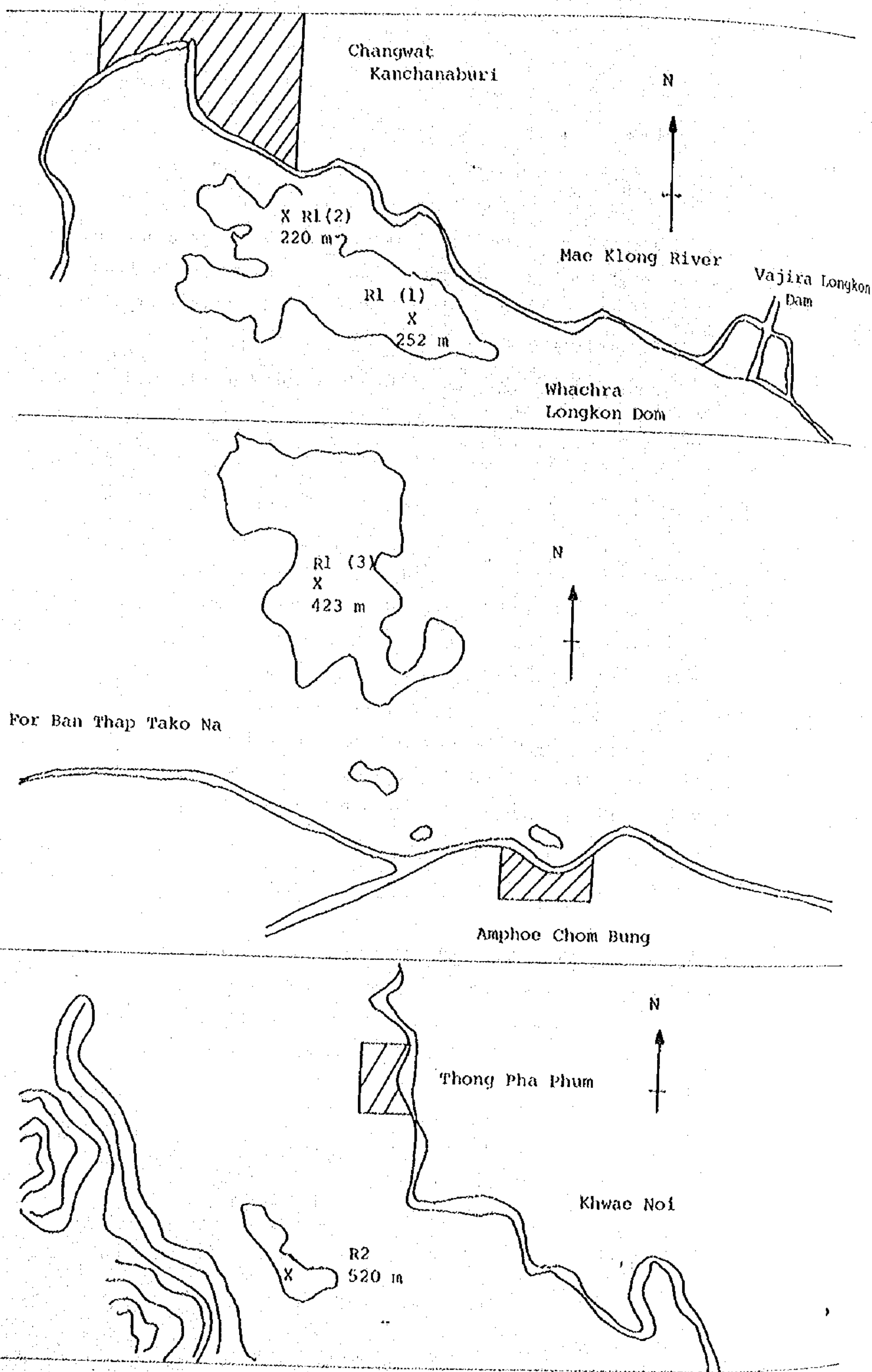
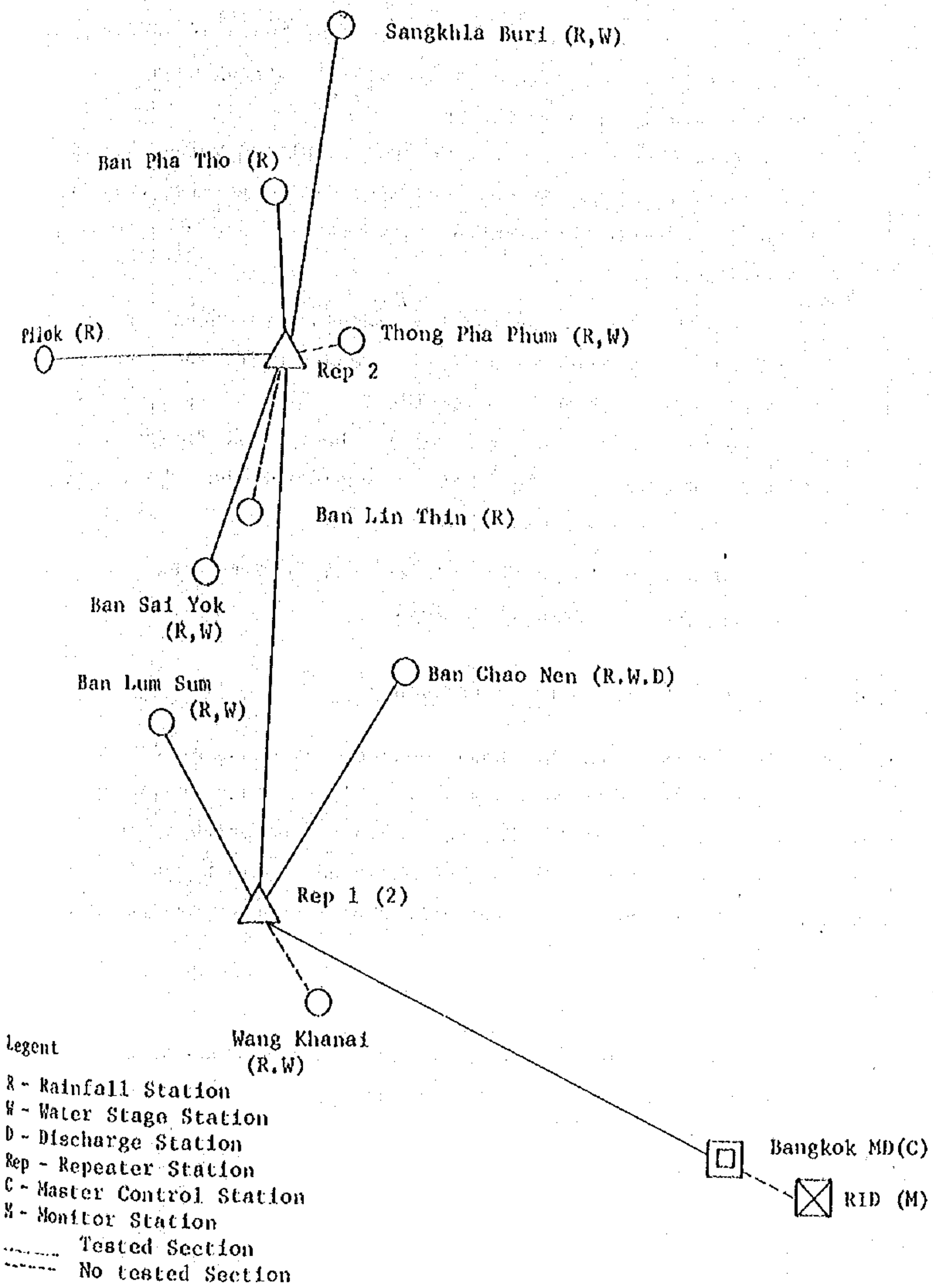


Fig 2 System Network



(2) Method and Results

a) Transmission test has been conducted by means of BHF(57.11 MHZ) radio telephone equipment and the field strength has been measured and S/N also checked.
The data obtained by the test and calculated values are shown in table 1 and 2. It has been made clear that the transmission for telemetering between the above-mentioned places is almost satisfactory.

b) The noise level in the testing frequency has been measured at M D office by means of a field strength meter and a quasi-peak meter, and recorded by a recorder.
Since the measured noise level is about 10-28 dB (peak value) or 10 dB (average value), it is considered that the reception of data will not present any problem.

c) As a result of the above measurement, transmitting power, kind of antenna are shown in table 3.

6. Proposal for allocating suitable frequency.

The radio propagation test has been conducted by means of VHF radio telephone sets using the frequency 57.11 MHZ, but this frequency is being used for a TV channel. For the radio telemetering system, it is proposed that 80-82 MHZ or 83.15 - 86 MHZ band should be assigned according to recommendation of the office of frequency management.

7. Others

1) It is hoped that the equipment supplied by the Japanese survey team will be put to effective use in Thailand.

Table 1. Valves Measured by Transmission Test

Section		Pr	Prn	C/N	I	S/N	Pt
BANGKOK	Rep (1)	87.0	104	17	13.5	30.5	7.5
BANGKOK	Rep (1)	87.0	118	31	13.5	13.5	7.0
Rep 1(1)	Ban Lum Sum	110.0	118	8	13.5	21.5	7.5
Rep 1(1)	Ban Chao Nen	92.0	118	26	13.5	39.5	7.0
Rep 1(2)	Ban Lum Sum	101.0	118	17	13.5	30.5	7.5
Rep 1(2)	Rep 2	100.0	122	22	13.5	35.5	7.5
Rep 1(2)	Rep 2	100.0	118	18	13.5	31.5	8.0
Rep 2	Ban Lum Sum	112.0	118	6	13.5	19.5	8.0
Rep 2	Ban Sai Yok	101.0	122	21	13.5	34.5	8.0
Rep 2	Saugkhla Buri	87.5	122	34.5	13.5	48	8.3
Rep 2	Ban Pa Tho	84.5	122	37.5	13.5	51	8.3
Rep 2	Pi Lok	94.0	122	28	13.5	41.5	7.5

Explanation of Symbols:

Pr : Receiving power

Prn : Receiving noise power

c/n : High frequency S/N

S/N : Standard S/N

Pt : Transmitting power

Table 2. Calculated values at Telemeter Network Design

Section		Pr	Prn	C/N	I	S/N	Pt
BANGKOK	Rep 1 (2)	80.9	104	23.1	12.2	>30	10
BANGKOK	Rep 1 (2)	80.9	118	37.1	12.2	>30	10
Rep 1 (2)	Wang Khanai	54.3	118	63.7	12.2	>30	3
Rep 1 (2)	"	49.1	118	49.1	12.2	>30	10
Rep 1 (2)	Ban Lum Sum	98.4	118	19.6	12.2	>30	10
Rep 1 (2)	"	98.4	118	19.6	12.2	>30	10
Rep 1 (2)	Ban Chao Nen	90.9	118	27.1	12.2	>30	10
Rep 1 (2)	"	90.9	122	31.1	12.2	>30	10
Rep 1 (2)	Rep 2	93.5	118	24.5	12.2	>30	10
Rep 1 (2)	Rep 2	93.5	122	28.5	12.2	>30	10
Rep 2	Thong Pha Phum	40.7	122	81.3	12.2	>30	3
Rep 2	"	35.5	122	86.5	12.2	>30	10
Rep 2	Ban Sai Yok	98.9	122	23.1	12.2	>30	10
Rep 2	"	102.4	122	19.6	12.2	>30	10
Rep 2	Ban Lin Thin	68.8	122	53.2	12.2	>30	3
Rep 2	"	67.1	122	54.9	12.2	>30	10
Rep 2	Ban Pa Tho	89.4	122	32.6	12.2	>30	10
Rep 2	"	92.8	122	29.2	12.2	>30	10
Rep 2	Sungkhla Buri	93.4	122	28.6	12.2	>30	10
Rep 2	"	96.9	122	25.1	12.2	>30	10
Rep 2	Pi Lok	97.5	122	24.5	12.2	>30	10
Rep 2		101	122	21	12.2	>30	10

Table 3. Type of Antenna and Transmitting Power

Location	Antenna	Transmitting Power (W)	Remarks
Bangkok (M.D)	3-element Yagi Ant	3	For RID
	5-element Yagi Ant Stack	10	For RI
" (RID)	3-element Yagi Ant	3	For MD
Repeater 1	5-element Yagi Ant Stack	10	For Bangkok
	5-element Yagi Ant Stack	10	For Repeater 2 and Observation Station
Whang Khanai	3-element Yagi Ant	3	
Ban Lum Sum	5-element Yagi Ant Stack	10	
Ban Chao Nen	5-element Yagi Ant	10	
Repeater 2	5-element Yagi Ant Stack	10	For Repeater 1
	3 element Yagi Ant 3 element Yagi Ant	10	For Observation Station
Thong Pha Pum	3-element Yagi Ant	3	
Ban Sai Yok	5-element Yagi Ant	10	
Ban Lin Thin	3-element Yagi Ant	3	
Ban Pa Tho	3-element Yagi Ant	10	
Pilock	3-element Yagi Ant	10	