REPORT OF PRELIMINARY SURVEY FOR SE BANG HIENG RIVER BASIN FLOOD FORECASTING PROJECT LAOS

1975

JAPAN INTERNATIONAL COOPERATION AGENCY

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Contents

CHAPTER I . GENERAL

1-1 Introduction

The Se Bang Hieng river basin is a huge plain extending in the southern part of Laos. Blessed with favourable natural conditions such as copious rainfall, production of cereals and livestock farming are very active in the basin and carry a heavy weight in the economy of whole Laos. For this reason, the Laotian government is hoping to develop the basin with Savannakhet as the centre for future development of southern Laos.

1-2 Formation and Itinerary of the Survey Team

The Japanese government sent the Preliminary Survey Team for the Se Bang Hieng River Flood Forecasting Project to Laos from January 26 to February 6, 1975. The team comprised three experts specialized in river engineering, hydrology and telecommunication. The assignment and affiliation of the experts are shown in Table 1-1.

Table 1-1 - Formation of the Survey Team

Affiliation as at March 1, 1975

Name	Assignment	Affiliation
Kazusuke NAKAO	Team leader, river engineering	River Councilor, River Division, Kanto Regional Construction Bureau, Ministry of Construction.
Tomomitsu FUJII	Hydrology.	Head of Water Management Planning Section, Operation Control Centre for the Tone River Dams Kanto Regional Construction Bureau, Ministry of Construction.
Kazuhiko TAKAYAMA	Telecommunication.	Telecommunication Specialist, Telecommunication Section, Accounting Division, Minister's Secretariat, Ministry of Construction.

During its stay in Laos, the team conducted a field survey and data collection with the kind cooperation of the Laotian government for establishment of a flood dorecasting system for the Se Bang Hieng river basin. Itinerary of the survey is shown in Table 1-2.

(1) Field Survey

The team conducted a field survey including simple surveying and interviews in the downstream area of the Se Bang Hieng basin in order to study the characteristics of the basin, to grasp the existing condition of the river channel, observation facilities and communication facilities, and to select the locations of observation stations.

(2) Data Collection

During its stay in Laos, the team made effort to collect the following data.

1) Data of meteorological, hydrological and hydraulic observations.
2) Data of climatic condition during flood periods.
3) Data of flooded areas and population, properties, and flood damages in such areas.
4) Data of administrative division of the basin and administrative organization.
5) Data on the existing condition of telecommunication system.

On the strength of these data, a simple analytical study was made on the plausible patterns and types of flood, propagation of flood wave, and feasibility of flood forecasting.

Table 1-2 - Itinerary of the Survey Team

Date and Day			Description
Jan	26	Sun	Arrival in Vientianne.
	27	Mon	Laotian holiday; Intra-team discussion on the itinerary and particulars of survey.
	28	Tue	Visit to the Service National de la Meteorologie; Arrangement for field survey and data collection at the Service National de l'Hydraulique et de la Navigation.
	29	Wed	Departure for Savannakhet for survey of the Se Bang Hieng river basin; Visits to Commander of District Headquarters of Laotian Army, Governor of Savannakhet province, Service Provincial de l'Hydraulique et de la Navigation, and Service Provincial de l'Agriculture.
	30	Thu	Survey of the Se Bang Hieng basin; Interview with the Vice-governor of Cham Pong province.
	31	Fri	Courtesy call on the Governor of Cham Pong province; Survey of the Se Bang Hieng basin.
Feb	1	Sat	Data collection at the Service Provincial de l'Hydraulique et de la Navigation.
	2	Sun	Completion of the basin survey, and return to Vientianne.
	3	Mon	Visit to the Service National de l'Hydraulique et de la Navigation, courtesy calls on the Minister and Vice-minister at the Ministry of Public Works and Transport, and reporting to Japanese Ambassador on the results of the field survey.
	4	Tue	Visit to the Service National de la Meteorologie for data collection; Preliminary discussion with Laotian side.
	5	Wed	Final discussion with Director General of and other Laotian officials.

Feb 6	Thu	Greetings offered to the Laotian government offices Japanese Embassy; Departure from Vientianne for Bangkok.

1-3 Summary of Survey Results

The survey disclosed that the Se Bang Hieng still retains its primeval state and that flood forecasting facilities and equipment are rather old and not well consolidated. The team noted that the availability of basic hydraulic and hydrologic data indispensable for studying the flood forecasting system was extremely limited, and found that consistent water stage data were available only for 1969 and 1970 at Done Hene on the Se Cham Phone and Keng Done on the Se Bang Hieng.

Although Done Hene and Keng Done are separated in distance by about 120 km, a simple analysis of the water stage data produced no appreciable gap in the flood occurrence time between the two points, suggesting the complexity of flood occurrence pattern in the lower Se Bang Hien basin. It seems that the effect of backwater from the Se Bang Hieng or the Mekong is quite large and prevails in considerably upper areas partly because of the topographical condition. In addition, the run-off speed from the main stream and tributaries is faster than was expected, so that the data of Done Hene station alone do not suffice for efficient flood forecasting.

Existing observation facilities are just too poor to cope with the complex flood occurrence pattern of the Se Bang Hieng. As things stand now, it is not possible to establish a simple forecasting system and operate it efficiently, not to speak of a highly efficient forecasting system incorporating a telecommunication network. Therefore, what is most urgently required at present is not to set up a flood forecasting system but to create a well organized observation network capable of collecting basic data with which to study the establishment of an effective forecasting system.

The team is of the opinion that once the observation network is established, it will entail no difficulty to collect the necessary data in a short period because floods occur almost every year in the Se Bang Hieng basin.

It must be added, however, that the survey made it clear that almost the entire basin should be covered by a network of optimal observation stations in order to establish a truly efficient flood forecasting system.

Establishment of a more efficient forecasting system employing telecommunication equipment for data transmission naturally calls for the availability of power source. At present, no constant power supply can be expected in the basin, and this will pose a serious problem for future planning of a telecommunication network.

The survey disclosed that bench marks for determining the absolute elevation of the reference height of water level gauges are not well consolidated and will therefore make it difficult to carry out levelling and other surveying works.

1-4 Recommendations

(1) Considering the poor consolidation of observation stations, power supply, bench marks, etc., it must be borne in mind that a considerably long period of time will be required to establish a flood forecasting system for the Se Bang Hieng river basin.

(2) Planning of a flood forecasting system should be preceded by the collection of basic hydraulic and hydrologic data. For this purpose, a network of suitable observation facilities should be set up.

(3) In order to clarify the behaviour of floods in the lower basins of the Se Cham Phone, the Se Sang Soi and the Se Bang Hieng, ordinary staff gauges should be installed at the following points.

Se Cham Phone	:	Done Hene, Keng Kok*, and Sup. 2.
Se San Soi	:	Muong Phalane and Buang Xang*.
Se Bang Hieng	:	Lahanam, Keng Done*, and Sup. 2.

Notes: * indicates existing station.

(4) In time with the installation of staff gauges, ordinary rain gauge stations should be established at the following points.

Se Cham Phone basin	:	A point upstream of Done Hene, Done Hene, and Keng Kok*.
Se San Soi basin	:	Muong Phalane, and Bung Xang.
Se Ban Hieng basin	:	Lahanam, and Savannakhet*.

Notes: * indicates existing station.

(5) While the flood from upper reaches of the Se Bang Hieng should never be disregarded, its influence cannot be estimated at the stations listed in Items (3) and (4) alone. It is therefore necessary to establish stage and discharge observation stations and rain gauge stations at a number of suitable points upstream of the confluence of the Se Cham Phone.

(6) Since the hourly rain depth exerts a heavy influence the rise of flood stage, it is advisable to install recording rain gauges in places where maintenance and inspection can be done with ease. Savannakhet station is recommended as one of such places.

(7) Method of communication between respective stations and Savannakhet should be determined after a careful study including proapagation test.

(8) Levelling should be conducted in order to find out the absolute elevation of the reference height of staff gauges to be installed at stage observation stations.

1-5 Acknowledgement

(1) The valuable assistance offered by the Laotian government officials whose names are listed below are gratefully acknowledged.

Laos Officers concerned participating in the Preliminary Survey on the Se Bang Hieng River Basin Flood Forecasting Project

I. Ministere des Travaux Publics et des Trranceport

1	Pagna Pak Savann	Directeur General

II. Service National do la Meteorologie

1	Khamtanh Kanhalikham	Directeur
2	Khamphou Manthourath (32)	Chef de Centre Technique
3	Khamthong Soukhathammavong	Chef de Centre Prevision Generale
4	Singkeo Malaythong	Chef de Bureau Hydrometeorole

III. Service National de l'Hydraulique et de la Navigation

1	Issara K. Sasorith	Directeur
2	Bouathong Phanthavady (35)	Chef Div. des Etudes Techniques et de l'Hyarologie
3	Hom Ratsima	Chef B. de l'Exploitation des Travaux, et donnes Hydrologique

IV. Service Provincial de la Meteorologie (Savannakhet)

1	Khamsoy Suongsombath	Chef

V. Service Provincial de l'Hydraulique et de la Navigation (Savannakhet)

1	Inthalongsine Sithimolada	

VI. Travaux Publics et des Tranceport (Savannakhet)

1	Lyton Lyfoung	Chef

(2) Deep gratitude is expressed to H. E. Mr. Singkapo Sikhotehounnamly, Minister for Public Works and Transport, and Mr. Rhagna Rihanngna Phithak, Secretary of State and Public Works, for sparing their precious time to grant an audience to the team.

(3) Thanks are also due to Mr. Phagna Boun Signavong, Governor of Savannakhet province, and Mr. Thao Thane Mahraj, Governor of Cham Phone province, who were both kind enough to spare time from business to make arrangements for the field survey and data collection.

Notes: Those whose names are prefixed by a circle participated in the field survey.

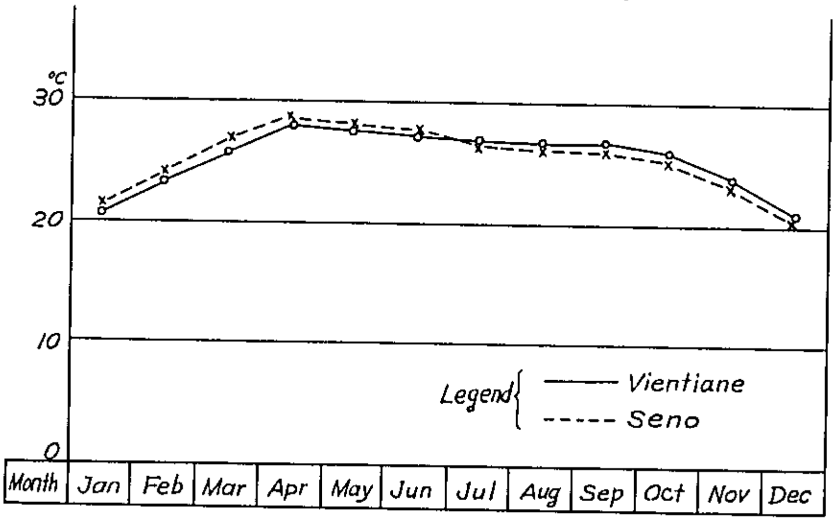
(4) The wishes to express its heartfelt thanks to Mr. Atsushi Hamamori from UN Typhoon Committee Secretarit who not only participated in the survey but also acted as interpreter for the team and coordinated the survey itinerary with the Laotian side.

CHAPTER II. GENERAL METEOROLOGICAL CONDITION

2-1 General

Rainfall through the Se Bang Hieng basin distributes itself into two seasons, the dry and the wet. The west season begins in late April and lasts until early October, and the remainder of the year is the dry season. Annual average temperature is about 25°C, and the monthly average temperature, averaging from 20 to 29°C, drops to the lowest of about 20°C from December through January and rises to the highest of 28 to 29°C in April and May. Annual transition of monthly average temperature in Vientianne and Seno (located just outside the western periphery of the Se Bang Hieng basin) is shown in Fig. 2-1.

Fig. 2-1 - Annual Transition of Temperature



In the wet season, monthly average rainfall ranges from 200 to 400 mm and number of rainy days averages about 20 days a month. In the dry season, monthly average rainfall is about 10 mm and rain falls only on two or three days a month. Thus, rainfall varies largely by season. Duration of sunshine also varies by season due to rainfall, averaging five to six hours in the wet season and about nine hours in the dry season.

Average values of climate in Laos are shown in Tables 2-1 - 2-8.

Table 2-1 - Atmospheric Pressure

	1	2	3	4	5	6	7	8	9	10	11	12	ANNEE
VIENTIANE	9946	9921	9900	9884	9870	9853	9847	9852	9872	9912	9931	9946	9894
LUANG-PRABANG	9807	9772	9756	9731	9717	9701	9701	9702	9750	9781	9800	9808	9750
SENO	9926	9897	9880	9864	9847	9833	9833	9834	9832	9886	9906	9923	9873
PAKSE	10012	9984	9975	9958	9949	9940	9937	9939	9947	9973	9994	10003	9969

	1	2	3	4	5	6	7	8	9	10	11	12	ANNEE
VIENTIANE	10140	10111	10089	10071	10056	10039	10034	10038	10059	10108	10122	10139	10084
LUANG-PRABANG	10102	10120	10100	10067	10056	10041	10045	10044	10071	10126	10147	10160	10095
SENO	10139	10110	10090	10072	10050	10041	10041	10040	10058	10097	10118	10138	10138
PAKSE	10119	10091	10081	10064	10055	10046	10044	10046	10053	10079	10100	10110	10074

Table 2-2 - Mean Atmospheric Temperature

STATIONS	MOIS												ANNEE
	1	2	3	4	5	6	7	8	9	10	11	12	
LUANG PRABANG $\frac{Tn+Tx}{2}$	205	230	257	280	287	286	275	275	275	261	235	208	256
T	187	214	245	268	273	273	264	262	259	246	219	187	241
VIENTIANE $\frac{Tn+Tx}{2}$	213	238	264	283	281	279	275	273	271	261	242	216	258
T	206	232	259	278	275	273	270	268	267	257	236	209	252
SENO $\frac{Tn+Tx}{2}$	210	243	272	289	286	280	273	273	289	256	240	215	259
T	209	237	270	282	277	273	263	265	261	251	234		253
PAKSE $\frac{Tn+Tx}{2}$	244	268	288	298	287	277	271	270	269	266	259	243	270
T	239	263	283	293	281	271	265	264	271	258	251	236	264

Table 2-3 - Relative Humidity

STATIONS	MOIS												ANNEE
	1	2	3	4	5	6	7	8	9	10	11	12	
LUANG-PRABANG	84	76	72	74	81	85	88	88	87	85	84	85	82
VIENTIANE	76	74	71	73	82	85	86	87	87	82	79	78	80
SENO	75	71	69	70	80	84	85	87	87	81	76	76	79
PAKSE	68	65	63	67	79	84	87	87	87	82	77	71	76

Table 2-4 - Dew Point

STATIONS	MOIS												ANNEE
	1	2	3	4	5	6	7	8	9	10	11	12	
LUANG-PRABANG	13.9	15.6	18.3	21.1	23.5	24.5	23.9	23.8	23.2	20.6	18.1	15.3	20.2
VIENTIANE	14.9	17.2	19.7	21.6	23.8	24.4	24.2	24.4	24.2	21.7	18.8	16.2	20.9
SENO	13.0	17.6	20.1	21.7	23.6	24.0	23.9	24.0	23.4	21.2	18.6	16.4	20.6
PAKSE	15.5	18.1	20.1	20.1	21.4	23.3	23.9	24.2	24.1	24.4	20.4	18.6	21.3

Table 2-5 - Evaporation in Millimeters

STATIONS	MOIS												ANNEE
	1	2	3	4	5	6	7	8	9	10	11	12	
LUANG-PRABANG	1.8	2.7	3.5	3.5	2.7	2.0	1.6	1.4	1.6	1.7	1.7	1.6	2.1
VIENTIANE	2.9	3.5	4.0	4.0	2.6	2.0	1.8	1.6	1.7	2.1	2.4	2.6	2.6
SENO	4.4	5.2	6.1	5.6	3.6	2.9	2.5	2.2	2.0	3.1	3.6	4.0	3.8
PAKSE	4.4	5.5	6.0	5.3	3.5	2.3	1.9	1.7	1.7	2.4	3.4	3.9	3.5

Table 2-6 - Duration of Sunshine

STATIONS	MOIS												ANNEE
	1	2	3	4	5	6	7	8	9	10	11	12	
LUANG-PRABANG	X	X	X	X	X	X	X	X	X	X	X	X	
VIENTIANE	7.6	6.6	6.2	6.1	5.6	X	4.1	4.0	3.8	7.8	8.1	8.4	6.
SENO	9.2	8.1	7.2	6.9	7.7	6.3	5.6	5.0	4.6	7.7	9.2	8.5	7.
PAKSE	X	X	X	X	X	X	X	X	X	X	X	X	

Table 2-7 - Rainfall

HAUTDUR TOTAL

STATIONS	MOIS												ANNEE
	1	2	3	4	5	6	7	8	9	10	11	12	
LUANG-PRABANG	13.8	17.1	29.8	101.0	157.2	180.0	231.9	281.5	170.9	73.1	27.4	12.8	18965
VIENTIAN	7.0	16.1	3.7	95.2	260.4	294.0	265.5	36.5	326.4	95.0	18.2	1.5	17405
SENO	3.8	23.1	24.2	78.1	194.1	255.5	264.7	327.0	332.0	9.9	9.1	0.3	16048
PAKSE	1.5	8.0	25.3	61.8	208.1	325.3	395.9	465.8	380.6	108.7	22.8	2.6	20064

Table 2-8 - Number of Rainy Days

ROMBRE DE JOURS

STATIONS	MOIS												ANNEE
	1	2	3	4	5	6	7	8	9	10	11	12	
LUANG-PRABANG	4	3	5	8	14	17	18	21	14	6	2	2	114
VIENTIANE	2	2	4	7	16	19	19	22	20	6	1	1	118
SENO	1	2	4	6	14	17	19	20	17	7	2	1	109
PAKSE	X	1	3	5	13	17	18	23	17	10	4	1	112

2-2 Climatic Condition Conductive to Heavy Flood

Floods in Laos can be broadly classified into the following two types.

1) Seasonal floods of the Mekong river.

2) Flash floods of main tributaries.

Seasonal floods of the Mekong occur in the northern part of Laos and mid-stream area of the Mekong in the August - September when south-westerly monsoon blows. In this period, strong rain often falls continously for several days and storm rainfall sometimes lasts for two or three days.

Flash floods occur mostly in the southern basins of the Se Ban Fay, the Se Ban Hieng and the Se Done. They are caused by the strong rain which is brought about by tropical depressions or storms passing through near the basins of these rivers.

The meteorological disturbances bringing strong rain to Southeast Asia are classified into the following five types.

1) Tropical cyclones.

2) Monsoon depressions.

3) Semi-stationary or stagnant front, trough line or convergence zone.

4) Trough line in the upper air moving in the east or west.

5) Local rainfall.

The southwesterly monsoon which prevails in the wet season often brings about heavy rainfalls from mid-May to late September. Humidity is high and the sky is overspread with clouds in this monsoon period. In June or July, however, drought continues for one or two weeks due to the anticyclone circulation aloft. After the drought, heavier rainfalls are brought about more frequently by tropical storms and typhoons. Specially in the middle southern mountainous area of Laos where the southwesterly monsoon hits the Annames range, heavy rainfalls often cause floods.

Floods are usually caused when a tropical storm develops or when an intertropical convergence zone passes in an active state.

CHAPTER III. FIELD SURVEY AND DATA COLLECTION

3-1 Field Survey

During its stay in Laos, the team conducted a field survey including simple surveying and interviews in the Se Bang Hieng lower basin with the collaboration of the Laotian government in order to study the characteristics of the basin, to grasp the existing condition of the river channel, observation facilities and communication facilities, and to select the locations of observation stations.

(1) Itinerary of Field Survey

The field survey was conducted for five days from January 29 to February 5. Details of the itinerary are described below.

<u>January 29 (Wed)</u>

Left Vientianne at 7:05 hrs by a domestic airliner of Royal Air Lao and arrived at Savannakhet at 8:15 hrs. Interviewed the Governor of Savannakhet province and was informed of the general situation of the province. Visited the Service Provincial de l'Hydraulique et de la Navigation with the request to collect necessary data. Visited the Service Provincial de la Agriculture and collected data of flooded areas and flood damage.

Inspected the rain gauging facilities and SSB equipment of the Service Provincial de la Meteorologie and the rain gauging facilities of the Service Provincial de l'Hydraulique et de la Navigation (both located in Savannakhet city).

<u>January 30 (Thu)</u>

Survey of the Se Bang Hieng basin was conducted for inspection of the following observation stations.

Bang Keng Done Water Stage Observation Station
Former Se Bang Hieng Bridge Water Stage Observation Station
Proposed Site of Lahanam Water Stage Observation Station
Keng Kok Water Stage Observation Station

Interviwed the Vice-governor of Cham Phone province and was informed of the population, flood damage, etc., and put up in Keng Kok.

<u>January 31 (Fri)</u>

Visited the Governor of Cham Phone province and was informed of the flood damage, flood preventive measures, and other problems in the province. Inspected the damage of the irrigation dyke at his request as well as the following two stations.

Done Hene Water Stage Observation Station
Seno Meteorological Observatory

<u>February 1 (Sat)</u>

Visited the Service Provincial de l'Hydraulique et de la Navigation and obtained water stage data, self-recorded data of Kent Done station, and data of flood damage and administrative division of the basin.

February 2 (Sun)

Completed the field survey. Left Savannakhet at 9:00 hrs and arrived at Vientiane at 10:15 hrs.

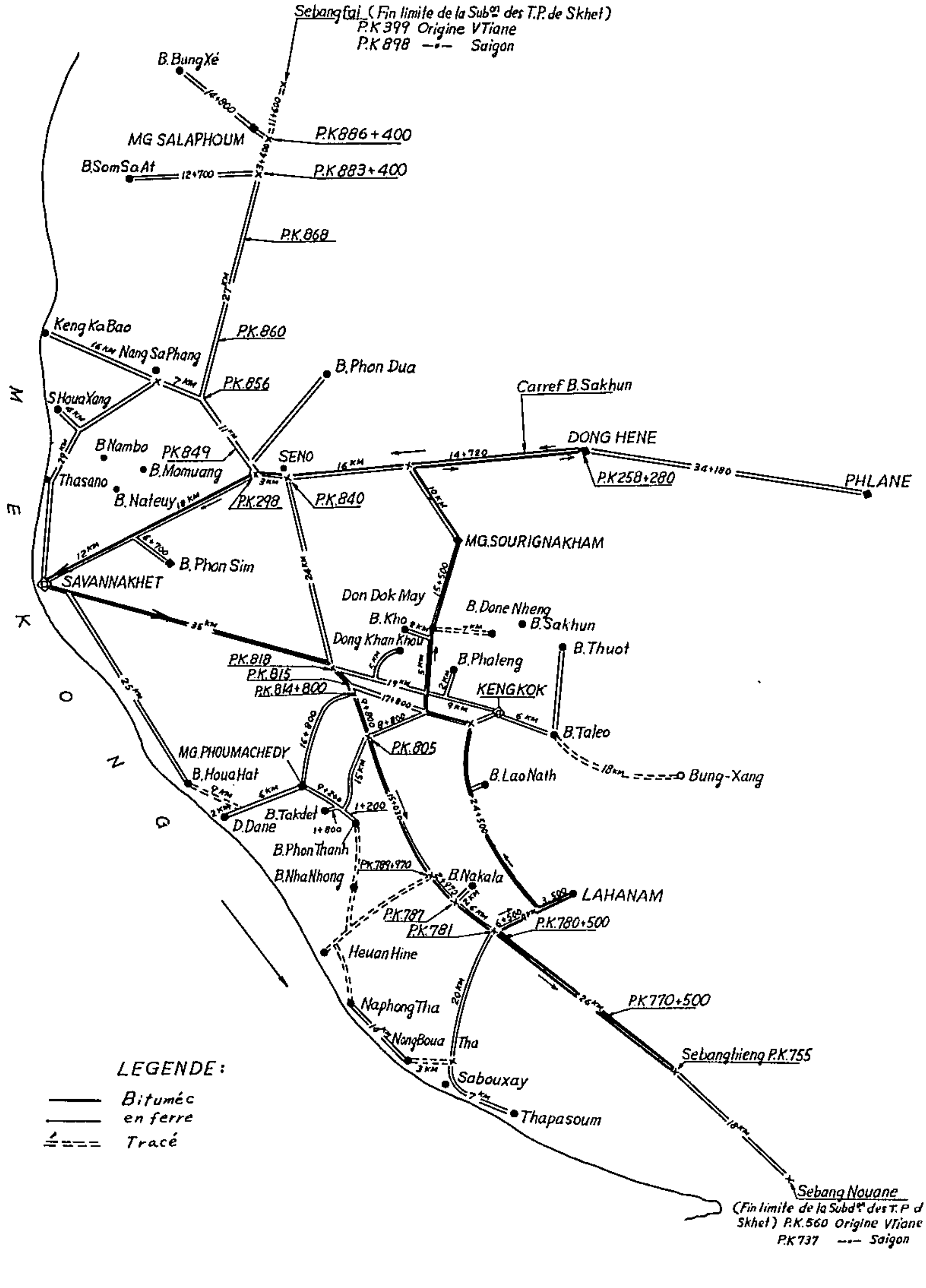


Fig. 3-1 - Route of Basin Reconnaissance

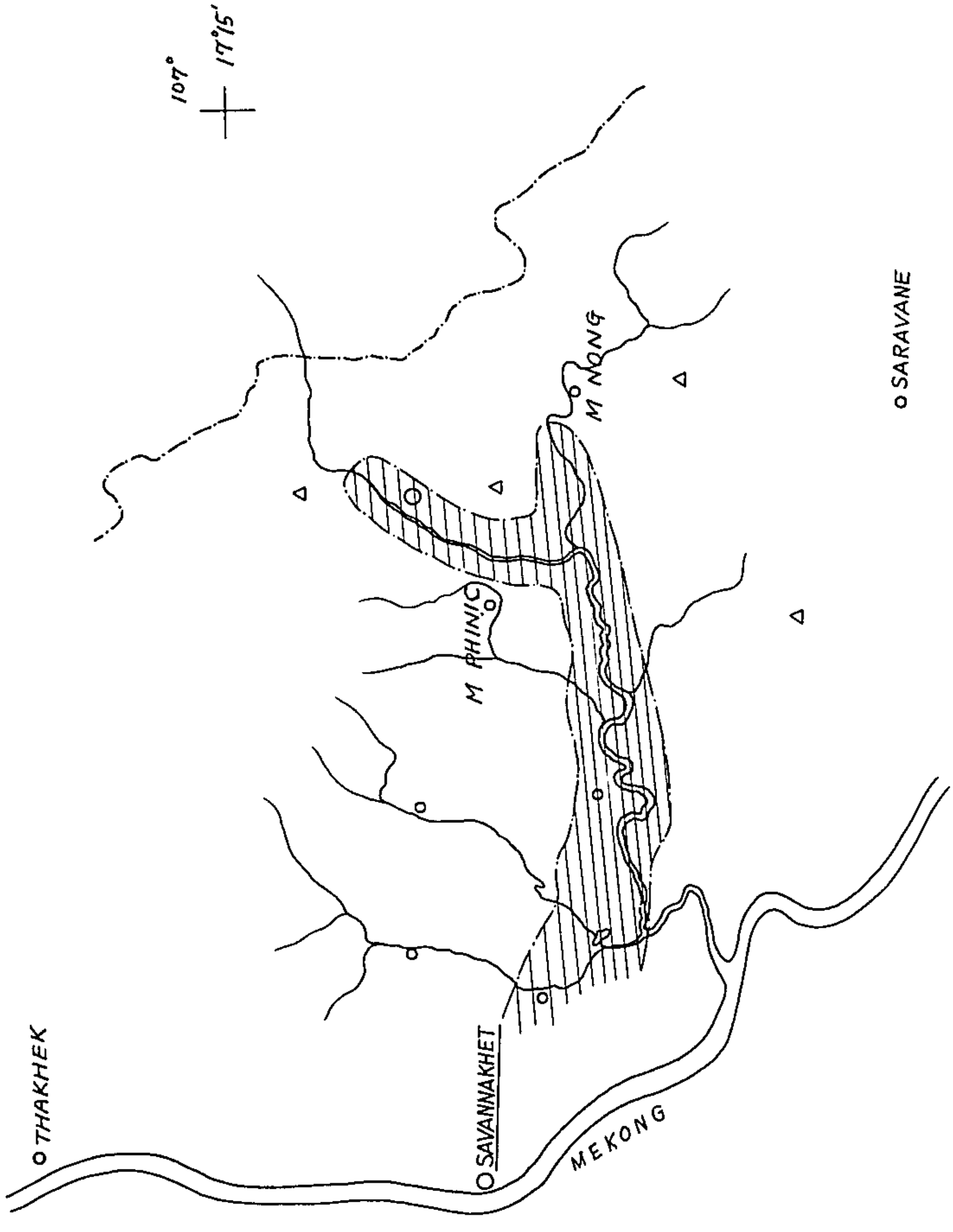


Fig. 3-2 - Flight Course for Basin Reconnaissance

(2) Transportation

The entire reconnaissance route of about 300 km was covered by two motorcars made available to the team by the Loatian government.

(3) Road Condition

Road linking the following points are unpaved but since they are well compacted and not rough, it is possible to drive at a speed of 60 - 80 km/h.

Savannakhet ---> Keng Done ---> Se Bang Hieng Bridge ---> Keng Kok ---> Done Hene ---> Seno

Between Keng Kok and Done Hene, however, it was noted that some bridges had been washed away by a flood. Traffic in this section is often cut off in the wet season.

Between Seno and Savannakhet, there runs National Highway No. 9 which is completely paved except in a section near Savannakhet where the road width expansion work is in progress.

Savannakhet is linked with Keng Done by National Highway No. 11 or No. 13. However, jeeps are the only means to reach Keng Done station because the road running between the national highway and the station is extremely rough. This road is sandy and has a length of 2 or 3 km, so that it will be difficult to get to the station by a motorcar specially in the wet season.

(4) Existing State of Observation Stations

Tables 3-1 - 3-3 show the existing state of the water gauge stations and rain gauge stations covered by the field survey.

However, two of the rain gauge stations in Table 3-3, Keng Kok and Done Hene, were not covered by the field survey.

Table 3-1 - Existing State of Water Gauge Stations (Inspected-1)

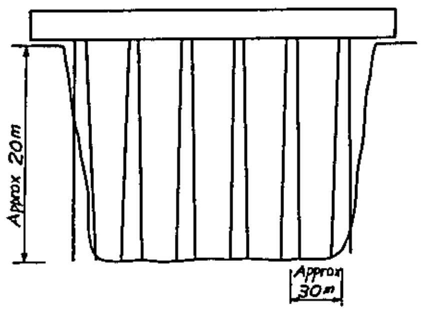
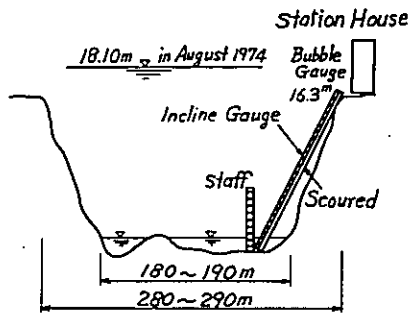
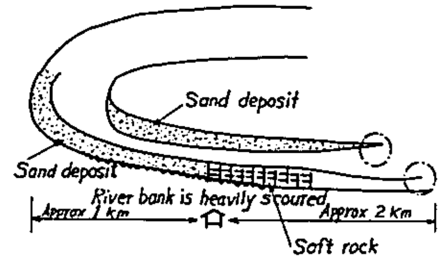
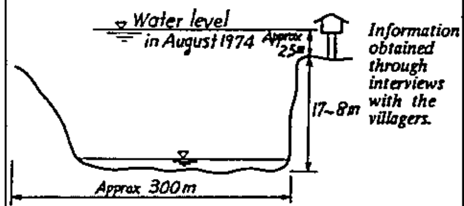
Name of Station	Ban Tang Gane (Se Bang Hieng Bridge)	Ban Keng Done	Lehanam (Proposed)
Name of River	Se Bang Hieng River	Se Bang Hieng River	Se Bang Hieng River
Observation Item	Water Stage	Water Stage	Water Stage
Equipment	Staff (Not installed at present)	Staff (Incline Gauge) Self-Recording (Bubble Gauge)	Staff
Range of Measurement	—	Staff 0 ~ 16. 30 m Self 0 ~ approx. 18 m	—
Data Recording Period	1965 ~ 1970	1963 ~ 1974	—
Reference Line Elevation	EL 108. 00 m	EL 121. 290 m	
Sketch			 indicates the proposed site of water gauge installatiin. Either point is recommendable if a station house is made available.
Remarks	Water level rose to about 1 m above the natural levee during the flood in August 1974, but no damage was caused because houses were built in elevated places. On the left bank side, there is a cluster of about 500 houses.	∘ Bubble gauge (U.S. made) was installed by the Mekong Committee. ∘ Water level rose to 18. 10 m (≒16. 30 + 1. 80) during the flood in August 1974, and caused the heaviest inundation in 130 years. ∘ Bang Keng Done is a village with 150 households and has a population of a little more than 1, 000. ∘ The access road is sandy and in a very bad condition and permits passage of only jeeps.	

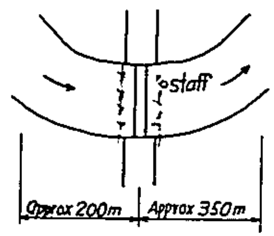
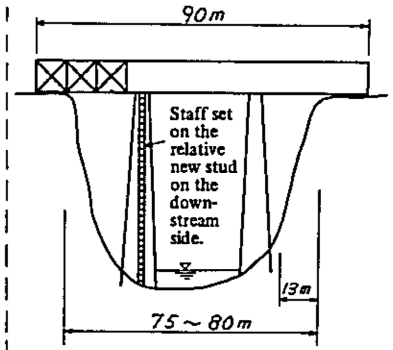
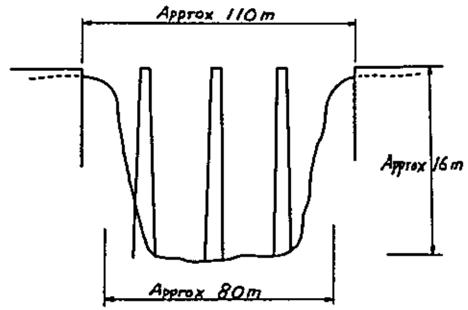
Table 3-2 - Existing State of Water Gauge Stations (Inspected-2)		
Name of Station	Keng Kok	Done Hene
Name of River	Se Cham Phone River	Se Cham Phone River
Observation Item	Water Stage	Water Stage
Equipment	Staff	Staff (Not installed at present.)
Range of Measurement	0 ~ 10 m	
Data Recording Period		1969 ~ 1971 (1971··Incomplete)
Reference Line Elevation	No levelling conducted yet.	No levelling conducted yet.
Sketch	 	
Remarks		◦ Bridge was destroyed two years ago during the war, and staff is not installed at present. ◦ The team was told that mines still remained uncleared in the neighbourhood.

Table 3-3 - Existing State of Rain Gauge Stations (Inspected and Covered by Data Collection)

Name of Station	Savannakhet	Savannakhet	Seno	Keng Kok	Done Hene
Competent Organization	Service Provincial de la Meteorologie	Service Provincial de l'Hydraulique et de la Navigation	Service National de la Meteorologie	Service National de la Meteorologie	Service National de la Meteorologie
Type	Ordinary	Ordinary	Ordinary	Ordinary	Ordinary
Dimension	12. 5 cm	20 cm	20 cm		
Data Recording Period	1966 - 1974			1965 - 1974	1964 - 1970

(5) Cham Phone Province

Cham Phone province is divided into six Muongs which are subdivided into 54 Tassengs and further into 474 Bans, and its provincial office is located in Keng Kok (Cham Phone). It covers an area of about 7,100 km^2 and has a population of about 137 thousand. With the exception of a small area in the south, the entire province is within the Se Bang Hieng basin and occupies about one-third of the basin area. Although mountains rising to a height of 200 - 500 m are found in the north and south, more than 90% of the area is a flat plain with a mild slope ranging in elevation from 130 to 150 m.

The downstream section of the Se Bang Hieng and its three tributaries, the Se Cham Phone, the Se Sang Soi and the Se Kum Kam, flow through the province. The lowland areas extending along these rivers are favourably conditioned for agriculture and livestock farming. Rice is the main crop, and many cows, hogs and buffaloes are raised in these areas. Buffaloes are used as draft animals. According to the Service Provincial de la Agriculture, the paddy field area in the province is 13,634 ha, although this figure is not very reliable. The team was informed that an area of 96,200 ha including paddy fields was submerged and 6,817 households suffered heavy damage during the great flood in August 1974. Table 3-4 shows some statistical data of the province.

Table 3-4 - Outline of Cham Phone Province

Muong	Major Town	Area km^2	Population		Number of Families	Number of Villages	Damage in 1974 Flood			Remarks
			Population	Year of Survey			Buffalo	Cow	Pig	
Cham Phong	Keng Kok	830	44,638	1973	6,591	100	19,232x0.80	7,704x0.80	4,805	
Souriya Kham	Lao Souriya	375	13,959	1971	2,275	45	2,234x0.30	2,040x0.30	-	
Song Khone	Lahanam	2,130	42,130	1973	6,174	129	15,547x0.55	17,202x0.51	2,671	
Phong	Phong	1,630	21,060	1972	2,988	91	5,817x0.85	3,812x0.85	1,350	
Phouvieng	Phouvieng	950	7,649	1970	894	45	-	-	-	
Phalane	Phalane	1,200	7,841	1973	2,139	64	-	-	-	
Total		7,115	137,277		21,061	474	Approx. 29,500	Approx. 19,476	8,826	

Table 3-5 - Population Distribution in Muong Song Khone

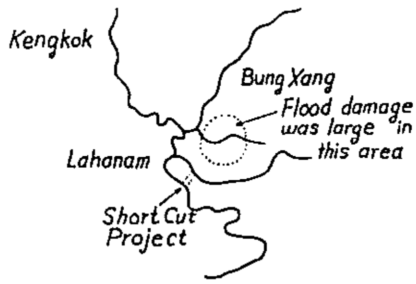
Unit : Person

Tasseng	Ban	Population
Lahanam	1	1,022
	2	1,035
	3	535
	4	138
	5	126
	6	75
	7	227
Lahakhou	1	922
	2	406
	3	371
	4	386
Paksong	1	1,131
Nong Khung	1	701
	2	432
	3	136
	4	116
	5	195
	6	216
Keng Done	1	1,011
	2	471
	3	403
	4	129
	5	372
	6	251
Song Khone	1	415
	2	370
	3	434
	4	414
	5	256
	6	348
	7	394
Nakharha	1	415
	2	693
	3	343
	4	143
	5	577
	6	161
	7	205
Phang Phine	1	233
	2	557
	3	359
	4	449
	5	376
	6	256
Phang Phine	7	202
	8	142
Nong Batha	1	743
	2	571
	3	261
	4	227
	5	442
	6	270
	7	334
	8	274
	9	177
	10	209
	11	369
	12	155
	13	103
	14	136
Sabho Sai	1	521
	2	382
	3	431
	4	465
	5	1,048
	6	234
	7	267
Naha Phua	1	312
	2	477
	3	666
	4	347
	5	1,064
	6	1,130
	7	452
	8	162
Phuai Khau	1	319
	2	390
	3	462
	4	531
	5	116
	6	306
	7	218
	8	178
	9	120
	10	158
	11	235
Se Bang Hieng	1	634
	2	410
	3	795
Se Bang Hieng	4	485
	5	332
	6	294
	7	270
	8	255
	9	166
	10	143
	11	58
Se Bang Nuang	1	858
	2	381
	3	149
	4	295
	5	182
	6	201
	7	224
	8	217
	9	104
	10	140
	11	135
Ta Nung	1	431
	2	195
	3	303
	4	479
	5	199
	6	151
Sangeh	1	337
	2	287
	3	230
	4	261
	5	239
	6	273
	7	123
	8	119
	9	140
	10	71
Muong Phong	1	279
	2	245
	3	123
	4	109
	5	138
	6	116
	7	374
	8	150
	9	192
	10	218

(6) Data Provided by Governor of Cham Phone Province

1) The flood in 1974 was the greatest ever recorded in 130 years, and it lasted for seven days from August 14 to 21. During this flood, more than 7,000 houses were submerbed and about 39 thousand people suffered damage. A heavy loss of domestic animals was also suffered in Donya Nong in Muong Phong where livestock farming was active.

Floods of similar magnitude occur once in three years or so. The following are the plausible causes of flood damage.



i) The province embraces the confluence of the Se Cham Phone and the Se Sang Soi.

ii) The rivers meander through the province.

iii) Elevation of damaged area is low.

A short-cut project was mapped out by the Laotian Army, but was dropped because its implementation involved technical difficulty (which the team understood was a geological problem).

2) In areas frequently subjected to flood damage, highly efficient land use is materialized.

3) When a flood occurs, a committee for preventing flood damage is organized.

4) With the recent introduction of an improved irrigation system, paddy has to be grown in the dry season. So long as irrigation water is available, dry season cropping promises greater yield than in the wet season.

5) Development of the province is impeded by the absence of facilities for water and power supply. Power transmission from Savannakhet incurs a unit cost of about 6,000,000 Kip/km or a total cost of about 420,000,000 Kip. A preliminary power plant programme was prepared but it is just a desk plan.

6) Data offered by the Vice-Governor of the province:

1. Damage caused by the flood in August 1974

Damaged paddy field area	627 ha
Average unit yield	1.5 - 2.0 t/ha
Unit sales price (unhusked)	138 Kip/kg
Estimated damage in value	627 ha x (1.5 - 2.0 t/ha) x 138 x 10^3
	≒ 100 - 170 million Kip

2. Yield per unit area

i)	First cropping by rain-fed cultivation	1.5 - 2.0 t/ha
ii)	Second cropping of RH8 (miracle rice) using artificial irrigation	3.0 - 4.0 t/ha

3. Average operational holding per farm household 1.5 - 2.0 ha.

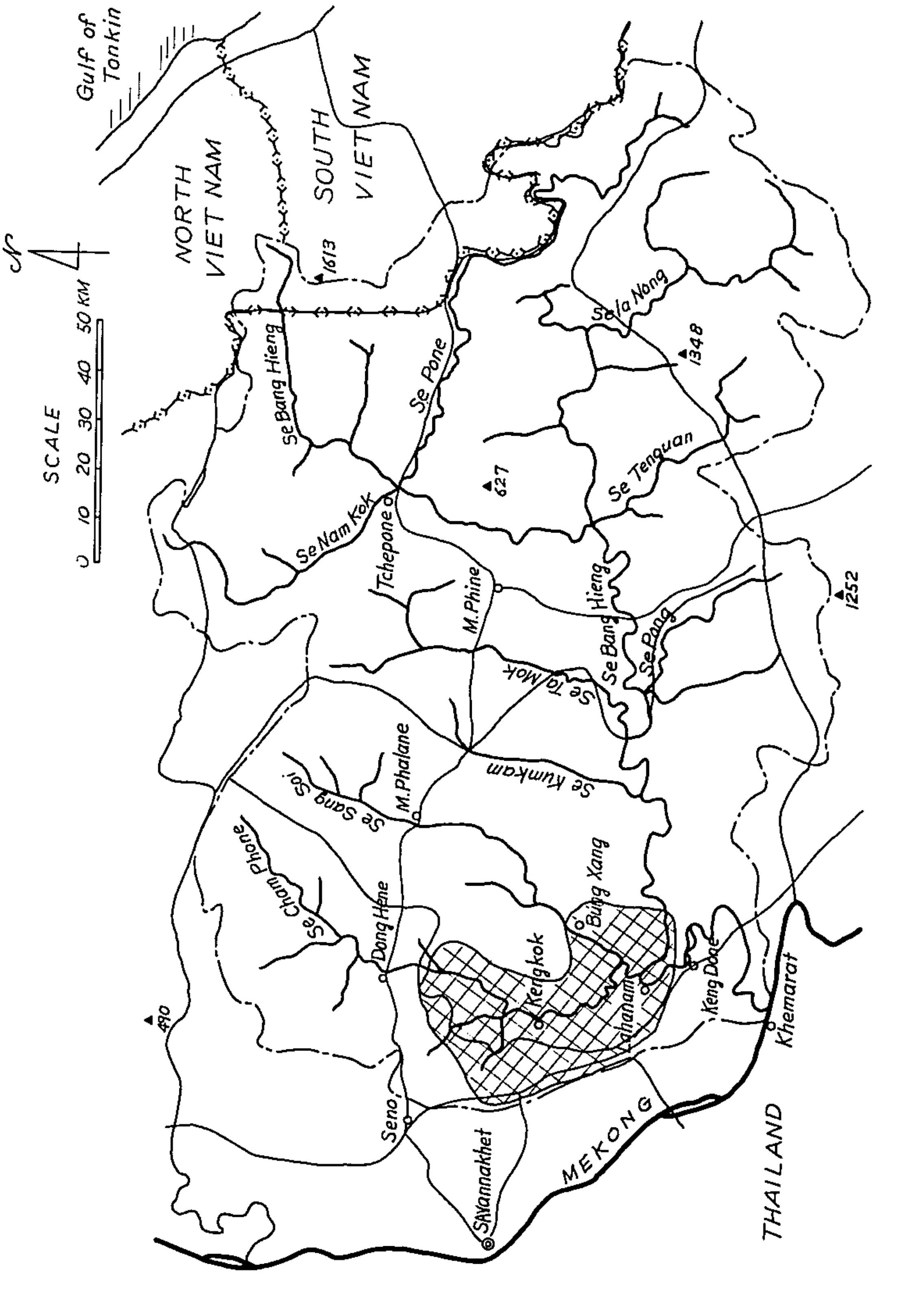


Fig. 3-3 - Flooded Area

3-2 List of Obtained Data

I. Reports

1. Lower Mekong Hydrologic Yearbook 1966 Volume I
2. Lower Mekong Hydrologic Yearbook 1966 Volume II
3. Lower Mekong Hydrologic Yearbook 1967 Volume II

   (Committee for Coordination of Investigations of the Lower Mekong Basin)

4. Bulletin de Statistiques 1973 No. 2
5. Bulletin de Statistiques 1974 No. 1

   (Royaume du Laos
   Ministere du Plan et de la Cooperation Service National de la Statistique)

6. Mekong et ses Affluents - Bulletins Hydrologiques Savannakhet 1960 a 1971

   (Ministere des Travaux Publics et des Transports Service National de l'Hydraulique et de la Navigation, Section Hydrologie)

II. Drawings

1. Carte Generale du Laos (1/1,250,000)
2. Cambodge - Laos - Vietnam (1/2,000,000)
3. Vientiane (1/10,000)
4. Administrative Division of the Province
5. Carte des Stations des Reseaux Hydrologiques de Savannakhet - Service Provincial (1/250,000)
6. Carte Geologique (1/2,000,000)

III. Data

1. Meteorological Condition which caused large floods
   (1) Characterictics of the Rainy Season
   (2) Meteorological Condition of Each Flood
       (a) 21 - 25 September, 1964
       (b) 1968
       (c) 1972
       (d) 1974
2. Daily Rainfall Data
   2-1. Done Hene 1964 - 70
   2-2. Keng Kok 1965 - 74
   2-3. Savannakhet 1966 - 74
3. Daily Water Stage Data
   3-1. Done Hene 1969 - 71
   3-2. Keng Done 1963 - 74
   3-3. Tang Gane 1965 - 70

CHAPTER IV. OUTLINE OF THE SE BANG HIENG RIVER

4-1 Outline of the Se Bang Hieng Basin

The Se Bang Hieng river basin is situated in the southern part of Laos and adjoins the Se Bang Fai river basin which extends immediately in the north. The two basins form the largest plain in the country. The Se Bang Hieng rises in the Laos-Viet Name borders, flows westwards with nine major tributaries and smaller rivers joining it like veins joining the nervure, and flows into the Mekong at a point about 90 km downstream of Savannakhet. It has a total length of about 370 km and a catchment area of about 19,600 km^2. It is one of the main tributaries of the Mekong and is known as the third largest river in Laos.

The greater part of its basin is a flat plain with some low hilly areas and ranges in elevation from 130 to 200 m, although moutains rising to a height of 800 - 1,000 m stretch in the eastern part near the boarder line.

Annual average rainfall in the basin is about 1,500 mm, with the western flat land area recording an average of about 1,000 mm and the eastern hilly area marking an average of 2,500 - 3,000 mm. Rainfall is brought about by the southwesterly monsoons, typhoons and tropical depressions, and concentrated in the wet season lasting from mid-April to mid-October. Virtually no rain falls in the dry season.

Since the basin embraces a great expanse of plain blessed with copious rainfall, it is one of the important granaries of Laos. Production of rice, the main product, accounts for 20% of the country's total. Agriculture in the basin is featured by the active livestock farming which includes pasturing, hog raising and poultry. Numbers of these domestic animals account for one-fourth or more of the country's total.

The basin is rather thinly populated, but bears a density which is 1.5 times the nation's average. In the lower basin of the Se Bang Hieng and in the basins of the Se Sang Soi and the Se Cham Phone, there are cities like Keng Kok, Songkhone, Lahanam, Phalane and Done Hene where population is concentrated. Population of the basin is not known clearly, but it is known that the population of the former Savannakhet province which covered almost the same as the basin was about 450 thousand. From this figure, the population of Savannakhet (about 60 thousand) and Seno must be decuted.

The greater part of the Se Bang Hieng basin was included in the former Savannakhet province in the past. At present, however, it is divided into three provinces, Savannakhet, Cham Phone and Tche Phone.

Three national highways run through the Se Bang Hieng Basin. Highway No. 13 starting from Seno runs southeast along the boundary of the basin and leads to Pakse. Highway No. 9 crosses the basin from Savannakhet and leads to South Viet Name via Seno, Done Hene, M. Phalane, M. Phine and Tchephone. Another Highway No. 23 runs southward from M. Phine in the direction of Saravane.

Red soil and sandstone prevail in almost the entire basin.

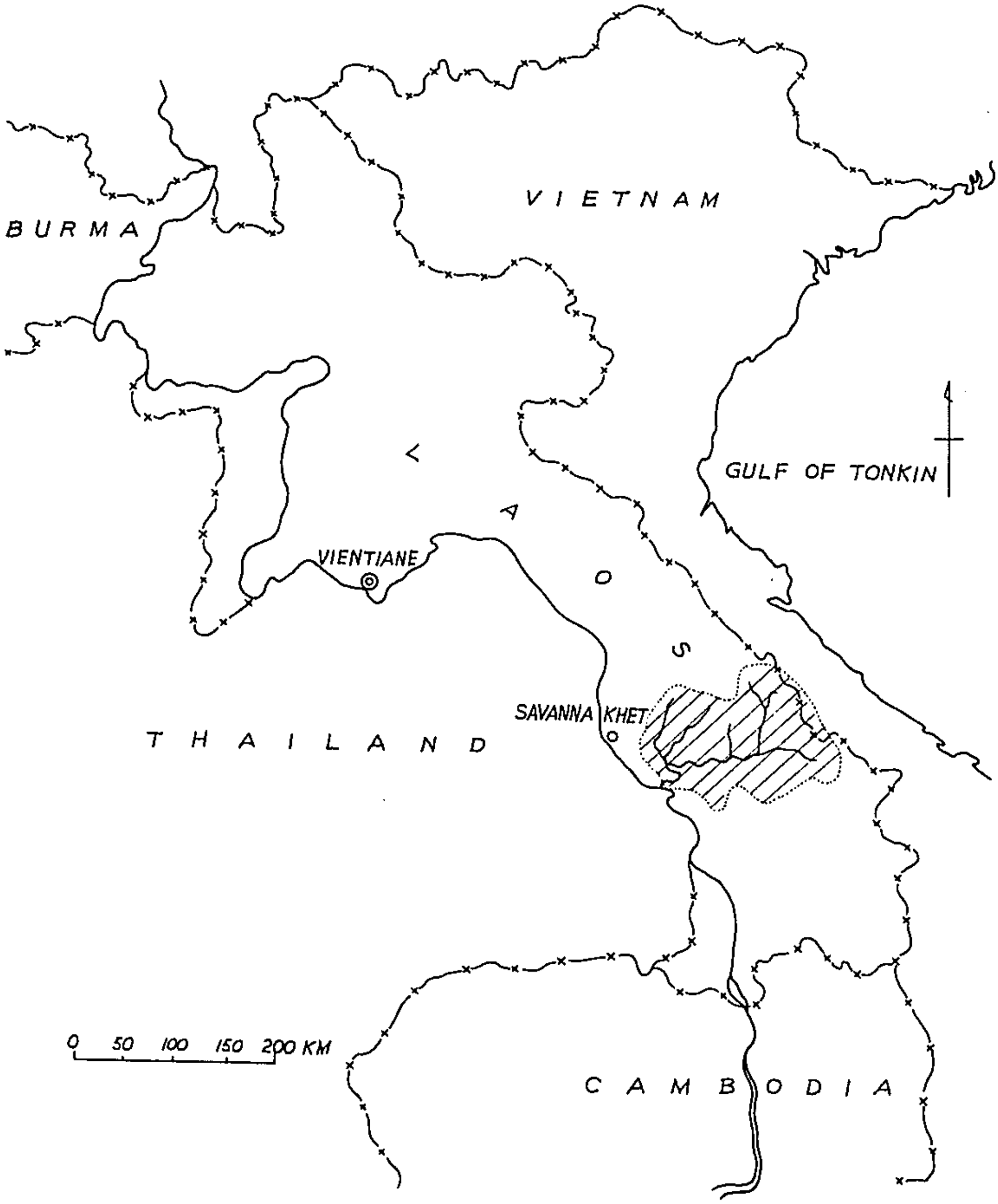


Fig. 4-1 - Location Map of Se Bang Hieng River Basin

4-2 Outline of Rivers

As shown in Table 4-1, the Se Bang Hieng has nine major tributaries. Five of them join the Se Bang Hieng on the right bank side and three on the left bank side.

The field survey could cover only the downstream section of the Se Bang Hieng and the Se Cham Phone due mostly to security problem rather than for the shortage of time. Insofar as could have been seen during the field survey, there were no sections where river improvement had been effected and the river channel was noted to be running through tableland, forming a canal with a single section. Since the rivers flow through the flat-land area with little gradient, they meander in an extreme degree so that scouring, formation of natural levees and silt deposition are repeated every year due to floods. However, since the river channel already has a depth of 10 to 15 m and the slope is very small, it seems that the main river channel does not change every year.

The downstream section of the Se Bang Hieng has a bed slope of about 1/5, 000, a width of about 300 m and a depth of 15 - 20 m. The Se Cham Phone has a bed slope of about 1/5, 000, a width of about 800 m and a depth of about 10 m.

Location of confluence, catchment area and length of main tributaries are shown in Table 4-1, and a basin model of the Se Bang Hieng is shown in Fig. 4-2.

Table 4-1 - Basic Data of Main Tributaries

Name of River	Tributary	Distance from Confluence with Mekong	Catch-ment Area	Length	Remarks
		km	km^2	km	
Se Bang Hieng			19, 600	370	Maximum length-Approx. 460 km inclusive of the Se Pone.
	Se Cham Phone	73	3, 040	162	Joins the Se Bang Hieng on the right bank.
	Se Sang Soi	73	2, 040	116	"
	Se Kum Kam	129	670	61	"
	Se Ta Mok	149	1, 500	96	"
	Se Nam Kok	298	1, 400	85	"
	Se Bang Hieng	298	1, 250	72	"
	Se Pone (Se Saynon)	297	1, 920	160	Joins the Se Bang Hieng on the left bank.
	Se La Nong	234	2, 480	145	"
	Se Tenouan	234	880	60	"
	Se Pong	165	1, 300	50	"
	Residual Basin		3, 120		

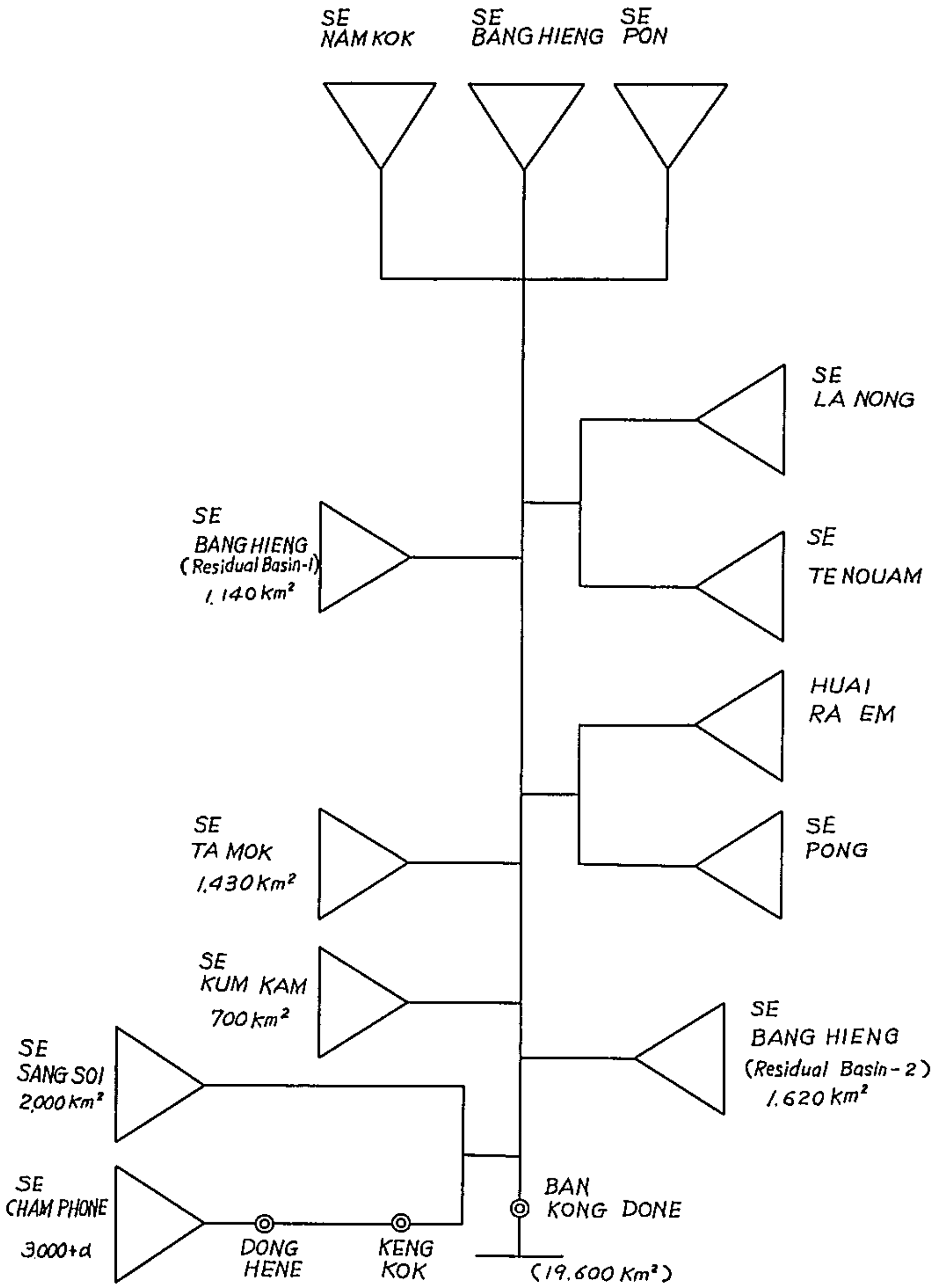


Fig. 4-2 - Basin Model of the Se Bang Hieng

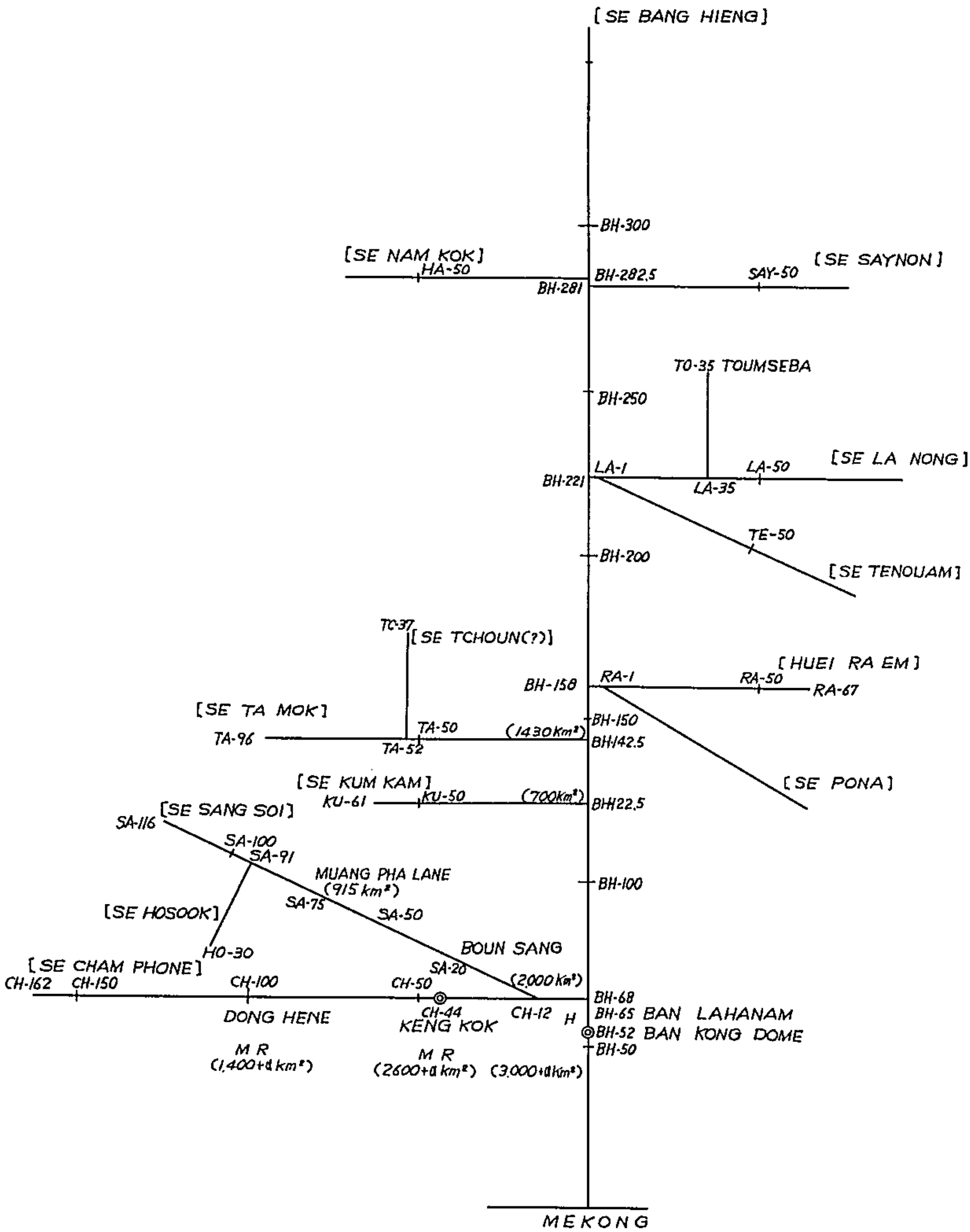


Fig. 4-3 - River Channel Model of the Se Bang Hieng

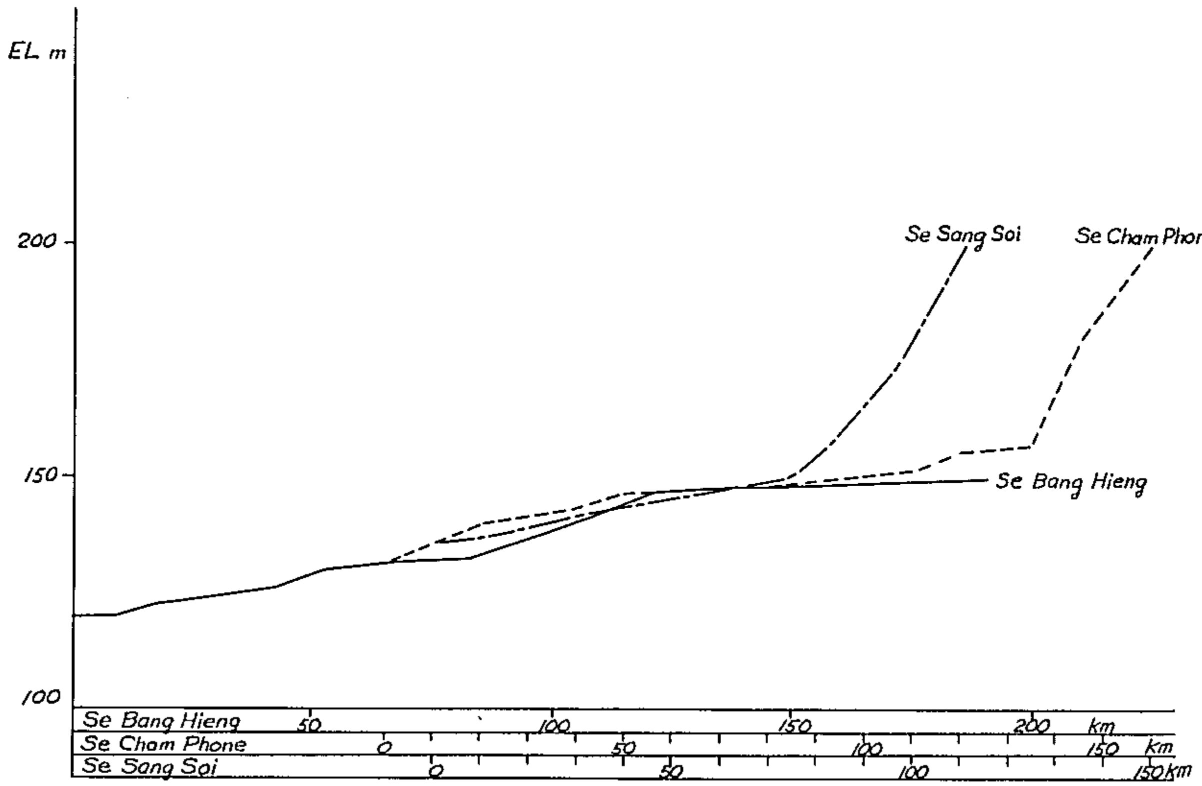


Fig. 4-4 - Profile of River Channel

4-3 Existing State of Observation Stations and Availability of Data

(1) Rain Gauge Stations

Continuous rainfall observation is conducted only at Keng Kok station in the basin. Table 4-2 shows the data of Done Hene station where observation was made for a substantially long time and Seno and Savannakhet stations which are located outside but near the basin. Most of the rain gauge stations are managed by the Service National de le Meteorologie but there is a station belonging to the Service National de l'Hydraulique et de la Navigation in Savannakhet.

There is a plan to establish new rain gauge stations at Bung Yang and Muong Phalane on the Se Sang Soi.

The record of the Mekong Committee shows the existence of the following stations and old data. Part of these old data was obtained during the present survey.

No.	Name of Station	Location	Period Covered by Data
28	THAKHEK	Outside Basin	1929-32, 35-39, 42, 56, 61-64
29	TCHEPONE	Inside Basin	1923-25, 27, 30-32, 35-38, 56
30	SENO	Outside Basin	1949-64
31	Savannakhet	Outside Basin	1927-29, 31-40, 56
32	LOABAO	Outside Basin	1930-33, 36-39
33	MUONG PHINE	Inside Basin	1929-33, 35-39
34	KENG KOK	Inside Basin	1931, 35-39
35	Bantam Pril	Outside Basin	1938
36	SARAVANE	Outside Basin	1929-33, 35-39, 42, 64

Table 4-2 - List of Rain Gauge Stations (Existing)

No.	Name of Station	River Basin		Classification	Location	Managed by	Duration of Observation	Remarks
		Main	Tributary					
1	Dong Hene	Se Bang Hieng	Se Cham Phone	Ordinary	N16°00' E105°47'	MET	1963 ~ 70	
2	Keng KOK	"	"	"	N16°26' E105°12'	MET	1964 ~ 74	
3	Seno	Mekong	–	"	N16°40' E105°00'	MET	1942 ~ 44 1947 ~ 74	
4	Savannakhet	Mekong	–	"	N16°33' E104°45'	MET	1964 ~ 74	
5	Savannakhet	Mekong	–	"	?	HY·NA		

(2) Water Gauge Stations

Bang Keng Done water gauge station, established by the Mekong Committee on the Se Bang Hieng mainstream at a point about 52 km upstream of the confluence with the Mekong, is known to have engaged in stage observation for a considerably long time and is operating at present. The zero point at this station is already determined by levelling.

Downstream of this station, there used to be Tang Gene water stage station on the Se Bang Hieng mainstream at a point about 23 km upstream of the confluence. Although this station is no longer in existence, its observation record is available and the zero point is also known. These two are the only water gauge stations established on the mainstream.

As for the stations on tributaries, Dong Hene station is established on the Se Cham Phone which has the data for 1969 - 1971 period (1971 incomplete) but has no staff gauges at present. Another station on this tributary, Keng Kok station, was established in November 1974 for stage and discharge observation. However, since this station started operation in the dry season, no data are available.

On the Se Sang Soi, ordinary staff gauges are installed at Bung Xang. This station was established in December 1974 for discharge observation as well but no data are available.

Thus, Bang Keng Done, Keng Kok and Bung Xang are the only water stage stations of the Se B ng Hieng, and stage data are available at Tang Gane, Ban Keng Done and Dong Hene.

The Service National de l'Hydraulique et de la Navigation is planning to install staff guages at Lahanam and Ban Sa Nhek on the Se Bang Hieng, at Dong Hene on the Se Cham Phone, and at Muong Phalane on the Se Sang Soi.

At the confluence with the Mekong river, Khemarat water gauge station is established on the Thai side and its data are available.

Table 4-3 - List of Water Stage Stations (Existing)

No.	Name of Station	Name of Riber		Classification	Ouration of Observation	Managed by	Zero Point	Remarks
		Main	Tributary					
1	Dong Hene	Se Bang Hieng	Se Cham Phone	Staff	1969 - 1971	HY. NA	MSL. m No levelling conducted yet	destroyed by bombing in 1971
2	Keng Kok	"	"	Staff	no data	"	No levelling conducted yet	Operation Started in November 1974 for stage and discharge observation
3	Ban Keng Done	Mekong	Se Bang Hieng	Bubble Gauge Self-Recording	1960 - 74	"	121.29	19,400 km^2
4	Bung Xang	Se Bang Hieng	Se Sang Soi	Staff	no data	"	No levelling conducted yet	Operation Started in December 1974 for stage and discharge observation
5	Tang Gane	Mekong	Se Bang Hieng	Staff	1965 - 1970	"	108.00	Not in existence
*	Khemarat	Mekong	-	"	Staff 1961- bubble 1965-	(Thailand)	108.381	395,000 km^2

(3) Availability of Data

Table 4-4 - Availability of Daily Rainfall Data

Station \ Year	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Dong Hene							○	⦶	○	⦶	⦶	⦶	○				
Keng Kok								○	○	○	○	○	○	○	○	○	○
Seno			○	○	○	○	○	○	○	○	○	○	○	○	○		
Savannakhet (MET)								○	○	○	○	○	○	○	○	○	○
Savannakhet (HY. NA)																	

Table 4-5 - Availability of Daily Stage Data

Station \ Year	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Tang Gane								○	○	◎	◎	◎	◎	Operation suspended and not resumed yet			
Ban Keng Done			○	○	○	○	○	○	○	◎	◎	◎	◎	○	⦶	○	○
Keng Kok																	Operation started
Dong Hene												◎	◎	⦶ Destroyed and not reconstructed yet			
Bung Xang																	Operation started
Khemarat									○	○	○	○	○	○	○		

Note 1) ◎ Data recorded at 7:00 hrs and 17:00 hrs available

○ Data recorded at 7:00 hrs available

Note 2) ⦶ Incomplete data

Table 4-6 - Availability of Daily Rainfall Data

At Mekong Committee

Station / Year	Tchepone	Seno	Savanna-khet	Muong Phine	Keng Kok	Bantam -Pril	Saravane
1923	○						
24	○						
25	⦶						
26							
27	⦶		⦶				
28			⦶				
29			⦶	⦶			○
30	⦶		○	○			○
31	⦶	⦶	⦶	⦶	⦶		⦶
32	⦶	○	⦶	○			⦶
33		○	⦶	○			○
34		○	○				⦶
35	○	⦶	○	○	○		○
36	○	⦶	⦶	○	⦶		○
37	○	⦶	⦶	○	⦶		○
38	⦶	○	⦶	⦶	⦶	⦶	○
39		○	⦶	⦶	⦶		○
40		⦶	⦶				
41							
42							○
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56	⦶	⦶	⦶				
57		⦶					
58		⦶					
59		○					
60		⦶					
61		○					
62		⦶					
63		○					
64		○					○

Note ⦶ : Incomplete Data

4-4 Flood Occurrence Condition

(1) Flood Level and Flood Discharge

Table 4-7 shows the annual peak water level and annual peak discharge recorded in the 15 year period from 1960 to 1974. As seen in the table, the peak values are recorded predominantly in September (about 2/3 of all), followed by August and then July. The highest of all peak values was registered by the flood in August 1974 which was the greatest ever recorded in 130 years. The Table also shows that the peak values were greater in 1961, 1964, 1968, 1972 and 1974 than in other years, indicating that heavy floods occur once in three to four years. (In August 1972, observation was not made but there were heavy rainfalls, and data indicate that the damage was substantially heavy)

Table 4-7 - Annual Peak Water Level and Discharge

Year	Month	Day	Peak Water Level	Peak Discharge	Remarks
			m	m^3/s	
1960	Aug	25	12.66	3,940	
1961	Sep	28	15.67	6,360	
1962	Sep	19	13.66	4,950	
1963	Aug	13	14.36	5,440	
1964	Sep	27	16.68	7,070	
1965	Sep	4	9.48	2,250	
1966	Sep	9	12.26	3,970	
1967	Sep	25	12.44	4,110	
1968	Sep	10	17.76	7,820	
1969	Sep	5	13.78	4,930	
1970	Sep	3	12.64	4,240	
1971	July	16	14.82	5,760	
1972			No observation		There were heavy rainfall in August
1973	Sep	4	10.46	2,790	
1974	Aug	20	18.62	8,500	

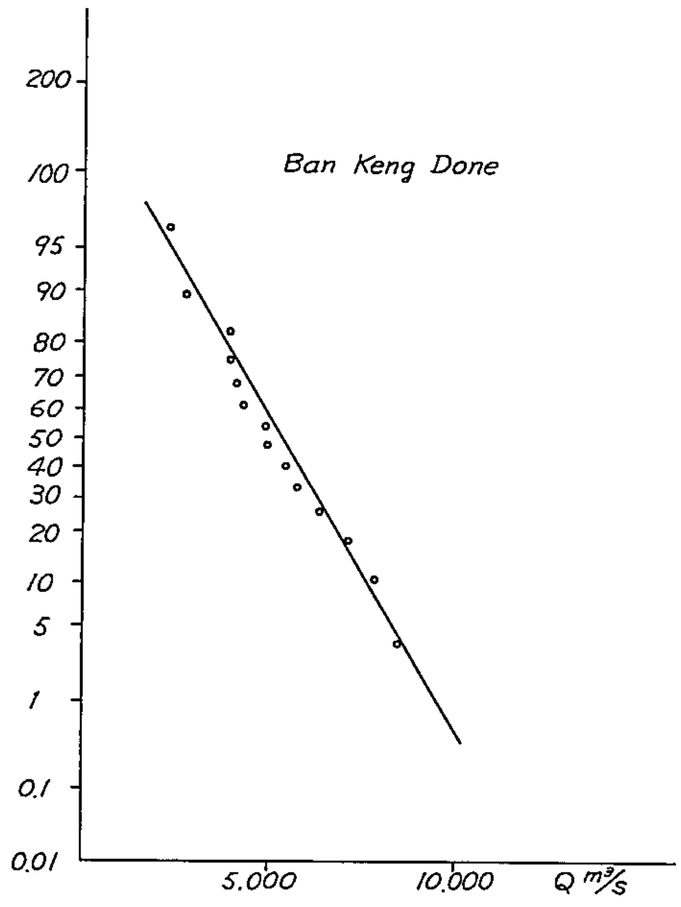


Fig. 4-5 - Exceedance Probability of Annual Peak Discharge, Bang Keng Done

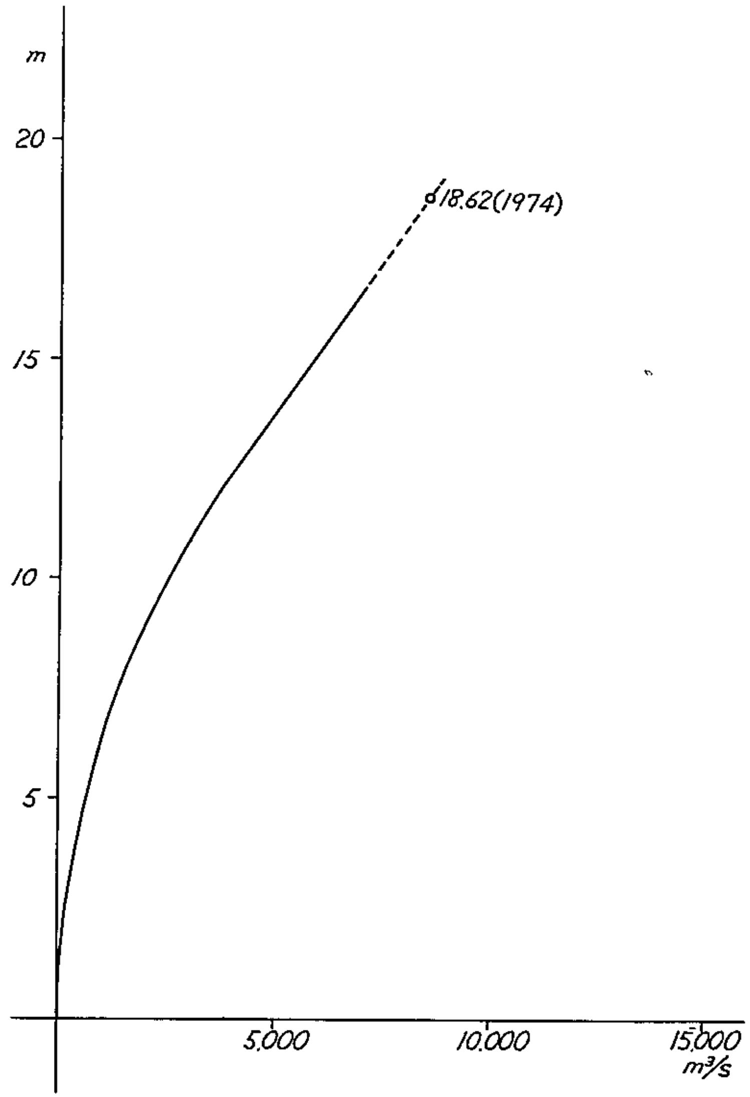


Fig. 4-6 - Stage-Discharge Curve at Ban Keng Done (Approximate)

(2) Meteorological Condition during Well Known Floods

1) Storm Tilda (September 21 - 25, 1964)

Rainfall concentrated in the 36 hours from September 22 to 23, although some rain fell before and after this period. The mass curves recorded at nearby stations were similar in shape, but the main rainfall apprarently moved towards west.

(Isoheytal map and its explanation were obtained, but the general meteorological condition and damages were unknown. See Figs. 4-7 and 4-8).

2) *1968 Flood (September 2 - 7, 1968)*

The following table shows the total rainfall data recorded at nine stations from September 2 to 7 (See Fig. 4-9).

Station	Total Rainfall	Station	Total Rainfall
Keng Kok	mm 224.0	Phiafay	214
Seno	217.1	Paksong	658.4
Savannakhet	180.5	Ubol	283
Kong sedone	144.0	Kuntown	89
Pakse	385.0	-	-

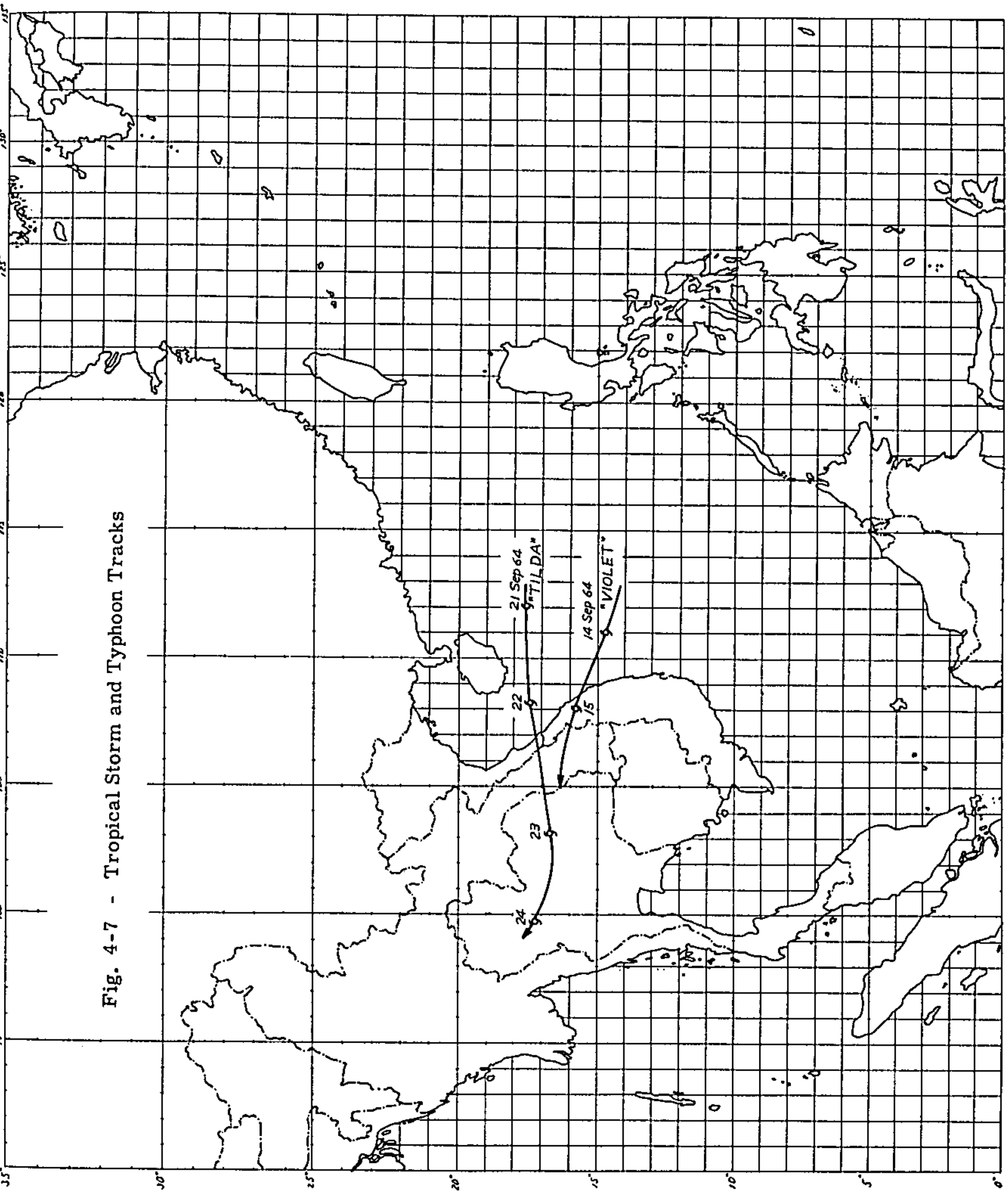


Fig. 4-7 - Tropical Storm and Typhoon Tracks

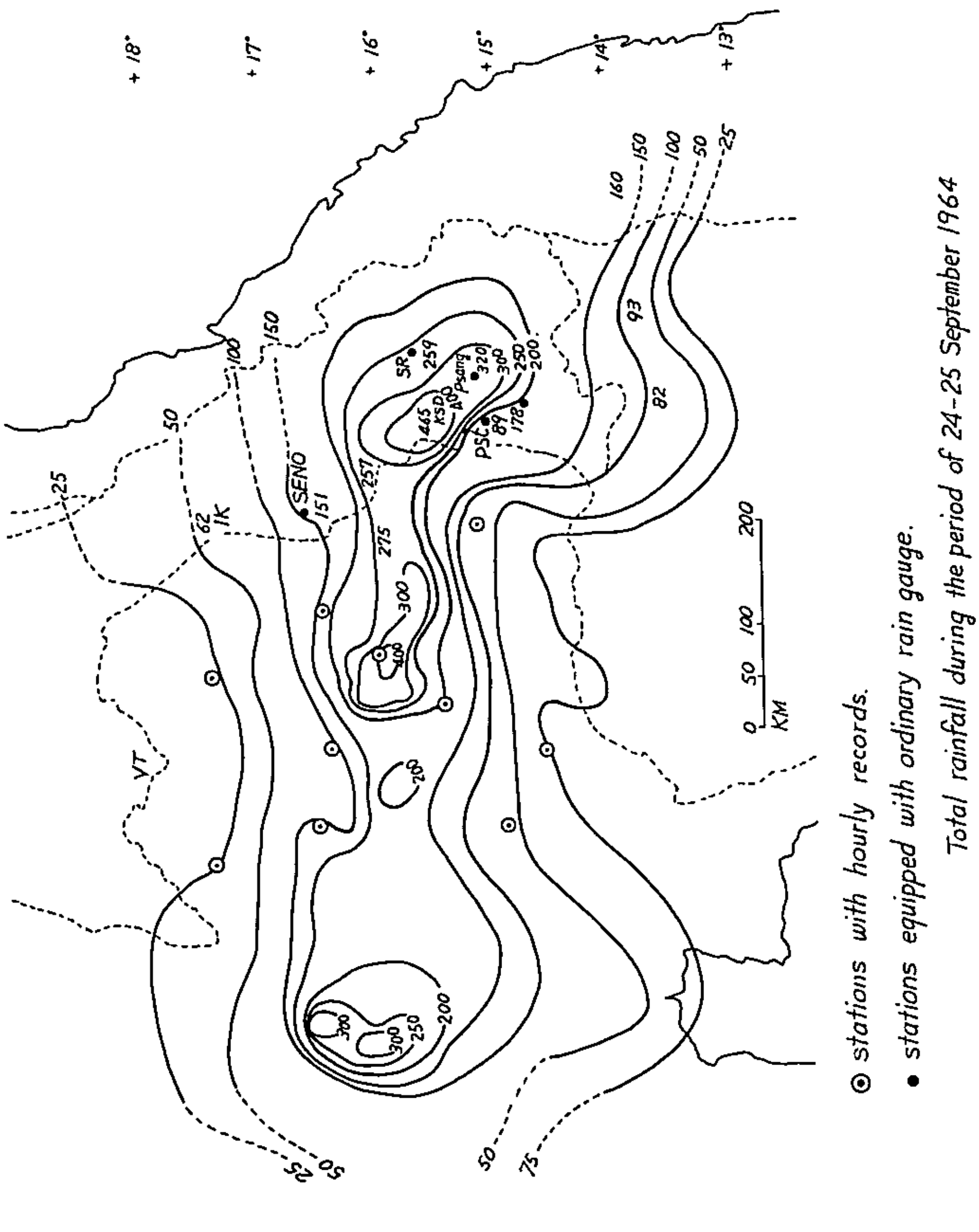


Fig. 4-8 - Isoheytal Map for Storm "Tilda"

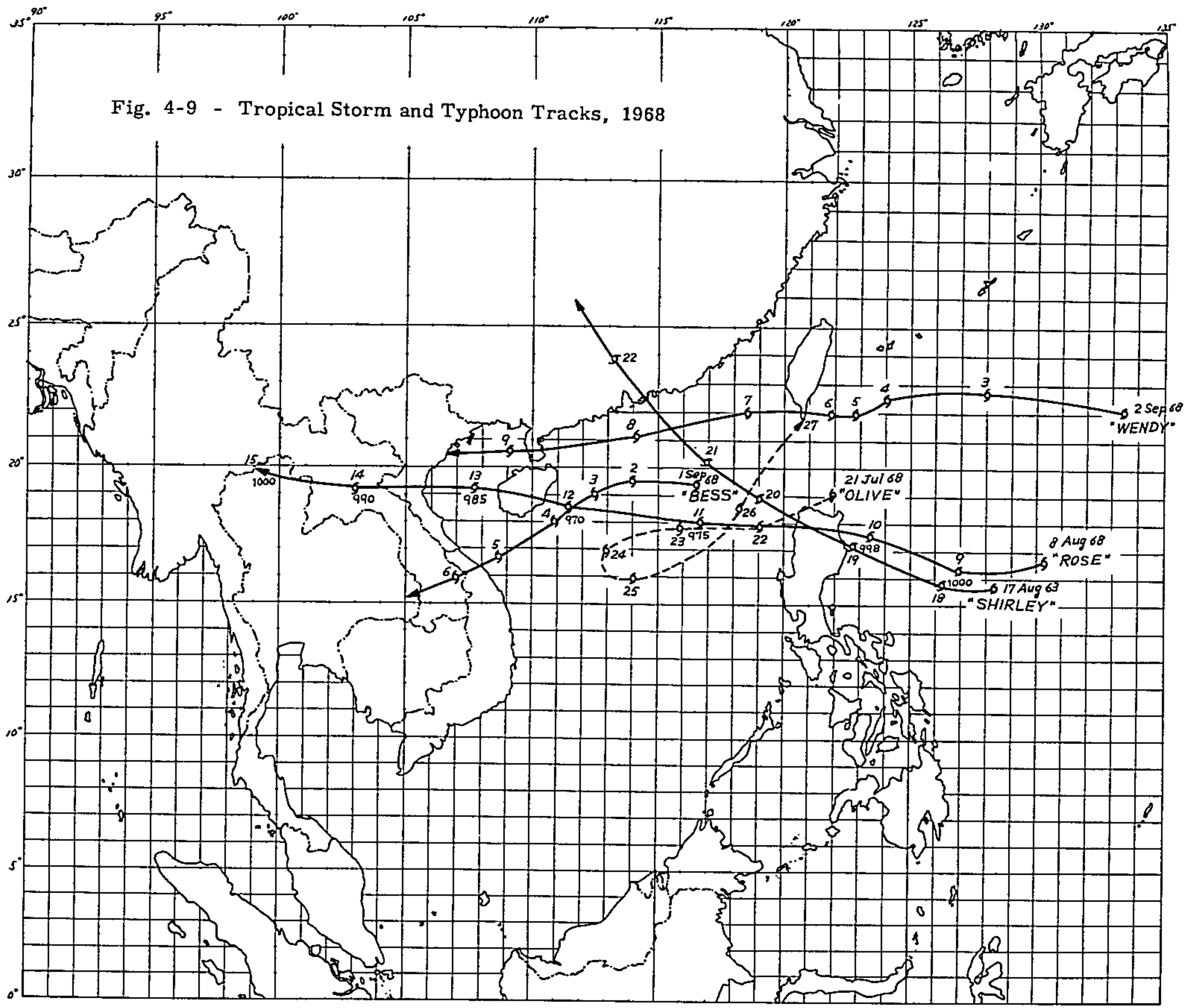


Fig. 4-9 - Tropical Storm and Typhoon Tracks, 1968

3) 1972 Flood in South Laos

In the latter half of July 1972, a southwesterly monsoon developed in the neighbourhood of Lat. 17°N. brought about a storm rainfall which caused a destructive flood in the provinces of Khammounane, Savannakhet, Cham Phone and Sedone.

Analysis of the fundamental meteorological data disclosed the following facts about this flood.

A tropical storm, Manie, developed in an area about 100 km south of Parcel islands on June 2, moved along Lat. 16°N. towards the central coast of Viet Name while increasing its intensity, and disappeared in the west of Thakhek on June 5. From midnight of June 3 to 4, a maximum 24-hour rainfall of 254 mm was recorded at Pakse. As a consequence, Mamie wetted the soil in the southern provinces of Laos. This made the southwesterly monsoon very active and gave a large surplus to the water balance of August.

Susan, a tropical storm, which later grew into a typhoon, developed in the north of Luzon island and moved towards South China from July 16, while the southwesterly monsoon became stronger and stronger and the cyclonic circulation remained stagnat above Gulf of Tonkin. At about the same time, the monsoon trough extending to Luzon island became active and produced a strong rainfall in the neighbourhood of Lat. 17° N. This trough remained active through the first half of August and brought about storm rainfalls in the provinces of Khammouane, Savannakhet, and Cham Phone.

From August 27 to 29, typhoon Cora brought about a destructive rainfall with three peaks which attacked the water sheds in Nam Ngum and Nam Theune, and Beloven plain in Laos.

<u>Damage of Cereals</u>

Savannakhet (Cham Phone)	3,500 ha, 60% affected.
Khammouane (Thakhek)	725 ha, 80% affected.

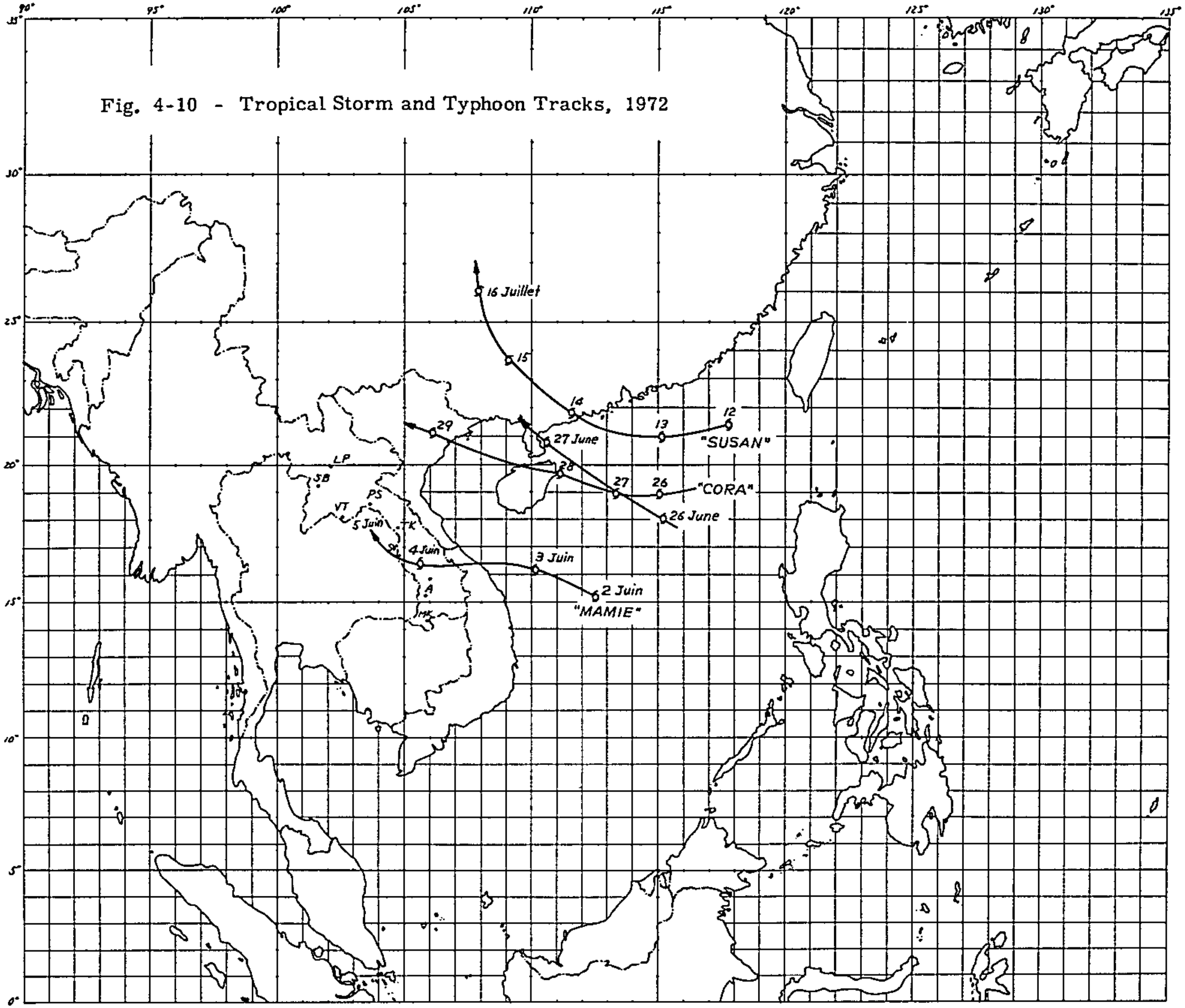
<u>Damage of Roads and Bridges</u>

Savannakhet	5,000,000 Kip	15,500,000 Kip (≑ US$26,000)
Sedone	1,000,000 Kip	
Champasack	8,000,000 Kip	
Sthandone	1,500,000 Kip	

Notes: Conversion rate in those days was K 600 to US$1.00.

Drought attacked the central and northern parts of Laos from July to August, 1972, causing a damage of crops. As a consequence, rice production in Vientiane, Sayaboury and Paklay dropped below the normal level.

Fig. 4-10 - Tropical Storm and Typhoon Tracks, 1972



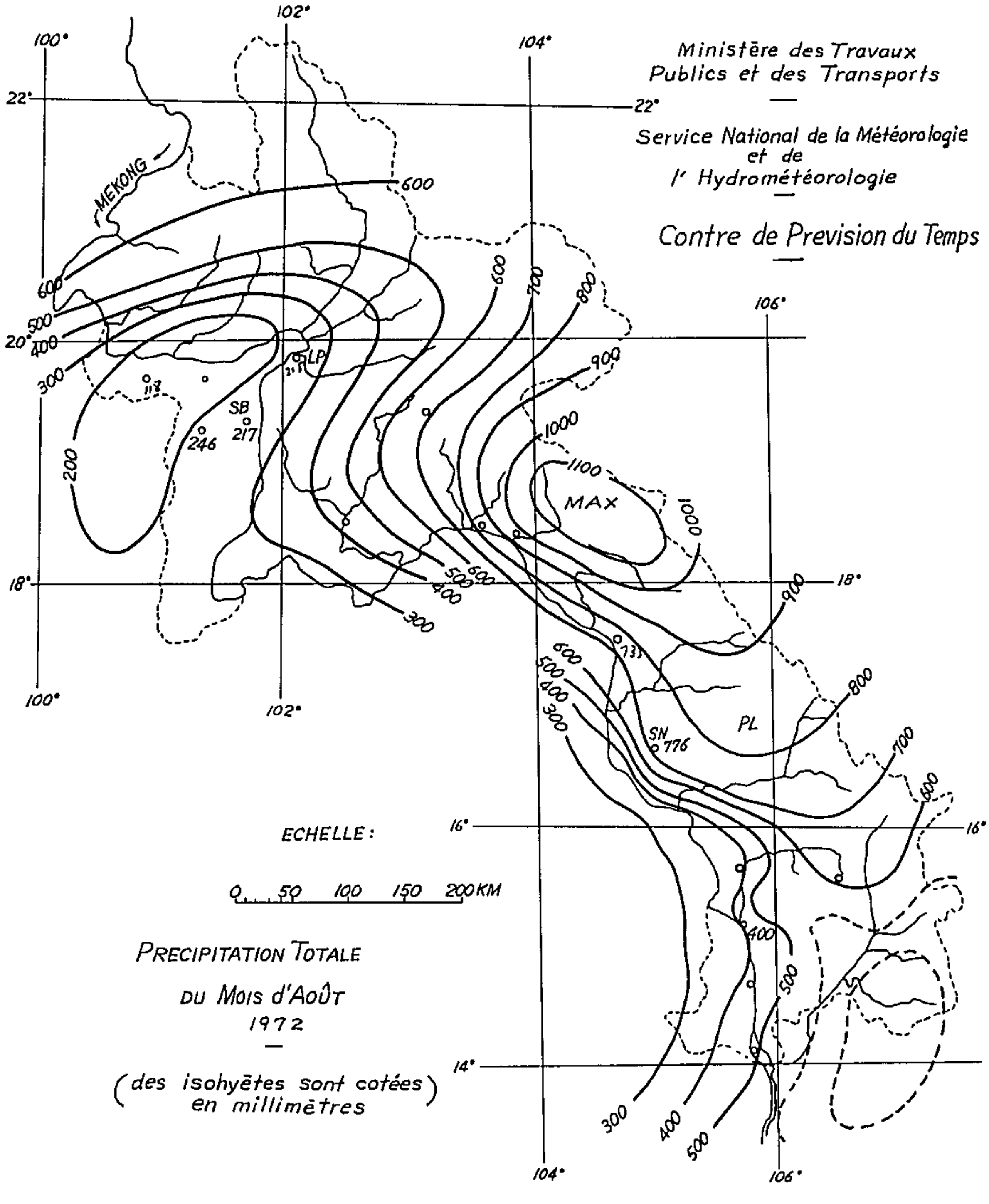


Fig. 4-11 - Isoheytal Map, 1972

4) 1974 Floods in Laos

In 1974, the following three peculiar meteorological phenomena were observed in Laos.

1. Cold season at the beginning of the year.
2. Long duration of the dry season.
3. Period of strong rainfall which brought about heavy damages in southern provinces.

The following are the facts disclosed about Item 3 (strong rainfall period).

A tropical depression which passed through the central part of Laos from August 15 to 16 activated the southwesterly monsoon and as a result, a heavy storm rain fell in south Laos, particularly in Cham Phone province, and cuased serious damages. According to the survey of provincial organizations, a paddy field area of 96,400 ha was inundated and 96% of cereals were damaged. 6,275 families or 37,370 persons who failed to escape the flood and many houses were in flood water for four days, and about 50,000 people were indirectly afflicted with a damage by the flood. Further, 33,670 heads of cattle lost feed. According to the local inhabitants, this flood was the greatest ever recorded since 1927.

Cumulative rainfall from August 13 to 16 was as follows.

Seno	417 mm
Savannakhet	337 mm
Keng Kok	180 mm
Selabam	225 mm
Pakse	240 mm

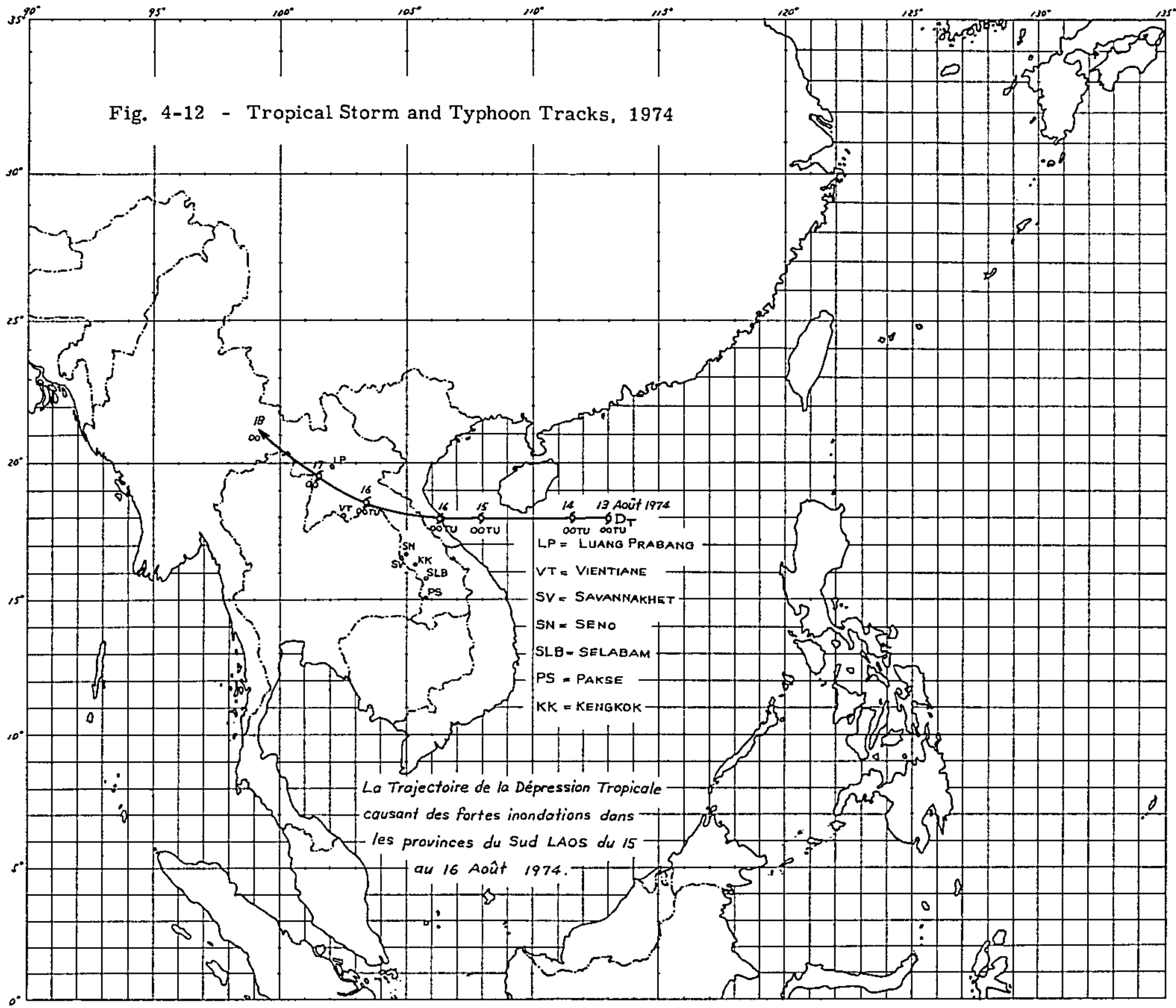


Fig. 4-12 - Tropical Storm and Typhoon Tracks, 1974

4-5 Dam Site on the Se Bang Hieng

As stated in the First Reconnaissance Report, there is possibility developing a large reservoir on the mid-stream section of the mainstream of the Se Bang Hieng, and there is a suitable dam site downstream of this mid-stream point. Although some revision was effected to the tailwater elevation and other factors consequent on the reviewal of the plan, Se Bang Hieng reservoir equals Nam Theun reservoir in scale as a tributary reservoir and is quite important in that it serves for flood control and covers the shortage of dry season discharge of the mainstream. At the dam site which covers a catchment area of 9, 000 km^2, the Se Bang Hieng is expected to have an annual mean discharge of 110 - 300 m^3/sec. Since the reservoir will have an effective storage capacity of 4. 6 billion m^3, the discharge can be maintained at 300 m^3/sec in the wet season and at 100 m^3/sec in the dry season, so that the dry season discharge of the mainstream can be satisfactorily increased. By maintaining a large discharge in the dry season and a small discharge in the wet season, power generation can be largely facilitated. The reservoir is expected to make possible the year-round operation of the power plants to be established on the downstream section of the Mekong and also alleviate the inundation of the basins of the Se Cham Phone and the Se San Soi which cover an area of about 100, 000 ha.

Outline of Se Bang Hieng Dam Programme is shown in Table 4-8.

Table 4-8 - Se Bang Hieng Dam Programme

Item		Se Bang Hieng No. 1	Se Bang Hieng No. 2
Catchment Area	Km^2	9,000	3,500
Annual Rainfall	mm	2,000 - 3,500	
Annual Average Discharge	10^9 m^3	7 - 8	
Average Discharge	m^3/sec	200 - 300	
Reservoir Plan			
Full Water Level	m	190	45
Ponding Area	Km^2	630	87
Effective Depth	m	8	1
Total Storage Capacity	10^9 m^3	11.2	0.38
Effective Storage Capacity	"	4.6	0.10
Dam			
Height	m	53	25
Length	m	530	800
Power Generation Plan			
Type		Dam Type	Dam Type
Intake Level	m	190	145
Tail Water Level	m	145	125 /1
Rated Head	m	41	20
Discharge for Firm Power	m^3/sec	300 (Dry Season)	320 (Dry Season)
Installed Capacity	KW	120,000	60,000
Annual Generated Energy	10^6 kwh	650	400

/1 This figure is based on the map (1/100,000) published by the and differs a little from the value measured by the Canadian team, but the difference is irrelevant to relative height.

Since the head cannot be taken at a large value due to the frequent inundation of roads and farmland, output is smaller than can be attained by the Nam Theun plan. However, the reservoir serves for flood control and supply of irrigation water, and contributes much to the large-scale irrigation improvement scheme covering the basins of the Se Cham Phone and the Se San Soi.

If a dam with a height of 26 m, full water level of 151 m and effective depth of 6 m is constructed at a point about 2 km downstream of Kha Tha located along the Se Cham Phone, an effective storage capacity of 230 million m^3 can be secured.

If, again, a dam with a height of 25 m, full water level of 14 m and effective depth of 4 m is constructed at a point about 2.5 km upstream of Boun San located along the Se San Soi, an effective storage capacity of 150 million m^3 can be attained.

These two reservoirs can perfectly control the floods in the basins of the two tributaries and can create 60,000 ha of new farmland area. About half of this newly created farmland area, or 32,000 ha, can be irrigated with water stored in the two reservoirs. The remainder of the new farmland area can also be irrigated with easy by supplying water from the right bank side of Se Bang Hieng Dam No. 2.
(This section was extracted from "Report of Comprehsneive Reconnaissance Survey of Main Tributaries in the Lower Mekong Basin, Japanese Survey Mission for Lower Mekong Basin Development Project, September 1961")

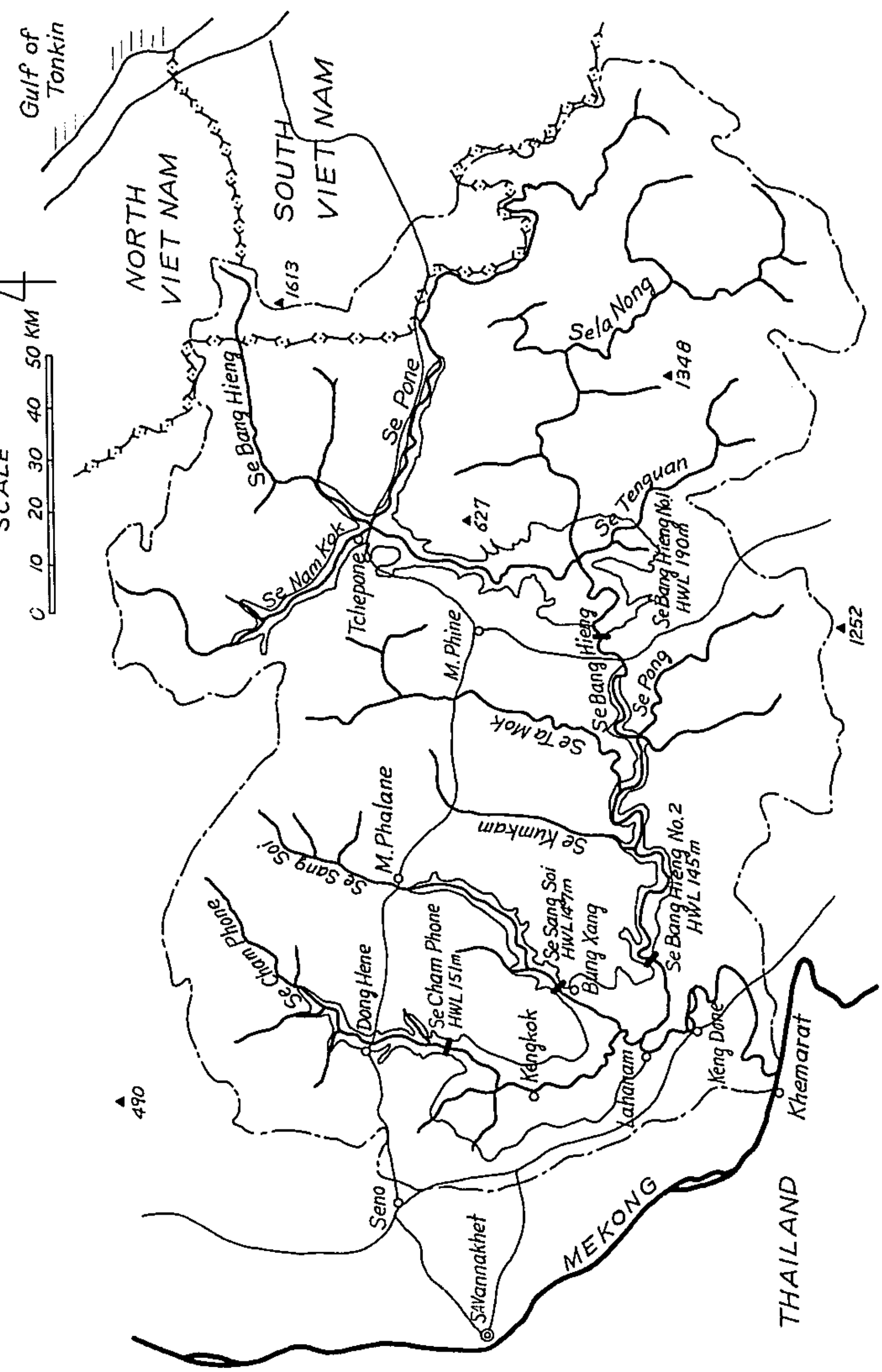


Fig. 4-13 - Dam Sites on Se Bang Hieng

4-6 Reference Data on the Se Bang Hieng River

(1) Reports

1) Report on Reconnaissance Survey of Main Tributaries in the Lower Mekong Basin, Japanese Survey Mission for Lower Mekong Basin Development Project, September 1961.

2) Report on Amplified Basin Plan, A Proposed Framework for the Development of Water and Related Resources of the Lower Mekong Basin, Volume I & II, 1970.

3) Inventory of Promising Tributary Projects in the Lower Mekong Basin, Volume II - Laos, Mekong Secretariat, Bangkok, December 1970.

Contents: Se Bang Hieng Proposed Water Resources Development Project (Dam Project), XXI-1 - XXII-1.

Two of the above three reports, 2) and 3), are available at TCS, Manila.

4) Note on the Proposed Flood Forecasting and Warning System in the Se Bang Hieng River Basin in Laos, September 1974, Typhoon Committee Secretariat.

(2) Data

1) Lower Mekong Hydrologic Yearbook, Committee for Coordination of Investigations for the Lower Mekong Basin, 1960 - 1972.

This yearbook is published up to 1972 edition, and is available at Mekong Committee or the Service National de l'Hydraulique et de la Navigation du Laos.

2) Hydrologic Data

1. Obtainable from the Service National de la Meteorologie du Laos.
2. "Resume Annuel du Temps au Laos" is published in French each year by the same organization.

3) Hydraulic Data

1. Obtainable from the Service National de l'Hydraulique et de la Navigation du Laos.
2. Most of original data are kept at the Service Provincial de l'Hydraulique et de la Navigation, Savannakhet.
3. "Mekong et ses Affluents" is published by the Service National de l'Hydraulique et de la Navigation. The team obtained "Savannakhet 1960 - 1971".

Most of the data listed in Items 1), 2) and 3) above were collected systematically during the present survey.

(3) Maps

1) 1/500, 000 maps can be obtained from the following company.
Maphouse Co., Ltd., 5th flr., Shibuya Parco Bldg., No. 15-1, Udagawa-cho, Shibuya-ku, Tokyo.

2) 1/1, 000, 000 maps and 1/250, 000 maps are available at map control Div.

of the Geographical Survey Institute of the Japan Ministry of Construction.

3) 1/100, 000 maps are available at JICA.

4) 1/2, 000, 000 maps and 1/1, 250, 000 maps were obtained at a bookstore in Vientiane.

5) 1/50, 000 maps are available at the competent government offices in Vientiane, but they were not obtained because they were excessive in number.

6) Geological maps (1/2, 000, 000) were obtained.

CHAPTER V. FLOOD ANALYSIS

5-1 Flood Analysis Based on Observation Data

(1) Relationship between Rainfall and Run-off

When the discharge record at Ban Keng Done which covers a relatively long period is compared with the rainfall data at Seno or Keng Kok, flood dicharge shown in Figs. 5-1 - 5-3 can be obtained for large floods which occurred in the 1961 - 1974 period. These figures indicate that in most floods, the discharge reaches its peak or increases close to the peak in two days after the main rainfall.

An attempt was made to express the relationship between rainfall and peak discharge in terms of simple correlation, but failed due to the diversity of flood occurrence patterns at Ban Keng Done.

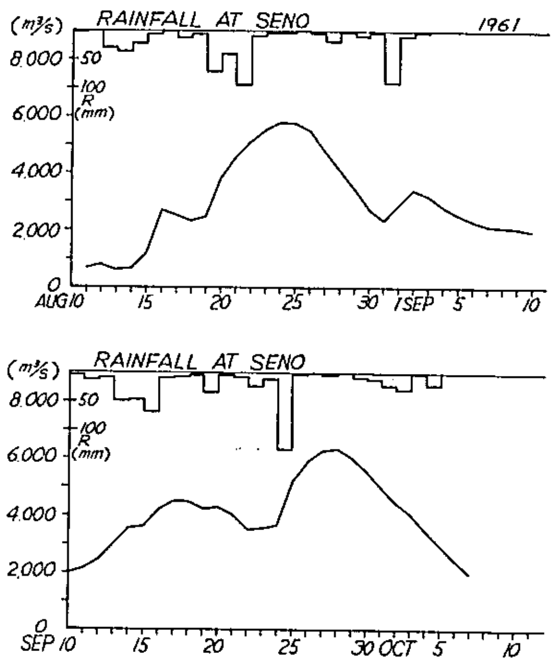


Fig. 5-1 - Flood Discharge at Ban Keng Done (1)

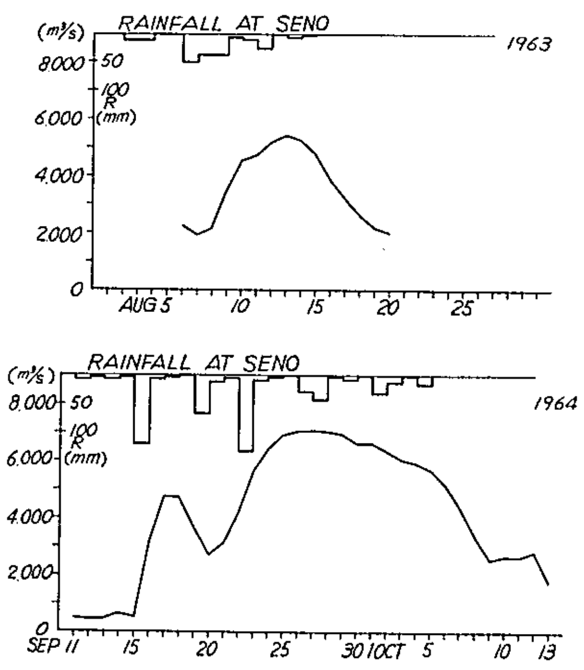


Fig. 5-2 - Flood Discharge at Ban Keng Done (2)

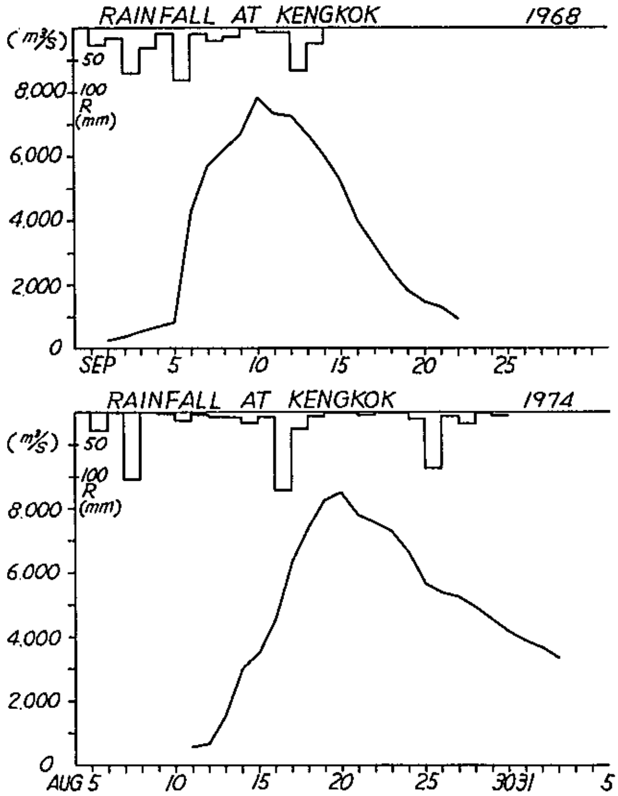


Fig. 5-3 - Flood Discharge at Ban Keng Done (3)

(2) Comparison of Flood Level

Since stage data recorded simultaneously at Dong Hene on the Se Cham Phone and at Keng Done on the Se Bang Hieng were available for 1969 1970, these data were compared with each other. The data at Dong Hene were used only for temporal comparison because the absolute elevation was not determined yet. Results of comparison are shown in Figs. 5-4 - 5-7.

Some of the floods shown in these figures are examined below.

In the flood which lasted from July 12 to 18, 1969, the discharge at the lower station, Keng Done, reached its peak before that at the upper station, Dong Hene while the main rainfall was being recorded at Keng Kok. If the figure is correct, therefore, it can be concluded that the flood at Keng Done was not directly influenced by the outflow from the Se Cham Phone but was caused by some other factors. Since the stage at Keng Done reached its peak before that at Khemarat, it would be reasonable to consider that the discharge at Keng Done was influenced by the flooding of the Se Bang Hieng itself in the middle and upper reaches.

In the flood which lasted from July 21 to 31, there was a time lag of about 1.5 days between the two stations but the stage rise at Keng Done was far greater. Since the stage at Khemarat rose considerably at this time, there could have been the influence of the backwater of the Mekong. From the figure, however, neither upstream nor down-stream stage rise can be definitely said to be the cause of the flood discharge at Keng Done.

In the case of the flood which lasted from September 3 to 10, 1969, exclusion of the dubious data recorded at Dong Hene on September 6 produces a time lag of 0.5 - 1.0 day. Since the stage rise at Dong Hene was small, it is likely that there was the influence of upstream and downstream stage rise of the Se Bang Hieng.

The flood on July 15, 1970 was rather small but there seems to have been a time lag of 0.5 - 1.0 day.

It is probable that a time lag of 0.5 - 1.0 day was also existent in the flood in August 1970.

As is clear from the above description, minus gap as well as plus gap of 0.5 - 1.0 day of peak discharge occurrence time exist between Dong Hene and Keng Done, and this points to the need for hourly and not daily measurement of water stage. Hence, flood forecasting should be so planned as will meet such need.

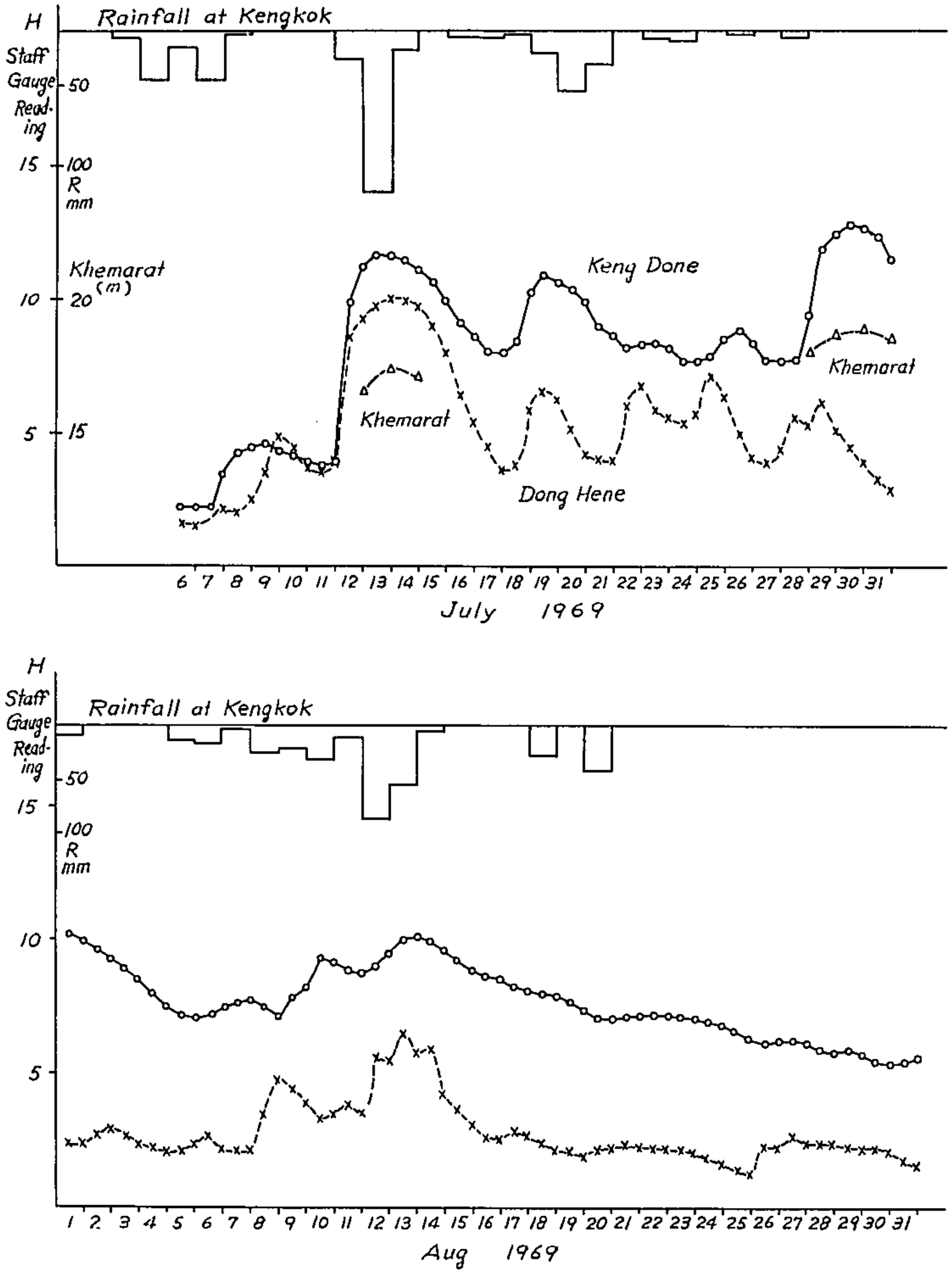


Fig. 5-4 - Comparison of Flood Level (1)

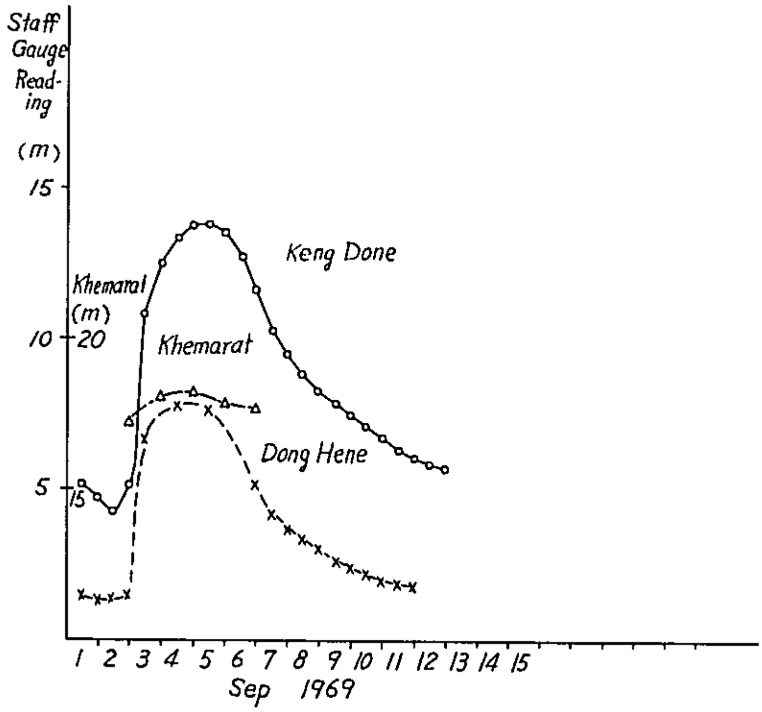


Fig. 5-5 - Comparison of Flood Level (2)

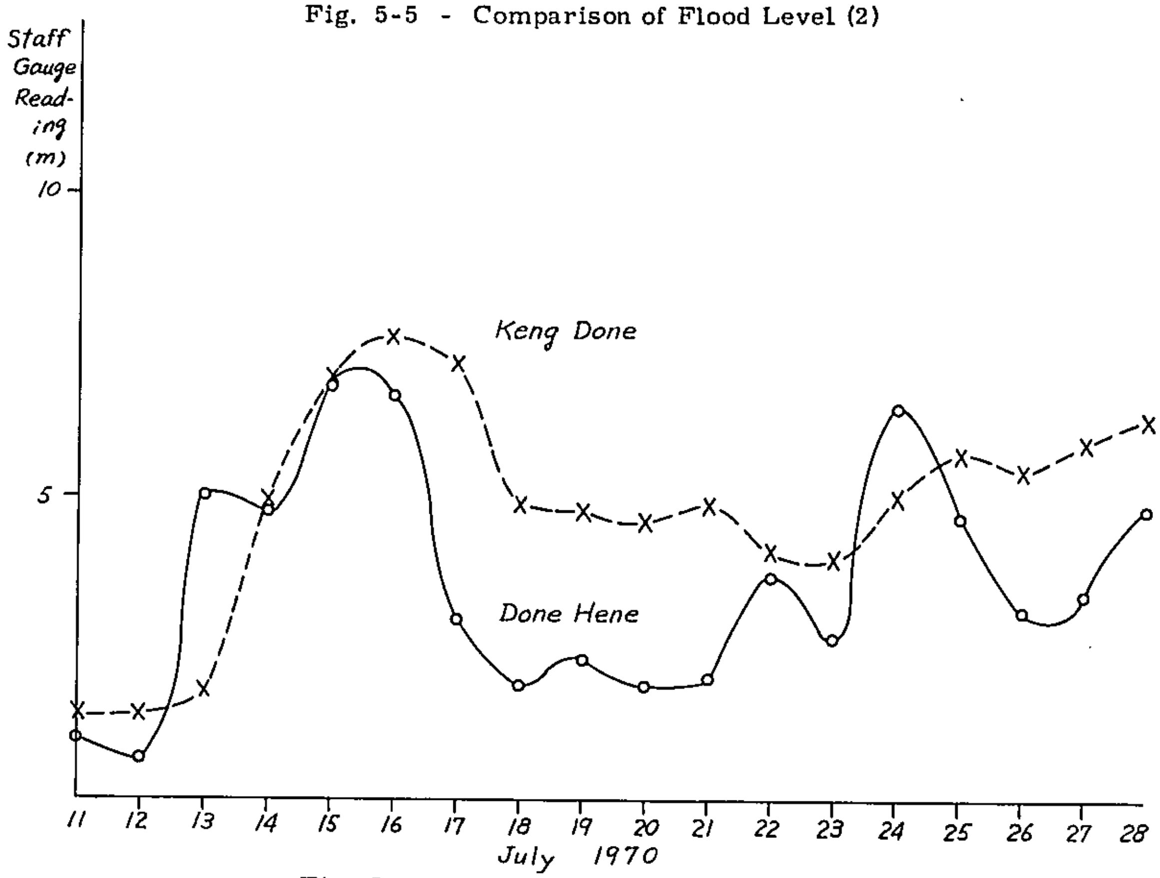


Fig. 5-6 - Comparison of Flood Level (3)

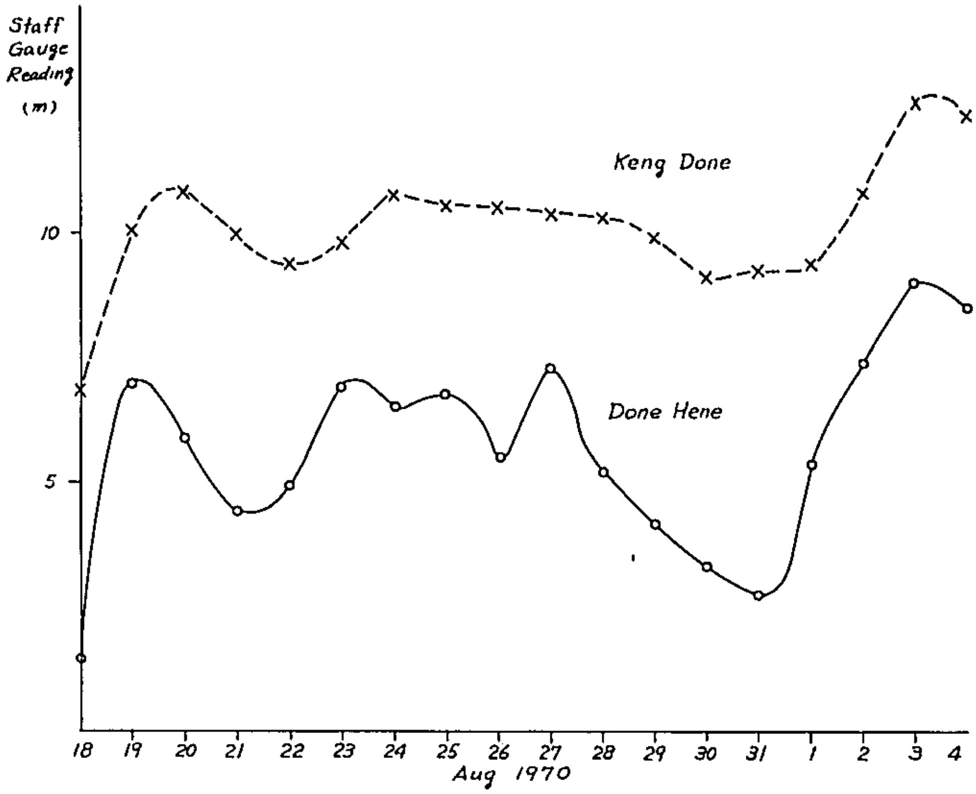


Fig. 5-7 - Comparison of Flood Level (4)

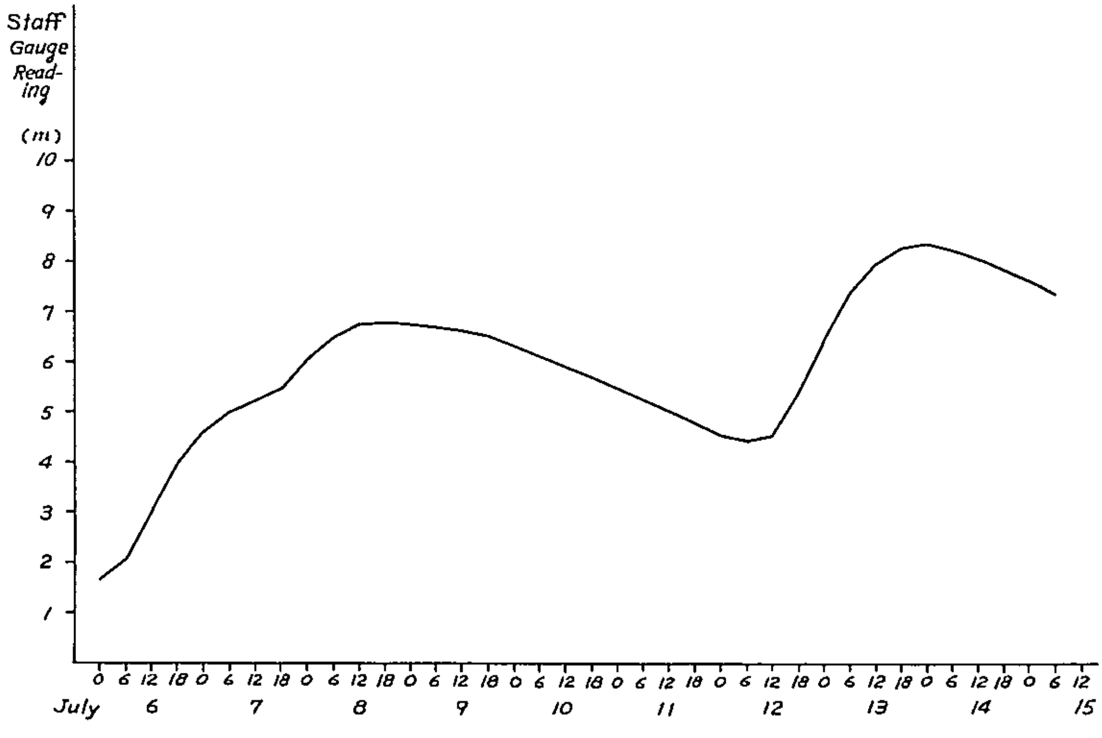


Fig. 5-8 - Hourly Stage Record at Ban Keng Done

Table 5-1 - Flood Level and Flood Discharge at Ban Keng Done

Year	Month	Day	Flood Level	Flood Discharge	Year	Month	Day	Flood Level	Flood Discharge
			m	m^3/s				m	m^3/s
1968	September	1	2.87	230	1974	August	11	4.87	600
		2	3.63	350			12	5.13	660
		3	4.60	550			13	7.92	1,550
		4	5.12	650			14	10.75	2,960
		5	5.67	800			15	11.67	3,490
		6	12.74	4,230			16	14.60	5,560
		7	14.68	5,620			17	15.61	6,300
		8	15.38	6,130			18	17.08	7,360
		9	16.08	6,630			19	18.28	8,220
		10	17.76	7,820			20	18.62	8,500
		11	17.02	7,310			21	17.67	7,770
		12	16.95	7,250			22	17.32	7,530
		13	16.18	6,700			23	17.00	7,300
		14	15.23	6,040			24	16.16	6,690
		15	14.18	5,260			25	14.72	5,650
		16	12.40	4,000			26	14.37	5,400
		17	11.22	3,210			27	14.22	5,300
		18	9.84	2,420			28	13.75	4,950
		19	8.60	1,810			29	13.29	4,600
		20	7.78	1,480			30	12.67	4,180
		21	7.30	1,310			31	12.30	3,900
		22	6.28	980		September	1	12.01	3,700
							2	11.42	3,340

5-2 Flood Analysis by Backwater (Non-uniform Flow) Calculation

(1) Outline

The following five cases can be conceived of as possible patterns of flood occurrence in the Se Bang Hieng lower basin.

1) Flood due to the run-off caused by rainfall in the upper basin of the Se Bang Hieng.
2) Flood due to the run-off caused by rainfall in the Se Cham Phone basin and the Se Sang Soi basin.
3) Flood due to the backwater resulting from the influence of the stage rise of the Se Bang Hieng on the run-off of the Se Cham Phone or the Se Sang Soi.
4) Flood due to the backwater resulting from the influence of the stage rise of the Mekong upon the run-off of the Se Bang Hieng.
5) Flood caused by the run-off the Se Cham Phone or the Se Bang Soi as a result of the stage rise of the Se Bang Hieng which is attributable to the stage rise of the Mekong.

Patterns 1) and 2) occur in any basin, and the occurrence of patterns 3), 4) and 5) is considered probable because the bed slop of the Se Bang Hieng and its tributaries are as mild as about 1/5, 000. In the case of inland rivers with a mild bed slope, the behaviour of flood flow must be checked by non-uniform flow calculation because their level is prone to change by the inflow of water from tributaries.

(2) Conditions for Non-uniform Flow Calculation

In order to find the behavior of a flood flow by non-uniform flow calculation, the following conditions must be given.

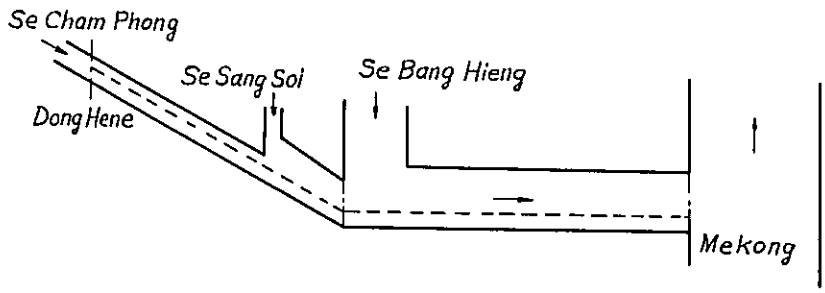
1) Characteristics of channel section
   Cross-sectional area, width, wetted perimeter, and hydraulic mean depth at each water level (depth) obtained for sections with suitable intervals.
2) Bed slopw if the abolute elevation of the water level for each section is unknown.
3) Distance between sections.
4) Roughness coefficient of river channel.
5) Water level at downstream end.
6) Discharge between each pair of sections.

Conditions 1), 2) and 3) can be obtained by surveying at site, 5) and 6) can be obtained by observation at site. If stage observation data based on known absolute elevation (Condition 7)) at a number of places including the upstream end are available in addition to conditions 1), 2), 3), 5) and 6), then condition 4) can be estimated by trial calculation.

In the case of the Se Bang Hieng, however, these fundamental conditions cannot be given because the only data available are the water stage in two places and discharge in one place in the downstream section, water depth in one place in mid-stream section of the Se Cham Phone, and the approximate distance between alignments measured at these five places by an odometer. Accordingly, calculation must necessarily based on the daring assumptions described below, and its results should not be construed as anything more than mere reference data. In the coming years, effort should be made to collect basic data by surveying and observation rather than to analyse floods by calculation.

Conditions assumed for the calculations are as follows.

1) The section from the confluence with the Mekong to the confluence of the Se Cham Phone was covered for the Se Bang Hieng, and the section from the confluence with the Se Bang Hieng and Dong Hene was covered for the Se Cham Phone. No other river channel sections were considered because the lack of their data makes the verification impossible.



Notes: Broken line indicates the design section.

2) River channel section

The Se Band Hieng was assumed to have a rectangular section with a width of 200 m by visual and odometer measurement made at Se Bang Hieng Bridge, Keng Done and Lahanam.

The 12 km section of the Se Cham Phone from the confluence with the Sa Bang Hieng to the confluence of the Se Sang Soi was assumed to have a rectangular section with a width of 100 m on the basis of the 1/200, 000 map and the relationship between upstream and downstream sections, although this section was not covered by the field survey.

The section of the Se Cham Phone upstream of the confluence of the Se Sang Soi is considered to have width of 60 - 70 m from the visual and odometer measurement made at Keng Kok and Done Hene. For the purpose of calculation, however, this upstream part was assumed to have a rectagular section with a width of 60 m. This width proved to be a little too small after the calculation.

3) Bed slope

Since the absolute elevation of section is unknown, elevations of points along the river banks were picked up from the 1/100, 000 map to assume the bed slope. As a result, a slope of 1/5, 000 was adoped for all the design sections.

4) Bed elevation at confluence with the Mekong

Since the zero point at Kheramat water gauge station has an elevation of

108.381 m, a bed elevation of EL 108 m was adopted in consideration of minor difference in the distance from the zero point to the river bed.

5) Discharge distribution

Discharge data are available only at Keng Done station so that the discharge to be distributed to respective channels are unknown. For this reason, the peak discharge at Keng Donewas distributed to its dominant area which was assumed to be about 10,000 km^2. With the discharge of the Se Bang Hieng taken at 1, that of the Se Cham Phone + the Se Sang Soi turned out to be 0.5 and that of the Se Cham Phone 0.3. For the Se Cham Phone, however, inflow was taken into consideration and a discharge of 0.14 corresponding to the area upstream of Done Hene was decreased gradaully to 0.3 at the downstream end.

(3) Verification

Validity of verification could not be furanteed because of the lack of data. However, verification was conducted on the flood of September 4 - 5, 1969 on the basis of the assumptive conditions described in the preceding item in order get a rough idea.

Discharge at Keng Done was about 5,000 m^3/sec, and water stage was recorded at Khemarat, Keng Done and Dong Hene. Water stage at Dong Hene was estimated from the bed slope because the abosolute elevation was not obtained yet.

Results of calculation are shown in Fig. 5-9.

While it is considered that $n \doteqdot 0.032$ between Khemarat and Keng Done, the difference due to roughness coefficient is not sufficiently expressed between Keng Done and Done Hene. Calculation covering the entire course from Khemarat to Done Hene disclosed that $n = 0.025$.

The data recorded on July 14, 1969 were plotted for reference. Since the discharge at Keng Done was about 3,300 m^3/sec on this day, n can be taken at about 0.030.

In the Collection of Hydraulic Formulae, it is stated that $n = 0.025 - 0.06$ in the case of large natural watercourses not given any artificial work and having regular sections without boulders or shrubbs.

It may therefore be said that the roughness coefficient of the Se Bang Hieng and the Se Cham Phone ranges from 0.025 to 0.035.

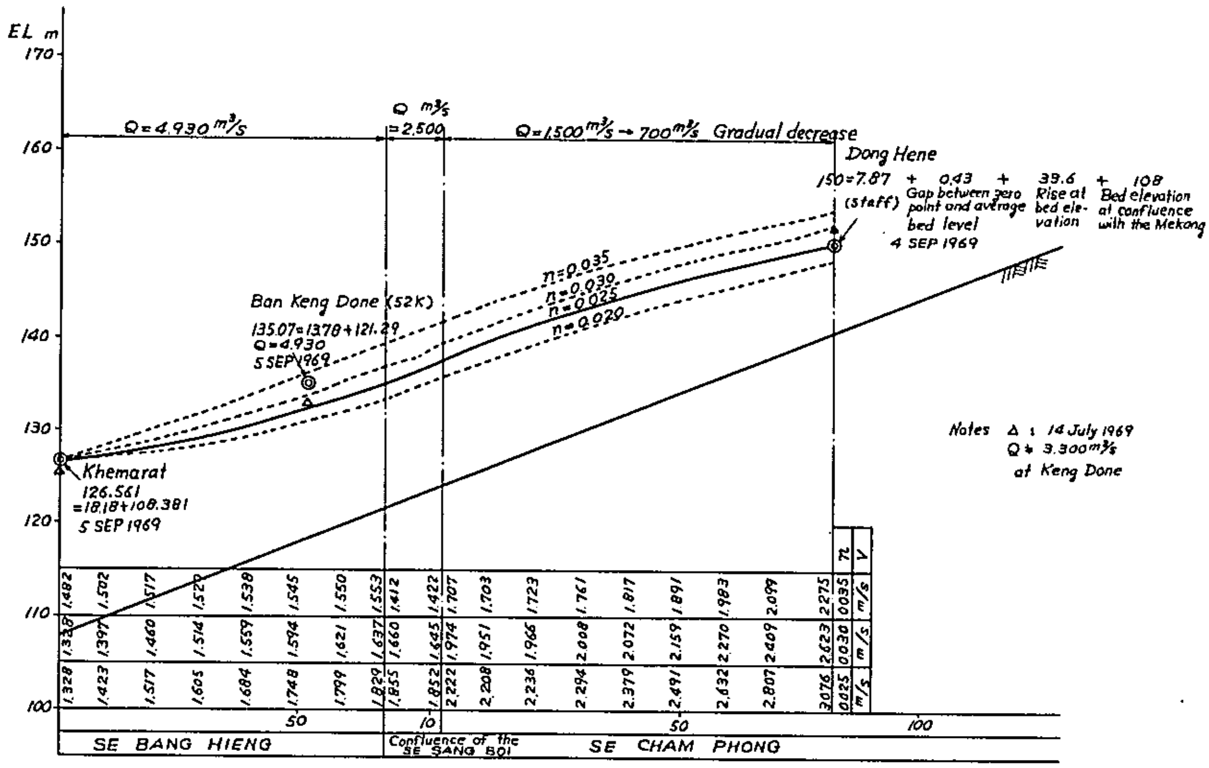


Fig. 5-9 - Example of Verification of Non-uniform Flow Calculation

(5) Influence of Downstream End Water Level

The verification calculation described in the preceding item revealed that n = 0.025 - 0.035, but a lower value of n = 0.025 was adopted here for the calculation which was based on assumptive conditions stated in Item (2).

In order to find the influence of downstream end water level, non-uniform flow calculation was worked out by setting the water level of the Mekong (H_L) at three values, 115 m, 125 m and 135 m and by taking the discharge at Keng Done also at three values, 6,000 m^3/sec, 8,000 m^3/sec and 10,000 m^3/sec, whereby the results shown in Figs. 5-10 - 5-12 were obtained.

The calculation disclosed that drop down is produced at H_L = 115 m, almost uniform flow at H_L = 125 m, and backwater at H_L = 135 m, and that the influence of drop down disappears within 60 km from the downstream end but that of backwater reaches far into upstream.

The above tendency is clearly manifested in Figs. 5-14 - 5-15 which show the results of calculation worked out for the Se Bang Hieng only by varying the roughness coefficient and bed slope.

From the above, it is seen that backwater due to the Mekong's stage rise of 10 m incurs a stage rise of 2 - 4 m at the confluence of the Se Cham Phone and about 1 m rise even at Keng Kok.

The backwater influence will be mitigated by flood because the calculation was carried out on the assumption that no flood would occur. It is to be noted, however, that the backwater of the Mekong and the Se Bang Hieng will exert a considerable influence in the flooded area.

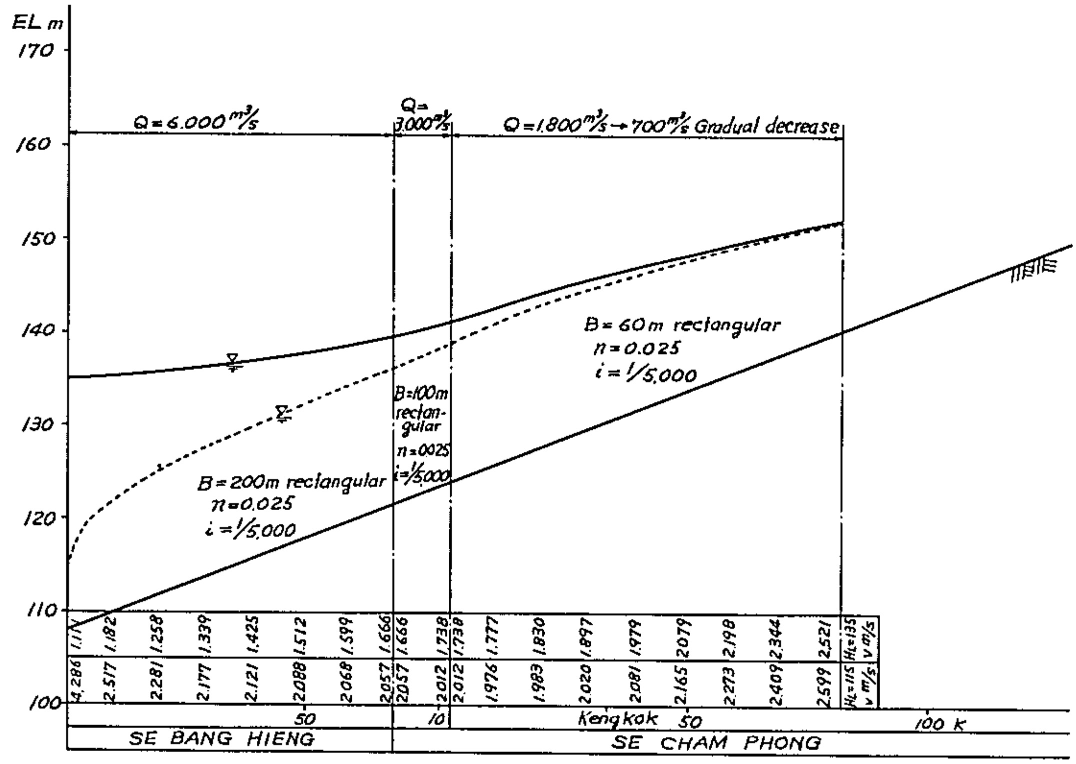


Fig. 5-10 - Influence of Downstream End Water Level (1)

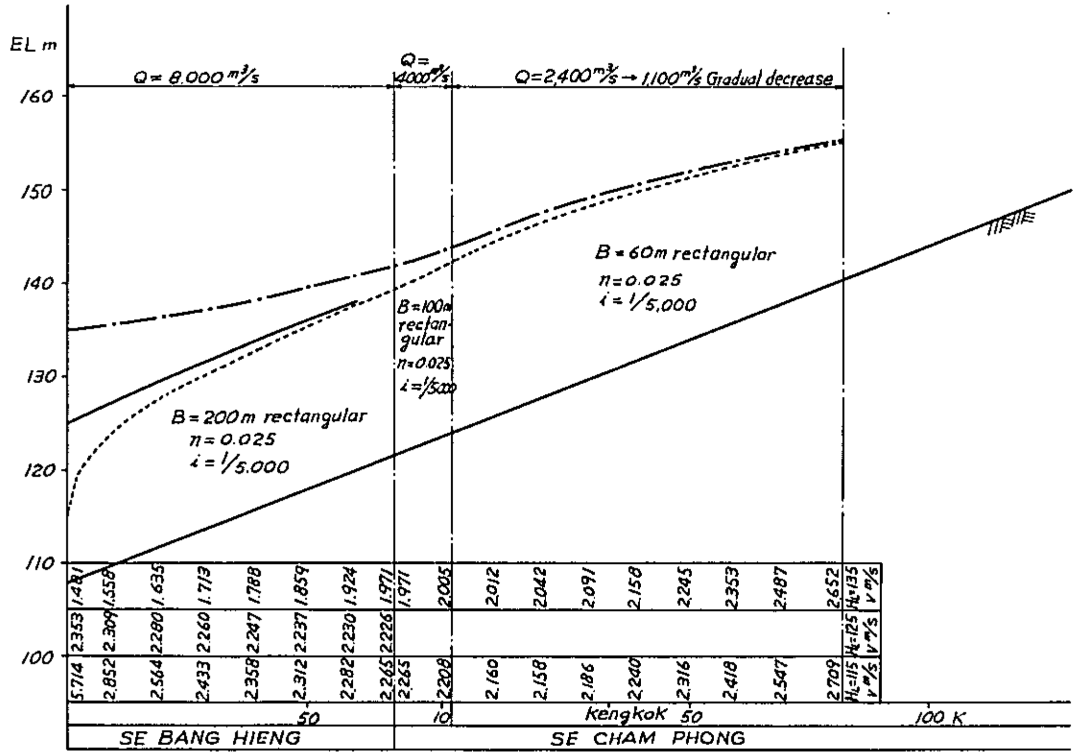


Fig. 5-11 - Influence of Downstream End Water Level (2)

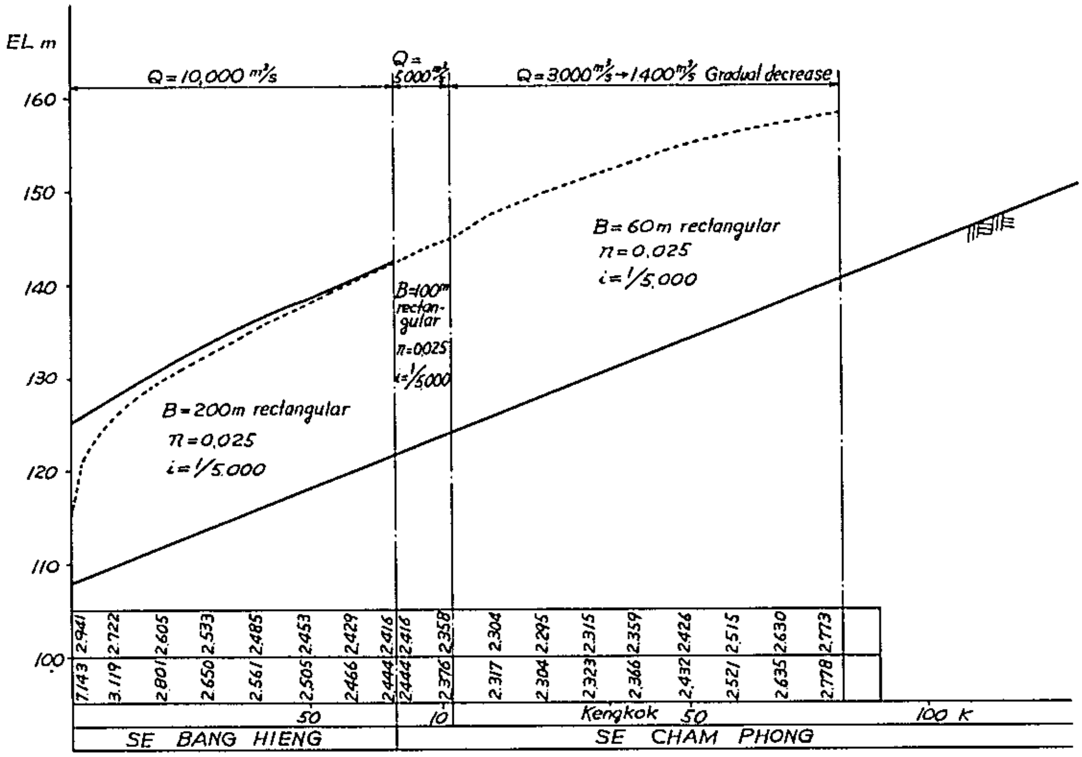


Fig. 5-12 - Influence of Downstream End Water Level (3)

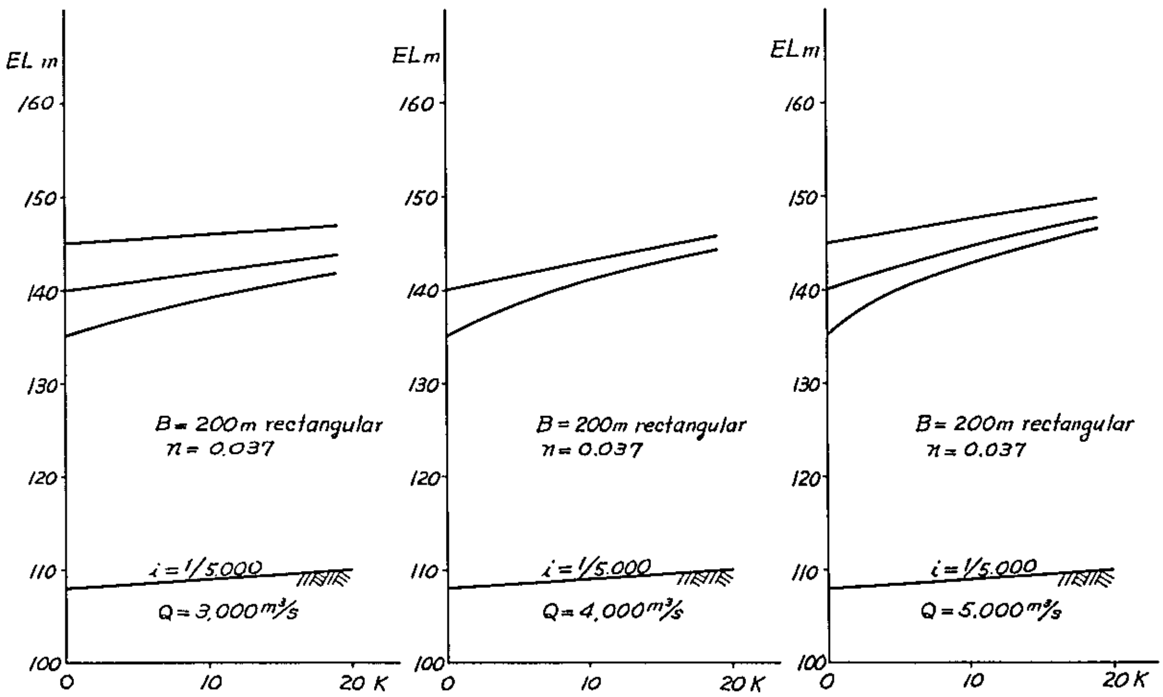


Fig. 5-13 - Influence of Downstream End Water Level (4)

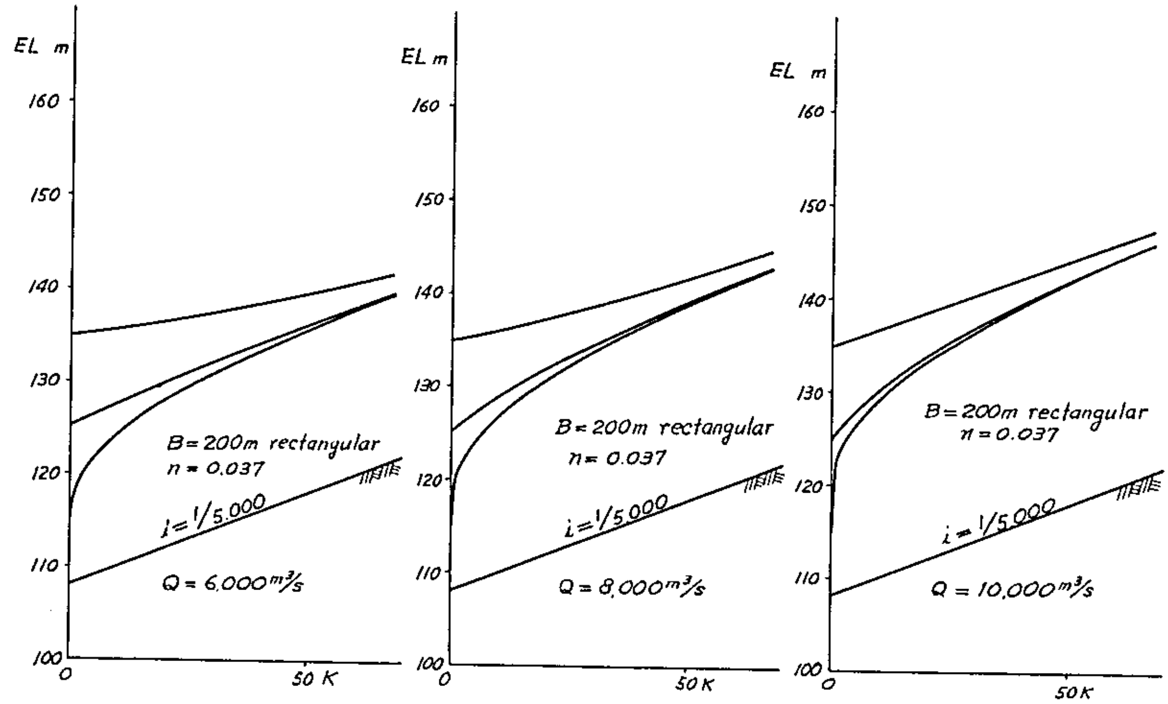


Fig. 5-14 - Influence of Downstream End Water Level (5)

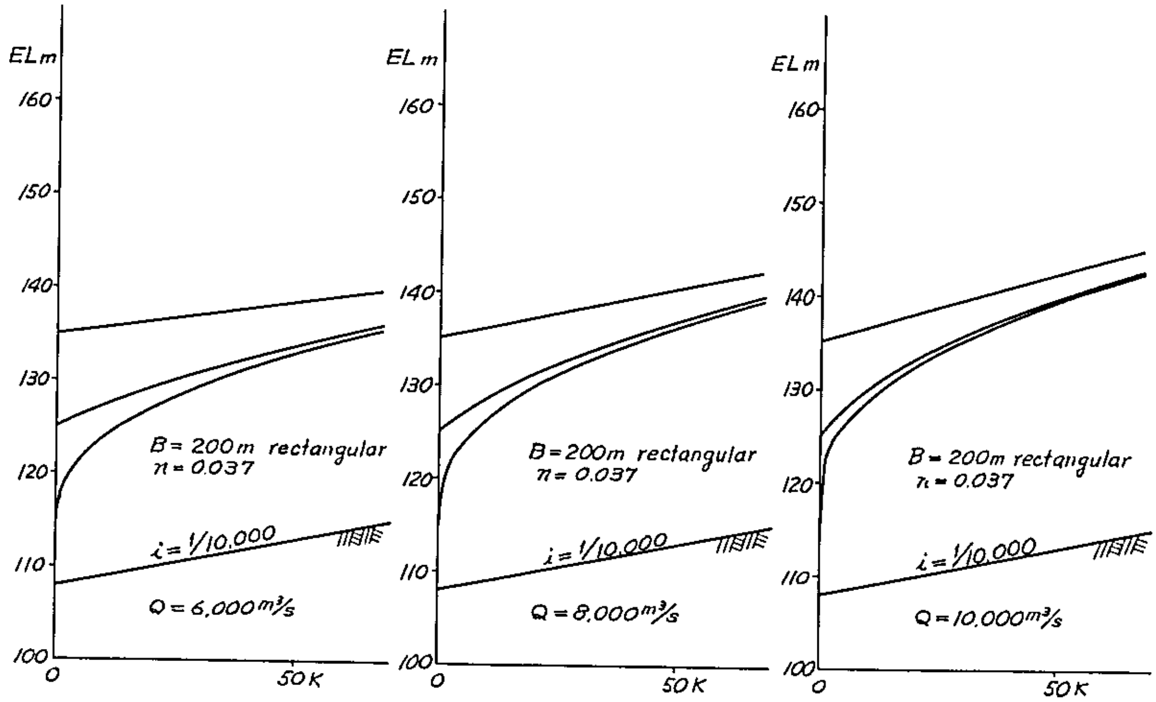


Fig. 5-15 - Influence of Downstream End Water Level (6)

CHAPTER VI. ANALYSIS OF FLOOD FORECASTING SYSTEM

6-1 Existing Condition of Flood Forecasting Facilities and Past Proposals

6-1-1 Existing Condition of Flood Forecasting Facilities

(1) Observation Facilities

Table 6-1 shows the existing condition of the observation facilities of the Se Bang Hieng basin.

Table 6-1 - Existing Condition of Observation Facilities

Station	River	Rain Gauge		Water Gauge		Discharge observation
		Ordinary Gauge	Recording Gauge	Ordinary Gauge	Recording Gauge	
Keng Kok	Se Cham Phong	○		○		○
Bung Xang	Se Sang Soi			○		○
Keng Done	Se Bang Hieng			○	○	○
Savannakhet	Mekong (Located outside the basin)	○		○	○	○
Khemarat	Mekong			Thai ◌	Thai ◌	
Seno	(Located outside the basin)	○				

Notes: In Savannakhet, an ordinary rain gauge is installed at both MET station and HY & NA station.

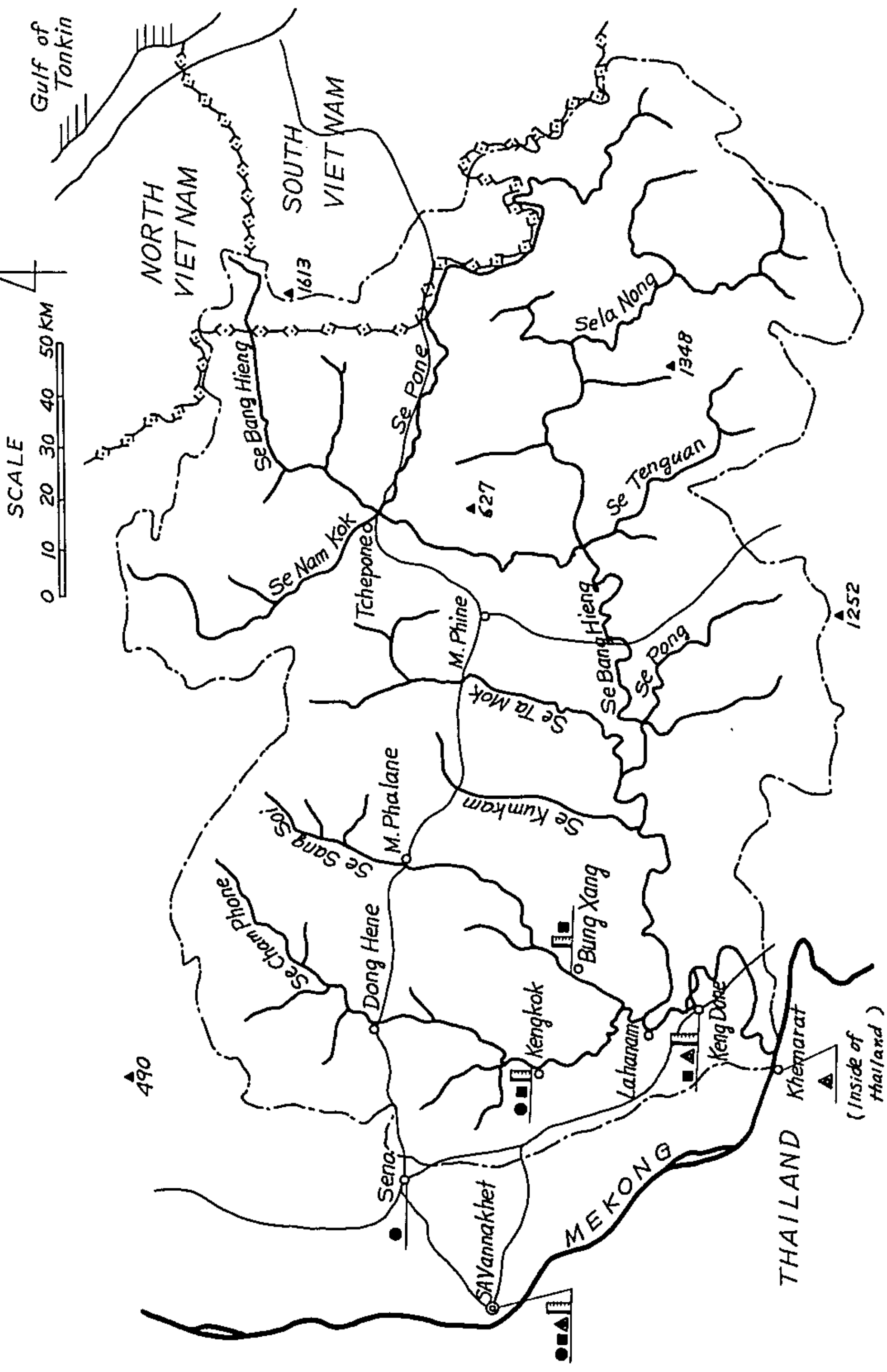


Fig. 6-1-1 - Locations of Observation Stations (Existing in 1974)

(2) Communication Facilities

Communication facilities used for transmission of hydrological and meteorological data are outlined below.

1) Service National de la Meteorologie

The existing telecommunication system is composed of SSB sets only.

A circuit is opened between Bangkok and Vientiane for international communication of meteorological data by voice, teletype and facsimile using 1 kW MARDEUX product (France) and 1 kW SNEJIUKA product (USSR). For domestic meteorological data transmission, Vientiane is linked with weather stations at Houei Say, Luang Probang, Sayaboury, Savannakhet, Pakse, Seno, Vangvieng and Paklay by 150 w SSB sets made by ITT of USA AME of France.

The frequency ranges from 2.3 MHz to 11 MHz. The Telecommunication Division of the Service National de la Meteorologie is staffed by about 30 engineers and operators who are engaged in the operation and maintenance of transmitters and receivers as well as in the services at airports and receiving centre. The block diagram of the meteorological communication system is shown in Fig. 6-1-2.

2) Service National de l'Hydraulique et de la Navigation

Communication facilities of this organization are rather poor. RCA SSB sets installed by the Mekong Committee in Vientiane, Luang Prabang, and Savannakhet are used for fixed time communication with Pnom Pneh and Bangkok in four frequencies from 3 to 9 MHz.

When the team was in Laos, the SSB set in Vientiane was out of order.

The communication system is needful of much improvement specially in the Se Bang Hieng basin because electric power is not supplied to the greater part of it, not to speak of wire telephone facilities. Some measures should be taken to provide communication means for flood forecasting and prevention of flood damage.

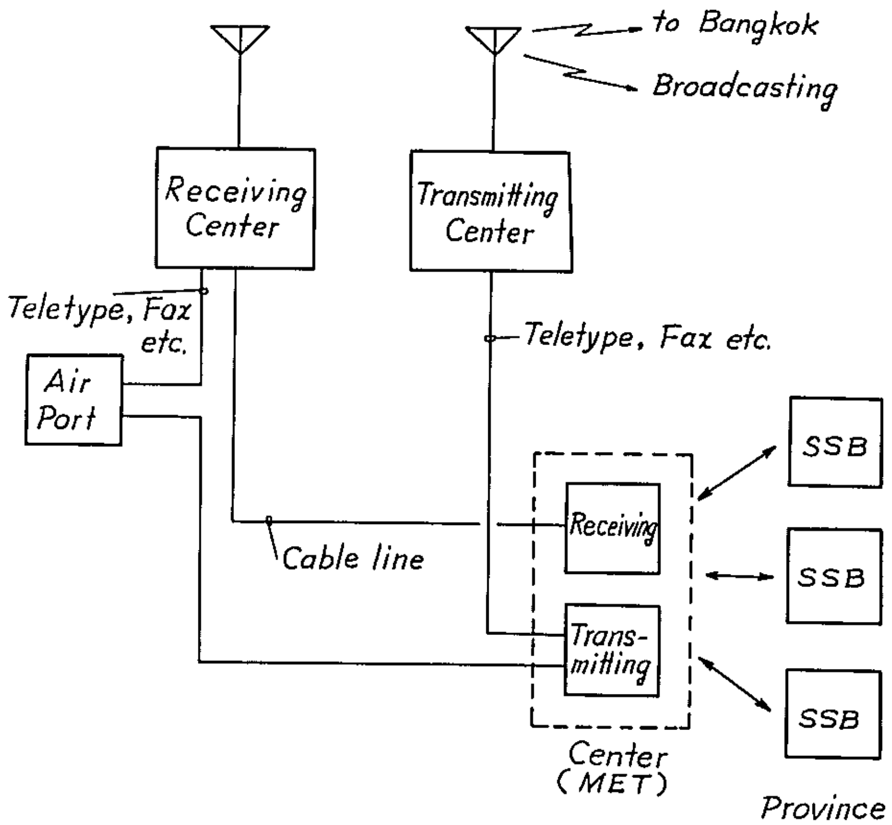


Fig. 6-1-2 - Meteorological Communication System

6-1-2 Observation Network Plan of the Laotian Government

The observation network plan mapped out by the Laotian government to cover the flood plain embracing the lower basins of the Se Bang Hieng, the Se Cham Phone and Se Sang Soi envisages the installation of the following facilities within a relatively small area.

Additional stage, discharge and rainfall observation facilities at Done Hone and M. Phalane, additional rain gauges at Buang Xang, and additional stage and discharge observation stations at Lahanam and Sa Nheki.

This plan is now being examined by the Service Provincial de l'Hydraulique et de Navigation in Savannakhet.

Locations of observation stations are shown in Fig. 6-2.

6-1-3 Observation Network Proposed by TCS

The observation network proposed by TCS is shown in Fig. 6-3.

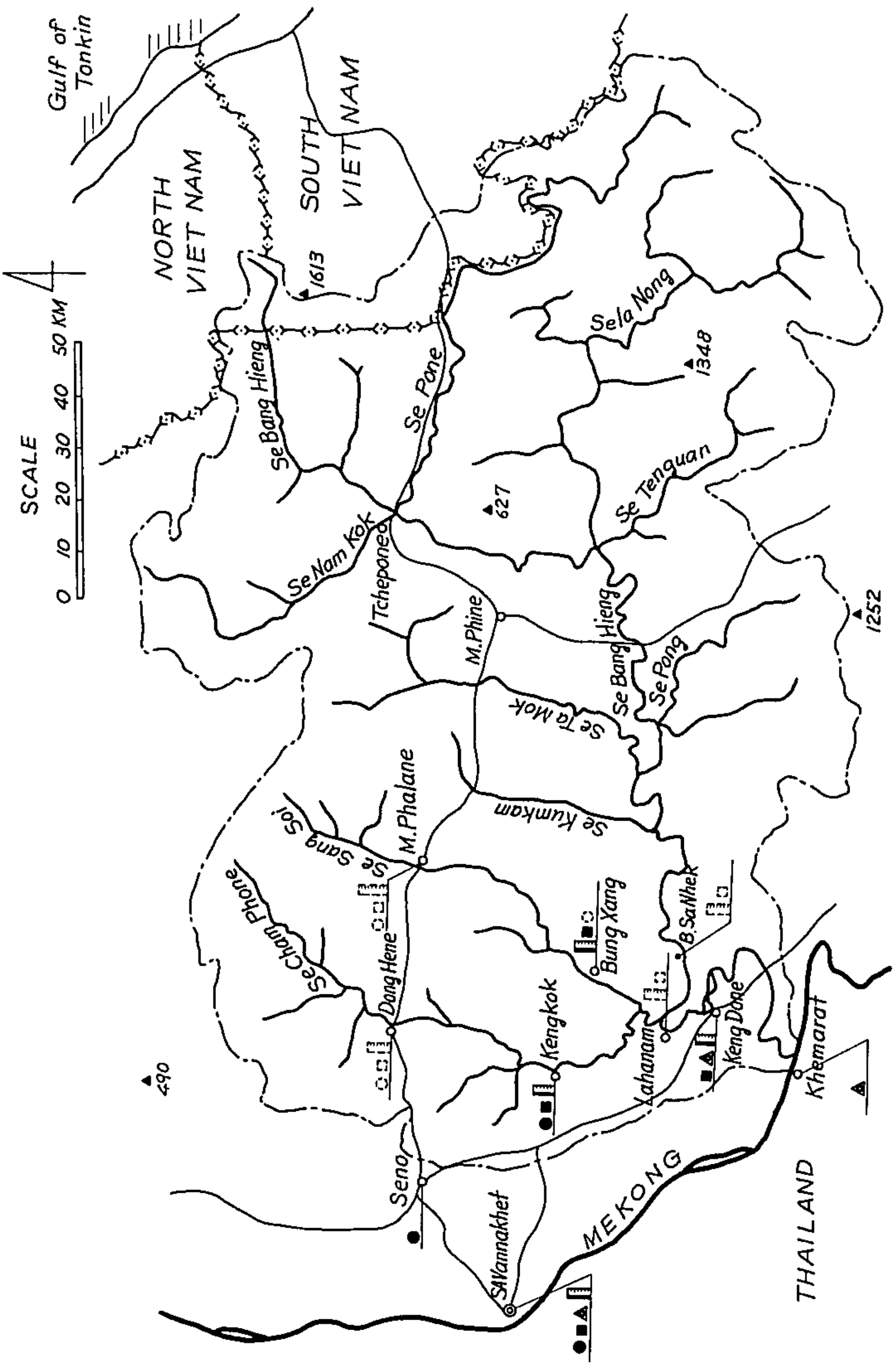


Fig. 6-2 - Observation Network Planned by Laotian Government (HY-NA)

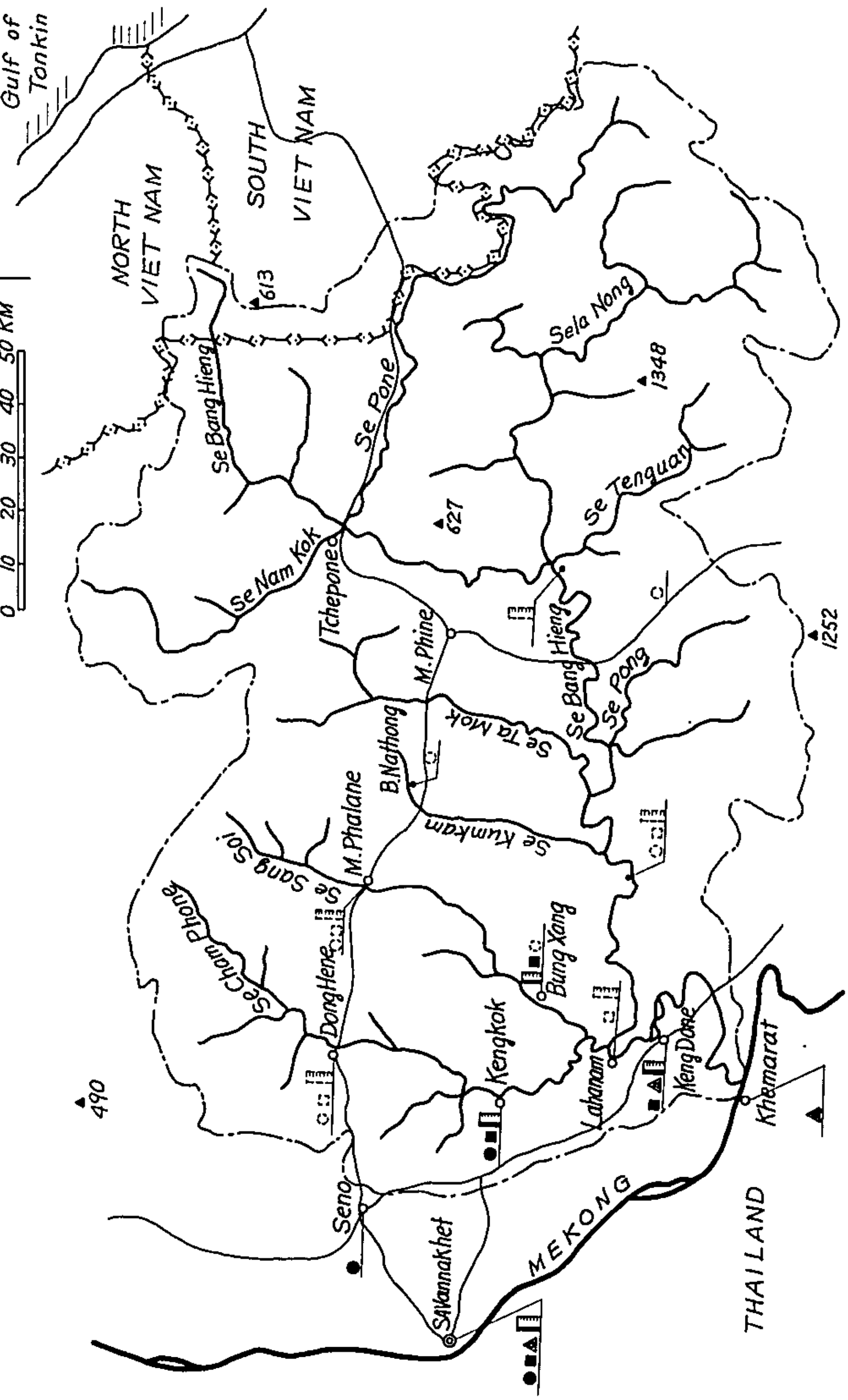


Fig. 6-3 - Observation Network Proposed by TCS

6-2 Analysis for Establishment of a Flood Forecasting System

6-2-1 Target Area and Target Point of Flood Forecasting

While the selection of target area is an essential prerequsite to the examination of any flood forecasting system, the data obtained by the team for this purpose are not sufficient.

Insofar as can be deduced from the collected data, it is considered advisable that the extensive flood plain embodying the lower basins of the Se Bang Hieng and its two tributaries, the Se Cham Phone and the Se Sang Soi, be selected as the target area for the time being.

This flood plain, which covers an area of 1, 000 km^2, is found within Cham Phong province and stetches over four Muongs, i. e., Cham Phone, Souriyakhan, Phong, and Song Khone. The central city of all these Muongs excepting Muong Souriyakhan is known to be frequently subjected to flood damage.

For this reason, the target point at which flood is to be forecast should be set at Lahanamn the Se Bang Hieng (centre of Muong Song Khone), Keng Kok on the Se Cham Phong (capital of Cham Phong Province and centre of Muong Cham Phong) and Bung Xang on the Se Sang Soi (located near the central city of Muong Phong). As for the target points on the Se Bang Hieng and the Se Cham Phone, it is desirable to establish supplementary target points in their respective upper flood plains because these plains are known to be often inundated.

These supplementary target points are tentatively called Target Sup. 1 and Target Point Sup. 2.

6-2-2 Flood Occurrence Pattern and Need for Data Transmission

If flood forecasting and warning is to be conducted at the five target points including the two supplementary points, flood water level over the river banks, and starting time and duration of overtopping must be known at these points because rivers in the target areas are natural rivers without aritificial levees. When the inhabitant are given such information, they are to take necessary measures for transporting stored cereals and domestic animals to a safe place and escaping the flood as well as to make themselves ready to withstand the difficulties during and after the flood without trying to engage themselves in flood protection work. Such information is also required by local administrative organizations in making preparations for the maintenance of public security, prevention of diseases and provision of rescue services.

Needless to say, the above-mentioned measures produce no successful results if taken after overtopping starts, so that the necessary information should be conveyed quickly and as accurately as possible so as not cause any confusion.

For "quick warning of a flood at each target point", the flood data must be forecast in some way or other. The quicker the forecasting time, the lower becomesthe accuracy of information, so that the forecasting system must function according to the required time and accuracy of forecast.

Let us now see what types of flood could occur at the five target points.

1) Lahanam

i) Flood caused by rainfall in the middle and upper basins of the Se Bang Hieng.

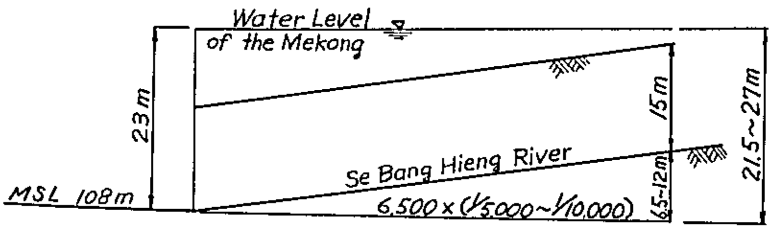
ii) Flood caused by the run-off of the Se Cham Phong and the Se Sang Soi.

iii) Flood caused by the backwater resulting from the stage rise of the Mekong.

Types i) and ii) are readily understandable, but type iii) calls for some explanation about the degree of backwater influence.

At Khemarat water gauge station established near the confluence of the Se Bang Hieng and the Mekong, the highest stage recorded in the past is MSL 131.05 (September 16, 1966). This is equivalent to a water depth of about 23 m of the Mekong. Since the ground elevation in the neighbourhood of Lahanam ranges from 130 to 135 m, inundation could occur in some places due to the backwater from the Mekong.

When the river bed elevation at the confluence is estimated at MSL 108 m from the zero point elevation at Khemarat water gauge station and the depth and bed slope of the Se Bang Hieng are taken at 15 m and 1/5,000 - 1/10,000 respectively, overstopping could occur near Lahanam by the inflow of the Mekong's river water in the horizontal direction as illustrated below.



From the results of the non-uniform flow calculation, it can be seen that if the water level of the Mekong rises about 10 m when the Mekong's level is about equivalent to the depth of Se Bang Hieng's uniform flow and the Se Bang Hieng is flooding, Lahanam is subject to a backwater influence of 2 - 3 m. If the Mekong has a low water level and flows down by drop down, rise of its level incurs little influence. Therefore, when the Mekong has a somewhat high level and is likely to produce backwater with further level rise, its influence should be carefully checked.

For these reasons, not only the flood discharge from upstream but also the flood condition of the Mekong should be examined carefully in the forecasting system for Lahanam target point.

2) Supplementary Target Point 1 (Ban Sa Nhek)

   i) Flood caused by rainfall in the middle and upper basins of the Se Bang Hieng.

   ii) Influence of backwater resulting from the flood of the Se Cham Phong and the Se Sang Soi.

   iii) Influence of backwater resulting from the level rise of the Mekong.

3) Kengkok and Supplementary Target Point 2

   i) Flood caused by the rainfall in the Se Cham Phong basin.

   ii) Influence of backwater caused by the flood of the Se Bang Hieng.

   iii) Influence of backwater caused by the flood of the Se Sang Soi.

   iv) Influence of backwater caused by the level rise of the Mekong.

4) Bung Xang

   i) Flood caused by the rainfall in the Se Sang Soi basin.

   ii) Influence of backwater caused by the flood of the Se Bang Hieng.

   iii) Influence of backwater caused by the flood of the Se Cham Phong.

   iv) Influence of backwater caused by the level rise of the Mekong.

In the vicinity of Keng Kok and Bung Xang, the ground elevation ranges from 135 to 140 m so that flooding due to the backwater of the Mekong is not considered to occur. Results of the non-uniform flow calculation indicate that when the Se Cham Phong is flooding, a 10 m rise of the Mekong's level incurs an influence of 0.5 - 1 m at Keng Kok. Influence of the similar degree is expected for Bung Xang, although no calculations were worked out. Therefore, when the flood of the Mekong and the Se Bang Hieng occurs simultaneously, influence of the Mekong must be carefully checked at these two points. Results of the non-uniform flow calculation also indicate that when backwater of 2 - 3 m is produced at the confluence of the Se Cham Phong by the level change of the Se Bang Hieng, an influence of 0.6 - 0.9 m seems to occur at Keng Kok. This can be considered a considerably great influence because the ground elevation near the confluence is virtually the same as that at Keng Kok. It is estimated that an influence of similar degree will be imposed on Bung Xang.

The following figure shows an observation system prepared from the discussion advanced above.

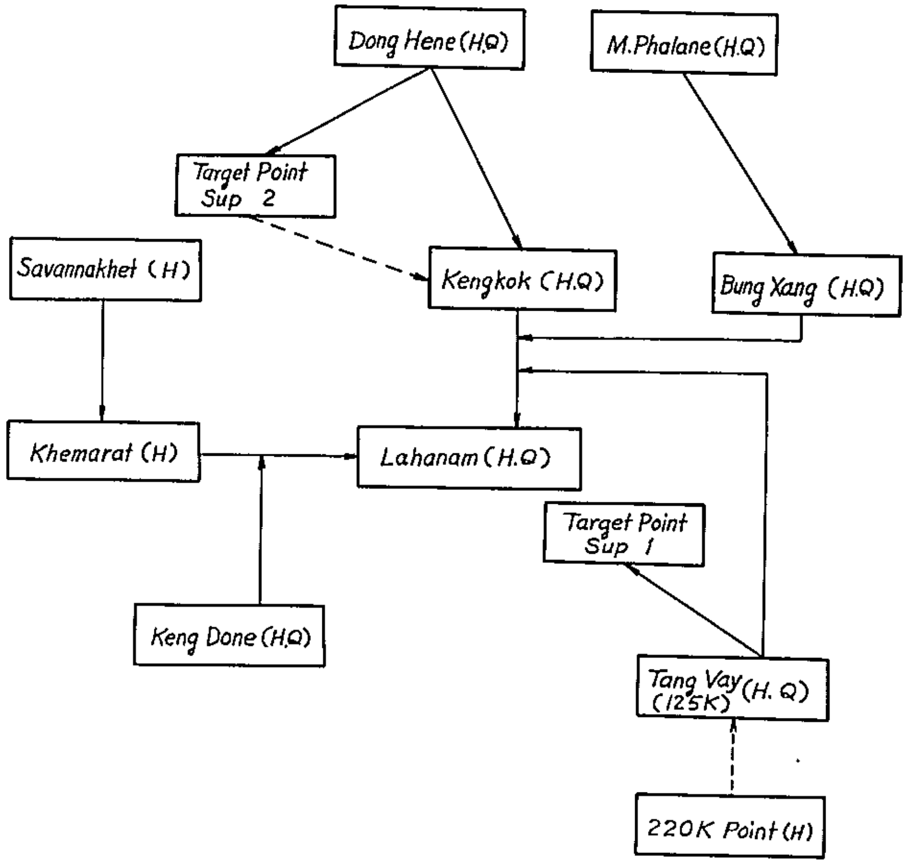


Fig. 6-4 - Example of Observation System

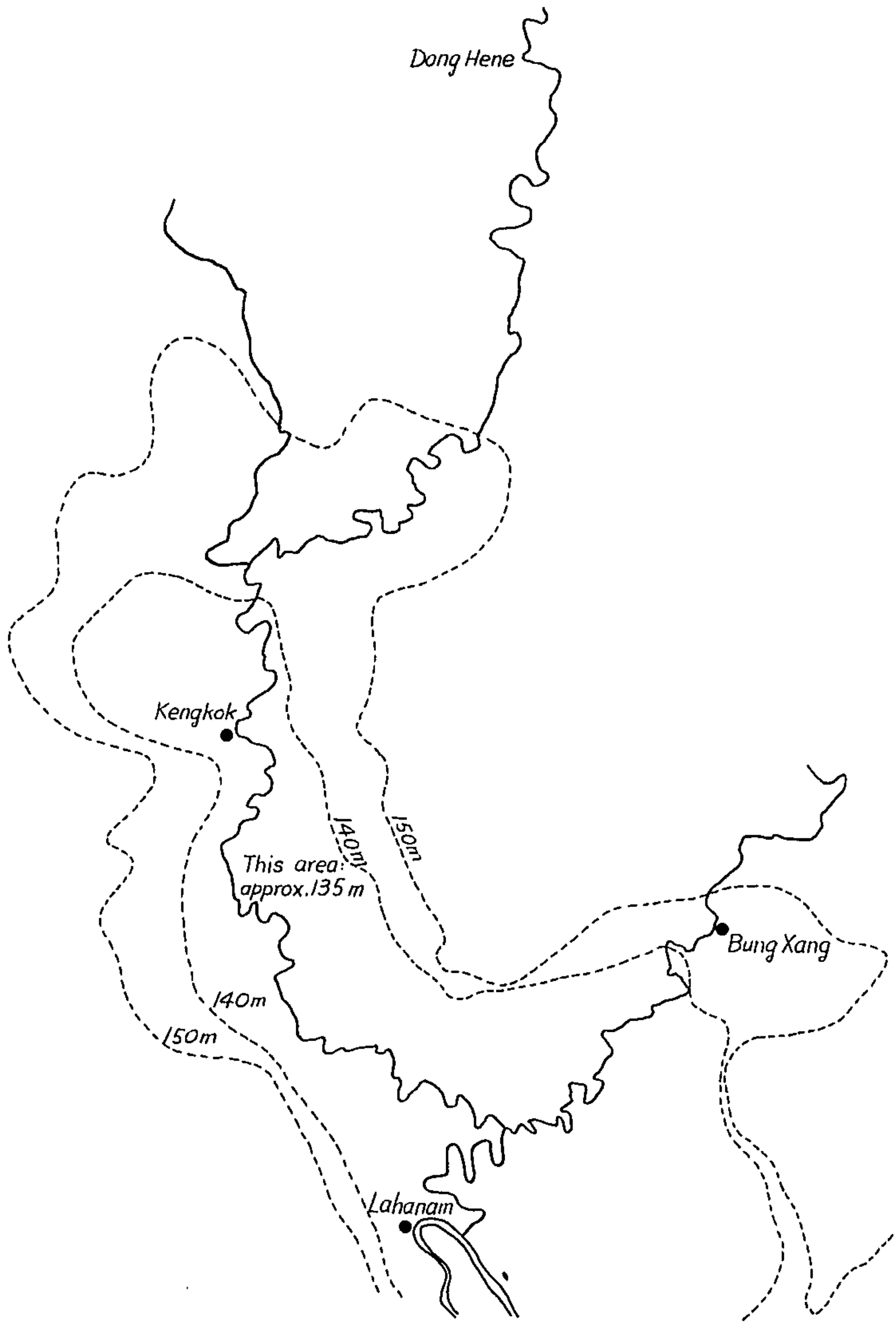


Fig. 6-5 - Contour Map Showing Flooded Area

Let us study how quickly the flood can be forecast when the observation network illustrated in Fig. 6-5 is established. It must be noted that this study produces only a rough idea because there are no systematic hydraulic data and the flow velocity in river channels is not known.

If a velocity of 1.5 - 2 m/sec is assumed for the flood flow of the Se Bang Hieng and a velocity of 1 - 1.5 m/sec for the flood flow of the Se Cham Phong and the Se Sang Soi using the results of non-uniform flow calculation, the reaching time from one point to another as estimated from the distance obtained from the 1/200,000 map turns out to be as shown in Fig. 6-7.

Fig. 6-7 shows that flood forecast to Lahanam, the main target point on the Se Bang Hieng, can be made only half a day in advance from Tanyvay at 125 km point and one day in advance even from the 220 km point. In the case of the flood of the Se Cham Phong and the Se Sang Soi, forecast from the upstream stations, Dong Hene and M. Phalane, can be made only one day in advance. Further, forecast to Bung Xang and Keng Kok which are the main target points on the Se Sang Soi and the Se Cham Phong respectively can be made only 0.6 - 0.7 day in advance from their respective upstream stations, M. Phalane and Dong Hene. It follows, therefore, if flood forecast for the Se Bang Hieng and its tributaries were to made more than a day in advance, it is necessary to establish rain gauge stations at further upstream points on respective rivers. And if the flood forecast for the Se Cham Phong and the Se Sang Soi were to be made one day in advance to their target points, establishment of upstream rain gauge stations is necessary.

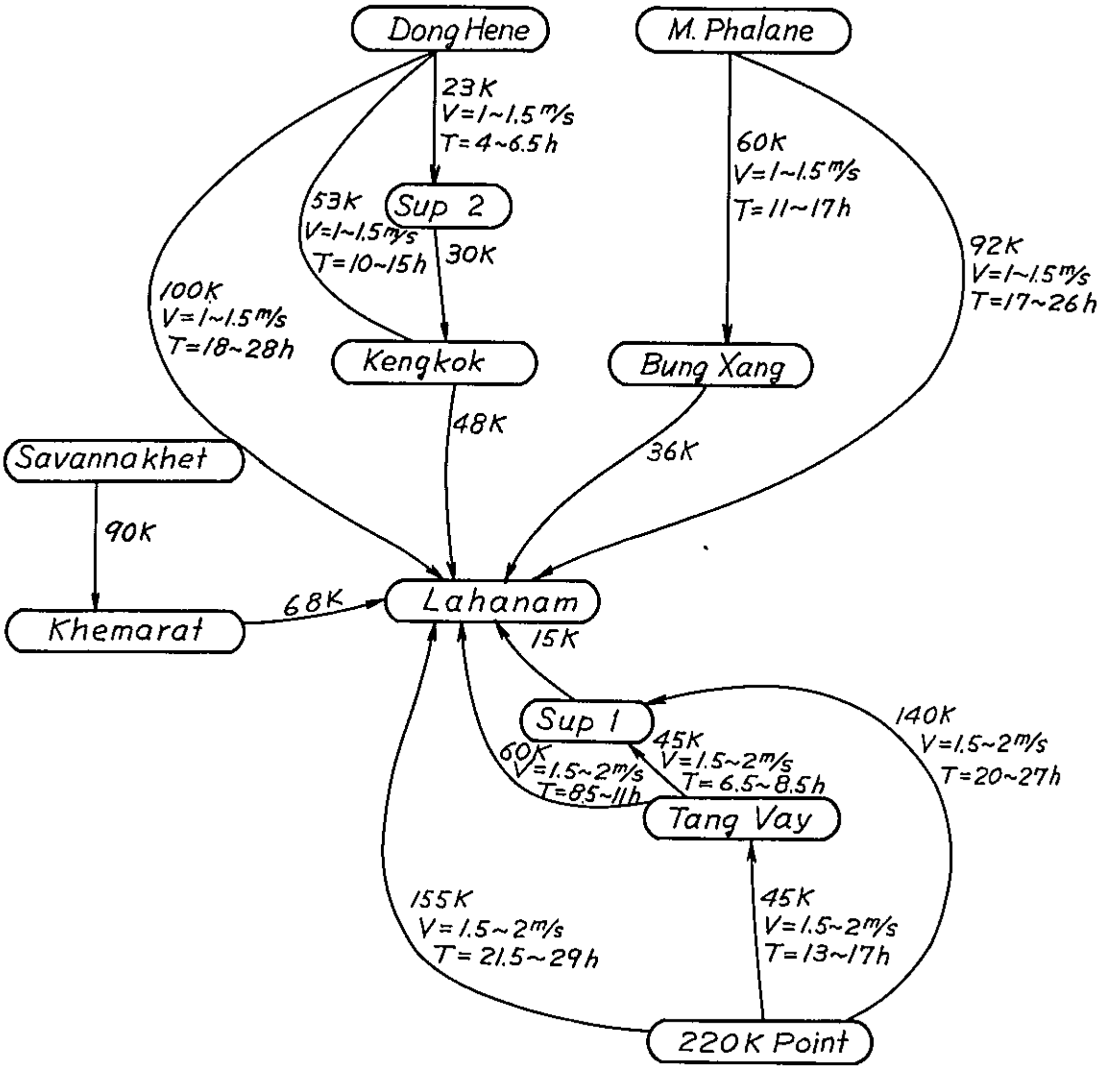


Fig. 6-6 - Flood Reaching Time (Approximate Value)

It is desirable to study the establishment of an observation network covering the entire Se Bang Hieng basin from the viewpoint elucidated above. However, considering the poor availability of existing facilities and the spare population which is likely to make it impossible to maintain newly established estations in good service condition, it becomes necessary to limit the number of stations to a minimum.

Since the system should cover the lower Se Bang Hieng basin extending downstream of Tangvay and the basins of the Se Cham Phong and the Se Sang Soi, it is desirable that rainfall, stage and discharge data can be obtained for these areas.

As regards the middle and upper basins of the Se Bang Hieng, it must be noted that three tributaries, i.e., the Se Kum Kam, the Se Ta Mok and the Se Pong, join the mainstream between 120 K and 220 K. In order to obtain the inflow of these tributaries into the Se Bang Hieng, establishment of a dense network is required, but this is a matter to be examined at some future date. Hence, these three tributaries were taken as a single river and a single respresentative rain gauge station was set in each of the three basins in expectation of the possibility of discovering the relationship between the rainfall at the three stations and the discharge at Tangvay. Of these stations, M. Phime and M. Pouvieng are the centres of Muongs, but no suitable cluster can be found in the Se Kum Kam basin.

A catchment area of about 8, 000 km^2 extends upstream of 220 K point. In the proposed system, the discharge from upstream of 220 K is planned to be obtained at 220 K to find the relationship between the rainfall in the upstream basin and the discharge at 220 K. Establishment of a water gauge station near Tchepone is conceivable, but this will be of little use unless the observation network of the Se La Nong is made denser. Rainfall observation in the area upstream of 220 K is expected to entail difficulty except at Tchepone because of the sparse population and the remoteness from Savannakhet. Hence, the possibility of radar facilities should be studied. It is to be noted that the proposed locations of rain gauge stations were picked up from among clusters which appeared large on the map. Fitness of these locations excepting Tchepone and possibility of establishing the stations in other places are therefore unknown. At Tchepone, an ordinary rain gauge is installed and recorded data are available.

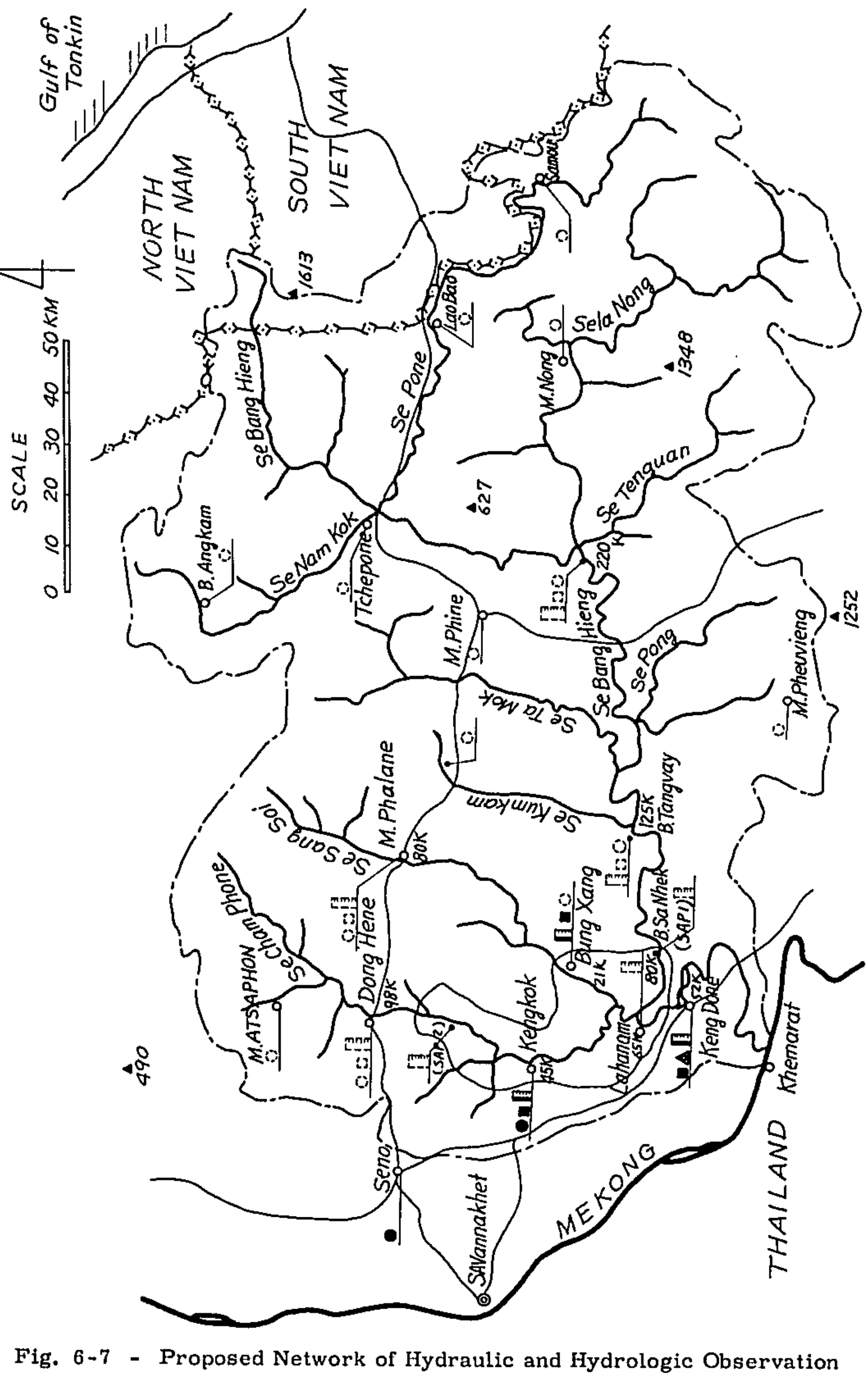


Fig. 6-7 - Proposed Network of Hydraulic and Hydrologic Observation

6-2-3 Proposed Examination Procedure of Flood Forecasting System

(1) Outline

Design of a flood forecasting system presupposes the availability of basic hydraulic and hydrologic data with which to study the adequacy of the system.

In the case of the Se Bang Hieng basin, there are no systematically consolidated data and the quantity of data available in time series (secularly) is extremely limited. Data recorded in the past at a number of stations do not suffice for the required analytical study, so that any design of a flood forecasting system is sure to end in a mere desk plan.

Design of a flood forecasting system for the Se Bang Hieng basin should therefore be preceded by the collection and consolidation of basic hydraulic and hydrologic data, and this must be expedited with full understanding of the objectives of flood forecasting and along the lines of the desirable state of the future observation network so that the established network will incorporate only the necessary facilities.

Since the establishment of a network covering the whole Se Bang Hieng basin is next to impossible at the present stage, it must be implemented in a number of stages. When actually installing observation facilities, measures for easy maintenance and inspection should be devised and enforced because population is sparse and power is not available in the greater part of the basin.

At the present stage, nothing definite can be said about the time required for the completion of the network, but the stage-wise surveys and preparations may be planned as follows.

1) Stage I

In this stage, necessary observation facilities (simple ones in the beginning) should be installed in the lower basins of the Se Bang Hieng, the Se Cham Phong and the Se Sang Soi, and propagation tests of communication equipment should be conducted. All this can be started at the present time.

2) Stage II

The system analysis should be conducted using newly collected data and if any of the stations must be turned into permanent ones as a result of the analysis, installation of self-recording equipment should be promoted.

Simple observation facilities should be installed in the Se Bang Hieng basin downstream of Tangway (125K) as well as in the upper Se Sang Soi basin, with propagation tests of communication equipment also conducted.

3) Stage III

The system analysis should be collected using newly collected observation data, with effort made for determination of permanent stations in lower basins of both main stream and tributaries extending downstream of 125 K point and for installation of recording gauges at such stations. Further, simple observation facilities should be established in lower basins of both main stream and tributaries extending downstream of 220 K.

As for the area upstream of 220 K, the need for establishing rain gauge stations and the possibility of installing radar rain gauges should be studied.

4) Stage IV

In lower basins of both main stream and tributaries extending downstream of 220 K, effort should be made for determination of permanent stations and installation of recording gauges at such stations. If the need for establishing rain gauge stations were confirmed from the study made in Stage III, reconnassiance survey should be conducted to map out a facilities installation plan. At the same time, propagation tests should be conducted and the installation plan of radar rain gauges should be worked out if the use of such gauges were found practicable.

In addition, a telemetering system covering the entire Se Bang Hieng basins should be mapped out in preparation of the design of a flood forecasting centre.

5) Stage V

Establishment of the flood forecasting centre, installation of telemetering equipment and radars, and establishment of the method of flood forecasting.

6) Stage VI

Maintenance and operation of stations.

Needless to say, each stage does not end in a year but could be extended over a number of years.

Table 6-2 shows the conceptual arrangement of the six stages.

Table 6-2 - Examination Procedure of Flood Forecasting System

		I	II	III	IV	V	VI	Remarks
Rainfall Gauge	Ordinary	○	○	○				
	Self-Recording		◌	○	○			
Water Stage	Staff	○	○	○				
	Self-Recording		◌	○	○			
Discharge Observation	Price Current Meter	○	○	○				
	Boat etc	○	○	○				
Hydrologie and Hydraulic Data Analysis			○	○	○	○	○	
Telecommunication Experiment		○	○	○	○			
Telemetering					•	○		
Radar				•	•	○		
Control Center					•	○	○	
Maintenance and Inspection							○	
Remarks		To be started whenever possible						
			Data Collection Period					

Notes •----- Investigation

◌---- Implementation preferable

○---- Implementation

(2) Draft of Stage-wise Plan

Details of Stages I and II can be proposed as follows.

1) Stage I

The lower basin of the Se Bang Hieng, the Se Cham Phong and the Se Sang Soi are the only area to be covered in the beginning. For flood forecasting of the Se Bang Hieng basin, this area must be set as the target area.

Need for a flood forecasting system for this area can be supported by the fact that it suffers flood damage once in two or three years. Therefore, study on the establishment of a flood forecasting system should be started in this stage for the western part of the basin although the survey of the middle and upper basins of the Se Bang Hieng is not practicable.

The survey in this stage should be aimed at selection of locations of stations at which to collect the basic data for system analysis, formulation of an installation plan, and propagation tests.

Fig. 6-9 and Table 6-3 show details of observation stations.

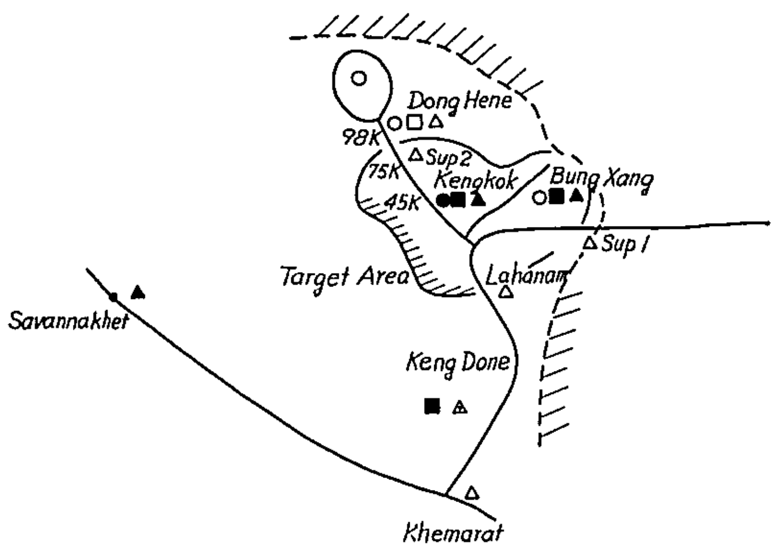


Fig. 6-8 - Conceptual Map Showing Observation Network in Stage I

Table 6-3 - Equipment Needed in Stage I Survey

Equipment / Point	Hydraulic and Hydrologic Observation Equipment						Telecommunication Equipment			
	Rain Gauge (ordinary)	Rain Gauge (self-recording)	Water Gauge (Staff)	Water Gauge (self-recording)	Current Meter (on bridge)	Current Meter (w/o bridge)	Fixed Type	Portable Type	Jeep	Remarks
Upstream point of Dong Hene	O									
Dong Hene	O		O	◌		O		O	O	Survey shown at the left calls for the availability of the following: · Jeep 2–3 · Communication equipment Fixed 2 Mobile 2–3
Sup 2			O					O	O	
Kengkok	•		•	◌	O		O			
Bung Xang	O		•	◌		⊘		O	O	
Sup 1			O					O	O	
Lahanam	O		O	◌		O	O			O···· New installation. ◌···· To be implemented if possible. • ···· Already installed.
Keng Done			•	•		O		O	O	
Khemarat			O	◌				O	O	
Savannakhet	•	O	•				Receiving			

2) Stage II

In this stage, data collected by the observation facilities installed in Stage I should be analyzed in order to promote the installation of recording gauges at stations which need to be turned into permanent ones within the area covered by Stage I.

Expansion of the survey area presupposes the improvement of social situation. However, if survey in the upstream area is possible in any substantial degree, then it should be implemented for establishment of observation stations and propagation test as in Stage I.

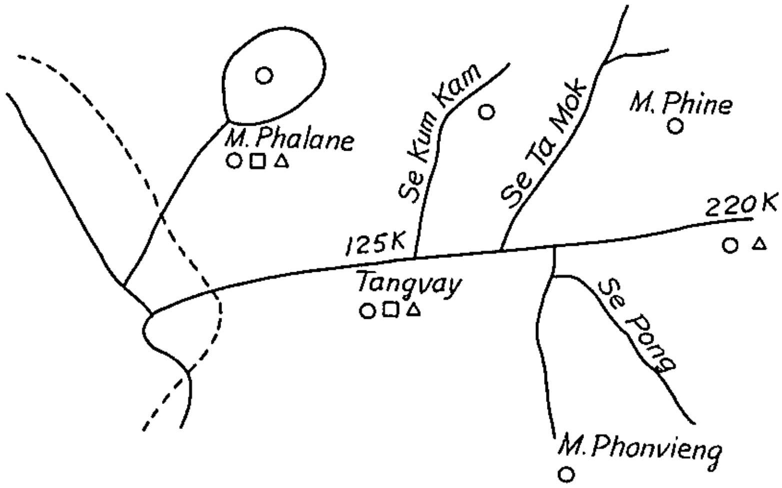


Fig. 6-9 - Conceptual Map of Observation Network in Stage II

Table 6-4 - Equipment Required in Stage II Survey

Point \ Equipment	Hydraulic and Hydrologic Observation Equipment						Telecommunication Equipment			
	Rain Gauge (Ordinary)	Rain Gauge (Self-recording)	Water Gauge (Staff)	Water Gauge (Self-recording)	Current Meter (on bridge)	Current Meter (w/o bridge)	Fixed Type	Portable Type	Jeep	Remarks
Up stream of M. Phalane	○									Survey shown at the left calls for the availability of the following: ° Jeep 2 - 3 ° Communication Equipment Fixed 2 Mobile 2 - 3
M. Phalane	○		○	◌		(?)	○			
Tang Vay	○		○	◌		(?)		○	○	
Up stream of Se Kum Kam	○									
M. Phine	○							○	○	
M. Phouvieng	○									
220 K Point	○		○	◌		(?)		○	○	
Remarks	○---- New installation ◌---- May be implemented it possible (?)---- Existence of bridge unknown									

(3) Equipment Required in Stage I

Cost of the equipment required in Stage I is studied in this item.

Table 6-5 shows the cost of equipment for hydraulic and hydrologic observation.

Table 6-5 - Cost of Hydraulic and Hydrologic Observation Equipment

(Unit: Thousand Yen)

Equipment	Specification	Unit	Quantity	Unit Cost	Amount	Remarks
Ordinary rain gauge	Rain backet - 20 cm gauging cylinder storage bottle	set	4	50	200	
Recording rain gauge	Tipping backet type	set	1	800	800	
Staff gauge	Wooden	m	120	5	600	Tributary 10m x 1.5 Main stream 20m x 1.5
Current Meter	Direct Reading Type	set	2	300	600	One set each for tributary and main stream
Boat	Capacity - 5 passengers	set	2	300	600	One set each for tributary and main stream
Sub-total					2,800	
Recording Water Gauge		set	5	2,200	11,000	
Total					13,800	

Notes: Installation cost is not included.
Recording water gauge is not necessary for the second and subsequent surveys.

The cost of telecommunication equipment and transportation equipment is shown in Table 6-6.

Table 6-6 - Cost of Telecommunication Equipment

Unit: Thousand Yen

Equipment	Specification	Unit	Quantity	Unit Cost	Amount
Radio Communication Equipment	150MHZ 10W Type CRI-15	set	4	320	1,280
Battery	12V 32AH	set	4	16	64
Accumulator	18V 4A	set	4	30	120
Generator	Portable type 100V 800VA	set	4	110	440
Antenna	Yagi Antenna foldable, 150MHZ	set	4	75	300
Pole	10 m	set	4	110	440
Jeep	With cooler	set	2	2,000	4,000
Total					6,644

Notes: When conducting a propagation test, field strength meter (1 unit, 450 thousand yen), wattmeter (2 units, 320 thousand yen), slidanc (2 units, 20 thousand yen, and tester (2 units, 40 thousand yen) are required in addition to the equipment listed above. The total cost of these additional instrument is 1,210 thousand yen.

To sum up, observation equipment costing a total of about 10,000 thousand yen and experimental equipment costing a total of about 1,200 thousand yen are required in the first survey excluding self-recording water gauges.