APPENDIX B

HYDROLOGIC AND HYDRAULIC ANALYSIS

APPENDIX B HYDROLOGIC AND HYDRAULIC ANALYSIS

CONTENTS

			Page
CHAPTER	I	HYDROLOGY OF KHLONG U-TAPHAO BASIN	
	1.1	River Systems and Sub-basins of Khlong U-Taphao.....	B-1
	1.2	Inventory of Rainfall and Water Level Observatories.....	B-1
	1.3	Hydrologic Characteristic.....	B-2
		1.3.1 Meteorological Condition	B-2
		1.3.2 Rainfall Distribution and Frequency.....	B-2
CHAPTER	II	FLOOD RUNOFF ANALYSIS OF KHLONG WA	
	2.1	Available Hydrologic Data.....	B-4
	2.2	Hydrologic Model.....	B-4
		2.2.1 Model Structure.....	B-4
		2.2.2 Model Calibration.....	B-4
	2.3	Application to Khlong Wa Basin	B-5
	2.4	Establishment of Typical Rainfall Pattern for Khlong Wa Basin	B-6
CHAPTER	III	HYDRUALIC ANALYSIS	
	3.1	Flooding Simulation in the Middle/Downstream Reaches...	B-9
		3.1.1 River Channels and Floodplains Conditions.....	B-9
		3.1.2 Construction of Simulation Model.....	B-10
		3.1.3 Boundary Conditions.....	B-10
		3.1.4 Simulation of Yr. 2000 Flood.....	B-11
		3.1.5 Simulation of Probable Floods.....	B-11
	3.2	Inundation Map for Middle/Downstream of Khlong Wa	B-11

TABLES CONTENT

		Page
Table 1.2-1	List of Rainfall Stations in Khlong U-Taphao River Basin and Its Vicinity	B-12
Table 1.2-2	List of Stream Flow Gauging Station in Khlong U-Taphao River Basin	B-13
Table 1.3-1	Average Basin Rainfall : Khlong U-Taphao and Khlong Wa River Basin	B-14
Table 1.3-2	Frequency Analysis of Maximum Rainfall in Khlong U-Taphao River Basin and Khlong Wa Sub Basin	B-15

FIGURES CONTENT

		Page
Figure 1.1-1	Khlong U-Taphao River Basin	B-16
Figure 1.2-1	Location of Rainfall and Stream Flow Gauging Stations	B-17
Figure 1.3-1	Monthly Distribution of Climatic Variables at Hat Yai Airport	B-18
Figure 1.3-2	Thiessen Polygon of Khlong U-Taphao River Basin	B-19
Figure 1.3-3	Spatial Rainfall Distribution during 18 - 24 Nov. 1988	B-20
Figure 1.3-4	Spatial Rainfall Distribution during 18 - 24 Nov. 2000	B-21
Figure 1.3-5	Temporal Rainfall Distribution during 18 - 24 Nov. 2000	B-22
Figure 1.3-6	Temporal Rainfall Distribution at A.Muang, Songkhla During 18 - 24 Nov. 1988	B-23
Figure 1.3-7	Frequency Analysis of Maximum Rainfall in Khlong U-Taphao River Basin	B-24
Figure 1.3-8	Frequency Analysis of Maximum Rainfall in Khlong Wa Sub Basin	B-25
Figure 2.2-1	Schematic Representation of Hydrologic Cycle and Model RUNOFF-CASH	B-26
Figure 2.2-2	Rainfall Distribution at St. X.113	B-27
Figure 2.2-3	Result of Hydrologic Model Calibration	B-27
Figure 2.3-1	Khlong Wa Sub-basins applied to the Hydrologic Model	B-28
Figure 3.1-1	Profile of Khlong Wa	B-29
Figure 3.1-2	Typical Existing Cross Section of Khlong Wa	B-30
Figure 3.1-3	Schematic Diagram of the Mathematical Model for the existing Condition of the Flood Plain	B-31
Figure 3.1-4	Profile of the Computed Maximum Water Level and the Observed Flood mark	B-32
Figure 3.1-5	Discharge Hydrograph at St. X.174 on November 2000	B-33
Figure 3.1.6	Water level at St. X.174 on November 2000	B-34
Figure 3.1.7	Maximum Water Surface Profile of the probable floods of Khlong Wa	B-35
Figure 3.1.8	Discharge Hydrographs of the probable flood at St. X 174	B-36
Figure 3.2-1	The Inundation map along Khlong Wa	B-37

APPENDIX B. HYDROLOGIC AND HYDRAULIC ANALYSIS

CHAPTER I HYDROLOGY OF KHLONG U-TAPHAO BASIN

1.1 River Systems and Sub-basins of Khlong U-Taphao

The U-Taphao Basin is in the southern part of Thailand. Its catchment area is about 2,325 sq.km (**Figure 1.1-1**) and Khlong U-Taphao is the main river, originated from the mountainous range along the Thai-Malaysian Border with the total length of 165 km. (including Khlong Sadao). Generally, the Khlong U-Taphao is called after the confluence of Khlong Sadao and Khlong Prik (vicinity to the gauging station X112) about 36 km from the remote upstream. Therefore, the length of Khlong U-Taphao is approximately 129 km and the average slope is about 1:2,700. The runoff from the basin is discharging to the Songkhla Lake on the east of the peninsular. Apart from the main river, there are many laterals on the east and west river basin. The sub-basin area on the east is about 924 sq.km., while on the west is of 1,496 sq.km. Among these laterals, Khlong Wa on the eastern sub-basin with the catchment area of 118.2 sq.km was thought to be one of the catchement attributed significant damages to the Hat Yai Municipality in the year 2000 flood.

1.2 Inventory of Rainfall and Water Level Observatories

There are 35 rainfall stations in the Khlong U-Taphao Basin and its neighboring area as shown in **Figure 1.2-1** and **Table 1.2-1**. Generally the rainfall record is available in daily basis. However, there are few stations providing a shorter time interval record as tabulated below.

Code	Name	Time Interval	Record Available	Authority
58013	A. Muang C. Songkhla	3-hour	1981-2001	MET
58112	Kho Hong Agriculture Meteorological Station	3-hour	1999-2000	MET
58221	Khlong La Pang (X113) A. Sadao	Automatic	2000	RID
58332	Hat Yai International Airport	3-hour	1981-1984 1986-1987 1989-2001	MET
58341	Khlong U-Taphao (X173) B. Khlong Ngae	Automatic	1990-1997 2000	RID
568401	Sadao Hydro-meteorological Station	3-hour	1998-2001	MET

Note MET- Meteorological Department
RID – Royal Irrigation Department

For the stream flow gauging stations, there are 12 stations available in the basin. The data record of 9 stations is available with water level and flow record while the remaining is only water level as shown in **Table 1.2-2**. In the sub-basin concerned of

Khlong Wa, the data is quite limited. Neither flow record nor hourly rainfall record, necessary for the flood analysis, is available.

1.3 Hydrologic Characteristics

1.3.1 Meteorological Conditions

The seasonal monsoons of the Southwest and Northeast govern the climate condition of the basin. The Southwest Monsoon starts from May-October, while the Northeast Monsoon commences from November-April. The basin has nearly all year round rainfall. The rainy period starts from May until December. November and December experience the large amount of rainfall. This plenty of rainfall is in part due to the typhoon, originated in the South China Sea, prevails passing the basin during November.

Based on the climatological data at the Hat Yai International Airport Station (1971-2000), some important data is summarized in table below and **Figure 1.3-1**.

Description		Southwest Monsoon May-Oct.	Northeast Monsoon Nov.-Apr.	Year
Mean Pressure	Hecto pascal	1,009.3	1,010.9	1,010.1
Mean Temperature	Celsius	26.4	26.5	26.8
Mean Relative Humidity	%	81.3	80.8	81.0
Total Rainfall	mm	860.8	825.4	1,686.2
Total Day of Thunderstorm	day	63.4	29.9	93.3

1.3.2 Rainfall Distribution and Frequency

Generally, the annual rainfall in the Khlong U-Taphao Basin is relative high of about 1,700 mm (Thiessen Polygon technique, **Figure 1.3-2** and Average Basin Rainfall, **Table 1.3-1**). Its temporal monthly distribution is erratic and the period of September-December has a high risk of flood as it accounts nearly 55% of the total rainfall

For the Khlong Wa Sub-basin, the average annual rainfall is about 1,830 mm, 8% higher than that of the Khlong U-Taphao Basin. This indicates that, generally, the lower part of the basin has a potential to have a greater rainfall than the upper basin. In such a case, the Hat Yai Municipality has a great potential to be affected by the flash flood from the nearby basin as what happened in the year 2000.

The floods during 19-23 November 1988 and 18-24 November 2000 are the most severe floods that caused the extensive damage to the Hat Yai Municipality. The total rainfall depths of the whole river basin during those periods (considering 18-24 November) are 286 mm and 532 mm respectively. **Figure 1.3-3** and **Figure 1.3-4** show the spatial

rainfall distribution of these two events, which can be summarized as tabulated in table below

Description	Cumulative Rainfall Depth (mm)						
	18 Nov	19 Nov	20 Nov	21 Nov	22 Nov	23 Nov	24 Nov
November 1988							
U-Taphao River Basin	15.8	66.1	200.8	271.2	277.8	286.2	286.3
Khlong Wa Sub-basin	20.5	87.5	247.9	320.7	334.6	346.5	346.5
November 2000							
U-Taphao River Basin	29.2	55.8	109.3	284.2	442.0	510.9	532.7
Khlong Wa Sub-basin	37.9	92.8	197.4	606.6	746.3	862.7	877.7

According to the spatial distribution of the rainfall during the flood periods in November 1988 and November 2000, it is clearly seen that in the year 2000 the intense rainfall occurred in the area closed to the Hat Yai Municipality. In the year 1988, however, the more uniformity of the rainfall over the whole catchment can be observed. **Figure 1.3-5** shows the Temporal Rainfall Distribution of the basin for the flood event in the year 2000. The rainfall intensity increased gradually from the upper part (station X113) to the lower part of the catchment (station 58112) where the Hat Yai Municipality is located. With this phenomenon, the flash flood in the year 2000 from the nearby catchment cannot be avoided.

For the flood event in 1988, only hourly rainfall data at A. Muang Songkhla Station is available and is depicted in **Figure 1.3-6**. At this station, the rainfall intensity in the year 1988 is more intense than that in the year 2000 but the total depth is much lower.

Based on the Gumbel Distribution, the frequency of occurrence of the maximum rainfall in the Khlong U-Taphao River Basin and Khlong Wa Sub-basin is shown in **Table 1.3-2**, **Figure 1.3-7** and **Figure 1.3-8**. Referring to the results obtained, the maximum 7-day rainfall for the flood events in year 1988 and year 2000 is equivalent to the recurrence interval of 4 years and 45 years for the Khlong U-Taphao River Basin and of 3.5 years and 300 years for the Khlong Wa Sub-basin respectively.

CHAPTER II FLOOD RUNOFF ANALYSIS OF KHLONG WA

2.1 Available Hydrologic Data

In general, it can be said that the availability of the hydrologic data for flood runoff analysis in the Khlong Wa Basin is very limited. Only one station for water level record at station X174 (near the catchment outlet) and one rainfall station (daily record) are available. These data are not directly useful, as those required for flood runoff analysis are flow hydrographs and rainfall data with hourly basis intervals. Hence, some procedures are applied to compromise the deficit of the hydrologic data as follows:

(1) Selecting another sub-basin where sufficient hydrologic data is available for the hydrologic model calibration and verification. In this regard, the sub-basin at X113 (129 sq.km.) is selected. It is the small river basin with mountainous type, which is suitable to represent the sub-basin in the remote area. Nevertheless, only one complete set of hydrologic data of the year 2000 is available. Therefore, just model calibration can be performed.

(2) As there is no hourly rainfall record available in the Khlong Wa Basin, the rainfall records at the nearby stations of the Hat Yai International Airport Station (58332) and the Kho Hong Agriculture Meteorological Station (58112) are applied.

(3) Due to the insufficient hydrologic data, the results from the hydrologic model will be verified hydraulically by comparing the observed flood marks in the year 2000 with the computed water levels. Two flood marks for year 2000 are available at the gauging station X174 and at the factory about 10.6 km upstream from the catchment outlet.

2.2 Hydrologic Model

2.2.1 Model Structure

The hydrologic model used in the flood runoff analysis is the commercial model called RUNOFF-CASH (Conceptual Analysis and Synthesis of Hydrographs). As implied by the name, it is a conceptual model, which simplifies the hydrologic cycle of which the dominant processes of losses, storage and transfer are represented adequately to analyze rainfall and runoff time series and to synthesize the hydrological processes on the catchment scale. **Figure 2.2-1** shows the schematic representation of the hydrologic cycle and the model RUNOFF-CASH.

2.2.2 Model Calibration

As aforementioned that the hydrologic model cannot be calibrated in the Khlong Wa Basin due to the lack of the hydrologic data, flow hydrograph and hourly rainfall record. The model is therefore calibrated by using another sub-basin at X113 as the representative basin. The catchment characteristic of sub-basin X113 can be briefed as follows:

Catchment Area	129	sq.km
Channel Length	20.7	km

Channel Slope 1:527

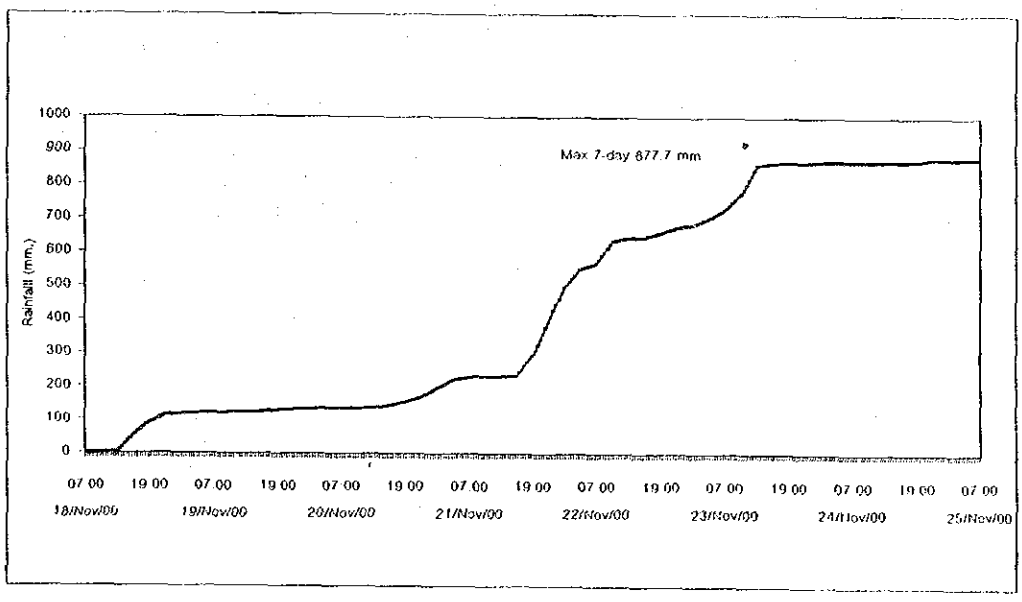
The hydrologic data during the recent flood period of 19-30 November 2000 is used for model calibration. **Figure 2.2-2** shows the rainfall distribution of the sub-basin with the total depth of 353.3 mm. The result from the calibration is found satisfactorily as shown in **Figure 2.2-3**, which can be summarized as shown in table below.

Description		Observed	Computed	% Different
Total Rainfall	mm	353.3	353.3	-
Effective Rainfall	mm	178.9	177.8	0.6
Losses	%	49.4	49.7	0.6
Flood Peak	cms	128.2	127.4	0.6
Flood Volume	cu.m.	230,805.0	229,331.0	0.6

The calibrated model parameters obtained from this sub-basin will be applied in the Khlong Wa Basin where the validity of the hydrologic model will be examined through the hydraulic analysis.

2.3 Application to Khlong Wa Basin

In applying the hydrologic model to the Khlong Wa Basin, the basin of 118.2 sq.km is sub-divided into 15 sub-basins as shown in **Figure 2.3-1**. The hydrologic model is applied to each sub-basin to estimate flood hydrographs during the flood period of 18-24 November 2000 with the amount rainfall of 878 mm. The rainfall pattern is duplicated from that of the nearby station Kho Hong Agriculture Meteorological Station (58112) as shown in Figure below. The estimated flood peak for each sub-basin is compiled as shown in Table below.



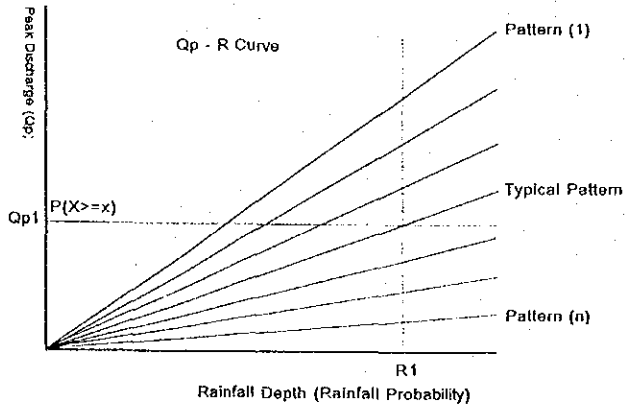
Sub-basin No.	Sub-basin Area (sq.km.)	Flood Peak (cms.) 18-24 Nov 2000
1	2.9	12.2
2	5.3	22.4
3	2.3	9.7
4	1.9	8.0
5	5.5	23.2
6	1.1	4.6
7	2.1	8.9
8	3.3	13.9
9	3.2	13.5
10	7.4	31.2
11	8.8	37.2
12	1.5	6.3
13	21.5	90.8
14	19.0	80.2
15	32.4	136.8
Total	118.2	

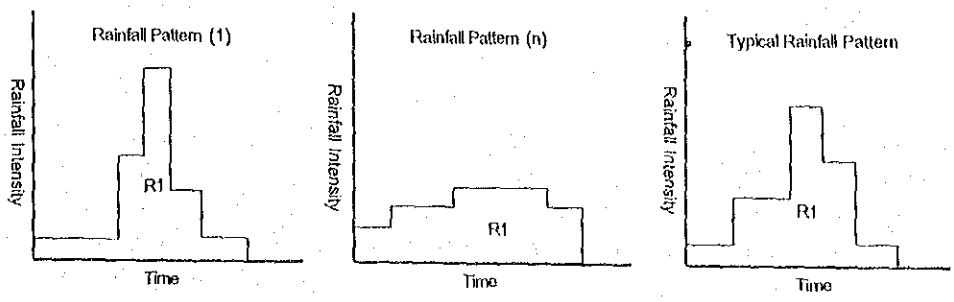
The flood hydrographs from each sub-basin is then routed through the channel and flood plain of the Khlong Wa Basin to verify the validity of the hydrologic model by comparing the observed and computed flood marks. The details of this simulation study will be discussed in **Chapter III Hydraulic Analysis**.

2.4 Establishment of Typical Rainfall Patter for Khlong Wa Basin

Flood discharge probability of the Khlong Wa Basin is estimated from the rainfall probability of its basin since no flood discharge records are available. However, the flood discharge varies according to the temporal distribution pattern of the rainfall even if its depth is equal. The rainfall pattern with the concentrated (sharp) distribution generates a higher flood peak discharge than that of the flatter distribution pattern. Hence, the typical rainfall temporal distribution pattern should be set up for the flood runoff analysis. In such a case, the probabilities of estimated flood discharge would entirely depend upon the probabilities of the rainfall.

Due to the reason aforementioned, the typical temporal rainfall pattern is assumed to be the rainfall pattern that gives the median of the simulated peak discharge [P (X>=x) = 0.5]. For this assumption, the rare rainfall pattern such as pattern (1) and pattern (n) will be neglected. The schematic of Typical Rainfall Pattern Establishment is described as Figures below.





The typical temporal rainfall pattern of the Khlong Wa Basin is selected from among the actual hourly (3-hour) rainfall records at the Hat Yai International Airport Station since it has a long record period. The nearer station at Kho Hong Agriculture Meteorological Station has only 3-year records (year 2000-2001).

Sixteen (16) storm rainfalls have been observed at the Hat Yai International Airport since 1981 and 3-hour rainfall data are available for all storm rainfalls. In the analysis, the temporal pattern with the maximum 3-day rainfall is selected according to the reasons as follows:

(1) Most of the storms continued for more than 2 days.

(2) Peak flood discharge varies depending on the magnitude of rainfall in the early stage of storm duration since a considerable portion of the rainfall in the early stage is lost of stored in the basin.

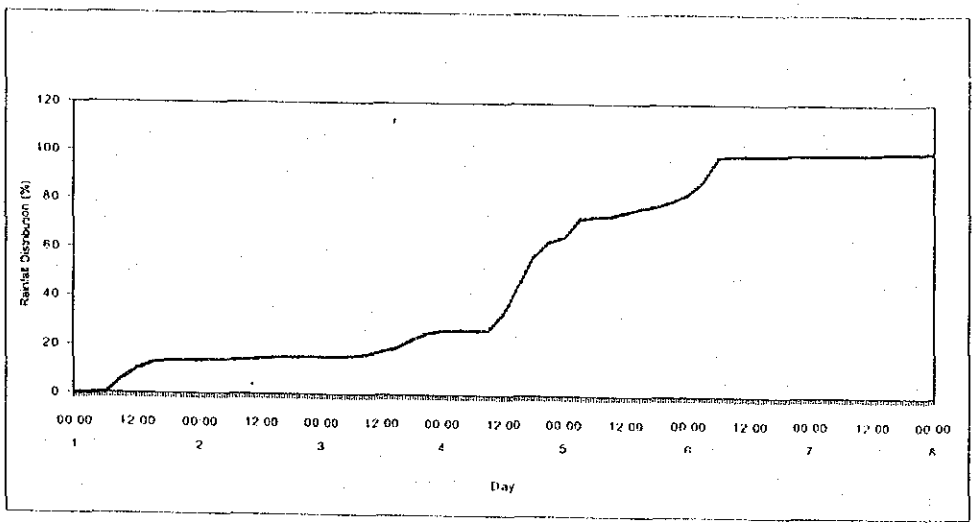
(3) The severe flood in the year 2000 continued for 1 week with the concentrating period of 3 days.

The maximum 3-day rainfall depth of 16 storms ranges from 73.4 mm in 1998 storm to 467.9 mm in 2000 storm with an average of 164.8 mm. Basing on all these rainfall pattern, the maximum 3-day rainfall with a 25-year return period (450 mm) of the Khlong Wa Basin is applied to estimate the peak discharge per unit area. The 25-year return period rainfall is chosen because it is the design period for flood protection scheme for the Khlong U-Taphao Basin. The results are shown in Table below.

Probability P(X>=x)	Rainfall Record		25-year Return Period Peak Discharge/Unit Area (mm)
	Year	Depth (mm)	
0.06	1992	170.6	10.57
0.12	1999	135.1	5.25
0.18	1983	230.2	4.98
0.24	2001	130.9	4.35
0.29	1990	106.0	4.01
0.35	1998	73.4	3.98
0.41	1996	83.3	3.70
0.47	1995	136.8	3.63
0.53	1993	136.0	3.59
0.59	1987	217.3	3.50
0.65	2000	467.9	3.45
0.71	1984	157.4	3.45

0.76	1994	114.1	3.45
0.82	1997	155.1	2.93
0.88	1986	185.0	2.45
0.94	1991	138.2	2.19
Kho Hong	**2000**	**597.7**	**3.67**

The median peak discharge is 3.63 mm of the year 1995 rainfall pattern or 3.59 mm of the year 1993 rainfall pattern, which is very closed to that obtained from the pattern at the Kho Hong Agriculture Meteorological Station in the year 2000. Therefore, the rainfall pattern of the year 2000 at the Kho Hong Agriculture Meteorological Station, located closer to the Khlong Wa Basin, is selected as a typical rainfall pattern for the Khlong Wa Basin as shown in Figure below.



Based on the typical rainfall pattern, the peak discharges of various return periods for each sub-basin are estimated as tabulated in Table below. These sub-basin hydrographs would be then routed through the Khlong Wa Basin to obtain the basin hydrograph at the basin outlet (see **Chapter III Hydraulic Analysis**).

Sub-basin		Peak Discharge at Various Return Period (cms)							
No.	Area (sq.km)	5	10	15	25	50	100	200	500
1	2.9	2.8	4.2	5.0	6.3	7.8	9.4	11.0	13.0
2	5.3	5.2	7.7	9.4	11.4	14.3	17.2	20.0	23.8
3	2.3	2.2	3.3	4.1	5.0	6.2	7.5	8.7	10.3
4	1.9	1.9	2.8	3.4	4.1	5.1	6.2	7.2	8.5
5	5.5	5.4	8.0	9.8	11.9	14.8	17.9	20.8	24.7
6	1.1	1.1	1.6	2.0	2.4	3.0	3.6	4.2	4.9
7	2.1	2.0	3.0	3.7	4.5	5.7	6.8	7.9	9.4
8	3.3	3.2	4.8	5.9	7.1	8.9	10.7	12.5	14.8
9	3.2	3.1	4.6	5.7	6.9	8.6	10.4	12.1	14.4
10	7.4	7.2	10.7	13.2	16.0	19.9	24.0	28.0	33.2
11	8.8	8.6	12.8	15.7	19.0	23.7	28.6	33.3	39.5
12	1.5	1.5	2.2	2.7	3.2	4.0	4.9	5.7	6.7
13	21.5	21.0	31.2	38.3	46.4	57.9	69.8	81.3	96.5
14	19.0	18.5	27.6	33.8	41.0	51.1	61.7	71.9	85.3
15	32.4	31.6	47.0	57.7	69.9	87.2	105.2	122.5	145.4

CHAPTER III HYDRAULICS ANALYSIS

3.1 Flooding Simulation in the Middle/Downstream Reaches

3.1.1 River Channels and Floodplains Conditions

(i) Profile of the Khlong Wa

The Khlong Wa starts from a mountain Southeast of the Na Mom District, and flows towards the Na Mom District before turning left and flows westward to the Khlong U-Taphao. The basin is fan-shaped, as shown in Figure 2.3-1, with a total catchment area of about 118 square kilometers. The stream can be divided into three reaches, upstream, middle, and downstream reaches. The upstream reach, which has steep slope, runs from the mountain to the valley bed at the Na Mom District. The middle reach, which runs from the Na Mom District to the Kanchanavanich Road, has a bed slope of about 1:850. The downstream reach has about the same slope as that of the middle reach, but it is strongly influenced by the water level in the Khlong U-Taphao during flooding. Figure 3.1-1 shows the profile of the Khlong Wa, starting from the Khlong U-Taphao to km 22+020.

(ii) The Cross-section of the River

In the upstream reach the cross-section of the Khlong Wa is rather small and the channel width is only about 10 meters. In the middle reach of the Khlong Wa, the channel cross-section width is in the order of 15 to 20 meters. The floodplain in the middle reach is about 400 to 700 m wide. The bed material of the stream in this reach consists mainly of cobble, gravel and coarse sand. There are some encroachments of the floodplain in the middle reach by residential houses, factories, and roads at present. The channel width in the downstream reach is about 20 to 30 meters. The downstream reach of the Khlong Wa is more developed and has a lot of residential houses in the adjacent floodplains. At the end of the middle reach of the Khlong just upstream of the Kanchanavanich Road, flow capacity of the channel has been deteriorated by many factors, including the width of the channel, the buildings on both banks of the Khlong, the highway bridge opening at the Kanchanavanich Road, and sharp turning plan form of the Khlong at this location. During high flood flow, the discharge in excess of this constricted channel reach capacity may overtop the Kanchanavanich Road, or, flow over the floodplain to another near by bridge opening at the Kanchanavanich Road, about 450 meters to the south of the bridge on the Khlong Wa. This floodplain and bridge opening should be maintained as flood passageway in the future, otherwise the combined flood drainage capacity of the Khlong Wa and the floodplain will be further deteriorated. Figure 3.1-2 shows the typical cross-section of the Khlong Wa.

(iii) Bridges

There are 10 road bridges and 3 railway bridges built across the Khlong Wa between Khlong U-Taphao to Na Mom District and there are also 2 bridges built on Khlong Muang. These bridges have caused some drainage problems, especially the bridge close to the office building of the Regional Electricity Authority and the bridge at Ban

Khuan Chong. The former bridge has a width of an opening about 12 meters and becomes constriction to flow in the channel. In addition, there are a lot of buildings on both banks of the Khlong Wa close to the bridge, which also hamper flow over the floodplains. The opening of the latter bridge is only about 10 meters wide and also one of major constriction in the channel.

3.1.2 Construction of Simulation Model

Generally speaking, flood flow in each reach of the Khlong Wa is characterized by different factors. In the upstream reach where the longitudinal slope of the stream is steep and the valley is narrow, the flood hydrograph has high peak and steep rising limp. In the middle reach of the stream, during large flood, water spreads into the floodplains on both sides of the stream resulting in attenuation of the peak discharge of the flood by storage effect of the floodplains. In the lower reach of the Khlong Wa, the flood level is strongly influenced by the river stage of the Khlong U-Taphao.

(i)Model Components

The mathematical model for simulation of the flood flow is one-dimensional mathematical model, the Mike 11 model, based on full hydrodynamic equation, or the St Venant Equations. The components of the model are the stream channel network, floodplains, bridges, roads cutting through the floodplain, weirs, swamps, and retarding basins. Figure 3.1-3 shows the schematic diagram of the mathematical model for the existing condition of the floodplain.

(ii) Geometric Data

The geometric data used in the model construction are as the followings.
- Cross section of the Khlong Wa surveyed by the RID
- Topographic map with a scale of 1:10,000 prepared by RID
- Bridge geometry data by the DOH
- Road level, highway no. 43 and Kanchanavanich Road, by the DOH
- Bridge opening geometry surveyed by the Consultant staffs.

3.1.3 Boundary Conditions

The boundary conditions of the model are the runoff hydrograph from various sub-basin of the Khlong Wa Catchment and the water level at the confluent of the Khlong Wa and Khlong U Taphao.

(i) Runoff from Sub-basins

In calculation of the runoff from the Khlong Wa Basin ,the basin is subdivided into 15 small sub-basins as shown in Section 2.4 of Appendix B

(ii) Flood Level in Khlong U-Taphao

The downstream boundary condition for the mathematical model is the water level in the Khlong U-Taphao. The water levels at the confluence between the Khlong U-Taphao and Khlong Wa are required for both existing condition and the with project condition. For the existing condition the water level is estimated from the water levels measured at the X44 and X90 Gauging Stations for various return periods. For the with project condition, the full bank flow water level at beginning of the RID's D1 drain channel is adopted (25-year water level by RID design of D1 drain channel).

3.1.4 Simulation of Yr. 2000 Flood

The mathematical model for the existing condition of the Khlong Wa was constructed and the flood marks of the Yr-2000 flood were used in calibration of the model. The runoff of the Yr-2000 flood was estimated based on the actual rainfall pattern at Khao Kho Hong Rainfall Station. The simulation was performed for a period of 3 days, the 21st–24th November 2000. The results of the simulation are then compared with the observed flood marks. Figure 3.1-4 shows the profile of the computed maximum water level and the observed flood marks. The computed maximum flood levels and the observed flood levels are practically in good agreement. The discharge, including flow in the floodplain, and stage hydrographs at the streamflow Gauging Station X174 during 21st - 23rd November 2000 are shown in Figure 3.1-5 and 3.1-6, respectively.

3.1.5 Simulation of Probable Floods

To estimate of the flood damage in the floodplain of the Khlong Wa, maps showing the flood depth in the floodplain for various return period must be established. The mathematical model calibrated in Section 4.1.4 can now be used as a tool for calculating the flood depth along the riverine. The simulated floods are based on the runoff calculated from the rainfall depths and the hourly rainfall pattern at Khao Kho Hong Rainfall Station. The floods with return period of 5, 10, 25, 50, and 100 years are simulated and the profiles of the maximum water level of the probable floods are shown in Figure 3.1-7. The discharge hydrographs of the probable flood at the Kanchanavanich Road (St.X174) , including flow on the adjacent floodplains, are as shown in Figure 3.1-8.

3.2 Inundation Map for Middle/Downstream of Khlong Wa

The inundation maps for the middle and downstream reach of the Khlong Wa showing the boundaries of the probable floods have been prepared, by using the topographic map and the maximum flood profiles, as shown in Figure 3.2-1

Table 1.2-1 List of Rainfall Stations in Khlong U-Taphao River Basin and Its Vicinity

No.	Code	Name	Location						Record Period	Authority
			Lat. N			Long. E				
			0	'	"	0	'	"		
1	55012	A. Muang C. Satun	06	37	16	100	04	09	1952-2000	MET
2	55022	A. Thung Wa C. Satun	07	06	27	99	45	34	1967-2000	MET
3	55132	A. Khuan Ka Long C. Satun	06	50	00	100	05	00	1992-2001	MET
4	55142	A. Khuan Don C. Satun	06	48	00	100	05	00	1923-2001	MET
5	58013	A. Muang C. Songkhla	07	12	21	100	35	58	1952-2000	MET
6	58022	A. Hat Yai	07	00	03	100	27	40	1952-2000	MET
7	58032	A. Rattaphum	07	08	00	100	15	30	1952-2000	MET
8	58052	A. Chana	07	54	50	100	44	35	1953-2000	MET
9	58062	A. Thepha	06	49	37	100	58	04	1952-2000	MET
10	58072	A. Na Thawi	06	44	23	100	41	44	1957-2000	MET
11	58082	A. Saba Yoi	06	36	55	100	57	21	1956-2000	MET
12	58092	A. Sathing Phra	07	28	18	100	26	30	1953-2000	MET
13	58102	A. Sadao	06	38	10	100	25	30	1952-2001	MET
14	58112	Kho Hong Agriculture Meteorological Station	07	00	50	100	30	00	1954-2000	MET
15	58122	Thepha Resettlement	06	46	00	100	58	00	1957-2000	MET
16	58132	Rattaphum Resettlement	07	04	00	100	16	00	1964-2000	MET
17	58170	Chamuang A. Rattaphum	07	07	13	100	13	51	1963-2000	RID
18	58180	Plak Pling A. Na Thawi	06	44	35	100	42	06	1965-2000	RID
19	58210	Khlong Wad Irrigation Project A. Hat Yai	07	00	34	100	26	14	1975-2000	RID
20	58221	Khlong La Pang (X.113) A. Sadao	06	37	59	100	23	46	1980-2000	RID
21	58232	A. Na Mom	06	58	00	100	33	00	1982-2000	MET
22	58271	Pak Ro (X.88) A. Rattaphum	07	15	00	100	26	42	1985-1986	RID
23	58301	Khlong Sadao (X.172) Ban Huai Khu A. Sadao	06	35	38	100	29	25	1988-2000	RID
24	58312	A. Khuan Niang	07	11	03	100	21	38	1988-2000	MET
25	58320	Khlong Cham Hai-Hoi Khong	06	49	47	100	21	36	1988-2000	RID
26	58332	Hat Yai International Airport	06	55	45	100	23	47	1988-2000	MET
27	58341	Khlong U-Taphao (X.173) B. Khlong Ngae	06	47	44	100	26	46	1989-2000	RID
28	58372	A. Singha Nakhon	07	17	00	100	31	00	1995-2000	MET
29	58390	Sadao Reservoir	06	35	08	100	29	56	1999-2000	RID
30	58400	Sangwanwit School	06	43	50	100	16	33	2000	RID
31	58410	Na Thongsuk School	06	55	44	100	32	35	2000	RID
32	58420	Khlong U-Taphao (X.90) B. Bang Sala	06	55	39	100	26	37	2000	RID
33	6E+05	A. Khlong Hoi Khong C. Songkhla	06	52	00	100	23	00	1995-2001	MET
34	6E+05	A. Bang Klam C. Songkhla	07	05	10	100	25	13	1997-2001	MET
35	6E+05	Sadao Hydro-meteorological Station	06	47	44	100	23	39	1998-2001	MET

Note : MET : The Meteorological Department

RID : Royal Irrigation Department

Table 1.2-2 List of Stream Flow Gauging Station in Khlong U - Taphao River Basin

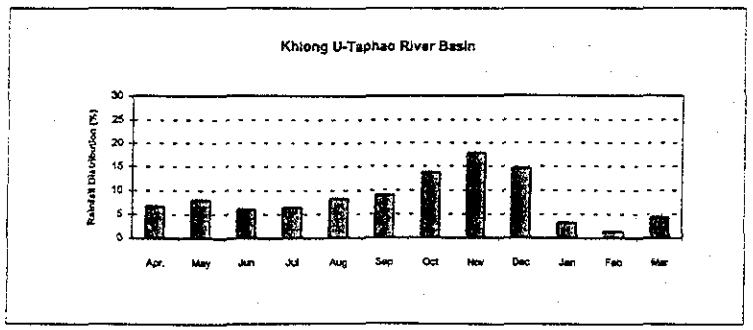
No.	Code	River	Stream	Location					Drainage	Water Level		Discharge
				At or Near	Amphoe	Changwat	Lat. N	Long. E	Area (sg.Km)	Type of Gage	Period	Data
1	X.14	Khlong U Tapao	Khlong Wat	Khao Don Nga Chang	Hat Yai	Songkhla	06 56 36	100 13 50	15	A	1953-1971	1953-1971
2	X.44	Khlong U Tapao	-	Hat Yai	Hat Yai	Songkhla	07 00 02	100 27 32	1,740	V	1967-Cont'd	1967-1988, 1999-Cont'd
3	X.71	Khlong U Tapao	Khlong Tam	Highway Bridge (B.Khuan Lang 3)	Hat Yai	Songkhla	06 59 55	100 25 58	127	V	1967-Cont'd	1967-1981, 1983-Cont'd
4	X.90	Khlong U Tapao	-	B. Bang Sala	Hat Yai	Songkhla	06 55 39	100 26 37	1,562	V, A	1971-1998, 1999-Cont'd	1971-Cont'd
5	X.111	Khlong Lam	Khlong Sadao	B. Phrai	Sadao	Songkhla	06 39 37	100 26 09	256	V	1979-Cont'd	1979-Cont'd
6	X.112	Khlong U Tapao	Khlong Lam	B. Prik I	Sadao	Songkhla	06 42 11	100 26 10	493	V	1979-Cont'd	1979-1996
7	X.113	Khlong U Tapao	Khlong Lam	B. Thung Prap I	Sadao	Songkhla	06 37 59	100 23 46	129	V	1979-Cont'd	1979-Cont'd
8	X.172	Khlong Sadao	Khlong sadao	B. Huai Khu	Sadao	Songkhla	06 35 38	100 29 25	94	A	1988-Cont'd	1988-1991
9	X.173	Khlong U Tapao	-	B. Khlong Ngae	Hat Yai	Songkhla	06 47 44	100 26 46	982	V	1989-Cont'd	1990-Cont'd
10	X.174	Khlong U Tapao	Khlong Wa	B. Khlong Wa	Hat Yai	Songkhla	06 59 42	100 29 05	103	V	1989-Cont'd	-
11	X.181	Khlong U Tapao	-	B. Khot Yang	Hat Yai	Songkhla	07 03 27	100 27 16	2,078	V	1993-Cont'd	-
12	X.194	-	Tala Sap Songkhla Pak Khlong U Tapao	B. Laem Pho	Hat Yai	Songkhla	07 09 17	100 28 15	-	A	1999-Cont'd	-

Note : V = Vertical Staff Gage

A = Automatic Recorder

Table 1.3-1 Average Basin Rainfall : Khlong U-Taphao River Basin and Khlong Wa Sub-basin

No.	Code	Station Name	No.of data	Thiessen Polygon Factor		Rainfall (mm.)												
			(Year)	U - Taphao	Khlong Wa	Apr.	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
1	55132	A. Khuan Ka Long C.Satun	10	0.024	-	162.7	160.3	185.6	200.7	325.7	317.5	336.8	196.1	109.6	34.4	38.5	112.5	2,180.4
2	58022	A. Hat Yai	41	0.040	0.043	93.0	134.6	100.8	101.3	122.8	138.2	244.8	390.2	303.9	85.4	18.2	37.2	1,770.5
3	58032	A. Rattaphum	40	0.020	-	95.3	126.3	69.6	93.5	98.3	106.0	225.7	385.9	307.2	82.2	27.7	45.4	1,663.0
4	58102	A. Sadao	32	0.257	-	119.7	170.1	96.0	98.6	105.5	150.5	241.5	222.0	125.0	42.9	15.1	58.3	1,445.2
5	58112	Kho Hong Agriculture Meteoroligical Station	41	0.053	0.045	80.4	157.2	101.6	120.7	125.8	140.6	250.7	401.0	320.2	101.2	23.3	43.9	1,866.6
6	58232	A. Na Mom	15	0.091	0.912	91.7	138.5	101.6	118.5	155.5	143.3	206.5	389.2	339.6	69.2	25.9	50.7	1,830.2
7	58320	Khlong Cham Hai-Hoi Khong	11	0.166	-	131.8	95.1	112.0	124.8	158.3	161.7	260.8	310.9	209.9	52.0	21.5	108.2	1,746.9
8	58332	Hat Yai International Airport1/	19	0.127	-	118.5	163.4	117.8	116.0	124.4	177.0	197.1	296.8	276.7	57.3	21.2	67.3	1,733.7
9	58341	Khlong U Tapao (X.173) B. Khlong Ngae	11	0.139	-	132.6	145.0	127.9	116.5	188.1	143.0	225.2	285.7	243.3	49.0	29.2	121.5	1,807.0
10	568017	A. Bang Klam C. Songkhla	1	0.083	-	79.1	53.2	37.2	72.4	126.7	126.9	197.2	393.1	503.3	55.9	43.9	41.4	1,730.2
		Khlong U - Taphao		1.000		114.8	137.5	103.6	110.9	141.4	154.2	232.5	303.4	246.5	55.9	23.6	73.9	1,698.2
		Distribution (%)				6.8	8.1	6.1	6.5	8.3	9.1	13.7	17.9	14.5	3.3	1.4	4.3	100.0
		Khlong Wa			1.000	91.3	139.2	101.6	117.8	152.8	142.9	210.1	389.8	337.2	71.3	25.5	49.8	1,829.2
		Distribution (%)				5.0	7.6	5.6	6.4	8.4	7.8	11.5	21.3	18.4	3.9	1.4	2.7	100.0



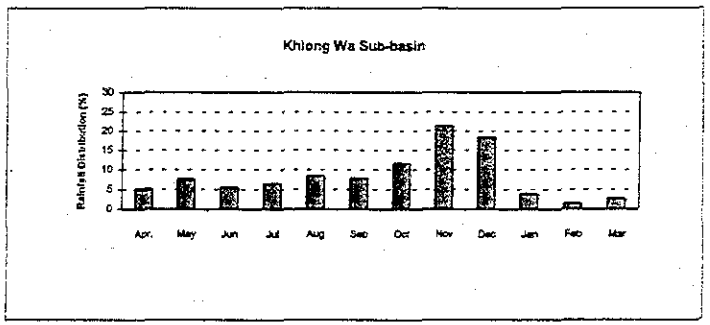


Table 1.3-2 Frequency Analysis of Maximum Rainfall in Khlong U-Taphao River Basin and Khlong Wa Sub-basin

5-year Return Period

No.	Code	Station Name	Thiessen Polygon Factor		Maximum Rainfall (mm.)			
			U - Taphao	Khlong Wa	1-day	3-day	5-day	7-day
1	58022	A. Hat Yai	0.090	0.047	169.1	265.5	316.0	363.9
2	58032	A. Rattaphum	0.033	-	157.9	263.5	314.8	354.5
3	58102	A. Sadao	0.384	-	123.1	170.6	208.7	267.0
4	58112	Kho Hong Agriculture Meteorological Station	0.156	0.953	174.7	300.9	356.5	404.0
5	58332	Hat Yai International Airport1/	0.337	-	136.2	247.3	296.6	332.1
		U - Taphao	1.000		140.8	228.4	274.5	321.9
		Khlong Wa		1.000	174.5	299.2	354.6	402.1

10-year Return Period

No.	Code	Station Name	Thiessen Polygon Factor		Maximum Rainfall (mm.)			
			U - Taphao	Khlong Wa	1-day	3-day	5-day	7-day
1	58022	A. Hat Yai	0.090	0.047	199.9	316.6	373.0	431.3
2	58032	A. Rattaphum	0.033	-	197.7	324.4	382.6	425.6
3	58102	A. Sadao	0.384	-	143.3	200.7	245.9	321.7
4	58112	Kho Hong Agriculture Meteorological Station	0.156	0.953	209.9	364.8	430.4	486.7
5	58332	Hat Yai International Airport1/	0.337	-	159.1	303.4	362.2	404.7
		U - Taphao	1.000		165.9	275.4	329.8	388.7
		Khlong Wa		1.000	209.4	362.6	427.7	484.1

20-year Return Period

No.	Code	Station Name	Thiessen Polygon Factor		Maximum Rainfall (mm.)			
			U - Taphao	Khlong Wa	1-day	3-day	5-day	7-day
1	58022	A. Hat Yai	0.090	0.047	229.5	365.7	427.7	496.0
2	58032	A. Rattaphum	0.033	-	235.9	382.9	447.7	493.7
3	58102	A. Sadao	0.384	-	162.6	229.5	281.6	374.2
4	58112	Kho Hong Agriculture Meteorological Station	0.156	0.953	243.7	426.2	501.2	566.0
5	58332	Hat Yai International Airport1/	0.337	-	181.1	357.2	425.1	474.4
		U - Taphao	1.000		189.9	320.5	382.9	452.8
		Khlong Wa		1.000	243.0	423.3	497.8	562.7

100-year Return Period

No.	Code	Station Name	Thiessen Polygon Factor		Maximum Rainfall (mm.)			
			U - Taphao	Khlong Wa	1-day	3-day	5-day	7-day
1	58022	A. Hat Yai	0.090	0.047	296.6	476.8	551.5	642.5
2	58032	A. Rattaphum	0.033	-	322.4	515.3	594.9	648.1
3	58102	A. Sadao	0.384	-	206.5	294.7	362.4	493.0
4	58112	Kho Hong Agriculture Meteorological Station	0.156	0.953	320.1	565.0	661.7	745.6
5	58332	Hat Yai International Airport1/	0.337	-	230.9	479.1	567.7	632.1
		U - Taphao	1.000		244.4	422.7	503.0	597.9
		Khlong Wa		1.000	319.0	560.9	656.5	740.8

500-year Return Period

No.	Code	Station Name	Thiessen Polygon Factor		Maximum Rainfall (mm.)			
			U - Taphao	Khlong Wa	1-day	3-day	5-day	7-day
1	58022	A. Hat Yai	0.090	0.047	363.0	586.8	674.1	787.4
2	58032	A. Rattaphum	0.033	-	408.0	646.3	740.7	800.8
3	58102	A. Sadao	0.384	-	249.9	359.3	442.4	610.7
4	58112	Kho Hong Agriculture Meteorological Station	0.156	0.953	395.8	702.5	820.6	923.5
5	58332	Hat Yai International Airport1/	0.337	-	280.1	599.8	708.8	788.2
		U - Taphao	1.000		298.2	523.8	621.8	741.5
		Khlong Wa		1.000	394.3	697.1	813.7	917.1

***1,000*-year Return Period**

No.	Code	Station Name	Thiessen Polygon Factor		Maximum Rainfall (mm.)			
			U - Taphao	Khlong Wa	1-day	3-day	5-day	7-day
1	58022	A. Hat Yai	0.090	0.047	391.6	634.1	726.7	849.8
2	58032	A. Rattaphum	0.033	-	444.8	702.6	803.4	866.5
3	58102	A. Sadao	0.384	-	268.5	387.1	476.8	661.2
4	58112	Kho Hong Agriculture Meteorological Station	0.156	0.953	428.3	761.6	888.9	999.9
5	58332	Hat Ysi International Airport1/	0.337	-	301.3	651.7	769.4	855.3
		U - Taphao	1.000		321.4	567.3	673.0	803.2
		Khlong Wa		1.000	426.6	755.6	881.2	992.9

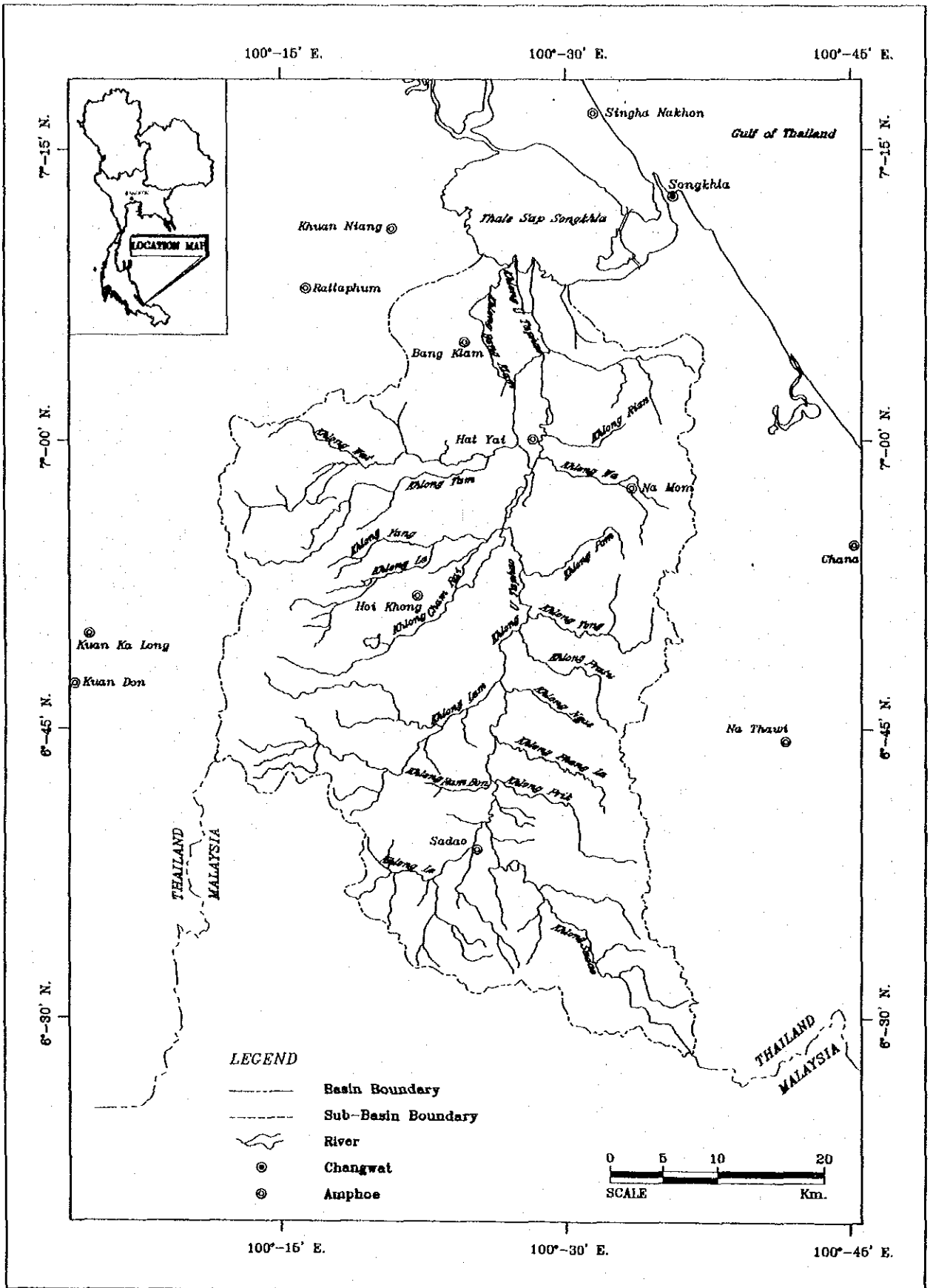


Fig. 1.1-1 Khlong U-Taphao River Basin

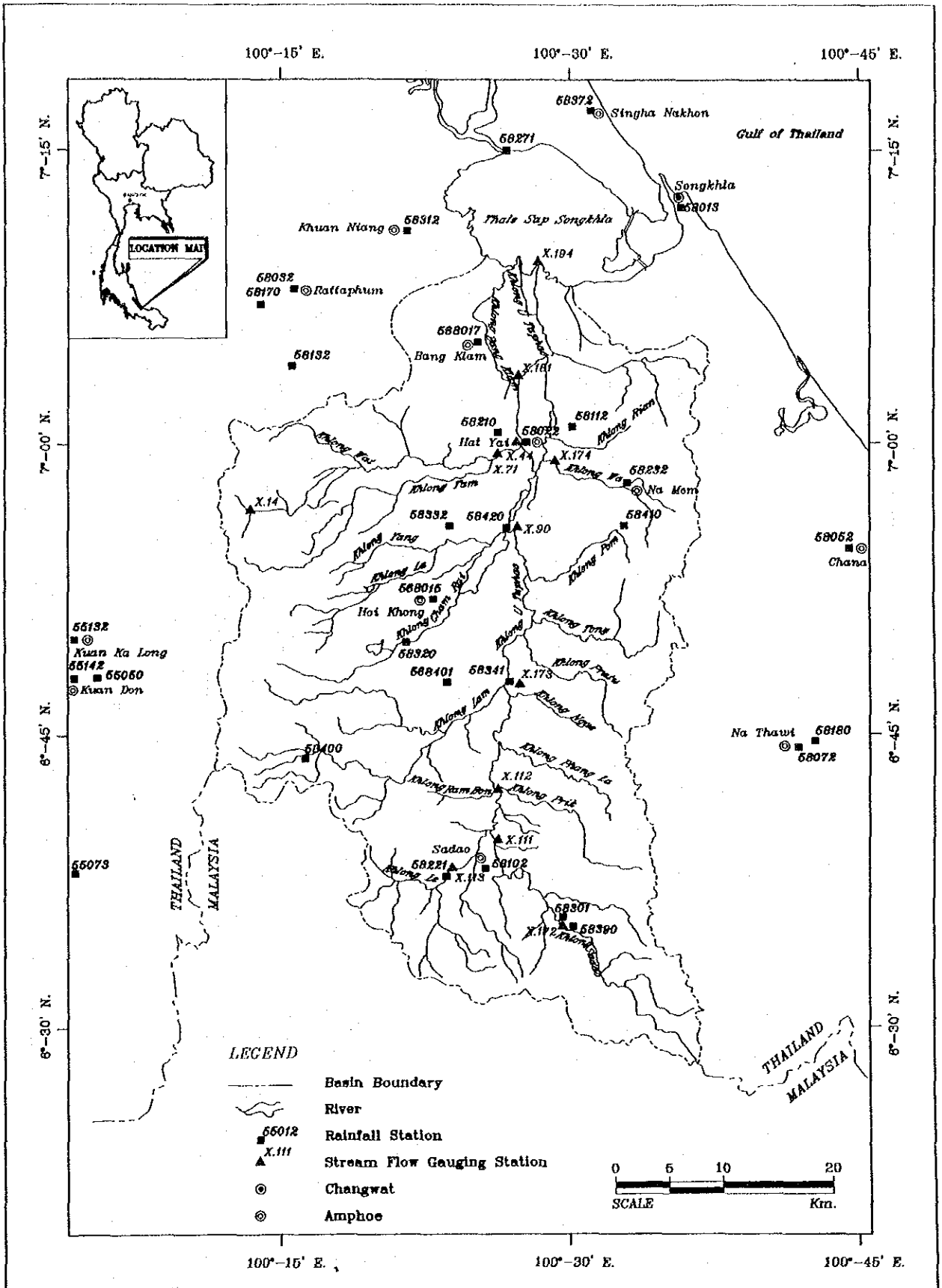
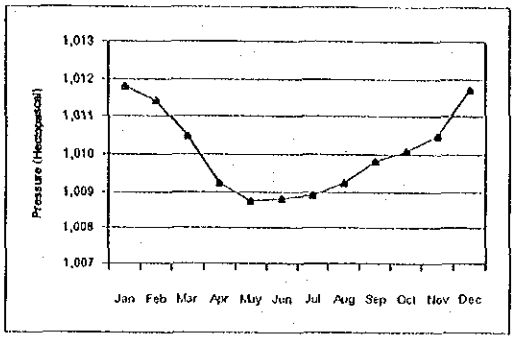
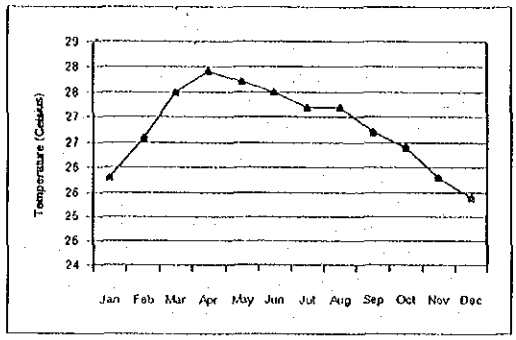


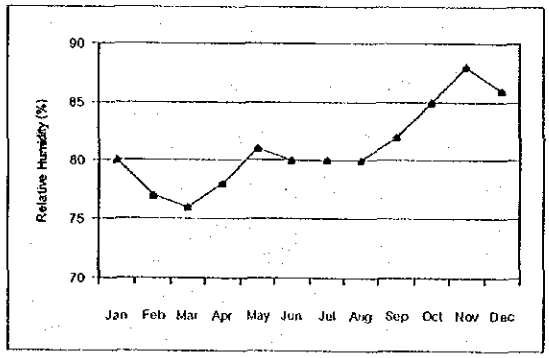
Fig. 1.2-1 Location of Rainfall and Stream Flow Gauging Stations



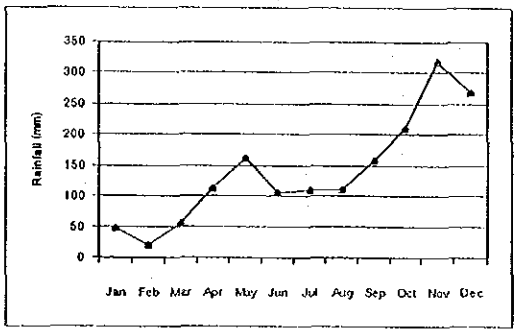
Pressure



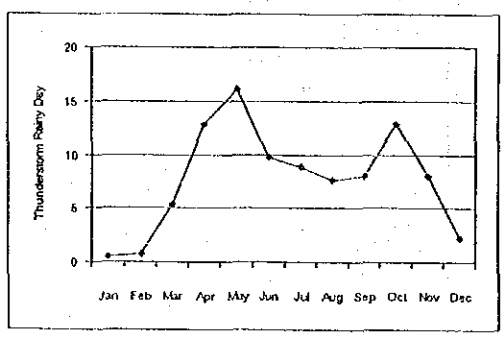
Temperature



Relative Humidity

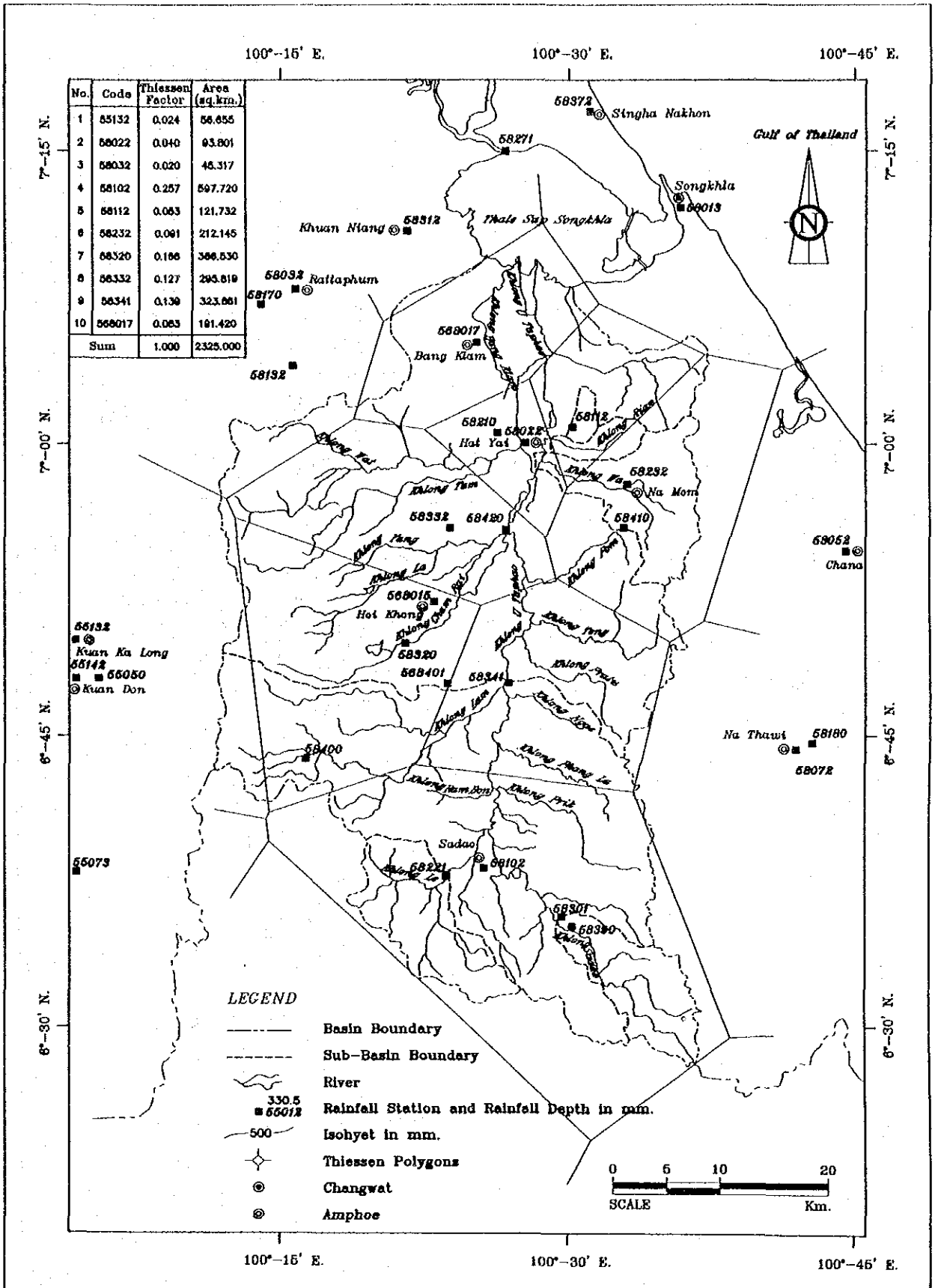


Rainfall



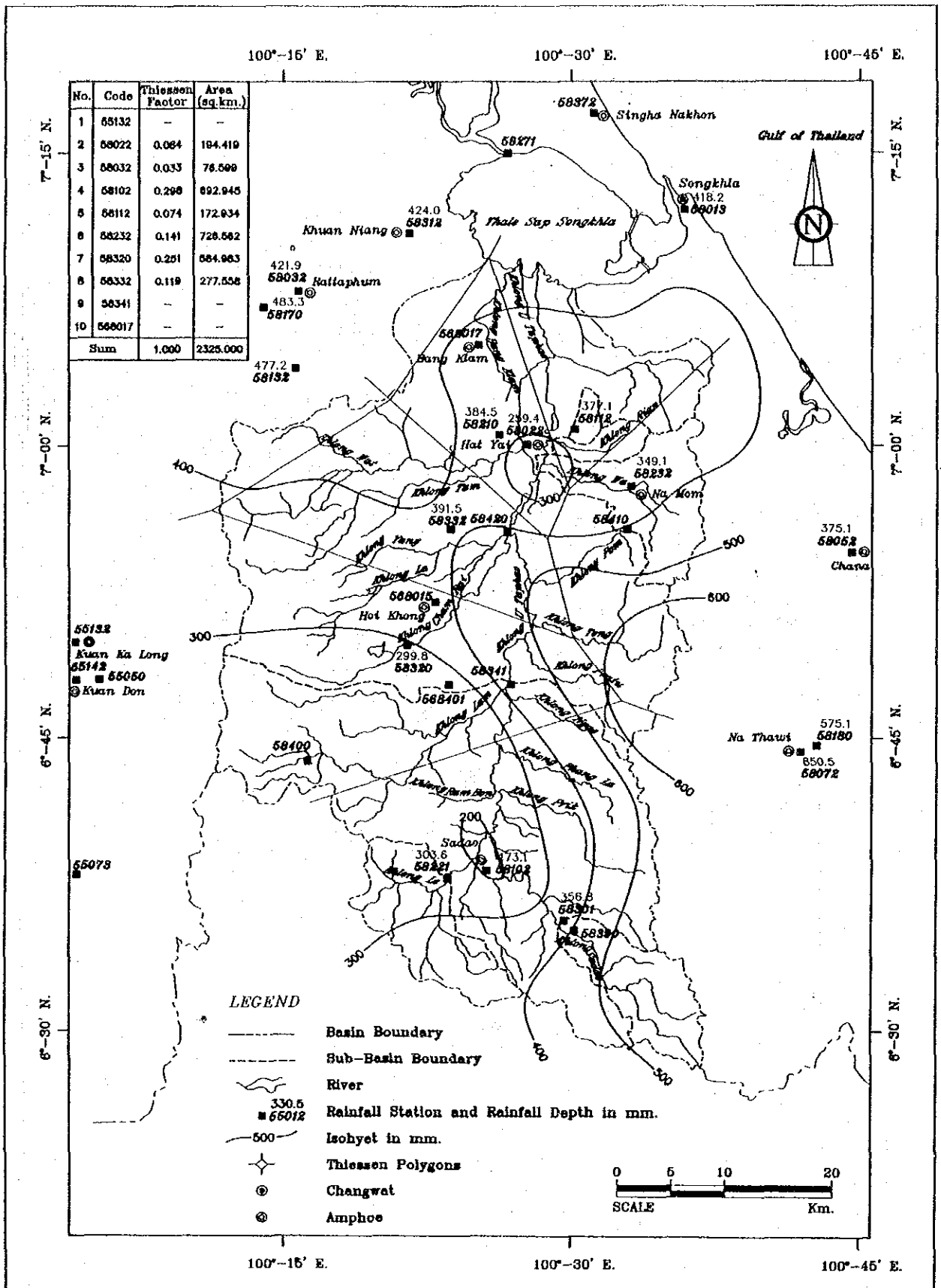
Rainy Day

Fig. 1.3-1	**Monthly Distribution of Climatic Variables at Hat Yai International Airport**



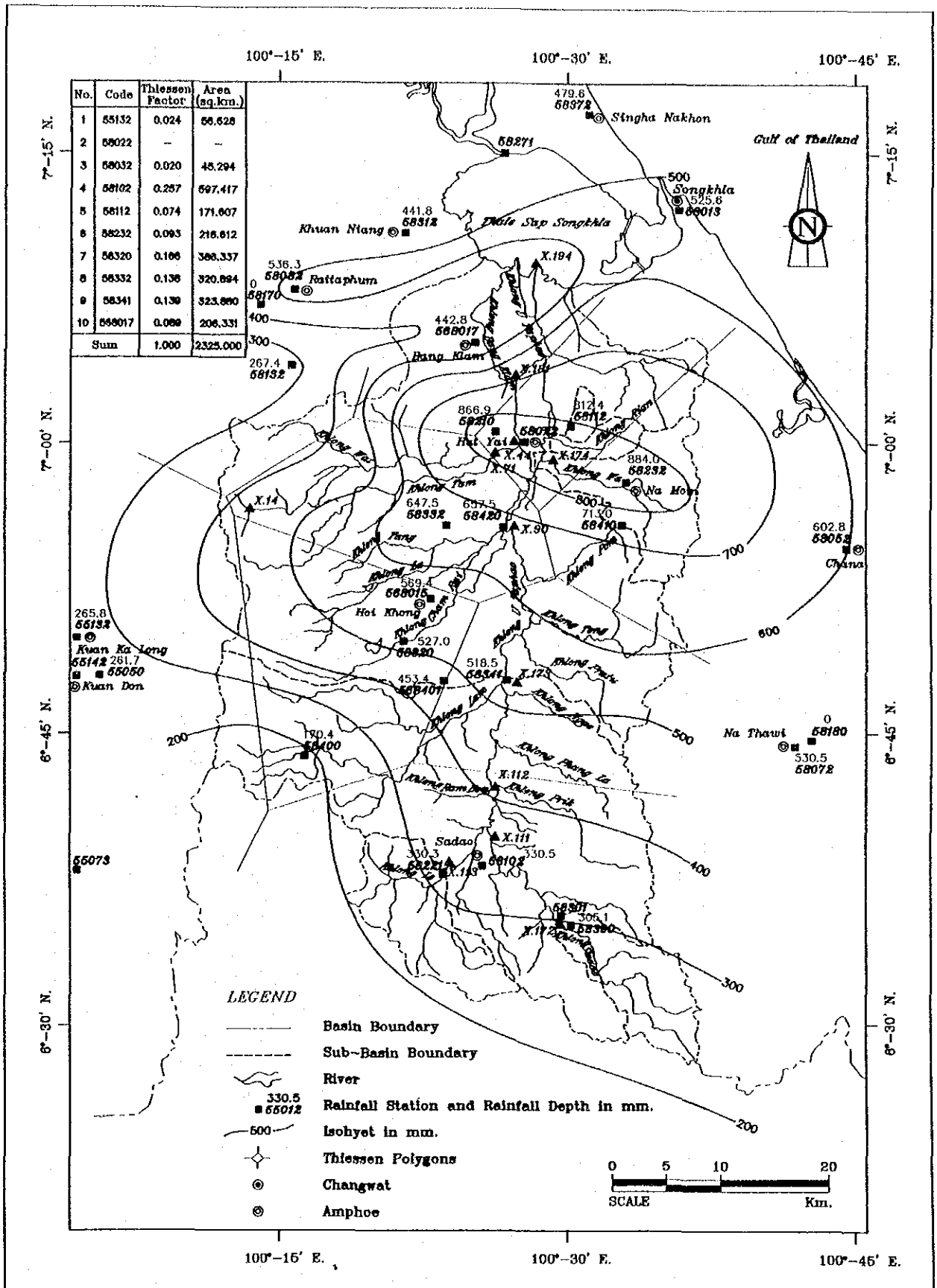
No.	Code	Thiessen Factor	Area (sq.km.)
1	55132	0.024	56.655
2	58022	0.040	93.801
3	58032	0.020	46.317
4	58102	0.257	597.720
5	58112	0.053	121.732
6	58232	0.091	212.145
7	58320	0.166	386.530
8	58332	0.127	295.819
9	58341	0.139	323.861
10	568017	0.083	191.420
Sum		1.000	2325.000

Fig. 1.3-2 Thiessen Polygon of Khlong U-Taphao River Basin



No.	Code	Thiessen Factor	Area (sq.km.)
1	55132	–	–
2	58022	0.084	194.419
3	58032	0.033	76.599
4	58102	0.298	692.945
5	58112	0.074	172.934
6	58232	0.141	328.582
7	58320	0.251	584.963
8	58332	0.119	277.558
9	58341	–	–
10	568017	–	–
Sum		1.000	2325.000

Fig. 1.3-3 Spatial Rainfall Distribution during 18-24 Nov.1988



No.	Code	Thiessen Factor	Area (sq.km.)
1	55132	0.024	56.628
2	55022	--	--
3	56032	0.020	45.294
4	56102	0.257	597.417
5	56112	0.074	171.607
6	56232	0.093	216.612
7	56320	0.166	386.337
8	56332	0.138	320.894
9	56341	0.139	323.860
10	568017	0.089	206.331
Sum		1.000	2325.000

Fig. 1.3-4 Spatial Rainfall Distribution during 18-24 Nov.2000

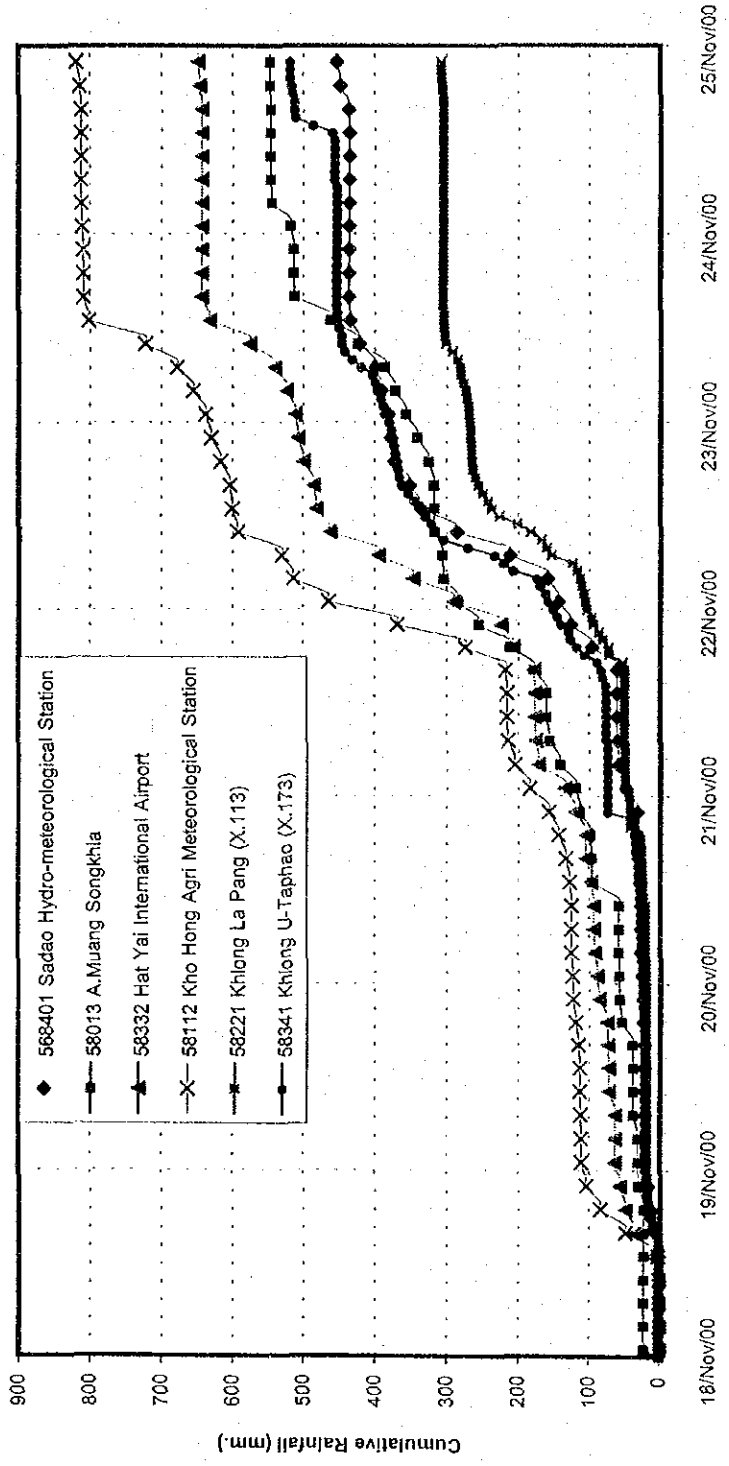


Fig. 1.3-5 **Temporal Rainfall Distribution during 18-24 Nov. 2000**

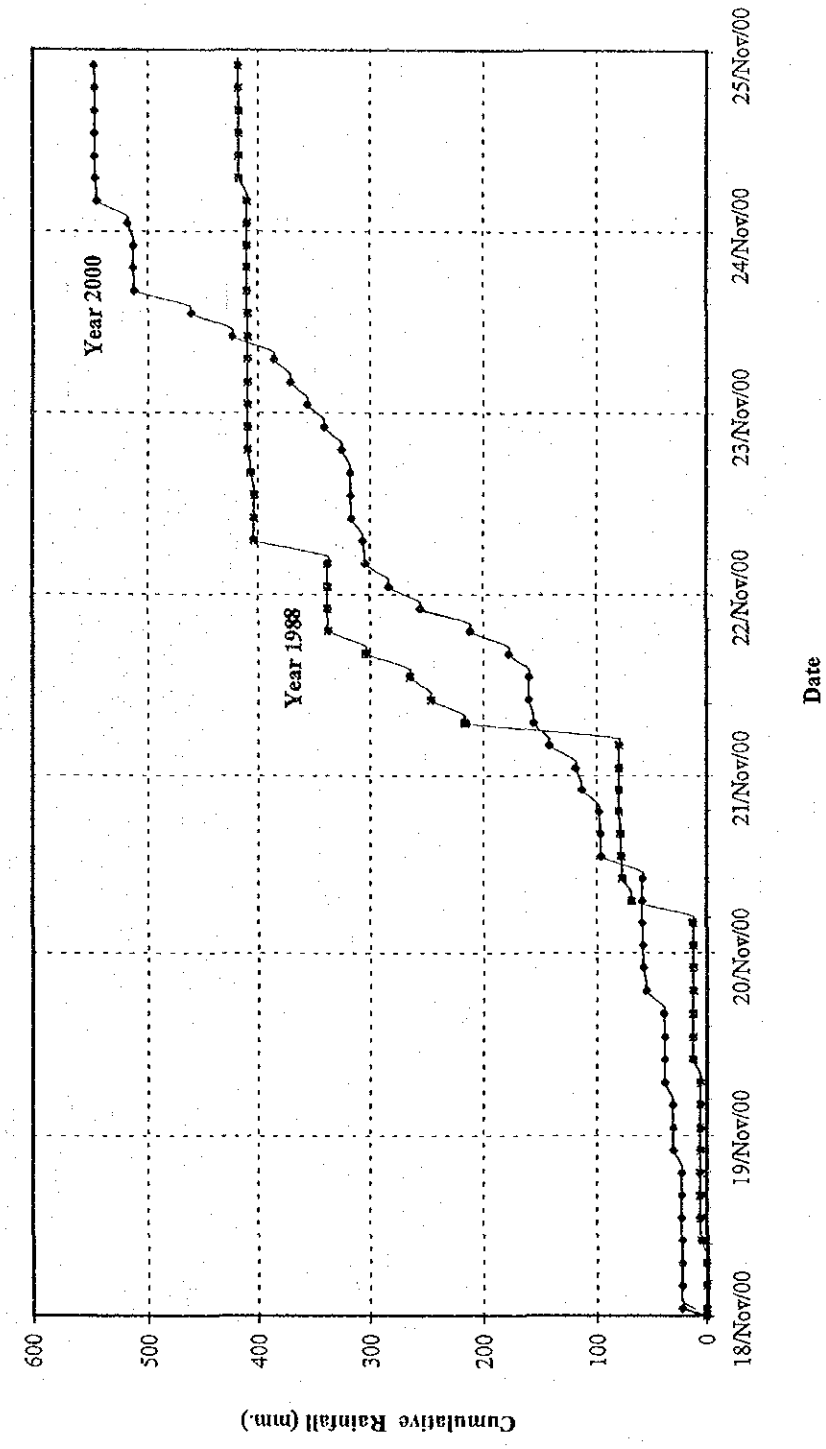


Fig.1.3-6	**Temporal Rainfall Distribution at A.Muang C.Songkhla (58013) during 18-24 Nov. 1988**

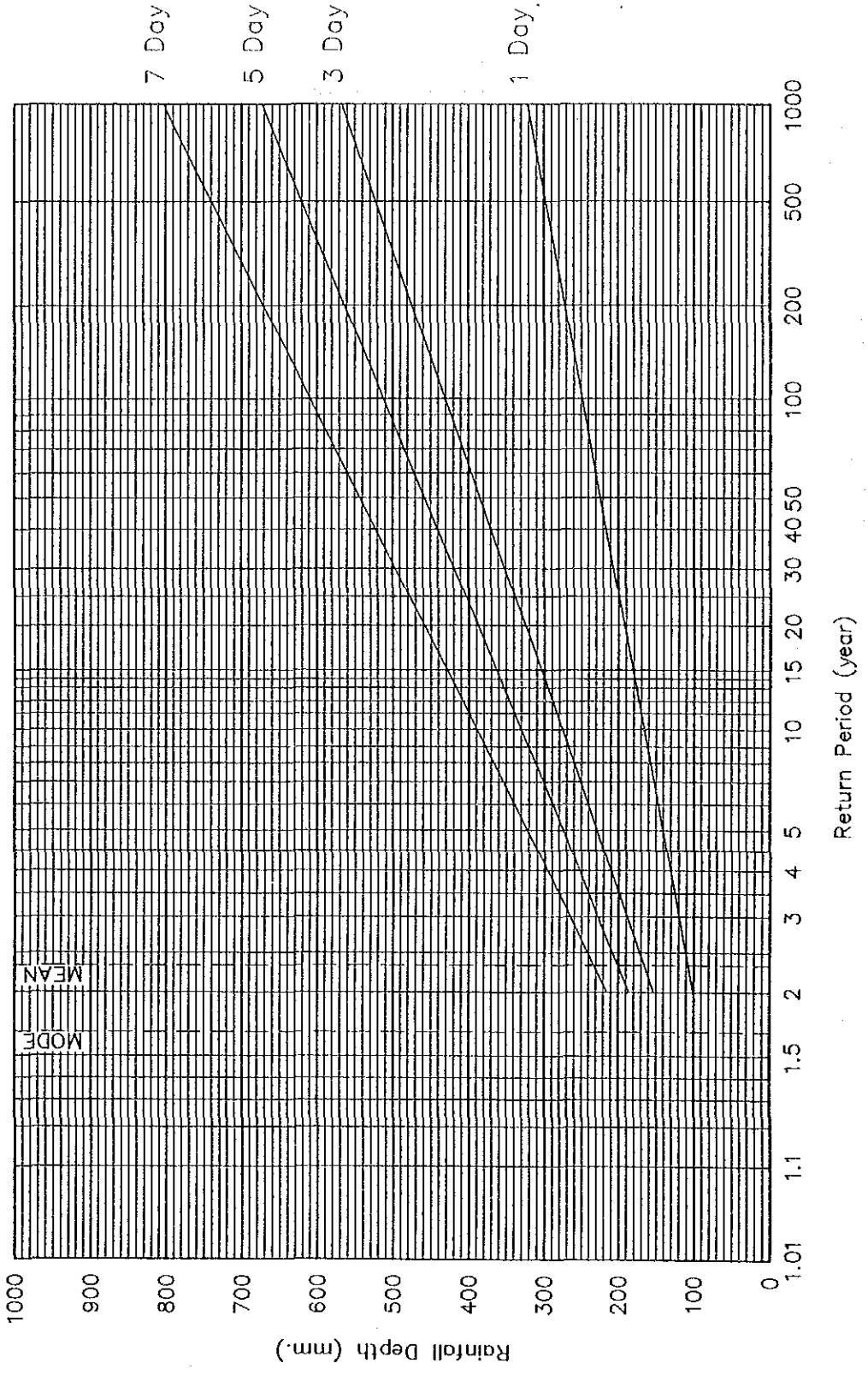


Fig. 1.3-7	Frequency Analysis of Maximum Rainfall in Khlong U-Taphao River Basin

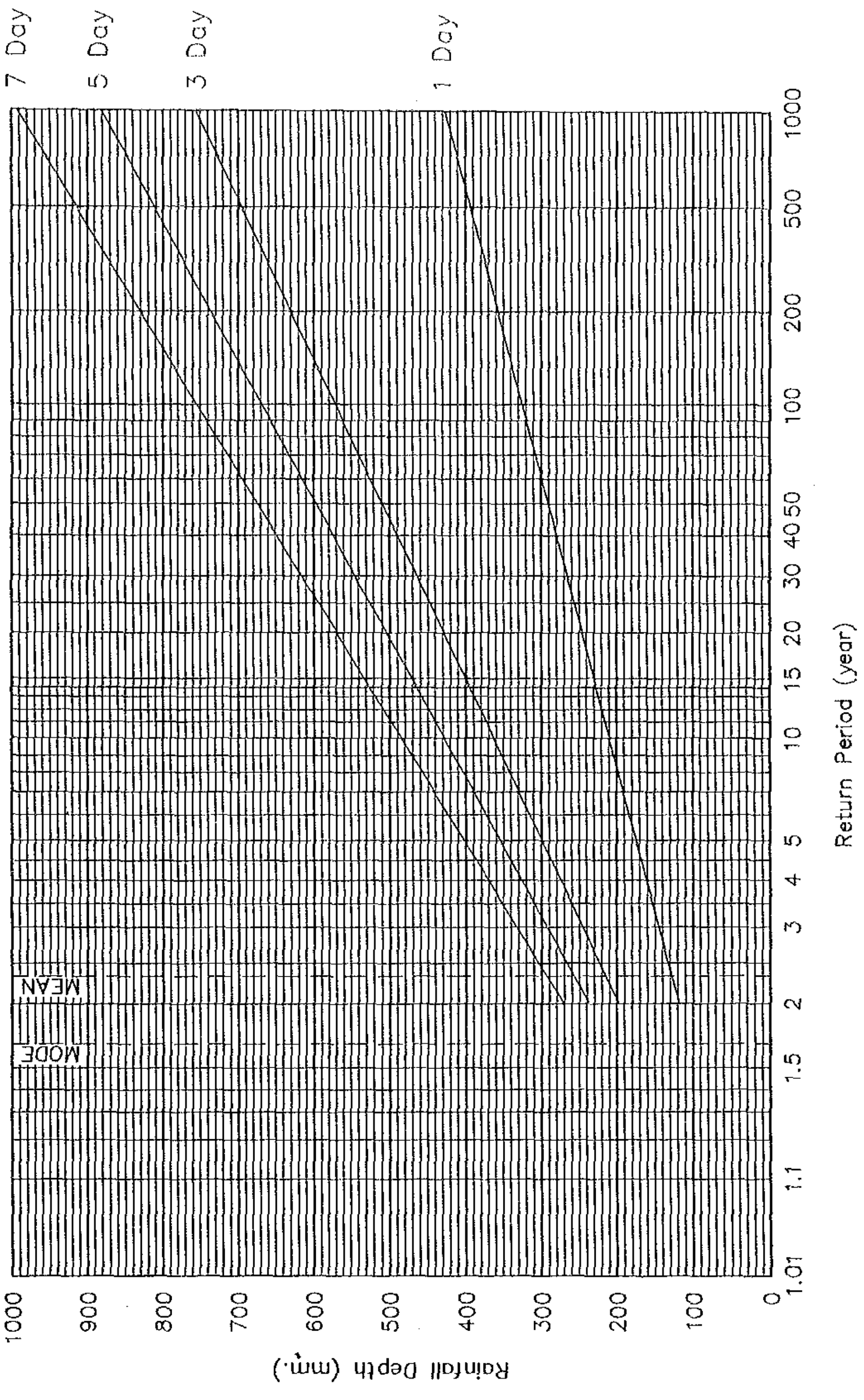
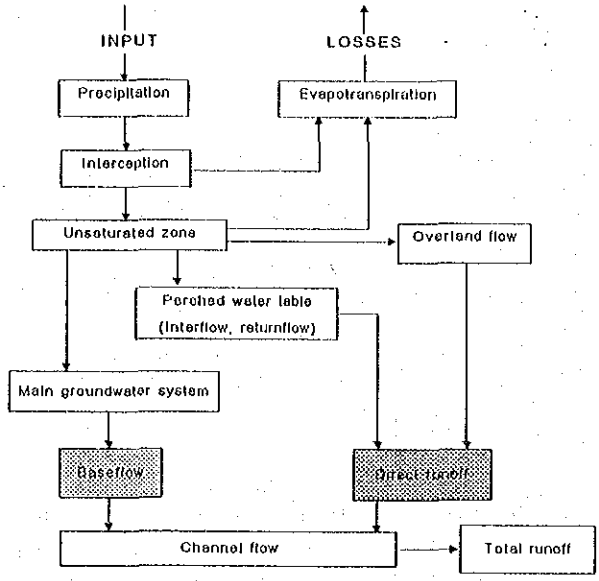
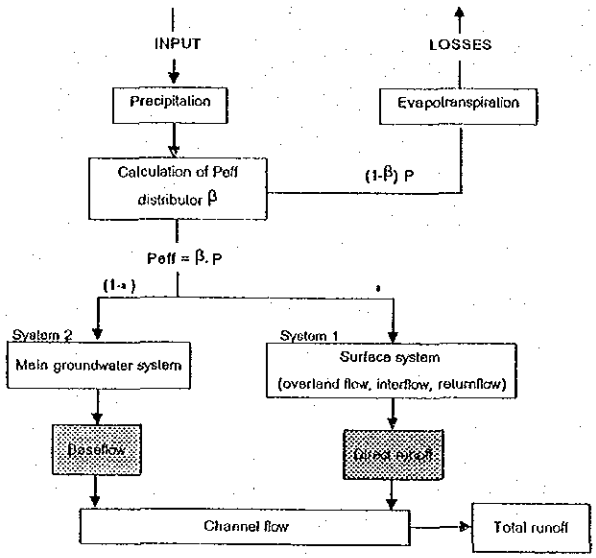


Fig. 1.3-8	Frequency Analysis of Maximum Rainfall in Khlong Wa Sub-Basin



a) Schematic Representation of Hydrologic Cycle



(b) Schematic Representation of Model RUNOFF-CASH

Fig 2.2-1	Schematic Representation of Hydrologic Cycle and Model RUNOFF-CASH

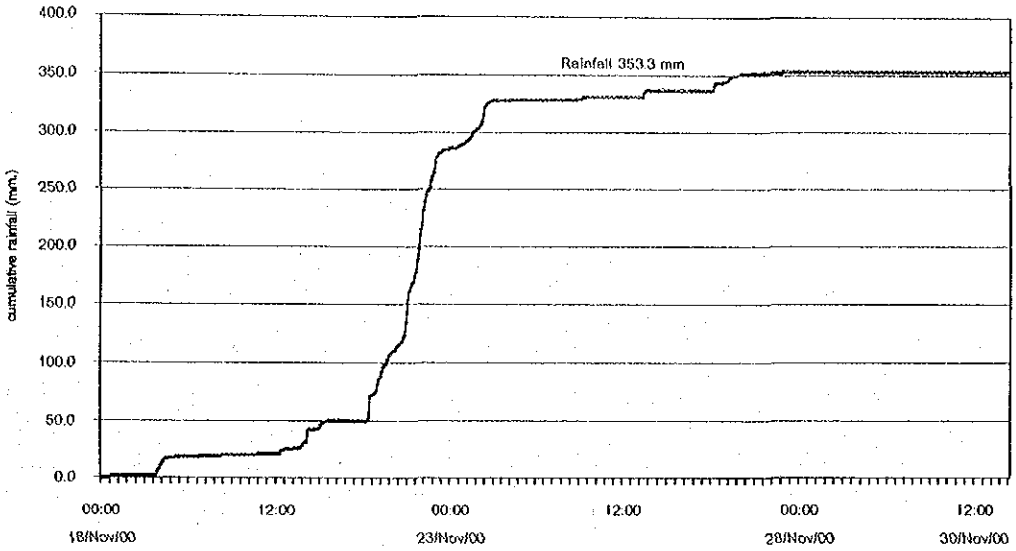


Fig. 2.2-2	Rainfall Distribution at X.113

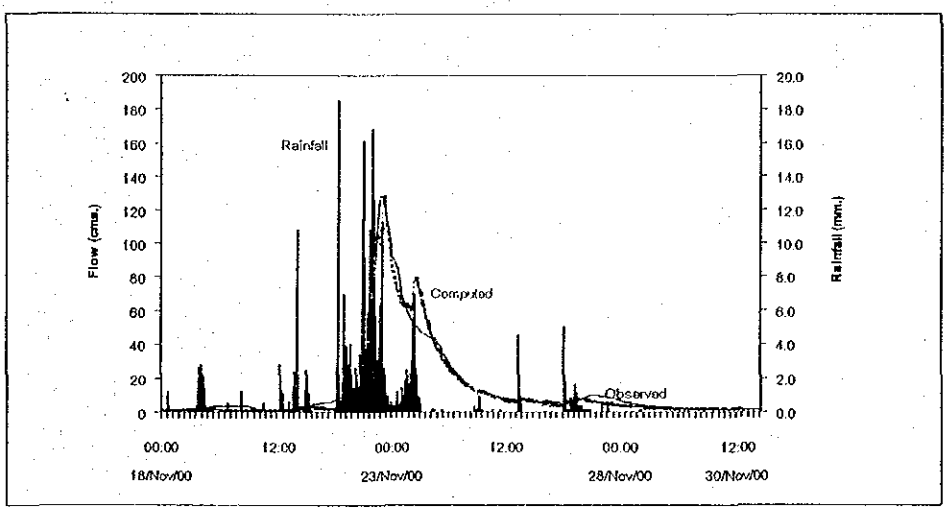


Fig. 2.2-3	Result of Hydrologic Model Calibration

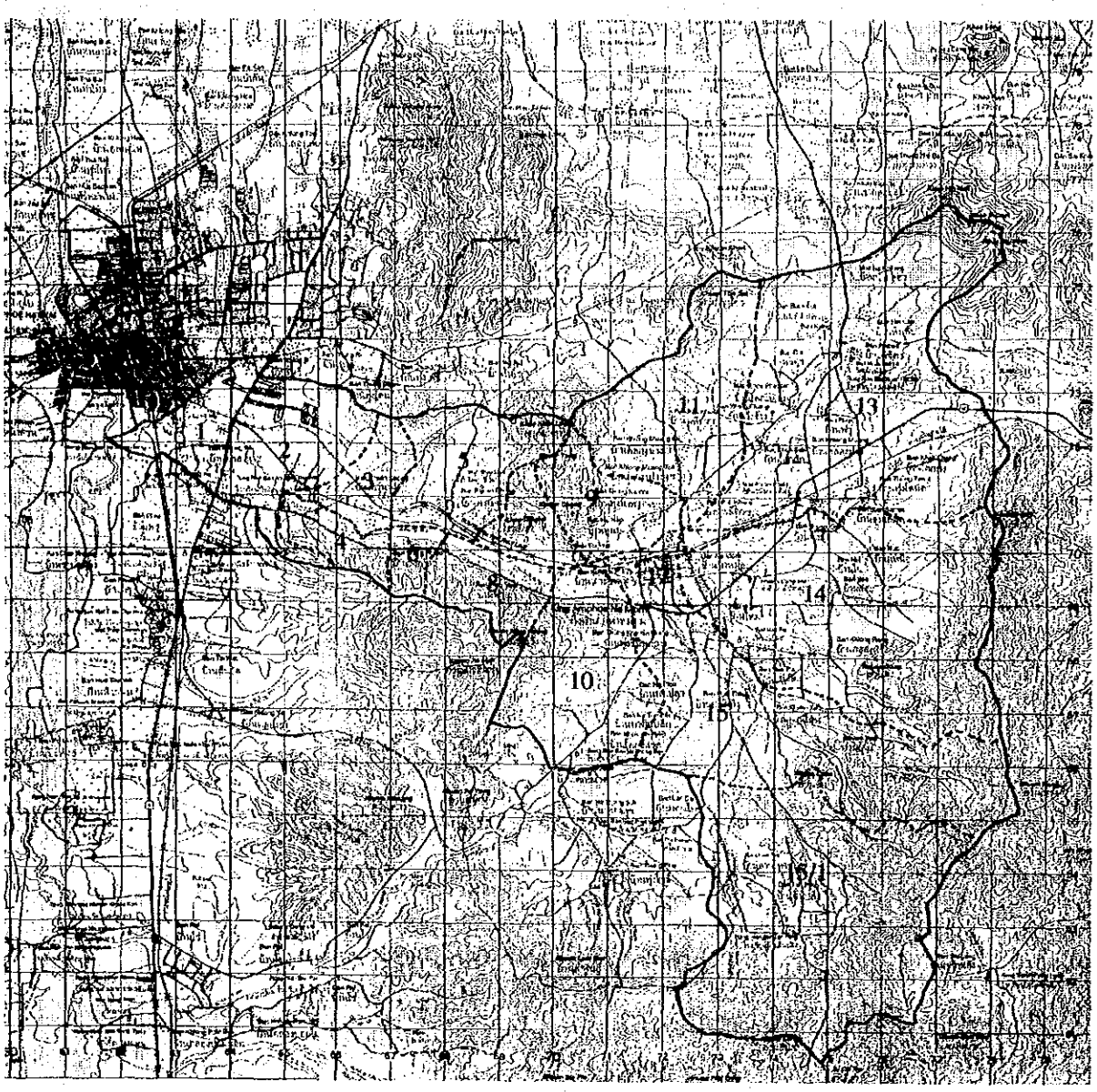


Fig. 2.3-1 Khlong Wa Sub-basins applied to the Hydrologic Model

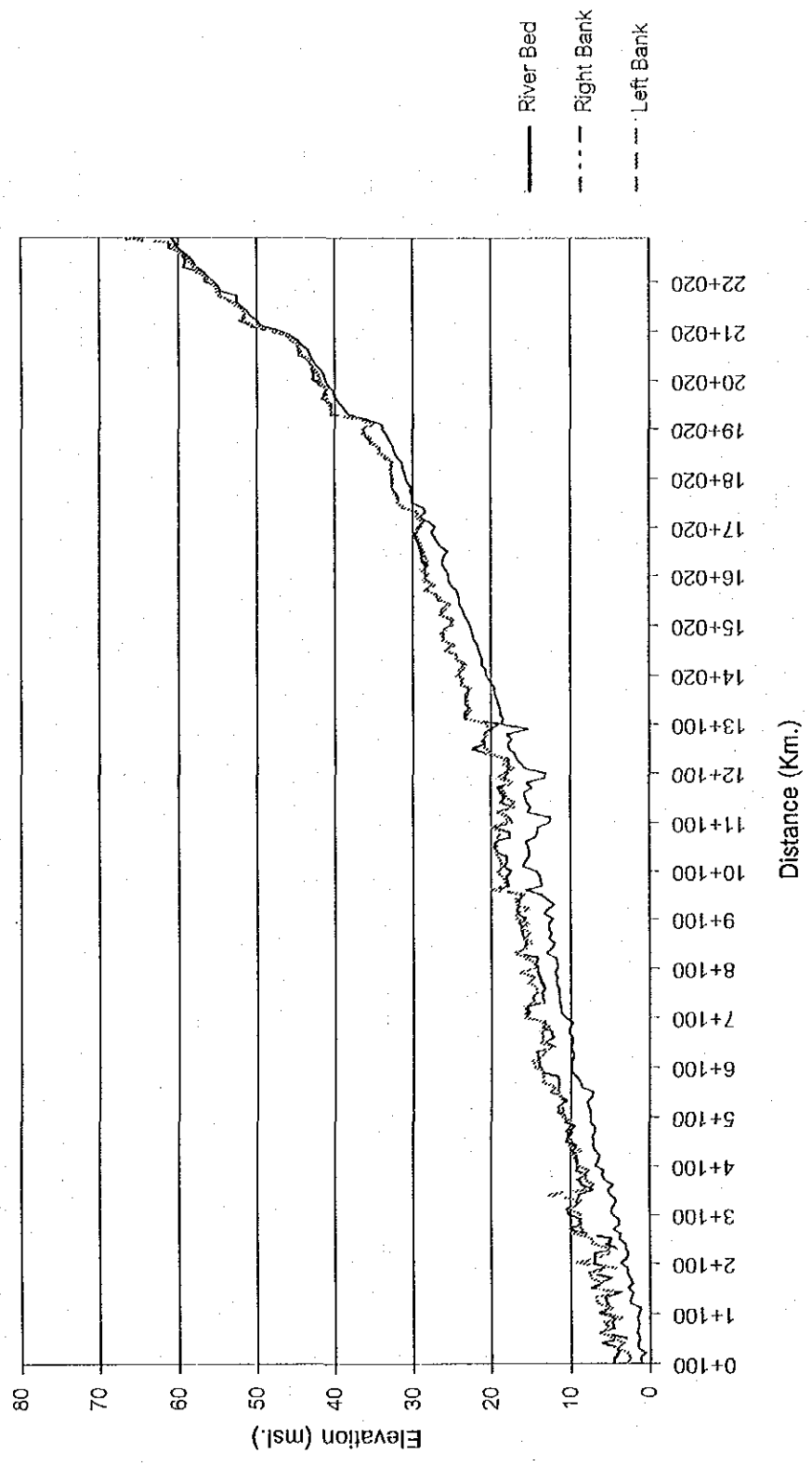


Fig. 3.1-1	Profile of Khlong Wa River

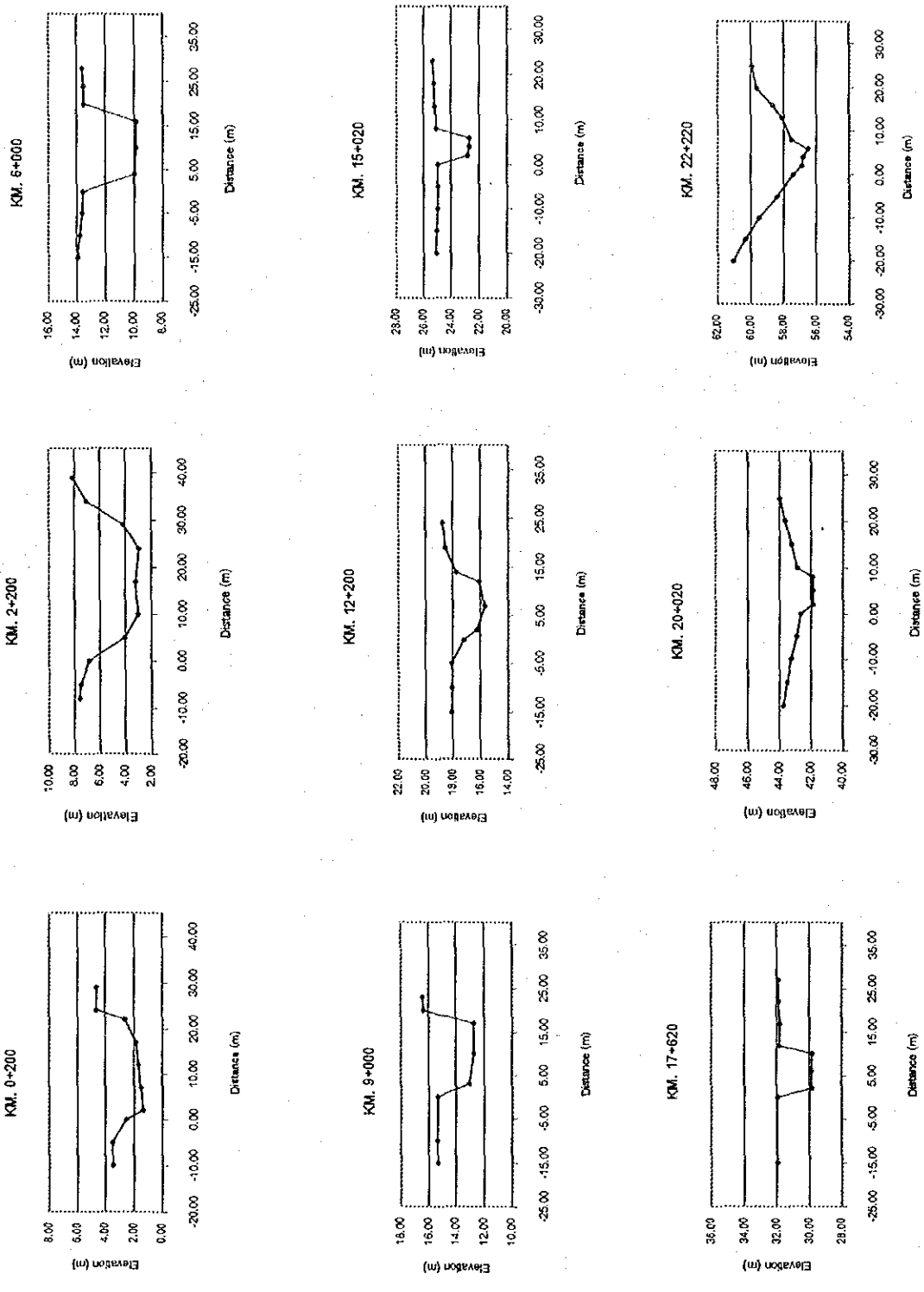


Fig. 3.2-1 **Typical Existing Cross - Section of Khlong Wa**

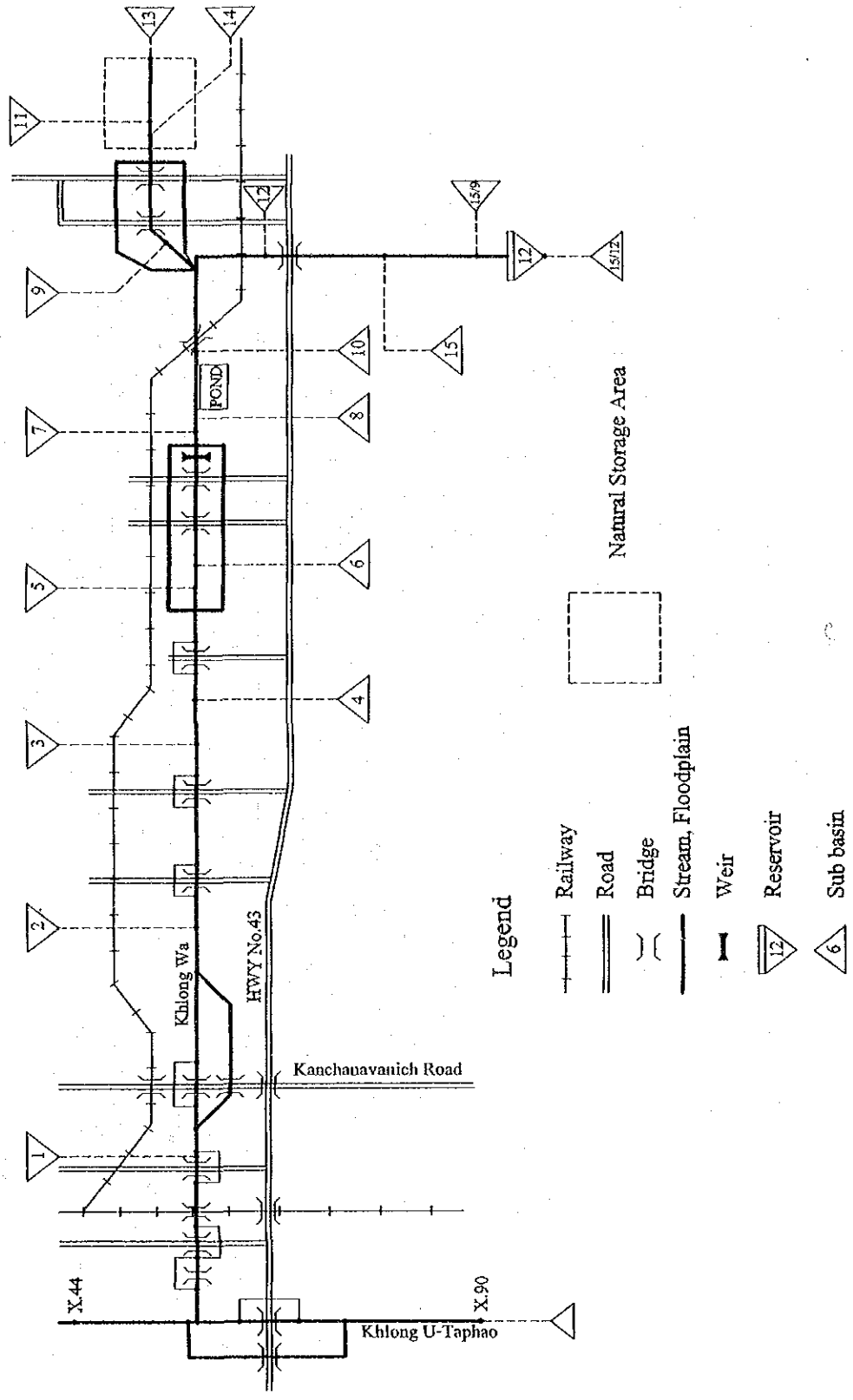


Fig. 3.1-3

Schematic Diagram of The Mathematical Model for The Existing Condition of The Flood Plain

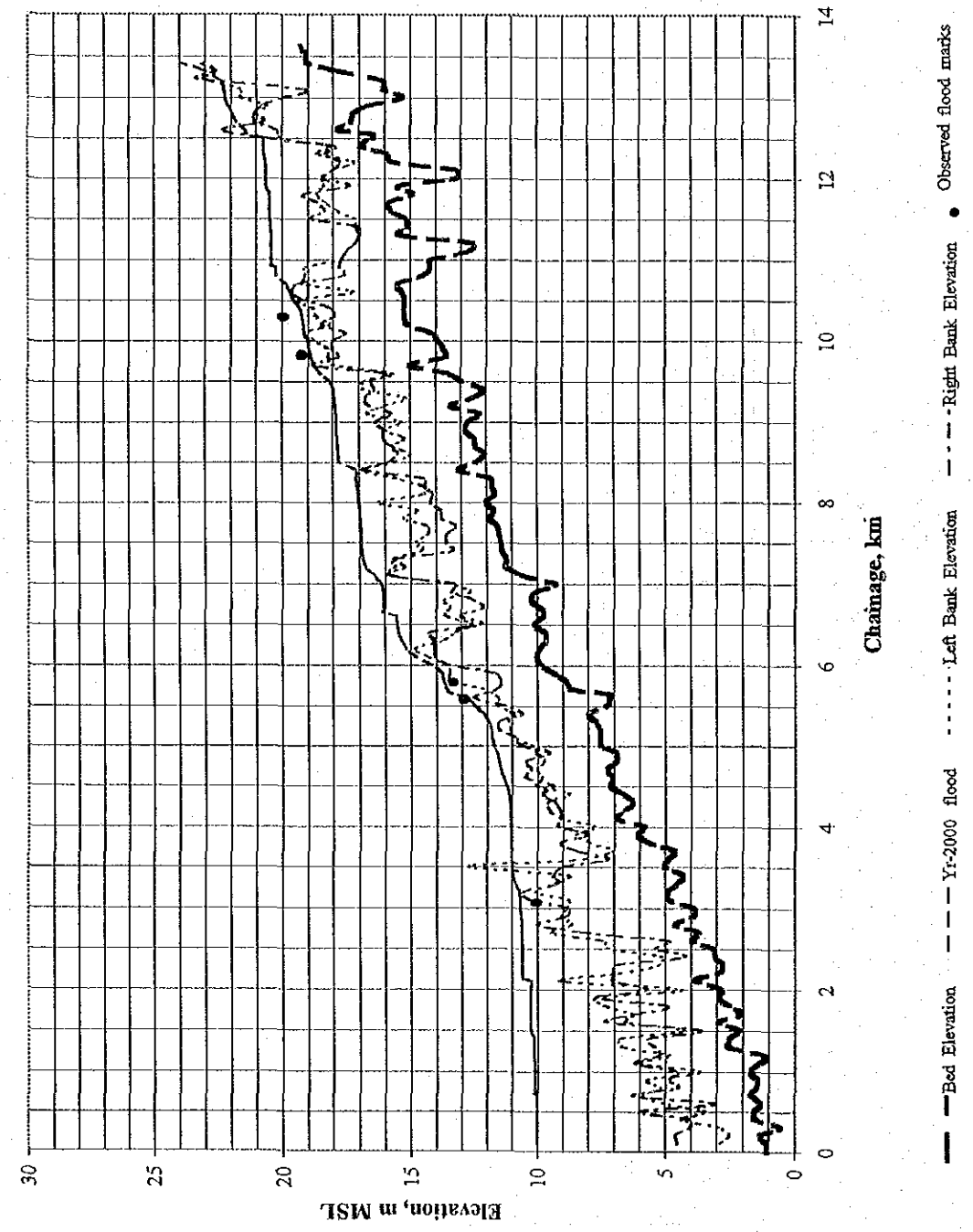


Fig. 3.1-4	Profile of the computed maximum water level and the observed flood marks

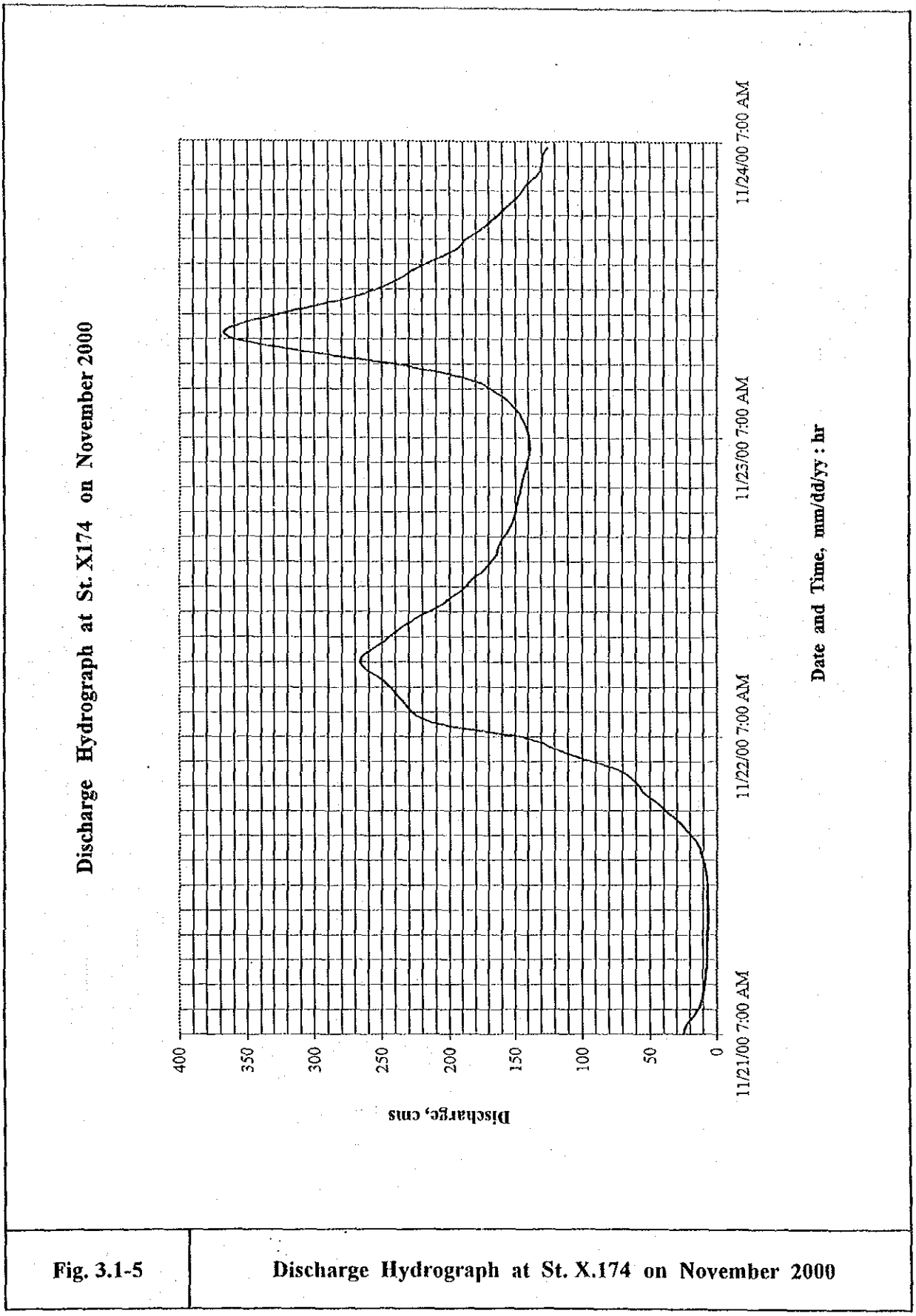


Fig. 3.1-5	Discharge Hydrograph at St. X.174 on November 2000

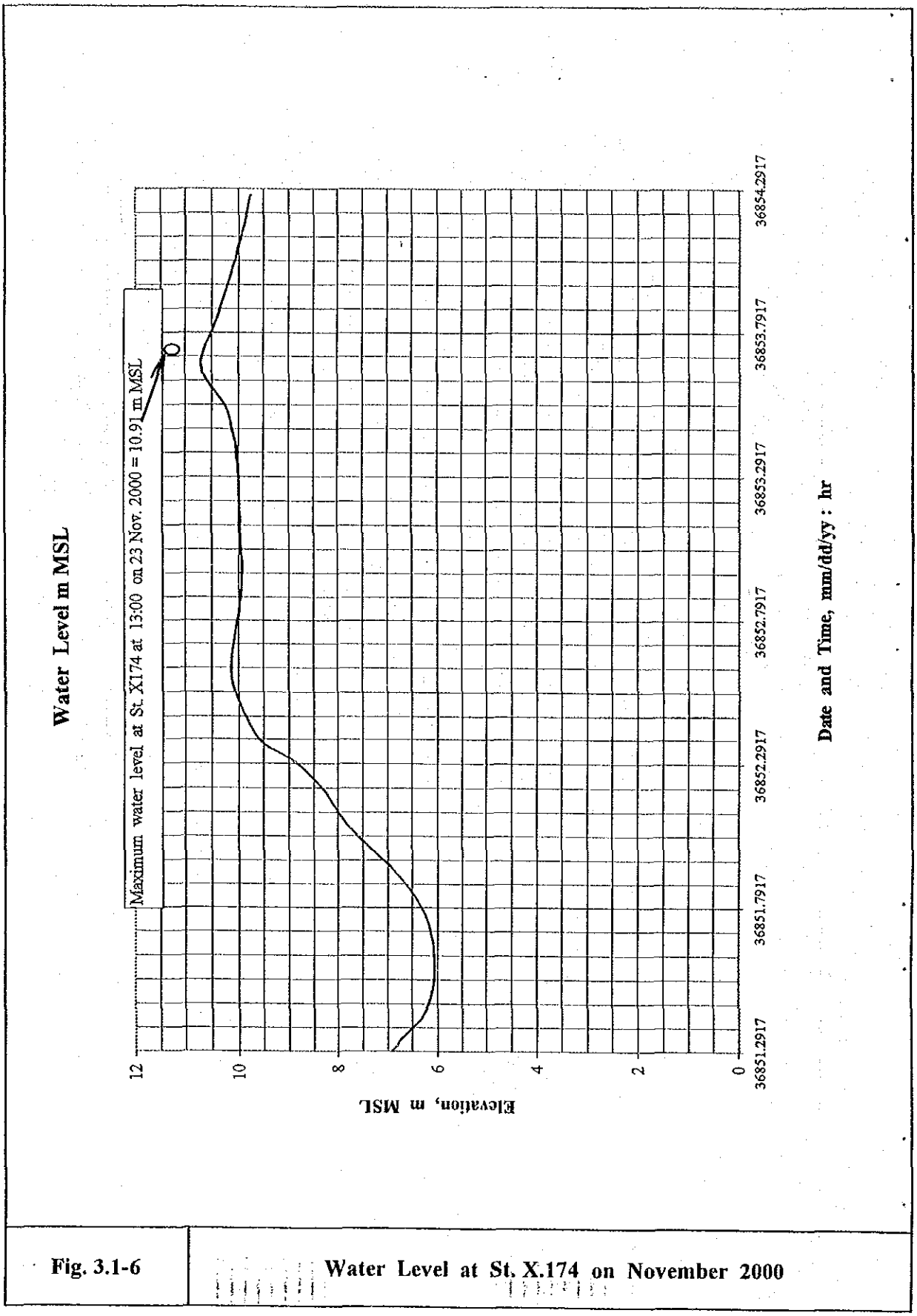


Fig. 3.1-6 Water Level at St. X.174 on November 2000

Fig. 3.1-7

Maximum Water Surface Profile of the Probable Flood of Khlong Wa

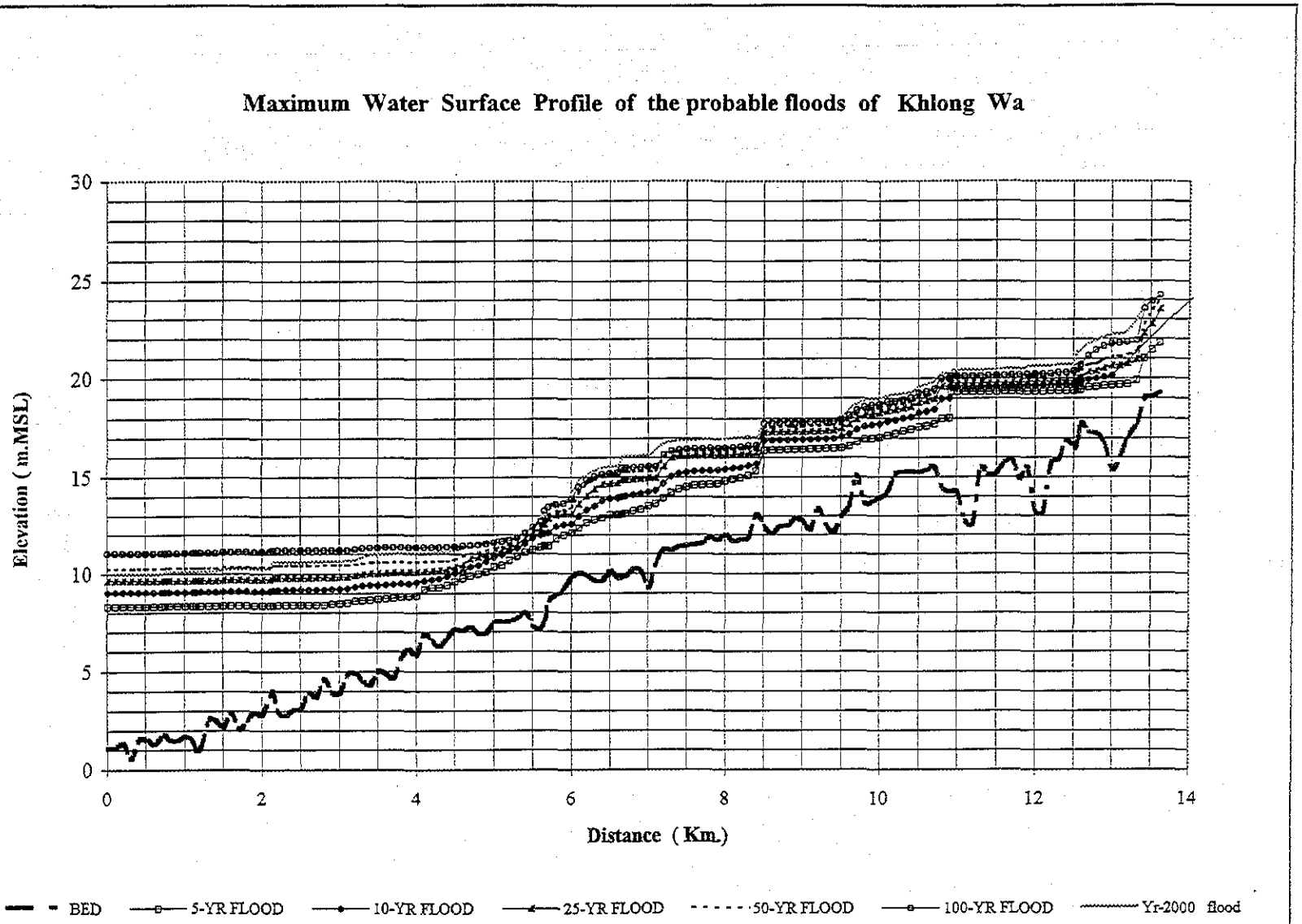
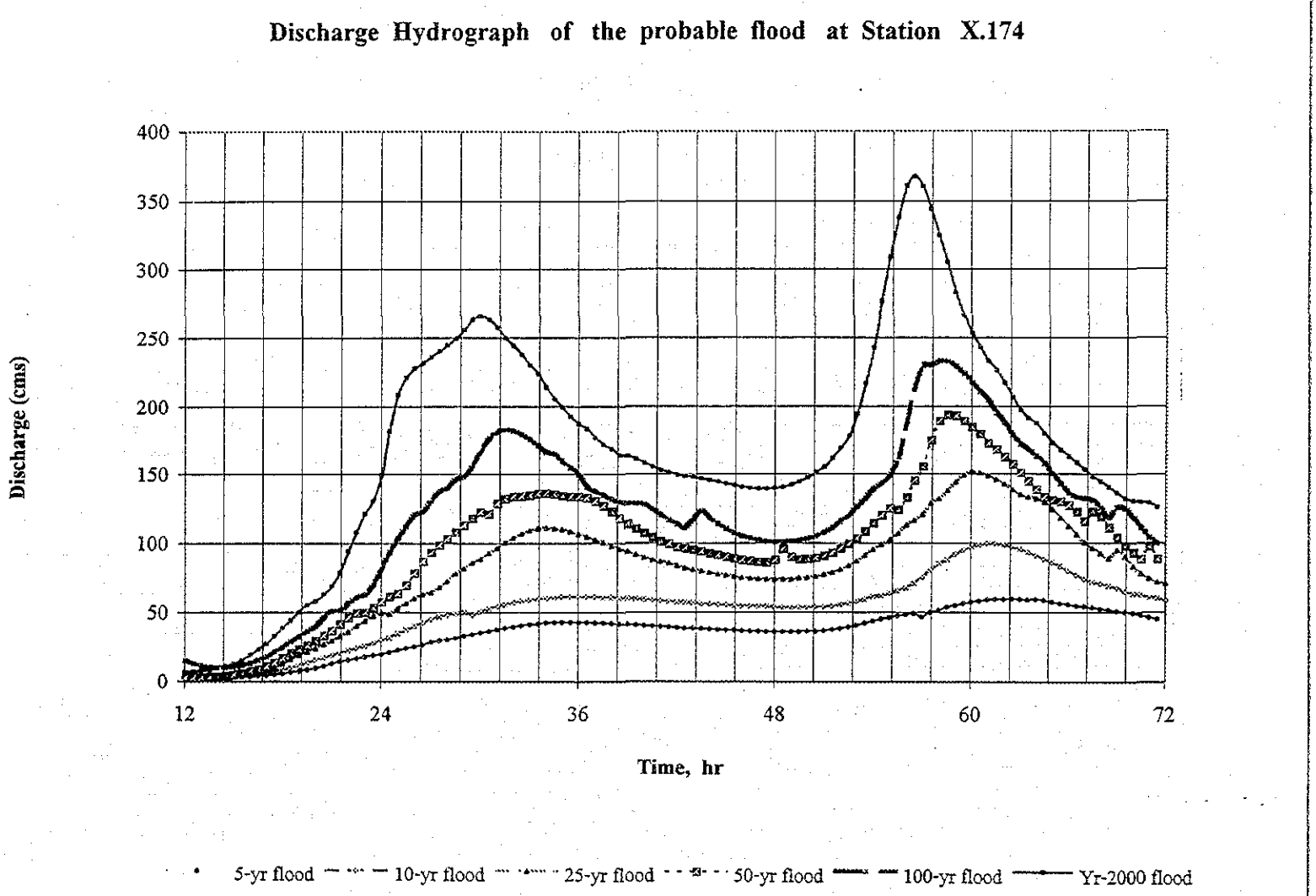


Fig. 3.1-8

Discharge Hydrographs of the probable flood at Station X.174



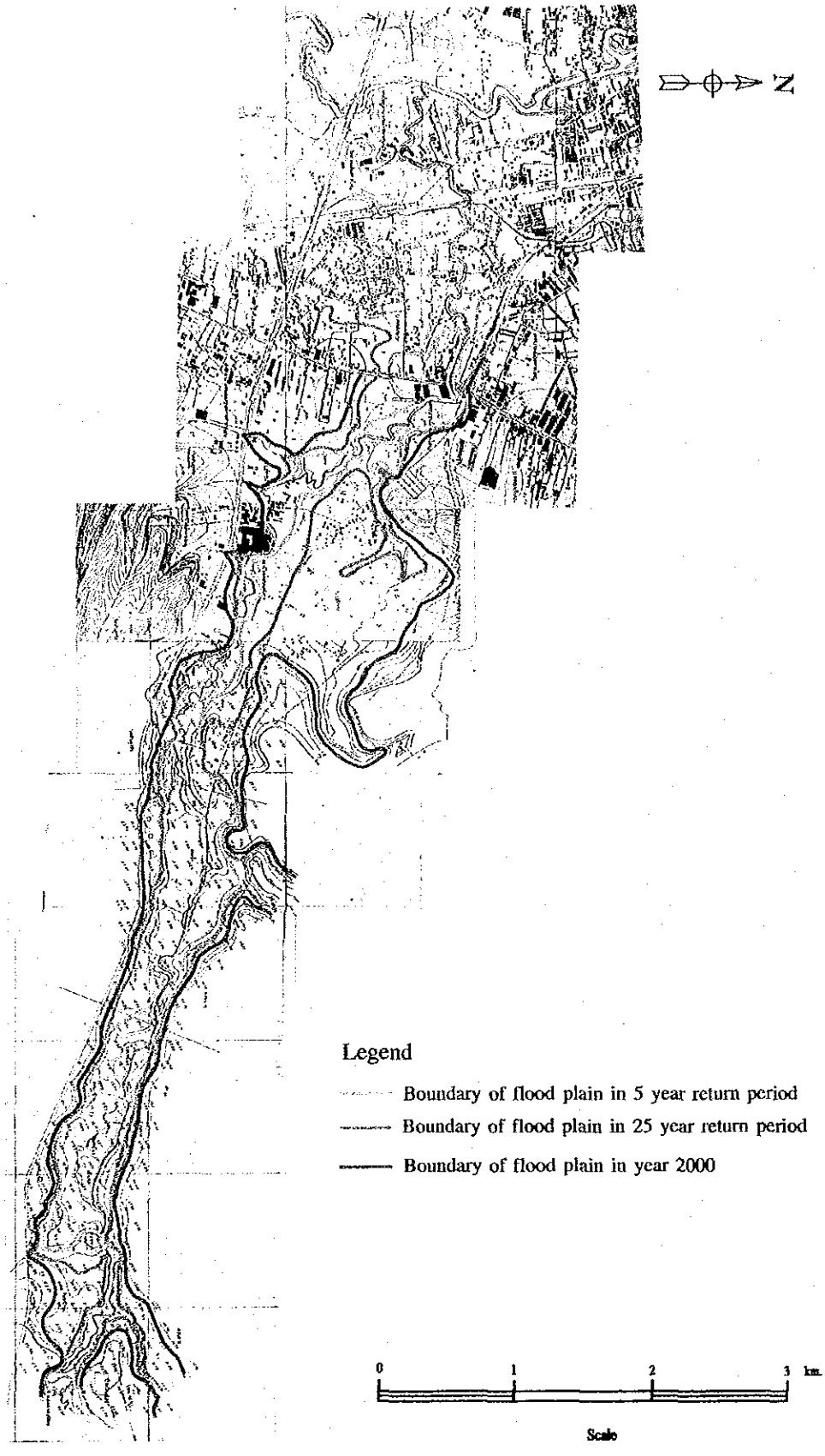


Fig. 3.2–1	Inundation Map Along Khlong Wa

APPENDIX C

FLOOD DAMAGES AND ECONOMIC ANALYSIS

APPENDIX C FLOOD DAMAGE AND ECONOMIC ANALYSIS

CONTENTS

Page

CHAPTER 1 FLOOD DAMAGE RECORDS IN THE PAST

1.1 Flood Damages during 1916-1989 ..... C-1
1.2 Records of 1988 Flood Damage in Hat Yai District. C-1
1.2.1 Damage Records C-2
1.2.2 Estimated Damage Costs under Present Socio-economic Situation (2002 (Price) C-3
1.3 Records of 1988 Flood Damages in Hat Yai District C-3
1.4 Records of 1999 Flood Damage in Hat Yai District C-4
1.5 Records of 2000 Flood Damage in Hat Yai District C-5

CHAPTER 2 INTERVIEW SURVEY ON 2000 FLOOD

2.1 Analysis and Results C-9
2.2 Community Leader C-9
2.2.1 Cause of floods and trends C-9
2.2.2 Measures of flood prevention and reduction of impact from flood C-10
2.2.3 Proposed alternatives for flood prevention project C-11
2.3 Flooded people C-11
2.3.1 Respondent and head of household C-11
2.3.2 Members of household, age group, and working status C-12
2.3.3 Household Incomes and expenditures C-12
2.3.4 Housing conditions and values C-13
2.3.5 Flood experience C-14
2.3.6 Flood damages in 2000 ..... C-15
2.3.7 Work absence caused by flood and vehicle used during flood C-16
2.3.8 Vehicle used during normal time and flood time C-17
2.3.9 Expenses on house and farm restorations after flood C-17
2.3.10 Difficulties during flood C-18
2.3.11 Diseases that found after flood C-19
2.3.12 Flood awareness and effective warning period C-20
2.3.13 Preparation before flood C-20
2.3.14 Relieves received during flood and after flood C-21
2.3.15 Perception of the project C-21
2.3.16 Attitude toward the flood prevention project C-22
2.3.17 Attitude toward flood warning system, town planning C-23
2.3.18 Cooperation with the project C-24

Page

CHAPTER 3 ESTIMATED DAMAGE

3.1 Estimated Flood Damage Cost C-25
3.1.1 Principal Area C-25
3.1.2 Supplementary Area C-27
3.2 Average Annual Flood Damage C-28
3.2.1 Past Flood Damage in Principal Area C-28
3.2.2 Past Flood Damage in Supplementary Area C-29
3.2.3 Future Annual Flood Damage in Principal Area C-31
3.2.4 Future Annual Flood Damage in Supplementary Area C-31

CHAPTER 4 OTHER BENEFITS

4.1 Water Supply C-32
4.2 Dry Season Rice Crop Production C-32
4.3 Orchard Production C-33

CHAPTER 5 ECONOMIC ANALYSIS

5.1 Economic Evaluation C-42
5.2 Conversion Factor C-42
5.3 Development Costs C-43
5.4 Economic Evaluation of Proposed Project C-45

TABLES CONTENT

Page

Table 1 Hat Yai's Flood records during 1916-1988 ..... C-1
Table 2 Summarized estimated damage costs of 1988 flood C-2
Table 3 Consumer's Price Index 1981-2002 (1994=1000) C-3
Table 4 Consumer's Price Index and multiplier C-3
Table 5 Damages base on 2002 price C-3
Table 6 List of non-valuation damages caused by 1998 (30 October 1998 – 12 November 1998) flood, Hat Yai District C-4
Table 7 List of infrastructure damages caused by 1998 flood, Hat Yai District C-4
Table 8 List of non-valuation damages caused by 1999 (23 January 1999 – 28 January 1999) flood in Hat Yai District C-4
Table 9 List of infrastructure damages caused by 1999 (23 January 1999 – 28 January 1999) flood in Hat Yai District C-5
Table 10 List of non-valuation damages caused by flood during 20 November 2000 – 4 December 2000 at Hat Yai and Na Mom Districts C-6
Table 11 List of measurable damages caused by flood during 20 November 2000 – 4 December 2000 at Hat Yai and Na Mom Districts C-7
Table 12 Estimate damages from past floods C-8
Table 13 Distribution of samples adopted for socioeconomic field survey C-9
Table 14 Cause of flood as indicated by Municipal and TAO C-10
Table 15 Possible cause for worse or better impacts from flood in the future C-10
Table 16 Measure of flood prevention and reduction of impact from flood as proposed by community leaders C-11
Table 17 Long term plan to prevent flood C-11
Table 18 Age of respondent or head of household, place of birth, and year of living at present place C-12
Table 19 Members of household, age group, and working status C-12
Table 20 Estimated average household incomes and expenditures in 2001 ..... C-13
Table 21 Housing condition occupied by respondent and their values C-14
Table 22 Flood Experience Duration and height of last flood C-14
Table 23 Damage to household caused by 2000 flood C-15
Table 24 Damages to farms C-15
Table 25 Type of work outside resident and work absence caused by flood C-16
Table 26 Vehicle used during normal time and during flood time C-17
Table 27 Expenses on house maintenance after flood C-17
Table 28 Expenses on farm maintenance after flood C-17
Table 29 Difficulties in lodging, cooking, and sleeping during flood C-18
Table 30 Diseases that found after flood C-19
Table 31 Flood awareness and effective warning period C-20
Table 32 Average preparation Costs before flood C-20
Table 33 Relieves received during flood C-21
Table 34 Relieves received after flood C-21
Table 35 Perception of the project C-22

Page

Table 36 Attitude toward the flood prevention project C-22
Table 37 Response to question :Do you agree with flood warning system and town planning C-23
Table 38 Willingness for cooperation with the project C-24
Table 39 Past trend of consumer's price index 1988-2002 ..... C-27
Table 40 Estimated damage cost of 1998 flood in principal area C-27
Table 41 Estimated damage cost of 1999 flood in principal area C-28
Table 42 Population, household and village in supplementary area C-28
Table 43 Land use in supplementary area C-28
Table 44 Estimated flood damage cost by year2000 flood in supplementary area C-29
Table 45 Flood damage costs C-29
Table 46 Estimated flood damage at difference return period in principal area C-30
Table 47 Estimated flood damage caused by various floods in supplementary area C-30
Table 48 Estimated flood damage at difference return period in supplementary area C-31
Table 49 Future average flood damage costs in principal area base on GPP of Songkhla Province C-32
Table 50 Future average flood damage in supplementary area base on GPP of Songkhla Province C-32
Table 51 Derivation of Benefit from Water Supply base on 2002 constant price C-33
Table 52 Derivation of financial and economic cost and Returns of Second Rice Production base on 2002 constant price C-34
Table 53 Financial Cost of Rambutan Production per rai base on 2002 constant price.. C-35
Table 54 Economic Cost and Return of Rambutan Production per rai base on 2002 constant price C-36
Table 55 Financial Cost and Return of Durian Production per rai base on 2002 constant price C-37
Table 56 Economic Cost and Return of Rambutan Production per rai base on 2002 constant price C-38
Table 57 Financial Cost and Return of Longong Production per rai base on 2002 constant price C-39
Table 58 Economic Cost and Return of Longong Production per rai base on 2002 constant price C-40
Table 59 Summary of benefits from orchard base on 2002 constant price C-41
Table 60 Conversion factors used for converting financial value into economic value.. C-43
Table 61 Financial Cost of the project at 2002 constant price C-44
Table 62 Economic Cost of construction and O&M at 2002 constant price C-45
Table 63 Summary of Flood Damage in Financial and Economic Cost C-46
Table 64 Summary of Other Benefit in Financial and Economic Cost for Phase 1 ..... C-47
Table 65 Economic Benefit / Cost Comparison and Derivation of Economic Indicators for Phase 1 ..... C-48
Table 66 Economic Benefit / Cost Comparison and Derivation of Economic Indicators for Phase 2 ..... C-49
Table 67 Economic Benefit /Cost Comparison and Derivation of Economic Indicators C-50

FIGURES CONTENT

Page

Figure 3.1-1 Principal and Supplementary area..... C-26
Figure 3.2-1 Damage cost-flood frequency curve of principal area base on 2002 price C-29
Figure 3.2-2 Damage cost-flood frequency curve of supplementary area base on 2002 price C-31

APPENDIX C
FLOOD DAMAGE AND ECONOMIC ANALYSIS

CHAPTER 1 FLOOD DAMAGE RECORDS IN THE PAST

1.1 Flood Damages during 1916-1989

Large Hat Yai and Songkhla flood event in the past dated back to 1833, during the King Rama the third when Songkhla Governor requested 1,000 Tons of rice from Bangkok as relief for flood victims[1]. Neither date nor damage record was mentioned. Later floods which were recorded some details, either flood height or date or damages was first made in 1916. From then to 1989, available flood records are as follows: (Table 1)

Table 1 Hat Yai 's Flood records during 1916-1988

year	Flood height (mm.)	Date/ Month	Area (sq. Km.)	Cost of Damage (Baht)
1916	200	Nov.-Dec.		
1942	60	Nov.-Dec.		
1959				200,000
1961				1,200,000*
1962	70	Nov.-Dec.		2,700,000
1966	70	5-7 Dec.		
1967	70	6 Jan.		
1972				
1973	76			6,700,000*
1975	70	Nov.-Dec.		
1981	50		10	
1983	60	14 Dec.		
1987	40	8 Dec.		
1988	143		20	1,000,000,000

Note: * There were lives lost in flood; 1972 was a flood year without any records; all blank cells mean no data available.

** *Town Plan, Town Development and Hat Yai City and Vicinity Town Plan* Development Master Plan Project

1.2 Records of 1988 Flood Damage in Hat Yai District

Flood in 1988 was peaked during 22-24 November when the flood depth inside Hat Yai was between 1.5-2.0 meters. The flood was a result from a torrential rain recorded at 375 mm. during 19-23 November. The measured rainfall in a few days was far more exceeding whole month of November thirty-year averaged of 296 mm. Magnitude and suddenness of flood caused so much damaged that not only to commercial and residential areas, but also most highway and farmlands in Songkhla Province were flooded. Flood area covered 20 sq. Km. or 95% of Hat Yai

---

1 Society of Arts and Environment Conservation, Document for seminar on Southern Flood, an Avoidable Tragedy, January 1989

municipality area of 21 sq. Km.. This situation, at that time, was regarded as most severe flood ever.

1.2.1 Damage Records

Damages caused by 1988 flood was not completely itemized, however, the lump sum of both direct and indirect damages were estimated at 1,000 million Baht base on 1988 price.

Damage records available are as follows:

Commercial units closed not only during the flood period but also a week after flood. About 300 million Baht of gross incomes were lost.

Trading slumped after flood. Customers reduced 30-50% from normal, monthly gross incomes reduced more than 80% from previous year. The effects last in about one month.

Physical damage caused by about one meter depth flood to all buildings and housings. Each intermediate scale commercial unit damaged between Baht 50,000-100,000. Department stores damaged Baht 5-10 million each.

Damages to tourism industry was estimated about Baht 70 million during flood.

Slumps of incoming tourists last for over a months, signs of recovery appeared from new year period.

Physical damages to tourism to related industries. About 67 out of 85 hotels were damaged from fairly to severely. Total cost of damaged were estimated Baht 100 million. Restaurants, entertainment and recreation places were also damaged.

Revenue of railway reduced 33% from previous November from Baht 5.6 million.

Summarized damages of the flood are estimated as shown in Table 2

Table 2 Summarized estimated damage costs of 1988 flood

Damages	Damage Costs (Million Baht)
1. Damages as reported in aggregate amount for 1988 flood	*1,000.00
2. Infra structure (included in 1.)	-
3. Damages to farm s	13.05
4. Damages on households	**177.22
5. Loss of Revenue from Tourists	**198.08
6. Loss of absent from work	85.95
Total	1,474.31

Note: * Included infrastructure, damage to commercial posts, part of tourism, communication and railway

** Additional from the amount previously calculated

1.2.2 *Estimated Damage Costs under Present Socio-economic Situation (2002 Price)*

Table 3. Consumer's Price Index 1981-2002 (1994=100)

Year	Index	Year	Index
1981	61.30	1992	92.10
1982	64.50	1993	95.10
1983	66.90	1994	100.00
1984	67.50	1995	105.80
1985	69.20	1996	112.00
1986	70.40	1997	118.20
1987	72.20	1998	127.60
1988	74.90	1999	127.90
1989	79.00	2000	129.40
1990	83.70	2001	131.00
1991	88.50	2002	132.50

Table 4 Consumer's Price Index and multiplier

	1988	1998	1999	2000
CPI	74.9	127.6	127.9	129.4
Multiplier for derivation of 2002 price	1.77	1.04	1.04	1.02

Note : CPI for the year 2002 is 132.5

When apply the multipliers to damages at current price the damage base on 2002 price are as shown in Table 5

Table 5. Damages base on 2002 price

(Unit: Baht Million base on 2002 price)

-	1988	1998	1999	2000
Secondary Source	1,769.03	-	-	14,683.54
Infra structure	-	2.35	3.26	1,050.58
Farm	23.09	0.95	15.80	44.77
Household Damaged	313.51	12.96	51.02	607.91
Loss of Tourist Revenue	350.41	153.81	251.06	546.21
Absent from work	152.05	11.00	41.57	515.96
Total	2,608.08	181.06	362.71	17,448.97

1.3 Records of 1998 Flood Damages in Hat Yai District.

Due to continued rainfall during October 31-November 10 1998, measuring 250 mm. coupled with high tide, causing floods in many districts in Songkhla Province including Hat Yai.

Among 16 districts in Songkhla Province, 13 including Hat Yai were flooded. During 30 October 1998-12 November 1998 (13 days). Damages as officially reported are relatively less than other floods as listed in Table 6 and 7.

Table 6 List of non-valuation damages caused by 1998 (30 October 1998-12 November 1998) flood, Hat Yai District

Household affected (No.)	812
Person Affected (No.)	2,685
Died person (No.)	1

Table 7 List of infrastructure damages caused by 1998 flood, Hat Yai District

Infra structure	No.	Damage (฿)
Road (No.)	29	1,880,000
Bridge (No.)	7	350,000
Sub total (infrastructure)		2,230,000
Fish/Shrimp Pond (No.)	1	30,000
Total Damage		2,260,000

Note : No damage reported from Khlong Wa
Source : Local Government Office, Songkhla Province

(Baht Million)

-	1988	1998	1999	2000
Secondary Source	*1,000.00	-	-	**14,340.00
Infra structure	-	2.26	3.15	-
Farm	13.05	0.92	15.26	43.72
Household Damaged	177.22	12.48	49.25	593.69
Loss of Revenue from Tourists	198.08	148.12	242.34	533.43
Absent from work	85.95	10.59	40.13	503.89
Total	1,474.31	174.37	350.12	17,040.73

Note : * Included infrastructure, damage to commercial posts, part of tourism, communication and railway
** Included infrastructures, household damage, hospitals, hotels, industries, and commercial posts.

1.4 Records of 1999 Flood Damage in Hat Yai District.

Damages caused by flood during 23 January 1999-28 January 1999 (5 days) in 10 districts in Songkhla including Hat Yai. Cost of damages is shown in Table 8 and 9.

Table 8. List of non-valuation damages caused by 1999 (23 January 1999-28 January 1999) flood in Hat Yai District

Household affected (No.)	5,116
Person Affected (No.)	22,965
Moved Household (No.)	42
Moved Persons (No.)	150
House Damaged (No.)	5,116

Table 9 List of infrastructure damages caused by 1999 (23 January 1999-28 January 1999) flood in Hat Yai District

Infra structure	Number	Value
Road (No.)	72	3,070,000
Weir (No.)	1	80,000
School (No.)	10	na
Drainage Structure (No.)	2	3,150,000
Crop damaged (rai)	7,828	14,716,000
Fish/Shrimp Pond (No.)	54	540,000

Source : Local Government Office, Songkhla Province

(Baht Million)

-	1988	1998	1999	2000
Secondary Source	*1,000.00	-	-	**14,340.00
Infra structure	-	2.26	3.15	-
Farm	13.05	0.92	15.26	43.72
Household Damaged	177.22	12.48	49.25	593.69
Loss of Revenue from Tourists	198.08	148.12	242.34	533.43
Absent from work	85.95	10.59	40.13	503.89
Total	1,474.31	174.37	350.12	17,040.73

Note: * Included infrastructure, damage to commercial posts, part of tourism, communication and railway

** Included infrastructures, household damage, hospitals, hotels, industries, and commercial posts.

1.5 Records of 2000 Flood Damage in Hat Yai District.

Flood in 2000 was at peak between 21-25 November 2000. The main cause was abnormally heavy rain from northeast monsoon. During 21-23 November 2000, rainfall of 597.5 mm. measured in Hat Yai and surrounding areas, causing sudden flood in all Hat Yai with the depth of 1.5-2 meters.

Damage in Hat Yai area and surroundings were estimated by many agencies independently. Each of reported different result as to be described below.

A. Songkhla Chamber of Commerce

Songkhla Chamber of Commerce estimated damage costs by item as follows:

(1) Damage to 10,000 households out of 40,000 including vehicles and household assets the amount of Baht 10,000 million.
(2) Damage to 6 private hospitals, 50 clinics, and 20 dental clinics the amount of Baht 640 million.
(3) Damage to 50 hotels of any size amounting Baht 1,000 million.
(4) Damage to 17 large scale industrial factories such as seafood industry, rubber industry, sawmills, etc. the amount of 900 million.

(5) Damage to about 160 general small scale industries such as machining, garage, electrical equipment, and etc. the amount of Baht 900 million.
(6) Damage to about 200 business offices the amount of Baht 900 million.

Total damage costs of above items were 14,340

B. Municipal

Hat Yai's Municipal estimated the damage to infrastructures the amount of Baht 1,855 million, which was the damage costs of following items.

(1) 64 roads in Hat Yai,
(2) 3 bridges,
(3) 3 pumping stations,
(4) numbers of dikes, drainage ditch, traffic and public lighting, parks, signs, housing, waste water treatment structure, solid waste dumping site, weather station, offices, equipment and vehicles, and etc..

C. Songkhla Province

As resulted from latest flood during 20 November 2000- 4 December 2000 (15 days), Local Government Office reported the damages and estimated cost of damages as shown in Table 10 and Table 11 respectively.

Table 10. List of non-valuation damages caused by flood during 20 November 2000- 4 December 2000 at Hat Yai and Na Mom Districts

	Hat Yai	Na Mom	Total
Households affected (Thousand)	25.28	5.20	30.48
Person affected (Thousand)	79.13	16.50	95.63
Died and missing person (No.)	27	2	29
Wounded (No.)	373		373
Moved Houschold (No.)	1,034	200	1,234
Moved Persons (No.)	5,170	1,000	6,170
House Damaged (No.)	1,088	33	1,121

Table 11. List of measurable damages caused by flood during 20 November 2000- 4 December 2000 at Hat Yai and Na Mom Districts

Item	Hat Yai	Cost of Damage (฿ Mill.)	Na Mom	Cost of Damage (฿ Mill.)	Total	Total Cost of Damage (฿ Mill.)
Crop damaged (Thousand rai)	28,800	32.80	.75	0.82	29.55	33.62
Livestock Damaged (Thousand head)	31.1	10.92	11	0.66	42	11.58
Road (No.)	657	57.00	139	27.23	796	84.23
Bridge (No.)	56	21.88			56	21.88
Weir (No.)	15	0.67	6	4.30	21	4.97
Drainage (No.)	105	2.50	41	2.90	146	5.39
Other structures (No.)	1,378	4.13			1,378	4.13
School (No.)	117	90.56	4	0.21	121	90.77
Religion Shrine (No.)	90	10.19			90	10.19
Government Office (No.)	27	6.63	1	0.06	28	6.69
Total Damage		237.28		36.18		273.46

Source : Local Government Office, Songkhla Province

D. Other Agencies

Beside own estimation, Local Government Office received additional damage information from various government offices as follows:

(1) NESDB estimated that damage costs of 2000 flood were 17,832 Million Baht.
(2) Community Development Office reported Damages to community development infrastructures including their officers the amount of 7. 29 Mil. Baht.
(3) Infrastructures under the responsibility of Accelerated Rural Development Department including roads, village water works system, and water resource infrastructures are reported to be 98. 8 Mil. Baht in damage.
(4) Songkhla Electricity Office reported damages of 32. 39 Mil. Baht on their assets.
(5) Songkhla Public Health Office reported Damages to health service and health infrastructure the amount of 133. 85 Mil. Baht
(6) Songkhla Industry Office reported Damages to manufacturing factories the amount of 253 Mil. Baht
(7) Songkhla Highways Office reported Damages to highways under its responsibility the amount of 15. 11 Mil. Baht

Part of these additional damages are already counted in damage cost estimation made by Local Government Office, particularly road under which many agencies such as ARD, Municipal, TAO, and DOH are responsible. However, damage cost estimation made by different agencies on the same damage are basically different. Therefore, in order to keep estimation reasonably

conservative, estimation made by LGO will initially be adopted as minimum damages. Additional Damages to economic activities, houses and vehicles and etc. will be further estimated, to achieve nearest total damage costs. Estimation is shown in Table 12.

Table 12. Estimate damages from past floods

(Baht Million)

-	1988	1998	1999	2000
Secondary Source	*1,000.00	-	-	**14,340.00
Infra structure	-	2.26	3.15	-
Farm	13.05	0.92	15.26	43.72
Household Damaged	177.22	12.48	49.25	593.69
Loss of Revenue from Tourists	198.08	148.12	242.34	533.43
Absent from work	85.95	10.59	40.13	503.89
Total	1,474.31	174.37	350.12	17,040.73

Note: * Included infrastructure, damage to commercial posts, part of tourism, communication and railway

** Included infrastructures, household damage, hospitals, hotels, industries, and commercial posts.

CHAPTER 2 INTERVIEW SURVEY ON 2000 FLOOD

Fieldwork survey for socioeconomic study was made by using questionnaire to interview the target flooded people: farmer and non-farmers, and community leaders. Two types of questionnaires were designed for this purpose: flooded people and community leaders.

Target areas are within Hat Yai and outside Hat Yai with emphasis on within Hat Yai area. By this order, total number of 108 samples were split to73: 36 (68%: 32%) for within Hat Yai: outside. For flooded people within Hat Yai, 60 samples or 82% were allocated for non-farmers, 10 samples or 14% were allocated for farmers, and 3 samples or 4% for community leaders. For outside Hat Yai, a total of 35 questionnaires were used: 7 (20%) for non-farmers 21 (60%) for farmers and 7 (20%) for community leaders. Details are shown in Table 13

Table 13. Distribution of samples adopted for socioeconomic field survey

	Target Group	Hat Yai		Outside Hat Yai		Total/Average	
		No.	%	No.	%	No.	%
1	Non Farmer	60	82.2%	7	20.0%	67	62.0%
2	Farmer	10	13.7%	21	60.0%	31	28.7%
3	Community Leader	3	4.1%	7	20.0%	10	9.3%
4	Total	73	100.0%	35	100.0%	108	100.0%

Field survey was made during 11 March 02 – 15 March 02 by five trained enumerators recruited from fourth year university students in Songkhla. All of them speak local dialect. A Socio- economist from Pal Con supervised fieldwork activity and checked all filled questionnaires to ensure validity of the information received.

The filled questionnaires have been processed and analyzed. Parts of the results are included in this report.

2.1 Analysis and Results

Results of survey are presented in two separate parts: community leaders and people with flood experience. Their results are as follows:

2.2 Community Leader

Of ten community leaders interviewed, the results are as follows:

2.2.1 Cause of floods and trends

Majority of community leaders believed that the main causes of flood were insufficient drainage structures and siltation in the canals. Less important causes were weeds in canals and overflow from the rivers. (Table 14)

Table 14. Cause of flood as indicated by Municipal and TAO

Cause:	% (n=10)
Insufficient drainage structures	60.0
Siltation in canals	60.0
Abundance of weeds in canals	30.0
Overflow from the river because of narrower channel due to agriculture	30.0
Overflow from the river because of narrower channel due to construction	20.0
Drainage system being constructed	10.0

About 70% of the leaders believed that flood condition in the future would be worse, whereas the remaining believed that the condition would be better. The reason for those who believe that the trend would be worse is that there would have more wastewater from expanding communities in the future. Besides forest destruction upstream will be more, water runoff would be faster. For those who believed that the condition would be better because the drainage system being constructed will have been finished. (Table 15)

Table 15. Possible cause for worse or better impacts from flood in the future

Flood condition will be worse because:	
More waste water from expand community	42.9%
More forest destruction	42.9%
More over flow from the rivers	28.6%
Flood condition will be better because:	
Drainage system will have been finished	100.0%

2.2.2 Measures of flood prevention and reduction of impact from flood

Measures of flood prevention and reduction of impacts from flood made in each community are not different. Measures to prevent flood are to clean the water channels and having mobile units to help the people when they need, including distribution of sandbags. For mitigation measure, the municipal or TAO distribute consuming goods, provided transportation, moving the people to dry places, provided passenger vehicles and also provided house repair services. Source of budgets is mainly from their own or from the Department of Local Government, only in some cases when budget was met from other agencies (Table 16).

Table 16. Measures of flood prevention and reduction of impact from flood as proposed by community leaders

Preventive Measures		Mitigation Measures	
Clean drainage channels	50%	Distributed goods	70%
Organized mobile helping units	20%	Provided passenger boats	30%
Distributed sand bags	10%	Moved the flooded people	30%
		Provided passenger vehicles	10%
		Provided house repair service	10%
Source of Budgets			
Volunteer Territory Defense Org.		TAO	
TAO		Dep. Of Local Government	
Dep. Of Local Government			

In view of long term plan to prevent flood, the leaders prefer to improve drainage system, clean deposits siltation from canals and water channels using their own budget. Some of them have no plan at all (Table 17).

Table 17. Long term plan to prevent flood

Long term plan	%
Improve drainage system	40.0
Clean siltation from canal and water channels	40.0
No plan	30.0

2.2.3 Proposed alternatives for flood prevention project

When asked for their opinion on alternatives to prevent flood in the future, half of them (50%) proposed to divert water incoming to town to other direction or having flood plain absorbing excess water. Other proposal (40%) proposed that the project should consider solving flood from Na Mom District first. The last proposal (10%) was to clean the water channels to make water flows more freely.

2.3 Flooded people

2.3.1 Respondent and head of household

The head of household should be the interviewed person if available. If he or she may not be available, their spouse could replace the head of household for interview. Characteristic of the head of household can be described as follows.

Average ages of head of household in both areas are in middle forties. Place of birth of household, proportionally Hat Yai area has less native born than outside. The majority of the people who moved from other places have moved in for over ten years (Table 18)

Table 18. Age of respondent or head of household, place of birth, and year of living at present place

	Hat Yai	Outside	Total/Average
Age of respondent (year)	43.48	43.60	43.52
Age of head of HH (year)	44.02	47.90	45.13
Born here (%)	54	93	65
Move from other places (%)	46	7	35
For how long, if moved from other place			
Less than 5 year (%)	25		24
5 - 10 year (%)	28		26
Over 10 year (%)	47	100	50

2.3.2 Members of household, age group, and working status

Average number of household member of the samples is 4.18, a little difference between Hat Yai and outside. Age group under 15 years old is averaged at 22% whereas 60 year and over is about 10%; remaining of 69% is in the group of 15-59 years or workable age (Table 19).

Table 19. Members of household, age group, and working status

	Hat Yai	Outside	Total/Average
Av. No. of household members	4.21	4.10	4.18
Age group			
Less than 15 year (%)	21.92	21.60	21.81
15 - 59 year (%)	68.49	69.00	68.63
60 year and over (%)	9.59	9.50	9.56
Working status			%
Staying at home	43.15	35.30	40.93
Work outside or going to school	56.85	64.70	59.07
In case of staying at home			
Under school age	16.67	14.60	16.17
Work at home	58.73	51.20	56.89
Staying at home but no work	24.60	34.10	26.95
In case of going out			
Going to school	40.36	37.30	39.42
Work outside	59.64	62.70	60.58
Average distance (Km.)	8.25	24.90	13.43

2.3.3 Household Incomes and expenditures

Household incomes and expenditures are rough estimate from three sources: agriculture, non-agriculture, and wages. Agriculture and non-agriculture activities are net come from production (value of output deducted by cost of production), whereas wages are the amounts received from employers. Amounts of incomes and expenditures are shown in Table 20.

Table 20 Estimated average household incomes and expenditures in 2001

	In Hat Yai	Outside	Total/Average
Agriculture			
Gross incomes in 2001 (Baht)	25,364	86,166	42,736
Farm expenditure in 2001 (Baht)	12,490	26,594	16,520
Net farm incomes (Baht)	12,874	58,661	25,956
Non agriculture activities			
Gross incomes (Baht)	193,035	60,661	155,214
Expenditure (Baht)	119,282	13,107	88,947
Net Incomes (Baht)	73,753	47,553	66,267
Wages and salaries	72,266	40,269	63,124
Household incomes	158,893	146,483	155,347
Household expenditures (Baht)			
Foods, liquor, cigarettes	57,656	30,853	49,998
Dwelling, housing, rents, etc.	10,892	-	7,780
Cloths	4,012	1,949	3,422
Medicines and health care	2,559	842	2,068
Electricity, water, fuel, gas, charcoals	15,437	7,463	13,159
Education	19,230	2,154	14,351
Transportation and communication	22,061	8,468	18,177
Ritual and religion	795	42	580
Total Household Expenditure	132,642	51,771	109,536
Household net incomes (savings)	26,251	94,712	45,811

2.3.4 Housing condition and value

Type of building in Hat Yai is row houses, whereas outside Hat Yai is more single houses. Size of land plot includes farmlands, which should not represent size of land plot for housing. Size of lower floor or ground floor, which subject to be flooded first, is averaged 121 sq. meters. Materials used for building houses are more of brick or concrete than woods. Levels of land plots can be same, higher, or lower than the road outside, but level with the road is more than the rest. The lowest floors are level with the ground in more cases. Usage of the building is equally either for dwelling or both business and dwelling. Only in a few cases where they use for business only (Table 21)

Table 21. Housing condition occupied by respondent and their values

Type of building	Hat Yai	Outside	Total/Average
Single house	36	96	53
Row house	67	4	49
Size of land plot (sq. Wah)	554	814	628
Lowest floor (sq. M.)	104	166	121
Materials			%
Woods	11	14	12
Half wood half concrete	17	46	26
Concrete building	71	39	62
Level of land plot			
Higher land road	46	14	37
Level with road	43	36	41
Lower than road	11	50	22
Lowest floor			
Lifted from ground	14	21	16
Level with ground	67	75	69
How high from road (cm.)	49	50	49
Value			
Present Value of H (Baht)	515,976	188,200	391,818
Land Value (Baht)	752,596	215,300	542,715
Usage			
Dwelling only	40	68	48
Business or work only	4	4	4
Both	56	29	48

Note : A Wah is equivalent to two meters, then one sq. Wah is 4 sq. Meters

2.3.5 Flood experience

Almost all respondents were ever flooded. Average height of flood is averaged was 164 cm. in Hat Yai, 91 cm. outside Hat Yai. (Table 22)

Table 22. Flood Experience Duration and height of last flood

Ever flooded?	Hat Yai	Outside	Total/Average
Yes	97	82	93
No	3	18	7
No. of Flood	1	1	1
Duration of flood (day)	5	3	4
Average flood height (cm.)	164	91	127
Point at which flood is measured			%
the road	16	21	17
front yard	6	14	8
lower floor	77	46	68
farm land	1	18	6

2.3.6 Flood damages in 2000

Direct damages to flooded people in both areas were much different. In Hat Yai area damages was average at about 74,000 Baht per HH whereas average damages outside was averaged at about 7,300 Baht, ten times difference. Finished goods are the item that damaged most for both areas. Second most damaged are electrical appliances for in Hat Yai case but for outside is loss of incomes. Details of damages are shown in Table 23. Damages to farmlands are shown in Table 24.

Table 23. Damage to household caused by 2000 flood

Baht

List of damages	Hat Yai	Outside	Total/Average
Damaged to finished goods	9,826	2,331	7,138
Damage to electrical app.	4,538	184	3,247
Loss of incomes	4,949	1,798	3,663
Damage to vehicles	2,734	476	1,958
Damage to furniture	2,303	333	1,651
Damage to machinery	404		289
Damage to hh utensils	618	619	467
Damage to other parts of the house	532	450	394
Damage to lower floor	303	548	239
Damage to upper floor	187	159	137
Damaged to raw material and inputs	164	395	125
Damage to cloth	238	48	170
Total	26,796	7,341	19,478

Table 24. Damages to farms

	In Hat Yai	Outside	Total/Average
Samples	3	7	10
Damage to Crops			
Average total area (rai/sample households)	11.0	5.4	7.1
Ever flooded?			
Yes (%)	67	86	80
No (%)	33	14	20
Maximum flood (cm.)	100	158	158
Damaged (rai)	1.4	4	3.3
Damaged cost (Baht/farmer household)	20,000	4,388	9,072
No protection (%)	100	100	100
Fishpond			
Average total area (rai)	2	0.14	0.76
Ever flooded (%)	100	100	100
Maximum flood (cm.)	100	150	150
Average damage (rai)	1.75	0.1	0.65
Cost of damage (Baht)	2,000	2,000	2,000
No protection (%)	100.00	100	100
Pigs			
Average no. per household (head)	46		13.8
Maximum flood (cm.)	100		100
Average damage (head / hh)	46		13.8

	In Hat Yai	Outside	Total/Average
Average cost of damage (Baht/hh)	200,000		60,000
Poultry			
Average cost of damage (Baht/hh)		1,100	770

2.3.7 Work absence caused by flood and vehicle used during flood

Types of work of household member working outside resident are normally: Shop, office, factory staff; Government, state enterprise; and General labor, and construction. In a fewer cases types of work are selling goods at a fixing point, vendor, and transportation. All of them stop working for average 13 days by year 2000 flood because they could not work with flood situation. In some cases government or employers told them not to work (Table 25)

Table 25. Type of work outside resident and work absence caused by flood

	In Hat Yai	Outside	Total/Average
Type of work outside resident			%
Shop, office, factory staff	30	36	32
Government, state enterprise	23	36	27
General labor, and construction	23	19	22
Selling goods at a fixing point	17	9	14
Vendor	4		3
Transportation	2		1
Work Interruption			
Days absent from work for members work outside			(days)
Year 2000 flood	13	12	13
previous yr.	11	21	15
reason for not working			%
Can not work	35	21	31
Employer told not to work	8	2	6
Government announcement	4	2	3
Busy with flood	11	2	8
Work at home			
Days absence from work			(days)
Year 2,000 flood	17	19	18
previous yr. flood	15	27	21
Reason for not working			%
Can not work	49	76	55
Employer told not to work	9		7
Government announcement	4		3
Busy with flood	30	10	25
Members staying at home			%
Stop working	96	71	91
Stop if flood is high		14	3
Work less	4	14	6

2.3.8 Vehicle used during normal time and flood time

During normal time, the most common vehicles used are motorcycles and cars or pickup trucks. During flood time, they use less motorcycles, cars, and pickup truck but instead walking (Table 26)

Table 26. Vehicle used during normal time and during flood time

	In Hat Yai	Outside	Total/Average
Vehicle used during normal time			%
Motorcycle	45	40	44
Car or pickup truck	15	17	16
walking	5	4	5
Bicycle	5	9	6
Bus	5	2	4
Vehicle used during flood			%
Walking	29	49	36
Motorcycle	3	2	3
Bicycle	1	4	2
Car or pickup truck		6	2

2.3.9 Expenses on house and farm restorations after flood

After flood, affected households had to restored their properties nearest to the condition before flood. These involved cost of time and money in restoration. Farm activities had to be delayed for a period of time before they can resume normal activities (Table 27 and 28)

Table 27. Expenses on house maintenance after flood

	In Hat Yai	Outside	Total/Average
Head of household (days)	12	6	11
Members (days)	14	14	14
Hired labor (Baht)	637	300	502
Materials (Baht)	4,187	2,071	3,870
Emptying septic tank (Baht)	220		220
Other expenses (Baht)	2,039		2,039
Total cash expenses (Baht)	7,083	2,371	6,631

Table 28. Expenses on farm maintenance after flood

Farm expenses	In Hat Yai	Outside	Total/Average
Head of household (days)	19	19	19
Members (days)	14	18	17
Hired labor (Baht)		1,475	1,475
Materials (Baht)	350		350
Seed and stock animal (Baht)	620	1,433	925
Other expenses (Baht)	120	279	247
Days idle before resuming activity	49	30	39
Total cash expenses (Baht)	1,139	3,217	3,036

2.3.10 Difficulties during flood

Included in questionnaires are questions relating to difficulties. Included in questionnaires are possible difficulties in: using of pipe water, using of electricity and hazard from electricity, laundry, food and goods purchasing, urination, bowel, child watching, high water alert, animals and poisonous animals alert, eating, sleeping, cooking fuel, and cooking. Related questions are what is the trouble in such difficulties, how difficult, and what did they do in such situation. The trouble of difficulties fell into a great deal of inconvenience were normally solved by moving to upper floor or moving away from the house that they used to live. Part of the difficulties are shown in Table 29.

Table 29. Difficulties in lodging, cooking, and sleeping during flood

	In Hat Yai	Outside	Total/Average
Lodging			%
Inconvenience	76	68	73
Limited, no place to live	16		11
How difficult			%
A great deal	46	7	35
Bearable	27	36	30
Not much difficult	19	25	20
What did you do			%
Moved to stay at other place	19	18	18
Moved to upper floor	36	14	30
Cooking			
What are difficulties			
Inconvenient	96	64	87
How difficult			
A great deal	26		18
Bearable	33	18	29
Not much difficult	37	46	40
What did you do			
Receiving relief items	13	18	14
Help from neighbors	6	4	5
Use available dry place	24		17
Sleeping			
What are difficulties			
Inconvenience	44	43	44
Could not sleep	41	7	32
How difficult			
A great deal	26	7	20
Bearable	29	7	22
Not much difficult	31	36	33
What did you do?			
Moved to live outside	11		8
Self adaptation	21		15

2.3.11 Diseases that found after flood

Questions about disease after flood as listed in questionnaires include foot disease, foot rot, diarrhea, skin disease, and eye disease. Diseases that found in large extent or magnitude are foot disease, foot rots, and skin disease. Treatment that is widely adopted is self-treatment. Details are as shown in Table 30.

Table 30. Diseases that found after flood

	In Hat Yai	Outside	Total/Average
Foot disease			%
Magnitude			
Widely	13	7	11
Fairly	16		11
Some	14	11	13
Treatment			%
See doctor	9	4	7
Self-treatment	26	7	20
No treatment	1		1
Receiving fee treatment	7	7	7
Foot rot			%
Magnitude			
Widely	4		3
Fairly	7	4	6
Some	7	11	8
Treatment			
See doctor	4	4	4
Self-treatment	11	7	10
Free medicine	3	4	3
Diarrhea			%
Magnitude			
Widely	1		1
Some	4		3
Treatment			
See doctor	1		1
Self prescription	3		2
Free medicine	1		1
Eye disease			%
Magnitude			
Fairly	1		1
Treatment			
No treatment	1		1
Skin disease			
Magnitude			
Widely	3	4	3
Some	3		2
Treatment			
Self-treatment	3	4	3
Free medicine	3		2

2.3.12 Flood awareness and effective warning period

Most people aware of flood hazard was coming in less than 12 hrs. although a few of them may aware of flood for 3-5 days before actual flood. As result most people could not prepare to encounter flood situation. No effective formal source of information to inform the people to prepare for flood as most people indicated that to aware of flood hazard is self-perception from the climate situation. Most of the respondents reported that the minimum effective period to inform the people should be between 1-6 days in advance (Table 31)

Table 31. Flood awareness and effective warning period

	In Hat Yai	Outside	Total/Average
How long before flood, did you aware of flood hazard?			%
less than 12 hr.	22.9	21.4	22.4
1-2 days	1.4	3.6	2.0
3-6 days		3.6	1.0
Did not know	75.7	71.4	74.5
Could you be prepared?			
yes	11.4	46.4	21.4
no	88.6	53.6	78.6
Who informed you			
Municipal	1.4		1.0
Neighbor	11.4	7.1	10.2
Self perception	87.1	92.9	88.8
For how long should the people be informed?			
1-6 days	78.6	89.3	81.6
7 days	14.3	10.7	13.3

2.3.13 Preparation before flood

The people who has experience with flood problem before, used to prepared flood protection by making protection dike to prevent water coming into resident. Some people may prepare dried foods that can be kept for a long time without refrigeration for consumption during long duration flood. Average cost of preparation is shown in Table 32.

Table 32. Average preparation Costs before flood

Baht

	In Hat Yai	Outside	Total/Average
Cost of preparation before flood	381	85	296
Making protection dike	6	9	6
Prepare dried foods	271	234	261
Insured against flood	45	-	32
Total	703	328	595

2.3.14 Relieves received during flood and after flood

During flood duration and shortly after, much publicity were made through various mass media. This encouraged many private charity organizations and government agencies provide consumer and medical goods to donate to flooded people. Details are shown in Table 33 and 34.

Table 33. Relieves received during flood

	In Hat Yai	Outside	Total/Average
Type of donation			(%)
Foods (%)	50.0	35.7	45.9
Cloths, shoes (%)	2.9	7.1	4.1
Medicines (%)	11.4	28.6	16.3
Pumping services (%)	1.4		1.0
Value (Baht)	142	154	146
Donation agency			(%)
Privates, foundation (%)	34.8	20.0	30.3
Government (%)	65.2	80.0	69.7
Delivery point			(%)
At home (%)	63.0	75.0	66.7
At designated point (%)	37.0	25.0	33.3

Table 34. Relieves received after flood

	In Hat Yai	Outside	Total/Average
Type of donation			(%)
Foods	44	50	46
Cloths, shoes	6	7	6
Medicines	20	25	21
Pumping services	1		1
Value (Baht)	238	207	228
Donation agency			(%)
Privates, foundation	43	13	32
Government	64	88	72
Delivery point			(%)
At home	51	63	55
At designated point	55	38	49

2.3.15 Perception of the project

From survey, it is obvious that very few people know about flood prevention project. For those who know, the sources of information are radio and government officials. However, from their understanding, the project will develop only water pumping station. Responsible agency is Royal Irrigation Department (Table 35)

Table 35. Perception of the project

	In Hat Yai	Outside	Total/Average
Did you know about the project before?			%
Yes (%)	4		3
No (%)	96	100	97
Source of information			%
Radio (%)	33		33
Government official (%)	67		67
From your understanding, what will be developed			%
Water pumping station (%)	100		100
What is responsible agency			
Royal Irrigation Department (%)	33		33
Does not know (%)	67		67

2.3.16 Attitude toward the flood prevention project

After explanation about the project is given, the respondents are requested to provide opinion on the project. The response is favorable as most of them agreed that the comprehensive flood prevention project should be developed because it is a way to reduce economic hazards. For those who disagreed, they were afraid that the project might cause floods in other areas, waste of budget, and it may not function effectively. In their opinion, what the project should do are as described in Table 36.

Table 36. Attitude toward the flood prevention project

	In Hat Yai	Outside	Total/Average
Are you agree with the project?			%
Yes	93	96	94
No	7	4	6
If yes, because:			
Reduce economic hazards	83	86	85
Reduced epidemic	18	14	17
Increase farm outputs	5	4	4
Reduced flood damage	8	4	7
If no, because:			
Waste of budget	20	100	33
Cause floods to other places	60		50
It may not work	20		17
What would be better to do			
Look after all areas equally	12	7	11
Better public relations	2		1
Better coordination	8		5
Should have reservoir	2	7	3
Any thing effective is acceptable, do not depend on government budget only	15	7	13
The project should be finished quickly	8		5
The roads that block the flood should be lined with drainage pipes	2		1

	In Hat Yai	Outside	Total/Average
The trapped water should be drained to the sea	3	4	3
Lopburi Ramet Rd. should be drained before Hat Yai	5		3
Lopburi Ramet Rd. should have more bridges, instead of filling	2		1
Water channels should be clean for better flow	23	48	30
Add drainage channel from Khlong Wa Bridge to U Taphao	2		1
Widen Khlong U-Taphao	2		1
The water from highlands should be blocked	2		1
Question about managing the large amount of water	2		1
The flood should be drained to the area where no people lives	2	4	2
If not agree, what should be done instead			
Hat Yai is not the cause of flood, flood is from Ban Phru -Tunglung	40		33
Agree only if the project is HM King initiation	20		17
Others	40		33

2.3.17 Attitude toward flood warning system, town planning

All respondents agree with flood warning system, because the flood victims might have time to prepare, then the damages could be minimized. Town planning was agreeable by majority of the respondents with having some respondents questioned about this approach (Table 37).

Table 37. Response to question: Do you agree with flood warning system and town planning?

	In Hat Yai	Outside	Total/Average
Agree with flood warning system?			
Yes, because the flood victims may have time to prepare, then the damages could be minimized	100	100	100
Agree with town or land use planning for preventing flood?			
Yes, because it may help reducing flood	56	61	57
No, because to enforce town plan is to make some people suffer	9		6
Preventing was not appropriate because no public informing has been made	3		2
It is a problem solving in long term	7		5
It is doubtful that the propose project is effective	7	4	6
Problem solving should be made at the right place	1		1
Make channels from upstream	1		1

	In Hat Yai	Outside	Total/Average
Did not agree because of using high budget	1		1
Reduce sedimentation in water channels	1		1
There should have a plan before implementation, so that there will have nothing to obstruct water flow	1	7	3
Total town plan should be backed up by law	1		1

2.3.18 Cooperation with the project

If it is necessary to develop the project, assuming in such condition that part of development may need some part or all the land of the respondent for structure construction, how will they cooperate. Positive and negative responses are almost equally split. For those who were willing to cooperate, most of them need compensation at the market rate although a few of them need no compensation at all. The main reason for unwilling to cooperate because they have no other land to live besides this plot. (Table 38)

Table 38. Willingness for cooperation with the project

%

	In Hat Yai	Outside	Total/Average
Willing to donate land, free of charge for project development	6		4
Willing to cooperate but need compensation base on official rate	19	21	19
Willing to cooperate but need compensation base on market rate	39	43	40
Unwilling to cooperate	41	21	36
Depend on other people	1	14	5
Reason for unwilling to cooperate			
Having a small piece of land	24	83	34
Fearing the compensation rate is too low	3		3
Do not want to leave the land	10		9
Having no other land besides this land	62	17	54