Japan International Cooperation Agency (JICA)

Thailand Office

Ministry of Agriculture and Cooperatives

Royal Irrigation Department

The Kingdom of Thailand

The Study
on
Emergency Flood Prevention Planning
for
Hat Yai District, in Khlong U-Taphao River Basin
(FY. 2002)

Final Report

Main Report

November 2002

Sanyu Consultants (Thailand) Limited

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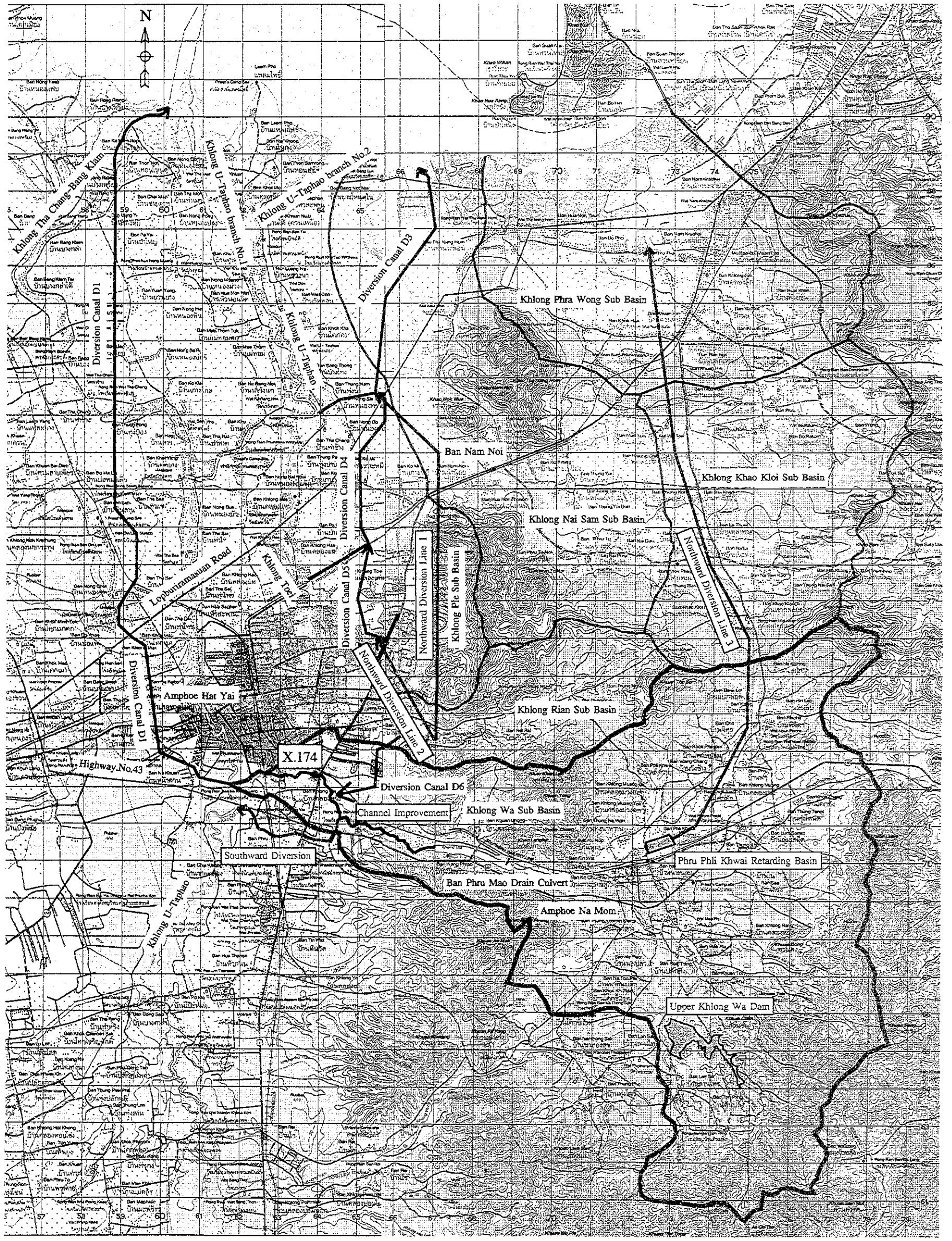


Location Map of Study Area and Proposed Project Components

THE STUDY ON EMERGENCY FLOOD PREVENTION PLANNING FOR HAT YAI DISTRICT IN KHLONG U-TAPHAO RIVER BASIN

SUMMARY

1. Introduction

Hat Yai municipality, an urbanized area of Hat Yai district, is an important economic center of the southern region of Thailand. It has an area of approximately 21 Sq.km. and the population of 157,800 people as of 2001. Hat Yai is located on a low floodplain of the Khlong U-Taphao basin where the Khlong U-Thapao and several tributaries join. Storm water of the Khlong U-Taphao basin rushes to Hat Yai and is finally drained to the Songkhla Lake through the Khlong U-Thapao and its tributaries. However, Hat Yai district has frequently suffered from severe floods due to the insufficient flood protection and drainage systems. In addition, the existing city development where obstruct the natural drainage canal, also cause flood events especially on severe floods in Year 1988 and 2000.

In the Year 2000 flood event, Hat Yai municipal area was attacked by the heavy flash floods of its eastern hilly area in addition to the floods of the Khlong U-Taphao. However, flood prevention measures for the above eastern hilly area have not been established yet.

In response to the request of the Government of Thailand, the Japan International Cooperation Agency (JICA) Thailand Office conducted the study on the flood prevention measures of Hat Yai district, focusing on the floods from the eastern hilly areas during the period of February 2002 to October 2002.

The Study was carried out by a Study Team commissioned by JICA Thailand Office, composed of experts from the Thailand consulting firms; Sanyu Consultants (Thailand) Ltd. and PAL Consultants Co., Ltd. JICA dispatched a Japanese expert to give advises on the study activities of the Team. In the Thailand side, the Office of Budget Programming and Project Planning, Royal Irrigation Department (RID) was responsible to coordinate and manage the implementation of the Study.

2. Objective of the Study

The Objective of the Study is, in order to encourage to establish a system on comprehensive and participatory flood management on Hat Yai municipality and its surrounding areas, to consolidate an idea on the flood management through provision of technical information, such as presenting structural measures for the flood prevention of the downstream reaches of the Khlong Wa, as well as proposing its related organizational arrangements, to the concerned agencies.

3. Area of the Study

The Study Area will cover the Khlong Wa sub-basin with an drainage area of about 120 Sq.km. and related areas in the Khlong U-Taphao basin. The Khlong Wa sub-basin is located on the eastern hilly areas of Hat Yai municipality and the flood runoff from the sub-basin directly affected the Hat Yai Municipality, causing serious damages during the flood event in the year 2000.

4. Existing Flood Mitigation Plan

The government had been implementing the flood prevention plan of the Khlong U-Taphao basin since 1988 when a serious flood disaster occurred in Hat Yai district. The major flood prevention projects included in the plan were:

(i) Dredging of existing channels

(ii) Construction of new diversion channels

(iii) Urban drainage improvement of Hat Yai municipality including construction of polder dikes.

A certain progress had been made in implementation of the dredging of existing channels and urban drainage improvement; however, the construction of new diversion channels had not started yet due to land acquisition problems until November 2000 when the largest flood in the recent years occurred. In February 2001, the government rearranged the previous flood prevention plan in consideration to the flood disaster in November 2000. The proposed flood prevention plan includes both structural and non-structural measures of various agencies.

The proposed structural measures for major flood prevention and urban drainage are as described below.

(1) Dredging of 4 existing channels in the lowermost reaches of the Khlong U-Taphao (Khlong U-Taphao, Khlong U-Taphao branch No.1, Khlong U-Taphao branch 2 and Khlong Tha Chang-Bang Klam)

(2) Construction of 5 new diversion channels (D1, D3, D4, D5 and D6). The total length is approximately 46 km.

(3) Construction of retention ponds in the Khlong Ple basin and a retention pond in the Khlong Rian basin

(4) Construction of Flood Protection Dike on both right and left banks of the Khlong U-Taphao

(5) Improvement of Urban Drainage including with construction of 5 pump stations, improvement of 3 existing pump stations, construction of drainage pipes and culverts, and others.

(6) Construction of 18 Bridges and 2 Culverts on the highways, roads and railway.

(7) Construction of 6 Flood Control Reservoirs in the upper basin of the Khlong U-Taphao and they are under the feasibility study stage.

The following non-structural measures are proposed to supplement the above-mentioned structural measures.

(1) Establishment of Flood Forecasting and Waning System with a telemeter system for the whole basin of the Khlong U-Taphao.

(2) Optimum land use plans are proposed for the whole basin of the Khlong U-Taphao and Hat Yai urban area to cope with flood problems.

(3) Reforestation and Watershed Management including with reforestation in watersheds, improvement of watershed ecology and construction of soil/water conservation weirs.

The above projects will be implemented in three (3) phases: short-term, medium-term and long term. The short-term projects are expected to be mostly completed within 2001. The medium-term projects are supposed to be implemented during 2002 to 2005. Completion of the long-term projects is scheduled to be after 2005.

5. Problem Conditions

The eastern mountainous areas of Hat Yai Municipality compose of 3 sub-basin namely Khlong Ple sub-basin, Khlong Rian sub-basin and Khlong Wa sub-basin. The characteristics and problem of each sub-basin can be described as follows,

5.1 Khlong Ple Sub-basin

The areas from Khao Kho Hong to the low hill are steep slope and connect to the plain that located by Hat Yai Municipality. Flood that happened in this area is flash flood occurred from the rapid flow from the high mountain.

As separated to several sub-basins, the counter measures for flash flood problem on 25 year return period can be activated by small retarding ponds. In case of the larger flood than 25 year, the big retarding pond construction will be faced with the land acquisition problem. Hence, the water diversion method may be the way to alleviate the flash flood problem. At present, the retarding pond to cope with 25 year flood return period near Khao Kho Hong is under construction by the municipality.

5.2 Khlong Rian Sub-basin

General topographic condition is plain surrounded by Khao Kho Hong, Khao Khan Lao and Khuan Ton Sai. The river slope is rather steep and river basin is small. The flash flood occurred in this basin can be mitigated by the retarding basin or water diversion.

Now, Hat Yai Municipality has been constructing the retarding pond. Besides, RID has plan to build the diversion channel from Khlong Rian to Khlong Wa and the feasibility study on reservoir construction in Khlong Rian basin are under going. If these plans are accomplished as scheduled, the flash flood problem in Khlong Rian basin will be solved.

5.3 Khlong Wa Sub-basin

This area is plain surrounded by mountain and high plain. The basin is shaped like a fan. The river slope is steep and causes flash flood from upstream to the river mouth within 2-3 hours. After heavy rain in Khlong Wa basin, the runoff will flow through Khlong Wa and overflow the community along the river banks such as Ban Khlong Wa. If the big flood occur, it will finally flow to Hat Yai municipality as incident in Year 2000.

The countermeasures are determined by construction of Diversion channel D1 from junction of Khlong Wa and Khlong U-Thapao to Songkhla Lake. The new diversion channel will make flood in Khlong Wa flow faster and smoother and the water level effect from Khlong U-Thapao at the junction will be less.

The procedures of this study consist of the following items;

- Estimation of Flood amount in Khlong Wa
- Construction of control structures in order to control the flood in upper Khlong Wa basin.
- Improvement of the existing channel
- Water diversion

6. Study Results

6.1 Hydrologic and Hydraulic Analysis

The Khlong U-Taphao basin covers an area of 2,325 Sq.km. of Songkhla province and flows down 165 km. northward passing through Hat Yai municipality to finally enter the Songkhla Lake. The Khlong U-Taphao drains 1,832 Sq.km. at Hat Yai municipality

The Khlong Wa joins the Khlong U-Taphao on the east bank immediately upstream of Hat Yai municipality. The river drains 118 Sq.km. with a total trunk river length of 22.8 km. at the confluence with the Khlong U-Taphao

The floods of November 1988 and November 2000 are the typical large floods in the recent years. The basin was affected by the continuous rainfalls of a long period on both flood times. The rainfalls in both floods continued for seven (7) days during 18-24 November 1988 and 18-24 November 2000, respectively. The accumulated rainfall of the Khlong U-Taphao and Khlong Wa basins during both floods are shown below.

Item	Total (mm.)
Nov. 1988	
U-Taphao Basin	286.3
Wa Basin	346.5
Nov. 2000	
U-Taphao Basin	532.7
Wa Basin	877.7

The rainfall return periods of the 1988 and 2000 floods in the Khlong U-Taphao and Khlong Wa basins are estimated as follows.

Basin/Rainfall	Return Period of Rainfall	
	1988 Flood	2000 Flood
Khlong U-Taphao Basin		
Maximum 3-Day Rainfall	7-year (255.4 mm)	65-year (401.6 mm)
Maximum7-Day Rainfall	4-year (286.3 mm)	45-year (532.7 mm)
Khlong Wa Basin		
Maximum 3-Day Rainfall	5-year (300.2 mm)	300-year (665.3 mm)
Maximum7-Day Rainfall	3-year (346.5 mm)	300-year (877.7 mm)

The return period of the 2000 flood is estimated at about 50 years in the Khlong U-Taphao basin and 300 years in the Khlong Wa basin.

The 1988 and 2000 floods recorded the following peak water levels at the 3 gauging stations.

River	Station	Peak Water Level (m.msl.)	
		1988 Flood	2000 Flood
Khlong U-Taphao	X 90	10.69	10.79
Khlong U-Taphao	X 44	7.47	8.52
Khlong Wa	X 174	Not Observed	10.91

The flood runoff of the Khlong Wa is estimated by combining the flood runoff simulation of the basin (watershed) and flood routing in the channel (including flood plain). The former simulation is called hydrologic simulation and the latter is hydraulic simulation.

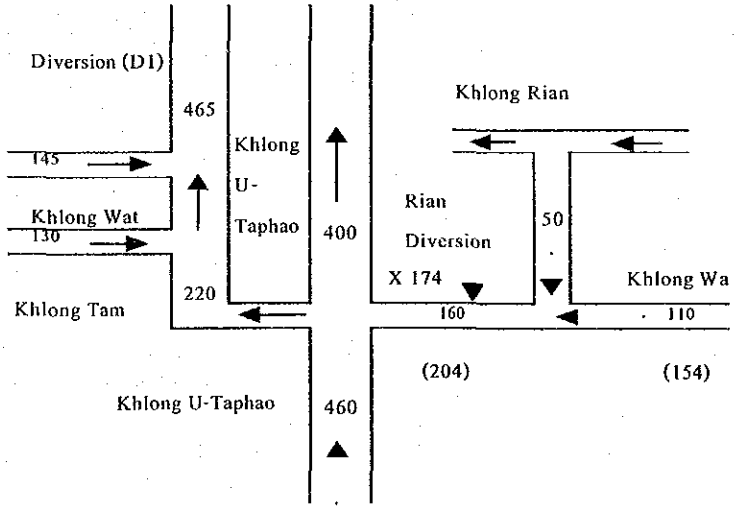
Flood discharge probability of the Khlong Wa is estimated from rainfall probability of its basin since no flood discharge records are available. From this study, the year 2000 rainfall pattern at Kho Hong Agriculture Meteorological Station is not rare and will frequently occur and very close to the studied result median values. Hence, it is adopted as the typical rainfall pattern of the Khlong Wa basin.

The probable peak discharges at St. X 174 are shown below along with that of the 2000 flood.

Item	Probable Flood					2000 Flood
	5-year	10-year	25-year	50-year	100-year	300-year
Peak Discharge at X 174 (cms.)	60	100	154	194	233	367

6.2 Flood Mitigation Project

The existing design discharge of the rivers/diversion channels around Hat Yai municipality is shown below.



The discharge of the Khlong Wa with a 25-year return period is estimated to be154 cms. at St. X 174 excluding the Rian diversion discharge of 50 cms. However, it is considered difficult to increase the design discharge of the Khlong U-Taphao and diversion channel (D1) since their projects are ongoing. Hence, the discharge of 204 cms. at St. X 174 needs to be

reduced to the existing design discharge of 160 cms. by regulating 44 cms. in the upper reaches of the Khlong Wa basin.

The development plans are specified as 2 phases. Phase 1 will be flood control and mitigation in Khlong Wa for 25 year return period flood. The components will be consisted of Flood control dam, Retarding basin and Improvement of the existing channel. The second phase will be the countermeasure to decrease floods over 25 year by northward diversion. The flood in Upper Khlong Bang Not basin or Khlong Khao Kloi basin also will be mitigated as well as flood problem in Ban Nam Noi community.

6.2.1 Flood Mitigation Plan Phase 1

(1) Flood Control Dam

The 12 dam sites had been identified based on the topographic map and field survey and finally Dam sites No. 12 : Upper Khlong Wa Dam is selected for Flood Control Dam, its co-ordinate 47 NPH 733-658 in topographic map sheet No. 5122 IV, or Latitude 6°-55′-31.61″N and Longitude 100°-34′-67.67″ E The dam is located in Ban Plak Thing, Village No.6 in Khlong Rang Sub-district, Na Mom district and it for southeastern 4.30 km. from Na Mom district.

- Catchment Area			18.60	Sq.km
- Elevations	:	Dam Crest	+75.00	m. msl.
		Spillway Crest	+72.00	m. msl.
		River Bed	+43.00	m. msl.
		Dead Storage Level	+48.00	m. msl.
		Normal Water Supply Level	+66.00	m. msl.
		High Water Flood Control Level	+72.00	m. msl.
		Flood Surcharge Water Level	+73.00	m. msl.
- Reservoir Volume	:	Dead Storage	0.30	MCM
		Water Used Storage	4.90	MCM
		Flood Storage	4.70	MCM
		Total	9.90	MCM
- Dam	:	Crest Width	8.00	m.
		Crest Length	800.00	m.
		High	32.00	m.
		Spillway Crest Length	20.00	m.
- Total cost			230.00	million ฿

The Upper Khlong Wa Dam will reduce discharge at St. X 174 from 154 cms. to 128 cms.

(2) Phru Phli Khwai Retarding Basin

Phru Phli Khwai is a swamp located near Ban Phli Khwai village no.4 in Phichit Sub-basin, Na Mom district and about half kilometer northeast of Na Mom district. Its co-ordinate is 47 NPH 725-704 in topographic map, sheet no 5122 IV or Latitude

06°-53′-07.50″ N and Longitude 100°-33′-52.39″ E. It has an area of about 300 rai or 0.5 square kilometers.

-	Catchment Area		48.08	Sq.km
-	Retard Basin (Pond) :	Area	0.50	sq.km.
		Depth	4.00	m.
		Volume	2.00	MCM.
		Normal Water Level	+21.00	m. msl.
-	Surrounding Dike :	Length	3,000.00	m.
		Crest elevation	+22.50	m. msl.
-	Improvement existing channel from the outlet of retarding basin		2.00	km.
-	Outlet works :	Crest elevation	+21.00	m. msl.
		Crest length	40.00	m.
		Sluice Gate, Size 1.00x2.00 m.	1	set
-	Total cost		114.00	million ฿

The Phru Phli Khwai retarding basin can reduce discharge amount at St. X174 from 154 cms. to 142 cms.

(3) Integration of Flood Control Dam and Retarding Basin

The peak discharge at St. X 174 will be reduced from 154 cms. to 118 cms. by integration of the proposed Upper Khlong Wa Dam and Phru Phli Khwai retarding basins.

(4) Improvement of Existing Channel

The calculated discharge of the existing Khlong Wa (118 cms) from this study more than the proposed design discharge (110 cms.), hence the existing capacity of Khlong Wa have to be checked and the narrow section than that estimated discharge shall be enlarged.

It is founded that the existing Khlong Wa from Km. 1+470, railway bridge (Hat Yai - Padang Besa) to km. 9+000 shall be improved. The conceptual design for Khlong Wa is dredging to widen the cross-section and the dredged earth material can be embanked for dike construction.

The section of Khlong Wa between Km. 0+000 to Km. 1+470 and Km. 9+400 to the end of Khlong Wa are unnecessary to be improved. Because the first section is in the flood plain area and no dike in right bank of Khlong U-Taphao. The second section is in flood plain of Khlong Wa and no community in the bank of Khlong Wa.

- For discharge capacity of Khlong Wa : 168 cms. (after the junction of diversion channel D6 and Khlong Rian) between Km 1+470 to Km. 4+200, need to be improved of about 2,030 m.

- For discharge capacity of Khlong Wa : 118 cms. (before diversion channel D6 junction)between Km. 4+200 to Km 9+000, the total channel length of about 3,580 m. need to be improved.

- The total cost is 31 million ฿

(5) Benefits of Phase 1

The total Benefits of flood mitigation project Phase 1 are as follow.

- Total cost in phase 1 (3 Projects) 375.00 Million ฿

NPV	63.33	million ฿
B/C ratio	1.30:1	
IRR/Year	15.33	%

6.2.2 Flood Mitigation Plan Phase 2

Flood control dam and retarding basin in Khlong Wa basin can reduce the peak flood on Khlong Wa to 118 cms. However it still exceed standard capacity of Khlong Wa (110 cms). The improvement of the existing Khlong Wa by enlargement the existing section and dike construction will cause many problems, hence some amount of the peak flood shall be diverted to another basin.

(1) Northward Diversion Channel Line 3

This diversion will be started from Phra Phli Khwai retarding basin in Khlong Wa Basin near Na Mom district, it pass through the Khlong Khao Kloi Sub-basin (Khlong Bang Not basin) and Khlong Phra Wong basin and empty to the Songkhla lake.

The northward diversion channel line 3 will reduce the peak flood in Khlong Wa basin about 40% and reduce the peak flood in Khlong Khao Kloi Sub-basin about 100% (or 60% of Khlong Bang Not Basin at Ban Nam Noi). This line can tackle the frequent flood problem in Ban Nam Noi village.

- Total length 21+802 km.
  Tunnel length 6+560 km.
  Open Channel length 15+242 km.

- Total cost is 1,445 million ฿

(2) Benefit of phase 2

The total Benefit in phase 2 of flood mitigation project (1 project) is as follow:

NPV	80.50	million ฿
B/C ratio	1.09:1	
IRR/year	13.09%	

6.2.3 Total Flood Mitigation Project

The total flood mitigation projects consist of 2 phases and 4 sub-projects. The total benefits of the projects are as follow:

- Total cost in project (4 projects) 1,820 million ฿
  NPV 127.51 million ฿
  B/C ratio 1.13:1
  IRR/year 13.65%

6.2.4 The other Study

The other study is the benefit and cost comparison study between the new project and the project in the old plan, which is not implemented now.

(1) The Northward Diversion Channel Line 1

The northward diversion channel line 1 will be started from retarding pond of Khlong Rian near Ban Thung Don, northward to the RID diversion channel D3. This diversion channel will divert the peak flood from Khlong Rian sub-basin and Khlong Ple sub-basin (or Khao Kho Hong). In this condition, the 3 RID's diversion channels namely D4, D5 and D6 will be cancelled and the RID diversion channel D3 will be enlarged.

- Total length 10+310 km.
  Tunnel length 6+588 km.
  Open channel length 3+722 km.

- Total cost 1,391 million ฿

- The total cost of the northward diversion channel line 1 is higher than the existing plan for RID's diversion channel D4, D5 and D6.(653 million ฿)

(2) The Northward Diversion Channel Line 2

This diversion will be started from retarding pond of Khlong Rian near Ban Thung Don to the middle of RID diversion channel D5. It will divert the peak flood from Khlong Rian sub-basin only. In this condition, the RID diversion channel D6 will be cancelled and the 2 RID's diversion channels (D4 and D5) will be expanded in order to take the increased runoff amount from the northward diversion line 2

- The diversion length (Tunnel) 3+110 km.

- The total cost for this diversion (included new D4 and D5) is 1,073 million ฿

- The northward diversion channel line 2 (sets) cost is more expensive than the RID's diversions channels (653 million ฿).

- The northward diversion channel line 2 cannot be implemented because the RID diversion channels D4 and D5 can not be expanded by limitation of right of way.

(3) The Southward Diversion Channel

The southward diversion channel will divert runoff from Khlong Wa to upstream retarding basin of Khlong U-Taphao located upper the highway No. 43. Its line will be started from Khlong Wa at Km. 5+000 passed Ban Phru sub-district Municipality and crossed the 2 highways and one railway line.

- The diversion length 3+650 km.
  Tunnel 0+800 km.
  Open and Close box culvert 1+200 km.
  Open Channel 1+650 km.

- The total construction cost 165 million ฿

- The southward diversion channel line cost (construction cost only) is expensive than the improvement of existing Khlong Wa (total 31 million Baht), so it is not feasible.

- This diversion will be feasible when the improvement of Khlong Wa at Ban Khlong Wa, Km. 1+470 (Railway : Hat Yai to Badang Besa) to Km. 3+140 can not be done.

6.2.5 Operation Plan

The structural measures in this study can be considered as 2 phases for flood mitigation plan. The first phase plan will be completed after finishing of flood control dam and Phru Phli Khwai retarding basin construction and Khlong Wa improvement. The second phase will be finished after completion of Northward Diversion Channel Line 3 construction. Total construction period will be 7 years. The first phase will be started from the first year to the fourth year and the second phase will be started from the third year to the seventh year. The study and construction periods of the project are depicted as table belows.

Phase 1 Plan	Operation period (year)			
	1	2	3	4
Flood Control Dam				
- Study,Survey and detail design	———	——		
- Land Acquisition		———		
- Construction			———	———
Phru Phli Khwai retarding basin				
- Study,Survey and detail design	———			
- Land Acquisition		———		
- Construction		——	———	———
Improvement of Existing Channel				
- Study,Survey and detail design	———			
- Land Acquisition		——		
- Construction		——		

Phase 2 Plan	Operation period (year)				
	3	4	5	6	7
Northward Diversion Line 3					
- Study,Survey and detail design	———	———			
- Land Acquisition		———	———		
- Construction			——	———	———

7. Flood Damage Survey

The objective of this survey is to estimate the cost of average annual flood damage on Hat Yai district. The estimated damage cost is used for the economic evaluation of the proposed project as the project benefit. The damage costs are estimated for as many items of direct and indirect damages as possible. The damage costs to be estimated include following items

Damage Item	Contents
1. Direct Damage	
(1) Household Damage	House Building, Household Effects
(2) Farm Damage	Crops, Livestock
(3) Infrastructure Damage	Road, Bridge, School, Drainage System, Government Office, etc.
(4) Industrial Damage	Large Factory, Small Industry, Business Office, Hotel, Hospital, etc
2. Indirect Damage	
(1) Wage Loss	Wage Loss
(2) Tourism Revenue Loss	Revenue Loss from Tourist
(3) Other Loss	Transportation, Tele-communication, Evacuation, Secondary Business Loss etc.

The total damage costs of direct and indirect damages are estimated at 7,862 million Baht at 2002 price with the following summarized breakdown.

(Unit: million Baht at 2002 price)

Damage Item	Damage Cost	Remarks
1. Direct Damage	5,670.1	
(1) Household Damage	918.7	
(2) Farm Damage	54.6	
(3) Infrastructure Damage	270.0	
(4) Industrial Damage	4,426.8	
2. Indirect Damage (Tangible)	2,191.4	
(1) Wage Loss	988.5	
(2) Tourism Revenue Loss	1,184.2.	
(3) Flood Preparedness and Relief Cost	18.7	
3. Indirect Damage (Intangible)	-	Secondary business loss, health and sanitation problems, etc.
4. Total	7,861.5	

The average annual flood damage cost of Hat Yai district is estimated at 1,892 million Baht/year.(1-100 years return period). The average annual flood damage cost of Hat Yai district in the future is estimated as follows on the assumption that the damage potential will increase in proportion to the growth of Gross Provincial Product (GPP).The principal area, the benefit from flood damage cost in this study used 25-50 year return period is estimate at 138 million Baht/year.(30% for phase 1 and 70% for phase 2 in flood mitigation plan).The supplement area has benefit from flood damage cost used 1-50 year return period is estimated at 132 million Baht/year.(For phase 2 in flood mitigation plan).

(Unit: million Baht at 2002 price)

Year	Present (2002)	2005	2010	2015	2020
GPP	51,310	55,290	62,592	69,329	76,485
Future Annual Flood Damage					
For principal area					
- 1-100 Yrs. return period	1,892	2,039	2,308	2,556	2,820
- 25-50 Yrs. return period	138	148	168	186	205
For supplementary area					
- 1-50 Yrs. return period	132	142	161	178	196

8. Preliminary Environmental Evaluation

By reviewing the proposed project components, existing environmental conditions in the project area and recommended environmental impact mitigation measures, engineering analysis and economic evaluation of each proposed project component, the following conclusions can be reached:

(1) The Upper Khlong Wa flood control dam is engineeringly and economically feasible. Its main benefits would be related to flood prevention and control, socio-economic improvement, land use development, water quality/public health improvement and tourism development. On the other hand, its significant impacts would be caused by property compensation, relocation of affected people and adverse socio-economic impact on these people. Other adverse impacts would be of minor significance, none of which cannot be solved. So, fair compensation for the lost and affected properties is necessary.

(2) The Phru Phli Khwai retarding basin is a good project component. It is engineeringly, environmentally and economically feasible. Flood reduction would be its important benefit. No serious environmental impact of this project component is anticipated.

(3) The Khlong Wa channel improvement project component is desirable because it would prevent overbank flows after Khlong Wa has received water from the Upper Khlong Wa dam, the Phru Phli Khwai retarding basin and the Khlong Rian diversion discharge. No important adverse environmental impact is anticipated. Actually, there is no need for a further environmental study for this project component.

(4) Four flood water diversion routes are considered and the Northward Diversion Channel line 1 and line 3 are founded to be the good diversion lines in this study, with respect to flood reduction, socio-economic/transportation/tourism benefits. All adverse effects are of a minor importance. This project component is feasible based on engineering, environmental and economic aspects.

The conclusions discussed above can be summarized in Table below;

Project Component	Feasibility Assessment			Further Environmental Study Required
	Engineering	Environmental	Economic	
1. Upper Khlong Wa Flood Control Reservoir	✓✓	✓	✓	IEE
2. Phru Phli Khwai Retarding Basin	✓✓✓	✓✓✓	✓	-
3. Integration of 1 and 2	✓✓	✓✓	✓✓	IEE
4. Northward Flood Diversion Channel line 3	✓✓	✓✓	✓	IEE for selected - Line
5. Khlong Wa Channel Improvement	✓✓✓	✓✓✓	✓✓	-
6. Integration of 3, 4 and 5	✓✓	✓✓	✓✓	IEE for all Project components

Note: ✓ Feasible; ✓✓ Moderately feasible; ✓✓✓ Highly feasible.

9. Comprehensive flood management

The government has prepared a structural plan consisting of various sub-projects for the flood prevention of Hat Yai district. However, the capacity of the structural plan is limited and it can meet only the floods smaller than that of 25-year return period. The existing channels and new diversion channels will overflow when a larger floods than 25-year one occurs, damaging Hat Yai district. Further, disorderly land development of the flood plains will increase flood peak in the downstream, resulting in decrease of the safety factor of the structural plan.

To cope with these problems, the structural plan should be supplemented by non-structural measures to the possible extent. The major and effective non-structural measures for Hat Yai district are considered to be (i) establishment of flood forecasting and warning system and (ii) land use control in flood plain.

According to the interviews, very few people know about the ongoing flood prevention project. Even the people, who know the project, their knowledge is very limited., about 40% of the respondents are willing to offer the land at market price and 20% are willing to cooperate even at official price. However, the others are not willing to cooperate with the projects mainly due to (i) they have only a small piece of land and (ii) they have no other land than the project land.As evident from the above interview survey, more intensive public relations may be necessary for the smooth implementation of the projects.

10. Recommendations

The ongoing structural measures including the dredging of the downstream reaches of the Khlong U-Taphao, construction of the diversion channels (D1, D3, D4, D5 and D6), polder dikes, urban drainage and construction of the related bridges will be successfully implemented under the strong coordination of the existing related committees. Several flood control dams (reservoirs) in the upper Khlong U-Taphao basin are being studied by RID. Improvement of the existing channel, construction of a retarding basin and a flood control dam are proposed for the Khlong Wa basin by this Study. Besides 2 Northward diversion channel lines are considered as other alternatives. Public hearing on the proposed project plan will be made by the concerned agencies (agency that conducts the feasibility study together with local government/organization) before finalization of the project plan.

The existing land use zoning of the lowermost flood plain of the Khlong U-Taphao (located between St. X 90 and highway No.43) should be immediately reviewed. Land filling of the flood plain or reduction of the flooding area by encroachment will change the existing flood behavior in a complicated manner. The land use zoning of this flood plain should be reviewed based on detailed hydraulic simulation in the channels and flood plains. According to the existing coordination system, the Land Development Department is responsible for planning the optimum land use of the entire basin of the Khlong U-Taphao including the Khlong Wa basin. On the other hand, Department of Town and Country Planning is responsible for preparation of the urban development plan of Hat Yai and its surrounding area. Those plans should be prepared in due consideration to the necessary land use control of the flood plains.

In this Study, construction of Upper Khlong Wa dam and Phru Phli Khwai retarding basin is proposed for flood prevention of Hat Yai district. This flood control plan will produce little benefits on the people of Na Mom district although a large land is lost. Hence, the two (2) projects should be planned to produce benefits on both areas of Hat Yai and Na Mom districts to the possible extent. For this purpose, the proposed dam and retarding basin are planned for multiple uses including flood control, water supply, irrigation and other uses. The water use plan should be determined through discussions with the local government/organization and the representatives of the concerned communities. Further, technical information on the project plans should be open to the public to obtain the people's understanding on the projects before finalization of the project plan. The public participation in the project planning will be conducted in the stage of feasibility study.

THE STUDY ON EMERGENCY FLOOD PREVENTION PLANNING FOR HAT YAI DISTRICT IN KHLONG U-TAPHAO RIVER BASIN

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THE STUDY ON EMERGENCY FLOOD PREVENTION PLANNING FOR HAT YAI DISTRICT IN KHLONG U-TAPHAO RIVER BASIN

MAIN REPORT

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Hat Yai municipality, an urbanized area of Hat Yai district, is an important economic center of the southern region of Thailand (see, Fig. 1.1-1). It has an area of approximately 21 sq.km. and the population of 157,800 people as of 2001. Hat Yai is located on a low floodplain of the Khlong U-Taphao basin where the Khlong U-Thapao and several tributaries join. Storm water of the Khlong U-Taphao basin rushes to Hat Yai and is finally drained to the Songkhla Lake through the Khlong U-Thapao and its tributaries (see, Fig. 1.1-2). However, Hat Yai district has frequently suffered from severe floods due to the insufficient flood protection and drainage systems.

In November 1988, a strong tropical depression brought about a heavy rainfall (more than 600 mm.) in a wide area of the southern part of Thailand and caused flood and debris damages at many locations. Hat Yai district was also seriously damaged by this depression.

In December 1988, H.M. the King gave a suggestion relating to the flood mitigation in Hat Yai district, Songkhla province as a guideline for the government to revive and develop the flooding areas not to have the same event occurrences in the future.

According to His Majesty's guideline, the emergency flood prevention measures on the Hat Yai areas were outlined. The flood prevention measures identified dredging of the existing channels as well as construction of diversion channels to reduce flood discharge passing through the urban area.

Thereafter, in November 2000, severe floods affected the southern region of Thailand again. At this time, the largest flood in the recent years attacked Hat Yai district with a total rainfall of more than 600 mm. The government recapitulated the flood prevention measures of Hat Yai district by setting a committee consisting of concerned agencies immediately after the flood.

The committee enumerated possible flood prevention measures including improvement of the existing channels, construction of diversion channels, storage reservoirs, improvement of the existing urban drainage system and setting up of flood forecasting/warning system. Those projects are being studied or arranged for implementation or executed.

In the 2000 flood event, Hat Yai municipal area was attacked by the heavy flash floods of its eastern hilly area in addition to the floods of the Khlong U-Taphao. However, flood prevention measures for the above eastern hilly area have not been established yet. Urgent preparation of the optimum flood prevention measures for this area has been awaited.

In response to the request of the Government of Thailand, the Japan International Cooperation Agency (JICA) Thailand Office conducted the study on the flood prevention measures of Hat Yai district, focusing on the floods from the eastern hilly areas during the period of February 2002 to October 2002.

1.2 Objective of the Study

The objective of the Study is, in order to encourage to establish a system on comprehensive and participatory flood management on Hat Yai municipality and its surrounding areas, to consolidate an idea on the flood management through provision of technical information, such as presenting structural measures for the flood prevention of the downstream reaches of the Khlong Wa, as well as proposing its related organizational arrangements, to the concerned agencies.

1.3 Area of the Study

The Study Area will cover the Khlong Wa sub-basin with an drainage area of about 120 sq.km. and related areas in the Khlong U-Taphao basin. The Khlong Wa sub-basin is located on the eastern hilly areas of Hat Yai municipality and the flood runoff from the sub-basin directly affected the Hat Yai Municipality, causing serious damages during the flood event in the year 2000.

1.4 Implementation of the Study

The Study was carried out by a Study Team commissioned by JICA Thailand Office, composed of experts from the Thailand consulting firms; Sanyu Consultants (Thailand) Ltd. and PAL Consultants Co., Ltd. JICA dispatched a Japanese expert to give advises on the study activities of the Team.

In the Thailand side, the Office of Budget Programming and Project Planning, Royal Irrigation Department (RID) was responsible to coordinate and manage the implementation of the Study.

The Study started in early February 2002 with completion in early October 2002. During the course of the Study, three (3) kinds of reports were presented to RID as follows: Inception Report in early February 2002, Progress Report in late March 2002, Draft Final Report in early September 2002 and Final Report in early October 2002.

Further, summary of the study results was presented in the seminar held by RID in the end of Year 2002.

1.5 Composition of Report

This Report consists of two (2) volumes in English and one (1) volume in Thai, as follows:

Volume I : Main Report

Volume II : Supporting Report

Volume III : Executive Summary Report (Thai version)

The Main Report presents the summarized results of the Study. On the other hand, the Supporting Report gives a further explanation of the studies, as follows:

Appendix A: Socio-economy and Land Use

Appendix B: Hydrologic and Hydraulic Analysis

Appendix C: Flood Damage and Economic Analysis

CHAPTER II KHLONG U-THAPAO AND WA BASIN

2.1 Natural Conditions

2.1.1 River System

(1) Khlong U-Taphao

The Khlong U-Taphao basin covers an area of 2,325 sq.km. of Songkhla province located in the southern part of Thailand. The main river of the basin originates in the mountain range with an elevation of 700 m. msl., located along the Thai-Malaysian border and flows down 165 km northward passing through Hat Yai municipality to finally enter the Songkhla Lake. The lake is open to the Gulf of Thailand.

The main river is usually called the Khlong Sadao for the upper reaches (36 km. distance) of Tambon Sadao municipality and Khlong U-Taphao for the downstream reaches (129 km. distance) of Tambon Sadao municipality. The average river slope of the Khlong U-Taphao with a 129 km. distance is estimated at 1:2,700.

The Khlong U-Taphao drains 1,832 sq.km. at Hat Yai municipality with 15sub-basins as shown in Fig. 1.1-2. The catchment area of each sub-basin is shown below.

No.	Name	C.A. (sq.km.)	No.	Name	C.A. (sq.km.)
1	Khlong Wa	185.7	9	Khlong Po Mo	16.2
2	Khlong Tam	155.6	10	Khlong Pom	31.9
3	Khlong Cham Rai-Hoi Khong	285.4	11	Khlong Tong	90.3
4	Khlong Lam	286.3	12	Khlong Pratu	59.0
5	Khlong Ram Bon	31.1	13	Khlong Phang La	71.5
6	Khlong La Pang	175.3	14	Khlong Prik	61.1
7	Khlong Rian	19.1	15	Khlong Sadao	246.2
8	Khlong Wa	117.6		Total	1,832.3

(2) Khlong Wa

The Khlong Wa joins the Khlong U-Taphao on the east bank immediately upstream of Hat Yai municipality. The river drains 118 sq.km. with a total trunk river length of 22.8 km at the confluence with the Khlong U-Taphao. The Trunk River originated in the Khao Ok Kai runs northward through the hilly area of rubber plantation to the center of the basin where some tributaries join from the east and north. Thereafter, it flows down westward passing through the river valley to join the Khlong U-Taphao.

The Khlong Wa basin is shaped like a fan covering the entire Nam Mom district. The urbanized area of Nam Mom district is located in the center of the basin.

The Khlong Wa basin is divided into eight (8) major sub-basins as shown in Fig. 2.1-1. The divided sub-basin area and river lengths are shown below.

Sub-basin	Catchment Area (sq.km.)	River Length (km)
1. Upper Khlong Wa	24.3	11.0
2. Lower Khlong Wa	34.9	13.1
3. Khlong Na Mom	3.2	1.5
4. Khlong Ban Phli Kwai	7.8	3.5
5. Khlong Muang	22.1	6.5
6. Khlong Ban Sae	10.8	5.0
7. Khlong Ko Wao	7.4	6.5
8. Khlong Hin Dam	7.7	4.5
Total	118.2	

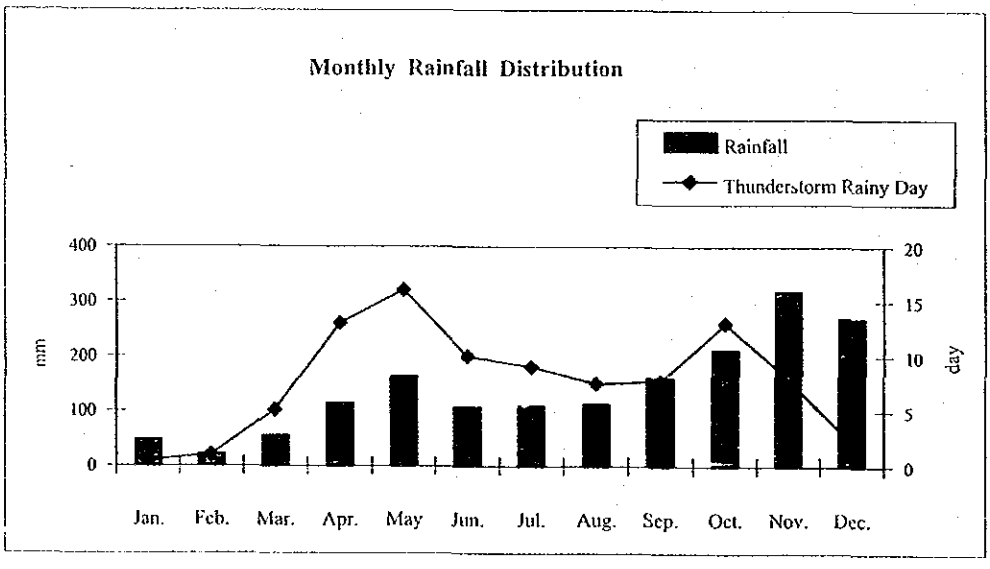
The slope of the trunk river is shown in Fig.2.1-2.

2.1.2 Climate and Hydrology

The climate conditions of the Khlong U-Taphao basin are governed by the seasonal monsoons of the southwest and northeast. The southwest monsoon occurs during May to October, while the northeast monsoon is dominant during November to April. The basin has rainfall nearly all the year round. The rainy period continues from May to December during which in November and December, the basin is affected by a large amount of rainfall. This plenty of rainfall is in part due to the typhoon originating in the South China Sea and passing the basin during November.

The general climates of the Khlong U-Taphao basin including the Khlong Wa basin are presented based on the data of the Hat Yai International Airport as follows. The monthly mean temperature slightly varies from 25.4°C in December to 27.9°C in April with a yearly average of 26.8°C. Monthly rainfall is abundant from October to December and scarce from January to March. The average annual rainfall is estimated at 1,686 mm of which 799 mm or 47% of the total rainfall occurs during October to December, while only 124 mm or 7% is distributed during January to March. The average annual rainy day counts 93 days.

Distributions of the monthly rainfall and thunderstorm rainy day are shown below.



2.1.3 Topography and Geology

(1) Topography

The topographical condition of the study area, mainly said in Khlong U-Taphao basin, where are covered in several Districts; Northern part is Bang Klam District, Central part is Hat Yai District, Southern part is Sadao District, Western part is Khlong Hoi Khong District and Eastern part is Na Mom District. Topographically, in the northern part and central part consist of the flood plain area where is deposited by the alluvial sediment transportation. In the western part is surrounded by parts of mountainous range which similar to the eastern part. And in the southern part is composed of the hilly area. The average elevation is about 20-60 m.msl. for central plain and 100-400 m.msl. for hilly areas and mountainous range. The Bantad-Sankalakhiri mountainous range where is the highest elevation in this area is the natural-boundary line between Thailand and Malaysia.

(2) Geology

The geological condition in the study area consists of 4 rock types; (a)Carboniferous Rock (b)Triassic Rock (c)Igneous Rock (d)Quaternary Deposits as shown in Fig.2.1-3. The description can be explained as following:-

(a) Carboniferous Rock (C)
Rock formation is composed of quartzite, quartzitic sandstone, bedded chert, shale, siliceous shale and siltstone. The color is brown, yellowish-brown, greyish-white, grey, dark-grey, reddish-brown, purple and dark-red. The fossil evidence can be found Brachiopod, Pelecypod and Trilobite. The outcrops are located mainly in western part.

(b) Triassic Rock (TR)
Rock formation consists of conglomerate, sandstone, siltstone, mudstone and shale. The common color is found in greenish-grey to brown. The typical fossil is group of Daonella, Posidonia and Ammonite trace.

(c) Igneous Rock (TrJ_{gr} and KT_{gr})
Main igneous rock is the granite in Mezosoic Era (Jurassic-Triassic and Cretaceous) which intruded through the Carboniferous rock. The typical granite can be found biotite granite, biotite-muscovite granite, and muscovite-tourmaline granite and tourmaline granite. The common texture is porphyritic and exfoliated. The outcrops cover in the western and eastern parts

(d) Quaternary Deposits (Q)
The Quaternary deposits mainly consist of gravel, sand, silt, clay and mud, which are divided into 2 types;

(i) Alluvial deposits (Qa). The deposition occurs in peneplain of several sub-basins Khlong U-Taphao.

(ii) Terrace deposits (Qt). The location of terrace deposits cover to colluvium and around foot of hill. The elevation is about 60-100 m. MSL. The thickness of deposition is vary from 15-20 m.

2.2 Land Use

2.2.1 Existing Land Use

The existing land use of the Khlong U-Taphao basin is classified as shown in the following table based on the land use map prepared by this Study. The existing land use of the Khlong Wa is also shown in the same table.

Category	Khlong U-Taphao Basin		Khlong Wa Basin	
	Area (ha)	(%)	Area (ha)	(%)
1. Urban and Built-up Land	19,212	8.8	229	1.9
2. Agricultural Land	163,820	75.1	11,079	92.3
Para Rubber Plantation	151,028	69.3	8,501	70.8
Rice Field	8,349	3.8	700	5.8
Oil Palm, Orchard and Coconut	3,682	1.7	1,741	14.5
Others	761	0.3	137	1.2
3. Forest Land	30,751	14.1	409	3.4
4. Waterbody	1,728	0.8	-	-
5. Miscellaneous Land	2,566	1.2	292	2.4
Total Land	218,077	100.0	12,009	100.0

The land of the Khlong U-Taphao basin is largely developed for rubber plantation (69%), and urban and village use (9%). Rice land is limited (4%) and it is located in the West Bank lowland of the Khlong U-Taphao. Forest is small (14%) and it is reserved only on the west and southeast mountain ranges.

In the Khlong Wa basin, almost all the land is planted with rubber (71 %). Small rice lands are distributed in the central lowland of the basin. The urban and built-up areas concentrate on the center of the basin and downstream river valley along the highway.

The existing land use map of the Khlong Wa basin is shown in Fig. 2.2-1. For the existing land use map of the whole Khlong U-Taphao basin, see Appendix A Chapter III.

2.2.2 Town Plan of Hat Yai

The comprehensive town plan of Hat Yai district has been prepared according to the ministerial regulations No. 452. The town planning covers the following 10 Tambons (T): T. Nam Noi, T. Khu Tao, T. Kha Kham, T. Khlong Hae, T. Thung Yai, T. Kho Hong, T. Khuang Lang, T. Cha Loong, T. Thung Tam Sao and T. Ban Phru.

The town plan of Na Mom district has not been prepared yet.

The land use zoning of the comprehensive town plan for Hat Yai district is shown in Fig.2.2-2.

2.3 Socio-economy

2.3.1 Administrative Unit

Hierarchy of the local administration is in the order of province, district, tambon and village (or muban). The Khlong U-Thapao basin belongs to Songkhla province. The province is divided into 16 districts of which five (5) districts are included in the Khlong U-Taphao basin. They are: Khlong Hoi Khong, Na Mom, Bang Klam, Sadao

and Hat Yai districts. The five (5) districts are divided into 34 Tambons and further divided into 255 villages.

For local administration, a municipality is organized to administer a large densely populated community, while a Tambon Administration Organization (TAO) is organized to administer all villages within the tambon without overlapping with the municipal area.

The administrative units in the Khlong U-Taphao basin are summarized below.

District	Area (sq.km.)	Nos. of Tambon	Nos. of Village	Nos. of Municipality	Nos. of TAO
Khlong Hoi Khong	275	4	32	-	4
Na Mom	118*	4	29	-	4
Bang Klam	148	4	36	-	4
Sadao	812	9	66	4	8
Hat Yai	814	13	92	3	12
Total	2,167	34	255	7	32

*: Na Mom district area is assumed to completely overlap with the Khlong Wa basin area.

Hat Yai district includes Hat Yai municipality and Tambon Ban Pru municipality.

The Khlong Wa basin covers the entire area of Na Mom district.

2.3.2 Population

(1) Existing Population

The existing population of the Khlong U-Taphao basin is estimated at 464,298 with a population density of 214 person/sq.km. as of 2001. The number of households is estimated to be 133,791 with an average household size of 3.47.

The population and number of households are distributed in each district as shown below. Further, those of Hat Yai municipality are also shown below.

District	Area (sq.km.)	Population	Pop. Density (person/sq.km.)	Nos. of Households	Ave. Size of Household
Hat Yai	814	310,995	382	94,502	3.29
Na Mom	118	20,279	172	5,578	3.64
Sadao	812	84,991	105	21,467	3.96
Khlong Hoi Khong	275	22,216	81	5,459	4.07
Bang Klam	148	25,817	175	6,785	3.81
Total/Average	2,167	464,298	214	133,791	3.47
Hat Yai Municipality	21	157,806	7,515	45,776	3.45

The existing population and number of households in the Khlong Wa basin are estimated as shown below by assuming that Na Mom district area completely overlaps with the Khlong Wa basin.

District	Area (sq.km.)	Population	Pop. Density (person/sq.km.)	Nos. of Households	Ave. Size of Household
Khlong Wa Basin	118	20,279	172	5,578	3.64

(2) Future Population

The future population in the Khlong U-Taphao basin is projected by following the growth trends in the past (1991-2001). The results are shown below. For the growth trends in the past, see Appendix A.

Year	Hat Yai			Na Mom	Other Districts	Total
	Urban	Rural	Total			
2002	163,600	144,600	308,200	20,600	134,200	463,000
2005	170,400	148,100	318,500	21,300	138,200	478,100
2010	181,700	154,100	335,800	22,500	145,000	503,200
2015	192,900	160,000	353,000	23,800	151,700	528,400
2020	204,200	166,000	370,200	25,000	158,400	553,600

2.3.3 Gross Regional Product

(1) Existing Gross Regional Product

The gross provincial product (GPP) of Songkhla province accounts for about 1.6% of the gross domestic product (GDP) of Thailand at present. The GPP in 1999 was 76,617 million Baht with a per capita GPP of 58,846 Baht at 1999 price. The main economic sectors in 1999 were agriculture (35%), services (17%) and wholesale/retail trade (12%). Manufacturing shared nine percent (8%).

The total population of the Khlong U-Taphao in 1999 was 451,330. The gross regional product of the Khlong U-Taphao basin in 1999 is estimated to be 26,559 million Baht at 1999 price by assuming the same per capita GPP of Songkhla.

(2) Future Gross Regional Product

The future gross provincial product (GPP) of Songkhla is projected by following the growth trend in the past (1993-1999), which is the mixture of up and down trends. The projected GPP in the future are summarized below.

(Unit: million Baht)

	2000	2002	2005	2010	2015	2020
GPP (1988 price)	48,878	51,310	55,290	62,592	69,329	76,485
GPP (2002 price)	86,514	90,819	97,863	110,788	122,712	135,378
GPP Growth (times)	-	1.00	1.08	1.22	1.35	1.49

Note: 1) Growth trends in the past are reported at 1988 constant price.
2) Inflation during 1988 and 2002 is assumed to be 1.77 times.

For details, see Appendix A.

2.3.4 Industrial Factory and Commercial Business in Hat Yai District

Hat Yai District is the main industrial area of Songkhla province. Number of the industrial factories, investment amount and number of labor in 2000 are summarized below, compared to those of Songkhla province.

Item	Hat Yai District	Songkhla Province	Ratio (%)
Number of Industrial Factory (Nos.)	652	1,202	54
Investment (million Baht at 2000 price)	15,783	27,592	57
Number of Labor (person)	32,774	66,664	49

The factories produce marine food products, rubber base products, rubber wood processing, and metal/chemical products for local demand and others. In 2000, 7,520 commercial businesses are registered in Hat Yai district.

Hat Yai District is the main Anchor City for across border trade with Malaysia and Singapore. Hat Yai imported value of 45,198 million Baht and exported value of 126,927 million Baht in 2000.

2.3.5 Tourism Industry in Hat Yai District

(1) Existing Tourism Industry

In 2000, about 4.4 million tourists visited Hat Yai District with an average stay of 2.14 days. They spent 27,861 million Baht with an average one person per day expenditure of 2,960 Baht. Breakdowns of the domestic and foreign tourists are shown below.

Item	Domestic	Foreign	Total
Tourist Number (1,000 person)	2,668	1,734	4,402
Average Stay (day)	2.09	2.21	2.14
Revenue from Tourist (million Baht)	13,870	13,991	27,861

There are 96 hotels, guesthouses and other accommodations with a total room of 9,174.

(2) Future Tourism Industry

The yearly number of tourists visited Hat Yai District varied irregularly during 13 years (1988-2000). However, the aggregate trend during the whole period is a minimal increase.

The future tourist number is projected following the growth trend in the past as shown below. On the other hand, the average length of stay is assumed to be the same as in 2000.

Item	2000	2002	2005	2010	2015	2020
Domestic Tourist (1,000 person)	2,668	2,555	2,589	2,662	2,775	2,887
Foreign Tourist (1,000 person)	1,734	1,581	1,585	1,594	1,605	1,635
Total (1,000 person)	4,402	4,136	4,174	4,256	4,380	4,522
Average Stay (day)	2.14	2.14	2.14	2.14	2.14	2.14

For details, see Appendix A.

2.4 Existing Flood Mitigation Plan

2.4.1 General

The government had been implementing the flood prevention plan of the Khlong U-Taphao basin since 1988 when a serious flood disaster occurred in Hat Yai district. The major flood prevention projects included in the plan were:

(i) Dredging of existing channels,

(ii) Construction of new diversion channels and

(iii) Urban drainage improvement of Hat Yai municipality including construction of polder dikes.

A certain progress had been made in implementation of the dredging of existing channels and urban drainage improvement; however, the construction of new diversion channels had not started yet due to land acquisition problems until November 2000 when the largest flood in the recent years occurred.

In February 2001, the government rearranged the previous flood prevention plan in consideration to the flood disaster in November 2000. The proposed flood prevention plan includes both structural and non-structural measures of various agencies. The plan is summarized below.

2.4.2 Design Flood Discharge Distribution

The structural flood prevention measures of Hat Yai district were proposed to meet the flood with a 25-year probability. The design flood discharge is distributed to the existing channels and new diversion channels based on the following flood prevention policies.

(1) Floods from the upper Khlong U-Taphao and Khlong Wa are discharged by improving the existing channel of the Khlong U-Taphao and constructing a new diversion channel (D1).

(2) Entrance of the Khlong Toci is closed and it drains only internal water of Hat Yai municipality.

(3) Flood from the Khao Kho Hong area is discharged by constructing new diversion channels (D3, D4 and D5).

(4) Flood from the Khlong Rian basin is diverted to the Khlong Wa by constructing a new diversion channel (D6).

(5) Retention ponds are proposed for the Khlong Ple and Khlong Rian basins to reduce the design flood discharge of the diversion channels (D3, D4, D5 and D6).

(6) Hat Yai municipality is enclosed by a polder system and the internal water is drained by improving the existing drainage system.

The design discharge distribution to the existing channels and new diversion channels are shown in Fig. 2.4-1.

2.4.3 Proposed Structural Measures

The proposed major flood prevention and urban drainage projects are as described below.

(1) Dredging of Existing Channels: Four (4) existing channels in the lowermost reaches of the Khlong U-Taphao (Khlong U-Taphao, Khlong U-Taphao branch No.1 and No.2 and Khlong Tha Chang-Bang Klam) are dredged. Total budget is 91 million Baht. The executing agency is RID.

(2) Construction of New Diversion Channels: Five (5) new diversion channels (D1, D3, D4, D5 and D6) are constructed. The total length is approximately 46 km. Total budget is 1,800 million Baht. The executing agency is RID.

(3) Construction of Retention Pond: Several retention ponds in the Khlong Ple basin and a retention pond in the Khlong Rian basin are constructed to control the flood runoff from the eastern hilly areas of Hat Yai municipality. Total budget is 310 million Baht. The executing agency is Hat Yai municipality.

(4) Construction of Flood Protection Dike: Flood protection dikes are constructed on both right and left banks of the Khlong U-Taphao to protect Hat Yai municipal area. Total budget is 383 million Baht. The executing agency is Hat Yai municipality.

(5) Improvement of Urban Drainage: The urban drainage of Hat Yai municipality is improved. The project includes construction of five (5) pump stations, improvement of three (3) existing pump stations, construction of drainage pipes and culverts, and others. Total budget is 709 million Baht. The executing agency is Hat Yai municipality.

(6) Construction of Bridges and Culverts: 18 brides and two (2) culverts are constructed on the highways, roads and railway in relation to the above-mentioned flood prevention measures. Total budget is 91 million Baht. The executing agencies are Department of Highways, Public Works Department, Department of Rural Development Acceleration and State Railways of Thailand.

(7) Construction of Flood Control Reservoirs: Flood control reservoir is considered as a long-term project to increase the safety factor against the flood disaster of Hat Yai district. Six (6) reservoirs were identified in the upper basin of the Khlong U-Taphao for feasibility study. The executing agency is RID.

Locations of the above major projects are shown in Fig. 2.4-2.

2.4.4 Proposed Non-structural Measures

The following non-structural measures are proposed to supplement the above-mentioned structural measures.

(1) Establishment of Flood Forecasting and Waning System: A flood forecasting and warning system with a telemeter system is established for the whole basin of the Khlong U-Taphao. For this purpose, necessary automatic rainfall and water gauging stations are installed and flood runoff simulation model is established. The executing agencies are RID for flood forecasting and warning system, RID/Meteorological Department for installation of automatic rainfall/water gauging stations.

(2) Land Use Planning: Optimum land use plans are proposed for the whole basin of the Khlong U-Taphao and Hat Yai urban area to cope with flood problems. The executing agencies are Land Development Department for land use planning of the

whole basin and Department of Town and Country Planning for greater Hat Yai urbanization plan.

(3) Reforestation and Watershed Management: The project is proposed as a long-term one. The project includes (i) reforestation in watersheds, (ii) improvement of watershed ecology (iii) construction of soil/water conservation weirs. The executing agency is Royal Forest Department.

2.4.5 Implementation Program and Progress

The above projects will be implemented in three (3) phases: short-term, medium-term and long term. The short-term projects are expected to be mostly completed within 2001. The medium-term projects are supposed to be implemented during 2002 to 2005. Completion of the long-term projects is scheduled to be after 2005. The original implementation program and actual progress of each project are summarized below.

(1) Short-term

Project	Progress
Dredging of Existing Channels	Completed.
Construction of New Diversion Channels	Delayed due to land acquisition problems. Expected to start in 2003.
Improvement of Urban Drainage (Urgent Projects)	Urgent projects (construction. of 2 new Pumping.Station, improvement of 3 existing Pumping Station and const. of drainage pipes) are almost completed.
Construction of Bridges and Culverts	Will be completed within 2002
Establishment of Flood Forecasting and Waning System	Installation of automatic gauging stations will be completed within 2002. Study and design of flood forecasting/warning system will be completed within 2002.
Land Use Planning (Part)	Land use planning for whole basin will be completed within 2002. Study on Hat Yai urbanization plan is almost completed.

(2) Medium-term

Project	Remarks
Construction of Retention Pond	Several in Khlong Ple basin, 1 in Khlong Rian basin
Construction of Flood Protection Dike	Khlong U-Taphao river banks
Improvement of Urban Drainage (Remaining Projects)	Construction of 3 new Pumping.Station, Construction. of drainage pipes/culverts and others.
Survey/Design of Flood Control Reservoirs	Six (6) reservoirs
Land Use Planning (Remaining)	Improvement of Hat Yai urbanization plan

(3) Long-term

Project	Remarks
Construction of Flood Control Reservoirs	*Project will be authorized after feasibility study.*
Reforestation and Watershed Management	Upstream watersheds

CHAPTER III HYDROLOGIC AND HYDRAULIC ANALYSIS

3.1 Hydrologic Records and Analysis in Khlong U-Thapao and Khlong Wa Basin

3.1.1 Rainfall

(1) Available Data

Daily rainfall data are available at 35 stations in and around the Khlong U-Taphao basin of which the following seven (7) stations are located in and around the Khlong Wa basin.

Code	Name	Available Period	Authority
58022	A. Hat Yai	1952-2001	MED
58112	Kho Hong Agricultural Meteorological Station	1954-2001	MED
58210	Khlong Wad Irrigation Project A. Hat Yai	1975-2001	RID
58232	A.Na Mom	1982-2001	MED
58332	Hat Yai International Airport	1981-2001	MED
58410	Na Thongsuk School	2000-2001	RID
58420	Khlong U-Taphao (X 90) B. Bang Sala	2000-2001	RID

Note: MED: Meteorological Department, RID: Royal Irrigation Department

For location of the 35 rainfall stations, see Fig. 3.1-1. For their inventories, refer to Appendix B.

However, hourly rainfall observation is limited to the following six (6) stations.

Code	Name	Daily Data	Hourly Data		Authority
		Period	Interval	Period	
58013	A. Muang C. Songkhla	1952-2001	3-hour	1981-2001	MET
58112	Kho Hong Agriculture Meteorological St.	1954-2001	3-hour	1999-2001	MET
58221	Khlong La Pang (X 113) A. Sadao	1980-2001	Automatic	2000-2001	RID
58332	Hat Yai International Airport	1981-2001	3-hour	1981-2001*	MET
58341	Khlong U-Taphao (X 173) B. Khlong Ngae	1989-2001	Automatic	1989-2001	RID
568401	Sadao Hydro-meteorological Station	1998-2001	3-hour	1998-2001	MET

*: No data are available for the years of 1985 and 1988.

Among the above six (6) stations, two (2) stations (Kho Hong Agriculture Meteorological Station and Hat Yai International Airport) are located around the Khlong Wa basin.

(2) Rainfall Distribution of Historical Floods

The floods of November 1988 and November 2000 are the typical large floods in the recent years. The basin was affected by the continuous rainfalls of a long period on both flood times. The rainfalls in both floods continued for seven (7) days during 18-24 November 1988 and 18-24 November 2000, respectively.

The daily rainfall distribution of the Khlong U-Taphao and Khlong Wa basins during both floods are shown below.

Item	Daily Rainfall Distribution (mm)							Total
	18 Nov.	19 Nov.	20 Nov.	21 Nov.	22 Nov.	23 Nov.	24 Nov.	
Nov. 1988								
U-Taphao Basin	15.8	50.3	134.7	70.4	6.6	8.4	0.1	286.3
Wa Basin	20.5	67.0	160.4	72.8	13.9	11.9	0.0	346.5
Nov. 2000								
U-Taphao Basin	29.2	26.6	53.5	174.9	157.8	68.9	21.8	532.7
Wa Basin	37.9	54.9	104.6	409.2	139.7	116.4	15.0	877.7

Spatial distribution of the total rainfalls of the above two (2) floods in the Khlong U-Taphao basin is shown in Fig. 3.1-2 and Fig. 3.1-3.

The rainfall in November 1988 distributed over the whole basin in a comparatively uniform pattern. However, the rainfall in November 2000 concentrated in the eastern hilly area of Hat Yai municipality including the Khlong Wa basin.

(3) Rainfall Frequency

The return periods of the maximum one (1) day, three (3) days, five (5) days and seven (7) days rainfalls in the Khlong U-Taphao and Khlong Wa basins are calculated as shown below.

Basin/Rainfall	Return Period (year)				
	5	10	20	100	500
Khlong U-Taphao Basin					
1-Day Rainfall (mm)	140.8	165.9	189.9	244.4	298.2
3-Day Rainfall (mm)	228.4	275.4	320.5	422.7	523.8
5-Day Rainfall (mm)	274.5	329.8	382.9	503.0	621.8
7-Day Rainfall (mm)	321.9	388.7	452.8	597.9	741.5
Khlong Wa Basin					
1-Day Rainfall (mm)	174.5	209.4	243.0	319.0	394.3
3-Day Rainfall (mm)	299.2	362.6	423.3	560.9	697.1
5-Day Rainfall (mm)	354.6	427.7	497.8	656.5	813.7
7-Day Rainfall (mm)	402.1	484.1	562.7	740.8	917.1

From the above calculations, the rainfall return periods of the 1988 and 2000 floods in the Khlong U-Taphao and Khlong Wa basins are estimated as follows.

Basin/Rainfall	Return Period of Rainfall	
	1988 Flood	2000 Flood
Khlong U-Taphao Basin		
Maximum 3-Day Rainfall	7-year (255.4 mm)	65-year (401.6 mm)
Maximum7-Day Rainfall	4-year (286.3 mm)	45-year (532.7 mm)
Khlong Wa Basin		
Maximum 3-Day Rainfall	5-year (300.2 mm)	300-year (665.3 mm)
Maximum7-Day Rainfall	3-year (346.5 mm)	300-year (877.7 mm)

The return period of the 2000 flood is estimated at about 50 years in the Khlong U-Taphao basin and 300 years in the Khlong Wa basin.

3.1.2 Water Level and Discharge

(1) Available Data

The water level has been observed at 12 water gauging stations of the Khlong U-Taphao and its tributaries. For location of the stations, see Fig. 3.1-1. For their inventories, refer to Appendix B.

Among them, water level and discharge data at the following three (3) stations: X 44, X90 and X 174 are important to evaluate the floods on Hat Yai district. Flood of the upper Khlong U-Taphao basin is collected at St. X 90 and thereafter, flows down through the flood plain located between St. X 90 and Highway No.43. The flood peak is largely regulated by this flood plain. The regulated flood reaches St. X 44 after being joined by the flood of the Khlong Wa immediately downstream of the highway No.43.

The inventory of the three (3) stations is shown below.

Code	River	Catchment Area (sq.km.)	Water Level		Discharge Data
			Gauge Type	Period	Period
X 90	Khlong U-Taphao	1,562	Staff, Automatic	1971-2001	1971-2001
X 44	Khlong U-Taphao	1,740	Staff	1967-2001	1967-1988, 1999-2001
X 174	Khlong Wa	115	Staff	1989-2001	-

No discharge has been observed at St. X 174 of the Khlong Wa. Even at St. X 90 and St. X 44, no large flood discharge has been observed since water overflows the riverbanks at a large flood time.

(2) Records of Historical Flood

The 1988 and 2000 floods recorded the following peak water levels at the three (3) gauging stations. The peak discharges of both floods were not observed even at St. X 90 and St. X 44 since the floodwater overflowed the riverbanks.

River	Station	Peak Water Level (m.msl.)		Estimated Peak Discharge (cms.)	
		1988 Flood	2000 Flood	1988 Flood	2000 Flood
Khlong U-Taphao	X 90	10.69	10.79	Not Observed	Not Observed
Khlong U-Taphao	X 44	7.47	8.52	Not Recorded	Not Observed
Khlong Wa	X 174	Not Observed	10.91	-	-

3.2 Flood Runoff Simulation of Khlong Wa Basin

3.2.1 Methodology

The Khlong Wa is divided into three (3) parts: upper reaches (upstream of Na Mom), middle reaches (between Na Mom and St. X 174) and lower reaches (downstream of St. X 174).

Storm water in the upper sub-basin runs off to Na Mom through a number of small streams. The floodwater is retarded in the flood plain located immediately upstream of Na Mom. Thereafter, the floodwater runs through the river valley from Na Mom to St. X 174, collecting the storm water runoff from the middle reach sub-basin. The floodwater is again retarded in the flood plain of the river valley in the middle

reaches. In the lower reaches, the floodwater of the Khlong Wa is affected by the backwater of the Khlong U-Taphao.

The flood retarding effects of the flood plains and by the backwater are considered significant. Accordingly, the flood runoff of the Khlong Wa is estimated by combining the flood runoff simulation of the basin (watershed) and flood routing in the channel (including flood plain). The former simulation is called hydrologic simulation and the latter is hydraulic simulation in this Report.

The flood runoff of the Khlong Wa is simulated through the following procedures.

(1) There is no available hourly rainfall data within the Khlong Wa basin. However, data of 3-hour rainfall are available only for the recent two (2) years of 2000-2001 at Kho Hong Agriculture Meteorological Station (code: 58112), which is located outside the basin but close to the northwest basin boundary. Hence, the 3-hour rainfall data of the 2000 flood at this station are used for construction of the hydrologic simulation model.

(2) There is no available discharge data in the basin. Therefore, the hydrologic simulation model is constructed by using the simulation model constructed for a similar sub-basin in the Khlong U-Taphao basin in terms of catchment area, topography, land use and geology. The Khlong La Pang sub-basin is only one (1) similar sub-basin where hourly rainfall and discharge data are available.

(3) The hydraulic simulation model is constructed by inputting the conditions of channel profile/cross-section, topographic conditions of flood plain, bottlenecks in channel and hydraulic boundary conditions at the lowermost channel section.

(4) The integrated flood runoff simulation model of hydrologic and hydraulic models is calibrated for the 2000 flood by comparing the calculated river water levels and the flood marks obtained by an interview survey.

3.2.2 Hydrologic Simulation

(1) Construction of Simulation Model

A commercial model called RUNOFF-CASH (Conceptual Analysis and Synthesis of Hydrographs) is used for the simulation. As implied by the name, it is a conceptual model, which simplifies the hydrologic cycle. The dominant processes of losses, storage and transfer are presented adequately to analyze rainfall and runoff time series, and to synthesize the hydrological processes depending on the catchment scale. For details, see Appendix B.

The hydrologic simulation model of the Khlong Wa is constructed by calibrating the flood runoff simulation model of the Khlong La Pang sub-basin for the 2000 flood. The Khlong La Pang is one of the upstream tributaries joining the Khlong U-Taphao immediately upstream of Sadao municipality. It drains 129 sq.km. at the water gauging station (X 113) where hourly rainfall and discharge were observed at the 2000 flood.

The calibrated results of the 2000 flood in the sub-basin (X.113) are shown in Fig. 3.2-1. For details, see Appendix B.

(2) Hydrologic Simulation of Khlong Wa

The Khlong Wa basin is divided into 15 sub-basins as shown in Fig. 3.2-2. Using the model constructed for the Khlong La Pang basin simulates the flood runoff of each sub-basin at the 2000 flood. The 3-hour rainfall data at Kho Hong Agriculture Meteorological Station of the 2000 flood is used for the simulation.

The total rainfall during 18-24 November 2000 is 878 mm with the hourly rainfall distribution shown in Fig. 3.2-3. This rainfall is applied for all the 15 sub-basins. The flood discharge hydrograph of unit area is estimated as shown in the same Figure.

The simulated flood peak of each sub-basin is summarized below.

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

3.2.3 *Hydraulic Simulation*

(1) Construction of Simulation Model

A commercial model called MIKE 11 is used for this hydraulic simulation. This is a one-dimensional mathematical model developed based on full hydrodynamic equation or the St Venant Equations. The components of the model include stream channel network, flood plain, bridge, road intersecting flood plain, weirs, swamp, and retarding basin. The model calculates flood flow through channel network/flood plain, flood retarding in flood plain/swamp/retarding basin, and flood flow obstruction by bridge/weir/road.

The major used data include river profile/cross-section, topographic map (1: 10,000) of flood plain, bridge opening and elevation, and road elevation.

Fig. 3.2-4 shows the schematic diagram of the mathematical model under the existing conditions of the flood plain.

The water level at the confluence of the Khlong Wa with the Khlong U-Taphao is the most basic hydraulic boundary condition of the model. The water level is estimated from those at St. X 44 and St. X 90. For details, see Appendix B.

(2) Model Calibration for the 2000 Flood

The constructed hydraulic simulation model is calibrated by comparing the computed water levels with the flood marks of the 2000 flood at several locations between St. X 174 and the 10.8 km river distance.

The flood runoffs of 15 sub-basins calculated by the hydrologic simulation model are put into the hydraulic model. Then, the water level at each river section along the Khlong Wa is calculated by the hydraulic simulation model. The water level at the confluence with the Khlong U-Taphao is estimated from the water level records at St. X 44 and St. X 90 to provide the downstream hydraulic boundary condition of the model. The estimated maximum water level at the confluence is 9.99 m msl.

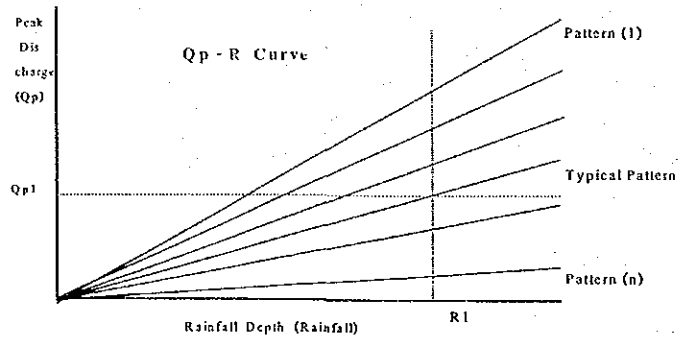
The computed maximum water levels are more or less in agreement with the flood marks as shown in Fig.3.2-5.

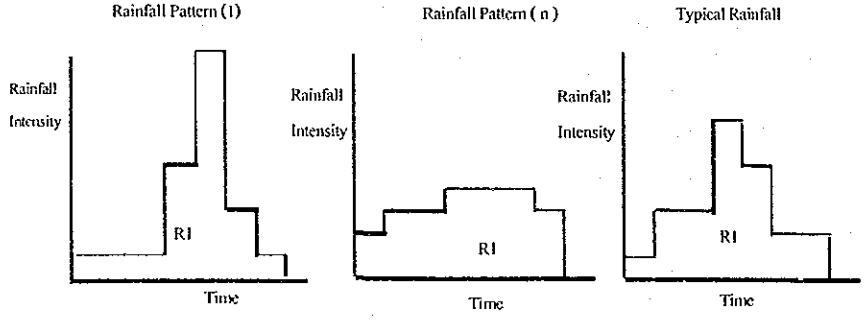
(3) Simulation of 2000 Flood

The simulated maximum water level profile of the Khlong Wa at the 2000 flood is estimated as shown in Fig. 3.2-5. The flood discharge hydrograph at St. X 174 is shown in Fig. 3.2-6.

3.3 Typical Rainfall Pattern of Khlong Wa Basin

Flood discharge probability of the Khlong Wa is estimated from rainfall probability of its basin since no flood discharge records are available. However, the flood discharge varies according to the temporal distribution pattern of rainfall even if the rainfall depth is equal. Rainfall of concentrated (sharp) distribution pattern generates a larger flood peak discharge than that of flat distribution pattern. Hence, the flood discharge with a certain probability is estimated by simulating the rainfall of typical temporal pattern with the corresponding probability. For the above discussions, see the following figure.





In the above figure, the fringe patterns of Qp-R curves: pattern (1) and pattern (n) are considered rare. The central pattern of Qp-R curves may frequently occur. In this Study, the typical rainfall pattern is assumed to be the rainfall pattern that gives the median of the simulated peak discharges.

The typical temporal rainfall pattern of the Khlong Wa basin is selected from among the actual hourly (3-hour) rainfall records at Hat Yai International Airport since the hourly (3-hour) rainfall records at Kho Hong Agriculture Meteorological Station (the nearest station of the Khlong Wa basin) are limited to the period of 2000-2001. Sixteen (16) storm rainfalls have been observed at Hat Yai International Airport since 1981 when rainfall observation started. Three (3) hour rainfall data are available for the all storm rainfalls.

On the other hand, the storm duration to analyze temporal pattern is assumed to be three (3) days from the following reasons.

(1) Most of the storms continued for more than two (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 or stored in the basin.

(3) The 2000 flood continued for one (1) week with the concentrating period of three (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.

On the other hand, the maximum 3-day rainfall with a 25-year probability* in the Khlong Wa basin is estimated to be 450 mm. Hence, the flood peak discharge to be generated from unit area of the Khlong Wa basin by the rainfall of 450 mm is estimated for the above 16 storm rainfall patterns. The results are shown below.

Note: *: The flood mitigation plan of the Khlong U-Taphao is prepared to meet the flood with a 25-year return period

Order	Rainfall		Unit Area Peak Discharge (mm)	Order	Rainfall		Unit Area Peak Discharge (mm)
	Pattern	Record (mm)			Pattern	Record (mm)	
1	1992	170.6	10.57	10	1987	217.3	3.50
2	1999	135.1	5.25	11	2000	467.9	3.45
3	1983	230.2	4.98	12	1984	157.4	3.45
4	2001	130.9	4.35	13	1994	114.1	3.45
5	1990	106.0	4.01	14	1997	155.1	2.93
6	1998	73.4	3.98	15	1986	185.0	2.45
7	1996	83.3	3.70	16	1991	138.2	2.19
8	1995	136.8	3.63	**(Kho Hong)**	**(2000)**	**(597.7)**	**3.67***
9	1993	136.0	3.59				

*: Peak runoff of the 2000 flood simulated by the rainfall pattern at Kho Hong Agriculture Meteorological St.

The median peak discharge per unit area is estimated at 3.63 mm of the year 1995 rainfall pattern or 3.59 mm of the year 1993 rainfall pattern. On the other hand, the unit area peak discharge of the year 2000 rainfall pattern at Kho Hong Agriculture Meteorological Station is 3.67 mm that is very close to the above-mentioned median values. This rainfall pattern is not rare and will frequently occur.

From the above discussions, the year 2000 rainfall pattern at Kho Hong Agriculture Meteorological Station is adopted as the typical rainfall pattern of the Khlong Wa basin. The typical rainfall pattern of the Khlong Wa basin is illustrated in Fig. 3.3-1.

3.4 Probable Flood Discharge and Water Level of Khlong Wa

The flood discharges of various return periods (5, 10, 25, 50 and 100 years) in the Khlong Wa are estimated by simulating the typical pattern rainfalls of corresponding return periods.

3.4.1 Flood Runoff of Basin

The flood runoff of 15 sub-basins is calculated for the rainfalls of 5, 10, 25, 50 and 100 years return periods. The peak discharges of each basin corresponding to the above return periods are summarized below, compared to those of the 2000 flood. In this calculation, the probable rainfalls of various return periods are estimated for the maximum 7-day rainfall.

Sub-basin		Peak Discharge at Various Return Period (cms.)					2000 Flood
No.	C.A.	5-year	10-year	25-year	50-year	100-year	300-year
	(sq.km.)	(402.1 mm)	(484.1 mm)	(595.0 mm)	(675.0 mm)	(740.8 mm)	(877.7 mm)
1	2.9	2.8	4.2	6.3	7.8	9.4	12.2
2	5.3	5.2	7.7	11.4	14.3	17.2	22.4
3	2.3	2.2	3.3	5.0	6.2	7.5	9.7
4	1.9	1.9	2.8	4.1	5.1	6.2	8.0
5	5.5	5.4	8.0	11.9	14.8	17.9	23.2
6	1.1	1.1	1.6	2.4	3.0	3.6	4.6
7	2.1	2.0	3.0	4.5	5.7	6.8	8.9
8	3.3	3.2	4.8	7.1	8.9	10.7	13.9
9	3.2	3.1	4.6	6.9	8.6	10.4	13.5
10	7.4	7.2	10.7	16.0	19.9	24.0	31.2
11	8.8	8.6	12.8	19.0	23.7	28.6	37.2
12	1.5	1.5	2.2	3.2	4.0	4.9	6.3
13	21.5	21.0	31.2	46.4	57.9	69.8	90.8
14	19.0	18.5	27.6	41.0	51.1	61.7	80.2
15	32.4	31.6	47.0	69.9	87.2	105.2	136.8

Note: Probable rainfall depth is the maximum 7-day rainfall

3.4.2 Probable Discharge and Water Level

The discharge and water level hydrographs at each river section of the Khlong Wa are calculated for the basin flood runoffs of 5, 10, 25, 50 and 100 years return periods.

The discharge hydrographs of 5, 10, 25, 50 and 100 years return periods at St. X 174 are shown in Fig. 3.4-1, compared with the discharge hydrograph of the 2000 flood. The probable peak discharges at St. X 174 are shown below along with that of the 2000 flood.

Item	Probable Flood					2000 Flood
	5-year	10-year	25-year	50-year	100-year	300-year
Peak Discharge at X 174 (cms.)	60	100	154	194	233	367

The maximum water level profiles of the Khlong Wa of 5, 10, 25, 50 and 100 years return periods are shown in Fig 3.4-2, compared with that of the 2000 flood.

In the hydraulic simulation of various probable floods, the boundary conditions (water level hydrographs of various return period at the confluence with the Khlong U-Taphao) were given from the estimated probable water level hydrographs at St. X 44 and St. X 90.

3.4.3 Retarding Effects in the Flood Plain

There are two (2) large flood plains in the upstream of St. X 174. One is located immediately upstream of Na Mom and another is located in the river valley between Na Mom and St. X 174. These flood plains regulate flood peak. The flood retarding effect in the upper river reaches of St. X 174 is estimated for the flood of 25-year return period as shown below.

Condition	25-Year Probable Peak Discharge At St. X 174 (cms.)
Existing Condition	154
Without Flooding Condition	178
Retarding Effect in Flood Plain	24

3.5 Flood Risk Map in Khlong Wa Flood Plain

From model simulation study, the water level in flood plain of Khlong Wa basin for various flood return periods are calculated. Fig.3.5-1 show the boundary of flood plain in 5 years, 25 years return period and flood in year 2000. The 5 years return period boundary is considered as the flood risk water level in Khlong Wa.

3.6 *Flooding Area from Satellite Image*

Satellite images from Satellite so called Landsat-5TM (Nov.5,1989) and ERS2 (Nov.18,1999)show the frequent flooded area in Khlong Wa basin. The main flooded area are composed of 3 sub basin including with some area in Khlong Ko Wao. The sub basin area can be seen from Fig.2.1-1 and the flooded sub basin are listed below,

1. Khlong Ban Phli Khwai , sub basin area no. 4
2. Khlong Muang , sub basin area no. 5
3. Khlong Ban Sae , sub basin area no. 6

For Bang Not river basin or Ban Nam Noi river basin in upper area of Khlong Khao Kloi sub basin, flooded area are spread widely in Khlong Khao Kloi, Khlong Saphan Pun and Khlong To Fai. For details, see Appendix G.