CHAPTER 3 ESTIMATED DAMAGE

3.1 Estimated Flood Damage Cost

Although the targets of flood prevention areas are Hat Yai Municipality, Na Mom Districts, and Kor Hong TAO, however it is found during the course of study that, when second phrase of the project will be developed, the structures will not only prevent floods in the targeted area but also prevent floods for other areas. By this reason, the damage areas are classified into principal area, which is the originally planned targeted area as one, and supplementary area, which is extra area as another (See Fig.3.1-1). Damages of each area is defined as follows

3.1.1 Principal Area

The principal area cover Hat Yai Municipality including Kor Hong TAO, and Na Mom District. Estimation of damages is base on following conditions.

The damage costs of 1998 and 1999 floods are estimated at 2002 price based on the following assumptions.

(1) Damage cost on household effects is estimated as the products of number of affected households and unit damage cost applied for 2000 flood.

(2) For the damage costs on crops and infrastructures, the estimated costs of local government, Songkhla Province are employed.

(3) Industrial damage cost is estimated on the assumption that it is also proportional to the household damage.

(4) Indirect damage cost is estimated on the assumption that it is also proportional to the number of affected people.

(5) The socio-economic situations namely damage potential in 1998 and 1999 are almost the same as those in 2002.

(6) The multiplier for price escalation is assumed 1.04 for both periods of 1998 to 2002 and 1999 to 2002, in accordance with past trend of consumer's price index (Table 39)

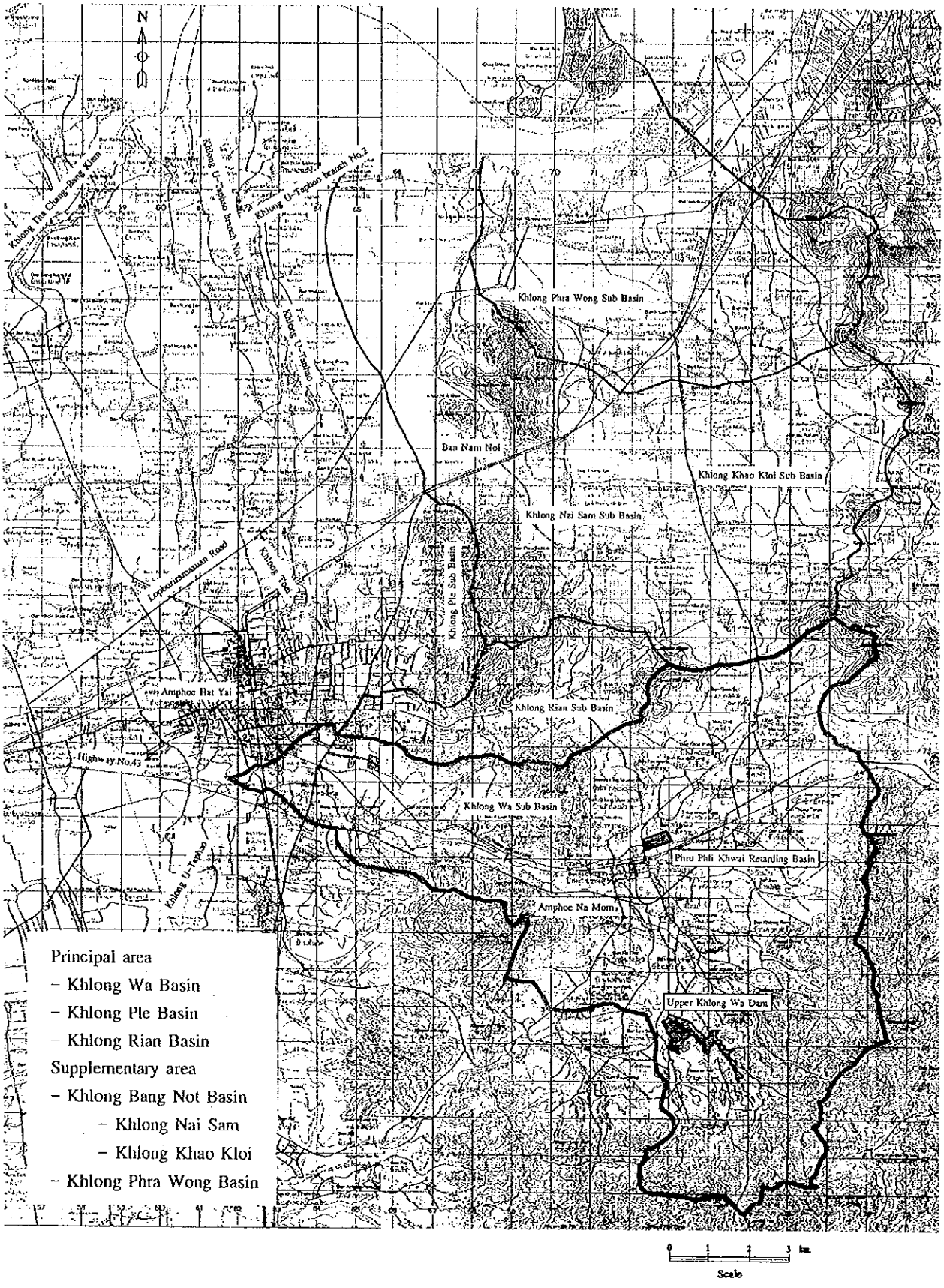


Fig. 3.1-1 Principal and Supplementary area

Table 39 Past trend of consumer's price index 1988-2002

Year	CPI	% Changed
1988	74.9	2.7
1989	79.0	4.1
1990	83.7	4.7
1991	88.5	4.8
1992	92.1	3.6
1993	95.1	3.0
1994	100.0	4.9
1995	105.8	5.8
1996	112.0	6.2
1997	118.2	6.2
1998	127.6	9.4
1999	127.9	0.3
2000	129.4	1.5
2001	131.0	1.6
2002	132.5	1.5
Average Annual Change (%)		4.0*

* converted to multiplier = 1+(4.0/100) =1.04

The total damage cost of 1998 flood is estimated at 168.7 million Baht at 2002 with the following breakdowns. (Table 40)

Table 40 Estimated damage cost of 1998 flood in principal area

(Unit: million Baht at 2002 price)

Damage Item	Damage Cost	Remarks
1. Direct Damage	94.3	
Household damage	15.8	812 affected house x unit damage (19,478 B)
Farm damage		
Infrastructure damage	2.4	2.33 million B x 1.04
Industrial damage	76.1	4,426.8 million B x 15.8 million B/918.7 million B
2. Indirect damage (Tangible)	74.4	2,191.4 million B x2685 persons/79,130 persons.
3. Total	168.7	

The total damage cost of 1999 flood is estimated at 1,237.5 million Baht at 2002 price with the following break down (Table 41)

Table 41 Estimated damage cost of 1999 flood in principal area

(Unit: million Baht at 2002 price)

Damage Item	Damage Cost	Remarks
1. Direct Damage	601.4	
Household damage	99.6	5,116 affected house x unit damage (19,478 B)
Farm damage	15.3	14.72 million B x 1.04
Infrastructure damage	6.6	6.3 million B x1.04
Industrial damage	479.9	4,426.8 million B x 99.6 million B/918.7 million B
2. Indirect damage (Tangible)	636.0	2,191.4 million B x 22,965 persons/79,130 persons.
3. Total	1,237.4	

3.1.2 Supplementary Area

Supplementary area cover the areas of three Tambons, namely: Tambon Takham and Tambon Nam Noi, both are in Hat Yai District, and Tambon Phra Wong under Muang Songkhla District. Details are as follows:

Table 42 Population, household, and village in supplementary area

Tambon	Takham	Nam Noi,	Phra Wong	Total
District	Hat Yai	Hat Yai	Muang Songkhla	2 Districts
Number of Village under Prevention	8	10	7	25
Population in 2000	7,500	12,085	19,235	38,820
Household	2,127	3,344	5,793	11,264

Total area of 25 villages is 90 sq. Km. or 56,250 Rai. Land uses of these villages are as follows:

Table 43 Land use in supplementary area

Land Use	Rai	%
Paddy Land	250	35
Rubber Plantation (highlands)	215	30
Forest (mountain)	107	15
Community	36	5
Industry	36	5
Mangrove	72	10
Total	715	100

Similar to Hat Yai and Na Mom, these villages are also suffering from flood particularly paddy land, community, and industries.

For year 2000 flood damages in this area are estimated as follows.

From above cost-flood frequency curve, flood damage cost can be estimated as shown in Table 46

Table 46 Estimated flood damage at different return period in principal area

Return Period	Probability	Probability Interval	Damage (Mil. Baht)	Average Damage (Mil. Baht)	Annual Loss (Mil. Baht)
1.1	0.900				
		0.40		800	
2	0.500		1,600		320
		0.30		2,245	
5	0.200		2,890		674
		0.10		3,644	
10	0.100		4,398		364
		0.05		5,093	
20	0.050		5,788		255
		0.01		6,005	
25	0.040		6,223		60
		0.02		6,887	
50	0.020		7,551		138
		0.01		8,205	
100	0.010		8,859		82
Total					
1 to 100 Yr.					1,892
Over 25-50					138
Econ. Value*					129.72

Note : Standard conversion factor of 0.94 (See Table 60 Chapter 5)is applied

The average annual flood (1.1-100 year floods) damage cost of Hat Yai district is estimated at 1,892 Million Baht/year. For the damage portion that exceeds 25 year but not more than 50 year is averaged at 138 Million Baht/year.

3.2.2 Past Flood Damage in Supplementary Area

Damages cost of other yeas floods (years 1988 1998 and 1999) beside year 2000 are estimated by using proportionate flood damage of principal year as shown in Table 47.

Table 47 Estimated flood damage caused by various floods in supplementary area

(Unit : Million Baht at 2002 price)

Item	1998 Flood	1999 Flood	1988 Flood	2000 Flood
Flood Damage Cost in Principal Area	168.7	1,237.4	4420.0	7,861.5
Estimated Flood Damage Cost in Supplementary Area	1.0	45.5	289.0	514.0
Flood Return Period (Year)	2	3	7	68

From the above table, the flood damage cost-flood frequency curve is prepared as shown in Fig. 3.2-2

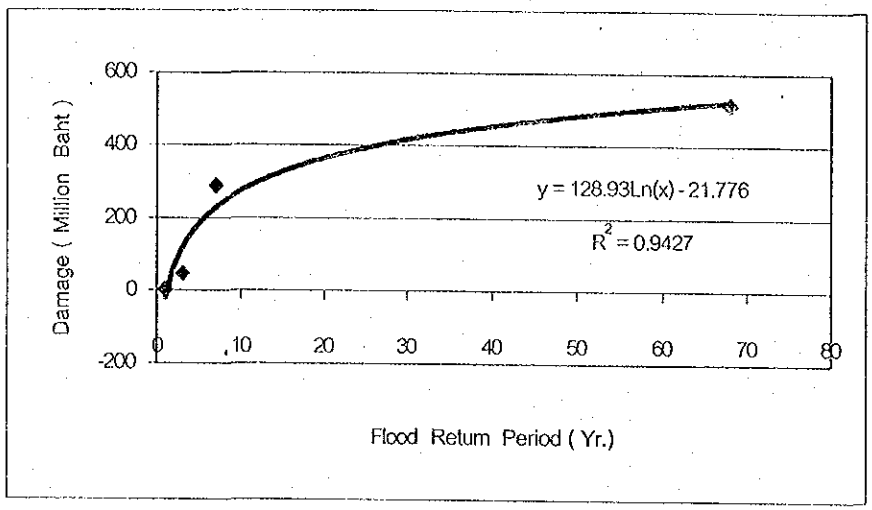


Fig 3.2-2 Damage cost-flood frequency curve of supplementary area base on 2002 price

From above cost-flood frequency curve, flood damage cost can be estimated as shown in Table 48

Table 48 Estimated flood damage at difference return period in supplementary area

Return Period	Probability	Probability Interval	Damage (Mil.Baht)	Average Damage (Mil.Baht)	Annual Loss (Mil.Baht)
1.1	0.900		0		
		0.40		56	
2	0.500		111		22.23
		0.30		170	
5	0.200		229		51.06
		0.10		274	
10	0.100		319		27.40
		0.05		363	
20	0.050		408		18.17
		0.01		422	
25	0.040		437		4.22
		0.02		481	
50	0.020		526		9.63
		0.01		571	
100	0.010		616		5.71
Total					138.42
1 to 50 Yr.					132.71
Econ. Value					124.75

Note : Standard conversion factor of 0.94 (See Table 60 Chapter 5)is applied

3.2.3 Future Annual Flood Damage in Principal Area

The average annual flood damage cost of principal area in the future is estimated on the assumption that the damage potential will increase in proportion to the growth of Gross Provincial Product (GPP). (Table 49)

Table 49 Future average flood damage costs in principal area base on GPP of Songkhla Province

(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					
1.1-100 year flood	1,892	2,039	2,308	2,556	2,820
Over 25 to 50 year flood	138	148	168	186	205

3.2.4 Future Annual Flood Damage in Supplementary Area

Similar to principal area, future annual flood damage for supplementary area are estimated as follows:

Table 50 Future average flood damage costs in supplementary area base on GPP of Songkhla Province

(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	132	142	161	178	196

3.2.3 Future Annual Flood Damage in Principal Area

The average annual flood damage cost of principal area in the future is estimated on the assumption that the damage potential will increase in proportion to the growth of Gross Provincial Product (GPP). (Table 49)

Table 49 Future average flood damage costs in principal area base on GPP of Songkhla Province

(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					
1.1-100 year flood	1,892	2,039	2,488	3,361	5,010
Over 25 to 100 year flood	220	237	289	390	582

3.2.4 Future Annual Flood Damage in Supplementary Area

Similar to principal area, future annual flood damage for supplementary area are estimated as follows:

Table 50 Future average flood damage costs in supplementary area base on GPP of Songkhla Province

(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	138	149	169	187	206

CHAPTER 4 OTHER BENEFITS

Other benefits are miscellaneous benefits additional to Emergency Flood Prevention Planning for Hat Yai District in Khlong U-Taphao River Basin. With existence of two reservoirs built to retard flows of Khlong Wa, at the same time the water can be used for domestic water supply for ten villages of four Tambons within proximity of five Kms. from the reservoirs. Besides it can be used to irrigate the paddy land and orchards can be developed from abandoned paddy land and old rubber-plantation areas. Each benefit is estimated as follows.

4.1 Water Supply

The reservoirs can supply the water to ten villages of four Tambons located near the reservoirs in Na Mom District. At present, they depend on deep well and shallow well as sources of domestic water. The water from the reservoir is better alternative to replace the conventional sources.

The benefit from water supply is estimated as in Table 51.

Table 51 Derivation of Benefit from Water Supply base on 2002 constant price

Year	Population* (Thousand)	Water Requirement** (1,000 Cu.m per Yr.)	Value *** (Million Baht)	Economic Value **** (Million Baht)
1	7.12	311.90	0.31	0.29
2	7.23	316.89	0.32	0.30
5	7.59	332.35	0.33	0.31
10	8.05	352.77	0.35	0.33
15	8.46	370.77	0.37	0.35
20	8.90	389.68	0.39	0.37
30	9.83	430.45	0.43	0.40
40	10.86	475.48	0.48	0.45
50	11.99	525.23	0.53	0.49

*Growth rates between 1-1.6% per annum, corresponding to previous trend of the area is applied; ** Base on average daily consumption of 120 liters per head;*** base on estimated cost of deep well, that is 1 Baht per cubic meter; **** standard conversion factor of 0.94 is adopted for this case (see Table 60 Chapter 5 for conversion factor)

The water can be supplied to target communities in the fifth year of the flood prevention project.

4.2 *Dry Season Rice Crop Production*

About 1,500 Rai of paddy rice areas locating partly in Hat Yai and partly in Muang Songkhla Districts are presently planting wet season rice only. With the water supply from reservoirs, about 500 Rai can be used for planting dry season paddy rice. Benefits from this can be estimated as follows (Table 52)

Table 52 Derivation of financial and economic cost and Returns of Second Rice Production base on 2002 constant price

	Amount per Rai	Unit Price	Financial Value (Baht per Rai)	CF *	Economic Value (Baht per Rai)
Land Preparation**			250	0.7	175
Seeds	15 Kg.	6	90	0.94	84.6
Chemical Fertilizer	30 Kg.	7.5	225	0.92	207
Other Chemicals/Supplies			150	0.94	141
Pumping (O+Depreciatn)			300	0.7	210
Planting labor	2 Manday	125	250	0.94	235
Tending Labors	2 Manday	125	200	0.94	188
Harvesting and Threshing **			250	0.7	175
Total Expenditure			1,415		1,206
Production	500 Kg.	4.8	2,400	***1.05	2,520
Net Return per Rai			685		1,104
per 500 Rai			342,500		552,200

See Table 60 Chapter 5; **Hired machinery and operator; *** Future constant price in 2015 derived from World Bank Development Prospects Group, January 18 ,2002

Department of Agricultural Extension, "Alternatives for Agricultural Productions" 1997

Dry season rice crop production can be started by year 5 of the Flood Prevention Project.

4.3 Orchard Production

Without water supply, many areas such as paddy land, old rubber plantation area, and unclassified land are left idle. With water supply, these lands can be developed into orchard. Many kinds of fruit trees can be planted. However, for the study, orchard farm model would be three common fruits: rambutan, durian and longong. Among these fruits, rambutan requires least investment, whereas longong returns best income but highest risks due to short marketing life; it can not be preserved in any form. Durian requires moderate investment and returns good incomes.

Of 1,000 Rai of lands that can be developed for orchard, for this study, aggregate farm models will be 300 Rai for rambutan, 350 Rai each for durian and longong respectively. Financial benefit from rambutan is estimated in Table 53 whereas economic benefit is estimated in Table 54 Financial and economic benefits from Durian are estimated in Tables 55 and Table 56, whereas Longongs' are estimated in Table 57 and Table 58 respectively. Summary of benefits from orchard is shown in Table 59.

Table 53 Financial Cost of Rambutan Production per Rai base on 2002 constant price

(Unit: Baht per Rai)

Yr.	1	2	3	4	5	6	7	8	9	10	11-15	16~25
Land Preparation												
Land Leveling	370											
Layout and Marking	50											
Pitting	98	10										
Planting	67	5										
Tending												
Tilling	68	80	108	101	127	127	133	150	175	175	175	175
Spraying	85	85	85	78	115	93	93	93	110	110	110	110
Fertilizing	29	35	53	60	75	77	77	85	85	85	107	107
Pruning	25	29	42	53	146	165	179	314	330	406	340	340
Harvesting				135	227	330	482	534	666	658	246	246
Transporting				100	55	149	160	304	315	342	369	369
Material												
Seedling	420	30										
Chemical Fertilizer	75	89	156	208	367	384	394	453	463	555	555	555
Manure	120	133	150	193	270	300	316	383	417	433	500	500
Weedicide	225	225	225	133	117	117	100	100	100	100	90	90
Fuel	106	131	131	169	188	188	200	200	200	200	238	238
Using of Equipment	283	283	283	283	283	283	283	283	283	283	283	283
Total Expenditure	2,021	1,135	1,233	1,513	1,970	2,213	2,417	2,899	3,144	3,347	3,013	3,013
Production (Kg./rai)				425	525	586	714	882	1,036	1,224	1,598	2,425
Return (Baht/Rai)				4,250	5,250	5,860	7,140	8,820	10,360	12,240	15,980	24,250
Net Return (Baht/Rai	-2,021	-1,135	-1,233	2,737	3,280	3,647	4,723	5,921	7,216	8,893	12,967	21,237

Table 54 Economic Cost and Return of Rambutan Production per Rai base on 2002 constant price

(Unit: Baht per Rai)

	CF	1	2	3	4	5	6	7	8	9	10	11-15	16-25
Land Preparation													
Land Leveling	0.70	259	-	-	-	-	-	-	-	-	-	-	-
Layout and Marking	0.94	47	-	-	-	-	-	-	-	-	-	-	-
Pitting	0.94	92	9	-	-	-	-	-	-	-	-	-	-
Planting	0.94	63	5	-	-	-	-	-	-	-	-	-	-
Tending													
Tilling	0.94	64	75	102	95	119	119	125	141	165	165	165	165
Spraying	0.94	80	80	80	73	108	87	87	87	103	103	103	103
Fertilizing	0.92	27	32	49	55	69	71	71	78	78	78	98	98
Pruning	0.94	24	27	39	50	137	155	168	295	310	382	320	320
Harvesting	0.94	-	-	-	127	213	310	453	502	626	619	231	231
Transporting	0.70	-	-	-	70	39	104	112	213	221	239	258	258
Material													
Seedling	0.94	395	28	-	-	-	-	-	-	-	-	-	-
Chemical Fertilizer	0.94	71	84	147	196	345	361	370	426	435	522	522	522
Manure	0.94	113	125	141	181	254	282	297	360	392	407	470	470
Weedicide	0.88	198	198	198	117	103	103	88	88	88	88	79	79
Fuel	0.70	74	92	92	118	132	132	140	140	140	140	167	167
Using of Equipment	0.70	198	198	198	198	198	198	198	198	198	198	198	198
Total Expenditure		1,704	954	1,045	1,281	1,717	1,923	2,110	2,529	2,756	2,941	2,611	2,611
Production (Kg./rai)	-	-	-	-	425	525	586	714	882	1,036	1,224	1,598	2,425
Return (Baht/Rai)	-	-	-	-	4,250	5,250	5,860	7,140	8,820	10,360	12,240	15,980	24,250
Net Return (Baht/Rai	-	-1,704	-954	-1,045	2,969	3,533	3,937	5,030	6,291	7,604	9,299	13,369	21,639
Present Value (Baht/Rai)	-	50,407	-	-	-	-	-	-	-	-	-	-	-
Annual Equivalent		6,427											

Annual Equivalent of net present value of benefit for 300 rai is 300 x 6,427 = 1,928,061 or 1.93 Million Baht per year

Table 55 Financial Cost and Return of Durian Production per Rai base on 2002 constant price

(Unit: Baht per Rai)

	1	2	3	4	5	6	7	8	9	10~25
Cost of Production										
Land Preparation (Baht/Rai)	250									
Seedling (Baht/Rai)	360									
Manure	250	250	250	250	500	500	750	750	1,000	1,000
Chemical Fertilizer (15-15-15)	13	25	38	50	75	88	100	113	125	138
Chemical Fertilizer (12-24-12)					75	88	100	113	125	135
Chemical Fertilizer (13-13-21)					25	25	25	50	50	50
Pesticide	150	250	400	700	1,000	1,500	1,800	1,800	2,000	2,500
Weedicide	350	350	300	300	250	250	200	200	200	200
Fuel	250	250	250	300	300	350	350	400	400	400
Supporting rod and rope	100	100	100	100	300	300	300	500	500	500
Other expenses	195	124	142	185	315	385	437	493	540	605
Labor	880	640	800	1,000	1,400	1,640	2,000	2,360	2,720	2,880
Total	2,798	1,989	2,280	2,885	4,240	5,126	6,062	6,779	7,660	8,408
Production (Kg./Rai)					176	738	1,152	2,000	2,340	2,700
Price (Baht/Kg.)					18	18	18	18	18	18
Value (Baht/Rai)					3,228	13,535	21,128	36,680	42,916	49,518
Net Return (Baht/Rai)	-2,798	-1,989	-2,280	-2,885	-1,012	8,409	15,066	29,901	35,256	41,110

Table 56 Economic Cost and Return of Durian Production per Rai base on 2002 constant price

(Unit: Baht per Rai)

	CF	1	2	3	4	5	6	7	8	9	10~25
Cost of Production	-	-	-	-	-	-	-	-	-	-	-
Land Preparation (Baht/Rai)	0.70	175	-	-	-	-	-	-	-	-	-
Seedling (Baht/Rai)	0.94	338	-	-	-	-	-	-	-	-	-
Manure	0.94	235	235.00	235	235	470	470	705	705	940	940
Chemical Fertilizer (15-15-15)	0.94	12	23.50	36	47	71	83	94	106	118	130
Chemical Fertilizer (12-24-12)	0.94	-	-	-	-	71	83	94	106	118	127
Chemical Fertilizer (13-13-21)	0.94	-	-	-	-	24	24	24	47	47	47
Pesticide	0.88	132	220	352	616	880	1,320	1,584	1,584	1,760	2,200
Weedicide	0.88	308	308	264	264	220	220	176	176	176	176
Fuel	0.70	175	175	175	210	210	245	245	280	280	280
Supporting rod and rope	0.94	94	94	94	94	282	282	282	470	470	470
Other expenses	0.94	183	117	133	174	296	362	411	463	508	569
Labor	0.94	827	602	752	940	1,316	1,542	1,880	2,218	2,557	2,707
Total Expenditure		2,480	1,774	2,041	2,580	3,839	4,629	5,494	6,156	6,972	7,646
Production (Kg./Rai)	-	-	-	-	-	176	738	1,152	2,000	2,340	2,700
Price (Baht/Kg.)	-	-	-	-	-	18	18	18	18	18	18
Value of Production (Baht/Rai)	-	-	-	-	-	3,228	13,535	21,128	36,680	42,916	49,518
Net Return (Baht/Rai)	-	-2,480	-1,774	-2,041	-2,580	-611	8,905	15,633	30,524	35,943	41,872
Present Value (Baht/Rai)	-	135,110									
Annual Equivalent		17,227									

Annual Equivalent of net present value of benefit for 350 rai is 17,227x350 = 6,029,450 or 6.03 million Baht per year

Table 57 Financial Cost and Return of Longong Production per Rai base on 2002 constant price

(Unit: Baht per Rai)

	1	2	3	4	5	6	7	8	9	10~25
Cost of Production										
Land Preparation (Baht/Rai)	250									
Seedling (Baht/Rai)	360									
Manure	250	250	250	250	500	500	750	750	1,000	1,000
Chemical Fertilizer (15-15-15)	13	25	38	50	75	88	100	113	125	138
Chemical Fertilizer (12-24-12)					38	88	51	63	76	88
Chemical Fertilizer (13-13-21)					38	25	51	63	76	88
Pesticide	200	200	325	325	625	1,500	1,500	1,875	1,875	1,875
Weedicide	438	438	375	375	325	325	250	250	250	250
Fuel	250	250	250	300	300	350	350	400	400	400
Other expenses	266	118	126	134	163	215	250	272	308	330
Labour	720	480	480	820	1,040	1,360	1,840	2,000	2,240	2,880
Total	2,747	1,761	1,844	2,254	3,104	4,451	5,142	5,786	6,350	7,049
Production (Kg./Rai)					520	832	936	1,041	1,249	1,560
Price (Baht/Kg.)					35	35	35	35	35	35
Value (Baht/Rai)					18,200	29,120	32,760	36,435	43,715	54,600
Net Return (Thou Baht/Rai)	-2,747	-1,761	-1,844	-2,254	15,096	24,669	27,618	30,649	37,365	47,551

Table 58 **Economic Cost and Return of Longong Production per Rai base on 2002 constant price**

(Unit: Baht per Rai)

	- CF	1	2	3	4	5	6	7	8	9	10-25
Cost of Production	-	-	-	-	-	-	-	-	-	-	-
Land Preparation (Baht/Rai)	0.70	175	-	-	-	-	-	-	-	-	-
Seedling (Baht/Rai)	0.94	338	-	-	-	-	-	-	-	-	-
Manure	0.92	230	230	230	230	460	460	690	690	920	920
Chemical Fertilizer (15-15-15)	0.92	12	23.00	35	46	69	81	92	104	115	127
Chemical Fertilizer (12-24-12)	0.92	-	-	-	-	35	81	47	58	70	81
Chemical Fertilizer (13-13-21)	0.92	-	-	-	-	35	23	47	58	70	81
Pesticide	0.88	176	176.00	286	286	550	1,320	1,320	1,650	1,650	1,650
Weedicide	0.88	385	385	330	330	286	286	220	220	220	220
Fuel	0.70	175	175	175	210	210	245	245	280	280	280
Other expenses	0.94	250	111	118	126	153	202	235	256	290	310
Labour	0.94	677	451	451	771	978	1,278	1,730	1,880	2,106	2,707
Total Expenditure		2,420	1,554	1,629	2,003	2,781	3,982	4,632	5,204	5,729	6,386
Production (Kg./Rai)	-	-	-	-	-	520	832	936	1,041	1,249	1,560
Price (Baht/Kg.)	-	-	-	-	-	35	35	35	35	35	35
Production Value (Baht/Rai)	-	-	-	-	-	18,200	29,120	32,760	36,435	43,715	54,600
Net Return (Thou Baht/Rai)	-	-2,420	-1,554	-1,629	-2,003	15,419	25,138	28,128	31,231	37,986	48,214
Present Value (Baht/Rai)	-	175,928	-	-	-	-	-	-	-	-	-
Annual Equivalent		22,431									

Annual Equivalent of net present value of benefit for 350 rai is 22,431x350 =7,850,850 or 7.85 million Baht per year

Table 59 Summary of benefits from orchard base on 2002 constant price

(Unit: Million Baht)

Year	300 Rai of Rambutan (Million Baht)	350 Rai of Durian (Million Baht)	350 Rai of Longong (Million Baht)	Total 1000 Rai orchard (Million Baht)
1	-0.51	-0.87	-0.85	-2.23
2	-0.29	-0.62	-0.54	-1.45
3	-0.31	-0.71	-0.57	-1.60
4	0.89	-0.90	-0.70	-0.71
5	1.06	-0.21	5.40	6.24
6	1.18	3.12	8.80	13.10
7	1.51	5.47	9.84	16.83
8	1.89	10.68	10.93	23.50
9	2.28	12.58	13.30	28.16
10	2.79	14.66	16.87	34.32
11	4.01	14.66	16.87	35.54
12	4.01	14.66	16.87	35.54
13	4.01	14.66	16.87	35.54
14	4.01	14.66	16.87	35.54
15	4.01	14.66	16.87	35.54
16~25	6.49	14.66	16.87	38.02
ENPV	15.12	47.29	61.57	123.99
Annual Equivalent	1.93	6.03	7.85	15.81

CHAPTER 5 ECONOMIC ANALYSIS

5.1 Economic Evaluation

Economic analysis is made to measure the feasibility of the project. The indicators used for measurement here are Net Present Value (NPV), B/C (Benefit/Cost) ratio, and internal rate of returns (IRR).

NPV is defined as the product of subtraction of Present Value of Benefits over Present Value of Costs. The project that is considered feasible must return the positive value of subtraction product, or, in other words, present value of cost must be less than present value of benefits base on a given interest rate or opportunity cost of investment capital. Interest rate as generally adopted for development project s in Thailand is 12% per annum.

B/C ratio is the ratio between Present Value of Benefits over Present Value of Costs base on a given interest rate. If the ratio is 1 : 1 or more, then the project will be considered feasible.

IRR is the rate, when apply, will produce equal present value of both costs and benefits. The rate would indicate the maximum opportunity cost of capital investment the project might sustain viably. For economic analysis when economic costs and benefits are applied the term EIRR (Economic Internal Rate of Return) will be used in place of IRR.

5.2 Conversion Factor

Conversion factor is coefficient used for converting both cost and benefits from financial or market value into economic value. Economic value or actual value of goods and services is assumed or shadowed under such condition that, with perfect market competition and without taxation, what the value of those goods and services would be. Each particular goods and services has its' own conversion factor since each of them is different in aspects of extent of competition and rate of taxes levied on them. For project assessment, economic value of both cost and benefit will be used to reflect the actual condition. Conversion factors of different items as calculated by the World Bank are as follows. (Table 60)

Table 60 Conversion factors used for converting financial value into economic value

Particulars	Conversion Factor
Standard Conversion Factor	0.94
Specific Conversion Factors for followings:	
Consumers' goods	0.95
Labour	0.94
Electricity	0.90
Intermediate goods	0.94
Capital goods	0.84
Margin for traders	0.69
Fertilizer	0.92
Pesticide	0.88
Construction material	0.80
Seeds	0.94
Transportation	0.87
Fuel oil and lubricant	0.70
Steel	0.83
Cement	0.91
Timber	0.92
Farm machinery	0.70
Agricultural chemicals	0.94
Civil work	0.92
Building	0.84
Road	0.80

Source :Thailand/Indochina Division, East Asia and Pacific Programs Dept., the World Bank, "Shadow Price For Economic Appraisal of Projects and Application to Thailand" 1983

5.3 Development Costs

The project is two phrases. Phrase 1 consists of flood control dam, Phru Phli Kwai and existing channel improvement. Development period of the project spreads from year 1 to year 4. Phrase 2 is to develop further the Northward Diversion Line 3. Development of this phase start from year 3 to year 7 (five years). Financial cost of the project including land acquisition and O&M is presented in Table 61.

From Table 61 economic costs of construction and O&M can be estimated by using standard conversion factor (0.94) as follows. (Table 62)

Table 61 Financial Cost of the project at 2002 constant price

Unit: Million Baht

	1	2	3	4	5	6	7	8	9~50
Phrase 1									
Flood Control Dam									
Study,Survey, Design	15	10	-	-	-	-	-	-	-
Land Acquisition	-	42	-	-	-	-	-	-	-
Construction	-	-	80	83.0	-	-	-	-	-
O&M	-	-	-	-	3.26	3.26	3.26	3.26	3.26
Phru Phli Kwai Retarding Basin									
Study,Survey, Design	151	-	-	-	-	-	-	-	-
Land Acquisition	-	36	-	-	-	-	-	-	-
Construction	-	13	25	25.0	-	-	-	-	-
O&M	-	-	-	-	1.26	1.26	1.26	1.26	1.26
Existing Channel Improvement									
Survey, Design	1	-	-	-	-	-	-	-	-
Land Acquisition	-	14	-	-	-	-	-	-	-
Construction	-	16	-	-	-	-	-	-	-
O&M	-	-	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Total in Phase 1									
Study,Survey, Design	31	10	-	-	-	-	-	-	-
Land Acquisition Cost	-	92	-	-	-	-	-	-	-
Construction	-	29	105	108	-	-	-	-	-
O&M	-	-	0.32	0.32	4.84	4.84	4.84	4.84	4.84
Total Financial Cost	31	131	105.32	108.32	4.84	4.84	4.84	4.84	4.84
Phrase 2									
Northward Diversion Channel Line 3									
Study,Survey, Design	-	-	20	15	-	-	-	-	-
Land Acquisition	-	-	-	30	47	-	-	-	-
Construction	-	-	-	-	143	800	400	-	-
O&M	-	-	-	-	-	-	-	26.86	26.86
Total Financial Cost	-	-	20	45	190	800	400	26.86	26.86
TOTAL 2 PHRASES									
Study,Survey, Design	31	10	20	15	-	-	-	-	-
Land Acquisition	-	92	-	30	47	-	-	-	-
Construction	-	29	105	108	143	800	400	-	-
O&M	-	-	0.32	0.32	4.84	4.84	4.84	31.70	31.70
Total Financial Cost	31	131	125.32	153.32	194.84	804.84	404.84	31.70	31.70

Table 62 Economic cost of construction and O&M at 2002 constant price

(Unit: Million Baht)

	1	2	3	4	5	6	7	8-50
Total Phrase 1								
Study,Survey, Design	29.14	9.40	-	-	-	-	-	-
Construction Cost	-	27.26	98.70	101.52	-	-	-	-
O&M	-	-	0.30	0.30	4.55	4.55	4.55	4.55
Total Economic Cost	29.14	36.66	99.00	101.82	4.55	4.55	4.55	4.55
Phrase 2								
Study,Survey, Design	-	-	18.80	14.10	-	-	-	-
Construction Cost	-	-	-	-	134.42	752.00	376.00	-
O&M	-	-	-	-	-	-	-	25.25
Total Economic Cost	-	-	18.80	14.10	134.42	752.00	376.00	25.25
Total 2 Phrases	-	-	-	-	-	-	-	-
Study,Survey, Design	29.14	9.40	18.80	14.10				
Construction Cost	-	27.26	98.70	101.52	134.42	752.00	376.00	-
O&M	-	-	0.30	0.30	4.55	4.55	4.55	29.80
Total Economic Cost	29.14	36.66	117.80	115.92	138.97	756.55	380.55	29.80

Note : Standard conversion factor from financial to economic of 0.94 (Table 60 of Chapter 5) is adopted.

Period of analysis for this project is 50 years without replacement cost during the period.

5.4 Economic Evaluation of Proposed Project

Summary of flood damage and other benefit for phase 1 and phase 2 are shown in Table 63 and Table 64

When compare cost of the project and its' benefits, the results are favorable as all indicators surpass all the set criteria, that means the project is economically feasible. Details are as shown in Table 65 to Table 67.

Table 63 Summary of Flood Damage in Financial and Economic Cost

(Unit : Million Baht)

Operation Year	Flood Damage of Principal Area				Flood Damage of Supplementary Area		Phase 1		Phase 2	
	Financial Cost	Benefit Cost			Financial	Benefit	Financial Cost	Benefit Cost	Financial Cost	Benefit Cost
		Total	Phase 1	Phase 2						
1	138.00	129.72	38.92	90.80			41.40	38.92		
2	138.00	129.72	38.92	90.80			41.40	38.92		
3	138.00	129.72	38.92	90.80			41.40	38.92		
4	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
5	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
6	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
7	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
8	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
9	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
10	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
11	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
12	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
13	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
14	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
15	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
16	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
17	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
18	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
19	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
20	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
21	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
22	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
23	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
24	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
25	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
26	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
27	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
28	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
29	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
30	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
31	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
32	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
33	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
34	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
35	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
36	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
37	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
38	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
39	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
40	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
41	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
42	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
43	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
44	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
45	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
46	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
47	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
48	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
49	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
50	138.00	206.80	38.92	90.80	132.71	124.75	41.40	38.92	229.31	215.55
Present Value	1,146.02	1,532.24	323.18	754.08	1,100.54	1,034.53	343.81	323.18	1,901.63	1,787.55

Note : Flood damage of principal area estimated 30 % for phase 1 and 70% for phase 2.

Table 64 Summary of Other Benefit in Financial and Economic Cost for Phase 1

(Unit : Million Baht)

Operation Year	Water Works		Dry Season Paddy		Rambutan 300 Rai		Durian 350 Rai		Longong 350 Rai	
	Financial Cost	Benefit Cost	Financial Cost	Benefit Cost	Financial Cost	Benefit Cost	Financial Cost	Benefit Cost	Financial Cost	Benefit Cost
1	0.31	0.29	0.07	0.11	-0.61	-0.51	-0.98	-0.87	-0.96	-0.85
2	0.32	0.30	0.17	0.28	-0.34	-0.29	-0.70	-0.62	-0.62	-0.54
3	0.32	0.30	0.24	0.39	-0.37	-0.31	-0.80	-0.71	-0.65	-0.57
4	0.32	0.30	0.27	0.44	0.82	0.89	-1.01	-0.90	-0.79	-0.70
5	0.33	0.31	0.31	0.50	0.98	1.06	-0.35	-0.21	5.28	5.40
6	0.33	0.31	0.34	0.55	1.09	1.18	2.94	3.12	8.63	8.80
7	0.34	0.32	0.34	0.55	1.42	1.51	5.27	5.47	9.67	9.84
8	0.34	0.32	0.34	0.55	1.78	1.89	10.47	10.68	10.73	10.93
9	0.34	0.32	0.34	0.55	2.16	2.28	12.34	12.58	13.08	13.30
10	0.35	0.33	0.34	0.55	2.67	2.79	14.39	14.66	16.64	16.87
11	0.35	0.33	0.34	0.55	3.89	4.01	14.39	14.66	16.64	16.87
12	0.36	0.34	0.34	0.55	3.89	4.01	14.39	14.66	16.64	16.87
13	0.36	0.34	0.34	0.55	3.89	4.01	14.39	14.66	16.64	16.87
14	0.36	0.34	0.34	0.55	3.89	4.01	14.39	14.66	16.64	16.87
15	0.37	0.35	0.34	0.55	3.89	4.01	14.39	14.66	16.64	16.87
16	0.37	0.35	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
17	0.38	0.36	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
18	0.38	0.36	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
19	0.38	0.36	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
20	0.39	0.37	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
21	0.39	0.37	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
22	0.40	0.38	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
23	0.40	0.38	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
24	0.40	0.38	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
25	0.41	0.39	0.34	0.55	6.37	6.49	14.39	14.66	16.64	16.87
26	0.41	0.39	0.34	0.55						
27	0.42	0.39	0.34	0.55						
28	0.42	0.39	0.34	0.55						
29	0.42	0.39	0.34	0.55						
30	0.43	0.40	0.34	0.55						
31	0.43	0.40	0.34	0.55						
32	0.44	0.41	0.34	0.55						
33	0.44	0.41	0.34	0.55						
34	0.45	0.42	0.34	0.55						
35	0.45	0.42	0.34	0.55						
36	0.46	0.43	0.34	0.55						
37	0.46	0.43	0.34	0.55						
38	0.47	0.44	0.34	0.55						
39	0.47	0.44	0.34	0.55						
40	0.48	0.45	0.34	0.55						
41	0.48	0.45	0.34	0.55						
42	0.49	0.46	0.34	0.55						
43	0.49	0.46	0.34	0.55						
44	0.50	0.47	0.34	0.55						
45	0.50	0.47	0.34	0.55						
46	0.51	0.48	0.34	0.55						
47	0.51	0.48	0.34	0.55						
48	0.52	0.49	0.34	0.55						
49	0.52	0.49	0.34	0.55						
50	0.53	0.50	0.34	0.55						
Present Value	2.86	2.69	2.31	3.75	14.64	15.38	45.90	47.31	60.32	61.57

Table 65 Economic Benefit / Cost Comparison and Derivation of Economic Indicators for Phase 1

(Unit : Million Baht)

Project Year	Operation Year	Total Cost of Phase 1			Total Benefit					Net Benefit Phase 1
		Const. Cost	O & M Cost	Total Cost	Flood Damage	Water Works	Dry Sea. Paddy	Orchard	Total Benefit	
1		29.14		29.14					0.00	-29.14
2		36.66		36.66					0.00	-36.66
3		98.70	0.30	99.00					0.00	-99.00
4		101.52	0.30	101.82					0.00	-101.82
5	1		4.55	4.55	38.92	0.29	0.11	3.16	42.48	37.93
6	2		4.55	4.55	38.92	0.30	0.28	7.90	47.40	42.85
7	3		4.55	4.55	38.92	0.30	0.39	11.07	50.68	46.13
8	4		4.55	4.55	38.92	0.30	0.44	12.65	52.31	47.76
9	5		4.55	4.55	38.92	0.31	0.50	14.23	53.96	49.41
10	6		4.55	4.55	38.92	0.31	0.55	15.81	55.59	51.04
11	7		4.55	4.55	38.92	0.32	0.55	15.81	55.60	51.05
12	8		4.55	4.55	38.92	0.32	0.55	15.81	55.60	51.05
13	9		4.55	4.55	38.92	0.32	0.55	15.81	55.60	51.05
14	10		4.55	4.55	38.92	0.33	0.55	15.81	55.61	51.06
15	11		4.55	4.55	38.92	0.33	0.55	15.81	55.61	51.06
16	12		4.55	4.55	38.92	0.34	0.55	15.81	55.62	51.07
17	13		4.55	4.55	38.92	0.34	0.55	15.81	55.62	51.07
18	14		4.55	4.55	38.92	0.34	0.55	15.81	55.62	51.07
19	15		4.55	4.55	38.92	0.35	0.55	15.81	55.63	51.08
20	16		4.55	4.55	38.92	0.35	0.55	15.81	55.63	51.08
21	17		4.55	4.55	38.92	0.36	0.55	15.81	55.64	51.09
22	18		4.55	4.55	38.92	0.36	0.55	15.81	55.64	51.09
23	19		4.55	4.55	38.92	0.36	0.55	15.81	55.64	51.09
24	20		4.55	4.55	38.92	0.37	0.55	15.81	55.65	51.10
25	21		4.55	4.55	38.92	0.37	0.55	15.81	55.65	51.10
26	22		4.55	4.55	38.92	0.38	0.55	15.81	55.66	51.11
27	23		4.55	4.55	38.92	0.38	0.55	15.81	55.66	51.11
28	24		4.55	4.55	38.92	0.38	0.55	15.81	55.66	51.11
29	25		4.55	4.55	38.92	0.39	0.55	15.81	55.67	51.12
30	26		4.55	4.55	38.92	0.39	0.55	15.81	55.67	51.12
31	27		4.55	4.55	38.92	0.39	0.55	15.81	55.67	51.12
32	28		4.55	4.55	38.92	0.39	0.55	15.81	55.67	51.12
33	29		4.55	4.55	38.92	0.39	0.55	15.81	55.67	51.12
34	30		4.55	4.55	38.92	0.40	0.55	15.81	55.68	51.13
35	31		4.55	4.55	38.92	0.40	0.55	15.81	55.68	51.13
36	32		4.55	4.55	38.92	0.41	0.55	15.81	55.69	51.14
37	33		4.55	4.55	38.92	0.41	0.55	15.81	55.69	51.14
38	34		4.55	4.55	38.92	0.42	0.55	15.81	55.70	51.15
39	35		4.55	4.55	38.92	0.42	0.55	15.81	55.70	51.15
40	36		4.55	4.55	38.92	0.43	0.55	15.81	55.71	51.16
41	37		4.55	4.55	38.92	0.43	0.55	15.81	55.71	51.16
42	38		4.55	4.55	38.92	0.44	0.55	15.81	55.72	51.17
43	39		4.55	4.55	38.92	0.44	0.55	15.81	55.72	51.17
44	40		4.55	4.55	38.92	0.45	0.55	15.81	55.73	51.18
45	41		4.55	4.55	38.92	0.45	0.55	15.81	55.73	51.18
46	42		4.55	4.55	38.92	0.46	0.55	15.81	55.74	51.19
47	43		4.55	4.55	38.92	0.46	0.55	15.81	55.74	51.19
48	44		4.55	4.55	38.92	0.47	0.55	15.81	55.75	51.20
49	45		4.55	4.55	38.92	0.47	0.55	15.81	55.75	51.20
50	46		4.55	4.55	38.92	0.48	0.55	15.81	55.76	51.21
51	47		4.55	4.55	38.92	0.48	0.55	15.81	55.76	51.21
52	48		4.55	4.55	38.92	0.49	0.55	15.81	55.77	51.22
53	49		4.55	4.55	38.92	0.49	0.55	15.81	55.77	51.22
54	50		4.55	4.55	38.92	0.50	0.55	15.81	55.78	51.23
Present Value		190.01	30.63	214.43	323.21	2.69	3.75	107.42	277.76	63.33
NPV										63.33
B/C ratio (:1)										1.30
IRR/Year										15.33%

Table 66 Economic Benefit / Cost Comparison and Derivation of Economic Indicators for Phase 2

(Unit : Million Baht)

Project Year	Operation Year	Total Cost of Phase 2			Total Benefit			Net Benefit
		Const. Cost	O & M Cost	Total Cost	Flood Damage		Total Benefit	
					70 % Principal Area	Supplementary Area		
3		18.80		18.80			0.00	-18.80
4		14.10		14.10			0.00	-14.10
5	1	134.42		134.42			0.00	-134.42
6	2	752		752.00			0.00	-752.00
7	3	376		376.00			0.00	-376.00
8	4		25.25	25.25	90.80	124.75	215.55	190.30
9	5		25.25	25.25	90.80	124.75	215.55	190.30
10	6		25.25	25.25	90.80	124.75	215.55	190.30
11	7		25.25	25.25	90.80	124.75	215.55	190.30
12	8		25.25	25.25	90.80	124.75	215.55	190.30
13	9		25.25	25.25	90.80	124.75	215.55	190.30
14	10		25.25	25.25	90.80	124.75	215.55	190.30
15	11		25.25	25.25	90.80	124.75	215.55	190.30
16	12		25.25	25.25	90.80	124.75	215.55	190.30
17	13		25.25	25.25	90.80	124.75	215.55	190.30
18	14		25.25	25.25	90.80	124.75	215.55	190.30
19	15		25.25	25.25	90.80	124.75	215.55	190.30
20	16		25.25	25.25	90.80	124.75	215.55	190.30
21	17		25.25	25.25	90.80	124.75	215.55	190.30
22	18		25.25	25.25	90.80	124.75	215.55	190.30
23	19		25.25	25.25	90.80	124.75	215.55	190.30
24	20		25.25	25.25	90.80	124.75	215.55	190.30
25	21		25.25	25.25	90.80	124.75	215.55	190.30
26	22		25.25	25.25	90.80	124.75	215.55	190.30
27	23		25.25	25.25	90.80	124.75	215.55	190.30
28	24		25.25	25.25	90.80	124.75	215.55	190.30
29	25		25.25	25.25	90.80	124.75	215.55	190.30
30	26		25.25	25.25	90.80	124.75	215.55	190.30
31	27		25.25	25.25	90.80	124.75	215.55	190.30
32	28		25.25	25.25	90.80	124.75	215.55	190.30
33	29		25.25	25.25	90.80	124.75	215.55	190.30
34	30		25.25	25.25	90.80	124.75	215.55	190.30
35	31		25.25	25.25	90.80	124.75	215.55	190.30
36	32		25.25	25.25	90.80	124.75	215.55	190.30
37	33		25.25	25.25	90.80	124.75	215.55	190.30
38	34		25.25	25.25	90.80	124.75	215.55	190.30
39	35		25.25	25.25	90.80	124.75	215.55	190.30
40	36		25.25	25.25	90.80	124.75	215.55	190.30
41	37		25.25	25.25	90.80	124.75	215.55	190.30
42	38		25.25	25.25	90.80	124.75	215.55	190.30
43	39		25.25	25.25	90.80	124.75	215.55	190.30
44	40		25.25	25.25	90.80	124.75	215.55	190.30
45	41		25.25	25.25	90.80	124.75	215.55	190.30
46	42		25.25	25.25	90.80	124.75	215.55	190.30
47	43		25.25	25.25	90.80	124.75	215.55	190.30
48	44		25.25	25.25	90.80	124.75	215.55	190.30
49	45		25.25	25.25	90.80	124.75	215.55	190.30
50	46		25.25	25.25	90.80	124.75	215.55	190.30
51	47		25.25	25.25	90.80	124.75	215.55	190.30
52	48		25.25	25.25	90.80	124.75	215.55	190.30
53	49		25.25	25.25	90.80	124.75	215.55	190.30
54	50		25.25	25.25	90.80	124.75	215.55	190.30
Present Value		814.97	209.39	933.78	752.99	1,034.53	1,014.29	80.50
NPV								80.50
B/C ratio (:1)								1.09
IRR/Year								13.09%

Table 67 Economic Benefit / Cost Comparison and Derivation of Economic Indicators

(Unit : Million Baht)

Project Year	Operation Year	Total Cost			Total Benefit						Net Benefit
		Phase 1	Phase 2	Total Cost	Flood Damage Phase 1	Flood Damage Phase 2	Water Works	Dry Sea. Paddy	Orchard	Total Benefit	
1		29.14		29.14						0.00	-29.14
2		36.66		36.66						0.00	-36.66
3		99.00	18.80	117.80						0.00	-117.80
4		101.82	14.10	115.92						0.00	-115.92
5	1	4.55	134.42	138.97	38.92		0.29	0.11	3.16	42.48	-96.49
6	2	4.55	752.00	756.55	38.92		0.30	0.28	7.90	47.40	-709.15
7	3	4.55	376.00	380.55	38.92		0.30	0.39	11.07	50.68	-329.87
8	4	4.55	25.25	29.80	38.92	215.55	0.30	0.44	12.65	267.86	238.06
9	5	4.55	25.25	29.80	38.92	215.55	0.31	0.50	14.23	269.51	239.71
10	6	4.55	25.25	29.80	38.92	215.55	0.31	0.55	15.81	271.14	241.34
11	7	4.55	25.25	29.80	38.92	215.55	0.32	0.55	15.81	271.15	241.35
12	8	4.55	25.25	29.80	38.92	215.55	0.32	0.55	15.81	271.15	241.35
13	9	4.55	25.25	29.80	38.92	215.55	0.32	0.55	15.81	271.15	241.35
14	10	4.55	25.25	29.80	38.92	215.55	0.33	0.55	15.81	271.16	241.36
15	11	4.55	25.25	29.80	38.92	215.55	0.33	0.55	15.81	271.16	241.36
16	12	4.55	25.25	29.80	38.92	215.55	0.34	0.55	15.81	271.17	241.37
17	13	4.55	25.25	29.80	38.92	215.55	0.34	0.55	15.81	271.17	241.37
18	14	4.55	25.25	29.80	38.92	215.55	0.34	0.55	15.81	271.17	241.37
19	15	4.55	25.25	29.80	38.92	215.55	0.35	0.55	15.81	271.18	241.38
20	16	4.55	25.25	29.80	38.92	215.55	0.35	0.55	15.81	271.18	241.38
21	17	4.55	25.25	29.80	38.92	215.55	0.36	0.55	15.81	271.19	241.39
22	18	4.55	25.25	29.80	38.92	215.55	0.36	0.55	15.81	271.19	241.39
23	19	4.55	25.25	29.80	38.92	215.55	0.36	0.55	15.81	271.19	241.39
24	20	4.55	25.25	29.80	38.92	215.55	0.37	0.55	15.81	271.20	241.40
25	21	4.55	25.25	29.80	38.92	215.55	0.37	0.55	15.81	271.20	241.40
26	22	4.55	25.25	29.80	38.92	215.55	0.38	0.55	15.81	271.21	241.41
27	23	4.55	25.25	29.80	38.92	215.55	0.38	0.55	15.81	271.21	241.41
28	24	4.55	25.25	29.80	38.92	215.55	0.38	0.55	15.81	271.21	241.41
29	25	4.55	25.25	29.80	38.92	215.55	0.39	0.55	15.81	271.22	241.42
30	26	4.55	25.25	29.80	38.92	215.55	0.39	0.55	15.81	271.22	241.42
31	27	4.55	25.25	29.80	38.92	215.55	0.39	0.55	15.81	271.22	241.42
32	28	4.55	25.25	29.80	38.92	215.55	0.39	0.55	15.81	271.22	241.42
33	29	4.55	25.25	29.80	38.92	215.55	0.39	0.55	15.81	271.22	241.42
34	30	4.55	25.25	29.80	38.92	215.55	0.40	0.55	15.81	271.23	241.43
35	31	4.55	25.25	29.80	38.92	215.55	0.40	0.55	15.81	271.23	241.43
36	32	4.55	25.25	29.80	38.92	215.55	0.41	0.55	15.81	271.24	241.44
37	33	4.55	25.25	29.80	38.92	215.55	0.41	0.55	15.81	271.24	241.44
38	34	4.55	25.25	29.80	38.92	215.55	0.42	0.55	15.81	271.25	241.45
39	35	4.55	25.25	29.80	38.92	215.55	0.42	0.55	15.81	271.25	241.45
40	36	4.55	25.25	29.80	38.92	215.55	0.43	0.55	15.81	271.26	241.46
41	37	4.55	25.25	29.80	38.92	215.55	0.43	0.55	15.81	271.26	241.46
42	38	4.55	25.25	29.80	38.92	215.55	0.44	0.55	15.81	271.27	241.47
43	39	4.55	25.25	29.80	38.92	215.55	0.44	0.55	15.81	271.27	241.47
44	40	4.55	25.25	29.80	38.92	215.55	0.45	0.55	15.81	271.28	241.48
45	41	4.55	25.25	29.80	38.92	215.55	0.45	0.55	15.81	271.28	241.48
46	42	4.55	25.25	29.80	38.92	215.55	0.46	0.55	15.81	271.29	241.49
47	43	4.55	25.25	29.80	38.92	215.55	0.46	0.55	15.81	271.29	241.49
48	44	4.55	25.25	29.80	38.92	215.55	0.47	0.55	15.81	271.30	241.50
49	45	4.55	25.25	29.80	38.92	215.55	0.47	0.55	15.81	271.30	241.50
50	46	4.55	25.25	29.80	38.92	215.55	0.48	0.55	15.81	271.31	241.51
51	47	4.55	25.25	29.80	38.92	215.55	0.48	0.55	15.81	271.31	241.51
52	48	4.55	25.25	29.80	38.92	215.55	0.49	0.55	15.81	271.32	241.52
53	49	4.55	25.25	29.80	38.92	215.55	0.49	0.55	15.81	271.32	241.52
54	50	4.55	25.25	29.80	38.92	215.55	0.50	0.55	15.81	271.33	241.53
Present Value		214.43	933.78	958.84	323.21	1,787.52	2.69	3.75	107.42	1,086.35	127.51
NPV											127.51
B/C ratio (:1)											1.13
IRR/Year											13.65%

APPENDIX D

FLOOD - MITIGATION MEASURES

APPENDIX D FLOOD MITIGATION MEASURES

CONTENTS

FIGURES CONTENT

FIGURES CONTENT

FIGURES CONTENT

TABLES CONTENT

APPENDIX D FLOOD MITIGATION MEASURES

CHAPTER 1 CURRENT HAT YAI FLOOD MITIGATION PLAN

1.1 Flood Prevention Project

1.1.1 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 shown in Fig. 1.1-1.

1) Dredging of 8 Existing Channels
   - Khlong U-Taphao, length 27.180 km. for max. discharge 420 cms.
   - Khlong U-Taphao branch No.1, length 6.260 km. for max. discharge 50 cms.
   - Khlong U-Taphao branch No.2, length 2.860 km. for max. discharge 30 cms.
   - Khlong Tha Chang-Bang Klam, length 17.960 km. for max. discharge 180 cms.
   - Khlong Hae, length 3.930 km. for max. discharge 40 cms.
   - Khlong Wat, length 3.625 km. for max. discharge 120 cms.
   - Khlong Tam, length 3.625 km. for max. discharge 80 cms.
   - Khlong Wa, length 3.400 km. for max. discharge 80 cms.

2) Construction of 3 New Diversion Channels
   - Diversion channel No.D1,length 21.435 km. for max. discharge 210 cms.
   - Diversion channel No. D2, length 3.840 km. for max. discharge 40 cms.
   - Diversion channel No. D3, length 7.650 km. for max. discharge 60 cms.

3) Urban Drainage Improvement of Hat Yai Municipality

   The above mentioned Urban Drainage Improvement are comprised of the following works ; Improvement of the urban drainage, such as Khlong Toei, construction an embankment to prevent the overflow from the right bank of Khlong U-Taphao and the dike to block all of the section of the northern railway bridges routes, and construct a regular and pumping station so as to be capable for draining the rain from the closure area. The 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.

1.1.2 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 Toei is closed and it drains only internal water of Hat Yai municipality.
(3) Constructing new diversion channels (D3, D4 and D5) discharges flood from the Khao Kho Hong area.
(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. Improving the existing drainage system so as to drain the internal water.

The design discharge distribution to the existing channels and new diversion channels are shown in Fig. 1.1-2.

1.2 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 as named below in the downstream reaches and the bifurcating branches of the Khlong U-Taphao are dredged. Total budget is 91 million Baht. The executing agency is RID.
- Khlong U-Taphao
- Khlong U-Taphao branch No.1
- Khlong U-Taphao branch No.2
- Khlong Tha Chang-Bang Klam

(2) Construction of New Diversion Channels: Five (5) new diversion channels are constructed. The total length is approximately 46 km. Total budget is 1,800 million Baht. The executing agency is RID. The lengths of each diversion channel according to the construction drawing are as follows,

- Diversion Channel line No. D1 length 21+343.718 km.
- Diversion Channel line No. D3 length 8+200 km.
- Diversion Channel line No. D4 length 6+920 km.
- Diversion Channel line No. D5 length 4+900 km.
- Diversion Channel line No. D6 length 3+160 km.

(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 bridges 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 the 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. 1.1-1

1.3 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.

1.4 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 project 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 P.S., improvement of 3 existing P.S. and construction of drainage pipes) are almost completed.
Construction of Bridges and Culverts	Will be completed within 2002
Establishment of Flood Forecasting and Warning 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 P.S., 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

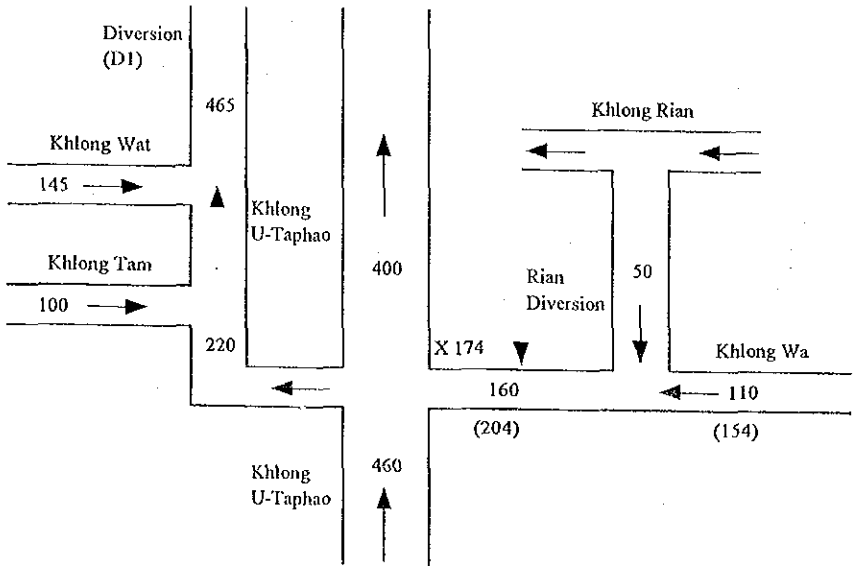
Project	Progress
Construction of Flood Control Reservoir	Project will be authorized after feasibility study.
Reforestation and Watershed Management	Upstream watersheds

CHAPTER 2 FLOOD MITIGATION POLICY OF KHLONG WA

2.1 Design Flood Discharge of Khlong Wa

The ongoing flood mitigation projects of Hat Yai district were planned to meet the flood discharge with a 25-year return period. The proposed design discharges of the existing Khlong U-Taphao and new diversion channel (D1) are 400 cms. and 220 cms., respectively. They were determined taking into account the discharge of 160 cms. from Khlong Wa including the Rian diversion discharge of 50 cms.. The proposed Rian diversion channel joins the Khlong Wa at 4.0 km. distance from the confluence with Khlong U-Taphao or immediately upstream of the water gauging station X 174 (located at 3.4 km. distance).

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



However, the safety factor of the Khlong Wa existing design discharge (110 cms.) is not enough and its return period is estimated to be approximately 10-year. The return period of the design discharge of the Khlong Wa should be graded up to 25-year to be consistent with that of the Khlong U-Taphao.

The discharge of the Khlong Wa with a 25-year return period is estimated to be 154 cms. at St. X 174 excluding the Rian diversion discharge of 50 cms. or 204 cms. including the Rian diversion discharge of 50 cms. as shown in the above figure. However, it is considered difficult to increase the design discharge of the Khlong U-Taphao and diversion channel (D1) since their projects are ongoing according to the above-mentioned design discharge distribution. 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.

2.2 Necessity of Flood Discharge Regulation

As mentioned above, a flood discharge of 44 cms. needs to be regulated in the upper reaches of the Khlong Wa basin. For this purpose, possible regulation measures are studied in the followings:

- Flood Control Dam, details of studying shown in Chapter 3
- Retarding Basin, details of study shown in Chapter 4
- Improvement of existing channel, detail of study shown in Chapter 5
- Northward diversion channel, details of study shown in Chapter 6
- Southward diversion channel, details of study shown in Chapter 7

CHAPTER 3 CONSTRUCTION OF FLOOD CONTROL DAM

3.1 Identification of Possible Dam and Reservoir

In this study, the possible dam sites are selected base on the topographic maps scale 1:50,000, map series No. L7017 by Royal Thai Survey Department. The 12 dam sites are identified. Their location and characteristics are shown in Fig. 3.1-1 and Table 3.1-1.

3.1.1 Catchment Area and Storage Capacity

From 12 dam sites, the details of location and characteristic are as following:-

(1) Flood Control Dam No. 1: Khlong Ban Phli Khwai Dam

(a) General Data

Type of project	Dam and Reservoir for flood control	
Location	Between Ban Phli Khwai and Ban Khlong Muang Tok, Village No.4 and No. 6 respectively in Phichit Sub-district, Na Mom District and 1.50 km. North of Na Mom District	
Co-ordinate at	47 NPH 726-716 in topographic map, sheet No. 5122 IV	
Latitude	6°- 58′ - 42.39″ N	
Longitude	100°- 33′ - 44.27″ E	
Catchment Area	7.125	sq.km.

(b) Dam and Reservoir

River bed elevation	18.000	m. msl
Retention level	20.000	m. msl
Dam : Crest elevation	22.000	m. msl
Length	500.00	m.
Height	4.00	m.
Water surface at retention level	0.631	sq.km.
Capacity of reservoir	0.499	MCM

Location and area-capacity curve shown in Fig. 3.1-2 and Fig. 3.1-3

(2) Flood Control Dam No. 2: Upper Khlong Muang Dam

(a) General Data

Type of project	Dam and Reservoir for flood control	
Location	At Ban Khok Phayom, Village No. 3 in Phichit Sub-district, Na Mom District and 4.00 km. Northeast of Na Mom District	
Co-ordinate at	47 NPH 744-728 in topographic map, sheet No. 5122 IV	
Latitude	6°- 59′ - 21.85″ N	
Longitude	100°- 34′ - 45.05″ E	
Catchment Area	10.375	sq.km.

(b) Dam and Reservoir

River bed elevation	30.000	m. msl
Retention level	40.000	m. msl
Dam : Crest elevation	42.000	m. msl
Length	700.00	m.
Height	12.00	m.
Water surface at retention level	0.508	sq.km.
Capacity of reservoir	1.518	MCM

Location and area-capacity curve shown in Fig. 3.1-4 and Fig. 3.1-5

(3) Flood Control Dam No. 3 : Lower Khlong Muang 1 Dam

(a) General Data

Type of project	Dam and Reservoir for flood control		
Location	At Ban Wang Chang, Village No. 4 in Phichit Sub-district, Na Mom District and 2.50 km. Northeast of Na Mom District		
Co-ordinate at	47 NPH 738-715 in topographic map, sheet No. 5122 IV		
Latitude	6°- 58′ - 38.48″ N		
Longitude	100°- 34′ - 24.25″ E		
Catchment Area		12.350	sq.km.

(b) Dam and Reservoir

River bed elevation	18.900	m. msl
Retention level	20.000	m. msl
Dam : Crest elevation	22.000	m. msl
Length	500.00	m.
Height	3.10	m.
Water surface at retention level	0.235	sq.km.
Capacity of reservoir	0.118	MCM

Location and area-capacity curve shown in Fig. 3.1-6 and Fig. 3.1-7

(4) Flood Control Dam No. 4 : Lower Khlong Muang 2 Dam

(a) General Data

Type of project	Dam and Reservoir for flood control		
Location	At Ban Phli Khwai, Village No. 4 in Phichit Sub-district, Na Mom District and 2.00 km. Northeast of Na Mom District		
Co-ordinate at	47 NPH 735-712 in topographic map, sheet No. 5122 IV		
Latitude	6°- 58′ - 29.67″ N		
Longitude	100°- 34′ - 16.77″ E		
Catchment Area		20.600	sq.km.

(b) Dam and Reservoir

River bed elevation	18.500	m. msl
Retention level	20.000	m. msl
Dam : Crest elevation	22.000	m. msl
Length	830.00	m.
Height	3.50	m.
Water surface at retention level	0.661	sq.km.
Capacity of reservoir	0.442	MCM

Location and area-capacity curve shown in Fig. 3.1-8 and Fig. 3.1-9

(5) Flood Control Dam No. 5 : Upper Khlong Ban Sae Dam

(a) General Data

Type of project	Dam and Reservoir for flood control		
Location	At Ban Sae, Village No. 4 in Khlong Rang Sub-district, Na Mom District and 3.70 km. East of Na Mom District		
Co-ordinate at	47 NPH 758-694 in topographic map, sheet No. 5122 IV		
Latitude	6°- 57′ - 29.67″ N		
Longitude	100°- 35′ - 29.25″ E		
Catchment Area		5.450	sq.km.

(b) Dam and Reservoir

River bed elevation	35.000	m. msl
Retention level	40.000	m. msl
Dam : Crest elevation	43.000	m. msl
Length	600.00	m.
Height	8.00	m.
Water surface at retention level	0.254	sq.km.
Capacity of reservoir	0.447	MCM

Location and area-capacity curve shown in Fig. 3.1-10 and Fig. 3.1-11

(6) Flood Control Dam No. 6 : Lower Khlong Ban Sae Dam

(a) General Data

Type of project	Dam and Reservoir for flood control		
Location	At Ban Sae, Village No. 4 in Khlong Rang Sub-district, Na Mom District and 3.40 km. East of Na Mom District.		
Co-ordinate at	47 NPH 755-695 in topographic map, sheet No. 5122 IV		
Latitude	6°- 57′ - 33.91″ N		
Longitude	100°- 35′ - 19.18″ E		
Catchment Area		5.850	sq.km.

(b) Dam and Reservoir

River bed elevation	32.500	m. msl
Retention level	40.000	m. msl
Dam : Crest elevation	43.000	m. msl
Length	750.00	m.
Height	10.50	m.
Water surface at retention level	0.499	sq.km.
Capacity of reservoir	1.271	MCM

Location and area-capacity curve shown in Fig. 3.1-12 and Fig. 3.1-13

(7) Flood Control Dam No. 7 : Lower Khlong Ko Wao Dam

(a) General Data

Type of project	Dam and Reservoir for flood control		
Location	At Ban Khlong Rang, Village No. 1 in Khlong Rang Sub-District, Na Mom District and 3.00 km. Southeast of Na Mom District.		
Co-ordinate at	47 NPH 744-684 in topographic map, sheet No. 5122 IV		
Latitude	6°- 56′ - 57.39″ N		
Longitude	100°- 34′ - 43.75″ E		
Catchment Area		4.625	sq.km.

(b) Dam and Reservoir

River bed elevation	32.500	m. msl
Retention level	40.000	m. msl
Dam : Crest elevation	42.000	m. msl
Length	180.00	m.
Height	9.50	m.
Water surface at retention level	0.200	sq.km.
Capacity of reservoir	0.450	MCM

Location and area-capacity curve shown in Fig. 3.1-14 and Fig. 3.1-15

(8) Flood Control Dam No. 8 : Upper Khlong Ko Wao Dam

(a) General Data

Type of project	Dam and Reservoir for flood control		
Location	At Ban Khlong Rang, Village No. 1 in Khlong Rang Sub-district, Na Mom District and 4.50 km. Southeast of Na Mom District.		
Co-ordinate at	47 NPH 756-675 in topographic map, sheet No. 5122 IV		
Latitude	6°- 56′ - 26.74″ N		
Longitude	100°- 35′ - 24.38″ E		
Catchment Area		3.175	sq.km.

(b) Dam and Reservoir

River bed elevation	47.50	m. msl
Retention level	65.000	m. msl
Dam : Crest elevation	68.000	m. msl
Length	680.00	m.
Height	20.50	m.
Water surface at retention level	0.365	sq.km.
Capacity of reservoir	2.385	MCM

Location and area-capacity curve shown in Fig. 3.1-16 and Fig. 3.1-17

(9) Flood Control Dam No. 9 : Lower Khlong Wa Dam

(a) General Data

Type of project	Dam and Reservoir for flood control		
Location	At Ban Mae Pia and Ban Plak Thing, Village No. 4 and No. 6 respectively in Khlong Rang Sub-District, Na Mom District and 3.00 km. Southeast of Na Mom District.		
Co-ordinate at	47 NPH 736-674 in topographic map, sheet No. 5122 IV		
Latitude	6°- 56′ - 24.46″ N		
Longitude	100°- 34′ - 16.77″ E		
Catchment Area		27.800	sq.km.

(b) Dam and Reservoir

River bed elevation	32.500	m. msl
Retention level	40.000	m. msl
Dam : Crest elevation	43.000	m. msl
Length	300.00	m.
Height	10.50	m.
Water surface at retention level	0.645	sq.km.
Capacity of reservoir	1.494	MCM

Location and area-capacity curve shown in Fig. 3.1-18 and Fig. 3.1-19

(10) Flood Control Dam No. 10 : Khlong Hin Dam Dam

(a) General Data

Type of project	Dam and Reservoir for flood control		
Location	At Ban Mae Pia, Village No. 4 in Khlong Rang Sub-district, Na Mom District and 4.60 km. Southeast of Na Mom District.		
Co-ordinate at	47 NPH 753-666 in topographic map, sheet No. 5122 IV		
Latitude	6°- 55′ - 58.37″ N		
Longitude	100°- 35′ - 13.65″ E		
Catchment Area		4.850	sq.km.

(b) Dam and Reservoir

River bed elevation	49.000	m. msl
Retention level	70.000	m. msl
Dam : Crest elevation	73.000	m. msl
Length	350.00	m.
Height	24.00	m.
Water surface at retention level	0.384	sq.km.
Capacity of reservoir	3.222	MCM

Location and area-capacity curve shown in Fig. 3.1-20 and Fig. 3.1-21

(11) Flood Control Dam No. 11 : Khlong Ba Dam

(a) General Data

Type of project	Dam and Reservoir for flood control		
Location	At Ban Mae Pia, Village No. 4 in Khlong Rang Sub-district, Na Mom District and 4.80 km. Southeast of Na Mom District.		
Co-ordinate at	47 NPH 750-663 in topographic map, sheet No. 5122 IV		
Latitude	6°- 55′ - 47.78″ N		
Longitude	100°- 35′ - 03.90″ E		
Catchment Area		1.150	sq.km.

(b) Dam and Reservoir

River bed elevation	53.000	m. msl
Retention level	70.000	m. msl
Dam : Crest elevation	73.000	m. msl
Length	180.00	m.
Height	20.00	m.
Water surface at retention level	0.087	sq.km.
Capacity of reservoir	0.626	MCM

Location and area-capacity curve shown in Fig. 3.1-22 and Fig. 3.1-23

(12) Flood Control Dam No. 12 : Upper Khlong Wa Dam

(a) General Data

Type of project	Dam and Reservoir for flood control				
Location	At Ban Plak Thing, Village No. 6 in Khlong Rang Sub-district, Na Mom District and 4.30 km. Southeast of Na Mom District.				
Co-ordinate at	47 NPH 733-658 in topographic map, sheet No. 5122 IV				
Latitude	6°- 55' - 31.63" N				
Longitude	100°- 34' - 07.67" E				
Catchment Area		18.600			sq.km.

(b) Dam and Reservoir,

River bed elevation	43.000,	43.000,	43.000	m. msl
Retention level	70.000,	75.000,	80.000	m. msl
Dam : Crest elevation	73.000,	78.000,	83.000	m. msl
Length	850.00,	980.00,	1,100.00	m.
Height	30.00,	35.00,	40.00	m.
Water surface at retention level	0.828,	1.061,	1.522	sq.km.
Capacity of reservoir	8.159,	12.882,	19.341	MCM

Location and area-capacity curve shown in Fig. 3.1-24 and Fig. 3.1-25

3.1.2 Flood Discharge

The objective of flood control dam is to reduce 25 years return period of flood peak discharge. The hydrograph of each catchment area of flood control dam by year 2000 of 7 days rainfall pattern at Khao Kho Hong station are shown in Fig. 3.1-26 to Fig. 3.1-37, the summary data are shown in Table 3.1-2.

3.1.3 Submerged Land and Houses

From catchment area of each flood control dam, the flood control dam No. 2, No. 3, No. 4, No. 9 and No. 12 are interested because their catchment area are about 10% or more of Khlong Wa basin, so they can reduce flood peak in Khlong Wa after construction.

From the field survey, the study team found that some dam sites, houses are located in retention area, as shown in Fig. 3.1-38. Besides, some reservoirs are situated in the villages, so the retention level can not be uplifted. The summary of the results and preliminary study are shown in the table below:

Item No	Name	Reservoir Capacity (MCM)	25 Yr. Flood Volume (MCM)	Details of Dam Sites and Reservoirs	Final Possibility
1	Khlong Ban Phli Khwai Dam	0.499	1.815	The reservoir is in 2 Villages, Ban Phli Khwai and Ban Khlong Muang Tok, cannot uplift the retention level and the capacity is small	Cancel
2	Upper Khlong Muang Dam	1.518	2.644	The reservoir is in Ban Khok Prayom, cannot uplift the retention level and the capacity is small	Cancel
3	Lower Khlong Muang 1 Dam	0.118	3.147	The reservoir is near Ban Phli Khwai, cannot uplift the retention level, the capacity and water height in reservoir is small	Cancel
4	Lower Khlong Muang 2 dam	0.442	5.249	The reservoir is near Ban Phli Khwai, cannot uplift the retention level, the capacity and water height in reservoir is small	Cancel
5	Upper Khlong Ban Sae Dam	0.447	1.389	The reservoir is near Ban Sae and is in para rubber plantation, the catchment area is small , it cannot reduce peak flood in Khlong Wa basin	Cancel
6	Lower Khlong Ban Sae Dam	1.271	1.491	The reservoir is near Ban Sae and is in para rubber plantation, the catchment area is small , it cannot reduce peak flood in Khlong Wa basin	Cancel
7	Lower Khlong Ko Wao Dam	0.456	1.178	The reservoir is in Ban Khlong Rang, and it has some house in reservoir, cannot uplift the retention level more, the catchment area and capacity is small, it cannot reduce peak flood in Khlong Wa basin	Cancel
8	Upper Khlong Ko Wao Dam	2.385	0.809	The reservoir is in para rubber plantation, the catchment area is small, it cannot reduce peak flood in Khlong Wa basin	Cancel
9	Lower Khlong Wa Dam	1.494	7.084	The location of dam site is good, it has 2 house, and para rubber plantation in reservoir. The reservoir is near Ban Khuan Ton. If the retention level is uplifted for more capacity , Those houses shall be moved..	Cancel
10	Khlong Hin Dam Dam	3.222	1.236	The reservoir is in para rubber plantation, the catchment area is small, it cannot reduce peak flood in Khlong Wa basin	Cancel
11	Khlong Ba Dam	0.626	0.293	The reservoir is in para rubber plantation, the catchment area is small, it cannot reduce peak flood in Khlong Wa basin	Cancel
12	Upper Khlong Wa Dam	8.159 (19.314)	4.739	The reservoir is in para rubber plantation, no house in reservoir at maximum retention, can reduce peak flood in Khlong Wa basin.	Used for Flood Control Dam

3.2 Effects of Flood Discharge Regulation

To evaluate the effectiveness of the flood control dam in reducing flood peak discharge, the 25 years flood and the hydrodynamic model are used in study. The new set of the input hydrographs to the model will include the effect of the flood control reservoir and is then routed through the model. The new results of the calculation by the hydrodynamic model are then compared to those of the existing condition. Fig. 3.2-1 shows the discharge hydrographs for the existing condition and with reservoir condition. The proposed reservoir can reduce the flood peak discharge at the X.174 station, Kanchanavanich road by 26 cms and flood peak level by 8 cm.

3.3 Proposed Dam and Reservoir

From the Identification, of possible dam and reservoir in item 3.1, the final selection is Upper Khlong Wa dam for flood control dam in Khlong Wa basin.

Reservoir capacity of Upper Khlong Wa dam can be considered as two storage level, the first storage is about 5.20 MCM (including dead storage) for minimum water use, such as water supply, irrigation, and the second storage is about 4.70 MCM for flood control. The two storage is divided at +66.000 m. msl. level, the first storage level will be started on rainfall season up to the control water level +66.000 m.msl., the second storage level will be started on middle of December. Water will be stored at the full capacity level of reservoir.

For the selection of spillway dimensions. Flood in 100 yrs. return period and yr. 2000 are used for reservoir routing. The study are separated in 3 cases as follows:

- case 1: No water in flood storage volume
- case 2: Water is stored at half of flood storage volume
- case 3: Water is stored at full of flood storage volume

The three crest length of spillway for this study are as 15.00 m., 20.00 m. and 25.00 m. Summary of the study are shown in Table 3.3-1. Finally, 20.00 m. crest length of spillway is selected for this project. The reservoir routing for flood 25, 50, 100, 200 and 500 yrs. Return period and also for yr. 2000 are shown in Fig. 3.3-1 to Fig. 3.3-6 respectively and the summarized figures are shown in Table 3.3-1

3.4 Construction Cost

3.4.1 Dam Components and Dimensions

The principal dimensions of the Upper Khlong Wa dam can be described as follows, layout and cross-section are shown in Figure 3.4-1.

- Catchment Area 18.6 Sq.km.

- Peak Discharges

25-yr.	40	cms.:
100-yr.	60	cms..
for the year 2000	80	cms..

- Elevations

Dam Crest	+75.0	m.msl.
Spillway Crest	+72.0	m.msl.
River Bed	+43.0	m.msl.
Dead Storage	+48.0	m.msl.
Normal Full Supply Water Level	+66.0	m.msl.
High Water Level	+72.0	m.msl.
Flood Surcharge Water Level	+73.0	m.msl.

- Lengths.

Dam Crest	800	m.
Spillway Crest	20	m.

- Area

Reservoir Area at Dam Crest	1.1	sq.km.

- Reservoir Volume

Dead Storage	0.3	MCM
Water used Storage	4.9	MCM
Flood Storage	4.7	MCM
Total Storage	9.9	MCM

- Dam

Earth Zone Dam		
Dam Crest Width	8	m.
U/S face slope	1 : 3	
D/S face slope	1 : 2.5	
Embankment Volume	0.8	MCM

- Spillway

Design Discharge	40	cms.
Side Channel Spillway Crest Length	20	m.
Trough Width	5	m.
Chute base Width	5	m.
Chute Wall Height	3.5	m.
Stilling Basin	USBR Type 4	
Basin width	5	m.
Basin Wall Height	5	m.

- River Outlet

Circular Concrete Pipe Diameter	1.5	m.
Steel lining thickness	5	mm.
Length	180	m.
High pressure gate	Ø 0.9	m.
(2 gates i.e. guard gate and operating gate)		

3.4.2 Project Construction Budget Estimation

(1) **Construction Cost Estimation:** The estimation will refer to the Feasibility Study result of Khlong Haeng Reservoir project located in Krabi Province. The study was carried out by a joint venture of Resources Engineering Consultants Co.,Ltd., Tesco. Ltd. and Sanyu Consultants (Thailand) Ltd. in 1999. The Khlong Haeng dam is a earth zoned dam with similar dam height to this Upper Khlong Wa dam. By analyzing the bill of quantity and cost estimate of the Khlong Haeng dam, it comes out that the unit total construction cost at year 2002 price compared to total dam earth volume is 170 Baht/Cu.m. of dam volume.

Therefore for the Upper Khlong Wa Dam, the total construction cost can be estimated as 0.8x170 = 136 mB.

(2) **Land Acquisition:** The project land is required for the reservoir area, dam body and access road. The total land area required is estimated to be 700 rai. The present land use is para rubber plantation.

The study team visited the site and enquired a number of people living in the area about various socio-economic aspects. The land of the project area belongs to privates and official ownership documents are present. Therefore, to acquire these lands, the government have to pay at the market price. On average the market price for these lands is 50,000 B/rai.

Therefore it is estimated that the land acquisition for the Upper Khlong Wa dam will cost 700x0.05 = 35 mB.

(3) **Total Budget:** In addition to the estimates for total construction and land acquisition costs, a 20% contingency for physical and price is added to get total budget price for the Upper Khlong Wa dam and 25 mB. for study (feasibility and environmental), survey and detail design. The total budget price is thus calculated to be 230 mB. as follows

Construction cost + 20% Contingency	=	136+27	= 163	mB.
Land acquisition + 20% Contingency	=	35+7	= 42	mB.
Study (feasibility and environmental), survey and design			= 25	mB.
Total			= 230	mB.

(4) **Implementation Plan:** Total used four (4) years as following
- Study, survey and details design used 2 years in first and second years
- Head Acquisition implemented in second year.
- Construction in third and fourth years.

CHAPTER 4 CONSTRUCTION OF RETARDING BASIN

4.1 Identification of Possible Retarding Basin

In this study, two retarding basin sites are studied, namely the Phru Phli Khwai and the Phru Mao retarding basin sites.

The Phru Phli Khwai, a swamp located about half kilometer northeast of the Na Mom District, has an area of about 300 rai (about 0.50 square kilometers). Figure 4.1-1 shows location of the Phru Phli Khwai retarding basin. Photograph in Figure 4.1-2 shows a picture of the Phru Phli Khwai existing condition.

The Phru Mao, use to be a swamp area adjacent to the Khlong Wa, is located about 3.5 kilometers further downstream. It has been developed by constructing a control structure across the Khlong Wa, creating a small storage above the control structure. Photograph in Figure 4.1-2 shows the existing control structure at the Phru Mao and Figure 4.1-3 shows the location of the retarding basin.

4.1.1 Storage Capacity Curve

The storage capacity curve of the Phru Phli Khwai and Phru Mao are as shown in Figure 4.1-4 and Figure 4.1-5 respectively.

4.1.2 Submerged Land and Houses

The Phru Phli Khwai is a swamp and no house locates in its area. But the Phru Mao area, a few houses are on the left bank and a small village is situated near this pond on the right bank. There are many houses in the flood plain area.

4.2 Effect of Flood Discharge Regulation

The effects of the retarding basins on flood reduction have been studied based on the 25 years return period flood. The results of the hydrodynamic model simulation after construction of the retarding basins are then compared with those of the existing conditions to evaluate the effectiveness of the basins.

4.2.1 Phru Phli Khwai

The contemplated Phru Phli Khwai retarding basin is assumed to have an area about 0.5 square kilometer and effective depth for flood storage of 4.00 meters below the surrounding ground area. The natural ground level of the area surrounding the Phru Phli Khwai is supposed to be about +21.00 m.msl. Inflow and outflow from the retarding basin is assumed to be naturally controlled by gravity flow. The bed of the river channel downstream of the retarding basin must be dredged to enough low level so that the retarding basin can be drained freely until water level in the basin is below the minimum level for flood storage. Whole runoff from three sub-basins, with a combined catchment area of 49 square

kilometers, is assumed to be diverted to the retarding basin. The storage volume of the Phru Phli Khwai is then incorporated into the model and the 25 years flood runoff hydrographs from the sub-basins of the Khlong Wa are then input into the model and routed through the model. The Phru Phli Khwai retarding basin can reduce the flood peak at the Kanchanavanich road of only about 12 cms. as shown in Figure 4.2-1. The combined inflow flood peak discharge of the retarding basin is about 93 cms, whereas the peak outflow discharge from Phru Phli Khwai is about 75 cms. or a reduction of discharge of about 18 cms. as shown in Figure 4.2-2.

4.2.2 Phru Mao

The Phru Mao retarding basin study has been carried out for two scenarios. The first scenario of the study assumes that the embankment on both sides of the existing control structure is raised by 1.00 meter and the second scenario assumes that the embankments is always above the maximum water level during flood. The existing control structure is left intact during the simulation. It has been found that the maximum water levels upstream of the control structure for the 25 years flood for the first and second scenario increase from +19.70 m. msl. to 20.36 m. msl. and 20.77 m. msl, respectively. Whereas, the peak discharge reductions at the Kanchanavanich road is only 3 cms. for the first scenario and 20 cms for the second scenario. Figure 4.2-3 and 4.2-4 shows the flood hydrograph at the Kanchanavanich road and the maximum water level upstream of the Phru Mao control structure after construction of the Phru Mao retarding basin, respectively. Much higher flood depth upstream of the Phru Mao control structure can be expected if the embankments on both sides of the control structure are raised.

4.3 Proposed Retarding Basin

The proposed retarding basin in Khlong Wa basin is Phru Phli Khwai. After improvement, it can reduce the peak discharge at Kanchanavanich road (Station X.174) about 18 cms. as shown in Figure 4.2-2.

The combined effect of the Phru Phli Khwai retarding basin and the flood control dam No. 12 is also simulated including flow in the flood plain, is reduced the peak flood at station X.174 about 118 cms. (see Figure 4.3-1)

4.4 Construction Cost

4.4.1 Component and Dimension

The Phru Phli Khwai is a natural low lying area located at Ban Phli Khwai. The area lies on both banks of a tributary of Khlong Wa. The project envisages an excavation of the area large enough to provide a detention storage of 2 MCM. cubic meter. The area to be developed is now partly used as rice fields, desert or wet land. The size is about 300 rai, half of which is estimated to be under private ownership.

The excavated soil will be used to construct a surrounding dike with top elevation at +22.50 m.msl. At most downstream end of the area, the natural ground elevation is at +21.00 m.msl. And the dike will then be 1.50 meter high, shown in Figure 4.4-1.

At the basin outlet, a set of broadcrested spillway with total crest length of 40 m. at +21 m.msl. and sluice gate is provided. The gate location is exactly at the stream centerline to release, at shortest distance, outflow into the stream. At downstream of the gate, the stream will have to be dredged to a necessary distance depending on longitudinal slope of the stream. The dredging will ensure that the bottom of the stream will not be higher than the gate sill for free flow condition to occur downstream of the gate.

During flood season, the gate will be lifted to allow any runoff in the detention basin to pass to downstream at a limited discharge rate. For small or medium storm, it is expected the runoff will be retarded in the basin and, after storm, will gradually release via the gate opening. For heavy storm the runoff should partly flow via the gate opening and partly flow over the boardcrested weir.

The design features can be summarized as follows.

•	Detention Basin		
	Area coverage	300	rai
	Excavated earth volume	2,000,000	cu.m.
	Surrounding Dike		
	Length	3,000	m.
	Volume	30,000	cu.m.
	Basin Depth	4.0	m.
•	Spillway		
	Type	Broadcrested	
	Material	Reinforced Concrete	
	Design Discharge	40	cms..
	Crest length	40	m.
	Crest Elevation	+21.0	m.msl.
	Afflux Depth	0.6	m.
•	Sluice Gate		
	Design Discharge	2	cms..
	Vertical Steel Gate Leaf		
	Size	1.0x2.5	sq.m.
	Thickness	3	mm.
	Frame and Lifting Device		
	RID standard device for 200 kg. hoist Load.		

4.4.2 Budget Price Estimation

(1) Earth Work

Excavation of low lying area	2,000,000	cu.m @ 25 B = 50 mB.
Diking 3,000 m. length	30,000	cu.m @ 40 B = 1.2 mB.
Dredging channel downstream of the gate	10,000	cu.m @ 25 B = 0.25 mB.
Total earth work	50+1.2+0.25	= 51.45 mB.

(2) Structural Work: A lump sum estimate is adopted, which is assumed to be 1 mB.

Spillway and Sluice 1.00 mB.

(3) Land Acquisition: As about half of the 300 rai area is estimated to be under private ownership. The government will have to buy this land at market price. The land price as found by questioning people in the area is on average 0.2 mB./per rai. It is much higher than that of the Upper Khlong Wa reservoir due to the fact that the area is located close to the Na Mom district center.

Therefore the land acquisition cost is estimated to be 0.5x300 @ 0.2 = 30.00 mB.

(4) Total Budget Price: The sum of all cost estimates previously identified has to be increased by 20% to allow for physical and price contingency and 15 mB for study (feasibility and environmental), survey and detail design in order to become the total budget price.

Construction cost + 20% contingency	= (51.45+1.00)+10.49	=62.94 mB.
	Say	63 mB.
Land acquisition + 20% contingency	= 30.00 + 6.00	= 36 mB.
Study, survey and design		= 15 mB.
	Total	= 114 mB.

(5) Implementation Plan: Total used four (4) years as following

- Study, survey and design implemented in first year
- Land acquisition implemented in second years.
- Construction implemented in second-fourth years.

CHAPTER 5 IMPROVEMENT OF EXSITING CHANNEL

5.1 Discharge Capacity of Existing Channel

The existing channel of Khlong Wa will be studied started from the junction of Khlong Wa and Khlong U-Taphao to Na Mom district at the railway bridge (km. 13+160 of Khlong Wa). The main report shown the first period of study between Km. 0+000 to Km. 4+200 for important section.

From cross section and profile of Khlong Wa, survey by RID, the bed channel has steep slope between 1:250 to 1:1,500. The average slope is 1:754. Fig. 5.1-1 shown the profile of bed channel, right bank, left bank and average grade line of Khlong Wa. Figure 5.1-2 shown the existing capacity of Khlong Wa and water surface as minimum bank of section.

5.2 Necessity of Channel Improvement

From flood mitigation plan by RID, flood capacity of Khlong Wa for 25 years return period in the Hat Yai is about 110 cms. From combination of the Phru Phli Khwai retarding basin and flood control dam in item 4.3 in Chapter 4, the peak flood in Khlong Wa can be reduced to 118 cms.

The peak flood about 118 cms is greater than existing capacity of Khlong Wa between Km. 3+500 to Km. 5+500, Km. 6+200 to Km. 9+300 and Km. 11+200 to Km. 12+400. (from Figure 5.1-2). From section Km. 0+000 (Khlong U-Taphao) to Km. 1+470 (Railway to Padang Besa) of Khlong Wa, existing capacity is less than flood runoff but it is in flood plain of Khlong U-Taphao, so no improvement is considered. After discharge is diverted from Khlong Rian by diversion channel D.6, diversion amount is about 50 cms, the capacity of Khlong Wa between Km. 0+000 to Km. 4+200 will increased to 168 cms. The existing capacity of Khlong Wa between Km. 0+000 to Km. 2+700 and Km. 3+400 to Km. 4+200 is then not sufficient enough for peak flood, hence the channel improvement is required.

Figure 5.2-1 show the location and improvement of Khlong Wa, diversion channel D.6.

5.2.1 Effect of Channel Improvement and Flood Plain Encroachment Study

Many channel improvement scenarios for the Khlong Wa have been studied to get better understanding about the effects of channel improvement on the discharge and water level along the Khlong Wa. The effects of construction of the dikes along the stream banks, channel improvement , and backwater effect from the Khlong U-Taphao are the main purposes of the study.

(a) Construction of Dike on the River Banks and Land Filling in the Flood Plain

A study on the effects of construction of dikes along the Khlong Wa has been performed by using the 25 years return period flood. The dikes are assumed to be located near the banks and extend from the mouth of the Khlong Wa to the Na Mom District and rain water can be drained from the catchment area into the Khlong Wa by gravity or pumps. The flood water is assumed to be confined between the dikes. The results of the hydrodynamic simulation show that the flood peak discharge in the Khlong Wa at the Kanchanavanich road increases from 154 cms to 178 cms. and the maximum flood level increase from +10.20 m.msl to +11.00 m.msl. Figure 5.2-2 shows the flood hydrograph at the Kanchanavanich road.

Instead of dike construction, if the flood plain is developed and land is filled up, as generally practiced in the area, so that rain water can freely drained into the Khlong and no flooding occur during 25 years flood. The maximum water level in the Khlong Wa will be increased over the whole length of the Khlong as shown in Figure 5.2-3.

(b) Widening and Dredging of the Channel

Generally speaking, instead of constructing dikes along the banks of the Khlong Wa, flood depth along the Khlong Wa may be reduced by widening and dredging the Khlong. However, the extend of such improvement should be carefully planned and study so that there will be no serious adverse effect on some area along the river banks. Study on the effect of channel widening has been carried out by assuming that the Khlong is widen to the same width from the Khlong U-Taphao confluence to the Na Mom District. Improvement of the channel by widening and dredging the channel bed will also result in higher peak discharge in the downstream area as shown in Figure 5.2-2.

(c) Effect of the Khlong U-Taphao Water Level on the Downstream Reach of the Khlong Wa

Flooding in the downstream reach of the Khlong Wa is not only caused by the high upstream flood peak but the backwater effect from the Khlong U-Taphao as well. Figure 5.2-4 shows the profiles of the 25 years flood in Khlong Wa under different water level in Khlong U-Taphao. It can be seen that the maximum water level at the Khlong U-Taphao govern the water level in the downstream reach of the Khlong Wa.

5.2.2 Appropriate Location for Channel Improvement

General speaking, both diking and channel improvement can lead to higher peak discharge and shorter time to peak of the hydrograph in the downstream reach of the Khlong Wa. In the case of dike construction, attenuation effect of the flood

plain will disappear and depth and velocity of flow in the channel will increase. As a result, flow rate and flood peak will increase. In case of dike construction, internal drainage systems and pumping stations or land filling may be required in some area, so that the rain water can be drained into the Khlong. In case of channel improvement, if the channel in upstream area is wide and deep enough, the flow in the upstream area may be confined within the banks of the Khlong and the water can be drained quickly from the upstream area, but flooding may occur in the downstream area due to higher flood peak. Figure 5.2-3 shows the profile of the maximum water level of the 25 years flood in the Khlong Wa after it has been widened to 60 meters from the Khlong U-Taphao to the Na Mom District. The maximum water level in the upstream area is reduced whereas the maximum water level in the downstream becomes higher. Channel improvement, construction of dikes, or flood plain encroachment in the upstream area will give adverse effect of flood reduction plan for Hat Yai and are against the benefit from flood peak reduction by construction of storage in upstream area. Therefore, the improvement should be restricted to local constrictions at certain bridges, and the downstream reach of the Khlong in more urbanized area. Moreover, the flood plains in the middle reach of the Khlong should be preserved.

5.3 Construction Cost

5.3.1 Component and Dimension

The channel improvement works comprises dredging of channel bed and side slope, and the construction of dikes (2-m high) on both banks of the channel.

The improvement is required where the existing capacity of channel at bankfull condition is less than the 25-year flood discharge of 118 cms.

From Km. 0+000 to Km. 1+470 of Khlong Wa is in flood plain of Khlong U-Taphao between Khlong U-Taphao and railway. No dike on right bank of Khlong U-Taphao in this section, this area will be inundated from Khlong U-Taphao flood. So this section of Khlong Wa, no improvement except dredging for increased cross-section.

From Km. 8+480 to Km. 12+400 of Khlong Wa is in flood plain of Khlong Wa basin, no dredging and dike in this area, so no improvement in this section.

Based on the existing Khlong Wa capacity the following portions will be improved.

From Km.	To. Km.	Distance (m)	Discharge (cms)
1+470	2+700	1,230	168
3+400	4+200	800	168
4+200	5+500	1,300	118
6+200	8+480	2,280	118
	Total	5,610	

The conceptual design and estimated for Khlong Wa improvement said that the cross-section have the same size, the average dredging volume is estimated to be 30 cu.m. and 45 cu.m. per one meter length of channel for 118 cms. and 168 cms. respectively. The channel side slope is 1:2, (shown in Figure 5.3-1)

The dredged earth material will further be employed as dike construction material. Therefore the dike volume is also 25 cu.m. per meter length of channel. The dike has a side slope of 1:1 and a height of 2 m. Plan ,Profile and cross-section are shown in Fig.5.3-2 - Fig.5.3-5.

No details for land acquisition, assumed that it has to reconstruct the fence or other structure and another. This average cost is estimated about 2,000 Baht per length of channel.

5.3.2 Total Construction Budget Price

Practical and conservative unit construction costs of earth works are applied. Also a contingency of 20% to allow for physical and price variation is adopted. Hence the total budget for construction can be estimated below.

(1) Total cost

Survey and detailed design		1	mB.
Construction cost :			
Dredging			
2,030 m. x 45 cu.m. @ 35 B	=	3.198	mB.
3,580 m. x 30 cu.m. @ 35 B	=	3.759	mB.
Dike			
5,610 m x 25 Cu.m @ 42 B	=	5.891	mB.
	=	12.848	mB.
20% contingency	=	2.570	mB.
Sum. = 15.418 mB. say	=	16	mB.
Land Acquisition			
5.10 m. @ 2,000 B	=	11.220	mB.
20% contingency	=	2.244	mB.
Sum. = 13.464 mB. say	=	14	mB.

(2) Implementation Plan : Total used 2 years for this project as following
- Survey and detail design implementation first year.
- Construction and Land acquisition implemented in second year.

CHAPTER 6 CONSTRUCTION OF NORTHWARD DIVERSION

6.1 Diversion and Intercept Discharge

Flood control dam and Phru Phli Khwai retarding basin in Khlong Wa basin, can reduce the peak flood on Khlong Wa to 118 cms which still exceed standard capacity of Khlong Wa, (110 cms). If the peak flood in Khlong Wa is required to be lesser than the standard capacity, some amount of peak flood shall be diverted to another basin.

From the above reason, the Northward diversions are considered. These diversions will divert runoff from the eastern catchment area of Na Mom District. The diversion route will start from Phru Phli Khwai, run through Khlong Khao Kloi sub-basin, Khlong Phra Wong sub basin and empties to Songkhla lake. It can reduce the peak flood of Khlong Wa about 40%.

At the end of Khlong Wa, diversion channel D.6 divert flood amount from Khlong Rian about 50 cms. to Khlong Wa. The peak flood in Khlong Wa will increase to 168 cms. that is higher than the standard capacity of Khlong Wa in this section. So the study team consider diverting this flood from Khlong Rian to another basin, instead of Khlong Wa.

The diversion channel of RID in the Right Bank of Khlong U-Taphao are comprised of 4 lines, namely line No. D.3, line No. D.4, line No. D.5 and line No. D.6. If the new diversion line from Khlong Rian to another basin is proposed, some of the diversion channels of RID, will be cancelled such as D.6 and some will be improved such as D.3.

6.2 Routes Profile and Cross-section

The three new northward diversion lines are consisted of 2 line, from Khlong Rain sub-basin and from Khlong Wa sub-basin 1 line. The routes and profile of new diversion are shown on topographic map scale 1:50,000.

6.2.1 The Northward Diversion Line 1

The route of the northward diversion line No. 1 will be started from retarding pond of Khlong Rian near Ban Thung Don, it go to the north to the diversion channel D.3. In this condition, the 3 RID's diversion channels will be cancelled such as D.4, D.5 and D.6 and the diversion channel D.3 will be enlarged. The location and profiles of this line are shown in Figure 6.2-1 and Figure 6.2-2 respectively.

6.2.2 The Northward Diversion Line 2

The route of the northward diversion line No.2 will be started from retarding pond of Khlong Rian near Ban Thung Don, it go to the northwest to the middle of the diversion channel D.5. In this condition, the diversion channel D.6 will be cancelled and the diversion channel D.5, D.4 and D.3 will be improved.

The location and profiles of this line are shown in Figure 6.2-3 and Figure 6.2-4 respectively.

6.2.3 The Northward Diversion Line No.3

The route of the northward diversion line No.3 will be started from Phru Phli Khwai retarding basin in Khlong Wa basin near Na Mom District, it pass through the Khlong Khae Kloi basin and Khlong Phra Wong basin, and fill to the Songkhla lake.

This diversion line will reduce the peak flood in Khlong Wa about 40%, The location and profiles of this line are shown in Figure 6.2-5 and Figure 6.2-6 respectively.

6.3 Diversion Channel and Appurtenant Structures

6.3.1 Northward Diversion Line 1

This diversion scheme is planed to divert runoff from the eastern sub catchment of Hat Yai municipality to RID diversion line No. D3, which ultimately discharge into the Songkhla lake. It will intercept runoff from various small sub basins which are namely Khlong Rian, Khlong Ple Nos. 1-6. The alignment of the diversion route is shown also in the Figure 6.2-1. The diversion scheme discharges are as shown in table below.

Station Km.	Description	Design Discharge (cms.)
0+000	Meeting with RID Diversion line No. D3	
0+800	Lopburirámasuan Road	125
3+722	Karnchanawanich Road	125
4+400	Khlong Ple 6	95
4+980	Khlong Ple 5	95
5+850	Khlong Ple 4	80
6+510	Khlong Ple 3	80
6+900	Khlong Ple 2	55
8+520	Khlong Ple 1-1	55
8+900	Khlong Ple 1-2	50
10+310	Khlong Rian	45

The most part of the diversion structure is a tunnel beneath Khao Kho Hong. The rock is composed of Palaeo-Mesozoic meta-sedimentary rocks and intrusive granites. The tunnel is expected to pass sand stone and granite.

A circular section tunnel is, at this stage, considered for simplicity reason. For the design discharges given, the tunnel is assumed to be just flowing full. The open

channel flow formula is thus applied. Figure 6.3-1 shown the typical section of tunnel.

The tunnel will start from Khlong Rian (Km. 10+310) to a point just after the Kanchanavanich road (about Km. 3+700) where the tunnel will transform into an open channel which will subsequently cross the Lopburiramasuan road at the bridge (now under construction: Km. 0+800) where the planed RID diversion line No. D4 is expected to pass. As the designed channel section at the bridge has the water surface elevation of +2.797 m. msl., the outflow from the diversion channel will have to conform with this elevation. Moreover the alignment of the diversion channel will be set so that it is normal to the bridge for good hydraulic performance.

For simplicity in this analysis, it is assumed that the diversion channel for the reach between Km. 3+700 to Km. 0+800 is identical to the RID diversion Line No. D4 channel. The RID diversion line No. D4, No. D5 and No. D6 will be cancelled for northward diversion line 1 and RID diversion line No. D3 will be increased by this amount.

It is noted that additional side channel spillway (concrete paved bank at the elevation of +2.797 m.msl.) for diverting excess flow is needed at the location suitable to release the excess flow to the nearby Khlong Bang Not.

The hydraulic design result for the tunnel from Km 10+312 to Km 3+700 is shown in Table 6.3-1. The hydraulic profile is shown in Figure 6.2-2.

6.3.2 Northward Diversion Line 2

This diversion line 2 is an alternative to the Northward Diversion Line 1. The scheme no.2 divert Khlong Rian runoff at the same location as that of the scheme no.1 to the middle of RID diversion line No. D5 by using tunnel as shown in Figure 6.3-1.

The diverted discharge is 50 cms.. Therefore the total capacity of the system of D5, D4 and D3 will be increased by this amount. The comparison between with and without the diversion scheme no.2 is shown in table below.

RID Diversion Channel	Discharge (cms.)	
	Without Northward Diversion Line 2	With Northward Diversion Line 2
D6	50	0
D5	5	5 (no change)
D4	30	65
D3	45	95
	65	65 (no change)
	110	160
	140	190

6.3.3 Northward Diversion Line 3

(1) **Component:** This diversion line comprises an open channel (dredging of the existing tributary discharging into Phru Phli Khwai) diverting water from Phru Phli Khwai, two tunnel reaches underneath Khao Kloi hill and high land near Ban Khuan Hin, and concrete-lined unlined open channels.

(2) **Scheme Discharges:** The design discharges for various reaches of the diversion line 3 are depicted in below table.

Reach No.	Kilometer From	Kilometer To	Distance (m)	Description	Q (cms.)
1	21+802	20+000	1,802	Dredged Channel connecting Phru Phli Khwai	40
2	20+000	15+000	5,000	Tunnel beneath Khao Kloi hill	40
3	15+000	9+560	5,440	Open Channel	75
4	9+560	8+000	1,560	Tunnel beneath highland near Ban Khuan Hin	75
5	8+000	5+200	2,800	Open Channel	75
6	5+200	0+000	5,200	Open Channel	114
		Total	21,802		

(3) **Tunnel Design:** A horse shoed-shape tunnel cross section also called "2r-type" cross-section is adopted. This shape is slightly different form the circular section. The Figure 6.3-1 shows a comparison between the two. Advantage of the horse shoed-shape is that it is more convenient during construction in transferring materials over the lower tunnel section (tunnel bottom) in and out of the tunnel.

The hydraulic design for the tunnel reaches no.2 and no.4 is made below.

Reach No.2

Q = 40 cms. Longitudinal Slope 1 : 1,200
r_1 = 2.5 m. r_2 = 5 m.
Flow depth d = 1.40 r_1
= 3.50 m.

d/r = 1.4
A = $\alpha . r_1^2$ = 2.52×2.50^2 = 15.75 sq.m.
R = $\beta . r_1^2$ = 0.60×2.50 = 1.50 m.
Manning n = 0.015

$$V = \frac{1}{0.015} \times (1.50)^{(2/3)} \times (1/1,200)^{0.5}$$
= 2.52 m/s
Q = 15.75×2.52
= 40 cms.
OK.

Reach No.4

Q = 75 cms. Longitudinal Slope 1 : 1,000
r_1 = 3.1 m. r_2 = 6.2 m.
Flow depth d = 1.40 r_1
= 4.34 m.

d/r_1 = 1.4
A = $\alpha . r_1^2$ = 2.52×3.1^2 = 24.22 sq.m.
R = $\beta . r_1^2$ = 0.60×3.1 = 1.86 m.
Manning n = 0.015

$$V = \frac{1}{0.015} \times (1.86)^{(2/3)} \times (1/1000)^{0.5}$$
= 3.18 m/s
Q = 3.18×24.22
= 77 cms.
> 75 OK.

(4) Channel Design: From design discharge, the corresponding hydraulic designs of channel reaches are summarized in table below.

Reach No	Q (cms.)	Longitudinal Bed Slope (1:S)	Side Slope (1:m)	lining	Bed Width (m)	Water Depth (m)	Freeboard (m)
1	40	1:4,000	1:2	unlined	10	3.0	1.0
3	75	1:1,000	1:1.5	Concrete lining	8	2.3	0.7
5	75	1:1,600	1:2	unlined	12	2.8	1.2
6	114	1:3,000	1:2	unlined	16	3.6	1.4

(5) Hydraulic Profile: From the designs of tunnel and channel previously described, the hydraulic profile can be suitably drawn as shown in Fig.6.3-2. and appurtenant structures shown in Fig.6.3-3 and Fig.6.3-4

6.4 Construction Cost

6.4.1 Northward Diversion Line 1

(1) Tunnel

The construction cost estimation in this report is done at conceptual level, using referenced projects in Thailand. The unit costs used here are proportional to the tunnel diameter, in which the unit costs from the referenced projects are based. The cost estimates for the tunnel of diversion scheme line 1 is shown in table below.

Diameter (m)	Length (m)	Unit Cost (mB./m)	Price (mB.)
4.5	1,332	0.106	141.192
4.6	1,400	0.111	155.400
5.0	1,070	0.125	133.750
6.5	2,810	0.203	570.430
Total			1,000.772

(2) Open Channel

The cross-sectional area of the design open channel between km. 0+000 to km. 3+722 is the same as cross-sectional area of RID diversion channel D3. The construction cost is estimated as follow.

Length	3.722	m.
Excavation	30	cu.m./linear meter
Rate	35	B/cu.m.
Price	3.908	mB.
Compaction	120	cu.m./linear meter
Rate	42	B/cu.m.
Price	18.759	mB.
Total	22.667	mB.

(3) Land Acquisition

Land Acquisition in this route is the same at RID diversion channel D3 and D4. The cost is shown in table below.

Open Channel

0+000 - 3+722	Row = 80 m.	Area = 186.1	Rai
Price average	@ 0.7 mB/rai	Price = 130.27	mB.
13+900 - 13+970	Row = 80 m.	Area = 4.5	Rai
Price average	@ 1.2 mB/rai	Price = 5.4	mB

Tunnel

3+722 - 13+900	Row = 40 m.	Area = 254.45	Rai
average	= 0 mB/rai, in government office		

(4) Total Budget

Construction Cost

Tunnel	=	1,000.772	mB.
Open Channel	=	22.667	mB.
Land Acquisition	=	135.670	mB.
		1,159.109	mB.

20% contingency	=	231.822	mB.
		1,390.931	mB.
Say	=	1,391	mB.

6.4.2 Northward Diversion Line 2

The Northward diversion line 2 will divert Khlong Rian runoff about 50 cms. to middle of RID diversion channel D5 by tunnel. The tunnel size diameter is 4.50 meters, between km. 0+110 to km. 3+110 with slope 1:375, and km. 0+000 to km. 0+110 with slope 1:10,000 which this section will be changed from tunnel to open channel at RID diversion channel D5.

The cross section of RID diversion channel D5 and D4 will be expanded in order to take increased runoff from Northward diversion line 2. The RID diversion channel D3 has large cross-section enough to take the increased runoff and diversion channel D6 is cancelled, as same as the northward diversion line 1.

(1) Tunnel

The construction cost for

Diameter	4.50	meters
Length	3,110	meters
Unit cost	0.106	mB/m.

(2) Land Acquisition

Some area is in the government office, say 50% for private ownership.

Total area	0+000 - 3+110	Row = 40	m.
	Area = 78 Rai		
Private ownership	= 39 Rai	Say = 40	Rai

Price average @ 2.00 mB./rai

Total price = 2 x 40 = 80 mB.

(3) Total Budget

Construction cost

Tunnel	=	324.66	mB.
Land Acquisition	=	80.00	mB.
		409.66	mB.
20% contingency	=	81.93	mB.
		491.59	mB.
Say	=	492	mB.

6.4.3 Northward Diversion Line 3

(1) **Tunnel:** Experiences from other projects are applied to estimate the construction cost of the tunnels designed.

(a) **For the reach no.2**

r_2 = 5.00 m. Concrete (t) = 0.30 m.
Area = 3.3×2.80^2 = 26 sq.m.
Unit Cost = 350,000 x 26/80 x 1.1
= 125,000 B/m.
Total Cost = 5,000 x 0.125 = 625 mB.

(b) **For the reach no.4**

r_2 = 6.2 m. Concrete (t) = 0.35 m.
Area = 3.3×3.45^2 = 40 sq.m.
Unit Cost = 350,000 x 40/80 x 1.1
= 190,000 B/m.
Total Cost = 1,560 x 0.19 = 296.4 mB.

(2) **Open Channel:** The cross-sectional areas of the designed open channel reaches no.1, 3, 5 and 6 are determined for the reach average excavation depths. The corresponding excavation areas for the cross-sections are calculated, which give the average excavation volume per meter length of canal.

The material excavated will be placed on both banks of the channel and compacted to provide diking.

Also it is estimated that the right of way required for the channel and dikes on both banks is approximately equal to 3 times of the channel top width.

The following unit construction rates are adopted.

Excavation	35	B/cu.m
Compaction	42	B/cu.m
Concrete lining (0.1 m thickness)	500	B/sq.m.

The construction costs for this estimated to be 197.2 mB. as shown below.

Reach No.	Length (m)	Average (m)	Row (m)	Excavation		Compaction		Living		Total Cost (mB)
				(cu.m)	(mB)	(cu.m)	(mB)	(sq.m)	(mB)	
1	802	6	120	39,000	1.365	39,000	1.638	-	-	3.003
3	5,440	7	120	791,520	27.703	791,520	33.244	113,260	56.63	117.577
5	2,800	5	110	319,200	11.172	319,200	13.406	-	-	24.578
6	5,200	5	110	676,000	23.660	676,000	28.392	-	-	52.052
Sum	14,242	-	-	1,825,720	63.9	1,825,720	76.68	113,260	56.63	197.210

(3) Land Acquisition: Land along the route of the diversion line 3 is found to be occupied by people. By inquiry, the correspondents said they have official ownership documents. Therefore in this study it is asserted that to acquire these lands the government will have to pay to the people affected and the rate of 50,000 B/rai as an average land price is adopted.

The calculation of budget for land acquisition, which is totally 55.2 mB, is shown below.

Reach No.	Right of Way (m)	Length (m)	Area to be acquired		Unit Rate (B/rai)	Price (mB)
			(sq.m)	(rai)		
1	44	802	35,288	22.1	50,000	1.105
2	30	5,000	150,000	93.8	50,000	4.69
3	120	5,440	652,800	408.0	50,000	20.4
4	30	1,560	46,800	29.3	50,000	1.465
5	110	2,800	308,000	192.5	50,000	9.625
6	110	5,200	572,000	357.5	50,000	17.875
	Total	21,802	1,764,888	1,103.2	50,000	55.16

(4) Total Budget: The total budget comprises construction costs of tunnel and open channel, land acquisition cost, and 20% contingency for physical and price variations.

The total budget is estimated to be 1,445 mB as shown below

Study (feasibility and environmental), survey and detail design = 35 mB.

Construction Cost

Tunnel 625+296.4	=	921.4	mB.
Open channel	=	197.2	mB.
20% contingency		223.7	mB.
Sum = 1,342.3 mB say	=	1,343	mB.
Land Acquisition	=	55.2	mB.
20% contingency		11.1	mB.
Sum = 66.3 mB say	=	67	mB.

(5) Implementation Plan: Total used five (5) year for this project as following

- Study, survey and detail design implemented in first and second years.
- Land acquisition implemented in second and third years.
- Construction is implemented in third – fifth years.

6.5 Comparison Cost for Northward Diversion Line

The RID diversion channel D6 will divert runoff from Khlong Rian to Khlong Wa and flow to Khlong U-Taphao and Hat Yai municipality. But the 2 new diversion lines namely line 1 and line 2 will divert water to downstream flood plain of Khlong U-Taphao from Hat Yai municipality.

For Northward diversion line 1, the RID diversion channel D3 has no changed for all section. The RID diversion channel D4, D5 and D6 will be cancelled.

For Northward diversion line 2, the section of RID diversion channel D3 will not be changed and D6 will be canceled as same as the northward diversion line 1. The RID diversion channel D4 and D5 will be changed section in order to take the increased runoff, which divert from Khlong Rian.

The comparison costs of all diversion are shown in table below.

Unit : million Baht

Diversion line	Existing Plan	New Plan for Northward Diversion	
		Line 1	Line 2
RID Diversion Channel			
- D4	271	-	307
- D5	210	-	274
- D6	172	-	-
Northward Diversion Line			
- Line 1	-	1,391	-
- Line 2	-	-	492
Total	653	1,391	1,073

Summary

1. The existing plan for RID's Diversion channel D4, D5 and D6, the total cost are cheapest but they will cause impact on people surrounded.

2. The northward diversion line, the total cost (not including study, survey and detail design) is higher than the existing plan and it will cause the most serious impact to the people.

3. The northward diversion line 1, the total cost is the most expensive but it will cause the minimum impact to the people.