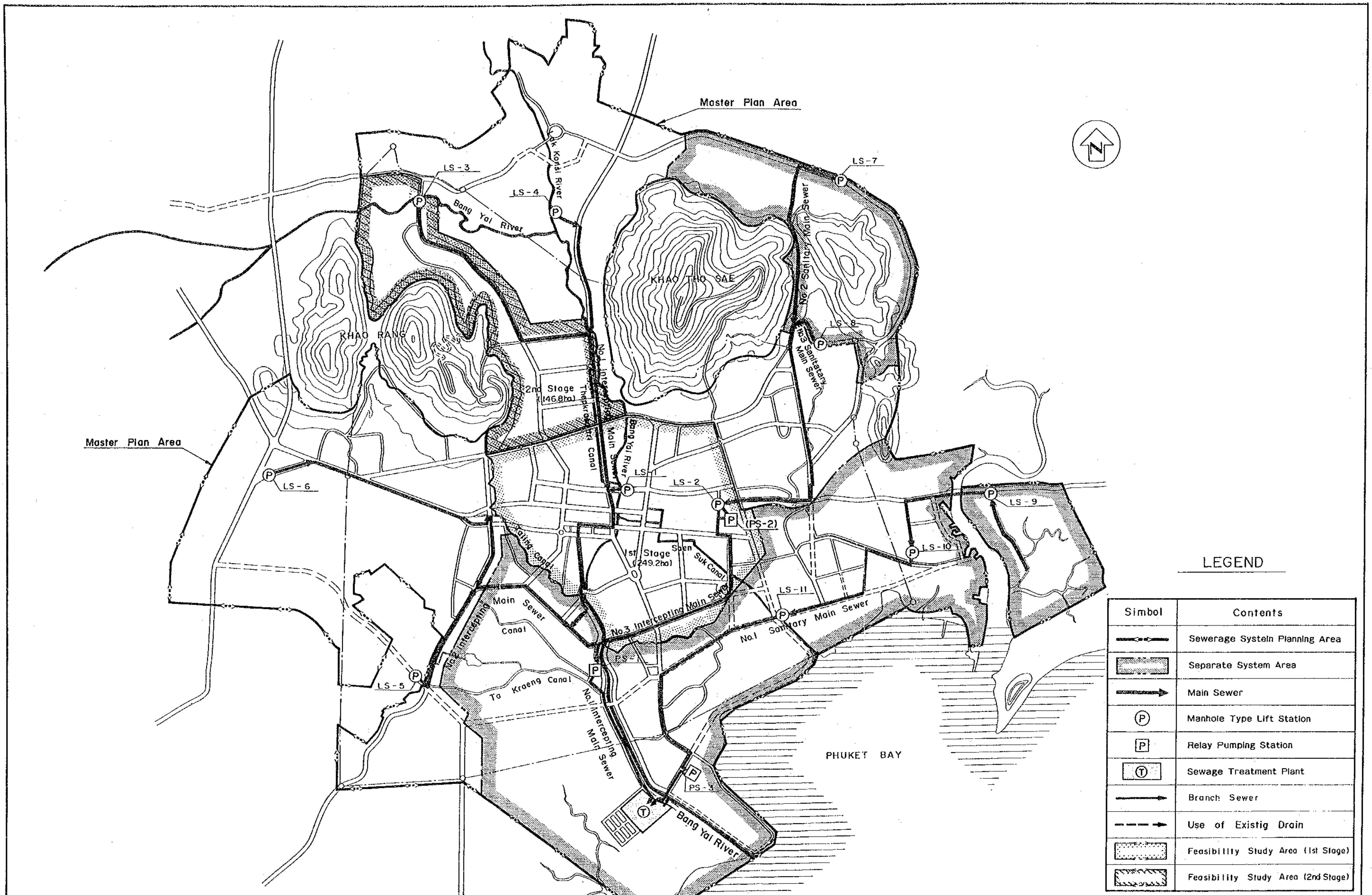


Fig. 3.7
LAYOUT OF FEASIBILITY STUDY AREA

The following can be noted from the above mentioned tables.

(i) The Feasibility Study area's population and sewage flow ratio against that of the Master Plan area are 41% and 56%, respectively.

(ii) 48% out of total BOD load generated in the study area in 2006 is discharged into the Bang Yai river at upstream of Taling Chan Br., while the remainder is discharged into the Taling Chan canal, the Ta Kraeng canal and the Tajin river.

(iii) 79% of total BOD load discharged into the Bang Yai river at upstream of Taling Chan Br. is covered in the Feasibility Study area.

(iv) Since the present population discharges wastewater into the Bang Yai river upstream of Taling Chan Br. in the Feasibility Study area, where the total BOD loading per capita is estimated at 18,000 prs and 90 mg/l, the generated BOD load in the area is calculated at approx. 810 kg/d including contamination from hotels, hospitals and others.

Therefore, it is forecasted that the Bang Yai river will be more polluted about 2.5 times as much as at present, should this project not be implemented.

(v) The Feasibility Study area covers 79% of BOD load to be generated in the above mentioned area within the Master Plan area.

2) For Bang Yai river, its water quality practically depends on the limited river flow for its maintenance or scarce flow during dry seasons. It is therefore quite difficult to estimate the river's common water quality.

Based on a field survey done during a dry season, a systematic water quality investigation was carried out as mentioned in Chapter 2.4. Investigations show that the water quality can be improved as shown in the following Table 3.11, provided this Feasibility Study Project will be fully implemented.

Table 3.11 Comparison of Bang Yai River's BOD with and without the Improvements proposed in this Study

Location	Present as of Jan. 25, 1990	In 2006 without the Project	In 2006 with the Project
R-1 (Yaovaraj Br.)	0.95 mg/l	0.95 mg/l	0.95 mg/l
R-2 (Taonpradit Br.)	3.10	14	6.0
R-3 (Taling Chan Br.)	13.25	30	7.5
R-4 (River Mouth)	12.40	-	-

As is evident in the above table, the river water quality will be considerably improved when the project is carried out on schedule.

CHAPTER 4

PRELIMINARY DESIGN FOR SEWERAGE IMPROVEMENT

CHAPTER 4 : PRELIMINARY DESIGN FOR SEWERAGE IMPROVEMENT

4.1 Design Criteria

The preliminary design is conducted for the following facilities:

(i) Sewer piping system with interceptor
(ii) Pumping station
(iii) Sewage treatment plant with drying beds

The detailed design criteria for the structures on the above mentioned would be basically similar to those used and described in the Master Plan Report.

The other design criteria and design condition related to the hydraulic and structural design of pipeline and equipment are as follows:

(1) Sewer Design Criteria

1) Minimum size of sewer

The minimum diameter for a public sanitary interceptor sewer is 200 mm to 250 mm or 250 mm in bottom width for storm sewer and combined sewer, respectively.

2) In-pipe velocity

(a) Sanitary sewers and interceptor sewers shall be so designed to provide a sewage flow velocity ranging from a minimum of 0.6 m/sec and a maximum of 3.0 m/sec.

(b) Storm sewers shall be so designed to provide a sewage flow velocity ranging from a minimum velocity of 0.8m/sec and a maximum of 3.0 m/sec.

(2) Manhole and Installation Depth of Sewers Inside Manholes

1) Maximum manhole interval

The maximum manhole intervals are as follows:

Pipe Diameter	<500 mm	<800 mm	<1,500 mm	>1,800 mm
Max. Interval	60 m	90 m	120 m	200 m

2) Minimum depth of cover

As a rule, the minimum depth of cover for sewers shall be 1.0 m. However, some clearance shall be given at crossings with other pipes including drains, other utilities and rivers.

4.2 Preliminary Design

4.2.1 Fundamental Design Conditions

(1) Determination of Design Conditions

- Design target year	2001 (B.E. 2544)
- Design area	Block Nos. 2, 3 and 10 Total 396 ha.
- Design population	29,600 in 2001
- Design wastewater flow	18,300 m^3/day (Design mean dryweather flow)
- Sewage collection system	Combined collection system
- Design water quality	Influent BOD 120 mg/l Influent SS 100 mg/l
- Removal efficiency	BOD target : 90% SS target : 75%
- Site area for sewage treatment plant	Approx. 5 ha in line with the Master Plan

(2) Condition of Sewer Construction

1) The soil in the study area is generally of uniform stratum of mainly loose medium silty clay and loose fine sand with "N" value from 1 to 10 appearing at the depth of 3 to 10 meters from ground surface.

Ground water level is rather high from 0.8 to 2 m below ground surface depending on the specific locations. Excavations for the proposed sewerage facilities extend from the existing ground surface to a depth of approximately 3 m to 8 m below. Therefore, sewer installation shall be done with due consideration to the excavation and sheeting methods to be used.

The following comparison tables for sewer installation are presented to explain the basic design conception. In conclusion, open cut by sheet piling and slurry shield methods are proposed for the preliminary design. In this connection, it is highly recommended that the construction method be studied more deeply in the detailed design, taking into account the soil condition, ground water level and traffic condition so that a smoother flow of the construction works can be attained.

Comparison of the Sewerage Line (Small Diameter Pipe)

	Characteristics
Open Cut By Sheet Piling	1).U-Type Steel sheet piles are used, because they are popular in Thailand. 2).Water Proof is not always perfect, but this method can keep the continuation against the earth pressure. 3).This is the most popular and economical method, but protection work should be needed to perform for the under ground facilities.
Pilot Pipe System (Ironmole Method)	1).Pit size is usually small and it is easy to install the machine, which can be disassembled. 2).This method is applicable from 0 to 50 of N-value. 3).This method is applicable under the condition of high groundwater level. 4).Construction accuracy is good. 5).Pipe size is free to chose by changing the adaptor and the cost is low. 6).As operation is complicated the construction speed is low. 7).Jacking Penetration of pilot pipes needs lubricant because of frictional resistance. 8).A slurry pressure method of this system needs a complicated device and the construction term is slow.
Horizontal Auger (Horizonger Method)	1).This method can be applicable for stiff ground. 2).This method can be applicable for a wide range of the soil condition because of its selection of a auger head suitable for the ground. 3).Construction accuracy is relatively high because of the continuous survey by a razer transit. 4).It is possible to reach the existing manhole. 5).Construction speed is high. 6).The control of the pipe direction needs the skill depending on the soil condition. 7).This method is not applicable for the fragile ground under high groundwater level.
Slurry Shield (Unclemole Method)	1).Construction speed is high. 2).This method is suitable for sandy ground under high groundwater level. 3).Construction accuracy is high because of the use of a television camera. 4).As the machine handling is comparatively easy, it is possible for only one technician to control the machine. 5).This method hardly influences the ground surface. 6).The cost of the method is comparatively high. 7).The maximum grain size to construct is 50 mm.

Comparison of the Sewerage Line

	Characteristics
Open Cut By Sheet Piling	1).U-Type Steel sheet piles are used, because they are popular in Thailand. 2).Water Proof is not always perfect, but this method can keep the continuation against the earth pressure. 3).This is the most popular and economical method, but protection work should be needed to perform for the under ground facilities.
Manual Shield	1).This method is suitable for the self-support soil and the excavation is performed by man power. 2).Excavated soil is transported outside by a muck car.
Earth Pressure Type Shield	1).The face is held by excavated material filled in the chamber. 2).Excavated material is taken out by screw conveyer and then transported outside by a muck car.
Slurry Shield	1).The face is held by slurry filled in the chamber. 2).Excavated material is mixed with slurry and transported as fluid to treat(ment) plant on the ground by a slurry pump.

2) A lift pump station, which is also commonly called an inside-manhole pump, is provided at three spots. This station is designed without screens nor private power plant.

3) A pumping station is provided near Poonphol Br. to minimize the excavation cost for laying sewer lines. This station is protected by a screen and grit-chamber with private power plant.

(3) Design Conditions for Civil Engineering Works

1) The proposed site of the sewage treatment plant will be at the reclaimed land previously filled with solid waste, and after the project construction the adjoining solid waste disposal land and night-soil treatment plant will be continuously utilized.

2) The proposed site area has a soil stratum consisting of very soft clay and loose sand with "N" value from 0 to 1 up to depths of 10 meter. The "N" value is 13 for depths ranging from 10 to 13 meters.

The bearing layer of the pile foundation is designed to be -11m from ground surface. Since most of the facilities are presumed to be constructed on pile foundations, the plan is to keep the length as short as possible.

3) In the architectural plan of the operation building, attention will be focused on the following points.

- to centralize operations within the operations building as much as possible.

- to minimize building space requirements with due consideration to the need to provide an operation panel room, switch room, water examination room, general office and workers' rooms with temporary sleeping quarters.

(4) Design Conditions for Mechanical and Electrical Equipment

1) The proposed equipment will be selected in due consideration of common practices and minimal skills requirement for operation and maintenance works. In line with this, locally manufactured equipment will be used as much as possible.

2) Stand-by equipment will be provided in principle. However, in a cases where the system will not be affected by providing a by-pass routes in case certain equipment develop mechanical troubles, no stand-by equipment or reserve facilities will be provided.

3) Input voltage is designed to be 11 kv, considering that the total load of the equipment will be 8,000 kW in the Master Plan level in year 2006. Subsequently the electric power will be distributed to each plant at a voltage of 400V and 230V.

4) The generator load will be designed considering the security of the pump station plant at minimum demand conditions and as well as the operational office's minimum power requirements.

5) To ensure the stability of treatment works, certainty of operations, increase in treatment efficiency, improvement of working conditions and need to minimize power costs, proper instrumentation will be provided and centralized to the operations building.

4.2.2 Preliminary Design

(1) Sewer System

The trunk sewers and intercepting lateral sewers with interceptor manholes are designed in accordance with the basic design conception of the Master Plan, which means that sewer pipe size and installation depth are to be followed as specified in the Master Plan.

The proposed route of sewer system is shown in previous Fig.3.7. Preliminary flow calculation and drawings are prepared for reference as shown in Annex Table 4.1 and Annex Figs.4.1 to 4.10.

The following table shows the major facilities of the sewer system.

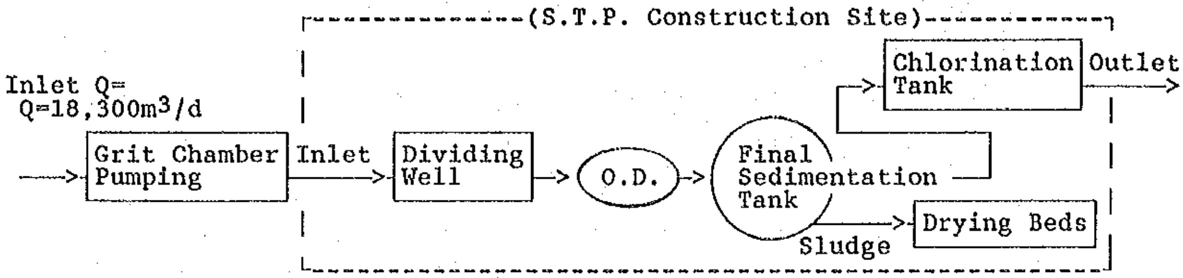
Table 4.1 Major Facilities of Sewer System

Item	Size	Length of Sewer	Remark
Lateral Sewer			
(Open cut)	φ100 mm	750 m	PVC
	150	1,105	"
	200	1,645	"
	250	480	"
	300	1,090	RCP
	400	550	"
	500	525	"
(Presser Sewer)	φ200 mm	90 m	CIP
Sub-Total		6,235 m	
(Interceptor)	75 unit		
Trunk Sewer			
(Open Cut)	φ250 m	180 m	PVC
	400	1,875	RCP
	500	10	"
	600	1,200	"
	800	2,120	"
	1,000	905	"
	1,200	300	"
	1,500	210	"
(Jacking)	φ1,000 mm	60 m	"
(Presser Sewer)	φ300 mm	60 m	CIP
	800	1,120	"
(Inverted Siphon)	φ500 mm x 2	40 m	"
Sub-Total		8,080 m	
Total		14,315 m	

Pump Station (Lift Station)	2 spot	φ300mm x 12.5m³/min x 2 unit/spot
	1	500 x 25 x 3

(2) Sewage Treatment Process

On the basis of the Master Plan, the sewage treatment facilities to be constructed in the proposed sit are sewage receiving and dividing well, oxidation ditchs, final sedimentation tanks, chlorination tank, drying beds and their relative equipment. The following figure shows the treatment process and treatment flow.



Note: (1) Unit----m^3/day
(2) Daily average flow (D.W.F.)

The outline of the sewage treatment facilities are shown in the following table while the layout of the facilities is illustrated in Fig.4.1. Other related preliminary design drawings are prepared for reference as shown in Annex Figs. 4.11 to 4.20.

Table 4.2 Major facilities of Sewage Treatment Process

Name of Facility	Specification	No. of Unit
- Dividing Well		1 unit
- Oxidation Ditch	4.0m x 106m x 2.5mH	8 "
- Final Sedimentation Tank	ϕ19.5m x 2.5mH	4 "
- Chlorination Tank	2.0m x 16m x 1.5mH x 4	1 "
- Drying Beds	12.6m x 20m	20 "
- Operation Office	18m x 18m	1 "

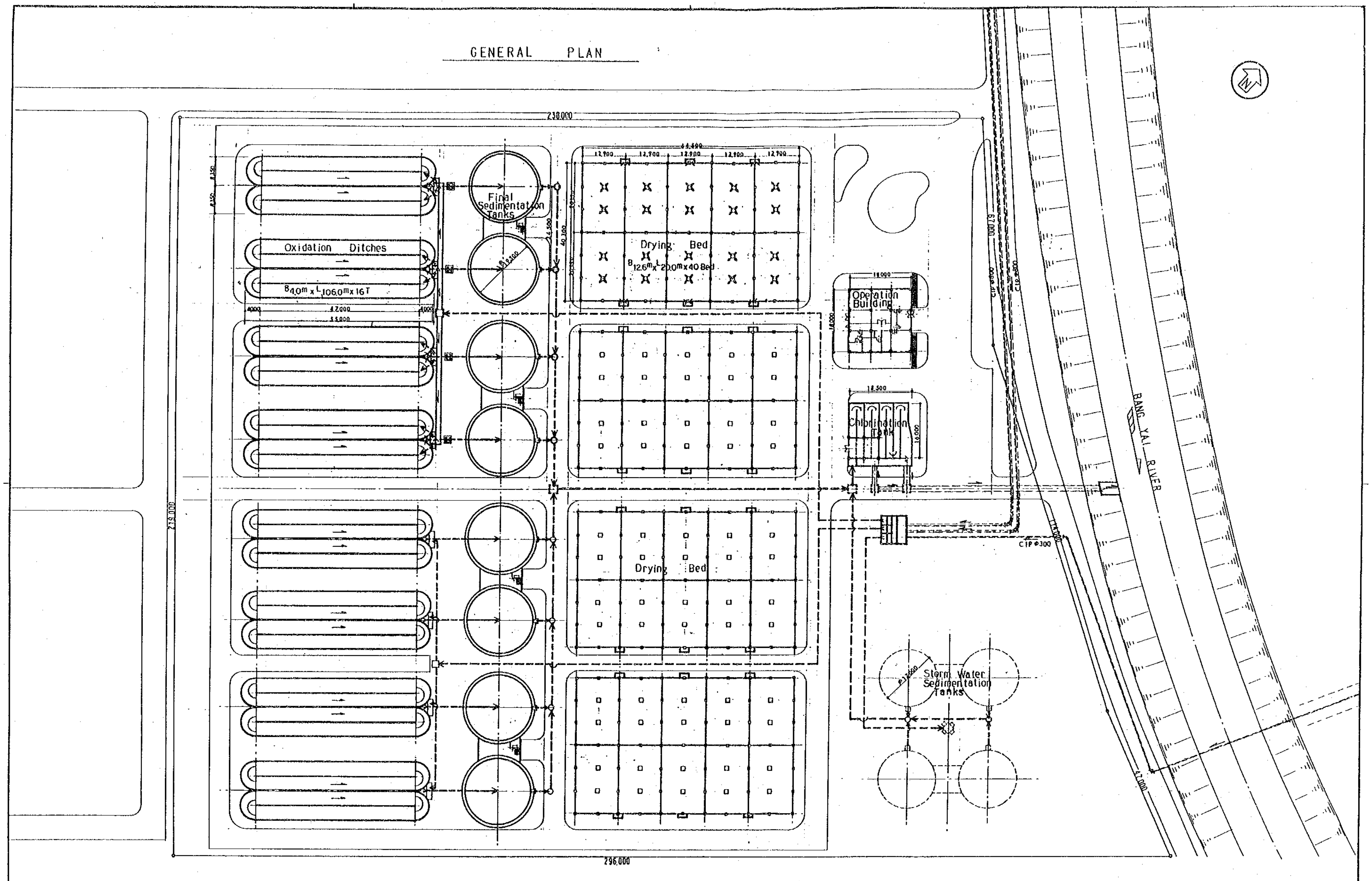


Fig. 4.1
SEWAGE TREATMENT PLANT
GENERAL PLAN

4.3 Cost Estimate

4.3.1 Condition of Cost Estimate

1) The project cost consists of the construction cost, land acquisition, engineering services fee, government administration, and physical contingency. As for the construction cost, the following cost allocation parameters which are used in Tailand are adopted.

- Construction Cost
  - Direct Cost
    - Material Cost
    - Labor Cost
    - Heavy Equipment
    - Fuel
    - Hauling
  - Indirect Cost
    - Site Expense (%)
    - Profit (%)
    - Tax

All the costs are based on the mid-1989 price level. It is noted that construction costs, particularly material costs, have been rapidly rising since 1988. The increase in prices in 1988 - 1989 ranges from 4% to 50% depending on the type of materials. The average price increase in 1989 is predicted to range from 20 to 30%. In this study, however, cost escalation was not considered.

2) Generally for construction of structures including sewers, pumping stations and treatment facilities, most of the materials required are available in Thailand, except for mechanical and electrical equipment which have to be imported. The official unit prices of these basic materials are shown in the following table. With respect to those mechanical and electrical equipment which will have to be imported, estimated costs are based on previous international biddings.

Unit Cost of Major Materials for Civil Works
(as of August, 1989)

Items	Units	Price (Baht)
Cement	kg	85
Sand for Concrete	m^3	150
Gravel for Concrete	m^3	240
Round for (9 to 25 mm)	ton	13,000
Hard wood (1st class)	ft3	450
Gasoline (Diesel oil)	liter	6.5
Manhole (0.8 x 0.8 x 1.5D)	set	9,000
Reinforced concrete pile	concrete m^3	3,200

The detailes of the unit cost is shown in Appendix.

3) Currency Portion

a. Foreign Currency Portion

Included under the foreign currency portion of this project are the following:

- Depreciation cost of construction and manufacturing equipment
- Instrument equipment
- Freight and insurance of imported materials and goods

b. Local Currency Portion

Covered under the local currency portion are the following:

- Labor wages
- Timber, cement, concrete aggregate, and other local materials
- Steel and coating materials and welding rods
- Inland transportation

4) The direct costs of the project should be transformed into economic costs. For this purpose, the project cost and operation and maintenance costs are considered in the study. These costs will be converted into economic costs by applying shadow pricing factors.

5) Engineering services fee is computed based on the estimated profession fees and other cost items which are necessary for the

detailed design and construction supervision works in both the first and second stage implementation.

6) Land acquisition and compensation cost are not estimated because the proposed construction sits are publicly owned.

7) The currency exchange rate used is;

US dollar 1.00 = Baht 25.4 = Japanese Yen 145

4.3.2 Construction Cost

In estimating the costs, the following shall be taken note to clarify the element of the project implementation cost first.

Provide by the Government contribution

(i) construction of sewers (include in this estimate)
(ii) construction of pumping station (")
(iii) construction of treatment facilities (")
(iv) operation and maintenance (")
(v) land acqusition (exclude in this estimate)
(vi) preparation of source facilities to supply power and water to the project facilities (exclude in this estimate)

Provided by the private contribution

(i) house connection to sewer
(ii) maintenance of cesspool or septic tank

(1) Sewer construction cost

Table 4.3 Sewer Construction Cost

Unit: 10^3Baht

	Item	Size	Lengh	Price(Baht)
1. Direct Cost				
(1)	Lateral Sewers			
	1) Open Cut	φ100 - 500mm	6,145m	10,080
	2) Pressure Sewer	φ200	90	220
	3) Intercepter		75 unit	490
(2)	Trunk Sewers			
	1) Open Cut	φ250 - 1,500mm	6,800m	61,070
	2) Jacking	φ1,000	60	2,120
	3) Pressure Sewer	φ300 - 800	1,180	14,740
	4) Inverted Siphon	φ500	40	1,710
(3)	Light Station		3 spot	1,230
	Total (1)			91,660
2. Indirect Cost				
(1)	Overhead (Direct cost x 0.06)			5,500
(2)	Profit (Direct cost x 0.085)			7,790
(3)	Freight			250
	Total (2)			13,540
Gross Total (1+2)				105,200
3. Tax (Gross Total x 0.041)				4,300
Construction Cost (1+2+3)				109,500

(2) Sewage treatment plant construction cost

Table 4.4 Sewage Treatment Plant Construction Cost

unit: 10^3 Baht

1. Direct Cost		
(1) Civil Works		
1) Pumping Station	12m x 31m x 9.5mH	9,900
2) Operation Building	18m x 24m x 4mH	2,300
3) S.T.P. Facilities		34,780
4) Earth Works		4,410
Sub-Total		51,390
(2) Mechanical Installation Cost		
1) Pump Station		11,920
2) S.T.P. Facilities		44,850
Sub Total		56,770
(3) Electrical Installation Cost		
1) Pump Station		26,300
2) Control & Instrumentation for S.T.P.		23,700
Sub Total		50,000
Total (1)		158,160
2. Indirect Cost		
(1) Overhead (Direct Cost x 0.06)		9,490
(2) Profit (Direct Cost x 0.085)		13,440
(3) Freight		10,270
Total (2)		33,200
Gross Total (1+2)		191,360
3. Tax (Gross Total x 0.041)		7,840
Construction Cost (1 + 2 + 3)		199,200

(3) Allocation to Phased Construction

The total estimated construction cost for the proposed Feasibility Study project is summarized and allocated to 1st and 2nd construction phases as follows:

Table 4.5 Construction Cost for Proposed Sewerage System

unit: 10^3 Bhat

Facility	Estimated Construction Cost	Allocation Phase 1	Allocation Phase 2
Sewer	190,500	96,130	13,370
Pumping Station & S.T.P.	199,200	172,055	27,145
Total	308,700	268,185	40,515

4.3.3 Operation and Maintenance Costs

For estimation of the costs, comparabe information obtained from the Bangkok Sewerage System Project report and cities with similar systems in Japan have been reviewed, and the results are used as the basis for reasonable cost estimations.

(1) Sewer Cleaning

On the assumption that frequency of cleaning for public sewer is once in every three years and unit cost for cleaning is Baht 28.5 per meter, the maintenance cost is estimated as follows:

$$\frac{8,080 \text{ m} + 6,235 \text{ m}}{3} \times 28.5 \text{ B/m} = 136 \times 10^3 \text{ B/year}$$

Where: 8,080 m = Length of trunk sewer

6,235 m = Length of lateval sewer

(2) Pumping and Lift Station

1) Pump station

(i) Labor cost

To estimate the labor cost for operation of the pump station, the operational organization and monthly labor cost is assumed as follows:

	Unit Cost/Month	Prs.	Price/year
Chief engineer	4.79×10^3 Baht	1	57×10^3 Baht
Technician	4.04	2	97
Labor	2.20	2	53
Total		5	207

(ii) Operation Cost

- Power expense:
  $1,290$ kWh/day x 365 day/year x 1,856 B/kWh = 874×10^3 B/year

- Fuel expense:
  On the assumption that 600 PS generator operates for 8 hours per month instead of power failure:

$$\frac{600 \text{ PS} \times 0.175 \text{ kg/PS/hr} \times 8 \text{ hr/mo} \times 12 \text{ mo/yr} \times 1.1}{850} \times 6.5 \text{ B/l}$$

$= 85 \times 10^3$ B/year

(iii) Maintenance Cost

- Expense of civil structure: to sum up 1% per year of total civil construction cost;

  $7,405 \times 10^3$ B x 0.01/y = 74×10^3 B/year

- Expense for mechanical: to sum up 3% per year of total mechanical cost;

$10,335 \times 10^3$ B x 0.03/y = 310×10^3 B/year

- Expense for electrical: to sum up 1% per year of total electrical cost;

$21,674 \times 10^3$ B x 0.01/y = 217×10^3 B/year

2) Lift station

There are three lift stations in the Feasibility Study area. The operation and maintenance cost for the stations is estimated to sum up to 210×10^3 Baht based on 70×10^3 Baht per unit cost.

(3) Sewage Treatment Facilities

(i) Labor cost

The labor cost is estimated as follows on the assumption that operational organization and mostly labor cost for the sewage treatment facilities are shown below.

Unit : 10^3Baht

	Unit Monthly Cost	Number	Annual Cost
Manager	7.34	1	88
Chief	4.79	1	57
Technician	4.04	3	145
Labor	2.20	4	106
Total		9	396

(ii) Operation cost

- Power expense:

2,500 kW/d x 365 d/y x 1,856 B/kWh = $1,694 \times 10^3$ B/year

- Chlorination expense:

$$18,300\ m^3/d \times 3 \times 10^{-3} \times 365\ d/y \times 15.6\ B/kg = 313 \times 10^3\ B/year$$

(iii) Maintenance cost

- Expense for civil structure: to sum up 1% per year of total civil construction cost:

$$30,954 \times 10^3\ B \times 0.01/y = 310 \times 10^3\ B/year$$

- Expense for mechanical: to sum up 3% per year of total mechanical cost except oxidation ditch process and 2% for the oxidation ditch process:

$21,290 \times 10^3\ B \times 0.03/y =$	$639 \times 10^3\ B/year$
$17,905 \times 10^3\ B \times 0.02/y =$	358×10^3
Total	$997 \times 10^3\ B/year$

- Expense for electrical: to sum up 1% per year of total electrical cost:

$$19,279 \times 10^3\ B \times 0.01/y = 193 \times 10^3/year$$

(4) Allocation to Phased Construction

The total estimated operation and maintenance cost for the proposed feasibility project is summarized and allocated to phased construction as follows.

Table 4.6 Operation and Maintenance Cost for Proposed Sewerage System

Unit: 10^3 Baht/year

Facilities	Estimated O-M Cost	Allocation	
		Phase 1	Phase 2
Sewer	136	107	29
Pump station			
- Labor	207	207	0
- Operation	1,169	1,009	160
- Maintenance	601	519	82
S.T.P			
- Labor	396	396	0
- Operation	2,007	1,733	274
- Maintenance	1,500	1,299	201
Total	6,016	5,270	746

4.4 Implementation Schedule

As the construction of a sewerage system is one of the important public works, it is imperative that the construction work should be ensured within the practical shortest period. In line of this, the construction of the project will be done in two stages with the more urgently needed facilities included in the first stage and the rest to be carried out during the second stage. The construction planning was based on the required work quantities and climatological conditions. The critical component for the accomplishment of the works is the sewer construction work which will cover a total length of 13km including jacking works. The tentative implementation schedule of the project is shown under Table 4.7 and annual disbursement schedule of construction cost is presented in Table 4.8.

Table 4.7 Tentative Project Implementation Schedule for Sewerage System

Procedures	1st Phase	2nd Phase
Financial Arrangement	by Dec.,1990	by Sep.,1997
Tender Design	Jul., 1991 to Mar., 1992	Jan., to Jul., 1998
Tendering and Contract Award	May to Dec., 1992	Aug., to Dec., 1998
Construction	Jan., 1993 to Dec., 1995	Jan., 1999 to May, 2000

Table 4.8 Project Implementation Schedule

Unit: x 1000 Baht

Phase	Phase I							Phase II			
Item / Year	1990	1991	1992	1993	1994	1995	Total Cost	1998	1999	2000	Total Cost
Financial Arrangement											
Design & Bidding											
Construction											
Oxidation Ditch											
Final Sedimentation											
Chlorination Tank											
Operation Building											
Drying Bed											
Pumping Station											
Sewer											
Cost											
Construction Cost		—	—	42,044	94,629	131,512	268,185	—	21,100	19,415	40,515
Engineering Services		9,386	9,386	2,682	2,682	2,682	26,818	1,051	1,500	1,500	4,051
Contingency (Physical)		1,357	939	4,473	9,731	13,556	30,056	105	2,260	2,092	4,457
Total Cost by Year		10,743	10,325	49,199	107,042	147,750	325,059	1,156	24,860	23,007	49,023

CHAPTER 5

FORMULATION OF DRAINAGE IMPROVEMENT PLAN

CHAPTER 5 : FORMULATION OF DRAINAGE IMPROVEMENT PLAN

5.1 Summary of Existing Drainage System

The storm drainage system in the city is almost developed except for a part of the eastern and northern areas in the town. The existing public drainage system widely employs street gutters constructed along the paved streets, which is also used in discharging wastewater generated from houses and buildings as previously mentioned in this report.

Most of the surface water run-off in the city drains into the Bang Yai river or its tributary canals through such street gutters. There are, however, perennial problems such as inundation and water pollution, with related environmental and sanitation issues which are faced by the city.

Floods within the study area are classified into two types: one is that of flood waters coming from the Bang Yai river (external floods), while the other is that of floods caused by storms and rains (internal floods). The main reasons for flooding attributed to the the Bang Yai river are the inadequacies and deficiencies in river maintenance and the limited flow capacity of the river. External floods generally occur in the low-lying fringe areas caused by overflows from the river once in every three or five years.

On the other hand, internal floods in some areas occur several times a year. Internal floods are generally caused by insufficient drainage facilities which are mostly improperly and inadequately maintained. The additional causes of floods are as follows:

i) Limited capacity of existing drainage street gutters and canals;

ii) Improper design and construction of drainage facilities;

iii) Clogging of existing drainage gutters and canals; and

iv) Insufficient capacity of discharge pump.

In addition to the above, the major river and canals in the study area are affected much by the tidal events such that river water flows into some outlets of street gutters during high tide. At some outlets, sluice gates are installed to prevent intrusion of river water during floods.

5.2 Outline of Proposed Master Plan

5.2.1 Zoning of Drainage System

The existing storm drainage system in the study area can be classified roughly into four zones. Since these have no particular names, the Study Team arbitrarily named these areas as follows: Central drainage area, Taling Chan canal area, Ta Kraeng canal area and Tajin river area. These names and zoning are presented in Fig.5.1.

The coverage and extent of each area is summarized as follows:

(1) Central Drainage Area

This area covers northwestern and central areas of the city with an approximate area of 810 ha, discharging collected storm water through street gutters into the Bang Yai river and the Saen Suk canal. This area has lots of outlets to drain storm water and wastewater into the river through street gutters and drain pipes collecting wastewater directly from households, along the rivers and through natural stream or excavated ditches at the undeveloped drainage areas.

(2) Taling Chan Canal Area

This area is located in the western part of the city including a part of foot of Mt. Rang. It covers about 110 ha of drainage

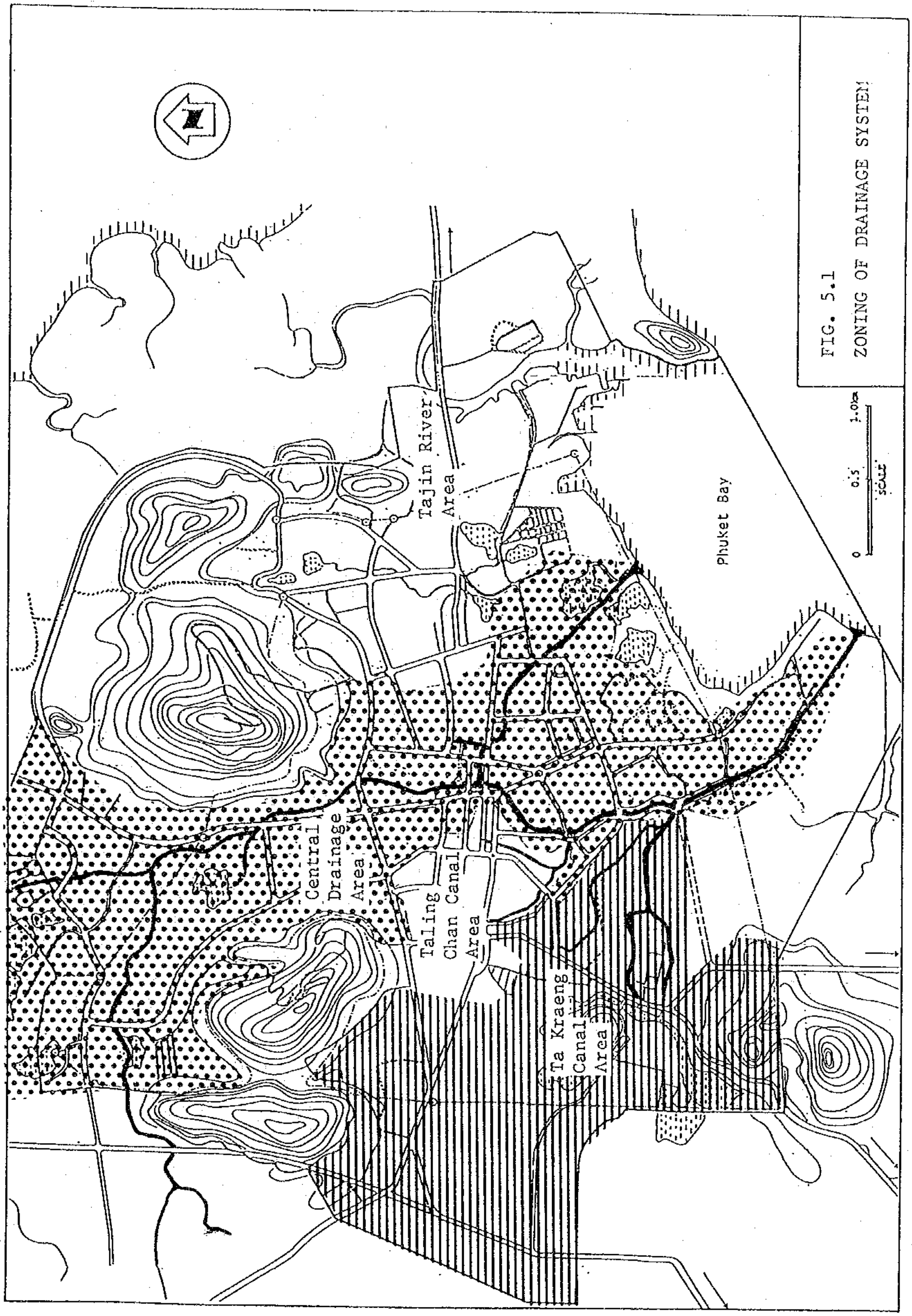


FIG. 5.1
ZONING OF DRAINAGE SYSTEM

area. Collected storm water through the street gutters is discharged into the Taling Chan canal. This canal consists of two small streams which start from Patiphat Rd. and Phang Nga Rd., joining with main canal after crossing Bangkok Rd. and finally joins after crossing Takuapa Rd. with the Bang Yai river near the Taling Chan bridge.

Since the junction point with the Bang Yai river is affected by sea water intrusion during high tides, there is a discharge pump station with sluice gates which is operated by the city to regulate the level of the river water. As the capacity of the canal and the discharge pump is insufficient to drain the storm water, severe flooding occurs during or after heavy rains in this zone. Because of the lack of the drainage facilities around Bangkok Rd. and Thailand Rd., these floods had caused suffering to the resident. To cope with the problems, improvement works on the drains have been carried out by the city.

(3) Ta Kraeng Canal Area

The Ta Kraeng canal area is located in the southwestern part of the study area and covers about 500 ha. The canal originates from the pond at the Royal Memorial park at the western side of Patiphat Rd. Where it joins a small tributary running north of the main canal at around 170m from the confluence with the Bang Yai river. The canal is about 5.0m wide with a depth of 1.5m near the confluence.

There are lots of ponds in the Royal Memorial park which could be used effectively for flood control because of their potential use for impounding flood water. Although the catchment area of this basin is approximately 10 km^2, the canal is also affected by the sea water intrusion which reduces its net discharge capacity rendering it much less effective in draining storm water. This results in frequent flooding more particularly at the Chao Fa Rd., a road that runs from the downtown to the deep sea port district of the city.

(4) Tajin River Area

The Tajin river originates at the northeast of the city, then changes its route westward along Sri Suthad Rd., then turns southward flowing into the fishing port. Though the river is outside of the Phuket city, it is included in the study area because it goes though sections included in the DTCP town planning boundary for Phuket City.

This area covers the east side of the study area and comprises an area of about 350ha. However, as the storm drainage system is not yet completely developed, storm water runs off into the river through small streams or excavated ditches and small canals.

5.2.2 Approach of Improvement Plan

(1) Determination of Subject Area

Among the four divided drainage areas, only the Tajin river area will not be included yet for this particular project, because this area is not yet developed as a residential area. The other three areas are included in the subject area.

(2) Rainfall Intensity Considered in the Plan

Improvement of storm drainage facilities is studied with the design based on probable rainfalls with five-year return period for main drains and canals, and two-year return period for lateral drains.

(3) Approach of Improvement Plan

Main drain mentioned above are distinguished from lateral drain as follows:

- main street gutters connected into rivers, and not include lateral (soi) gutters for the central drainage zone.

- main street gutters connected into the Taling Chan canal, and also retarding pond or retarding pond with discharge pump facilities which are newly proposed for the Taling Chan zone.

- main street gutters connected into the Ta Kraeng canal, and also new diversion canal or retarding pond or retarding pond with discharge pump facilities which are newly proposed for the Ta Kraeng zone.

On the basis of the result of computerized analysis about the existing drain capacity, the improvement plan indicate the location with due consideration on the discharging shortage section of the facilities and its desirable length to meet the design probable rainfall.

CHAPTER 6

PRELIMINARY DESIGN FOR DRAINAGE IMPROVEMENT

CHAPTER 6 : PRELIMINARY DESIGN FOR DRAINAGE IMPROVEMENT

6.1 Design Criteria

The preliminary design is prepared for the following structures:

- street storm gutter
- combined sewer pipe
- retarding pond with discharge pump

For the hydraulic design of the gutter and pipeline, the design criteria will be applied in consonance with those specified in the Master Plan and the preliminary design criterria for sewage treatment improvement facilities cited earlier in this report.

In calculating rainfall intensity past rainfall data was obtained from local meteorological records. The other design condition and formulas or equations used to calculate a probable rainfall, and in sizing drains are as follows:

(i) Capacity of drain : Manning's formula

(ii) Rainfall run off : Rational equation

(iii) Rainfall intensity :

Return period

2 year $$I = \frac{4,856}{t + 28.3}$$

3 year $$I = \frac{4,926}{t + 23.5}$$

5 year $$I = \frac{6,118}{t + 27.4}$$

(iv) Sewage flow can be neglected for the above calculations, because it is too small compared to the normally much higher stormwater flow.

6.2 Preliminary Design

6.2.1 Public Drainage Area

(1) Determination of the Drains with Inadequate Sizes

The capacity of the existing drainage system to handle stormwater that may result from rainfalll with probable 2, 3 or 5-year return periods was analyzed with the aid of computers. The result is shown in Table 6.1.

On the basis of the this study, drainage sections that would be rendered inadequate in size to meet stormwater flow caused by such 2 and 5-year return period projected were easily identified and highlighted with a cricle as could be seen at the left side of Table 6.1. Having been identified to be inadequate as such, the actual required sizes or sections for these drains are determined for inclusion in the proposed improvement program.

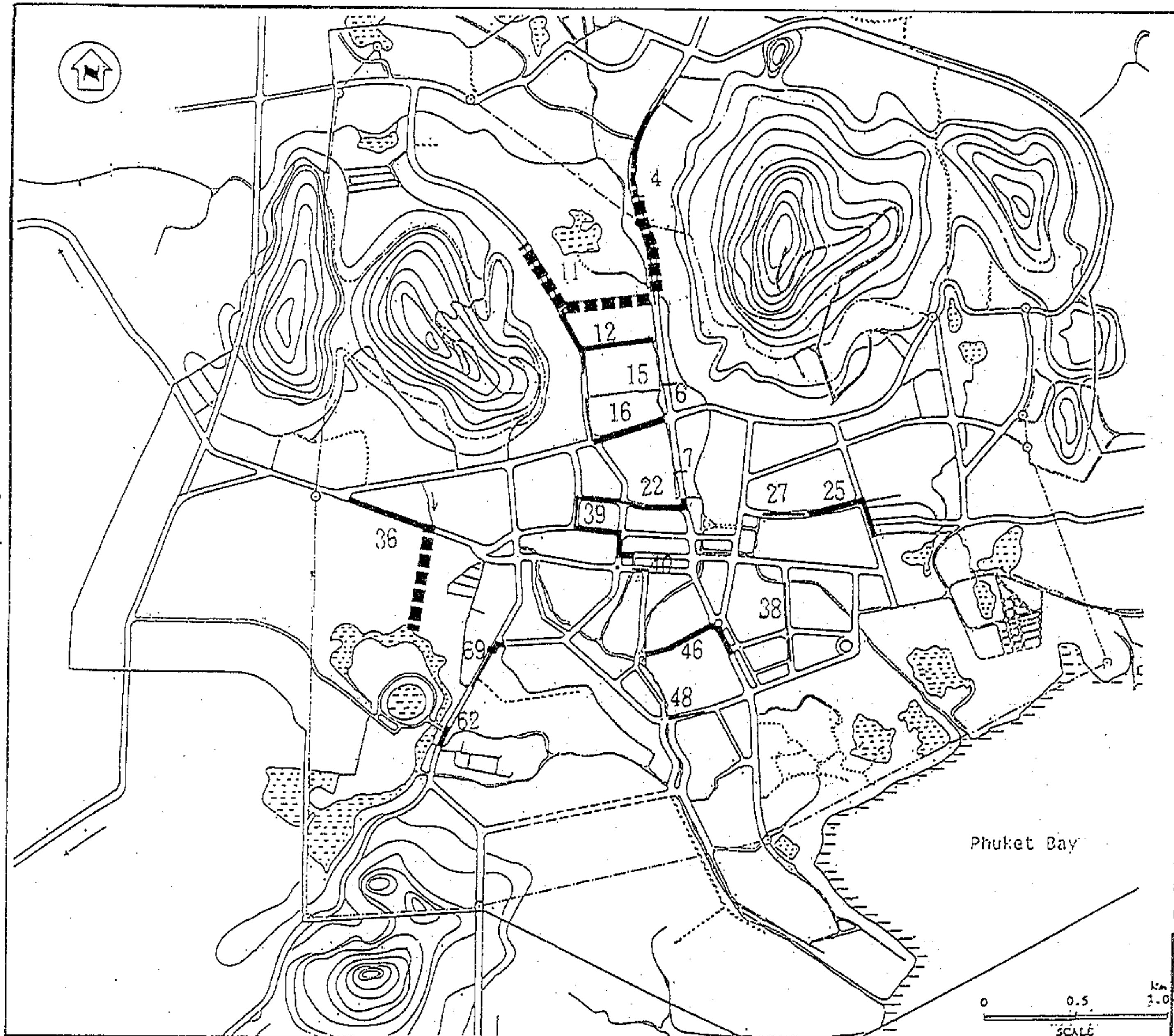
(2) Preliminary Design

With regard to those sections which have been determined to be in need of replacement or improvement, the preliminary design and their locations correspondingly shown in Fig.6.1.

Though cast-in-place concrete culverts are presently used as main street drains, these proposed replacement or reinforcement sections are designed by assuming the use of concrete pipes and box culverts depending on the size of the planned sections.

Table 6.1 Flow Capacity of U-shaped Drain Ditch and Discharge for Each Return Period

POINT	DEPTH H (m)	WIDTH W (m)	AREA (sq m)	SLOPE	ROUGH COEFF. n	Q-EXIT. (cu m/s)	DRAINAGE AREA (ha)	RUNOFF COEFF. (f)	CONCENT TIME (min)	Q-2years (cu m/s)	Q-3years (cu m/s)	Q-5years (cu m/s)
1	0.7	0.4	0.28	0.0060	0.015	0.42	2.2	0.50	19	0.31	0.35	0.37
2	0.5	0.8	0.40	0.0030	0.015	0.54	1.4	0.50	10	0.25	0.29	0.29
3	0.8	0.6	0.48	0.0110	0.015	1.22	2.3	0.50	15	0.36	0.41	0.42
(4)	1.0	0.4	0.40	0.0080	0.015	0.72	64.0	0.50	41	6.23	6.79	7.35
5	0.5	0.4	0.20	0.0060	0.015	0.28	0.7	0.50	12	0.12	0.13	0.14
(6)	0.5	0.4	0.20	0.0010	0.015	0.12	1.1	0.50	15	0.17	0.20	0.20
(7)	0.4	0.4	0.16	0.0040	0.015	0.18	2.9	0.50	14	0.46	0.53	0.54
8	0.4	0.4	0.16	0.0010	0.015	0.09	0.3	0.50	8	0.06	0.07	0.07
9	0.7	0.4	0.28	0.0050	0.015	0.38	0.5	0.30	8	0.06	0.07	0.07
10	1.5	1.0	1.50	0.0020	0.015	2.33	6.3	0.30	36	0.40	0.43	0.47
(11)	0.8	0.8	0.64	0.0020	0.015	0.79	60.0	0.50	72	4.03	4.30	4.77
(12)	1.0	0.3	0.30	0.0050	0.015	0.36	3.9	0.40	18	0.45	0.51	0.54
13	1.0	0.4	0.40	0.0030	0.015	0.44	20.0	0.45	36	1.89	2.07	2.23
14	1.0	0.4	0.40	0.0020	0.015	0.36	2.9	0.35	16	0.31	0.35	0.36
(15)	1.0	0.6	0.60	0.0020	0.015	0.67	4.4	0.40	11	0.60	0.70	0.71
(16)	1.0	0.4	0.40	0.0040	0.015	0.51	19.0	0.30	17	1.70	1.93	2.00
17	1.0	0.5	0.50	0.0150	0.015	1.40	4.4	0.30	22	0.35	0.40	0.42
18	1.0	0.5	0.50	0.0020	0.015	0.51	1.1	0.30	8	0.12	0.14	0.14
19	0.8	1.0	0.80	0.0190	0.015	3.35	0.8	0.50	3	0.15	0.17	0.17
20	1.7	0.4	0.68	0.0050	0.015	1.02	0.5	0.40	8	0.07	0.09	0.09
21	1.1	1.1	1.21	0.0190	0.015	5.70	46.0	0.50	53	3.82	4.11	4.51
(22)	0.4	0.4	0.16	0.0010	0.015	0.09	7.9	0.50	19	1.13	1.27	1.33
23	1.7	0.6	1.02	0.0020	0.015	1.22	0.1	0.50	10	0.02	0.02	0.02
24	1.6	1.1	1.76	0.0020	0.015	2.89	16.9	0.35	23	1.56	1.74	1.83
(25)	1.6	0.8	1.28	0.0040	0.015	2.52	25.0	0.45	18	3.28	3.71	3.86
26	1.1	0.8	0.88	0.0040	0.015	1.64	4.3	0.45	18	0.56	0.64	0.66
(27)	0.8	0.4	0.32	0.0020	0.015	0.28	5.2	0.35	12	0.61	0.70	0.72
28	0.7	0.5	0.35	0.0020	0.015	0.34	0.9	0.35	9	0.11	0.13	0.13
29	0.6	0.5	0.30	0.0020	0.015	0.28	1.3	0.35	11	0.16	0.18	0.18
30	1.7	1.0	1.70	0.0020	0.015	2.69	5.3	0.60	17	0.95	1.07	1.11
31	1.0	0.4	0.40	0.0030	0.015	0.44	0.4	0.70	9	0.10	0.12	0.12
32	1.0	0.4	0.40	0.0040	0.015	0.51	0.4	0.70	9	0.10	0.12	0.12
33	1.1	0.4	0.44	0.0080	0.015	0.80	2.3	0.70	14	0.51	0.59	0.60
34	1.1	0.5	0.55	0.0050	0.015	0.90	0.6	0.70	11	0.14	0.17	0.17
35	1.7	1.0	1.70	0.0390	0.015	11.87	29.0	0.45	19	3.72	4.20	4.38
(36)	1.4	1.0	1.40	0.0070	0.015	4.01	101.0	0.50	28	12.10	13.42	14.27
37	0.8	0.5	0.40	0.0110	0.015	0.93	0.5	0.70	9	0.13	0.15	0.15
(38)	1.1	0.8	0.88	0.0010	0.015	0.82	9.3	0.40	18	1.08	1.23	1.28
(39)	1.4	1.0	1.40	0.0020	0.015	2.15	26.2	0.50	21	3.58	4.03	4.22
(40)	1.1	0.4	0.44	0.0020	0.015	0.40	2.5	0.70	14	0.56	0.64	0.66
41	0.7	0.5	0.35	0.0010	0.015	0.24	0.4	0.56	8	0.07	0.09	0.09
42	0.8	0.4	0.32	0.0020	0.015	0.28	2.5	0.50	12	0.42	0.48	0.49
43	1.0	0.6	0.60	0.0410	0.015	3.05	0.5	0.70	9	0.13	0.15	0.15
44	1.2	1.0	1.20	0.0040	0.015	2.53	3.5	0.50	11	0.60	0.69	0.71
45	1.2	1.0	1.20	0.0040	0.015	2.53	2.7	0.70	11	0.65	0.75	0.76
(46)	0.6	1.0	0.60	0.0030	0.015	1.33	14.0	0.50	19	2.00	2.25	2.35
47	0.8	0.7	0.56	0.0020	0.015	0.65	1.4	0.40	10	0.20	0.23	0.23
(48)	1.2	0.6	0.72	0.0020	0.015	0.83	6.4	0.50	15	1.00	1.14	1.17
49	0.6	0.5	0.30	0.0010	0.015	0.20	0.3	0.30	9	0.03	0.04	0.04
50	0.7	0.5	0.35	0.0010	0.015	0.24	0.3	0.30	9	0.03	0.04	0.04
51	1.7	0.7	1.19	0.0030	0.015	1.90	5.8	0.50	16	0.88	1.00	1.04
52	1.5	1.0	1.50	0.0020	0.015	2.33	4.4	0.45	15	0.62	0.70	0.73
53	0.8	0.6	0.48	0.0010	0.015	0.37	1.7	0.50	13	0.28	0.32	0.33
54	0.7	0.8	0.56	0.0010	0.015	0.47	1.0	0.50	9	0.18	0.21	0.21
55	1.2	0.8	0.96	0.0010	0.015	0.91	5.2	0.50	15	0.81	0.92	0.95
56	0.8	0.6	0.48	0.0030	0.015	0.64	1.8	0.50	11	0.31	0.36	0.36
57	0.7	0.8	0.56	0.0020	0.015	0.67	1.5	0.70	9	0.38	0.44	0.45
58	1.0	0.8	0.80	0.0020	0.015	1.03	0.4	0.30	10	0.04	0.05	0.05
59	1.2	0.8	0.96	0.0010	0.015	0.91	3.1	0.50	17	0.46	0.52	0.54
60	0.5	0.3	0.15	0.0280	0.015	0.40	2.9	0.40	16	0.35	0.40	0.42
61	0.6	0.4	0.24	0.0040	0.015	0.29	1.0	0.70	8	0.26	0.30	0.31
(62)	1.0	0.4	0.40	0.0010	0.015	0.26	1.5	0.70	11	0.36	0.42	0.42
63	0.8	1.0	0.80	0.0040	0.015	1.54	1.0	0.70	10	0.25	0.29	0.29
64	1.0	1.0	1.00	0.0020	0.015	1.43	1.5	0.70	10	0.37	0.43	0.43
65	1.5	0.4	0.53	0.0040	0.015	0.94	1.9	0.70	13	0.43	0.50	0.51
66	1.1	1.0	1.10	0.0020	0.015	1.61	1.3	0.70	13	0.30	0.34	0.35
67	1.0	0.8	0.80	0.0070	0.015	1.94	0.9	0.40	8	0.13	0.16	0.16
68	1.0	0.8	0.80	0.0030	0.015	1.27	0.9	0.40	8	0.12	0.14	0.14
(69)	1.3	0.8	1.04	0.0010	0.015	1.00	9.5	0.40	17	1.13	1.28	1.33



PROPOSED PLAN FOR IMPROVEMENT

4.	□ H2000mm×W2500mm	I = 1.0‰	L = 510m,
	□ H1600mm×W2000mm	I = 1.0‰	L = 240m,
	φ 1500mm	I = 1.4‰	L = 240m,
	φ 1000mm	I = 2.5‰	L = 140m,
6.	φ 400mm	I = 4.0‰	L = 20m,
7.	φ 800mm	I = 1.7‰	L = 20m,
11.	□ H1440mm×W2400mm	I = 0.7‰	L = 500m,
	□ H1380mm×W2300mm	I = 0.8‰	L = 450m,
12.	φ 1500mm	I = 1.3‰	L = 410m,
	φ 1000mm	I = 3.0‰	L = 230m,
	φ 600mm	I = 5.5‰	L = 140m,
15.	φ 300mm	I = 5.5‰	L = 100m,
16.	φ 1200mm	I = 1.8‰	L = 430m,
	φ 800mm	I = 4.5‰	L = 230m,
22.	φ 1500mm	I = 1.0‰	L = 380m,
	φ 600mm	I = 5.5‰	L = 250m,
25.	φ 1500mm	I = 0.9‰	L = 270m,
	φ 1200mm	I = 1.1‰	L = 210m,
27.	φ 800mm	I = 1.7‰	L = 130m,
	φ 400mm	I = 4.0‰	L = 100m,
36.	□ H1600mm×W3200mm	I = 2.5‰	L = 550m,
	φ 800mm	I = 5.0‰	L = 500m,
38.	φ 800mm	I = 1.7‰	L = 290m,
	φ 600mm	I = 2.4‰	L = 170m,
39.	φ 1200mm	I = 1.4‰	L = 60m,
	φ 1000mm	I = 2.2‰	L = 320m,
	φ 800mm	I = 1.7‰	L = 160m,
40.	φ 800mm	I = 1.6‰	L = 80m,
46.	φ 1200mm	I = 1.1‰	L = 530m,
48.	φ 500mm	I = 3.0‰	L = 150m,
62.	φ 500mm	I = 3.0‰	L = 200m,
69.	φ 800mm	I = 1.7‰	L = 225m,

Fig. 6.1
PROPOSED IMPROVEMENT OF DRAINAGE TO MANAGE FOR PROBABLE RAINFALL

(3) Construction Cost

Table 6.2 shows the construction cost for improvement of public drainage area.

Table 6.2 Construction Cost for Improvement of Public Drainage Area

Unit: 10^3 Baht

1. Direct Cost		
Route	Length	Cost
4	1,130 m	25,076
6	20	29
7	20	51
11	950	13,226
12	780	3,486
15	100	137
16	660	2,410
22	630	2,776
25	480	2,516
27	230	481
38	460	1,076
46	530	2,242
48	150	258
Total (1)	6,140 m	53,758
2. Indirect Cost		
Overhead (Direct Cost x 0.06)		3,225
Profit (Direct Cost x 0.085)		4,569
Total (2)		7,794
Gross Total (1+2)		61,552
3. Tax (Gross Total x 0.041)		2,523
Construction Cost (1+2+3)		64,075

6.2.2 Taling Chan Canal Area

(1) Inland water in this area is drained into the Bang Yai river through the Taling Chan canal. Rain water in the Taling Chan canal is usually drained into the Bang Yai river by a pump, because the water level of the Bang Yai river is higher than that of the Taling Chan canal. The conjunction of the Taling Chan canal is closed by gates in order to prevent back water from the Bang Yai river. Since the existing pump is out of order, new pump of which specification is not determined yet during our study period will be installed in near future.

In order to solve the inundation in this area due to heavy rain, it is recommended to divert rain water to the Bang Ping river instead of the Bang Yai river because an adequate pumping station to drain into the Bang Yai river is costly. Drainage system with retarding pond and drainage system with pumping station and retarding pond were studied to provide an appropriate drainage system.

The peak discharge for 5 year probable daily rainfall is estimated at 5.4 m^3/s which is equivalent to 5 $m^3/s/km^2$ in specific discharge. Total runoff volume is 114,000 m^3. Drainage system with retarding pond retains whole runoff volume. Drainage system with pumping station and retarding pond retains runoff volume of 31,000 m^3 and drains remaining discharge up to 2.5 m^3/s in peak.

The project cost for each scheme is estimated based on the unit construction cost established for Master Plan. The summary of project cost is as follows:

Table 6.3 Summary of Project Cost
(Taling Chan Canal Area)

Unit: 1,000 Baht

Work Item	Pond	Pump & Pond
1. Retarding pond	7,700	4,650
2. Pumping station	0	11,810
Direct Cost	7,700	16,460
3. Land Acquisition & Compensation Cost	7,830	3,720
4. Engineering Service & Government Administration	1,160	2,150
5. Physical Contingency	3,340	4,470
Total	20,030	26,800

Total project cost excluding price contingency for the drainage system with retarding pond is more economical than that for the system with pumping station and retarding pond. In addition, pumping station requires careful operation and maintenance with expensive O&M Cost. Therefore it is recommended to adopt the drainage system with retarding pond only.

A preliminary design of the Taling Chan drainage system is as shown in Fig. 6.2. The required capacity and main dimensions of the retarding pond are as follows:

Catchment area	: 1.1 km^2
5-year probable rain	: 143 mm/day
Duration	: 7 hours
Runoff factor	: 73 %
Storage capacity	: 114,000 m^3
Utilized depth	: 1.80 m
Area	: 66,000 m^2 or 42 rai (550 m x 120 m)
HWL	: +1.00 m
LWL	: -0.80 m
Outlet facilities	: Flap gate
Associated works	: Diversion canal from Taling Chan canal

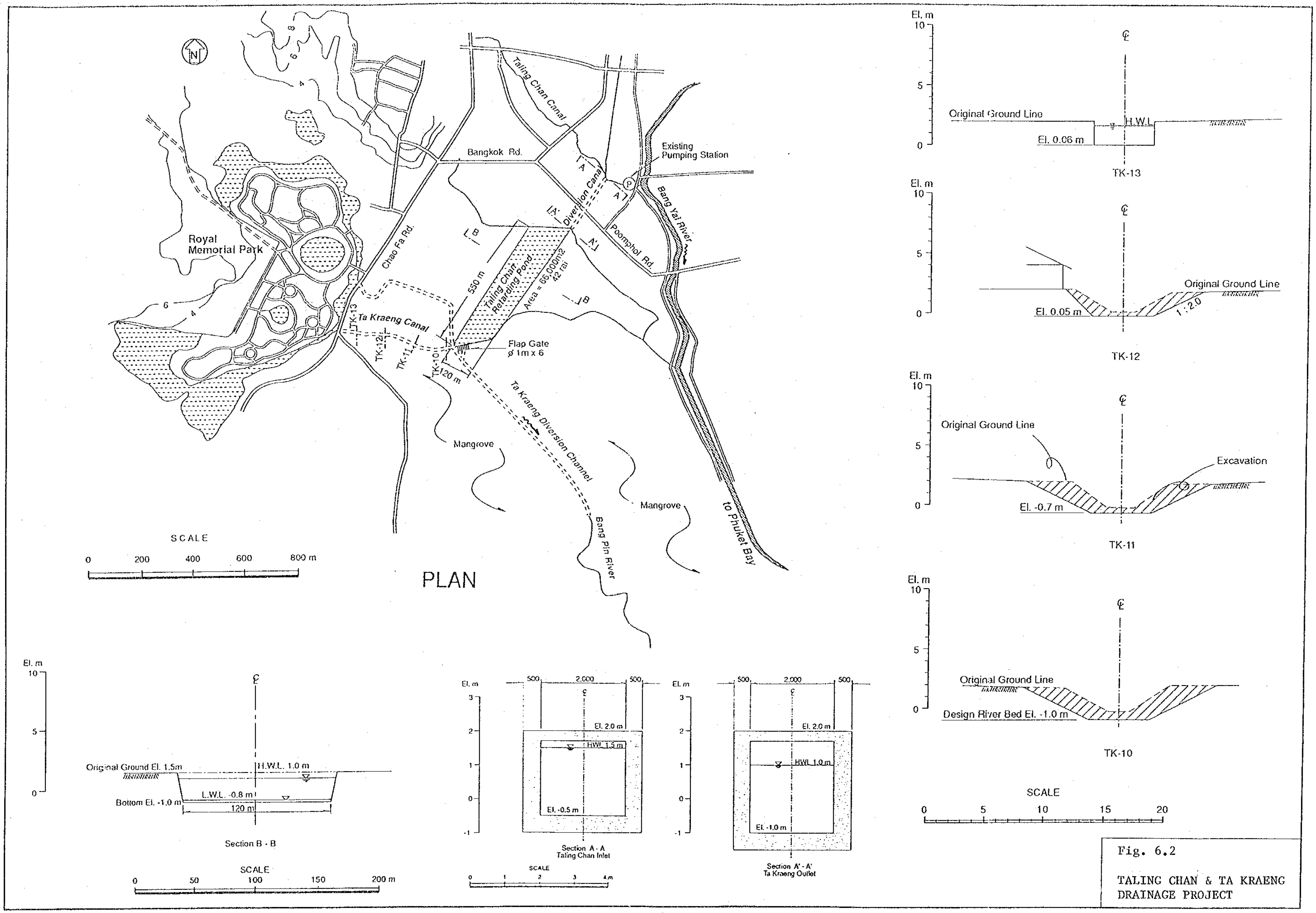


Fig. 6.2

TALING CHAN & TA KRAENG DRAINAGE PROJECT

Retarding pond in the southern area of the city surrounded by the Ta Kraeng canal retains rain water temporarily and drains into the Bang Ping river during the low tide by flap gates.

High water level (HWL) and low water level (LWL) of the pond are tentatively decided as shown above, referring to the cross sectional survey of the Tailing Chan canal, Ta Kraeng canal and the tidal movement of the Phuket bay.

(2) Construction Cost

In addition to the construction cost for the retarding pond, the construction cost for sewer improvement surrounding Krabi Rd., Cee Buk Rd. and Phang Hga Rd., where the location of improvement sewers involved, is required to add.

The sewer construction cost is estimated as under Table.

Table 6.4 Sewer Construction Cost (Taling Chan Canal Area)

1. Direct Cost		
Route	Length	Cost x 10^3 Baht
39	540 m	1,689
40	80	206
Total (1)	620 m	1,895
2. Indirect Cost		
Overhead (Direct Cost x 0.06)		113
Profit (Direct Cost x 0.085)		161
Total (2)		274
Gross Total (1+2)		2,259
3. Tax (Gross Total x 0.041)		92
Construction Cost (1+2+3)		2,351

Therefore, total project cost is summarized as follows under Table 6.5.

Table 6.5 Construction Cost for Drainage Improvement of Taling Chan Area

Unit: 10^3 Baht

Item	Specification	Cost
Sewer Improvement	φ 800 - 1,200 x 620 m	2,351
Retarding Pond	114,000 m^3	20,030
Project Cost		22,381

6.2.3 Ta Kraeng Canal Area

(1) Ta Kraeng New Diversion Canal

Rain water from the Ta Kraeng drainage basin of 9.0 km^2 is drained into the Bang Yai river through the Royal Memorial park and Ta Kraeng canal. Rain water is regulated by ponds in the Royal Memorial park.

In order to discharge the rain water of 5 year probable rainfall, it is recommended to improve the Ta Kraeng canal and construct diversion canal to connect the Bang Ping river.

The peak discharge for 5 year probable rainfall is estimated at 25 m^3/s which is equivalent to 3 $m^3/s/km^2$ in specific discharge taking into consideration retarding effect by ponds. The existing cross section of the canal is enlarged to cope with this peak discharge and the flood is released to the Phuket bay through the Bang Pin river by the new diversion canal. The preliminary design drawing is presented in Fig. 6.2. The canal construction cost is estimated as follows:

Table 6.6 Canal Construction Cost
(Ta Kraeng Canal Area)

Work Item	1,000 Baht
1. Excavation of Canal	1,800
2. Land Acquisition & Compensation Cost	1,750
3. Engineering Service & Government Administration	270
4. Physical Contingency	760
Total	4,580

(2) Construction Cost

As showing in preceding Fig. 6.1 the inadequate in size of existing drainage in the city is required to improved to meet storm water of design probable rainfall.

The construction cost for the sections to be improved is as follows:

Table 6.7 Construction Cost
(Ta Kraeng Canal Area)

Route	Length	Cost x 10^3 Baht
1. Direct Cost		
36	1,050 m	16,046
62	200	344
69	225	578
Total (1)	1,475 m	16,968
2. Indirect Cost		
Overhead (Direct Cost x 0.06)		1,018
Profit (Direct Cost x 0.085)		1,357
Total (2)		2,575
Gross Total (1+2)		19,543
3. Tax (Gross Total x 0.041)		801
Construction Cost (1+2+3)		20,344

Thus the total project cost is summarized as shown in Table 6.8.

Table 6.8 Construction Cost for Drainage Improvement of Ta Kraeng Canal Area

Unit: 10^3 Baht

Item	
Sewer Improvement ϕ 500 - 800, Box Cal.	20,344
Canal Construction	4,580
Project Cost	24,924

CHAPTER 7

FORMULATION OF FLOOD CONTROL PLAN

CHAPTER 7 : FORMULATION OF FLOOD CONTROL PLAN

7.1 Brief Description of Existing River Condition

7.1.1 Bang Yai River Basin

Phuket city, provincial capital, is located on the southeastern corner of the Phuket island which embraces an area of about 543 km^2. The city is developed on the coastal plain of the Bang Yai river.

The Bang Yai river basin is located at the southern part of the Phuket island. A mountain range with 200 m to 400 m in height creates watershed boundary at western half of the basin. The highest point is El. 540 m and the catchment area of the basin is about 72 km^2.

The Bang Yai river originates from the Mts. Phanthurat and Tad in north and from the Mt. Mai Sipson in south. The mountainous area in upper reaches is highly forestry. There are many tin mining ponds in the middle reaches. Rain water is conserved much in these areas. The lower reaches are developed as commercial and financial center of the province.

7.1.2 River Condition

The rivers from the Mt.Phanthurt and Mt. Mai Sipson join at a junction upstream of Ban Ket Ho and Tambon Kathu. The river flows eastward collecting water from the Lak Konsi river and turns to the south at the Rang hill and Mt. Toh Sae for the Phuket City. In the city, the Bang Yai river is diverted by the Saen Suk canal before and after crossing the Thalang road. The river collects water through the Thepkrasattri canal, Taling Chan canal and Ta Kraen canal and finally flows into the Phuket bay.

The length of the Bang Yai river between the Mt. Phanthurt and the estuary is about 18.1 km. The river bed slope is about 1/400 in the upper reaches, 1/600 in the middle reaches and 1/1,000 in the lower reaches. The longitudinal river profile is as shown in Annex Fig.7.1. The river cross section is generally small because of the low run-off rate of the basin. The width of channel ranges from 2-4 m to 8-15 m. The flow capacity, ground elevation of both banks and width of channel are summarized in Annex Table 7.1. Annex Fig. 7.2 shows the flow capacity up to the bank of the river.

The flow capacity is estimated at 20 to 70 m^3/s by non-uniform calculation based on the cross section which has been prepared by a local survey team employed by the JICA study team. Its current turbulently rages occasionally during heavy rainfall in short time and threaten the city. Since the flow capacity of the Bang Yai river is quite small, the city is often inundated.

The water of Bang Yai river is not used for any purpose, while some mining ponds are used for water supply and recreational purposes, e.g., park.

7.1.3 River Structures

Upstream of the Bang Yai mainstream, the Bang Wad dam was built for water supply and is now under control of RID. The principal feature of the dam and reservoir is listed below:

- Dam type	: Earth fill
- Dam crest	: El. 47.00 m
- Catchment area	: 5.4 km^2
- Full supply level	: El. 43.00 m
- Low water level	: El. 28.00 m
- Effective storage	: 7,440,000 m^3
- River outlet	: Dia. 0.5 m x 3 nos.
- Emergency spillway	: Dia. 2.0 m x 1 nos.
- Spillway type	: Morning glory type

There are 13 bridges and 9 box culverts in the City. 5 bridges are located in the central area of the City and are regarded as poorly and inadequately designed.

There are some aqueduct and cables across the Bang Yai river which are of low elevations relative to the river. Most of street drains and drainage canal, which join the Bang Yai river, are provided with gates at confluences. These gates are closed at flood time in order to prevent back flow of water from the Bang Yai river.

The City office carries out improvement or reinforcement works at the Bang Yai river every year to protect week structures in this area against floods. Funds are provided through local budgetary appropriations.

7.2 Flood and Flood Damage Analysis

7.2.1 Flood Analysis

(1) Meteo-hydrological Measurement

There are three meteorological stations on the Phuket island. One is in the Phuket City, another one is at the Phuket airport of the northern part of the island and the third is at the Bang Wad dam in the Bang Yai river basin. The locations of the observatories are shown in Annex Fig. 7.3.

Summaries of the daily meteo-bydrological readings of the city for 22 years from 1968 (B.E.2511) to 1989 (B.E.2532) and automatic rainfall record on some major heavy rain were available for the Master Plan study. Daily maximum rainfall by month are shown in Annex Table 7.2. As seen in the Annex Table 7.2, annual maximum rainfall occurs from May to November, that is, during the rainy season.

Probable basin rainfall for some return periods was analyzed for the flood control study and rainfall intensity in short duration was analyzed for the drainage study in the city.

There were no available discharge data for the Bang Yai river before the JICA study team installed the water level recorders. The flow characteristics of the Bang Yai river was initially studied for the Master Plan using only one small flood which was measured by the Study Team at the Thalang bridge in the city on 25 August 1989, since the hourly rainfall distribution data during these days was available.

JICA provided one set each of automatic and manual rain gauges, two sets of automatic water level gauges with staff gauge and current meter at the Master Plan study stage. Type of recorders, location and commencement of observation are as follows:

Recorder	Location	Commence date
Automatic rain	Bang Wad dam	20 Sept.1989
Ordinary rain	Ban Maireab School,Katu	29 Sept.1989
Automatic water level	Yaovaraj bridge	4 Oct. 1989
Automatic water level	Private bridge in front of Wittayalai School, Thepkrasattri road	4 Oct. 1989

These locations are also shown in Annex Fig. 7.3. The agencies in charge of observation and maintenance are as follows:

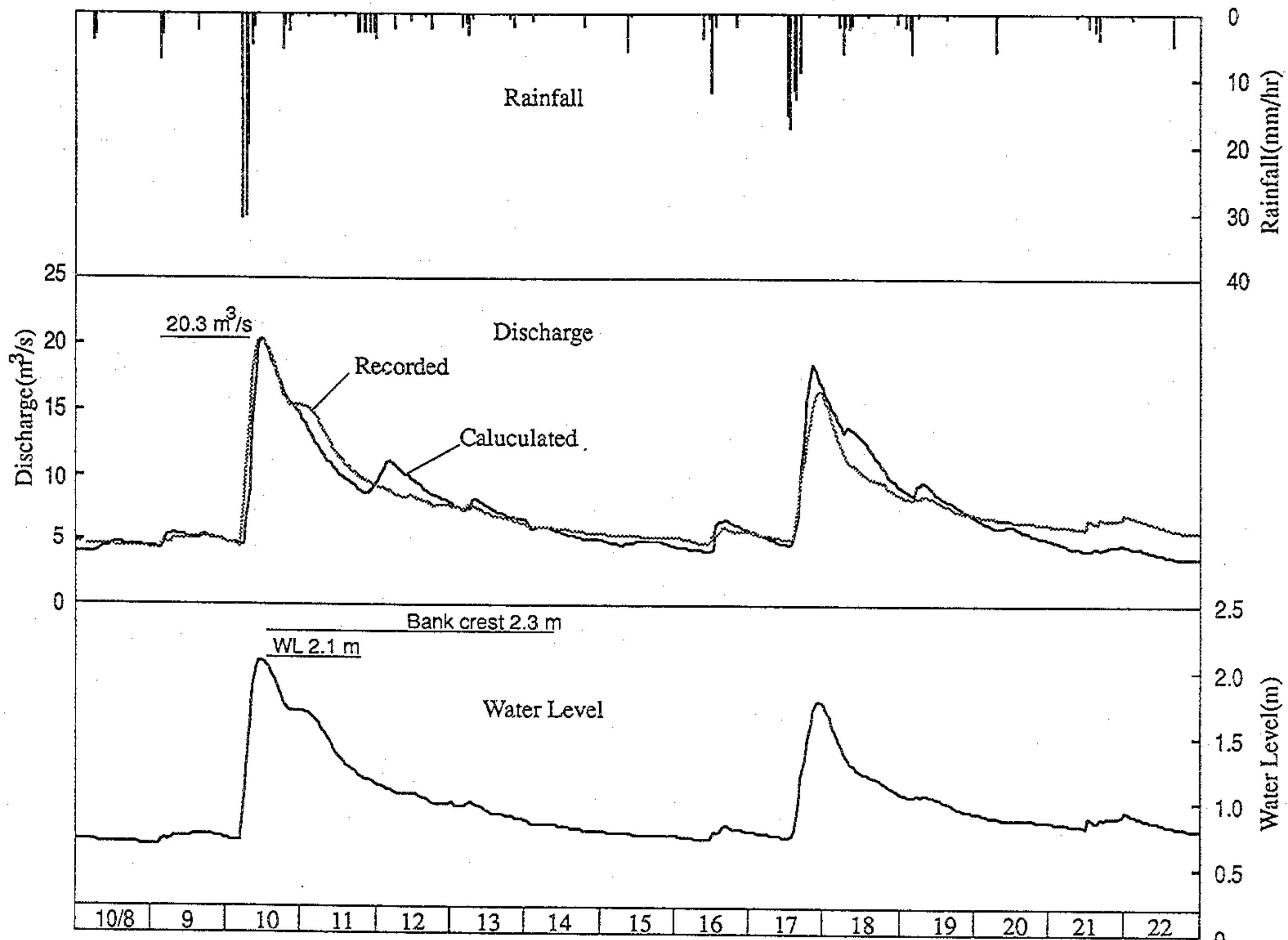
- Rain gauge (automatic) ..... RID Bang Wad dam office
-     - do - (manual) ..... PWD
- Water level gauge ..... PWD
- Discharge measurement ..... PWD

Monthly rainfall at Phuket city, Bang Wad dam and Ban Maireab school are shown in Annex Table 7.3.

(2) Run-off Analysis

With the use of these newly installed automatic rain and water level recorders, the basin characteristics were much more ascertained. The automatic water level recorder at the Thepkrasattri road has recorded two small floods in October 1989 as shown in Fig. 7.1. The flood analysis performed in the Master Plan study stage is considerably revised herein.

Hourly rainfall distribution at Phuket city and Bang Wad dam for October 1989 were obtained through the automatic recorders shown in Annex Fig. 7.5. However, the hourly rainfall distribution at



Water level gauging station at Thepkrasattri road

Fig. 7.1 FLOOD SIMULATION ON THE FLOOD IN OCTOBER 1989

Hourly rainfall distribution at Phuket city and Bang Wad dam for October 1989 were obtained through the automatic recorders shown in Annex Fig. 7.5. However, the hourly rainfall distribution at the Ban Maireab school, where manual rain gauge was installed, provided quite adequate data for use in this study.

Discharge measurement by current meter has been carried out six times at the gauging station at Thepkrasattri road by PWD Phuket office. The first measurement on 10 October measured just the peak of small flood that occurred on that day. Records of discharge measurement and the rating curve at Thepkrasattri is shown in Annex Fig.7.4. The peak discharge on 10 October was 20.2 m^3/s.

These recorded water level readings were converted to discharge from the rating curve. The basin characteristics for flood were clarified on the basis of discharge data and hourly basin rainfall in October applying the Nakayasu's unit hydrograph. The time factors, T1 and T3, were derived as shown in Table 7.1:

Table 7.1 Time factors of Unit Hydrograph for Bang Yai

Sub-basin	Catchment Area(km^2)	T1(hrs)	T0.3(hrs)
Bang Wad+School	33.6	4	30
Phuket	16.1	1	24

Since the rainfall data at Bang Maireab school became available only starting October 1989, influence areas of the Bang Wad dam rain gauge (CA=17.0 km^2, including the catchment of reservoir, CA=5.4 km^2) and Ban Maireab school (CA=22.0 km^2) are correlated for use in the analyses for this study.

The water surface of the Bang Wad reservoir was 1.50 m below the spillway crest at the time of the two floods in October. Therefore, the catchment area of the reservoir was excluded from the analysis.

Assuming that the base flow during a period from midnight of 8

October 1989 to midnight of 23 October varies straight from 4.0 m^3/s to 2.0 m^3/s, the average runoff factor of direct runoff is calculated to be 36.3 %. The computed hydrograph is shown in Fig. 7.1 which compares well with the recorded hydrograph.

Owing to the retarding effect of numerous tin mine ponds in the basin, the time factors of the unit hydrograph, especially T0.3 are quite longer than normally expected.

Since the time factors of unit hydrograph were revised, the past flood including the flood on the August 25, 1989 are reanalyzed.

1) 1989 August Flood

The catchment areas of the sub-basin of Bang Wad and Phuket described in Interim Report are a little modified. That is, the same catchment areas adopted for the 1989 October flood shown above are applied for the reanalysis of 1989 August flood. Time factors are of course the same as for the October flood. The reanalyzed flood hydrograph of August flood is shown in Annex Fig.7.5. The peak discharge of 36.7 m^3/s in the former analysis is revised to 19.1 m^3/s. According to the information by Phuket Municipality, the October flood was much serious than the August flood, then the revised unit hydrograph might be considered to be fitting enough.

2) Other Past Floods

The rains, which brought about considerable floods, are much heavier than those in August and October 1989 except April 1986. Even though under the same land use conditions as the present, the flood mechanism for heavier rain might somewhat differ from those for a moderate rain, because the retarding effects by ponds will diminish the heavy rain. This consideration is reflected into a shorter time factor of unit hydrograph as shown below:

Table 7.2 Time Factors of Unit Hydrograph for Heavy Rain

Sub-basin	Catchment Area(km^2)	T1(hrs)	T0.3(hrs)
Bang Wad	39.0	4	20
Phuket	17.6	1	16

The catchment area of the Bang Wad reservoir, 5.4 km^2, is counted for other past floods because the Bang Wad reservoir was always full before the heavy rain. The Northern area of 1.5 km^2 to be cut by the floodway which was constructed by DMR is also counted because the floodway was not completed yet that time.

Applying the revised unit hydrograph to the basin rainfall of heavy rain, the hydrographs of the past major floods are revised as shown in Annex Figs. 7.5 and 7.6 with their peak runoffs and runoff factors.

(3) Probable Rainfall

Daily maximum rainfall data by month at Phuket city, Bang Wad dam and Ban Maireab school are shown in Annex Table 7.2. Probable basin rainfall with return period was recalculated by adding latest data in 1989 as shown below:

Table 7.3 Probable Rainfall

Return period(year)	Basin rain(mm)
100	196
50	183
30	173
20	164
10	150
5	134
2	108

(4) Probable Flood

Probable flood is derived from the probable one-day rainfall, whose pattern is applied from that of the 27 September, 1986 flood, since the pattern would give the most serious flood.

Probable flood at the branching point of the proposed east floodway and base point 2 which is the water level gauging station at the Thepkrassatri road are derived respectively. The each flood hydrograph is presented in Fig. 7.2. Peak discharge of the probable floods are shown below:

Table 7.4 Peak Discharge of Probable Floods

Return period (year)	Peak Discharge m3/s) Point(1)	Point(2)
50	132	145
30	121	133
20	112	123
10	98	108
5	85	94
2	65	72

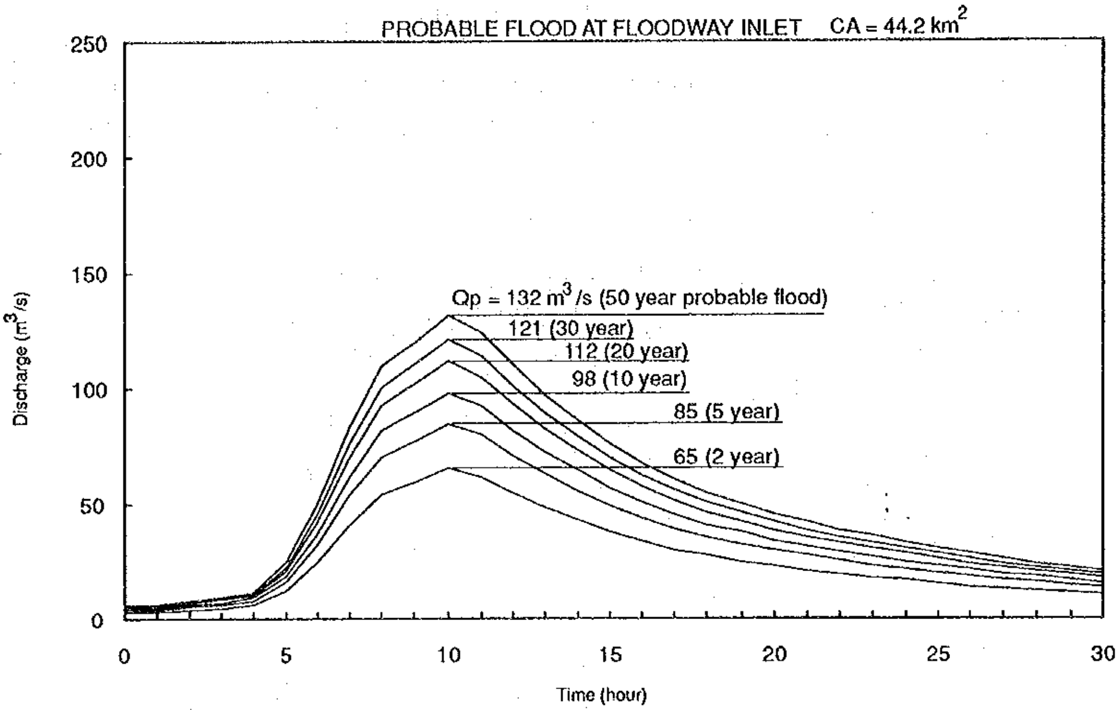
7.2.2 Flood Routing

In order to estimate inundation area and depth by the probable floods, flood routing was carried out applying non-uniform flow calculation. Nine cross sections across the Bang Yai river from the estuary to the upstream of the Yaovaraj bridge are considered as shown in Fig. 7.3.

Boundary condition is set at the estuary in El. 1.0 m which is the mean high tide level. Roughness coefficient is assumed to be 0.1 taking into consideration floods which flow through buildings.

The inundation area by probable flood is as shown in Fig. 7.3. The results show that flood overflows from the Bang Yai river between the upstream of Yaovaraj Br. and Damrong Br. and also overflows between Phang Nga Br. and Phoonphol Br. The Phuket City might be inundated entirely by floods which occur once in five years or more.

The highest inundation depth is expected at 1.5 m by the flood with the recurrence period of 5 years and 1.7 m by the flood in the recurrence period of 30 years. The difference of inundation depth among probable floods is not so much but it will take longer inundation time by the magnitude of probable floods.



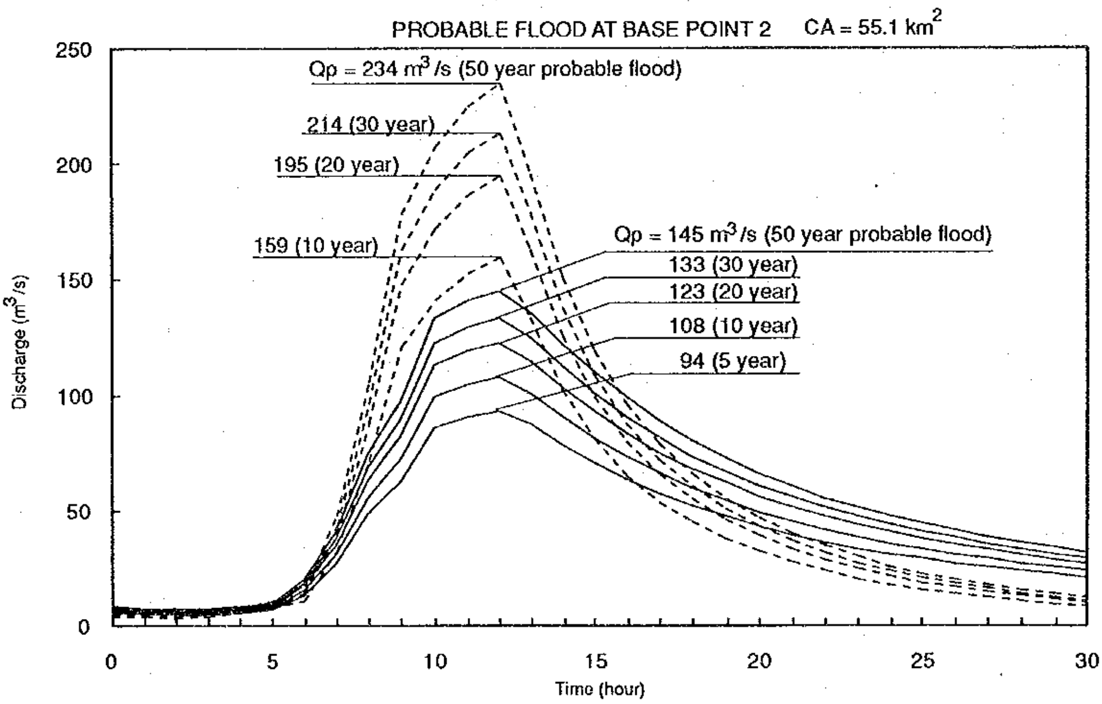


Fig. 7.2
PROBABLE FLOOD HYDROGRAPH

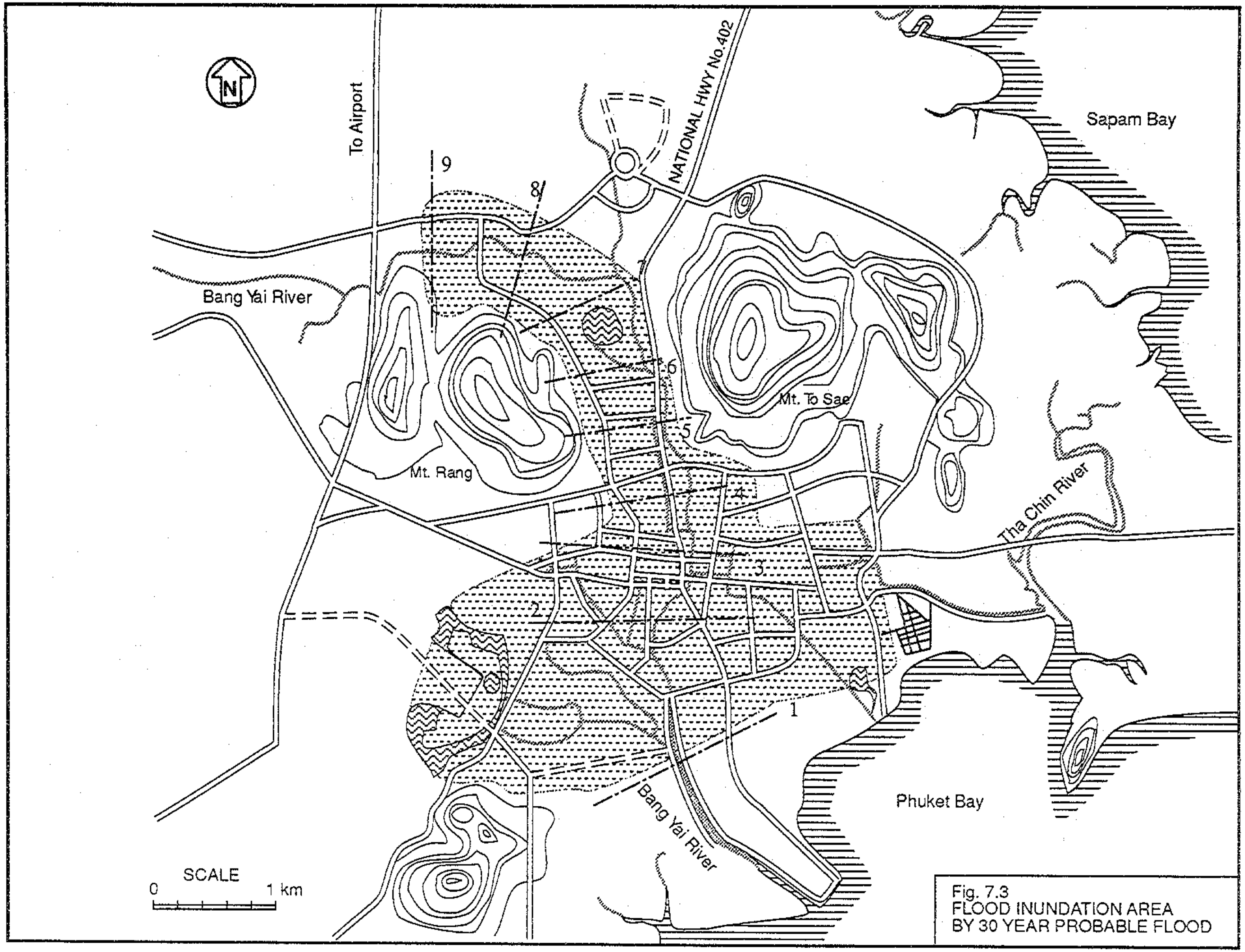


Fig. 7.3
FLOOD INUNDATION AREA
BY 30 YEAR PROBABLE FLOOD

7.2.3 Flood Damage Analysis

The Phuket downtown is the central area of commerce, finance and material transportation to resort area. There are also many government offices and educational facilities located in the City.

The existing land use of the study area shows a vague radial urbanization pattern along major roads centering on the commercial and high density residential area. High density residential zones and commercial zones are located in the area between the Phuket Road and Kra Road. Low density residential zones spread surrounding the central area. Commercial area spreads downtown and along major roads such as Phuket road, Thepkrasattri road and Chao Fa road.

On the contrary, there is the habitual inundation area owing to the low lying ground elevation. For the economic evaluation of the proposed flood control plan, flood damage by probable flood is assessed taking into consideration the land use and the results of interview survey carried out in Aug. 1989.

The procedure of flood damage analysis is as follows:

(i) Demarcation of inundated area based on the flood routing and topographic map at scale 1:4,000.

(ii) Enumeration of residential houses, restaurants, shops and governmental offices in the inundated area.

The number of buildings in the municipality was obtained from a tax register map prepared by the Municipality office. Annex Fig. 7.7 shows the tax resister map. Tax area is divided into 10 zones. Each zone is subdivided into about 20 sub-areas of 3 to 5 ha on average.

The total number of buildings as of 1988 in the municipality was estimated as shown in (1) of Table 7.5.

movable by category of building as mentioned above.

The monetary value of the buildings and indoor movable (household effects) by category is assumed as shown in (2) of Table 7.5.

(iv) Estimation of inundation depth from the results of flood routing.

(v) Damage rate is multiplied by monetary assets, resulting in flood damage value for each category.

Damage rates which were established based on the statistic damage record in Japan were applied. They are tabled in (3) of Table 7.5.

The distribution of the inundated buildings was derived from the results of flood routing by inundation depth. It is shown in (4) of Table 7.5.

Flood damage by probable flood was estimated by the following formula.

$$D = Rij1 \cdot (Bi \cdot Cj) \cdot Vi1 + Rij2 \cdot (Bi \cdot Cj) \cdot Vi2$$

where, D: Total amount of damage

Bi: Number of buildings by category, i= 1,3

Vi1, Vi2: Value of buildings(1) and household effects(2)

Cj: Distribution ratio by inundation depth, j=1,3

Rij1, Rij2: Damage rate by inundation depth

Flood damage by probable flood was estimated as shown in (5) of Table 7.5.

Table 7.5 Flood Damage

(1) Number of Buildings

	No. of Buildings
Residence :	5,704
Commercial :	2,017
Public Utilities:	110
Total	7,831

(2) Value of Buildings & Household Effects — Unit : Baht

	Residential	Commercial	Public
Buildings	200,000	400,000	900,000
Household Effects	80,000	150,000	120,000

(3) Damage Rate

		Inundation Depth		
		0.0 - 0.49 m	0.5 - 0.99 m	1.0 - 1.99 m
1. Residence &Commercial	Buildings	0.124	0.210	0.308
	Household Effects	0.086	0.191	0.331
2. Public Utilities	Buildings	0.180	0.314	0.419
	Household Effects	0.127	0.276	0.379

(4) Inundation Area in % of Total Area 850 ha

Return Period	Inundation Depth		
(yrs)	0.0 - 0.49 m	0.5 - 0.99 m	1.0 - 1.99 m
5	19.9%	0.6%	0.0%
10	20.5%	0.6%	0.0%
20	22.3%	0.7%	0.0%
30	22.9%	0.7%	0.0%

(5) Flood Damage

5-year Probable Flood — Unit : 1,000 Bahts

		Inundation Depth			
		0.0 - 0.49 m	0.5 - 0.99 m	1.0 - 1.99 m	Total
1. Residence	Buildings	28,134	1,376	15	29,525
	Household Effects	7,805	501	7	8,312
2. Commercial	Buildings	19,897	973	11	20,881
	Household Effects	5,175	332	4	5,511
3. Public Utilities	Buildings	3,544	179	2	3,724
	Household Effects	333	21	0	354
		64,887	3,381	39	**68,300**

10-year Probable Flood — Unit : 1,000 Bahts

		Inundation Depth			
		0.0 - 0.49 m	0.5 - 0.99 m	1.0 - 1.99 m	Total
1. Residence	Buildings	29,016	1,463	17	30,496
	Household Effects	8,050	532	7	8,589
2. Commercial	Buildings	20,521	1,035	12	21,567
	Household Effects	5,337	353	5	5,695
3. Public	Buildings	3,655	190	2	3,847
	Household Effects	344	22	0	366
		66,922	3,596	43	**70,600**

20-year Probable Flood — Unit : 1,000 Bahts

		Inundation Depth			
		0.0 - 0.49 m	0.5 - 0.99 m	1.0 - 1.99 m	Total
1. Residence	Buildings	31,612	1,704	27	33,343
	Household Effects	8,770	620	12	9,401
2. Commercial	Buildings	22,357	1,205	19	23,581
	Household Effects	5,815	411	8	6,233
3. Public	Buildings	3,982	221	3	4,207
	Household Effects	375	26	0	401
		72,910	4,188	69	**77,200**

30-year Probable Flood — Unit : 1,000 Bahts

		Inundation Depth			
		0.0 - 0.49 m	0.5 - 0.99 m	1.0 - 1.99 m	Total
1. Residence	Buildings	32,461	1,789	28	34,278
	Household Effects	9,005	651	12	9,668
2. Commercial	Buildings	22,957	1,265	20	24,242
	Household Effects	5,971	432	8	6,410
3. Public	Buildings	4,089	232	3	4,325
	Household Effects	385	27	0	412
		74,868	4,396	72	**79,300**

7.3 Outline of Proposed Master Plan

7.3.1 Basic Concept of Master Plan

Phuket City is undergoing significant developments. Properties are increasing and concentrated in the City due to highly dense land use and associated economic activities.

The mitigation of flood damage is therefore one of the priority needs of the city together with improvement of sewerage network. The magnitude of past floods can be seen from the photographs as shown in Annex Figs. 7.8 to 7.10.

Phuket City has great potentiality for growth as a political, commercial, and tourism center in the Province. Thus, the safety level of protection against flooding must be set appropriately for the future status of Phuket City.

The flooding occurred in August 1986 is the most serious one experience for inhabitants in the City area. This flood is regarded as a 20-year flood, that is, it occurs every 20 years or so. The formulation of the Master Plan for flood control mainly considers the probable flood with a 30-year return period in order to protect the City from the severest flood that recorded in the past. 30 year probable rainfall on the basin is estimated at 173 mm/day.

The peak runoff of the probable flood is obtained as shown below:

Table 7.6 Peak Runoff of Probable Flood(m^3/s)

Return period (year)	Point 1		Point 2	
	Case 1	Case 2	Case 1	Case 2
2	26	37	40	50
5	51	75	80	100
10	81	120	126	159
20	98	146	152	195
<u>30</u>	<u>107</u>	<u>160</u>	<u>165</u>	<u>214</u>
50	116	176	179	234

Case 1: Existing land use condition
Case 2: Retarding effect by ponds is not considered.

For planning the necessary facilities for flood control, the discharge of Case 2 was adopted as the design discharge.

7.3.2 Alternative Scheme

The following structural measures will be considered in combination in view of river channel hydraulics, inundation conditions, present and future land use, and basin topography.

- River improvement
- Floodway
- Flood retarding pond

The general location map of structural measures to be considered are illustrated in Annex Fig. 7.11. A flood control dam is not appropriate considering topographic condition and cost effectiveness.

(1) River improvement

The main works to be considered for overall channel improvement are as follows:

- Widening and dredging of existing channel
- Levee construction.

- Construction of reinforced concrete retaining walls along existing natural banks
- Dredging and removal of general debris
- Reconstruction of Saen Suk intake
- Replacement and reconstruction of bridges

(2) Floodway

Potential routes are identified on the topographic map of scale 1:4,000 as well as by field reconnaissance as shown below:

- North diversion plan
  Extension plan of north floodway constructed by DMR was studied from technical and financial viewpoints.

- East diversion plan
  A promising route for the east diversion plan is from Sam Kong village to Lak Konsi village via the north side of the Phuket Teacher's college.

- South diversion plan
  The channel starts upstream of the bridge at the national highway No.402 and flows into the ponds in the Royal Memorial park near the Chao Fa road. After regulation by the ponds, floodwater flows into sea through the Ta Kraen canal and Bang Pin river. This plan includes channel improvement of Ta Kraeng canal to meet the design flow capacity. This canal is diverted to the Bang Pin river in stead of the Bang Yai river.

(3) Flood retarding pond

The low-lying flat area lying in and beside the ring road in Katu district is promising sites for a flood retarding basin.

The size of retarding pond for the combined scheme with floodway was set and is listed in Table 7.7:

Table 7.7 Size of Retarding Pond

Sub-basin No.	No.1	No.2 & 3	No.4	Total
Pond area (ha)	40	20	35	95

A total of eight alternative plans were introduced to select the optimum plan. The alternative schemes considered were as below:

Table 7.8 Applied Measure of Each Alternative Scheme

	Scheme	River improvement	Flood retarding pond	Floodway
1	A	Large scale	none	none
2	B	Medium scale	Large scale	none
3.	C-1	Small scale	none	North
4.	C-2	- do -	- do -	East
5.	C-3	- do -	- do -	South + East
6.	D-1	- do -	Small scale	North
7.	D-2	- do -	- do -	East
8.	D-3	- do -	- do -	South + East

a. Scheme A

This involves solely the improvement of the Bang Yai river. The scale of channel improvement is largest among eight alternative plans.

b. Scheme B

The largest possible flood retarding pond retarding pond with corresponding improvement of Bang Yai river is considered in this alternative.

c. Schemes C-1, C-2 and C-3

These schemes involve floodway and channel improvement. Three promising floodway routes are considered in combination with channel improvement in the city area.

d. Schemes D-1, D-2 and D-3

Structural measures such as channel improvement, flood retarding pond and floodway are introduced under this alternative

The applied distribution of design discharge is illustrated by each respective alternative plan as shown in Annex Figs. 7.12 and 7.13.

The cost estimates of alternative plans were made for selecting the optimum Master Plan for flood control from the economical point of view. The project cost for each alternative scheme is given below:

Table 7.9 Project Cost of Each Alternative Plan

Alternative Plan	Project Cost (฿ 10^6)
A	2,282
B	1,623
C-1	428
C-2	340
C-3	401
D-1	391
D-2	335
D-3	409

7.3.3 Proposed Master Plan

The alternative schemes do not have any particular technical difficulties. Therefore, the Master Plan is selected taking into consideration the economical view point and certain social factors that influence such project.

According to the Phuket municipal office, it is very difficult to acquire the land in the retarding pond area. Therefore, it is recommended that scheme C-2 should be selected as the Master Plan for flood control because it will not bring about any serious social problem. Besides, it offers the least capital cost among the alternatives considered.

The proposed Master Plan, scheme C-2, will protect the City from flood using the east floodway. Minor improvements to the Bang Yai river and replacement of the bridges in the City will be required to minimize local floods from the residual basin.

The general layout of the Master Plan is illustrated in Fig. 7.4. The main features of this scheme is as follows:

(i) East floodway

The flood from the Bang Yai river basin is diverted to the Sapam bay completely by the east floodway and the discharge from the diversion point into the town is limited to 5 m^3/s. The design discharge is 152 m^3/s at the diversion inlet and 184 m^3/s at the outlet of the floodway taking into account the runoff from the residual basin. The design discharge was revised in this F/S stage.

(ii) River improvement

The river bed design was determined with consideration for the existing bed slope and river bed elevation at the road bridges. Annex Fig: 7.14 shows the design high water level of the Bang Yai river showing the river bed design. Basedon to hydraulic calculations, channel capacity in some places is not sufficient. The measures for river improvement such as vertical concrete walls, wet masonry and earth embankment were recommended to match the local flood.

Increasing the height of the existing retaining wall is recommended at narrow channel sections along Thepkrasattri road. The bending portion of river course behind the gas station will be changed to a new channel following the smooth curve. The intake structure at Saen Suk and six bridges are recommended to be reconstructed.

Principal feature is as shown below in Table 7.10.

Table 7.10 Principal Feature of Proposed Master Plan

I. River improvement		
- Channel dredging	:	33,800 m^3 (L=1,300 m)
- Embankment	:	74,400 m^3 (L=1,700 m)
- Revetments (wet masonry)	:	600 m
- Heightening of existing retaining wall	:	200 m (h=1.0 m)
- Reconstruction of bridge	:	6 bridges Phoonphol br. Phang Nga br. Toanpradit br. Sooksabai br. Pra-Aram br. Thepkrasattri br.
- Reconstruction of Saen Suk intake		
II. East Floodway		
- From just upstream Yaovaraj Bridge (Sam Kong Village) to Sapam bay		
- Length	:	4,325 m
- Width of channel	:	28 m at bottom
- Side slope	:	1:2.0 with revetment
- Excavation volume	:	1,500,000 m^3

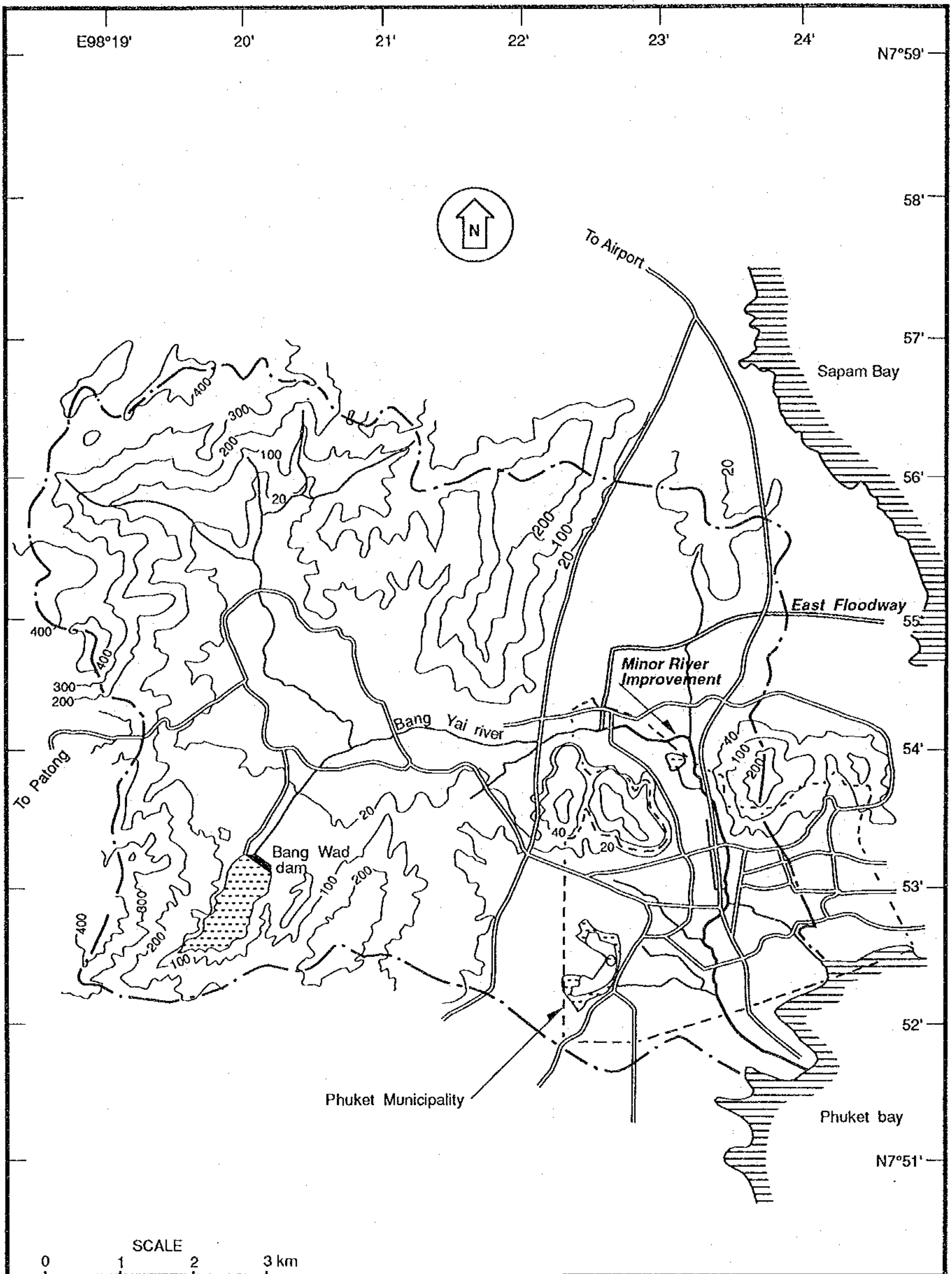


Fig. 7.4 GENERAL LOCATION MAP OF FLOOD CONTROL PROJECT FOR MASTER PLAN

7.4 Formulation of Urgent Flood Control Plan

7.4.1 Basic Concept of Urgent Flood Control Plan

Phuket municipality has been developed rapidly in recent years and its assets are also increasing and concentrating in the Municipality. The Master Plan is formulated to protect the design flood which is adopted from 30 year probable flood taking into consideration technical, socio-economic and environmental points of view. An urgent flood control plan is formulated as a part of the Master Plan.

Feasibility study is made to evaluate the urgent flood control plan from the viewpoint of cost effectiveness of flood damage reduction, socio-economic effects such as the stability of civil life and economic activity in Phuket municipality and environmental conservation.

As a result of the review of the hydrological analysis on flood, probable flood was revised and became small. It is judged that the relation in project cost among the alternative schemes for the master plan study does not change and scheme "C-2" is recommended. Therefore the urgent flood control plan is formulated based on the Master Plan and it consists of the east floodway and minor river improvement. The scale and dimensions of the facilities are studied herein.

7.4.2 Optimization of Urgent Flood Control Plan

Design scale is studied in comparison with cost effectiveness of alternative schemes which are formulated to control 5 year, 10 year, 20 year and 30 year probable floods. Cost estimates were made for each alternative scheme as shown in Annex Tables 7.4 to 7.7. These project costs are compared with flood reduction benefit by probable flood in terms of total net present value. Annual flood damage by probable flood is estimated by the flood damage analysis and are as follows:

Table 7-11 Damage by Probable Flood

Unit: 1,000 Bahts

Peak Flood (m^3/s)	Return Period (years)	Exceedance (%)	Probability Range	FLOOD Damage	Mean	Annual	Cumulated
72	2	50	0.500	0	0	0	0
94	5	20	0.300	68,300	34,150	10,200	10,200
108	10	10	0.100	70,600	69,450	6,900	17,100
123	20	5	0.050	77,200	73,900	3,700	20,800
133	30	3	0.0167	79,300	78,250	1,300	22,100
Total			0.967			22,100	

Project cost, annual cumulated benefit and economic internal rate of return (EIRR) for each scheme is shown below.

Table 7-12 Economic Internal Rate of Return

Unit: 1,000 Bahts

Return Period	Project Cost	Annual Benefit	EIRR (%)
5	147,400	10,200	6.2
10	149,900	17,100	10.4
20	155,500	20,800	12.1
30	160,200	22,100	12.5

EIRR for return period of 30 years is the highest among the alternative schemes. The difference of the project costs between the scheme for 30 year probable flood and that for 5 year probable flood is 12,800,000 Bahts only. It is 8 % of the project cost for 30 year probable flood and is not so different. Therefore the development scale for 30 year probable flood is recommended to implement although it is the target for the Master Plan.

Assuming that discount rate is 10%, annual equivalent cost, benefit, B/C and B-C are derived as presented in Table 7-13:

Table 7-13 B/C and B-C

Unit: 1,000 Bahts

Return Period	Annual Cost	Annual Benefit	B/C	B-C
5	16,100	10,200	0.63	-5,900
10	16,400	17,100	1.04	700
20	17,000	20,800	1.22	3,800
30	17,500	22,100	1.26	4,600

CHAPTER 8

PRELIMINARY DESIGN FOR URGENT FLOOD CONTROL PLAN

CHAPTER 8 : PRELIMINARY DESIGN FOR URGENT FLOOD CONTROL PLAN

8.1 Design Standard and Criteria

Preliminary design for flood control plan is made on the basis of design standard and criteria in Japan, because appropriate standard or criteria is not prepared in Thailand yet. Basic design standard and criteria applied for floodway are as follows:

- Design rainfall : 30 year probable rainfall
- Design hyetograph : rainfall pattern in August 1986
- Applied flood analysis: unit hydrograph method
- Design discharge : 121 m^3/s at diversion inlet
- Channel hydraulics : Manning's formula
- Roughness coefficient : 0.03 for concrete lining slope protection channel

8.2 Preliminary Design

8.2.1 Flood Distribution Plan

Flood control facilities are designed under proposed flood distribution plan. The proposed flood distribution plan is presented in Fig. 8.1.

The design discharge before the diversion inlet is 121 m^3/s. Out of 121 m^3/s, 116 m^3/s is diverted to the Sapam bay completely by the floodway and the discharge from the diversion point into Phuket town is limited to 5 m^3/s.

The Lak Konsi river is one of tributaries and the river length is 2.4 km. Its catchment area is 10.2 km^2 which covers northeastern part of the Bang Yai basin. Flood discharge from 1.5 km^2 of its catchment area is diverted to the Sapam bay by connecting the floodway on their conjunction near the Teacher's college. Inland water from Taling Chan canal and Ta Kraeng canal will be diverted to the Bang Pin river to reduce the discharge of the Bang Yai river.

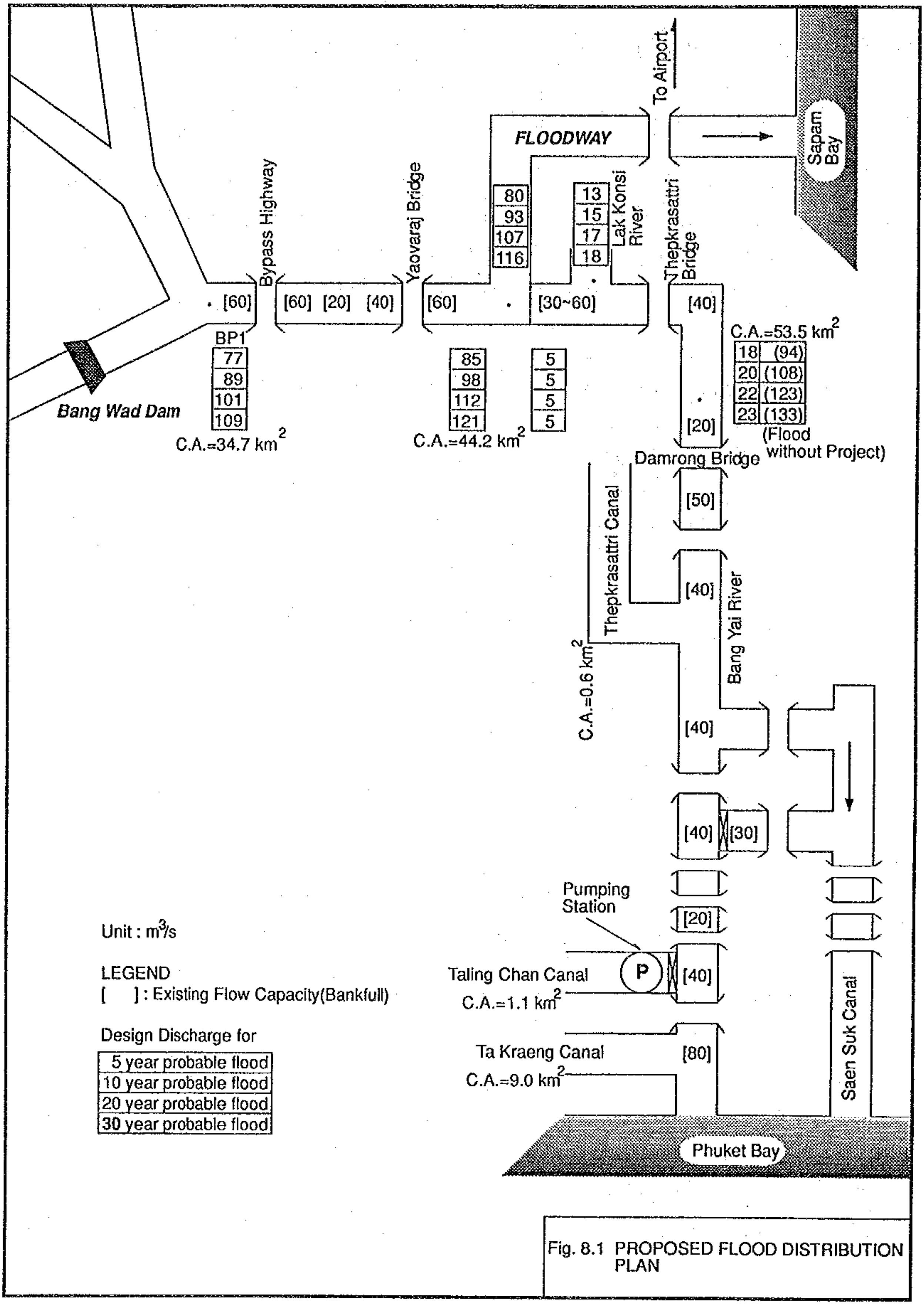


Fig. 8.1 PROPOSED FLOOD DISTRIBUTION PLAN

8.2.2 Floodway

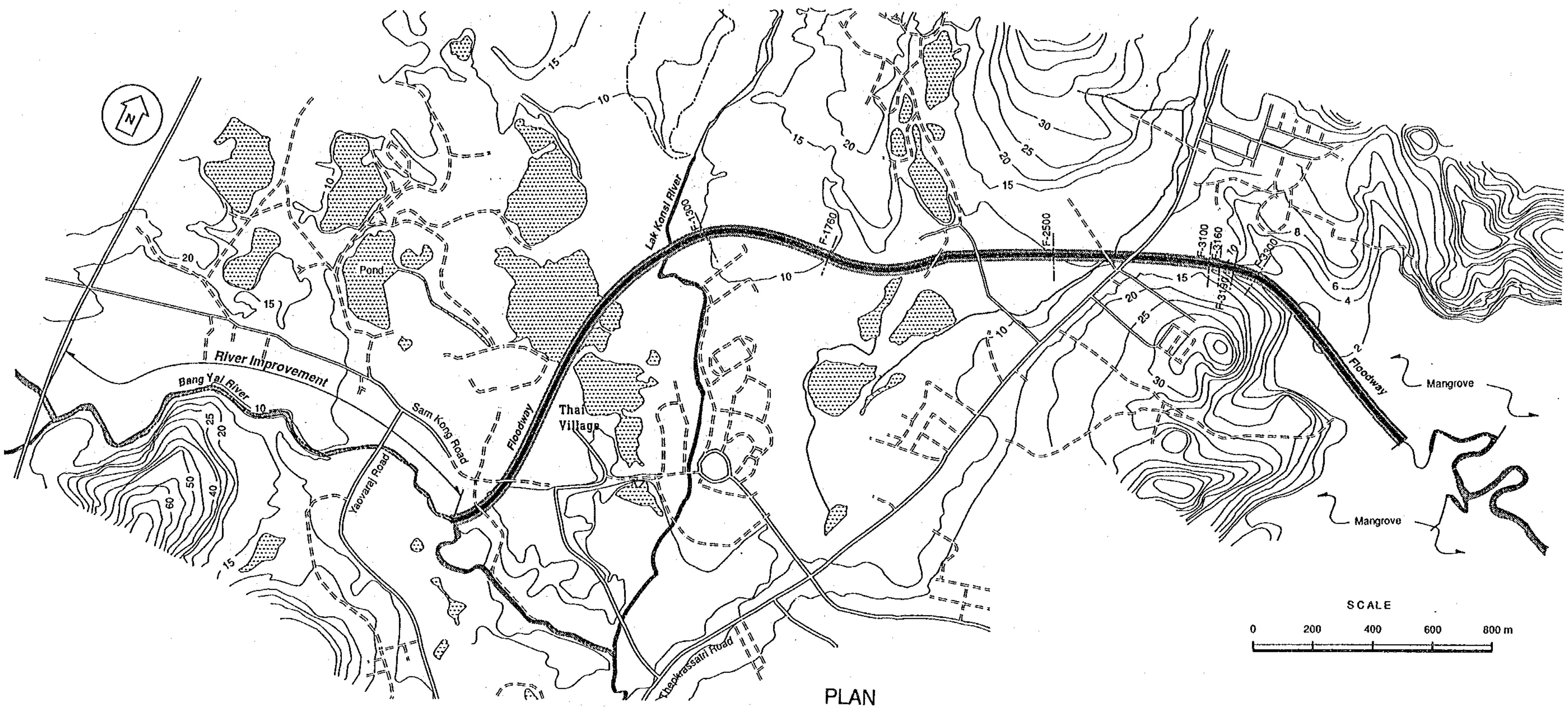
The location of diversion inlet is determined at 400 m downstream from the Yaovaraj bridge under agreement with the municipality office. Almost lands along the floodway route are not utilized yet except that the land between the Thepkrasattri road and the Sapam bay is used for small scale rubber plantation. Preliminary design drawings are presented in Figs. 8.2 and 8.3.

Trapezoidal cross section is employed for the floodway. Diversion inlet is constructed as concrete structure with side slopes of 1:0.5. The floodway after the diversion inlet is designed as trapezoidal cross section with side slopes of 1:2.0. The side slopes are protected by revetment. The design river bed width is 11 m. Bed slope of the floodway is designed at 1/1,000 for smooth connection between the floodway diversion inlet and outlet.

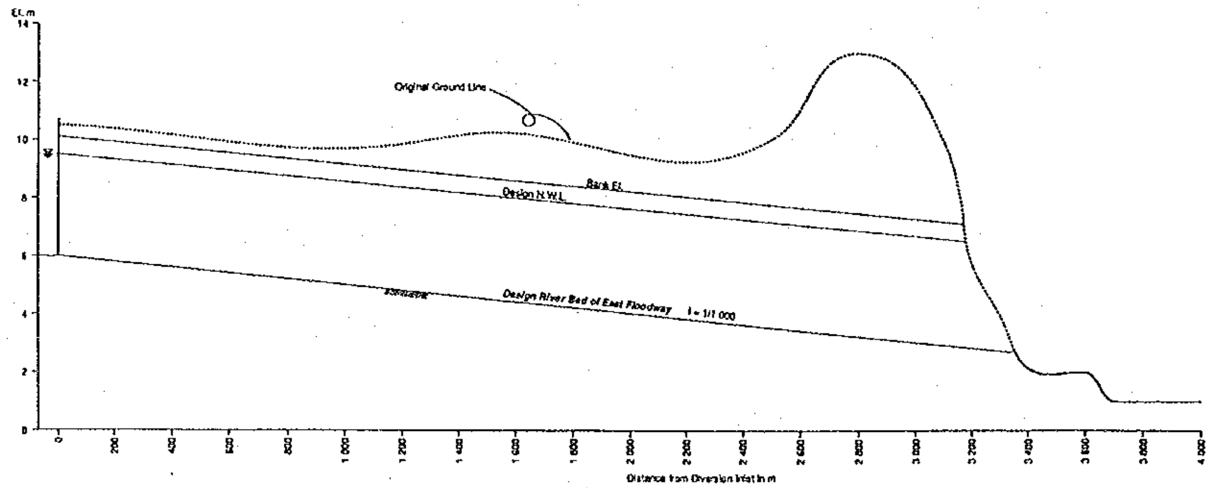
Design discharge of 116 m^3/s is adopted for 30 year probable flood. The design high water depth is determined for 4.2 m. The design velocity is 1.9 m/s. Freeboard for the floodway bank is adopted at least 60 cm from the design high water level.

8.2.3 Bang Yai River Improvement

In order to flow the design discharge of 121 m^3/s, river improvement work is necessary for the Bang Yai river between the Bypass highway and the diversion inlet. Excavation of river will be made to meet the design discharge. Side slopes of the Bang Yai river is excavated to make slopes milder than 1:0.5. The river bed is excavated to make the bed width at least 8 m. Preliminary design of this river improvement is shown in Fig.8.4.



PLAN



Profile

Fig. 8.2 FLOODWAY
GENERAL PLAN & PROFILE

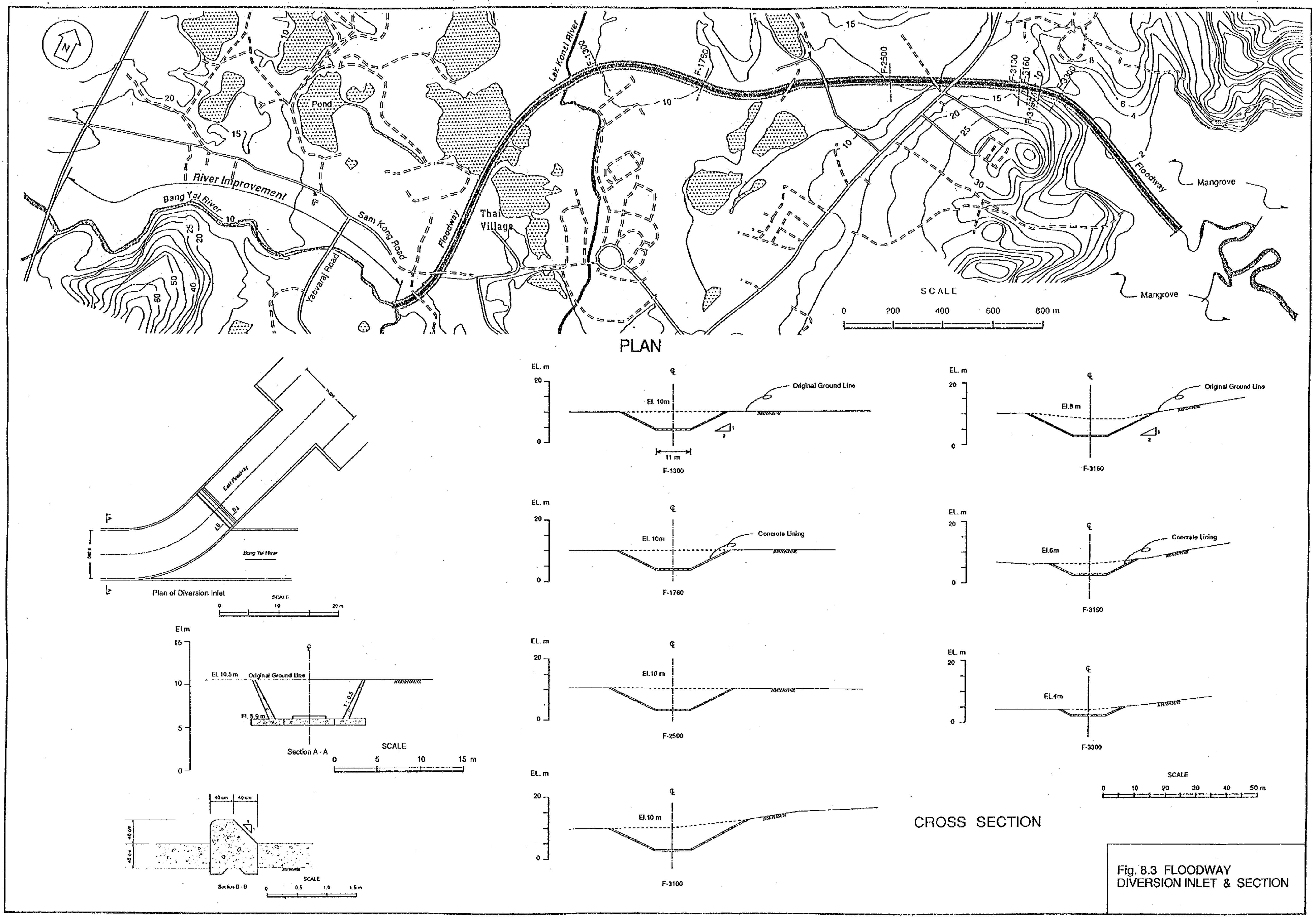


Fig. 8.3 FLOODWAY DIVERSION INLET & SECTION

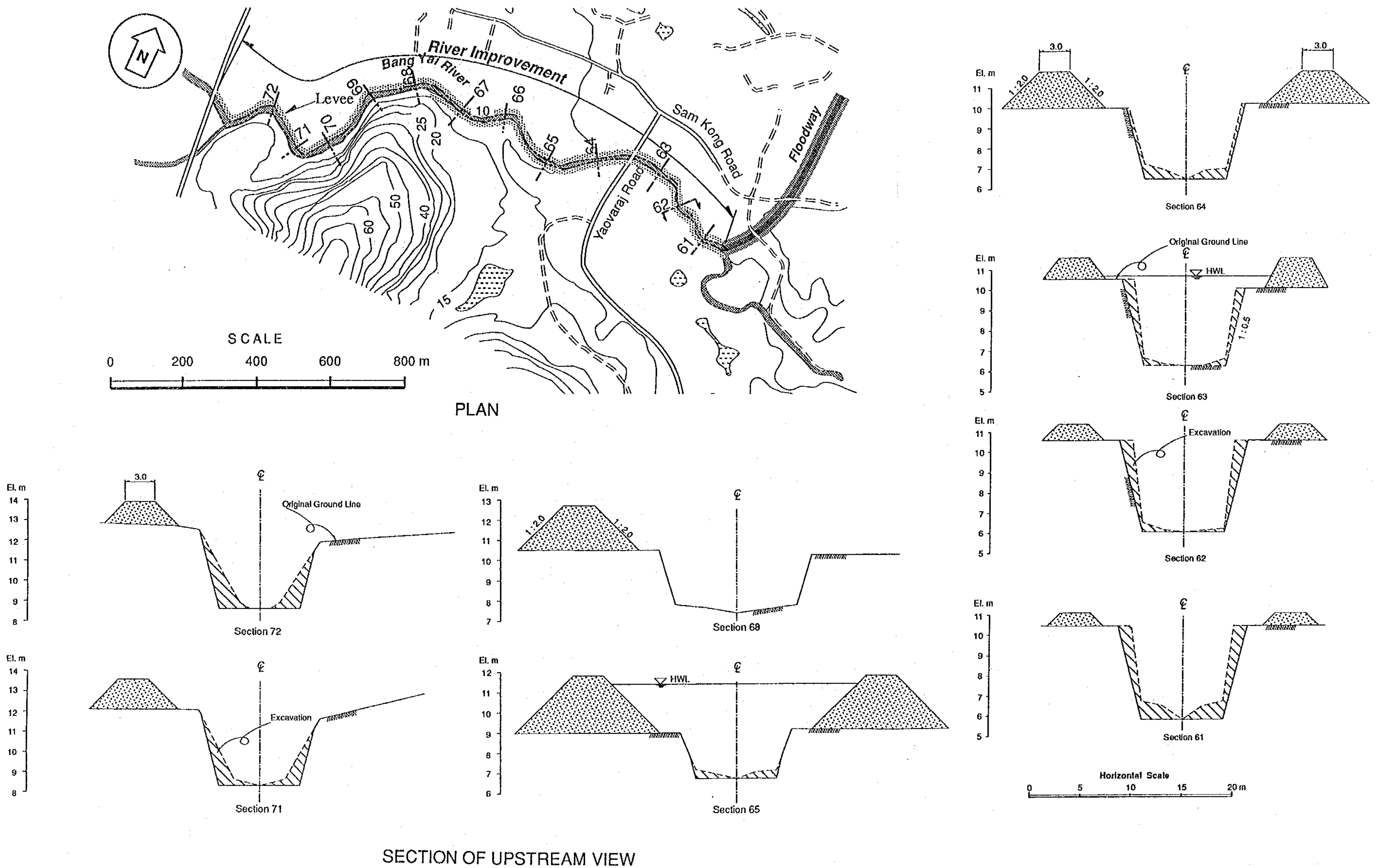


Fig. 8.4 RIVER IMPROVEMENT PLAN & SECTION

The high water depth will be 4.7 m for the design discharge of 121 m^3/s. Since the water level is higher than bank elevation, levee is constructed along the river, 1,700 m in length. The design velocity is estimated at 2.5 m/s. Retaining wall will be constructed along the upstream and downstream of the diversion point for 25 m in length respectively.

Replacement of the bridges in the Municipality will be required to mitigate local floods from the residual basin. Six bridges are recommended to be reconstructed.

The Saen Suk canal, of which the length was 2.0 km, was constructed to divert flood water from the Bang Yai river. Most reaches of this canal is protected by vertical concrete wall. It is recommended to reconstruct the diversion inlet to release local flood from residual basin effectively.

8.3 Construction Plan

8.3.1 Implementation Schedule

The project features of the proposed flood control project are as shown in Table 8.1.

In this connection, additional survey and restudy are conducted, and then refer to Chapter 8.6.

Table 8.1 Principal Features of Proposed Flood Control Plan

I. River improvement

Location: between the Bypass highway and the inlet of floodway

- Channel excavation : 18,400 m^3 (length = 1,700 m)
- Levee Embankment : 10,470 m^3 (length = 1,700 m x 2)

Reconstruction of bridge :
1. Phoonphol bridge
2. Phang Nga bridge
3. Toanpradit bridge
4. Sooksabai bridge
5. Pra-Aram bridge
6. Thepkrasattri bridge

Reconstruction of Saen Suk intake

II. Floodway

East floodway

Location: from 400 m downstream of Yaovaraj Bridge (Sam Kong Village) to Sapam bay

- Length : 3,430 m
- Bed width : 11.0 m
- Side slope : 1:2.0 with revetment
- Excavation volume : 442,000 m^3

Implementation programme for the flood control project is assumed as shown in Fig.8.5.

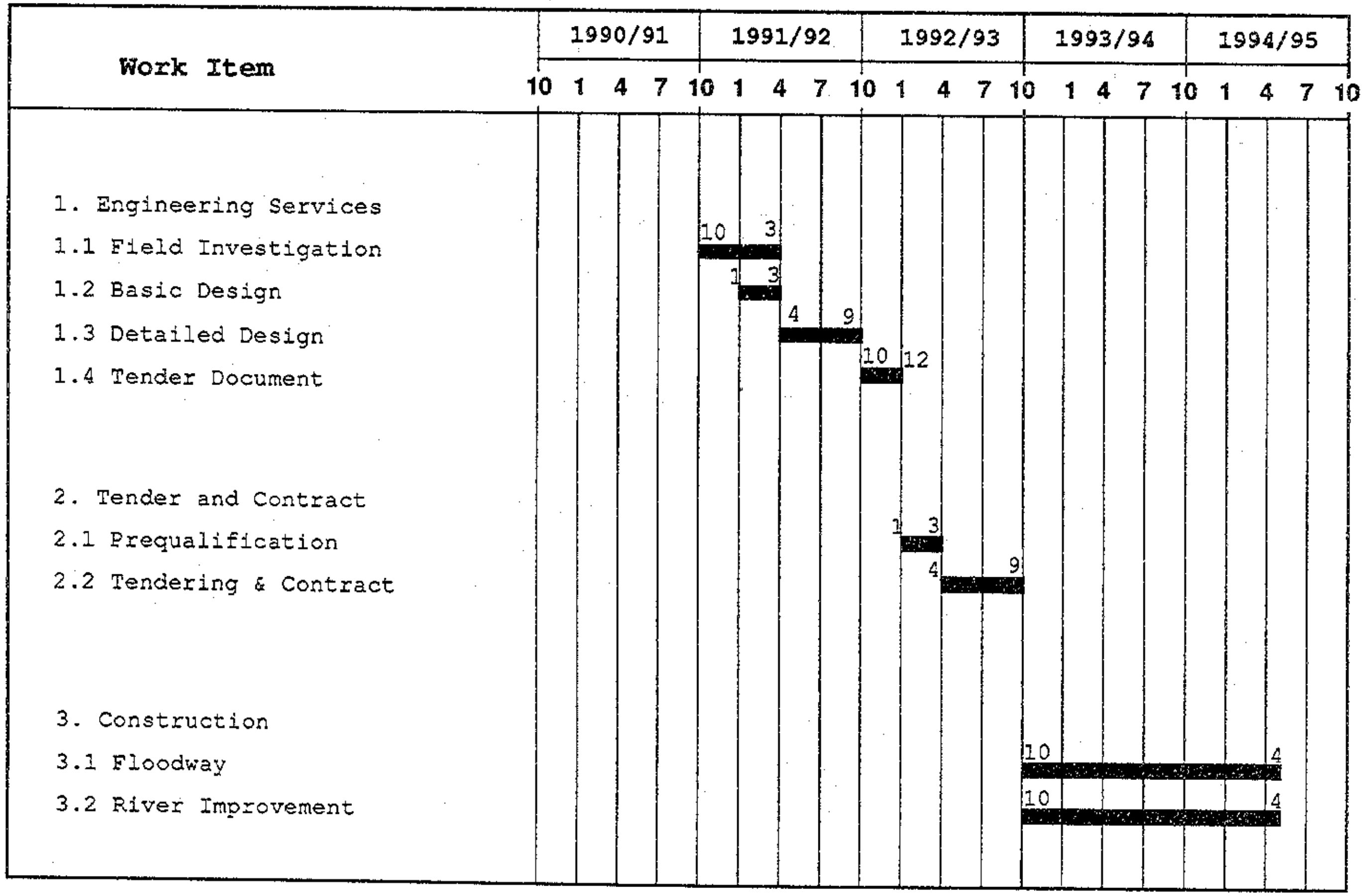


Fig. 8.5 IMPLEMENTATION PROGRAM FOR FLOOD CONTROL PROJECT

Assuming that the construction of the floodway will be completed by April 1995 (BE 2538), implementation schedule is expected as follows:

1) Preparation of budget, loan agreement and selection of consultants

   1 year from October 1990 (BE 2533) to September 1991 (BE 2534)

2) Additional field investigation, detailed design and preparation of tender documents

   15 months from October 1991 (BE 2534) to December 1992 (BE 2535)

   Detailed field investigation is required for 6 months especially on topographic survey such as cross sectional survey of the floodway and the Bang Yai river and also geological survey along the floodway route.

   Engineering detailed design will be required to estimate reliable quantity of works and prepare design drawings, bill of quantities and tender documents. Following periods are required for engineering services.

   - Field investigation : 6 months
   - Basic design : 3 months
   - Detailed design : 9 months

3) Tender call and contract

   9 months from January 1993 (BE 2536) to September 1993 (BE 2536)

4) Commencement of construction

   October 1993 (BE 2536)

5) Completion of construction

April 1995 (BE 2538)

8.3.2 Construction Schedule

The main civil works consist of the following work items:

1) Preparatory works
2) Floodway excavation
3) Slope protection
4) Construction of diversion inlet
5) River excavation
6) Levee construction
7) Saen Suk inlet works

The construction is expected to be completed in 2 years. Preliminary construction time schedule, which is to be settled after an overall scrutiny on the detailed planning and logical construction sequence at detailed design stage, is shown in Fig. 8.6. The construction schedule is considered as follows:

Preparatory Works

The preparatory works to be made by the contractor will be carried out for two months in October and November 1993 (BE 2536).

Main Construction Works

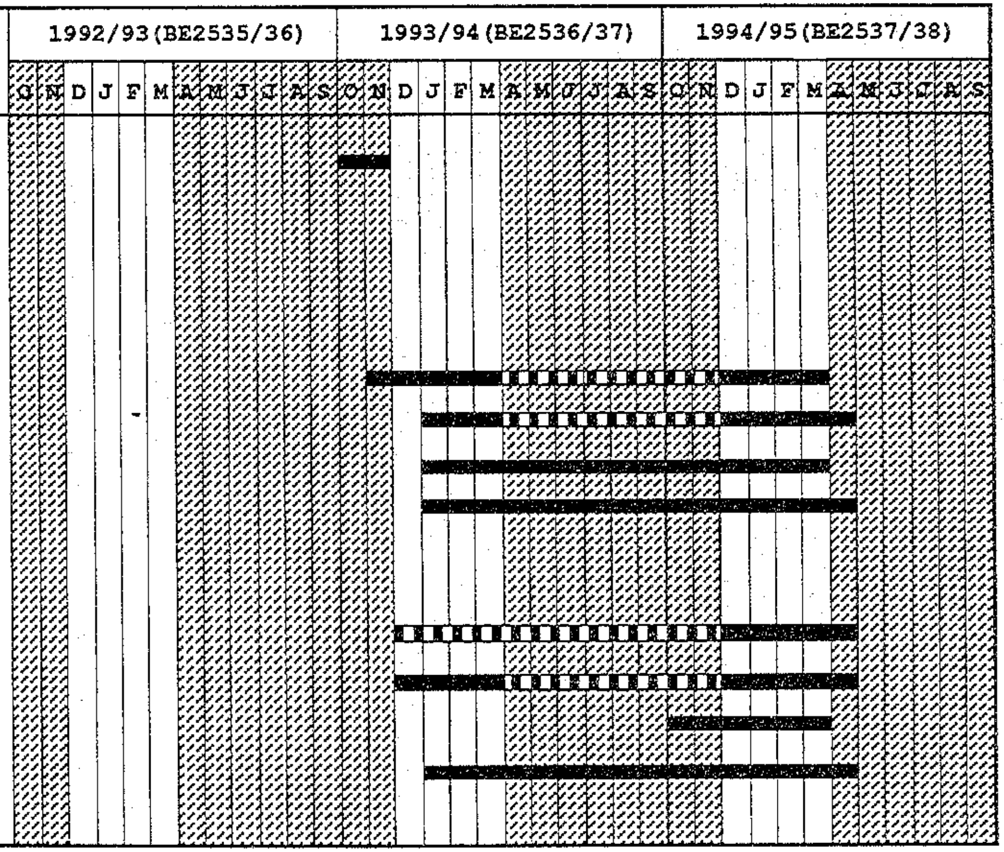
The construction plan is prepared under consideration that the most of all works will be greatly affected by dry and rainy season.

Floodway excavation of 442,000 m^3 will be commenced in November 1993 (BE 2536) and completed in March 1995 (BE 2538). Revetment work will be carried out during a period from January 1994 to April 1995.

Diversion inlet will be constructed from January 1994 to March 1995. It will be connected to the Bang Yai river in March 1995.

Channel excavation of the Bang Yai river about 18,400 m^3 will be commenced in December 1993. Levee embankment work will be done during a period from December 1993 to April 1995. Saen Suk innovation work will start in October 1994 and be completed in March 1995.

DESCRIPTION	UNIT	QUANTITY
1. Preparatory Works	L.S.	
2. Floodway		L=3,430 m
2.1 Excavation	m3	442,000
2.2 Revetment	m2	55,000
2.3 Diverison Inlet	L.S.	
2.4 Bridge	m2	1,900
3. River Improvement		L=1,700 m
3.1 Excavation	m3	18,400
3.2 Levee	m3	10,500
3.3 Saen Suk Inovation	L.S.	
3.4 Bridge	m2	480



: Rainy season

Fig. 8.6 CONSTRUCTION SCHEDULE OF FLOOD CONTROL PROJECT

8.3.3 Work Items and Quantities

Main work items of civil works are the floodway and the Bang Yai river improvement. Work quantities are estimated based on the topographic map with a scale of 1: 4,000. Major work quantities are listed in Table 8.2:

Table 8.2 Major Work Quantities

Work item	Unit	Quantities
FLOODWAY(L=3,430 m)		
Excavation	m3	442,000
Revetment		
- Slope protection	m2	55,000
- Foot&Top protection	m	6,860
Diversion Inlet		
- Concrete	m3	500
- Reinforcement bar	t	40
- Backfill	m3	700
Bridge	m2	1,900
RIVER IMPROVEMENT(L=1,700 m)		
Excavation	m3	18,400
Levee embankment	m3	10,470
Retaining wall		
- Excavation	m3	2,000
- Concrete	m3	600
- Reinforcement bar	t	48
- Backfill	m3	1,400
Saen Suk Innovation		
- Concrete	m3	200
- Reinforcement bar	t	16
- Sluice gate (2.0 m x 2.0 m)	no	2
Bridge	m2	480

Embankment material about 10,470 m3 will be supplied from the excavated material of the floodway.

8.4 Cost Estimate

8.4.1 Condition of Cost Estimate

The project cost is composed of (i) the construction cost, (ii) land acquisition and compensation cost, (iii) engineering service fee, (iv) government administration cost, (v) physical contingency and (vi) price contingency.

(i) Construction cost

The construction cost is estimated from unit price of respective work item and the work quantity.

(ii) Land acquisition and compensation cost

The land acquisition cost is estimated based on the data collected from the land department in Phuket municipality. The compensation cost for houses is estimated from the unit cost per square meter based on the data collected in the Municipality.

(iii) Engineering service fee

The engineering service fee is the cost necessary for the engineering services such as the detailed design of the project, preparation of tender documents and supervision of the construction works, etc. The cost for engineering services is estimated at 10% of the direct construction cost

(iv) Government administration cost

The implementation of the project also requires administration by the government. The government administration cost is assumed to be 2.5% of the direct construction cost with land acquisition and compensation cost as local currency portion.

(v) Physical contingency

The physical contingency is an allowance to be prepared in consideration of the accuracy in the cost estimate. It is taken at 20% of the sum of the construction cost, engineering service fee and government administration cost taking into account the accuracy of this study.

(vi) Price contingency

The price contingency is an allowance to inflation of materials, construction equipment and labour wage. Price contingency is applied from annual inflation rate of 2 % for foreign currency portion and 10 % for local currency portion based on the data of construction price index.

Unit price for the feasibility study is estimated taking into consideration labour wage, construction equipment and material prices collected from the Municipality office, PWD, RID, DMR, some contractors and construction equipment companies.

The recent results of similar international competitive biddings in Thailand and adjacent countries are referred for making proper unit price.

Unit price is estimated by foreign and local currency portion at the price level of August 1989. The following exchange rate is used for conversion.

Japanese Yen 1 = ฿ 0.175
U.S.$1 = ฿ 25.1

The following basic conditions are applied for the cost estimate.

(a) The construction work will be conducted by contractors selected through international competitive bidding.
(b) The engineering services are performed by selected consultants.
(c) Most of the construction materials are to be supplied by the contractors mainly from local markets.
(d) Construction machineries, equipment including spare parts are to be brought by the contractors. The costs are estimated as the foreign currency portion.
(e) Costs for freight, insurance and inland transportation are included in the costs of all materials and equipment, which are to be imported, but import tax and duty are not included.

The unit price estimated for the respective work item is presented in Table 8.3:

Table 8.3 Estimated Unit Price

Work item	Unit	Unit price F.C. (Yen)	Unit price L.C. (฿)
Excavation	m^3	190	9
Embankment	m^3	300	13
Revetment			
- Slope protection	m^2	2,950	195
- Foot&Top protection	m	3,800	250
Backfill	m^3	170	7
Concrete	m^3	6,500	290
Reinforcement bar	t	17,440	4,350
Bridge	m^2	41,500	2,740
Sluice gate (2.0 m x 2.0 m)	no	1,660,000	109,700
Flap gate (ϕ 1 m)	no	580,000	38,400

8.4.2 Project Cost

The project cost is estimated as shown in Table 8.5. The summary of project cost is as shown in Table 8.4:

Table 8.4 Summary of Project Cost

Unit: ฿ 1,000

WORK ITEM	F.C.	L.C.	Total
1. Preparatory Works	6,870	2,440	9,310
2. Floodway	62,290	21,960	84,250
3. River Improvement	6,440	2,390	8,830
Direct Cost	75,600	26,790	102,390
4. Land Acquisition & Compensation Cost	-	17,900	17,900
5. Engineering Service & Government Administration	7,560	5,680	13,240
6. Physical Contingency	16,630	10,080	26,710
Sub-total	99,790	60,450	160,240
7. Price Contingency	8,740	26,870	35,610
Total	108,530 55%	87,320 45%	195,850 100%

Total project cost excluding price contingency is estimated at ฿ 160 million. It comprises of ฿ 100 million of the foreign currency portion and ฿ 60 million of the local currency portion.

Table 8.5 Project Cost for Flood Control

WORK ITEM		Unit	Quantity	Foreign Currency Unit Price (Baht)	Foreign Currency Amount (B1,000)	30 year flood Local Currency Unit Price (Baht)	Local Currency Amount (B1,000)
1. Floodway					(62,290)		(21,960)
Excavation	Soil	m3	442,000	33	14,590	9	3,980
Levee							
	Embankment	m3	0	53	0	13	0
Revetment							
	Slope Protection	m2	55,000	520	28,600	195	10,730
	Foot&Top Protection	m	6,860	670	4,600	250	1,720
Inlet	Concrete	m3	500	1,140	570	290	150
	Reinforcement Bar	t	40	3,050	120	4,350	170
	Backfill	m3	700	30	20	7	0
Bridge		m2	1,900	7,260	13,790	2,740	5,210
2. River Improvement					(6,440)		(2,390)
Channel	Excavation	m3	18,400	33	610	9	170
Levee	Embankment	m3	10,470	53	550	13	140
Retaining Wall							
	Excavation	m3	2,000	33	70	9	20
	Concrete	m3	600	1,140	680	290	170
	Reinforcement Bar	t	48	3,050	150	4,350	210
	Backfill	m3	1,400	30	40	7	10
Bridge		m2	480	7,260	3,480	2,740	1,320
Saen Suk Inovation							
	Concrete	m3	200	1,140	230	290	60
	Reinforcement Bar	t	16	3,050	50	4,350	70
	Gate (2 m x 2 m)	no.	2	290,500	580	109,700	220
3. Miscellaneous		10% x (1.+2.)			(6,870)		(2,440)
Access & Service Road							
Yards							
Direct Cost					**75,600**		**26,790**
4. Land Acquisition & Compensation							(17,900)
Land Acquisition		l.s.					10,900
Houses		nos.	20			350,000	7,000
5. Engineering &	10% x (1~3)				7,560		5,680
Administration	2.5% x (1~3,LC4)						
6. Physical Contingency	20% x (1~5)				16,630		10,070
Total					**99,790**		**60,440**
Grand Total		**$6,380 (x 1,000)**		=	**¥914,700 =**		**B160,230**

Exchange rate Baht
US$1 = 25.1
¥1 = 0.175

8.4.3 Disbursement Schedule

The project cost is disbursed based on the implementation programme and construction schedule. Disbursement schedule of the financial cost is presented in Table 8.6.

8.4.4 Operation and Maintenance Cost

The operation and maintenance cost for the flood control facilities is assumed to be 0.5 % of the direct construction cost including its physical contingency. Annual O&M cost is estimated at ฿ 614,000.

Table 8.6 Disbursement Schedule of Financial Project Cost

(Unit : B1,000)

30 year flood

Item	Summary		1989/90		1990/91		1991/92		1992/93		1993/94		1994/95	
	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.
1. Preparatory Works	6,870	2,440									6,870	2,440		
2. Civil Works														
2.1 Floodway														
2.1.1 Excavation	14,590	3,980									10,300	2,810	4,290	1,170
2.1.2 Revetment	33,200	12,450									19,530	7,320	13,670	5,130
2.1.3 Diversion Inlet	710	320									500	230	210	90
2.1.4 Bridge	13,790	5,210									9,730	3,680	4,060	1,530
2.2 River Improvement														
2.2.1 Excavation	610	170									300	80	310	90
2.2.2 Levee	550	140									390	100	160	40
2.2.3 Retaining Wall	940	410									470	200	470	210
2.2.4 Saen Suk Inovation	860	350											860	350
2.2.5 Bridge	3,480	1,320									2,460	930	1,020	390
Sub-total of 2.	68,730	24,350									43,680	15,350	25,050	9,000
Sub-total 1. to 2.	75,600	26,790									50,550	17,790	25,050	9,000
3. Land Acquisition and Compensation		17,900						3,580		8,950		5,370		
4. Administration Expenses		3,010						180		230		1,780		820
5. Engineering Services	7,560	2,680					3,020	1,070	760	270	2,670	950	1,110	390
Sub-total 1. to 5.	83,160	50,380					3,020	4,830	760	9,450	53,220	25,890	26,160	10,210
6. Physical Contingency	16,620	10,080					600	970	150	1,890	10,640	5,180	5,230	2,040
Sub-total 1. to 6.	99,780	60,460					3,620	5,800	910	11,340	63,860	31,070	31,390	12,250
7. Price Contingency	8,740	26,870					150	1,220	60	3,750	5,260	14,420	3,270	7,480
Grand Total	108,520	87,330					3,770	7,020	970	15,090	69,120	45,490	34,660	19,730

8.5 Recommendation

8.5.1 Recommendation for Further Study

Economic feasibility of the project for 30 year probable flood is the highest among the alternative schemes. In addition, the difference of the project costs between the scheme for 30 year probable flood and that for 5 year probable flood is 12,800,000 Bahts and 8 %. It is not so much different. Therefore it is recommended to implement the project to control 30 year probable flood which is the target flood for the Master Plan.

Work quantities of the floodway and river improvement were estimated from the preliminary design drawings which was made based on the topographic map in a scale of 1: 4,000 prepared by DTCP. It is recommended to carry out topographic survey and geological and soil mechanical survey for floodway route to estimate more accurate work quantities.

It is expected that the project will not bring about negative environmental impact, according to field reconnaissance which was made along the floodway route to assess environmental impact. However, it is recommended to carry out detailed environmental impact study to get understanding and cooperation of the citizens in the project area.

In order to formulate practical and comprehensive counter measures against flood, hydrological analysis is essential using rainfall and discharge data. It is recommended to establish proper organization for data management system among related governmental offices, such as PWD Phuket office, RID Bang Wad dam, Meteorological Department in Phuket and Phuket Municipality.

8.5.2 Recommendation for Non-structural Measures

(1) Restriction of land use along the river course and mining ponds.

The central area of the Phuket city is densely utilized for