(2) Per Capita Consumption

Since the per connection consumption has been steadily increasing in spite of decreasing per house population, the apparent per capita consumption has been rapidly increasing from 336 lpcd in 1984 to 456 lpcd in 1988 as shown in Annex Table 3.3. Generally speaking, water consumption of governmental offices, schools, hospitals, factories, hotels and general restaurants is excluded as the per domestic consumption is discussed as compared with the other city.

Table 3.8 shows the distributions of the number of connections and water consumption categorized into domestic, commercial, governmental, industrial, hotel and other use by annual water consumption scale. As can be seen, a share of domestic and commercial consumption is 55.96% and 24.35% of total consumption, respectively. Now provided that those are all domestic consumption, per capita consumption is calculated with a per house population of 4.30 to be 377 lpcd.

However, it is hard to categorize into common domestic consumption, because there are big consumers like 2,000 to 30,000 m^3/y and small like less than 100 m^3/y. As to small consumers, it is supposed that they mainly use own well water, for there are allegedly approximately 5,000 shallow wells in the city area.

Lack of data on consumption categorized into domestic, commercial, governmental, industrial, restaurant and other use makes the forecast per capita consumption difficult. To overcome this problem, on the assumption of domestic consumers who use water consumption of 100 up to less than 1,500 m^3/y among categorized as domestic and commercial users, an amount of the domestic water consumption is estimated as 2,061,616 m^3/y with connection number of 4,521, which is marked with four-cornered frame in Table 3.8.

These consumers can be assumed as the common domestic consumers such as resident houses and or houses being small restaurant, which will be hereinafter referred to as "basic consumers/consumption" in domestic and commercial consumption and the other bigger consumers is referred to as "additional consumers/consumption" in this report.

The present per capita basic consumption is accordingly calculated to be 291 lpcd by means of a per house population of 4.30.

As compared with other similar cities in Thailand, this value is considerably high. To cope with the gap, an interview was con ducted to group the present water usage for common inhabitants. The outcome of the interview is presented in Annex Table 3.5.

Table 3.8 Water Consumption and Number of Connections by Scale

Upper : No. of Conn.
Lower : Consump. (cu. m/y)

Scale	Dom.	Com.	Gov.	Sch.	Hoe.	Fac.	Hot.	Res.	Total	Share (%)
30,000 -	1	1	2		1	2	1		8	0.14
	92191	62199	70670		76712	103508	30431		435711	10.37
10,000 - 30,000	2	4		3		6	3		18	0.31
	36177	66813		49126		112725	54105		318946	7.59
5,000 - 10,000	18	17	5	4		3	4	6	57	0.97
	117562	120234	32173	28754		23238	29954	40695	392610	9.34
3,000 - 5,000	39	36	6	3	1	3	3	6	97	1.65
	147746	136698	24931	10789	3216	10015	11446	22174	367015	8.73
2,000 - 3,000	63	39	4	2			1	7	116	1.98
	149649	92753	9429	4254			2398	17113	275596	6.56
1,500 - 2,000	92	54	1				2	4	153	2.61
	159775	93508	1551				3630	6719	265183	6.31
1,000 - 1,500	257	99	6	1	1			6	370	6.31
	306445	120812	7503	1242	1277			6545	443824	10.56
500 - 1,000	874	279	12	5	1			11	1182	20.16
	604473	195886	8891	3997	823			8442	822512	19.57
100 - 500	2574	438	25	2	2		1	2	3044	51.91
	703824	130176	6746	475	483		218	855	842777	20.06
100	712	102	1	1	1		1	1	819	13.97
	33646	4139	34	44	75		46	94	38078	0.91
Total	4632	1069	62	21	7	14	16	43	5864	100.01
	2351488	1023218	161928	98681	82586	249486	132228	102637	4202252	100.00
Share (%)	78.99	18.23	1.06	0.36	0.12	0.24	0.27	0.73	100.00	
	55.96	24.35	3.85	2.35	1.97	5.94	3.15	2.44	100.00	

Source : Phuket Municipal Waterworks

The survey resulted to the following findings:

- A water meter is installed at almost every house.
- Number of persons per family is 4.4
- Number of families per water meter is 1.4
- Number of persons per household is 6.0
- Water consumption per person is 226 l/d

This result is slightly different from the information provided by the city water works. The main reason for this difference seems that, (1) the number of survey sampling may be small and not representative of all, which is 389 households or 3.4 percent of total houses in the city, and (2) the population per one water meter connection of 4.3 in 1989 as shown in the city water works records seems to be a little bit smaller.

In this report, estimation of future water demand is promoted on the basis of the city data.

(3) Per Student Consumption

At present, 13 schools/colleges are supplied with water from the Phuket City Waterworks as shown in Table 3.9. Some schools have multiple connections. The per student consumption range from 29.8 lpcd at Satri Phuket School to 5.7 lpcd at Kanjanawittaya School. Eliminating the data at Satri Phuket, Phuket Thai Hua and Kajanawittaya Schools which show extremely high and low values, the average per student consumption is 11.7 lpcd.

(4) Per Bed Consumption

Six medical establishments including hospitals and clinics are supplied from the Phuket City Waterworks. The calculated per bed consumption at three hospitals, which have available data for calculation of per bed water consumption, are 818 l/d as shown in Table 3.10.

(5) Per Room Consumption

The consumption at hotels shares 3.2% of the total. This fact suggests that Phuket City is the center of politics, administration, economy, commerce and culture in the Phuket Province and tourism is only one component of various city activities different from Patong and Pattaya where tourism is the sole industry, though a city water supply system does not cover all hotels. Some hotels with connections do not use tap water or seem to try to reduce the weight of tap water with the use of well water as shown in Table 3.11.

Table 3.9 Per Student Water Consumption of Schools

Name of School/College	Consump. (m^3/yr)	No. of Student (pers.)	Per Student (lpcd)	Code No.
Satri Phuket	29,047	2,674	29.8	1-2,4,7,424,3-245
Thesaban Plukpanya	4,618	1,282	9.9	1-191
Phibun Sawasdee	3,124	766	11.2	1-326
Ban Taladnua	2,261	675	9.2	1-327,371
Thesaban Ban-Bangnieo	2,961	1,071	7.6	2-234,849
Phuket Technical College	13,701	1,747	21.5	2-2027
Phuket Thai Hua	855	389	6.0	3-130
Phuket Wittayalai	8,305	2,654	8.6	3-272
Tram Supaphakdee	3,047	343	24.3	4-505
Kanjanawittaya	1,242	596	5.7	5-7
Anuban Phuket	5,086	1,500	9.3	5-790
Phuket Development Agency	44	N.A	-	5-1231
Not Identified	14,715	N.A	-	6-82
Thesaban Muang Phuket	8,855	916	26.5	6-471
Not Identified	820	N.A	-	6-854
Total	98,681			

Source : Phuket Municipal Waterworks

Table 3.10 Per Bed Water Consumption of Hospitals

Name of Hospital	Consump. (m^3/yr)	No. of Beds (beds)	Per Bed (l/bed)	Code No.
Juttipanit Company Hos.	250	N.A	-	2-900
Dr. Bancherd Tantivit	75	N.A	-	3-99
Sirirot Hospital	1,277	35	100.0	3-324
Dr. Sompot Crop. Hos.	3,216	30	293.7	6-345
Vachira Hospital	76,712	207	1,015	6-233
Not Identified	233	N.A	-	6-433
Mrs. Sanwan Tantungtong	823	N.A	-	7-128
Total	82,580 (81,205)	(272)	(818)	

Source : Phuket Municipal Waterworks

Table 3.11 Per Room Water Consumption of Hotels

Name of Hotel	Consump. (m^3/yr)	No. of Rooms (rooms)	Per Room (l/room)	Code No.
June Hotel	9,881	28	966.8	1-245
Imperial Hotel	20,130	39	1,414.1	2-10
Siam Hotel	7,159	20	980.7	2-8
999 Hotel	4,622	29	436.7	2-872
Montri Hotel	30,431	72	1,158.0	2-1254
Duen-Akat Hotel	1,715	N.A	-	3-22
Suksabye Hotel	7,091	53	366.6	3-264
City Hotel	0	165	-	3-385
On On Hotel	3,755	53	194.1	4-8
Sintawee Hotel	264	137	5.3	4-17,21
Thavorn Hotel	23,673	200	324.3	4-207
Damrong Hotel	3,069	79	106.4	5-509
Kittikorn Hotel	10,302	25	1,129.0	5-769
Siri Hotel	0	30	-	6-79
Phuket Merlin Hotel	1,915	180	29.1	6-216
Phuket Motel	5,823	29	550.1	6-343
Kohsawan Hotel	2,398	16	410.6	6-495
P.S. Inn Hotel	0	86	-	7-262
Total	132,228			

Source : Phuket Municipal Waterworks

The average per room consumption is calculated to be 1.160 l/d eliminating those with room consumption less than 500 m^3/d.

3.2.3 Future Water Demand

(1) Domestic and Commercial consumption

1) Basic consumption

The per capita consumption was 291 l/d in 1988 as mentioned previously. This value is considerably high compared to those in other municipalities.

In the forecast of future water demand, it is assumed that the rapid growth of water demand as it was is not expected in the future and the per capita consumption will be 300 l/d in the target year of 2006.

2) Additional consumption by big consumers

In 1988, an amount of 1,275,305 m^3/y was used by 366 big consumers for domestic and commercial purpose, which was equivalent to 61.9% of basic consumption. This absolute amount is assumed to be constant up to the target year.

(2) Governmental Consumption

An amount of 161,928 m^3/y was consumed for governmental purpose in 1988. The governmental consumption is considered to be pro portional to the magnitude of administrative population which was 61,048 persons, therefore, the per capita consumption for governmental use was 7.3 l/d. This unit consumption is assumed not to change in future.

(3) School Consumption

As stated earlier, the per student consumption was 11.7 l/d, say 12 l/d in 1988.

It is assumed that this value will not change in the future. It is assumed that the number of pupils and students is proportional to the total population. In other words, the ratio of the number to the total population is assumed to be equal to the present ratio.

$$\frac{\text{No. of Pupils \& Students}}{\text{Total Population}} = \frac{23,631}{61,908} = 38\%$$

Based on the future population discussed in Section 3.1 and the above ratio, the number of pupils and students in the year 2006 is estimated at 30,000.

$$78,200 \times 38\% = 29,800$$

(4) Hospital Consumption

According to the Public Health Statistics, the average ratio of population to hospital bed was 862 persons/bed at the provincial level in 1986 and the administrative target is 700 persons/bed in 1991 and 600 persons/bed in 2006. There are one public hospital with 207 beds, four private hospitals with 149 beds in total and 39 private clinics in the city area as of August 1989. The per bed population at the public hospital is reported at 560.7 persons, below the target of 600 persons in 2006. Therefore, Phuket City is medically in a good condition and the construction of a new hospital is not expected.

Since the per bed consumption is assumed to be not remarkably larger than the present average value of 818 l/d bed in future, it will be 1.0 m^3/d bed in the year 2006.

(5) Hotel Consumption

The per room consumption was 1.3 m^3/d in 1988, which is assumed not to change in the future.

(6) Industrial Consumption

As shown in Table 3.12, an amount of 249,486 m^3/y was consumed at 14 factories in 1988 out of which some have already reportedly closed. The area along both sides of the Tha Chin river is settled as an industrial zone by DTCP, however the existing factories are mostly small and the location of water-consuming type industry is hardly considered in the future. Therefore, industrial consumption is assumed to be constant in the future.

(7) Restaurant Consumption

The restaurant consumption was 102,637 m^3/y equivalent to 5.0% of the basic consumption in 1988. Since the restaurant business is considered to grow with the development of the city, it is assumed that the rate of the restaurant consumption to the basic consumption will be constant in the future.

The future water demand is accordingly summarized in Table 3.13.

Table 3.12 Industrial Water Consumption

Name of Factory	Kind of Product	Consumption (m^3/y)	Code No.
Mr. Wirot Saelim		3,550	1-430
Mr. Leng Sae-eal		3,406	2-213
Mr. Yingyong Komolmit	Fish Canning	58,439	5-343
Plapon Industry Company	Fish Mill	8,720	5-403
Mr. Kanchan Uakanjanawilai		17,753	5-427
Mr. Damrus Jeantrakul		19,734	5-632
Mr. Wirat Tanpaan		27,114	5-639
Mr. Phachong Tansudanon		12,986	5-640
Mr. Sombun Damrongkiatkul		6,287	5-641
Mr. Suwan Polbangchong		8,231	5-650
Frozen Fish Organization	Frozen Fish Storage	45,069	5-704
Pattanachai Ship Company	Shipbuilding & Repair	12,076	5-880
Mr. Paibun Chodwaranon		23,062	5-897
Mr. Chitti Pratip Na Talang		3,059	5-1052
Total		249,486	

Source : Phuket Municipal Waterworks

Table 3.13 Future Water Demand

1. Domestic and Commercial Consumption		
(1) Basic Consumption		23,460 m^3/d
Population	78,200 pers.	
Per Capita Consumption	300 lpcd	
(2) Additional Consumption		3,494
Additional Consumption	1,275,305 m^3/y	
2. Governmental Consumption		782
Per Capita Consumption/year	10 lpcd	
3. School Consumption		360
No. of Students	30,000 pers.	
Per Student Consumption	12 lpcd	
4. Hospital Consumption		356
No. of Beds	356 beds	
Per Bed Consumption	1.0 $m^3/d/bed$	
5. Hotel Consumption		4,200
No. of Hotel Rooms	3,500 rooms	
Per Room Consumption	1.2 $m^3/d/room$	
6. Industrial Consumption		684
Industrial Consumption/year	249,486 m^3/y	
7. Restaurant Consumption		1,164
Rate of Restaurant Consumption	5% of Basic Consumption	
Total		34,500 m^3/d

3.2.4 Maximum Daily and Hourly Water Demand

As shown in Table 3.14, the peak factors or the ratio of the maximum daily consumption to the average daily consumption range between 1.09 and 1.16.

Since the past peak factors are relatively constant, a peak factor of 1.20 shall be used for the calculation of future maximum daily water demand.

$34{,}500\ m^3/d \times 1.20 = 41{,}400\ m^3/d$ in 2006

There is no data on the ratio of the maximum hourly consumption to the maximum daily consumption. A peak factor of 1.40 for the peak hourly consumption is assumed taking into account the factor of the similar cities.

$41{,}400\ m^3/d \times 1.40 = 57{,}960\ m^3/d$ in 2006

Table 3.14 Peak Factor

Item	1984	1985	1986	1987	1988
Maximum Daily (m^3/hr)	400	410	480	520	580
Average Daily (m^3/hr)	350	380	420	450	520
Peak Factor	1.14	1.09	1.14	1.16	1.12

Source: Phuket Municipal Waterworks

CHAPTER 4

EXISTING SEWERAGE SYSTEM

CHAPTER 4 : EXISTING SEWERAGE SYSTEM

4.1 Sewerage System in Study Area

4.1.1 General

Sewerage system, known as the public sanitary sewerage system, means structures and facilities for the removal and disposal of domestic and industrial waste and storm water. In the Phuket City, public storm drains contributing to surface drain and sullage or domestic wastewater drains are mostly installed along the streets.

In the newly developed area, the sullage and septage are discharged to the rivers and the sea through the storm drainage system. In the center of the town, the sullage is also drained into street gutters, however, about one-third of the volume of human waste from resident houses is leaching into the ground.

The existing storm drainage system, therefore, serves likely as combined sewage collection system, although not originally planned for such purpose. This has resulted to not only river and sea water pollution but also groundwater problems.

A part of storm drains are of insufficient flow gradient to drain such a small quantity of sullage and septage, especially during the dry season having been originally designed for large volumes. The accumulation of sewage and sludge have been obnoxious and unhealthy.

4.1.2 Existing Storm Drainage

The Phuket City has been occasionally attacked by large scale of inundation due to the following two main reasons:

- Structural defects of drainage facilities and insufficiency of drainage network in the city area.
- Insufficiency of channel capacity of the Bang Yai river

The first reason above is discussed in this Section. The second reason is discussed from the viewpoint of flood control in the overall basin (Chapter 6).

(1) Existing Drainage Condition

Most of the rainfall in the Phuket City area is drained into the Bang Yai river or its branch canals through side gutters along streets. These gutters are also utilized as the drain of domestic wastewater from kitchens and toilets. At some outlets of gutter, sluice gates are installed to prevent intrusion of river water during flood. Normally, the gates fully open.

The flow direction of drained water and location of outlets into channels or rivers are shown on the comprehensive map of drainage system prepared by the Engineering division of the City and as confirmed by field investigations by the Study Team. The result is shown in Fig. 4.1.

(2) Problems and Defects on the Existing Drainage System

1) The percentage of paved road in the city area is comparatively high and side gutters are mostly present. However, the flow capacity of the gutters seems not enough compared to the corresponding drainage area.

In addition, the flow gradient of gutters could not be enough to topographic conditions. Clogging by sand deposits or garbage can be seen at some locations which results to flooding and trouble on public traffic.

Flooding in the city was observed on September 2, 1989 by the Study Team when a relatively strong rainfall occurred. The areas inundated are shown in Annex Fig. 4.1.

The areas commonly inundated by storm water were preliminarily identified through interviews of the residents and officials in the city office, taking into account the observations on September 2, 1989. The locations identified as frequently inundated areas are also shown in Annex Fig. 4.1.

2) Since the storm drains and channels were constructed mainly to collect and convey surface water, the structures could hardly drain the sullage water due to insufficient flow gradient. This has created an increasingly unhealthy condition in the town.

3) The drainage system suffers from poor maintenance owing to city staff problems, inadequate finance and the refusal of the residents to cooperate. It is important that the gutter be free from litter to maintain the public drainage in working condition.

4.1.3 Existing Toilet System

(1) General

There are no officially published reports in relation to toilet systems in Phuket City. The toilet types seem to be classified into four (4) types as shown in Annex Fig. 4.2.

Types A and B as shown in the figure are pour-flush toilets on site permeation and are most common not only in Phuket but in whole Thailand. These are called "Cesspool" in this report. Flush toilets with cistern and septic tank or Thai standard type are used in hotels and condominiums. Even if a type of toilet with septic tank (Thai standard) is available, most residents use pour-flush toilet.

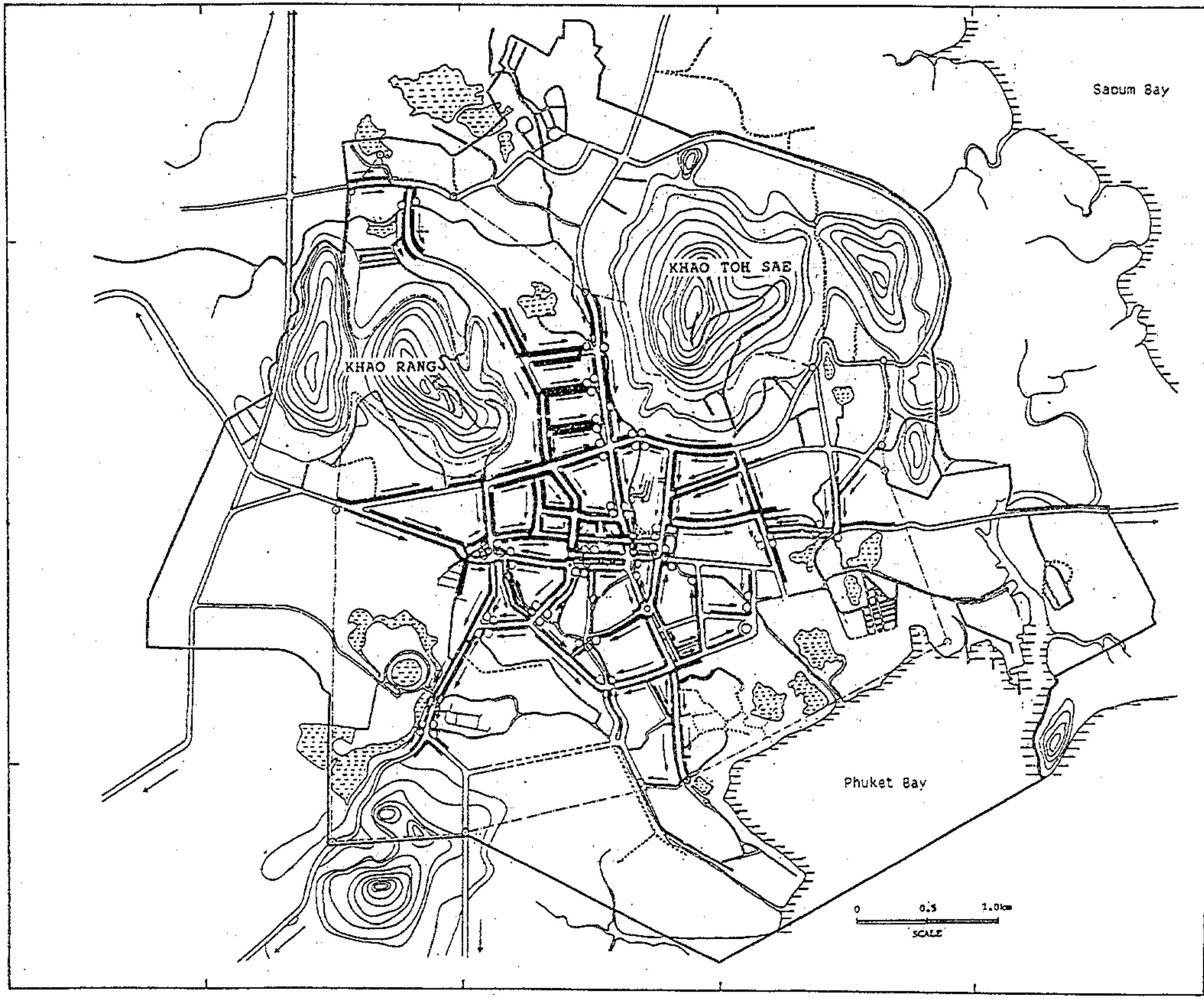


Fig. 4.1
FLOW DIRECTION AND LOCATION OF OUTFALL

(2) Domestic Toilet

In order to understand existing practices on how to dispose liq uids and/or waste water discharged from the toilet systems, an interview survey was conducted for residents by the Study Team.

The survey was carried out in three patterns. One is by way of random sampling at six zones out of ten zones in the city, where 232 residents were interviewed. Another one is for whole households in specified area by the Study Team where there are 27 houses, and the third is for the Municipal officials, gathering answers from 130 out of 250 officials. The survey areas are shown in Annex Fig. 4.3.

The result of the survey is shown in Annex Tables 4.1. and 4.2 summarized as follows:

1) No information on the type of toilet was given by approximately 10 percent of all interviewees. These houses could be assumed to be using cesspool type of toilet because there are no identified effluent drain pipes to be connected with.

2) Forty-four (44) percent of the houses of the interviewees use the pour-flush cesspool (the toilet onsite permeation) and the remainder uses septic tank or Thai standard type.

3) For Municipal officials, the percentage of houses using cesspool and septic tank (Thai standard type) are 64 and 35, respectively.

4) For random sampling in the City area, the results are 29 and 71 percent, respectively. This includes a lot of new development resident areas in the selected survey areas.

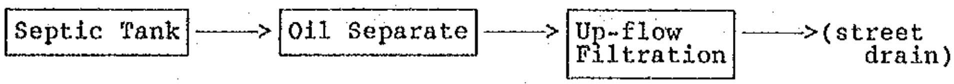
As recommended by the Phuket City, Thai standard type toilets has been used in newly constructed houses since four (4) years ago.

(3) Hotel Toilet

Large scale hotels which have more than 100 rooms have self-treatment facilities of medium-low treatment grade like aerated septic tanks. Newly constructed hotels and condominiums having more than 80 rooms are now required to have high grade treatment facility as shown below:

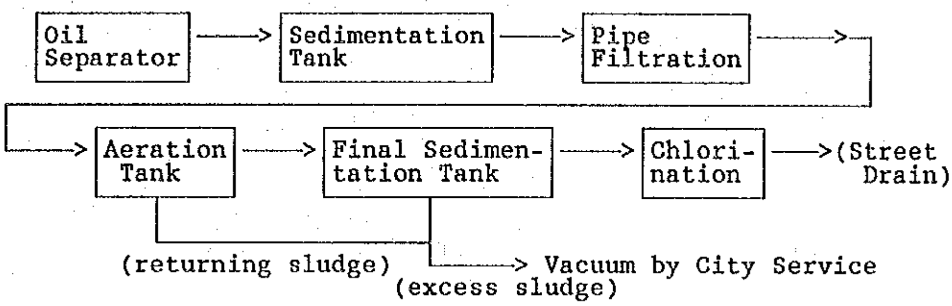
[Septic Tank] ——> [Activated Sludge Method Treatment Plant] ——>(street drain)

While hotels and other buildings having less than 80 rooms or so are free of legal obligation, they are generally instructed to accept the following process:



The following is an example of newly constructed building subjected to interview during the field survey.

- Name of hotel : Metropole Hotel
- Opening business : January 1990 (for Phase I)
- Number of rooms : Phase I, 250 rooms
- Sewage Treatment plant process



- Construction Cost : Civil portion B 2,000,000
  Equipment B 2,000,000

- Space for treatment: 8 m x 32 m x 4 m depth

(4) Sludge Disposal

Cesspools and/or septic tanks are commonly used in the study for human excrete disposal or toilet system. As mentioned, the liquid effluent from them is infiltrated into the ground on-site or discharged to the street drain. The sludge accumulated in the tanks is removed by vacuum lorries and disposed in a sludge treatment plant.

Such sludge disposal is the city obligation, not private business. At present, the city has 2 vacuum cars, one has a capacity of 10 cu.yard and the other 6 cu.yard. An additional vacuum car is proposed to be purchased.

The charge for sludge removal service is Baht 200 per visit of vacuum sludge in the city area. Additional transportation charge is collected if outside the city administration area depending on the distance.

The volume of removed sludge by the city service is recorded at 7.545 cu.m in 1988, including inside and outside of the city. The volume for domestic households and for hotels is 6.988 cu.m or 93 percent and 557 cu.m or 7 percent, respectively.

Total income and expense for the sludge disposal services are shown in Annex Tables 4.3 and 4.4, respectively.

4.2 Existing Sewage Treatment Plant in Thailand

4.2.1 Pattaya Sewage Treatment Plant

(1) General

Pattaya is a famous seaside resort in Thailand. Magnificent with beautiful scenery and not very far from Bangkok, it is very popular among tourists, local and foreigners alike.

Pattaya has contributed greatly to the tourist industry. A lot of commercial buildings and residences are being built up. This consequently results in increased volume of waste water disposed into the sea. The City is now facing the problem of seawater pollution in the area near the beach.

To cope with this problem, a sewage treatment plant with capacity of 1,500 cubic meters was originally constructed. At present, a new alternate sewage treatment plant designed and implemented by PWD is in service.

The present sewerage system in the City consists of three particular zones depending on sewage collection area. The zoning is shown in Annex Fig. 4.4.

As can be seen, Pattaya City employs two different sewage collection systems: one refers to separate sewage collection system in zone 1 and the other is combined sewage collection system in zones 2 and 3.

(2) Existing Sewerage System Situation in Zone 1

1) Service Area

Zone 1 covers an area of 650 rais (104 ha) between Pattaya 1 and 2 road starting from North Pattaya road near Orchid Lodge Hotel to South Pattaya road. This area is the center of Pattaya and probably has half the total number of bedroom in terms of hotels, bungalows and guest houses.

2) Sewer System

The sewer system of zone 1 is a separate sewage collection system. The sanitary sewage from hotels, bungalows and residences are connected through their individual septic tanks or cesspool tanks into the sewer system, while wastewater, cooking and washing drain from these buildings are drained directly into the sewers. The sewage, sanitary and wastewater are pumped for treatment before discharging into the sea. Storm drains being entirely separated storm sewers carry rainwater directly to the sea.

The sewers cover lateral drainage as branch sewers in Soi being connected with the trunk sewer along Pattaya 1 Road. Sewer diameters ranges from 200 mm to 800 mm. There are five relays and lift stations along Pattaya 1 road for elevation of water level to be transmitted to the main pumping sump well located at the point where Central Pattaya road meets Pattaya 1 road. The wastewater at the main pumping sump well is pumped up to the sewage treatment plant on Soi Kasem Suwan.

The sewerage system had two stages of construction. First, a separate sewer network was constructed by Pattaya City in 1984, discharging collected wastewater to the sea without final treatment. In 1986, PWD introduced a public sewerage system with sewage treatment plant in this area. It was observed that the plant would be located inland in Soi Kasem Suwan due to limited space near the beach.

As a result of the location of the plant, the sewer system was reluctantly changed from natural flow to pump system in order to utilize the complex existing sewer line. The history of construction progress is presented in Annex Fig. 4.5 and 4.6.

3) Situation of Sewage Treatment Plant

The existing facilities were designed on the basis of the following characteristics:

- Planned sewage flow: Max. 6,000 cu.m/day
  Min. 4,000 cu.m/day

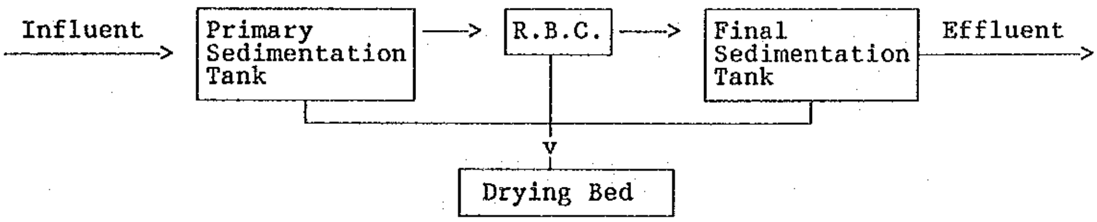
- Sewage treatment process : Rotating Biological Contractor Process (RBC)

  With this process, sewage pass through the rotating disks, organic matters are absorbed, oxidized and assimilated by the biological fixed film on the disks and corpulent film falls down from the disks.

- Water quality : Influent BOD 150 mg/l
  SS 130 mg/l

  Effluent BOD <20 mg/l
  SS <30 mg/l

- Flow composition process :



On the operation condition of the plant, no information has been collected to date by the Study Team. The following are the findings on the operation of the plant observed on July 21, 1989.

a. Suitable configuration of the treatment facilities for operational point of view

b. No weekly record taken in general on influent flow, BOD and SS of wastewater, and effluent BOD, SS of treated water

c. Inappropriate operation performance of the primary and final sedimentation tanks. No free flow of water across the overflow weir to the treated trough. (Water level of treated trough should be lower than that in sedimentation tank).

(3) Projected Sewerage System in Zone 2

1) Service Area

The projected service area of zone 2 covers approximately 750 rais (120 ha). This zone refers to the area along east side of Pattaya 2 Road from North pattaya to Central Pattaya Road. The area parallel to both side of Central Pattaya road and between Pattaya 2 and 3 road from Central Pattaya and south Pattaya road. There are mostly residences and shopping houses, restaurants as well as plazas and inns.

2) Project Sewer System

Zone 2 is planned to employ a combined sewage collection system different from zone 1 in which separate system is employed. Annex Fig. 4.6 shows the planned trunk sewer in zone 2.

During rain, wastewater flow collected into sewers becomes more in combined sewerage, resulting in overflow discharge of storm water than the design flow from sump well to the sea. The storm drainage are open cut channels with 1.5 m x 1.5 m in size, which are shown in preceding Annex Fig. 4.6.

A ratio of combined sewer overflow to the design sewerage flow is equal to twice, which means twice the design flow.

3) Sewage Treatment Plant for Zone 2

A sewage treatment plant for zone 2 is going to be extended to the existing sewage treatment plant in zone 1 with the same capacity and process. The extension project was to commence by the end of 1989 under the supervision of PWD.

(4) Projected Sewerage System in Zone 3

1) Service Area

Service area of this zone encircles approximately 500 rais (80 ha). between Pattaya 1 and Ko Phai road from South Pattaya to King Ko Phai road. Annex Fig. 4.4 shows the service area.

Original treatment plant in the South Pattaya, located at Pattaya road Soi 17 Rd. behind Pattaya Nukul School, had a capacity of 1,500 cu.m/day. With a large expansion of the area, it was estimated that there was about 3,000 cu.m of wastewater a day in 1988. The excess wastewater has been discharged directly to Pattaya Canal or to the sea. This polluted the beach particularly the area near the estuary of Pattaya canal.

2) Planned Sewer System

The construction of wastewater collection system for this area is planned to start at the same time as zone 2. The sewer system consists of:

- Reinforced concrete drain
  ϕ 0.4 - ϕ 1.0 m with total length of approximately 5,000 m

- Open channel in length of approximately 600 m

- Pumping pressure pipe

  ϕ 300 - ϕ 400 mm with total length of approximately 800 m

- Two sump wells with pumps

3) Projected Sewage Treatment Plant

The original treatment plant in the area has been scrapped and now building a new treatment plant designed by PWD. The new treatment plant has a capacity of 5,000 cu.m/day, employing the same treatment process technically as the new treatment plant in Soi Kasemsuwan.

4.2.2 Patong Sewage Treatment Plant

(1) General

Patong Sewage Treatment Plant is one of the newest and modernized plants in Thailand same as Pattaya Sewage Treatment Plant. Since it is the nearest plant to the study area, its design concept may be helpful in the study. The outline and the design criteria of the plant are described below.

The plan of Patong Sewage Treatment Plant have been emphasized and promoted, since Tourism Resources Development Study for the Phuket island conducted by TAT had been recognized as better measure for the conservation of nature in order to keep and develop the tourism resources. The PWA had been promoting the project for expansion of water supply. The discharge from domestic use was predicted to grow rapidly. Additionally since there were so many construction plans for hotels and considering the operation situation of existing septic tanks and absorption tanks as not sufficient in treated water quality, the project of sewerage system would become more important.

The project schedule of the STP is as follows:

- Year 1985 to 1986 — Study Stage
- Year 1986 (6 months) — Design Stage
- Year 1987 to 1989 (20 months) — Construction Stage
- Year 1989 (from July) — Operation

(2) Outline of Sewerage System

The sewerage treatment plant has a capacity of 2,250 cu.m/day. Financial resource was Thailand government budget, and the approximate construction cost is as follows:

Table 4.1 Construction Cost

Total Construction Cost	Baht	15,480,000.-
- Sewers (include pumping station)	Baht	5,800,000.-
- Civil work in plant (includes pipes in plant)	Baht	7,500,000.-
- Mechanical work	Baht	1,000,000.-
- Office (architectural work)	Baht	530,000.-

A separate system was selected for the Patong Beach due to the following reasons:

- Since Phuket is in the heavy rain zone, the rainfall is considerably intensive. Partial treatment of sewage mixed with rainfall is not economical.

- The town is in tourism industry area and residential population is small. That means house connection is comparatively easy. The geological condition is economical for the separate system.

- Separate system surpasses another at environmental protection.

The process of the plant was selected as oxidation ditch method. The comparison items to evaluate alternatives were as follows at that time.

- Wastewater quantity and its characteristics
- Wastewater quality
- Land price
- Maintenance cost
- Easiness in controlling
- Surrounding condition

The alternative processes compared were:

- Stabilization pond
- Rotating biological contractor
- Oxidation ditch

The evaluation of each alternatives were done accordingly as follows:

- Construction cost

- Whole project of "stabilization pond" was lowest cost when the land price was not over 460,000 baht per rai.

- First stage of "stabilization pond" cost was almost the same as "oxidation ditch" when the land price was not in excess of 250,000 baht/rai. When the land price was over this, "oxidation ditch" was the cheapest.

- Interest

- Design water quality criteria

Influent	BOD	150 mg/l
	SS	130 mg/l
Effluent	BOD	20 mg/l
	SS	30 mg/l

- Sludge Treatment: Drying bed

- Sludge disposal : Conditioner for plants (tree, flower)

As to the operation and maintenance, the plant is now operated temporarily by a private company. However, PWD is requesting the Katu Sanitary District to organize the personnel for the plant operation. The requested personnel are:

- Sanitary Engineer (Head) one person
- Scientific (Water analysis) one person
- Technical (Thai name) two persons
- Laborer five persons

The operation started just before July 1989 and the influent water quality was rather weak because the number of connection was still 50%. The quality record is as follows:

Table 4.2 Influent/Effluent Water Quality in Patong Beach STP

July-August 1989

Item	Unit	Influent	Effluent
BOD5	mg/l	64 to 75	12 to 14
COD	mg/l	214 to 270	34 to 42
SS	mg/l	45 to 52	19 to 21

4.2.3 Others

Construction of sewerage system in Thailand has been engaged in by PWD. In addition to the Pattaya and Patong sewerage treatment plants, PWD has proposed plan as shown below:

(1) Khon Kaen Sewage Treatment Plant

The plan was completed in 1989 and now operating with a capacity of 14,000 cu.m/day. Total design flow is 25,500 cu.m/day. Water quality criteria is BOD 45 mg/l and SS 60 mg/l in effluent. Per capita domestic flow rate is 140 lpcd in daily mean flow. The treatment process is stabilization pond. The reasons of the selection are:

- Lowest cost for construction and maintenance
- Available road land for plant in the city

The design was done by TISTR Australian Team, and financial re source of construction was World Bank.

(2) Nakon Rachasima Sewage Treatment Plant

The construction has been ongoing since 1987. The collection system is combined system and the reasons for the selection are as follows:

- Almost 60% of existing drain could be used as lateral sewer in combined system
- Cost effective
- House connection problem would be aided

The service area is 7,480 ha and the target year 2001. Design capacity is 32,000 cu.m/day in daily mean and water quality criteria are BOD 150 mg/l in influent, BOD 40 mg/l and SS 60 mg/l in effluent. Per capita domestic flow rate is 225 lpcd in daily mean flow. The sewage treatment process is stabilization pond. The reasons for the selection are the same as Khon Kaen. The design was done by PWD and financial resource is World Bank.

4.3 Design Criteria

Existing design criteria of PWD for sewage treatment plant are as follows, according to "Appendix 8 of Feasibility Study of Sewerage and Treatment System for Chonbuti Regional City."

(1) Stabilization Ponds

1)	BOD loading rate	:	45 kg/rai/day
2)	Depth	:	2.0 m
3)	Detention time	:	Not specified
4)	BOD removal efficiency	:	85%
5)	Chlorination	:	Baffle Type Contract time (no description)

(2) Aerated Lagoons (completely mixed)

1) Use first order kinetics, n equals pond volume

$$Le = \frac{Lo}{\left[1+\frac{kt}{n} \right]^{n}}$$

2) k = 2.5/day at 20 deg.C

3)	Detention time	: Not specified
4)	Depth	: 3.5 m
5)	BOD loading	: Use formula in (1)
6)	Aerator	: Use low speed aerators 0.21 kg-O_2/kW/hr Mixing power 6 kW/1,000 cu.m
7)	Secondary clarifier	: Surface overflow rate 16 cu.m/ sq.m/day
8)	Chlorination	: Same as stabilization ponds
9)	Efficiency	: 90%
10)	Drying Bed	: 0.025 sq.m/person

(3) Activated Sludge (Conventional)

1)	Primary clarifier	: Surface loading 35 cu.m/sq.m/day
2)	Aeration tank	: BOD 0.5 kg/cu.m/day t = 6 hrs
3)	Aerators	: Same as aerated lagoons
4)	Secondary clarifier	: Surface loading 25 cu.m/sq.m/day
5)	Chlorination	: Same as stabilization ponds
6)	Sludge stabilization tank	: Use t of 10 days to reduce sludge order problem from primary clarifier
7)	Drying beds	: Use 0.03 cu.m/person for sludge from sludge stabilization tank

(4) Oxidation Ditch (completely mixed)

1)	Aeration tank	: Use BOD loading = 0.1 t = not specified

2) Rotor : Use cage rotor
O_2 = 3 kg-O_2/m/hr
ditch volume = 12,000 gal/ft of rotor

3) Secondary clarifier : Same as aerated lagoons

4) Drying beds : Same as aerated lagoons

(5) Rotating Biological Contractor (RBC)

1) Primary clarifier : Same as activated sludge

2) Aeration tank : Use surface area from Fig.4.7 as recommended by Mr. Kenji Kaneko (*)

Sizing of RBC : Use Annex Table 4.5 recommended by Mr. Kenji Kaneko (*)

3) Secondary clarifier : Use overflow rate according to Annex Fig.4.8 as recommended by (*)

4) Sludge stabilization tank : Same as activated sludge

5) Drying bed : Same as activated sludge

(Note: * Kenji Kaneko "Technical Forum on Sewage Works and Related Technologies" Prepared by International Engineering Consultants Association (Japan), Japan Sewage Works Association, Technology Transfer Institute).

(6) Street Drain in Phuket Town

According to the Engineering Division of the Phuket City, street drains are designed as follows:

1) Velocity : Not checked

2) Slope : Basically not less than 1:200 when inevitable, not less than 1:500

(Some places were designed in 1:500)

3) Width : Not less than 0.40 m

4) Depth : Not less than 0.50 m

5) Traction force : Not checked

6) Outlet to Khlong : River water level is not considered

7) Consideration to wastewater: Not considered

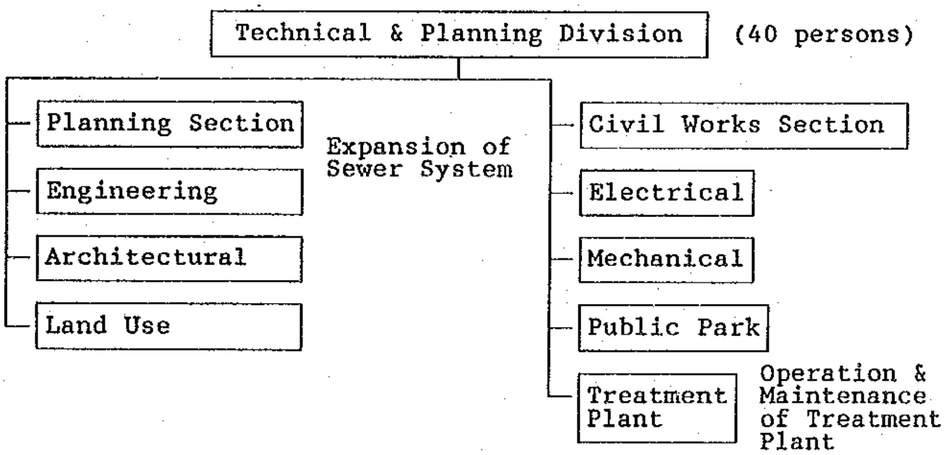
8) Interval length of manhole where drain is covered : If less than 800 L = 8.0 m
: If more than 800 L = 10.0 m

4.4 Organization and Management

(1) Pattaya Sewerage System

According to the master plan for the Pattaya Sewerage System, there are two (2) treatment districts: (1) Soi Kasemsuwan and (2) Soi Pattaya. The construction period is divided into two phases, Phase I (1985-1988) is the Soi Kasemsuwan Sewage Treatment Plant with a treatment capacity of 4,000 cu.m/d and is now in operation and which is scheduled to be expanded to 8,000 cu.m/d in Phase II (1989) with the Soi Pattaya Sewage Treatment Plant with a treatment capacity of 5,000 cu.m/d. Those expansion/construction works has not commenced due to budgetary constraints.

In the organization of the City of Pattaya, the technical and planning division is responsible for implementation of sewage works as shown below. The sewage charge collection is undertaken by the financial division.



(not yet promoted to sub-section)

The permanent staff, namely one engineer for repair of equipment and one scientist for water quality analysis are stationed at the Soi Kasemsuwan Treatment Plant. Ten temporary workers are also employed. The electrical and mechanical engineers in the other sub-section may help the plant work.

The sewage flow is measured with the V-notch at the outlet of the chlorination chamber. The plant is operated in the range of 3,000 to 3,800 cu.m/d by by-passing some flow to keep the treatment efficiency.

July 19	3,623 cu.m/d	
20	3,143	
21	3,216	With by-passing
22	3,083	"
23	3,548	"
24	3,272	"
25	3,575	

The incoming sewage flow fluctuates heavily due to direct pumping to the plant with no equalization tank. The treatment efficiency is apt to drop in the morning, in the weekend and during the tourism season from November to March.

The water quality analysis of influent and effluent is conducted daily. The analytical parameters include BOD, COD, pH, SS, dissolved solid, residual chlorine, etc., but not T-N and T-P. The analysis is now suspended due to the expansion work of the laboratory and analytical instrument trouble. The BOD values were reportedly 100 to 150 mg/l in influent and less than 20 mg/l in effluent before the suspension of analysis.

There are now 40 connections which cover almost hotels in the treatment district in Phase I. According to the plant staff, the problem is in the high sewage charge. One hotel with 477 rooms hesitated to connect its pipe to a sewer system due to the annual payment of an amount of 2 million Baht. The sewage charge system was reviewed at the committee composed by PWD, Chulalongkorn University, NEB and TISTR and approved by the City Council. The annual budget for sewage works is 2 million Baht.

Table 4.3 Estimation of Expenditure

Power for a Sewage Treatment Plant	0.186 B/cu.m
Power for Pump Stations	0.217
Personnel	0.195
Maintenance (2% of Construction Cost)	0.377
Sub-total	0.975
Depreciation for Equipment (10% of Equipment Cost)	0.685
Depreciation for Structures (3.3% of Construction Cost)	0.396
Sub-total	1.081
Total	2.056

(2) Patong Sewerage System

The Patong Sewerage System is composed of sewers, a pump station, and a sewage treatment plant, which was constructed by PWD with the government budget and has been in operation since July 1989.

The Patong Sanitation Office is divided into three sections under the control of the Sanitation Board: (1) police, (2) engineering and (3) public health. There are four personnel in the public health section responsible for sewage works. This section is responsible not only for sewage works but also for other public health matters, therefore, no one exclusively works for sewage works in the office. Two laborers are also employed for operation and maintenance of the sewage treatment plant. The Chief of the Patong Sanitation Office considers the three staff, namely, one engineer, one electrician and one administrative staff as necessary for implementation of sewage works and will request DOLA to dispatch at least one of them at government expenditure.

The office expects that the expenditures for operation and maintenance will be 1.0 million Baht in 1989 and 1990, respectively, while the income from the sewage charge was estimated at 0.5 million Baht in 1989. The people consider the sewage charge as one of many duties imposed on them and doubt the necessity to pay since they consider that they have no obligation to pay for public service.

At present, 100 hotels/houses are connected to the sewerage sys tem, but 30% out of them did not follow the guidelines for house connection works to install the house inlet for solid removal, and the grease trap in the connection line to sewers. The neglect of these guidelines brings the sewer cleaning works once in every three months.

The sewage charge is defined as follows:

Sewage Charge System

Category	Connection Fee	Sewage Fee
1. Residential House Commercial House	100 B/house	400 B/house/year
2. Residential House with not more than three floors	100 B/house	400 B/house/year
3. Residential House with more than three floors	200 B/house	500 B/house/year
4. Restaurant/Food Shop	10 B/sq.m	40 B/sq.m/year
5. Hotels	50 B/room	600 B/room/year

Remarks: When the hotel with its own private sewerage system discharges effluent to a public sewerage system, both fees are reduced by 20%.

Estimation of Expenditure and Income

1. Expenditure

1.1	Power	0.40 B/m sewage
1.2	Chemical	0.44
1.3	Wage	0.16
	Total	1.00

Daily Sewage Flow 2,250 m/day

Daily Expenditure 2,250 x 1.00 = 2,250 B/day

2. Income (In Service Area I)

2.1	Hotel/Bungalow	2,068 rooms
2.2	Residential/Commercial	300 houses

Annual Income from Hotel/Bungalow 2,068 x 600
= 1,240,800 B/yr

Annual Income from Residential/Commercial 300 x 400
= 120,000

Total = 1,360,800

Daily Income = 3,728 B/day

3. Profit

Daily Profit	3,728 - 2,250	= 1,478 B/day
Annual Profit	1,478 x 365	= 539,470 B/yr.

According to the above estimation, the office intends to cover the expenditures for operation and maintenance with the income from the sewage charge, but worries whether they can fully collect the sewage charge as expected.

CHAPTER 5

WATER QUALITY ANALYSIS

CHAPTER 5 : WATER QUALITY ANALYSIS

5.1 Water Pollution Control Standard

The standards on the regulation for water pollution control in Thailand are divided into two categories, effluent standard in which the limiting values of parameters defining the effluent quality are set, and receiving water quality criteria in which the limiting value of parameters defining the receiving water quality are set.

The domestic effluent standards as shown in Annex Table 5.1 are applied to all houses which have the legal obligation to install septic tanks.

The surface water quality standards as shown in Annex Table 5.2 is at present applied only to the lower stream of the Chao Phraya river.

The coastal water quality standards as shown in Annex Table 5.3 is applied only to the Karon Bay, Phuket for swimming and coral reef conservation.

Therefore, there are no standards applicable to water bodies in the Phuket City except for effluent standards. RCDP supposes Class 3 as the target and Class 4 as the minimum in the Bang Yai river or in the coastal water of the Phuket Bay in the report on "Pre-Feasibility Study for Regional Cities Development Project II" (October 1988).

5.2 Water Quality of River and Drainage

5.2.1 Backflow of Sea Water

The extent of the backflow of sea water into the rivers and drainage channels in the study area was investigated by analyzing water samples from various stations.

(1) Stations for Investigation

Stations where samples were taken for investigation are shown in Fig. 5.1.

- Bang Yai River .... Sts. 1-5
- Street Drains .... Sts. 6-8
- Suen Suk River .... Sts. 9-11
- Tributary of the Tha Chin River .... St. 12
- Sea Water .... St. 13

(2) Date and Time of Sampling

August 19, 1989 at the high tide and the low tide
.... Sts. 1-8

August 24, 1989 at the high tide
.... Sts. 9-13

(3) Method of Sampling

Samples were taken at 15 - 20 cm above the river bed. At the stations where the depth of water was not deep enough (i.e. Sts. 6 and 7), surface water was taken.

(4) Items and Results of Analysis

The items and results of the analysis are shown in Annex Table 5.4.

(5) Discussion

As obviously shown by the analytical figures of electric conductivity and Cl concentration in Annex Table 5.4, the water at St. 5 (near the Poonpol Bridge) in the Bang Yai river was influenced by sea water. At St. 5, difference between the water levels at the high tide and low tide was evidently observed, which also suggests the backflow of sea water. On the other hand, water at Sts. 1-4 seemed not influenced by sea water since difference between the water levels at the high tide and low tide was not observed, which is substantiated by the results of the analysis.

As to the street drains (Sts. 6-8), the backflow of sea water is not found from the results of the analysis as well as from the change in the water level between the tides.

As to the Suen Suk river (Sts. 10-11) and the tributary of the Tha Chin river (St. 12), sea water is probable on the basis of the data of Sts. 1-8, although data on the water levels were not available. There was only single sampling.

(6) Conclusion

1) As to the Bang Yai river, the backflow of sea water was extended up to near the Poonpol Bridge (St. 5), influencing quality of water. However, no influence of sea water was observed at St. 4 and upstream.

2) As to the street drains (Sts. 6-8), influence of sea water was not recognized.

3) As to the Suen Suk river (Sts. 9-11), no influence of sea water was recognized at St. 9, but influence is probable downstream of St. 10.

4) As to the tributary of the Tha Chin river (St. 12), the backflow of sea water is probable.

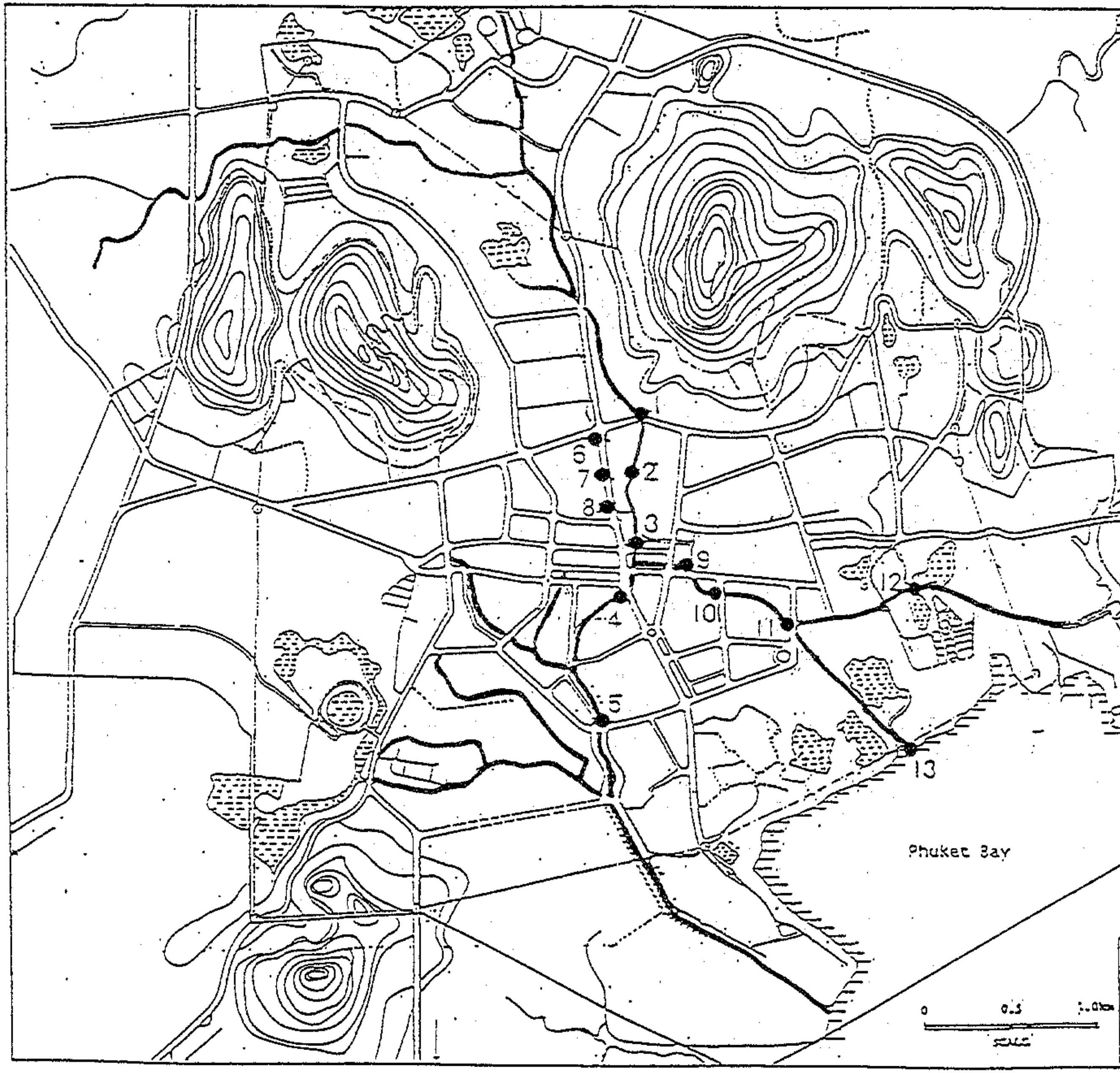


Fig. 5. 1

LOCATION OF STATION

5.2.2 Water Quality of River and Drainage

Water quality of the Bang Yai river and its tributaries and drainage channels were investigated.

(1) Stations for Investigation

Stations where samples were taken for investigation are shown in Fig. 5.2.

1)	Bang Yai river	Sts. R-1, 2, 3 and 4
2)	Street drains	Sts. B-1, 2, 3 (upstream of the pump station) and 5
3)	Suen Suk river	St. B-4
4)	Drainage channel	St. D-1, 2 and 3
5)	Septic tank effluent	St. C-1 (Pearl Hotel)
6)	Cesspool effluent	St. C-2 (Nimit Market)

(2) Date and Time of Sampling

Date and time when samples were taken for investigation are shown in Annex Tables 5.5 to 5.7. All samples were collected during low tide.

(3) Sampling Method

The middle layer of water was taken.

(4) Items and Results of Analysis

Analytical items and results are shown in Annex Tables 5.5 to 5.7.

(5) Discussion

The results of water quality analysis on the rivers and drainages are systematically summarized in Fig. 5.3.

The figure indicates that there was significant difference between water quality of the Bang Yai river examined during rainy and dry seasons. BOD, COD, SS, T-P and T-N values of the Bang Yai river are discussed in this section.

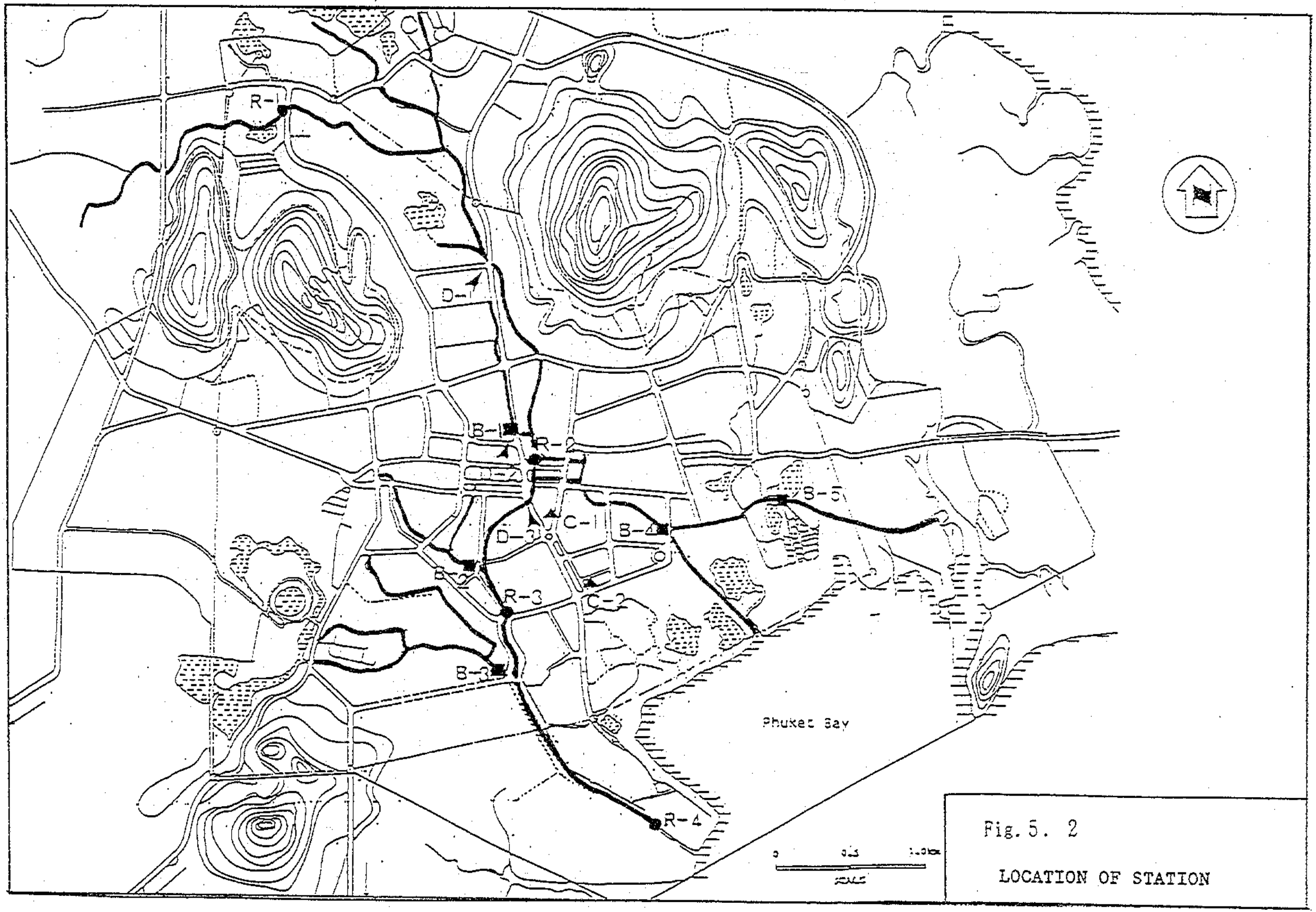
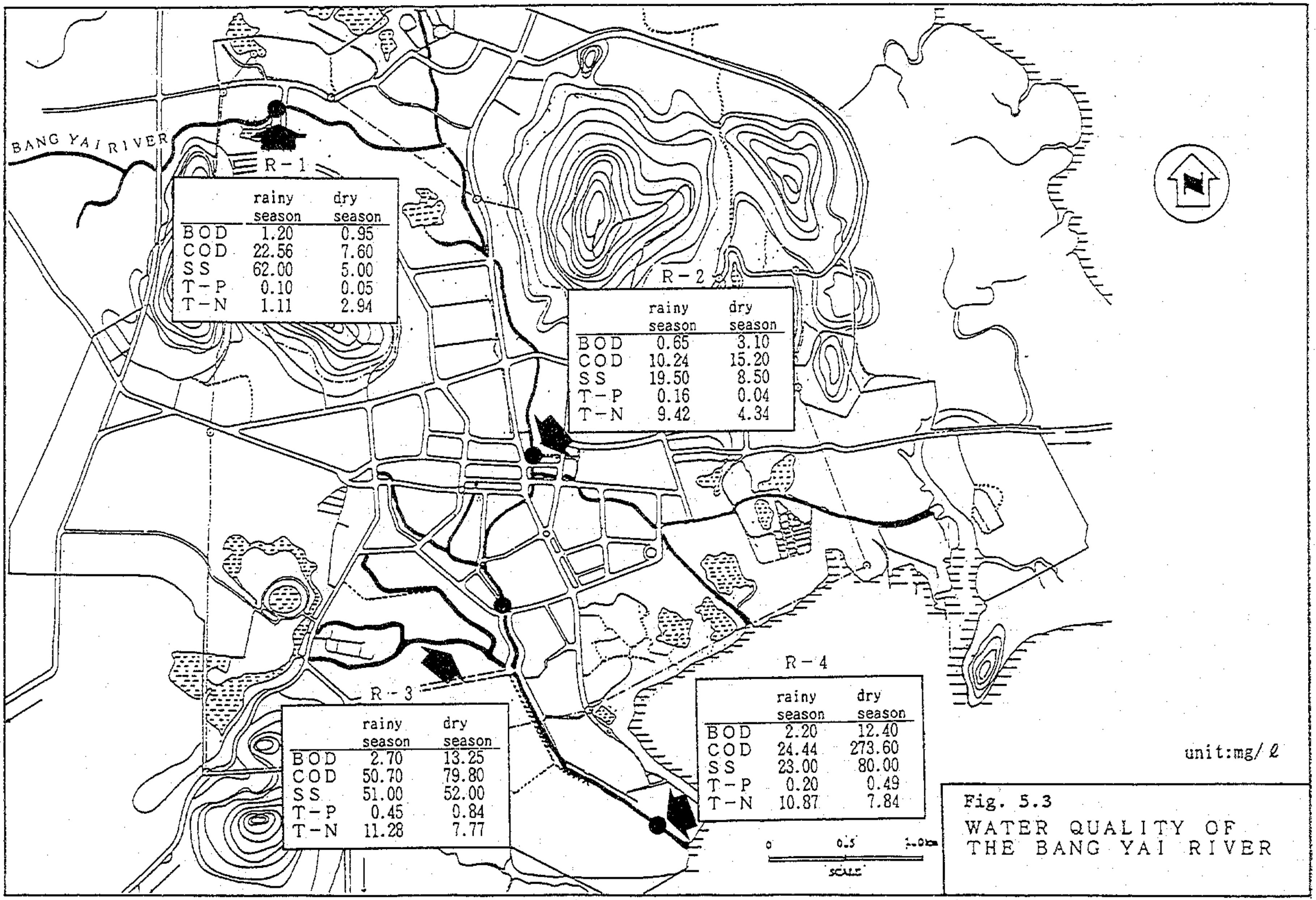


Fig. 5. 2

LOCATION OF STATION



R－1

	rainy season	dry season
BOD	1.20	0.95
COD	22.56	7.60
SS	62.00	5.00
T－P	0.10	0.05
T－N	1.11	2.94

R－2

	rainy season	dry season
BOD	0.65	3.10
COD	10.24	15.20
SS	19.50	8.50
T－P	0.16	0.04
T－N	9.42	4.34

R－3

	rainy season	dry season
BOD	2.70	13.25
COD	50.70	79.80
SS	51.00	52.00
T－P	0.45	0.84
T－N	11.28	7.77

R－4

	rainy season	dry season
BOD	2.20	12.40
COD	24.44	273.60
SS	23.00	80.00
T－P	0.20	0.49
T－N	10.87	7.84

Fig. 5.3
WATER QUALITY OF THE BANG YAI RIVER

1) BOD:

BOD values at St. R-1 were equal during rainy and dry seasons, probably due to no or little inflow of domestic sewage and wastewater into the upper stream than St. R-1. BOD values at St. R-2, R-3 and R-4 during dry season were 5 to 6 times as high as that during rainy season. In these areas, storm water is considered to dilute the river during rainy season resulting in the reduction of BOD value. BOD values measured at several points suggest that the Bang Yai river is more polluted at the downtown and slightly renewed near the estuary (St. R-4) owing to exchanging water for sea water. The reason why BOD value at St. R-1 is higher than that at St. R-2 during rainy season remains unknown.

2) COD:

In general, COD value and BOD value were higher in the lower stream both during rainy and dry seasons. However, COD value at St. R-1 was higher than that at St. R-2 during rainy season, which is unexplainable for the present. These results indicate that the lower stream is more polluted. Since construction waste water and sea water are flowing in near St. R-4, it is possible that Ca and Mg in construction waste water and Cl^- in sea water artificially brought the unexpected high COD value at St. R-4.

3) SS:

SS value at St. R-1 and St. R-2 was higher during rainy season than during dry season, which is probably ascribed to the dilution of the river water by storm water. Data during dry season shows that SS value was also higher in the lower stream.

4) T-P, T-N:

T-P and T-N values changed from the upper stream to the lower stream in the same way as BOD and COD values did, both during rainy and dry seasons. That T-P values at St. R-1 and R-2 were higher during rainy season than during dry season may be attributed to the effect of phosphate in SS.

It can be seen from the above analysis and study that the Bang Yai river is mostly polluted at the section between St. R-2 and R-3, being the downtown of the city and water quality near the estuary is slightly renewed by an exchange with sea water.

Water quality of the Suen Suk river and the street drains (from St. B-1 to St. B-5) was worse during dry season than during rainy season, as the Bang Yai river was so. Those probably happened as a result of dilution of the river water by storm water.

Near St. B-1 where water quality was bad during dry season, BOD is 50 mg/l, water was staying and rotten, because only small volume of domestic sewage and waste water were flowing into the river, and the spot was affected by the backflow of sea water.

Water near St. B-4, whose quality was also bad, is pushed back toward the upper direction at high tide and pulled down toward the lower direction at low tide, resulting to water staying there without flowing away and gradually becoming rotten.

Drainage channel (from St. D-1 to St. D-3) is running through the heart of a crowded city unlike other street drains and rivers and has comparatively high BOD and COD values. This can be explained by the inflow of domestic sewage and waste water. This hypothesis is also supported by data on the bacteria examination of water samples as shown in Annex Table 5.6. In addition, many hotels and houses are now under construction in the city area, followed by huge volume of construction waste water discharged from the construction spots into the river. Such construction waste water has high pH because it contains components of concrete. Therefore, its influx into the river makes pH of water more alkaline and COD value higher. Pollution of the river with inorganic compounds in construction waste water is assumed to proceed furthermore with the advancement of more and more construction.

5.2.3 Investigation on BOD of Drainage Channel

Three spots within the study area were chosen and their BOD values were examined to confirm the water quality of common domestic sewage.

(1) Stations for Investigation

Stations where samples were taken for investigation are shown in Fig. 5.4. These stations are existing in the area without institutions discharging huge volume of waste water.

(2) Date and Time of Sampling

Date and time when samples were taken for investigation are shown in Table 5.1.

(3) Sampling Method

The middle layer of water was taken.

(4) Items and Results of Analysis

Analyzed items and its results are presented in Table 5.1.

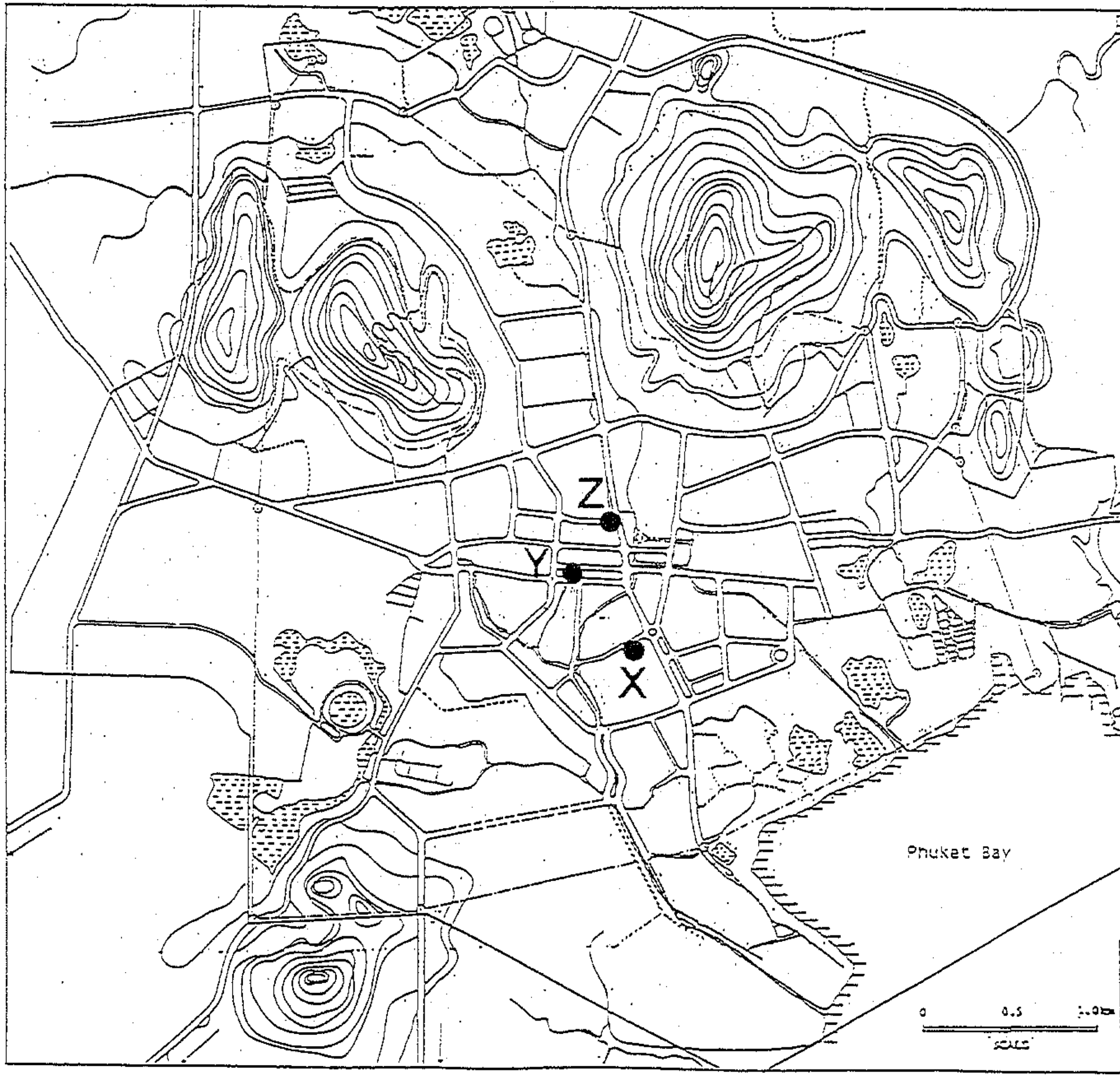


Fig. 5. 4

LOCATION OF STATION

Table 5.1 Result of BOD Analysis

Station	Date	Time	pH	BOD (mg/L)	EC (S/cm)	SS(by HACH) (mg/L)
X	01/27/'90	9:38	7.6	> 100	720	62
X	01/27/'90	12:32	7.6	> 100	960	96
X	02/02/'90	9:43	7.2	> 58.0	477	162
X	02/02/'90	12:35	6.9	> 100	662	138
Y	01/27/'90	9:50	7.3	> 100	835	91
Y	01/27/'90	12:40	7.4	> 100	980	80
Y	02/02/'90	9:50	7.3	> 88.5	739	64
Y	02/02/'90	12:45	7.0	> 100	712	93
Z	01/25/'90	10:35	7.0	> 150.0*	470	90
Z	01/27/'90	10:00	7.2	> 100	614	91
Z	02/02/'90	10:00	7.2	> 96.5	538	74

pH, EC, SS : Analyzed by Japan Study Team
BOD : Analyzed by Marine Biological Center
*) Analyzed by Songkla University

(5) Discussion

Samples were taken after breakfast time and lunch time, when the dirtiest water probably appeared to flow. Additionally, samples were taken again at the same time a week later. At St. Z, samples were taken three times at the same time on different days. As a result, BOD value was approximately more than 100 mg/l as shown in Table 5.1. It is difficult to discuss the significance, for the accurate results of BOD analysis could not be taken from the Marine Biological Research Center in Phuket to whom the analysis were entrusted. The center reported to the Study Team the results as only "more than 100 mg/l" in case of the values were over 100 mg/l, and the accurate value is unknown. However, the following can be concluded.

1) The highest BOD value of samples which were taken at each station was more than 100 mg/l.

2) There was little day-to-day variation in BOD value of samples taken around 12:30 at each station.

3) BOD values of samples taken after breakfast time were lower than those taken after lunch time at St. X and St. Y. At St. Z, samples were taken only at one time in a day and thus intra-day variation of their BOD values is unknown.

After all, water samples taken around 12:30 at St. X and St. Y and taken around 10:00 at St. Z had BOD values of more than 100 mg/l. In other words, water flowing through drainage channels within the study area has BOD value of more than 100 mg/l around 12:30, if not affected by discharge of wastewater from hotels and schools.

The published reports regarding water quality of the Bang Yai river and sea water are summarized in Annex Figs. 5.1 and 5.2.

5.3 Industrial Wastewater

The report "Project of the Pollution Solution Planning in the Main Town" prepared by NEB in 1987 is quoted in this discussion.

Analytical data on industrial wastewater in the Phuket City are indicated in Annex Tables 5.8 and 5.9. The location of factories are shown in Annex Fig. 5.3.

As can be seen from Annex Table 5.9, very high values of BOD, which is one of the most important index of water pollution, were observed in wastewater from the freezing and storage, canning, slaughter house, Chinese noodle, canned goods, and feed product (fine fish) factories. They discharged heavily polluted wastewater so that the BOD values amounted over 3,000 mg/l. Most of them except the Chinese noodle factory, gather in an industrial complex near the coast, or southeast of the Phuket City.

In contrast, a rubber factory seemed to be the main cause of pollution within the study area. The work procedure carried out by this rubber factory is shown below.

Rubber Factory

Plantation (Rubber Sheets) ——> Washing (By Water) ——> Smoked ——> Cut ——> Compress ——> Factory

Washing ——> Waste Water

This rubber factory discharges only the waste water used for washing rubber sheets and such waste water is considered not to contain any components causing pollution. pH of the waste water was approximately 7.3. The above results indicate that no factories discharging waste water capable of polluting the river are existing within the study area.

CHAPTER 6

DRAINAGE AND FLOODING CONDITION

CHAPTER 6 : DRAINAGE AND FLOODING CONDITION

6.1 Flooding Condition

6.1.1 Overview of Flooding Condition

The channel capacity of the Bang Yai river is very small considering intensive rainfall characteristics and topographic features which cause a sharp increase in flood discharge within a very short time.

The Bang Yai basin has an average annual rainfall of 2,500 mm with the heaviest falls between May to October. Monsoon dominated storm rainfall intensity is relatively high. Such heavy rainfall during the wet season causes large-scale flooding in Phuket city.

The downstream reaches of Bang Yai river are affected by tidal movement approximately up to the intake of the Saen Suk canal. Consequently the drainage efficiency of street drain is adversely affected by the tidal backwater.

Furthermore, structural defects at some bridges and poor road alignment cause frequent local inundation downtown. The shortage of sectional area at road bridges aggravate proper channel hydraulics for drainage.

The main reasons for flooding in Bang Yai river are therefore insufficiency and defects in the drainage facility and capacity of the river.

6.1.2 Past Major Floods

Although hydrological information on past floods such as flood discharge and water level, even damage data is not available, it is currently acknowledged that the flooding which occurred in 1986 was the worst case within the last two decades. The inundated area was very large and covered most of the Municipal area. Based on interview surveys, some areas were inundated for up to three days during this flood.

The Study Team collected a comprehensive set of photographs taken on Sep. 27, 1986 during this flood from the Municipality office. Further, photographs of flooding in Phuket city on Oct. 15, 1975 and Aug. 15, 1983 are also available.

The photographs of flooding in 1986 indicate a maximum inundated depth of the order of 0.8 - 1.0 m and considerable high velocity flow along the streets downtown. A detailed hydrological analysis and flood damage study are given in Chapters 11 and 12.

6.1.3 Flood Damage Survey

An interview survey was conducted to grasp the situation of inundation in the study area. The surveyed areas were selected among those frequently inundated on the basis of the information furnished by officials of the Municipality. Demarcation of the survey area for flood damage estimation was made to correspond with land tax area divisions prepared by the Municipality office. The specification of survey is summarized below:

Period	: from Aug.17 - Aug.24, 1989
No. of samples	: 215
Major survey items	: - Frequency of inundation
	- Inundation depth and duration
	- Rainfall duration
	- Value of houses
	- Value of household effects
	- Wage loss
	- Assets of factories and shops
Method of survey	: Home visiting interview

Answer in respective interview sheet are tabulated in Annex Table 6.1. The frequency of answers of questionnaires on inundation depth and inundation duration is summarized in Tables 6.1 and 6.2.

According to the Tables, most of interviewees replied up to 1.0 m for inundation depth (80%) and up 3 days for inundation duration (75%). Flood damage by the flood in September 1986 is estimated in Chapter 12.

Through the interview survey, the reactions of inhabitants indicate a strong requirement for measures to overcome the flooding problem.

6.1.4 Flood in August 1989

Intensive heavy rain was observed from Aug. 24 to 25, 1989 in Phuket city. The total rainfall was 100 mm over two days with the heaviest intensity 25 mm recorded from 3:00 a.m. to 4:00 a.m. on Aug. 25 at the station of Meteorological Dept. in Phuket city. The Study Team carried out inspection of flow conditions in the Bang Yai river as well as in street drains downtown. Although no overtopping of flow was observed along the Bang Yai river, the area with defective street drains downtown was identified. Discharge measurement was also made at the Taonpradit Bridge and the entrance of the Saen Suk canal. The bridge is located 55 m upstream from the branch point of the Saen Suk canal. The measured result is summarized as follows:

- Taonpradit Br. (upstream side) of Thalang road

Time	: 12:00 - 13:00, Aug 25
Method	: By current meter
Discharge	: 17 m^3/sec (Bang Yai river)
Ave. velocity	: 1.5 m/sec
Max. water depth	: 1.6 m
Weather	: Occasionally raining

Table 6.1 Frequency of Inundation Depth (Answer of interview survey)

Unit : No.

Area code	0.00 - 0.50 m	0.51 - 1.00 m	1.01 - 2.00 m	2.01 - 3.00 m	Others	Total
01	9	4	1	-	3	17
02	15	8	5	1	1	30
03	11	-	1	-	-	12
04	6	12	3	1	1	23
05	22	16	3	1	1	43
06	15	5	2	-	2	24
07	2	-	1	-	-	3
08	7	3	2	1	4	17
09	20	8	1	-	7	36
10	7	3	-	-	-	10
Total	114 53%	59 27%	19 9%	4 2%	19 9%	215

Table 6.2 Frequency of Inundation Duration (Answer of interview survey)

Unit : No.

Area code	Less 1.0 day	1.1 - 3.0 days	3.1 - 7.0 days	Others	Total
01	3	8	4	2	17
02	6	19	4	1	30
03	3	5	2	2	12
04	2	19	1	1	23
05	12	12	17	2	43
06	19	3	1	1	24
07	1	1	1	-	3
08	3	11	1	2	17
09	19	10	1	6	36
10	4	2	1	3	10
Total	72 33%	90 42%	33 15%	20 9%	215

- Saen Suk canal (rectangular section)

Time	:	11:00 - 11:30, Aug 25
Method	:	Float measurement
Discharge	:	2.6 m^3/sec
Ave. velocity	:	1.4 m/sec
Max. water depth	:	0.45 m

When the measurement was done,the water level had descended about 5 cm from the peak level judging from the water mark on the wall. At this stage, the water level had reached to within 20 cm of the concrete bridge girders and about 80 cm from the bankfull.

By contrast, the water surface had covered the girder about 5 cm at the neighboring downstream bridge along Phang Nga Rd. A lot of floating matter, such as garbage, weeds, wood, other domestic disposals were being stopped by this bridge.

The hydrograph of this flood is estimated based on the rainfall record at the Phuket city and Bang Wad dam in Section 11.2.

6.2 Existing Channel Improvement and Flood Control Measures

6.2.1 A Floodway Project

A floodway construction project managed by the Mineral Resources Department (DMR) with the aim of diverting the water of Bang Yai river from Sam Kong village to the Sapam bay is on going. However, the project encountered technical and financial problems in the course of construction works and progress is behind schedule.

This project started in 1977 at the request of the Phuket Municipality which had been suffering from repeated flooding of the Bang Yai river. For the background and principal features of the project, a brief note and a drawing which shows a plan of the channel route and longitudinal profile prepared by DMR is available. This information can be summarized as follows:

(1) Objective

Before starting construction, waste water from tin mines situated between national highway No. 402 and the Provincial road (bypass) had been discharging southward into the Bang Yai river together with storm water from the hilly area on the western side. It would appear that muddy flow from these tin mines could have caused reduction of channel capacity in the downstream reaches of the Bang Yai river. In order to protect Phuket city against flooding, diversion of water in the catchment should have been implemented urgently.

(2) Project feature

The project scheme as originally contemplated in March 1974 was as follows:

- Channel length : 7.0 km
- Excavation volume : 1.1 million m^3
- Channel section : 5 m (w) x 2 m (h)
- Construction cost : ฿ 9.0 million

After the construction works had been commenced, DMR reviewed the original plan together with two other alternative routes by request of the Municipality, the three schemes including the original route were as follows:

No. 1 : from Sam Kong vil. to Sapam vil.
(north diversion plan)
No. 2 : from Sam Kong vil. to Ku Ku vil.
(east diversion plan)
No. 3 : from Sam Kong vil. to Phuket bay
(south diversion plan)

The principal figures of these schemes were as follows:

Table 6.3 Principle Figures of Three Schemes

No.	Length (km)	Earth works Excav. (m3)	Earth works Embank. (m3)	Max. height Excav. (m)	Max. height Embank. (m)	Slope
1	5.7	1,186,000	51,000	20.2	4.0	0.0010
2	2.9	781,000	-	20.0	-	0.0017
3	5.3	190,000	277,000	24.8	5.0	0.0020

As the land for route No.1 had been donated, route No.1 was proceeded with as planned originally.

(3) Chronological excavated volume

The volume of earth excavation and relevant expenditure was approximately as follows:

Table 6.4 Volume of Earth Excavation

Year	Excavated volume (m^3)	Expenditure (฿ million)
1977	50,000	0.4
1978	50,000	0.4
1979	100,000	1.6
1980	100,000	1.6
1981	76,120	1.5
1982	80,000	1.6
1983	80,000	1.6
1984	80,000	1.6
1985	80,000	1.6
1986	80,000	1.6
Total	776,120	13.5

Up to now approximately 4.0 km has been excavated. Although no detailed information is available, RCDP provides the following figures as of 1988.

- Total volume of excavation : 956,120 m^3
- Total cost : ฿ 17.0 million

(4) Problems

Serious erosion and sliding of excavated slopes has occurred during construction due to the loose soil characteristics. To overcome this problem, more gentle side slopes and berms in the channel section have been provided. The great increase in earth work volume has exhausted DMR's budget for the project.

According to the drawing prepared by DMR, the length of channel remaining to be excavated is still 2.2 km and bed of the channel should be deepened approximately 8.5 m from present level on average to connect with the Bang Yai river at the proposed site.

(5) Present status

The present cross section of canal has 3 to 4 m of bed width with a flow capacity of approximately 20 m^3/sec and a slope of 0.1%. Some portions of the side slopes have been eroded or slipped due to storm water. In order to stabilize the channel shape, revetments, with stone masonry or sodding will be required.

The drainage of storm water from about 1.5 km^2 of the catchment area to outside of Bang Yai river catchment has been made possible by the current excavation works.

According to an official in DMR Phuket office, DMR does not intend to continue excavation work on the remaining portion of the channel but they will maintain the stretches already constructed.

6.2.2 Dredging and Revetment Works

The catchment of the Bang Yai river has been extensively stripped by tin mine operations in the past. The alluvial soil from these areas causes a high sediment load in the river and is deposited in the downstream reaches due to the decrease in flow velocity. The deposited area of sediment extends significantly from the river mouth into the Phuket bay. It seems that the Phuket bay has been gradually made shallow by the alluvial deposits and it is now difficult to transport it further offshore. This may cause river bed rising of the Bang Yai river. Dredging of the channel bed by the Municipality is currently carried out to maintain the channel section.

Revetment works with concrete or wet masonry are being carried out every year by the Municipality. This revetment has been provided to a large extent along the downstream reaches of Bang Yai parallel to the Thepkrasattri Road. By mean of the provision, hydraulic advantage can be expected in terms of less roughness of the channel.

For most of the course of the Saen Suk canal, revetment has al ready been provided with RC columns and panels. As well as functioning to release part of the discharge of the Bang Yai river, this canal can receive storm water in most of the downtown area to protect against flooding.

The Taling Chan canal joins the river about 500 m downstream from its junction with Saen Suk, on the right hand side. This canal was constructed to drain storm water from Mt. Rang and the western area downtown. Continuous RC wall are suspended by beams at intervals of 3-5 m form the canal from just upstream of the pumping station to the upstream end near Ranong road.

6.2.3 Levee Construction

After the flood in 1986, the Municipality constructed a levee about 800 m and 1.5 - 2.0 m high along the right bank of Bang Yai river before it changes the course towards south. There is another smaller levee about 200 m and less 1.0 m high along a tributary joining just upstream of Thepkrasattri bridge.

Annex Fig. 6.1 shows the location of existing drainage facilities and channel structures.

CHAPTER 7

STUDY OF FUNDAMENTAL PLANNING CONDITIONS FOR SEWERAGE

CHAPTER 7 : STUDY OF FUNDAMENTAL PLANNING CONDITIONS FOR SEWERAGE

7.1 Fundamentals for Sewerage Planning

7.1.1 Target Year

The target year for the sewerage improvement project is 2006 (B.E.2549) or 17 years from 1989.

It suits with the following rationale.

(i) Typical planning periods for long-term sewerage projects in Japan are 15 to 20 years.

(ii) The town plan of Phuket currently prepared by DTCP will present a future land use plan for 2008, which can be a base for the study.

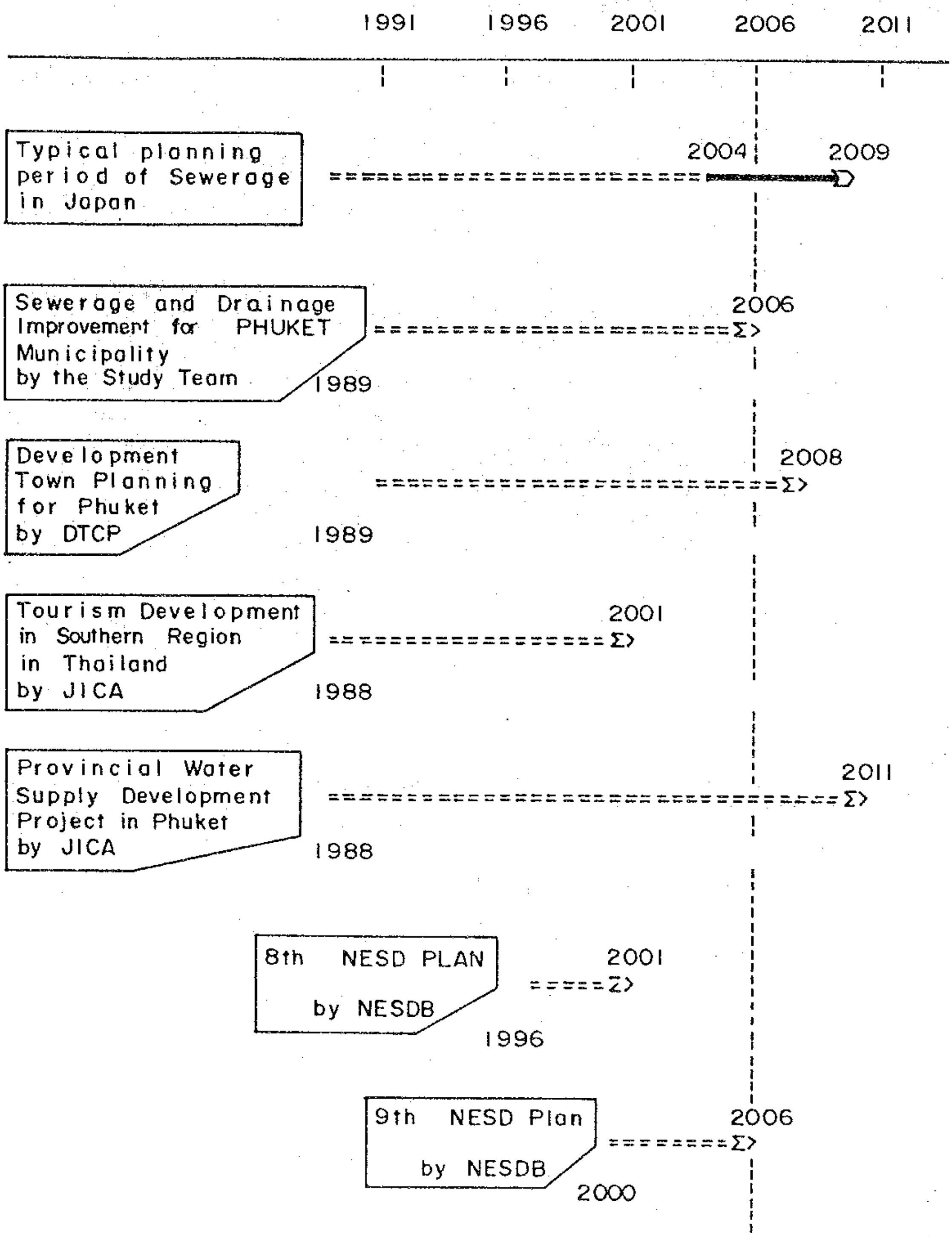
(iii) Quite a few plans relevant to the study set target years in the Christian Era with 1 or 6 as the last figure, such as 2001 of the Study on Potential Tourism Area Development for the Southern Region in Thailand by JICA, 2001 of Phuket City Development Project by AIDAB, 2011 of the Provincial Water Supply Project by JICA and 2006 of the 9th National Economic and Social Development Plan by NESDB.

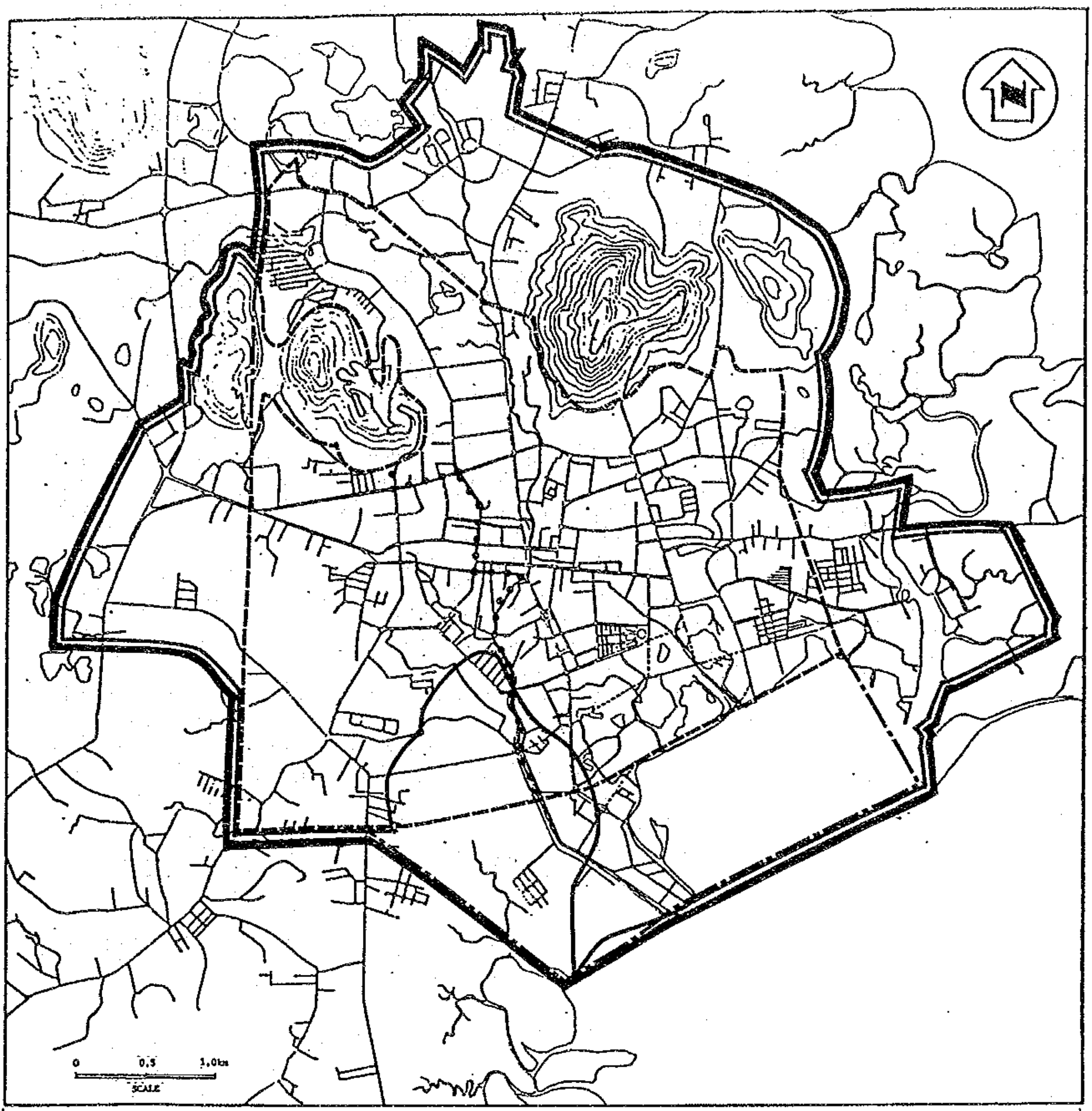
Relationship of the target year between proposed and related project is shown in Table 7.1.

7.1.2 Project Area

The project area for sewerage improvement is the DTCP town planning area and the area between the DTCP town planning boundary and the Bang Ping river as shown in Fig. 7.1.

Table 7.1 TARGET YEAR OF RELATED PROJECT





LEGEND

Study Area for Sewerage Improvement

DTCP Town Plan Area

Present Municipal Boundary

Expanded Municipal Boundary in Future

Tambon Boundary

Fig.7.1
STUDY AREA FOR
SEWERAGE IMPROVEMENT

7.1.3 Population of Project Area

The population of the project area in 2006 is estimated at 78,200.

7.1.4 Planned Sewage Flow

A planned sewage flow shall consider amount of wastewater, which is normally equivalent to that of water supply, and ground water infiltration.

Infiltration of groundwater into the sewers is not preferable for sewerage system.

Joints of sewer and lateral sewer junction to main sewer are the main points of groundwater infiltration. As groundwater table in the study area is very high like 0.7 to 2.0 meter and the sewer pipes to be used is popular with cement-mortar joint, appreciable unwanted infiltration volume is anticipated for the planning. Accordingly the use of the pipes with modern compression-type rubber ring joint, PVC pipe and flexible socket which connects main sewer with PVC lateral pipe are recommended.

Generally infiltration volume is estimated 10 to 20 % of total wastewater in case of employment of such joint method. In this study 20 % of total water consumption will be adopted. Collection rate of sewage into sewer is usually adopted 80 % of total water consumption in Thailand.

Accordingly, the planned sewage flow in 2006 is estimated as follows:

Planned sewage flow = Collected sewage into sewer + Ground water infiltration
= Water consumption x (0.8 + 0.2)
= 34,500 m^3/d

7.1.5 Planned Sewage Quality

Domestic wastewater always fluctuates in terms of both quantity and quality. Because of the fluctuation, even if daily BOD loading can be obtained, it cannot be a representative of acceptable BOD loading for planning. Also in Phuket there is no biological laboratory to analyze biological characteristic such as BOD. Therefore, to obtain the acceptable BOD loading as well as other beneficial data for this study seems very difficult.

(1) Domestic Wastewater

According to the above constraints, the BOD loading of domestic wastewater for this study was evaluated by reviewing existing literatures and relevant design background of the existing sewage treatment plant in Thailand.

In accordance with the literature study by Dr. Duncan Mara, various daily per capita BOD5 contributions are presented in Table 7.2. Also the figures breakdown are shown in Table 7.3. It is noted that a suitable design value for tropical developing countries is about 40 gpcd.

Table 7.2 Daily BOD Loading per Capita (1)

Name of Country	BOD Loading
	(gpcd)
- Zambia	36
- Kenya	23
- South East Asia	43
- India	30 - 45
- Russia France	24 - 34
- U.K.	50 - 59
- U.S.A	45 - 78
- Japan (2)	50 (3)

Note (1) Source: Duncan Mara, "Sewage treatment in Hot Climate",
(2) Source: Guidelines for a sewerage planning
(3) Based on 1975

Table 7.3 Average Breakdown Figure for Daily per Capita BOD5 Contribution

Unit: gpcd

	(1) USA	(2) Tropic	(3) Japan
Personal washing	9	5	
Dish washing	6	8	32
Garbage disposal (4)	31	-	
Laundry	9	5	
Toilet-Faeces	11	11	18
Urine	10	10	
Paper	2	1	
Total	78	40	50

Note (1) F.K. Ligmam et.al. "Journal of the Environmental Engineering Division", ASCE 100, 201 (1974)
(2) Conservative Estimates
(3) Guideline for sewerage planning
(4) Sink-Installed garbage grinder
(5) Includes allowance for food scraps
(6) Cleansing material may not be paper - water and leaves are common alternatives.

With regard to the data in Table 7.3, total BOD loading for toilet in U.S.A., tropical and Japan are 23, 22 and 18 gpcd, respectively. As can be seen, these rates are not significantly different and presumably independent with its location.

As for Nakhon Ratchasima sewage treatment plant, BOD loading was also discussed at that time. The literature BOD loading for tropical (22 gpcd) was acceptably employed as for toilet, while the rate for sullage was estimated on the basis of actual water quality survey in the site as follows:

BOD loading for sullage = 13 - 2.2 gpcd
= 10.8 gpcd

Where, 13 gpcd : obtained from the field survey
2.2 gpcd : (toilet BOD loading)
x (Spread rate of septic tank in the area)
x (removal efficiency)
= 22 x 0.25 x (1-0.6)

1) In case of separate collection system

With reference to the previous section, in case that the toilet wastewater is jointly wasted with sullage, the estimated BOD loading of the mixture is 32.3 gpcd. (22+10.8 = 32.8 gpcd). This figure is a bit low in comparison with the literature rate for tropical (40 to 43 gpcd).

As mentioned previously, it is very difficult to obtain the accurate field data for planning in a short period. Therefore, it is designed that the current estimated BOD loading of sullage (10.8 gpcd) be reviewed. Based on the field data at Nakhon Ratchasima and the record rate for tropical, 10.8 and 18 gpcd, respectively, a reasonable design figure of 15 gpcd is recommended for this study.

Note: (10.8+18)/2 = 14.4 say 15 gpcd

In addition, as BOD loading from human wastes is assumed to be stable. A figure of 23 gpcd is recommended to be applied during the target year of 2006. On the other hand, the rate for sullage is suggested in Japan's guideline to increase at 0.5 to 1.0 gpcd each year. This growth rate brings out 1.5 to 3 percent increase in amount yearly, supposing sullage value is 32 gpcd in 1975. The increasing rate of 3 percent is recommended for future planning in this study. This is less than 4 percent which was employed in the planning of Nakhon Ratchasima project.

Accordingly the projected BOD loading is shown as follows:

Table 7.4 Projected BOD Loading in Separate System Case

Unit: gpcd

Description	1989	1996	2001	2006
Toilet	22	22	23	23
Sullage	20	23	27	31
Total	42	45	50	54

2) In case of combined collection system

Based on the result of interview survey on the toilet unit type executed by the Study Team, septic tank and Thai standard type are shared 25 and 11 percent respectively out of interviewees for the city officials.

Assuming that newly constructed houses will employ septic tanks and existing cesspools shall be improved to septic tanks by the target year, and removal ratio of BOD is expected to be 50 percent. BOD loading of septage at present and in 2006 are as follows:

BOD loading of septage in 1989

$22 \times (0.25+0.11) \times 0.5 = 4.0$ gpcd

BOD loading of septage in 2006

$23^{*} \times 1.00 \times 0.5 = 11.5$ gpcd

* contributed by using toilet paper.

The growth of sullage BOD loading is the same as separate system as mentioned before.

Accordingly the projected BOD loading is shown as follows:

Table 7.5 Projected BOD loading in Combined System Case

Unit: gpcd

Description	1989	1996	2001	2006
Toilet	4	7	10	12
Sullage	20	23	27	31
Total	24	30	37	43

(2) Industrial Wastewater

As mentioned in socio-economic condition, chapter 2.2.5 Industry, there are 214 factories but mostly small sized business.

Main factories which are comparatively big water consumer are listed with BOD loading in the following table.

Table 7.6 Water Quantity and BOD Loading by Industrial Wastewater

Type of Factory	No.	Flow m3/day	BOD mg/l	Load Kg/d
Rubber sheet	1	25	278	7.0
Feed Product (Fine Fish)	3	20x3	3,750	22.5
Chinese Noodle	12	7x12	3,000	24.0
Slaughter House	1	2	3,100	6.2
Canned Goods (Fish)/1	1	100	3,200	320
Cold Storage	1	10	110	1.0
	19	281	(1.350)	379.7

Source: NEB "Report on the project of the pollution planning in the city town

Note: /1 Temporarily closed

In 1986, discharged wastewater amounted to 281 m3/day. The industrial growth of manufacturing from 1981 to 1985 in Phuket Province as shown Annex Table 7.1 has not increased and manufacturing in the study area is forecast not to expand in the future. Therefore, it is not appropriate to change industrial wastewater volume from the present 281 m3/day on the viewpoint of sewerage planning. The BOD loading will be 379.7 kg/day.

Since BOD loading of daily per capita in 2006 is forecast 54 gpcd in case of separate system, influent BOD is given as follows:

BOD loading from

Domestic	78,200 prs. x 54 gpcd	=4,222,800	g/d
Hotel	3,500 rooms x 1.8 prs. x 54 gpcd =	340,200	g/d
Factory		379,700	g/d
Total		4,942,700	g/d

Flow from

Influent flow	= 34,500m^3/d x 0.8 =	27,600	m^3/d
Groundwater infiltration	= 34,500 x 0.2 =	6,900	m^3/d
Total		34,500	m^3/d

$$\text{Influent BOD} = \frac{4,942,700 \text{ g/d}}{34,500 \text{ m}^3\text{/d}} = 143 \text{ mg/l}$$

While in case of combined system, the above influent BOD comes out as follows:

Domestic	78,200 prs. x 43 gpcd	=3,362,600	g/d
Hotel	3,500 rooms x 1.8 prs. x 43 gpcd	= 270,900	g/d
Factory		379,700	g/d
Total		4,013,200	g/d

$$\text{Influent BOD} = \frac{4{,}013{,}200 \text{ g/d}}{34{,}500 \text{ m}^3\text{/d}} = 116 \text{ mg/l} \doteqdot 120 \text{ mg/l}$$

7.2 Design Criteria

7.2.1 Sewer

(1) Design Sewage Flow

1) Sanitary sewer

Sanitary sewers will be, in principle, based on the design maximum hourly wastewater flow, but in the case of this city a large allowance will be made for sanitary sewers due to the considerable amount of storm water infiltrating into the sanitary sewers.

As a concept of allowance:

(i) Method of calculation depending on population density

$$Qw = D \times Qd \qquad D = \left(\frac{256}{EP/ha}\right)^{0.81} + 1.3$$

Where,

Qw: design wet weather flow
Qd: design dry weather flow
D : dilution rate depending on the density of population
EP/ha: equivalent population per hectare

When equivalent population is less than 75 pers./ha
D = 4 will be the upper limit.

In this city the mean density of population at 38 pers./ha is lower than 75 pers./ha, so the sewage amount will be four times the design maximum hourly wastewater flow.

(Source : "Sewerage Design and Operation Seminar [17. Sep. '85]" stipulated by PWD)

(ii) Method of bringing the sanitary sewage amount to intercepting sewers

Sewage amount of intercepting sewers is designed so as to be three times the design maximum hourly wastewater flow.

Its equation is:

(0.8 Q x 1.2 x 1.4 + 0.2Q) x 3 = 4.632 Q..(a)

where,
0.8 Q: 80 % of daily mean sewage amount infiltrating into the intercepting sewers
1.2 x 1.4: converted to design maximum hourly wastewater
0.2 Q: groundwater infiltration

Design maximum hourly wastewater flow of separate system will be:

0.8 Q x 1.2 x 1.4 = 1.344 Q..............(b)

Magnification: (a)/(b) = approx. 3.45 ≒ 4.0 = D

In this planning, the sewage amount of 3.45 times the design maximum hourly wastewater flow equivalent to that of intercepting sewers is adopted considering economic efficiency.

2) Storm sewer

Storm sewers shall be designed with the design maximum storm flow.

(i) Calculation Equation

The design maximum storm flow shall be calculated with the following rational method:

$$Q = (1/360)\ CIA$$

where,
C: runoff coefficient calculated from the basic runoff coefficient by surface type
I: average rainfall intensity within reaching time (mm/hr) The rainfall intensity formula shall be a Talbot type with an inlet time of 7 minutes.
A: drainage area (ha)
Q: design maximum storm flow (m^3/sec)

(ii) Return Period

The return period of 2 to 5 years is generally adopted for designing storm sewers. In this city 5 years is adopted considering the present economic growth.

3) Combined sewer

Combined sewers shall be designed with the sum of design maximum storm flow and design maximum hourly sanitary sewage flow.

4) Interceptor

Interceptors shall be designed with three times design maximum hourly sanitary sewage flow.

(2) Equation for Flow Calculation

The flow in sewers shall be calculated with the following Manning's Formula.

$$V = (1/n)\ R^{2/3}\ I^{1/2}$$

where,
V: velocity in m/sec
n: roughness coefficient
R: hydraulic radius in m
I: inclination in decimal

The following roughness coefficients shall be used as standards:

Clay pipe	0.013
Reinforced Concrete Pipe	0.013
Hard Polyvinyl Chloride Pipe	0.010
Cast-in-Place Concrete Channel	0.015

(3) In-Pipe Velocity

1) Sanitary sewer, intercepting sewer

Sanitary sewers shall be given a minimum velocity of 0.6 m/sec and a maximum velocity of 3.0 m/sec.

2) Storm sewers and combined sewer

Those shall be given a minimum velocity of 0.8 m/sec and a maximum velocity of 3.0 m/sec.

7.2.2 Pump Station

(1) Design Sewage Flow

1) Pump station connected to sanitary sewers

Pump equipment: design maximum hourly sanitary sewage flow & peak wet weather flow

The grit chamber shall not be provided with the manhole type lift station.

Relay pumping station shall have screen facilities.

2) Pump station connected to interceptors

(i) In dry weather

Grit chamber: design maximum daily sanitary sewage flow

Pump equipment: design maximum hourly sanitary sewage flow

(ii) In wet weather

Grit chamber: design maximum daily sanitary sewage flow

Pump equipment: three times design maximum hourly sanitary sewage flow

Relay pumping station shall have screen facilities.

(2) Grit Chamber

Type: Gravity

Overflow Rate: 1,800 $m^3/m^2/d$ (in dry season)
5,400 $m^3/m^2/d$ (in rainy season)

In-chamber Average Velocity: 0.30 m/sec

7.2.3 Treatment Plant

(1) Design Sewage Flow

Sewage treatment and sludge handling facilities shall be designed with the design average daily sanitary sewage flow for both separate and combined system. However, wastewater transmission conduits shall be designed with the design maximum hourly sanitary sewage flow for a separate system and three times the design maximum hourly sewage flow for a combined system.

(2) Primary Sedimentation Tank

	Separate System	Combined System
Sedimentation Time	1.5hr	2.0hr
Overflow Rate	40 $m^3/m^2/d$	30 $m^3/m^2/d$
Weir Loading	below 250 $m^3/m/d$	below 200 $m^3/m/d$

In case of Oxidation Ditch Process which does not require the primary sedimentation tank for a combined system, the wet weather sedimentation tank is recommended to provide, being designed with a sedimentation time of 30 minutes for the design maximum hourly sanitary sewage flow. However, in this stage of the Master plan, construction space will be only planned.

(3) Aeration Tank

(i) Conventional activated sludge process and oxidation ditch process.

	Conventional Activated Sludge Process	Oxidation Ditch Process
BOD-SS Loading	0.3 kg-BOD/kg-SS/d	0.1 kg-BOD/kg-SS/d
MLSS	1,500 to 2,000 mg/l	2,000 to 3,000 mg/l
Aeration Time	6 to 8 hr	10 to 16 hr
Return Sludge Ratio	0.25 to 0.30	0.80 to 1.50

(ii) Rotating Bio-Disk Process

BOD Surface Loading	10 g/sq.m/d
Liquid/Area Ratio	10 l/sq.m

(4) Final Sedimentation Tank

	Conventional Activated Sludge Process and Rotating Biological Contactor Process	Oxidation Ditch Process
Sedimentation Tank	2.5 hr	3.0 hr
Overflow Rate	30 $m^3/m^2/d$	15 $m^3/m^2/d$
Weir Loading	below 150 $m^3/m/d$	below 120 $m^3/m/d$

(5) Chlorination Chamber

Contact Time 15 min

(6) Sludge Drying Bed

	Conventional Activated Sludge Process and Rotating Bio-Disk Process	Oxidation Ditch Process
Drying Period	22 days	18 days
Solid Loading	4.5 $kg/m^2/d$	4.5 $kg/m^2/d$

(7) Sludge Moisture Content

	Conventional Activated Sludge Process and Rotating Bio-Disk Process	Oxidation Ditch Process
Raw Sludge	98 %	-
Excess Sludge	99.2 %	99.3 %

CHAPTER 8

STUDY OF SEWAGE COLLECTION SYSTEM

CHAPTER 8 : STUDY OF SEWAGE COLLECTION SYSTEM

8.1 General

With regard to planning purpose of the study, two alternative sewage collection patterns: separate and combined sewer systems are comparatively considered. Experience has shown that apparently, for surrounding environmental impact and water pollution control, a separate system is advantageous as the best solution. However, under the following conditions, a combined system may be more desirable to promote the diffusion of sewerage economically.

a. Amount of pollution of receiving watercourse during rain is acceptable.

b. Existing public drainage, which is collecting surface and sullage water together, can be intercepted to combined sewers so that lateral sewers are shortened.

In this Chapter, selection of alternatives for planning, collection style, in the case of both separate and combined systems for the study area is discussed, taking the possibility of utilizing the current drainage facilities into consideration. Then, the advantages and disadvantages of these systems are evaluated taking into account the following:

(i) Difference in performance for environmental and sanitary improvement between the separate and combined sewer systems.

(ii) Foresee trouble issues for each system after completion of the project.

(iii) Construction cost and operation and maintenance cost com parison.

(iv) Other factors affecting the selection of the sewage collection system.

8.2 Present Drainage Situation

A review of existing drainage problems in Phuket City is discussed herein. In this article, only present situation of drainage system in the study area is concentrated. Further suitable consideration of overall sewerage system can be developed. Data are obtained basically by direct site visit. Pertinent details are as follows:

(1) Public Sewers

1) Almost all public sewers in Phuket City are polluted fundamentally by domestic wastewater discharged. Consequently, this not only degrades environment but also threats health. The city is facing environmental and satiation problems. Mosquitoes and flies remarkably abound the city particularly along some roads

such as Thalang, Rasda, Ranong, Montri, Phang Nga and Phuket Rd. A recent monitoring reported that at Bang Yai river, water is being polluted especially from central of the city up to its estuary. Radical pollutant is presumably the domestic wastewater discharged from the town.

2) In Phuket City a combination of closed conduits (covered cast-in-place concrete culverts and reinforced concrete pipes) and open conduits (uncovered cast-in-place concrete channels, U-type gutters and excavated ditches) are presently in practice. However, open conduits result in not only aesthetic but also sanitary problems. Illegal refuse dumping channels (open channels) and excavated ditches are used. Unless preventive measures are rendered, all open conduits should be replaced by closed conduits.

3) During dry weather period, velocity in almost all public sewers is observed low, therefore, resulting in the settlement of particles in the drains, since during that period water from mountain, stream, and groundwater are not very much even in truck sewers. Possibly these drains may be constructed for the purpose of discharging storm drainage. Accordingly, it is assumed that such drain might be used as a communal wastewater drainage in dry weather.

4) Public sewers located along Komara Pat. Ranong and Montri Rd. are poorly operated resulting to clogging. The existing sewers are old and in some areas, reverse slope are provided. These problems, however, are considered easy to cope with.

5) Heavy rain in the Bang Yai river or high tide at the Andaman sea results to backwater or stagnation in some upstream and downstream public sewers. This phenomenon is commonly experienced in some areas such as Kamara Pat Rd., Dec-Buk Rd., Thalang Rd., Phang Nga Rd., Surin Rd. and at the outfalls to the Bang Yai river and its tributaries. A number of gates, therefore, are installed to control this phenomenal effect. At Taling Chan canal, downstream of the Bang Yai river, one drainage pump is installed. The capacity of the pump is insufficient to cope with flood in the area.

6) In comparison with the city's catchment area, trunk sewers seem easily drained to the Bang Yai river and its tributaries Drainage modification in some areas, particularly where low flow is reported is recommended.

(2) Domestic Wastewater Discharge

In Thailand, the human excrete disposal/treatment unit is septic tank or cesspool. Modern treatment units such as anaerobic filter are increasingly being employed particularly for newly constructed buildings like hotels and condominiums.

On domestic wastewater in almost all households, it is common that only wastewater from restroom(s) is discharged to such on-site treatment unit and subsequently into public sewers. Wastewater from other sources such as kitchen, in contrast, are directly discharged into the public sewers.

According to the study, a set of recommendations is as follows:

1) At present, the Thai style pour-flush toilet with septic tank and cesspool is the most suitable and successful treatment, and expected to continue even with change of treatment unit from cesspool to septic tank.

In order to develop the most effective sewerage system, however, the introduction of other possible alternative methods which include the provision of flush toilet and direct connection of the water closets to public sewers require remarkable understanding and cooperation of residents.

2) Both treated and untreated domestic wastewater are commonly dis charged into public sewer nearby. In case no public sewer is available, the wastewater is drained to surrounding areas and then infiltrated into the ground. This results in health threat and groundwater contamination.

3) Street gutters are regularly lined passing the houses. Domestic wastewater flows into the street drains through those gutters together with storm water collected from roof and street. Separation of these discharged wastewater from storm water seems not to be done easily.

4) Biological Oxygen Demand (BOD) concentration of excreting wastewater is reportedly low in comparison with the domestic wastewater from other sources. It is impossible to achieve proper water pollution control without alleviation of BOD loading in the domestic wastewater.

5) Septic tank and other new type on-site treatment units of which septage in general discharges into street drains are mainly pro vided for hotels, schools, public facilities and newly constructed housing. However, majority of the existing units are cesspools wherein effluent is haphazardly infiltrated into the ground.

6) In order to increase the effectiveness of the service, the method to connect the cesspool outlet to street drains might be considered, but not practicable due to structural problem. Innovation of cesspool to septic tank seems practical but requires residential cooperation as well as public support. Existing pour-flush water closets should also be replaced by any standard flushing water closet since the former yields scouring. However, it seems difficult to get cooperation with people in the area who are used to their life style and do not see advantages for changing.

7) Settled sludge at bottom of septic or cesspools is presently collected by municipal nightsoil collection vehicles once or twice a year. The collected sludge is transported to an existing nightsoil treatment plant, digestion tank and drying bed.

(3) Construction Condition

Pertinent details concerning construction of sewerage system of the Phuket City are summarized as follows:

1) By geographical condition, Bang Yai river and its tributaries run passing the central of the city. Many river crossing construction are anticipated and consequently inverted siphon sewers and pumping stations are required. Construction cost will be predominantly high. To minimize the cost, trunk sewer drains must be carefully selected to optimize the number of crossings.

2) Sewer profiles at the southern part of the city are expected to be profound since the area is rather flat. For planning purposes of sewage collection system, however, minimum depth of all pipes is essential since high water level has been recorded.

3) Route and construction method of the trunk sewers located along congested traffic roads such as Theptrasattri, Phuket, Montri, Jawaraj, Rasda and Ranong must be seriously selected in order to minimize traffic troubles.

4) Streets such as Thalang, Phang Nga, Rasda and Ranong are narrow and densely inhabited. Construction planning is required in order not to trouble business in the areas.

5) Sewerage system of the city consists of several public sewers. Overall installation of house connected pipes is therefore consuming.

6) The only existing underground construction are water distribution pipes. These should not adversely affect the construction of the project.

7) Even the existing drainage network is well provided for the city. However, with further study on the flow capacity, some improvements may be requested.

8.3 Selection of Alternative Systems

8.3.1 Definition

Though there are two methods, in principle, for sewage collection system, namely: separate and combined system, in fact, several ideas and plans to utilize existing drainage facilities economically are considered.

For decision of proper sewage collection system for the city, definitions of the selected alternatives is necessary.

8.3.2 Outline of Selected Alternatives

(1) Separate System

The separate system, which conducts only wastewater to treatment plant, never releases wastewater to stream drains during wet weather. Therefore, it is advantageous in terms of water pollution control. Also, in the areas where conventional storm drainage facilities are in relatively good repair, only wastewater drainages are required for completion of sewerage system.

As mentioned in present drainage situation in Chapter 8.2, storm water facilities are utilized as combined sewer discharging domestic wastewater.

Accordingly, general separate system is selected as alternative. The main sewer line is presented in Fig. 8.1, but no lateral sewer is shown.

(2) Combined System

Generally, combined system refers to a system where sanitary sewerage and storm water are discharged into combined sewer with closed conduits. However, there is no sufficient justification to build another combined lateral sewers with closed conduits for the study area for the following:

1) There are street gutters in good condition which are also used for wastewater discharge. That means a combined sewage collection system is still employed in the area. Thus, it is apparent that new construction of general combined sewer is advantageous for improvement of surrounding conditions but not economically.

2) Existing rivers and canals, when improved in line with this particular project, will serve adequately for handling storm runoff, being acceptable to receive the amount of pollution from waste water. Therefore, it is hardly acceptable to build new trunk sewer to discharge storm water together with sanitary waste toward the downstream.

Consequently, a proposed combined system as alternative is referred to as an abnormal combined system as detailed below:

a. The existing street gutters would be utilized as lateral sewers to collect storm and waste water as in present practice.

b. A combined sewer is not designed to collect and deliver all combined flow to treatment facilities, because the volume of the combined flow at wet weather is too enormous to be treated economically. Therefore, only a portion of the combined flow, three times of D.W.F. (dry weather flow) in this study, may be delivered to a sewage treatment facility, and the excess is diverted to discharge directly into the rivers or other receiving waters nearby. Since the major rivers and canals, however, are tidal, separate system should be employed partially in such areas, because some outlets of the street gutters into the river are affected by the sea water level.

The main sewer line of the proposed combined system is shown in Fig. 8.2 but no lateral sewer is shown.

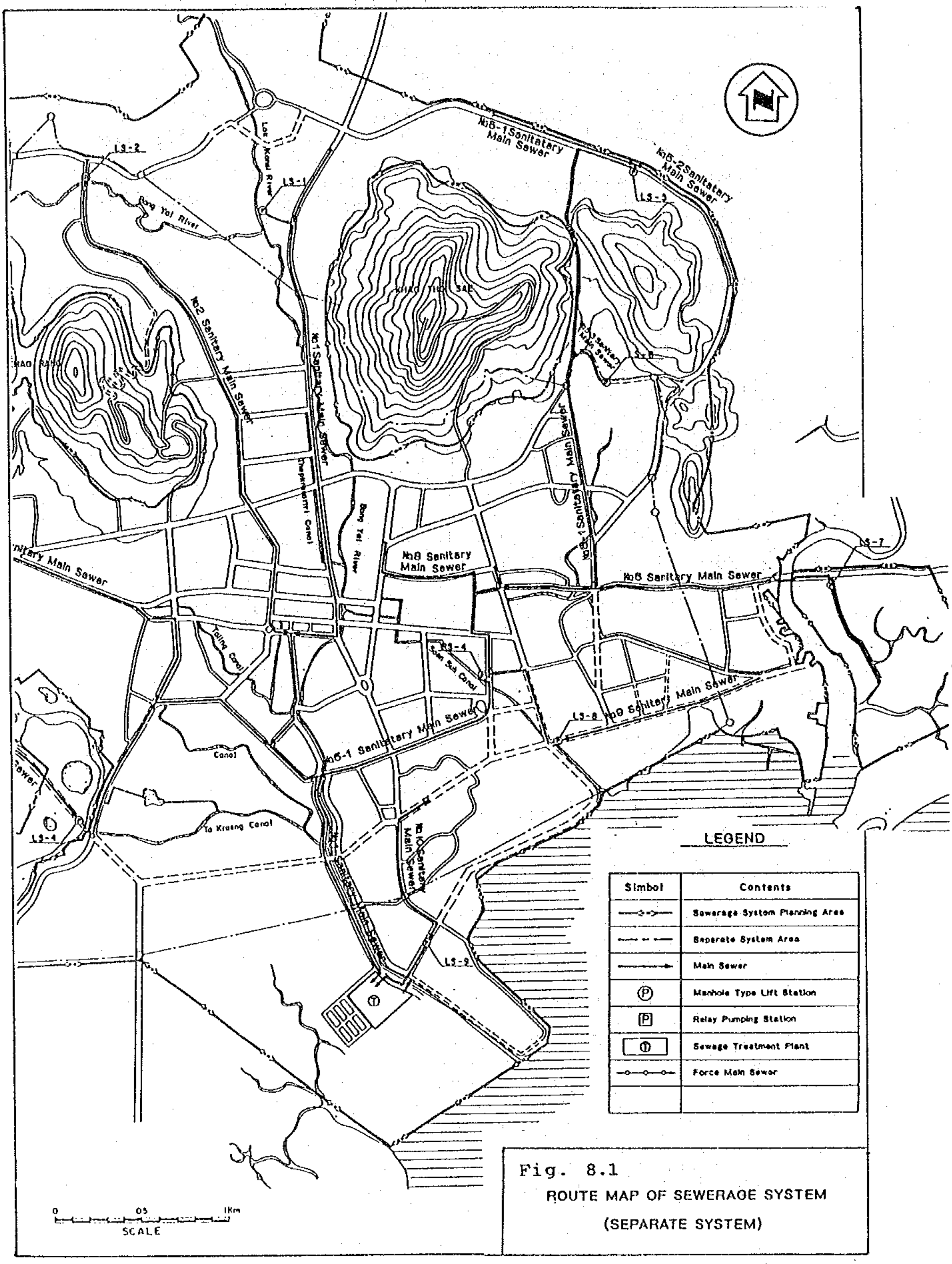


Fig. 8.1

ROUTE MAP OF SEWERAGE SYSTEM

(SEPARATE SYSTEM)

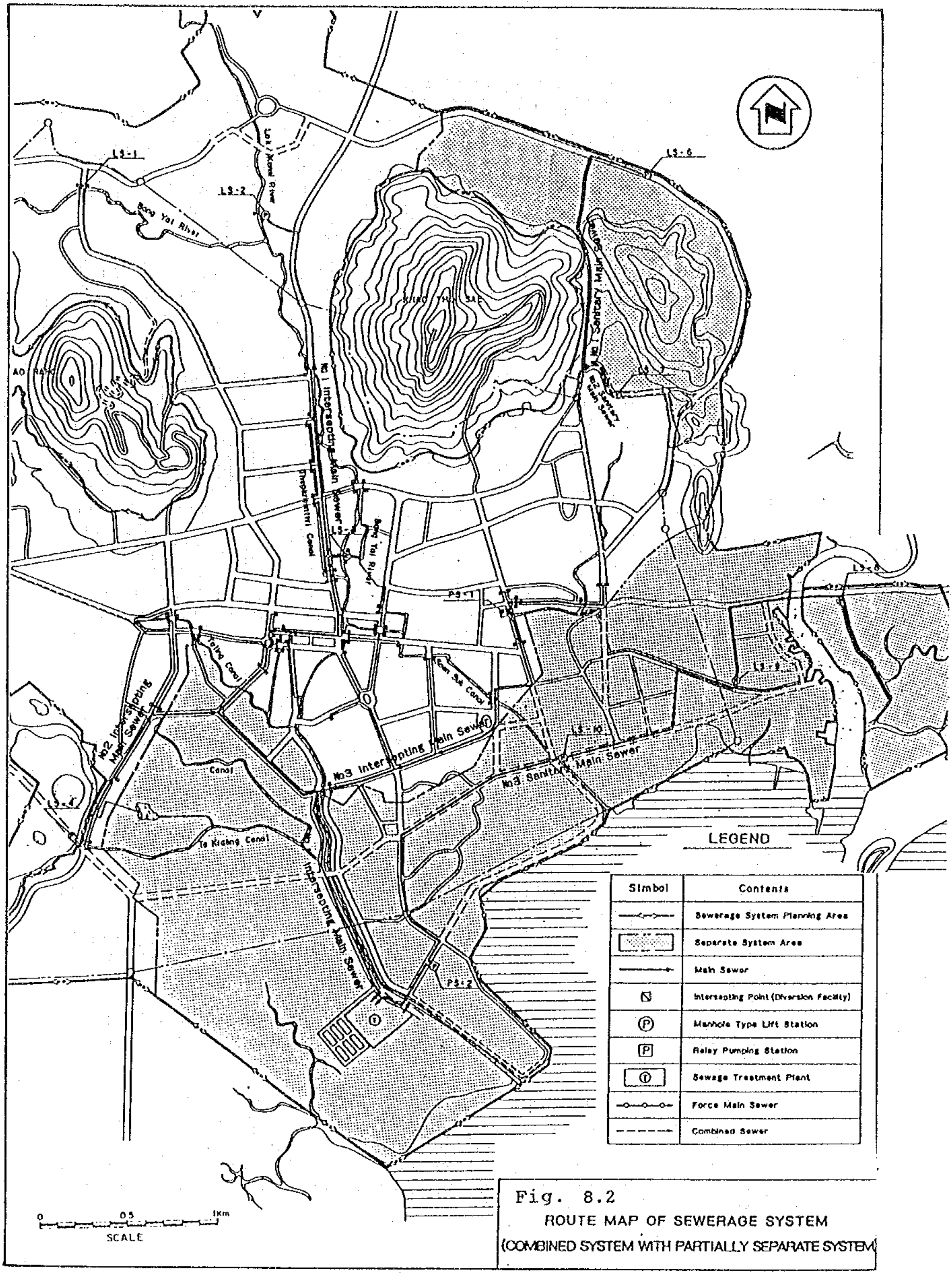


Fig. 8.2
ROUTE MAP OF SEWERAGE SYSTEM
(COMBINED SYSTEM WITH PARTIALLY SEPARATE SYSTEM)

8.4 Comparison Alternative

8.4.1 General Advantages and Disadvantages on Improvement of Environmental Conditions

To determine the most suitable sewerage system for Phuket City from a viewpoint of improvement of environmental condition, various relevant factors are taken into consideration, including rainfall characteristics, topography, life style, water uses, existing drainage facilities and other physical conditions

In order to select a proper sewer system, the following evaluations have been discussed taking the above factors into account.

(1) Discussion

1) A basic factor affecting the selection of sewer system is existing drainage situation. The relevant situation in the study area is detailed in Chapter 8.2. The current drainages are composed mainly of side gutters along streets. These gutters are also utilized as the drain of domestic waste from kitchen and toilet in most of the study area. This means that although not satisfactory, combined system is still in operation in the area. And conversion of these existing facilities to separate system will not be practicable at least for the time being.

2) Suppose a separate system is employed without issuing regulations on the sewerage system and upgrading of public comprehension and awareness, connection of house drains with public sewer system will not be done smoothly.

In addition to the above, the existing pour-flush toilet should be changed to flushing type unit to reduce troubles because clogging by litter could be a serious problem owing to the small house connection pipe.

3) Generally, the most significant disadvantage of a combined system is that when it rains, the system causes pollution to the receiving water due to overflow of untreated wastewater. In case of the study area, sanitary wastewater discharged to the gutters will generally be diluted at the time of rain. The overflows from combined sewers will therefore be greatly diluted which will have a minimum impact on rivers and canals receiving the overflow.

Interceptor has a capacity of three times of D.W.F., which means BOD values of the overflow into the receiving water becomes lower than 40 mg/l.

4) According to involvement of 3xQ (D.W.F.) into combined sewer, high tendency of pollutant including deposits within the street gutters and sewers and on the road are flushed off into the sewer and discharged to the treatment facilities at the beginning of storm weather, thus limits water pollution of the receiving water.

5) The combined system renders unfavorable problems with respect to surrounding environmental condition especially during dry weather, because the existing open street gutter is being utilized as presently practiced.

(2) Conclusion

1) In case of separate sewer system, surrounding condition in the city and the river and sea will be improved. Contamination of the underground water will be diminished.

2) No septic tank and cesspool shall be allowed to be constructed for new houses and buildings after completion of the separate sewers. To reduce maintenance trouble, the existing power-flush toilets should be changed to flushing type units.

3) Groundwater pollution caused by leaching from cesspool can be overcome in case of separate system, because no on-site treatment and direct connection from water closet to sewers are allowed.

4) Table 8.1 describes briefly the comparisons of alternative on environmental condition. Other factors to be considered in the alternative are relevant costs of construction and operation and maintenance.

Table 8.1 Comparison of Alternative Sewage Collection Systems

	Separate Sewer System	Combined Sewer System
Definition	(1) Sanitary sewage and storm water are collected principally by sewers and storm drains separately.	(1) Sanitary sewage and storm water are collected together by the combined sewers.
Method of Sewage Collection	(1) Sanitary sewage is discharged into sanitary sewers while storm water is discharged into the existing street drains as presently practice. (2) Domestic waste and watercloset and other industrial wastewater will be connected with sanitary sewers to be newly constructed.	(1) Sanitary sewage is discharged into the existing street drains just like storm water as is into presently practiced. (2) Domestic waste and watercloset and other industrial wastewater will be connected with the existing street drains or sewers to be newly constructed.
Improvement of Environmental Conditions	(1) Environmental conditions in the City as well as at the rivers and the sea will be upgraded. (2) No septic tank and cesspool will be required to construct for new house and buildings after completion of the project. To reduce the environmental effects the existing pour-flush toilet should be changed to flush-type unit. (3) Groundwater pollution caused by wastewater infiltration can be overcome.	(1) Environmental conditions of the rivers and the sea will be upgraded. (2) In the area where the existing street drains are poorly flowed mainly because insufficient slope has been provided, environmental impacts can be easily reduced by reconstruction these street drains. (3) The surface water of initial period of rain will contain high level of pollutants, being discharged to the street drains and conveyed into sewage treatment plants.
Foreseen Trouble Issues	(1) Without issuing of regulations on sewerage and upgrading of public comprehensions and awareness on environment, to connect house drains with the public sewer system may not be done smoothly. (2) For separate sewage system, if the existing open drains are connected with sanitary sewer, overloading of the sewer system may take place, particularly during rain period. (3) Since the sanitary sewers are rather small, clogging by litter may be a serious problem in the future without upgrading a public environmental understanding.	(1) It is foreseen that the existing cesspools will be remained even after the completions of the project. Hopefully, however water pollution in canals and the sea is reduced whether or not environmental conditions in the study area are improved. (2) Users will be double charged for both sewerage and septic tank cleaning services. (3) Since the existing street drains are used for combined sewer as presently practice, clogging by litter may be a serious problem in interceptors and at pumping station without upgrading public understanding of this problem. (4) Earth and sand will flow into interceptors and also into a sewage treatment plant during rain, which will pile in the bottom of the channels, sedimentation tanks and so on for a long time.
Construction	(1) Installation of lateral sewers and house connections is required in the City side.	(1) It has been experienced before that, in general, wherever storm sewers have already been existed to employ a combined sewerage system is much more considerate than a separate system. By contrast, with some constraints such as the necessity of interception system and observed high tide as for this study, this statement is reliable. (2) Fewer or limited amount of lateral sewers and lesser house connections will be required in the City side.

8.4.2 Cost Analysis of the System

(1) Outline of Facility

The following table shows the major facilities of each alternative. Whereas, trunk sewer of each alternative is shown in Fig.8.1 and 8.2 in manner of simplification.

Table 8.2 Comparison on Major Facilities of Sewer

Item	Size	Length of sewer Separate system	Length of sewer Combined system	Remarks
Sewer (open cut)	φ 100 mm	———	200 m	PVC
	150	———	100	"
	200	7,630 m	3,150	"
	250	550	1,200	"
	300	2,900	450	RCP
	400	2,450	2,600	"
	500	3,500	2,950	"
	600	1,050	800	"
	800	1,750	2,850	"
	1,000	1,100	700	"
	1,200	350	750	"
	Sub-total	21,280	15,750	
Sewer (jacking)	φ 600	———	20	RCP
	800	590	———	"
	1,000	———	40	"
	1,500	1,230	1,230	"
	Sub-total	1,820	1,290	
Pressure Sewer	φ 100	1,450	1,150	CIP
	125	400	700	"
	150	50	———	"
	200	500	350	"
	250	———	50	"
	300	———	300	"
	350	———	20	"
	500	20	———	"
	Sub-total	2,420	2,570	
Total		25,540 m	19,610 m	
Lateral sewer	φ 200-250	53,750 m	15,450 m	PVC
Sewer Total		79,290 m	35,060 m	
Inverted siphon	φ 200 x 2	———	5 unit	
	φ 300 x 2	2 unit	2	
	φ 400 x 2	2	———	
	φ 500 x 2	———	1	
	φ 600 x 2	1	2	
	φ 800 x 2	3	2	
	φ 1,200 x 2	———	1	
Total		8 unit	13 unit	
Pump station	Lift station	9 unit	10 unit	
	Pump station	1	2	
Total		10 unit	12 unit	

(2) Cost Analysis

Although it is generally more favorable to provide a separate system than to provide a combined system, the cost advantage of both systems may vary depending upon the content of facilities to be provided. Therefore, cost analysis is made to compare both systems, considering local construction aspect.

1) Unit cost estimation

With regard to cost analysis, model unit cost is estimated first. The estimated until cost for sewer construction is presented on Figs. 8.3 to 8.6. Relative unit cost is as follows:

a. sewer construction cost (open cut method)
b. sewer construction cost (normal jacking method)
c. pumping station cost
d. annual operation & maintenance cost

2) Conclusion of cost analysis

The estimated total capital cost and operation & maintenance cost of each alternative are summarized in the following table.

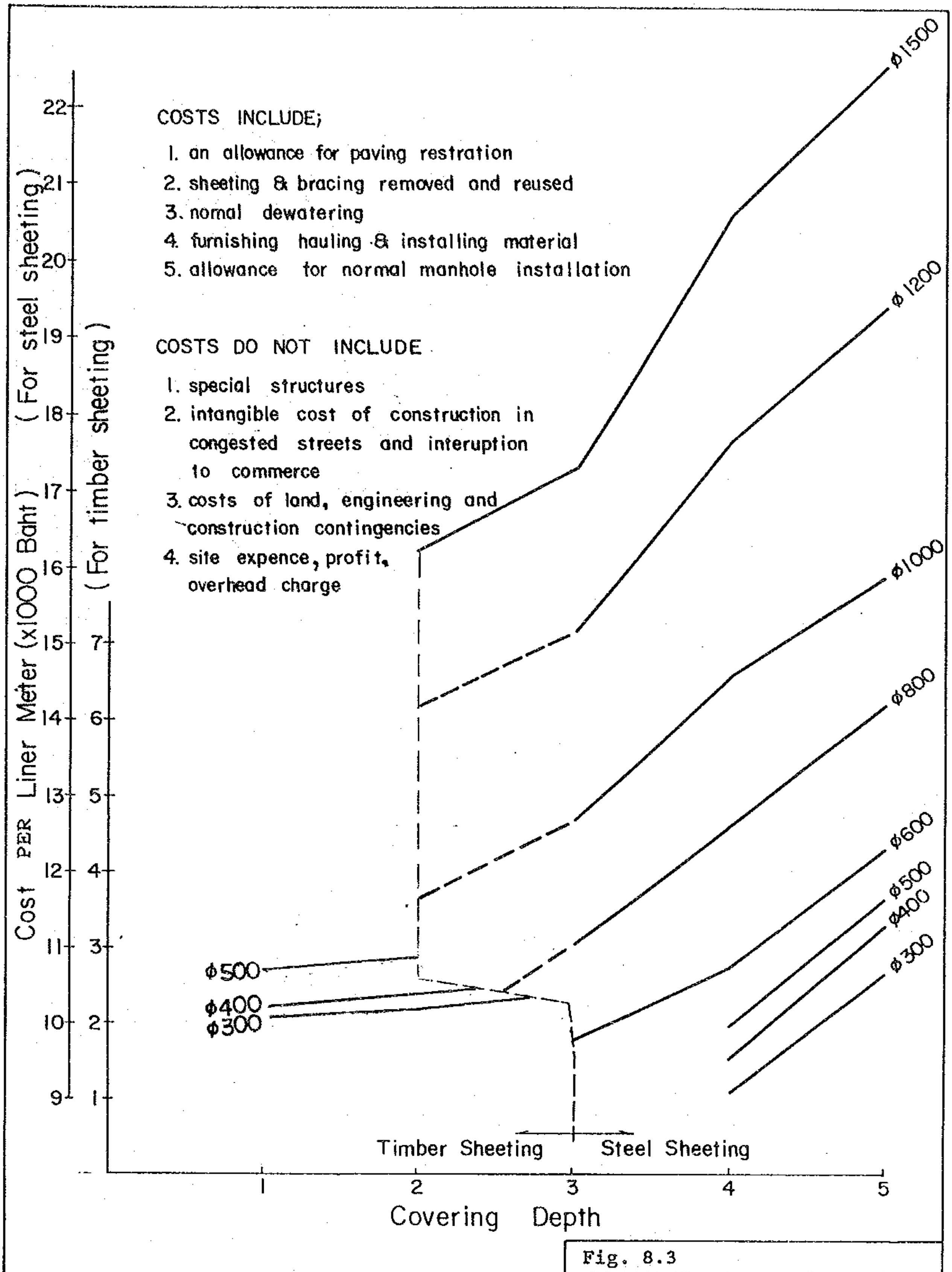


Fig. 8.3
ESTIMATED COST OF SEWER CONSTRUCTION (open cut method)

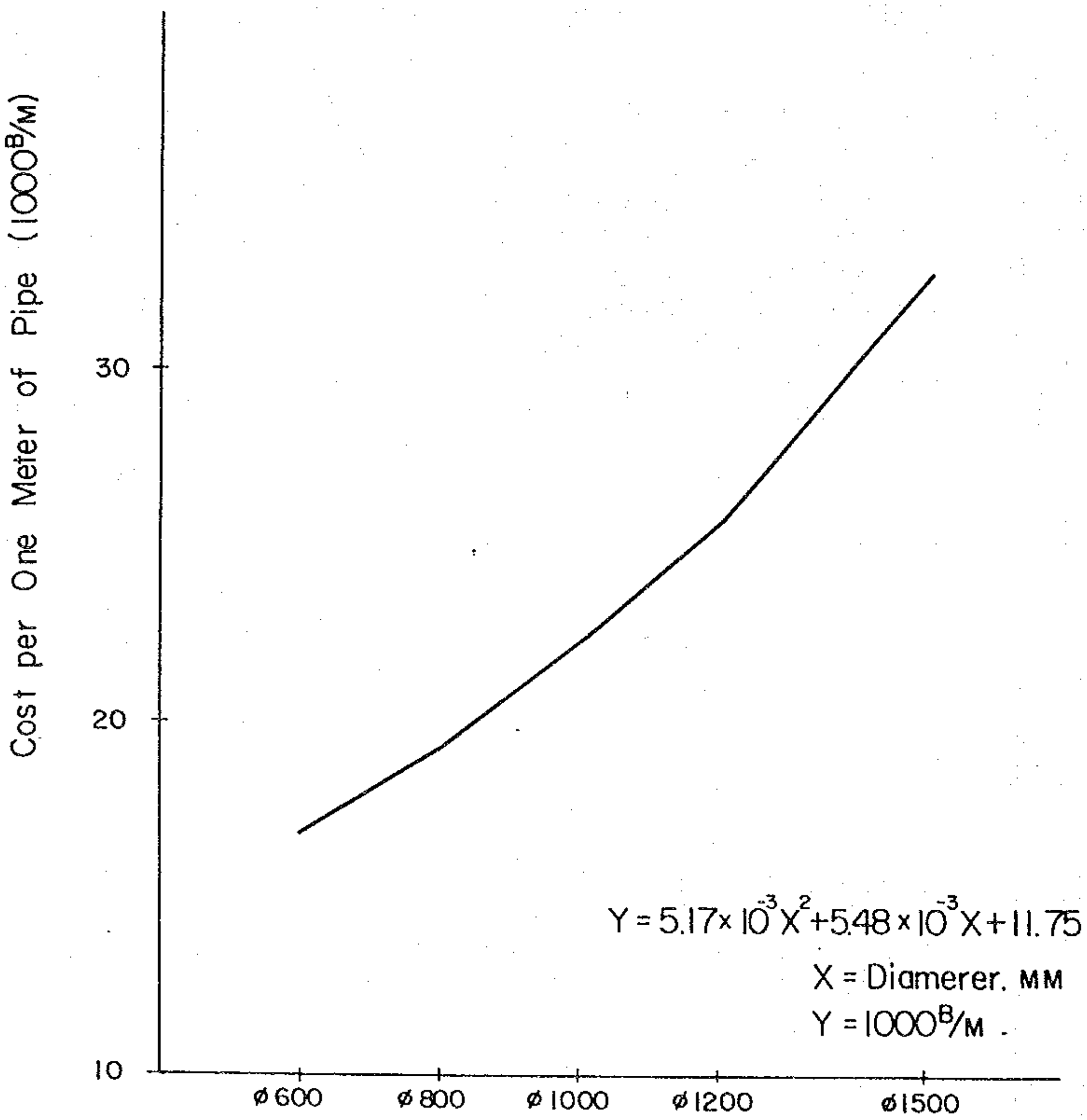


Fig. 8.4
ESTIMATED COST OF SEWER CONSTRUCTION (NORMAL JACKING METHOD)

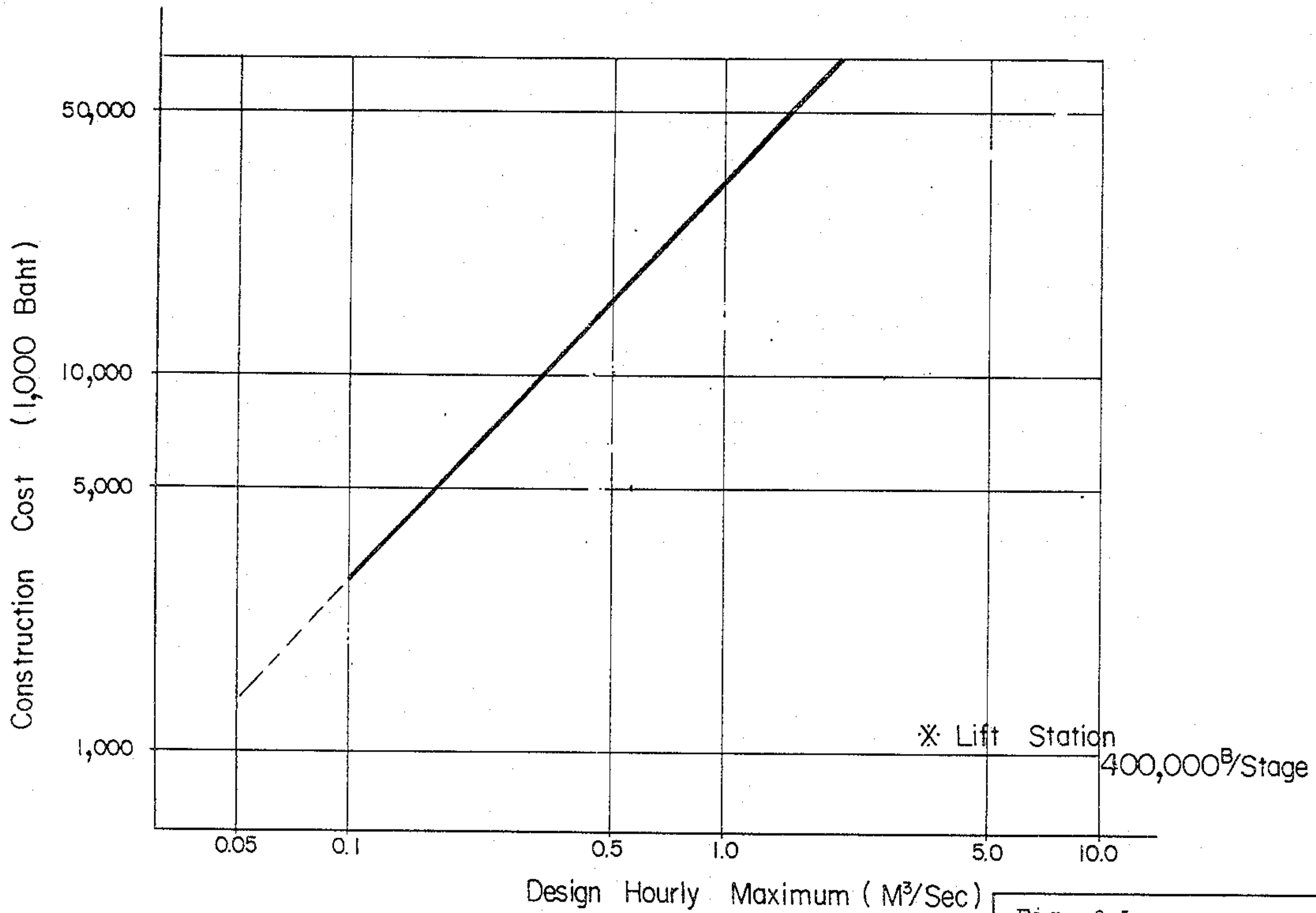


Fig. 8.5
CONSTRUCTION COST
FOR PUMPING STATION

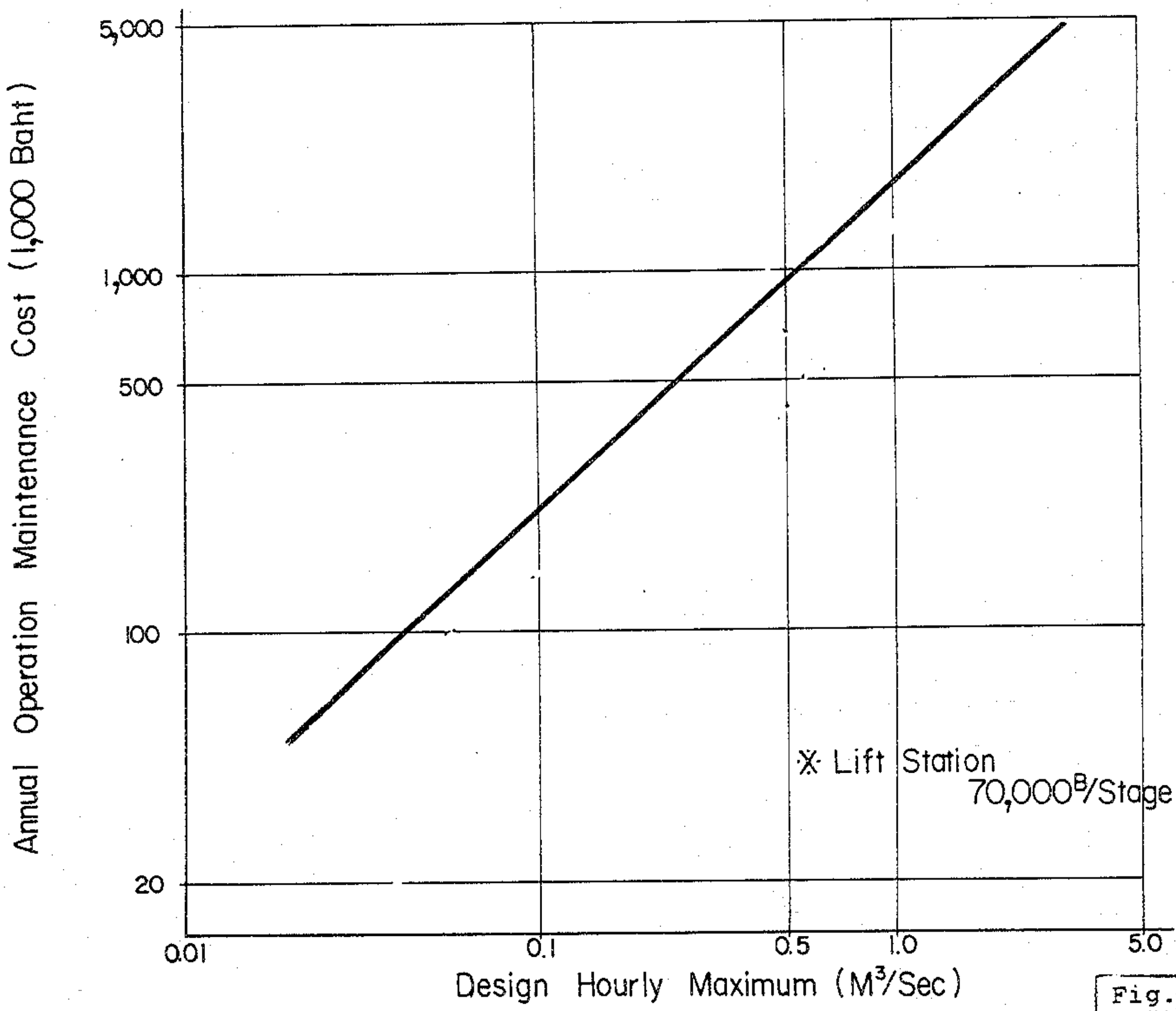


Fig. 8.6
ANNUAL OPERATION AND MAINTENANCE COST OF PUMPING STATION

Table 8.3 Summary of Cost Comparison of Separate and Combined System for Construction (Direct Cost)

Item	Estimated Capital Cost (Million Baht)	
	Separate system	Combined system
Direct Cost		
Sewer installation	159.4	152.5
Lateral sewer installation	69.9	20.1
Inverted siphon	7.7	10.8
Pump station	8.0	9.1
Others	——	0.5
Total (Rate)	245.0 (127%)	193.0 (100%)

Table 8.4 Summary Cost Comparison of Separate and Combined System for Operation & Maintenance

Item	Estimated Maintenance Cost (Million Baht per year)	
	Separate system	Combined system
Cleaning of sewer (one time/three years)	0.82	0.35
Operation Cost (for pump)	1.05	0.95
Total	1.87 (144%)	1.30 (100%)

The cost estimates indicate that the combined system would be more inexpensive than the separate system in both capital cost and operation and maintenance cost. The total estimated capital cost of the separate system is exceeding by about 27 percent over the cost of the combined system. Besides, operation and maintenance cost of the former is also exceeding by about 44 percent over the cost of the latter.

The major reason is definitely difference of the length of lateral sewers to be provided.

8.4.3 Recommendations

On the basis of the various studies and field surveys on the existing drainage facilities, it is recommended that the regional sewerage system should be basically a separate system, but in response to immediate needs, existing public drains shall be adopted as temporary combined sewers until such time when financing for a complete separate system is possible.

The intercepting sewer of the recommended combined system would be adaptable to translate to trunk sewer of a separate system technically in view of not only diameter of the sewer but also pipe networks.

CHAPTER 9

STUDY OF SEWAGE TREATMENT AND DISPOSAL

CHAPTER 9 : STUDY OF SEWAGE TREATMENT AND DISPOSAL

9.1 Sewage Treatment

9.1.1 General

With regard to the selection of an optimum treatment process, the common practicable processes are comparatively considered first.

a. Activated Sludge Process
   - Conventional Activated Sludge Process
   - Modified Aeration Process
   - Oxidation Ditch Process
   - Extended Aeration Process
   - Step Aeration Process
   - Contact Stabilization Process
   - Modified Aeration Process
   - High-Rate Activated Sludge Process

b. Rotating Biological Contactor Process

c. Trickling Filter Process
   - Low-Rate Trickling Filter Process
   - High-Rate Trickling Filter Process

d. Stabilization Pond Process
   - Aerated Lagoon Process
   - Aerobic Pond Process
   - Facultative Pond Process

In view of the basic purpose of this project comparative alternatives will be selected from the above treatment processes.

9.1.2 Selection of Alternative

(1) Low-rate Trickling Filter

This treatment process has an advantage in loading fluctuation of the influent sewage. Therefore, this process is considered possible to cope with the fluctuation of the inflow due to rain fall during rainy season. However, as the proposed site of treatment plant is located within the enclosure of the existing solid waste disposal land filled with odor and filter flies, and is contiguous with the residential area, further environmental deterioration should be avoided.

The water head loss of the filter bed in this process is greater by 1.5 m to 3.0 m than that in the other processes. If the premise is inclined, this process can be of great advantage by using gravity flow, but it is not suitable for flat ground like the proposed site of treatment facility.

The design filter loading in this process has been 1 to 3 m^3/m^2 per day so far. Assuming that the loading is 3 m^3/m^2 per day, required surface area will be 12,000 m^2 (30 m x 16 ponds), which