PUBLIC WORKS DEPARTMENT
MINISTRY OF INTERIOR

# FEASIBILITY STUDY ON SEWERAGE AND DRAINAGE IMPROVEMENT PROJECT FOR PHUKET MUNICIPALITY IN THE KINGDOM OF THAILAND

# MASTER PLAN REPORT

AUGUST 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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# FEASIBILITY STUDY
# ON
# SEWERAGE AND DRAINAGE IMPROVEMENT PROJECT
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PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a study on the Sewerage and Drainage Improvement Project for Phuket Municipality and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a survey team headed by Mr. Kenji Hori , Nippon Jogesuido Sekkei Co., Ltd. composed of members from the above company and Nippon Koei Co., Ltd. from July to October, 1989 and from January to February, 1990.

The team held discussions with concerned officials of the Government of Thailand, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

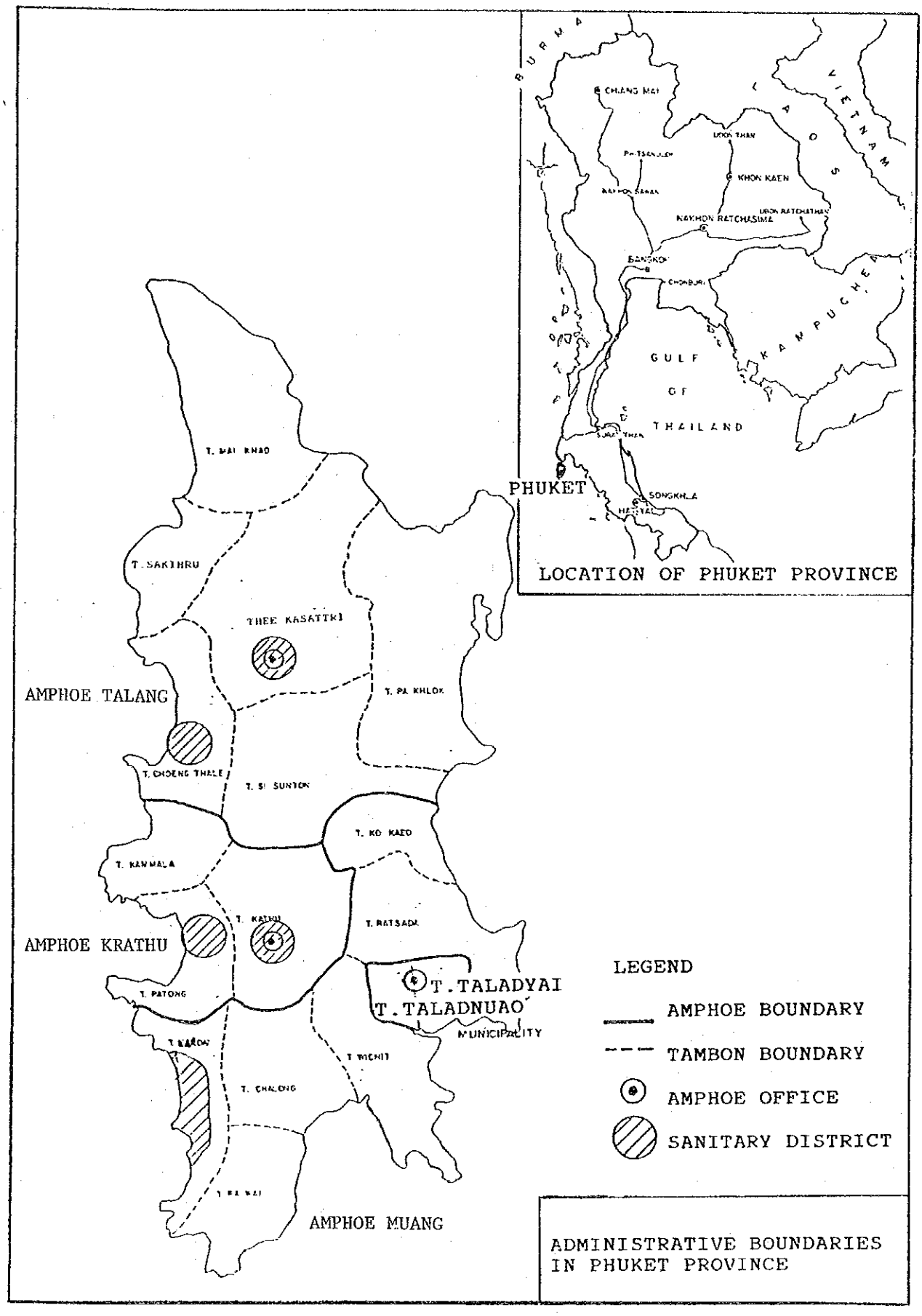
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our tow countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

August, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency


BURMA
LAOS
VIETNAM
KAMPUCHEA
GULF
OF
THAILAND
CHIANG MAI
KHON KAEN
NAKHON RATCHASIMA
BANGKOK
CHONBURI
SONGKHLA
PHUKET
LOCATION OF PHUKET PROVINCE
T. MAI KHAO
T. SAKTHRU
THEE KASATTRI
T. PA KHLOK
AMPHOE TALANG
T. CHOENG THALE
T. SI SUNTON
T. KO KAEO
T. KAMMALA
T. KATHU
T. RATSADA
AMPHOE KRATHU
T. PATONG
T. TALADYAI
T. TALADNUAO
MUNICIPALITY
T. KARON
T. WICHIT
T. CHALONG
T. RAWAI
AMPHOE MUANG
LEGEND
AMPHOE BOUNDARY
TAMBON BOUNDARY
AMPHOE OFFICE
SANITARY DISTRICT
ADMINISTRATIVE BOUNDARIES
IN PHUKET PROVINCE

## ABBREVIATIONS

The following abbreviations have been adopted in this report.

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Thai Government Organizations :

| | | |
|---|---|---|
| AIT | - | Asian Institute of Technology |
| BOS or BS | - | Bureau of Sanitation, BMA |
| BMA | - | Bangkok Metropolitan Administration |
| CPD | - | City Planning Division, Office of Under Secretary of State for BMA |
| DPH | - | Department of Public Health |
| DOH | - | Department of Highways |
| DOI | - | Department of Industry, Ministry of industry |
| DOLA | - | Department of Local Administration |
| DOR | - | Department of Religion |
| DTCP | - | Department of Town and Country Plannning |
| DTEC | - | Department of Technical and Economic Cooperation |
| EGAT | - | Electricity Generating Authority Thailand |
| FRS | - | Foreign Relations Section, Office of Under Secretary of State for BMA |
| HWD | - | Highway Department, Ministry of Communication |
| IEAT | - | Industrial Eastate Authority of Thailand |
| LD | - | Land Department |
| LTD | - | Land Transport Department |
| MD | - | Meteorological Department |
| MOA | - | Ministry of Agriculture |
| MOI | - | Ministry of Interior |
| NEB | - | Office of the Nation Environment Board |
| NESDB | - | National Economic and Social Development Board |
| NHA | - | National Housing Authority |
| NICA | - | National Institute of Coastal Aquaculture |
| NSO | - | National Statistical Office |
| OPP | - | Office of Policy and Planning |
| OUD | - | Office for Urban Development |
| PAT | - | Port Authority of thailand |
| PEA | - | Provincial Electricity Authority |
| PSU | - | Prince Songkhla University |
| PWA | - | Provincial Waterworks Authority |
| PWD | - | Public Works Department |
| RCDP | - | Regional Cities Development Project |
| RID | - | Royal Irrigation Department |
| RTG | - | Royal Thai Government |
| RTSD | - | Royal Thai Survey Department |
| TAT | - | Tourist Authority Of Thailand |
| TISTR | - | Thailand Istitute of Scientific and Technological Research |
| TOCD | - | Techcical Office for Cities Development |

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Other Organizations :

| | | |
|---|---|---|
| ADB | - | Asian Development Bank |
| AIDAB | - | Australian International Development Assistance Bureau |
| IBRD | - | International Bank for Reconstruction and Development |
| JICA | - | Japanese International Cooperative Agency |
| UNDP | - | United Nations Development Programme |
| WB | - | World Bank |

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Technical Term :

| | | |
|---|---|---|
| A/C | - | Asphaltic Concrete |
| BCR | - | Benefit/Cost Ratio |
| B.E. | - | Buddhist Era |
| BOD, BOD5 | - | Biochemical Oxygen Demand |
| DF/R | - | Draft Final Report |
| CI | - | Castiron, grey |
| CIF | - | Cost Insurance and Freight |
| CL | - | Chloride Ion |
| COD | - | Chemical Oxygen Demand |
| DO | - | Dissolved Oxygen |
| DS | - | Dissolved Solids |
| DWF | - | Dry Weather Flow |
| EIRR | - | Economic Internal Rate of Return |
| FIRR | - | Financial Internal Rate of Return |
| F/R | - | Final Report |
| F/S | - | Feasibility Study |
| FY | - | Fiscal Year |
| GPP | - | Gross Provincial Product |
| H2S | - | Hydrogen Sulfide |
| IC/R | - | Inception Report |
| IT/R | - | Interim Report |
| JSWA | - | Japan Sewage Works Agency |
| IRR | - | Internal Rate of Return |
| Klong | - | Canal (Thai word) |
| M/P | - | Master Plan |
| MPN | - | Most Probable Number |
| msl, MSL | - | Mean sea Level |
| NPV | - | Net Present Value |
| O & M | - | Operating and Maintenance Costs |
| p.a. | - | Per Annum |
| pH | - | pH Value |
| PVC | - | Polyvinyl Choride Pipe |
| SS | - | Suspended Solids |
| SW | - | Solid Waste |
| TOR | - | Terms of Refernce |
| TS | - | Total Solids |
| WS | - | Water Supply |
| WT | - | Water Temperature |
| WW | - | Wastewater |

---

Units of Measurement :

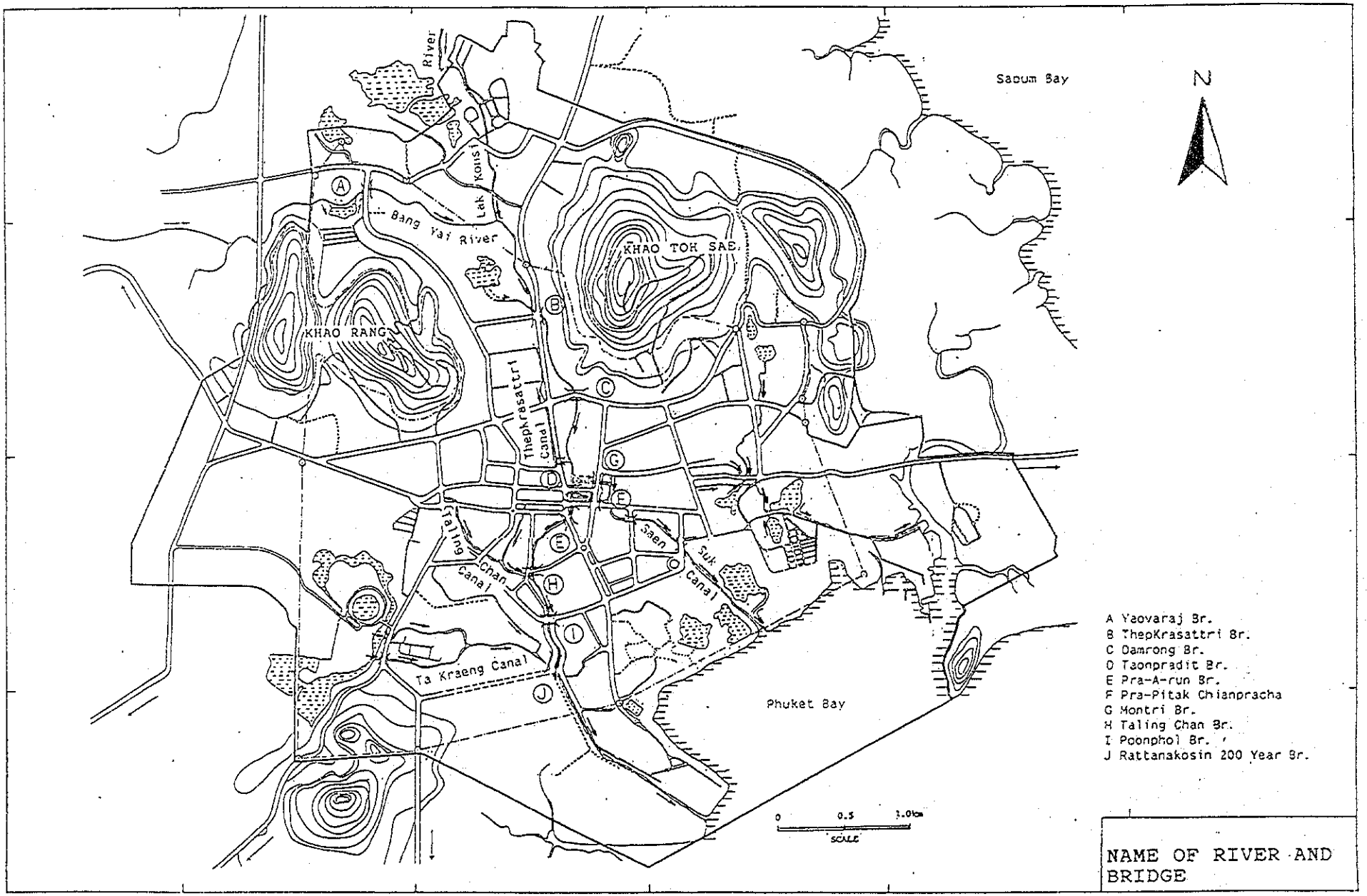
| | | | | |
|---|---|---|---|---|
| ฿, B | - | baht | - | Thai Currency |
| M฿, MB | - | million baht | - | Thai Currency |
| °C | - | degree Celsius | - | Temperature Unit |
| cfs,ft3/s | - | cubic foot per second | - | Flow Rate Unit |
| d | - | day | - | Time Unit |
| cm | - | centimeter | - | Length Unit |
| cms,m3/s | - | cubic meter per second | - | Flow Rate |
| ft | - | foot | - | Length Unit |
| gal | - | U S gallon | - | Volume Unit |
| g, gm | - | gram | - | Weight or Mass Unit |
| gpcd | - | gram per capita per day | - | Loading Consumption Rate |
| gpm | - | U S gallon per minute | - | Flow Rate |
| ha | - | hectare | - | Area Unit |
| h, hr | - | hour | - | Time Unit |
| HP | - | horse power | - | Power Unit |
| Hz | - | hertz (cycle per second) | - | Frequency Unit |
| kg | - | kilogram | - | Weight Unit |
| km | - | kilometer | - | Length Unit |
| kV | - | kilovolt | - | Electric Potential Unit |
| kW | - | kilowatt | - | Power Unit |
| kWh | - | kilowatt-hour | - | Energy Unit |
| l | - | liter | - | Volume Unit |
| lb | - | pound | - | Weight or Mass Unit |
| lpcd | - | liter per capita per day | - | Water Consumption Rate |
| m | - | meter | - | Length Unit |
| mm | - | millimeter | - | Length Unit |
| m/sec | - | meter per second | - | Velocity Unit |
| m2 | - | square meter | - | Area Unit |
| m3 | - | cubic meter | - | Volume Unit |
| m3/s, cms | - | cubic meter per second | - | Flow Rate |
| m3/day | - | cubic meter per day | - | Flow Rate |
| m3/min | - | cubic meter per minute | - | Flow Rate |
| m3/day/m2 | - | cubic meter per day per square meter | - | Surface Loading |
| m3/m2/day | - | cubic meter per square meter per day | - | Surface Loading |
| mg | - | milligram | - | Weight or Mass Unit |
| mg/l | - | milligram per liter | - | Density Unit |
| ppt | - | part per thousand | - | Density Unit |
| Rai, rai | - | rai | - | Thai Unit Measurement of Area |
| rpm | - | revolution per minute | - | Angular Velocity |
| s,sec | - | second | - | Time Unit |
| sq km | - | square kilometer | - | Unit Measuerment of Area |
| yr | - | year | - | Time Unit |

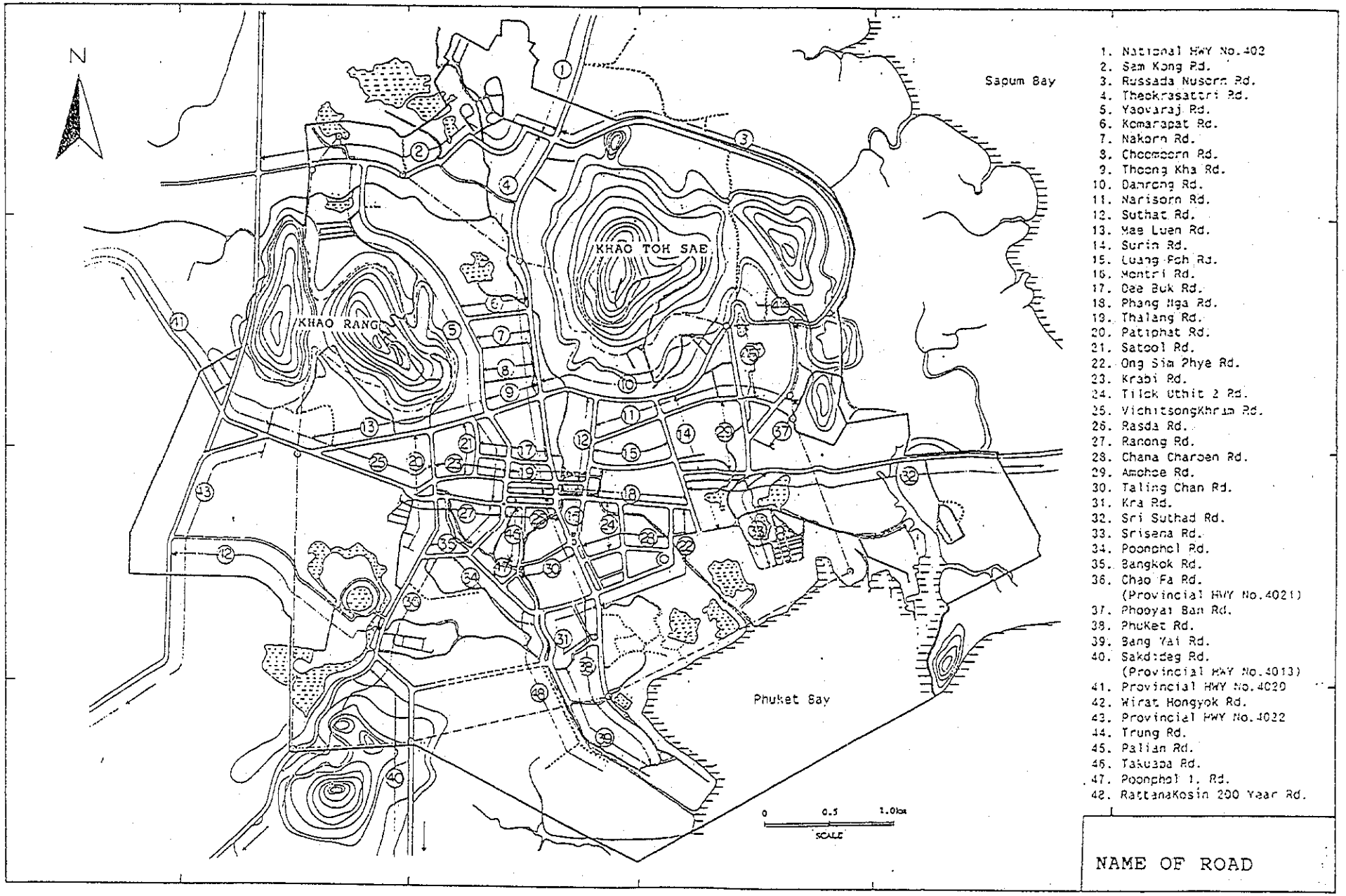
Conversion Table :

| | | | |
|---|---|---|---|
| 1 acre | = | 2.53 | rai |
| 1 cfs | = | 0.0283 | cms |
| 1 cms | = | 35.31 | cfs |
| 1 ft | = | 0.3048 | m |
| 1 ft2 | = | 0.0929 | m2 |
| 1 ft3 | = | 0.0283 | m3 |
| 1 hectare | = | 6.25 | rai |
| 1 inch | = | 2.54 | cm |
| 1 inch | = | 25.4 | mm |
| 1 kg | = | 2.205 | pounds |
| 1 km | = | 0.6214 | miles |
| 1 km2 | = | 100 | hectares |
| 1 m | = | 3.28 | ft |
| 1 m2 | = | 10.7584 | ft2 |
| 1 m3 | = | 35.31 | ft3 |
| 1 mile | = | 1.6093 | km |
| 1 ngan | = | 400 | m2 |
| 1 rai | = | 1600 | m2 |
| 1 tarangwa | = | 4 | m2 |
| 1 ton | = | 1000 | kg |
| 1 wa | = | 2 | m |

Currency Conversion:

| | | |
|---|---|---|
| 1 Baht | = | 5.7 Yen |
| 1 U.S. Dollar | = | 143 Yen |
| 1 Yen | = | 0.175 Baht |


Sapum Bay
N
Kous Lak
Bang Yai River
KHAO TOH SAE
KHAO RANG
Thephrasattri Canal
Taling Chan Canal
Saen Suk Canal
Ta Kraeng Canal
Phuket Bay
A
B
C
D
E
F
G
H
I
J
0 0.5 1.0km
SCALE
A Yaovaraj Br.
B ThepKrasattri Br.
C Damrong Br.
D Taonpradit Br.
E Pra-A-run Br.
F Pra-Pitak Chianpracha
G Montri Br.
H Taling Chan Br.
I Poonphol Br.
J Rattanakosin 200 Year Br.
NAME OF RIVER AND BRIDGE


N
KHAO RANG
KHAO TOH SAE
Sapum Bay
Phuket Bay
0
0.5
1.0km
SCALE
1. National HWY No.402
2. Sam Kong Rd.
3. Russada Nusorn Rd.
4. Thaokrasattri Rd.
5. Yaowaraj Rd.
6. Komarapat Rd.
7. Nakorn Rd.
8. Choomporn Rd.
9. Thoong Kha Rd.
10. Damrong Rd.
11. Narisorn Rd.
12. Suthat Rd.
13. Mae Luen Rd.
14. Surin Rd.
15. Luang Poh Rd.
16. Montri Rd.
17. Dee Buk Rd.
18. Phang Nga Rd.
19. Thalang Rd.
20. Patiphat Rd.
21. Satool Rd.
22. Ong Sim Phye Rd.
23. Krabi Rd.
24. Tilok Uthit 2 Rd.
25. VichitsongKhram Rd.
26. Rasda Rd.
27. Ranong Rd.
28. Chana Charoen Rd.
29. Amphoe Rd.
30. Taling Chan Rd.
31. Kra Rd.
32. Sri Suthad Rd.
33. Srisena Rd.
34. Poonphol Rd.
35. Bangkok Rd.
36. Chao Fa Rd.
(Provincial HWY No.4021)
37. Phooyai Ban Rd.
38. Phuket Rd.
39. Bang Yai Rd.
40. Sakdideg Rd.
(Provincial HWY No.4013)
41. Provincial HWY No.4020
42. Wirat Hongyok Rd.
43. Provincial HWY No.4022
44. Trung Rd.
45. Palian Rd.
46. Takuapa Rd.
47. Poonphol 1. Rd.
48. RattanaKosin 200 Year Rd.
NAME OF ROAD

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ANNEX

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# CHAPTER 1

# EXECUTIVE SUMMARY

# CHAPTER 1 : EXECUTIVE SUMMARY

## 1.1 Background Information

Phuket Island is a scenic resort located in the southern part of Thailand, considered as one of the most popular tourist spots in the country. Being the capital of the island, Phuket City has become the center of activities of the tourism industry in the area, triggering the rapid growth of related services. This has resulted to the sharp increase in the amount of wastewater to an extent beyond natural purification, posing environmental and sanitary problems to waterways and surroundings.

At present, there is no public sewerage system in Phuket City. Human excreta are disposed through cesspools or septic tanks installed at almost all houses and buildings in the town area, with the effluent allowed to leach into the ground or discharge into the watercourse through street gutters or the nearest drain. Wastewater from washing, baths and kitchens is also discharged to the nearest drains, making the watercourse which traverses the area as a convenient receiving body for a large portion of all sorts of wastes.

Phuket City is situated on the coastal plain of the Bang Yai river which has a catchment area of 72 $km^3$ and a bankful capacity of about 30 $m^3/sec$. This capacity is quite small, causing the frequent inundation of the city in the occurrence of heavy rainfall.

Based on the study of rainfall and basin characteristics, the highest flood peak occurred on 27 September 1986, corresponding to the largest recorded flood which inundated most of the city area.

Aware of these predicaments, the city since 1980 has emphasized their solutions in its plan for the development of the basic infrastructure and in fact has advocated the establishment of a comprehensive public sewerage and flood control master plan for the area.

## 1.2 Purpose and Scope of the Study

The main purposes of the study on the sewerage system and flood control for Phuket City are as follows:

(1) Develop a comprehensive master plan for sewerage system in which the main elements of the relevant subjects are properly forecast and generally defined for implementation in successive phases to meet the present and future needs in the study area up to the year 2006 on the basis of technical and socio-economic considerations.

(2) In particular, identify sewerage projection area, and sewage collection system, develop implementation program and explore possible sources of funds and incomes for construction, operation and maintenance.

(3) Develop a long term master plan for flood control in which the

major elements of the relevant subject matters are properly forecast and generally defined for implementation in successive phases to meet the present and future needs in the study area on the basis of technical and socio-economic considerations.

(4) In particular, identify scale and effectiveness of flood control plan, develop implementation program and explore possible sources of funds and incomes for construction and maintenance.

(5) Undertake studies and formulate recommendations concerning the proper organization to effectively and smoothly carry out the planning and designing, construction, operation, management and administration of both the sewerage system and the flood control plan, respectively.

(6) Recommend high priority areas for implementation of sewerage system and interim measures for implementation of flood control plan to be selected for Feasibility Study as urgent construction and rehabilitation project.

## 1.3 Findings and Recommendations

### 1.3.1 Findings

(1) Current Situation of Sewerage System

1) Like in other big cities in Thailand, surface runoff and domestic wastewater in Phuket City are discharged into storm gutters constructed along the paved streets.

In newly developed areas, the sullage from kitchens, washing, bath and septage are discharged to rivers or the sea through the storm drainage system. In the center of the town, sullage is also drained into the street gutters, but approximately one-third volume of human waste discharged from households is infiltrated into the ground and the remainder is drained into the gutters. (Refer to Chapter 4.1.3.)

The existing storm drainage system, therefore, practically serves as a combined sewage collection system, even if it was not originally planned for such purpose. This results not only in the pollution of waterways but also in groundwater pollution.

2) To understand the current situation on the disposal of domestic wastewater and existing toilet system, a questionnaire was passed to residents and Municipal officials. The outcome of the survey showed that 44 percent of the households use pour-flush cesspool type toilet which is on-site leaching, and the remaining 56 percent use septic tank or Thai standard type. Result of the survey is summarized and discussed in Chapter 4.1.3.

(2) Existing Storm Drainage System

1) Phuket City has been occasionally subjected to widespread inundation due to the following fundamental reasons.

a. Defects on drainage facilities and insufficient existing drainage network in the city area

b. Insufficiency of channel capacity of Bang Yai river

2) Most of the runoff in the city is drained into the Bang Yai river or its tributary canals through the street side drains. At some outlets of side drains, sluice gates are installed to prevent intrusion of river water during flood.

Capacity of the drains are not enough to convey the whole storm water from road surfaces, especially at the skirts of Mt. Rang and Mt. Toh Sae.

3) The drainage sewers are poorly maintained because of the limited implementation staff, limited finance and lack of public cooperation. It is very important to regularly maintain and clean the existing drainage facilities (Refer to Chapter 4.1.2).

4) It is emphasized that the flooding which occurred in 1986 was the worst in the last two decades. The inundated area was remarkably wide and covered most of the city.

5) An interview survey was conducted to grasp the inundation situation in the study area. The summary of interview survey result is attached in Annex Table 6.1.

(3) Tidal Areas

The major rivers and canals in Phuket, namely Bang Yai river, Saen Suk and Ta Kraeng canals are tidal rivers. Reversal of the seawater flow are assessed to occur a little upstream of the sewage lift pump station located on Takua Pa Rd. along Bang Yai river, and at the river crossing on Tilok Uthit 2 Rd. along Saen Suk river. The effects of seawater level are observed to reach a little upstream of the river crossing on Thalang Rd. along Bang Yai river, and at the middle point between Dee Buk Rd. and Thoong Kha Rd. along Thepkrasattri channel. (Refer to Chapter 5.2.1 (5) and 8.2. (1). 5).)

(4) Flooding Condition

1) Overview of Flood Condition

Although hydrological information on past floods such as flood discharge and water level, and even flood damage data are not available, it is widely believed that the flooding which occurred in 1986 was the worst in the last two decades. According to the interview survey, the inundation during the said event was so serious that some areas were submerged for up to 3 days.

The Study Team collected from the files of the city office photographs taken during the historical floods of September 27, 1986, October 15, 1975 and August 15, 1983. By means of these photographs and information from the interview survey, the flood prone area was reasonably delineated for the flood damage study. (Refer to Chapter 11.2)

2) Existing Flood Control Measures

a. Floodway Project by DMR

A floodway construction project managed by the Department of Mineral Resources (DMR) to divert the water of Bang Yai river from Sam Kong village to the Sapum bay is ongoing. However, the project encountered technical and financial problems in the course of implementation, casting doubts on its timely completion.

According to an official in the DMR Phuket office, DMR does not intend to continue with the excavation work to complete the floodway.

b. Levee Construction

After the flood of 1986, Phuket City constructed a levee along the right bank of Bang Yai river before its course to veers the south, with a length of about 800 m and 1.5 - 2.0 m high. A small levee about 200 m long and less 1.0 m high also exists along a tributary joining Bang Yai river just upstream of Thepkrasattri Br.

c. Mining Pond

It is noteworthy to indicate that mining pits scattered in the basin presently contribute to the attenuation of flood peak discharge because of their inherent detention capacity. If these pits are filled and densely built up in the future, more serious flooding in the downstream area brought about by a rapid concentration period is predicted. Potentials and effectiveness of the pits were duly examined. (Refer to Chapter 11.2).

### 1.3.2 Conclusions

On the basis of the field investigation on the current situation of sewerage as well as drainage and flooding of the study area, definition of fundamental planning in relation to the project implementation is considered. The basic aspect of such consideration are summarized as follows:

(1) Target Year for Sewerage Plan

The target year for the sewerage improvement project is proposed to be the year 2006 (2549) or 17 years from 1989. (Refer to Chapter 7.1.1 )

(2) Study Area for Sewerage Plan

The proposed study areas refer to the following:

1) DTCP planning area for Phuket City

2) Area between the DTCP planning boundary and the Bang Ping river

(3) Population of Project Area

Population of the Project area in the target year of 2006 is estimated at about 78,200. (Refer to Chapter 3.1.2 and 7.1.3)

The Master Plan of a sewerage system for the study area will be planned on basis of the estimated service population.

(4) Design Sewage Flow

1) Per capita sewage flow for domestic

In 1988, the amounts of water production and consumption were 4,663,520 cu.m. and 4,207,750 cu.m., respectively. The average annual growth rate of water consumption was 13.4 percent in the past four years, owing mainly to the favorable increase in the number of connections.

The breakdown of the number of connection is 74.6 percent for residential, 22.8 percent for commercial and the remaining 2.6 percent for government and industrial use.

The apparent per capita consumption has rapidly increased from 336 lpcd in 1984 to 456 lpcd in 1988 on precondition of 4.58 persons per household in 1984 and 4.30 persons per household in 1988, respectively.

If small water consumers or those who use less than 100 cu.m/y and large water consumers or those who use more than 1,500 cu.m/y were excluded and the rest are classified as common households, the amount of 2,061,616 cu.m/y (49%) is used up at 4,521 such connections (77%). Based on the above figures and on the assumption of 4.3 persons per household, the present per capita domestic consumption is calculated to be 291 l/d.

Compared with other similar cities in Thailand, this value is considerably high. Accordingly, in the forecast of future water demand, rapid growth of per capita domestic water demand is not expected, hence only a slight increase in the per capita consumption is proposed at 300 l/d in 2006. The absolute amount of big consumers is assumed to continue until the target year. (Refer to Chapter 3.2.2 and 3.2.3).

2) Water consumption for business and others

Water consumption for business establishments and others including government offices, hotel, restaurant, etc. are summarized in table 1.1:

Table 1.1 Water Consumption for Business

| | | |
|---|---|---|
| Domestic Consumption | 78,200 ps x 300 lpcd | 23,460 cu.m/d |
| Other Domestic Consumption | same as present | 3,494 " |
| Governmental Consumption | 7,820 ps x 10 lpcd | 782 " |
| School Consumption | 30,000 ps x 12 lpcd | 360 " |
| Hospital Consumption | 356 beds x 1.0 cu.m/d.bed | 356 " |
| Hotel Consumption | 3,500 rooms x 1.2 cu.m/d.rm | 4,200 " |
| Industrial Consumption | same as present | 684 " |
| Restaurant Consumption | 5% of Domestic consumption | 1,164 " |
| Total | | 34,500 cu.m/d |

The above amount of water consumption is study area-wide and on the assumption of the following:

- No private shallow well is required but City Waterworks serve all houses by the year of 2006.
- Every figure in the future development plan prepared by the Study Team is followed.

The apparent per capita consumption based on the above analysis is 440 l/d. (Refer to Chapter 3.2.2 and 3.2.3)

3) In the calculation of planned sewage flow, 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 $m^3/d$

(Refer to Chapter 7.1.4.)

(5) BOD Loading

1) Domestic Wastewater

It is noted that a suitable design value of daily per capita BOD5 contribution of domestic waste for tropical developing countries is about 40 gpcd in 1975, broken down into 22 gpcd for toilet-feces and 18 gpcd for other domestic sullage.

With reference to a relevant design background of the existing sewage treatment plant in Thailand, the proposed daily per capita BOD loading discharged from domestic households including sullage and water closet is 42 gpcd in 1989 and projected to

dually increase to 54 gpcd in the year 2006 as shown in Table 1.2:

Table 1.2 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 |

For the purpose of sewerage planning, the above BOD values are based on the assumption that all watercloset are connected to public sewers.

Therefore, in case of introduction of combined sewage collection system, an arrangement to mitigate BOD loading is required be cause at present, cesspool type toilet where leaching is infiltrated into the ground is used in 44 percent of the households in the study area. (Refer to Chapter 7.1.5.)

In this case, the proposed BOD loading is 24.2 gpcd in 1989 and projected to gradually increase to 43 gpcd in 2006. (Refer to Chapter 7.1.5)

Table 1.3 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) Planned Sewage Quality

From the result of the study on sewage collection system, a combined sewer system with partially separate sewer was recommended.

Therefore, the planned sewage quality turned out as follows:

Table 1.4 Planned Sewage Quantity

| | |
|---|---|
| - BOD Loading | |
| Combined system area | |
| Domestic 61,000 ps. x 43 gpcd | = 2,623,800 g/d |
| Hotel 3,500 rooms x 1.8 ps./R x 43 gpcd | = 270,900 g/d |
| Separate System Area | |
| Domestic 17,200 ps. x 54 gpcd | = 728,800 g/d |
| Factory | = 379,700 g/d |
| Total | 4,202,400 g/d |
| - Wastewater quantity | |
| Wastewater = (water supply demand) x (1 - water loss rate) | |
| = 34,682 $m^3$/d x (1 - 0.2)= 27,746 $m^3$/d | |
| Infiltrated groundwater = (water supply demand) x 0.2 | |
| = 34,682 x 0.2 = 6,936 $m^3$/d | |
| Total | 34,682 $m^3$/d |

Accordingly, the influent BOD is calculated is follows:

$$BOD = \frac{4,202,400 \text{ g/d}}{34,682 \times 10^3 \text{ l/d}} = 121 \text{ mg/l} \quad \text{say } 120 \text{ mg/l}$$

(Refer to Chapter 7.1.5)

(6) Sewage Collection System

For decision-making on the appropriate sewage collection system for the city, definitions of the proposed systems are illustrated herewith for ready reference. Discussions on advantages and disadvantages of each alternative and foreseen problems are also included. Pictorial detail of two alternatives, namely a separate system and combined system are shown in Fig. 8.1 to 8.2, respectively. (Refer to Chapter 8.)

With reference to the above alternatives, it is noted that these alternative plans are recommended on the premise that the proposed sewage treatment facilities will be located in the area which is presently used for garbage disposal.

Conclusions on the preliminary comparisons of alternatives re garding improvement of environmental conditions and foreseen trouble issues are summarized in the following table:

## Table 1.5 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.<br>(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.<br>(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.<br>(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.<br>(3) Groundwater pollution caused by wastewater infiltration can be overcome. | (1) Environmental conditions of the rivers and the sea will be upgraded.<br>(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.<br>(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.<br>(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.<br>(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.<br>(2) Users will be double charged for both sewerage and septic tank cleaning services.<br>(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.<br>(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.<br>(2) Fewer or limited amount of lateral sewers and lesser house connections will be required in the City side. |

(7) Sewage Treatment Process

Comparison of the alternatives was elaborated on the construction cost, operation and maintenance cost various operational characteristics. An overall evaluation was made to select the optimum treatment process. The result was summarized as follows:

Table 1.6 Comparison of Sewage Treatment Processes

| | Conventional Activated Sludge Process | Rotating Biological Contactor Process | Oxidation Ditch Process |
|---|---|---|---|
| Construction Cost | A | C | A |
| O/M Costs | A | C | A |
| Various Characteristics | C | B | A |
| Overall Evaluation | B | C | A |

From result of the evaluation the oxidation ditch process was recommended as the optimum sewage treatment process for the project. (Refer to Chapter 9.3)

(8) Proposed Improvement of Drainage Facilities

1) It is observed that the existing storm water drainage system generally has a corresponding capacity of a rainfall return period of 1 to 1.5 years. In the planning of the drainage system in the study area, topographical conditions, maximum utilization of the existing drainage system, power-saving and the uniform level of capacity for the whole system should be considered.

In this connection, the recommended improvement plan is divided into 3 planning areas. One is the public drainage area covering almost all of the town except the southeastern part of the city; the second is Taling Chan retarding pond area covering the present Taling Chan pumping station area; and the third is Ta Kraeng new diversion canal area covering the foot of Khao Rang and the public park.

2) The proposed improvement of drainage facilities in the above mentioned public drainage area are planned to manage a 5-year probable rainfall.

Total length of drain and box culvert to be constructed is approximately 8,200 m.

3) The recommended improvement of drainage system in Taling Chan canal area consists of the construction of a retaining pond, to temporarily store storm water at times of intense rainfall and high river stage and then discharge it into the Bang Yai river during the low tide. Operation of the existing pumping station

in conjunction with the retaining pond will be further studied in the Feasibility Study Stage. The proposed retaining pond has a volume of approximately 114,000 cu.m. and is designed to manage a 5-year probable rainfall without considering the use of the pumping station. (Refer to Chapter 10.2.4)

4) It is recommended to enlarge the existing cross section of Ta Kraeng new diversion canal to cope with the peak storm discharge and to release the flood flow to the Phuket bay through the proposed new diversion canal. Since the ground level along the canal is nearly same as the high water level, a low levee is constructed considering an adequate free board to meet the runoff of a 5-year probable rainfall.

(9) Proposed Master Plan Implementation Cost of Sewerage System

The implementation costs of sewerage system excluding land acquisition, engineering fee and contingency, are as follows:

Table 1.7 Implementation Costs

| Facilities | Estimated Capital Cost |
|---|---|
| Sewers | 204.2 Baht $10^6$ |
| S.T.P. | 321.0 |
| Drainage | 108.3 |
| Total | 633.5 |

(10) Alternative Plan of Flood Control

1) Planning Scale of Flood Control

The peak discharge during the flood of 1986 is estimated at 154 cu.m/sec, which magnitude is equivalent to a flood discharge with a return period of about 20 years. In order to ensure the safety of Phuket City against such a large flood, the planning scale of Master Plan for flood control was decided at 30 years probability.

Master Plan aims at a long-term stability of facilities and livelihood of the inhabitants in the basin. On the other hand, provisional plan is also considered to meet urgent social requirements as early as possible.

2) Alternative Plans on Flood Control

The following structural measures were selected to formulate competitive alternative plans.

- River improvement
- Floodway
- Flood retarding pond

The existing channel capacity of the Bang Yai river is inadequate and significantly narrow sections exist in the downtown

area. Widening and improvement of river course was considered including replacement and reconstruction of the bridges. Construction of floodway to convey flood flow coming from outside the Municipal area was considered. Potential route was identified on topographic map of scale 1:4,000 as well as through field reconnaissance .

Low flat area located near the ring road in Katu district was considered as site for the flood retarding basin. In order to minimize embankment and excavation volume, appropriate scale of development was preliminarily examined on the topographical map.

The components of respective alternative plans are tabulated below:

Table 1.8 Components of Alternative Plans

| Scheme | River Improvement | Flood Retarding Pond | Floodway |
|---|---|---|---|
| 1. A | Large Scale | x | x |
| 2. B | Middle Scale | Large Scale | x |
| 3. C-1 | Small Scale | x | North |
| 4. C-2 | - do - | x | East |
| 5. C-3 | - do - | x | South + East |
| 6. D-1 | - do - | Small Scale | North |
| 7. D-2 | - do - | - do - | East |
| 8. D-3 | - do - | - do - | South + East |

(11) Proposed Master Plan on Flood Control

The project costs for each scheme were estimated as follows:

Table 1.9 Project Costs of Alternatives

| Scheme | Total Project Cost (Baht $10^6$) |
|---|---|
| 1. A | 2,282 |
| 2. B | 1,623 |
| 3. C-1 | 428 |
| 4. C-2 | 340 |
| 5. C-3 | 401 |
| 6. D-1 | 391 |
| 7. D-2 | 335 |
| 8. D-3 | 408 |

The alternative schemes do not have any particular technical difficulties. Therefore, the master plan is selected mainly on the basis of socio-economic considerations.

According to the Phuket municipal office, it is very difficult to acquire the land in the retarding pond area. Therefore, it is concluded and recommended that scheme C-2 should be selected as the master plan for flood control because it will not bring

about any serious social problem and the cost do not differ appreciably from that of the least cost scheme D-2.

The outline of each project is as follows:

(i) East floodway

The flood regulated by the retarding ponds is diverted to the Sapam bay completely through the east floodway and the discharge from the diversion point into the town is limited to 5 cu.m/s. The design discharge is 152 cu.m/s at the diversion inlet and 184 cu.m/s at the outlet of the floodway taking into account the runoff from the residual basins.

(ii) River improvement

The design river bed was determined in consideration of the inadequacy of channel capacity in some sections. The measures for river improvement were determined to match the existing channel structures, such as vertical concrete walls, wet masonry and earth embankment.

Embankments along both banks are required near the river mouth to a distance of around 600 m upstream, and on the left bank between Ratanakosin 200 year bridge, a length of about 480 m. Further, raising of the existing retaining wall is recommended at narrow channel sections along Thepkrasattri road. The river bend behind the gas station will be changed to a new channel with a smooth curve. Saen Suk intake and six bridges are recommended to be reconstructed.

The principal feature of the proposed plan is presented as below.

1) River Improvement

- Channel dredging: 33,800 $m^3$ (l=1,300 m)
- Embankment: 74,400 $m^3$ (l=1,700 m)
- Revetment: 600 m
- Raising of existing retaining wall: 200 m (h=1.0 m)
- Reconstruction of Saen Suk offtake

2) Floodway

East floodway

- From just upstream of Yaovaraj bridge (Sam Kong village) to Sapum bay.
- Length: 4,330 m
- Width of channel: 28 m at bottom
- Slope: 1:2.0 with revetment
- Excavation: 1,500,000 $m^3$

### 1.3.3 Recommendations

(1) Proposed Sewage Collection System

1) Generally a separate sewer system is advantageous for it conducts only wastewater to treatment plant and never releases wastewater to storm drains during wet weather. However to respond to the immediate needs, a combined sewer system utilizing the existing storm water drainage facilities is recommended for the study area.

2) The intercepting sewers of the recommended combined system can be transformed to trunk sewers of a separate system in the future from the viewpoint of not only the size of the sewers but the main sewer network as well. It should be considered when financing for a complete separate system is possible in the future.

(2) Proposed Sewage Treatment Process

1) Because of its advantage in the overall evaluation which took into account the construction cost, operation and maintenance cost and various characteristics, the oxidation ditch process is recommended.

2) As for sedimentation tank for storm water in the proposed treatment process, simple tanks with short detention time and which have no mechanical scraper is recommended in order to restrict removal of particle BOD element in this process considering easy handling in the sludge dewatering, and to save on the implementation cost.

3) Drying beds are recommended for sludge dewatering without any thickener and digester because the sludge from the oxidation ditch process is comparatively more stable than in other treatment methods.

The sludge loading is desirable to be less than 4.0 kg/sq.m but 4.5 kg/sq.m loading is suggested in this study to avoid over-investment, since sludge drying is considerably affected by natural weather condition. Review of planning is recommended in this regard.

# CHAPTER 2

# THE STUDY AREA

# CHAPTER 2 : THE STUDY AREA

## 2.1 Natural Condition

### 2.1.1 General

Phuket is a tiny island located in southern Thailand with an area of about 543 $km^2$ and a population of 168,000. It lies within 98° 21' East longitude and 7° 58' North latitude in the west coast of the Andaman sea. The island stretches about 50 km from north to south and 20 km from east to west.

The provincial capital, Phuket City, is located at the south-eastern part of the island and has a population of about 50,000. The city is established on the coastal plain of the Bang Yai river.

Bang Yai river is a small stream with a catchment area of 56 $km^2$ at the entrance of the municipality, and a low flow discharge of around 0.4 m3/s. However, big floods occasionally occur after a few hours of heavy rainfall, often threatening the city. Since the flow capacity of the Bang Yai river is only about 35 $m^3/s$, the city is frequently inundated. The heaviest inundation occurred on 11 November 1986 (B.E.2529).

### 2.1.2 Topography and Geology

(1) Topography

Phuket City has developed on the delta of the Bang Yai river. Topography of the city area is generally flat except for the dominant features of two mountains, Mt. Toh Sae and Mt. Khao Rang.

Mt. Toh Sae (285 meters in elevation) locates northeast of the city and Mt. Rang (160 meters in elevation) stands in the northwest.

The Bang Yai river originates at Mt. Phanthurat, flows to the east at north side of Mt. Rang, changes flow direction to the south at the foot of Khao Toh Sae, and runs between Mt. Rang and Mt. Toh Sae through the city center into Phuket bay.

The elevation of ground surface is about 10 meters in the northern part of the city and gradually declines to zero at the river mouth in the southern part.

In the rainy season, storm water from the watershed rapidly collects into the Bang Yai river and flows down quickly to the city area.

The flow capacity of the Bang Yai river is not large enough to drain storm water instantly, thereby resulting to inundations.

(2) Geology

Geological survey was carried out in order to have an insight on the outline of subsurface condition of the area.

The locations of 9 boring holes are shown in Annex Figs. 2.1 and 2.2.

Boring survey result of BH-1 to BH-6 is used for sewerage facility planning and that of BH-7 to BH-9 is for flood control.

The drilling and sampling were executed during the period between September 25 and October 3, and laboratory testings were performed sequentially. The test results are presented in Volume II of this report.

Boring survey revealed the following:

(i) Subsurface condition is not uniform. Each boring log varies individually except BH-5 and BH-6. Every point has its own stratum composition.

(ii) Hard stratum of silty clay with N value more than 30 which ap pears at a depth of 10 to 14 meters from ground surface is a possible bearing stratum for sewerage facilities.

Sandy layer or clayey layer overlying the above stratum is not considered satisfactory for foundation stratum.

(iii) It was impossible to drill deeper than 10 meters because hard material was encountered at the location of BH-2. The same condition was experienced in a borehole located 2 meters away which was later drilled.

(iv) Boring logs from BH-7 to BH-9 which are located upstream of the Bang Yai river outside the city show that both sandy soil and clayey soil are obtainable near ground surface.

The geological profile along the Bang Yai river is presented in Annex Fig. 2.3. This was drawn on the basis of 6 boring logs by connecting similar stratum of adjacent boring logs.

Details of soil condition at particular location can be obtained from Volume II of this report.

2.1.3 Meteorology and Hydrology

There are three meteorological stations in the island. One is in the city, another one is at the Phuket airport in the northern part of the island and the third is at the Bang Wad dam in the Bang Yai river basin.

The meteorological station at the airport is well equipped and connected with Bangkok headquarters by telemeter.

The meteorological station in Phuket city is also well equipped

and in good operating condition. Items observed at the station and instruments used are as follows:

| | | |
|---|---|---|
| Air temperature | : | mercurial thermometer,<br>highest and lowest mercurial thermometer |
| Dew Point | : | by a correlation chart between air temperature, wet bulb temperature and dew point |
| Relative humidity | : | dry and wet bulb mercurial thermometer |
| Atmospheric pressure | : | mercury barometer,<br>aneroid auto-recording barometer |
| Rainfall | : | ordinary gauge, dia=20 cm<br>auto-recording (one-day roll), dia=36 cm |
| Evaporation | : | 120 cm dia evaporation pan |
| Wind direction | : | equipment type is not identified |
| Wind velocity | : | Robinson 3-cup anemometer |

All the items are measured and recorded every three hours. All the data measured here are reported to the Meteorological Department in Bangkok once a month and only the daily summary is kept at the station. The daily summary consists of daily rainfall, daily highest and lowest air temperature, and daily relative humidity at 07:00 o'clock every morning.

The air temperature (monthly average highest and lowest, and at 07:00 o'clock), the relative humidity at 07:00 o'clock, and the monthly rainfall are illustrated below:

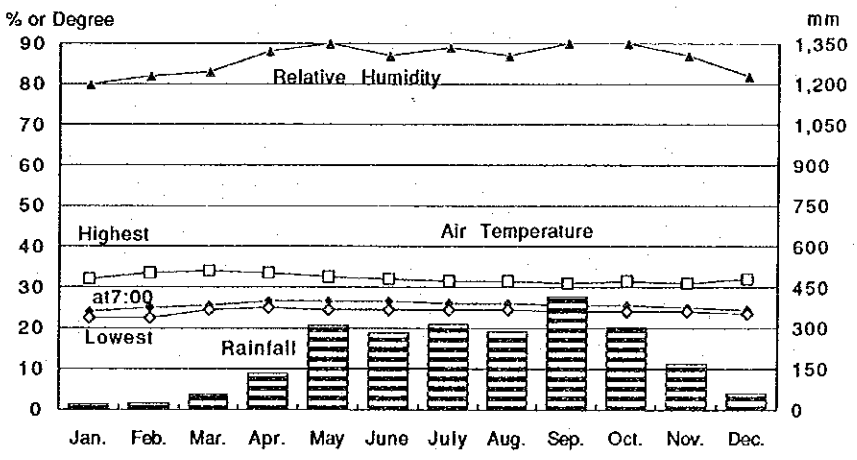



Fig. 2.1 Air Temperature and Relative Humidity

Variation of the air temperature and relative humidity in a day during the month of August 1989 and January 1990 are illustrated below:

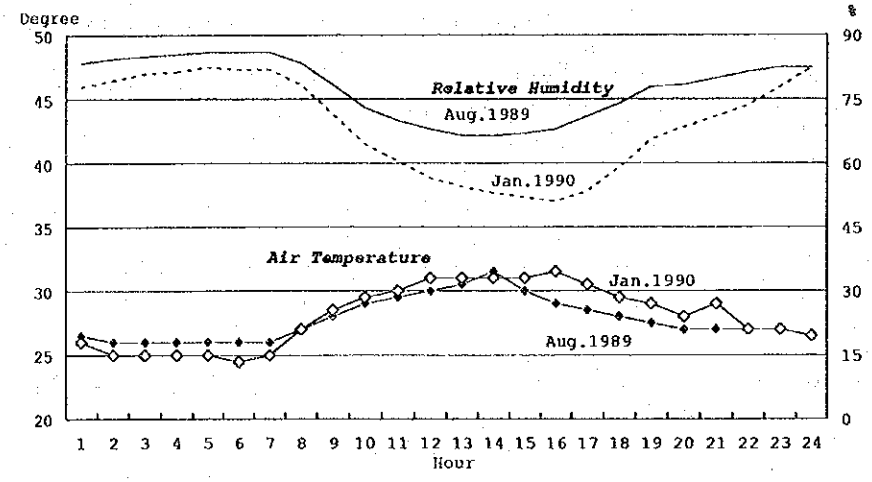



Fig. 2.2 Variation of Air Temperature and Relative Humidity

As seen in these figures, hourly and seasonal variations of air temperature is small, however, the relative humidity varies appreciably diurnally and seasonally. Difference of relative humidity in the rainy season (August) and dry season (January) is remarkable, and the relative humidity is strongly related to the amount of rain.

The available data for this study are the daily summary data of the city for 22 years from 1968 (B.E.2511) to 1989 (B.E.2532) and a rainfall auto-record on some major heavy rains.

The maximum daily rainfall of every month of every year for 22 years at the city are shown in Table 2.1. As seen in the table, the maximum daily rainfall occurs in May through November, that is, in the rainy season.

The monthly average rainfall from 1968 to 1989 at Phuket is tabulated in Fig. 2.3.

Table 2.1 Maximum Daily Rainfall at Phuket City

Unit: mm

| Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec | Yearly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 12 | 0 | 0 | 37 | 143 | 85 | 75 | 90 | 82 | 45 | 19 | 54 | 143 |
| 1969 | 39 | 16 | 16 | 6 | 61 | 129 | 50 | 53 | 57 | 52 | 48 | 3 | 129 |
| 1970 | 11 | 2 | 31 | 53 | 78 | 62 | 71 | 32 | 38 | 40 | 52 | 23 | 78 |
| 1971 | 22 | 42 | 44 | 2 | 74 | 95 | 83 | 96 | 110 | 72 | 43 | 21 | 110 |
| 1972 | 0 | 2 | 3 | 52 | 53 | 38 | 32 | 32 | 57 | 30 | 24 | 29 | 57 |
| 1973 | 2 | 21 | 23 | 29 | 64 | 99 | 85 | 81 | 100 | 37 | 49 | 28 | 100 |
| 1974 | 0 | 2 | 12 | 73 | 53 | 76 | 123 | 43 | 61 | 135 | 66 | 20 | 135 |
| 1975 | 33 | 10 | 20 | 70 | 71 | 60 | 59 | 15 | 130 | 83 | 30 | 12 | 130 |
| 1976 | 0 | 2 | 15 | 46 | 87 | 106 | 104 | 86 | 102 | 53 | 27 | 20 | 106 |
| 1977 | 12 | 16 | 0 | 16 | 34 | 70 | 34 | 80 | 87 | 84 | 27 | 4 | 87 |
| 1978 | 13 | 0 | 14 | 80 | 38 | 69 | 87 | 67 | 50 | 22 | 35 | 23 | 87 |
| 1979 | 2 | 1 | 0 | 34 | 50 | 53 | 80 | 38 | 80 | 36 | 14 | 15 | 80 |
| 1980 | 2 | 44 | 54 | 34 | 48 | 69 | 85 | 110 | 41 | 48 | 32 | 29 | 110 |
| 1981 | 1 | 0 | 25 | 42 | 53 | 46 | 33 | 53 | 72 | 33 | 124 | 17 | 124 |
| 1982 | 1 | 23 | 19 | 28 | 68 | 23 | 135 | 23 | 55 | 44 | 45 | 16 | 135 |
| 1983 | 9 | 0 | 28 | 42 | 48 | 43 | 36 | 118 | 88 | 82 | 44 | 11 | 118 |
| 1984 | 14 | 1 | 35 | 90 | 42 | 90 | 62 | 29 | 76 | 47 | 28 | 73 | 90 |
| 1985 | 34 | 39 | 29 | 47 | 66 | 67 | 50 | 82 | 133 | 68 | 32 | 46 | 133 |
| 1986 | 9 | 12 | 3 | 124 | 127 | 44 | 78 | 81 | 173 | 76 | 90 | 10 | 173 |
| 1987 | 5 | 0 | 18 | 15 | 80 | 25 | 19 | 95 | 60 | 66 | 126 | 45 | 126 |
| 1988 | 8 | 38 | 20 | 41 | 59 | 35 | 57 | 55 | 55 | 42 | 141 | 12 | 141 |
| 1989 | 6 | 1 | 112 | 31 | 60 | 31 | 68 | 78 | 90 | 102 | 19 | 7 | 112 |
| Max. | 39 | 44 | 112 | 124 | 143 | 129 | 135 | 118 | 173 | 135 | 141 | 73 | 173 |

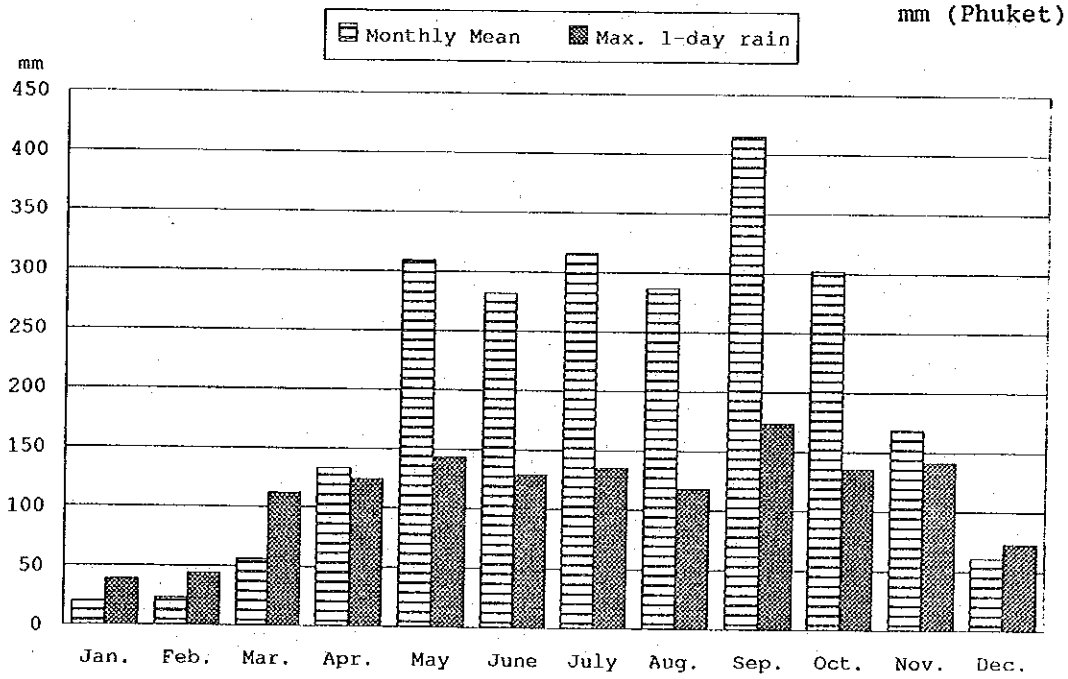



Fig. 2.3 Average Monthly Rainfall

The meteorological data at the Bang Wad dam consisting of daily rainfall, air temperature, evaporation, wind velocity, and stor age water level from December 1982 (B.E.2525) to date are available.

There are no available streamflow data for the Bang Yai river. The only measured flood was a small flood which occurred on 25 August 1989, and had a peak run-off of around 35 $m^3/s$ (to be revised, see Feasibility Study Report) at the Taonpradit bridge in the city. The hourly distribution of rainfall on those days is available, enabling the determination of the flow mechanism of the Bang Yai river which is described in Section 11.2.

For the basin-wide flood analysis, a probable basin average rainfall with an appropriate return period is applied and analyzed in Section 11.2, and for the street ditch in the city a short duration intense rainfall is applied and analyzed in Section 10.2.

Tidal height of Phuket is predicted by Hydrographic Department of Royal Thai Navy. Tide at Phuket is a regular semi-diurnal and the spring range at Phuket is 300 cm.

The Japan International Cooperation Agency (JICA), provided one set each of automatic and manual rain gauges and two sets of automatic water level gauges. Collected data will beneficially be used for a further detailed design of the study.

According to the mutual agreement between the Study Team, PWD Phuket office, RID Bang Wad dam office, Meteorological Department in Phuket City and Phuket Municipality, the equipment have been installed at the following locations:

a. Rain gauge (automatic)
   - At the meteorological observatory, Bang Wad dam

b. Rain gauge (manual)
   - At Ban Maireab School in Kratu

c. Water level gauge (2 sets)
   - Station A
     At just downstream side of Yaovaraj bridge
   - Station B
     At just upstream of footpath bridge in front of Wittayalai School along Thepkrasattri road.

In addition, the responsibility for the observation and maintenance of the equipment during the period of absence of the Study Team in Phuket until completion of the Project were discussed. The PWD Phuket branch office agreed to take the initiative to coordinate record management at each station with the following temporary agencies charged with the responsibility for observation and maintenance of equipment:

- Rain gauge (automatic) ..... RID Bang Wad dam
- - do - (manual) ..... PWD

- Water level gauge ..... PWD at Station A
- - do - ..... PWD at Station B

The location of the said observation stations are shown in Fig. 2.4.

Observation using the newly installed equipment started in early October 1989 and valuable data have been accumulated. Analysis of these data is discussed in the succeeding feasibility study report.

### 2.1.4 River, Ponds and Sea

(1) Naming of River, Road and Bridge

Individual names of rivers, canals, roads, and bridges located in the Study Area were identified through field reconnaissance. In case any of these are unknown, the Study Team assigned names to them for easy reference in the succeeding documents. These names are listed in Annex Figs. 2.4 and 2.5.

(2) Bang Yai River and its Basin

The Bang Yai river basin is located at the southern part of the Phuket island between 7° 52' and 7° 57' North latitudes, and 98° 18'and 98° 25' East longitudes. A mountain range 200 m to 400 m in height forms the watershed boundary in the western half of the basin. The highest point in the basin is at El 540 m and the catchment area of the basin is about 72 $km^2$.

The Ban Yai river, which originates at the southwestern part of the basin, flows northeast and veers eastward at the Ket Ho river confluence. It meanders in the middle reaches and turns southward near Thepkrasattri Rd. After passing through a narrow strip between Mt. Rang and Mt. Toh Sae, it runs through the central area of the Phuket City and flows into the Phuket bay at Sapanhin area. The total length of the river is about 18.1 km.

In the upstream portion of the Bang Yai mainstream, the Bang Wad dam has been built for water supply and is now under control of RID. The principal features of the dam and the reservoir are as described in Annex Fig. 2.6 and summarized below:

- Dam type : Earth fill
- Dam crest : El 47.00 m
- Dam height : 26 m
- Catchment area : 5.4 $km^2$
- Max. water level : El 44.00 m
- Full supply level : El 43.00 m
- Low water level : El 28.00 m
- Effective storage : 7,440,000 $m^3$
- Outlet : Dia. 0.5 m x 3 nos.
- Spillway : Dia. 2.0 m x 1 nos.

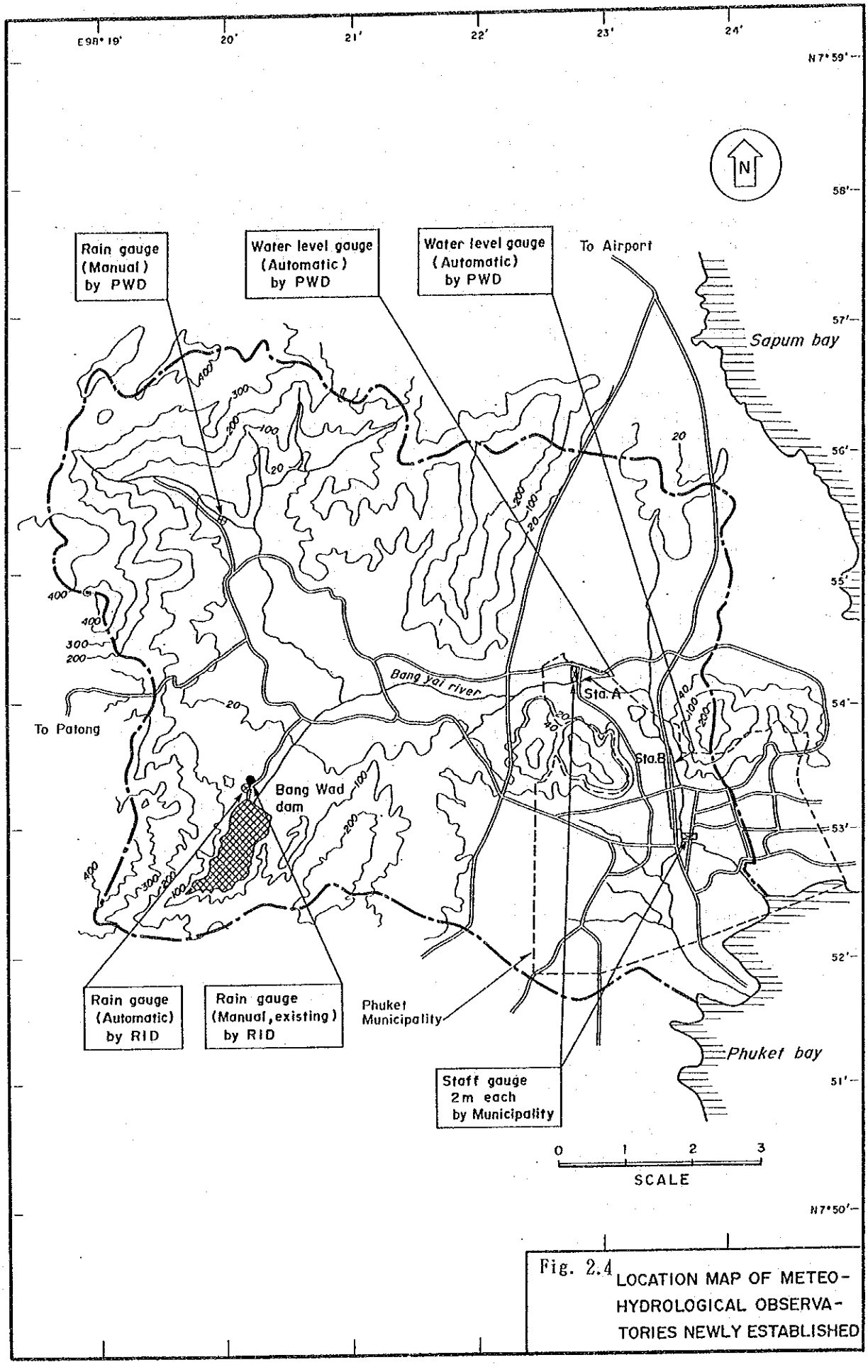



Fig. 2.4 LOCATION MAP OF METEO-HYDROLOGICAL OBSERVATORIES NEWLY ESTABLISHED

The flow capacity of 20 to 70 $m^3$/sec of the Bang Yai river is estimated based on the cross-section survey. The width of channel ranges from 2-4 m to 8-15 m in the upstream and downstream reaches, respectively. A longitudinal profile of the Bang Yai river is shown in Fig. 2.5. The flow capacity, ground elevation of both banks and width of channel are summarized in Annex Table 2.1. Fig. 2.6 shows the flow capacity.

(3) Tributaries and Branch Canals

The feature of tributaries and branch canals is described below and their longitudinal profiles are shown in Annex Fig. 2.7.

a. Ket Ho river

This river originates at the northwestern mountain range of the basin and flows southeastwards until it joins the Bang Yai mainstream near national highway No. 4020 to Patong. The length and catchment area of the river at the confluence are 7.9 km and 23.5 $km^2$, respectively. The Bang Tho Sung dam is planned on a small tributary of this river to meet the increasing water demand of Phuket City and Katu district. The catchment area and the effective storage volume of reservoir is 4.8 $km^2$ and 2,860,000 $m^3$, respectively. A preliminary study has been completed by RID in March 1989.

b. Lak Konsi river

This river starts at the northeastern part of the basin and flows southward passing through the Phuket Teacher's College and joins the mainstream near Thepkrasattri Rd. The river consists of small creeks in low flat area lying north of the College. The catchment area and the length of the river are 10.2 $km^2$ and 2.4 km, respectively.

c. Thepkrasattri canal

This canal flows in a southerly direction parallel with Thepkrasattri Rd. and turns eastward before reaching Dee Buk Rd. It joins the Bang Yai river after crossing Thepkrasattri Rd. a distance of approximately 80 m. The canal section is about 5.0 m(w) x 1.5 m(d) and length is 0.94 km.

d. Saen Suk canal

This canal was constructed to divert flood water from the Bang Yai river. At the branching point, two units of sluice gate with 1.8 m(w) x 1.8 m(h) are installed to control discharge. It flows into the Phuket bay after running through the environmental preserved and recreation area. Most reaches of this canal are protected by vertical concrete wall. Total length is 2.0 km.

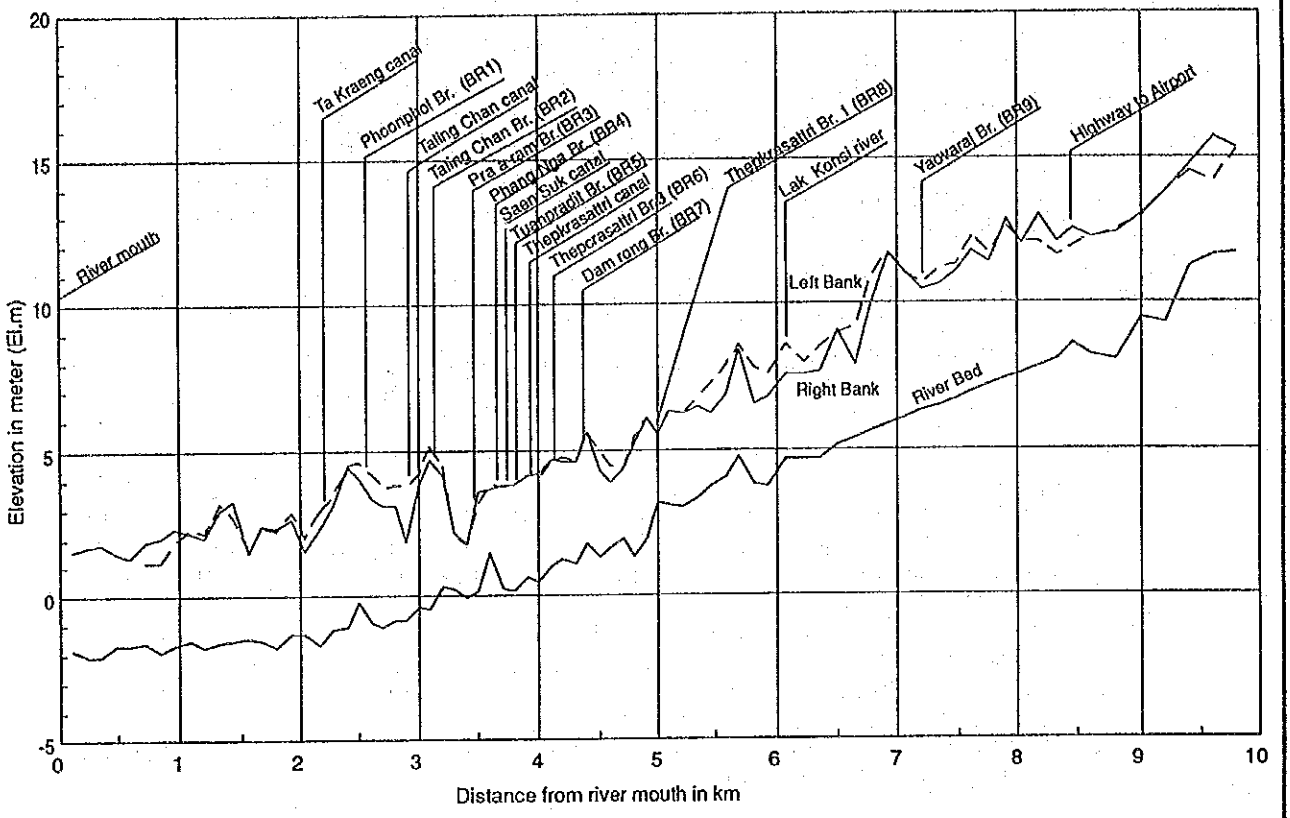



Fig. 2.5 LONGITUDINAL PROFILE OF BANG YAI RIVER

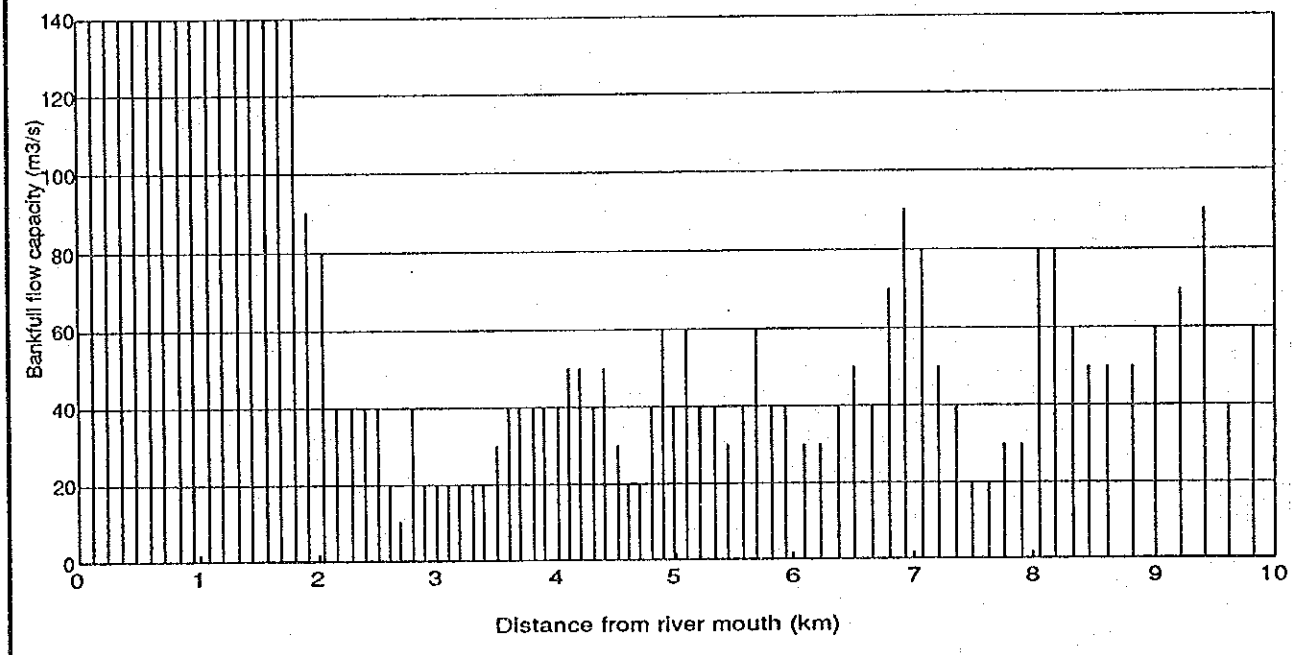



Fig. 2.6 FLOW CAPACITY OF BANG YAI RIVER

e. Taling Chan canal

This canal consists of two small streams which starts from Pati phat Rd. and Phang Nga Rd. It joins the main stream after crossing Bangkok Rd. At Takuapa Rd. a pumping station and sluice gates having 1.2 m(w) x 2.0 m(h) x 4 nos. are operated by the city. The gates are controlled in connection with the fluctuation of water level in the Bang Yai river which is dependent on the tide level.

f. Ta Kraeng canal

This canal originates from the pond at the newly constructed Royal Memorial park on the western side of Patiphat Rd. in the city area. A small tributary which is running north of the main canal joins at around 170 m from the confluence with the Bang Yai river. The width and the depth of this canal are about 5.0 m and 1.5 m, respectively, near the confluence.

(4) Ponds

There are many tin mine ponds either operating or abandoned over the Bang Yai river basin. Most of them are filled with water. Rainfall on the surface of the ponds and its surrounding area is temporarily stored and then flows into rivers depending on the difference in water level between such ponds and rivers. The total area of ponds in the basin is approximately 150 ha. The natural retarding function of these ponds contributes to the mitigation of flood peak discharge.

(5) Sea

The Phuket bay where the Bang Yai river flows into is quite shallow with almost 3 to 5 m at the deepest portion. It seems that sediment deposit extensively develops from the river mouth to the offshore area and makes difficult the approach of vessels to the coast. A fishery port is constructed at the estuary of the Ta Jen river located in the east side of the bay. Further, several mining pontoons are operating near the coast. Increasing wastewater discharge from the city area is one of the reasons for the deterioration of ecological conditions of the bay.

## 2.2 Socio-Economic Condition

### 2.2.1 Economic Conditions

With an abundant nature and resources, the Kingdom of Thailand has been enjoying a steady economic growth centering around the primary industries. Despite an inevitable slow down in early 1980s caused by the worldwide recession, a new wave of economic recovery and expansion featuring the industrialization of the manufacturing, agriculture and service sectors has brought the country's economy back on track. Major national economic indices are shown below.

Table 2.2 Major National Economic Indices

Unit : %

| Description | 4th NESDP 1977-1981 Record | 5th NESDP 1982-1986 Record | 6th NESDP 1987-1991 Target | Recent Estimate |
|---|---|---|---|---|
| Annual average real growth rate: | | | | |
| Gross Domestic Product | 6.6 | 5.3 | over 5 | 7.0 |
| GDP, Agriculture sector | 3.9 | 4.1 | 2.9 | 1.9 |
| GDP, Manufacturing " | 8.0 | 5.2 | 6.6 | 9.2 |
| Consumer price | 11.6 | 2.9 | 2.3 | 3.7 |
| Share to nominal GDP: | | | | |
| Saving | 21.7 | 20.5 | 23.7 | - |
| Investment | 26.9 | 24.1 | 24.9 | - |
| National current balance (deficit) | 6.2 | 3.6 | 0.9 | 2.8 |
| National financial " (deficit) | 3.3 | 3.6 | 2.6 | - |

Source : Estimation by NESDB in June 1988 (B.E.2531)

Under the 6th National Economic and Social Development Plan (1987-1991), Phuket is nominated as a 2nd-generation regions urban growth center for development plans of economic/social/environmental infrastructure services and tourism promotion.

The former key industries with labor intensive features such as tin mining and rubber plantation have been adversely affected by drastic setback of international trade in both quantity and market price. Hence, the industrial frame of Phuket is being restructured with these industries to be replaced by tourism as prime industry.

As one of the most accessible southern resorts, well known

Phuket with its traditional culture and natural beauty has immeasurable economic potential that can be appropriately developed.

The tourism industry in Phuket island consists of hotel accommodations in various seaside resorts supported jointly and in close cooperation with local agriculture, mining, manufacturing and several service industries. Furthermore, advance investments for environmental improvement and implementation of such infrastructures as transportation, communication and public utilities have been rapidly expanding in the city for the last 5 years.

As a result of these accelerated activities, there has been a remarkable increase in the construction of new hotels, shops, residences and public buildings as well as urban traffic intensities and population growth including non-registered immigrants from the other provinces.

As the growing center in Phuket Province in every respect of administration, transportation, communication, commerce, community and culture, the City of Phuket has been urgently requested to fulfill its water supply and sewerage system as well as clarification and flood control of khlongs. This is the reason for the appraisal of the Project.

As a proof of the above, the economic indices are shown in Annex Tables 2.3 to 2.6.

On the national level, the mainstay - agricultural crop production has been growing amountwise but slowing down in its relative share. In turn, manufacturing has been boosted up, particularly in recent years with plans launched for export to the industrial economies and achieve to rank as top industry. These larger sectors are followed by wholesale and retail trade and services.

Meanwhile, on the provincial level, mining and quarrying as the prime factor in local economy for several decades has been declining into half of the peak production. Agriculture, centering around fisheries, has been steadily expanding and maintaining its 2nd place ranking.

Such deterioration of mining industry in the provincial economy was alternatively compensated by services, wholesale & retail trade, transportation & communication and banking, insurance & real estate sectors, which shared 18 - 10%, respectively, at an even balance in 1987. In view of growth rate, those service industries and infrastructures have also shown remarkable increment so as for allout promotion of tourism industry.

Phuket City does not have adequate economic indices, hence an estimation based on the GPDP of Phuket Province is made as per Annex Table 2.7 and 2.8, taking geographic and demographic frames into consideration. Whereas, more condensed economic characteristics than that of provincial level can be clearly observed, in consequence, a comparison of per capita domestic

products in 1987, are given follows:

| | | | Baht at current price | (%) |
|---|---|---|---|---|
| Per capita | GDP | - Thailand | 23,021 | 100 |
| " | GRDP | - Southern Region | 16,725 | 73 |
| " | GPDP | - Phuket Province | 32,913 | 143 |
| " | GMDP | - Phuket City | 37,446 | 163 |

Phuket maintains a high living standard and aggressive potential as a vivid example of achievement and economic development upon successful reconstruction of industrial structures suitable for local character to international market.

In order to grasp current consciousness of inhabitants on present sanitary condition and desire for purification of rivers and canals in the study area, an interview survey with questionnaires was conducted in parallel with flood damage survey. Further, the trend of domestic and foreign tourists visiting Phuket City was also investigated by person to person interview at bus terminals and several major hotels in the downtown area.

The result of the surveys emphasizes that:

- The pollution and flood of the Bang Yai river are conspicuously disturbing the human life of inhabitants.

- Currently, the rivers and canals are merely utilized as disposal channels for sewage and garbage dumps.

- Even when there is flood, one third of the household members have to commute for work or school.

- The citizens are eagerly expecting the recovery of such environments and the reuse of the rivers and canals to the maximum possible extent.

- Among the prospective development schemes by the municipality, people point out the implementation of water supply & sewerage system as first priority followed by road construction.

- Despite a variety of locations, the residents near rivers maintain rather higher community standard, are amenable to such plan, and are willing to pay for the implementation and operation.

- Even for those who had traveled to the city for the first time, most of the travelers are aware of deterioration of the rivers and had hoped they can come back again with the river water already purified.

### 2.2.2 Education

In the study area, there are 5 post-secondary level schools, 4 secondary schools, 21 primary schools including 2 schools attached to secondary schools, and 12 nurseries including 10 nurseries attached to higher level schools.

In all, there are approximately 23,600 students and pupils and 1,350 teachers. 6 schools have dormitories. Over 1,700 students come from other provinces. There is no school in the eastern part of the study area. Schools in the study area are listed in Annex Table 2.9.

### 2.2.3 Tourism

In 1987, a total of 7,800 hotel rooms in Phuket Province had approximately 547,000 guest arrivals. The number of hotel rooms was 2.7 times the 1982 level and the number of guest arrivals became 2.8 times during the period.

Peak months are January and December. In 1986, the guest arrivals in December was 55,200 or 2.1 times those in September. Similarly the hotel occupancy in December was 79%, while that in September was 37 percent resulting in the year's average occupancy of 57 percent.

In the Study Area, there are 30 hotels and 1,881 hotel rooms, in contrast with 23 hotels and 1,328 rooms in 1987. Now 6 hotels have over 100 rooms, among which Pearl Hotel is largest with 300 employees.

Most existing hotels are located in the city center. Existing hotels and the numbers of rooms in the study area are shown in Annex Table 2.10.

### 2.2.4 Hospitals

1 government hospital and 4 private hospitals provide 356 beds. There are also 39 small private clinics.

The government hospital has 95 medical staff consisting of 21 doctors, 17 nurses and 57 assistant nurses.

The 4 private hospitals have a total of 258 employees including 17 doctors, 47 nurses and 42 assistant nurses.

### 2.2.5 Industry

There are 214 factories employing a total of 2,327 persons, or an average of 11 persons per factory. Number of factories which employ more than 20 persons is 14 or 6.5 percent of total factories.

The following are major factories in the Study Area.

Table 2.3 Major Factories in Study Area

| Type of industry | Output | Employees |
|---|---|---|
| Cashew nut | 43.2 t/Y | 35 |
| Cashew nut | 9.96 t/Y | 20 |
| Cashew nut | 6 t/Y | 33 |
| Cashew nut | 3.6 t/Y | 20 |
| Stone crush | 22,000 $m^3$/Y | 31 |
| Stone crush | 25,000 $m^3$/Y | 20 |
| Fish can | 18,000,000 cans/Y | (temporarily closed) |
| Fine fish | 100 t/day | 35 |
| Fine fish | 1,500 t/year | 26 |
| Fine fish | 12,000 t/year | 20 |
| Furniture | 1,200 sets/Y | 30 |
| Rubber | 4,800 t/Y | 46 |
| Rubber hoses | 600 hoses/Y/each size | (closed) |
| Shell souvenirs | 2,000 sets/Y | 23 |
| Storage of sea food & production of ice | ice cubes 36,000 t/Y sea animal 3,680 t/Y | 43 |
| Car repair | 720 cars/Y | 21 |
| Total | | 402 |

Source: List of Industrial Establishments 1987
Industrial office of Phuket Province

Economy of Phuket Province is shifting towards service-oriented structure.

There are some preliminary industrial development plans but they are outside the Study Area. One example is an industrial estate plan in Amphoe Thalang, which is light industry utilizing the airport. Another example is an industrial estate plan behind the newly opened deep sea port. But this idea has some difficulty such as land problems, environmental problems, etc. The new deep sea port area may be developed as a tourism base instead.

Especially in the city area where land prices are high, major industrial development cannot be expected. Only small scale industries such as handicrafts can be promoted, but the sites will be more likely outside the city area.

### 2.2.6 Sanitary

#### (1) Nightsoil Treatment and Disposal

In Phuket City, household commonly possesses simply on-site treatment unit as excreta disposal, either cesspool or septic tank. Popularly practical sanitary pour-flush toilet is locally employed. With regard to this type of toilet, small amount of water is required. Basically, connection pipe links the residential water closet with either septic tank or cesspool.

At hotel and condominium, a universal flushing toilet is applied and wastewater is discharged into a medium treatment plant em ploying a biological treatment process such as anaerobic filtration or simple septic tank.

Wastewater gathered in septic tank and others are normally allowed to discharge to the nearby public sewer and that passing to a cesspool is also allowed to infiltrate into the ground. However, new construction of cesspool type of toilet has not been allowed since 4 years ago in the city.

From time to time, accumulated sludge settled at the bottom of treatment units would be removed from the units and then transported by vacuum nightsoil collection vehicle to the existing municipality sludge disposal site which was provided with the assistance of US-AID.

(2) Public Hygiene

Historical record on the occurrence of water-borne diseases in Phuket and Nationwide is comparatively presented in Annex Table 2.11.

## 2.3 Land Use

### 2.3.1 Existing Land Use

The existing land use of the Study Area shows a vague radial urbanization pattern along major roads centering on the commercial and high density residential area as in Fig. 2.7.

(1) Residential Use

High density residential zones are also commercial zones located in the central area with the Fountain Circle and Phuket Rd. - Kra Rd., intersection as two central points.

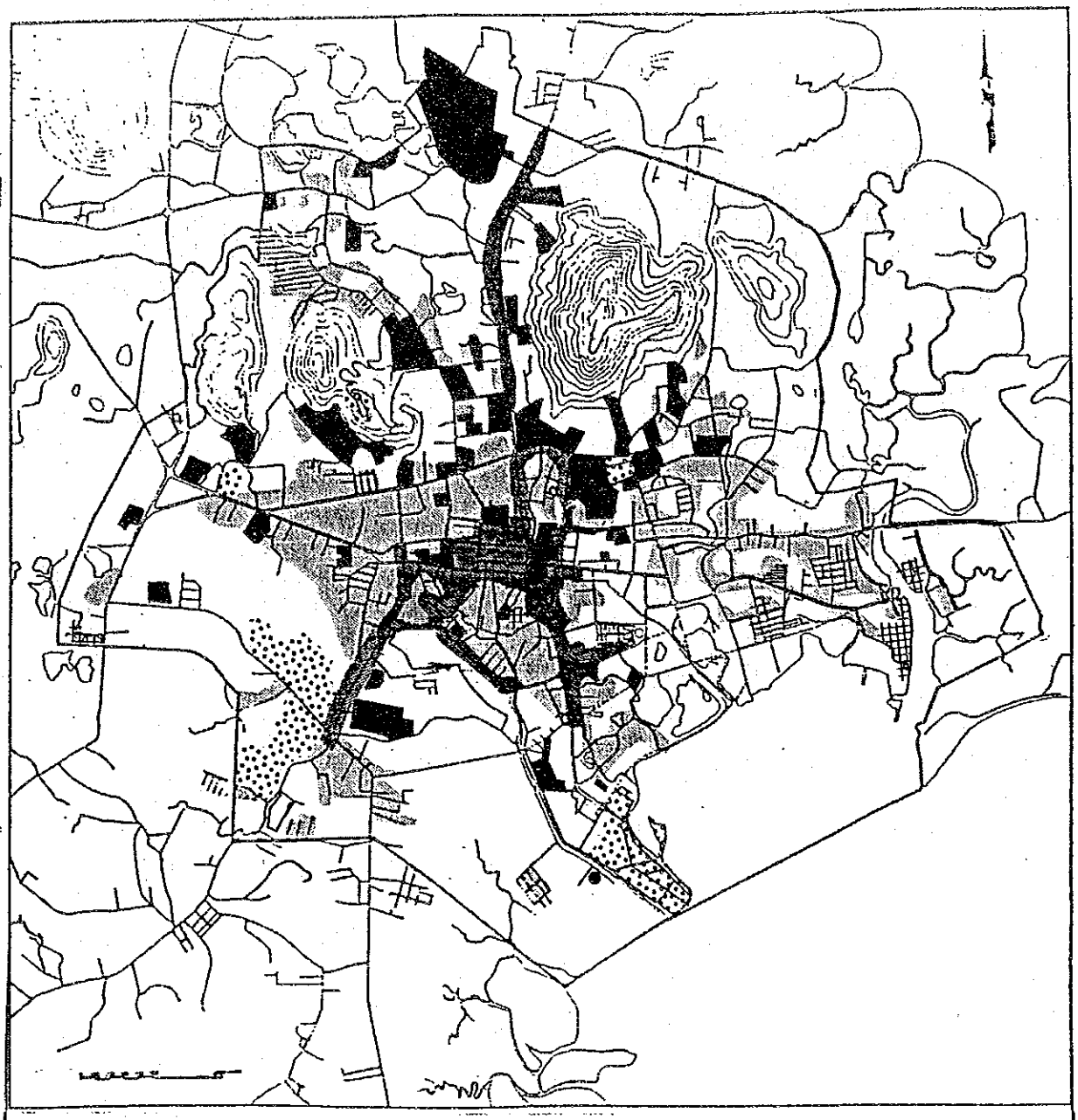
Low density residential zones spread around the central area.

Except for the northern foot of Rang Hill, northern zones, south-eastern zones and south-western zones have the lowest population density. In general, population density of areas outside the city is also low.

At least 5 areas with low standard house conditions are identified in the city. 528 families with 2,224 family members live in these areas.

(2) Commercial Use

Commercial activities are developed in the central area and along major roads spread from the center such as Phuket Rd., Thepkrasattri Rd. and Chao Fa Rd.



LEGEND

- RESIDENTIAL ZONE
- COMMERCIAL ZONE
- INDUSTRIAL AND WAREHOUSE ZONE
- RECREATIONAL AND ENVIRONMENTAL PROTECTION ZONE
- PUBLIC FACILITY ZONE (SCHOOL, TEMPLE, GOVERNMENT ETC)

Fig. 2.7
EXISTING LAND USE PATTERN

The old city market and many other commercial and business enterprises including most branches of Bangkok based companies are located in the central area.

The new city market and ocean department stores are located in the south-east of the center connected to other commercial enterprises along Phuket Rd.

Many car and motorcycle related shops are seen along Thepkrasattri Rd.

(3) Industrial and Warehouse Uses

Both sides of the Tajin river near the fishing port is the only area where some factories and stores are located together. They are fish processing and ship-yard industries.

Except a rubber factory besides Phuket Rd., other industrial establishments in the study area are of small scale.

(4) Rural and Agricultural Uses

On Toh Sae Hill sides and in the hilly areas along the north-eastern boundary of the study area, rural or agricultural land use is observed.

In other areas, only small areas of agricultural land use such as nurseries and chicken farms are scattered.

(5) Recreational and Environmental Protection Uses

There are 3 large scale parks in the study area.

(i) Rang Hill
(ii) Public Park
(iii) Sapan Hin

In addition, there are a stadium along Vichitsongkhram Rd. and a sports ground in front of the municipal office.

(6) Schools

Schools with large campus area are located outside the city center, but there is no school in the eastern part of the study area.

(7) Religious Institutions

There are 7 Buddhism temples, 5 churches, 1 mosque and 14 Chinese shrines as well as cemeteries. In the temples, there are 190 priests in the rainy season and 52 novices.

(8) Government Offices and Public Facilities

Most government offices and public facilities are located north-east of the city center.

### 2.3.2 Development Plans and Projects

(1) The Sixth National Economic and Social Development Plan 1987 - 1991 (B.E.2530 - 2534) by NESDB.

The plan selected Phuket City as an urban growth center.

(2) Upper-South Sub-Regional Development Plan by JICA in 1985 (B.E.2528).

The plan designated Phuket City and Surat Thani as the sub-region development centers.

(3) Development Plan of Phuket Province by DTCP in 1985.

(4) Development Plan of Phuket Province by the provincial office in 1988.

(5) The Study on Potential Tourism Area Development for the Southern Region in Thailand (-2001) by JICA in 1989.

The plan designated Phuket City as a town tourism development center.

(6) The 5-Year Development Plan of the city by the municipality office (1987-1991).

(7) Provincial Water Supply Project for Phuket Province (-2011) by JICA.

(8) Regional Cities Development Project by Australian International Development Assistance Bureau.

The feasibility study is on-going to improve major infrastructure.

(9) Town Plan (1988-2008) currently prepared by DTCP.

The plan will delineate the future land use and transportation network.

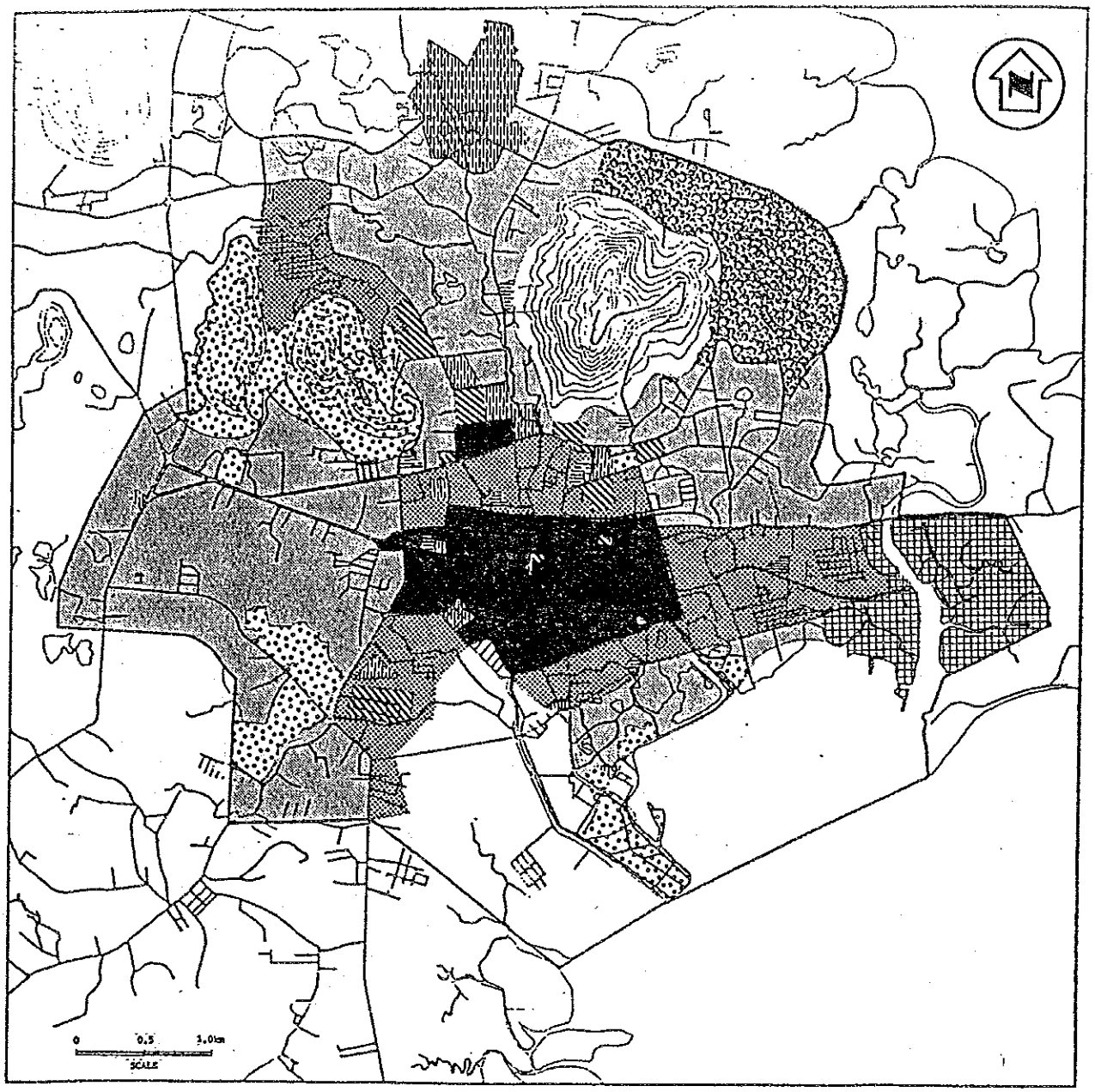
(10) On-going Building Projects and Plans.

At least 2611 housing and commercial units and 1432 hotel rooms are under construction or planned for construction mostly outside the city center so that urban areas will be largely expanded in future.

### 2.3.3 Future Land Use Pattern and Road Network

DTCP is currently preparing the future land use and transportation network plans.

Fig. 2.8 shows the preliminary future land use plan, which presents expanded urbanization.




**LEGEND**

- Low Density Residential Zone
- Medium Density Residential Zone
- Commercial & High Density Residential Zone
- Industrial Zone
- Agricultural & Rural Zone
- Recreational & Environmental Protection Zone
- Educational Zone
- Religious Zone
- Government Office & Public Service Zone

Fig. 2.8
**LAND USE PLAN**
**(PRELIMINARY)**

# CHAPTER 3

# POPULATION AND WATER DEMAND

# CHAPTER 3 : POPULATION AND WATER DEMAND

## 3.1 Population

### 3.1.1 Past and Present Population

(1) Past Population Trend

The trend of population of Phuket City and adjacent areas since 1980 has the following characteristics:

(i) The average growth rate of population of Phuket City was 0.55% per annum, which was lower than those of Amphoe Muang, Phuket Province and the nation.

The neighboring cities of Tambon Rasada and Tambon Vichit showed very high population growth rates.

Table 3.1 shows the relation of population growth rates between Phuket City and the neighboring cities.

(ii) The city's natural growth rate was high at 3.25% but the net migration rate was also high at (-)2.74% resulting in the low net growth rate.

Amphoe Muang's natural growth rate was low at 0.61% but the net migration rate was high at 2.67% resulting in the high net growth rate.

One cause for the out-migration from the city and the in-migration to the neighboring area is the move-out of younger generation such as new settlement of new families.

As a proof of the above, the factors for population changes of Phuket City and Amphoe Muang are shown in Table 3.2.

Table 3.1
Past Population of Thailand, Phuket Province, Amphoe, Neighboring Tambon and Phuket Municipality

Unit : persons
%

| Year | Thailand | Phuket Province | Amphoe Talang | Amphoe Kratu | Amphoe Muang | Tambon Rasada | Tambon Vichit | Phuket Munici. |
|---|---|---|---|---|---|---|---|---|
| 1979 | | 130270 | | | | | | 44406 |
| GrowthRate | | 2.61 | | | | | | 1.69 |
| 1980 | 46700000 | 133669 | 38919 | 12621 | 33785 | 7189 | 8404 | 45155 |
| GrowthRate | 2.14 | 1.96 | | | 4.12 | 6.06 | 4.95 | 0.59 |
| 1981 | 47700000 | 136286 | | | 35176 | 7625 | 8820 | 45421 |
| GrowthRate | 2.10 | 1.75 | | | 3.48 | 4.72 | 3.70 | 0.11 |
| 1982 | 48700000 | 138672 | 43020 | 13780 | 36399 | 7985 | 9146 | 45473 |
| GrowthRate | 2.05 | 2.30 | 2.09 | 2.00 | 4.33 | 11.68 | 2.89 | 0.98 |
| 1983 | 49700000 | 141863 | 43917 | 14055 | 37974 | 8918 | 9410 | 45917 |
| GrowthRate | 2.01 | 2.37 | 2.47 | 0.75 | 3.78 | 6.64 | 4.01 | 1.62 |
| 1984 | 50700000 | 145229 | 45001 | 14161 | 39408 | 9510 | 9787 | 46659 |
| GrowthRate | 1.97 | 1.54 | 1.10 | 2.25 | 3.05 | 6.40 | 2.06 | 0.47 |
| 1985 | 51700000 | 147467 | 45498 | 14480 | 40609 | 10119 | 9989 | 46880 |
| GrowthRate | 1.93 | 1.92 | 0.86 | 2.22 | 3.85 | 6.23 | 4.28 | 1.17 |
| 1986 | 52700000 | 150295 | 45889 | 14802 | 42174 | 10749 | 10417 | 47430 |
| GrowthRate | | 0.95 | 0.95 | 2.01 | 2.85 | 3.65 | 9.09 | -1.08 |
| 1987 | | 151716 | 46325 | 15099 | 43375 | 11141 | 11364 | 46917 |
| GrowthRate since 1980 | 2.03 | 1.83 | 2.52 | 2.59 | 3.63 | 6.46 | 4.40 | 0.55 |

Source : Analysis Report for Phuket Town Plan, DTCP 1988
Other Statistics Reports

Table 3.2

Factors for Population Changes of Phuket Municipality and Amphoe Muang

Unit : %

| Year | [ Phuket Municipality | | | | | | ][ Amphoe Muang excluding Phuket Municipality | | | | | ] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Birth Rate | Death Rate | Natural Growth Rate | In-Migration Rate | Out-Migration Rate | Net Migration Rate | Birth Rate | Death Rate | Natural Growth Rate | In-Migration Rate | Out-Migration Rate | Net Migration Rate |
| 1977 | 3.240 | 0.708 | 2.532 | 11.946 | 12.144 | -0.198 | 2.272 | 0.544 | 1.728 | 6.412 | 4.922 | 1.490 |
| 1978 | 3.416 | 0.919 | 2.497 | 11.757 | 12.480 | -0.723 | 2.486 | 0.775 | 1.711 | 7.664 | 5.756 | 1.908 |
| 1979 | 3.671 | 0.867 | 2.804 | 12.303 | 13.621 | -1.318 | 2.270 | 0.824 | 1.446 | 8.233 | 6.603 | 1.630 |
| 1980 | 4.206 | 0.946 | 3.260 | 13.412 | 15.218 | -1.806 | 2.177 | 0.706 | 1.471 | 8.772 | 6.592 | 2.180 |
| 1981 | 4.122 | 0.879 | 3.243 | 12.842 | 15.775 | -2.933 | 1.557 | 0.682 | 0.875 | 10.061 | 6.760 | 3.301 |
| 1982 | 3.855 | 0.962 | 2.893 | 10.904 | 13.792 | -2.888 | 1.383 | 0.615 | 0.768 | 8.020 | 5.575 | 2.445 |
| 1983 | 4.061 | 0.890 | 3.171 | 12.235 | 14.581 | -2.346 | 1.340 | 0.555 | 0.785 | 7.960 | 6.410 | 1.550 |
| 1984 | 4.321 | 0.941 | 3.380 | 11.506 | 13.476 | -1.970 | 0.844 | 0.454 | 0.390 | 9.125 | 5.894 | 3.231 |
| 1985 | 4.721 | 1.048 | 3.673 | 10.665 | 14.029 | -3.364 | 0.750 | 0.370 | 0.380 | 7.666 | 5.301 | 2.365 |
| 1986 | 4.676 | 1.005 | 3.671 | 10.987 | 13.680 | -2.693 | 0.560 | 0.358 | 0.202 | 9.239 | 5.624 | 3.615 |
| 1987 | 3.572 | 0.884 | 2.688 | 8.034 | 11.926 | -3.892 | 0.447 | 0.432 | 0.015 | 8.734 | 6.090 | 2.644 |
| Simple Average since 1980 | 4.192 | 0.944 | 3.247 | 11.323 | 14.060 | -2.737 | 1.132 | 0.522 | 0.611 | 8.697 | 6.031 | 2.666 |

Source : Analysis Report for Phuket Town Plan, DTCP 1988

(2) Present Population and Number of Families

According to the Analysis Report for Phuket Town Plan by DTCP and study by the municipal office, the total population of the study area in 1988 is estimated at 61,908 as shown in Table 3.3.

Regarding the number of families and family size, data is available only inside the DTCP planning area. Within the area, the average family size is 4.7 persons per family. Inside the municipality, families are smaller while outside the municipality, families are larger on the average.

A family is defined as a group of persons sharing living quarters and living expenses or a person who lives by oneself occupying a dwelling. Single family means a family with only one pair of husband and wife or less.

At the moment, the city is experiencing a tourism and building boom, and the number of unregistered population such as construction workers, service ladies in addition to students and workers at the fishing ports from other areas is roughly estimated at a level of 10,000. The number will decrease after the construction boom. On the other hand, there seem to be a considerable number of population registered in the city but living outside. Considering these uncertainties, we study only the registered population in quantitative terms.

(3) Population Distribution

Population distribution in the Study Area in 1988 is shown in the preceding Table 3.4 and Fig. 3.1. The Study Area is divided into 3 parts, that is, DTCP area, S zone and Bang Ping zone. Then DTCP area is divided into In-Municipality area and Out-Municipality area. The former consists of 5 groups of zones and the latter consists of 3 zones. The present municipality area is In-Municipality area plus S zone, which is excluded from DTCP area because the zone used to be covered by mangroves and still under control of the Ministry of Agriculture.

The total Study Area is approximately 2600 ha and the average population density is approximately 24 persons/ha.

- Zones with 110 persons/ha (17.6 persons/Rai) or more are:

(i) the zone of the old city market and the local bus station and the zone behind Soi Putorn (A4 and A6),

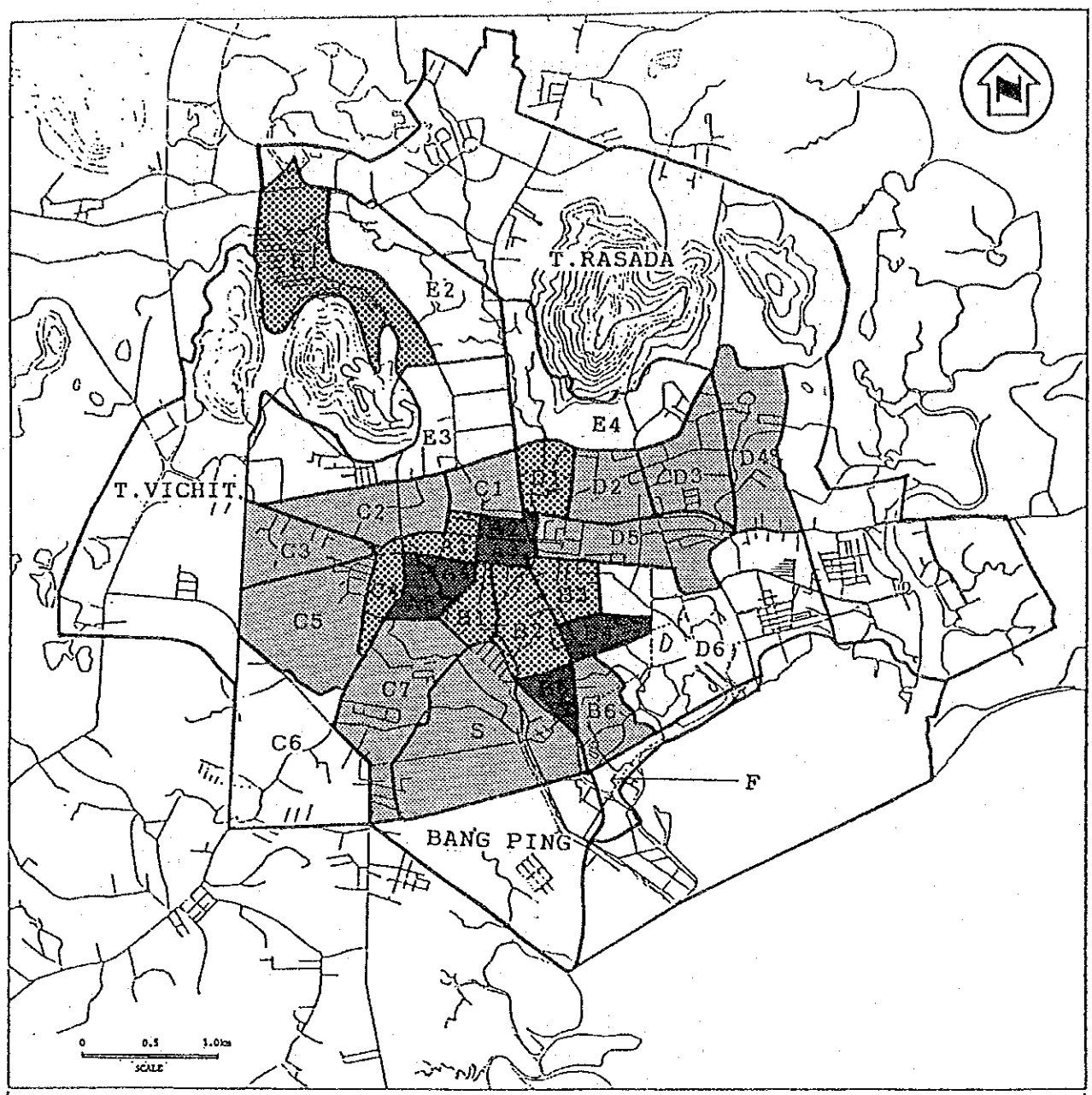
(ii) zones surrounded by Dee Buk Rd., the Bang Yai river, Rasada Rd. and Yawaraj Rd. (A2 and A3),

(iii) Nimit and the new city market zone (B4), and

Table. 3.3 Present Population by Zone

| Zone | Area(Rai) | Area(ha) | Population | Pop/Rai | Pop/ha |
|---|---|---|---|---|---|
| A1 | 91.2 | 14.592 | 1530 | 16.78 | 104.85 |
| A2 | 35.2 | 5.632 | 970 | 27.56 | 172.23 |
| A3 | 51.2 | 8.192 | 1383 | 27.01 | 168.82 |
| A4 | 41.6 | 6.656 | 1640 | 39.42 | 246.39 |
| A5 | 73.6 | 11.776 | 1303 | 17.70 | 110.65 |
| A total | 292.8 | 46.848 | 6826 | 23.31 | 145.71 |
| B1 | 102.4 | 16.384 | 1638 | 16.00 | 99.98 |
| B2 | 208 | 33.28 | 1870 | 8.99 | 56.19 |
| B3 | 128 | 20.48 | 1900 | 14.84 | 92.77 |
| B4 | 64 | 10.24 | 1466 | 22.91 | 143.16 |
| B5 | 64 | 10.24 | 1221 | 19.08 | 119.24 |
| B6 | 198.4 | 31.744 | 1631 | 8.22 | 51.38 |
| B total | 764.8 | 122.368 | 9726 | 12.72 | 79.48 |
| C1 | 147.2 | 23.552 | 1120 | 7.61 | 47.55 |
| C2 | 224 | 35.84 | 1691 | 7.55 | 47.18 |
| C3 | 224 | 35.84 | 1688 | 7.54 | 47.10 |
| C4 | 96 | 15.36 | 1023 | 10.66 | 66.60 |
| C5 | 344 | 55.04 | 1643 | 4.78 | 29.85 |
| C6 | 566.4 | 90.624 | 1754 | 3.10 | 19.35 |
| C7 | 408 | 65.28 | 1698 | 4.16 | 26.01 |
| C total | 2009.6 | 321.536 | 10617 | 5.28 | 33.02 |
| D1 | 128 | 20.48 | 1772 | 13.84 | 86.52 |
| D2 | 176 | 28.16 | 1035 | 5.88 | 36.75 |
| D3 | 256 | 40.96 | 1339 | 5.23 | 32.69 |
| D4 | 336 | 53.76 | 1558 | 4.64 | 28.98 |
| D5 | 304 | 48.64 | 1634 | 5.38 | 33.59 |
| D6 | 870.4 | 139.264 | 1876 | 2.16 | 13.47 |
| D total | 2070.4 | 331.264 | 9214 | 4.45 | 27.81 |
| E1 | 448 | 71.68 | 4023 | 8.98 | 56.12 |
| E2 | 451.2 | 72.192 | 1128 | 2.50 | 15.63 |
| E3 | 640 | 102.4 | 1637 | 2.56 | 15.99 |
| E4 | 496 | 79.36 | 1236 | 2.49 | 15.57 |
| E total | 2035.2 | 325.632 | 8024 | 3.94 | 24.64 |
| In-Munici. | 7172.8 | 1147.648 | 44407 | 6.19 | 38.69 |
| T.Rasada | 4843.45 | 774.952 | 12600 | 2.60 | 16.26 |
| T.Vichit | 2064 | 330.24 | 1530 | 0.74 | 4.63 |
| F zone | 706.25 | 113 | 0 | 0.00 | 0.00 |
| Out-Munici | 7613.7 | 1218.192 | 14130 | 1.86 | 11.60 |
| DTCP Area | 14786.5 | 2365.84 | 58537 | 3.96 | 24.74 |
| S zone | 596.875 | 95.5 | 2511 | 4.21 | 26.29 |
| Bang Ping | 750 | 120 | 860 | 1.15 | 7.17 |
| Study Area | 16133.375 | 2581.34 | 61908 | 3.84 | 23.98 |

Source : Analysis Report for Phuket Town Plan, DTCP 1989




LEGEND

Population Density

110 Persons/ha (17.6 Persons/Rai) or More

55 - 110 Persons/ha (8.8 - 17.6 Persons/Rai)

25 - 55 Persons/ha (4 - 8.8 Persons/Rai)

Fig. 3.1
PRESENT POPULATION DENSITY BY ZONE

(iv) Takua Thoong Rd. Zone (A5).

- Zones with 55 - 110 persons/ha (8.8 - 17.6 persons/Rai) are:

(i) neighboring zones to the above densely inhabited zones (A1, B1, B2, B3, C4 and D1) and

(ii) the northern foot of Rang Hill zone (E1).

- Zones with 25 - 55 persons/ha (4 - 8.8 persons/Rai) are remaining

zones south of Maeruan Rd., Thoon Kha Rd. and Dam Rong Rd. within the city boundary except south-eastern zones and south-western zones.

Comparison of the present population distribution with the land use plan of the preceding Fig. 2.7 (Page 2-19) and Fig. 3.1 indicates that Tambon Vichit and south-eastern areas in the municipality (D5 and D6) have the greatest capacity to absorb additional population.

### 3.1.2 Future Population

To estimate the future population, various methods were tried as itemized below.

(1) Regression Analysis of Population Trend

Arithmetic, geometric and logarithmic regression analyses were tried as in Table 3.4 and Fig. 3.2. Extrapolation of the past population trend based on these regression analyses estimates the city's population in 2006 at around 55,000 or less. But this does not consider explicitly the current economic and building boom and so the results tend to be under-estimation.

Table 3.4 Regression Analysis of Phuket Municipality's Population

| Year | Arithmetic Regression | Geometric Regression | Logarithm Regression | Growth Rate = 1.3% |
|---|---|---|---|---|
| 1991 | 48,930 | 48,933 | 46,417 | 49,073 |
| 1996 | 50,784 | 50,882 | 46,476 | 52,347 |
| 2001 | 52,637 | 52,909 | 46,534 | 55,839 |
| 2006 | 54,490 | 55,016 | 46,592 | 59,564 |

Arithmetic Regression : Population = -689,067 + 370.667 x Year

Geometric Regression : Population = $0.00859574 \times 1.007843^{Year}$

Logarithmic Regression: Population = -129,900 + 23,210.7 x LN(Year)

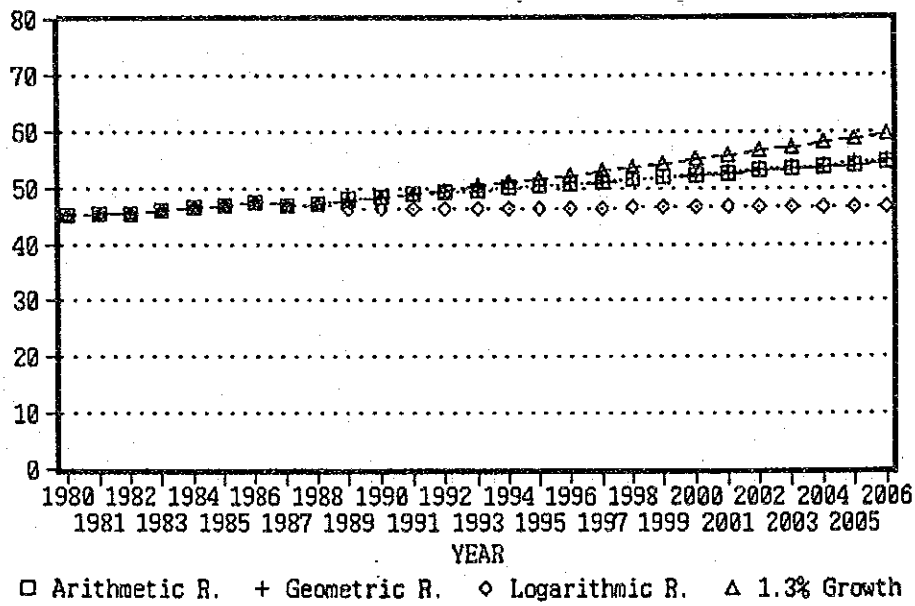



Fig. 3.2 Estimate of Phuket City's Future Population

(2) Expected Fixed Growth Rate

Assumptions of the natural increase rate of 1.3%, which is the national target for 1991, and of the balance of in and out migration result in approximately 60,000 for the city's population as in the preceding Table 3.3 and 78,000 for the Study Area's population in 2006.

(3) Simplified Cohort Analysis

Simplified cohort analysis based on the combined population change by births, deaths and migration between 1980 and 1988 results in a slow increase of the city's population to 50,000 in 2004 and decrease afterwards, due to increasing of the out-migration and aging of the population. This analysis assumes that the past pattern of out-migration especially of the young generation will not change in the future. Result of the estimation is shown in Table 3.5.

(4) Bottom-up Approach

In order to incorporate the current housing boom and the long term land use plan, the following bottom-up approach is applied.

(i) An increase of population by on-going and planned building project can be estimated at approx. 5,400 as follows:

2,686 units x 4 persons x 50 % = 5,372 persons

Where:
2,686 = Number of housing units to be built
4 = Family size for the new units
50 % = Ratio of residents from outside the study area assumed by the Study Team

Population by zone on completion of the building projects is shown in column (c) in Table 3.6.

(ii) To indicate the minimum planned population by zone in 2006 consistent with the land use plan, population density of each land use category is assumed as follows and is multiplied by the area shown in Table 3.7, and estimated population is set out in Table 3.6.

| | |
|---|---|
| Low density residential zone | = 25 persons/ha |
| Medium density residential zone | = 55 persons/ha |
| Commercial and high density residential zone | = 110 persons/ha |
| Industrial zone | = 15 persons/ha |
| Rural and agricultural zone | = 5 persons/ha |
| Other zones | = 0 persons |

Table. 3.5 Cohort Analysis of Population of Phuket Municipality

| Age Group | 1980 | Ratio | 1988 | 1996 | 2004 | 2012 |
|---|---|---|---|---|---|---|
| Male | | | | | | |
| 0 - 7 | 3600 | 0.9145645 | 3270 | 3374 | 3034 | 2552 |
| 8 - 15 | 3792 | 0.8606666 | 3098 | 2815 | 2904 | 2612 |
| 16 - 23 | 4030 | 0.8689873 | 3295 | 2692 | 2446 | 2523 |
| 24 - 31 | 3573 | 0.8217546 | 3312 | 2708 | 2213 | 2010 |
| 32 - 39 | 2411 | 0.9212338 | 3291 | 3051 | 2495 | 2038 |
| 40 - 47 | 1911 | 0.9454997 | 2280 | 3112 | 2885 | 2359 |
| 48 - 55 | 1303 | 0.8644546 | 1652 | 1971 | 2690 | 2494 |
| 56 - 63 | 683 | 0.9294045 | 1211 | 1535 | 1831 | 2500 |
| 64 - | 751 | 0.8133891 | 1166 | 1934 | 2822 | 3785 |
| Male total | 22054 | | 22576 | 23191 | 23319 | 22872 |
| Female | | | | | | |
| 0 - 7 | 3433 | 0.7614752 | 2723 | 2809 | 2526 | 2124 |
| 8 - 15 | 3789 | 0.9567117 | 3284 | 2605 | 2688 | 2417 |
| 16 - 23 | 4520 | 0.8999155 | 3410 | 2956 | 2344 | 2419 |
| 24 - 31 | 3784 | 0.9217256 | 4166 | 3143 | 2724 | 2161 |
| 32 - 39 | 2448 | 0.9527987 | 3605 | 3970 | 2994 | 2596 |
| 40 - 47 | 1844 | 1.0789344 | 2641 | 3890 | 4283 | 3231 |
| 48 - 55 | 1356 | 1.0386075 | 1915 | 2743 | 4040 | 4448 |
| 56 - 63 | 822 | 0.8756453 | 1187 | 1677 | 2402 | 3538 |
| 64 - | 1015 | 0.7678824 | 1411 | 1995 | 2820 | 4009 |
| Female tot | 23010 | | 24342 | 25786 | 26821 | 26942 |
| Both | | | | | | |
| 0 - 7 | 7033 | 1.6760398 | 5993 | 6183 | 5561 | 4676 |
| 8 - 15 | 7581 | 0.9075474 | 6383 | 5419 | 5591 | 5029 |
| 16 - 23 | 8550 | 0.8844449 | 6705 | 5648 | 4790 | 4942 |
| 24 - 31 | 7356 | 0.8746023 | 7478 | 5851 | 4937 | 4171 |
| 32 - 39 | 4859 | 0.9374694 | 6896 | 7021 | 5489 | 4634 |
| 40 - 47 | 3755 | 1.0127197 | 4920 | 7002 | 7168 | 5589 |
| 48 - 55 | 2659 | 0.9499866 | 3567 | 4713 | 6730 | 6942 |
| 56 - 63 | 1505 | 0.9019932 | 2398 | 3212 | 4233 | 6038 |
| 64 - | 1766 | 0.7878324 | 2577 | 3929 | 5641 | 7794 |
| Total | 45064 | | 46918 | 48978 | 50140 | 49814 |

Note : Ratio for 0 - 7 cohort is calculated by

$$\frac{\text{Population of 0 - 7 cohort in 1988}}{\begin{array}{l}(( \text{Female population of 16 - 23 cohort in 1980} * 0.205 \\ + \text{Female population of 24 - 31 cohort in 1980} * 0.2628 \\ + \text{Female population of 32 - 39 cohort in 1980} * 0.1372 \\ + \text{Female population of 40 - 47 cohort in 1980} * 0.054)/0.659)\end{array}}$$

where the denominator is the weighted average of fertile female population according to the Contraceptive Prevalence Survey in 1984. The weighted average in a certain year is multiplied by the fixed ratio to obtain the population of 0 - 7 cohort in the next target year.

Source : Analysis Report for Phuket Town Plan, DTCP 1989
Estimation by the Study Team

Table 3.6 Comparison of Population Changes by On-Going Projects and by Land Use Plan

| Zone | Present Population (a) | No. of Units of Projects (b) | Population after Projects (c) | Population by Land Use Plan (d) | Larger Population between (c) & (d) (e) |
|---|---|---|---|---|---|
| A1 | 1530 | 0 | 1530 | 1482 | 1530 |
| A2 | 970 | 0 | 970 | 604 | 970 |
| A3 | 1383 | 0 | 1383 | 901 | 1383 |
| A4 | 1640 | 0 | 1640 | 732 | 1640 |
| A5 | 1303 | 24 | 1351 | 1295 | 1351 |
| A total | 6826 | 24 | 6874 | 5015 | 6874 |
| B1 | 1638 | 36 | 1710 | 1529 | 1710 |
| B2 | 1870 | 0 | 1870 | 3661 | 3661 |
| B3 | 1900 | 108 | 2116 | 2222 | 2222 |
| B4 | 1466 | 153 | 1772 | 1087 | 1772 |
| B5 | 1221 | 0 | 1221 | 518 | 1221 |
| B6 | 1631 | 270 | 2171 | 1925 | 2171 |
| B total | 9726 | 567 | 10860 | 10041 | 12757 |
| C1 | 1120 | 0 | 1120 | 1223 | 1223 |
| C2 | 1691 | 75 | 1841 | 1187 | 1841 |
| C3 | 1688 | 100 | 1888 | 896 | 1888 |
| C4 | 1023 | 0 | 1023 | 442 | 1023 |
| C5 | 1643 | 0 | 1643 | 776 | 1643 |
| C6 | 1754 | 0 | 1754 | 1766 | 1766 |
| C7 | 1698 | 20 | 1738 | 2869 | 2869 |
| C total | 10617 | 195 | 11007 | 9158 | 12252 |
| D1 | 1772 | 37 | 1846 | 1125 | 1846 |
| D2 | 1035 | 100 | 1235 | 948 | 1235 |
| D3 | 1339 | 0 | 1339 | 967 | 1339 |
| D4 | 1558 | 0 | 1558 | 1344 | 1558 |
| D5 | 1634 | 306 | 2246 | 4120 | 4120 |
| D6 | 1876 | 50 | 1976 | 3730 | 3730 |
| D total | 9214 | 493 | 10200 | 12235 | 13828 |
| E1 | 4023 | 566 | 5155 | 3479 | 5155 |
| E2 | 1128 | 0 | 1128 | 1805 | 1805 |
| E3 | 1637 | 262 | 2161 | 2783 | 2783 |
| E4 | 1236 | 0 | 1236 | 983 | 1236 |
| E total | 8024 | 828 | 9680 | 9050 | 10979 |
| In-Munici. | 44407 | 2107 | 48621 | 45499 | 56689 |
| T.Rasada | 12600 | 143 | 12886 | 7952 | 12886 |
| T.Vichit | 1530 | 169 | 1868 | 4623 | 4623 |
| F zone | 0 | 0 | 0 | 100 | 100 |
| Out-Munici | 14130 | 312 | 14754 | 12675 | 17609 |
| DTCP Area | 58537 | 2419 | 63375 | 58174 | 74298 |
| S zone | 2511 | 267 | 3045 | - | 3045 |
| Bang Ping | 860 | 0 | 860 | - | 860 |
| Study Area | 61908 | 2686 | 67280 | - | 78203 |

Note : No.of Units of Projects
= Known No.of Housing Units
- Outside Study Area
- Estimate of Unkown No.of Units
= 2579-53+160
= 2686

Source: Analysis Report for Phuket Town Plan, DTCP 1989
Analysis and Estimation by the Study Team

Table 3.7 Area by Land Use Plan Category in Each Zone

Unit : ha

| Zone | LU1 | LU2 | LU3 | LU4 | LU5 | LU6 | LU7 | LU8 | LU9 | Others | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0 | 0 | 13.472 | 0 | 0 | 0 | 0.44 | 0.68 | 0 | 0 | 14.592 |
| A2 | 0 | 0.28 | 5.352 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5.632 |
| A3 | 0 | 0 | 8.192 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.192 |
| A4 | 0 | 0 | 6.656 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.656 |
| A5 | 0 | 0 | 11.776 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11.776 |
| A total | 0 | 0.28 | 45.448 | 0 | 0 | 0 | 0.44 | 0.68 | 0 | 0 | 46.848 |
| B1 | 0 | 0 | 13.904 | 0 | 0 | 0 | 2.48 | 0 | 0 | 0 | 16.384 |
| B2 | 0 | 0 | 33.28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33.28 |
| B3 | 0 | 0 | 20.2 | 0 | 0 | 0.12 | 0 | 0 | 0.16 | 0 | 20.48 |
| B4 | 0 | 0 | 9.88 | 0 | 0 | 0.36 | 0 | 0 | 0 | 0 | 10.24 |
| B5 | 0.2 | 9.32 | 0 | 0 | 0 | 0 | 0.64 | 0 | 0.08 | 0 | 10.24 |
| B6 | 20.744 | 9.2 | 0 | 0 | 0 | 1.6 | 0 | 0 | 0.2 | 0 | 31.744 |
| B total | 20.944 | 18.52 | 77.264 | 0 | 0 | 2.08 | 3.12 | 0 | 0.44 | 0 | 122.368 |
| C1 | 0 | 22.232 | 0 | 0 | 0 | 0 | 0 | 1.32 | 0 | 0 | 23.552 |
| C2 | 23.72 | 10.8 | 0 | 0 | 0 | 0 | 1.32 | 0 | 0 | 0 | 35.84 |
| C3 | 35.84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35.84 |
| C4 | 14.68 | 0 | 0.68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15.36 |
| C5 | 31.04 | 0 | 0 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 55.04 |
| C6 | 70.624 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 90.624 |
| C7 | 0 | 52.16 | 0 | 0 | 0 | 0 | 2.72 | 0 | 10.4 | 0 | 65.28 |
| C total | 175.904 | 85.192 | 0.68 | 0 | 0 | 44 | 4.04 | 1.32 | 10.4 | 0 | 321.536 |
| D1 | 0 | 20.48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20.48 |
| D2 | 0 | 17.24 | 0 | 0 | 0 | 2.4 | 2.8 | 1.72 | 4 | 0 | 28.16 |
| D3 | 38.68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.28 | 0 | 40.96 |
| D4 | 53.76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 53.76 |
| D5 | 4.8 | 14 | 29.36 | 0 | 0 | 0 | 0 | 0 | 0.48 | 0 | 48.64 |
| D6 | 34 | 79.384 | 20.4 | 0 | 0 | 4.8 | 0 | 0.68 | 0 | 0 | 139.264 |
| D total | 131.24 | 131.104 | 49.76 | 0 | 0 | 7.2 | 2.8 | 2.4 | 6.76 | 0 | 331.264 |
| E1 | 2.4 | 62.16 | 0 | 0 | 0 | 0 | 0.72 | 0 | 6.4 | 0 | 71.68 |
| E2 | 72.192 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72.192 |
| E3 | 79.64 | 0 | 7.2 | 0 | 0 | 0 | 8 | 1.56 | 6 | 0 | 102.4 |
| E4 | 39.32 | 0 | 0 | 0 | 0 | 0 | 3.4 | 1.84 | 2.8 | 32 | 79.36 |
| E total | 193.552 | 62.16 | 7.2 | 0 | 0 | 0 | 12.12 | 3.4 | 15.2 | 32 | 325.632 |
| In-Munici. | 521.64 | 297.256 | 180.352 | 0 | 0 | 53.28 | 22.52 | 7.8 | 32.8 | 32 | 1147.648 |
| T.Rasada | 184 | 21.2 | 0 | 102 | 136 | 0 | 56 | 0.32 | 0.48 | 274.952 | 774.952 |
| T.Vichit | 184.92 | 0 | 0 | 0 | 0 | 144.2 | 0.64 | 0.48 | 0 | 0 | 330.24 |
| F zone | 4 | 0 | 0 | 0 | 0 | 107.84 | 1.16 | 0 | 0 | 0 | 113 |
| Out-Munici | 372.92 | 21.2 | 0 | 102 | 136 | 252.04 | 57.8 | 0.8 | 0.48 | 274.952 | 1218.192 |
| DTCP Area | 894.56 | 318.456 | 180.352 | 102 | 136 | 305.32 | 80.32 | 8.6 | 33.28 | 306.952 | 2365.84 |
| S zone | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 95.5 | 95.5 |
| Bang Ping | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 120 | 120 |
| Study Area | 894.56 | 318.456 | 180.352 | 102 | 136 | 305.32 | 80.32 | 8.6 | 33.28 | 522.452 | 2581.34 |

Note : LU1 : Low density residential zone
LU2 : Medium density residential zone
LU3 : Commercial and high density residential zone
LU4 : Industrial zone
LU5 : Agricultural and rural zone
LU6 : Recreational and environmental protection zone
LU7 : Educational zone
LU8 : Religious zone
LU9 : Government office and public service zone
Others : Outside the Town Plan Area

Source : Analysis Report for Phuket Town Plan, DTCP 1989
Analysis and Estimation by the Study Team

The results of the estimated population by land use plan assuming minimum population density are shown in column (d) of Table 3.6.

(iii) By comparing the results of the above (i) and (ii), and assuming the larger population for each zone, the total population for the Study Area can be estimated approximately at 78,200, which is estimated on preceding Table 3.6.

(5) Selected Method and Results of Estimation

Among the above methods, the bottom-up approach reflects the current housing boom, the long term land use plan and is consistent with the macroscopic trend shown in the expected fixed growth rate case. Therefore, the bottom-up approach method will select to estimate the future population of the study area in this report.

Allocation of the zonal population to each land use category is made according to the share of the assumed density times as shown in Annex Table 3.1.

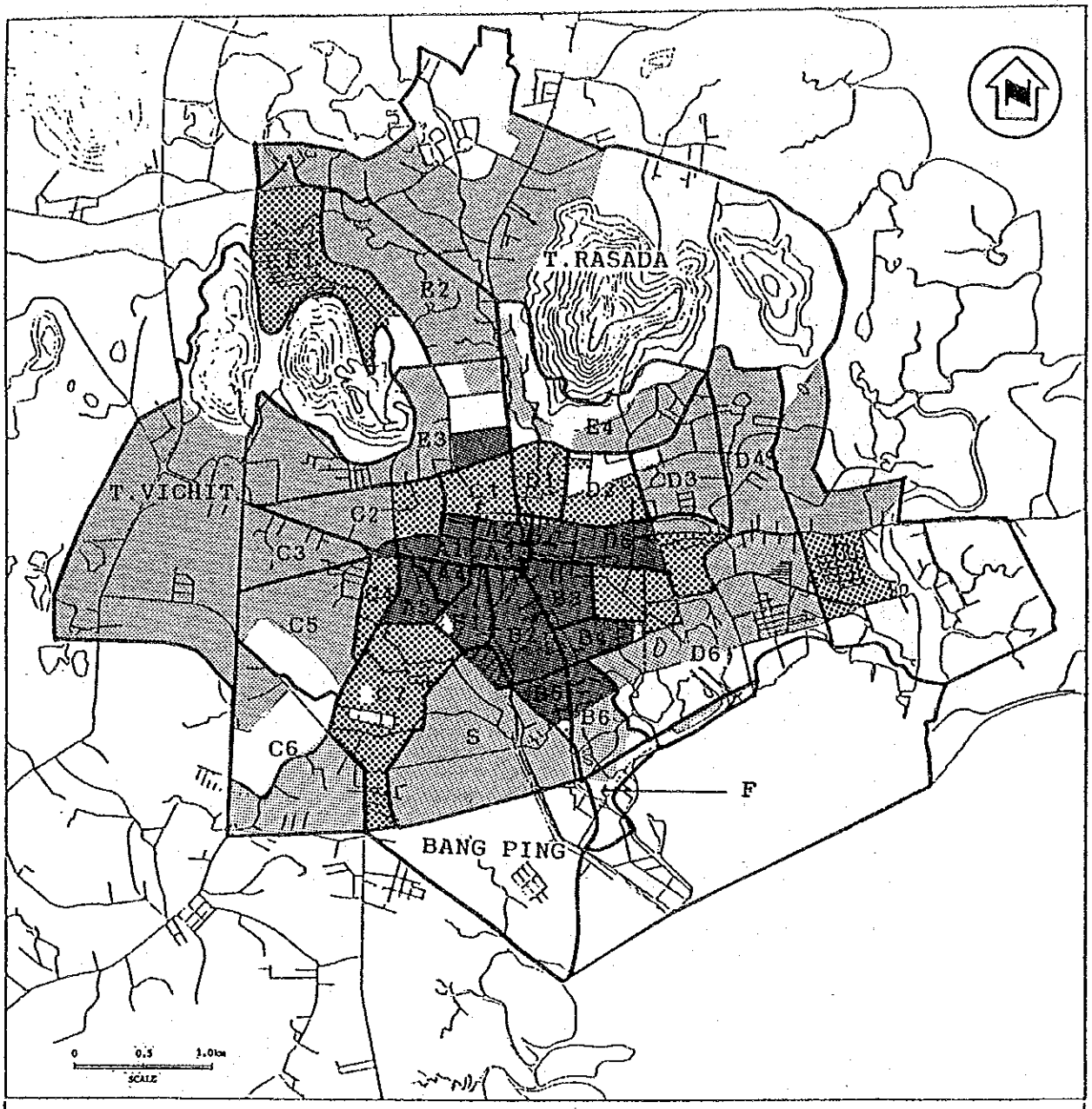
The number of families in 2006 is estimated assuming 3.7 persons/family according to the Homes Research Report prepared in 1987 for the Seminar on Demographic and Economic Forecast for Thailand.

Population density by zone and land use category in 2006 is de picted in Fig. 3.3.

(6) Population Distribution in Intermediate Phases

Based on the assumption of 1.3% growth rate per annum which is closely approximate value to the bottom-up approach method adopted for population estimation of 2006, the population distribution in 2001 is calculated as in Annex Table 3.2.

According to the Homes Research Report, average family sizes in the study area in 1996 and 2001 are estimated at 4.9 and 3.9, respectively. So the numbers of families in 1996 and 2001 are calculated to be 14,000 and 18,800, respectively.




LEGEND

Population Density

110 Persons/ha (17.6 Persons/Rai) or More

55 - 110 Persons/ha (8.8 - 17.6 Persons/Rai)

25 - 55 Persons/ha (4 - 8.8 Persons/Rai)

Fig. 3.3
ESTIMATED
POPULATION DENSITY
DISTRIBUTION IN 2006

## 3.2 Water Demand

### 3.2.1 Existing Water Supply System

The city area of Phuket is supplied with water by the Phuket City Waterworks. The water source is surface water stored in six abandoned tin-mining pits scattered in the northern part of the city. Raw water is pumped to the treatment plant located on the foothill of Mt. To Sae. The treatment plant has processes of coagulation-sedimentation, rapid filtration and chlorination and consists of three modules of which capacities are 80 $m^3/h$, 250 $m^3/h$ and 250 $m^3/h$, respectively. Treated water is stored in a series of three clear water reservoirs with capacities of 200 $m^3$, 500 $m^3$ and 1,000 $m^3$, respectively and distributed directly to the service area by clear water pumps.

The layout of the treatment plants is shown in Annex Fig. 3.1.

Phuket City agreed to receive a tap water supply of 6,000 $m^3/d$ from the Provincial Waterworks Authority (PWA) on June 12, 1989 which has a water treatment plant with a rated treatment capacity of 24,000 $m^3/d$ (1,000 $m^3/h$) near the Bangwad Reservoir, 3.4 km west of the city and supplies tap water to Patong, Kathu and Deep Sea Port areas. Tap water is purchased by the city at a rate of four baht per $m^3$.

The people unserved by a city water supply system mainly rely on shallow wells for water source. The number of shallow wells is estimated at approximately 5,000 by the Phuket City Waterworks, but some of them are not used due to water pollution problems.

### 3.2.2 Historical Water Consumption

(1) General

The annual amounts of water distribution and consumption were 4,663,520 $m^3$ and 4,207,750 $m^3$ in 1988, respectively. The water consumption is 11.9% up from the previous year and has a remarkable average annual growth rate of 13.4% in the past four years as shown in Annex Table 3.3 and Annex Fig. 3.2.

The water consumption is measured with a water meter at each connection, while the water distribution is estimated with the rated pump discharge and operation hours. The apparent unaccounted-for water ratio was 10.0% very low in 1988 and has varied from 16.2% to 10.0% in the past four years.

The number of connections has been favorably increasing with an average annual growth rate of 6.7% both inside and outside the city area. The number of connections outside the municipal area shared 9.8% of the total in 1988, 8 points up from 1985 as shown in Annex Table 3.4. The breakdown of the number of connections was 74.6% for residential, 22.8% for commercial, 1.4% for governmental and remaining 1.2% for industrial use.