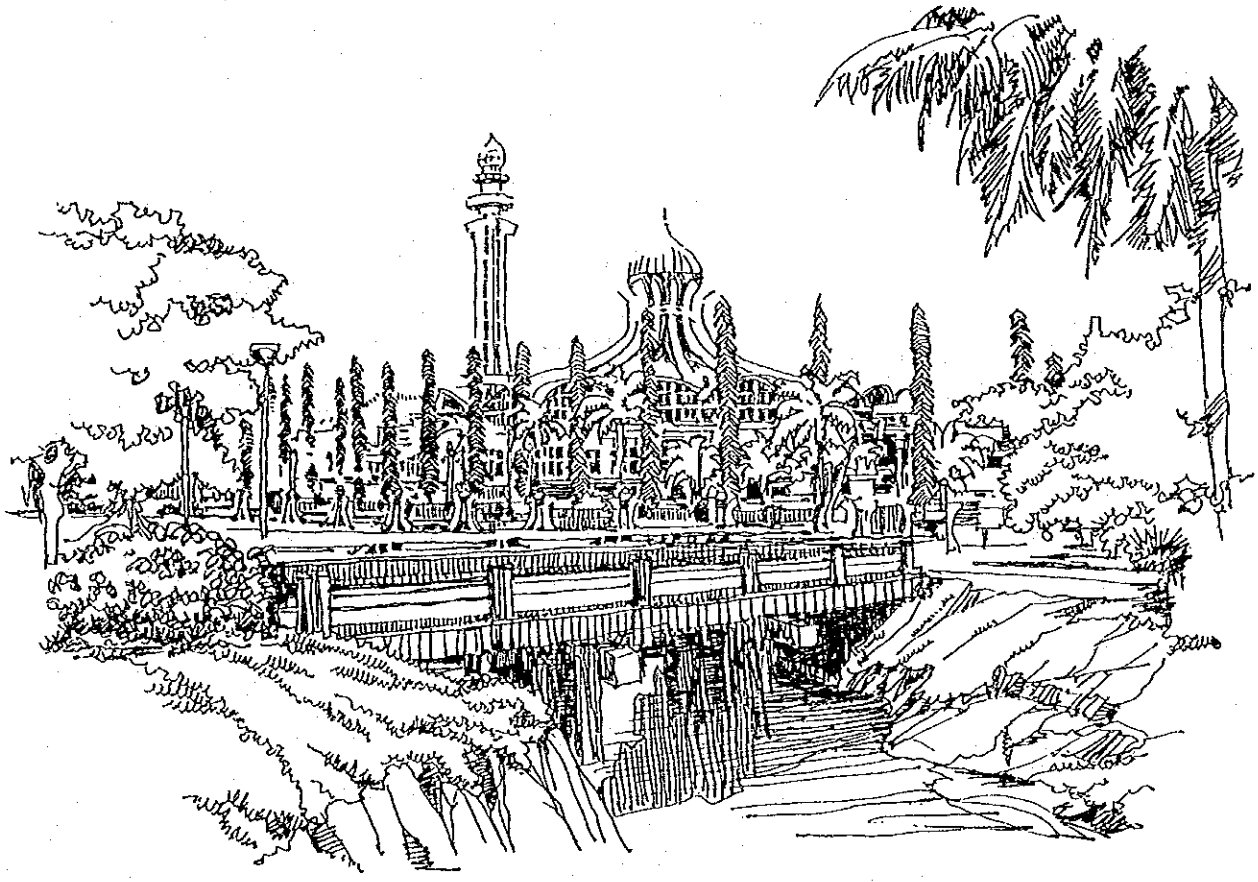
GOVERNMENT OF MALAYSIA

# THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

## MAIN REPORT



MARCH 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

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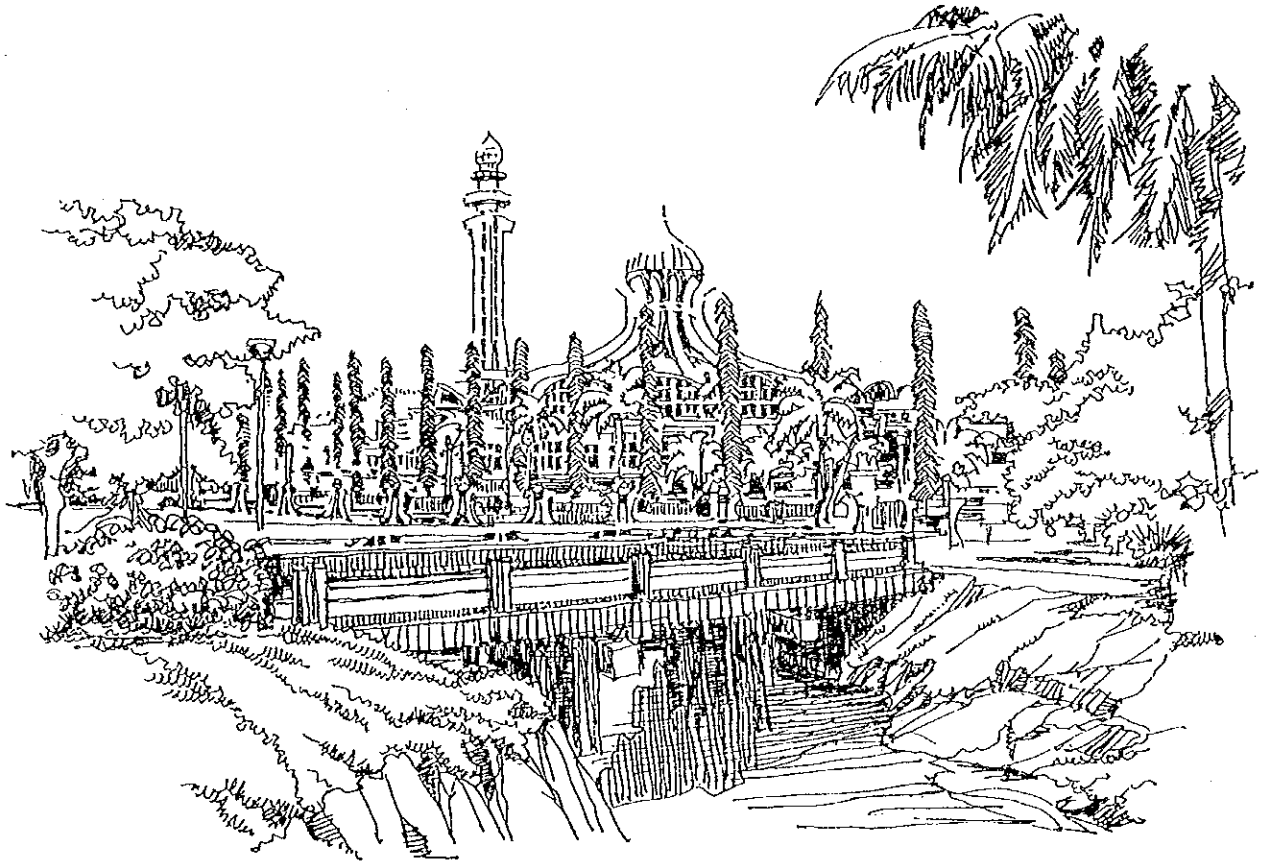
## MAIN REPORT



MARCH 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

## PREFACE

In response to a request from the Government of Malaysia, the Japanese Government decided to conduct a study on the Flood Mitigation and Drainage in Penang Island and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Malaysia a study team headed by Mr. Yoshiaki Kaneko, and composed of members from the Pacific Consultants International and Nippon Koei Co., Ltd., four times between July 1989 and January 1991.

The team held discussions with the officials concerned of the Government of Malaysia, 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 two countries.

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

March 1991

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency.

THE STUDY

ON

FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

Mr. Kensuke YANAGIYA
President
Japan International
Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled "THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND". This report has been prepared by the Study Team in accordance with the contract signed on 4 July 1989 and 11 June 1990 between the Japan International Cooperation Agency and the Joint Venture of Pacific Consultants International and Nippon Koei Co., Ltd.

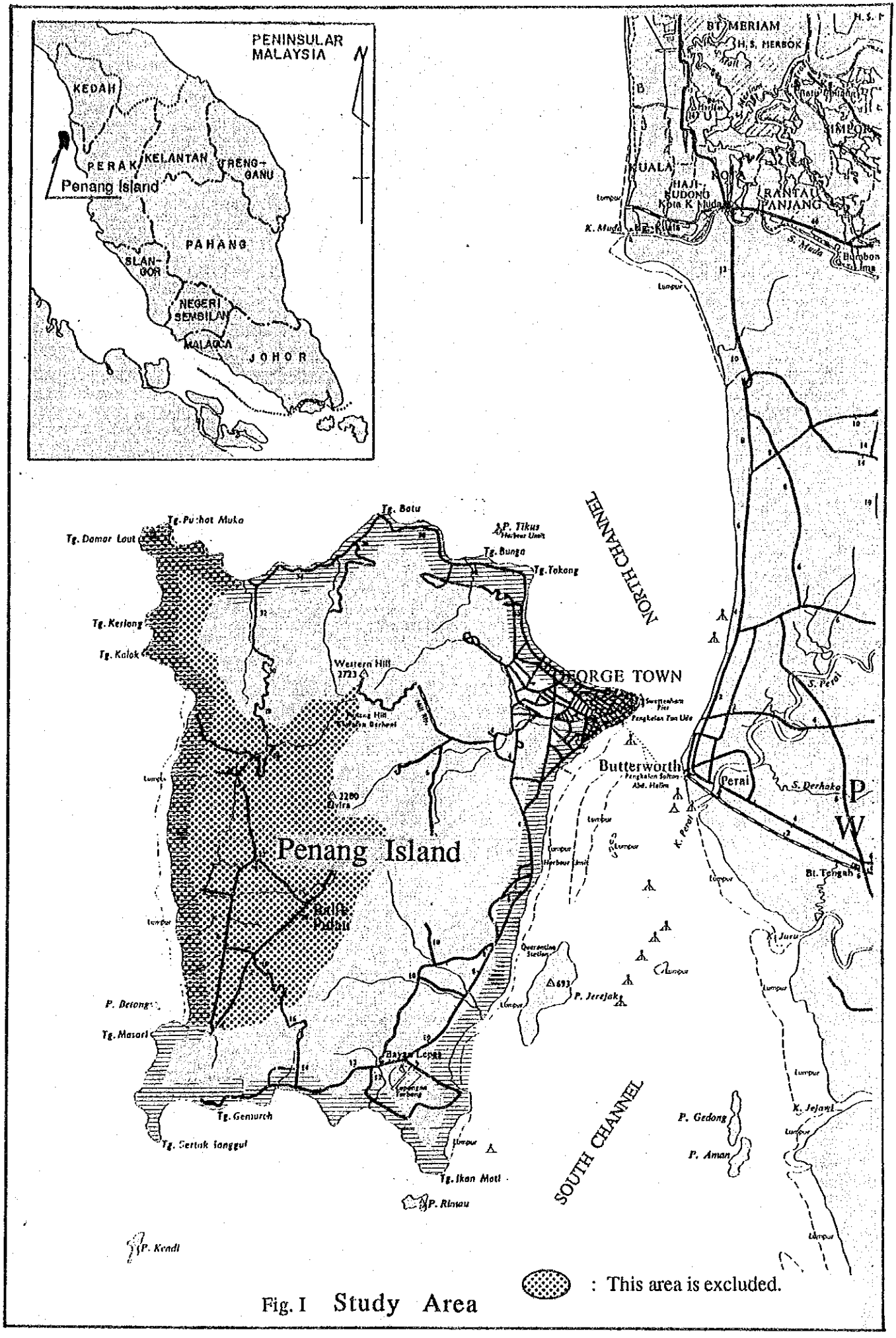
The report examines the feasible flood mitigation measures in the basin, presents a flood mitigation and drainage master plan and the results of a feasibility study on an urgent project comprising river improvement works, retention ponds, and drainage works.

The report consists of the Executive Summary, Main Report, and Supporting Report. The Summary summarizes the results of all studies. The Main Report contains background conditions, flood mitigation and drainage Master Plan, urgent flood mitigation and drainage plan, conclusions and recommendations. The Supporting Report includes data and technical details. In additions, a Data Book has been prepared and is submitted herewith.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Malaysia, and also to officials and individuals of the Government of Malaysia for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the socio-economic development and well-being of Penang Island.

Yours Faithfully,

Yoshiaki KANEKO
Team Leader



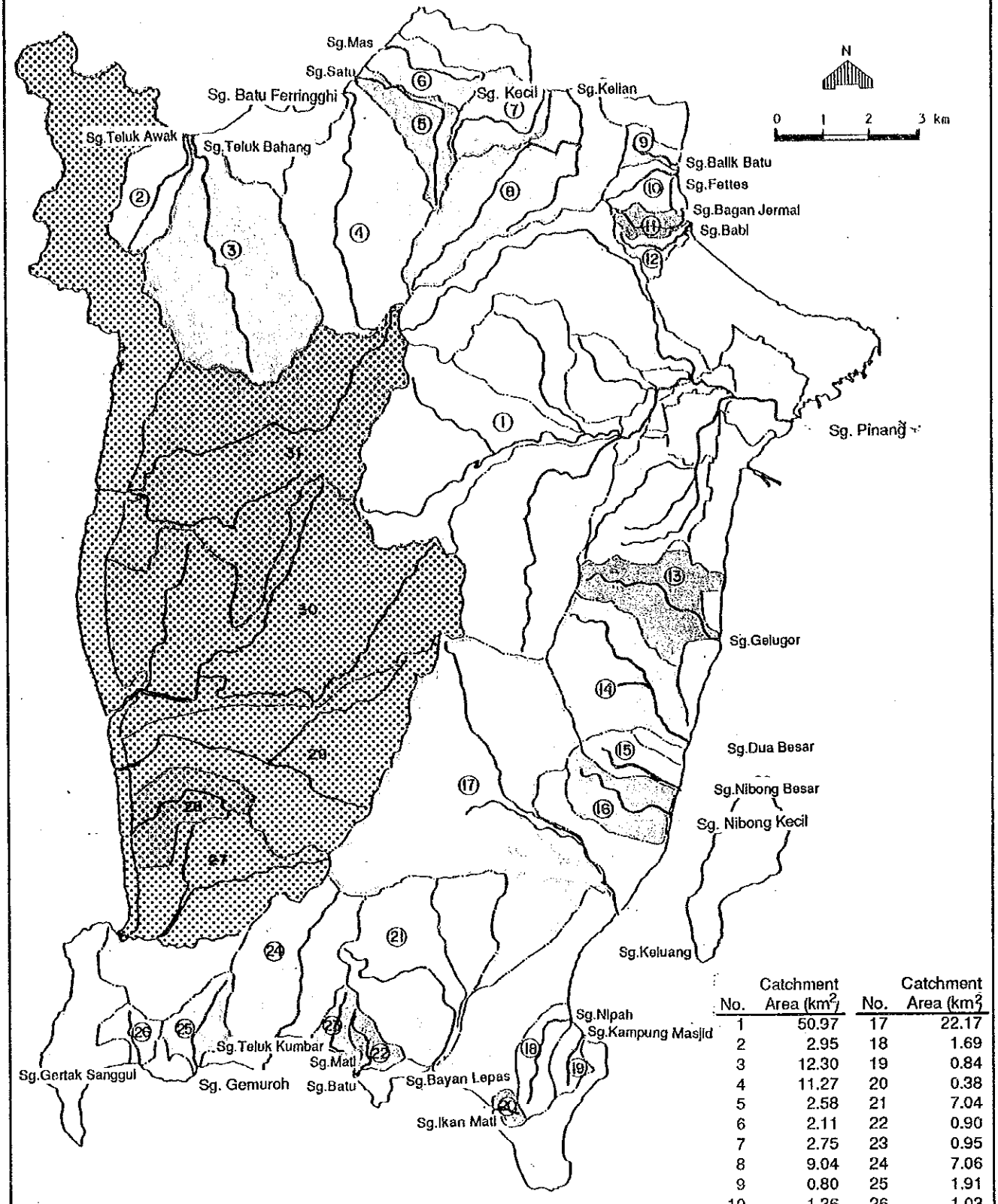

: This area is excluded.

Fig. I Study Area

Flood Condition at Caunter Hall

Flood Condition at Pesiaran Perak


Flood Condition at Jln. Perak




| No. | Catchment Area ($km^2$) | No. | Catchment Area ($km^2$) |
|---|---|---|---|
| 1 | 50.97 | 17 | 22.17 |
| 2 | 2.95 | 18 | 1.69 |
| 3 | 12.30 | 19 | 0.84 |
| 4 | 11.27 | 20 | 0.38 |
| 5 | 2.58 | 21 | 7.04 |
| 6 | 2.11 | 22 | 0.90 |
| 7 | 2.75 | 23 | 0.95 |
| 8 | 9.04 | 24 | 7.06 |
| 9 | 0.80 | 25 | 1.91 |
| 10 | 1.36 | 26 | 1.03 |
| 11 | 0.83 | 27 | 11.04 |
| 12 | 0.84 | 28 | 3.24 |
| 13 | 4.07 | 29 | 13.79 |
| 14 | 6.19 | 30 | 20.63 |
| 15 | 1.50 | 31 | 19.99 |
| 16 | 2.77 | | |

FIG. II RIVERS IN THE STUDY AREA

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



JICA

# SUMMARY

# SUMMARY

## 1. INTRODUCTION

Penang Island, with a total area of about 300 square kilometers, is located just off the northwest coast of Peninsular Malaysia (See Figure I).

The city of Georgetown is one of the most urbanized areas in Malaysia. It is in the rapidly urbanizing region along the east coast of the Island affected by recurrent flooding and high tides.

This necessitated the mitigation of flood damage in the basin; hence the identification of this project, "The Study on Flood Mitigation and Drainage in Penang Island."

This Study was carried out by the Study Team of the Japan International Cooperation Agency (JICA) in collaboration with the officials concerned of the Federal Government of Malaysia from July 1989 to March 1991.

## 2. OUTLINE OF THE STUDY AREA

The study area encompasses all of Penang Island except the west coast. There are 31 main river systems on the Island. The Sg. Pinang basin that encompasses the city of Georgetown, has a catchment of about 50 sq.km; it is the largest and most built-up river system on the Island.

The climatic characteristics of the Island is tropical and humid with high rainfall. The annual mean rainfall is 2,400 mm and 3,000 mm in the southeast side and northwest side of the Island, respectively.

The population in the Study Area was estimated to be about 547,300 in 1986. By the year 2000 it is expected to be in the 630,000 to 667,000 range.

The existing land use pattern of the Penang Island in the year 1988 was comprised of a built-up area of 22.2%, an agricultural area of 40.7% and a natural forest area of 25%. In the year 2010, the built-up area is expected to expand to 48% with major expansion being centered around the northern and eastern coastal zones encompassing Teluk Bahang, Georgetown, and Batu Maung.

## 3. OBJECTIVES OF THE STUDY

The objectives of the Study are:

(a) To formulate the Master Plan of flood mitigation and drainage in Penang Island and to identify the priority areas, and

(b) To conduct the Feasibility Studies on the flood mitigation and drainage projects in the identified priority areas.

## 4. FLOODS AND FLOOD DAMAGE

### 4.1 Causes of Floods

Flooding in the Penang Island is caused both by depression-type monsoon storms and thunderstorms, and high tides.

Depression-type monsoon storms are of long duration (2 to 3 days) with low intensity, and are widespread over the entire Island. These storms may heavily damage large catchments.

Thunderstorms are typically of short duration (3 to 5 hours) with high rainfall intensity and cause serious damage to small streams. Furthermore, in the lowlying areas along the east coast of the Island, monsoons and thunderstorms in coincidence with high tides at times cause severe flood damages.

The causes of flooding, other than unfavorable natural conditions in the river basins of the Island, are summarized below:

- Increase of run-off coefficient of the basin due to rapid urbanization.
- Loss of natural potential retention ponds due to filling up for housing development.
- Improvement of trunk drain or tributaries to an excessive level compared to the discharge capacity of downstream reaches.
- Bamboo tree, branches and garbage floating in the river channel during floods.
- Construction of steep slope drain system for housing development in hilly areas.
- Sediment run-off into trunk drain or river due to soil erosion caused by land development.
- Inadequate flow capacity of river channel or trunk drain.

- Insufficient clearance at bridge crossings.

- Lack of pumping facilities in lowlying areas located below high tide level.

### 4.2 Flood History

The most severe flood occurred in October 1980 inundating 2 sq.km area of the central part of Georgetown to a depth of 0.5 to 1.0 m for a duration of 1 to 2 days.

Flash floods caused by thunderstorms occur frequently in the Georgetown area every year.

### 4.3 Flood Damage

The flood damage is estimated for general properties, such as houses and household effects, shops, warehouses and agricultural crops, public properties, such as roads, electricity supply and telecommunication, and indirect flood damages.

The flood damage estimated for the existing river conditions and the land use conditions in Sg. Pinang basin projected for the year 2010, using various return periods of flood, are as follows.

| | Return Period (Year) (1990 Price) | | | | |
|---|---|---|---|---|---|
| | 1.1 | 5 | 10 | 30 | 50 |
| Flood Damage ($M\$10^6$) | 6.7 | 20.2 | 105.4 | 219.9 | 287.4 |

The annual average flood damage reaches 27.6 million M$ under the land use conditions in the year 1990, and 30.1 million M$ in 2010.

## 5. FLOOD RUN-OFF ANALYSIS

### 5.1 Rainfall Analysis

Daily rainfall data observed for 35 years at 7 stations in the Island have been obtained and were statistically analyzed by means of the Gumbel method.

There are 4 stations in the Sg. Pinang basin. Their average probable daily rainfall was adopted for the run-off analysis. The average probable rainfall of 50-year return period is 291 mm.

As a design rainfall, a one day rainfall was adopted for the two major rivers, Sg. Pinang and Sg. Keluang.

For the other small rivers, the rainfall intensity curve prepared by DID was adopted.

### 5.2 Flood Run-off Analysis

Flood run-off analysis was conducted by using the simulation model of storage function method for the two major rivers, Sg. Pinang and Sg. Keluang.

The constants of the storage function model for the basin were determined based on the observed flood data in the Sg. Pinang.

For the other small rivers, the Rational Method was adopted for the flood run-off analysis.

For the trunk drains, a modified Rational Method was adopted.

The peak discharge of a 50-year flood at Jln.Jelutong bridge in the Sg. Pinang is 270 $m^3/s$.

## 6. MASTER PLAN FOR FLOOD MITIGATION

### 6.1 Basic Considerations

The basic considerations in formulating the comprehensive Flood Mitigation Master Plan are as follows:

- Both the structural and non-structural measures were considered to limit the flood damage to an acceptable level in all of the basins.
- The Master Plan is formulated under the conditions of a design rainfall return period of 50 years and the projected land use pattern in the year 2010.
- The formulated Master Plan should be compatible with the existing completed or ongoing river improvement plans and the land reclamation plans for the coastal areas.

### 6.2 Master Plan Alternatives for Sg. Pinang Basin

Six possible alternative protective measures of flood mitigation are evaluated with respect to their technical feasibility, economic viability and for the selection of the most suitable alternative as the Master Plan.

Each alternative consists of a combination of several structural measures, such as river improvement, diversion

channel, flood control dam and retention pond for the Sg. Pinang and its tributaries, but only river improvement works for all of the other rivers.

## 6.3 Structural Measures of Master Plan

The structural measures of flood mitigation of the selected optimum plan, master plan, are illustrated in Fig. S-1 and Fig. S-2 and described below.

(1) Sg. Pinang and Georgetown Area

1) Construction of the Air Terjun Diversion channel under the Jln. Gottlieb and Jln. Bagan Jermal (1.74 km in length).

2) Construction of Dondang Retention Ponds having a total area of 8.4 ha.

3) Channel improvement (16.5 km) to the Sg. Pinang and its tributaries, including jetty of 710 m in length.

4) Reconstruction of 44 bridges.

(2) Other Rivers

The envisaged structural measures for all rivers other than the Sg. Pinang are mainly of channel improvements including diversion channel.

1) The total length of channel improvement is 35.4 km for the 23 rivers.

2) The total number of bridges to be re-constructed are 39.

## 6.4 Non-structural Measures of Master Plan

The following non-structural measures are recommended in the Master Plan:

i) Soil erosion & run-off control.

ii) Removal of floating garbages, bamboos and branches.

iii) Formulation of design criteria for river and related structures.

iv) Instituting a flood warning system.

Beside these non-structural measures, an institutional reform for the existing Comprehensive Flood Mitigation Committee was proposed clearly defining its functional authority and responsibility, so that its jurisdiction would

encompass the overall watershed management of the whole island.

## 6.5 Implementation Program

Implementation of the master plan is divided into three phases, with a total period of eighteen years, as shown in Fig. S-1 and summarized below.

**Phase I (Urgent Project)**

For the Sg. Pinang system, river improvement works of the Sg. Pinang and its tributaries, construction of Air Terjun Diversion Channel and Dondang Retention Ponds will be executed as the urgent project works.

In the areas outside Georgetown, river improvement works of Sg. Keluang and its tributaries, and the construction of Relau Diversion Channel will be executed.

River improvement works for the downstream stretches of Sg. Gelugor and Sg. Dua Besar are also included.

**Phase II**

In the Georgetown area, river improvement works of Sg. Air Terjun and upstream reaches of Sg. Dondang will be executed.

In the areas outside Georgetown, Sg. Fettes, Sg. Bayan Lepas, Sg. Teluk Bahang, Sg. Teluk Awak, Sg. Mas and Sg. Nibong Kecil will be improved.

**Phase III**

The remaining 14 rivers will be improved.

## 6.6 Project Cost for the Master Plan

The total project cost for the Flood Mitigation Master Plan is estimated to be 260.7 million M$ in 1990 financial price. The cost breakdown for each of the three phases is as follows:

(Unit: $10^6$ M$)

| | | | Total Cost |
|---|---|---|---|
| Phase I * 1991 - 1995 | Sg. Pinang<br>Other Rivers | 135.5<br>40.2 | 175.7 |
| Phase II 1996 - 2000 | Sg. Pinang<br>Other Rivers | 20.5<br>26.0 | 46.5 |
| Phase III 2001 - 2010 | Other Rivers | 38.5 | 38.5 |

*: The cost of urgent drainage project (37.9 million M$) is not included.

### 6.7 Economic Evaluation of Flood Mitigation Master Plan

The economic evaluation of the Master Plan for Sg. Pinang and other 23 rivers were made in terms of the Economic Internal Rate of Return (EIRR), based on the following assumptions:

(1) The annual operation and maintenance costs are 1.0% of economic construction cost.

(2) The project benefits are realized 5 years after the commencement of the project implementation.

(3) The social discount rate is 8.0 %.

(4) The opportunity cost of capital is 8.0%.

The results of economic evaluation for major rivers are as follows:

| River | EIRR | B/C |
|---|---|---|
| Sg. Pinang | 15.1 | 1.9 |
| Sg.Keluang | 14.6 | 2.15 |

## 7. DRAINAGE MASTER PLAN

### 7.1 Review of Previous Master Plan

The drainage Master Plan Study for Penang Island was carried out by MPPP in 1985. This Master Plan mainly covers the drainage systems in Georgetown which discharge via 42 man-made outfalls to the North and South Channels or directly to the rivers (see Fig.S-3). In the areas outside Georgetown, flood problems of some major rivers were studied. However, drainage problems of the main drains were not included in the previous study by MPPP.

In this study, the previous study was reviewed taking into account the present and future land use conditions (especially, the Land Reclamation Plan by PDC and Outer Ring Road Plan) for Georgetown area.

For the areas outside Georgetown, the drainage study was carried out to solve the inner water problems which are anticipated even after the completion of river improvement works.

## 7.2 Study Areas

The study areas for the drainage Master Plan for the above-mentioned 42 drainage basins in Georgetown and areas outside Georgetown which are the present and future flood prone areas.

## 7.3 Basic Considerations

Based on the latest information of the land reclamation plan and results of the review of the previous study, the following concepts were adopted for formulation of the drainage Master Plan.

- Eight (8) outfalls along the Gurney Drive in the North Channel are to be reorganized after taking into consideration landscape, environment and maintenance.

- Seven (7) outfalls (S-6 to S-16 and S-18) are to be extended up to the proposed Coastal Road. Other outfalls in the reclamation area in the South Channel are to be connected to a new waterway without extension.

- For the S-10 Prangin Road and S-18 Macalister Road catchments, the combination of a pump station and retention pond were adopted.

- For the undeveloped lowlying areas, the basic strategy is to fill up the area with a ground level suitable for future development instead of installing pumping facilities.

- The design flood protection level having a 10 years return period was adopted.

## 7.4 Proposed Drainage Master Plan

The major components of the drainage Master Plan in Georgetown consist of the realignment of existing main drains, including the extension of the outfall in the future reclamation area, reorganization of drainage catchment and pump drainage plan for lowlying areas.

The major drainage works in Georgetown are as follows:

(1) Drainage works in North Channel

- Improvement to 7.2 km main drains.
- 1.8 km extension of the existing outfalls due to the proposed Outer Ring Road.

(2) Drainage works in South Channel

- Improvement to 8.0 km main drains.
- 3.5 km extension of the existing outfalls.
- S-10 retention pond with 22,000 $m^3$ in storage capacity and pump station with 6.0 $m^3/s$ in capacity.
- S-18 Retention Pond of 56,000 $m^3$ in storage capacity and pump station of 2.0 $m^3/s$ in capacity.

(3) Drainage works in the areas outside Georgetown

The drainage plan in the areas outside Georgetown mainly consists of improving river tributary and existing drains, and land filling. The major drainage facilities are as follows:

- Improvement of existing earth channel for 2550 m stretch of the diversion channel of Sg. Dua Besar, original Sg. Gelugor and Sg. Kg. Seronok.
- Improvement of existing drain for 85 m stretch in Minden Heights.
- Improvement of existing concrete channel of Sg. Kg. Seronok for 200 m stretch.
- Construction of new road side drain of 1200 m in length on Jln. Sg. Relau.
- Construction of new drain of 450 m in length from Jln. Relau to Sg. Relau.

## 8. URGENT FLOOD MITIGATION PLAN

### 8.1 Priority Areas

The existing urban areas of Georgetown and the downstream reach of Sg. Keluang often suffer from flood damage and require immediate attention. For this reason, an urgent flood mitigation plan, based on the Master Plan, was

studied to formulate the priority projects for immediate implementation, aiming at mitigating flood damage in the Sg. Pinang and Sg. Keluang basins.

## 8.2 Urgent Flood Mitigation Facilities

The flood mitigation facilities of the Urgent Projects are as follows:

- River improvement works (13.32 km in length) for the stretches of the Sg. Pinang system.
- River improvement works (5.25 km in length) for Sg. Keluang system.
- Dondang Retention Ponds.
- Air Terjun Diversion Channel (1.74 km) and Relau Diversion Channel (1.53 km).
- River Improvement works (0.50 km in length) for Sg. Gelugor
- River improvement works (2.10 km in length) for Sg. Dua Besar.

River Improvement

| | | |
|---|---|---|
| Sg. Pinang | - | Deepening and widening of 3.15 km river stretches after completion of ongoing river improvement works. |
| | - | Extension of river mouth portion (0.71 km in length). |
| | - | Reconstruction of 7 bridges including 2 small bridges. |
| Sg. Air Itam | - | Deepening and widening of 3 km river channel. |
| | - | Reconstruction of 3 bridges. |
| Sg. Jelutong | - | Deepening and widening of 2.14 km of river channel. |
| | - | Reconstruction of 17 bridges. |
| Sg. Dondang | - | Deepening and widening of 4.32 km of river channel between confluence to Sg. Air Itam and retention pond A. |
| | - | Reconstruction of 8 bridges. |
| Sg. Keluang | - | 1.74 km of river improvements will be executed including a river course extension of 0.20 km. |
| Sg. Ara | - | 1.87 km of river improvement will be executed. |

Sg. Relau - 1.64 km of river improvement will be executed in the upstream portion of diversion point.
- Reconstruction of 3 bridges.

Sg.Gelugor - 0.50 km of river improvement will be executed in the downstream portion.

Sg.Dua besar - 2.10 km of river improvement will be executed in the downstream stretch.

Diversion Channel

- Air Terjun Diversion Channel

This channel consists of the construction of a 1.55 km stretch of concrete box culvert, and the deepening and widening of the downstream reach of Sg. Babi.

- Relau Diversion Channel

A diversion channel (1.53 km in length) connecting Sg. Relau to Sg. Ara will be constructed through the planned new development area.

Retention Pond

- Dondang Retention Ponds

Three retention ponds will be constructed by excavation of existing ground.

The total proposed pond area, using parks and open areas proposed by MPPP, is 8.44 ha and the total pond capacity is 198,500 $m^3$.

These retention ponds will regulate the discharge of Sg. Dondang from 80 $m^3/s$ to 60 $m^3/s$ and serve as a retention pond during floods with return periods exceeding 30-years.

The ponds will normally be used as park land to cater for the needs of diversified facilities for sports and recreational activities.

| | | |
|---|---|---|
| Retention pond A | Storage capacity: | 79,000 $m^3$ |
| | Area for ponding: | 30,500 $m^2$ |
| | Depth: | 4.24 m |
| Retention pond B | Storage capacity: | 73,000 $m^3$ |
| | Area for ponding: | 32,700 $m^2$ |
| | Depth of the pond: | 4.18 m |
| Retention pond C | Storage capacity: | 46,500 $m^3$ |
| | Area for ponding: | 21,200 $m^2$ |
| | Depth of the pond: | 4.77 m |

## 9. URGENT DRAINAGE PLAN

### 9.1 Priority Areas

The center of Georgetown suffers from recurrent floods and needs the immediate implementation of flood mitigation works. After completing the urgent flood mitigation works for Sg. Pinang, all drainage areas in Georgetown will no longer have flooding problems caused by overflow from the river. However, many drains will still have flooding problems due to poor drainage system.

This drainage problems is very serious especially for the large drainage basin in the low lying area.

The feasibility study for drainage plan was carried out for three priority areas in Georgetown (See Fig. S-4).

### 9.2 Urgent Drainage Facilities for Urgent Projects

The major construction works of urgent drainage projects consist of improvement of main drains of about 6.09 km stretches, construction of two pump stations and two retention ponds.

Improvement of Main Drains

S-10 basin : A stretch of 1,660 m along Jln. Prangin is to be widened and deepened, and a stretch between the existing outfall and proposed new retention pond will be connected with extension drain.

S-18 basin : A stretch of 820 m along Jln. Macalister will be improved by widening and deepening. The existing outfall will be changed to discharge into the proposed retention pond through the newly extended stretch along Leboh Sandilands. The extension length is 910 m.

N-12 basin : 2,660 m trunk drains along Jln. Perak and Jln. Pangkor are to be improved. The outfall of this drain is to be extended by 36 m in the future.

Retention Pond

Two retention ponds were planned to be constructed at the new outfalls of S-10 and S-18 drains.

These ponds would serve to store inner water during high tides by closing the tidal gates to protect the lowlying area from tidal effects and to reduce the run-off peak discharge as a result of decreased pump capacity.

The areas of water surface of S-10 and S-18 ponds are 1.9 ha and 2.4 ha respectively. The storage capacity of S-10 pond is 22,000 $m^3$, and that of S-18 pond is 56,000 $m^3$.

Pump Station

Two pump stations are planned to be constructed at the retention pond sites. S-18 pump station has two horizontal axial flow pumps with a capacity of 1 $m^3/s$ each. While S-10 pump station has three pumps of the same type having a capacity of 2 $m^3/s$.

## 10. PROJECT COST FOR URGENT PROJECTS

The financial cost for the urgent projects is estimated based on the price that prevailed in 1990. The cost breakdown is given below:

Unit : Million M$

| Project | Amount (M$) | Equivalent US$ |
|---|---|---|
| - Sg. Pinang | 135.5 | (50.17) |
| - Sg. Keluang System* | 40.2 | (14.90) |
| - Georgetown Drainage | 37.9 | (14.05) |
| Total | 213.6 | (79.12) |

* (including Sg. Gelugor and Sg. Dua Besar)

Total financial cost is 213.6 million M$.

The annual disbursement of investment costs was allocated on the basis of the implementation schedule and summarized as follows.

Annual Disbursement Schedule for Financial Cost
of Urgent Projects

Unit : Million M$

| Year/Projcet | Flood Mitigation | | | | Drainage | | | |
|---|---|---|---|---|---|---|---|---|
| | Sg.Pinang | | Sg.Keluang | | Drainage | | Sub Total | |
| | F.C. | L.C. | F.C. | L.C. | F.C. | L.C. | F.C. | L.C. |
| 1991 | 0.6 | | 0.2 | | 0.4 | | 1.2 | |
| 2.5 | | 0.6 | | 0.2 | | 0.5 | | 1.3 |
| 1992 | 0.6 | | 0.2 | | 0.5 | | 1.3 | |
| 62.9 | | 47.1 | | 13.6 | | 0.9 | | 61.6 |
| 1993 | 10.0 | | 3.2 | | 9.1 | | 22.3 | |
| 95.5 | | 52.9 | | 15.4 | | 4.9 | | 73.2 |
| 1994 | 7.8 | | 2.5 | | 7.1 | | 17.4 | |
| 26.1 | | 3.9 | | 1.2 | | 3.6 | | 8.7 |
| 1995 | 8.0 | | 2.5 | | 7.2 | | 17.7 | |
| 26.6 | | 4.0 | | 1.2 | | 3.7 | | 8.9 |
| | 27.0 | 108.5 | 8.6 | 31.6 | 24.3 | 13.6 | 59.9 | 153.7 |
| Total 213.6 | 135.5 | | 40.2 | | 37.9 | | | |

AS requested by the Steering Committee Meeting on 22th January 1991 and taking into account implementation capacity of DID as well as other constraints, the revised implementation schedule as shown Fig. L-11 in APPENDIX L was prepared.

It shall be noted that the results of the economic analysis has been based on the original implementation schedule. With the proposed revision due to implementation capacity of DID, there is a need to re-evaluate the economic analysis results.

For detailed breakdown of cost items, refer to Tables 10-1 through 10-4 (Page 10-7 to 10-10).

## 11. EVALUATION OF URGENT PROJECT

### 11.1 Economic Evaluation

(1) Comparison of Cost and Benefit

The economic evaluation of the urgent projects was made based on the assumption that the benefit increases exponentially between 1996 to 2010 and remains constant after 2010.

Among three urgent projects, Sg. Pinang project area includes Georgetown Drainage project area.

In this common flood prone area, the flooding problems can not be solved by the sole project and the effect of flood mitigation or drainage project would be

achieved only after implementing together these two projects.

Hence, for the economic evaluation, these two projects were also evaluated as one project.

The annual disbursement schedule for each project is shown in Table 13-1.

The results of evaluation are as follows;

| Project | EIRR (%) | NPV (1,000 M$) | B/C |
|---|---|---|---|
| Sg. Pinang Project | 17.5 | 132,212 | 2.34 |
| Sg. Keluang Project | 14.6 | 33,829 | 2.15 |
| Georgetown Drainage Project | 8.6 | 1,713 | 1.06 |
| Sg. Pinang & Georgetown Drainage Project | 16.0 | 133,925 | 2.06 |

As shown in the above table, all urgent projects are judged feasible because:

- Economic internal rates of return for each project shows a higher level than the opportunity cost of capital (=8%).
- Two other evaluation indicators approve of the implementation of the projects.

It is concluded that the three urgent projects are feasible and that their implementation are recommended.

(2) Sensitivity Analysis

The above evaluation indicators were examined by sensitivity analysis. EIRR values for each project are summarized below:

| Project Title | Cost 20% up | Benefit 20% down | Cost 20% up and Benefit 20% down |
|---|---|---|---|
| Sg. Pinang Project | 15.1 | 14.6 | 12.4 |
| Sg. Keluang Project | 12.8 | 12.5 | 10.9 |
| Georgetown Drainage Project | 6.8 | 6.4 | 4.8 |
| Sg. Pinang & Georgetown Drainage Project | 13.7 | 13.2 | 11.1 |

Results show that two flood mitigation projects are feasible even in the possible worst case with cost 20% higher than the original and benefit 20% less than original. While, in the case of evaluation for sole drainage project, the investment efficiency goes down lower than the opportunity cost capital.

However, as described before, this drainage project should be evaluated together with Sg. Pinang Flood Mitigation project.

Furthermore, besides the damage reduction benefits estimated in monetary terms, Georgetown Drainage project generates the intangible benefits such as improvement of sanitary conditions in the urban center which is affected by high tides.

Finally, it is concluded that three flood mitigation and drainage projects are all feasible and their implementation are recommended.

### 11.2 Social Impact

The major social impacts of the project are as follows:

(1) Land use potential of the flood prone area will be enhanced. The estimated flood prone area in the case of a 50-year return period is 14.8 square kilometer for Georgetown and 3.8 square kilometer for Sg. Keluang basin.

(2) Environment of people's public health and amenities will be improved. By 2010 it is estimated that 258,000 persons in Georgetown will benefit from the project.

## 12. OTHER STUDIES

In connection with the flood mitigation and drainage study, the following studies were carried out:

(1) Water Quality Improvement

Pollution conditions of rivers in the Island were classified and pig farming wastewater discharge and inadequate domestic wastewater treatment were identified as major causes of river pollution. To improve the pollution conditions, it was recommended to implement a wastewater control from pig farming and to strengthen domestic wastewater treatment.

As additional studies, operational methods of the existing communal plant were investigated and improvement measures were recommended. While

improvement of Sg. Dondang water quality by direct purification were investigated, and it was found that its water quality was too polluted to apply direct purification.

(2) Preliminary Environment Impact Assessment

As a requirement of the Government, a preliminary E.I.A. study on this project was conducted by a research team from the University Science Malaysia.

The major findings and conclusions on the preliminary E.I.A. study are as follows:

1. The major adverse impacts are caused at construction phase while the enhancement to the environment occurs at the stage of operation, and firm management action and mitigating measures would be practised during construction and operation.

2. When the project is completed, it is anticipated that the flood problem of Sg. Pinang would be greatly improved if not solved.

## 13. CONCLUSION AND RECOMMENDATIONS

(1) The Master Plan on Flood Mitigation of the Rivers in Penang Island is proposed consisting of both structural and non-structural measures. The structural measures are river improvement works, retention ponds and diversion channels. The proposed plans for the major rivers are both technically and economically feasible, and are socially justifiable.

(2) The proposed urgent drainage plan for S-10, S-18 and N-12 consists of drain improvement, retention ponds and pump stations. The proposed plan is both technically and economically feasible, and is justifiable.

(3) The immediate implementation of the urgent project, (Phase I) of three phases of Master Plan, is strongly recommended, because of the presence of flood prone built-up areas and lowlying areas that experience frequent flood damage as a result of flash floods and high tides.

(4) The required land acquisition for the project shall be completed before the commencement of construction works in order to ensure smooth project implementation. It is also recommended that the appropriate authority control the type of

development within the river reserve in order to facilitate land acquisition activity in the future.

(5) It is strongly recommended that the Comprehensive Flood Mitigation Committee of Penang Island under SEPU be instituted in order to realize the overall watershed management of the island.

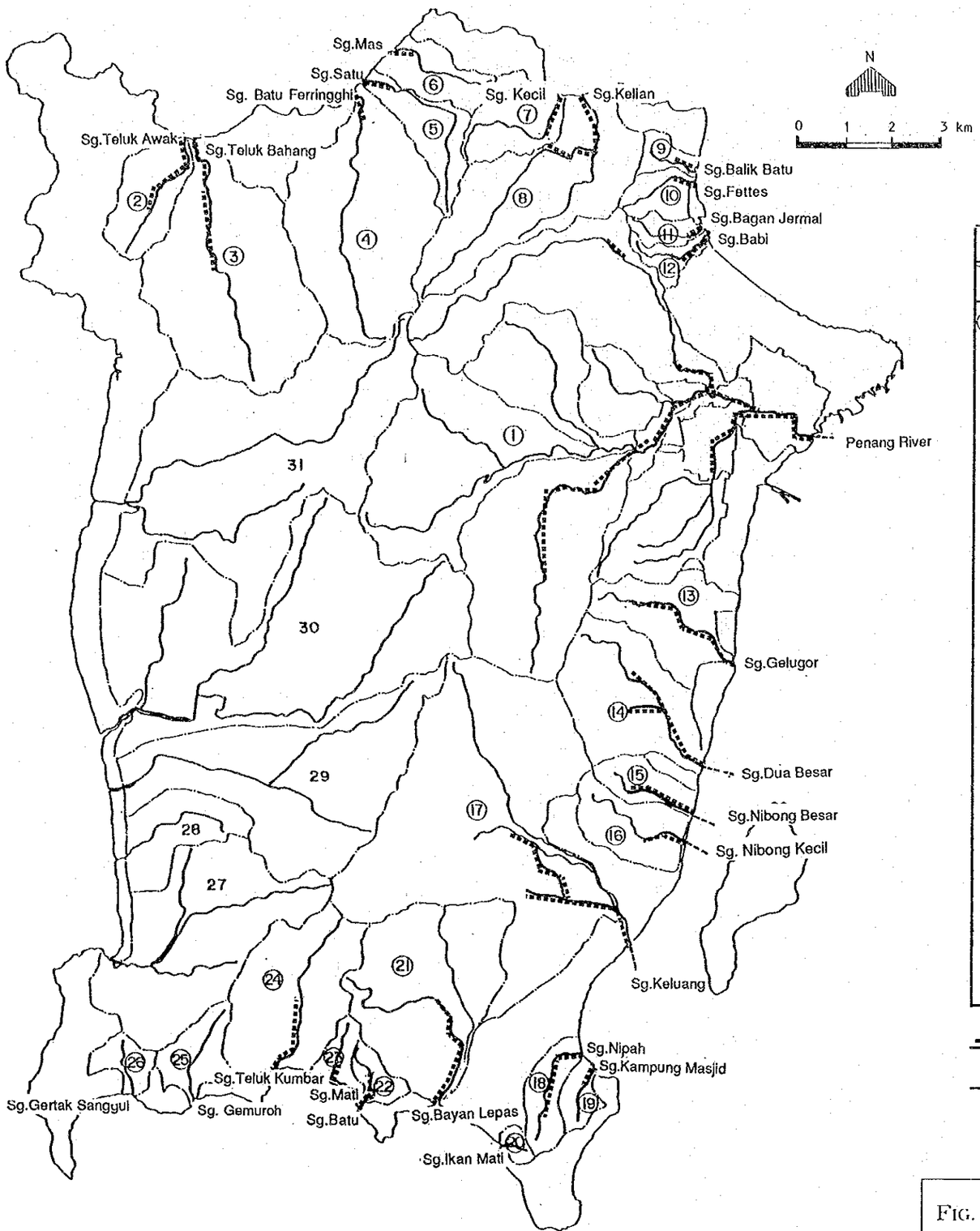
(6) For the lowlying areas along the east coast of the island, as a basic strategy, it is recommended to fill up the areas to a ground level sustainable for future development instead of installing pumping facilities.

(7) It is recommended that land development activities on hilly or mountainous terrains, especially in the Penang Hill, be strictly controlled to prevent such disasters, as debris flow, or sediment run-off.

(8) It is recommended that criteria for installing localized retention ponds (sedimentation ponds) be formulated in accordance with the degree of land development activities in the basins in order to control sediment run-off.

(9) Since it has been revealed that most rivers are polluted by garbage disposal and discharge of domestic and pig farming waste into the rivers, it is proposed i) to strengthen the sewage treatment in the Island, ii) to implement effective regulations concerning wastewater discharge from pig farming and iii) to strictly prohibit the dumping of garbages.

(10) It is necessary to publicize the importance of maintaining conducive and clean river environment. In this regard, it is highly recommended that the public be informed not to throw garbage into the river or drain.




## IMPLEMENTATION SCHEDULE FOR FLOOD MITIGATION MASTER PLAN

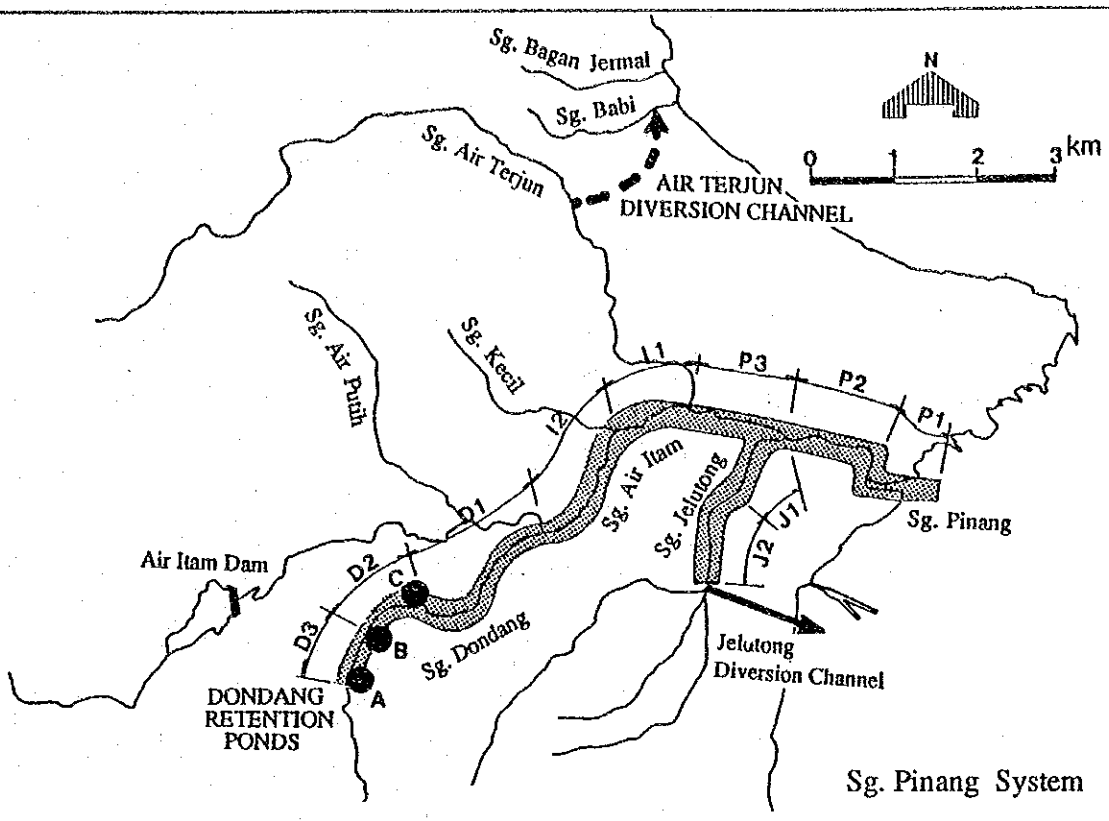
| Phase | | I (Urgent Project) | | | | | II (Mid-Term Plan) | | | | | III (Long-Term Plan) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rivers \ Year | | '91 | '92 | '93 | '94 | '95 | '96 | '97 | '98 | '99 | 2000 | '01 | '02 | '03 | '04 | '05 | '06 | '07 | '08 | '09 | 2010 |
| (Rivers) | | | | | | | | | | | | | | | | | | | | | |
| Sg. Pinang, | 3.15 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Jelutong, | 2.14 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Air Itam, | 3.00 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Dondang, | 5.30 km | | | | | | | | | | | | | | | | | | | | |
| - Air Terjun diversion, | 1.74 km | | | | | | | | | | | | | | | | | | | | |
| - Dondang retention ponds | 8.4 ha | | | | | | | | | | | | | | | | | | | | |
| Sg. Keluang | 3.38 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Ara | 1.87km | | | | | | | | | | | | | | | | | | | | |
| - Relau diversion channel | 1.53 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Air Terjun | 2.20 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Gelugor | 2.10km | | | | | | | | | | | | | | | | | | | | |
| Sg. Dua Besar | 3.30 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Fettes | 0.60 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Bayan Lepas | 2.40 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Teluk Bahang | 3.13 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Teluk Awak | 2.10 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Mas | 0.60 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Bagan Jermal | 0.30 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Nibong Besar | 1.05 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Nibong Kecil | 0.90 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Kampung Masjid | 0.60 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Nipah | 1.90 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Batu Ferringghi | 0.40 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Satu | 0.50 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Kecil | 0.70 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Kelian | 2.80 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Balik batu | 0.50 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Babi | 1.00 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Ikan Mati | 0.15 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Batu | 1.00 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Mati | 0.80 km | | | | | | | | | | | | | | | | | | | | |
| Sg. Teluk Kumbar | 1.70 km | | | | | | | | | | | | | | | | | | | | |

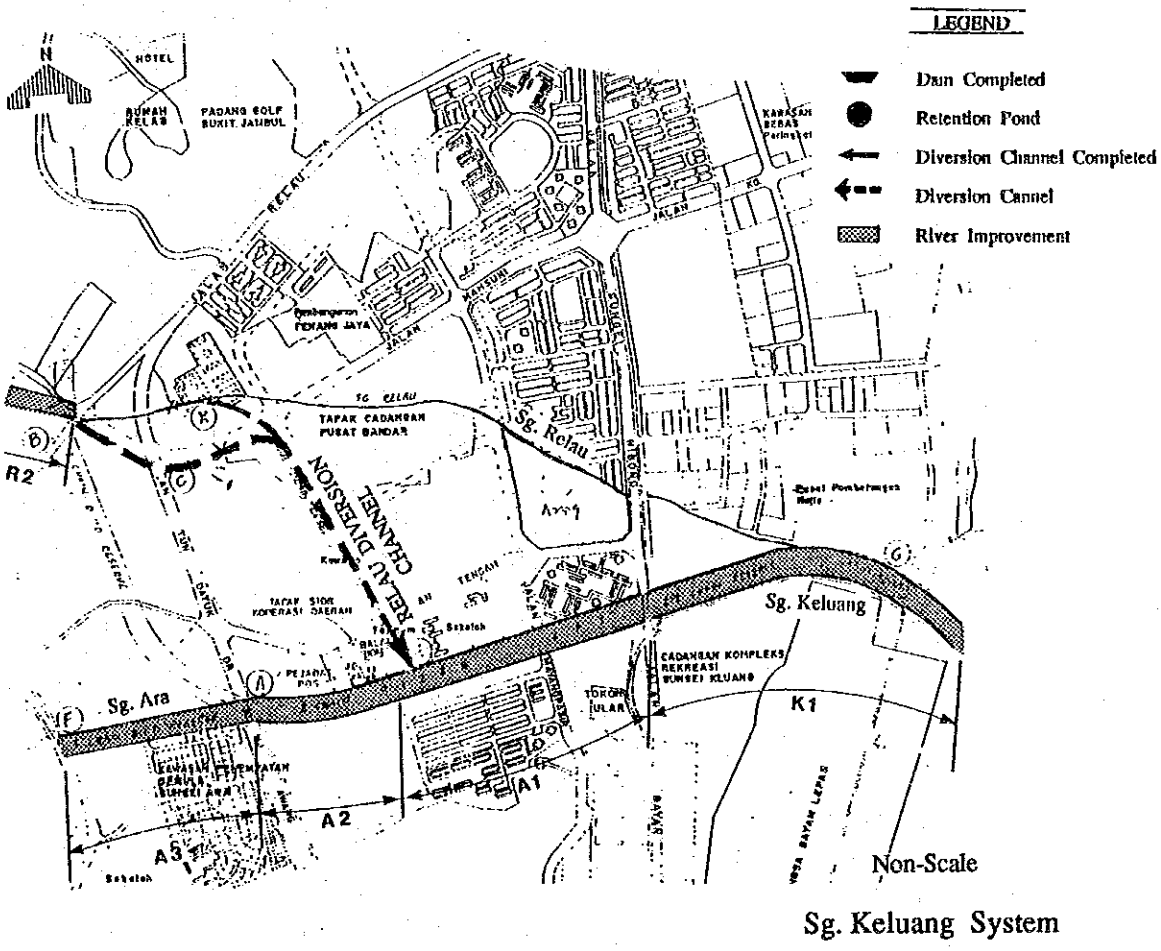
▬▬▬ ..... SECTION TO BE IMPROVED

- - - - - - - ..... EXTENSION

FIG. S-1 PROPOSED RIVER IMPROVEMENTS OF FLOOD MITIGATION MASTER PLAN

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND




| FIG. S-2 | PROPOSED FLOOD MITIGATION FACILITIES OF SG. PINANG SYSTEM AND SG. KELUANG SYSTEM |
|---|---|

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

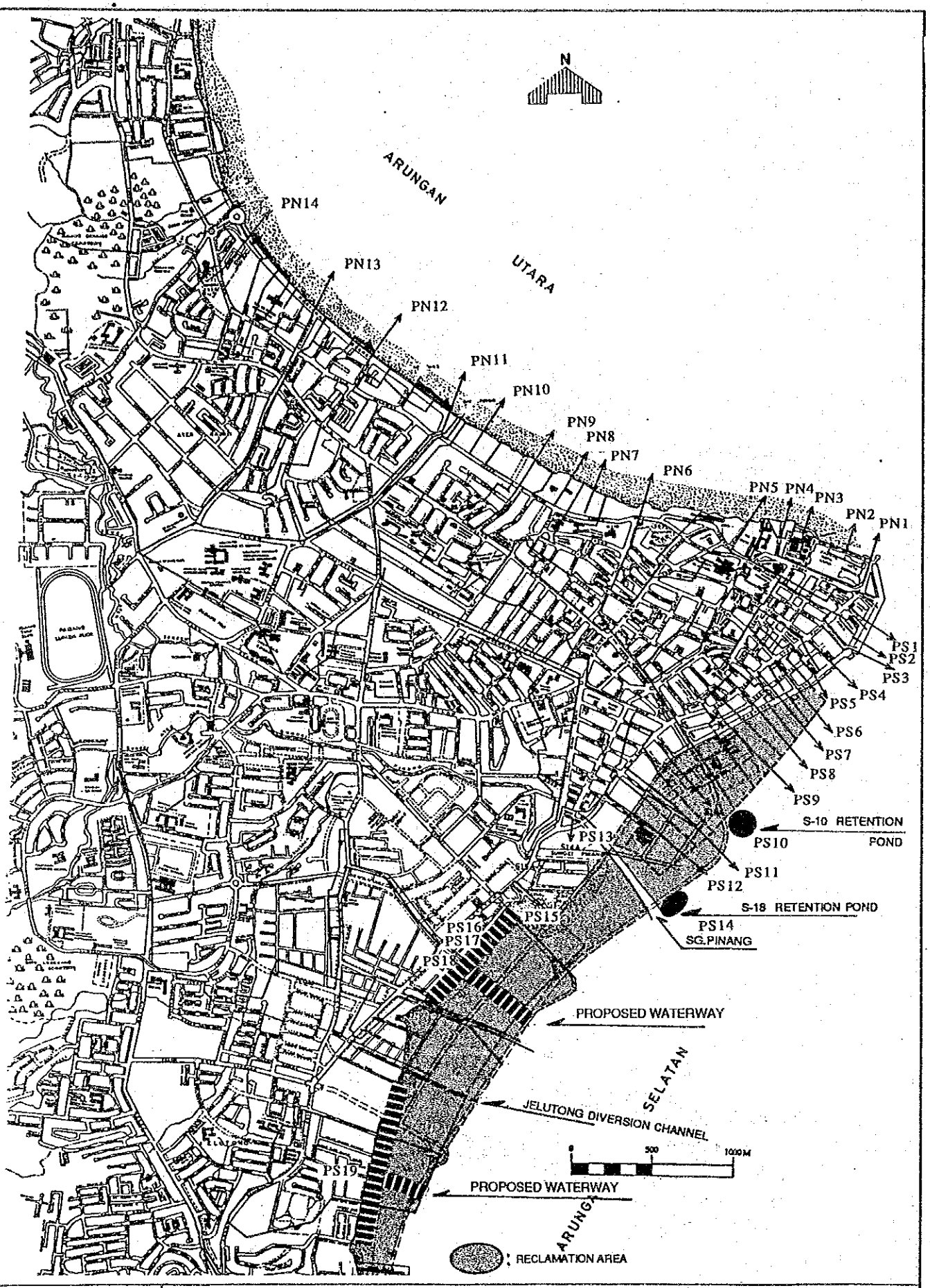



FIG. S-3 PROPOSED DRAINAGE OUTFALLS IN GEORGETOWN

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



JICA

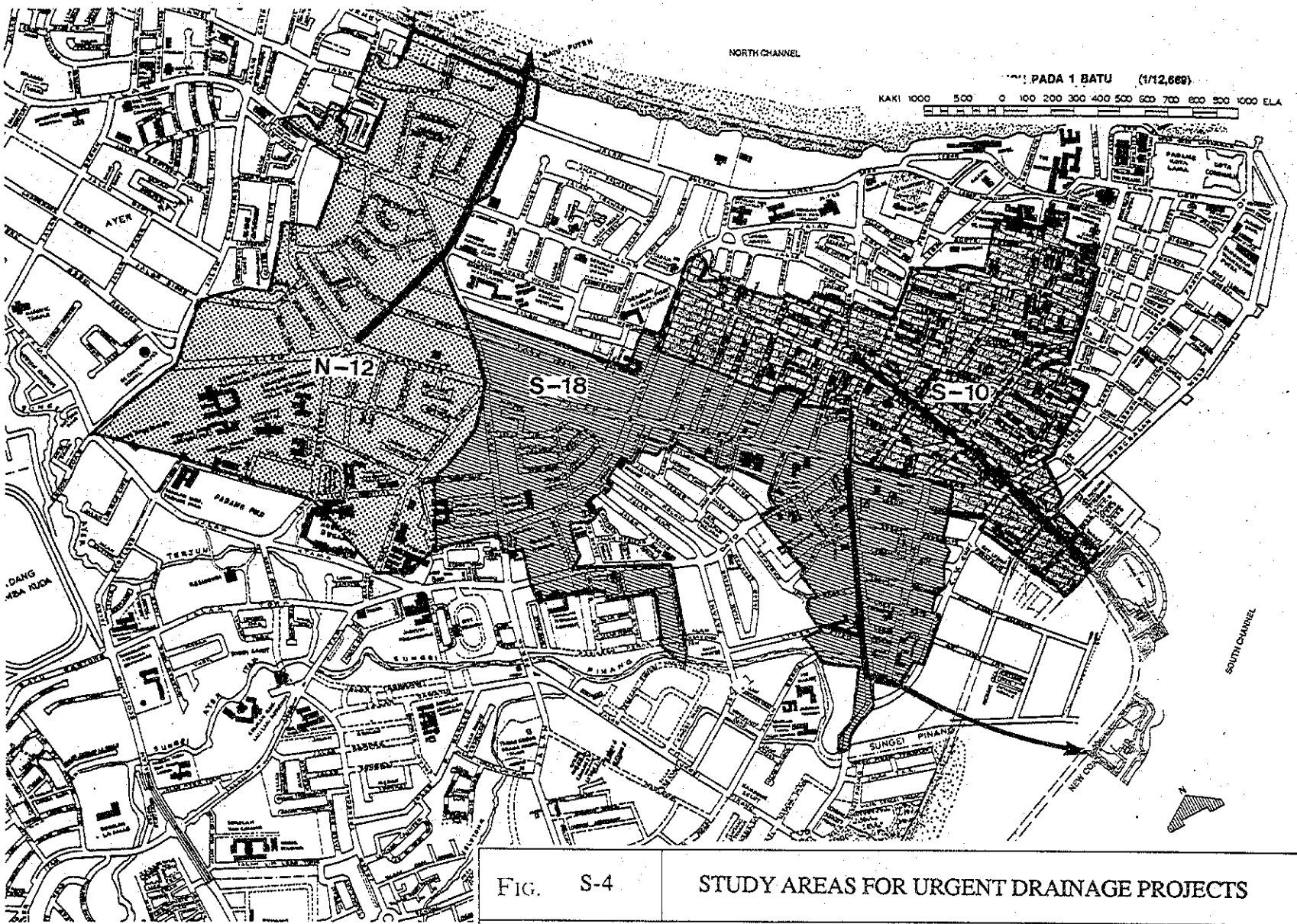



FIG. S-4 STUDY AREAS FOR URGENT DRAINAGE PROJECTS

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

# MAIN REPORT

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# *Chapter 1 INTRODUCTION*

# CHAPTER 1 INTRODUCTION

## 1.1 BACKGROUND OF THE STUDY

Penang Island, with a total area of about 300 sq. km, is located just off the northwest coast of Peninsular Malaysia. The total population of the island in 1985 was about 450,000 out of which about 260,000 lived in the City of Georgetown.

The main river system in the island is the Sg. Pinang system with a catchment area of 51 sq. km. The lower reaches of the Sg. Pinang flows through the City of Georgetown and severe flood damages occur whenever the river overflows its banks.

The rainy season is from August to January, and flooding usually occurs in the months of September and October. The most severe floods in recent years occured in October 1980, when over 2 sq. km in Georgetown was inundated for 1 to 2 days to a depth of 0.5 to 1 m. More than 10,000 people were affected and the flood damage was estimated to be about M$ 3.0 million. Another severe flood occurred on October 11, 1985.

The role and responsibilities of the various Departments and Agencies in the planning, development and maintenance of flood mitigation and urban drainage works both within and outside the City of Georgetown are not clearly defined. This has led to confusion and duplication in the role and functions of various Agencies resulting in a decrease in efficiency and effectiveness of flood mitigation and urban drainage works.

As a result of intensive development of the island, flooding has become not only frequent but also very intense. In the past, considerable undeveloped land in the Sungai Pinang catchment area helped to reduce the intensity of floods by serving as pondage areas. Such conditions are no longer available and, as a result, flooding in the past several years has become very serious.

As a consequence, flood mitigation and drainage plan has become an obvious requirement. The Government of Malaysia has therefore requested technical assistance for the Project "the Study on Flood Mitigation and Drainage in Penang Island" from the Japanese Government.

In response to this request, the Government of Japan, in accordance with the relevant laws and regulations in force in Japan, has decided to conduct the Study on Flood Mitigation and Drainage in Penang Island in Malaysia.

In March 1989, JICA dispatched a mission headed by Dr. Fumio Yoshino to Malaysia for the preliminary survey as

well as to hold discussions concerning the scope of work for the Study.

The scope of work was agreed upon between the Government of Malaysia and JICA on March 2, 1989.

In accordance with the scope of work, the JICA Study Team carried out the Study on Flood Mitigation and Drainage in Penang Island from July 1989 to March 1991.

## 1.2 OBJECTIVES AND AREA OF THE STUDY

The objectives of the Study are:

(a) To formulate the Master Plan of flood mitigation and drainage in Penang Island and to identify the priority areas;

(b) To conduct the Feasibility Study on the flood mitigation and drainage projects in the identified priority areas.

The Study area covers all of Penang Island except the west coast, as shown in Fig. I.

## 1.3 IMPLEMENTATION OF THE STUDY

The Drainage and Irrigation Department (DID) was assigned as the counterpart agency for the Japanese Study Team. The Economic Planning Unit, the organization representing Malaysia, performed as the main coordinating body to other relevant organizations for the smooth implementation of the Study, while JICA was assigned as the representative organization of Japan.

The Study was carried out from July 1989 to March 1991, by the Japanese consultant team retained by JICA and the counterpart staff of DID and MPPP. The JICA Advisory Committee acted as advisors to the JICA Study Team.

**(1) JICA Study Team**

| | | |
|---|---|---|
| Mr. Yoshiaki Kaneko | (PCI): | Team Leader<br>Flood Mitigation /<br>Institutional Framework |
| Mr. Toshiyuki Sato | (PCI): | Deputy Team Leader /<br>River Planner |
| Mr. Yasuo Iwasaki | (PCI): | Hydrologist |
| Mr. Tsutomu Kameyama | (PCI): | Hydrologist |
| Mr. Masayuki Shiraishi | (NK) : | Urban Drainage Engineer |
| Mr. Tatsuro Kawagoe | (NK) : | Structural Engineer |

| | | |
|---|---|---|
| Mr. Hiroshi Tanaka | (PCI): | Urban / Landuse Planner<br>Environmental Expert<br>Landscaping |
| Mr. Akira Takechi | (PCI): | Water Quality Engineer |
| Mr. Kazuo Ono | (PCI): | Sewerage Engineer |
| Mr. Kiyoto Yamazaki | (NK) : | Construction Planner |
| Mr. Akihisa Kojima | (PCI): | Economist |
| Mr. Takeo Shibatani | (PCI): | Geologist |
| Mr. Yoshihiro Kamada | (NK) : | Survey Expert |
| Mr. Kousuke Tsuru | (NK) : | Survey Expert |

**(2) JICA Advisory Committee**

| | | | |
|---|---|---|---|
| Dr. Fumio Yoshino | (MOC) | : | Chairman |
| Mr. Osamu Suzuki | (MOC) | : | Member |
| Mr. Tadatoshi Matsuishi | (MOC) | : | Member |
| Mr. Makoto Murayama | (TM) | : | Member |

**(3) Steering Committee**

| | | |
|---|---|---|
| Dr. Gan Khuan Poh | : | Economic Planning Unit (Chairman) |
| Mrs. Rosmah bt Hj. Jentra | : | Economic Planning Unit |
| Mrs. Lin Mui Kiang | : | Economic Planning Unit |
| Ir. Liew Chin Loong | : | Economic Planning Unit |
| Mrs. Rozaini bt Abdullah | : | Economic Planning Unit |
| Mr. Arisfadilah bin Sariat | : | Economic Planning Unit |
| Ir. Lim Sek Ming | : | Economic Planning Unit |
| Mrs. Wan Normah bt Wan Daud | : | Economic Planning Unit |
| Ir. Joseph Yeoh | : | Department of Irrigation and Drainage |
| Mr. Akinori Masuda | : | Department of Irrigation and Drainage |
| Ir. Lim Teik Keat | : | Department of Irrigation and Drainage |
| Mrs. Nur Wahidah Wong bt Abdullah | : | State Economic Planning Unit, Penang |

| | | |
|---|---|---|
| Ir. Kazal Sinha | : | Ministry of Housing and Local Government |
| Mr. Ong Soon Haw | : | Ministry of Housing and Local Government |
| Ir. Lim Cheng Kee | : | Penang City Council |
| Ir. Leong Kok Khaw | : | Penang City Council |
| Mr. Abdul Razak bin Abdul Manap | : | Department of Environment |
| Ir. Saw Hin Seang | : | Department of Irrigation and Drainage, Penang |

**(4) Technical Committee**

| | | |
|---|---|---|
| Ir. Joseph Yeoh | : | Department of Irrigation and Drainage (Chairman) |
| Mr. Akinori Masuda | : | Department of Irrigation and Drainage |
| Ir. Poh Thuan Poon | : | Department of Irrigation and Drainage |
| Ir. Lim Teik Keat | : | Department of Irrigation and Drainage |
| Mrs. Nur Wahidah Wong bt Abdullah | : | State Economic Planning Unit |
| Mr. Jamail bin Saaid | : | Lands and Mines Office, Penang |
| Ir. Leong Kok Khaw | : | Penang City Council |
| Ir. Lim Cheng Kee | : | Penang City Council |
| Ir. Chin Joo Negan | : | Penang Development Corporation |
| Mr. Anwar Ahmad | : | Public Works Department, Penang |
| Mr. Ibrahim Abd. Majid | : | Department of Environment, Northern Regoin |
| Mr. Sin Kam Wa | : | Survey Department, Penang |
| Ir. P'ng Ewe Kee | : | IADP Penang |
| Ir. Saw Hin Seang | : | Department of Irrigation and Drainage, Penang |

| | | |
|---|---|---|
| Ir. Chu Meng Heng | : | Department of Irrigation and Drainage, Penang |
| Mrs. Khairiah bt. Hj. Mohd. Talha | : | Town and Country Planning Department, Penang |

**(5) Counterparts**

DID and MPPP

Special Abbreviations:

| | | |
|---|---|---|
| MOC | : | Ministry of Construction |
| TM | : | Tokyo Metropolitan Government |
| PCI | : | Pacific Consultants International |
| NK | : | Nippon Koei |

## 1.4 COMPOSITION OF REPORT

This report consists of four (4) volumes: Main Report, Supporting Report, Drawings and Data Book.

The Main Report presents the summarized results of all the studies. In Chapters 2 through 5 the basic information for the Study is described. In Chapter 6, the Master Plan for the Rivers in Penang Island, and in Chapter 7, the Master Plan for Drainage in Penang Island are presented.

In Chapters 8 through 13, the feasibility study of the urgent projects of flood mitigation and drainage are described.

Chapter 14 concerns water quality improvement. Chapter 15 covers landscaping of the river corridor. In Chapter 16, the conclusion and recommendations are presented.

The Supporting Report consists of the following studies:

A: Topographical Survey

B: Topography and Geotechnical Conditions

C: Urban and Land Use Planning Study

D: Socioeconomic Conditions

E: Present Conditions of the Rivers and Basins in Penang Island

F: Floods and Flood Damage

G: Meteo-Hydrological Conditions and Flood Run-off Analysis

H: Formulation of Flood Mitigation Master Plan

I: Formulation of Drainage Master Plan

J: Urgent Flood Mitigation Plan

K: Urgent Drainage Plan

L: Construction Plan and Cost Estimate

M: Evaluation of Urgent Flood Mitigation and Drainage Projects

N: Operation and Maintenance Plan for Urgent Projects

O: Landscaping of River Corridor

P: Environmental Aspects

Q: Consideration on Water Quality Improvement

The drawings for the river and drainage plans are as follows:

I. Master Plan of Rivers in Penang Island.

II. Master Plan of Trunk Drains in Georgetown.

The Data Book contains the data of the following surveys:

I. Preliminary Environmental Impact Assessment.

II. Water Quality and Soil Investigation.

III. Tables of Water Levels for 10 and 100 year Floods in 25 Rivers in Penang Island.

## 1.5 ACKNOWLEDGEMENT

In undertaking the Study, the Study Team has attached great importance to the incorporation of relevant views of departments and agencies of the Government of Malaysia on various aspects covered by the Study. The contributions to the Study by the officials of the Economic Planning Unit, the Drainage and Irrigation Department, the Penang Town Council, and other individuals who have provided information and data, participated in discussions, given valuable advice, and provided other forms of assistance to the Study are gratefully acknowledged.

Heartfelt gratitude is also extended to the officials of the Embassy of Japan in Malaysia, the Ministry of Foreign Affairs and Ministry of Construction of the Government of Japan, who each gave advice and provided various types of support during the performance of the

Study. In reality, the Study can be regarded as a joint effort by the Malaysian and Japanese officials, the Japanese Study Team, and other concerned individuals. The Study Team sincerely hopes that this effort will contribute to the future development of flood mitigation and drainage in Penang Island and to its socio-economic development and general well-being.

# Chapter 2 BACKGROUND OF STUDY AREA

# CHAPTER 2 BACKGROUND OF STUDY AREA

The existing conditions of the Study area, identified based on the collected data and information, and the results of the field investigations, such as the topographic survey, the survey of river bed materials, the water quality survey, the hydrological observation and the flood damage survey that were conducted by the Study Team, are dealt with briefly in this chapter.

## 2.1 NATURAL CONDITIONS

### 2.1.1 Topography

The Penang Island with an area of 285 $km^2$ is located 3 km off Butterworth on the west coast of Peninsular Malaysia. The topography of Penang Island can be broadly divided into two geomorphic units: namely, the Hill Country and the Lowland Areas. The topography of the island is shown in Fig. 2-1.

The Hill Country is mainly confined to the central part of the island with the highest summit at Bukit Western, which is about 830 m high. The terrain is very rugged with waterfalls and rapids in some streams. The Lowland Areas are generally near the coastal plains and swamps. They include beaches and small isolated hills. The Lowland Areas occupy about 40% of the total island area.

Slope analysis of Penang Island is also shown in Fig.2-1.

### 2.1.2 Meteorology

The climatic characteristics of the Study area is almost uniform in temperature, with high humidity and heavy rainfall. Meteorological observations in Penang Island have been carried out at Penang Hill, Penang Hospital and Bayan Lepas.

The monthly meteorological data at Bayan Lepas are shown in Table 2-1. The annual average temperature is 27.8°C and the annual mean relative humidity is 72%. The annual mean rainfall in Penang Island is 2,400 mm on the southeast side and 3,000 mm on northwest side.

There are two monsoon seasons, the northeast monsoon (November to January) and the southwest monsoon (April and May). The maximum amount of precipitation generally occurs in September and October.

### 2.1.3 Geology and Geotechnical Conditions

Penang Island mainly consists of granitic rocks. Alluvial deposits are not very common except in the Georgetown area and in the west coast irrigation area.

The volume of eroded materials, such as rock, gravel, and sand is considered to be quite large, based on the type of granitic rocks.

Eleven exploratory borings, with a total length of 210 m, and related laboratory tests were carried out by the JICA Study Team.

Based on this investigation and the collected data, the following geotechnical conditions were confirmed:

- In the coastal area there are soft alluvial deposits of sand and clay to a depth of 10 m - 16 m below ground level. Loose sandy and soft clayey sediments are deposited to a depth of about 50 m.

- The middle part of Georgetown is composed of loose-medium dense sand and silty sand with some gravel. Below this strata, there are stiff, silty clay layers and medium dense sand layers. The bearing layer is estimated to be deeper than 20 m.

- Upstream areas consists of granitic rock, talus deposits, boulder deposits and gravel and sand.

## 2.2 HYDROLOGY

### 2.2.1 Rainfall

The mean annual rainfall in the Island is about 2,800 mm. The recorded maximum 24 hour rainfall was 252.5 mm at the station located in the upstream of Sg. Air Terjun.

The mean monthly rainfall observed at seven stations on the Island are shown in Fig.2-2.

Probable areal rainfall in the Sg. Pinang basin is estimated by means of the Gumbel method and is shown in Table 2-2.

The 50 year 24 hour areal rainfall for the Sg. Pinang basin is 291 mm.

### 2.2.2 River Discharge

Four water level gauging stations existed on the island before 1982. However, there is no useful data on water level or discharge available. For this Study, three gauging stations were set up in the Sg. Pinang at Jalan

Perak, the Sg. Air Itam at Jalan Scotland, and the Sg. Air Terjun at Brook Road.

Data on water level is available from September, 1989.

### 2.2.3 Tidal Water Level

Data on tide level of Penang Island are available in "Record Cerapan Air Pasang Surut 1985" which was published by the Director General of Survey and Mapping, Dept. of Survey and Mapping. The data was observed at Kedah Pier in Penang Island.

The tide level data obtained from this record is given below:

| | | RL |
|---|---|---|
| EHW | | +1.615 |
| MHWS | +2.5 A.C.D | +1.08 |
| NHWN | +1.8 A.C.D | +0.38 |
| MSL | +1.6 A.C.D | +0.18 |
| MLWN | +1.3 A.C.D | -0.12 |
| MLWS | +0.6 A.C.D | -0.82 |
| LAT | +0.2 A.C.D | -1.22 |
| R.L | : Reduced Level | |
| A.C.D | : Admiralty Chart Datum | |

These values have been used mostly by DID for their hydraulic analysis of the river.

In addition, 4 tide poles were set up to check the tidal fluctuation along Penang Island for this Study.

A slight difference (about 10 cm) in tide level was observed between the two points in the northern and southern part of the Island.

The tide level was also recorded at Kedah pier by the Port Authority for three years since 1985.

The MHWS of this station is +1.095 (R.L.) and the EHW is +1.615 (R.L.).

### 2.2.4 Sediment

The erosion and sediment run-off in Penang Island are mainly caused by development and other human related activities such as housing, mining, quarrying and cultivating.

No observed data concerning the amount of sediment run-off exists.

In this Study, the river bed material test was carried out for nine major rivers to clarify the sediment conditions in the river course. The depth of siltation at the downstream stretches of the Sg. Pinang was also surveyed.

Of the nine rivers, the Sg. Pinang, the Sg. Balik Batu, the Sg. Fettes and the Sg. Keluang are severely affected by sediment input and siltation due to land development, resulting in a reduction in flow capacity.

The river beds of the other rivers seem to be stable and are not significantly affected by sediment input.

The siltation depth of the Sg. Pinang is about 80 cm and the quantity of silt is roughly estimated to be about 10,000 $m^3$, of which 80% is deposited in the estuary.

This siltation amount is equivalent to about 15% of the excavation work of river improvement at the estuary of the Sg. Pinang.

## 2.3 SOCIO-ECONOMY

### 2.3.1 Population

Georgetown is the third most populated city of Malaysia, surpassed only by the federal capital, Kuala Lumpur and Ipoh, which is also located in the northern region.

The total population of Penang Island, the Study area, in 1986 was estimated at about 547,300 while that of the whole state at about 1,068,900. The future population of the Study area in the year 2000 is estimated to be in the range of 630,000 to 667,000.

### 2.3.2 Regional Economy

Penang Island continues to be the economic center of the northern region of the Peninsular Malaysia. In fact, the state capital, Georgetown, is ranked second only to Kuala Lumpur in terms of economic activity for the whole nation.

The G.D.P per capita of the State of Penang (Pulau Pinang) was 10% higher than the national average in 1985.

The G.D.P of the State grew by 8.9% in 1988, compared to 6.6% in the previous year. The national economic growth rate for the year 1989 was forecasted to be 6.5%, while that of the State of Penang, a robust 9%.

## 2.4 LAND USE

### 2.4.1 Existing Land Use Pattern

The existing land use pattern of Penang Island in 1988, as shown in Fig. 2-3, is mainly comprised of a built-up area of 22.2%, an agricultural area of 40.7% and a natural forest area of 25%.

The built-up area mainly covers Georgetown and its vicinity, northwards to Tanjong Bunga and Batu Ferringghi, westwards to Air Itam and Paya Terubong and southwards to Bayan Baru and Bayan Lepas.

### 2.4.2 Future Land Use Pattern

The future land use pattern is shown in Fig. 2-4. In the year 2010, the built-up area is expected expanding to 48%. Major expansion of built-up areas would center around northern and eastern coastal zones encompassing Teluk Bahang, Georgetown, and Batu Maung.

A large scale reclamation project of an area of 570 ha which has been undertaken by the Penang Development Corporation (PDC) along Batu Maung and Penang Bridge, being planned for completion in 1995, would further add to the built-up area of Penang Island. Moreover, about 210 ha of coastal area along Penang Bridge and Prangin Street Ghaut is also proposed for reclamation. Fig. 2-5 shows the future reclamation areas.

## 2.5 EXISTING AND FUTURE BASIN CONDITIONS

There are 31 main rivers in Penang Island as shown in Fig. 2-6. Among them, the Sg. Pinang is the largest river with comparatively large tributaries as shown in Fig. 2-7-1.

The existing and future basin conditions of these rivers are shown in Table 2-3. The catchment area of all rivers other than the Sg. Pinang are less than 25 sq.km.

Six rivers will require channel extensions in their river mouth reaches, the lengths of extension ranging from 490 to 900 m, in consideration of future land reclamation.

The existing (1988) and future (2010) area of urbanization of each catchment of the 31 rivers are shown in Fig. 2-8.

The existing discharge capacities of the major rivers are shown in Fig. 2-9 and Fig. 2-10, and the comprehensive evaluation of each river is shown in Table 2-4.

## 2.6 FLOOD CONDITIONS

### 2.6.1 Features of Flooding

In Penang Island, floodings are caused both by depression-type monsoon storms and thunderstorms, and spring high tides.

Depression-type monsoon storms are of long duration (2 to 3 days) with low rainfall intensities, and are widespread over the whole island. These monsoon storms do

not usually cause serious damage to small catchments, but may heavily damage large catchments.

Thunderstorms are typically of short duration (3 to 5 hrs) with high rainfall intensities and can cause serious damage to small streams. This flash flooding occurs throughout the year and inundate lowlying areas, riversides of small streams, and/or drainage areas with inadequate flow capacities several times a year.

Furthermore, in the east coast areas of the island, where lowlying areas exist, monsoon storms and thunderstorms in coincidence with high spring tides at times cause severe damage.

In Georgetown, some lowlying areas become inundated even by spring tides, with no apparent rainfall.

### 2.6.2 Past Major Floods

Flooding in the Sg. Pinang basin has occurred, so far, mainly in the centre of old Georgetown along the Sg. Pinang and its tributaries, the Sg. Air Terjun, the Sg. Air Itam and the Sg. Jelutong.

Since the completion of the Sg. Jelutong diversion channel, flooding in the Sg. Jelutong area has been mitigated.

In other basins, flooding has occurred mainly in the lower basins. However, due to recent intensive land development in the upper basin, especially in the hilly side, flooding now occurs even in the upper or middle basin, such as in the Sg. Dondang, the Sg. Gelugor or the Sg. Relau.

The most severe recent floods occurred in October 1980 inundating an area of 2 $km^2$ in the central part of Georgetown with a depth of 0.5 to 1.0 m for a duration of 1 to 2 days. More than 10,000 people were affected by these floods.

Table 2-5 shows the highest flood water level and rainfall pattern for each flooding that occurred in Georgetown, based on the available past flood records from 1926 to 1987. The flood prone areas within the city limits are shown in Fig. 2-11.

Floods outside city limits usually occur in areas along the main rivers and mostly in the downstream reaches. The flood affected areas of each river basin are shown in Table 2-6 and Fig. 2-12.

Among these areas, the following are severely affected by floods:

| | |
|---|---|
| - Sg. Gelugor Catchment: | - Around Jalan Permai in Brown Garden. |
| | - Minden Heights |
| - Sg. Dua Besar Catchment: | - Saw Kit Garden, Pesta site and lowlying areas along its tributaries. |
| - Sg. Keluang and Sg. Ara Catchment: | - Mayan Pasir Residential area and lowlying area along Sg. Ara. |
| | - Jalan Tengah area. |
| - Sg. Tiram Catchment: | - Lowlying area at Bayan Lepas |

## 2.7 FLOOD DAMAGE

Flood damage is estimated by multiplying the average property value in the flood prone area by the damage ratios which are set according to the water depth. Damaged items in the Master Plan stage are limited to the general property and public property (direct damage). Other flood damage potential (indirect damage) were added in the feasibility study stage.

### 2.7.1 Probable Flood Damage

The flood damages were estimated for five cases of rainfall return periods for each river basin.

The probable flood damages (direct and indirect damages) in the Sg. Pinang basin under the land use conditions in the year 2010 are as follows:

(1989 Price)

| | Return Period (Year) | | | | |
|---|---|---|---|---|---|
| Flood Damages | 1.1 | 5 | 10 | 30 | 50 |
| Total ($M\$10^6$) | 6.5 | 19.6 | 102.1 | 213.1 | 278.5 |

### 2.7.2 Average Annual Flood Damage

The average annual flood damage is calculated as a sum of flood damage segments derived from the probability of flood damage, multiplied by the corresponding probability of occurrence, from a non-damageable run-off up to 50-year probable flood.

The average annual flood damage in the Sg. Pinang basin reached 26.7 million M$ under the land use conditions in the year 1990, and will reach 29.1 million M$ by 2010.

## 2.8 EXISTING RIVER WATER QUALITY

In order to assess the water quality of the rivers in Penang Island, a water quality survey was conducted in 26 rivers in the Study area in September and October, 1989. In addition, water quality data was collected from previous studies and surveys. The major findings of the results of the water quality survey and analysis are summarized as follows:

### 2.8.1 Classification of Rivers by Pollution Conditions

Fig. 2-13 shows the BOD concentrations at the mouth of each river, which represent the degree of general pollution. BOD in dry and rainy seasons are illustrated in Fig. 2-13 and it is apparent that BOD in dry seasons of most rivers are considerably higher than those in rainy seasons. This is due to dilution effects of rainfall run-off. Water pollution is more severe in a dry season than in a rainy season, hence an improvement of dry season water quality shall be emphasized.

There are three extremely polluted rivers, the Sg. Nibong Kecil, the Sg. Nipah and the Sg. Gertak Sanggul, with BOD levels in the range of 80 - 120 mg/l. These rivers are, in fact, open sewers, as this BOD level is similar to that of wastewater.

The degree of pollution in other rivers can be assessed based on the Environment Quality Standards of Malaysia. The Standards prescribe the allowable level for several water quality parameters by class which is applied to a certain area or section of the river considering the beneficial use of the river water. Although no class has been applied to any river in Penang Island, it is reasonable to assign a Class IV designation as no specific beneficial water use is expected.

Consequently, the rivers in the Study area can be classified as shown in Table 2-7.

### 2.8.2 Water Quality Conditions of Sg. Pinang

Fig.2-14 illustrates the BOD level in the Sg. Pinang system. As can be seen in the figure, the Sg. Pinang is polluted from the uppermost stretch and its tributaries are also severely polluted, except at the Sg. Air Terjun.

River water quality with BOD exceeding 30 mg/l are not aesthetically admissible in terms of appearance and odor. In addition, existing water quality is not suitable for creating a water front park environment proposed in the areas along the the Sg. Pinang. Hence, improvement of river water quality is a prerequisite.

## 2.9 ENVIRONMENTAL CONDITIONS

Existing environmental conditions of Penang Island have various aspects of natural environment woven with dynamic human activities comprising of urbanization, industrialization, tourism and other developments throughout the ages up to the present time.

### 2.9.1 Natural Vegetation

The vegetation and flora of Penang Island is recognized as evergreen rainy forest formation and the most typical family of forest vegetation is the Dipterocarpaceae, a predominant tree of timber.

The Island forest may be classified under four groups: Lowland Dipterocarp forest, Hill Dipterocarp forest, Marine alluvial (Mangrove) swamp forest and Riparian fringes. These forests are threatened with extinction caused by various human activities such as rapid urbanization, housing development, mining and coastal development activities.

However, these valuable forests have been recognized as beneficial natural resources by the government authorities concerned, as well as the local citizens. The necessary efforts for their conservation have already been commenced. Fig. 2-15 shows the environmentally sensitive areas in Penang Island.

### 2.9.2 Agricultural Vegetation

Formation of the agricultural vegetation depends on the land use pattern at different altitudes. Moreover, the vegetation reflects a characteristic trend of land productivity. Most of the rubber and fruit orchards are distributed in hilly areas at an altitude range of 45 m and 300 m. Mixed horticulture is generally distributed in lowland areas, and coconut, rice and other diversified crops are the ones mainly planted.

### 2.9.3 Wildlife, Birds and Fishes

Due to the limited environmental sphere, only a few kinds of small animals remain on the island. In the forest areas, animals such as wild pigs, long tailed macaques, dusky leaf-monkeys, malayan flying foxes, python and water monitors are in abundance. But, even their population is rapidly decreasing under the pressure of urbanization and other human activities.

Bird species are relatively rich in kind and about 100 species are reported to inhabit on the island. Among these birds species, 15 kinds may belong to the 78 endangered protected birds.