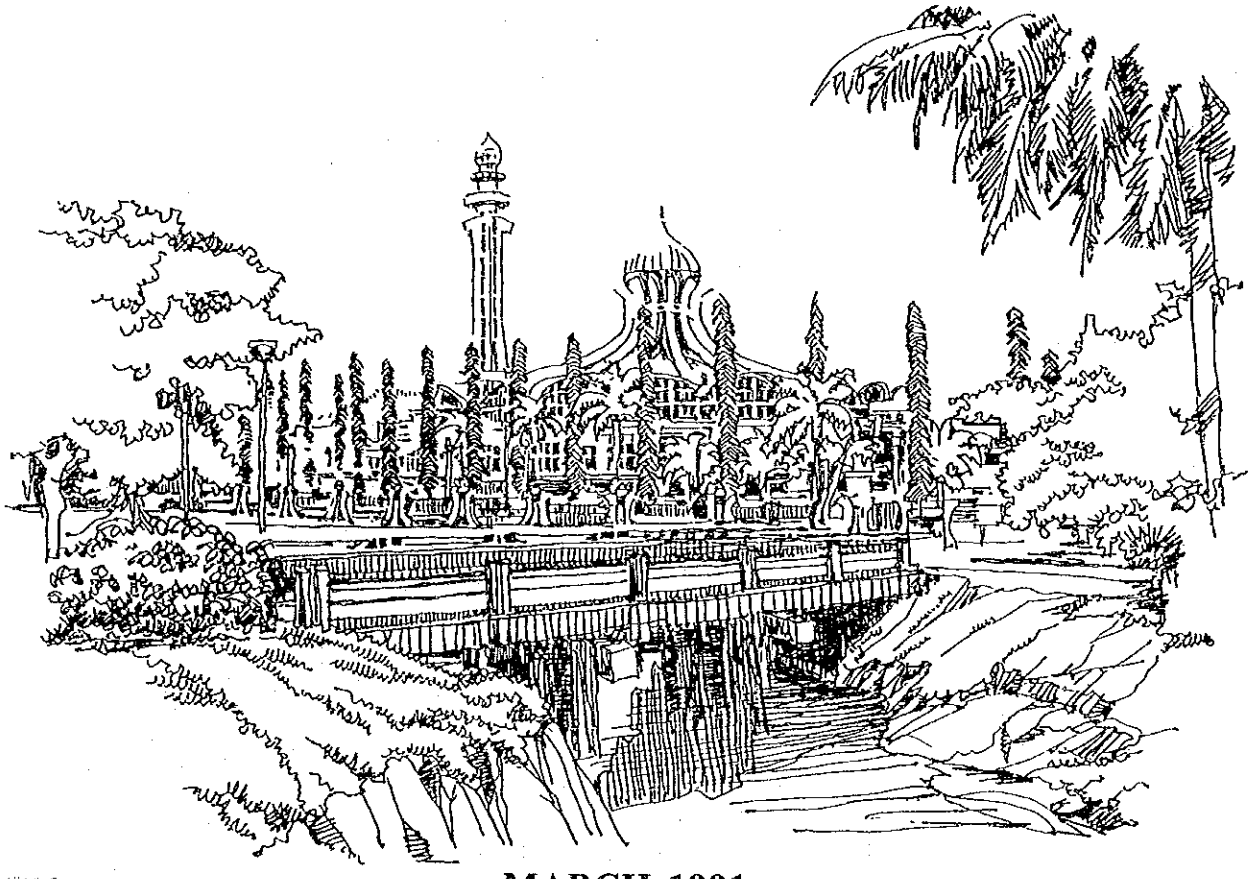
GOVERNMENT OF MALAYSIA

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

SUMMARY REPORT



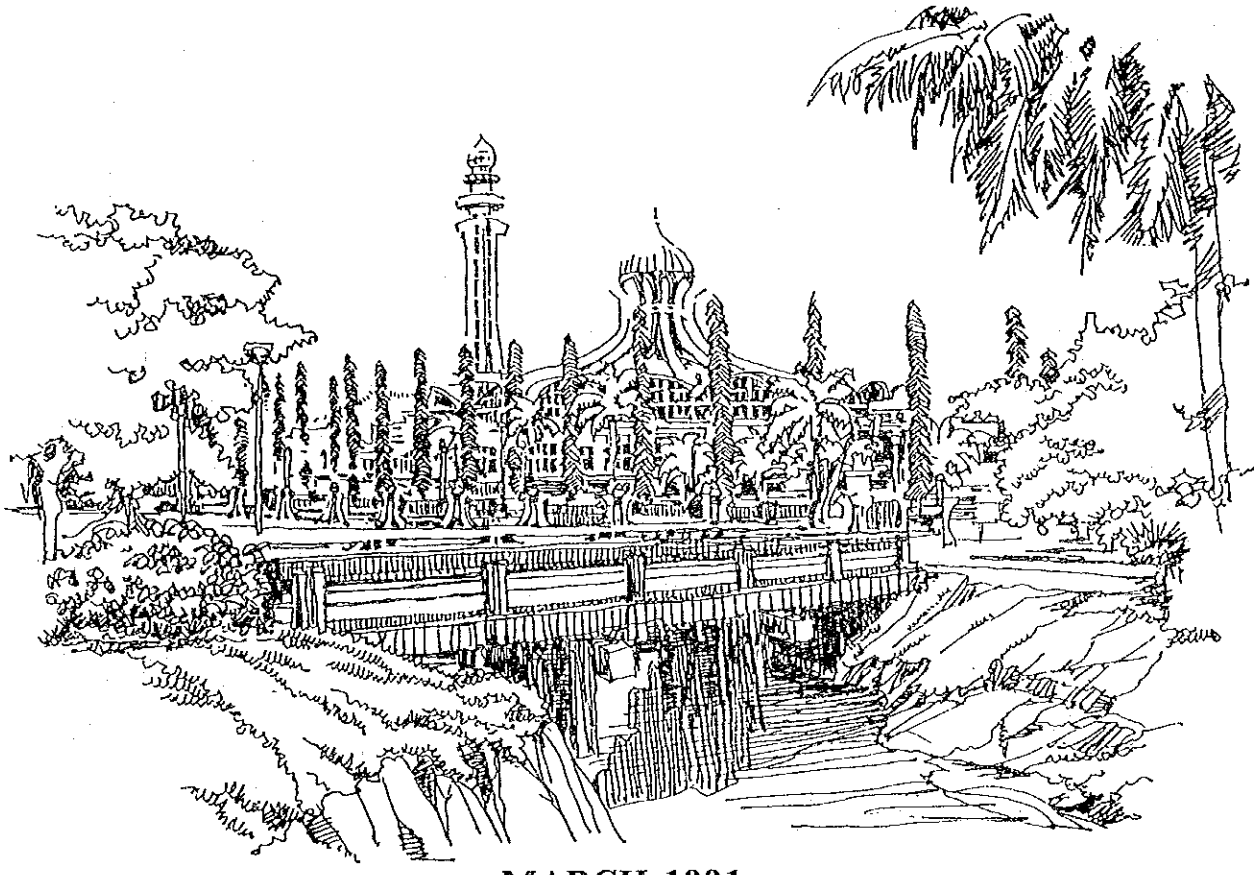
MARCH 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

GOVERNMENT OF MALAYSIA

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

SUMMARY 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 Kancko, 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

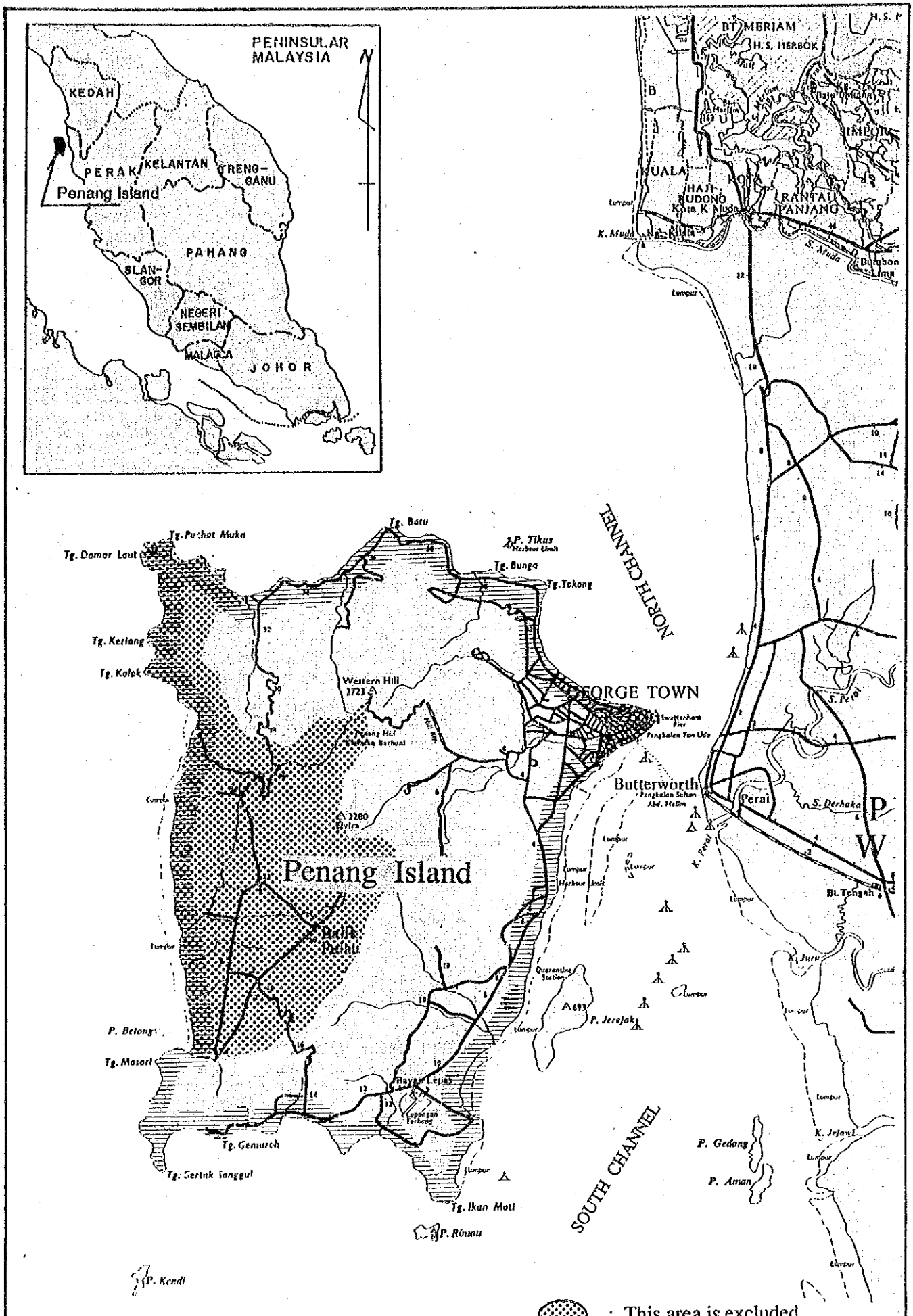
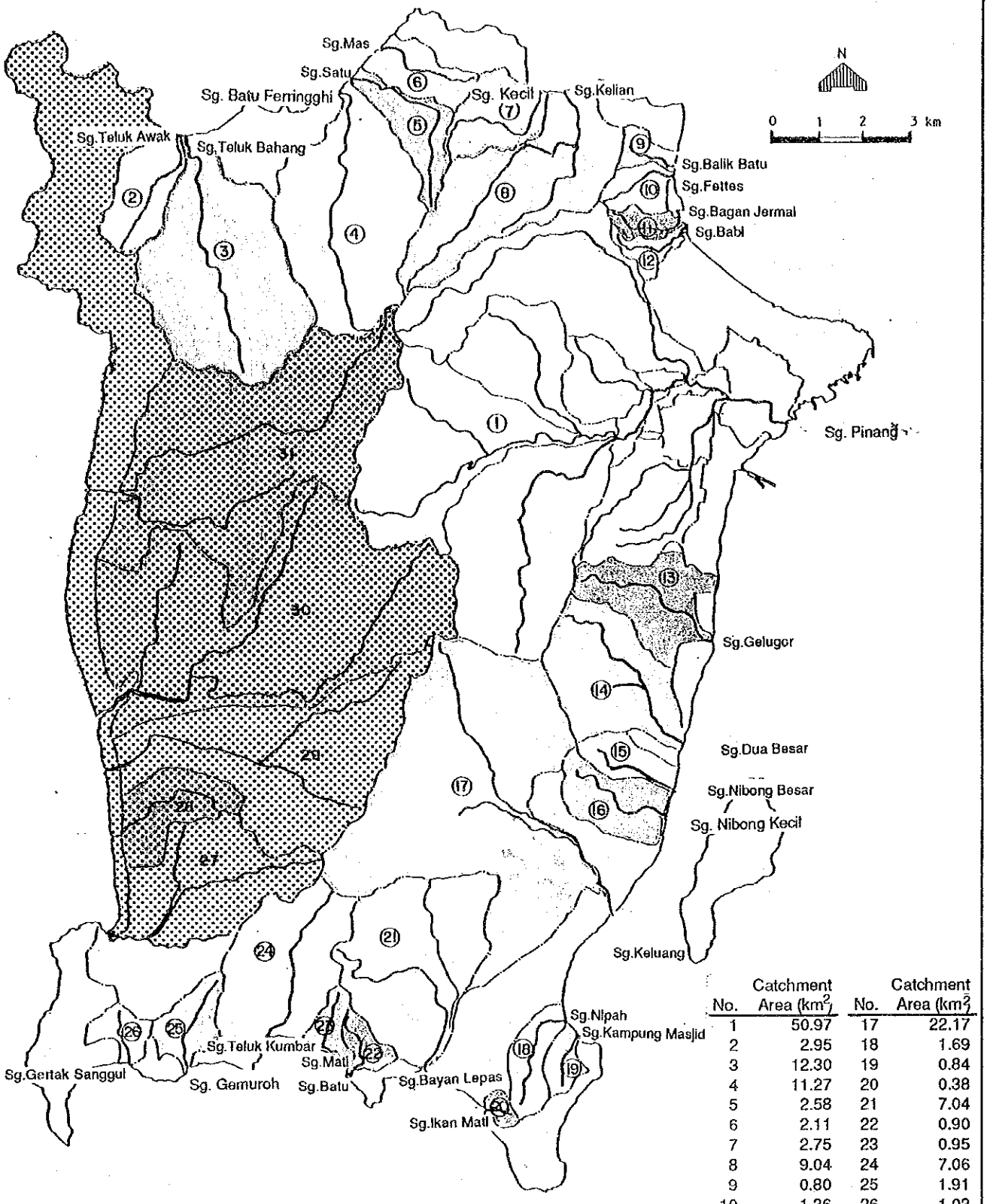


Fig. I Study Area

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		

: This area is excluded.

FIG. II RIVERS IN THE STUDY AREA

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

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 Other Rivers	135.5 40.2	175.7
Phase II 1996 - 2000	Sg. Pinang Other Rivers	20.5 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 belcw:

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.

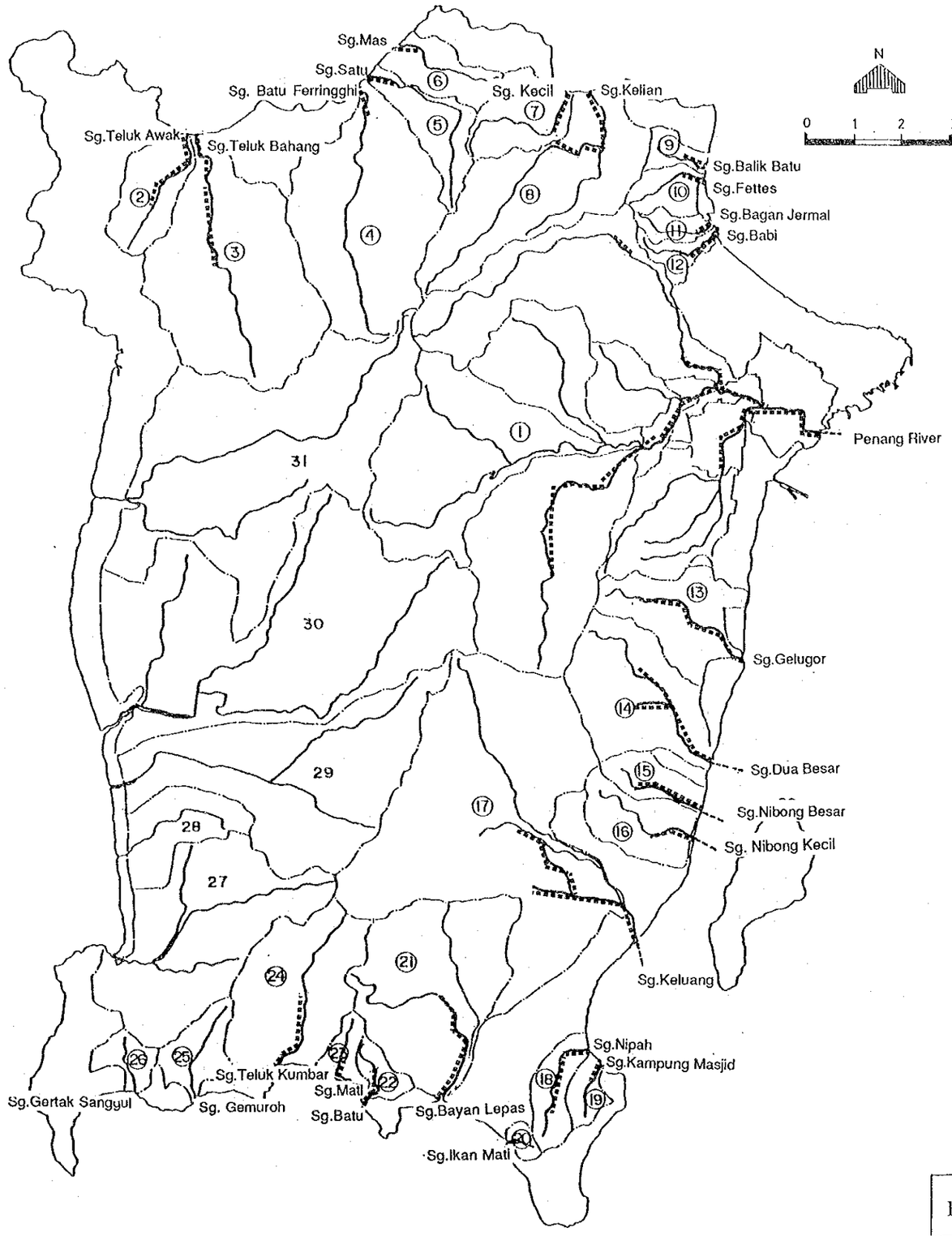
(6) For the lowlying areas along the east coast of the island, as a basic strategy, it is recommended to fill up the areas to a ground level sustainable for future development instead of installing pumping facilities.

(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

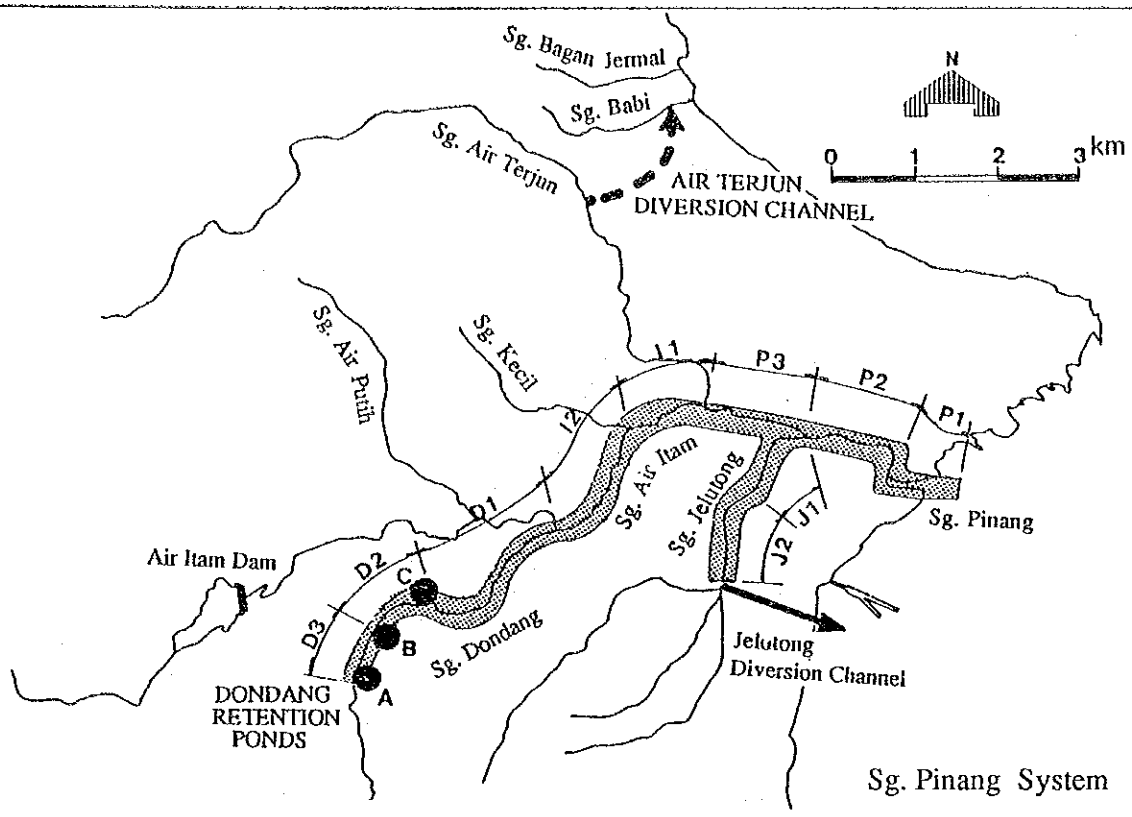
Phase		I (Urgent Project)					II (Mid-Term Plan)					III (Long-Term Plan)									
Rivers \ Year		'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	'01	'02	'03	'04	'05	'06	'07	'08	'09	2010
(Rivers)																					
Sg. Pinang,	3.15 km																				
Sg. Jelutong,	2.14 km																				
Sg. Air Itam,	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

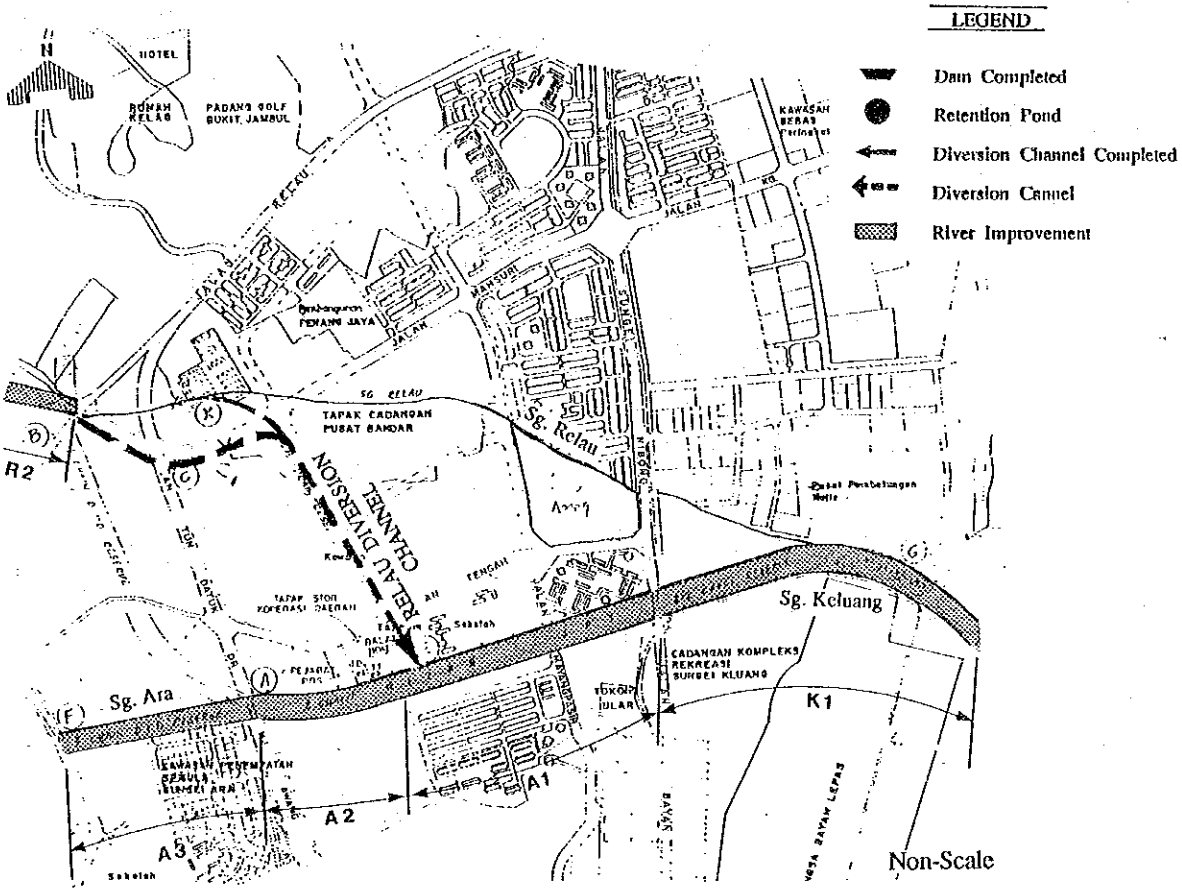
..... EXTENSION

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

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



Sg. Pinang System



Sg. Keluang System

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

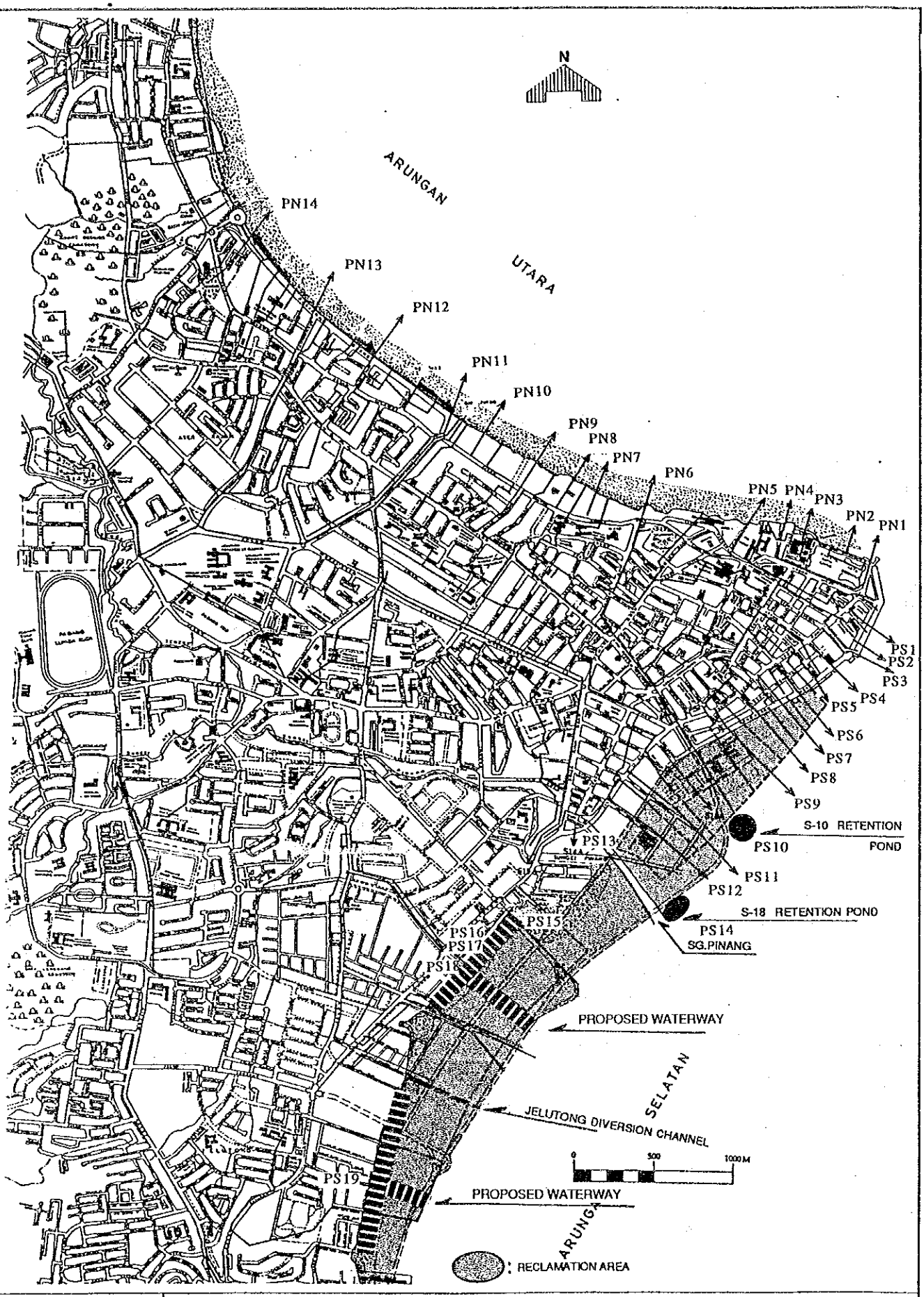


FIG. S-3 PROPOSED DRAINAGE OUTFALLS IN GEORGETOWN

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

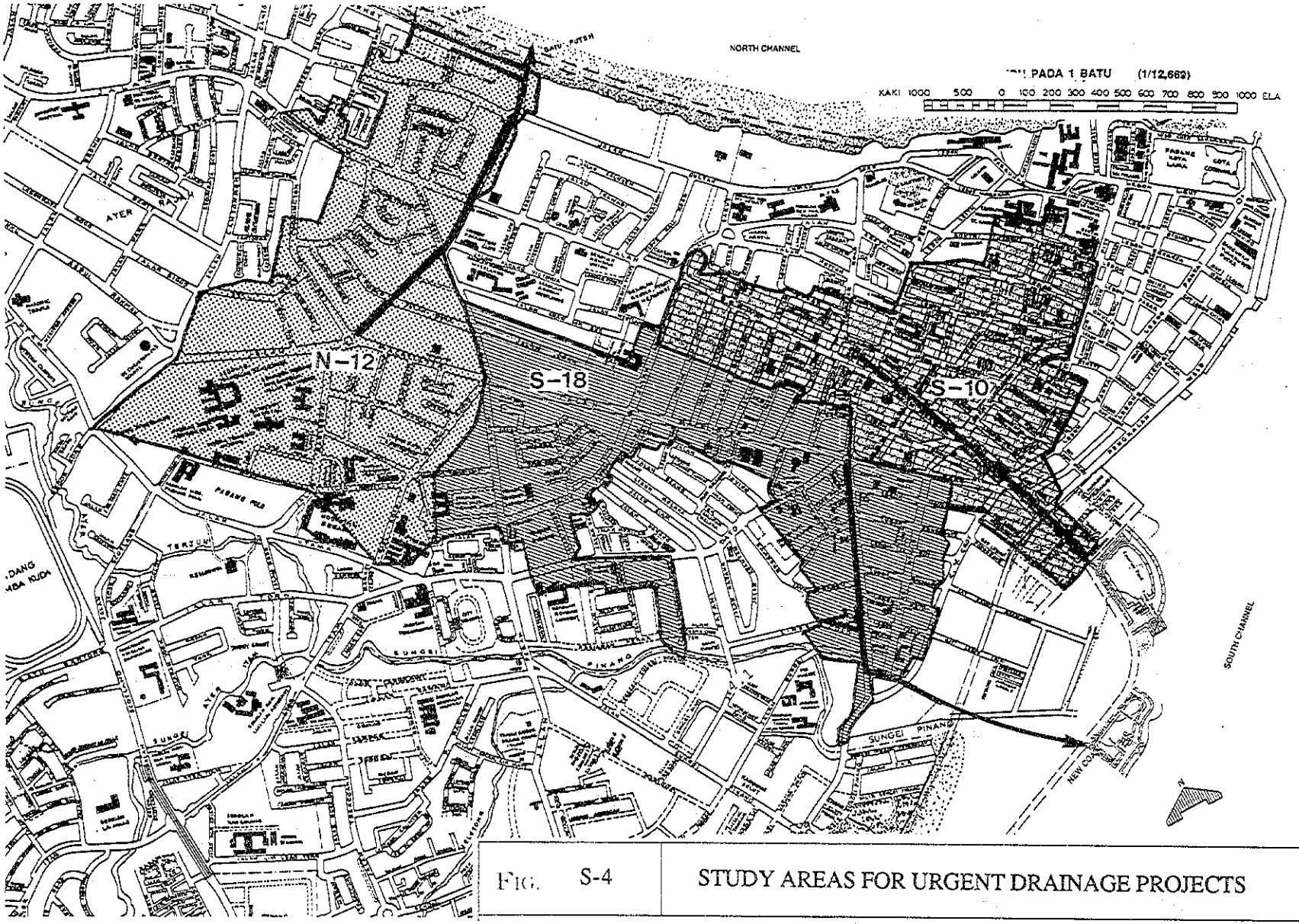


FIG. S-4 STUDY AREAS FOR URGENT DRAINAGE PROJECTS

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND