社会開発協力部報告書

No. 8

REPUBLIC OF INDONESIA
MINISTRY OF PUBLIC WORKS
DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT

STUDY REPORT
ON
PADANG AREA FLOOD CONTROL PROJECT

MAIN REPORT

DECEMBER 1983

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

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PREFACE

In response to the request of the Government of the Republic of Indonesia, the Government of Japan decided to conduct a feasibility study on the Padang Area Flood Control Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Indonesia a study team headed by Mr. Hiroshi Ono, NIKKEN Consultants, Inc., from January 30 to October 9, 1983.

The team exchanged views with the officials concerned of the Government of Indonesia and conducted a field survey in Padang, West Sumatra. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

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

December 1983

Keisuke ARITA
President
Japan International
Cooperation Agency
Tokyo, Japan

LETTER OF TRANSMITTAL

Tokyo, December 1983

Mr. Keisuke ARITA
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir:

We are pleased to submit hereby the final report of Padang Area Flood Control Project for the Government of the Republic of Indonesia.

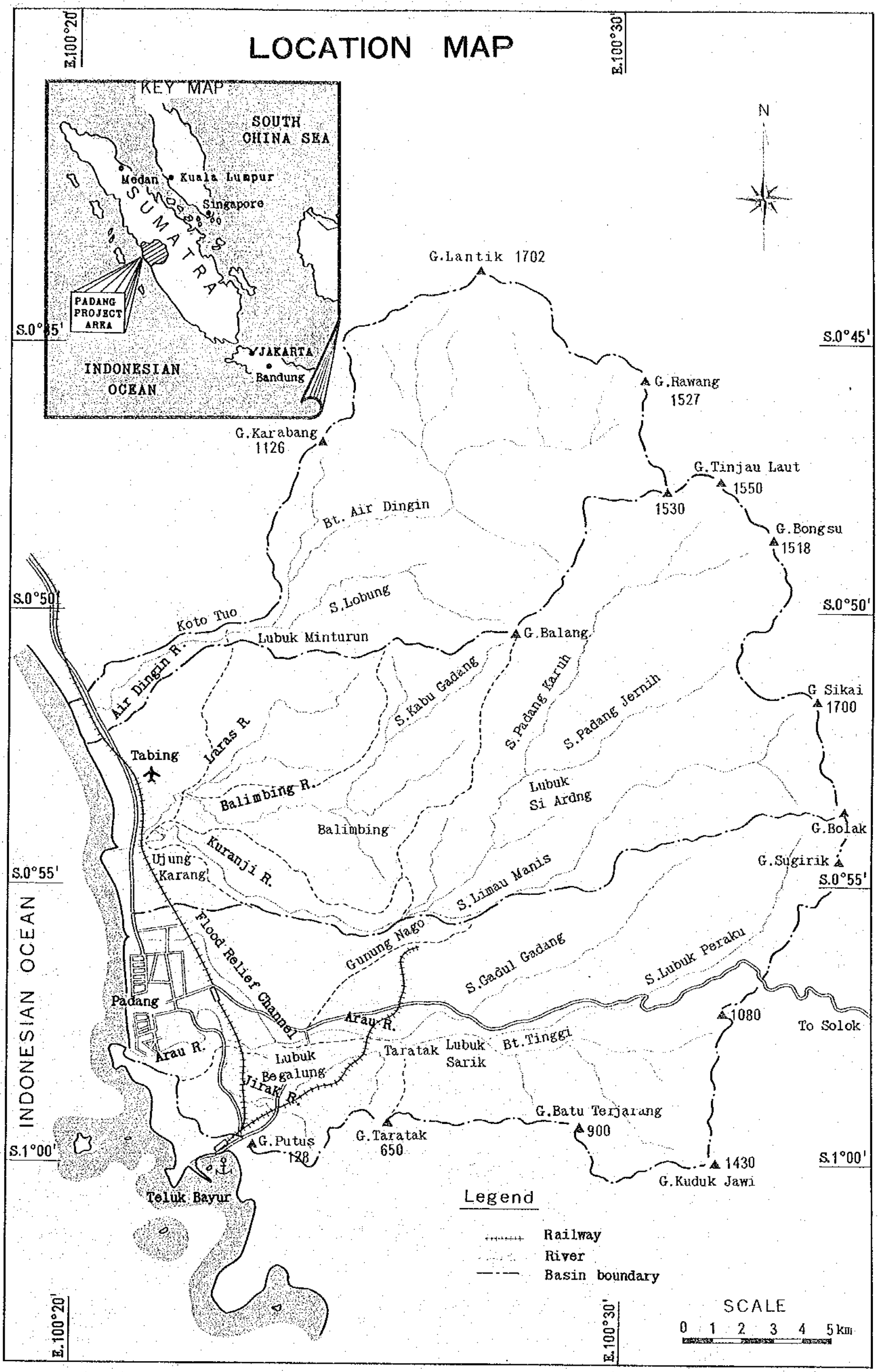
This report has been prepared by the Study Team aiming at the formulation of a comprehensive flood control and drainage plan and an urgent flood control project for immediate implementation in the urban area of Padang, the capital of West Sumatra Province, and its surrounding area.

The Study Team carried out the studies in Indonesia over the periods from January 30 to October 9, 1983. In Japan, the report was completed taking account of the conclusions obtained in the discussion meetings held in Padang and Jakarta.

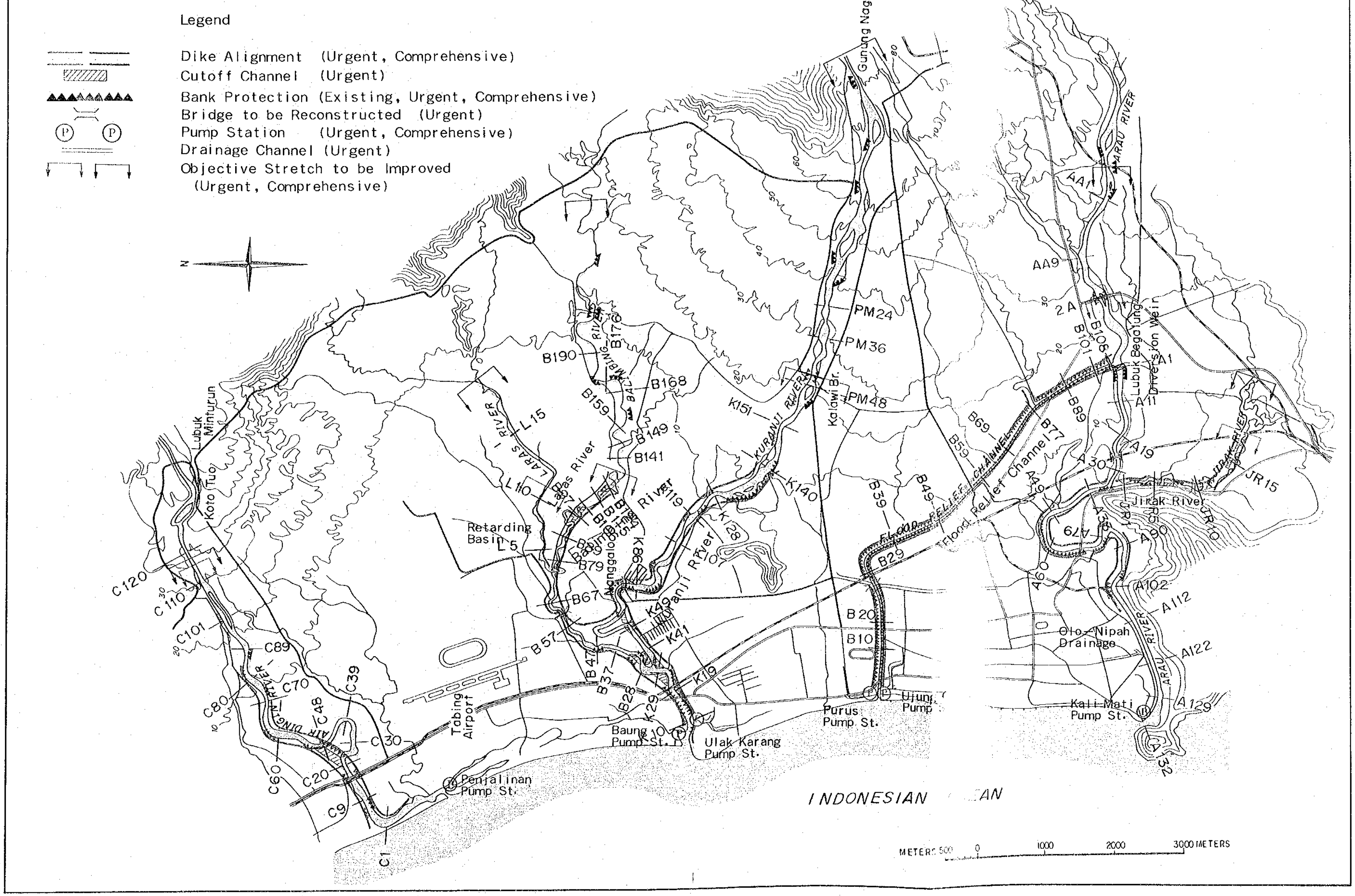
In submitting this report, we wish to express our sincere appreciation and gratitude to the personnel concerned of your Agency, the Embassy of Japan in Jakarta and authorities concerned of the Government of Indonesia for the courtesies and cooperation extended us during our field surveys and studies.

Yours very truly,

Hiroshi ONO
Leader,
Study Team for Padang Area
Flood Control Project


LOCATION MAP
KEY MAP
SOUTH CHINA SEA
Medan
Kuala Lumpur
Singapore
SUMATRA
PADANG PROJECT AREA
JAKARTA
Bandung
INDONESIAN OCEAN
E.100°20'
E.100°30'
S.0°45'
S.0°50'
S.0°55'
S.1°00'
N
G.Lantik 1702
G.Rawang 1527
G.Karabang 1126
G.Tinjau Laut 1550
1530
G.Bongsu 1518
Bt. Air Dingin
S.Lobung
Koto Tuo
Lubuk Minturun
G.Balang
Air Dingin R.
S.Kabu Gadang
S.Padang Karuh
S.Padang Jernih
G Sikai 1700
Tabing
Laras R.
Balimbing R.
Lubuk Si Ardng
Balimbing
G.Bolak
G.Sugirik
Ujung Karang
Kuranji R.
S.Limau Manis
INDONESIAN OCEAN
Flood Relief Channel
Gunung Nago
S.Gadul Gadang
S.Lubuk Peraku
Padang
Arau R.
1080
To Solok
Taratak
Lubuk Sarik
Bt.Tinggi
Lubuk Begalung
Jirak R.
G.Batu Terjarang 900
G.Putus 128
G.Taratak 650
1430
G.Kuduk Jawi
Teluk Bayur
Legend
Railway
River
Basin boundary
SCALE
0 1 2 3 4 5km

GENERAL LAYOUT OF THE PROJECT



SUMMARY

1. General

This final report (the Report) has been prepared based on the Scope of Work which was agreed on November 11, 1982 between the Japan International Cooperation Agency and the Directorate General of Water Resources Development, Ministry of Public Works, the Republic of Indonesia. The Report presents first the results of the study of a comprehensive flood control and drainage plan and next those of the feasibility study of an urgent flood control project planned for immediate implementation.

2. Present Conditions of Padang Area and Necessity of Countermeasures

The city of Padang is the capital of West Sumatra province, and is increasing in prosperity as a commercial centre situated at a strategic point in respect of communication and transportation. In 1981, the land area of the City was 646 km^2, containing a population of 494,000. The study area comprises the urban area of Padang city and its surrounding alluvial lands formed by the Arau, Kuranji and Air Dingin rivers. The basins of the rivers are located on the western slopes of the Barisan mountains in West Sumatra province and have catchment areas of 172 km^2, 213 km^2 and 131 km^2 respectively. The Arau river runs in the southern part of the city, while the Air Dingin river runs in the northern part and the Kuranji river runs in the central part of the city. Between the Arau and Kuranji rivers, a flood releif channel bifurcates from the Arau river and empties into the Indonesian Ocean.

The climate of the area is dominated by monsoons. The average annual rainfall is about 4,200 mm. The wet season covers a period from October through December with a less severe wet season in April and May.

The city of Padang and its surrounding alluvial lands have freqently suffered from inundation damage due to flooding. As a means of flood control in the area, a flood relief channel with diversion facilities was constructed in 1918 for the purpose of protecting the area from floodings of the Arau and Kuranji rivers. However, the capacity of the flood control and drainage facilities in the area are not adequate yet. The area has suffered severe flood damage as often as five times in the last ten years. The damage caused by the floods in 1972 and 1980 was particularly serious.

To make matters worse, the urban area of Padang city is expanding rapidly and new settlements are developing even in low-lying lands surrounding the existing urban area. The social and economic damage due to flooding is seriously increasing in these areas.

In order to prevent repeated flood damage, implementation of a countermeasure for flood control is strongly needed. Although a master plan of Padang city has been prepared for future urban development aiming at the year of 2003, no comprehensive flood control and drainage plan has been made. In this study, a comprehensive flood control and drainage plan was firstly formulated aiming at reducing flood damage not only in the existing urban area but also in adjoining lands for future urban expansion. The results of the study show that the economic benefits of the plan at the present state of development are not so high while a large fund is required to implement such a big project. That is, it is too early to implement the comprehensive plan immediately. However, the fact that the existing urban area of Padang city suffers from frequent flood damage cannot be overlooked any longer. Therefore, realization of an emergent flood control measure is urgently required for the existing urban area.

For this reason, based on the comprehensive plan, an urgent flood control plan was formulated as a project for immediate implementation in consideration of the urgency of countermeasures as well as the technical and economic effectiveness under the present condition.

3. Study of Comprehensive Flood Control and Drainage Plan

3.1 The comprehensive plan

Based on the results of the field investigation, study of the present conditions and a review of previous studies, conceivable alternative schemes for a comprehensive flood control and drainage plan were developed, and the final plan was formulated based on a comparative study of the alternative schemes.

In this study, the comprehensive plan is aimed at relieving both the existing and future urban areas of Padang city from flooding. A return period of 50 years was adopted as the scale of design flood for the mainstreams including the flood relief channel, 25 years for the tributaries and 10 years for the urban drainage, in accordance with the scale of design floods actually adopted for flood control plans in Indonesia.

The comprehensive plan proposes the works : (1) channel improvement over a total length of 55 km on the mainstream of the Arau, on the flood relief channel, on the mainstreams of the Kuranji and Air Dingin rivers and on their major tributaries, (2) construction of the Laras retarding basin, (3) reconstruction of the Lubuk Begalung weir, (4) construction of drainage outlet culverts, (5) reconstruction of five bridges, (6) improvement of major drainage channels over a length of 43 km, and (7) construction of six drainage pumping stations.

The major items of the plan are outlined below.

Arau river system

The proposed improvement plan of the Arau river system comprises channel improvement on the mainstream of the Arau river over a length of 10.6 km, on the flood relief channel over the whole stretch of 6.7 km and on the Jirak river over a length of 4.6 km. Both the mainstream weir and the flood relief channel weir of the diversion weir at Lubuk Begalung are planned for reconstruction. In connection with the channel improvement, three bridges, three drop structures and two siphons are also planned for reconstruction.

Kuranji river system

The proposed improvement plan of the Kuranji river system comprises channel improvement on the mainstream of the Kuranji river over a length of 13.5 km, on the Balimbing river over a length of 9.7 km and on the Laras river over a length of 4.2 km and construction of the Laras retarding basin. Two bridges on the Kuranji and Balimbing rivers are planned for reconstruction in connection with the channel improvement. The Laras retarding basin (1.5 km^2) on the right side looking downstream of the Laras river will be constructed in order to reduce flood discharge.

Air Dingin river

The proposed improvement of the Air Dingin river is channel improvement over a length of 5.2 km. The bulk of the works is excavation of the existing river channel to secure adequate carrying capacity. Construction of dikes is planned for 2.7 km in the lower reaches. The existing sand spit at the river-mouth will be left as it is.

Urban drainage

The urban drainage plan proposes improvement of major drainage channels over a total length of 43 km and construction of six drainage pumping stations.

3.2 Project cost, benefit and evaluation

The construction cost is estimated at Rp. 69,700 million (equivalent to US$ 71,820 thousand) under the current price condition (June 1983 price). The comprehensive plan has been evaluated under two development conditions, i.e., the present and future development conditions. Average annual benefit is estimated at Rp. 8,280 million (US$ 8,540 thousand) under the present condition and Rp. 11,650 million (US$ 12,010 thousand) under the future development condition. The economic internal rate of return works out at 10.5 % under the present condition and 14.7 % under the future condition.

4. Feasibility Study of Urgent Flood Control Project

4.1 The Project

The urgent flood control project aims at prevention of flood damage in the existing urban area and residential area to be developed in the near future. A return period of 25 years was adopted as the scale of design flood for the mainstream including the flood relief channel, 10 years for the tributary and 5 years for the urban drainage, examining three alternatives from the standpoint of economic effectiveness.

The project proposes : (1) channel improvement over a total length of 36 km on the mainstream of the Arau river, on the flood relief channel, on the mainstream of the Kuranji river, on the Air Dingin river and on their major tributaries, (2) construction of the Laras retarding basin, (3) reconstruction of the flood relief channel weir of the Lubuk Begalung weir, (4) construction of 52 drainage culverts, (5) reconstruction of five bridges, (6) improvement of major drainage channels over a total length of 3 km, and (7) construction of three drainage pumping stations. The principal features of the flood control works are listed in the attached table.

The major items of the project is outlined below.

Arau river system

The proposed improvement of the Arau river system is composed of channel improvement on the mainstream of the Arau river over a length of 8.5 km, on the flood relief channel over the whole stretch of 6.7 km and on the Jirak river over a length of 2.5 km. The flood relief channel will be improved to have the same proposed cross-sections as the comprehensive plan, while the channel of the mainstream will be improved only in the stretch between the suspension bridge and the confluence of the Jirak river. The Lubuk Begalung diversion weir will be reconstructed only on the flood relief channel side. Although the weir body of the mainstream side will not be reconstructed under this project, reinforcement of the downstream apron and repair of the bridge on the weir will be carried out. Two bridges, three drop structures and two siphons on the flood relief channel and one bridge on the Jirak river will be reconstructed in connection with channel improvement.

Kuranji river system

The proposed improvement of the Kuranji river system comprises channel improvement on the mainstream of the Kuranji river over a length of 7.5 km, on the Balimbing river over a length of 4.2 km and on the Laras river over a length of 1.2 km and construction of the Laras retading basin. The excessively meandering reaches will be put in order by means of cutoffs. In connection with channel improvement, Nanggalo bridge on the mainstream of the Kuranji river will be extended by one span and Tunggul Hitam bridge on the Balimbing river will be reconstructed. The Laras retarding basin, which has an area of 1.5 km^2, on the right side of the Laras river will be newly constructed to reduce flood discharge.

Air Dingin river

The proposed improvement of the Air Dingin river is channel improvement over a length of 5.2 km. The channel will be improved mainly by excavation of the existing channel, while low dikes will be built in the lower reaches over a length of 3 km from the river-mouth. The excessively meandering stretch located upstream of Muara Penjalinan bridge will be put in order by means of a cutoff. The existing sand spit at the river-mouth will be left as it is.

Urban drainage

The urban drainage improvement proposes : (1) to construct three drainage pumping stations at the terminals of the Ujung Gurun, Purus and Ulak Karang drains, and (2) to improve the drainage channels over a total length of 3 km in the lower reaches of the Ujung Gurun, Purus, Ulak Karang and Olo-Nipah drains.

4.2 Evaluation

Project cost

The construction cost is estimated at Rp. 45,250 million which is equivalent to US$ 46,650 thousand under the current price condition (June 1983 price).

Economic evaluation

The economic construction cost, average annual benefit and annual operation and maintenance cost are estimated at Rp. 43,680 million (US$ 45,030 thousand), Rp. 7,340 million/year (US$ 7,570 thousand/year) and Rp. 156 million/year (US$ 161 thousand/year) respectively. The internal rate of return of the project works out at 14.7 %.

Project effects and impact

Employment which will accuse from the project will come to one million man-days of unskilled labor during the construction period. After the project has been completed, about 2,600 ha of land and 21,300 houses will be relieved from flooding. About 800 ha of open land or swampy area will be expected to be utilized for residential quarters owing to mitigation of flooding.

4.3 Required Funds

Funds required for project implementation are estimated considering price contingency and cost disbursement on the implementation schedule of the project. The required funds amount to Rp. 74,920 million (US$ 77,240 thousand) which consists of US$ 43,750 thousand in the foreign currency portion and Rp. 32,490 million (US$ 33,490 thousand) in the local currency portion.

4.4 Conclusion

The study has conclusively proved that the Padang Area Urgent Flood Control Project is inevitably necessary for securing and promoting the regional economic development and the public welfare, and that the project is technically sound and economically feasible. It is therefore recommended that the project will be implemented as soon as possible.

LIST OF PRINCIPAL FEATURES OF WORKS, COSTS AND BENEFIT OF THE PADANG AREA URGENT FLOOD CONTROL PROJECT

1. Principal Features of Flood Control Works

Excavation/dredging works	33.4 km,	$1,790 \times 10^3$ m^3
Embankment works	50.5 km,	310×10^3 m^3
Bank protection works		
Wet masonries	18.1 km,	83,700 m^2
Dry masonries	8.8 km,	28,300 m^2
Gabions	4.0 km,	14,200 m^3
Groins	0.5 km,	10,500 m^3
Ground sill works		3 places
Reconstruction of structures		
Diversion weir		1 place
Bridges		5 bridges
Drop structures		3 places
Syphons		2 places
Construction of drainage culverts		52 places
Construction of drainage pumping stations		3 stations
Improvement works of drainage channels		3.0 km

2. Project Cost and Benefit

Construction cost	Rp. $45,250 \times 10^6$ (US\$ $46,650 \times 10^3$)
Required funds	
Foreign currency	US\$ $43,750 \times 10^3$
Local currency	Rp. $32,490 \times 10^6$ (US\$ $33,490 \times 10^3$)
Total	Rp. $74,920 \times 10^6$ (US\$ $77,240 \times 10^3$)
Operation and maintenance cost	Rp. 156×10^6/yr (US\$ 161×10^3/yr)
Economic cost	Rp. $43,680 \times 10^6$ (US\$ $45,030 \times 10^3$)
Average annual benefit	Rp. $7,340 \times 10^6$/yr (US\$ $7,570 \times 10^3$/yr)
Internal rate of return	14.7 %

STUDY REPORT

ON

PADANG AREA FLOOD CONTROL PROJECT

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TERMINOLOGY

Administrative districts

Kab. = Kabupaten	Regency
Kec. = Kecamatan	Subdistrict
Kodya = Kotamadya	City
Kel. = Kelurahan	Village (urban area)
Kp. = Kampung	Village (rural area)
Prop. = Propinsi	Province

Institutions

Balai Kota	City Hall
Bina Marga	Highway development
Cipta Karya	Housing, building and urban development
DGCK	Directorate General of Cipta Karya
DGWRD	Directorate General of Water Resources Development
DPMA = Direktorat Penyelidikan Masalah Air	Directorate of Research of Water Problems
DPU = Dinas Pekerjaan Umum	Public Works Service
DPUTL = Departemen Pekerjaan Umum dan Tenaga Listrik	Ministry of Public Works and Electricity
JICA	Japan International Cooperation Agency
PDAM = Perusahaan Daerah Air Minum	Water Enterprise of Padang Municipality
PLN = Perusahaan Listrik Negara	National Electric Corporation
Pusant Meteorologi dan Geofisika	Center of Meteorology and Geophysics

Natural objects

Bt. = Batang	River
Banjir Kanal	Flood relief channel or flood diversion channel
G. = Gunung	Mountain
S. = Sungai	River
Sawah	Paddy field or rice field

UNITS AND CONVERSION FACTORS

1) Length

mm	= millimeter
cm	= centimeter
m	= meter
km	= kilometer

2) Area

ha	= hectare	= $10^4 m^2$
km^2	= square kilometers	= $10^6 m^2$

3) Volume

l, ltr	= liter = 1,000 cm^3
m^3	= cubic meter
mcm	= million cubic meter

4) Weight

mg	= milligramme
g	= gramme
kg	= kilogramme
t, ton	= metric ton = 1,000 kg
qwt	= kwintal = quintal = 100 kg

5) Time

s, sec	= second
min	= minute
h, hr	= hour
d	= day
yr	= year

6) Money

US$	= United States Dollar
Rp.	= Rupiah
¥	= Japanese Yen
US$	= Rp 970 = ¥ 240

7) Others

MSL	= Mean Sea level
kwh	= kilowatt hour
mkwh	= mega kilowatt hour
%	= per cent
ppm	= parts per million
HP	= house power
°C	= degree centigrade
°D	= degree of hardness
10^3	= thousand
10^6	= million
10^9	= billion

CHAPTER I INTRODUCTION

1.1 Purpose of Report

This report entitled "Study Report on Padang Area Flood Control Project" was prepared in accordance with the Scope of Work agreed on November 11, 1982 between the Japan International Cooperation Agency (JICA) and the Directorate General of Water Resources Development (DGWRD), Ministry of Public Works.

This report presents the study on a comprehensive flood control and drainage plan and the feasibility study with respect to an identified and priority project which was formulated as an urgent flood control project for immediate implementation.

The report is supported by fifteen (15) appendices, one (1) drawing and one (1) data book. See below :

Appendix A Hydrology
Appendix B Geology and Soil-mechanics
Appendix C Socio-economy
Appendix D Fluvio-geomorphology
Appendix E Present Conditions of Rivers
Appendix F Flood Runoff and Flooding Mechanism
Appendix G Flood Damage
Appendix H Review on Previous Flood Control Activities
Appendix I Urban Drainage
Appendix J Comprehensive Flood Control and Drainage Plan
Appendix K Urgent Flood Control Plan
Appendix L Construction Plan and Cost Estimate for Urgent Flood Control Project
Appendix M Economic Evaluation for Urgent Flood Control Project
Appendix N Land Conservation
Appendix O Potentiality of Water Resources Development
Drawings
Data Book
Part I Data on Rainfall, Water Level and Discharge

Part III Data on Geological and Soil-mechanics Investigation

Part IIII Existing Cross-section and Profile of River Channel and Major Urban Drainage Channel

Part IV Output of Computer on Flood Runoff Analysis

Part V Output of Computer on Hydraulic Simulation Analysis

Part VI Number of Buildings Inundated

1.2 Progress of Study

In accordance with the Scope of Work, JICA dispatched a study team on January 30, 1983. On February 9, 1983, a meeting was held to discuss the contents of the Draft Inception Report. After modifying the contents of the report, the Inception Report for the study was submitted to DGWRD on February 10, 1983.

Based on the work plan described in the Inception Report, the study was carried out from early February to late March in Indonesia, from middle May to middle June in Japan, and from middle June to early October in Indonesia.

During the above study period, the Progress Report and Interim Report were submitted to DGWRD on March 28 and July 25, 1983 respectively. The Draft Final Report was submitted to DGWRD on October 3, 1983, in Indonesia.

The Team completed the final report based on the comment and recommendation made by the Government of Indonesia on the Draft Final Report.

This report submitted herein comprises the results of the study.

1.3 Personnel Assigned

The study has been carried out under the organization as shown in Fig. 1.1. The members of the Advisory Committee, the Study Team and the counterpart personnel are listed in Table 1.1.

1.4 Transfer of Knowledge

Transfer of knowledge and technical know-how to the Indonesian counterpart personnel have been made by each expert through the daily work. During the study period in Indonesia, technical discussions between experts and counterpart personnel were held on February 16, March 16, June 22, August 4, August 6 and September 29. In addition, the training of three counterpart personnel was executed for about one month in Japan from late November to late December 1983.

CHAPTER II BACKGROUND AND OBJECTIVE OF STUDY

2.1 Background of Study

The city of Padang is the capital of West Sumatra province, and is prospering as a commercial centre being situated at a strategic point in terms of communication and transportation.

The study area comprises the urban area of Padang and its surrounding alluvial lands formed by the Arau, Kuranji and Air Dingin rivers. Administratively, the study area belongs to Kotamadya Padang, West Sumatra province. The total population and land area of Kotamadya Padang as of 1981 were 494,000 and 646 km^2 respectively, giving an average population density of 765 per square kilometer.

The basins of the Arau, Kuranji and Air Dingin rivers are located on the western slopes of the Barisan mountains in West Sumatra, having catchment area of 172 km^2, 213 km^2 and 131 km^2 respectively. The Arau river runs in the southern part of the city of Padang, while the Air Dingin river runs in the northern part and the Kuranji river runs in the middle of the city. Between the Arau and Kuranji rivers, a flood relief channel bifurcates from the Arau river and empties into the Indonesian Ocean.

The climate of the area is dominated by monsoons. The average annual rainfall is about 4,200 mm. The wet season is from October through December with a less severe wet season in April and May. The mean temperature and mean relative humidity are 26° C and 83% throughout the year.

The city of Padang and its surrounding alluvial land formed by the said rivers suffers from frequent floodwater inundation damage. As a countermeasure for the flood damage in the area, a flood relief channel with a diversion facility was constructed in 1918 aiming to protect the urban area of Padang from flood water of the Arau and Kuranji rivers.

However, the capacity of flood control and drainage facilities in the area is not yet adequate. In fact, the area has suffered extensive flood damage five times in the last ten years. The damage caused by floods in 1972 and 1980 was particularly serious.

To make matters worse, in the city of Padang as in other principal cities in Indonesia, the urban area is expanding rapidly and new settlements are developing even in the low-lying land surrounding the existing urban area. The social and economic damage due to floodings in these areas is increasing, this cannot be overlooked any longer. In order to prevent continueing flood damage, implementation of flood control countermeasures is urgently required.

The Government of Indonesia has requested the Government of Japan to give technical assistance for making a study of the Padang Area Flood Control Project. In response to the request, the Government of Japan decided to conduct the study and entrusted it to JICA. JICA dispatched a preliminary survey team headed by Mr. Y. Yano for the period from 1st to 14th November in 1982, and the Scope of Work for the study was agreed between JICA and DGWRD on November 11, 1982.

In accordance with the Scope of Work for the study, JICA dispatched a study team on January 30, 1983 and the study was commenced that day.

2.2 Objectives of the Study

The purpose of the study was to provide a comprehensive flood control and drainage plan in Padang area and to conduct a feasibility study for an urgent flood control project for immediate implementation. The study area includes the basins of the Arau, Kuranji and Air Dingin rivers. The study contains the following.

a. Study of a comprehensive flood control and drainage plan in Padang area comprising the lower portion of the basins of the Arau, Kuranji and Air Dingin rivers.

b. Feasibility study on a priority project to be formulated as an urgent flood control project for immediate implementation.

c. Study of the present situation of water utilization and potential for water resources development and land conservation.

d. Transfer of knowledge and technical know-how to the Indonesian counterpart personnel in the course of the study.

CHAPTER III PRESENT CONDITIONS

3.1 Natural Resources

3.1.1 Topography

The basins of the Arau, Kuranji and Air Dingin rivers cover an area of about 530 km^2 bounded by (1) the Bukit Batu Putih, Bukit Berlimpit and Bukit Balang ridges on the north, (2) the Bukit Putus, Bukit Taratak, Bukit Sarang Labah and Bukit Terjarang ridges on the south, (3) the Bukit Lubuk Begalung, Bukit Sugirik ridges and Mount Bongsu on the east, and (4) the Indonesian Ocean on the west. It is geographically located between latitudes 00°43'S and 01°01'S and longitudes 100°20'E and 100°33'E.

The upper mountainous basins are characterised by thick primary and secondary tropical forests on the very steep slopes of deep and narrow valleys in which the tributaries of the main rivers rise. The mountains rise over 1,800 m. The middle part of the basins up to elevation 150 m MSL lies in a cultivated plain land that varies from 8 to 12 km in width. The lower basin with elevation less than 30 m MSL is made up of finer alluvial materials mainly consisting of sands and gravel. The city of Padang lies on the lower plain between the Arau and Air Dingin rivers.

3.1.2 Climate

The climate of the objective area is characterized by both the dry and wet monsoons which are dominant in Sumatra Island during May through August and October through December respectively. Climatic conditions of the basins are explained by use of data available from two meteorological stations, Tabing and Gunung Nago stations. Tabing station is located in the coastal area while Gunung Nago station is situated in the mountainous area. The conditions are summarized in Table 3.1.

Mean temperature is 25.9°C at Tabing and 27.0°C at Gunung Nago. Annual mean relative humidity is 83% at Tabing and 91% at Gunung Nago. Annual mean sunshine hour ratio is 51% and 46% respectively. Wind velocity fluctuates between 3 km/hr and 4 km/hr which is almost the same at the two stations throughout the year. Annual evaporation observed at these stations shows 1,500 mm and 1,700 mm on the average.

3.1.3 Geology and Soil-mechanics

(1) Geology

From the geological viewpoint, the study area is roughly classified into plain and mountainous regions. The plain region is further classified into coastal plain, fluvial plain and volcanic fans.

The general geological feature is as follows :

a. Coastal plain (below El. 10 m)	: gravel mixed with sand
b. Fluvial plain (El. 10 m - 80 m)	: sand and gravel with andesite cobble stones
c. Volcanic fan (El. 80 m - 150 m)	: mainly andesite and tuffbreccia.
d. Mountainous region (above El. 150 m)	: volcanic rock containing conglomalate, tuff, andesite and basalt.

(2) Soil Profile

The soil profile along the coastline is characterized by 3 distinct layers, i.e., sandy soil layer (1st layer) of 10 to 15 m thickness, cohesive soil layer (2nd layer) of about 15 m thickness, and sand and gravel layer (3rd layer), from the ground surface. The cohesive soil layer becomes thinner from sea coast toward east and seems to end around the boundary of coastal plain and fluvial plain.

(3) Bearing Capacity

As a whole, the ground in the fluvial plain is composed of sand and gravel layers and it has enough bearing capacity with N-value more than 30. The following foundation treatment measures are recommendable for designing the structures in the coastal plain :

a. Pile foundation borne by the 3rd layer for the big and heavy structures such as pumping stations and bridges.

b. Group pile foundation borne by the 1st layer for the drainage sluice.

c. Foundation directly on the 1st layer for dikes.

(4) Embankment Materials

According to the site reconnaissance and bed material sampling, the river bed materials in the lower reaches are applicable to embankment materials of dikes. The bed materials in the middle and upper reaches may not always be applied to the dike because of its coarse size.

Based on the survey by the test pit it is clarified that the river bank materials in the coastal plain are clay, silt, sand, gravel and their mixture, and are suitable for embankment materials for dikes.

(5) Workability of Construction Equipment

Judging from the soil and foundation investigation, ordinary construction equipment is workable in the study area except for the back marsh area behind the Tabing airport.

3.2 Hydrology

3.2.1 Rainfall

Mean annual rainfall depth in the Arau, Kuranji and Air Dingin river basins varies from 3,000 mm to 5,000 mm as shown in Fig. 3.1. The most part of the basins receives more than 3,000 mm annual rainfall which is relatively higher compared with those in other regions out of the boundary. The recorded maximum daily rainfall depths are 301 mm at Tabing and 353 mm at Bandar Buat stations.

For the purpose of knowing the actual annual pattern of rainfall, mean monthly rainfall depth at Tabing station which has the longest daily records is estimated as shown in Table 3.2. Annual pattern at

Tabing station is also shown together with its maximum and minimum in Fig. 3.2. It is recognized that the basins receive much rainfall during the months from September to December while the secondary peak is observed in April.

Probable 1 day and 2 day rainfall depths at Tabing calculated by use of the Gumbel method are shown in Table 3.3.

3.2.2 Streamflow

Monthly mean daily discharges at Lubuk Begalung, Gunung Nago and Lubuk Minturun stations are prepared as shown in Table 3.4 and Fig. 3.3. It shows almost the same trend as that of rainfall, that is, big discharge appears in April and during the period from October through December.

3.2.3 Tide

Tidal records at Teluk Bayur are summarized below.

Gauge readings from Low Water Springs

HHL	MHHL	Mean sea level	MLLL	LLL
1.67 m	1.39 m	0.89 m	0.47 m	0.24 m

It is seen that the tide fluctuates ordinarily between 1.67 m and 0.24 m from low water springs which is taken as the datum of the gauge.

3.2.4 Water Quality

According to the report of Padang Water Supply Project, Nov. 1982, the water quality of the Kuranji river at Kampung Melayu is suitable for municipal water supply, while that of the Arau river was not recommended.

On the other hand, the report "Pekerjaan Survey Hidrometri dan Sedimentasi Sungai Batang Arau & Batang Kuranji di Propinsi Sumatera

Barat" in 1981 presents that the water quality of both the Arau and Kuranji rivers is acceptable for irrigation usage.

3.2.5 Sediment

Average annual sediment at Lb. Sarik, Lb. Begalung and G. Nago is estimated by the Study Team using both observed data on sediment included in the report "Pekerjaan Survey Hidrometri dan Sedimentasi Sungai Batang Arau & Batang Kuranji di Propinsi Sumatera Barat" in 1981 and flow duration curves. They are shown below :

River	Site	Catchment Area (km^2)	Ave. Annual Sediment	
			(t/yr.)	($t/km^2/yr.$)
Arau	Lb. Sarik	64	84×10^3	1309
Flood relief channel	Lb. Begalung	-	138×10^3	-
Kuranji	G. Nago	120	173×10^3	1439

The average annual sediment seems to be comparatively small in consideration of the fact that a big amount of annual rainfall depth is observed in the basins.

In addition, sediment transport capacity, which corresponds to discharge carrying capacity, is calculated by use of sediment formulae based on the data on grain size distribution and the existing channel conditions. It gives an outline of sediment transport distribution that more amount of sediment is appeared in the middle reaches compared with that in the downstream reaches.

Fluctuation of river channel is also examined by the Study Team from the aspects of meandering, profile and cross-section. Information on meandering is given by topographic maps which were prepared in 1893 and 1974 respectively. Remarkable fluctuation on river course can be seen in the Kuranji and Air Dingin rivers, while the Arau river shows almost the same courses during 80 years. On the other hand, typical trend of fluctuation on profile and cross-section, which is examined by use of river survey results in 1973, 1979, 1982 and 1983, could not appeared except middle reaches of the Air Dingin river, in which river bed is decreasing owing to exploitation.

Regarding sediment problems at river mouth of the Arau river, it seems that dredging works are to be required periodically for maintenance of its quay.

3.3 Socio-economy

3.3.1 Population and Households

The population and the land area of Padang city in 1981 were 494,000 persons and 646 km^2 respectively. The population density of Padang city is 765 pers/km^2. The average population growth ratio was about 3.4% per year during the last 10 years from 1971 to 1981, while that of the old urban area (Padang Lama) comprising Kec. Padang Selatan, Padang Barat, and Padang Timur was about 2.3% per year during the same period. On the other hand, the population growth ratios of the new urban area (Padang Baru) of Kec. Padang Utara and Nanggalo which are located on the north of the old urban area are respectively 7.6 % and 9.7 % per year.

3.3.2 Regional Economy

The city of Padang has various economic activities such as commerce, trading, industry, agriculture. In 1981, the city has possessed 2,900 firms concerned in commerce and trading and 1,000 warehouses with about 136,000 m^2 in total space for handling the firm's goods. The city has also possessed 424 registered manufacturers in 1981. The major industries are rubber processing, food and drink production and textiles. The biggest one is cement production at Indarung. The main agricultural products is paddy. In 1981, about 58,300 tons of paddy were yielded from about 14,000 ha of the harvested area. The average annual yield was 4.2 ton/ha.

3.3.3 Regional Infrastructure

In 1980, Padang city has roads 621 km long in total consisting of the state roads 43 km long, provincial roads 29 km long, districts roads 160 km long, village roads 259 km long and other roads 130 km long. Pavement ratio was however only 40 % to the whole road network. In 1981, the total volume of supplied electricity was about 44,000 mkwh and the total piped water consumption was about 6 mcm.

3.4 Present Conditions of Rivers and Drainage Facilities

3.4.1 Present Conditions of Rivers

(1) River System

The study area contains the Arau, the Kuranji and the Air Dingin rivers which are located on the western slopes of the Barisan Mountains in West Sumatra province, having catchment areas of 172 km^2, 213 km^2 and 131 km^2 respectively. The three river basins and their profiles are shown in Figs. 3.4 and 3.5 respectively.

(2) Arau river

The Arau river originates in Mt. Bolak and flows down southwestwards on the western steep slopes of the mountain along deep and narrow valleys. At Lubuk Sarik, it joints the Tinggi river of about the same dimension. Afterwards, the Arau river flows westwards and joints the Gadul Cadang river at Taratak. Downstream from Taratak, the topography changes from hill to plain. At Lubuk Begalung, a flood relief channel is diverted from the main stream, installed with two diversion weir. Downstream from the main-river weir, the Jirak river joints from the left at a point about 500 m downstream from the railway bridge. Afterwards, the mainstream flows down taking a meandering course through the urban area of Padang and finally empties into the Indonesian Ocean.

(3) Flood relief channel

The flood relief channel was constructed in 1918, to divert a part of the flood runoff of the Arau river. The channel starts from the diversion weir at Lubuk Begalung and takes a route toward the north-west direction. Then at Kp. Pinang Balik, it bends toward the west. The stream finally empties into the Indonesian Ocean. The channel from Lubuk Begalung to the sea is 6.7 km long. There are 3 drop structures in the channel in its middle reaches which drops the bed level by 4 m in total. The rehabilitation works of the flood relief channel are being carried out from the upstream reaches by the government.

(4) Kuranji river

The Kuranji river originates on the western slope of Mt. Bungsu and flows the south-westward on the steep slopes of narrow valleys. Afterwards, the Kuranji river flows through the mountainous area and joints the Limau Manis river at Gunung Nago. Downstream from the confluence of the Limau Manis river, there is an irrigation weir which was constructed in 1973. Downstream from Gunung Nago, the surrounding topography changes from hill to plain. From Gunung Nago, the river flows to the westward with meandering through the alluvial plain and joints the Balimbing river at Ujung Karang. Afterwards, the Kuranji river finally empties into the Indonesian Ocean.

(5) Air Dingin river

The Air Dingin river originates on the southern slope of Mt. Lantik and flows to the south-westward on the steep slopes of narrow valleys. At Koto Tuo, downstream from the road bridge, there is an irrigation weir and the surrounding topography changes from hill to plain. Afterwards, the river flows westward with meandering through the alluvial plain and finally empties into the Indonesian Ocean. At the rivermouth, the sand spit is observed. This sand spit has forced the river course southwards before discharging into the sea.

(6) Exploitation of sand and gravel on river bed

A lot of sand and gravel on the river bed of the Arau, Kuranji and Air Dingin rivers is being exploited, especially the exploitation of cobble stone is remarkable in the middle reaches of the said rivers. The exploitation volume is estimated at about 110,000 m^3/yr in the three rivers.

(7) Carrying capacity of river channels

Carrying capacity of the existing channels is estimated with regard to the Arau river, the flood relief channel, the Kuranji, Balimbing and Air Dingin rivers, based on calculation by the non-uniform flow method.

The summarized carrying capacity is shown in Table 3.5.

3.4.2 Present Condition of Drainage in Urban Area

The urban area of Padang is located on the coastal plain with an area of approximately 20 km^2 and in the present study the area is divided into two, i.e., (1) the old urban area located between the Arau river and the flood relief channel and (2) the new urban area located between the flood relief channel and the Air Dingin river.

The existing drainage system in the old urban area covers about 10 km^2 as shown in Fig. 3.6 and the main drainage systems of the area are (1) Jati and Anak Jati, (2) Kali Mati, (3) Olo I and II, and (4) Bandar Purus and Purus Kebun. These existing drainage systems are as a whole, not maintained well and poorly functioning.

The new urban area is rapidly being urbanized. New housing estates and industrial and commercial areas take the place of the former farm lands. The existing drainage area is shown in Fig. 3.7. Integral plan for the urban drainage system is not made yet for this area.

Regarding the drainage in the low-lying areas listed below, sufficient terminal drainage facilities are not equipped and the drainage in these areas is affected by the backwater due to flood water of river and high tide.

a. Kali Mati
b. Bandar Purus and Purus Kebun
c. Purus river
d. Ulak Karang river
e. Baung river
f. Penjalinan.

3.4.3 Flood Control and Drainage Facilities

(1) Flood diversion facilities at Lubuk Begalung

To secure the function of diversion, the flood-diversion weir was constructed on the flood-relief-channel side of the bifurcation and the main-river weir on the main-river side at the same time as the construction of the flood relief channel in 1918. The weir is located at about 7.5 km upstream from the river-mouth of the Arau. The main river weir is about 65 m in total width and consists of 7 openings and 4 sand-flush gates, while the relief-channel weir consists of 5 openings as shown in Fig. 3.8. Although stoplogs are put in the main-river weir except an opening located at the left end of the weir, it seems to be difficult to control in time of flood, because the stoplogs are too heavy to lift and no lifting equipment is installed. The 4 sand-flush gates are respectively equipped with a wooden gate-leaf. The gate leaves were replaced with new ones in 1982.

The steel girders of the main-river weir have been corroded extremely and surface concrete of upper part of the piers is off in places. But the floor slabs are not much abraded. The river bed immediately downstream of the main-river weir is remarkably lowered due to scouring. In 1979, ground sills composed of cribs and gabion were constructed at two places. Fig. 3.9 shows them.

For the purpose of knowing the stability of the existing main-river weir, the Study Team checked the stability of the weir structure against sliding and overturning. As a result, it is confirmed that the weir structure withstands against sliding and overturning under the present condition putting stoplogs.

According to the results of a hydraulic model test by the Bengawan Solo river laboratory in 1982, the diverted discharge and its ratio under the existing conditions are as follows :

Discharge before diversion (m^3/s)	Main river		Flood relief channel	
	Discharge (m^3/s)	Ratio (%)	Discharge (m^3/s)	Ratio (%)
1. All sand-flush gates closed				
500	293	59	207	41
700	427	61	273	39
2. All sand-flush gates opened				
500	329	66	171	34
700	444	63	256	37

(2) Bank protection works

Gabion works are mostly used bank-protection (bronjong). The location and the length of bank protection works are shown in Fig. 3.10.

(3) River dikes

River dikes exist only on both banks of the flood relief channel. The other rivers have no dike.

(4) Drainage facilities

The existing drainage outlet structures are non-gated or poorly functioning. The structures which exist along the flood relief channel and the Arau river are shown in Fig. 3.11. Any other drainage facilities are not found in the urban area.

3.5 Floods

3.5.1 Flooding Characteristics

The river basins are situated in the heavy rainfall zone by the monsoon and characterized by the topographic features of the river channel profiles with steep slope. Such heavy rainfall brings frequently about inundation in the low-lying area of the basin.

Sumatra experiences two monsoons: the northwestern monsoon from October to April and the southwestern monsoon from May to September. In West Sumatra, main wet season occurs from October to December, and in April and May the secondary peak in rainfall appears. In the Padang area, floods usually occur in November or December, late in the wet season, and in April or May during the transitional season of monsoon.

Considering the duration and sharpness of flood peaks, it may be said that the 3 rivers are so-called shotgunlike rivers. After heavy rain in the mountain areas, the water stage rises rapidly in the lower reaches as well as in the middle reaches and the river water overtops its banks exceeding the channel capacity. Moreover, the debouching of river water in flooding is frequently aggravated by high tides.

The flooding in the plain thus may be caused by the following factors:

a. Overbank flow of flood water due to low river channel capacity.

b. Insufficient capacity of the drainage system.

c. Backwater effect of flood water level in the river channel and tide level.

Regarding the urban area located between the Arau and the Kuranji rivers, intensive inundation seems to be caused by the combination of two or more of the above factors. Fig. 3.12 shows inundation area and typical flood flow directions.

3.5.2 Past Major Floods

According to the data on the past remarkable floods collected from DPU, West Sumatra and the information from local people during the field survey, the major floods in the past were the floods in May 1972, April 1979, November 1980, November 1981, and December 1982. The main features of the floods in terms of rainfall and inundated area are as follows :

Item	Unit	Flood				
		May 1972	Apr.1979	Nov.1980	Nov.1981	Dec.1982
2-day rainfall						
Tabing	mm	393	264	314	212	128
Gunung Nago	mm	-	298	301	-	-
Inundated area	ha	3,942	2,809	3,340	1,444	1,281

It is recognized that the both floods of May 1972 and November 1980 were heavy from the above table.

3.6 Flood Damage

3.6.1 Present Land Use

According to the Report/1, the present land use of Padang city in

/1 Rencana Induk Kota Padang, 1982

1981 was 14.5% for urban area, 36.0% for agricultural land and 49.5% for forest.

The present land use was surveyed in the plain area of the three river basins of the Arau, the Kuranji and the Air Dingin. On the basis of the topographic map of scale 1/5,000 surveyed in 1974 after modifying by new aerophoto taken in 1981, the present land use map is prepared as shown in Fig. 3.13.

The results of survey show that the land use of the plain area in 1981 was 27% for residential area, 48% for paddy field, 25% for other agricultural land and area including road, channel, etc. They are shown in Table 3.6.

3.6.2 Flood Damage

Flood damges are estimated, in principle, from properties in the flooding area multiplied by the damage ratio depending on the flooding conditions. The damages are estimated for the respective properties such as house and household effects, shops and warehouses, agricultural crops, public facilities and others.

The flooding conditions such as area, depth and duration of flooding or inundation are obtained based on the calculation results by the flood simulation model described in APPENDIX F.

All the monetary values are expressed by the economic prices as of the beginning of June 1983. The conversion rate of foreign and local currencies is assumed at : US$ 1 = ¥ 240 = Rp. 970.

(1) Probable flood damages

The probable flood damages are estimated for the present situation of basin development. The floods taken up for the studies are 2,5,10,25,50 and 100 year return periods.

For the estimation of amount of damages, the objective flooding area is divided into the following eight blocks.

a. Arau river system
   - Block 1 : Arau mainstream and flood relief channel
   - Block 2 : Jirak river
   - Block 3 : Interior drainage area

b. Kuranji river system
   - Block 4 : Kuranji mainstream
   - Block 5 : Balimbing and Laras rivers
   - Block 6 : Interior drainage area

c. Air Dingin river system
   - Block 7 : Air Dingin river
   - Block 8 : Interior drainage area

The flood damages are estimated for every return period and for every block. The estimated flood damages are summarized in Table 3.7. The total flood damages for respective return periods are as follows :

Return period (year)	Flood damages (Rp. 10^6)			
	Arau river	Kuranji river	Air Dingin river	Total
2	920	570	240	1,730
5	9,510	1,750	360	11,630
10	16,110	3,520	710	20,340
25	22,800	4,790	1,690	29,270
50	23,590	5,490	3,070	32,160
100	25,000	6,220	3,160	34,380

(2) Annual average flood damages

The annual average flood damages are estimated as a cumulus of flood damage segments derived from probable flood damages multiplied by the corresponding probability of occurrence, from non-damageable runoff up to 100 year probable flood.

The calculated annual average flood damages are as follows :

a. Arau river system
   - Block 1 : Arau mainstream and flood relief channel : 2,400 (Rp.10^6/year)

	- Block 2 : Jirak river	:	70	($Rp.10^6$/year)
	- Block 3 : Interior drainage area	:	2,480	(")
	- Sub-total	:	4,950	(")
b.	Kuranji river system			
	- Block 4 : Kuranji mainstream	:	510	(")
	- Block 5 : Balimbing and Laras rivers	:	290	(")
	- Block 6 : Interior drainage area	:	370	(")
	- Sub-total	:	1,170	(")
c.	Air Dingin river system			
	- Block 7 : Air Dingin river	:	330	(")
	- Block 8 : Interior drainage area	:	30	(")
	- Sub-total	:	360	(")
d.	Total	:	6,480	(")

3.7 Fluvio-geomorphology

Geomorphologic features of the Arau, Kuranji and Air Dingin rivers and their drainage basins are presented based on the findings through the aerophoto interpretation and field survey.

The plain located along the middle and lower reaches of the three rivers are formed not only with sands and gravels transported by these rivers in flood time during the Holocene epoch, but also with volcanic detritus, lahar, etc. due to volcanic eruptions during the Pleistocene epoch.

During the formation process of the plain, the topography was influenced by crustal movement and eustatic movement.

The geomorphologic elements of these plains are volcanic fan, alluvial fan and coastal plain. A schematic geomorphologic profile is shown in Fig. 3.14.

When a flood control plan is made, it is necessary to know in detail the natural environment of the area to be protected from flooding. For the purpose of knowing the geomorphological feature of the area, a geomorphological map is made as entitled "A Geomorphological Survey

Map of Padang City and Surrounding Area in West Sumatra Indicating Areas Subject to Flooding". This map is enable to know the flood conditions, not only of the past but of the future, in respect to the extent of the areas to be submerged by floods, the direction of flood current, change of river course, possibility of erosion, deposits, other items that may help in defining the type of flood.

3.7.1 Volcanic and Alluvial Fans

(1) Geomorphologic elements in the plain

When eruption or big collapse of volcano occurred, a lot of volcanic detritus, lahar, ashes, etc. flowed down on the slope or along the valley and deposited at the foot of the volcano forming a volcanic fan. Then, when the eruption or big collapse ceased, rainfalls or stream flow began to erode the fan. And then the fan changed to dissected fan just the same as that formed by upheaval ground movement.

Pyroclastic flow terrace (Volcanic Fan) is developed well along the Air Dingin river. Alluvial fan is developed well along the Kuranji river remarkably. And small alluvial fan is developed along the lower reaches of the Air Dingin river and middle reaches of the Arau river but none in the lower reaches.

The geomorphology of the fan consists of three geomorphological elements i.e, alluvial fan, slightly hilly area and narrow long dissected fan. The fan of the Arau river is small. The fan is developed in the upper reaches from the small canyon at Baru Pulau Air and none in lower reaches. The fan along the Air Dingin river is developed from the lower edge of the volcanic fan to the coastal sand spits. There are many abandoned river channels on the fan of the Air Dingin and Arau rivers.

The coastal plain is located about 1.6 - 3 km from the coastline. The area consists of slightly hilly sand-spits and back-marshes. Big swampy area is located between the sand-spits near Tabing airport and foot of the volcanic fan. Coral reef is developed at the river mouth of the Kuranji river. The surface of the coral reef is covered by sand.

(2) Process of geomorphological development in the plain

Although the formation age of the coral reef is not estimated yet, it seems that the age is in the last interglacial age during the Würm Ice Age or post glacial age. At that time, the location of the mouth of the Kuranji river was different from the present mouth and big lagoon was located at the back side of the coral reef. After that the base of the fan of the Kuranji river was formed by pyroclastic flow down to the plain due to the big volcanic eruption. Then the pyroclastic flow was covered by sand and gravel about 5 to 10 m thick and the fan was formed. Although formation age of the fan is not estimated yet, it seems to be in Würm Ice Age (18,000 years B.P.) when the sea water level was lowered about 100 m than that of the present due to the glacial eustatic sea level change.

Around 6,000 years ago, sea water level was upheaved and reached 4 to 6 m higher than that of the present due to the glacial eustatic sea level change. Some part of the fan and phroclastic flow were eroded and new fan was formed. After advanced 6,000 years B.P., sand spits have been formed. The line of sand spits were increased to sea side because of lowering of the sea water level and deposition of sand. The formation process of the basin of the Arau and Air Dingin rivers are different from that of the Kuranji river.

(3) Comparison of the fluvial action among three rivers

Due to the push of the fan of the Kuranji river, the Arau river was narrowed near Baru Pulau Air. There are several knick points in the small canyon as shown in Fig. 3.15. There is big difference on the fluvial action between the upper reaches and lower reaches of the knick point. Based on the analysis of the species, diameters and roundness of the gravels in the river bed and topography along the river, it is estimated that the deposition of the upper reaches of the knick point is big, but small in the lower part. The considerable part of the sand and gravel were stopped by the knick point in the canyon, and only smaller gravel is allowed to flow down via knick point. At the canyon, big gravel is supplied not only from the both bank but also from the river bed. Then the maximum diameter of the largest gravel is increased. But the volume of sand and gravel which flow down to the lower reaches via knick point is small. The deposition of the lower course of the Arau river is smallest among the three rivers.

The fan of the Kuranji river is being dissected especially in the upper part, not only by the mainstream of the Kuranji but also the tributaries on the fan. In the case of the Air Dingin river, the erosion of the pyroclastic flow and terrace are vivid. By the eroded sand and gravel, new alluvial fan has formed between the volcanic fan and sand spits. The shifting of the river course is frequent in the fan.

3.7.2 Coastal Plain

The coastal plain develops along the coastline between the river mouths of the Kuranji and Air Dingin. The plain is characterized by the slightly hilly sand spits and low-lying back marshes as shown in Fig. 3.16.

The sand spits located along the coast line are formed only with sand. But the sand spits located inland region are covered with humus soil about 50 cm thick. Back-swamps are also covered with the same soil. The sand spits located in the inland region were formed in earlier age than those along the coast line. When the inland spits were formed, the sea-water level was slightly higher than that of the present.

All the sand spits and back-marshes are parallel with coastline. The natural drainage of these areas seems to be difficult due to topography. The artificial drainage must be considered. Due to the urbanization of Padang city, houses are being constructed not only on the sand spits but also in the back-marshes.

(1) Geomorphological consideration on supply of sand and its movement

The sand of the coast is supplied from the rivers and transported by littoral current and washed ashore by waves. As has been mentioned above, the deposition of the Kuranji river is biggest among the three rivers. By the existence of the coral reef, the direction of the river mouth of the Kuranji is winded to north slightly. Due to the direction, the sand and silt which is transported by the Kuranji river is distributed in the northern part of the river mouth of the Kuranji.

The main direction of the littoral current is estimated from north to south, because the river mouth of the Air Dingin is winded to south and the gravel coming from the Kuranji river is found at the southern coast of the Kuranji.

(2) Geomorphological consideration on the coastal erosion

The deposition is predominant than erosion between the Kuranji and Air Dingin rivers. It is found by the map which was prepared in 1883 that there was sand bank at the right bank of the river mouth of the Kuranji. Utilizing the map and geomorphological land classification map, the coast line in 1883 can be traced, and it is confirmed that the coast line was advanced about 200 m from 1883 to present. At that time, direction of the river mouth of the Air Dingin was at a right angle to the coast line. But the river mouth was winded to south and jointed with the Kuranji river on the map in 1982. This shows that big deposition occurred by the Air Dingin and other rivers located in the north.

At present the erosion is predominant than deposition at the coast of the Padang plain except the coast between the Kuranji and Air Dingin rivers. One of the important reason of the coastal erosion is related with the supply of sand and gravel from the rivers. The volume of the sand and gravel which are transported by the three rivers is estimated not so big. Because these sand and gravel are transported not from the upper mountains but from the fan and pyroclastic flow. Especially, the volume of the Arau river is small.

It is estimated that the coastal erosion is related with not only the natural features of the rivers, but also artificial works on the river channels such as construction of weir, exploitation of the bed materials and so on.

3.8 Present Water Balance

In order to clarify the conditions of availability and requirement of surface water under the present situation of basin, the water balance is studied for the Arau, Kuranji and Air Dingin rivers.

The present water requirement is estimated as a sum of water required for the existing irrigation system and present water use for industries and municipal water supply. The irrigation water requirement is estimated for every week considering the growing stage of paddy.

Regarding the availability of surface water, the one in five year dependable runoff is estimated, firstly, on the monthly data basis, since the statistical analysis for preparation of the flow duration with shorter duration can hardly be done due to the paucity of discharge records. The dependable runoff is estimated from the one in five year monthly rainfall at Tabing station by use of relationship between rainfall and runoff at each balance point.

On the other hand, relationship between monthly average runoff and minimum 10-day average runoff of the month is studied based on the runoff records as available. The monthly average dependable runoff is converted into minimum 10-day average runoff of each month using the monthly runoff versus 10 day runoff relationship. Finally the water requirement and the 10-day average available water are compared with each other.

3.8.1 Present Water Requirement

The surface water of the Arau, Kuranji and Air Dingin rivers including their tributaries are used mainly for irrigation, industrial and municipal water supply, and hydroelectric power generation.

A total of 11.5 m^3/s of surface water is required at present, which consists of 10.8 m^3/s for irrigation, 0.5 m^3/s for industry and 0.2 m^3/s for municipal water supply. The water requirement of each river is summarized in the following table, of which monthly requirement is shown in Table 3.8.

River	Water requirement (m^3/s)			
	Irrigation	Industry	Mun. water supply/1	Total
Arau	1.167	0.487	-	1.654
Kuranji	5.901	-	0.220	6.121
Air Dingin	3.755	-	-	3.755
Total	10.823	0.487	0.220	11.530

Irrigation water shares the major part of the present water requirement. The irrigation water in the above table is the water requirement estimated for the existing irrigation systems shown in Fig. 3.17.

There are two hydroelectric power plants, i.e., PLTA Rasak Bunga in the Arau river and PLTA Kuranji in the Kuranji river. For these plants 1.80 m^3/s and 2.55 m^3/s of water is taken from the Arau and Kuranji rivers, respectively, and returned to the respective rivers, which are not included in the table of water requirement mentioned above.

3.8.2 Available Water

Taking account of the locations of stream gauging stations and intake facilities, the following points are selected for water balance study :

River	Balance point	Drainage area (km^2)
Arau	Lb. Sarik sta.	64
Kuranji	G. Nago weir	120
Balimbing	S. Guo weir	11
Air Dingin	Lb. Minturun sta.	116

/1 Padang Water Supply Project, Feasibility Study and Detailed Engineering, Lahmeyer International, Nov. 1982.

Since the period of available surface flow data is short, the available water at each balance point is estimated from the rainfall data at Tabing station by use of relationship between monthly rainfall at Tabing station and monthly average runoff at each balance point. Tabing station has longer period of rainfall records since 1948.

According to the results of correlation study, the monthly average runoff at each balance point is related to monthly rainfall as follows :

a. $Q = 0.0273\ R = 1.12\ R\ A\ /\ 2{,}630$ for Lb. Sarik station
b. $Q = 0.0461\ R = 1.01\ R\ A\ /\ 2{,}630$ for G. Nago weir
c. $Q = 0.00422\ R = 1.01\ R\ A\ /\ 2{,}630$ for S. Guo weir
d. $Q = 0.0391\ R = 0.89\ R\ A\ /\ 2{,}630$ for Lb. Minturun station

where,

Q : Monthly average runoff at each balance point (m^3/s)
R : Monthly rainfall at Tabing station (mm/month)
A : Drainage area (km^2)

Based on the discharge data as available at Lubuk Sarik and Lubuk Minturun stations, the ratio of minimum 10-day average runoff in a month and monthly average runoff is studied. On the average, the minimum 10-day average runoff is 68 percent of the monthly average runoff.

The monthly average available water at each balance point is estimated from the rainfall data at Tabing station by use of the relationship between monthly rainfall and runoff derived in the previous paragraph. The minimum 10-day average runoff of each month is estimated from the monthly average available water multiplied by the ratio 0.68. The 10-day runoff is taken up as the available water of each month. The results of calculation are shown in Table 3.8.

3.8.3 Water Balance

The present water requirement and available water at each balance point are shown in Table 3.8 and Fig. 3.18. The water balances at the maximum requirement and the minimum availability are summarized as follows :

River	Balance point	Balance at max. requirement (m^3/s)		Balance at min. Availability (m^3/s)	
		Qr	Qa	Qr	Qa
Arau	Lb. Sarik	1.65	3.08	1.59	2.34
Kuranji	G. Nago	4.97	5.20	4.69	3.95
Balimbing	S. Guo	1.16	0.48	1.09	0.36
A. Dingin	Lb. Minturun	3.76	4.41	3.53	3.35

(Qr : Water requirement, Qa : Available water)

Although the study made in the previous sections are on the preliminary level, the present water balance could be concluded as follows :

a. The water in the Arau river is deemed to be enough to the present water requirement.

b. The water in the main Kuranji and Air Dingin seems to be almost enough to the present water requirement except the month of minimum availability.

c. The water at S. Guo is not enough to the present irrigation water requirement, since the catchment area is too small to supply water to the wide irrigation area between the Balimbing and Laras rivers.

CHAPTER IV REVIEW ON PREVIOUS FLOOD CONTROL ACTIVITIES

4.1 Existing and Ongoing Flood Control Works

The Padang area has been suffering from flooding since the Dutch ages. Floodings before the construction of flood relief channel (Banjir Kanal) were caused by the flood water both from the Arau and Kuranji rivers. Channel capacity of the Arau river was insufficient, in addition, flood water from the Kuranji river flowed into the Padang area through the Jati river and other irrigation canals. Flood relief channel was proposed intending to divert a part of the flood runoff of the Arau river, to prevent the flood runoff of the Kuranji from attacking Padang city, and to drain the both runoffs directly to the sea. The construction works of the flood relief channel and diversion structure at its head were started in 1911 and finished in 1918.

The flood relief channel and flood diversion structure in Lubuk Begalung are the most important existing flood control facilities.

Incessant efforts for protection of Padang area from floods have been made by the DPU, West Sumatra and its related authorities. Table 4.1 shows the past budgets for the flood control of the Arau, Kuranji and Air Dingin rivers and for Padang coast protection since 1969/70 fiscal year.

The works executed so far are mainly local bank protection, rehabilitation and maintenance of the flood relief channel, and jetty construction for Padang coast protection from erosion. These works seems to be properly executed and performing their expected functions. These works, however, are not carried out under a comprehensive basin-wide flood control plan, since the works are executed with the limited fund and are those of remedial measures.

4.2 Previous Flood Control Studies and Related Projects

(1) Flood protection and control of Padang and environments

The study was made by P.T. Indah Karya for DGWRD in 1973 through 1975, and the study results are involved in a series of reports. This study initiated the current studies on flood control of the Padang area.

Among these reports, the first report; Reconnaissance Report for the Flood Protection and Control of Padang and Environments presents the basic concept of flood protection and control as follows :

a. To retard flood runoff in the upper reaches by means of re-afforestation, and river terracing/check dams
b. To accelerate drainage in the lower reaches by means of channel improvement and cut-off channels
c. To prevent flood water from overflowing by means of levees on both river banks, and decreasing flood runoff by floodway and watershed separation
d. To drain local rain by means of construction and rehabilitation of drainage canals
e. To regulate land use so as to reduce damages.

The report proposes the following flood control works to be implemented as the short term works :

a. River training and levee construction
b. Rehabilitation of the Arau, flood relief channel and its flood control structure
c. Rehabilitation and construction of drainage canals and gates.

(2) West Sumatra Design Unit Reports

The reports were prepared by the Design Unit of Pengairan, DPU, West Sumatra in 1977 through 1981, under a technical cooperation by Sir William Halcrow & Partners under assignment by Overseas Development Administration, London. Most of these reports are so-called technical notes.

(3) Padang Kampung Improvement Program (Padang KIP)

The captured program was prepared by FENCO Consultants for DGCK in 1980, as a part of the Urban Development in 7 Medium Size Cities.

The Padang KIP project covers an area of 258 ha and is implemented in 4 phases as follows, (refer to Fig. 4.1) :

Phase	Fiscal Year	Kampung	Net area (ha)	Population
I	1980/81	Purus I	44	8,751
II	1981/82	Ujung Gurun, Purus II	55	14,430
III	1982/83	Alang Lawas, Pasar Gadang, Pondok	77	16,093
IV	1983/84	Seberang Padang, Parak Gadang	82	15,205
	TOTAL		258	54,479

The Phase I and II works were completed and Phase III works and detailed engineering for Phase IV are ongoing. Drainage improvement included in the KIP program is, in general, for tertiary drains of small size.

(4) Padang Drainage Improvement Project

P.T. Indah Karya with advisor from DHV Consulting Engineers is conducting the detailed engineering of Padang Drainage Improvement Project for DGCK, aiming to propose drainage improvement works in order to reduce the floodings and to improve the sanitary condition of drains, in the old city area bounded by the flood relief channel, the Arau river and the Indonesian Ocean (approximately 1,000 ha : refer to Fig. 4.2).

The services were commenced in August 1982 and the study is still ongoing. Series of supporting reports and background papers have been prepared so far. Interim Report I was published in May 1983 and Interim Report II will be submitted at the beginning of November 1983.

According to the survey and studies made so far, the layout of the existing and proposed drainage systems is shown in Figs. 4.2 and 4.3. The Damar system and Jati I and II system have alternative drainage routes through the existing Purus I drain and Jati drain instead of construction of new outlets.

One of the proposed drainage systems, the Olo-Nipah system was subject to the preliminary design selected as the first priority area.

(5) Other studies

Study on Water Resources Development Plan in the Padang Metropolitan Area (Study Perencanaan Pengembangan Sumber-sumber Air Wilayah Metropolitan Padang) was made for DGWRD by P.T. Virama Karya in 1981.

Feasibility Study and Detailed Engineering for the Padang Water Supply Project was made for DGCK by Lahmeyer International in November 1982.

Padang City Master Plan (Rencana Induk Kota Padang 1983 - 2003) was set up lately in January 1983 by Pemerintah Kotamadya Daerah Tingkat II Padang (refer to Fig. 4.4).

Regarding the studies on Padang coast, Prestudy on Padang Coast Problems (Prestudy Masaalah Pantai Padang) was prepared by DPUTL, West Sumatra in 1971. Lately, Final Report on Inspection and Investigation Works of Deposition Effects of Jetties in Padang Coast (Final Report on Pekerjaan Pengamatan dan Penelitian Krib Terhadap (Pengaruh) Endapan Pantai Padang) was prepared for DPU, West Sumatra by C.V. Tri Udaya Sakti in 1983.

The studies mentioned above are also referred to in planning the Padang Area Flood Control Project.

CHAPTER V FORMULATION OF COMPREHENSIVE FLOOD CONTROL AND DRAINAGE PLAN

5.1 General

Based on the results of the field investigation, study of the present conditions of the study area and review of previous studies, conceivable alternative schemes for comprehensive flood control and drainage plan were developed, and the final plan was formulated based on a comparative study of the alternative schemes. The results of the comparative study and the proposed comprehensive plan are presented in this chapter.

5.2 Objective Area for Comprehensive Plan

The urban area of Padang has been developed on the coastal plain between the Arau and Air Dingin rivers. But the recent general trend of urbanization is to extend eastward from the existing urban area.

According to the master plan of Padang city which envisions the future city development at the target year of 2003, the new urban zone is planned mainly to the area located between the existing urban area and the foot of mountain on the east as shown in Fig. 4.4.

Within the three river basins, the future city area of Padang is to be about 130 km^2. In the present study, the comprehensive flood control and drainage plan is prepared in order to relieve the existing and future urban areas of 130 km^2 from flooding.

5.3 Alternative Schemes

5.3.1 Flood Control Method

The flood control method should adopt the optimum measure taking account of regional characteristics of the river basin such as topography, scale of catchment area, type of flood runoff, flooding conditions, etc. In general, the following measures were considered optimum for flood controls :

Upper basin	:	flood regulation by reservoir
Middle basin	:	flood retardation by retarding basin and flood prevention by channel improvement
Lower basin	:	flood diversion by diversion channel and flood prevention by channel improvement

(1) Flood control method in upper basin

The river slopes upstream of the Arau, Kuranji and Air Dingin are very steep, more than 1/40. The flood runoff is therefore of the flash type with time of concentration of about 5 hours. The effective measures of flood control for such rivers is to store a flood runoff by reservoir in the upper basin. In the upper basin, the river has very steep slopes of deep and narrow valleys. The only appropriate dam site with reservoir is found at Danau Kering in the upstream reaches of the Limau Manis river of the Kuranji river basin. The location of this Limau Manis dam is shown in Fig. 5.1. The catchment area of this dam is 17.5 km^2. The reduction of peak discharge by regulation of the dam was calculated using the flood runoff simulation model described in APPENDIX F. The result of calculations show that about 10 % of peak discharge in the case of 50 yr probable flood is effectively reduced by dam construction. The result of the comparative study with the improvement of the existing channel shows that a dam would prove more expensive than channel improvement. This countermeasure is therefore not recommendable for the purpose of flood control only. On the other hand, from the viewpoint of development of natural energy under the difficulty in acquisition of oil, this dam scheme might be taken up as multipurpose project providing hydropower in the future.

With regard to the proposal on the previous study report by P.T. Indah Karya to build a series of stepped dams (check dams) in the upper reaches of the Arau and Kuranji rivers, the Study Team checked the reduction of peak discharge by means of the stepped dams by calculation using the flood runoff simulation model described in APPENDIX F.

The result of the calculation shows that the reduced peak discharge by stepped dams is very small for the following reasons : (1) the rivers are too steep for any effective storage to be provided to attenuate flood discharges, and (2) flattening of the river bed slope would be local and the delay in time of concentration would be small. Therefore, the stepped dam measure is not recommended.

As mentioned in Section 3.7, there are several knick points near the new railway bridge of the Arau river. The deposition of the upper reaches of the knick points is big, but a considerable portion of the sand and gravel is stopped by the knick points, smaller gravel is allowed to flow down via the knick points. The deposition of the lower reaches of the Arau river is small. In case of the Kuranji river, the lowering of the river bed is accelerated by the Gunung Nago weir. The facts mentioned above show that construction of check dam is unnecessary to reduce sediment runoff in the upper basin.

The re-afforestation and forest maintenance are necessary and commendable practices to reduce runoff in the upper basin, but the effects of such activities of watershed management would be expected only after extended effort over a long period. On the other hand, the model forest scheme as proposed by Andalas University is outlined in APPENDIX C. This proposal should be encouraged from the viewpoint of conservation of the forest in the upper basin.

(2) Flood control method in middle basin

In the middle basin of the three rivers, most of the plain area has been developed as agricultural land or residential quarters. The possible area for a retarding basin is found only in the small area on the right side of the Laras river where the land has not been developed yet because of swamping during the wet season. This area may be considered for a retarding basin.

Since the middle reaches of the existing channel has adequate carrying capacity, excepting the Balimbing and Laras rivers, a continuous dike along the whole stretch is unnecessary. Therefore, channel improvement by means of dike construction and excavation of the channel is recommended as the most effective for the middle reaches.

(3) Flood control method in lower basin

In the lower reaches of the rivers, the existing channel has inadequate carrying capacity in all stretches. Improvement of the existing channel or construction of a diversion channel should be considered.

With regard to a diversion channel, the following two schemes are studied in order to reduce flood discharge of the existing channel.

a. A new diversion channel to divert the excess flood water from the Arau river by construction of a 4.7 km channel from a point upstream of the Lubuk Begalung weir to the Teluk Bayur harbor.

b. Separation of the Balimbing river from the Kuranji catchment by construction of a 2.4 km channel to the sea.

The results of the cost estimate show that the construction costs of the above measures would be more expensive than the cost of improvement of the existing channel. Moreover, in the case of new diversion of the Arau river, a sediment problem would be brought to the Teluk Bayur harbor.

Another conceivable flood control method is improvement of the existing channel which is the principal flood control measure in the lower reaches. No other measure would be effective in the lower reaches of the three rivers. Therefore this method is recommended.

5.3.2 Alternative Schemes

With regard to river stretches subject to channel improvement under the comprehensive plan, the improvement at the upstream end of the channel was determined by consideration of the results of the fluvial geomorphological study, i.e. the new railway bridge site for the Arau river where the knick point exists, the Gunung Nago weir site for the

Kuranji river and the Koto Tuo weir site for the Air Dingin river. The determined river stretches are as follows :

Name of River	Length (km)	Stretch
1. Arau river	10.6	rivermouth - new railway bridge
2. Jirak river	4.6	confluence to mainstream - new railway bridge
3. Flood relief channel	6.7	whole stretch
4. Kuranji river	13.5	rivermouth - Gunung Nago weir
5. Balimbing river	9.7	confluence to mainstream - 2 km upstream of Lolong Kanan bridge
6. Laras river	4.2	confluence to Balimbing - Kp. Air Pacah
7. Air Dingin river	5.2	rivermouth - Koto Tuo weir

Locations of these stretches are shown in Fig. 5.1.

Since the existing channels have insufficient capacity, channel improvements to increase the carrying capacity are required by means of construction or heightening of the dike and excavation of the channel. According to the results of the fluvial geomorphological study, the fluvial action of the rivers is strong in the stretch between the Gunung Nago weir and Kalawi bridge of the Kuranji river and in the middle reaches of the Air Dingin river. The shifting of river course in the said stretches is frequent. Therefore no diking system is adopted for the channel improvement plan in those stretches. A retarding basin in the Laras river basin is considered as one of the alternative schemes. For the drainage in the urban area, drainage outlet structures are considered in the channel improvement. Pumping stations are also considered at the drainage outlets of the low-lying area. The conceivable alternative schemes thus set up are shown in Tables 5.1 to 5.3 (refer to Fig. 5.2).

5.4 Design Flood for Alternative Schemes

At present, a level of 20-year to 50-year flood is actually adopted for the flood control project in Indonesia as shown in Table 5.4. In consideration of the above circumstances, the present situation and future development plan of Padang city, levels of design flood for the comprehensive flood control and drainage plan of the objective rivers are adopted as follows :

River	Return period
a. Arau river, flood relief channel, Kuranji and Air Dingin rivers :	50-year
b. Tributaries such as Jirak, Balimbing and Laras rivers :	25-year
c. Drainage facilities :	10-year

Based on the results of flood runoff analysis as shown in Table 5.5, the design flood discharges for each alternative scheme are determined as shown in Fig. 5.3.

5.5 Comparison of Alternative Schemes

The required construction work, land acquisition and compensation were estimated for each alternative scheme. The construction cost is composed of the cost for civil works and the cost of land acquisition and compensation. The cost required for civil work is calculated by multiplying work quantity by unit cost. The estimated construction costs are shown in APPENDIX J. They are summarized below.

River	Construction cost (Rp. 10^6)		
1. Arau river	Scheme A-1 25,141	Scheme A-2 25,266	Scheme A-3 24,033
2. Kuranji river	Scheme K-1 16,404	Scheme K-2 15,955	
3. Air Dingin river	Scheme D-1 5,579	Scheme D-2 6,278	

The comparative study on technical and least cost basis makes it clear that (1) for the Arau river, Scheme A-3 results in lower cost than the other Schemes A-1 and A-2, (2) for the Kuranji river, Scheme K-2 results in lower cost than Scheme K-1, although the difference of the cost between the two is slight and (3) for the Air Dingin river, Scheme D-2 results in higher cost than Scheme D-1, furthermore Scheme D-2 will be more expensive, and in addition to the cost, an appreciable maintenance cost would be required to maintain the river-mouth.

Therefore, it is considered reasonable to select Schemes A-3, K-2 and D-1 for the comprehensive flood control and drainage plan.

5.6 Proposed Comprehensive Flood Control and Drainage plan

5.6.1 Design Flood Discharge

The design flood discharge distribution for the proposed comprehensive plan is shown in Fig. 5.4.

5.6.2 Proposed Plan

The comprehensive plan proposes the works : (1) channel improvement over a total length of 55 km on the mainstream of the Arau, on the flood relief channel, on the mainstreams of the Kuranji and Air Dingin rivers and on their major tributaries, (2) construction of the Laras retarding basin, (3) reconstruction of the Lubuk Begalung weir, (4) construction of drainage outlet culverts, (5) reconstruction of five bridges, (6) improvement of major drainage channels over a length of 43 km, and (7) construction of six drainage pumping stations.

The proposed river channel alignment is shown in Fig. 5.5. The outline of the proposed comprehensive plan is as follows :

(1) Arau river

The proposed improvement plan of the Arau river system comprises channel improvement on the mainstream of the Arau river over a length of 10.6 km, on the flood relief channel over the whole stretch of 6.7 km and on the Jirak river over a length of 4.6 km. Both the mainstream weir and the flood relief channel weir of the diversion weir at Lubuk Begalung are planned for reconstruction (Fig. 5.6). In connection with the channel improvement, three bridges, three drop structures and two siphons are also planned for reconstruction.

(2) Kuranji river

The proposed improvement plan of the Kuranji river system comprises : (1) channel improvement on the mainstream of the Kuranji river over a length of 13.5 km, on the Balimbing river over a length of 9.7 km and on the Laras river over a length of 4.2 km, and (2) construction of the Laras retarding basin. In the lower reaches of the Kuranji and Balimbing rivers and in the lower and middle reaches of the Laras river, the channel improvement will be made by a diking system. Two bridges on the Kuranji and Balimbing rivers are planned for reconstruction in connection with the channel improvement. The Laras retarding basin on the right side looking downstream of the Laras river will be constructed in order to reduce flood discharge.

(3) Air Dingin river

The proposed improvement of the Air Dingin river is channel improvement over a length of 5.2 km. The bulk of the works is excavation of the existing river channel to secure adequate carrying capacity. Construction of dikes is planned in the lower reaches only. The existing sand spit at the river-mouth will be left as it is.

(4) Urban drainage

The urban drainage plan proposes improvement of major drainage channels over a total length of 43 km and construction of drainage pumping stations.

The length of drainage channel to be improved and the proposed capacity of pumping station are shown in Table 5.6.

5.6.3 Construction Cost

Construction costs are composed of the costs of civil work, land acquisition and compensation, contingency and engineering and administration. Cost required for civil work is accounted by multiplying work quantity by unit cost. Engineering and administration cost is assumed to be 15 % of the sum of the civil works, land acquisition and compensation costs. Cost for contingency is assumed at 10 % of the above costs. The construction cost for the comprehensive plan is estimated at Rp.69,662 $\times 10^6$ as shown in Table 5.7.

5.7 Economic Evaluation

5.7.1 Economic Cost

The economic construction cost for the comprehensive plan was estimated by deducting tax and contractor's profit from the Rupiah currency portion of the construction cost. The tax and contractor's profit to be deducted are assumed to be 4 % and 10 % respectively. The economic construction cost estimated is Rp. 67,056 $\times 10^6$.

5.7.2 Benefits

Benefits are the expected reduction of flood damages for private properties, farm crops, public facilities and so on, and the expected development effect for the land which has not been utilized during the wet season.

For evaluation of the comprehensive plan, the benefits are estimated under two conditions, i.e., the present conditions defined after completion of the project assuming the execution of the works in 7 years and the future development conditions based on the Master Plan of Kotamadya Padang.

The average annual benefits estimated are Rp. 8,283 $\times 10^6$ under the present conditions and Rp. 11,645 $\times 10^6$ for the future conditions after development.

5.7.3 Internal Rate of Return

Based on the economic cost and the benefits mentioned above, internal rate of return for the comprehensive plan is calculated assuming a project life of 50 years. The results show that the project is expected to yield an internal rate of return of 10.5 % under the present conditions and 14.7 % for the future conditions.

CHAPTER VI URGENT FLOOD CONTROL PLAN

6.1 General

The comprehensive flood control and drainage plan was formulated to reduce flood damage not only in the existing urban area but also allows for urban expansion. The economic benefits of the plan at the present state of development are not so high, and a large fund is required to implement such a big project. However, as mentioned in the foregoing Chapter III, the existing urban area of Padang city suffers from frequent flood damage which cannot be overlooked any longer. Realization of an urgent flood control measure is required for the existing urban area.

For this reason, an urgent flood control plan based on the comprehensive plan was prepared to formulate a priority project for immediate implementation in consideration of the urgency of countermeasures as well as the technical and economical effectiveness under the present conditions. The urgent flood control plan aims at mitigation of flood damage in the existing urban area and area to be developed as residential quarter in the near future.

6.2 Necessity of Urgent Flood Control Project

The city of Padang and its surrounding alluvial lands formed by the Arau, Kuranji and Air Dingin rivers suffer from frequent inundation damage due to the inadequent capacity of flood control and drainage facilities. In fact, the area has suffered extensive flood damage five times in the last ten years. The damage caused by floods in 1972 and 1980 was particularly serious.

To make matters worse, the urban area of Padang city is expanding rapidly and new settlements are developing even in the low-lying land surrounding the existing urban area. The social and economic damage due to flooding in these areas is increasing. In order to mitigate the flood damage, implementation of flood control measures is urgently required.

5.3 Design Flood

In order to select a level of design flood for the urgent plan, three alternative plans were examined by the scale of the following design floods.

River	Return period of design flood (yr)		
	Plan-A	Plan-B	Plan-C
1. Mainstream	10	25	50
2. Tributary	5	10	25
3. Drainage channel	2	5	10

The results of a cost estimate or the comparative study are summarized below.

Alternative plan	Ave.annual benefit (Rp.10^6)	Economic cost (Rp.10^6)	B/C with discount rate of 12 %
1. Plan-A	5,694	37,383	1.19
2. Plan-B	7,415	43,678	1.24
3. Plan-C	8,320	66,500	0.90

The above table shows that Plan-B has high economic value of B/C as compared with the other alternatives. In the above table, flood control benefits are estimated taking into account reduction of flood damages under the present situation for private properties, farm crops, public facilities and the development effect of land to be expected from the project.

The plan with 25 year design flood is therefore proposed as the urgent flood control plan from the standpoints of high economic value and socio-economic conditions in the area.

On the other hand, according to the flood damage survey, the past remarkable floods in Padang city were the floods of May 1972, October

1976, April 1979, November 1980 and November 1981. Among them, the flood of May 1972 was the biggest since 1960 which corresponds to about 23 year return period. The river channel to be improved by the urgent flood control plan will have sufficient capacity to carry the said flood. The determined design flood discharge is shown in Fig. 6.1.

6.4 Proposed Urgent Flood Control Plan

6.4.1 River Stretches for Proposed Urgent Flood Control Plan

By the considering the flood prone area and carrying capacity of the existing river channel, the stretches of the rivers taken for planning for the urgent flood control works were determined. The upstream end of the stretch for channel excavation and embankment was determined based on the comparison of proposed high-water level with river bank elevation.

The river stretches for the proposed urgent flood control works are shown in Table 6.1.

6.4.2 Improvement Plan of River Channels and Related Structures

Considering the existing conditions and the proposed comprehensive plan, the river channels and their related structures for the urgent flood control plan were designed.

The project proposes : (1) channel improvement over a total length of 36 km on the mainstream of the Arau river, on the flood relief channel, on the mainstream of the Kuranji river, on the Air Dingin river and on their major tributaries, (2) construction of the Laras retarding basin, (3) reconstruction of a part of the flood relief channel weir of the Lubuk Begalung weir, (4) construction of 52 drainage culverts, (5) reconstruction of five bridges, (6) improvement of major drainage channels over a total length of 3 km, and (7) construction of three drainage pumping stations.

The proposed river channel alignments are shown in Fig. 6.2. The outline of the improvement plan of river channels and related structures are as follows :

(1) Arau river

The proposed improvement of the Arau river system is composed of channel improvement on the mainstream of the Arau river over a length of 8.5 km, on the flood relief channel over the whole stretch of 6.7 km and on the Jirak river over a length of 2.5 km. The flood relief channel will be improved to have the same proposed cross-sections as the comprehensive plan, while the channel of the mainstream will be improved only in the stretch between the suspension bridge and the confluence of the Jirak river. The Lubuk Begalung diversion weir will be reconstructed only on the flood relief channel side. Although the weir body of the mainstream side will not be reconstructed under this project, reinforcement of the downstream apron and repair of the bridge on the weir will be carried out. Fig. 6.3 shows the preliminary design of the Lubuk Begalung weir to be reconstructed. It is recommended that the dimension of the weir should be determined by hydraulic model test. The Jirak river is to be improved by diking. Two bridges for the relief channel and one bridge for the Jirak river are to be reconstructed due to widening of the channel. Three drop structures and two siphons on the relief channel are to be reconstructed. Culverts at outlet of drain are to be constructed.

(2) Kuranji river

The proposed improvement of the Kuranji river system comprises : (1) channel improvement on the mainstream of the Kuranji river over a length of 7.5 km, on the Balimbing river over a length of 4.2 km and on the Laras river over a length of 1.2 km, and (2) construction of the Laras retarding basin. The existing channels will be improved by building dikes together with excavation. The excessively meandering reaches will be put in order by means of cutoffs. In connection with channel improvement, Nanggalo bridge on the mainstream of the Kuranji river will be extended by one span and Tunggul Hitam bridge on the Balimbing river will be reconstructed.

The Laras retarding basin on the right side of the Laras river is to be constructed to reduce the flood discharge. The area of the retarding basin is to be about 1.5 km^2 and the storage capacity is to be about $1 \times 10^6 m^3$ with 1 m depth on average. On the boundary of the retarding basin, low dike and drainage channel are to be constructed to show the boundary line and to store the water during a flood.

(3) Air Dingin river

The proposed improvement of the Air Dingin river is channel improvement over a length of 5.2 km. The channel will be improved mainly by excavation of the existing channel, while low dikes will be built in the lower reaches over a length of 3 km from the river-mouth. The excessively meandering stretch located upstream of Muara Penjalinan bridge will be put in order by means of a cutoff. The existing sand spit at the river-mouth will be left as it is.

6.4.3 Improvement Plan for the Urban Drainage Channel and Related Structures

(1) Improvement plan for major drainage channels

Within the comprehensive plan, the necessary stretches of the major drainage channels to be improved urgently were selected considering existing urbanization, flooding conditions and priority ranking in old urban area proposed by the Cipta Karya.

Stretches subject to the improvement and design discharges are as follows :

Drainage channel	Length to be improved (m)	Design discharge (m^3/s)
1. Olo-Nipah	590	25 - 14
2. Ujung Gurun	810	18 - 10
3. Purus	580	13
4. Ulak Karang	1,030	6.5 - 2.5

The stretches to be improved are shown in Fig. 6.4

(2) Plan of terminal drainage facilities

At the terminal of the Ujung Gurun, Purus and Ulak Karang drains, a pumping station is planned for urgent construction. The required capacity of the pump plant was estimated based on hydraulic analysis and the study of economic aspects. The study results are described in APPENDIX I. The capacity of the pump plant is determined as shown below.

Pumping station :	Ujung Gurun	Purus	Ulak Karang
Pump capacity (m^3/s) :	3.5	2.0	3.5

6.4.4 Proposed Urgent Flood Control Works

Based on the proposed river channel mentioned above, the following major works are proposed for the urgent flood control project in this study.

(1) Mainstream of Arau river including Jirak river

a. Excavation/dredging of channel and embankment of dike.
b. Bank protection by means of wet masonry and gabion.
c. Construction of outlet culverts.
d. Reconstruction of bridge.
e. Ground sill on river bed.

(2) Flood relief channel

a. Excavation/dredging of channel and embankment of dike.
b. Bank protection by means of wet masonry and dry masonry.
c. Construction of outlet culverts and drainage pumping stations.
d. Reconstruction of drop structure on channel bed, bridge, syphon and diversion weir.
e. Drainage channel improvement.

(3) Kuranji river including Balimbing and Laras rivers and Laras retarding basin

a. Excavation/dredging of channel and embankment of dike.

b. Bank protection by means of wet masonry, dry masonry, gabion and groin.

c. Construction of outlet culverts and a drainage pumping station.

d. Reconstruction of bridge.

e. Ground sill on river bed.

f. Drainage channel improvement.

(4) Air Dingin river

a. Excavation of channel and embankment of dike.

b. Bank protection by means of wet masonry and gabion.

c. Construction of outlet culverts.

d. Ground sill on river bed.

The proposed work quantity is as follows :

River channel improvement

Excavation/dredging works	$1,789 \times 10^3 m^3$
Embankment works	$310 \times 10^3 m^3$
Bank protection works	
Wet masonry	83,700 m^2
Dry masonry	28,300 m^2
Gabion	14,200 m^3
Groin	10,500 m
Reconstruction of diversion weir	1 place
Reconstruction of syphons	5 bridges
Reconstruction of drop structures	3 places
Reconstruction of syphons	2 places
Ground sill works	3 places
Construction of drainage culverts	52 places

Drainage channel improvement :

Construction of drainage pumping stations	3 stations
Drainage channel improvement	3.0 km

6.4.5 Land Acquisition and Compensation

The channel improvement plan was prepared in such a way as to minimize the quantity of houses to be relocated. Land acquisition and house compensation due to construction work are to be carried out by the city office of Padang. The quantity is shown in Table 6.2. They are summarized below :

Item	Unit	River channel improve't	Drainage channel improve't	Total
Land acquisition	ha	106	9	115
House compensation	nos	244	58	302

CHAPTER VII

CONSTRUCTION PLAN AND COST ESTIMATE FOR URGENT FLOOD CONTROL PROJECT

7.1 General

The construction works for urgent flood control project consist mainly of excavation/dredging, embankment and bank protection for channel improvement, constructions of structures such as diversion weir, drainage culvert, bridge and drop structures, and construction of drainage pumping stations and improvement of major drainage channels in the urban area.

In the present study, two alternative construction plans are studied for executing the urgent flood control project. One is a seven-year plan that consists of 5 years for execution of main civil works and the another is a five-year plan that consists of 3 years for execution of main civil works. In conclusion, the seven-year construction plan is adopted and is explained in this CHAPTER.

7.2 Construction Schedule

7.2.1 Basic Line of Construction Schedule

The construction schedule for implementing the project is prepared based on the following consideration.

a. Annual workable days for civil works are assumed to be 180 days based on the rainfall records in the project area.

b. The whole works are broadly divided into five work divisions of the Arau, flood relief channel, Kuranji and Air Dingin rivers, and urban drainage.

c. Considering the scale of the project and the past experiences in Indonesia, all construction works will be executed on full-contracting basis. The mechanized construction method will principally be applied to the main construction works. Man power construction will, however, be adopted as much as possible, taking into account employment opportunity in and around the project area.

7.2.2 Construction Schedule

The construction schedule of seven-year plan is given in Fig. 7.1. This schedule comprises five years for construction works and less than two years for the preparation. The schedule is summarized below.

a. The project mobilization which includes financing, establishment of project organization will be commenced in April 1984.

b. Detailed design will be commenced in April 1985 and completed by June 1986. Immediately after completion of the detailed design, tendering will be started, and it will be completed by June 1987.

c. Land acquisition and house compensation will be commenced in the first year of 1985 ahead of the execution of civil works.

d. Main civil works will be executed within 5 years from July 1987 to September 1991.

7.3 Construction Cost

7.3.1 Basic Conditions of Cost Estimate

The construction cost mainly comprises main construction cost, cost for land acquisition and house compensation, engineering and administration cost, and contingency. The following assumptions are made for the cost estimate of the project.

a. Price level at June 1983 are applied to the estimate.

b. Adopted conversion rates between currencies are as follows.

US$ 1 = Rp. 970 = ¥ 240.

c. The unit prices are divided into foreign and Rupiah components.

d. All of the construction works are to be executed by full-contracting basis. Required construction machinery and equipment are to be provided by contractors.

e. The unit cost is divided into foreign and Rupiah components.

f. The cost of civil works consists of cost for preparation, direct civil and miscellaneous works. The cost for preparatory works is assumed to be 8 % of cost for direct civil works, and the cost for miscellaneous works is assumed to be 10 % of civil works.

g. Engineering cost is estimated based on the expertise required. Administration cost is assumed to be 10 % of the total local component of main construction cost, and cost for land acquisition and house compensation.

h. Physical contingency of the cost estimate is assumed to be 10 % of the total cost. Price contingency is disregarded, since it is considered in the study of the required fund in CHAPTER IX.

7.3.2 Construction Cost

The main construction cost and cost for land acquisition and house compensation for the project are estimated on the unit cost basis. The unit construction cost comprises direct cost, 20 % of site expenses, 15 % of overhead and profit, and 2.5 % of tax. The unit construction cost for major works is listed in Table 7.1.

The construction cost is estimated at Rp. 45,254 × 10^6 consisting of US$ 31,307 × 10^6 and Rp. 14,886 × 10^6. The breakdown of the construction cost is given in Table 7.2. They are summarized below.

Item	Foreign C. (US$ 10^3)	Local C. (Rp. 10^6)	Eq. Total (Rp. 10^6)
Civil works	22,779.8	9,627.1	31,723.7
Land acquisition and house compensation	-	1,819.9	1,819.9
Administration	-	1,144.7	1,144.7
Engineering	5,680.8	940.6	6,451.0
Physical contingency	2,846.4	1,353.7	4,114.7
Grand Total	31,307.0	14,886.0	45,254.0

7.4 Operation, Maintenance and Replacement Cost

The operation and maintenance cost for the facilities after completion of the project is assumed to be annually 0.5 % of the total cost of main civil works. The estimated operation and maintenance cost is Rp. 156×10^6/year.

Some of the project facilities, especially metal structures such as sluice gate, pump plants, etc. have shorter useful life than the other facilities and are required replacement at a certain time within 50 years of the project life. The durable period of the metal works is assumed to be 25 years on an average. Total replacement cost is estimated at Rp. $3,620 \times 10^6$. The total operation, maintenance and replacement cost is estimated at Rp. $11,653 \times 10^6$.

CHAPTER VIII

ORGANIZATION AND MANAGEMENT

8.1 Present Organization

The Arau river, flood relief channel, Kuranji and Air Dingin rivers, and their tributaries are at present administrated and managed by DPU West Sumatra. All flood control works of the above mentioned rivers are being implemented by the Water Resources Division of DPU West Sumatra. Also the existing river facilities are operated and maintained by DPU.

The present organization for flood control works in Padang area is shown in Fig. 8.1. The organization for the Padang Area Flood Control Project is not established yet because the project is being on the study stage at present.

8.2 Organization for Implementation of Project

The Ministry of Public Works will entirely be responsible for the implementation of the project, and necessary consultations will be made by the organizations concerned. For implementing the Padang area flood control project, establishment of a project office in Padang will be required. The organization for the project is recommendable as shown in Fig. 8.2.

The Directorate General of Water Resources Development will be the executing agency for the project. The Directorate of Rivers under the control of the Directorate General of Water Resources Development will take charge of coordination with all the relevant governmental agencies and regional administrative organizations in implementing the project.

The project manager is to be appointed by the Ministry to take all the responsibility to the Ministry for the proper implementation of the project. The staffs as shown in Fig. 8.2 will be also appointed to support the project manager. They will support execution of detailed survey, design and planning, preparation of tender documents and specifications for civil works, preparation of tender documents and specifications for equipment including materials and spare parts if necessary and land acquisition.

Foreign consultants will have to be employed to assist the implementation of the project including the field work of the detailed design and supervision.

8.3 Organization for Operation and Maintenance

The organization for operation and maintenance of the facilities to be constructed or improved by the urgent flood control project is recommendable as shown in Fig. 8.3.

The management of the flood control facilities will be entrusted by the Ministry to the provincial government.

CHAPTER IX

EVALUATION FOR URGENT FLOOD CONTROL PROJECT

9.1 Economic Evaluation

9.1.1 Economic Cost

The economic construction cost for the urgent flood control project was estimated by deducting tax and contractor's profit from the local currency portion of the construction cost. This tax and contractor's profit to be deducted are assumed to be 4 % and 10 % respectively. The estimated economic construction cost is Rp. 43,678 × 10^6.

9.1.2 Benefits

Benefits are the expected reduction of flood damages for private properties, farm crops, public facilities and so on, and the expected development effect for the land which has not been utilized during the wet season. For evaluation of the project, the benefit is estimated under the condition after completion of the project assuming the construction work is completed in 7 years. The average annual benefit estimated is Rp. 7,339 × 10^6.

9.1.3 Comparison of Cost and Benefit

Based on the economic cost and the benefits, internal rate of return (IRR) for the project is calculated assuming a project life of 50 years as shown in Table 9.1. The results show that the project is expected to yield IRR of 14.7%. The benefit - cost ratio (B/C) is calculated at 1.24 in discount rate of 12 %.

9.1.4 Sensitivity Test

Sensitivity of IRR of the project has been examined adopting increase in cost and decrease in benefit. The sensitivity test shows the value of IRR of the project exceeds 12 %, even if the cost goes up by

20 % or the benefit goes down by 20 %. The result of the comparison of cost and benefit is shown graphycally in Fig. 9.1.

9.2 Financial Aspects

9.2.1 Required Funds

The funds required for the implementation of the project were estimated on the following assumption: The contingency in price is assumed at 15 % per year for the local currency portion and 6 % per year for the foreign currency portion taking account of the rate of rise in prices for the last 5 years.

The funds for the project were estimated at Rp. 74,921 million, which consists of Rp. 32,486 million in the local currency portion and US$ 43,748 thousand (equivalent to Rp. 42,435 million) in the foreign currency portion including price contingency during the construction period. These are summarized in Table 9.2.

9.2.2 Disbursement Schedule

The schedule of annual disbursement of the fund mentioned above is planned as shown in Table 9.3.

9.3 Project Effect and Social Impact

9.3.1 Stabilization of people's Livelihood

At present, flood damage occurs every year. Many houses and farm lands in the project area suffer extensive damage from floods. After the proposed project is completed, about 2,640 ha of land and 21,330 houses in the project area will be relieved from flooding.

The other intangible benefits such as environmental improvement for living, stabilization of people's livelihood and so on can be expected by the implementation of the project.

9.3.2 Incremental Land for Residence

The increase in residence quarter by the project is expected from the reduction in flood damage and improved land condition. Increase in the land for residence is expected to be 840 ha.

9.3.3 Employment Opportunity

The implementation of the project will provide employment opportunities to workers and landless farmers in and around the project area. The unskilled labor requirement for the project is estimated at 1.0 million man-days during the construction period.

9.3.4 Relocation of Houses

There exist about 300 houses in the location of the proposed channel which will have to be relocated. About 10 ha for residential land will be required for this relocation.

On the other hand, about 20 ha of land newly created by the implementation of the project can be used for this purpose.

9.3.5 Environmental Aspects

Generally, it is expected that the natural environmental conditions in the neighbouring area of such a large scale project worsen. In the case of the Padang area flood control project, the work is to improve the existing river channel. However this project is not expected to have any detrimental impact on the environment.

With regard to salt water intrusion into rivers, no problem is anticipated at present, as some groundwater is being used by inhabitants near the river mouth. It seems that the salt water intrusion into rivers is limited to the lowest reaches owing to comparatively steep river slopes and not a little streamflow during the dry season. Since the river channel is planned to have almost the same configuration as the existing channel, the additional extent of salt water intrusion seems to be slight. The implementation of the project will not produce any adverse effects of salt water intrusion.

Accordingly it seems that the present environmental situation will not change due to the implementation of the project except the relocation of houses as described in the preceding paragraph.

9.3.6 Development Effects of Construction of the Laras Retarding Basin

Owing to construction of the Laras retarding basin, the land around the retarding basin will be protected from flooding so that the land may be developed as a residential quarter. For the purpose of effective use during non-flood time, construction of a park with a small pond inside the retarding basin is recommended to provide a recreation area.

9.4 Recommendations

Prior to the commencement of the project, the following are recommended to be carried out by the local currency.

a. Establishment of a project office in Padang.

b. Execution of some preparatory works such as surveying and soil-mechanics survey work.

c. Execution of channel improvement over a length of 800 m in the downstream reaches from Sebarang Padang bridge of the Arau river : As the area along the said reaches suffers from frequent serious flooding, a channel improvement is urgently required to reduce flood damage in an early stage. Because the construction work of the project is expected to be commenced three or four years later.

CHAPTER X

LAND CONSERVATION

This chapter presents reconnaissance survey results on the land conservation problem of the Arau, Kuranji and Air Dingin river basins. The present study aims at grasping the existing land conservation problems and giving some considerations on them.

For the convenience of description, the study area is divided into three, i.e., upper basin, plain area, and Padang coast. The upper basin is the non-cultivated mountainous area in the upper reaches of the object rivers. The plain area is the cultivated lands on the volcanic fan, alluvial fan and coastal plain. The Padang coast is the coastline stretching between the river mouths of the Arau and Air Dingin.

10.1 Upper Basin

10.1.1 Present condition

The upper basin is mainly formed of Tertiary volcanic rocks. Pretertiary metamorphic rocks are found in and around Indarung. Exposed rocks are seen in places.

The vegetation of the upper basin seems to be fairly good. No collapse is found on the mountain slopes. Almost all these forest are specified as natural environment conservation forest or protection forest by Dinas Kehutanan.

The channels are observed to be stable covered with large boulders transported, possibly, by the eruptions of volcanoes.

10.1.2 Recommendation

Since no collapse is found in the mountainous areas and sediment yield seems not much, land erosion control in the upper basin is not deemed to be necessary.

From the viewpoint of flood control in the plain area, the existing forest has contributed to the reduction in peak runoff by storing rainfall and retarding the runoff. If the forest are devastated, the flooding in the plain would be more destructive than ever. In order to maintain the land and water conservation functions of the existing upper basin, it is recommendable to conserve the forest by the properly arranged land use regulation. The regulation is duly necessary in privately owned forest adjacent to the developed plain area to prevent the land erosion and the destructive mud flow. The model forest scheme (Kebun Raya Setia Melia scheme) proposed by Andalas University is expected to promote the forest conservation.

10.2 Plain Area

The plain area covers the volcanic fan, alluvial fan and coastal plain. The river channels in the volcanic fan are braided or flat and wide. In addition, the main stream course is changeable.

On the other hand, the river channels in the alluvial fan and coastal plain meander in places eroding the river banks. Because of milder channel slope, the flood runoff from the upper basin often overflows in the plain. In the coastal plain, sand spits formed by tide and wave actions may interfere in gravity drainage.

In the alluvial fan, the lowering of river bed is remarkable especially in the Arau river near Kp. Baru and the Air Dingin river near Kp. Koto Tuo.

The river bed should be stabilized so as to prevent the damage of river structures, and to ensure the stable water supply for irrigation, municipal and industrial use.

The major problems in the plain area are the bank erosion and flooding. The countermeasures on these problems are discussed in the chapter for flood control planning.

10.3 Padang Coast

10.3.1 Present condition

The present conditions of the Padang coast are shown briefly in Fig. 10.1.

(1) Coast between Arau river and flood relief channel

According to Masalah Pantai Padang prepared by DPU, West Sumatra in 1978, erosion of coastline in this portion occurred after the completion of the flood relief channel. The coastline regressed about 60 m by now. According to the latest survey, the coastline surveyed in 1983 advance in the southern and northern stretches and regressed in the central stretches in comparison with the survey results in 1977.

The coast erosion in this stretch seems to be neutralized as a whole due to the effects of the jetties.

(2) Coast between flood relief channel and Kuranji river

The coastline is regressive for the whole stretch except the left bank of the Kuranji river mouth where the coral reef is exposed and maintains the coast stable. According to the verbal information on site, the coast regressed by around 20 m during these 20 to 35 years.

(3) Coast between Kuranji and Air Dingin rivers

Based on the site reconnaissance and verbal information obtained on site, the coastline in this stretch is considered advancing as a whole. In the southern half of this stretch, new housing areas are developing on the newly created lands.

10.3.2 Recommendation

The existing Padang coast protection works are deemed to be well considered and functioning well. However an incessant maintenance effort may be necessary, as far as the coast has inherent nature of regression.

The coast protection works should be planned and designed in due consideration of results of investigation and studies on the mechanism of the erosion. Since the coastal problems are affected by many factors, the mechanism is rather complicated, which may require a variaty of investigation and studies.

DPU, West Sumatra already conducted some investigation and compiled in the reports. Among these, observation of waves are not included yet although the characteristics of waves are most important and fundamental data for the study on coastal problems.

It is recommendable to collect wave data such as wave height, wave length, wave period, wave direction, and seasonal variation of these wave characteristics, by means of both observation and analysis.

CHAPTER XI

POTENTIALITY OF WATER RESOURCES DEVELOPMENT

11.1 Irrigation Water Development

The existing irrigation systems cover almost all the irrigable flat plain of the river basins subject to the study except for the urbanized area. None of new irrigation system nor extension of the existing system is proposed in the study area.

On the contrary, the farm land adjacent to the urban area replaced by the housing, industrial and commercial areas in recent year. The paddy field in the Kotamadya Padang decreases year by year. According to the Master Plan Kotamadya Padang prepared in 1983, only some agricultural lands will remain mostly in the existing Gunung Nago (right) and Lubuk Minturun irrigation systems by the year 2003.

In consideration of the circumstances mentioned above, it could be concluded that there is little demand for futher irrigation water development in the study area. On the contrary, the existing irrigation water which shares the major part of present water use in the basin would be used for the other municipal and industrial purpose in future keeping pace with the replacement of agricultural land to municipal and industrial lands.

11.2 Municipal and Industrial Water Development

Regarding the future demand for the municipal and industrial water, study had been made in the Feasibility Report on Padang Water Supply Project, DGCK, prepared in November 1982. According to the study, the annual average demand amounts to about 1.7 m^3/s in 2005. In order to fulfill the demand, a new treatment plant will be installed at Gunung Nago to provide 0.25 m^3/s with water from the Kuranji river, and the remaining 1.2 m^3/s of water will be taken from the Air Dingin river.

Other than the treated water mentioned above, the factories may need untreated water to be taken directly from the river although it is not known yet at present. It also be noted that DPU, West Sumatra has a plan to take 3.0 m^3/s[/1] of water from the Kuranji river for the flushing purpose of drainage channels in the urban area such as the Jati canal.

The water demand for the municipal and industrial uses is still small comparing with the existing irrigation water use which may decrease gradually keeping pase with the urbanization of the study area. The resources of surface water in the study area could be said enough to endorse Padang's municipal and industrial development.

11.3 Mini-hydroelectric Power Development

A preliminary study on potentiality of developing mini-hydroelectric power by use of flows in the steep slope irrigation canals is conducted for the electrification of rural villages. The study firstly outlines the current and future electric supply systems in Kotamadya Padang. Then the potential hydroelectric power is estimated for the selected irrigation canals.

11.3.1 Electric Supply System in Padang

Electric power in Padang area is mainly supplied by PLN (Perusahaan Listrik Negara). The service area of the PLN is still limited in the urban areas. Most of the rural villages are not served with electricity yet. Some of them have their own diesel generators of small scale. Factories, hotels and other business corporations also have their own power generation systems together with the PLN electric supply system. However, these private power systems are being replaced by the PLN power system.

Electricity by PLN in Padang area has been generated in the PLTD Simpang Haru. In March 1983, PLTG Bandar Buat began its operation and by the end of 1983 PLTA Danau Maninjau will be in operation. These three plants are incorporated with each other and supply the

/1 Bandung Btg. Kuranji Gunung Nago, Padang, Mei 1979, Department P.U Ditjen Pengairan Direktorat Irigasi.

electric power to Padang city and its surrounding areas. Outline of these power plants are as follows. The electric power sources in Padang area will be by far strengthened by the end of 1983 :

Item	PLTD S. Haru	PLTG B. Buat	PLTA D. Maninjau
Capacity (MW)	30	42	68
Power source	Diesel	Gas	Water
Start of operation	Existing	Mar. 1983	Sept. 1983 (partial) Dec. 1983 (full)

Notes

PLTD : Pembangkit Listrik Tenaga Diesel (Diesel electric power plant)

PLTG : Pembangkit Listrik Tenaga Gas (Gas electric power plant)

PLTA : Pembangkit Listrik Tenaga Air (Hydroelectric power plant)

11.3.2 Potential Mini-hydroelectric Power

Selection of Potential Sites

Judging from the irrigation water records and irrigation area of each canal system, the canals of which discharge exceed 1.0 m^3/s are (a) Limau Manis, (b) Gunung Nago left, (c) Gunung Nago right, (d) Sungai Latung, (e) Koto Tuo left, and (f) Koto Tuo right irrigation canals.

On these irrigation canal systems, site conditions were inspected. As a result of inspection the Sungai Latung, Koto Tuo left and right canals are those of milder slope and considered not suitable for hydroelectric power generation. Based on the canal profile surveyed by the Study Team, the potential sites are selected at the following places where the canal slope is more than 1/50 and the higher head can be obtained with shorter leading channel.

a. Limau Manis - 1 power plant
b. Limau Manis - 2 power plant