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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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

THE STUDY ON KAMPAR-INDRAGIRI RIVER BASIN DEVELOPMENT PROJECT

VOLUME 2

MAIN REPORT

(FINAL REPORT)

DECEMBER 1995

CTI ENGINEERING CO., LTD.
IN ASSOCIATION WITH
NIPPON KOEI CO., LTD.

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PREFACE

In response to a request from the Government of the Republic of Indonesia, the Government of Japan decided to conduct the study on Kampar-Indragiri River Basin Development Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Indonesia a study team headed by Mr. Yoshiyuki Tomioka, CTI Engineering Co., Ltd., from January 1993 to November 1995.

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

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

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

December 1995

Kimio Fujita

President

Japan International Cooperation Agency

JICA STUDY TEAM

KAMPAR-INDRAGIRI RIVER BASIN DEVELOPMENT PROJECT

December 1995

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to submit herewith the Final Report for the study on KAMPAR-INDRAGIRI RIVER BASIN DEVELOPMENT PROJECT, which dealt with the formulation of the master plan and the feasibility study for priority projects selected in the master plan study.

The Final Report consists of the Summary; the Main Report which contains the details of the project formulation process, conclusion and recommendations; the Supporting Report which includes sector-wise technical details; and the Data Book with site observation records, collected data and calculation output.

We wish to express our grateful acknowledgment to the officials of the Japan International Cooperation Agency, the Advisory Committee, the Ministry of Foreign Affairs, the Ministry of Construction, the Embassy of Japan in Indonesia for their assistance and advice extended to the Study Team.

We sincerely hope that the study results will contribute much to the socio-economic development of Riau and West Sumatra provinces.

Very truly yours,

Yoshiyuki Tomioka
Team Leader
JICA Study Team

Encl.: a/s

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COST ESTIMATE IS BASED
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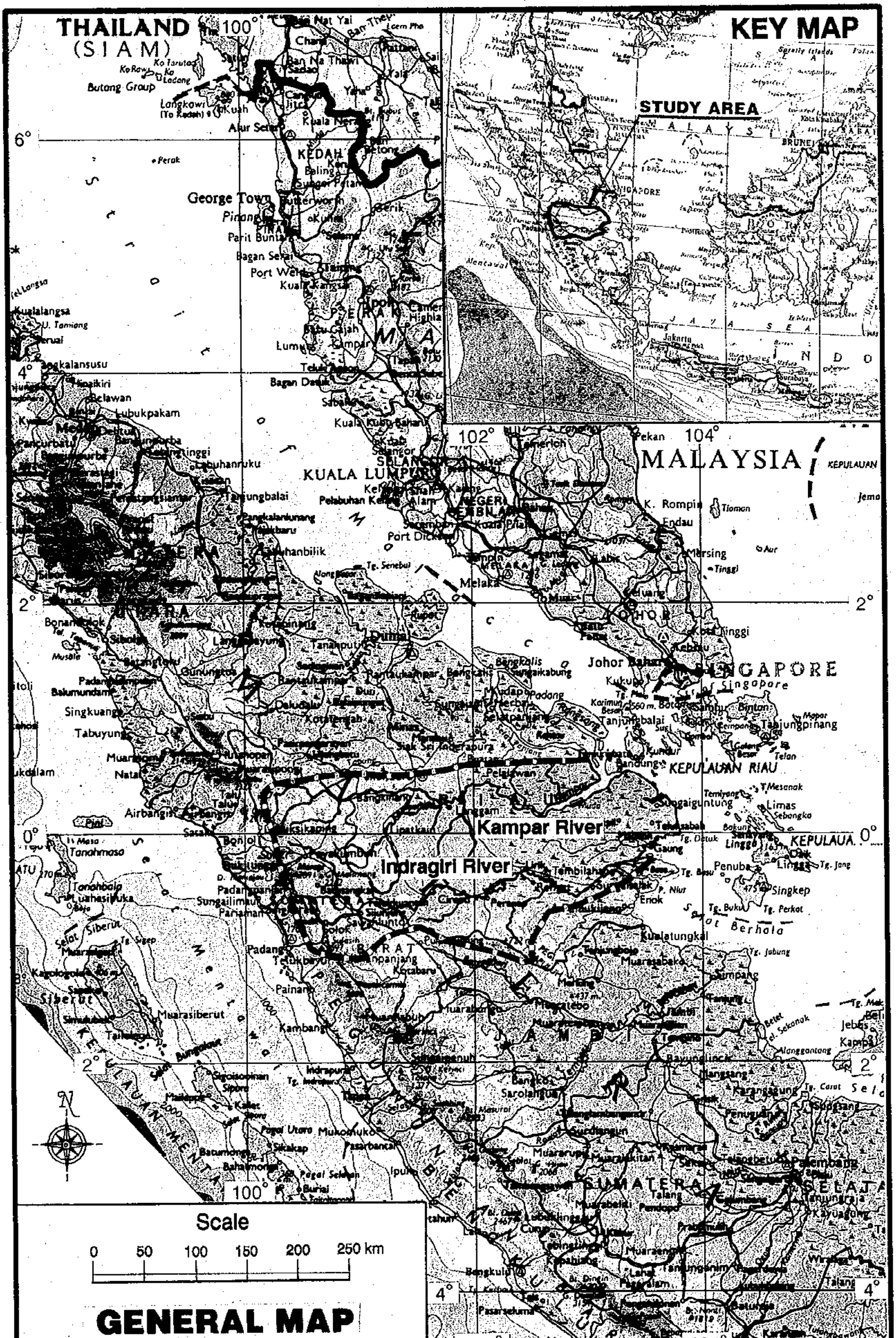
THAILAND
(SIAM)
KEY MAP
STUDY AREA
MALAYSIA
KUALA LUMPUR
George Town
SINGAPORE
KEPULAUAN RIAU
Kampar River
Indragiri River
SUMATERA
Scale
0 50 100 150 200 250 km
GENERAL MAP

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ABBREVIATIONS

1. INDONESIAN GOVERNMENT AGENCIES

GOI	:	Government of Indonesia
BAPPENAS	:	Badan Perencanaan Pembangunan Nasional (National Development Planning Board)
BAPPEDA	:	Badan Perencanaan Pembangunan Daerah (Provincial Development Planning Board)
DPU	:	Departemen Pekerjaan Umum (Ministry of Public Works)
DGWRD	:	Directorate General of Water Resources Development
DJCK	:	Directorat Jenderal Cipta Karya (Directorate General of Human Settlement)
DOR	:	Directorate of Rivers
DPUP	:	Dinas Pekerjaan Umum Propinsi (Provincial Public Works Services)
P3SA	:	Proyek Pengembangan dan Penyelidikan Sumber-Sumber Air (Water Resources Development and Investigation Planning Project)
PGM	:	Pusat Meteorologi dan Geofisika (Meteorology and Geophysics Center)
PLN	:	Perusahaan Umum Listrik Negara (State Electricity Corporation)
IHE	:	Institute of Hydraulic Engineering
PDAM	:	Perusahaan Daerah Air Minum (Water Supply Public Corporation)

2. JAPANESE GOVERNMENT & INTERNATIONAL ORGANIZATIONS

GOJ	:	Government of Japan
JICA	:	Japan International Cooperation Agency
MOC	:	Ministry of Construction, Japan
ADB	:	Asian Development Bank
IBRD	:	International Bank for Reconstruction and Development (World Bank)

3. MEASUREMENT UNITS

(Length)

mm	:	millimeter(s)
cm	:	centimeter(s)
m	:	meter(s)
km	:	kilometer(s)

(Area)

mm^2	:	square millimeter(s)
cm^2	:	square centimeter(s)
m^2	:	square meter(s)
km^2	:	square kilometer(s)
ha	:	hectare(s)

(Weight)

g, gr	:	gram(s)
kg	:	kilogram(s)
ton	:	tonne(s)

(Time)

s, sec	:	second(s)
min	:	minute(s)
h, (hr)	:	hour(s)
d, (dy)	:	day(s)
y, (yr)	:	year(s)

(Volume)

cm^3	:	cubic centimeter(s)
m^3	:	cubic meter(s)
ℓ, l, ltr	:	litter(s)
mcm	:	million cubic meter(s)

(Electrical Unit)

W	:	watt(s)
kW	:	kilowatt(s)
MW	:	megawatt(s)
kWh	:	kilowatt-hour
MWh	:	megawatt-hour
GWh	:	gigawatt-hour
V	:	volt(s)
kV	:	kilovolt(s)
Hz	:	Hertz

(Speed/Velocity)

cm/sec, cm/s	:	centimeter per second
m/sec, m/s	:	meter per second
km/hr, km/h	:	kilometer per hour

(Stress)

kg/cm^2	:	kilogram per square centimeter
t/m^2 (ton/m^2)	:	ton per square meter

(Discharge)

ℓ/sec, ℓ/s, ltr/s	:	litter per second
m^3/sec, m^3/s	:	cubic meter per second
m^3/yr, m^3/y	:	cubic meter per year

(Note: Other combined units may be constructed similarly as above)

4. MONETARY TERMS

¥	:	Japanese Yen
US$	:	United States Dollar
Rp.	:	Indonesian Rupiah

5. INDONESIAN TERMS

Jawa	:	Java
Propinsi	:	Province
Kabupaten, Kab.	:	District (Regency)
Kotamadya, Kodya.	:	Municipality
Kecamatan, Kec.	:	Sub-District
Desa, Kampung or Kp.	:	Village (Rural Area)
Kelurahan	:	Village (Urban Area)
Sungai, Sei, Batang	:	River
Gunung	:	Mountain
Rawa	:	Swamp
Danau	:	Lake
Laut	:	Sea

CHAPTER 1 INTRODUCTION

1.1 Background

The Kampar-Indragiri river basin, the study area, is located in the central part of Sumatra Island, occupying approximately 50,000 km^2 of the West Sumatra and Riau provinces. Due to the insufficient flow capacity of river channels in the upper reaches and the low and flat topography of the middle and lower reaches, areas along both the Kampar and Indragiri rivers suffer from habitual inundation during rainy seasons.

Pekanbaru City, the capital of Riau Province, and other cities in the study area also suffer from the chronic shortage of water supply during dry seasons, particularly, municipal and industrial water supply. The problem on water shortage is further aggravated by the concentration of population in the urban areas and transmigration from Java Island.

Appropriate measures for flood damage and shortage of water supply in the study area including Pekanbaru City are indispensable to the economic development and stabilization of people's livelihood leading to the further economic development of not only the West Sumatra and Riau provinces but the whole of Indonesia as well. To this end, the Government of Indonesia had requested technical cooperation from the Government of Japan to carry out the Study on Kampar-Indragiri River Basin Development Project, hereinafter referred to as the Study.

1.2 Objectives of the Study

The Study has the following three objectives:

(1) To formulate the Overall Development Plan for the Kampar-Indragiri River Basin in which priority projects will be selected;

(2) To carry out a Feasibility Study for the priority projects selected through the study on the Overall Development Plan as the objectives requiring urgent solution; and,

(3) To transfer technology to government counterpart personnel concerned through the studies in Indonesia and in Japan.

1.3 Study Area

The Study Area is within the watershed boundaries of the Kampar and Indragiri rivers, covering about 50,000 km^2 which include parts of the West Sumatra and Riau provinces (refer to Fig. 1.3.1). Pekanbaru City, the capital of Riau Province, is included in the study area for the study on a water resources development plan to supply municipal, industrial and flushing water for drainage canals in the city.

1.4 Scope of Work

The Study shall cover the fields of flood control, water resources development and river stabilization of the Kampar-Indragiri river basin, including Pekanbaru City for water supply. To achieve the objectives of the Study mentioned in Section 1.2 above, the Study shall include the following items of work:

(1) Overall Development Plan

- Data and information collection;
- Review of previous relevant studies;
- Field survey and investigation;
- Analysis on flood control and water resources development;
- Formulation of Overall Development Plan;
- Facilities planning;
- Cost Estimate;
- Economic evaluation;
- Preliminary environmental analysis;
- Preparation of project implementation schedule; and
- Selection of priority projects.

(2) Feasibility Study

- Collection of additional data and information;

- Detailed analysis on priority projects;
- Preliminary design of facilities;
- Construction plan and schedule;
- Cost estimate;
- Economic and financial evaluation;
- Environmental impact analysis;
- Preparation of environmental management plan;
- Preparation of environmental monitoring plan; and
- Recommendation of organization for operation and maintenance.

CHAPTER 2 PHYSICAL CHARACTERISTICS OF STUDY AREA

2.1 Topography

The study area of about 50,000 km^2 is situated in the central part of Sumatra Island and belongs to both the Riau and West Sumatra provinces. About five-sixths of the area belongs to Riau Province and the rest belongs to West Sumatra Province.

The Barisan range which is the backbone of Sumatra Island occupies the western part of the study area belonging to West Sumatra Province. The highest peak of the Barisan range in the study area is Mt. Merapi with elevation of 2,891 m above MSL (mean sea level).

The western slope of the Barisan range which is the outside boundary of the study area reaches the Indian Ocean with very steep slope. On the other hand, the eastern slope in the study area is rather gentle and extends eastward to the swamp area which had developed in the eastern part of the study area until the Malacca Strait.

The study area is divided into three areas: the western mountainous area with elevation above 100 m MSL which occupies one-third of the study area, the central hilly area with elevation between 100 m and 10 m MSL which occupies another one-third of the study area, and the eastern swamp area with elevation below 10 m MSL which occupies the rest.

Almost all of the mountainous area is covered with dense forests, plantations and small paddy fields. The hilly area is covered with thin forests, plantations and paddy fields along rivers and the swamp area is covered with dense but low forests and small paddy fields developed by transmigrates from Java Island.

Since the eastern slope of the Barisan range is gently extending to the swamp area, big rivers, the Kampar and Indragiri rivers, have developed. The Kampar and Indragiri rivers meander very much in the hilly and swamp areas, and both rivers form many dis-tributaries near their river mouths. Many small towns and villages are scattered along the rivers and their tributaries.

2.2 Geology

According to modern interpretations, the Island of Sumatra is part of the Continental Sundaland Plate which includes most of Southeast Asia. Subduction of oceanic crust from the Indian Ocean occurs currently in North-Northeast direction, obliquely beneath Sumatra at a rate of 6 cm per year. The subduction zone is marked by a trench, off the west coast of Sumatra. Subduction leads to magma generation, followed by intrusion and to stress build-up in the overlying plate.

The stress is accommodated by folding and faulting. Some geologists suggest that in the case of Sumatra the subduction already began in Permian times, with an increasing activity from Tertiary to Recent times and culminating with the formation of a volcanic arc along the Barisan range, striking NW-SE, in the west part of Sumatra.

Stresses induced by the oblique subduction have been released by dextral fault movement, parallel to the plate margin. An example is the NW-SE striking Sumatra Fault System. The east part of the island corresponds to the back-arc environment, where a series of elongated, extension basins have been generated. This area is called the Central Sumatra Basin. The features named above control the present tectonic activity of the island.

The area concerned in this project is bounded by the Barisan range and their foothills on its SW side. All the investigated dam sites are located in this zone. To the NE, the study area extends as far as the river mouths of the Kampar and Indragiri rivers.

Regional Geological Setting

The project area is covered by the following geological maps (scale 1/250,000), edited by the Geological Survey (Bandung):

(1) Solok Quadrangle (unpublished)
(2) Padang Quadrangle
(3) Pekanbaru Quadrangle
(4) Rengat Quadrangle

The first map covers the contemplated dam sites and the three others cover the areas where river improvement works have been proposed. Fig. 2.2.1 is a simplified geological map of the entire study area. The geological history of this area can be summarized as described below.

The sedimentation started in the Carboniferous-Permian times, with the deposition of clastic sediments (shale, quartzite, sandstone) and some limestone of the Kuantan formation. The formation is supposed to be 5,000 m thick. During the Upper Mesozoic these rocks have been subjected to folding, faulting and metamorphism, accompanied by granite and diorite intrusions. This activity was probably related to the Thai-Malayan orogenesis. The rocks of the Kuantan formation have been deformed and slightly metamorphosed (greenschist facies) at that time.

There are no Jurassic or Cretaceous rocks in this area. Therefore the idea of a long period of non-deposition has to be considered.

The Tertiary deformation is controlled by basement block faulting and wrenching (Sumatra Fault System). The development of a dextral wrench fault is consequent with the oblique subduction of the Indian Ocean Plate. The general result of the Tertiary to Quaternary period of faulting was the uplift of the Barisan volcanic arc and the development of the basin and range topography in the Barisan foothills. In the foothills, the grabens are filled by Tertiary sediments while the horsts expose pre-Tertiary basement. Examples can be seen in the Pekanbaru Quadrangle.

The oldest Tertiary formation in the study area is exposed only in the Barisan mountains. The sedimentation intensified during early Miocene, evidenced by large exposures of the Ombilin formation in the Barisan range and the Telisa formation in the foothills area, both consisting of marl, limestone and sandstone. Basalt and andesite flows in the Barisan range mark a new phase of tectonic activity during the Middle Miocene. At this time, the sedimentation stopped in the Barisan range. Outcrops of the Pliocene Palembang formation, consisting of claystone, sandstone and tuff, can be found only in the foothills and the Central Basin.

The last major period of uplift and block faulting occurred during the Plio-Pleistocene. In the Barisan range, the volcanic activity is evidenced by the andesitic-basaltic breccias of the Malintang, Talong and Marapi mountains and the deposition of pumice tuff and volcanic ash, exposed in the area of Payakumbuh.

The uplift and subsidence continue to the present day in the foothills area. Further east, the subsidence results in large areas of alluvium, deep swamps and coastal deposits.

Faults

The main, active structure in the Solok Quadrangle is the NW-SE striking Sumatra Fault System, mentioned before. It is a Miocene structure, showing dextral, horizontal movement. Numerous faults with parallel trend are present. They appear to have only a vertical sense of movement and their relationship to the wrenching is not clear. Most of them have a long, continuous movement record, from the Miocene to the Plio-Pleistocene. Earlier N-S trending faults exist in the Central Sumatra Basin. There is evidence of their reactivation during the Miocene and even Quaternary.

At present, the basement movements continue, accompanied by uplift and subsidence. Some of the fault structures described above are still active while others have been reactivated. Hot springs and high heat flows are testifying the fault activity.

2.3 Meteorology

The study area is located in the Riau and West Sumatra provinces in the central part of Sumatra Island which lies along the Malayan Peninsula. This region is in the southern part of Southeast Asia and is in the Intertropical Zone. The climate of Southeast Asia is controlled by the Asian monsoons; hence, the climate of the study area is under the monsoon's influence.

Asian monsoons principally consist of four seasons, i.e., the two seasons named northeast monsoon season and southwest monsoon season and the two inter-monsoon periods of the above two seasons.

The northeast monsoon season lasts approximately from November to March and winds are in very constant direction. The average rainfall and surface wind direction in January, which is typical of northeast monsoons in Southeast Asia, are shown in

Fig. 2.3.1. This period is rainy season, because the northeast wind coming across the China Sea bring humid air which causes rainfall on the eastern slope of the Barisan mountains of Sumatra Island.

The period of southwest monsoon season is dry season which lasts from about June to September, as shown in Fig. 2.3.1. The southwest monsoon is generally weaker than the northeast monsoon. The southwest wind is humidified by the Indian Ocean and causes rainfall on the western slope of the Barisan range which is outside the study area, but the weaker winds will not cause heavy rainfall.

2.4 Land Use

2.4.1 Physical Description of Study Area

Vegetation

Vegetation in the study area can be classified into four types; namely, forest, plantation, farm crops and grass/bush. These types of vegetation conform to the topographical features which are categorized into three, as follows.

(1) Mountainous Area

The mountainous area is located at the upper reaches of the Kampar and Indragiri river basins and is composed of steep slopes. Primary and secondary forests cover almost all of the area. Some protected forest areas are found in the mountainous area.

(2) Hilly Area

The hilly area is located in the middle reaches of the Kampar and Indragiri river basins. This area has a large number of population and is well developed. Therefore, artificial vegetation such as plantation and farm crops are widely distributed.

(3) Flat Plain Area

The flat plain area is composed of swamp and alluvial plain areas. The swamp area occupies the downstream areas of the Kampar and Indragiri river basins with low altitude of approx. below EL 20 m. Alluvial plains are distributed along the Kampar and Indragiri rivers. Wide alluvial plains have been developed for farm crops, plantation crops and grass/bush. On the other hand, the swamp area is covered with primary and secondary forests.

Soil

The study area is categorized into three regions from the agricultural aspect, as mentioned below.

- The eastern coastal swampland which consists of swamp area and alluvial plain along the Kampar and Indragiri rivers and their tributaries and distributaries;
- The eastern plains and hills located between the coastal swampland in the east and the Barisan range in the west; and
- The Barisan range.

Soil of the two regions is further classified into soil groups and soil from the viewpoint of land system and soil-forming processes, as follows:

Soil Group and Topography

Topographical Region	Soil Group	Soil
Eastern Coastal Swampland	Alluvial plain soil	Tidal swamp soil Riverine alluvial soil Meander valley alluvial soil Alluvial valley soil Fan alluvial soil
	Peat soil	Shallow pear swamp soil Peat swamp soil Deep peat swamp soil
Eastern Plain and Hill	Old marine terrace soil	
	Undulating plain soil	
	Hilly plain soil	
Barisan Range		

The areal ratio of soil groups in the study area is summarized below.

Unit: %

Soil Group	Kampar River Basin	Indragiri River Basin	In-between Area
Alluvial Plain Soil	5	13	30
Peat Soil	31	9	70
Old Marine Terrace Soil	10	8	0
Undulating Plain Soil	17	17	0
Hilly Plain Soil	10	16	0
Barisan Range	27	37	0
Total	100	100	100

2.4.2 Present Land Use

The present land use in the study area is classified into seven categories. The areal ratio of each category is given in Table 2.4.1, as summarized below.

Unit: %

Category	Kampar River Basin	Indragiri River Basin	In-between Area	Study Area
Forest	67.5	55.0	97.7	69.8
Bush and Grassland	7.0	7.9	0.8	6.0
Shifting Cultivation	3.8	4.9	0.3	3.4
Wetland Cultivation	1.6	4.4	0.5	2.3
Upland Cultivation	1.0	2.6	0.6	1.4
Tree Crops/ Estate	19.0	24.8	0.1	16.9
Settlement	0.1	0.4	0.0	0.2
Total	100.0	100.0	100.0	100.0

2.4.3 Future Land Use

The future land use plan (draft) has been prepared by the Regional Development Planning Bureau (BAPPEDA) in Riau and West Sumatra provinces, as shown in Table 2.4.2 and Fig. 2.4.1 and summarized below.

Category	Total	
	Area (ha)	Ratio (%)
(1) Area to be Protected for Future Use	921,970	18.0
(2) Food Crop Farming, Animal Husbandry, Agro Industry Area	186,170	3.6
(3) Plantation Development Area	1,789,660	34.8
(4) Forestry Development Area	1,194,540	23.2
(5) Urban Development and Transmigration Settlement Area	71,230	1.4
(6) Area to be Developed in Accordance with Central Government Policy	31,500	0.6
(7) City Development Area	24,350	0.5
(8) Other Purpose Development Area	478,720	9.3
(9) Conservation Area	441,460	8.6
(a) Conservation Forest, Wildlife, Natural Resources	-	-
(b) Erosion Area	-	-
Total	5,139,600	100.0

CHAPTER 3 SOCIO-ECONOMY

3.1 Development Policy

3.1.1 National Development Policy

In Indonesia, two national development plans are presently being implemented, the Second Long Term Development Plan and the Sixth Five-Year Development Plan.

(1) Second Long Term Development Plan

The Second Long Term Development Plan (PJP II) of 25 years from 1994 to 2019 is a continuing process aiming to create and develop a physically and mentally self-reliant nation. In PJP II, the national economic growth is projected at 7% per annum on average supported by the population growth rate which will decrease to around 0.9% per annum at the end of PJP II. When these objectives are attained, GNP per capita will become around US$2,600 in 2019 which is almost four times the present, US$650.

(2) Sixth Five-Year Development Plan

The Sixth Five-Year Development Plan (REPELITA VI) is to be implemented from 1994 to 1999. Economic growth is projected at 6.2% per annum on average. The target growth by sector is summarized in the table below.

Sector	Average Growth Rate (%)
(1) Agriculture	3.4
(2) Processing Industry	9.4
(Non-oil and -gas Processing)	10.3
(3) Others	6.0
(Leadership Sector)	4.6
National Economy	6.2

3.1.2 Regional Development Policy

The regional development policy is as described below.

(1) Second Long Term Development Plan

The target of the regional development plan in PJP II is a stable, real, dynamic, harmonious and responsible regional autonomy, as well as a more even development distribution along with its outputs in the frame of increasing public prosperity.

The target of economic development is to attain a speedy growth of the gross regional domestic product (GRDP) for the non-oil and -gas sector, which is estimated on annual average at approx. 3.7% for Riau Province and 7.6% for West Sumatra Province.

The social development targets are (1) to increase the degree of public health and nutrition which is measured through, among other things, two indicators of social prosperity, i.e., longer life expectancy to 72.7 years for Riau Province and 72.3 years for West Sumatra Province and the lowering of infant mortality to 2.0% (Riau Province) and 2.1% (West Sumatra Province); (2) to decrease the population growth rate; and, (3) to attain a steady distribution and increase of basic and vocational education quality, as well as to accomplish the implementation of a nine-year compulsory education. The poverty problem is also planned to be eradicated.

(2) Sixth Five-Year Development Plan

The priority of the regional economic growth is put on the non-oil and -gas sector. The target of growth of the non-oil and -gas industry is set at 7.0% and 6.5% per annum for Riau and West Sumatra provinces, respectively. The growth rates of each sector in non-oil and -gas industry are as follows:

Unit: % per annum

Non-Oil and -Gas Sector	Riau Province	West Sumatra Province
Agriculture	5.4	3.0
Construction	7.5	8.6
Trade and Transportation	6.4	7.3
Services	5.2	6.8
Others	1.3	7.3
Average	7.0	6.5

3.2 Population

3.2.1 Present Population

The present population in Indonesia and the study area is described as below.

(1) Indonesia

The total population of Indonesia has increased from 119,208 thousand in 1971 to 179,379 thousand in 1990 with an average growth rate of 2.17% per annum. During the same period, the Island of Sumatra showed the growth rate of 3.00% per annum.

The average annual growth rate of population has decreased from 2.39% during the period from 1971 to 1980, to 1.98% during from 1980 to 1990 (refer to Table 3.2.1). It is forecasted that the total population of Indonesia will increase to 210,439 thousand in the year 2000 with the average annual growth rate of 1.61% in the period from 1990 to 2000.

(2) Study Area

The population of the study area in 1982 and 1991 is summarized below (refer to Table 3.2.2).

Unit: 1,000 persons

Particulars	1982	1991	Annual Growth Rate (%)
Study Area in Riau Province	1,288	1,847	4.09
Study Area in West Sumatra Province	2,216	2,564	1.64
Total	3,504	4,411	2.59 (Ave.)

3.2.2 Population Density

Population density in Indonesia and the study area is described as below.

(1) Indonesia

The population density of Indonesia has increased during the period from 1971 to 1990, as shown in the table below (refer to Table 3.2.3).

Year	Population Density (person/km^2)	Annual Growth Rate (%)
1971	62.1	
1990	93.5	2.17 (1971/1990)
2000	109.6	1.61 (1990/2000)

Note: Amounts indicated for the year 2000 are projected figures.

(2) Study Area

The population density of the study area has increased for the period from 1982 to 1991, as shown in the table below (refer to Table 3.2.4).

Year	Population Density (person/km^2)	Annual Growth Rate (%)
1982	41.5	
1991	52.2	2.59

3.2.3 Population Projection of Study Area

The future population in the study area is projected based on past statistical data and the national and regional development plans, PJP II and REPELITA VI. Projection is made for 25 years at five-year intervals from 1994 to 2019. The result of population projection is summarized in the table below (refer to Table 3.2.5).

Unit: person

River Basin	1994	1999	2004	2009	2014	2019
Kampar	1,018,950	1,245,799	1,532,341	1,895,697	2,314,705	2,811,499
Indragiri	2,335,479	2,547,980	2,759,616	3,005,185	3,246,077	3,500,579
Total	3,354,429	3,793,779	4,291,957	4,900,882	5,560,782	6,312,078

3.3 Present Economic Condition

3.3.1 National Economic Condition

The national economic condition is as described below.

(1) Gross Domestic Product

The gross domestic product (GDP) of Indonesia for the period from 1984 to 1991 is summarized below (refer to Table 3.3.1).

Unit: Rp. 10^9

1984	1985	1986	1987	1988	1989	1990	1991	Annual Growth Rate (%)
83,037	85,082	90,080	94,518	99,936	107,437	115,217	123,181	5.80

Note: At the constant market price in 1983.

(2) Gross Domestic Product per Capita

GDP per capita of Indonesia for the period from 1987 to 1993 is summarized in the table below (refer to Table 3.3.2).

Unit: Rp. 1,000

1987	1988	1989	1990	1991	1992	1993	Annual Growth Rate (%)
556	576	615	647	679	711	744	4.95

Note: At the constant market price in 1983.

(3) Gross Domestic Product by Industrial Sector

The breakdown of the gross domestic product (GDP) of Indonesia by industrial sector in 1993 at the constant market price in 1983 is shown in the table below (refer to Table 3.3.3).

Kind of Industry	Amount (10^9 Rp.)	Share (%)
Manufacturing Industries	29,035	20.8
Agriculture, Livestock, Forestry & Fisheries	24,512	17.6
Trade, Hotel and Restaurants	23,114	16.6
Mining and Quarrying	19,588	14.0
Others	43,322	31.0
Total	139,571	100.0

3.3.2 Regional Economic Condition of Study Area

The regional economic condition of the study area is as described below.

(1) Gross Regional Domestic Product

The gross regional domestic product (GRDP) of the study area for the period from 1986 to 1990 is summarized in the table below.

Unit: Rp. 10^9

Particulars	1986	1987	1988	1989	1990	Annual Growth Rate (%)
Study Area in Riau Province	526	561	607	669	743	9.02
Study Area in West Sumatra Province	927	921	926	918	975	1.27
Total	1,453	1,482	1,534	1,587	1,717	4.28 (Ave.)

Note: At the constant market price in 1983.

(2) Gross Regional Domestic Product per Capita

The gross regional domestic product per capita of the study area for the period from 1986 to 1990 is summarized in the table below.

Unit: Rp. 1,000

Particulars	1986	1987	1988	1989	1990	Annual Growth Rate (%)
Study Area in Riau Province	344	361	385	413	414	4.79
Study Area in West Sumatra Province	386	378	373	364	391	0.28
Average	370	371	377	383	401	2.03

Note: At the constant market price in 1983.

(3) Gross Regional Domestic Product by Industrial Sector

GRDP of major industries of the study area in 1990 is summarized in the table below.

Industry	Amount (Rp. 10^9)	Share (%)
Agriculture	625	36.4
Trade, Hotel and Restaurant	403	23.5
Manufacturing Industry	150	8.7
Transportation and Communications	138	8.0
Others	401	23.4
Total	1,717	100.0

Note: At the constant market price in 1983.

CHAPTER 4 HYDROLOGICAL ANALYSIS

4.1 Available Data

Data for the hydrological analysis have been collected from meteorological stations, rainfall stations and water level gaging stations located in and around the study area. Rainfall data were collected from 26 rainfall stations and discharge data, from 13 water level gaging stations. The rainfall data of 23 rainfall stations out of the 26 were identified as available data (refer to Fig. 4.1.1).

4.2 Rainfall Analysis

4.2.1 Procedure of Rainfall Analysis

The rainfall analysis was carried out to estimate flood runoff discharge for the flood control plan and low flow discharge for the water resources development plan in accordance with the following procedure.

- Identification of necessary rainfall data
- Selection of rainfall gaging stations
- Supplementation of lacking rainfall data
- Calculation of average basin rainfall
- Calculation of probable rainfall
- Establishment of rainfall depth-duration curve of short duration
- Analysis of rainfall patterns during past notable floods
- Determination of design rainfall
- Calculation of probable maximum precipitation (PMP)

4.2.2 Available Data and Supplementation of Lacking Data

The available data collected from 23 rainfall stations consist of daily rainfall data of 19 stations and hourly rainfall data of 4 stations. Not all the rainfall data are complete because some stations have lacking data. The lacking data were supplemented by correlation with neighboring stations that have complete data.

4.2.3 Average Basin Rainfall and Probable Rainfall

The collected and supplemented data are of point rainfall. Average basin rainfall was developed from point rainfall by Thiessen Polygon Method (refer to Fig. 4.2.1) and Area Reduction Factor (refer to Fig. 4.2.2) for the low flow and flood runoff analyses. Probable rainfall was calculated for flood runoff analysis using average basin rainfall (refer to Tables 4.2.1 and 4.2.2).

Temporal distribution of probable rainfall for sub-basins with areas larger than 500 km^2 was determined by the distribution of past notable floods and the model hyetograph of the central concentration type was adopted for sub-basins with areas of less than 500 km^2.

4.2.4 Design Rainfall and Probable Maximum Precipitation

The design rainfall for flood runoff analysis was obtained at each reference point for several probable rainfalls under the following three factors.

- Total volume of rainfall;
- Temporal distribution of rainfall; and
- Spatial distribution of rainfall.

A spillway of a rockfill dam is designed with design discharge of probable maximum flood (PMF) which was calculated using probable maximum precipitation (PMP). PMP was calculated by the Hershfield Method for areas where rainfall records are available but other climatic records are hardly obtained for Kampar Kiri No. 1 and Upper Sinamar dams which are planned to be rockfill dams. The results of calculation are summarized below.

Probable Maximum Precipitation (PMP)

Unit: mm

Name of Dam	1-day Rainfall	2-day Rainfall	3-day Rainfall
Kampar Kiri No. 1 Dam	224.0	453.8	475.3
Upper Sinamar Dam	294.0	428.9	596.8

4.3 Flood Runoff Analysis

4.3.1 Procedure of Flood Runoff Analysis

Flood runoff analysis has been conducted in accordance with the following procedures:

- Selection of method of flood runoff analysis;
- Selection of reference points and division of basin;
- Determination of constants for runoff model; and
- Calculation of probable flood hydrograph and probable maximum flood.

4.3.2 Method of Flood Runoff Analysis

Storage Function Model was employed to estimate flood hydrograph, which is suitable for river basins with a few discharge data for verification. Constants for the Storage Function Model were decided from the past major floods in 1986, 1989 and 1991 against all the sub-basins mentioned below. The basic project flood was determined from the estimated flood hydrograph and calculated at reference points on the objective rivers.

Reference points are generally selected on points of major flood control facilities such as dams, and confluence of major tributaries which become base points for hydraulic and hydrological analysis. For this Study, the following reference points have been selected (refer to Fig. 4.3.1).

Kampar River Basin		
Reference Point		C.A.
Name	No.	(km^2)
Kapoernan	6	699
Kotapanjang	12	3,337
Kiri No. 1	20	1,187
Kiri No. 2	28	552
Lipat Kain	37	3,284
Kiri+Kanan	54	12,284
Kerinci	58+61	16,768
Telukmeraniti	56+70	21,497

Indragiri River Basin		
Reference Point		C.A.
Name	No.	(km^2)
Sinamar 1	3	828
Agam	6	450
Sinamar 2	3+6	1,278
Low. Sinamar	12	1,779
Sukarami	24	534
Sukam	44	485
Kuantan	53	7,453
Peranap	61+64	10,885
Japura	67	12,320
Kualacenake	72+75	15,100

The Kampar and Indragiri river basins have been divided into 18 and 19 sub-basins, respectively, as shown in Fig. 4.3.1. Schematic illustration of the sub-basins are presented in Fig. 4.3.2 and flood runoff analysis was carried out by sub-basin.

4.3.3 Probable Flood Hydrograph

Probable flood hydrographs were developed by the Storage Function Model for all reference points and probabilities of 2-, 5-, 10-, 25-, 50- and 1,000-year return periods. The peak discharges of the hydrographs of the basic project floods, which are called Standard Flood Discharges for 50-year return period, are summarized in the following table.

Kampar River Basin			Peak	Specific	Indragiri River Basin			Peak	Specific
Reference Point		C.A.	Discharge*	Discharge	Reference Point		C.A.	Discharge*	Discharge
Name	No.	(km^2)	(m^3/s)	(m^3/s/km^2)	Name	No.	(km^2)	(m^3/s)	(m^3/s/km^2)
Kapoernan	6	699	1,365	2.0	Sinamar	3+6	1,278	2,094	1.6
Kotapanjang	12	3,337	3,997	1.2	Low.Sinamar	12	1,779	2,421	1.4
Kiri No. 1	20	1,187	1,630	1.4	Low.Kuantan	53	7,453	6,545	0.9
Kiri No. 2	28	552	1,399	2.5	Peranap	61+64	10,885	6,777	0.6
Lipat Kain	37	3,284	3,101	0.9	Japura	67	12,320	6,998	0.6
Kiri + Kanan	54	12,284	6,790	0.6	Kualacenake	72+75	15,100	7,659	0.5
Kerinci	58+61	16,768	7,034	0.4	Sinamar	3	828	1,840	2.2
Telukmeraniti	56+70	21,497	7,951	0.4	Agam	6	450	1,107	2.5
					Sukarami	24	534	1,482	2.8
					Sukam	44	485	1,414	2.9

* Peak Discharge = 50-year return period

4.3.4 Design Discharge for Design of Dam Spillway

In the Overall Development Plan, six damsites were selected for both flood control and water resources development plans. Four dams are planned as concrete gravity dams and the remaining two dams as rockfill dams.

In designing spillways of these dams, flood discharges of 1,000-year return period and probable maximum flood (PMF) are employed as design discharges of spillways for concrete gravity dams and rockfill dams, respectively. The flood discharges of 1,000-year return period were obtained by the same manner as other probabilities. The probable maximum floods were calculated using probable maximum precipitation studied in Section 4.2, Rainfall Analysis. The results of calculation of design discharges for spillways of the six dams are summarized below.

Design Discharge of Spillway

Dam Features			Peak Discharge (m^3/s)		Specific Discharge ($m^3/s/km^2$)
Location of Dam Site	Type of Dam	C.A. (km^2)	1,000-year Return Period	PMF	
Kapoeman	Concrete Gravity	699	2,181		3.1
Kiri No. 1	Rockfill	1,187	-	7,274	6.1
Kiri No. 2	Concrete Gravity	552	1,992		3.6
Sukam	Concrete Gravity	360	1,755		4.9
Upper Sinamar	Rockfill	1,580	-	8,383	5.3
Kuantan	Concrete Gravity	7,453	10,047		1.3

4.4 Low Flow Analysis

4.4.1 Average Basin Rainfall

The low flow analysis was carried out to prepare daily discharges for the water resources development plan. Since observed discharge data collected were not sufficient both in number and recording period, daily discharges were developed from the average basin rainfall as studied in Section 4.2, Rainfall Analysis.

4.4.2 Runoff Model and Simulated Discharge

The daily discharges were calculated for the same sub-basins established for the flood control plan by Tank Model applying average rainfall for the period of 12 years from 1981 to 1992 and were calibrated by observed discharge data to determine values of constants for the Tank Model. The results of low flow analysis are summarized below.

Particulars	Unit	Kampar River Basin	Indragiri River Basin
Rainfall	mm	2,513	2,338
Average Discharge at River Mouth	m^3/s	1,010	591
Catchment Area	km^2	24,548	16,268
Specific Discharge	$m^3/s/100km^2$	4.11	3.63
Runoff Height	mm	1,298	1,145
Loss (Evapotranspiration)	mm	1,215	1,193

4.5 Inundation Analysis

4.5.1 Inundation Analysis for Overall Development Plan

Identification of Flood Area

Through the flood damage investigation in the study area, five habitual inundation areas were identified. Two areas are along the middle and lower reaches of the Kampar and Indragiri rivers and the other three areas are in the upper reaches of the Indragiri River. Recent large floods caused inundation in these areas in 1978, 1986 and 1991.

Inundation Analysis Model

The inundation analysis was carried out with the Two-Dimensional Unsteady Flow Model to estimate area and inundation depth of the identified inundation areas for several flood probabilities of 2- to 50-year return periods.

Establishment of Inundation Model

Flood inundation models have been prepared for the five inundation areas under the following conditions:

- Inundation areas are to be divided into mesh blocks of 1,860 m by 1,860 m which is equivalent to one minute of longitude and latitude in the middle reaches and 465 m by 465 m which is equivalent to a quarter of one minute in the upper reaches of the Indragiri River.
- The average ground height of each mesh is to be obtained using the topographic map with a scale of 1/50,000.

As the initial condition for computation, it is necessary to give overflow discharge to the inundation area and the overflow section. The following initial conditions were taken into account:

- The overflow sections selected are of poor flow capacity estimated by the non-uniform calculation method.

- It is assumed that in probable flood hydrographs, the surplus discharge over the flow capacity overflows at the overflow section. The overflow discharge *(dQ)* at the overflow section is given by the surplus discharge *(Q)* minus the flow capacity *(q)* at the overflow section in the hydrographs, as follows:

$$dQ = Q - q$$

Study Results

The study results of the inundation analysis for the Overall Development Plan are summarized below.

Unit: km^2

Return Period (Year)	Inundation Area				
	Kampar River	Indragiri River			
	Middle Reaches	Middle Reaches	Paya-kumbuh	Solok	Sijunjung
50	2,151	1,460	284	106	60
25	2,136	1,406	273	102	59
10	2,025	1,356	254	95	56
5	1,902	1,314	234	83	54
2	1,752	1,237	131	60	47

4.5.2 Inundation Analysis for Priority Projects

The inundation analysis for priority projects was carried out with the same procedure and method as the Overall Development Plan. The areas of flood control projects are limited to Bangkinang area along the Kampar Kanan River and Rengat area along the Indragiri River.

The study results are summarized below and shown in Fig. 4.5.1. In this figure, the inundation areas are divided into mesh blocks of 250 m by 250 m.

Unit: km^2

Return Period (Year)	Inundation Area	
	Kampar River	Indragiri River
	Bangkinang	Rengat
10	-	27
5	99	25
2	92	23

4.6 Tidal Analysis

4.6.1 Tidal Level

Data on tidal level were obtained from the office of DINAS HIDRO-OCEANOGRAFI TNI-AL. Tables of tidal level from 1993 to 1994 at two stations, Blandong in the Kampar River and Kuala Lajau in the Indragiri River, were collected. The collected mean tidal level and mean high water spring are as calculated below.

Item	Blandong/ Kampar River	Kuala Lajau/ Indragiri River
Mean Tidal Level	2.10 m	2.50 m
Mean High Water Spring	4.05 m	3.90 m

4.6.2 Saltwater Intrusion

Saltwater intrusion at both Kampar and Indragiri river mouths was analyzed and lengths of saltwater wedges were calculated with an equation developed by Schijband and Schoufeld. The results of calculation of saltwater wedge lengths are summarized below.

River	Project	Q(m^3/s)	B (m)	H (m)	L (km)
Kampar	At present	275	1,570	7.45	229
	Future without project	300	1,630	7.45	222
	Future with project	352	1,730	7.45	210
Indragiri	At present	170	745	6.90	160
	Future without project	108	660	6.90	195
	Future with project	187	785	6.90	156

Q : monthly minimum flow discharge
B : river width
H : water depth from high water spring level
L : length of saltwater wedge

CHAPTER 5 OVERALL DEVELOPMENT PLAN

5.1 General

The Overall Development Plan is formulated with flood control as well as water resources development as the primary purpose. Hydropower generation is incorporated as a secondary purpose if dam is employed for the primary purpose.

Formulation of the Overall Development Plan is based on the premises given below.

(1) Basic Considerations

The basic considerations to formulate the Overall Development Plan are as follows:

- Target year is set at 2019 in accordance with the agreement between the Preparatory Study Team of JICA and the DGWRD, DPU;
- Future land use proposed in REPELITA VI is a basis for planning; and
- The proposed land use is to be realized by the year 2019.

(2) Flood Protection Areas

The areas considered for flood protection in the Kampar and Indragiri river basins as identified in Section 5.3, Flood Control Plan, are outlined below. The selection of such areas was made in due consideration of necessity and economic feasibility.

(a) Kampar River Basin

- Bangkinang and surrounding agricultural areas along the Kampar Kanan River.
- Agricultural areas and towns scattered along the Kampar Kiri River.
- Areas along the Kampar River.

(b) Indragiri River Basin

- Areas along the middle to lower reaches of Kuantan-Indragiri River.

- Payakumbuh, Solok and Sijunjung/Muara areas in the upper reaches.

(3) Water Demand Areas

The major demand areas for water resources development as identified in Section 5.6, Water Resources Development Plan, are outlined below.

(a) Kampar River Basin

- Irrigation water demand area proposed by DPU in Rantauberangin Irrigation Development Project.
- Domestic water demand area in Pekanbaru City.

(b) Indragiri River Basin

- Irrigation water demand area proposed by DPU in Lubukjambi Irrigation Development Project.

(4) Hydropower Generation Areas

Hydropower generation is basically considered to be subsidiary to flood control and water resources development. As discussed in Section 5.7, Hydropower Development Plan, hydropower generation is possible at the following dams:

(a) Kampar River Basin

- Kampar Kiri No. 1 Dam
- Kampar Kiri No. 2 Dam

(b) Indragiri River Basin

- Kuantan Dam
- Upper Sinamar Dam
- Sukam Dam

5.2 Selection of Possible Damsites

Through the study on potential water sources, the development of river surface water by construction of dams was identified as a possible water source in the study area. In addition, employment of dams as one of the countermeasures of flood control is considered.

From these considerations, construction of dams for flood control and water resources development is incorporated into the planning of facilities. As the first step for the formulation of the Overall Development Plan, possible damsites in the study area are selected.

5.2.1 Selection of Candidate Damsites

Through the study on hydropower development in the Kampar and Indragiri rivers conducted by PLN, and the field reconnaissance and investigation on the topographic map with the scale of 1/50,000, the 10 dams enumerated below were identified as candidate dams which are studied further in detail in the formulation of the Overall Development Plan. Five of these dams are in the Kampar river basin and the other five are in the Indragiri river basin. Their locations are shown in Fig. 5.2.1, and potential capacities and features are summarized in Table 5.2.1.

(1) Kampar River Basin

- Kapoernan Dam
- Mahat Dam
- Kototengah Dam
- Kampar Kiri No. 1 Dam
- Kampar Kiri No. 2 Dam

(2) Indragiri River Basin

- Upper Sinamar Dam
- Lower Sinamar Dam
- Upper Kuantan Dam
- Kuantan Dam
- Sukam Dam

5.2.2 Selection of Possible Damsites

The selection of possible damsite from the candidate damsites has been made, as described below.

(1) Criteria for Selection

Possible damsites incorporated in the study on the Overall Development Plan were selected from the candidate damsites based on the following criteria.

- Dams for flood control should have a catchment area of more than 30% of the catchment area at the reference point considering the effects of dam;
- Dams to be proposed should have a catchment area of at least more than 400 km^2 and an effective storage capacity of more than $100 \times 10^6 m^3$ considering economic feasibility; and
- Dams with geological problems on foundation should be eliminated.

(2) Possible Dams

The following six dams were selected as possible dams from the ten candidate dams for further study in the Overall Development Plan in accordance with the criteria for selection mentioned above. The locations of possible dams are as shown in Fig. 5.2.1.

- Kapoeman Dam
- Kampar Kiri No. 1 Dam
- Kampar Kiri No. 2 Dam
- Upper Sinamar Dam
- Sukam Dam
- Kuantan Dam

The other four candidate dams were excluded for further study due to reasons mentioned below.

Dam Excluded	Reason for Exclusion
Mahat Dam	Existence of a Buddhist temple in the reservoir area
Kototengah Dam	No effective storage
Lower Sinamar Dam	Limestone foundation
Upper Kuantan Dam	No effective storage

(3) Comparison between Single Large Dam and Several Small Dams

A dam with a large storage capacity is efficient and economical for flood control and water resources development. However, a large dam has greater environmental and social impacts than a small dam. To reduce the impacts, the construction of several small dams becomes an alternative.

As discussed elsewhere, the Kuantan Dam on the Indragiri River is one of the priority projects for flood control and water supply. This dam is large and has the gross storage capacity of $1{,}570\times10^6m^3$ or an effective storage capacity of $1{,}145\times10^6m^3$. To compensate for this large dam, many small dams shall have to be constructed and this will be very costly and unrealistic.

For instance, the gross storage capacity of a standard scale small dam with a height of 10 m on a river channel with a width of 100 m and riverbed slope of 1/500 in a hilly area comes to $2.5\times10^6m^3$. To have the storage capacity equal to the Kuantan Dam, about 600 small dams are required. On the other hand, the gross storage capacity of a small weir with a height of 4 m on a river channel with a width of 200 m and riverbed slope of 1/5,000 in the lower stretch comes to $8.0\times10^6m^3$, and 200 weirs are required.

The construction of a lot of small dams is therefore unrealistic and very costly even if the scale is sufficiently small. Furthermore, flood control by many small dams is operationally difficult because the complete combined operation of all dams is required due to small storage capacities, and flood protection may have to be made by a complete dike system. A single large dam is accordingly recommended in the present study, if the required storage is large enough to fulfill the envisaged function of the dam. Small dams are to be considered locally depending on water demand.

5.3 Flood Control Plan

5.3.1 Present River Condition

Whole Basin

The Kampar and Indragiri river basins lie in 0°40'N to 1°05'S latitude and 100°10'E to 103°30'E longitude. The river lengths and catchment areas of the Kampar and Indragiri rivers as well as the delta area near the sea in-between the two rivers are given in the table below. Fig. 5.3.1 shows the river system in the study area.

Particulars	Kampar River	Delta In-between	Indragiri River	Total
River Length (km)	580	193*	706	-
Catchment Area (km^2)				
Riau Province	21,086	10,580	8,809	40,475
West Sumatra Province	3,462	0	7,459	10,921
Total Catchment Area	24,548	10,580	16,268	51,396

* River length of Gaung River.

Kampar River System

The Kampar River has two major tributaries, the Kampar Kanan and Kampar Kiri rivers, and they join each other at Langgam approx. 40 km southeast of Pekanbaru City.

(1) Kampar Kanan River

The Kampar Kanan River which has a catchment area of 5,231 km^2 originates at Mt. Gadang (EL 2,060.3 m) in the Barisan Mountains. In the mountain area, it flow north, then gradually turns to east. It joins the Kapurnangadang and Mahat rivers at the upper reaches of the Kotapanjang Dam which is presently under construction for hydropower development by PLN. In the upper reaches of Bangkinang, it has a flow capacity of about 1,000 m^3/s and between Danaubingkuan and Teratakbuluh, about 700 m^3/s.

(2) Kampar Kiri River

The Kampar Kiri River which has a catchment area of 7,053 km^2 originates in the Barisan Mountains in the border of the Riau and West Sumatra provinces. In the upper reaches, it has two tributaries, the Sibayang and Singingi rivers which have catchment areas of 1,606 km^2 and 1,678 km^2, respectively.

The flow capacity of the Sibayang River is about 1,000 m^3/s, while the Kampar Kiri River has 200-400 m^3/s in the lower stretch of the confluence with the Teso River.

(3) Kampar River

After joining the Kampar Kanan and Kampar Kiri rivers, the Kampar River flows east with meandering. It joins another tributary, the Nilo River which has a catchment area of 3,133 km^2. The width of the river exceeds 1.0 km downstream from the 100 km point and around 7 km at the river mouth.

At the river mouth, tidal phenomenon "bore" takes place. Bore is a kind of big tidal wave which takes place at spring tide.

Indragiri River System

The Indragiri River has some major tributaries in the upper reaches, the Sinamar, Ombilin and Sukam rivers. The upper reaches of the Indragiri River is called the Kuantan River from the confluence of the Ombilin and Sukam rivers until Japura.

(1) Sinamar River

The Sinamar River which has a catchment area of 2,492 km^2 originates from Mt. Putus (EL 1,930 m) in the Barisan Mountains. It joins the Lampasi and Agam rivers near Payakumbuh City. The flow capacity of the Sinamar River is small at 200-400 m^3/s in the upper and lower reaches.

(2) Ombilin River

The Ombilin River which has a catchment area of 2,187 km^2 originates from the Dibaruh Lake. Between the Dibaruh Lake and the Singkarak Lake is called the Lembang River. The Singkarak Lake which has a water area of 130 km^2 is under development for hydropower generation by PLN. The flow capacity of the Lembang River is as small as 400 m^3/s near Solok City.

Water of the Singkarak Lake flows out to the Ombilin River, then flows toward east in the hilly area and joins with the Sukam River at Muara Town. After joining the Sukam River, the name changes to the Kuantan River.

(3) Sukam River

The Sukam River which has a catchment area of 1,490 km^2 originates from the Barisan Mountains. It joins with the Ombilin River near Muara and Sijunjung towns. After joining with the Ombilin River at Muara Town, it is called the Kuantan River.

(4) Kuantan River

The upper reaches of the Indragiri River between Muara and Japura of 320 km is called the Kuantan River. The Kuantan River flows down toward east in gentle hilly area and the riverbed gradient is 1/630 at the downstream of Muara until Lubukkambacang. After Lubukkambacang, the riverbed gradient becomes very gentle with 1/3,500 to 1/6,000 and the river has a flow capacity of 1,200 m^3/s to 1,500 m^3/s in this stretch.

(5) Indragiri River

After Japura, the river is called the Indragiri River. Between Japura and the river mouth, it flows in a swamp area for 215 km. Rengat and Tembilahan towns are located along this stretch.

5.3.2 Flood Damage Condition

Flood prone areas were identified based on the flood damage survey at fields, as shown in Fig. 5.3.2. As shown in the illustration, flooding problem in the basins can be divided broadly into two; namely, local problems in the upper reaches and general problems in the middle and lower reaches.

The local problems in the upper reaches are in West Sumatra Province. These are in Solok, Payakumbuh and Sijunjung/Muara areas. The maximum areas of inundation are approximately 5, 10 and 25 km^2, respectively.

The inundation areas in the middle and lower reaches are along the Kampar Kanan, Sibayang, Singingi, Kampar Kiri and Kampar rivers in the Kampar river basin, and along the Kuantan-Indragiri and the Cenako rivers in the Indragiri river basin. The inundation areas of the Kampar and Indragiri rivers are about 1,800 and 900 km^2, respectively. These are all storage type inundation.

(1) Upper Reaches

Solok, Payakumbuh and Sijunjung/Muara areas were identified as flood prone areas in the upper reaches. Floods hit these areas almost every year due to the insufficient flow capacity of rivers. To increase the present flow capacity of existing rivers, DPU had conducted or is conducting river improvement works in Payakumbuh, Solok and Muara areas.

(2) Middle and Lower Reaches

The present flow capacity in this stretch has been estimated as follows

River	Flow Capacity (m^3/s)
Kampar Kanan River	
Bangkinang Area	750 - 1,000
Lower Reaches	700 - 800
Kampar Kiri River	
Sibayang	500
Upper Reaches of Kampar Kiri River	600
Lower Reaches of Kampar Kiri River	200
Kampar River	around 1,200
Indragiri River	around 1,200

As the flood-prone area map shows (refer to Fig. 5.3.2), areas along the rivers are flood plain and easily inundated by normal floods. Floods occur almost every year and once they occur, inundation continues for 7 to 10 days in lower areas. Field interview survey revealed the following notable floods in recent years:

- January 1995
- November 1993 (Upper reaches of the Indragiri River)
- December 1991 to January 1992
- January 1991
- January 1989
- February 1988
- January 1986
- 1978
- 1964 (the historical largest flood)

5.3.3 Related Projects

Existing projects related to flood control, sediment control, river maintenance, etc., are as mentioned below. Fig. 5.3.3 shows the location of these projects.

(1) Completed and Ongoing Projects

Projects already implemented and under construction in the Kampar-Indragiri river basin are as follows:

- Radio Communication/Warning System (Kampar and Kuantan-Indragiri Rivers)
- Kotapanjang Hydropower Project (Kampar Kanan River)
- Lembang River Improvement Project (Upper Indragiri River Basin)
- Sinamar-Lampasi River Improvement Project (Upper Indragiri River Basin)
- Muara Area River Improvement Project (Upper Indragiri River Basin)
- Singkarak Hydropower Project (Indragiri River Basin)
- River Works in Middle and Lower Reaches of Indragiri River

(2) Projects under Planning and Designing

The following projects are under planning and designing:

- Trans-Sumatra Canalization Project for the Lower Kampar-Indragiri Delta

- Projects included in REPELITA VI, Riau and West Sumatra Provinces (refer to Fig. 5.3.3)
- Rengat Area Detailed City Layout Plan

5.3.4 Objective Flood Protection Areas

Objective flood protection areas for the present overall plan have been identified as follows (refer to Fig. 5.3.4) in due consideration of present flood damage conditions and related projects, as discussed in the previous chapters, as well as the proposed land use plan under REPELITA VI.

(1) Kampar River Basin

- Bangkinang-Airtiris area along the Kampar Kanan River
- Proposed agricultural lands in lower reaches of the Kampar Kanan River
- Areas along the Sibayang River
- Areas along the upper reaches of the Kampar Kiri River
- Existing and proposed agricultural lands along the Kampar River

(2) Kuantan-Indragiri River Basin

- Towns and agricultural areas in the upstream reaches, namely, Payakumbuh, Solok and Sijunjung/Muara areas in the Upper Indragiri River.
- Towns along the lower reaches of the Kuantan River from Telukkuantan to Airmolek.
- Rengat area.
- Existing and proposed agricultural lands along the middle and lower reaches of the Kuantan-Indragiri River.

5.3.5 Planning Criteria for Overall Development Plan

<u>Target Year</u>

The target year for flood control planning refers to the year whose conditions serve as the basis for determining the design scale of the Project. For this project the target year is set at 2019.

Design Scale

The design scale, namely the return period of design rainfall for flood control planning, is decided at 5 to 10-year for the Initial Phase of the Overall Development Plan and 50-year for the Final Phase in due consideration of the "Flood Control Manual, CIDA-DPU, June 1993" and design scales adopted to other projects in Indonesia. The following table shows the design scales adopted to this Project.

Unit: Year return period

Particulars	Initial Phase (Urban/Rural)	Final Phase
Kampar River System		
Kampar Kanan River	5 / 5	50
Kampar Kiri River	-	50
Kampar River after confluence	-	50
Indragiri River System		
Sinamar/Lampasi/Agam Rivers	10 / 10	50
Lembang River	10 / 10	50
Sukam/Palangki Rivers	10 / 10	50
Kuantan-Indragiri River	10 / 5	50

Standard Flood Discharge

Standard flood discharges which correspond to the design scales determined above are as follows. The calculation has been as conducted in CHAPTER 4, HYDROLOGICAL ANALYSIS.

River	Catchment Area	Initial Phase		Final Phase	
		Return Period	Standard Flood Discharge	Return Period	Standard Flood Discharge
	(km^2)	(Year)	(m^3/s)	(Year)	(m^3/s)
Kampar River System					
Kampar River at Bangkinang	3,337	5	2,800	50	4,000
Sibayang River	1,187	5	1,050	50	1,650
Singingi River	552	5	550	50	950
Kampar Kiri River	3,284	-	-	50	3,100
Kampar River at Langgam	12,284	-	-	50	6,800
Indragiri River System					
Kuantan River at Lubukjambi	7,453	5	3,900	50	6,550
Kuantan River at Peranap	10,885	5	4,300	50	6,800
Kuantan River at Japura	12,320	5	4,500	50	7,000
Sinamar River	1,278	10	1,550	50	2,100
Lembang River	359	10	500	50	1,000
Sukam River	360	10	700	50	1,050
Kuantan River at Muara	6,169	10	3,950	50	5,450

Design Criteria

The design criteria considered for flood control planning are as follows:

(1) River Improvement

(a) High Water Level

The design high water levels are maintained as low as possible.

(b) Channel Alignment and Longitudinal Profile

The alignment of the improved river channel basically follows the present alignment. Although comparison of construction cost is carried out, the following principles are considered. Continuous shortcuts are basically avoided in order to maintain the present river regime. However, extreme meandering portions are to be shortcut to realize smooth flow during floods and to minimize improvement cost..

(c) Cross Section

Basically, compound cross sections will be adopted. Dike dimensions will be determined based on the Flood Control Manual.

(2) Flood Control Dam

Dams are basically planned as multipurpose dams.

(a) Regulation Type

Natural regulation (non-gated) will be adopted if physical conditions and the function of the dam allow.

(b) Capacity

Optimum scales of dams will be determined through optimization study with river improvement considering reservoir capacity allocation with other purposes.

5.3.6 Premises for Flood Control Planning

Flood Control Effect of Kotapanjang Dam

The Kotapanjang Dam which is presently under construction by PLN does not have a storage capacity for flood control because it was planned for hydropower generation purposes only. However, if a flood flow down when the reservoir water level is lower than the high water level, a certain effect of flood control can be expected.

The reservoir operation simulation was carried out for floods from 1971 to 1992. The simulation results show that in some years, floods hit the area when the reservoir water levels were at high water level. Therefore, the flood control effect of the Kotapanjang Dam cannot always be expected.

Indragiri-Gaung Floodway

DPU had conducted a feasibility study for the Kampar-Indragiri Zone for the canalization in the east coast of Sumatra. The floodway is proposed in this plan to divert a maximum discharge of 500 m^3/s from the Indragiri River to the Gaung River. Detail design has also been started for this floodway. Accordingly, this floodway is considered as a prerequisite for the present study.

5.3.7 Applicable Alternative Measures

For flood control, the following four measures are considered as applicable countermeasures:

- Construction of flood control dam;
- Improvement of existing river channel;
- Establishment of retarding basins; and,
- Construction of floodways.

Applicable alternative structural measures for each river were identified considering the natural conditions, as follows (refer to Fig. 5.3.5).