JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

DEPARTMENT OF IRRIGATION AND DRAINAGE
MINISTRY OF AGRICULTURE
MALAYSIA

COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

VOLUME 2

MAIN REPORT

(FINAL REPORT)

DECEMBER 1995

CTI ENGINEERING CO., LTD.
IN ASSOCIATION WITH
INA CORPORATION

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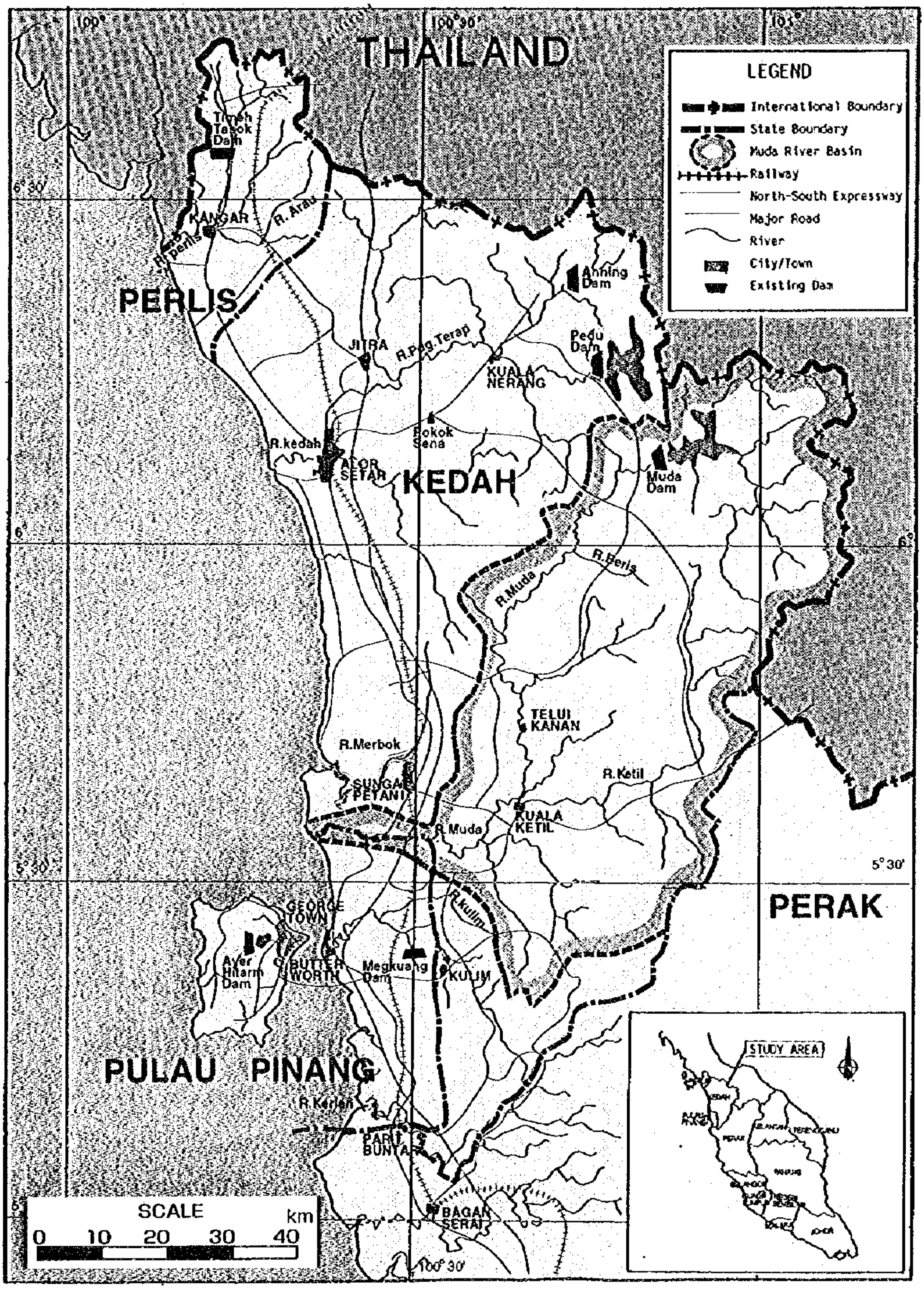
THAILAND
LEGEND
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PERLIS
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R. kedah
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R. Kulim
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STUDY AREA
SCALE
km
0 10 20 30 40

GENERAL MAP

PREFACE

In response to a request from the Government of Malaysia, the Government of Japan decided to conduct the Study on Comprehensive Management Plan of Muda River Basin and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Malaysia a study team headed by Mr. Katsuhisa Abe, CTI Engineering Co., Ltd., and composed of members from CTI Engineering Co., Ltd. and INA Corporation, four times between March, 1993 and October, 1995.

The team held discussions with the officials concerned of the Government of Malaysia, and conducted 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 Malaysia for the close cooperation extended to the Team.

December 1995

KIMIO FUJITA
President
Japan International Cooperation Agency

December 1995

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

Sir:

LETTER OF TRANSMITTAL

We are pleased to submit herewith the Final Report on the Study on Comprehensive Management Plan of Muda River Basin, Malaysia. The report contains the advice and suggestions of authorities concerned of the Government of Japan and the Japan International Cooperation Agency (JICA), as well as the formulation of comprehensive river basin management projects. Also included are the comments made by the Economic Planning Unit, the Department of Irrigation and Drainage and other authorities concerned of the Government of Malaysia during the technical discussions on the Draft Final Report in Malaysia.

The Final Report presents the Master Plan covering the entire Muda river basin and the whole states of Kedah and Pulau Pinang as well as a part of Perlis in the aspect of the water resources management plan proposed for the Study.

In view of the urgency and necessity of socio-economic development, we recommend that the Government of Malaysia shall adopt all means possible to promote the comprehensive river basin management projects to the next stage of project implementation at the earliest possible time.

Finally, we wish to take this opportunity to express our sincere gratitude to the Government of Japan, particularly, JICA, the Ministry of Foreign Affairs, the Ministry of Construction and other offices concerned. We also wish to express our deep appreciation to the Economic Planning Unit, the Department of Irrigation and Drainage and other authorities concerned of the Government of Malaysia for the close cooperation and assistance extended to the JICA Study Team during the Study.

Very truly yours,

KATSUHISA ABE
Team Leader
JICA Study Team

Encl.: a/s

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Members for Study on Comprehensive Management Plan of Muda River Basin

ABBREVIATIONS AND GLOSSARY

GOVERNMENT OFFICES

DID	:	Department of Irrigation and Drainage
DOC	:	Department of Chemistry
DOE	:	Department of Environment
DOF	:	Department of Fisheries
DOH	:	Department of Health
DOS	:	Department of Statistics
DSM	:	Department of Survey and Mapping
DWNP	:	Department of Wildlife and National Parks
EPU	:	Economic Planning Unit
EXCO	:	State Executive Council
FDHPM	:	Forest Department Headquarters Peninsular Malaysia
JICA	:	Japan International Cooperation Agency
JKR	:	Jabatan Kerja Raya (= PWD)
JPS	:	Jabatan Pengairan dan Saliran (= DID)
JPT	:	Jabatan Pengairan dan Taliair (= DID)
LKIM	:	Lembaga Kemajuan Ikan Malaysia (= Malaysian Fisheries Development Authority)
MD	:	Marine Department
MMS	:	Malaysia Meteorological Service
MOA	:	Ministry of Agriculture
MOF	:	Ministry of Finance
PWD	:	Public Works Department
MADA	:	Muda Agricultural Development Authority
IADP	:	Integrated Agricultural Development Project
PWA	:	Penang Water Authority
KEDA	:	Kedah Regional Development Authority
KSDC	:	Kedah State Economic Development Corporation
PDC	:	Penang Development Corporation
SPC	:	State Planning Committee
SEPU	:	State Economic Planning Unit

WATER QUALITY TEST/ELEMENTS

As	:	Arsenic	Mg	:	Magnesium
BOD	:	Biological Oxygen Demand	N	:	Nitrogen
Ca	:	Calcium	Na	:	Sodium
Cd	:	Cadmium	NH4-N	:	Ammonia Nitrogen
Cl	:	Chlorine	P	:	Phosphorus
Cn	:	Cyanide	Pb	:	Lead
Cr	:	Chromium	PCB	:	Polychlorinate Biphenyl
COD	:	Chemical Oxygen Demand	Ra	:	Radium
DO	:	Dissolved Oxygen	Sr	:	Strontium

F	:	Flouride	SS	:	Suspended Solids
Fe	:	Iron	T-N	:	Total Nitogen
Hg	:	Mercury	T-P		Total Phosphorus
K	:	Potassium			

UNITS OF MEASUREMENT

(Area)			*(Other Measurements)*		
Ha, ha	:	hectare	cusec	:	cubic feet per second
m^2	:	square meter	dia.	:	diameter
km^2	:	square kilometer	H	:	hertz
			kW	:	kilowatt
(Weight)			m^3/s	:	cubic meter per second
Kg, kg	:	kilogram	V	:	volt, voltage
ton	:	1,000 kg	Sq., sq.	:	square
			Cu., cu.	:	cubic
(Volume)			Km, km	:	kilometer
GRT	:	Gross Relative Tonnage	sec, s	:	second
L, l, ltr	:	liter			
m^3	:	cubic meter			
MCM	:	million cubic meters			

MALAYSIAN TERMS

Kg.	:	kampong (village)
P., Pulau	:	island
Sg.	:	sungai (river)

CURRENCY

RM	:	Malaysian Ringgit
US$	:	United States Dollar
¥	:	Japanese Yen

OTHERS

EIA	:	Environmental Impact Assessment
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
LSD	:	Land and Survey Datum
NDP	:	National Development Policy
VSB	:	Very Short Band
PMF	:	Probable Maximum Flood
TWL	:	Tail Water Level
PKP	:	Perlis, Kedah and Penang
355-day discharge	:	the discharge to exceed river flow discharge 355 days a year

CHAPTER 1. INTRODUCTION

1.1 Background

The Muda River is located in the northwestern part of Peninsular Malaysia. In terms of administrative boundary, the upper and middle reaches of the basin belong to the State of Kedah, and the river downstream forms the boundary between the states of Kedah and Pulau Pinang.

The river has been developed as one of the important water resources for agriculture as well as domestic/industrial water supply for both the states of Kedah and Pulau Pinang. Riverbed sand is also extensively mined for use as construction materials. Furthermore, the river is used as a navigation channel for local fishing boats, particularly, around the river mouth. Thus, the river is used for various purposes, but such river uses at the same time contain many associated conflicts and problems to the river environment such as:

(a) increment of flood damage potential due to the increment of properties in habitual flood inundation areas;

(b) shortage of water supply associated with the ever-increasing water demand;

(c) river erosion/sedimentation caused by the inappropriate sand mining operations; and

(d) difficulty to fishing boat navigation due to sediment deposits at the river mouth.

Intensive basin development in the future will also pose a potential problem to the water quality of Muda River. Such problem will possibly aggravate and thus hinder the well-balanced river development unless a comprehensive management plan is introduced.

No comprehensive river basin management plan has been implemented so far and the Government of Malaysia is expecting to use the comprehensive management plan to be formulated for the Muda river basin as a model case to serve as a guide and reference for other river basins in the country. A request for technical cooperation has been made to the Government of Japan to carry out the Study on Comprehensive Management Plan of Muda River Basin (hereinafter referred to as the Study) and, in response to the request, the Government of Japan had decided to undertake the Study which was entrusted to the Japan International Cooperation Agency (JICA), the office responsible for the implementation of technical cooperation programs of the Government. A preliminary study team was dispatched to Malaysia from October 17 to November 4, 1993, and the Study with a study period of 18 months started in March 1994.

1.2 Objectives of the Study

The Study is to formulate a comprehensive management plan for the Muda river basin by integrating the following four components and setting the year 2010 as the target year: (a) flood mitigation plan; (b) water resources management plan; (c) river environmental management plan; and (d) watershed management and monitoring plan. All of these plans are to be formulated on the master plan level.

The objectives of each component of the comprehensive plan are as discussed below.

(1) Flood Mitigation Plan

Both the structural and non-structural plans for flood mitigation shall be studied with particular attention to the natural retarding effect of the river basin. The effect of the present sand mining activities to the stability of the river channel shall also be studied to ensure the success of the proposed river channel improvement.

(2) Water Resources Management Plan

The structural measures to develop water resources shall be studied according to the results of a review made on previous plans. The appropriate water allocation plan in an extra drought year shall also be formulated in due consideration of the interstate requirements of Kedah, Pulau Pinang and Perlis.

(3) River Environmental Management Plan

The plan for the management of quantity and quality of river flow shall be formulated. The management plan for land use along the river corridor and dam reservoir shall also be studied with particular attention to the improvement of river environment.

(4) Watershed Management and Monitoring Plan

The zoning plan for the entire watershed shall be formulated to control the excessive basin development activities that could cause adverse effects on the aforesaid river management plan. The monitoring plan for river activities and basin development activities shall also be formulated to maintain a well-balanced river management. The monitoring plan shall include an institutional set-up to ensure the proposed monitoring and river management works.

1.3 Study Area

The study area for all components of the comprehensive plan except the water resources management plan shall be within the limits of the Muda river basin. Since the water supply area of the water resources of Muda River extends beyond the Muda river basin and covers the whole states of Kedah and Pulau Pinang as well as a part of the State of Perlis, the water demand projection as well as the water supply and demand simulation shall be made for the whole water supply area of Muda River.

The states of Kedah, Pulau Pinang and Perlis are located in the northwestern part of Peninsular Malaysia, occupying a total of 11,252 km^2, i.e., 9,426 km^2 for the State of Kedah, 1,031 km^2 for the State of Pulau Pinang, and 795 km^2 for the State of Perlis. The upper and middle reaches of Muda River belong to the State of Kedah, while the river downstream with a length of about 30 km forms the boundary between the states of Kedah and Pulau Pinang. The Muda river basin has a catchment area of 4,210 km^2, most of which is located within the State of Kedah.

Each of the above three states is administratively divided into several districts, and each district is further divided into parishes called *Mukim* in Malaysian term. The three states cover 17 districts and 239 mukims, out of which the Muda river basin covers 6 districts and 28 mukims.

1.4 Contents of Report

The results of the Study are compiled in four volumes; namely, Volume 1, Summary; Volume 2, Main Report; Volume 3, Supporting Report; and Volume 4, Data Book. The Main Report gives a general presentation of all the results of the Study, which is compiled in brief in the Summary. The Supporting Report is divided into eight Sectors as enumerated below which present the details of the sector studies with supporting data compiled in the Data Book.

- (a) Sector I : Hydrology
- (b) Sector II : Flood Mitigation Plan
- (c) Sector III : Water Resources Management Plan
- (d) Sector IV : River Environmental Management Plan
- (e) Sector V : Watershed Management and Monitoring Plan
- (f) Sector VI : Construction Plan and Cost Estimate
- (g) Sector VII : Socio-Economy
- (h) Sector VIII : Institutional Setup Plan

CHAPTER 2. PHYSICAL FEATURES OF THE STUDY AREA

2.1 Topography, Geography and Soils

Almost all of the northeastern half of the Muda river basin is mountainous, fringed by hilly lands with elevations of more than EL 76 m (250 feet), as shown in Fig. 2.1.1.

The mountainous area is composed of two mountain ranges. One mountain range stretches along the northern half centerline of the basin starting from Mt. Tek Bidan (EL 842 m) in the middle reaches until Mt. Bt. Pakir Terbang (EL 574 m) at the northern end of the basin and includes the mountains with elevation of EL 500 to EL 900 m. The other is called "Bintang Range" stretching from the highest Mt. G. Bintang (EL 1,862 m) in the southeastern end until the northeastern end of the basin and includes many high mountains of more than EL 1,000 m forming the national boundary between Malaysia and Thailand.

The geographical features of the mountain area are represented by the granites developed in the period of orogenesis after late Carboniferous. The plain area in the middle reaches is mainly composed of complex argillaceous rocks, cherts and interbeds of sandstone. As for the middle reaches of Ketil River around Baling, however, the geographic features show a complexity of shales/slates, quartzite/hornfel and limestone that are often crystallized.

The soils of the basin are composed of the alluvial soil, the sedentary soil and the lithosols. The alluvial soil spreads out in the lower reaches from the confluence of the main stream and Ketil River, where the land is fertile and used as paddy production area. The plain area in the middle and upper reaches is covered with sedentary soils where rubber plantation is extensively developed. In the upper mountainous area, the dominant soil is lithosols which is little fertile and not suitable for agricultural production.

2.2 Climate

The study area has two typical monsoons; namely, the northeast monsoon and southwest monsoon. The northeast monsoon usually occurs from November to

February. During this season, the northeast monsoon unloads its moisture contents over the east coast of Peninsular Malaysia. However, the study area located in the west coast receives a little rain during this monsoon due to the sheltering effect of the central mountain range running from north to south in Peninsular Malaysia.

The southwest monsoon usually reaches the west coast of Peninsular Malaysia from the Indian Ocean and prevails over Peninsular Malaysia from May to August. The monsoon contains heavy moisture and causes the fairly heavy rainfall in the study area from April to May.

In the transition period between the above two monsoons, from September to November, the western wind prevails and causes the heaviest rainfall in the study area in a year. Thus, the study area tends to have two rainy seasons in a year; one is from April to May and another, from September to November (refer to Fig. 2.2.1).

The annual rainfall depth in the Study Area is about 2,000 to 3,000 mm. The heavy annual rainfall is observed around the central mountain of Gunong Jerai and the southern mountainous areas declining northward and to the river mouth (refer to Fig. 2.2.2).

The temperature in the study area is around 27°C on average, and its annual variation is less than 2°C. The humidity in the study area varies from the lowest of about 75% in January to the highest of about 88% in October. The annual average sunshine hours is around 7 hours varying from the minimum of less than 6 hours in September to the maximum of more than 8 hours in February. The monthly pan evaporation at Alor Setar is about 135 mm on average containing the lowest of 110 mm in November and the highest of 175 mm in January.

2.3 River Morphology

2.3.1 River System

Muda River with a catchment area of 4,210 km^2 originates in the north mountainous area of Kedah State and flows down toward the south. It changes its course towards the west coast after passing the confluence of the main stream and its tributary, Ketil River. The total length of the main stream is about 180 km.

There are three major tributaries of the Muda river system; namely, Ketil River with a catchment area of 868 km^2, Sedim River with 626 km^2 and Chepir River with 335 km^2. Ketil River is the largest tributary including its secondary tributary, Kupang River, that has a catchment area of 147 km^2.

2.3.2 River Channel Profile

The main channel of Muda River has a length of about 180 km with a slope of 1/2,300 from the river mouth to Muda Dam. The channel lengths and slopes of the tributaries are 70 km and 1/750 for Ketil River, 30 km and 1/550 for Sedim River, and 25 km and 1/800 for Chepir River.

The channel width is 300 m near the river mouth and tends to be narrower upstream. The channel tends to erode due to the sand mining operations, aggravating bank erosion and riverbed degradation. The average riverbed had subsided by 2 to 5 m for the period 1983 to 1994, as proven by the longitudinal profile survey in those years (refer to Fig. 2.3.1) and, in parallel with the subsidence of the riverbed, the water level has also been lowering by 1 to 2 m for the past 20 to 30 years (refer to Fig. 2.3.2).

The riverbed subsidence seriously affects river structures such as bridges and water intake facilities. Foundation piles of the bridge at Ldg. Victoria are exposed by 2 to 3 m above the eroded riverbed (refer to Fig. 2.3.3). Moreover, the lowering of water level also causes difficulty in abstracting water from the river at the existing intake points.

On the other hand, the river mouth tends to be affected by the accumulation of sediment causing aggravation of the riverbed and development of sand bar. DID dredged 1.2 km of the outer channel in 1986, deepening the channel bed to 4 m below LSD, but it silted up by 2 to 3 m in 76 months after dredging (refer to Fig. 2.3.4). The shallowest point surveyed in 1994 is 2 m below LSD at 0.5 km off the river mouth, causing difficulty to navigation during low tide. Judging from the sand mining operations on the river as well as the bed materials mentioned in later subsections, the major cause of sediment accumulation around the river mouth could be either ocean sand drift or the suspended/wash load supplied from Muda River.

2.3.3 Channel Flow Capacity

The bankfull flow capacity was estimated by non-uniform calculation using the updated channel survey results in 1994 (refer to Fig. 2.3.5). The lower stretches of Muda River tends to have a smaller flow capacity than the upper stretches. At many points downstream of the confluence with Sedim River, the flow capacity is to accommodate the flood discharge of less than a 2-year return period. Moreover, low-lying areas are scattered along the Ketil and Chepir rivers where flood inundation of even a 2-year return period occur. In the upper stretches of Muda River from the confluence with Chepir River, however, the river forms a valley, and the elevation of riverbanks is high enough to accommodate the flood discharge of 10-year return period.

2.3.4 River Water Quality

DOE had carried out water quality sampling at 10 sites in the Muda river system for the period 1978-1994 (refer to Fig. 2.3.6). The water quality records by DOE indicate low concentrations of BOD, SS and NH4-N of Muda River. In this connection, DOE had evaluated that Muda River is clean and suitable for domestic water supply (refer to Table 2.3.1).

To clarify the data of DOE, the JICA Study Team also carried out a water quality survey at 10 sites in November 1994 and in May to June 1995 (refer to Fig. 2.3.7). Evaluation of the survey results was made based on the classifications (I, IIA, IIB, III, IV and V) prepared by DOE (refer to Tables 2.3.2 and 2.3.3). Among the classifications, indices of more than Class IV are not acceptable for domestic water supply.

As shown in Tables 2.3.2 and 2.3.3, classified as Class IV or V are the following water quality items: DO, Turbidity, BOD, T. Coliform, NH3-N, Fe, COD, F, Coliform and Se. The water quality changes by various conditions such as discharge, rainfall, sampling location, time, etc. It is, however, necessary to pay a special attention to the water quality indices classified as Class IV and V.

Moreover, among the sampling points, point F-2 contains a low quality of BOD. The point F-2 is located along Jerung River and river discharge directly flows into the downstream of Muda River, which could aggravate the major water intake facilities placed therein.

This low water quality is attributed to the effluent from a rubber factory, as proven by the fact that water quality at sampling point F-1 which is located upstream of the factory shows non-problematic result. The factory has a treatment system with some ponds, however, a part of the effluent is occasionally released directly to the river. Under these conditions, it is indispensable to continue intensive monitoring works on the effluent from the rubber factory, and to execute certain control works.

2.3.5 River Flow Regime

Both the Muda and Kedah rivers tend to have a high flow regime twice a year; one from September to November and another from April to May. The maximum discharge is usually recorded during the primary rainy season from September to November. On the other hand, the lowest flow regime usually occurs either in February or March.

The daily average river flow discharge both for Muda and Kedah rivers was estimated through the Tank Model Simulation. The simulation period is 33 years from 1951 to 1991, and the average flow regime for these years was estimated at five reference points, as below.

River Flow Regime of Muda and Kedah River

Station Name	River System	Catch-ment Area (km^2)	River Flow Regime (m^3/s)					
			Mean	Max.	95-day Discharge	185-day Discharge	275-day Discharge	355-day Discharge
Muda River:								
Nami	Main	1,220	25	145	34	22	11	4
Jeniang	Main	1,740	45	294	62	39	20	8
Victoria	Main	4,010	105	367	145	87	47	20
Kupang	Ketil	704	24	260	30	18	10	5
Kedah River:								
Lengkus	Main	1,270	24	245	23	9	5	4

2.3.6 Riverbed Material

A riverbed material survey was made to know the particle size distribution and specific gravity of riverbed materials at thirty (30) sampling sites. The locations of sampling sites are as shown in Fig. 2.3.8, and the results of laboratory tests on the samples are as shown in Figs. 2.3.9 and 2.3.10.

It was clarified from the results of the laboratory tests that sand (0.074 to 4.76 mm) and gravel (4.76 to 76.2 mm) are dominant on the main stream and tributaries, and the riverbed materials sampled upstream tend to be coarser.

The riverbed materials sampled at the north side of the river mouth are very fine and muddy, while those at the south side are coarse and sandy. Moreover, a sand bar has formed from north to south of the river mouth, as shown in Fig. 2.3.11. These noteworthy facts show that there is a dominant southward ocean current around the mouth of Muda River carrying sandy materials from the north to the south.

2.3.7 River Bed Load

Sediment in the river channel is divided into bed load, suspended load and wash load. Among them, bed load is the most influential in the change of sandy riverbed like the Muda River. In this connection, the bed load sampling test was carried out at 5 locations (refer to Fig. 2.3.8).

Rating curves between the observed bed load and flow discharge were developed for each sampling point from the results of the sampling test, as shown in Fig. 2.3.12. Furthermore, based on the daily discharge records and the bed load rating curves, it was estimated that the annual bed load of Muda River is about 10,000 m^3 (refer to Table 2.3.4).

2.3.8 Fauna and Flora

Muda River had been well known as a habitat of freshwater turtles. However, the number of turtles has remarkably decreased since the sand mining was intensively made. It would now be a kind of endangered species. The artificial breeding of freshwater turtles has been carried out on Penang Island since 1980 and the young turtles have been released to Muda River as well as the rivers in Penang Island. In addition to the freshwater turtles, the following species of fish live in Muda River: River Crab, Climbing Perch, Freshwater Catfish, Swamp Eel, Featherback, Gourami, Snakehead and Goby.

Forest areas cover a large part of the Muda river basin and most of them are delineated as forest reserve by FDHPM. In the forest reserve area, the dominant species identified through the survey for Beris Dam Project are Kedondong, Kelat, Kerwing, Periang and Nyatoh.

Natural vegetation along Muda River is, however, quite limited except the upstream area of Muda Dam. The dominant vegetation along the river are the planted agricultural trees such as rubber tree, oil palm tree, fruit/garden trees, and nippa palm.

CHAPTER 3. FLOOD CONDITIONS

3.1 Flood Prone Areas and Types of Flood

Due to the poor flow capacity of river channels, floods occur almost every year and affect the low-lying residential and agricultural areas. DID had identified the flood-prone areas where three types of flood occur; namely, (a) flash flood; (b) flood associated with extensive inundation; and (c) tidal flood. The flood-prone areas are in the lower and middle reaches, as shown in Fig. 3.1.1.

In the middle reaches, flood-prone areas have been identified in and around the potential urban centers such as Sic and Baling. The typical type of flood at these areas is the flash flood. Flash floods occur due to short but very intensive local rainfall. When such flash floods occur, floodwater levels tend to suddenly rise but subside within a short period after the rainfall stops.

In the middle reaches, the flood-prone area has also been identified in and around Kuala Ketil where the development of an urban center associated with an extensive industrial area is planned. This area tends to be affected by flood associated with extensive inundation due to widespread and prolonged heavy rainfall. This type of flood often lasts for more than two or three days.

In the lower reaches, the flood-prone area is located along the downstream from Muda Barrage. This flood-prone area is threatened with flooding by a combination of high tide and flood runoff discharge flowing from the upstream. When flood runoff discharge flows down during high tide, the flood runoff water rises by the backwater effect of the high tide and may spill over the banks.

3.2 Maximum Flood Recorded

The maximum flood recorded occurred in November 1988, the worst since the flood in 1967. In this flood, rainfall continued from November 20 to 23, 1988, and the heavy rainfall was biased to the northern mountainous areas (refer to Fig. 3.2.1). The daily rainfall at Pedu Dam exceeded 200 mm on November 20. Such biased heavy rainfall in the northern area caused spilling over the Muda dam crest. At

Ldg. Victoria which is located in the lower reaches, the flood discharge exceeded 1,000 m^3/s for three days from November 24 to 26. Moreover, at the Jeniang Gauging Station which is located in the middle reaches, the water level continued to exceed the danger level for six days from November 21 to 26.

Due to such high water level, inundation occurred along almost all the entire stretch in the middle and lower reaches. In the "Annual Flood Report, 1988," the flood damage to riverbanks in the Muda river system was estimated at RM 1,224,000, but no casualties were reported.

The inundation areas were identified on 1 is to 10,000 toposheets newly prepared in 1994 through a series of field investigation and interview surveys (refer to Figs. 3.2.2, 3.2.3 and 3.2.4). The total inundation areas and number of houses and buildings affected are as tabulated below.

Flood Inundation Area and Number of Houses Affected by 1988 Flood

River	Survey Area	Inundation Area (km^2)	No. of Houses and Buildings Affected
Muda	River Mouth to Jeniang Barrage	65	5,300
Ketil	Muda River to Baling Town	9	600
Chepir	Muda River to Sik Town	4	200
Total		78	6,100

The recurrence probability of the 1988 flood at Ldg. Victoria, Jeniang Cable and Kuala Pegang was estimated through normal log distribution. As the results, the return period of 1988 flood is as long as 140 years at Jeniang and 45 years at Ldg. Victoria, while that of Kuala Pegang is 5.5 years because of less rainfall in the Ketil river basin, as summarized below.

Recurrence Probability of 1998 Flood

River	Discharge Station	Return Period of 1988 Flood Discharge	Return Period of 1988 Flood Rainfall
Muda	Ldg. Victoria	45.0 years	30 years*
	Jeniang Cable	140.0 years	40 years*
Ketil	Kuala Pegang	5.5 years	10 years**

* 3-day rainfall
** 1-day rainfall

In mid-September 1995, flood caused by Tropical Storm Ryan occurred in the Muda river basin. Newspapers had reported that the water level rose over danger levels at the downstream and middle stretches of the Muda and Ketil rivers and many people living along these rivers had evacuated to relief centers. This flood seems to be a little smaller than the 1988 flood judging from the water level records obtained.

3.3 Probable Rainfall and Probable Flood Runoff Discharge

3.3.1 Probable Rainfall

The dominant storm rainfall duration was clarified for each reference point in the Muda river basin on the basis of the hourly rainfall records in eleven storms. Then, the probable rainfall for each storm rainfall duration was estimated by the logarithmic normal distribution of annual basin average maximum rainfall for a 34-year period from 1959 to 1992. The results of the estimation are as tabulated below.

Probable Rainfall at Each Reference Points in Muda River Basin

Reference Point	Catchment Area (km^2)	Rainfall Duration	Probable Rainfall for Each Return Period (mm)					
			2-year	5-year	10-year	20-year	50-year	100-year
Jeniang	1,740	3-day	120	144	159	172	188	199
J. S. Omar	3,330	3-day	104	123	134	144	156	165
Ldg. Victoria	4,010	3-day	100	119	130	140	153	161
K. Pegang	704	1-day	59	72	81	88	97	104
Sik	153	1-day	69	82	90	97	105	111

3.3.2 Probable Flood Runoff Discharge

Based on the probable basin rainfall with 1- or 3-day rainfall duration, the actual hourly rainfall recorded in the 11 major floods was enlarged in the following manner:

$$T^N = R^N / Ra$$

Where,

T^N : Adjustment rate for N-year return period

R^N : Probable basin rainfall of N-year return period for fixed rainfall duration

Ra : Recorded rainfall in actual flood

N : Return period (5, 10, 20, 50 and 100-year)

The recorded hourly rainfall enlarged as described above was assumed as the model hyetograph of N-year return period for each of the 11 actual major floods. Then, the flood discharge hydrographs corresponding to each return period were estimated by applying the model hyetographs and the Storage Function Model used for flood runoff simulation.

The peaks of the estimated flood discharge hydrographs were provisionally assumed as the probable discharge enlarged from the 11 actual major floods. The typical probable flood discharge was then assumed as the value to cover 70% of the above peak discharges enlarged from the 11 actual major floods. On the premise of the coverage rate of 70%, the fourth largest enlarged peak discharge was selected as the typical probable discharge.

In the above estimation of the probable flood runoff discharge, however, the natural flood regulation effect by the existing Muda Dam was not taken into consideration. Muda Dam is solely a water supply purpose dam and does not have any specific flood control capacity. However, the dam inflow discharge is naturally regulated by the surcharge volume above the spillway crest.

The dam water level will increase as the dam inflow discharge increases, and the water impounded by the dam starts to overflow when the water level exceeds the crest level of the spillway. The overflow discharge could be calculated by the dam inflow discharge together with its reservoir storage capacity curve and its spillway discharge rating curve. Thus, the following probable flood runoff discharges were estimated on the premise of the natural regulation by Muda Dam, and adopted as the final estimated values for the Muda river basin (refer to Fig. 3.3.1).

Probable Discharge at Reference Points in Muda River Basin

Reference Point	Catchment Area (km^2)	Probable Discharge for Each Return Period (m^3/s)				
		5-year	10-year	20-year	50-year	100-year
Muda Dam Site	984	230	270	310	370	420
Jeniang	1,740	390	470	560	680	770
J. S. Omar	3,330	700	810	920	1,060	1,160
Ldg. Victoria	4,010	810	950	1,080	1,260	1,340

3.4 Probable Flood Inundation Area

The probable extent of flood inundation caused by the runoff discharge of 100-year return period was estimated through the non-uniform calculation using the topographic and channel survey results taken in 1994 (refer to Figs. 3.4.1 and 3.4.2). Belt-shaped areas along the Muda and Ketil rivers are possibly submerged under flood water. The width was as wide as 1 to 5 km in the lower stretches of Muda River downstream of the confluence with Ketil River, while it was narrower and 1 km at the maximum in the upstream valley. Such definite tendency was not found for Ketil River, and it varied from 0.5 m to 2 km due to local topographic conditions. The total inundation areas and the number of houses and buildings located there are as summarized below.

Probable Flood Inundation Area

River	Stretch	Length (km)	Inundation Area (km^2)	No. of Houses and Buildings
Muda River	River Mouth to Ldg. Victoria (Lower Muda River)	40.3	45.0	5,640
	Kuala Ketil Town Stretch *1	5.4	1.4	610
	Ldg. Victoria to Prop. Jeniang Barrage *2	72.9	33.1	560
Ketil River	Muda River to Kg. Tg. Merbau *2	39.2	16.9	1,200
	Baling Town Stretch	0.8	0.3	200
Chepir River	Sik Town Stretch	0.8	0.2	160
Total		159.4	96.9	8,370

*1: Left side of the stretch from Cross Section No. 60 of Muda River to Cross Section No. 1 of Ketil River.
*2: Excluding Kuala Ketil Town Stretch.

3.5 Existing Flood Mitigation Facilities

The Muda river system has hardly been provided with flood mitigation works other than the construction of a Muda river bund and the flood forecasting and warning system. The Muda river bund was constructed downstream along the left bank of the Muda main stream by a private enterprise about a century ago (refer to Fig. 3.5.1). It has been maintained and rehabilitated by DID. The purpose of the bund is to confine flood discharge of the Muda River in its own course and protect the low-lying Pulau Pinang area from flooding. The latest rehabilitation of the bund was carried out in 1987. In the 1988 flood, the bund was able to get rid of overflow with a freeboard of 9 inches.

In addition to the above bund construction, DID had established a flood forecasting and warning system which is composed of water level monitoring stations, warning stations and flood operation rooms. The State DID Kedah had established water level monitoring stations at ten (10) sites and the State DID Pulau Pinang, at two (2) sites (refer to Fig. 3.5.2). For each of the monitoring stations, three (3) critical water levels are designated; namely, alert, warning and danger levels.

The water level readings are reported to the state flood operation room once in three hours when the water level exceeds the alert level, and every hour when it exceeds the danger level. The water level readings of Jeniang and Jam. Syed Omar are also sent to DID Pulau Pinang.

Among the monitoring stations, six (6) stations are scheduled to be equipped with a telemeter data transmission system. These stations are Jeniang, Jam. Syed Omar, Pinang Tunggal and Bumbung Lima along Muda River, and Kg. Baru and Rumah Pam Pulai along Ketil River.

The warning stations with sirens are located in the upstream areas which are subject to flash floods. The sirens are automatically activated when the river stage reaches the warning level; thus, giving immediate warning to the surrounding population.

The flood operation rooms are set up annually at DID state and district offices from the 1st of August to the 15th of January to forecast the flood conditions and issue the necessary instructions. The rooms are provided with communication equipment such as VHF set, telephones and facsimile machines to receive or send information such as rainfall, water level, warnings, flood damage and evacuation.

CHAPTER 4. PRESENT USE OF MUDA RIVER

4.1 River Structure

The Muda Dam was constructed in 1969 on the main stream about 130 km upstream from the river mouth. The dam catchment area and active storage capacity are 984 km^2 and 160 million m^3, respectively. The dam stores almost all of the basin runoff discharge conveying it into the adjacent Pedu Dam that has an active storage capacity of 1,049 million m^3 in the upper reaches of the Kedah River. The water conveyed to Pedu Dam is principally used for the Muda irrigation scheme of about 97,000 ha; hence, the present competent authority for operation and maintenance is MADA. Thus, the catchment area of Muda Dam is a part of the Muda river basin in terms of topography, but it belongs to the Kedah river basin in terms of hydrology.

The Muda Barrage was also constructed in 1972 about 10 km upstream from the river mouth to supply domestic and industrial water as well as irrigation water for the State of Pulau Pinang and the southern part of the State of Kedah. The present competent authority for operation and maintenance of the barrage is the Penang Water Authority (PWA).

Moreover, there are 12 intake facilities for domestic/industrial water supply and 28 intake facilities for irrigation water supply. These intake facilities are operated by various organizations such as DID and PWD in the State of Kedah and DID and PWA in the State of Pulau Pinang. All major intake facilities are located along the impounding extent of Muda Barrage, abstracting about 80% of the basin total intake volume except the volume conveyed from Muda Dam to Pedu Dam (refer to Tables 4.1.1 to 4.1.3 and Figs. 4.1.1 to 4.1.2).

4.2 River Sand Mining

As of September 1993, there were 95 permit holders for mining operations on the Muda river channel in the State of Kedah. As for the State of Pulau Pinang, a total of 9 mining sites have been designated. These mining sites are concentrated between Muda Barrage and the proposed Jeniang Barrage, as shown in Fig. 4.2.1.

The annual sand mining volumes recorded for the recent three years were about 500,000 m^3 in 1991, 900,000 m^3 in 1992 and 1,200,000 m^3 in 1993. According to the officials concerned, however, the mining volume in 1990 reached the peak and was much more than those in recent three years due to use as construction material for the North-South Expressway.

These mining volumes are much greater than the annual bed load of about 10,000 m^3 and, therefore, have caused serious subsidence of the riverbed. The present mining activities have also affected the surrounding river environment due to the following unfavorable conditions:

(a) Abandonment of mining equipment in river channels and riverbanks;

(b) Pipes and ropes crossing the river course, which hamper navigation;

(c) Illegal construction of access road to the river channel which reduce the river channel width; and

(d) Absence of proper drainage from sand stockpiles.

4.3 Water Supply from the River

4.3.1 Water Demand

The present water demand to be supplied from Muda and Kedah River is estimated at about 2,026 million m^3/year which is divided into of about 339 million m^3/year for domestic and industrial water and 1,687 million m^3/year for irrigation water, as summarized below.

Present Water Demand

Demand Items	Gross Demand		Required from River	
	($10^6m^3/yr$)	(%)	($10^6m^3/yr$)	(%)
1. Domestic/Industrial				
(a) Kedah State	129	4.5	136	6.7
(b) Pulau Pinang State	166	5.8	194	9.6
(c) Perlis	9	0.3	9	0.4
Sub-Total	304	10.6	339	16.7
2. Irrigation Water				
(a) Muda Scheme	1,977	68.9	1,391	68.6
(b) Balik/Seberang	156	5.4	80	4.0
(c) Others	433	15.1	216	10.7
Sub-Total	2,566	89.4	1,687	83.3
Grand Total	2,870	100.0	2,026	100.0

Domestic/industrial water is supplied to the states of Kedah, Pulau Pinang and Perlis. Among the three states, the State of Pulau Pinang is the largest domestic/industrial water user abstracting 194 million m^3/year solely from the downstream of Muda River. The State of Kedah is the second largest abstracting about 136 million m^3/year. The remaining volume of about 9 million m^3/year is supplied to the State of Perlis from both Muda and Kedah River.

The total population served for domestic and industrial water is estimated at 837,000 in the State of Kedah, 750,000 in the State of Pulau Pinang and 42,000 in the State of Perlis. The service factor is about 97% in Pulau Pinang, 67% in Kedah and 83% in Perlis.

Irrigation water is supplied to 60 schemes. Among them the Muda irrigation scheme is the largest water user occupying 97,000 ha over the State of Kedah to the State of Perlis. The irrigation water demand from the Muda and Kedah rivers to the Muda scheme is about 1,391 million m^3/year (about 70% of the total water demand). The Seberang Perai irrigation scheme of 8,000 ha is the second largest user which is located in State of Pulau Pinang with the water demand of about 80 million m^3/year (about 4% of the total demand) being abstracted from the Muda River.

In addition to the above two main granary areas, there are 58 secondary and minor irrigation schemes of 18,800 ha in total composed of 34 schemes (8,400 ha) in Muda river basin and 24 schemes (10,400 ha) in Kedah river basin. Most of the schemes are located either in the fringes of Muda or on the right bank of the Muda lower reaches. The water demand from the rivers to these schemes is estimated at 220 million m^3/year (about 11% of the total demand).

4.3.2 Water Deficit

When the natural river flow discharge is deficient in supplying the above water demand, such deficiency is supplemented by the release from the storage volume of the three existing dams, the Muda, Pedu and Ahning dams. The supplementary supply from the existing dams is, however, not always guaranteed due to the limitation of dam storage volume. Moreover, the three existing dams are designed to supply the

Muda irrigation and its surrounding area, but not the area located downstream from Muda Dam due to the existing water conveyance system described in Section 4.1.

According to the interview survey, Muda as well as other existing irrigation schemes have been suffering from chronic shortage of irrigation water supply and the reduction of paddy planted areas was often required due to the water shortage. Serious water shortage tends to occur in the least rainfall months of January to March, and even domestic and industrial water supply was curtailed on these months in the drought year of 1978.

4.3.3 Water Use Ratio

The present water use ratio of the annual average intake water volume to the annual average natural runoff discharge volume is estimated at about 64% for the Kedah river system. Such high water use ratio indicates that the present water resources development for the Kedah river system by the three existing dams (Pedu, Muda and Ahning dams) has reached the critical level and it is virtually difficult to induce further water resources development. In contrast, the water use ratio of the Muda river system is estimated at 14%, and thereby, the future water resources development for the study area could be made only in the Muda river basin. In fact, all ongoing water resources development projects such as the Beris dam project and the Jeniang transfer system project placed their projected water sources on the Muda river system.

4.4 Navigation

The Muda river mouth is being used as a port by about 200 fishing boats. There are landing and mooring facilities in Kedah State (the right bank) and Pulau Pinang State (left bank). All of the boats are as small as 10 GRT with draft of 1.0 m, however, navigation has to be suspended during low tide due to the siltation at the river mouth.

Aside from the navigation of fishing boats around the river mouth, no other navigation prevail due to the development of a road network with bridges and the sand mining activities which hinder navigation because of ropes and pipes crossing the river channel. There is only one regular ferry crossing the downstream of Muda River from the Muda Barrage between Kota Kuala Muda at the right bank in the State of Kedah and Penaga Village at the left bank in the State of Pulau Pinang. The carrying capacity of the ferryboat is, however, limited to less than five passengers.

CHAPTER 5. ONGOING BASIN DEVELOPMENT CONDITIONS

5.1 Gross Domestic Product

The Gross Domestic Product (GDP) of the states of Kedah, Pulau Pinang and Perlis is expected to increase from about RM 13,000 million in 1993 (at the 1978 price) to RM 20,000 million in 2000, and the average annual growth rate is to be 7.5% for 1990-2000, which is almost equivalent to the national average. A notable growth of around 10% per year of GDP is expected in the secondary sector (industry sector), while the growth in the primary sector (agricultural sector) will diminish to less than 5%.

5.2 Agricultural Development

About 1,780 km^2 or 42% of the Muda river basin has been developed as agricultural land and the remaining area of about 2,400 km^2 is mostly kept as forest/shrub area. Settlement area covers only 0.05% of the entire basin (refer to Table 5.2.1 and Fig. 5.2.1).

Agricultural lands extend particularly in the lower and middle reaches along Muda River and its tributaries. A greater part of the agricultural land is used as rubber plantation area occupying about 33% of the basin. The remaining area consists of mixed horticulture area (4%), paddy area (3%), and oil palm area (2%). The mixed horticulture areas are usually located near settlement areas and tend to be unevenly distributed on the riverside areas.

The share of the agricultural sector in the economy of the State of Kedah has been gradually declining; i.e., from 54.2% share in 1980 and 37.5% in 1990. This declining tendency is attributed to the transfer of labor to non-agricultural activities. It is, however noted that a specific national policy emphasizes a target to secure a minimum self-sufficiency level of 65% for rice production by the year 2010. Due to this national policy, the future rice production will not be drastically reduced as compared with the present rice production. In parallel with the decline of agricultural GDP, the expansion of agricultural land has been minimal. In fact, the period

1982-1990 recorded the overall development area of only about 2.5% over eight years or 0.3% annual growth.

5.3 Forest Reserve

The present forest area spreads out in the upper reaches of Muda River, and this area is delineated as forest reserve under the control of the Forest Department (refer to Fig. 5.3.1). The total area of the forest reserve area is 2,361 km^2 or 56% of the Muda river basin (refer to Table 5.2.1). Logging could be legally made in most parts of the present forest reserve area, which may be attributed to the fact that logging is the second biggest source of revenue for the State of Kedah.

The logging schedule/volume could not be clarified due to insufficiency of basic information. However, it was confirmed through the latest aerial photographs as well as the field reconnaissance that the catchment area of the proposed Reman dam sites has been cleared entirely and used as rubber plantation, which will possibly aggravate the quality of water in the reservoir. Furthermore, due to lack of coordination, there is no assurance that the existing Muda dam reservoir will be well protected by the delineated forest reserve.

5.4 Population

The Muda river basin covers 28 *Mukims* in the State of Kedah, occupying about 44% of the State of Kedah. The population in the State of Kedah is, however, unevenly distributed to the low-lying coastal area, and Muda river basin which is mostly located in the inland area is less populated. The total population of the basin is less than 30% of the state total (refer to Table 5.4.1).

The average population density of the Muda river basin is estimated at about 86 persons/km^2 in 1991 which is less than the average of the entire State of Kedah (138 persons/km^2). There is, however, a large spatial variation of the basin population density, which is roughly divided into the following three groups: (a) high population density of about 443 persons/km^2 in the lower reaches of Muda River; (b) middle population density of about 132 persons/km^2 in the lower reaches of Ketil River; and

(c) low population density in the middle and upper reaches of Muda River (refer to Table V.5.4.2 and Fig. 5.4.1).

The high population density in the lower reaches of Muda River is due to the fact that the lower reaches is adjacent to the major urban area of Sungai Petani in the State of Kedah and Butterworth in the State of Pulau Pinang.

The middle population density in the lower reaches of Ketil River is almost equivalent to the average total. The lower reaches of Ketil River is rather populated particularly in and around the existing major settlement areas of Kuala Ketil, Kupang and Baling.

The low population density in the middle and upper reaches of Muda River corresponds to about 10% of the state average. Such extremely low population density is attributed to the hilly topography and poor soil associated with insufficient infrastructures. Most of the basin belong to this area of low population density; therefore, the basin average population density falls below the state average.

5.5 Urban Development

There are eight (8) major urban areas with a population of more than 10,000 in the State of Kedah. The total population of these urban areas is about 425,000, corresponding to 33% of the state total. All of these urban areas are, however, located in the low-lying coastal area and out of the Muda river basin. To redress the partial concentration of population in the coastal area, the Kedah Regional Development Authority (KEDA) has proposed to develop 30 urban centers in the inland area by the year 2000. Among these 30 urban centers, KEDA projected six centers in the Muda river basin; namely, Baling, Kuala Ketil, Kupang, Bukit Selambau, Jeniang and Sik. (refer to Fig. 5.5.1). These urban centers are projected to have the following population by the year 2000 assuming the annual population growth of 3.5%.

Projected Population in Six Urban Centers in Muda River Basin

Name of Town	Population in 1991	Population in 2000
(a) Baling	6,500	9,200
(b) Kuala Ketil	4,800	6,800
(c) Kupang	3,000	4,200
(d) Bukit Selambau	2,900	4,100
(e) Jeniang	2,500	3,500
(f) Sik	2,200	3,100
Total	21,900	30,900

All of these centers except Bukit Selambau are located adjacent to the river channel, so that aggravation of river functions could locally occur, particularly, in the aspect of river water quality and flood damage potential.

5.6 Industrial Development

As shown in Table 5.6.1, an industrial area of about 1,800 ha has been developed, and out of the developed area, about 1,500 ha is now in operation in the states of Kedah and Pulau Pinang. Thus, the occupancy rate of the industrial development area, i.e., the ratio of industrial area in operation to the industrial development area, is estimated at about 80%.

The present industrial area in the State of Kedah has been developed either by the Kedah State Economic Corporation (KSDC) or the Kedah Regional Development Authority (KEDA). The area developed by KSDC is mostly for the large and medium scale industries being biased in the coastal area and taking an overwhelming share of about 97% of the state total. On the other hand, the area developed by KEDA is for small and medium scale industries mainly in the inland area.

There are three industrial areas located in the Muda river basin; namely, Baling, Sik, and Jeniang, all of which were developed by KEDA. However, these industrial areas in the basin cover only 14.52 ha in total, which correspond to 2.2% of the state total.

The industrial areas in the State of Pulau Pinang are mainly developed by the Pinang Development Corporation (PDC). Such industrial areas concentrate in and around Butterworth in Seberang Perai and Bayang Lepas in Pinang Island due to the convenient use of the international seaports and airports. About 70% of the water demand in these industrial areas are supplied from Muda River.

The accumulated industrial development area is projected by the state government to be about 5,700 ha in total (2,830 ha in the State of Kedah and 2,870 ha in the State of Pulau Pinang) by the year 2000 (refer to Table 5.6.2). There are 39 industrial development areas projected in the year 2000 (refer to Fig. 5.6.1). Among these industrial areas, six areas are located in the Muda river basin; namely, Kuala Ketil, Baling, Sik, Jeniang, Tikam Batu and Bukit Selambau. All of these sites are to be developed as a part of the aforesaid urban centers except Tikam Batu. Particularly, Kuala Ketil will have a noteworthy growth due to easy access to the present intensive industrial areas in and around Sungai Petani, Kulim and Butterworth.

The industrial area in Kuala Ketil currently does not exist but will be about 740 ha in the year 2000. The area is placed along the left bank of the Muda main stream between the confluence of Ketil River and Sedim River covering a substantial part of the probable flood inundation area of 100-year return period, as shown in Fig. 5.6.2. Thus, the proposed industrial area in Kuala Ketil contains a flood damage risk, and a certain coordination will be required between industrial development and the river management for flood mitigation.

5.7. Present River Basin Management and Monitoring System

5.7.1 Overall System

The present monitoring system for Muda River covers three (3) territories which are independently managed by the State of Kedah, the State of Pulau Pinang and MADA (refer to Table 5.7.1 and Fig. 5.7.1). Monitoring by the State of Kedah and the State of Pulau Pinang is respectively made within the limits of each state boundary. The catchment area of Muda Dam is, however, not included in the monitoring coverage of the State of Kedah although the area is located within the state. Instead, the catchment is under the monitoring of MADA for the sake of irrigation supply from Muda Dam to the Muda irrigation scheme.

Thus, there does not exist any integrated monitoring system for the entire river basin. Furthermore, the existing system is available to monitor the river hydrology including rainfall, the water level, the flow discharge and the water quality, but not available to monitor sediment load, the indispensable information to control river channel erosion caused by the present excessive sand mining operations. There exists no system to monitor the river environments such as river biology (fauna and flora), river scenery, and also to monitor the basin land development conditions as well as the forest reserve conditions that are the dominant factors on the basin runoff conditions and the basin sediment yield. Moreover, the number of existing hydrological monitoring stations is not necessarily sufficient as described in CHAPTER 6.

5.7.2 The System Controlled by the State of Kedah

The major monitoring items are water level and rainfall for flood forecasting and warning. There are ten (10) water level monitoring stations, out of which three (3) stations are for common use of rainfall monitoring. All monitored data are transmitted on real time base through VHF or telephone system to the State DID Office which is located at Alor Setar. It is, however, scheduled that the data transmission system from six (6) monitoring points is improved to a telemetry system in 1994.

River channel erosion and/or sedimentation are also monitored by DID through periodical on-site inspection. Furthermore, the water quality of Muda River is monitored by DOE at 17 sampling points. In addition to the DOE's sampling point, PWD also monitors the water quality at its 17 intake points and sends the results of monitoring to DOE.

Low flow water level is monitored by DID at its 28 irrigation intake points and also by DOE at its 17 intake points for domestic and industrial water. The monitored data are, however, sent to their head offices on non-real time base. Furthermore, the schedule of water intake is independently made in accordance with the low flow data monitored at each intake point. Thus, nobody knows the integrated water intake volume from the entire river stretch, and the monitored data are not substantially reflected to the comprehensive control of low flow regime as well as water allocation for each intake point of Muda River.

5.7.3 The System Controlled by MADA

The monitoring system under MADA was developed to rationalize water allocation for the Muda irrigation scheme using local rainfall and the runoff discharge from the catchment area of Muda Dam as the water source. There are 70 rainfall monitoring stations consisting of 39 manual gauging stations and 31 telemetry gauging stations. Among the telemetry gauging stations, 26 stations are commonly used by water level gauging stations at key locations along Kedah River and at the inlet point of the conveyance tunnel from Muda Dam to Pedu Dam. Water quality is also monitored at the reservoir of the Pedu and Muda dams. All monitored data could be transmitted to the head office of MADA which is located in the suburbs of Alor Setar on real time base. Thus, monitoring on the catchment area of Muda Dam is independently made by MADA, and rather isolated from monitoring on the lower reaches of the dam.

5.7.4 The System Controlled by the State of Pulau Pinang

There are two (2) water level gauging stations along the downstream of Muda River. These gauging stations are used, in principle, for flood forecasting and warning, as well as monitoring of low water level of the downstream stretch of Muda River within the State of Pulau Pinang. The water level monitored by the State of Kedah at two stations (Jeniang and Jam Shed Omar) are also transmitted to the State of Pulau Pinang for the sake of flood forecasting and warning. Thus, as far as flood forecasting and warning is concerned, interstate monitoring is made, although it is still in a preliminary level.

5.8 Institutional Setup for River Management

5.8.1 Existing Institutional Framework

The activities related to river management in both the states of Kedah and Pulau Pinang are managed by various government and/or semi-government agencies under the supervision of the State Executive Council (EXCO), the State Planning Committee (SPC) and the State Economic Planning Committee (SEPC), which are all chaired by Menteri Besar of the State of Kedah or the Chief Minister in the case of the State of Pulau Pinang.

The principal task of EXCO is to formulate the state development policies. The main functions of the State Planning Committee is to promote in the state and to advise the State Government, within the framework of the national policy, the conservation, use and development of all lands in the state. The SPC is therefore responsible for the physical planning of land use in the state.

The State Economic Planning Committee acts as the coordinating body for the development policy established by EXCO, and the development projects proposed by each agency in charge. All development projects submitted by each agency for implementation are subject to the final approval of SEPC and EXCO.

The Secretariat to SEPC is the State Economic Planning Unit (SEPU), the lead developing planning agency at the state level. It acts as the liaison between the Economic Planning Unit at the federal level and the various agencies at the state level. It is also responsible for the formulation of development plans and for policy advice within the state, for coordination of development initiatives among different agencies and administrative support services to EXCO and various committees regarding development issues. The main water use agencies in the states of Kedah and Pulau Pinang are as discussed below.

The functions of the State Drainage and Irrigation Department are to provide irrigation facilities for cultivation of padi (rice) and other crops, to provide drainage facilities for the advancement of agricultural activities, to maintain and to improve river flow which includes flood mitigation works, and to collect hydrological data for studies to evaluate the development and management of water resources.

In Kedah, domestic and industrial water supply is the responsibility of the Kedah State Public Works Department. In Pulau Pinang, however, under the Penang Water Enactment, 1972, which was passed on August 7, 1972 and became effective in January 1973, the functions and duties related to the supply of water in the State of Pulau Pinang were transferred from the City Council of George Town and the Public Works Department of Penang to the Penang Water Authority (PWA).

MADA which was established in 1970 is responsible for the Muda Irrigation Scheme with paddy development as its main activity. Since MADA is the largest water user in the Kedah river basin, it is also responsible for water allocation and management within the basin, through the operation of the Muda, Pedu and Ahning dams.

Other agencies which are indirectly involved in river management and/or river basin management are the State Forestry Department, the State Land and Mines Department, the local authorities, and the State Town and Country Planning Department.

5.8.2 Major Issues and Problems

Through the interview survey on the above institutional setup, two (2) major problems were initially recognized. The first problem is the lack of a state inter-agency coordinating body to implement a comprehensive management work. Due to the lack of such coordinating body, various inconsistent river management works are seen in each of the states of Kedah and Pulau Pinang. In the State of Kedah, the present water intake from Muda River is, for instance, made independently by PWD for the domestic/industrial demand and by MADA/DID for the irrigation demand without any coordination among them. Even the present irrigation schemes managed solely by DID have their own water intake schedule without any coordination with the other schemes. SPC is apparently having a function to coordinate the inter-related agencies and to determine/approve rather general and/or broad directions of waterworks. However, the function of SPC does not extend to the formulation of a detailed and well-coordinated implementation plan for river management.

The second problem is the lack of an interstate coordinating body for the river management works among the states of Kedah, Pulau Pinang and Perlis. The present water resources of Muda River is used by the states; however, there does not exist any integrated coordinating body as well as any agreement among the states to allocate the water supply for each state. This problem is currently rather latent as water shortage of Muda River has been seldom experienced. However, the future more intensive use of water resources of the Muda River would induce a serious argument among the states.

An interstate committee for the development of the Northern Region has been organized by four (4) states, that is, Perlis, Kedah, Perak and Pulau Pinang. The chief minister of each state is a major member of the committee, and the secretariat office is placed in the State of Pulau Pinang. The committee is likely to have a function to discuss/coordinate the development policy for Muda River, but the detailed implementation plan for the river management works for Muda River could not be made through the committee.

CHAPTER 6. FLOOD MITIGATION PLAN

6.1 Structural Plan

6.1.1 Design Flood Level

The design flood level is proposed to correspond to the probable flood runoff discharge of 50-year return period in due consideration of the recurrence probability of the recorded maximum flood in 1988, the guidelines prepared by DID, and the design flood levels applied in the recent flood mitigation plans on the strategic rivers.

Among the floods recorded since 1967, the 1988 flood has the largest scale causing the flood inundation of about 78 km^2 in the low-lying area in the Muda river basin. The recurrence probability of the peak discharge at Ldg. Victoria in the 1988 flood was estimated at about 45-year return period (refer to CHAPTER 3, Subsection 3.2).

A return period of 50 to 100 years has been applied for recent flood mitigation plans on the strategic rivers. Moreover, the guidelines for the design flood prepared by DID applies the design flood of 25 to 50-year return period for agricultural areas and 100-year return period for urban areas. The present flood prone areas in the Muda river basin are used as agricultural land, but several urban and industrial development plans are being implemented as described in CHAPTER 5, Sections 5.5 and 5.6. In due consideration of such ongoing urban and industrial development plan, the design scale of 50-year return period specified in the guideline is found adequate for the basin development conditions of the Muda river basin.

6.1.2 Target River Stretch and Design Discharge

The flood-prone areas widely spread along Muda River and its tributaries (refer to CHAPTER 3, Section 3.1). It is, however, economically unfeasible to provide all the stretches with structural measures. Structural measures shall be concentrated to high priority stretches to be selected considering their land use, population, assets, future development and severity of flood damage. For the other low priority stretches, non-structural measures shall be considered to minimize flood damage, preserving the existing retarding effect.

Therefore, four (4) stretches were selected as target stretches for the structural flood mitigation plan. The target stretches selected and their design discharge are summarized as below (refer to Fig. 6.1.1).

Target River Stretch for Structural Flood Mitigation Works

River	Stretch	Length (km)	Reference Point	Design Discharge (m^3/s)
Muda River	Lower Muda River	40.3	Ldg. Victoria	1,300 *
	Kuala Ketil Town	3.5	Jam. Syed Omar	1,100 *
Ketil River	Kuala Ketil Town	1.9	Confluence with Muda River	700
	Baling Town	0.8	Pulai	500
Chepir River	Sik Town	0.8	Sik Town	130

* Regulated discharge by Muda Dam Reservoir.

It is herein noted that the existing Muda Dam has a significant natural flood regulation effect by its retention volume and, therefore, such natural regulation effect is incorporated into the design discharge listed above.

6.1.3 Alternative Structural Measures

Structural measures generally include river channel improvement and construction of a bypass floodway, a retarding basin and a flood mitigation dam reservoir. Among them, a bypass floodway is difficult for Muda river basin due to the topographic conditions. A suitable area for a retarding basin also was not found along the rivers.

As for the flood mitigation by dam reservoir, there are several potential dam sites in the Muda river basin. The catchment area of these potential dam sites are, however, extremely small and the flood mitigation effects by them are judged to be nil. Consequently, river channel improvement works are solely selected as the possible structural measures for Muda river basin.

This river channel improvement aims at increasing flow capacity of the channel by deepening, widening and canalizing the existing river channel and constructing dikes on the banks. Among the target river stretches, the Lower Muda River of 40 km in length will have long continuous dikes to confine the design discharge in a design channel. On the other hand, the short target stretches such as Kuala Ketil Town, Baling Town and Sik Town are to be protected by short dikes with particular attention to minimize the adverse effects on the present natural retarding effects caused by the short dikes.

6.1.4 Preliminary Design of River Improvement Plan

The preliminary design for the four (4) target river stretches were made as discussed below.

(1) River Alignment

The proposed river alignment is, in principle, to follow the existing alignment so as to minimize construction cost, land acquisition, house evacuation and relocation of the existing structures. As for the target stretch for Kuala Ketil Town improvement works, however, a cut-off channel is proposed to reform an excessive meandering stretch that tends to decrease flow capacity and cause bank erosion.

(3) Longitudinal Profile

The existing average riverbed profile is proposed as the longitudinal profile considering that the existing riverbed has been formed as the result of long-term natural phenomena and could be stable should the present excessive sand mining be suspended. The design high water level is also set below the ground level of the hinterland so as to minimize the flood damage potential.

(4) Cross Section

Among the target river stretches, the stretch for the Lower Muda River Improvement Works adopts the compound cross section composed of a low water channel and a high water channel to minimize embankment height and to assure channel stability. The cross section of the low water channel is determined to confine the existing flow capacity of 600 m^3/s. As for other target river stretches, however, the single cross section is adopted in due consideration of difficulty of land acquisition, smaller design discharge and the present shape of the single cross section.

(5) Principal Features of River Improvement

Based on the aforesaid design discharge as well as design criteria, the preliminary design of river improvement works was made for each of the target river stretches (refer to Figs. 6.1.2 to 6.1.9). The principal features of river improvement works are as summarized below.

Principal Features of River Improvement Works

Description	Unit	Lower Muda River	Kuala Ketil Town		Baling Town	Sik Town
			Muda River	Ketil River		
Stretch Length	m	40,300	1,870	920	750	800
Design Discharge	m^3/s	1,300	1,100	700	500	130
River Width	m	180 - 1,000	100	70	53	30
Excavation/Dredging	$10^3 m^3$	10,400	522		37.5	6.2
Embankment	$10^3 m^3$	1,100	22.4		12.8	14.4
Revetment	$10^3 m^2$	83	23.1		12.1	13.6
Sluices to be Constructed	location	28	3		2	2
Barrage to be Reconstructed	location	1	0	0	0	0
Drops to be Reconstructed	location	0	1	1	0	0
Pump stations to be Relocated	location	3	0	0	0	0
Bridges to be Reconstructed	location	2	0	1	3	0
Bridges to be Reinforced	location	3	0	0	0	0
Land Acquisition	ha	510	11.8		2.3	1.5
House Evacuation	house	189	9		28	12

The existing flow capacity at the Muda Barrage is estimated at only 250 m^3/s or less than 20% of the design discharge of 1,300 m^3/s. Therefore, it is indispensable to reconstruct the barrage as a major part of river improvement works for the target river stretch of Lower Muda River (refer to Fig. 6.1.10). The reconstruction will include the excavation of a 1,300 m long cut-off channel to increase the channel flow capacity and to facilitate the construction of a barrage on dry land. The land for cut-off channel is mostly owned by the State of Kedah, therefore, the related land acquisition can be minimized.

The present state boundary is set up along the center line of the Muda river channel, therefore, the above proposed cut-off channel may change the state boundary between the states of Kedah and Pulau Pinang. The center line of the channel will move by a maximum of 350 m towards the Kedah side, and some 30 ha of land would shift to the territory of the State of Pulau Pinang. Nevertheless, the alignment of the cut-off channel is proposed as the optimum plan from the engineering viewpoints, and a certain agreement between the states will be required to delineate the new state boundary in connection with construction of the new cut-off channel.

6.1.5 Preliminary Design of River Mouth Improvement Works

In addition to the aforesaid river channel improvement works, the improvement for the river mouth is proposed to cope with the present siltation and to facilitate the navigation around the river mouth.

In the "National River Mouths Study by JICA in 1994" (hereinafter referred to as NRMS), the Muda river mouth was studied as one of the objective river mouths, and the following two alternative works were proposed as countermeasures against river mouth siltation (refer to Fig. 6.1.11):

Case 1	Capital and Maintenance Dredging
Case 2	Capital Dredging and Combination of Submerged Jetty and Maintenance Dredging

Cost comparison of the above two alternatives was made through the updated hydrological data surveyed in 1994. As a result, Case 1, Capital and Maintenance Dredging, is proposed as the optimum measure. The following table gives the total cost for each alternative as estimated in terms of net present value assuming that the project life is 30 years and the discount rate is 8%.

Unit: RM 1,000

Alternative	Initial Cost	Maintenance Cost	Total Cost
Case 1	681	6,682	7,363
Case 2	3,569	5,095	8,664

6.2 Non-Structural Flood Mitigation Measures

6.2.1 River Reserve and Controlled Area

A "river reserve area" and a "river controlled" area is defined as a buffer between a river and its adjacent area to protect it from undesirable activities. Their importance has been fully acknowledged among the officials concerned. A river reserve area has been proposed by DID for years but not successfully executed for the Muda river basin.

The riverside areas of Muda River are being affected by the recent sprawling land developments. They are exclusively used as private land and far from management.

For realizing orderly and harmonized development of the river environment, the delineation of adequate space for a river reserve area is urgently required. From this viewpoint, a river reserve area and a river controlled area is proposed for the Muda River from the viewpoint of flood mitigation. The required land acquisition and functions of these areas are summarized as below.

(1) River Reserved Area

Entire land in this area is subject to land acquisition by the government, and any private land development works are frozen under jurisdiction of the river management body. The river reserved area shall be used as the space for the river improvement works as well as the space for operation and maintenance as described below:

(a) Space for River Improvement Works

Resettlement/relocation is one of the difficult problems encountered in the implementation of construction work. Many works have encountered this problem and some of them have been suspended because of it. To minimize resettlement/relocation, probable areas for future river improvement works is desirable to be protected from any development, and to be acquired as soon as possible.

(b) Space for Operation and Maintenance Work

For operation and maintenance work, a road is desirable to be constructed on riverbanks.

(2) River Controlled Area

The present private land located in this area is not subject to land acquisition by the government, but all land development therein is to be controlled through evaluation and approval by the river management body so as to fulfill the following functions:

(a) Function as Natural Retarding Basin

Flood inundation areas function as natural retarding basin to reduce flood discharge to the downstream stretches. A decrease of such inundation areas by development may result in the increase of burden to the downstream areas. In addition, the increase of assets in these areas may lead to the increase of flood damage potential. Therefore, disorderly development in the inundation areas shall have to be avoided.

(b) Space for Bank Erosion and Meandering

A meandering river like the Muda River needs a buffer area for possible bank erosion/meandering, if no protection works such as revetment and groin are provided.

(c) Buffer Area for River Structures

A river structure such as dike shall be protected from undesirable activities which may affect it. In Japan, a buffer/belt area with a width of 20 m along a dike is designated as a river controlled area.

The DID Manual proposes a standard minimum width of a river reserve area according to the river width. For example, the minimum width of a river reserve area is 50 m on each bank when the river width is greater than 40 m. As described above, however, a river reserve area and a river controlled area have some functions, each of which needs a different width to suit local conditions.

In this Study, the river reserved area for Muda River is proposed in due consideration of the necessary space for the proposed river improvement works as well as the necessary river operation and maintenance works. While, the river controlled area is proposed as the extent of the possible flood inundation area of 100-year return period, the possible extent of the river erosion and meandering and a belt area of 20 m in width along the proposed river dike. The proposed river reserve area and river controlled area cover an area of about 57 km^2 in total along a stretch of 113 km of the main stream from the river mouth to the proposed Jeniang Barrage and a stretch of 41 km long of Ketil River from the confluence with the main stream to Kg. Tg. Merbau, as shown in Figs. 6.2.1 to 6.2.2, and in 1/20,000 topo-sheets in the Data Book.. The average width of river reserve area and river controlled area is about 69 m and 167 m, respectively both for right and left banks, as listed below:

Proposed River Reserve Area and River Controlled Area

River	Stretch	Stretch Length (km)	River Reserve Area		River Controlled Area	
			Area (km^2)	Width* (m)	Area (km^2)	Width* (m)
Muda	Lower Muda River (River Mouth to Ldg. Victoria	40.3	5.6	69	1.6	20
	Ldg. Victoria to Proposed Jeniang Barrage	72.9	Nil	Nil	33.1	227
Ketil	Muda River to Kg. Tg. Merbau	41.0	Nil	Nil	16.9	206
	Total (or Average)	154.2	5.6	69 (Ave.)	51.6	167 (Ave.)

* Average width on one side.

According to Fig. 6.2.3, the river channels have changed their courses at some portions at a maximum of 500 m for the last 28 years. Floodwaters may possibly erode the riverbanks along the boundary of the proposed reserve areas, but it is difficult to identify such probable erosion portions at present. Periodical monitoring is, therefore, very important and, if such portions are found by monitoring, a structural countermeasure such as revetment shall be provided, or the river reserve areas shall be extended to cover the probable erosion areas.

6.2.2 Recommendation for Improvement of Flood Forecasting and Warning System (FFWS)

DID has been making great efforts to improve the existing FFWS, which include the installation of warning stations with siren and telemetric rainfall and water level gauges. It is noteworthy that no loss of life was reported even during the 1988 flood, mainly owing to adequate warning and evacuation activities of the agencies concerned. However, areas that could be improved still remain, and some recommendations are made as below.

(1) Improvement of Rainfall Monitoring Network

Rainfall data are essential for flood forecasting. However, the existing rainfall stations are concentrated in the middle and downstream stretches of the basin, and the upstream mountainous areas are regarded as hydrological blind areas. In particular, the non-existence of rainfall gauge in the catchments of Muda and the proposed Beris dams is a serious problem for dam operation during floods.

As described in CHAPTER 9, several rainfall gauges, which are desired to be equipped with telemeter, shall be newly installed in the upstream areas to attain even distribution of rainfall gauges in the river basin.

(2) Integration of FFWS

Hydrological information such as water level and rainfall is monitored by three organizations, DID Kedah, DID Pulau Pinang and MADA in the Muda river basin. Data which are monitored individually by the three organizations are seldom exchanged among them, although they have a system to transmit a few water level data of DID Kedah to DID Pulau Pinang. Flood forecasting and warning activities are also done individually by the states of Kedah and Pulau Pinang.

For taking a prompt action during floods and to avoid the duplication of facilities and activities, a basin-wide integrated organization shall have to be established with the function of integrating and centralizing all the FFWS works in the river basin. The Technical Secretariat which is proposed as an implementation organization of river management in SECTOR VIII, Institutional Setup Plan, can be the integrated organization for the FFWS.

(3) Establishment of Warning System over Downstream of Dam and Barrage

Dams and barrages release water to the downstream for the purpose of irrigation or industrial/domestic water, or execute emergency release during a flood. If people are in a river channel for fishing, swimming or playing when an upstream dam or barrage starts to release water, they may possibly be killed by the released water surging from the structure. To avoid such a man-made flood disaster, a warning system over the downstream stretches of dams and barrages shall have to be established.

CHAPTER 7. WATER RESOURCES MANAGEMENT PLAN

7.1 Projection of Water Demand

7.1.1 Premises for Projection of Domestic and Industrial Water Demand

The future domestic and industrial water demand has been projected through the following conventional formulas:

Treated Water Demand = *(Population) × (Service Factor) × PCDC + (C/I Demand) + (Unaccountable Water) + (Industrial Water)*

Source Water Demand = *(Treated Water Demand) ÷ (TP Ratio) + (Industrial Water)*

where,

PCDC	:	Per Capita Daily Consumption
C/I Demand	:	Commercial and Institutional Demand
TP Ratio	:	Treatment Plant Water Use Ratio (assumed at 0.95)

In the above formulas, the treated water demand expresses the actual water consumption of users, while the source water demand is the necessary water to be supplied from a water source to meet the treated demand.

The water resources of Muda River serve the domestic and industrial water demand in the states of Kedah, Pulau Pinang and Perlis. Among the states, the source of water demand of the State of Pulau Pinang will rely solely on Muda River in the year 2010, while the states of Kedah and Perlis will rely on a combination of sources, Muda and Kedah rivers. In the year 2010, the service factor for public water supply in all states will reach 100%, and the served population for the states will increase as below (refer to Tables 7.1.1 and 7.1.2).

Population to be Served with Public Domestic and Industrial Water

Water Source	State	Served Population	
		Present	Projected in 2010
Solely from Muda River	Pulau Pinang	750,000	1,612,000
	Kedah	299,000	910,000
	Sub-Total	1,049,000	2,522,000
From both Muda and Kedah River	Kedah	538,000	928,000
	Perlis	42,000	40,000
	Sub-Total	580,000	968,000
Grand Total		1,629,000	3,490,000

In parallel with the increment of the above served population, the industrial area in the states will also remarkably increase, as listed below, from about 1,554 ha in the year 1993 to 8,140 ha in the year 2010 (refer to SECTOR V, WATERSHED MANAGEMENT AND MONITORING PLAN). The demand for these industrial areas was estimated assuming an average unit demand of 33,000 liters/ha/day.

Industrial Area to be Served with Public Domestic and Industrial Water

Water Source	State	Industrial Area (ha)	
		Present	Projected in 2010
Solely from Muda River	Pulau Pinang	881	3,980
	Kedah	47	1,517
	Sub-Total	938	5,497
From both Muda and Kedah River	Kedah	616	2,642
Grand Total		1,554	8,139

In addition to the served population and the industrial areas, various parameters such as per capita consumption, commercial/institutional water and unaccounted water are required to project the future water demand. These parameters were estimated in due consideration of historical data, recent relevant study and design criteria and standard. The results of estimation are as tabulated below.

Parameters for Projection on Domestic and Industrial Water Demand

Description	Per Capita Daily Consumption (liters/person/day)	Rate of Commercial/ Institutional Demand to Total Domestic Demand (%)	Unaccounted Water Ratio to Total Domestic Demand (%)
Urban (P. Pinang)	300	30	15
Urban (Kedah & Perlis)	280	30	15
Semi-Urban	200	15	20
Rural	160	10	30

7.1.2 Premises for Projection of Irrigation Water Demand

The future irrigation water demand has been projected through the following conventional formulas:

Gross Demand = $DS(t) - DS(t\text{-}1) + ET(t) + P(t) + DR(t)$

Net Demand = *Gross Demand* $- R(t)$

Demand from River = *(Net Demand) / IF*

Where,

$DS(t)$	:	Standing water depth in the field including soil saturation on day "t". [$DS(t) - DS(t\text{-}l)$ herein represents the water depth stored in the field from day "t-l" to "t".]
$R(t)$	:	Rainfall depth
$ET(t)$	:	Evapotranspiration
$P(t)$	:	Percolation
$DR(t)$	:	Discharge drained from the field
IF	:	Irrigation losses (consisting of conveyance/diversion losses and field distribution losses).

Muda River, together with Kedah River, presently supplies the irrigation water to 60 schemes that include 2 main granary schemes, Muda and Seberang Perai; 11 secondary granary schemes; and 48 non-granary schemes. In due consideration of the "National Agricultural Policy (1992-2010)," it is assumed that the extent of the main and secondary irritation areas in 2010 remains the same as that of the present.

The present irrigation intensity in the main granary areas has already reached the maximum limit and, therefore, will also remain the same as that of the present. However, the intensity of the secondary granary areas in the off-season will increase from the present rate of 80% to 100% in 2010, considering the current activities done by MADA, DID and other related agencies.

As for other non-granary areas, out of the present 47 schemes, 21 schemes will be maintained as irrigation areas in due consideration of their agricultural development potentials. Based on the assumptions mentioned above the irrigation areas in the year 2000 and 2010 are as projected below.

Present and Projected Irrigation Area

(Unit: ha)

Irrigation Area	Number of Schemes		Main Season		Off-Season	
	1993	2010	1993	2010	1993	2010
Main Granary Area	2	2	105,222	103,955	105,222	103,955
Secondary Granary Area	11	11	6,676	6,676	5,335	6,676
Other Non-Granary Area	47	21	12,158	7,076	6,126	925
Total	60	34	124,056	117,707	116,683	111,556

In addition to the aforesaid projection irrigation areas, there are essential factors to estimate the future irrigation demand such as farming activities, evapotranspiration and percolation, and presaturation and standing water. These factors were assumed with reference to the present actual values as well as the values applied in recent studies.

7.1.3 Projected Water Demand

Based on the premises described in Subsections 7.1.1 and 7.1.2, the total water demand for domestic/industrial as well as irrigation water is as projected below.

Projected Water Demand

Demand Items	Present				Projected in 2010			
	Gross Demand		Required from River		Gross Demand		Required from River	
	($10^6 m^3/yr$)	(%)	($10^6 m^3/yr$)	(%)	($10^6 m^3/yr$)	(%)	($10^6 m^3/yr$)	(%)
1. Domestic/Industrial								
(a) Kedah State	129	4.5	136	6.7	271	9.0	281	13.1
(b) Pulau Pinang State	166	5.8	194	9.6	300	9.9	350	16.2
(c) Perlis	9	0.3	9	0.4	9	0.3	9	0.4
Sub-Total	304	10.6	339	16.7	580	19.2	640	29.7
2. Irrigation Water								
(a) Muda Irrigation scheme	1,977	68.9	1,391	68.6	2,010	66.6	1,230	57.2
(b) Balik/Seberang	156	5.4	80	4.0	170	5.6	100	4.4
(c) Others	433	15.1	216	10.7	260	8.6	180	8.4
Sub-Total	2,566	89.4	1,687	83.3	2,440	80.8	1,510	70.3
Grand Total	2,870	100.0	2,026	100.0	3,020	100.0	2,150	100.0

As estimated above, the domestic and industrial water demand taken from the river source will increase from 339 million m^3/year at present to 640 million m^3/year or 1.9 times of the present value in the year 2010. This remarkable increment is attributed to the population growth, the increment of per capita water consumption and the intensive industrial development.

In contrast with the domestic/industrial water demand, the total irrigation water demand will slightly decrease due to the following reasons:

(a) The total irrigation area in off-season is projected to decrease from the present 116,683 ha to 111,556 ha in the year 2010;

(b) In the Muda irrigation area, the tertiary irrigation canals are being improved; hence, the irrigation efficiency is increased from 56% at present to 63% in the year 2010; and

(c) Among others, the irrigation water demand for Seberang Perai only will increase. This is due to the projected alternation of irrigation schedule, which was clarified through the interview survey made in this study.

7.2 Screening of Necessary Water Supply Facilities

7.2.1 Design Drought Level and Objective Facilities for Screening

A certain water deficit will possibly occur due to the aforesaid incremental water demand projected by the year 2010, unless a new water resource development project is implemented. In due consideration of such water deficit, a water demand and supply simulation was made to select the necessary water supply facilities to meet the projected water demand in the year 2010 under a proposed design drought level.

The design drought level is herein proposed to correspond to a 10-year return period in drought recurrence probability that is generally applied in the water development plan. The water supply and demand balance is simulated for a 30-year period from 1962 to 1991, and the objective drought year is assumed as the third largest water deficit year in the simulation period.

The necessary water supply facilities were selected through the screening of (a) Beris Dam, (b) Jeniang Transfer Canal, (c) Naok Dam, and (d) Reman Dam. These objectives of screening were the major facilities proposed in previous relevant studies. Aside from the objectives of screening, several potential dam sites were preliminary identified in the previous studies; namely, Tawar Muda, Batak-temin, Sari and Durinang. The active storage of these potential dam sites is, however, extremely small, so that they were excluded from the objectives of screening.

The water demand and supply balance simulation was made on the premise of the existing water supply facilities as well as these proposed influential facilities. Through the simulation, the frequency of occurrence of water deficit was estimated for the following three assumed levels of water supply facilities.

Level 1	Existing facilities (Pedu Dam, Muda Dam, and Ahning Dam) + Beris Dam
Level 2	Existing Facilities + Beris Dam + Jeniang Transfer Canal + Naok Dam
Level 3	Existing Facilities + Beris Dam + Jeniang Transfer Canal + Naok Dam + Reman Dam

7.2.2 Priority in the Use of Dam Reservoirs

The simulation model includes the Kedah river system and the Muda river system, since the water source in Muda River is conveyed to Kedah River. Both river systems are connected by the diversion tunnel from Muda dam reservoir at present, and possibly further by the proposed Jeniang transfer system in future.

In the simulation, these river systems will have the water supply from dam reservoirs in accordance with the following priorities:

(1) Kedah River System

First Use	Pedu and Muda dam supply for the entire deficit in the Kedah river system.
Second Use	When the storage volume of Pedu and Muda dams fall to zero, Ahning Dam starts to supply the deficit in the northern part of the Kedah river system, and Naok and Remand dams also start to supply the deficit in the southern part of the Kedah river system. The northern part of Kedah river system is herein defined as the northern part of Muda irrigation scheme from Badang Terap River, while the southern part is the remaining part of Muda (refer to Fig. 7.2.1).

(2) Muda River System

First Use	Beris Dam supplies the entire deficit in the Muda river system.
Second Use	When the storage volume of Beris Dam falls to zero, Naok and Reman dams start to supply the entire deficit in the Muda river system.

7.2.3 Frequency of Occurrence of Water Deficit

The frequency of water deficit was estimated assuming the following levels of water supply facilities:

(1) Level 1 (Existing Dams + Beris Dam)

The annual minimum storage volume of the existing dam reservoirs (Muda, Pedu, and Ahning) and the proposed Beris dam reservoir were estimated based on the water supply and demand balance simulation, as shown in Tables 7.2.1 and 7.2.2. As shown in Table 7.2.1, the Muda river system has a water deficit for 5 years among the 30 years of simulation period with the annual minimum storage volume of Beris Dam falling at the zero level, while the Kedah river system has a water deficit for 10 years with the annual minimum storage volume of Ahning Dam.

At present, runoff discharge in the catchment area of Muda Dam is once stored by Muda Dam and conveyed through the Pedu dam reservoir into the Kedah river system. Such present water conveyance system does not improve in case that Beris Dam is solely constructed without the Jeniang Transfer Canal. Accordingly, the sole construction of Beris Dam will increase the present water supply capacity for the Muda river system including the State of Pulau Pinang, but will not improve the water deficit of the Kedah river system.

(2) Level 2 (Existing Facilities + Beris Dam + Jeniang Transfer Canal + Naok Dam)

The storage volume of Naok Dam can supply both the Muda and Kedah river systems except the northern part of the Muda irrigation scheme. Thus, the water deficit in both Muda and Kedah river systems could improve in this case.

As shown in Tables 7.2.3 and 7.2.4, however, the water deficit of the Muda river system occurs for 5 years among the 30 years of simulation period with the annual minimum storage volume of Beris Dam at the zero level. The years of water deficit are the same as those in Level 1 (Sole Construction of Beris Dam). Thus, Naok Dam could hardly improve the deficit of the Muda river system, and this is attributed to its small storage capacity.

On the other hand, the year of water deficit for the Kedah river system is reduced from 10 to 6 years of the water deficit estimated in the aforesaid case of sole construction of Beris Dam. The reduction of water deficit years is attributed to the fact that the storage volumes of Beris Dam and Naok Dam could be supplied to the Kedah river system through the Jeniang Transfer Canal.

(3) Level 3 (Existing Facilities + Beris Dam + Jeniang Transfer Canal + Naok Dam + Reman Dam)

The storage volume of both the Naok and Reman dams could be supplied to both the Muda and Kedah river systems; therefore, the water deficit in both Muda and Kedah river systems could be remarkably improved.

As shown in Tables 7.2.5 and 7.2.6, the water deficit of the Muda river system and the Kedah river system occurs for only 2 years among the 30 years of simulation period with the annual minimum storage volume of Naok and Reman dams at the zero level.

The two years of water deficit for Kedah river system is, however, applied only to the southern part of the Muda irrigation scheme, but not to the northern part. The northern part of Muda irrigation scheme could be supplied only from the existing Muda, Pedu and Ahning dams due to the topographic conditions, and will have 7 years of water deficit as proven by the years when the storage volume of Ahning dam falls to zero (refer to Table 7.2.5).

7.2.4 Screening of Necessary Water Supply Facilities

The frequency of water deficit for each level of water supply facilities is as summarized below.

Number of Water Deficit Years for Alternative Water Supply Facilities

Level	New Water Supply Facilities Assumed	Number of Water Deficit Years during 30-Year Simulation Period	
		Muda River System	Kedah River System
Level 1	Beris Dam	5 years	10 years
Level 2	Beris Dam + Jeniang Transfer Canal + Naok Dam	5 years	6 years
Level 3	Beris Dam + Jeniang Transfer Canal + Naok Dam + Reman Dam	2 years	2 years

The design drought level of a 10-year return period in drought recurrence probability is to guarantee the full water supply until the third largest drought year during the 30-year simulation period and, among the levels of the new water facilities, only Level-3 could satisfy such drought design level. In other words, all the proposed facilities (Beris Dam, Jeniang Transfer Canal, Naok Dam and Reman Dam) are required to guarantee a full water supply for the projected water demand in the year 2010.

The active storage capacity and available supply area for these existing and proposed dams are as summarized below (refer to Fig. 7.2.1).

Existing and Proposed Dam Reservoirs for Water Resources Development

Water Supply Area	Available Dam Supply Source	Catchment Area (km^2)	Active Storage Capacity ($10^6 m^3$)
Northern and southern part of Muda irrigation scheme	Pedu (Existing)	171	1,049
	Muda (Existing)	941	160
	Ahning (Existing)	120	200
Southern part of Muda irrigation scheme and the whole supply area for Muda river system	Beris (Proposed)	116	114
	Naok (Proposed)	15	27
	Reman Proposed)	32	240

It is herein noted that the northern part of the Muda irrigation scheme is out of the available supply area from the proposed Beris, Naok and Reman Dams, and excluded from the area where the design drought level is guaranteed by Level 3. In the northern part, the water supply facilities in Level 3 could cause 7 years of water deficit among the 30 years of simulation period as described above. However, such excessive water deficit years could be reduced to the design drought level, when the comprehensive dam operation rule is applied instead of the simple priority use of dam reservoir assumed in the simulation. Details of the comprehensive dam operation rule are described in the following Section 7.3.

7.3 Dam Operation Rule for Balanced Water Supply

7.3.1 Purpose of Dam Operation Rule for Balanced Water Supply

It is proposed through the simulation on water supply and demand balance to construct the Beris, Naok and Reman dams as the necessary new water sources to meet the projected water demand in the year 2010. In the simulation, however, the operation rule for the existing dams (Muda, Pedu and Ahning dams) and the proposed dams is subject to the simple priority in the use of the dam reservoirs in such that Naok and Reman dams start their water supply after the storage volumes of the existing Pedu and Ahning dams fall to zero.

Such simple priority in the use of dam reservoirs could cause more frequent water deficit in the northern part of the Muda irrigation scheme than other objective water supply areas, as described in Subsection 7.2.4. Hence, an attempt was made to improve the dam operation rule to induce a more critical and well-balanced water supply.

7.3.2 Selected Dam Operation Rule for Balanced Water Supply

Among the objective dams, only the Pedu and Ahning dams are available to supply water to the northern part of the Muda irrigation scheme. Should Naok and Reman dams start their water supply for the southern part of Muda irrigation scheme before the storage volumes of Pedu and Ahning dams fall to a certain level, the storage volume of Pedu and Ahning dams can be saved and used for water supply of the northern part during its drought period. As a result, the water deficit in the northern area can be improved.

In due consideration of the above conditions, trial simulation was made to select the optimum rule assuming various timings for starting the water supply from each dam. As the result, the following rule is proposed to minimize the frequency of water deficit for all objective water supply areas including the northern part of the Muda irrigation scheme.

Dam Operation Rule for Balanced Water Supply

Dam Storage Volume Storage (10^6m^3)		Dams to Supply Kedah River System		Dam to Supply Muda River System
Pedu and Muda Dam	Naok and Reman Dam	Northern Part	Southern Part	
> 400	Full	Pedu	Pedu	Beris, Naok, Reman *2
300 - 400	> 150	Pedu, Ahning *1	Naok, Reman *1	Beris, Naok, Reman *2
	< 150	Pedu, Ahning *1	Naok, Reman, Ahning *3	Beris, Naok, Reman *2
< 300	> 150	Pedu, Ahning*1	Naok, Reman, Beris *1	Beris, Naok, Reman *2
	< 150	Pedu, Ahning*1	Naok, Reman, Ahning, Beris *1	Beris, Naok, Reman *2

*1: Necessary water supply is allocated to each dam in accordance with the rations of their residual reservoir volume.
*2: After residual storage volume of Beris Dam falls to zero, Naok and Reman dams start water supply.
*3: When necessary water supply from Naok and Reman dams is deficient, Ahning Dam starts to supplement the deficiency.

When the above dam operation rule is applied, the annual minimum storage volume of all existing dams as well as Naok and Reman dams falls to zero for only two years among the 30 years of simulation period (Table 7.3.1). This condition indicates that the design drought level of a 10-year return period in drought recurrence probability can be guaranteed for all objective water supply areas including the northern part of the Muda irrigation scheme.

7.4 Comprehensive Dam Operation Rule

7.4.1 Purpose of Comprehensive Dam Operation Rule

The dam operation rule mentioned in the previous subsection does not contain any factor to adjust dam water supply volume corresponding to the drought conditions, so that the dams need to continue full water supply until their storage volumes fall to zero. Such operation rule could minimize the water deficit period, but also cause an extremely large shortage of water supply during the zero period of dam storage volume. To avoid such undesirable condition, an attempt was made to improve the aforesaid dam operation rule.

Before the dam storage volume drops to zero, the dam reservoir should start to curtail its water supply and stock the water for the future water deficit. Such curtailment might sometimes result in wasting the water source due to recuperation of river flow regime. It is, however, difficult to know the precise future river flow regime and, therefore, such curtailment should be made on fixed reservoir conditions regardless of the future river flow conditions. In this connection, alternative curtailment rules were prepared, and the optimum rule was selected from them to minimize the index on the drought damage mentioned in the succeeding subsection.

7.4.2 Index to Express Drought Damage

The following indices are conventionally used to express drought damage:

(a) Drought Percent Day = ∑ [deficit (%) × [number of drought days]]

(b) Square Draught Percent Day = ∑ {[deficit (%)]^2 × [number of drought days]}

(c) Function of Drought = ∑ {[deficit (%)]^2 × [water demand] × [number of drought days]}

(d) Amount of damage caused by the drought.

The above index (d) will be the most reliable index to evaluate the effect. It is, however, difficult to adopt this index in this Study due to lack of available basic data for the index. Instead of the amount of damage, the magnitude of water deficit could be expressed by a combination of the deficit ratio and the number of deficit days as expressed by indices (a) to (c).

In index (a), the deficit ratio and the number of deficit days are equally evaluated; for instance, the magnitude of deficit is evaluated as the same for the following two cases:

(a) Case 1: 100% of deficit ratio × 10 days of deficit = 1000 % day

(b) Case 2: 10% of deficit ratio × 100 days of deficit = 1000 %day

However, the conditions of deficit in Case 1 is more serious than that of Case 2 freezing all civil life during a deficit period. From this viewpoint, the deficit ratio should be emphasized more than the number of deficit days, and indices (b) and (c) will be more preferable than index (a). In this Study, index (c) was finally selected as the most preferable index to evaluate, because index (b) cannot express the difference of water deficit by the water demand volume. Among the alternative rules, the optimum rule should minimize the value of index (c) expressed as the drought damage.

7.4.3 Optimum Comprehensive Dam Operation Rule

Through the step-trial simulation, the optimum dam operation rule was selected minimizing index (c) in Subsection 7.4.2. The selected optimum operation rule is to follow the same process of dam water supply as that for balanced water supply, when the storage volume of Pedu and Muda dams is more than 300 million m^3. The optimum rule is, however, to start its curtailment of dam water supply when the storage volumes of Pedu and Muda dams fall to 300 million m^3 with the following curtailed ratios:

Optimum Dam Operation Rule

Dam Storage Volume Storage ($10^6 m^3$)		Dam to Supply Kedah River System		Dam to Supply Muda River System	Curtailed Ratio of Dam Water Supply
Pedu and Muda Dam	Naok and Reman Dam	Northern Part	Southern Part		
> 400	Full	Pedu	Pedu	Beris, Naok, Reman*2	0%
300 - 400	> 150	Pedu, Ahning *1	Naok, Reman*1	Beris, Naok, Reman*2	0%
	< 150	Pedu, Ahning *1	Naok, Reman, Ahning*3	Beris, Naok, Reman*2	0%
200 - 300	> 150	Pedu, Ahning*1	Naok, Reman, Beris*1	Beris, Naok, Reman*2	10%
	< 150	Pedu, Ahning*1	Naok, Reman, Ahning, Beris *1	Beris, Naok, Reman*2	10%
100 - 200	> 150	Pedu, Ahning*1	Naok, Reman, Beris*1	Beris, Naok, Reman*2	30%
	< 150	Pedu, Ahning*1	Naok, Reman, Ahning, Beris *1	Beris, Naok, Reman*2	30%
< 100	> 150	Pedu, Ahning*1	Naok, Reman, Beris*1	Beris, Naok, Reman*2	50%
	< 150	Pedu, Ahning*1	Naok, Reman, Ahning, Beris *1	Beris, Naok, Reman*2	50%

*1: Necessary water supply is allocated to each dam in accordance with the ratios of their residual reservoir volume.
*2: After residual storage volume of Beris Dam falls to zero, Naok and Reman dams start water supply.
*3: When necessary water supply from Naok and Reman dams is deficient, Ahning dam starts to supplement the deficiency.

7.4.4 Water Deficit in Extraordinary Drought Year

Due to the above curtailment of dam water supply, the annual minimum storage volume of the existing dams as well as Beris Dam will never fall to zero as shown in Table 7.3.2, but the shortage of dam water supply is unavoidable in an extraordinary drought year. In this connection, the water deficit ratio, as well as the number of water deficit days, is estimated.

In the estimation, the priority of water supply in the deficit years is given to the domestic and industrial water demand rather than the irrigation water demand. That is, the supply volume for each irrigation scheme is first curtailed according to the ratio of its demand volume to the total demand volume. If a deficit still remains, the necessary curtailed volume is allotted to the domestic and industrial water demand. Thus, estimated are the water deficit conditions under two dam operation rules as summarized below.

Water Deficit in Extraordinary Drought Year

Dam Operation Rule	Deficit Year	Basic Demand from River (10^6 m^3/year)	Annual Deficit Volume (10^6 m^3/year)	Number of Deficit days in a year (days)	Average Curtailed Ratio for Deficit Days (%/year)	Function of Drought * (% day 10^6m^3)
Rule for Balanced Water Supply	1982	1,922	179	37	54	14,293
	1983	2,061	125	21	43	7,383
Optimum Rule	1980	2,031	2	52	8	629
	1982	1,922	80	89	11	1,478
	1983	2,061	158	51	23	9,867
	1985	2,199	11	40	3	68
	1987	2,170	23	86	3	125

Note: Expressed as $\sum\{[\text{deficit } (\%)]^2 \times [\text{water demand}] \times [\text{number of drought days}]\}$

As estimated above, the number of deficit days under the optimum dam operation rule is more than that under the rule for balanced water supply. However, the optimum operation rule could reduce the average deficit volume during the deficit days and minimize the function of drought applied as the index to evaluate the drought damage in Subsection 7.4.2.

CHAPTER 8. RIVER ENVIRONMENT MANAGEMENT PLAN

8.1 River Maintenance Flow

As described in CHAPTER 7, the proposed structural plan on the water resource development for the Muda river basin contains the construction of Beris Dam, Jeniang Transfer Canal, Naok Dam and Reman Dam, which may cause a substantial change on the natural river flow regime. On the other hand, there does not exist any standard or regulation to set up the river maintenance flow that is defined as the minimum requirement of the river flow discharge and to be guaranteed by the water released from the proposed dam reservoirs.

The river maintenance flow is essential to maintain the appropriate river environment, particularly, on the river water quality during a period of the low flow regime. From this point of view, the future water quality of Muda River was clarified and the necessary river maintenance flow was determined.

8.1.1 Estimation of Future River Water Quality

The water quality of Muda River was evaluated by the concentration levels of BOD, SS, T-N and T-P in 1993, 2000 and 2010, applying the following formula:

$$PL = PL(r) \times AR \times 1000 \div Q$$

where,

PL	:	Concentration of pollution load at the check point (mg/l)
PL(r)	:	Gross weight of pollutant load released from each pollution source (mg/s)
AR	:	Arrival Rate to the checkpoint
Q	:	River flow discharge (m^3/s).

The checkpoints selected to evaluate the water quality were the railway bridge of Muda River at Pinang Tuggal [hereinafter referred to as Point M(P)] and the downstream end of Ketil River Tuggal (hereinafter referred to as Point K). The pollutant source of Muda River at these checkpoints is classified into the following six (6) categories:

(a) Residential Wastewater;

(b) Industrial Wastewater;

(c) Commercial Industry Wastewater;

(d) Livestock Farm Wastewater;

(e) Wastewater from Agricultural Land; and

(f) Others.

The gross weight of pollutant loads released from the above sources has been estimated by multiplying the quantity of the pollutant load with its corresponding unit weight (refer to Tables 8.1.1 to 8.1.6). As the results of the estimation, the concentration of pollutant load was estimated for each checkpoint as summarized below.

Present and Future Water Quality of Muda River

(Unit: mg/l)

Discharge	Item	Checkpoint M(P)			Checkpoint K		
		1993	2000	2010	1993	2000	2010
Annual Average for 30-years from 1964 to 1993.		Discharge = 84 m^3/s			Discharge = 30 m^3/s		
	BOD	1.60	1.75	2.16	1.65	1.65	1.77
	SS	44.88	48.99	49.33	37.14	37.17	37.22
	T-N	1.01	0.97	1.04	0.68	0.65	0.65
	T-P	0.20	0.23	0.27	0.14	0.17	0.17
355-day discharge of the third lowest for 33-years from 1959 to 1993.		Discharge = 16 m^3/s			Discharge = 6 m^3/s		
	BOD	8.44	9.18	11.33	8.25	8.24	8.85
	SS	256.65	257.20	258.96	185.70	185.84	186.08
	T-N	5.31	5.11	5.48	3.38	3.23	3.25
	T-P	1.08	1.19	1.42	0.72	0.76	0.83

The estimated water quality in the years 2000 and 2010 shows that the pollution level in the future will not remarkably increase. Furthermore, when the river channel flow discharge is around the annual average discharge, the water quality of the river is still within Class III which is defined by DOE as the allowable level (≈ 6 mg/l in BOD concentration) for domestic water supply.

However, when the river flow discharge falls to the level of the third lowest 355-day discharge (the value to exceed river flow discharge of 355 days a year) for 33 years, the water quality will exceed the allowable level. Thus, the water quality of Muda River is, although generally evaluated to be clean, possibly to exceed the allowable level for domestic water supply during a dry season in the drought year.

8.1.2 Dominant Factors for Determination of River Maintenance Flow

The river maintenance flow is essential for the maintenance of river water quality as well as other various factors. Among others, the following items were selected as the dominant factors to determine the necessary river maintenance flow discharge in due consideration of the features of Muda River:

(a) To maintain the appropriate river water quality throughout the year;

(b) To conserve the natural low flow regime as before construction of the proposed dam;

(c) To conserve the river ecology system; and

(d) To conserve the river scenery.

Other than the above four items, the river maintenance flow contains various functions in general, but they were not considered in this Study. The functions not considered and the reasons are as discussed below.

(1) Maintenance Flow to Facilitate Water Abstraction from River

The difficulty to abstract water by intake facilities usually occur due to the lowering of river water level. However, the principal reason for the lowering of water level is the lowering of riverbed caused by the present excessive sand mining operations. Accordingly, river maintenance flow could not be the fundamental solution to maintain the water level for the intake facilities. Instead of the river maintenance flow, the construction of barrage or reconstruction of intake facilities will be the short-term remedy to maintain the water level for intake facilities. Furthermore, a long-term plan is indispensable to control the present sand mining operations and to check the tendency of lowering of the water level.

(2) Maintenance Flow to Prevent Clogging at River Mouth

The clogging of river mouth develops due to sedimentation of ocean drifting sand causing difficulty of navigation during low tide. However, it is not feasible to flush out the sediment by river maintenance flow. Instead of river