SECTOR G

HYDROLOGICAL ANALYSIS

1. BASIN DIVISION AND RIVER SYSTEM

1.1 Basin Division

The Study Area in the Musi River Basin covers a total drainage basin of approx. 60,000 km^2, which is located between 2°17’ S and 4°58’ S and between 102°4’ E and 105°20’ E. In this study, this basin is divided into sub-basins that correspond to the eight main tributaries of the Musi River; namely, the Komering, Ogan, Lematang, Kelingi, Semangus, Lakitan, Rawas, and Harileko rivers, as illustrated in **Annex G1.1.1** and summarized in **Table G1.1.1.**

Table G1.1.1 Catchment Area, River Length and Distance from River Mouth by Sub-Basin

No.	Sub-Basin	Catchment Area*1 (km^2)	River Length (km)	Distance From Respective River Mouth (km)
1	Komering	9,908	328	78
2	Ogan	8,233	313	88
3	Lematang	7,340	348	165
4	Semangus	2,146	183	391
5	Kelingi	1,928	98	421
6	Lakitan	2,763	140	374
7	Rawas	6,026	208	344
8	Harileko	3,765	334	229
9	Others	17,833*2	640*3	-
Total		59,942	-	-

*1 Source: Musi River Basin Study, 1989
*2 Padang and Remaining Musi River Basin
*3 Musi Main Stretch

1.2 River System

The Study Area is drained by the Musi River mainstream and its tributaries; namely, Komering, Ogan, Lematang, Semangus, Kelingi, Lakitan, Rawas and Harileko rivers. To have a clearer idea on the river system, the Musi River Basin is divided into three areas; namely, Mountain Area, Flood Plain Area and Coastal Plain Area, as described below.

1.2.1 Mountain Area

The Musi River flows for approx. 640 km from the Barisan Mountain Range to the Bangka Strait, passing through Sekayu and Palembang City. The origin in the Barisan Mountain Range is southwest of the study area at the elevation of about 1,300 m MSL and about 40 km west of Lubuk Linggau. Its tributaries also originate in this mountain range.

At the upstream of the Komering River, Ranau Lake is situated with discharge control gates to the downstream of the Komering River. The design water level of this lake has been decided at 571.4 m in another study.

1.2.2 Floodplain Area

(1) Upstream of Sekayu

The area at the upstream of Sekayu City is drained by the Musi River and the tributaries; Rawas, Lakitan, Semangus and Kelingi.

Near Muarakelingi City, the Kelingi River joins the Musi River from the west and the stream flow changes its direction from north to northeast. The Musi River further flows down and is joined again from the east by the Semangus River at 30 km downstream of the confluence with the Kelingi River. Then, the Musi River runs near Muaralakitan City where the confluence with Lakitan River is located. Of the tributaries in the study area, the Lakitan and Kelingi rivers have steep slopes, while the Semangus and Harileko rivers in the coastal plain area have gentle slopes.

Further downstream, the Musi River runs for 30 km from Muaralakitan City to the junction with the Rawas River. After the junction, the Musi River changes its flow direction again from northeast to east and runs for 90 km to Sekayu City.

(2) From Sekayu to Palembang

In the stretch from Sekayu to Palembang, the Musi River is joined by three rivers; the Harileko River, the Lematang River and the Ogan River. The Harileko River, with a slender basin, joins in an acute angle from the north at 25 km downstream of Sekayu. This river has a gentle slope as compared with the other tributaries.

The Musi River further flows down to the east and merges with the Lematang River that comes from the south. After merging, the Musi River becomes twice as wide as the upstream sections and the meandering becomes more significant as the river flows downstream. According to the report of the Musi River Basin Study in 1989, the Lematang River Basin is inundated due to over-spilling mainly over the left bank, and the middle reaches of this river is usually inundated in the wet season.

Moreover, the Ogan and Komering rivers also join from the south around Palembang. The Ogan River meanders with high sinuosity and has narrow and deep channels, while the Komering River has a low sinuosity and the channel is wide and shallow with sandbars. Additionally, braiding of the Komering River had developed due to the rise of riverbed caused by sediment deposits generated from the easily erosive banks or basin, such as sandy materials with little vegetation protection.

At the middle reach of the Komering-Ogan River the flow is diverted toward the Ogan River through the diversion channels of Randu, Jambu, Bengkudo, Muara Baru and Ampar due to tectonic movement. As of October 2002, the water flow toward the Komering River has been interrupted due to collapse in the left bank and the weirs at the Randu that direct the flow to the Ogan River.

1.2.3 Coastal Plain Area (Downstream of Palembang)

Around Palembang, the Musi River bends from east to north and flows for about 100 km to the river mouth. The river bifurcates at 25 km downstream from Palembang and the left river is commonly called the Musi River, while the right one is the Padang River. As for the river width, the Musi River becomes remarkably wider starting from the downstream of Palembang; i.e., three or four times wider than the stretch upstream of Palembang. The river width after Palembang reaches 1,000 m on the average and about 3,000 m at the river mouth.

2. HYDROLOGICAL OBSERVATION SYSTEM

2.1 Existing Conditions

2.1.1 General

The hydrological conditions (rainfall, water level and discharge) in the Musi River Basin are observed mainly by two agencies, namely, the Musi Balai PSDA under the Dinas PU Pengairan and the BMG (Meteorological and Geophysical Agency) under the Ministry of Transportation. Data Management is performed separately and coordination between these two agencies is insufficient.

Before 1998, the hydrological data observed by Project PSAPB under Dinas PU has been transmitted continuously to the Center of Research and Development in Bandung (called Pusat Penelitian and Pengembangan: Puslitbang in Indonesia). However, due to the insufficient budget for observation allotted to Project PSAPB after 1998, recording sheets could not be procured and adequate observers could not be assigned at the stations. Consequently, the observation was finally discontinued at all stations at the beginning of 2002.

In 2002, the responsibility for observation was supposed to be transferred from Project PSAPB to Musi Balai PSDA whose organization-chart is shown in **Annex G2.1.1**. The main task of Musi Balai PSDA is to provide technical services in support of the utilization of water resources at South Sumatra Province. According to the plan, this organization started to function as a pilot project for the period 2002-2003 with Grant Aid funds from the Government of the Netherlands (IWIRIP).

The hydrological observation network of Balai PSDA has not been fully functioning because the survey on conditions of existing observation stations was then still in progress.

2.1.2 Rainfall Observation

(1) Observation Agency and Location

Rainfall observation has been conducted by Musi Balai PSDA at 14 gaging stations and by BMG at more than 40 stations in and around the Musi River Basin. As to the rainfall gage stations of BMG, unfortunately, the staff of BMG in Kenten did not know the number of stations within their jurisdiction. **Annex G2.1.2** and **Annex G2.1.3** present the location of the above stations.

(2) Inventory

Annex G2.1.4 and **Annex G2.1.5** give the inventory of data at gaging stations. Information on the installation period of gaging stations was missing, and the oldest data on record was at the beginning of the 1970s.

(3) Gage Type

Two types of gages record rainfall in the Musi River Basin: non-recording gages and recording gages. A recording gage is a device that automatically records the depth of rainfall in intervals down to one minute in duration. The non-recording gages are read manually at longer time intervals. Non-recording gages generally consist of open receptacles with vertical sides, in which the depth of rainfall is measured with a graduated measuring cylinder or dipstick.

All the gages of BMG except for the one in the Plaju Station at Palembang Airport are of the latter type. Musi Balai PSDA had installed both the latter type and the former type at all sites.

2.1.3 Water Level Observation

(1) Observation Agency and Location

Musi Balai PSDA is the principal agency responsible for the water level observation in the rivers of South Sumatra. There are 22 automatic water level gages with staff gage operated by Musi Balai PSDA in the Musi River Basin. They are listed in **Annex G2.1.4** and their locations are given in **Annex G2.1.2.**

(2) Inventory

Judging from the compilation of water level data and the past reports (Musi River Survey, 1989), the daily water level has been observed by PWRS of South Sumatra since the beginning of the 1970s. Hourly water level appeared on the record sheets after 1985; hence, it is presumed that the automatic water level recorders began to be installed at the stations after 1985. The inventory of observed data is given in **Annex G2.1.4.**

(3) Gage Type and Zero Datum

According to the staff of Musi Balai PSDA and the results of field survey by the JICA Study Team, the water level gages at the Musi River and its tributaries are of the float type, installed in a shelter house and stilling well. The staff gage is also installed near the automatic water level gage station.

Water level is the elevation above some arbitrary zero datum of the water surface at a station. Generally, the datum is sometimes taken as the mean sea level but there are a few stations in the Musi River Basin that have the datum from mean sea level.

2.1.4 Discharge Measurement

Discharge measurements have been carried out from the beginning of the 1970s at 52 stations. Based on the discharge measurements, the Center of Research and Development in Bandung prepares the relationship between water level and discharge (i.e., Discharge Rating Curve), then, calculates the daily discharge using such relationship. The location of stations, the discharges of which have been estimated recently, is shown in **Annex G2.1.6.** Discharge measurements, as well as water level and rainfall observations, were also suspended starting from 2002.

2.1.5 Management of Hydrological Observation

No definite organization has managed the hydrological observation station in South Sumatra Province. The management history is as listed below.

(1) Between 1976 and 1985, the hydrological observation station in South Sumatra was managed by the Project of Development Planning of Water Resources (P3SA);

(2) Until 1987, it was managed by the Investigation Directorate of Water Problem (DPMA);

(3) Between 1987 and 1995, it was managed by the hydrology unit in the region;

(4) In 1996, it was managed by the Branch Office (Cabang Dinas); and

(5) Between 1996 and 2001, the station was managed under Project PSAPB (Development Project of Water Resources and Flood Control) and the Hydrology Division in Sub-Dinas of Bina Program Water Resource Service.

Project PSAPB implemented the operation and maintenance works until these were handed over to Balai PSDA. O&M has been discontinued gradually during Project PSAPB's control as mentioned before due to the insufficient budget for hydrological activities (only Rp. 50 million for Fiscal Year 2001). Additionally, the proper institutional approach for managing hydrological activities has not been developed, even under Balai PSDA.

Therefore, the strengthening of hydrological activities as the primary responsibility of the Balai PSDA in fiscal year 2002 is recommended under the Project IWIRIP (Indonesia Water Resources and Irrigation Reform Implementation Project), which is funded under the Netherlands's Grant Aid Program. In short, the following items are recommended:

(1) To undertake a detailed inventory of the hydrometric stations and equipment (current meter, etc.) in the field and in storage, their conditions and approximate costs of repair/upgrade by 31 May 2002;

(2) Through an SK of Dinas PSDA for role-sharing (with the inventory as attachment), to transfer management of all hydrometric assets from Project PSAPB to BPSDA;

(3) To transfer or co-opt some of the staff of Project PSAPB (training/working in hydrology) to the Balai PSDA;

(4) For Balai PSDA to set up an asset register and implement annual inspection/monitoring of the hydrometric network;

(5) For Balai PSDA to manage the operation (observation/data collection/database) and maintenance of the hydrometric network;

(6) For Balai PSDA to prepare a three-year hydrometric rolling plan to repair/rehabilitate hydrometric stations (priority for discharge measuring and rain gage stations) and to prepare list of equipment with cost for procurement; and

(7) For Balai PSDA to prepare the annual hydrology report starting from Fiscal Year 2003.

According to Musi Balai PSDA, Items (1), (2) and (3) were carried out in 2002 and it plans to deal with Item (4), (5) and (6) in fiscal year 2003.

2.1.6 Result of Inventory Survey under IWIRIP

As itemized and explained above, the inventory survey of hydrological stations was carried out in 2002. The result of the inventory is shown in **Annex G2.1.7** and it is summarized in **Table G2.1.1**.

Table G2.1.1 Result of Inventory Survey for Hydrological Stations

Station Type	No. of Station Corresponding to Condition of Equipment				Cost for Repair (Rp. mil.)
	Good	Broken or Destroyed	Unknown	Total	
Climatology	0	4	0	4	183.5
Water Level (Automatic)	3	19	1	23	255.0
Rainfall (Automatic)	0	13	9	22	100.3
Water Level (Staff Gage)	0	6	0	6	9.0
Total	3	42	10	55	547.8 (exclude Tax)

2.2 Evaluation of Existing Monitoring System

2.2.1 Data Treatment

The hydrological data observed by Dinas PU Pengairan has been input manually on recording sheets without saving it in digital format on media such as Floppy Disk, Hard Disk, or CD-ROM. Additionally, during the survey by the JICA Study Team, it was found that a lot of the recording sheets were missing for the reason that Musi Balai PSDA is in the process of renovation or reorganization of the hydrological observation station.

Musi Balai PSDA intends to establish a hydrological database with the software "MICROSOFT-ACCESS". For that purpose, a local consultant was employed to carry out the inventory survey for the hydrological network starting from October 15, 2002 and the survey had ended within 2002.

When the digital database is established in the future, it is recommended that the data be saved in a digital format on some media as a precaution in case the database is broken, that is, the establishment of a dual data storage system is recommended. Additionally, the location of stations ought to be plotted on the map and conditions should be defined at certain intervals (e.g., stock of materials, observer's name, maintenance record, normal/irregular condition, etc.). It is preferable to register the information on the GIS system with the inventory items (e.g., station name, management organization, address, coordinate, altitude and Data of Operation Start, etc). This is to be made under IWIRIP within financial year 2002.

In IWIRIP, the collected data will be stored in the database and published as the annual hydrological report. Under this system, data management would definitely improve.

2.2.2 Data Transfer/Collection

According to the plan of Musi Balai PSDA, all of the hydrological data recorded in the field will be collected by the staff of the Musi Balai PSDA office or transferred by the observer at the Observatory.

The data collection/transfer system should correspond to the aim of observation. For example, Musi Balai PSDA also plans to use hydrological data to support flood warning. In this case, the flood forecasting system based on hydrological analysis should be established and the data ought to be transferred to the system through some communication system immediately when rain of high intensity occurs.

2.2.3 Distribution of Stations and Measurement

(1) Rainfall Gaging Station

According to the location map (**Annex G2.1.2**), the distribution of rainfall gaging stations managed by Musi Balai PSDA is biased toward the eastern part of the Musi River Basin. The distribution of station becomes uniform, however, when the rainfall gaging station managed by BMG (see **Annex G2.1.3**) is taken into account. Additionally, although the network of station is still relatively sparse, the density is almost adequate for the rainfall monitoring of large general storm as shown in **Table G2.2.1**.

Table G2.2.1 Catchment Area of Sub-basins, Number and Density of Rainfall Gaging Stations

No.	Sub-Basin	Catchment Area (km^2)	No. of Station (BPSDA)	No. of Station (BMG)	Total No. of Station	Density (km^2/sta.)
1	Komering	9,908	1	7	8	1,238
2	Ogan	8,233	0	6	6	1,372
3	Lematang	7,340	1	7	8	917
4	Semangus	2,146	0	0	0	-
5	Kelingi	1,928	2	1	3	642
6	Lakitan	2,763	4	2	6	460
7	Rawas	6,026	4	1	5	1,205
8	Harileko	3,765	0	1	1	3,765
9	Others	17,833	2	9	11	1,621
Total		59,942	14	34	48	1,248

Normally, a relatively sparse network of stations would suffice for the study of large general storms or for determining annual averages over large areas of level terrain. However, in the case of the Musi River Basin, the network of station managed by Musi Balai PSDA has the characteristic of both bias and sparseness. Hence, there is difficulty in studying the hydrological conditions of the whole Musi River Basin using only the network of Musi Balai PSDA. Under this circumstance, it is recommended that from now on Musi Balai PSDA should cooperate with BMG in monitoring rainfall.

(2) Water Level Gaging Station

The site of water level gages should also be determined from the viewpoint of intended use of data; for example, to monitor the water level for the purpose of flood warning, for setting up the river improvement plan, for monitoring the condition for navigation, for setting up the water supply plan and for the evaluation of water quality.

In the case of Musi River Basin, the water level observation system does not satisfy the points of view or purposes mentioned above. Especially, there are only two stations in the Komering River Basin, although the sub-basins are important irrigation areas and have sedimentation problems disturbing river navigation. Furthermore, no observation station is installed at the middle and upper parts of the Musi River (main stretch) as well as the Harileko River and Semangus River.

(3) Sediment Discharge Measurement

Although one of the major issues of the Musi River Basin is erosion and sedimentation, there is no enough accumulation of sediment discharge data. As discussed in **7. Sedimentation** in this Sector Report, available observed sediment load is only for Upper Komering River in 1986-87. Periodical and continuous sediment discharge monitoring for the whole basin is needed.

2.2.4 Data Processing System

Data processing includes the tabulation of data, the calculation of average value, the extraction of extreme data, the visualization of data and so on. So far, these processes have been carried out manually on recording sheets; hence, aside from the mistakes committed in the recording of data, parts of the processing also contain errors and in some cases the processing was suspended.

In consideration of the above conditions, quality improvement involving personnel in charge of hydrological observation/processing is needed to ensure accuracy and the continuous processing in case the hydrological observation resumes in future. Visualization of hydrological data with the use of computers is also effective for minimizing errors or mistakes.

2.2.5 Relationship with Other Organizations

As mentioned in Subsection 2.1.1, hydrological data observation is made mainly by two agencies (BMG and Musi Balai PSDA) and data management is also done separately. With the planned transfer of responsibilities, adequate budget is required for Balai PSDA to acquire data from the other agencies. As for rainfall observation, the transfer of date from another agency will make the acquisition of hydrological information easier without the installation and management of new stations.

2.3 Recommended Hydrological Monitoring Network

In the case of Musi River Basin, the hydrological monitoring network should be built in consideration of the following intended use of data:

Water Use Management

Hydrological Analysis

Water Quality Monitoring

In this sector report, therefore, the recommended monitoring system is described from the viewpoint of Hydrological Analysis (for flush floods and local inundation, basin-wide water balance analysis, study on irrigation development, study on basin-wide water quality and so on) and water use management. As to the system for the water quality monitoring, the necessity and recommendation are explained in another section.

2.3.1 Monitoring Network for Water Management

The monitoring network for water use management should basically cover hydrological matters, especially, water level and rainfall. Based on the present condition and the necessity of data for basin water use management mentioned above, the improvement of the monitoring network is recommended as presented below.

(1) Rainfall Gaging

(a) Coordination with Other Organizations

As mentioned in **2.2.3 Monitoring Network for Flood Warning**, the distribution of stations becomes uniform when the rainfall gaging station managed by BMG is taken into account. In that case, the density of stations is adequate for the water management in the whole Musi River Basin.

Nevertheless, the coordination between Musi Balai PSDA and BMG is very important. The supply of rainfall data from BMG to Musi Balai PSDA for the purpose of basin water use management should be discussed between them, especially, on whether or not it shall be compensated from the budget of Musi Balai PSDA.

(b) Interval of Recording

The gages of Musi Balai PSDA are of the automatic recording type and those of BMG are the manual type except for the one in Plaju Station at Palembang Airport. The automatic recording type is of course preferable because it supplies accurate and short-term (every minute) to daily data, but for the purpose of basin-wide management, daily data would suffice.

(c) Integrated Data Storage and Processing System

Important is that all the data observed at stations of Musi Balai PSDA and BMG should be stored and processed under a single system for the use of water management in the Musi River Basin. Thus, coordination between Musi Balai PSDA and BMG is deemed important.

(d) Development and Renewal of Inventory

The Inventory of rainfall gaging stations should be developed and periodically updated. Coordinates (latitude and longitude) are important for use in GIS. The Inventory should cover the following items:

- Station name
- Management organization (Musi Balai PSDA or BMG)
- Location (address)
- Coordinates and altitude
- Date of operation start
- Other information (status of equipment, etc.)

(2) Water Level Gaging and Discharge Measurement

(a) New Construction of Station

The distribution of stations has been evaluated Subsection 2.2.3 for the purpose of using data for river water use management. Since the water level observation system seems to be unsatisfactory for this purpose, five water level gaging stations are proposed for construction/installation at the following locations to strengthen the present monitoring system, as shown in **Figure G2.3.1**.

- Musi River at Tebingtinggi (upstream of the Musi River)
- Musi River at Sekayu (midstream of the Musi River)
- Harileko River upstream point from confluence with the Musi River
- Semangus River upstream point from confluence with the Musi River
- Organ River at Baturaja

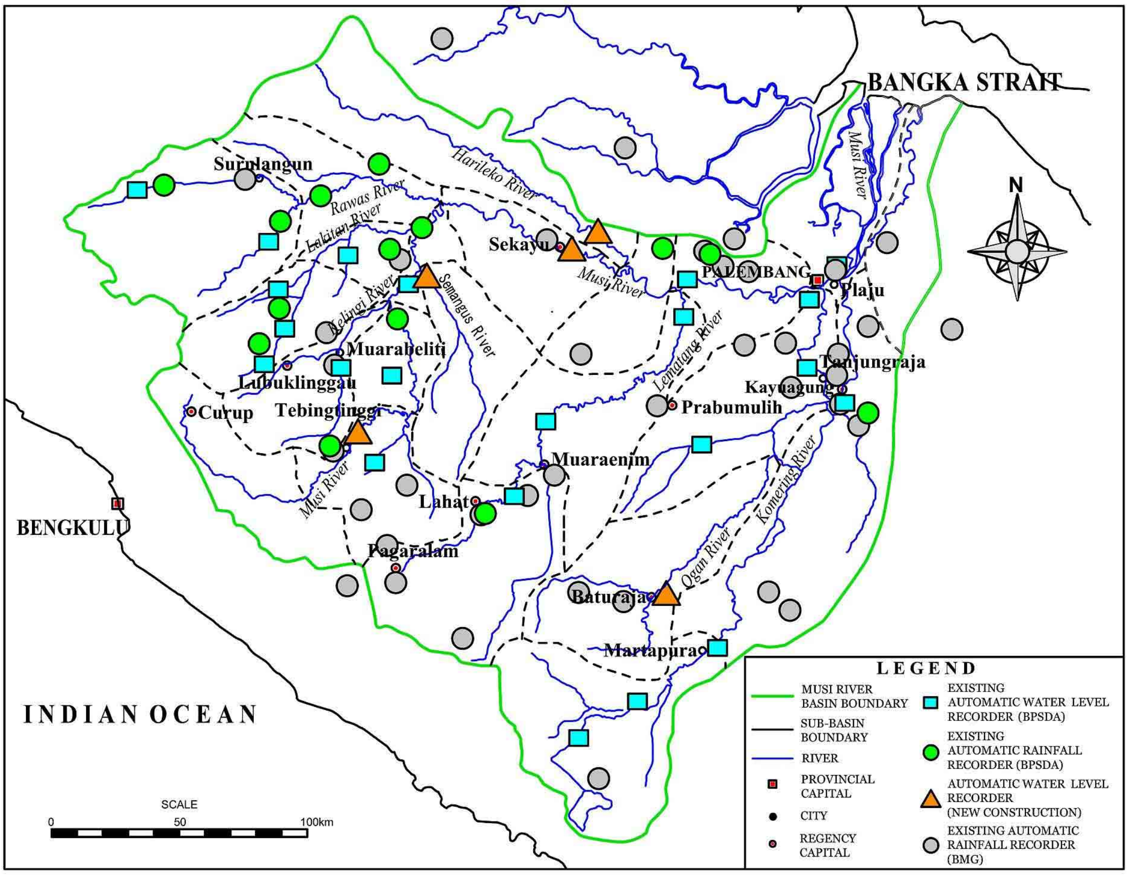

Figure G2.3.1 New Instillation of Water Level Gaging Stations

The list of automatic water level gaging stations including those proposed above is listed in **Table G2.3.1**.

Table G2.3.1 Existing and Proposed Water Level Gaging Stations

No.	Station Name	H-Q curve	No.	Station Name	H-Q curve
1	Karang Anyar	No	15	Tanjung Raja	O.K.
2	Martapura	O.K.	16	Tanjung Beringin	O.K.
3	Kota Agung	O.K.	17	Pinang Belarik	O.K.
4	Tanjung Raja	O.K.	18	Lebak Budi	O.K.
5	Terawas	O.K.	19	Mambang	O.K.
6	Megang Sakti	O.K.	20	Ulak Bandung	O.K.
7	Tebing Abang	No	21	Cipodadi	O.K.
8	BandarJaya (K.Agung)	No	22	Menanga	No
9	Rantau Bingin	O.K.	23	Tebingtinggi *1	No
10	Sungai Rotan	O.K.	24	Sekayu *1	No
11	Tanjung Rambang	No	25	Harileko *1	No
12	Ulak Surung	O.K.	26	Semangus *1	No
13	Mariana	No	27	Baturaja, Ogan *1	No
14	Pulau Kidak	O.K.	-	-	-

*1: proposed under the present program
OK: H-Q curve available but data is not updated in most cases.

(b) Adjustment of Zero Datum

Water level is the elevation above some arbitrary zero datum of the water surface at a station. Only a few stations in the Musi River Basin have the datum from mean sea level. The inventory of stations should be developed and all stations' datum should be expressed as mean sea level value.

(c) Development and Renewal of Inventory

Inventory of the water level gaging stations should be developed and periodically updated. Coordinates (latitude and longitude) are important for the use in GIS. The inventory should cover the following items:

- Station name
- River name
- Catchment area of the river
- Location (address) of the station
- Coordinates and altitude of datum
- Date of operation start
- Other information (status of equipment, etc.)

(d) Discharge Measurement

Development of the relation between water level and discharge (Discharge Rating Curve) should also be conducted periodically. **Table G2.3.1** shows the availability of H-Q curve at each station. In this Table, the status marked "O.K." means that there is an H-Q curve, but data is not updated in most cases. Thus, discharge measurement at all the water level gaging stations is necessary once in every two months.

(e) Sediment Discharge Measurement

As discussed in the previous section, there is no accumulation of sediment discharge data for the Musi River Basin. It is proposed to conduct sediment discharge measurement at the same time of the discharge measurement.

(3) Hydrological Monitoring System Establishment Program (Program 5-1)

Hydrological monitoring covers meteorological data, rainfall, river water stage, river flow, and sediment discharge. The program includes the following activities. Responsible agency is Musi Balai PSDA

(a) Inventory Survey (Program 5-1-1)

Musi Balai PSDA shall undertake a detailed inventory of the hydrometric stations and equipment (current meter, etc.) in the field and in the storage, their conditions and approximate costs of repair and upgrade. Prepare a plan to repair and rehabilitate hydrometric stations (priority for rainfall gaging stations and discharge measurement) and to prepare list of equipment with cost for procurement. It has been almost completed already.

(b) Establishment of Organization (Program 5-1-2)

Establish Water Resources Data and Information Unit in Musi Balai PSDA (**Program 6-5-1**). Musi Balai PSDA should coordinate with BMG and establish a rule for rainfall data transfer from BMG to Musi Balai PSDA.

(c) Capacity Building (Program 5-1-3)

Musi Balai PSDA shall grasp present capability of hydrometric monitoring group and prepare a capacity building plan. Conduct capacity building to technical personnel for hydrological monitoring work. Cost shall be 5-person, 1-month per year at Rp. 5 million per year.

(d) New Construction and Improvement of Facilities (Program 5-1-4)

New construction of the hydrometric station shall be made for the proposed five water level gaging stations. Based on the inventory, necessary improvement of the facilities shall be conducted. A typical water level gaging station is illustrated in **Figure G2.3.2**.

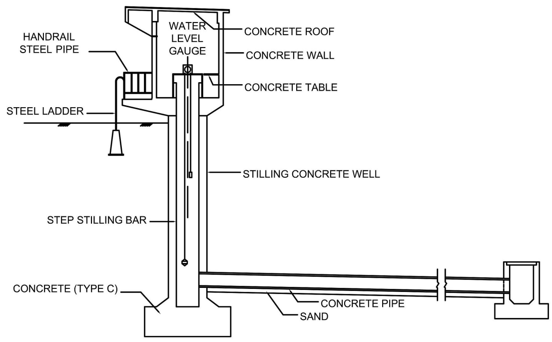

Figure G2.3.2 Typical Structure of Water Level Gage

Cost for the new construction of the water level gaging station is estimated at Rp.240 million per station.

Rehabilitation of monitoring facilities shall be conducted based on the inventory survey to be conducted under the Program 5-1. Present status of the existing facilities is presented in **Annex G2.1.7**. Estimated cost for improvement is as follows:

- Improvement of Climatology Station: Rp.183.5 million
- Improvement of Rainfall Recorder: Rp. 100.3 million
- Improvement of River Water Level Recorder
  with Staff Gage: Rp. 264 million

(e) Monitoring (Program 5-1-5)

Hydrological monitoring work shall consist of field monitoring work, e.g., maintenance of stations, retrieval of recorded data, field measurement work, and office work for data storage and processing. Of these, office work for data storage and processing shall be conducted under the **Program 5-4**. Filed monitoring work shall be conducted as follows:

Field monitoring work consists of the following work:

- Maintenance of the station and equipment
- Retrieval of recorded data
- River water discharge measurement
- River sediment discharge measurement

In order to implement these field monitoring work, subject stations are grouped into 12 sites. Numbers of water level recorders, rainfall gages, and climatological stations in each group are as shown below. Necessary days for monitoring work have been decided considering the trip from

Palembang and maximum of two locations river water discharge and sediment discharge measurement work per day.

River water discharge measurement and river sediment discharge measurement work is proposed to be conducted once every two month. According to the work plan as shown in **Table G2.3.2**, a total of net 31 days are needed to cover all the sites, thus one team can conduct this work every two months.

Table G2.3.2 Field Monitoring Site and Necessary Days for Monitoring Work

	Site Name	No. of W.L.R.	No. of R.G.	No. of C.S.	Necessary Days for Monitoring Work
1	Upstream of Komering	3	0		3
2	Downstream of Komering and Ogan	4	1		3
3	Midstream of Ogan	1	0		2
4	Upstream of Ogan	1	0		2
5	Downstream of Lematang	2	2		2
6	Midstream of Lematang	2	1	1	2
7	Sekayu	2	0		2
8	Rawas	1	3		2
9	Lakitan	4	2		4
10	Confluence of Semangus	3	3		3
11	Upstream of Kelingi and Musi	4	1	1	5
12	Others	0	0	2	1
	Total				31

W.L.R.: Water Level Recorder
R.G.: Rainfall Gage
C.S.: Climatological Station

Necessary input for the monitoring work has been estimated as follows:

Table G.2.3.3 Input for Monitoring Work

Item	Quantity	Unit Cost	Cost
1. Man Power			
Chief Hydrographer	1	Rp. 18 million/year	Rp. 18 million/year
Assistant Hydrographer	2	Rp. 10 miilion/year	Rp. 20 miilion/year
Supporting Staff	2	Rp. 5 million/year	Rp. 10 million/year
Driver	1	Rp. 5 million/year	Rp. 5 million/year
Boat Operator	1	Rp. 5 million/year	Rp. 5 million/year
Assistant Boat Operator	1	Rp. 5 million/year	Rp. 5 million/year
2. Equipment			
Vehicle	2	Rp. 185 million/unit	Rp. 370 million (Initial invest)
Boat	1	Rp. 220 million/unit	Rp. 220 million (Initial invest)
Discharge measurement equipment	1	Rp. 100 millio/l.s.	Rp. 100 millio (Initial invest)
Bed load measurement equipment	1	Rp. 110 million/unit	Rp. 110 million (Initial invest)
Miscellaneous equipment	1	Rp. 5 million/2-month	Rp. 30 million/year
Total		Initial Investment	Rp. 800 million
		Annual Cost	Rp. 93 million

(f) Hydrological Database Establishment (Program 5-4)

Establishment of Numerical Database

Musi Balai PSDA is presently establishing the numerical database using Microsoft ACCESS. This system shall storage rainfall and water level data. Necessary data processing should be included in the system.

Water quality database should also be established. Use of Microsoft ACCESS is recommended to unite the numerical database.

Establishment of GIS Database

The JICA Study Team has already established a GIS database for Musi River Basin. The database has been used in the study for land use analysis, environment analysis and forest disappearance analysis. It was proofed that the water management work can be more efficient by using the GIS Database. To use the GIS technology efficiently in daily management work, the following shall be needed.

The GIS environment has three factors, GIS Engineer, GIS Database and GIS Application. The GIS database and GIS application must be stored in computer hardware. To maintain the computers, system administrators must be included in the environment. In Musi Balai PSDA, the following GIS environment (GIS group) is proposed by this study.

Table 2.3.4 Cost for Database Establishment and Maintenance

Item	Quantity	Unit Cost	Cost
1. System Development			
Numerical database (Water Quality)	1	Rp. 50 million/l.s.	Rp. 50 million (Initial invest)
2. Maintenance Man Power			
Computer System Asministrator	1	Rp. 18 million/year	Rp. 18 million/year
Database Manager	1	Rp. 15 million/year	Rp. 15 million/year
GIS Engineer	2	Rp. 12 million/year	Rp. 24 million/year
3. Hardware and Software			
Arc View 8.2	2	Rp. 30 million/unit Rp. 5.5 million/year	Rp. 60 million (Initial invest) Rp. 11 million from 2nd year
ArcInfo 8.2	1	Rp. 270 million/unit Rp. 57 million/year	Rp. 270 million (Initial invest) Rp. 57 million from 2nd year
Office Soft	3	Rp. 4 million/unit	Rp. 12 million (Initial invest)
Computer	3		Already Donated by JICA
Plotter	1		Already Donated by JICA
Printer	1		Already Donated by JICA
Scanner	1	Rp. 11 million/unit	Rp. 11 million (Initial invest)
Total		Initial Investment	Rp. 403 million
		Annual Cost	Rp. 125 million

2.3.2 Monitoring Network for Flood Warning

Among hydrological analysis, the analysis for flush flood and debris flow (Local Phenomena) is mooted on this section, since other basin-wide phenomena can be analysed on the basis of recommended network in **2.3.1 Monitoring Network for Water Management**.

Flush floods and debris flow has been inflicting damage on villages and infrastructure in the upper Musi River Basin. There had also been casualties at the damage area (see Sector H). Recently, flush floods and debris flow had occurred at the upstream of the Lematang River, the Komering River and the Musi River main stream because of the steep slopes and the abundant rainfall. To mitigate damage from flush floods and debris flow, the flood forecasting and warning system has become available as a non-structural measure. Its set up is as discussed below.

(1) Rain Gage

To establish the flood forecasting system, the proper number of monitoring stations is required. The proper number should be determined with the following factors taken into account:

- Degree of area variation in rainfall
- Model of flood forecasting
- Flood forecasting point

Further, the following factors should be taken into consideration in selecting the site of rain gage stations:

- Position of one gage station in relation to other stations
- Limits of area to be covered by the gage station
- Condition of location of gage station site
- Ease of maintenance and other pertinent factors

However, in this study, it is difficult to analyze all the factors mentioned above. Thus, in this section, the number of stations is assumed using the WMO guideline as reference. With this WMO guideline, the required minimum rain gage station density in terms of area for the six zones has been determined, as indicated in **Table G2.3.5.**

Table G2.3.5 Minimum Required Rain Gage Station Density

Geographical Features	Ordinary Rain Gage Station (km^2/per Sta.)	Automatic Rain Gage Station (km^2/per Sta.)
Coastal Zone	900	9,000
Mountainous District	250	2,500
Flat Land	575	575
Hilly District	575	575
Islet	25	25
Urban Area	-	10-20
Polar Region/Arid Region	10,000	100,000

Catchment areas damaged by debris and flush floods range from 100 km^2 to 200 km^2. Therefore, the adequate number of stations for the damage area in the Upper Musi River Basin has been estimated at one station at least for each tributary's basin in accordance with **Table G2.3.5**.

Additionally, if a monitoring network is needed in the damage area, the degree of accuracy desired and the scale of rainfall gage network should be determined with due consideration given to the relative ease of building and maintaining these stations, their cost efficiency, and other pertinent factors.

(2) Water Level Gage

In selecting sites for water level/discharge gage stations or in preparing a layout plan for them, generally, the following locations should be considered:

- Flood Forecasting Point: Location should be immediately upstream of a key city or village and where clear indications can be given as to whether or not water level/discharge measured are critical in the city or village.
- Dam Reservoir: For the purpose of monitoring the reservoir water level.
- Other locations considered essential from the standpoint of flood forecasting or flood defence.

Practically, the site of water level gage is roughly determined in consideration of the present damage area, as shown in **Table G2.3.6.**

Table G2.3.6 Proposed Water Level Gaging Site for Flood Forecasting

No.	Sub-Basin	Site with Existing Gages	Proposed Site	Damage Area
1	Komering	- Martapura	- Muaradua	-Muaradua -Kisam River
2	Ogan	-	-	-
3	Lematang	- Muara Enim	- Lahat - Pagar Alam - Keriging Area	-Muara Enim -Keringing River -Pagar Alam
4	Semangus	-	-	-
5	Kelingi	- Rantau Bingin	-	-
6	Lakitan	- Mengan Sakit - Tanjung Raja - Teraeas - Ulak Sulung	-	-
7	Rawas	- Tanjung Beringin - Puluk Kidak	-	-
8	Harileko	-	-	-
9	Musi	-	- Tebing Tinngi	-Talang padang

(3) Type of Gage at Monitoring Station

There are three kinds of rain gage: ordinary rain gage, automatic rain gage and radar rainfall gage. Among these types, the telemeterized automatic rain gage is normally suitable for flood forecasting services.

(4) Flood Forecasting Method

Flood forecasting provides predictions of flood outbreak time, flood discharge, and the extent of flood inundation. **Annex G2.3.2** gives a flowchart for building a calculation model for flood forecasting and **Annex G2.3.3** is a flowchart for flood calculations in case of flood.

On the whole, the forecasting method is classified into (1) Rainfall Forecasting, (2) Forecasting by Correlation, and (3) Forecasting by Runoff Calculation. Among these methods, the rainfall forecasting seems difficult to perform flood forecasting under the present circumstance in the Musi River Basin because of insufficient information regarding meteorological characteristics in the mountainous area. On the other hand, the other two methods will be available only after the local rainfall analysis is made in detail.

3. ANALYSIS ON OBERVED DATA

3.1 Rainfall

3.1.1 Monthly Rainfall Analysis

The variations of monthly rainfall at the principal rainfall gaging stations (selected from Palembang to Mountainous Area) are shown in **Figure G3.1.1**. Rainfall normally starts to increase in September, peaks between December and January or March, then, starts to decrease in May.

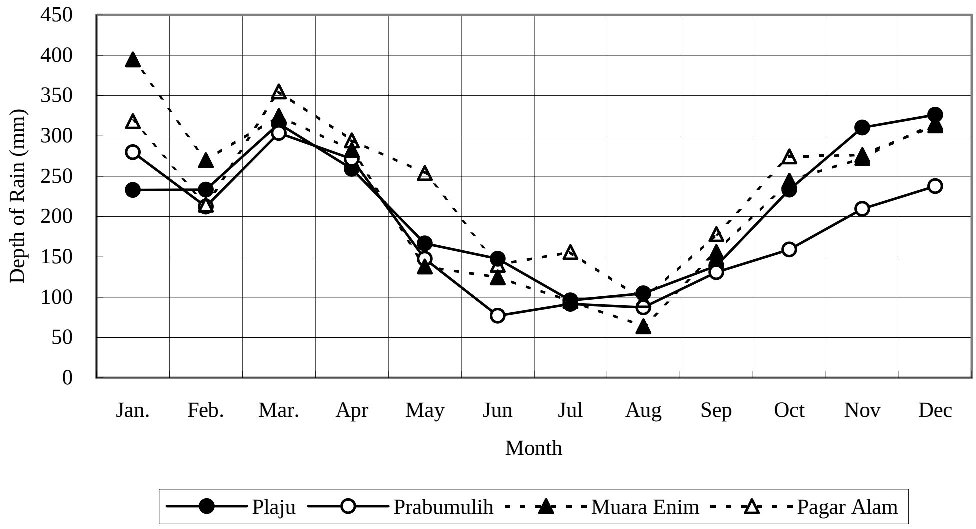

Figure G3.1.1 Monthly Rainfall at Principal Stations

3.1.2 Annual Rainfall

Annex G3.1.1 presents the isohyetal map of annual rainfall at the Musi River Basin. This map shows the northeast-to-southwest increase and the variation across the coastal plain into the interior ranging approximately from 2,000 mm around the coastal area to 3,000 mm around the mountainous area and foothills.

3.1.3 Storm Rainfall

The duration and concentration of storm rainfall are important factors to grasp one of the rainfall characteristics. Further, it is used to set up the design hydrograph through runoff analysis for the drainage planning for Palembang. Therefore, the mass curves and concentration rate graphs were prepared for fixing the duration and concentration type of storm rainfall. The fixation was carried out using the rainfall record at the Kenten Station in Palembang where the short-duration rainfall has been observed by BMG.

(1) Duration

The mass curves at the Kenten Station are given in **Figure G3.1.2** and these curves show that the duration of storm rainfalls can be fixed at 12 hours. The time series of these rainfalls are tabulated in **Annex G3.1.2**.

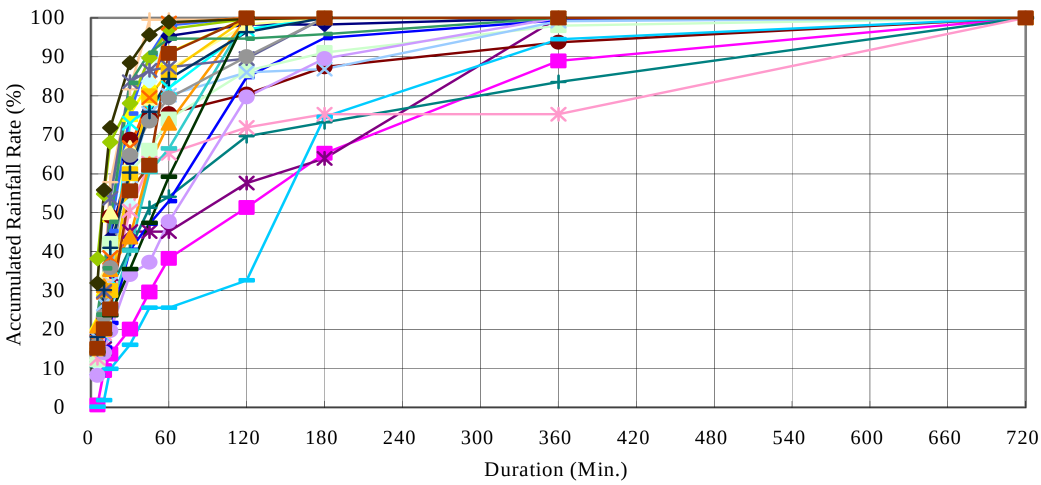

Figure G3.1.2 Mass Curves of Rainfall (Over 50 mm) at Plaju

(2) Rate of Concentration

The average concentration ratio of storm rainfall is illustrated in **Figure G3.1.3**. The figure shows that more than 70% of storm rainfall occurs at the beginning of rain. As a result of this analysis, it was determined that intense rainfall concentrates in the front of the storm rainfall around Palembang.

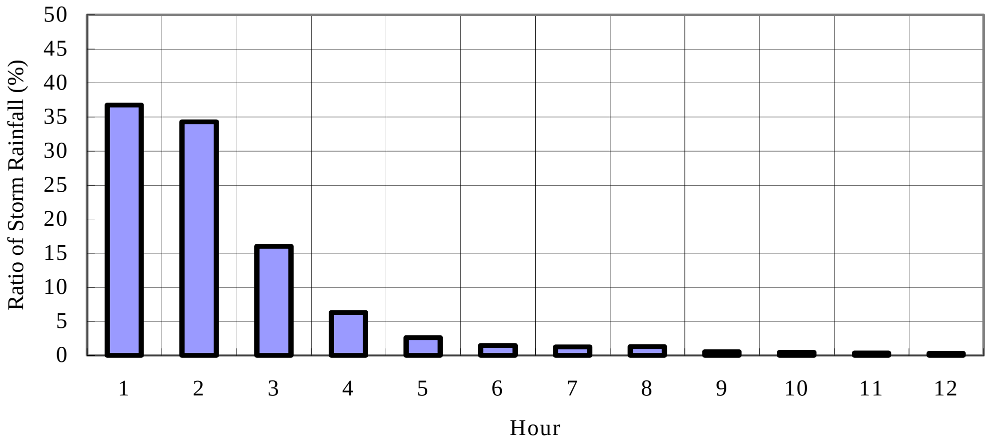

Figure G3.1.3 Ratio of Concentration of Storm Rainfall

(3) Probable 12-Hour Rainfall

The maximum 12-hour rainfall in every observation year (1994-2001) is summarized in **Table G3.1.1**.

Table G3.1.1 Maximum 12-Hour Rainfall (Kenten Station at Palembang)

Year/Month	1994/4	1995/6	1996/11	1997/5	1998/3	1999/10	2000/4	2001/12	Ave.
Rainfall (mm)	89.5	153.3	121.7	108.0	100.0	84.5	98.5	103.2	107.3

The probable 12-hour rainfall was calculated from the data presented in the table above. The Gumbel-Chow method, which has been commonly used in the static analysis for extreme-value, was employed in the calculation of recurrence probability. The probable 12-hour rainfall for each probability period is shown in **Table G3.1.2** and **Figure G3.1.4**.

Table G3.1.2 Probable 12-Hour Rainfall (Kenten Station at Palembang)

Return Period	1/2	1/5	1/10	1/15	1/20	1/30	1/50	1/100
Probable Rainfall (mm)	104.0	122.5	133.9	140.8	145.3	151.8	160.1	171.1

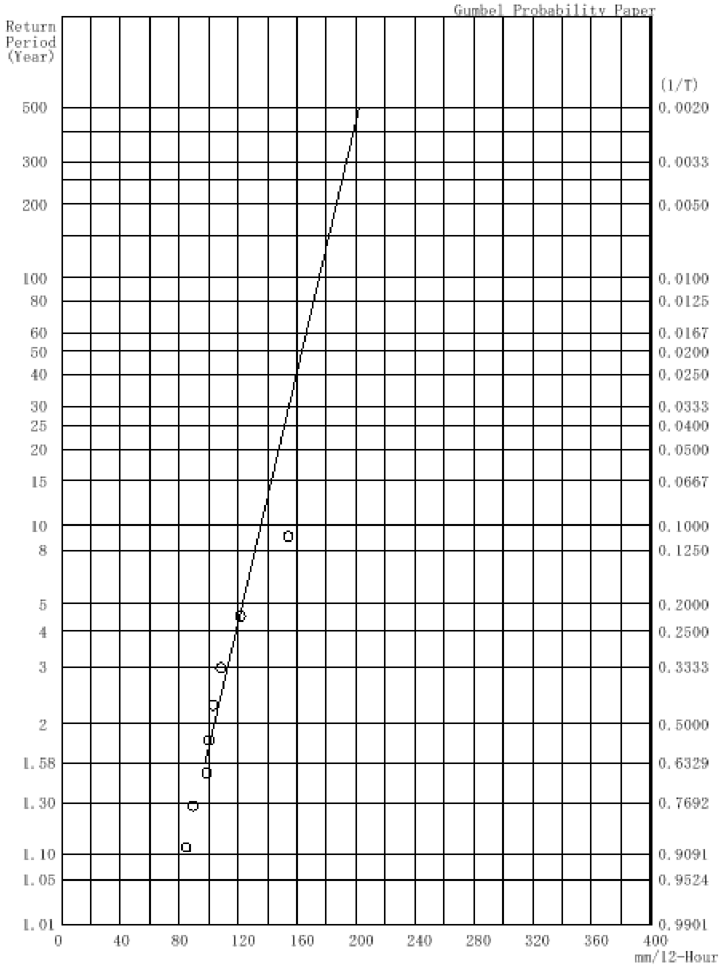

Figure G3.1.4 Probable 12-Hour Rainfall (Kenten Station at Palembang)

3.2 Discharge

3.2.1 Discharge Rating Curve

The rating curves built by the Center of Research and Development are summarized in **Table G3.2.1**. Rating curves at the Banding Agung, Batu Puti, Tanjung Beringin and Muara Rupit stations, as well as the water level at Ciptodadi(K), were not collected, and discharge measurements at the Semangus and Harileko rivers have not yet been carried out.

Table G3.2.1 Rating Curves

No.	Sub-Basin	Station	Catchment Area (km^2)	Equation of Rating Curve
1	Komering	Martapura	4,267	$Q=79.849(H+0.120)^{1.364}$
		Kota Agung	1,228	$Q=42.193(H+0.050)^{1.859}$
		Banding Agung	887	-
		Tirtonadi	117	$Q=2.041(H+0.260)^{2.086}$
2	Ogan	Tanjung Raja	6,314	$Q=39.846(H+0.995)^{1.757}$
		Batu Puti	970	-
3	Lematang	Lubak Budi	2,040	$Q=80.465(H+0.182)^{1.764}$
		Pinang Belarlic	3,676	$Q=2.455(H+2.558)^{2.775}$
		Sungai Rotan	6,990	$Q=64.135(H+0.554)^{1.262}$
4	Semangus	-	-	-
5	Kelingi	Ulak Surung	374	$Q=40.012(H+0.060)^{1.600}$
		Rantau Bingin	887	$Q=49.348(H+0.160)^{1.158}$
6	Lakitan	Mengang Sakit	292	$Q=0.567(H+1.318)^{2.606}$
		Terawas	332	$Q=7.436(H-0.041)^{2.057}$
		Tanjung Raya	75	$Q=9.698(H+0.300)^{2.968}$
7	Rawas	Pulo Kidak	1325.0	$Q=98.467(H-0.110)^{1.968}$
		Tanjung Beringin	906	-
		Muara Rupit	3,138	-
8	Harileko	-	-	-
9	Musi	Ulak Bandung	409	$Q=1.224(H+1.300)^{2.852}$
		Ciptodadi (K)	227	$Q=3.943(H-0.020)^{1.495}$
		Darma Bakti	74	$Q=0.723(H-0.220)^{2.439}$
		Ciptodadi (T)	86	$Q=4.111(H-0.290)^{1.427}$
		Mambang	7,745	$Q=8.699(H+1.450)^{2.150}$
		Tebing Abang	33,275	$Q=720.4(H-1.570)^{1.085}$

3.2.2 Estimation of Probable Discharge from Observed Data

Probable discharges were estimated from the data observed at the discharge measurement stations and used for the assumption of probable discharges at principal points to establish the boundary conditions for the drainage plan and countermeasure for flood.

(1) Data Availability

The annual maximum water levels at discharge measurement stations are tabulated in **Annex G3.2.2**. The annual maximum water level was taken from the observation data of Dinas PUP and the annual report published by the Center of Research and Development in Bendung (1991, 1997-1999).

(2) Probable Discharge at Discharge Measurement Station

The probable peak water levels at discharge measuring stations were estimated by the Gumbel Method and tabulated in **Annex G3.2.3**. **Table G3.2.2** presents the probable peak discharge calculated from the probable peak water level and rating curves are given in **Table G3.2.1**.

Table G3.2.2 Probable Discharge (m^3/s)

Basin	Station Name	Catchment Area (km^2)	1/10	1/20	1/30	1/50	1/100
Komering	Martapura	4,267	906	1,028	1,103	1,199	1,335
	Kota Agung	1228	630	677	703	738	788
	Tirtonadi	117	52	57	60	64	69
Ogan	Tanjung Raja	6,314	1,102	1,152	1,179	1,215	1,265
	Batu Puti	970	855	996	1,080	1,191	1,350
Lematang	Lubak Budi	2,040	1,134	1,358	1,496	1,676	1,927
	Pinang Belarik	3,676	1,417	1,651	1,796	1,987	2,260
	Sg.Rotan	6,990	841	884	909	940	983
Kelingi	Ulak Surung	374	381	471	525	598	700
	Rantau Bingin	887	508	563	595	634	689
Lakitan	Megang Sakti	292	61	65	68	71	76
	Terawas	332	550	650	712	796	914
	Tanjung Raya	75	145	175	193	219	255
Rawas	Pulo Kidak	1325	445	551	614	701	723
Musi	Ulak Bandung	409	246	291	319	356	412
	Darma Bakti	73.8	27	32	36	41	48
	Ciptodadi	86.3	42	49	52	57	64
	Mambang	7,745	2,276	2,875	3,006	3,375	3,909
	Tebing Abang	33,275	4,490	5,006	5,307	5,683	6,190

Based on **Table G3.2.2**, the distribution of discharge at principal points is plotted and generally assumed at the downstream of Palembang, as shown in **Annex G3.2.4**.

3.3 Water Flow Regime

3.3.1 Seasonal Variation of River Flow

River flows vary seasonally in accordance with the seasonal change of rainfall. The variation of monthly mean discharge at the principal stations is shown in **Figure G3.3.1**. The river flow at almost all stations marks the peak in February or March, while the lowest is between July and September.

Figure G3.3.1 (1) shows the monthly average discharge at the Lematang River where the three stations are installed at the lower, middle and upper reaches.

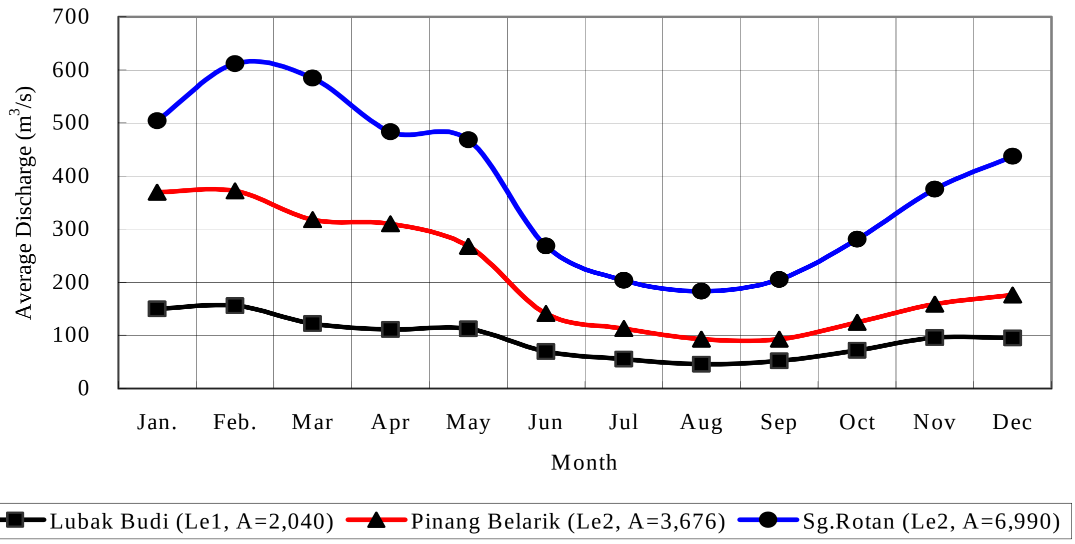

Figure G3.3.1 (1) Seasonal Variation of River Flow

Figure G3.3.1 (2) shows the flow variation in a river with a relatively large catchment area.

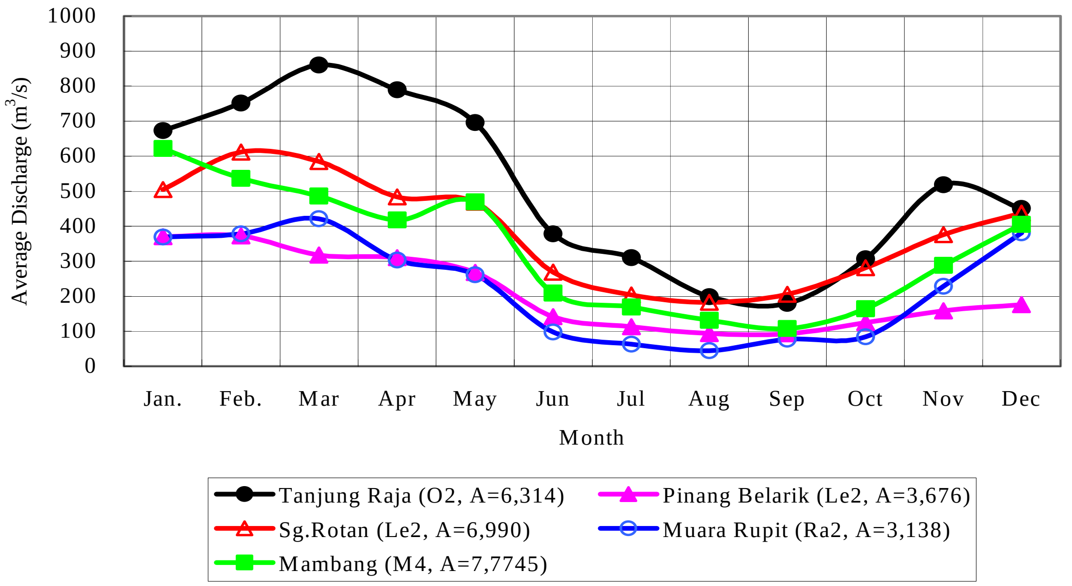

Figure G3.3.1 (2) Seasonal Variation of River Flow

3.3.2 Annual Average Flow Regime

Based on the daily discharge data available at principal stations in the Musi River Basin, the annual average flow regimes at the stations after 1991 are as listed in **Table G3.3.1**.

Table G3.3.1 Annual Average Flow Regime

Basin	Station Name	Catchment Area (km^2)	Max	25 %	50 %	75 %	95 %	Ave. (Wet)	Ave. (Dry)	Annual Ave.
Komering (1)	Martapura	4,267	320.5	145.0	110.5	90.2	55.7	145.9	98.1	120.7
	Kota Agung	1,228	167.3	54.3	38.6	26.1	11.1	52.0	35.2	43.6
	Banding Agung	887	34.3	20.8	12.2	5.3	2.1	20.1	7.4	13.7
Komering (2)	Tirtonadi	117	41.5	18.0	9.6	3.5	1.1	17.2	5.7	11.5
Ogan (2)	Tanjung Raja	6,314	1,056.8	772.5	420.0	261.0	60.3	702.3	314.5	507.9
Ogan (1)	Batu Puti	970	775.8	68.4	28.2	9.7	2.6	92.4	31.1	61.7
Lematang (1)	Lubak Budi	2,040	524.4	116.4	69.2	47.1	11.4	115.2	64.4	89.7
Lematang (2)	Pinang Belarik	3,676	930.7	268.5	158.5	98.8	55.2	301.3	120.4	210.6
	Sg.Rotan	6,990	840.6	564.6	319.1	204.0	98.6	520.0	248.8	384.1
Kelingi	Ulak Surung	374	252.3	29.5	20.6	12.7	2.2	29.7	17.6	23.7
	Rantau Bingin	887	338.3	67.3	42.8	27.4	12.7	74.9	39.2	57.0
Lakitan (1)	Megang Sakti	292	47.6	14.5	8.6	5.0	2.0	14.4	8.0	11.2
	Terawas	332	255.1	29.7	15.4	8.7	2.9	35.6	16.7	26.2
	Tanjung Raya	75	44.7	6.2	3.7	2.0	0.6	6.8	3.1	4.9
Rawas (1)	Pulo Kidak	1,325	660.6	103.9	43.6	21.2	9.0	131.2	36.2	83.6
	Tanjung Beringin	906	720.0	141.0	48.1	19.4	3.8	167.1	50.3	108.6
Rawas (2)	Muara Rupit	3,138	1,134.0	311.0	175.0	65.4	19.6	352.6	98.7	225.5
Musi (2)	Ulak Bandung	409	207.8	27.7	17.1	11.3	4.5	30.5	17.2	23.9
Musi (3)	Ciptodadi	227	38.7	11.7	6.0	2.8	0.8	12.8	5.8	9.3
	Darma Bakti	74	27.8	3.0	1.3	0.5	0.2	3.6	1.1	2.4
	Ciptodadi	86	28.5	8.1	4.4	1.9	0.7	9.0	3.0	5.9
Musi (4)	Mambang	7,745	1,367.3	489.8	262.9	150.3	45.6	505.3	188.1	346.4

Ave.: Average

3.4 Water Volume Analysis

Based on the collected data, the water volume at each sub-basin was estimated. The simple continuity equation for the basin was used for the water volume analysis.

$$P = Q + E + S$$

Where:

P : Rainfall
Q : Runoff in mm
E : Actual Evapotranspiration
S : Charge in water storage

The equation stipulates that input is equal to output plus the increase in storage of water in the catchment. However, the total volume was estimated taking the long-term accumulation into consideration, i.e., the equation above takes the form $P=Q+E$.

Then, the actual evapotranspiration E for Southern Sumatra was determined at around 80% of the potential evapotranspiration in the Musi River Basin Study of 1989 (see **Annex G3.4.1**). The results of this analysis are given in **Table G3.4.1**.

Table G3.4.1 Results of Water Volume Analysis

Sub-Basin	CA (km^2)	EP (mm)	Actual EP (EP*0.8 mm)	Mean Annual Rainfall (mm)	Runoff Volume		
					mm/year	Volume/year (bil. m^3)	m^3/s
Komering	9,908	1,430	1,144	2,588	1,444	14.3	453.7
Ogan	8,233	1,483	1,186	2,633	1,447	11.9	377.7
Lematang	7,340	1,448	1,158	2,984	1,826	13.4	424.9
Semangus	2,146	1,500	1,200	3,042	1,842	4.0	125.3
Kelingi	1,928	1,450	1,160	3,236	2,076	4.0	126.9
Lakitan	2,763	1,450	1,160	3,000	1,840	5.1	161.2
Rawas	6,026	1,400	1,120	2,646	1,526	9.2	291.6
Harileko	3,765	1,400	1,120	2,600	1,480	5.6	176.7

4. RUNOFF ANALYSIS ON FLOW REGIME ESTIMATION FOR MUSI RIVER AND TRIBUTARIES

4.1 Objective of Runoff Analysis and Target Area

Runoff Analysis was carried out at each sub-basin (Refer to **Annex G1.1.1**) for the purpose of gap-filling of natural discharge time series data for the water balance analysis in Sector I. The runoff simulation model covered the entire Musi River Basin of about 60,000 km^2.

4.2 Establishment of Runoff Simulation Model

4.2.1 Outline of Model Structure

The runoff model was established by using the software MIKE 11, which was applied for the runoff analysis in the Musi River Study of 1989. In the MIKE 11 model, runoff generated in the sub-basins is calculated by the NAM Module (Tank Model Type), which simulates the rainfall-runoff process in rural river basins as a lumped model.

The NAM module treats each sub-basin as one unit. The parameters and variables are thus representing average values for the entire sub-catchment. Hence, some of the parameters can be evaluated from physical catchment data, but the final parameter estimation must be performed by calibration applying concurrent input and output time series. The model operates by continuously accounting for the moisture content in the four different and mutually interrelated storage tanks (**Annex G4.2.1**).

4.2.2 Data Availability

The hydrological data (rainfall, water level and discharge) presented in this report were collected from BMG and Musi Balai PSDA.

According to the report entitled “Musi River Basin Study in 1989”, the BMG has been observing rainfall in the Musi River basin since 1970. Unfortunately, however, the data before 1985 were either incomplete or contain many gaps (missing data), so that only data between 1985 and 2001 were collected from BMG. Data of Musi Balai PSDA from 1985 containing many gaps were also collected. The inventory of collected data is given in **Annex G2.1.4** and **Annex G2.1.5**.

4.2.3 Boundary Conditions for Simulation Model

The simulation model (NAM Module) requires input data as the boundary conditions. These data include simulation period, time interval, catchment area, rainfall, potential evaporation, and the parameters decided by the physical condition of the basin, which are determined as follows:

(1) Simulation Period and Time Step

The simulation period is fixed at 15 years between 1986 and 2001, taking data availability into account. The simulation runs with interval (time step) of one day.

(2) Catchment Delineation

Based on the Musi River Basin Study in 1989, the catchment area is as delineated in **Figure G1.1.1**. The delineated catchment areas of sub-basins are summarized in **Table G4.2.1**.

Table G4.2.1 Catchment Area of Sub-Basins

Sub-Basin	Catchment area*1 (km^2)	Sub-Basin	Catchment area*1 (km^2)
Komering 1	4,527	Kelingi	1,928
Komering 2	5,381	Harileko	3,765
Ogan 1	3,990	Musi 1	2,389
Ogan 2	4,232	Musi 2	2,740
Lematan 1	3,930	Musi 3	1,013
Lematan 2	3,410	Musi 4	564
Semangus	2,146	Musi 5	2,499
Lakitan 1	2,290	Musi 6	1,648
Lakitan 2	473	Musi 7	1,822
Rawas 1	3,548	Musi 8	2,646
Rawas 2	2,478	Padang	2,513

*1 Source: Musi River Basin Study, 1989

(3) Daily Basin Mean Rainfall

The time series of daily basin mean rainfall of each sub-basin for the period of 15 years from 1986 to 2000 were input to the runoff module of MIKE 11.

Thiessen Method was applied to calculate daily basin mean rainfall. The location of stations and Thiessen polygon are illustrated in **Figure G4.2.1**. The weight resulting from the component ratio of polygons for each basin is summarized in **Annex G4.2.2**.