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GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA

REGIONAL WATER RESOURCES STUDY OF SOUTH JOHOR

VOL. 4

ANNEX

D. METEOROLOGY AND HYDROLOGY
E. GROUNDWATER RESOURCES
F. WATER QUALITY

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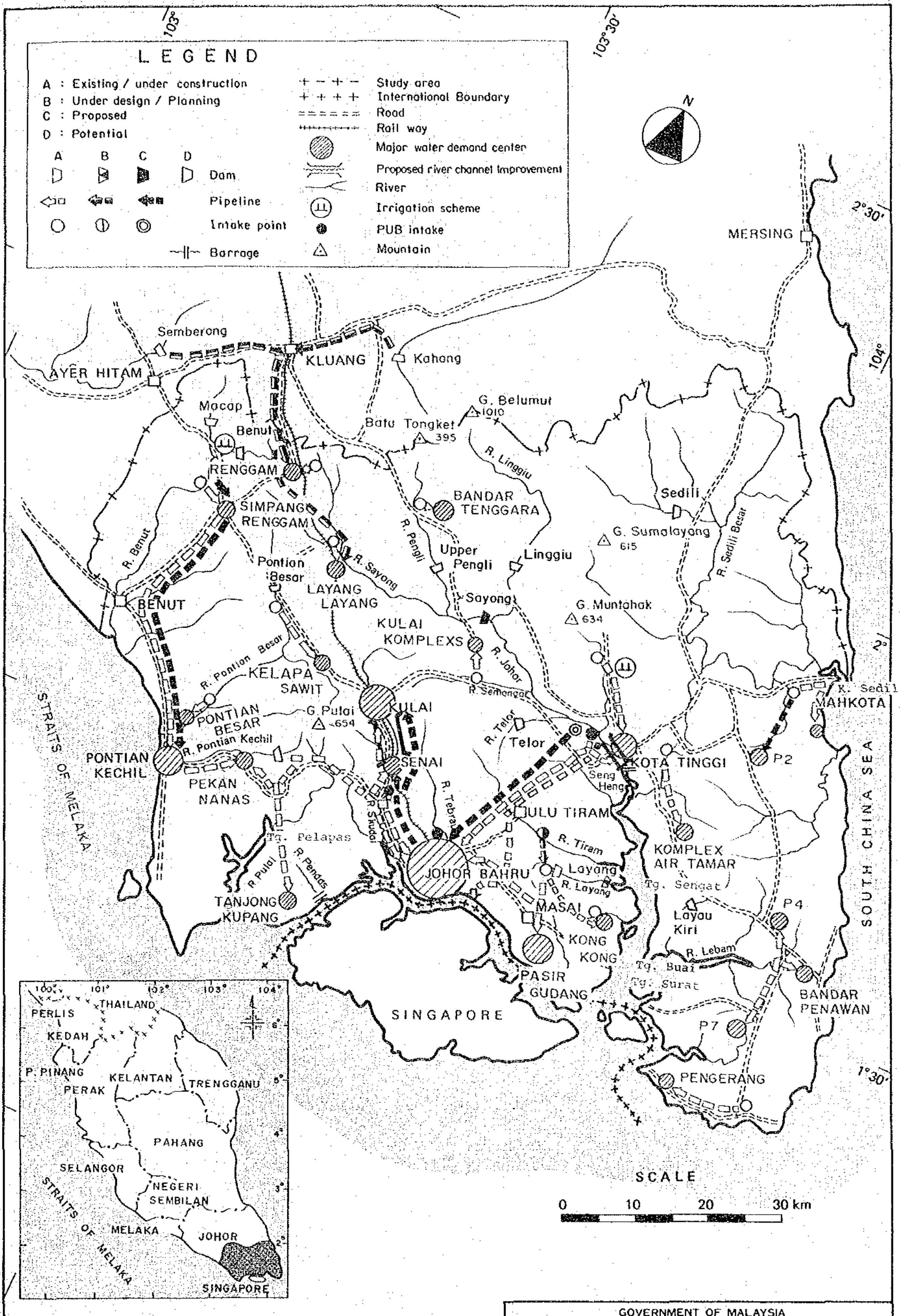
JAPAN INTERNATIONAL COOPERATION AGENCY

NATIONAL WATER RESOURCES STUDY, MALAYSIA

REGIONAL WATER RESOURCES STUDY OF SOUTH JOHOR

LIST OF VOLUMES



GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA
SOUTH JOHOR
REGIONAL WATER RESOURCES STUDY

JAPAN INTERNATIONAL COOPERATION AGENCY

ABBREVIATIONS

(1) Oreganization/Plan

4MP (5MP) : Fourth (Fifth) Malaysia Plan
DID (JPT) : Drainage and Irrigation Department
DOA : Department of Agriculture
DOE : Department of Environment
EPU : Economic Planning Unit
FELCRA : Federal Land Consolidation and Rehabilitation Authority
FELDA : Federal Land Development Authority
GSD : Geological Survey Department
JICA : Japan International Cooperation Agency
KEJORA : Lembaga Kemajuan Johor Tenggara
MOA : Ministry of Agriculture
MOH : Ministry of Health
MTR : Mid-Term Review of 4MP
NEB : National Electricity Board
NWRS : National Water Resources Study
PUB : Public Utility Board (Singapore)
PWD (JKR) : Public Works Department
RESP : Rural Environmental Sanitation Program
RISDA : Rubber Industry Smallholders Development Authority
WHO : World Health Organization

(2) Others

B : Benefit
BOD : Biochemical Oxygen Demand
C : Cost
COD : Chemical Oxygen Demand
D & I : Domestic and Industrial
dia. : Diameter
DRC : Dry Rubber Content
EIRR : Economic Internal Rate of Return
EL. : Elevation Above Mean Sea Level
Eq. : Equation
FFB : Fresh Fruit Bunch
Fig. : Figure
GDP : Gross Domestic Project
GNP : Gross National Product
GRP : Gross Regional Project
HWL : Normal High Water Level
O & M : Operation and Maintenance
Q : Discharge
Ref. : Reference
SS : Suspended Solid
VA : Value Added

ABBREVIATIONS OF MEASUREMENT

Length

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

Area

cm^2 = square centimeter
m^2 = square meter
ha = hectare
km^2 = square kilometer

Volume

cm^3 = cubic centimeter
l = lit = liter
kl = kiloliter
m^3 = cubic meter

Weight

mg = milligram
g = gram
kg = kilogram
ton = metric ton

Time

s = second
min = minute
h = hour
d = day
y = year

Other Measures

% = percent
° = degree
' = minute
" = second
°C = degree in centigrade
10^3 = thousand
10^6 = million

Derived Measures

m^3/s = cubic meter per second
Mgd = million gallon per day
Mld = million litre per day

Money

M$ = Malaysian Ringgit
M¢ = Malaysian Cent

CONVERSION FACTORS

	From Metric System	To Metric System
Length	1 cm = 0.394 inch 1 m = 3.28 ft = 1.094 yd 1 km = 0.621 mile	1 inch = 2.54 cm 1 ft = 30.48 cm 1 yd = 91.44 cm 1 mile = 1.609 km
Area	1 cm^2 = 0.155 sq.in 1 m^2 = 10.76 sq.ft 1 ha = 2.471 acres 1 km^2 = 0.386 sq.mile	1 sq.ft = 0.0929 m^2 1 sq.yd = 0.835 m^2 1 acre = 0.4047 ha 1 sq.mile = 2.59 km^2
Volume	1 cm^3 = 0.0610 cu.in 1 lit = 0.220 gal.(imp.) 1 kl = 6.29 barrels 1 m^3 = 35.3 cu.ft 10^6 m^3 = 811 acre-ft	1 cu.ft = 28.32 lit 1 cu.yd = 0.765 m^3 1 gal.(imp.) = 4.55 lit 1 gal.(US) = 3.79 lit 1 acre-ft = 1,233.5 m^3
Weight	1 g = 0.0353 ounce 1 kg = 2.20 lb 1 ton = 0.984 long ton = 1.102 short ton	1 ounce = 28.35 g 1 lb = 0.4536 kg 1 long ton = 1.016 ton 1 short ton = 0.907 ton
Energy	1 kWh = 3,413 BTU	1 BTU = 0.293 Wh
Temperature	°C = (°F − 32)·5/9	°F = 1.8°C + 32
Derived Measures	1 m^3/s = 35.3 cusec 1 kg/cm^2 = 14.2 psi 1 ton/ha = 891 lb/acre 10^6 m^3 = 810.7 acre-ft 1 m^3/s = 19.0 mgd	1 cusec = 0.0283 m^3/s 1 psi = 0.703 kg/cm^2 1 lb/acre = 1.12 kg/ha 1 acre-ft = 1,233.5 m^3 1 mgd = 0.0526 m^3/s
Local Measures	1 lit = 0.220 gantang 1 kg = 1.65 kati 1 ton = 16.5 pikul	1 gantang = 4.55 lit 1 kati = 0.606 kg 1 pikul = 60.6 kg

Exchange Rate

(1985)

US$1 = M$2.41
¥100 = M$0.980

ANNEX D
METEOROLOGY
AND HYDROLOGY

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

1. INTRODUCTION

This ANNEX describes the results of meteorological and hydrological study carried out during the period from July 1984 to October 1985.

The study aimed at;

(1) to estimate daily runoff for continuous 22 years period from 1963 to 1984 at the proposed damsites and existing and proposed intakes within the Region for the convenience of the water demand and supply balance study;

(2) to estimate inflow flood discharge to the proposed dams; and

(3) to estimate sediment load and inflow to the reservoirs to be created by the proposed dams.

2. THE STUDY AREA

2.1 Location

The study area (the Region) is located in the southernmost part of the peninsular Malaysia between $103^{\circ}11'$ and $104^{\circ}18'$ east in longitude and between $1^{\circ}16'$ and $2^{\circ}14'$ north in latitude. The Region faces the Melaka Straits in the west and faces to the South China Sea in the east. Singapore lies few miles away across the Johor Straits in the south. Total area of the Region is about 7,350 km^2 which occupy 38% of the Johor State. Most of the Region is covered by plains and low hills, though mountainous area extends near the region boundary in the northeast.

2.2 Rivers

The Region is composed of nine major river basins. They are the Benut, Pontian Kechil and Pontian Besar rivers running towards the Melaka Straits, Skudai, Tebrau and Johor rivers which discharge into the Johor Straits, and the Sedili Besar and Sedili Kechil rivers which empty themselves to the South China Sea. Gradients of the river bed are gentle at most stretches due to low undulating topography. Accordingly, discharge in lower reach of the rivers are much influenced by tide.

The Johor river, the largest river system in the Region, originates from near Renggam town and finally flows into the east end of the Johor Straits. Main tributaries forming the basin are Pengli, Sayong, Sebol, Jengeli, Linggiu, Semangar, Telor, Seluyut, Permandi, Tiram, Layang and Lebam. Flood innundation area extends along upper and middle reaches. Jungle swamps can be seen along the upstream reaches of the Linggiu, Pengli, Sayong and Semangar rivers.

The Public Utility Board of Singapore has an intake to withdraw the river water at just upstream of Kota Tinggi. Present abstraction thereby is around 100 x 10^6 m^3/y. Other intakes provided by the PWD are located in the Sayong, Pengeli, Linggiu, Semangar and Seluyut rivers. The abstraciton thereby are in the range of 0.2 and 0.7×10^6 m^3/y.

The backwater caused by high tide is observed upto the point in-between Kg. Semangar and Kg. Bahru 70 km upstream from the Johor Straits. In the Layang river which flows from west to east joining western bank, construction of Layang dam is underway to supply water of 40 Mgd (total capacity of scheme Ia and Ib) to Johor Bahru and Pasir Gudang from 1986. Lebam dam located upstream of Lebam river was completed for water supply of 1.6 Mgd. The total catchment area of Johor river at its river mouth is 2,687 km^2.

The Pulai river running to south from G. Pulai (EL. 654 m) is featured by extensive swamps with mangrove. Most of the basin is low populated and undeveloped. At the upstream end, Gunong Pulai Dam with intake owned by PUB are located. The catchment area excluding Gunong Pulai area is 292 km^2.

The Skudai river runs through the most developed area in the Region. Industrial and agro-industrial factories are concentrated along the Skudai valley. Kulai and Senai towns are the centers of these highly populated areas in the valley. Accordingly, increase of the river water pollution due to domestic sewage and industrial effluent is remarkable recently. PUB operates an intake having capacity of 35 Mgd at lower reach about 17 km from estuary. The catchment area of the Skudai river is 297 km^2.

The Tebrau river flows in parallel with the Skudai river and flows into the Johor Straits at east end of Johor Bahru. The river regime and development level in the basin is resemble to the Skudai river. There is a PUB intake of 30 Mgd at about 14 km upstream from estuary. The total catchment area is 258 km^2.

The Benut river basin locates at northeast end in the Region and its catchment area is 568 km^2. Macap dam having 77 km^2 of catchment area is located at Macap river, the main tributary of Benut river. Ulu Benut irrigation scheme depends on the river water at just upstream from the confluence of the Machap river. The paddy irrigation area is 177 ha.

The Pontian Besar river rises in G. Pulai and flows southwards to the Melaka Straits. The middle reach of the river crosses the marshy area which extends in parallel with the west coast line in the Region. The catchment area of the river is 323 km^2.

The Pontian Kechil river also rises in G. Pulai and flows to the south and empties itself to the Straits of Melaka. The stream runs through the plain area without large meander. Pontian Kechil town is located at the estuary. The catchment area is 92 km^2.

The Sedili Besar river originates northeast boundary of the Study Region and flows into the South China Sea. The main river meanders and most of the channels are unstable. Flood usually occurs at local catchment and it is accentuated by backwater of tidal effect. The total catchment area of 1,397 km^2 at its estuary is the second largest in the Region.

The Sedili Kechil river is the other river system which flows out to the South China Sea in the Region. This river flows through highly dissected area and effectively confines flood water until it comes to the sea. Except for the downstream reach of the river, flooding is not usual. Total catchment area of the river is 302 km^2.

3. AVAILABLE DATA

3.1 Meteorological Data

3.1.1 Rainfall data

There are 84 rainfall gauging stations in the Region as of February in 1984. DID has operated 72 stations out of 84 and MMS has operated remaining 12 stations. Among the 72 stations of DID, 64 stations are legistered in the hydrological data bank system established in DID Headquarter in Kuala Lumpur. Other eight stations are identified as State stations and the records are stored in Hydrological Section of State DID in Johor Bahru. Automatic recording instrument are operated at 15 stations. The inventory of the rainfall gauging stations is compiled in Tables 1 to 3 including the stations closed before February 1984 (Ref. 1). Further, the tables describe 16 stations located outside of the Region for reference of runoff study. Stations are densely dispersed in the central and west coastal areas as compared with the eastern area.

DID Headquarter compiles and stores the daily rainfall records conveyed from State DID in the computer system. Hourly record at the automatic stations are also stored in the system. DID summarizes the data thus compiled and prepares the Hydrological Data Book (Ref. 2).

In this study the obtained daily rainfall record were examined. In taking account of the duration and interruption of the record, 64 stations were selected in total as the key stations to utilize the data recorded therein. The data collection was focussed on the data recorded in 22 year period from 1963 to 1984 because the runoff data are available for this period. Location of the selected stations is shown in Fig. 1.

Figs. 2 to 4 show the duration of the daily rainfall record. In case that the interruption period is shorter than one month, the daily rainfall record at adjacent stations was transposed to supplement the interrupted period after examining the correlation between the rainfall records at the stations. The supplemented and transposed stations and the period supplemented are as follows:

Supplemented Station No.	Supplemented Period	Transposed Station No.
1737128	Nov. 1 - Nov.30 1977	1836001
1738129	Mar. 1 - Mar.31 1977	1738131
1933121	Dec.20 - Dec.31 1981	1834122
	Jan. 1 - Jan.31 1982	
	Jul.20 - Jul.29 1982	
2038001	Oct. 1 - Oct.31 1977	2138002

Annual rainfall record at selectd station between 1963 and 1984 is tabulated in Tables 4 to 7. Based on the annual mean value for the 22 years, an isohyetal map was developed as shown in Fig. 5.

The hourly rainfall records during the period of about two weeks starting from a week before and ending a week after the past major storm rainfall was collected for flood studies. Records were collated considering the daily rainfall record at adjacent stations. Thus available records were selected for the flood study. Table 8 shows the relationship between the period of selected flood events and condition of collected hourly record.

3.1.2 Pan-evaporation data

DID has two Pan-Evaporation monitoring stations in Johor Bahru and Benut. The recorded data have been processed by DID and monthly forest and open evaporation rate are summarized in a study report prepared by the Hydrology Branch of DID (Ref. 3). The study report makes discussion on estimating methods of evaporation for Peninsular Malaysia based on available climatic and evaporation data. The study report also compiles the rates estimated at the six MMS stations locating in the Region. The installed equipment at DID Johor Bahru is Class A Evaporation pan and Hargreaves method have been adopted to estimate the evaporation rates mentioned above. Tables 9 and 10 show the monthly rates for open water and forest at the stations.

3.1.3 Other meteorological data

Other meteorological data such as air temperature, relative humidity and sunshine hour are observed at meteorological stations operated by MMS (Ref. 4). In the Region, eight meteorological stations are on operation since 1976. The inventory of the stations are tabulated in Table 11. The table shows the duration of the record collected.

3.2 Hydrological Data

3.2.1 Water level and runoff data

Runoff data recorded at 16 hydrological stations in the Region were collated in the hydrologic study. The locations thereof are shown in Fig. 1 together with the selected raingauge stations.

All the hydrological stations are operated and maintained by DID. The water stage records of these stations are converted into discharge applying the rating curves at the headquarter of DID. The rating curves are occasionally reviewed and updated on the basis of discharge measurement data regularly conducted once a month. The daily water stage and runoff of these stations are stored in the data bank of DID. Monthly mean, maximum and minimum runoff record are summarized in Hydrological data book by DID (Ref. 5). Fig. 6 shows the inventories of the hydrological stations and the period of daily runoff observations.

In the Johor river basin, five hydrological stations are operated at present. Kg. Rantau Panjang hydrological station has the longest runoff record from September 1963. It is located approximately 10 km downstream from the confluence of the Linggiu and Sayong rivers. Other four stations are located in the tributaries of the Pengli, Sayong, Linggiu, and Permandi rivers. One in the Pengli river was newly installed in 1983 at just upstream from the confluence with the Sayong river. Stations of "Jam. Johor Tenggara" and "Ran.

Janah Jengeli" are operated at about 3 km upstream and 2 km downstream from the proposed Sayong and Linggiu Dam sites.

In the Parit Madirono which is one of the drainage cannals of the Benut river, one station is operated since 1979. In upper reach of the Sedili Besar river, one station had been installed in 1965. Since tidal discharge intrudes to the gauge site, this station has been closed in 1974. In substituting this station, a new station was installed in 1982 beside the highway bridge along the road some 52 miles far from Kota Tinggi to Mersing. In the Mupor river, a tributary of Sedili Besar river, one station has been operated from 1970 and 1985 January. Furthermore, State DID operates two more gauging stations at Kg. Maju Jaya in the Tebrau river and at Kg. Saleng in the Skudai river respectively.

The runoff data recorded at Kg. Rantau Panjang hydrological station was collated. As the consequence, the rating table for the period from 1970 to 1977 was revised and applied to estimate the runoff in this period.

Discharge measurement and water stage records at Kg. Maju Jaya and at Kg. Saleng are performed by Johor State DID. In the case of Kg. Maju Jaya, two staff gauges are used from time to time. Because operation of the PUB barrage affects to the discharge at the location of the lower gauge by backwater action, upstream gauge is used in such situation. However it was hard to segregate the data recorded at the upper gauge from ones recorded at lower gauge. The discharge measurement data at Saleng were examined and rating curves were developed. Since the discharge measurement record distribute widely, three different rating curves were developed to apply to chronologic water stages as shown in Fig. 7. Thus the recording period was divided into three periods of 1974-75, 1976-78 and after 1979.

Moreover, a station in the Semberong river (BT. 2 Ayer Hitam/Yong Peng) is also included into the stations to be evaluated for selection of the key stations though this station is located outside of the basin. The station is operated at Brizay Bridge about 2 miles far from Ayer Hitam to Yong Peng.

3.2.2 Sediment load data

Measurement of suspended sediment load is carried out regularly once a month at two hydrological stations in the Region. Among them, Kg. Rantau Panjang hydrological station in the Johor river has the longest recording period from March 1978. The measurement at Ran. Tanah Jengeli hydrological station in the Linggiu river started from January 1980. Laboratory analysis of the collected samples at the stations were made at Research Station of DID in Kuala Lumpur.

4. METEOROLOGY

4.1 Climate

The climate of the Region is generally characterized by the northeast monsoon and the southwest monsoon. However, influences of these monsoons vary from place to place in the Region. Relatively uniform temperature, high moisture and heavy thundery rainfall form an equatorial climate throughout the year over the Region. Divisions of climate season is dominated by wind direction, rainfall amount and rainfall pattern.

The northeast monsoon brings fairly heavy rainfall from October or November to January, especially in the east coastal area. The monsoon tend to associate the tropical depressions which is formed above the South China Sea. In the east coast, around 60% of annual rainfall is attributable to the northeast monsoon.

From May to September, the southwest monsoon reaches to the Region across the Melaka Straits. The main feature of this monsoon is the occurrence of "Sumatras" which means early morning squalls. An effect by the monsoon on rainfall is not so remarkable because the highlands of Sumatra forms shelter against heavy rainfall. Thus influence of the northeast monsoon transcends over the southwest monsoon in the Region.

In the transition period between the monsoons, February to April and October, the winds are gentle and variable on direction. The Region usually has secondary peak of monthly rainfall in April.

4.2 Rainfall

As shown in the isohyetal map of Fig. 5, annual rainfall in the Region varies 2,200 mm to 2,800 m and is estimated approximately 2,460 mm as a regional mean annual rainfall. Northeast part of the Region generally receives heaviest rainfall in the Region while the other heavy rainfall was recorded in southeast area around the G. Pulai.

East and west coastal areas have different rainfall pattern depending on the effect of northeast monsoon. Because of faint influence of northeast monsoon, west coastal area is featured by relatively uniform rainfall throughout the year. On the other hand, the northeast monsoon causes quite heavy rainfall in the east coastal area.

Regarding to the annual amount within the whole Region, wet year is chronologically noticed in 1954, 1964, 1967, 1969, 1980 and 1984. Further, daily maximum rainfall from 1946 to 1984 recorded at stations selected are tabulated in Table 12 to 18. The largest values after 1946 within the Region is 363 mm at Ldg. Nam Heng (No. 1639132) on December 9th, 1954, followed by 346 mm at Ldg. Permatang (No. 1739130) on December 9th, 1954 and 337 mm at Kolam Air (No. 1537115) on December 9th, 1969.

4.3 Evaporation

According to the isopleth maps of forest and open water evaporation throughout Peninsular Malaysia attached WATER RESOURCES PUBLICATION No.5, the evaporation is relatively uniform within the Region. Annual evaporation rate for forest and open water are conceived to range from 1,300 mm to 1,600 mm and 1,400 mm to 1,800 mm respectively as shown in Table 9 and 10. The rate is slightly lower than the mean of Peninsular Malaysia due to gentle wind velocity and high relative humidity.

Monthly variation is generally little and monthly rate seldom exceeds $\pm 20\%$ of the average value at each station. The maximum occurs in March and the minimum during northeast monsoon in December.

4.4 Other Meteorological Conditions

Table 19 shows the monthly mean air temperature recorded at eight stations. The mean annual air temperature varies from 25°c to 28°c by station. The highest air temperature usually occurs from May to June and the lowest is recorded from December to January. The mean monthly air temperature of the Region are almost constant throughout the year with variability of less than 2°c.

The mean monthly relative humidity at 1:00 PM at the stations above is summarized in Table 20. In general, relative humidity varies in conformity with seasonal rainfall pattern in the Region. Commonly the highest value occurs in October to December and the lowest in February. The relative humidity fluctuates diurnally in reverse to the change of the air termperature and at night rises to above 95%.

The daily sunshine hour record is available at only a principal station at Johor Bahru International Airport as shown in Table 21. At Johor Bahru the sunshine hours in January to March are six to seven hours, and four to five hours in September to December.

5. HYDROLOGY

5.1 Surface Runoff

The average daily runoff at Kg. Rantau Panjang in the Johor river is estimated to be 33.6 m^3/sec on the basis of the records of 22 years from 1963 to 1984. This amount is equivalent to 938 mm of runoff depth within the catchment area of 1,130 km^2. The monthly runoff is shown in Table 22. The monthly mean runoff at Jam. Johor Tenggara and Ran. Tenah Jengeli are tabulated in Tables 23 and 24.

The Region experienced serious drought in 1971 and 1976. And the minimum daily mean runoff of 2.5 m^3/sec was recorded at Kg. Rantau Panjang on December 10, 1964. In respect of the annual mean runoff, 1974 is the most driest year since the commencement of the recording.

The mean annual inflow discharge at the eight proposed damsites were estimated for the 22-year period of 1963 to 1984 based on the result of the runoff studies and are shown in Table 25.

Further, surface water resources in peninsular Malaysia is discussed in the study report of "Water Resources Publication No.12 in 1982" by DID. This study analyzed runoff record and compiled for the 75 catchments for the data in 1959-1975. According to the isopleth map derived from the report, the average annual runoff value throughout the Region varies 800 mm to 1,600 mm.

5.2 Flood

It is noted that past extreme flood in the Region is one occurred in December 12th 1969 when daily mean runoff of 642 m^3/sec was recorded at Kg. Rantau Panjang.

To estimate probable flood discharge at each damsite, storage function method is applied. The observed and the generated hydrographs at Jam. Johor Tenggara were compared and it is concluded the equation to estimate the parameter of model developed for the Tone river in Japan is applicable to the Johor river. Probable flood hydrographs ar generated by the composite model applying various probable basin rainfall. The specific discharge for peak discharge of 1,000-year probable flood estimated at the proposed damsites varies from 4.1 $m^3/sec/km^2$ to 7.1 $m^3/sec/km^2$.

The possible maximum flood are estimated bas d on the possible maximum precipitation referring the experienced maximum storm in Mersing area. The specific discharge of the possible maximum flood for each damsite is in the range of 7.0 $m^3/sec/km^2$ and 11.5 $m^3/sec/km^2$.

5.3 Sediment

Adequate measurement record of suspended load to estimate the annual sediment yield in the Region is limited. The sediment record is available at Kg. Rantau Panjang station of 1,130 km^2 in the Region. The annual sediment yield bas d on the record observed at the station is estimated to be 40,000 m^3. This small figure is deemed to be attributable to the effect of the stagnation of discharge in the ma shy areas located along the upstream reach. The annual sediment yield of 0.5 mm/yr was adopted to all the proposed dam plannings referring the values adopted to the existing dam design.

6. RUNOFF STUDIES

6.1 General

After collation of the collected data, four hydrological stations such as Kg. Rantau Panjang (the Johor river), Ran. Tanah Jengeli (the Linggiu river), Jam. Johor Tenggara (the Sayong river) and Saleng (the Skudai river) were selected as the key stations. The stations have relatively long recording durations and the data therefrom were judged to be reliable for the Study.

Runoff record at the stations selected include more or less interrupted period. In order to examine water balance study by continuous record, it was necessary to interpolate the missing runoff data through runoff simulation study. For the purpose, Tank Model Method was applied to generate daily runoff on the basis of daily rainfall. Finally the runoff depth at arbitrary location was estimated on the basis of the daily runoff at the key stations taking account of the rainfall depth (Ref. 6).

6.2 Basin Division

The Region is roughly divided into four major basins in consideration of the topographies and land cover conditions. They are Benut-Pontian, Johor, Skudai-Tebrau and Sedili river basins. The loss is considered homogeneous within a major basin.

Then each major basin was divided into three to seven sub-basins considering the rainfall pattern and depthes. Accordingly, the runoff-depth is assumed to be uniform over a sub-basin. Basin division in the Region for runoff study is shown in Fig. 8. Major basin areas and their number of sub-basin are as follows:

Benut-Pontian	3 sub-basins	1,430 km^2
Johor	7 sub-basins	3,110 km^2
Skudai-Tebrau	3 sub-basins	1,010 km^2
Sedili	5 sub-basins	1,800 km^2
	18 sub-basins	7,350 km^2

6.3 Definitions

(1) 5-day runoff

For the convenience of analysis, each calendar month is divided into six periods; first five days from 1st to 5th, 6th to 10th, 11th to 15th, 16th to 20th, 21st to 25th and the remainder of the month. Each period is called the 5-day period and arithmetic mean of daily discharge in each 5-day period is named the 5 day-runoff which might be expressed in m^3/sec or 10^6 m^3.

(2) Natural runoff

The daily runoff record observed at a hydrological station is more or less affected by water abstraction at upstream reach from the station. However, the daily runoff record is assumed to reflect the natural runoff herein, because daily-basis water abstraction is not significant so far. It is principally estimated based on the recorded water level and is supplemented by a simulation model if it is interrupted. The assumption might lead the figures of conservative side in succeeding water demand and supply balance study.

(3) Rainfall loss

Rainfall loss is composed of evapotranspiration, increase in soil moisture and ground water recharge. In the simulation study, the annual loss is calculated as the difference between rainfall and natural runoff.

(4) Key station

The selected hydrological station is named the key station and it is regarded as representing the hydrological conditions of the river basins concerned.

6.4 Selection of Key Station

Available water stage record and runoff data are discussed in Clause 3.2.1 and Fig. 6 shows the duration of daily runoff data collected. Discharge measurement works in the Johor river are well established.

As key stations for the runoff studies, the stations which have the catchment area more than 100 km^2 were selected. Accordingly, seven stations of Pt. Madirono Weir, Permandi, Jambatan (the Seluyut river), Layang Layang, Jambatan (the Sebol river), BT32 JB/Mersing (the Mupor river) and Maju Jaya (the Tebrau river) were excluded. Although Saleng station (the Skudai river) has only 91 km^2 in catchment area, this was selected because it has longer duration period of 11 years. The station in Felda Inas (the Pengli river) was not selected because the recording period is as short as one year.

In case of stations at Hilir Sayong, and Linggiu, water stage record were not available.

Thus, stations of Kg. Rantau Panjang, Jam. Johor Tenggara, Ran. Tanah Jengeli and Saleng are selected as key stations. Runoff record are not available in the major river basin of Benut-Pontian and Sedili. And Kg. Rantau Panjang was adopted as the key station for the basins in consideration of duration and reliability of the observed record. The sub-basins which refer to a key station to estimate the daily runoff thereof are summarized as follows:

Key Station (number)	River Basin (sub-basin No.)
Kg. Rantau Panjang (1737451)	Johor river basin (JO3, JO4, JO5, JO6 and JO7)
	Benut Pontian river basin (BP1, BP2 and BP3)
	Sedili river basin (SD1, SD2, SD3, SD4 and SD5)
Jam. Johor Tenggara (1846402)	Sayong river basin (JO1)
Ran. Tanah Jengeli (1846401)	Linggiu river basin (JO2)
Saleng	Skudai-Tebrau river basin (ST1, ST2, and ST3)

Out of the selected key stations, runoff simulation by tank model was carried out for the stations of Pengli "A" (the Pengli river) and BT2 Ayer Hitam/Yong Peng (the Semberong river). However, as the observed record have considerable interruptions, sufficient caribration were not possible for the stations. Thus estimate of daily runoff in each basin was derived from the results of the simulation at the key stations above.

Although four intakes of PWD are located in Renggam, Layang Layang, upper reach of the Pengli river and lower reach of the Linggiu river, the scale of water abstraction at the intakes is considered negligibly small compared with the river flow discharge. In addition, no large storage dam exists upstream of Kg. Rantau Panjang. Thus the observation record is assumed natural runoff at each key station.

6.5 Procedure of Simulation Study

(1) A tank model was constructed to simulate the runoff at the station in Kg. Rantau Panjang. Detailed process of simulation is described in the following section 6.6.

(2) The caribration of the model was made to obtain the good fit to the following data:

(a) annual loss

(b) duration curve of daily runoff in each year, and

(c) monthly mean runoff.

(3) Caribration was performed by means of the trial and error method and models which entails the best fits were adopted for the relevant key stations.

(4) Daily runoff at four key stations was generated for 22 years from 1963 to 1984 applying the estimated basin rainfall to the models.

(5) If continuity of the supplemented runoff to the original data was judged unreasonable after supplement by simulated data, minor adjustment was made finally.

(6) The estimated daily natural runoff at key stations were converted into the 5-day natural runoff.

6.6 Simulation Model

There are some simulation methods widely used for estimating runoff from rainfall data. They are Tank Model, Stanford Watershed Model, Sacramento Model, etc. Among them, the Tank Model method developed by Dr. Sugawara was applied in this Study. Methodology of runoff simulation is basically equivalent to PKP Part I Study in 1984.

(1) Basic concept of tank model

A tank of the model is basically considered to have two holes, one at the bottom and the other at the side as shown in Fig. 9. When the tank is filled with water, the water will be released from these holes. In the runoff analysis, water released from the side hole corresponds to runoff to a stream and water from the bottom hole goes into the ground water zone.

The depth of water released from a hole is given by the following relation:

$I = a.H$

where, I: Depth of water released (mm/day)

a: Coefficient of hole

H: Water depth above hole (mm)

For the purpose of natural runoff simulation, four tanks combined vertically are usually used as shown in Fig.11. The top tank corresponds to the surface runoff, the second tank to the subsurface runoff and the third and fourth to base flow from the ground water, respectively.

In the course of the simulation, daily rainfall depth is put into the top tank and the depth of water released from a hole is calculated by the above equation. The water from the bottom hole is put into the second tank and the same process is repeated to the fourth tank. The depth of stream runoff is given as the sum of the water released from side holes. Loss due to evapotranspiration is expressed by subtracting the depth of daily evapotranspiration from the storage of the top tank.

(2) Soil moisture content

The top tank has a special structure simulating soil moisture content in surface soil layers as shown in Fig. 11. This structure is effective for the area having distinct wet and dry seasons where surface soils are usually dried up in the dry season.

In this model soil moisture structure is divided into two parts, the primary and the secondary soil moisture. These soil moisture zones are set in the bottom of the top tank.

Moisture in these two zones is transferable depending on their relative moisture ratio as expressed below.

$T2 = TC\ (XP/PS - XS/SS)$

where, T2: Transfer of moisture between primary and secondary layers (plus sign indicates transfer from primary to secondary and minus sign vice versa)

PS: Primary soil moisture capacity

SS: Secondary soil moisture capacity

XP: Primary soil moisture depth

XS: Secondary soil moisture depth

TC: Constant

When primary soil moisture is not saturated and there is free water in lower tanks water goes up by capillary action so as to fill the primary soil moisture with the transfer speed T1 as given below.

$$T1 = TB\ (1 - XP/PS)$$

where, T1: Transfer of capillary action from lower tank

TB: Constant

(3) Zoning

In the non-humid basin, where some part is wet and the remaining part dry, the surface runoff occurs only in the wet area while in the dry area all the rainfall is absorbed as soil moisture. When the rainy season begins, the wet area grows larger, starting from a small area along the river. It can be assumed that the wet area spreads along the river.

In order to approximate the continuous change of wet area, the drainage area is divided into four zones from the uppermost zone to the lowermost zone as shown in Fig. 12. In the beginning of the dry season the uppermost zone (S1) from the river is firstly dried up and the dried up area is expanded to S2, S3 and S4 from the mountainous area to the river sides with the dry season goes by.

The areal ratios of zone S1 : S2 : S3 : S4 are the important parameters in this model. In this study, the areal ratio of zoning is assumed to be expressed by a geometrical progression as shown below.

$$A1 : A2 : A3 : A4 = a^3 : a^2 : a^1 : 1$$

where, Ai: Area of zone i
a : Equal ratio

Equal ratio is determined based on the calibration.

The vertical structure of each zone is assumed to be expressed by the series of four tanks with the same parameters.

(4) Composite tank model

Consequently the tank model for a river basin is composed of 4 x 4 tanks as shown in Fig. 10. In this Figure, the direction of water released from hole is illustrated. In addition, a tank having two holes at the side is used for simulating the river channel storage. Thus a basin was simulated integratedly by the composit model of tanks.

6.7 Input Data

(1) Evapotranspiration

Pontential forest evaporation was adopted to the evaporation from the tank in this simulation study. The forest evaporation rate is available in WATER RESOURCES PUBLICATION NO. 5.

As mentioned in Clause 3.1.2, forest evaporation rates at seven climatological stations are available (including Ayer Hitam station). Monthly rate for four major river basin are calculated as the mean value of the rate for the relevant two or three stations.

River Basin	Station
Benut-Pontian	Ayer Hitam, Pontian Kechil
Johor	Layang Layang, Kong Kong, Kota Tinggi
Skudai-Tebrau	Johor Bahru, JPT Johor Bahru
Sedili	No station

In case of Sedili river basin, the monthly rate of Johor river basin is applied.

Further, the monthly rate calculated as above was adjusted so as to give the same average annual basin forest evaporation obtained by the map of "Peninsular Malaysia Forest Evaporation" attached to the report. The monthly rate of each river basin are shown in Table 26. The daily depth of the forest evaporation was subtracted from the top tanks of the composite tank model in runoff simulation.

(2) Basin mean rainfall

Average basin daily rainfall for the four key stations is estimated by unweighted mean value of point rainfall at raingauge stations. Duration period of the selected stations for each basin are shown in Tables 27 and 28. When a station has interrupted period between 1963 and 1982, the basin mean rainfall is calculated by excluding the station.

For runoff simulation at Ran. Tanah Jengeli station, three stations of No. 1737128, No. 1836001 and No. 1838148 were selected considering the rainfall pattern. However, no record before 1971 is available for the three stations selected. Thus, runoff simulation at this station is carried out only for the period of 1972 to 1984.

6.8 Calibration

The simulation models for four key stations were so calibrated to have good fit to following three aspects of runoff.

(a) annual loss

(b) daily duration curve in each year, and

(c) monthly mean runoff

In the catchment area of the Ran. Tanah Jengeli, raingauge stations having sufficient duration of record before 1972 are quite limited as mentioned in the previous clause. Thus runoff simulation and generation of missing period is carried out for the period of 1972-1984 when rainfall data are rather sufficient. The runoff data at Kg. Rantau Panjang were converted to the Ran. Tenah Jengeli station for the period from 1963 to 1971.

(1) Annual loss

Tables 29 and 30 show the annual balance between runoff and loss for observed and simulated data. Observed runoff depth and loss in the Tables partly involve simulated values for the period of interruptions.

The annual loss based on the observed data is calculated as the differential value between annual basin rainfall and annual runoff. Considering the potential basin evapotranspiration in the Region, it is deemed that the annual loss varies from 1,000 mm to 1,600 mm. The entailed loss by the simulation generated at each key station fell within the range for the whole period.

In order to compare annual loss between estimated and generated values, the difference at the four key stations in each year is summarized in Tables 31 and 32.

(2) Daily duration curve

The duration curve developed based on the generated runoff was compared with ones based on the estimated runoff. The model parameters were so calibrated to obtain the curve with good fit. In case of Saleng station, calibration in this aspect is not available because the duration curve on the basis of the recorded data can not be developed due to the missing data.

In general large discharge has some errors, mainly because stage discharge curve in high stage is not constructed based on the actual observations. On the other hand, lower stage runoff adjusted by the actual observations is usually reliable. Since water demand and supply balance study requires a certain accuracy in lower stage runoff, fitting to the duration curve was mainly made for the lower stage runoff.

(3) Monthly mean runoff

Monthly mean runoff generated by the model were compared with monthly runoff estimated on the basis of the recorded water level. Figure 13 shows the monthly runoff comparison of the runoff generated with the runoff estimated at four Key stations. The simulated runoff sufficiently fits to the estimated runoff.

(4) Tank parameters

Tank parameters of the simulation model were adjusted from three viewpoints as mentioned above. After the final calibration, total four types of the model were developed at each key station. Final tank parameters of the model are summarized in Table 33. All models started in the same initial condition. Initial storages of each tank and initial channel storage for the model are tabulated in Table 34.

6.9 Natural Runoff at Key Stations

After the runoff simulation at the key stations, supplement for the interrupted period by with the calculated values during the period of 1963-1984 were carried out.

After the supplement with the calculated value, continuity of daily runoff between the observed and calculated values was carefully examined. In case that the supplement is judged unreliable considering from the continuity of natural river flow, interpolation is made by assuming that runoff fluctuates linearly by day.

As mentioned in Section 6.7, runoff simulation at Ran. Tanah Jengeli was carried out for the period of 1972-1984, because daily rainfall record before 1972 is not available. The daily runoff at the station was supplemented by the completed daily runoff at Rantau Panjang hydrological station during the period from 1963 to 1971. Daily runoff hydrographs at key stations which are supplemented by simulated runoff record are shown in Figs. 14 to 17. Further, observed and simulated daily runoff hydrographs at Pengli "A" and BT2 Ayer Hitam/Yong Peng are shown in Fig. 18 and Fig. 19 for reference. The daily runoff is converted to the natural 5-day runoff as an arithmetic mean value.

The converted 5-day natural runoff between at Rantau Panjang and total value of two tributaries, that is the Sayong river and the Linggiu river which is estimated based on the runoff at Jam. Johor Tenggara and Ran. Tanah Jengeli hydrological stations were compared. In case that the total of the sub-basins exceed the values at Rantau Panjang, the 5-day natural runoff in the two sub-basins was adjusted so as to coincide with the values at Rantau Panjang. The adjustment ratio is assumed in proportion to the runoff volume of the sub-basins. The adjusted 5-day runoff at each key station converted are tabulated in Tables 35 to 46. Final annual water balance between runoff and loss at each key station based on the completed daily runoff for 22 years form 1963 to 1984 are shown in Table 47. Daily runoff duration curve for the period at the key stations is illustrated in Fig. 20.

6.10 Sub-basin Runoff

In order to estimate the 5-day natural runoff at an arbitrary location form the 5-day natural runoff data of key station, each river system is divided into several sub-basins as shown in Fig. 8. The 5-day runoff of the sub-basins for the period of 1963-1984 is estimated by transposing the 5-day natural runoff at key station assuming that the rainfall loss during that period is evenly distributed in the river basin.

The method of conversion from the key station is expressed by the following equation:

$$Q = CQo$$
$$C = A(R-Lo)/Ao(Ro-Lo)$$

where, C : Conversion ratio

Q : Daily runoff at the objective sub-basin

Qo: Daily runoff at the key station in the same river basin

A : Catchment area of the objective sub-basin

Ao: Catchment area at the key station

R : 1963-1984 average annual basin rainfall of the objective sub-basin

Ro: 1963-1984 average annual basin rainfall at the key station

Lo: 1963-1984 average annual rainfall loss at the key station

Conversion ratios from the key station to sub-basin are summarized in Table 47. The 5-day natural runoff at an arbitrary location within sub-basin is estimated by the specific 5-day natural runoff of the objective sub-basin derived from the runoff at the key station.

6.11 River Maintenance Flow

In general river maintenance flow shall be quantitatively set to maintain proper function of each river stretch from various viewpoints. In conformity to the development level of areas along rivers, volume of the maintenance flow will vary to respond to the interested requirement such as fishery, navigation, groundwater recharge, water quality control, water supply, amenity, tidal discharge control and so on.

The intake system of PUB Kota Tinggi in the Johor river was forced to interrupt its operation in April 1983 due to saline intrusion from the estuary. It was April 21st when the minimum daily discharge of 3.0

m^3/sec at Rantau Panjang was recorded. The daily discharge at PUB Kota Tinggi intake site is estimated at 4.1 m^3/sec on this occasion.

The discharge less than 2.9 m^3/sec was experienced at Rantau Panjang in 1976. The corresponding runoff at PUB intake in Kota Tinggi is estimated at 4.0 m^3/s. However, any indication on deterioration of river environment along the Johor river has not been reported. Considering from the fact, it is deemed reasonable to determine the minimum flow discharge especially in taking account of saline intrusion.

Next to the annual minimum daily discharge at PUB Kota Tinggi of 4.1 m^3/sec in January 1983 and 4.0 m^3/sec in 1976, the minimum value is 5.6 m^3/sec recorded in 1981. Assuming that water abstraction volume at the PUB intake at that time is 60 Mgd (3.2 m^3/sec), remaining discharge is estimated at 2.4 m^3/sec which is equivalent to 0.15 m^3/sec/100 km^2. As mentioned above, no trouble has been reported at this time. The discharge volume is judged to be sufficient to defend against saline intrusion. Thus this value is applied for the river maintenance flow in the whole basin of the Johor river.

As for other rivers, any record or information regarding the low flow and its influence to the river could not made available through the site reconnaissance in 1984.

Therefore, 99% flow discharge was arbitrarily applied as the river maintenance flow except the Johor river. In detail, the value is obtained by the duration curve developed by series method between 1963 and 1984. The specific discharges of maintenance flow volume ranges from 0.27 m^3/sec/100 km^2 to 0.64 m^3/sec/10 km^2.

7. Flood Studies

7.1 Storage Function Method

7.1.1 General concepts

The storage function method presumes a storage defined by the balance of inflow and outflow, and computes the discharge in time series from the changing volume of storage as a parameter. In this method, the discharge at a certain section in a river basin model is assumed to follow the expornential function as below:

$$S = KQ^P \qquad (1)$$

where,

S : Storage (m^3)
Q : Discharge (m^3/sec)
K, P : Constants

Assuming an arbitrary time period of dt-hrs in time series, the difference in storage is the balance of inflow (rainfall) and discharge as represented below.

$$dS = A \cdot F \cdot r \cdot dt \cdot 1000 - Q \cdot dt \cdot 3,600 \qquad (2)$$

where,

A : Catchment area (km^2)
F : Runoff coefficient
r : Rainfall intensity (mm/hr)
Q : Discharge (m^3/s)
dS : Increment in storage (m^3)
dt : Time period (hrs)

In the Eq.(2), the first and second terms of the right side are respective rainfall and discharge volumes of the period. Dividing the both sides of the equation by dt x 3600,

$$dS/dt = 1/3.6\ A.F.r - Q \qquad (3)$$

For the sake of simplicity, we introduce the storage and discharge expressed in depths over the catchment:

$$S = s\ .\ A\ .\ 1000 \qquad (4)$$

$$Q = q\ A\ /\ 3.6 \qquad (5)$$

where,

s : Storage depth (mm)

q : Discharge depth (mm)

Eqs. (1) and (3) are reformed as below:

$$s = kq^p \qquad (6)$$

$$ds/dt = r - q \qquad (7)$$

The framework of the storage function method is expressed in Eqs. (6) and (7).

7.1.2 Simulation procedure

Fig. 21 gives a schematic presentation of a storage-discharge relationship. Let qt and qt+1 respectively the discharge at state t and t+1, and S_t and S_{t+1} the corresponding storages.

Eq.(7) is interpreted into a differential form

$$S_{t+1} - S_t = t\ [r_{t+1} - (q_{t+1} + q_t)/2] \qquad (8)$$

and S_{t+1} is $S_{t+1} = k\ q_{t+1}^{p}$ (9)

Therefore,

$$r_{t+1} + S_t/dt - q_t/2 - (kq_{t+1}^{p})/dt - (q_{t+1})/2 = 0 \qquad (10)$$

Let the left side of Eq.(10) be F(q):

$$F(q)= r_{t+1} + S_t/dt - q_t/2 - (kq_{t+1}^{p})/dt - (q_{t+1})/2 = 0 \quad (11)$$

Eq.(11) has q_{t+1} as the only unknown value, and can be solved by Newton's method.

$$F'(q) = -Kpq_{t+1}^{p-1}/dt -1/2=0 \qquad (12)$$

By assuming the first approximate value of q to be qt+1(1) and substituting this value into Eq.(11) and Eq.(12), second approximate value can be obtained by following equation,

$$q_{t+1}(2) = q_{t+1}(1) - F(q_1)/F'(q_1)$$

The computation is repeated to nearly equal zero of $F(q_1)/F'(q_1)$ and then $q_{t+1}(2)$ is identified as q_{t+1}.

The storage depth at the time of (t+1) is obtained by Eq.(9). By this equation the average outflow depth qm between the time of (t) and (t+1) is

$$qm = (q_t + q_{t+1})/2$$

7.2 Composition of Model

7.2.1 Structure of applied model

In order to estimate probable flood of each proposed dam, a simple storage function model was applied. Each basin of the proposed dam scheme was simulated by one basin model and one channel model as illustrated in Fig. 22.

In the Sayong River, flood plain of the middle reach contributes to retard flood peak discharge under the present condition. The Sayong reservoir is proposed involving this natural retarding basin. The retarding effect in the channel of upper reach beyond Layang Layang is judged to be negligible small. Thus, the retarding effect in the river channel is not considered to estimate the inflow flood to the Sayong dam. The discharge of the basin model is considered as the inflow flood discharge of Sayong dam.

In catchments of other proposed dam, the composite models constructed in the Sayong catchment are applied. Each parameter of basin and cannel models at proposed catchments are set in Clause 7.2.4.

7.2.2 Model at Jambatan Johor Tenggara

(i) Design Storm

The design storm employed to caribrate the hydrograph which is obtained through the storage function method is the one occurred on December 2nd-3rd, 1978. Total amount of rainfall during the period was 289 mm recorded at Sek. Men. Bekit Besar gauging station.

(ii) Basin Rainfall

The hourly recording of the rainfall in and around the basin is available only at Sek. Men. Besar gauging station. To estimate the average amount over the catchment, the daily rainfall records were referred. Fig. 23 presents the isohyetal contours in the period of the design storm. Based on the map, basin rainfall is estimated at 124 mm. The amount above is applied as the basin rainfall to generate a synthetic hydrograph at Jam. Johor Tenggara.

(iii) Parameters

The parameters of channel model is estimated to be k=100 and p=0.80 considering the topographic condition based on the map of scale 1 to 10,000. Then, the parameters of the basin model was studied examining the computed hydrograph to the observed one. As the results, k=20 and p=0.8 were obtained at Jam. Johor Tenggara. Fig. 24 shows the observed runoff hydrograph and estimated inflow and outflow hydrographs at Jam. Johor Tenggara. The hyetograph of the basin rainfall is also illustrated in the figure. As shown in the figure above, the composite storage function generate the flood discharge which has a good fit to the recorded flood discharge.

For the river basin, k and p values are given as a function of parameter, I, of mean slope of the basin by the following equations.

$$k = 118.84 \times I^{0.3}$$
$$p = 0.175 \times I^{-0.235}$$

This is empirically developed in the Tone River basin in Japan. By substituting 0.0015 for I-value, which is mean slope of the Sayong river basin up to Jam. Johor Tenggara gauging station, the parameters is computed to be k=17 and p=0.8 respectively.

Although k-values obtained by two methods as explained above has a little difference, it is deemed that the equation of the Tone River can be applied in the Region. Therefore, it is determined to set the parameters of the bain model for the other objective dam sites.

7.2.3 Storm duration and rainfall pattern

The hydrological study report by DID (Ref. 7), indicates that the total rainfall depth does not increase significantly after 12 hours laps. Based on the characteristic feature of storm rainfall in the Region, it is considered that the rainfall in 1-day is the main cause of the flood. Thus, 1-day rainfall in a basin is employed to estimate the probable flood of each damsite.

In order to determine the hourly pattern of the design storm rainfall, available hourly rainfall records was analyzed. Non-dimensional accumulative rainfall curves of each record series are illustrated in Fig. 25. In respect of intensity of the initial six hours, the maximum was recorded in 1981 at Simpang Mawai Kuala Sedili (No. 1839196). Considering the feature of the storm rainfall in the Region about it is judged that the hourly distribution recorded at

Simpang Mawai is representative. Thus, the hourly pattern in 1981 recorded at the station was applied to estimate the probable storm rainfall.

7.2.4 Basin rainfall

As for estimating basin rainfall for each catchments, selection of raingauge station was made. In case that no station is located in the catchment area, stations nearby were selected considering the isohyetal map of mean annual rainfall. In the catchment area where plural stations are located, daily basin rainfall is estimated as an alithmetic mean of point rainfall of the selected stations. In selection of the rainfall stations, at least a station was selected per 100 km^2.

Series of annual maximum daily rainfall record for available period were obtained for each catchment area. By using the series data, frequency analysis for computing probable basin rainfall of 1-day duration was carried out assuming five kinds of statistic distribution: they are Iwai, Pearson Type III, Gumbel, Hazen, and Chow's Methods. Judging from the result of fitting by respective method, it was determined to adopt the probable rainfall from Pearson Type III distribution.

The report of U.S. Bureau of Reclamation (Ref. 8) explains in detail on maximizing and transposing three major storms of January 1971, December 1960 and January 1956 observed at Mersing. An envelop curve of PMP established based on the storms was referred. Applying to the envelop curve, PMP for the duration of 24-hrs was estimated at 570 mm (Ref. 9).

For the transposition of PMP, a ratio between mean annual basin rainfall over the original position of each catchment and over the Mersing area were computed. Further, area reduction factor was also applied to the obtained PMP. The area reduction factor was quoted from the hydrological study report by DID aforesaid which had been cited from "Design of Small Dam". Table 48 shows summary of the probable basin rainfall and PMP for the catchments of each proposed damsite.

7.2.5 Setting parameters

As mentioned in Clause 7.2.2, the parameters of basin model for the catchments of the proposed dam were estimated through the equation of the Tone River. Mean slopes, I, of the each basin were obtained on the map in a scale 1 to 63,360. Applying the value of mean slope to the equations, the parameters, k and p, were obtained. The parameters for a channel model is determined on the map of scale 1 to 63,360 topographically. For Sayong, Linggiu and Sedili basins, the map of scale 1/10,000 newly established in 1985 was also utilized. Computed parameters at each objective dam site are summarized in Table 49.

7.3 Probable Flood

Various probable floods were computed by using a storage function model with the parameters set in Clause 7.2.5. The specific discharge of baseflow at the initial stage of floods was assumed to be 0.04 $m^3/s/km^2$. This baseflow was obtained by the daily mean discharge during wet season (November to January) in 1963 through 1984 at Kg. Rantau Panjang hydrological gauging station. This rate of baseflow is applied for all proposed damsites. The inflow hydrograph into the reservoir after the completion of dam were computed as a routed outflow discharge including baseflow from the basin model. The peak discharge of probable floods at each damsite in return period of 2, 5, 10, 20, 50, 100, 200, 500, 1,000, 10,000 and of PMF are tabluated in Table 50. The computed inflow hydrographs at Sayong damsite are shown in Fig. 26.

8. SEDIMENT STUDY

8.1 Data Analysis

In general, relationship between suspended sediment load and water discharge is logarithmically represented by an equation as follows:

$$Q_s = K\,Q^n$$

where, Qs : Suspended load (ton/day)

Q : Water discharge (m^3/sec)

K, n : Constants

Observed records at Kg. Rantau Panjaug are scattered as shown in Fig. 27. Based on the records, parameters k and n is estimated to be 25.31 and 0.5524 through the method of least squares. However, n is statistically known to be between 2 and 3. This is deemed to be attributable to the extreme gentle river channel slope and the retarding effect of marshy areas located along the river. It is judged that to estimate the suspended load from river basins by fitting equation shown above is not appropriate.

On the other hand, the study result in the report of KEJORA (Ref. 10) could be referred. In this report, erosion and sitlation in river channels related to forest clearance in KEJORA is explained in detail. In addition, sediment load estimates for 12 drainage basins were made based on the available measurements of total or suspended solids and the mean annual runoff.

8.2 Annual Sediment Yield

Sediment studies were conducted referring other dam projects locating in and around the Region. Applied values of annual sediment yield in the basin concerned are listed as below:

	Project	River	Annual sediment yield applied (mm/y)
(1)	Macap Dam	R.Benut	0.48 mm (1 acre-ft per square mile)
(2)	Bekok and Semberong Dam	R.Bekok and R.Semberong	0.48 mm (")
(3)	Layang Dam	R.Layang	0.11 mm (3300 m^3/y for 30.5 km^2 of catchment)

The values applied in Macap, Bekok and Semberong dam projects are obtained by referring the studies undertaken by the USBR for Klang Gates Dam in Selangor. The suspended sediment load for Layang Dam was quoted from the report titled JOHOR TENGAH AND TANJONG PENGGERANG REGIONAL MASTER PLAN (Ref. 11 and 12).

It is concluded that the same value of annual sediment yield taken in Kelang Gates dam project is applied for the proposed dams.

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TABLES

Table 1 INVENTORY OF RAINFALL GAUGING STATIONS (1/3)

Station Number	Station Name	District	Recorded Period	Nos. of Recorded Years
1334108	Ldg. Getah Kukup	PO	1936-1984	49
1433105	Rumah Sakit Umun	PO	1932-1976	45
1437001	Pejabat Kerajaan	JB	1948-1961	14
1437116	Stor JPT Johor Bahru	JB	1961-1984	24
1438001	SEDC, Pasir Gudang	JB	1981-1984	4
1438118	Ldg. Sg. Buloh	JB	1931-1970	40
1439118	Ldg. Sg. Buloh	JB	1970-1980	11
1442001	Desaru Tg. Penggarang	KT	1979-1984	6
1534001	Komplek Perumahan	PO	1976-1984	9
1534002	Pusat Kemajuan Per. Pekan Nanas	PO	1978-1984	7
1534103	Stn. Penyelidekan Nenas	PO	1954-1981	28
1534104	Ibu Bekalan JKR	PO	1937-1984	48
1535106	Ldg. Gunong Pulai	JB	1927-1984	58
1535107	Balai Bomba, Pekan Nanas	PO	1965-1979	15
1536110	Ldg. Senai	JB	1932-1984	53
1536111	Ldg. Buan Heng, Skudai	JB	1926-1984	59
1537112	Ldg. Timur, Johor Bahru	JB	1933-1984	52
1537113	Ldg. Tebrau	JB	1931-1984	54
1537114	Ldg. Mount Austin	JB	1931-1984	54
1537115	Kolam Air	JB	1931-1984	54
1538117	Ldg. Sg. Pelentong	JB	1936-1984	49
1539134	Ldg. Sg. Tiram	JB	1936-1984	49
1539136	Ldg. Lim & Lim Bhd, Masai	JB	1935-1984	50
1540135	Ldg. Telok Sengat	KT	1936-1984	49
1541001	Kangar Chemara	KT	1970-1972	3
1541137	Ldg. Sg. Papan	KT	1928-1984	57
1541138	Ldg. Kg. Bahru, Sg. Papan	KT	1970-1971	2
1541139	Johor Silica	KT	1972-1984	13
1632001	Benut, Johor Barat	PO	1981-1984	4
1633101	Parit Ranchang, Air Beloi	PO	1950-1955	6
1635102	Ldg. Kulai Young, Kulai	JB	1931-1984	54

Table 2 INVENTORY OF RAINFALL GAUGING STATIONS (2/3)

Station Number	Station Name	District	Recorded Period	Nos. of Recorded Years
1636001	Balai Polis Kg. Seelong	JB	1980-1984	5
1636109	Ldg. Kelan, Kulai	JB	1935-1984	50
1637001	FELDA Ulu Tiram/Ulu Tebrau	JB	1970-1984	15
1637133	Ldg. Ulu Tiram	JB	1936-1970	35
1639132	Ldg. Nam Heng	KT	1935-1984	50
1640141	FELDA Air Tawar 1	KT	1969-1984	16
1732001	Parit Marirono Site 1	PO	1978-1984	7
1732002	Parit Marirono Site 2	PO	1978-1984	7
1732003	Parit Marirono Site 3	PO	1978-1984	7
1732004	Parit Marirono Site 4	PO	1978-1984	7
1734001	Loji Pembersih Bt. Batu	JB	1970-1984	15
1735142	FELDA Kg. Tek Wah Heng	JB	1965-1984	20
1736126	Ldg. Sayong, Kulai	JB	1970-1977	8
1737001	Sek. Men. Besar, Kota Tinggi	KT	1974-1984	11
1737127	Bkt. Besar FELDA, Kota Tinggi	KT	1970-1974	5
1737128	SRJK Kg. Rantau Panjang	KT	1970-1979	10
1738001	Rumah Sakit Umum	KT	1932-1961	30
1738129	Rumah Tapis Air	KT	1961-1984	24
1738131	Ldg. Getah Malaya	KT	1934-1984	51
1739001	B27 Jalan J. Bahru/Mersing	KT	1971-1974	4
1739002	Ldg. Mawai	KT	1974-1984	11
1739003	Ldg. Permatang	KT	1975-1984	10
1739130	Ldg. Permatang	KT	1937-1975	39
1739195	Ulu Mapor	KT	1970-1977	8
1740001	FELDA Bkt. Wah Ha	KT	1977-1984	8
1832001	Empangan Sg. Macap	KG	1982-1984	3
1833092	Ldg. Wessyington, Rengam	KG	1927-1984	58
1833093	P. Perbekalan Air, SPG. Rengam	KG	1970-1984	15
1833123	Ldg. Benut, Rengam	KG	1949-1984	36
1834122	Ldg. Rengam, Rengam	KG	1912-1984	73
1834124	Penyelidekan Chemara, Layang Layang	KG	1934-1984	51
1835001	Ldg. Pekan, Layang Layang	KG	1977-1984	8

Table 3 INVENTORY OF RAINFALL GAUGING STATIONS (3/3)

Station Number	Station Name	Dis-trict	Recorded Period	Nos. of Recorded Years
1836001	Rancangan Ulu Sebol	KT	1975-1984	10
1836002	Ldg. Ulu Sebol	KT	1979-1984	6
1836144	Khemah Hutan Pengeli	KT	1970-1975	6
1836145	Jambatan Jln. Pengeli	KT	1970-1984	15
1837147	Lombong Linggiu	KT	1970-1971	2
1838148	Kerja Air, Kota Tinggi	KT	1970-1976	7
1839196	Simpang Nawai - Kuala Sedili	KT	1965-1984	20
1840001	Logi Pembersih Sg. Gembut	KT	1974-1984	11
1840197	B43, Jln. J. Bahru/U. Sedili	KT	1970-1974	5
1841199	Pengkalan Kg. Sedili Kecil	KT	1970-1984	15
1932091	Ldg. Nyanyo, Kluang	KG	1953-1961	9
1933121	Ldg. Getah See Sun, SPG. Rengam	KG	1933-1984	52
1933151	Ldg. Lambak, Kluang	KG	1936-1984	49
1937149	Lombang Sin Seng, Kota Tinggi	KT	1971-1984	14
1938194	Jambatan Perhutanan Ulu Sedili	KT	1970-1977	8
1941198	SRJK Kg. Tg. Lembu	KT	1971-1977	7
2038001	Rancangan Belia Sg. Ara	ME	1975-1984	10
2138001	Rancangan RISDA Sg. Ambat	ME	1975-1984	10

Remarks: Description of district

JB Johor Bahru

KT Kota Tinggi

PO Pontian

KG Kluang

ME Mersing

Table 4 ANNUAL RAINFALL (1/4) Unit: mm

Year	Station Number							
	1334108	1433105	1437116	1438118	1534103	1534104	1535106	1535107
1963	2,045	2,504	1,904	1,839	2,697	2,175	2,074*	-
1964	3,464	2,590	3,189	2,412	3,641	3,158	2,348	-
1965	2,965	2,702	1,937	1,507	3,723	2,727	2,406	-
1966	2,087	2,203	2,573	1,907	2,414	2,543	1,809	2,529
1967	2,615	2,909	3,304	2,459	3,839	3,419	1,888	2,807
1968	2,383	2,464	2,535	1,348	2,423	2,356	1,545	2,797
1969	3,076	2,724	2,958	1,932	3,271	3,059	1,829	3,183
1970	1,905	1,934	2,361	-	3,101	2,894	2,734	3,465
1971	2,339	1,370	1,640	-	1,911	1,913	2,062	2,597
1972	2,402	2,320	1,942	-	2,500	2,251	1,949	2,298
1973	2,940	2,274	2,958	-	-	2,476	2,829	2,555
1974	2,383	2,158	2,195	-	2,010	1,885	2,038	2,470
1975	3,210	2,471	1,903	-	2,237	2,295	2,270	2,559
1976	2,552	-	1,921	-	2,408	2,732	1,597	2,311
1977	2,225	-	2,228	-	2,109	2,892	-	2,050
1978	2,346	-	2,813	-	-	-	2,560	2,569
1979	2,561	-	2,224	-	-	2,639	2,203	-
1980	-	-	-	-	-	2,806	2,589	-
1981	1,634	-	-	-	-	2,357	2,561	-
1982	1,985	-	-	-	-	2,862	2,748	-
1983	2,408	-	2,557	-	-	1,838	3,158	-
1984	2,914	-	3,011	-	-	3,331	2,658	-
Average	2,497	2,356	2,429	1,915	2,735	2,600	2,329	2,630

Remarks: *, Including interporation

Year	Station Number							
	1536110	1536111	1537112	1537113	1537114	1537115	1538117	1539134
1963	2,129	1,027	1,762	2,063	1,789	1,763	2,203	2,018
1964	2,760	1,495	2,758	3,068	2,708	2,911	3,051	2,780
1965	2,621	2,412	-	2,200	1,877	2,021	2,129	1,921
1966	2,255	2,423	2,321	2,470	2,574	2,631	2,604	2,510
1967	2,867	2,785	3,161	2,946	3,184	3,272	3,484	3,259
1968	2,380	2,448	2,379	2,504	2,232	2,414	2,632	2,162
1969	2,877	2,672	2,566	2,528	3,003	3,176	2,495	2,580
1970	2,571	2,755	2,226	2,247	2,294	2,295	3,737	2,417
1971	1,956	2,130	1,782	1,723	1,801	1,548	1,670	2,508
1972	2,093	2,564	2,447	2,399	2,264	1,890	2,041	1,884
1973	2,730	2,910	2,699	3,048	2,575	2,268	2,933	2,723
1974	1,589	1,972	1,924	1,507	2,108	2,436	2,050	2,219
1975	2,154	2,583	2,339	2,236	2,374	2,082	2,426	2,462
1976	2,021	2,217	1,982	2,233	2,284	-	2,096	2,056
1977	1,962	2,371	1,921	2,128	1,938	-	1,917	1,986
1978	2,125	2,636	2,499	2,929	3,002	-	2,340	2,593
1979	2,696	2,588	2,282	2,543	2,480	-	2,224	2,030
1980	2,891	2,851	2,825	2,956	-	-	2,353	2,522
1981	2,107	2,235	1,843	2,175	1,896	-	2,093	1,629
1982	2,453	2,158	2,655	2,543	2,369	-	2,169	-
1983	2,066	-	2,384	2,727	2,850	-	2,521	2,814
1984	2,610	-	-	-	2,813	2,398	3,156	2,530
Average	2,360	2,362	2,338	2,437	2,401	2,365	2,469	2,362

Table 5 ANNUAL RAINFALL (2/4)

Unit: mm

Year	1539136	1540135	1541137	1631084	1632095	1632096	1635102	1636109
	Station Number							
1963	2,250	1,898	2,409	1,869	2,341	1,605	2,381	2,575
1964	3,055	2,781	3,953	3,269	3,207	2,811	3,171	2,627
1965	2,021	1,605	-	1,856	2,090	1,616	2,716	2,248
1966	2,662	1,842	-	1,885	2,237	981	2,531	2,797
1967	3,196	3,249	-	3,593	2,208	1,031	4,092	3,357
1968	2,234	2,482	-	3,124	2,222	802	2,082	2,570
1969	2,156	-	-	2,841	2,937	1,297	3,284	3,212
1970	2,602	2,632	-	2,238	2,320	3,289	2,848	2,908
1971	2,093	2,849	2,818	2,132	2,209	2,689	2,591	2,021
1972	1,675	2,514	1,897	1,985	1,844	3,022	2,203	2,231
1973	2,411	2,963	2,313	2,155	1,529	3,592	2,102	2,420
1974	1,776	2,536	2,272	1,852	1,674	2,403	2,143	1,646
1975	2,291	2,944	2,281	1,980	2,150	2,540	2,228	2,342
1976	2,148	2,302	2,251	1,749	-	2,224	2,690	1,863
1977	1,911	2,249	2,254	1,881	-	-	2,154	1,758
1978	2,164	2,055	2,741	2,080	1,861	-	2,304	2,409
1979	2,111	2,052	2,294	2,005	1,354	-	2,240	2,518
1980	2,298	1,836	2,470	1,755	1,446	3,263	3,239	2,513
1981	1,544	1,638	2,342	2,089	1,710	2,531	3,272	2,077
1982	1,744	1,966	2,455	-	2,112	-	3,488	2,153
1983	2,283	-	-	-	-	-	-	1,936
1984	2,635	2,665	-	-	1,618	3,350	-	2,613
Average	2,239	2,353	2,475	2,228	2,056	2,297	2,688	2,400

Year	1637001	1637133	1639132	1640141	1730081	1730082	1731083	1731094
	Station Number							
1963	-	2,222	2,511	-	1,941	1,305	1,093	2,507
1964	-	2,982	3,352	-	2,943	2,275	1,625	2,602
1965	-	2,563	2,454	-	2,183	1,366	994	2,303
1966	-	2,502	2,890	-	2,515	1,627	1,259	2,142
1967	-	3,000	3,273	-	2,768	2,106	1,070	2,823
1968	-	2,357	2,332	-	2,605	1,830	1,269	2,455
1969	-	2,777	2,553	-	2,601	1,862	1,528	2,849
1970	-	-	2,470	-	2,536	1,840	1,551	2,706
1971	2,112	-	2,153	-	1,976	1,748	1,011	1,805
1972	2,407	-	1,788	-	1,760	1,394	903	2,168
1973	2,720	-	2,404	-	2,262	2,021	979	2,530
1974	1,978	-	1,899	1,755	2,335	-	1,009	1,916
1975	2,465	-	2,615	2,267	2,077	1,810	735	2,118
1976	-	-	2,307	2,208	2,122	2,198	892	2,088
1977	-	-	2,153	-	2,307	2,446	604	1,884
1978	2,379	-	2,595	-	2,457	2,560	-	2,237
1979	2,067	-	2,370	2,734	1,640	1,879	-	2,216
1980	3,016	-	2,555	4,169	-	2,918	-	2,371
1981	2,205	-	1,999	3,077	-	2,683	-	2,402
1982	2,318	-	2,382	-	-	2,598	-	2,189
1983	2,226	-	-	-	-	1,967	-	1,780
1984	2,569	-	2,817	2,568	-	-	-	2,780
Average	2,372	2,629	2,470	2,683	2,296	2,022	1,101	2,312

Table 6 ANNUAL RAINFALL (3/4) Unit: mm

Year	1734001	1735125	1737128	1738129	1738131	1739003	1739130	1740001
	Station Number							
1963	-	2,412	-	2,392	2,438	-	2,267	-
1964	-	3,122	-	3,415	3,117	-	3,804	-
1965	-	1,975	-	2,192	2,433	-	2,545	-
1966	-	2,382	-	2,862	3,055	-	3,536	-
1967	-	2,715	-	3,316	3,105	-	3,914	-
1968	-	2,111	-	2,157	2,380	-	2,740	-
1969	-	2,767	-	2,135	2,538	-	2,753	-
1970	-	2,858	-	2,741	2,171	-	2,568	-
1971	1,366	1,891	-	2,684	2,283	-	2,554	-
1972	2,300	2,153	2,016	2,017	2,014	-	2,046	-
1973	-	2,466	2,156	2,725	2,492	-	2,573	-
1974	1,973	2,203	2,146	2,308	2,263	-	2,044	-
1975	2,327	2,491	2,514	2,962	2,495	2,884	2,885	-
1976	2,777	2,271	1,964	1,663	2,129	2,659	-	-
1977	2,112	2,130	2,079*	2,196*	2,166	2,322	-	-
1978	2,498	2,558	2,358	2,492	2,714	2,779	-	2,747
1979	2,343	2,355	-	2,108	2,449	2,833	-	3,138
1980	2,758	2,541	-	2,088	2,458	2,755	-	2,134
1981	2,137	1,854	-	1,840	1,851	2,833	-	2,887
1982	2,766	2,426	-	1,933	2,157	2,436	-	2,839
1983	1,974	-	-	2,934	-	-	-	-
1984	3,175	-	-	-	-	-	-	-
Average	2,387	2,384	2,176	2,436	2,435	2,687	2,787	2,749

Remarks: *, Including interporation

Year	1829077	1829078	1829079	1833092	1833093	1833123	1834122	1834124
	Station Number							
1963	1,753	1,848	1,775	1,876	-	2,054	2,134	2,045
1964	2,967	3,059	3,008	2,868	-	2,873	2,601	2,722
1965	1,619	2,116	2,152	1,856	-	2,048	2,149	2,082
1966	2,185	2,741	2,300	2,485	-	2,195	2,306	2,092
1967	2,446	2,545	2,587	3,352	-	2,705	2,739	2,508
1968	2,079	2,311	2,506	2,709	-	2,576	2,512	2,266
1969	2,624	2,482	2,779	2,840	-	2,543	2,962	2,599
1970	2,390	2,440	2,550	2,688	-	2,228	2,450	2,274
1971	1,406	1,894	-	1,729	1,867	1,474	1,913	1,652
1972	-	-	-	2,365	2,377	2,211	2,268	2,380
1973	-	2,134	-	2,030	-	2,199	2,341	2,184
1974	-	-	-	1,845	-	1,879	1,752	2,136
1975	-	-	-	2,104	-	2,036	2,194	2,048
1976	-	-	-	2,381	2,440	2,181	1,940	1,803
1977	-	-	-	1,771	1,891	1,940	1,804	2,435
1978	-	-	-	2,201	2,130	2,030	1,697	2,268
1979	-	-	-	2,024	1,953	2,221	2,015	2,223
1980	-	-	-	2,358	2,639	2,378	2,222	2,647
1981	-	-	-	2,307	2,155	1,999	1,870	-
1982	-	-	-	2,017	-	2,254	2,179	-
1983	-	1,791	-	2,014	-	1,821	-	2,363
1984	-	2,698	-	2,470	2,475	2,409	-	-
Average	2,163	2,338	2,457	2,286	2,214	2,193	2,202	2,249

Table 7 ANNUAL RAINFALL (4/4)

Unit: mm

Year	Station Number							
	1836001	1838148	1840001	1841199	1926001	1926051	1926052	1927053
1963	-	-	-	-	-	1,931	2,044	2,562
1964	-	-	-	-	-	2,814	2,955	3,360
1965	-	-	-	-	-	2,218	2,377	2,307
1966	-	-	-	-	-	2,263	2,682	2,474
1967	-	-	-	-	-	2,331	2,119	2,367
1968	-	-	-	-	-	2,337	1,853	2,567
1969	-	-	-	-	-	2,391	2,422	2,177
1970	-	-	-	-	-	2,093	2,419	2,441
1971	-	-	-	-	-	1,950	2,439	2,080
1972	-	2,686	-	2,171	-	1,708	2,051	1,871
1973	-	2,091	-	1,441	2,854	2,222	-	2,406
1974	-	3,808	-	833	3,013	2,211	-	2,486
1975	-	2,783	2,674	-	3,119	2,399	-	3,229
1976	2,235	-	-	-	2,811	1,963	-	3,106
1977	2,268	-	2,922	-	2,686	-	-	2,994
1978	2,652	-	2,508	-	2,309	2,175	-	3,965
1979	2,474	-	2,641	-	2,529	2,132	-	-
1980	2,263	-	-	-	2,873	2,186	-	-
1981	2,210	-	2,326	-	2,905	2,308	-	-
1982	2,452	-	-	-	2,531	2,164	-	-
1983	2,247	-	-	-	-	-	-	-
1984	2,725	-	-	3,012	3,636	4,098	-	-
Average	2,392	2,842	2,614	1,864	2,842	2,295	2,336	2,649

Year	Station Number							
	1933121	1933151	2032071	2033152	2033153	2033155	2038001	2138001
1963	1,829	1,699	1,887	1,439	2,004	1,078	-	-
1964	2,191	2,438	2,662	1,779	2,612	1,285	-	-
1965	1,689	2,109	2,480	1,635	2,046	-	-	-
1966	2,314	2,118	-	2,180	2,208	1,961	-	-
1967	2,748	2,520	2,751	3,196	3,247	2,187	-	-
1968	-	-	2,044	2,025	2,395	2,123	-	-
1969	2,590	2,634	2,531	2,514	2,190	1,910	-	-
1970	2,474	2,274	2,775	2,820	2,903	2,364	-	-
1971	1,976	2,982	2,479	2,408	2,552	2,149	-	-
1972	2,624	2,011	1,837	1,809	1,885	2,368	-	-
1973	2,380	2,228	-	2,219	2,379	2,366	-	-
1974	2,272	1,621	1,963	1,754	1,771	1,505	-	-
1975	2,760	1,630	1,718	1,660	-	2,402	-	-
1976	1,822	2,185	1,825	2,165	-	2,777	2,599	2,803
1977	1,443	-	1,530	-	-	2,128	2 67*	3,261
1978	2,424	1,937	1,945	-	-	-	2,945	2,132
1979	1,948	1,891	1,781	-	-	-	2,435	2,512
1980	2,607	2,123	2,143	2,199	-	-	2,153	1,972
1981	2,817*	1,573	1,578	-	-	-	2,534	3,092
1982	3,149*	2,217	1,743	2,340	-	-	-	4,078
1983	3,548	2,287	1,555	-	-	-	-	-
1984	-	2,599	2,170	-	-	-	3,656	3,170
Average	2,380	2,154	2,070	2,134	2,349	2,043	2,713	2,878

Remarks: *, Including interporation

Table 8 AVAILABLE HOURLY RECORD

Station Name	Number	Periods 1969 Dec II	1978 Nov III	1978 Dec I	1979 Nov III	1979 Dec III	1981 Dec II - III	1982 Dec III
I. Runoff								
1. Ran. Tanah Jengeli ($209\ km^2$)	1836401	–	–	o	o	–	o	o
2. Jam. Johor Tenggarah ($624\ km^2$)	1836402	–	–	o	x	–	x	x
3. Kg. Rantau Panjang ($1,130\ km^2$)	1737451	o	o	x	–	–	o	x
II. Rainfall								
1. Balai Polis Kg. Seelong	1636001	–	–	–	–	–	o	x
2. Sek. Men Bekit Besar	1737001	–	–	o	–	o	o	x
3. Penyelidekan Chemara, Layang Layang	1834124	–	–	–	x	–	x	x
4. Simpang Mawai, Kuala Sedili	1839196	–	–	o	–	o	o	x
5. Lombong Sin Seng	1937149	–	–	–	x	–	x	o

Remarks: I, II & III, 1st ten day, 2nd ten days and remainders of month (1st – 10th, 11th – 20th, 21st – end)

–, No record

x, Unreliable

o, Available

Table 9 MONTHLY OPEN WATER EVAPORATION

Unit: mm

Station	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Layang Layang	H	140	131	154	141	143	130	145	149	141	154	139	132	1,699
Pontian Kecil	H	137	131	147	135	136	129	138	133	138	138	128	125	1,615
Johor Bahru	H	142	130	148	137	135	124	132	138	136	145	135	133	1,635
JPT Johor Bahru	AP	128	126	139	120	123	112	121	119	121	126	112	108	1,455
Kong Kong	H	138	134	157	140	137	129	137	136	137	149	133	122	1,649
Kota Tinggi	H	149	147	166	154	155	142	144	149	152	157	144	141	1,800

Remarks: Method code

H: Hargreaves AP: Class A Evaporation Pan

Table 10 MONTHLY FOREST EVAPORATION

Unit: mm

Station	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Layang Layang	H	122	115	135	122	124	114	126	130	123	134	121	114	1,480
Pontian Kecil	H	119	114	128	117	119	112	120	116	120	120	111	109	1,405
Johor Bahru	H	124	113	129	120	118	108	114	120	119	126	118	116	1,425
JPT Johor Bahru	AP	114	112	124	106	109	100	107	106	108	112	99	96	1,293
Kong Kong	H	120	116	137	121	119	113	120	119	119	130	116	106	1,436
Kota Tinggi	H	130	128	145	134	135	124	126	130	132	136	126	122	1,568

Remarks: Method code

H: Hargreaves AP: Class A Evaporation Pan

Table 11 INVENTORY OF METEOROLOGICAL STATIONS

Station Name	Altitute (EL.m)	Location	Kind of Data: Air Temperature	Relative Humidity	Sunshine Hour	Nos. of day with Thunderstorm
Johor Bahru* International Airport	38	1°38'N 103°40'E	1976-1982	1976-1982	1976-1982	1976-1982
Chemara Research Layang Layang	30	1°49'N 103°28'E	1976-1982	1976-1983	-	-
Hospital Johor Bahru	15	1°28'N 103°45'E	1976-1982	1976-1983	-	-
Hospital Kota Tinggi	9	1°44'N 103°54'E	1976-1982	1976-1983	-	-
Hospital Pontian Kecil	5	1°29'N 103°23'E	1976-1982	1976-1983	-	-
MARDI Alor Bukit	3	1°30'N 103°27'E	1981-1982	1981-1982	-	-
Pusat Pertanian Kong Kong	38	1°36'N 103°49'E	1976-1982	1976-1982	-	-
R.R.I Kota Tinggi	15	1°44'N 103°55'E	1981-1982	1981-1982	-	-

Remarks: *, Principal Station (others are climatological stations)

Table 12 ANNUAL MAXIMUM DAILY RAINFALL (1/7)

Unit: mm

Year	Station Number								
	1334108	1433105	1437116	1438118	1534103	1534104	1535106	1535107	1536110
1946	-	-	-	-	-	152.4	-	-	-
1947	-	-	-	-	-	85.1	-	-	-
1948	185.4	164.8	-	184.1	-	196.8	-	-	75.4
1949	73.4	92.5	104.9	-	-	137.9	-	-	114.3
1950	101.9	84.6	79.8	-	-	73.6	82.3	-	63.5
1951	122.7	150.4	131.6	-	-	71.9	107.9	-	76.6
1952	128.8	115.3	135.1	90.4	-	93.5	75.2	-	101.6
1953	68.8	109.7	74.4	109.2	-	95.2	64.0	-	132.1
1954	106.8	133.9	192.8	279.4	138.7	137.2	129.5	-	157.6
1955	86.4	146.0	110.2	133.3	74.4	92.7	93.0	-	88.9
1956	55.9	130.3	113.8	109.2	133.3	115.8	105.9	-	104.1
1957	101.6	108.5	99.3	88.9	95.0	88.9	80.5	-	116.8
1958	83.1	120.9	102.6	107.9	86.4	77.0	118.1	-	104.2
1959	88.9	96.0	114.6	144.8	110.2	104.6	98.3	-	144.8
1960	90.4	68.1	102.1	66.5	97.0	95.5	79.2	-	86.4
1961	101.6	129.3	99.3	142.2	122.9	115.6	112.3	-	88.9
1962	94.5	99.3	88.4	79.9	86.4	83.1	84.3	-	75.4
1963	112.8	86.9	120.6	114.3	81.3	85.1	75.7	-	104.2
1964	165.9	61.2	103.1	127.0	114.3	73.6	88.9	-	124.5
1965	116.1	134.9	76.7	129.5	147.8	80.0	109.2	-	110.5
1966	83.6	75.1	94.5	63.5	87.4	89.9	51.2	83.8	85.9
1967	103.1	128.3	149.6	132.1	132.8	116.8	40.6	123.4	155.4
1968	191.3	114.3	117.9	64.8	72.1	105.4	31.7	115.3	75.4
1969	161.5	190.5	271.8	44.4	136.4	124.2	69.8	148.8	233.2
1970	62.4	114.3	80.0	-	90.7	101.6	97.8	119.9	87.1
1971	81.3	107.9	98.0	-	70.4	92.7	67.1	106.2	88.4
1972	124.2	76.7	104.9	-	86.6	88.9	112.5	80.0	80.3
1973	82.8	112.5	157.7	-	178.1	81.3	150.1	71.6	145.5
1974	96.5	147.6	89.9	-	89.9	86.9	95.5	136.9	68.8
1975	83.6	95.0	138.9	-	88.4	76.7	85.1	96.0	62.6
1976	113.0	-	83.0	-	110.0	250.0	42.0	92.0	70.5
1977	121.0	-	-	-	95.0	187.0	90.0	124.0	98.5
1978	175.0	-	66.5	-	110.0	120.0	166.0	100.0	82.0
1979	145.0	-	289.0	-	150.5	163.0	74.0	-	75.0
1980	-	-	125.0	-	103.0	107.0	65.0	-	120.0
1981	84.0	-	-	-	120.0	104.0	69.0	-	92.0
1982	96.0	-	-	-	-	91.0	60.0	-	79.0
1983	110.0	-	88.5	-	-	74.5	63.0	-	65.0
1984	260.0	-	132.0	-	-	100.0	75.5	-	63.0

Table 13 ANNUAL MAXIMUM DAILY RAINFALL (2/7)

Unit: mm

Year	1536111	1537112	1537113	1537114	1537115	1538117	1539134	1539136	1540135
	Station Number								
1946	-	-	-	-	133.6	-	-	-	-
1947	-	-	-	-	115.0	-	-	-	-
1948	152.9	139.7	198.4	185.4	93.7	133.1	-	125.7	-
1949	75.4	96.8	76.2	80.5	94.0	90.4	-	152.4	94.0
1950	108.5	75.4	73.6	139.7	83.8	115.8	89.9	76.7	122.7
1951	104.6	121.9	129.6	202.2	117.1	84.3	238.3	65.0	167.6
1952	124.0	129.6	86.4	116.8	114.3	99.6	105.7	107.9	128.4
1953	87.6	66.3	88.9	87.6	101.3	89.9	153.4	92.7	80.0
1954	174.0	190.5	152.4	300.0	161.0	233.2	259.2	258.1	74.7
1955	66.5	97.8	177.8	221.5	99.6	106.9	125.7	161.5	202.0
1956	134.6	74.2	99.6	97.8	71.9	93.5	104.1	165.1	222.5
1957	131.8	79.9	129.8	57.7	77.6	61.2	75.0	80.0	93.0
1958	129.5	73.7	93.7	91.9	95.0	68.8	49.6	87.6	80.8
1959	129.5	130.8	120.6	111.0	114.3	137.9	54.3	96.5	109.0
1960	92.7	76.2	87.6	80.8	99.2	89.7	129.6	105.4	152.4
1961	96.5	111.5	85.3	113.8	82.5	131.1	82.5	82.0	83.1
1962	46.0	115.3	102.9	75.7	84.3	92.5	95.2	121.2	105.7
1963	49.7	106.4	126.0	116.6	133.9	108.5	111.8	110.2	84.8
1964	67.1	123.7	146.3	115.6	93.5	149.1	189.5	133.9	121.4
1965	96.0	73.7	62.0	60.5	74.4	105.2	115.3	115.6	51.2
1966	90.4	74.2	115.6	82.3	88.9	83.8	83.8	115.3	76.7
1967	117.9	210.8	147.4	168.9	157.7	213.6	192.5	232.4	120.6
1968	82.3	156.2	111.0	121.7	108.2	127.0	128.5	101.6	104.1
1969	301.2	266.7	86.4	175.5	336.5	297.7	308.9	286.8	163.8
1970	107.7	101.6	98.6	111.5	73.9	76.2	114.3	66.8	99.2
1971	75.4	55.9	82.3	75.6	83.8	69.8	243.8	107.4	129.6
1972	162.1	107.7	107.4	108.2	134.1	75.4	96.8	82.8	94.5
1973	72.1	203.7	167.1	93.2	129.0	257.0	184.1	203.7	163.6
1974	88.9	95.5	54.9	79.5	129.0	69.6	75.6	65.0	75.6
1975	80.5	96.0	128.0	75.2	155.1	95.2	86.9	68.1	83.1
1976	108.5	73.5	122.0	67.0	-	97.5	152.0	210.0	123.0
1977	142.0	78.0	160.0	65.0	-	79.0	104.0	101.0	115.5
1978	206.0	295.0	280.0	170.0	-	88.0	215.0	274.0	100.0
1979	92.0	96.0	90.0	93.0	-	73.0	83.0	95.0	88.0
1980	125.0	150.0	81.0	93.5	-	76.0	152.5	200.5	95.0
1981	136.5	96.0	75.0	96.5	-	146.8	92.0	100.0	51.0
1982	73.5	114.5	100.0	83.5	-	99.6	117.0	121.0	125.0
1983	-	74.5	105.0	132.0	125.5	105.0	132.0	250.0	98.0
1984	-	115.0	121.0	145.0	100.5	98.9	107.0	183.0	92.0

Table 14 ANNUAL MAXIMUM DAILY RAINFALL (3/7)

Unit: mm

Year	1541137	1631084	1632095	1632096	1635102	1636109	1637001	1637133	1639132
	Station Number								
1946	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-
1948	190.5	-	-	-	221.0	170.2	-	142.0	166.1
1949	75.1	-	-	-	55.9	95.2	-	102.4	142.3
1950	160.0	-	82.0	-	56.6	88.9	-	-	109.2
1951	184.4	114.8	88.9	-	56.9	119.8	-	-	209.0
1952	135.9	62.2	96.8	-	109.2	150.6	-	105.2	132.1
1953	133.9	113.3	91.5	-	79.9	102.9	-	50.3	136.7
1954	316.5	165.9	167.6	-	194.3	181.6	-	208.8	362.7
1955	73.4	88.9	104.2	-	94.4	111.3	-	99.1	138.7
1956	149.1	83.6	137.2	-	160.0	98.3	-	113.8	217.4
1957	93.7	100.8	114.3	-	75.7	51.1	-	99.1	96.8
1958	143.5	76.6	89.9	-	173.7	104.1	-	68.1	113.5
1959	150.4	152.4	152.4	-	129.5	97.3	-	94.5	171.4
1960	91.5	120.6	158.7	-	107.9	88.9	-	101.6	135.1
1961	91.9	86.1	114.3	-	102.9	80.0	-	114.3	79.5
1962	119.9	88.9	74.4	71.1	59.9	96.0	-	105.4	93.5
1963	82.3	64.8	67.1	82.8	104.1	96.0	-	83.3	90.7
1964	165.6	101.6	79.9	104.9	94.5	120.6	-	137.2	125.7
1965	81.5	63.5	59.9	47.2	141.5	92.7	-	88.9	90.4
1966	-	96.0	51.2	28.7	86.9	82.3	-	120.1	96.5
1967	-	190.5	140.2	51.1	192.5	222.2	-	271.8	208.3
1968	-	142.2	76.2	30.5	84.6	103.1	-	146.6	150.1
1969	-	168.4	174.8	100.4	151.4	166.1	-	188.7	202.2
1970	54.3	78.5	70.4	113.2	69.3	94.0	-	-	85.1
1971	125.0	179.2	70.9	85.6	88.9	81.6	65.3	-	133.3
1972	96.8	117.9	88.9	131.3	82.3	110.5	129.5	-	73.6
1973	174.0	89.7	96.0	111.3	112.5	129.6	192.0	-	102.9
1974	88.4	111.3	93.2	117.6	96.8	64.0	87.4	-	75.4
1975	75.0	85.6	197.9	68.8	80.0	82.0	115.0	-	84.1
1976	213.0	80.0	290.5	63.0	88.0	76.0	95.0	-	208.5
1977	105.0	100.0	70.5	53.5	80.0	57.0	71.0	-	108.0
1978	250.0	93.5	45.5	65.5	62.0	285.0	277.5	-	292.5
1979	182.0	95.5	49.0	93.0	79.5	90.0	84.0	-	205.5
1980	120.0	83.5	50.0	104.0	140.0	83.0	90.0	-	105.0
1981	120.0	96.5	30.0	96.0	98.0	99.1	100.5	-	91.5
1982	144.0	90.0	108.0	105.0	101.0	53.0	122.5	-	148.0
1983	-	95.0	34.5	122.0	-	45.0	154.0	-	149.0
1984	-	50.0	70.5	200.0	-	45.0	129.0	-	75.0

Table 15 ANNUAL MAXIMUM DAILY RAINFALL (4/7)

Unit: mm

Year	1640141	1730081	1730082	1731083	1731094	1734001	1735125	1737128	1738129
	Station Number								
1946	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-
1948	-	129.8	-	-	-	-	158.7	-	116.8
1949	-	105.4	-	-	-	-	95.5	-	144.8
1950	-	142.0	-	-	-	-	103.4	-	107.2
1951	-	83.6	84.3	-	122.9	-	104.2	-	119.9
1952	-	116.1	109.2	-	87.9	-	136.9	-	147.4
1953	-	114.3	116.1	-	72.1	-	94.2	-	111.0
1954	-	145.8	159.0	-	156.0	-	129.3	-	177.8
1955	-	90.7	107.4	-	91.5	-	118.1	-	90.4
1956	-	109.2	164.3	-	94.2	-	121.2	-	212.1
1957	-	99.6	117.6	-	125.5	-	73.9	-	105.2
1958	-	63.5	85.6	-	84.1	-	122.4	-	101.6
1959	-	115.8	88.1	19.0	123.2	-	132.8	-	127.0
1960	-	100.4	57.7	30.7	47.2	-	79.2	-	96.8
1961	-	85.1	56.1	34.0	179.6	-	82.8	-	79.9
1962	-	147.6	54.6	28.7	79.9	-	81.8	-	95.2
1963	-	102.4	82.3	43.7	86.4	-	113.3	-	92.2
1964	-	108.7	83.1	41.1	141.5	-	112.0	-	153.7
1965	-	137.2	57.4	32.0	88.9	-	66.0	-	82.5
1966	-	80.0	60.7	37.6	137.2	-	94.7	-	138.4
1967	-	151.6	132.3	37.1	190.5	-	181.6	-	137.7
1968	-	79.8	88.6	39.6	104.2	-	104.1	-	105.4
1969	-	117.3	167.9	66.8	153.7	-	178.3	-	190.5
1970	-	83.3	85.3	34.5	113.8	-	85.1	-	118.1
1971	-	108.2	145.0	32.0	132.1	81.8	112.5	-	89.7
1972	-	67.3	104.6	31.2	96.5	122.0	63.0	106.9	98.8
1973	-	83.1	111.0	29.5	89.4	92.7	109.7	127.8	114.3
1974	61.2	90.9	112.0	75.0	160.0	89.9	83.6	80.0	145.0
1975	70.1	77.0	120.9	65.0	95.5	67.6	96.0	115.1	73.4
1976	244.5	79.0	98.0	41.0	101.0	86.5	95.5	91.0	162.0
1977	60.5	145.0	100.5	39.0	87.0	84.0	130.5	61.0	118.0
1978	213.0	165.5	90.0	-	87.5	146.0	221.5	227.0	227.0
1979	214.5	85.0	102.0	-	129.0	132.0	128.5	-	196.0
1980	158.5	100.0	235.0	-	91.5	92.0	115.5	-	72.0
1981	79.0	74.0	125.0	-	82.5	95.5	80.0	-	100.0
1982	105.5	59.0	90.0	-	114.0	128.0	102.0	-	207.0
1983	70.5	104.0	130.0	-	110.5	85.0	-	-	180.5
1984	65.0	155.0	172.0	-	157.5	115.0	-	-	122.5

Table 16 ANNUAL MAXIMUM DAILY RAINFALL (5/7)

Unit: mm

Year	Station Number								
	1738131	1739003	1739130	1740001	1829077	1829078	1829079	1833092	1833093
1946	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-
1948	159.9	-	-	-	127.0	109.7	117.9	126.2	-
1949	158.7	-	-	-	121.4	113.3	105.7	69.8	-
1950	94.7	-	-	-	79.2	77.7	70.1	81.5	-
1951	200.8	-	-	-	102.9	81.8	84.3	138.2	-
1952	76.7	-	228.6	-	156.2	137.9	114.3	127.0	-
1953	106.9	-	76.6	-	131.6	108.5	113.3	88.9	-
1954	309.1	-	345.6	-	170.9	171.2	180.3	158.0	-
1955	173.7	-	139.7	-	93.0	81.6	96.8	94.2	-
1956	146.0	-	198.1	-	114.3	135.1	122.0	96.0	-
1957	88.6	-	105.2	-	91.5	107.9	86.4	98.6	-
1958	99.3	-	72.9	-	91.5	160.0	119.8	71.1	-
1959	145.5	-	142.2	-	98.3	114.6	109.2	133.3	-
1960	98.0	-	122.0	-	81.6	-	99.3	77.7	-
1961	60.2	-	91.9	-	96.0	174.0	159.0	83.8	-
1962	101.3	-	132.1	-	61.2	85.9	108.7	99.1	-
1963	84.8	-	77.5	-	81.3	83.8	83.8	79.8	-
1964	171.4	-	175.5	-	81.6	156.7	171.4	115.0	-
1965	113.8	-	89.2	-	53.4	64.8	85.1	81.0	-
1966	121.2	-	84.8	-	69.1	94.0	80.0	72.1	-
1967	229.6	-	175.3	-	152.4	165.1	122.9	165.6	-
1968	218.2	-	81.0	-	77.5	75.4	101.1	108.7	-
1969	183.9	-	273.3	-	127.0	124.5	137.2	144.5	-
1970	62.0	-	116.3	-	102.6	84.1	145.3	69.6	-
1971	108.7	-	97.8	-	68.8	88.1	-	104.9	109.2
1972	73.6	-	75.6	-	-	60.5	-	103.1	106.9
1973	106.8	-	88.9	-	-	91.5	-	107.7	90.7
1974	79.0	-	79.0	-	-	75.9	-	59.9	87.1
1975	88.4	118.4	118.4	-	-	75.1	-	95.0	85.6
1976	78.0	200.0	-	-	-	-	-	93.0	85.5
1977	115.0	101.0	-	-	-	-	-	72.5	87.0
1978	192.0	192.0	-	115.5	-	-	-	69.5	86.0
1979	212.0	171.0	-	225.5	-	-	-	80.0	85.0
1980	114.0	84.0	-	135.5	-	-	-	68.0	115.0
1981	98.0	122.5	-	240.0	-	-	-	127.0	110.0
1982	103.5	193.0	-	235.0	-	-	-	75.0	160.5
1983	125.0	-	-	-	-	117.5	-	101.0	74.3
1984	111.5	-	-	-	-	127.5	-	70.0	98.0

Table 17 ANNUAL MAXIMUM DAILY RAINFALL (6/7)

Unit: mm

Year	Station Number								
	1833123	1834122	1834124	1836001	1838148	1840001	1841199	1926001	1926051
1946	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-
1948	-	159.5	135.9	-	-	-	-	-	-
1949	-	78.8	67.3	-	-	-	-	-	-
1950	77.2	107.4	94.0	-	-	-	-	-	-
1951	104.6	131.1	127.5	-	-	-	-	-	-
1952	110.7	136.7	143.5	-	-	-	-	-	-
1953	75.4	107.4	77.2	-	-	-	-	-	-
1954	145.3	141.0	168.9	-	-	-	-	-	-
1955	94.7	82.3	97.3	-	-	-	-	-	-
1956	86.9	117.3	118.9	-	-	-	-	-	-
1957	82.0	110.5	104.6	-	-	-	-	-	-
1958	64.3	170.9	72.6	-	-	-	-	-	-
1959	150.4	142.3	107.7	-	-	-	-	-	-
1960	69.1	73.4	68.3	-	-	-	-	-	-
1961	63.8	97.8	80.5	-	-	-	-	-	-
1962	134.4	86.9	92.7	-	-	-	-	-	144.3
1963	115.0	75.2	70.4	-	-	-	-	-	65.8
1964	118.4	114.8	116.6	-	-	-	-	-	93.0
1965	77.2	106.8	83.8	-	-	-	-	-	69.8
1966	104.9	109.0	75.6	-	-	-	-	-	103.4
1967	124.7	165.4	163.1	-	-	-	-	-	119.6
1968	105.4	102.4	99.8	-	-	-	-	-	71.1
1969	155.2	159.3	156.2	-	-	-	-	-	71.1
1970	83.8	99.2	97.8	-	-	-	-	-	103.1
1971	71.1	122.4	82.5	-	-	-	-	-	112.5
1972	83.1	78.2	83.8	-	93.2	-	96.0	-	78.0
1973	97.3	116.3	79.8	-	114.3	-	53.6	103.1	95.8
1974	75.6	70.9	85.3	-	89.9	-	82.5	131.1	121.9
1975	90.9	77.0	87.4	-	90.4	76.5	-	86.9	76.5
1976	77.0	75.0	56.5	105.0	-	200.0	-	96.9	94.0
1977	79.0	136.5	97.5	92.0	-	148.0	-	145.0	105.0
1978	65.0	78.0	113.0	197.0	-	138.0	-	81.0	95.0
1979	113.5	105.0	85.0	192.0	-	287.5	-	95.0	110.0
1980	71.0	74.0	124.5	81.0	-	58.0	-	112.0	106.6
1981	82.5	84.0	-	140.0	-	80.0	-	111.0	83.5
1982	91.0	93.0	-	102.0	-	70.1	-	140.0	94.0
1983	80.0	100.0	207.0	178.0	-	-	250.0	57.0	120.0
1984	104.0	123.0	134.0	120.0	-	-	295.5	123.0	140.0

Table 18 ANNUAL MAXIMUM DAILY RAINFALL (7/7)

Unit: mm

Year	Station Number									
	1926052	1927053	1933121	1933151	2032071	2033152	2033153	2033155	2038001	2138001
1946	-	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-	-
1948	-	-	167.6	-	135.9	-	-	130.6	-	-
1949	101.6	-	131.6	-	83.6	-	-	86.9	-	-
1950	73.7	-	150.4	76.2	71.4	101.6	-	88.9	-	-
1951	91.5	86.6	247.6	139.7	138.7	139.7	-	194.3	-	-
1952	99.2	109.2	149.6	183.0	170.4	150.0	-	243.2	-	-
1953	92.7	81.6	91.4	96.5	123.7	86.4	-	63.5	-	-
1954	81.3	82.3	214.6	203.2	278.9	163.8	287.0	284.5	-	-
1955	203.7	139.7	107.9	95.2	109.7	81.3	132.1	115.6	-	-
1956	124.5	85.9	63.5	95.2	147.8	150.0	125.7	126.5	-	-
1957	183.0	79.2	76.2	119.6	138.4	86.4	129.8	103.1	-	-
1958	151.1	118.1	71.9	101.6	117.3	73.7	62.6	86.4	-	-
1959	252.2	100.1	104.6	118.6	146.0	99.2	132.8	132.3	-	-
1960	100.6	99.1	99.6	63.8	59.7	82.5	70.9	95.2	-	-
1961	116.8	99.6	88.9	71.1	73.4	88.9	81.6	110.5	-	-
1962	136.7	111.0	88.9	83.8	83.3	73.7	77.7	48.4	-	-
1963	66.8	104.2	64.3	83.1	130.0	49.7	91.5	49.7	-	-
1964	81.6	110.2	152.4	160.0	160.5	54.6	145.0	49.7	-	-
1965	88.9	79.2	83.8	87.4	126.0	82.3	119.4	63.5	-	-
1966	275.3	115.1	114.3	84.1	82.5	91.5	140.5	57.5	-	-
1967	156.2	110.5	144.8	94.7	148.6	184.1	175.5	88.9	-	-
1968	66.5	70.1	88.9	151.1	79.8	70.1	118.6	51.2	-	-
1969	116.3	94.5	152.4	290.3	160.0	347.7	194.6	228.6	-	-
1970	84.1	109.7	152.4	158.0	138.4	180.3	165.9	89.4	-	-
1971	91.2	111.5	114.3	215.1	143.3	141.0	150.4	129.3	-	-
1972	70.1	69.3	119.4	117.6	116.1	117.9	97.3	108.7	-	-
1973	-	95.0	153.2	192.5	155.7	206.5	197.4	177.8	-	-
1974	-	83.6	150.0	91.9	135.9	83.3	93.0	77.7	-	-
1975	-	69.6	150.3	69.1	75.4	77.0	79.0	94.0	-	-
1976	-	102.5	73.0	128.0	67.0	76.5	-	86.0	125.5	216.5
1977	-	98.5	60.0	47.0	94.5	79.5	-	84.0	102.5	157.0
1978	-	102.5	65.0	95.0	109.0	91.5	-	-	105.0	126.0
1979	-	-	50.0	96.0	79.0	76.5	-	-	161.0	146.0
1980	-	-	65.0	86.0	91.0	105.5	-	-	63.0	154.5
1981	-	-	90.0	76.0	96.5	81.5	-	-	203.0	150.0
1982	-	-	81.0	73.0	49.0	129.0	-	-	105.0	240.0
1983	-	-	80.0	90.0	58.5	-	-	-	194.0	110.0
1984	-	-	150.0	90.0	156.0	-	-	-	282.0	120.0

Table 19 MONTHLY MEAN AIR TEMPERATURE

Unit: %

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Johor Bahru International Airport (Senai)	25.0	25.6	25.8	25.9	26.3	26.0	25.7	25.6	25.6	25.5	25.3	25.2	25.6
Chemara Research Layang Layang	25.5	26.4	27.0	27.3	27.6	27.2	26.9	26.7	27.1	26.9	26.9	26.0	26.6
Hospital Johor Bahru	27.1	27.3	27.5	27.5	27.5	27.5	27.3	27.1	27.3	27.1	27.0	26.9	27.3
Hospital Kota Tinggi	26.4	26.9	27.3	27.6	27.7	27.4	26.8	26.9	26.9	27.2	27.0	26.5	27.1
Hospital Pontian Kecil	25.9	26.3	26.5	26.7	26.9	26.8	26.4	26.3	26.4	26.3	26.4	26.1	26.4
MARDI Alor Bukit	25.9	26.8	27.0	26.9	27.2	27.2	26.7	26.7	26.5	26.5	26.7	26.2	26.7
Pusat Pertanian Kong Kong	26.1	26.5	27.1	27.3	27.7	27.5	27.0	27.1	27.0	27.1	26.9	26.3	27.0
R.R.I. Kota Tinggi	26.4	27.3	27.2	27.3	27.5	27.4	26.9	26.8	26.8	26.8	27.0	26.2	27.0
Mean	26.0	26.6	26.9	27.1	27.3	27.1	26.7	26.7	26.7	26.7	26.7	26.2	26.7

Table 20 MONTHLY MEAN RELATIVE HUMIDITY AT 1:00 PM

Unit: °C

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Johor Bahru International Airport (Senai)	65	62	64	70	69	69	71	71	70	71	73	73	69
Chemara Research Layang Layang	66	63	64	68	68	68	70	70	67	69	71	71	68
Hospital Johor Bahru	69	66	67	69	69	71	72	71	72	72	72	74	70
Hospital Kota Tinggi	64	62	62	68	69	69	70	70	70	71	70	72	68
Hospital Pontian Kecil	69	69	73	75	75	75	75	76	75	76	76	74	74
MARDI Alor Bukit	74	66	69	72	73	64	66	66	67	68	71	69	69
Pusat Pertanian Kong Kong	68	66	66	69	68	69	73	72	71	72	73	73	70
R.R.I. Kota Tinggi	68	64	66	71	72	66	70	66	68	68	68	73	68
Mean	68	65	66	70	70	69	71	70	70	71	72	72	70

Table 21 MONTHLY MEAN SUNSHINE HOURS

Unit: hrs

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Johor Bahru International Airport	6.2	6.4	6.4	5.7	5.7	5.9	5.7	5.2	4.5	4.7	4.1	4.8	5.4

Table 22 MONTHLY RUNOFF AT RANTAU PANJANG

River : Johor
Catchment Area: 1,130 Km²

Unit : $10^6 m^3$

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1963	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	56.8	81.7	116.9	131.2	-
1964	87.9	84.7	283.9	128.6	149.5	32.1	90.5	32.7	71.0	56.3	24.1	169.9	1211.2
1965	135.5	36.5	20.1	62.7	113.0	39.1	29.2	59.7	36.8	115.4	172.4	165.0	985.4
1966	115.7	45.0	52.8	83.5	63.2	65.1	91.9	108.7	72.1	107.1	154.7	150.0	1109.8
1967	234.9	269.3	142.5	122.6	181.1	69.5	51.4	31.1	60.4	64.8	N.R.	N.R.	-
1968	N.R.	N.R.	N.R.	(98.2)	102.1	65.6	N.R.	N.R.	N.R.	(91.4)	137.1	102.6	-
1969	80.9	26.4	20.1	N.R.	(99.1)	114.6	83.8	115.7	88.1	135.0	82.2	376.1	-
1970	81.4	48.9	39.1	139.2	146.5	68.4	(110.6)	(69.9)	48.5	49.7	122.1	129.9	-
1971	265.4	28.3	N.R.	N.R.	(14.7)	23.6	25.2	59.5	59.1	(36.7)	N.R.	(174.4)	-
1972	42.5	29.6	16.1	84.0	95.4	61.7	19.8	28.7	67.4	45.8	121.6	116.5	-
1973	114.9	83.7	58.9	123.9	124.8	92.8	72.1	(71.8)	72.3	90.5	103.2	73.9	90.2
1974	22.2	49.1	38.8	53.4	64.3	57.8	65.6	32.9	97.5	64.3	43.0	51.4	640.3
1975	33.8	23.0	90.5	142.3	133.7	98.2	78.2	(58.9)	64.8	(42.3)	103.4	85.2	-
1976	23.0	10.0	N.R.	N.R.	(57.1)	31.6	39.1	32.7	29.0	105.0	72.6	162.9	-
1977	165.0	72.3	34.8	17.9	46.9	55.0	36.2	55.7	61.7	151.6	140.5	(79.0)	-
1978	162.0	40.4	64.0	82.2	122.7	43.0	86.2	38.0	39.1	(50.4)	122.1	(198.2)	-
1979	120.5	(44.5)	74.7	140.8	54.6	57.5	56.5	48.5	85.3	(58.7)	(324.0)	126.2	-
1980	98.0	46.4	50.9	87.1	91.1	82.9	61.6	128.0	(100.3)	(135.3)	162.3	178.4	-
1981	(48.8)	17.2	(25.7)	114.8	143.6	51.8	40.4	28.4	47.4	75.0	85.5	214.0	-
1982	101.0	37.0	71.0	160.7	149.5	118.7	75.8	79.6	57.3	58.4	139.5	(239.7)	-
1983	164.5	44.0	40.7	25.7	79.5	48.2	55.2	105.0	142.3	76.3	140.7	369.6	1291.7
1984	243.5	452.0	187.5	111.2	163.1	110.2	113.8	76.1	50.3	83.3	113.0	218.8	1922.8
Average	134.9	76.0	75.7	98.9	112.5	66.1	61.7	62.4	65.4	85.0	113.5	166.0	1127.2