REPUBLIC OF THE PHILIPPINES
NATIONAL IRRIGATION ADMINISTRATION

FEASIBILITY REPORT ON THE GUMAIN RIVER IRRIGATION PROJECT

APPENDIXES VOLUME I

APPENDIX I HYDROLOGY
APPENDIX II GEOLOGY AND DAM CONSTRUCTION MATERIALS
APPENDIX III SOILS AND LAND CLASSIFICATION
APPENDIX IV AGRICULTURE AND AGRO-ECONOMY

FEBRUARY 1985

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO JAPAN

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LIST OF REPORTS

1. MAIN REPORT

2. APPENDIXES VOLUME 1

APPENDIX I	HYDROLOGY
APPENDIX II	GEOLOGY AND DAM CONSTRUCTION MATERIALS
APPENDIX III	SOILS AND LAND CLASSIFICATION
APPENDIX IV	AGRICULTURE AND AGRO-ECONOMY

3. APPENDIXES VOLUME 2

APPENDIX V	OPTIMIZATION OF PROJECT SCALE
APPENDIX VI	DAM AND RESERVOIR
APPENDIX VII	IRRIGATION AND DRAINAGE
APPENDIX VIII	HYDROPOWER
APPENDIX IX	ORGANIZATION AND MANAGEMENT
APPENDIX X	CONSTRUCTION PLAN AND COST ESTIMATE
APPENDIX XI	PROJECT EVALUATION

4. APPENDIXES VOLUME 3

APPENDIX XII	DRAWINGS

ABBREVIATION AND GLOSSARY OF TERMS

Abbreviations used in this report are listed below:

1. Length and Height

mm : millimeter
cm : centimeter
m : meter
km : kilometer
MSL : mean sea level
EL : elevation above MSL

2. Area

cm^2 : square centimeter
m^2 : square meter
km^2 : square kilometer
ha : hectare
MSM : million square meter

3. Volume

lit, ℓ : liter (= 1,000 cm^3)
m^3 : cubic meter
MCM : million cubic meter

4. Weight

mg : milligram
g : gram
kg : kilogram
t (ton) = 1,000 kg

5. Time

sec : second
min : minute
hr : hour
yr : year

6. Electric Measures

kV : kilovolt
kW : kilowatt
kWh : kilowatt-hour
MW : megawatt
MWh : megawatt-hour
GWh : gigawatt-hour

7. Other Measures

% : percent
PS : horse power
°C : centigrade
m^3/sec, m^3/s : cubic meter per second
lit/sec/ha, lit/s/ha : liter per second per hectare
cm/sec, cm/s : centimeter per second
t/ha: ton per hectare
ppm : part per million
No(s), no(s) : number(s)
SPT : standard penetration test

8. Currency

US$: US Dollar
₱ : Philippine Peso
(US$1.00 = ₱14.0 = ¥240)

9. Other Abbreviations

(A)

ACA	-	Agricultural Credit Administration
AD	-	Agriculture Division
ADB	-	Asian Development Bank
AMC	-	Area Marketing Cooperative
APIP	-	Aurora Peñaranda Irrigation Project
ARBA	-	Agrarian Reform Beneficiaries Association
AW	-	Association Worker
AWMT	-	Assistant Water Management Technician

(B)

BAEcon	-	Bureau of Agricultural Economic
BAEx	-	Bureau of Agricultural Extension
BAI	-	Bureau of Animal Industry
BC	-	Billing Clerk
BCD	-	Bureau of Cooperative Development
BFAR	-	Bureau of Fisheries and Aquatic Resources
BFCD	-	Bureau of Flood Control and Drainage
BISA	-	Barangay Irrigation Service Association
BPI	-	Bureau of Plant Industry
BPW	-	Bureau of Public Works
BS	-	Bureau of Soils

(C)

CBP	-	Central Bank of the Philippines
CDLF	-	Cooperatives Development Loan Fund
CIA	-	Communal Irrigators Association
CIS	-	Communal Irrigation System
CISP	-	Cooperative Insurance System of the Philippines
CLSU	-	Central Luzon State University
CMSP	-	Cooperative Marketing System of the Philippines
COA	-	Commission of Audit
CRB	-	Cooperative Rural Bank
CRIS	-	Caulaman River Irrigation System

(D)

DPB	-	Development Bank of the Philippines
DT	-	Ditchtender
DCSPCMAI	-	Del Carmen Sugar Producer's Cooperation Marketing Association Inc.

(E)

EOD	-	Engineering and Operations Division

(F)

FACOMA	-	Farmers' Cooperative Marketing Association
FAD	-	Farmers' Assistance Division
FAO	-	Food and Agricultural Organizaiton
FBC	-	Farmers' Barrio Cooperative
FIA	-	Farmer-Irrigators' Association or Farmer-Irrigation Association
FIG	-	Farmer-Irrigators' Group or Farmer-Irrigation Group
FIO	-	Farmer-Irrigators' Organization
FL	-	Farmers' Leader
FSDC	-	Farm Systems Development Corporation

(G)

GK	-	Gatekeeper
GOP	-	Government of the Philippines

(I)

IA	-	Irrigation Association
IAO	-	Irrigation Association Organizer
IBRD	-	International Bank for Reconstruction and Development
IGL	-	Irrigators' Group Leader
IOMP	-	Input and Output Monitoring Program
IRRI	-	International Rice Research Institute
ISA	-	Integrated Services Association
ISF	-	Irrigation Service Fee

(J)

JICA	-	Japan International Cooperation Agency

(K)

KAISA	-	Kalipunan Ng Mga Integrated Service Association
KKK	-	Kilusang Kabuhayan at Kaunlaran

(L)

LBP	-	Land Bank of the Philippines
LES	-	Luzon Experimental Station

(M)

MA	-	Ministry of Agriculture
MAR	-	Ministry of Agrarian Reform
MEC	-	Ministry of Education and Culture
MF	-	Ministry of Finance
MHS	-	Ministry of Human Settlements
MITI	-	Ministry of Industry, Trade and Investment
MLG	-	Ministry of Local Government
M-99	-	Masagana 99 Program (national rice program)
MPWH	-	Ministry of Public Works and Highways
MRRTC	-	Maligaya Rice Research and Training Center

(N)

NASUTRA	-	National Sugar Trading Corporation
NASUDECO	-	National Sugar Development Corporation
NCSO	-	National Census and Statistics Office
NEA	-	National Electrification Administration
NEDA	-	National Economic and Development Authority
NFA	-	National Food Authority
NFAC	-	National Food and Agriculture Council
NIA	-	National Irrigation Administration
NIS	-	National Irrigation System
NPC	-	National Power Corporation
NSDB	-	National Science Development Board
NWRC	-	National Water Resources Council

(O)

OECF	-	Overseas Economic Cooperative Fund, Japan

(P)

PAGASA	-	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PATC	-	Philippine Agricultural Training Council
PCARR	-	Philippine Council for Agricultural Research Resources
PCIC	-	Philippine Crop Insurance Corporation
PDA-ADCC	-	Provincial Development Committee - Agricultural Development Coordinating Council
PDSO	-	Provincial Development Staff Office
PELCO-II	-	Pampanga II Electric Cooperative, Inc.
PGRIS	-	Porac Gumain River Irrigation System
PHILSUCOM	-	Philippine Sugar Commission
PIS	-	Pump Irrigation System
PNB	-	Philippine National Bank
PPA	-	Philippine Port Authority
PSPCMAI	-	Porac Sugar Producer's Cooperative Marketing Association Inc.

(R)

RIS	-	River Irrigation System
RP	-	Republic of the Philippines
RUG	-	Rotation Unit Group

(S)

SEC	-	Securities and Exchange Commission

(U)

UNDP	-	United Nations Development Program
UPLB	-	University of the Philippines, Los Baños
UPRIIS	-	Upper Pampanga River Integrated Irrigation System
USAID	-	United States Agency for International Development
USBR	-	United States Bureau of Reclamation

(W)

WCCC	-	Water Control Coordinating Center
WM	-	Watermaster
WMT	-	Water Management Technologist
WMTC	-	Water Management Training Center

(Z)

ZE	-	Zone Engineer

APPENDIX I

METEOROLOGY AND HYDROLOGY

APPENDIX I METEOROLOGY AND HYDROLOGY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX I METEOROLOGY AND HYDROLOGY

CHAPTER 1 GENERAL

1.1 Scope

The meteorological and hydrological investigation and study were conducted to make clear the meteorological and hydrological properties in and around the study area for the development plan of the project with the following activities:

(1) Collection of meteorological and hydrological data,

(2) Review and examine of available basic data collected,

(3) Installation of two rainfall gauges and one staff gauge,

(4) Discharge measurements,

(5) Study of flood and drought discharges, and

(6) Sampling for water quality and sediment load analysis.

All the meteo-hydrological records collected and the computer outputs of simulation studies made in the meteo-hydrological study are listed in the "Data Book".

1.2 River Basin

In the study area, there are three major rivers, namely the Gumain, Porac and Caulaman rivers. These rivers are expected as the irrigation water sources for the project. The general characteristics of these river basins illustrated in Fig. 1.1 are as follows:

The river basins of the Gumain, Porac and Caulaman are situated in the southwestern part of the Pampanga river basin, between the latitudes of 14°50'N - 15°08'N and longitudes of 120°20'E - 120°38'E. These rivers originate in the Cabusilan Mountains of the western mountainous zone known as the Zambales Mountains.

The Gumain river joins the Porac river and flows through the Porac-Gumain diversion channel to the Guagua river in the Pampanga delta, and the Caulaman river whose name is changed to Balsic river near its mouth, flows directly into the Pampanga Bay.

The Gumain river lies between the Porac and Caulaman rivers, and flows from the northwest to the southeast. The river length including the Porac-Gumain diversion channel is measured to be 37 km from the headwaters to the confluence of the Guagua river. The average gradient of upper portion is about 4.2% and lower portion 0.125%.

In the Gumain river, there are three water level gauging stations, namely Summer Place station, Pabanlag station and Sta. Cruz station. The catchment areas of these stations are 115 km^2 at Summer Place station, 122 km^2 at Pabanlag station and 370 km^2 at Sta. Cruz station, respectively. The catchment area of the proposed dam site is 114 km^2 at just downstream of the confluence of two major tributaries. The maximum altitude is 1,580 m above sea level. In the upstream basin of Pabanlag station, about 95% of the catchment area is the mountainous area covered with grass (46%), tropical grass (9%) and thin scrub (33%) and the remaining is merely used for cultivation of paddy, taro and banana.

The Porac river basin lies contiguously to the Gumain river basin on the north. The river originates in the mountain with maximum altitude of 1,150 m and flows to the east in the mountains and to the south in the fan and plain.

The Porac river has two water level gauging stations, namely Del Carmen station and Valdez station. The catchment area of Porac river is 111 km^2 at Del Carmen station and 118 km^2 at Valdez station. The basin is mainly composed of mountainous and hilly area (93%), and is covered with grass (40%), tropical grass (15%) and scrub (20%) in the upstream basin of Del Carmen station.

The Caulaman river basin is on the south of Gumain river basin. The river rises from western mountains with maximum elevation of about 850 m and flows to the east in the mountainous area and to the south in the downstream reaches.

In the Caulaman river, there is one water level gauging station, namely Pabanlag station. The river has a catchment area of 72 km^2 at this station. About 94% of the Caulaman river basin is the mountainous and hilly area as well as the Gumain river basin. Land use of the Caulaman river basin is composed of grass (22%), woods (40%) and scrub (29%) and the remaining consists of cultivated field (3%) and tropical grass (6%).

Three river basins are summarized in the following table:

River Basin	Gumain	Porac	Caulaman
Point	Pabanlag	Del Carmen	Pabanlag
Catchment Area (km^2)	122	111	72
River Length (km)	23	30	16
Mean Elevation of Catchment Area (m)	580	280	275
Topography			
Mountain	95%	79%	85%
Hill	-	14%	9%
Plain	5%	7%	6%
Gradient	1/12	1/18	1/15
Land Category (%)			
Grass (weed)	46	40	22
Tropical Grass	9	15	6
Woods	11	6	40
Scrub	33	20	29
Upland Crops Field	1	19	3

CHAPTER 2 METEOROLOGICAL AND HYDROLOGICAL DATA

2.1 General

The Climate in the Philippines is characterized in terms of precipitation during different seasons of the year. There are four climatic types in the Philippines based on rainfall distribution as follows:

Type I : This is characterized by two pronounced seasons - one dry from November to April, the other wet during the rest of the year. The localities under this type are shielded from the northeast monsoon and cyclonic storms.

Type II : This is characterized by no dry season with pronounced maximum rain period from November to January. The regions experiencing this type are along or very near the eastern coast and are sheltered neither from the northeast monsoon and the trade winds nor from cyclonic storms.

Type III : This is characterized by no pronounced maximum rain period but with a short dry season lasting from one to three months. The localities under this type are only partly sheltered from the northeast monsoon and trade winds and open to the southwest monsoon or at least to frequent cyclonic storms.

Type IV : This type has no pronounced maximum rain period and no dry season. Rainfall is more or less evenly distribution throughout the year.

Fig. 1.2 shows the Climate Map of the Philippines and annual variation of monthly rainfall at ten representing points in the Philippines is illustrated in Fig. 1.3.

The main air streams dominating the climate in the Philippines are most generally distinguished as the Northeast Monsoon, the Indian Southwesterlies, and the North and South Pacific Trades as shown in Fig. 1.4.

The study area falls within the Type I of Climate: that is, it has two pronounced seasons, the dry season from November to April and the wet season during the rest of the year.

2.2 Meteorological Data

In and around the study area, there are two meteorological stations, namely Basa Air Base and Hacienda Luisita as shown in Fig. 1.5. The meteorological data excluding rainfall data cover about twelve years at Basa Air Base and sixteen years at Hacienda Luisita. General climatic characteristics such as temperature, relative humidity, sunshine duration, wind velocity and evaporation are given in Table 1.1 and illustrated in Fig. 1.6.

(1) Temperature

The seasonal trend of temperature in the study area is characterized by its narrow variation. The annual mean temperature is 27.1 °C, showing the maximum monthly mean of 28.7 °C in May, and the minimum monthly mean of 25.6 °C in January at Basa Air Base.

(2) Relative Humidity

The relative humidity varies between the dry and wet seasons, about 79% on an average during the wet season, and about 69% during the dry season at Basa Air Base. The lowest relative humidity occurs in January, while the highest in July.

(3) Sunshine

The mean monthly percentage of sunshine at Hacienda Luisita ranges from 31.7% to 75.6% and an annual mean percentage is 55.8%. The minimum duration occurs in August and the maximum in April.

(4) Wind Velocity

The monthly mean wind velocity varies from 2.5 m/sec in October to 3.5 m/sec in February with an annual mean of 3.2 m/sec at Basa Air Base.

(5) Evaporation

The annual mean A-pan evaporation reaches 1,785 mm equivalent to a daily mean of about 4.9 mm equivalence at Hacienda Luisita. The maximum monthly mean evaporation of 221 mm or 7.4 mm/day occurs in April and the minimum of 102 mm or 3.3 mm/day in August.

2.3 Rainfall Data

At the beginning of August 1983, after field reconnaissance at the proposed dam site and at the catchment area, two rainfall gauges were installed. One was established at the left bank of the proposed dam site while the other was installed about 6 km upstream of the proposed dam site within the catchment area. In installation of the rainfall gauges, accessibility, maintenance and influence of the wind were considered. The followings are the specification of the rainfall gauges:

Detector	:	Tipping bucket-type
Sensitivity	:	0.5 mm
Recording System	:	50 tip
Chart Paper	:	Roll-type
Chart Drive	:	1.5 V battery clock
Chart Speed	:	6 mm/hr
Recording Period	:	3 months
Dimensions	:	(W) 335 mm x (H) 575 mm x (D) 315 mm
Weight	:	Approx. 18 kg

The location of the installed rainfall gauges is shown in Fig. 1.7. The maintenance and operation for two rainfall gauges are being done by NIA.

Rainfall data of twenty-four stations including two stations installed by JICA Study Team in and around the study area were collected. The location of these stations is shown in Fig. 1.5, and the information on data availability is summarized in Table 1.2 and Fig. 1.8. Mean monthly rainfalls at twenty-four stations are presented in Table 1.3, and the monthly rainfall patterns are illustrated in Fig. 1.9.

2.4 Runoff Data

There are six water level gauging stations in the Gumain, Porac and Caulaman rivers as shown in the following table and the location of six stations is shown in Fig. 1.1.

Name of Station	Location		Drainage Area (km^2)	Years Recorded	Remarks
	Latitude	Longitude			
1. Pabanlag Station in Gumain River	14°59'12"N	120°28'18"E	122	1944-1971 1982-1983	/1
2. Del Carmen Station in Porac River	14°59'34"	120°32'05"	111	1945-1972	/1
3. Pabanlag Station in Caulaman River	14°57'30"	120°27'45"	72	1954-1971 1973,1978	/1
4. Summer Place Station in Gumain River	15°01'05"	120°28'03"	115	1983	/2
5. Valdez Station in Porac River	14°58'55"	120°32'06"	118	1958-1975	/3
6. Sta. Cruz Station in Gumain Floodway	14°55'00"	120°04'08"	370	1958-1975	/3

Remarks: /1: Upstream of the existing diversion dam
/2: Upstream of the existing diversion dam, installed by NIA, 1983
/3: Downstream of the existing diversion dam

The Bureau of Public Works (BPW) installed the staff gauges at these stations except for the Summer Place station. The daily water levels, three times a day were read and the discharge measurements were carried out. Based on the rating curve, the observed daily water levels were converted into discharges, which were published in the volume of the Surface Water Supply Bulletin of BPW. However the observation of water levels at these five stations was suspended in the 1970's due to the deterioration of the staff gauges.

On the other hand, at the Pabanlag station in the Gumain river, NIA reset a staff gauge on February 1982. At the Summer Place station, one staff gauge was installed by JICA Study Team at the beginning of August 1983, near the Summer Place. The water level at the staff gauge was read twice a day by NIA since the middle of August 1983. Further, at the beginning of November 1983, NIA installed an automatic water level recorder on the opposite site of the staff gauge in the Summer Place. Operation and maintenance is also being conducted by NIA.

Discharge records at the above mentioned six stations were collected from National Water Resources Council (NWRC) and NIA. Available period of records for water level and discharge data is shown in Fig. 1.10. The monthly average discharge records of five stations except for the Summer Place station are shown in Table 1.4.

2.5 Discharge Measurement

The discharge measurements were carried out by use of current meter and float to develop the rating curve at the Summer Place gauging station and to examine the low flow of each river. The locations of discharge measurements are as follows:

i) Gumain River - at the water level gauging station near Summer Place

ii) Porac River - at about 1 km upstream from the existing Porac Diversion Dam

iii) Caulaman River - at just upstream of the existing Caulaman Diversion Dam

2.6 Water Quality

For the purpose of checking the water qualities of the Gumain, Porac and Caulaman rivers for irrigation, the water samples were analysed at the NIA Laboratory, Muñoz, N.E. Water samples were collected at the following locations:

i) Gumain River - at the water level gauging station near Summer Place

ii) Porac River - at the existing Porac Diversion Dam site and Del Carmen Bridge site located at about 1 km upstream of the dam

iii) Caulaman River - at the existing Caulaman Diversion Dam site

The result of water quality analysis is listed in Table 1.5.

2.7 Sediment and River Bed Materials

The samplings of suspended loads and river bed materials of the Gumain river were carried out at the water level gauging station site near Summer Place and the samples were sent and analysed at the NIA Laboratory and UPRIIS Laboratory N.E.

The list of sedimentation data collected is shown in Table 1.6 and the result of grain size analysis is illustrated in Fig. 1.11.

CHAPTER 3 WATER RESOURCES

3.1 Rainfall Characteristics

(1) General

The annual mean rainfall over the whole area in the Philippines ranges as much as 2,000 mm. On the west-side of the Philippines, in which the study area is located, heavy rainfall occurs in July and August during the southwest monsoon season. On the contrary, during the northeast monsoon season between December to March, rainfall in the area is scarcely observed, which shows remarkable annual variation.

The mean annual rainfall in the study area is about 2,400 mm in the north-western part, about 2,000 mm in the eastern part and 2,600 mm in the southern part. The annual mean rainfall increases gradually toward the west. About 90% of the annual rainfall occurs during the wet season and the heavy precipitation generally falls in August.

(2) Rainfall in Mountain Range

To examine the rainfall in the western mountain range, daily correlation coefficients between Basa Air Base and other four rainfall stations consisting of Nabuclud (Catchment Area), Pasbol (Dam Site), Floridablanca (PGRIS) and Porac were calculated by use of daily rainfall records from August to October 1983. Since good correlation could not be got by using single correlation method, double-mass curve method was adopted. Fig. 1.12 shows that the rainfall at Basa Air Base well coincides with other stations. Based on Fig. 1.12, the correlation coefficients were estimated to reveal the relation between the rainfall of Basa Air Base and those of other stations. The following table indicates the results:

Rainfall Station	Elevation (m)	Single Correlation Method	Double Mass-Curve Method	
		Coefficient	Coefficient	Slope
Basa Air Base	50			
Nabuclud (Catchment area)	441	0.774	0.993	1.128
Pasbol (Dam site)	182	0.575	0.998	1.053
Floridablanca (PGRIS)	20	0.414	0.993	0.892
Porac	95	0.541	0.980	1.145

Based on the above results, the relation between elevation and ratio to daily rainfall at Basa Air Base is shown in Fig. 1.13 and formulated as follows:

$$\text{Log}H = 4.10R - 2.30$$

where, H: Elevation (m)

R: Ratio to daily rainfall at Basa Air Base (slope of segment in double mass-curve)

(3) Rainfall in the Project Area

For making examination of the tendency on regional distribution of annual rainfall in the study area, double mass-curve analysis of annual rainfall between Basa Air Base and PASUMIL, Clark Air Base, Porac, San Fernando and Talisai Balanga was made. Fig. 1.14 and the following table show the results.

Rainfall Station	Number of Years	Double Mass-Curve Method	
		Coefficient	Slope
Base Air Base	25		
PASUMIL	14	0.998	1.105
Clark Air Base	18	0.999	0.879
Porac	14	0.996	0.866
San Fernando	8	0.998	0.870
Talisai Balanga	8	0.995	1.028

According to the above, it can be said that the annual rainfall in the study area increase gradually toward the west and decrease toward the north, and the rainfall at Basa Air Base shows the representative one in the study area.

Further, for purpose of checking the quality of rainfall data at Basa Air Base, the monthly and 10-day correlation coefficients were computed to reveal the relation between the rainfalls of Basa Air Base and those of other stations. Table 1.7 shows that the rainfall at Basa Air Base well coincides with the other stations.

From the above-mentioned results and having considerable long period of rainfall record, the rainfall at Basa Air Base could be used as the basic data for hydrological analysis.

(4) Isohyetal Map

Based on the rainfall data in and around the study area mentioned in the previous section, an isohyetal map was prepared as shown in Fig. 1.15. In the western mountain range including the Gumain, Porac and Caulaman river basins, rainfall was cleared to be higher than that of lower area according to the rainfall data. This isohyetal map was made considering altitude, topography and prevailing wind system. From this map, the annual mean rainfall of the river basins were estimated as below:

Description	Name of River		
	Gumain	Porac	Caulaman
Catchment Area (km^2)	114	111	72
Mean Elevation (m)	580	280	275
Annual Mean Rainfall (mm)	2,900	2,270	2,750

(5) Long Term Rainfall Fluctuation

Rainfall fluctuation in a long term at the selected stations, namely Basa Air Base, PASUMIL, Clark Air Base, Iba and Cabanatuan, was studied by moving average method as shown in Fig. 1.16. Resulting from this figure, it is judged that the beginning of 1970's is a wetter period, 1960's an average period, and 1950's and the beginning of 1980's are dryer periods.

3.2 Reliability of River Runoff

(1) Rating Curve of River Runoff

The rating curve at Summer Place station in the Gumain river which is located near Summer Place at Floridablanca, was prepared in this study based on discharge data measured by JICA Study Team and NIA during the period of August 1983 to June 1984. The rating curve is illustrated with discharge data in Fig. 1.17.

The Pabanlag station in the Gumain river was located before 1979 at about 7 km west of the Floridablanca municipal office and about 200 m upstream from the wooden bridge at southwest side of Basa Air Base and it was destroyed by the flood. NIA re-established a new gauge on said wooden bridge on February 1982.

The discharge records at these stations are available for the period of twenty-three years from 1959 to 1979 and from 1982 to 1983. In order to check the reliability of the rating curve before 1972, the used rating curve and measured discharges are illustrated in Fig. 1.18. The figure shows the fairly well coincidence between curve and discharges. The rating curve after 1972 was prepared in this study based on the discharge data collected from NWRC and NIA.

The Del Carmen station in the Porac river was located about 1.5 km upstream from Del Carmen bridge passing through the barrio road on the left bank of the river. It was about 2 km upstream the Porac diversion dam. The rating curve at Del Carmen station was remade on the basis of discharge measurement records. On the basis of this rating curve, water level data were converted into discharges, which are summarized in Fig. 1.19 to make the comparison with actual discharge data. From this figure, it is judged that the estimated discharge is more relative to the rainfall at Basa Air Base than actual discharge data.

The Pabanlag station in the Caulaman river was situated at about 1.0 km from the Pabanlag village and about 1.5 km upstream the existing Caulanan diversion dam. The rating curve at Pabanlag station was also remade. The estimated discharge is more reliable than actual discharge as shown in Fig. 1.20.

(2) Reliability of River Runoff

In order to examine the reliability of discharge records of the Gumain, Porac and Caulaman rivers, a single correlation method was adopted. The monthly and 10-day correlation coefficients were calculated using the actual discharge data and estimated discharge data for the period of lacking water level data. The following table indicates the results.

Station	10-day correlation coefficient	Pabanlag St. in Gumain R.	Del Carmen St. in Porac R.	Pabanlag St. in Caulaman R.
		Monthly correlation coefficient		
Pabanlag St. in Gumain R.			0.67 (304)	0.75 (198)
Del Carmen St. in Porac R.	0.61 (918)			0.51 (165)
Pabanlag St. in Caulaman R.	0.67 (615)	0.55 (516)		

Remarks: ( ): Numbers of Samples

According to the above, it was difficult to reveal the relation among the discharges of the Gumain, Porac and Caulaman rivers by use of a single correlation method.

On the other hand, the discharge records in the Summer Place estimated by JICA Study Team on the Gumain river show almost same values with the records at the Pabanlag station in the Gumain river as shown in Fig. 1.21, though the period is short.

In addition, for examining the relation between the runoff depth of rivers and rainfall depth in the basins, the monthly runoff depth of the Gumain, Porac and Caulaman rivers were plotted against the accumulated monthly rainfall at Basa Air Base as illustrated in Fig. 1.22. Its monthly correlation coefficients were also estimated as follows (See Fig. 1.23):

Name of Station	Correlation Coefficient	Number of Months
Gumain river at Pabanlag	0.896	221
Porac river at Del Carmen	0.681	113
Caulaman river at Pabanlag	0.737	120

The runoff depths of the Gumain river well coincide with the rainfall depth of Basa Air Base but the Porac and Caulaman rivers are not coincidental. The reasons for the above are considered as follows:

- The rating curve of Gumain river at the Pabanlag station used for estimating discharge coincides with actual discharge measurements.
- The discharge records at the Summer Place station made by JICA Study Team on the Gumain river show correlate well with records of the Gumain river at the Pabanlag station.
- The river beds of Porac river at the Del Carmen station and Caulaman river at the Pabanlag station change with the frequent flooding of these rivers, but no modifications are made to their curves.

From the above, it was decided that the discharges of Porac and Caulaman rivers should be estimated from those of the Gumain river.

3.3 Evaluation of River Runoff

To examine the relation between the discharges of the Gumain river and those of the Porac and Caulaman rivers, the accumulated monthly specific discharges of Porac river at Del Carmen station and Caulaman river at Pabanlag station were plotted against the discharges of the Gumain river at Pabanlag station as shown in Fig. 1.24.

In this figure, the slope of the segment of the double-mass curve for the Gumain and Porac rivers varies from 1 : 0.6 to 1 : 0.8, and that for the Gumain and Caulaman rivers indicates 1 : 0.9. From the above, the discharges of the Porac and Caulaman rivers can be estimated using the conversion factors for the discharges of the Gumain river of 0.7 and 0.9, respectively as shown below:

$$Q_P = 0.7 \times Q_G \times \frac{A_P}{A_G}$$

$$Q_C = 0.9 \times Q_G \times \frac{A_C}{A_G}$$

where, Q_G: Runoff of Gumain river

Q_P: Runoff of Porac river

Q_C: Runoff of Caulaman river

A_G: Drainage Area of Proposed Gumain Dam Site, 114 km^2

A_P: Drainage Area of Existing Porac Diversion Dam Site, 111 km^2

A_C: Drainage Area of Existing Caulaman Diversion Dam Site, 72 km^2

3.4 Long-Term Runoff Analysis

(1) Purpose and Methodology of Analysis

In order to conduct the long-term water balance study on the Gumain Irrigation Project, the streamflow discharge records for sufficient long period are required at respective locations of major streams. The available streamflow data, however, is limited at the Pabanlag station in Gumain river. The purpose of the long-term runoff analysis is to supplement the streamflow discharges during the period of lacking discharge data from the available data through hydrological runoff model.

The Tank Model method was selected suitable to analyse especially long-term runoff among several hydrological runoff models. The Tank Model was used to generate 10-day streamflow discharges from 10-day rainfall. Coefficients of Tanks are determined through simulation until obtaining the nearest possible discharges with the observed discharges by trial and error. Accuracy of the model depends on the accuracy of streamflow observation data and duration of observation.

The daily rainfall data at Basa Air Base was adopted as representative rainfall for runoff simulation since more than 20 years daily rainfall data are available only at Basa Air Base.

(2) Analysis of Missing Daily Rainfall at Basa Air Base

As seen in the Fig. 1.8, daily rainfall data at Basa Air Base is not completed for the available period of observed monthly rainfall data. To estimate the missing daily rainfalls at Basa Air Base, single correlation method was adopted. Table 1.8 shows the correlation coefficient between the rainfall at Basa Air Base and that at selected other rainfall stations. From this table, the missing daily rainfall was supplied from rainfall records at the station indicating the highest correlation coefficient of all.

(3) Tank Model Calculation

A Tank Model is usually composed of 3 to 4 storage tanks, and 4 tanks model was adopted in this study.

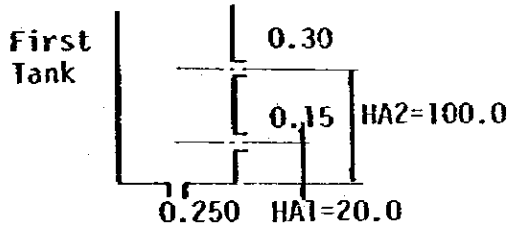
Each tank has several runoff holes at different heights and an infiltration hole at a bottom. It is generally interpreted that the upper two tanks correspond to the surface runoff, the third tank to the intermediate runoff and the bottom tank gives base flow and infiltration to the ground water. Rainfall is put to the first tank and it outflows from the side holes and penetrates to the lower tanks.

The coefficients of tank made by a trial and error method were given as follows:

i) Catchment Area: 122 km^2 (Pabanlag station)

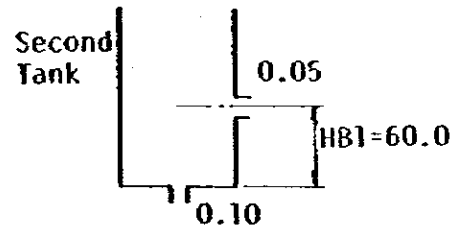
ii) First Storage Height

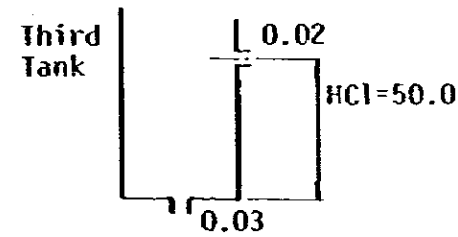
First Tank	0 mm
Second Tank	0 mm
Third Tank	0 mm
Fourth Tank	10,000 mm

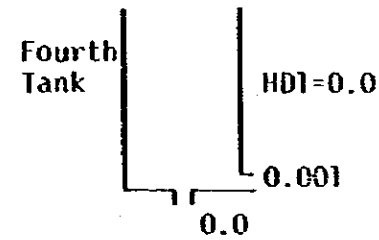


iii) Evaporation

Month	Evaporation (mm/day)
Jan.	5.2
Feb.	6.2
Mar.	6.4
Apr.	7.8
May	7.0
Jun.	5.4
Jul.	4.8
Aug.	4.3
Sep.	4.8
Oct.	4.6
Nov.	4.9
Dec.	4.7







iv) Rainfall Station: Basa Air Base

v) Coefficient of Premium: 1.2

For estimation of the rainfall within the catchment area, the rainfall at Basa Air Base was modified according to the areal distribution of rainfall shown by the isohyetal map.

(4) Runoff of Gumain, Porac and Caulaman Rivers

Trial and error calculations were conducted by computer until obtaining the model to simulate the discharges similar to the observed discharge values applying rainfalls at the Basa Air Base. Applying these models, the 10-day discharges were generated for 26 years from 1958 to 1983 at the Pabanlag station having the catchment area of 122 km^2 in the Gumain river. For evaluation of model's accuracy, simulated 10-day discharge and observed one were plotted in Fig. 1.25.

Table 1.9 shows the result of comparison between the observed runoff depth and that evaluated by the Tank Model method. In consideration of the runoff coefficients and the runoff hydrographs based on the actual and estimated discharges, actual annual runoff discharges of 1960, 1961 and 1964 were changed with the estimated discharges as well as the interpolation for missing data, though the discharge records were collected.

10-day discharges at the Pabanlag station in the Gumain river are summarized in Table 1.10. Based on these discharges and the equations discussed in the previous Section 3.3, the discharges at the proposed Gumain Dam site, existing Porac Diversion Dam site and existing Caulaman Diversion Dam site can be estimated. The 10-day mean discharge at each site is shown in Table 1.11 and the monthly mean discharge is summarized as follows:

(Unit: m^3/sec)

Month	Gumain Dam Site (C.A = 114 km^2)	Porac Diversion Dam Site (C.A = 111 km^2)	Caulaman Diversion Dam Site (C.A = 72 km^2)
Jan.	1.81	1.23	1.03
Feb.	1.64	1.12	0.93
Mar.	1.55	1.06	0.88
Apr.	1.58	1.08	0.90
May	4.70	3.20	2.67
Jun.	9.10	6.20	5.17
Jul.	16.08	10.96	9.14
Aug.	22.45	15.30	12.76
Sep.	17.74	12.09	10.08
Oct.	9.60	6.54	5.46
Nov.	4.90	3.34	2.79
Dec.	2.51	1.71	1.43
Average	7.85	5.35	4.46

CHAPTER 4 FLOOD DISCHARGE

4.1 Observed Flood Discharges of Gumain River

There are no useful information concerning floods of the Gumain river except the observed annual maximum discharges at the Pabanlag station in the Gumain river. The probable flood analysis based on the annual maximum daily discharges was made by Hazen method. The estimated probable discharges are as follows:

(C.A. = 122 km^2)

Return Period (Year)	50	100	200	500	1,000	10,000
Discharge (m^3/sec)	278	309	341	385	419	543
Specific Discharge (m^3/sec/km^2)	2.29	2.53	2.80	3.16	3.43	4.45

Since annual maximum discharges were estimated based on the flood water level read on the staff gauges by gauge keeper, no special flood observation was made but just observed at daily fixed time. There is a possibility to have missed the actual flood gauge height occurred in the night. Accordingly, it was judged that the probable discharges were not fairly estimated by those data.

4.2 Methodology of Analysis

Because of difficulty to estimate the probable discharges using the observed discharges, the following three approaches were adopted in the present study to decide design floods and to confirm the dam safety against probable maximum flood.

i) Probable Flood by rational formula

ii) Envelope of unusual flood ever recorded in all over the Philippines

iii) Probable Maximum Flood (PMF) converted from Probable Maximum Precipitation (PMP) by a synthetic unitgraph

In the meantime there is a standard in Japan concerning the dam design flood as quoted below:

The design flood of a dam should be the largest one among:

- Flood having the recurrence period of 200 years at dam site.

- Recorded maximum flood at dam site.

In case of a fill type dam, the above discharge should be multiplied by 1.2. The spillway should have the capacity to discharge the design flood without taking into consideration the storage effect of the reservoir. According to the above Japanese standard, it may not be necessarily required to consider PMF. However, it is required strongly for the present study to see the ultimate limit of the probable flood which is obtained by the reasonable procedure from the view point of meteo-hydrology, since the flood of the Gumain river system is expected to be unusually large.

The flood corresponding to a recurrence period of 10,000 year is not adopted in the present study as an indicator for the above limit of the probable flood, because the statistical analysis does not always give a reasonable limit of the flood, although the recurrence period of 10,000 year is often used as a limit. If the sample of flood records has a high variance and skewness, 10,000 year flood would be unreasonably high.

Thus it was decided to adopt the above three approaches in the present flood study.

4.3 Probable Flood by Rational Formula

Calculation of probable flood by rational formula was carried out by analysing probable rainfalls, rainfall intensities, times of flood concentration and runoff coefficients. Rational formula is expressed below:

$$Q = \frac{1}{3.6} \cdot f \cdot r \cdot A$$

where, Q: Peak discharge (m^3/sec)
f: Runoff coefficient
r: Rainfall intensity (mm/hr)
A: Catchment area (km^2)

In the above formula, the rainfall intensity is defined as average rainfall in mm/hr during the time of concentration which means surface runoff time from the remotest point of stream channel in the basin to the calculation point.

(1) Probable Rainfall

Probable rainfalls were estimated by use of rainfall data at Basa Air Base considering the location of rainfall station and the observation period. The probable rainfalls on t-year return period at Basa Air Base were computed using Iwai, Gumbel and Hazen plot methods and those of 200-year return period are summarized as below:

(Unit: mm)

Rainfall	Iwai Method	Gumbel Method	Hazen Method
1 - day	516.5	647.8	647.8
3 - day	1,380.5	1,329.1	1,230.5

The Gumbel method was adopted to apply the estimation of the design probable rainfall by reason of well coincidence to the plotting position of rainfall. The probable rainfall computed by the Gumbel method at the Basa Air Base is illustrated on Fig. 1.26.

(2) Rainfall Intensity

The rainfall intensities of the past floods were estimated by use of the Mononobe formula as described below:

$$r = \frac{R24}{24}\left(\frac{24}{t}\right)^n$$

where, r: Rainfall intensity (mm/hr)
R_{24}: Daily rainfall (mm/day)
t: Time of concentration (hr)
n: Constant

The time of concentration was presumed at about 2 hours considering length and gradient of the Gumain river. Accordingly, regarding the constant value of "n" in the above formula, it was proved by the relation between maximum hourly rainfalls and maximum daily rainfalls as shown in Table 1.12 on the basis of the following equation:

$$n = \text{Log}\ (24Rt/R_{24}) / \text{Log}\ (24/t)$$

where, Rt: 1-hour and 3-hour rainfall (mm)
R_{24}: Daily rainfall (mm)
t: Time of concentration (hour)

The relation between "n" and "R_{24}" is shown in Fig. 1.27.

(3) Time of Flood Concentration

There are no data for estimation of time of flood concentration on the Gumain river. Since rivers in Philippines are considered to have the similar characteristics to those in Japan rather than continental rivers, the lag time (time of concentration) of the Gumain river was calculated and compared by the following four empirical equations:

i) Kadoya, Fukushima's Equation

$$tp = CA^{0.22} \cdot r^{-0.35}$$

where, tp: Time of concentration (min.)
C: Constant given by land category C = 200
A: Catchment area (km^2)
r: Rainfall intensity (mm/hr)

ii) Nakayasu's Equation

$Qg = 0.21\ L^{0.7}$ for L shorter than 15 km

$= 0.4 + 0.058\ L$ for L longer than 15 km

where, L: Length of longest watercourse from point of interest to watershed divide, measured in km

iii) Ruchiha's Equation

$t = L / W$ $\quad W_1 = 72\ (H/L)^{0.6}$ (km/hr)

$W_2 = 20\ (h/l)^{0.6}$ (m/sec)

where, H/L: Gradient of watercourse

iv) Equation by U.S. Corps of Engineer for Mountain Drainage Area

$$Lag = 1.2\ \left(\frac{L.Lc}{S^{0.5}}\right)^{0.38}$$

where, L, Lc: in miles

S: Overall slope in feet per mile of longest watercourse from point of interest to divide

The results are shown as follows:

(Unit: hr)

Equation	Proposed Gumain Dam	Proposed Gumain Diversion Dam
Kadoya, Fukushima	1.99	1.99
Nakayasu	1.42	1.55
Ruchiha	1.72	2.34
U.S. Corps of Engineer	1.97	2.20

From the above, the lag time of the Gumain river was estimated to be about 2.0 ha given by the Kadoya, Fukushima's equation indicating a mean value.

(4) Runoff Coefficient

The runoff coefficient "f" of the Gumain river is given to 0.8 as classified below:

Land Category	Runoff Coefficient
Steep mountain area	0.75 - 0.9
Tertiary hills	0.7 - 0.8
Undulating land and forest	0.5 - 0.75
Flat cultivated land	0.45 - 0.6
Irrigated paddy field	0.7 - 0.8

(5) Peak Discharge

The peak and specific discharges of probable floods at the proposed Gumain dam site and diversion dam site are given in Table 1.13 and summarized below:

Return Period		5	10	100	200	500
Proposed Gumain Dam Site (CA = 114 km^2)	Peak Discharge (m^3/sec)	1,130	1,290	1,974	2,184	2,465
	Specific Discharge (m^3/sec/km^2)	9.9	11.3	17.3	19.2	21.6
Proposed Gumain Diversion Dam Site (CA = 115 km^2)	Peak Discharge (m^3/sec)	1,140	1,301	1,991	2,201	2,484
	Specific Discharge (m^3/sec/km^2)	9.9	11.3	17.3	19.1	21.6

4.4 Envelope of Unusual Flood in Philippines

According to the Feasibility Report on Agos River Hydropower Project in March 1981 by JICA, there are 409 gauging stations all over the Philippines as of the end of 1969. The maximum flood records of each station were picked up in the Water Supply Bulletin of BPW. The specific discharges of the above flood records were plotted in a logarithmic paper to the drainage area and the corresponding Creager's C exceeds 54 at five stations as shown in Fig. 1.28. Four stations out of the above five are located in the North Luzon and the one in Central Luzon. In Central Luzon, it is concluded that the Creager's equation of C = 60 gives an adequate enveloping curve.

The above enveloping curve gives flood discharges at the proposed damsite as shown below together with 200-year floods for the comparison.

(Unit: m^3/sec)

	Drainage Area in km^2	Envelope	200-year Flood	1.2 x 200-year Flood
Proposed Gumain Dam Site	114	2,520 ($q = 22.1\ m^3/sec/km^2$)	2,184	2,621

The envelope shows a higher flood discharge than the 200-year flood and less than 1.2 x 200-year flood for the design flood of proposed Gumain dam.

4.5 Probable Maximum Flood (PMF)

(1) Probable Maximum Precipitation (PMP)

Heavy storms are generally caused by typhoons in the Philippines, therefore, heavy rain spreads in large area and continues for long duration in general. The design storm for the dam and reservoir was derived from maximum depth duration curve of rainfall shown in Fig. 1.29. The curve was obtained by enveloping observed maximum point rainfalls in the Philippines at various durations.

As shown in Fig. 1.29, the curve was controlled entirely by the following rainfall values observed at Baguio City:

	Duration (hours)									
	3	5	6	9	12	18	24	39	72	87
Depth (cm)	23	36	40	55	72	105	122	158	207	229
Year	1918	1910	1910	1911	1913	1967	1967	1911	1911	1911

Source: Magat River Project F/S Report, Vol. II, NIA, June 1973.

In deriving the design storm, the following adjustments described below were made to the envelope values.

i) Maximizing the Storm

A 10 percent increase above envelope curve was assumed in maximizing the storm efficiency, i.e.

Storm maximizing factor = 1.10

This increase was used by the BPW in their "1964 Report".[1]

ii) Transposition of Maximized Point Rainfall

The maximized point rainfalls at Baguio City (envelope values plus 10 percent) were transposed to the watershed by an adjustment factor (AF).

$$AF = \frac{\text{mean seasonal rainfall over watershed}}{\text{mean seasonal rainfall at Baguio}}$$

In the above, seasonal rainfall is from May to October. The corresponding mean seasonal rainfall at Baguio is 3,118.4 mm as below:

Jan.	10.0 mm
Feb.	11.1
Mar.	45.6
Apr.	102.4
May	276.3
Jun.	463.7
Jul.	613.8
Aug.	823.7
Sep.	658.4
Oct.	282.5
Nov.	135.9
Dec.	34.6
Annual	3,458.0

Source: Magat River Project Feasibility Report, Vol. II, APP, A&B, NIA, June 1973.

Period of record: 1949 - 1969

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[1]: Spillway Design Flood for Potential Dam and Reservoir Site in Central Luzon Basin, Designing Branch, Flood Central and Drainage Division, BPH, Manila, July 1964.

ii) Mean Seasonal Rainfall over Watershed

The mean seasonal rainfall over the watershed of the proposed Gumain dam was determined indirectly by means of an elevation versus a rainfall premium relationship as shown in Fig. 1.13. The average elevation of the watershed measured to be 580 m and the elevation of Basa Air Base to be 50 m. The rainfall premium over the watershed estimated from the relationship is 1.27. Therefore the seasonal rainfall over the watershed was estimated to be 2,755 mm by the product of the seasonal rainfall (2,169 mm) at the Basa Air Base and 1.27.

iv) Overall Adjustment Factor (OAF)

The overall adjustment factor (OAF) which was applied to the Baguio envelope values to arrive at the maximum probable point rainfalls at the watershed of Gumain dam is as follows:

AF = 2,755 mm/3,118 m = 0.88

OAF = 1.1 x 0.88 = 0.97

v) Design Storm

The maximum probable point rainfalls after applying overall adjustment factors were finally reduced to average rainfall depths over the proposed Gumain dam watershed by applying reduction factors obtained from the maximum depth - area - duration curve as shown in Fig. 1.30.

The maximum depth - area - duration curves were obtained from a 100-year design storm which was derived in the previous study "Spillway Design Floods by BPW".

The computation of design storm for the watershed is shown in Table 1.14.

(2) Rainfall-Intensity Pattern

The most critical arrangement of intensities with time was made for rainfall intensities to increase to a maximum near the end of the storm. Such an increasing pattern of intensities was followed in the re-arrangement of rainfall increments of the design storm with a slight adjustment on the occurrence of the peak rainfall. The design storm as re-arranged, increases up to afternoon of the third day from beginning of the storm and decreases gradually to the end of the storm.

According to the above-mentioned "Spillway Design Flood by BPW", the maximum rainfall also occurred on the third day. The duration of the storm was assumed to be 108 hours (4.5 days) and the re-arranged storm rainfalls for the watershed of the proposed Gumain dam are shown in Table 1.14.

The minimum precipitation losses used to compute effective rainfall are as follows:

- Initial loss 25 mm
- Retention loss 1.5 mm/hr

Use of these rates resulted in 93% runoff.

(3) Synthetic Unitgraph

As described in the foregoing paragraph, rivers in the Philippines are considered to have the similar characteristics to Japanese rivers. The rainfall-runoff relation of the Gumain river system has not been clarified yet. Hence a synthetic unitgraph developed by Dr. Nakayasu for Japanese rivers was adopted to convert Probable Maximum Precipitation (PMP) into Probable Maximum Flood (PMF), which is expressed by the following equation:

$$Q_p = \frac{0.2778 \cdot A \cdot R_o}{0.3 \cdot t_p + t_k}$$

$$\frac{Q}{Q_p} = \left(\frac{t}{t_p}\right)^{2.4} \qquad \text{for } t = 0 \text{ to } t = t_p$$

$$\frac{Q}{Q_p} = 0.3^{(t - t_p)/t_k} \qquad \text{for } t = t_p \text{ to } t = t_p + t_k$$

$$\frac{Q}{0.3 \times Q_p} = 0.3^{[t - (t_p + t_k)]/(1.5 + t_k)} \qquad \text{for } t = t_p + t_k \text{ to } t = t_p + 2.5 \cdot t_k$$

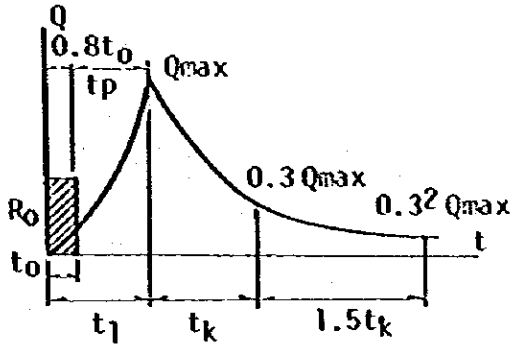
$$\frac{Q}{0.3^2 \cdot Q_p} = 0.3^{[t - (t_p + t_k + 1.5 \cdot t_k)]/(2.0 \cdot t_k)} \qquad \text{after } t = t_p + 2.5 \cdot t_p$$

where, A: Drainage area in km^2

R_o: Unit rain in mm for the unit duration of t_o hour

t_p: Basin lag in hour from the beginning of rain to the peak of unitgraph

t_k: Period in hour from the peak to the time of $Q = 0.3 \cdot Q_p$



The lag time of the Gumain river at the proposed Gumain damsite was estimated to be two hours in the foregoing section. The following unitgraph was obtained by Nakayasu's synthetic unitgraph method.

Description		Dam Site
Drainage Area	(km^2)	114
t_p	(hour)	4
t_k	(hour)	4
Q_p	(m^3/sec)	6.09

(4) Probable Maximum Flood (PMF)

PMP for the Gumain watershed was converted to PMF using the unitgraph obtained in the previous section so as to give the severest flood for the reservoir. The hydrograph of PMF is given in Fig. 1.31. From the result of computation, PMF for Gumain dam having the peak discharge of 2,850 m^3/sec and 4.5 days flood volume of 268 MCM, was obtained as the meteo-hydrological maximum limit of the probable flood at the site.

4.6 Design Flood

(1) Spillway Design Flood

Various floods estimated at proposed damsite in the foregoing sections are summarized below:

(Unit: m^3/sec)

Description	Proposed Gumain Dam Site
Drainage Area (km^2)	114
1. 1.2 x 200-year flood	2,650
2. Envelope of unusual floods for Central Luzon	2,520
3. PMF	2,850
4. 10,000-year flood	3,365

Among the above four estimations of flood peak discharge, the figure obtained by the envelope for Central Luzon became lower than others. Therefore it was concluded that the design flood of spillway was based on the 1.2 times of 200-year flood for the fill type dam without considering the storage effect of reservoir in accordance with the Japanese standard.

Since a fill type dam is very week against flood over-topping and its collapse would cause a great damage in the lower basin, the fill type dam should be designed to be safe even for the maximum flood which is probable at the dam site meteo-hydrologically. The peak discharge of the PMF for the Gumain dam was obtained to be 2,850 m^3/sec which corresponds to the recurrence period of about 2,800 years. The spillway design flood for the Gumain dam is shown below:

Description	Design Discharge	PMF for Dam Safety
Flood discharge (m^3/sec)	2,650	2,850
Recurrence period (year)	1,500	2,800

(2) Diversion Design Flood

The peak discharge of the diversion design flood was obtained at the 10-year flood and the coffer dam shall have the enough height against overtopping by the 25-year flood. The diversion design flood is shown below:

Description	Diversion Design Flood	Coffer Dam Design Flood
Peak Discharge (m^3/sec)	1,290	1,550
Return Period (year)	10	25

(3) Check of Design Floods

The design floods of the spillway and diversion for earth and fill dams in the Philippines ever studied are tabulated in Table 1.15 and plotted in a logarithmic paper to the drainage area as shown in Fig. 1.32. From this figure, it is judged that the design floods determined by the above mentioned methods indicate proper values.

4.7 Flood Routing

(1) General

A reservoir routing study was made based on the following equation to assure the dam safety against the probable maximum flood.

$$(S_1 - S_2)/dt = (I_1 + I_2)/2 - (Q_1 + Q_2)/2$$

where, S: Reservoir storage in m^3, subscript 1 and 2 mean time of beginning and end of the period dt

dt: Time step in sec

I: Inflow in m^3/sec

Q: Outflow in m^3/sec

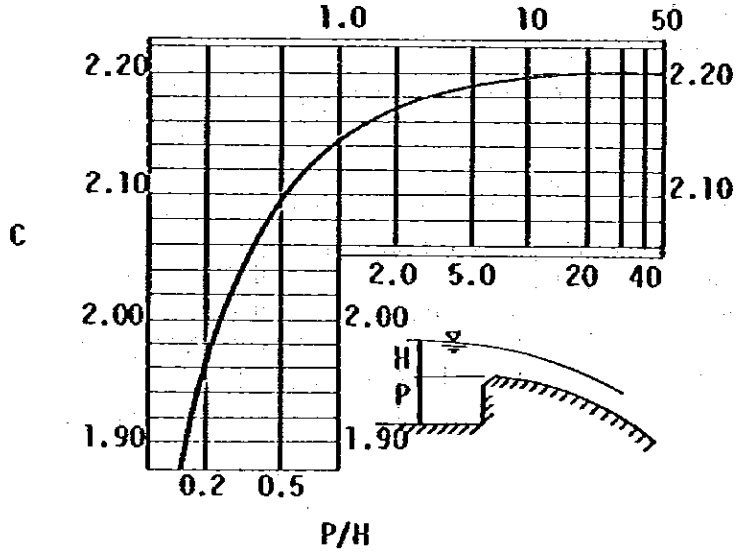
The discharge capacity of overlow weir is obtained by the following equation:

$$Q = C \cdot L \cdot H^{3/2}$$

where, Q: Overflow discharge in m^3/sec

L: Width of weir

C: Coefficient for overflow weir given by the following figure



The full water level (FWL) of the Gumain dam was determined to be 153.50 m by the optimization of dam scale. Spillway dimensions were decided to have the discharge capacity to release spillway design discharge of 2,650 m^3/sec at the high water level (HWL) of 157.50 m.

(2) Reservoir Routing for PMF

The reservoir routing study of the Gumain dam for the PMF was carried out as illustrated in Fig. 1.33 and the result is summarized below:

FWL	153.50 m
HWL	157.50 m
PMFL/1	157.26 m
Max. Inflow	2,850 m^3/sec
Max. Outflow	2,432 m^3/sec
Spillway Design Flood	2,650 m^3/sec

Remarks: /1: Maximum reservoir water level during flood routing for PMF

As shown in the above table, the maximum reservoir water level becomes to be lower than the high water level for spillway design discharge of 2,650 m^3/sec. Therefore, it is judged that the proposed Gumain dam has safety even for the probable maximum flood.

CHAPTER 5 SEDIMENT AND WATER QUALITY

5.1 Sediment

In order to determine the capacity of sedimentation of the proposed Gumain reservoir, the sediment yield of the Gumain river basin was estimated on the basis of the data on sediment transport.

For estimation of sediment transport, sediment was divided into two components of bed load and suspended load.

(1) Bed Load

Sato-Kikkawa-Ashida formula was adopted to estimate the bed load. This formula is expressed as follows:

$$\frac{q_B s_g}{U_*^3 f\ (\tau_c/\tau_o)} = 0.623 \quad (n \geq 0.025)$$

where, q_B: Bed load per unit river width per unit time ($m^3/sec/m$)

s: Submerged specific gravity (ton/m^3)

g: Acceleration of gravity (= 9.8 m/sec^2)

U_*: Friction velocity (m/sec)

τ_o: Tractive force of flow (ton/m^2)

τ_c: Critical tractive force (ton/m^2)

n: Coefficient of roughness

Using the cross-section at the Summer Place gauging station downstream of 1.5 km from the proposed dam site, the bed loads for various water discharges were calculated applying d_m = 3.50 cm (d_{65}) river bed material obtained from the results of grain size analysis as shown in Fig. I.11.

The relation between bed load and water discharge is shown as the following equation:

$$Q_B = 6.80 \times 10^{-4} \cdot Q^{2.76}$$

where, Q_B: Daily weight of bed load (ton/day)

Q: Discharge (m^3/sec)

(2) Suspended Load

Suspended load measurements near the proposed dam site were conducted three times since 1983 but these measurement records are too short to analyze the sediment load in the reservoir.

Long term measurements of suspended load on Gumain river were conducted at Sta. Cruz Station, the following formula was obtained as shown in Fig. 1.34.

$$Qs = 1.59 \cdot Q^{1.90}$$

where, Q_S: Daily weight of suspended load (ton/day)

Q: Discharge (m^3/sec)

(3) Sediment Load at Proposed Dam Site

Applying daily discharges of the Gumain river during the period from 1944 to 1983, annual total sediment load at the proposed Gumain dam site having the catchment area of 114 km^2 was computed using the above-mentioned formula. The average sediment load for 40 years is summarized below:

Q_B ($10^3 m^3$/yr)	Q_S ($10^3 m^3$/yr)	$Q_B + Q_S$ ($10^3 m^3$/yr)	$(Q_B+Q_S)/A$ (m^3/yr/km^2)
2.6	104.3	106.9	940

Remarks: Q_B: Annual total bed load

Q_S: Annual total suspended load

$(Q_B+Q_S)/A$: Specific sediment load

A: Catchment area at Gumain dam site (= 114 km^2)

From the above, the design sediment load was estimated to be 1,000 m^3/km^2/year considering some adjustment factors such as trap efficiency of the reservoir, etc.

5.2 Water Quality

According to "United State Department of Agriculture (USDA)", the irrigation water is classified into four groups as shown in Fig. 1.35 with respect to sodium hazard depending on the sodium-adsorption ratio (SAR) value and the specific conductance. The SAR is defined as:

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++} + Mg^{++})/2}}$$

Where, the concentration of the ions is expressed in equivalents per million (epm).

The results of analysis of water samples are summarized below:

Site	Number of Sample	E.C. MMHOS/ cm 25°	PH	SAR	Sodium Hazard	Salinity Hazard
Gumain R. Pabanlag	29	214	8.32	0.89	S1	C1
Gumain R. Diversion Dam	1	233	8.30	1.00	S1	C1
Porac R. Diversion Dam	1	301	5.80	0.51	S1	C2
Porac R. Del Carmen Bridge	1	189	7.50	0.55	S1	C1
Caulaman R. Diversion Dam	1	192	8.30	0.60	S1	C1

From the above, the value for the sodium absorption ratio (SAR) is less than 1.0 and the maximum conductivity is only 301 micromhos per cm.

According to the above mentioned water quality classification standard, such values are all within the tolerable limit. In fact, no adverse effects have been noted by using the river water for irrigation during the past years.

CHAPTER 6 RECOMMENDATION

The hydrological analysis in this study was made mainly for the assessment of available irrigation water in the three rivers, namely Gumain, Porac and Caulaman rivers, and probable flood discharges for the Gumain dam. The analysis was made by the maximum use of available data obtained in and around the study area, but reliable data on hydrology was limited in this study, especially the discharge records of Porac and Caulaman rivers and the rainfall records in the mountain areas. In order to confirm more detailed hydrological conditions in the area, the following observation networks are recommended to be urgently carried out:

(1) To establish water level gauging stations in the Porac and Caulaman rivers and also rainfall gauging stations in their watersheds.

(2) To install rainfall gauges in the south-western part of the project area.

(3) To strengthen observation system at the existing two water level gauging stations of Gumain River, namely Pabanlag and Summer Place Stations.

Table 1.1 SUMMARY OF CLIMATIC CONDITIONS

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Average
Mean Temperature Basa Air Base (°C) (1958 - 1981)	25.6	26.0	27.1	28.6	28.7	27.8	27.3	26.8	27.1	27.0	26.7	26.2	324.9	27.1
Mean Maximum Temperature Basa Air Base (°C) (1963 - 1981)	30.6	31.4	32.8	34.3	33.8	32.2	31.3	30.5	31.5	31.7	31.3	30.6	382.0	31.8
Mean Maximum Temperature Hacienda Luisita (°C) (1968 - 1983)	31.5	32.2	34.0	35.3	35.1	33.4	32.5	32.5	32.2	33.0	32.3	31.8	395.8	33.0
Mean Minimum Temperature Basa Air Base (°C) (1963 - 1981)	20.6	20.6	21.5	23.0	23.8	23.4	23.3	23.1	22.8	22.8	22.3	21.8	269.0	22.4
Mean Minimum Temperature Hacienda Luisita (°C) (1968 - 1983)	19.0	19.5	20.3	21.9	23.0	23.3	22.7	22.5	22.6	21.7	20.8	19.5	256.8	21.4
Mean Relative Humidity Basa Air Base (%) (1970 - 1974)	67.1	67.9	67.9	66.7	70.9	78.8	82.9	82.5	79.0	78.8	73.0	72.5	888.0	74.0
Mean Relative Humidity Hacienda Luisita (%) (1968 - 1980)	66.5	61.9	58.6	57.5	68.7	75.9	79.4	82.3	79.7	74.3	68.8	67.2	840.8	70.1
Mean Sunshine Duration Hacienda Luisita (%) (1969 - 1983)	63.4	71.2	67.4	75.6	64.1	46.2	41.9	31.7	41.3	50.5	58.9	57.6	669.8	55.8
Mean Wind Velocity Basa Air Base (M/S) (1958 - 1981)	3.3	3.5	3.3	3.4	3.0	3.3	3.1	3.2	2.8	2.5	3.2	3.2	37.8	3.2
Mean Wind Velocity Hacienda Luisita (M/S) (1968 - 1980)	3.3	3.1	3.4	3.1	2.5	2.4	2.3	2.2	2.0	2.4	3.3	3.5	33.5	2.8
Mean Evaporation Hacienda Luisita (MM) (1958 - 1983)	154.0	169.4	213.0	221.0	182.5	129.5	115.7	102.3	104.7	122.7	128.3	141.5	1,784.6	148.7

Table 1.2 RAINFALL GAUGING STATIONS

No./1	Name of Station	Belonging /2	Belonging /3	Elevation	Location Latitude (N)	Location Longitude (E)	Kind of/6 Date	Date Available
1.	Basa Air Base	N.	/4	50.0	14°59'	120°30'	D.	1958 - 1983
2.	Pasumil	N.	PHILSUCOM	35.0	15°02'	120°31'	D.	1968 - 1981
3.	Santa Cruz Porac	N.	PAGASA	95.0	15°04'	120°33'	D.	1969 - 1983
4.	Santa Rita	N.	"	25.0	15°00'	120°34'	D.	1975 - 1983
5.	Cabanbagan Bacolor	N.	"	21.0	15°00'	120°39'	D.	1970 - 1979
6.	Lubao	N.	"	2.0	14°50'	120°36'	D.	1975 - 1981
7.	Armenia Dam Tarlac	N.	PDDP	100.0	15°27'	120°30'	D.	1977 - 1979
8.	Carangian Tarlac	N.	"	50.0	15°27'30"	120°33'	D.	1975 - 1979
9.	Hacienda Luisita	N.	PAGASA	43.0	15°27'	120°38'	D.	1967 - 1980
10.	Amucao Tarlac	N.	PDDP	31.0	15°28'	120°41'	D.	1975 - 1979
11.	La Paz	N.	"	23.0	15°23'	120°43'	D.	1975 - 1979
12.	Dolores Capas	N.	"	46.0	15°21'30"	120°35'30"	D.	1975 - 1979
13.	Clark Air Base	N.	/5	163.0	15°09'27"	120°33'	D.	1946 - 1963, 1968 - 1975
14.	San Agustin Arayat	N.	PAGASA	44.0	15°09'	120°46'	D.	1966 - 1978
15.	San Fernando	N.	"	36.0	15°02'	120°42'	D.	1970 - 1974, 1976 - 1983
16.	San Matias	N.	"	25.0	15°00'	120°42'	D.	1975 - 1978
17.	Cansinala Apalit	N.	"	5.0	14°58'	120°51'	D.	1967 - 1983
18.	Masantol	N.	"	3.0	14°52'	120°42'	D.	1970 - 1983
19.	Talisai Balanga	N.	"	20.0	14°41'	120°33'	D.	1970 - 1979
20.	Iba	N.	"	4.0	15°20'	119°59'	M.	1949 - 1983
21.	Marcelino	N.	"	40.0	14°59'	120°09'	M.	1948 - 1964, 1975 - 1983
22.	Cabanatuan	A.	PDDP	30.0	15°29'	120°58'	D.	1951 - 1982
23.	Pasbol (Dam site)	A.	NIA, JICA	182.0	15°01'50"	120°27'50"	H.	1983
24.	Nabuclud (Catchment area)	A.	"	441.0	15°01'30"	120°24'30"	H.	1983

Remarks: /1: Rainfall station number in Fig. 1.5
/2: A: Automatic gauge, N: Normal gauge
/3: PHILSUCOM; Philippines Sugar Commission, Central Luzon Experimental Station
PAGASA ; Philippines Atmospheric, Geophysical and Astronomical Services Administration
NIA ; National Irrigation Administration
JICA ; Japan International Cooperation Agency
PDDP ; Feasibility Report on the Pampanga Delta Development Project
/4: Philippine Basa Air Force Base
/5: American Air Force Base
/6: M: Monthly data
D: Daily data
H: Hourly data

Table 1.3 MEAN MONTHLY RAINFALL

(Unit: mm)

Station No.	Name	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1.	Basa Air Base	6.5	6.7	9.8	26.9	145.9	344.7	519.2	632.1	376.4	151.0	59.0	22.7	2,300.9
2.	Pasumil	31.3	25.9	35.7	51.1	147.6	320.7	430.1	571.9	416.3	250.8	130.0	86.4	2,497.8
3.	Santa Cruz Porac	7.1	11.1	14.9	32.9	165.5	211.2	483.6	442.9	293.1	202.9	101.4	43.7	1,878.7
4.	Santa Rita	6.3	3.1	27.3	13.3	207.0	246.1	305.9	542.2	310.9	171.9	74.6	34.9	1,533.4
5.	Cabanbagan Bacolor	6.3	7.9	16.3	29.0	124.8	266.4	460.3	480.7	256.9	194.8	85.6	36.5	1,960.1
6.	Lubao	6.2	2.9	25.3	1.1	274.2	238.4	505.9	807.4	378.0	253.4	106.0	75.7	2,329.7
7.	Armeria Dam Tarlac	7.8	0.7	14.6	34.1	84.5	208.1	407.2	360.7	247.0	160.6	90.8	9.3	1,625.4
8.	Carangian, Tar.	14.1	4.8	13.5	40.2	319.8	285.9	269.3	478.8	292.4	245.2	85.3	26.3	2,075.6
9.	Hashienda Luisita	10.3	0.9	13.7	53.4	143.5	226.4	370.9	340.8	297.8	153.4	80.4	21.9	1,656.8
10.	Amucao Tarac	10.7	4.8	6.4	16.3	178.5	287.4	268.3	421.1	335.3	122.9	65.5	19.1	1,736.3
11.	La Paz	10.2	1.6	8.9	25.0	200.7	182.0	286.5	334.5	329.5	171.2	32.9	16.8	1,429.8
12.	Dolores Capas	17.5	0.8	3.5	29.2	232.1	219.0	322.3	373.3	348.0	163.7	67.3	19.3	1,796.0
13.	Clark Air Base	11.8	10.3	24.9	42.7	169.6	245.9	369.3	444.5	313.8	166.0	97.6	55.2	1,951.6
14.	San Agustin Arayat	15.3	3.6	21.7	31.4	165.2	225.7	379.5	409.4	268.8	170.2	118.5	53.3	1,811.6
15.	San Fernando	7.2	6.3	18.9	22.1	145.2	230.5	423.1	455.3	270.2	188.9	82.5	38.2	1,743.2
16.	San Matias	2.8	0.0	21.6	14.5	323.4	431.2	148.2	310.2	189.3	167.9	61.2	77.7	1,122.4
17.	Cansinara Apalit	3.1	1.4	10.9	10.0	106.1	161.7	360.4	399.5	164.8	153.6	91.5	36.7	1,386.4
18.	Masantol	11.2	3.3	20.3	18.8	113.9	212.7	356.6	513.4	270.3	210.4	88.1	41.8	1,815.9
19.	Talisai Balanga	14.6	7.9	16.6	25.0	218.4	270.6	643.3	840.5	332.8	257.6	120.7	50.0	2,797.8
20.	Iba	3.2	3.0	12.5	18.9	277.4	542.5	798.7	1,061.6	608.2	218.8	84.1	23.7	3,652.6
21.	San Marcelino	4.4	6.4	26.8	35.1	239.2	498.7	592.4	993.6	522.6	291.9	96.4	37.1	3,344.6
22.	Cabanatuan	6.5	5.3	13.7	31.0	171.8	256.4	319.5	397.9	313.5	173.7	138.7	40.1	1,850.3
23.	Pasbol	-	-	-	-	-	-	-	-	-	-	-	-	-
24.	Nabuclud	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1.4(1) MONTHLY AVERAGE DISCHARGE RECORD (PABANLAG STATION OF GUMAIN RIVER)

(CA = 122 km2, Unit: m3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1944	2.88	2.35	2.23	2.35	1.83	5.62	30.83	16.06	9.94	10.81	---	---	---
1945	---	---	---	---	---	---	---	---	---	11.12	8.49	3.73	---
1946	2.20	1.72	1.34	1.65	1.86	7.78	28.05	19.13	26.57	12.01	4.32	2.71	9.16
1947	2.22	1.91	1.64	2.32	2.14	7.81	14.71	13.53	15.73	14.06	12.87	8.68	8.17
1948	4.35	2.59	2.12	2.06	2.22	6.02	15.59	40.95	30.67	10.28	5.16	4.03	10.54
1949	2.35	1.88	1.51	1.39	1.21	1.92	9.51	9.66	10.10	11.45	5.15	2.88	4.94
1950	2.08	2.39	2.38	2.01	2.48	6.83	18.19	26.46	10.57	19.96	5.60	2.83	8.56
1951	2.89	1.58	1.33	1.35	8.14	6.27	6.50	28.13	8.91	8.60	4.41	5.28	6.89
1952	2.49	1.98	1.66	2.46	3.36	8.09	8.76	31.02	18.27	12.67	7.26	3.48	8.48
1953	2.49	1.93	1.77	1.61	2.25	6.35	16.26	33.16	20.51	8.12	9.14	3.50	8.98
1954	2.32	1.84	1.89	1.59	1.39	1.70	1.62	10.83	17.08	9.54	16.55	3.22	5.79
1955	2.26	2.05	1.93	1.75	1.42	2.57	9.22	30.93	22.13	13.11	4.13	2.85	7.91
1956	1.97	1.60	1.11	1.89	2.50	2.62	7.86	24.97	43.48	5.75	4.01	3.35	8.41
1957	2.07	2.10	1.61	0.97	0.65	6.07	25.01	30.65	11.10	14.12	2.57	1.97	8.33
1958	1.59	1.42	1.49	1.20	1.11	17.93	26.74	20.84	34.00	11.36	4.52	3.02	10.51
1959	2.45	1.79	1.30	1.23	1.52	1.19	2.12	17.03	10.56	1.93	2.12	0.99	3.70
1960	1.09	0.95	0.93	1.09	1.29	13.90	8.94	73.25	24.62	21.66	8.62	6.56	13.66
1961	5.44	4.80	4.83	4.34	6.54	27.56	31.85	19.32	15.63	9.25	3.74	2.48	11.35
1962	1.63	1.35	1.75	2.38	2.03	1.87	27.68	15.12	42.41	5.57	4.05	2.82	9.10
1963	1.69	1.76	1.41	1.41	1.77	23.24	14.55	15.85	30.51	6.15	3.35	2.20	8.65
1964	1.51	2.10	5.67	8.16	9.33	14.53	7.67	30.64	13.35	13.24	5.66	6.77	9.92
1965	2.64	1.94	1.64	1.85	7.38	16.11	24.37	14.89	12.76	12.23	5.76	3.03	8.78
1966	2.42	2.05	2.28	2.26	44.32	15.62	19.74	28.09	32.74	9.52	9.94	3.58	14.84
1967	1.01	0.93	1.54	1.99	2.59	15.12	15.45	32.07	18.19	---	---	---	---
1968	---	---	---	---	1.76	1.66	9.70	25.79	25.01	2.55	2.93	2.16	---
1969	2.26	2.00	1.38	0.44	1.16	3.66	8.90	16.20	16.26	8.87	3.40	3.20	5.67
1970	2.11	2.27	1.67	1.26	1.12	6.43	11.71	17.61	34.35	19.22	10.30	4.45	9.39
1971	2.65	1.85	1.52	1.53	2.66	10.93	32.39	14.70	10.43	31.16	13.29	6.88	10.95
1972	3.59	3.09	3.55	3.23	6.60	14.52	102.21	43.25	9.71	4.33	4.33	3.64	16.96
1973	3.68	2.29	1.81	1.70	1.93	---	14.76	22.50	6.85	23.16	2.78	1.73	---
1974	1.54	1.42	1.45	1.40	4.43	20.26	2.37	49.80	1.84	16.79	8.00	2.78	9.42
1975	1.53	1.44	2.05	2.05	2.05	2.89	2.97	20.79	8.45	13.27	5.10	2.15	5.44
1976	2.11	2.11	2.11	2.11	27.45	16.28	17.14	24.22	20.88	7.63	3.68	3.35	10.80
1977	2.06	2.10	---	2.11	---	3.26	11.09	18.37	39.82	5.94	15.21	1.70	---
1978	1.57	1.45	1.28	1.27	1.85	2.22	7.24	41.66	9.75	12.33	1.85	1.83	7.11
1979	1.72	1.64	1.64	1.61	1.82	1.71	5.28	---	16.39	12.12	3.84	2.59	---
1980	---	---	---	---	---	---	---	---	---	---	---	---	---
1981	---	---	---	---	---	---	---	---	---	---	---	---	---
1982	---	---	1.87	1.96	1.60	8.63	---	---	28.67	6.82	3.93	3.38	---
1983	2.73	2.63	2.51	2.55	2.67	3.38	6.48	15.31	6.62	9.09	3.34	2.81	5.03
Mean	2.33	1.98	1.95	2.01	4.61	8.69	16.77	25.51	19.34	11.51	6.10	3.40	8.26
Max.	5.44	4.80	5.67	8.16	44.32	27.56	102.21	49.80	43.48	31.16	16.35	8.68	16.96
Min.	1.01	0.95	0.93	0.44	1.11	1.19	1.62	9.66	1.84	1.93	1.85	0.99	3.70

Remarks: ---: No data

Table 1.4(2) MONTHLY AVERAGE DISCHARGE RECORD (DEL CARMEN STATION OF PORAC RIVER)

(CA = 111 km2, Unit: m3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1945	---	---	---	---	---	---	---	---	---	2.41	2.16	2.16	---
1946	1.89	1.36	1.46	1.52	1.18	4.59	7.82	10.27	20.63	5.78	2.26	2.26	5.09
1947	1.96	1.90	2.46	1.52	1.07	2.43	8.02	5.23	7.73	13.91	10.05	9.27	5.49
1948	2.20	1.81	1.75	1.84	1.55	2.55	11.63	34.44	25.78	5.83	3.30	3.33	8.07
1949	2.64	2.18	1.61	1.57	0.97	1.23	9.25	2.58	4.44	6.69	1.96	2.28	3.14
1950	1.12	1.18	1.95	2.01	1.59	2.37	9.11	25.17	4.23	17.23	2.74	2.09	6.01
1951	1.77	0.95	0.93	0.82	7.69	4.45	2.78	25.37	1.82	2.20	3.29	4.34	4.75
1952	2.30	1.87	1.81	2.85	2.79	2.48	1.45	26.71	12.43	8.32	5.93	3.21	6.04
1953	2.61	2.05	1.84	1.63	2.68	5.57	14.82	31.51	6.93	5.68	2.04	3.80	6.83
1954	2.34	1.76	1.21	1.35	1.37	2.02	1.11	4.98	5.61	3.62	8.09	1.47	2.90
1955	1.99	1.17	0.84	0.97	0.94	2.73	12.18	17.54	11.71	12.56	1.69	1.16	5.49
1956	1.04	0.75	0.70	1.00	1.10	1.62	1.91	4.31	3.02	1.97	2.13	2.56	1.80
1957	2.49	0.58	0.57	0.66	0.70	1.02	1.73	2.22	2.36	2.59	2.62	2.42	1.67
1958	1.74	0.51	0.77	0.49	0.52	1.33	2.05	1.60	1.80	2.26	1.91	1.93	1.42
1959	1.53	0.99	0.93	0.77	1.70	1.49	1.70	3.93	5.11	3.35	2.99	2.66	2.27
1960	---	0.82	0.81	1.03	0.83	5.01	1.55	31.60	10.94	14.11	4.22	2.91	---
1961	1.25	1.00	0.89	0.78	0.84	4.31	9.85	5.14	6.71	3.39	2.80	2.24	3.28
1962	1.35	1.38	1.59	1.46	1.39	1.75	36.42	3.07	9.75	2.98	2.75	2.43	5.58
1963	2.15	1.73	1.43	1.15	1.09	6.63	5.55	7.58	8.14	5.00	2.57	2.74	3.82
1964	2.71	2.45	2.01	1.31	1.33	6.17	7.76	11.42	6.84	7.71	4.93	4.04	4.91
1965	2.36	2.10	1.79	1.27	1.64	4.50	16.83	5.68	4.95	6.84	4.38	2.97	4.64
1966	2.46	2.41	2.35	2.32	12.88	8.82	6.93	12.85	46.47	4.74	8.88	3.69	9.36
1967	1.85	1.68	0.91	0.89	0.88	18.82	8.59	33.37	6.55	5.43	5.95	1.73	7.20
1968	5.93	6.05	6.18	4.84	10.14	3.68	3.93	17.67	29.43	10.72	1.23	3.15	8.58
1969	2.21	4.38	4.30	5.98	5.49	6.89	16.97	19.12	18.68	12.54	0.67	0.53	8.00
1970	0.30	0.55	0.82	0.23	0.16	0.78	8.49	10.14	28.93	12.35	8.24	1.73	6.09
1971	0.03	0.37	1.19	1.24	2.46	1.35	0.45	0.24	2.12	7.26	9.63	10.35	3.07
1972	4.81	3.68	4.41	5.36	8.23	---	---	---	---	---	---	---	---
1973	---	---	---	---	---	---	---	---	---	---	---	---	---
1974	---	---	---	---	---	---	---	---	---	---	---	---	---
1975	---	---	---	---	---	---	---	---	---	---	---	---	---
1976	---	---	---	---	---	---	---	---	---	---	---	---	---
1977	---	---	---	---	---	---	---	---	---	---	---	---	---
1978	---	---	---	---	---	---	---	---	---	---	---	---	---
1979	---	---	---	---	---	---	---	---	---	---	---	---	---
1980	---	---	---	---	---	---	---	---	---	---	---	---	---
1981	---	---	---	---	---	---	---	---	---	---	---	---	---
1982	---	---	---	---	---	---	---	---	---	---	---	---	---
1983	---	---	---	---	---	---	---	---	---	---	---	---	---
Mean	2.11	1.73	1.76	1.73	2.73	4.60	7.56	13.69	11.22	7.12	4.05	3.10	4.79
Max.	5.93	6.05	6.18	5.98	12.88	18.82	36.42	34.44	46.47	17.23	10.05	10.35	---
Min.	0.03	0.37	0.57	0.23	0.16	0.78	0.45	0.24	1.80	1.97	0.67	0.53	---

Remarks: ---: No data

Table 1.4(3) MONTHLY AVERAGE DISCHARGE RECORD
(PABANLAG STATION OF CAULAMAN RIVER)

(CA = 72 km2, Unit: m3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1954	---	---	---	---	---	---	---	---	10.17	3.21	3.23	0.74	---
1955	0.56	0.55	0.46	0.35	0.28	0.32	3.07	5.46	2.99	3.21	0.95	0.72	1.59
1956	0.32	0.27	0.24	1.32	0.82	0.55	1.85	12.31	20.86	2.82	1.39	0.90	3.63
1957	0.72	0.45	0.32	0.41	0.54	1.86	12.56	52.31	6.57	5.84	0.92	0.80	7.04
1958	0.67	0.62	0.47	0.40	0.45	10.72	26.82	7.23	30.75	2.29	0.98	0.59	6.84
1959	0.49	0.48	0.42	0.38	0.49	0.58	0.47	8.57	7.69	1.13	1.02	0.55	1.86
1960	0.35	0.31	0.32	0.38	0.41	5.44	1.55	12.16	4.37	3.70	1.32	0.78	2.15
1961	0.65	0.60	0.53	0.44	0.46	3.01	32.74	17.48	8.06	5.52	1.74	0.98	6.02
1962	0.61	0.53	0.45	0.49	0.50	0.50	47.49	9.33	11.19	2.38	1.07	0.74	6.35
1963	0.63	0.54	0.54	0.39	0.50	11.46	10.10	18.24	51.41	2.64	1.55	1.60	8.28
1964	1.99	1.98	2.03	2.13	2.07	10.37	5.94	9.96	7.62	7.84	4.16	2.82	4.91
1965	1.25	1.15	0.73	0.84	1.84	5.99	27.98	6.32	4.22	1.26	0.90	0.52	4.46
1966	0.43	0.43	0.46	0.40	33.92	4.89	5.56	7.07	7.55	2.26	2.19	0.76	5.55
1967	0.59	0.52	0.51	0.49	0.61	3.62	13.15	14.23	5.74	4.53	6.26	1.52	3.43
1968	---	---	0.67	0.53	0.69	0.69	0.29	4.02	8.24	3.14	2.19	1.39	---
1969	0.38	0.41	0.46	0.40	0.32	0.50	35.74	5.98	5.63	2.31	1.00	1.14	5.01
1970	0.74	0.57	0.44	0.35	0.30	1.56	3.59	5.73	29.59	0.69	0.64	0.55	3.71
1971	0.46	0.39	0.44	0.64	0.55	1.32	5.86	1.03	0.61	3.30	1.68	1.28	1.47
1972	---	---	---	---	---	---	---	---	---	---	---	---	---
1973	0.62	0.58	0.55	0.53	0.52	0.48	0.86	1.09	1.08	1.97	0.61	---	---
1974	---	---	---	---	---	---	---	---	---	---	---	---	---
1975	---	---	---	---	---	---	---	---	---	---	---	---	---
1976	---	---	---	---	---	---	---	---	---	---	---	---	---
1977	---	---	---	---	---	---	---	---	---	2.52	2.31	2.86	---
1978	1.47	1.47	1.48	1.47	1.64	2.23	2.74	4.88	2.54	2.44	1.56	1.60	2.15
1979	---	---	---	---	---	---	---	---	---	---	---	---	---
1980	---	---	---	---	---	---	---	---	---	---	---	---	---
1981	---	---	---	---	---	---	---	---	---	---	---	---	---
1982	---	---	---	---	---	---	---	---	---	---	---	---	---
1983	---	---	---	---	---	---	---	---	---	---	---	---	---
Mean	0.74	0.68	0.61	0.62	2.84	3.89	12.71	10.68	12.27	3.06	1.80	1.16	3.22
Max.	1.99	1.98	2.03	2.13	33.92	11.46	47.49	52.31	51.41	7.84	6.26	2.82	---
Min.	0.32	0.27	0.24	0.35	0.28	0.32	0.29	1.03	0.61	0.69	0.61	0.52	---

Remarks : --- : no data

Table 1.4(4) MONTHLY AVERAGE DISCHARGE RECORD
(VALDEZ STATION OF PORAC RIVER)

(CA = 118 km^2, Unit: m3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1958	---	---	---	---	---	---	---	---	---	1.94	0.39	0.14	---
1959	0.21	0.33	0.28	0.31	0.22	0.13	0.19	1.60	3.98	1.08	0.67	0.20	0.77
1960	0.20	0.44	0.51	0.48	0.27	3.06	2.09	31.67	9.77	6.22	0.89	0.43	4.70
1961	0.58	0.72	0.85	0.64	0.60	2.72	20.47	11.44	8.53	3.09	0.41	0.55	4.26
1962	0.60	0.70	0.83	1.26	1.15	0.84	---	---	---	1.28	0.95	0.59	---
1963	0.57	0.65	0.62	0.66	0.69	23.10	5.78	11.75	39.02	1.78	0.59	0.20	7.08
1964	0.36	0.74	0.68	0.61	0.29	11.17	7.48	15.53	5.76	5.71	0.32	0.68	4.13
1965	0.55	0.64	0.80	0.70	0.37	0.69	10.71	4.16	4.58	2.92	1.26	0.90	2.38
1966	1.36	1.85	1.76	1.48	25.89	---	---	17.14	22.36	0.83	1.27	0.38	---
1967	0.14	0.49	0.50	0.62	0.38	6.10	8.35	13.91	12.40	8.93	5.98	0.72	4.90
1968	0.82	1.36	1.21	0.73	0.51	0.51	0.60	3.76	6.54	0.49	0.30	0.17	1.41
1969	0.25	0.37	0.36	0.16	0.13	0.15	0.66	3.22	0.88	0.83	0.91	1.10	0.76
1970	0.99	1.30	1.01	0.87	0.82	1.06	0.97	0.91	4.12	0.76	1.28	1.29	1.28
1971	0.89	0.70	0.73	0.71	0.75	0.89	3.36	0.39	0.42	2.57	0.84	0.96	1.11
1972	0.24	0.28	0.30	0.31	0.36	0.32	40.85	7.76	1.43	0.23	0.25	0.25	4.45
1973	0.29	0.27	---	---	0.17	0.16	0.21	0.27	0.22	1.91	0.25	0.23	---
1974	0.33	0.09	0.15	0.24	0.35	2.39	0.39	6.32	0.33	1.12	0.89	0.35	1.09
1975	0.30	0.13	0.29	0.27	0.27	0.32	0.41	0.20	0.29	0.22	0.20	0.40	0.28
Mean	0.51	0.65	0.68	0.63	1.96	3.35	6.83	8.13	7.54	2.35	0.98	0.53	2.55
Max.	1.36	1.85	1.76	1.48	25.89	23.10	40.85	31.67	39.02	8.93	5.98	1.29	---
Min.	0.14	0.09	0.15	0.16	0.13	0.13	0.19	0.20	0.22	0.22	0.20	0.14	---

Remarks: ---: No data

Table 1.4(5) MONTHLY AVERAGE DISCHARGE RECORD
(STA. CRUZ OF GUMAIN FLOODWAY)

(CA = 370 km^2, Unit: m^3/sec)

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1958	---	---	---	---	---	---	---	---	---	12.95	3.71	1.43	---
1959	0.31	0.16	0.12	0.17	1.53	0.29	0.85	22.18	25.93	6.23	5.48	2.22	5.55
1960	0.77	0.14	0.12	0.27	1.30	66.37	45.30	226.89	101.46	83.79	17.45	3.12	45.82
1961	0.30	0.12	0.25	0.15	3.36	21.63	61.20	35.97	46.22	14.69	0.60	0.30	15.51
1962	0.10	0.14	0.08	0.04	0.04	0.02	94.52	61.02	170.53	15.73	5.45	2.27	29.24
1963	0.29	0.04	0.02	0.02	0.03	102.45	81.47	78.93	190.44	10.71	0.02	0.19	38.66
1964	0.29	0.02	0.03	0.02	6.99	20.81	50.63	104.66	67.32	50.36	8.68	25.41	28.13
1965	0.15	0.05	0.41	5.58	5.33	8.65	48.88	10.46	10.80	4.15	0.20	0.15	7.98
1966	0.10	0.07	0.06	0.10	124.40	12.00	10.20	32.72	144.77	2.24	49.90	97.70	39.71
1967	0.55	0.45	0.21	0.17	0.16	116.54	99.26	137.36	24.77	18.50	45.22	1.33	37.24
1968	0.79	27.82	23.95	25.54	44.58	70.06	86.10	105.72	93.38	32.28	0.32	0.19	42.59
1969	0.10	0.02	0.03	0.05	0.24	18.99	59.36	152.94	24.11	12.16	1.98	0.54	22.85
1970	10.19	2.09	0.33	0.23	0.22	21.17	111.94	48.32	221.58	14.14	10.75	0.01	36.74
1971	---	---	0.01	0.48	18.91	25.07	197.38	48.30	11.43	155.45	9.12	2.11	50.42
1972	---	---	---	---	---	---	---	---	---	---	---	---	---
1973	0.12	0.12	0.11	0.07	0.05	0.12	34.57	52.17	16.32	124.86	21.28	21.67	22.95
1974	11.15	3.93	0.50	---	---	---	98.23	13.06	10.68	12.07	13.57	7.93	19.23
1975	9.85	6.05	---	---	---	---	---	---	---	---	---	---	---
Mean	2.34	2.79	1.87	2.35	14.80	34.58	72.00	72.15	77.38	35.64	12.11	10.41	25.29
Max.	11.15	27.82	23.95	25.54	124.40	116.54	197.38	226.89	221.58	155.45	49.90	97.70	50.42
Min.	0.10	0.02	0.01	0.02	0.03	0.02	0.85	10.46	10.68	2.24	0.02	0.01	5.55

Remarks: ---: No data

Table 1.5 WATER QUALITY ANALYSIS

Data Collected	E.C. μMHOS/cm 25°	Ca Meq/l	Mg Meq/l	Na Meq/l	K Meq/l	CL Meq/l	SO_4 Meq/l	CO_3 Meq/l	HCO_3 Meq/l	pH	Sediment Concentration PPM	Remarks
Gumain River, Pabanlag												
1982 May 8	255	0.70	0.70	1.03	0.08	0.65	0.22	0	1.75	6.50		
-do-	255	0.85	0.55	0.96	0.05	0.75	0.29	0	1.40	6.50		
1982 Nov. 29	198	0.80	0.45	0.62	0.03	0.30	0.40	0.20	1.15	8.20		
-do-	198	0.75	0.55	0.60	0	0.30	0.40	0.20	1.15	8.40		
-do-	198	0.75	0.55	0.60	0	0.35	0.40	0.60	0.65	8.20		
1982 Nov. 2	196	0.70	0.60	0.60	0.04	0.45	0.23	0.30	1.10	8.40		Left
-do-	193	0.75	0.60	0.60	0.04	0.35	0.23	1.10	1.15	8.40		Center
-do-	198	0.75	0.55	0.62	0.04	0.45	0.23	0.30	1.15	8.40		Right
1982 Dec. 28	184	0.50	0.55	0.76	0.04	0.45	0.25	0.60	0.55	9.30	3.00	Left
-do-	204	0.70	0.50	0.76	0.04	1.00	0.25	0.30	0.55	8.60	2.00	Center
-do-	207	0.70	0.45	0.76	0.05	0.60	0.25	0.30	1.15	8.50	4.00	Right
193 Jan. 31	227	0.75	0.55	0.82	0.05	0.65	0.25	0.20	1.25	8.50	0.60	Left
-do-	227	0.80	0.55	0.82	0.05	0.65	0.25	0.30	1.15	9.00	0.30	Center
-do-	221	0.70	0.60	0.82	0.05	0.60	0.25	0.30	1.00	9.00	0.40	Right
1983 Mar. 3	198	0.80	0.35	0.86	0.04	0.60	0.28	0.20	1.00	8.50		
-do-	198	0.75	0.45	0.86	0.07	0.60	0.28	0.20	1.00	8.50		
-do-	198	0.80	0.40	0.86	0.07	0.60	0.25	0.20	1.00	8.50		
1983 May 11	280	0.95	0.50	1.17	0.06	0.80	0.27	0.20	1.40	8.60		Left
-do-	280	0.85	0.70	1.17	0.06	0.80	0.27	0.20	1.40	8.60		Center
-do-	280	0.90	0.50	1.20	0.06	0.85	0.27	0	1.50	8.30		Right
1983 July 29	186	0.75	0.50	0.52	0.03	0.40	0.18	0	1.30	8.00	19.00	
-do-	186	0.90	0.40	0.52	0.03	0.45	0.18	0	1.25	8.00	19.00	
-do-	186	0.65	0.65	0.52	0.03	0.45	0.18	0	1.30	8.00	6.00	
1983 Oct. 5	176	0.85	0.45	0.42	0.03	0.35	0.23	0.30	0.95	8.30	3.00	Left
-do-	179	0.85	0.45	0.42	0.03	0.40	0.21	0.40	0.85	8.30	3.00	Center
-do-	179	0.85	0.45	0.42	0.03	0.40	0.21	0.40	0.85	8.30	3.00	Right
1983 Nov. 4	299	0.85	0.60	0.70	0.05	0.60	0.33	0.20	1.05	8.20		Left
-do-	211	0.80	0.60	0.62	0.08	0.40	0.33	0.30	1.10	8.20		Center
-do-	211	0.85	0.55	0.62	0.02	0.50	0.33	0.30	1.00	8.20		Right
Mean	214	0.78	0.53	0.72	0.04	0.54	0.27	0.23	1.11	8.32		
Gumain River, Diversion Dam												
1984 Jan. 17	233	1.00	0.40	0.84	0.06	0.10	0.33	0.20	1.60	8.30		
Porac River, Diversion Dam												
1984 Jan. 17	301	1.05	1.05	0.52	0.34	0.15	0.40	0	2.25	5.80		
Porac River, Upstream of Diversion Dam												
1984 Jan. 17	189	0.75	0.55	0.44	0.10	0.15	0.15	0	1.60	7.50		
Caulasan River, Diversion Dam												
1984 Jan. 17	192	0.90	0.50	0.50	0.02	0.10	0.10	0.30	1.45	8.30		

Table 1.6 SUSPENDED SEDIMENT RECORDS

Porac River at Valdez, Floridablanca

Date	Discharge (m^3/sec)	Average Suspended Sediment (mg/l)
1963 Jun. 12	1.364	46.28
1964 Feb. 3	0.793	100.57
Apr. 27	0.618	120.58
Aug. 25	11.367	103.15
Oct. 29	0.216	15.46
Nov. 9	0.204	10.19
Dec. 21	1.050	21.17
1965 Jan. 25	0.262	26.15
Mar. 2	0.760	136.37
Apr. 25	0.700	112.39
Apr. 30	0.481	76.53
1966 Aug. 15	55.101	2,053.33
Sep. 12	84.854	1,784.67
Oct. 10	0.915	879.51
Nov. 11	0.189	1,879.86
Dec. 18	0.253	119.88
1967 Feb. 7	0.780	4,476.42
Jul. 20	1.323	1,011.96
Sep. 4	17.088	1,849.22
Nov. 8	6.080	8,587.61
1968 Jun. 17	0.235	1,757.10
Jul. 10	0.907	41.78
Sep. 19	7.930	529.79
Dec. 6	0.183	44.41
Dec. 14	0.373	118.43
1969 May 12	0.098	26.93
Jun. 26	0.0798	27.63
Aug. 23	0.588	1,185.22
1970 Jun. 17	1.118	41.77
Aug. 23	0.588	52.91
Sep. 9	5.350	67.03
1971 Mar. 18	0.740	109.65
May 5	0.698	100.56
Jun. 25	1.053	18.95

Gumain Floodway at Santa Cruz, Lubao

Date	Discharge (m^3/sec)	Average Suspended Sediment (mg/l)
1963 Jun. 12	8.654	179.26
1964 Feb. 3	0.018	17.54
Apr. 27	0.022	9.91
Aug. 25	45.791	243.85
Oct. 29	4.474	41.34
Nov. 9	3.704	63.72
Dec. 21	6.743	40.60
1965 Jan. 23	0.198	14.81
Mar. 2	0.031	84.41
Apr. 27	0.011	32.53
1966 Aug. 8	20.294	193.85
Sep. 7	513.394	6,066.15
Oct. 5	8.611	7,067.85
Nov. 21	162.655	634.04
Dec. 21	5.064	480.85
1967 Feb. 14	0.043	738.20
Jul. 24	6.837	1,651.24
Sep. 5	32.089	1,033.4
Nov. 10	3.586	1,281.86
1968 Feb. 12	0.043	26.26
Apr. 5	0.041	40.7
Jun. 21	0.751	642.94
Sep. 20	18.223	170.12
Dec. 6	0.556	76.86
1969 Feb. 14	0.387	111.92
May 15	0.044	52.37
Jun. 27	4.745	99.59
Aug. 2	89.642	235.86
1970 Jun. 17	7.510	55.44
1971 Jul. 14	14.317	99.55

Table 1.7(1) CORRELATION COEFFICIENT AND SIMPLE LINEAR REGRESSION OF MONTHLY RAINFALLS

Dependent Variable	Data Period	Number of Observation	Correlation Coefficient	Total Rainfall (mm)		Regression Coefficient	
				Independent Variable	Dependent Variable	Intercept (b)	Coefficient (a)
2. Pasuail	1968-81*	65	0.92	12,003.6	13,084.4	0.90	3.96
3. Santa Cruz Porac	1969-81*	144	0.93	29,853.2	26,013.8	1.27	-22.88
4. Santa Rita	1975-83*	92	0.94	14,245.4	14,721.7	1.05	-13.64
5. Cabanbangan Bacol	1969-83*	164	0.95	31,983.4	27,379.0	1.22	8.85
6. Lubao	1975-81*	69	0.90	11,646.3	16,308.2	0.68	8.10
7. Armeria Dam Tarl	1977-79*	32	0.89	4,951.0	5,228.5	1.22	-43.83
9. Hacienda Luisita	1967-82*	155	0.80	30,647.7	22,614.5	1.42	-9.82
10. Aduçao Tarlac	1976-80*	51	0.85	8,610.2	8,529.1	0.95	9.42
11. La Paz	1975-83*	91	0.83	15,222.9	12,868.0	1.11	10.91
12. Dolores Capas	1975-80*	54	0.88	10,111.7	9,763.5	1.15	-20.77
13. Clark Air Base	1958-75*	130	0.92	31,855.5	26,185.2	1.38	-31.87
14. San Agustion Arayat	1967-78*	104	0.92	24,337.0	17,063.5	1.79	-59.38
15. San Fernando	1970-83*	151	0.93	30,181.4	23,992.8	1.35	-14.96
16. San Matias	1975-78*	34	0.76	6,055.6	4,489.6	1.00	45.27
17. Cansinala Apalit	1967-83*	160	0.91	31,607.7	21,212.3	1.44	7.00
18. Masantol	1669-81*	144	0.92	29,853.2	22,899.5	1.54	-37.10
19. Talisai Balanga	1970-79*	120	0.93	26,634.4	27,977.7	0.93	-8.11
22. Cabanatuan	1958-82*	239	0.76	49,283.5	39,688.2	1.39	-24.11
23. Pasbol (Dam site)	1983	3	(1.00)	422.6	402.0	1.00	7.38
24. Nabuclud (Catchment)	1983	2	(1.00)	422.6	451.5	1.31	-83.99

Table 1.7(2) CORRELATION COEFFICIENT AND SIMPLE LINEAR REGRESSION OF 10-DAY RAINFALLS

Dependent Variable	Data Period	Number of Observation	Correlation Coefficient	Total Rainfall (mm)		Regression Coefficient	
				Independent Variable	Dependent Variable	Intercept (b)	Coefficient (a)
2. Pasuail	1968-81*	199	0.88	12,367.1	13,497.9	0.88	2.79
3. Santa Cruz Porac	1969-81*	432	0.88	29,853.2	26,013.8	1.26	-6.72
4. Santa Rita	1975-83*	277	0.99	14,266.0	14,751.0	1.02	-2.88
5. Cabanbangan Bacol	1969-83*	491	0.91	32,004.5	27,387.4	1.18	-0.79
6. Lubao	1975-81*	207	0.84	11,646.3	16,308.2	0.54	5.71
7. Armeria Dam Tarl	1977-79*	98	0.80	5,827.8	5,754.3	1.15	-8.26
9. Hacienda Luisita	1967-82*	465	0.70	30,647.7	22,614.6	1.32	1.71
10. Aduçao Tarlac	1976-80*	153	0.78	8,610.2	8,529.1	0.89	6.90
11. La Paz	1975-83*	276	0.73	15,243.5	12,874.1	1.05	6.24
12. Dolores Capas	1975-80*	162	0.81	10,111.7	9,763.5	1.06	-1.61
13. Clark Air Base	1958-75*	408	0.86	31,855.5	26,185.2	1.35	-8.29
14. San Agustin Arayat	1967-78*	312	0.83	24,337.0	17,063.5	1.65	-12.25
15. San Fernando	1970-83*	458	0.89	30,237.5	24,033.7	1.30	-1.95
16. San Matias	1975-78*	102	0.77	6,055.6	4,489.6	0.37	20.93
17. Cansinada Apalit	1967-83*	480	0.82	31,607.7	21,212.3	1.30	8.30
18. Masantol	1969-81*	432	0.87	29,853.2	22,899.5	1.42	-6.06
19. Talisai Balanga	1970-79*	360	0.85	26,634.4	27,977.7	0.90	3.67
22. Cabanatuan	1958-82*	717	0.63	49,283.6	49,688.3	1.14	5.91
23. Pasbol	1983	10	0.93	443.2	412.5	0.77	12.53
24. Nabuclud	1983	7	0.93	443.2	464.5	0.71	16.45

Remarks: Independent variable is rainfall at Basa Air Base.

The Equation of Simple Linear Regression

$$Y = (a) + (b)\,X$$

where, Y: Rainfall at Basa Air Base
X: Rainfall at Each Stations

Table 1.8 SIMPLE LINEAR REGRESSION TO INTERPOLATE DAILY RAINFALL AT BASA AIR BASE

Name of Station	Year of No Data at Basa Air Base							Daily Rainfall /3		10 Days Rainfall		Monthly Rainfall	
	1958	1965	1966	1967	1968	1969	1983	Correlation Coefficient (A)	Simple Linear Regression (B)	(A)	(B)	(A)	(B)
3. Santa Cruz						0	/1	0.54	y=0.79x+4.67 /2	0.88	y=1.26x-6.72	0.93	y=1.27x-22.88
9. Hacienda Luisita					0	0	0	0.36	y=0.64x+8.08	0.70	y=1.32x+1.71	0.80	y=1.42x-9.82
13. Clark Air Base					0	0		0.62	y=0.91x+3.76	0.86	y=1.35x-8.29	0.92	y=1.38x-31.87
14. San Agustin Aryat				0	0	0		0.50	y=0.93x+5.5	0.83	y=1.65x-12.25	0.92	y=1.79x-59.38
17. Cansinala Apalit					0	0		0.48	y=0.73x+6.68	0.82	y=1.30x+8.30	0.91	y=1.44x+7.00
22. Cabanatuan	0	0	0	0	0	0		0.34	y=0.59x+8.02	0.63	y=1.14x+5.91	0.76	y=1.39x-24.11

Remarks :

/1 : 0 ; Avalable data

/2 : x ; Rainfall at each stations (mm)
y ; Rainfall at Basa Air Base (mm)

/3 : Samples are daily rainfall (>0 mm/day)

/4 : The equation of Simple Linear Regression to Interpolate Daily Rainfall

1958 - 1966 : y=0.59x+8.02 x : Daily rainfall at Cabanatuan
1967 : y=0.73x+6.68 x : Daily rainfall at San Agustin Aryat
1968 - 1969 : y=0.91x+3.76 x : Daily rainfall at Clark Air Base
1983 : y=0.64x+8.08 x : Daily rainfall at Hacienda Luisita

Table 1.9 ANNUAL RUNOFF DEPTH OF GUMAIN RIVER

Year	Rainfall at Basa Air Base (mm)	Observed Runoff Depth of Gumain River (mm)	Runoff Coefficient	Calculated Runoff Depth of Gumain River (mm)	Runoff Coefficient
1958	(2202.2)/1	2716.5	1.23	2027.8	0.92
1959	1285.5	957.3	0.74	1174.1	0.91
1960	3217.2	3537.5	1.10	2905.8	0.90
1961	1469.5	2934.7	2.00	1357.6	0.92
1962	2889.9	2351.0	0.81	2603.5	0.90
1963	2875.9	2235.5	0.78	2629.9	0.91
1964	1878.5	2571.0	1.36	1702.6	0.91
1965	1744.1	2269.4	1.30	1568.7	0.90
1966	(2759.2)	- /2	-	2480.9	0.90
1967	(2626.4)	-	-	2458.9	0.94
1968	(1923.0)	-	-	1764.3	0.92
1969	(1951.3)	1466.0	0.75	1768.2	0.91
1970	2420.7	2428.2	1.00	2167.4	0.90
1971	2580.6	2831.1	1.10	2295.6	0.89
1972	5515.0	4396.6	0.79	5089.1	0.92
1973	2007.5	-	-	1869.1	0.93
1974	3651.8	2435.6	0.67	3313.8	0.91
1975	1853.2	1406.5	0.76	1674.8	0.90
1976	2673.6	2800.4	1.05	2519.9	0.94
1977	1799.4	-	-	1577.1	0.88
1978	2680.6	1838.3	0.68	2482.1	0.93
1979	1452.0	-	-	1314.4	0.91
1980	1758.1	-	-	1520.3	0.86
1981	1460.7	-	-	1360.2	0.93
1982	1479.4	-	-	1381.9	0.93
1983	(1097.7)	1300.1	1.18	980.0	0.89
Mean/3	2279.0	2380.9	1.04	2076.5	0.91
Mean/4	2469.8	2380.9	0.96	2250.7	0.91

Remarks : /1 ; Estimated Rainfall , /2 ; No Data
/3 ; All Samples , /4 ; Samples to be excluded no data year

Table 1.10(1) 10-DAY DISCHARGE AT PABANLAG STATION IN GUMAIN RIVER

Name of Station: Gumain River Pabanlag
Catchment Area : 122.0 km2

(Unit: m3/sec)

YEAR		JAN.	FEB.	MAR.	RPR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1958	1 -10	16.20	14.00	18.90	11.80	11.70	369.80	29.70	133.32	574.88	128.92	56.80	32.50	1398.52
	11-20	15.00	14.70	12.40	12.30	11.10	132.18	572.80	63.30	163.54	80.14	43.30	31.30	1152.06
	21---	18.70	11.20	12.10	12.00	11.60	35.90	226.58	449.46	299.70	143.06	35.50	29.90	1285.20
MONTHLY TOTAL		49.40	39.90	43.40	36.10	34.40	537.88	829.08	646.08	1038.12	352.12	135.60	93.70	3835.78
1959	1 -10	25.00	20.40	13.70	13.10	15.00	11.40	13.10	156.76	283.60	38.70	9.50	10.10	610.36
	11-20	25.00	18.00	13.00	11.80	15.10	11.10	20.40	53.64	21.50	12.40	38.89	9.80	250.63
	21---	25.90	11.80	13.60	12.00	17.00	13.10	32.20	317.48	11.75	10.65	14.60	10.70	490.78
MONTHLY TOTAL		75.90	50.20	40.30	36.90	47.10	35.60	65.70	527.88	316.85	61.75	62.99	30.60	1351.77
1960	1 -10	16.42	15.37	12.91	18.55	24.73	89.39	145.75	392.96	286.16	159.88	60.36	29.47	1251.96
	11-20	13.13	13.09	12.89	20.15	19.66	33.69	107.13	761.92	156.31	154.65	50.06	23.49	1366.15
	21---	17.41	13.07	12.69	26.21	77.85	302.59	93.76	503.27	306.96	73.00	36.48	21.75	1485.03
MONTHLY TOTAL		46.96	41.52	38.50	64.89	122.23	425.68	346.65	1658.15	749.43	387.51	146.91	74.70	4103.13
1961	1 -10	16.64	14.27	22.51	13.28	13.11	29.03	195.56	40.42	135.99	63.62	27.17	13.75	583.35
	11-20	14.47	14.05	13.77	13.25	22.52	26.85	126.60	105.49	96.46	80.63	21.43	13.69	549.20
	21---	14.43	13.87	13.53	16.47	38.06	207.77	53.03	206.73	147.81	42.89	16.39	13.50	784.49
MONTHLY TOTAL		45.54	42.19	49.82	43.00	73.69	263.65	375.18	352.64	378.76	187.14	64.99	40.94	1917.05
1962	1 -10	19.95	14.00	16.92	18.17	21.54	21.51	25.16	181.88	970.48	70.70	51.10	30.70	1442.11
	11-20	15.20	13.30	17.50	23.28	17.50	18.60	220.37	123.83	117.14	52.80	39.80	27.70	687.02
	21---	15.40	10.40	19.69	29.98	23.96	16.00	618.80	162.97	184.54	49.20	30.70	29.00	1190.64
MONTHLY TOTAL		50.55	37.70	54.11	71.43	63.00	56.11	864.33	468.68	1272.16	172.70	121.60	87.40	3319.77
1963	1 -10	16.80	17.40	14.90	13.00	14.70	238.96	130.45	63.44	437.31	86.75	37.14	24.70	1095.55
	11-20	17.00	18.20	14.00	14.20	17.80	65.34	208.04	330.52	360.50	55.06	33.78	24.06	1158.50
	21---	18.50	13.60	14.90	15.00	22.30	393.02	112.60	97.37	117.53	48.69	29.58	19.47	902.56
MONTHLY TOTAL		52.30	49.20	43.80	42.20	54.80	697.32	451.09	491.33	915.34	190.50	100.50	68.23	3156.61
1964	1 -10	13.88	13.41	12.82	12.41	12.18	83.41	182.49	148.51	99.23	94.46	42.56	38.20	753.54
	11-20	13.83	13.20	12.62	12.31	28.09	31.86	137.31	131.84	106.78	108.13	40.80	53.61	690.39
	21---	13.63	13.03	12.60	12.19	45.54	337.76	66.09	191.37	110.60	69.96	63.07	24.37	960.20
MONTHLY TOTAL		41.33	39.65	38.04	36.91	85.80	453.03	385.89	471.72	316.61	272.55	146.42	116.18	2404.13
1965	1 -10	28.30	20.50	16.40	18.50	22.06	117.34	104.74	168.82	143.80	207.93	56.50	32.72	937.61
	11-20	28.30	19.50	16.40	18.50	20.50	84.22	289.32	122.11	144.79	97.09	71.44	30.89	943.06
	21---	25.46	14.38	18.04	18.50	186.35	281.75	361.53	170.78	94.12	76.10	44.88	31.87	1323.76
MONTHLY TOTAL		82.06	54.38	50.94	55.50	228.91	483.31	755.59	461.71	382.71	381.12	172.82	95.48	3204.43
1966	1 -10	27.56	20.50	23.26	22.60	22.80	167.20	137.68	242.56	452.64	164.32	129.16	21.90	1432.18
	11-20	24.40	20.50	22.60	22.60	500.56	142.00	236.07	396.36	390.29	54.90	53.10	35.05	1898.43
	21---	23.18	16.40	24.86	22.60	850.71	159.37	238.18	231.89	139.30	76.00	116.00	30.06	1928.55
MONTHLY TOTAL		75.14	57.40	70.72	67.80	1374.07	468.57	611.93	870.81	982.23	295.22	298.26	87.01	5259.16

Table 1.10(2) 10-DAY DISCHARGE AT PABANLAG STATION IN GUMAIN RIVER

Name of Station: Gumain River Pabanlag
Catchment Area : 122.0 km2

(Unit: m3/sec)

YEAR		JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1967	1 -10	12.90	5.04	14.20	17.40	28.00	231.63	58.96	323.52	146.41	82.56	49.09	19.10	988.81
	11-20	12.10	12.00	15.00	21.20	24.40	87.52	90.64	404.70	183.49	86.75	30.29	14.52	982.62
	21---	6.40	10.40	18.50	21.00	27.80	134.35	329.61	266.08	215.89	49.59	24.47	13.58	1117.67
MONTHLY TOTAL		31.40	27.44	47.70	59.60	80.20	453.50	479.21	994.30	545.79	218.90	103.85	47.21	3089.10
1968	1 -10	13.43	13.01	12.43	12.02	15.82	25.29	18.87	109.69	363.60	19.11	45.41	18.78	667.46
	11-20	13.25	12.80	12.23	11.89	16.43	16.02	26.00	131.74	225.64	18.50	28.71	23.40	536.62
	21---	13.21	12.64	12.14	11.88	22.35	14.40	255.87	558.11	160.97	41.51	13.70	24.80	1141.58
MONTHLY TOTAL		39.89	38.45	36.80	35.79	54.60	55.71	300.74	799.54	750.21	79.12	87.82	66.98	2345.65
1969	1 -10	22.60	24.40	14.70	4.70	4.20	21.90	22.28	315.65	153.78	154.24	34.30	39.56	812.31
	11-20	22.60	17.66	15.31	4.00	13.69	66.92	26.87	132.28	188.80	75.04	30.50	29.39	623.06
	21---	24.86	13.94	12.65	4.40	18.19	21.09	226.72	54.13	145.33	45.79	37.32	30.24	634.66
MONTHLY TOTAL		70.06	56.00	42.66	13.10	36.08	109.91	275.87	502.06	487.91	275.07	102.12	99.19	2070.03
1970	1 -10	18.70	26.97	18.90	12.80	11.20	30.69	169.54	197.80	587.36	181.15	107.89	52.90	1415.90
	11-20	18.49	20.91	19.28	12.40	11.70	129.03	130.39	141.55	290.37	255.68	109.42	43.00	1162.22
	21---	28.31	15.77	13.64	12.70	11.94	33.12	63.05	206.42	152.89	178.97	91.70	42.12	850.63
MONTHLY TOTAL		65.50	63.65	51.82	37.90	34.84	192.84	362.98	545.77	1030.62	595.80	309.01	138.02	3428.75
1971	1 -10	34.73	18.50	16.85	14.40	31.04	55.25	82.86	210.67	105.19	364.72	115.00	117.14	1166.33
	11-20	25.99	18.50	14.40	14.96	18.17	189.03	309.77	146.05	93.49	437.85	110.42	61.03	1439.66
	21---	21.53	14.80	15.84	16.40	39.47	85.48	611.41	99.05	115.72	163.53	173.17	35.20	1391.60
MONTHLY TOTAL		82.25	51.80	47.07	45.76	88.68	329.76	1004.04	455.77	314.40	966.10	398.59	213.37	3997.59
1972	1 -10	43.00	30.51	36.71	29.95	36.16	130.86	390.09	932.76	71.60	41.54	44.73	42.20	1830.11
	11-20	32.55	30.34	35.99	33.81	40.17	114.05	957.13	304.27	169.31	43.47	42.18	36.31	1839.58
	21---	35.74	28.80	37.37	33.26	109.53	190.79	1821.25	103.57	50.53	49.14	42.93	34.37	2537.28
MONTHLY TOTAL		111.29	89.65	110.07	97.02	185.86	435.70	3168.47	1340.60	291.44	134.15	129.84	112.88	6206.97
1973	1 -10	34.54	26.56	19.54	16.68	19.58	25.54	111.18	34.00	70.01	313.34	30.40	17.78	719.15
	11-20	38.50	21.34	18.02	16.46	19.26	53.88	301.05	144.74	75.52	322.50	25.55	17.30	1054.12
	21---	41.16	16.20	18.70	17.78	20.85	78.08	45.25	518.76	59.96	82.17	27.38	18.54	944.83
MONTHLY TOTAL		114.20	64.10	56.26	50.92	59.69	157.51	457.48	697.50	205.49	718.01	83.33	53.62	2718.11
1974	1 -10	16.20	14.36	15.03	14.10	14.30	362.65	16.40	278.78	20.14	16.60	75.77	51.15	895.48
	11-20	15.35	14.14	14.54	13.98	20.15	228.25	33.65	975.58	17.78	121.75	48.69	16.98	1528.84
	21---	16.30	11.34	15.50	13.90	94.75	17.93	23.53	289.39	17.22	382.08	115.63	18.19	1014.86
MONTHLY TOTAL		47.85	39.84	45.07	41.98	137.20	607.93	73.58	1543.75	55.14	520.43	240.09	86.32	3439.18
1975	1 -10	16.70	14.76	20.74	20.34	20.54	24.24	21.10	180.64	102.39	42.77	97.52	21.90	583.64
	11-20	15.79	14.24	20.42	20.30	20.62	28.95	30.52	307.68	93.87	150.76	33.84	21.34	758.33
	21---	16.68	11.32	22.45	20.94	22.45	33.66	40.48	156.05	57.35	217.93	21.50	23.29	644.10
MONTHLY TOTAL		49.17	40.32	63.61	61.58	63.61	86.85	92.10	644.37	253.61	411.46	152.86	66.53	1986.07

Table 1.10(3) 10-DAY DISCHARGE AT PABANLAG STATION IN GUMAIN RIVER

Name of Station: Gumain River Pabanlag
Catchment Area : 122.0 km^2

(Unit: m^3/sec)

YEAR		JAN.	FEB.	MAR.	RPR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1976	1 -10	21.10	21.10	21.10	21.10	21.10	41.50	244.08	260.00	64.00	101.98	36.80	53.81	907.67
	11-20	21.10	21.10	21.10	21.10	21.14	21.10	38.07	234.12	395.42	63.14	36.80	27.43	921.62
	21---	23.21	19.03	23.21	21.10	809.04	425.68	249.07	256.80	166.87	71.44	36.80	22.61	2124.86
MONTHLY TOTAL		65.41	61.23	65.41	63.30	851.28	488.28	531.22	750.92	626.29	236.56	110.40	103.85	3954.15
1977	1 -10	20.58	21.18	14.78	21.10	13.99	20.58	43.08	183.03	250.50	81.30	20.66	18.90	709.68
	11-20	20.02	20.78	14.57	21.10	13.97	36.31	69.55	109.31	601.48	74.02	410.94	16.34	1408.39
	21---	23.21	16.80	14.34	21.10	26.74	40.93	231.07	277.14	342.76	28.95	24.56	17.60	1065.20
MONTHLY TOTAL		63.81	58.76	43.68	63.30	54.71	97.82	343.70	569.48	1194.74	184.27	456.16	52.84	3183.27
1978	1 -10	15.80	14.91	13.06	12.69	12.78	23.90	18.22	143.81	67.10	196.16	18.78	18.30	555.51
	11-20	15.77	15.15	12.69	12.75	12.60	21.60	22.90	425.81	25.73	58.40	18.30	18.30	658.00
	21---	17.13	10.58	14.01	12.78	32.02	21.25	183.21	721.79	201.79	129.17	18.30	20.13	1382.16
MONTHLY TOTAL		48.70	40.64	39.76	38.22	57.40	66.75	224.33	1291.41	292.62	383.73	55.38	56.73	2595.67
1979	1 -10	18.02	16.40	16.40	16.36	16.00	17.19	64.50	274.05	139.41	228.94	41.28	33.54	882.09
	11-20	17.19	16.40	16.40	16.00	20.86	17.94	20.18	516.21	169.41	92.51	37.14	23.47	963.71
	21---	18.20	13.12	18.04	16.00	19.52	16.32	79.06	191.16	182.78	54.27	36.80	23.17	668.44
MONTHLY TOTAL		53.41	45.92	50.84	48.36	56.38	51.45	163.74	981.43	491.60	375.72	115.22	80.18	2514.24
1980	1 -10	13.22	12.66	12.36	12.13	11.87	12.21	121.87	84.02	71.25	41.46	99.09	21.23	513.38
	11-20	13.05	12.51	12.25	12.01	18.65	19.13	148.09	57.62	496.64	29.84	45.29	16.20	881.25
	21---	12.86	12.46	12.24	11.88	11.81	118.66	227.99	71.57	152.96	100.72	26.36	12.62	752.14
MONTHLY TOTAL		39.13	37.63	36.85	36.02	42.31	150.01	497.95	213.21	700.85	172.03	170.74	50.05	2146.77
1981	1 -10	12.56	12.00	11.63	11.29	11.04	82.50	121.87	88.00	45.57	103.85	36.69	20.81	557.82
	11-20	12.39	11.80	11.53	11.17	12.96	314.71	150.58	185.38	41.04	68.11	30.42	15.85	866.84
	21---	12.20	11.70	11.42	11.05	14.88	131.97	55.25	88.65	70.17	43.92	34.88	11.89	495.98
MONTHLY TOTAL		37.15	35.50	34.57	33.52	38.88	529.19	325.70	362.02	157.69	215.89	101.99	48.54	1920.64
1982	1 -10	11.84	11.27	20.50	18.55	17.57	18.35	376.99	181.93	464.90	76.70	45.64	35.00	1279.24
	11-20	11.66	11.08	17.98	22.54	15.45	15.20	157.17	225.59	299.27	67.01	38.96	33.80	915.71
	21---	11.47	16.40	19.47	17.70	16.72	225.24	153.21	840.94	96.04	67.62	35.00	35.86	1535.67
MONTHLY TOTAL		34.97	38.75	57.95	58.79	49.74	258.79	687.37	1248.46	860.21	211.33	119.60	104.66	3730.62
1983	1 -10	29.48	26.36	24.44	25.40	27.32	40.85	28.52	43.08	45.26	78.96	37.06	29.24	435.97
	11-20	27.32	26.60	25.40	25.40	26.60	30.20	126.45	356.85	37.52	91.20	32.60	28.80	814.94
	21---	27.94	20.56	27.94	25.64	28.90	30.20	44.66	94.68	115.68	108.80	30.68	29.14	584.82
MONTHLY TOTAL		84.74	73.52	77.78	76.44	82.82	101.25	199.63	474.61	198.46	278.96	100.34	87.18	1835.73

Table 1.10(4) 10-DAY DISCHARGE AT PABANLAG STATION IN GUMAIN RIVER

Name of Station: Gumain River Pabnalag
Catchment Area : 122.0 km2

(Unit: m3/sec)

YEAR		JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
TOTAL	1 -10	536.15	459.85	455.68	422.40	470.33	2293.18	2875.05	5370.11	6150.55	3140.66	1406.41	845.38	24425.73
	11-20	499.44	441.90	432.29	439.47	987.64	1935.69	4557.04	6868.49	4960.99	2732.31	1502.65	693.04	26050.93
	21---	522.52	373.61	449.47	454.46	2600.33	3365.52	6441.46	7125.60	3697.22	2405.15	1178.38	623.98	29237.70
MONTHLY TOTAL		1558.11	1275.35	1337.43	1316.32	4058.29	7594.39	13873.54	19364.20	14808.77	8278.12	4087.44	2162.40	79714.36
MEAN	1 -10	20.62	17.69	17.53	16.25	18.09	88.20	110.58	206.54	236.56	120.79	54.09	32.51	939.45
	11-20	19.21	17.00	16.63	16.90	37.99	74.45	175.27	264.17	190.81	105.09	57.79	26.66	1001.96
	21---	20.10	14.37	17.29	17.48	100.01	129.44	247.75	274.06	142.20	92.51	45.32	24.00	1124.53
MONTHLY MEAN		59.93	49.05	51.44	50.63	156.09	292.09	533.60	744.78	569.57	318.39	157.21	83.17	3065.94

Table 1.11 MEAN 10-DAY DISCHARGE AT GUMAIN DAM SITE AND PORAC AND CAULAMAN DIVERSION DAM SITES

(Unit: m^3/sec)

Dam Site		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Proposed	1-10	1.93	1.65	1.64	1.52	1.69	8.24	10.33	19.30	22.10	11.29	5.05	3.04
Gumain	11-20	1.80	1.59	1.55	1.58	3.55	6.96	16.38	24.68	17.83	9.82	5.40	2.49
Dam Site	21-	1.71	1.68	1.47	1.63	8.50	12.10	21.05	23.28	13.29	7.86	4.23	2.04
(CA = 114 km^2)	Monthly	1.81	1.64	1.55	1.58	4.70	9.10	16.08	22.45	17.74	9.60	4.90	2.51
Porac	1-10	1.32	1.12	1.12	1.04	1.15	5.62	7.04	13.15	15.06	7.70	3.44	2.07
Diversion	11-20	1.23	1.08	1.06	1.08	2.42	4.74	11.16	16.82	12.15	6.69	3.68	1.70
Dam Site	21-	1.17	1.15	1.00	1.11	5.79	8.25	14.35	15.87	9.06	5.36	2.88	1.39
(CA = 111 km^2)	Monthly	1.23	1.12	1.06	1.08	3.20	6.20	10.96	15.30	12.09	6.54	3.34	1.71
Caulaman	1-10	1.10	0.94	0.93	0.86	0.96	4.68	5.87	10.97	12.56	6.42	2.87	1.73
Diversion	11-20	1.02	0.90	0.88	0.90	2.02	3.96	9.31	14.03	10.13	5.58	3.07	1.42
Dam Site	21-	0.97	0.95	0.84	0.93	4.83	6.88	11.97	13.23	7.55	4.47	2.40	1.16
(CA = 72 km^2)	Monthly	1.03	0.93	0.88	0.90	2.67	5.17	9.14	12.76	10.08	5.46	2.79	1.43

Remarks: Discharge is mean daily discharge during 10 days.

Table 1.12 CONSTANT 'n' FOR ANNUAL MAXIMUM HOURLY RAINFALL

Station No. 3 Sta.Cruz, Polac

Year	R_{24}	1 hr.		3 hr.	
		R_1	n /1	R_3	n
1968	-	-		-	
1969	125.5	52.9	0.728	90.1	0.840
1970	159.0	30.6	0.481	49.8	0.441
1971	139.2	46.8	0.657	72.7	0.687
1972	344.3	42.5	0.341	67.2	0.214
1973	122.5	42.8	0.669	54.0	0.606
1974	174.0	60.0	0.664	93.0	0.698
1975	140.5	40.9	0.611	55.1	0.549
1976	245.4	39.4	0.424	88.4	0.508
1977	207.0	36.0	0.449	-	
1978	-	-		-	

Station No. 14 San Augstin, Arayat

Year	R_{24}	1 hr.		3 hr.	
		R_1	n	R_3	n
1965	-	-		-	
1966	324.1	62.2	0.480	82.6	0.342
1967	145.8	34.0	0.541	41.2	0.392
1968	117.3	42.2	0.678	50.9	0.598
1969	93.7	54.0	0.826	81.5	0.932
1970	122.2	65.9	0.805	79.7	0.794
1971	114.6	31.9	0.597	40.1	0.495
1972	196.8	47.6	0.553	71.5	0.513
1973	189.3	40.5	0.514	64.7	0.483
1974	170.7	76.0	0.745	138.0	0.897
1975	103.1	51.9	0.784	83.2	0.896
1976	168.2	34.4	0.500	54.5	0.458
1977	-	-		-	

Station No. 17 Casinala, Apalit

Year	R_{24}	1 hr.		3 hr.	
		R_1	n	R_3	n
1967	-	-		-	
1968	134.7	42.5	0.637	48.0	0.503
1969	110.5	31.4	0.604	52.7	0.643
1970	61.5	29.3	0.766	54.5	0.941
1971	72.7	44.5	0.846	52.0	0.838
1972	306.2	41.5	0.371	75.0	0.323
1973	150.1	28.0	0.471	51.0	0.480
1974	203.7	29.6	0.393	49.5	0.319
1975	171.7	30.5	0.456	53.1	0.435
1976	204.2	32.0	0.416	61.0	0.418
1977	-	-		-	

Remarks : /1 : $n = \text{Log}\ (24\ Rt\ /\ R_{24})\ /\ \text{Log}\ (\frac{24}{t})$

Table 1.13 PEAK AND SPECIFIC DISCHARGES OF PROBABLE FLOODS IN GUMAIN RIVER

Proposed Gumain Dam Site (A=114km²)

Return Period T (year)	R24 (mm/day)	1.27R24 (mm/day)	n	t /1 (hr.)	I /2 (mm/hr)	f /3	Qp /4 (m³/sec)	q=Qp/A (m³/sec/km²)
10,000	995.1	1,263.8	0.350	1.70	132.8	0.80	3,365	29.5
500	729.1	926.0	0.365	1.90	97.8	-do-	2,465	21.6
200	647.8	822.7	0.370	1.99	86.2	-do-	2,184	19.2
100	586.2	744.5	0.375	2.06	77.9	-do-	1,974	17.3
50	524.4	666.0	0.380	2.14	69.5	-do-	1,761	15.4
30	478.5	607.7	0.385	2.21	63.4	-do-	1,607	14.1
25	462.1	586.9	0.387	2.24	61.2	-do-	1,550	13.6
20	441.9	561.2	0.390	2.27	58.6	-do-	1,485	13.0
10	378.1	480.2	0.405	2.39	50.9	-do-	1,290	11.3
5	311.7	395.9	0.440	2.50	44.6	-do-	1,130	9.9
2	211.3	268.4	0.520	2.73	34.6	-do-	877	7.7

Proposed Gumain Diversion Dam Site (A=115km²)

Return Period T (year)	R24 (mm/day)	1.27R24 (mm/day)	n	t (hr)	I (mm/hr)	f	Qp (m³/sec)	q=Qp/A (m³/sec/km²)
500	729.1	926.0	0.365	1.91	97.2	0.80	2,484	21.6
200	647.8	822.7	0.370	1.99	86.1	-do-	2,201	19.1
100	586.2	744.5	0.375	2.06	77.9	-do-	1,991	17.3
50	524.4	666.0	0.380	2.15	69.5	-do-	1,777	15.4
30	478.5	607.7	0.385	2.22	63.3	-do-	1,618	14.1
20	441.9	561.2	0.390	2.28	58.6	-do-	1,498	13.0
10	378.1	480.2	0.405	2.39	50.9	-do-	1,301	11.3
5	311.7	395.9	0.440	2.51	44.6	-do-	1,140	9.9
2	211.3	268.4	0.520	2.74	34.6	-do-	885	7.7

Remarks : /1 ; Time of flood concentration
/2 ; Rainfall intensity in a period of "t"
/3 ; Runoff coefficient
/4 ; Flood discharge on T-year return period

Table 1.14 COMPUTATION OF DESIGN STORM AND EFFECTIVE RAINFALL FOR GUMAIN DAM WATERSHED (D.A. 114 km2)

Rainfall Duration (hours) (A)	Max. Point Rainfall in Philippines (mm) (B)	Design Pt. Rainfall for Watershed (mm) (C)	Percent of Point Rainfall (%) (D)	Design Storm (mm) (E)	Rainfall (mm) (F)	Rearranged Rainfall (mm) (G)	Initial Loss (mm) (H)	Retention Loss (mm) (I)	Effective Rainfall (mm) (J)
0	0	0	0	0	0	0	0	0	0
2	345	335	94.9	318	318	25	25	3	0
4	490	475	95.3	453	135	26	0	3	20
6	600	582	95.7	557	104	26	0	3	23
8	700	679	96.2	653	96	26	0	3	23
10	780	757	96.6	731	78	26	0	3	23
12	860	834	96.7	805	75	27	0	3	24
14	930	902	97.1	876	70	27	0	3	24
16	1,000	970	97.2	943	67	28	0	3	25
18	1,060	1,028	97.4	1,001	58	28	0	3	25
20	1,120	1,086	97.5	1,059	58	28	0	3	25
22	1,175	1,140	97.7	1,114	55	28	0	3	25
24	1,230	1,193	97.8	1,167	53	28	0	3	25
26	1,280	1,242	97.9	1,216	49	28	0	3	25
28	1,330	1,290	98.0	1,264	48	29	0	3	26
30	1,380	1,339	98.0	1,312	48	33	0	3	30
32	1,430	1,387	98.0	1,359	47	33	0	3	30
34	1,475	1,431	98.1	1,404	45	33	0	3	30
36	1,520	1,474	98.2	1,447	43	33	0	3	30
38	1,560	1,513	98.2	1,486	39	33	0	3	30
40	1,600	1,552	98.2	1,524	38	37	0	3	34
42	1,640	1,591	98.2	1,562	38	38	0	3	35
44	1,678	1,628	98.2	1,599	37	43	0	3	40
46	1,715	1,664	98.2	1,634	35	47	0	3	44
48	1,750	1,698	98.2	1,667	33	48	0	3	45
50	1,785	1,731	98.2	1,670	33	53	0	3	50
52	1,820	1,765	98.2	1,733	33	58	0	3	55
54	1,855	1,799	98.2	1,767	33	67	0	3	64
56	1,890	1,833	98.2	1,800	33	75	0	3	72
58	1,925	1,867	98.2	1,833	33	96	0	3	93
60	1,960	1,901	98.2	1,866	33	135	0	3	132
62	1,995	1,934	98.2	1,899	33	318	0	3	315
64	2,030	1,968	98.2	1,932	33	104	0	3	101
66	2,060	1,998	98.3	1,964	32	78	0	3	75
68	2,090	2,027	98.3	1,993	29	70	0	3	67
70	2,120	2,056	98.3	2,021	28	58	0	3	55
72	2,150	2,084	98.3	2,049	28	55	0	3	52
74	2,180	2,113	98.3	2,077	28	49	0	3	46
76	2,209	2,141	98.3	2,105	28	48	0	3	45
78	2,238	2,171	98.4	2,135	28	45	0	3	42
80	2,267	2,199	98.4	2,164	28	39	0	3	36
82	2,296	2,227	98.4	2,192	28	38	0	3	35
84	2,326	2,256	98.4	2,220	28	35	0	3	32
86	2,355	2,285	98.4	2,248	28	33	0	3	30
88	2,381	2,310	98.5	2,275	27	33	0	3	30
90	2,409	2,337	98.5	2,302	27	33	0	3	30
92	2,437	2,364	98.5	2,329	27	33	0	3	30
94	2,465	2,391	98.5	2,355	26	32	0	3	29
96	2,492	2,417	98.5	2,381	26	28	0	3	25
98	2,519	2,443	98.5	2,407	26	28	0	3	25
100	2,544	2,468	98.6	2,433	26	28	0	3	25
102	2,571	2,493	98.6	2,459	26	27	0	3	24
104	2,599	2,520	98.6	2,485	26	26	0	3	23
106	2,625	2,546	98.6	2,510	25	26	0	3	23
108	2,650	2,571	98.6	2,535	25	25	0	3	22
Total					2,535	2,535	25	162	2,348

Remarks:
- Column B: Values obtained from Maximum Depth-Duration (Envelope) Curve, Fig. 1.29.
- Column C: Maximum point rainfall over watershed. Column (B) multiplied by overall adjustment factor of 0.97.
- Column D: Values obtained from Maximum Depth-Area-Duration Curve, Fig. 1.30, using interpolated values for 114 sq.km.
- Column E: Average rainfall over watershed. Column (C) multiplied by Column (D).
- Column F: Increment of average rainfall under Column (E).

Table 1.15 DESIGN FLOODS OF SPILLWAY AND DIVERSION IN THE PHILIPPINES

No.	Name of Dam	Drainage Area A (km^2)	Spillway Design Flood Qs (m^3/s)	Spillway Design Flood qs=Qs/A ($m^3/s/km^2$)	Diversion Design Flood Qd (m^3/s)	Diversion Design Flood qd=Qd/A ($m^3/s/km^2$)
1	Pantabangan	853	4,200	4.9	1,640	1.9
2	San Roque	1,250	12,800	10.2	4,600	3.7
3	Balog-Balog	405	3,830	9.5	1,980	4.9
4	Magat	4,143	30,600	7.4	5,500	1.3
5	Ambuklao	686	8,700	12.7	-	-
6	Binga	936	6,100	6.5	-	-
7	Angat	568	5,800	10.2	-	-
8	Palsiguan	153	3,070	20.1	950	6.2
9	Jalaur	109	3,098	28.4	386	3.5
10	Catubig	252	2,700	10.7	532	2.1
11	Pamacsalan	28	930	33.2	400	14.3
12	Caliraya	91.5	1,500	16.4	-	-
13	Mabini	225	4,000	17.8	1,500	6.7
14	Matuno	553	5,500	10.0	-	-

Remarks : Data is obtained from NIA.
- ; No data

Fig. I.1 GUMAIN, PORAC AND CAULAMAN RIVER BASINS

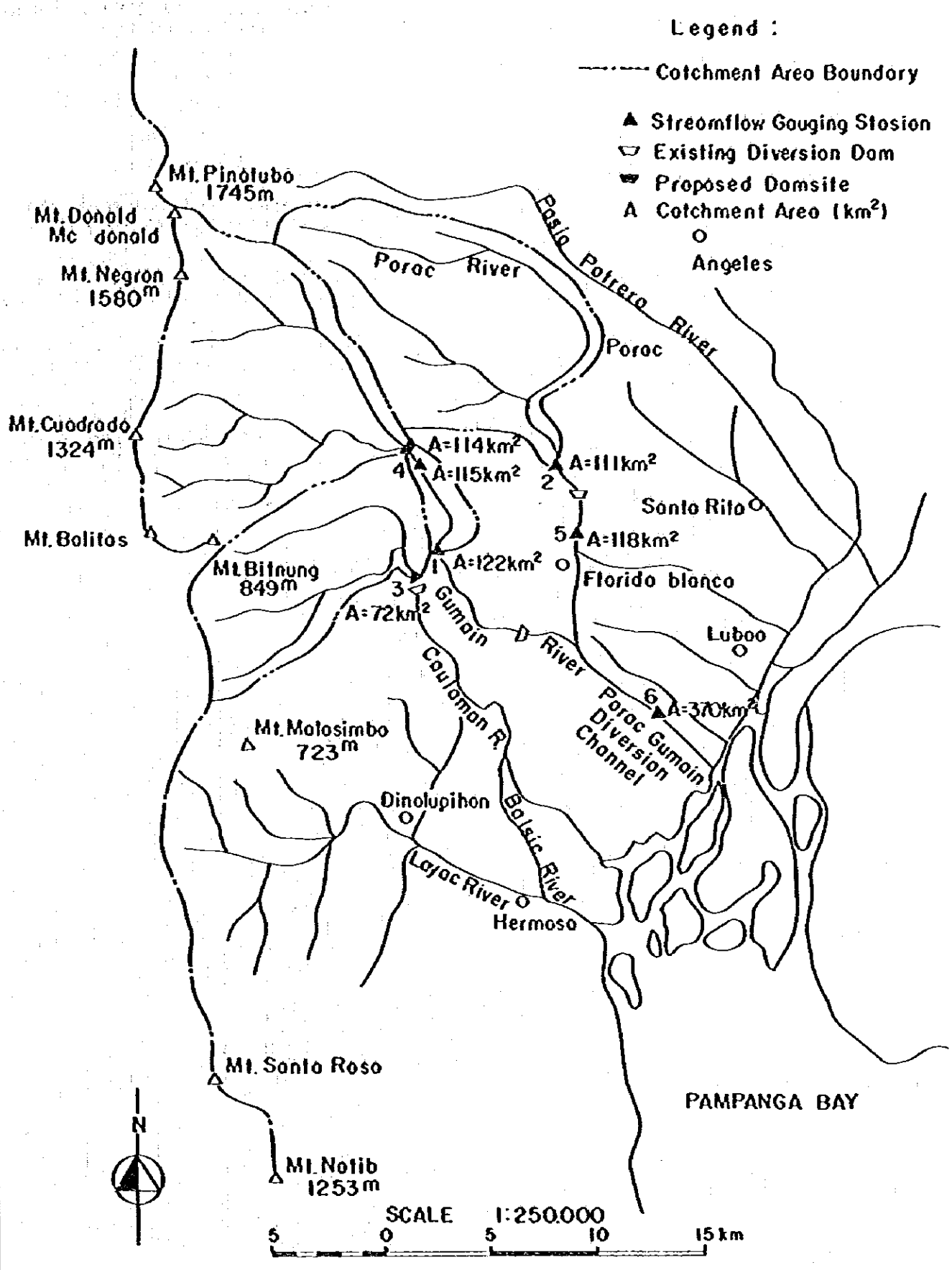


Fig. 12 CLIMATE MAP OF THE PHILIPPINES

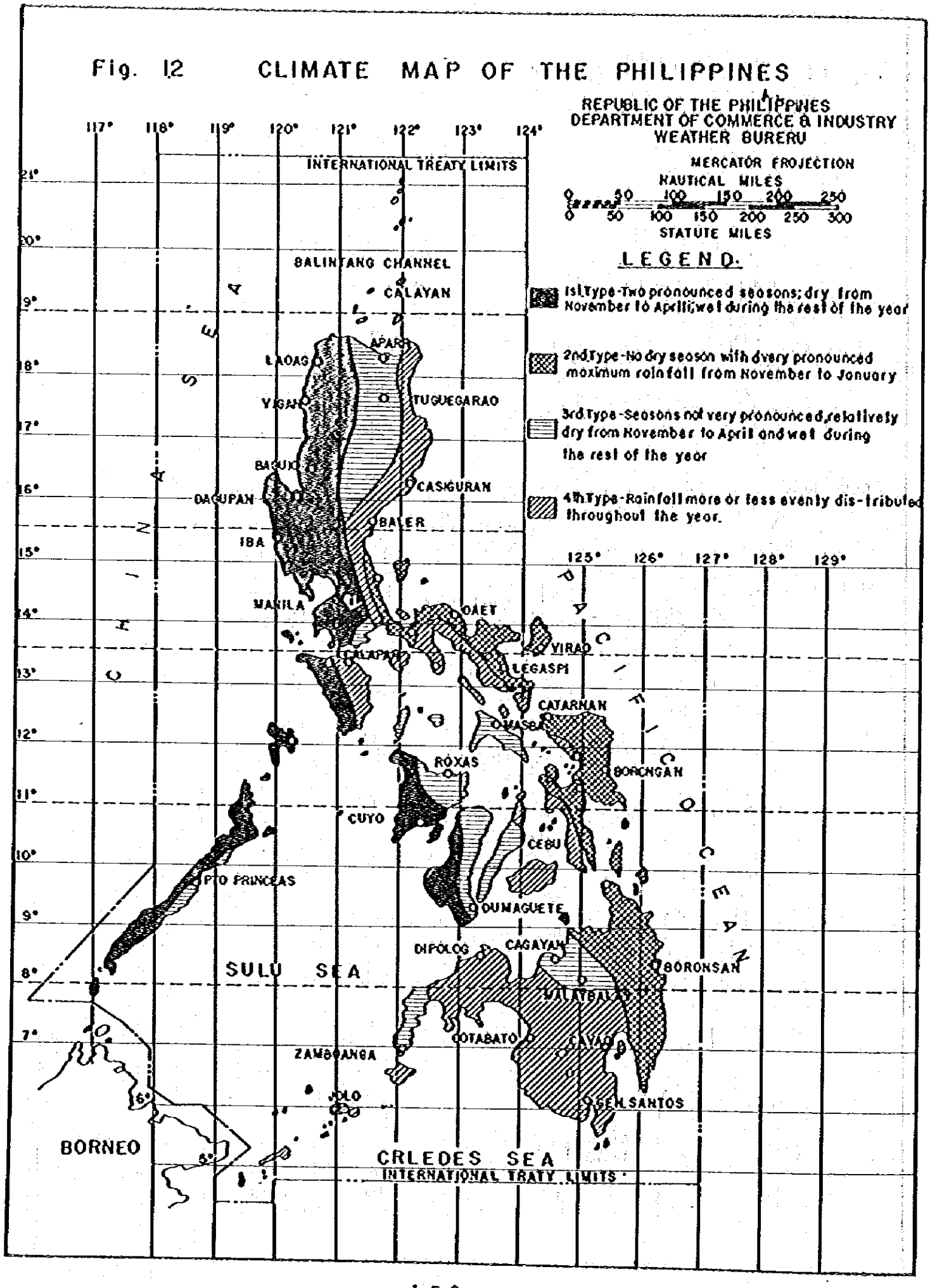


Fig. 1.3 MONTHLY RAINFALL DISTRIBUTION PATTERN

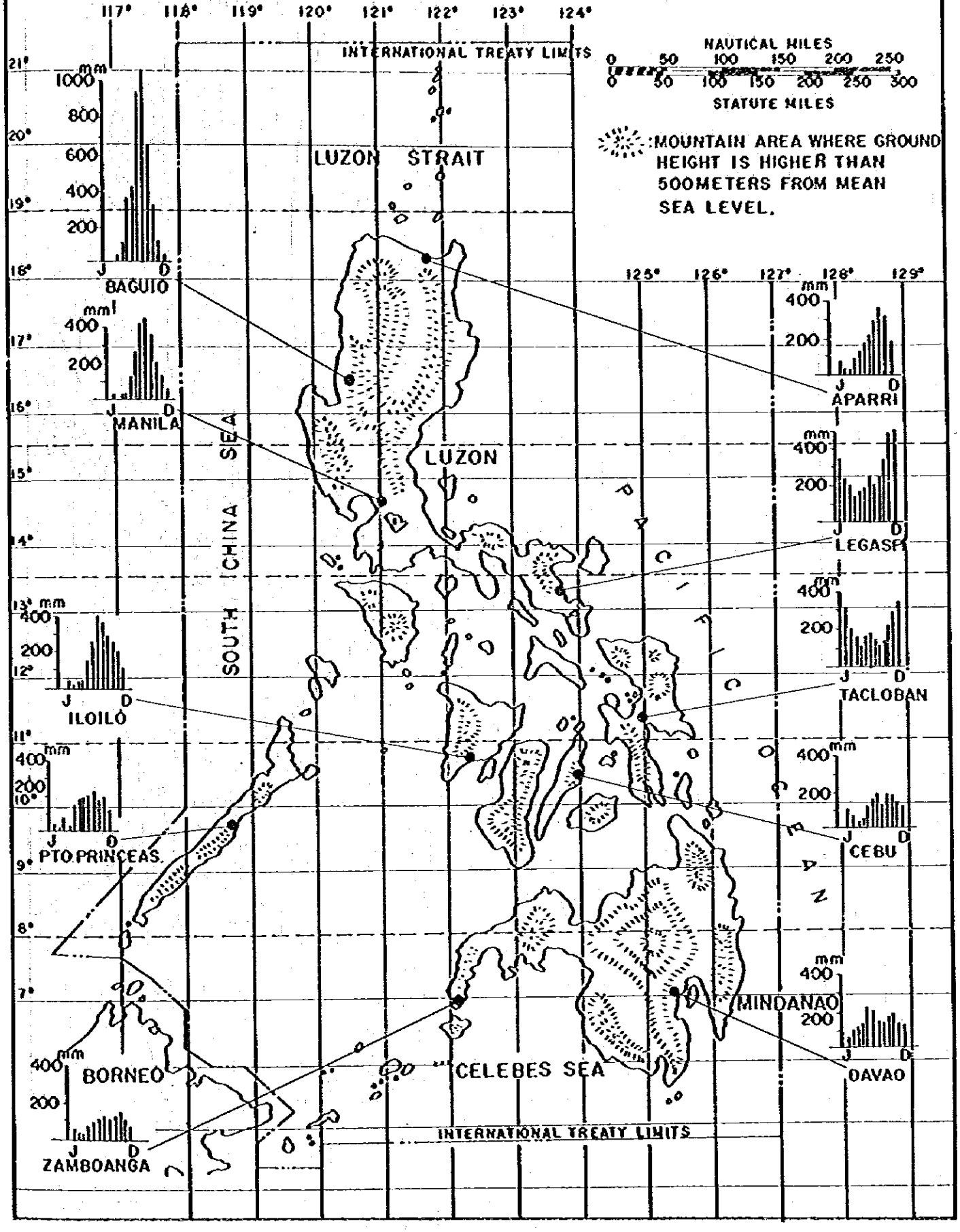


Fig. 1.4 FOUR DIFFERENT STREAMS IN THE TROPICAL NORTHWESTERN PACIFIC DURING MAY TO DECEMBER.

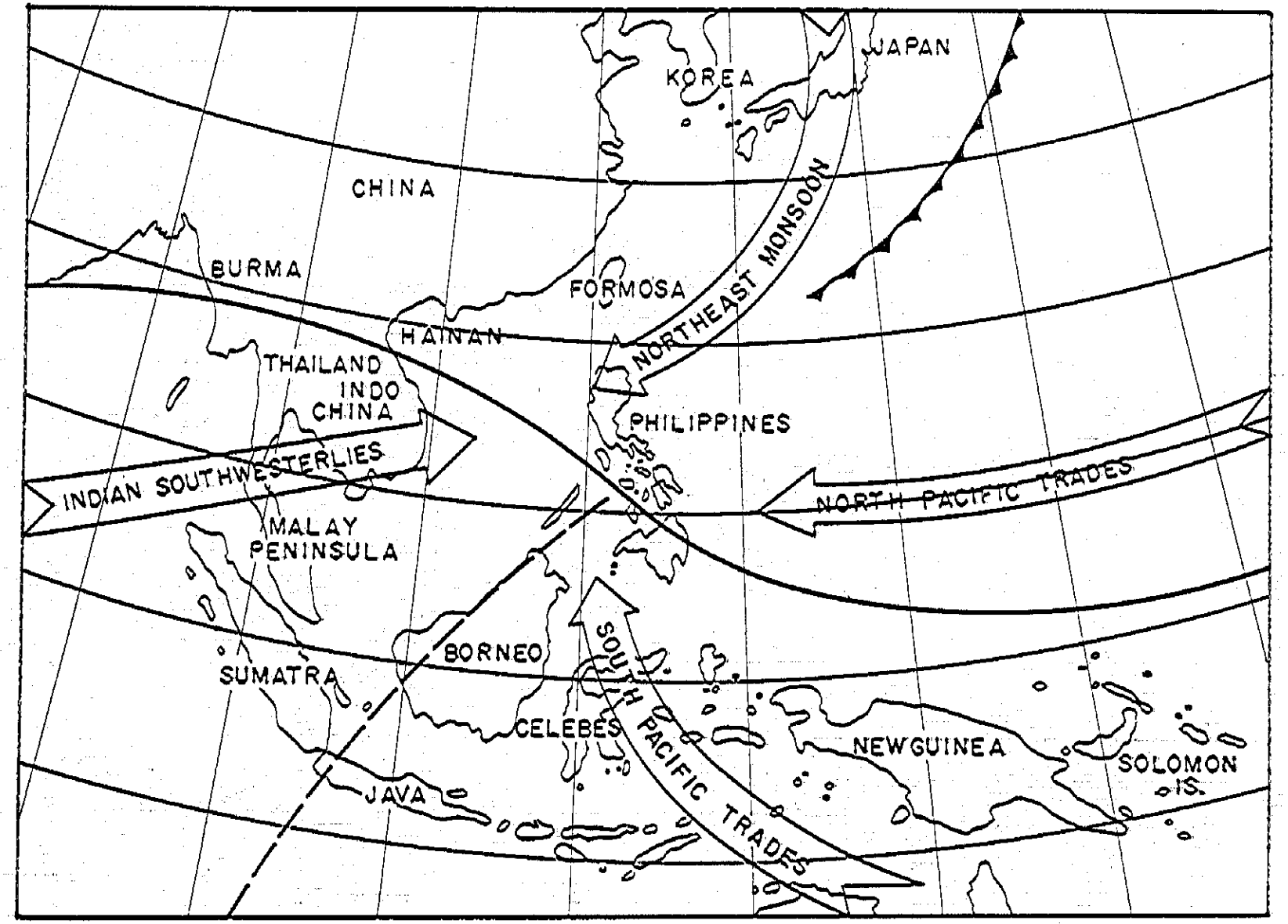


Fig. 1.5
LOCATION OF METEOROLOGICAL AND HYDROLOGICAL STATIONS

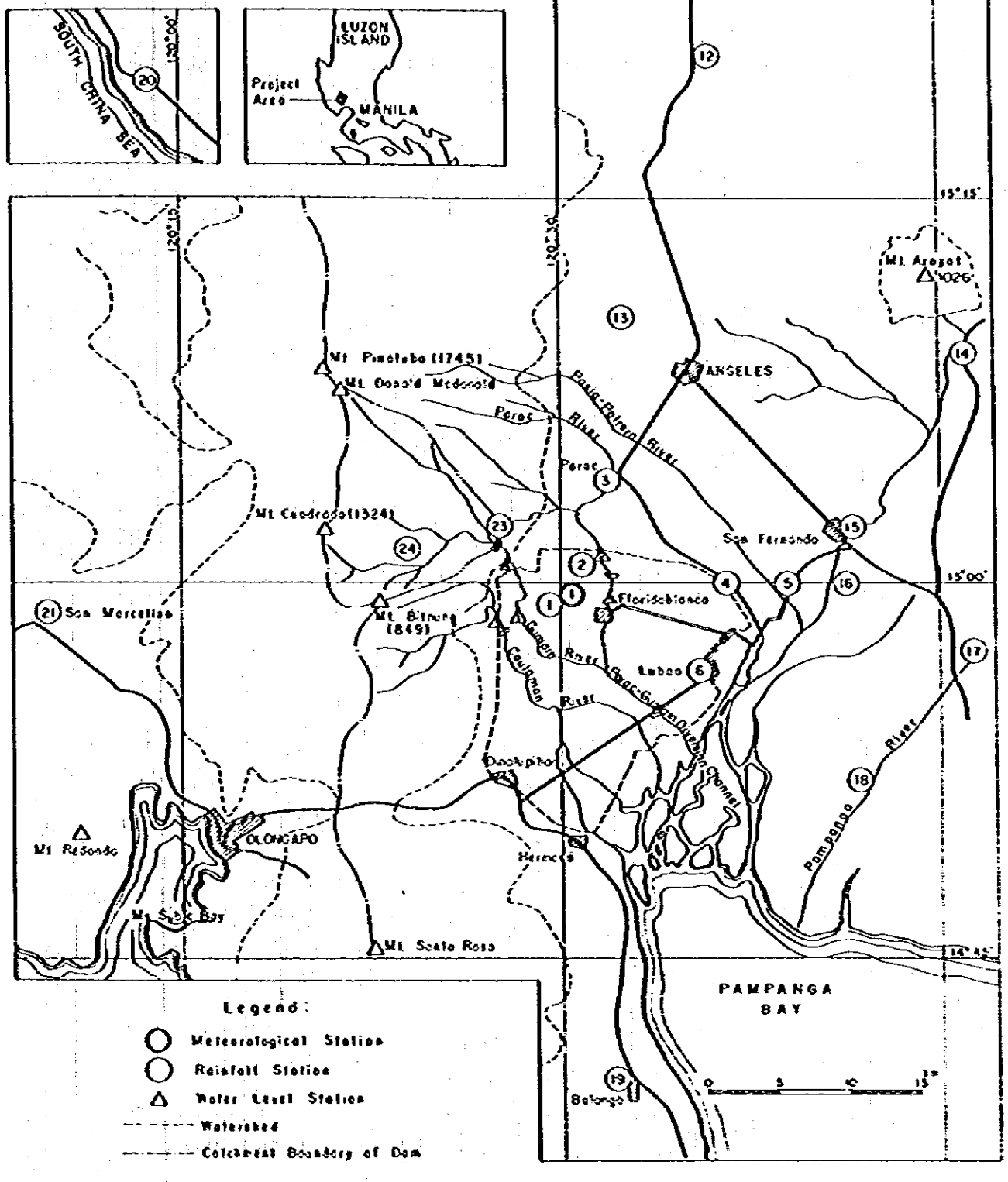


Fig. 1.6 METEOROLOGICAL CHARACTERISTICS

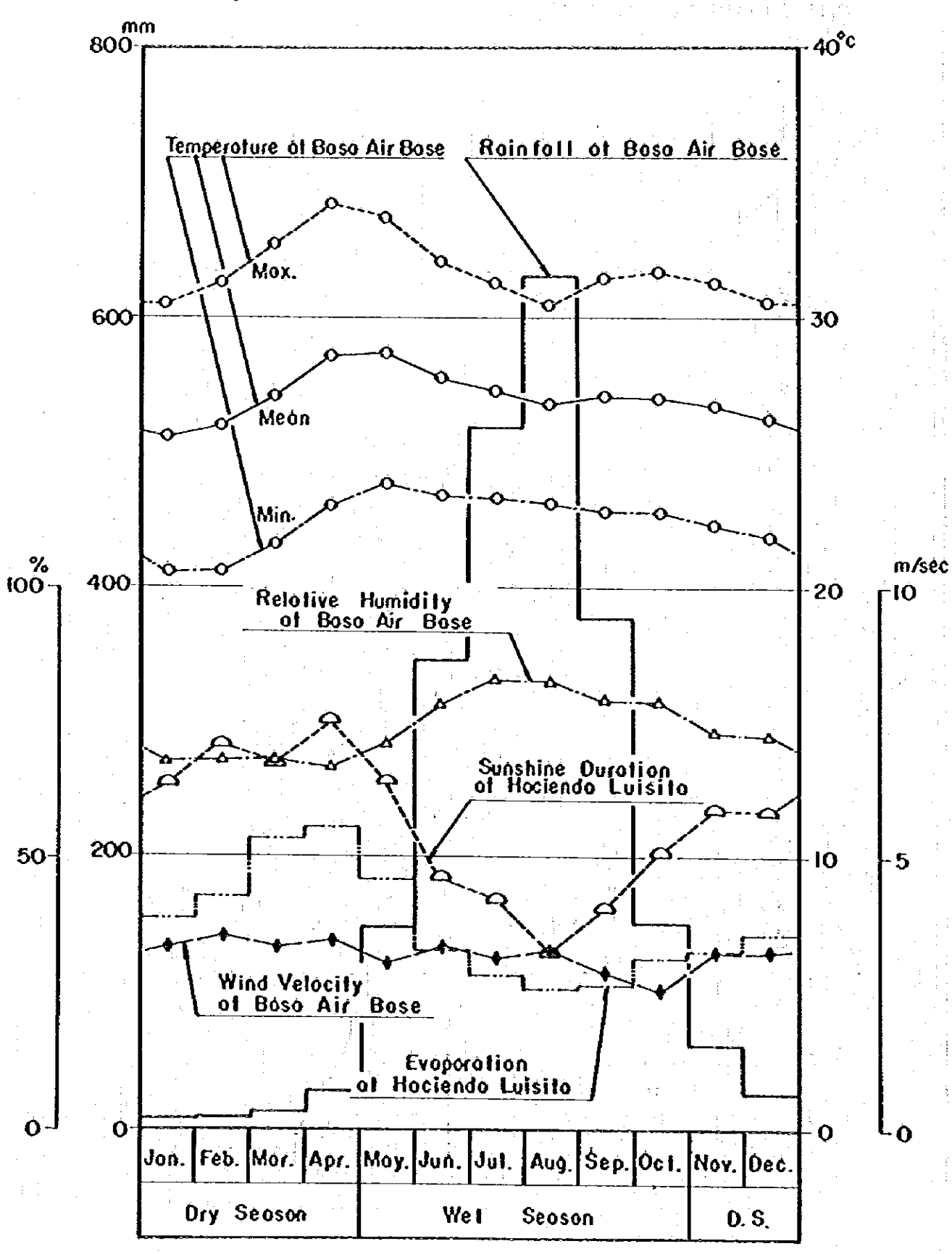


Fig.I.7 LOCATION MAP OF INSTALLED RAINFALL AND WATER LEVEL GAUGES

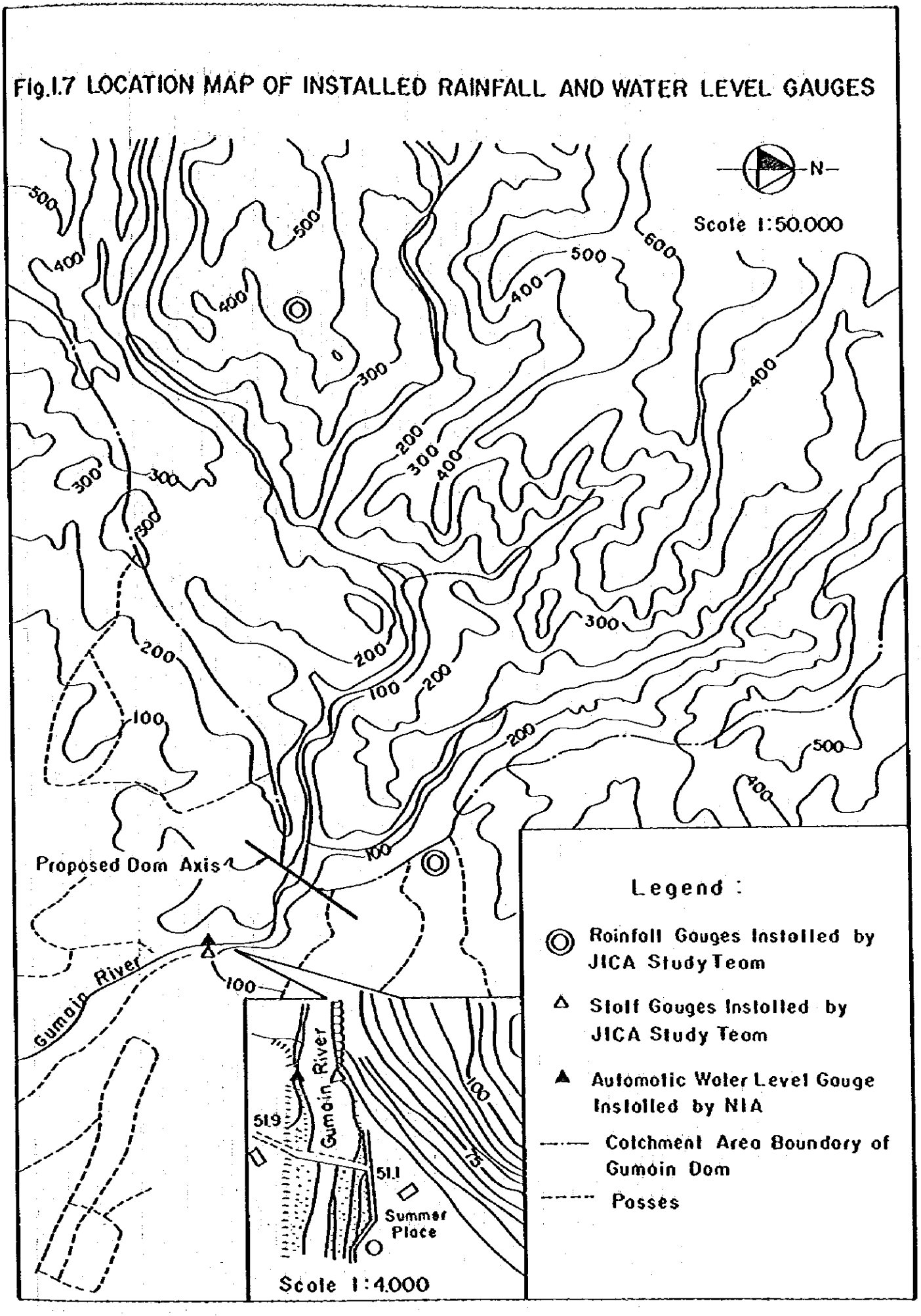


FIG. I.8 AVAILABLE RECORDS OF RAINFALL

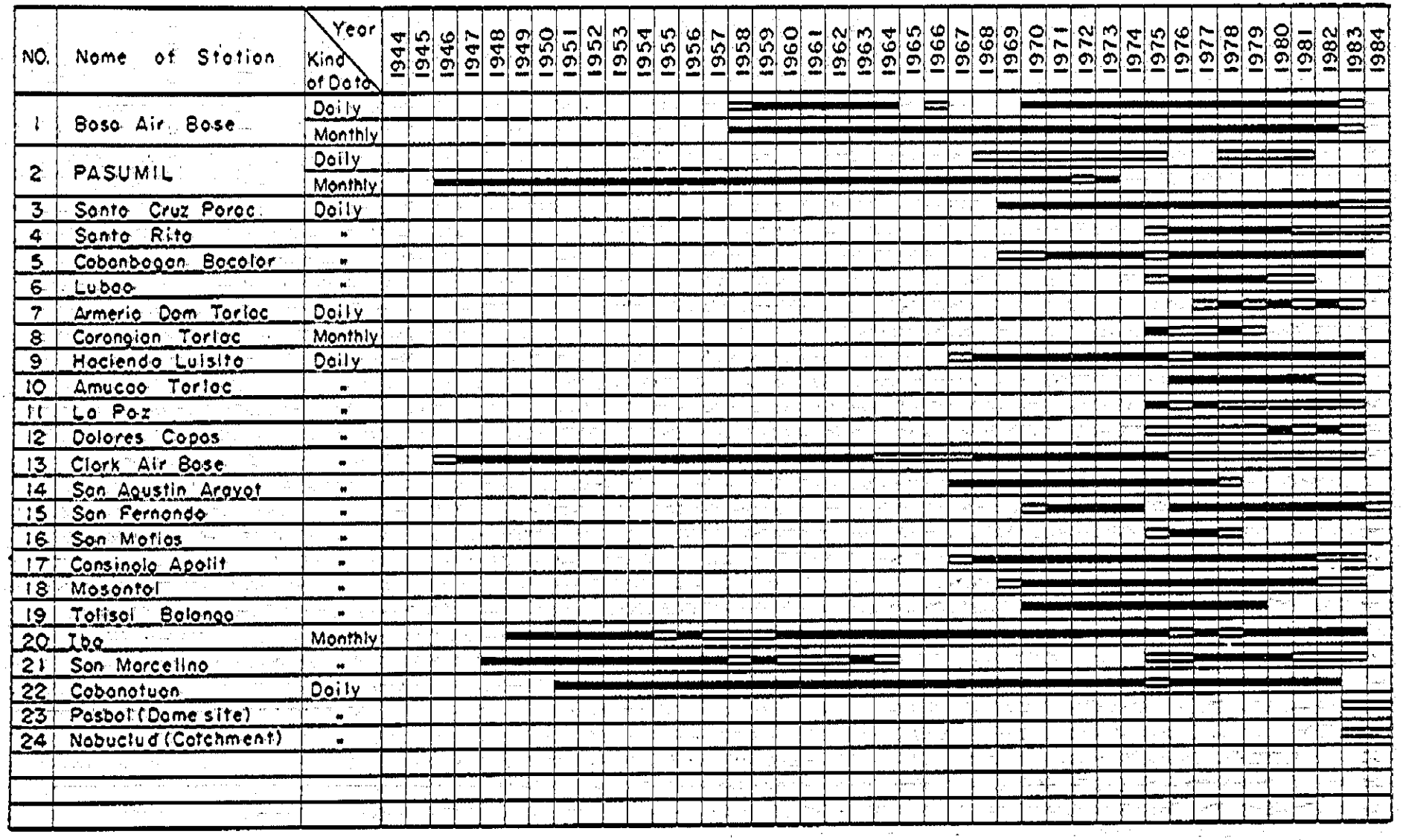


Fig. 1.9 (1) PATTERN OF MEAN MONTHLY RAINFALL

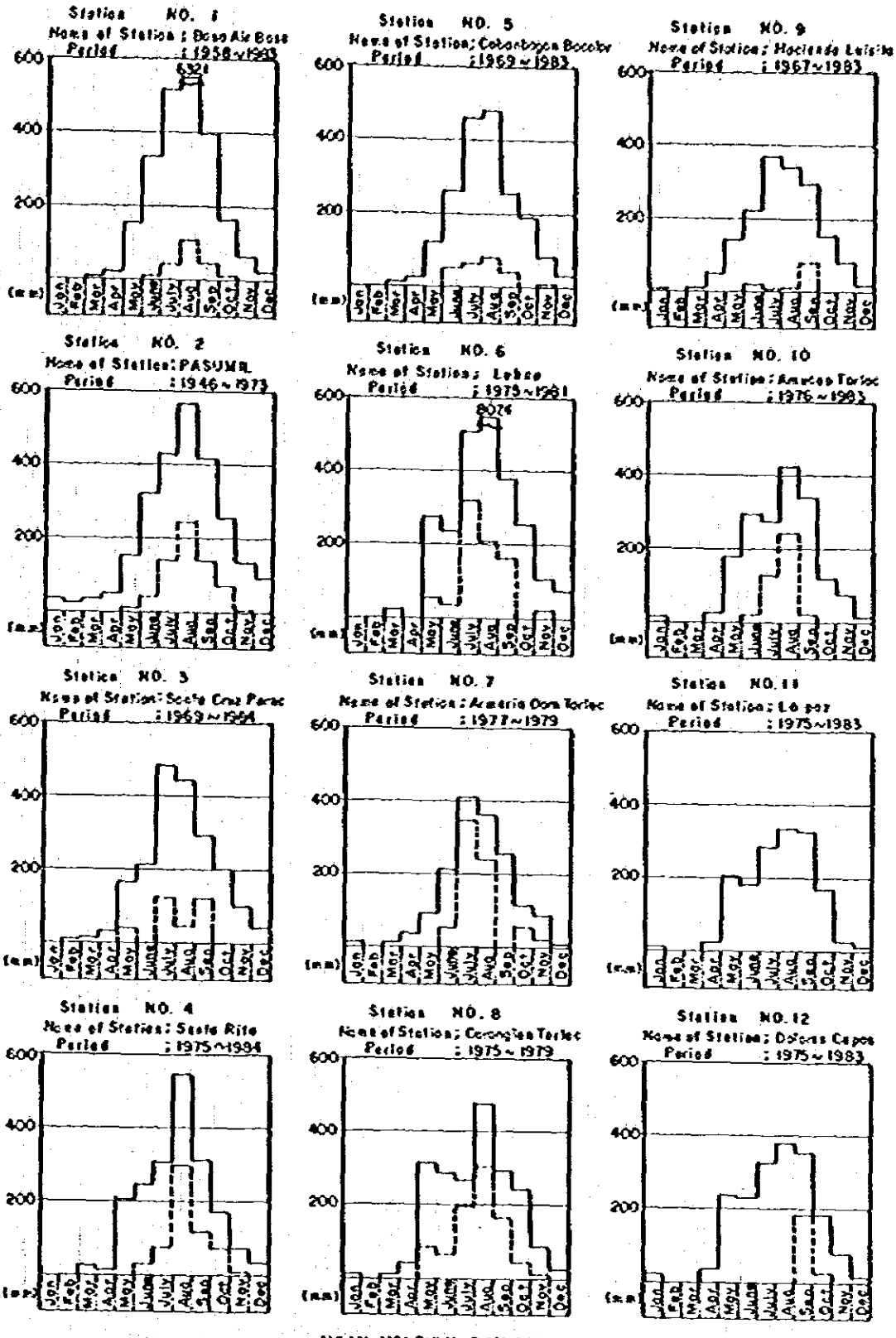


Fig. 1.9 (2) PATTERN OF MEAN MONTHLY RAINFALL

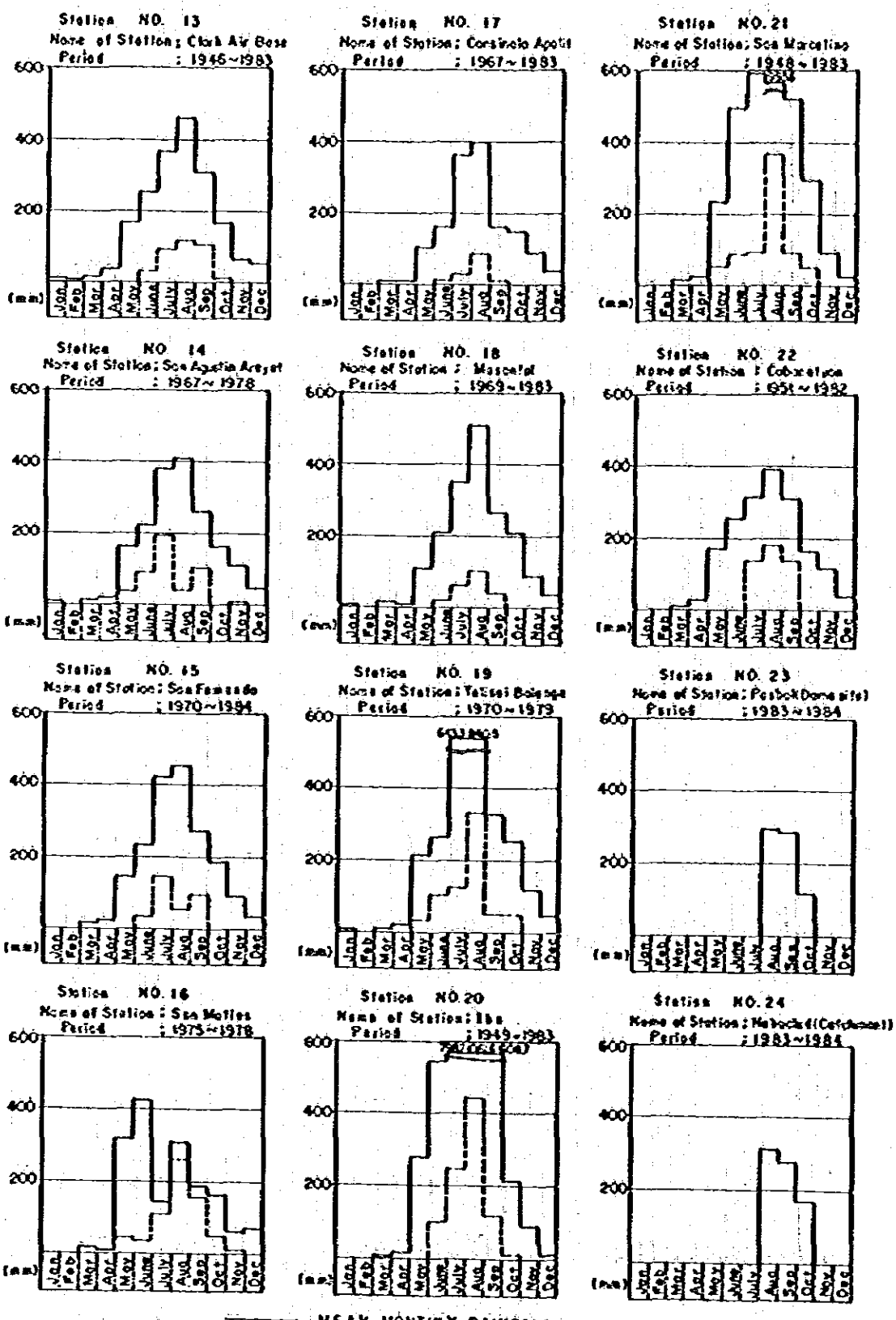


Fig.1.10 AVAILABLE PERIOD FOR WATER LEVEL AND DISCHARGE RECORDS

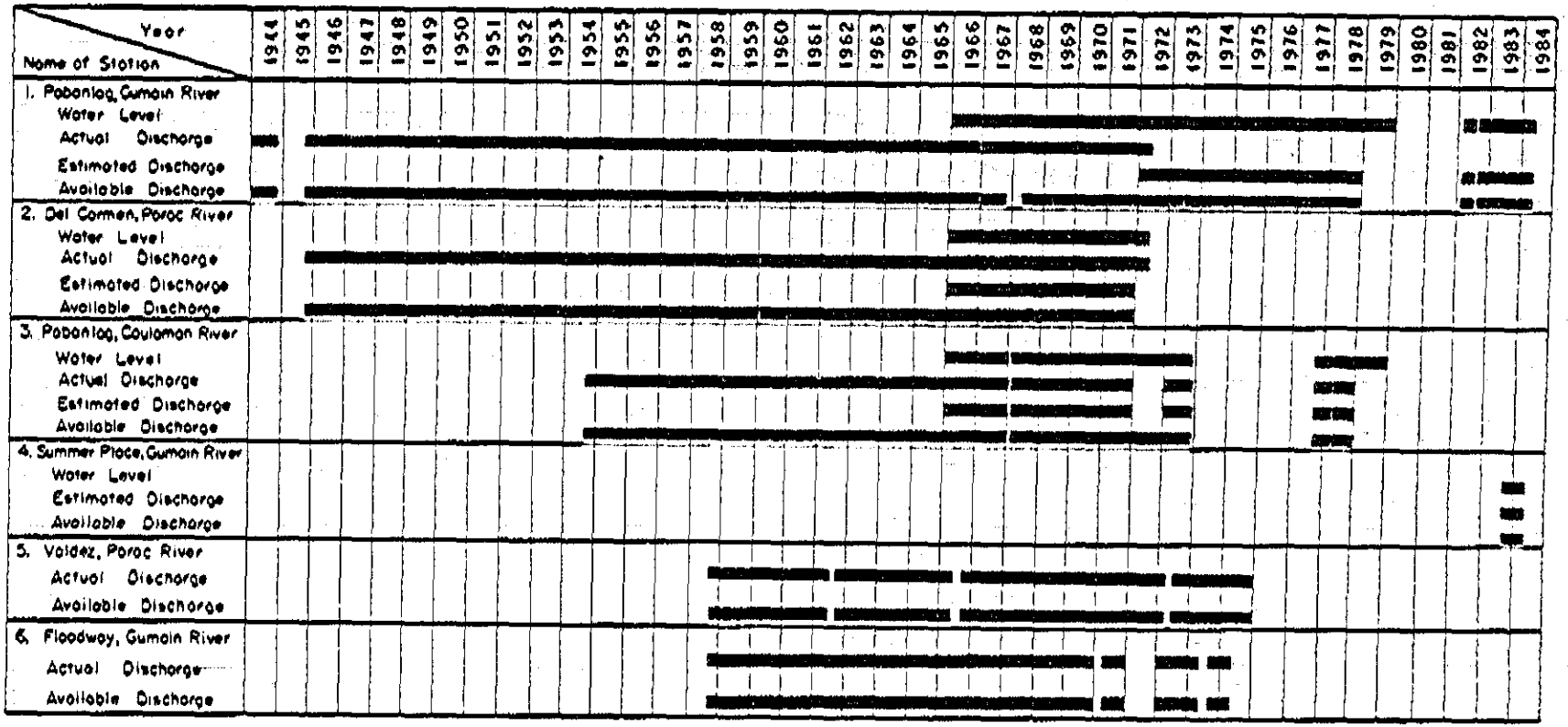
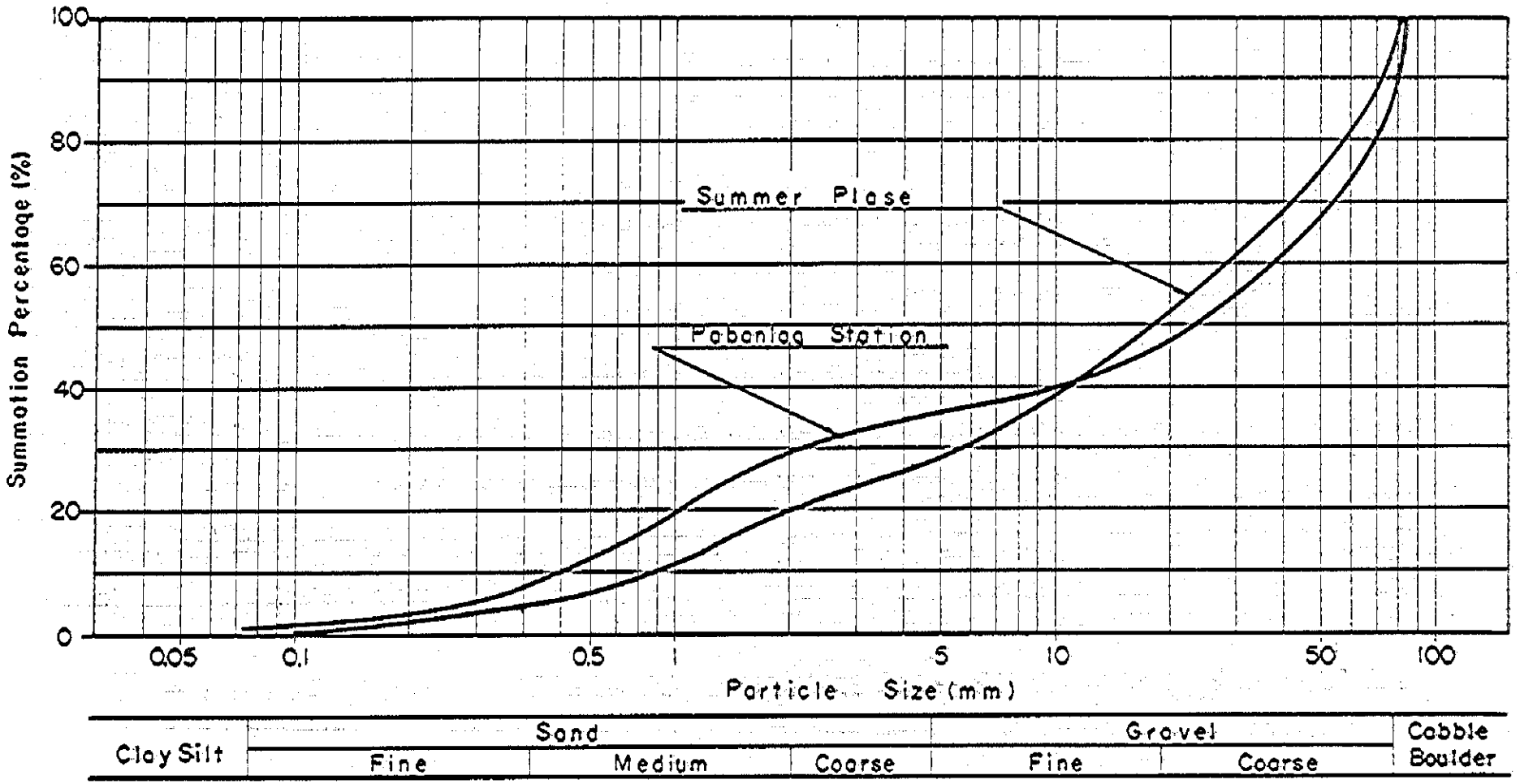
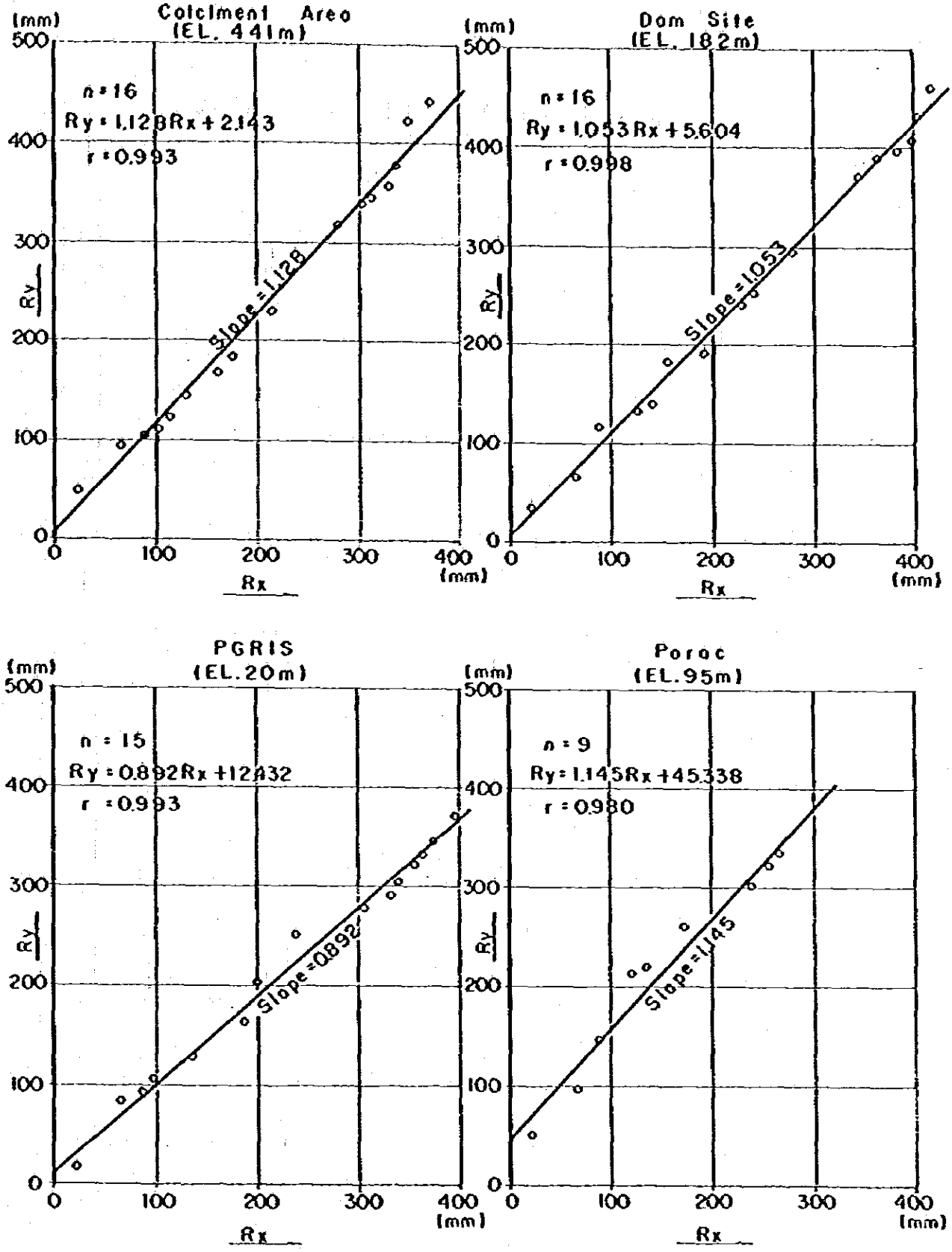


Fig. I.11 GRAIN SIZE ANALYSIS ON GUMAIN RIVER



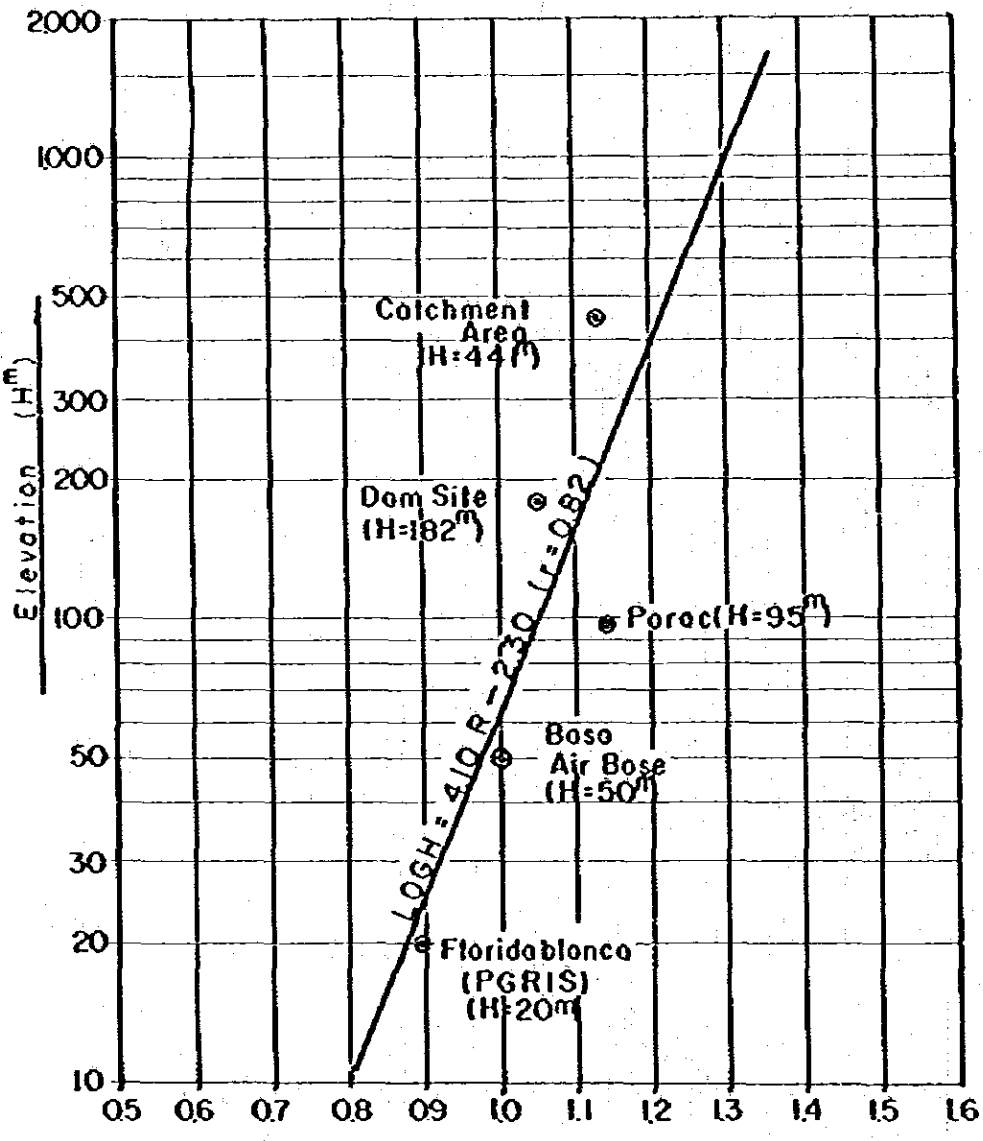
I-5.12

Fig. 1.12 DOUBLE MASS-CURVE ANALYSIS OF DAILY RAINFALL



Remarks: Rx : Accumlated Daily Rainfall (R≧5mm) at Base Air Base
Ry : Accumlated Daily Rainfall (R≧5mm) at Other Station

Fig. 1.13 ELEVATION V.S RATIO



Remarks: Ratio Shows Slope of Segment in Double Moss-Curve

Fig.II4 DOUBLE MASS-CURVE FOR RAINFALLS AT BASA AIR BASE AND OTHER STATIONS

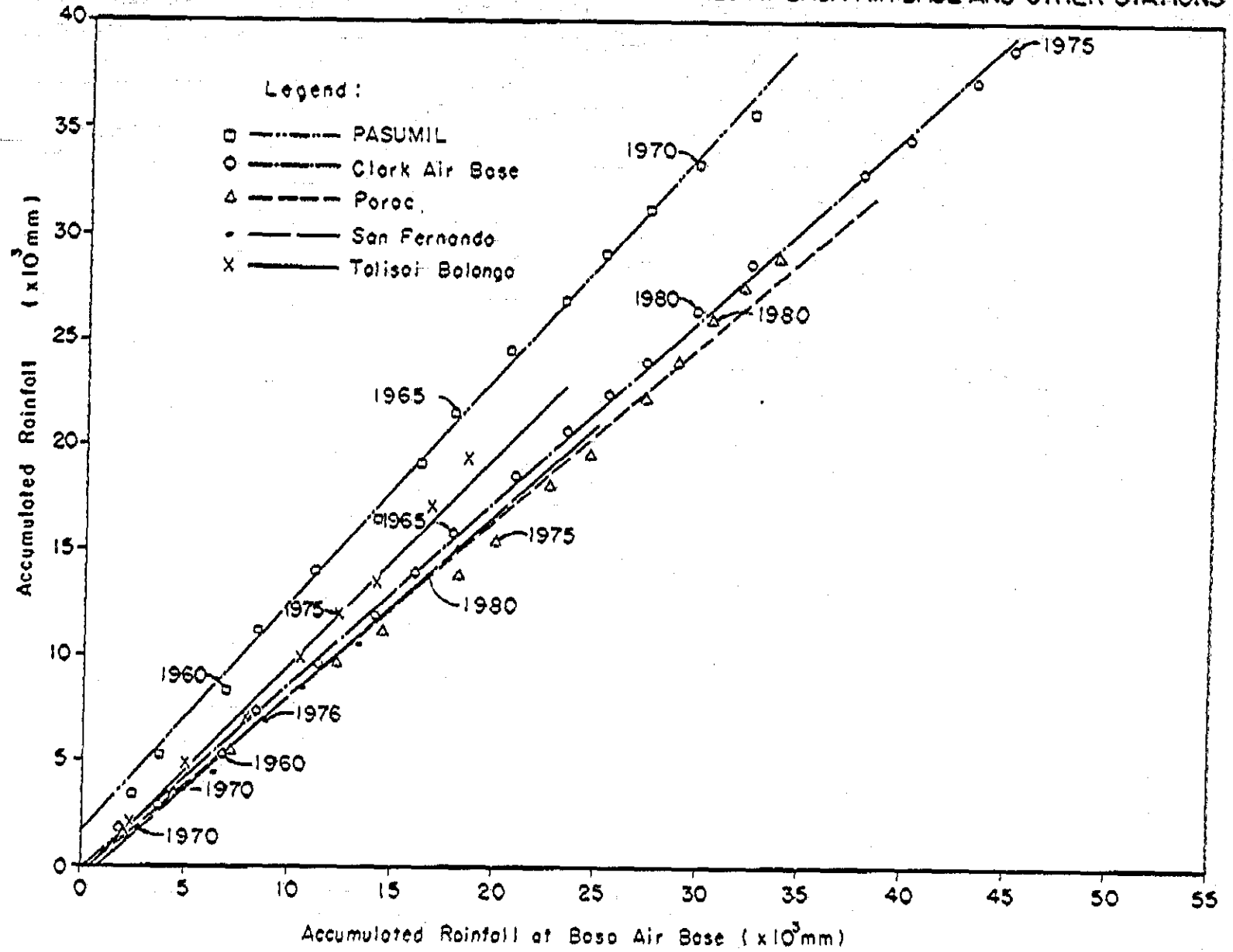


Fig. 1.15 ISOHYETAL MAP IN THE STUDY AREA

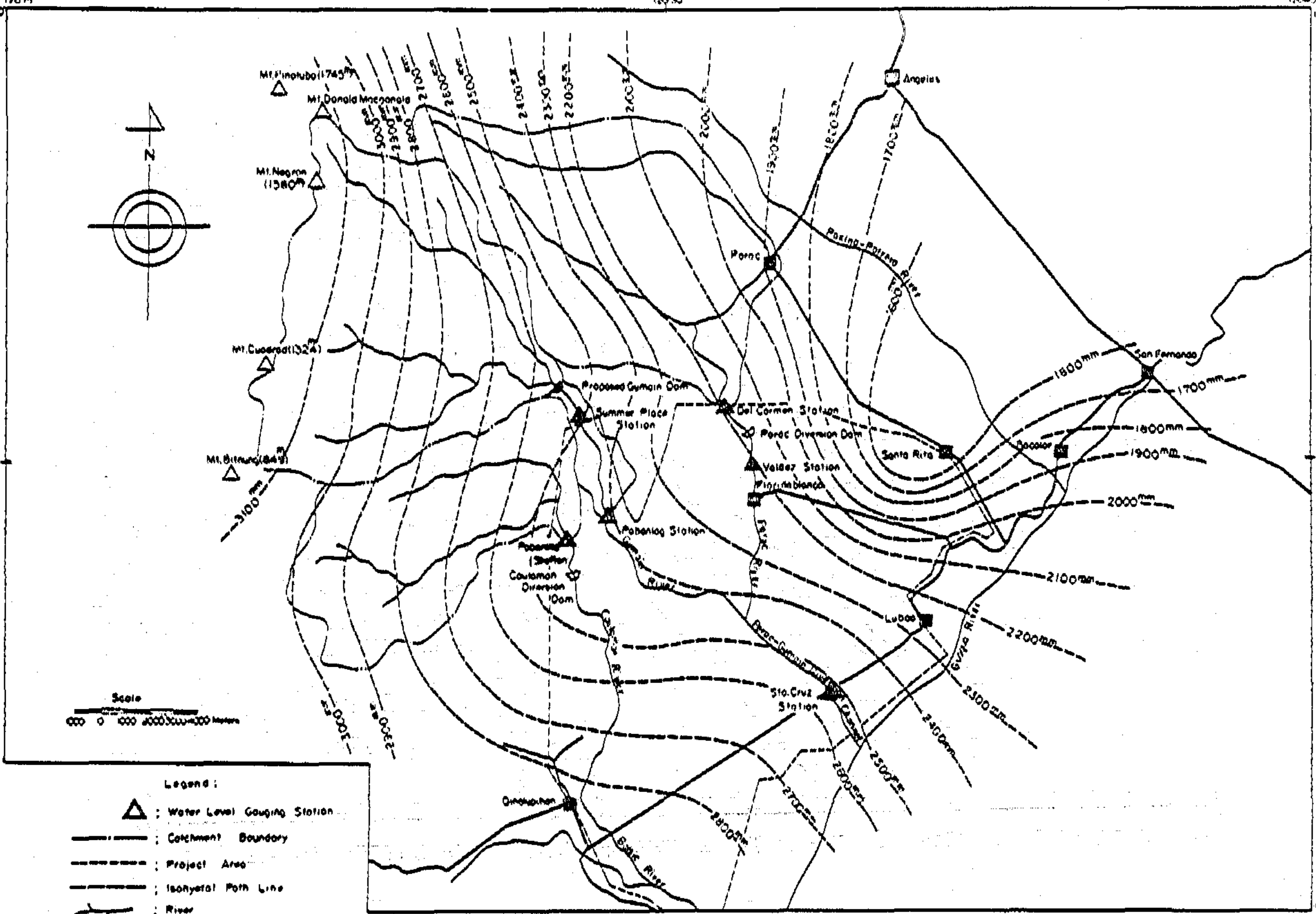
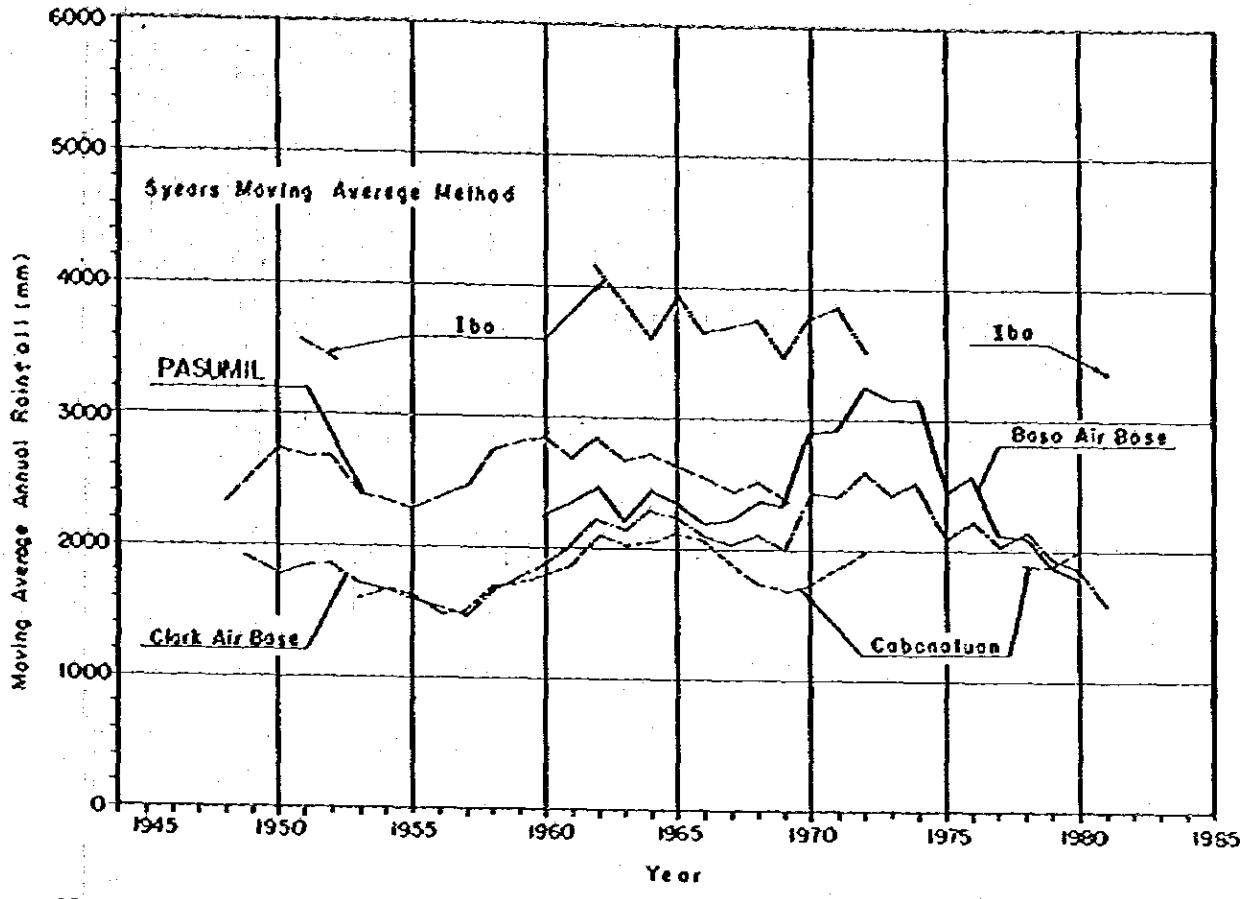


Fig. I. 16 FLUCTUATION OF ANNUAL RAINFALL



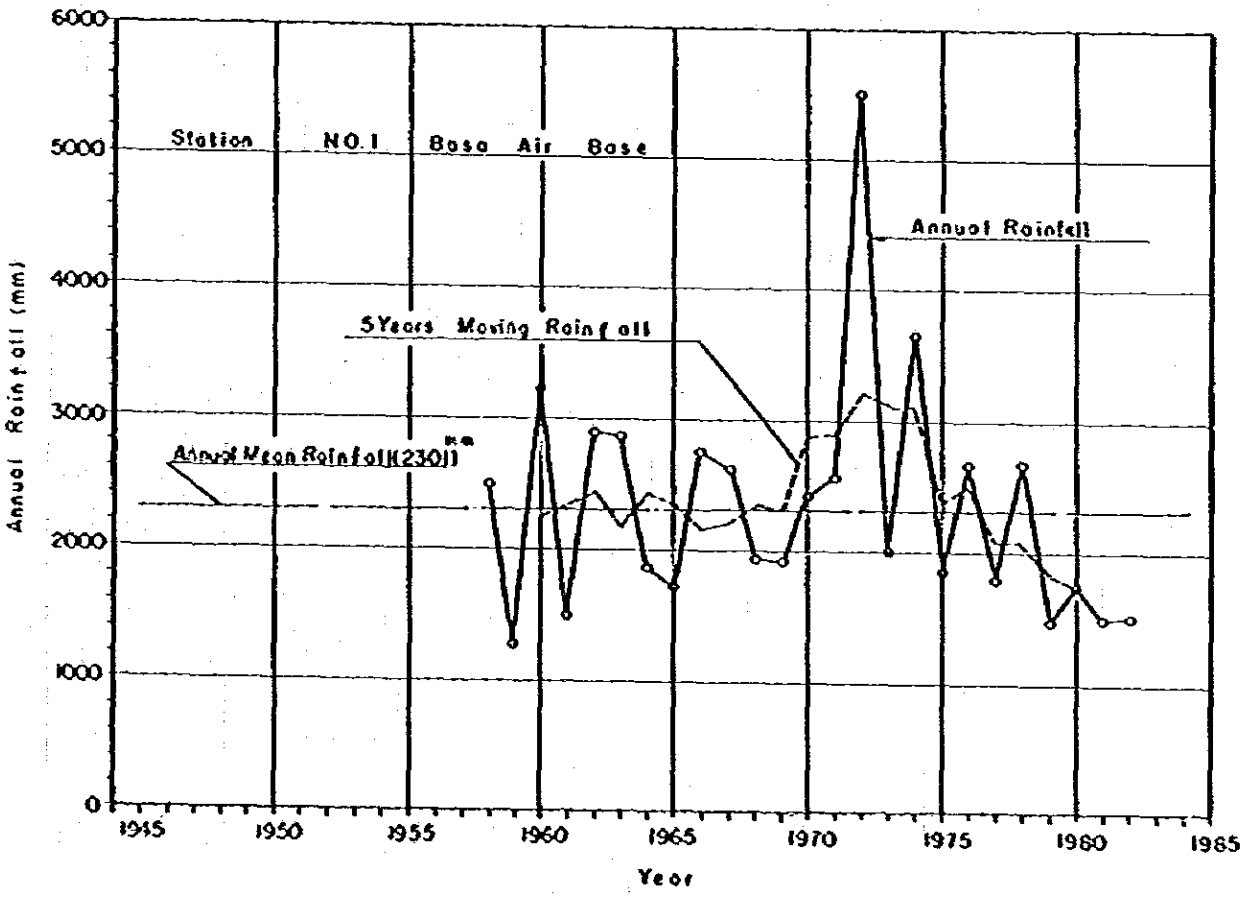
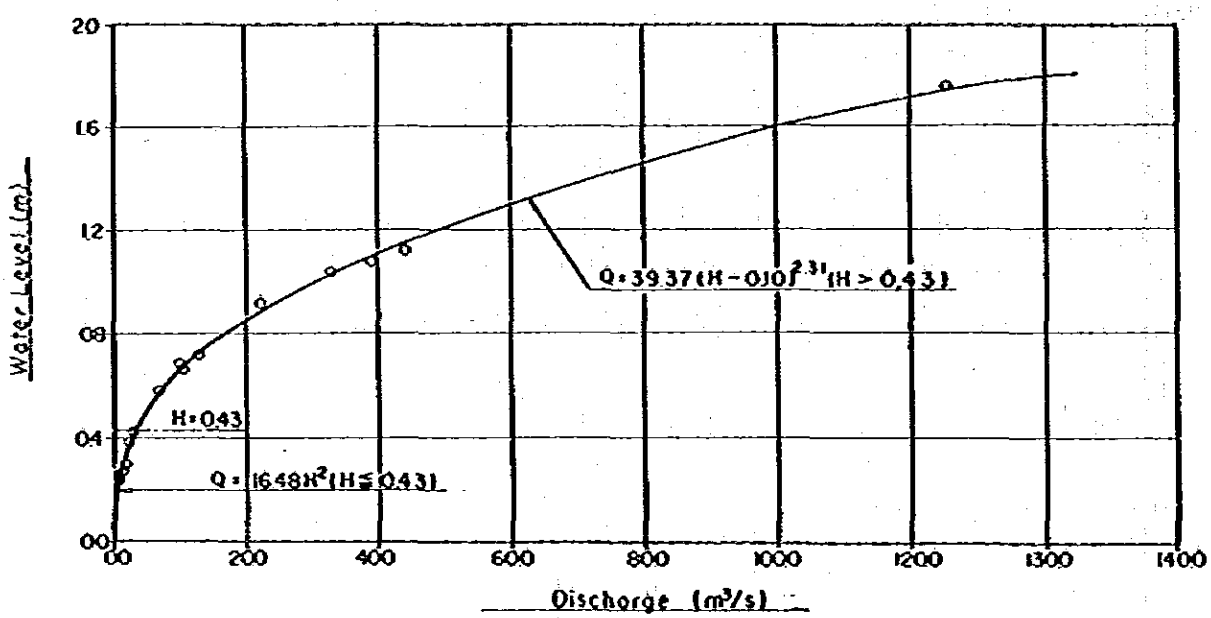


Fig. I.17 RATING CURVE AT SUMMER PLACE STATION IN GUMAIN RIVER

Number	Date	Observed		Calculated	Number	Date	Observed		Calculated
		Gauge Hight (m)	Discharge (m^3/s)	Discharge (m^3/s)			Gauge Hight (m)	Discharge (m^3/s)	Discharge (m^3/s)
1	8-10-83	0.44	3.15	3.26	11	10 12 83	0.72	13.05	13.05
2	8-10-83	0.44	3.16	3.26	12	12-2-83	0.30	1.68	1.48
3	8-11-83	0.58	7.20	7.22	13	2-7-84	0.27	1.18	1.20
4	8-11-83	0.58	7.35	7.22	14	2-14-84	0.27	1.15	1.20
5	8-11-83	0.66	10.48	10.32	15	4-4-84	0.27	1.47	1.20
6	8-12-83	0.92	22.05	24.89	16	6-15-84	0.38	2.62	2.38
7	8-12-83	1.04	32.76	34.13	17	6-20-84	0.68	10.09	11.19
8	8-12-83	1.11	43.99	40.29					
9	8-16-83	1.76	125.69	126.95					
10	8-28-83	1.08	39.56	37.57					



RIVER CROSS SECTION

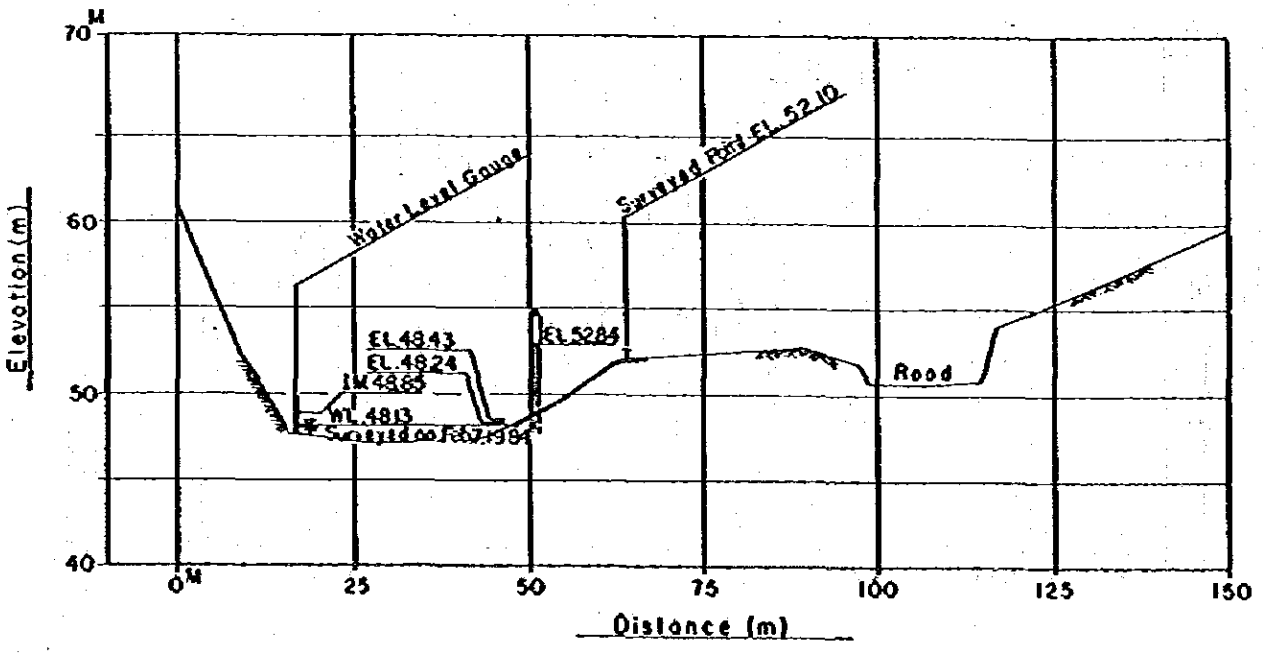
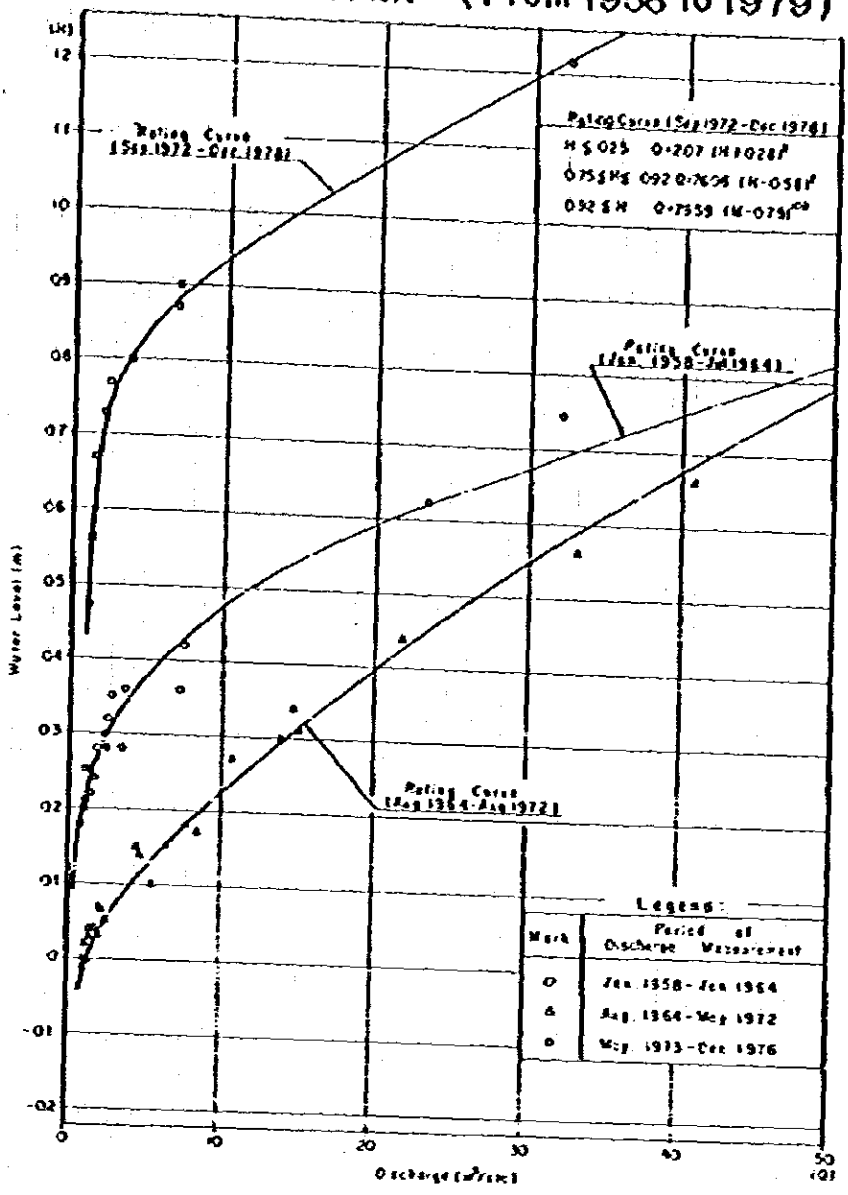


Fig. 1. 18 RATING CURVE AT PABANLAG STATION IN GUMAIN RIVER (From 1958 to 1979)



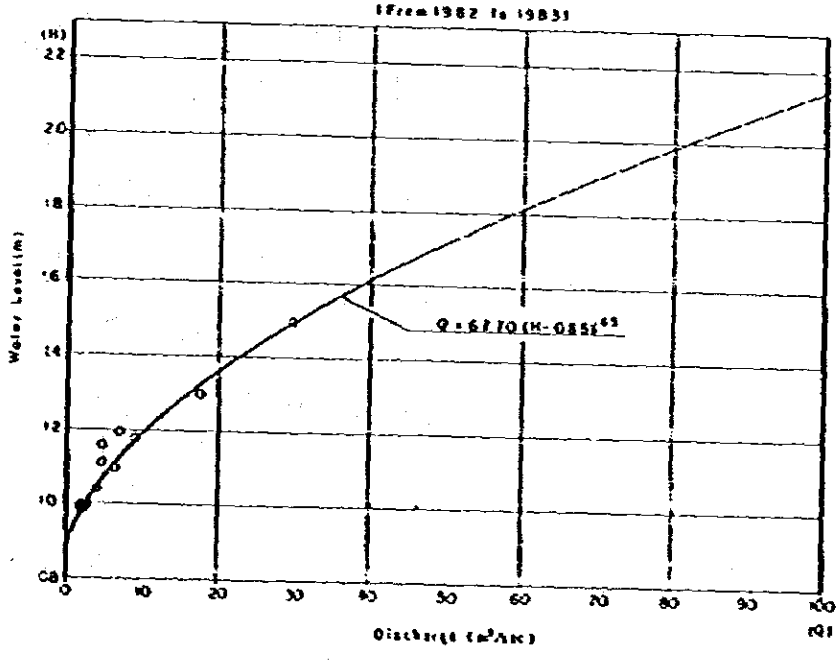


Fig. I.19 RATING CURVE AT DEL CARMEN STATION IN PORAC RIVER

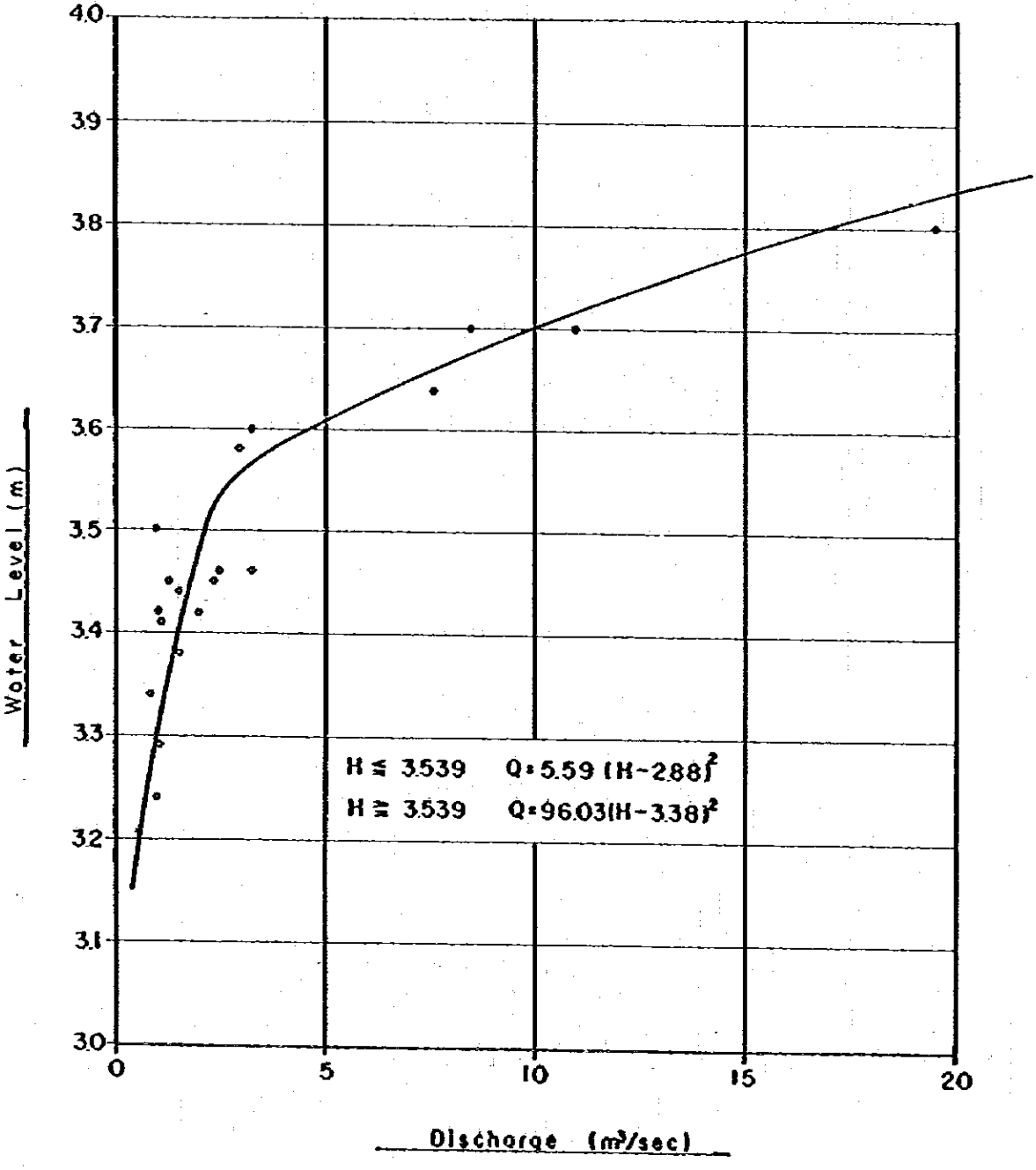
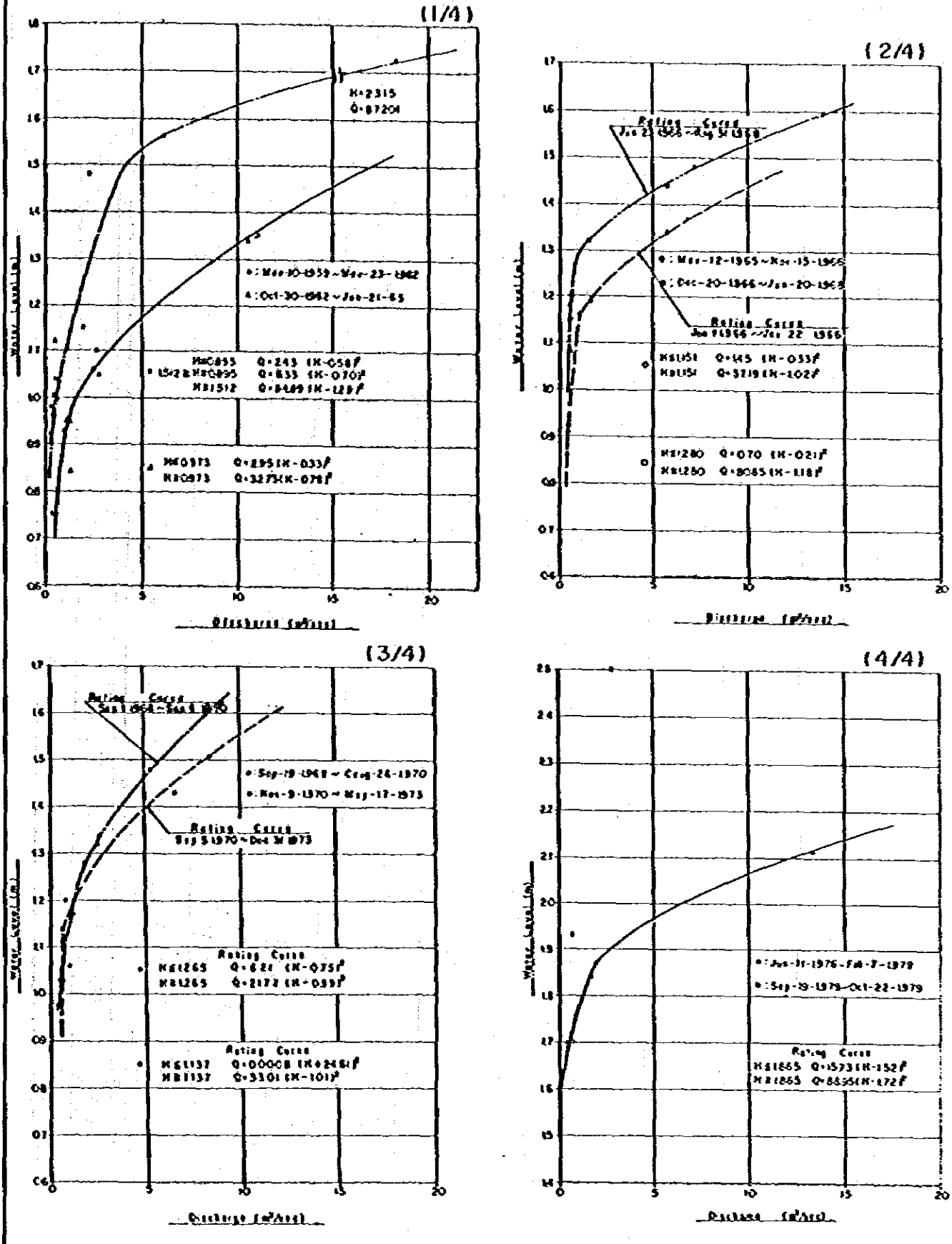


Fig.I.20 RATING CURVE AT PABANLAG STATION IN CAULAMAN RIVER



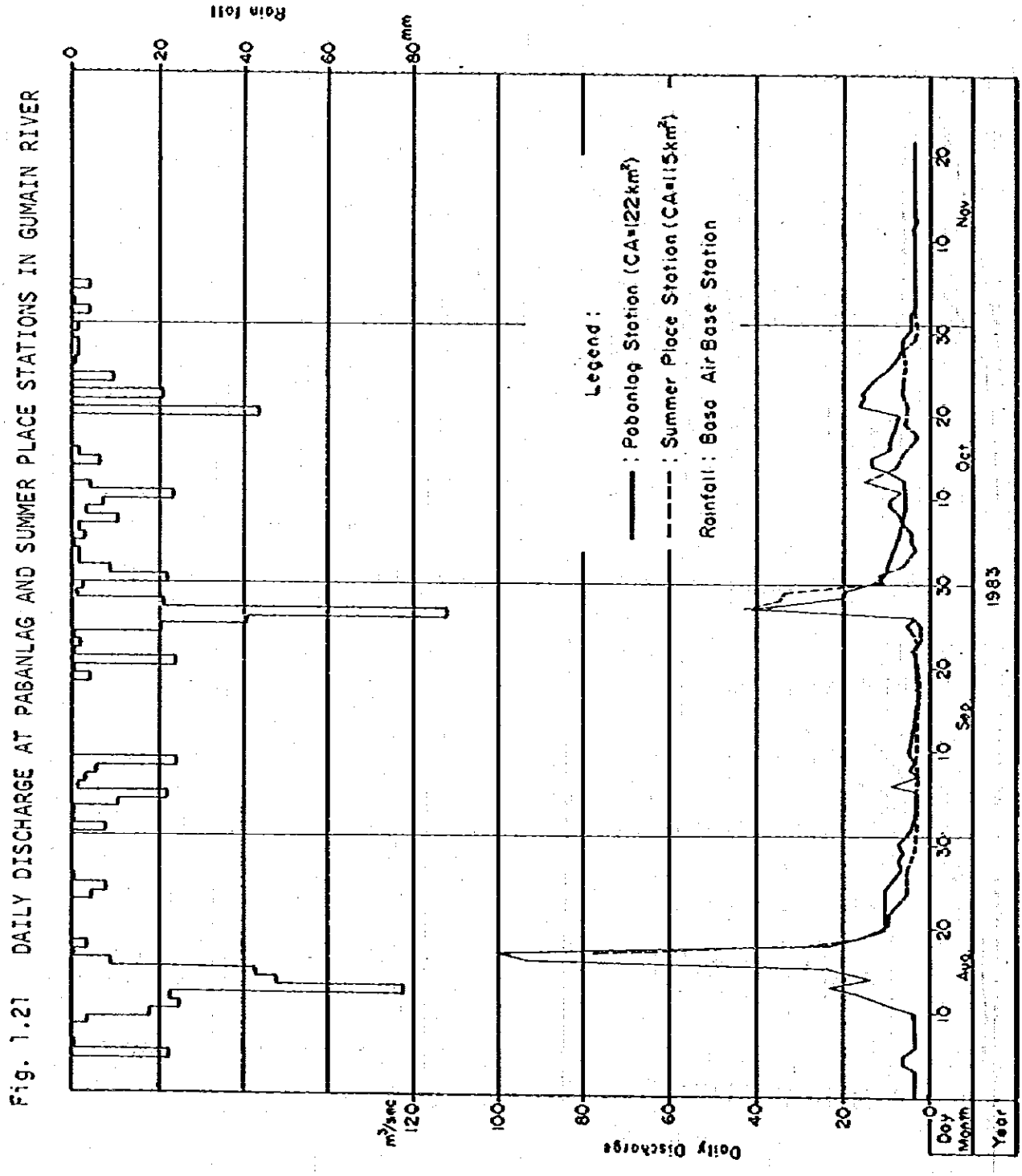


Fig. 1.21 DAILY DISCHARGE AT PABANLAG AND SUMMER PLACE STATIONS IN GUMAIN RIVER

Fig. I.22 DOUBLE MASS-CURVE FOR RUNOFFS OF GUMAIN, PORAC AND CAULAMAN RIVERS AND RAINFALLS AT BASA AIR BASE

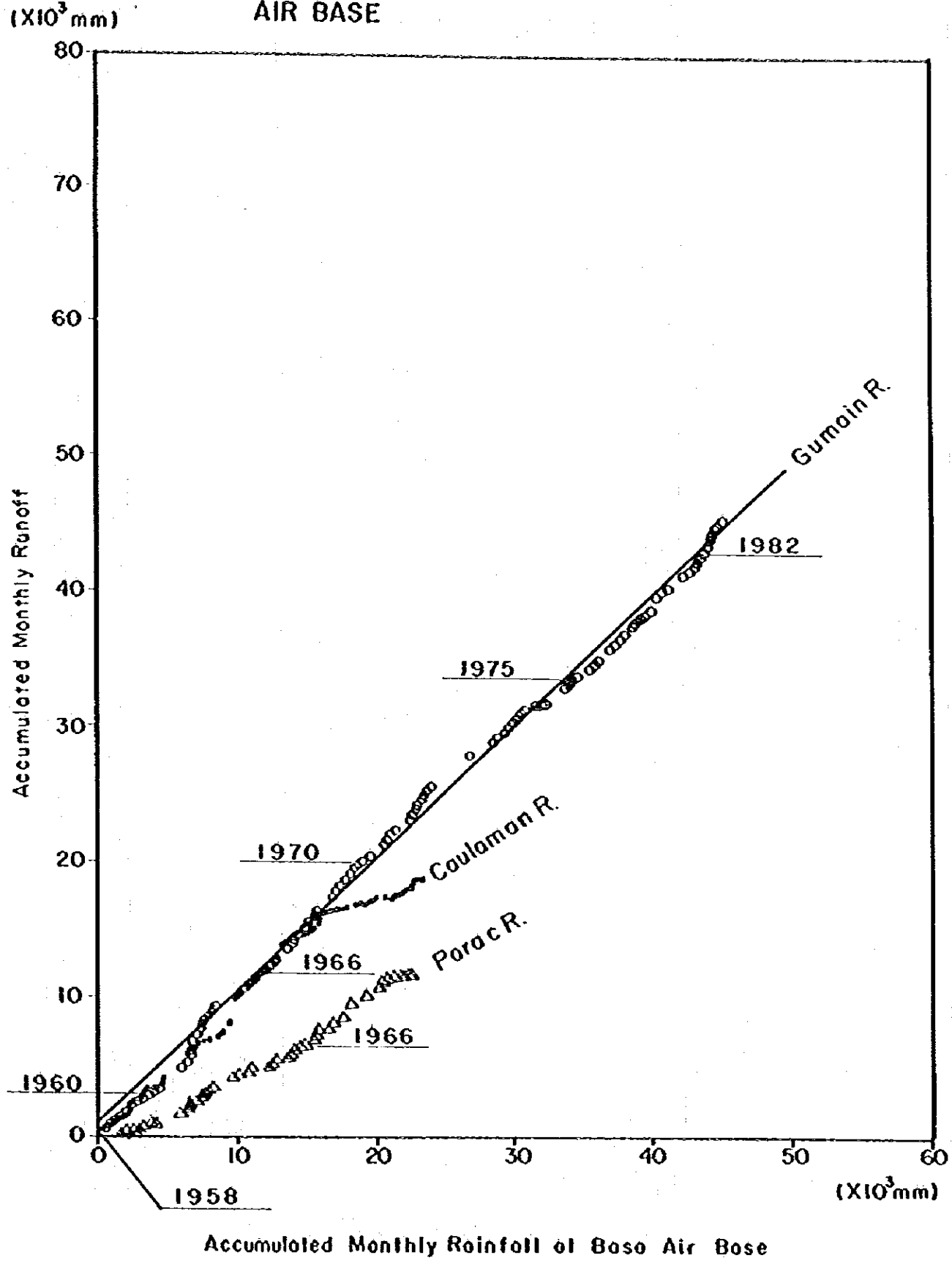
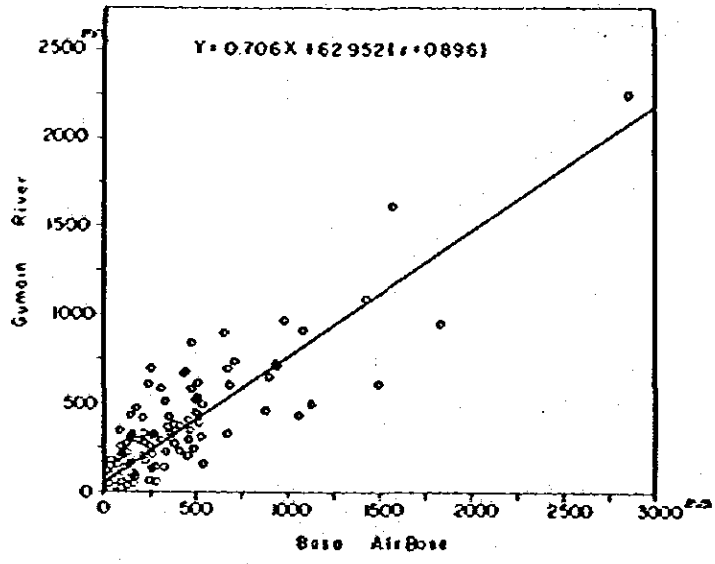
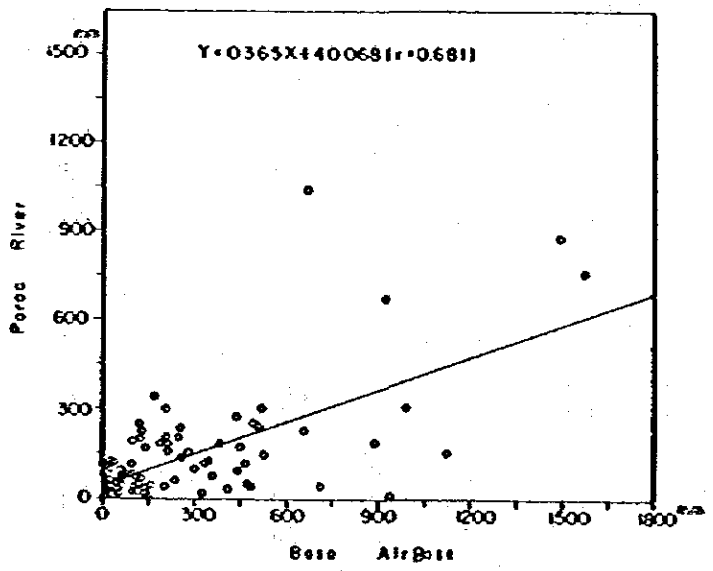


Fig. 1.23 MONTHLY RAINFALL-DISCHARGE RELATION





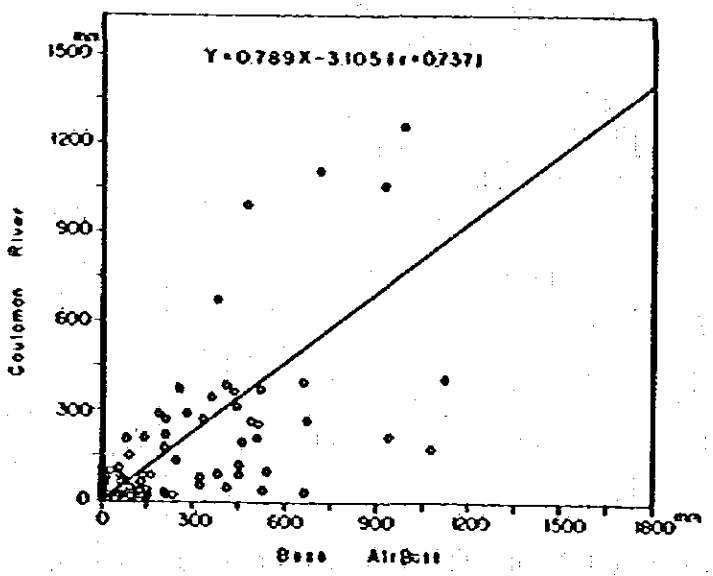
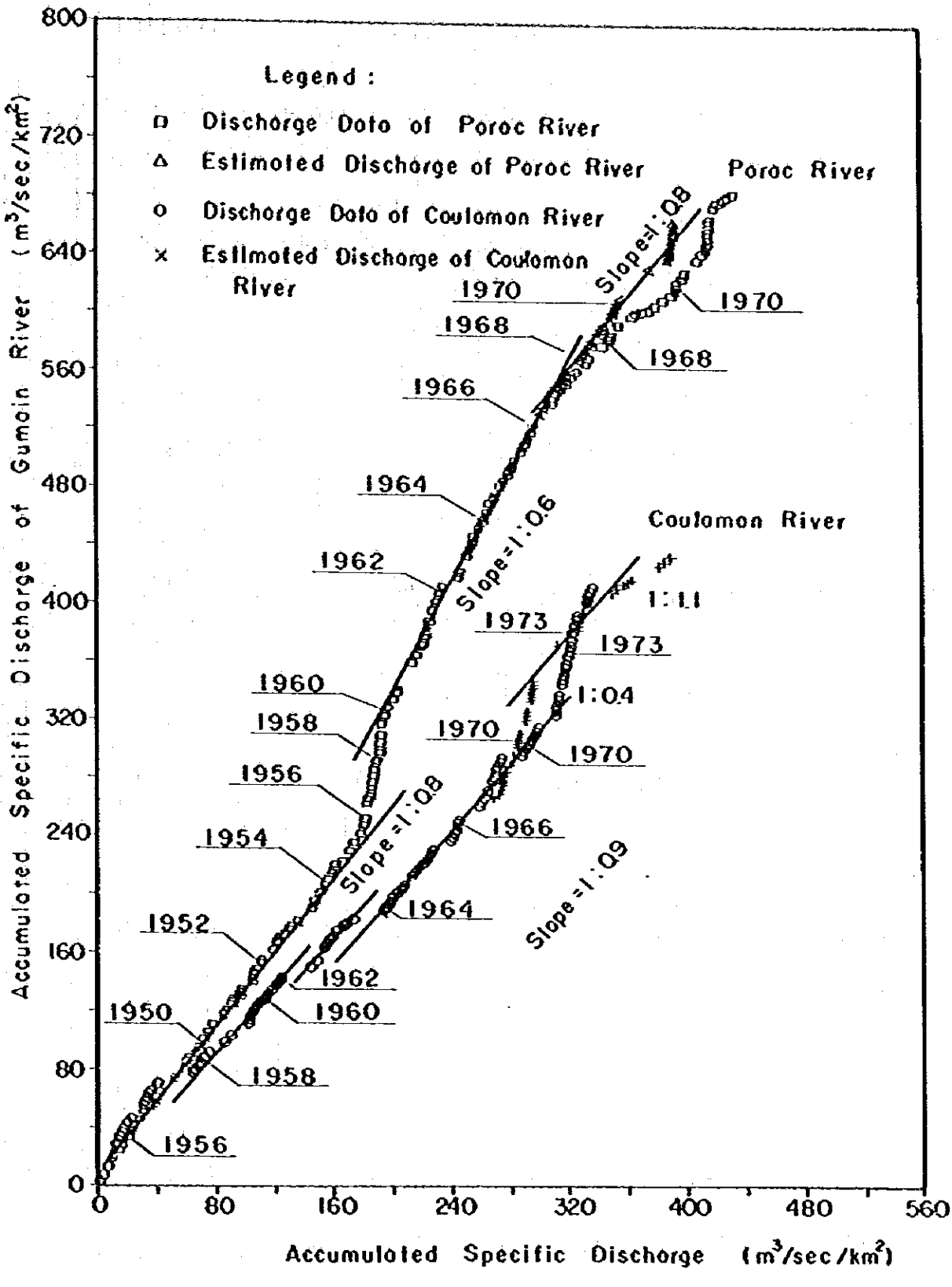


Fig. I.24 DOUBLE MASS-CURVE FOR DISCHARGES OF GUMAIN, PORAC AND CAULAMAN RIVERS



Remerks: Samples are Monthly Rainfalls.

Fig. 125 COMPARISON OF SIMULATED AND OBSERVED 10-DAY DISCHARGES AT PABANLAG STATION IN GUMAIN RIVER

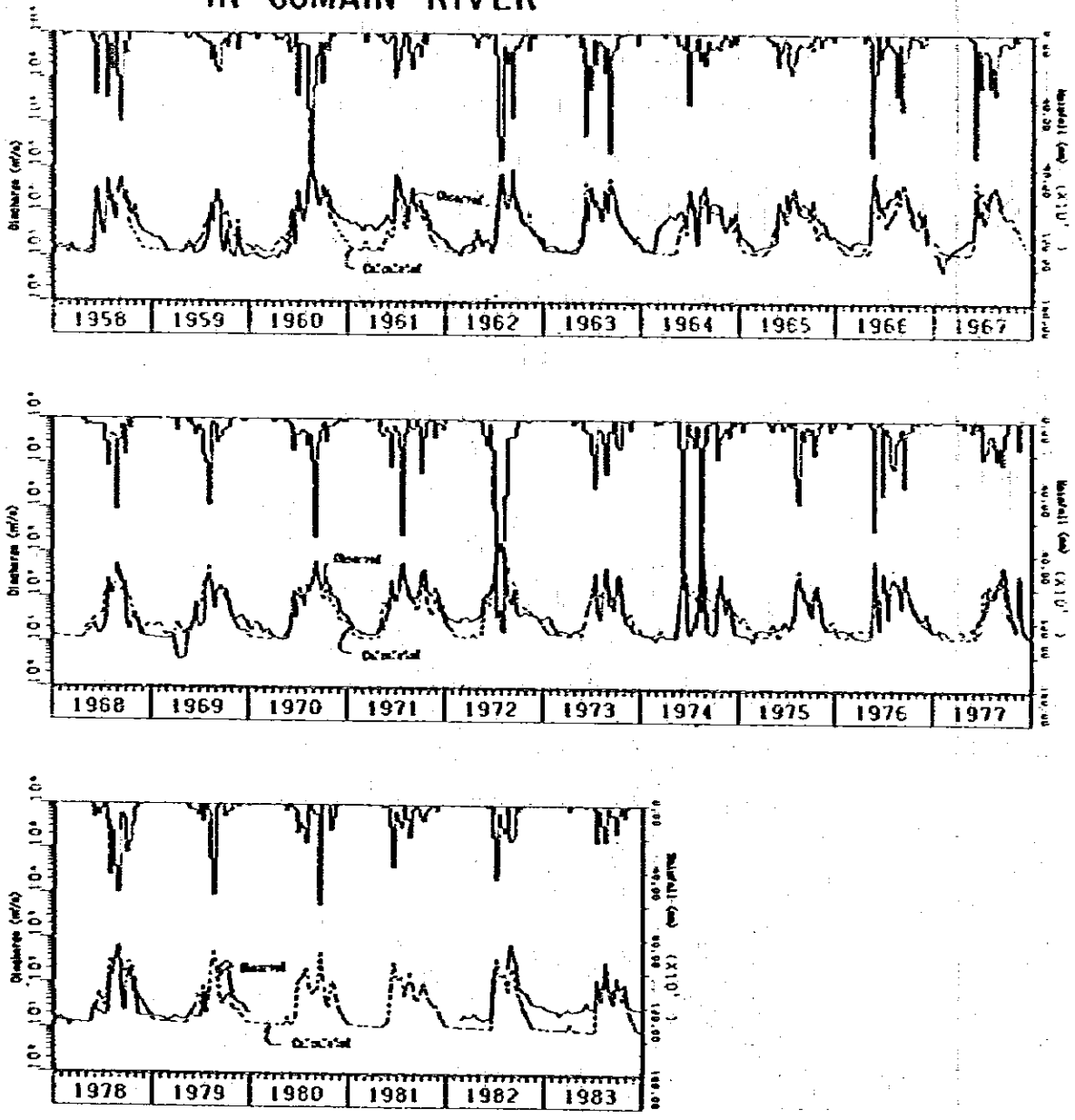


Fig. 1.26 PROBABLE RAINFALL AT BASA AIR BASE

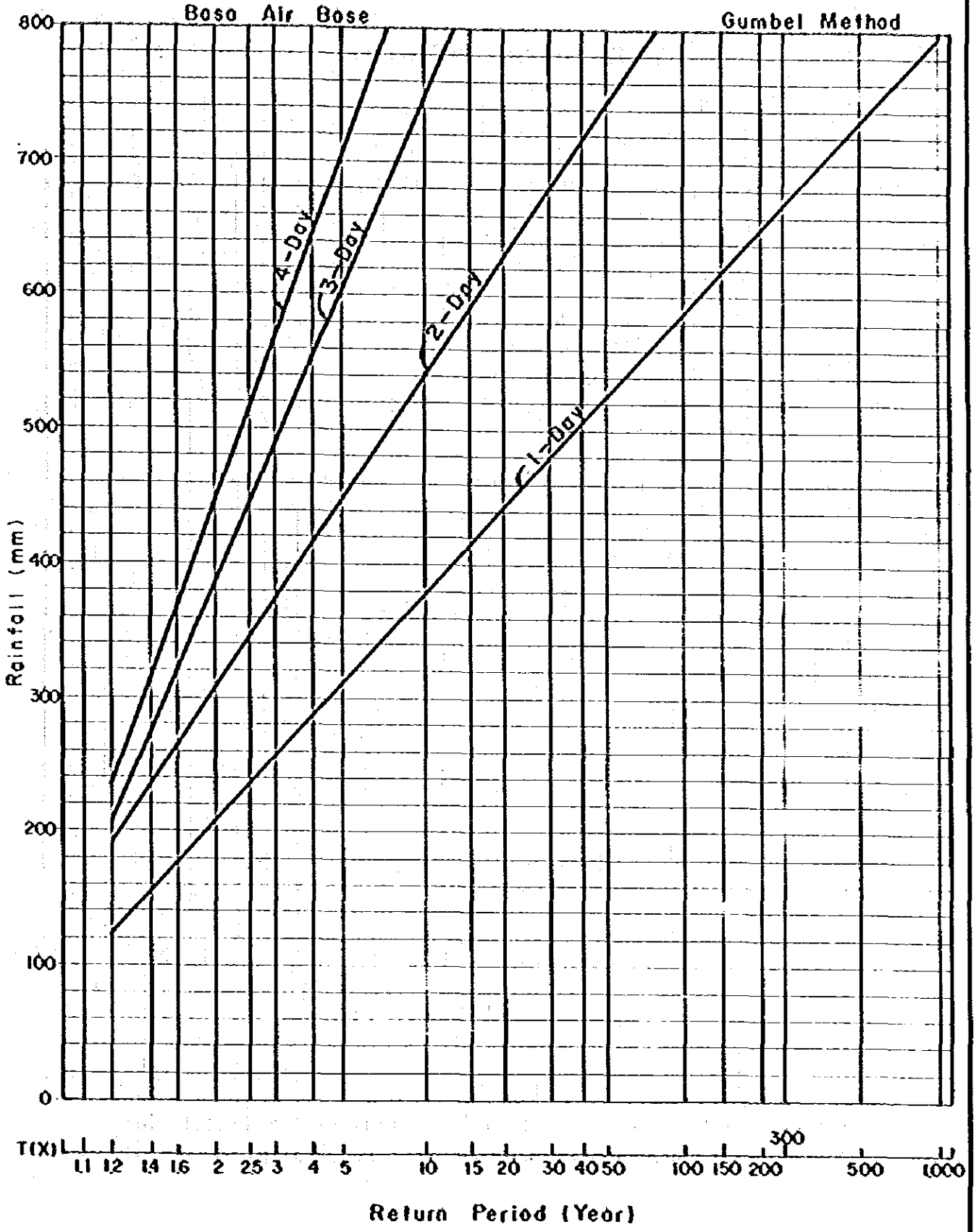
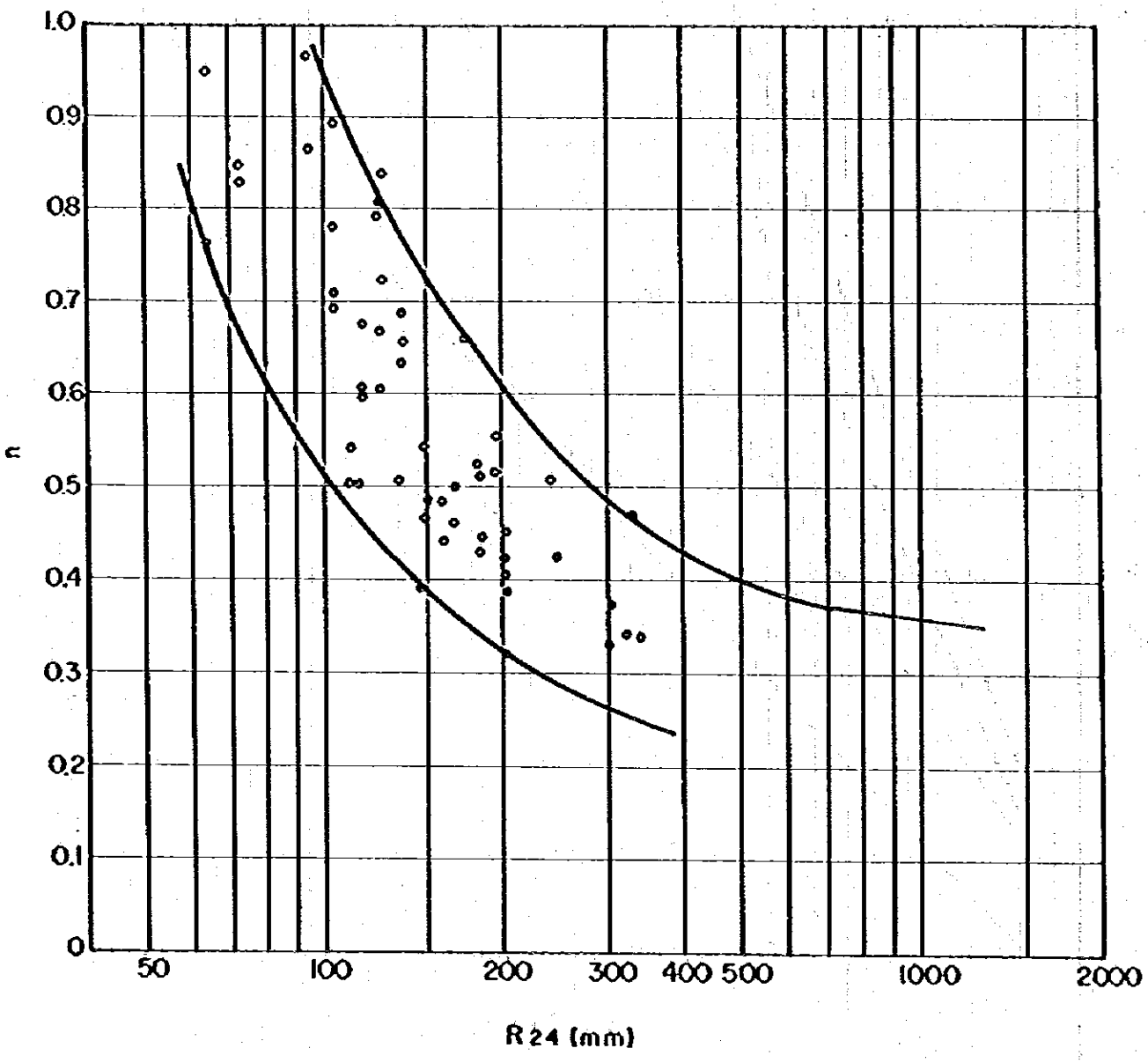


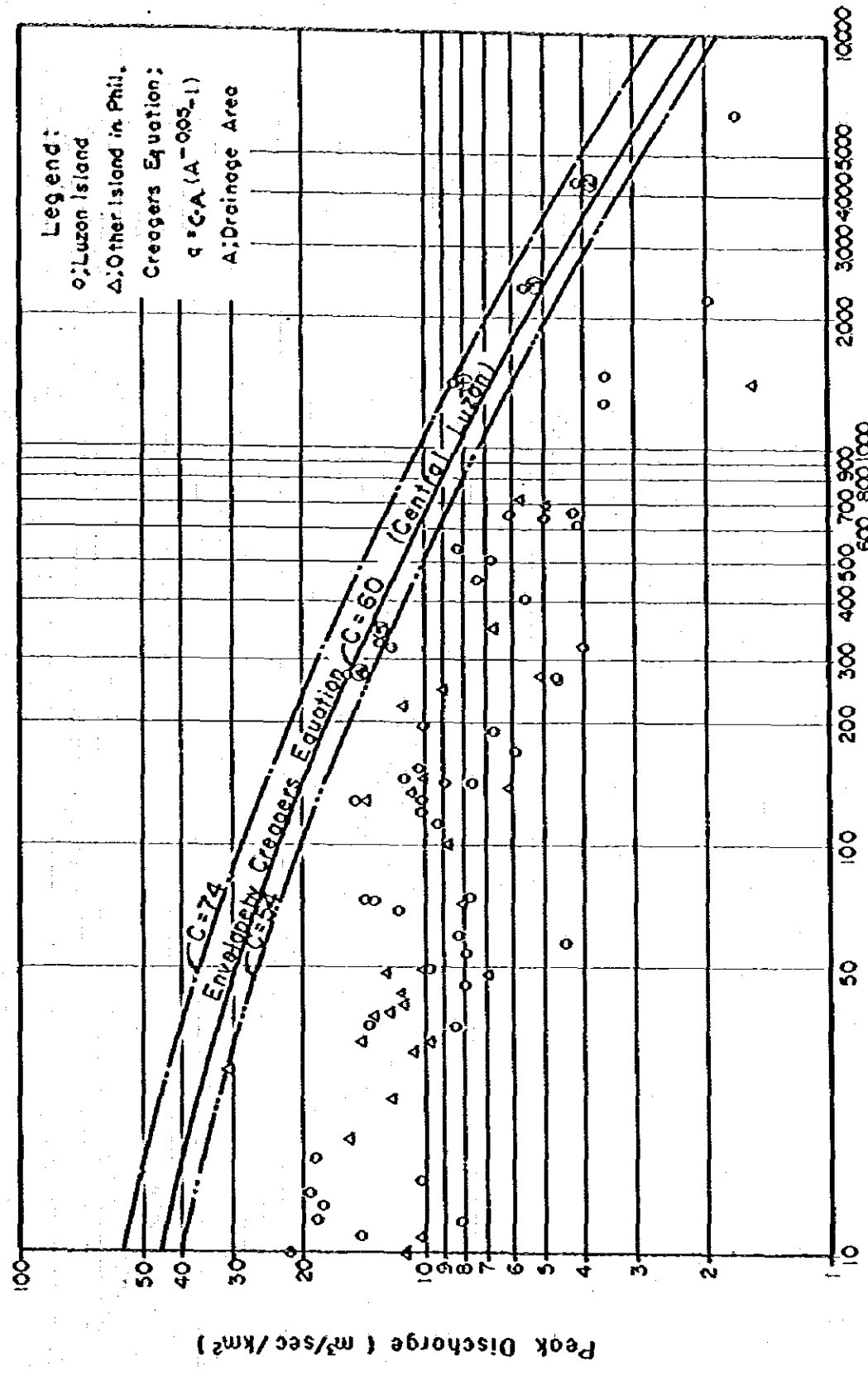
Fig. I.27 RELATION BETWEEN "n" and "R_{24}"



Notes; Plotting Position is on the Basis of the Calculation

$n = \text{Log}\,(24R_1/R_{24}) / \text{Log}\,(24/t)$

Fig. I.28 UNUSUAL FLOOD IN PHILIPPINES AS OF 1969



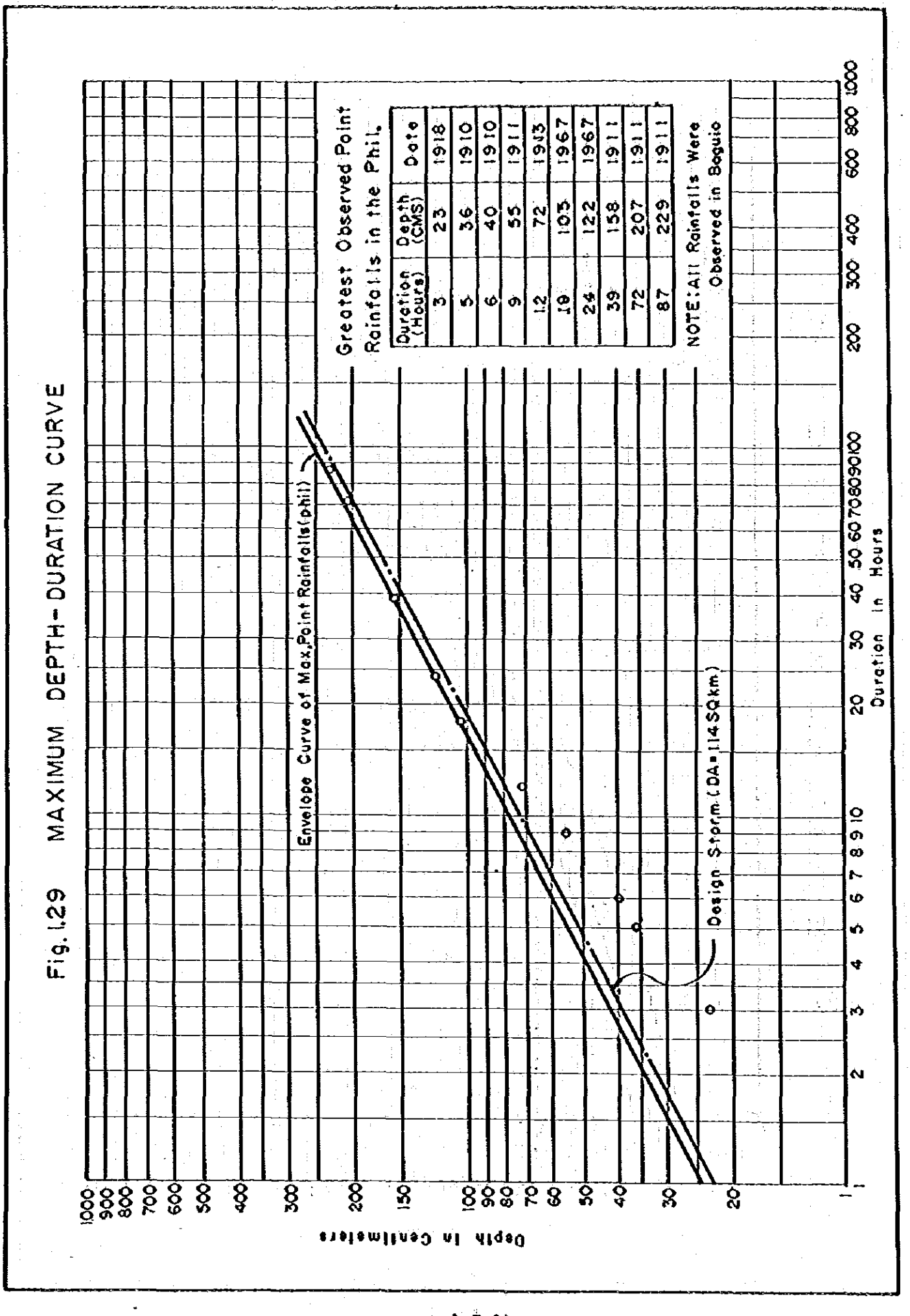


Fig. 1.29 MAXIMUM DEPTH-DURATION CURVE
Greatest Observed Point Rainfalls in the Phil.
Duration (Hours) | Depth (CMS) | Date
3 | 23 | 1918
5 | 36 | 1910
6 | 40 | 1910
9 | 55 | 1911
12 | 72 | 1913
18 | 103 | 1967
24 | 122 | 1967
39 | 158 | 1911
72 | 207 | 1911
87 | 229 | 1911
NOTE: All Rainfalls Were Observed in Baguio
Envelope Curve of Max. Point Rainfalls (phil)
Design Storm (DA = 114 SQkm)
Depth in Centimeters
Duration in Hours

Fig. 1.30 MAXIMUM DEPTH-AREA-DURATION CURVE

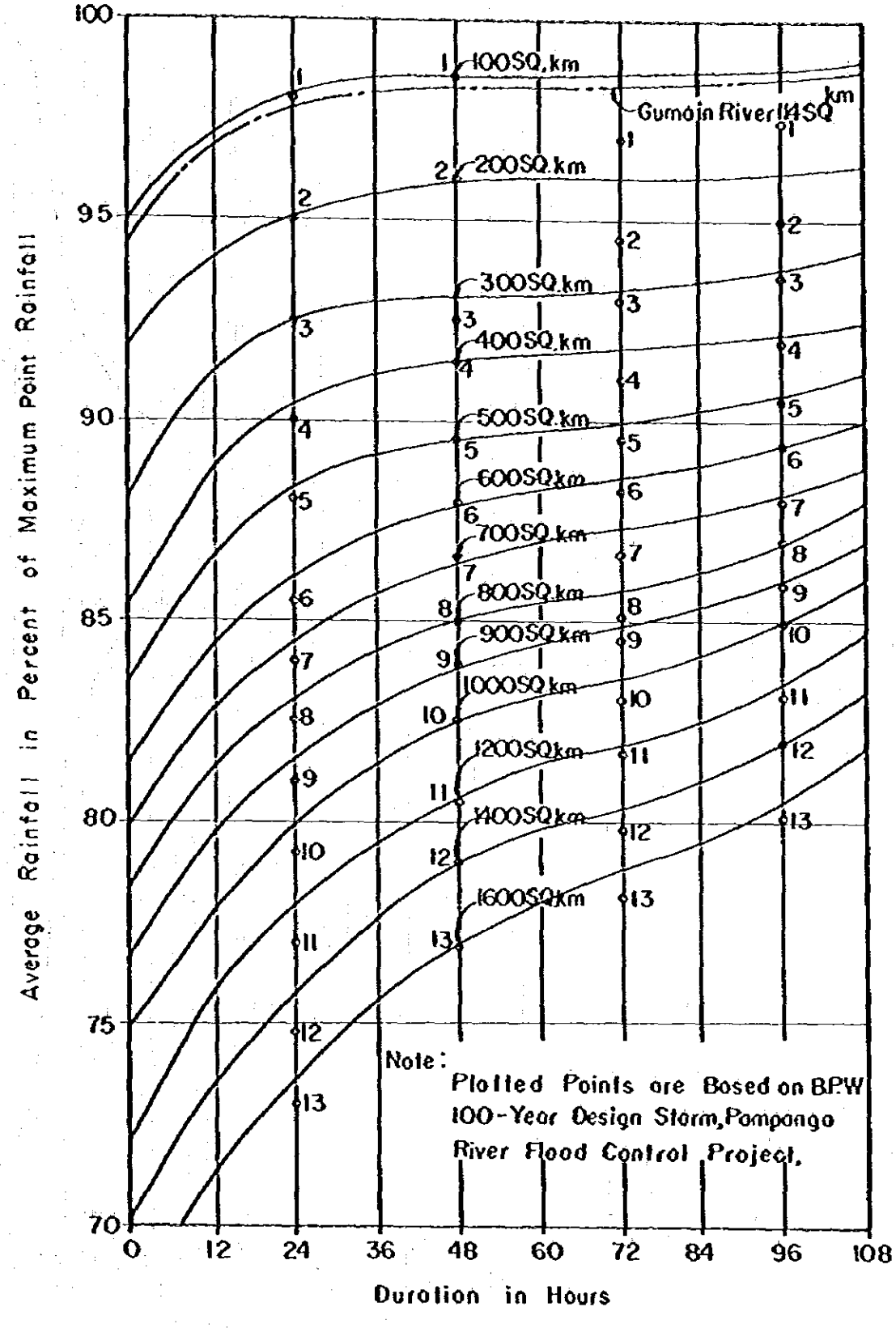


Fig.I.31 HYDROGRAPH OF PROBABLE MAXIMUM FLOOD
(PROPOSED GUMAIN DAM SITE C.A=114 km²)

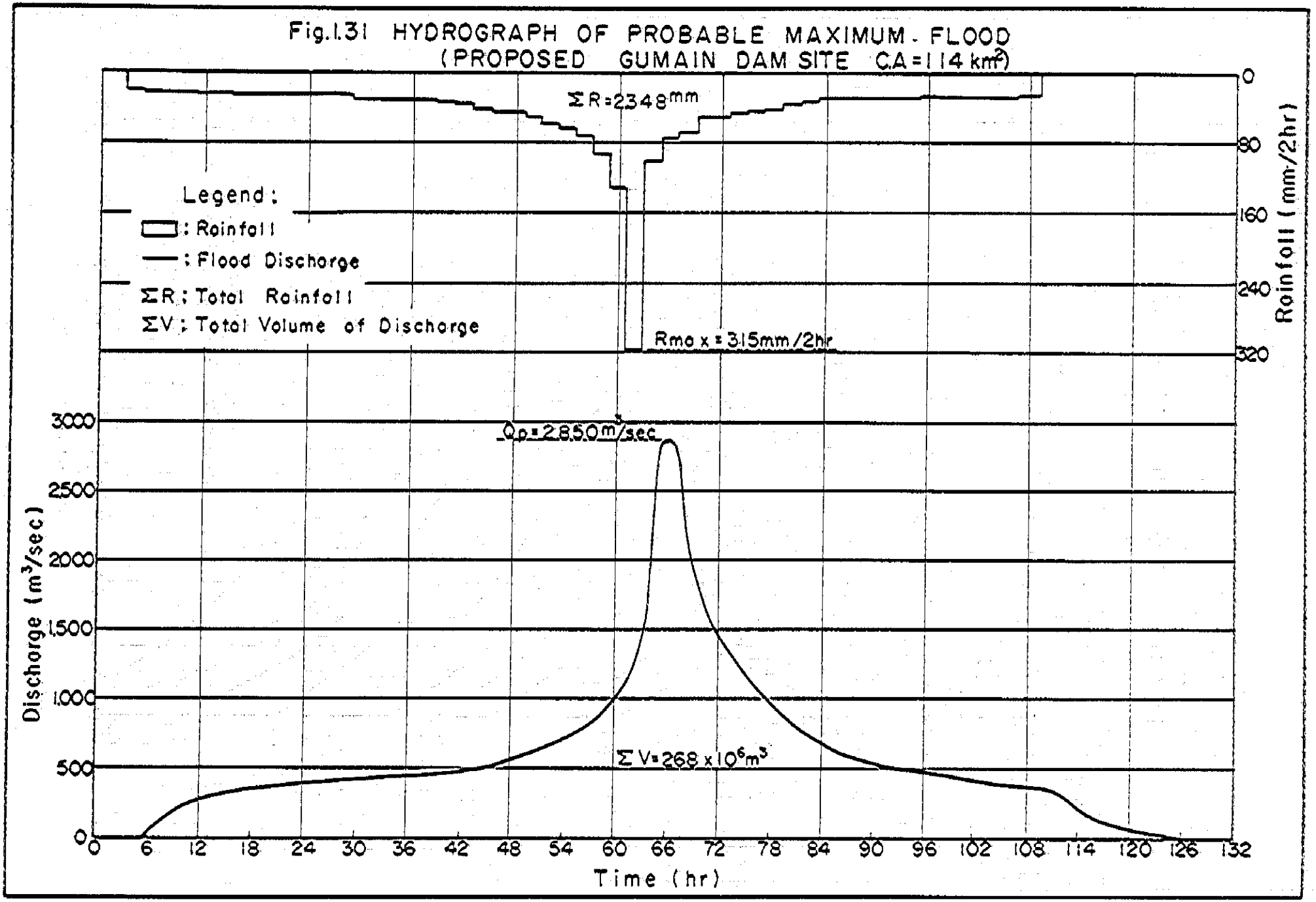
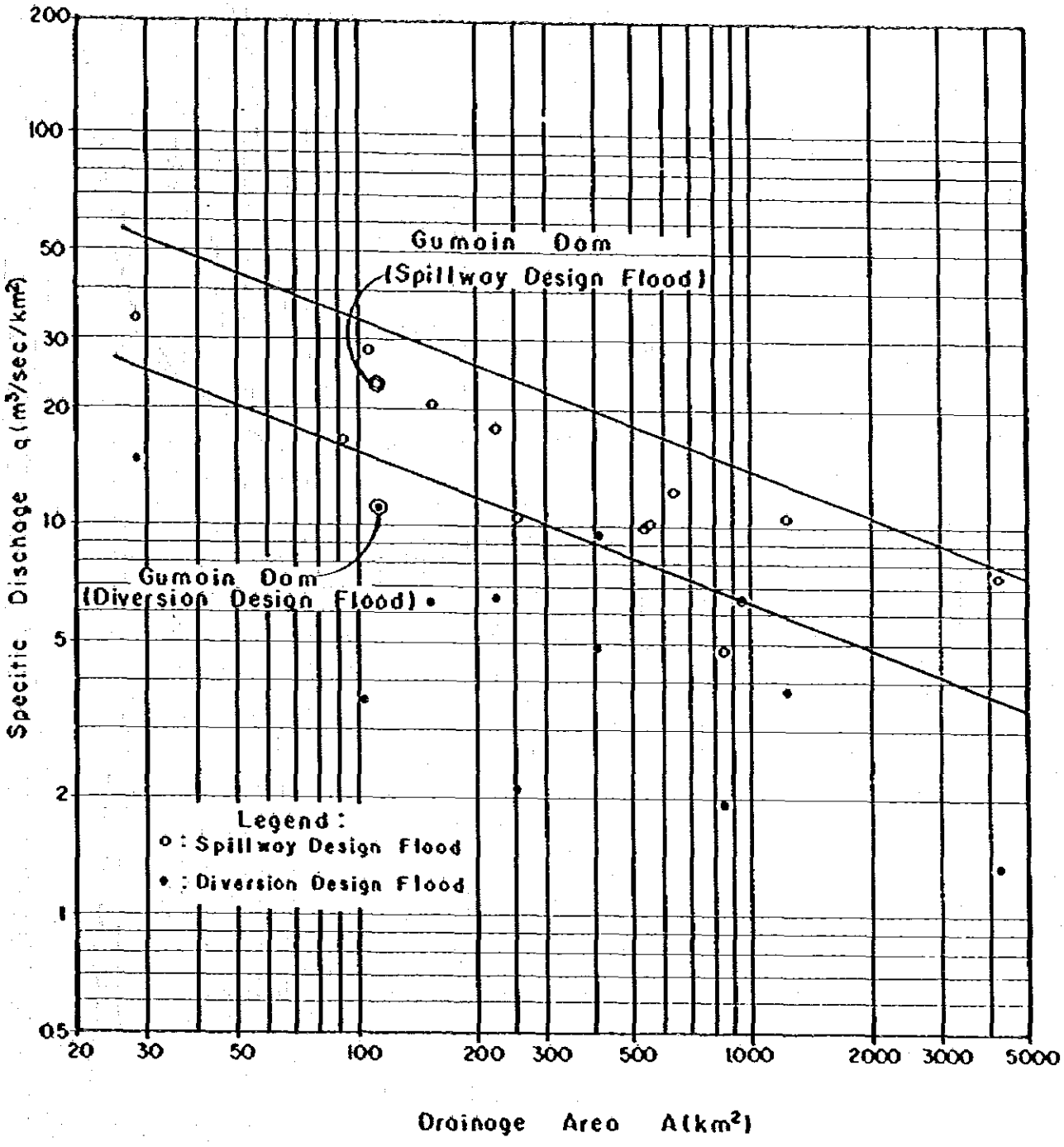


Fig1.32 DRAINAGE AREA(A) VS SPECIFIC DISCHRGE(q)



Remarks : Data is obtained from NIA.

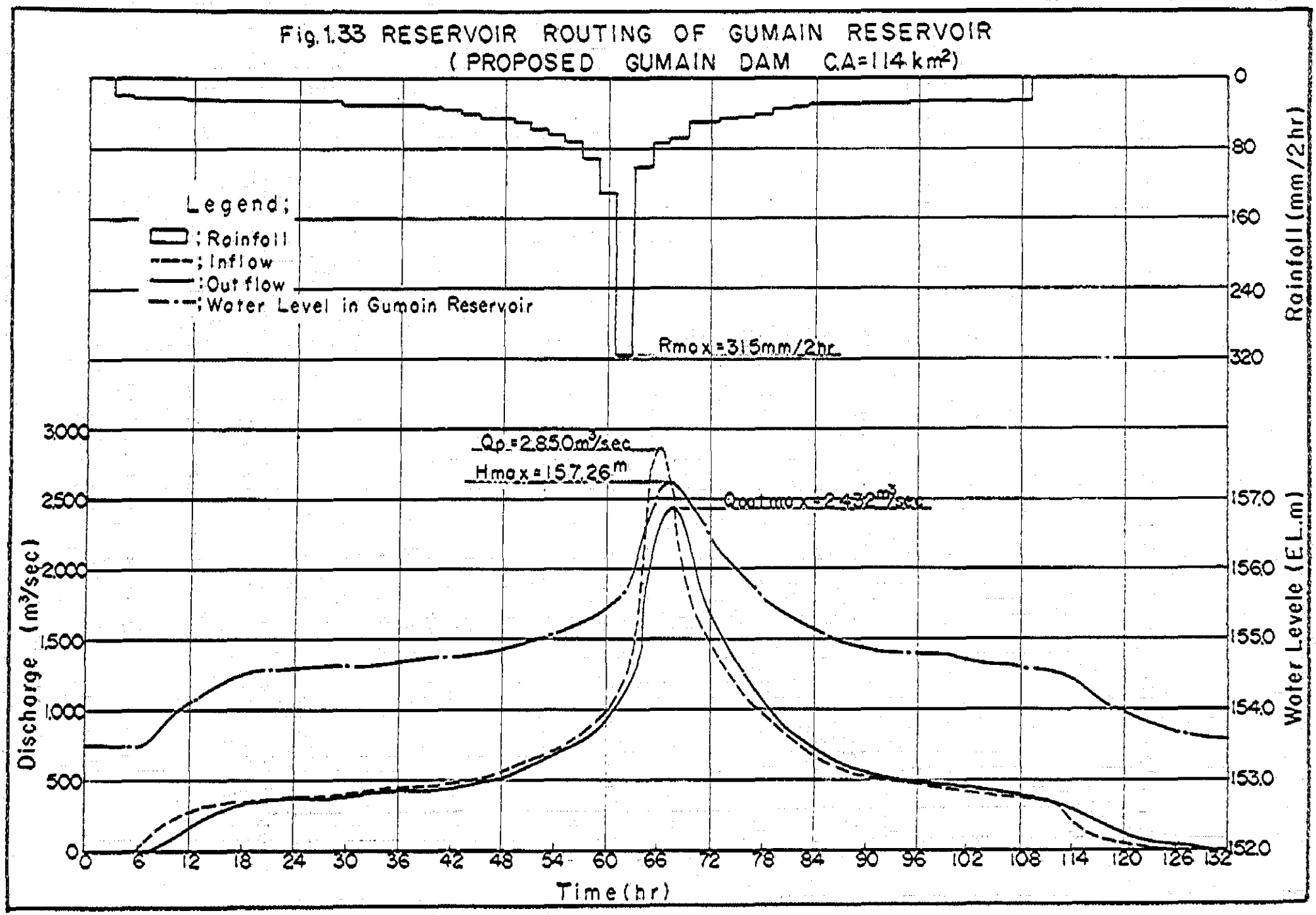


Fig. 1.33 RESERVOIR ROUTING OF GUMAIN RESERVOIR
(PROPOSED GUMAIN DAM C.A=114 km²)
Legend;
; Rainfall
; Inflow
; Out flow
; Water Level in Gumain Reservoir
Rmax=31.5mm/2hr
Qp=2,850m³/sec
Hmax=157.26m
Qoutmax=2,432m³/sec
Discharge (m³/sec)
Rainfall (mm/2hr)
Water Levele (EL.m)
Time (hr)
0
500
1,000
1,500
2,000
2,500
3,000
80
160
240
320
152.0
153.0
154.0
155.0
156.0
157.0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
102
108
114
120
126
132

Fig. I.34 RELATION BETWEEN SEDIMENT LOAD AND DISCHARGE

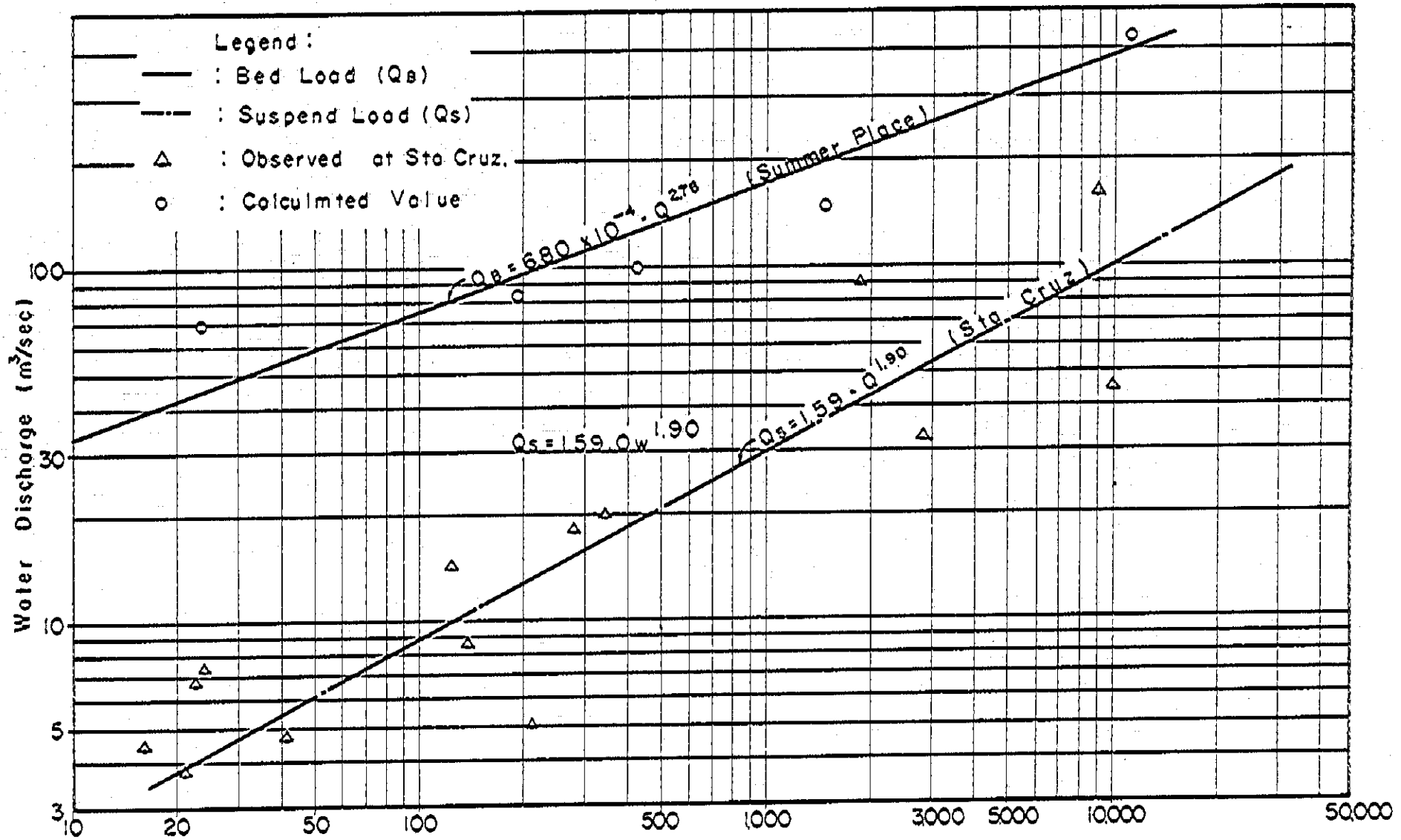
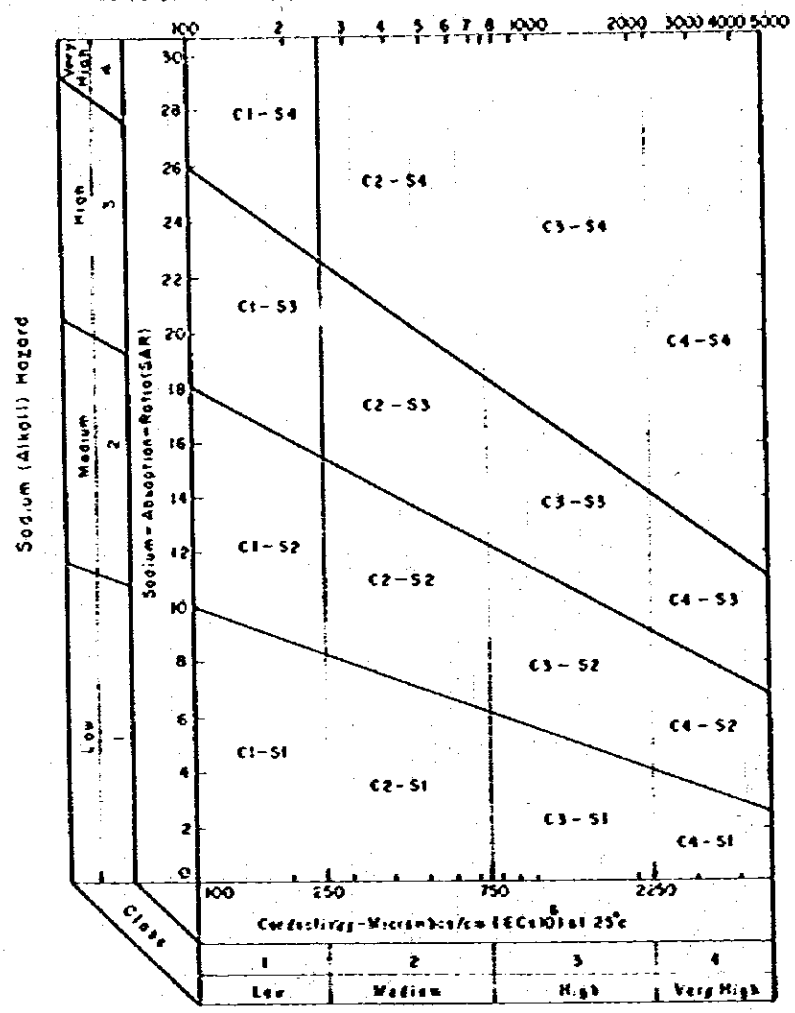


Fig. 1.35 WATER QUALITY CLASSIFICATION



S_1	Low sodium water can be used for irrigation in almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium sensitive crops such as stonefruit trees and avocados may accumulate injurious concentrations of sodium.	C_1	Low salinity water can be used for irrigation with most crops on most soils with little likelihood, that soil salinity will develop. Some leaching is required but this occurs under normal irrigation practices, except in soils of extremely low permeability.
S_2	Medium water will present an appreciable sodium hazard in fine textured soils having high cation exchange capacity, especially under low leaching conditions unless gypsum is present in the soil. This water may be used on coarse textured or organic soils with good permeability.	C_2	Medium salinity water can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.
S_3	High sodium water may produce harmful levels of exchangeable sodium in most soils, and will require special soils management; good drainage, high leaching, and organic matter conditions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible in the case of waters of very high salinity.	C_3	High salinity water cannot be used on soils with restricted drainage, even with adequate drainage, special treatment for salinity control may be required, and plants with good salt tolerance should be selected.
S_4	Very high sodium water is generally unsatisfactory for irrigation purposes, except at low and perhaps medium salinity where the solution of calcium from the soil or used of gypsum or other amendments may make the use of these waters feasible.	C_4	Very high salinity water is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage condition must be adequate, irrigation water must be applied in excess to provide considerable leaching and very salt-tolerance crops should be selected.

APPENDIX II

GEOLOGY AND DAM CONSTRUCTION MATERIALS

APPENDIX II GEOLOGY AND DAM CONSTRUCTION MATERIALS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES