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THE REPUBLIC OF THE PHILIPPINES
NATIONAL IRRIGATION ADMINISTRATION

FEASIBILITY STUDY REPORT
ON
THE IMPROVEMENT PROJECT
OF
THE OPERATION & MAINTENANCE
OF
NATIONAL IRRIGATION SYSTEMS (UPRIIS)

APPENDIXES

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FEBRUARY 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF APPENDIXES

ABBREVIATIONS

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

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 = ₱11.0 = ¥240)

9. Other Abbreviations

(A)

AD - Agriculture Division
ADB - Asian Development Bank
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
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
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

(D)

DPB - Development Bank of the Philippines
DT - Ditchtender

(E)

EOD - Engineering and Operations Division

(F)

FACOMA - Farmers' Cooperative Marketing Association
FAD - Farmers' Assistance Division
FAO - Food and Agricultural Organization
FBC - Farmers' Barrio Cooperative
FIA - Farmer-Irrigators' Association or Farmer-Irrigation Association
FIG - Farmer-Irrigators' Group or Farmer-Irrigation Group
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

(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
MPWH - Ministry of Public Works and Highways
MRRTC - Maligaya Rice Research and Training Center

(N)

NCSO - National Census and Statistics Office
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

(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
PDC-ADCC	-	Provincial Development Committee - Agricultural Development Coordinating Council
PIS	-	Pump Irrigation System
PNB	-	Philippine National Bank

(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
UPCA	-	University of the Philippines College of Agriculture at 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

10. Abbreviations on the Upper Pampanga River Integrated Irrigation Systems

LTRIS	-	Lower Talavera River Irrigation System
MCIS	-	Murcon Creek Irrigation System
PBRIS	-	Pampanga Bongabon River Irrigation System
PCCA	-	Pamaldan Cinco Cinco Area
PEÑRIS	-	Peñaranda River Irrigation System
PRIS	-	Pampanga River Irrigation System
RMA	-	Rizal Munic Area
SAE	-	San Agustin Extension
SDA	-	Sto. Domingo Area
TRIS	-	Talavera River Irrigation System
VCIS	-	Vaca Creek Irrigation System

APPENDIX I

METEOROLOGY AND HYDROLOGY

APPENDIX I METEOROLOGY AND HYDROLOGY

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CHAPTER 1 METEOROLOGY

The climate of the project area belongs to the First Type of PAGASA classification, which is characterized by the distinct dry and wet seasons caused by the tropical monsoon. The wet season usually extends from May to October and the dry season covers the remaining months of the year.

Annual mean temperature is around 27°C at Cabanatuan City, January or February is the coolest month, while April or May is the hottest, and the fluctuation of the monthly mean temperature is quite small. The annual mean relative humidity at Cabanatuan City is 76.7%. The maximum monthly mean relative humidity is in August and minimum in April. Annual mean sunshine hour at San Miguel, Tarlac province is 6.1 hr a day. The maximum monthly mean sunshine hour is observed in April, the minimum in August.

Wind wpeed observed in the Pampanga River Basin is light, 2.4 km/hr and 3.8 km/hr at San Miguel, Tarlac and Cabanatuan City, respectively.

Annual mean evaporation observed at San Miguel, Tarlac and Baliwag are 1,768 mm and 1,815 mm respectively. The maximum monthly evaporation occurs in April and minimum in August.

The summary of the climatic data is presented in Table 1.1.

CHAPTER 2 WATER RESOURCES

2.1 Rainfall

2.1.1 Rainfall Records

Daily rainfall records were collected at 59 stations in and around the Project Area as shown in Fig. 1.1. Locations of these stations are shown in Fig. 1.2 and Table 1.2. Collected data show that only Cabanatuan City has continuous records covering more than 30 years and most of the stations have records for less than 10 years.

2.1.2 Annual and Monthly Rainfall

Rainfall in the Project Area arises mainly from the combination of tropical typhoon and monsoon. Average annual rainfall varies from 1,800 mm in the central part of the area to 2,800 mm in the mountain areas and Fig. 1.3 shows isohyetal map of the annual rainfall.

Yearly variation of rainfall at Cabanatuan City is shown in Fig. 1.4, and mean annual rainfall is 1,862 mm. At the Pantabangan dam, the mean annual rainfall for 7 years is 1,849 mm.

For the convenience to know the general rainfall pattern, the mean monthly rainfalls at major stations in the Project Area are shown in Table 1.3 and in Fig. 1.5. About 90% of the total annual rainfall is concentrated in the wet season and August is generally the month of heaviest rainfall. Monthly rainfall is summarized in Table 1.4.

2.1.3 Intensity and Duration of Rainfall

Rainfall depths for the specific durations ranging from 5 min to 24 hr were taken at 23 stations.

On the basis of the observed rainfall depths, the maximum rainfall depths at 23 stations for specific durations of 5 min to 24 hr are presented in Table 1.5.

To analyze the patterns of hourly rainfall distribution, rainfall distribution curves were prepared for the major typhoons of August 1974 flood and May 1976 flood. The distribution curves are presented in Fig. 1.6.

The maximum hourly rainfall intensity was recorded at 130.6 mm/hr at San Isidro. Within the Project Area, 113.0 mm/hr was recorded at Cabanatuan. The average value of maximum hourly rainfall intensity for 23 stations is 83.5 mm/hr. As for the daily rainfall intensity, the maximum value of 424.9 mm/day was recorded at Tayabo. Average intensity for 23 stations is 224.7 mm/day. The maximum value of 311.5 mm/day was recorded at Cabanatuan.

2.2 Streamflow

2.2.1 Daily Discharges

Streamflow data were collected to analyze the long-term stream runoff and to estimate the available water resources in the project area. Water level observations were, until recently, conducted by NWRC at 15 stations in the Upper Pampanga river basin as shown in Fig. 1.7. It is, however, being continued at only 2 stations during big flood by PAGASA as a part of its flood forecasting activity.

Besides the above, the daily discharge observations as shown in Fig. 1.7 are also conducted by the UPRIIS at 4 stations on the Pantabangan dam, the Talavera diversion dam, the Peñaranda diversion dam and the Bangkerohan for the purpose of irrigation water management.

2.2.2 Streamflow Characteristics

The monthly mean discharges of 4 gauging stations are presented in Table 1.6 and the mean monthly discharges of 3 stations are graphed in Fig. 1.8. The annual pattern of the stream flow varies widely according to the typhoon, but generally, the wet season flow appears during the months of June through November. The drought period is from January to April, especially, the streamflow becomes extremely small in March and April.

Average annual inflow to the Pantabangan dam for 7 years (1976 - 1982) is about 1,336 MCM or 1,500 mm which gives annual runoff rate of 81.1% against mean annual rainfall of 1,849 mm.

CHAPTER 3 FLOOD RUNOFF ANALYSIS

3.1 Methodology for Analysis

In the stage of Feasibility Study on the Pampanga Delta Development Project conducted from 1980 to 1981 by JICA, Storage Function Method was applied to the estimation of flood runoff discharge. Storage coefficients were checked and determined by simulating the selected 3 major floods of October 1973, August 1974 and May 1976.

Based on the above results, the Storage Function Method and storage coefficients determined by the said study were applied to analyze flood runoff at the Talavera river in the Upper Pampanga river basin.

3.2 Flood Runoff Calculation

(1) Equations

The equations of the Storage Function Method are described below.

Equation for the drainage are:

$$S_1 = K \cdot q_1{}^p \text{ (storage equation)} \quad \ldots\ldots\ldots\ldots \quad (3.1)$$

$$r - q_1 = \frac{ds_1}{dt} \text{ (continuity equation)} \quad \ldots\ldots\ldots\ldots \quad (3.2)$$

where, S_1: storage in a drainage area (mm)
q_1: effective rainfall (mm)
r: rainfall in the drainage area (mm)
k, p: storage-coefficient

The factors such as primary runoff percentage, f_1, and saturation rainfall Rsa, are used for estimates of effective rainfall. The following assumptions were used in the calculation.

1) The runoff consists of flood and base flows.

2) The drainage area is divided into the infiltration and primary areas.

3) In the infiltration area, the rainfall is infiltrated up to saturation point after that all rainfall becomes runoff. The rainfall volume from the beginning to saturation point is called the saturation rainfall (Rsa).

4) In the primary area, all rainfall changes to runoff, and a ratio of primary and drainage areas is called the primary runoff percentage (f_1).

The effective rainfall in the primary area, q_1 is calcualted by the following equation which is a transformation of Eqs. 3.1 and 3.2.

$$q_1(t) = 2[r(t) - \frac{K}{\Delta t}\{q_1{}^P(t) - q_1{}^P(t - \Delta t)\}] - q_1(t - \Delta t)$$

where, Δt: time interval in calculation .... (3.3)

In the calculation, the trial and error procedure is used. The effective rainfall in the saturation area, q_{sa1} is calculated by the following equation.

$$q_{sa1} = 0, \ (\sum r < Rsa) \quad \text{.................................} \quad (3.4)$$

$$q_{sa1} = q_1, \ (\sum r > Rsa) \quad \text{.................................} \quad (3.5)$$

where, $\sum r$: cumulative rainfall from the beginning

The discharge from a drainage area is calculated by use of the following equation.

$$\bar{Q} = \frac{1}{3.6} f_1 A q_1 + \frac{1}{3.6} (1 - f_1) A q_{sa1} + Q_1 \quad \text{................} \quad (3.6)$$

$$Q(t) = \bar{Q}(t - T_1) \quad \text{.......................................} \quad (3.7)$$

where, Q: runoff from a drainage area (m^3/s)

$\bar{Q}$: hypothetical runoff (m^3/s)

q_1: effective rainfall in the primary area

q_{sa1}: effective rainfall in the saturation area

f_1: primary runoff percentage

A: drainage area (km^2)

Q_1: base flow (m^3/s)

T_1: lag-time

Equation for the channel:

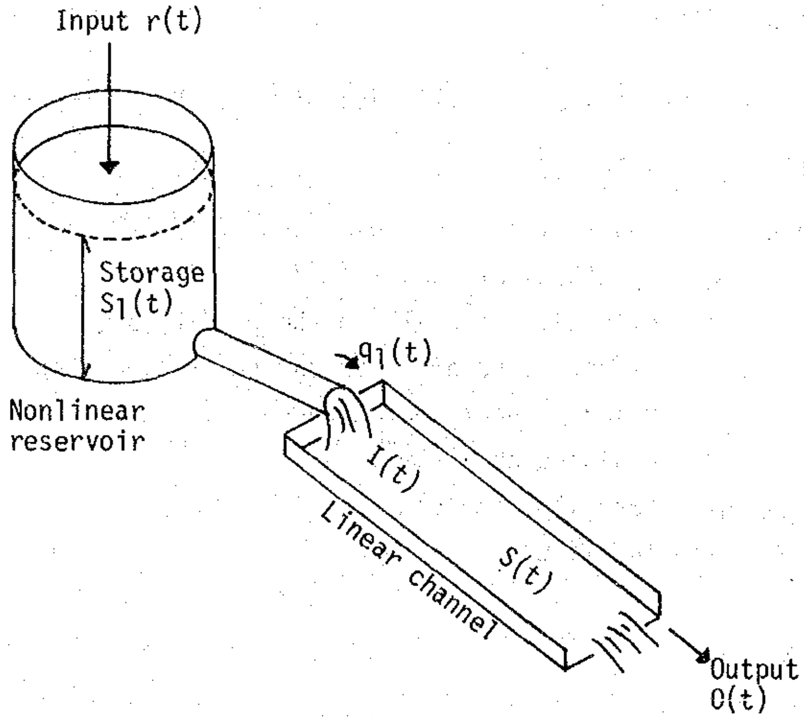
$$S_1 = K\,O_1^{p} - T_1 O_1 \text{ (storage eq.)} \qquad (3.8)$$

$$I - O_1 = \frac{dS_1}{dt} \text{ (continuity eq.)} \qquad (3.9)$$

$$O(t) = O_1(t + T_1) \text{ (eq. of retarded runoff)} \qquad (3.10)$$

where, S_1: storage in the channel (m^3/s)
O_1: discharge at the middle point in the channel (m^3/s)
I: inflow at the channel entrance (m^3/s)
K, p: storage coefficient
T_1: time-lag
O: outflow at the channel exit (m^3/s)

Basic model element of storage function method is illustrated below.



Storage coefficients are presented in Tables 1.7 and 1.8. Figs. 1.9 and 1.10 represent the sub-basins of the Upper Pampanga river basin and the runoff calculation model diagram, respectively. The basin areas in the Rio Chico and Talavera rivers were partly subdivided for the present study.

(2) Object Flood for Estimation of Probable Flood Runoff Discharges

Considering the characteristics of past flood, the pattern of the May 1976 flood (typhoon Didang) was selected in the study of probable flood runoff. The May 1976 flood was the biggest in rainfall volume at Cabanatuan City and also the highest in water level at Arayat and Sulipan since 1960.

Probable average rainfall in the Upper Pampanga river basin are shown in Table 1.9.

(3) Probable Flood Runoff Discharges

Probable flood runoff discharges were estimated for 5 magnitudes of 50-yr, 20-yr, 10-yr, 5-yr and 2-yr return periods. The probable flood estimation were conducted for present channel condition in the major rivers.

The peak discharges of probable flood hydrographs at major points are presented in Table 1.10.

As for the flood runoff discharges for the improved channel condition, the analysis is summarized in Appendix IV.

CHAPTER 4 LONG-TERM RUNOFF ANALYSIS

4.1 Purpose and Methodology of Analysis

In order to conduct the long-term water balance study on the UPRIIS, the streamflow discharge records for sufficient long period are required at respective locations of major streams. The available streamflow data, however, are limited at 4 stations of Pantabangan dam, Talavera diversion dam, Peñaranda diversion dam and Bangkerohan. The purpose of the long-term runoff analysis is to generate the streamflow discharges at required points from the available data through hydrological runoff model.

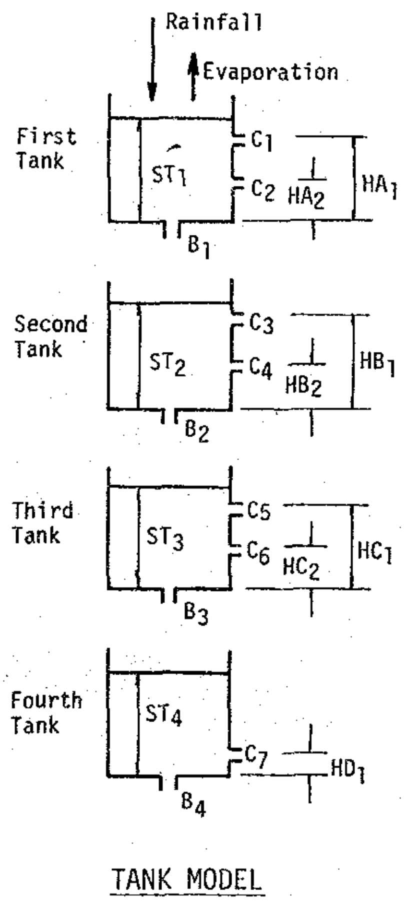
The Tank Model method was selected suitable to analyze especially long-term runoff among several hydrological runoff models. The Tank Model is the hydrological model to generate daily streamflow discharges from daily rainfall. Coefficients of Tanks are to be determined through simulation until obtaining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

The daily rainfall data at Cabanatuan City was adopted as representative rainfall for runoff simulation since more than 30 years daily rainfall data are available only at Cabanatuan.

4.2 Tank Model Calculation

Tank Model is usually composed of 3 to 4 storage tanks and 4 tanks model was adopted in the study as illustrated right.

Each tank has several runoff holes at different height and an infiltration hole at bottom. It is generally interpretated 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 sample calculation is given as follows:



TANK MODEL

Assuming coefficients:

First tank; HA_1 = 20 mm, HA_2 = 5 mm
C_1 = 0.3, C_2 = 0.1, B_1 = 0.4

Second tank; HB_1 = 10 mm, HB_2 = 5 mm
C_3 = 0.1, C_4 = 0.05, B_2 = 0.1

Third tank; HC_1 = 10 mm, HB_2 = 5 mm
C_5 = 0.05, C_6 = 0.0, B_3 = 0.05

Fourth tank; HD_1 = 0 mm
C_7 = 0.001, B_4 = 0.0005

Previous day's storage; ST_1 = 0.0, ST_2 = 0.0
ST_3 = 0.0, ST_4 = 100 mm

Rainfall; 1st day 40 mm, 2nd day 0 mm

Evaporation; 5 mm/day

<u>1st day calculation</u>

1st tank;

$$Q_1 = (ST_1 + R - HA_1) \times C_1 = (0 + 40 - 20) \times 0.3 = 6 \text{ mm}$$

$$Q_2 = (ST_1 + R - HA_2) \times C_2 = (0 + 40 - 5) \times 0.1 = 3.5 \text{ mm}$$

$$QB_1 = (ST_1 + R) \times B_1 = (0 + 40) \times 0.4 = 16 \text{ mm}$$

$$ST_1 = ST_1 - (Q_1 + Q_2 + QB_1) - EV + R$$
$$= 0 - (6 + 3.5 + 16) - 5 \times 0.5 + 40 = 12 \text{ mm}$$

Note: EV = EV x 0.5 for rainfall of more than 5 mm/day

2nd tank;

$$Q_3 = (ST_2 + QB_1 - HB_1) \times C_3$$
$$= (0 + 16 - 10) \times 0.1 = 0.6 \text{ mm}$$

$$Q_4 = (ST_2 + QB_1 - HB_2) \times C_4$$
$$= (0 + 16 - 5) \times 0.05 = 0.55 \text{ mm}$$

$$QB_2 = (ST_2 + QB_1) \times B_2$$
$$= (0 + 16) \times 0.1 = 1.6 \text{ mm}$$

$$ST_2 = (ST_2 + QB_1) - (Q_3 + Q_4 + QB_2)$$
$$= (0 + 16) - (0.6 + 0.55 + 1.6) = 13.25 \text{ mm}$$

3rd tank; $Q_5 = (ST_3 + QB_2 - HC_1) \times C_5$
$= (0 + 1.6 - 10) \times 0.05$ = negative = 0 mm

$Q_6 = (ST_3 + QB_2 - HC_2) \times C_6$
$= (0 + 1.6 - 0) \times 0.02 = 0.03$ mm

$QB_3 = (ST_3 + QB_2) \times B_3$
$= (0 + 1.6) \times 0.05 = 0.08$ mm

$ST_3 = (ST_3 + QB_2) - (Q_5 + Q_6 + QB_3) = 1.49$ mm

4th tank; $Q_7 = (ST_4 + QB_3 - HD_1) \times C_7$
$= (100 + 0.08 - 0) \times 0.001 = 0.1$ mm

$QB_4 = (ST_4 + QB_3) \times B_4$
$= (100 + 0.08) \times 0.0005 = 0.05$ mm

$ST_4 = (ST_4 + QB_3) - (Q_7 + QB_4) = 99.93$ mm

1st day's runoff $= Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7$
$= 6 + 3.5 + 0.6 + 0.55 + 0 + 0.03 + 0.1$
$= 10.78$ mm

for 1 km^2 of catchment area
10.78 mm x 1 km^2/86400 = 0.125 m^3/sec

2nd day calculation

1st tank; $Q_1 = (12 + 0 - 20) \times 0.3$ = negative = 0 mm
$Q_2 = (12 + 0 - 5) \times 0.1 = 0.7$ mm
$QB_1 = (12 + 0) \times 0.4 = 4.8$ mm
$ST_1 = 12 - (0 + 0.7 + 4.8) - 5 + 0 = 1.5$ mm

2nd tank; $Q_3 = (13.25 + 4.8 - 10) \times 0.1 = 0.81$ mm
$Q_4 = (13.25 + 4.8 - 5) \times 0.05 = 0.65$ mm
$QB_2 = (13.25 + 4.8) \times 0.1 = 1.81$ mm
$ST_2 = (13.25 + 4.8) - (0.81 + 0.65 + 1.81) = 14.78$ mm

3rd tank; $Q_5 = (1.49 + 1.81 - 10) \times 0.05$ = negative = 0 mm
$Q_6 = (1.49 + 1.81 - 0) \times 0.02 = 0.07$ mm
$QB_3 = (1.49 + 1.81) \times 0.05 = 0.17$ mm
$ST_3 = (1.49 + 1.81) - (0 + 0.07 + 0.17) = 3.06$ mm

4th tank; $Q_7 = (99.93 + 0.17 - 0) \times 0.001 = 0.1$ mm

$QB_4 = (99.93 + 0.17) \times 0.0005 = 0.05$ mm

$ST_4 = (99.93 + 0.17) - (0.1 + 0.05) = 99.95$ mm

2nd day's runoff $= 0 + 0.7 + 0.81 + 0.65 + 0 + 0.07 + 0.1$

$= 2.33$ mm

for 1 km^2 of catchment area

$2.33 \text{ mm} \times 1 \text{ km}^2/86400 = 0.027 \text{ m}^3/\text{sec}$

4.3 Streamflow Generation

Trial and error calculations were conducted by computer until obtaining the model to simulate the streamflow discharge similar to the observed discharge values applying rainfall at Cabanatuan. Three independent tank models were determined as representative runoff model at Pantabangan dam, Talavera diversion dam and at Peñaranda diversion dam. For the evaluation of model's accuracy, simulated 10 days discharge and observed one are plotted in Fig. 1.11. Applying these models, the streamflow discharges of daily and 10 days total are generated for 32 years from 1951 to 1982 from the daily rainfall data at Cabanatuan for the following 6 stream points.

Pantabangan dam tank model

- Pantabangan dam (Catchment Area A = 954 km^2)
- Pampanga diversion dam (A = 1,006 km^2)
- Pampanga Bongabon diversion dam (A = 2,049 km^2)

Talavera river tank model

- Talavera diversion dam (A = 313 km^2)
- Lower Talavera diversion dam (A = 401 km^2)

Peñaranda river tank model

- Peñaranda diversion dam (A = 513 km^2)

The tank model of the Pantabangan dam was applied to the Pampanga diversion dam and the Pampanga Bongabon diversion dam and the tank model of the Talavera diversion dam was used for the Lower Talavera diversion dam. In the case of the Pampanga Bongabon diversion dam, the rainfall was modified according to the areal distribution of rainfall shown by the isohyetal map so as to express the characteristics of the Coronel river.

CHAPTER 5 SEDIMENTATION

5.1 Sampling and Analysis of Riverbed Materials

The sampling and physical analysis of riverbed materials were conducted by the UPRIIS staff in order to estimate sediment transport capacity of the existing channels. Riverbed materials were sampled at 34 sites in the 5 major rivers. Location of sampling sites is shown in Fig. 1.12 and the sampling numbers are summarized below:

River	No. of Sampling
Pampanga	10
Talavera	9
Talavera Main Canal	4
Rio Chico	5
Peñaranda	2
Bulo	4
Total	34

Using the sampling data, grain size distribution and specific gravity were analyzed. The results are shown in Table 1.11 and Fig. 1.13.

No sampling of river water for estimation of suspended load was conducted because big and medium scaled floods did not occur during the study period.

5.2 Sedimentation

5.2.1 Sediment Discharge

Sediment discharges of the present river channels were estimated at major points by applying Brown formula and sediment discharge rating curves were prepared. In estimating the sediment discharge of the channels, the following 3 formulas of Brown, Engelund-Hansen and Einstein-Brown are well-known to be simple in calculation and to give satisfactorily accurate results. These formulas give more or less similar results, but in general, the Brown formula gives the medium values. In addition to these formulas, Sato-Kikkawa-Ashida formula is also shown below for reference.

a) Brown formula

$$Q_s = 10 \left(\frac{U^2}{(W_s/W_w-1)\ gd} \right) Ud \times (8.64 \times 10^4\ B)$$

$$= 0.994 \times 10^6 B\ (RI)^{2.5}/d$$

b) Engelund-Hansen formula

$$Q_s = 0.05\, W_s V^2 \left(\frac{d}{g(W_s/W_w - 1)} \right)^{0.5} \left(\frac{t_0}{(W_s - W_w)\, d} \right)^{1.5} \times (8.64 \times 10^4 B)$$

$$= 0.414 \times 10^6\, BR^{2.83} I^{2.5}/d$$

c) Einstein-Brown formula

$$Q_s = PW_s F_1 \left(g(W_s/W_w - 1)\, d^3 \right)^{0.5} \times (8.64 \times 10^4 B)$$

$$F_1 = \left(\frac{2}{3} + \frac{36\, n_w^2}{gd^3\, (W_s/W_w - 1)} \right)^{0.5} - \left(\frac{36\, n_w^2}{gd^3\, (W_s/W_w - 1)} \right)^{0.5}$$

$$Q_s = 0.864 \times 10^5\, PB \left((10.78\, d^3 + 2.6 \times 10^{-11})^{0.5} - 5.1 \times 10^{-6} \right)$$

d) Sato-Kikkawa-Ashida formula

$$Q_s = P_s F(t_0/t_c)\, W_s \frac{U^3}{(W_s/W_w - 1)g} \times (8.64 \times 10^4 B)$$

$$= 1.021 \times 10^5\, B\, F(t_0/t_c)\, (RI)^{1.5}$$

where, Q_s: sediment discharge (m^3/day)

U: friction velocity (m/sec); $U = (gRI)^{0.5}$

d: grain size of bed materials (m)

B: river width (m)

W_s, W_w: unit weight of sediment and water (ton/m^3); (W_s = 2.65 ton/m^3 and W_w = 1.00 ton/m^3)

v: mean velocity (m/sec)

t_0: tractive force of flow (ton/m^2); $t_0 = W_w RI$

R: hydraulic mean depth (m)

I: energy gradient of flow

p: sediment function given in Fig. 1.14

p_s: factor related to Manning's roughness; $P_s = 0.623$ for $n > 0.025$

$F(t_0/t_c)$: function of the ratio t_0/t_c as shown in Fig. 1.14

t_c: critical tractive force of bed materials (ton/m^2), which is given in Fig. 1.14 by Iwagaki.

n_w: kinematic viscosity of water; $n_w = 8.50 \times 10^{-7}$ m^2/sec for temperature 27°C

g: acceleration of gravity, $g = 9.8$ m/sec^2

Estimated sediment discharges are presented in Fig. 1.15 for major rivers of the Pampanga, the Talavera, the Rio-Chico and the Peñaranda.

5.2.2 Sediment Transport Capacity

Based on the sediment discharge curves shown in Fig. 1.15 and daily discharges of the river, the annual sediment transport capacities of the present river channels were estimated and shown in Fig. 1.16 together with the results of sediment discharge measurements.

Evaluating from the Fig. 1.16, the sediment transport capacity of the present river channel exceeds the expected sediment discharge except lower reaches of the Rio Chico and the Pampanga where these rivers flow into the San Antonio swamp. In the Talavera river, the transport capacity falls due to the sediment discharge at the Talavera and the Lower Talavera diversion dams because of dam structures. However, the capacity and discharge are about balanced and serious problems against the ordinary operation and maintenance are not expected, by providing proper execution of sluice gate operation of the diversion dams during flood.

Table 1.1 CLIMATIC CONDITIONS IN THE PAMPANGA BASIN

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Mean Temperature (°C)													
San Miguel (1968 - 1979)	25.1	25.0	27.0	28.6	28.8	28.1	27.4	26.8	27.3	26.8	26.3	25.4	26.9
Baliwag (1970 - 1979)	24.1	25.1	26.2	27.4	27.4	27.7	27.2	26.9	27.0	26.7	26.4	25.5	26.5
Cabanatuan (1976 - 1979)	25.9	23.5	27.4	29.3	28.6	28.3	28.2	27.1	27.6	27.7	27.0	26.5	27.3
Mean Maximum Temperature (°C)													
San Miguel (1968 - 1979)	31.0	31.7	33.9	35.3	34.7	33.3	32.1	30.9	31.6	31.7	30.2	30.7	33.3
Baliwag (1970 - 1979)	29.6	29.5	31.9	33.0	32.6	32.1	31.1	29.4	31.2	30.7	30.7	29.7	31.0
Mean Minimum Temperature (°C)													
San Miguel (1968 - 1979)	18.8	19.0	20.3	21.9	23.1	23.2	22.8	23.2	22.6	22.3	21.6	20.2	21.6
Baliwag (1970 - 1979)	19.9	19.7	20.2	21.7	22.8	23.7	23.6	23.2	23.3	22.6	22.2	21.3	22.0
Mean Relative Humidity (%)													
San Miguel (1968 - 1979)*	83.1	75.4	77.6	71.9	79.2	86.0	87.9	90.7	88.8	86.5	82.5	82.3	82.7
Cabanatuan (1976 - 1979)	73.1	67.8	66.1	63.1	76.8	80.4	83.8	88.0	85.6	81.9	77.9	75.6	76.7
Sunshine Hour (hr/day)													
San Miguel (1968 - 1979)	6.2	7.3	7.1	8.3	7.5	5.2	5.1	3.9	4.1	5.6	6.3	6.5	6.1
Mean Wind Speed (km/hr)													
San Miguel (1968 - 1979)	2.7	3.1	3.2	3.1	2.2	2.0	1.7	1.6	1.4	1.7	2.6	3.4	2.4
Cabanatuan (1976 - 1979)	4.2	4.8	3.6	3.6	3.9	2.5	2.9	3.3	4.6	3.2	4.6	4.9	3.8
Evaporation (mm/month)													
San Miguel (1968 - 1979)	145.8	152.3	194.1	204.2	170.2	138.2	127.5	112.5	126.9	130.5	131.4	134.5	1,768.1
Baliwag (1970 - 1979)	143.5	141.1	177.6	191.1	171.4	152.2	141.3	133.0	152.4	143.3	133.7	134.3	1,815.0

*: Relative Humidity measured at 8:00 A.M.

Source: Feasibility Report on the Pampanga Delta Development Project, Feb. 1982 JICA

Table 1.2(1) LOCATION OF RAINFALL STATIONS

No.	Station Name	Lat. N	Long. E	Province
1.	Tris Dam Tayabo San Jose City	15°51'08"	121°01'04"	Nueva Ecija
2.	Pantabangan Dam	15°50'45"	121°08'45"	"
3.	Palayupay Pantabangan	15°49'34"	121°06'25"	"
4.	Camanacsacan San Jose City	15°46'25"	120°59'17"	"
5.	Pris Dam Rizal	15°43'42"	121°05'35"	"
6.	Tondod San Jose City	15°43'16"	120°58'06"	"
7.	Ltris Dam Llanera	15°42'10"	121°00'10"	"
8.	Baloc Santo Domingo	15°38'24"	120°53'16"	"
9.	Sibul Talavera	15°38'12"	120°57'34"	"
10.	Pinahan General Natividad	15°37'43"	121°03'36"	"
11.	Pbris Dam Natividad	15°36'30"	121°06'00"	"
12.	Sapan Buho General Tinio	15°35'32"	121°05'24"	"
13.	Murcon Dam Talavera	15°34'31"	120°59'18"	"
14.	Ilog Baliwag	15°33'	120°48'	"
15.	Quezon	15°32'47"	120°48'45"	"
16.	San Juan Aliaga	15°32'	120°46'	"
17.	Bantug Talavera	15°30'33"	120°54'47"	"
18.	Bangad Cabanatuan	15°30'12"	121°02'20"	"
19.	Pamaldan Cinco-Cinco Cabanatuan	15°29'32"	120°55'30"	"
20.	Cabanatuan City	15°29'	120°58'	"
21.	San Jose Peñaranda	15°28'50"	121°00'30"	"
22.	Gabaldon	15°28'	121°20'	"
23.	Zaragoza	15°26'55"	120°46'54"	"
24.	Concepcion Zaragoza	15°26'48"	120°45'02"	"
25.	Soledad Sant Rosa	15°26'12"	121°00'18"	"
26.	Zaragoza	15°26'08"	120°45'00"	"
27.	Mallorca San Leonardo	15°22'37"	120°58'48"	"
28.	Lambakin Jaen	15°22'12"	120°51'59"	"
29.	Papaya	15°20'08"	121°02'24"	"
30.	Gapan	15°19'	120°57'	"
31.	Mangino Gapan	15°18'45"	120°58'10"	"
32.	San Isidro	15°17'55"	120°54'10"	"
33.	Manggs San Isidro	15°14'50"	120°54'50"	"
34.	Concepcion Cabiao	15°14'30"	120°49'15"	"
35.	Bulak Gapan	15°14'10"	120°58'45"	"
36.	Cabiao	15°14'05"	120°54'30"	"
37.	Sibul Spring	15°09'54"	121°06'22"	Bulacan
38.	Batasan San Miguel	15°09'30"	120°55'15"	"
39.	Salacot San Miguel	15°09'	120°59'	"
40.	Santa Rita San Miguel	15°08'30"	120°57'30"	"
41.	Calawitan San Ildefonso	15°05'	120°55'	"
42.	Talacsan San Rafael	14°58'	120°59'	"
43.	Sabang Baliwag	14°58'	120°55'	"
44.	Marungo Angat	14°56'	121°02'	"
45.	Makinabang Baliwag	14°55'	120°53'	"
46.	Angat	14°54'	121°10'	"

(to be continued)

Table 1.2(2) LOCATION OF RAINFALL STATIONS

No.	Station Name	Lat. N	Long. E	Province
47.	San Lorenzo Norzagaray	14°54'	121°02'	Bulacan
48.	Ipo Norzagaray	14°52'	121°09'	"
49.	Catmon Malolos	14°51'	120°49'	"
50.	Borol II Balagtas	14°49'	120°54'	"
51.	Minuyan San Jose del Monte	14°49'	121°03'	"
52.	Santa Maria	14°49'	120°57'	"
53.	Obando	14°42'	120°56'	"
54.	Surgui Camiling	15°51'	120°25'	Tarlac
55.	San Clemente	15°43'	120°21'	"
56.	Anoling Camiling	15°40'	120°15'30"	"
57.	Santa Ignacia	15°36'	120°25'	"
58.	Gerona	15°36'	120°37'	"
59.	Mambaran Mayantoc	15°34'	120°20'	"
60.	San Jacinto Victoria	15°33'	120°35'	"
61.	Amucao Tarlac	15°28'	120°41'	"
62.	Carangian Tarlac	15°27'30"	120°33'	"
63.	Hacienda Luisita San Miguel	15°27'	120°38'	"
64.	Armenia Dam Tarlac	15°27'	120°30'	"
65.	La Paz	15°23'	120°43'	"
66.	Dolores Capas	15°21'30"	120°35'30"	"
67.	Arayat	15°09'50"	120°46'30"	Pampanga
68.	San Agustin Arayat	15°09'	120°46'	"
69.	Candaba	15°07'06"	120°51'43"	"
70.	Santa Cruz Porac	15°04'	120°33'	"
71.	Bahay Pare Candaba	15°02'24"	120°52'48"	"
72.	San Fernando	15°02'	120°42'	"
73.	Cabambagan Bacolor	15°00'	120°39'	"
74.	San Matias Santo Tomas	15°00'	120°42'	"
75.	Becuran Santa Rita	15°00'	120°34'	"
76.	Balucoc Apalit	14°58'	120°51'	"
77.	Cansinala Apalit	14°58'	120°46'36"	"
78.	Sulipan Apalit	14°56'08"	120°45'30"	"
79.	Masantol	14°52'	120°42'	"
80.	Lubao	14°50'	120°36'	"
81.	Talisai Balanga	14°41'	120°33'	Bataan
82.	Mariveles	14°26'	120°29'	"

Table 1.3(1) ANNUAL VARIATION OF MONTHLY RAINFALL AT SELECTED STATIONS

Month	1. TRIS Dam			2. Pantabangan Dam			9. Sibul Talavera		
	Mean	Max.	Min	Mean	Max	Min	Mean	Max	Min
Period	1970 - 1980			1976 - 1982			1972 - 1979		
Jan	7.3	23.6	0	0.2	1.0	0	13.4	44.5	0
Feb	8.6	3.1	0	0.1	0.5	0	0.4	1.8	0
Mar	21.4	67.8	0	7.2	22.4	0	10.0	38.2	0
Apr	30.0	181.4	0	24.4	62.7	0	25.6	93.1	0
May	305.3	1,363.9	82.5	255.0	906.0	26.6	275.0	904.3	55.5
June	290.7	616.1	0.8	226.2	441.0	93.7	294.2	487.7	195.7
July	413.5	1,290.0	122.9	369.3	497.5	206.2	358.2	1,027.1	148.5
Aug	463.1	766.6	229.3	392.4	799.0	137.0	444.7	648.6	261.8
Sept	275.3	414.1	141.2	280.8	399.0	169.5	253.8	396.1	133.8
Oct	255.2	545.9	12.0	150.0	477.0	2.0	289.5	510.8	22.4
Nov	158.4	451.1	37.1	138.1	334.7	10.0	103.5	213.4	22.0
Dec	42.1	106.5	0.5	4.8	11.6	0	41.5	149.4	1.2
Total	2,270.9			1,848.5			2,109.8		
Wet Season (May to Oct)	2,003.1			1,673.7			1,915.4		
Percentage	88			91			91		

(to be continued)

Table 1.3(2) ANNUAL VARIATION OF MONTHLY RAINFALL AT SELECTED STATIONS

Month	15. Quezon			20. Cabanatuan City			31. Maringao Gapan		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Period	1970 - 1980			1951 - 1980			1975 - 1982		
Jan	9.8	26.4	0	6.4	67.3	0	13.7	41.7	0
Feb	3.1	16.3	0	5.1	49.5	0	3.8	12.7	0
Mar	8.8	19.8	0	12.1	69.8	0	12.2	34.7	1.0
Apr	30.7	134.4	0	29.2	261.4	0	20.2	58.5	0
May	200.6	357.5	34.7	171.9	931.1	0	246.2	839.3	89.1
June	266.5	588.3	0.5	257.9	590.9	0	247.4	419.8	86.3
July	367.2	1,131.9	151.0	305.2	1,064.7	141.9	300.9	560.4	177.0
Aug	351.7	569.9	130.2	399.8	628.3	182.1	380.8	601.7	197.3
Sept	294.4	442.0	204.5	307.9	628.7	140.9	342.3	526.0	197.8
Oct	246.3	430.4	5.6	179.7	584.2	0	168.0	455.6	2.0
Nov	103.1	293.0	21.4	142.9	445.2	14.0	67.2	161.5	20.4
Dec	40.0	109.1	0	44.0	197.1	0	52.6	176.6	0
Total	1,922.2			1,862.1			1,955.3		
Wet Season (May to Oct)	1,726.7			1,622.4			1,685.6		
Percentage	90			87			86		

Table 1.4.(1) MONTHLY RAINFALL RECORD

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Tris Dam, Tayabo, San Jose City, N.E.													
1970	-	-	-	-	-	-	243.4	452.0	326.7	263.4	51.6	70.4	-
1971	1.6	0.8	8.4	0	186.2	529.4	425.3	259.6	322.0	369.2	114.2	106.5	2,323.2
1972	19.1	3.1	13.3	24.9	169.8	188.4	1,290.0	445.5	230.2	12.0	37.1	13.0	2,445.4
1973	0	0	0	0	82.5	213.1	122.9	505.0	193.5	382.2	104.7	0.5	1,604.4
1974	5.1	1.3	14.5	181.4	106.0	346.4	303.4	766.6	141.2	545.9	223.2	45.7	2,680.7
1975	23.6	0	67.8	0	127.6	182.8	175.5	428.2	289.6	181.5	-	82.7	-
1976	0	0	52.1	54.9	1,363.9	616.1	269.0	374.8	377.5	16.9	-	17.8	-
1977	0	0.8	0	0	97.4	-	504.0	507.5	414.1	-	127.1	0	-
1978	-	-	-	-	-	319.4	297.7	723.8	-	451.8	-	-	-
1979	-	-	-	9.1	318.4	220.1	436.4	402.3	173.2	205.2	-	-	2,292.6
1980	9.1	-	15.2	0	276.1	0.8	481.0	229.3	284.7	123.7	451.1	-	-
Mean	7.3	8.6	21.4	30.0	305.3	290.7	413.5	463.1	275.3	255.2	158.4	42.1	2,269.3
Max.	23.6	3.1	67.8	181.4	1,363.7	616.1	1,290.0	766.6	414.1	545.9	451.1	106.5	2,680.7
Min.	0	0	0	0	82.5	0.8	122.9	229.3	141.2	12.0	37.1	0.5	1,604.4
Pantabangan Dam													
1976	0	0	22.4	21.9	906.0	441.0	206.2	313.1	236.7	2.5	33.5	11.6	2,194.9
1977	0.5	0	1.5	0	131.8	93.7	405.2	503.4	301.2	2.0	176.3	0	1,615.6
1978	0	0	1.0	62.7	113.5	203.5	278.7	799.0	399.0	477.0	10.0	3.5	2,347.9
1979	0	0	4.5	35.9	257.1	111.1	372.5	326.0	281.0	197.0	73.6	10.4	1,669.1
1980	1.0	0.4	9.8	4.0	209.1	99.1	452.7	137.0	380.6	95.7	334.7	3.5	1,727.6
1981	0	0	0	1.4	141.0	349.7	497.5	330.4	197.7	148.4	200.5	0.0	1,866.6
1982	0	0.5	11.5	45.2	26.6	285.5	372.5	338.0	169.5	127.5	-	-	-
Mean	0.2	0.1	7.2	24.4	255.0	226.2	369.3	392.4	280.8	150.0	138.1	4.8	1,848.5
Max.	1.0	0.5	22.4	62.7	906.0	441.0	497.5	799.0	399.0	477.0	334.7	11.6	2,347.9
Min.	0	0	0	0	26.6	93.7	206.2	137.0	169.5	2.0	10.0	0	1,615.6

(to be continued)

Table 1.4(2) MONTHLY RAINFALL RECORD

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Sibul Taravera, N.E.													
1972	35.8	0	9.0	48.3	212.0	218.9	1,072.1	428.1	258.9	22.4	33.4	11.8	2,350.7
1973	0.3	0.3	0	1.1	98.3	254.6	175.8	592.2	133.8	388.8	140.3	1.2	1,786.7
1974	44.5	0	5.3	93.1	55.5	287.2	363.0	648.6	190.0	510.8	182.7	73.4	2,454.1
1975	13.0	0	38.2	-	105.1	167.7	159.3	295.7	293.7	235.8	22.0	149.4	-
1976	0.3	1.8	5.1	0.3	904.3	447.5	148.5	315.4	250.1	-	29.0	13.2	-
1977	-	-	-	-	-	-	-	261.8	396.1	-	213.4	0	-
1978	0	0	12.2	0	-	487.7	230.2	571.4	-	-	-	-	-
1979	0	0.8	0	11.0	-	195.7	-	-	-	-	-	-	-
Mean	13.4	0.4	10.0	25.6	275.0	294.2	258.2	444.7	253.8	289.5	103.5	41.5	2,197.2
Max.	44.5	1.8	38.2	93.1	904.3	487.7	1,072.1	648.6	396.1	510.8	213.4	149.4	-
Min.	0	0	0	0	55.5	195.7	148.5	261.8	133.8	22.4	22.4	0	-
Quezon, N.E.													
1970	-	-	-	-	-	-	-	-	-	223.2	48.6	33.3	-
1971	8.7	5.3	10.4	0	357.5	353.8	208.2	130.2	334.7	315.6	137.5	109.1	1,971.0
1972	21.6	0	13.7	134.4	238.6	226.9	1,131.9	495.7	345.1	5.6	21.4	18.2	2,653.1
1973	2.0	0	0.3	15.5	78.5	281.1	280.2	358.9	237.0	429.7	97.8	0	1,781.0
1974	0	0	2.8	93.7	34.7	320.9	397.5	540.2	243.6	376.4	203.8	41.4	2,255.0
1975	26.4	16.3	7.9	18.3	205.3	287.6	172.7	316.2	254.1	220.7	13.5	77.7	1,616.8
1976	6.4	0	18.3	0	292.5	588.3	151.0	250.6	294.5	41.7	14.7	40.0	1,698.0
1977	10.4	0	1.0	24.4	224.7	-	301.9	347.4	204.5	-	145.7	0	-
1978	-	-	19.8	10.2	-	230.5	284.4	569.9	-	430.4	-	-	-
1979	-	-	0	2.0	210.3	108.5	298.1	268.6	-	182.4	54.5	-	-
1980	2.8	-	13.5	8.4	163.0	0.5	445.9	239.0	442.0	237.1	293.0	-	-
Mean	9.8	3.1	8.8	30.7	200.6	266.5	267.2	351.7	294.4	246.3	103.1	40.0	1,995.8
Max.	26.4	16.3	19.8	134.4	357.5	588.3	1,131.9	569.9	442.0	430.4	293.0	109.1	-
Min.	0	0	0	0	34.7	0.5	151.0	130.2	204.5	5.6	21.4	0	-

(to be continued)

Table 1.4(3) MONTHLY RAINFALL RECORD

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Cabanatuan City, N.E.													
1951	1.8	0	0	14.5	193.0	224.3	278.5	446.3	188.3	45.5	214.2	88.6	1,695.5
1952	3.1	3.5	11.5	10.9	231.1	355.7	142.6	308.4	308.4	210.1	42.5	65.9	1,693.7
1953	1.0	3.0	27.4	25.4	255.7	208.0	215.1	485.7	213.3	120.1	148.8	71.7	1,775.2
1954	1.5	17.0	5.3	89.4	39.7	94.1	225.9	289.3	262.3	152.3	162.1	0.3	1,338.9
1955	22.5	0.8	0	16.5	79.0	130.9	218.5	417.2	278.8	134.1	95.6	30.7	1,424.4
1956	5.1	0	2.5	261.4	66.3	64.2	162.3	355.7	505.1	113.8	289.7	90.0	1,916.1
1957	23.2	1.0	7.3	13.7	88.6	333.7	271.8	365.1	217.8	82.3	176.2	0	1,600.7
1958	0	19.0	0	0	55.6	310.2	286.6	264.2	367.9	-	-	-	-
1959	-	-	32.8	0	42.1	94.6	179.0	558.0	214.7	80.0	138.7	9.9	-
1960	2.6	49.5	10.2	55.6	160.5	245.0	231.7	622.7	452.7	403.2	39.9	3.3	2,276.9
1961	0	1.3	56.0	2.0	156.1	590.9	460.0	492.3	267.5	158.5	82.4	1.0	2,268.0
1962	4.6	0	2.8	37.2	133.5	308.4	468.4	280.0	453.8	35.6	57.6	0.3	1,782.2
1963	0	27.4	1.3	0	145.0	528.3	217.3	389.3	385.1	12.2	14.0	63.4	1,783.3
1964	9.3	1.4	69.8	7.2	124.2	400.6	233.7	429.9	288.8	330.0	287.5	97.1	2,369.5
1965	0	0	0	135.6	162.9	354.0	608.1	262.9	245.0	119.4	116.1	19.4	2,023.8
1966	1.8	0	7.9	24.4	586.8	116.1	223.5	462.0	226.8	114.1	344.4	54.6	2,162.4
1967	2.6	0	0.8	14.1	202.3	384.8	262.1	400.2	628.7	255.8	86.7	0	2,238.1
1968	5.8	0	0	22.1	144.1	90.4	242.0	567.0	338.5	125.5	51.3	0	1,586.7
1969	6.5	0	0	6.8	87.2	283.0	360.7	242.4	314.8	128.2	57.5	13.0	1,500.1
1970	1.5	1.3	4.9	22.8	16.6	234.6	169.0	361.9	179.3	222.6	76.5	34.5	1,325.5
1971	1.3	2.3	11.5	0.8	279.7	237.2	354.5	213.0	239.4	360.1	161.9	186.7	2,048.4
1972	67.3	0	31.5	12.9	190.2	144.4	1,064.7	434.9	305.4	17.5	38.7	18.4	2,325.9
1973	5.6	3.3	0.3	1.9	126.4	249.5	246.3	610.3	146.9	584.2	191.9	9.0	2,175.6
1974	0	0	1.0	73.2	14.5	323.6	258.3	628.3	144.6	400.0	226.6	72.3	2,142.4
1975	13.3	0.3	16.8	7.7	121.4	349.3	205.9	253.6	339.7	255.5	35.0	139.4	1,737.9
1976	2.4	13.5	11.2	0.8	931.1	468.6	141.9	330.6	350.3	28.5	32.6	44.8	2,356.3

(to be continued)

Table 1.4(4) MONTHLY RAINFALL RECORD

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1977	6.4	0	8.9	6.9	109.6	170.7	389.0	391.7	285.9	0	190.9	0	1,560.0
1978	0	5.4	0	0	0	291.8	433.4	604.9	563.8	514.1	34.9	15.7	2,464.0
1979	0	0	0	0.2	194.4	0	224.8	302.4	140.9	87.4	127.0	12.5	1,089.6
1980	1.2	0.6	41.3	11.6	218.2	170.2	390.1	182.1	411.5	123.3	477.6	26.8	2,054.5
Mean	6.4	5.1	12.1	29.2	171.9	257.9	305.2	399.8	307.9	179.7	142.9	44.0	1,862.1
Max.	67.3	49.5	69.8	261.4	931.1	590.9	1,064.7	628.7	628.3	584.2	445.2	197.1	2,464.0
Min.	0	0	0	0	0	0	141.9	182.1	140.9	0	14.0	0	1,089.6
Mangino Gapan, N.E.													
1975	32.5	0	25.5	14.1	123.2	254.5	189.6	382.6	201.2	296.5	40.9	176.6	1,737.2
1976	7.8	4.6	7.2	0.8	839.3	376.9	177.0	197.3	526.0	34.8	20.4	28.2	2,220.3
1977	10.9	0	1.0	0	184.4	113.7	294.2	269.4	385.1	2.0	161.5	0	1,422.2
1978	0	5.1	2.3	30.0	100.5	317.8	217.1	548.1	496.7	455.6	44.9	33.6	2,251.7
1979	3.0	3.8	2.3	58.5	184.2	162.8	251.7	392.2	197.8	59.5	110.5	-	-
1980	41.7	0.3	34.7	0.3	203.2	86.3	416.4	274.2	335.2	46.4	24.7	24.7	1,488.1
1981	-	-	-	-	245.4	419.8	560.4	601.7	254.2	281.2	-	-	-
1982	0	12.7	-	37.6	89.1	-	-	-	-	-	-	-	-
Mean	13.7	3.8	12.2	20.7	246.2	247.4	300.9	380.8	342.3	168.0	67.2	52.6	1,823.9
Max.	41.7	12.7	34.7	58.5	839.3	419.8	560.4	601.7	526.0	455.6	161.5	176.6	2,251.7
Min.	0	0	1.0	0	89.1	86.3	177.0	197.3	197.8	2.0	20.4	0	1,422.2

Table 1.5 MAXIMUM RAINFALL DEPTH FOR INDICATED DURATION

(Unit: mm)

Station	Period	Min. 5	10	20	30	60	Hrs 2	3	6	12	24
1. Tayabo	1970 - 1977	16.0	25.0	48.6	68.4	90.0	100.4	111.0	191.0	265.5	424.9
3. Palayupay	1970 - 1974	11.8	20.6	34.3	50.0	73.3	75.5	81.0	81.0	99.0	107.9
5. Pris dam	1970 - 1976	20.1	31.0	43.1	61.3	77.6	106.9	136.6	163.8	238.6	279.2
8. Baloc	1970 - 1975	29.4	29.4	41.2	54.5	87.0	104.0	107.9	156.0	164.9	185.2
9. Sibul Talavera	1972 - 1977	17.0	28.1	42.8	54.1	74.3	99.0	102.0	114.7	135.2	146.0
13. Murcon dam	1970 - 1977	36.0	37.6	56.3	68.5	92.7	95.6	116.2	132.9	162.8	239.3
14. Ilog Baliwag	1975 - 1977	18.0	27.0	48.0	61.0	95.0	132.5	136.0	137.5	161.6	187.2
15. Quezon	1970 - 1977	16.7	26.5	33.2	52.0	104.0	155.0	176.3	202.8	236.0	270.0
17. Bantug-Talavera	1975 - 1977	16.9	26.7	36.9	38.3	48.9	71.8	90.2	114.1	131.5	131.5
18. Bangad Cab.	1970 - 1976	22.0	33.0	53.4	53.4	87.4	117.0	155.0	202.0	253.0	268.3
20. Cabanatuan city	1973 - 1975	13.4	23.0	42.6	62.0	113.0	147.5	156.0	183.0	226.2	311.5
21. San Jose	1974 - 1977	20.0	35.5	42.7	45.5	61.6	66.1	68.4	99.0	169.4	206.7
24. Conception Zaragosa	1970 - 1972	15.6	28.1	45.8	54.1	64.5	75.4	76.4	76.9	76.9	118.5
27. Mallorca	1971 - 1975	19.4	24.0	39.8	45.6	63.4	72.5	76.9	96.1	165.6	178.5
28. Lambakin	1970 - 1974	16.7	23.7	45.0	55.5	84.6	105.6	108.7	108.7	163.8	248.2
30. Gapan	1971 - 1977	22.5	31.3	51.0	56.0	83.1	101.5	106.1	133.0	194.4	208.6
31. Manglino Gapara	1974 - 1977	14.1	26.6	47.2	50.2	65.3	76.7	88.7	134.2	180.1	180.1
32. San Isidro	1975 - 1977	29.5	39.8	79.3	105.7	130.6	133.7	133.7	178.0	243.0	251.0
33. Manga San Isidro	1974 - 1977	15.5	24.9	39.1	44.0	61.9	71.3	93.1	174.0	237.0	237.8
34. Concepcion Cabiao	1974 - 1977	23.8	39.6	44.6	49.3	69.2	96.2	99.3	101.6	180.6	236.0
35. Bulak Gapan	1974 - 1977	24.6	35.5	53.5	71.4	105.9	117.3	147.2	173.9	240.8	240.8
40. Sta. Rita	1974 - 1977	43.6	49.5	65.3	81.2	95.0	102.0	103.0	127.7	181.1	229.4
41. Clawitan	1974 - 1977	22.0	31.0	44.4	75.8	92.9	107.1	110.1	111.5	201.0	280.6
Mean		21.1	30.3	46.9	60.3	83.5	101.3	112.2	138.8	187.3	224.7
Max.		43.6	49.5	65.3	105.7	130.6	155.0	176.3	202.8	265.5	424.9
Min.		11.8	20.6	33.2	38.3	48.9	66.1	68.4	76.9	76.9	107.9

Table 1.6 MEAN MONTHLY DISCHARGE

(Unit: m3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Pantabangan Dam Inflow (A = 954 km2)/1												
1976	10.6	7.8	6.4	10.4	346.4	127.0	59.9	77.9	95.0	35.8	13.1	8.1
1977	7.8	5.9	6.3	5.3	17.5	9.1	62.3	59.4	110.9	27.7	47.4	8.7
1978	8.9	6.8	6.0	2.5	4.9	33.6	40.4	289.3	169.1	208.6	64.4	19.2
1979	9.7	6.9	3.3	4.9	12.7	19.0	57.5	70.5	48.9	72.8	20.9	7.7
1980	16.3	15.9	21.0	7.5	20.6	38.2	89.0	44.2	94.0	43.9	233.6	17.5
1981	18.6	15.5	15.7	10.2	6.2	58.3	139.2	104.0	60.5	32.3	21.8	24.6
1982	9.5	9.4	11.0	7.9	7.3	10.9	52.7	72.4	56.5	28.8	-	-
Mean	11.6	9.7	10.0	7.0	59.4	42.3	71.6	102.5	90.7	64.3	66.9	14.3
Max.	18.6	15.9	21.0	10.4	346.4	127.0	139.2	289.3	169.1	208.6	233.6	24.6
Min.	7.8	5.9	3.3	2.5	4.9	9.1	40.4	59.4	48.9	27.7	13.1	7.7
Talavera Dam Inflow (A = 313 km2)												
1972	8.7	10.5	11.8	6.2	14.8	14.5	-	-	-	-	-	-
1973	5.1	6.9	5.8	4.9	8.9	10.3	12.9	16.0	18.0	23.4	14.1	10.2
1974	3.2	6.3	5.9	6.4	6.5	14.8	10.4	23.6	16.8	22.8	23.5	11.0
1975	6.8	4.8	6.8	6.4	4.6	-	6.5	11.6	15.7	16.3	-	5.3
1976	2.8	2.6	-	-	-	-	-	-	-	-	-	-
Mean	5.3	6.2	7.6	6.0	8.7	13.2	9.9	17.1	16.8	20.8	18.8	8.8
Max.	8.7	10.5	11.8	6.4	14.8	14.8	12.9	23.6	18.0	23.4	23.5	11.0
Min.	2.8	2.6	5.8	4.9	4.6	10.3	6.5	11.6	15.7	16.3	14.1	5.3
Peñaranda Diversion Dam Inflow (A = 513 km2)												
1977	9.5	6.7	-	-	-	-	15.9	12.2	4.9	17.8	32.9	14.7
1978	8.3	8.5	13.6	10.3	6.8	7.1	12.6	15.7	24.4	27.9	145.4	16.9
1979	9.8	9.4	9.3	-	-	14.9	14.4	15.3	13.6	17.1	21.3	15.8
1980	10.3	8.0	6.5	10.3	8.1	-	25.8	19.9	28.2	20.6	28.1	15.0
1981	10.8	8.4	6.3	7.9	17.9	13.4	29.6	25.5	22.7	23.6	23.6	17.8
Mean	9.7	8.2	8.9	9.5	10.9	11.8	19.7	17.7	18.8	21.4	50.3	16.0
Max.	10.8	9.4	13.6	10.3	17.9	14.9	29.6	25.5	28.2	27.9	145.4	17.8
Min.	8.3	6.7	6.3	7.9	6.8	7.1	12.6	12.2	4.9	17.1	21.3	14.7
Coronel River Flow at Bangkerohan (A = 709 km2)												
1979	19.9	10.1	8.2	9.5	11.8	22.7	19.1	35.5	18.1	45.7	30.3	18.2
1980	15.2	13.1	13.5	8.2	17.4	20.1	23.7	22.6	49.5	34.9	76.3	25.0
1981	10.1	9.3	8.3	5.5	9.5	17.1	39.0	28.5	17.7	21.5	35.4	22.1
1982	14.2	12.8	11.0	11.1	10.7	10.9	24.4	32.9	23.0	14.8	-	14.0
1983	14.0	15.8	9.6	6.4	4.4	-	-	-	-	-	-	-
Mean	14.7	12.2	10.1	8.1	10.8	17.7	26.6	29.9	27.1	29.2	47.3	19.8
Max.	19.9	15.8	13.5	11.1	17.4	22.7	39.0	35.5	45.9	45.7	76.3	25.0
Min.	10.1	9.3	8.2	5.5	4.4	10.9	19.1	22.6	17.7	14.8	30.3	14.0

Remarks: /1: Catchment Area included Aurora River Basin (64 km2)

Table 1.7 STORAGE COEFFICIENTS ON SUB-BASINS

Sub-basin No.	Catchment Area (Km^2)	Storage Coefficient K	P	F_1	Lag-time (hr)
A. Upper Pampanga Basin					
101	890	59.34	0.519	0.5	1.33
102	383	67.02	0.472	0.5	0.79
103	135	40.56	0.406	0.5	0.41
104	84	35.91	0.447	0.5	0.68
105	166	88.26	0.522	0.5	0.62
106	47	37.20	0.435	0.5	0.52
107	259	57.40	0.533	0.5	0.62
108	143	23.04	0.633	0.5	1.97
109	375	38.46	0.729	0.5	1.66
110	389	33.84	0.806	0.5	1.25
111	125	27.04	0.558	0.5	1.27
112	226	24.86	0.596	0.5	2.30
113	250	45.36	0.641	0.5	0.32
114	40	11.40	1.000	0.5	0.55
Sub-total	3,512				
B. Rio Chico-Talavera Basin					
201	337	75.33	0.591	0.5	3.90
202	147	75.33	0.591	0.5	3.90
203	177	51.24	0.800	0.5	0.67
204	245	79.20	0.712	0.5	3.13
205	133	79.20	0.712	0.5	3.13
206	391	79.20	0.712	0.5	3.13
207	245	45.80	0.873	0.5	0.64
208	197	40.43	0.963	0.5	1.41
209	185	37.26	1.000	0.5	0.82
210	464	54.63	0.761	0.5	1.11
211	430	68.04	0.641	0.5	1.84
212	69	11.00	1.000	0.5	0
Sub-total	3,020				
C. Sierra Madre Mountain Basin (North Candaba)					
301	62	37.26	1.000	0.5	0.15
302	220	54.52	0.762	0.5	1.09
303	46	74.40	0.435	0.5	0.30
304	164	41.40	0.945	0.5	1.68
305	78	65.08	0.483	0.5	0.82
306	330	83.40	0.546	0.5	2.07
307	241	86.10	0.533	0.5	2.09
308	140	11.00	1.000	0.5	0.0
Sub-total	1,281				

Table 1.8 DISCHARGE-STORAGE RELATION OF CHANNEL

Channel No. /1	River Name	Existing Channel Q (m^3/s)	Existing Channel S (m^3/s)	Proposed Channel Q (m^3/s)	Proposed Channel S (m^3/s)
No 14	Pampanga	50	1,090	50	1,090
(Point 26)		100	1,650	100	1,650
		200	2,500	200	2,500
		300	3,200	300	3,200
		500	4,400	500	4,400
		700	5,350	700	5,350
		840	6,000	840	6,000
		1,000	6,700	1,000	6,700
		1,500	8,600	1,500	8,600
		2,000	21,000	2,000	21,000
		2,250	30,000	2,300	32,000
		2,300	100,000	3,000	38,000
				4,000	45,000
				5,000	52,000
				7,000	64,000
No 21, 22	Talewera	50	660	50	660
(Point 40, 43)		100	990	100	990
		150	3,350	150	3,350
		200	7,700	200	7,700
		300	26,000	270	18,000
		400	60,000	500	26,000
				1,000	40,000
				2,000	60,000
No 23, 24	Rio Chico	50	390	50	390
(Point 49, 53)		90	560	90	560
		130	1,800	130	1,800
		185	5,800	185	6,000
		200	7,800	300	7,900
		250	16,000	500	10,800
		300	29,000	1,000	16,300
		2,400	70,000	2,000	24,600
No 25	Rio Chico	50	480	50	480
(Point 58)		100	700	100	700
		140	840	140	840
		200	3,500	240	7,700
		240	7,600	300	8,700
		300	18,500	500	12,000
		400	65,000	1,000	18,000
				2,000	27,500
				3,000	35,000

/1: Refer to Fig. 1.10

Table 1.9 PROBABLE AVERAGE RAINFALL IN THE UPPER PAMPANGA RIVER BASIN

Return Period (year)	Probable Rainfall (mm)						
	1-day	2-day	3-day	4-day	5-day	6-day	7-day
2	77.1	119.6	141.3	159.4	173.1	193.1	211.7
5	116.5	198.8	264.2	280.3	316.9	340.3	365.1
10	142.6	251.2	315.8	360.3	412.3	437.8	466.6
20	167.7	301.4	382.4	437.2	503.6	531.2	564.1
50	200.2	366.5	468.7	536.6	621.9	652.2	690.2
80	216.6	399.6	512.6	587.1	682.1	713.8	754.3
100	224.4	415.3	533.4	611.1	710.5	742.9	784.7
150	238.7	443.7	571.1	654.5	762.2	795.8	839.7
200	248.7	463.9	597.9	685.3	798.8	833.2	878.8
500	280.6	528.0	682.9	783.2	915.4	952.4	1,002.9
1,000	304.8	576.5	747.1	857.3	1,003.4	1,042.5	1,096.9

Notes

1. Probable average rainfalls in the Upper Pampanga river basin were estimated from the probable rainfalls at Cabanatuan City through the correlation curves.

2. Probable average rainfalls were estimated in the stage of Feasibility Study on Pampanga Delta Development Project from 1980 to 1981 by JICA.

Table 1.10 PEAK DISCHARGE OF PROBABLE FLOOD

(Present conditions with Pantabangan dam)
Unit: m^3/s

Point	Location	Return Period (yr)				
		1/2	1/5	1/10	1/20	1/50
Upper Pampanga						
2		611	987	1219	1450	1450
3		588	875	975	1089	1292
16	Coronel R.	294	660	911	1152	1465
17	Coronel R.	290	647	812	978	1169
20		1118	1961	2432	2890	3463
23	Cabanatuan	1208	1977	2366	2726	3205
25		1354	2240	2704	3134	3692
33	Peñaranda R.	237	542	753	948	1197
34	Peñaranda R.	230	530	733	865	1046
35	San Isidro	1543	2409	2722	3099	3303
Talavera						
36		225	448	677	927	1276
39		303	606	900	1238	1708
40		203	303	346	390	448
42		224	345	404	459	532
43		185	253	292	316	345
Rio Chico						
48	Ilog-Baliwag R.	146	291	393	491	637
49		127	205	244	273	378
52		230	505	717	921	1199
53		190	280	435	587	752
57		469	790	976	1348	1718
Bulo						
62		58	106	152	209	282

Table I.11(1) RESULTS OF SIEVE ANALYSIS OF RIVERBED MATERIAL

(Sampling and analysis by UPRIIS)

Sampling No.	Location	Percentage of Weight Passing through Sieve											Mean Diameter D65 (mm)	Specific gravity (g/cc)
		37.5mm	19.0	9.5	4.76	2.0	0.6	0.42	0.25	0.106	0.053	0.002		
Pampanga R.														
1	P - 1	100	84	71	47	27	11	8	6	3			8.0	2.69
2	4	100	94	72	42	17	5	3	1				8.0	2.70
3	6					100					87	51	-	2.62
4	11				100	98	84	64	31	8	1		0.45	2.63
5	13					100					51	27	-	2.67
6	15		100	91	75	55	26	18	12	1			3.0	2.64
7	17	100	70	40	26	17	8	5	2				18.0	2.68
8	19	100	91	79	67	52	13	8	4	1			4.0	2.66
9	22	100	90	80	68	52	19	11	6	1			3.8	2.70
10	23	100	97	76	57	38	14	9	5	1			6.4	2.69
Talavera R.														
11	T - 1	100	91	76	61	43	13	6	3	1			5.5	2.70
12	9		100	96	73	49	32	23	6	1			3.5	2.67
13	13	100	98	73	53	39	27	19	8	1			7.0	2.70
14	15		100	92	75	64	55	50	31	1			2.2	2.68
15	17					100					24	6	0.37	2.65
16	19				100	99	94	86	56	7	0.3		0.28	2.70
17	21	100	92	75	59	43	21	16	8	1			5.5	2.70
18	22	100	91	76	61	38	13	10	6	1			6.0	2.64
19	23	100	77	54	30	16	7	5	3	1			14.0	2.67

Table 1.11(2) RESULTS OF SIEVE ANALYSIS OF RIVERBED MATERIAL

(Sampling and analysis by UPRIIS)

Sampling No.	Location	Percentage of Weight Passing through Sieve											Mean Diameter D65 (mm)	Specific gravity (g/cc)
		37.5mm	19.0	9.5	4.76	2.0	0.6	0.42	0.25	0.106	0.053	0.002		
Talavera Main Canal														
20	1.0k	100	87	78	48	27	13	8	3	1			6.8	2.70
21	3.0					100	91	89	85	26	14	2	0.19	2.62
22	5.0					100	55	45	32	10	5	2	0.80	2.60
23	7.0					100	72	65	58	31	20	4	0.42	2.60
Rio Chico R.														
24	R - 3					100					48	26	0.17	2.60
25	4					100					64	28	0.06	2.64
26	5					100					86	38	0.01	2.66
27	7		100	96	88	77	63	54	26	5			0.75	2.70
28	12					100					69	36	0.035	2.66
Peñaranda R.														
29	PN- 2	100	89	69	38	20	9	8	7	2			8.6	2.66
30	4					100					13	1	0.47	2.64
Bulo R.														
31	B - 2.5	100	85	70	52	32	7	3	1				8.0	2.70
32	B - 7.5		100	94	73	36	10	6	3	1			3.8	2.68
33	B -12.5	100	94	79	60	40	19	12	5	1			5.4	2.68
34	B -17.5			100	98	89	22	12	4	1			1.3	2.67

Fig. 1.1 AVAILABLE RECORDS OF DAILY RAINFALL

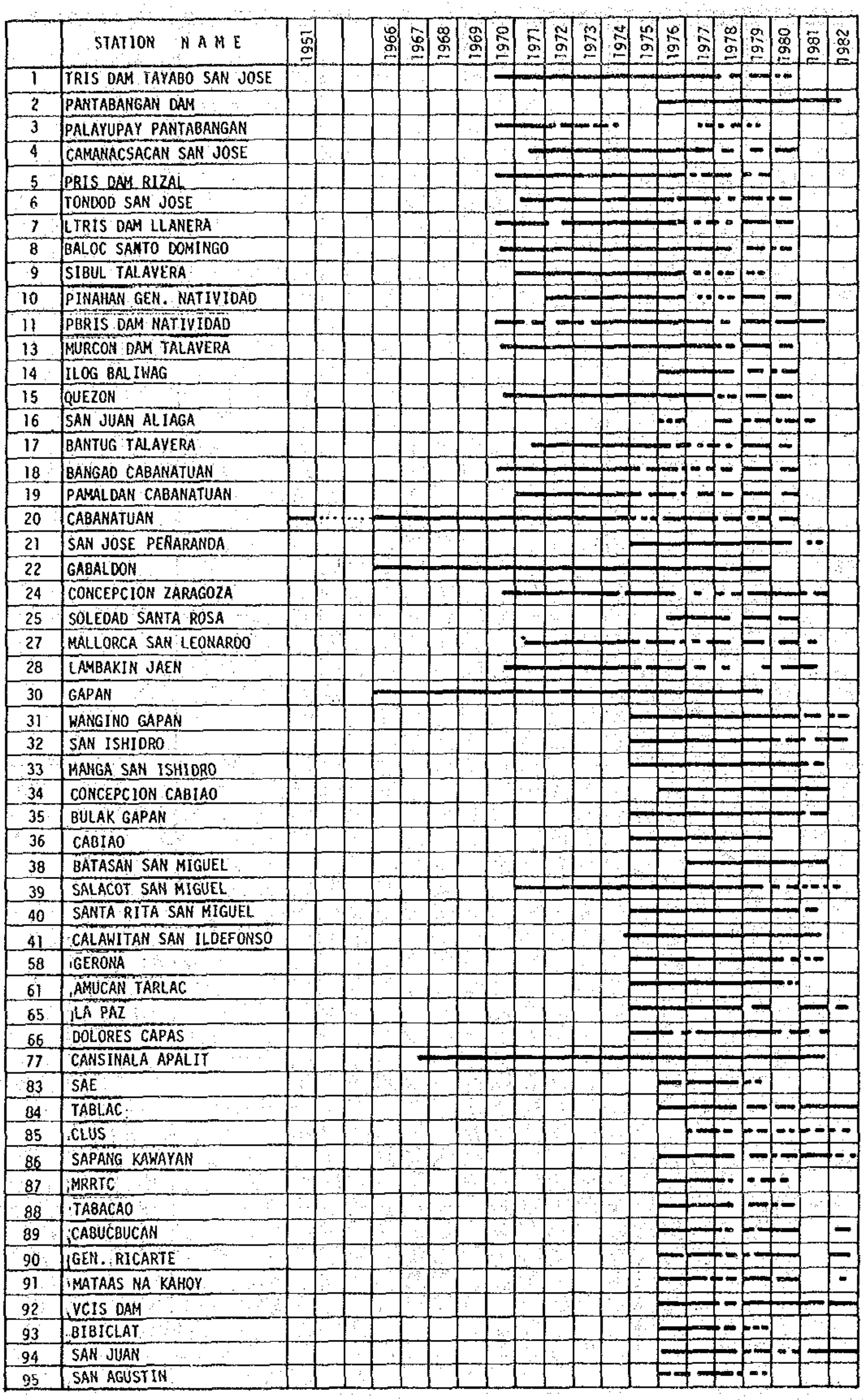


Fig. 1.2 LOCATION MAP OF RAINFALL STATIONS

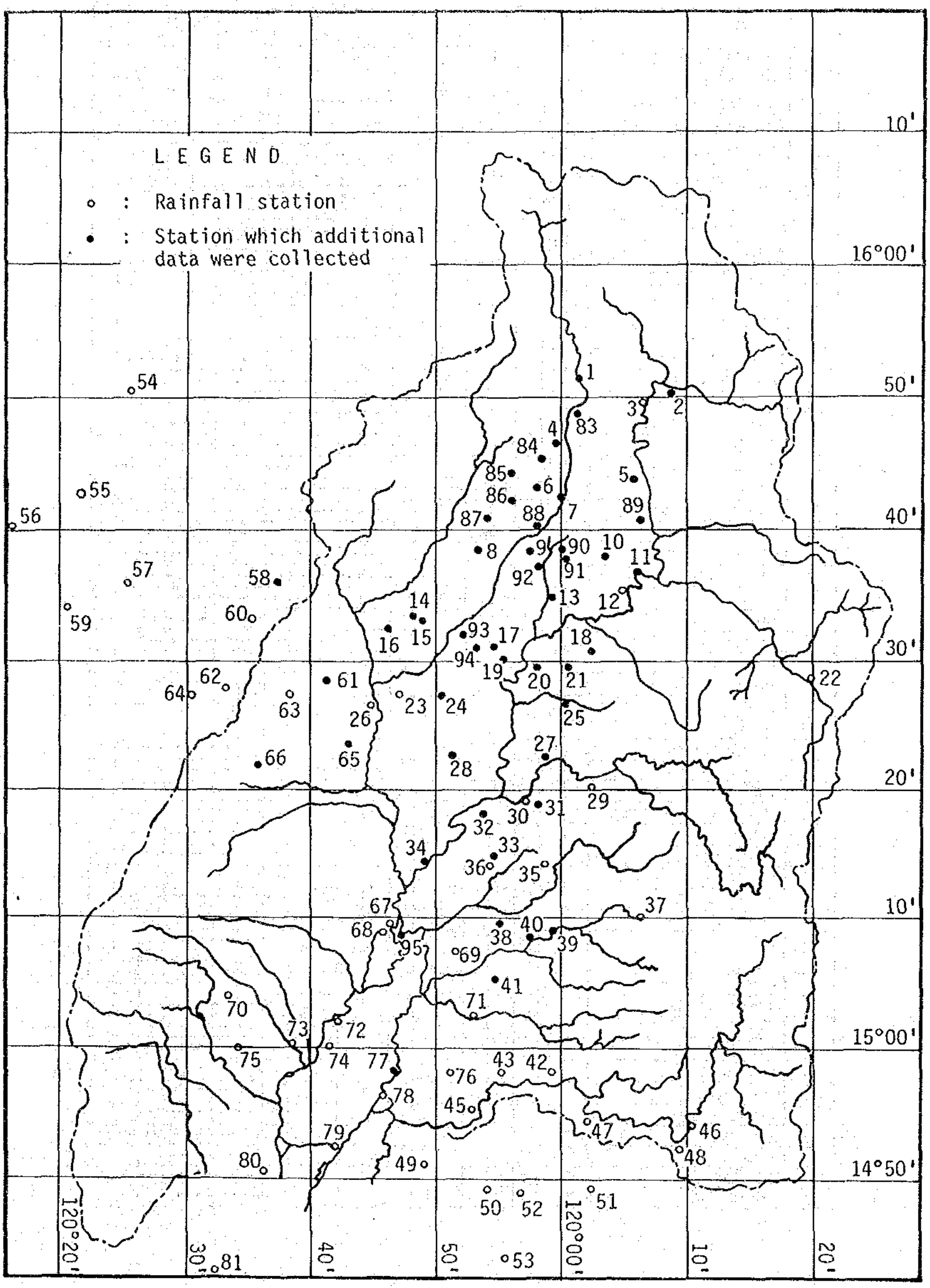


Fig. 1.3 MEAN ANNUAL RAINFALL MAP

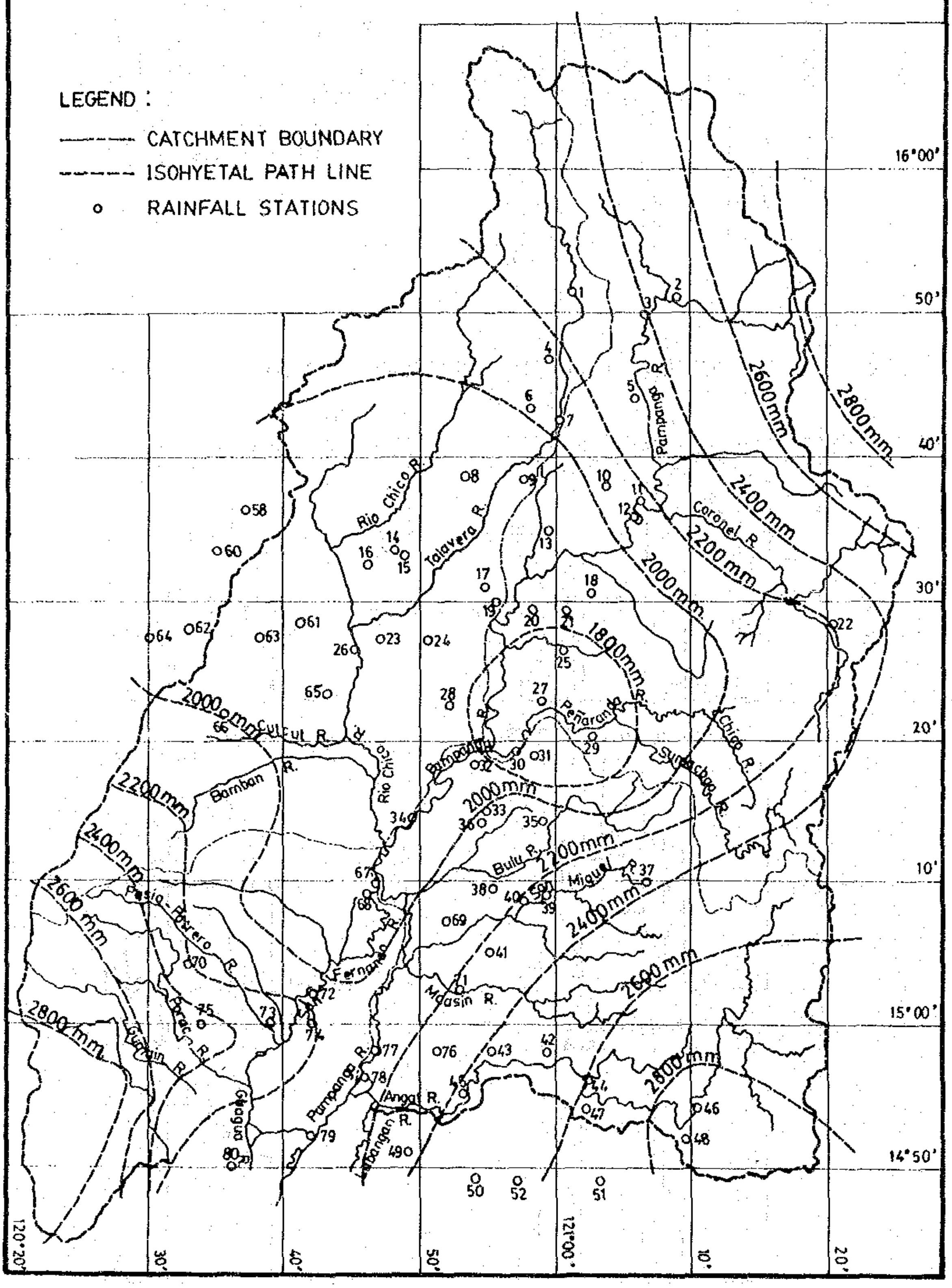


Fig. 1.4 YEARLY VARIATION OF ANNUAL RAINFALL

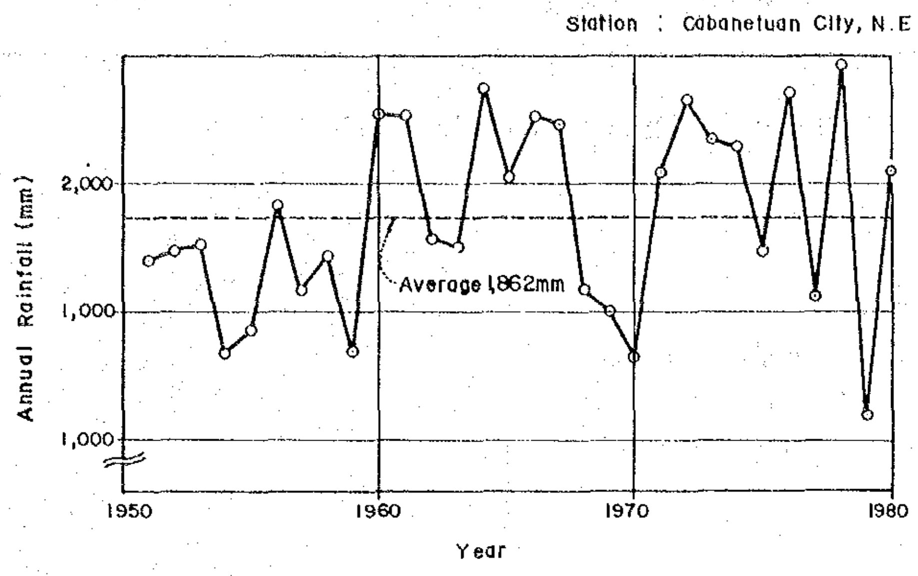


Fig. 1.5 ANNUAL PATTERN OF MEAN MONTHLY RAINFALL

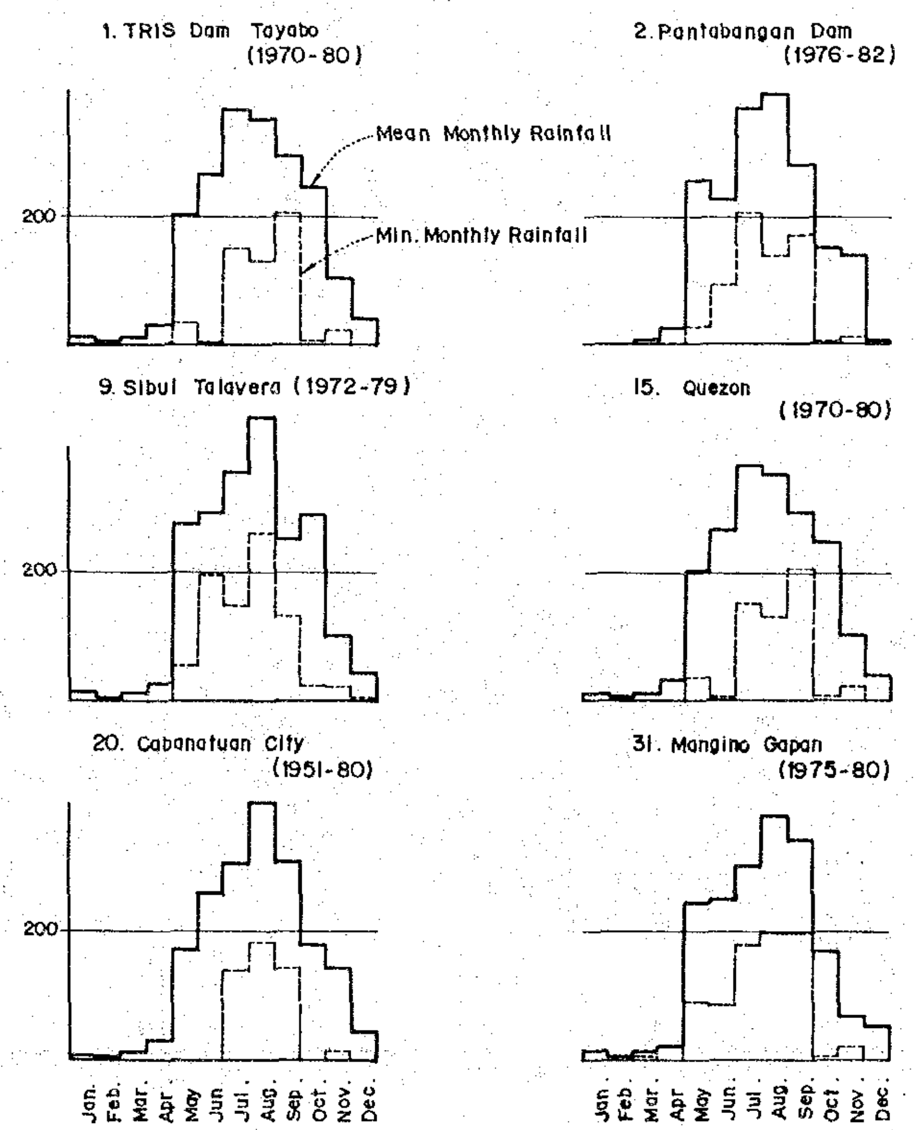


Fig. 1.6(1) RAINFALL DISTRIBUTION

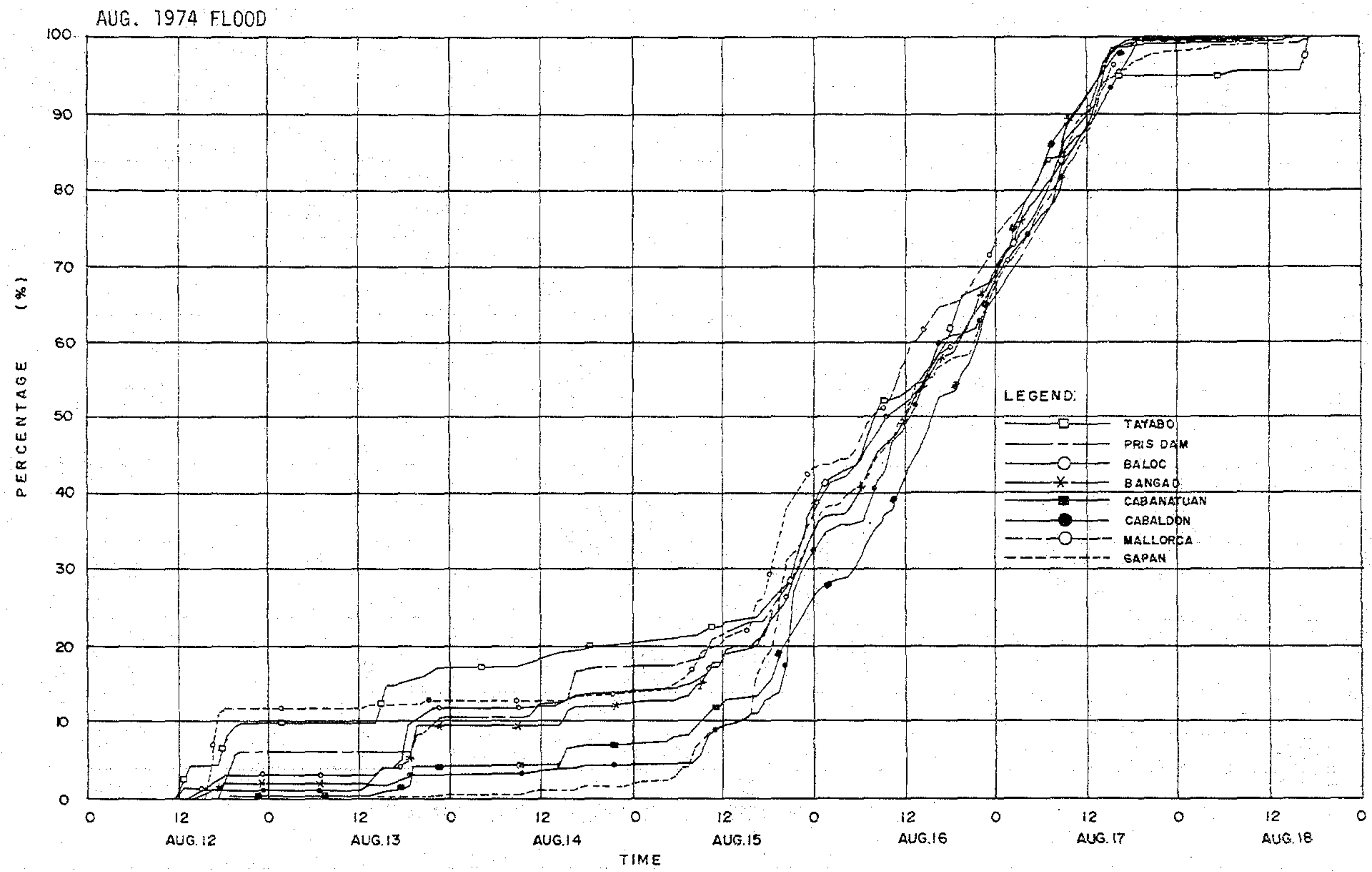


Fig. 1.6(2) RAINFALL DISTRIBUTION

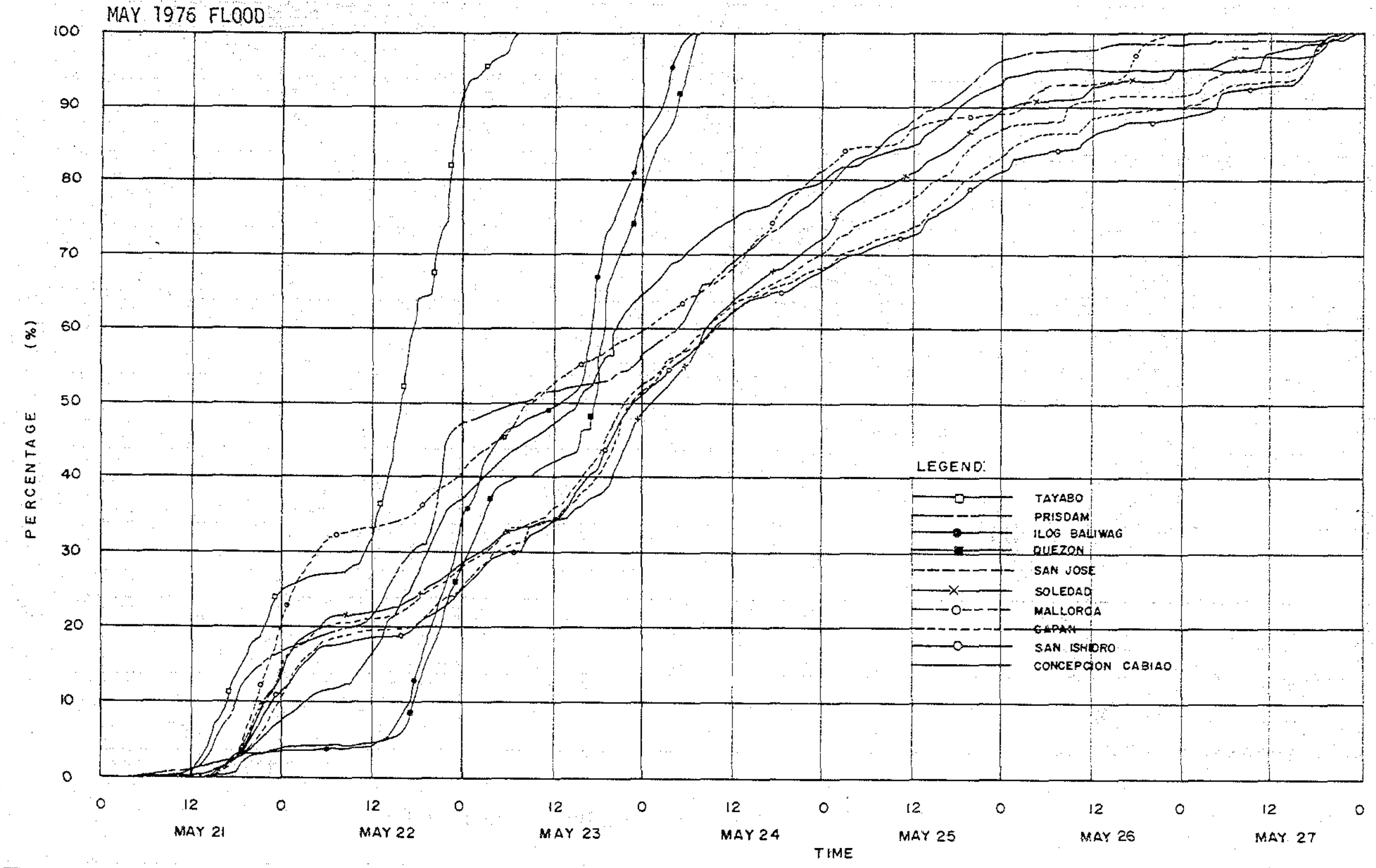


Fig. 1.7 LOCATION MAP OF GAGING STATION AND DISCHARGE OBSERVATION STATION

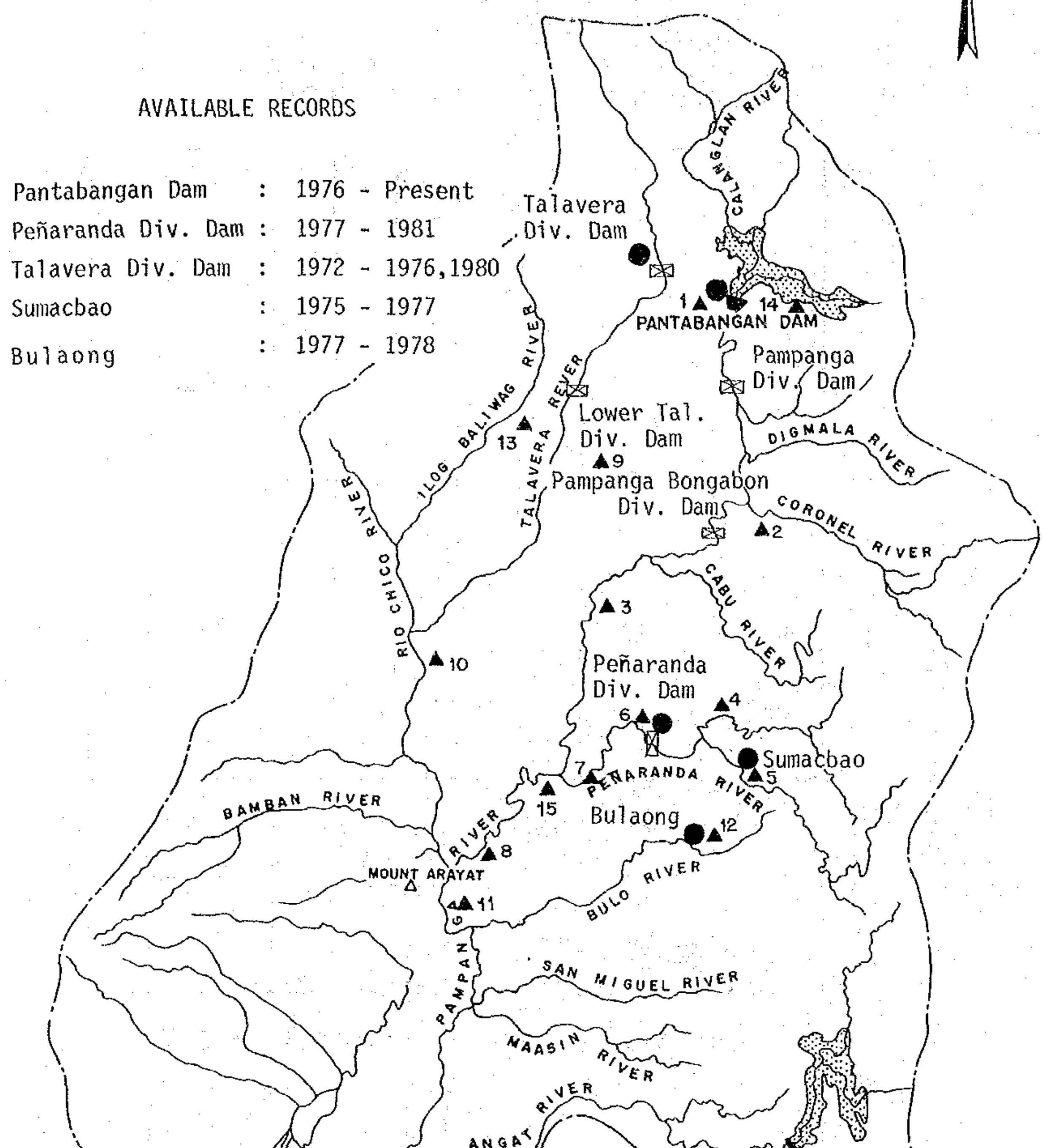


Fig. 1.8 ANNUAL PATTERN OF MEAN MONTHLY DISCHARGE

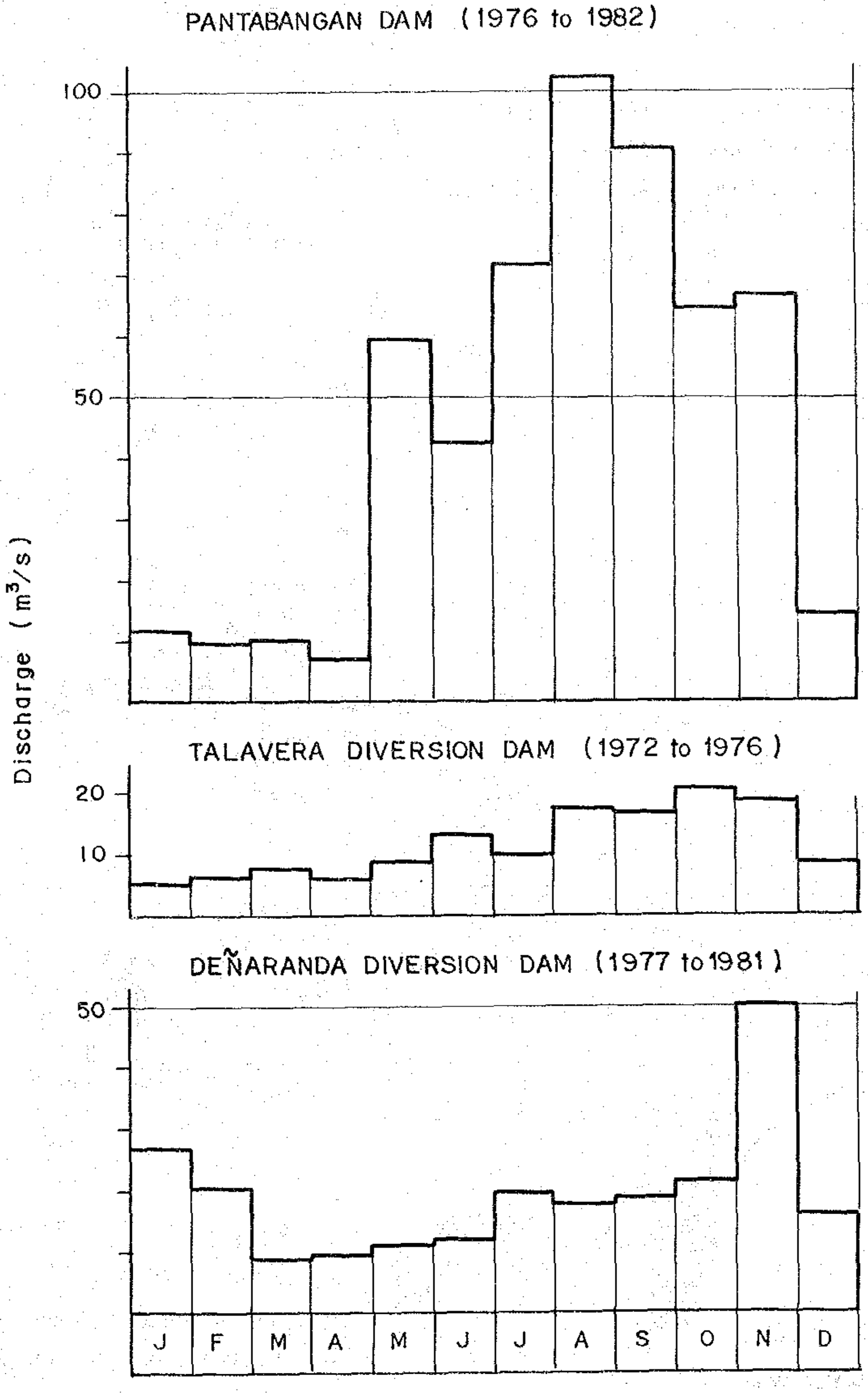


Fig. 1.9 SUB-BASINS OF THE UPPER PAMPANGA RIVER BASIN FOR RUNOFF ANALYSIS

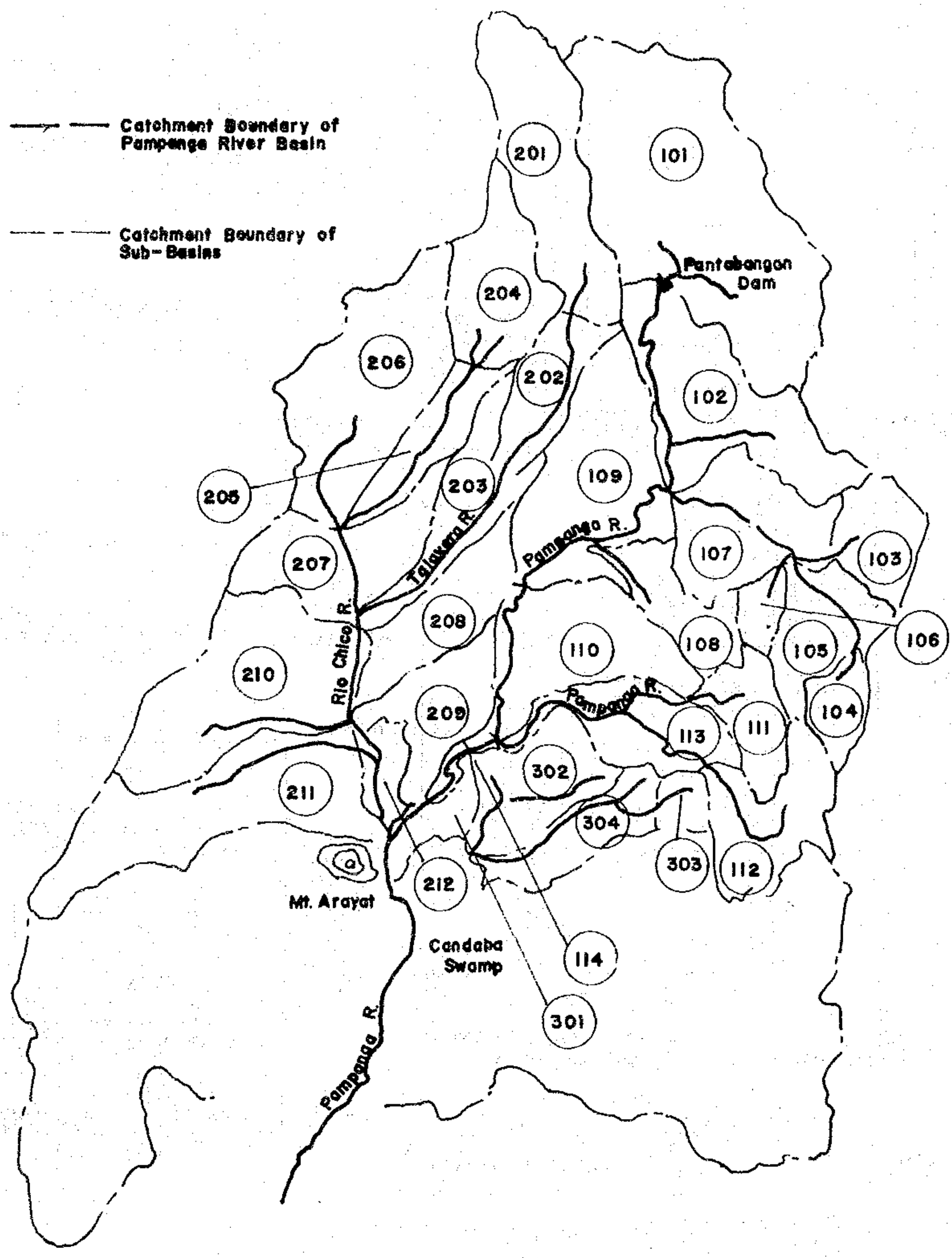


Fig. 1.10 RUNOFF CALCULATION MODEL DIAGRAM

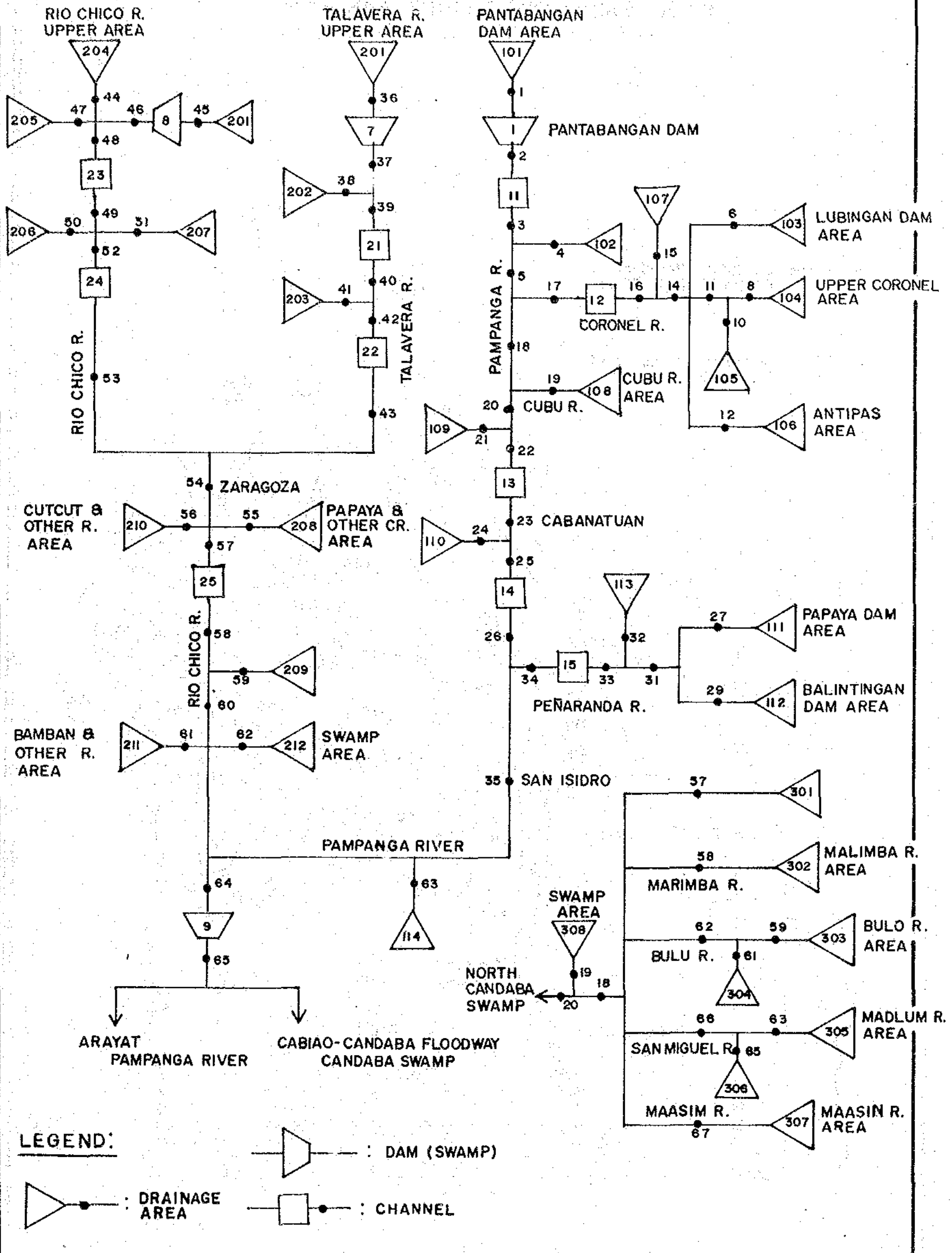


Fig. 1.11 RUNOFF HYDROGRAPH

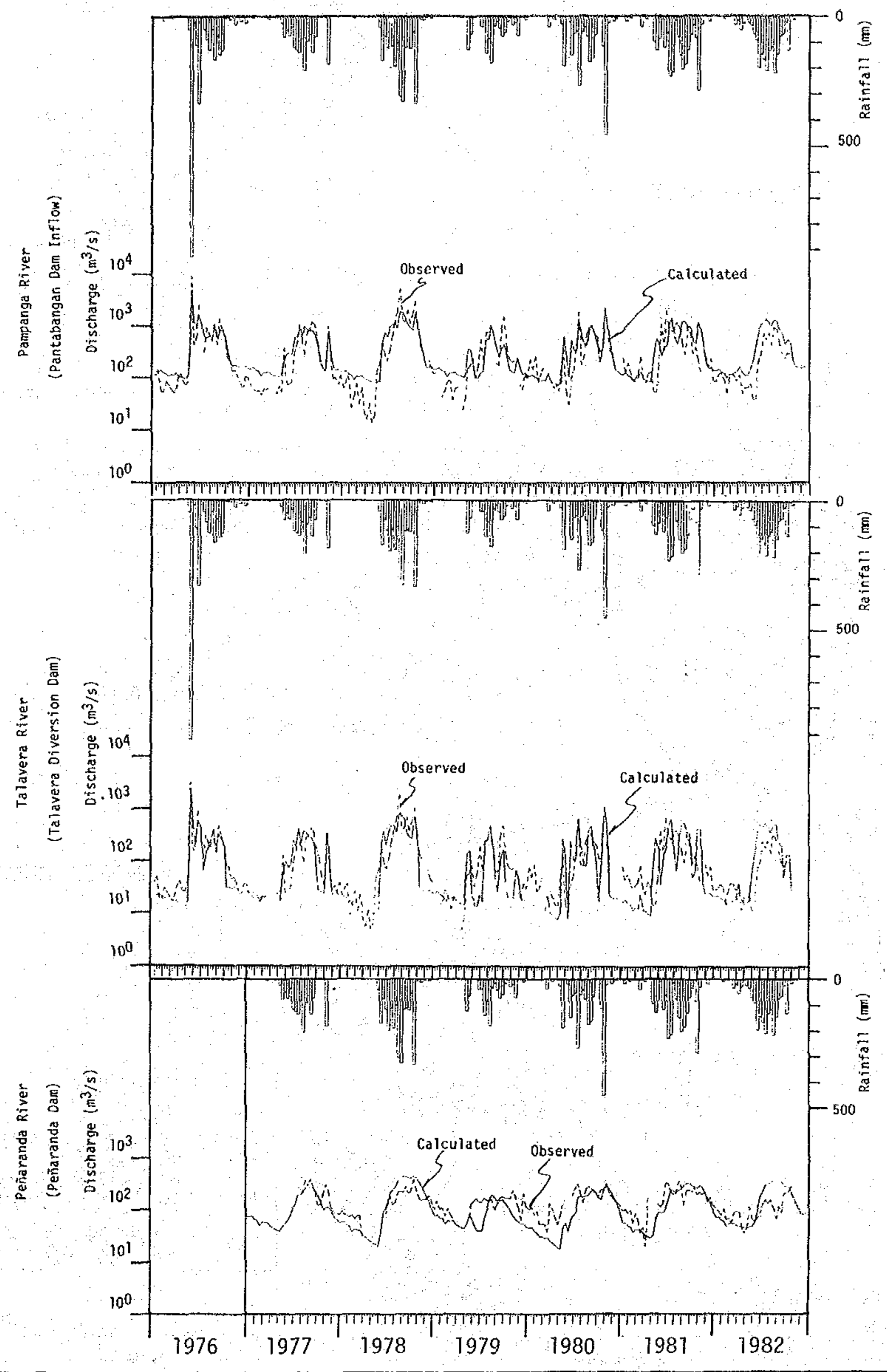


Fig. 1.12 LOCATION MAP OF CROSS SECTIONAL SURVEY AND SEDIMENT SAMPLING

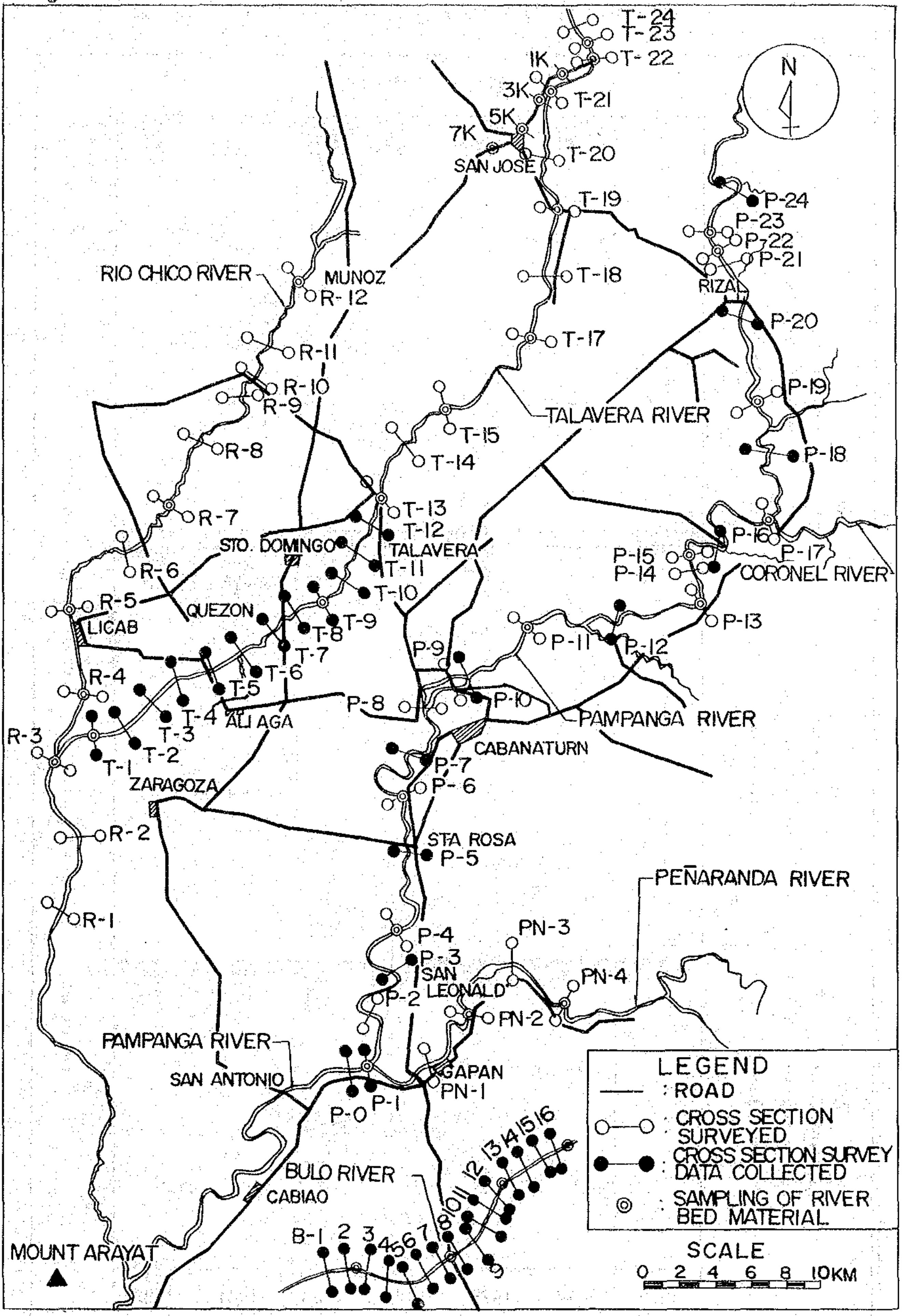
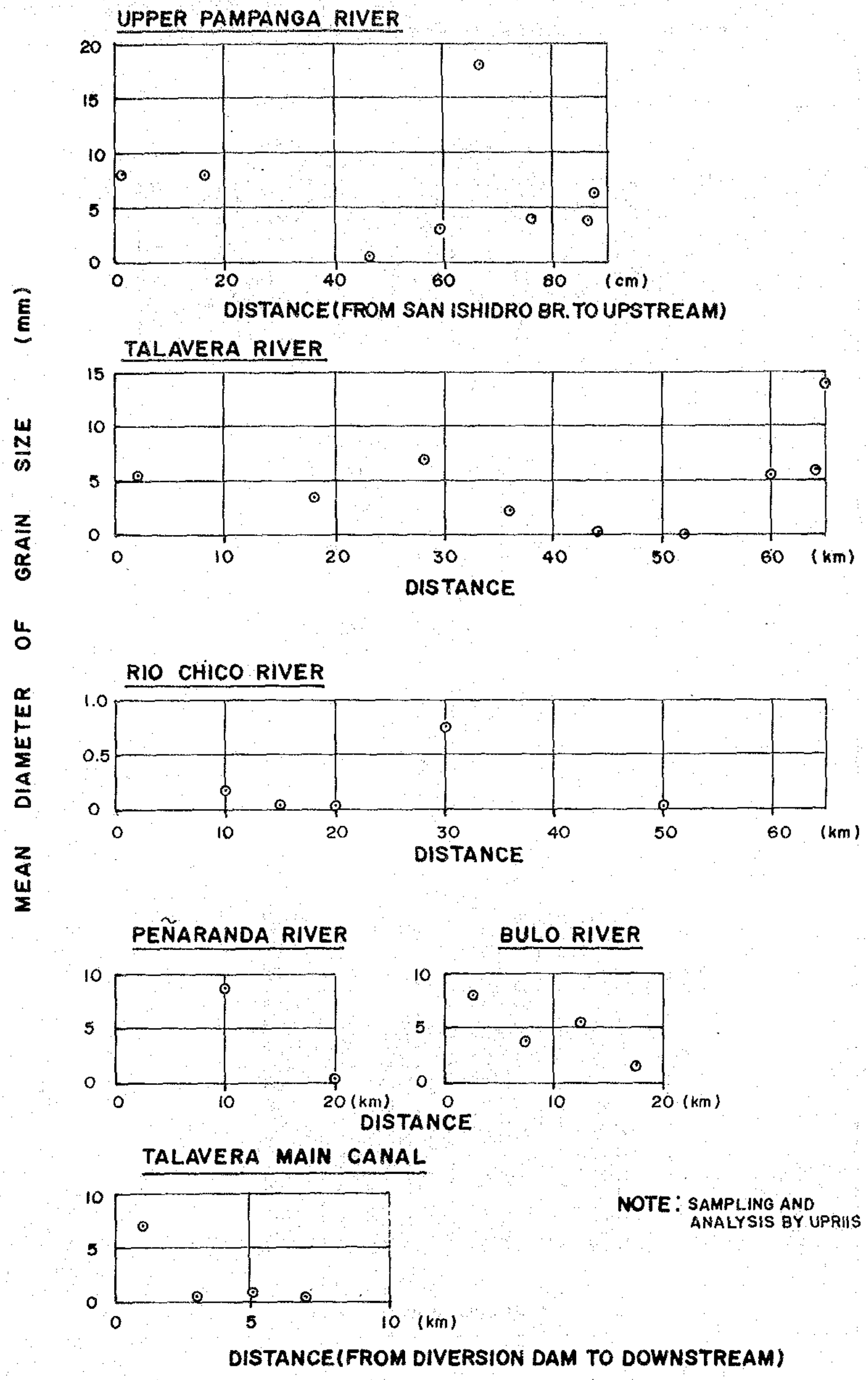


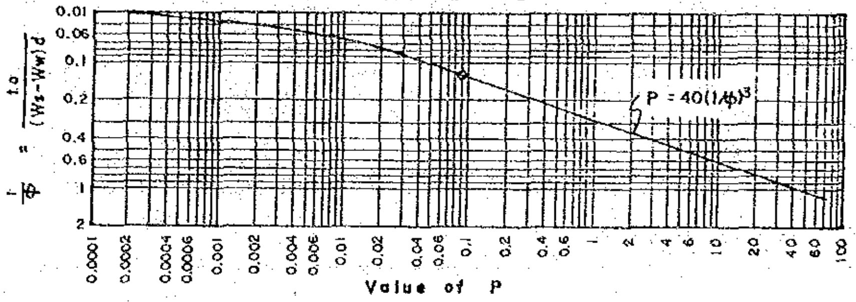
Fig. 1.13 MEAN DIAMETER OF GRAIN SIZE FOR EACH RIVER



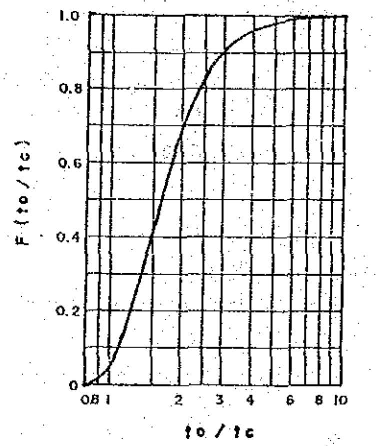
NOTE: SAMPLING AND ANALYSIS BY UPRIIS

FIG. 1.14 DIAGRAMS FOR SEDIMENT FORMULAS

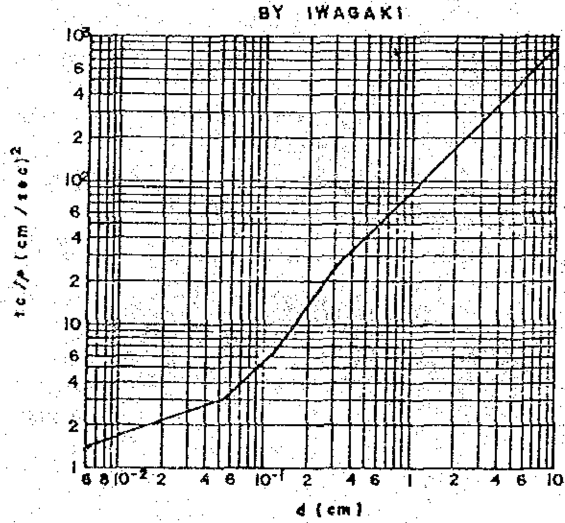
SEDIMENT FUNCTION
BY EINSTEIN-BROWN



SEDIMENT FUNCTION
BY SATO-KIKKAWA-ASHIDA



CRITICAL TRACTIVE FORCE
BY IWAGAKI

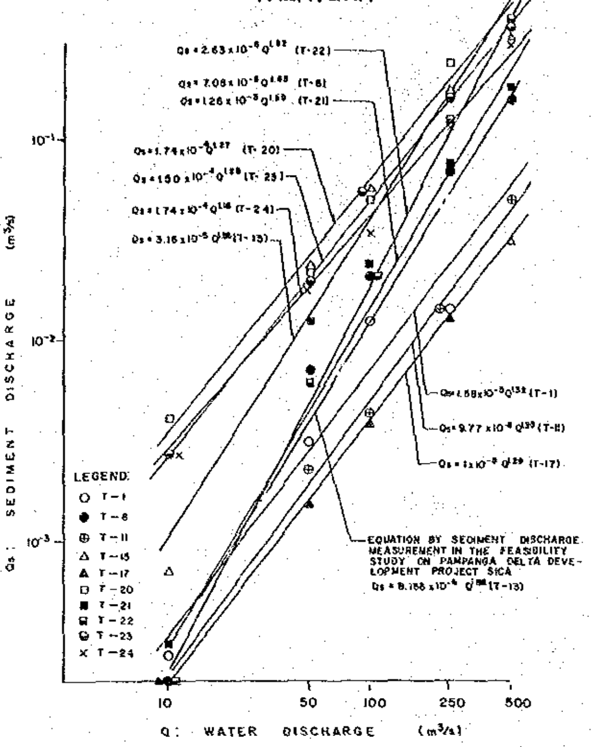


Note :
ρ : density of water (Ww/g)

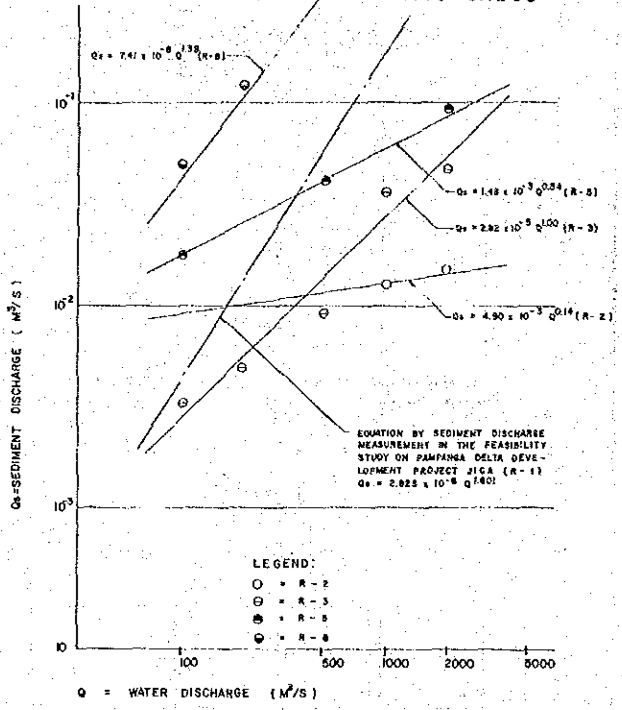
Fig. 1.15 RELATIONSHIP BETWEEN Q AND Qs IN THE EXISTING RIVERS

(by Brown Formula)

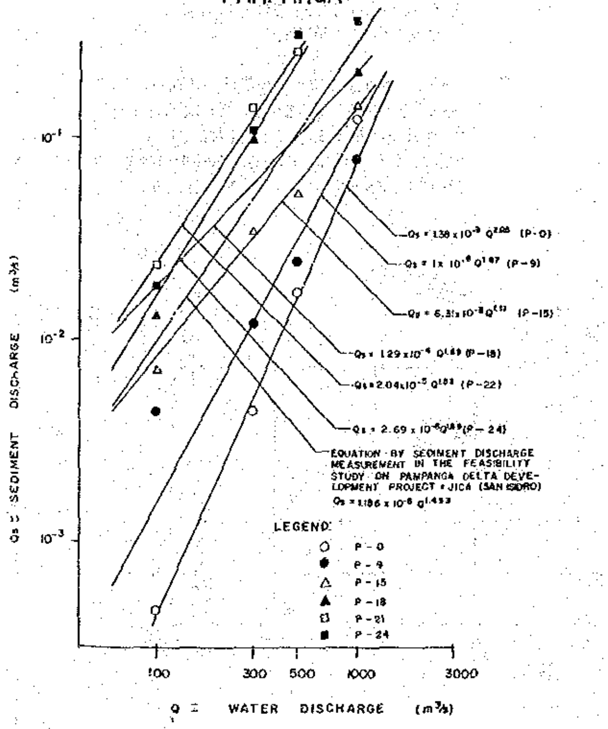
- TALAVERA



- RIO CHICO



- PAMPANGA



- PEÑARANDA

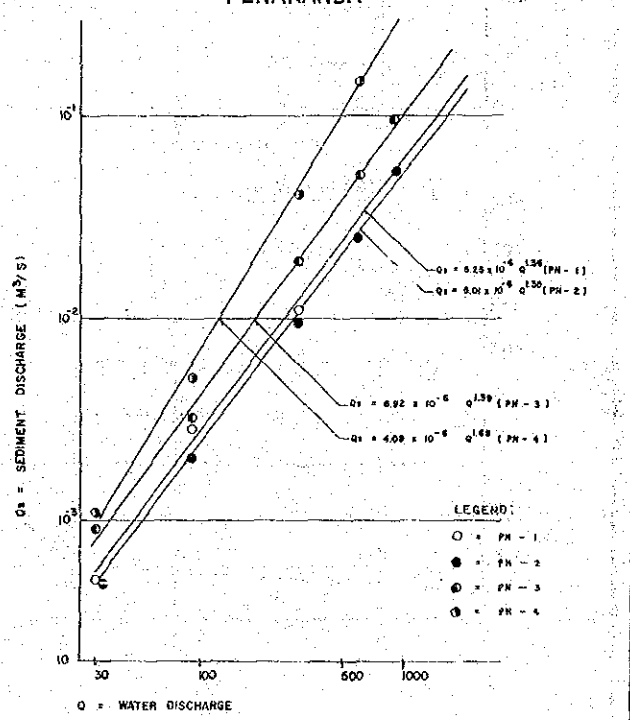
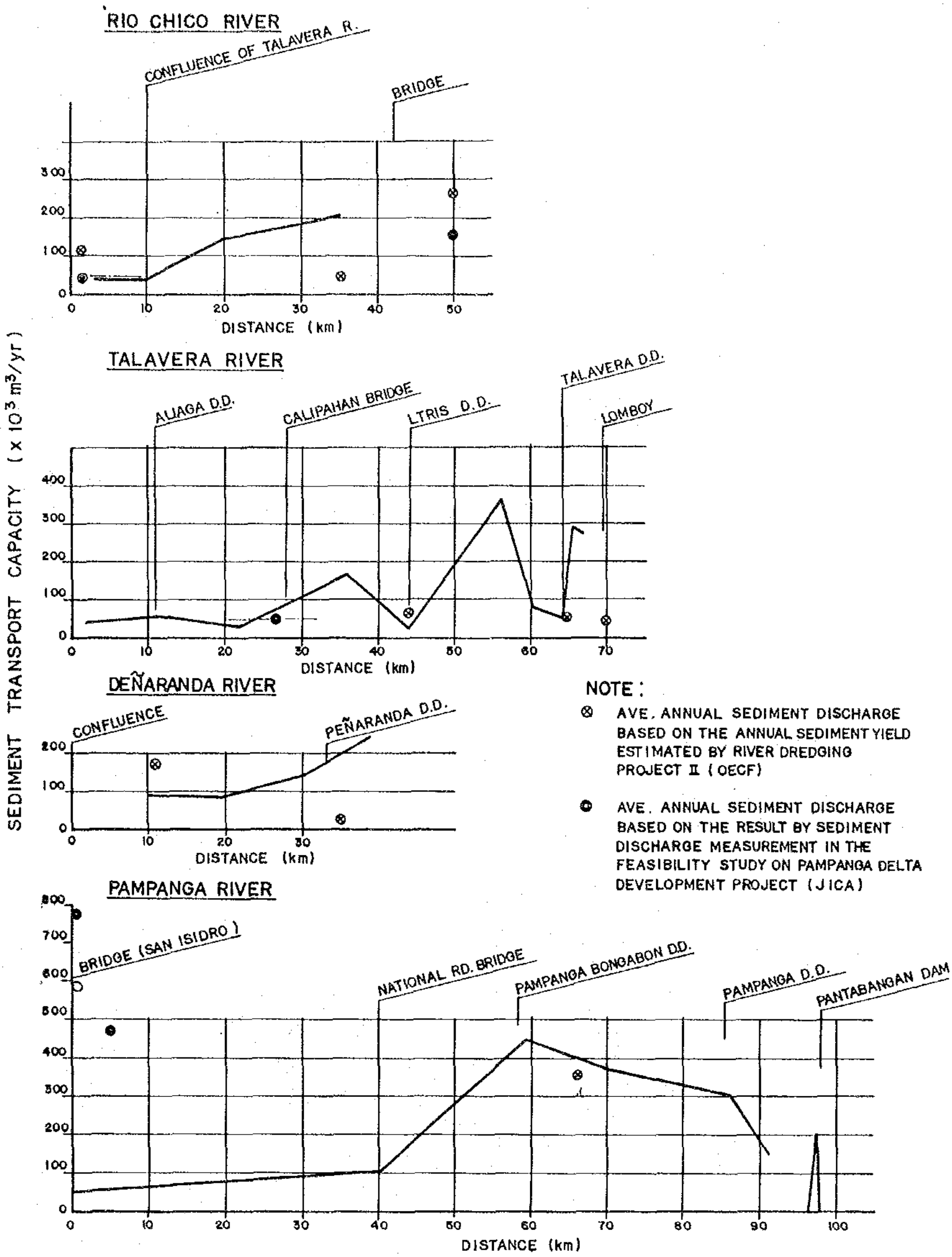


Fig. 1.16 SEDIMENT TRANSPORT CAPACITY OF THE EXISTING CHANNEL

(by Brown Formula)



NOTE:

⊗ AVE. ANNUAL SEDIMENT DISCHARGE BASED ON THE ANNUAL SEDIMENT YIELD ESTIMATED BY RIVER DREDGING PROJECT II (OECF)

● AVE. ANNUAL SEDIMENT DISCHARGE BASED ON THE RESULT BY SEDIMENT DISCHARGE MEASUREMENT IN THE FEASIBILITY STUDY ON PAMPANGA DELTA DEVELOPMENT PROJECT (JICA)

APPENDIX II

IRRIGATION

APPENDIX II IRRIGATION

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APPENDIX II IRRIGATION

CHAPTER 1 INTRODUCTION

The study on "Irrigation" is carried out being paid on the improvement and rehabilitation of the existing irrigation systems in the Upper Pampanga River Integrated Irrigation System (UPRIIS).

To grasp the present situation of irrigation systems such as water delivery and water management, the data and information are collected during the survey period which are listed on Table 2.1. And the following field surveys were conducted by the JICA study team and UPRIIS counterparts.

1) Inventory survey for irrigation canals and related structures.

2) Sketch survey for the diversion dams and re-use structures (35 points)

3) Cross section survey for rivers and creeks.

River & Creek	Cross Section
- Pampanga	18
- Talavera	18
- Peñaranda	6
- De Babuyan	14
- Vaca	10
- Murcon	9
- Carol	8
- Other creeks	81

4) Experiment on time-lag measurement which was excuted for about 7 km length in the selected lateral C-9a in the PEÑRIS proper area.

CHAPTER 2 EXISTING IRRIGATION SYSTEM

2.1 General Description

The project area of 157,000 ha extends over the vast flat alluvial plain located in the upper reaches of the Pampanga river. It consists of the Upper Pampanga River Integrated Irrigation Systems (UPRIIS); 150 km north of Manila, and its neighboring area.

Historically there existed following nine (9) national irrigation systems serving about 67,000 ha in the project area before the integration.

System	Design Area (ha)	Water Resource
(1) Peñaranda River Irrigation System (PEÑRIS proper)	17,670	Peñaranda River
(2) Talavera River Irrigation System (TRIS)	10,000	Talavera River
(3) San Agustin Extension (SAE)	1,000	Talavera River
(4) Pampanga River Irrigation System (PRIS)	12,000	Pampanga River
(5) Murcon Creek Irrigation System (MCIS)	6,000	Murcon Creek
(6) Vaca Creek Irrigation System (VCIS)	2,400	Vaca Creek
(7) Pamaldan Cinco-Cinco Area (PCCA)	1,450	Cinco-Cinco Creek
(8) Pampanga-Bongabon River Irrigation System/* (PBRIS proper)	13,050	Pampanga River
(9) Lower Talavera River Irrigation System (LTRIS)	3,200	Talavera River
Total	66,770	

/*: Include Bical-Bical Creek Irrigation System (1,050 ha)

These systems were the run-of-river type systems and relied upon the direct diversion of unregulated stream flow. So shortage of water often occurred, which hindered agricultural development in the project area. In order to solve such problems, "The Upper Pampanga River Project, (UPRP)" was begun in 1969 with assistance from IBRD and completed in 1975.

The major works of the Upper Pampanga River Project were to construct the Pantabangan dam in the Pampanga river and the diversion canal to supply the irrigation water to several existing irrigation systems. Furthermore, the existing irrigation facilities in the systems were improved or rehabilitated through the project.

After the implementation of the Pantabangan dam, the UPRIIS has started operation at 1975 wet season. At the same time, the following national irrigation systems were improved or constructed and integrated by the diversion canals.

System	Design Area (ha)	Water Resource
(1) Santo Domingo Area (SDA)	10,500	De Babuyan Creek
(2) Rizal Munic Area (RMA)	2,500	Pampanga River
(3) Platero Area (PLATERO)	600	Pampanga River
(4) Aliaga Area (ALIAGA)	4,000	Pampanga River
(5) Pampanga-Bongabon River Irrigation System, Extension (PBRIS ext'n)	13,000	Pampanga River
Total	30,600	

Since then, the UPRIIS has been expanding the irrigation service area to the outlying area through rehabilitation and construction of irrigation systems. The PEÑRIS Proper area was integrated into the system in 1977. Further under "the Aurora Peñaranda Irrigation Project", the Peñaranda River Irrigation System Extension (PEÑRIS ext'n) area was rehabilitated and integrated into the UPRIIS in 1982.

The UPRIIS consists of four (4) irrigation Districts administratively. General layout of UPRIIS is shown in Fig. 2.1. General description of the present irrigation systems by District is as follows.

(1) District I

Irrigation systems in the District I comprise TRIS, SAE and SDA. The systems lie in the upper portion of the UPRIIS and are bounded on the northwest by the Ilog Baliwag river, on the east and south by the Talavera river. The gross area of District I is about 34,000 ha.

There are two major intake structures such as the Talavera diversion dam (TRIS dam) and the 5-Bay in the District I.

The TRIS dam located in head portion of the District I serves TRIS and SAE areas. The 5-Bay diversion dam is located on the De Babuyan creek serving SDA system. Lower portion of TRIS area (TRIS Lower) and SDA receive supplemental water provided by the Pantabangan dam through diversion canal No.1 and Pampanga diversion dam (PRIS dam).

General layout of the irrigation systems in District I is shown in Fig. 2.2.

(2) <u>District II</u>

Irrigation systems in the District II consist of RMA, PRIS, LTRIS, VCIS and MCIS. The systems are bounded on the north by the diversion canal No.1, on the east by the Pampanga river, on the south by the diversion canal No.2 and ALIAGA main canal (Lateral AM) and on the west by the Talavera river. The gross area of District II is about 32,000 ha.

The Pampanga diversion dam (PRIS dam), the Lower Talavera diversion dam (LTRIS dam), the Vaca dam, the Murcon dam and the diversion canal No.1 are the major irrigation facilities in District II.

The PRIS dam is located on the Pampanga river at about 21.5 km downstream of the Pantabangan dam, and serves PRIS and RMA mainly. The LTRIS, VCIS, MCIS, TRIS lower and SDA are served by the PRIS dam supplementally.

The LTRIS dam is located at about 19 km downstream of TRIS dam, and serves LTRIS area. The VACA dam and the MURCON dam are located on the Vaca and Murcon creeks and serve the VCIS and MCIS area, respectively.

The Diversion canal No.1 connects the PRIS dam with TRIS main canal and integrates the systems of RMA, LTRIS, VACA, TRIS lower and SDA.

General layout of the irrigation systems in District II is shown in Fig. 2.3.

(3) <u>District III</u>

The irrigation systems in this District are composed of PBRIS proper, PBRIS extension, PLATERO, PCCA and ALIAGA. The gross area is about 54,000 ha. District III are bounded on the north by the diversion canal No.2 and lateral AM, on the east by PBRIS proper main canal, on the south by the Peñaranda river and San Antonio swamp and on the west by the Along-Along creek.

The Pampanga Bongabon diversion dam (PBRIS dam) is main intake structure in the District IV. The PBRIS dam is located on the Pampanga river at 34.5 km downstream of PRIS dam. The PBRIS diversion dam serves all systems above through the diversion canal No.2 and transmits the supplemental water to PEÑRIS at District IV through the PBRIS main canal and lateral G-2 extension.

General layout of the irrigation systems in District III is shown in Fig. 2.4.

(4) District IV

There are two systems of PEÑRIS proper and extension in the District IV, where lies in the lowest portion of UPRIIS. This District is bounded on the northwest by the Peñaranda and Pampanga rivers, on the east by the lateral C and C extension and on the south by North Candaba swamp. The gross area is about 36,000 ha.

The Peñaranda diversion dam (PEÑRIS dam) is the only intake structure in the District IV. The PEÑRIS dam is located in the Peñaranda river at about 16 km upstream of Gapan.

District IV, located at the tail end of the other systems, suffers from water shortage during the dry season. On the contrary, the lower portion of this District is inundated due to overbank spills of the creeks and the effect of backwater from the Candaba swamp in the wet season. General layout of the irrigation systems in District IV is shown in Fig. 2.5.

2.2 Water Resources

The water resources in the UPRIIS are i) the Pampanga river with reservoir function by the Pantabangan dam, ii) the Talavera river, iii) the Peñaranda river and iv) major creeks in the project area.

The mean annual runoff of the Pampanga river is about 1,450 MCM at the Pantabangan dam whose drainage area is 954 km^2. The maximum monthly runoff of about 275 MCM in August and the minimum of about 18 MCM in April are observed. The effective storage capacity of the Pantabangan dam is 2,800 MCM which is used for generation of hydroelectric power and irrigation in UPRIIS. The water released from the Pantabangan dam is intaked at the Pampanga diversion dam (PRIS dam) and the Pampanga Bongabon diversion dam (PBRIS dam) located in about 21.5 km and 56 km downstreams from the Pantabangan dam, respectively.

The drainage area of the Pampanga river is about 52 km^2 at the PRIS dam excluding the drainage area at the Pantabangan dam. As the runoff from the drainage area of 52 km^2 is negligibly small, the irrigation area served by the PRIS dam depends on the water from the Pantabangan dam.

The drainage area at the PBRIS dam is about 1,043 km^2 excluding the drainage area at the Pantabangan dam. There are major tributaries such as the Coronel and Digmala rivers. The runoff from these rivers is observed to have constant flow during dry season. The mean annual runoff of the Coronel river is about 670 MCM at Bangkerohan. The mean monthly runoff fluctuates ranging from 120 MCM in November to 20 MCM in April. The area served by the PBRIS dam is irrigated by the uncontrolled stream flow from the above rivers and water from the Pantabangan dam.

The mean annual runoff of the Talavera river is about 380 MCM at the Talavera diversion dam (TRIS dam) whose drainage area is about 313 km^2. The maximum monthly runoff of about 56 MCM in October and the minimum of about 16 MCM in April are observed. The TRIS upper and SAE depend on the stream flow of the Talavera river only, the irrigation area in the dry season is restricted due to the shortage of water.

The mean annual runoff of the Peñaranda river is about 600 MCM at the Peñaranda diversion dam (PEÑRIS dam) whose drainage area is about 513 km^2. The maximum monthly runoff of about 130 MCM in November and the minimum of about 20 MCM in February are observed. The irrigation area served by the PEÑRIS dam is so large compared with the river flow. The water shortage also occurs in the dry season. So additional water is supplied by the PBRIS dam through the PBRIS proper main canal and lateral G-2 extension.

There is no available discharge record of the major creeks such as the De Babuyan, Vaca and Murcon. The drainage areas of the De Babuyan creek at 5-Bay, the Vaca creek at the Vaca dam and the Murcon creek at the Murcon dam are about 35 km^2, 48 km^2 and 79 km^2, respectively. The available discharges of these creeks are expected to be small. These systems are supplied by the supplementary water from the Pantabangan dam.

The discharge record of the Talavera river is also not available at the Lower Talavera diversion dam (LTRIS dam) of which drainage area is about 88 km^2 after the TRIS dam. The LTRIS area served by the LTRIS dam is also received the supplementary water from the Pantabangan dam.

The monthly mean discharges at four stations, the Pantabangan dam, the TRIS dam, the PEÑRIS dam and Bangkerohan are presented in Table 2.2.

2.3 Potential Irrigation Service Area

For the purpose of operation, the UPRIIS office delineates the potential irrigation service area of 103,600 ha, as shown in the following table.

District	Service Area (ha)
I	24,500
II	25,400
III	28,400
IV	25,300
Total	103,600

These figures may represent the practical existing condition of the UPRIIS system excluding such area as affected by inundation or by flood damage. It is essential for formulation of irrigation plan to define the physical potential area of the system and to clarify the practical irrigation service area.

The study on delineation of the potential irrigation service area was conducted by using the available maps and data collected. Greater part of the area is defined from the map of the "Irrigation Network" on a scale of 1/4,000 prepared by NIA during the period of 1970 - 1983. The topographic map of 1/4,000 and the data of land classification were also utilized.

As a result of study, the potential service area is obtained at 116,900 ha. The breakdown of the area by each irrigation system and by District is summarized in Table 2.3.

The irrigation network of the UPRIIS was prepared in the form of diagram which explains the alignment of canal system, potential irrigation service area by lateral level and the source of irrigation water. The terminal unit of area expressed in the network is set at the end of lateral canal. The network is presented in Figs. 2.6 and 2.7(1) to (4).

2.4 Irrigation Facilities

The irrigation facilities of the UPRIIS are composed of eight diversion dams, 46.6 km of diversion canal, 236 km of main canal, 1,281 km of lateral and related canal structures. Construction of the on-farm level water distribution system was carried out based on the design criteria which provided one turnout structure with every 50 ha and one farm ditch with every 10 ha. The inventory of irrigation facilities is summarized in Table 2.4. Field inspection was conducted to these facilities covering all major structures and canals of about 435 km. On-farm level facilities were also inspected for the sample area covering about 7,760 ha.

Evaluation of these existing irrigation systems was conducted from the standpoint of sufficient and equitable distribution of water to each paddy field at proper time. As a result, it is concluded that the present physical conditions of these systems are considerably deficient. Major problems noted are inoperable control structures, inaccurate or non-workable measuring structures and siltation and erosion of canals. Further insufficient maintenance and need of repair were found serious in many canal portions and structures and if untreated, major rehabilitation or total reconstruction will be required within a few years. Constraints in the operation and maintenance of irrigation facilities are summarized in Fig. 2.8.

2.4.1 Diversion Dam

Major problems found at diversion dams are difficulties in operation of sluice gates and intake gates caused by siltation in front of gate, damage on the lifting mechanism and by lack of proper maintenance such as lubrication, painting and periodical cleaning.

2.4.2 Canal

Major problems noted on canals are siltation, bank erosion and sloughing and scouring at downstream of structures. Siltation problems are often found at smaller laterals and tail portion of canal where flow velocity becomes small and canal receives suspended load from upstream. In larger canal portion, the siltation does not exceed the degree of ordinary maintenance work if executed. Siltation problems are noted at i) upstream portions of the diversion canal No. 1 where the canal receives sediment inflow from the adjacent hill erosion, ii) TRIS main canal where sediment inflows from the Talavera river.

Bank erosion and sloughing are common in most part of canal systems. Major causes are poor embankment, lack of grass cover, animal watering and excessive people traffic near domestic area.

Bank erosion is the major source of silt load to downstream and it gives serious affect to the bank stability. Scouring at structure outlet is found at most of canal structures. Urgent repair works are needed at a few locations where the erosion develops to threaten the canal bank stability.

2.4.3 Related Structures

(1) Gate

Noticeable problem is lack of operable gate at most structures of head gates, turnouts and checks. Stop logs often made of banana logs are commonly used for control. Smooth and accurate operation and control of water distribution are not possible by means of stop log. In many gates, the stem and lifting mechanism are damaged indicating unsuitable design and fabrication to meet with the hydraulic pressure and lack of maintenance for lubrication. Roller gate and worm gearing lifting system should be introduced for larger gates.

(2) Head Gates and Turnouts

In addition to the problems of no gates or damaged gate, location and number of turnouts should be reviewed. Unauthorized turnouts are found many for smaller canals. Installation elevation of turnouts is too high and adequate capacity is not obtained with normal water surface, which resulted in overchecking.

(3) Checks

Many types of check structures are found but standard type combined with gate and overflow spillway is very few. Most of them have no spillway outlet to the downstream. When stop log or inoperable gate was slotted, upstream canal is always under the threat of overchecking or overtopping of bank. Thresher crossing type check has often too narrow flow area resulting overchecking at upstream even with full opening of check.

(4) Syphons

Major problems are siltation and plugging of syphon barrels and lack of screens or trashlacks.

(5) Structures for Canal Safety

Structures to control excess water and the safety of canal system for emergency and for heavy rainfall are most neglected in the present system. Spillways and wasteways are very few. Freeboard of canal is always insufficient because of overchecking, siltation and consolidation settlement or erosion of bank.

2.4.4 Farm Road

The survey was conducted for farm roads and service roads using 1/4,000 scale map and construction drawing of canals. Service roads along main canals and laterals are the major farm transportation networks within the service area in addition to the national roads connecting major cities. The length and standard width of service roads are summarized in the following table.

Service Roads

Item	Length (km)					Width (m)
	I	II	III	IV	Total	
1. Diversion canal	6.6	12.2	27.8	0	46.6	7.5
2. Main canal	53.2	52.6	44.3	42.0	192.1	5.0
3. Laterals	217.3	175.5	188.3	145.2	726.3	3.0 - 5.0
Total	277.1	240.3	260.4	187.2	965.0	

The condition of service roads along main canals and major laterals is maintained generally good. Near the tail end portion of canals and along smaller laterals, service condition becomes worse. Canal bank roads of these portions are too low and saturated by canal water and by drainage water along outside of embankment. Many tail end portions can not be accessible and no evidence of maintenance is observed.

2.5 Constraints in Existing Irrigation System

2.5.1 General

The physical potential irrigation service area in the UPRIIS was estimated at 116,900 ha as mentioned in Section 2.3. On the other hand, actually irrigated area is estimated on the basis of weekly farming activity reports prepared by WCCC UPRIIS. In spite that UPRIIS has large potential irrigation service area, actually irrigated area is restricted. An average irrigated area during the period of four years from 1979 to 1982 accounts for 84,900 ha in dry season and 91,800 ha in wet season as summarized in the following table. This table indicates that irrigated area is only 73% of potential irrigation service area in dry season and 78% in wet season.

Area Under Irrigation

(Unit: ha)

Year	Dry Season		Wet Season	
	Scheduled	Actual	Scheduled	Actual
1979	87,200	85,300	90,600	90,800
1980	85,000	84,100	90,000	89,100
1981	84,200	83,400	92,300	92,300
1982	84,800	86,900	96,200	95,100
Average	85,300	84,900	92,300	91,800

The details of the irrigated area are explained in Table 2.5.

As indicated in Table 2.5, the difference of the area between the potential irrigation area and the actually irrigated area is mostly found at the tail portion of the system or at the area where some constraining factors exist. It is considered that such difference of the area seems to result from the following causes.

1) Since irrigation development has been excuted without assessment of water resources, the potential irrigation service area has contained the area where irrigation water could not be provided inherently due to shortage of water resources.

2) The potential irrigation service area contains the area where irrigation farming can not be practised during wet season due to inundation and overbank spills.

3) The potential area contains the area in which irrigation water can not be supplied due to the deficiencies of irrigation facilities, as explained in Fig. 2.8.

4) Efficient use of irrigation water has been hindered because of low irrigation efficiency resulting from problems on management of water delivery and control of system facilities as shown in Fig. 2.9. As a result, actually irrigated area has decreased.

Among the above causes, the causes of item (2) are made clear in Appendix III and IV, and the causes of item (3) were already clarified in Section 2.4.

In order to clarify and confirm the constraints with respect to items (1) and (4), assessment of present water sources and irrigation efficiency is prerequisite.

The present water resources have been assessed by the results of water balance between the irrigation water requirement based on the scheduled cropping pattern and present available discharge.

The actual irrigation efficiency in UPRIIS has been assessed by the results of water balance study based on the actual farming activity and actual water delivery. The Pantabangan dam operation and time-lag in the water conveyance systems were also studied with referring to the irrigation efficiency.

Detailed studies on these assessment are made in the following sections.

2.5.2 Conditions for Water Balance Calculation

In the water balance study, the irrigation water requirement and the available discharge are estimated according to the following conditions.

(1) Irrigation Water Requirement

The irrigation water requirement is estimated on the basis of the criteria used in the UPRIIS Office for the operation. The criteria is presented in Reference-1. The water requirement is estimated based on the following cropping patterns and rainfall data.

i) Cropping Pattern

The cropping calendar in UPRIIS is scheduled by WCCC for each irrigation system prior to the start of operation. This scheduled cropping pattern is recorded in the "Evaluation Report" prepared by WCCC. The scheduled cropping patterns are standardized for the calculation of water requirement as shown in Figs. 2.10.

Actual cropping pattern in UPRIIS is quite different from the pattern scheduled by WCCC. The actual cropping pattern was estimated based on the "Weekly Farming Activity Report" which provides the actual irrigated area classified by farming period of land preparation, land soaking and normal irrigation.

ii) Effective Rainfall

Forty one numbers of daily rainfall gauging station exist within the UPRIIS area. After the necessary data arrangement such as correlation analysis, the representative daily rainfall during the period of 1979 to 1982 is generated by means of Thiesen polygon method for each District. Effective rainfall is calculated with daily water balance calculation for each cropping calendar assuming 50 mm high of paddy dike. Details are explained in Reference-2.

iii) Irrigation Efficiency

Losses to be considered in the water balance study are farming loss, operation loss and conveyance loss. The conveyance loss is taken as the same value that the UPRIIS Office applies. It is presented in Table 2.6. Considering the irrigation efficiency analysis reported in the "Evaluation Report", the following values are applied to calculate the theoretical diversion requirement as one of the standard to analyze the actual efficiency.

- Farming efficiency :	Dry season:	80%
	Wet season:	75%
- Operation efficiency :		85%

(2) Available Discharge

The river and creek discharge are estimated as follows. The water release from the Pantabangan dam for power generation is considered in this water balance.

i) River Discharge

The river discharge at corresponding diversion dam sites is generated from the river discharge record and the inflow record of the Pantabangan dam. The stations and period of the estimated river discharge are as follows.

River	Station	Period
Talavera River	TRIS Dam	Jan. 1976 - Oct. 1982
Talavera River	LTRIS Dam	Jan. 1976 - Oct. 1982
Pampanga River	PRIS Dam	Jan. 1976 - Oct. 1982
	PBRIS Dam	Jan. 1976 - Oct. 1982
Peñaranda River	PEÑRIS Dam	Jan. 1977 - Oct. 1982

In the water balance studies, accumulated discharge for 10 days is applied. However the discharge of the rivers fluctuate so largely day by day in wet season that an intake efficiency of river discharge in the studies is assumed as follows:

Dry season (December to May) : 100% of 10 days discharge

Wet Season (June to November) : 70% of 10 days discharge

ii) Creek Runoff

There are several systems which depend largely on the creek runoff. The discharge records for creek runoff are only available in District IV during the period of 1974 - 1976. The runoff analysis on these data is executed to estimate 10 days average runoff by means of correlation between rainfall and creek runoff. Among the analyzed three creeks of the Malake, Mabuga and Kapalangan, the result of runoff analysis on the Malake creek is adopted as it shows the highest correlation coefficient of 0.81.

As a result, the creek discharge is estimated on the basis of the following formula:

$$Q = K \cdot R + a$$

where, Q: creek discharge for 1 km^2 of drainage area (m^3/sec/10 days)

K: coefficient (0.00485)

R: 10 days rainfall (mm)

a: constant (0.1)

In addition to the runoff by rainfall, the return flow to the creek from paddy field is also estimated. Considering the result of study made by Dr. S.I. Bhuiyan, IRRI, the rate of return flow is set at 30% of total irrigation supply to the relevant paddy field.

iii) Power Generation

Water release from the Pantabangan dam for power generation is set at the following figures when there is no release required for irrigation. Additional release for power generation is not considered when there is an irrigation requirement for dam.

Minimum Water Release for Power Generation

1975 - 1981 : 604,800 m^3/day

1982 - present: 864,000 m^3/day

2.5.3 Present Water Resources

Availability of present water resources was studied through the water balance calculation for the following three irrigation area.

Case 1. The potential irrigation area of 116,900 ha

Case 2. The irrigation area of 87,000 ha excluding whole Peñaranda River Irrigation System from the potential irrigation area

Case 3. The irrigation area of 109,000 ha excluding Peñaranda River Irrigation System Extension from the potential irrigation area

The water resources of Peñaranda river irrigation system (PEÑRIS) consist of natural flow of the Peñaranda river, natural flow of Pampanga river at the Pampanga Bongabon diversion dam (PBRIS dam) and supply water from the Pantabangan dam. The water intaked by PBRIS dam is conveyed to PEÑRIS through the PBRIS main canal and lateral G-2 supply canal whose carrying capacity is 15 m^3/sec at maximum. As a result of water balance, the water required for PBRIS dam is more than this carrying capacity. It is necessary to enlarge the canal section of lateral G-2 in order to irrigate the whole area of PEÑRIS.

Further under the Aurora Peñaranda Irrigation Project, the PEÑRIS ext'n area was integrated into the UPRIIS in 1982 without the detailed assessment of water resources.

From above reasons the studies of case 2 and 3 were executed in this section.

(1) Water Balance for Potential Irrigation Area

The results of this water balance at the Pantabangan dam is summarized in Table 2.7. The results indicate that the water resources of the Pantabangan dam is not sufficient to irrigate the whole potential irrigation area.

(2) Water Balance for the Area Excluding PEÑRIS

The results of the water balance is shown in Table 2.8. It indicates that the reservoir volume of the Pantabangan dam is restored at the end of every wet season for the irrigation area of 87,000 ha.

(3) Water Balance for the Area Excluding PEÑRIS Ext'n

As for the water balance for the area excluding PEÑRIS ext'n area only, the result is shown in Table 2.9. It also indicates that the water resources of the Pantabangan dam is not sufficient to irrigate the area of 109,000 ha excluding PEÑRIS ext'n area like the water balance for potential irrigation area for case 1.

As a result of above three cases studies, the present water resources are considered available to irrigate the area ranging from 87,000 ha to 109,000 ha without any improvement plan for the water resources or water management.

In the next chapter, further study will be conducted to define the service area after clarifying the other constraining factors.

2.5.4 Irrigation Efficiency

Irrigation efficiency in UPRIIS is assessed from the standpoint of system operation at the diversion dams and the Pantabangan dam.

(1) System Operation at Diversion Dams

The water balance study was made to investigate the present status of system operation for 8 crop seasons from 1979 to 1982. In this study, crop water requirement and diversion requirement were calculated based on the actual cropping pattern. The actual irrigation efficiency is expressed by the ratio between calculated diversion requirement and recorded diversion amount.

The results of water balance by major diversion dams are shown in Fig. 2.11.

The actual irrigation efficiency is shown in Table 2.10 and summarized as follows:

Diversion Dam System	Irrigation Efficiency (%)	
	Dry Season	Wet Season
TRIS	-	20
PRIS	51	29
PBRIS	51	30
PEÑRIS	87	32
Theoretical Efficiency	54	51

In this study irrigation efficiency in dry season at TRIS is not evaluated due to lack of dependable information on farming activity.

There is clear difference in the irrigation efficiency between the dry season and the wet season. The theoretically calculatd diversion water requirements from the actual cropping pattern meet with the recorded amount of diversion water satisfactorily in dry season, except PEÑRIS dam system. Most of the irrigation systems gain more than 50% in efficiency in the dry season.

Very high efficiency attained in the dry season at the PEÑRIS diversion dam will be explained by the use of supplemental pump irrigation from ground water and use of return flow which are disregarded in the calculation.

In the wet season, the pattern is greatly different from that in the dry season. The actually diverted amount is much greater than the calculated diversion requirement. The irrigation efficiency in the wet season is significantly low as much as 30%. One of the major constraints in the water distribution and control exists at this low efficiency in wet season.

The reason of the low efficiency in the wet season is not imputed only to the physical defects of structures as far as higher efficiency is attained in dry season. It will be derived from the low efficiency of utilizing the effective rainfall.

(2) Pantabangan Dam Operation

Based on the result of water balance for the actual cropping area, the diversion water requirement for the Pantabangan dam is calculated and compared with the record of dam operation as shown in Fig. 2.12. The difference between the calculated requirement of water release from the dam and the recorded water release in wet season may be explained by the disturbance caused by rainfall.

In the dry season, excessive amount of release from the dam is noticeable compared with the calculated amount of water release. However, there is no such significant requirement at the diversion dam sites of the PRIS and PBRIS systems.

Excessive water release from the Pantabangan dam constrains the project water resource particularly.

2.5.5 Time-lag Analysis

Time-lag between the diversion point and each turnout of canal is one of the constraining factors in the distribution of water in such system of run-of-river type having long conveyance line without storage facilities on the way.

The time-lag between the Pantabangan dam and the end point of major irrigation canals was calculated based on the result of field experiments and the unsteady flow simulation method.

(1) Field Experiment

For the analysis of time-lag in the conveyance channel, the unsteady flow simulation method is adopted. The status of flow in the channel is simulated by converting the hydraulic unsteady flow formula into the computerized numerical differentiation. The unsteady flow simulation is explained in Reference-3.

In this method, it is required to obtain the representative value of the equivalent roughness coefficient as to represent the hydraulic condition of channel including not only the roughness of the perimeter but also the headloss of water created by structures along the channel.

Field experiment was executed to obtain the representative value of the equivalent roughness coefficient selecting the canal of C-9 in the Peñaranda irrigation system. After emptying the canal, flow discharge of 2.6 m^3/sec was released from the headgate and lag time from the headgate was measured at 7 points located about 1 km interval. The result of measurement is simulated by the unsteady flow simulation model and the equivalent roughness coefficient is obtained at 0.035. The result of simulation is shown in Fig. 2.13. The effect of simulation is observed at the terminal point of measurement.

(2) Time-lag Simulation

Adopting the value of 0.035 as a representative roughness coefficient, the time-lag for each major canal and lateral is simulated.

Necessary characteristics of canal such as canal gradient, bed width and side slope are obtained from the design drawings or construction drawings available. Discharge of canal for simulation is set at 1.2 ℓ/sec/ha.

The results of simulation are summarized in Fig. 2.14. The time-lag in the river or creeks is calculated assuming the flow velocity at about 0.5 m/sec.

Based on the result of simulation, the longest time-lag is found between the Pantabangan dam and the terminal of the Peñaranda main canal at 65 hours or about 3 days equivalent to the average velocity of 0.54 m/sec. The longer time-lag will be certainly expected for the smaller discharge.

It is clear that the time-lag is one of the constraints inherent in the UPRIIS in the wet season. The operation and control at a diversion dam site are affected by the fluctuation of the river discharge, the change in farming activity and rainfall. The effect of river discharge fluctuation can be alleviated by adjusting the intake gate without time loss if there is a trained resident gate keeper except night time. The change of farming activity occurs gradually and the control of water can usually respond to the change providing the sufficient information obtained from the field. The rainfall, however, once occurs, the system can react only after certain time-lag, while the excess water will be flooding to paddy fields or wasted from the tail end of the canal.