No. 1

REPUBLIC OF THE PHILIPPINES
NATIONAL IRRIGATION ADMINISTRATION

FEASIBILITY STUDY ON THE MATUNO RIVER DEVELOPMENT PROJECT

VOLUME 3
APPENDIX II HYDROPOWER COMPONENT

FEBRUARY 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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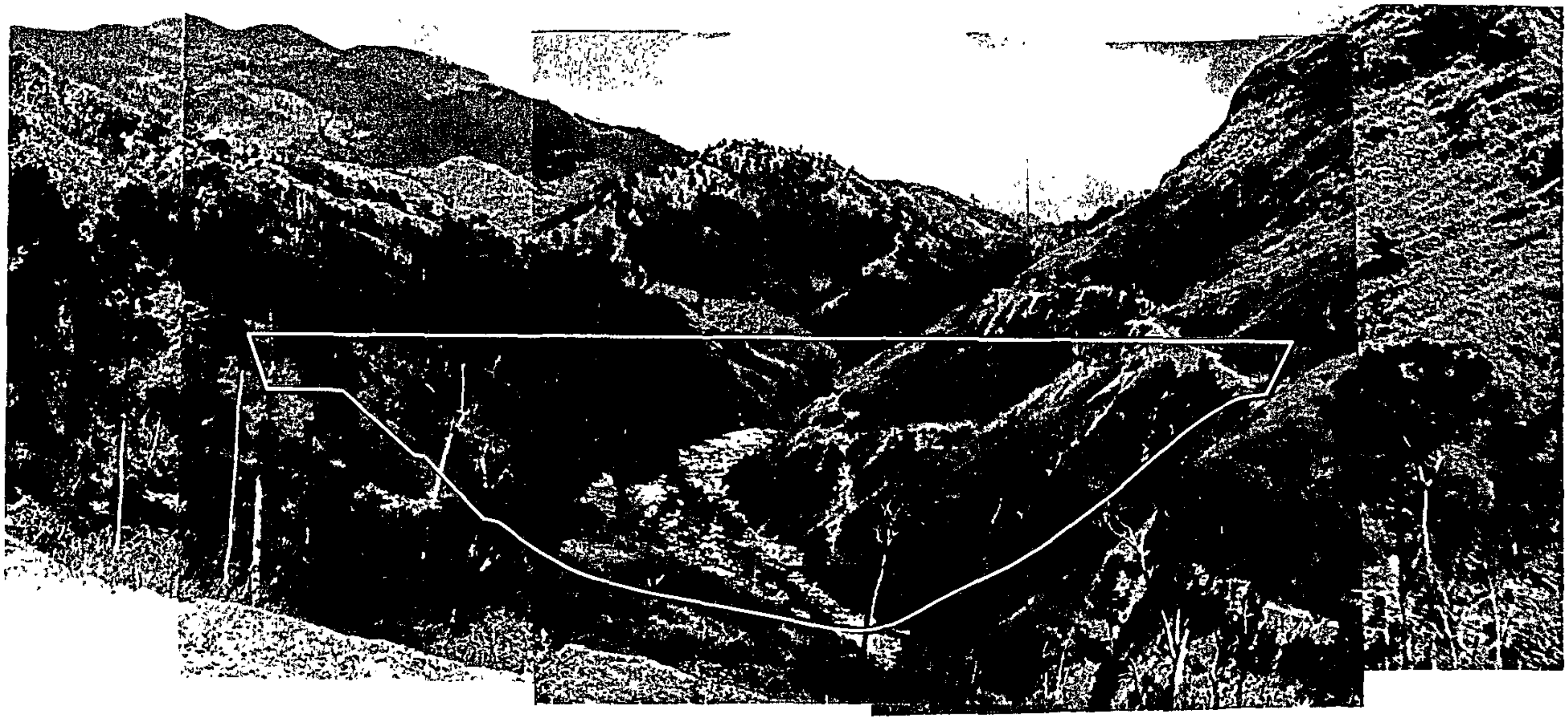
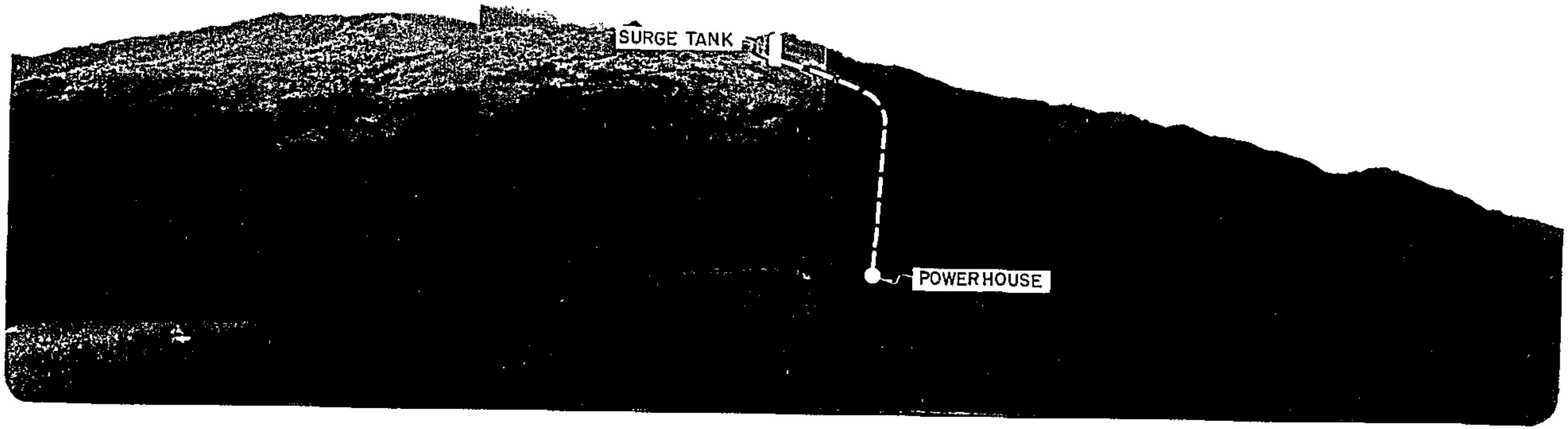
FEASIBILITY STUDY

Volume 1	Main Report
Volume 2	Appendix I (Agriculture Component)
Volume 3	Appendix II (Hydropower Component)
Volume 4	Drawings
Volume 5	Data Book



VIEW FROM DOWNSTREAM SIDE ON B_1 - DAM SCHEME



VIEW FROM DOWNSTREM SIDE ON PENSTOCK AND POWER HOUSE SCHEME

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ABBREVIATIONS AND UNIT

NIA	National Irrigation Administration of Philippines
JICA	Japan International Cooperation Agency
MOE	Ministry of Energy
NEA	National Electrification Administration
NAPOCOR (NPC)	National Power Corporation of Philippines
MERALCO (MECO)	Manila Electric Company
NUVELCO	Nueva Vizcaya Electric Cooperative, Inc.
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
MPWH	Ministry of Public Works and Highways
US$	United States Dollars
₱	Philippine Pesos
FC	Foreign Currency
LC	Local Currency
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
O & M	Operation and Maintenance
L.F.	Load Factor
AMSL	Above mean sea level
EL.	Elevation in m AMSL
W.L. (WL)	Water level in m AMSL
H.W.L. (HWL)	High water level in m AMSL
L.W.L. (LWL)	Low water level in m AMSL
F.W.L. (FWL)	Flood water level in m AMSL
D.F.W.L. (DFWL)	Design flood water level in m AMSL
mm	millimeter
cm	centimeter

m	meter
km	kilometer
m^3	cubic meter
km^2	square kilometer
ha	hectare
m^3/sec (CMS)	cubic meter per second
m^3/sec month	Water volume equivalent to the discharge of 1 m^3/sec for the duration of 1 month
kg	kilogram
t (ton)	metric ton
l	liter
%	percent
°C	degree centigrade
°	degree (angle or temperature)
N	north latitude
S	south latitude
rpm	revolution per minute
Hz	Hertz (cycles per second)
kcal	kilocalorie
kV	kilovolt
kVA	kilovolt ampere
MVA	megavolt ampere
W	Watt
kW	kilowatt
MW	megawatt
kWh	kilowatt hour
MWh	megawatt hour
GWh	gigawatt hour
V	Volt
BTU	British Thermal Unit

II-1 METEOROLOGY AND HYDROLOGY

II-1 METEOROLOGY AND HYDROLOGY

1.1 General

The project area lies in a typical tropical monsoon area being affected by the northeast monsoon from October to December and the southwest monsoom from May to September. The trade wind prevails during the rest of the year when the monsoon is weak. Therefore, normally December to April are comparatively dry having less than 100 mm rainfall as shown in Fig. 1-2 to 1-13.

The high mountains surrounding the Matuno River basin cause the rising of humid air mass inflow, hence heavy showers often precipitate on the slope facing the inflow direction with less rainfall on the slope of opposite side. The higher the elevation of the slopes, much more rainfall occurs than the low-lying area as shown in Fig. 1-14, 1-15.

The Matuno River is one of the tributaries on the left bank of the Magat River covering about 585 km^2 of water shed. The river basin is mostly covered by thick natural forest due to difficult access mainly attributable to the high surrounding mountains ranging from 1,200 m to 2,900 m. Only a few hundred houses inhabitted by local people scatter at higher slopes of those mountains. Hence the water and land conservation is still maintained in an excellent condition without appreciable water pollution and heavy sediment as well.

On the contrary, the two neighboring river basins, Santa Cruz and Sta. Fe Rivers, have been already considerably developed, resulting in fairly devastated conditions with highly denuded and consequent high sediment load.

On the left bank along the Magat River downstream from the Matuno, there extend fertile cultivated land along with the municipalities of Bayombong, Solano, Bagabag and Ibung totalling about 13,000 ha net.

The water shed of the Matuno River lies in a tropical monsoon area between 16^o-23'N and 16^o-44'N in latitude. The basin has a rectangular shape with a north-south long side of about 35 km and east-west short side of about 18 km. The western divide is composed of very high range of 2,000 to 2,900 m, while the eastern and northern divides are mostly composed of lower mountains ranging from 1,200 m to 1,600 m. The river flows from north to south until it bends to eastward at about 10 km upstream from the Bato Ferry Bridge.

The total river length is about 80 km draining 585 km^2 of the basin before joining with Magat. The basin is mostly covered with thick natural forest well reserved due to difficult access.

The surface flow measurement records are available at Bante Gauging Station having 558 km^2 of the catchment area. The annual average run-off of about 38 m^3/sec (about 1,200 million m^3/year) is available. The record covers 20 years from January 30, 1957 to November 15, 1976, which were used for hydrological studies for this project. After three and a half years' interruption, the water gauging at Bante was resumed since April 1, 1980 by NIA for this project study.

The lowest discharge is normally recorded in April. In few abnormal drought years it goes down to 7 to 8 m^3/sec. But normal years have 12 to 15 m^3/sec.

1.2 PREVIOUS STUDY AND DATA AVAILABLE

1.2.1 Previous Study

The previous studies regarding this Project are listed as follows:

i) Preliminary survey Report on Matuno River Development Project, August 1980 (JICA)

ii) Magat River Project Feasibility Report, June 1973 (NIA and USBR)

iii) Cagayan River Flood Control Basin-Wide Study, July 1981 (Philtech)

iv) Date of water quality analysis of NIA's Munios Laboratory

1.2.2 Runoff Records

There were three stream gauging stations in the Matuno river basin and Magat river basin as shown in the following table.

Past Stream Gauging Stations in the Matuno/Magat River System

No.	Name of Station	River	Location			Drainage Area	Year Recorded
			Lat.	Long.	EL.		
			(N)	(E)	(m)	(km^2)	
1.	Bante	Matuno	16°25'30"	121°03'30"	385	558	1957 - 1976
2.	Bato	Magat	16°25'55"	121°07'01"	291	1,784	1960 - 1976
3.	Oscariz	Magat	16°46'44"	121°29'37"	150	4,150	1948 - 1972

1.2.3 Flood Records

Annual maximum discharge records are avairable at Bante G.S. on the Matuno river from 1957 to 1976 and Bato G.S. on the Magat river from 1960 to 1976. The records are avairable in the Water Supply Bulletin published by BPW. But, during the investigation study at site, we heard that the maximum peak flood happend in November 1980 which is officially recognized to be a maximum experienced flood due to the typhoon ARING passed nearby Matuno river basin. And it is described by sub-section 1.4.3 that the fact of peak discharge was approximately 2,300 m^3/sec. While, the second highest flood is 770 m^3/sec in October 1973 and the third is 640 m^3/sec in November 1967.

1.2.4 Meteorological Records

For the hydrological analysis, the basin avarage rainfall calculated from five rainfall stations in and around the Matuno River basin is 2,460 mm. The location and recorded period of those stations are shown in the following table:

Rainfall Gauging Stations around the Matuno River Basin

No.	Name of Station	Location			Years Recorded
		Lat. (N)	Long. (E)	EL. (m)	
1.	Consuelo Sta. Fe	16°10'	120°57'	540.0	1956 - 1960
2.	Barat (Salinas)	16°23'	121°06'	357.0	1948 - 1979
3.	Dupax	16°17'	121°05'	310.0	1968 - 1980
4.	Bobok Bocad	16°27'	120°50'	770.0	1966 - 1981
5.	Solano	16°31'	121°11'	280.0	1967 - 1979

1.2.5 Evaporation Reocrds

There are standard evaporation pans installed at Bagabag, Solano and Bayombong which are located within the distance of about 10 - 40 km from the proposed B_1 damsite. Pan evaporation records show the annual total of 1,884 mm accounting for daily average of 5.16 mm. April has the highest evaporation of 7.98 mm/day and December records the lowest of 3.84 mm/day.

1.2.6 Sediment Records

In the past, three times of suspended load measurements were carried out on Matuno river, but there are many records on Magat river.

Therefore, additional measurements were carried out five times at Bante gauging station, and the abundant data on Magat river were referred for the sediment suty for this project.

1.2.7 Collected Meteorological and Hydrological Records

The collected data around the Matuno river basin is tabulated as shown in Table 1-1.

1.3 Meteorology

1.3.1 Rainfall

The annual average rainfall at Barat (later at Salinas) for 19 years from 1957 to 1975 is 1,837 mm at the elevation of 370 m. According to the records, August has the highest rainfall and February is the most dry month. However, in several years much rainfall occurs even in January, February or March due to abnormal prolongation of the prominent northwest monsoon. The monthly rainfall record at Barat is shown in Table 1-6.

The number of rainy days is shown in Table 1-7 and 1-8, separately more than 1 mm/day and 10 mm/day. The annual average rainy days more than 1 mm/day are 96 days a year and those of more than 10 mm/day are 53 days a year. Therefore, the annual workable days may be 269 days even in a conservative estimate including sundays and holidays.

The corrected annual average discharge (37.97 m^3/sec) at Bante Gauging Station corresponds to effective rainfall depth of 2,146 mm a year, while the annual average rainfall recorded at Barat (later at Salinas) is only 1,837 mm. Even the basin average rainfall calculated from five rainfall stations in and around the Matuno River basin (20 years from 1956 to 1975) is 2,460 mm. It suggests that the rainfall in high elevation area is more than that of low-lying area, but the actual rainfall stations are mostly located at low elevation areas except the records at Bocod.

Therefore, the relation between the annual rainfall and the elevation was analyzed as follows:

The annual rainfall records at different elevations near the Matuno River basin were collected as listed below:

Name of Observatory	Annual Rainfall (mm)	Elevation (m)
Mt. Polus Pass, Banaue	4,570	1,900
Bocod	2,641	820
Sta. Fe	2,243	503
Barat (Salinas)	1,837	357
Solano	1,477	250
Bagabag	1,947	230
Ilagan	1,942	150

The relation between the annual rainfall (R in mm) and the elevation (H in m) is expressed in the following formula.

$$R = 1,420 + 1.633 H$$

As the average ground elevation of the Matuno River basin is calculated to be 1,240 m, the basin average rainfall is approximately presumed to be 3,445 mm a year. It means that the annual average run-off coefficient is 62.3% at Bante Gauging Station.

As the higher elevation area has much more rainfall, JICA Hydrologist set up an automatic recording rain gauge on July 18, 1982 at a place 5.5 km upstream from B_1 damsite having an elevation of about 750 m above MSL. The records obtained up to now was still very few, but its continuous observation will further clarify the relation of rainfall with elevation in future. Anyway it shall be noticed that the analysis on rainfall shall be made always taking into consideration the above fact.

1.3.2 Air Temperature

The annual average temperature at Baretbet (EL. 222 m) is 26.2°C. The hottest month is April and the coolest is December as shown in the following Table 1-2. The absolute high temperature reaches about 38°C (100.4°F) in April and the maximum temperature in December is still as high as about 33°C (91.4°F). While the minimum temperatures in May to July are about 21°C (69.8°F) and that of December is about 15°C (59°F). Therefore no snow and no frost occurs except very high mountains.

1.3.3 Relative Humidity and Wind Velocity

The monthly average humidity recorded at San Mateo, Isabela is shown also in Table 1-2. The most humid months are August and September (90.7 and 90.6%) due to much rainfalls, while the lowest month is December (80.1%).

The monthly mean wind speed recorded at San Mateo, Isabela is also shown in Table 1-2. The highest in November is 0.89 m/sec. and the lowest in June is 0.51 m/sec. However, when a typhoon passes in the vicinity of the project area, the maximum momentary wind speed reaches even to the level of 60 m/sec. But the frequency of typhoon attacking this area is normally once in 10 years or so.

1.3.4 Evaporation

The monthly average evaporation measured by a standard pan (average of three places, i.e. Bagabag, Solano and Bayombong) is shown in Table 1-2. The annual total amounts to 1,884 mm accounting for a daily average of 5.16 mm. The highest evaporation occurs in April averaging to 7.98 mm/day and the lowest in December to 3.84 mm/day. Those evaporation records quite coincide with the dryness of the corresponding month.

The evaporation loss from the reservoir surface is estimated to be 70% of the above pan-measured evaporation. It comes about 0.15 m^3/sec on an average in case of the EL. 520 m of HWL at B_1 dam, which will have the largest surface area of 3.5 km^2 at the proposed high water level.

1.4 Hydrology

1.4.1 Hydrological Surveys and Studies

1) General

The water gauging of Matuno River was commenced at Bante Gauging Station from January 30, 1957 by the Ministry of Public Works. The water level was observed twice a day with a staff gauge set up on the left bank. At the same time, the river flow measurement was also commenced since then by using a cableway with a current meter.

The water level observation was interrupted on November 15, 1976. All the discharge records by this date are published in the "Water Bulletin" issued by the Ministry of Public Works. During those 20 years from 1957 to 1976, the discharge measurement with a current meter was made 54 times accounting for about three times a year on an average. Those measurements, however, cover the discharge range from 4.6 m^3/sec at the lowest to 302 m^3/sec at the highest.

The Ministry of Public Works further provided with an automatic water level recorder at Bante since August 15, 1963 in addition to the staff gauge.

After about three and a half years' interruption, the water gauging at Bante was resumed since April 1, 1980 by NIA for the Matuno Project study. The water level observation and discharge measurements were made by a hydrometrist in Provincial Irrigation Office (PIO), Bayombong under the NIA Regional Office for Region II at Cawayan, Isabela Province. The water level observation is made by the recording gauge and staff gauge readings twice a day as before. Since June 1980, an automatic rainfall recorder and a standard evaporation pan (120 cm in diameter) were also set up on the right bank of the gauging station.

The discharge measurement with a current meter was made 6 times in 1980, 14 times in 1981 and 25 times in 1982. Those measurements since 1980 cover a discharge range from 12 m^3/sec to 109 m^3/sec.

In February and March 1982, a joint team of PIO Hydrometrist and JICA Hydrologist made 6 times of discharge measurements and found that the Bante gauging site has somewhat irregular flows due to river bend and steep gradient of downstream portion, causing heavy scouring of the river bed during increasing flow and heavy deposition during decreasing flow. The wooden frame on the right bank supporting the cable wire was already decayed making the gauging operation during high water season dangerous.

Therefore, the JICA Hydrologist recommended to shift the water gauging cableway about 150 m upstream section after 7 times of discharge measurements at this new section as shown in Fig. 1-17. This upstream site has a straight river channel and a less gradient. But the scouring and depositing phenomena are inavoidable due to fairly steep gradient of around 1/300.

The NIA shifted this gauging cableway to the upstream site in June 1982 as recommended. Since then the discharge measurements were made 15 times at this new Bante cableway site up to January 1983.

All the records of discharge measurements are shown in the attached Table.

2) Analysis of Roughness Coefficient

During the discharge measurements made in February to December 1982, the river flow surface gradients were measured by levelling and the roughness coefficients at the new Bante Gauging Station were calculated by applying the Manning's formula. The average value of 24 times of measurements is 0.0286 as shown below.

No.	Date	Q (m^3/sec)	A (m^2)	V (m/sec)	I	R (m)	N
1.	Feb. 17/82	17.24	13.27	1.30	1/294	0.45	0.0263
2.	Feb. 18/82	15.83	12.08	1.31	1/294	0.41	0.0246
3.	Feb. 22/82	19.30	15.47	1.25	1/294	0.50	0.0294
4.	Feb. 24/82	17.42	13.74	1.27	1/294	0.47	0.0277
5.	Feb. 26/82	16.16	12.77	1.27	1/294	0.43	0.0262
6.	Mar. 2/82	15.17	11.78	1.29	1/294	0.40	0.0245
7.	Mar. 3/82	15.21	12.08	1.26	1/294	0.41	0.0241
8.	Apr. 6/82	21.54	16.14	1.33	1/294	0.52	0.0283
9.	May 5/82	14.82	11.78	1.26	1/194	0.42	0.0260
10.	July 13/82	37.93	21.60	1.76	1/385	0.58	0.0201
11.	July 14/82	35.43	24.90	1.42	1/400	0.70	0.0278
12.	July 21/82	63.73	34.43	1.85	1/370	1.02	0.0285
13.	July 23/82	46.63	29.38	1.59	1/333	0.89	0.0319
14.	July 26/82	42.40	23.95	1.77	1/500	0.73	0.0205
15.	Aug. 3/82	49.42	26.21	1.89	1/333	0.80	0.0250
16.	Aug. 4/82	48.56	32.07	1.51	1/308	0.98	0.0372
17.	Sept.14/82	46.54	26.89	1.73	1/385	0.83	0.0260
18.	Oct. 12/82	45.88	29.40	1.56	1/389	0.85	0.0293
19.	Nov. 18/82	30.11	22.46	1.34	1/328	0.64	0.0306
20.	Nov. 19/82	32.11	22.79	1.41	1/313	0.65	0.0301
21.	Nov. 19/82	32.55	24.53	1.33	1/317	0.70	0.0333
22.	Dec. 2/82	36.96	25.23	1.46	1/313	0.72	0.0311
23.	Dec. 3/82	41.81	27.65	1.51	1/290	0.74	0.0318
24.	Dec. 28/82	42.29	27.72	1.53	1/250	0.75	0.0341
					$\bar{I}$ = 1/315		$\bar{N}$ = 0.0286

The above range of the roughness coefficients for the natural river channel consisting of sand and gravel without any grass seems reasonable.

3) Correction of Daily Discharges

In the past, four different rating curves have been applied to convert the water level into discharge by MPW. But the conversion itself was often miscalculated. Therefore, the JICA Hydrologist first made actual discharge measurements with a current meter in 1982 and early 1983 and found the river section at Bante Gauging Station changes in accordance with flood season and dry season as shown in Fig. 1-18, 1-19.

Normally in flood season, the river bed is scoured by floods, but in dry season it recovered again due to sediment deposition. However, in a long run, the river bed at Bante has a tendency of rising at an average rate of 1 m per 10 years or so.

From the above analysis, new rating curves to be applied to each season were decided and past daily discharges were fully corrected as show in Fig. 1-20, 1-21. The original daily water level records and original daily discharge records are shown in Databook.

By this procedure, the annual average discharge for the past 20 years from 1957 to 1976 is estimated to be 37.9 m^3/sec (1,197 million m^3/year) at Bante Gauging Station having catchment area of 558 km^2. The monthly average discharges at B_1-damsites of catchment area 550 km^2 was fixed by applying the catchment area ratio.

The annual average discharges available at the proposed "B_1" damsite is thus estimated at 37.4 m^3/sec (1,179 million m^3/year). The monthly discharges available at B_1 damsites is shown on Table 1-3.

1.4.2 Design Flood Discharge

1) General

The annual maximum discharge recorded in 20 years from 1957 to 1976 is listed up on Table 1-9. But on November 5 and 6 in 1980 the past maximum flood peak occurred being recorded to be 2,300 m^3/sec. The other flood peaks recorded are not so big as shown in the Table 1-9. The second biggest is 770 m^3/sec in October 1973, the third is 640 m^3/sec in November 1967 and the fourth is 610 m^3/sec in October 1971. Others are less than 500 m^3/sec. However, those flood peak discharges are converted from the highest water level observed twice a day. Therefore, it is not so correct because there might be missing observation of the true highest flood peak occurred between the observed times. So that the probable flood analysis was made from daily rainfall records by means of "storage function method" as explained below.

2) Basic Principle

The actual flood hydrograph observed during typhoon "Nitang" and its relevant rainfall was analyzed by computer model of the storage function method. The constants of the function were determined from the analysis. Then, the probable flood hydrographs as well as peak discharges were estimated from the probable 1-day rainfalls of the dam basin. The hyetographs were obtained by Talbot's formula. The design flood discharge was taken at 1.2 times of 200 yr probable flood, which is 7,600 m^3/sec.

3) Storage Function Method

The storage function method was applied to obtain hydrographs from rainfalls. It is expressed by the following equations:

$$S_\ell = K \cdot Q_\ell^p \quad \cdots\cdots \quad (a)$$

$$\frac{1}{3.6} \cdot f \cdot r_{ave} \cdot A - Q_\ell = \frac{dS_\ell}{dt} \quad \cdots\cdots \quad (b)$$

where: S_ℓ = basin storage (mm/hr)

$Q_\ell = Q(t + T_\ell)$

$Q(t)$ = outflow discharge (mm/hr)

T_ℓ = lag time (hr)

K, p = constants

f = run-off coefficient

r_{ave} = basin average rainfall (mm/hr)

A = watershed area (km^2)

t = time (hr)

Assuming p = 0.5, the value of K is obtained both from the actual hydrograph and the rainfall observed during typhoon "Nitang" (July 21 - 22, 1980). The result is shown in Fig. 1-22. The function resulted in $S_\ell = 10 \cdot Q_\ell^{0.5}$. The maximum water depth of 6.05 m during typhoon "Aring" (Nov. 4 - 6, 1980) corresponds to a discharge of 2,300 m^3/s. This value is quite near to the estimated value of 2,440 m^3/s by the said function as shown in Fig. 1-22. The storage function method, therefore, was proved to be appropriate.

4) Hyetograph for Probable Rainfall

First of all, the basin average daily rainfall was calculated from the daily rainfall records at Sta. Fe, Salinas, Legawe, Bocod and Dupax Rainfall Stations. From the basin average daily rainfalls, the annual maximum rainfalls in 1-day, 2-days, 3-days, 4-days and 5-days in each year were selected and probability calculation was made. The results of probable maximum rainfalls are shown in the following table:

Average Probable Rainfall of Matuno Dam Basin

(in mm)

Probability Period of Recurrence	Duration of Rainfall				
	1-Day	2-Days	3-Days	4-Days	5-Days
1,000 Years	302	406	491	619	817
500	283	385	465	578	746
200	258	357	430	529	655
100	240	334	402	483	589
50	223	311	373	441	525
30	206	293	351	410	479
20	195	278	332	385	443
10	173	250	298	340	381
5	150	219	260	292	318
2	113	167	196	216	228

The above daily probable rainfall seems little smaller than the normal cases obtained in the similar conditions. It is attributable to the fact that the rainfall stations used for the above analysis are located mostly at low elevation areas except Bocod. But the flood discharge analysis was made by applying the storage function method to the actual flood records and the actual daily rainfall records of the basin average. Therefore, even if any deviations exist between the above probable rainfall and the acutal rainfall in a high elevation area, the gap is fully covered by the process of analysis. In other words, the method naturally makes the flood run-off coefficient higher.

The actual flood hydrograph observed during typhoon "Nitang" and its relevant rainfall was analyzed by computer model of the storage function method. The run-off coefficients of floods are assumed in the range of 65% to 95% as shown below:

Probability	Run-off Coeff. (%)
Once in 5 years or more	65
Once in 20 years	70
Once in 30 years	80
Once in 100 years or less	95

Then, the hyetographs were obtained for probable rainfalls by Talbot's formula. It is expressed as follows:

$$I = \frac{b}{t + a}$$

where: I : rainfall intensity (mm/hr)

t : duration (hr)

a, b : constants

The ratio of 6-hour probable rainfall to 1-day rainfall was assumed to be 0.64. And the peak rainfall was assumed to occur at 0.8 times of total rainfall duration from the start of the rainfall.

The probable flood hydrographs as well as peak discharges were estimated from the probable rainfalls distributed as follows:

Probable 1-day rainfall

Unit: mm

Hour	Probability		
	1/1,000	1/200	1/100
2	5.0	4.3	4.0
4	6.0	5.2	4.8
6	7.3	6.2	5.8
8	9.2	7.9	7.3
10	11.8	10.1	9.4
12	15.8	13.4	12.5
14	21.9	18.7	17.4
16	32.8	28.0	26.0
18	54.4	46.5	43.2
20	98.2	83.8	77.9
22	31.3	26.7	24.8
24	8.6	7.3	6.8
Total	302.3	258.1	239.9

During the computer model analysis in various cases, it was confirmed that the highest flood peak discharge is caused by the maximum 1-day rainfall but not by any consecutive rains of 2-days or more, because the very rapid flood rising time never causes the overlapping of discharges in 2-days or more.

5) Probable Flood Hydrographs and Peak Discharges

The probable flood hydrographs were computed as shown in Fig. 1-23 to 1-25 The peak flood discharges thus computed are shown in the following table:

Probability (Period of Recurrence)	Peak food discharge at Bante G.S. (m^3/sec)	Specific discharge ($m^3/sec/km^2$)
2 Years	1,510	2.7
5 Years	2,160	3.9
10 Years	2,800	5.0
20 Years	3,210	5.8
30 Years	4,010	7.2
50 Years	4,390	7.9
100 Years	5,810	10.4
200 Years	6,310	11.3
1,000 Years	7,530	13.5
10,000 Years	10,300	18.5

The design flood discharge for rockfill dam is specified by the Ministry of Construction of Japan as to adopt 20% up of 200 years' probability. It becomes 7,600 m^3/sec. This level is quite similar to the flood peak of 1,000 year's probability. However, for the sake of caution, the probable peak discharge for 10,000 years was examined for the safety of structures as well as the safety of the reservoir operation. The results were explained in Paragraph 1.5.3, which showed that suitable gate operation could cut the peak discharge of 10,300 m^3/sec into 6,800 m^3/sec.

In the official minutes made in December 1983, NIA and NPC asked to adopt this peak discharge as the design flood. Taking into consideration the small reservoir surface area against the short flood reaching time, the Survey Team agreed to the above proposal. Therefore, the flood of 10,300 m^3/sec was adopted as the design flood.

1.4.3 Study on Maximum Flood by Floodmark

It is officially recognized that the maximum flood occurred on Nov. 5 to 6, 1980 when the typhoon ARING passed by Matuno river basin.

For the hydrological analyses, we tried to collect as many data as possible on the maximum experienced flood. However, the available data corresponding to the flood could not be found.

Fortunately, as we got data on the river cross section from NIA when the flood occurred as shown Fig. 1-28 From this surveyed section, the peak discharge is theoretically estimated as follows:

The roughness coefficient of the existing river channel is calculated to be n = 0.0286 by the discharge measurement at site. But the roughness coefficient for the flood estimations is taken to be n = 0.035, because roughness coefficient increases due to riverbed erosion when the flood occurs in future. On the other hand, the stream gradient at that time is calculated from the difference of water levels of the 2 sections system.

a. Assumed discharge from the section 100 m upstream and cableway section

$$Q = \frac{A_1 + A_2}{2} \cdot \frac{1}{n} \cdot I^{\frac{1}{2}} \cdot \left(\frac{R_1 + R_2}{2}\right)^{\frac{2}{3}}$$

where, A_1: river cross section 100 m upstream = 460.4 m^2

A_2: river cross section at cableway section = 353.33

n : roughness coefficient of river = 0.035

I : stream gradient = (392.07 - 391.20)/100 = 0.0087

R_1: hydraulic radius at the section 100 m upstream = 3.63

R_2: hydraulic radius at cableway section = 2.94

$$Q = \frac{460.4 + 353.3}{2} \times \frac{1}{0.035} \times 0.0087^{\frac{1}{2}} \times 3.29^{\frac{2}{3}}$$

$$= 406.85 \times 5.89 = 2{,}396 \ m^3/sec$$

b. Assumed discharge from cableway section and the section 100 m downstream

By the same equation, each value is replaced as follows:

A_2 = 353.3, A_3 = 338.7, I = (391.20 - 390.32)/100 = 0.0088 and R_2 = 2.94, R_3 = 2.95

$$Q = \frac{353.3 + 338.7}{2} \times \frac{1}{0.035} \times 0.0088^{\frac{1}{2}} \times 2.95^{\frac{2}{3}}$$

$$= 346.0 \times 5.52 = 1{,}910 \text{ m}^3/\text{sec}$$

c. <u>Assumed discharge from the section 100 m upstream and the section 100 m downstream</u>

$$Q = \frac{460.4 + 338.7}{2} \times \frac{1}{0.035} \times 0.0088^{\frac{1}{2}} \times 3.29^{\frac{2}{3}}$$

$$= 400.0 \times 5.89 = 2{,}356 \text{ m}^3/\text{sec}$$

Accordingly, the average of a, b and c is calculated to be 2,220 m^3/sec.

Therefore, the maximum flood in the past is estimated to be 2,300 m^3/sec approximately.

1.5 Flood Control and Reservoir Operation

1.5.1 Probability Analysis

The result of probable flood calculation described in this Chapter is summarized below.

Probability (Period of Recurrence)	Peak flood discharge at Bante G.S. (m^3/sec)	Specific discharge ($m^3/sec/km^2$)
2 Years	1,510	2.7
5 Years	2,160	3.9
10 Years	2,800	5.0
20 Years	3,210	5.8
30 Years	4,010	7.2
50 Years	4,390	7.9
100 Years	5,810	10.4
200 Years	6,310	11.3
1,000 Years	7,530	13.5
10,000 Years	10,300	18.5

The study for the flood control is made for the following 4 cases.

Case No.	Peak Discharge	Remarks
1	4,010 m^3/sec	30 year probable flood
2	7,600 m^3/sec	200 years +20%
3	7,600 m^3/sec	- do -
4	10,300 m^3/sec	Probable Maximum Flood

Note: /1 This is the case that the rain stops immediately after the peak precipitation.

It is not easy to forecast the flood magnitude. This flood control calculation is made considering the preliminary discharging method, so that the inflow flood magnitude into the reservoir should be estimated as correctly as possible. The inflow discharge into the reservoir shall be estimated by the H - Q curve at the discharge gaging station to be newly installed at the reservoir end. The discharge gaging station will be located at the place where river bed is higher than F.W.L. of EL. 522.0 m, which will be about 10 km upstream of the B_1 damsite. The automatic telemetering system shall be installed for transmitting the water level data for gate operation.

1.5.2 Gate Operation

During the non-flood season, and when the power generation is stopped, the required discharge for downstream irrigation and river maintenance is to be released through the river outlet tunnel by the operation of the jet flow gate installed. And the maximum discharge capacity of the jet flow gate is planned to be 146 m^3/sec, so that for the required discharge larger than 146 m^3/sec, the spillway gate is opened.

According to the dam control practice in Japan, the speed of the water level rise in the downstream river reaches is controled to be less than 50 cm per hour from the start of spillway gate being opened. The flood control study at this time also is subject to the above principle.

1.5.3 Flood Control

1) In case of 30 year probable flood ($Q = 4,010\ m^3$/sec)

As seen in Fig. 1-29, when the discharge of 150 m^3/sec at 8 hours and the discharge of 250 m^3/sec at 10 hours enter the reservoir from the begining of rain, it is presumed that the peak flood will reach 4,010 m^3/sec at 22 hours. During 8 hours the initial water level in the reservoir is kept at N.H.W.L. The comparative study for 3 cases of N.H.W.L. of 520.0, 510.0 and 500.0 is made.

For the initial water level of case-1, the gate is operated in such a way that inflow equal to outflow before the preliminary discharging. As the maximum preliminary discharging is selected to be 2,000 m^3/s considering the harmless discharge downstream, to make a drawdown from EL. 520.0 to 515.0. The drawdown is made in 4 hours, and at that time, the peak discharge is reduced to be 1,984 m^3/sec.

The final plan will be selected among the alternative cases studied by the authority responsible for the control of dam facilities. (Refer to Table 1-13)

2) In case of 7,600 m^3/sec

The calculation is made by the same method as the previous case. The result of the case for the largest peak cut is shown in Fig. 1-30.

In this case, the gate is operated in such a way that inflow equal to the outflow during 8 hours from the beginning of rain, and then the initial water level 520.0 is lowered down temporarily to EL. 515.0 m by the preliminary discharging. When the inflow reaches to the peak of 7,600 m^3/sec after the outflow increases together with the increase of inflow, the maximum outflow of 5,017.5 m^3/sec flows out by proper gate operation.

In this case, the peak cut ratio of outflow and the inflow becomes 35% approximately. (Refer to Fig. 1-30, Table 1-11)

3) In case of 7,600 m^3/sec, but rain stops immediately after the peak precipitation

Though this case is the same as case -2 on the flood peak discharge, as the inflow decreases sharply, the rise of water level stops immediately afterwards, and the maximum water level becomes 521.30 m. (Refer to Fig. 1-31, Table 1-12)

4) In case of 10,300 m^3/sec

The calculation is made by the same method as the previous study. The result of the case for largest peak cut is shown in Fig. 1-32.

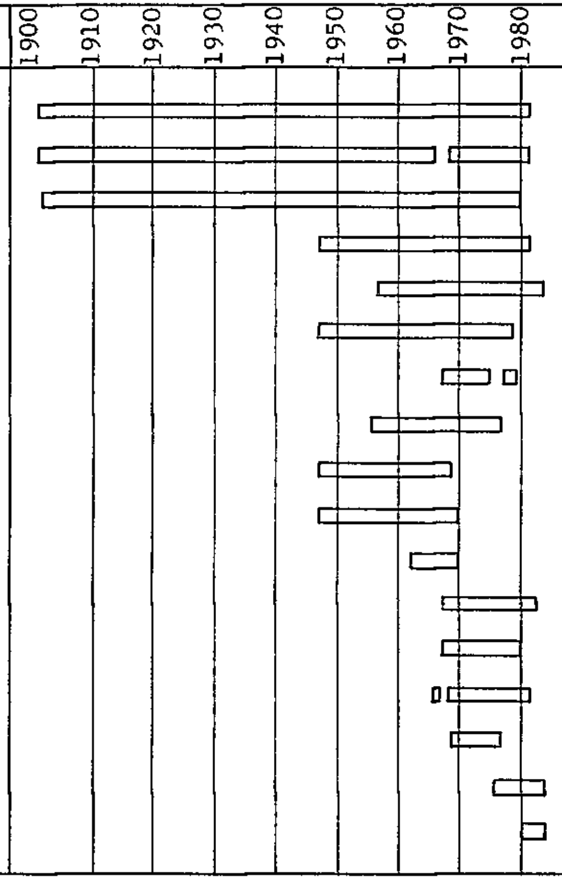
In this case, the gate will be operated in such a way that the inflow is equal to the outflow during 9 hours from the beginning of rain, then, the initial water level of EL. 520.0 m is lowered down to EL. 515.0 m temporarily by preliminaly discharging. When the peak inflow discharge reaches to 10,300 m^3/sec after the outflow increases together with the increase of inflow, the maximum outflow of 6,800 m^3/sec is discharged by the appropriate gate operation. (Refer to Fig. 1-32, Table 1-13)

And, at this time, the maximum water level becomes El. 524.70 m. Therefore, the bottom elevation of bridge girder and the top elevation of core are planned to be EL. 525.0 m and 525.50 m respectively, which are above the maximum water level.

Table 1-1 COLLECTED METEOROLOGICAL AND HYDROLOGICAL RECORDS

RAINFALL GAGING STATIONS

STATION	LOCATION LATI	LOCATION LONGI	ELV. (M)	REMARKS
APARRI CAGAYAN	18°22'	121°38'	4.00	
BAGUIO	16°24'	120°36'		
TUGUEGARAO CAGAYAN	17°37'	121°44'	18.60	
TUAO CAGAYAN	17°44'	121°27'	35.00	
CONSUELO STA. FE. NUEVA VIZCAYA	16°10'	120°57'	540.00	
SALINAS (BALAT) BAMBANG	16°23'	121°06'		
SOLANO NUEVA VIZCAYA	16°31'	121°11'		
ILAGAN ISAVELA	17°09'	121°53'	40.00	
BAGABA NUEVA VIZCAYA	17°37'	121°47'		
HERALD LUMBER CO MANKAYAN MT. PROV.	16°43'	120°50'		
MT. POLUS PASS BANAWE MT. PROV.	16°58'	121°01'		
LAGAWE IFUGAO	16°48'	121°04'	480.00	
DUPAX NUEVA VIZCAYA	16°17'	121°05'	310.00	
BOBK BOCOD GAGE NO.5	16°27'	120°50'	770.00	
AMBUKLAO BOCOD H.E. PLANT	16°29'	120°45'	720.00	
STO. DOMINGO BA MBANG NUEVA VISCAYA				
BANTE BAMBANG NUEVA VIZCAYA	16°27'	121°03'	385.00	



DISCHARGE GAGING STATIONS

STATION	LOCATION LATI	LOCATION LONGI	DRAINAGE AREA (km^2)	REMARKS
MATUNO RIVER BANTE BAMBANG N.V.	16°25'30"	120°03'30"	558	
MAGAT RIVER BATO BAYOMBONG N.V.	16°25'55'	121°07'01"	1,784	
MAGAT RIVER OSCARIZ SAN METRO ISAVELA	16°46'44"	121°29'37"	4,150	

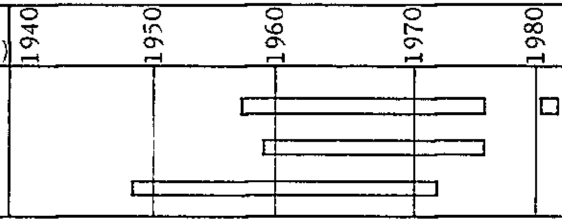


Table 1-2 General Meteorological Conditions of Project Area

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total or Mean
1. Air Temperature (oC) at Baretbet													
Average	23.0	26.1	28.4	29.4	26.3	25.8	25.5	25.5	28.1	27.3	25.8	23.0	26.2
Max.	32.8	36.2	37.3	37.8	34.8	32.6	35.8	32.6	35.6	33.9	34.5	32.8	-
Min.	16.1	16.7	15.6	19.5	21.2	21.2	21.1	21.1	21.1	21.1	17.8	15.6	-
2. Evaporation	111.8	140.1	194.5	208.3	183.2	171.5	175.2	177.3	162.3	139.9	114.8	105.4	1,884
Daily Mean	3.61	5.00	6.27	6.94	5.91	5.72	5.65	5.72	5.41	4.51	3.83	3.40	5.16
3. Relative Humidity (%) at San Mateo	84.0	85.0	86.6	87.7	87.5	87.8	88.9	90.7	90.6	/1 (54.9)	83.6	80.1	-
4. Wind Velocity at San Mateo (m/sec)		0.81	0.68	0.69	0.70	0.58	0.55	0.89	0.77	0.80	0.89	0.87	0.69

/1 : Not correct

Table 1-3 Revised Monthly Discharge at B1 Damsite
(Catchment Area: 550 km^2)

(m^3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Annual Mean
1957	34.90	22.90	20.41	20.39	18.88	20.07	25.18	30.70	47.47	36.08	38.81	26.76	342.55	28.55
1958	22.94	21.32	20.77	22.09	22.45	28.63	29.57	109.83	64.46	119.38	58.11	34.67	554.22	46.19
1959	28.39	22.38	25.30	16.43	22.68	17.57	18.23	23.96	37.48	36.64	63.10	69.41	381.57	31.80
1960	44.79	50.63	37.35	30.51	27.96	35.58	41.84	98.74	56.70	59.26	33.94	21.06	538.36	44.86
1961	14.17	11.99	16.62	14.23	18.32	23.88	29.17	30.03	36.05	61.85	21.48	16.10	293.89	24.49
1962	14.11	13.31	18.23	25.80	21.16	20.44	78.25	48.08	52.22	34.66	65.90	29.49	421.65	35.14
1963	22.05	32.04	24.91	18.88	22.03	61.30	48.90	76.63	86.20	47.08	30.32	56.25	526.59	43.88
1964	17.27	17.05	21.65	19.16	29.54	42.47	55.11	77.20	66.48	86.34	94.90	73.60	600.77	50.06
1965	67.46	39.01	21.06	18.88	22.01	33.38	46.95	27.15	69.81	45.22	32.53	21.72	445.18	37.10
1966	27.20	22.07	19.16	13.24	80.03	25.93	28.34	30.20	19.94	16.47	96.65	46.01	425.24	35.44
1967	25.44	15.33	9.49	26.64	36.12	85.04	69.52	56.09	69.40	67.66	80.95	18.75	560.43	46.70
1968	58.03	12.09	13.89	13.17	16.58	44.99	99.66	70.41	70.08	28.99	14.42	10.51	452.82	37.74
1969	8.34	7.87	7.47	8.14	8.17	9.75	39.99	50.93	62.32	59.03	25.73	25.30	313.04	26.09
1970	12.05	8.58	7.83	8.26	7.89	39.57	28.56	55.65	30.60	98.83	72.41	39.42	409.65	34.14
1971	24.49	25.81	30.22	19.42	31.26	31.15	44.25	56.49	46.54	122.96	72.93	57.57	563.09	46.92
1972	40.34	20.43	15.70	13.19	18.93	24.96	105.67	79.47	100.68	31.60	30.22	21.28	502.47	41.87
1973	13.33	12.31	10.54	8.78	13.86	19.44	24.86	29.09	49.92	147.64	77.34	48.92	456.03	38.00
1974	28.26	19.45	11.37	11.80	19.06	45.76	64.63	72.64	26.90	45.25	48.36	48.25	441.73	36.81
1975	40.14	21.23	15.70	16.73	10.80	11.16	13.22	40.32	80.50	21.35	23.60	29.47	324.22	27.02
1976	33.03	12.80	14.51	16.52	54.81	65.52	55.66	46.91	32.39	32.92	23.57	13.79	402.43	33.54
Total	576.73	408.60	362.18	342.26	502.54	686.59	947.56	1,110.52	1,106.16	1,199.21	1,005.27	708.33	8,955.93	
Mean	28.84	20.43	18.11	17.11	25.13	34.33	47.38	55.53	55.31	59.96	50.26	35.42		37.32

* Converted from Bante discharges by multiplying the catchment area ratio of 0.986

Table 1-4 Irrigation Water Requirement

(Unit: m^3/sec.)

Month / Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1957	-	-	-	-	-	0.04/2.36	-	0.18	-	-	-	0.09
1958	0.19	-	-	-	-	-	-	-	-	-	-	-
1959	-	-	-	-	-	0.18/3.06	-	0.35	-	-	-	-
1960	0.51/2.61	0.33/4.12	-	-	-	-	-	0.31	-	-	-	0.31/2.21
1961	0.51/2.61	0.33/4.12	-	-	-	-	-	0.31	-	-	-	-
1962	0.51/2.33	0.28/4.06	-	-	-	0.09	-	-	-	0.10	-	-
1963	0.23	-	-	-	-	-	-	-	-	-	-	-
1964	0.40	0.12	-	-	-	-	-	-	-	-	-	-
1965	-	-	-	-	-	-	-	0.51	-	-	0.14	-
1966	0.04	-	-	-	-	-	-	-	0.29	0.22	-	-
1967	0.07	0.05	0.23	-	-	-	-	-	-	-	-	-
1968	-	0.32	0.13	-	-	-	-	-	-	-	0.51	0.70/1.31
1969	0.72/1.12	0.47/7.86	0.30/7.23	0.05/4.56	-	0.99/10.61	-	-	-	-	-	-
1970	0.59	0.38/5.66	0.04/4.11	3.20	0.04/3.29	-	-	-	-	-	-	-
1971	0.14	-	-	-	-	-	-	-	-	-	-	-
1972	0.22	-	-	-	-	-	-	-	-	0.23	-	0.36/3.60
1973	0.54/4.41	0.32/2.18	0.25/2.60	0.08/5.06	0.10/1.93	0.30/3.31	0.40/1.28	0.07	-	-	-	-
1974	-	0.03	2.21/3.20	0 /0.93	-	-	-	-	0.28	-	-	-
1975	-	-	0.03/1.78	-	0 /1.09	0.87/13.46	0.78/9.16	-	-	0.18	-	-
1976	-	0.30/4.45	0 /0.67	0 /0.10	-	-	-	-	-	-	0.04	0.52/8.54

Note: In the form of A/B, "A" means the required discharge from dam for Manantan Intake, while "B" means the required discharge from powerstation for Magat Intake.
The numbers without the mark "/" means the required discharge from dam for Manantan Intake.

Table 1-5 Available Discharge for Hydropower

(Unit: m^3/sec)

Month / Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Mean
1957	34.86	22.90	20.41	20.39	18.88	17.71	25.18	30.52	47.47	36.08	38.81	26.67	339.88	28.32
1958	22.75	21.32	20.77	22.09	22.45	28.63	29.57	109.83	64.65	119.38	58.11	34.67	554.22	46.19
1959	28.39	22.38	25.30	16.43	22.68	14.33	18.23	23.61	37.48	36.64	63.10	69.41	377.98	31.50
1960	44.79	50.63	37.35	30.51	27.96	35.58	41.84	98.74	56.70	59.26	33.94	18.54	535.84	44.65
1961	11.05	7.54	16.62	14.23	18.32	23.88	29.17	29.72	36.05	61.85	21.48	16.10	286.01	23.83
1962	11.27	8.97	18.23	25.80	21.16	20.35	78.25	48.08	52.22	34.56	65.90	29.49	414.28	34.52
1963	21.82	32.04	24.91	18.88	22.03	61.30	48.90	76.63	86.20	47.08	30.32	56.25	526.36	43.86
1964	16.87	16.93	21.65	19.16	29.54	42.47	55.11	77.20	66.48	86.34	94.90	73.60	600.25	50.02
1965	67.46	39.01	21.06	18.88	22.01	33.38	46.95	26.64	69.81	45.22	32.53	21.58	444.53	37.04
1966	27.16	22.07	19.16	13.24	80.03	25.93	28.34	30.20	19.65	16.25	96.65	46.01	424.69	35.39
1967	25.37	15.28	9.26	26.64	36.12	85.04	69.52	56.09	69.40	67.66	80.95	18.75	560.08	46.67
1968	58.03	11.77	13.76	13.17	16.58	44.99	99.66	70.41	70.08	28.99	13.91	8.50	449.85	37.49
1969	6.50	-0.46	-0.06	3.54	8.17	-1.85	39.99	50.93	62.32	59.03	25.73	25.30	279.14	23.26
1970	11.46	2.54	3.68	5.06	4.46	39.57	28.56	55.65	30.60	98.83	72.41	39.42	392.24	32.69
1971	24.35	25.81	30.22	19.42	31.26	31.15	44.25	56.49	46.54	122.96	72.93	57.57	562.95	46.91
1972	40.12	20.43	15.70	13.19	18.93	24.96	105.67	79.47	100.68	31.37	30.22	17.32	498.06	41.51
1973	8.37	9.81	7.69	3.64	11.83	15.83	23.18	29.02	49.92	147.64	77.34	48.92	433.19	36.10
1974	28.26	19.42	5.96	10.87	19.06	45.76	64.63	72.64	26.62	45.25	48.36	48.25	435.08	36.26
1975	40.14	21.23	13.89	16.73	9.71	-3.17	3.28	40.32	80.50	21.17	23.60	29.47	296.87	24.74
1976	33.03	8.05	13.84	16.52	53.72	51.19	45.72	46.91	32.39	32.92	23.53	4.73	362.56	30.21
Total	562.05	377.67	339.40	328.39	494.90	637.02	926.00	1,109.10	1,105.76	1,198.48	1,004.72	690.55		731.16
Mean	28.10	18.88	16.97	16.42	24.75	31.85	46.30	55.46	55.29	59.92	50.24	34.53	438.71	36.66

Note: No each value is obtained to take the irrigation water requirement of Table from the monthly discharge at B1 damsite of Table .

Table 1-6 Monthly Rainfall at Barat (Salinas) Bambang N.V.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	TOTAL
1948	*16.9	19.6	4.8	215.9	92.0	49.3	492.0	294.9	421.9	165.1	240.5	214.4	2,227.3
1949	2.0	0	57.9	110.0	71.9	64.8	196.8	284.2	319.3	110.7	48.5	139.2	1,405.3
1950	0	10.4	112.3	62.7	84.3	158.2	112.5	289.8	450.1	250.4	31.0	13.5	1,575.2
1951	0	4.6	16.3	110.0	321.3	161.5	182.9	165.9	95.5	206.2	151.4	49.3	1,464.9
1952	6.9	7.1	84.6	78.0	290.8	211.3	47.5	284.5	180.1	189.7	38.4	155.4	1,574.3
1953	3.6	14.7	58.9	85.6	251.5	245.1	273.8	169.7	132.6	122.2	36.3	167.4	1,561.4
1954	1.5	0.5	104.1	104.1	200.7	5.6	304.8	183.9	109.5	13.2	233.9	3.6	1,265.4
1955	27.4	5.1	35.6	31.5	26.9	54.1	276.9	840.7	172.7	129.3	174.2	54.6	1,829.0
1956	10.2	0	12.7	113.8	71.9	239.3	165.3	185.3	187.9	135.9	238.8	169.4	1,530.5
1957	25.4	0	73.6	107.7	137.2	111.8	176.7	203.5	365.7	169.1	101.6	17.5	1,489.8
1958	15.1	4.9	16.2	75.0	168.2	111.2	94.7	417.3	302.7	328.7	91.7	9.4	1,635.1
1959	15.2	13.2	87.8	55.2	256.2	117.6	175.0	246.8	172.1	*222.2	190.1	77.8	1,629.2
1960	10.3	207.7	3.8	154.3	188.7	274.5	191.7	429.0	337.8	233.1	10.1	14.7	2,055.7
1961	2.0	0	137.0	107.4	124.8	176.3	337.8	123.5	69.0	213.9	130.6	129.1	1,551.4
1962	11.3	0	74.8	118.9	80.3	90.0	336.2	224.2	222.6	21.6	47.6	21.6	1,249.1
1963	14.4	13.7	63.7	*94.6	84.3	165.4	285.2	246.4	205.8	25.4	27.4	98.1	1,326.4
1964	4.5	1.8	11.9	33.8	226.4	156.9	131.5	241.0	259.8	380.0	254.5	139.5	1,841.6
1965	26.4	9.6	39.1	102.7	117.8	61.2	234.9	356.2	190.9	110.2	101.7	33.3	1,384.0
1966	15.8	0	53.3	71.9	450.1	117.4	136.2	303.0	82.9	82.8	198.3	47.9	1,559.6
1967	26.8	0	12.1	79.8	179.3	174.0	157.7	314.9	321.9	214.4	154.6	19.3	1,654.8
1968	36.3	0	38.1	72.4	136.4	20.8	113.1	357.4	220.5	41.5	35.6	27.9	1,100.0

- continued -

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	TOTAL
1969	0	0	38.1	0	94.0	18.5	1,316.8	1,793.2	*245.3	*222.2	*140.0	*78.9	3,947.0
1970	17.8	24.6	9.6	51.3	107.7	223.7	102.1	349.2	326.3	678.5	201.3	*78.9	2,171.0
1971	0	0	37.9	30.5	336.3	183.6	251.5	301.3	435.2	588.7	314.7	302.5	2,782.2
1972	99.1	0	80.7	295.1	171.0	81.3	983.9	433.9	310.1	88.1	170.5	57.6	2,771.3
1973	0	0	0	39.6	69.3	148.2	152.3	413.1	122.1	494.2	173.5	16.8	1,629.1
1974	7.1	0	0	116.9	172.4	0	136.8	164.2	150.2	358.1	266.3	*78.9	1,450.9
1975	31.8	0	49.1	45.3	190.5	101.0	165.7	293.4	219.0	150.2	139.7	144.9	1,530.6
1976	19.1	0	23.4	67.6	904.0	462.4	517.0	197.7	229.7	323.8	69.6	32.1	2,846.4
1977	24.4	30.6	0	64.6	182.2	201.5	151.2	255.1	254.2	90.6	248.2	0	1,502.6
1978	43.8	33.3	52.9	132.0	81.3	439.2	318.2	*339.8	571.4	544.1	108.6	76.4	2,741.0
1979	0	0	26.6	199.1	232.3	297.0	282.3	170.1	301.8	206.8	112.3	61.3	1,889.6
1980	20.5	*13.6	*44.3	*94.6	*190.7	*153.8	*275.0	*339.8	109.4	*222.2	140.0	*78.9	1,682.8
1981	37.9	45.6	*44.3	*94.6	*190.7	*153.8	*275.0	*339.8	*245.3	*222.2	*140.0	*78.9	1,868.1
Total	573.5	462.6	1,505.5	3,216.5	6,483.4	5,230.3	9,351.0	11,552.7	8,341.3	7,555.3	4,761.5	2,684.0	61,722.6
Mean	16.9	13.6	44.3	94.6	190.7	153.8	275.0	339.8	245.3	222.2	140.0	78.9	1,815.1

NOTE: *FILL-IN DATA USING MEAN FOR THE MONTH

Table 1-7 Number of Rainy Days at Salinas (Barat) R. S.
(more than 1.0 mm)

YEAR/MO.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JLY.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1956	1	0	2	8	4	10	8	14	11	10	12	17	97
1957	2	0	5	4	4	8	11	8	17	10	2	2	73
1958	4	2	1	3	10	8	13	22	18	15	5	2	103
1959	1	3	11	5	15	7	18	14	19	*12	11	8	124
1960	6	11	2	12	9	17	9	23	15	10	3	5	122
1961	0	0	9	7	12	9	17	9	4	17	7	1	92
1962	3	0	4	7	5	11	14	18	13	5	8	3	91
1963	4	7	2	0	3	9	16	14	17	5	2	7	86
1964	2	1	6	4	11	9	9	16	17	16	19	5	119
1965	4	3	4	8	7	7	12	7	12	11	12	5	92
1966	3	0	3	2	13	5	12	18	12	8	13	11	100
1967	7	*1	*4	7	7	12	12	19	19	12	8	6	114
1968	2	0	2	4	7	1	7	23	14	5	2	1	68
1969	0	0	1	0	1	3	13	17	*12	*12	*9	*7	74
1970	3	1	4	7	12	15	7	15	6	21	*9	18	118
1971	0	0	10	4	15	7	8	11	12	15	11	6	99
1972	2	0	3	14	10	5	28	12	15	10	11	7	117
1973	0	0	0	3	6	6	10	21	10	3	12	4	95
1974	1	0	0	4	12	0	8	8	5	14	10	8	70
1975	2	0	2	2	7	5	8	14	0	5	5	13	63
TOTAL	47	29	75	105	170	154	240	303	248	236	171	136	1,914
MEAN	2	1	4	5	9	8	12	15	12	12	9	7	95.7
													≒ 96/year

Note: * Fill-in data using mean for the month

Table 1-8 Number of Rainy Days at Salinas (Barat) R. S.
(more than 10 mm)

YEAR/MO.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JLY.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
1956	1	0	0	2	1	10	6	7	7	4	10	8	56
1957	1	0	3	4	4	4	8	5	9	5	2	1	46
1958	1	1	1	2	5	4	4	10	9	9	3	0	49
1959	1	0	3	3	6	5	6	9	6	*7	4	4	54
1960	0	6	0	5	6	12	5	13	12	6	0	0	65
1961	0	0	4	3	5	6	10	5	3	9	6	1	52
1962	0	0	1	3	4	4	6	8	7	0	2	1	36
1963	0	0	2	0	2	6	11	6	6	1	1	4	39
1964	0	0	0	2	6	6	4	7	12	9	9	3	58
1965	1	0	1	3	4	2	7	6	7	3	3	1	38
1966	0	0	2	2	13	5	7	12	3	3	5	0	52
1967	1	*0	*1	2	6	4	5	13	11	5	1	0	49
1968	1	0	1	3	5	1	6	15	9	1	2	1	45
1969	0	0	1	1	1	0	13	17	*7	*7	*4	*3	54
1970	0	1	0	1	3	8	4	9	5	15	*4	8	58
1971	0	0	0	2	11	5	6	8	10	15	6	6	69
1972	2	0	2	11	5	3	23	11	12	5	5	3	82
1973	0	0	0	3	3	5	5	11	4	18	5	1	55
1974	0	0	0	3	8	0	4	5	5	7	7	6	45
1975	2	0	2	2	7	4	5	13	0	5	3	7	50
TOTAL	11	8	24	57	105	94	145	190	144	134	82	58	1,052
MEAN	1	0	1	3	5	5	7	10	7	7	4	3	52.6 ≑ 53/year
Provable Workable Days	30	28	30	27	26	25	24	21	23	24	26	28	

Average = 26 days

Note: * Fill-in data using mean for the month

Table 1-9 Annual Maximum Discharge Record

Date	Max. Gage Height (m)	Max. Discharge (m^3/sec)
1957 Nov. 12	2.00	110.1
1958 Aug. 3	2.95	321.5
1959 Nov. 17	2.90	305.9
1960 Oct. 14	2.05	280.4
1961 Oct. 19	2.25	143.3
1962 July 22	3.50	498.4
1963 Aug. 15	3.60	443.0
1964 Oct. 15	4.08	299.0
1965 Sept.10	3.11	141.0
1966 Nov. 23	3.09	388.7
1967 Nov. 4	4.00	641.2
1968 Aug. 30	2.66	217.6
1969 July 28	2.20	148.6
1970 Oct. 15	2.80	344.2
1971 Oct. 13	3.55	610.2
1972 July 17	3.05	436.8
1973 Oct. 22	3.30	771.2
1974 Oct. 18	2.38	168.6
1975 Sept.28	2.75	293.8
1976 May 25	2.50	250.0

Table 1-10 Flood Routing for 30 year Probable Flood (1)

$Q = 4,010.0\ m^3/sec$

(1)	(2)		(3)	(4)	(5)	(6)	(7)		(8)
El.520.0	4.0	9.0	El.515.0	2,000.0	20.0	2,499.2	520.9 ≦	522.0	OK
"	6.0	11.0	"	"	"	2,235.8	521.6 ≦	"	"
"	8.0	13.0	"	"	"	2,026.5	521.8 ≦	"	"
"	10.0	15.0	"	"	"	2,158.0	520.4 ≦	"	"
"	12.0	17.0	"	"	"	2,346.5	518.9 ≦	"	"
El.520.0	4.0	9.0	El.517.5	2,000.0	12.0	2,827.8	521.3 ≦	522.0	OK
"	6.0	11.0	"	"	"	2,860.4	520.7 ≦	"	"
"	8.0	13.0	"	"	"	2,609.9	521.5 ≦	"	"
"	10.0	14.0	"	"	"	2,423.4	521.7 ≦	"	"
"	12.0	16.0	"	"	"	2,346.5	521.2 ≦	"	"
	Time of gate operation start (T)								
El.520.0	7.0			0	0	3,156.4	521.9 ≦	522.0	OK
"	9.0			"	"	3,172.7	521.6 ≦	"	"
"	11.0			"	"	3,193.3	521.3 ≦	"	"
"	13.0			"	"	2,954.2	522.0 ≦	"	"
"	15.0			"	"	3,029.6	521.4 ≦	"	"

Remarks:
(1) = Initial reservoir water level (m)
(2) = Start and finish time for preliminary discharging operation from the beginning of rain (T) (hrs)
(3) = Reservoir water level after the preliminary discharging (m)
(4) = Maximum discharge of preliminary discharging (m^3/sec)
(5) = Deducted reservoir storage capacity ($x10^6 m^3$)
(6) = Maximum outflow (m^3/sec)
(7) = Surcharge water level (m)
(8) = Judgement on safety

Table 1-11 Flood Routing for 20% increased of 200 Year Probable Flood (7,600 m^3/sec) (2)

(1)	(2)		(3)	(4)	(5)	(6)	(7)		(8)
El.520.0	2.0	7.0	El.515.0	2,000.0	20.0	6,004.5	519.1 ≤	522.0	OK
"	3.0	9.0	"	"	"	6,020.8	518.7 ≤	"	"
"	4.0	11.0	"	"	"	5,433.2	521.5 ≤	"	"
"	6.0	13.0	"	"	"	5,485.8	520.7 ≤	"	"
"	8.0	15.0	"	"	"	5,017.5	522.07≑	"	"
El.520.0	4.0	7.0	El.517.5	2,000.0	12.0	6,004.5	521.4 ≤	522.0	"
"	5.0	9.0	"	"	"	6,020.8	521.1 ≤	"	"
"	7.0	11.0	"	"	"	6,041.4	520.7 ≤	"	"
"	9.0	13.0	"	"	"	6,067.7	520.3 ≤	"	"
"	11.0	15.0	"	"	"	5,561.2	522.07≑	"	"
	Time of gate operation start (T)								
EL.520.0	7.0			0	0	6,004.5	523.8 >	522.0	NO
"	9.0			"	"	6,020.8	523.4 >	"	"
"	11.0			"	"	6,041.4	523.1 >	"	"
"	13.0			"	"	6,067.7	522.7 >	"	"
"	15.0			"	"	6,105.4	522.2 >	"	"

Remarks:
(1) = Initial reservoir water level (m)
(2) = Start and finish time for preliminary discharging operation from the beginning of rain (T) (hrs)
(3) = Reservoir water level after the preliminary discharging
(4) = Maximum discharge of preliminary discharging (m^3/sec)
(5) = Deducted reservoir storage capacity ($x10^6 m^3$)
(6) = Maximum outflow (m^3/sec)
(7) = Surcharge water level (m)
(8) = Judgement on safety

Table 1-12 Flood Routing Results for 20% increased of 200 Year Probable (7,600 m^3/sec) (3)

(In case of rain stops immediately after the peak precipitation)

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
El.520.0	2.0	7.0	El.515.0	2,000.0	20.0	5,359.4	521.9 ≤ 522.0	OK
"	3.0	9.0	"	"	"	5,392.0	521.3 ≤ "	"
"	4.0	11.0	"	"	"	5,433.2	520.7 ≤ "	"
"	6.0	13.0	"	"	"	5,485.8	520.0 ≤ "	"
"	8.0	15.0	"	"	"	5,017.1	521.3 ≤ "	"
El.520.0	4.0	7.0	El.517.5	2,000.0	12.0	6,004.5	520.9 ≤ 522.0	OK
"	5.0	9.0	"	"	"	6,020.8	520.6 ≤ "	"
"	7.0	11.0	"	"	"	6,041.4	520.3 ≤ "	"
"	9.0	13.0	"	"	"	6,067.7	519.9 ≤ "	"
"	11.0	15.0	"	"	"	5,561.2	521.6 ≤ "	"
	Time of gate operation start (T)							
El.520.0	7.0			0	0	6,004.5	523.3 > 522.0	NO
"	9.0			"	"	6,020.8	523.0 > "	"
"	11.0			"	"	6,041.4	522.7 > "	"
"	13.0			"	"	6,067.7	522.3 > "	"
"	15.0			"	"	6,105.4	522.0 ≤ "	OK

Remarks:
(1) = Initial reservoir water level (m)
(2) = Start and finish time for preliminary discharging operation from the beginning of rain (T) (hrs)
(3) = Reservoir water level after the preliminary discharging
(4) = Maximum discharge of preliminary discharging (m^3/sec)
(5) = Deducted reservoir storage capacity ($x10^6 m^3$)
(6) = Maximum outflow (m^3/sec)
(7) = Surcharge water level (m)
(8) = Judgement on safety

Table 1-13 Flood Routing for Design Fload of 10,300 m³/sec (P.M.F.) (4)

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
El.520.0	2.0	6.0	El.515.0	2,500.0	20.0	8,165.8	520.5 ≦ 524.7	OK
"	3.0	8.0	"	"	"	7,332.8	524.7 ≦ "	"
"	5.0	10.0	"	"	"	7,389.0	523.7 ≦ "	"
"	7.0	12.0	"	"	"	7,460.4	522.7 ≦ "	"
"	9.0	14.0	"	"	"	6,823.0	524.4 ≦ "	"
El.520.0	4.0	7.0	El.517.5	2,500.0	12.0	8,165.8	522.8 ≦ 524.7	OK
"	5.0	9.0	"	"	"	8,187.9	522.3 ≦ "	"
"	7.0	11.0	"	"	"	8,216.0	521.8 ≦ "	"
"	9.0	13.0	"	"	"	8,251.7	521.3 ≦ "	"
"	11.0	15.0	"	"	"	7,563.0	523.7 ≦ "	"
	Time of gate operation start (T)							
El.520.0	7.0			0	0	8,165.8	525.1 > 524.7	NO
"	9.0			"	"	8,187.9	524.6 ≦ "	OK
"	11.0			"	"	8,216.0	524.1 ≦ "	"
"	13.0			"	"	8,251.7	523.6 ≦ "	"
"	15.0			"	"	8,303.0	523.0 ≦ "	"

Remarks:
(1) = Initial reservoir water level (m)
(2) = Start and finish time for preliminary discharging operation from the beginning of rain (T) (hrs)
(3) = Reservoir water level after the preliminary discharging
(4) = Maximum discharge of preliminary discharging (m^3/sec)
(5) = Deducted reservoir storage capacity ($x10^6m^3$)
(6) = Maximum outflow (m^3/sec)
(7) = Surcharge water level (m)
(8) = Judgement on safety

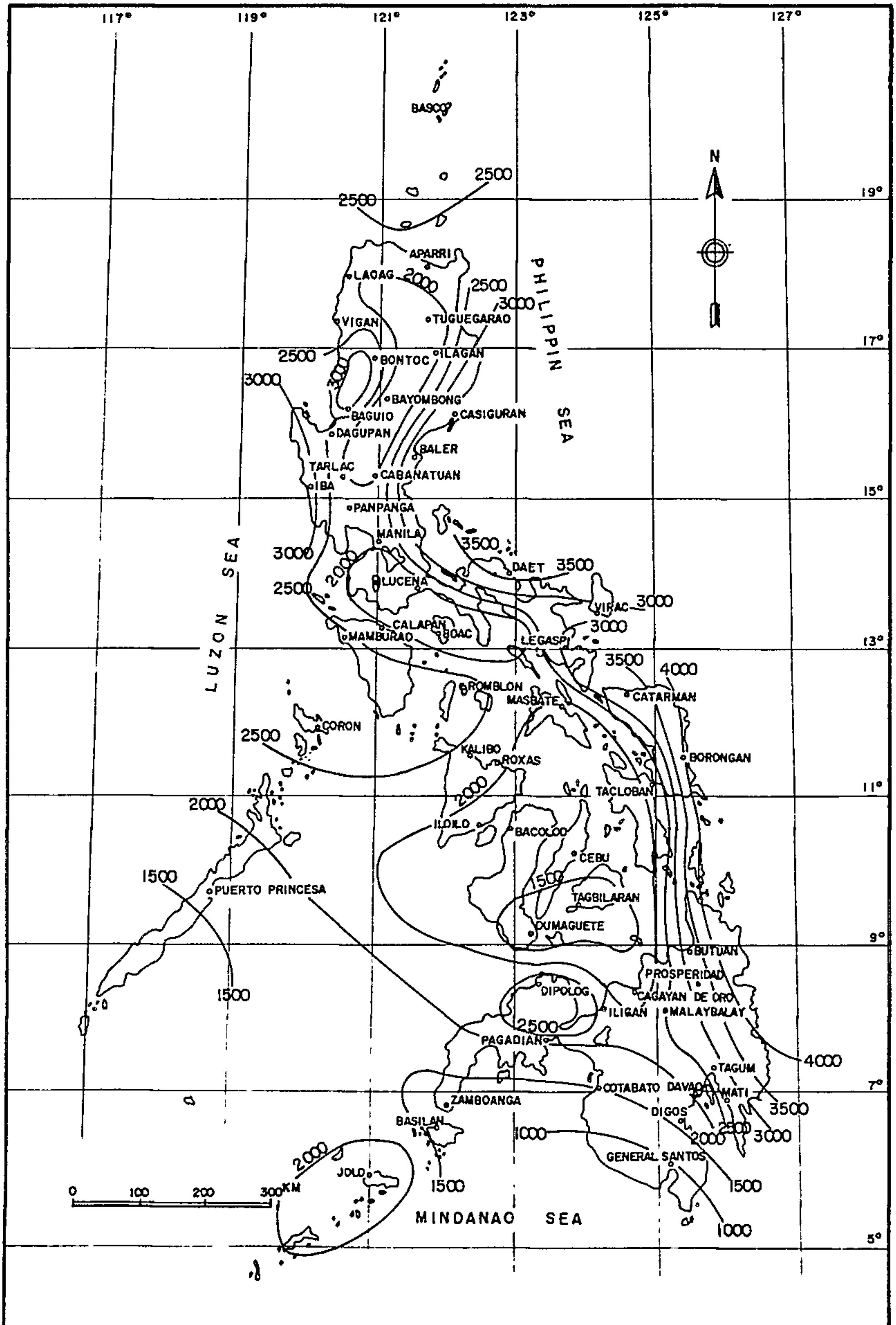


FIG. I-1 ANNUAL NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES

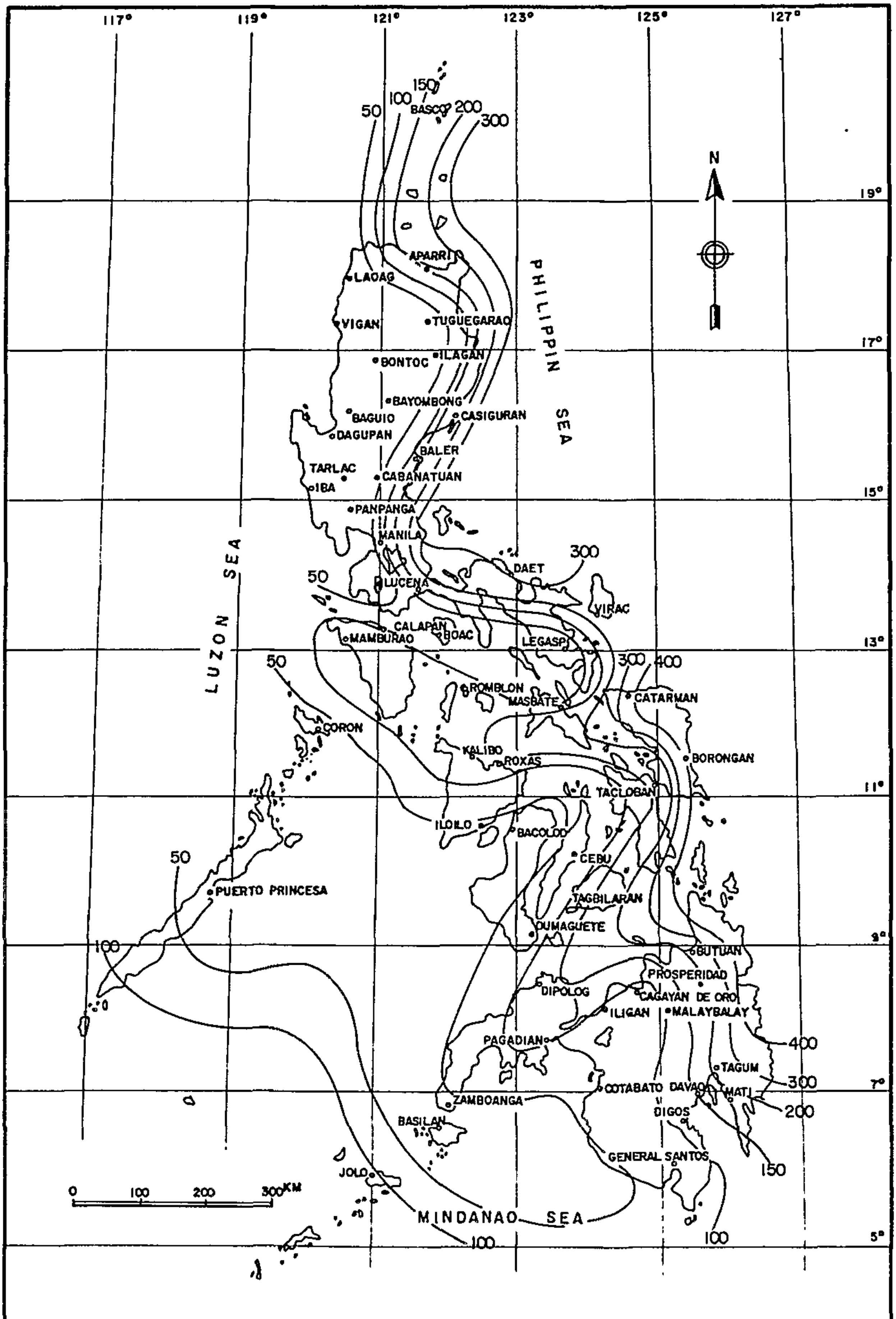


FIG. 1-2 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)

JANUARY 1951 – 1970

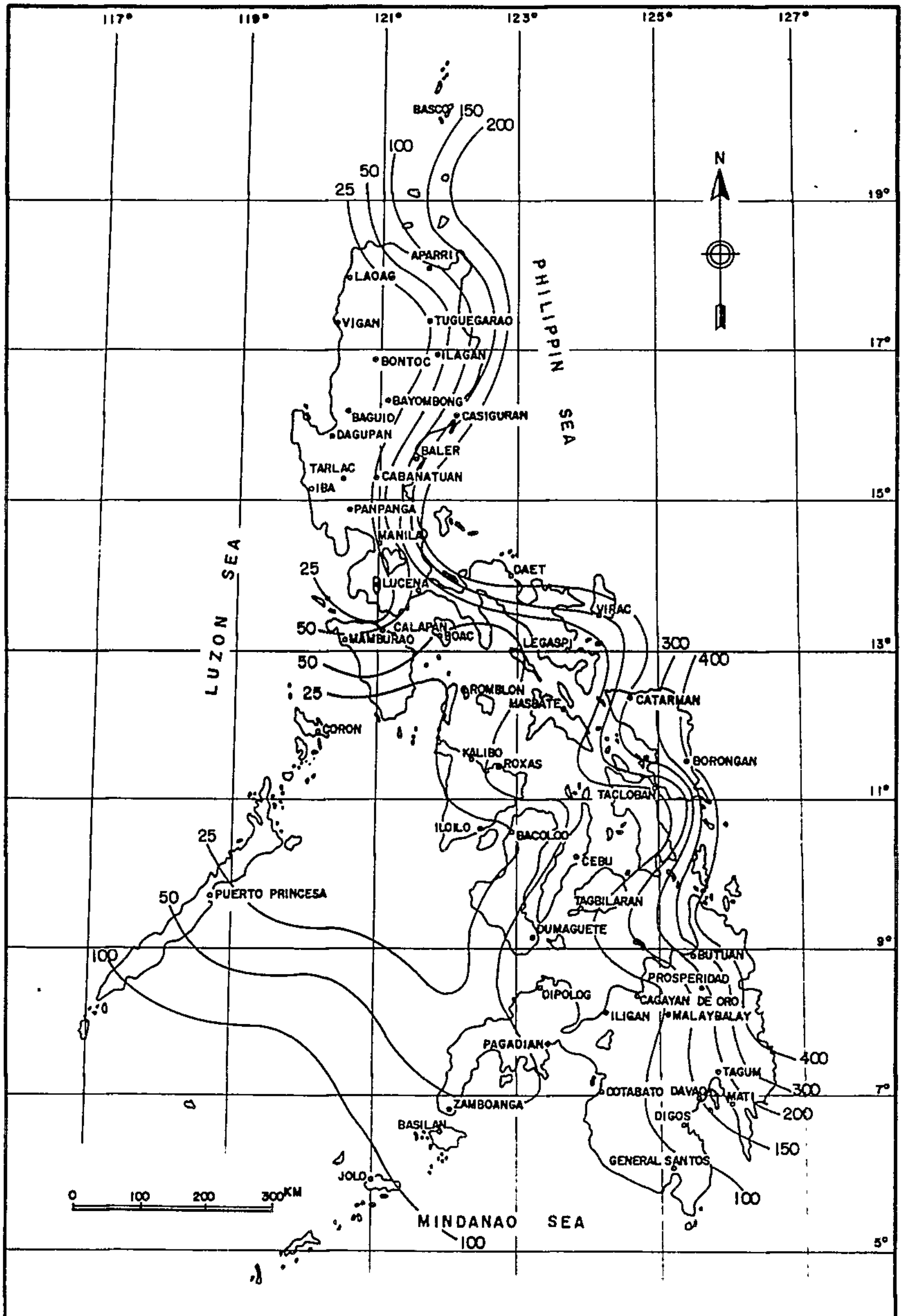


FIG. I-3 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)

FEBRUARY 1951 – 1970

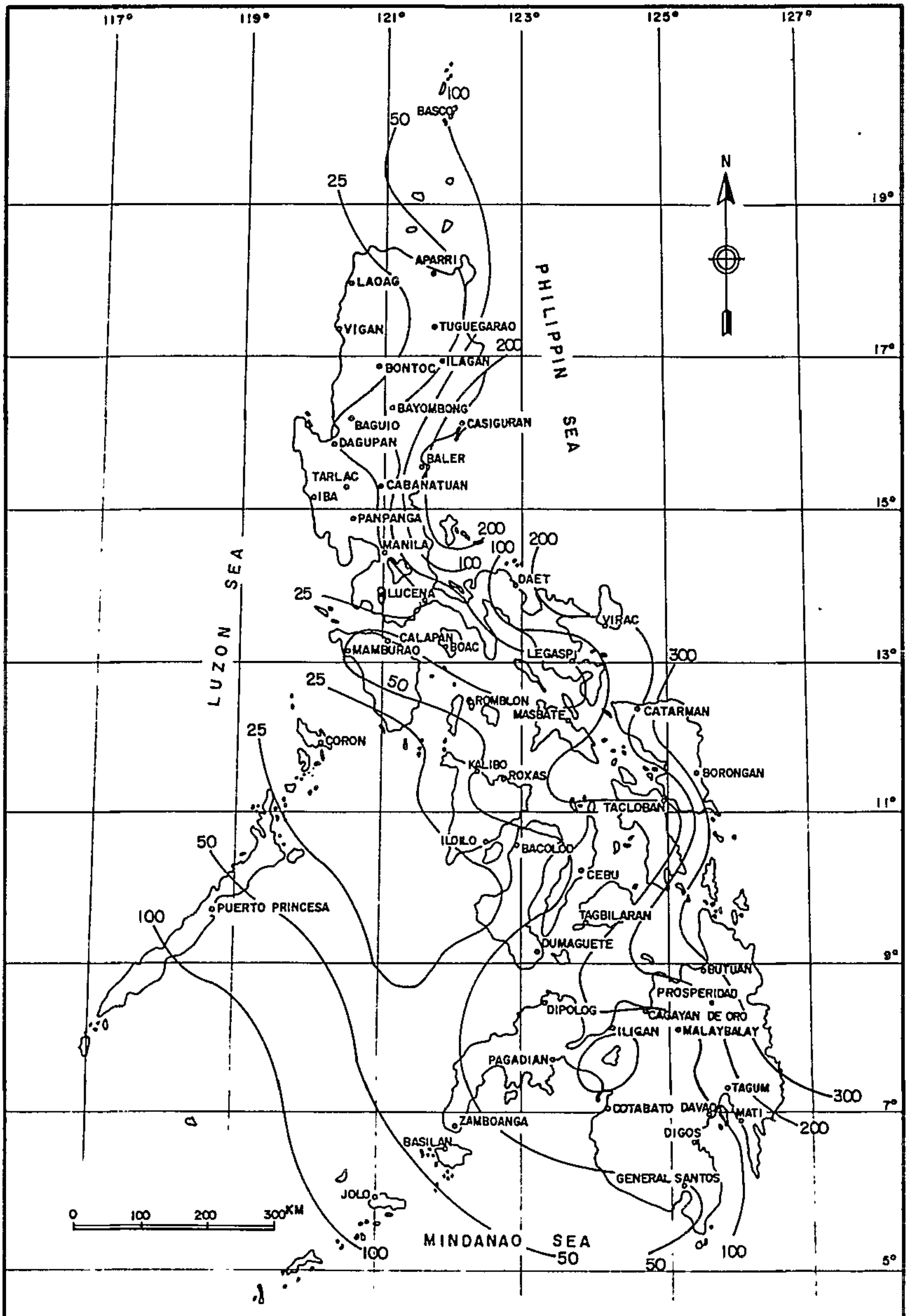


FIG. I-4 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)

MARCH 1951 – 1970

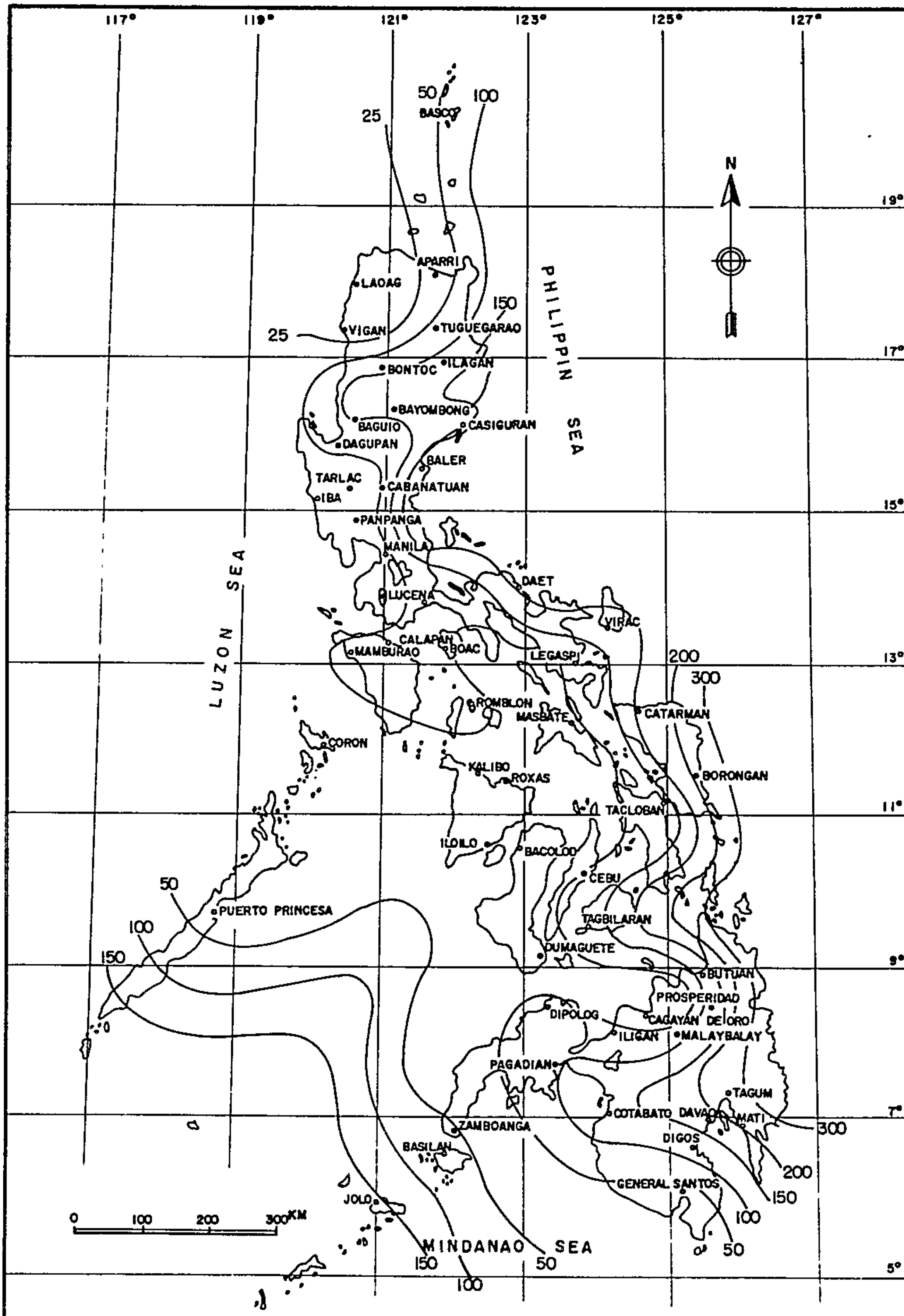


FIG. I-5 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)

APRIL 1951 – 1970

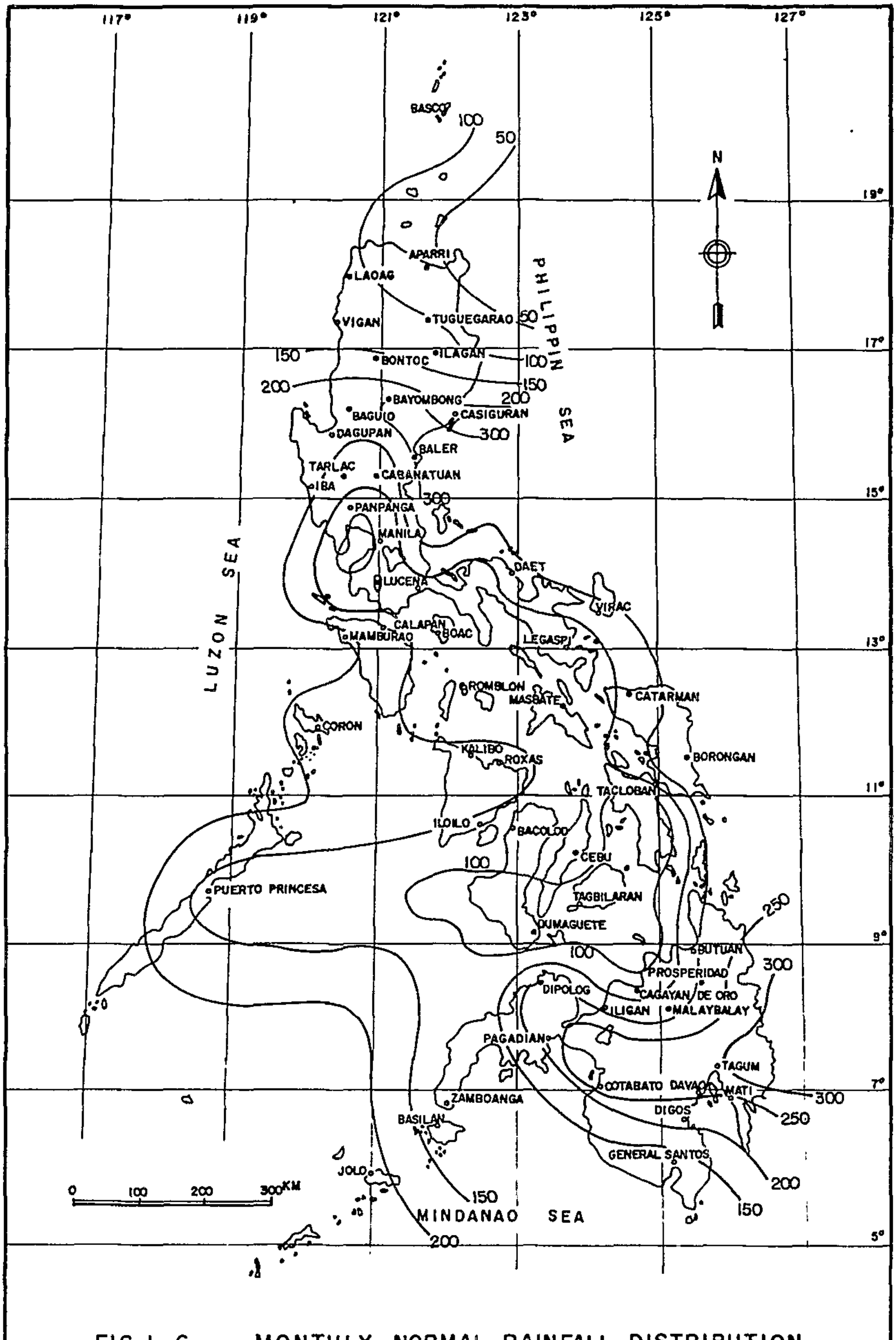


FIG. I-6 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)

MAY 1951 – 1970

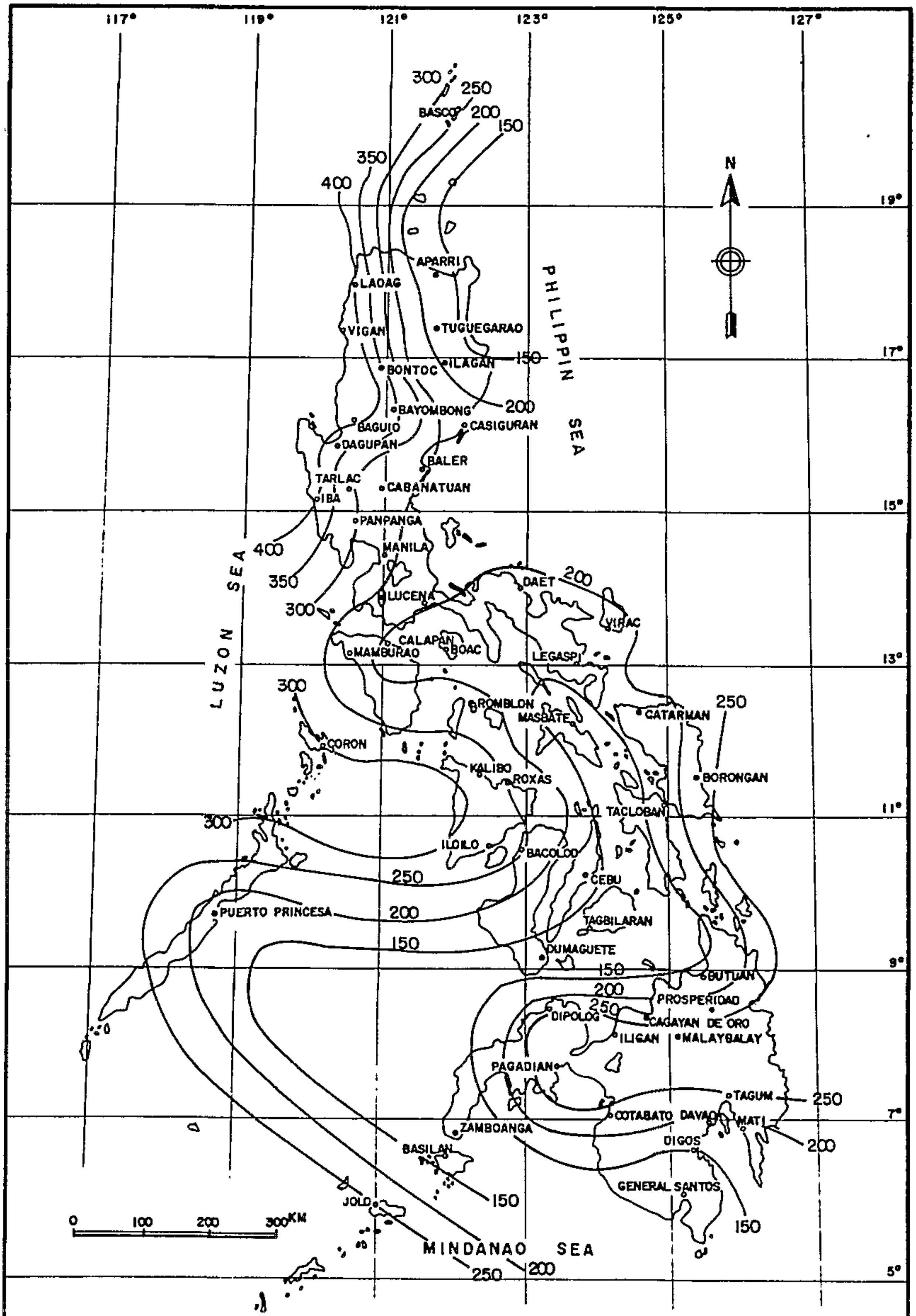


FIG. I-7 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS) JUNE 1951 – 1970

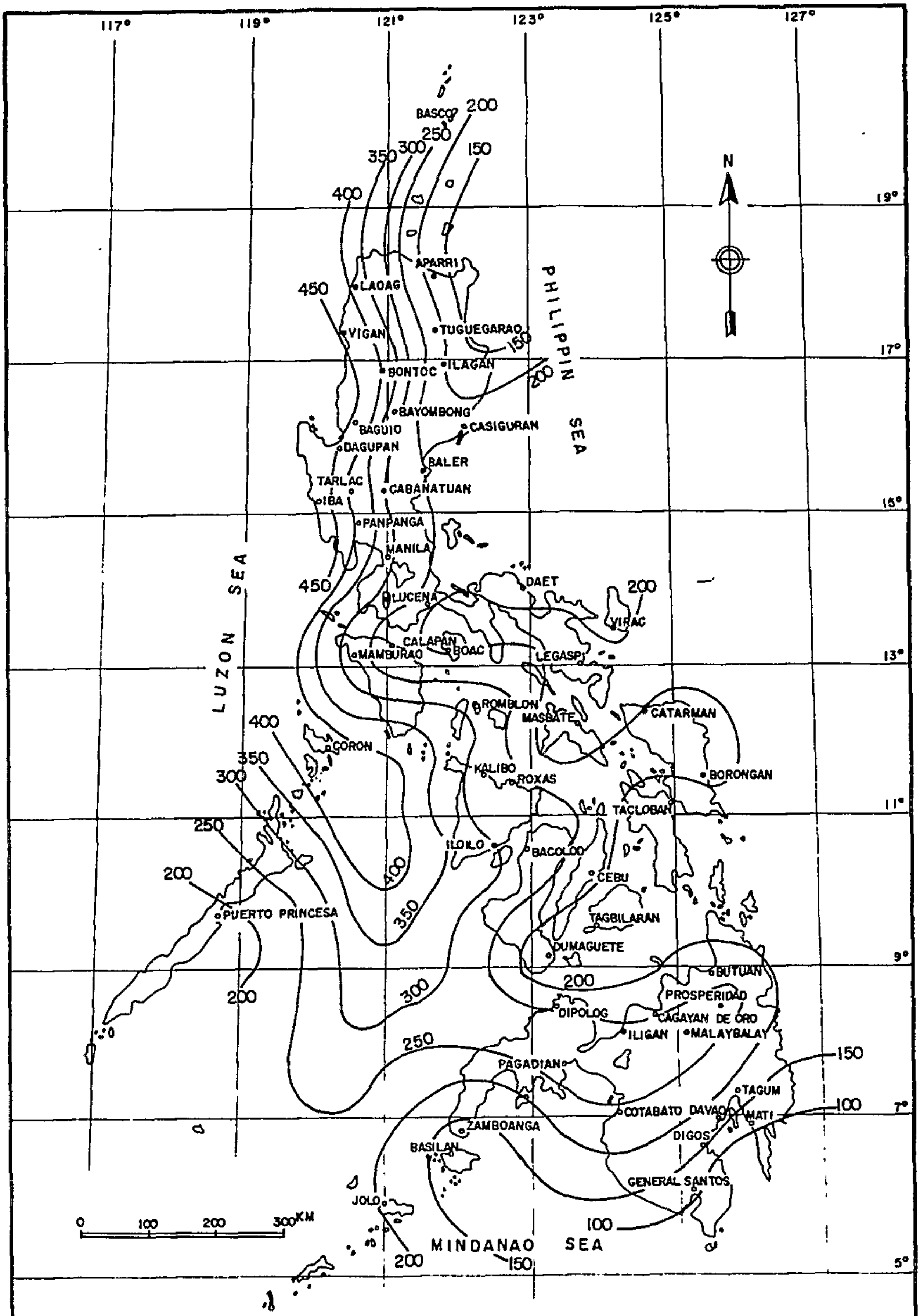


FIG. 1-8 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)

JULY 1951 – 1970

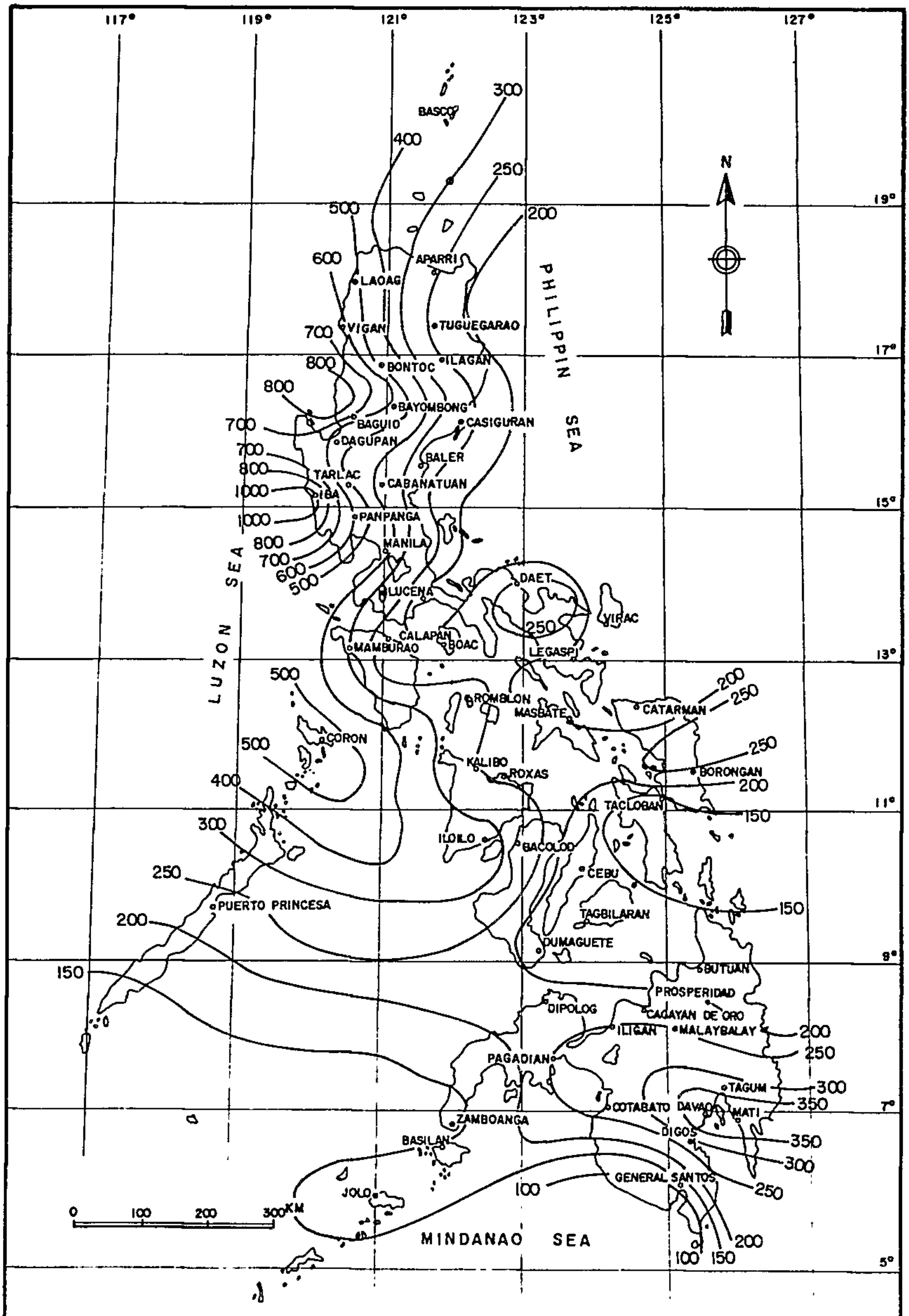


FIG. I-9 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)

AUGUST 1951 - 1970

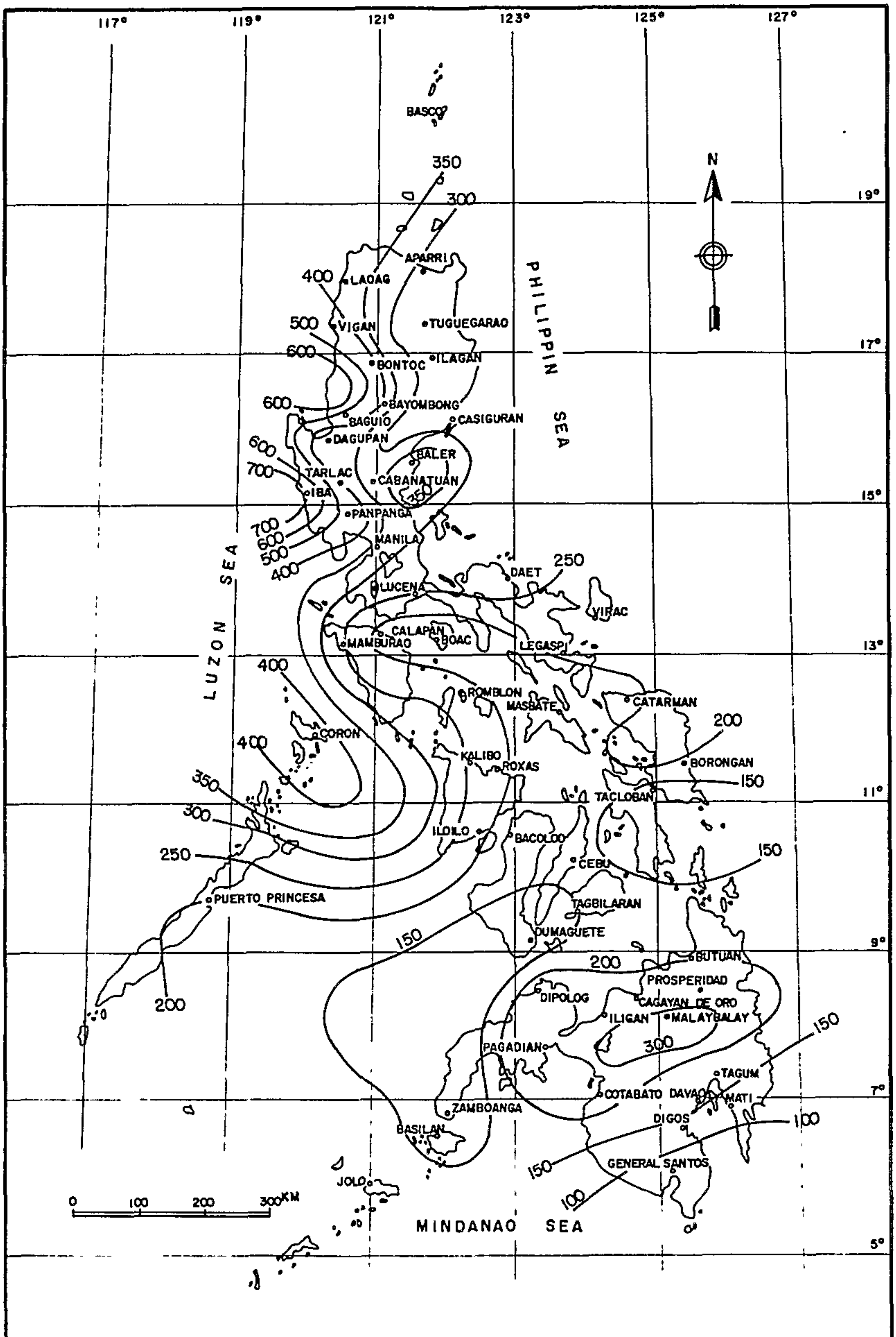


FIG. I-10 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)
SEPTEMBER 1951 – 1970

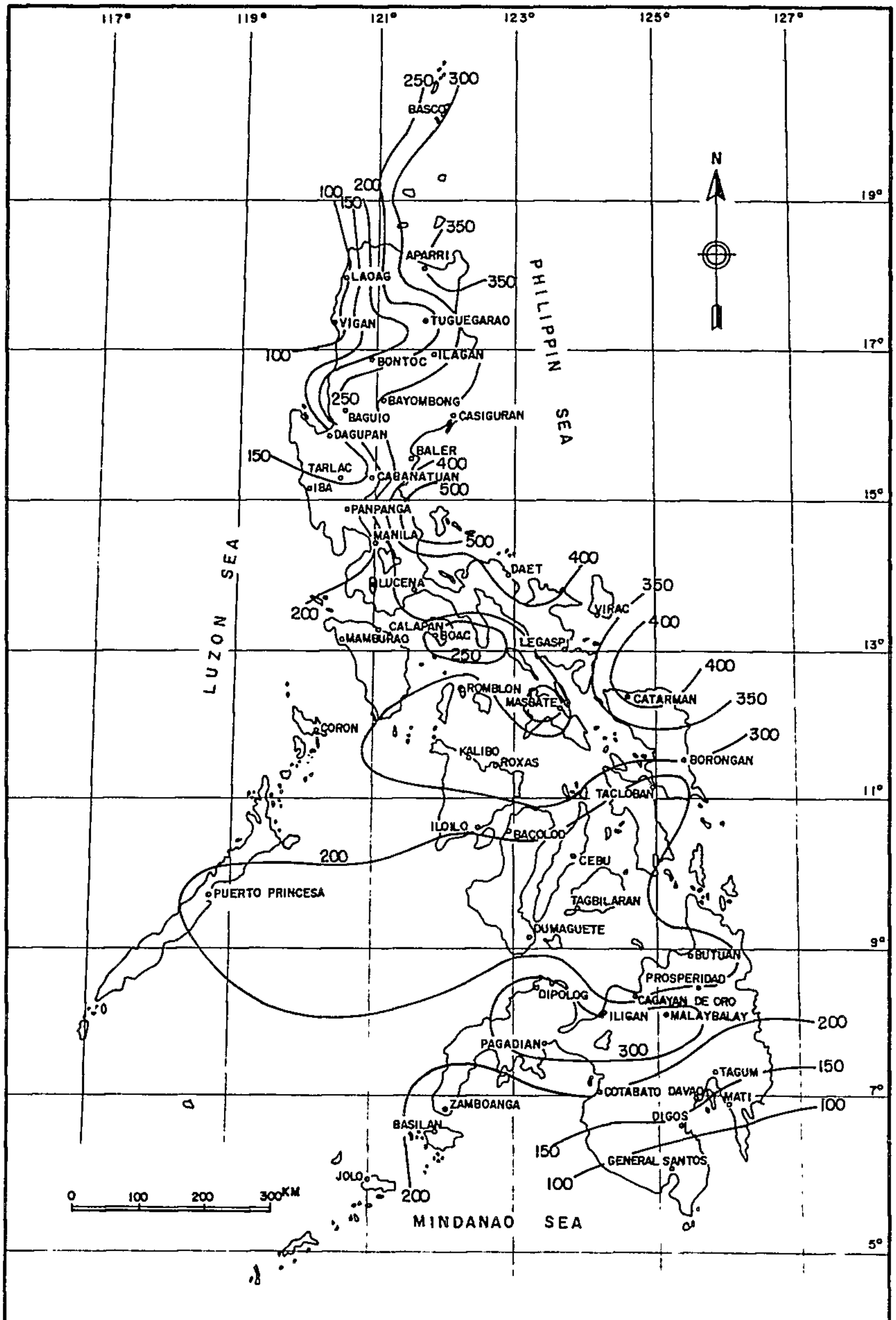


FIG. 1-11 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)

OCTOBER 1951 – 1970

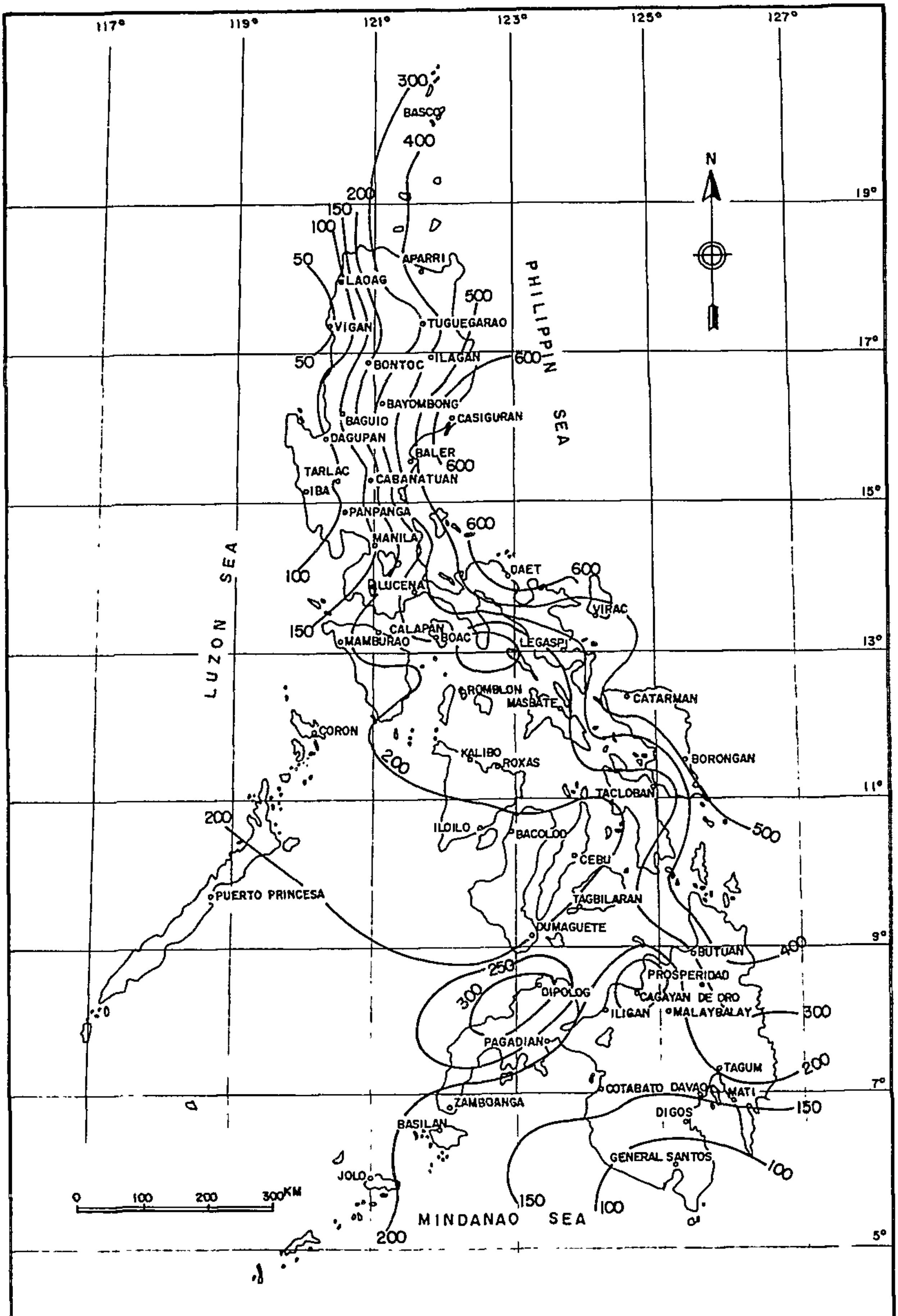


FIG. 1-12 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)
NOVEMBER 1951 – 1970

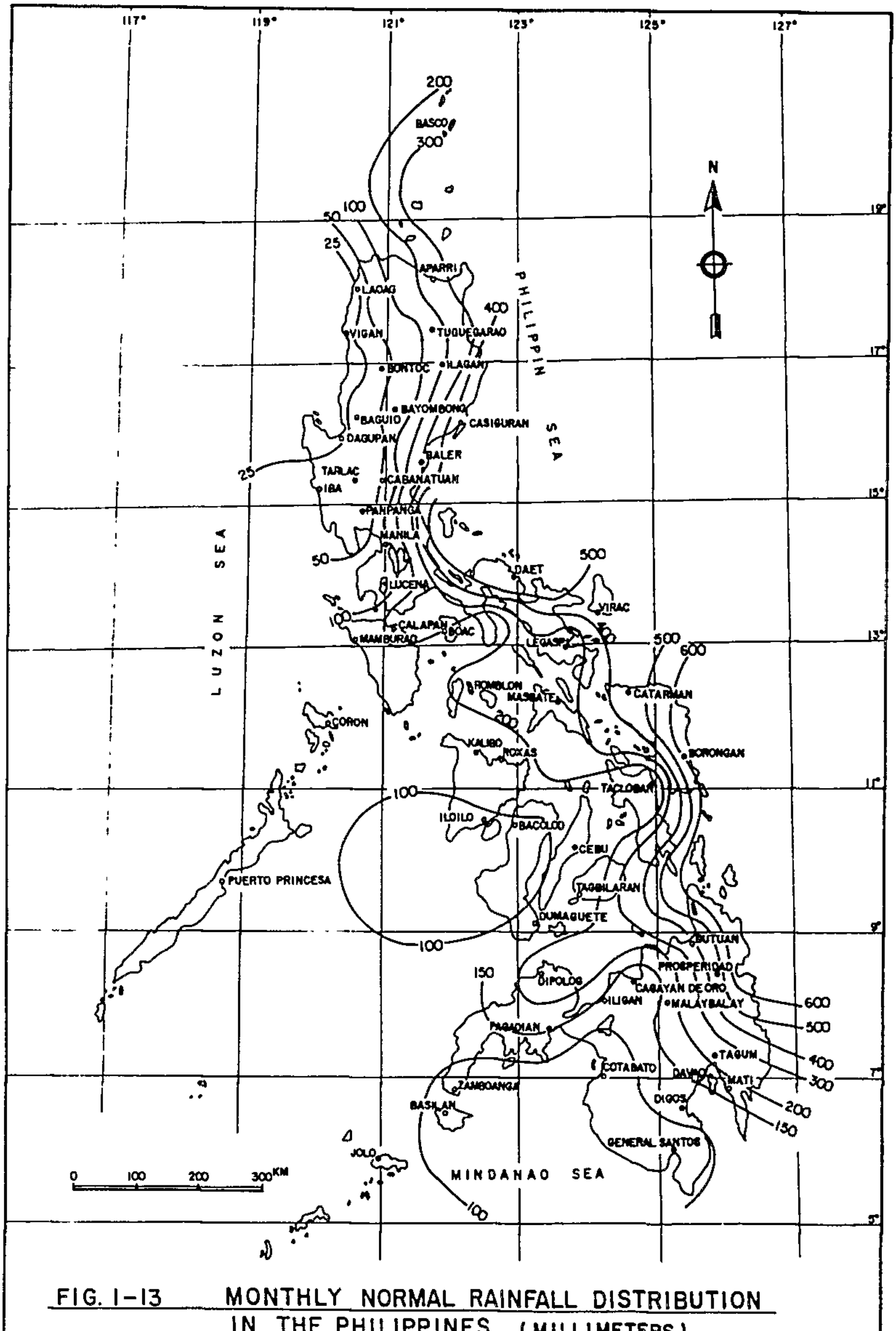


FIG. I-13 MONTHLY NORMAL RAINFALL DISTRIBUTION IN THE PHILIPPINES (MILLIMETERS)

DECEMBER 1951 - 1970

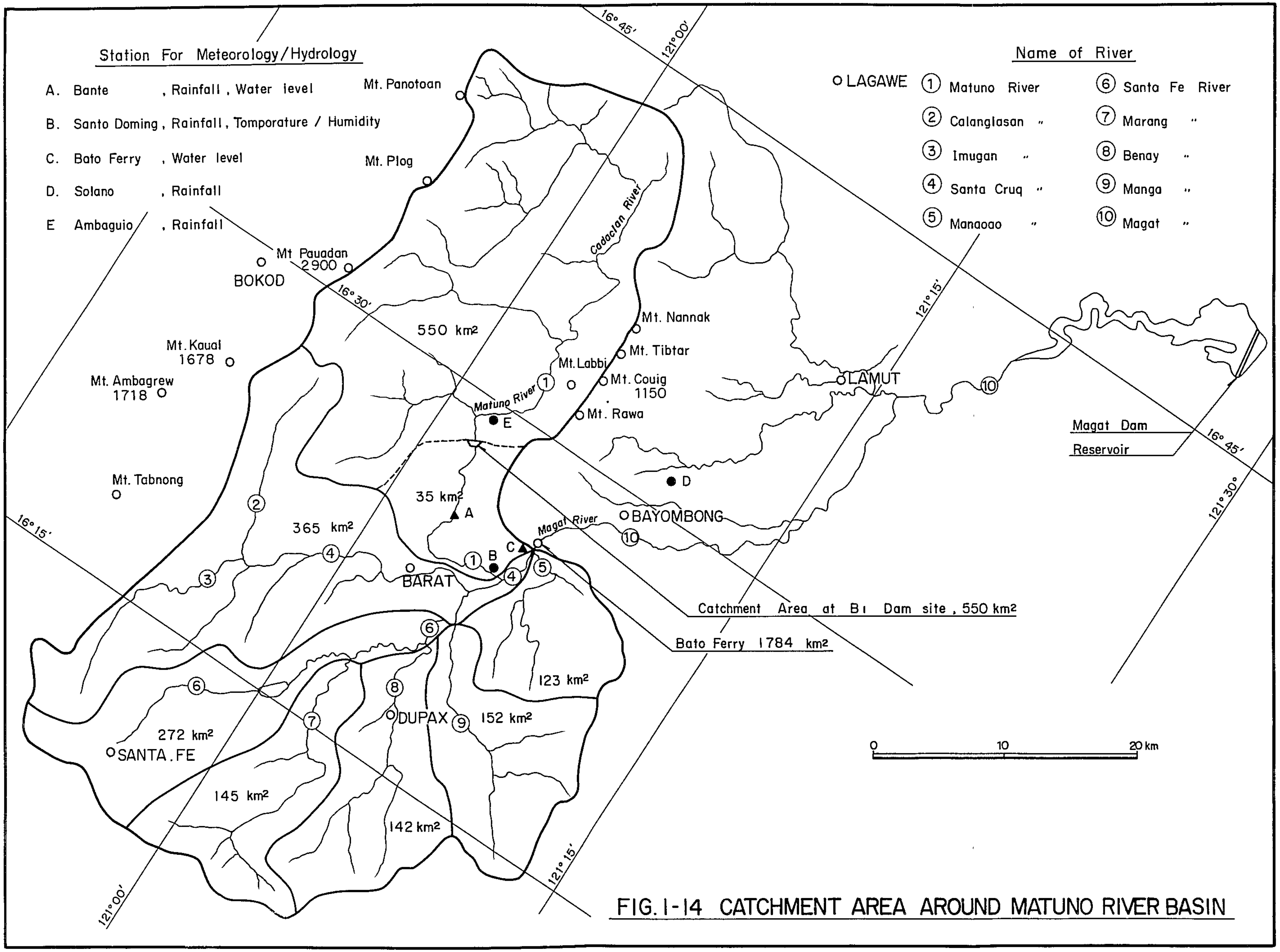


FIG. I-14 CATCHMENT AREA AROUND MATUNO RIVER BASIN

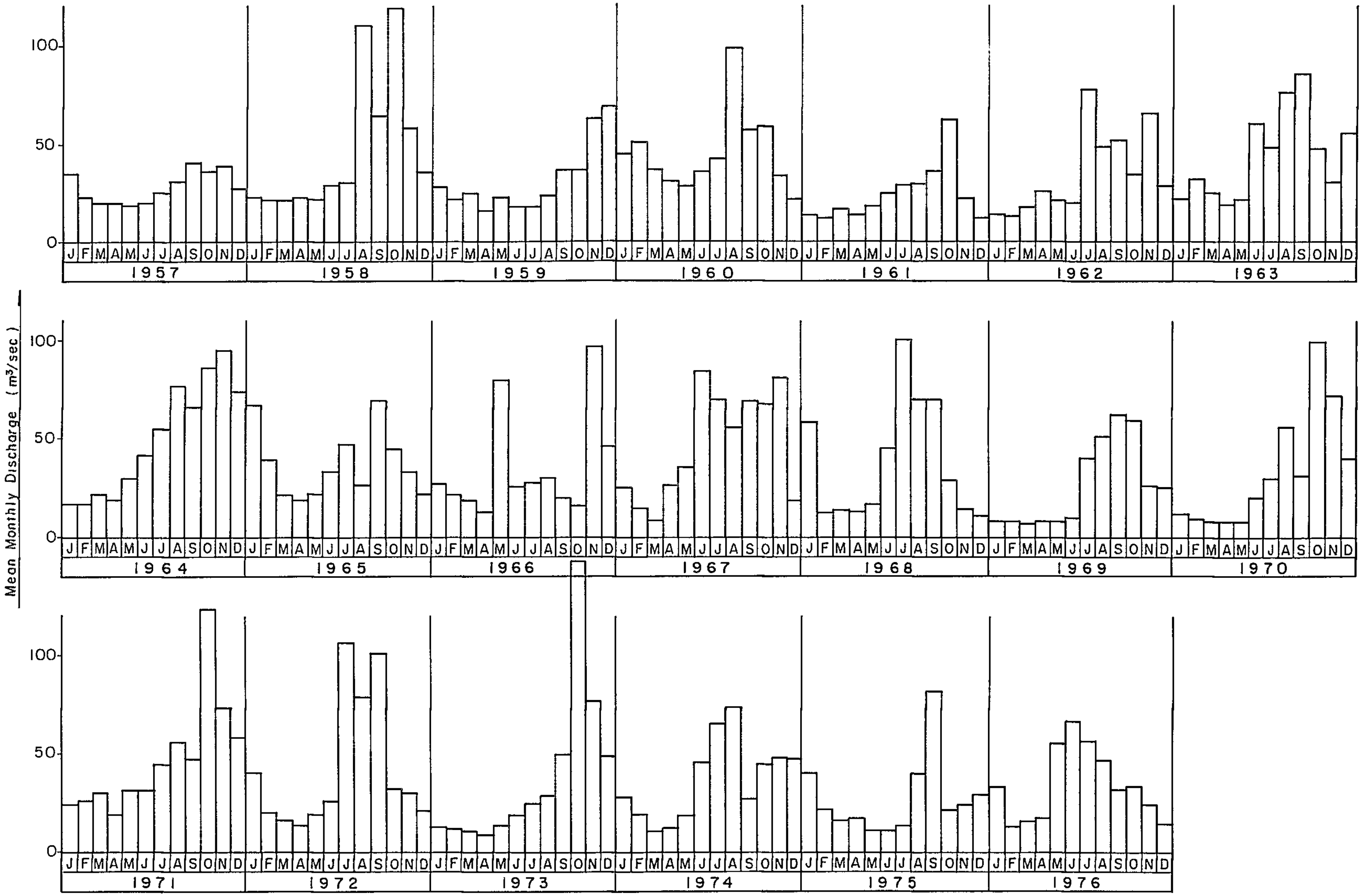


FIG. 1-15 REVISED MONTHLY DISCHARGE AT B1 DAMSITE

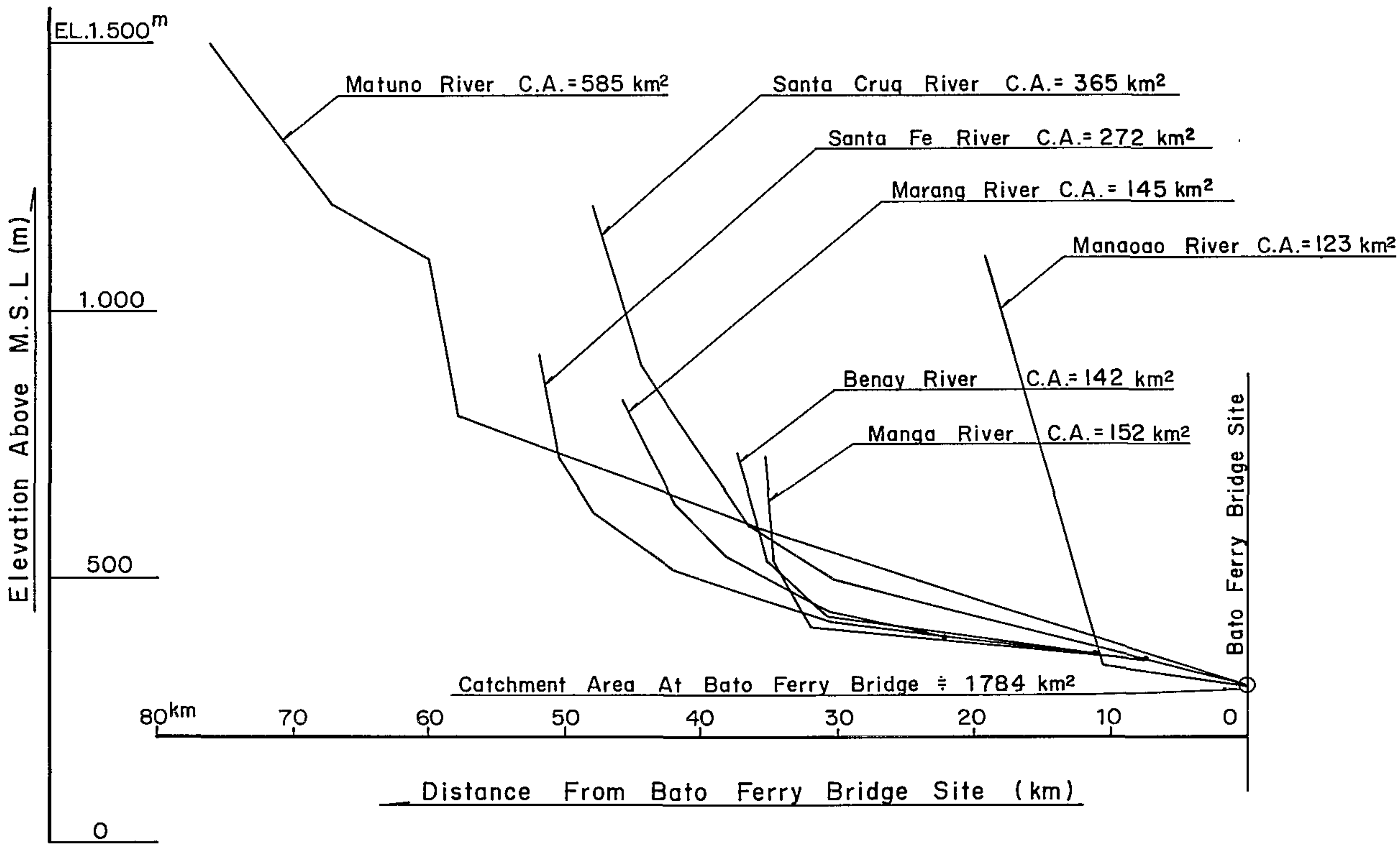


FIG. I-16 RIVER PROFILES UPSTREAM FROM BATO FERRY BRIDGE

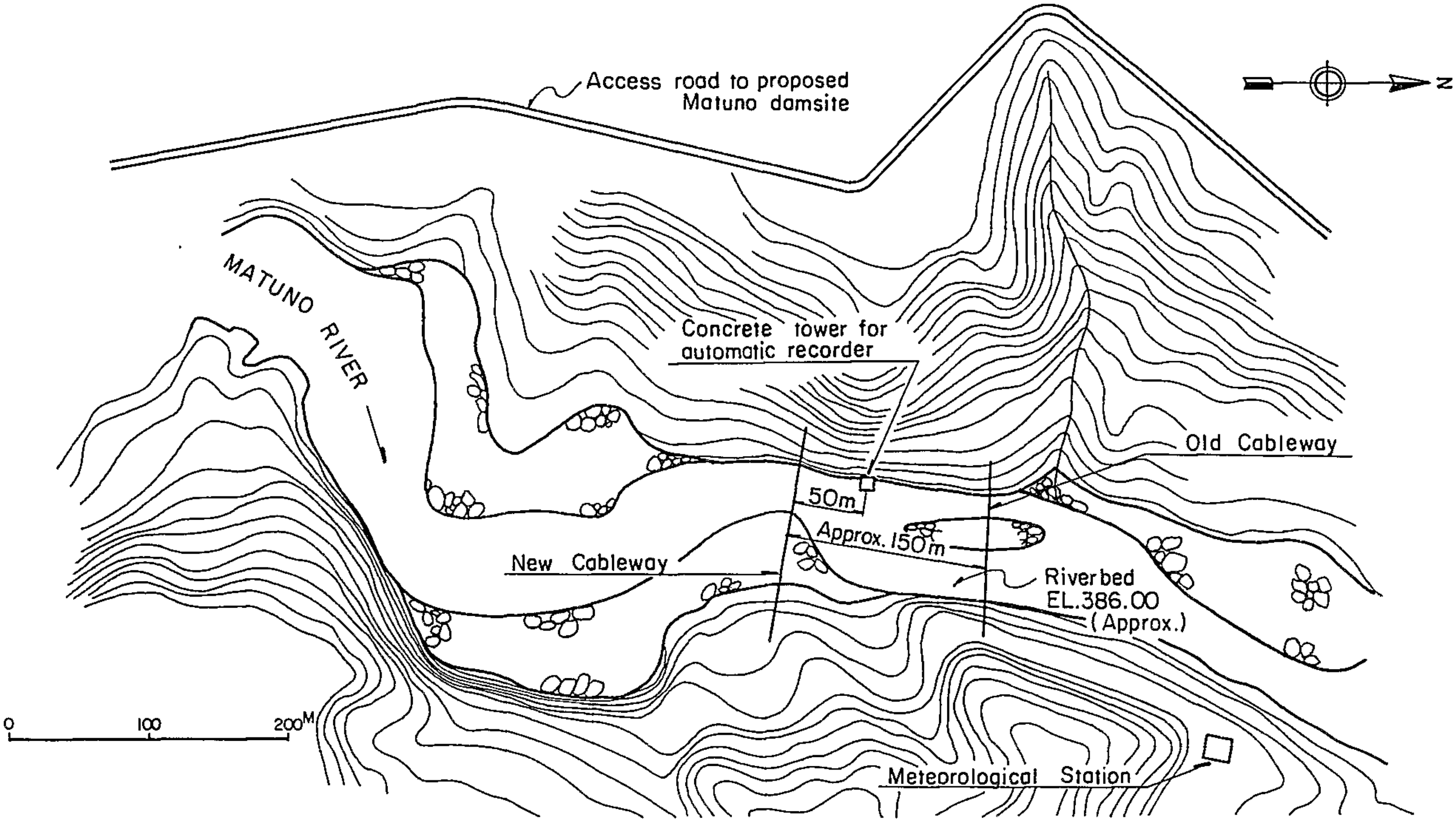


FIG. I-17 PRESENT CONDITION AT BANTE GAUGING STATION

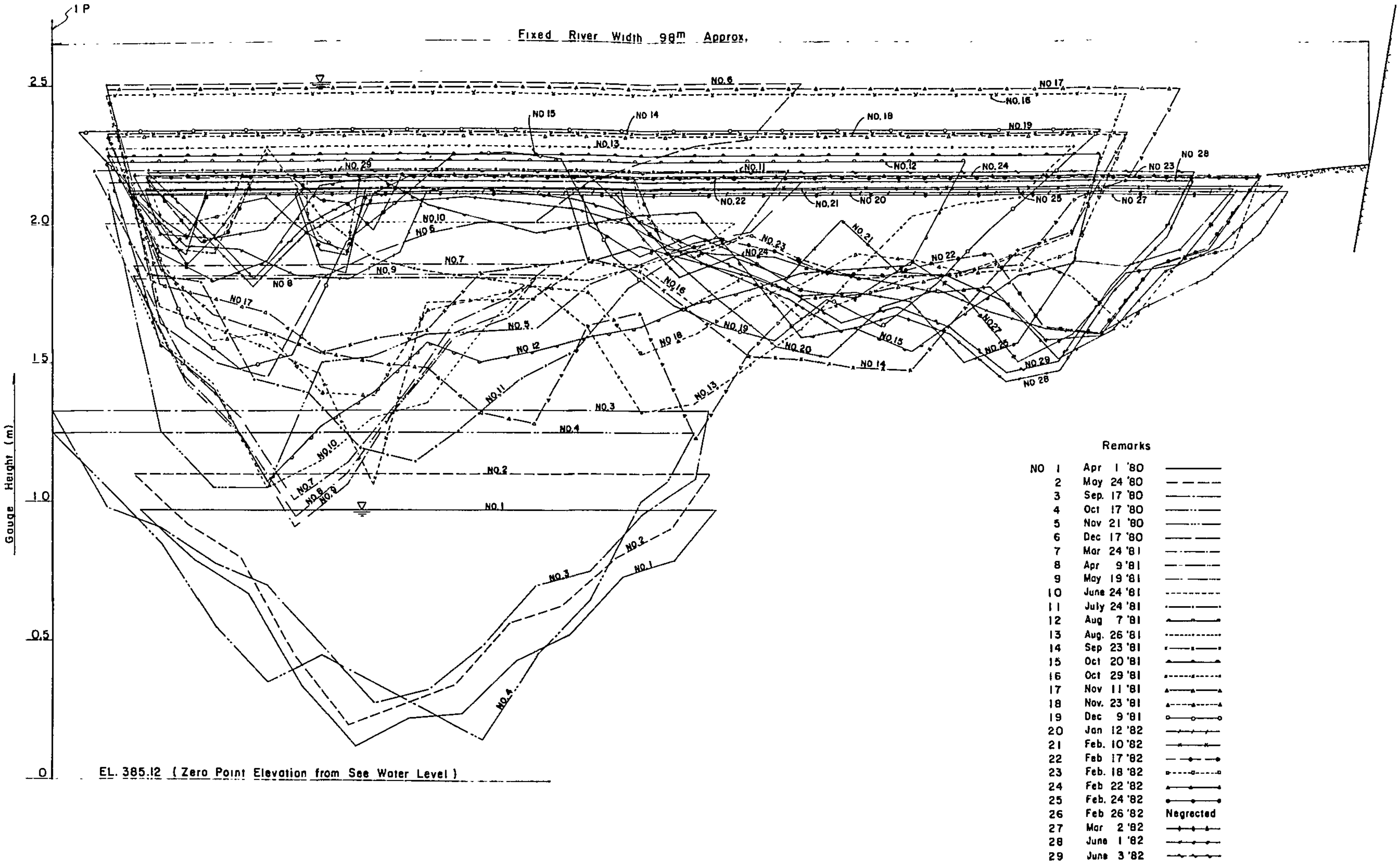


FIG. I-18 HISTORICAL CHANGE OF RIVER CROSS SECTION OF OLD CABLEWAY AT BANTE G.S.

SEKIREI A2 NO 455L

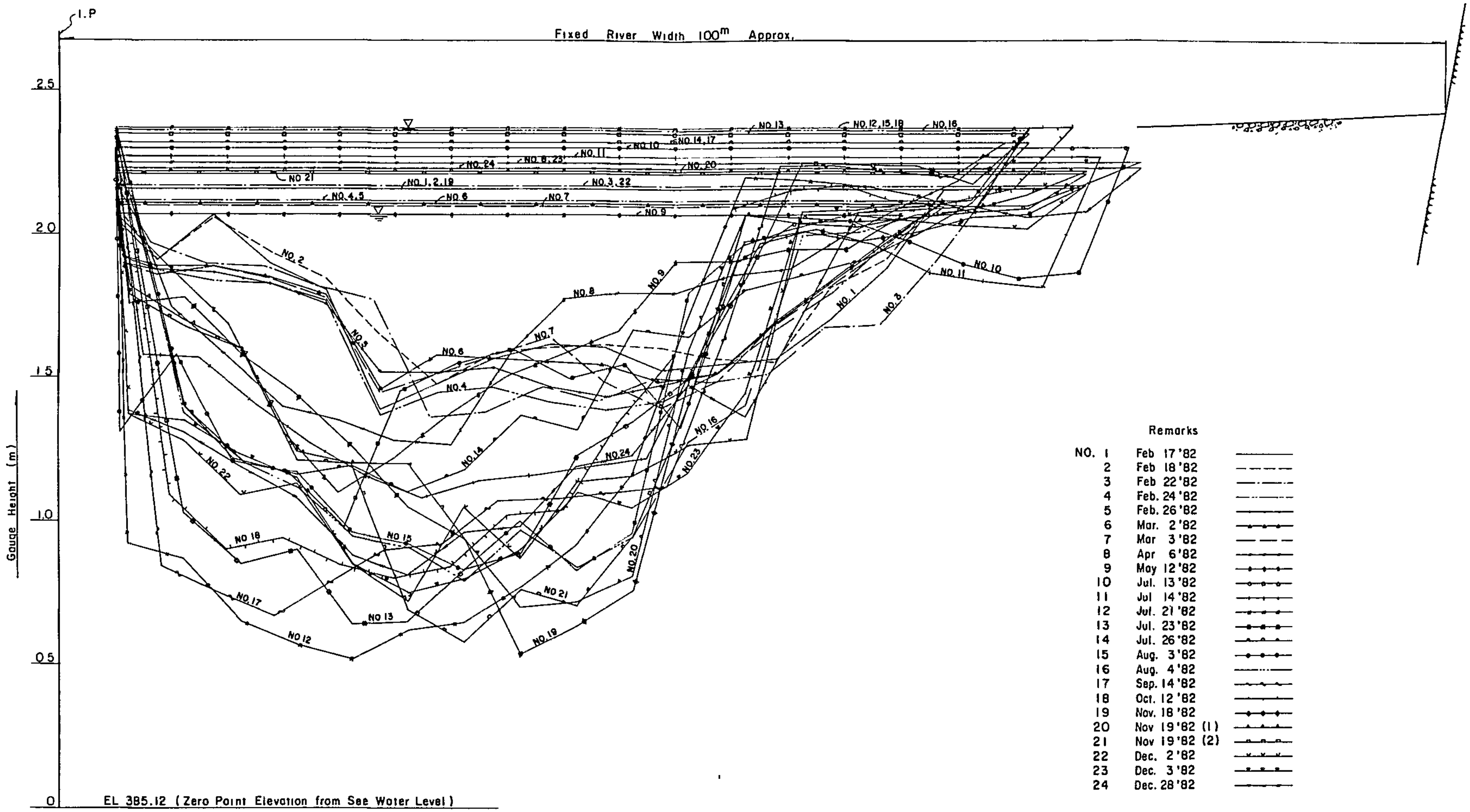


FIG. 1-19 HISTORICAL CHANGE OF RIVER CROSS SECTION OF NEW CABLEWAY AT BANTE G.S.

SEKIRO A2 NO 455L

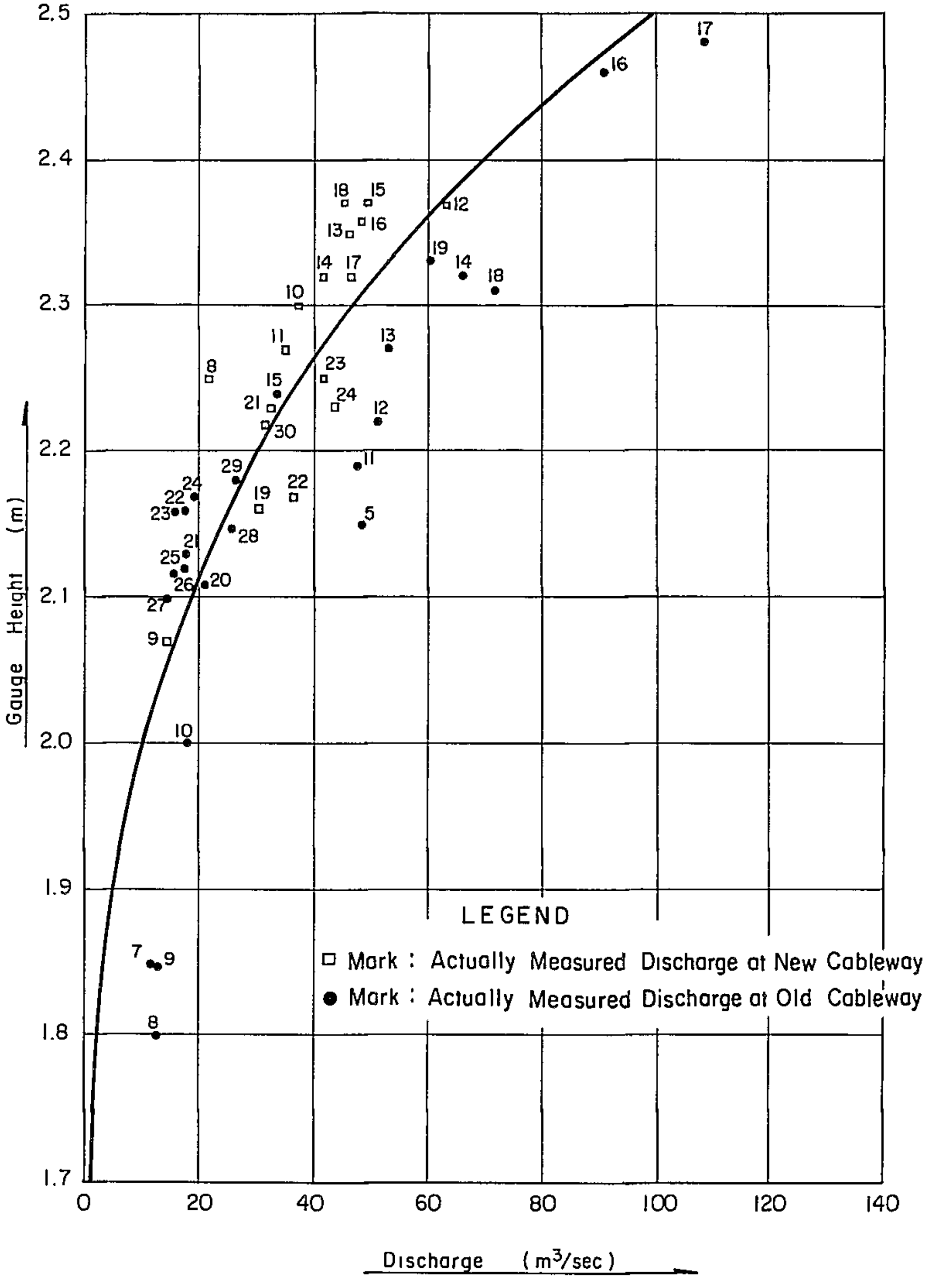
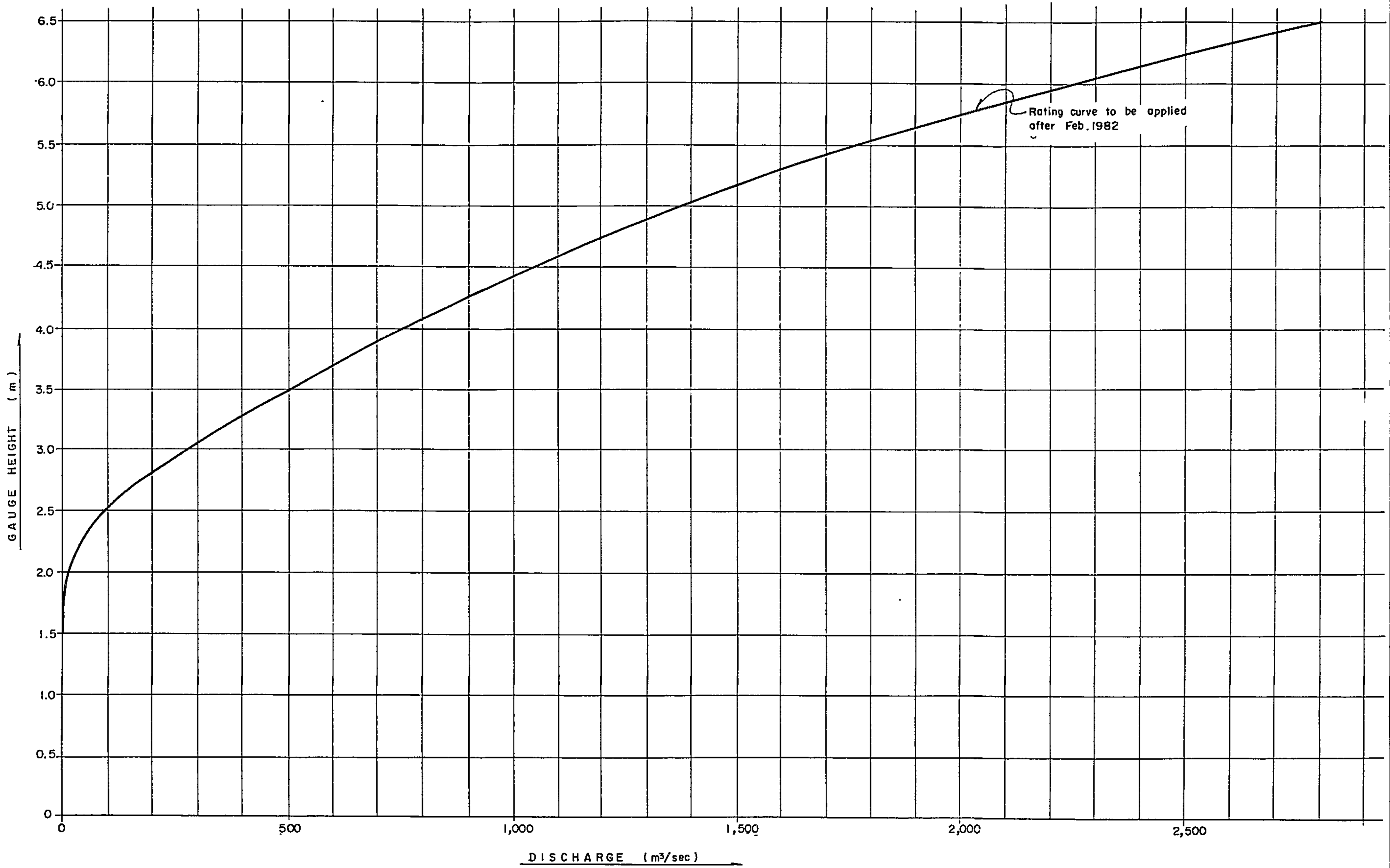
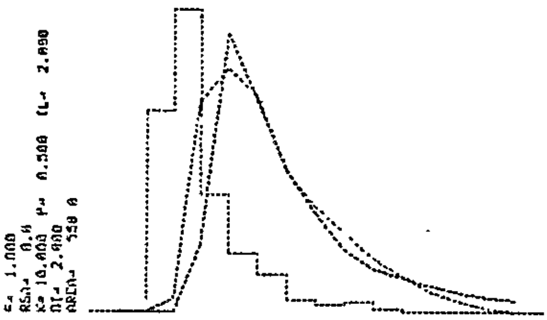


FIG. 1-20 REVISED RATING CURVE AT BANTE G.S.

FIG.I-21 RATING CURVE AT BANTE GAUGING STATION

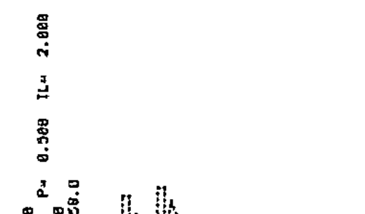


NITANG



RAIN	Q OVD	Q CAL	M^3/S
0.000	0.000	0.000	0.153
0.100	0.000	0.000	0.151
13.000	0.310	0.001	0.245
20.500	4.254	1.549	240.140
7.900	5.498	6.299	976.395
4.000	4.820	4.797	743.438
2.000	3.737	3.[illegible]	496.075
0.000	2.393	2.260	350.409
0.500	1.832	1.480	277.763
0.700	1.204	1.023	158.890
0.200	0.858	0.807	125.100
0.000	0.498	0.604	93.656
0.000	0.238	0.451	69.974
0.000	0.003	0.350	54.273
0.000	0.000	0.279	43.330

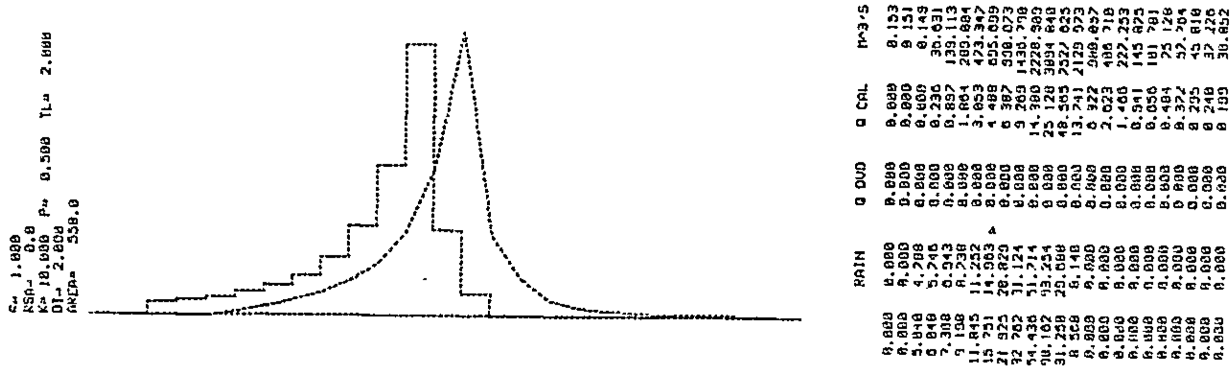
ARING



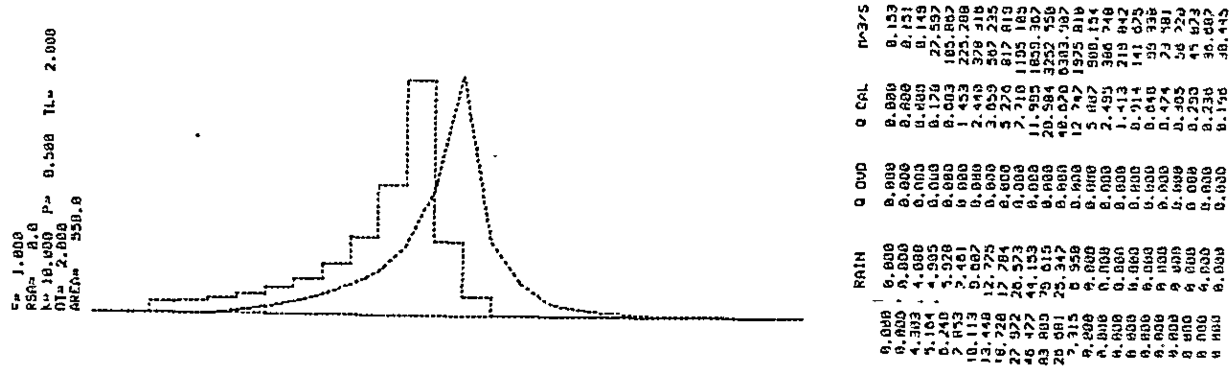
	RAIN	Q OVD	Q CAL	M^3/S
0.000	0.000	0.000	0.000	0.153
14.000	9.800	0.000	0.000	0.151
14.000	9.800	0.000	0.856	132.758
19.000	13.720	0.000	2.472	383.296
47.400	33.180	0.000	4.800	756.485
17.500	12.250	0.000	13.563	2102.293
26.000	18.200	0.000	7.723	1197.182
27.900	19.530	0.000	8.726	1352.644
17.000	11.900	0.000	9.500	1473.815
51.500	36.050	0.000	6.920	1072.077
35.600	24.920	0.000	15.758	2441.255
33.000	23.000	0.000	12.916	2002.073
26.400	18.480	0.000	12.017	1862.068
24.900	17.430	0.000	9.869	1528.413
11.400	7.980	0.000	8.977	1391.536
14.189	9.939	0.000	5.504	853.143
4.300	3.010	0.000	5.100	800.824
2.900	2.030	0.000	3.065	475.132
0.000	0.000	0.000	2.073	321.381
0.000	0.000	0.000	1.230	190.802
0.000	0.000	0.000	0.818	126.829
0.000	0.000	0.000	0.584	90.558
0.000	0.000	0.000	0.438	67.943
0.000	0.000	0.000	0.341	52.805
0.000	0.000	0.000	0.273	42.345
0.000	0.000	0.000	0.223	34.670
0.000	0.000	0.000	0.186	28.921
0.000	0.000	0.000	0.158	24.490
0.000	0.000	0.000	0.135	21.007
0.000	0.000	0.000	0.117	18.218
0.000	0.000	0.000	0.102	15.958
0.000	0.000	0.000	0.090	14.081
0.000	0.000	0.000	0.080	12.523
0.000	0.000	0.000	0.072	11.210
0.000	0.000	0.000	0.065	10.094
0.000	0.000	0.000	0.059	9.136
0.000	0.000	0.000	0.053	8.300

FIG. I-22 HYDROGRAPH OF TYPHOON NITANG AND ARING

1/1000



1/200



1/100

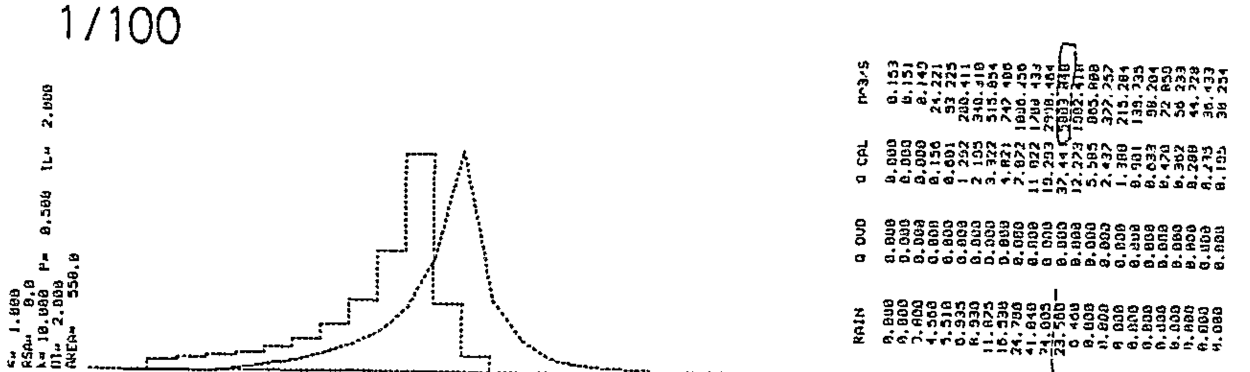
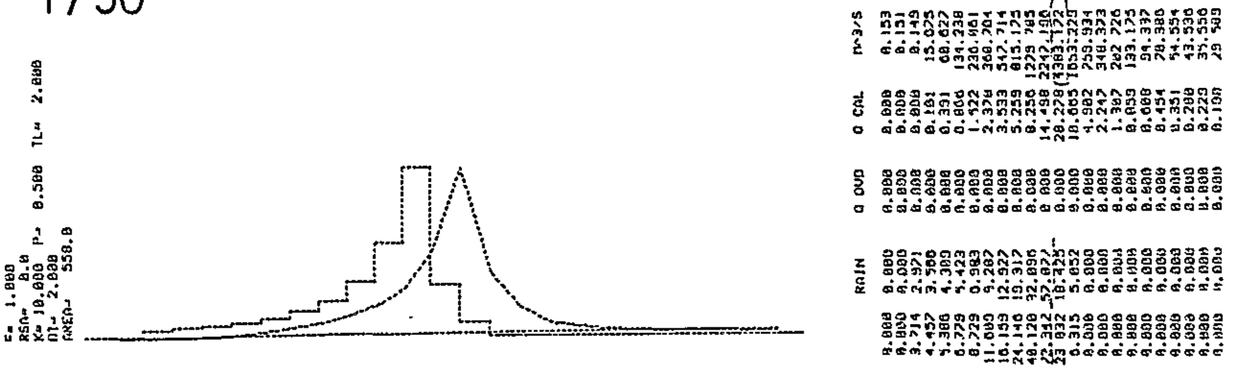
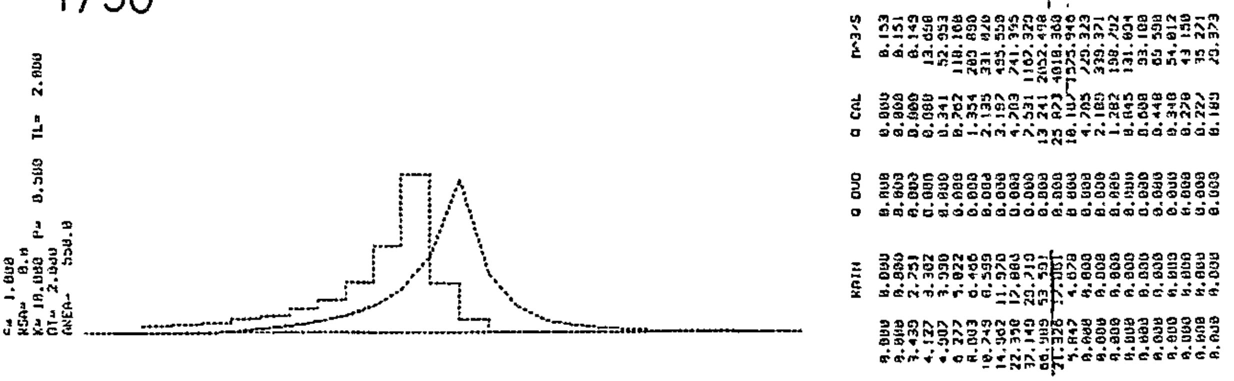


FIG. I-23 COMPUTED HYDROGRAPH OF PROBABILITY PERIOD (1)

1/50



1/30



1/20

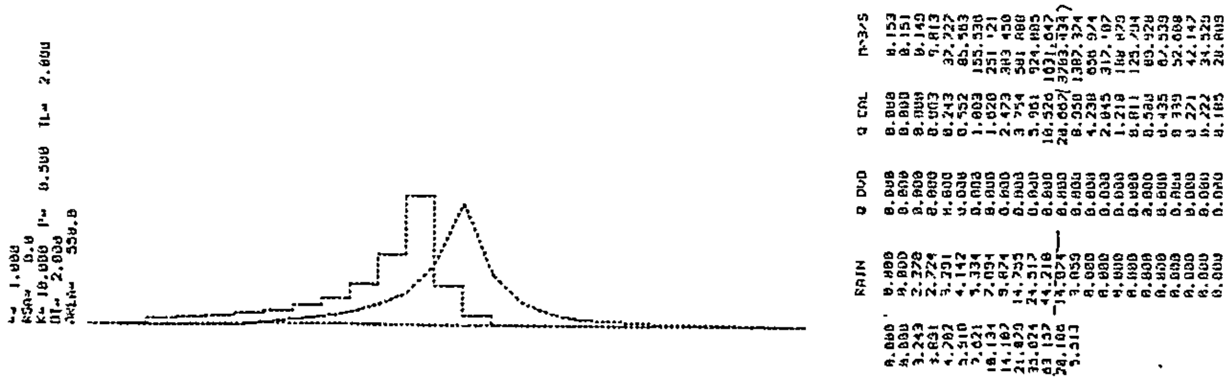
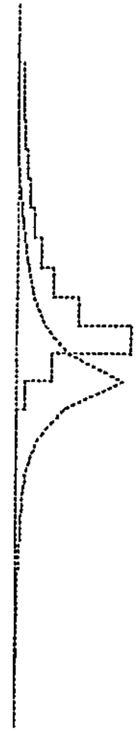


FIG. I-24 COMPUTED HYDROGRAPH OF PROBABILITY PERIOD (2)

1/10

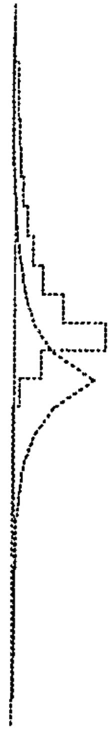
F= 1.000
RSA= 0.0
K= 10.000 P= 0.500 TL= 2.000
DT= 2.000
AREA= 550.0



	RAIN	Q OVD	Q CAL	M^3/S
0.000	0.000	0.000	0.000	0.153
0.000	0.000	0.000	0.000	0.151
2.091	2.823	0.000	0.000	0.149
3.469	2.420	0.000	0.052	8.865
4.192	2.934	0.000	0.190	30.816
5.276	3.693	0.000	0.454	70.419
6.794	4.756	0.000	0.836	129.584
9.035	6.324	0.000	1.367	212.819
12.576	8.803	0.000	2.113	327.622
18.792	13.154	0.000	3.236	501.731
31.225	21.857	0.000	5.170	801.445
56.306	39.414	0.000	9.160	1419.822
17.925	12.547	0.000	18.042	2795.656
4.915	3.440	0.000	8.253	1279.262
0.000	0.000	0.000	3.975	616.274
0.000	0.000	0.000	1.960	303.930
0.000	0.000	0.000	1.179	182.883
0.000	0.000	0.000	0.790	122.540
0.000	0.000	0.000	0.567	87.969
0.000	0.000	0.000	0.427	65.263
0.000	0.000	0.000	0.333	51.733
0.000	0.000	0.000	0.267	41.519
0.000	0.000	0.000	0.219	34.064
0.000	0.000	0.000	0.183	28.454

1/5

F= 1.000
RSA= 0.0
K= 10.000 P= 0.500 TL= 2.000
DT= 2.000
AREA= 550.0



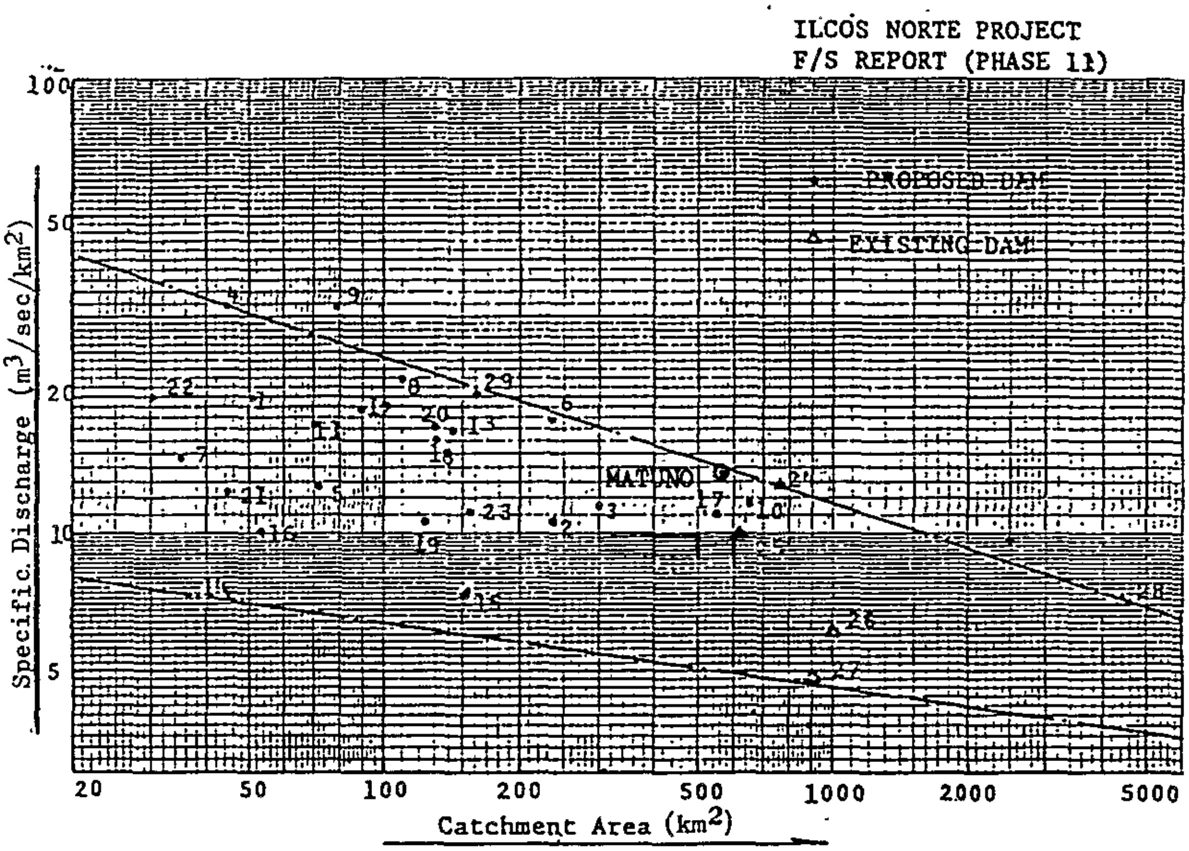
	RAIN	Q OVD	Q CAL	M^3/S
0.000	0.000	0.000	0.000	0.153
0.000	0.000	0.000	0.000	0.151
2.584	1.627	0.000	0.000	0.149
3.085	1.953	0.000	0.036	5.681
3.631	2.360	0.000	0.135	21.021
4.570	2.970	0.000	0.312	48.511
5.885	3.825	0.000	0.587	91.861
7.826	5.087	0.000	0.983	152.496
10.894	7.081	0.000	1.554	240.935
16.270	10.580	0.000	2.424	375.782
27.047	17.580	0.000	3.922	607.943
48.222	31.282	0.000	7.001	1085.299
15.527	10.092	0.000	13.890	2153.897
4.257	2.767	0.010	7.005	1085.790
0.000	0.000	0.000	3.505	543.390
0.000	0.000	0.000	1.800	279.048
0.000	0.000	0.000	1.105	171.284
0.000	0.000	0.000	0.749	116.178
0.000	0.000	0.000	0.542	84.089
0.000	0.000	0.000	0.411	63.724
0.000	0.000	0.000	0.322	49.927
0.000	0.000	0.000	0.259	40.255
0.000	0.000	0.000	0.213	33.123
0.000	0.000	0.000	0.178	27.735

1/2

F= 1.000
RSA= 0.0
K= 10.000 P= 0.500 TL= 2.000
DT= 2.000
AREA= 550.0

	RAIN	Q OVD	Q CAL	M^3/S
0.000	0.000	0.000	0.000	0.153
0.000	0.000	0.000	0.000	0.151
1.875	1.219	0.000	0.000	0.149
2.250	1.463	0.000	0.022	3.515
2.719	1.767	0.000	0.082	12.716
3.423	2.225	0.000	0.190	29.466
4.400	2.865	0.000	0.363	56.304
5.861	3.810	0.000	0.625	96.920
8.159	5.303	0.000	1.015	157.395
12.192	7.925	0.000	1.623	251.646
20.258	13.167	0.000	2.678	415.121
36.530	23.745	0.000	4.844	750.918
11.629	7.559	0.000	9.725	1507.431
3.180	2.072	0.000	5.521	855.841
0.000	0.000	0.000	2.930	454.226
0.000	0.000	0.000	1.582	246.096
0.000	0.000	0.000	1.002	155.329
0.000	0.000	0.000	0.691	107.212
0.000	0.000	0.000	0.506	78.540
0.000	0.000	0.000	0.387	60.049
0.000	0.000	0.000	0.305	47.416
0.000	0.000	0.000	0.247	38.330
0.000	0.000	0.000	0.204	31.734
0.000	0.000	0.000	0.172	26.669

FIG. I-25 COMPUTED HYDROGRAPH OF PROBABILITY PERIOD (3)



1.	ANTIPAS	16.	MARINGALO
2.	BALINTINGON	17.	MORIONES
3.	BALOG-BALOG	18.	O' DONNELL
4.	BANGAT	19.	PAPAYA
5.	BAYABAS	20.	PILA
6.	CAMILING	21.	SALAPANGAN
7.	GARLANG	22.	TIBU
8.	GUMAIN	23.	UPPER AMBAYOAN
9.	KALAANAN	24.	AMBUKLAO
10.	CATGIPSIPAN	25.	ANGAT
11.	LOWER CABU	26.	BINGA
12.	LUBAS	27.	PANTABANGAN
13.	LUBINGAN	28.	MAGAT
14.	MAASIM	29.	PALSIGUAN
15.	MARIMCA		

FIG. I-26 DESIGN FLOOD OF SPILLWAY IN LUZON ISLAND

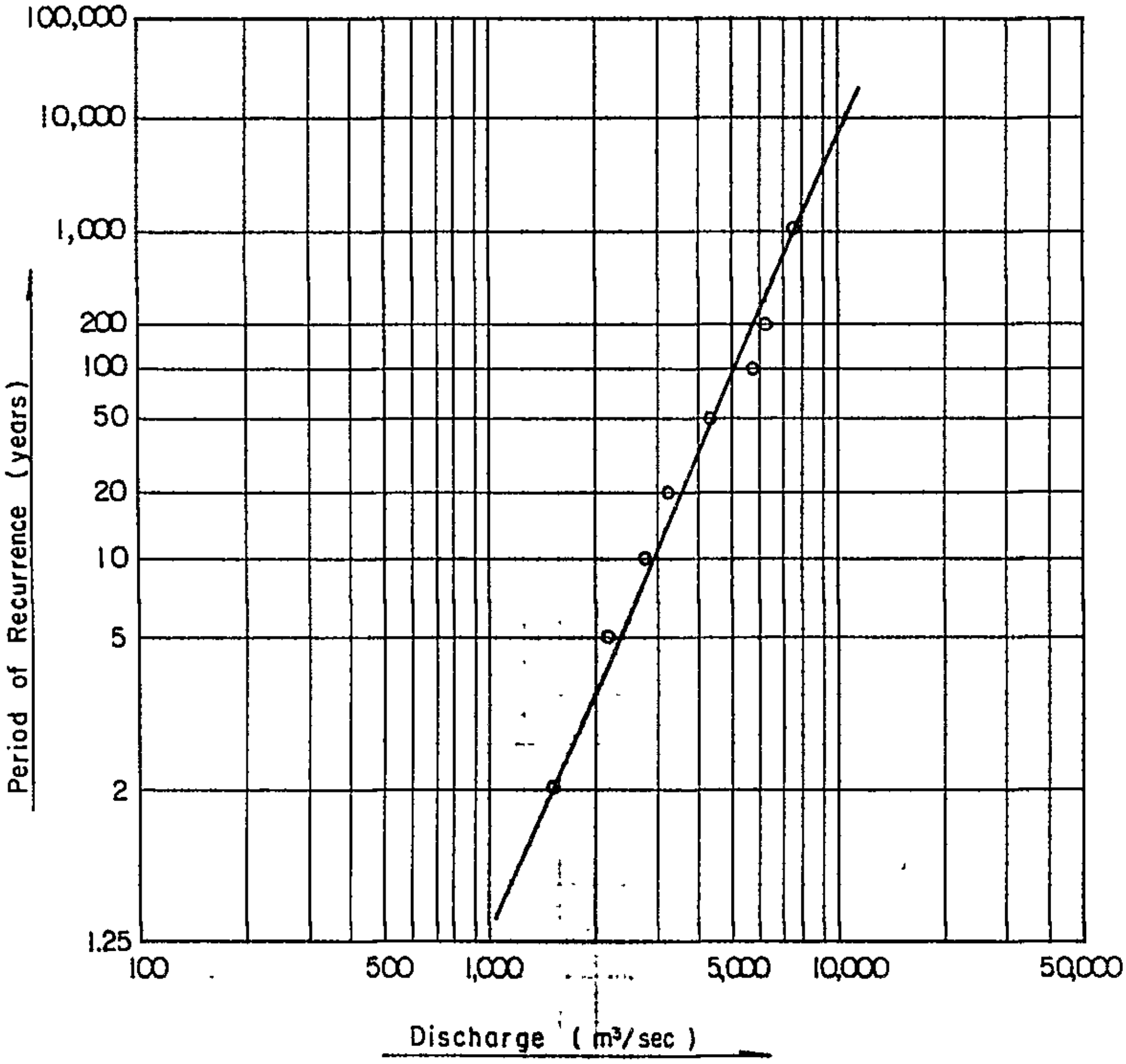


FIG. I-27 PROBABLE FLOOD PEAK DISCHARGE

Note : As a result of investigation at site the max experienced frood occured on Nov.05 to 06.1980 is estimated

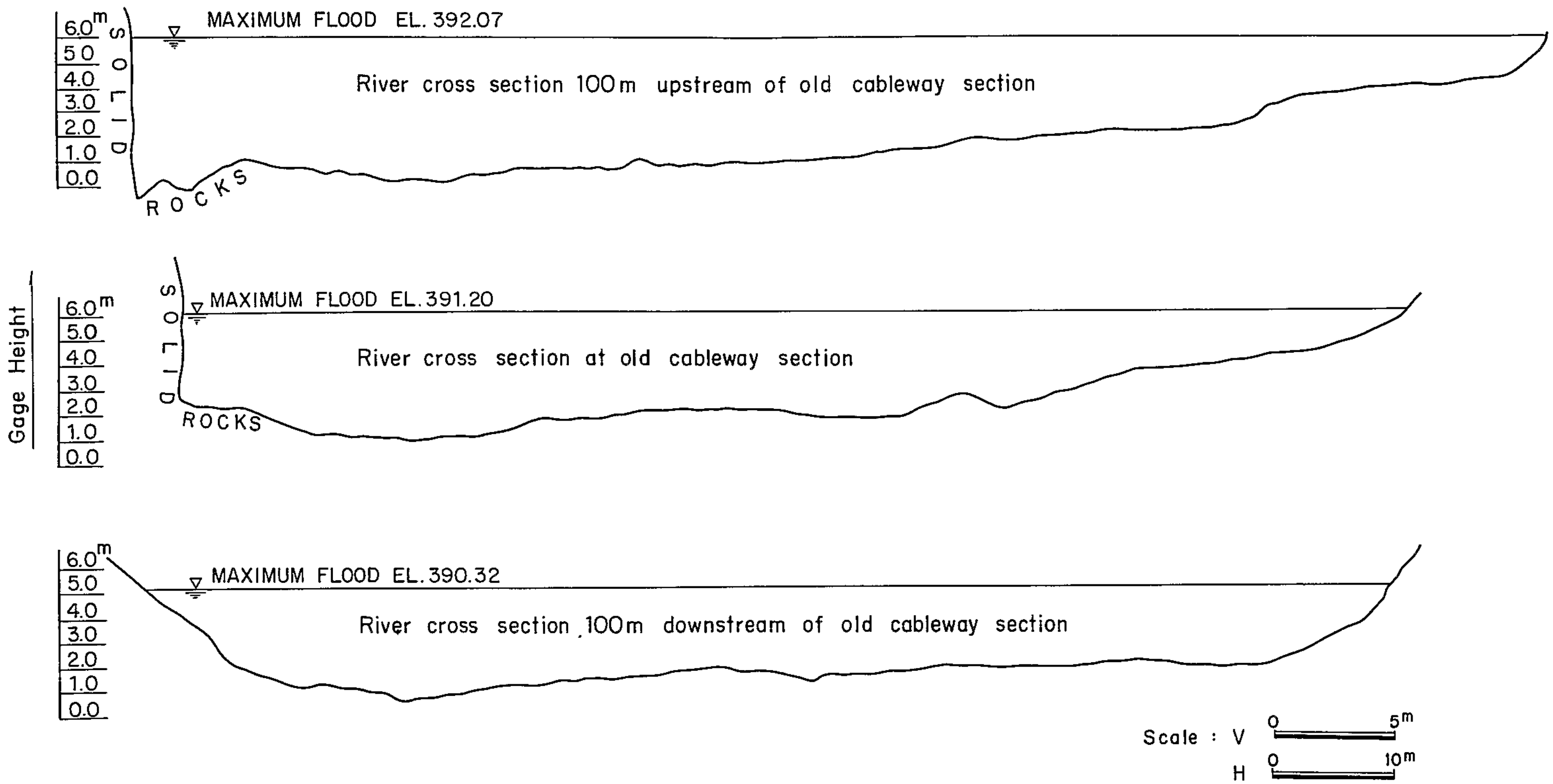


FIG. I-28 RIVER CROSS SECTION FOR MAXIMUM EXPERIENCED FLOOD AT BANTE G.S.

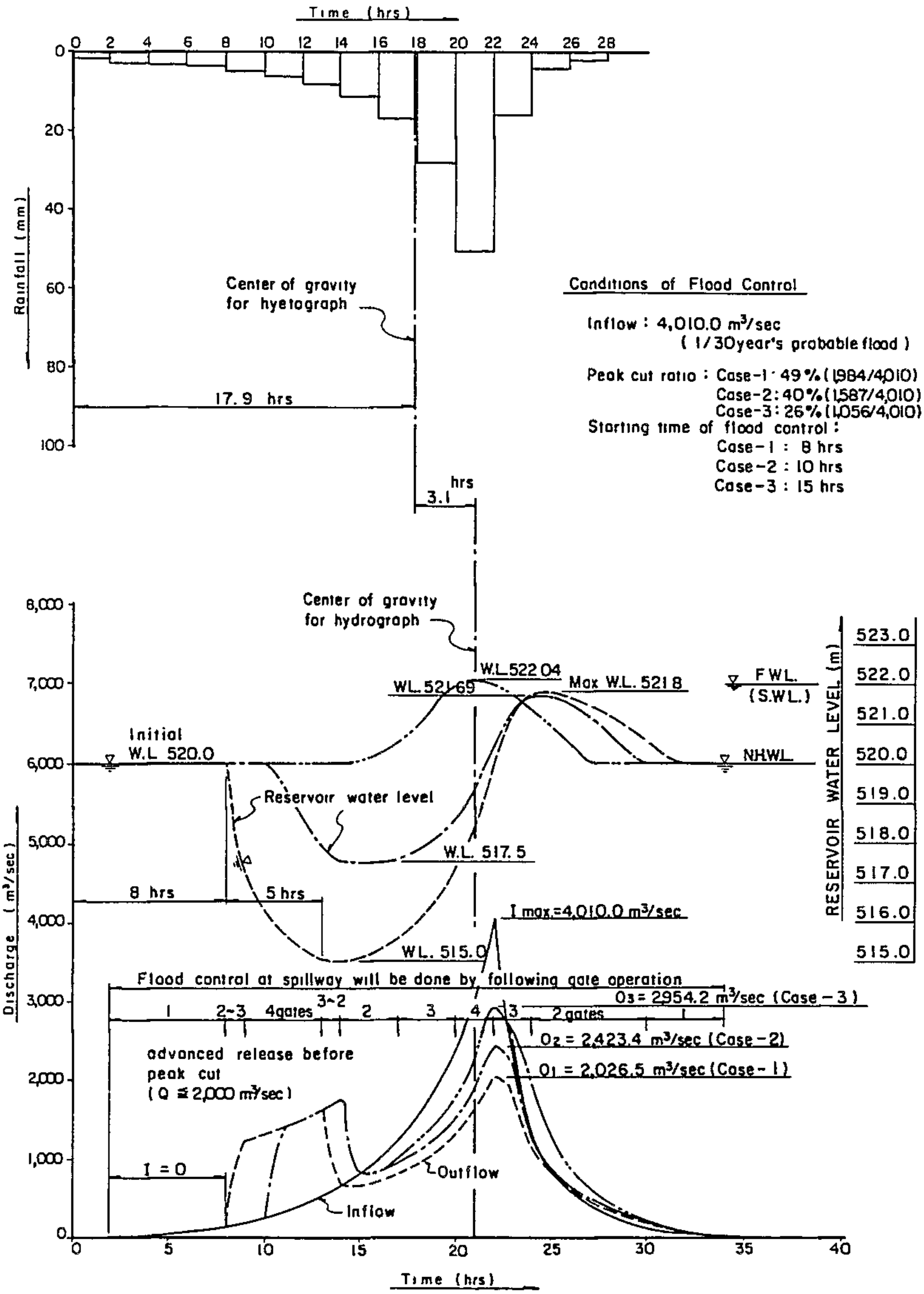


FIG. 1-29 FLOOD CONTROL AT SPILLWAY OF B1 DAM RESERVOIR (1)

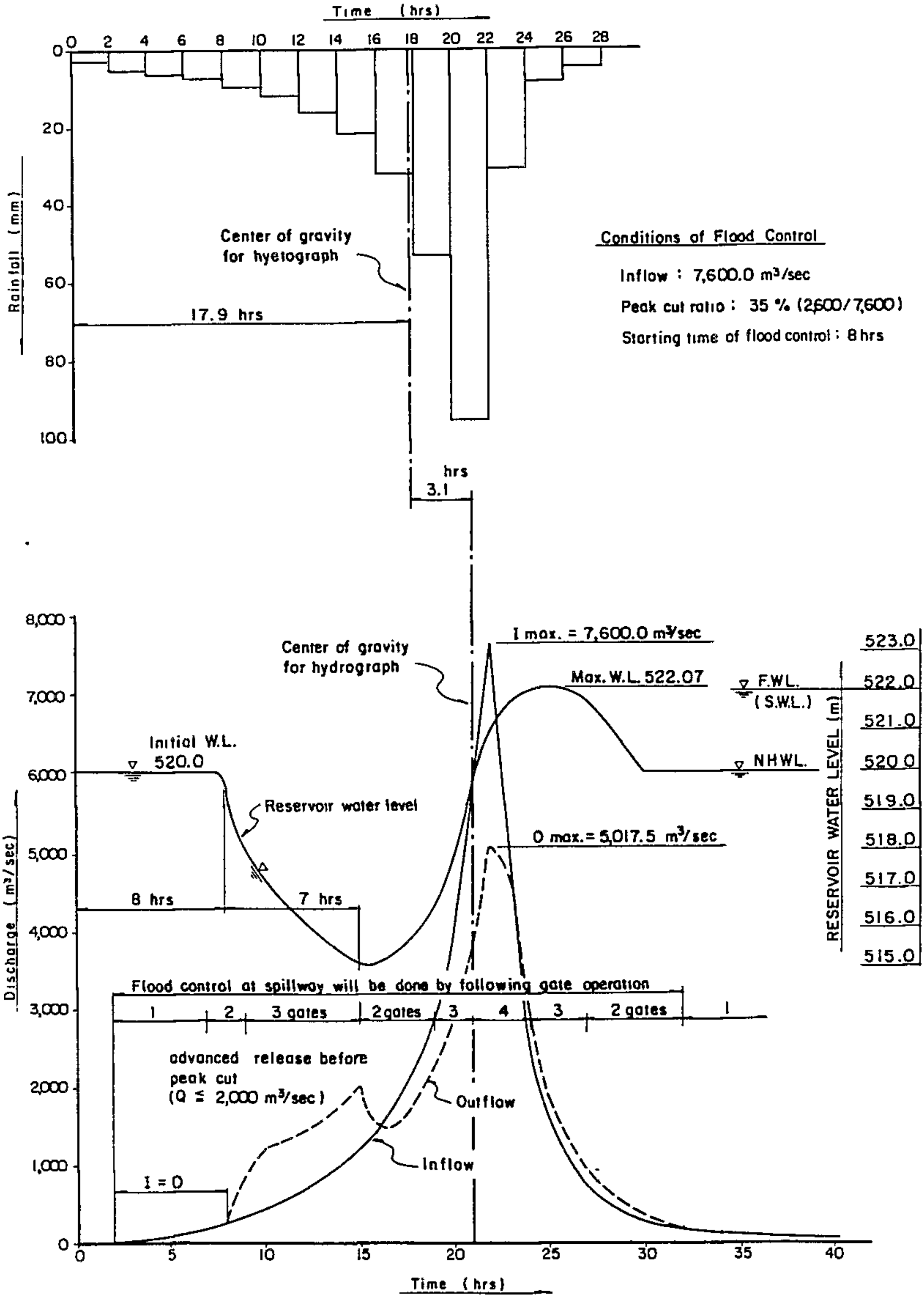


FIG. I-30 FLOOD CONTROL AT SPILLWAY OF Bi DAM RESERVOIR (2)

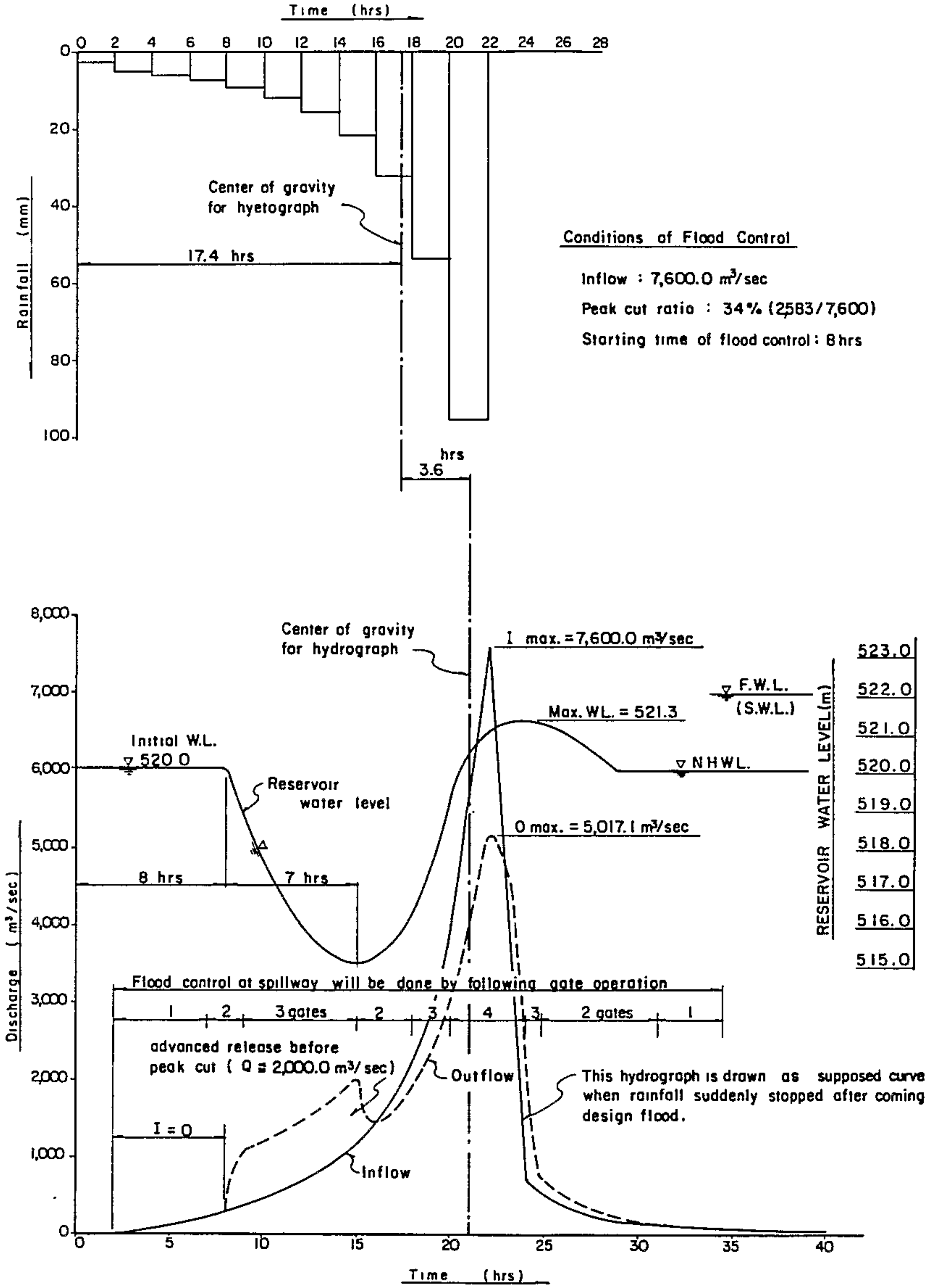


FIG. I-31 FLOOD CONTROL AT SPILLWAY OF B₁ DAM RESERVOIR (3)

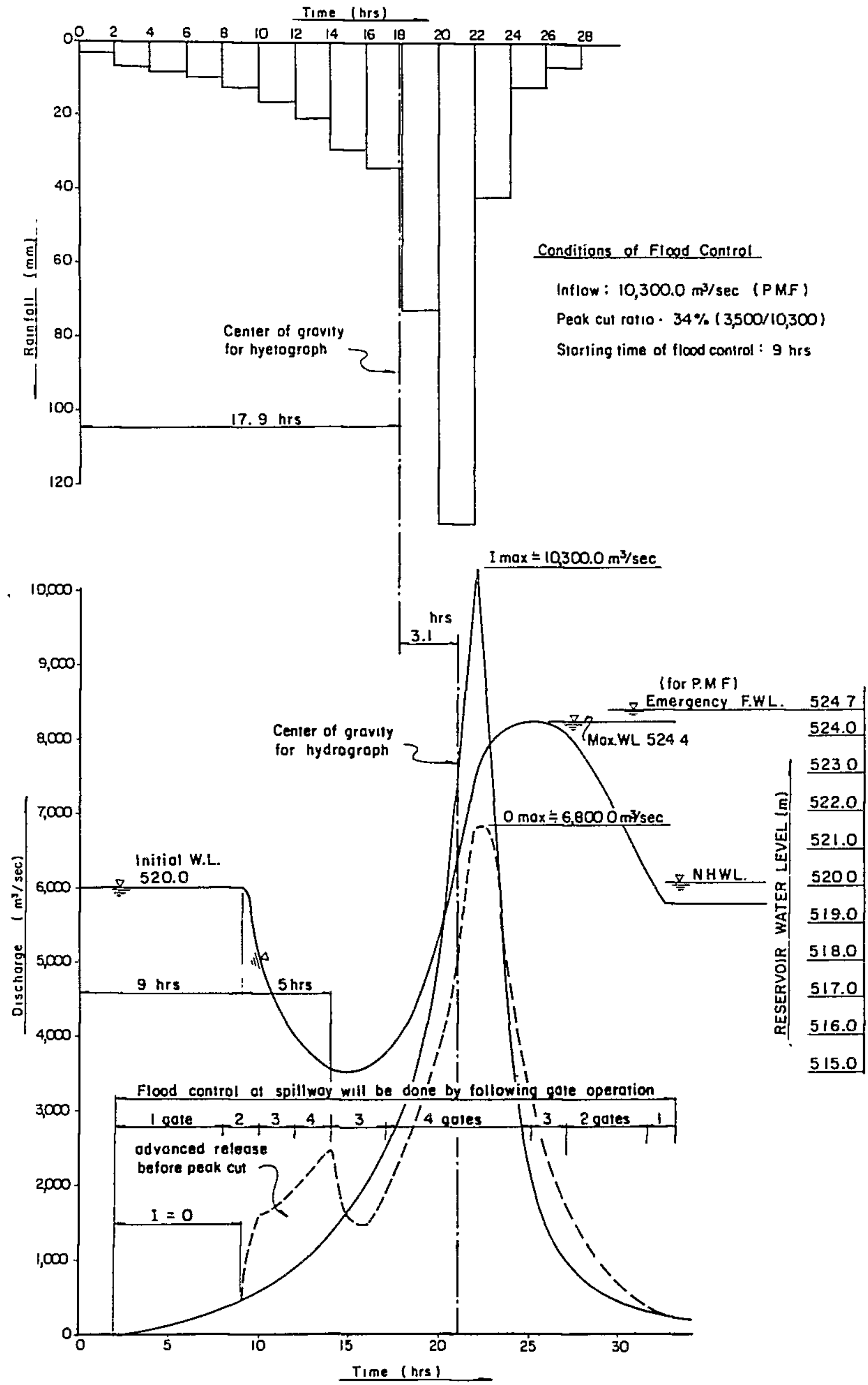


FIG. 1-32 FLOOD CONTROL AT SPILLWAY OF B1 DAM RESERVOIR (4)

II-2 SEDIMENT AND WATER QUALITY

II-2 SEDIMENT AND WATER QUALITY

2.1 Sediment Load

The suspended load measurement at Bante Gauging Station was carried out five times in 1982. But unfortunately in 1982 not high flood occurred due to little rainfall. Therefore the following results of measurements are deemed only reference for presumable sediment load.

Data of Suspended Load Measurement

Date	Discharge (m^3/sec)	Sediment Rate By Weight	Qs (t/day)
Mar. 2/82	14.67	1/28,090	45.1
Jul. 23/82	46.63	1/9,970	404
Jul. 26/82	42.40	1/8,602	426
Nov. 18/82	30.11	1/12,777	204
Dec. 28/82	42.29	1/9,250	395

The many measurement data are available for Magat River (NIA) and Agos River (NPC) as shown in Fig. 2-1. Those measurement data suggested that the daily weight of suspended load is proportional to the k power of the discharge (Q in m^3/sec) as expressed below:

$$Qs = aQ^k$$

where, Qs is daily weight of sediment in ton/day. In case of Matuno River, the formula can be expressed as follows:

$$Qs = 0.21Q^2$$

The annual suspended load quantity was estimated by applying the above formula on the daily discharge recorded at Bante Gauging Station. The annual average quantity of suspended load from 1957 to 1976 was estimated to be 242,000 t.

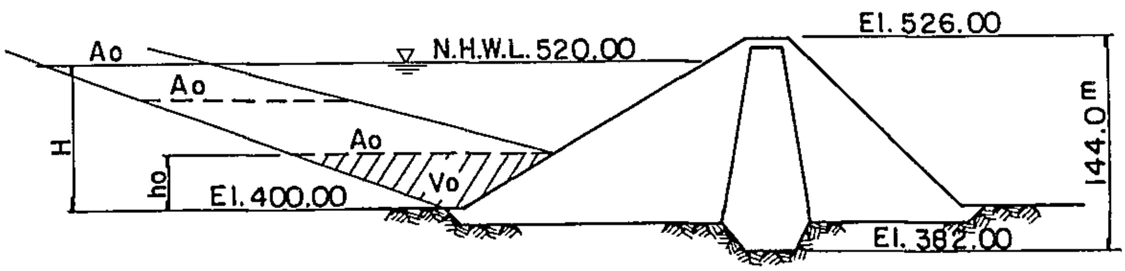
However, the daily discharge itself is the average value of momentary discharges for 24 hours. It is therefore, necessary to adjust by some factor. Also the bed load has to be added to the above suspended load. In addition, for estimation of total sediment quantity in coming 100 years, some increasing factor due to devastation of forest shall be also taken into consideration.

The adjustment factor for daily discharge is tentatively taken as 1.20, the addition of bed load is taken as plus 30% of suspended load, and the adjustment factor for future increase is tentatively taken as 1.30. Thus the composite factor becomes to 2.03 as the product of the above three factors.

Thus the total sediment load is estimated to be 490,000 ton per year, or 350,000 m^3 in volume when it deposits into the reservoir. The 100 years total becomes 35 million m^3. In case of hydropower generation, the low water level for intake shall be little higher than the above volume. Therefore, the dead storage for Matuno Dam is taken 40 million m^3 for planning.

2.2 Study on Elevation of sediment deposited at Dam

Generally, the sediment in the reservoir is deposited having a slope towards the dam. The elevation of sediment deposited at dam can be obtained by Area-Increment Method/1 mentioned below.



$$Vs = Ao\ (H - ho) + Vo$$

where, Vs : gross sediment volume for 100 years = 40 x 10^6 (m^3)

ho : sediment depth immediately upstream dam (m)

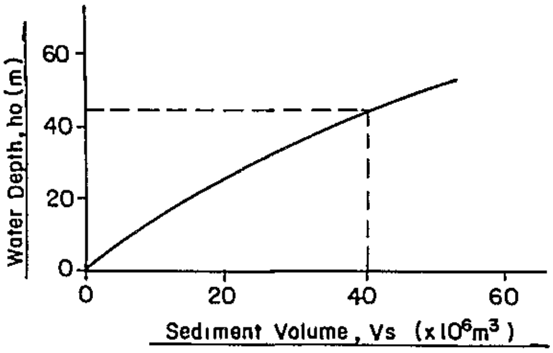
H : maximum water depth of dam (m)

Ao : sediment area measured at ho elevation (m^2)

Vo : sediment volume below ho, which is equal to reservoir storage volume below ho

In the first place, the elevation ho is assumed, and the value of Vs is calculated by the above equation until it becomes equal to presupposed value of Vs. By the above trial method, the relationship between the water depth and the sediment volume is obtained as shown below:

Note: /1 This method is developed by E.A. Cristofano of U.S. Bureau of Reclamation.

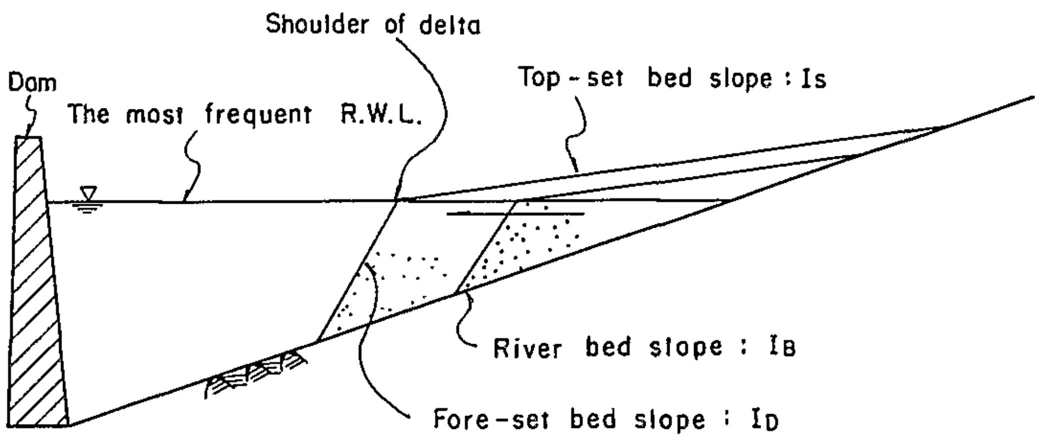


By using the above figure, the sediment volume of 40 x 10^6 m^3 for 100 years corresponds to the water depth of 46.0 m, which results in elevation of sediment of El. 446.00 (= El. 400.00 + 46.00). Therefore, the inlet elevation of the river outlet facilities is planned to be El. 450.00 having an allowance of 4.0 m.

2.3 Future Forecast on Reservoir Storage Capacity

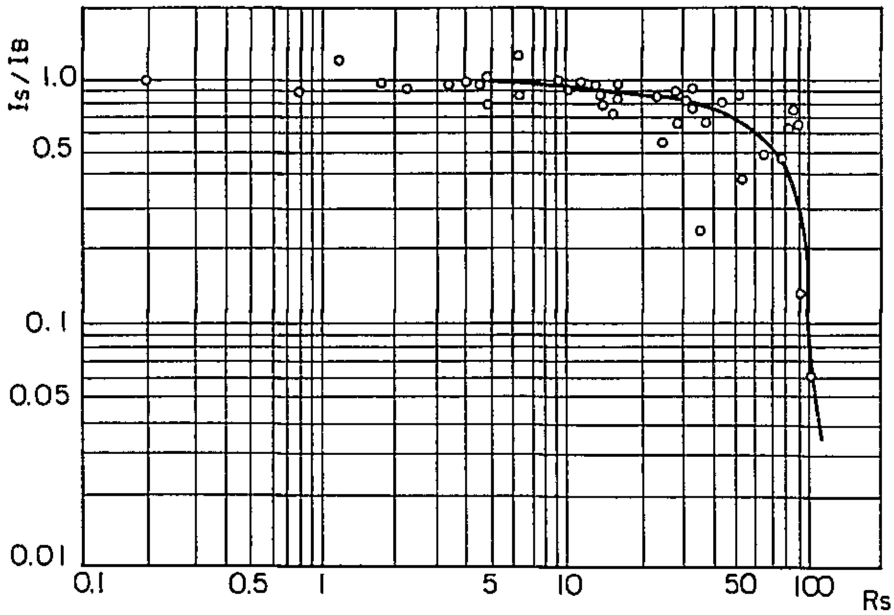
For the delta formation the Kira's method is applicable to predict the sediment distribution in the reservoir.

Dr. Kira paid attention on a relation between the sedimentation ratio Rs, which is defined as a ratio of accumulated reservoir sediment during a specified period after the initial water impoundment to the original gross reservoir storage capacity, and variation of reservoir bed slope after and before formation of the delta deposit defined as a ratio I_S/I_B, where I_S is so called top-set bed slope and I_B is the original river bed slope.



Sedimentation Mechanism of the Kira's Method

Based on the analysis of delta deposits in numerous reservoirs in Japan, Dr. Kira found a relation of Rs and I_S/I_B as shown below;



$$\text{Sediment ratio Rs (\%)} = \frac{\text{Sediment Volume}}{\text{Storage Capacity}} \times 100$$

Relation between Rs and Is / IB

The fore-set bed slope I_D was also found to be expressed in the following formula with respect to the top-set bed slope I_S;

$$I_D = 4.5 \ I_S^{1.36}$$

where both the slope should be expressed in percentage.

Based on the above formula, the storage capacity of Matuno dam after 50 years and 100 years were estimated. The results are shown in Fig. 2-2 and the following.

Period	Effective Storage Capacity (10^6 m^3)
Just after completion	97
After 50 years	88
After 100 years	78

According to the above estimation, the effective storage capacity will be decreased by 20 percent in 100 years. But the annual average electric energy to be generated decreases only about 5 percent.

Therefore, it is deemed to be permissible for the power development project.

2.4 Quality of River Water

Chemical analysis was made on 7 water samples from Matuno River and two samples from Magat River, the results of which are shown in the attached Table 2-1 and 2-2. Both river waters are chemically quite clean and can be used for any purpose.

The slightly higher content of sodium and chlorine in Magar River water than the Matuno River is attributable to the existence of salt spring near Salinas, the upstream of the Sta. Cruz River joining to Magat.

The pH values fall within a range from 7.6 to 8.5 showing slightly weak alkalinity. The calcium content of 17 to 38 ppm is attributable to the existence of limestone in the basin.

TABLE 2-1 RESULTS OF CHEMICAL ANALYSES OF RIVER WATER SAMPLE

No.	Sample Information	PH	Electrical conductivity	Na^+		K^+		Ca^{2+}		Mg^{2+}		Alkali Degree (HCO_3^-)	Cl^-		SO_4^{2-}		ca*	an*	ion
			U/cm	meg/l	mg/l	meg/l	mg/l	meg/l	mg/l	meg/l	mg/l	meg/l	meg/l	mg/l	meg/l	mg/l	meg/l	meg/l	meg/l
1	Matuno River (Bante) Oct. 23 '81	7.9	226	0.25	5.75	0	0	1.39	27.86	0.59	7.17	2.05	0.1	3.55	0.46	22.08	2.23	2.61	4.84
2	Matuno River (Bante) Oct. 29 '81	7.9	209	0.26	5.98	0	0	1.24	24.85	0.54	6.56	2.05	0.1	3.55	0.20	9.6	2.04	2.35	4.39
3	Matuno River (Bante) Nov. 11 '81	7.9	174	0.21	4.83	0	0	0.88	17.64	0.61	7.41	1.70	0.05	1.77	0.33	15.84	1.70	2.08	3.78
4	Matuno River (Bante)Q=54m³/s Apr. 20 '82	7.8	233	0.40	9.20	0.02	0.78	1.40	28.06	0.40	4.86	2.00	0.15	5.32	0.30	14.4	2.22	2.45	4.67
5	Matuno River (Bante) Apr. 26 '82	7.6	215	0.36	8.28	0.012	0.47	Ca+Mg 1.683	33.73			1.62	0.09	3.19	0.36	17.28	2.06	2.07	4.13
6	Matuno River (B site)Q=54m³/s	8.2	200	0.33	7.59	0.01	0.39	1.15	23.05	0.55	6.68	1.70	0.05	1.77	0.32	15.36	2.04	2.07	4.11
7	Matuno River (B site) Nov. 23 '82	8.5	241	0.40	9.20	0	0	1.40	28.06	0.70	8.50	1.70	0.25	8.87	0.25	12.0	2.50	2.20	4.70

TABLE 2-2 RESULTS OF CHEMICAL ANALYSES OF RIVER WATER SAMPLE

No.	Sample Information	PH	Electrical conductivity	Na^+		K^+		Ca^{2+}		mg^{2+}		Alkali Degree (HCO_3^-)	Cl^-		SO_4^{2-}		ca	an	ion
			U/cm	meq/l	mg/l	meq/l	mg/l	meq/l	mg/l	meq/l	mg/l	meq/l	meq/l	mg/l	meq/l	mg/l	meq/l	meq/l	meq/l
8	Magat River (Batu Ferry Bridge) Apr. 26 '82	8.2	329	0.60	13.79	0.03	1.17	1.90	38.08	0.55	6.68	2.53	0.50	17.73	0.29	13.92	3.08	3.32	6.40
	Magat River (Batu Ferry Bridge) Nov. 23 '82	8.4	293	0.49	11.27	0.01	0.39	1.70	34.07	0.85	10.32	1.90	0.35	12.41	0.25	12.0	3.05	2.50	5.55

* Ca: Caitions, * an: Anions

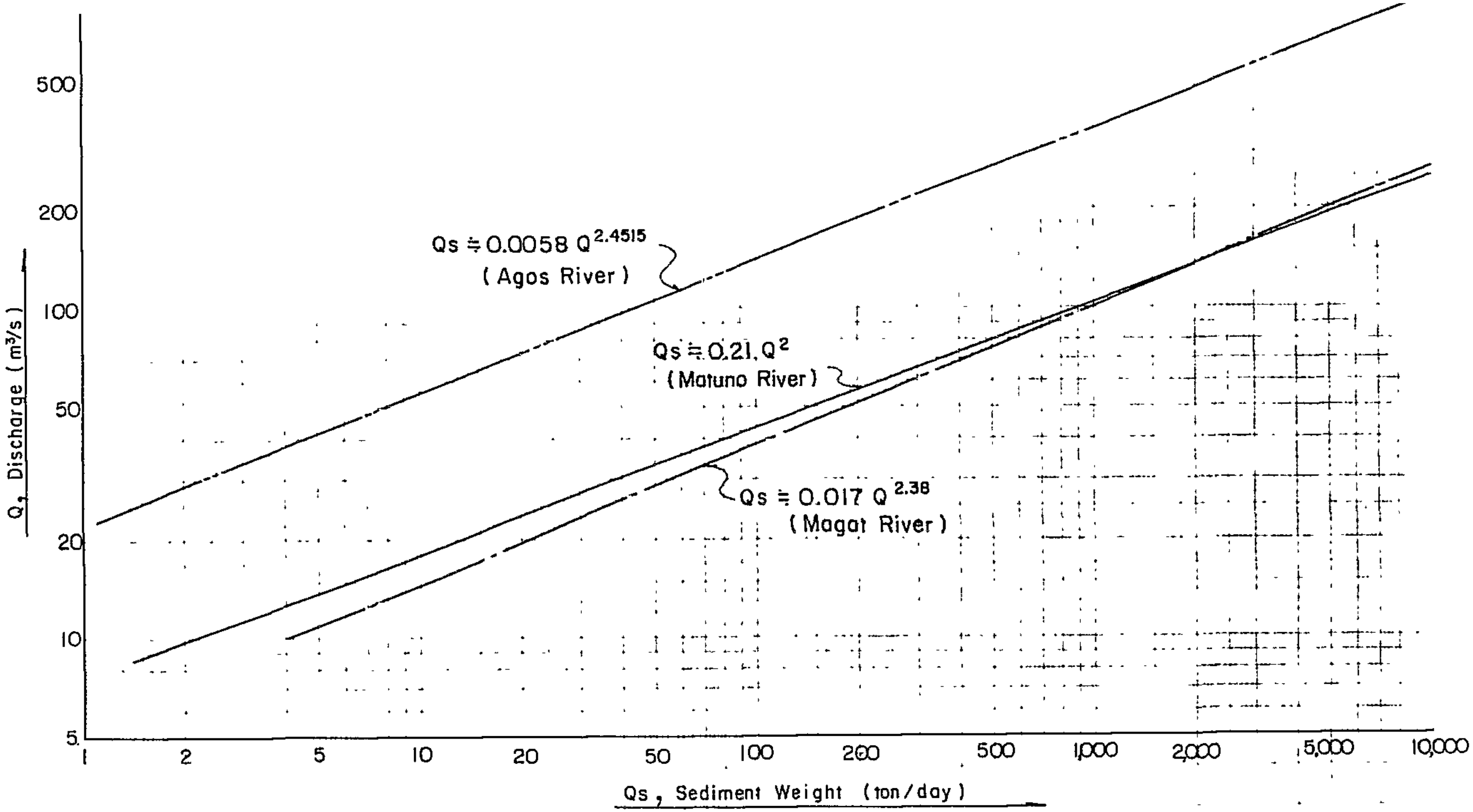


FIG. 2-1 SEDIMENT RATING CURVES

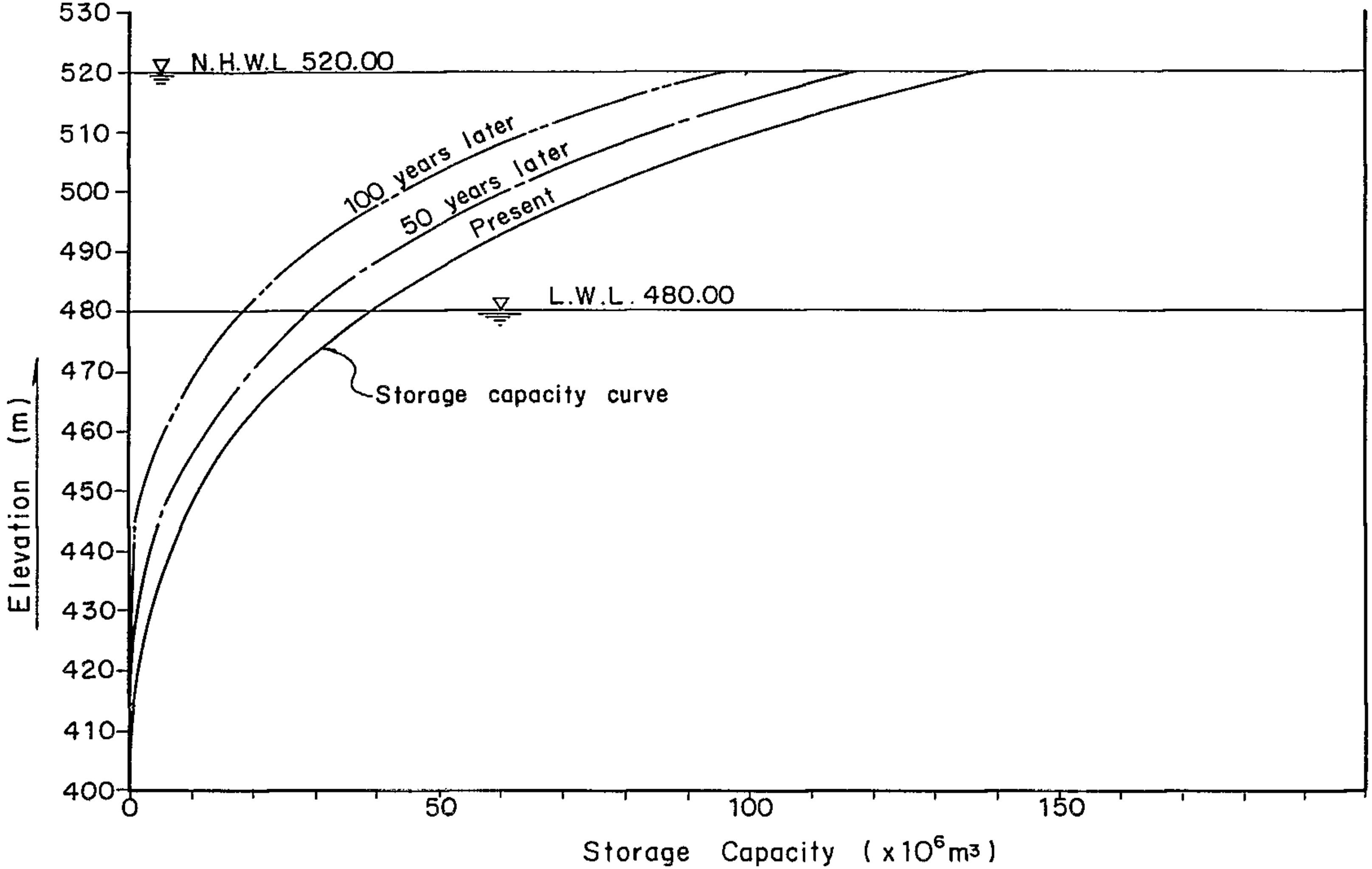
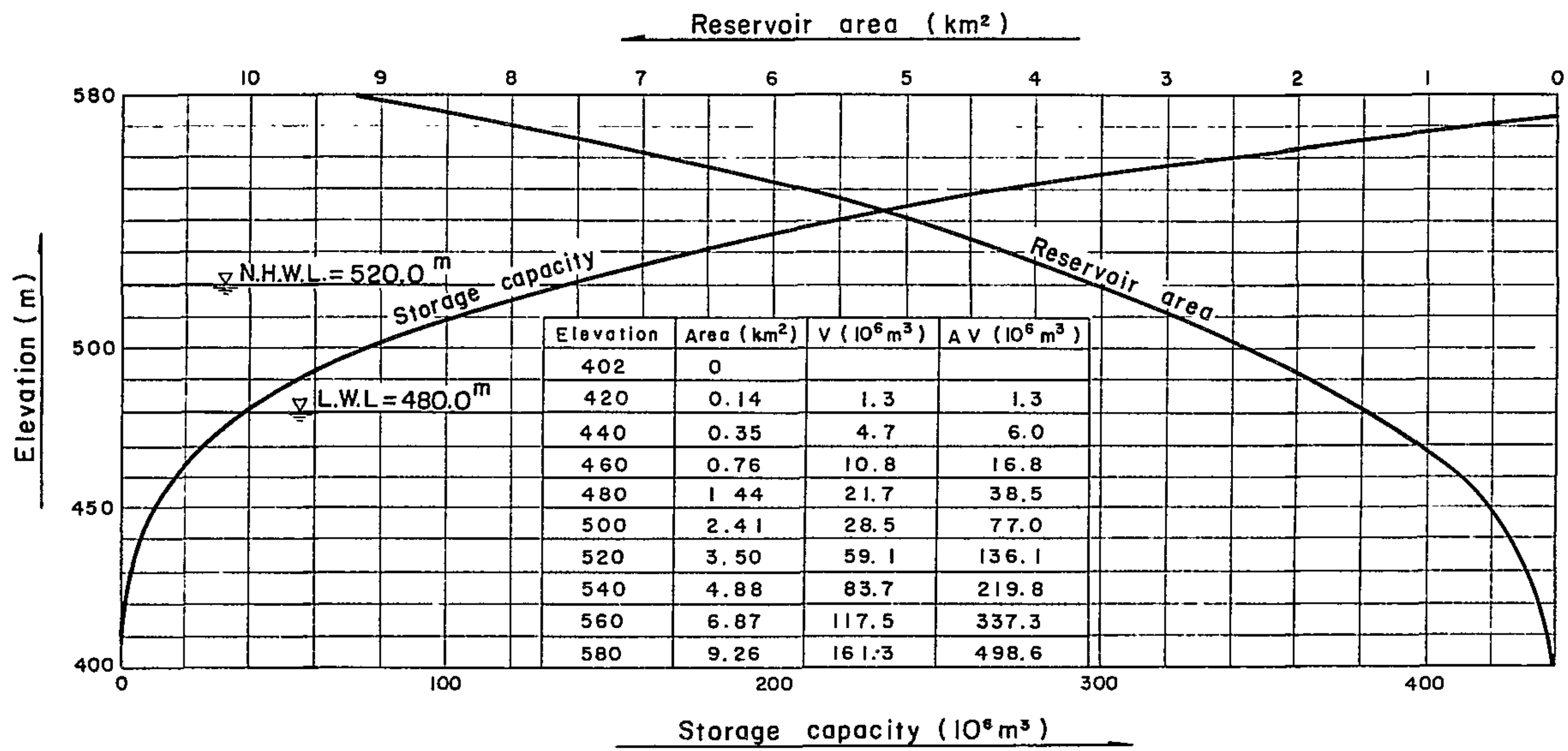


FIG. 2-2 FUTURE FORECAST ON RESERVOIR STORAGE CAPACITY

FIG. 2-3 STORAGE CAPACITY AND RESERVOIR AREA OF B1 DAM



Elevation	Area (km²)	V ($10^6 m^3$)	A V ($10^6 m^3$)
402	0		
420	0.14	1.3	1.3
440	0.35	4.7	6.0
460	0.76	10.8	16.8
480	1 44	21.7	38.5
500	2.41	28.5	77.0
520	3.50	59.1	136.1
540	4.88	83.7	219.8
560	6.87	117.5	337.3
580	9.26	161:3	498.6

II-3 GEOLOGY

II-3 GEOLOGY

3.1 General Geology

(Refer to the attached geological map)

3.1.1 General Topography

The Matuno River is one of the tributaries of Magat River, which is also a large tributary of Cagayan River. The Cagayan River is the largest river in the Philippines covering approximately 27,000 km^2 of a drainage area. The catchment of the Cagayan is bordered by Sierra Madre Range on the east being separated from the Pacific Ocean, by Luzon Central Cordillera on the west and by Caraballo Mountains on the south. The Cagayan flows mainly from the south to north draining an area about 270 km in north-south and 120 km wide in the east-west direction and finally flowing into Babuyan Channel near Aparri.

The Magat River, having approximately 5,000 km^2 of a catchment area, is one of the major trubutaries of Cagayan occupying the southwest upstream area of Cagayan. The Magat originates from the high mountain range situated near the junction of Central Cordillera and Caraballo Mountains and flows down in the hilly area with 160 km length finally joining with Cagayan at its middle reaches near Ilagan.

The Matuno River is a left bank tributary of Magat covering about 585 km^2 of drainage area. The Matuno River originates from the flanks of western mountain range with prominent peaks of, in order from north to south, Mt. Tabayok (EL. 2,812 m), Mt. Ranatoan (EL. 2,422 m), Mt. Pulog (EL. 2,922 m), Mt. Pauadan (EL. 2,344 m) and Mt. Pack (EL. 2,290 m). The catchment area forms a rectangular shape with about 35 km long side and 18 km short side as shown in Fig. 1-14.

The eastern mountain range divides the Matuno basin from the Cagayan Valley with a lower skyline consisting of mesa-shaped peaks of, from north to south, Mt. Tiblac (EL. 1,260 m), Mt. Cunig (EL. 1,150 m) and Mt. Pawac (EL. 1,535 m), the eastern slope of which forms very steep cliffs facing to the Cagayan Valley.

The main stream of Matuno flows down from north to south until 10 km upstream from the Batu Ferry Bridge, where the Matuno changes its flow direction almost perpendicular into eastward and joins with Magat River. The Matuno River basin is characterized by ragged mountainous topography and deeply dissected gorges all along the main stream and its relevant tributaries as well. A relative heights of the ridges against the river bed amounts often more than 800 m within a few km of horizontal distance. Slopes of both banks show often 45 degrees or more in inclinations. The river gradient is also as steep as 1/100 in the middle reaches and 1/200 in lower reaches as shown in Fig. 1-16.

3.1.2 Vegetation Cover

Almost all river basin is still well covered with thick natural forest with a few hundred houses inhabitted by local people scattered at high elevation areas. Due to very difficult access attributable to the high surrounding mountains, the Matuno River basin is still in a least development stage resulting in well conserved conditions of natural forest, soils and water sources. This excellent conditions of land and water conservation cause no appreciable water pollution, no heavy sediment and comparatively not much difference between wet season flow and dry season flow, far less than those of the other denuded river basins like neighboring Sta. Cruz and Sta. Fe rivers. It makes a good advantage to water utilization.

3.1.3 Geological Stratigraphy

Geology of the Matuno river basin forms a part of stratigraphy of Caraballo Mountains (See Table 3-1). Conglomerates of the Lower Miocene Natbang Formation are wide-spread in the basin. The Miocene Macde Limestones are widely developed covering unconformably the Natbang Formation. Geological structure show strongly north-south trends in general. A north-south trending fault borders the Natbang Formation on the east and separates it from volcanic facies of the Upper Cretaceous-Eocene Caraballo Group which develops in the eastern adjacent area of the Magat river basin.

3.1.4 Geology of the Project Area

The Project area covers the middle-lower reaches of the Matuno river valley and a part of the left bank of the Magat river in the east.

The contemplated sites of major project structures are as follows:

- The A-damsite which is proposed on the Matuno river immediately downstream from the confluence of the Nansiancan river to the Matuno main stream.
- The B_1-damsite which is proposed on the Matuno river about 15.0 km downstream from the A-damsite and at about 1.0 km north of Bante.
- Penstock and powerhouse alingment on the left bank slope of the Magat river at about 3 km north of Batu Ferry Bridge.
- A 6 km long tunnel alignment which connect the B_1-damsite and the Penstock-powerhouse site.

The Matuno river valley forms for the most part deep gorges with steep slopes or cliffs dissected among the mountainous area, in contrast to the wide open Magat River with gentler mountain slopes. These two valleys are bordered by a north-northeasterly trending watershed higher than EL. 900 m, while their confluence is located at around EL. 330 m of ground height.

As the topographic features are divided by the water shed between the Matuno and the Magat rivers, geological features are divided by a long stretched fault running north-northeasterly. The area to the west from the fault, of which major part falls under the Matuno river basin, is composed of the Natbang Formation of Lower Miocene and the Macde Limestones of the later ages of Miocene. To the east from the fault, bedrock on the left bank of the Magat valley consists of volcanic facies which is correlated with the Caraballo Group of Upper Cretaceous to Eocene.

The followings are descriptions of the geological units which are encountered in the Project area.

(1) The volcanic facies of the Caraballo Group

This formation is composed of andesite and partly basalt lavas, pyroclastic rocks, sandstones and shales, according to geological literatures (JICA 1976, Bureau of Mines and Geoscience Philippines 1981). On the slope on the left bank of the Magat river where the penstock-powerhouse alignment is proposed, bedrocks are covered extensively by thick talus deposits and slope-washes from the limestone ridge at the top of the slope. Some rare outcrops are only of andesite, hard but frequently jointed. Hard tuffs are observed at a small isolated hill on the side of a highway near Bayombong. Though it is difficult to obtain a detailed picture of distribution of its members, this formation, the oldest of this area, may be deemed to be well consolidated into hard rocks in fresh condition.

(2) The Natbang Formation

The dominant facies of the Natbang Formation in the Matuno river valley is conglomerate, which contains gravels of andesite, porphyrite, chert, limestone and slate, round or sub-round, a few millimeters up to 20 cm in diameter. The matrix is hard to moderately hard, fine to medium silty sandstone in some layers and grit composed of coarse angular particles in the others. Size of the contained gravels varies for layers, each of which has thickness ranging from several tens of centimeters to several meters. In this aspect, the layers may be classified as gravelly or cobbly conglomerate and pebbly conglomerate, though changes of these features are too frequent to present in geologic maps. Also, some of the layers are conglomeratic sandstones, which contain gravels only sparsely.

The conglomerates are occasionally intercalated by silt-stone and sandstone layers with about 10 cm to 3 m of thickness. Sandstones are grey colored and fine or medium grained, forming solid layers. Siltstones, often dark brown colored, are moderately hard and often form topographic depressions for their relative weakness against erosion. Shears are occasionally found on the margin of the siltstone layers. A thick siltstone bed crops out continouusly along the Nansiancan river, a right bank tributary of the Matuno river upstream of the A-damsite.

Intercalations of thin limestone layers are observed locally.

Though the conglomerates are very massive at large, yet they bear outstanding cleavages of bedding planes and joints, of which intervals vary from more than 5 m down to a few tens of centimeters at frequently jointed portions. Occasional traces of shear along the cleavages suggest dislocations in the beds, which occurred in the course of folding or tilting of the strata. However, these cleavages are not more frequent than the ordinary cases of bedrocks for the other dam foundations and are not deemed to be serious defect from engineering viewpoint.

(3) The Macde Limestone

The limestone are white colored, massive, homogeneous and hard, bearing fine crystals of calcite. Also occur clastic limestone in which angular limestone fragments are tightly cemented with calcareous matrix. The Macde limestone is located in the higher parts of the slopes around the Matuno river valley, mostly in the level higher than EL. 900 m, overlying unconformably the Natbang conglomerates. In the downstream area of the Matuno river, it develops to the lower altitude until, intersected by an east-west trending fault, it is exposed in the level of the river bed at the mouth of the Matuno gorge near its confluence with the Magat river.

Evidences of sink holes, though obscured by erosion, are observed locally in the terrain of the limestones. It is likely that solution cavities are developed in parts.

(4) Terrace deposits

Terrace is not well developed in the Matuno river valley and is observed only sporadically on the river bank, at several meters of height from the river bed. The deposits are gravels and boulders mixed with sandy and clayey materials. What appear remnants of a higher terrace are observed at around 130 m of height from the river bed but their forms are obscured by erosion.

An extensively developed thick terrace deposit with rather well sorted round gravels is located on the mild slopes on the left bank at the confluence of the Matuno and the Magat rivers.

(5) Talus deposits

Talus deposits on the Matuno river banks are for the most part formed by sliding of the slopes in small scale, and are composed of brown sandy soil and gravels originating from the decomposed conglomerate. Their distrubution is rather locally limited. The only talus deposit in large scale in the Matuno river valley is located on the right bank near Bante Gruging Station.

The higher parts of the slopes on the Matuno river are often covered with screes of angular limestone fragments and blocks. The thickness appears not more than a few meters.

Talus deposits which are wide-spread on the left bank slopes of the Magat river valley are composed of black clayey soil and limestone fragments and boulders, brought from the limestone zone at the top of the slopes. Their thickness is sometimes 40 m or more.

(6) River deposits

The deposits in the Matuno river bed consist of illsorted round gravels and cobbles mixed with sand. Their sources are the Natbang conglomerates and the Macde limestones. Boulders with more than 1 m of diameter are included frequently. Thickness of the river deposits ranges from several meters to ten meters according to the seismic exploration and the drilling.

(7) Faults and Foldings Observed

Whereas geological structure of the Matuno river basin is dominantly of north-south trend with bedding planes, major faults and axes of foldings, the Project area where the damsites are proposed shows different tendencies, separated from the other part of the basin by a couple of faults, that is, one running from east to west through 2 km north of the Nansiancan river and the other traversing the Nansiancan river from northeast to southwest near its confluence with the Matuno river. The Project area is bordered on the east by a long stretched fault from the geological province of the volcanic facies in the Magat river valley. In the Project area, the bedding planes of the Natbang Formation tend generally to strike at the east-west direction and dip northward in various degrees ranging from 20^{o} to 70^{o}.

A synclinal axis, which trends and plunges northeast, is located about 300 m upstream from the confluence of the Nansiancan river to the Matuno river. The entire area of the Natbang Formation in the Project area is located in the eastern wing of this syncline.

In the lowermost reaches of the Matuno gorge there are three east-westerly faults assumed from topographic lineament, which are deemed to have caused subsidence of a Macde limestone mass with 2 km by 5 km of dimension. This structural interpretation of the limestone mass in the lowermost reaches (the C-damsite contemplated in the initial stage of the Study) could be controversial. The alternative interpretation would be that this limestone be a member of the Natbang Formation. In this report, the latter interpretation is discarded, though not dicisively, because of the too big scale of the limestone for a member of the Natbang Formation.

(8) Correlation between Seismic Wave Velocity and Geological Layers

The measurements of seismic wave velocity made at A-damsite and B-damsite clearly revealed that there were four different layers, namely the First Layer with the lowest velocity of 0.2 to 0.4 km/sec., Second Layer with 0.6 to 0.8 km/sec., the Third with 1.2 to 1.6 km/sec. and the Fourth with 3.0 to 3.5 km/sec.

Those four different layers were identified by correlation with the results of core drilling made at the same damsites as shown below:

Layer	Velocity (km/sec.)	Materials Interpreted
First Layer	0.2 - 0.4	Top soils, loose talus
Second Layer	0.6 - 0.8	Consolidated talus deposit, heavily weathered rocks
Third Layer	1.2 - 1.6	Weathered Rocks
Fourth Layer	3.0 - 3.5	Fresh rock formation

The range of the seismic wave velocity in the Fourth Layer (3.0 to 3.5 km/sec.) is derived from the fresh conglomerate formation, which appears on the outcrops and the drill cores to have enough strength and hardness for the dam foundation of fill type dam, such as rockfill dam or earth dam.

The seismic exploration carried out along the penstock-power house alignment has revealed also four different seismic wave velocity layers as shown below:

Layer	Velocity Range (km/sec.)	Materials Interpreted
First Layer	0.3 - 0.5	Top Soils
	0.6 - 0.7	Residual soils
Second Layer	0.8 - 1.0	Talus, Sand & Gravel or heavily weathered rocks
Third Layer	1.6 - 1.8	Weathered rocks, consolidated Talus or Sand and Gravel
Fourth Layer	2.4 - 2.6	Fresh pyroclastic rocks, tuff or Weathered andesite
	3.0 - 3.4	Fresh rock formation, mainly andesite

The lower velocity layer having 2.4 to 2.6 km/sec. at the higher elevation than 500 m seems to represent the consolidated talus deposit with large limestone boulders. The same lower velocity zones between the fresh andesite zones may be the highly cracked andesite zones.