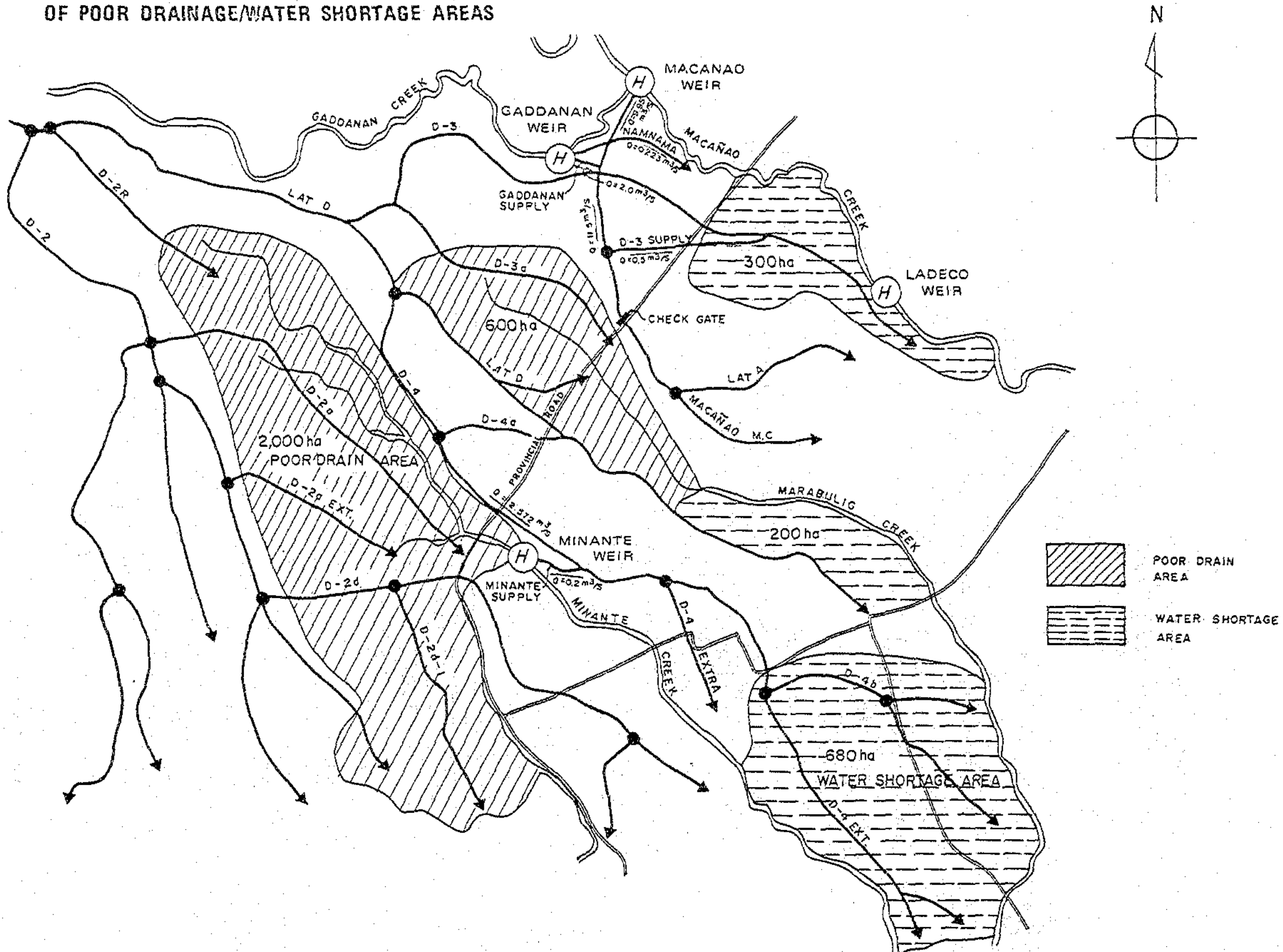
FIGURE C-5. MINANTE AND MACANAO RETURN FLOW SYSTEMS AND LAYOUT OF POOR DRAINAGE/WATER SHORTAGE AREAS



affected as poor drainage area. If the water level at the weir can maintain lower, the poor drainage area will be improved and, furthermore, the creek shall have enough capacity as the conveyance facilities of water supply for the Macanao system from the Maris main canal. However, for this idea, the intake gate and about 1.0 km of the Macanao main canal shall be modified to meet the requirement.

On the other hand, a weir on the Macanao main canal is installed at the crossing point of a provincial road about 3.5 km from the intake gate for the Lateral D-3 supply canal and some turn-outs. If the weir can be removed, the capacity of the Macanao main canal will be increased. In this case, 1.5 cu.m/sec of additional capacity is required at the intake of the Macanao weir. Consequently, the discharge of 0.223 cu.m/sec for the Namnama canal and 0.5 cu.m/sec for Lateral D-3 supply canal shall be added on Lateral D-3. Therefore, the expansion of canal section of Lateral D-3 will be required (see Figure C-5).

3.3. Improvement of Drainage Systems

(1) Drainage Problem in Service Area

There exist severe drainage problems in the areas of District III and District IV located on relative lower reaches of the service area with a flat topography. These areas are suffering from periodical inundation caused by stormy rainfalls with low return periods for the following reasons;

- An insufficient flow capacity of existing creeks,
- Lack of drainage canal density inclusive of project drain and on-farm drain,
- Obstruction in the drainage creek to divert re-use of water as return flow,

These drainage problem areas are illustrated in the O/M Drawings No.26 indicating drainage area and discharge, and also flow capacity of the creek is examined at selected sites by using surveyed cross section.

(2) Designed Peak Drainage Discharge on Creek Basis

Many natural creeks in the drainage problem areas are lying to drain the natural excess water by irrigation and stormy rainfalls, and they are connected with the major rivers such as the Magat, Siffu and Cagayan rivers. These creeks, however, are not well-maintained at present, resulting in the drainage problems in the area, therefore adequate countermeasures should be taken in the Project.

Since drainage modulus for planning peak drainage discharge has not been formulated yet in the Project, analytical method so called as the Mcmath formula is applied to estimate peak drainage discharge by stormy runoff. The Mcmath formula shown below, which is generally used in the NIA's projects gives fairly reliable results.

$$Q = C \times i \times S^{1/5} \times A^{4/5}$$

Where;

Q: Peak drainage discharge in cubic feet per second
C: Coefficient presenting the basin characteristics
i: Rate of rainfall in inch per hour for the time of concentration and frequency
S: Fall of main creek in feet per 1,000 feet, and
A: Area of basin in acre

In the above equation, daily maximum rainfall of 150 mm is adopted for design rainfall corresponding to return period of five-years, which is obtained based on the observation data at the Ilagan station.

Peak drainage discharges on creek basis are estimated by applying the above method, and the peak drainage discharges per hectare are in the ranges of 2.4 lit/sec/ha to 9.6 lit/sec/ha in the flat area and 11.1 lit/sec/ha to 27.8 lit/sec/ha in the mountainous area. The estimated peak drainage discharges is illustrated in the drainage flow diagram shown in the O/M Drawings No.28.

(3) Improvement Drainage System

The total length of the existing creeks or projected drainage is about 870 km, equivalent to 9.0 m/ha as shown blow. This figure is not so low as intensity of the main and sub-main drainage canals. However, due to lack of annual maintenance such as removal of water grass or constructed dike for fish trap, some drainage canals and creeks have not a sufficient capacity to drain excess water immediately.

Length of Drainage Creeks

District	Service Area (ha)	Creek Length (km)	Intensity (m/ha)
I	24,054	222.8	9.2
II	24,468	277.5	11.3
III	24,793	201.7	8.1
IV	24,087	171.7	7.1
Total	97,402	873.7	9.0

In the Project, a flow capacity of the existing drainage creeks will be examined compared with the designed peak drainage discharge already estimated, and some creeks having an insufficient cross sectional area to meet the said discharge should be improved.

ANNEX D

RESERVOIR OPERATION

D. RESERVOIR OPERATION

LIST OF TABLES

LIST OF FIGURES

1. WATER OPERATION CRITERIA

(1) Allocation of Siffu River Runoff

The Siffu river runoff varies from time to time with a wide range between 0.5 and 500 cu.m/sec as a daily mean discharge. Since the regulating capacity of the Siffu diversion dam is quite limited, amount of water to be diverted is also restricted within the limits of available runoff at the diversion dam. Accordingly the projected area of 2,959 ha, that is served by the Siffu North main canal (SNMC) taking priority of utilizing Siffu water, will be suffered from frequent shortage of irrigation water during dry period, especially in the months March and May.

Siffu River Runoff and Irrigation Demand

(unit: MCM/month)

	Siffu River Runoff			Irrigation Demand	
Month	Minimum	Maximum	Average	SNMC	SSMC
1	16.4	165.9	42.6	8.6	21.6
2	7.7	153.9	28.8	9.5	25.7
3	6.2	69.2	24.7	5.2	31.6
4	5.3	70.0	26.1	0.0	12.1
5	8.1	272.4	52.5	11.5	0.0
6	9.2	160.8	71.0	6.8	26.0
7	13.0	372.0	94.2	10.2	27.0
8	30.6	230.0	111.8	5.0	13.1
9	23.0	251.4	128.8	3.3	13.1
10	25.1	520.5	120.4	0.0	10.6
11	23.4	485.3	111.6	5.7	1.8
12	13.5	265.0	72.5	6.5	19.4
Total			884.9	72.3	202.0

In contrast with the above situation, 8,160 ha of irrigation area served by the Siffu South main canal (SSMC) utilizes surplus water of the Siffu river since supplemental water can be supplied through the Maris North Diversion Canal (NDC) from the Magat reservoir. It is therefore recommendable, as presently regulated, that the priority is given to the SNMC to utilize the Siffu river water.

As regards the water management at the Siffu diversion dam, necessary amount of water as scheduled is first diverted to the SNMC area, and then the SSMC area is irrigated with the Siffu excess water supplemented with the Magat water. In this connection, it is necessary to predict available flow in the Siffu river after a week at least, in consideration of a time-lag of water delivery through the Maris NDC as well as the role of water management in the MRIIS irrigation systems. However, estimation of the amount of water to be supplemented from the Magat reservoir may be practically done assuming that the same volume of river runoff would continue a week, since the prediction of river discharge is quite difficult when remarkable irregularity of basin rainfall and river runoff in turn is taken into consideration. It is therefore important to monitor the Siffu river discharge always, and not to accumulate prediction error.

(2) Return-Flow in Macanao Creek Area

The water balance study between available water resources and irrigation demand in the entire MRIIS shows that utilization of irrigation return-flow in the Macanao creek area should be continued. Return-flow from the upstream areas served by the MARIS lateral A-2, A-4 and B, 5,790 ha in total, is received at the points of Macanao and Ladeco check gate and utilized in the areas of 6,040 ha commanded by the Macanao East and West main canals. It is also planned that the balance of water (deficit) is supplemented from the Maris main canal through the Gaddanan supply canal. In this connection, rate of return-flow has been estimated at 45 percent after direct measurement of surface flow entering into and going out the upstream area.

In order to expect the most effective utilization of the return-flow, it will be required for the cropping schedule in the Macanao creek area to be linked with that in the upstream area, and to be shifted a little later. In addition according to water balance simulation, required capacity of the Gaddanan supply canal has been calculated at about 4.3 cu.m/sec.

(3) Operation of Magat Reservoir

The Magat reservoir is operated by the following optimum operation rule, which was proposed through simulation of the reservoir operation in consideration of the combined effect of dimension of the existing dam facilities, available inflow into the reservoir, losses and demand for dual purposes of irrigation and power generation.

Dam Facility

- Full Supply Level (FSL)	EL.193.0 m
- Full Supply Capacity	1,090 MCM
- Lowest Supply Level (LSL)	EL.160.0 m
- Minimum Storage	270 MCM
- Effective Storage	820 MCM

Inflow

- Maximum Annual Inflow	12,530 MCM/yr
- Minimum Annual Inflow	3,280 "
- Average	6,550 "
- 10-year Drought Inflow	4,200 "
- 5-year Drought Inflow	4,800 "
- 3-year Drought Inflow	5,450 "

Irrigation Demand

	Area (ha)	Demand (MCM/yr)
- Direct Service Area	80,243	2,537
- Supply to Macanao Area	6,040	90
- Supply to SSMC Area	8,160	62
- SNMC Area	2,959	-Siffu Runoff-
Total	97,402	2,689

Demand for Power Generation

- Magat Power Plant

Projected power generation by the NPC in 1985 is as follows;

Projected Power Generation by NPC

Month	Monthly Loading (MW)	Continuous Loading (MW)	Required Release (cu.m/sec-day)	Required Release (MCM)
Jan.	1,810	75.4	101	270
Feb.	1,940	80.8	113	270
Mar.	980	40.8	61	160
Apr.	750	31.3	50	130
May.	1,230	51.3	89	240
Jun.	1,680	70.0	128	330
Jul.	4,080	170.0	241	640
Aug.	6,120	255.0	330	880
Sep.	8,160	340.0	411	1,070
Oct.	5,400	225.0	256	690
Nov.	4,080	170.0	232	600
Dec.	2,600	108.3	140	370
Total				5,650

Note: Required release is estimated along the lower mode of operation curve.

- Baligatan Power Plant

Only irrigation release required at the Baligatan diversion dam for the area of 12,680 ha served by the South High main canal and Oscariz main canal is used to generate power.

2. MAGAT RESERVOIR OPERATION RULE

(1) Concept of Operation Rule

(a) Objective of Reservoir Operation

Irrigated areas in the MRIIS depend mostly on the water supply from the Magat reservoir. In consideration of seasonal pattern of rainfall in the service area, as well as of inflow into the reservoir, the Magat water has a significant importance for dry season crops under the vegetative and reproductive stages and for wet season crops under the initial irrigation stage. In these area under such situations, it must be intolerable and irresistible that the water supply from the reservoir be interrupted. It is, therefore, inevitably necessary that the reservoir is so operated as to ensure its storage by this time. In planning the rational operation of the reservoir against more complicated requirement of water for irrigation, an objective standard must be necessarily required to be established.

The operation of a reservoir is undertaken in a way that two purposes confronting each other can be adjusted. The first objective is to promote water releases effectively in response to the demand of the service area. However, as a result, promotion of water release accelerates consumption of available storage in the reservoir. Secondly, some countermeasures for unforeseen drought is needed. In preparation for the present and future drought, water releases are rather restricted intending preservation and restoration of the storage.

The above two objectives confronting each other may be achieved when the basic storage level by season is established and the reservoir is operated in accordance with the characteristics of the available storage zoned by the basic storage level. In principle, during the period when the reservoir levels are kept above the basic storage level, release of water is promoted in answer to the request of the service area. On the contrary, releases are restricted in preparation for drought when the reservoir level comes below the line. After categorized as above, water demand requested by beneficiaries takes the initiative in the former category and the initiative of the supplier side from aspect of reservoir control is superior in the latter. In addition, in the latter category, regulations are required for the reservoir administrator to control amount of water to be released. Accordingly, the restrictive release lines are to be established in order to divide the territory into a number of sub-zones.

As stated above, a combination of the Basic Storage Line (BSL) and the Restrictive Release Line (RRL) comprises a specified rule to control the reservoir storage, or the Storage Operation Rule (SOR).

(b) Basic Storage Line

i) Required Storage-Level for Drought

The Required Storage-Level for Drought (RSD) is defined as a stochastic time-series of storage required at each time during the period of irrigation. As a basis for the computation of the RSD, available inflow into and water requirement released from the reservoir, respectively P (i) and Y (i), where i denotes time interval for computation, must be prepared preliminarily.

$$Y\ (i) = \beta\ [\alpha\Sigma\{Dj\ (i) - Aj\ (i)\} - \Sigma R_k\ (i)]$$

where;

α, β:	Rates of irrigation loss
D:	Field irrigation requirement
A:	Effective rainfall
R:	Available water within the service area
j:	No. of irrigation block
k:	No. of available water source

and, $P\ (i) = Q\ (I) - \Sigma M\ (i)$

Where;

Q:	River runoff at damsite
M:	River constraint for use downstream

For computation of the RSD, water balances between P (i) and Y (i) are calculated at regular time intervals, and then accumulated backward starting from the ending date of irrigation or the critical lowest point of reservoir storage, toward the beginning of irrigation or the critical date showing the maximum storage in the reservoir. Since the comparison study of inflow and irrigation demand indicates that in the Magat reservoir the lowest level may commonly be observed at the end of June and in contrast, that the reservoir will be requested to be full of water at the end of December, the accumulation was made backward from the end of June toward the beginning of January.

$K(i) = P(i) - Y(i)$

$V(i) = V(i+1) - K(i)$, and

$V(i) \geqq 0$ or $V(i) = 0$ when $V(i) < 0$

where; $K(i)$: Balance of water

$V(i)$: Required storage

The $V(i)$ as defined above means in a specific year under consideration that the reservoir will not be empty at the end or the critical point of irrigation if the reservoir keeps a storage of $V(i)$ at the i-th interval of time period.

In each year, the computed $V(i)$ is arranged in a descending order from the maximum to the minimum, and the value $U_m(i)$ is defined as the m-th biggest value of $V(i)$, so that;

$$U_1(i) \geqq U_2(i) \geqq \cdots \geqq U_m(i) \geqq \cdots \geqq U_N(i)$$

Then based on the above statistics, the required storage with respect to an empirical probability of exceedance, Pm, is estimated by means of a probability paper plotting or other suitable methods. Here, Pm is given in the following simple equation;

$$Pm = \frac{m}{N+1}$$, where N denotes number of years.

Return period, Tm, is accordingly given;

$$Tm = \frac{1}{Pm}$$

When the value $Z_{Tm}(i)$ is defined as the storage required at the i-th time-interval of the period which corresponds to a dry year of Tm-year recurrence, a series of Z_{Tm} composes the required storage level for Tm-year drought, meaning that the reservoir storage will not come to zero with a probability of (1-Pm) at the end or the critical point of irrigation unless the available storage at the time falls below the required storage level.

ii) Basic Storage Line

Theoretically, any kind of value can be given for Pm and Tm. However, the existing dimension of the Magat reservoir limits the maximum allowable value of the Z_{Tm} at 820 MCM (= live storage between elevations 193.0 and 160.0)

Required storage levels calculated for each year were then put into statistical treatment through probability analysis to produce the RSD corresponding to Tm-year drought. In case of Magat, Tm was determined at three year (Tm = 3) taking into account available inflow, demand and the storage capacity of reservoir. It may be pointed out here that it will promote an excessive and intensified control of reservoir storage in case if Tm is taken more than three.

(c) Restrictive Release Line

The Restrictive Kelease Line (RRL) is defined as the line which dominates a territory prescribed by a rate of restrictive release (restrictive release divided by required demand). The RRL is applied only when the existing storage in the reservoir falls below the BSL (in case of storage deficit), and a rate of restrictive release is given in accordance with magnitude of storage deficit.

i) Required Storage during Storage Deficit

Prior to the establishment of the RRL, a definite policy for controlling release restriction must be decided. Here, the definite policy prescribes basic guidelines to preserve reservoir storage and to restore storage deficit. This gives a framework for duration and strength of release restriction, and in turn prescribes condition for calculation of the required storage during storage deficit.

Using P (i) and Y (i) prepared for calculation of the RSD,

$K(i) = P(i) - Z(i)$

$Z(i) = (1 - S) \times Y(i)$; During the period of restriction

Or $= Y(i)$; ordinary period without restriction,

where; S: rate of restrictive release

= restrictive release/required demand

Z (i): water release during storage deficit

The required storage during storage deficit, $V_s(i)$, is then given in the following equation;

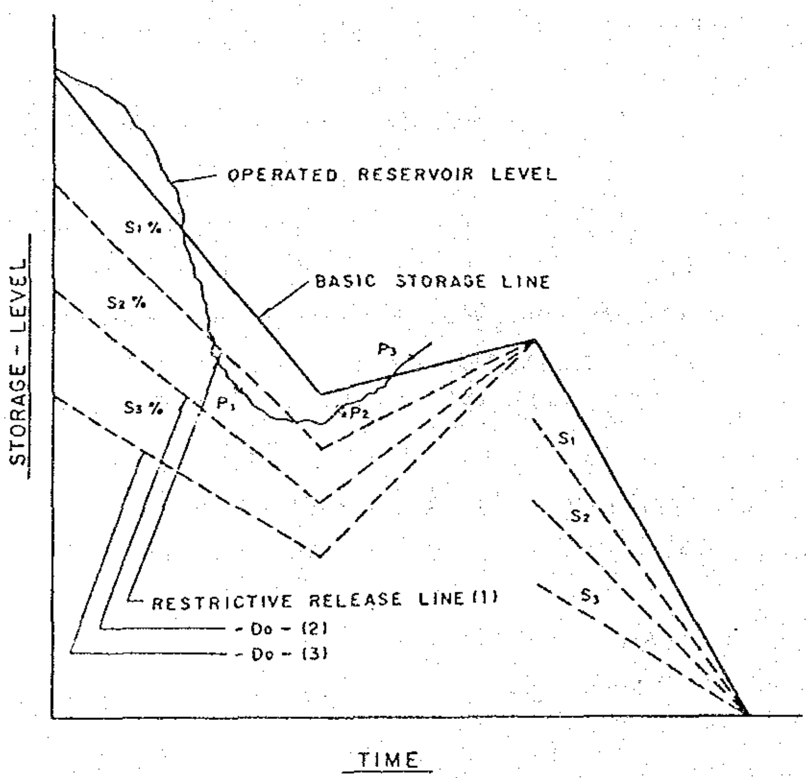
$V_s(i) = V_s(i + 1) - K(i)$,

Where $V_s(i) \geqq 0$ or $V_s(i) = 0$ when $V_s(i) < 0$

The $V_s(i)$ as defined above has a stochastic meaning that in a specified year under consideration, the reservoir will not be empty at the end or the critical point of reservoir operation if the reservoir keeps a storage of $V_s(i)$ at the i-th time interval of the period, under the condition that the water release is restricted with given rate during the period of storage deficit. Above figures are then inputted into statistical evaluation to produce the Restrictive Release Lines of given degree of release restriction.

(d) Reservoir operation based on Given Rule

The BSL and RRL compose the Storage Operation Rule (SOR). The actual operation of the reservoir based on the SOR is explained as illustrated below.



- The existing storage is assumed at the point P1.
- Then the restrictive rate of S2 is employed and the amount of water to be released is given at S2% x irrigation demand.
- After the lapse of time intervals, the reservoir recovers the point P3, from when the restrictive release is cancelled.

The reservoir storage is controlled in this manner having the BSL as a guideline.

3. WATER REQUIREMENT

As a basis for formulation and evaluation of the Project, hydrological analysis were conducted placing a great emphasis on the establishment of the optimal operation rule of the Magat reservoir inclusive of runoff estimation and water requirement for irrigation as well as for power generation. All analysis were based on the hydro-meteorological data available mainly from the site of existing Magat dam, Siffu diversion dam and Ilagan meteorological station collected for the period of recent 30 years from 1953 through 1985 exclusive of three years from 1973 to 1975.

Method, procedure and basic parameters presented in the existing O/M Manual were fully employed during the course of the study mainly for estimating water requirement for irrigation diversion including effective rainfall computation and various losses for water delivery and distribution, under the given condition of the target irrigation area of about 97,400 ha with a cropping intensity of 200 percent.

With regard to water requirement for hydropower generation, monthly typical loadings prepared in 1985 by the NPC was carefully reviewed and applied as a basis for constructing a rule of the reservoir operation, especially during the wet season.

(1) Requirement for irrigation

In order to characterize the cambined effect of irrigation demand, inflow and storage capacity of the reservoir, a preliminary study of reservoir operation was conducted without giving any specified operation rule and with water release just to meet irrigation requirement, estimated on the basis of cropping schedule adopted in the existing MRIIS O/M manual. The study revealed the fact that the reservoir capacity would be sufficient enough to satisfy irrigation demand even during a critical drought period of 15-year recurrence.

However, since the Magat runoff largely depends on typhoons visiting the drainage basin, and still more due to the fact that much weight in controlling water releases in wet season is given for power generation, there would be frequent occasions where the reservoir will not restore its storage at the end of wet season carrying over such effects in the succeeding cropping season, in case when the inflow is much less than expected.

So as to expect the most effective use of the reservoir water for the dual purposes of irrigaition and power generation, the proposed cropping schedule, in terms of an appropriate combination of cropping calendars in time and space anywhere in the service area was investigated aiming at i) expecting more effective rainfall on the field, ii) utilizing plenty of inflow during wet season, and iii) ensuring the period for irrigation facility maintenance at the end of dry season crop.

(2) Requirement for Power Generation

A comparative study was made between seasonal water demands for irrigation, as proposed, and water requirement for power generation projected for the Magat Power Plant by NPC in 1985.

Month	Irrigation Demand 1/ (cu.m/sec-day)	Projected Power Generation by NPC: Monthly Loading (MW)	Continuous Loading (MW)	Required Release 2/ (cu.m/sec-day)
Jan.	117.0	1,810	75.4	101
Feb.	134.9	1,940	80.8	113
Mar.	89.6	980	40.8	61
Apr.	55.4	750	31.3	50
May	102.2	1,230	51.3	89
Jun.	101.2	1,680	70.0	128
Jul.	139.8	4,080	170.0	241
Aug.	71.5	6,120	255.0	330
Sep.	41.2	8,160	340.0	411
Oct.	27.8	5,400	225.0	256
Nov.	44.8	4,080	170.0	232
Dec.	88.3	2,600	108.3	140

Notes: 1/ Average in 30 years, proposed cropping schedule
2/ Estimated along the lower mode of operation curve.

As is seen in the above table, required water release for power generation during dry period from January through June, with exception of June, would be covered by the irrigation water release so long as the reservoir water level is kept within a normal range of elevation. In other word, when the reservoir level is expected to be around the full water level at the beginning of January, the reservoir during dry season could be operated taking only irrigation aspect into consideration.

During wet season when inflow into the reservoir largely exceeds irrigation demand under the normal condition, the reservoir should be so operated that i) as much water release as possible be allotted for power generation, ii) as small amount of water as possible be wasted through spillage and iii) reservoir level be finally recovered to the full water level as frequent as possible at the end of December.

Accordingly even during wet season, a role of reservoir operation is constructed by means of establishing various modes of allowable release with respect to the available storage, aiming at the most effective utilization of the limited water resource for dual purposes of irrigation and power generation.

4. OPERATION RULE CURVE

As described previously, operation of the reservoir should be undertaken in such a way that two purposes confronting each other, namely i) promotion of effective water release and ii) restriction of releases in preparation for unforeseen drought, can be adjusted. To cope with this, it is useful to zone the storage area into two areas corresponding to the respective purpose. Under the normal condition, the reservoir will be operated so as to keep the Basic Storage Line (BSL). In the event when the actual storage volume sinks below the BSL, the Restrictive Release Line (RRL) may be applied. The BSL and RRL are planned by calculating the required storage-levels for the projected drought which indicate certain safely probability of the reservoir operation. The BSL and RRL finally compose the Storage Operation Rule.

(1) Basic Condition Given in Operation Study

(a) Physical Condition of Reservoir

Prior to the study, it was pointed out that the reservoir total storage volume at FSL (EL.193 m) revised in 1980 based on the contour map survey was reported at 1,090 MCM instead of 1,250 MCM, which is given in the "MRMP Feasibility Study Report".

Stage-Volume and Stage-Surface Area relationship of the Magat reservoir are given in Tables D-1 and D-2 respectively. Taking the full supply level at 193.0 m and the lowest supply level at 160.0 m, the effective storage of the reservoir is calculated at 820 MCM.

(b) Reservoir Inflow

A series of simulation study of reservoir operation involves evaluation of hydropower to be generated at the Magat and

Baligatan plants. Since the Magat inflow varies from time to time with a wide range depending on the frequency and time-distribution of typhoon visiting the watershed, and since the power generated largely depends on the available water-head in the reservoir, the time step for computation should be taken as small as possible. Daily computation was therefore envisaged on the basis of the daily average runoffs collected from both Magat and Siffu river systems.

(c) Evaporation Loss

Although pan-evaporations have been observed since 1980 up to date at various stations inclusive of Baretbed located at the upstream end of the reservoir, no station covers the entire period of analysis, 1953 to 1985. Evaporation from the open water surface was therefore estimated by use of the Modified Penman Method as shown in Table D-3.

(d) Seepage Loss

Seepage losses through dam embankment as well as through foundation were given as a function of the reservoir water level, based on the direct observations executed along the embankment near the Baligatian power plant and also conducted at the gallery (see Figure D-2).

(e) Rainfall on Reservoir Surface

Daily rainfalls collected from the Sagat station for the period of nine years from 1977 to 1985 were averaged, as given in Table D-4 to produce the daily average rainfall expected on the reservoir surface.

(f) Priority of Irrigation Diversion

As regards the area commanded by the Siffu diversion dam, the SNMC takes priority of diverting the Siffu river discharge. The SSMC utilizes excess water in the river, and a deficit is supplemented from the magat reservoir. On the contrary, the Magat reservoir provides irrigation water with the same priority to the entire service area excluding the Macanao return-flow area and the SSMC area. Second and third priorities are given for supplementary areas of the Macanao and SSMC, respectively.

(g) Minimum Requirement for Power Generation

According to proposed cropping schedule, the minimum power requirement during dry months from January through May will be satisfied by irrigation releases when the reservoir is operated within a normal range of storage. However additional water will necessarily be released for power generation in the month of June, since the irrigation release will not cover the minimum requirement for power generation.

Month	Minimum Power Requirement	Daily Output	Necessary Release
June	1,680 MW	70.0 MW	128 cu.m/sec

(h) Characteristic of Power Generator

Characteristic curve of power generator is given in detail in the paragraph 5 in this Annex.

(2) Required Storage for Drought

Based on the water balance at the Magat reservoir between inflow and required demand computed for the proposed cropping pattern inclusive of supply to the supplemental areas, required storages during the period of irrigation are computed for each year and are plotted as shown in Figure D-3. As is seen in the said figure, the reservoir will supply 100 percent of irrigation requirement in most years with exception of 1978 and 1983, if the reservoir maintains full of water at the beginning of each year. However the detailed water balance simulation also shows that water shortages will be resulted in many years when various losses due to evaporation and seepage, additional water release for power generation, and storage deficit at the initial stage of irrigation are taken into consideration.

The above required storages are then put into the statistical evaluation, applying the "exponential distribution", and required storages for drought (RSD) corresponding to three, five and ten year drought are obtained as given in Figure D-4. The basic storage line (BSL) is finally defined as the RSD corresponding to three-year drought.

On the basis of the BSL which corresponds to three year drought, required storages during storage deficit were then computed with given restrictive rate of 80 percent, 60 percent, 40 percent and 20 percent, as presented in Figure D-4. In this connection, required storage line corresponding to 10-year drought was defined as the "High Mode BSL" taking into account that i) the BSL was established relatively lower as compared with the operation curve presently adopted, and ii) power requirement during dry month was defined as the minimum. Consequently operation of the reservoir is explained briefly as follows;

- Under the normal condition when the reservoir maintains storage within a normal range, the reservoir is operated with the "Standard Mode BSL" as the target. When the reservoir stage exceeds the line, 100 percent of irrigation requirement is released from the reservoir, and the minimum power requirement is satisfied with this water.

- In case that the reservoir stage lowered the BSL, one of the RRL is applied in accordance with the magnitude of storage deficit, and rapid restoration of storage is envisaged.

- When the reservoir stage exceeds the High Model BSL, available storage above the line is allotted to power generation.

Accordingly under normal condition, the reservoir is operated between the Standard Mode BSL and High Mode BSL Operation curve. Operation rule curves thus determined are shown in Figure D-5.

(3) Reservoir Operation during Wet Months

Power generation takes the initiative in operating the reservoir during wet months from July to December. Despite that the output of the Magat plant during this period is recognised as the base load in the grid covering the entire Luzon, it will be almost impossible to be achieved when available water resources from the Magat basin is taken into consideration. From this point of view, target value of Magat power generation was examined, by means of trial, at about 75 percent of the NPC projection as shown below;

Month	Daily Average Output (MW) NPC Projection	Target	Rate (%)
July	170.0	120.0	70.6
Aug.	255.0	180.0	70.6
Sep.	340.0	240.0	70.6
Oct.	255.0	160.0	71.1
Nov.	170.0	160.0	94.1
Dec.	108.3	100.0	92.3
Average	211.4	160.0	75.7

(4) Operation Rule

Various lines for storage control mentioned in paragraph (2) and (3) comprise the reservoir operation rule as compiled in Figure D-6. It is noted here that the rate of allowable water release to the irrigation demand required is defined during dry months from

January to June, while releases are given as daily average discharge during wet months July to December.

(5) Reservoir Simulation Study

Simulation studies undertaken, inclusive of imaginary cases where the reservoir is operated for single purpose of irrigation, are summarized as follows;

Case	Wet Paddy Demand (MCM/yr)	Wet Paddy Deficit (MCM/yr)	Wet Paddy Rate (%)	Dry Paddy Demand (MCM/yr)	Dry Paddy Deficit (MCM/yr)	Dry Paddy Rate (%)
Irrigation Only	1,352.2	11.7	0.9	1,306.6	0.0	0.0
Irrigation + Power	1,352.2	56.5	4.2	1,306.6	48.0	3.7

Note: Demand stands for irrigation demand only.

(b) Storage Deficit and Irrigation Area Control

As already mentioned, the Magat runoff largely depends on typhoons visiting the drainage basin and irregularity is remarkable. In addition the effective storage of 820 MCM is considered too small as compared with the Magat runoff, about 6,550 MCM/year on average. Judging from the historical runoff record collected at the damsite, it will be many occasions where the storage is rapidly restored with one typhoon, and also frequent cases where disappointing small inflow comes into the reservoir in wet season. Therefore, it is unavodiable to waste almost 880 MCM/year of water through spillways, and at the same time it involves much risk for the agriculture side that water supply from the reservoir is interrupted. At the establishment of the operation rule, careful attention was paid so that water supply from the reservoir was not interrupted at the important and serious period of irrigation, but still more due to the fact that the power generation is given much weight in controlling water releases in wet season, the simulated result shows frequent occasions where the reservoir will not restore its storage at the end of wet season carrying over such effects in the succeeding cropping season, in the case when the inflow is much less than expected.

Therefore, if the storage deficit as summarized in the previous paragraph (5) is not acceptable from the agronomic point of view, necessary countermeasure, such as reduction of planting area in the succeeding cropping period on the basis of the available reservoir storage at the critical point of time, will be required in the actual practice of reservoir operation. Although it is desirable to estimate potentiality of irrigation as well as the area to be planted by a reasonable prediction of reservoir inflow combined with the presently available storage, it seems almost impossible to predict the inflow. Accordingly the study was made on the rate of irrigation area reduction based on simple correlation between storage deficit simulated and available storage at the end of March and September, respectively for wet season rice and dry season rice.

Figure D-7 presents such a correlation. Since the irrigation project generally allows crop damages of once in ten years, three exclusive points (i.e. 3/30 years = 1/10) are eliminated from the study. The remainders produce an envelope curve, which is defined as the "Area Reduction Curve". However in general, reduction of planting area promotes increase of reservoir stage which in turn promotes release of water for power generation, shortage of water for irrigation supply also increases and the correlation is modified. In this study three steps of modification were progressed as shown in Tables D-5 and D-6, as well as in Figure D-7. Cases of water balance simulation were summarized as follows.

Case	Wet Paddy			Dry Paddy		
	Demand (MCM/yr)	Deficit (MCM/yr)	Rate (%)	Demand (MCM/yr)	Deficit (MCM/yr)	Rate (%)
100% Projected Area	1,352.2	56.5	4.2	1,306.6	48.0	3.7
Reduction (1)	1,250.3	30.3	2.4	1,155.2	27.3	2.4
" (2)	1,183.0	22.1	1.9	1,092.4	20.6	1.9
" (3)	1,125.3	16.8	1.5	1,040.6	16.3	1.6

Note: Proposed cropping schedule was adopted for all cases.

In addition, average cropping intensities as analyzed for the period of 30 years are as under:

Case	Wet (%)	Dry (%)	Annual (%)
100% Projected Area	100.0	100.0	200.0
Area Reduction (1)	93.0	89.4	182.4
" (2)	88.4	85.0	173.4
" (3)	84.4	81.4	165.8

5. POWER GENERATED AND MAGAT WATER ALLOCATION

The Magat power plant is facilitated with a nominal capacity of 360,000 kW (90,000 kW x 4: 120 m^3/sec x 4 = 480 m^3/sec) and commenced its operation in August, 1983. The characteristics of the plant are as follows:

Magat Plant Characteristics (per plant)

Reservoir Elevation	Net Head	Turbine Output	Gate Opening	Discharge	Turbine Efficiency	Rate of Generation
(El.m)	(m)	(MW)	(%)	(m^3/sec.)	(%)	(KW/m^3/sec)
193.0(max)	89.0	90.0	75.0	113.0	91.3	796.46
185.0	81.0	90.0	86.7	124.0	91.4	725.81
174.0	70.0	70.0	84.5	112.5	90.8	622.22
160.0(min)	56.0	50.0	86.0	102.0	89.3	490.20

On the other hand the Baligatan power plant at present under construction has its capacity at 6,000 KW x 1, and utilizes irrigation release required for the Baligatan diversion dam.

Baligatan Plant Characteristics

Reservoir Elevation	Net Head	Turbine Output	Discharge	Rate of Generation
(El.m)	(m)	(MW)	(m^3/sec.)	(KW/m^3/sec)
193.0(max)	38.0	6,000	18.92	317.1
185.0	30.0	6,000	23.78	352.3
179.0	24.0	4,000	19.45	205.7
172.0(min)	15.0	1,580	12.94	122.1

Power to be generated at both the Magat and Baligatan plant has been involved in the simulation study of the Magat water balance system, and the simulated results following the proposed cropping schedule for irrigation and the proposed rule of reservoir operation are summarized as below:

Estimated Power Generation

(Unit: GWH/yr)

Case (Areal Control)	Magat Plant Max.	Magat Plant Min.	Magat Plant Ave.	Baligatan Plant Max.	Baligatan Plant Min.	Baligatan Plant Ave.
100% Projected Area	1,718.8	590.2	1,065.9	25.1	11.7	19.3
Area Reduction (1)	1,721.2	594.5	1,072.6	23.5	11.5	18.5
" (2)	1,722.1	597.2	1,075.7	22.5	11.0	17.8
" (3)	1,723.3	598.8	1,078.4	21.8	10.5	16.9

In this connection as a result of simulation, amount of the Magat water used for irrigation and power generation is summarized as under:

Magat Water Allocation

(Unit: MCM/yr)

Case (Areal Control)	Dual Purpose for Irrigation & Power (1)	Irrigation Only (2)	Power Only (3)	Spillage (4)	Water Used for Irrigation (1)+(2)	Water Used for Power (1)+(3)
100% Projected Area	2,506.8	56.3	3,100.4	867.6	(31.4%) 2,563.1	(68.6%) 5,607.2
Area Reduction (1)	2,309.9	42.8	3,305.0	872.8	(29.5%) 2,352.7	(70.5%) 5,614.9
" (2)	2,196.6	40.2	3,417.1	876.6	(28.5%) 2,236.8	(71.5%) 5,613.7
" (3)	2,095.0	41.2	3,514.3	879.7	(27.6%) 2,136.2	(72.4%) 5,609.3

Simulated results of Magat power generation were then compared with the actual achievement recorded in 1984 and 1985.

Comparison of Magat Power Generation

(Unit: GWH)

Year	Month	Actual Achievement	Simulated: 100% Area	Simulated: Reduction (1)	Simulated: Reduction (2)	Simulated: Reduction (3)
1984	1	45.504	55.44	47.21	43.59	39.84
	2	40.994	44.49	45.90	43.03	39.96
	3	31.925	28.40	25.93	26.80	25.17
	4	25.940	32.30	53.25	60.27	68.06
	5	128.616	178.92	177.05	176.38	182.83
	6	155.265	85.43	82.41	87.21	86.68
	7	110.246	110.58	111.57	111.00	109.56
	8	146.964	130.40	131.08	129.39	130.90
	9	143.260	153.72	154.39	152.92	153.12
	10	104.392	87.20	88.98	87.65	89.22
	11	116.236	127.28	127.41	127.46	127.51
	12	83.214	57.14	57.87	58.18	58.48
	Annual	1,132.556	1,091.30	1,103.05	1,103.88	1,111.33
1985	1	56.691	57.99	49.87	46.58	43.47
	2	45.447	44.76	45.36	44.59	42.19
	3	29.272	21.70	23.29	22.96	23.34
	4	17.982	20.79	21.19	21.03	21.16
	5	40.612	47.85	41.94	52.16	57.44
	6	51.014	63.50	85.54	83.97	82.87
	7	126.705	140.17	137.46	137.98	142.35
	8	130.213	106.43	105.87	106.11	107.52
	9	188.879	208.86	209.73	210.00	210.08
	10	112.990	184.86	185.17	185.24	185.25
	11	145.380	130.69	130.78	130.82	130.85
	12	81.570	80.99	81.68	81.98	82.20
	Annual	1,026.755	1,108.59	1,117.88	1,123.42	1,128.72

TABLE D-1. STAGE-VOLUME RELATIONSHIP OF MAGAT RESERVOIR

ELEVATION (M)	VOLUME IN MCM									
	00	01	02	03	04	05	06	07	08	09
150	158	167	177	188	198	209	221	232	245	257
160	(270)	284	298	312	327	342	358	376	394	413
170	433	454	475	496	519	542	566	590	616	642
180	668	696	724	753	783	814	845	878	911	945
190	980	1016	1053	(1090)	1129	1168	1209	1250		

TABLE D-2. STAGE-SURFACE AREA RELATIONSHIP OF MAGAT RESERVOIR

ELEVATION (M)	SURFACE AREA IN HA									
	00	01	02	03	04	05	06	07	08	09
150	965	1030	1070	1115	1150	1180	1210	1230	1245	1265
160	(1290)	1335	1375	1425	1490	1550	1615	1690	1760	1850
170	1950	2090	2230	2305	2350	2380	2420	2460	2500	2540
180	2580	2630	2680	2740	2795	2860	2950	3040	3150	3300
190	3470	3640	3760	(3890)	3950	4085	4165	4260		

TABLE D-3. OPEN-WATER EVAPORATION BY PENMAN

(Unit = mm/day)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1. Tmean (°C)	23.3	23.8	25.7	28.0	29.1	28.6	27.9	27.9	26.8	26.4	24.9	23.2
2. ea (mbar)	28.6	29.5	33.0	37.8	40.3	39.2	37.6	37.6	35.3	34.4	31.5	28.4
3. RHmean	0.71	0.69	0.63	0.58	0.56	0.66	0.68	0.64	0.67	0.79	0.80	0.78
4. ea (mbar)	20.3	20.4	20.8	21.9	22.6	25.9	25.6	24.1	23.7	27.2	25.2	22.2
5. (ea-ed)	8.3	9.1	12.2	15.9	17.7	13.3	12.0	13.5	11.6	7.2	6.3	6.2
6. U (km/day)	138	118	148	156	123	118	122	128	133	113	160	129
7. f(u)	0.64	0.59	0.67	0.69	0.60	0.59	0.60	0.62	0.63	0.58	0.70	0.62
8. Tmax	29.9	31.0	33.3	34.7	35.6	35.3	34.5	34.5	33.8	32.5	30.1	28.9
9. Tmin	16.7	16.3	17.8	20.3	2.18	21.7	21.2	21.0	20.4	20.2	19.2	18.6
10. (Tmax + Tmin)/2	23.3	23.7	25.6	27.5	28.7	28.5	27.9	27.9	27.1	26.3	24.7	23.8
11. 1 - W	0.28	0.27	0.25	0.23	0.23	0.23	0.23	0.23	0.24	0.25	0.26	0.27
12. (1-W)f(u)(ea-ed)	1.49	1.45	2.04	2.52	2.44	1.80	1.66	1.93	1.75	1.04	1.15	1.04
13. Ra	11.8	13.1	14.6	15.6	16.1	16.0	16.0	15.8	14.9	13.7	12.2	11.3
14. n(hr/day)												
15. N(")												
16. n/N	0.30	0.50	0.65	0.75	0.65	0.55	0.50	0.40	0.30	0.40	0.15	0.40
17. 0.25+0.50n/N	0.40	0.50	0.58	0.63	0.58	0.53	0.50	0.45	0.40	0.45	0.33	0.45
18. Rs=13*17	4.72	6.55	8.47	9.83	9.34	8.48	8.00	7.11	5.96	6.17	4.03	5.09
19. Rns=0.75Rs	3.54	4.91	6.35	7.37	7.01	6.36	6.00	5.33	4.47	4.63	3.02	3.82
20. f(T)	15.3	15.4	15.9	16.3	16.5	16.4	16.3	16.3	16.1	15.9	15.6	15.3
21. f(ed)	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17
22. f(n/N)	0.37	0.55	0.69	0.78	0.69	0.60	0.55	0.46	0.37	0.46	0.24	0.46
23. Rnl=20*21*22	0.96	1.44	1.76	2.03	1.82	1.57	1.43	1.20	0.95	1.17	0.64	1.20
24. Rn=Rns-Rnl	2.58	3.47	4.59	5.34	5.19	4.79	4.57	4.13	3.52	3.46	2.38	2.62
25. W	0.72	0.73	0.75	0.77	0.77	0.77	0.77	0.77	0.76	0.75	0.74	0.73
26. W.Rn	1.86	2.53	3.44	4.11	4.00	3.69	3.52	3.18	2.68	2.60	1.76	1.91
27. 12 + 26	3.35	3.98	5.48	6.63	6.44	5.49	5.18	5.11	4.43	3.64	2.91	2.95
28. ETo (C=1.0)	3.35	3.98	5.48	6.63	6.44	5.49	5.18	5.11	4.43	3.64	2.91	2.95
29. Open Water (kc=1.1)	3.7	4.4	6.0	7.3	7.1	6.0	5.7	5.6	4.9	4.0	3.2	3.2

TABLE D-4. DAILY MEAN RAINFALL AT SAGAT

(Year --- 1977 - 1985) (UNIT: mm)

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1	0.0	0.0	1.3	0.8	0.0	0.0	2.2	3.2	4.1	3.2	6.3	0.1
2	0.0	0.5	0.0	1.0	0.0	11.6	1.5	13.5	7.6	1.4	17.8	7.2
3	0.7	0.0	0.0	1.8	0.0	7.2	6.8	4.9	3.4	3.7	3.5	3.3
4	1.2	0.0	0.2	0.1	1.4	4.5	8.8	2.1	22.7	1.9	16.2	1.9
5	0.4	0.4	0.0	0.0	6.0	6.6	2.8	10.7	5.0	2.1	1.6	0.3
6	0.6	0.3	0.0	0.0	2.1	1.2	1.6	11.6	1.2	0.1	7.7	1.5
7	0.5	0.2	0.0	0.0	0.0	0.2	1.7	2.5	0.4	2.3	3.0	0.6
8	0.0	0.2	0.0	0.0	9.2	1.9	0.3	11.0	1.3	0.6	6.7	0.1
9	0.0	0.0	1.2	0.1	0.8	4.1	2.7	2.5	1.5	3.1	3.0	0.3
10	1.1	0.3	5.0	0.0	0.0	5.6	5.8	3.1	0.4	8.0	3.2	0.0
11	2.7	0.4	0.5	0.0	0.9	6.8	0.1	0.5	1.8	3.0	0.1	4.0
12	3.1	0.9	0.3	0.0	3.4	8.5	1.7	16.4	6.9	7.7	2.1	4.9
13	2.2	0.3	0.1	4.7	1.7	4.6	1.2	5.1	6.9	8.9	15.3	8.0
14	2.5	0.4	2.2	1.4	2.9	10.6	1.3	11.0	10.2	0.8	12.7	4.3
15	0.0	0.5	4.2	5.5	9.6	4.2	2.0	2.0	4.3	0.6	12.7	3.4
16	0.0	0.4	2.6	2.3	4.3	9.8	7.7	0.0	5.6	0.3	2.3	0.8
17	0.8	0.5	3.4	4.1	3.2	17.2	14.2	0.0	7.3	0.1	0.0	0.0
18	0.0	0.5	0.1	5.6	7.5	7.0	15.9	5.9	0.4	4.9	5.3	3.1
19	2.4	0.1	0.0	3.5	2.8	7.4	13.1	4.8	0.4	4.7	12.1	0.1
20	5.3	0.0	1.2	12.5	0.0	2.2	24.3	3.7	4.7	12.6	3.2	0.8
21	3.9	0.3	0.0	3.4	3.3	9.2	5.8	0.0	1.3	25.1	1.2	1.1
22	0.2	0.0	0.0	2.0	7.0	12.3	6.2	0.6	9.3	27.0	1.5	4.6
23	1.1	0.0	0.2	1.8	1.4	5.0	4.4	11.5	7.7	13.3	11.2	1.4
24	0.0	0.0	2.3	6.4	20.4	1.1	12.6	26.4	1.4	10.8	12.6	1.5
25	0.0	0.0	3.9	2.5	13.1	1.0	6.1	11.6	0.5	10.9	4.5	1.5
26	0.0	0.1	1.2	3.2	17.6	2.4	7.7	1.1	8.8	20.0	0.7	2.9
27	0.0	1.2	1.1	15.4	2.7	8.3	1.2	24.9	9.3	12.9	2.8	1.4
28	0.0	2.1	0.0	11.0	11.0	2.7	0.0	13.9	13.7	8.6	3.1	0.3
29	0.6	-	0.0	14.7	5.0	6.2	0.1	14.8	8.1	15.1	5.0	0.6
30	0.3	-	0.1	4.0	4.8	6.6	1.7	5.1	10.7	18.5	2.7	1.0
31	0.2	-	0.0	-	0.4	-	4.0	3.2	-	12.4	-	2.2
TOTAL	29.8	9.7	31.2	107.8	142.7	175.8	165.5	227.8	166.8	244.5	180.1	63.2

* ANNUAL REINFALL = 1545.0 (mm)

TABLE D-5. IRRIGATION AREA-SHORTAGE RELATIONSHIP DURING WET CROP

YEAR	W/O AREA REDUCTION			REDUCTION CURVE-1			REDUCTION CURVE-2		
	STAGE	SHORT.	RATE	STAGE	SHORT.	RATE	STAGE	SHORT.	RATE
	(EL.M)	(MCM)	(%)	(EL.M)	(MCM)	(%)	(EL.M)	(MCM)	(%)
1953	183.06	-	-	182.98	-	-	182.83	-	-
1954	183.90	140.0	10.4	184.05	123.6	13.8	183.99	83.6	14.9
1955	180.87	15.0	1.1	181.93	1.1	6.3	183.40	0.1	9.4
1956	181.41	-	-	183.68	-	-	183.99	-	-
1957	184.81	10.8	0.8	184.89	7.4	4.6	184.95	2.2	7.9
1958	171.54	180.1	13.3	173.85	43.0	15.5	174.76	6.0	19.3
1959	184.47	141.7	10.5	183.85	123.7	14.0	184.50	95.5	15.3
1960	184.67	0.9	0.1	183.77	0.2	-	184.06	-	-
1961	171.43	89.8	6.6	174.20	15.5	13.2	174.66	-	-
1962	180.11	-	-	183.62	-	-	183.93	-	-
1963	182.72	-	-	183.63	-	-	183.73	-	-
1964	181.17	-	-	181.57	-	-	181.69	-	-
1965	183.33	-	-	183.58	-	-	183.46	-	-
1966	183.91	64.0	4.8	183.86	54.8	8.9	184.14	55.8	12.7
1967	178.51	-	-	180.01	-	-	180.10	-	-
1968	184.51	-	-	183.85	-	-	184.67	-	-
1969	169.92	174.0	12.9	171.58	87.7	20.4	172.68	68.8	26.2
1970	183.41	9.3	0.7	184.41	3.1	4.6	184.56	-	-
1971	184.21	-	-	184.57	-	-	183.97	-	-
1972	184.40	-	-	184.32	-	-	183.57	-	-
1976	184.29	-	-	183.66	-	-	183.54	-	-
1977	181.60	-	-	183.21	-	-	183.30	-	-
1978	166.81	236.8	17.5	169.35	122.6	24.7	170.00	87.5	30.5
1979	175.75	80.9	6.0	178.25	-	-	179.40	-	-
1980	175.51	90.0	6.7	179.45	0.3	8.1	181.11	-	-
1981	180.06	-	-	181.88	-	-	182.13	-	-
1982	176.00	-	-	181.09	-	-	181.80	-	-
1983	181.59	445.6	33.0	182.82	326.9	29.8	183.35	263.5	29.0
1984	175.92	-	-	178.83	-	-	180.25	-	-
1985	169.34	16.3	1.2	171.46	-	-	172.99	-	-

NOTES: (1) STAGE...RESERVOIR WATER STAGE AT THE END OF MARCH
(2) SHORTAGE...IRRIGATION WATER SHORTAGE DURING WET SEASON CROP (MCM)
(3) RATE...RATE OF SHORTAGE (=SHORTAGE/DEMAND) (%)

TABLE D-6. IRRIGATION AREA-SHORTAGE RELATIONSHIP DURING DRY CROP

YEAR	W/O AREA REDUCTION STAGE (EL.M)	SHORT. (MCM)	RATE (%)	REDUCTION CURVE-1 STAGE (EL.M)	SHORT. (MCM)	RATE (%)	REDUCTION CURVE-2 STAGE (EL.M)	SHORT. (MCM)	RATE (%)
1953	187.77	-	-	187.73	-	-	187.53	-	-
1954	178.45	10.3	0.8	178.48	6.5	14.8	178.36	5.5	20.3
1955	185.01	-	-	185.07	-	-	185.08	-	-
1956	178.64	-	-	178.61	-	-	178.87	-	-
1957	188.36	99.7	7.6	188.37	53.9	13.2	188.43	34.2	15.6
1958	193.00	81.7	6.3	193.00	31.2	9.1	193.00	21.1	11.5
1959	179.03	0.2	-	178.96	-	-	178.98	-	-
1960	185.58	229.2	17.5	185.58	154.6	22.4	185.57	108.9	23.3
1961	183.19	100.1	7.7	183.04	60.8	16.5	183.23	55.7	20.9
1962	186.32	-	-	186.31	-	-	186.31	-	-
1963	189.77	38.5	2.9	189.77	26.6	10.4	189.77	23.3	13.9
1964	189.69	-	-	189.69	-	-	189.69	-	-
1965	184.73	3.5	0.3	184.82	-	-	184.84	6.1	28.7
1966	179.28	-	-	178.94	-	-	179.24	-	-
1967	193.00	-	-	193.00	-	-	193.00	-	-
1968	193.00	164.8	12.6	193.00	117.1	15.7	193.00	101.5	17.7
1969	179.64	-	-	179.63	-	-	179.35	-	-
1970	189.19	-	-	189.19	-	-	189.19	-	-
1971	193.00	-	-	193.00	-	-	193.00	-	-
1972	188.93	115.2	8.8	188.93	90.7	15.8	188.93	80.2	18.8
1976	190.28	16.3	1.2	190.28	11.9	9.0	190.28	10.7	12.6
1977	185.25	152.1	11.6	185.14	84.9	17.3	185.23	57.5	19.6
1978	193.00	-	-	193.00	-	-	193.00	-	-
1979	183.64	14.4	1.1	183.42	-	-	183.45	-	-
1980	183.03	-	-	182.97	-	-	183.09	-	-
1981	179.68	-	-	179.68	-	-	179.68	-	-
1982	178.26	48.3	3.7	178.08	27.5	16.6	178.19	20.3	21.6
1983	176.31	201.6	15.4	176.38	83.8	21.8	176.48	51.7	25.2
1984	180.49	163.9	12.5	180.64	69.6	18.5	180.60	47.7	22.0
1985	---			---			---		

NOTES: (1) STAGE...RESERVOIR WATER STAGE AT THE END OF SEPTEMBER
(2) SHORTAGE...IRRIGATION WATER SHORTAGE DURING DRY SEASON CROP (MCM)
(3) RATE...RATE OF SHORTAGE (=SHORTAGE/DEMAND) (%)

TABLE D-7. SHORTAGE OF IRRIGATION SUPPLY SIMULATED

YEAR	100% AREA WET	100% AREA DRY	WITH PROPOSED CROPPING SCHEDULE: REDUCTION-1 WET	REDUCTION-1 DRY	REDUCTION-2 WET	REDUCTION-2 DRY	REDUCTION-3 WET	REDUCTION-3 DRY
1953	-	-	-	-	-	-	-	-
1954	140.0	10.3	123.6	6.5	83.6	5.5	50.7	4.4
1955	15.0	-	1.1	-	0.1	-	-	-
1956	-	-	-	-	-	-	-	-
1957	10.8	99.7	7.4	53.9	2.2	34.2	-	20.0
1958	180.1	81.7	43.0	31.2	6.0	21.1	-	20.2
1959	141.7	0.2	123.7	-	95.5	-	83.9	-
1960	0.9	229.2	0.2	154.6	-	108.9	-	72.2
1961	89.8	100.1	15.5	60.8	-	55.7	-	45.7
1962	-	-	-	-	-	-	-	-
1963	-	38.5	-	26.6	-	23.3	-	21.1
1964	-	-	-	-	-	-	-	-
1965	-	3.5	-	-	-	-	-	-
1966	64.8	-	54.8	-	55.8	-	51.1	-
1967	-	-	-	-	-	-	-	-
1968	-	164.8	-	117.1	-	101.5	-	94.4
1969	174.0	-	87.7	-	68.8	-	56.1	-
1970	9.3	-	3.1	-	-	-	-	-
1971	-	-	-	-	-	-	-	-
1972	-	115.2	-	90.7	-	80.2	-	72.7
1976	-	16.3	-	11.9	-	10.7	-	10.0
1977	-	152.1	-	84.9	-	57.5	-	40.6
1978	236.8	-	122.6	-	87.5	-	56.9	-
1979	80.9	14.4	-	-	-	-	-	-
1980	90.0	-	0.3	-	-	-	-	-
1981	-	-	-	-	-	-	-	-
1982	-	48.3	-	27.5	-	20.3	-	15.0
1983	445.8	201.6	326.9	83.8	263.5	51.7	204.7	38.4
1984	-	163.9	-	69.6	-	47.7	-	33.7
1985	16.3	---	-	---	-	---	-	---
TOTAL	1696.2	1439.8	909.9	819.1	663.0	618.3	503.4	488.4
AVERAGE	56.5	48.0	30.3	27.3	22.1	20.6	16.8	16.3

TABLE D-8. MAGAT POWER PLANT CONTINUOUS OUTPUT

(UNIT = MW)

AREAL CONTROL		JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
100% PROJECTED AREA	MAX.	142.5	184.0	184.4	161.7	240.5	342.5	312.0	354.5	356.1	359.6	181.8	109.3	196.2
	MIN.	74.5	60.9	29.1	23.8	28.5	27.0	29.0	29.7	33.6	57.9	38.7	31.7	67.4
	AVE.	86.1	100.1	61.3	56.9	93.8	104.7	155.7	175.8	203.0	203.9	133.1	83.1	121.6
WITH REDUCTION CURVE-1	MAX.	147.3	181.4	199.2	182.3	238.0	333.5	309.7	354.8	356.3	359.9	181.9	110.7	196.5
	MIN.	63.5	61.8	29.8	25.2	32.3	32.8	31.0	29.5	32.4	57.4	38.8	31.6	67.9
	AVE.	79.7	102.6	60.3	60.6	94.1	108.9	159.3	176.7	203.6	204.1	133.1	84.0	122.3
WITH REDUCTION CURVE-2	MAX.	145.3	179.8	198.0	182.9	237.1	341.5	310.3	355.0	356.7	359.9	182.0	111.3	196.6
	MIN.	58.6	61.8	30.4	25.7	32.2	34.3	31.3	29.9	35.1	58.5	38.9	31.5	68.2
	AVE.	78.3	101.5	60.8	61.2	93.9	111.5	161.3	177.1	203.7	204.2	133.4	84.2	122.7
WITH REDUCTION CURVE-3	MAX.	144.2	178.3	208.0	182.7	245.7	333.4	308.5	355.1	357.2	360.0	182.1	111.8	196.7
	MIN.	53.6	57.4	31.4	26.4	31.7	34.6	32.6	29.7	32.8	58.7	39.0	31.5	68.4
	AVE.	75.6	102.8	60.5	61.9	94.2	112.6	163.2	178.0	203.8	204.6	133.2	84.5	123.0

TABLE D-9. BALIGATAN POWER PLANT CONTINUOUS OUTPUT

(UNIT = MW)

AREAL CONTROL		JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
100% PROJECTED AREA	MAX.	4.52	5.30	4.93	0.99	1.45	4.98	4.98	2.74	2.01	0.92	-	4.05	2.86
	MIN.	3.43	2.74	0.17	-	-	-	-	-	0.40	0.60	-	0.08	1.40
	AVE.	4.14	4.57	3.76	0.75	0.80	3.05	2.46	1.66	1.46	0.76	-	3.17	2.21
WITH REDUCTION CURVE-1	MAX.	4.21	4.91	4.57	0.95	1.38	4.77	4.71	2.62	1.91	0.86	-	3.77	2.68
	MIN.	3.06	3.00	0.84	-	-	-	-	-	0.34	0.49	-	0.72	1.32
	AVE.	3.75	4.28	3.73	0.78	0.83	3.16	2.39	1.54	1.35	0.68	-	2.94	2.11
WITH REDUCTION CURVE-2	MAX.	4.07	4.73	4.41	0.91	1.33	4.46	4.50	2.49	1.85	0.83	-	3.65	2.57
	MIN.	2.87	3.14	1.12	-	-	0.09	-	-	0.37	-	-	0.73	1.25
	AVE.	3.58	4.13	3.67	0.78	0.83	3.19	2.34	1.28	1.26	0.53	-	2.81	2.03
WITH REDUCTION CURVE-3	MAX	4.00	4.65	4.32	0.87	1.27	4.37	4.36	2.39	1.75	0.82	-	3.58	2.49
	MIN.	2.69	3.04	1.52	-	-	0.52	-	-	-	-	-	0.73	1.20
	AVE.	3.44	3.99	3.60	0.76	0.83	3.16	2.28	1.06	1.10	0.38	-	2.70	1.93

TABLE D-10. ENERGY FOR UNIT DISCHARGE CURVE OF MAGAT H.E.P

Water Level of Magat Reservoir	Net head m	Turbine Output kW	Wicket Gate Openning %	Plant Discharge C.M.S.	Turbine Efficiency	Energy for Unit Discharge kW/C.M.S.
EL. 193.0 (F.S.W.L.)	89.0	90	75.0	113.0	91.3	796.46
EL. 185.0 (R.S.W.L.)	81.0	90	86.7	124.0	91.4	725.81
EL. 174.0	70.0	70	84.5	112.5	90.8	622.22
EL. 160.0 (M.S.W.L.)	56.0	50	86.0	102.0	89.3	490.20

Note:

1/: This table was computed on the basis of "Magat Operation Diagram".

TABLE D-11. ENERGY FOR UNIT DISCHARGE CURVE OF BALIGATAN H.E.P

Water Level of Magat Reservoir	Net Head m	Plant Discharge C.M.S.	Efficiency of Turbine	Turbine Output		Generator Output kW	Energy for unit Discharge kW/C.M.S.	Adopted Value		
				kW	H.P.			Max. Discharge	kW	kW/C.M.S.
EL.193.0m (F.S.W.L)	38.0	18.92	0.881	6,208	8,445	6,022	318.3	18.92	6,000	317.1
EL.185.0m (R.S.W.L)	30.0	23.78	0.888	6,208	8,445	6,022	253.2	23.78	6,000	252.3
	30.0	16.6	0.908	4,431	6,029	4,298	258.9			
	30.0	10.0	0.885	2,602	3,540	2,524	252.4			
EL.179.0m	24.0	19.2	0.899	4,060	5,523	3,938	205.1	19.45	4,000	205.7
	24.0	15.9	0.903 5	3,379	4,597	3,278	206.2			
EL.172.0m (M.S.W.L)	15.0	12.6	0.857	1,587	2,159	1,539	122.1	12.94	1,580	122.1
	15.0	10.0	0.836	1,229	1,672	1,192	119.2			
(Min. Output)	15.0	7.6	0.823	919	1,250	891 3/	117.2			

Note:
1/: This table was computed on the basis of "Description of Hydraulic Turbine"
2/: The efficiency of generator is 0.97
3/: The minimum output is 890 kW (1,250 H.P.)

FIGURE D-1. DIAGRAM FOR MAGAT RESERVOIR SIMULATION

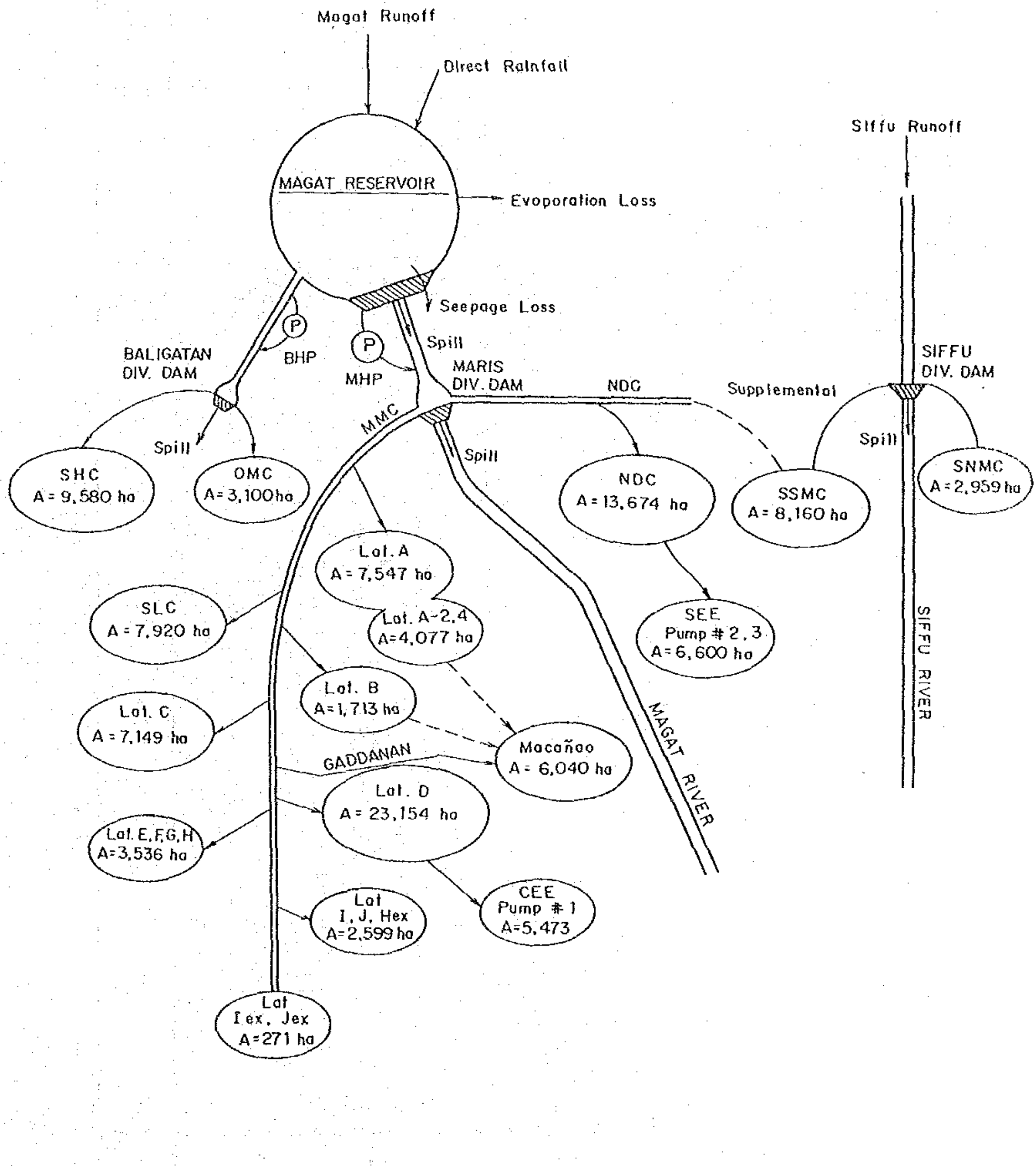


FIGURE D-2. SEEPAGE LOSSES FROM MAGAT RESERVOIR

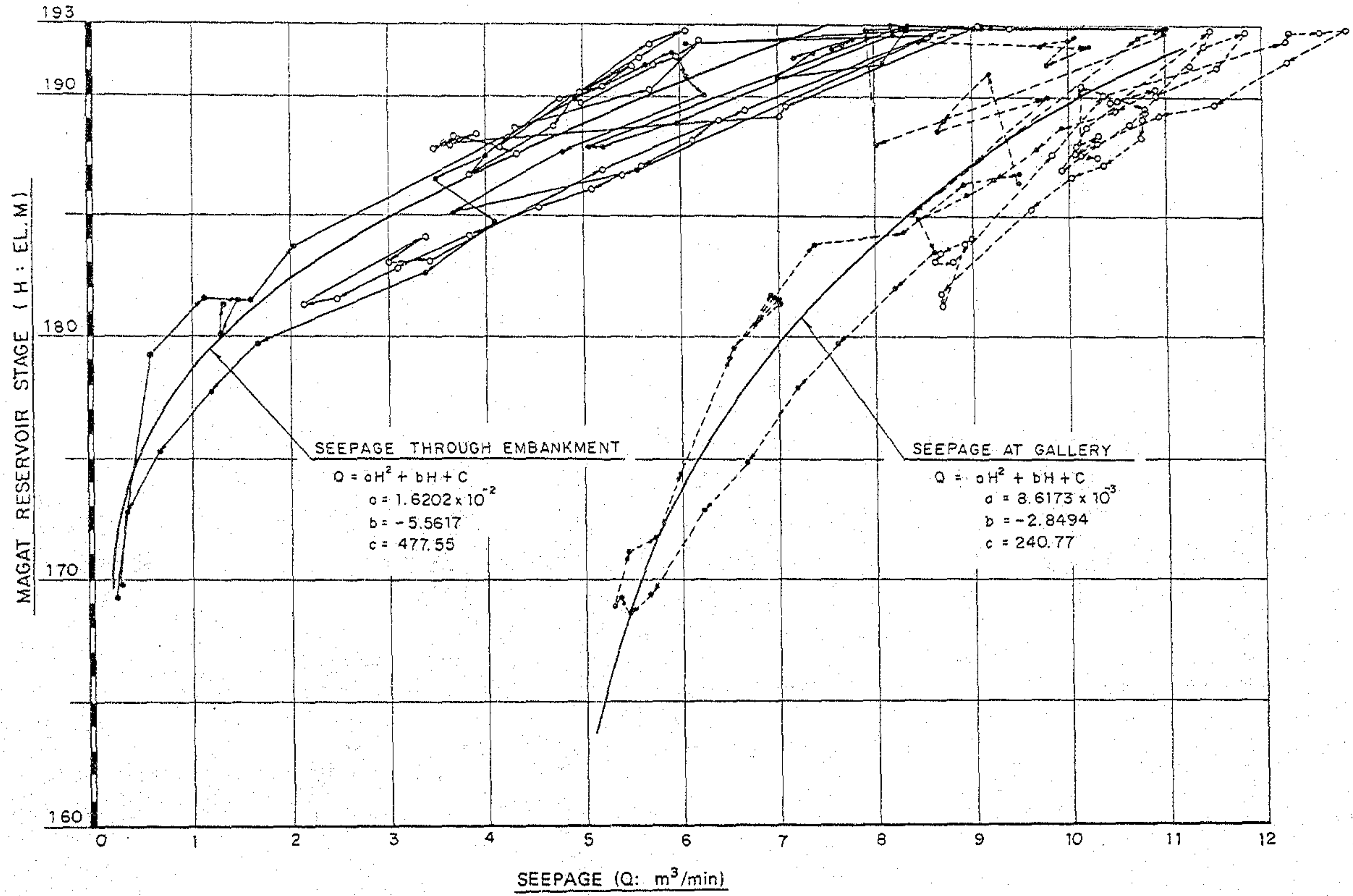


FIGURE D-3. REQUIRED STORAGE FOR EACH YEAR (PROPOSED CROPPING PATTERN)

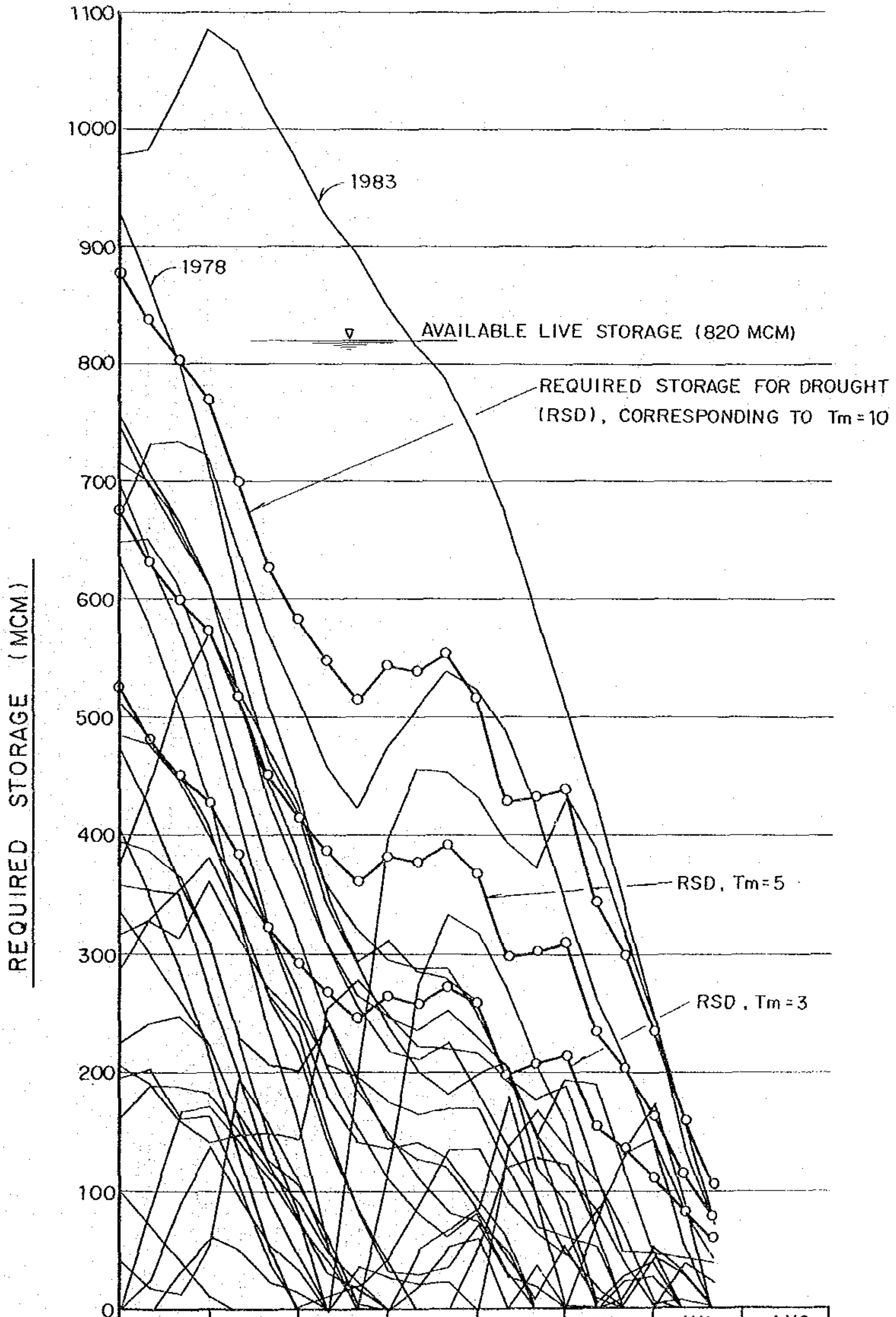
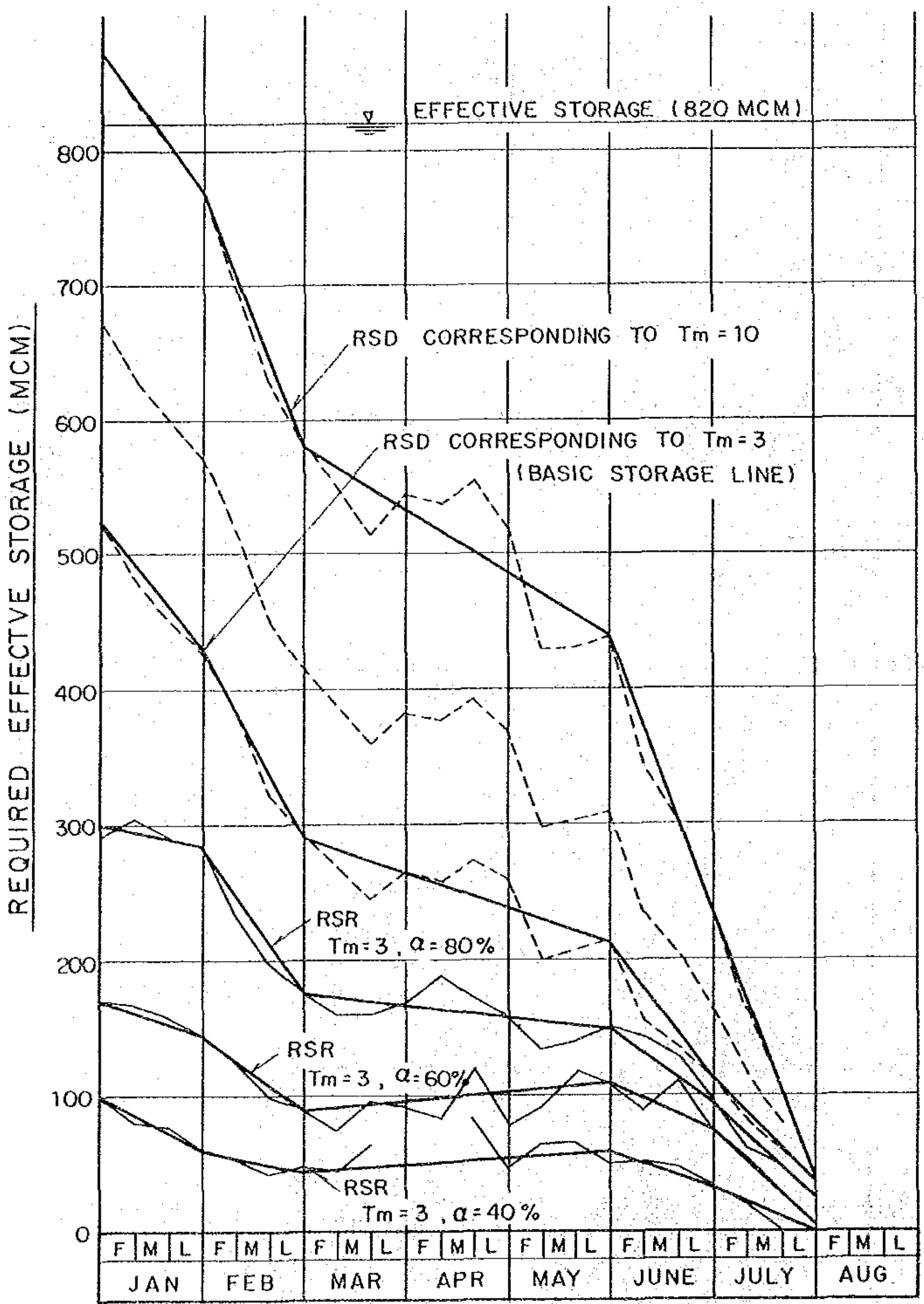


FIGURE D-4. REQUIRED STORAGE FOR DROUGHT AND REQUIRED STORAGE DURING RESTRICTIVE PERIOD



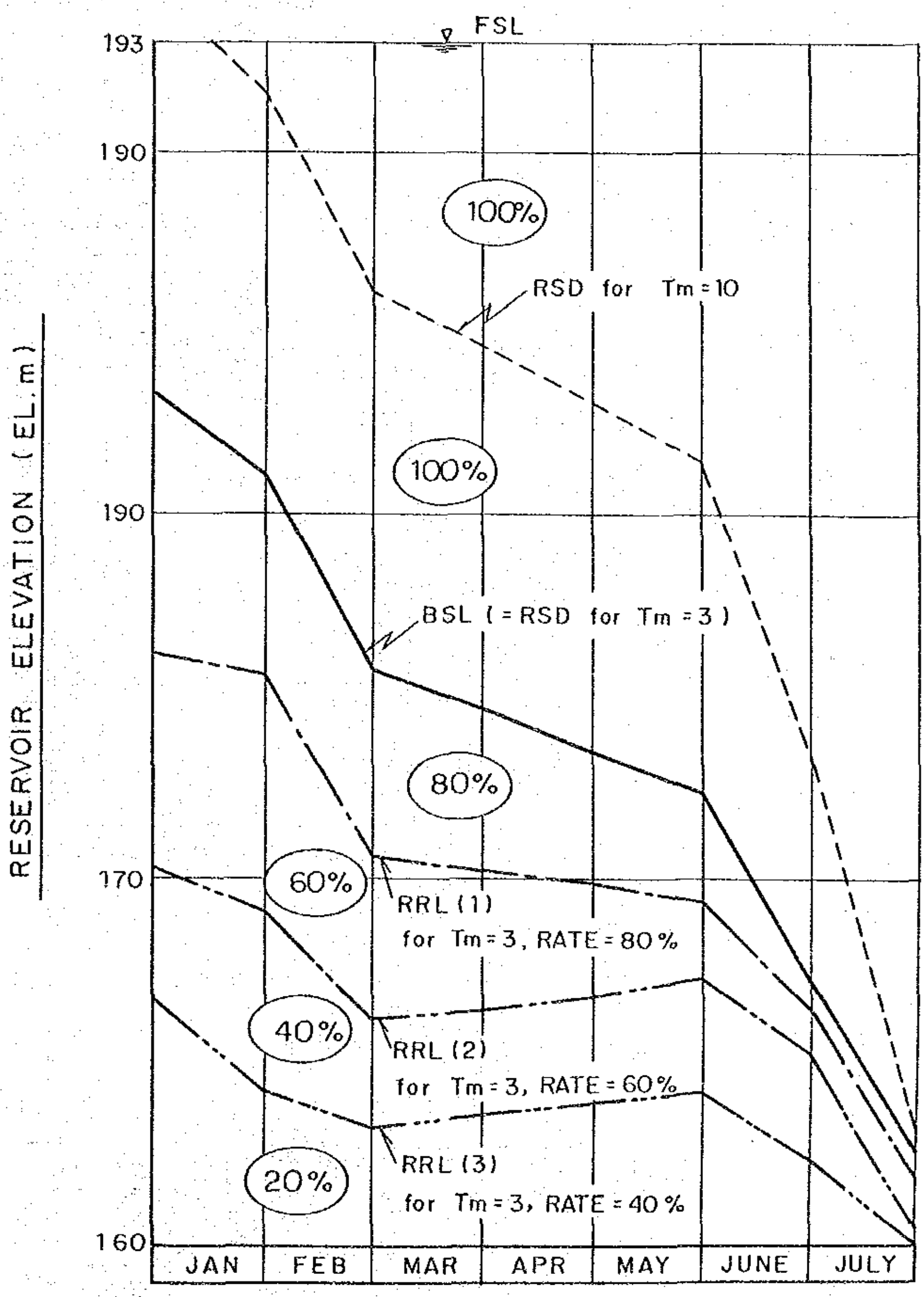
NOTE: RSD ···· REQUIRED STORAGE FOR DROUGHT

RSR ···· REQUIRED STORAGE DURING RESTRICTIVE PERIOD

α ···· RATE OF RESTRICTION

FIGURE D-5. OPERATION RULE CURVE DURING DRY PERIOD

Note ; Basic Storage Line (BSL) and Restrictive Release Lines (RRL) are approximated by straight lines, and then storage volumes are converted into elevations.

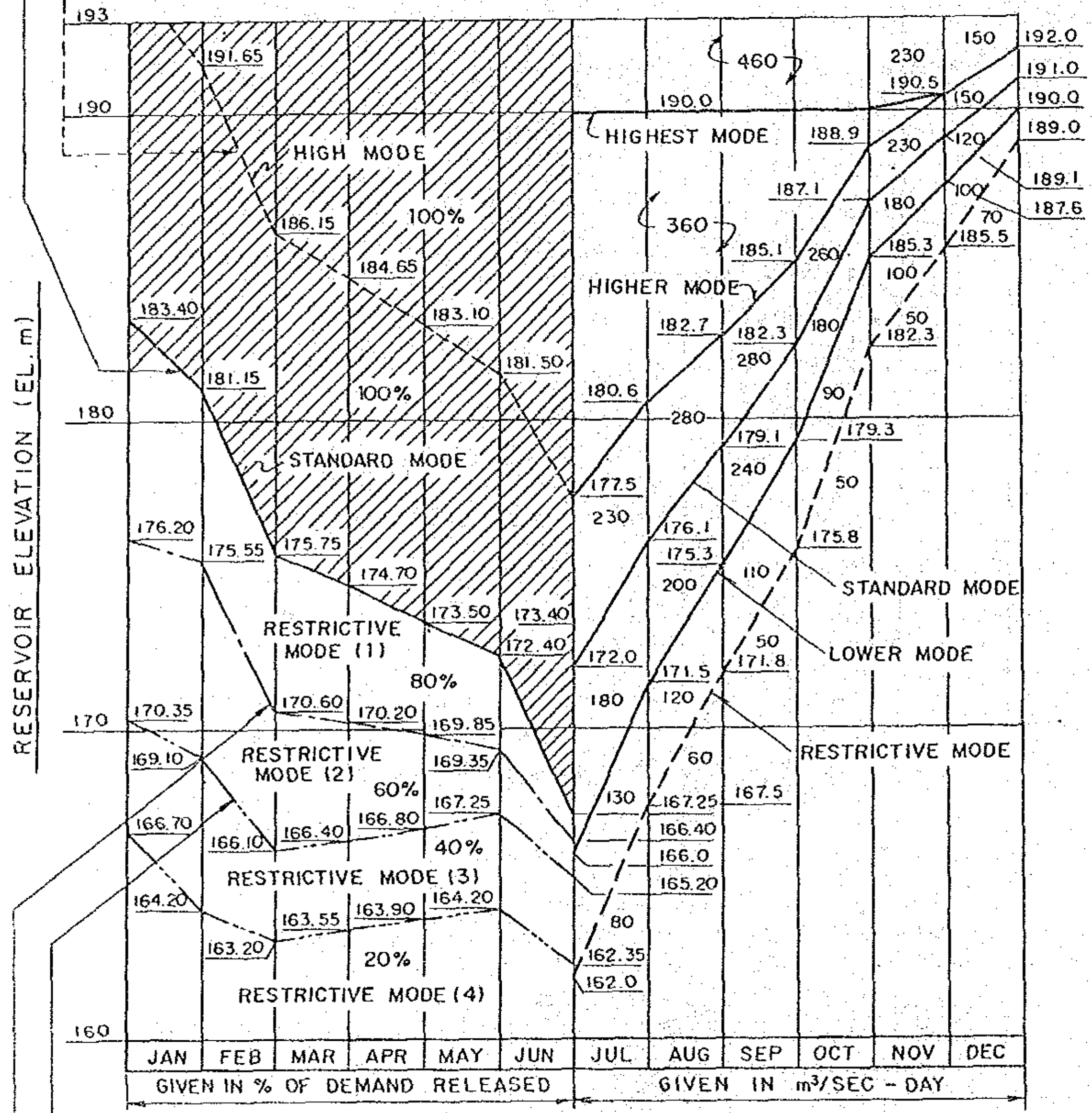


NOTES : BSL ····· BASIC STORAGE LINE
RSD ····· REQUIRED STORAGE FOR DROUGHT
RRL ····· RESTRICTIVE RELEASE LINE

FIGURE D-6. MAGAT RESERVOIR OPERATION RULE CURVE

Basic storage line which corresponds to required storage in preparation for 3-year drought. 100% of irrigation demand is allowable to be released, whenever the reservoir level is above this line.

Basic storage line which corresponds to required storage in preparation for 10-year drought. Available storage above this line is usable for power generation only whenever the reservoir level exceeds the line.



Restrictive release line (1) corresponding to 3-year drought with 40% saving of water. Above the line 60 % demand is releasable.

Restrictive release line (2) corresponding to 3-year drought with 20 % saving. Above the line, 80 % demand is releasable.

FIGURE D-7. ENVELOPE CURVE FOR IRRIGATION AREA REDUCTION

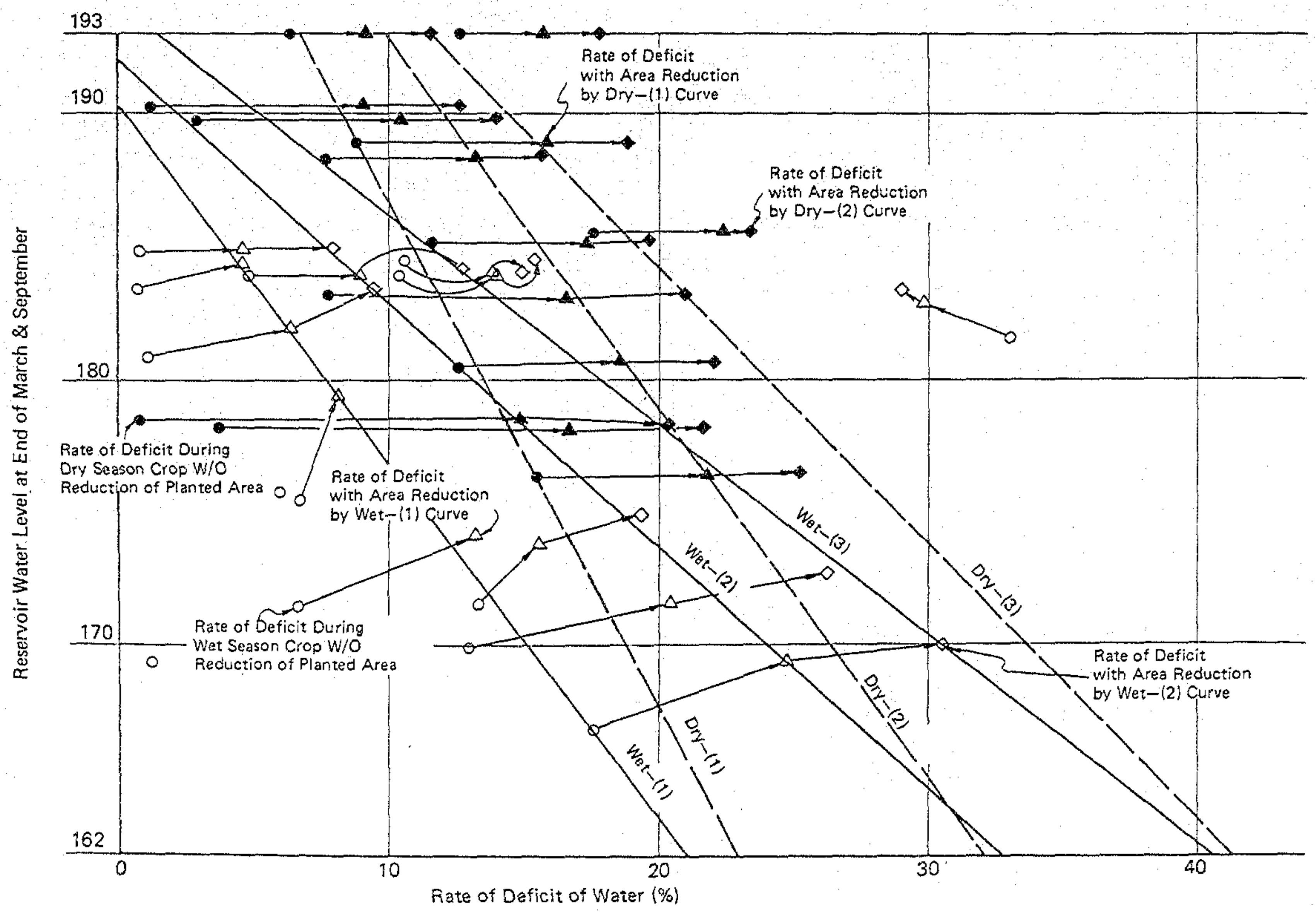


FIGURE D-8. RESERVOIR STAGE, SPILLAGE AND SHORTAGE SIMULATED
(PROPOSED CROPPING SCHEDULE WITH 100% PROJECTED AREA)

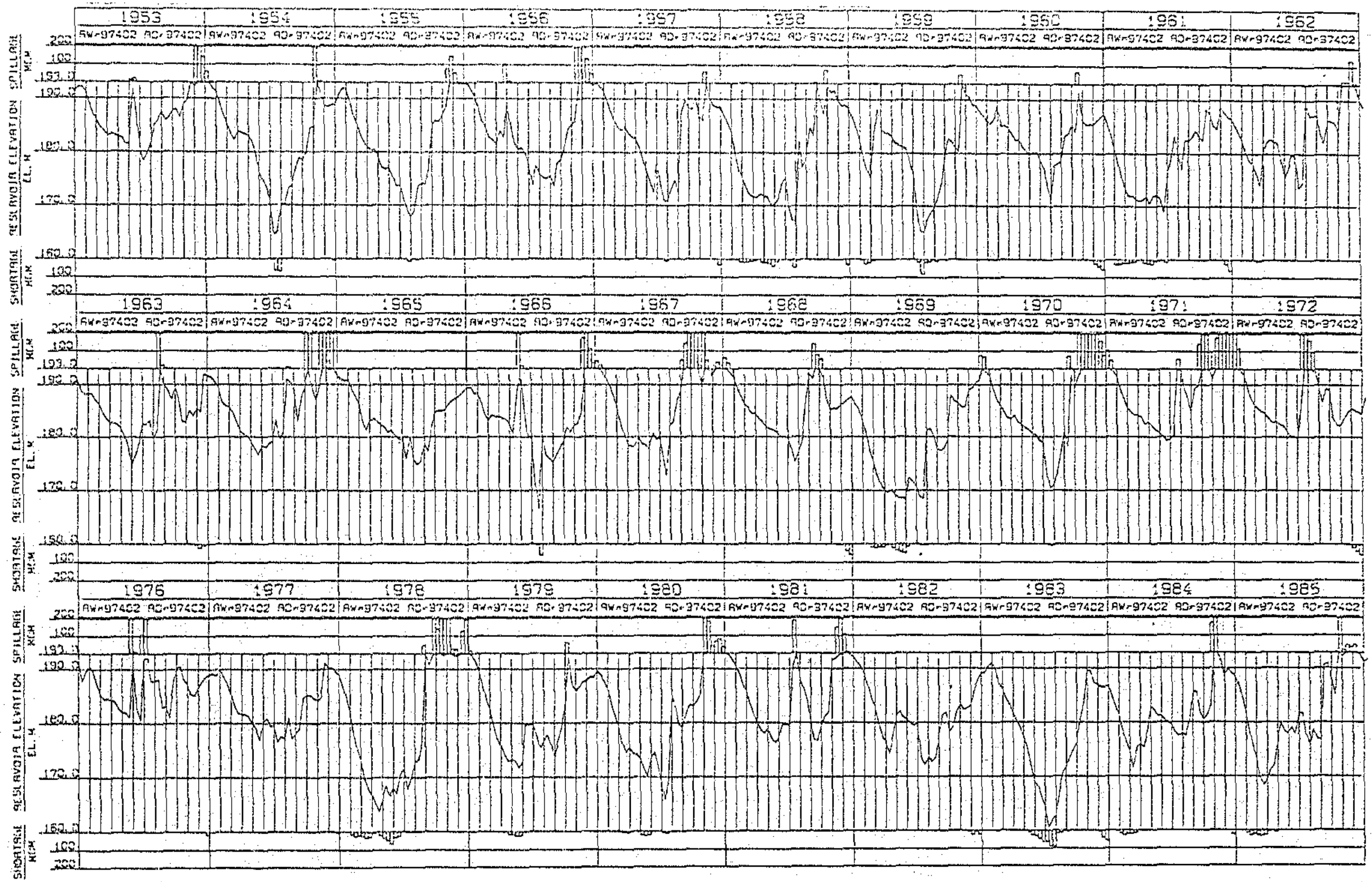


FIGURE D-9. WATER ALLOCATION SIMULATED
(PROPOSED CROPPING SCHEDULE WITH 100% PROJECTED AREA)

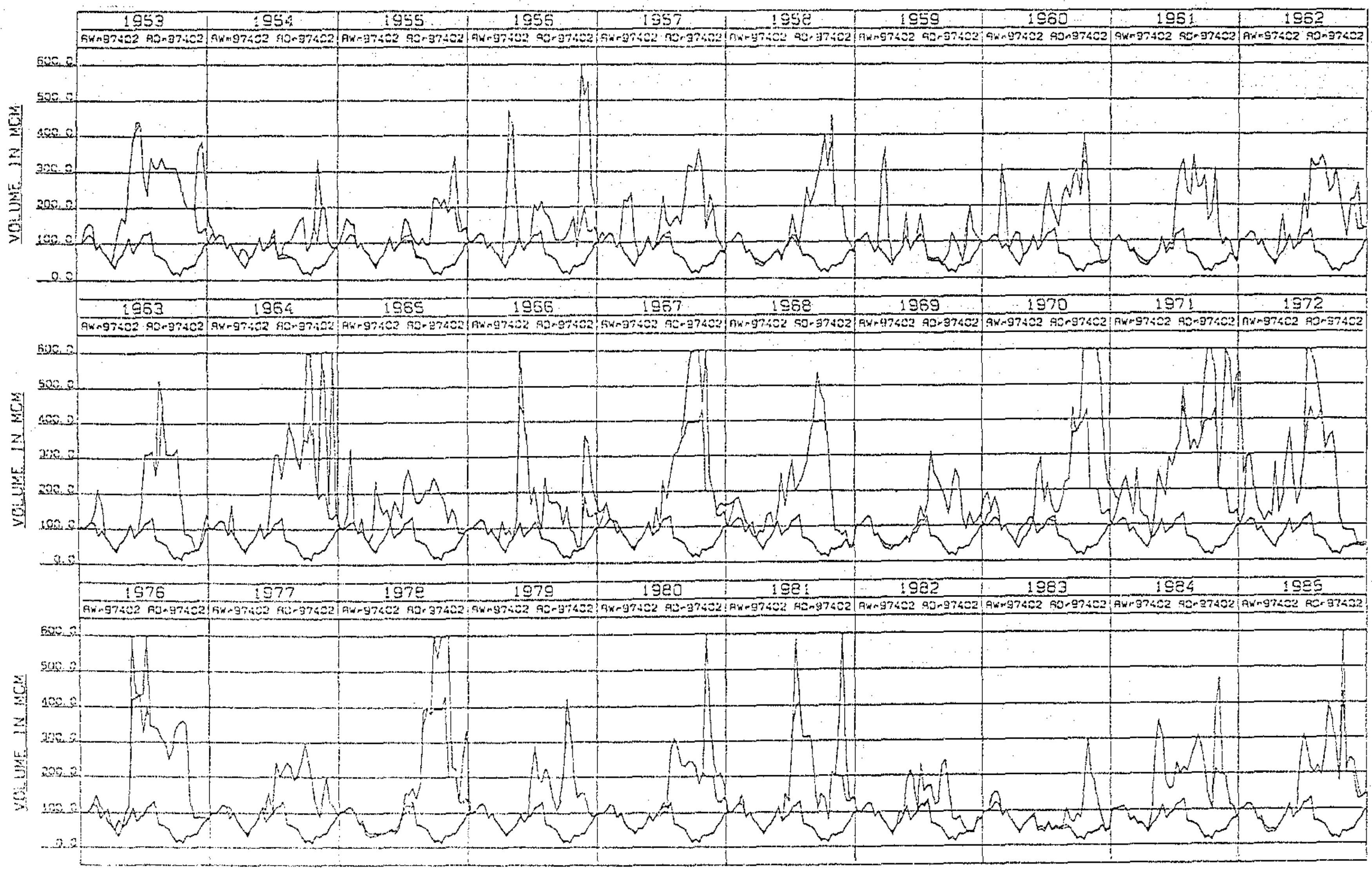


FIGURE D-10. POWER GENERATED AT MAGAT AND BALIGATAN PLANT
(PROPOSED CROPPING SCHEDULE WITH 100% PROJECTED AREA)

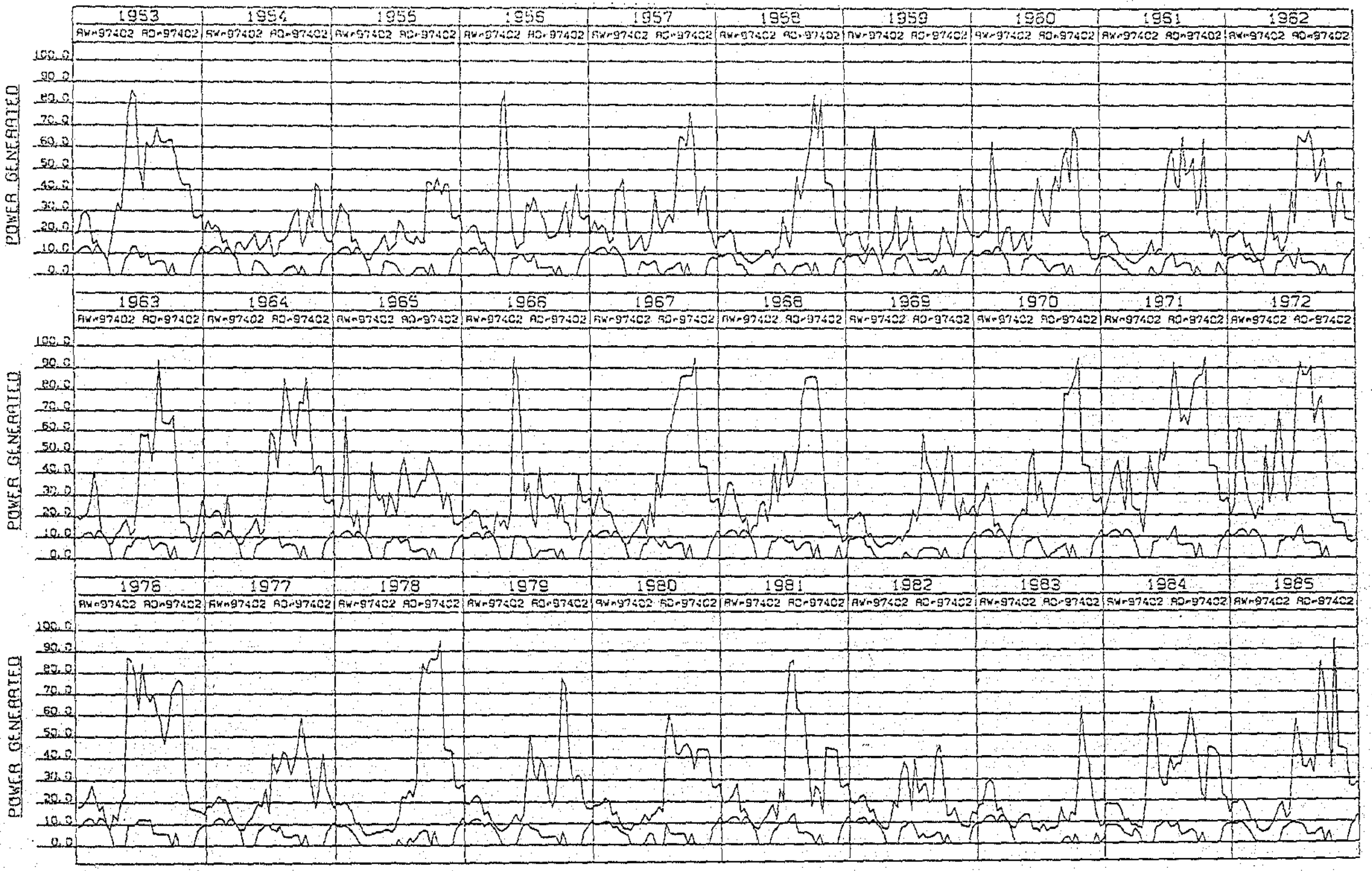


FIGURE D-11. OPERATION RULE CURVE AND SIMULATED STAGE
(PROPOSED CROPPING SCHEDULE WITH 100% PROJECTED AREA)

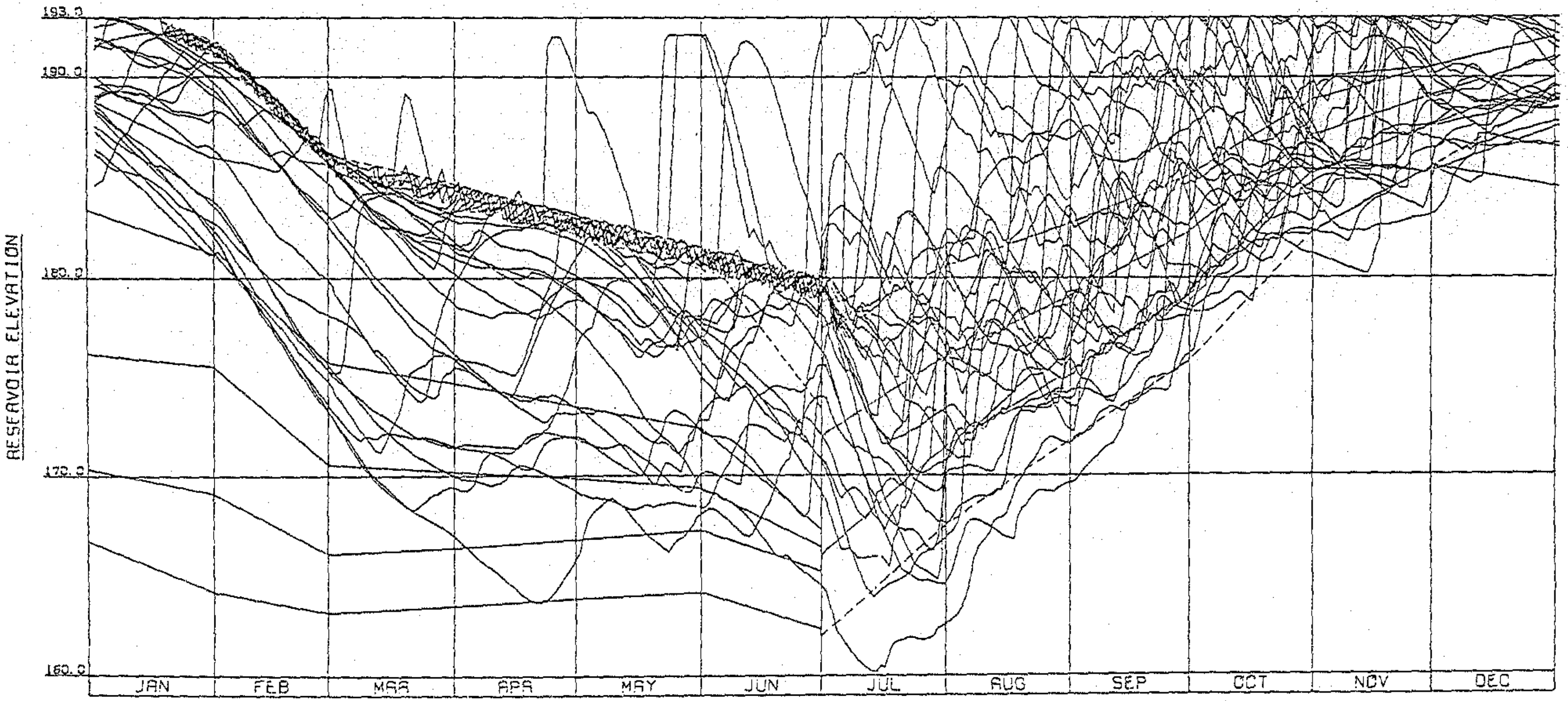


FIGURE D-12. SEASONAL PATTERN OF POWER GENERATED
(PROPOSED CROPPING SCHEDULE WITH 100% PROJECTED AREA)

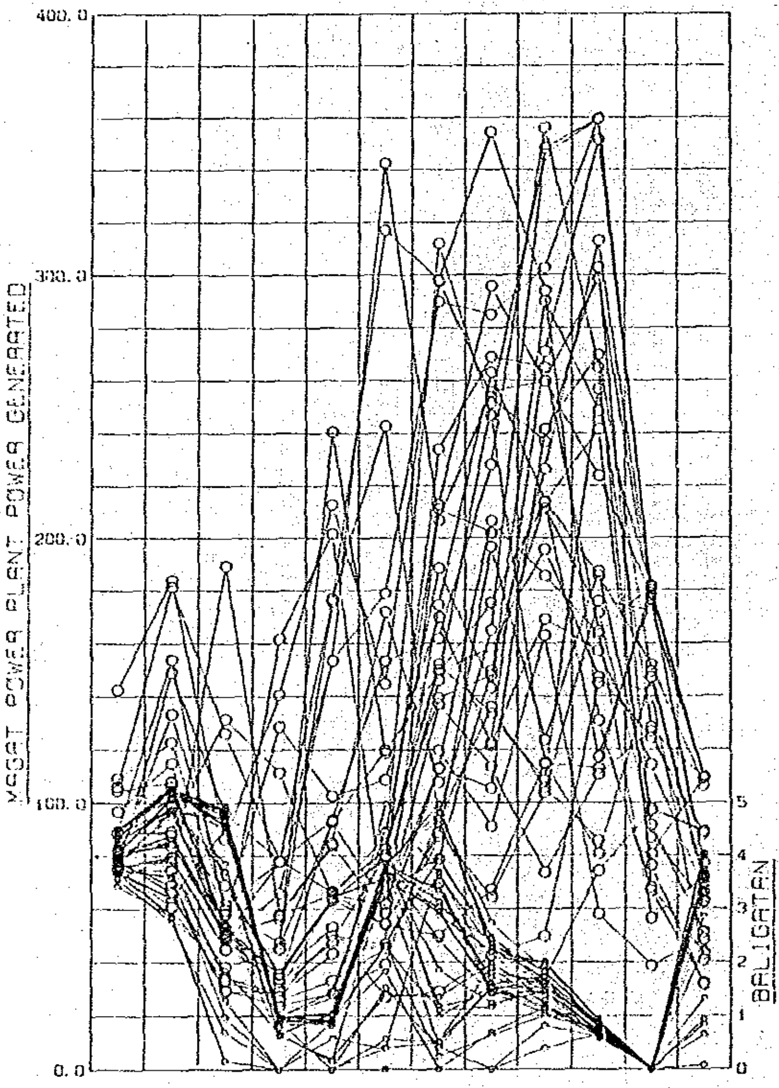


FIGURE D-13. RESERVOIR STAGE, SPILLAGE AND SHORTAGE SIMULATED
(PROPOSED CROPPING SCHEDULE WITH AREA REDUCTION)

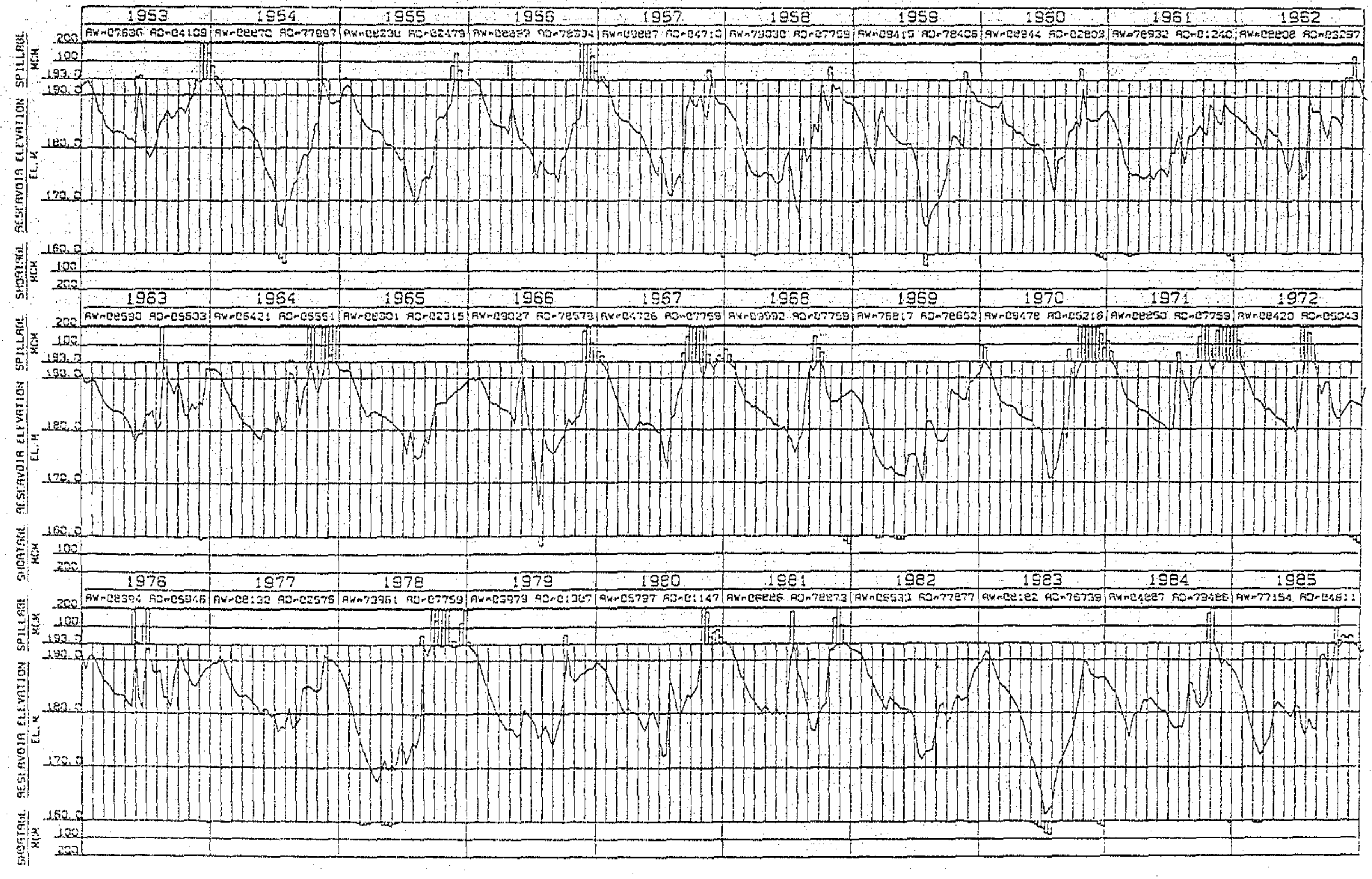


FIGURE D-14. WATER ALLOCATION SIMULATED
(PROPOSED CROPPING SCHEDULE WITH AREA REDUCTION)

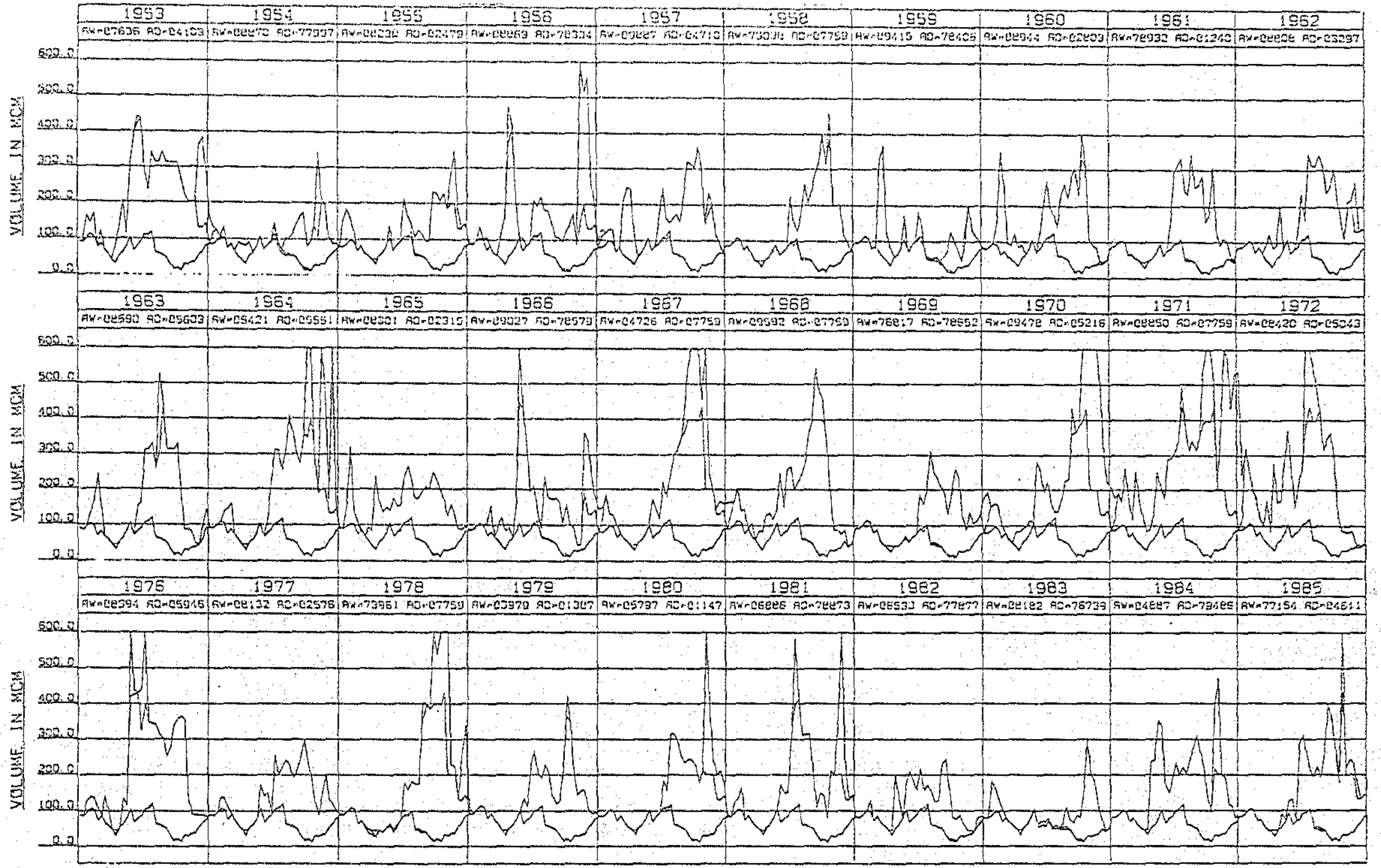


FIGURE D-15. POWER GENERATED AT MAGAT AND BALIGATAN PLANT
(PROPOSED CROPPING SCHEDULE WITH AREA REDUCTION)

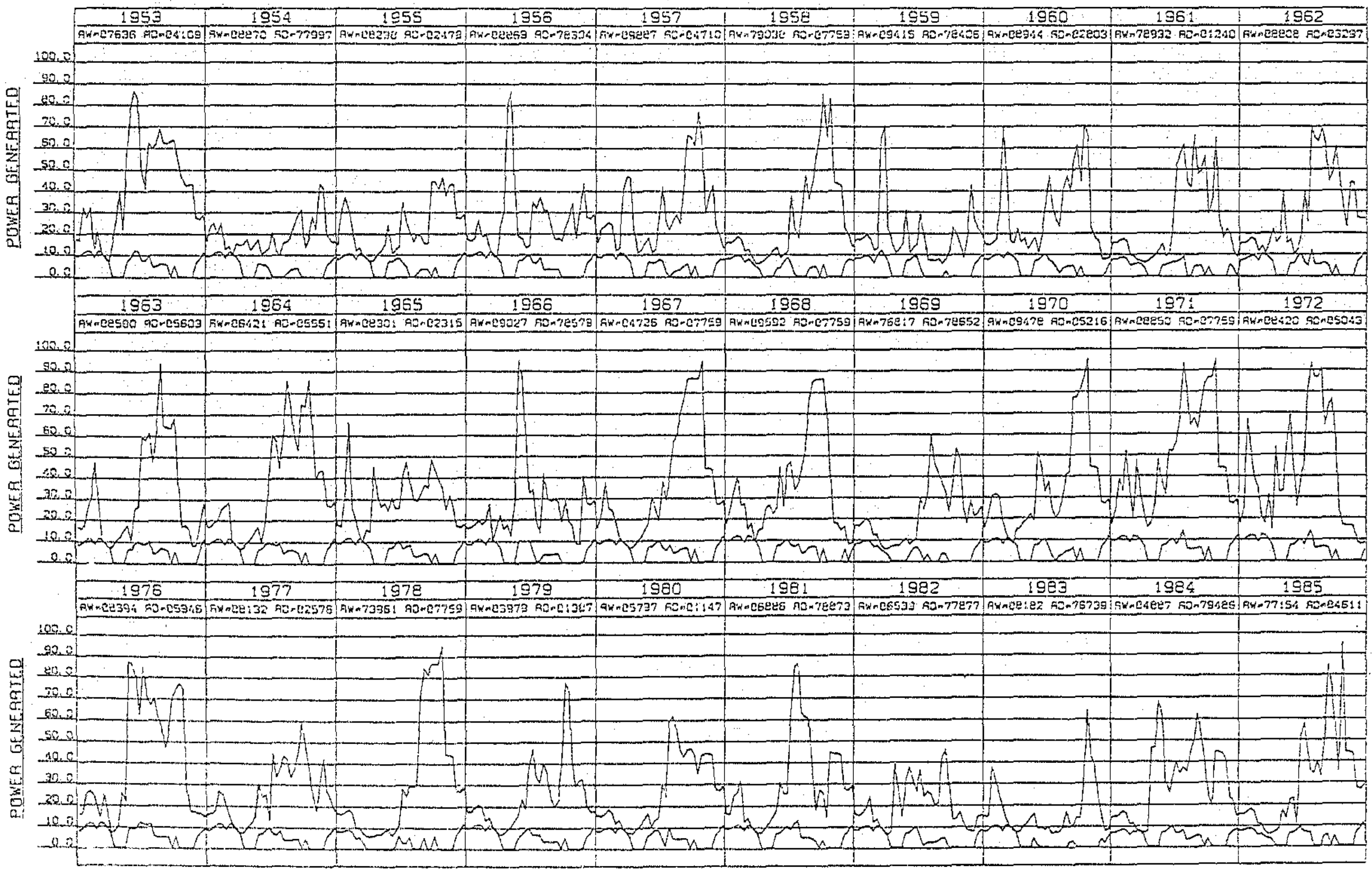


FIGURE D-16. OPERATION RULE CURVE AND SIMULATED STAGE
(PROPOSED CROPPING SCHEDULE WITH AREA REDUCTION)

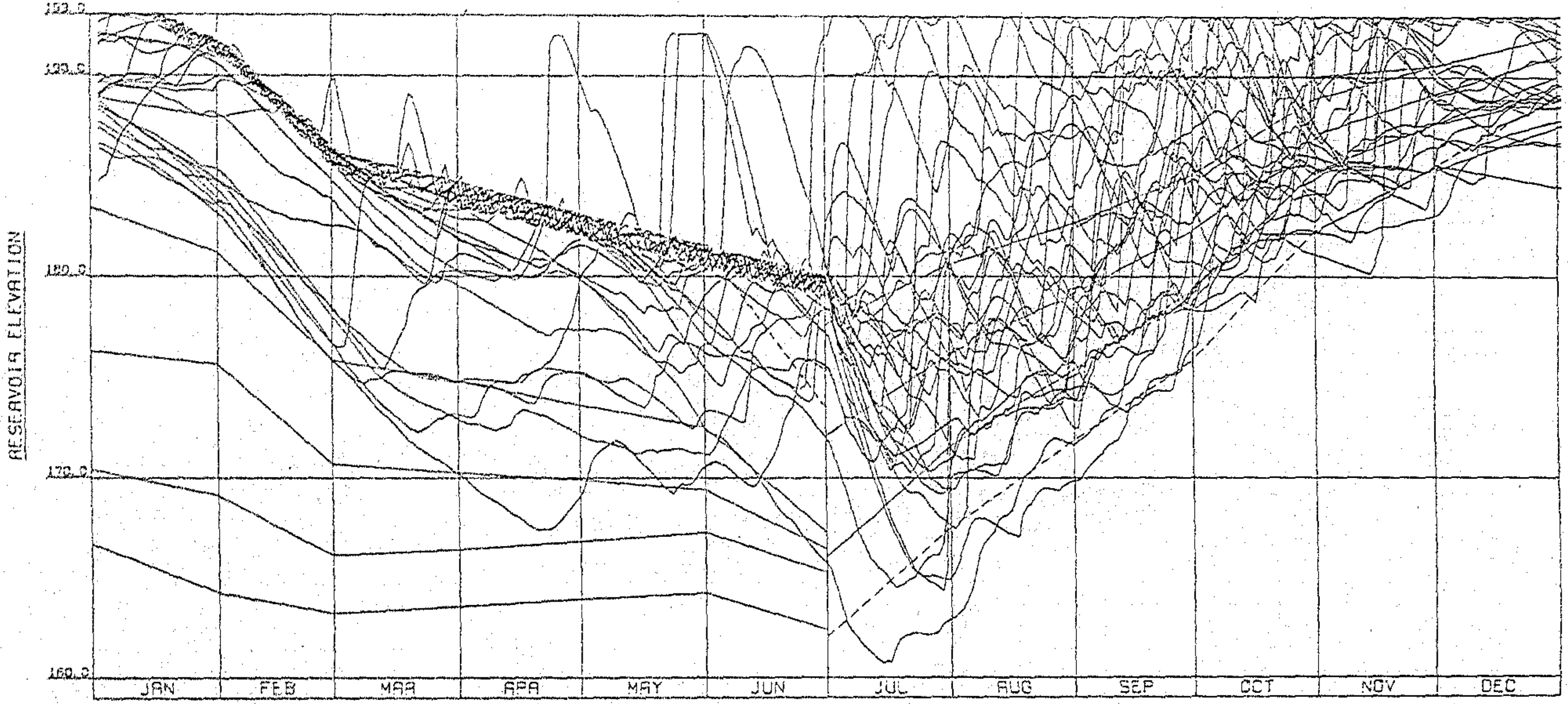


FIGURE D-17. SEASONAL PATTERN OF POWER GENERATED
(PROPOSED CROPPING SCHEDULE WITH AREA REDUCTION)

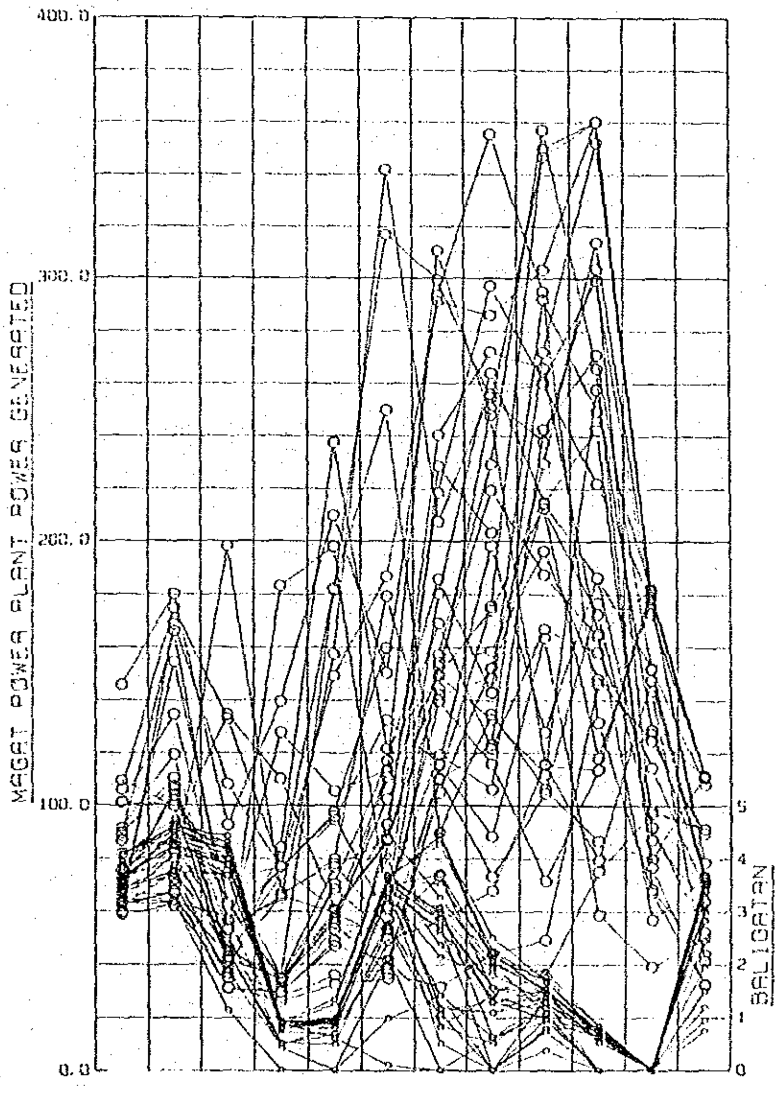


FIGURE D-18. ENERGY FOR UNIT DISCHARGE CURVE OF MAGAT H.E.P

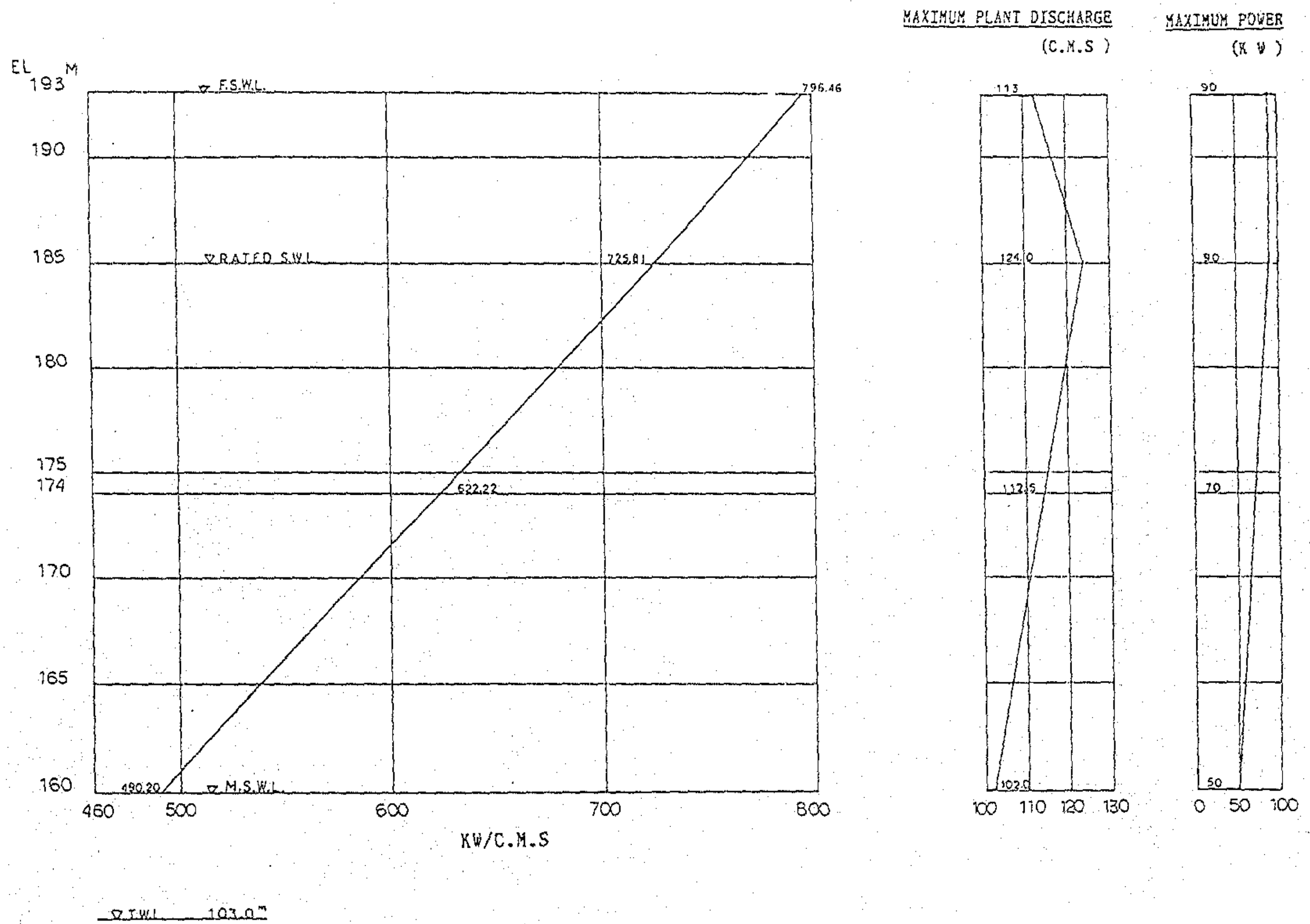


FIGURE D-19. ENERGY FOR UNIT DISCHARGE CURVE OF BALIGATAN H.E.P

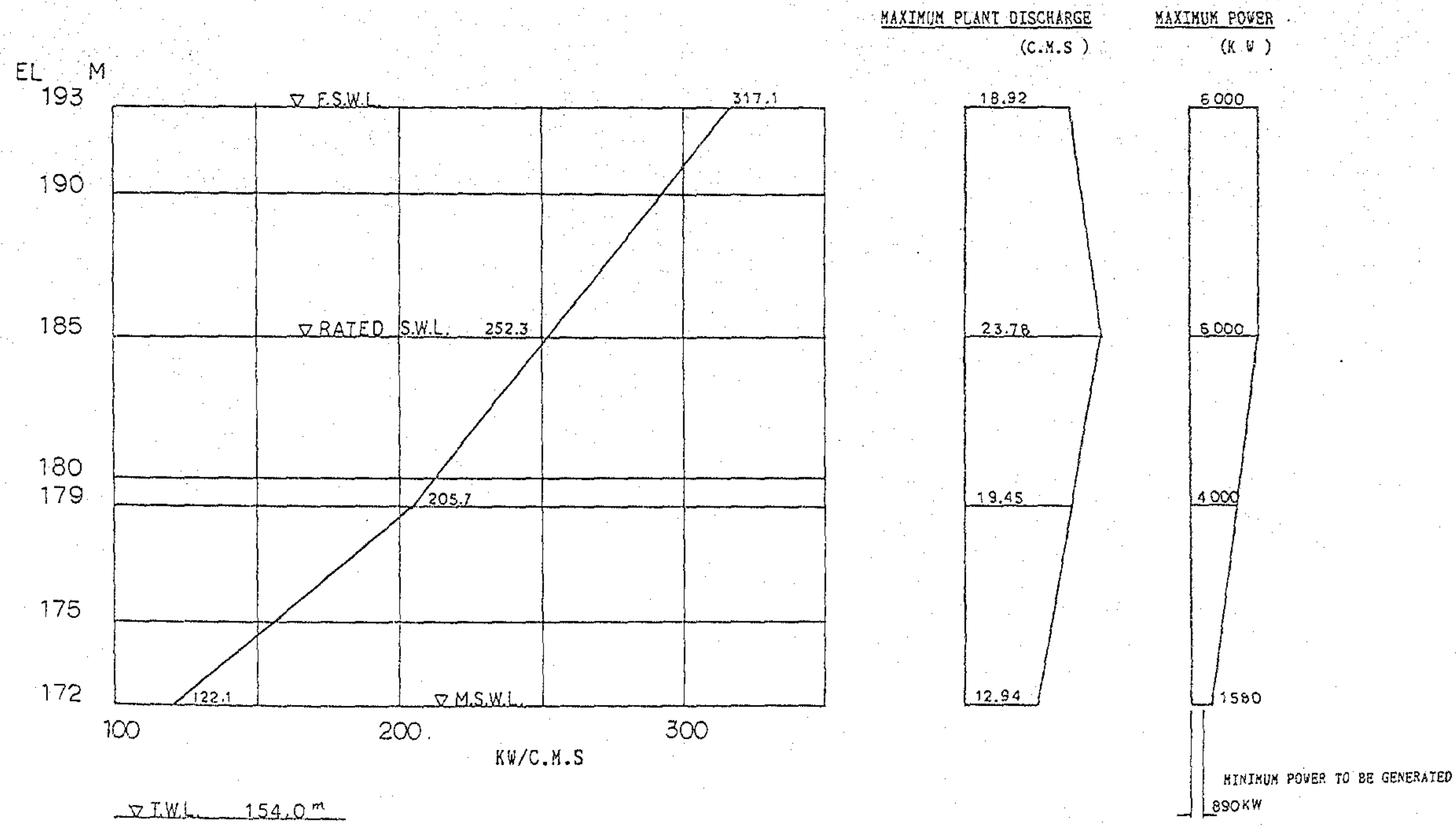
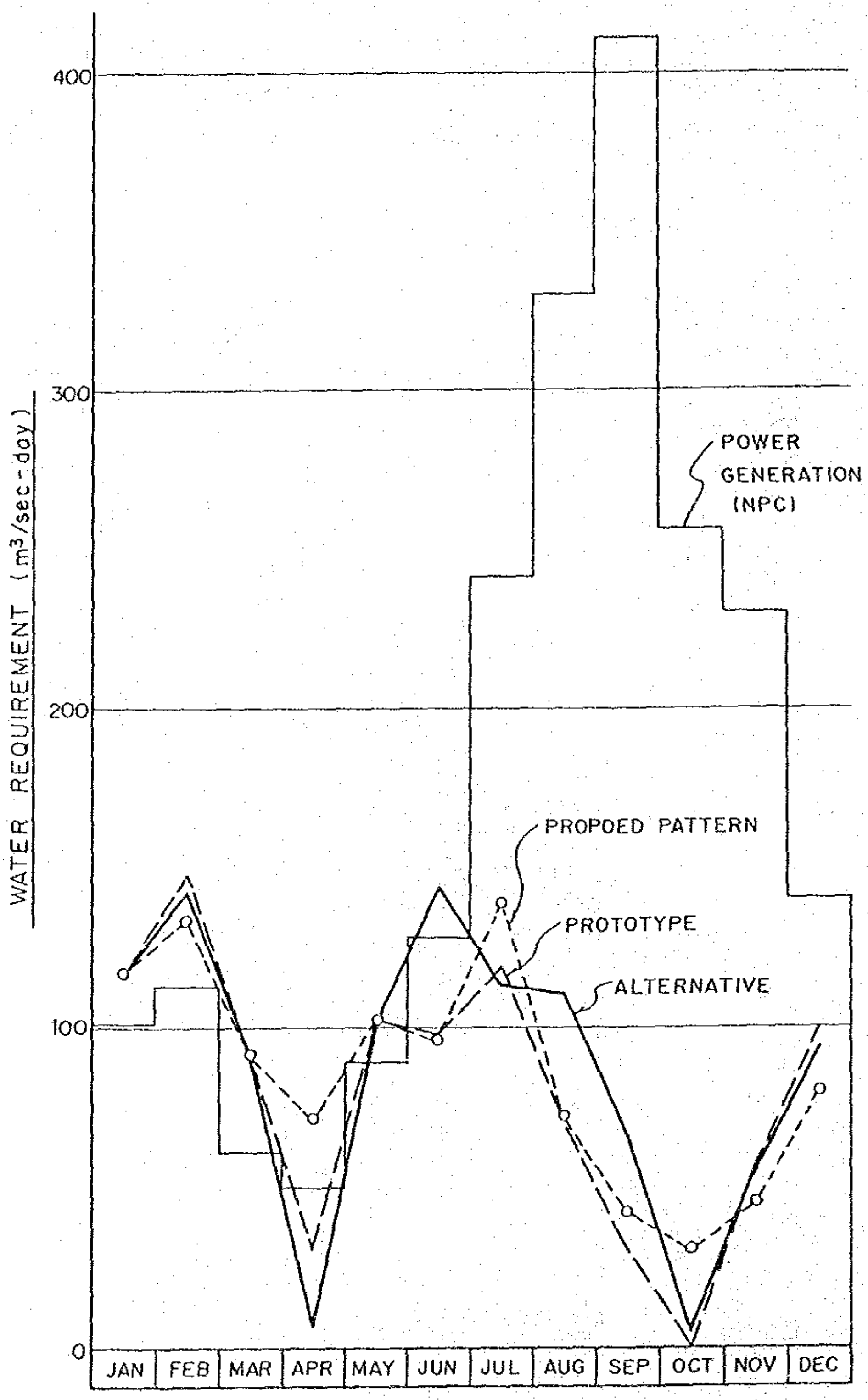


FIGURE D-20. WATER REQUIREMENT FOR IRRIGATION AND POWER



ANNEX E

WATER MANAGEMENT

E. WATER MANAGEMENT

LIST OF TABLES

LIST OF FIGURES

1. PRESENT WATER MANAGEMENT IN CANAL SYSTEM

1.1. Organization of Water Management

The water allocation to Service Area of 97,402 ha has been carried out by the O/M Head Office and four District Offices in the Service Area with 347 canals which extend over 1,490 km in total length. The upper part of the Maris main canal covering 55 percent of the Service Area, is managed directly by the O/M Head Office and play an important role for the water distribution in the Maris.

Each District Office covers Service Area of about 24,000 ha and 24 to 29 W.M divisions under the two Area Engineers.

The water management of each division headed by Water Master has been made by NIA staffs as Gate Keepers and Ditch Tenders, and Irrigators' Association (IA) or Farmers Irrigators' Group (FIG) by contract.

About 520 O/M Staffs are assigned to these divisions of WM so as to control about 3,800 gates including 2,900 turnout gates. The number of the gates to be controlled by the O/M Staffs under the District Manager is shown in Table E-1.

In order to check and review the actual amount of discharge in canal system, five hydrographers groups are assigned to the O/M Head Office and four District Offices. The main works in their responsibility are arrangement of rating table, management of hydrological data and O/M of hydrological equipment.

However, water distribution control at present has not been performed well due to several reasons such as imperfect system of inter-communication in the organization and unskilled practices of gate operation in canal system.

TABLE E-1. NUMBER OF O/M STAFFS IN EACH DISTRICT AND GATES OPERATED

Description		Dist. I	Dist. II	Dist. III	Dist. IV	Total
Service Area		24,054	24,468	24,793	24,087	97,402
Length of Canal	(km)	420	410	350	290	1,470
Gates						
Check	(place)	161	172	91	100	524
Head	(place)	87	101	100	65	353
Turnout	(place)	804	856	537	701	2,898
O/M Staffs in Division of WM						
Staff of NIA						
WM	(person)	26	29	21	23	99
GK	(person)	18	8	2	6	34
DT	(person)	22	80	68	55	225
Others by Contract						
IA	(unit)	61	29	29	21	140
Other	(person)	16	2	2	2	22
Total		143	148	122	107	520

1.2. Present Conditions of Canal Facilities in Water Management

The achievement of water management depends on the condition of canal facilities, especially the cross section of the canals and check, head and turnout gates. The details of those facilities are shown in Annex F. The present canal operation and situation are outlined below from the standpoint of water management.

Due to the fluctuation of the water level in the canals and inadequate gate control, serious scouring takes place immediate downstream of structures, especially drops and check gates while much silt deposit is found in the bottom of canal with the gentle slope, and at the downstream portions of the canal, where the silting materials are transported from the upstream and accumulated. Such canal conditions have resulted in poor rating table prepared by hydrologist. Moreover, some canals are insufficient in their cross section for passing the designed discharge.

The necessary canal improvement is outlined as follows;

Scouring rehabilitation	539 sites
Desilting works	449 km
Capacity improvement	85 km

Many important check gates, head gates and direct turn-out gates for water delivery in the system have not functioned properly, because of bending of frame and spindle of gates, demolish of concrete structures, lack of gate itself and so on. Therefore, it is necessary to repair and replace these gates as earlier as possible. The details are tabulated below in Table E-2 and E-3.

Kind of Gate	No. of Existing Gate (plcs)	No. of Troubling Gate (plcs)	Troubling Ratio (%)
Check	524	224	43
Head	353	92	26
Turn-out	2,898	690	24
Total/Ave.	3,775	1,006	27

TABLE E-2. CONDITION OF CHECK AND HEAD GATES

Name of Canal	Dist. I E (PCS)	Dist. I R (PCS)	Dist. II E (PCS)	Dist. II R (PCS)	Dist. III E (PCS)	Dist. III R (PCS)	Dist. IV E (PCS)	Dist. IV R (PCS)	Total E (PCS)	Total R (PCS)	Total R/E (%)
Check Gate											
1. Maris	16	15	157	79	—	—	39	39	212	133	63
2. CEE-G	—	—	—	—	—	—	18	12	18	12	67
3. CEE-P	—	—	—	—	—	—	4	2	4	2	50
4. SLC	72	32	—	—	—	—	—	—	72	32	44
5. NDC	—	—	—	—	46	0	—	—	46	0	0
6. SEEMC#1	—	—	—	—	5	1	—	—	5	1	20
7. SEEMC#2	—	—	—	—	12	4	—	—	12	4	33
8. OMC	7	0	14	2	—	—	—	—	21	2	10
9. SHC	66	6	—	—	—	—	—	—	66	6	9
10. SSMC	—	—	—	—	17	0	—	—	17	0	0
11. SNMC	—	—	—	—	11	2	—	—	11	2	18
12. MAC-E	—	—	—	—	—	—	35	27	35	27	77
13. RM	—	—	—	—	—	—	4	2	4	2	50
14. MAC-W	—	—	—	—	—	—	—	—	1	1	100
15. Ladeco	—	—	—	—	—	—	—	—	—	—	—
Total/Ave.	161	53	172	82	91	8	100	82	524	224	43
Head Gate											
1. Maris	14	7	96	18	—	—	27	25	137	50	36
2. CEE-G	—	—	—	—	—	—	16	13	16	13	81
3. CEE-P	—	—	—	—	—	—	4	1	4	1	25
4. SLC	26	1	—	—	—	—	—	—	26	1	4
5. NDC	—	—	—	—	30	0	—	—	30	0	0
6. SEEMC#1	—	—	—	—	23	0	—	—	23	0	0
7. SEEMC#2	—	—	—	—	12	3	—	—	12	3	25
8. OMC	6	0	4	0	—	—	—	—	10	0	0
9. SHC	41	6	—	—	—	—	—	—	41	6	15
10. SSMC	—	—	—	—	25	0	—	—	25	0	0
11. SNMC	—	—	—	—	10	5	—	—	10	5	50
12. MAC-E	—	—	—	—	—	—	11	9	11	9	82
13. RM	—	—	—	—	—	—	7	4	7	4	57
14. MAC-W	—	—	1	0	—	—	—	—	1	4	0
15. Ladeco	—	—	—	—	—	—	—	—	—	—	—
Total/Ave.	87	14	101	18	100	8	65	52	353	92	26

Note: E: Existing Gate. R: Gate to be repaired or replaced.

TABLE E-3. NUMBER OF TURN-OUT TO BE REPAIRED

Name of Canal	No. of Turn-out (pcs) Existing			To be Repaired			Trouble Ratio (%)		
	MC	Lat.	Total	MC	Lat.	Total	MC	Lat.	Ave.
1. Maris	85	-	85	30	-	30	35	-	35
Lat. A	-	281	281	-	46	46	-	16	16
Lat. B	-	65	65	-	10	10	-	15	15
Lat. C	-	178	178	-	36	36	-	20	20
Lat. D - Lat. D	-	489	489	-	141	141	-	29	29
- CEE-Gravity	31	93	124	3	16	19	10	17	15
- CEE-Pump	28	13	41	7	7	14	25	54	34
Lat. E-J	-	200	200	-	85	85	-	43	43
2. South Low	104	207	311	16	72	88	15	35	28
3. North Diversion									
NDC	40	168	208	6	48	54	15	29	26
SEEMC#1	4	79	83	0	5	5	0	6	6
SEEMC#2	18	37	55	2	2	4	11	5	7
4. Oscariz	31	68	99	3	14	17	10	21	17
5. South High	82	243	325	11	38	49	13	16	15
6. Siffu South	20	97	117	7	41	48	35	42	41
7. Siffu North	27	47	74	5	14	19	19	30	26
8. Macanao East									
MAC-E	40	60	100	0	16	16	0	27	16
Reina Mersedes	28	25	53	1	7	8	4	28	15
9. Macanao West	7	-	7	1	-	1	14	-	14
10. Ladeco	3	-	3	0	-	0	0	-	0
Total	548	2,350	2,898	92	598	690			
(%)	19	81	100	13	87	100	17	25	24

TABLE E-4. SERVICE AREA CONTROLLED BY TURN-OUT GATE IN MAIN CANAL

Name of Canal	Service Area (1) (ha)	Direct Turn-out of Main Canal: Service Area (2) (ha)	(2)/(1) x 100 (%)	No. of MCTO (pcs)	Interval Length (m)
Maris System					
1. Maris	40,496	1,856	5	85	320
2. CEE-Gravity	3,806	906	24	31	640
3. CEE-Pump	1,667	1,262	76	28	280
4. South Low	7,920	2,491	31	104	470
North Diversion System					
5. NDC	7,718	788	10	40	900
6. SEEMC#1	3,596	425	12	4	2,550
7. SEEMC#2	3,000	483	16	18	760
Baligatan Diversion System					
8. Oscariz	3,100	886	29	31	380
9. South High	9,580	1,703	18	82	730
Siffuris Diversion System					
10. Siffu South	7,520	1,810	24	20	1,350
11. Siffu North	2,959	842	28	27	930
Macanao System					
12. MAC-E	3,126	877	28	40	300
13. Reina Mercedes	1,776	695	39	28	410
14. Macanao West	171	-	-	7	430
15. Ladeco	967	415	43	3	2,670
Total/Ave.	97,402	15,439	16	548	590

The gate control can not follow the fluctuation of water level because the gate facilities have not been accommodated with electrified hoist.

About 19 percent of the total turn-out gates is placed directly along the main canals and covers 16 percent of the Service Area as shown in Table E-4. Under the situation, the much irrigation water has been introduced through the direct turn-out gates, especially in the upstream service area.

The improvement works should be implemented from the upstream to the downstream gradually, because the improvement works in the downstream are rather difficult due to flooding over the working site by the uncontrolled water from upstream, when improvement works at the upstream is not accomplished.

1.3. Present Method of Water Control

The present water control is carried out in following the rule to confirm the quantity of discharge by the water level with the staff gage and rating table.

The rating tables have been prepared by five Hydrographer Groups in O/M Head Office and four District Offices and established in the assumption that canal flow is uniform. However, actual canal flow becomes ununiform due to disturbance of the steady flow by many check gates in canals to result relatively poor accuracy of the tables.

The water of main canal is controlled and distributed by using the check gates and head gates which are operated in following the instruction of hydrologist or gate keeper, and these gates are operated irregularly. The water level of the main canals can not be, therefore, maintained constantly.

The operation of the head gates of Deteral canals and turn-out gates which is controlled corresponding with it's I.D.R and water level of main canal, is rather difficult under the situation mentioned above.

There exist 242 staff gages in the canal system including creeks. These staff gages are installed mostly in concrete piles with scales painted, but the most scales of these staff gages are not visible at present. Their locations are shown in O/M Drawings No. 17.

The arrangement of the rating tables has been carried out through out the investigation period of JICA Study Team. However, the ratio of the staff gage without the rating tables occupies 45 percent of the total staff gages as shown below;

Item	Main Canal (plcs)	Lateral Canal (plcs)	Creek (plcs)	Total (plcs)	Ratio (%)
No. of Canals	15	332	-	-	-
No. of Staff Gages	67	164	11	242	100
No. of S.G w/ Rating	36	85	11	132	55
No. of S.G w/o Rating	31	79	-	110	45

In taking into consideration this situation, JICA Study Team indicated to add the more discharge measuring points for the promotion of adequate water management and programmed the installation of new 98 staff gages and nine automatic gaging stations to keep the record of the water level in the specified canal point.

Locations of New Staff Gages

- The points in irrigation canals with capacity for designed discharge of more than two (2) cu.m/sec in principle (87 places)

- The points in 11 creeks crossing national highway

Location Recommended for Automatic Water Level Recorder

It is recommended that automatic water level recorders should be installed at the following points immediately;

- Head point of South High main canal (accomplished in 1986)
- Maris main canal below lateral D (")
- Head point of Siffu North main canal (")
- Head point of lateral D-2 in Maris (")
- Head point of Cauayan East Extention main canal
- Lateral D below lateral D-2 in Maris
- South high main canal below lateral SHC-19
- Head point of Siffu South main canal
- North Diversion main canal below lateral NDC-7

More recorders are needed to be installed, especially in the upstream of Maris main canal and head point of North Diversion main canal. It is further recommended that those recorders would be installed with the centralized monitoring system.

1.4. Present Water Control in Canal System

In order to study the actual flow conditions at the major points of the canals, the discharge measurement was conducted at 140 points during the field works in the phase II Study by JICA Team together with hydrological groups in the MRIIS O/M Head Office and District Offices. The location of measuring points and observed value of discharge are shown in O/M Drawings No. 18 and the difference between programmed discharge by the MRIIS O/M Head Office and delivered discharge by GK in major points of the canals is shown in Table E-5 (1) - (5).

TABLE E-5 (1). COMPARISON OF REQUESTED "Q" WITH OBSERVED "Q"

Main Canal /Major Lateral	Design Discharge Qd (Cms)	June 3 - June 9 Requested Discharge Qr (Cms)	Observed Discharge Qo (Cms)	(Qr ÷ Qd) x 100 (%)	(Qo ÷ Qr) x 100 (%)	June 10 - June 16 Requested Discharge Qr (Cms)	Observed Discharge Qo (Cms)	(Qr ÷ Qd) x 100 (%)	(Qo ÷ Qr) x 100 (%)
1. MARIS SYSTEM									
Intake	121.500	98.800	83.486	81	85	97.000	-	-	-
Lat. A	22.090	32.000	30.896	145	97	30.000	-	-	-
Lat. B	4.528	3.600	3.885	80	108	3.500	-	-	-
Lat. C	10.961	6.850	7.722	62	113	6.550	-	-	-
Lat. D	35.000	27.800	29.582	79	106	27.700	-	-	-
Bel. Lat. D	8.250	6.800	4.005	82	59	6.800	-	-	-
2. Oscariz	7.657	4.200	-	55	-	4.700	5.589	61	119
3. South High	26.042	11.000	-	42	-	13.000	10.880	50	84
4. South Low	17.560	14.000	-	80	-	14.000	-	-	-
5. North Diversion	59.000	23.000	-	39	-	25.000	-	-	-
6. Siffuris South	14.060	11.910	-	85	-	7.600	-	-	-
7. Siffuris North	5.230	3.790	-	72	-	4.800	-	-	-
8. Macanao East	9.950	2.400	-	24	-	7.000	-	-	-
9. Ladeco	3.080	2.800	-	81	-	3.100	-	-	-
10. Reina Mercedes	4.650	2.000	-	43	-	0.250	-	-	-
11. Cauayan East Ext.	8.060	5.000	-	62	-	0.450	-	-	-
12. - do - (pump)	3.440	-	-	0	-	-	-	-	-
13. Siffu East Ext. 1	0.600	-	-	0	-	-	-	-	-
14. Siffu East Ext. 2	7.400	-	-	0	-	-	-	-	-

TABLE E-5 (2). COMPARISON OF REQUESTED "Q" WITH OBSERVED "Q"

Main Canal /Major Lateral	Design Discharge Qd (Cms)	June 17 - June 23				June 24 - June 30			
		Requested Discharge Qr (Cms)	Observed Discharge Qo (Cms)	(Qr ÷ Qd) x 100 (%)	(Qo ÷ Qr) x 100 (%)	Requested Discharge Qr (Cms)	Observed Discharge Qo (Cms)	(Qr ÷ Qd) x 100 (%)	(Qo ÷ Qr) x 100 (%)
1. MARIS SYSTEM									
Intake	121.500	98.000	-	81	-	105.000	-	86	-
Lat. A	22.090	30.000	-	136	-	33.000	-	149	-
Lat. B	4.528	3.800	-	84	-	4.000	-	88	-
Lat. C	10.961	6.700	5.473	50	82	7.400	-	68	-
Lat. D	35.000	28.570	24.718	82	87	29.500	-	84	-
Bel. Lat. D	8.250	6.800	-	82	-	6.800	-	82	-
2. Oscariz	7.657	5.500	-	72	-	5.800	-	76	-
3. South High	26.042	13.000	-	50	-	15.000	-	58	-
4. South Low	17.560	14.000	14.934	80	107	16.000	-	91	-
5. North Diversion	59.000	26.000	-	44	-	26.000	24.772	44	95
6. Siffuris South	14.060	9.800	-	70	-	9.700	5.746	69	59
7. Siffuris North	5.230	3.430	-	66	-	3.400	2.869	65	84
8. Macanao East	9.950	7.000	-	70	-	6.500	4.983	65	76
9. Ladeco	3.080	3.000	-	97	-	2.500	-	81	-
10. Reina Mercedes	4.650	3.000	-	65	-	3.000	-	65	-
11. Cauayan East Ext.	8.060	5.000	7.221	62	144	5.500	-	68	-
12. - do - (pump)	3.440	-	-	0	-	-	-	0	-
13. Siffu East Ext. 1	16.600	5.430	-	33	-	6.400	-	39	-
14. Siffu East Ext. 2	7.400	-	-	0	-	-	-	-	-

TABLE E-5 (3). COMPARISON OF REQUESTED "Q" WITH OBSERVED "Q"

Main Canal /Major Lateral	Design Discharge Qd (Cms)	July 1 - July 7				July 8 - July 14			
		Requested Discharge Qr (Cms)	Observed Discharge Qo (Cms)	(Qr ÷ Qd) x 100 (%)	(Qo ÷ Qr) x 100 (%)	Requested Discharge Qr (Cms)	Observed Discharge Qo (Cms)	(Qr ÷ Qd) x 100 (%)	(Qo ÷ Qr) x 100 (%)
1. MARIS SYSTEM									
Intake	121.500	99.000	-	81	-	(87.000) 60.900	30.898	72	51
Lat. A	22.090	29.000	-	131	-	26.000	-	188	-
Lat. B	4.528	3.400	-	75	-	3.200	-	71	-
Lat. C	10.961	6.500	-	59	-	6.000	-	55	-
Lat. D	35.000	26.000	-	74	-	25.000	-	71	-
Bel. Lat. D	8.250	6.500	-	79	-	6.500	-	79	-
2. Oscariz	7.657	4.000	-	52	-	3.800	-	50	-
3. South High	26.042	14.000	-	54	-	14.000	-	54	-
4. South Low	17.560	14.000	-	80	-	14.000	-	80	-
5. North Diversion	59.000	23.000	-	39	-	23.000	-	39	-
6. Siffuris South	14.060	7.600	-	54	-	7.600	-	54	-
7. Siffuris North	5.230	2.700	-	52	-	2.700	-	52	-
8. Macanao East	9.950	6.500	-	65	-	6.500	-	65	-
9. Ladeco	3.080	3.000	-	97	-	3.000	-	97	-
10. Reina Mercedes	4.650	2.500	-	54	-	2.500	-	54	-
11. Cauayan East Ext.	8.060	4.700	-	58	-	14.700	-	58	-
12. - do - (pump)	3.440	-	-	0	-	-	-	-	-
13. Siffu East Ext. 1	16.600	5.400	-	33	-	5.400	-	33	-
14. Siffu East Ext. 2	7.400	-	-	0	-	-	-	-	-

TABLE E-5 (4). COMPARAISON OF REQUESTED "Q" WITH OBSERVED "Q"

Main Canal /Major Lateral	Design Discharge Qd (Cms)	July 15 - July 21				July 22 - July 28			
		Requested Discharge Qr (Cms)	Observed Discharge Qo (Cms)	(Qr ÷ Qd) x 100 (%)	(Qo ÷ Qr) x 100 (%)	Requested Discharge Qr (Cms)	Observed Discharge Qo (Cms)	(Qr ÷ Qd) x 100 (%)	(Qo ÷ Qr) x 100 (%)
1. MARIS SYSTEM									
Intake	121.500	87.000	-	72	-	91.000	104.298	75	114
Lat. A	22.090	25.200	-	114	-	28.000	32.994	127	118
Lat. B	4.528	3.300	-	73	-	3.500	1.636	77	47
Lat. C	10.961	6.000	-	55	-	6.000	6.803	55	113
Lat. D	35.000	25.700	-	73	-	25.000	23.193	71	93
Bel. Lat D	8.250	6.300	-	76	-	6.500	9.518	79	146
2. Oscariz	7.657	3.800	-	50	-	4.500	-	59	-
3. South High	26.042	15.000	-	58	-	12.000	-	46	-
4. South Low	17.560	16.000	-	91	-	15.000	-	85	-
5. North Diversion	59.000	21.500	-	36	-	23.000	15.921	39	69
6. Siffuris South	14.060	8.300	-	59	-	7.700	-	55	-
7. Siffuris North	5.230	2.880	-	55	-	3.000	-	57	-
8. Macanao East	9.950	5.000	-	50	-	6.500	-	65	-
9. Ladeco	3.080	2.180	-	71	-	2.500	-	81	-
10. Reina Mercedes	4.650	2.500	-	54	-	2.500	-	54	-
11. Cauayan East Ext.	8.060	4.500	-	56	-	4.500	-	56	-
12. - do - (pump)	3.440	-	-	0	-	-	-	0	-
13. Siffu East Ext. 1	16.600	6.450	-	39	-	5.400	-	33	-
14. Siffu East Ext. 2	7.400	-	-	0	-	4.200	-	57	-

TABLE E-5 (5). COMPARAISON OF REQUESTED "Q" WITH OBSERVED "Q"

Main Canal /Major Lateral	Design Discharge Qd (Cms)	July 29 - August 4 Requested Discharge Qr (Cms)	Observed Discharge Qo (Cms)	(Qr ÷ Qd) x 100 (%)	(Qo ÷ Qr) x 100 (%)
1. MARIS SYSTEM					
Intake	121.500	94.000	97.696	77	104
Lat. A	22.090	28.000	35.705	126	127
Lat. B	4.528	3.840	-	85	-
Lat. C	10.961	6.450	6.805	59	106
Lat. D	35.000	26.800	-	77	-
Bel. Lat. D	8.250	6.500	-	79	-
2. Oscariz	7.657	4.700	-	61	-
3. South High	26.042	12.000	-	46	-
4. South low	17.560	14.000	-	80	-
5. North Diversion	59.000	27.000	-	46	-
6. Siffuris South	14.060	7.800	-	55	-
7. Siffuris North	5.230	3.000	-	57	-
8. Macanao East	9.950	6.500	-	65	-
9. Ladeco	3.080	2.500	-	81	-
10. Reina Mercedes	4.650	2.500	-	54	-
11. Cauayan East Ext.	8.060	4.500	-	56	-
12. - do - (pump)	3.440	-	-	0	-
13. Siffu East Ext. 1	16.600	540	-	33	-
14. Siffu East Ext. 2	7.400	425	-	57	-

In addition, the discharge shown in O/M Drawings was calculated on the basis of weekly irrigation area requested by Water Master (WM) since the scheduled discharge in detail was unclear.

According to the result of discharge measurement, the actual discharge does not correspond to the scheduled discharge which is instructed to each District Office by Head Office. The differences in discharge are estimated at 20 to 40 percent in the main canals and 30 to 60 percent in the lateral canals.

This fact shows that actual distribution control at present has not been well performed mainly because of the following reasons;

Irrigation area on the farming stage basis is, in principle, reported to the WM through IA on the weekly basis depending on cropping conditions, and each IA in District Office estimates the diversion requirement at the head points of the canals on the basis of the irrigation area by turn-out.

However, this estimation for diversion requirement needs a large quantity of calculation every week, and as a result, the IA cannot estimate diversion requirement exactly and on schedule, so that the Water Masters and Gate Keepers do not grasp the discharge to be released.

The communication system between WM or GK/VT in charge of field work and AE as a key staff in charge of office works is inadequate, so that, in case released discharge is changed, GK/DT can not follow the change.

- The discharge distributed from diversions dam to main canals fluctuates hourly, especially in the Maris and North Diversion canal connecting to the Maris diversion dam.
- As previously described some check and head gates along the canals are deteriorated, so that the operation can not be made in accordance with the operation rule.

- Many turn-out gates are also broken and can not be closed, so that the discharge into the canals naturally flows through the turn-outs and is wasted into a drainage canals or creeks through farm ditches and the paddy fields.

- Many turn-out gates are not operated in accordance with the gate operation rule but by farmers own judgement, so that the upstream area can take easily much water, whereas the downstream area meets the water shortage problem.

- The present cropping calendar is not in accordance with the programmed one, so that the distribution water is rather difficult.

- The gate Keepers are not well trained with the gate operation rule and the operation method.

As a result of poor water management in canal system, the much irrigation water has been taken into the upstream service area, while the less in the downstream area. Therefore, the downstream area has suffered from inundation by the surplus irrigation water from the upstream area in the wet season and contrarily water shortage in the dry season.

The water released from the diversion dams and delivered through irrigation canals is not used actually for irrigation in the paddy fields regrettably, and wasted to drainage canals and creeks through paddy fields.

Every creeks, therefore, releases a considerable amount of discharge to the downstream area during the irrigation season as shown in Table E-6.

According to waste water study, the estimated waste water depth from the paddy per one crop season in the wet season amounts to about 700 mm per hectare. This fact indicates that the upstream area receives 140 percent discharge of water demand.

The existing water distribution control in major canals are as follows.

TABLE E-6. ESTIMATION OF WASTED WATER AMOUNT

(Period: June 3, 1986 to October 6, 1986)

Description	Unit	Marabulig Cr.	Minante Cr.	Nungnungan Cr.	Burgos Cr.	Paddad Cr.	Total/Average
Drainage Area	Sq.Km.	39.2	34.4	25.9	13.1	60.5	173.1
Rainfall 1/ (Jun.-Sep.'86)	mm	826	826	826	826	826	826
Total Run-off in Creek 2/	MCM	26.6	26.9	24.1	14.1	44.3	136.0
Estimated Run-off by Rainfall 3/	MCM	10.1	8.7	6.7	3.3	15.5	44.3
Wasted Water from Excess Irrigation	MCM	16.5	18.2	17.4	10.8	28.8	91.7
Irrigated Area in Wet Season '86	Ha	3,000	2,500	2,500	1,000	3,900	12,900
Wasted Water Depth	mm/crop season 4/	523	693	663	1,029	703	676

Note: 1/ Salvation Rainfall Station, Alicia.

2/ Converted value from observed water depth in creek.

3/ Total of estimated weekly run-off, run-off coefficients adopted are shown bellow.

Weekly Rainfall (mm)	Run-off Coefficient (%)	Weekly Rainfall (mm)	Run-off Coefficient (%)
0-10	0	41- 60	20
11-20	5	61-100	30
21-40	10	101	40

4/ 120 days

(a) Distribution Control in Maris Main Canal System

Maris Main Canal

- The check and head gates between the beginning point and the branching point of the Lateral D are desired to be changed into the power operation devices with remote control mechanism, so as to be operated properly and quickly, corresponding to the fluctuation of water level and diversion requirement in the canal, because these gates control a big discharge of canal covering a large area in the Maris canal system.

- The check gates installed near the Magat mini-hydroelectric power plants are operated manually. Then, their operation can not be made quickly to meet the water level fluctuation due to suspension of the power plants. These gates should be attached by hydraulic unit to overcome the stoppage of power supply.

- Set-up of the gate operation rules based on periodical discharge measurement and monitoring of water level in the major diversion should be made.

Lateral D

- Lateral D, which is the largest lateral canal in this system, commands a service area of about 22,000 ha and is connected with Cauayan East Extension canal (gravity) covering about 3,800 ha and Cauayan East Extension canal (pump) covering about 1,670 ha in its downstream.

- This canal located in the downstream of the Maris main canal system is under control of the two District Office (II and IV) and is characterised having numbers of lateral canal of 62. Therefore, severe water distribution control is requested.

- The discharge measurement has been carried out only at the seven points, head of Lateral D and Lateral D-2 and so on. It is necessary to monitor the water levels constantly at the boundary point of the Districts as well as the head point of Lateral D and Cauayan East Extention canal.

South Low Main Canal

- This canal has a length of 48.6 km and 32 check gates in the canal system, so that it can take about four to five days or more for the water to reach the end point of canal from the diversion dam in the case that the canal flow is controlled by check gate to keep the constant water level, and its velocity becomes as slow as 10 to 20 cm/sec. This time lag in the canal flow should also be taken into consideration, when the outflow amount from the reservoir is estimated.

- The 104 turn-out gates exist along this canal and this situation makes water management more difficult. Especially, the downstream area is always suffered from water shortage due to the over-intake in the upstream area and the time lag in canal flow. Severe distribution control in the upstream should be taken into consideration.

- No discharge measurement except the head point in this canal has been carried out. In view of this fact, it can be considered that distribution control is not made properly.

(b) Distribution Control in North Diversion Main Canal System

- The canal discharge of the North Diversion canal changes depending on the runoff of the Siffu river; namely, this canal covers about 14,310 ha in the period from June to December when the water of the Siffu river is enough, while covers 21,500 ha involving most service area of the Siffu South canal in the period from January to May. Therefore, it will be necessary to operate the hydraulic structures so as to limit discharge capacity up to 60 percent in the wet season when the Siffu river has a plenty of runoff at the Siffuris diversion dam.

- There exists two pumping stations in the downstream of this system covering service area of 6,600 ha including undeveloped service area. However, actual irrigated area is only 3,090 ha. This fact means that the distribution control in the upstream of this system should be made properly.

- The Quantity of intake water from the Maris diversion dam can not be grasped because the intake gate has no operation rule.

- Since there is no water allocation rule between the Maris and the Siffuris diversion dam, the North Diversion canal has a tendency to over-intake water from the Maris diversion dam.

(c) Distribution Control in South High Main Canal Systems

- This system covers a service area of 9,850 ha and the main canal has a length of 59.6 km. The present problems on the water management are mostly the same as those of the South Low main canal.

- The water management in this canal has not been established yet, because only few years have passed since the construction was completed.

(d) Distribution Control in Oscariz Canal System

- This system covers a service area of 3,100 ha and the length of the main canal is 11.8 km. This canal convey the irrigation water to the service area of District I and II. The calibration activity on the discharge in the canal system has been done and the water management has been conducted in relatively good condition.

(e) Distribution Control in Siffu South Main Canal Systems

- This system covers service area of 7,500 ha and the length of the main canal is 27.0 km. In the case that the water resources supplied by the Siffu river are not sufficient for the service area of this system, the irrigation water for the service area of about 7,190 ha in maximum is supplied through the North Diversion main canal. However, it will be considered that water distribution is in confusion because of no allocation rule between two water resources.

- Calibration activities of discharge are carried out only in the lateral canals.

(f) Distribution Control is Siffu North Main Canal Systems

- This system covers a service area of about 2,960 ha and the length of the main canal is 25 km. The runoff of the Siffu river is introduced to this system with the first priority through the right intake structure of the Siffuris diversion dam.

- The problem to be improved for the water management is a few because the calibration activities are made at the heads of the lateral canals, though the intake gate is operated without operation rule.

(g) Distribution Control in Macanao East Canal Systems

- This system covers a service area of about 4,900 ha and the length of main canal composed for the Macanao East and the Reina Mercedes is 23.5 km.

- The system relies its water sources mainly on the return flow in the Macanao creek gathering the surplus water from the Lateral A and B in the Maris canal system and is supplied with additional irrigation water from the Maris main canal through the Gaddanan creek. Though estimated quantity of available water at the Macanao diversion dam is presented in the O/M Manual prepared by the ADD, the services area in the downstream has suffered from the water shortage.

- The instable water management is made due to the lack of the rating activities.

2. IMPROVEMENT OF WATER MANAGEMENT IN CANAL SYSTEM

The water management in canal systems is to distribute the scheduled discharge correctly and timely from the main to the lateral canals and from the lateral canals to the service areas. In order to make a proper distribution, the following practices should be made systematically;

- To estimate the accurate discharge to be allocated to the canal.
- To carry out the proper discharge control at check, head and turn-out gates in accordance with the allocated discharge.
- To check the discharge in the canal at the major control points by the discharge measurement devices.
- To make data management appropriately on the water management.

The outline of the improvement of the above items is described in 3.2.6 of Main Report, and supplemented shown hereafter.

2.1. Improvement of Discharge Control

(1) Improvement of Organization for Water Management

- The water management in the upstream of the Maris main canal should be done by the Dam and Reservoir District so as to release water in one system consistently.
- The water management in the canal should be made directly by the O/M Staffs of NIA so as to make fair water distribution, and therefore, the GKs should be increased in number.
- The routine O/M works for existing DT should be turned over to the organized IA.
- The hydrologists in MRIIS O/M Head Office should be assigned to the following works.

- Arrangement and analysis of hydrological data
- Management of hydrological equipment
- Standardization of rating table for discharge measurement
- Preparation of standard form for various kinds of hydrological data to be collected

(2) Improvement of Equipment for Water Management in Canal

- In order to ensure rapid reaction and activity of water management, it should be required to increase the number of communication equipment.
- Staff gages should be installed at the upstream and downstream of check and head gates so as to make proper gate operation.
- In order to carry out discharge control, gaging stations with automatic water level recorder should be installed as many as possible.

(3) Improvement of Discharge Control

- The water distribution is regulated by adjusting the opening degree of check, head and turn-out gates considering the difference in hydraulic head between the upstream and downstream. Therefore, the water levels along the canal profile between checks should be kept continuous and constant as possible during the operation period.
- All water level and discharge should be kept in programmed conditions, especially, more attention should be paid to the following critical points in canals, such as, head gate of major lateral canal, check gates in the main canal, and O/M Baundary of the Water Master, as discharge transfer point.

2.2. Improvement of Discharge Measurement

(a) Improvement of Rating Table

A large number of check gates are provided, and operated in the main and lateral canals, and as a result, the flow in the canals with a gentle slope becomes ununiform flow. Therefore, the rating table for discharge measurement should be prepared in consideration of difference in hydraulic head and discharge.

The discharge released from gate is estimated by the following equation;

$$Q = CBd \sqrt{2g\ H}$$

where,
- Q; Discharge (cu.m/sec)
- C; Discharge coefficient (Basing on kind, materials of gate and stream condition)
- B; Width of gate (m)
- d; opening height of gate (m)
- g; Acceleration of gravity (9.8 m/sec^2)
- H; Energy head between upstream and downstream (m)

Accordingly, the gate opening height (H) is obtained as follows:

$$d = Q/(CB \sqrt{2gH}\ )$$

The gate opening height is obtained by assuming C value since others are known or observed values. However, C value must be decided based on the result of discharge measurement since it varies by kinds and materials of gates and stream condition of canal.

The discharge measurement is very important for this reason. Then, the JICA Study Team suggested the O/M Head Office to commence such discharge measurement to prepare the rating table with correct relation-ship between water (H) and discharge (Q) and to manage the gate opening according to programmed discharge.

In addition, as the total number of the check, head and turn-out gates is 3,800, the preparation works for the Opening Rate table corresponding to release from the gate should be started after the classification of gates by the kinds, dimensions and gate site condition.

(b) Improvement of the Implementation Schedule for Discharge Measurement

The periodical discharge measurement (calibration) at designated points should be made so as to review the actual distribution and prepared rating tables. The number of the points, critical and ordinal points, are tabulated below and the locations are shown in O/M drawings.

Point	District					Total
	Dam	I	II	III	IV	
Critical	12	39	34	26	41	152
Ordinal	-	74	47	64	39	224

2.3. Improvement of Data Management

In order to improve of the water management it is necessary to know actual achievement of water distribution. For this purpose, the following data should be properly managed;

- Weekly irrigation area and the programmed discharge
- Actual distributed discharge through gate control
- Measured discharge
- Adjustment result of rating table
- Hydrological data such as rainfall in Service Area and water level observed by automatic equipment
- Conditions of equipment for water management

The above data should be collected by District Offices and submitted to the O/M Head Office. The staffs/organizations assigned to management the data are shown in Table E-7 and the forms for observed data arrangement are illustrated in O/M Manual.