CHAPTER IV. DRAINAGE

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4.1 General

4.1.1 General Aspects of Drainage Problem

The drainage system is somewhat inadequate over the entire service area. Excess water in the field is usually drained through natural creeks and rivers.

There are two sorts of problem where drainage systems are concerned. Surrounded by the Pampanga, Angat, Maasim and other rivers, a large scale of submerged area lies in the lower reaches of the service area where frequent inundation damage occurs. It is reported, on the other hand, that many local areas of relatively high elevated are located along drainage creeks receiving local inundation mainly due to insufficient drainage facilities.

In the north side service area, there is a large expansion of submerged area where inundation reaches 4,000 to 14,000 ha with a maximum water level of 2.73 to 6.81 m above mean sea level, accompanied by a total submerged period of 27 to 128 days annually.

Because of the absence of the left bank level of the Pampanga River, and also because of the existence of the right bank levee flood water running down the Pampanaga River concentrates in the submerged area. Overflow of the North Candaba Swamp, as well as of the Maasim River, accelerate the depth and duration of inundation of the area. The high water stages during peak flood often allow flooding water to overflow into the area, and as the same time, they function as high external water levels during the period of depression resulting in continuous inundation in the service area which extend over a long period of time.

In the south side of the service area, along the Labangan and Santo Niño rivers, there is a considerable scale of area which usually suffers from inundation. A protection dike is constructed along the Labangan river with a top elevation of 4.0 to 6.0 m above mean sea level, and stretching 5 km from Calumpit to Hagonoy. The downstream part of the area, along the Santo Niño river from Hagonoy to Malolos, however, is bounded by a low elevated dike of around 2.0 m which allows an adverse flow of river water during high flood.

Also in this area, continuous high water levels in the river prevent the inundated water from being drained by gravity.

In total, 39 local portions, which lie scattered within the service area, are reported to be in need of improved drainage facilities. Most creeks in the area meander through fields, causing some restrictions on carrying capacities. The majority of drainage creeks are in need of desilting, while some are being widened or re-constructed.

To formulate the project, two methods of approach were undertaken during the course of the study. The method of characteristics was employed to estimate peak discharge as well as hydrograph in drainage canal or creek during the probable flood which would occur once in five years. The carrying capacities of the existing drainage facilities were evaluated by this, and necessary plans for imrpovement or construction were formulated.

On the other hand for submerged areas, long term water balance simulation studies were conducted on a daily basis. Possible flood protection plans were established to avoid adverse flow from the rivers and to reduce inundation water levels and duration of inundation in the service area.

4.1.2 Existing River Improvement Plan

In 1938 BPW commenced the investigations for the initial plan of the Pampanga River control program supported by the trends of public opinion, which was largely agitated by the three successive floods of 1935, 1936 and 1937. The plan was approved by the Flood Control Commission and the implementation started in 1939 with a plan to construct a system of levees, floodways, cut-offs and channels.

After an interruption of a number of years, which was due to World War II, BPW started the related studies in 1950 in order to establish the optimal solution in developing the area of the Pampanga river delta by means of constructing a storage reservoir for flood control as well as other multiple uses.

In 1962, BPW published a report on the "Proposed Reclamation of the Candaba and San Antonio Swamps", containing two potential plans for reclamation of the swamps, namely Scheme I and II, and a plan, namely, Scheme III, which covered flood control features in the Central Luzon area with a limited reclamation program. All three schemes were reviewed and evaluated by the USAID experts and Scheme III was endorsed.

The Angat and Pantabangan Multipurpose Dams were completed contributing to flood control of the river basins, by the ADB fund in 1967 and by the IBRD fud in 1974, respectively.

In 1977, UNDP prepared a report entitled "Pampanga Delta/Candaba Swamp Area Development Project". The report proposed, with regard to flood control, three major project components namely, (1) West Diversion Channel, (2) San Antonio Reservoir and (3) East Diversion Channel.

The UNDP studies were further extended under the technical cooperation of JICA from 1980 to 1981, and the feasibility study report on the "Pampanga Delta Development Project" was prepared in 1982. The JICA report selected the channel improvement plan of the Pampanga River as the most optimum basic plan for flood control. According to the report, improvement works mainly consist of embankment of levee, widening and excavation of the river channel in the roughly 40 km stretch between Candaba and Manila Bay with the aim of protecting the land of the South Candaba Swamp and downstream of the Pampanga below Sulipan against flooding from both the Pampanga and Angat Rivers.

At present, implementation of flood control works based on BPW Scheme III has been progressed intermittently since 1939, depending on the availability of funds, with about 70 percent of the entire scheme being completed by the beginning of 1980.

As for the Maasim River, the Upper Maasim Diversion Dam was completed in 1949 by BPW. The river channel downstream from the Lower Maasim Dam was improved during AMIADP from 1973 to 1978, excluding improvement of dams. It is noted that a plan for the improvement of the Maasim River from the confluence of the Pampanga River to 13 km upstream is also included in the "Pampanga Delta Development Project".

4.2 Present Drainage Condition

4.2.1 Present Drainage Systems

(1) General

The drainage system is somewhat inadequate over the entire service area. Excess water in the field is usually drained through natural creeks and rivers.

There are two sorts of problem where drainage systems are concerned. Surrounded by the Pampanga, Angat, Maasim and other rivers, a large scale of submerged area lies in the lower reaches of the service area which used to suffer from frequent inundations. It is reported, on the other hand, that many local areas of relatively high elevated are located along drainage creeks receiving local inundations mainly due to insufficient drainage facilities.

(2) Submerged Area

In the north side of the service area, there is a large expansion of submerged area where inundation reaches 4,000 to 14,000 ha with maximum water level of 2.73 to 6.81 m above mean sea level, accompanied by a total submerged period of 27 to 128 days annually.

Because of the absence of the left bank levee of the Pmapanga River, and also of existence of the right bank level flood water running down the Pampanga River concentrates in the submerged area. Overflow of the North Candaba Swamp, as well as of the Maasim River, accelerates the depth and duration of inundation of the area. The high water stages during peak flood often allow flooding water to overflow into the area, and the same time, they function as high external water levels during the period of depression resulting in continuous inundation in the service area which extends over a long period of time.

In the south side of the service area, along the Labangan and Santo Niño rivers, there extends a considerable scale of area which usually suffers from inundation. A protection dike is constructed along the Labanga River with a top elevation of 4.0 to 6.0 m above mean sea level, and stretching 5 km from Calumpit to Hagonoy. The downstream part of the area, along the Santo Niño River from Hagonoy to Malolos, however, is bounded by a low elevated dike of around 2.0 m which allows adverse flow of river water during high flood.

Also in this area, continuous high water levels in the river prevent the inundated water from being drained by gravity and inundation amounts to 850 ha to 2,000 ha with a maximum water level of 1.09 to 2.01 m above mean sea level accompanied by a total submerged period of 27 to 114 days annually.

(3) Local Areas being Submerged

In total, 39 local portions, which lie scattered within the service area, are reported to be in need of improved drainage facilities. Most creeks in the area meander through fields, causing some restrictions on carrying capacities. Most drainage creeks need to be desilted, while a few are the being widened or be constructed.

Improvement Required	No. of Drainage/Creek
Desilting	32
Widening	4
New Construction	3
Total	39

Although there was no opportunity for field examination because of the critically dry condition existing in the entire country during the period of survey, the damages to crops due to insufficient condition of drainage creeks are estimated, according to hearings and traces in/on the fields, to be less significant.

(4) Existing Drainage Facilities

There are 136 drainage creeks with a total length of 447.5 km within the boundary of the service area.

River	No. of Drainage/Creek	Total Length (km)
Pampanga	58	173.1
Angat	5	12.6
Maasim	25	80.9
Labangan	8	21.8
Pamarawan	9	28.3
Guiguinto	7	24.9
Bigaa	14	62.3
Santo Niño	8	33.3
Others	2	10.3
Total	136	447.5

All the canals and creeks are earthen canals with a side slope of 1:1 or steeper. The carrying capacity of the canals and creeks is rather small due to poor maintenance and aquatic vegetation. These obstacles have been causing some inundation damage to adjacent farm land during the heavy rainy season. In addition, most of the existing creeks are meandering with gentle hydraulic gradients.

In order to divert irrigation water during the dry season, a considerable number of appurtenant structures have been constructed along creeks especially at the crossing points of rural roads. Check structures with wooden stop logs raise the intake water level in a creek. Operation of the system by farmers, however, is not being made sufficiently and local floods are caused, to a great extent, by such bottlenecks situated along creeks.

In total, 11 drainage outlets, equipped with control gates, are situated at the end of drainage creeks along the Pampanga, Maasim and Labangan Rivers. Most of the control gates are reported to be in bad condition.

4.2.2 Inundation and Flood Damages

(1) General

Water stages in the Pampanga River recorded at both San Simon and Sulipan Apalit fluctuate over a wide range from 0.0 to 7.0 m above mean sea level, depending on run-offs from the drainage area of the river, which is reported as 7,715 sq.km at the confluence of the Angat River. Probable high water stages during floods with some frequency of occurence are estimated as follows.

Probable High Water Level in the Pampanga River

Return Period	San Simon	Sulipan Apalit
2 years	El. 5.0 m	El. 4.0 m
5	5.4	4.9
10	6.3	5.4
20	6.7	5.9

The area usually inundated lies in the westernmost part of the service area in an almost north to south orientation, bounded on the north by the Maasim River, on the west by the Pampanga river and on the south by the Angat River. The left bank of the Pampanga River, by which the area is bordered, has an elevation of 3.5 to 7.5 m above mean sea level.

As seen in Figure A.4.2-1, about 65 percent of the whole length of the bank is elevated between 5.0 and 6.0 m above mean sea level, allowing the river water to intrude into the area when the river stage exceeds 5.0 m. Figure A.4.2-2 shows the correlation of the maximum water stages in the Pampanga River and in the inundated area. From this figure, it is visualized that the water stage in the area rapidly approaches that in the Pampanga river when the river stage exceeds 5.0 m. The figure also explains that, when the river stage exceeds 6.0, the water stage in the area is almost the same as that in the river.

One of the reasons which accelerate the inundation in the area is the overflow of the Maasim river. Because of the insufficient carrying capacity of the river channel as well the non-functioning gates systems of the Upper and Lower Maasim Dams, flood runoff of the river is used to overtop both right and left banks during the time when discharge exceeds 100 cu.m/sec.

The overflowed water travels downward in the service area causing more serious inundation in the low elevated area.

The North Candaba Swamp is also known to be one of the water sources which provides excess water to the area. During the course of AMIADP the Maasim River was designed so that the excess water in the North Candaba Swamp was allowed to flow crossing over the river.

As seen in Figure A.4.2-3, inundations on the north side service area are concentrated in the four months from July to October, while some occurred in the past in the months of May, November and December.

(2) Flood Simulation Model

Because of lack of records on hydraulic/hydrologic measurement of flood in the area, a specified computation model for a flood simulation study was developed in order to reproduce a condition of flood in terms of flooding depth, duration and inundated area. Actual observation of hydrological data, such as rainfall on the field, water Stages in the Pampanga River as well as in the North Candaba Swamp and the Maasim River discharges, were inputted into the model for the purpose of simulating the flood which would have occured in the area during the past 16 years from 1960 to 1976. Years of 1972 and after 1977 were excluded from the study because of no available data.

A sophisticated analytical procedure for hydraulic simulation of flood problems has been advanced by many authorities employing the most modern mathematics, and has been applied to the real problems in the field of engineering practice. It is recognized, however, that the application of the most advanced procedure to simulate the hydraulic behavoir during flood in the submerged area which is treated as reservoir, is very elaborate, and that even with the use of high speed digital computer, the method would not produce a significant result, because of insufficiency of basic data required by the method.

The flood simulation study was undertaken, therefore, by employing a simple concept of simulation of the hydraulic behavoir in the drainage area. A conceptual definition of the lumped system of the reservoir was introduced, as defined below, to solve the present and/or proposed condition of the drainage systems within a certain acceptable engineering accuracy.

Figure A.4.2-4 shows the schematic diagram of the flood sumulation model constructed for the study.

Water balance was made in each element of drainage system applying a pseudo-dynamic type of equations expressed by i) equation of continuity and ii) equation of motion substituted by a traditional formula of discharge. Water budget diagram illustrated in Figure A.4.2-5 explains such a function of water balance. Equation of continuity is given as follows:

$$\frac{dV}{dt} = Qin - Q\ out$$

where V denotes the storage in the element under consideration, Q in, inflow caused by rainfall on the catchment, Q out, outflow from the element through the drainage facilities depending upon the capacity of facilities as well as the difference in water stage between the elements concerned, and t, time.

The above equation can be divided by the water surface area, which is given by a function of water stage as f (H), when time interval for computation Δt was taken to be small.

$$\Delta H = \frac{Q\ in - Q\ out}{f(H)} \cdot \Delta t$$

In an element, the water stage H at time t can therefore, be computed by the following equation based on the preceding water stage H' and time t'.

$$H = H' + \frac{Q\ in - Q\ out}{f(H)} (t - t')$$

Inflow Q in refers to the estimated runoff from the area, and outflow Q out is obtained by the following formulas as the function of internal and external water stages.

1) Natural Stream such as River, Creek or Canal

$$Q = \frac{1}{n} \cdot A \cdot R^{2/3} \cdot I^{1/2} \quad \text{(Manning's formula)}$$

The above equation can be expressed as follows when the condition of flow is given as illustrated in Figure A.4.2-6.

$$Q = \frac{1}{n} \cdot AR^{2/3} \cdot \left(\frac{\Delta H}{L} \right)^{1/2}$$

$$= \frac{1}{n\sqrt{L}} \cdot aD^{b} \cdot \sqrt{\Delta H}$$

$$= \frac{1}{n\sqrt{L}} \cdot a \left(\frac{Hi + Hj}{2} - SH \right)^{b} \cdot \sqrt{Hi - Hj}$$

where, A: cross-sectional area of flow (sg.m)

R: hydraulic mean depth (m)

n: Manning's roughness coefficient

L: distance between center of submerged area or block (m)

Hi, Hj: water stages in block I and J

a,b: constant

D: depth of water (m)

SH: sill height

2) Culvert or Sluiceway

Figure A.4.2-7 illustrates flow condition in a culvert or sluiceway.

$$Q = C1 \cdot B \cdot H2 \cdot \sqrt{2g\,(H1 - H2)} \quad \text{(ordinary flow)}$$

$$Q = C2 \cdot B \cdot H1 \cdot \sqrt{2g\,H1} \quad \text{(supercritical flow)}$$

where, H1, H2: internal and external water stages with respect to sill elevation (m)

B, H: width and height (m)

g: gravitational acceleration (= $9.8 m/sec^2$)

C1, C2: coefficient of discharge

The water budget of the submerged area can be obtained by considering the aforementioned equations as simultaneous equations. The objective area for simulation analysis was divided into blocks and each block was treated as a small reservoir. Blocks are linked to each other by drainage facilities such as river, creek, drainage canal or culvert, and the water stages in each block were traced by solving the simultaneous equations.

(3) Present Condition of Inundation and Flood Damage

Table A.4.2-1 presents the summary of the flood simulation study made for the submerged area of the Angat North under the present condition of drainage facilities. According to the computed results, the biggest inundation occurred in May, 1976 with the maximum water level of 6.81 m above mean sea level and the maximum inundated area of 13,700 ha.

The area suffers from inundations two to nine times a year with total duration of inundation of 27 to 128 days. The maximum water level of inundation varies depending on the flood involved from 2.73 to 6.81 m above mean sea level, resulting in an inundated area of 4,100 to 13,000 ha, in which 1,500 to 9,000 ha is counted within the service area.

The computed results were, then, put into the statistical evaluation and the followings were obtained.

Probable Dimension of Flood
(Angat North)

Return Period (Year)	Maximum Water Stage Pampanga (m)	N.Candaba (m)	The Area (m)	Inundated Area (ha)	Maximum Duration (days)	Total Duration (days)
2	5.12	6.07	4.29	8,790	41	81
5	5.86	6.93	5.25	11,000	65	116
10	6.34	7.48	5.88	12,250	82	140
20	6.82	8.03	6.47	13,330	99	163

Flood simulation study was also conducted for the submerged area in the Angat South service area as summarized in Table A.4.2-2. According to the computed results also in this area, the biggest inundation occurred in May, 1976 with the maximum water level of 2.10 m above MSL and the maximum submerged area of about 2,000 ha.

With total duration of inundation of 27 to 114 days, inundation occurs 7 to 16 times in this area annually. The maximum water level of inundation simulated varies from 1.09 m to 2.10 m above mean sea level, resulting in an inundated area of 850 to 2,000 ha.

The simulated results were then put into the statistical evaluation and the following were obtained.

Probable Dimension of Flood (Angat South)

Return Period (Year)	Maximum Level Labangan (m)	Maximum Level Area (m)	Inundated Area (ha)	Maximum Duration (days)	Total Duration (days)
2	2.83	1.40	1,250	24	87
5	3.40	1.97	1,970	30	98
10	3.75	2.02	1,990	34	106
20	4.11	2.13	2,030	37	117

4.2.3 Peak Flood Discharge Analysis

The method of characteristics was applied to estimate flood runoff from the submerged area where insufficient drainage canals or creeks exist.

The mechanism of surface runoff in such area may fall generally into three parts: i) behavior of rain water stored on a paddy, ii) behavior of rain water which flows down a sloping ground surface and iii) behavior of lateral inflow into drainage canals or creeks.

In a simplified stream condition, the behavior of unsteady flow in an open canal with distributed lateral inflow along the canal was studied hydraulically to establish the basic relation between the rate of inflow and runoff in canal or on a sloping surface of the drainage area.

Hydrographs using an approximate method which utilizes the characteristic equations, and the hydraulic characters of hydrographs resulting from simulated inflow at a given rate were investigated.

(1) Design Flood Rainfall

From the view of frequency and rainfall intensity, 7 day consecutive rainfall was adopted for the basis of flood analysis. The annual maximum 7-day rainfalls in the AMRIS area in the past 10 years vary from 203 mm in 1973 to 760 mm in 1972. As the design consecutive rainfall, a total of 551 mm/7 days with once in five years frequency was obtained by statistical evaluation. To determine the hourly distribution pattern of the design rainfall, actual pattern of rainfall, which was observed at Bahay Pare station during 21 to 27 May, 1976, was selected because i) the amount of rainfall is similar to that of the design rainfall and ii) the area was greatly damaged by this rainfall.

Annual Maximum Consecutinve Seven-Day Rainfall

Year	Month	Date	Rainfall in mm
1970	Ang.-Sep.	26-1	405.6
1971	Oct.	9-15	210.4
1972	Jul.-Aug.	27-2	759.7
1973	Jul.	10-16	202.7
1974	Aug.	11-17	626.0
1975	Aug.	8-14	237.0
1976	May	21-27	564.5
1977	Jul.	15-21	235.4
1978	Aug.	21-27	348.2
1979	Aug.	11-17	297.5
Design	Once in 5years probability		551.0

The design rainfall was thus distributed hourly in proportion to the observed pattern as shown in Figure A.4.2-8.

(2) Method of Characteristics

When the laws of resistance of Manning's type is used, unsteady flow in an open canal with a given uniform rate of lateral inflows would be expressed, for practical purpose, by the following equation.

$$A = n.\ I^{-1/2}.\ R^{-2/3}.Q = KQ^{P}$$

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \qquad \text{--------(1)}$$

The method of chracteristic was applied to solve the eqations and the characteristic curve is given as follows:

$$\frac{dx}{1} = \frac{dt}{dA/dQ} = \frac{dt}{PKQ^{P-1}} = \frac{dQ}{q} \qquad \text{------(2)}$$

where A: cross-sectional area of flow
n: Manning's roughness ciefficient
I: Water surface slope of flow
R: hydraulic radius
Q: discharge
K,P: constants
t: time
x: distance along canal
q: lateral inflow per unit length of canal

This means, solving equation (1) is equivalent to solving the following two equations on a characteristic curve expressed as $dx/dt = Q^{1-P}/PK$

$$qdt = PKQ^{p-1} \quad \text{or} \quad qt = KQ^{p} + \text{constant}$$

$$qdx = dQ \quad \text{or} \quad qx = Q + \text{constant} \qquad \text{---(3)}$$

The flow condition is given for a given magnitude of lateral inflow, q, taking constant = 0.

$$t = KQ^{p}/q \qquad \text{------------------------------(4)}$$

and $t = KxQ^{p-1}$ ------------------------------(5)

when q = 0, it is expressed on the characteristic curve that A = constant and Q = constant = $(A/K)^{1/p}$. The flow condition is, therefore, given simply as

$$x = (Q^{1-p}/PK) \cdot t \qquad \text{--------------------------(6)}$$

The retention capacity of paddy field is generally recognized to be responsible for the time lag of a paddy flood runoff. A paddy field surrounded by levees can be regarded as a small reservoir. Therefore, the concept of simple reservoir operation could be introduced to determine the flood runoff from a paddy field.

A storage function is introduced to calculate the specific run-off capacity from a paddy plot in the following equation.

$$\frac{dv}{dt} = I - 0 \text{ ---------------------------(7)}$$

V denoted storage on a paddy field, I and 0, are inflow and outflow into/from the paddy field, respectively, and t denotes time.

To determine the specific runoff rom the paddy field, the above equation was divided by the area, A, of the paddy field. The equation then becomes,

$$\frac{dH}{dt} = i - 0$$

where H refers to water depth on the paddy field, i, specific inflow, which is equal to the effective rainfall and 0, specific outflow, which is equal to the runoff from the paddy field through the spillway.

A differential equation given below is constructed to solve the above equation by computer as,

$$H_{t+1} = H_t + [Re,_{t \sim t+1} - (0_t + 0_{t+1})/2] \cdot \Delta t \text{ ---(9)}$$

Where Re, t-t+1 represent effective rainfall on a paddy plot between time t and t+1, and Δt is time interval given for computation. The specific runoff capacity from paddy field is, thus, computed corresponding to each time t, and then this is considered as a lateral inflow to drainage canal or ditch under consideration.

In the computation of unit area drainage design discharge using the above model, the specific inflow into the paddy field (effective rainfall) was assumed to follow the characteristics of the curve as shown in Figure A.4.2-11.

On the other hand, the specific outflow, which is equal to the runoff from the paddy field was computed using the following equation.

$$Q_1 = \frac{360}{As} \times c \times b \times (H - h)^{3/2}$$

where:

- c -coefficient of discharge
- As -drainage area commanded by a spillway, ha.
- H -flooding depth on the paddy field, m
- b -width of spillway, m
- h -height of spillway,m
- Q_1 -specific discharge through spillway, m

The runoff rom the paddy field is equal to the capacity of the spillway only to a certain point (Figure A.4.2-11). After that point the paddy runoff is already affected by the capacity of the farm drain which was determined using the Manning's equation as described below:

$$Q_2 = \frac{360}{Ad} \times \frac{1}{n} \times I^{1/2} \times \frac{[d\ (B + (z \times d))]^{5/3}}{(B + 2d\sqrt{1 + z^2})^{2/3}}$$

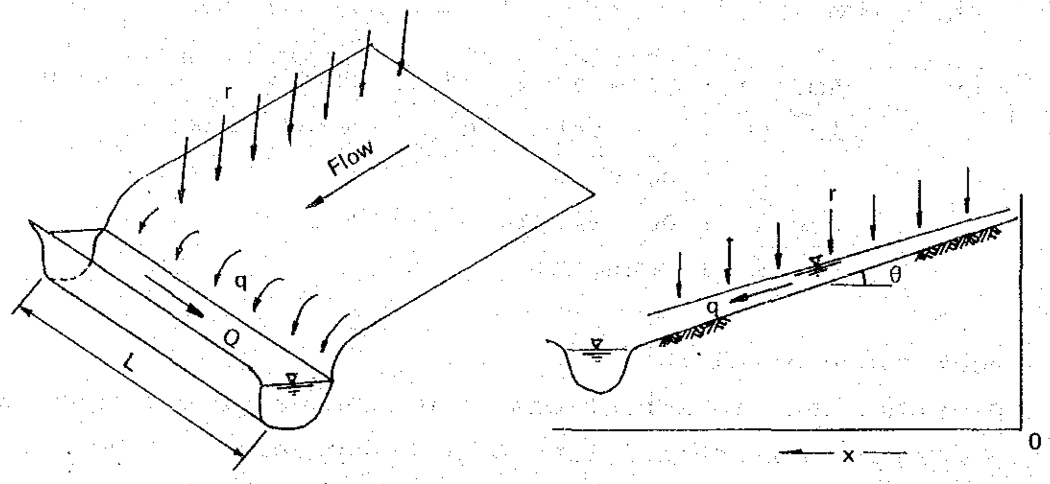
where:

- Q_2 -specific dishcharfe in farm drainage ditch, mm/hr
- Ad -command area of the ditch, has.
- B -bottom width, m.
- n -Manning's roughness coefficient
- I -longitudinal slope of the ditch
- d -depth of flow, m.
- z -side slope of the ditch

An application of the characteristic method could be summarized as follows:

1) For Slope

lateral inflow (r) =rainfall



° When r is not equal to zero,

$t = K.q^{p}/\delta r$

$t = K.x.q^{p-1}$

° when r = 0,

$t = pkx \,/\, q^{1-p} = 0.6\, q^{-0.4} (N/I^{1/2})^{0.6} x$

where, r : effective rainfall intensity in mm/hr

δ : conversion rate from mm/hr to cum/sec/m
$= 0.2778 \times 10^{6}$

q : discharge per unit width of slope in cum/sec/m

N : equivalent roughness coefficient for slope

I : slope inclination = Sin θ

x : flow distance in m.

2) For River, Creek, anal or Ditch

As discussed previouly with theoretical concept.

3) For Paddy Field

° For ditch

$Am = KQ^{p}m$

$$\frac{\partial Am}{\partial t} + \frac{\partial Qm}{\partial x} = (2.b.Q).\ \alpha, \text{ and}$$

° For lateral drainage canal

$$Ab = KQ_b^p$$

$$\frac{\partial Ab}{\partial t} + \frac{\partial Qb}{\partial x} = \frac{Qm}{2b}$$

where Am, Qm : Flow area and discharge in a dithch

Ab, Qb : -ditto- in a lateral canal

K, p : constant

a,b,l : see figure A.4.2-9

d : constant

(3) Peak flood discharge

Profiles and cross sections of drainages/creeks surveyed by NIA were used in calculation of K and p values. The values of the different variables used in the computations are:

Initial depth of water in paddy field = 0.1 m

Height of paddy spillway, H = 0.1 m

Bottom width of paddy spillway, b = 0.2 m

Bottom width of drainage ditch, B = o.3 m

Manning's roughness coefficient, n = 0.04

Depth of farm ditch with reference to paddy surface, Sh = 0.6 m

Side slope of ditch, z = 1:1

Longitudinal slope of farm ditch, I = 1:3000

Command area of paddy spillway, As = 1.5 ha

Command area of ditch, Ad = 30 ha

In order to estimate flood runoff from the drainage areas, objective areas were divided into blocks according to the commanding drainages/creeks, and they were modeled to be rectangles. Figure A.4.2-12 illustrates diagrams prepared for flood runoff analysis. Accompanied with estimated peak discharges during the design flood with once in five years occurrence, major hydraulic dimensions of the existing drainages/creeks are listed in Table A.4.2-3.

The computed peak discharges vary from 7.7 to 9.0 ℓ/sec/ha depending on the topographic or hydraulic condition of each canal/creek, and from this study the design unit discharge of drainage was determined at 8.0ℓ/sec/ha, almost corresponding to that given in NIA"s design criteria prepared for 10 years probable flood.

TABLE A.4.2-1 SUMMARY OF SIMULATED INUNDATION UNDER PRESENT CONDITION (ANGAT NORTH SUBMERGED AREA)

Year	Maximum External Water Stage		Inundation in the Area				
	Pampanga	N.Candaba	Maximum Water Stage	Maximum Area of Inundation	Time of 1/ Occurence	Maximum 1/ Duration	Total 1/ Duration
	(m)	(m)	(m)	(ha)		(days)	(days)
1960	5.74	7.00	5.29	11,205	2	86	101
1961	4.80	5.85	3.82	7,465	3	77	119
1962	5.71	6.84	5.21	11,093	2	86	87
1963	4.83	5.93	3.85	7,554	5	51	96
1964	4.27	5.38	3.51	6,527	7	43	128
1965	4.74	5.67	3.76	7,275	9	37	83
1966	5.06	6.08	4.07	8,207	7	23	95
1967	4.69	5.63	3.72	7,164	4	93	121
1968	4.90	6.21	3.90	7,706	6	42	69
1969	5.66	5.58	4.89	10,498	7	28	48
1970	4.97	6.30	3.96	7,870	6	28	63
1971	5.41	6.30	4.54	9,525	7	41	101
1972	-	-	-	-	-	-	-
1973	5.53	-	4.81	10,255	5	23	47
1974	6.37	7.83	6.26	12,695	7	40	97
1975	2.92	-	2.73	4,058	5	10	27
1976	7.03	8.80	6.81	13,731	5	30	115
Maximum	7.03	8.80	6.81	13,731	9	93	128
Minimum	2.92	-	2.73	4,058	2	10	27
Mean				8,927	5	46	87

Note: 1/ --- On a field of the elevation of 2.0 m above MSL.

TABLE A.4.2-2 SUMMARY OF SIMULATED INUNDATION UNDER PRESENT CONDITION

(ANGAT SOUTH SUBMERGED AREA)

Year	Maximum External Water Stage in Labangan (m)	Maximum Water Stage (m)	Maximum Area of Inundation (ha)	Time of 1/ Occurence	Maximum 1/ Duration (days)	Total 1/ Duration (days)
1960	3.36	1.98	1,942	8	28	91
1961	2.72	1.31	1,159	10	35	110
1062	3.28	1.65	1,583	10	34	82
1963	2.74	1.32	1,168	11	17	88
1964	2.41	1.09	854	14	27	114
1965	2.69	1.37	1,240	16	13	76
1966	2.87	1.45	1,350	12	22	72
1967	2.66	1.30	1,143	11	37	107
1968	2.78	1.17	966	11	27	66
1969	3.23	1.11	883	10	16	48
1970	2.82	2.04	1,992	11	15	64
1971	3.08	1.35	1,212	13	24	101
1972	-	-	-	-	-	-
1973	3.15	1.41	1,301	10	18	60
1974	3.89	2.06	2,015	9	19	90
1975	1.60	1.43	1,326	7	6	27
1976	4.32	2.10	2,046	12	26	93
Mean			1,386	11	23	81
Maximum	4.32	2.10	2,046	16	37	114
Minimum	1.60	1.09	854	7	6	27

Note: 1/ ..... On a field of the elevation of 0.5 m above MSL.

TABLE A.4.2-3(1) HYDRAULIC DIMENSION OF EXISTING DRAINAGE/CREEK (1)

No.	Name	Drainage Area	Length	Hydraulic Gradient	Bottom Width	Peak Discharge
		(Sq.Km.)	(m)		(m)	(cu.m/s)
	PAMPANGA RIVER BASIN:					
1	Anitap Dr.	0.30	1,230	700	2.0	0.233
3	Matique Dr.	0.65	2,470	5,000	3.0	0.505
4	Matique Cr.	3.50	1,230	3,000	3.0	2.740
5	Ebos Cr.	3.26	1,800	2,100	4.5	2.560
6	Sapang Boyo Cr.	1.86	1,440	3,200	8.2	1.458
7	Queros Cr.	13.64	1,420	500	7.0	10.640
8	Matukal Cr.	0.51	1,920	3,500	5.0	0.397
9	Pantaga Cr.	5.79	1,680	3,000	2.5	4.548
10	Caniupan Cr.	4.71	2,000	4,000	3.8	3.671
11	Sinabitan Cr.	3.13	2,200	3,000	3.0	2.453
13	Maynate Cr.	5.10	1,600	1,000	5.0	3.987
14	Sepo Cr.	3.82	830	3,000	7.0	2.993
15	Lawas Cr.	2.89	830	3,000	7.0	2.268
16	Maynanta Cr.	17.94	1,220	600	4.0	13.831
17	Bambang Cr.	1.30	1,650	3,000	15.0	1.033
18	Punglod Cr.	15.36	830	3,000	7.0	11.935
19	Bitukang Manok Cr.	14.67	5,510	3,000	15.0	11.414
20	- ditto -	13.72	1,840	3,000	15.0	10.733
21	- ditto -	13.19	4,290	3,000	15.0	10.350
22	- ditto -	12.26	2,450	3,000	15.0	9.600
23	- ditto -	11.21	1,590	3,000	15.0	8.749
24	- ditto -	9.89	1,470	3,000	15.0	7.695
25	- ditto -	9.30	4,160	1,000	15.0	7.219
26	- ditto -	6.99	4,530	1,000	15.0	5.427
27	- ditto -	5.67	4,650	1,000	15.0	4.445
28	- ditto -	3.68	6,120	1,000	15.0	2.883
30	Cansinala Cr.	37.18	3,920	1,800	7.0	28.121
31	Pantamukou Cr.	0.64	830	2,000	4.0	0.499
32	Pakate (2) Cr.	32.76	600	2,000	3.0	24.109
33	Pandpog Cr.	28.98	1,100	2,000	5.0	23.270
34	Calantipay Cr.	7.88	4,500	1,900	5.0	6.163
35	Calantipay-Dr.	2.61	1,380	1,900	3.0	2.044
36	- ditto -	1.71	1,930	1,400	3.0	1.331
37	Pandapog Cr.	20.15	900	2,000	7.0	15.676
38	Bitukang Manok Cr.	0.56	1,100	2,000	10.0	0.437
39	Pandapog Cr.	19.59	900	2,000	5.0	15.283
40	San Roque Dr.	3.97	2,750	2,000	3.0	3.106
41	Palique Cr.	2.25	2,250	2,000	2.0	1.764
42	Duyong Cr.	12.79	6,360	3,000	5.0	9.985
43	Duyong Dr.	3.50	2,380	2,900	3.0	2.742
44	Pinanacpon Cr.	2.54	3,030	400	2.0	2.045
45	Sapang Kawayan Cr.	2.83	2,250	2,500	5.0	2.210
46	- ditto -	0.69	960	2,500	5.0	0.537
47	Lugto Dr.	1.17	830	400	2.0	0.932

TABLE A.4.2-3(2) .. HYDRAULIC DIMENSION OF EXISTING DRAINAGE/CREEK(2)

No.	Name	Drainage Area	Length	Hydraulic Gradient	Bottom Width	Peak Discharge
		(Sq.Km.)	(m)		(m)	(cu.m/s)
48	Capalungan Cr.	68.90	1,100	3,000	4.0	54.762
49	Pusawan Cr.	24.74	4,130	3,000	2.5	19.262
50	Escaler (1) Cr.	8.35	3,030	4,000	5.0	6.555
51	Batasan (1) Cr.	12.60	5,500	1,800	3.0	9.816
52	- ditto -	7.65	2,200	1,800	3.0	6.003
53	Matang Tubig Dr.#2	0.99	1,650	900	1.2	0.771
54	Batasan (1) Cr.	6.66	330	1,800	3.0	5.189
56	Batasan (1) Cr.	6.66	550	1,800	3.0	5.203
57	- ditto -	2.27	690	1,800	2.0	1.776
58	Matang Tubig Cr.	3.74	4,400	1,300	1.8	2.930
59	Lakbangan Cr.	37.58	2,620	3,000	4.0	30.441
60	Escaler (2) Cr.	34.28	1,380	3,000	5.0	28.008
61	- ditto -	2.30	1,820	3,000	5.0	1.798
62	Tenejero Cr.	31.33	5,000	1,100	7.0	25.043
63	Batasan (2) Cr.	8.31	1,250	1,000	2.0	6.514
64	- ditto -	2.88	1,500	1,000	2.0	2.265
65	Inaon Cr.	5.43	3,850	600	2.0	4.242
66	Tenejero Cr.	22.00	4,240	3,900	3.0	17.526
67	Sinipit Dr.#2	4.45	3,300	2,200	2.0	3.470
68	Sinipit Cr.	7.85	3,580	600	2.0	6.157
69	Sta.Barbara Cr.	1.91	1,380	1,200	2.0	1.490
70	Cutcot Cr.	1.17	2,480	600	2.0	0.922
71	Sapang Bayan Cr.	18.39	1,800	4,000	5.0	14.532
72	Señora Cr.	1.65	900	4,000	1.5	1.293
73	Baubago Cr.	11.79	1,310	4,000	2.0	9.218
74	Balibago Cr.	3.80	3,810	3,000	2.0	2.977
75	Escaler (3) Cr.	7.99	2,570	3,000	1.0	6.222
76	Dulong Malabon Cr.	5.01	3,320	1,400	2.5	3.898
77	Escaler (3) Cr.	1.50	900	3,000	1.0	1.172
78	Sapang Sukol Cr.	3.19	3,580	2,000	0.8	2.493
	Total		173,100			
	ANGAT RIVER BASIN					
101	Makinabang Cr.	3.12	4,000	600	1.5	2.442
102	Talampas Cr.	1.13	1,400	600	3.0	0.882
103	San Pedro Cr.	6.75	3,000	700	3.0	5.260
104	- ditto -	7.13	400	700	3.0	6.440
105	Bacao Cr.	5.25	3,000	500	6.0	4.105
106	Culianin Cr.	3.12	800	1,500	2.5	2.441
	Total		12,600			

TABLE A.4.2-3(3) HYDRAULIC DIMENSION OF EXISTING DRAINAGE/CREEK(3)

No.	Name	Drainage Area	Lenght	Hydraulic Gradient	Bottom Width	Peak Discharge
		(Sq.Km)	(m)		(m)	(Cu.m./s)
	MAASIM RIVER BASIN					
201	Anitap (2) Cr.	2.61	2,060	700	3.5	2.053
202	Mangulyawan Cr.	2.05	1,240	4,000	3.0	1.606
203	Ayudante Cr.	6.56	2,750	4,000	2.5	5.116
204	Santiago Cr.	4.70	830	1,000	2.5	3.678
205	Pakate (1) Cr.	4.00	2,750	700	1.5	3.134
208	Pulong Plazan Cr.	39.49	4,130	1,400	2.5	31.723
209	- ditto -	10.92	3,750	1,400	2.5	8.556
210	- ditto -	2.87	3,710	1,400	1.8	2.248
211	San Roque Cr.	8.05	1,250	5,200	1.0	6.298
212	Sto.Niño Dr. #7	1.02	1,930	1,400	0.6	0.791
213	San Roque Cr.	5.77	130	1,400	4.0	4.519
214	Sto. Niño Dr. #1	1.85	2,750	1,400	1.2	1.465
215	San Roque Cr.	3.92	150	1,400	3.0	3.073
216	- ditto -	1.41	720	400	1.0	1.114
217	Sto. Niño Dr. #2	2.51	4,420	1,400	2.5	1.971
218	Maningsing Cr.	28.57	1,070	600	4.5	23.027
219	Lanay (1) Cr.	0.67	3,500	1,400	8.0	0.516
220	Maningsing Cr.	27.25	2,590	1,900	6.0	21.777
221	Adia Cr.	10.65	4,420	1,100	6.0	8.302
222	Pulong Bayabas Cr.	14.06	6,820	1,400	2.0	10.968
223	Lanay (2) Cr.	8.48	5,000	1,400	4.0	6.633
224	Paetan Cr.	7.37	6,020	1,900	7.5	5.757
225	Barangca Dr.	2.19	2,590	800	4.0	1.718
226	Ulingao Cr.	1.58	1,890	700	2.0	1.230
227	Sapang Sonara Cr.	4.97	1,380	3,000	1.5	3.873
228	Balajadia Cr.	3.82	3,030	3,000	2.0	2.989
229	Victoria Cr.	6.50	6,500	3,000	3.8	0.409
230	Sapan Putol Cr.	2.25	3,500	3,000	3.0	1.743
	Total		80,880			
	OTHER RIVER BASIN					
301	Sapang Pagkasinta Cr.	7.50	5,300	1,400	4.0	5.552
302	Calamitan Cr.	8.12	5,000	1,400	4.0	6.345
	Total		10,300			
	LABANGAN RIVER BASIN					
401	Iba Calumpit Dr.	2.72	3,020	900	2.5	2.121
402	Iba Hagnoy Dr.	13.64	2,200	5,000	1.5	10.626
403	San Marcos Cr.	2.28	3,300	5,000	1.5	1.792
404	Lugam Cr.	8.02	1,240	2,000	2.0	6.273
405	Balite Cr.	1.70	3,400	2,400	6.5	1.344
406	Lugan Cr.	6.32	2,340	2,000	1.5	4.949
407	Tuod Cr.	1.70	2,750	1,500	2.0	1.348
408	Lugam Cr.	2.83	3,580	2,000	2.0	2.208
	Total		21,830			

TABLE A.4.2-3(4) HYDRAULIC DIMENSION OF EXISTING DRAINAGE/CREEK (4)

No.	Name	Drainage Area	Length	Hydraulic Gradient	Bottom Width	Peak Discharge
		(Sq.km)	(m)		(m)	(cu.m/s)
	PAMARAWAN RIVER BASIN					
501	Balayong Cr.	7.26	3,300	3,000	4.0	5.652
502	- ditto -	1.28	830	3,000	4.0	0.997
503	Cakila Cr.	3.00	1,820	2,000	1.5	2.347
504	Balite River	20.30	1,380	3,000	3.0	16.051
505	- ditto -	17.49	1,100	3,000	2.0	13.660
506	San Nicolas River	2.81	4,130	3,000	10.0	2.194
507	Balite River	12.79	3,090	3,000	1.5	10.043
508	Pitpitan Cr.	4.00	5,500	3,000	4.0	3.131
509	Balite River	9.12	3,030	3,000	2.0	7.127
510	Taal Cr.	2.77	2,750	1,500	1.0	2.171
511	Santol Cr.	6.95	1,380	1,000	4.0	5.419
	Total		28,310			
	GUIGUINTO RIVER BASIN					
601	Guiguinto River	33.68	5,500	2,700	20.0	26.370
602	- ditto -	11.85	3,850	2,700	20.0	9.273
603	Taban Cr.	5.53	2,480	600	1.5	4.309
604	Daong River	12.85	2,480	900	3.5	10.033
605	Sapang Pritil Cr.	1.55	1,650	2,700	2.5	1.209
606	Daong River	5.92	1,380	1,100	3.0	4.624
607	- ditto -	5.55	2,480	1,100	2.5	4.319
608	Guiguinto Cr.	0.37	3,300	500	5.0	0.308
609	Daang Banska Cr.	4.00	1,750	3,000	2.0	3.120
	Total		24,870			
	BIGAA RIVER BASIN					
701	Matingao Cr.	1.06	1,650	3,500	2.5	0.823
702	Panginay Cr.	1.55	5,500	1,900	2.5	1.204
703	Ugon Cr.	5.75	7,700	1,100	2.8	4.476
704	Santol Cr.	65.40	1,930	1,100	4.0	57.172
705	Batia Cr.	8.00	3,580	600	6.0	6.249
706	Santol Cr.	57.40	2,480	1,100	4.0	50.969
707	Manatal Cr.	24.69	830	1,600	4.0	24.497
708	- ditto -	2.07	3,030	1,600	3.0	1.619
709	Malawak Cr.	14.61	6,880	700	3.0	11.392
710	Masuso Cr.	8.01	830	800	4.0	11.488
711	Masagana Cr.	5.39	3,500	700	4.0	9.435
712	Bulihar Cr.	31.48	3,750	1,100	5.0	25.367
713	Camachilihan Cr.	27.71	7,880	1,100	7.0	22.299
714	Malamig Cr.	16.13	6,360	300	4.0	12.619
715	Asana Cr.	10.42	6,400	1,300	4.5	8.132
	Total		62,300			

TABLE A.4.2-3(5) HYDRAULIC DIMENSION OF EXISTING DRAINAGE/CREEK(5)

No.	Name	Drainage Area	Length	Hydraulic Gradient	Bottom Width	Peak Discharge
		(Sq.Km)	(m)		(m)	(cu.m/s)
	SANTO NIÑO RIVER BASIN					
801	Capitangan Cr.	4.30	6,600	2,600	3.5	3.363
802	Malangam Cr.	32.65	8,250	3,300	3.0	25.415
803	- ditto -	16.47	2,580	3,300	3.5	14.841
804	Bulihan Cr.	2.80	2,280	3,300	4.0	2.198
805	Pinagbakahan Cr.	5.88	3,300	1,300	2.0	4.586
806	Mojon Cr.	16.18	1,650	1,700	3.0	12.698
807	- ditto -	12.21	2,310	1,700	3.0	9.587
808	Mabolo Cr.	2.07	2,500	1,700	3.0	1.629
809	Sumapa Cr.	8.00	2,480	1,700	3.0	6.261
810	Nabuag Cr.	2.34	1,380	1,200	2.0	1.843
	Total		33,330			
	Grand Total		447,520			

Remarks: (1) A specified station number was given in computation of flood hydrograph.

(2) Peak discharge was quoted from flood hydrograph computation made by the method of characteristics.

FIGURE A.4.2-1 DISTRIBUTION OF THE PAMPANGE LEFT BANK

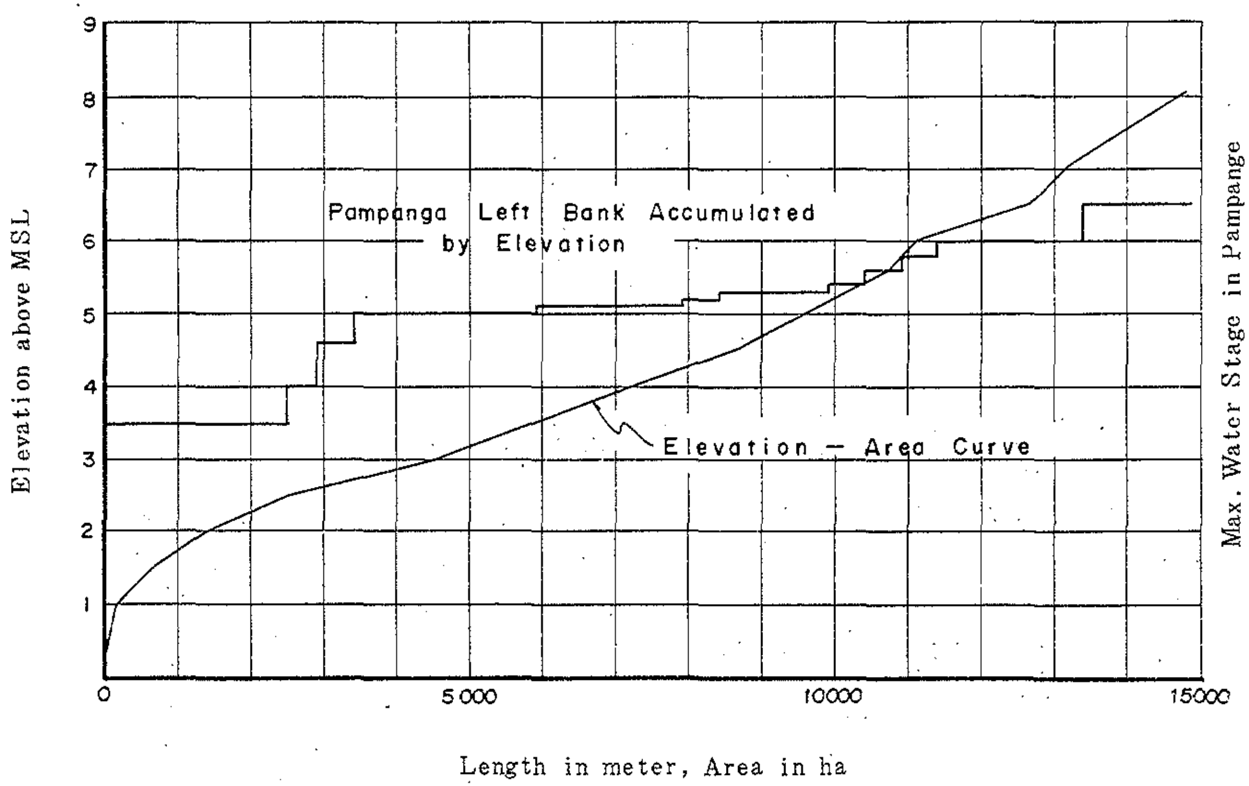


FIGURE A.4.2-2 CORRELATION OF MAXIMUM WATER STAGE

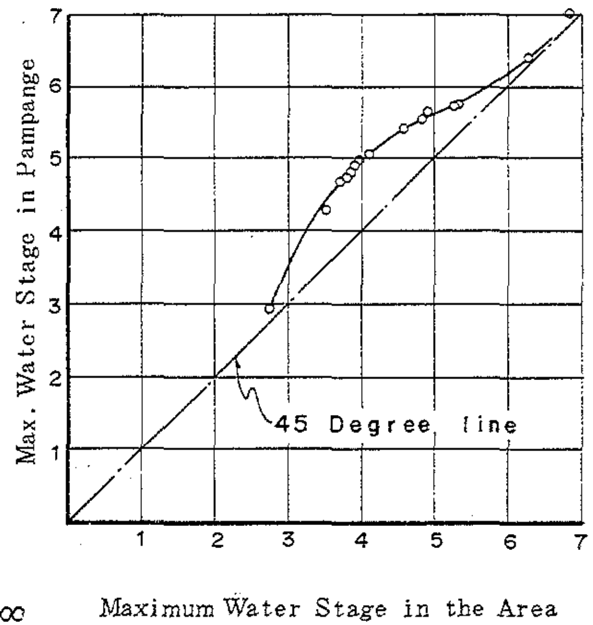


FIGURE A.4.2-3 DURATION OF INUNDATION ON A FIELD OF ELEVATION INDICATED

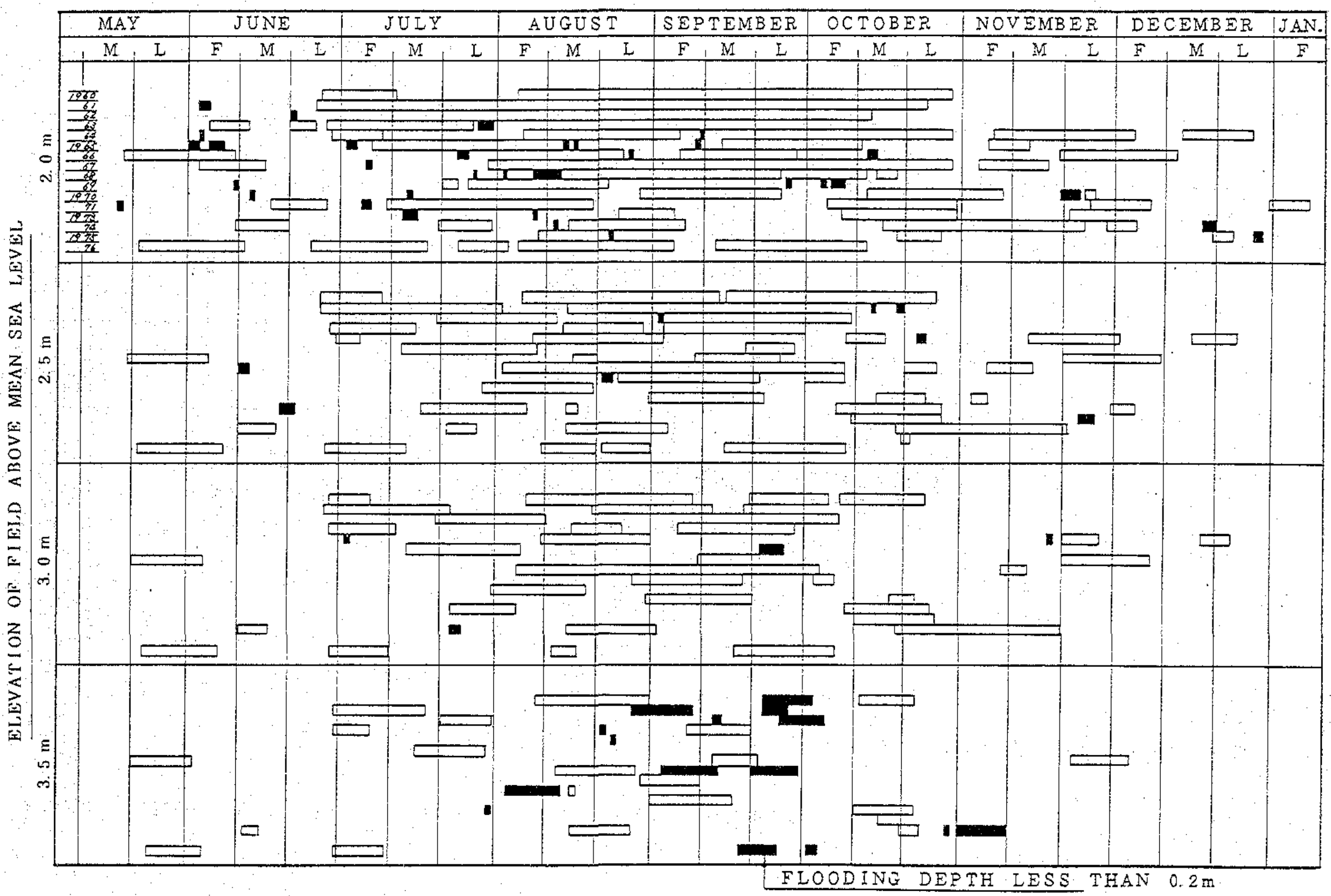
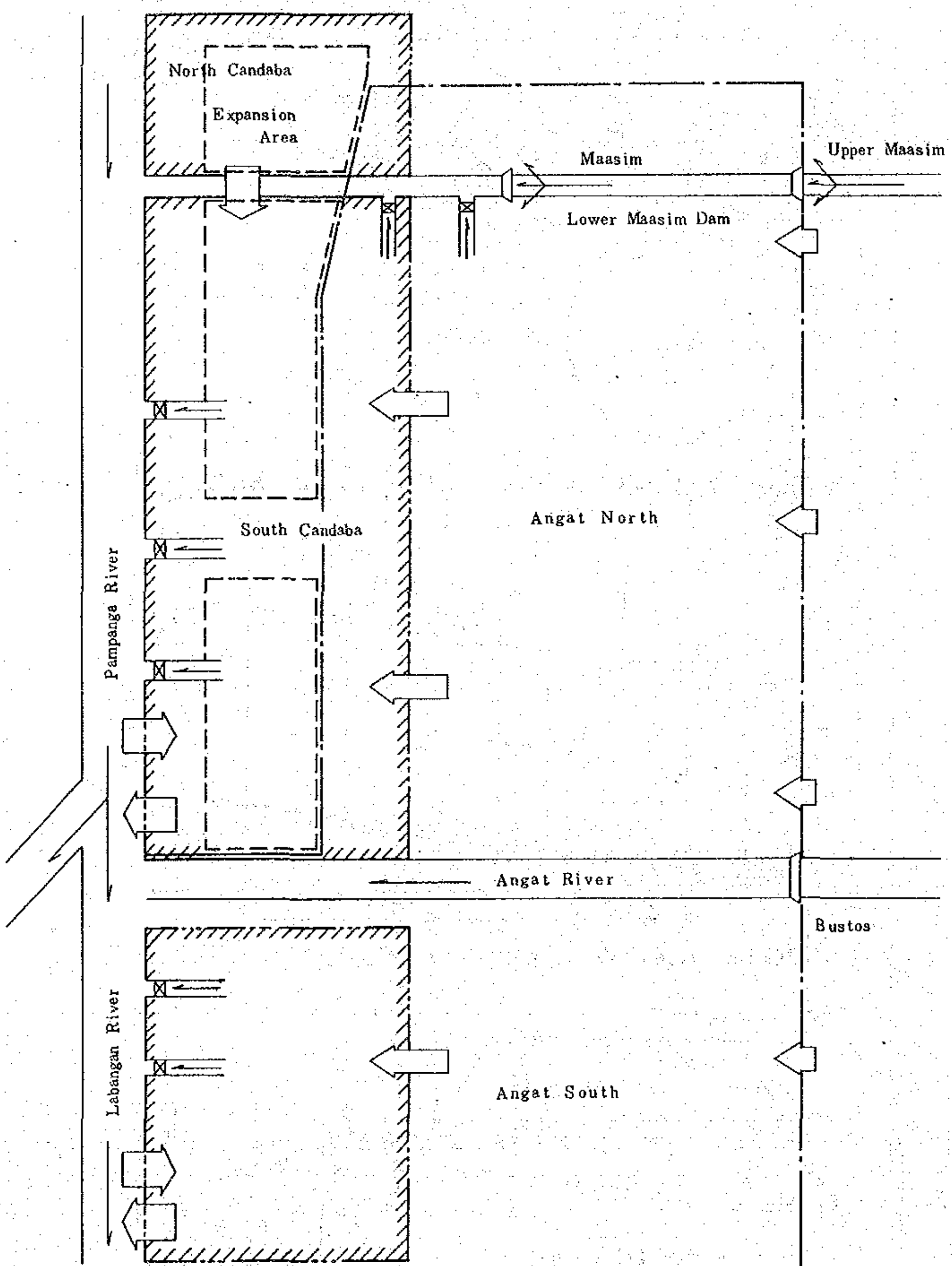


FIGURE A.4.2-4 DIAGRAM OF WATER BALANCE SIMURATION



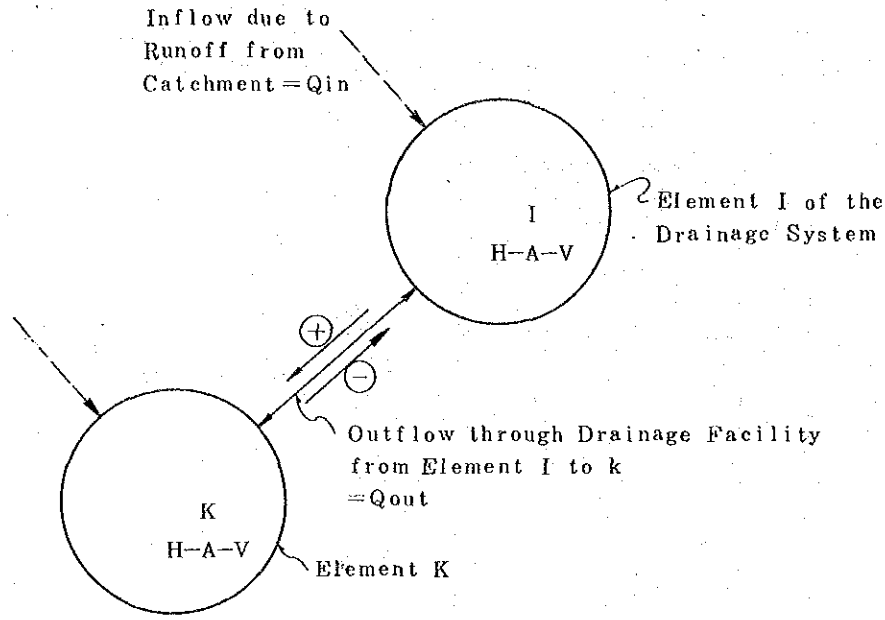


FIGURE A.4.2-5 WATER BUDGET DIAGRAM

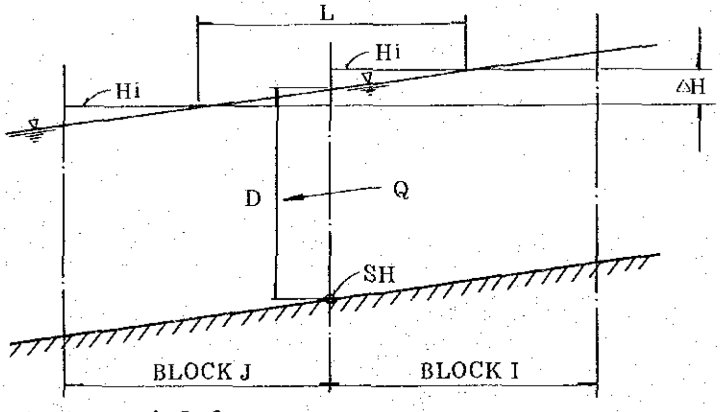


FIGURE A.4.2-6 FLOW IN CANAL/CREEK

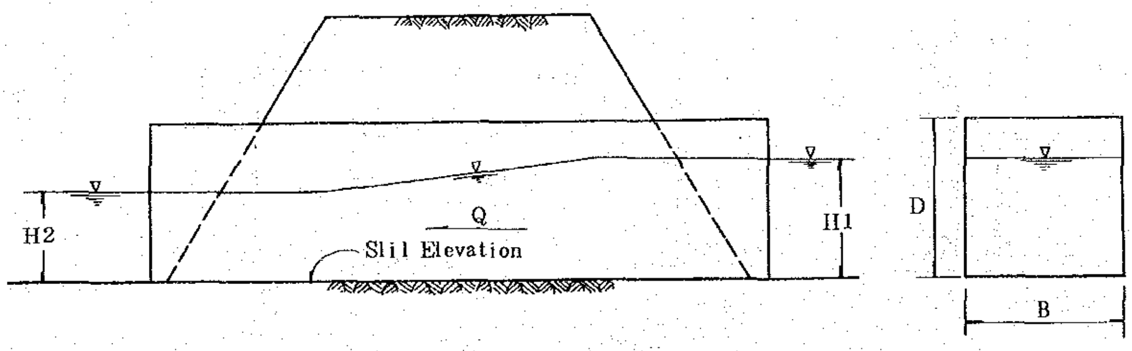


FIGURE A.4.2-7 FLOW IN CULVERT/SLUICE WAY

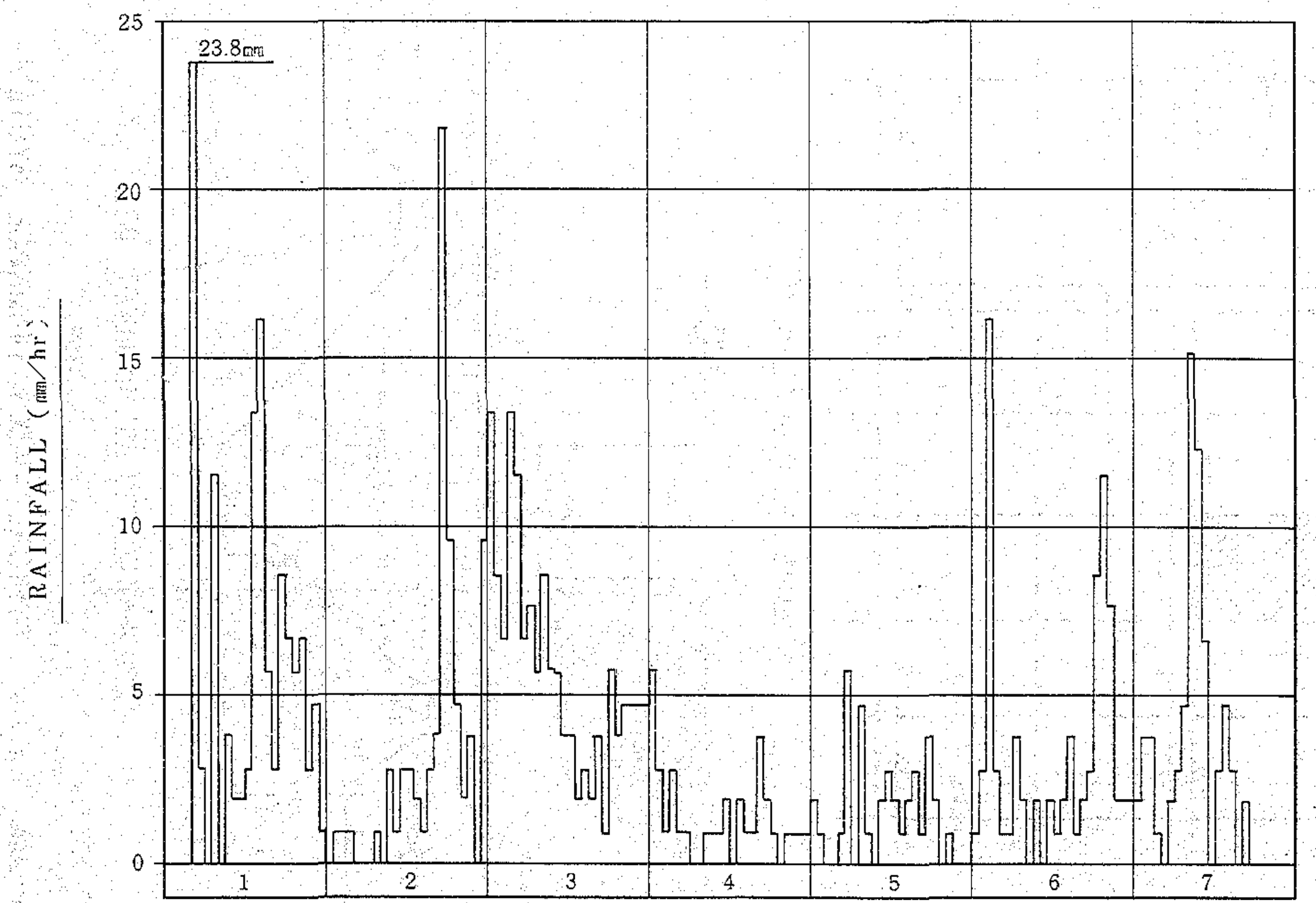
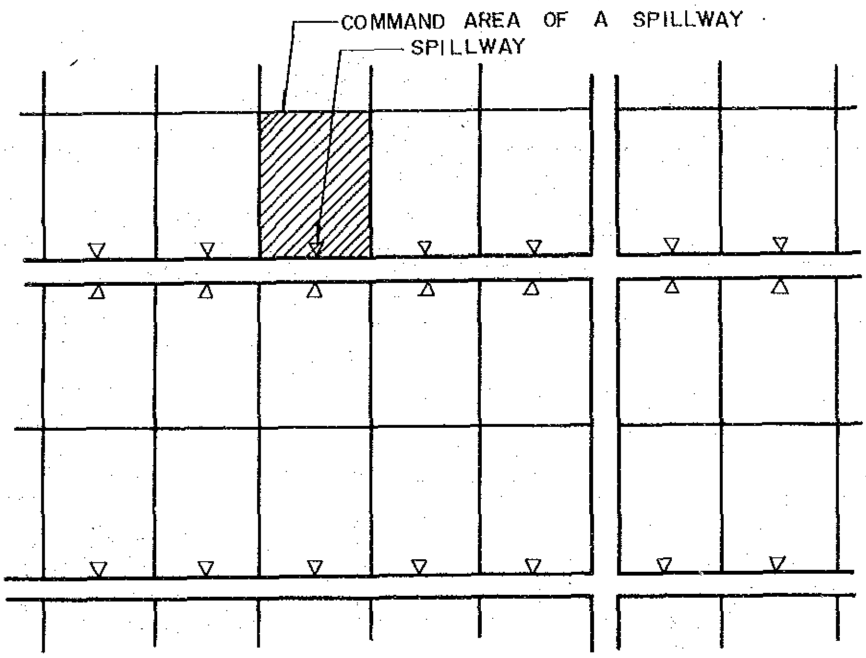
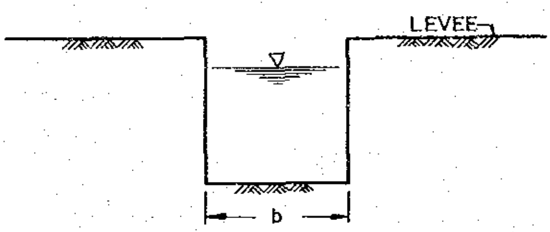


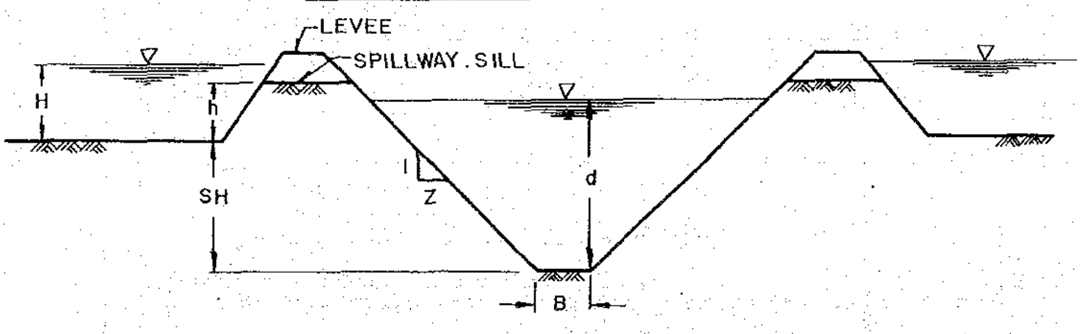
FIGURE A.4.2-8 HOURLY DISTRIBUTION OF 7-DAY CONSECUTIVE RAINFALL



PLAN OF PADDY FIELD



CROSS-SECTION OF A SPILLWAY



CROSS-SECTION OF DRAINAGE DITCH

FIGURE A.4.2-9 TYPICAL PADDY DRAINAGE SYSTEM

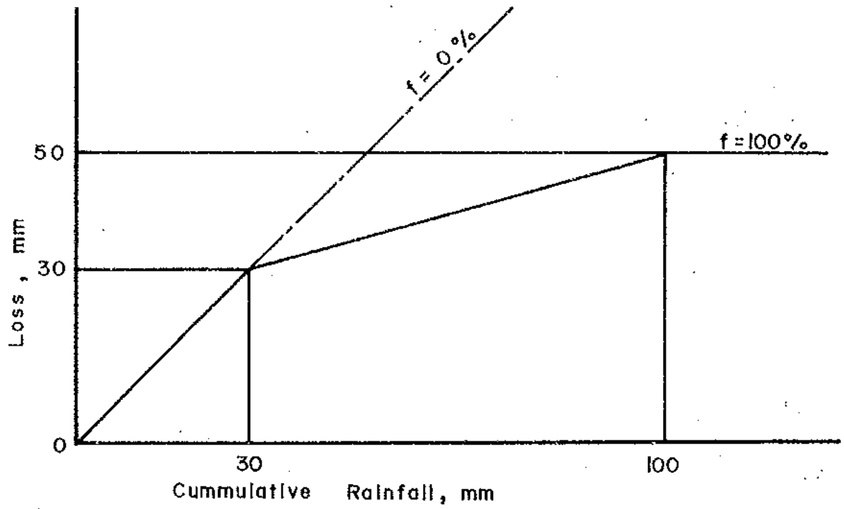


FIGURE A.4.2-10 EFFECTIVE RAINFALL IN PADDY FIELD

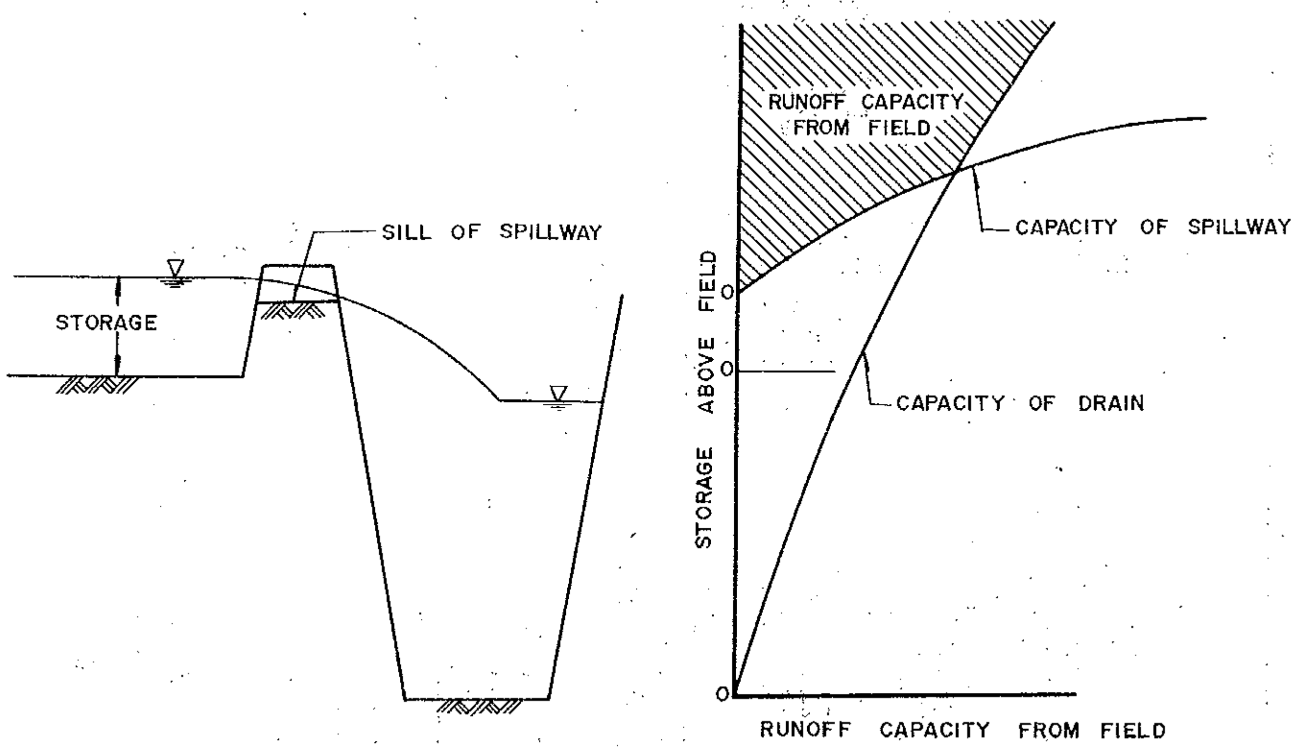


FIGURE A.4.2-11 RUNOFF CAPACITY FROM FIELD

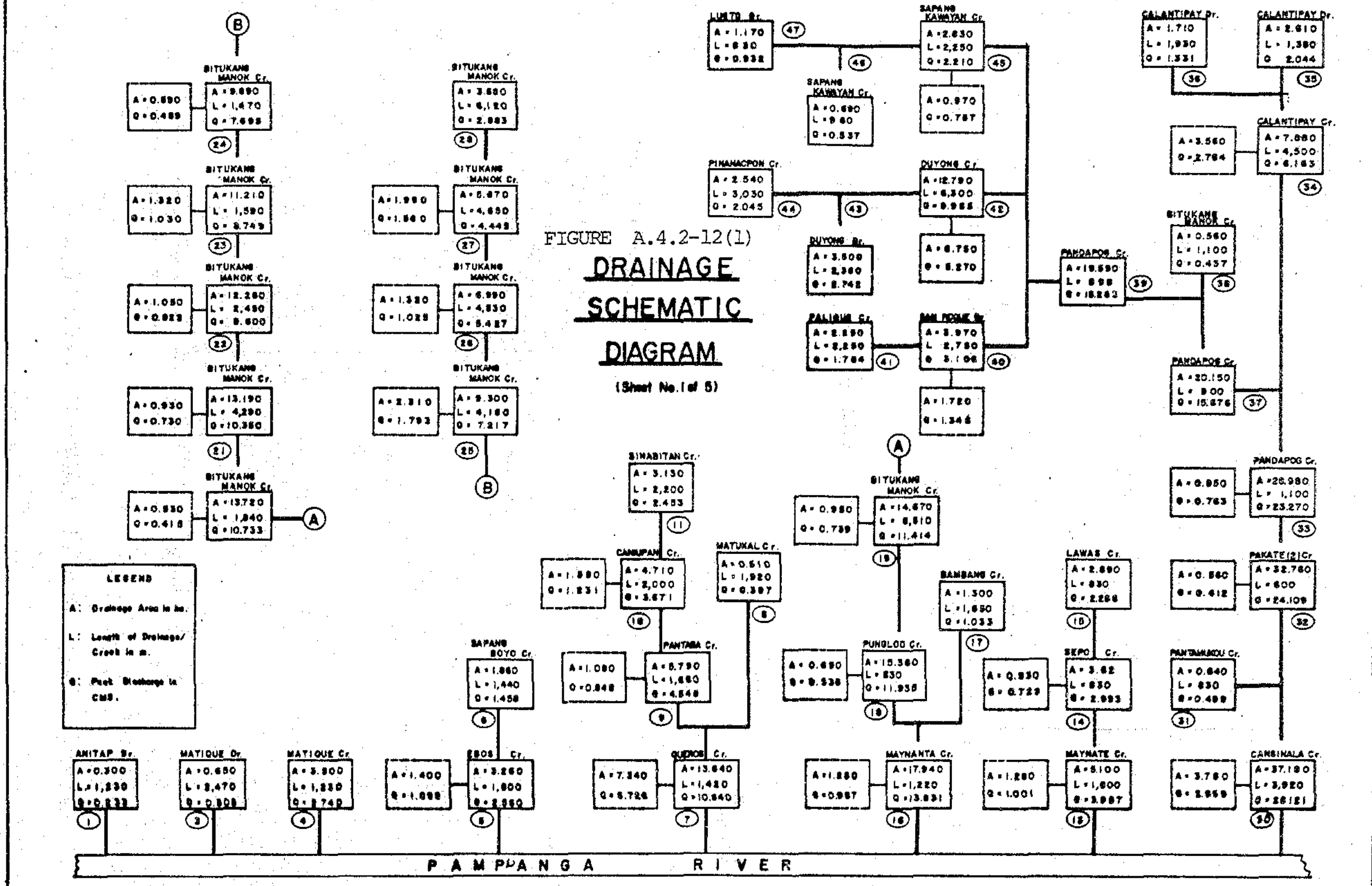


FIGURE A.4.2-12(1)

DRAINAGE SCHEMATIC DIAGRAM

(Sheet No.1 of 5)

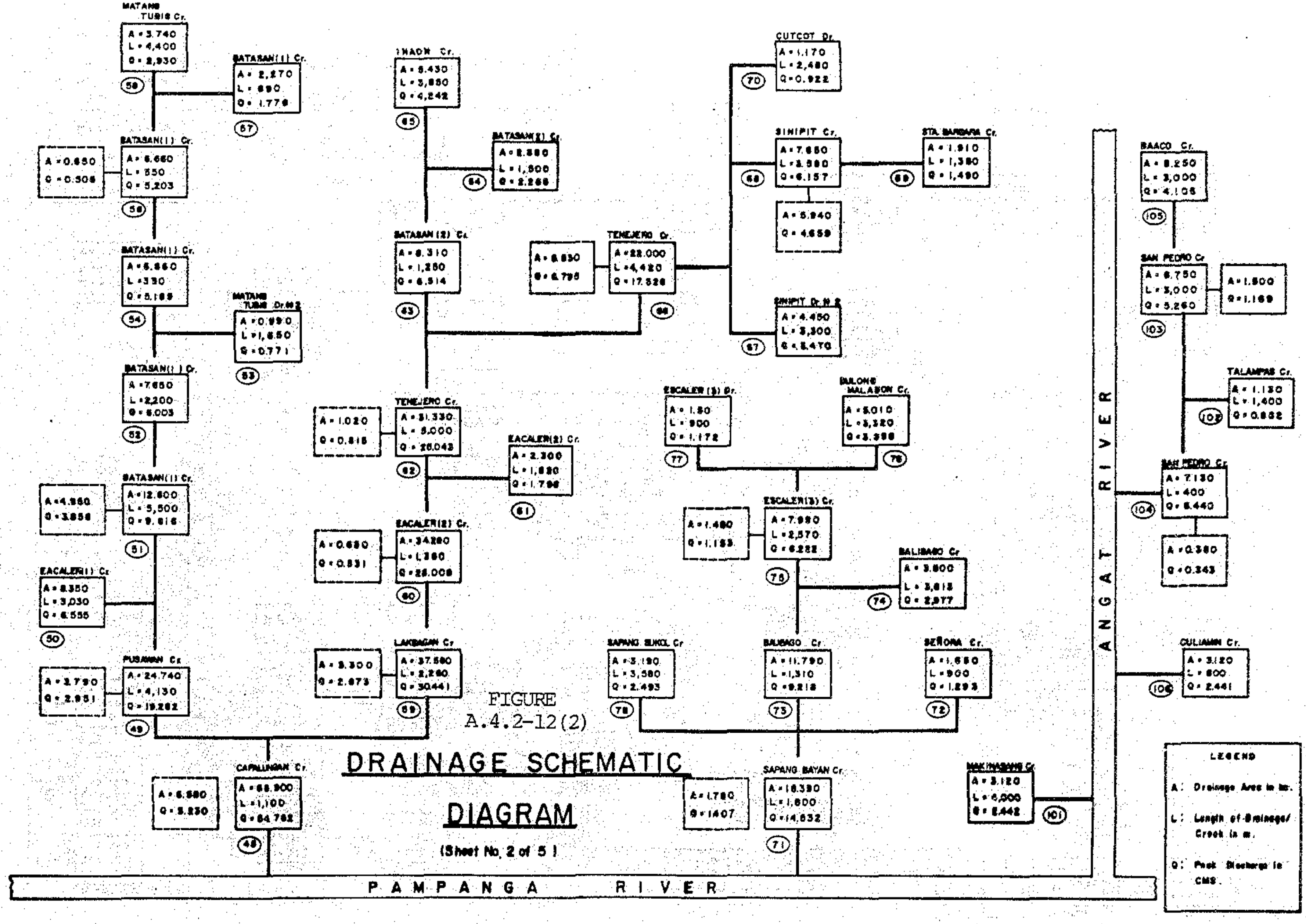


FIGURE A.4.2-12(2)

DRAINAGE SCHEMATIC DIAGRAM

(Sheet No. 2 of 5)

FIGURE A.4.2-12(3)

DRAINAGE SCHEMATIC DIAGRAM

(Sheet No.3 of 5)

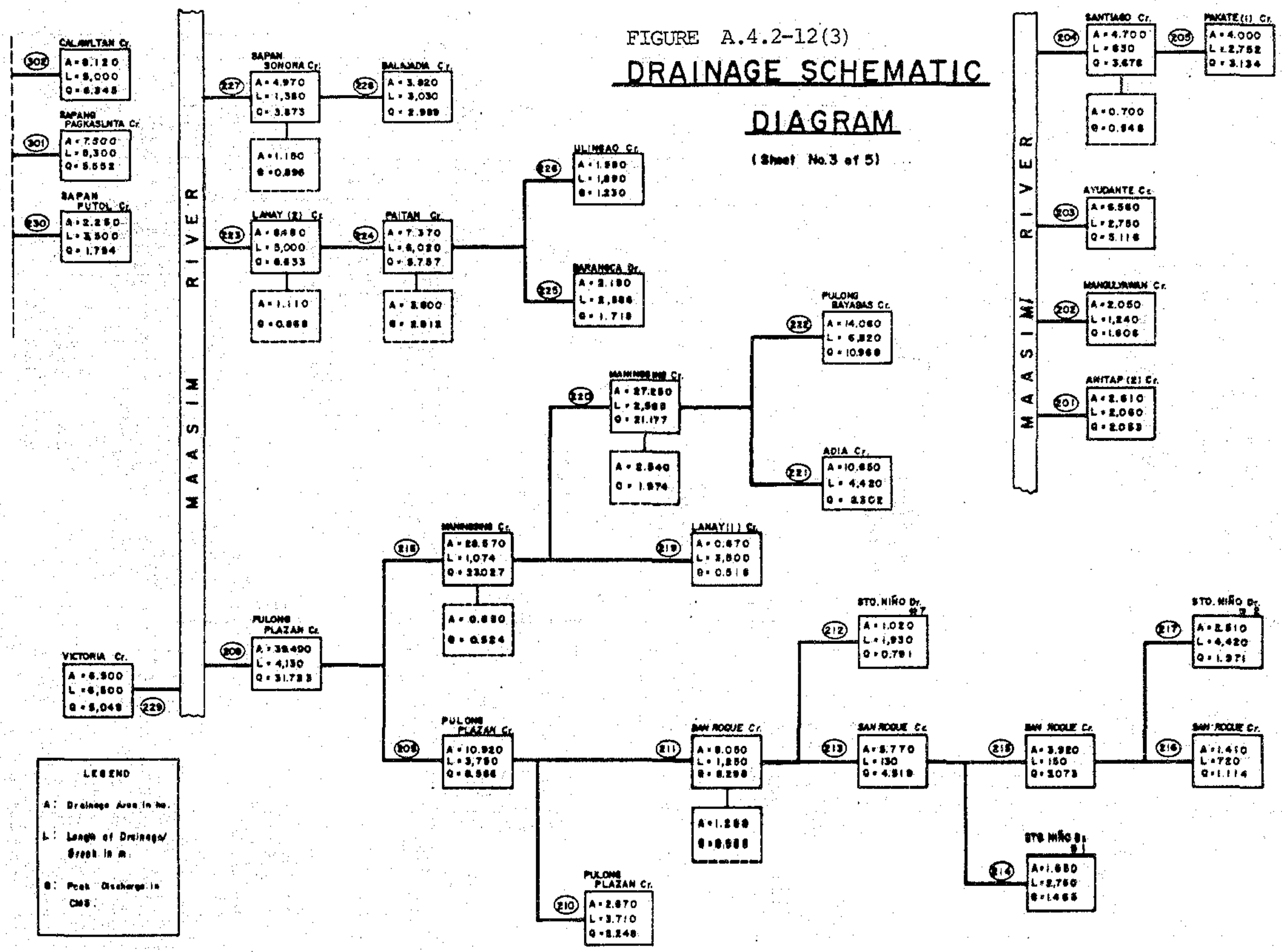


FIGURE A.4.2-12(4)

DRAINAGE SCHEMATIC DIAGRAM

(Sheet No.4 of 5)

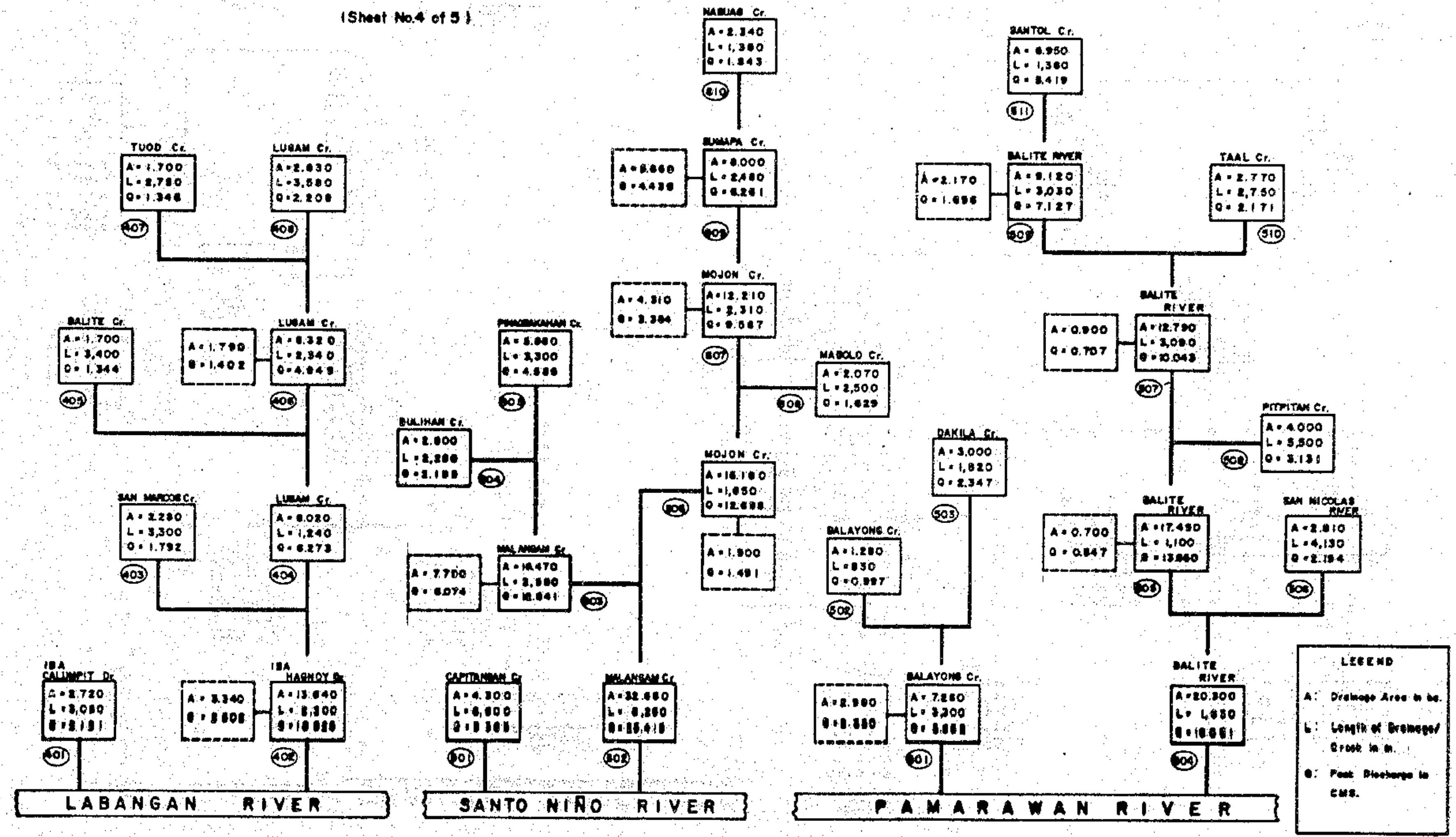
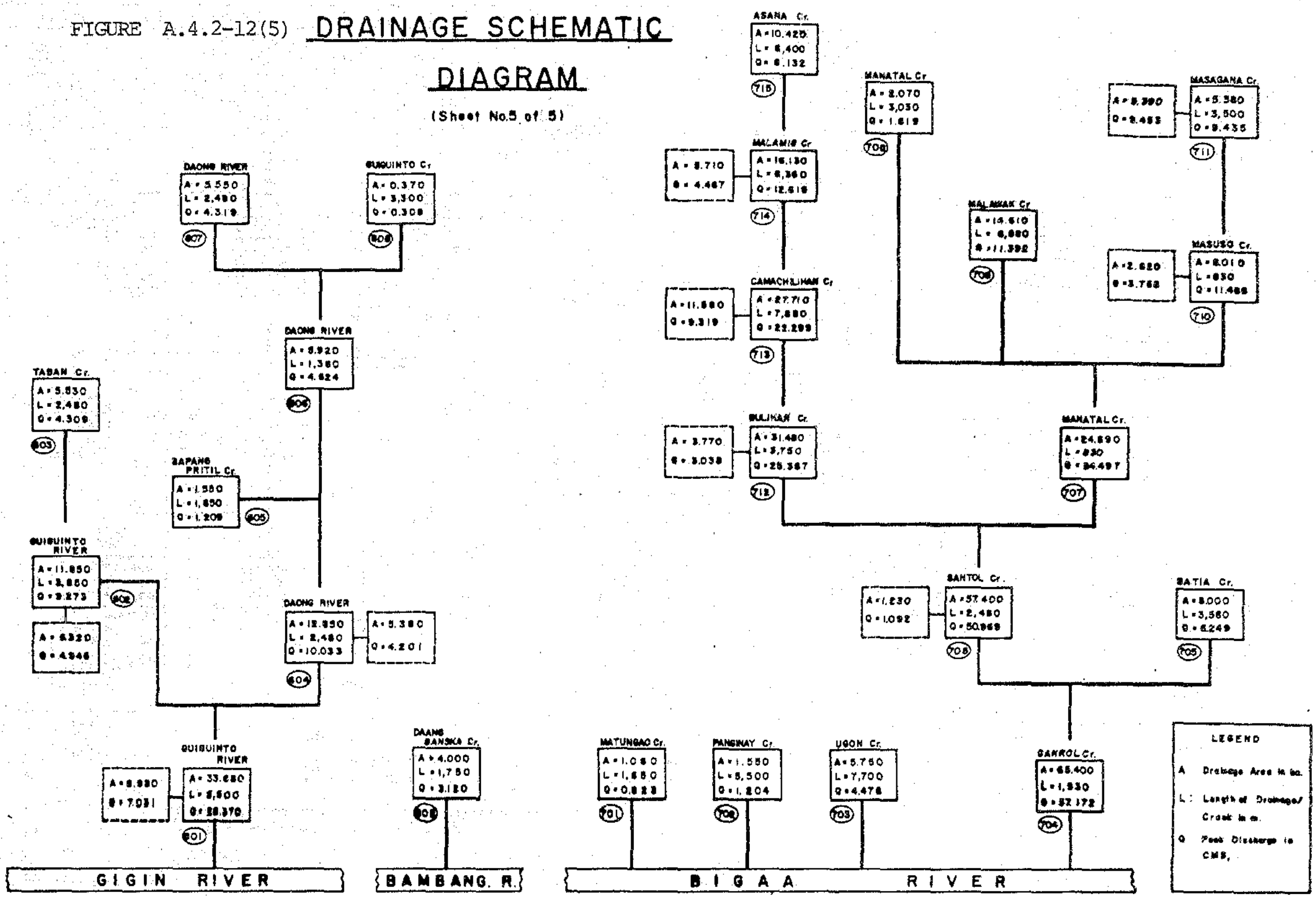


FIGURE A.4.2-12(5) DRAINAGE SCHEMATIC DIAGRAM

(Sheet No.5 of 5)



4.3 Drainage Scheme

4.3.1 Flood Protection Plan

In order to formulate the project concerning the possible flood protection plans, hydraulic simulation of long term water balance study was conducted on a daily basis for the submerged areas of the both Angat North and South service area. The simulated results were analysed aiming at evaluation of reduction of inundation damages in connection with benefits and construction costs.

(1) Angat North Submerged Area

1) Flood Protection Plans

The purpose of flood control by construction of protection dike along the left bank of the Pampanga and Massim Rivers is mainly to avoid adverse flow from the both rivers as well as from the North Candaba Swamp, and to reduce inundation water level and duration of inundation in the service area.

The following two alternative plans were studied as prototype for comparative purpose.

Plan-A : Protection dike was aligned along the left bank of the river just on the line proposed by the "Pampanga Delta Development Project".

Plan-B : Alignment was put inside the service area up to the line where existing irrigation facilities were extended.

Figure A.4.3-1 illustrates the proposed location of alignment.

So defining the prototype of each alternative plan as above, they were further classified into several sub-cases for comparative purpose.

Plan	Case		Desctiption
Plan-A, Plan-B	Case-1	:	Prototype of Plan-A and B in which only protection dike is costructed to avoid adverse flow of the river water.
	Case-2	:	In addition to Case-1, the Maasim River channel is improved so that no overtopping flow of flood enters the area.
	Case-3	:	In addition to Case-1, drainage outlets situated at the end of major drainage creeks, along the Pampanga and Maasim Rivers, are improved increasing their capacities twice as much as existing.
	Case-4	:	In addition to Case-1, pumping drainage systems are introduced. This case is further sub-divided into three as follows: Case-4-1 : With pumping capacity of 25 cu.m/sec Case-4-2 : - do - 50 cu.m/sec Case-4-3 : - do - 100 cu.m.sec

In every plans or cases, improvement of drainage facilities in the area, such as drainages, creeks and related structures, are inevitably required in the entire drainage system.

To examine the effects on controlling inundation in the area, the hydraulic computations by employing simulation model were carried out with regard to various combination of the above plans and cases. The simulated results were then put into the statistical evaluations, of which some are summarized in Table A.4.3-1.

2) Evaluation of the Comparative Study

From all of the computations, combinations of plans A and B with cases 1 to 3 were excerpted and put into evaluation. From this study the followings were clarified.

- Acreage as well as peak level of inundation decreases to a great extent in any combination of plan and case.
- Duration of inundation also decreases to some extent but the area still remains inundated to a great degree of damage when the area is planted to rice.
- Construction of protection dike contributes to prevention of adverse flow from the rivers. Runoff caused by the rainfall in the area is however forced to stagnate as long as the external water level in the river exceeds the internal level in the area.
- To prevent the area from overtopping flows of the Maasim River, an overall improvement plan of the river is to be progressed. (Case-2).
- Improvement of drainage outlets situated along rivers would have a negligible effect on inundation in the area. (Case-1)
- Case-1 as well as Case-2 are therefore not recommendable.
- To expect the perfect effects of drainage by pump, pumping facility with capacity of as much as 250 cu.m/sec is required.
- Increase of the river water level by constructing a protection dike along the river was estimated as given in Figure A.4.3-2 as well as in Table A.4.3-2, at 0.30 m and 0.21 m in the Pampanga River with plan A and B respectively, and at 0.17 m in the North Candaba Swamp, during flood which occur once in five years. About 1,000 houses within a location of the proposed river channel are estimated to be relocated in the higher land. Furthermore, about 540 hectares of the existing cultivated area along

the North Candaba Swamp are newly damaged by inundation, receiving negative benefit from the project.

- The top elevation of the protection dike is required to be 8.1 m above mean sea level, including 0.5 m allowance as a free board, against the estimated maximum level of 7.53 m in the Pampanga River which corresponds to approximately once in 50 years peak level.
- For the flood of once in five years probability, the required top elevation will be 6.9 m and 6.8 m above mean sea level, for plan A and B respectively.
- Combination of the alternative plan A and B, with case-1 and case-4 were put into economic evaluation in terms of benefit and cost ratio. Construction costs were calculated based on the survey in the field and references were made on the feasibility report on the Pampanga Delta Development Project by JICA. In calculation of the B/C raio, the following assumptions were employed.

i) Disbursement schdule for construction

1	2	3	4	5th year
10	20	25	25	20%

ii) Period of achieving full development in the whole area

1	2	3	4	5	6th year
5	20	50	80	95	100%

iii) Interest rate : 10%

iv) Length of analysis period : 50 years

v) Operation and maintenace cost
5% for a plan with pumping facilities
2% for a plan without pumping facilities

vi) Taking inundation damage of once in five years into consideration, yield was assumed at 3.7 ton/ha.

The project cost covers construction costs of dike, drainage outlets and the overall improvement cost of drainage facilities. The results of the calculation are as follows:

B/C Ratio for Alternative Plans

Plan-Case	Benefit Area (ha)	Benefit Amount (₱10⁶)	Protective Dike Pampanga Level	Protective Dike Cost 1/ (₱10⁶)	B/C Ratio
A-1	2,100	7.7	Maximum	133.5	0.26
B-1	1,420	5.2	- do -	97.6	0.25
A-1	2,100	7.7	1/5 Probable	93.1	0.38
B-1	1,420	5.2	- do -	61.3	0.40
A-4-2 2/	3,090	11.3	- do -	293.1	0.14
A-4-Ex. 3/	7,100	26.0	- do -	1,258.5	0.07

Remarks: 1/ Cost includes operation and maintenance cost.
2/ A plan furnished by pump of 50 cu.m/sec.
3/ A plan furnished by pump of 250 cu.m/sec.

Although cost for relocation of houses as well as negative benefit expected in the North Candaba are not included in calculations, the B/C ratio was seen to be very low. These plans are therefore, not recommendable if there is no accompaning improvement from the side of agronomy.

3) Consideration of Pattern-D Cropping Calendar

studies were made on duration, period and frequency of inundation. Inundation in the area is concentrated during the four months from July to October, as previously stated, depending on seasonal pattern of rainfall observed in the entire Pampanga River basin. The earlier stage of inundation, occurence and duration of inundation covering a period from May to July was examined.

Figure A.4.3-3 shows frequency of inundation of a field elevated 2.0 m to 3.5 m above mean sea level. From this, the period which terminates at the end of July was indicated to the agronomist for the purpose of finding a proper cropping calendar that was practically acceptable in the area as wet season rice. The proposed cropping pattern-D was so presented, and the study was further progressed based on this.

Figure A.4.3-4 illustrates height of planted rice with respect to its growing stage. Probable inundation occurs in the area after the rice is aged more than 50 days. For the purpose of theoretical comparison, allowable depth of inundation was set at 0.7 meters on a field planted to rice. Probable maximum water level of inundation during pattern-D cropping period was obtained after statistical treatment as given in Table A.4.3-3 as well as in Figure A.4.3-5.

Theoretical value of acreage to be possibly planted was obtained through procedures illustrated in Figure A.4.3-6 to A.4.3-12, for selected combinations of the proposed plans and cases, adding a Plan-C as existing without any plan of protection dike but only accompanied with the proposed cropping pattern-D.

Theoretically Possible Plated Area by Plan and Case

Plan & Case	1/5 Probable Inundation	Theoretically Possible Planted Area			
		Lowest Height	In the Area	Expansion	Total 5/
	(m)	(m)	(ha)	(ha)	(ha)
0. Present	3.80	4.50 4/	-	-	-
1. A-1	3.25	2.55	3,900	780	4,680
2. A-4-1 1/	3.05	2.35	4,170	930	5,100
3. A-4-2 2/	2.85	2.15	4,410	1,070	5,480
4. B-1	3.60	2.90	3,260	-	3,260
5. B-4-1 1/	3.30	2.60	3,810	-	3,810
6. B-4-2 2/	3.20	2.50	3,990	-	3,990
7. C 3/	3.80	3.10	2,900	330	3,230

Notes:
1/ With pumping facility of 25 cu.m/sec capacity
2/ -do- 50 cu.m/sec
3/ As existing without a plan of protection dike
4/ The lowest elevation presently planted to rice during wet season
5/ This is shown in Table A.4.3-4 together with required improvement and negative benefit.

As is clear above, it is possible to expect a considerable amount of benefit from the existing submerged area when the wet season rice is planted within the frame of the proposed cropping pattern-D.

Consequently, for the sake of conservation, the area of 2,223 hectares, elevated between 3.5 m and 4.5 m above mean sea level, is recommended to be included in the project.

In addition, simulated results of the above cases were put into economical evaluation. Calculated B/C ratio is presented in the following table. The study indicates that the proposed cropping pattern-D would contribute to some extent to the B/C ratio, but the highest ratio of 0.60 calculated for Case A-1 is still too low to be accepted by the project.

B/C Ratio for Plans with Fropping Pttern-D

Plan-Case	Pump Capacity	Improved area Existing	Improved area Expansion	Minus[1/] Benefit	Construction Cost	B/C Ratio
	(cms)	(ha)	(ha)	(ha)	(₱ 10^6)	
0. Present	-	-	-	-	-	-
1. A-1	-	3,900	780	540	143.8	0.60
2. A-4-1	25	4,170	930	540	256.3	0.30
3. A-4-2	50	4,410	1,070	540	368.8	0.22
4. B-1	-	3,260	-	540	107.9	0.56
5. B-4-1	25	3,810	-	540	220.4	
6. B-4-2	50	3,990	-	540	332.9	0.18
7. C	-	2,900	330	540	4.5	11.54

Note : 1/ Existing paddy field to be damaged by submergence.

(2) Angat South Submerged Area

In the Angat South service area, along the Labangan and Santo Ninõ Rivers, there is a considerable area which usually suffers from inundation. A protection dike is constructed along the Labangan River with a top elevation of 4.0 to 6.0 m above mean sea level, and stretching 5 km from Calumpit to Hagonoy. Downstream part of the area, along the Santo Ninõ River from Hagonoy to Malolos, however, is bounded by a low elevated dike of around 2.0 m allowing adverse flow of river water during high flood.

Also in this area, continuous high water levels in the river prevent the inundated water from being drained by gravity.

As is clear from the analysis progressed for the Angat North submerged area, as well as from the simulated results of the present drainage condition of the area, to prevent adverse flow of river water by means of heightening the existing river bank would not contribute perfectly to the improvement of ill drainage condition unless a pumping drainage system is introduced.

Economical evaluation made also indicates that costly plans of such kind are not recommendable from the economical point of view, since the submerged area is rather small scale, as compared with that in the Angat North, having a maximum inundation of less than 2,000 ha.

Consequently, the only plan acceptable is improvement of the existing drainage creeks and related appurtenant structures. In this area, in addition to the above, the drainage outlets situated at the end of major drainages are planned giving double the cross-sectional area. With the improvement plan of the existing drainage facilities, the area would be improved slightly on the peak level and area of inundation, and considerably on the duration of submergence.

Computed results of flood simulation are summarized in Table A.4.3-5. The probable dimensions of inundation after improvement of drainage facilities were analysed statistically as given in the followings.

Probable Dimension of Inundation (Angat South)

Return Period (Year)	Maximum Level Labangan (m)	Maximum Level Area (m)	Inundation Area (ha)	Maximum Duration (days)	Total Duration (days)
		(-0.08)	(-70)	(-7)	(-23)
2	2.83	1.32	1,180	17	64
		(-0.03)	(-10)	(-8)	(-21)
5	3.40	1.94	1,960	22	77
		(-0.02)	(+10)	(-10)	(-20)
10	3.75	2.00	1,980	24	86
		(-0.03)	(-20)	(-11)	(-22)
20	4.11	2.10	2,030	26	95

Note : Parenthesis indicates decrease in comparison with present figure.

4.3.2 Facility Improvement Plan and Design

Regarding the plan for improvement of drainage systems, no large scale improvement plan is needed. Construction of protection dikes along the rivers is not recommended in view of construction cost and benefit to be expected. Enlarging the drainage outlets situated at the end of major drainage creeks is avoided because it has no significant effects on improvement of inundation. To protect the area from the overtopping flow of the Maasim river, it requires an overall improvement plan of the river channel, and so the plan was not adopted by the project. Effects of installing pump facility were also studied, but this is not recommendable so far as benefit and costs are concerned.

Consequently, the only plan acceptable for the project is improvement of drainage creeks and related facilities. There exist many local portions which are in a bad drainage condition mainly due to insufficient carrying capacity and silting.

Based on the cross-sectional survey conducted during the second stage survey for the project, the available carrying capacity is checked against the probable maximum discharge of once in five years flood, and the proper cross-section is given to furnish the project.

Peak discharge in each drainage creek was calculated by the method of characteristics, as described in A.4.2.3 for the flood of once in five years frequency. The calculated peak discharge varies from 7.7 to 9.0 ℓ/sec/ha depending on the topographic or hydraulic condition of each creek, and from this study the design unit discharge of drainage was determined as 8.0 ℓ/sec/ha, almost correponding to that given in NIA's design criteria prepared for 10 years flood.

(1) Design Criteria on Determination of Cross-section of Drainage Canal/Creek

Determination of cross-section of drainage/creek to be rehabilitated or newly constructed was based on the design unit discharge obtained by the method of characteristics with flood rainfall of once in five years probability. Factors needed in determination of cross-section are given as follows:

1) Design unit discharge (q)

This is given at 8.0 ℓ/sec/ha

2) Design discharge (Q)

Design discharge is given in the following equation.

Q = drainage area x q (in ℓ/sec)

3) Longitudinal slope of drainage/creek (I)

This is determined in connection with elevation of field, existing slope of canal or land, and hydraulic condition of the related structures.

4) Cross-sectional dimension

Regarding bottom width of canal, the most effective hydraulic cross-section is recommendable from the view point of right of way. In determination of depth of water, excessive cut or embankment is to be avoided inview of the future siltation problem. Side slope of canal is taken at 1:1.5 for both cutting and embankment. In cases where geological features are concerned, a more gentle slope is to be adopted.

5) Roughness coefficient (n)

Regardless of rehabilitation or new construction, Manning's coefficient of roughness is taken as n=0.035.

(2) Drainage/Creek to be Rehabilitated or Constructed

Based on the request in the field for rehabilitation and new construction, result of survey as well as required carrying capacity, design was further progressed. Drainage canals and creeks necessarily be rehabilitated or newly constructed are finalized as follows:

Drainage Canal/Creek to Rehabilitated or Constructed

	Length in m
Rehabilitated	188,500
Costructed	13,800
Total	202,300

(3) Related Structures of Drainage/Creek

Related structures of drainage/creek comprise drainage culvert, check, bridge and flap gate. Furthermore in connec- tion with irrigation facilities, siphon and spillway are classified in this category. A newly constructed drainage canal needs crossing structures to be constructed along the canal. With rehabilitation of drainage/creek, on the other hand, improvement of related structures are also required.

Of the structures to be improved, greater attention was paid to dam checks situated along major creeks equipped by stop-logs, which function to keep the water level high for the purpose of irrigation water supply. Along the Bitokang Manok creek there exist 10 dam checks, of which five were considered to be in need of improvement by means of converting the stop-log system of the gate system for dual purpose, both irrigation and drainage.

Consequently from the study, related structures in need of rehabilitation and construction are counted as in the following table.

Number of structures for Rehabilitation and Construction

Structure	Rehabilitation (pcs)	Construction (pcs)	Total (pcs)
Check Gate	7	7	14
Head Gate	-	3	3
Siphon	1	1	2
Drainage Culvert	-	8	8
Road X'ing	-	6	6
Thresher X'ing	-	1	1
Bridge	1	10	11
Spillway	-	1	1
Road X'ing with check	-	1	1
Flap Gate	7	-	7
Total	16	38	54

TABLE A.4.3-1 PROBABILITY ANALYSIS ON THE SIMULATED RESULTS OF INUNDATION

Return Period	Present Condition	Alternative Plan-A			Alternative Plan-B		
		A-1	A-2	A-3	B-1	B-2	B-3
(1) Maximum Water Level of Inundation 1/							
2	4.29	3.60	3.16	3.59	3.87	3.43	3.80
5	5.25	4.24	3.56	4.18	4.61	3.94	4.46
10	5.88	4.60	3.80	4.50	5.05	4.21	4.85
20	6.47	4.92	4.00	4.77	5.44	4.43	5.20
(2) Maximum Inundated Area 2/							
2	8786	6165	4969	5861	3623	2759	3510
5	10997	7830	6112	7704	5081	3789	4834
10	12246	8747	6761	8889	6015	4407	5670
20	13328	9530	7325	10002	6892	4965	6447
(3) Maximum Duration of Inundation 3/							
2	41	25	25	25	25	25	25
5	65	44	44	44	42	41	41
10	82	58	59	58	55	53	54
20	99	74	75	74	68	64	66
(4) Maximum Annual Total Duration of Inundation 4/							
2	81	55	52	55	47	54	56
5	116	79	78	79	80	79	80
10	140	94	93	94	93	94	93
20	163	106	107	106	103	106	104

Remarks: 1/ Unit is meter above mean sea level
2/ Unit is hectares
3/ Unit is days
4/ Unit is days

TABLE A.4.3-2 OBSERVED AND ESTIMATED MAX. WATER LEVEL OF PAMPANGA RIVER AND NORTH CANDABA SWAMP

Year	Pampanga River			North Candaba Swamp		
	Present	Case-A	Case-B	Present	Case-A	Case-B
1960	5.74	5.90	5.90	7.00	7.17	7.17
1961	4.80	4.81	4.80	5.85	5.85	5.85
1962	5.71	6.00	5.93	6.84	6.91	6.91
1963	5.15	5.11	4.83	5.93	5.93	5.93
1964	4.27	4.38	4.38	5.38	5.38	5.38
1965	4.74	4.87	4.87	5.67	5.67	5.67
1966	5.06	5.28	5.22	6.08	6.08	6.08
1967	4.69	4.74	4.70	5.63	5.63	5.63
1968	4.90	4.97	4.97	6.21	6.23	6.23
1969	5.66	6.41	6.22	5.58	5.58	5.58
1970	4.97	4.97	4.97	6.30	6.32	6.32
1971	5.41	5.62	5.55	6.30	6.34	6.34
1972	- - - -	No Data	- - - -	- - - -	No Data	- - - -
1973	5.53	5.89	5.80	L	L	L
1974	6.37	7.20	7.03	7.83	8.26	8.26
1975	2.92	2.92	2.92	L	L	L
1976	7.03	7.53	7.53	8.20	8.80	8.80

Remarks: (1) Computed by the simulation model of long-term water balance study for proposed plans A and B, while actually observed water stage was used for computation of present condition.

(2) Symbol "L" stands for the water level which is lower than the top elevation of the Maasim river bank of overtopping portion.

TABLE A.4.3-3 MAXIMUM WATER STAGE OF INUNDATION DURING PROPOSED PATTERN-D CROPPING PERIOD

Year	Present Condition		Proposed Alternatives: A-1		A-4-1		A-4-2		B-1		B-4-1		B-4-2	
	Stage	Date	Stage	Date	Stage	Date	Stage	Date	Stage	Date	Stage	Date	Stage	Date
1960	3.38	Jul.1	2.81	Jul.1	2.58	Jun.28	2.44	Jun.28	3.12	Jun.28	3.02	Jun.28	2.89	Jun.28
61	3.82	Jul.7	3.70	Jul.6	3.48	Jul.6	3.15	Jul.6	3.82	Jul.3	3.67	Jul.6	3.42	Jul.6
62	3.19	Jul.20	3.10	Jul.20	3.06	Jul.20	3.02	Jul.20	3.44	Jul.20	3.39	Jul.20	3.33	Jul.20
63	3.82	Jun.30	2.87	Jun.30	2.57	Jun.29	2.41	Jun.29	3.42	Jun.30	3.23	Jun.29	3.09	Jun.29
64	3.05	Jul.2	2.77	Jul.1	2.59	Jul.1	2.41	Jul.1	3.03	Jul.1	2.94	Jul.1	2.81	Jun.30
1965	3.76	Jul.17	2.98	Jul.20	2.72	Jul.14	2.55	Jul.14	3.17	Jul.20	3.00	Jul.14	2.79	Jul.14
66	4.07	May 23	3.08	May 27	2.68	May 21	2.49	May 21	3.43	May 27	3.09	May 21	2.83	May 21
67	2.54	Jun.11	2.07	Jun.9	1.88	Jun.7	1.67	Jun.7	2.18	Jun.9	2.02	Jun.7	1.95	Jun.7
68	1.80	Jul.2	1.00*	-	1.00*	-	1.00*	-	1.00*	-	1.00*	-	1.00*	-
69	2.01	Jun.10	1.19	Jun.4	1.03	Jun.4	1.00*	-	1.25	Jun.4	1.00*	-	1.00*	-
1970	2.06	Jul.13	1.46	Jul.14	1.32	Jul.14	1.16	Jul.14	1.62	Jul.14	1.45	Jul.14	1.22	Jul.14
71	2.76	Jul.20	2.02	Jun.18	1.95	Jun.24	1.84	Jun.24	2.39	Jun.18	2.21	Jun.18	2.02	Jul.18
72														
73	2.07	Jul.15	1.41	Jul.15	1.00*	-	1.00*	-	1.46	Jul.14	1.00*	-	1.00*	-
74	3.66	Jun.12	2.91	Jun.12	2.76	Jun.12	2.57	Jun.12	3.15	Jun.12	3.05	Jun.12	2.95	Jun.12
1975	1.33	Jul.13	1.00*	-	1.00*	-	1.00*	-	1.00*	-	1.00*	-	1.00*	-
76	6.81	May 25	4.65	May 28	4.45	May 28	4.26	May 28	5.32	May 28	5.17	May 27	5.02	May 27

Remark: Symbol "*" stands for the lowest elevation of the inundated area.

TABLE A.4.3-4 REQUIRED IMPROVEMENT OF DRAINAGE, BENEFICIAL AREA AND OTHER PROFIT

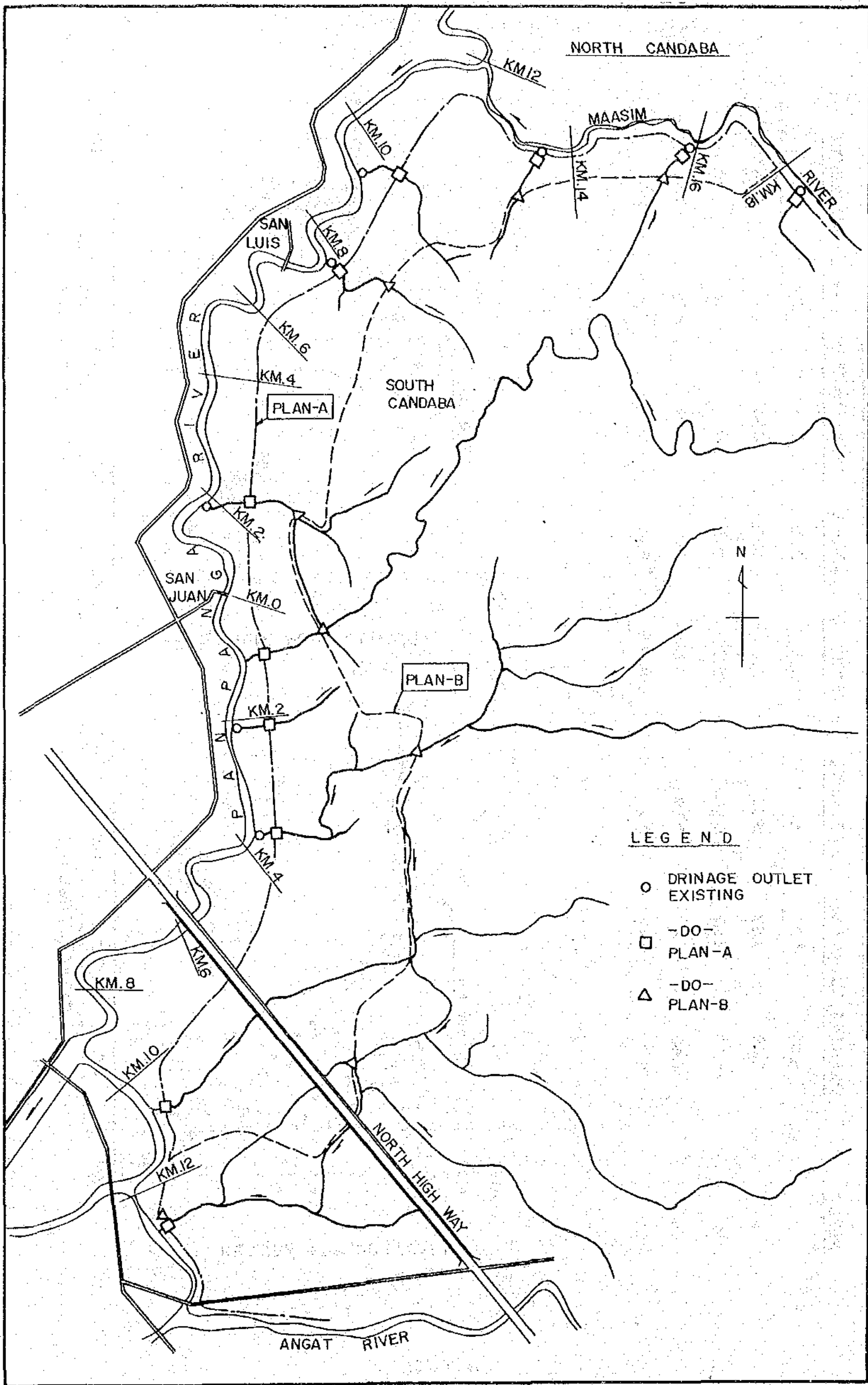
Case of Alternatives	Required Facilities for Improvement of Drainage Condition	Beneficial Area Expected from Project	Negative Benefit
Present	-	-	-
Case - A - A-1	1) Construction of Protection Dike-A 2) Improvement of Drainage/Creek	A=3,900 (Service Area) + 780 (Expansion) 4,680 ha (Total)	1) Relocation of 1,000 houses 2) Damage to 540 ha of paddy in the North Candaba area
A-4-1	1) Same as in Case A-1 2) -do- 3) Pumping Facility Q= 25.0 cu.m./sec	A=4,170 + 930 5,100 ha	1) Same as in Case A-1 2) -do-
A-4-2	1) Same as in Case A-1 2) -do- 3) Pumping Facility Q= 50.0 cu.m./sec	A=4,410 + 1,070 5,480 ha	1) Same as in Case A-1 2) -do-
Case - B B-1	1) Construction of Protection Dike-B 2) Improvement of Drainage/Creek	A=3,260 ha	1) Same as in Case A-1 2) -do-
B-4-1	1) Same as in Case -1 2) -do- 3) Pumping Facility Q=25.0 cu.m./sec	A=3,810 ha	1) Same as in Case A-1 2) -do-
B-4-2	1) Same as in Case B-1 2) -do- 3) Pumping Facility Q= 50.00 cu.m/sec	A=3,990 ha	1) Same as in Case A-1 2) -do-
Case - C	1) None 2) Improvement of Drainage/Creek	A=2,900 + 330 3,230 ha	1) None 2) -do-

TABLE A.4.3-5 SUMMARY OF SIMULATED INUNDATION AFTER IMPROVEMENT (ANGAT SOUTH SUBMERGED AREA)

Year	Maximum External Water Stage in Labangan	Inundation in the Area				
		Maximum Water Stage	Maximum Area of Inundation	Time of 1/ Duration	Maximum 1/ Duration	Total 1/ Duration
	(m)	(m)	(ha)		(days)	(days)
1960	3.36	1.77	1,713	6	21	73
1961	2.72	1.30	1,149	12	17	84
1962	3.28	1.63	1,558	9	24	60
1963	2.74	1.15	941	11	25	71
1964	2.41	1.20	1,002	15	24	90
1965	2.69	1.13	911	16	17	65
1966	2.87	1.40	1,280	13	19	72
1967	2.66	1.47	1,382	12	27	90
1968	2.78	1.16	946	12	15	48
1969	3.23	1.05	799	8	13	26
1970	2.82	2.04	1,993	10	10	44
1971	3.08	1.40	1,280	10	17	65
1972	-	-	-	-	-	-
1973	3.15	0.82	497	7	18	34
1974	3.89	2.07	2,016	6	10	37
1975	1.60	1.37	1,247	8	6	23
1976	4.32	2.09	2,040	8	20	43
Mean			1,297	10	18	58
Maximum	4.32	2.09	2,040	16	27	90
Minimum	1.60	0.82	497	6	6	23

Note: 1/·····On a field of the elevation of 0.5m above MSL.

FIGURE A.4.3-1 LOCATION OF PROTECTION DIKES



RETURN PERIOD	NORTH CANDABA SWAMP PRESENT	CASE A&B	DIFFERENCE	PAMPANGA RIVER PRESENT	CASE - B	DIFFERENCE	CASE - A	DIFFERENCE
2	6.07	6.07	Nil	5.12	5.23	0.11	5.29	0.17
3	6.49	6.52	0.03	5.46	5.62	0.16	5.70	0.24
5	6.93	7.10	0.17	5.86	6.07	0.21	6.16	0.30
10	7.48	7.78	0.30	6.34	6.61	0.27	6.72	0.38
20	8.03	8.48	0.45	6.82	7.14	0.32	7.26	0.44

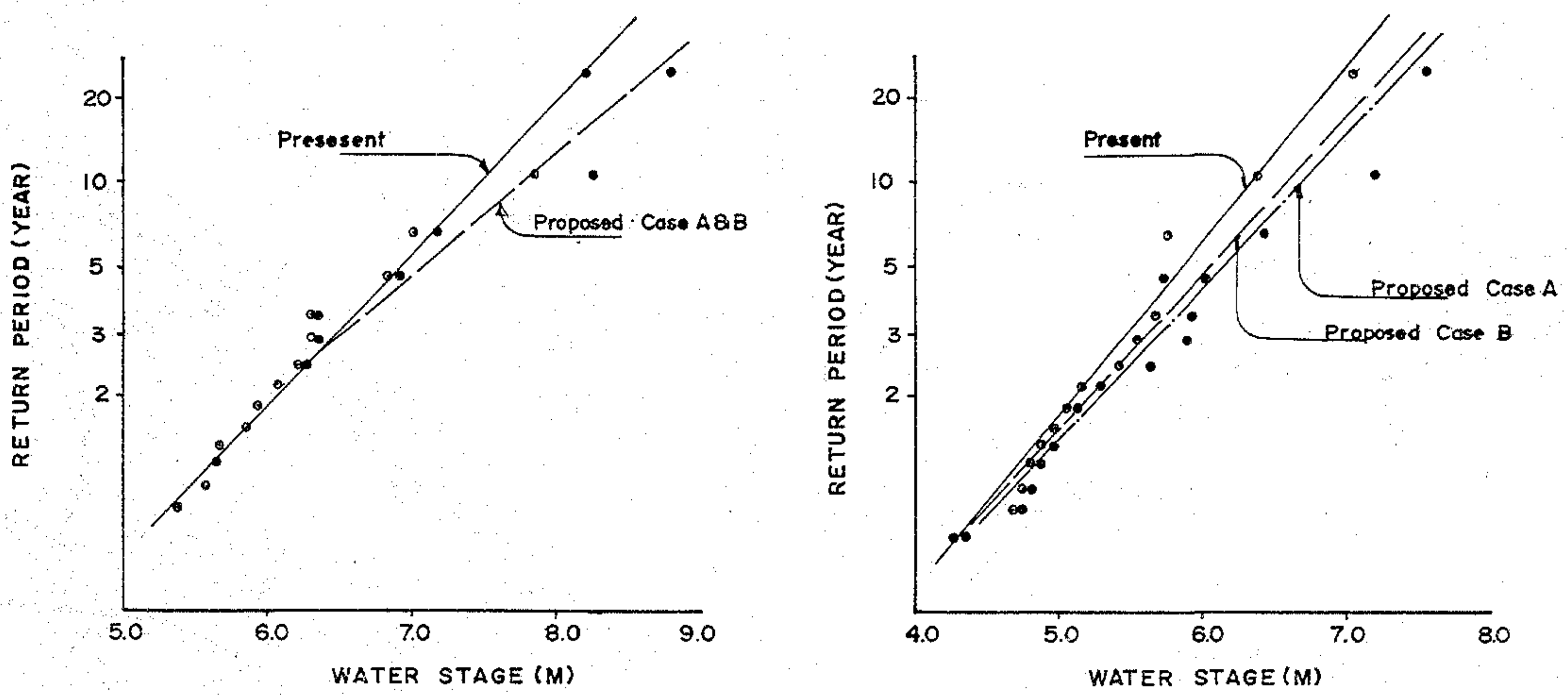


FIGURE A.4.3-2 PROBABLE MAXIMUM EXTERNAL WATER STAGE DURING FLOOD

FIGURE A.4.3-3 FREQUENCY OF INUNDATION ON A FIELD

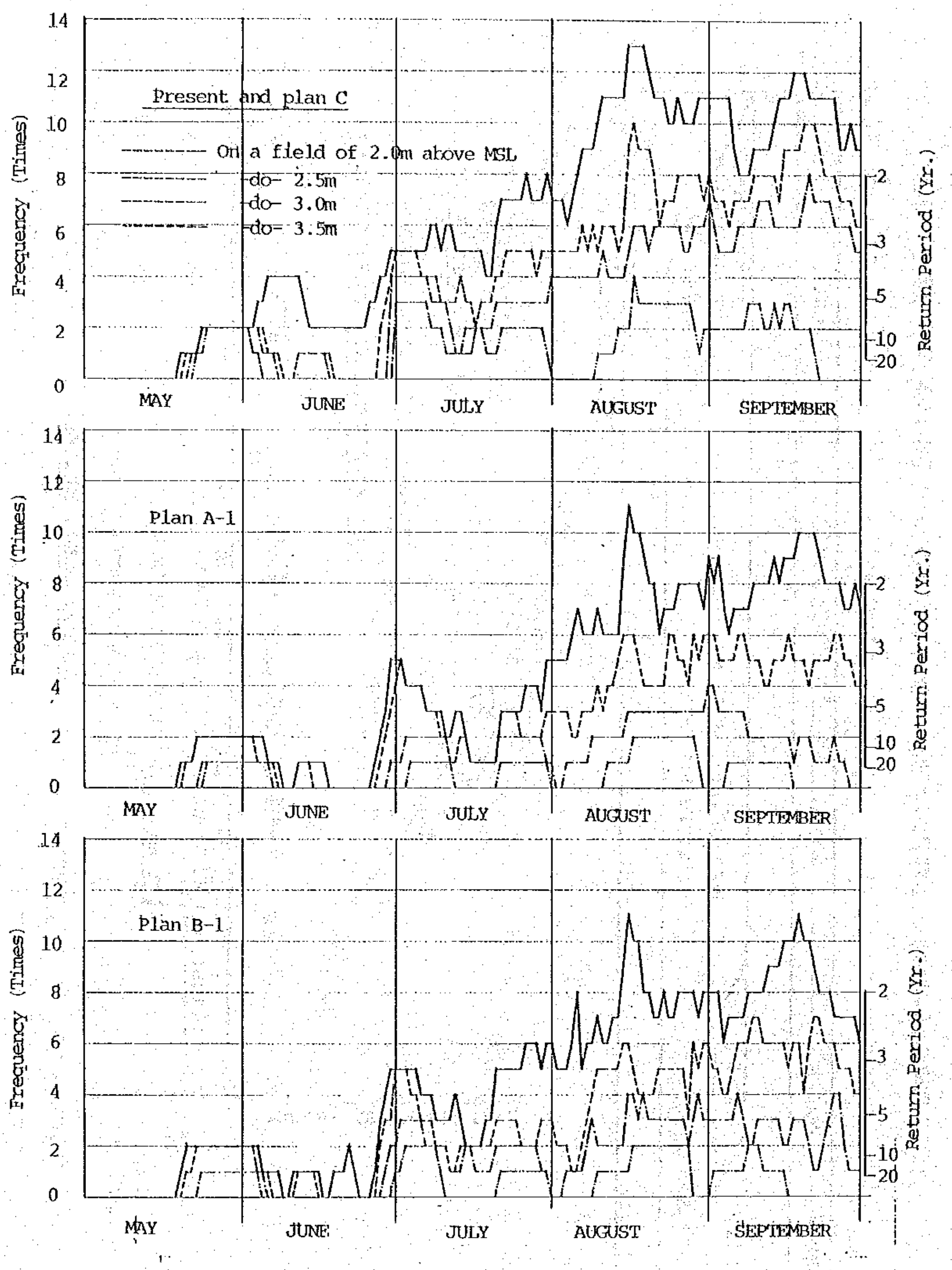
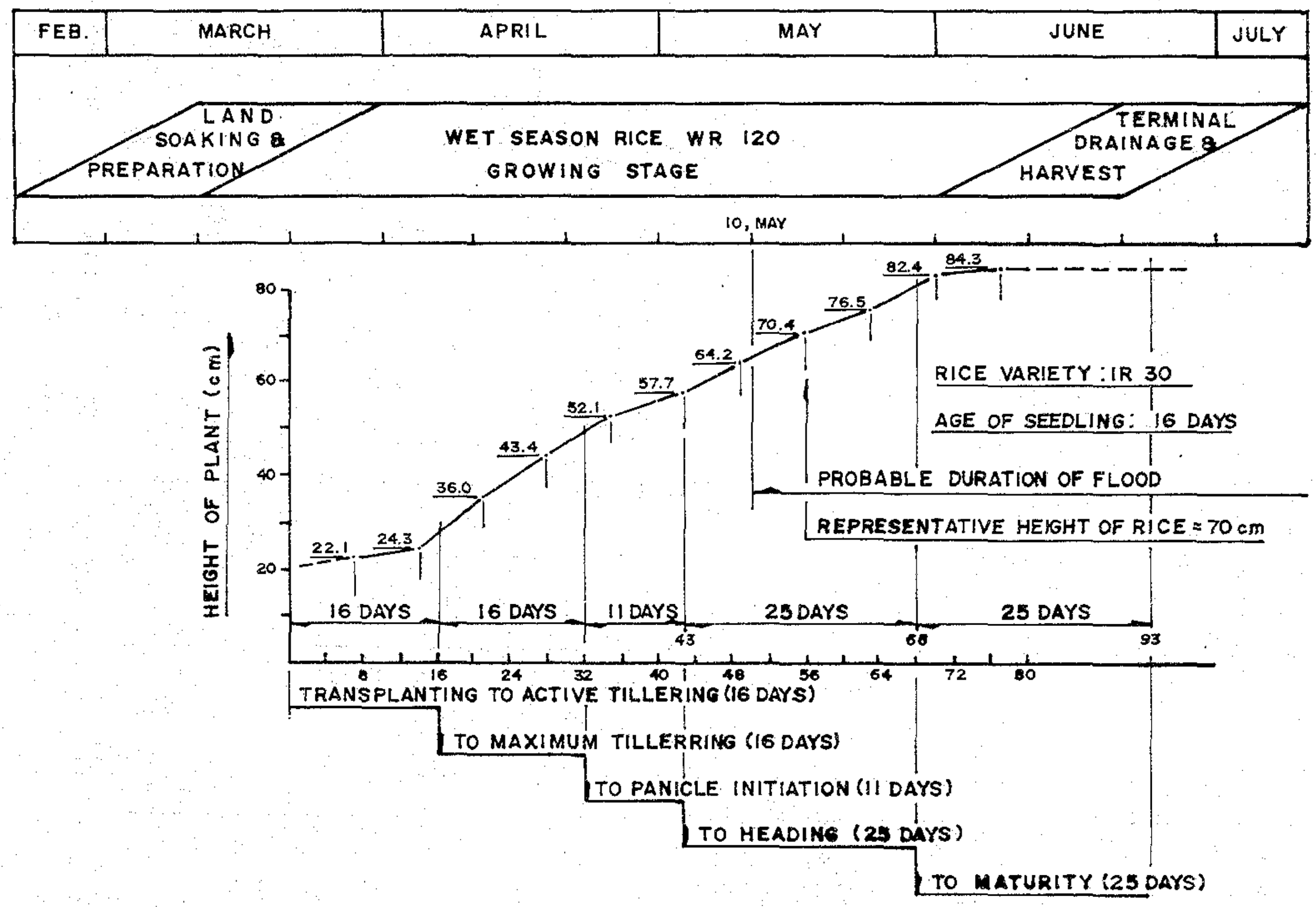


FIGURE A.4.3-4 GROWING OF RICE FOR PROPOSED CROPPING PATTERN-D



RETURN PERIOD	PROBABLE MAXIMUM STAGE BY CASE						
	PRESENT	A-1	A-4-1	A-4-2	B-1	B-4-1	B-4-2
2	2.90	2.30	2.05	1.85	2.60	2.30	2.20
3	3.35	2.75	2.50	2.30	3.05	2.80	2.70
5	3.80	3.25	3.05	2.85	3.60	3.30	3.20
10	4.20	3.90	3.65	3.45	4.30	3.95	3.85
20	5.00	4.55	4.30	4.10	4.90	4.60	4.50

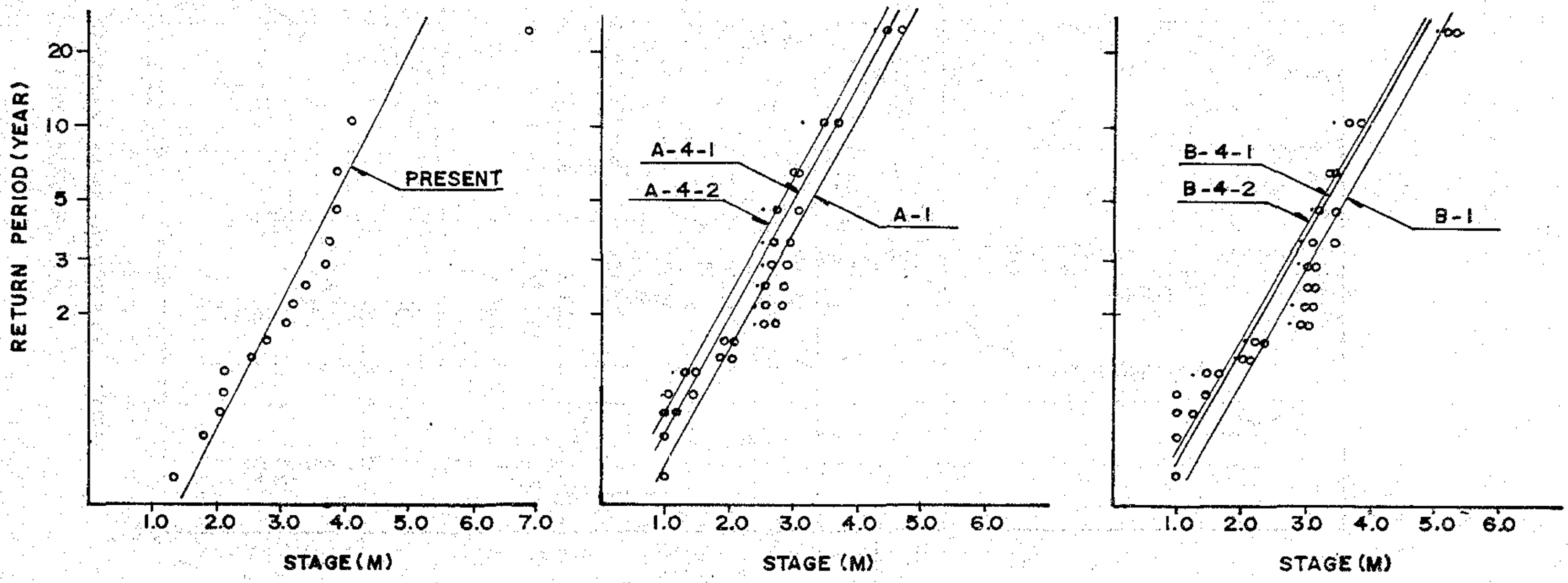


FIGURE A.4.3-5 PROBABLE MAX. STAGE OF INUNDATION DURING PATTERN-D CROPPING PERIOD

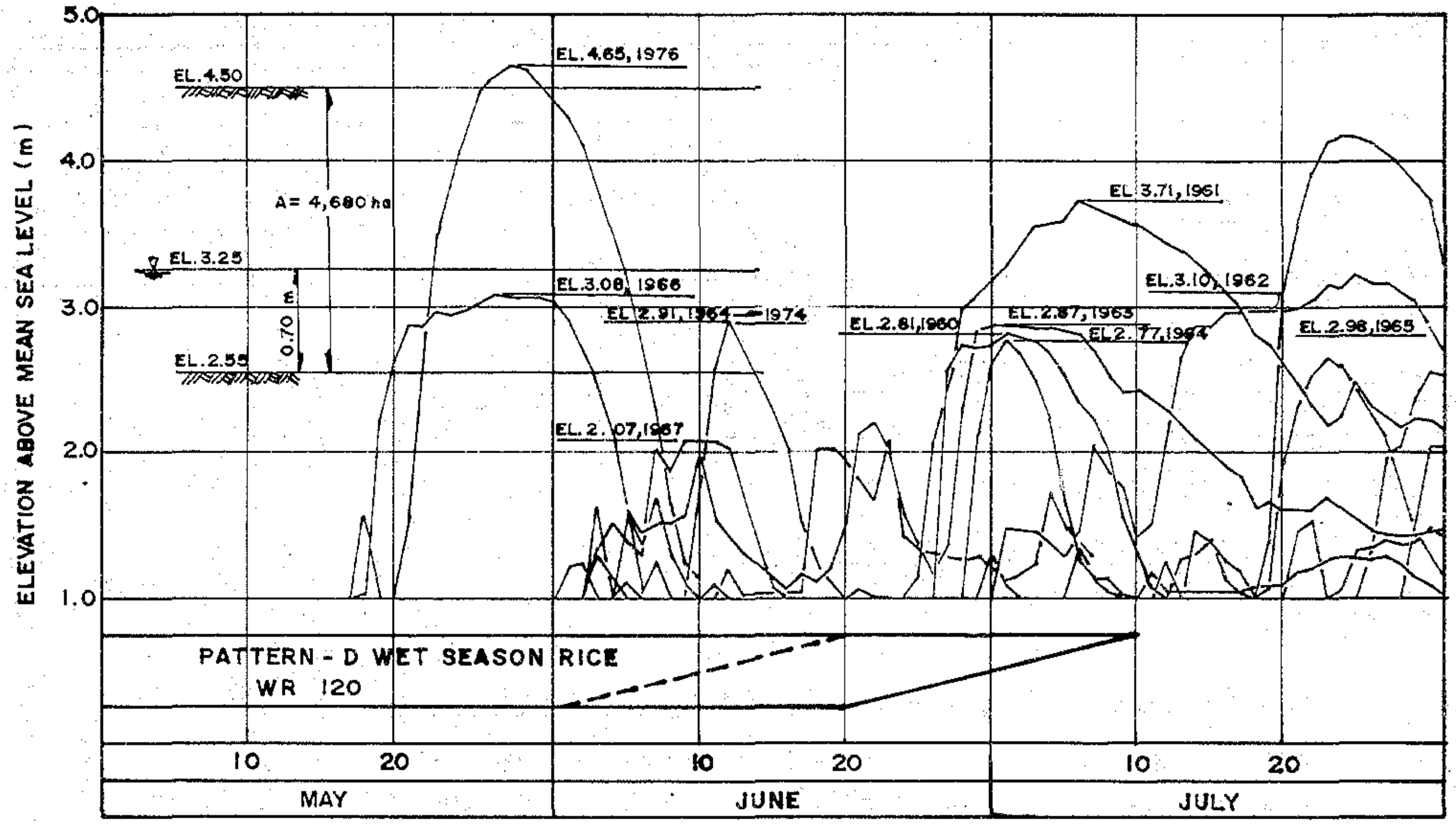


FIGURE A.4.3-6 SIMULATED INUNDATION OF THE AREA (CASE A-1)

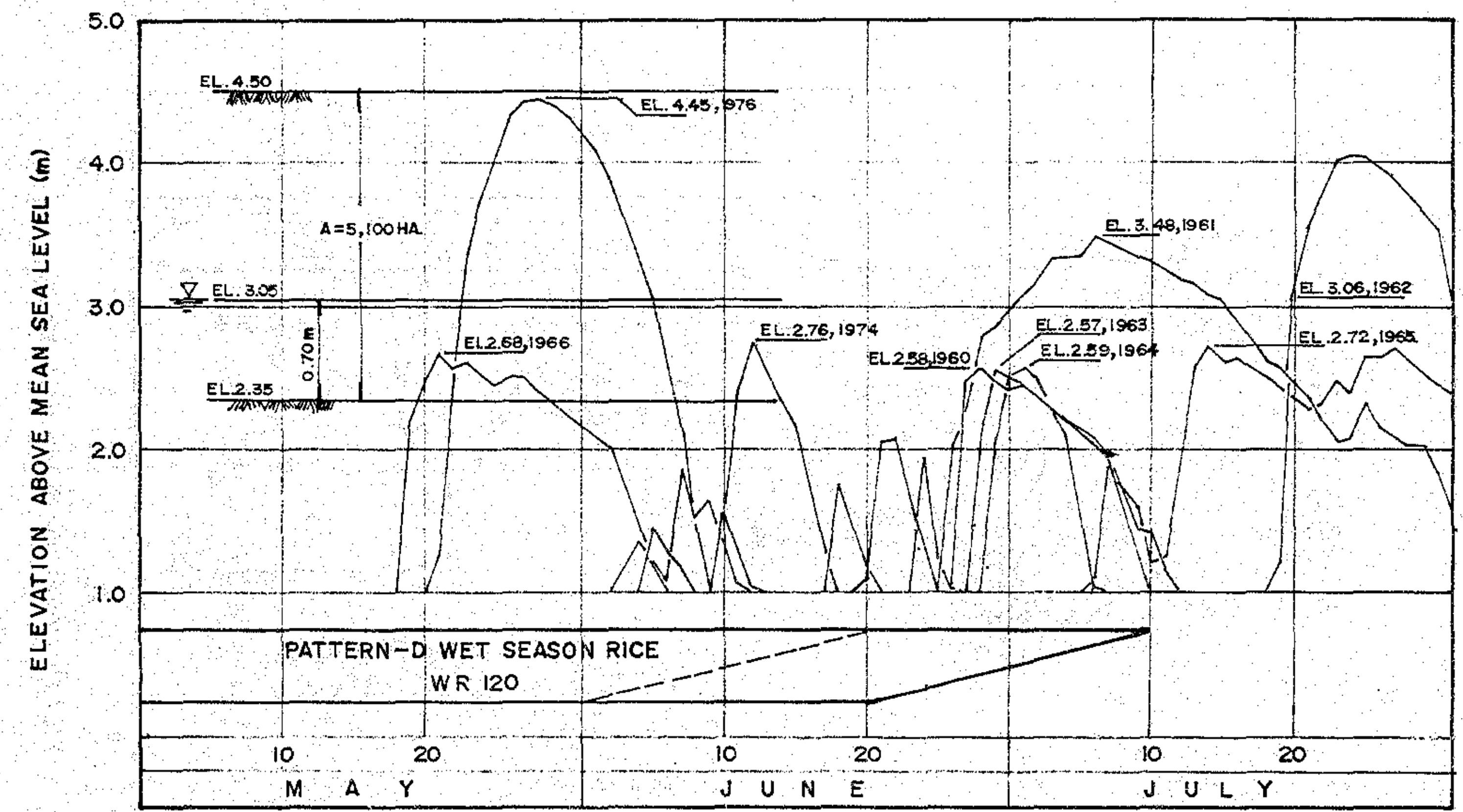


FIGURE A.4.3-7 SIMULATED INUNDATION OF THE AREA (CASE A-4-1)

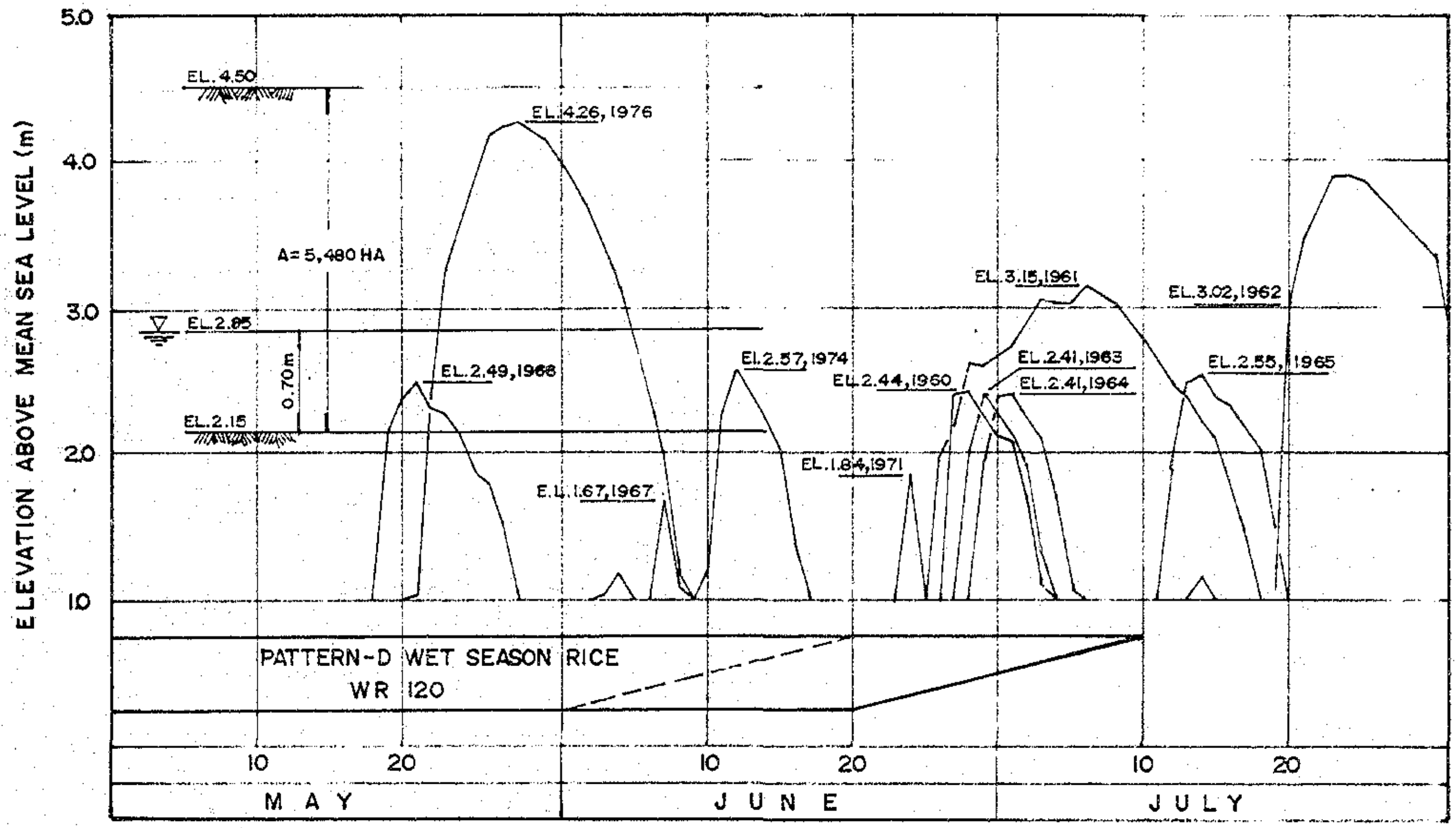


FIGURE A.4.3-8 SIMULATED INUNDATION OF THE AREA (CASE A-4-2)

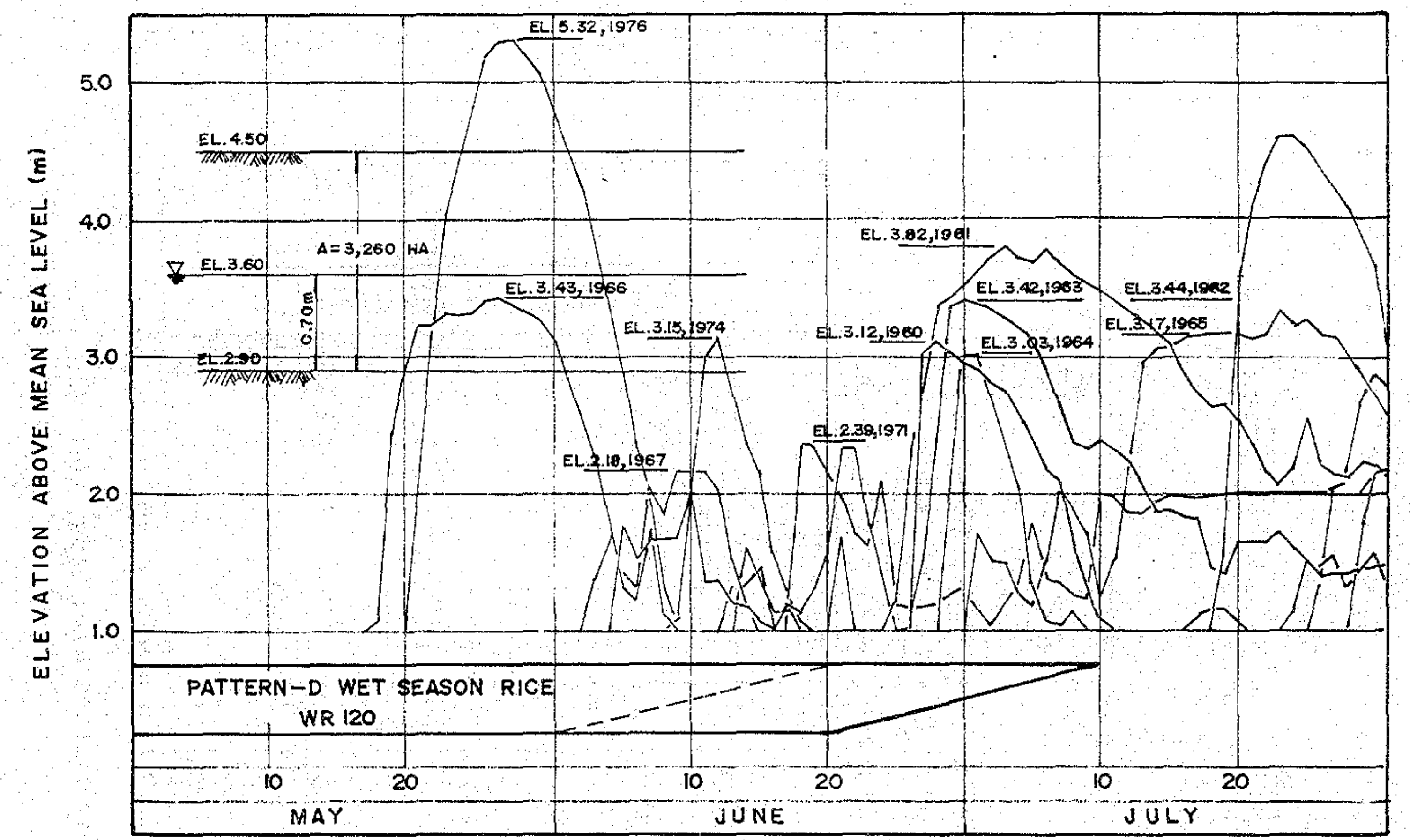


FIGURE A.4.3-9 SIMULATED INUNDATION OF THE AREA (CASE B-1)

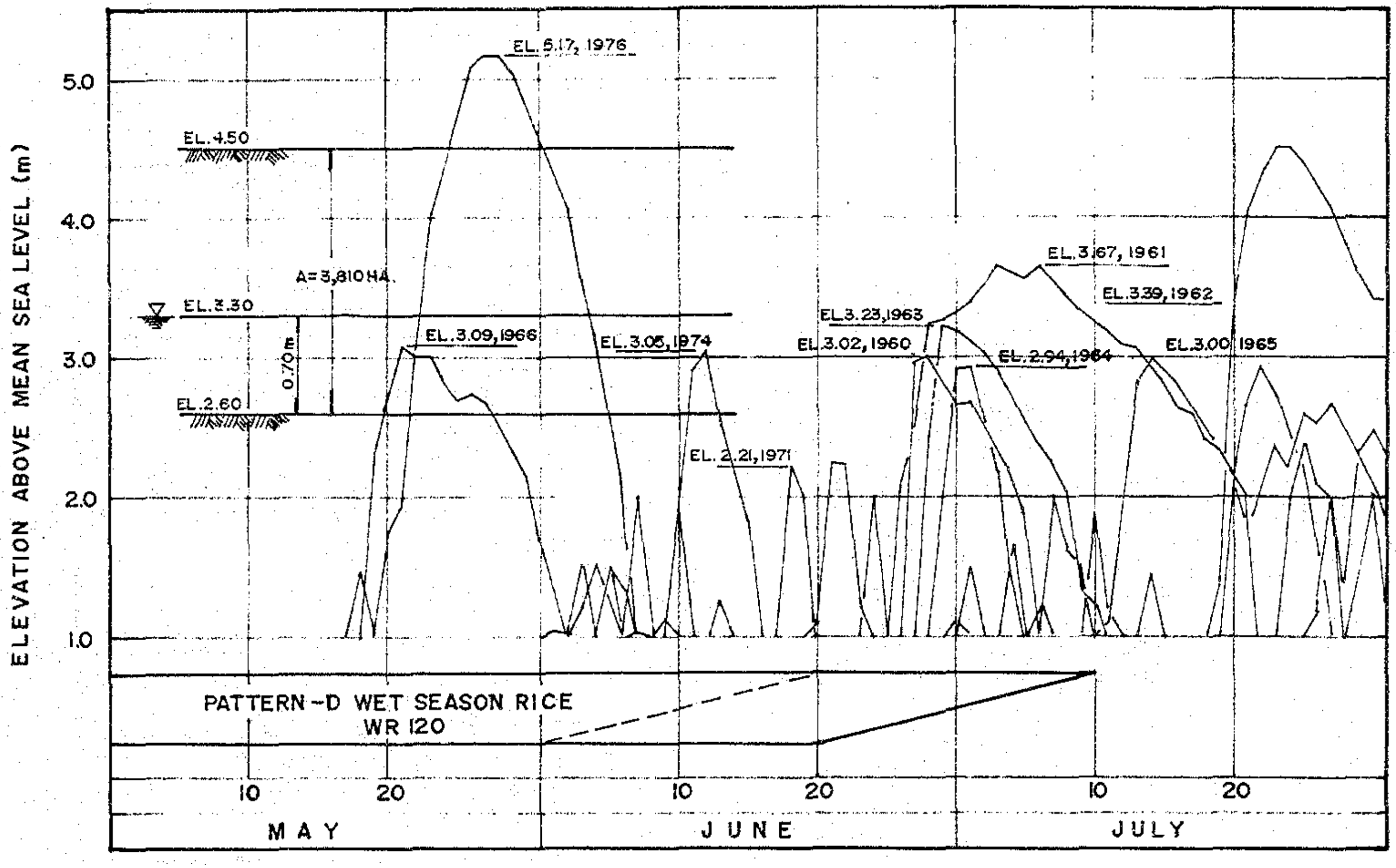


FIGURE A.4.3-10 SIMULATED INUNDATION OF THE AREA (CASE B-4-1)

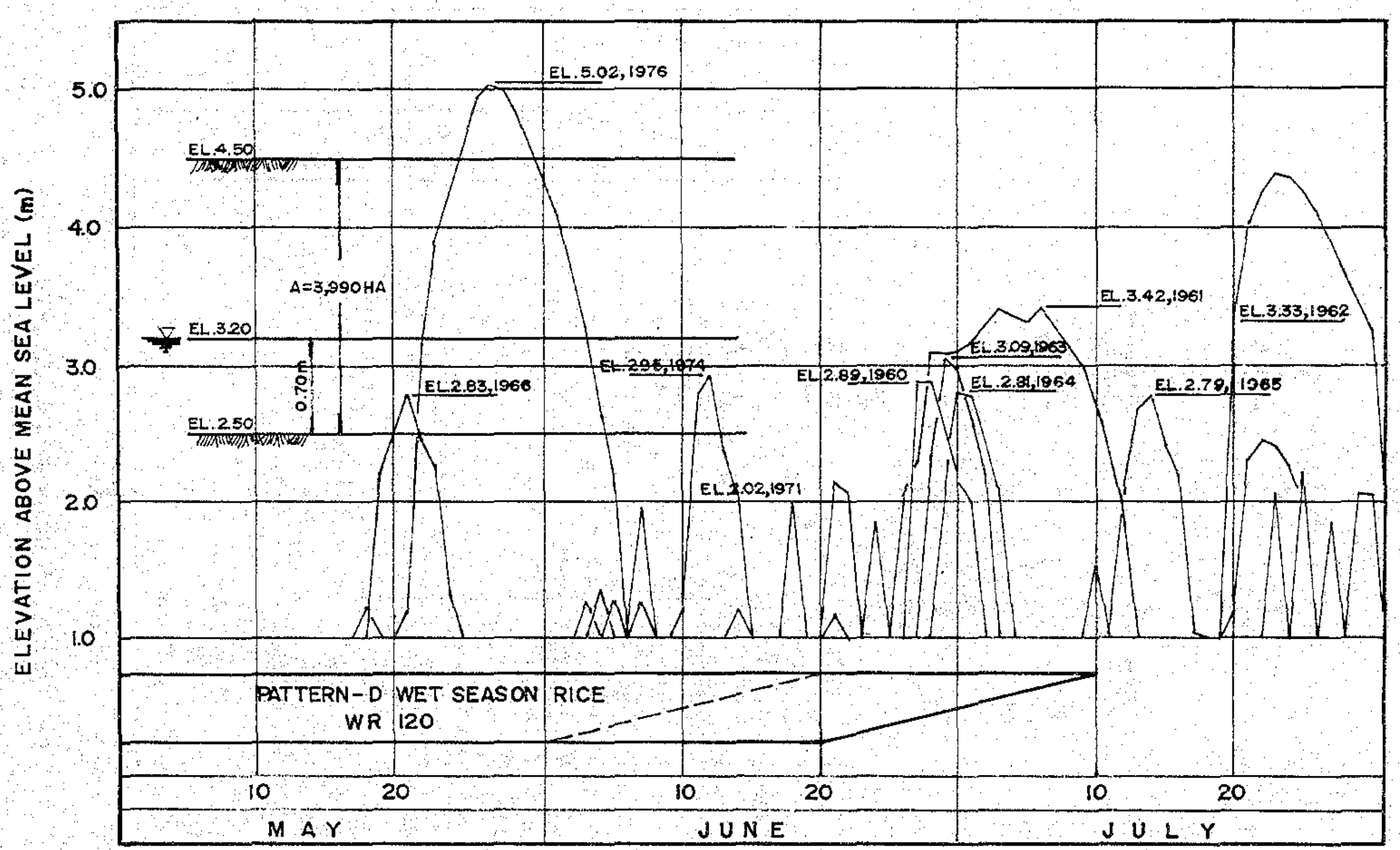


FIGURE A.4.3-11 SIMULATED INUNDATION OF THE AREA (CASE B-4-2)

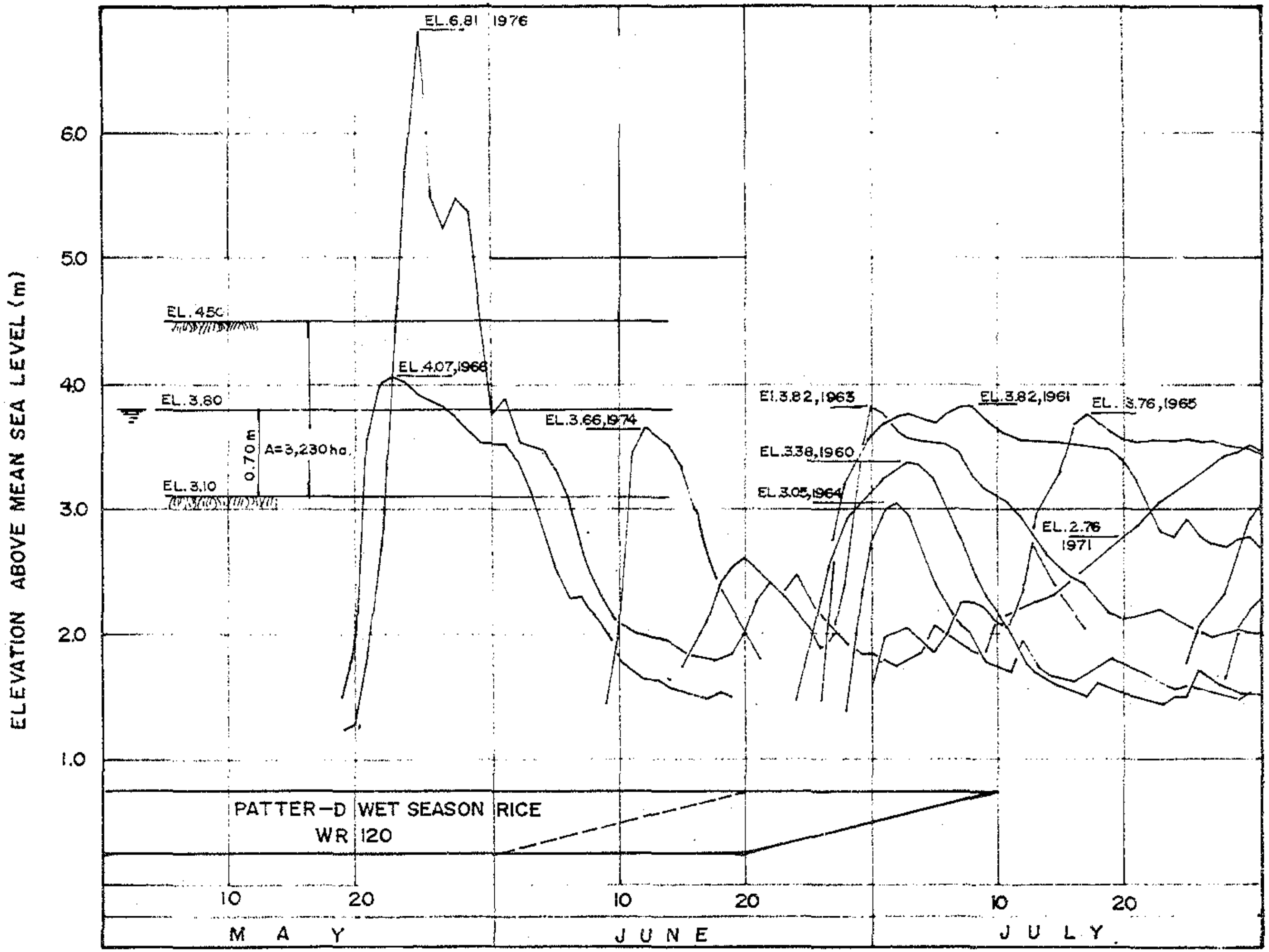


FIGURE A.4.3-12 SIMULATED INUNDATION OF THE AREA (CASE-C)

CHAPTER V. GEOLOGY AND SOIL

CHAPTER V. GEOLOGY AND SOIL

5.1 Introduction

Conservation of the existing farm lands and reclamation of the waste lands to increase agricultural production under the systematic supply of irrigation water would be a prerequisite for successful growth and development of farm economy in the Project Area.

The soil survey in relation to its geological features will present scientific information useful for making the reasonable and necessary land development.

Objectives of the soil survey conducted by the Feasibility Study Team are;

(1) to conduct soil profile observations for checking/confirming the results of the existing soil surveys;

(2) especially to concentrate the survey to find availability of the lands which will be expanded under the irrigation system; and

(3) to investigate the problems of soils and water quality for improving agricultural managements aimed at increasing farm production.

The survey was carried out between the end of the wet season and the beginning of the dry season in 1982 in cooperation with the Region III AMRIS Office at San Rafael, Bulcan.

5.2 Geological Features

5.2.1 Topography

The Project Area lies in the southern most area of the vast plain of Central Luzon extending from Manila Bay north to the Gulf of Lingayen. The Area is bounded by the Candaba Swamp on the north, piedomont areas of the low mountain ranges on the east, coastal marsh areas on the south, and the Pampanga River on the west.

A greater part of the Area is flat and low in elevation being several meters above the mean sea level, and even the highest portion is less than 15 m at the Bustos Dam Site. The land slopes down toward the west and extends south to Manila Bay.

The Project Area is dissected largely by the Angat River into the northern and southern portion, the former of which is channeled by the Maasim River. Both rivers irrigate almost all paddy fields of the Area, emptying into the Pampanga River.

Frequent big floods of the Pampanga River, however, have formed various physical features by braided streams throughout the Area. Not only the Candaba Swamp but also many creeks and marshes yet remain and interrupt the agricultural development. Some enclosed depressions along the Pampanga River are situated only one meter or so above the mean sea level. In this connection, a slight tidal influence may be observed particularly in the vicinity of coastal zone in the south. Another topographical hazard, though not serious, is rolling terrain at the southeast corner of the Area, where surface slope varies from one to five percent.

Figure A.5.2-1 gives the contour lines of the Project Area by meter. An alluvial fan topography is clearly shown from east to west with the Angat River in the center. The low alluvial lands below five meters cover around one third of the total Area.

5.2.2 Geology

The land is entirely composed of recent alluvium. Materials are derived to a great extent from the eastern flank of the Cordillera which contains iron, limestone and gold deposits, forming gently sloping alluvial terrace lands on both sides of the Angat River.

The western section of the Area is a delta plain with level alluvial deposits of tuffaceous materials. This portion lies at very low elevations from one to four meters. These basic materials reflect on the slightly alkaline property of the soils. An outline of the geological feature covering Region III is shown in the map of Figure A.5.2-2.

Most of the lands are clayey in texture although those of the river bank are rather sandy. Some portions in the fan area consist of gravelly subsoils containing debris of tuffaceous materials or laterite concretions. Such evidences are used as leading factors for soil classification in the Area.

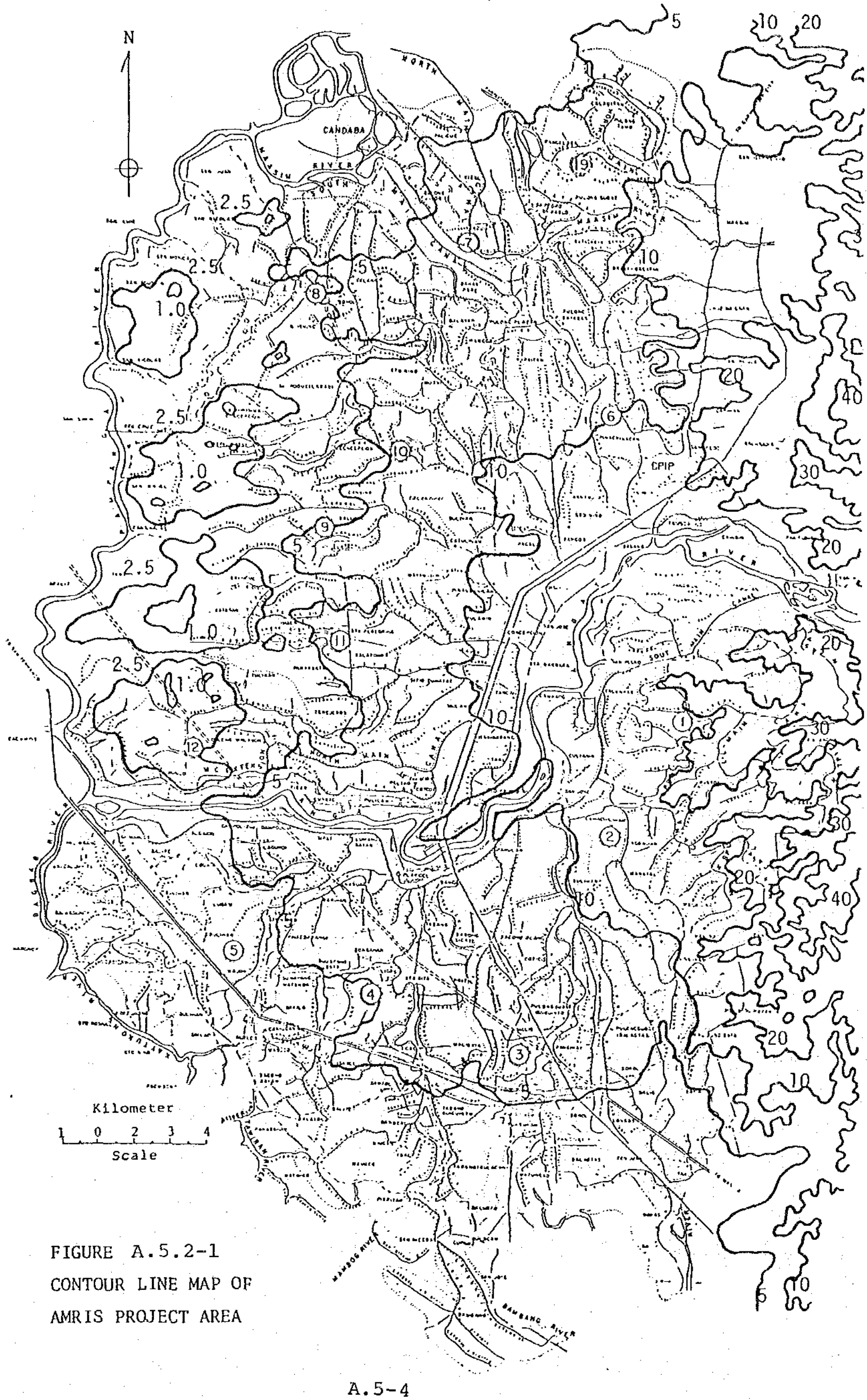
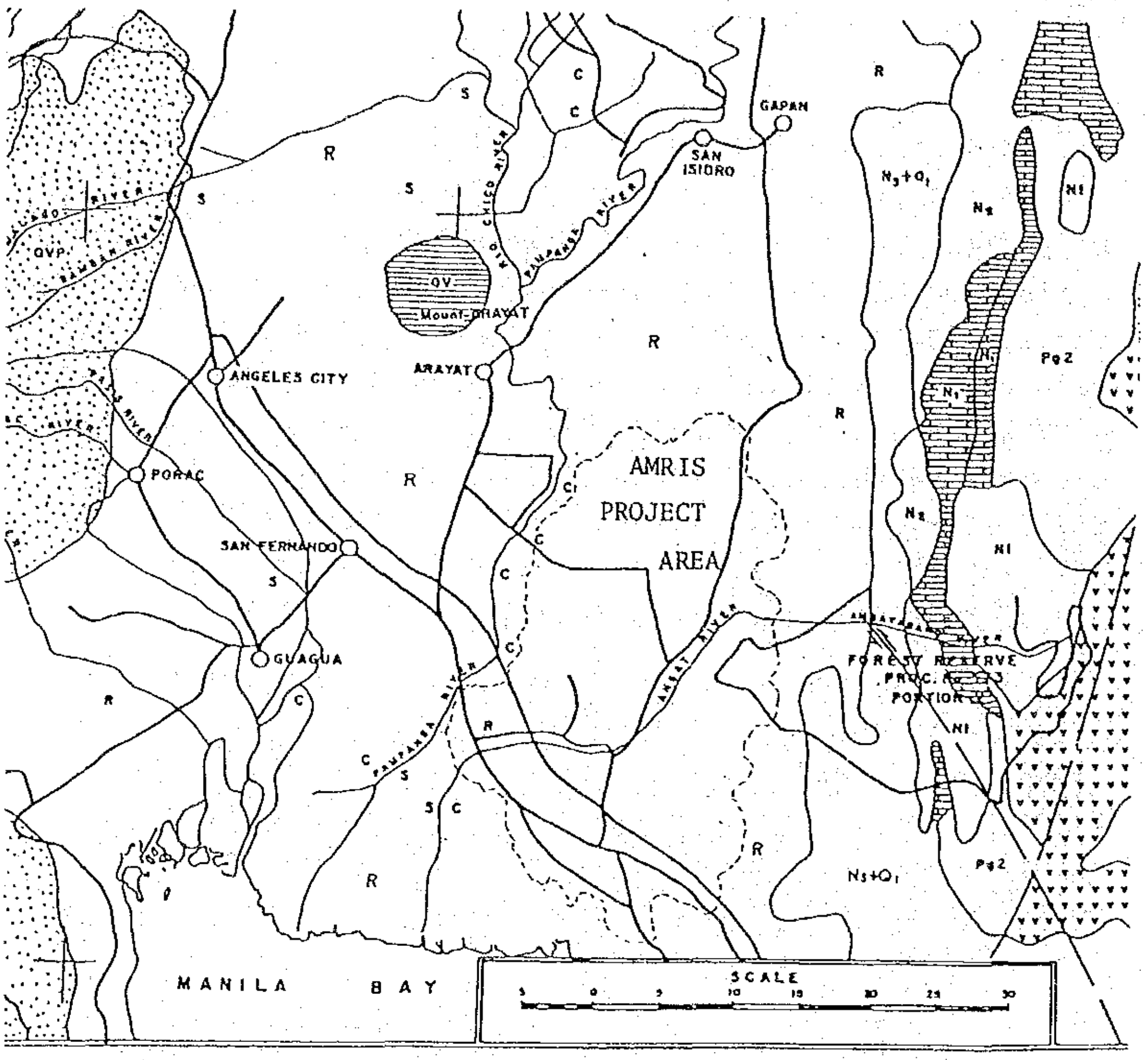


FIGURE A.5.2-1
CONTOUR LINE MAP OF
AMRIS PROJECT AREA



SEDIMENTARY AND METAMORPHIC ROCKS

R	RECENT
N_3+Q_1	PLIOCENE-PLEISTOCENE
N_2	UPPER MIOCENE-PLIOCENE
N_1	OLIGOCENE-MIOCENE
Pg_2	OLIGOCENE
Pg_1	PALEOCENE-EOCENE
KPg	UNDIFFERENTIATED
BC	BASEMENT COMPLEX (PRE-JURASSIC)

LEGEND

IGNEOUS ROCK

NI	NEOGENE
UC	CRETACEOUS-PALEOGENE
QVP	PLIOCENE-QUATERNARY
QV	PLIOCENE-QUATERNARY
UV	UNDIFFERENTIATED
K	CRETACEOUS-PALEOCENE

This pattern assigned to various sedimentary rock units indicates major limestone bodies of the same age.

Source: Bureau of Mines Phil. (1963)

FIGURE A.5.2-2 GEOLOGICAL MAP AROUND AMRIS AREA