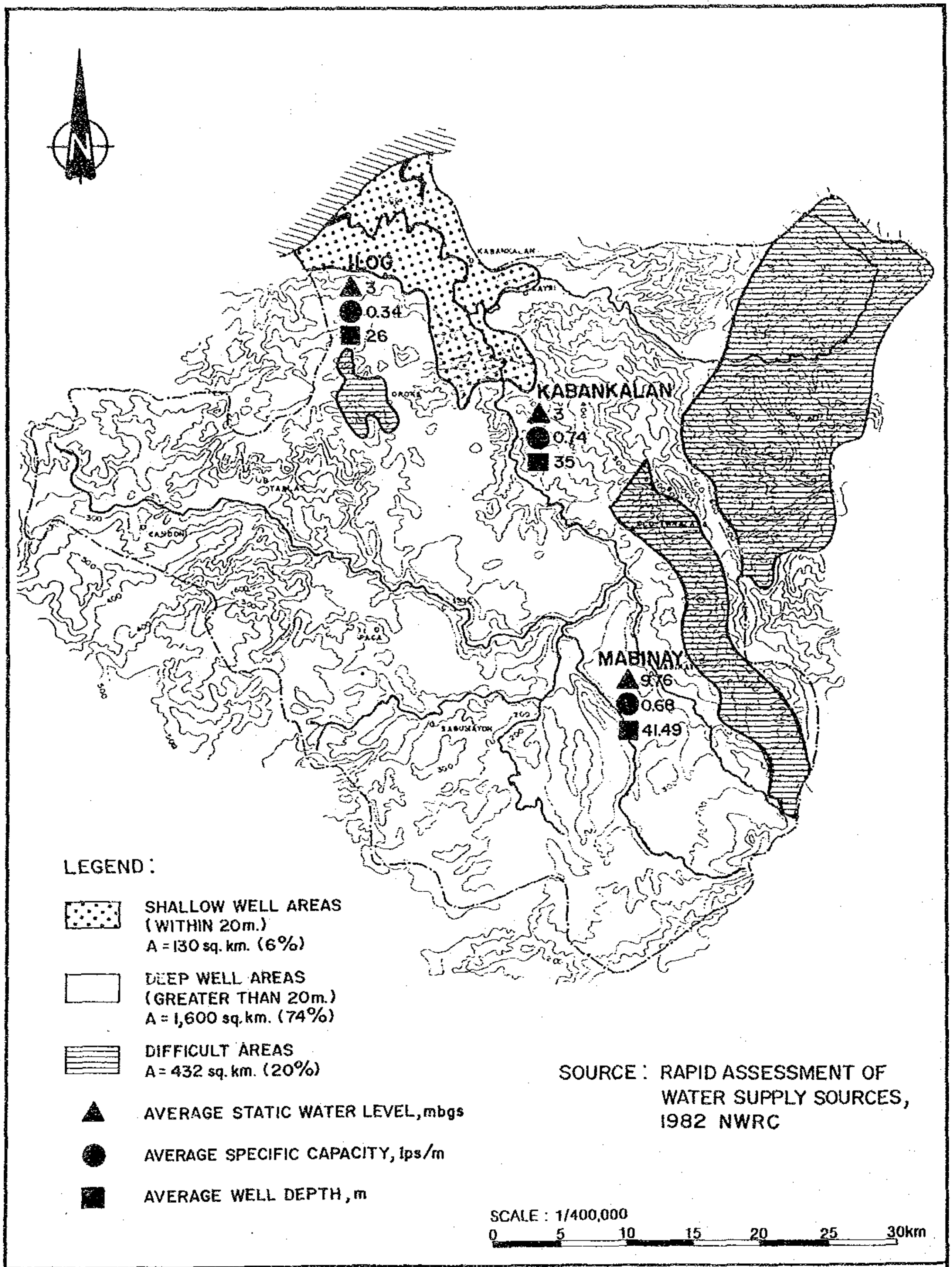
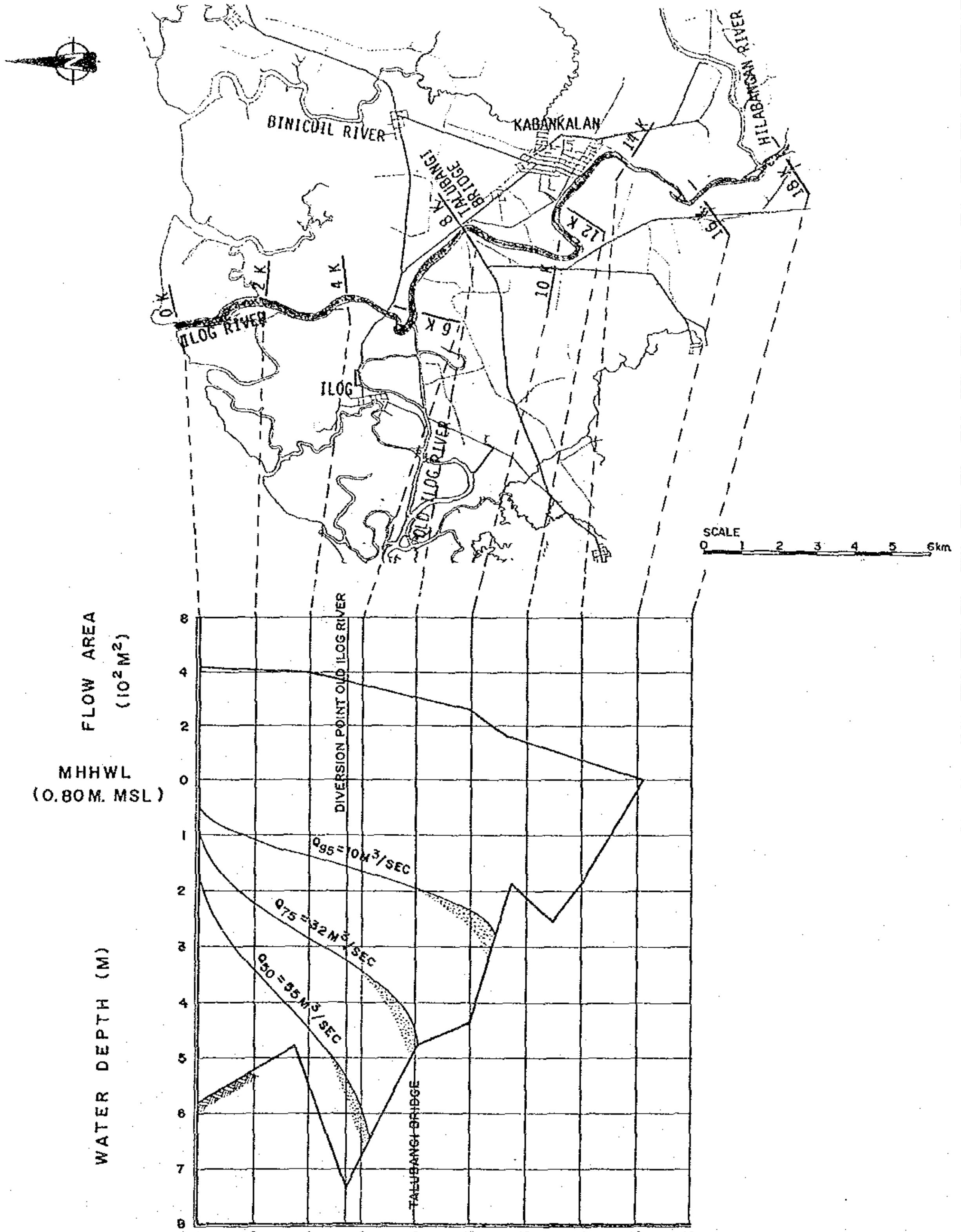
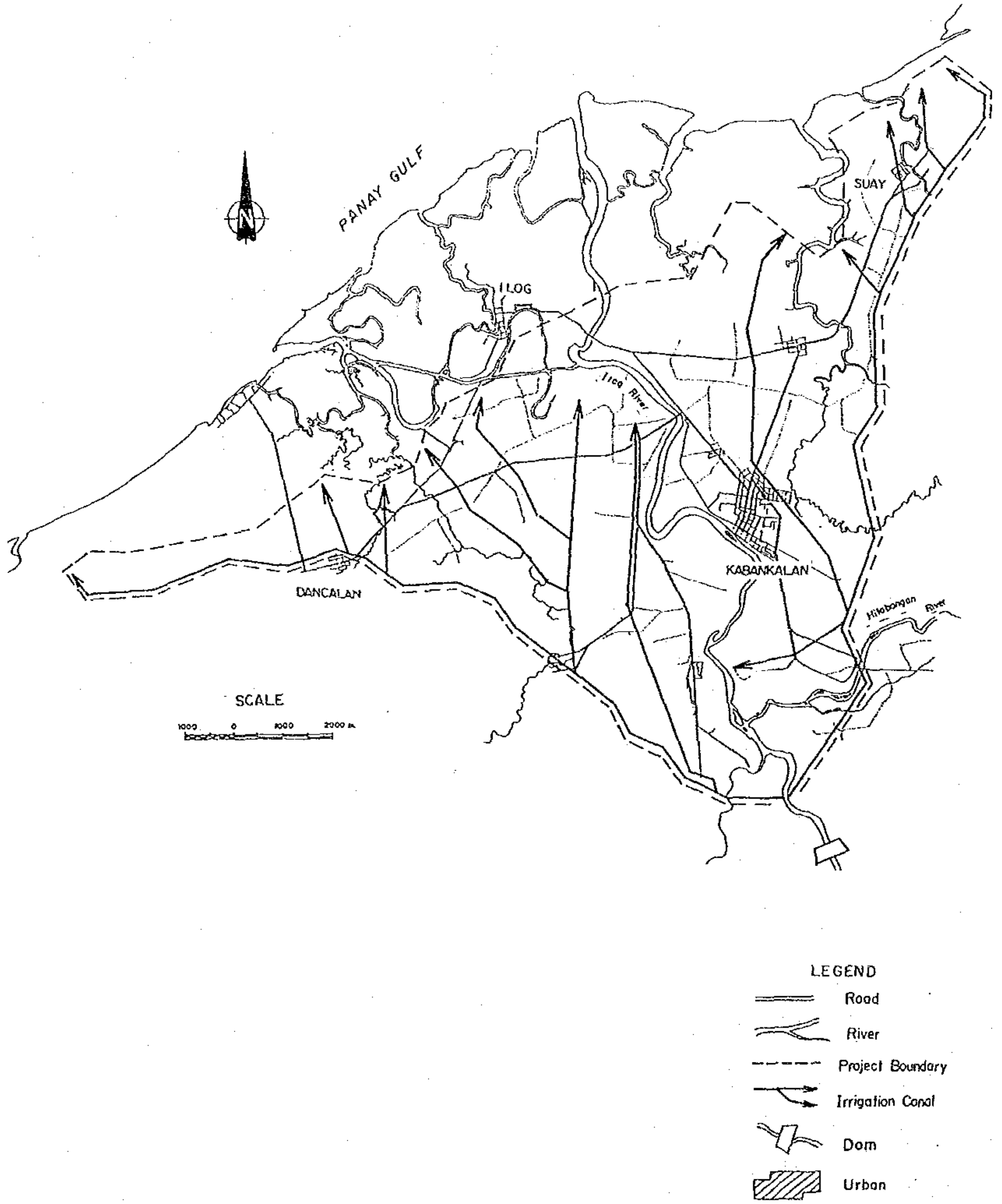


THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig. IV-1-6 GROUNDWATER MAP
JAPAN INTERNATIONAL COOPERATION AGENCY	



SOURCE : NATIONWIDE FLOOD CONTROL PLAN (NOV. 1982)

THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig. IV-1-7 SALTWATER INTRUSION IN ILOG RIVER
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig. IV-2-1 GENERAL LAYOUT OF ILOG IRRIGATION PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY	

V. FLOOD CONTROL

STUDY
ON
ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

SUPPORTING REPORT V. FLOOD CONTROL

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1. PRESENT CONDITION

In the sector of Flood Control Planning, the present condition is emphasized with flood inundation and flood damages as described hereunder:

1.1 Flood Inundation Condition

The data available to know the flood inundation condition mainly include flood inundation map observed for the flood in 1984 and flood mark recorded at the church of Barangay Linao. To supplement the data on flood inundation condition, the interview survey was conducted in the inundation area in this study period (refer to Table V-1-1). Judging from the data and interview survey results, the inundation condition in the lowland area is summarized as follows:

(1) The lowland area of this basin is habitually inundated and the inundation area spreads over the whole lowland area.

(2) The main causes of flood are typhoons and heavy rainfalls causing rivers or drainage canals to overflow.

(3) Inundation occures in every year or once every a few years in several places and even in the relative high land like Poblacion Kabankalan, it has experienced once every ten years. Inundation continues more than a day.

(4) The inundation water depth sometimes reaches more than 1 m in case of a severe flood like in 1984 and the water usually flows down with a relatively high velocity.

(5) The highest inundation depth which was marked in 1949 was about 2 m above the ground height according to the flood mark at the church of Barangay Linao. (Refer to Fig. V-1-1.)

(6) The flood inundation area in 1984 flood roughly covers the area of 125 km2 in the lower reaches. (Refer to Fig. V-1-2.)

1.2 Flood Damage

The interview-survey results indicate that the worst flood occurred in 1949 when the lower reaches was inundated for four days. A total of 730 lives perished, and half of the sugarcane plantation was damaged.

Typhoon Nitang which was considered to be the most powerful storm to batter the country since 1970, hit Western Visayas on September 2, 1984. In this region, lost were a total of 156 lives, of which 140 deaths were reported in Negros Occidental areas. Persons affected in the province amounts to more than 227,000, and properties and economic activities were seriously damaged. According to a report by the NEDA Regional Office IV, Typhoon Nitang's total direct damage in the province was estimated in monetary terms to have reached more than 600 million at the 1984 price level. The breakdown is presented in Table V-1-2.

During the past study period, Typhoon Ruping, which was more powerful than Typhoon Nitang, hit the Visayan Region on November 13, 1990 and inflicted severe damage on the Ilog- Hilabangan river basin. In the lower reaches, several portions of the river bank were eroded by floodwaters, washing away a wooden bridge, suspending operation of a sugar mill, and damaging agricultural crops and other properties, as presented in Fig. V-1-3. DPWH estimated the cost for repair/rehabilitation works of various infrastructures in Region VI and VII at P220 million and P184 million, respectively.

2. FLOOD INUNDATION ANALYSIS

It is necessary to identify the flood inundation condition to provide an effective control measure and to estimate the benefit which may accrue from this flood control project. The procedure of flood inundation analysis is as follows:

(1) Selection of methodology for flood inundation analysis;
(2) Formulation of flood inundation model;
(3) Setting of the initial condition for computation; and
(4) Calculation of flood inundation.

2.1 Selection of Methodology for Flood Inundation Analysis

The inundation area in the lower reaches is on the flat land with the gradient between 1/5,000 and 1/10,000 and inundation water widely spreads and flows down to the sea. Among the flood inundation types which are broadly classified into the storage type and the diffusion type, inundaiton condition in this area may belong the diffusion type judging from the aforementioned topographic condition in the inundation area.

In consideration of the flood inundation type and the topography of the flood prone area, the Two-Dimentional Unsteady Flow was selected over the other inundation model such as Mushkingum Model, the Simplified Unsteady Flow Model, the Two-Dimentional Unsteady Flow, etc.

2.2 Formulation of Flood Inundation Model

Flood inundation model is formulated under the following conditions:

(1) The whole inundation area is divided into mesh blocks of 500 m by 500 m.

(2) The average ground height of each mesh is obtained using the topographic map with a scale of 1/5,000 which was prepared in this study.

(3) Structures such as roads and railways which may hamper the smooth flow of inundation water are taken into consideration assuming them as weirs between the mesh blocks.

(4) Flood discharge overtop at points with low flow capacity and spread over the inundation area.

2.3 Basic Equation

The basic equations applied to the model were derived from the following equations:

(1) Euler's Equation of Motion

$$\begin{cases} \dfrac{\partial u}{\partial t} + u\dfrac{\partial u}{\partial x} + v\dfrac{\partial u}{\partial y} + w\dfrac{\partial u}{\partial z} = X - \dfrac{1}{\rho}\dfrac{\partial P}{\partial X} \\ \dfrac{\partial v}{\partial t} + u\dfrac{\partial v}{\partial x} + v\dfrac{\partial v}{\partial y} + w\dfrac{\partial v}{\partial z} = Y - \dfrac{1}{\rho}\dfrac{\partial P}{\partial Y} \\ \dfrac{\partial w}{\partial t} + u\dfrac{\partial w}{\partial x} + v\dfrac{\partial w}{\partial y} + w\dfrac{\partial w}{\partial z} = Z - \dfrac{1}{\rho}\dfrac{\partial P}{\partial z} \end{cases}$$

where,

u, v, w	: velocity of x, y and z direction
X, Y, Z	: gravity of x, y and z direction
ρ	: water density (= 1.0)
P	: pressure

(2) Equation of Continuity

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

For actual application to the two dimensional models, the above equations are expressed as follows:

(1) Equation of Motion

$$\frac{1}{gA_x}\frac{\partial Q_x}{\partial t} - \frac{Q_x B_x}{gA_x^2}\frac{\partial H}{\partial t} + \frac{\partial H}{\partial x} + \frac{|Q_x|Q_x}{F_x^2} = 0$$

$$\frac{1}{gA_y}\frac{\partial Q_y}{\partial t} - \frac{Q_y B_y}{gA_y^2}\frac{\partial H}{\partial t} + \frac{\partial H}{\partial y} + \frac{|Q_y|Q_y}{F_y^2} = 0$$

$$F_x = \frac{1}{n}R_x^{2/3}A_x$$

$$F_y = \frac{1}{n}R_y^{2/3}A_y$$

(2) Equation of Continuity

$$\frac{\partial(Bh)}{\partial t} + \frac{\partial Q_x}{\partial x} + \frac{\partial Q_y}{\partial y} = 0$$

where,

Q_x, Q_y	: discharge of x and y direction
A_x, A_y	: current area of x and y direction
B_x, B_y	: width of x and y direction
R_x, R_y	: hydraulic depth of x and y direction
n	: roughness coefficient
H	: water level
h	: water depth

These equations are finally transformed into finite difference form for numerical computation, as follows:

(1) Finite Difference Form of Equation of Motion

$$\frac{1}{gA_{I,J}^{n-1/2}}\frac{Q_{I,J}^{n}-Q_{I,J}^{n-1}}{\Delta t}-\frac{\left(\dfrac{Q_{I,J}^{n}-Q_{I,J}^{n-1}}{2}\right)^{2}\partial y}{g\left(A_{I,J}^{n-1/2}\right)^{2}}\frac{H_{I,J}^{n-1/2}-H_{I,J}^{n-3/2}}{\Delta t}$$

$$+\frac{H_{I+1/2,J}^{n-1/2}-H_{I-1/2,J}^{n-1/2}}{\Delta x}+\frac{\left|Q_{I,J}^{n-1}\right|Q_{I,J}^{n}}{\left\{\dfrac{1}{n}\left(\dfrac{A_{I,J}^{n-1/2}}{\Delta y}\right)^{2/3}\cdot A_{I,J}^{n-1/2}\right\}^{2}}=0$$

(2) Finite Difference Form of Equation of Continuity

$$\frac{(Bh)_{I,J}^{n}-(Bh)_{I,J}^{n-1}}{\Delta t}+\frac{Q_{I+1/2,J}^{n-1/2}-Q_{I-1/2,J}^{n-1/2}}{\Delta x}+\frac{Q_{I,J+1/2}^{n-1/2}-Q_{I,J-1/2}^{n-1/2}}{\Delta y}=0$$

where,

suffix I, J : mesh number

suffix n : computation step number

2.4 Initial Condition for Computation

The maximum inundation depth and the inundation area were examined under the probable flood discharge of 2-year, 5-year , 10-year, 25-year, 50-year and 100- year return period. As the initial condition for computation, it was necessary to give the overflow discharge to the inundation area as well as the overflow section.

In this consideration, the following initial conditions were considered:

(1) Two sections are selected as the overflow sections where the flow capacity is very poor compared with the adjacent stretches, i.e., between 17 km and 18 km of the Ilog River with a flow capacity of about 1,000 m^3/s and 4 km point with 500 m^3/s.

(2) It is assumed that in the probable flood hydrograph, the surplus discharge over the flow capacity of 1,000 m^3/s overflows at the section between 17 km and 18 km. The overflow discharge at the section of 4 km is given by the surplus

discharge over the flow capacity of 500 m^3/s in the flood hydrograph after subtracting the overflow discharge at the section between 17 km and 18 km.

2.5 Computation Results

The maximum inundation depths in each case are shown in Fig. V-2-1 expressed in figures and Fig. V-2-2 in patterns. Although the adequacy of the flood inundation model was not verified due to lack of information, this model seems to be applicable because the flood marks at the church from 1949 which are between 0.5 m and 1.7 m as described in Section 1.1 broadly correspond to the calculated inundation depth. (Refer to Fig. V-1-1.)

3. THE MASTER PLAN

3.1 Basic Concept of Formulation of the Master Plan

Flood damage in the Ilog-Hilabangan River Basin is most conspicuous in the flat land in the lower reaches as shown in Fig. V-1-2. Therefore, the master plan of flood control in the Ilog-Hilabangan River Basin is formulated for the mitigation of flood damage in this lower reaches.

<u>Project Scale and Target Year</u>

The appropriate project scale for the master plan was selected in consideration of the following:

(1) The project scale applied to the other major rivers in the country; and,
(2) The scale of the recorded maximum flood in the basin.

The master plan is sometimes named framework plan or basic plan which provides an ideal flood control plan, and the target year for completion of the plan is unspecified due to the enormous fund requirement and work volume. Since it is necessary to examine the economic viability of the master plan in this study, a tentative project completion year is assumed considering the availability of basic data.

Flood Control Measures

In general, two approaches can be employed to attain flood mitigation in a basin, i.e., structural and non-structural measures. These are discussed as follows:

(1) Structural Measures

The major structural measures generally applied for flood control include dam and reservoir, retarding basin, river improvement including cut-off channel, and diversion channel. Several alternative cases of structural measures were studied applying the measures individually or in combination with each other, and the appropriate combination of structural measures were selected from the economic and technical aspects.

(2) Non-structural Measures

Non-structural measures mainly include land use regulation, afforestation and reforestation, flood forecasting and flood warning. However, these measures may not be applicable in this river basin at present for the following reasons:

(a) In this river basin, most of the available land for agriculture are fully utilized and urbanization is not severe judging from the growth of population in the basin. Therefore, land use regulation on future land development is presumed not necessary.

(b) Afforestation and reforestation are useful to detain flood runoff from the aspect of land conservation. However, it takes a long time and enormous funds to fully generate the function, and therefore, this measure is not usually employed for flood control purposes but for other purposes such as forest development, environmental conservation, etc.

(c) A flood forecasting and warning system which can be introduced with less funds and within a short period of time is expected to be useful for flood damage mitigation. The system consists of sensitive equipment, and appropriate maintenance is necessary for efficient operation, together with trained operators/engineers and the spare parts to be provided from time to time. Judging from the present condition, the hydrological data necessary to formulate the flood forecasting system is not enough. Besides, it may be difficult to obtain knowledgeable operators/engineers and to timely provide the spare parts. Therefore, the installation of a flood forecasting and warning system seems to be still premature, though only this measure may be conditionally applicable among the said non-structure measures. To proceed to the establishment of the flood forecasting in the future, it is necessary to first prepare the hydrological data base in parallel with the arrangement of the organization and staff for the purpose. A model flood forecasting and warning system is shown in Annex for reference when applied in this basin.

Project Evaluation

Project evaluation was made by calculating the Internal Rate of Return (IRR), as well as the Cost-Benefit Ratio and the Net Present Value, on the basis of the project benefit and construction cost for the structural measures. Since the assets in the flood prone area are expected to increase in the future, the project benefit is estimated assuming the increase of assets such as houses and household effects.

3.2 Selection of Project Scale and Target Year

Project Scale

In accordance with the above concept, the project scale in the Ilog-Hilabangan River Basin is conceived as discussed below.

In the ongoing studies on flood control plan for the other major rivers such as Pasig River, Agno River, Cagayan River, Pampanga River and Panay River, the project scale of a 100-year return period was adopted. Among them, the Panay river basin conditions such as land use, flood damage and catchment basin are similar to those of the Ilog-Hilabangan River Basin.

The recently recorded maximum flood was in November 1990 caused by Typhoon Ruping. This flood seems to be of a 90-year return period according to the flood frequency analysis based on the flood data including this flood. Consequently, it is necessary to adopt the project scale of more than 90-year return period if this Master Plan is required to cover the project scale against a flood of bigger magnitude than the recorded maximum flood.

Judging from the said condition, a 100-year return period to the Master Plan of flood control in the Ilog-Hilabangan River Basin is proposed to be adopted.

Target Year

In accordance with the basic concept of formulation of the Master Plan, the target year for economic evaluation is assumed from the availability of the basic data. The year 2020 is employed for the target year on the following consideration.

Among the ongoing flood control plans, the furthest target year is 2020 which was adopted for the formulation of the Master Plan of the Pasig River Basin (refer to Fig. V-3-1). In the Ilog- Hilabangan River Basin, this year seems to be the furthest one to accurately presume future conditions such as population, land use, water demand and others.

3.3 Design Criteria

For the formulation of Master Plan, the following design criteria were applied.

Basic Project Flood

The basic project flood which is a basic figure to examine the flood control plan alternatives is 5,450 m3/s. This is derived by rounding the peak discharge of 5,430 m3/s corresponding to 100 year return period at the reference point downstream of the confluence with the Hilabangan River. The basic project flood of the Ilog River before the confluence is 4,300 m3/s and that of Hilabangan, 2,900 m3/s. Fig. V-3-2 shows the basic project flood in the Ilog-Hilabangan River Basin. Since the flow capacity of the existing river channel is about 500 m3/s at minimum, the excess discharge to be controlled by flood control measure is about 5,000 m3/s.

Design Highwater

The design high water level at the river mouth was set considering the mean high water spring of 1.5 m. To minimize the flood damage potential, the design high water in the stretch where many houses are located along the river course was set at the ground height, while that in the stretch where land use is more for agriculture was set, at least, below the recorded maximum flood mark or about 1.5 m high above the ground level.

3.4 Alternative Study Cases

3.4.1 Applicable Flood Control Measures

Selection of Applicable Measures

Judging from the river basin conditions, the following flood control measures are considered as applicable.

(1) River Improvement

This measure has been partially applied to this river basin and it seems to be effective. Cut-off channel which has also been provided in this river basin is included in this measures.

(2) Diversion Channel

This measure was once employed in this basin in the Bungul diversion channel and it seems to be still one of the applicable measures.

(3) Dam and Reservoir

As described in the Supporting Report, III. Dam Planning, this has been studied as one of the most effective measures, and still remains a high possibility.

(4) Retarding Basin

There is no site suitable for a retarding basin.

Among the above measures, river improvement including a cut-off channel are compared with the diversion channel from the similarity of their function on flood control, i.e., to confine the flood discharge in the channel and make it flow down safely to the sea or elsewhere. The dams selected at three sites are also further examined. In this connection, preliminary comparison studies between river channel and diversion channel and among dams/reservoirs are made to narrow down the applicable measures and simplify the comparative study as discussed hereafter.

Comparison between the River Improvement and the Diversion Channel

The objective river improvement stretch will be from the river mouth to 20 km for the Ilog River and from the confluence point with the Ilog River to 1.5 km for the Hilabangan River where the flood damage is expected.

In this case, a cut-off channel at the meandering section near Kabankalan and Talubangi is considered to be provided as an alternative study case. Therefore, two cases of river improvement plans are proposed as follows (Refer to Fig. V-3-3):

Case R1 : River channel alignment is proposed based on the existing river channel.

Case R2 : Cut-off channel is proposed at the meandering section near Kabankalan Municipality and Barangay Talubangi and existing river channel alignment is adopted to the remaining section. In this case, it is assumed that all the flood discharge flows down in the cut-off channel.

As for the diversion channel, the following three cases are proposed judging from the topographic condition (refer to Fig. V-3-3):

Case D1 : The channel will be diverted from the upper stream point at Kabankalan City (13.5 km), pass the eastern part of the city and connect with the existing Binicuil River.

Case D2 : The old Ilog River will be used as diversion channel by expanding the river width and excavation.

Case D3 : The channel will be diverted from the 15.0 km point, pass the western part of the Ilog-Hilabangan River and connect with the Salong River.

Discharge distribution to the existing river and diversion channels in the above-said cases is determined through a cost comparison study on several alternative cases.

The comparison results of the above alternative cases of river improvement and diversion channel are shown in Table V-3-1. Judging from this table, river improvement based on the existing river channel has an economical advantage over the other cases, because the excavation and embankment volumes for river improvement are less than those of the other alternative cases, while there is not much difference in the number of house evacuation and land acquisition among these cases. Eventually, river improvement along the existing channel (Case R1) is proposed as one of the applicable measures for further alternative study.

Comparison among Dams/Reservoirs

Among the possible dam sites shown in Fig. V-3-4, the following dam sites were selected through a comparative study on the topographic and geological conditions.

Case Dam1 : Ilog No.1 upper dam site
Case Dam2 : Ilog No.1 lower dam site
Case Dam3 : Hilabangan No. 1 dam site

To identify the most suitable dam site among the three dam sites, rough cost comparisons by effective storage capacity and regulation effect were made as shown in Table V-3-2 and Figs. V-3-5 and V-3-6, respectively. Judging from the figures, Ilog No. 1 lower dam site has an economical advantage over the other dam sites, while the number of house evacuation is not much different among the sites. Ilog No. 1 lower dam site is then proposed as one of the applicable measures for further alternative study.

3.4.2 Selection of Alternative Study Cases

From the study, it was identified that the dam and reservoir and river channel improvement are applicable measures for flood control in this river basin. In this connection, the following alternative cases are conceivable; namely, (1) river improvement only, (2) dam/reservoir only, and (3) combination of river improvement with dam/reservoir.

In the case of dam/reservoir, however, Ilog No. 1 lower dam cannot regulate the flood discharge up to the flow capacity of about 500 m3/s of the present river channel, because the flood discharge from the Hilabangan river basin is over 500 m3/s. Flood damage still occurs even if the Ilog No. 1 dam can regulate all the flood discharge from the Ilog River Basin. Although it is concieved that the flood discharge from the Hilabangan River Basin can be regulated by the Hilabangan No.1 dam, the construction cost is too high and not applicable judging from the cost comparison shown in Fig. V-3-5. Thus, the case of dam and reservoir only was eliminated and the following alternative cases were considered:

Case 1 : River improvement along the present river course
Case 2 : Combination of river improvement and Ilog No. 1 lower dam

3.5 Selection of Optimum Case

To select the optimum case, further comprative study on the two (2) alternative cases was made. The results of the study are discussed hereunder.

Cost Comparison of Alternative Cases

Basic cost, including direct construction cost and land acquisition cost was roughly estimated for the alternative cases. The construction cost is summarized in the following table. (Refer to Fig. V-3-7.)

Case No.	Discharge Distribution (m3/s) River Channel	Dam	Cost (million P) River Channel*	Dam	Total
Case 1	5,450	-	1,187	-	1,187
Case 2-1	4,800	650	1,012	1,440	2,452
2	4,000	1,450	779	1,560	2,339
3	3,400	2,050	639	1,670	2,309
4	2,750	2,700	534	1,810	2,344
5	2,300	3,150	481	3,400	3,881

* Cost estimate was based on unphased implementation schedule.

Optimum Case

Judging from Fig. V-3-7, river improvement should be the optimum flood control measure in this river basin, explained as follows:

(1) The river improvement plan is economically advantageous to the case of river improvement in combination with dam.

(2) In case of expansion of the present river width, social problems regarding house evacuation sometimes ensue. Although the number of house evacuation is not small at about 350 houses for this river improvement plan, which number is not much different from the 300 houses for dam construction, the plan is expected to be accepted because it is essential to assure safety from flood damage.

4. SELECTION OF URGENT PROJECT

The urgent project is selected within the framework of the Master Plan by narrowing down the area to be protected and/or lowering the project scale. In this connection, the following considerations were made to select the urgent project.

4.1 Area to be Protected

The Master Plan was formulated to protect the whole inundation area in the lower reaches by applying the river channel improvement. To narrow down the area to be protected by the urgent project, prioritization of the area may be considered and partial river improvement can be adopted to protect the area based on the priority. In this river basin, however, it is not so useful to identify the priority area in view of the following reasons:

(1) In this basin, land use for sugarcane is dominant, though some small urban areas exist. Under this land use condition, prioritization cannot be given.

(2) Judging from the inundation condition, partial river improvement is not effective because the overflow discharge widely spreads and sometimes flows down even in the area which is to be protected by partial river improvement.

Consequently, it is not realistic to select the urgent project by narrowing down the area to be protected.

4.2 Project Scale

A 100-year return period is adopted as the project scale of the Master Plan, of which implementation schedule is composed of two phases; namely, flood control works with a smaller scale are completed as the Urgent Project, and subsequently upgraded to the design scale in the second phase until the target year 2020. For the Urgent Project, a 25-year return period is adopted to narrow down the project scale, judging from the social requiremnt together with economic justification as discussed below.

<u>Social Requirement</u>

From the social aspect, reference was made to the relation between project scale and target year adopted to the other river basins (refer to Fig. V-3-1). A 30-year return period was applied to the priority project in the Pasig River Basin, a 25-year return period in the Cagayan River, and a 20-year return period in the Pampanga River, though some other rivers employ a 10-year return period depending on project necessity. The target completion years set for these projects range from 10 to 30 years after the planning time.

The project scale of a 25-year return period and the completion year may be suitable for the urgent flood control project in the Ilog-Hilabangan River Basin, though it is necessary to confirm the economic viability in the feasibility study stage.

Economic Aspect

The internal rate of return (IRR) of the Urgent Project was calculated to confirm the economic viability, and the IRRs of other alternative cases were also obtained as discussed in Supporting Report IX, Economic Evaluation.

The economic viability of the Urgent Project is figured at as high as 15.2% in IRR, and accordingly, the B/C exceeds 1.0 even at the discount rate of 15%. The Urgent Plan is thus acceptable enough from the economic viewpoint, although it is necessary to confirm its viability in the feasibility study stage.

4.3 Outline of Urgent Project

The urgent project will be formulated on the following considerations:

(1) As the flood control measure, river channel improvement is proposed for the river stretch described in the Master Plan.

(2) The project scale of a 25-year return period is applied.

TABLES

Table V-1-1 RESULT OF INTERVIEW SURVEY ON FLOODING CONDITIONS

No.	Place of Interview	Frequency of Flood	Cause of Flood	Inundation Condition: Period	Depth (m)	Source of Flood	Velocity	Property Damaged	Damage to Sugarcane	Source of Flood Information	Place of Evacuation
1	Poblacion Ilog	yearly	typhoon rainfall	7 days	2.5	mountain	high	houses, agric., animals	flooded	ocular	
2	Da-anbanwa, Kabankalan	once in 5 years	rainfall	24 hours	2.0	mountain	high	houses, agric., animals	fallen by flood	people in Barangay	
3	Brgy. Dancalan, Ilog	yearly	typhoon	36 hours	2.0	creek/ river	high	houses, agric., animals, roads	fallen by flood	radio	higher places
4	Brgy. Bista Alegre	yearly	rainfall	5 days	2.5	mountain	high	houses, agric., animals	spoiled roots	radio	school building
5	Brgy. Maralod, Ilog	once in a few years	typhoon	3 days	2.0	river	high	houses, agric., machinery		radio	
6	Brgy. Talubangi, Kabankalan	yearly	typhoon rainfall	7 days	2.5	mountain	high	houses, agric., animals	flooded	ocular	higher places
7	Brgy. Talubangi	once in 10 years	typhoon	2 days	1.0	river	high	houses, agric., animals		radio	school
8	Brgy. Binicuil, Kabankalan	once in 10 years	typhoon	48 hours	0.5	creek/ river	low	houses, agric.,			
9	Brgy. Salong Kabankalan	6 times in a year	typhoon	7 days	1.0	mountain	high	agric.	fallen by flood	Barangay officers	school building
10	Brgy. Linao	once in 10 years	typhoon rainfall	3 hours	2.0	river	high	houses, agric., animals	spoiled roots	radio	buildings
11	Poblacion Kabankalan	once in 10 years	typhoon	2 days	1.0	river	high	houses, agric., animals	fallen & spoiled roots	radio	school buildings
12	Sitio Panique, Brgy. Hilamonan, Kabankalan	once in a few years	typhoon	24 hours	4.5	river	high	houses, agric., animals	fallen by flood	radio	school building
13	Brgy. San Juan	once in 5 years	typhoon	3 days	2.0	river	high	houses, agric., animals, roads	spoiled roots	radio	factory
14	Hacienda San Lucas	yearly	typhoon	29 hours	1.0	river	high	houses, agric., animals, roads, machinery	fallen by flood	radio	higher places
15	Sitio Overflow, Brgy. Lupui, Kabankalan	yearly	typhoon rainfall	7 days	2.5	mountain	high	houses, agric., animals	fallen by flood	ocular	school building
16	Brgy. Overflow	yearly	typhoon	24 hours	2.0	river	high	houses, agric., animals		radio	higher places
17	Hacienda Calasa	once in a few years	typhoon	10 hours	2.5	river	high	houses, agric., animals, machinery	fallen by flood	radio	hill
18	Brgy. Orong Kabankalan	yearly	typhoon rainfall	2 days	3.0	creek/ river	high	agric.	fallen by flood	radio	higher places

Note : Locations of interview points are presented in Fig. 2.5-2.

Table V-1-2 SUMMARY OF DAMAGE BY TYPHOON NITANG IN NEGROS OCCIDENTAL PROVINCE

Damage Item	Quantity	Damage (million Pesos)
1. Deaths	140 persons	--
2. Injuries	4 persons	--
3. Housing Damage		
3.1 Houses damaged	9,001 units	9.0
3.2 Families affected	37,058 families	--
3.3 Persons affected	227,408 persons	--
4. Damage on Production		530.8
4.1 Agricultural crops	69,843 ha.	416.9
- Rice	44,817 ha.	211.2
- Corn	6,980 ha.	21.4
- Veg./root crops	1,181 ha.	22.0
- Banana	2,923 ha.	11.7
- Fruit trees	10,942 ha.	64.3
- Sugarcane	3,000 ha.	50.4 *
- Copra	6,938 M.T.	36.0
4.2 Fishery	5,044 ha.	109.0
4.3 Livestock and Poultry	42,410 heads	4.6
4.4 Forest	30,635 trees	0.3
5. Damage on Infrastructure		71.2
5.1 Power supply system		25.0
5.2 Road system		25.5
- National roads	294 km	8.1
- Barangay roads	105 sections	5.9
- Provincial roads	100 sections	11.5
5.3 Portworks	6 ports	2.2
5.4 School buildings	758 units	12.7
5.5 Irrigation canals, etc.		1.0
5.6 Other public facilities		4.8
6. Relief and Rehabilitation		4.6
Total		615.6

Source : NEDA, Region Office VI
Note * : Estimate.
Price level = Year 1984

Table V-3-1 COMPARISON OF ALTERNATIVE CASES IN RIVER IMPROVEMENT AND DIVERSION CHANNEL

Item	Unit	River Improvement		Diversion		
		Existing River (Case R1)	Shortcut (Case R2)	Binicuil (Case D1)	Old Ilog (Case D2)	Salong (Case D3)
Features						
Design Discharge						
Ilog River	m3/s	5,450.0	5,450.0	2,650.0	2,650.0	2,650.0
Diversion Channel	m3/s	-	5,450.0	2,800.0	2,800.0	2,800.0
Diversion Point		-	6.0k-15.0k	13.5k	6.0k	15.0k
Improved River Length						
Ilog River	km	20.0	11.0	20.0	20.0	20.0
Diversion Channel	km	-	6.0	11.0	6.5	11.0
Gradient						
Ilog River		1/5,000 -1/2,500	1/5,000 -1/2,500	1/5,000 -1/2,500	1/5,000 -1/2,500	1/5,000 -1/2,500
Diversion Channel		-	1/3,000	1/3,000	1/5,000	1/3,000
River Width						
Ilog River	m	160-300	160-300	80-140	80-140	80-140
Diversion Channel	m	-	230	140	150	140
Work Quantity						
Main Work						
Excavation	1000 m3	9,425.5	11,651.7	11,618.5	10,459.1	10,830.9
Embankment	1000 m3	966.7	1,444.1	1,575.5	1,393.7	1,686.9
Revetment	1000 m2	102.1	87.2	164.8	128.0	133.2
Bridge	m2	4,000.0	3,700.0	5,150.0	4,900.0	4,550.0
Sluice	unit	4.0	4.0	4.0	11.0	4.0
Drainage facility	unit	6.0	8.0	11.0	6.0	12.0
Diversion Weir	m	-	-	320.0	280.0	250.0
Compensation						
Land Acquisition	ha	222.6	307.5	277.5	205.1	256.7
House Evacuation	unit	354.0	211.0	404.0	311.0	246.0
Total Cost	mil.P.	1,187.0	1,363.7	1,547.5	1,322.4	1,401.2

Table V-3-2 COMPARISON OF ALTERNATIVE CASES IN DAM AND RESERVOIR

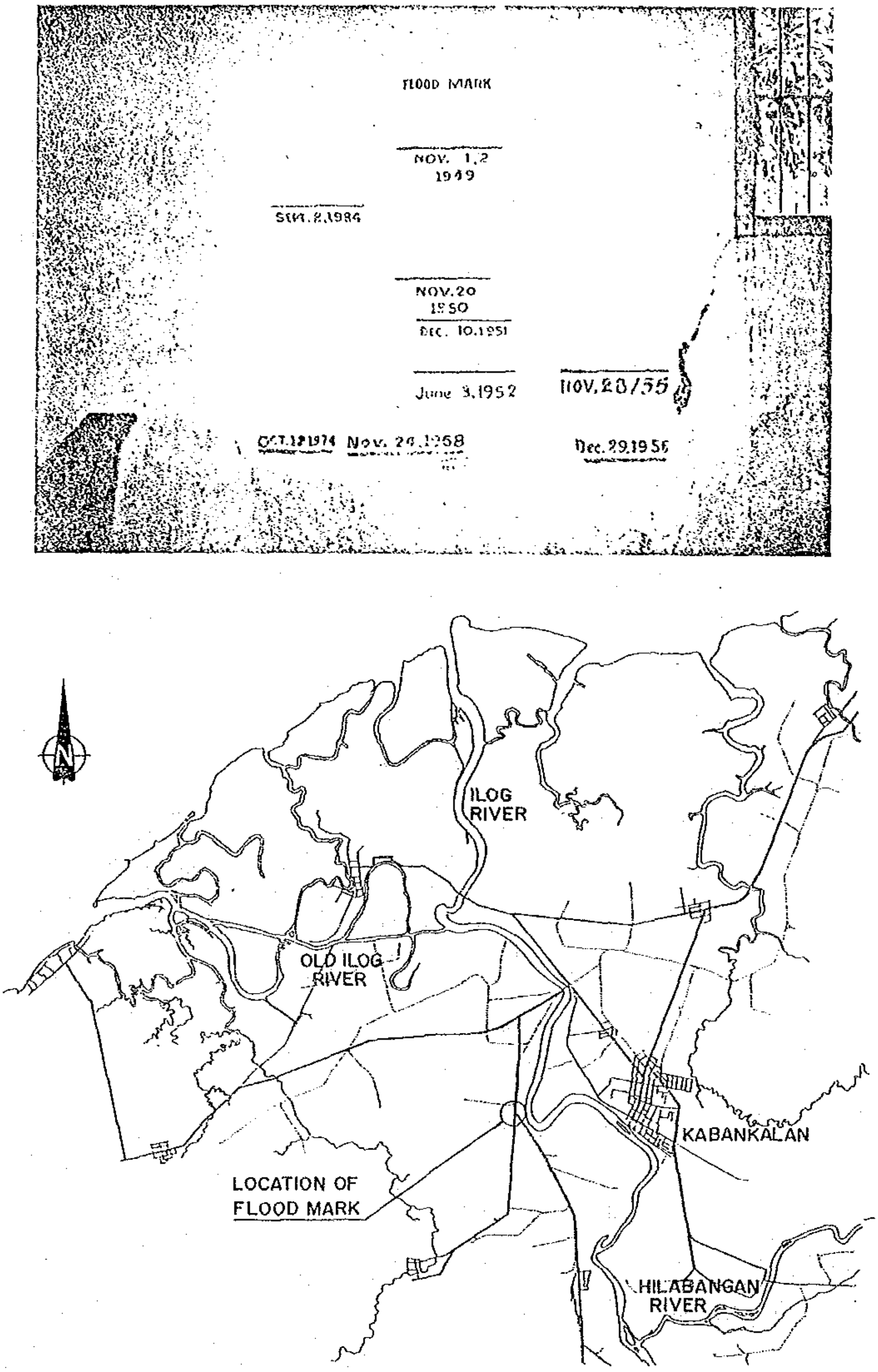
Item	Unit	Damsite									
		Ilog No.1 Upper Site			Ilog No.1 Lower Site					Hilabangan	
Catchment Area	km2	1,365			1,430					368	
High Water Level	EL. m	30	35	40	20	25	30	35	40	130	150
Storage Capacity	MCM	40	65	107	40	77	130	194	270	26	56
Effective Capacity	MCM	33	58	100	31	68	121	185	261	14	44
Sediment Volume	MCM	7	7	7	9	9	9	9	9	12	12
Dam Height	m	33.60	38.60	43.60	29.00	34.00	39.00	44.00	49.00	81.00	101.00
Dam Volume	MCM	0.60	0.70	0.84	0.55	0.82	1.12	1.80	2.32	2.35	4.30
Construction Cost *1	mil.P.	4,050	9,930	18,760	1,590	1,810	4,480	10,850	20,000	2,390	4,020
Dam	mil.P.	380	440	530	350	520	710	1,130	1,460	1,480	2,700
Spillway	mil.P.	750	770	800	740	790	850	1,000	1,110	910	1,320
Leakage Protection *2	mil.P.	2,420	8,220	16,930			2,420	8,220	16,930		
Sediment Control Dam *3	mil.P.	500	500	500	500	500	500	500	500		
House Evacuation	unit	195	225	265	85	150	220	255	300	10	15

Note *1 : Construction cost does not include compensation cost which is negligibly small compared with the total cost.

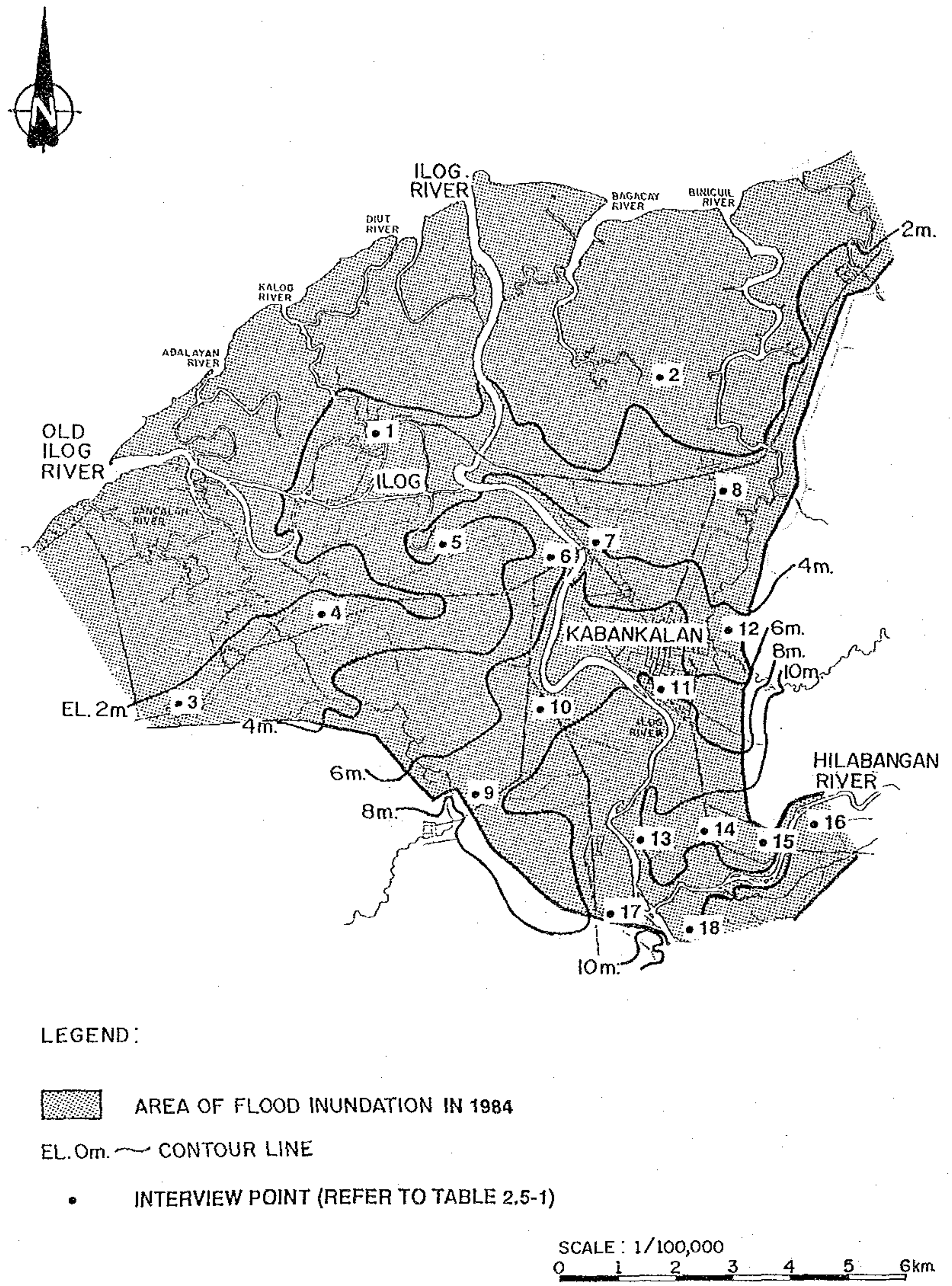
*2 : Concrete facing over the limestone zone up to the High Water Level.

*3 : Concrete gravity dam with a height of 30 m above the riverbed.

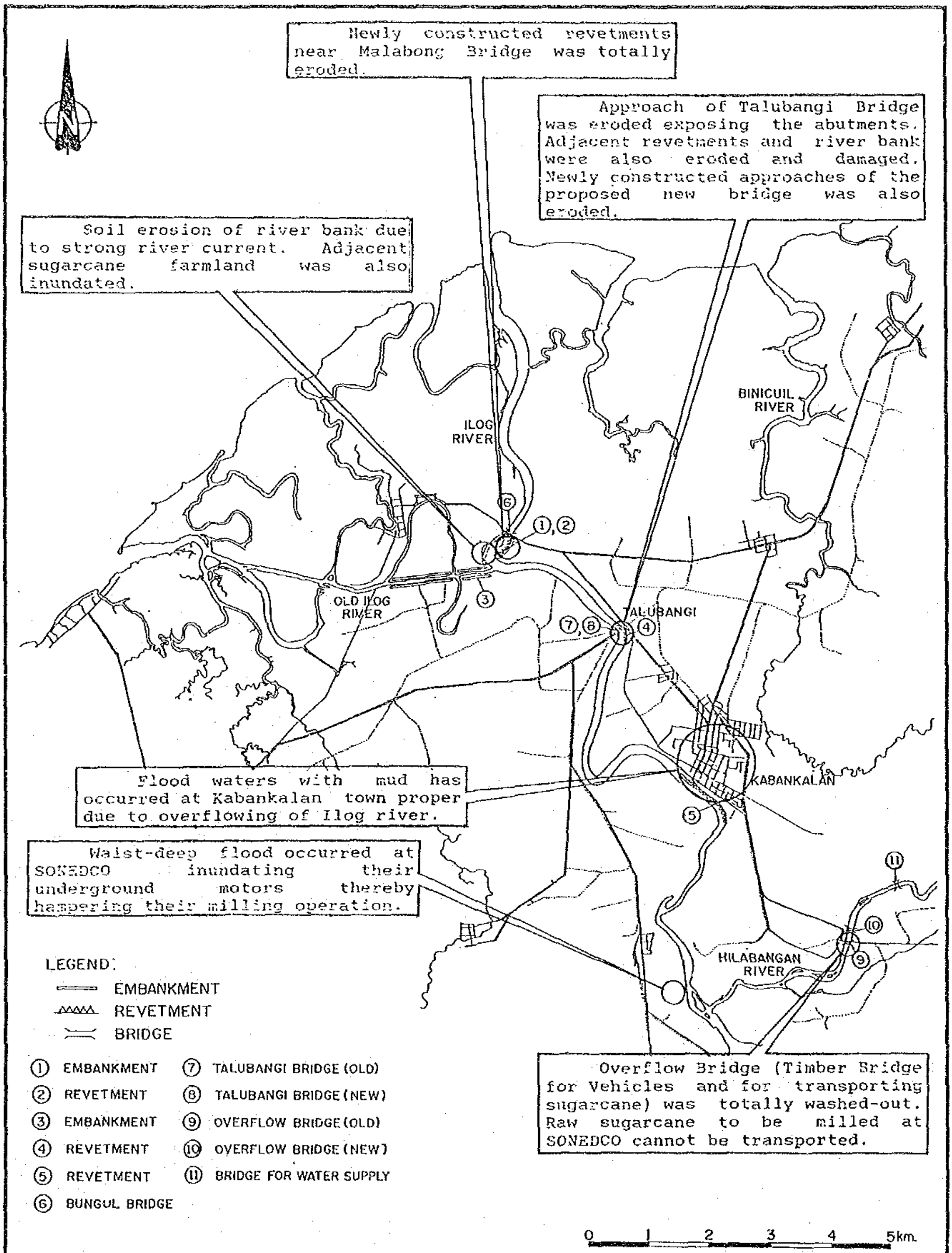
FIGURES



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-1-1 FLOOD MARK
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-1-2 FLOOD INUNDATION MAP
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.V-1-3 FLOOD DAMAGE OF TYPHOON RUPING

100-year Return Period Flood

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1																2.4	3.1	2.7	2.2								
2															1.2	1.5	2.4	2.3	2.6	2.2		2.9	2.4	1.9			
3														3.1	3.1	3.1	3.1	2.1	2.0	2.3	2.7	2.7	2.2	2.7	2.2		
4											1.3	1.3	2.8	3.1	3.1	3.0	2.2	1.6	2.3	2.5	2.4	2.2	2.2	2.6	2.4	1.9	
5										1.2	1.3	1.5	1.4	1.5	1.8	2.7	1.8	1.2	1.7	2.2	2.3	2.2	2.2	2.9	2.7		
6								2.3	1.4	1.3	1.5	1.3	1.5	1.0	1.2	1.2	1.2	0.7	1.2	2.2	2.3	2.4	2.2	2.7	2.8	1.7	
7								1.7	1.3	0.6	1.4	1.6	0.7	0.9	0.9	0.9	1.5	1.3	1.0	2.2	2.2	2.4	1.7	2.0	1.7		
8							1.5	2.4	2.8	2.3	1.6	0.9	0.4	0.9	0.4	0.7	1.2	1.6	0.4	1.2	1.3	1.7	2.4	1.9			
9					2.4	1.8	3.0	3.1	3.0	2.1	1.3	0.8	1.2	1.1	2.0	1.7	1.0	0.9	0.8	0.8	0.7	1.7	1.4	1.4			
10				1.6	2.4	0.8	1.5	2.1	1.8	1.7	0.0	0.0	0.4	0.2	0.4	0.5	1.1	2.0	0.6	0.0	0.3	0.5	1.5	1.9	1.6	0.4	
11				1.8	2.9	2.6	2.1	0.7	2.4	0.7	2.5	0.0	0.6	1.5	0.3	1.1	0.2	0.9	0.9	0.3	0.9	0.0	0.4	0.0	0.0	2.2	
12			1.7	1.9	2.7	3.0	2.6	1.0	2.1	1.7	1.7	1.8	1.8	1.8	1.8	1.8	0.9	0.8	0.3	0.3	0.1	0.5	1.1	1.7	1.9	0.2	1.8
13		1.3	2.7	2.7	2.6	1.9	2.1	2.1	2.2	2.3	1.3	1.8	1.1	0.3	0.0	0.4	0.7	0.5	0.7	0.6	0.2	0.8	0.3	0.0	0.8	1.3	1.1
14			2.0	2.5	2.1	2.0	1.4	2.2	2.3	1.7	2.4	2.5	1.6	1.7	1.7	1.5	0.6	0.9	0.8	0.1	0.3	0.4	0.2	0.8	1.0	2.0	0.7
15			1.2	1.3	1.3	2.3	0.9	2.3	2.4	2.1	2.9	2.5	2.1	2.5	2.4	1.5	0.9	0.2	0.0	0.5	0.2	0.5	0.3	0.7	1.2	0.9	
16				1.4	2.1	1.6	2.0	2.3	2.2	1.1	1.8	1.6	1.5	3.4	2.9	2.5	1.5	0.9	0.6	0.6	0.6	0.1	0.2	0.6	1.2	1.3	
17				1.2	2.2	1.1	2.1	1.2	0.7	0.3	1.2	1.8	0.8	0.9	1.3	2.4	1.6	1.3	0.7	1.1	0.9	0.0	1.2	1.4	0.9	1.0	
18				1.6	2.1	1.6	1.0	2.0	1.3	0.8	1.6	1.8	2.1	1.4	0.4	0.7	0.8	1.7	1.7	0.6	1.6	0.9	0.3	0.2	1.1	0.0	
19				1.6	2.0	0.9	0.0	0.2	1.8	1.6	1.5	1.7	2.1	1.8	1.7	1.9	1.2	1.6	2.0	1.2	2.4	2.0	0.4	0.5	1.7	0.0	
20					0.0	0.0	0.0	0.0	1.9	1.9	2.0	2.9	2.5	2.0	1.8	2.1	2.4	0.6	0.3	0.0	1.3	0.9	2.2	0.8	0.6	0.1	
21							0.0	0.0				2.6	2.5	2.1	1.9	2.0	1.8	1.5	1.3	1.1	3.6	3.5	0.0	0.7	0.2	0.2	
22													2.0	2.0	2.3	2.6	2.7	1.6	0.8	0.7	4.3	0.4	0.7	0.0	0.0	0.0	
23													0.0	1.1	1.6	2.1	2.4	2.4	1.7	1.4	3.0	4.2	0.3	0.0	0.0	0.0	
24													0.0	0.0	0.5	3.7	3.7	3.8	3.8	1.7	6.7	3.1	0.6	0.0	0.0	0.0	0.0
25																	3.7	4.3	4.0	1.9	5.3	6.8	6.9	2.8	3.7	2.0	0.0
26																		4.0	4.0	3.3	5.1	4.9	5.2	2.8	0.0	1.3	0.0
27																			2.1	3.4	2.2	4.2	4.9	2.9	1.6	1.4	0.9
28																				0.0	2.4	1.9	2.5	6.6	2.8	4.1	1.0
29																						0.3	1.9	3.4	3.8	3.6	0.3
30																								3.1	0.7	3.9	0.9

Unit : m

NOTE

☐ : Mesh unit (500 m x 500 m). Figures in meshes represent inundation depths.

THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.V-2-1 (1/6) MAXIMUM INUNDATION DEPTH BY RETURN PERIOD

50-year Return Period Flood

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1																2.1	2.8	2.4	1.9								
2															0.9	1.2	2.1	2.0	2.3	1.9		2.6	2.1	1.6			
3														2.8	2.8	2.8	2.8	1.8	1.7	2.0	2.4	2.4	1.9	2.4	1.9		
4											1.1	1.0	2.5	2.8	2.8	2.7	1.9	1.3	2.0	2.2	2.1	1.9	1.9	2.3	2.1	1.6	
5										1.0	1.1	1.2	1.1	1.2	1.5	2.4	1.5	0.9	1.4	1.9	2.0	1.9	1.9	2.6	2.4		
6								2.1	1.1	1.1	1.3	1.1	1.2	0.7	0.9	0.9	0.9	0.4	0.9	1.9	2.0	2.1	1.9	2.4	2.5	1.4	
7								1.5	1.1	0.4	1.2	1.4	0.5	0.7	0.7	0.7	1.3	1.1	0.7	1.9	1.9	2.1	1.4	1.7	1.4		
8							1.3	2.2	2.6	2.1	1.4	0.7	0.4	0.9	0.3	0.8	1.2	1.5	0.3	0.9	1.0	1.4	2.1	1.6			
9					2.1	1.5	2.7	2.8	2.7	1.9	1.1	0.6	1.1	1.1	2.0	1.7	0.9	0.8	0.7	0.5	0.4	1.4	1.1	1.1			
10				1.4	2.2	0.6	1.2	1.8	1.5	1.4	0.0	0.0	0.3	0.2	0.4	0.2	0.9	1.8	0.5	0.0	0.0	0.2	1.2	1.6	1.3	0.2	
11				1.6	2.7	2.4	1.9	0.5	2.2	0.5	2.3	0.0	0.5	1.4	0.2	0.9	0.1	0.7	0.7	0.2	0.8	0.0	0.2	0.0	0.0	2.0	
12			1.5	1.7	2.5	2.8	2.4	0.8	1.9	1.5	1.5	1.6	1.6	1.6	1.6	1.6	0.7	0.6	0.2	0.4	0.1	0.5	0.9	1.5	1.7	0.0	1.6
13		1.1	2.5	2.5	2.4	1.7	1.9	1.9	2.0	2.1	1.1	1.6	0.9	0.2	0.0	0.2	0.4	0.2	0.4	0.6	0.2	0.8	0.3	0.0	0.4	1.1	0.9
14			1.8	2.3	1.9	1.8	1.1	2.0	2.1	1.5	2.1	2.3	1.4	1.5	1.5	1.3	0.4	0.5	0.4	0.1	0.3	0.4	0.2	0.6	0.7	1.8	0.5
15			1.0	1.1	1.1	2.0	0.7	2.1	2.2	2.0	2.7	2.3	1.9	2.2	2.1	1.2	0.8	0.1	0.0	0.5	0.1	0.4	0.3	0.5	1.0	0.7	
16				1.2	1.9	1.3	1.8	2.1	2.0	1.0	1.6	1.4	1.2	3.1	2.6	2.3	1.4	0.8	0.5	0.6	0.6	0.1	0.1	0.5	0.9	1.0	
17				1.0	1.9	0.8	1.9	0.9	0.5	0.0	0.9	1.6	0.6	0.8	1.1	2.1	1.4	1.2	0.5	1.1	0.8	0.0	1.1	1.3	0.7	0.7	
18				1.4	1.8	1.3	0.8	1.9	1.2	0.7	1.5	1.7	1.9	1.2	0.2	0.6	0.6	1.6	1.6	0.6	1.5	0.8	0.2	0.0	0.6	0.0	
19				1.4	1.7	0.6	0.0	0.1	1.6	1.4	1.3	1.5	1.9	1.6	1.4	1.7	1.0	1.4	1.8	1.1	2.3	2.0	0.4	0.3	1.1	0.0	
20					0.0	0.0	0.0	0.0	1.8	1.8	1.8	2.7	2.3	1.7	1.5	1.9	2.1	0.3	0.3	0.0	1.2	0.8	2.1	0.4	0.3	0.1	
21							0.0	0.0				2.3	2.2	1.8	1.6	1.8	1.5	1.2	0.9	1.0	3.4	3.4	0.0	0.5	0.1	0.1	
22													1.7	1.7	2.0	2.3	2.4	1.3	0.5	0.4	4.1	0.1	0.1	0.0	0.0	0.0	
23													0.0	0.7	1.4	1.6	2.1	2.2	1.4	1.0	2.7	3.9	0.0	0.0	0.0	0.0	
24													0.0	0.0	0.3	3.5	3.4	3.5	3.6	1.3	6.3	2.7	0.1	0.0	0.0	0.0	0.0
25																	3.4	4.0	3.7	1.5	4.9	6.4	6.4	2.3	3.2	1.4	0.0
26																		3.7	3.6	2.9	4.6	4.4	4.7	2.3	0.0	1.1	0.0
27																			1.7	3.1	1.7	3.6	4.4	2.5	1.3	1.1	0.5
28																				0.0	1.9	1.4	2.2	6.2	2.4	3.8	0.7
29																						0.1	1.6	3.0	3.3	3.2	0.0
30																								2.7	0.6	3.6	0.5

Unit : m

NOTE

☐ : Mesh unit (500 m x 500 m). Figures in meshes represent inundation depths.

THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.V-2-1 (2/6) MAXIMUM INUNDATION DEPTH BY RETURN PERIOD

25-year Return Period Flood

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1																1.7	2.4	2.0	1.5								
2															0.5	0.8	1.7	1.6	1.9	1.5		2.2	1.7	1.2			
3														2.4	2.4	2.4	2.4	1.4	1.3	1.6	2.0	2.0	1.5	2.0	1.5		
4											0.7	0.7	2.1	2.4	2.4	2.3	1.5	0.9	1.6	1.8	1.7	1.5	1.5	1.9	1.7	1.2	
5										0.7	0.7	0.9	0.7	0.8	1.1	2.0	1.1	0.5	1.0	1.5	1.6	1.5	1.5	2.2	2.0		
6								1.8	0.8	0.8	1.0	0.7	0.9	0.3	0.5	0.5	0.7	0.3	0.5	1.5	1.6	1.7	1.5	2.0	2.1	1.0	
7								1.2	0.8	0.1	0.9	1.1	0.3	0.7	0.7	0.7	1.3	1.1	0.5	1.5	1.5	1.7	1.0	1.3	1.0		
8							1.0	1.9	2.3	1.8	1.1	0.4	0.3	0.8	0.3	0.7	1.2	1.5	0.3	0.5	0.6	1.0	1.7	1.2			
9					1.8	1.2	2.4	2.5	2.4	1.6	0.8	0.6	1.1	1.0	1.9	1.7	0.9	0.8	0.7	0.5	0.2	1.0	0.7	0.7			
10				1.0	1.8	0.2	0.9	1.5	1.2	1.1	0.0	0.0	0.3	0.1	0.4	0.0	0.9	1.9	0.5	0.0	0.0	0.0	0.8	1.2	0.9	0.1	
11				1.3	2.4	2.1	1.6	0.2	2.0	0.3	2.1	0.0	0.2	1.1	0.0	0.7	0.0	0.6	0.6	0.2	0.7	0.0	0.2	0.0	0.0	1.8	
12			1.2	1.4	2.2	2.5	2.1	0.6	1.7	1.3	1.3	1.4	1.4	1.3	1.3	1.3	0.4	0.4	0.2	0.3	0.0	0.4	0.9	1.5	1.6	0.0	1.3
13		0.8	2.2	2.2	2.1	1.4	1.6	1.7	1.8	1.9	0.8	1.3	0.6	0.0	0.0	0.0	0.1	0.0	0.2	0.5	0.1	0.7	0.3	0.0	0.2	0.9	0.6
14			1.5	2.0	1.6	1.5	0.8	1.8	1.9	1.3	1.9	2.1	1.1	1.3	1.2	1.0	0.1	0.3	0.2	0.1	0.3	0.3	0.2	0.4	0.4	1.5	0.2
15			0.7	0.8	0.8	1.7	0.5	1.8	1.9	1.7	2.5	2.0	1.6	1.9	1.8	0.9	0.5	0.0	0.0	0.5	0.1	0.4	0.2	0.3	0.8	0.5	
16				0.9	1.6	1.0	1.6	1.8	1.6	0.8	1.2	1.0	0.9	2.8	2.3	1.9	1.1	0.7	0.5	0.6	0.6	0.1	0.1	0.4	0.8	0.7	
17				0.7	1.6	0.5	1.7	0.8	0.5	0.0	0.5	1.4	0.4	0.6	0.8	1.8	1.1	1.1	0.4	1.1	0.8	0.0	1.0	1.1	0.5	0.3	
18				1.1	1.5	1.0	0.6	1.9	1.2	0.6	1.3	1.5	1.7	1.0	0.1	0.4	0.3	1.5	1.5	0.5	1.5	0.8	0.1	0.0	0.0	0.0	
19				1.1	1.4	0.3	0.0	0.1	1.5	1.2	1.1	1.3	1.6	1.3	1.1	1.5	0.8	1.2	1.7	1.0	2.2	1.8	0.3	0.0	0.0	0.0	
20					0.0	0.0	0.0	0.0	1.6	1.6	1.6	2.4	2.0	1.4	1.1	1.6	1.8	0.0	0.2	0.0	1.1	0.7	1.9	0.0	0.0	0.0	
21							0.0	0.0				2.0	1.9	1.5	1.3	1.5	1.2	0.9	0.3	0.9	3.3	3.2	0.0	0.0	0.0	0.0	
22													1.4	1.5	1.7	2.0	2.0	1.0	0.2	0.3	3.9	0.0	0.1	0.0	0.0	0.0	
23													0.0	0.3	1.3	1.6	1.8	1.9	1.1	0.6	2.4	3.6	0.0	0.0	0.0	0.0	
24													0.0	0.0	0.1	3.3	3.1	3.2	3.2	0.9	5.8	2.3	0.0	0.0	0.0	0.0	0.0
25																	3.1	3.7	3.3	1.1	4.5	6.0	6.1	1.9	2.8	1.1	0.0
26																		3.4	3.3	2.5	4.1	4.0	4.4	1.9	0.0	0.9	0.0
27																			1.4	2.7	1.3	3.3	4.1	2.1	0.8	0.8	0.2
28																				0.0	1.6	1.0	1.8	5.8	1.9	3.4	0.3
29																						0.0	1.3	2.5	2.8	2.8	0.0
30																								2.3	0.6	3.2	0.2

Unit : m

NOTE

☐ : Mesh unit (500 m x 500 m). Figures in meshes represent inundation depths.

THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.V-2-1 (3/6) MAXIMUM INUNDATION DEPTH BY FLOOD RETURN PERIOD

10-year Return Period Flood

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1																1.2	1.8	1.4	0.9								
2															0.0	0.3	1.1	1.0	1.3	0.9		1.6	1.1	0.6			
3														1.9	1.9	1.9	1.8	0.8	0.7	1.0	1.4	1.4	0.9	1.4	0.9		
4											0.2	0.1	1.6	1.9	1.9	1.8	1.0	0.3	1.0	1.2	1.1	0.9	0.9	1.3	1.1	0.6	
5										0.1	0.2	0.4	0.2	0.3	0.6	1.5	0.6	0.1	0.4	0.9	1.0	0.9	0.9	1.6	1.4		
6								1.2	0.2	0.3	0.5	0.3	0.6	0.3	0.5	0.4	0.7	0.3	0.3	0.9	1.0	1.1	0.9	1.4	1.5	0.4	
7								0.6	0.2	0.0	0.4	0.7	0.3	0.6	0.6	0.7	1.3	1.1	0.5	0.9	0.9	1.1	0.4	0.7	0.4		
8							0.4	1.3	1.7	1.2	0.5	0.3	0.3	0.8	0.3	0.7	1.2	1.5	0.3	0.2	0.0	0.4	1.1	0.6			
9					1.2	0.6	1.8	1.9	1.8	1.0	0.3	0.5	1.0	1.0	1.9	1.7	0.9	0.8	0.7	0.5	0.2	0.4	0.1	0.0			
10				0.4	1.2	0.0	0.3	0.9	0.6	0.5	0.0	0.0	0.2	0.1	0.4	0.0	0.9	1.9	0.5	0.0	0.0	0.0	0.1	0.5	0.2	0.0	
11				0.6	1.7	1.5	1.0	0.0	1.6	0.0	1.7	0.0	0.0	0.8	0.0	0.4	0.0	0.4	0.4	0.1	0.7	0.0	0.1	0.0	0.0	1.4	
12			0.5	0.8	1.6	1.9	1.5	0.2	1.3	0.8	0.8	1.0	1.0	1.0	1.0	1.0	0.1	0.2	0.1	0.2	0.0	0.3	0.8	1.4	1.2	0.0	0.9
13		0.2	1.6	1.6	1.5	0.8	1.0	1.3	1.4	1.4	0.3	0.9	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.6	0.2	0.0	0.1	0.8	0.4
14			0.9	1.4	1.0	0.9	0.4	1.3	1.4	0.8	1.3	1.6	0.6	0.8	0.7	0.5	0.0	0.2	0.1	0.1	0.3	0.3	0.1	0.3	0.3	1.3	0.0
15			0.1	0.2	0.2	1.1	0.1	1.4	1.4	1.2	1.9	1.5	1.1	1.3	1.2	0.4	0.2	0.0	0.0	0.4	0.1	0.4	0.2	0.1	0.6	0.4	
16				0.3	1.0	0.6	1.3	1.4	1.1	0.3	0.6	0.4	0.3	2.1	1.7	1.4	0.8	0.6	0.4	0.5	0.5	0.0	0.0	0.2	0.6	0.5	
17				0.1	1.0	0.2	1.4	0.7	0.4	0.0	0.3	1.1	0.1	0.1	0.2	1.3	0.7	0.9	0.2	0.9	0.7	0.0	0.7	0.9	0.4	0.3	
18				0.5	0.9	0.6	0.4	1.9	1.1	0.5	0.9	1.0	1.2	0.5	0.0	0.0	0.0	1.2	1.5	0.3	1.3	0.7	0.0	0.0	0.0	0.0	
19				0.5	0.8	0.0	0.0	0.0	1.2	0.9	0.7	0.8	1.0	0.6	0.7	1.1	0.4	0.8	1.5	0.8	1.9	1.6	0.0	0.0	0.0	0.0	
20					0.0	0.0	0.0	0.0	1.2	1.2	1.2	1.9	1.4	0.6	0.4	1.2	1.4	0.0	0.1	0.0	1.0	0.5	1.6	0.0	0.0	0.0	
21							0.0	0.0				1.5	1.3	1.1	0.8	1.1	0.7	0.4	0.0	0.6	3.0	3.0	0.0	0.0	0.0	0.0	
22													0.8	1.0	1.2	1.5	1.5	0.4	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	
23													0.0	0.0	0.7	1.1	1.3	1.3	0.4	0.3	2.0	3.2	0.0	0.0	0.0	0.0	
24													0.0	0.0	0.0	2.8	2.5	2.5	2.5	0.5	5.4	1.9	0.0	0.0	0.0	0.0	0.0
25																	2.4	3.0	2.6	0.3	4.1	5.5	5.6	1.4	2.3	0.5	0.0
26																		2.7	2.6	1.8	3.7	3.6	3.8	1.4	0.0	0.4	0.0
27																			0.7	2.0	0.4	2.9	3.5	1.5	0.0	0.4	0.0
28																				0.0	0.8	0.5	1.3	5.2	1.2	2.9	0.0
29																						0.0	0.7	1.9	2.2	2.2	0.0
30																								1.7	0.6	2.7	0.0

Unit : m

NOTE

□ : Mesh unit (500 m x 500 m). Figures in meshes represent inundation depths.

THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-2-1 MAXIMUM INUNDATION DEPTH BY (4/6) RETURN PERIOD
JAPAN INTERNATIONAL COOPERATION AGENCY	

5-year Return Period Flood

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1																0.9	1.6	1.1	0.6								
2															0.0	0.0	0.9	0.7	1.0	0.6		1.3	0.8	0.3			
3														1.6	1.6	1.6	1.6	0.6	0.4	0.7	1.1	1.1	0.6	1.1	0.6		
4											0.0	0.0	1.3	1.6	1.6	1.5	0.7	0.0	0.7	0.9	0.8	0.6	0.6	1.0	0.8	0.3	
5										0.0	0.2	0.4	0.2	0.1	0.4	1.3	0.5	0.1	0.2	0.6	0.7	0.6	0.6	1.3	1.1		
6								0.6	0.0	0.3	0.5	0.3	0.6	0.3	0.5	0.4	0.7	0.3	0.3	0.8	0.8	0.8	0.6	1.1	1.2	0.1	
7								0.0	0.0	0.0	0.4	0.7	0.3	0.6	0.6	0.7	1.3	1.1	0.5	0.9	0.7	0.8	0.1	0.4	0.1		
8							0.0	0.8	1.2	0.8	0.4	0.3	0.3	0.8	0.3	0.7	1.2	1.5	0.3	0.2	0.0	0.1	0.8	0.3			
9					0.6	0.1	1.3	1.4	1.3	0.6	0.3	0.5	1.0	0.9	1.9	1.7	0.9	0.8	0.7	0.5	0.2	0.4	0.1	0.0			
10				0.0	0.6	0.0	0.0	0.4	0.2	0.1	0.0	0.0	0.2	0.0	0.4	0.0	0.9	1.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
11				0.0	1.1	0.8	0.3	0.0	1.0	0.0	1.4	0.0	0.0	0.6	0.0	0.1	0.0	0.2	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.4	
12			0.0	0.0	0.9	1.2	0.8	0.0	0.6	0.1	0.5	0.6	0.6	0.7	0.7	0.7	0.0	0.0	0.1	0.1	0.0	0.3	0.7	1.3	0.0	0.0	0.3
13		0.0	0.8	0.8	0.7	0.1	0.5	0.7	0.7	0.6	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.5	0.1	0.0	0.0	0.4	0.2
14			0.1	0.6	0.2	0.3	0.0	0.7	0.8	0.3	1.0	1.2	0.4	0.5	0.4	0.3	0.0	0.1	0.0	0.0	0.2	0.2	0.1	0.2	0.2	0.9	0.0
15			0.0	0.0	0.0	0.5	0.0	0.8	0.8	0.8	1.5	1.0	0.8	1.1	1.0	0.2	0.2	0.0	0.0	0.4	0.0	0.3	0.1	0.1	0.5	0.3	
16				0.0	0.3	0.2	0.7	0.8	0.5	0.0	0.0	0.0	0.0	1.9	1.5	1.2	0.7	0.5	0.4	0.4	0.4	0.0	0.0	0.1	0.4	0.3	
17				0.0	0.2	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.7	0.8	0.2	0.8	0.6	0.0	0.5	0.7	0.3	0.2	
18				0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.4	0.2	1.2	0.6	0.0	0.0	0.0	0.0	
19				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.5	0.7	1.7	1.4	0.0	0.0	0.0	0.0	
20					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.8	0.4	1.5	0.0	0.0	0.0	
21							0.0	0.0				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.8	2.8	0.0	0.0	0.0	0.0	
22													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	
23													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	2.9	0.0	0.0	0.0	0.0	
24													0.0	0.0	0.0	1.2	0.9	0.8	0.7	0.2	5.1	1.5	0.0	0.0	0.0	0.0	0.0
25																	0.7	1.2	0.8	0.0	3.7	5.1	5.1	0.9	1.8	0.0	0.0
26																		0.9	0.9	0.9	3.3	3.1	3.3	0.8	0.0	0.0	0.0
27																			0.0	1.1	0.0	2.2	2.8	1.0	0.0	0.0	0.0
28																				0.0	0.0	0.1	0.7	4.4	0.5	2.4	0.0
29																						0.0	0.1	1.1	1.6	1.7	0.0
30																								1.1	0.6	2.1	0.0

Unit : m

NOTE

☐ : Mesh unit (500 m x 500 m). Figures in meshes represent inundation depths.

2-year Return Period Flood

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1																0.4	1.1	0.7	0.1								
2															0.0	0.0	0.4	0.3	0.5	0.0		0.7	0.1	0.0			
3														1.1	1.1	1.1	1.1	0.1	0.0	0.2	0.5	0.5	0.0	0.5	0.0		
4											0.0	0.0	0.8	1.1	1.1	1.0	0.2	0.0	0.3	0.5	0.4	0.2	0.1	0.4	0.2	0.0	
5										0.0	0.2	0.4	0.2	0.1	0.2	1.1	0.4	0.0	0.1	0.4	0.4	0.3	0.2	0.7	0.5		
6								0.0	0.0	0.2	0.4	0.3	0.5	0.3	0.5	0.4	0.7	0.3	0.3	0.6	0.5	0.6	0.3	0.5	0.6	0.0	
7								0.0	0.0	0.0	0.3	0.6	0.2	0.6	0.6	0.6	1.2	1.0	0.4	0.7	0.5	0.7	0.0	0.0	0.0		
8							0.0	0.7	1.1	0.6	0.4	0.3	0.2	0.7	0.3	0.6	1.0	1.4	0.2	0.0	0.0	0.0	0.3	0.0			
9					0.0	0.0	1.2	1.3	1.2	0.4	0.3	0.4	0.9	0.9	1.9	1.6	0.8	0.6	0.6	0.4	0.2	0.3	0.0	0.0			
10				0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.7	1.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
11				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
12			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
16				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
17				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
18				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
19				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
20					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
21							0.0	0.0				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
22													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
23													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
24													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25																	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26																		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27																			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28																				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29																						0.0	0.0	0.0	0.0	0.0	0.0
30																								0.0	0.0	0.0	0.0

Unit : m

NOTE

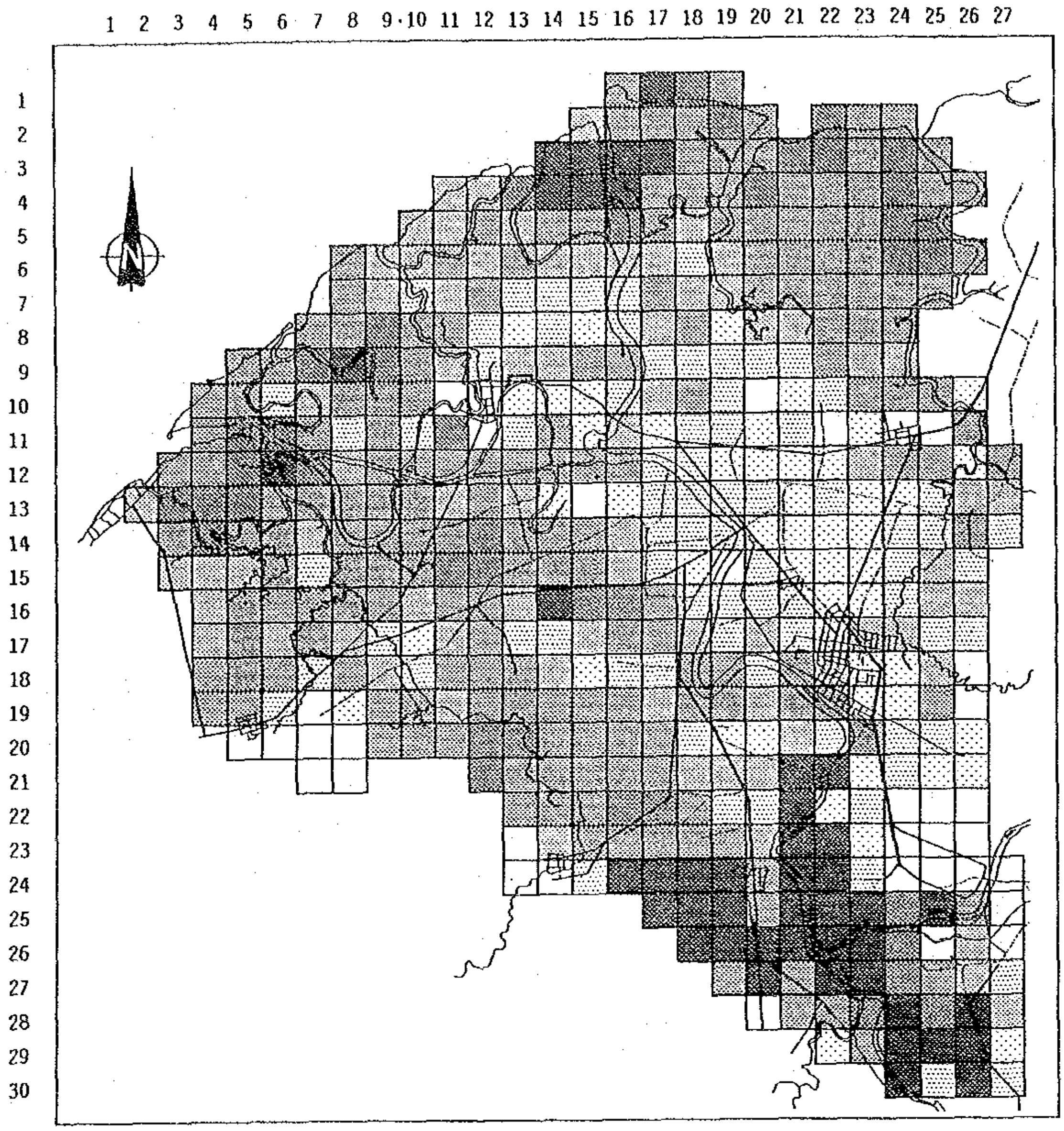
☐ : Mesh unit (500 m x 500 m). Figures in meshes represent inundation depths.

THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.V-2-1 (6/6) MAXIMUM INUNDATION DEPTH BY RETURN PERIOD

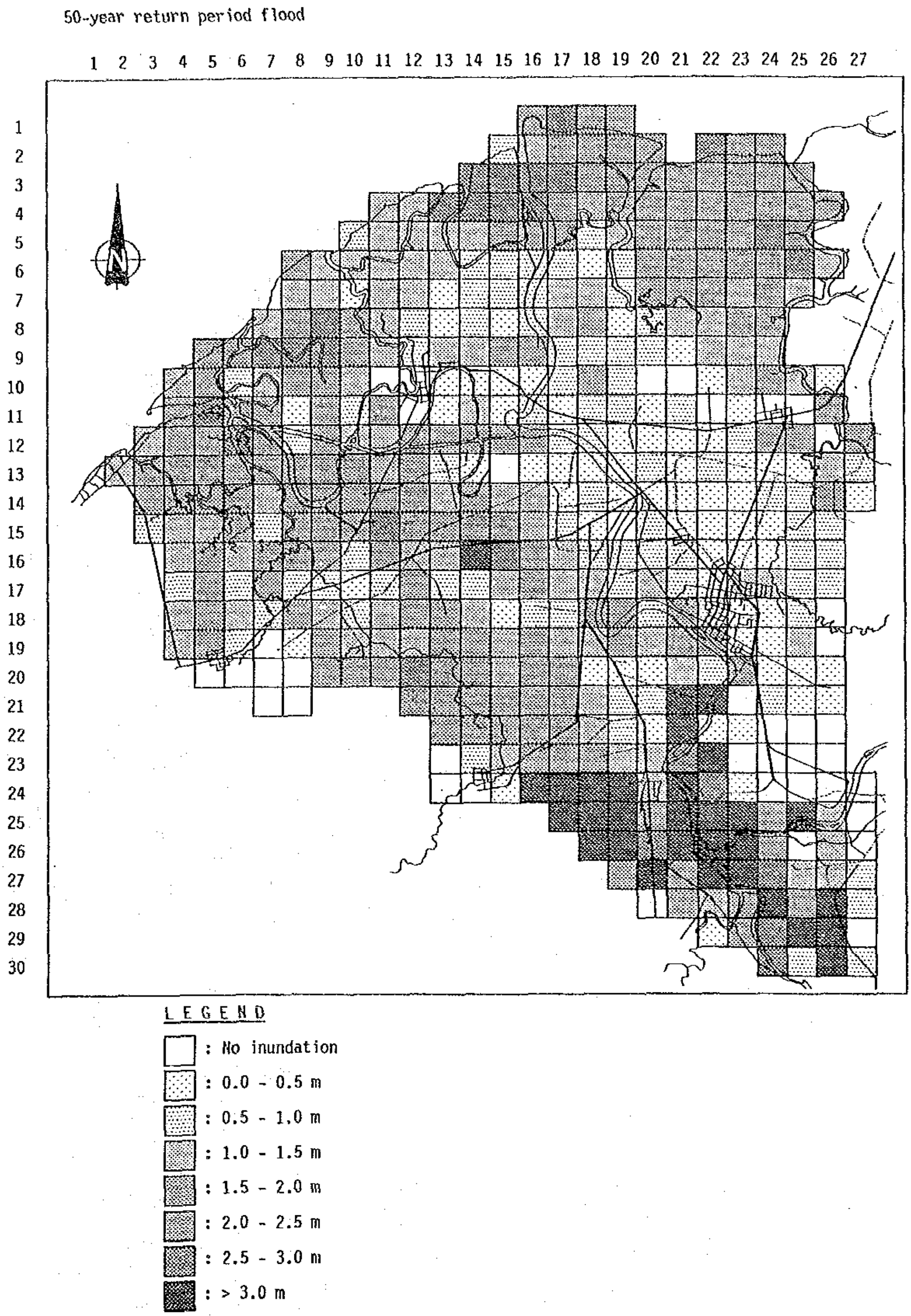
100-year return period flood



LEGEND

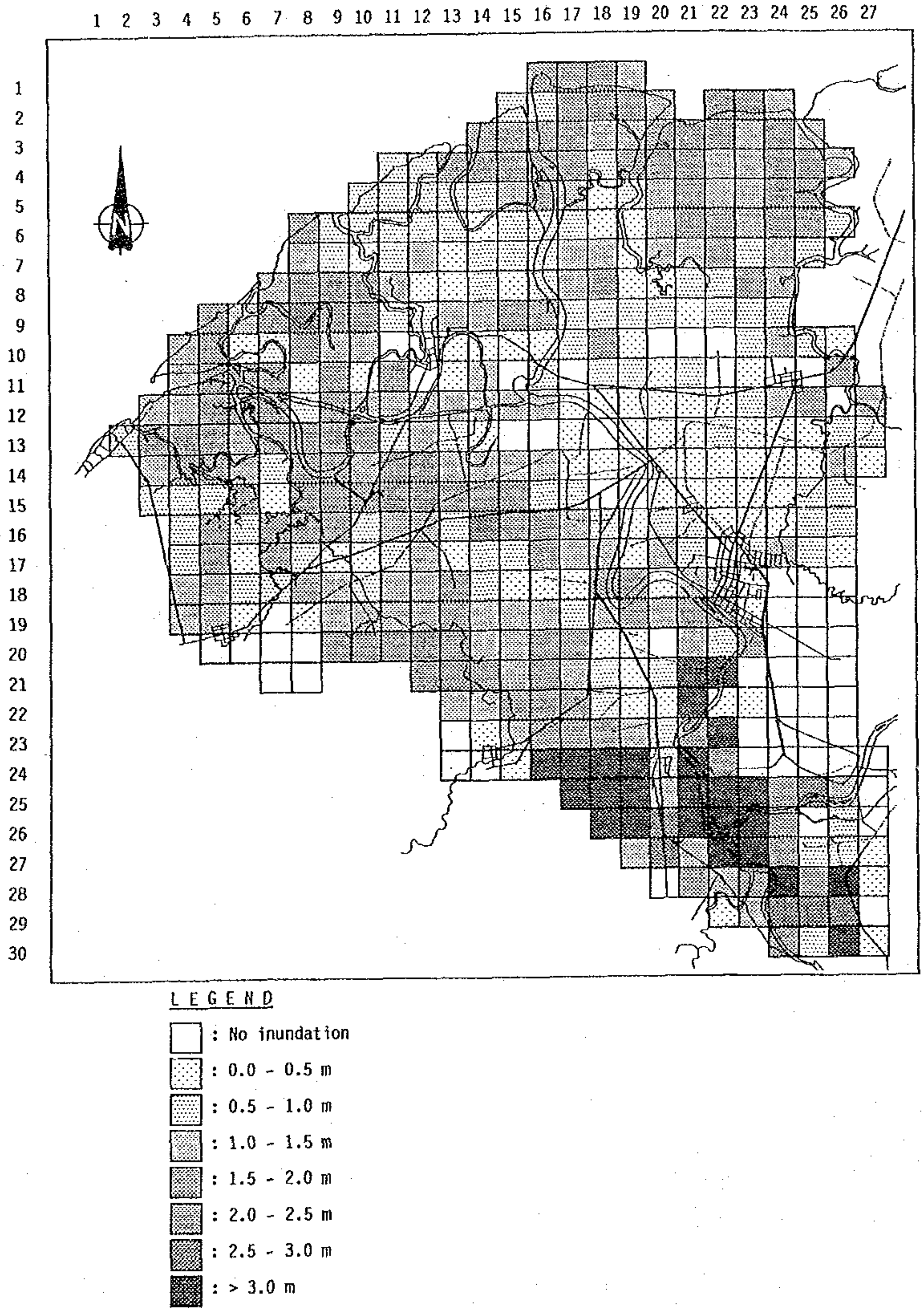
- : No inundation
- : 0.0 - 0.5 m
- : 0.5 - 1.0 m
- : 1.0 - 1.5 m
- : 1.5 - 2.0 m
- : 2.0 - 2.5 m
- : 2.5 - 3.0 m
- : > 3.0 m

THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-2-2 (1/6) MAXIMUM INUNDATION PATTERNS BY FLOOD RETURN PERIOD
JAPAN INTERNATIONAL COOPERATION AGENCY	

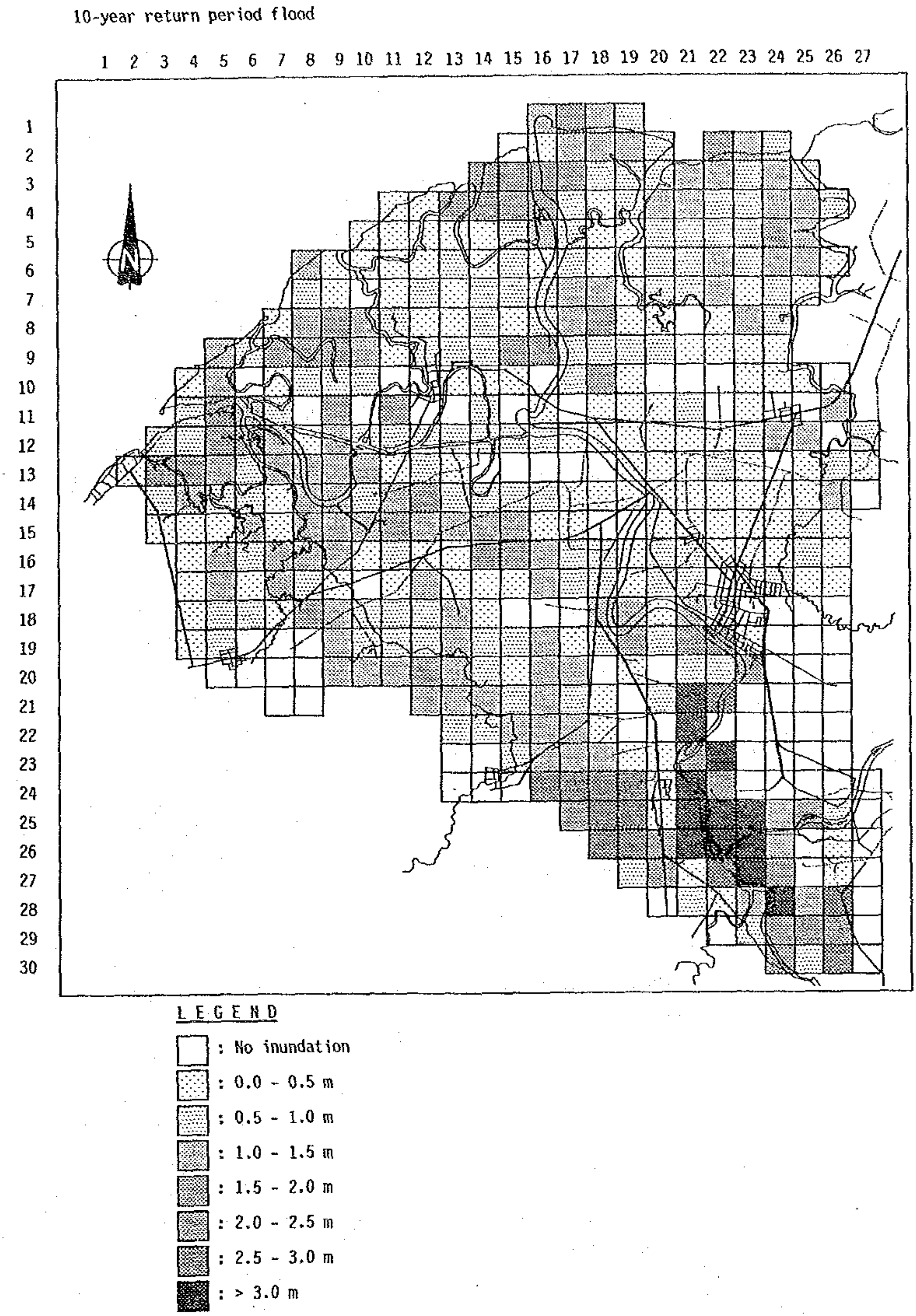


THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-2-2 MAXIMUM INUNDATION PATTERNS (2/6) BY FLOOD RETURN PERIOD
JAPAN INTERNATIONAL COOPERATION AGENCY	

25-year return period flood



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-2-2 (3/6) MAXIMUM INUNDATION PATTERNS BY FLOOD RETURN PERIOD
JAPAN INTERNATIONAL COOPERATION AGENCY	

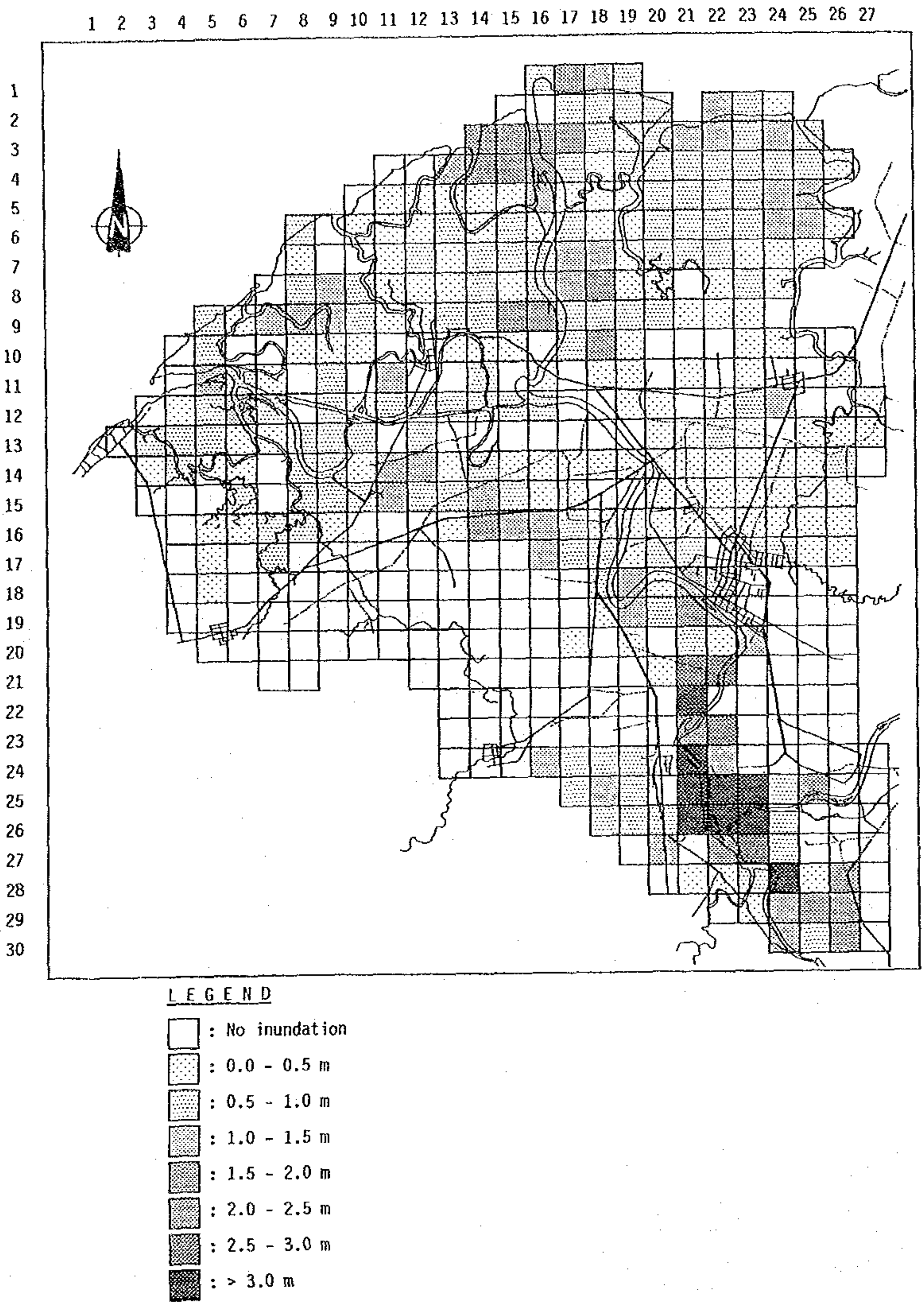


THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

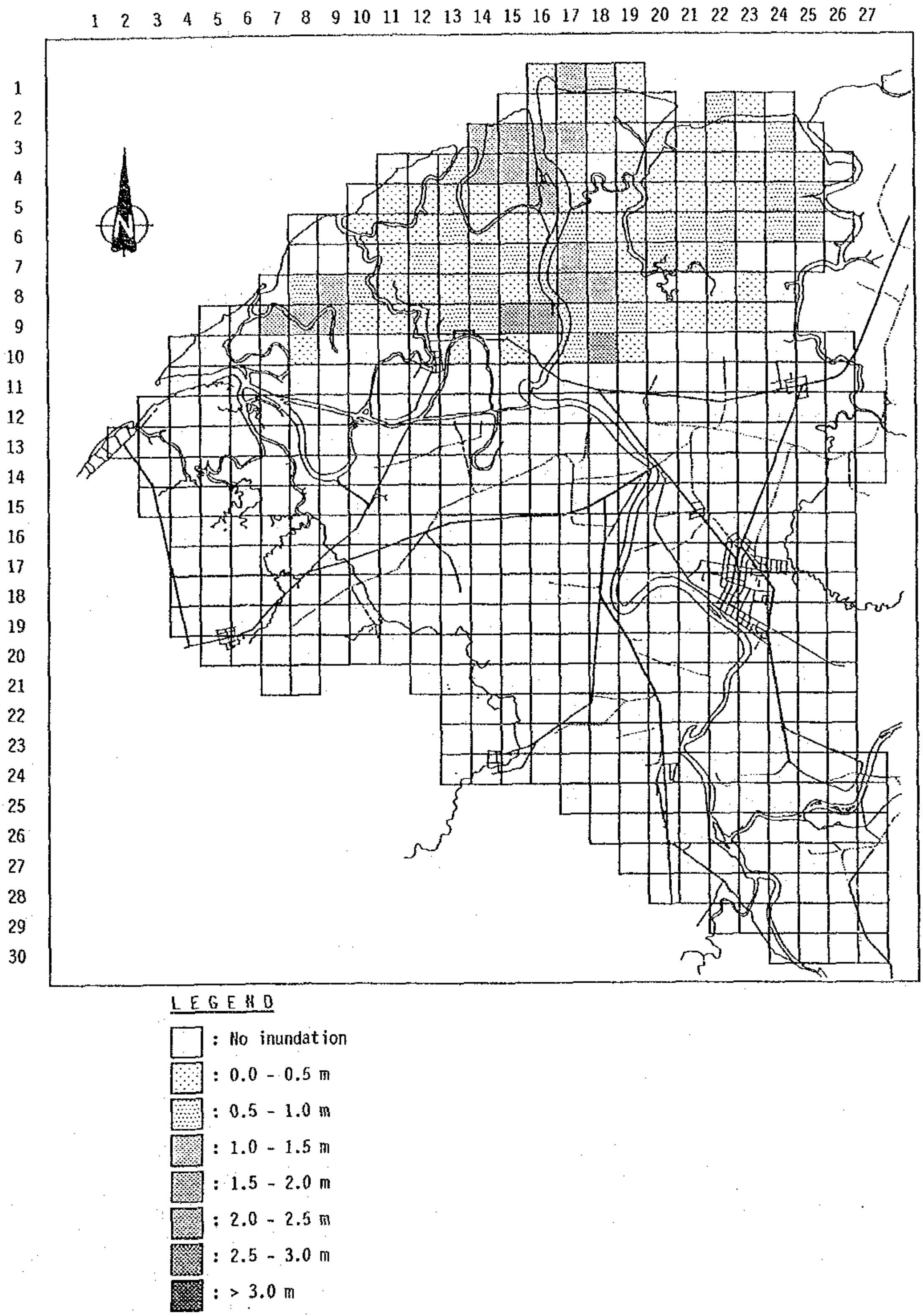
Fig.V-2-2 (4/6) MAXIMUM INUNDATION PATTERNS BY FLOOD RETURN PERIOD

5-year return period flood

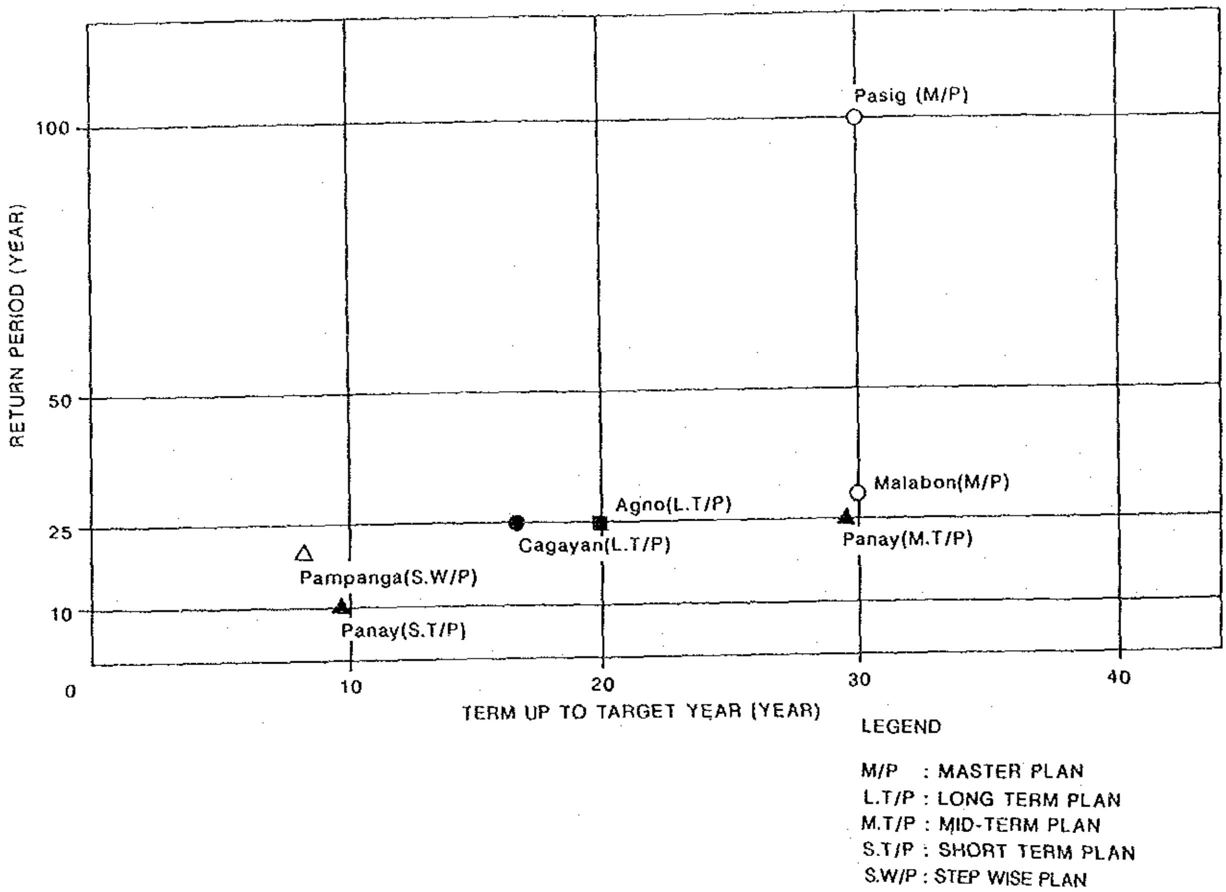


THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-2-2 (5/6) MAXIMUM INUNDATION PATTERNS BY FLOOD RETURN PERIOD
JAPAN INTERNATIONAL COOPERATION AGENCY	

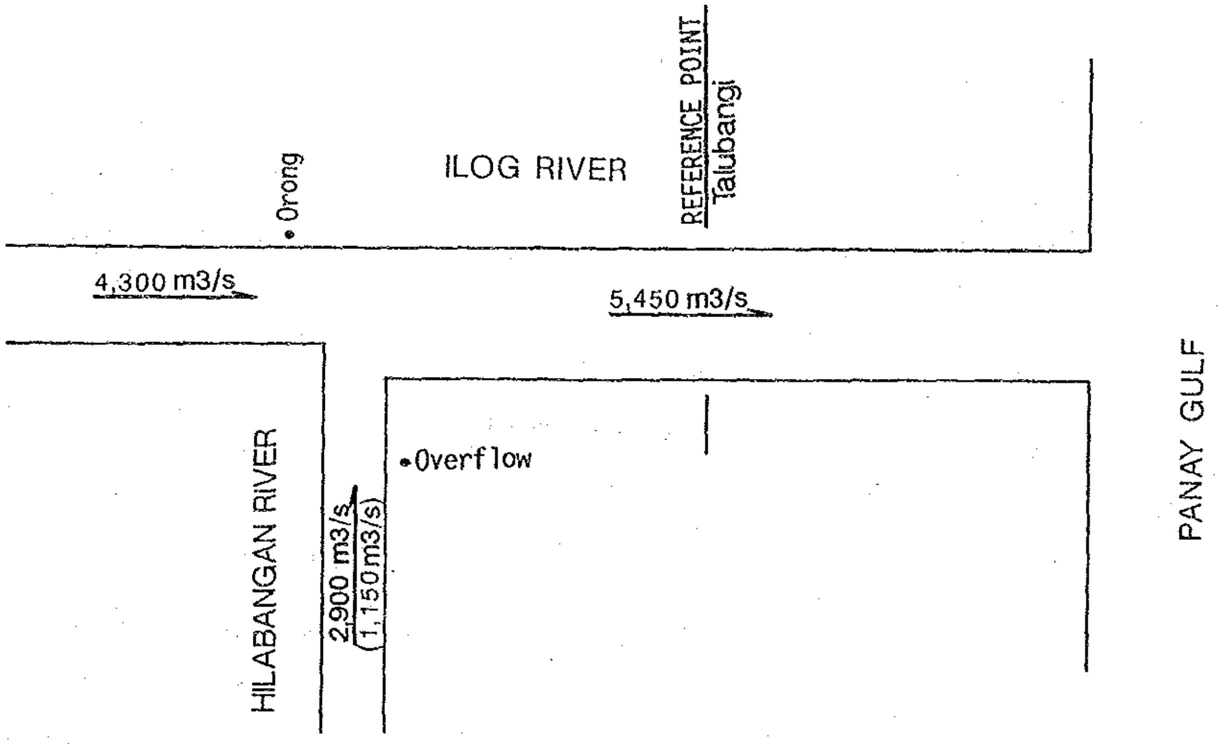
2-year return period flood



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.V-2-2 (6/6) MAXIMUM INUNDATION PATTERNS BY FLOOD RETURN PERIOD

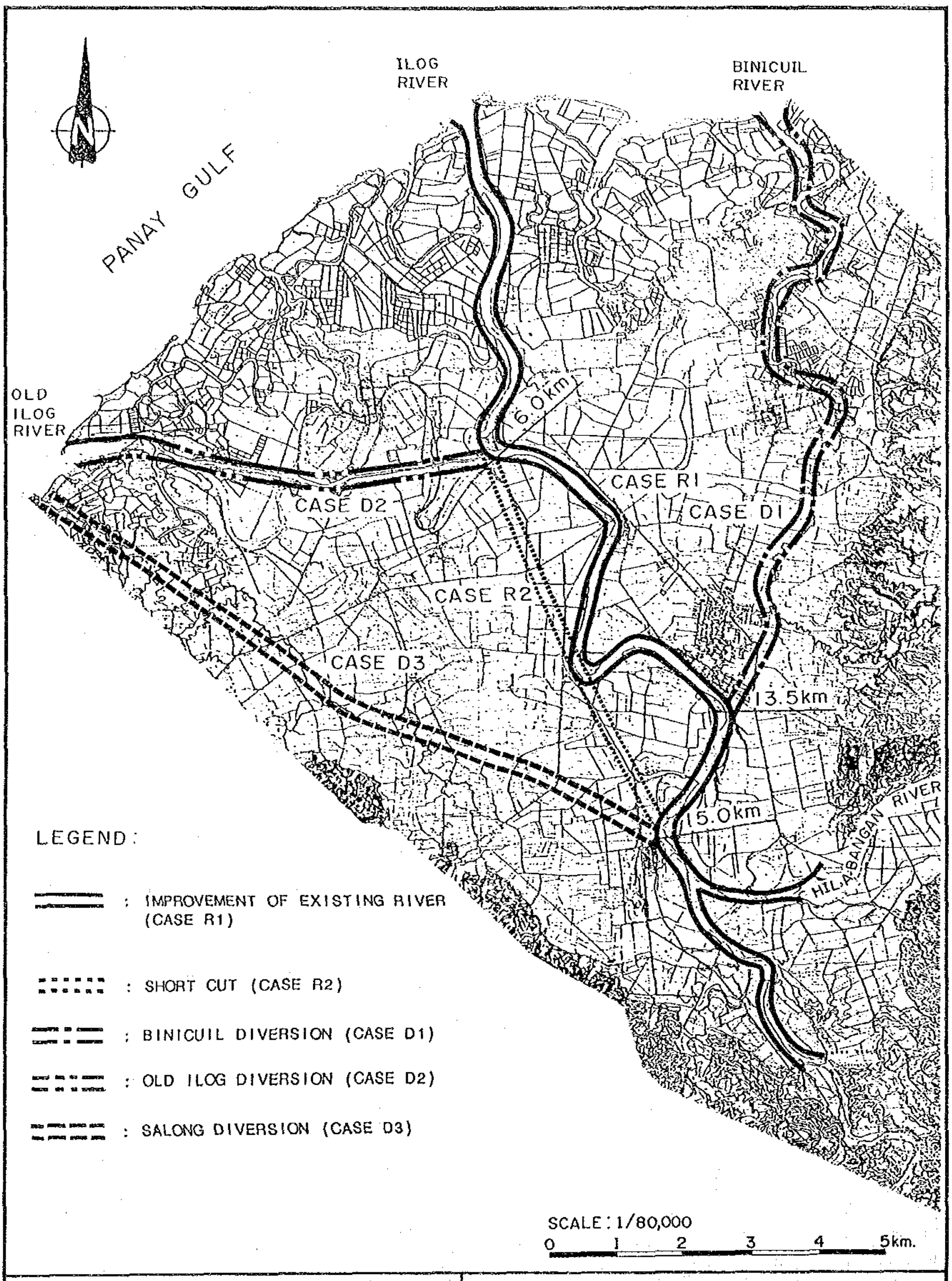


THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-3-1 TARGET YEAR AND PROJECT SCALE
JAPAN INTERNATIONAL COOPERATION AGENCY	

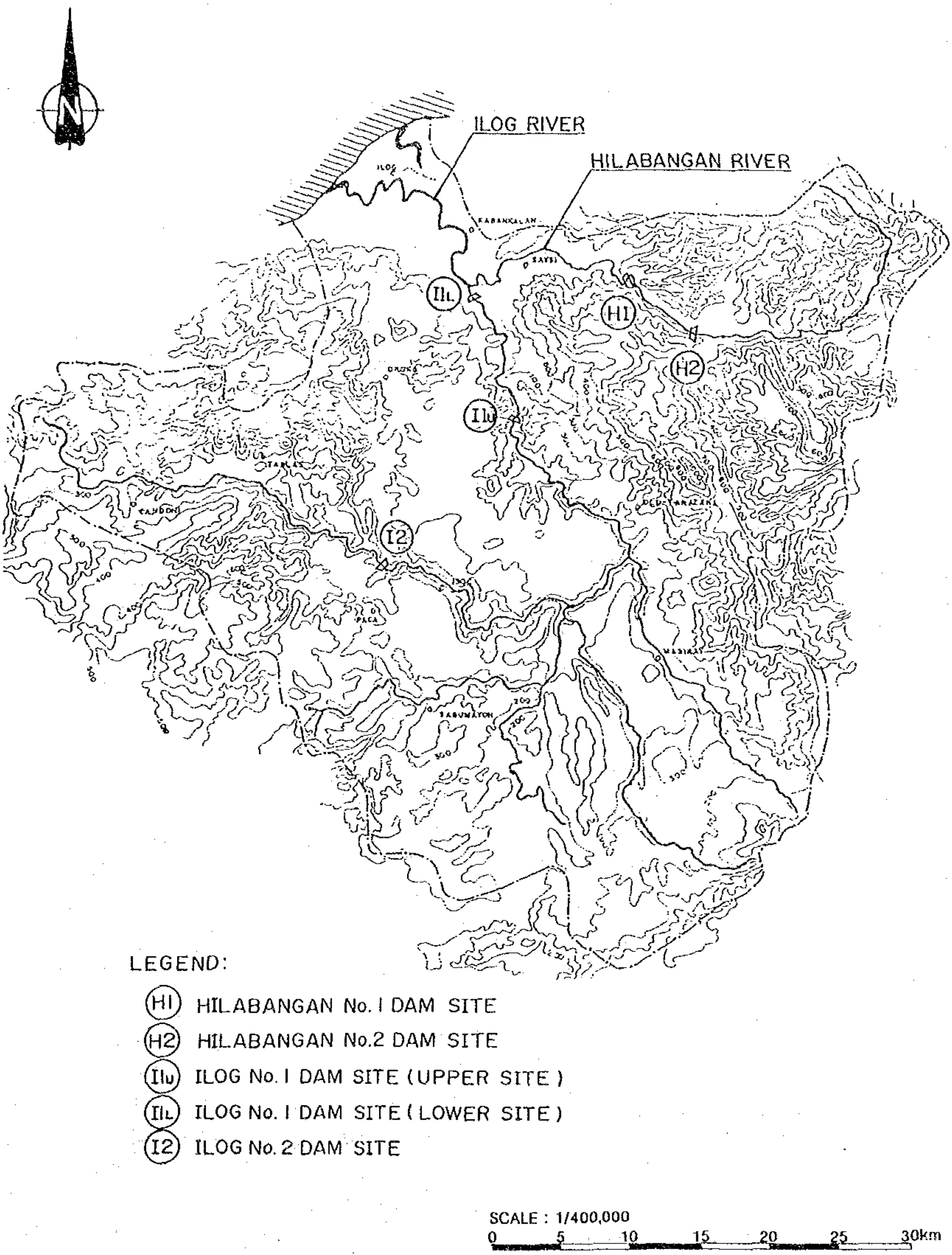


NOTE : FIGURE IN PARENTHESES IS THE FLOOD DISCHARGE OF HILABANGAN RIVER WHEN PEAK FLOOD OCCURS AT THE REFERENCE POINT

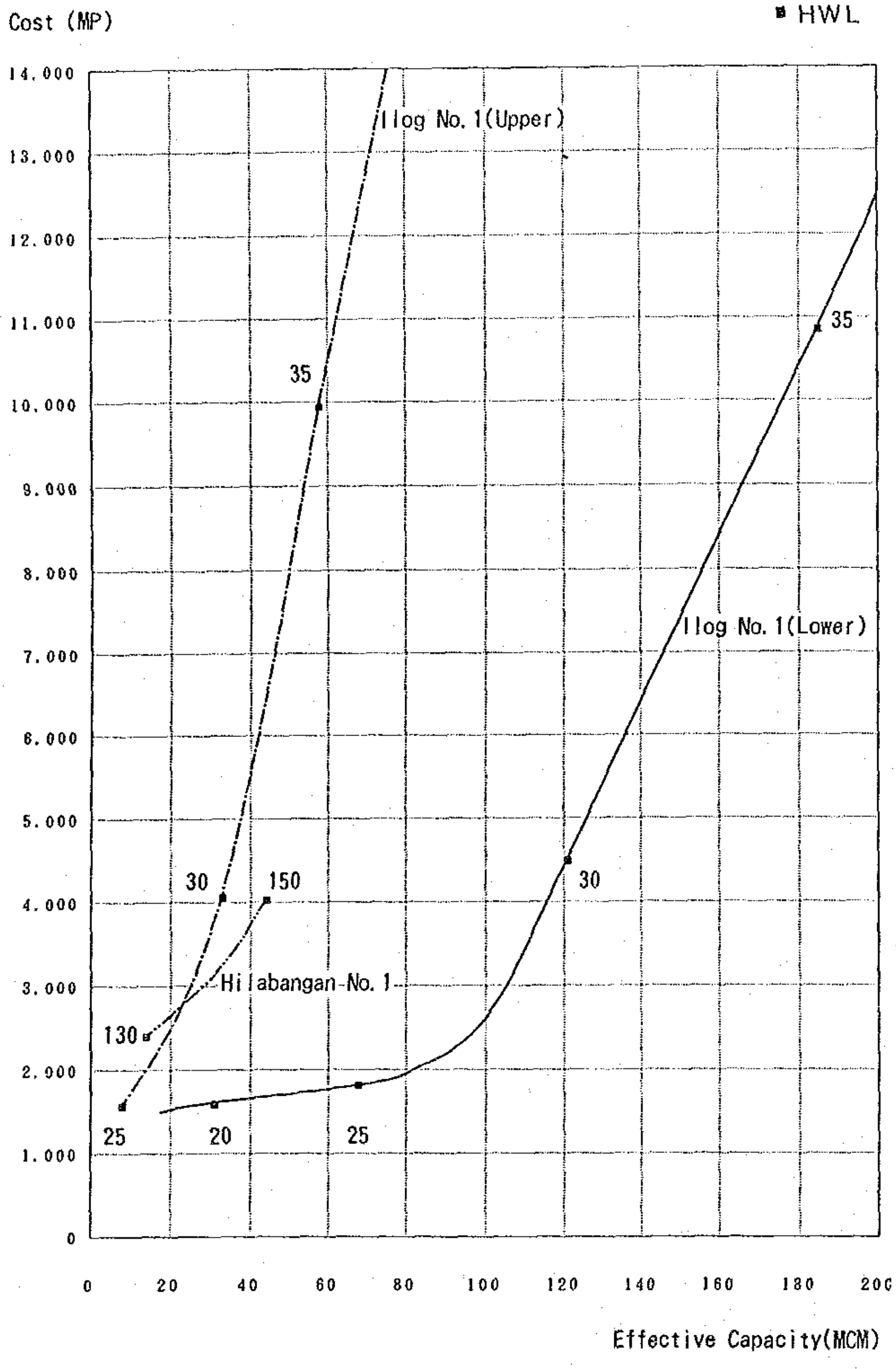
THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.V-3-2 BASIC PROJECT FLOOD



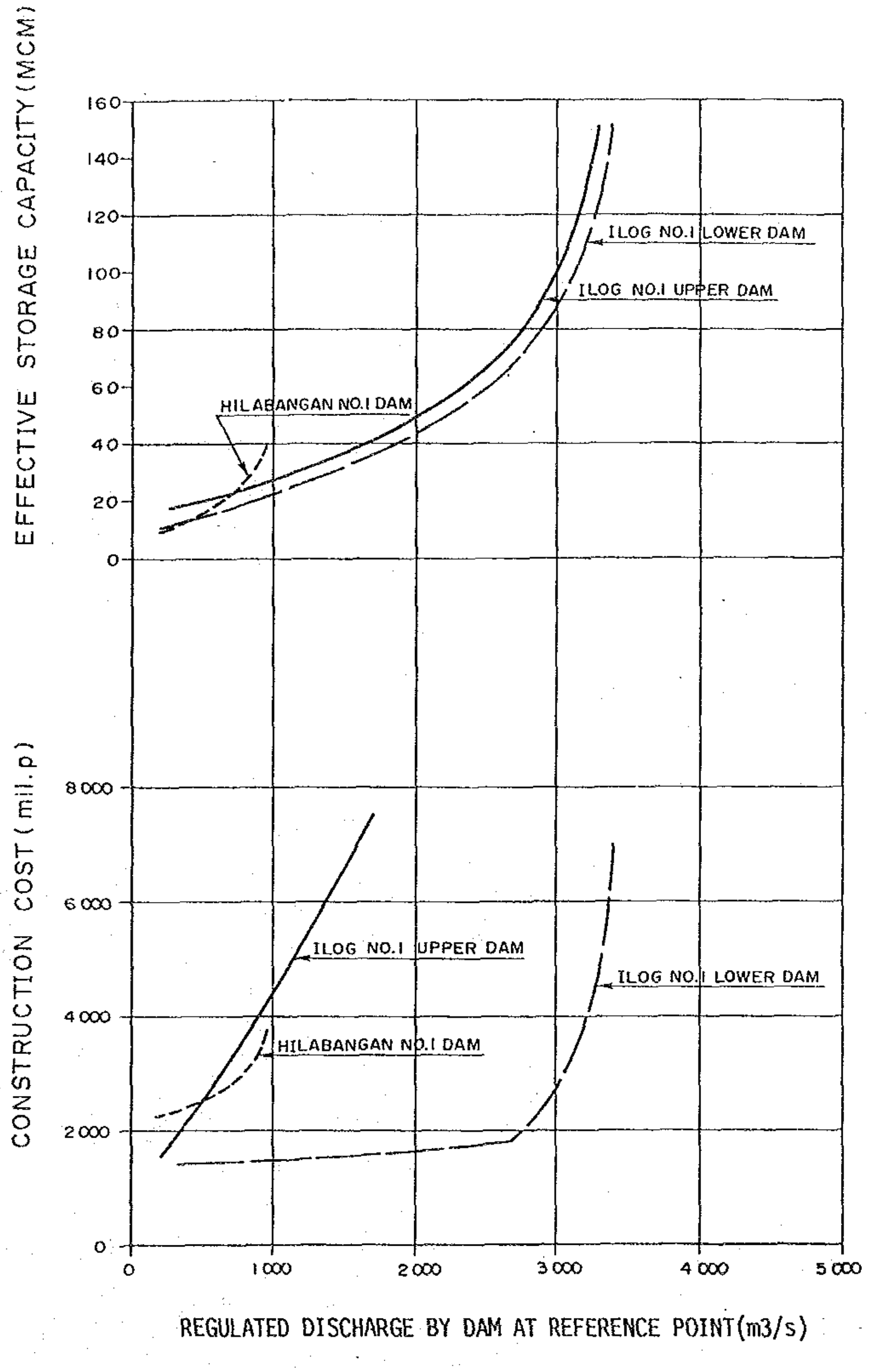
THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-3-3 ALTERNATIVE CASES OF RIVER IMPROVEMENT AND DIVERSION PLANS
JAPAN INTERNATIONAL COOPERATION AGENCY	



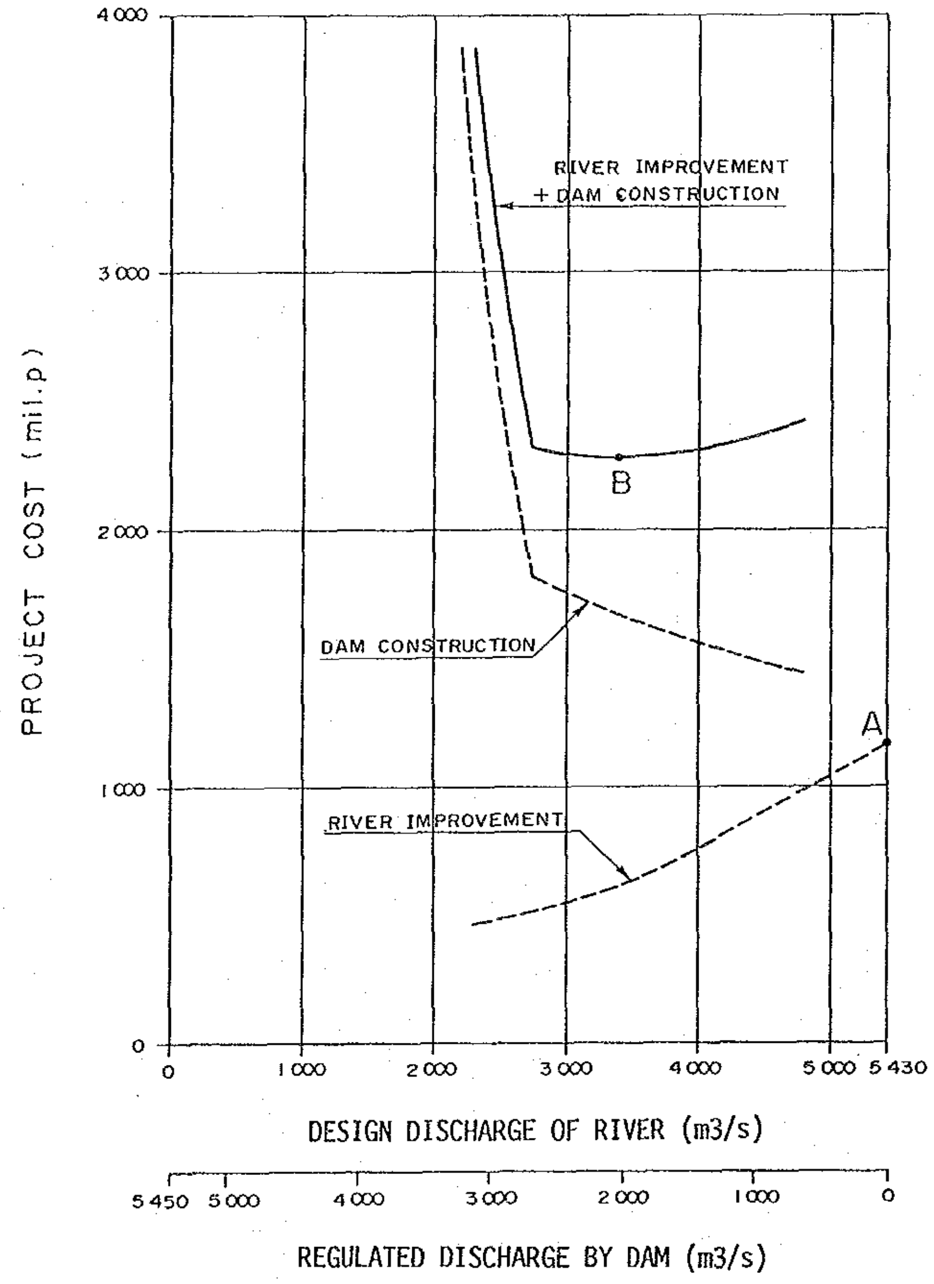
THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-3-4 LOCATION OF POSSIBLE DAM SITES
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-3-5 COST-EFFECTIVE CAPACITY CURVE
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-3-6 EFFECTIVE STORAGE CAPACITY AND CONSTRUCTION COST VERSUS REGULATION EFFECT
JAPAN INTERNATIONAL COOPERATION AGENCY	



NOTE A : PROJECT COST IN CASE OF ONLY RIVER IMPROVEMENT WORKS

B : MINIMUM PROJECT COST IN CASE OF COMBINATICON OF DAM AND RIVER IMPROVEMENT WORKS

THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.V-3-7 COST COMPARISON FOR ALTERNATIVE CASES
JAPAN INTERNATIONAL COOPERATION AGENCY	

ANNEX : FLOOD FORECASTING AND WARNING SYSTEM

FLOOD FORECASTING AND WARNING SYSTEM IN THE ILOG-HILABANGAN RIVER BASIN

1. Applicability of Flood Forecasting System

In accordance with the basic concept for formulation of the Master Plan, only the technical applicability of flood forecasting and warning system was examined in this Annex I. In the flood forecasting system, the flood discharge can be predicted on the basis of the observed hydrological data and the predicted flood discharge is disseminated to the agencies concerned, so that they may issue the flood warning and operate the flood fighting works.

In this connection, the effectiveness of the flood forecasting system is generally evaluated by the possible flood prediction time length and the accuracy of predicted flood discharge. Among these, the possible flood prediction time length depends on the runoff condition in the river basin emphasized with the travelling time of the flood, while the accuracy of predicted flood discharge is needed to confirm through the operation of flood forecasting system after establishment of the system.

Consequently, the applicability of the system is usually confirmed by checking the travelling time of the flood. In the Ilog-Hilabangan River Basin, the flood travelling time is presumed as 5 hours judging from the observed hydrological data and runoff analysis, which seems to be in the range to apply the flood forecasting system, since within this time length the works for flood forecasting and warning can be managed and thus the inhabitants are released from the sudden attack of flood.

2. Outline of the Flood Forecasting System

A flood forecasting and warning system is generally composed of the following subsystems:

(1) Hydrological observation network system
(2) Telemetering system
(3) Data management system and flood forecasting system
(4) Flood warning system

The outline of the flood forecasting system is briefly discussed as follows:

(1) Hydrological Observation Network System

The hydrological observation network will be composed of rainfall stations and water level gauging stations. To accurately obtain the rainfall information, nine (9) rainfall gauging stations which correspond to the density of about 200 km2/one station are proposed and three (3) water level gauging stations are proposed to calibrate the accuracy of the predicted flood discharge by this system. The location of the hydrological observation stations is shown in Fig. A-1 .

(2) Telemetering System

The telemetering system will be provided to collect the hydrological information at the real time basis. The following conditions are applied to formulate the telemetering system:

(a) A flood control center is set in DPWH in Kabankalan.

(b) A repeater station to once collect the hydrological information is set at a position with a fine prospect from the hydrological stations.

(c) The VHF band by simplex line is applied to the transmission line.

The telemetering system under the said conditions is shown in Fig. A-1.

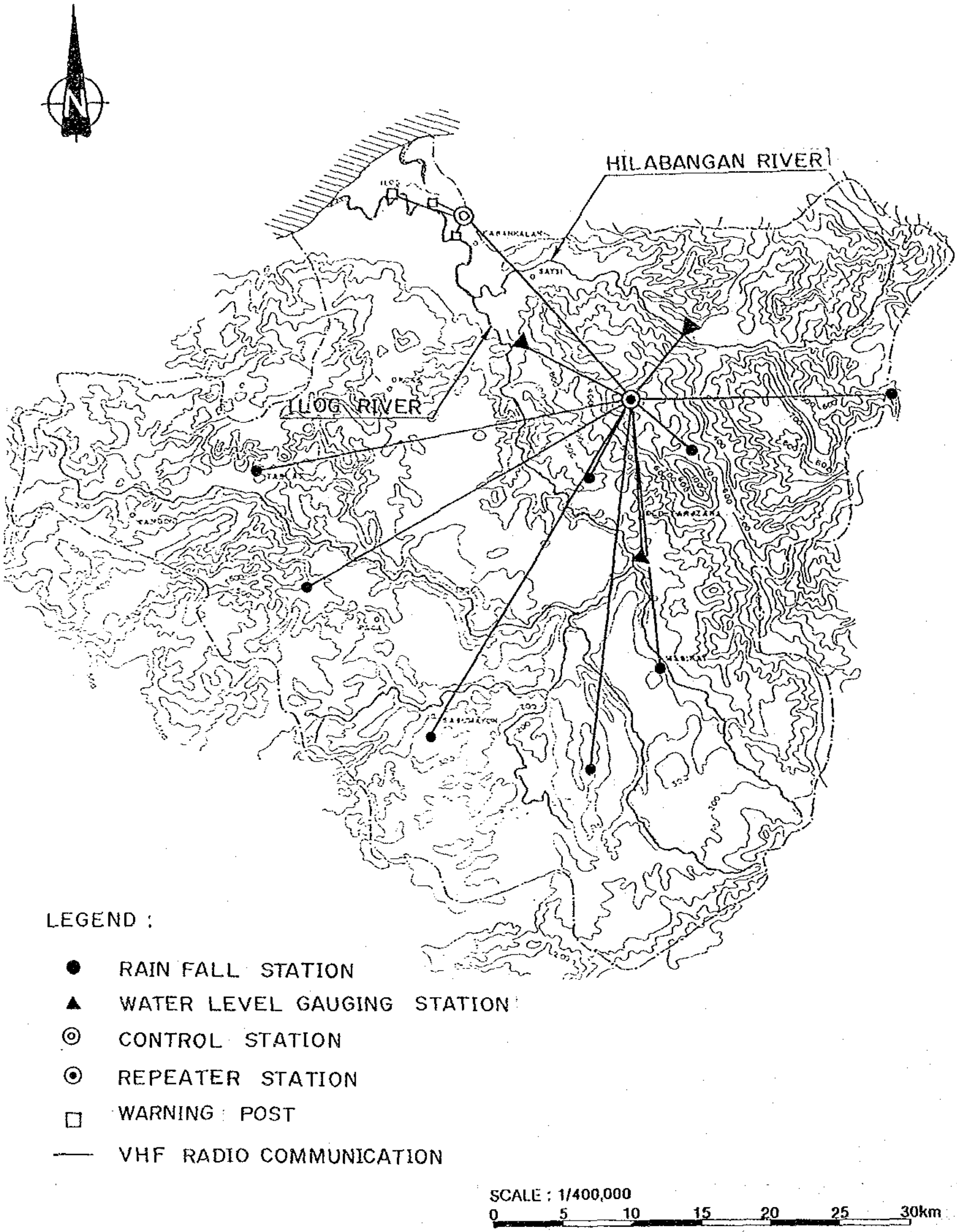
(3) Data Management System and Flood Forecasting System

In the data management system and flood forecasting system, data collected through the hydrological observation system are processed and used for flood discharge prediction. This system is composed of a personal computer with the display system as shown in Fig. A-2 .

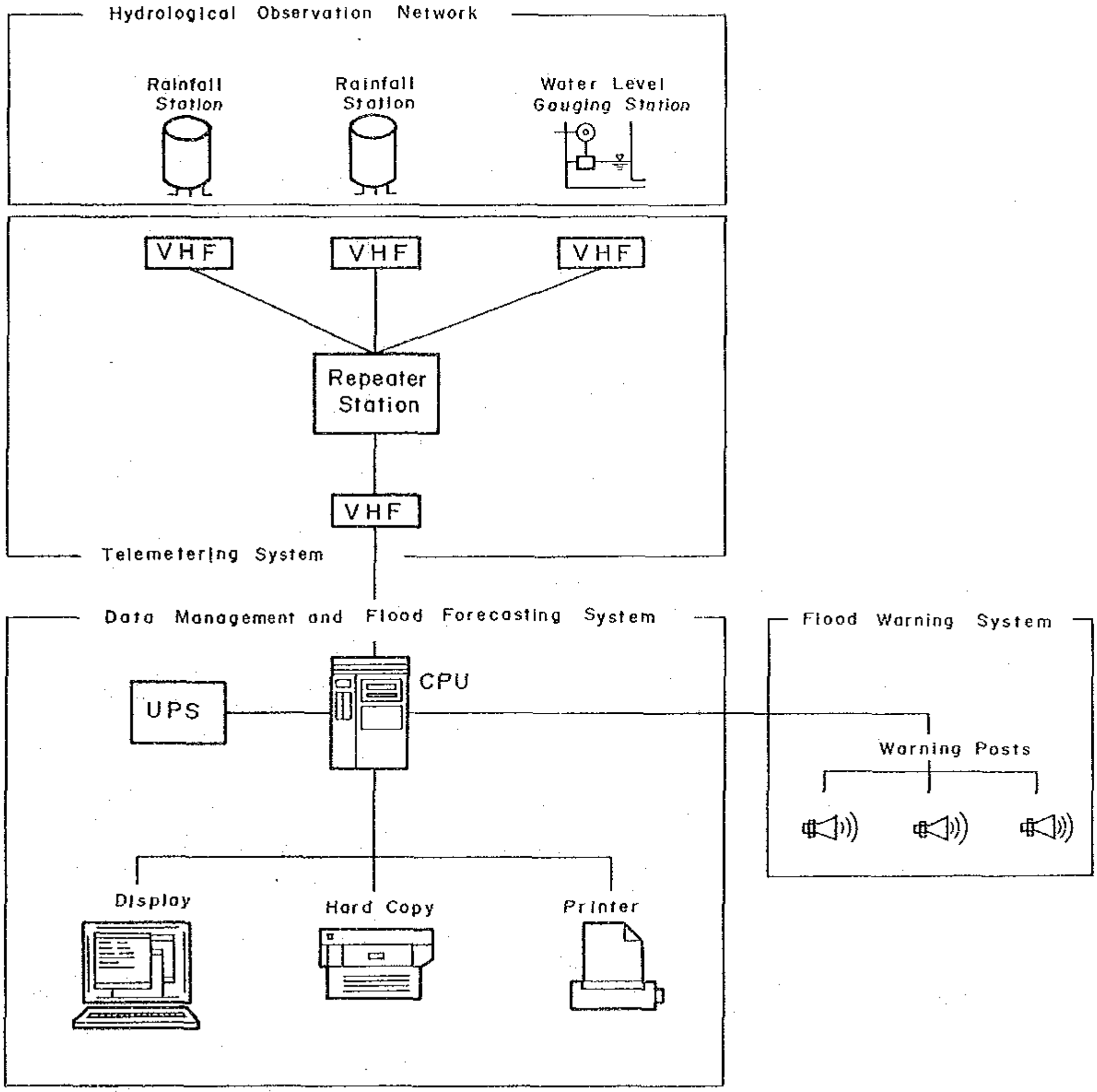
(4) Flood Warning System

The predicted flood discharge and water level by the flood forecasting system is issued by the flood warning system from the flood control center directly, or from the agencies concerned such as municipal offices, offices of civil defense, district offices and so on which are informed on the predicted flood discharge and water level by telephone from the flood control center.

To issue the flood warning, warning post will be provided at the densely populated area in the inundation area such as Kabankalan, Ilog, Talubangi and so on as shown in Fig. A-1.



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.A-1 PLAN OF FLOOD FORECASTING AND WARNING SYSTEM
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT	Fig.A-2 MODEL DIAGRAM FOR FLOOD FORECASTING AND WARNING SYSTEM
JAPAN INTERNATIONAL COOPERATION AGENCY	

VI. RIVER IMPROVEMENT

STUDY
ON
ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

SUPPORTING REPORT VI. RIVER IMPROVEMENT

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1. PRESENT RIVER CONDITIONS

1.1 General Features of River Channels

The Ilog-Hilabangan river system is composed mainly of two major rivers; namely, the Ilog River with a length of about 120 km, the principal drainageway of this basin and the Hilabangan River with a length of 35 km, one of the main tributaries of the basin, although the Ilog River diversifies into several branch rivers in the flatland of the lower reaches. (Refer to Fig. VI-1-1 and VI-1-2.)

The riverbed gradient of the Ilog River ranging from 1/140 to 1/3,100 is relatively gentle compared with that of the Hilabangan River. The change is not gradual from the upper to the lower reaches, i.e., the gradient in the lower reaches is sometimes steeper than that of the upper reaches. This means that the sediment produced in the upper reaches is transported rapidly in the steeper stretch, while some sediment is deposited in the gentle gradient stretch. On the other hand, the riverbed gradient of Hilabangan River ranging from 1/80 to 1/240 gradually changes from the upper to the lower reaches.

The width and depth of the Ilog River, which are related to the flow capacity of the river are variable in the upper reaches. In the lower reaches, the river width ranges between 100 m and 230 m and the river depth, between 5 m and 15 m. The branch rivers diversifying from the Ilog River such as Bagacay, Bungul, Old Ilog River, etc., have the river width ranging between 30 m and 150 m and river depth ranging between 2 m and 5 m, while the Hilabangan River has the river width of about 150 m and river depth of about 3 m (Refer to Fig.VI-1-3). Likewise, the Binicuil River, which may serve as a diversion channel of Ilog River, has the river width of between 10 m and 100 m and the river depth between 2 m and 5 m.

1.2 Flow Capacity

The flow capacity of the Ilog River, its tributary and branches such as the Hilabangan River, the Old Ilog River, the Bagacay River, etc., was examined under the following conditions:

(1) Non-uniform calculation is applied to the examination of flow capacity.

(2) The roughness coefficient of 0.03, which is usually applied to rivers in flat plane was employed judging from the present river condition.

(3) As the initial condition at the river mouth, the water stage of 1.5 m which corresponds to the mean high water spring observed at the gauging station of Banago, Bacolod was adopted.

(4) The cross-sections of the river channel taken from the surveying results in this study period were used for the calculation.

Non-uniform calculation results are shown in Fig. VI-1-4. Based on the above considerations and by comparing the water stage and the ground height along the river course, it was determined that the bankful flow capacity of the Ilog River ranges between 300 m^3/s and 2,000 m^3/s, and it is over 1,000 m^3/s in most stretches (refer to Case 1 in Fig. VI-1-5). In the stretch between 6.0 km and 16.0 km from the river mouth, it is presumed that the bankful flow capacity, which is estimated at about 1,000 m3/s, would become about 2,000 m^3/s if the inundation in the small area along the river course is considered (refer to Case 2 in Fig. VI-1-5). In the same manner, the bankful flow capacity of 300 m^3/s would become 500 m^3/s in the stretch between the river mouth and the 6 km point, considering minor inundations along the river course. Fig. VI-1-6 shows the flow capacity of a tributary and branch rivers.

1.3 Change of River Course

Changes in the Ilog river course at the delta area can be identified by comparing various information such as aerophotographs, topographic maps and river surveying results. In the study area, aerophotographs taken in 1970 and 1990 and topographic maps developed in 1956 and 1990 are available, although the river surveying results of the same section are not available. As per comparison of these aerophotographs and topographic maps, the following points were identified (refer to Fig. VI-1-7).

(a) Major river changes in 34 years are visible at two (2) points in the Hilabangan River, three (3) points in the Ilog River and two (2) points in Old Ilog River, and the extent of change is within 750 m. The other portions do not show any remarkable change.

(b) The change of the Ilog River at the diversion point to Bungul diversion channel is remarkable and the shift in its course is continuing.

(c) The Old Ilog river basin which had once changed the river course has been reducing the river width and depth after the Bungul diversion channel and cut-off channels have been constructed. Since then, the change of river course has not been severe due to the reduced water discharge.

1.4 Meandering of River Course

In the alluvial plain, the river naturally meanders because of the imbalance between the sediment flow capacity of the river and the friction with riverbed and bank materials, and river meandering is also influenced by obstacles to prevent the smooth flow of discharge. The behavior of the river on this matter could not be determined because of the compound elements involved.

As the general condition on meandering of the Ilog-Hilabangan River, the ratio of river length to the length of meander axis is referred. In comparison with the ratio of other rivers in the Philippines, the ratio of the Ilog-Hilabangan River is about 1.3 which is in the middle range of those of the other river basins (refer to Fig. VI-1-8). Judging from this fact, the meandering condition of the Ilog-Hilabangan River is not so severe.

1.5 River Facilities and Structures

In the Ilog-Hilabangan River, river structures have been provided according to purpose as follows. The location of river structures is shown in Fig. VI-1-9.

(1) For Flood Control

(a) Embankment of Bungul diversion channel in the stretch of 1,500 m at the left side and 500 m at the right side started in 1957 and completed in 1959.

(b) Embankment of cut-off channel with the total length of 3,500 m at both sides started 1974 and completed 1975.

(c) Revetment of Ilog River at Barangay Talubangi in a total stretch of 425 m; 168 m constructed in 1968 and 257 m extended in 1979.

(d) Revetment of Bungul diversion channel in a length of 65 m in 1979.

(e) Revetment of Ilog River at Kabankalan in the stretch of about 700 m started in 1980 and completed in 1984.

(f) Revetment of Bungul diversion channel in a stretch of 25 m started in 1990 and still ongoing as of October 10, 1990.

(2) For Transportation

(a) Wooden bridge, crossing the Hilabangan River at Barangay Overflow with the length of 83 m (year of construction is not clear).

(b) Steel bridge at Barangay Talubangi, with the length of 126 m constructed in 1927.

(c) Bungul concrete bridge with the length of 80 m crossing the Bungol diversion channel started in 1977 and completed in 1979.

(d) New bridge at Barangay Talubangi proposed at immediate downstream of the existing Talubangi bridge.

(e) New bridge crossing the Hilabangan River at Barangay Overflow which was started in 1990 and is still on-going.

(3) For Irrigation

(a) Intake facilities with three intake pumps at Ilog River for SONEDCO (sugar milling company) at Kabankalan Municipality.

(b) Intake facilities with two intake pumps at the Tablas River, a tributary of Ilog River, for Dacong Cogon Sugar and Rice Milling Company at Kabankalan Municipality.

(4) For Water Supply

(a) A bridge with water supply pipe crossing the Hilabangan River.

2. SEDIMENTATION

2.1 Present Contition

Although the data to specify the sedimentation condition in the Ilog-Hilabangan river basin is not available, sediment yield in the mountainous areas seems to be not severe because of the fairly good vegetation (refer to Fig. VI-2-1). Correspondingly, the sediment produced in the upper reaches does not severely affect the stability of the river channel in the lower reaches as stated below:

(1) The sediment transport capacity in the upper reaches of the Ilog River is not so big judging from the gentle riverbed gradient.

(2) River mouth expansion in the 34 years from 1956 to 1990 is 500 m in maximum and 200 m on an average in the stretch of 1,500 m along the shoreline, which are considered as moderate.

(3) The riverbed has not remarkably changed, judging from the longitudinal profile of the riverbed surveyed in 1982 and 1990 and the riverbed elevation based on discharge measurement notes by NWRC. (Refer to Figs. VI-2-2 and VI-2-3.)

2.2 Riverbed Material Survey

The riverbed material survey was conducted to obtain the basic data for the stability analysis of the riverbed and determine the applicability of the bed material to the embankment. Sampling of riverbed material was carried out at intervals of about 1 to 2 km (total of 25 points) as shown in Fig. VI-2-4.

Name of River	Number of Sampling Site
Ilog River	10
Hilabangan River	5
Binicuil River	4
Tributaries	6

Laboratory tests were conducted by the local contractor hired by the Study Team. The tests, testing method and the quantity are shown as follows:

Name of Test	Method	Quantity
Grain Size Analysis	Sieve Analysis and Hydrometer Analysis	25
Specific Gravity Test		25

The grain size composition for each sampling material are shown in Fig VI-2-5. Judging from the examined grain size distribution of riverbed materials, the Ilog-Hilabangan River is classified into the following 4 stretches in accordance with the characteristic of riverbed materials:

Stretch	D50 (mm)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Bungul Diversion	0.003	0	30	10	60
Middle Reach (Kabankalan)	0.006	0	50	10	40
Hilabangan River	2.0	65	30	5	0
Upper Reach* (Orong)	0.3	15	60	15	10

* The grain size distribution of this stretch was assumed as sandy-loam containing 10% gravel from the grain size distribution, annual discharge and gradient of riverbed of Ilog and Hilabangan rivers because there is a big difference between the grain size of sampling material and assumed grain size by photographs at Orong in the dry season.

The above results show the change of grain size and riverbed condition along the river. The clayey bed materials at the river mouth gradually change into sandy materials to the upstream of the Ilog River and the riverbed materials of the Hilabangan River is composed of materials coarser than those of the Ilog River.

On the other hand, the study on riverbed condition was conducted as follows:
Bed material load is generally classified into two modes: bed load and suspended load. Bed load is defined as coarse materials moving on or near the bed, while suspended load is material moving in suspension in a fluid, being kept by the upward components of turbulent currents or in colloidal suspension.

The riverbed material load of Ilog River contains fine materials whose grain size is less than 0.1 mm, called Wash Load. Further, the grain size of less than 0.01 mm which is called cohesive sediment, account for more than 10% of the total volume of the riverbed material. A river containing the cohesive sediment in the riverbed materials has the following characteristics:

(1) This type of river is generally formed under the condition of tidal stretch or a slow velocity stretch in the dry season.

(2) The ratio of river width and water depth is smaller than that of the ordinary river because this type of riverbed is eroded vertically when flood occurs.

Since the above characteristics fit the Ilog river channel condition, it is necessary to take this matter into account when the sediment study for riverbed stability is carried out.

2.3 Sediment Yield and Balance Analysis

Basic Condition

The Ilog River was defined as a river whose riverbed material contains cohesive sediment. The influence of cohesive sediment against riverbed fluctuation is, however, not still clear. Therefore, the sediment transport capacity was calculated based on the following conditions: Plenty of cohesive sediment will be transported as Wash Load with the size less than 0.1 mm when flood occurs. Therefore, riverbed fluctuation will be influenced mainly by the volume of Bed Load and Suspended Load.

The following formulas were employed for the estimation of sediment discharge:

(1) Bed Load : Sato-Kikkawa-Ashida's formula

$$q_B = \frac{u_*^3}{\left(\frac{\sigma}{\rho} - 1\right) g} \cdot \psi \cdot F(\tau_0 / \tau_c)$$

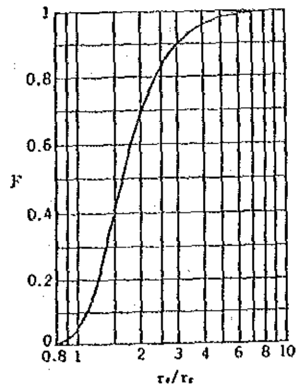
whree;

q_B : Volume of bed load per unit width per unit time
U_* : Friction velocity $= \sqrt{gHI_e}$
H : Water depth
I_e : Energy gradient
σ : Density of sand
ρ : Density of water
g : Acceleration due to gravity

$n \geq 0.025$: $\psi = 0.623$, $n < 0.025$: $\psi = 0.623 \times (40n)^{-3.5}$

Also;

F : Function of τ_0 / τ_c as shown in the following figure
n : Manning's roughness coefficient
τ_c : Critical tractive force, $\tau_c \rho = \rho g h I_e$



Relation between F and τ_0/τ_c in Sato, Yoshikawa & Ashida's formula

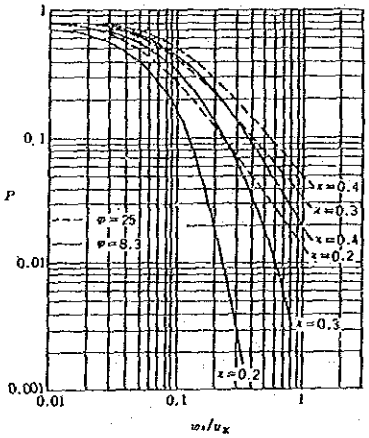
(2) Suspended Load : Lane-Kalinske's formula

$$q_s = qC_a P \, exp\left(\frac{6a_0 w_0}{khu_*}\right), \quad P = \int_0^1 \left[1 + \frac{1}{\kappa\psi}(1 + ln\,\eta)\right] exp\left(-\frac{6w_0}{\kappa u_*}\eta\right) d\eta$$

$$q_s = qC_0 P, \quad C_0 = a\Delta F(w_0)\left[1/2\left(\frac{u_*}{w_0}\right) exp\left\{-\frac{w_0}{u_*}\right\}^2\right]^n$$

where;

qs	:	Suspended load per unit width per unit time
q	:	Discharge per unit width
P	:	Function of w_0/u_*, Karman's constant κ and $\psi = \nu/u_*$ (refer to the following figure.)
Ca	:	Concentraton at control point $x = a_0$
C_0	:	Concentration at river bed (ppm)
$\Delta F(w_0)$	:	Proportion of sand particles with settling velocity of w_0 in the sand gravel of river bed (%)
a, n	:	Constants, a = 5.55, n = 1.61 and $\eta = z/h$



Relation between the value of P in Lane-Kalinske's Formula by Ashida and w_0/u_* (established by Ashida)

The six (6) reference points for this study (S15, S4, S7, S9, S11 and S22) were selected along the Ilog River and the Hilabangan River taking into account the following conditions:

(1) The reference points should be the sampling site of riverbed material.

(2) The reference points will be located at a straight channel.

(3) The grain size distribution of the reference point should represent the condition of each stretch.

(4) The rating curve and the average duration curve of discharge are obtainable to estimate the annual sediment transport capacity.

Results of Calculation

The results of the calculation are shown in Fig. VI-2-6 and Table VI-2-1. Judging from these results, the sediment transportation capacity is gradually decreased from upper reaches to lower reaches, and therefore, this situation may cause the aggradation of the riverbed in a long period.

However, this is a rough calculation to broadly examine the sediment balance under the present river condition which fluctuate year by year as well as the composition of riverbed materials, and in this sense the sediment imbalance seems to be not so large.

This concludes that the Ilog River is ralatively stable, whcih is also noticed from change of riverbed as described in Section 2.1 "Present Condition".

3. STUDY ON ALTERNATIVE CASES

3.1 Basic Project Flood

As mentioned elsewhere in this sectoral report, the project scale of a 100-year return period is applied for this flood control study.

The basic project flood of a 100-year return period which is a fundamental to examine the alternatives of river improvement plan is 5,450 m^3/s at the reference point of Talubangi downstream of the confluence with the Hilabangan River, while that of the Ilog River before the confluence is 4,300 m^3/s and that of Hilabangan River is 2,900 m^3/s.

3.2 Study Cases

In this river improvement sector, the following study cases are examined to select the optimum river improvement plan: (1) existing river improvement and (2) diversion channel.

(1) Existing River Improvement

This measure has been partially applied to this river basin and it seems to be effective. Cut-off channels which have also been provided in this river basin are included in this measure.

The objective river improvement stretch will be from the river mouth to 20 km for the Ilog River and from the confluence point with the Ilog River to 1.5 km for the Hilabangan River where the flood damage is expected.

In the case of river improvement, a cut-off channel at the meandering section near Kabankalan and Talubangi is considered to be provided as an alternative study case. Therefore, two cases of river improvement plans are proposed as follows (Refer to Fig. VI-3-1):

Case R1 : Existing River Channel Improvement;
River channel alignment is proposed based on the existing river channel.

Case R2 : Cut-off Channel;
Cut-off channel is proposed at the meandering section near Kabankalan Municipality and Barangay Talubangi and existing river channel alignment is adopted to the remaining section.

(2) Diversion Channel

This measure was once employed in this basin in the Bungul diversion channel and it seems to be still one of the applicable measures.

In this case, the following three cases are proposed judging from the topographic condition (refer to Fig. VI-3-1):

Case D1 : Binicuil Diversion Channel;
The channel will be diverted from the upper stream point at Kabankalan City (13.5 km point) and connect with the existing Binicuil River.

Case D2 : Old Ilog Diversion Channel;
The old Ilog River will be used as diversion channel by expanding the river width and excavation.

Case D3 : Salong Diversion Channel;
The channel will be diverted from the 15.0 km point and connect with the Salong River.

3.3 Outline for Alternative Cases

3.3.1 Existing River Channel Improvement (Case R1)

The river improvement plan is composed mainly of the following components: (1) alignment, (2) longitudinal profile, and (3) cross section. The basic principles for planning these components are as follows:

(1) Alignment

The existing river course, which has been relatively stable for a few decades is adopted to the alignment of this river improvement plan, though minor modification is taken to make it more smooth as seen in the section around the diversion point to Bungul diversion channel. The proposed alignment is shown in Fig. VI-3-2.

(2) Longitudinal Profile

The design riverbed elevation and gradient is set along the present average riverbed, which seems to be stable as mentioned in Section 2 "Present Condition", so that the design riverbed can be easily maintained. Eventually, the riverbed gradient for the river improvement stretch is as follows:

(a) Ilog River
1/5,000 ; from the river mouth to 7 km point
1/3,000 ; from 7 km point to 16 km point
1/2,500 ; from 16 km point to the upper stream

(b) Hilabangan River
1/350 ; from the confluence point to 1.5 km point

The design high water level at the river mouth was set at EL.3.0 m which was arrived at from the flood water velocity head adding to the mean high water spring of EL.1.5 m. To minimize the flood damage potential, the design high water in the stretch where many houses are located along the river course was set at the ground height, while that in the stretch where land use is more for agriculture was set, at least, below the recorded maximum flood mark or about 1.5 m high above the ground level.

As the result, the longitudinal profile of design water stage is 1/2,500 for the Ilog River and 1/350 for the Hilbangan River, starting from EL.3.0 m at the river mouth. The design longitudinal profile is shown in Fig. VI-3-2.

(3) Cross Section

In planning the cross section, one of the study points is to select the suitable cross section type, i.e., compound cross section or single cross section. In the case of Ilog-Hilabangan River, the single cross section is adopted on the following considerations:

(a) A compound cross section is generally applied to confine the low water discharge in the low water channel and the compound cross section has the advantage in maintaining the channel. In case of a single cross section the low water discharge flows down, changing the course at the bottom of a single cross section, and the river channel is sometimes subject to bank erosion resulting in the problem of maintenance of the channel.

    However, the river improvement stretch is in the tidal influence and the river channel is under submergence by sea water. Further, the low water discharge flows down without so much adverse influence such as bank erosion. Therefore, it is not necessary to provide a low water channel to maintain the river channel.

(b) In general, the compound cross section requires a wider river channel and a larger current flow area compared with the single cross section, usually resulting in the increase of construction cost. Since it is not recommendable to largely widen the present river channel in the stretch where Kabankalan Municipality and Barangay Tarubangi exist along the river course, it is preferable to apply a single cross section.

(c) In the stretch far from the tidal influence, a compound cross section is considered. However, this stretch which is presently of a single cross section seems to be stable and not so long. If the compound cross section is applied to this stretch, it is necessary to provide a transition section in this short stretch to connect the compound section to the single section, so that a compound cross section is not substantially advantageous compared with the increase in cost.

To make the basic project flood flow down under the design high water level, the cross section has the following river widths.

(a) Ilog River

B = 300 m ; from the river mount to 7 km point

B = 230 m ; from 7 km point to 16 km point

B = 160 m ; from 16 km point to the upper stream point

(b) Hilabangan River

B = 110 m ; from the confluence point to 1.5 km point

A typical cross section for the river improvement is shown in Fig. VI-3-2.

3.3.2 Cut-Off Channel (Case R2)

(1) Alignment

The cut-off channel is proposed only at the meandering section near Kabankalan Municipality and Barangay Talubangi which corresponds to the river stretch from 6 km to 15 km. (Refer to Fig. VI-3-3.)

A straight line is adopted to the alignment of this cut-opff channel, so taht the channel stretch of 3.0 km is shortened compared with the river improvement along the existing river channel (Case R1).

In this connection, it is assumed that all the basic project flood will be distributed to the cut-off channel, since to maintain both the existing river channel and cut-off channel is very hard when both the channels are used to discharge flood water.

(2) Longitudinal Profile

In accordance with the shortening of the river stretch, the design river bed gradient of the Ilog River is changed from that of Case R1 as follows:

(a) 1/5,000 ; from the river mouth to 5 km point
(b) 1/2,500 ; from 5 km point to 20 km point

The design high water of Case R1 is applied to this Case R2 under the same principle. The logitudinal profile of the Hilabangan River is the same as Case R1. (Refer to Fig. VI-3-3.)

(3) Cross Section

A single cross section with a bottom width of 230 m was employed to confine the basic project flood. (Refer to Fig. VI-3-3.)

3.3.3 Binicuil Diversion Channel (Case D1)

(1) Alignment

The Binicul diversion channel is diverted from 13.5 km point of the Ilog River passing by the eastern part of Kabankalan Municipality and connects with the Binicuil River at the distance of 1.5 km from the diversion point as shown in Fig. VI-3-4.

The alignment is drawn with the smooth curve along the existing Binicuil river channel. The total distance of the diversion channel is 11 km.

(2) Longitudinal Profile

The design river bed gradient of this diversion channel is set to connect the river bed height of EL.–0.433 m at the diversion point of the Ilog River and that of EL.–4.0 m of the Binicuil River, so that the design river bed gradient is 1/3,000.

The design high water level which is set in the same manner as that of Case R1 is 1/2,500 with the design high water level of 3.0 m at the river mouth. (Refer to Fig. VI-3-4.)

(3) Cross Section

For the decision of the design cross section, the distribution of design discharge between the Ilog River and diversion channel was examined through the cost comparison study for several cases of discharge distribution, and the discharge of 2,800 m^3/s was obtained as the least costly one. (Refer to Table VI-3-1.)

As the design cross section, the single cross section with the bottom width of 140 m is employed to confine the said design discharge. (Refer to Fig. VI-3-4.)

3.3.4 Salong Diversion Channel (Case D2)

(1) Alignment

The Salong diversion channel is diverted form 15.0 km point of the Ilog River passing by western part of Kabankalan Municipality and connect with the Salong River with the distance of about 4 km from the diversion point. (Refer to Fig. VI-3-5.)

The alignment is drawn with the smooth curve considering the existing Salong river channel. The total distance of the diversion channel is 10.7 km.

(2) Longitudinal Profile

The design riverbed gradient of this diversion channel is set connecting the riverbed height of EL.0.0 m at the diversion point of the Ilog River to the riverbed height of EL.–3.6 m of the Salong River, so that the design riverbed gradient is 1/3,000.

The design high water level set in the same manner as that of Case R1 is 1/2,500 with the design high water level of EL.3.0 m at the river mouth. (Refer to Fig. VI-3-5.)

(3) Cross Section

For the decision of the design cross section, the distribution of the design discharge among the diversion channel and the Ilog River was examined through the cost comparison study for several cases of discharge distribution and the discharge of 2,800 m^3/s was obtained as the most economic design discharge distribution. (Refer to Table VI-3-1.)

As the design cross section, the single cross section with the bottom width of 140 m is employed to confine the said design discharge. (Refer to Fig. VI-3-5.)

3.3.5 Old Ilog Diversion Channel (Case D3)

(1) Alignment

The Old Ilog diversion channel is proposed to be diverted at 6.0 km point of the Ilog

River, and the alignment is drawn in line with the existing Old Ilog River. (Refer to Fig. VI-3-6.)

(2) Longitudinal Porfile

The design riverbed gradient of this diversion channel is set considering the present riverbed gradient of the Old Ilog River, and a gradient of 1/5,000 was employed.

The design high water level set in the same manner as that of Case R1 is 1/2,500 with the design high water level of EL.3.0 m at the river mouth. (Refer to Fig. VI-3-6.)

(3) Cross Section

For the decision of the design cross section, the distribution of the design discharge among the diversion channel and the Ilog River was examined through the cost comparison study for several cases of discharge distribution and the discharge of 2,800 m3/s was obtained as the most economic one. (Refer to Table VI-3-1.)

As the design cross section, the single cross section with the bottom width of 150 m is employed to confine the said design discharge. (Refer to Fig. VI-3-6.)

3.4 Selection of Optimum River Improvement Plan

The comparative study results of the above-said alternative cases of river improvement and diversion channel are shown in Table VI-3-2. Judging from this table, river improvement based on the existing river channel has an economic advantage over the other cases, because the excavation and embankment volumes for river improvement are less than those of the other alternative cases, while there is not much difference in the number of house evacuation and land acquisition among these cases. Eventually, river improvement along the existing channel (Case R1) is proposed as one of the applicable measures for further alternative study. Figs. VI-3-7 to VI-3-10 show the features of optimum river improvement plan.

3.5 River Improvment Plan for Further Alternative Study

Through the comparative study among the alternative cases, the river improvement along the existing river channel is selected as most applicable one. As the further alternative study, it is necessary to conduct a comparative study between dam and river improvement or their combinations.

In this connection, the river improvement plan for several design descharge distribution cases are examined to select the optimum combination cases for the dam. The river improvement plan is prepared reducing the river width in accordance with the discharge distribution, while the alignment and longitudinal profile is set in the same manner as that of the Case R1.

The construction cost for each discharge distribution is shown in Table VI-3-3.

4. PRELIMINARY DESIGN OF RELATED STRUCTURES

4.1 Related River Structures

The following river structures are provided to obtain the required flow capacity, stabilize the river channel and guarantee the existing condition:

(1) Dike

To pass the design discharge safely, dikes are planned at both sides of the river channel from the river mouth to the mountainous portion. The top elevation of the dike was obtained by adding a freeboard to the Design High Water Level.

(2) Revetment

For the protection of the dike and the river channel from erosion, revetment is applied at the water colliding front of the meandering sections. Furthermore, since turbulent river flow occurs at the upper and lower portions of structures, revetment is provided at both sides of sluices, drainage facilities and abutments of bridges.

(3) Sluice

Sluices are proposed at the confluence of related rivers (Old Ilog River, Bagacay River, Bungul River) to prevent the flood discharge of the Ilog River from flowing into the related river and to supply freshwater to fishponds.

(4) Drainage Facilities

Drainage facilities are to be provided at the area surrounded by dike and the existing area such as the traces of the old river course to drain inner water.

(5) Bridge

There are two bridges existing across the Ilog River, namely Talubangi Bridge and Bungul Bridge. In connection with the construction of dike along both sides of the river, it is necessary to reconstruct these bridges.

4.2 Preliminary Design

Related structures, as described herein, are dike, revetment, sluice, drainage facility and bridge. These are designed in consideration of the availability of construction materials near the project sites, structural stability, construction efficiency and economy.

Design Criteria

The basic design in this study was made on the basis of the following two standards:

(1) Design Guidelines, Criteria and Standards (Prepared by DPWH)

(2) Technical Standard for River and Sabo Facilities (Prepared by the Ministry of Construction of Japan)

Structural Design

(1) Dike

The standard design section of river dike is shown in Fig. VI-4-1. The dike height is determined by adding a freeboard to the design high water level which is reckoned on the design flood discharge.

Freeboard, which is the margin of height to guard against overtopping and wave wash, is given by the design flood discharge.

Top width should be planned in consideration of dike stability and function of road during maintenance operations. Top width is also given by the design flood discharge.

The side slopes on both landside and riverside of the dike are designed as 2:1 from the aspect of dike stability. Berms are provided along the slopes of high dikes as erosion control measures and also to improve the stability of the side slopes. When the crest height from the riverbed is more than 5 m, berms of the riverside shall be provided at 5 m in height from the riverbed elevation with a width of 10 m. When the crest height from the existing ground is more than 3 m, berms of the landside shall be provided at 3 m in height from the crest elevation with a width of 3 m.

(2) Revetment

Revetment, which is a flood control structure constructed along dike slopes for protection against scouring and wave wash, is designed with the use of wet masonry 0.3 m thick. The standard design section of revetment is shown in Fig. VI-4-2. The base concrete of revetment should be above mean sea level to execute all works in the dry condition. Under the base concrete, concrete sheet pile foundation combined with percolation control is constructed. Height of revetment is based on the required design high water level.

(3) Sluice

Sluice gates protect the tributary catchment areas from the flood flow of the main river and lead riverwater or brackishwater to tributaries. The standard design of sluice gates, classified into two types (Type A and Type B) in accordance with the size, are shown in Figs. VI-4-3 and VI-4-4, respectively. Type A, which is placed at Bagacay River, Old Bungul River and so on, has one box culvert of 1.5 m by 1.5 m. Type B, which is placed at Old Ilog River, has three box culverts of 3 m by 3 m. These are determined not to change the existing conditions based on the existing river width. To prevent differential settlement, wooden or reinforced concrete piles are provided at the foundation.

(4) Drainage Facility

Drainage facility, which is provided to drain landside water, is composed of a box culvert of 1 m by 1 m with flap gate under the dike and drainage ditch at landside.

(5) Bridge

There are two bridges, Talubangi and Bungul Bridge, to be reconstructed according to the river improvement plan. Judging from the existing condition of these bridges, the following widths are to be applied.

Talubangi Bridge: 10 m wide for two-lane traffic and railway
Bungul Bridge : 4 m wide for one-lane traffic

The standard designs are shown in Figs. VI-4-5 and VI-4-6 so as to conceptually understand the type of bridge structures.

TABLES

Table VI-2-1 RATING CURVE AND ANNUAL SEDIMENT DISCHARGE OF REFERENCE POINTS

Reference Point	Discharge (m3/s)	Rating Curve: Bed Load (m3/s)	Rating Curve: Suspended Load(m3/s)	Rating Curve: Total (m3/s)	Disbribution (%)	Annual Sediment Discharge: Bed Load (m3/yr)	Annual Sediment Discharge: Suspended Load(m3/yr)	Annual Sediment Discharge: Total (m3/yr)
S15 (3.5k)	10	0.000E+00	2.491E-39	2.491E-39	9.6	0	0	0
	20	0.000E+00	2.695E-15	2.695E-15	41.1	0	0	0
	50	2.077E-06	5.118E-07	2.589E-06	27.1	18	4	22
	100	7.381E-05	1.139E-04	1.877E-04	7.9	184	284	468
	200	5.823E-04	3.550E-03	4.132E-03	9.9	1,818	11,084	12,902
	500	5.860E-03	9.537E-02	1.012E-01	3.0	5,544	90,223	95,768
	1,000	2.314E-02	6.274E-01	6.506E-01	1.4	10,215	277,018	287,233
					Total	17,779	378,613	396,392
S4 (7.0k)	10	0.000E+00	1.318E-36	1.318E-36	9.6	0	0	0
	20	0.000E+00	3.139E-14	3.139E-14	41.1	0	0	0
	50	4.893E-07	1.684E-06	2.173E-06	27.1	4	14	19
	100	6.702E-05	2.390E-04	3.060E-04	7.9	167	595	762
	200	4.278E-04	5.283E-03	5.711E-03	9.9	1,336	16,495	17,831
	500	3.366E-03	1.091E-01	1.124E-01	3.0	3,184	103,188	106,372
	1,000	1.112E-02	6.096E-01	6.207E-01	1.4	4,909	269,151	274,060
					Total	9,600	389,444	399,044
S7 (12.0k)	10	0.000E+00	9.019E-12	9.019E-12	9.6	0	0	0
	20	2.534E-07	5.619E-07	8.153E-07	41.1	3	7	11
	50	1.037E-04	2.435E-04	3.472E-04	27.1	886	2,081	2,967
	100	5.117E-04	3.554E-03	4.066E-03	7.9	1,275	8,854	10,129
	200	1.510E-03	2.242E-02	2.393E-02	9.9	4,715	69,989	74,704
	500	3.762E-03	1.322E-01	1.360E-01	3.0	3,559	125,083	128,642
	1,000	7.633E-03	4.684E-01	4.761E-01	1.4	3,370	206,819	210,189
					Total	13,809	412,833	426,642
S9 (15.0k)	10	2.774E-04	2.421E-04	5.195E-04	9.6	840	733	1,573
	20	1.295E-04	2.512E-04	3.807E-04	41.1	1,678	3,256	4,934
	50	8.282E-04	3.857E-03	4.685E-03	27.1	7,078	32,965	40,043
	100	1.799E-03	1.373E-02	1.553E-02	7.9	4,483	34,210	38,693
	200	3.200E-03	3.425E-02	3.745E-02	9.9	9,991	106,919	116,910
	500	6.224E-03	1.317E-01	1.379E-01	3.0	5,888	124,574	130,462
	1,000	9.280E-03	3.547E-01	3.640E-01	1.4	4,097	156,591	160,688
					Total	34,054	459,248	493,303
S11 (19.0k)	10	0.000E+00	1.733E-09	1.733E-09	17.8	0	0	0
	20	9.704E-06	2.302E-06	1.201E-05	42.2	129	31	160
	50	1.282E-04	2.996E-04	4.278E-04	21.4	865	2,022	2,887
	100	5.283E-04	3.046E-03	3.575E-03	7.9	1,316	7,590	8,906
	200	1.645E-03	1.879E-02	2.043E-02	7.7	3,995	45,616	49,611
	500	5.967E-03	1.422E-01	1.482E-01	2.2	4,140	98,688	102,828
	1,000	1.501E-02	5.842E-01	5.992E-01	0.8	3,787	147,379	151,166
					Total	14,232	301,325	315,557
S22 (3.3k) (Hilabangan)	10	5.131E-04	3.368E-04	8.499E-04	73.2	11,838	7,770	19,608
	20	1.663E-03	1.947E-03	3.610E-03	12.3	6,452	7,553	14,005
	50	4.963E-03	1.053E-02	1.549E-02	9.3	14,555	30,881	45,437
	100	9.974E-03	3.270E-02	4.268E-02	3.3	10,379	34,035	44,414
	200	1.959E-02	1.054E-01	1.250E-01	1.6	9,883	53,189	63,072
	500	4.912E-02	4.495E-01	4.986E-01	0.1	2,169	19,845	22,013
	1,000	7.968E-02	1.162E+00	1.241E+00	0.1	2,513	36,638	39,151
					Total	57,790	189,910	247,700

Table VI-3-1 STUDY ON OPTIMUM DISCHARGE DISTRIBUTION IN EACH DIVERSION CASES

ALTERNATIVE CASE	ITEMS	UNIT	Case 1	Case 2	Case 3
	DISCHARGE DISTRIBUTION				
	ILOG RIVER	m3/s	1,900.0	2,650.0	3,700.0
	DIVERSION	m3/s	3,550.0	2,800.0	1,750.0
	RIVER WIDTH				
	ILOG RIVER	m	80-100	110-140	160-200
	DIVERSION	m	180	140	110
BINICUIL DIVERSION (0.0K-13.5K)	CONSTRUCTION COST *				
	ILOG RIVER	mil.P.	295.4	356.6	529.6
	DIVERSION	mil.P.	941.3	858.7	699.5
	COMPENSATION COST				
	ILOG RIVER	mil.P.	2.6	7.3	18.4
	DIVERSION	mil.P.	59.7	49.9	35.3
	TOTAL COST	mil.P.	1,299.1	1,272.5	1,282.8
	DISCHARGE DISTRIBUTION				
	ILOG RIVER	m3/s	1,900.0	2,650.0	3,700.0
	DIVERSION	m3/s	3,550.0	2,800.0	1,750.0
	RIVER WIDTH				
	ILOG RIVER	m	100	140	200
	DIVERSION	m	190	150	120
OLD ILOG DIVERSION (0.0K-6.0K)	CONSTRUCTION COST *				
	ILOG RIVER	mil.P.	130.1	165.3	231.1
	DIVERSION	mil.P.	358.2	307.7	257.1
	COMPENSATION COST				
	ILOG RIVER	mil.P.	1.6	3.7	8.3
	DIVERSION	mil.P.	12.7	9.6	4.9
	TOTAL COST	mil.P.	502.6	486.3	501.5
	DISCHARGE DISTRIBUTION				
	ILOG RIVER	m3/s	1,900.0	2,650.0	3,700.0
	DIVERSION	m3/s	3,550.0	2,800.0	1,750.0
	RIVER WIDTH				
	ILOG RIVER	m	80-100	110-140	160-200
	DIVERSION	m	180	140	110
SALONG DIVERSION (0.0K-15.0K)	CONSTRUCTION COST *				
	ILOG RIVER	mil.P.	332.2	387.3	538.8
	DIVERSION	mil.P.	843.4	773.0	699.5
	COMPENSATION COST				
	ILOG RIVER	mil.P.	3.3	9.0	22.4
	DIVERSION	mil.P.	59.9	50.1	42.8
	TOTAL COST	mil.P.	1,238.7	1,219.3	1,303.5

Note : This cost is including the indirect cost such as administration cost, engineering services and so on.