APPENDIX E

RIVER CONDITIONS

APPENDIX E

RIVER CONDITIONS

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CHAPTER I RIVER MORPHOLOGY

1.1 River System

The Laoag River, one of the major rivers of the Philippines, is situated in the province of Ilocos Norte which lies in the northwestern part of the island of Luzon. It has a total drainage area of 1,332 km^2, occupying some 39% of the provincial area of 3,399 km^2. The Laoag River Basin covers one city (Laoag City, capital of the province, about 500 km north of Manila) and nine other municipalities.

The Laoag River system is formed by numerous river networks with headwaters originating from the Luzon Central Cordillera, the largest and highest block of mountains along the west coast of Northern Luzon which extends to some 300 km at an elevation of as high as 2,000 m. The Laoag River flows down westward from the mountains and forms the alluvial fans in the middle reaches. After passing the downstream flood plains, it finally empties into the South China Sea, 8 km downstream of Laoag City (refer to Fig. E.1.1).

The main course is called "Laoag River" in the lower reaches after the confluence with Cura River, and "Bongo River" in the upper and middle reaches where it is joined by many tributaries that flow down the alluvial fans along its right bank. The major tributaries are the Papa, Solsona, Madongan, Cura and Labugaon rivers, as shown in Fig. E.1.1.

According to topographic conditions, the basin can be divided into four (4) sub-basins. These sub-basins are as described below.

(1) Upper Basin

The upper basin is the watershed of the six (6) major tributaries and the Bongo River. These tributaries originate from the western steep slopes of the Central Luzon Cordillera. With ground elevations suddenly changing from 2,300 m to 100 m within a distance of 20 km to 30 km, the basin is the source of sediment to the Laoag River System.

The six (6) major tributaries, with lengths of 8 km to 1 0 km and ground elevations ranging from 130 m to 30 m, run down the alluvial fans. The Bongo River, the southmost tributary, flows toward the north, joining the other tributaries along the edge of the fan.

The alluvial fans, covering an area of 201 km^2, are cut into sections by a number of reticulated channels which branch out from the major tributaries. This fan area is mainly utilized as an irrigated paddy field.

The upper basin consists of the following topographic components:

Mountains/Hills	:	633.9 km^2
Alluvial Fan	:	201.1 km^2
Total Area	:	835.0 km^2

The topographic characteristics of each tributary are summarized in the following table.

River	River Length (km)		Drainage Area in Mountains (km^2)	Average River Slope (%)	
	Whole Stretch	Alluvial Fan Area		Mountain Area	Alluvial Fan
Cura	29.5	12.5	69.5	8.00	0.48
Labugaon	25.0	3.7	100.5	6.57	1.08
Solsona	29.6	10.8	79.0	9.55	0.75
Madongan	35.0	9.1	153.8	7.86	1.06
Papa	18.5	7.2	51.4	11.42	1.23
Bongo	35.5	22.7	57.0	6.02	0.38

(2) Middle South Basin

The middle south basin is located on the left bank along the Bongo and Laoag rivers. This has an area of 160.0 km^2 with the hilly area accounting for about 70%.

The hills bound the Laoag River basin on the west, running from south to north at a ridge elevation ranging from 200 m to 500 m. Many small tributaries originate from this hilly area, and a narrow inland valley extends in the area surrounded by the hills. The tributaries drain flood water through this gently sloping valley where rice paddies are mainly cultivated. These tributaries finally flow into the Bongo or Laoag rivers.

Among the major tributaries, the Magalis and Suyo creeks drain into this basin. Magalis creek is the southmost tributary with a drainage area of 68.1 km^2, and Suyo creek is the northmost one with a drainage area of 50.0 km^2. The topographic features of both rivers are as follows:

Creek	Creek Length (km)		Drainage Area (km^2)	Average River Slope (%)	
	Whole Stretch	Alluvial Plain		Hilly Area	Alluvial Plain
Magalis	19.2	9.4	68.1	7.90	0.16
Suyo	17.0	14.5	50.0	6.68	0.41

(3) Middle North Basin

The middle north basin is the drainage area of the Guisit River. The Guisit River originates from the north ridge which has an elevation ranging from 300 m to 1,000 m. The basin has an area of 178.3 km^2, with mountains and hills accounting for 76%.

The channel of Guisit River has a relatively gentle slope of 0.41%. The topographic features of this river are as summarized below:

Drainage Area	:	178.3 km^2
River Length		
Whole Stretch	:	24.7 km
Alluvial Plain	:	14.5 km
Average River Slope		
Hills/Mountains	:	6.52%
Alluvial Plain	:	0.41%

(4) Lower Basin

The lower basin covers the lower reaches from the confluence of the Bongo and Cura rivers. A narrow alluvial plain extends between the hilly land. The alluvial plain along the Laoag River with a length of 31.6 km is highly developed as agricultural land and residential area. The river course in this stretch has a mild slope, ranging from 0.0212% at the river mouth to 0.0901% at the upstream end.

This basin has an area of 158.8 km^2, with the alluvial plain area accounting for 64% (101.6 km^2). The remaining area of 57.2 km^2 is a hilly land.

1.2 River Profile

As described in the preceding section, the Laoag River system consists of six (6) major rivers; namely, Laoag, Bongo, Cura/Labugaon, Solsona, Madongan and Papa. The Laoag River and the lower part of Bongo River flow through the alluvial plain, while the others flow through the alluvial fan. The conditions of both rivers are obviously different.

The following are the geomorphologic characteristics of these rivers.

1.2.1 Laoag River

(1) Alignment and Longitudinal Profile

Geomorphologic condition in the whole stretch of Laoag River is characterized by two natural bends. One is located 2 km upstream of the river mouth, and the other is located just upstream of the town of Sarrat (hereinafter called "Sarrat bend"). Their lengths are about 4 km and 7 km, respectively. The riverbed gradient apparently changes at the boundary of these bends, as shown in Figs. E.1.3 to E.1.5. The average slopes of the riverbed are as follows:

From river mouth to 5.4 km	:	0.0212%
From 5.4 km to 16.2 km	:	0.0690%
From 16.2 km to 23.4 km (Sarrat Bend)	:	0.0847%
From 23.4 km to 30.6 km	:	0.0901%

The river width ranges from 400 m to more than 1,000 m. The narrowest section of about 300 m wide is located at the upper portion of the Sarrat bend, and forms a natural constriction. Furthermore, the large point bars formed along both bends have an enormous storage volume to control the excessive sediment.

(2) Sandbar Configuration and Movement

Point bar is firmly formed in each bend. Alternating sandbars are formed between the bends, with about 5 km of wave length. In the space of 10 km long restricted by both bends, sandbars have repeated expansion and contraction movements. In the upstream portion of Sarrat bend, sandbars are formed with less than 3 km of wave length. This movement is also blocked by the Sarrat bend.

(3) Bank Erosion

With the formation of point bars and alternating sandbars, bank erosion occurs alternatively on each bank. Once erosional banks are formed, they are almost fixed or not too movable because of the restriction created by both bends.

Under these conditions, deep local scouring of 2 to 4 m occurs along the erosional bank, as presented in Figs. E.1.4 and E.1.5. Flood water always converges and scours on the fixed erosional bank, causing deep local scouring. In particular, the concave banks along the bending portions are very much deeply scoured.

1.2.2 Bongo River

(1) Alignment and Longitudinal Profile

The lower part of Bongo River flows along the end of the alluvial fan, gathering stream water through the fans. In the upper stretch of the confluence with Papa River, the Bongo River flows through the alluvial fan formed by itself. For easy understanding, Bongo River is divided into two (2) stretches, the lower and upper portion, as described below.

(a) Lower Bongo River

The lower part of Bongo River extends from the confluence with Cura River to the confluence with Papa River, about 11 km long. In this stretch, the riverbed slope gradually increases from 0.151% to 0.200%, while the river width gradually decreases from 600 m to 300 m, as shown in Fig. E.1.6.

(b) Upper Bongo River

The upper part of Bongo River flows down through the alluvial fan. This stretch has a length of 12 km and a width of 300 m to 400 m on average. The riverbed slope gradually increases from 0.311% to 0.943%, as shown in Fig. E.1.7.

(2) Sandbar Configuration and Movement

(a) Lower Bongo River

Most of the stretch of the Lower Bongo shows a straight channel alignment. Single or dual mode of alternating sandbar is formed on the riverbed. The wave length of sandbar is about 2 km.

The movement of sandbars is restricted by the confluence with major tributaries, Solsona and Papa, which are located at both ends of the stretch. Therefore, these alternating sandbars are likely fixed with allowance for small expansion and contraction.

(b) Upper Bongo River

Alternating sandbars are formed in the stretch of 6 km between the confluences with Papa and Cabulalaan rivers. The average wave length is about 1.2 km.

In the upper stretch from the confluence with Cabulalaan River, a braided bed composed of small scale bars is formed, as shown in Fig. E.1.7. These sandbars can easily progress downwards with flood water easily shifting it with braiding, resulting in bank erosion.

(3) Bank Erosion

(a) Lower Bongo River

The stream of Bongo River is pressed on the left bank due to perpendicular-shaped junctions with torrents running down the steep channels on the alluvial fan. Flood water mainly erodes the left bank where terraces are formed by deposits of silt and clay. The flood water washes out the toe portion first then the bank finally collapses.

As shown in Fig. E.1.6, local scouring is not so serious compared with the Laoag River. Sandbars are smaller and there are no bends.

(b) Upper Bongo River

During Typhoon Gloring in 1996, at least two bank portions were seriously eroded. One site is the bend located just upstream of the junction with Magalis creek and the other site is the right bank of 48.6 km to 50.4 km where the river course is most frequently braided. These are illustrated in Fig. E.1.7.

Around the fan apex of the Bongo River, there are few distributaries which were formed in the past. Therefore, there is a low possibility of channel shifting. Fig. E.1.7 indicates the potential channel shifting zone based on aerial photo interpretation.

1.2.3 Cura/Labugaon River

(1) Alignment and Longitudinal Profile

At present, the Cura/Labugaon River has the most developed braided channel. There are many distributaries formed over the alluvial fan area.

The Cura River has a more gentle slope of 0.763% around the fan apex while the Labugaon River has a slope of 1.08%. After joining together, the Cura River gradually reduces its riverbed slope to 0.331% at the confluence with Bongo River, as shown in Fig. E.1.8. River width varies in each branch from less than 100 m to 1,000 m.

(2) Sandbar Configuration and Movement

Along each branch, small scale bars are formed. Immediately after the 1996 typhoon Gloring, big scale alternating bars were observed in the middle reaches encompassing the small scale bars. These bars can progress downwards, dominate the flood flow direction and cause bank erosion.

(3) Bank Erosion

In 1996 during typhoon Gloring some portions of the riverbank were eroded by strong current in a semi-circle shape following the sandbar formation. The main stream and eroded bank observed after the typhoon are shown in Fig. E.1.8. Before the typhoon, the main streamflow of Labugaon River was towards the northwest along the mountain ridge in the fan apex. The river course shifted to the south after the typhoon due to heavy sedimentation which clogged the former channel.

1.2.4 Solsona River

(1) Alignment and Longitudinal Profile

The Solsona River System which includes the Madongan River has the largest drainage area among the major tributaries running through the alluvial fan. The river channel changes its slope of 0.137% at the fan end to 1.54% at the fan apex. The present diking system was constructed in 1993. The width between dikes ranges from 230 to 330 m and the depth is 3.2 to 4.5 m with freeboard of 1.0 m.

Channel alignment has five bends. One is located at the upstream end, and the rest in the middle reaches as shown in Fig. E.1.9. These bends dominate the sandbar formation and flood water convergence.

(2) Sandbar Configuration and Movement

Alternating sandbars are clearly observed in the lower and middle reaches. In the lower reach, flood water and transported sediment from the Madongan River dominate sandbar formation while bends dominate in the middle reach. Sandbars have a wave length of about 2 km in the lower reach and about 1 km in the middle reach. Movement of those sand bars is restricted by the confluence and bends.

After the 1996 typhoon Gloring, alternating sandbars were observed with similar wave lengths in the middle reaches.

(3) Bank Erosion

During large floods, the predominant sandbar is the single alternating bar formation. Fig. E.1.9 shows the comparison between floods of the 1992 typhoon Maring and 1996 typhoon Gloring. Breached sections in the diking system of both floods fit well with the convergence points of sandbars.

Bank erosion and dike breach could occur following the sandbar formation. Thus, the dike sections converged by flood waters can be pointed out as appropriate for river protective structures.

The potential channel shifting zone is located along the left bank 3 km long from the upstream end. If this section is breached, flood waters will flow towards the southeast following the former channel, then join with the Cuyep-cuyep River or cause inundation in the area encompassed by the Solsona and Cuyep-cuyep rivers.

1.2.5 Madongan River

(1) Alignment and Longitudinal Profile

The Madongan River has the largest distributary system which spread out 80 degrees radially from the fan apex. The river channel changes its slope of 0.452% at the confluence with Solsona River to 1.35% at the fan apex. A steep channel with a slope of 1.35% extends over 5.5 km downstream of the fan apex. The present diking system was also constructed in 1993. It has a width of 300 m between dikes and a depth of 3.6 m with freeboard of 1.0 m.

Channel alignment has one bend at the upstream as shown in Fig. E.1.10. The other portion has an almost straight alignment.

(2) Sandbar Configuration and Movement

Dual mode alternating bars are predominant in the Madongan River channel. These sandbars can easily move forward and erode the existing dike in a wide range.

(3) Bank Erosion

The concave bank of the upstream bend has always suffered bank erosion and local scouring. If this bank is completely washed out, flood water can spread out through the former channel over the fan areas. This potential channel shifting zone is located along the concave bank as shown in Fig. E.1.10.

In the Madongan River excluding the upstream bends, bank erosion will occur randomly as dual mode sandbars progress during floods.

1.2.6 Papa River

(1) Alignment and Longitudinal Profile

The Papa River channel has the steepest slope of 1.85% in the fan apex among the major tributaries. Its present diking system was also constructed in 1993. It has a width of 223 m between dikes and a depth of 4.0 to 4.2 m with freeboard of 1.0 m.

Channel alignment has one bend at the upstream as shown in Fig. E.1.11. The other portion has an almost straight alignment.

(2) Sandbar Configuration and Movement

Alternating sandbars are formed in the upper and middle reaches. The bend at the upstream dominate sandbar formation and movement until the middle reaches. Sandbars have a wave length of about 1.2 km.

(3) Bank Erosion

Fig. E.1.11 shows breached sections and flow directions in the floods of 1992 typhoon Maring and 1996 typhoon Gloring. In the upper and middle reaches, breached sections of the diking system in both floods fit well with the convergence points of sandbars. Furthermore, breached sections in the lower reaches by 1992 typhoon Maring follow the former meandering course.

Serious local scouring occurs along the concave bank of the upstream bend. It is caused by flood water convergence as well as high current due to steep slope.

Around the fan apex of Papa River, distributary channels are not formed so there is small possibility of channel shifting. Flood water after dike breach tends to flow outside along the dike and finally return to the river channel after running hundreds meters outside.

1.3 Historical Change of Rivers

1.3.1 Historical Change of Alignment

The following data were collected to clarify the historical changes of river course.

(1) Aerial Photograph

(a) Photo taken by NIA in 1975, covering the alluvial fan area with a scale of 1:8,000;

(b) Photo taken by NIA in 1991, covering the whole basin with a scale of 1:8,000; and

(c) Photo taken by the JICA Study Team in 1996, covering most of the basin with a scale of 1:20,000.

(2) Topographic Map (1:50,000)

(a) Map based on aerial-photos in 1947 to 1953; and

(b) Map based on aerial-photos in 1977.

Using the above information, the historical changes of river courses were examined as illustrated in Figs. E.1.12 and E.1.13. The historical changes in each river course are summarized below.

(1) Laoag River

There is no particular change in river course from the 1950's to date. There are two big bends which were formed by geological dynamics. These bends are located near Mount Cavit and between Sarrat and Dingras. Point bars, with length of about 3 km and 5 km are formed on the convex bank along those bends. These stabilized sandbars regulate the movement of alternating bars. Therefore, the convergence sites of flood water or erosional banks are stationary.

(2) Bongo River

The change in river course is mainly influenced by the location of the confluence with other tributaries like the change in confluence point with the Madongan River. The

Bongo River channel is always pushed against its left bank at the confluence with the major tributaries.

Regarding longitudinal change, channel form changes from braided channel to alternating sandbar formation around the confluences with Magalis creek and Papa River. The upper reaches of these confluences have a riverbed slope of more than 0.3%, while the lower reaches have a slope of less than 0.2%. The upper reaches can be regarded as an alluvial fan area.

(3) Cura/Labugaon River

The Cura/Labugaon River forms a braided stream system from the fan apex to the confluence with the Bongo River. In the 1950's the main stream flow through the south course. After typhoon Wanda in 1962, Gening in 1967 and Huling in 1973, the main stream changed to the north course. This has not changed since then. However, flood waters continuously erode the riverbank due to progressive meandering.

Based on the historical change, the stretch around the confluence of the Cura and Labugaon rivers which is located around the fan apex, is the most essential to be provided with structural measures. This stretch is formed with many branch channels and one of the channels connects with the Solsona River just north of the Solsona town proper.

(4) Solsona River

According to history, two big floods swept the town of Solsona in 1855 and 1904. Then Solsona was annexed to Dingras.

In the 1950's the main stream ran through a straight course toward the west from the fan apex. After the three typhoons in the 1960's and the early 1970's, the main stream changed its course to the former channel of the south route. The areas along the former channel were restored as agricultural land at that time. Flood water again devastated these areas until the early 1990's.

The main stream was finally stabilized to the present channel by the urgent disaster prevention works in 1993.

(5) Madongan River

The Madongan River is the most intensively braided river among the major tributaries. At least seven channels were radially developed from the apex in the alluvial fan until the early 1950's.

In 1975 the main stream concentrated to the southern three distributaries. In 1991 the main stream changed to the northernmost channel, which was selected as object of the urgent disaster prevention works.

In 40 years of tracking, the Madongan River frequently shifted its main stream along the former distributary channels. However, the stretch affected is only limited to about 2.5 km long from the fan apex.

(6) Papa River

Compared with the Cura/Labugaon and Madongan rivers, the Papa River is a less intensive braided river. Flood water destroyed the agricultural land along its course due to the progressive meandering. Although the Papa River has the steepest slope, no significant distributary channel exists around the fan apex. Thus, there is a small possibility of channel shifting.

1.3.2 Historical Riverbed Variation

There are no available cross section data to verify the historical changes in riverbed variation in the basin. The only data concerning riverbed variation are water level at two stations, Gilbert Bridge and Dingras. Although the data have some interruptions for 39 years, historical change of riverbed can be examined by using the lowest water level of each year.

Fig. E.1.14 shows the historical change of lowest water level at both stations. The data are adjusted in accordance with replacement of water gauge. With only observed lowest water level as tool for examining historical change, riverbed variation cannot be verified significantly.

1.4 River Mouth Clogging

1.4.1 River Mouth Geomorphology

(1) Coast

According to the sounding results, the nearshore has a gentle slope of 1.0 to 1.1% between 0 m and -10 m in depth. Its contour line runs in parallel with the shoreline. The nearshore around the river mouth is gentle and stabilized. Offshore bar is formed around a depth of -4 m where the wave is broken.

(2) River Mouth

River mouth terrace, 500 m long from the mouth, is formed below -2 m. There are two outlets in the mouth, south and north outlets. The south terrace is larger than the north, so that a major part of the flood waters have been passing through the south outlet.

The predominant direction of sand drift can be judged from the direction of river mouth bar development. River mouth bar develops from north to south in the Laoag river mouth. Thus, the predominant direction of sand drift is southward, but sand drift may change direction according to season.

1.4.2 Change of River Mouth during Rainy Season

Topographic change of the river mouth was continuously observed during this study period. Fig. E.1.15 illustrates the topographic changes of the river mouth from the end of March to the beginning of August, 1996. The monitoring results are summarized below.

(a) During the dry season, the south outlet is always clogged. To open the outlet, continuous maintenance dredging is necessary.

(b) At the beginning of the rainy season, a drain channel can be formed at the outlet even by small-scale flood.

(c) During big-scale floods, the clogging sandbar is easily washed out, then a wide channel is formed.

The following were the observed changes in the river mouth.

(1) Changes during Dry Season (March 21 to May 17)

Every dry season, the residents of Brgy. La Paz dredge a channel at the south outlet using a bulldozer. However, this outlet was clogged by sand drift deposits, 30 m wide and 2 m high, by May 17. On the other hand, the north outlet shifted 250 m to the south due to the development of river-mouth bar. Surface water still flows through a channel 20 m wide and 1 m deep. According to the residents, the north outlet has never been clogged in a year.

(2) After Moderate Rainfall (May 25)

The Laoag river basin received moderate rainfall during typhoon Ditang in May 22. According to the DPWH observation, water level at the Gilbert Bridge rose from 0.5 m to 1.2 m. After the rain, stream water washed out the sandbar, then formed its own waterway 50 m wide and more than 2 m deep. At that time the south outlet was still clogged.

(3) After Typhoon Gloring (August 10)

Typhoon Gloring brought heavy downpour in the basin from July 24 to July 25. The peak discharge at the Gilbert Bridge reached 9,500 m^3/s, which is equivalent to a 15-year return period.

After the big-scale flood, the river mouth drastically changed. Two channels 350 m wide by 3 m deep and 150 m wide by 2 m deep were formed at the south outlet. At the north outlet flood water also washed out the sandbar, then enlarged the existing channel to 300 m wide and 3 m deep.

1.4.3 Backwater Effects

During the heavy rains due to Typhoon Gloring, the river-mouth bar may have been washed out in the early stage of the flood, because no inundation occurred in the two villages of La Paz and Gabu which are located along both banks near the river mouth. If there were any effects of backwater caused by river mouth clogging, these villages should have been inundated during the flood.

From the viewpoint of flood control, the river-mouth bar will be easily eroded in the early stage of the design flood. Thus, maintenance dredging works or river training structures are not necessary.

In addition, to quantify the backwater effects of river mouth clogging, non-uniform flow calculation was made. In this calculation the following two cases were considered:

(a) River mouth with sand bar formation referring to the cross section survey results executed in April 1996.

(b) River mouth in which sand bar is washed out referring to the topography after typhoon Gloring.

Fig. E.1.16 shows the backwater effects of river mouth clogging by the peak discharge of 11,200 m^3/s as the design flood. The estimated effects are as follows:

(a) The maximum difference of 1 m occurs at the river mouth, then the difference is gradually reduced.

(b) The water level difference at the bend near Cavit, 4.5 km upstream of the river mouth, is estimated at less than 0.1 m.

(c) At the Gilbert Bridge, 8.3 km upstream of the river mouth, the difference is only 0.01 m which shows that backwater effect due to river mouth clogging is very minimal to the upper reaches.

1.5 Riverbed Materials

The difference in longitudinal changes of riverbed materials removed from the surface layer cannot be traced in the alluvial fan area due to enormous sediment supplied from the mountain streams. The surface layer of boulders and cobbles changes longitudinally with the changes in riverbed gradient. The typical distribution of riverbed material are summarized below.

Sediment Size	Fan Apex & Middle Reach of Fan	Fan End	Laoag River
Large Cobbles & Small Boulders (128 - 512 mm)	8%	-	-
Very Coarse Pebbles & Small Cobbles (32 - 128 mm)	21%	16%	10%
Medium & Coarse Pebbles (8 - 32 mm)	29%	32%	22%
Very Fine & Fine Pebbles (2 - 8 mm)	23%	25%	35%
Sand (0.125 - 2 mm)	19%	27%	33%

The surface of river course around the fan apex is covered by boulders with grain size of 300 to 1,000 mm. In the middle and lower reaches of the fan area, the predominant grain size of surface layer is reduced to 100-200 mm. Furthermore, it is reduced to 50-100 mm in the Laoag River channel.

1.6 Flood Carrying Capacity of Rivers

Present flow capacities of the river channels were assessed by non-uniform flow calculation using Manning's roughness coefficient of $n = 0.035$ for channels in the Laoag, lower Bongo and Guisit rivers, and $n = 0.04$ for channels in the major tributaries of the alluvial fan, based on the surveyed channel cross-sections conducted by the JICA Study Team during the dry season of 1996.

(1) Laoag - Bongo River

Since there is no diking system along the river channels, the present flow carrying capacity was calculated based on the top of banks. The Laoag River has bankful flow capacities of about 5,000 m^3/s (about a 2-year probability) downstream from Sarrat town and 2,000 m^3/s to 5,000 m^3/s (a 2-year to 4-year) upstream of the confluence with the Guisit River. The Bongo River has flow capacities ranging from 500 m^3/s to 2,000 m^3/s (about a 5-year). (See Fig. E.1.17)

(2) Guisit River

The present bankful carrying capacity of Guisit River ranges from 500 m^3/s to 1,000 m^3/s (a 2- to 10-year) as shown in Fig. E.1.18.

(3) Papa River

Since there is an existing diking system along the downstream portion of the dam, the present carrying capacity was calculated on account of 1 m freeboard at the top of dikes. Fig. E.1.19 shows the carrying capacity ranging from 1,000 m^3/s to 1,500 m^3/s (more than a 100-year).

(4) Madongan River

The present carrying capacity of this river was calculated considering 1 m elevation below the top of the existing diking system. Fig. E.1.19 shows the carrying capacity. Madongan River has a flow capacity of 2,000 m^3/s, more or less, equivalent to a return period of 25-year.

(5) Solsona River

The dike of Solsona River has flow capacities ranging from 1,000 m^3/s to 1,300 m^3/s at the elevation 1 m below the dike top as shown in Fig. E.1.20, equivalent to a 25-year return period.

(6) Labungaon/Cura River

Since the Labugaon/Cura River is not controlled yet, it can freely change its course. The river channel is very wide but very shallow. The present bankful flow carrying capacities lie between 500 m^3/s and 2,000 m^3/s (Fig. E.1.20).

CHAPTER II EXISTING RIVER STRUCTURES

2.1 Urgent Disaster Prevention Works

During the first half of the 1990's, three major tributaries, namely, Papa, Madongan, and Solsona rivers were confined by diking system under the Urgent Disaster Prevention Works (UDPW), as a part of the Ilocos Norte Irrigation Project (INIP), Phase I.

INIP (Phase I) implemented by NIA included the construction of five diversion dams (Labugaon, Solsona, Madongan, Papa and Nueva Era), construction of link roads to connect the five dams, and improvement/construction of irrigation and drainage canals covering 10,890 ha. INIP (Phase I) was started in the middle of 1981 and major works were completed in 1986 with financial assistance from OECF.

Immediately after completion of these facilities, the irrigation facilities were considerably damaged by successive typhoons. NIA decided to protect the service area from disasters through the urgent flood control works.

The UDPW were executed from 1992 to 1993 for the three tributaries, using the OECF Loan balance of INIP (Phase I). Major features of urgent improvement works of the three tributaries are listed below and details are shown in Table E.2.1.

Items	Unit	Solsona River	Madongan River	Papa River
Design Flood Scale	year	1/20	1/20	1/20
Design Flood Discharge	m^3/s	940, 1,096 and 2,671	1,615	780
Channel Length improved	m	11,065	8,487	7,352
Channel Width	m	230 to 330	300	223
Bed Slope		1/76 to 1/714	1/114 to 1/190	1/60 to 1/200
Levee Length	m	19,574	13,020	12,177
Channel Excavation	m^3	1,361,000	1,227,000	712,000
Levee Embankment	m^3	647,000	436,000	299,000
Cost	pesos	120 million	107 million	52 million

2.2 Present River Control Works

Except for UDPW, to date, only locally small-scale river control works have been done in the Laoag River System, such as stone concrete bank protections (revetments) and spur dikes. These works were mainly implemented by District Offices I and II, Region I, of DPWH.

2.3 Existing River Structures

Existing structures constructed along/in the river channels of the Laoag - Bongo and its major tributaries are (1) river control structures such as dikes, spur dikes, and revetments, and (2) irrigation facilities such as diversion dams, pumping stations, brush dams (temporary embankment for irrigation water supply), and others (bridges, roadway crossings and drainage openings/culverts). The location of these structures is shown in Fig. E.2.1.

2.3.1 River Control Structures

(1) Dikes

Systematic dikes were constructed along the Papa, Madongan and Solsona rivers using only alluvial materials (sand/gravel) excavated from the riverbed under the UDPW. As shown in Figs. E.2.2 and E.2.3, their dimensions are: width of 4.0 m, 1:2.0 side slopes for both river and landside, and 1.0 m of freeboard.

(2) Spur Dikes

A spur dike is a river control measure well used singly or in series in the whole Laoag River System to provide protection from bank erosion. Applied spur dikes as shown in Fig. E.2.4 are made of stone available locally forming a trapezoidal section. Structural dimensions of these impermeable spur dikes are crest width of 1.5 to 3.0 m and slopes of 1:1.5 to 1:2.0 for both sides. Height of spur dikes is designed to be submerged during flood. Almost all spur dikes are inclined downstream.

As proof of the effective application of spur dikes, a series of spur dikes at Dingras town has shown satisfactory results. The Dingras spur dikes were constructed in 1975 in a series of 14 units to prevent bank erosion at the left bank of the Laoag River (30 km upstream of river mouth) (refer to Fig. E.2.5). These spur dikes with a height of 3 m are submerged during floods. They are more or less made of stones of 30 cm in diameter. Average length of spur dikes is about 40 m. The distance between spur dikes is about 100 m. They were built at right angles to the river bank or inclined slightly downstream. At present, deposits between them are well developed as if a new bank was produced.

(3) Revetments

In the Laoag River System two types of revetment were constructed; stone concrete revetment and gabion mattress. Gabion type revetment can be found at the Papa, Madongan and Solsona rivers to protect the diking system. On the other hand, stone concrete revetment were provided at important locations such as the right bank of the Laoag city urban area and along the bridge approaches (refer to Fig. E.2.6; details of typical revetment).

At some sections stone concrete revetments were damaged. Observation shows that anchorage of slope protection into riverbed is not enough against toe scouring and structural strength of revetment is not sufficient to withstand itself in the absence of the toe protection; because concrete covers only the surface of stones for about 10 cm. The voids between stones should be filled with mortar to reinforce the structure.

2.3.2 Irrigation Facilities and Others

(1) Diversion Dams

Diversion dams to take water for irrigation purpose were constructed as part of INIP (Phase I) in the middle 1980's. They are located at the top of alluvial fans of the Labugaon, Solsona, Madongan, Papa and Bongo rivers. Their major design features are listed in Table E.2.1 and Figs. E.2.7 to E.2.11. After the completion, these dams were repaired under the UDPW because they (especially aprons) were severely damaged by cascading boulders due to successive floods.

(2) Pumping Stations for Irrigation Water Supply

There are three NIA pumping stations r constructed in the middle 1970's along the left bank of the Laoag River:

Name	From river mouth (km)	No. of Pump Units	Pump Capacity (m^3/min)	Designed Service Area (ha)
Bonga Pump #1	16.8	2	37.85	660
Bonga Pump #2	11.7	3	151.41	1,800
Bonga Pump #3	5.8	2	34.06	600

(3) Brush Dams

A number of brush dams for the intake of irrigation water were installed by the local communities along the rivers. Brush dams, small transverse embankments, were constructed using river bed materials. Since they are not equipped with gates, flood waters can easily enter the canals.

(4) Bridges

There are seven bridges crossing the major rivers; 5 bridges crossing the Laoag-Bongo River and 2 bridges crossing the Cura River. Gilbert Bridge crossing the Laoag River at Laoag City has the longest span of 748 m (4 lanes). The other bridges with 2 lanes were constructed in the middle 1980's as part of the Ilocos Norte Rural Road Development by DPWH with financial assistance from OECF. The bridges in the alluvial fan area are sometimes damaged by flood scouring between abutments and road approach due to insufficient revetment around the abutments. No remarkable scouring around bridge piers were observed. Major features of these existing bridges are listed in Table E.2.2 and shown in Fig. E.2.12 and Fig. E.2.13.

(5) Roadway Crossings

Concrete paved roadway crossings were constructed on the riverbeds of the Papa, Madongan and Solsona rivers for convenience of the communities under the UDPW. At present, these paved road crossings have also the function of riverbed fixation. Scouring of 1 m to 2 m deep immediately downstream of roadway crossings and aggradation of the riverbed in the upstream portion of the roadway are observed.

(6) Drainage Openings/Culverts

To drain water in the inland area, pipe culverts or box culverts are installed; several of them exist at Brgy. Gabu and Laoag urban area in the lower reaches. In the middle reaches they can be seen along the Papa, Madongan and Solsona rivers.

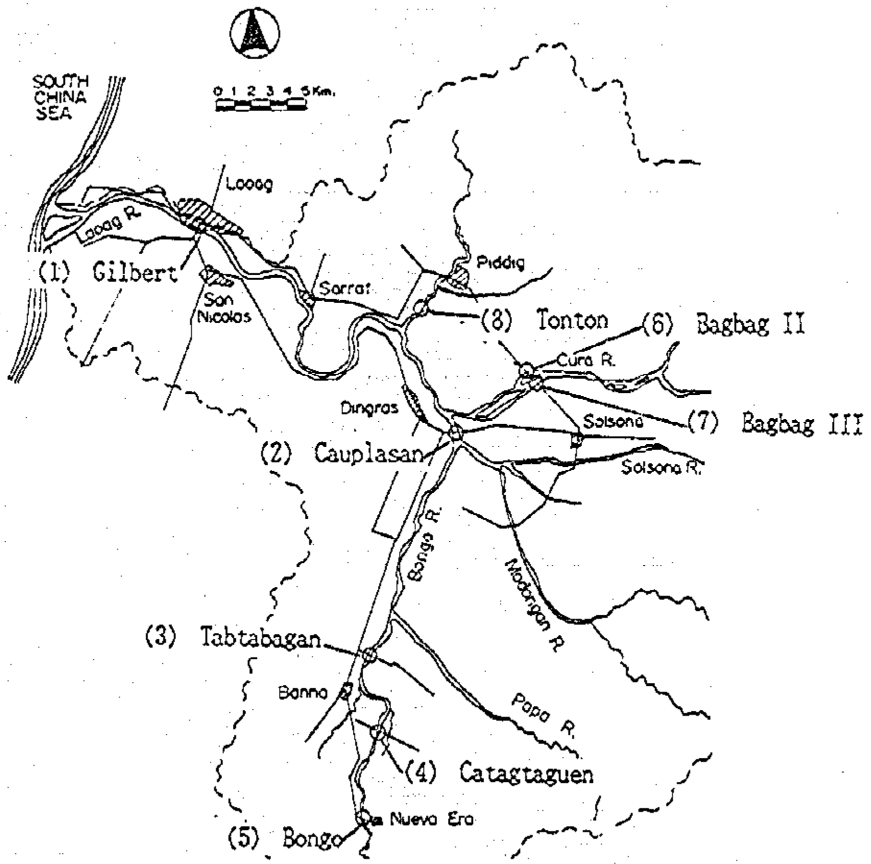
TABLES

Table E.2.1 Principal Features of Urgent Disaster Prevention Works

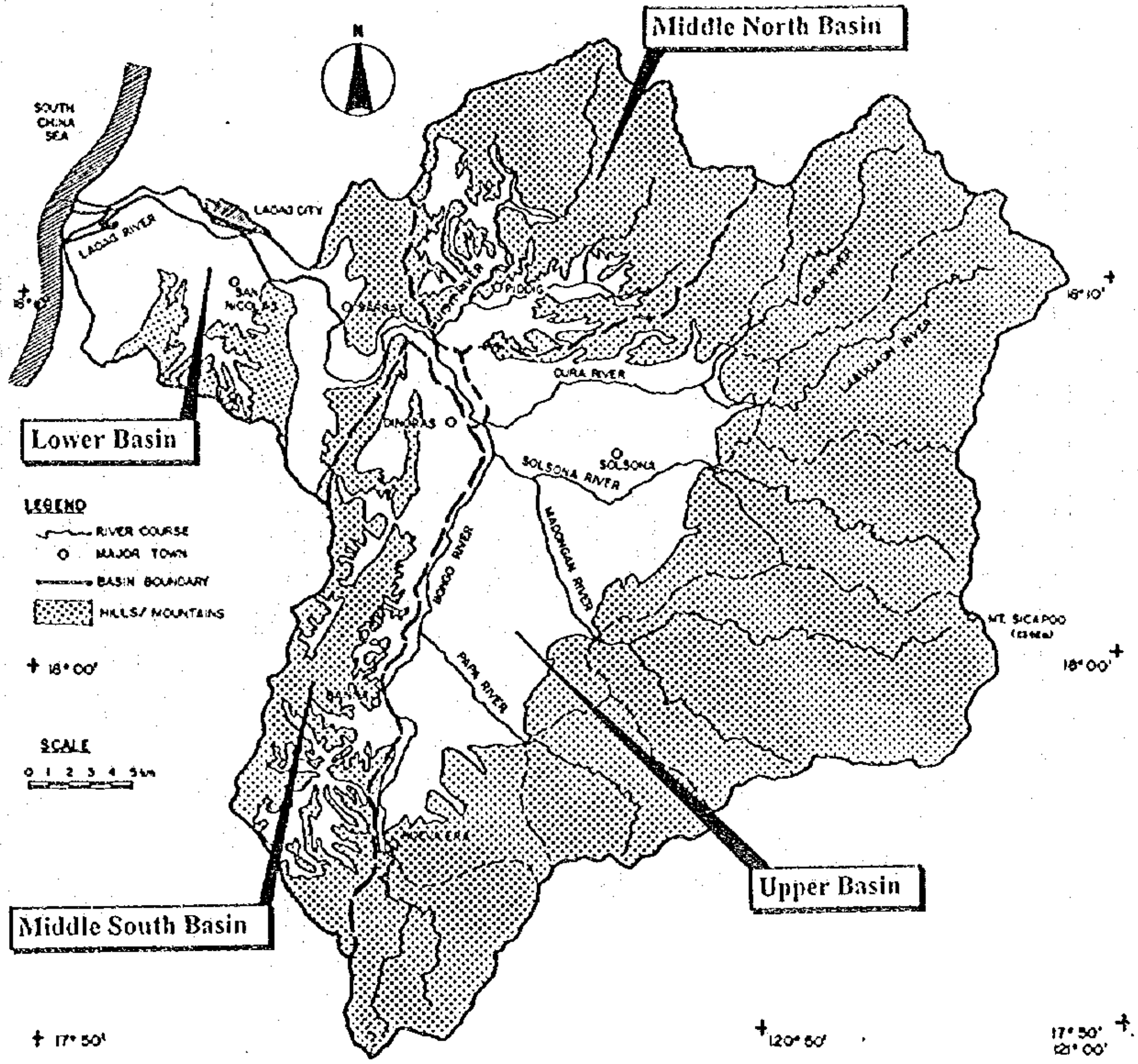
	Unit	Solsona River	Madongan River	Papa River
Design Scale	Year	1/20	1/20	1/20
Design Discharge	m3/s	940, 1096 & 2,671	2,136	1,039
Channel Length	m	11,065	8,487	7,352
Channel Width	m	230 - 330	300	223
Low Water Channel Width	m	100 - 200	97 - 128	89
Depth (Low Water Channel)	m	1.0 - 1.2	1.0 - 1.15	0.9 - 2.5
Depth (High Water Channel)	m	1.2 - 2.3	1.45 - 1.6	0.7 - 2.1
Freeboard	m	1.0	1.0	1.0
Design Bed EL. of Dam Fixed Weir	EL.	110.95	124.85	135.85
Design Bed EL. of Beginning Point	EL.	106.15	120.00	132.74
Design Bed EL. of End Point	EL.	23.63	26.66	41.20
Design Bed Slope		1/76 - 1/714	1/114 - 1/190	1/60 - 1/200
Dike Length	m	19,574	13,020	12,177
- Type 1 (Compacted w/ Gabion)	m	837	1,486	375
- Type 2 (Compacted)	m	2,230	981	1,457
- Type 3 (Dump Excavated Mat.)	m	8,559	2,001	4,437
- Dump Fill	m	7,948	8,553	5,908
Open Dike	nos	0	3	0
Intake	nos	3	8	2
Drainage Culvert	nos	10	3	3
Drainage Opening	nos	3	4	3
Roadway Crossing	nos	1	1	1
Spur Dike	nos	102	0	0
Gabion	m3	5,503	19,157	2794
Bamboo Skelton	pcs	8,759	2,403	3835
Earthwork	m3	2,008,000	1,663,000	1,010,000
- Channel Excavation	m3	1,361,000	1,227,000	712,000
- Dump Fill	m3	400,000	287,000	187,000
- Compacted Embankment	m3	97,000	130,000	72,000
- Boulder/Cobble Embankment	m3	150,000	19,000	39,000
Rivised Contract Cost	mill. pesos	120	107	52
Construction Period	months	23	22	15

Table E.2.2 Major Existing Bridges

	Bridge Name	Location	Length (m)	Width (m) (Nos. of Lanes)	Bottom EL. of Girder (m)	Nos. of Span	Pier Type	Superstructure Type
(1)	Gilbert	Laoag R., 8.3km	748	18 (4)	10.57	15	Solid Shaft	Steel
(2)	Cauplasan	Bongo R., 32.0km	813	9 (2)	30.42	11	Solid Shaft	Steel
(3)	Tabtabagan	Bongo R., 44.0km	300	5 (2)	47.50	20	Solid Shaft	Reinforced Concrete
(4)	Catagtaguen	Bongo R., 48.6km	270	5 (2)	65.29	18	Solid Shaft	Reinforced Concrete
(5)	Bongo	Bongo R., 53.6km	247	9 (2)	110.20	7	Two Columns	Steel/Reinforced Con.
(6)	Bagbag II	Cura R., 4.8km	315	9 (2)	40.70	21	Two Columns	Reinforced Concrete
(7)	Bagbag III	Cura R., 4.8km	225	9 (2)	42.12	15	Two Columns	Reinforced Concrete
(8)	Tonton	Guisit R., 1.6km	75	8 (2)	24.92	6	Two Columns	Reinforced Concrete



FIGURES



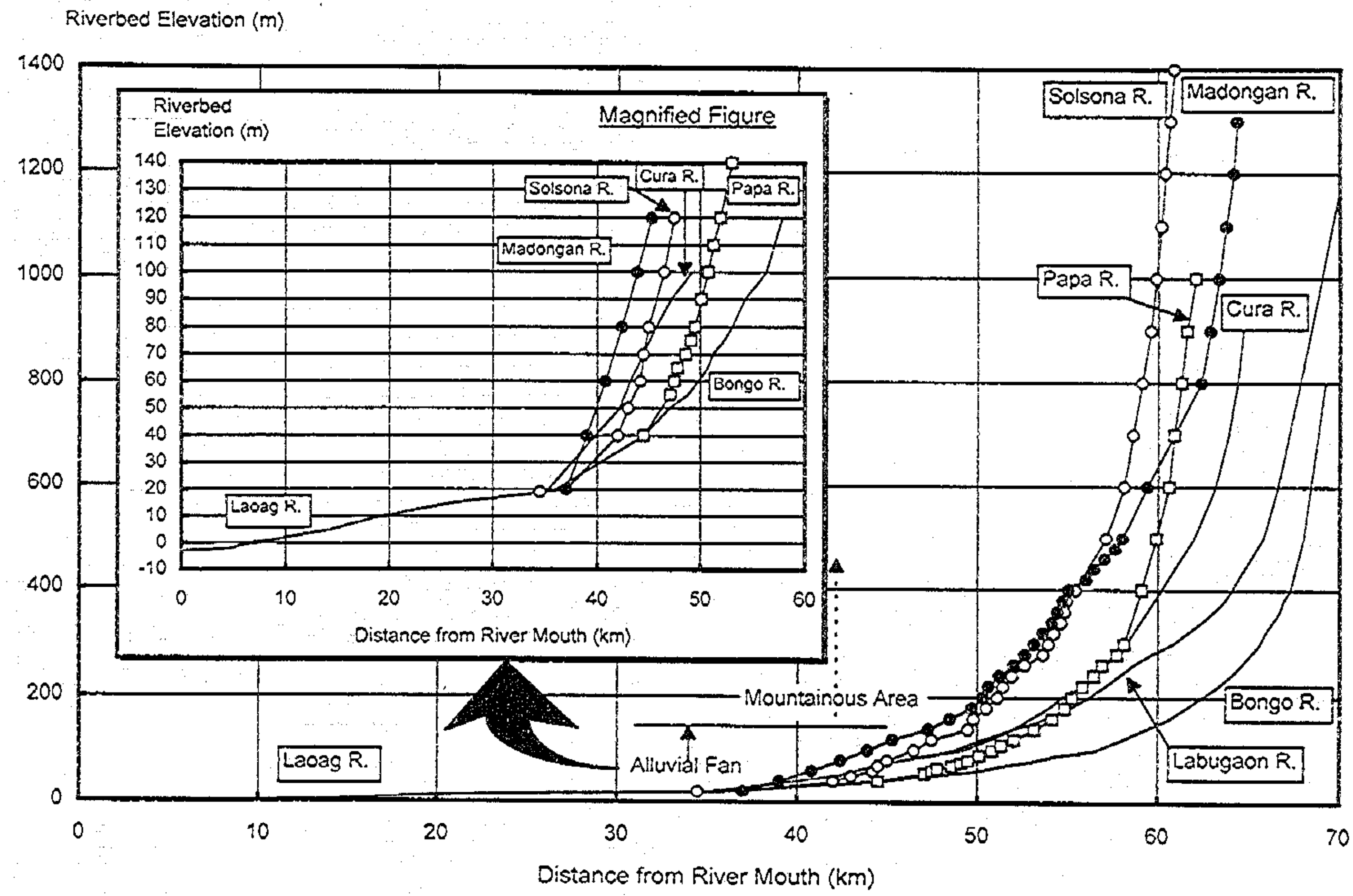
Sub-Basin	Topographic Components	Area	Remarks (Major Tributaries)
Upper Basin	Mountains/Hills	633.9 km²	Cura R., Labugaon R.,
	Alluvial Fan	201.1 km²	Solsona R., Madongan R.,
	Total	835.0 km²	Papa R., Bongo R.
Middle South Basin	Hills	109.0 km²	Magalis C., Suyo C.
	Alluvial Plain	51.0 km²	
	Total	160.0 km²	
Middle North Basin	Mountains/Hills	135.5 km²	Guisit R.
	Alluvial Plain	42.8 km²	
	Total	178.3 km²	
Lower Basin	Hills	57.2 km²	
	Alluvial Plain	101.6 km²	
	Total	158.8 km²	
Whole Basin	Mountains/Hills	935.6 km²	(70.2 %)
	Alluvial Fan	201.1 km²	(15.1 %)
	Alluvial Plain	195.4 km²	(14.7 %)
	Total	1332.1 km²	

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. E.1.1

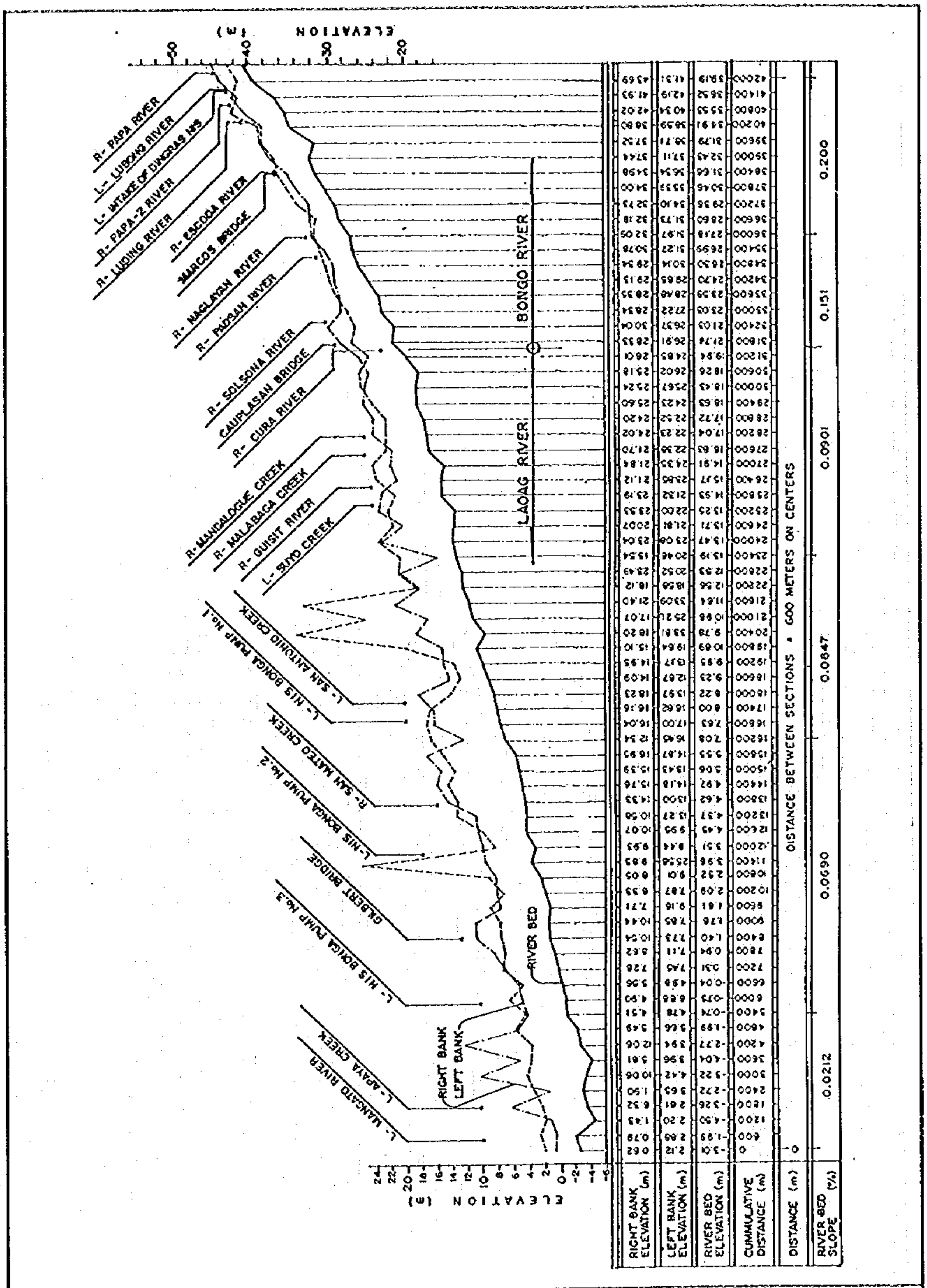
Location and Main Features of Laoag River Basin



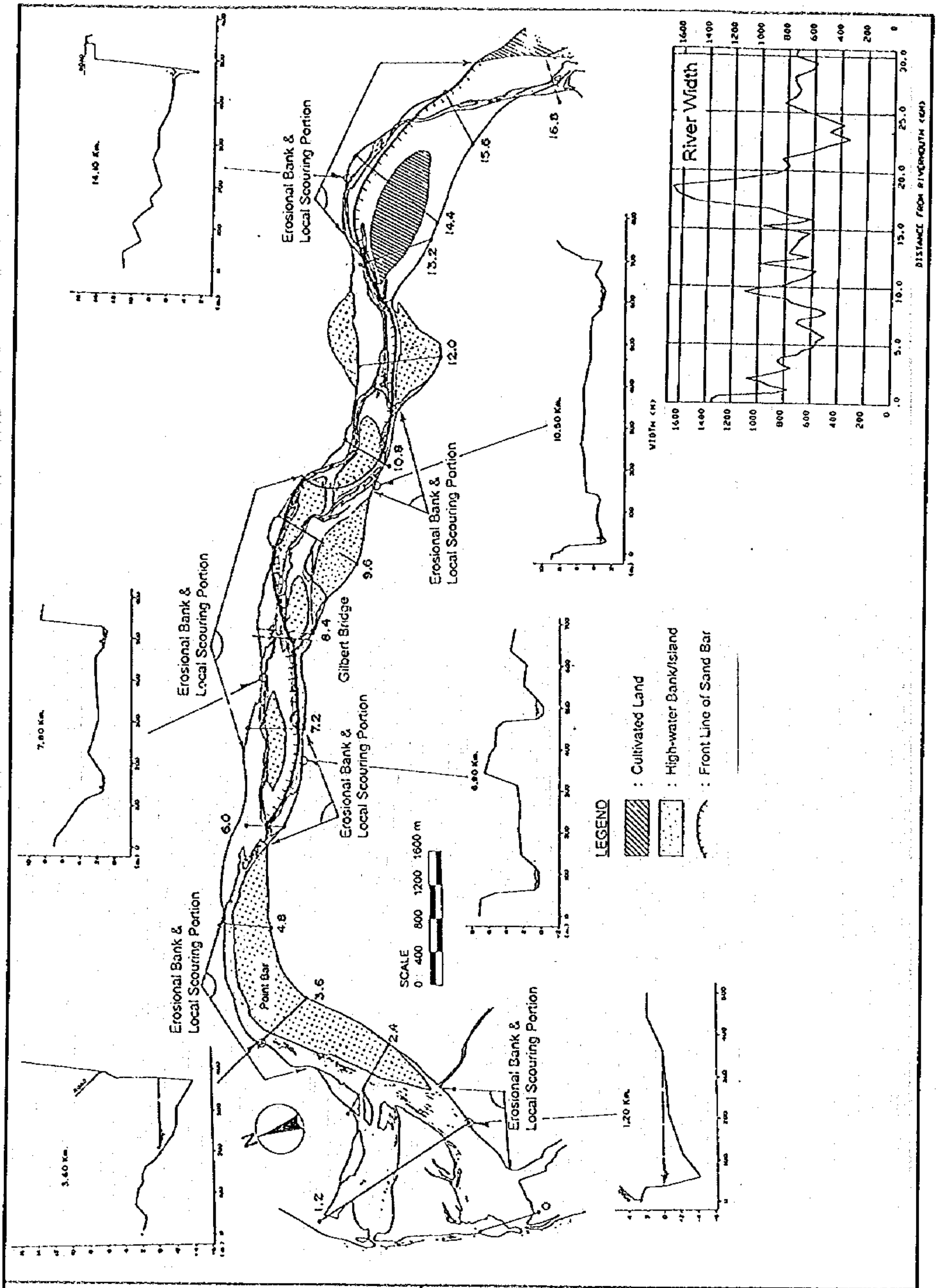
Note (Average Riverbed Slope)

1) Laoag River : 0.074 %
2) Cura River : 0.48 % (Alluvial Fan), 8.00 % (Mountains)
3) Labugaon River : 1.08 % (Alluvial Fan), 6.57 % (Mountains)
4) Solsona River : 0.75 % (Alluvial Fan), 9.55 % (Mountains)
5) Madongan River : 1.06 % (Alluvial Fan), 7.86 % (Mountains)
6) Papa River : 1.23 % (Alluvial Fan), 11.42 % (Mountains)
7) Bongo River : 0.38 % (Alluvial Fan), 6.02 % (Mountains)

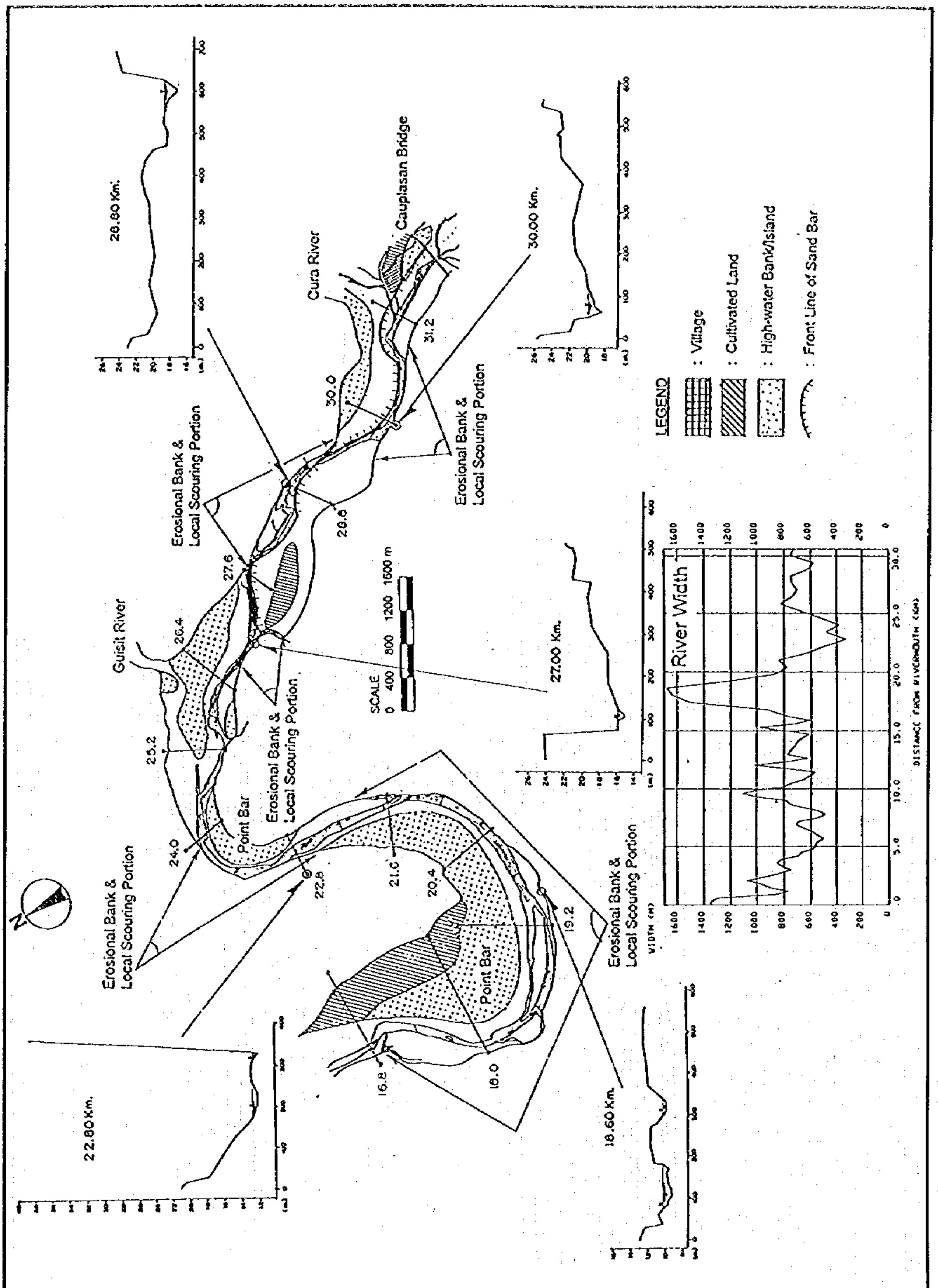
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.1.2
JAPAN INTERNATIONAL COOPERATION AGENCY	Longitudinal Profile of Laoag River System



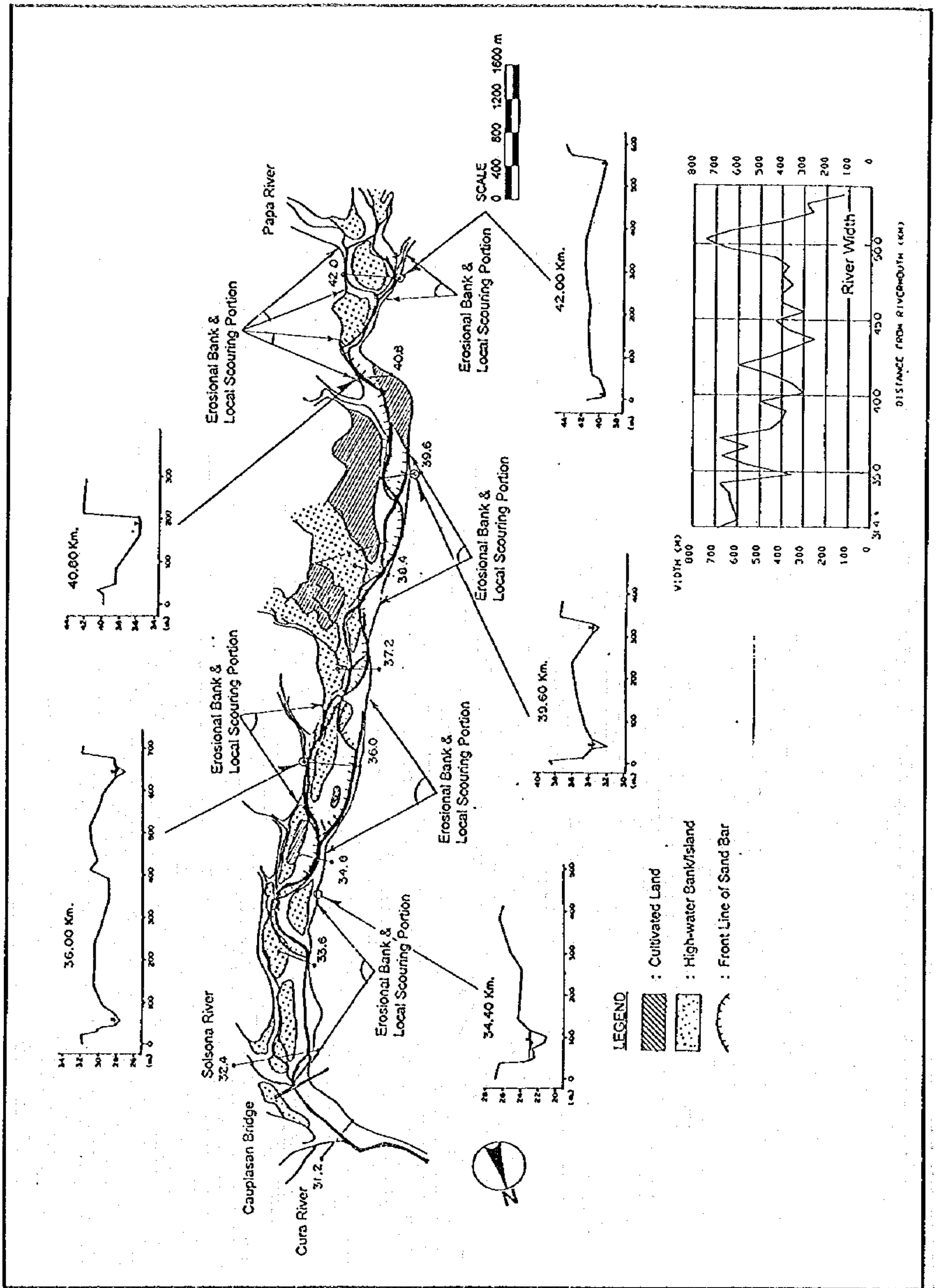
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.1.3
JAPAN INTERNATIONAL COOPERATION AGENCY	**Longitudinal Profile of Laoag and Lower Bongo Rivers**



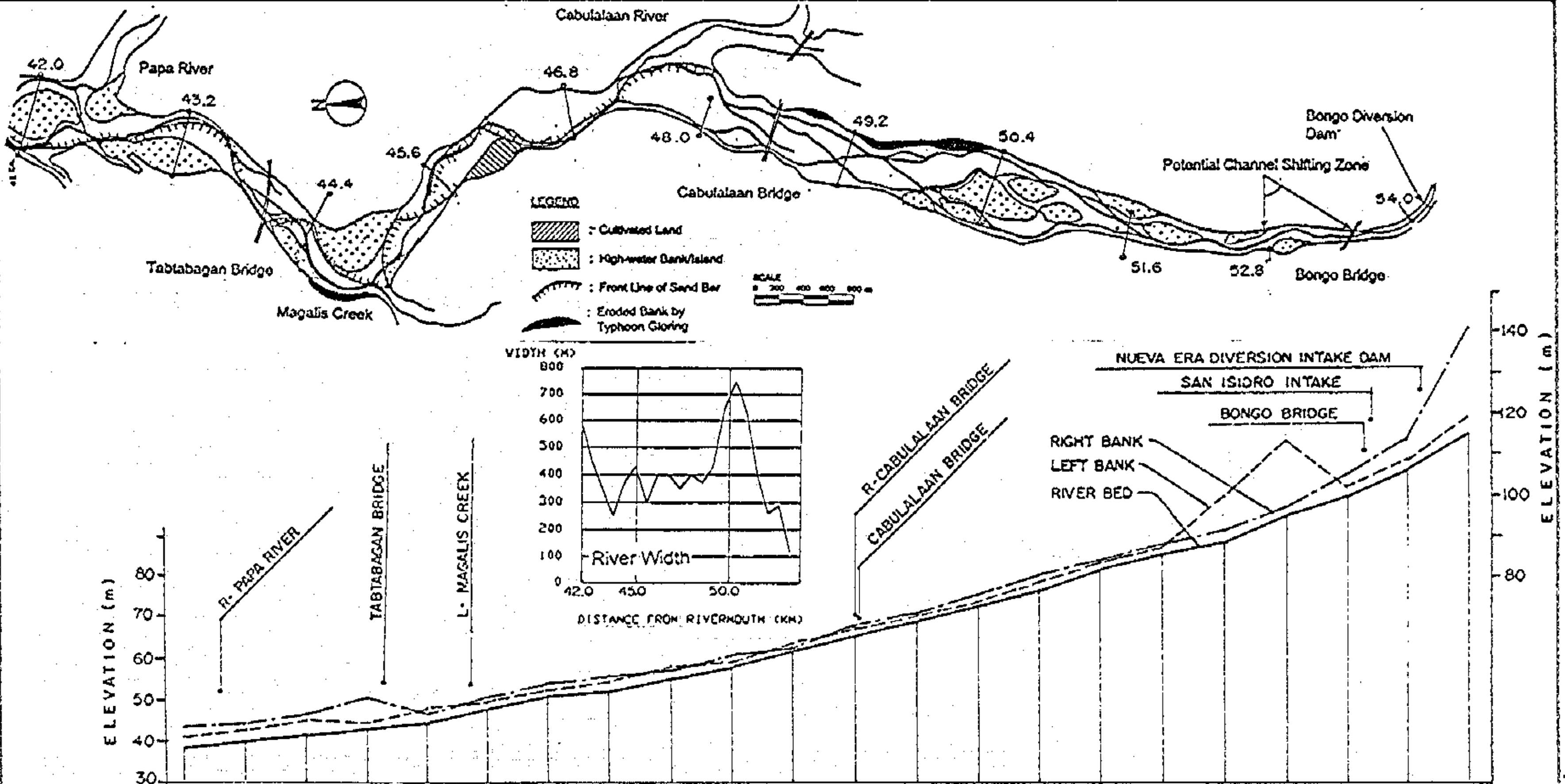
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.1.4
JAPAN INTERNATIONAL COOPERATION AGENCY	River Morphology in Lower Laoag River



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.1.5
JAPAN INTERNATIONAL COOPERATION AGENCY	River Morphology in Upper Laoag River



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.1.6
JAPAN INTERNATIONAL COOPERATION AGENCY	River Morphology in Lower Bongo River



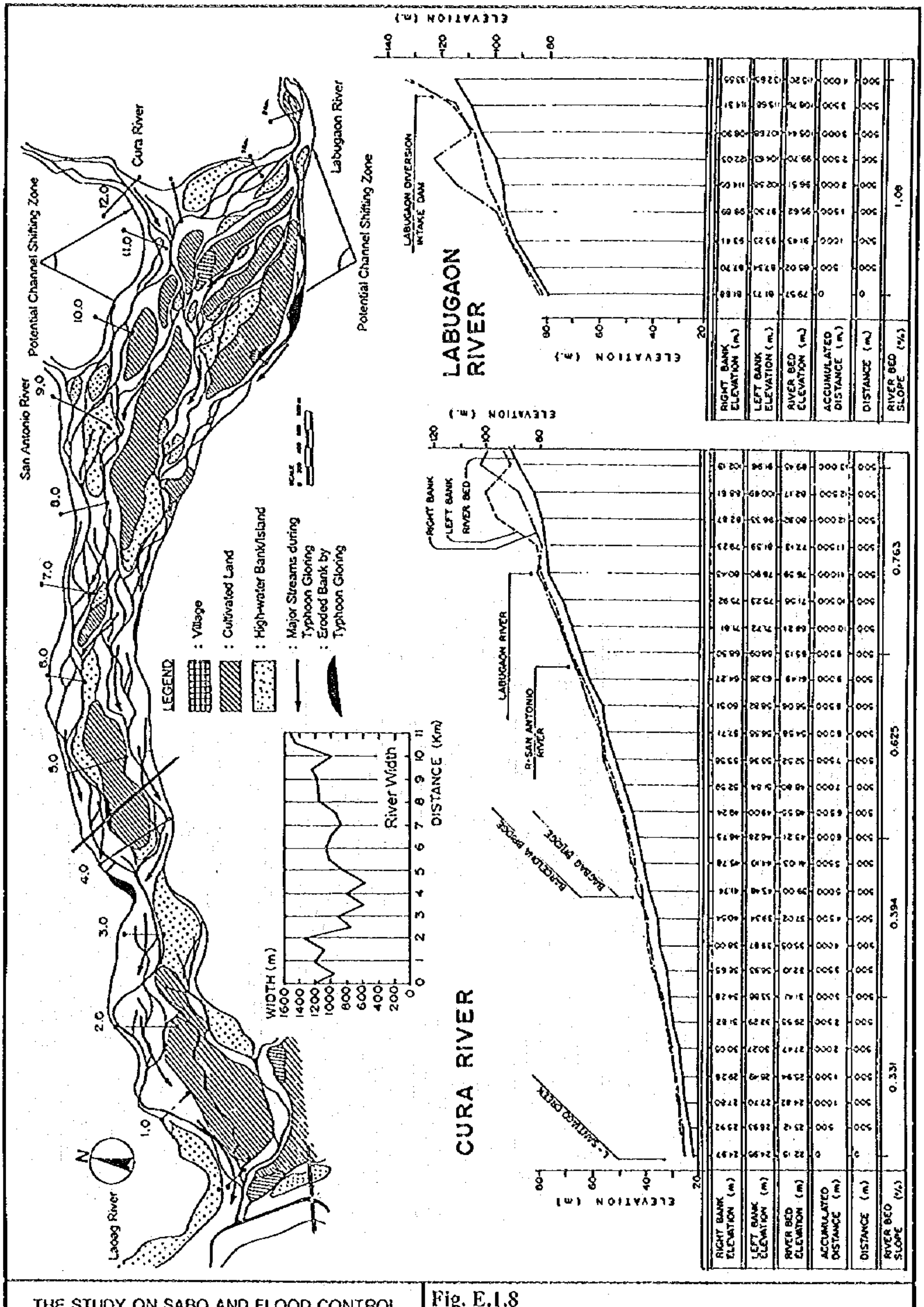
RIGHT BANK ELEVATION (m)	43.90	44.07	45.65	51.57	47.26	50.83	54.40	56.25	58.02	61.02	63.40	67.65	71.21	76.07	81.31	84.67	88.70	92.93	97.81	106.41	114.14	141.58
LEFT BANK ELEVATION (m)	41.31	42.56	45.18	44.79	48.42	50.30	52.81	55.03	58.42	60.13	63.45	67.52	71.04	74.37	79.55	84.13	88.56	100.22	113.61	102.38	108.84	119.44
RIVER BED ELEVATION (m)	39.19	40.06	41.48	43.52	44.76	46.51	51.24	52.16	55.69	58.38	62.48	65.90	69.65	73.61	77.27	82.81	85.24	89.73	96.03	100.06	106.03	114.67
ACCUMULATED DISTANCE (m)	42000	42600	43200	43800	44400	45000	45600	46200	46800	47400	48000	45600	49200	49800	50400	51000	51600	52200	52600	53400	54000	54600
DISTANCE (m)	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
RIVER BED SLOPE (%)	0.311						0.483						0.662						0.943			

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

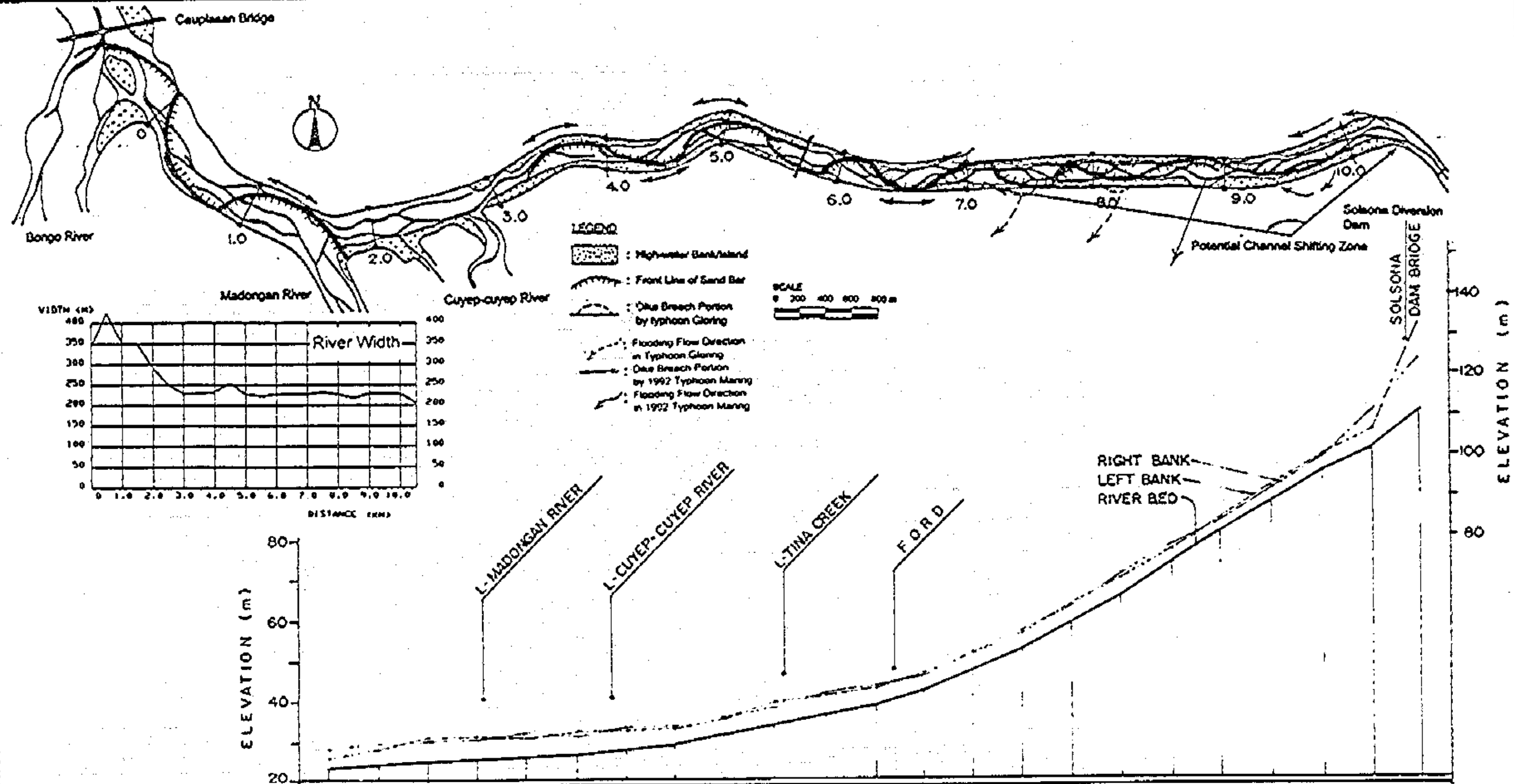
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. E.1.7

River Morphology in Upper Bongo River



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.1.8
JAPAN INTERNATIONAL COOPERATION AGENCY	River Morphology in Cura/Labugaon River



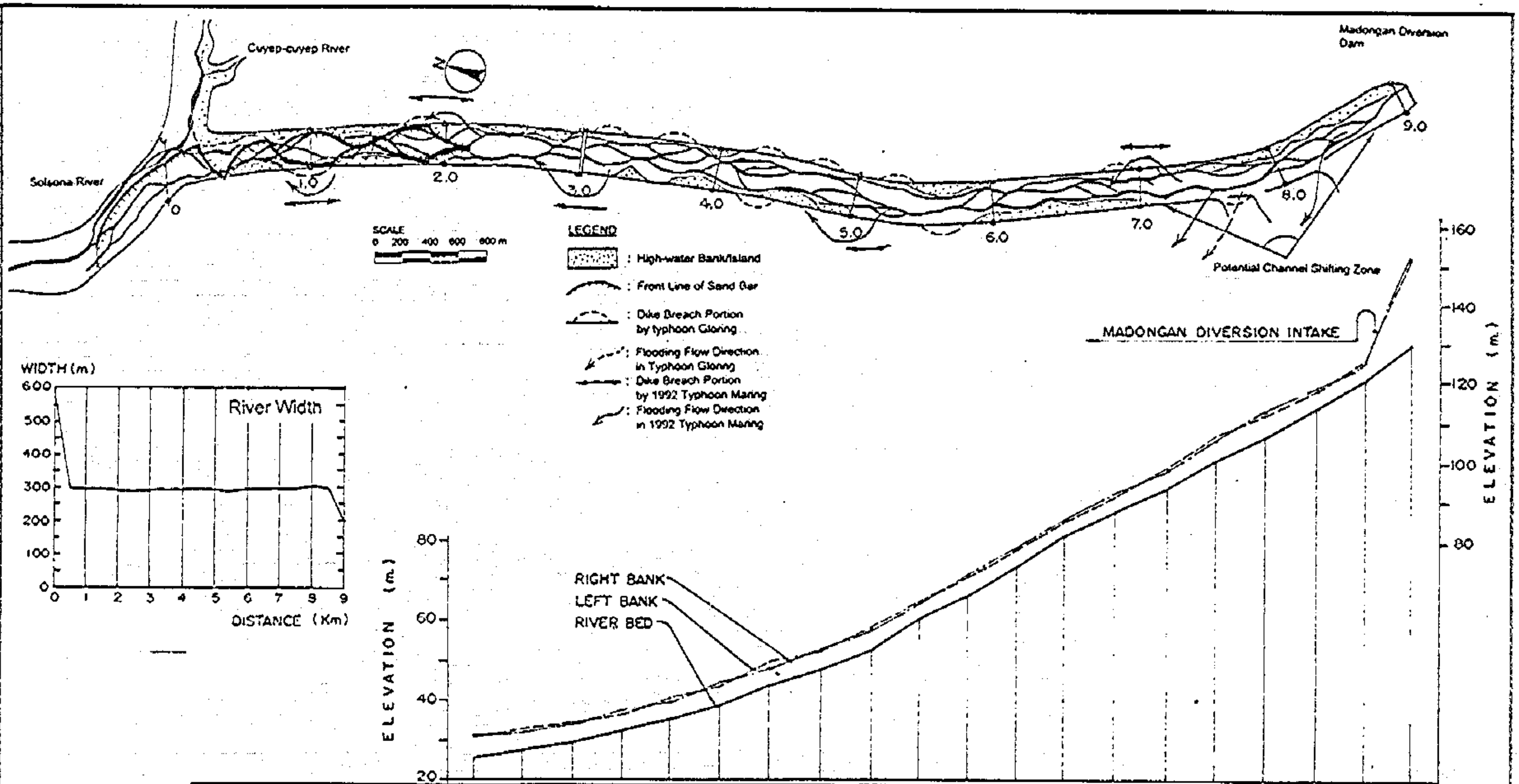
RIGHT BANK ELEVATION (m.)	28.60	29.93	30.25	30.56	31.37	31.34	32.97	33.76	35.96	38.00	41.28	43.43	46.32	51.74	56.85	62.75	70.14	77.26	84.41	92.24	99.95	110.89	123.61
LEFT BANK ELEVATION (m.)	26.49	28.72	30.78	31.32	30.76	32.62	32.79	33.56	38.91	39.25	40.92	43.38	46.77	51.74	56.47	62.96	69.59	76.44	84.54	92.51	100.15	106.72	122.44
RIVER BED ELEVATION (m.)	23.24	24.14	25.12	25.30	26.25	27.16	28.37	29.54	31.70	34.32	36.68	38.70	42.54	47.59	52.46	58.06	65.69	73.22	80.78	88.93	96.47	101.93	110.75
ACCUMULATED DISTANCE (m.)	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11500
DISTANCE (m.)	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
RIVER BED SLOPE (%)		0.137			0.186				0.385				0.917		1.12			1.54					

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. E.1.9

River Morphology in Solsona River



RIGHT BANK ELEVATION (m.)	30.83	32.59	34.63	36.85	40.40	43.63	49.89	52.90	58.04	64.43
LEFT BANK ELEVATION (m.)	30.95	31.93	34.61	37.44	39.55	44.54	47.98	52.96	58.01	64.22
RIVER BED ELEVATION (m.)	25.36	27.60	29.89	32.85	35.64	39.23	44.00	48.15	53.14	60.54
ACCUMULATED DISTANCE (m.)	0	500	1000	1500	2000	2500	3000	3500	4000	4500
DISTANCE (m.)	0	500	500	500	500	500	500	500	500	500
RIVER BED SLOPE (%)	0.452		0.595		0.862				1.35	

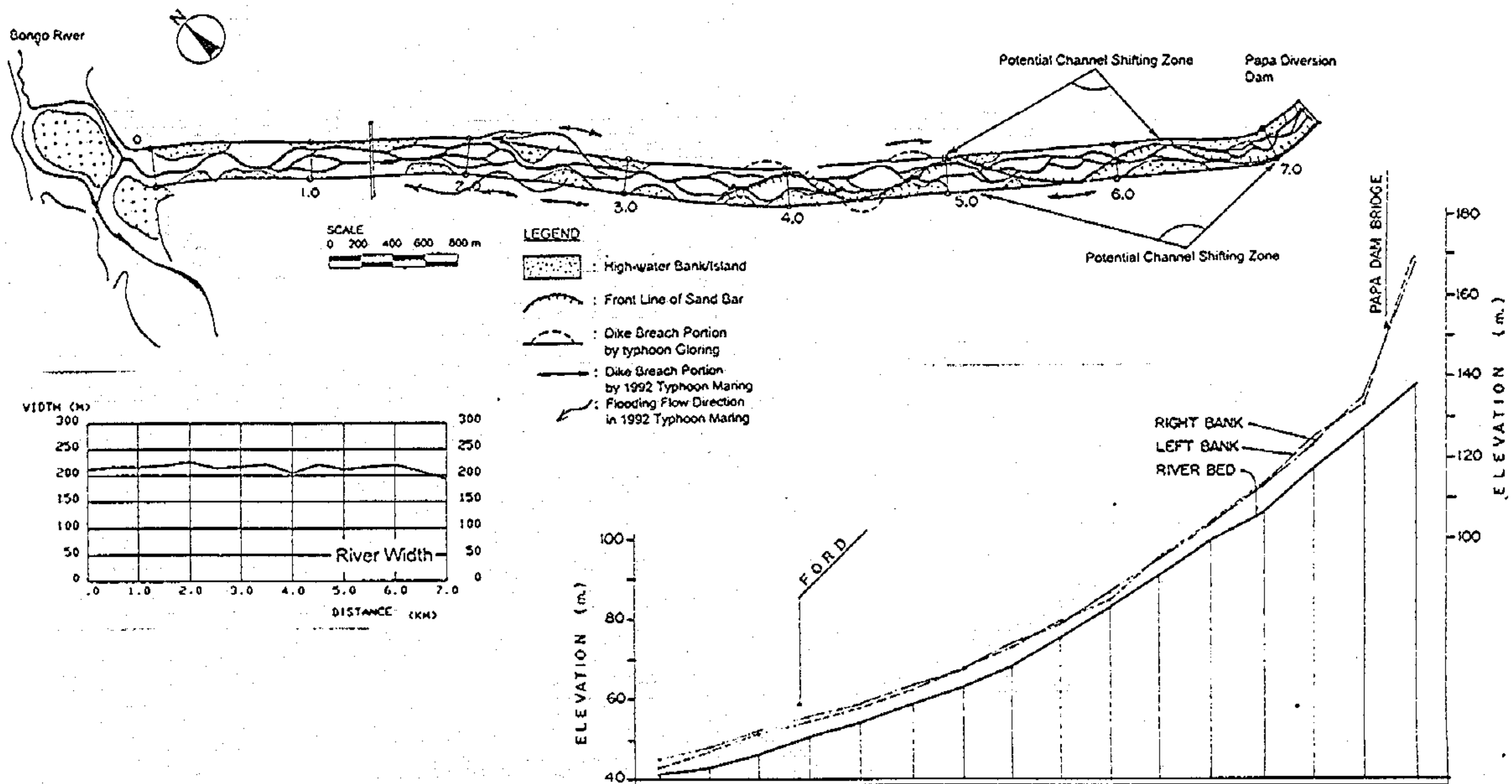
RIGHT BANK ELEVATION (m.)	70.37	77.83	85.00	91.51	99.39	106.67	112.74	118.20	125.47	151.91
LEFT BANK ELEVATION (m.)	70.85	78.12	83.04	91.74	99.30	105.52	113.29	119.30	125.43	152.25
RIVER BED ELEVATION (m.)	66.24	73.51	80.81	87.27	93.72	100.56	106.78	114.00	120.32	129.95
ACCUMULATED DISTANCE (m.)	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500
DISTANCE (m.)	500	500	500	500	500	500	500	500	500	500
RIVER BED SLOPE (%)										

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. E.1.10

River Morphology in Madongan River



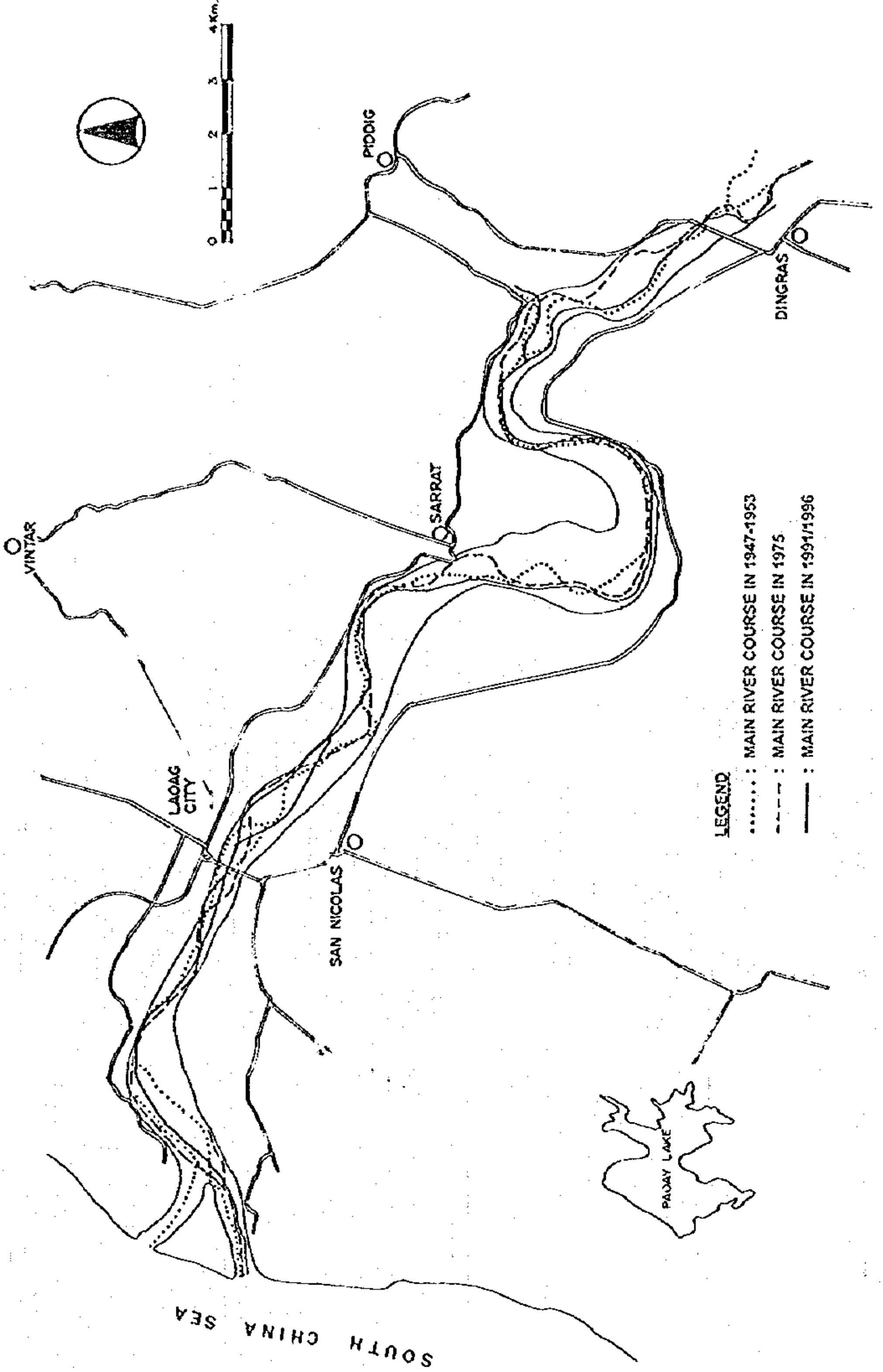
RIGHT BANK ELEVATION (m.)	45.12	47.86	51.59	55.14	58.53	62.77	67.64	73.65	78.54	86.64	94.85	103.58	113.21	123.65	134.56	168.13
LEFT BANK ELEVATION (m.)	42.83	47.26	50.82	54.79	58.09	62.27	67.75	72.91	79.65	84.99	94.92	103.65	113.77	125.11	133.16	169.14
RIVER BED ELEVATION (m.)	41.00	43.31	46.21	50.65	54.30	58.70	63.10	68.49	75.08	82.87	90.50	99.95	106.29	117.79	127.30	138.15
ACCUMULATED DISTANCE (m.)	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
DISTANCE (m.)	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
RIVER BED SLOPE (%)	0.54			0.847				1.20		1.54			1.85			

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

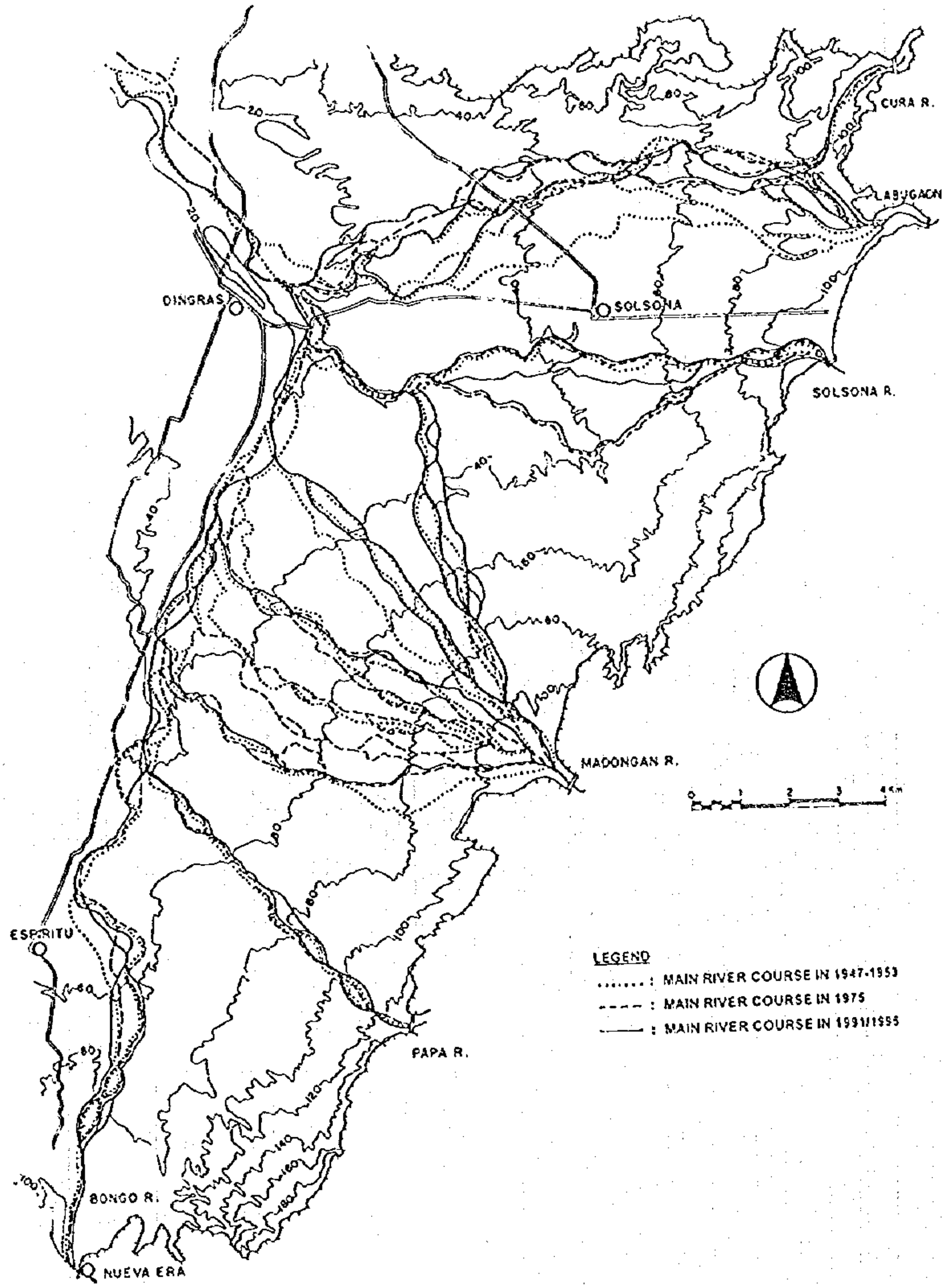
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. E.1.11

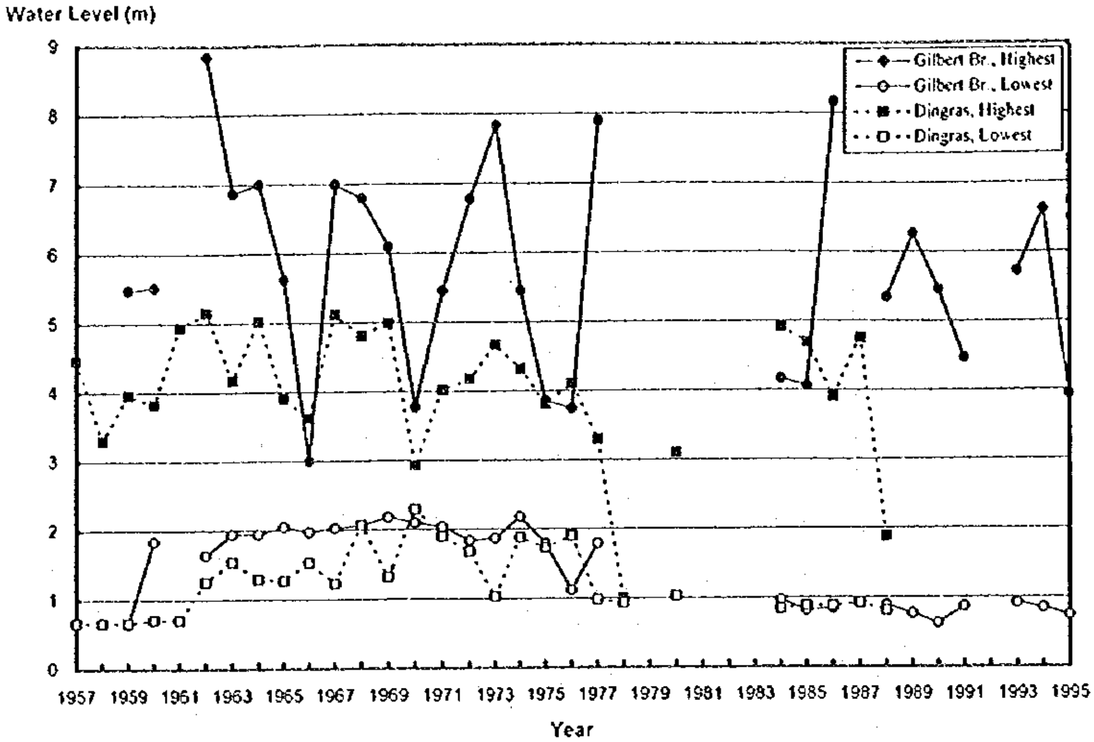
River Morphology in Papa River



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.1.12
JAPAN INTERNATIONAL COOPERATION AGENCY	Changes in Laoag River Course from 1947 to 1996



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	**Fig. E.1.13** **Changes in River Courses of Upper Tributaries from 1947 to 1996**

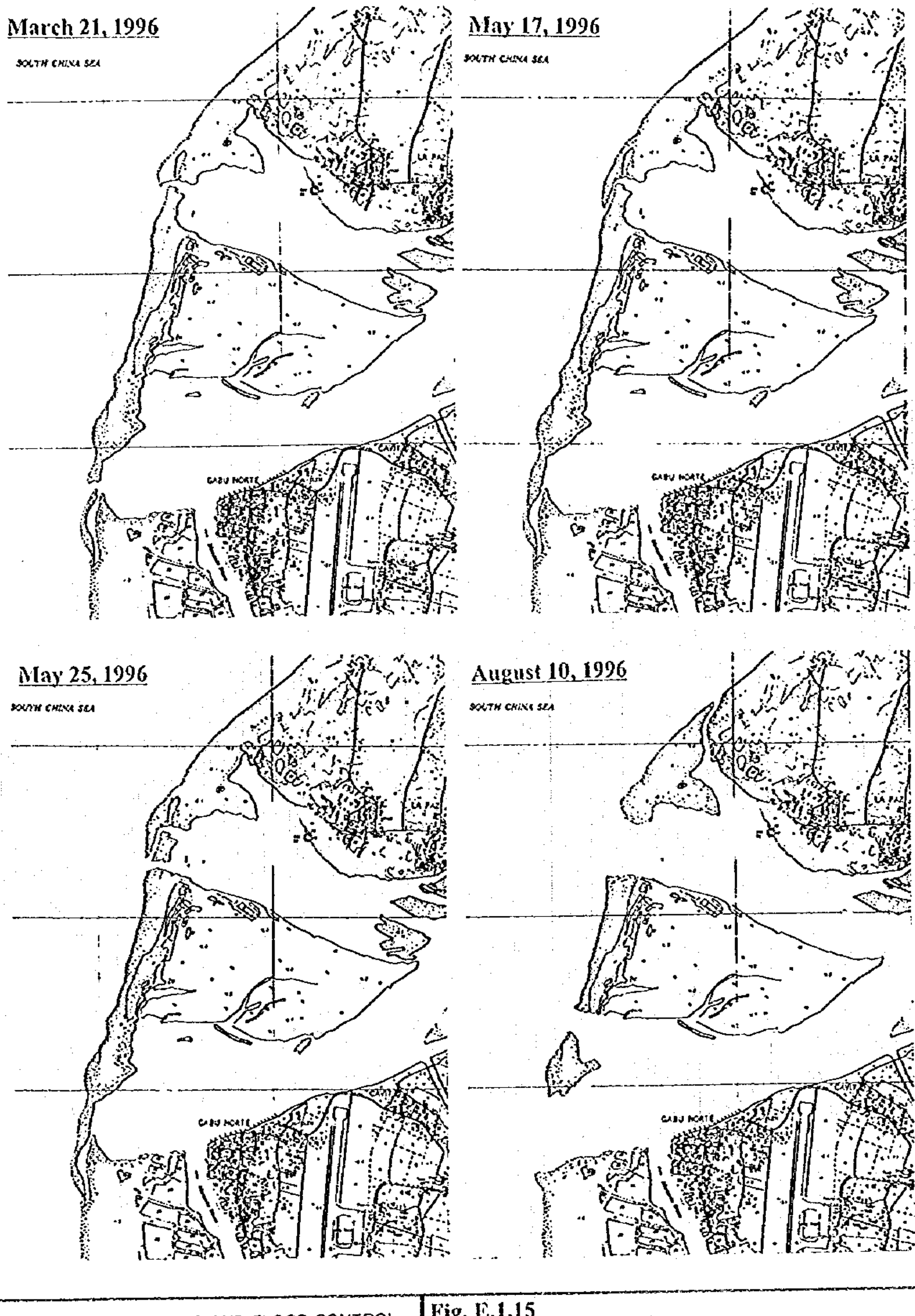


Observed Water Level by Region I Office, DPWH

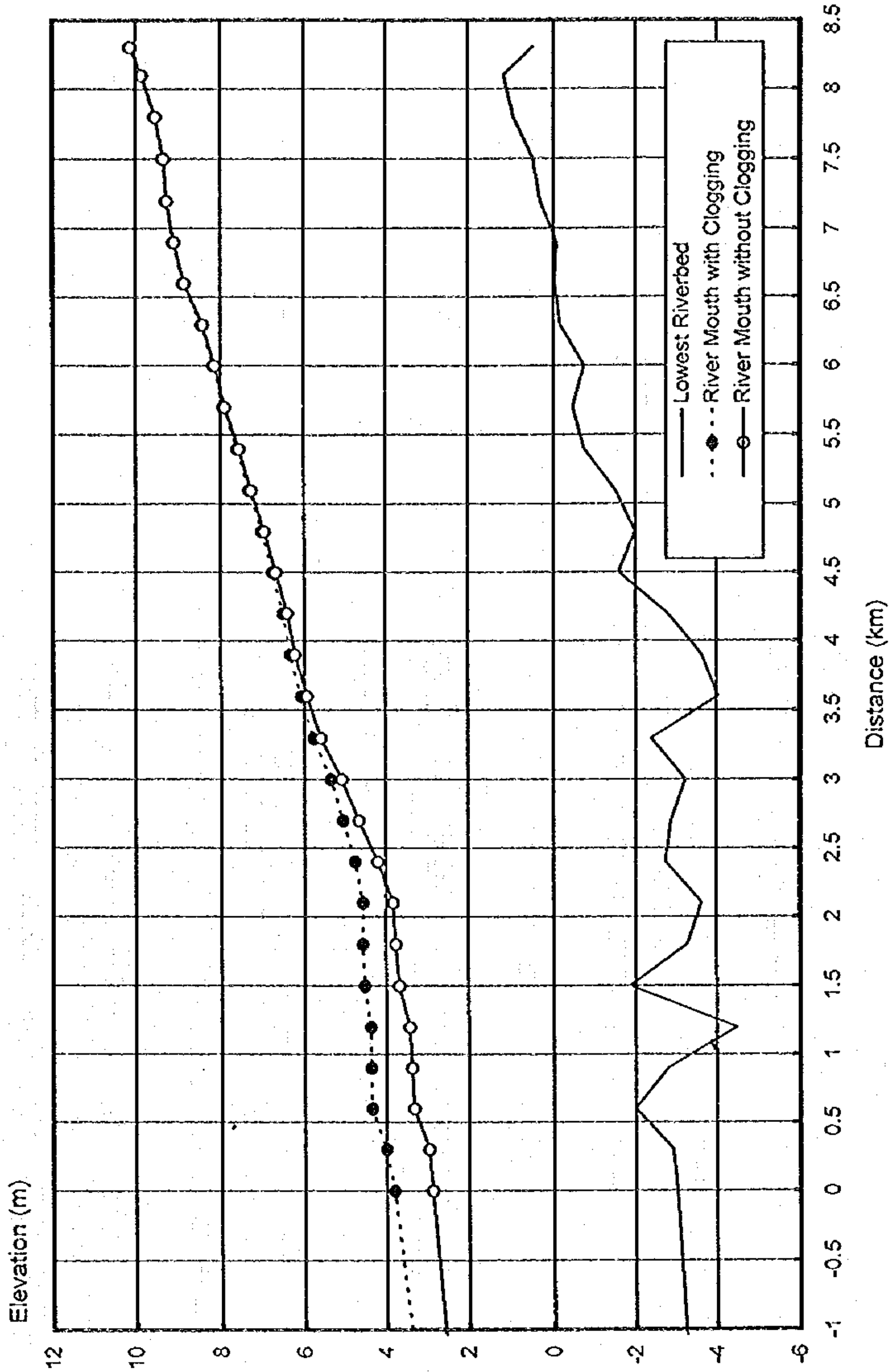
Year	Gilbert Br.		Dingras		Year	Gilbert Br.		Dingras	
	Highest	Lowest	Highest	Lowest		Highest	Lowest	Highest	Lowest
1957			4.46	0.66	1977	7.90	1.79	3.30	0.98
1958			3.30	0.66	1978			1.00	0.93
1959	5.48	0.65	3.96	0.66	1979				
1960	5.52	1.84	3.82	0.71	1980			3.10	1.03
1961			4.94	0.71	1981				
1962	8.85	1.64	5.15	1.25	1982				
1963	6.87	1.94	4.17	1.54	1983				
1964	7.00	1.94	5.02	1.29	1984	4.17	0.97	4.91	0.84
1965	5.63	2.05	3.90	1.27	1985	4.07	0.82	4.69	0.88
1966	3.00	1.97	3.62	1.53	1986	8.17	0.85	3.91	0.88
1967	7.00	2.03	5.12	1.23	1987			4.75	0.92
1968	6.80	2.06	4.81	2.07	1988	5.35	0.89	1.88	0.81
1969	6.10	2.18	4.99	1.32	1989	6.27	0.77		
1970	3.77	2.10	2.93	2.29	1990	5.47	0.63		
1971	5.46	2.04	4.02	1.90	1991	4.47	0.87		
1972	6.78	1.84	4.18	1.68	1992				
1973	7.83	1.87	4.67	1.03	1993	5.73	0.92		
1974	5.46	2.18	4.32	1.88	1994	6.62	0.85		
1975	3.86	1.79	3.81	1.73	1995	3.94	0.74		
1976	3.75	1.12	4.11	1.90					

Fig. E.1.14

Observed Water Levels at Laoag City and Dingras from 1957 to 1995

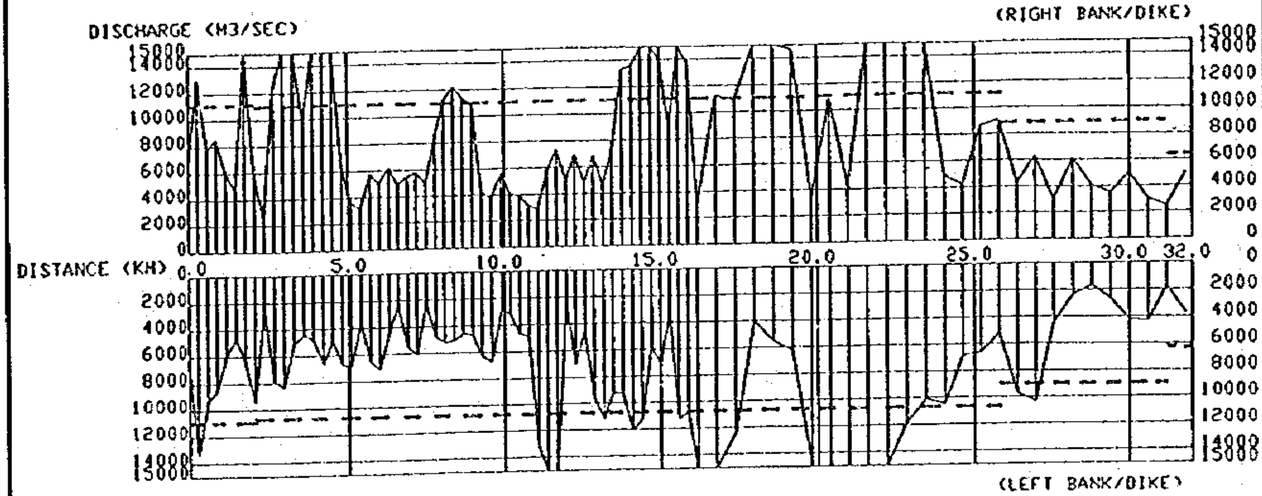


THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.1.15
JAPAN INTERNATIONAL COOPERATION AGENCY	Topographic Changes of River Mouth in 1996

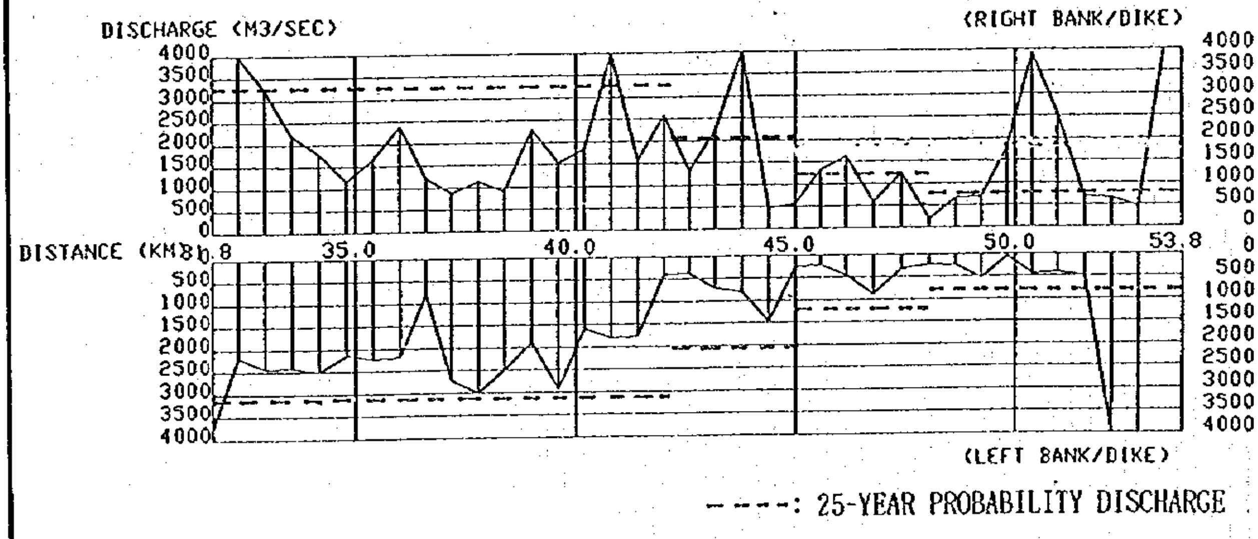


THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	**Fig. E.1.16** **Backwater Effects Due to River Mouth Clogging**

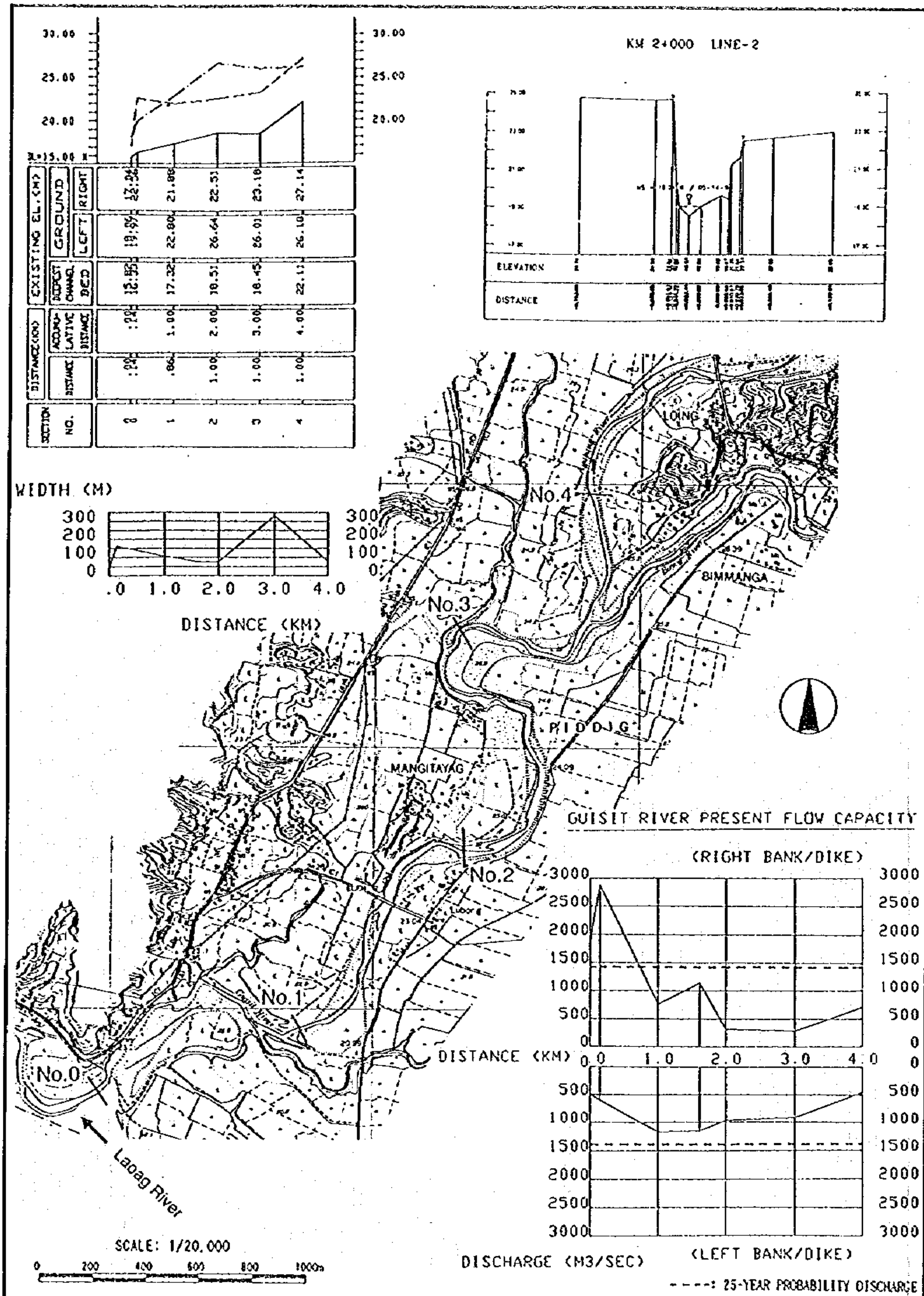
LAOAG RIVER PRESENT FLOW CAPACITY



BONGO RIVER PRESENT FLOW CAPACITY



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. E.1.17 Present Flow Capacity of Laoag and Bongo Rivers

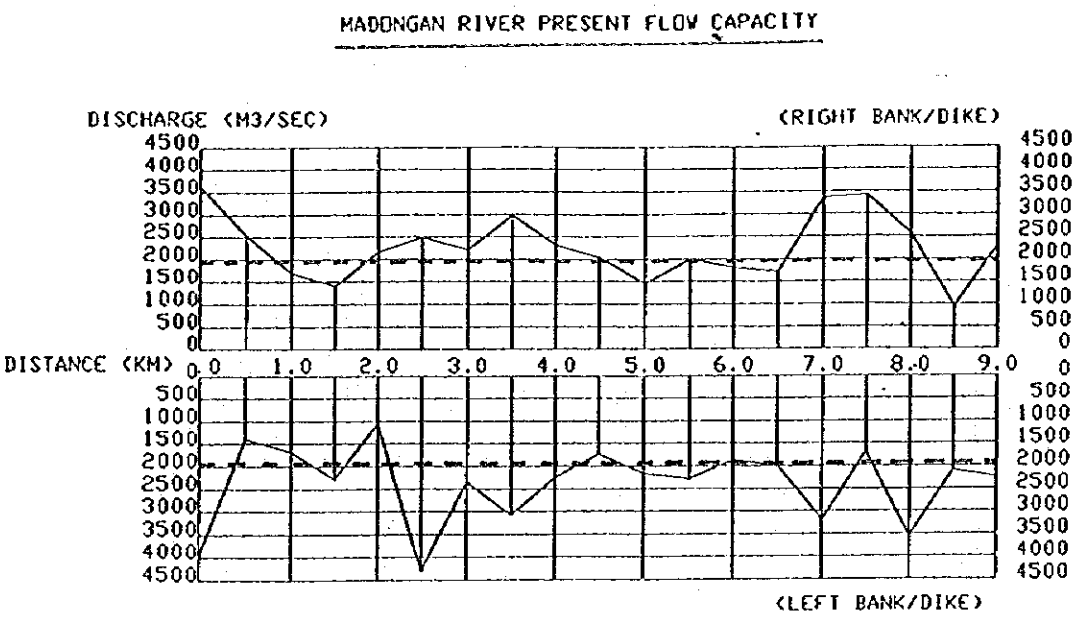


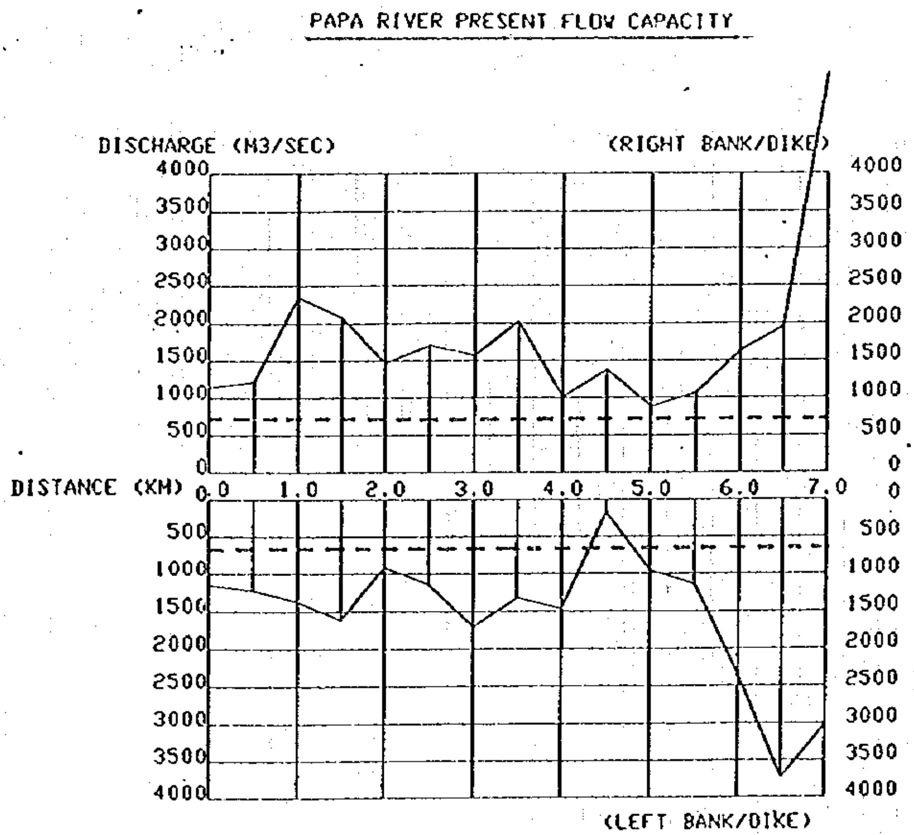
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. E. 1.18

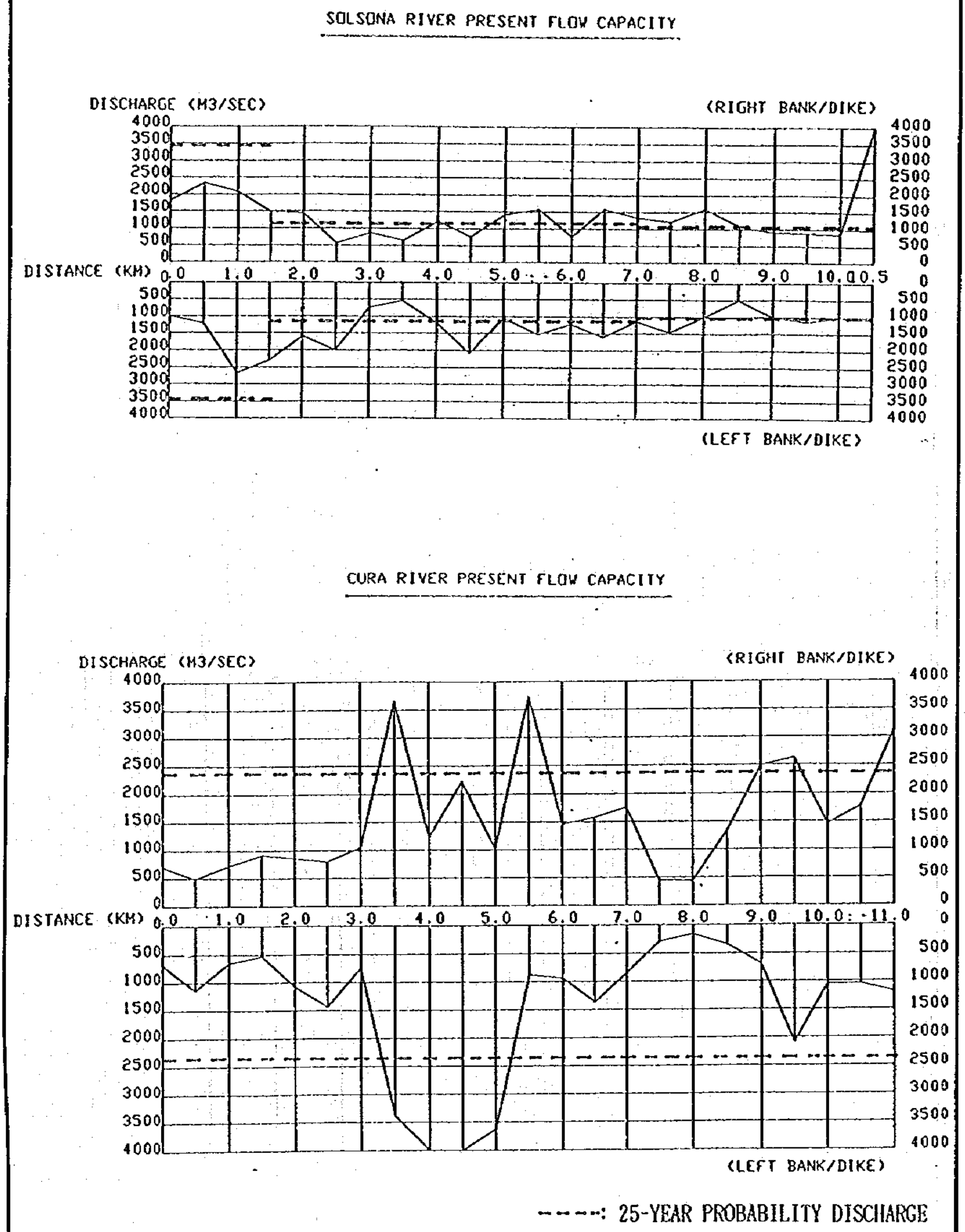
Present Flow Capacity of Guisit River



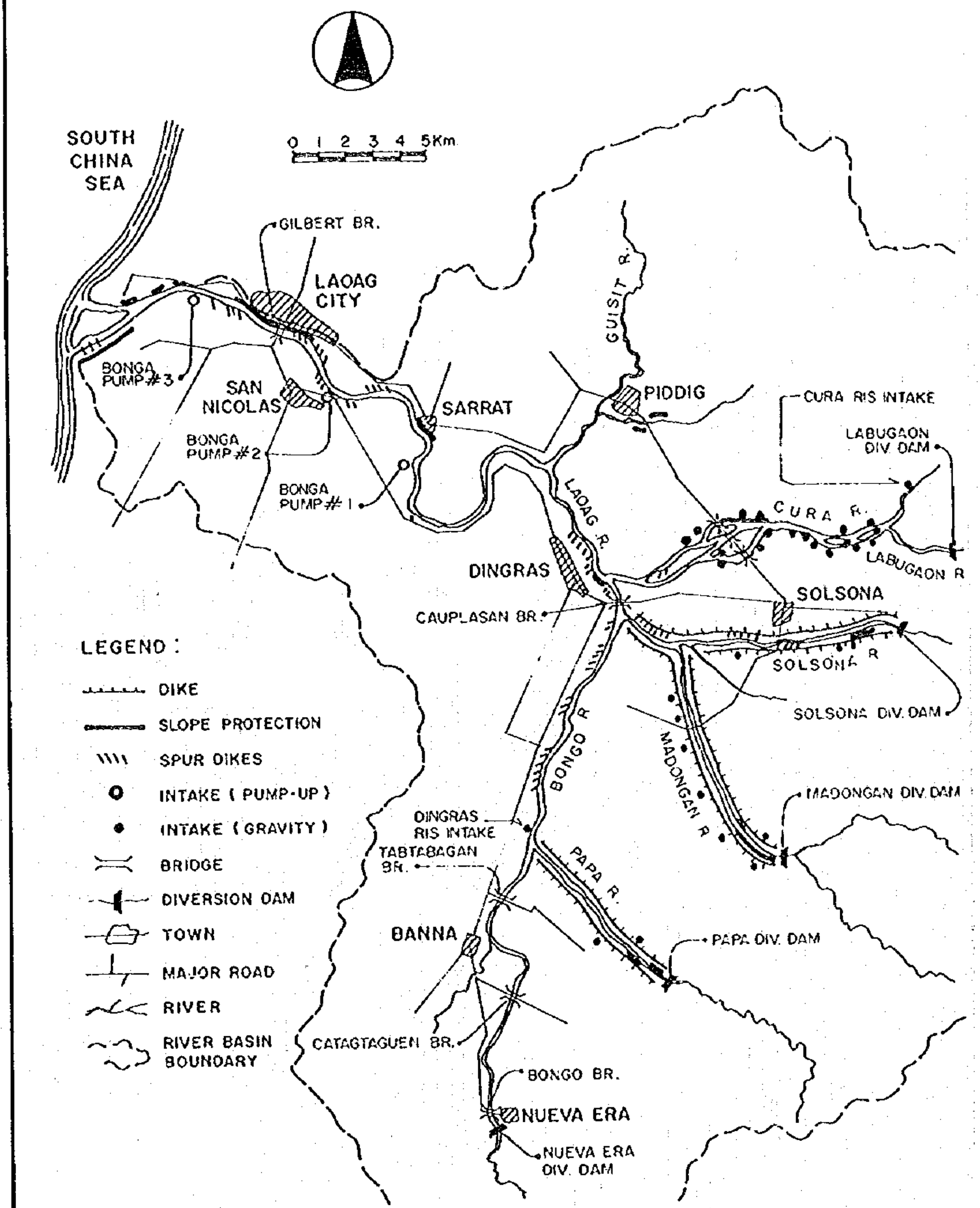


- - - -: 25-YEAR PROBABILITY DISCHARGE

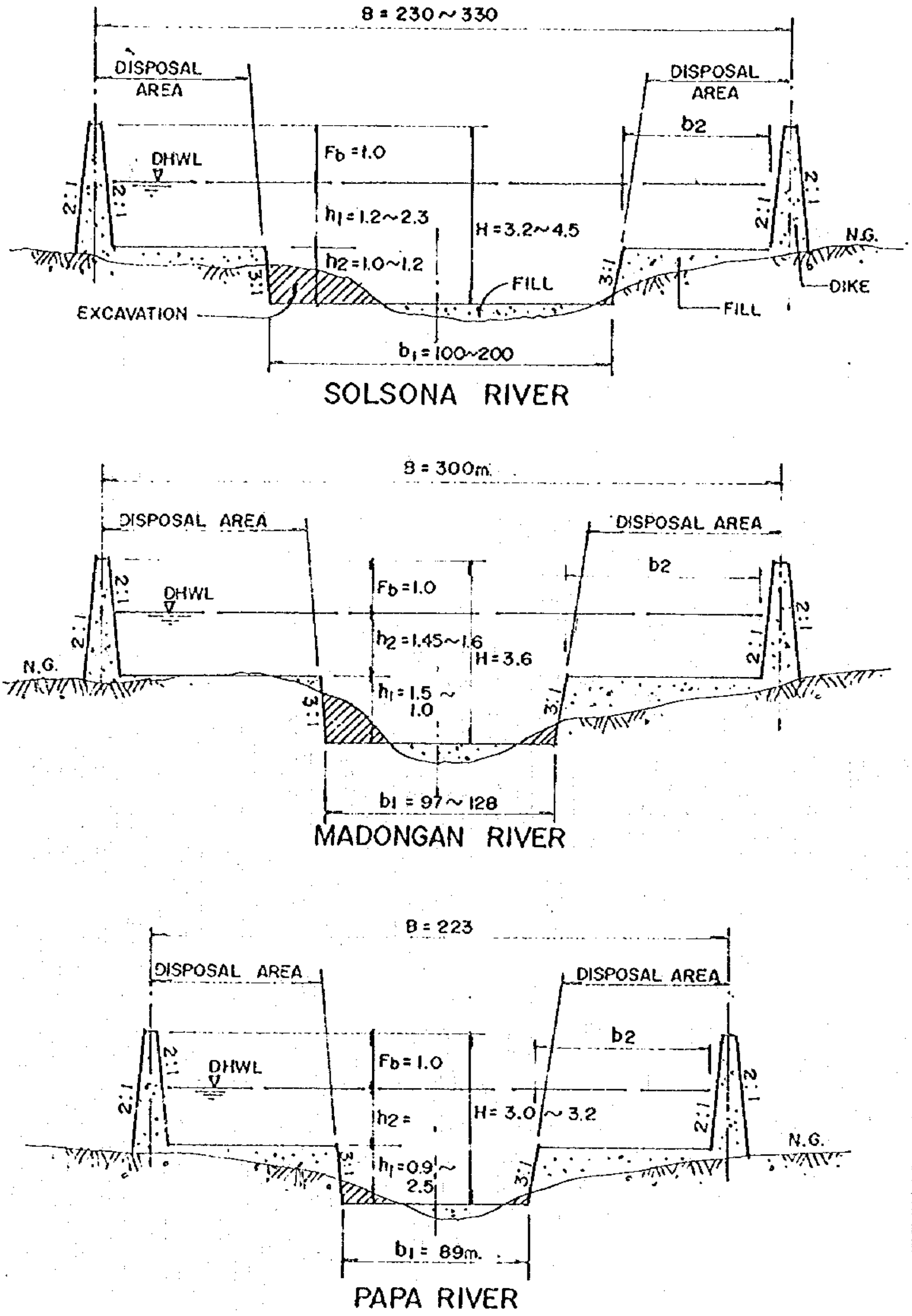
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. E.1.19 Present Flow Capacity of Madongan and Papa Rivers



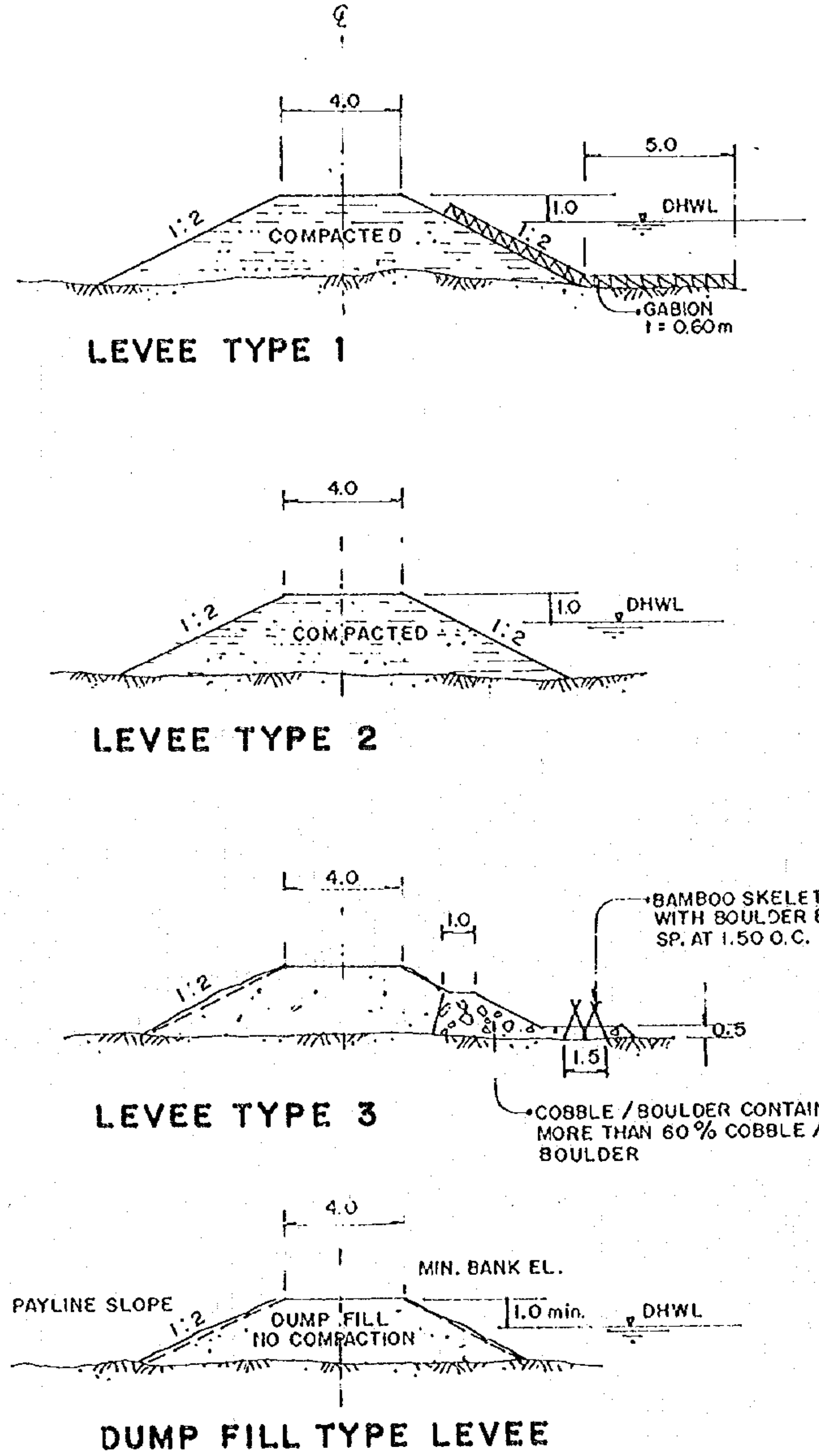
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.1.20
JAPAN INTERNATIONAL COOPERATION AGENCY	Present Flow Capacity of Solsona and Cura Rivers



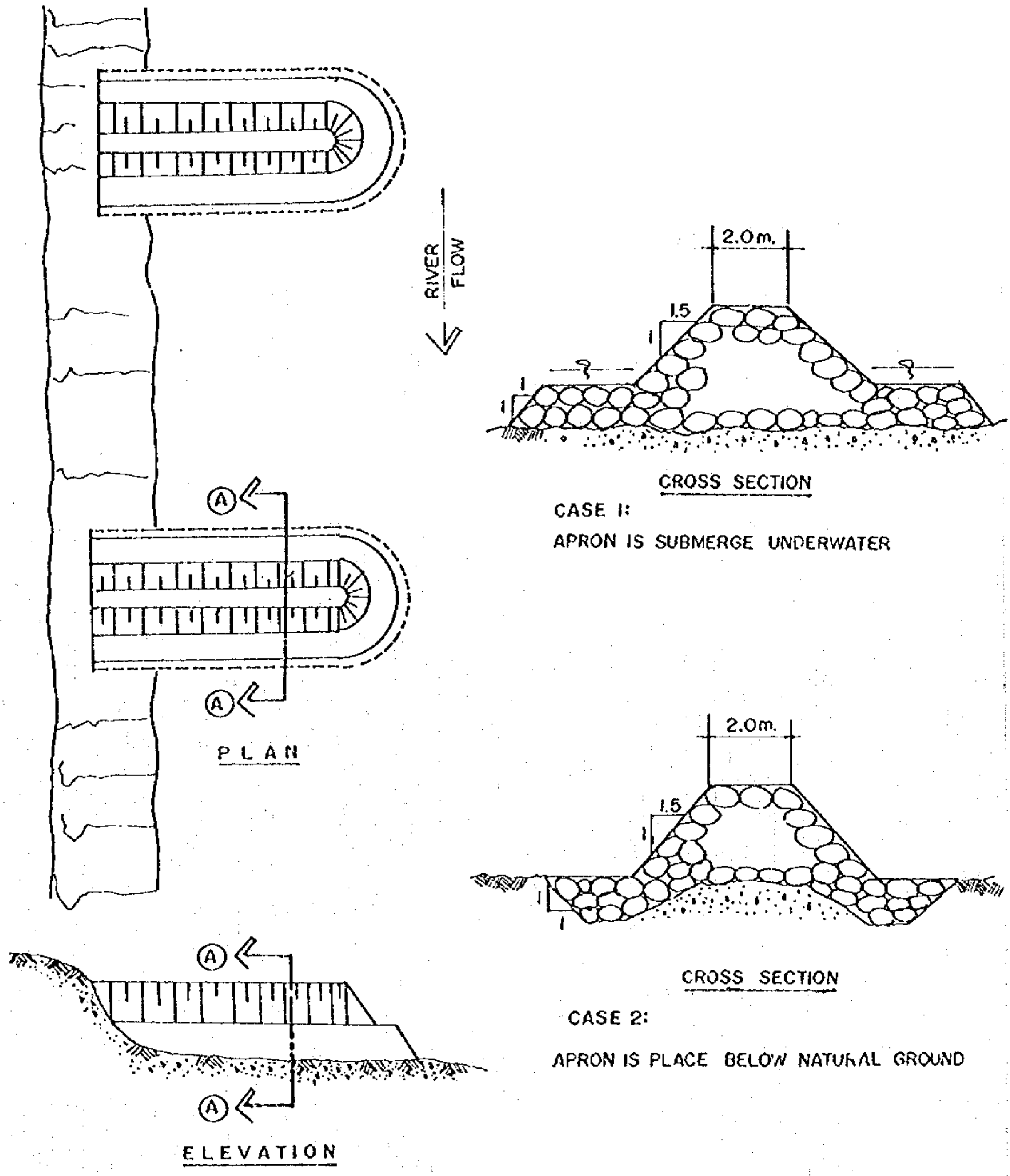
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.2.1
JAPAN INTERNATIONAL COOPERATION AGENCY	Existing River Structures



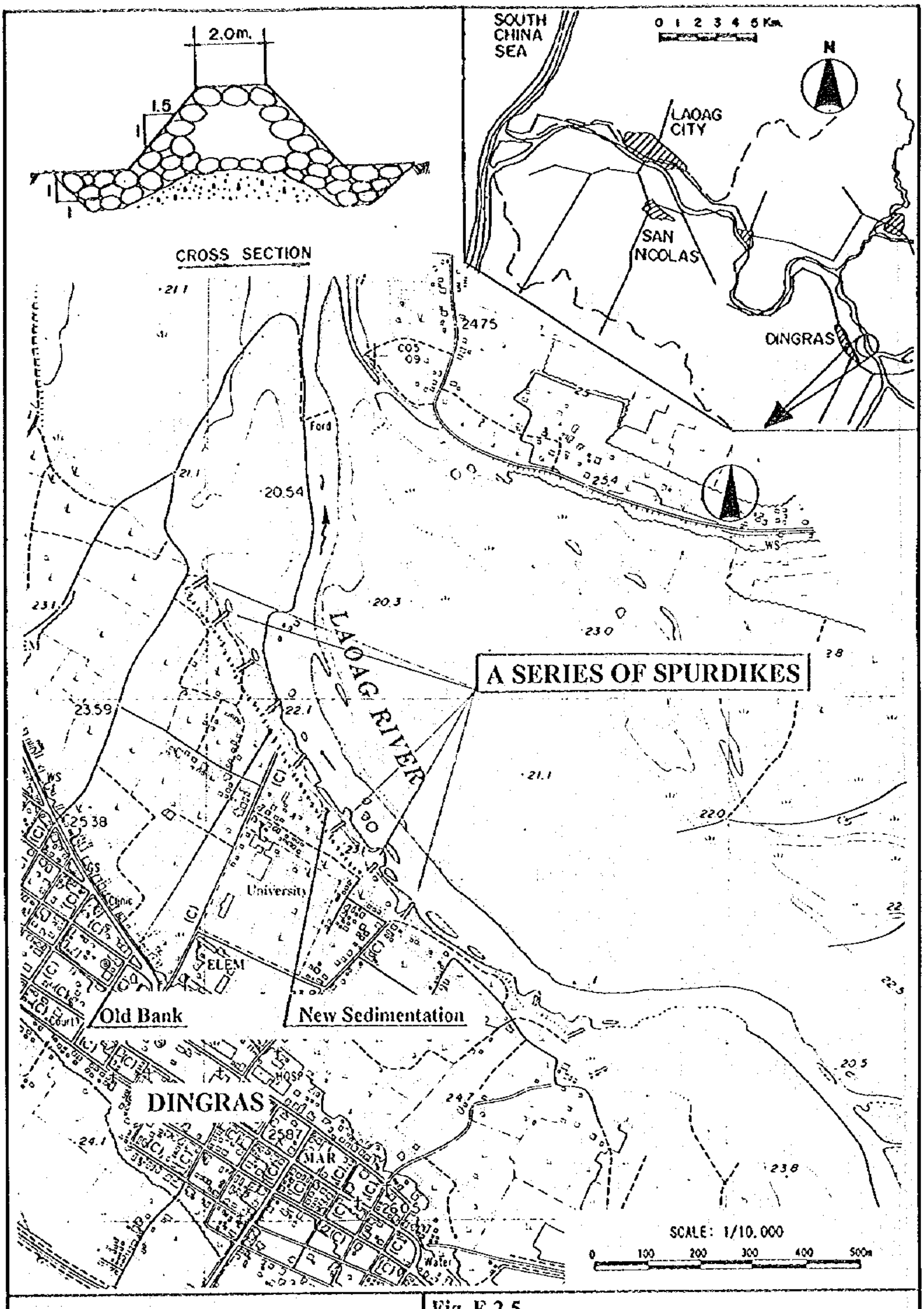
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	**Fig. E.2.2** **Standard Cross-Section of River Improvement under UDPW**



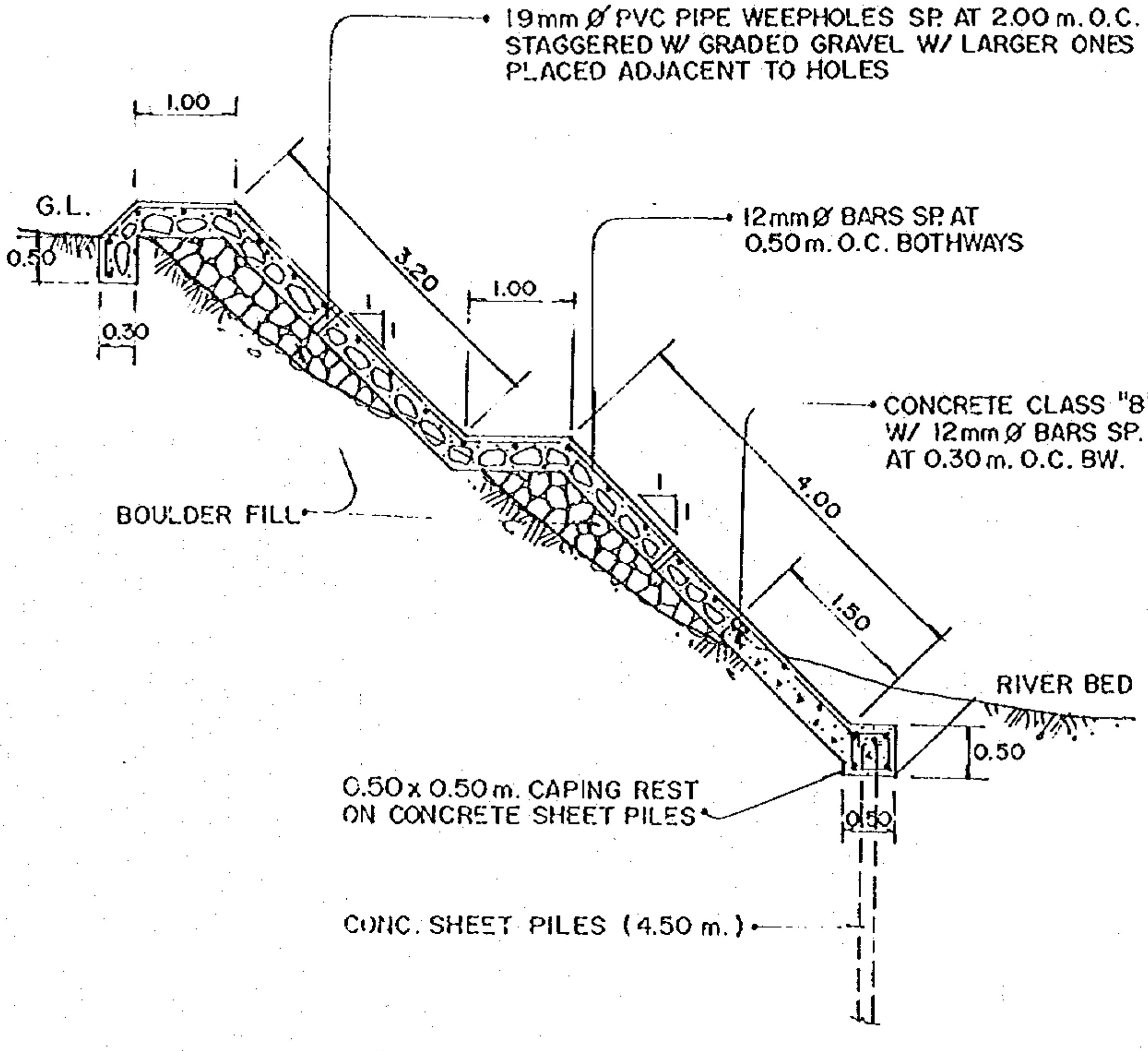
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.2.3
JAPAN INTERNATIONAL COOPERATION AGENCY	Existing Typical Dikes Constructed under UDPW



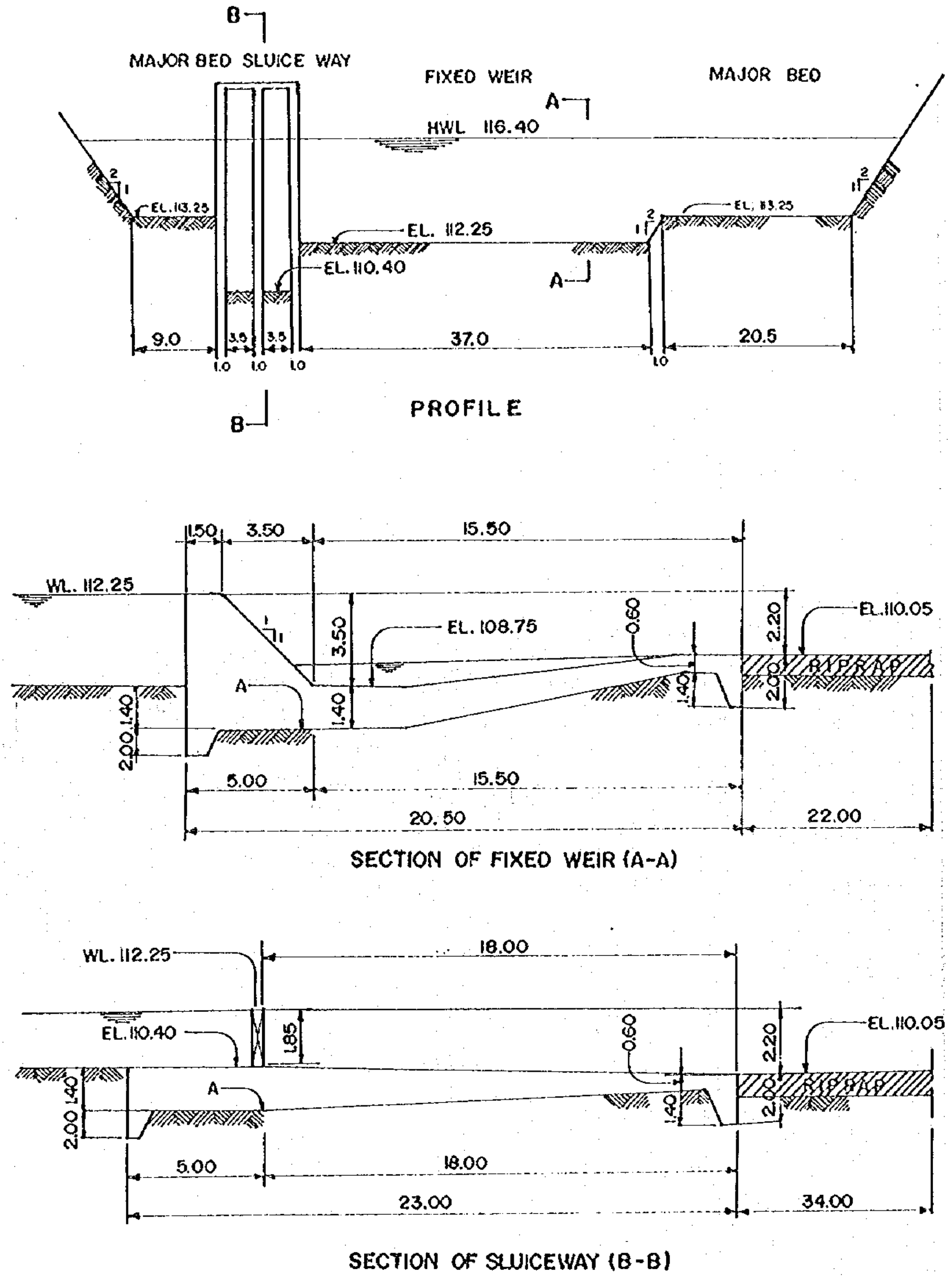
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.2.4
JAPAN INTERNATIONAL COOPERATION AGENCY	Typical Existing Spurdike



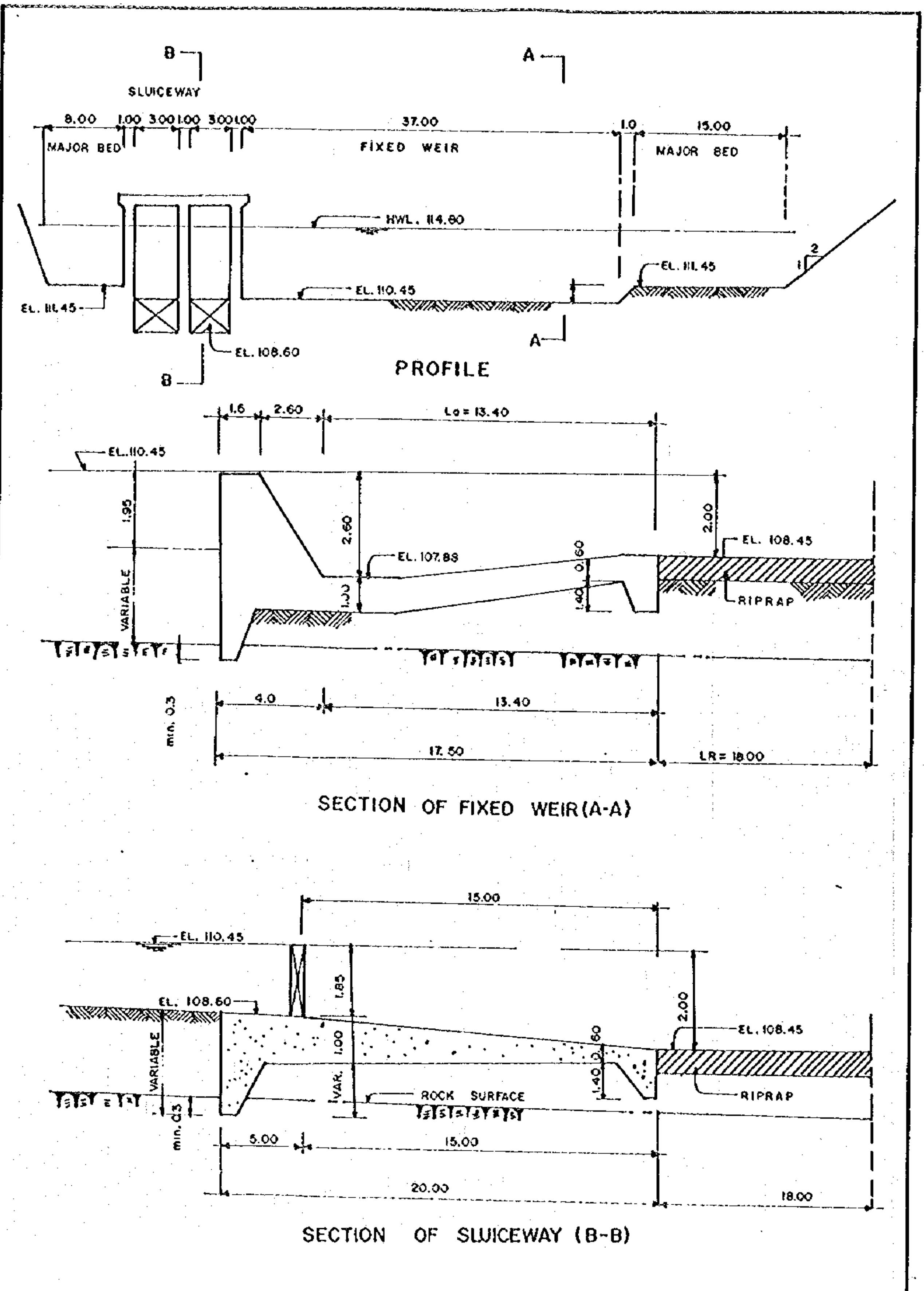
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.2.5
JAPAN INTERNATIONAL COOPERATION AGENCY	Existing Series of Spurdikes at Dingras



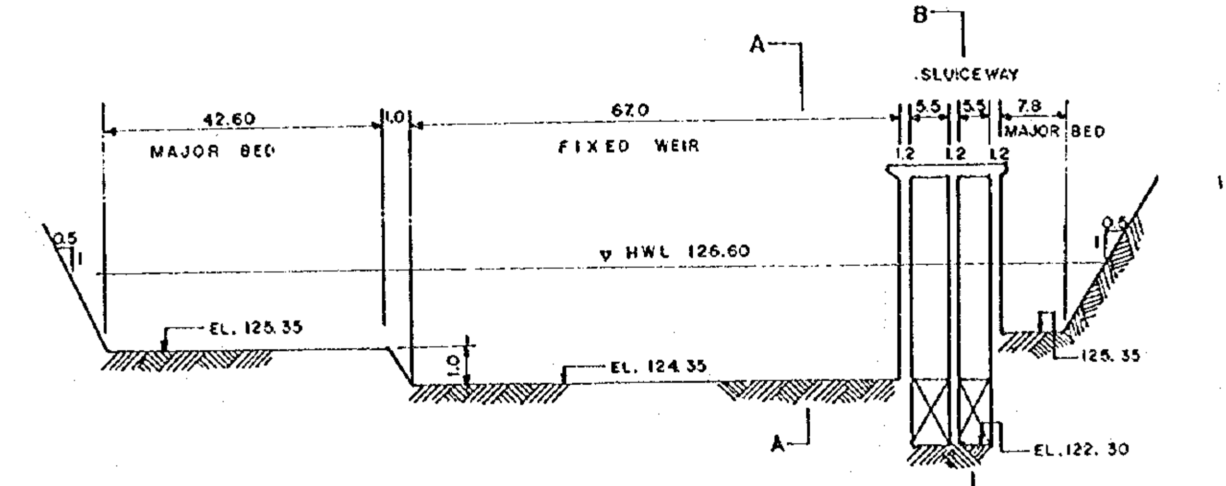
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	**Fig. E.2.6**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Existing Revetment at Laoag City**



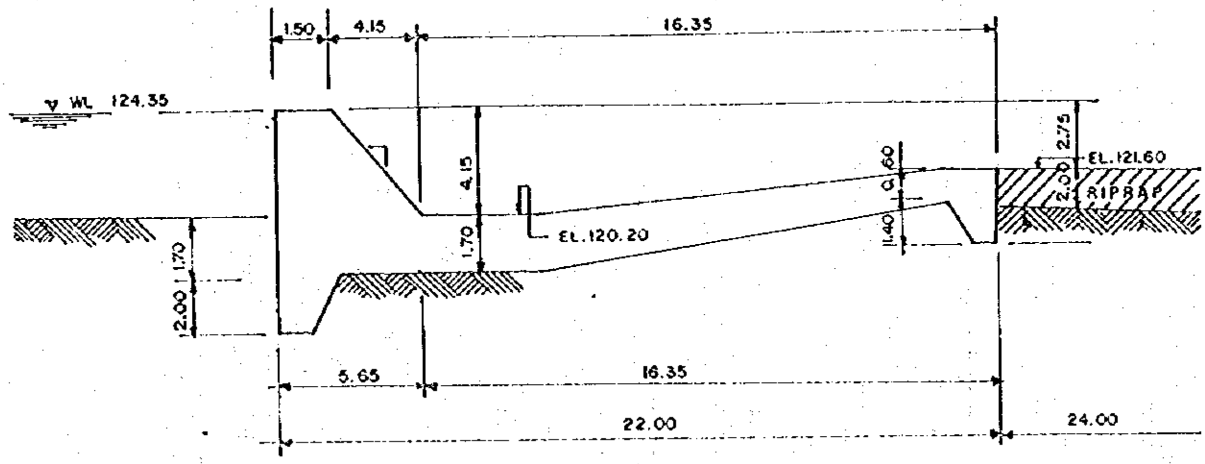
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.2.7
JAPAN INTERNATIONAL COOPERATION AGENCY	Existing Labugaon Diversion Dam



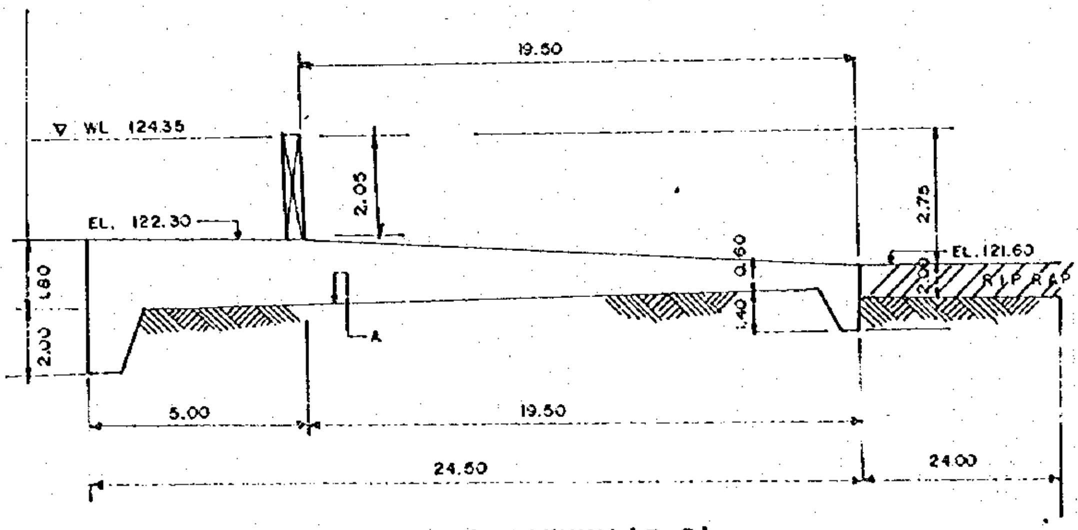
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	**Fig. E.2.8**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Existing Solsona Diversion Dam**



PROFILE

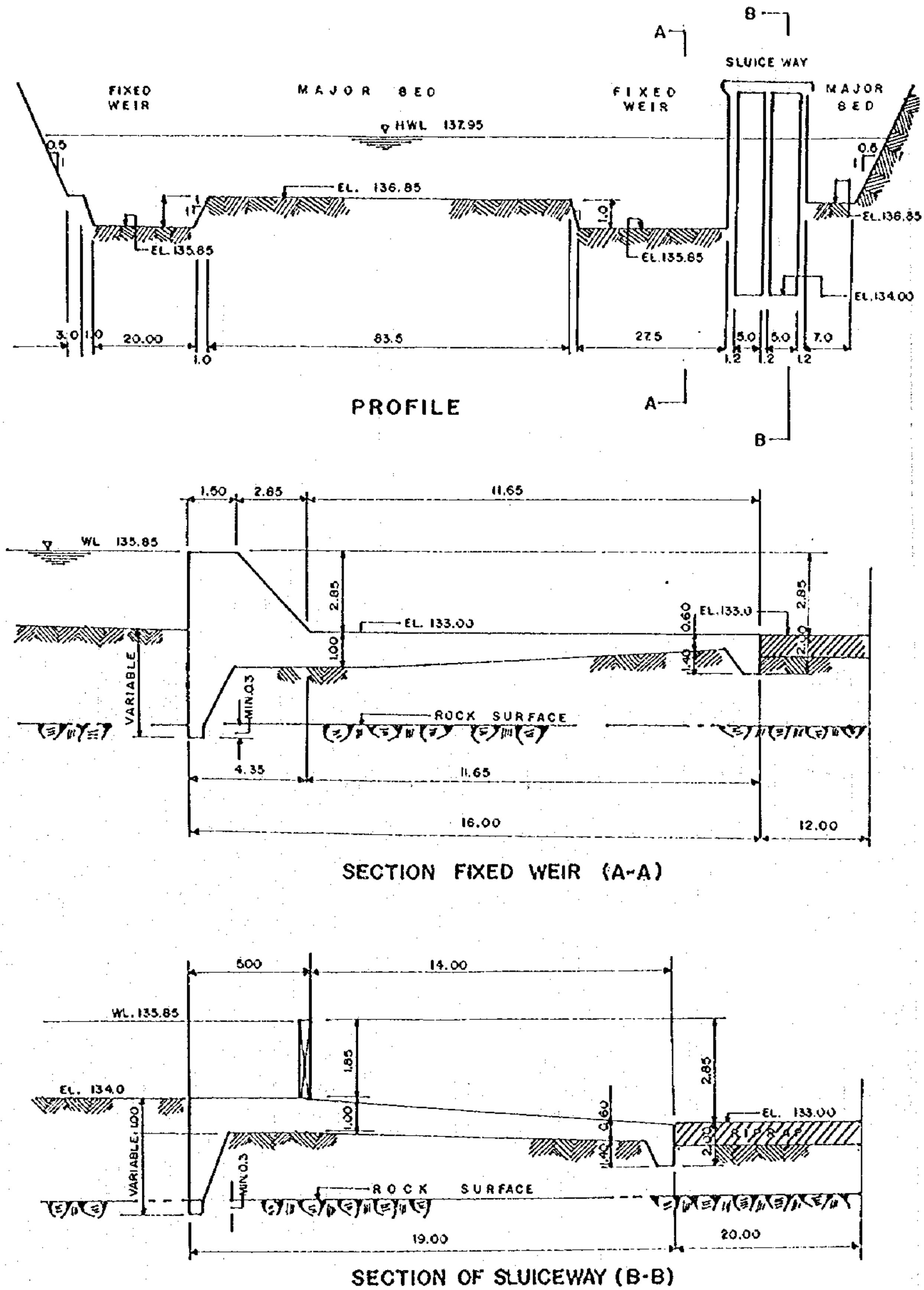


SECTION OF FIXED WEIR (A-A)

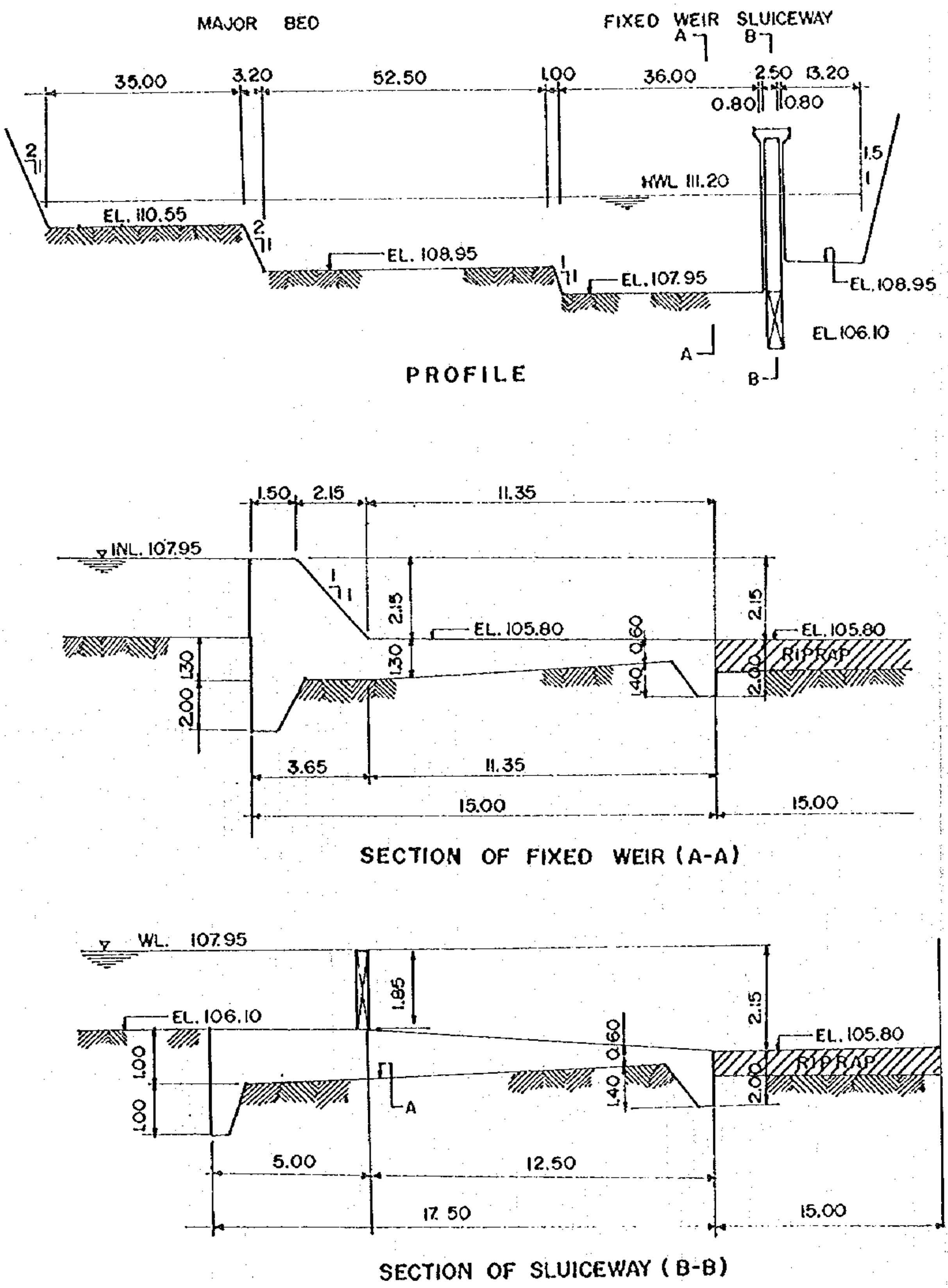


SECTION OF SLUICEWAY (B-B)

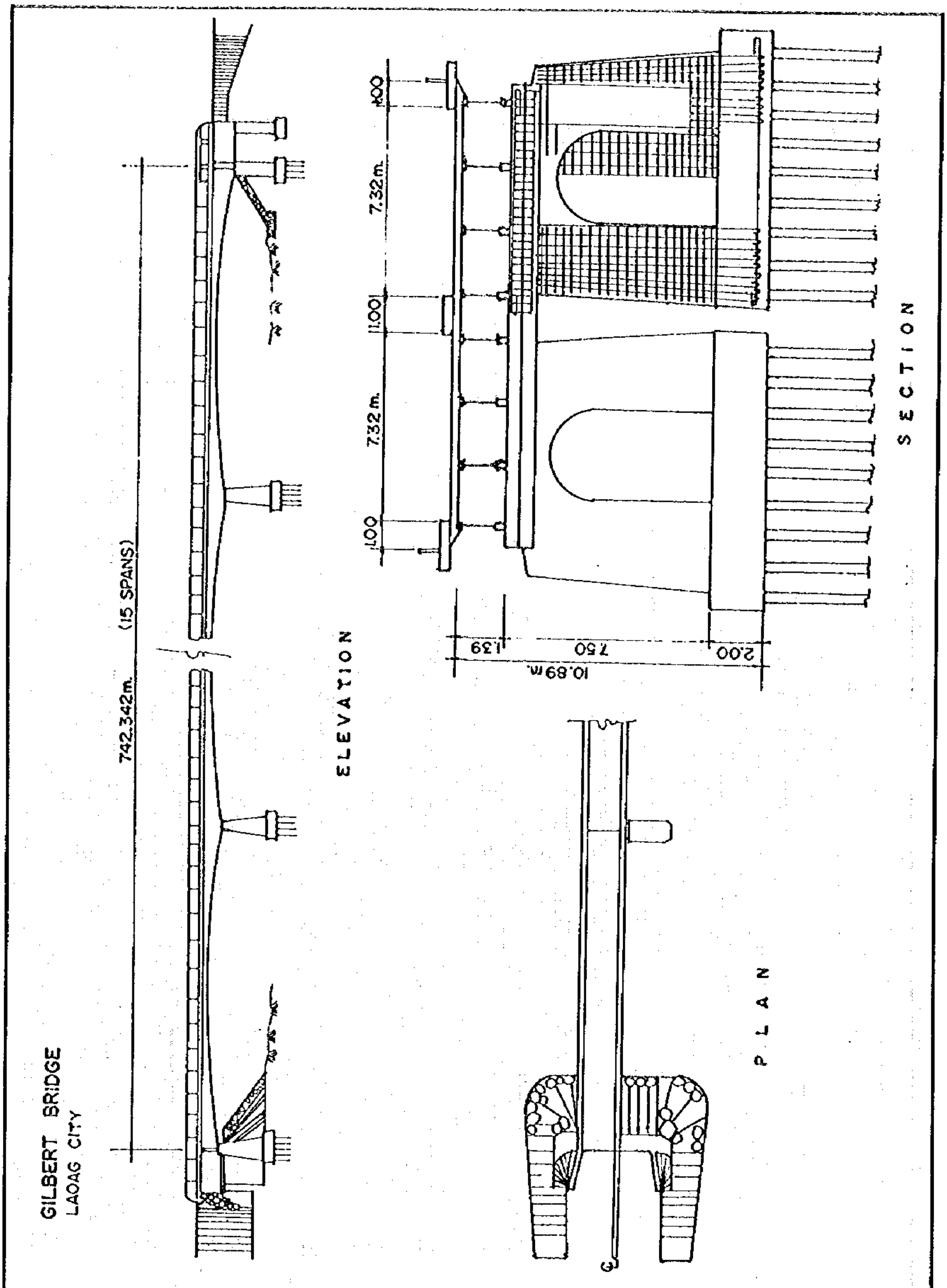
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.2.9
JAPAN INTERNATIONAL COOPERATION AGENCY	Existing Madongan Diversion Dam



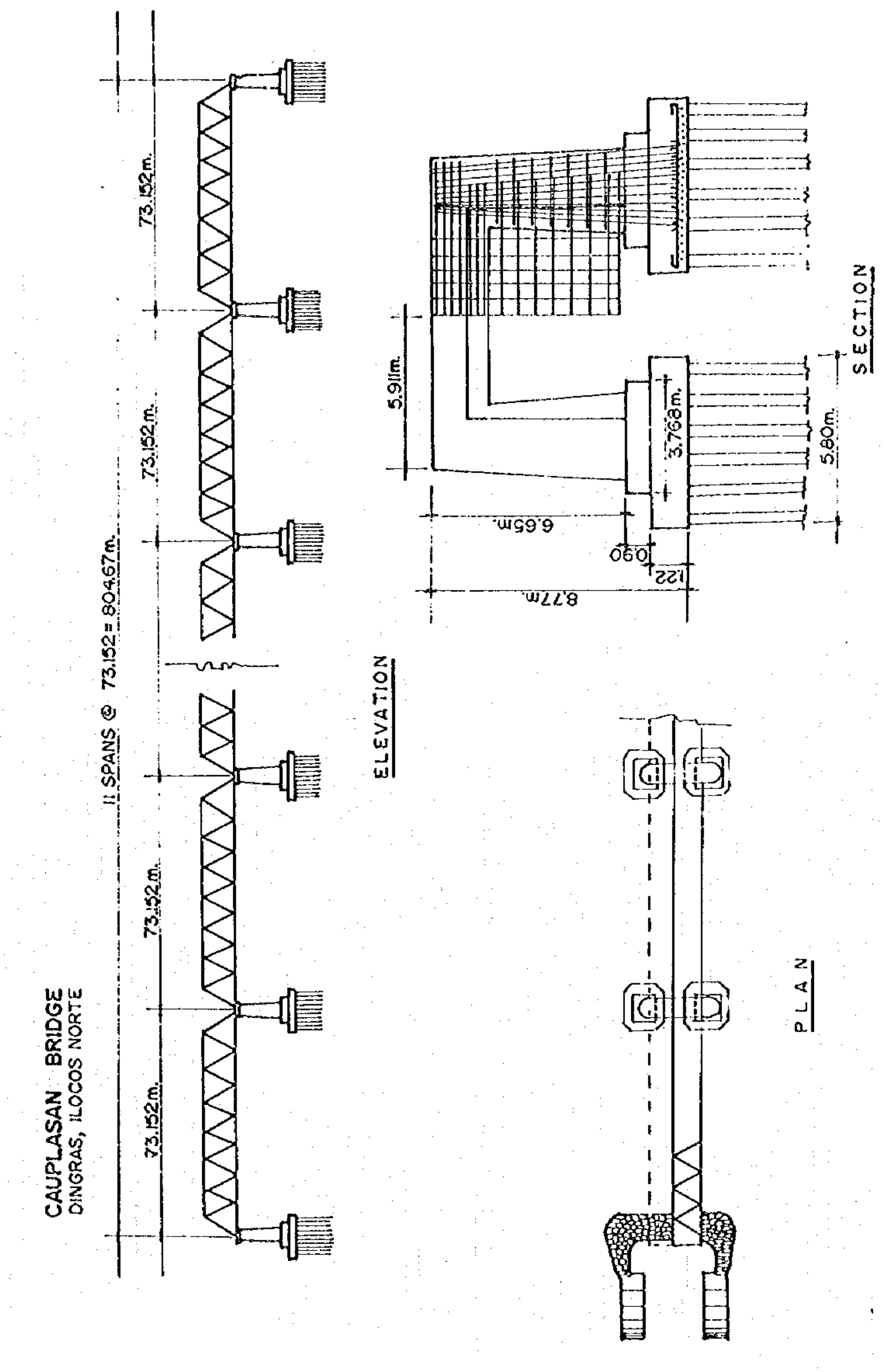
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.2.10
JAPAN INTERNATIONAL COOPERATION AGENCY	Existing Papa Diversion Dam



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.2.11
JAPAN INTERNATIONAL COOPERATION AGENCY	Existing Nueva Era Diversion Dam



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	**Fig. E.2.12**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Existing Gilbert Bridge**



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. E.2.13
JAPAN INTERNATIONAL COOPERATION AGENCY	Existing Cauplasan Bridge