7.5 Rivers and Dams

7.5.1 Disaster Damage Conditions

Regarding the earthquake damages to the river facilities and dams, we investigated the facilities mainly in the Agno river system and the Pampanga river system. Figure 7.5.1 shows the extent of damage and the main investigation sites.

The condition of the damage to the rivers and dams caused by the earthquake, based on our own field investigation and on our survey of concerned persons, as well as on the individual investigations by the Agno and the Pampanga River Flood Control System offices of DPWH, is displayed in Table 7.5.1.

7.5.2 Damage to Rivers

At the Agno river system, we observed damaged river facilities on a wide scale; cracks at the crests of the earth dikes and settlement and sliding of the dikes were marked; some of them had collapsed. Furthermore, cracks and collapsing were observed at the parapet levees and revetments.

In comparison, at the Pampanga river system, there were few damaged sites; however, a collapse of the earth dike near Mt. Arayat was particularly remarkable.

No remarkable damage was seen at the gates; the gates have been operating smoothly.

The condition of the damages according to the field investigation at each site were as follows.

(1) The Tarlac river, a branch of the Agno river (Paniqui site) (No.1 and No.3 in Table 7.5.1-I)

Large cracks occurred at the crowns of earth dikes of 5 - 6m in height, and sliding collapses occurred. The materials of the earth dike were mainly composed of fine sands. Some places were temporarily rehabilitated with sand-bag piling.

The parapet revetments, made of plain concrete using boulders, were such that the foundations were laid directly on the natural ground; though these revetments were badly damaged, the revetments in which foot protection on the river frontage had been conducted by the placing of boulders suffered little or no damage.

Furthermore, the No.6 water level gauging station on the river bank was inclined, and the conduit pipes were broken. (Figure 7.5.2, Photo. 7.5.1 to 7.5.5)

(2) The Agno river (Villasis to Bayambang sites) (No.10 in Table 7.5.1-I)

Many cracks were observed at the crowns of earth dikes of 5 to 6m in height; some earth dikes sank about 1m as a whole, or, some of the earth dikes slid and collapsed. Sliding occurred in the direction in which the ground height, inside or outside of the dike, was relatively lower. The main materials of the earth dikes seemed to be silt.

Furthermore, the neighboring Calvo Bridge had collapsed on the left bank, and big shearing cracks occurred at the abutments on the right bank. Also, damage of cracks and settlement was observed on the parapet levees stretching up to the bridge. (Figure 7.5.3, Photo. 7.5.6 to 7.5.8)

(3) The Agno river (Bayambang to Urbiztondo sites) (No.11 in Table 7.5.1-I)

Several oblique cracks on the crowns of earth dikes of about 5m in height, and big collapses caused by sliding were observed.

According to a housewife who saw the collapse at its actual location, serious horizontal shaking occurred, cracks opened, and then the earth dikes slid.

Both sides of the earth dikes were marsh and; the ground conditions were very bad. (Figure 7.5.4, Photo 7.5.9 to 7.5.11)

(4) The rivers in Dagupan city
(No.24 in Table 7.5.1-I)

At Dagupan, where serious liquefaction occurred, the parapet revetments in the city were badly damaged; some revetments sank under the water surface (the opposite bank in Photo 7.5.12); the parapet revetments which had the concrete foundation piles of 30-foot in length anchored by concrete blocks were damaged by liquefaction. (Photo 7.5.12, 7.5.13)

(5) The Pampanga river (Apalit to Arayat sites)
(No.4 in Table 7.5.1-II)

The steel sheet piles revetments (sheet length: 30 feet) constructed at the position where the water rushes against the banks had fallen down towards the river side.

(6) The Pampanga river (Arayat to Cabiao sites)
(No.5 in Table 7.5.1-II)

At the position where the water rushes against the banks of the Pampanga river near the foot of Mt. Arayat, cracking and collapsing of the earth dikes occurred; as to the earth dike damaged most severely, one-third of its body remained and was just before the complete collapse. At the upstream side close to the damaged site, emergency groyne work was being conducted; four groynes, including the one under construction, were expected in all.

Though the height of the earth dike was about 6m, the foot of the dike on the river side was supposed to be quite deep due to scour. The material of the earth dike was silt. (Photo 7.5.14 to 7.5.16)

7.5.3 Damage to Dams

We investigated the following dams; the Ambuklao Dam and the Binga Dam of the Agno river system, and the Pantabangan Dam complex (composed of the Pantabangan Dam, the Aya Dam and the Masiway Dam) and the Angat Dam of the Pampanga river system.

The dams were badly damaged; cracking and settlement of the crests of the dams and shallow sliding on the slopes of the dams were observed mostly in the Ambuklao Dam, the Binga Dam and the Masiway Dam.

However, since all the dams had become decrepit and maintenance on them seemed not sufficient, lots of damages were also observed which were unrelated to the earthquake.

Table 7.5.2 shows a list of the principal features relating to the investigated dams. All the dams are fill-type dams; and, except for the Masiway Dam which is a reregulating dam, they are all high dams above 100m.

Here the condition of the damage to each dam is described. (Table 7.5.2)

(1) The Ambuklao Dam (Figure 7.5.5, 7.5.6)
(No.1 to 6 in Table 7.5.1-III)

1) Though cracks had occurred at the crest of the dam. However, we could not confirmed this, since the rehabilitation of the crest by a bulldozer had been done (Photo 7.5.17).

2) Settlement of the crest of the dam was about 50cm, and undulation of the crest caused by uneven settlement was observed. (Photo 7.5.18, 7.5.19)

3) Some longitudinal cracks were observed on the upstream slope, and shallow sliding had occurred. (Photo 7.5.20 to 7.5.22)

4) Openings in the expansion joints were observed on parts of the separate walls between the fill dam and the spillway. (Photo 7.5.23)

5) The downstream slope of the dam seemed to be stable. (Photo 7.5.24)

6) The spillway was not damaged.

7) Many landslides had occurred on both the cutting faces of the left bank of the spillway and on the slopes on the circumference of the dam. (Photo 7.5.25)

8) The transmission yard just under the dam was damaged by sliding the slope behind. (Photo 7.5.26)

9) The change in seepage from the dam could not be determined, since analysis was not completed.

(2) The Binga Dam (Figure 7.5.7 to 7.5.8)
(No.1 to 7 in Table 7.5.1-IV)

1) Many deep longitudinal cracks, 10 to 20cm wide, occurred at the crest. In particular, large cracks occurred from the center to the left, mainly at the upstream side of the crest. And, at the top of the upstream and the downstream slopes, longitudinal cracks occurred throughout the whole length of the crest. (Photo 7.5.27 to 7.5.29)

2) Some transverse cracks, 1 to 2cm wide, were observed a little to the spillway side of the crest.

3) Settlement of the crest of the dam was not observed apparently.

4) No damages were observed on the downstream slopes, except for the small landslides around the ex-construction road on the slope. (Photo 7.5.30)

5) The riprap of the upstream slope of the dam seemed to be stable. (Photo 7.5.31)

6) No damages were observed in the spillway, except that the No.2 gate which was not operational.

7) Many landslides were observed on the circumference of the reservoir, mainly around the left and right abutments of the dam. However, the cut slope on the left bank of the spillway had been damaged before 1988, the year previous to the earthquake, as shown in Figure 7.5.9. (Photo 7.5.32, 7.5.33)

8) It is said that seepage from the dam has not changed between before and after the earthquake.

9) It is said that the power generation facilities were not damaged.

10) Figure 7.5.10 shows the results of a survey of a section of the dam on February 1988, the year previous to the earthquake; considerable settlement is observed in the Figure.

(3) Pantabangan Dams (Figure 7.5.11 to 7.5.14)
(No.1 to 10 in Table 7.5.1-V)

1) Settlement of 0.2 to 0.5m was observed at the crest of

the left bank side of the Pantabangan Dam. (Photo 7.5.34)

2) The upstream and downstream slopes of the Pantabangan Dam were stable. (Photo 7.5.35, 7.5.36)

3) Landslides occurred on the road to the Pantabangan Dam, and the damaged portions were rehabilitated with wire mats. (Photo 7.5.37)

4) The pressurized water from the intake tower was leaking out from the vacuum relief valves and flange joints of vacuum relief pipes in the gate chamber; the volume of leakage was estimated to be $2m^3$ per minute. (Photo 7.5.38, 7.5.39)

5) No apparent damages were observed at the Aya Dam, including the spillway. (Photo 7.5.40)

6) The Masiway Dam, which is the reregulating dam for the Pantabangan Dam, was badly damaged, even though the dam height is as low as 24m.

7) Longitudinal cracks of a maximum of 2.5m deep occurred at the crest of Masiway Dam, and some cracks had been observed by digging the pits. (Photo 7.5.41, 7.5.42)

8) The crest of Masiway Dam sank about 0.5 to 1m. (Photo 7.5.43)

9) Some landslides occurred on the upstream and the downstream slopes of the Masiway Dam, and the swelling of the slope was observed. (Photo 7.5.44, 7.5.45)

10) The spillway of the Masiway Dam was not damaged.

11) Some cracks were observed on the revetments on the right side of the spillway. (Photo 7.5.46)

12) At the Masiway Dam, in addition to a concrete spillway with gates, a spillway of earth dike, called Fuse Dike, with a 5m lowered crest is installed on the left bank side; longitudinal cracks and settlement were observed on the crest of the Fuse Dike, and landslides were observed on the upstream slope of the Fuse Dike. (Photo 7.5.47)

13) The No.1 diversion canal (near Rizal), which is an irrigation canal downstream from the Pantabangan Dam, the bridge across the canal, and the pavements on the both sides of the bridge were badly damaged. (Figure 7.5.16, Photo 7.5.48, 7.5.49)

(4) Angat Dam (Figure 7.5.17, 7.5.18)
(No.1 to 4 in Table 7.5.1-VI)

1) Settlement and cracks were not observed on the crest of the dam. (Photo 7.5.50)

2) The upstream and downstream slopes of the dam were not damaged. (Photo 7.5.51)

3) Landslides were observed at the slope on the way to the ex-batcher plant.

4) Though we could not investigate the site due to our time schedule, it is reported that leakage from the penstock, an increase in seepage from the auxiliary dam which is 3km east of the main dam, and landslides on the roads to the auxiliary dam occurred.

5) The seismometer installed at the lower part of the Angat Dam had been removed for repairs at the time of the earthquake.

7.5.4 Recommendations for Restoration

(1) Temporary restoration of river facilities

1) For levees, after investigating the changes, such as cracks, settlement and landslides, temporary restoration, as shown in Table 7.5.3, should be conducted in accordance with the conditions of the damage.

   In all cases, sand-bag piling is an effective measure at the temporary rehabilitation stage, and rapid countermeasures should be considered.

2) Sand-bag piling is also an effective measure for damage to parapet levees.

3) For damage to revetments or to river banks directly impacted by water flow, sand-bag piling should be performed. For seriously scoured places, the use of wire cylinders (gabions) or groyne work to change the flow-direction should be considered.

(2) Permanent rehabilitation of rivers

1) For levees, permanent restoration, as shown in Table 7.5.4, should be performed in accordance with the conditions of the damage. The improvement rehabilitation using revetments and cut-off sheet piles should be considered, if necessary.

2) Parapet levees should be reconstructed, or, the repair and reinforcement of damaged parts should be done.

3) Revetments and river banks directly impacted by water flow should be reconstructed, or repaired and reinforced, and additionally, foot protection work such as dumping of boulders or concrete blocks in front of revetments and river banks should be considered.

(3) Temporary restoration of dams

1) The positions where cracks occurred should be covered with vinyl sheets or sand-bags in order to prevent the seepage of the rain, and the location, width and depth of the cracks should be confirmed by digging pits.

   In this case, it is convenient for the investigation if limewater is previously poured into the cracks.

2) To maintain the original height vis-a-vis settlement, sand-bag piling or banking should be performed.

3) Positions of slope failure of dams should be rehabilitated with sand-bags. If there is a possibility of promoting sliding, sand-bag piling or wire cylinders (gabions) should be considered as toe weight.

4) Damaged riprap should be rehabilitated with sand-bag piling.

5) In the cases where an increase of seepage is recognized, the reservoir water-level should be lowered as much as possible.

(4) Permanent rehabilitation of dams

1) Since dams are important structures, the first thing to do for their permanent rehabilitation is to thoroughly grasp the condition of the damage.

   That is, the deformations of dams and the change of the amount of seepage from dams should be confirmed not only by visual observation but also by surveying and measurement.

2) For cracks, damaged positions should be excavated as in the case of river levees, then banking and compaction should be redone.

If the cracks reach as far as the core, the core of those parts should be repaired.

3) To deal with settlement, after repairing the cracks, banking should be done up to the original height.

If settlement extends as far as the core, the core should also be restored up to the original height.

4) For collapse of the slopes of dams, the damaged positions should be restored to the original shape by banking, taking unification with the remaining parts into consideration.

In this case, the internal angle of friction and the cohesion of the materials used for the dam embankment should be tested. And, the stability of the dam vis-a-vis sliding, giving consideration to seismic force, should be examined again. If there is any unstability, the grade should be improved.

5) Damaged riprap should be replenished. The materials of the riprap are seen as not being able to withstand the erosion of waves, since the riprap is slightly small. Therefore, larger materials should be used.

6) For the damaged slopes of reservoir circumferences, particularly the cut slopes excavated for spillway works, shotcreet (concrete spraying) should be conducted, if necessary.

(5) Others

For temporary and permanent rehabilitation after river disaster or for regular river works, since wire cylinders (gabions) are very useful measures, their application should be promoted.

Further, since the degree of damage to dams depends upon quality of the maintenance, a prudent policy should be adopted for the maintenance of dams.

Table 7.5.1 Damage Inventory on River Structures and Dams (1/8)

Name of River/Dam	Location				Extent of Damage	Name of personnel accompanied/ interviewed	Authority in Charge	Remarks
	No.	City/Town	Province	Region				
I. Agno river 1.1 Tarlac river	*1 ①	Ranga-ayan, Paniqui (Tarlac RCP)	Tarlac	III	Concrete revetment (depression of about 1.0 m, l=500 m)	Mr. J. N. Rigor (Project Manager of AFCS)	*2 AFCS (DPWH)	
	2	Gerona, Paniqui & Monoada (Tarlac RCP)	- do -	- do -	Earth dike (depression with large cracks, l=21.8 km)	Mr. F.D. Ginez (Engineer IV)		
	③	Gerona, Paniqui & Monoada (Tarlac RCP)	- do -	- do -	Earth dike (depression with large cracks, l=25 km)	Mr. A. Cayabyab		
	4	Sinait (Tarlac RCP)	- do -	- do -	Concrete revetment (depression)			
	5	Salapungan, Aqase and Sta Cruz (Tarlac RCP)	- do -	- do -	Earth dike and revetment (depression of about 1.5 m & large cracks along the rip-rap, l=5.2 km)			
	6	San Isidro (Tarlac RCP)	- do -	- do -	Side slope and headwall (large cracks)			
1.2 Agno river	7	San Jose, Urdaneta (Mitura RCP)	Pangasinan	I	Concrete revetment (l=90 m)			
	8	Viray - Depalo earth dike, Tayug, Nutividad	- do -	- do -	Earth dike (depression of about 2 m with large cracks, left l=9.77 km, right l=9 km)			
	9	Viray - Depalo earth dike, Bantog, San Quintin	- do -	- do -	Earth dike (depression of about 2 m with large cracks, l=5.2 km)			
	⑩	Villasis - Bayambang earth dike, Macayo Gualsic, Caranglaan, Atayuan	- do -	- do -	Earth dike (large cracks & depression of about 1.5 m, l=8.4 km)			

Remarks: *1: Ⓝⓞ sites inspected by the Japanese Expert Team
*2: Agno River Flood Control System Office

Table 7.5.1 Damage Inventory on River Structures and Dams (2/8)

Name of River/Dam	Location				Extent of Damage	Name of personnel accompanied/ interviewed	Authority in Charge	Remarks
	No.	City/Town	Province	Region				
1.2 Agno river (Continued)	(11)	Bayambang - Urbiztondo earth dike, San Carlos City	Pangasinan	I	Earth dike (large cracks, l=32 km with exceptions)			
	12	Anulid - Bautista earth dike, Bautista	- do -	- do -	Earth dike (depression of about 2 m with large cracks, l=5.82 km)			
	13	Villasis - Bayambang earth dike, Puelay Villasis	- do -	- do -	Earth dike (large cracks & depression of about 1 m, l=60 m)			
	14	Asingan - San Manuel earth dike, Asingan San Manuel	- do -	- do -	Earth dike (heavily damaged, l=300 m)			
	15	Sta. Tomas	- do -	- do -	Earth dike and concrete revetment (l=7.6 km with exceptions)			
	16	Alcala	- do -	- do -	Earth dike and boulder dike (depression of about 1.5 m, l=200 m)			
	17	Sta. Maria - Tayug earth dike	- do -	- do -	Earth dike (cracks & depression of about 1 m, l=12.06 km with exceptions)			
	18	Villasis - Alingan earth dike	- do -	- do -	Earth dike (large cracks, l=3.05 km)			
	19	Bayambang	- do -	- do -	Concrete revetment (l=60 m)			
	20	Umingan (Banila RCP)	- do -	- do -	Earth dike (large cracks & depression of 1 m, l=8.82 km with exceptions)			
	21	Balungao (Banila RCP)	- do -	- do -	Earth dike (partially damaged)			

Table 7.5.1 Damage Inventory on River Structures and Dams (3/8)

Name of River/Dam	Location				Extent of Damage	Name of personnel accompanied/ interviewed	Authority in Charge	Remarks
	No.	City/Town	Province	Region				
1.3 Allied rivers	22	Binalonan (Tagamusing RCP)	Pangasinan	I	Concrete revetment (large cracks)			
	23	San Fabian (Cayanga RCP)	- do -	- do -	Concrete revetment (heavily damaged, l=180 m)			
	24	Dagupan (Pantal RCP)	- do -	- do -	Concrete revetment (heavily damaged, l=113 m)			
	25	Banday, San Fabian (Bued RCP)	- do -	- do -	Concrete revetment (large cracks, l=256 m)			
	26	Alamines, Cabatuan, Balangobong (Cabatuan RCP)	- do -	- do -	Concrete revetment (partially damaged)			
	27	Calasiao (Marusay RCP)	- do -	- do -	Bank protection (partially damaged, depression of about 0.5 m)			
	28	Mangaldan (Angalacan RCP)	- do -	- do -	Boulder spur dikes (partially damaged, depression of about 0.5 m)			
	29	San Jacinto (Abeloleng & Angalacan RCP)	- do -	- do -	Boulder spur dikes (depression of about 2 m)			
	30	Nalsian, Calasiao (Marusay RCP)	- do -	- do -	Gravity wall (partially damaged, l=85 m)			
	31	Pias, Mapandan (Abeloleng RCP)	- do -	- do -	Boulder spur dikes (partially damaged)			
	32	Sta. Barbara (Sinocaran RCP)	- do -	- do -	Earth dike (partially damaged)			
	33	Banaoang, Tulcao Lusip, Sta. Barbara (Marusay RCP)	- do -	- do -	Earth dike and spur dikes (partially damaged)			
	34	Sison (Bued RCP)	- do -	- do -	Concrete revetment (partially damaged)			
	35	Cabalitian, Asingan	- do -	- do -	Revetment (partially damaged)			

Table 7.5.1 Damage Inventory on River Structures and Dams (4/8)

Name of River/Dam	Location				Extent of Damage	Name of personnel accompanied/interviewed	Authority in Charge	Remarks
	No.	City/Town	Province	Region				
II. Pampanga river	1	Zaragosa and Aliaga	Nueva Ecija	III	Earth dike (settled down by about 2 m, l=100 m)	Mr. E.B. Dizon (Project Manager of PRCS)	* PRCS (DPWH)	
	2	Jaen	- do -	- do -	Revetment (sagged by about 0.3 m, l=25 m)	Mr. R.O. Oroceo (Co-manager)		
	3	Cabiao - San Isidro	- do -	- do -	Spur dike (2 m of scoured)	Mr. N.O. Tolentino (Sr. Civil Engineer)		
	(4)	Apalit - Alayat set back levee	Pampanga	- do -	Revetment (eroded, l=30 m)			
	(5)	Alayat - Cabiao ring levee	- do -	- do -	River bank (eroded, l=200 m)			
	6	Concepcion	Tarlac	- do -	Dike (eroded, l=300 m)			
	7	Luar	Nueva Ecija	- do -	Dike (eroded)			
	8	Zaragosa	- do -	- do -	Dike (settled down by about 2 m, l=250 m)			

Remarks: *: *Pampanga River Control System*

Table 7.5.1 Damage Inventory on River Structures and Dams (5/8)

Name of River/Dam	Location				Extent of Damage	Name of personnel accompanied/ interviewed	Authority in Charge	Remarks
	No.	City/Town	Province	Region				
III. Ambuklao dam		Agno river	Benguet	I		Mr. T.D. Delizo (Engineer, Hydro Eng'g Design Division, NAPOCOR)	NAPOCOR	
3.1 Embankment	①				- Cracks on the dam crest			
	②				- Settlement of embankment (approximate depth 0.5 m)			
	③				- Cracks on the upstream slope (W=10 cm, l=30 m near right abutment, under monitoring the movement of cracks by pitting)	Mr. A.L. Aguila (Supt. on Duty, Engineer at the Ambuklao Hydroelectric Plant)		
3.2 Retaining wall (sustaining embankment)	④				- Expansion joint (partially damaged)			
3.3 Reservoir	⑤				- Landslide (many landslides; occurred around the reservoir, especially at the cut slope of the left abutment) Note: (1) Seepage amount is not yet examined in detail based on the measured record. (2) Damage on hydroelectrical equipment in the power house is under checking. Generation is stopped temporarily from Aug. 2.			
3.4 Switchyard	⑥				- Relay equipments damaged due to landslide of the cut slope behind			

Table 7.5.1 Damage Inventory on River Structures and Dams (6/8)

Name of River/Dam	Location				Extent of Damage	Name of personnel accompanied/ interviewed	Authority in Charge	Remarks
	No.	City/Town	Province	Region				
IV. Binga dam 4.1 Embankment	①	Agno river	Benguet	I	- Cracks on the dam crest (it lasts from edge to edge along the dam axis, w=10 cm, d=2 m)	Mr. T.D. Delizo (Engineer, Hydro Eng'g Design Division, NAPOCOR) Mr. J.C. Rico (Manager of Binga Hydroelectric Plant)	NAPOCOR	
	②				- Transverse cracks on the dam crest near the spillway (6 nos., w=2 cm, d=2 m)			
	③				- Landslides along the road on the downstream slope			
4.2 Spillway	④				- Gate No. 2 (radial gate) is not operational.			
4.3 Reservoir	⑤				- Landslide (many landslides occurred around the reservoir, especially at the both abutments.) Note: (1) No abnormal change of seepage amount is observed at before and after the earthquake. (2) No damage is found on the hydromechanical equipment in the power plant.			

Table 7.5.1 Damage Inventory on River Structures and Dams (7/8)

Name of River/Dam	Location				Extent of Damage	Name of personnel accompanied/ interviewed	Authority in Charge	Remarks
	No.	City/Town	Province	Region				
V. Pantabangan dam		Pampanga river	Nueva Ecija	III		Mr. Domingo (Engineer, NIA Head Office)	NIA	
5.1 Main dam								
5.1.1 Embankment	①				- Settlement of embankment (d=0.2m - 0.5 m)	Mr. J.S. Tolentino (Chief of Dam & Reservoir Division, UPRIIS*)		
5.1.2 Access Road to dam	②				- Landslide			
5.1.3 Diversion Tunnel	③				- Leakage from the vacuum relief valves			
5.2 Aya dam					- None	Mr. C.C. Tenorio (Operator of Gates and Valves)		
5.3 Masiway dam								
5.3.1 Embankment	④				- Cracks on the dam crest (max depth 2.5 m)			
	⑤				- Cracks on the fuse dike			
	⑥				- Settlement of embankment (d=0.5 - 1 m)			
	⑦				- Swell of the upstream and downstream slopes due to settlement of embankment			
	⑧				- Collapse of the revetments near the right abutment			
5.4 Irrigation canal	⑨				- Collapse of the embankment of the diversion canal No.1			
	⑩				- Collapse of the bridge across the diversion canal No.1			

Remarks: * Upper Pampanga River Integrated Irrigation Systems

Table 7.5.1 Damage Inventory on River Structures and Dams (8/8)

Name of River/Dam	Location				Extent of Damage	Name of personnel accompanied/ interviewed	Authority in Charge	Remarks
	No.	City/Town	Province	Region				
VI. Augat dam		Augat river (Pampanga river system)	Bulacan	III		Mr. F.V. De Jesus (Manager of Augat Hydro Power Plant)	NAPOCOR	
6.1 Main Dam					- None			
6.2 Penstock	1				- Leakage from penstock (amount is not yet confirmed)			
6.3 Access road to batcher plant	②				- Cracks on the surface of cut slope			
6.4 Access road to Dike	3				- Landslide			
6.5 Dike (about 3 km eastward from the main dam)	4				- Increase of seepage through foundation			

Data source: (1) Damage survey result by Agno River Flood Control System Office and Pampanga River Control System Office

(2) Site Inspection and interview to the personnels in charge by the Japanese Expert Team

Table 7.5.2 Principal Feature of Existing Multipurpose Dam

NAME OF DAM	RIVER SYSTEM (Stream)	DAM				SPILLWAY				RESERVOIR						POWER		Operation in Charge
		Crest Elev. (m)	Crest Length (m)	Height (m)	Volume ($10^6 m^3$)	Discharge Capacity (m^3)	Gate			Drainage Area (km^2)	Surface Area at NHWL (km^2)	DFWL (Elm)	NHWL (Elm)	LWL (Elm)	Total Storage ($10^6 m^3$)	Installed Capacity (MW)	Commis-sioning Year	
							Nos. of Gate	Height (m)	Width (m)									
Ambuklao	Agno (Agno)	758.0	560	129.0	5.8	11,000	8	12.5	12.5	690	7.5	754.0	752.0	700.0	329	75.0	1956.57	NAPOCOR
Binga	Agno (Agno)	586.0	215	107.4	1.9	10,600	6	12.5	12.5	860	1.9	579.5	575.0	555.0	87	100.0	1960	NAPOCOR
Pantabangan	Pampanga (Pampanga)	232.0	1,615	107.0	12.9	4,200	3 Length of non-gated overflow weir : 15.0 m	10.0	8.0	916	63.1	230.0	221.0	171.5	2,996	100.0	1977	NIA
Masiway	Pampanga (Pampanga)	135.0	500	24.0	-	-	3 3 stoplogs non-gated overflow weir (Fuse Dike)	-	-	-	-	-	-	-	-	-	1977	NIA
Angat	Pampanga (Angat)	221.5	368	131.0	-	5,600	3	15.0	12.5	568	23.0	219.0	212.0	180.0	941	220.0	1967.69	NAPOCOR

REMARKS: DFWL : Design Flood Water Level
NHWL : Normal High Water Level
LWL : Low Water Level

Table 7.5.3 Methods used for temporary restoration of levees (1/2)

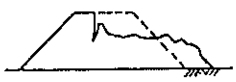
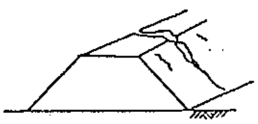
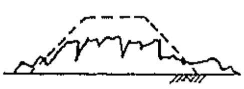
Status of damage		Method of temporary restoration
Schematic sketch of damage (pattern)	State of damage	
	Cracks are limited to crown of bank.	Execute sandfilling or sandbag piling at the damaged part to prevent rainwater infiltration into bank.
	Wash-out or collapse of slope, or, occurrence of cracks/level difference is limited to top of slope.	Execute sandbag piling at the collapsed part to prevent rainwater infiltration into bank, leakage through bank and scouring of bank. Sometimes, execute cutback of collapsed part, or rebanking to its original shape using collapsed earth material.
	Slide collapse of bank, or, occurrence of longitudinal cracks or level difference extends center of crown of bank.	Execute sandbag piling at the collapsed part to prevent rainwater infiltration into bank, leakage through bank and scouring of bank and to secure the crown height of bank. Sometimes, execute cutback of collapsed part or rebanking to its original shape using collapsed earth material.
	Transverse crack/ level difference occurs in bank.	Execute sandbag piling, sand filling or cutback to prevent rainwater infiltration into bank, leakage through bank and scouring of bank and to secure the crown height of bank.
	Collapse extends to foundation ground and original shape of bank is not kept at all.	Execute sandbag piling, cutback or rebanking to prevent rainwater infiltration into bank, leakage through bank and scouring of bank, to secure the crown height of bank and to ensure the stability of bank. Sometimes, execute driving the cut-off sheet piles at the toe of the front slope to prevent leakage through the foundation ground.

Table 7.5.3 Methods used for temporary restoration of levees (2/2)

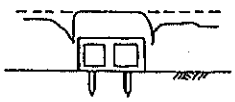
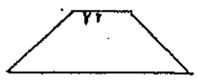
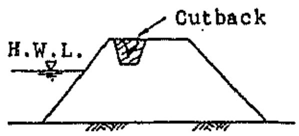
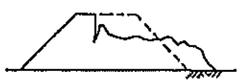
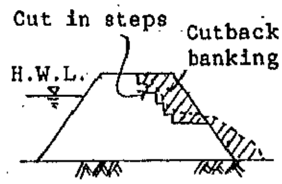
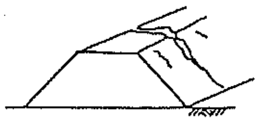
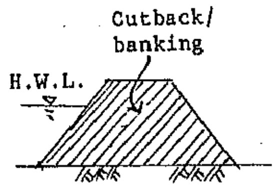
Status of damage		Method of temporary restoration
Schematic sketch of damage (pattern)	State of damage	
	Bank is deformed due to uniform settlement, keeping its shape to some extent.	Execute sandbag piling or rebanking to secure the crown height of bank and to prevent leakage through bank.
	Embankment fill behind a structure sinks or cracks.	Execute sandbag piling or rebanking to prevent rainwater infiltration into bank and leakage through bank and to secure the crown height of bank.

Table 7.5.4 Methods used for permanent rehabilitation of levees

Schematic sketch of damage (pattern)	Method of permanent rehabilitation	Typical illustration
	Excavate, fill and compact the damaged part to ensure the stability of bank against high water, etc.	
 	Cut the slope in steps and rebank it to its original shape using collapsed earth material, to ensure the stability of bank.	
 	Excavate, rebank and compact the cracked or weakened portion to ensure the stability of bank. Construct the counterweight fill or improve the foundation, if necessary.	
	Fill the deformed part to ensure the stability of bank against high water, etc.	

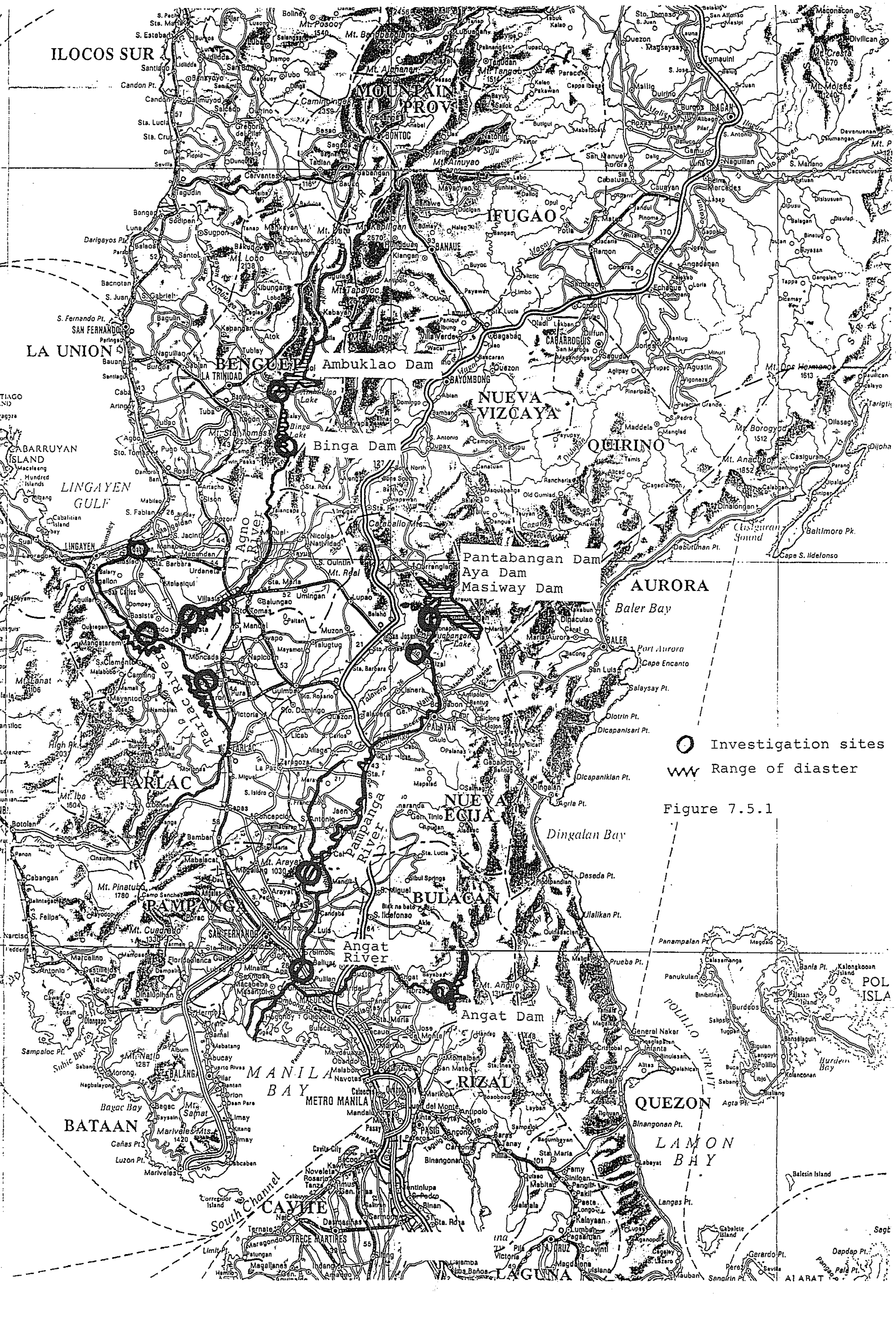

Investigation sites
Range of diaster
Ambuklao Dam
Binga Dam
Pantabangan Dam
Aya Dam
Masiway Dam
Angat Dam
Angat River
Pampanga River
Agno River
Tarlac River
ILOCOS SUR
LA UNION
BENGUET
MOUNTAIN PROV
IFUGAO
NUEVA VIZCAYA
QUIRINO
AURORA
NUEVA ECIJA
TARLAC
PAMPANGA
BULACAN
RIZAL
QUEZON
BATAAN
CAVITE
LAGUNA
METRO MANILA
MANILA BAY
LINGAYEN GULF
LAMON BAY
Baler Bay
Dingalan Bay
POLILLO STRAIT
South Channel

Figure 7.5.1

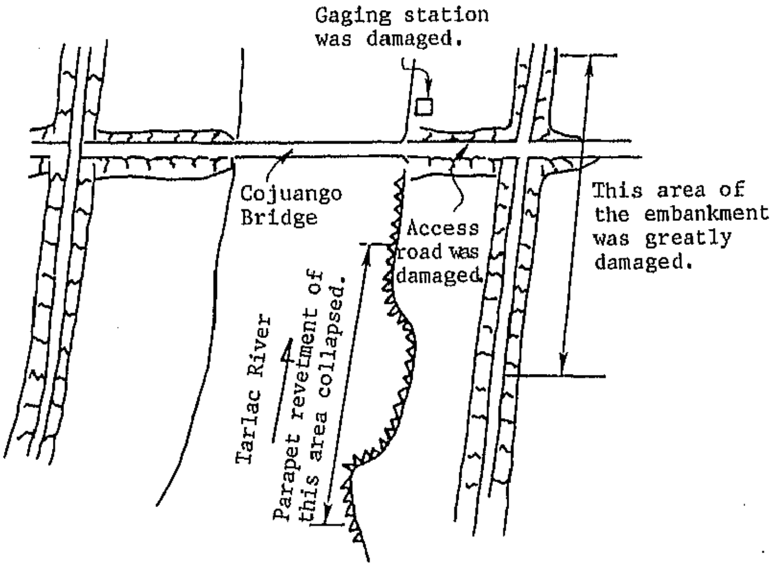


Figure 7.5.2

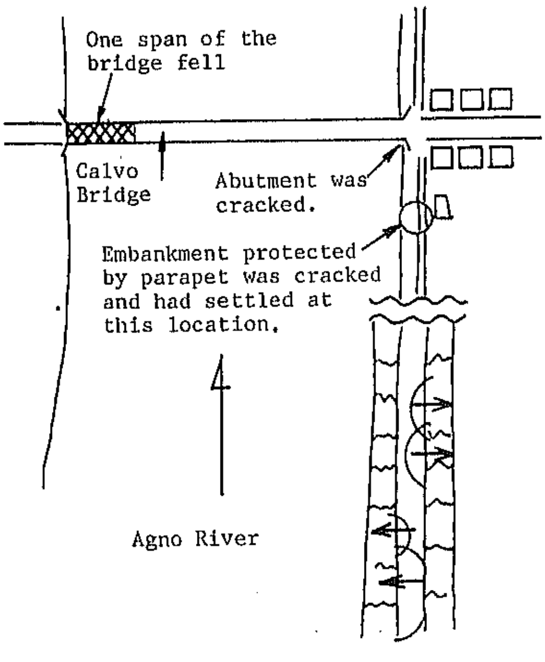


Figure 7.5.3

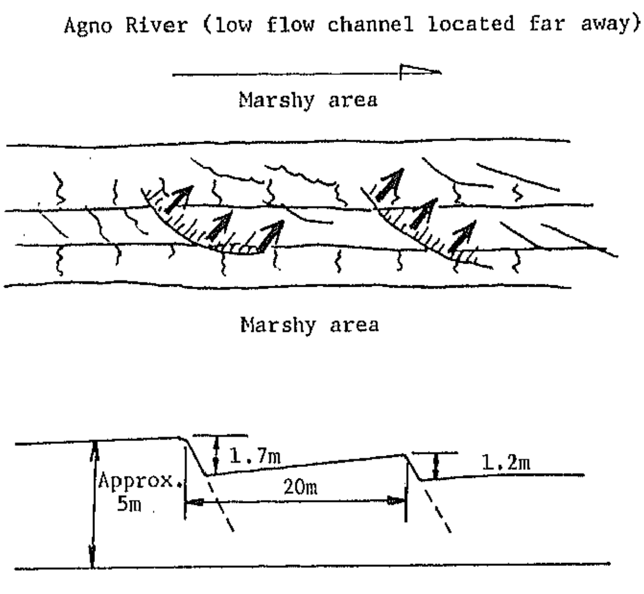


Figure 7.5.4

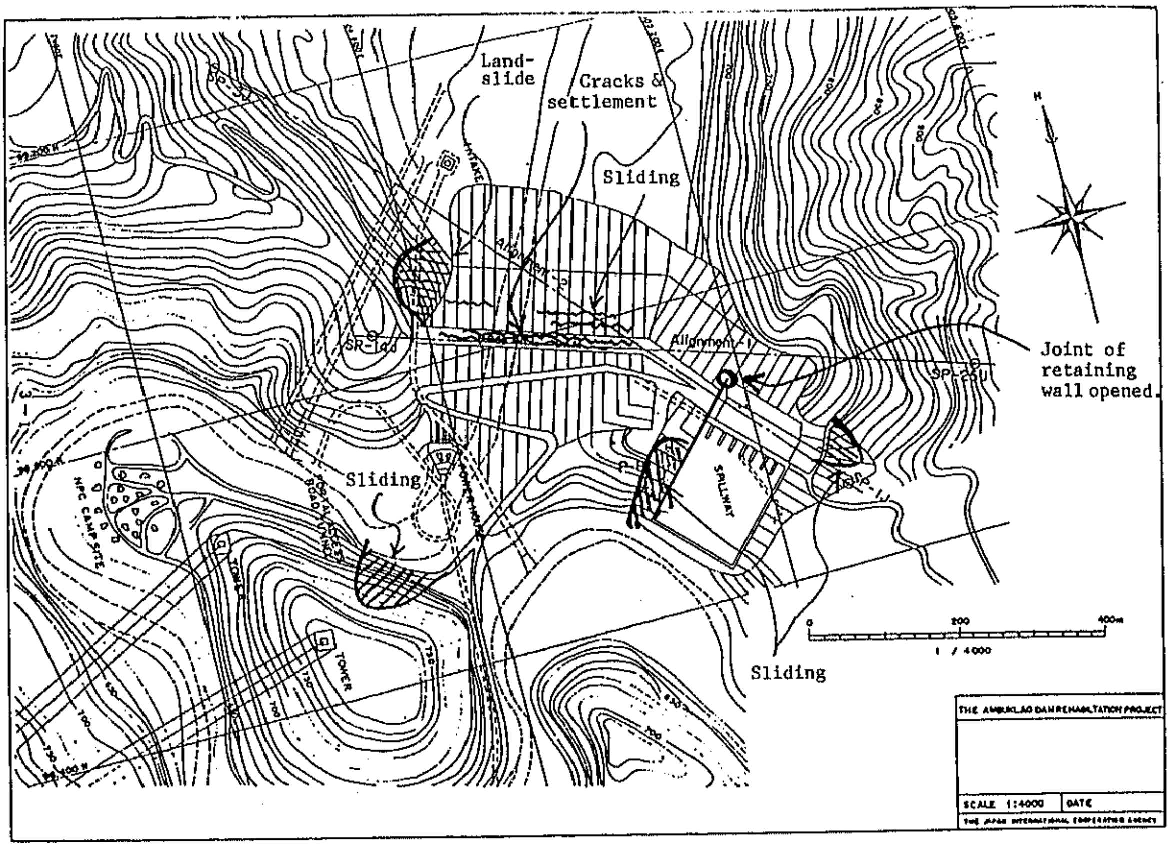


Figure 7.5.5 Plan of Ambukulao Dam

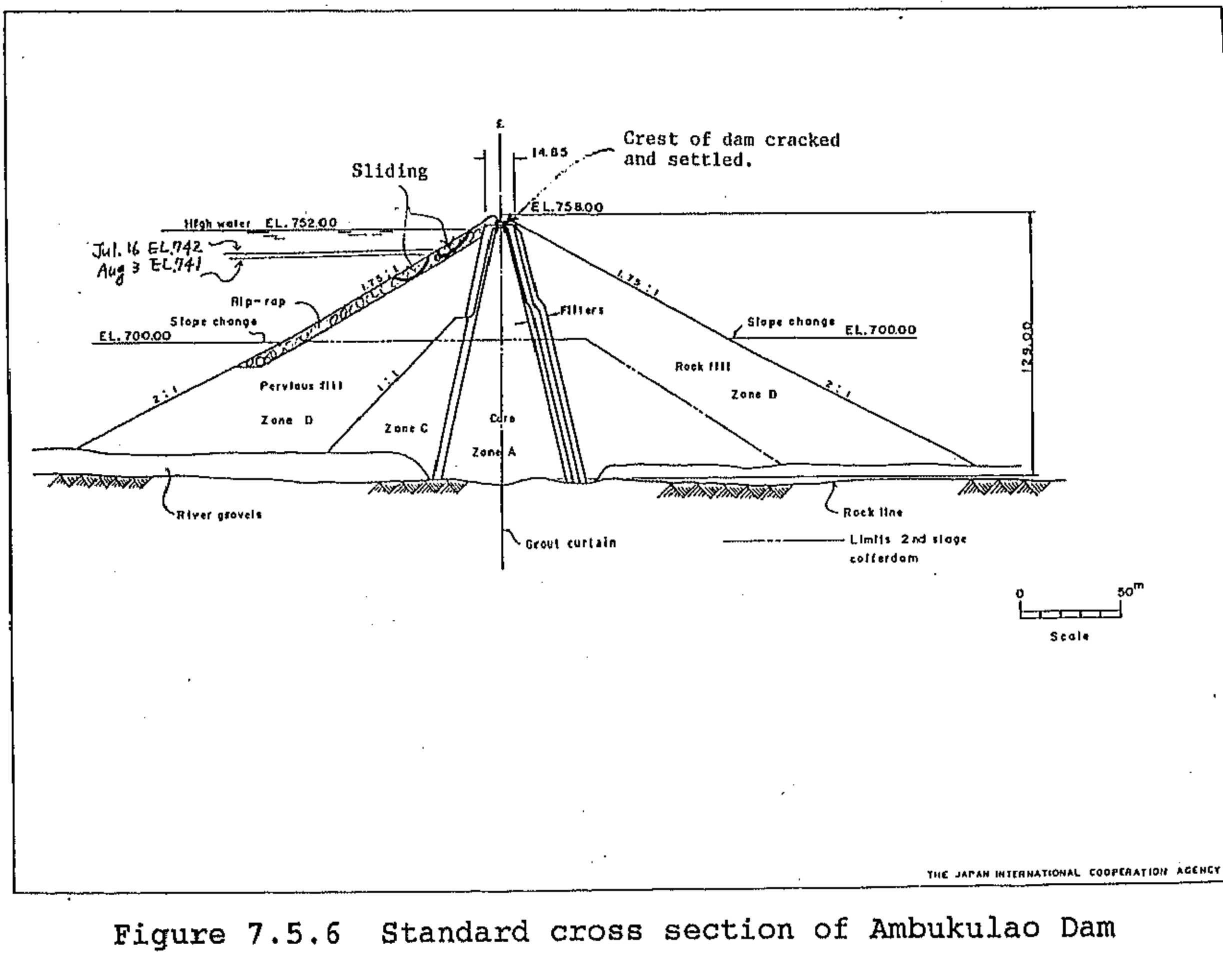


Figure 7.5.6 Standard cross section of Ambukulao Dam

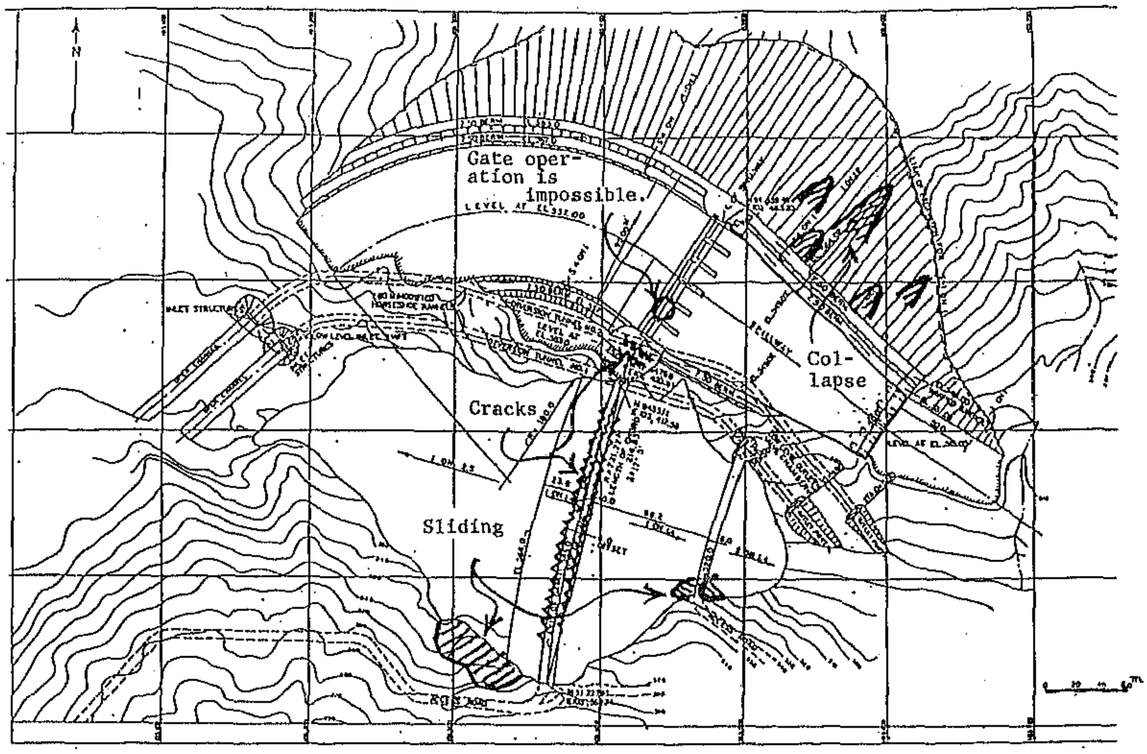


Figure 7.5.7 Plan of Binga Dam

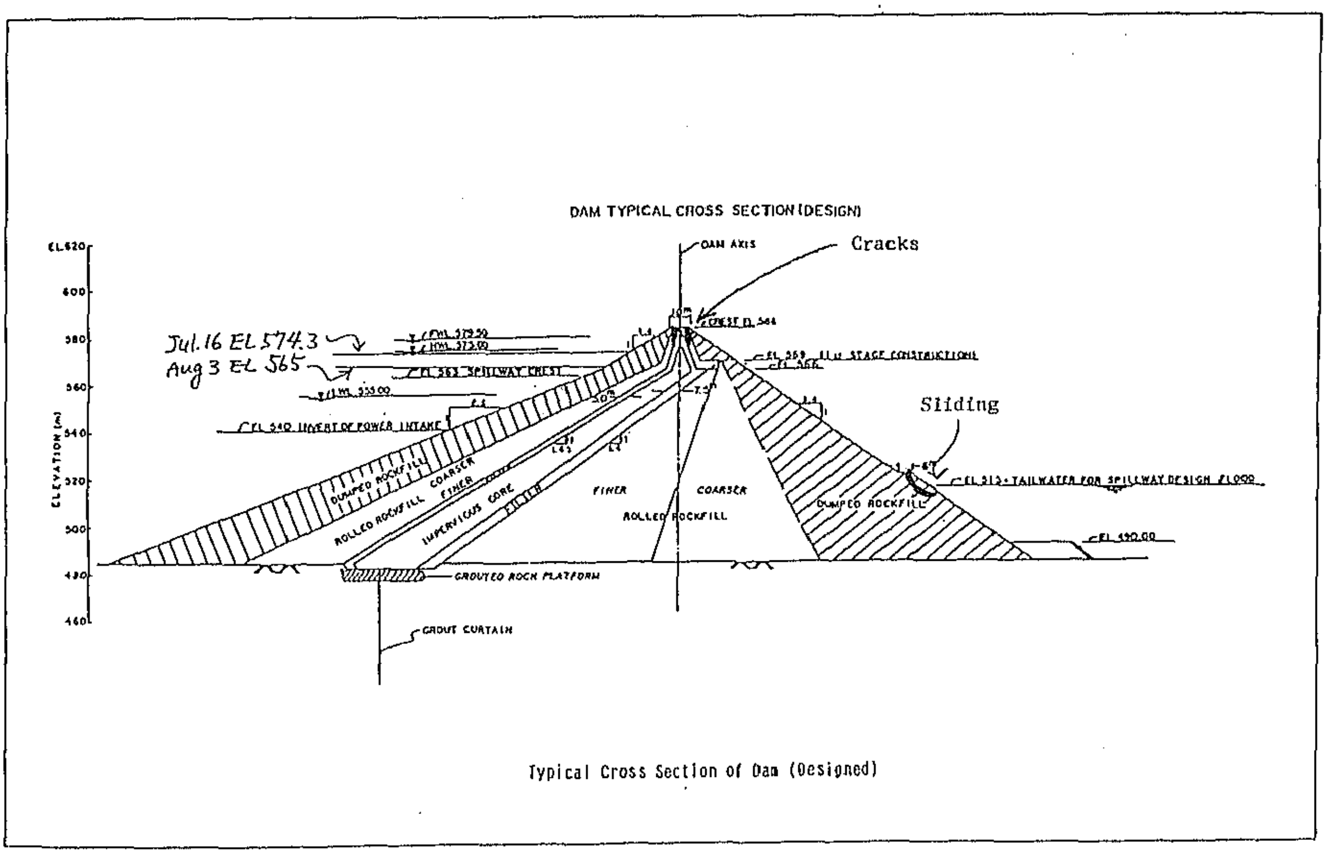


Figure 7.5.8 Standard cross section of Binga Dam

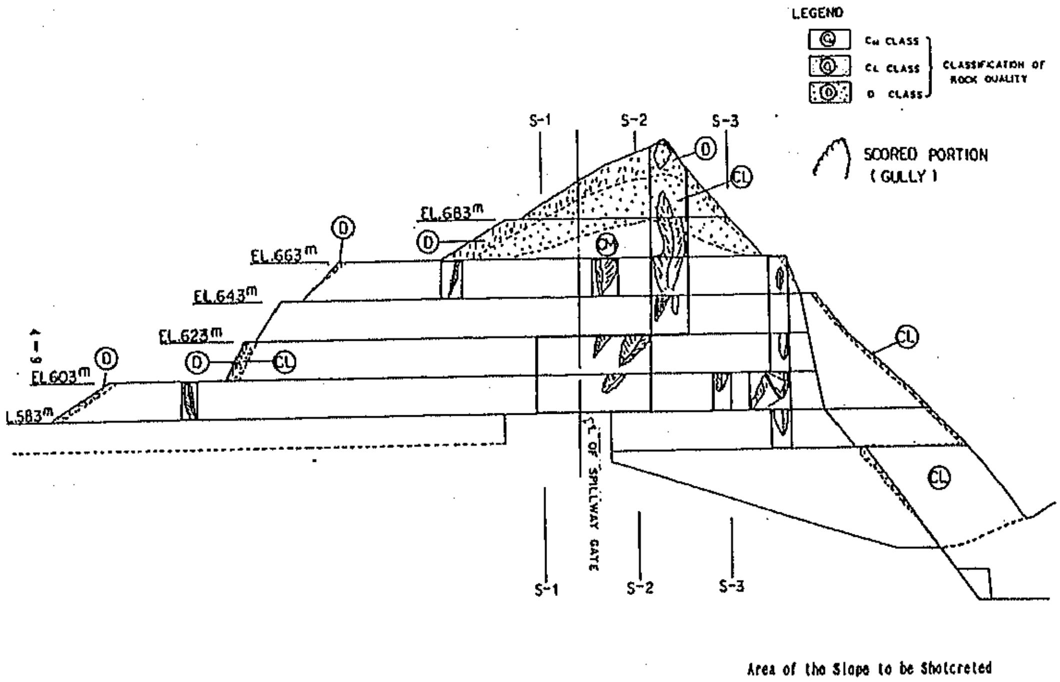


Figure 7.5.9 Cut slope of the left bank of Binga Dam

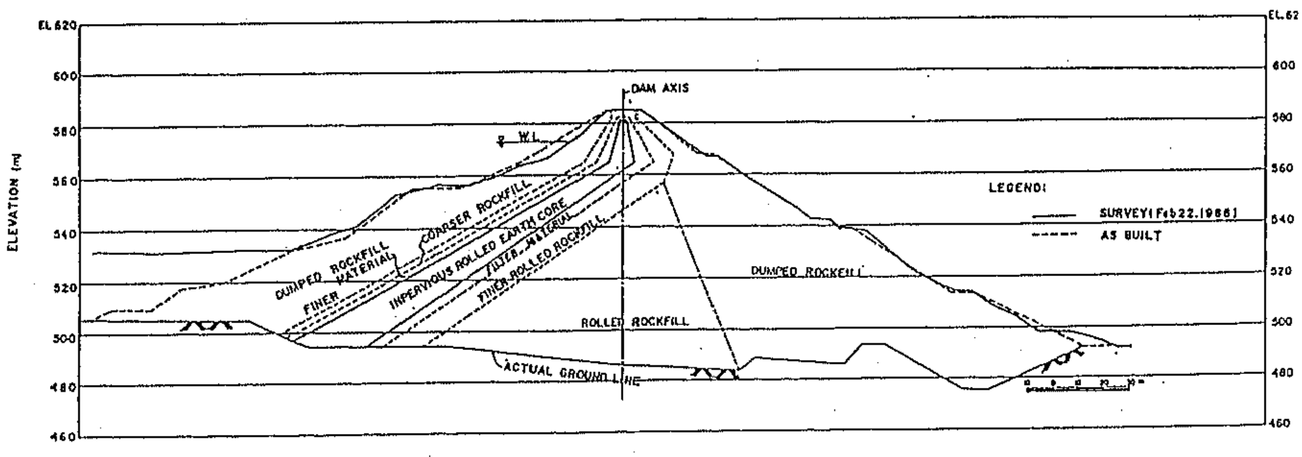


Figure 7.5.10 Profile of Binga Dam

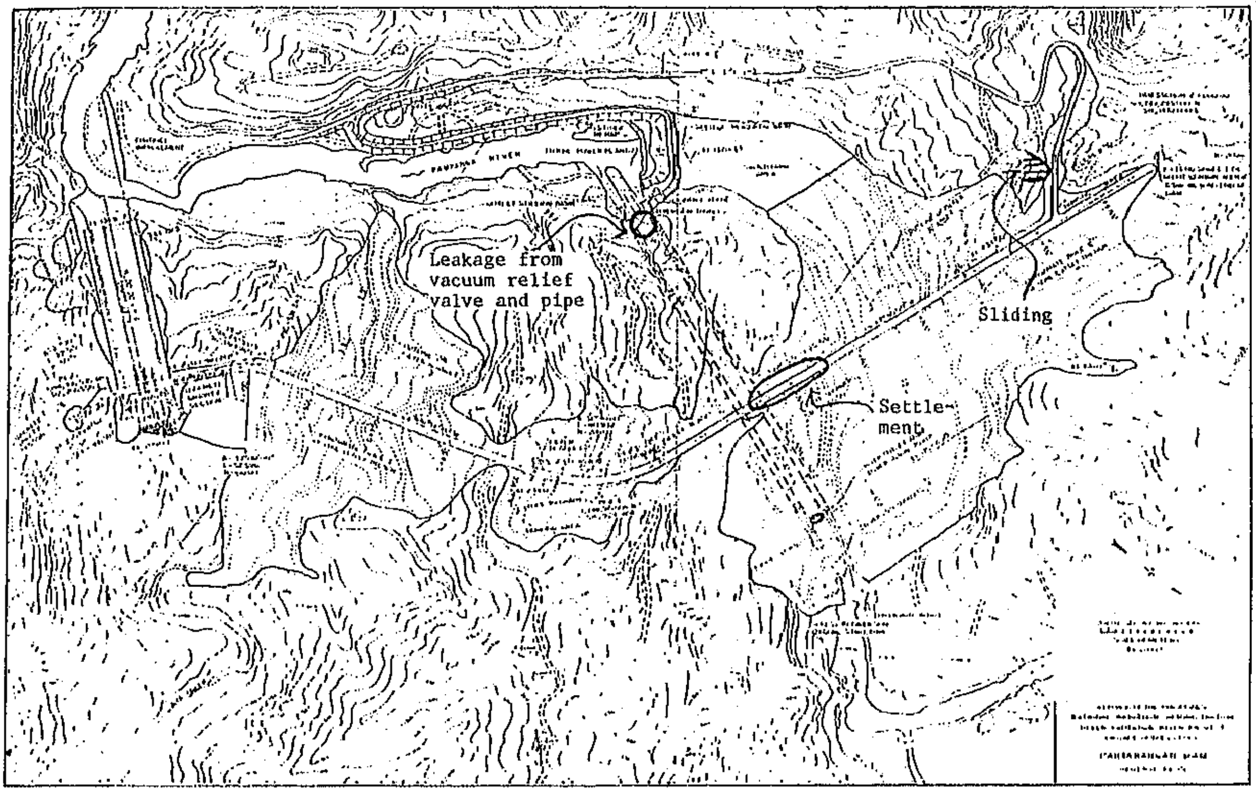


Figure 7.5.11 Plan of Pantabangan Dam and Aya Dam

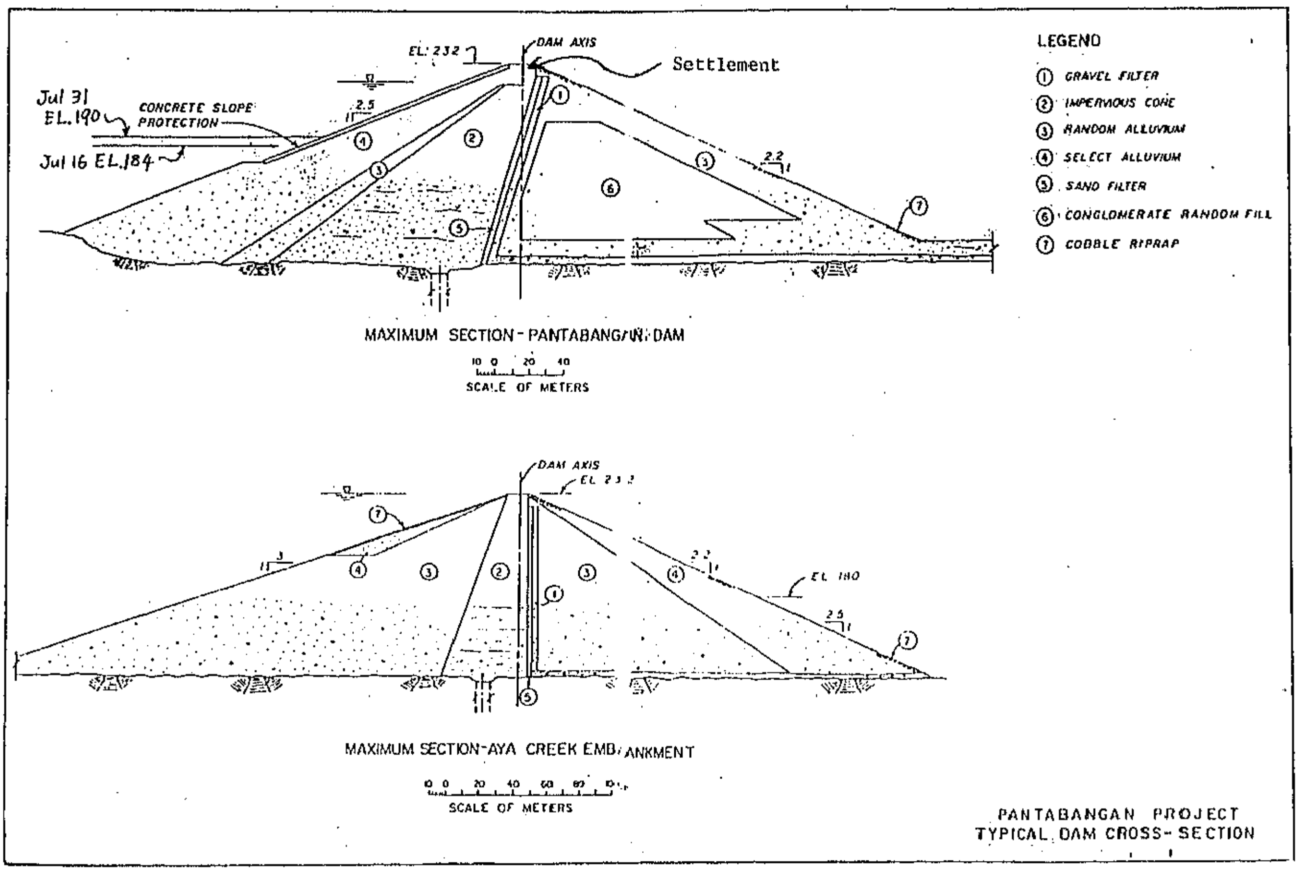


Figure 7.5.12 Standard cross section of Pantabangan Dam and Aya Dam

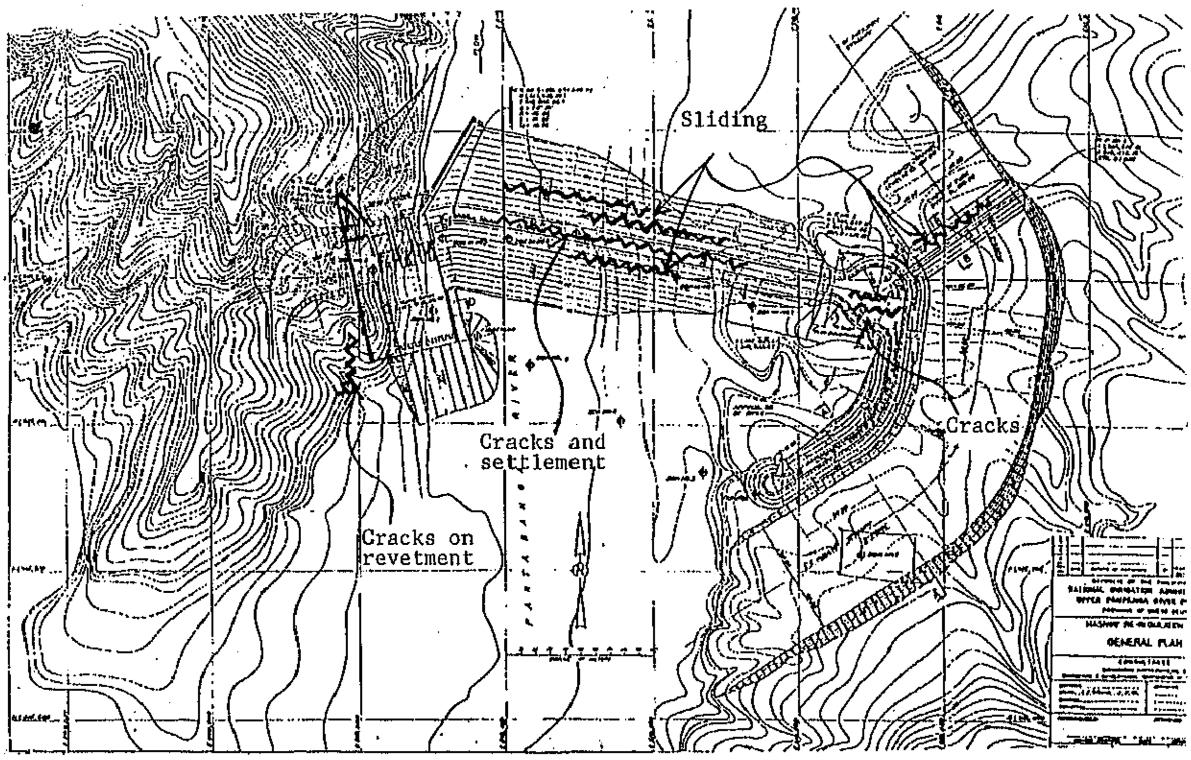


Figure 7.5.13 Plan of Masiway Dam

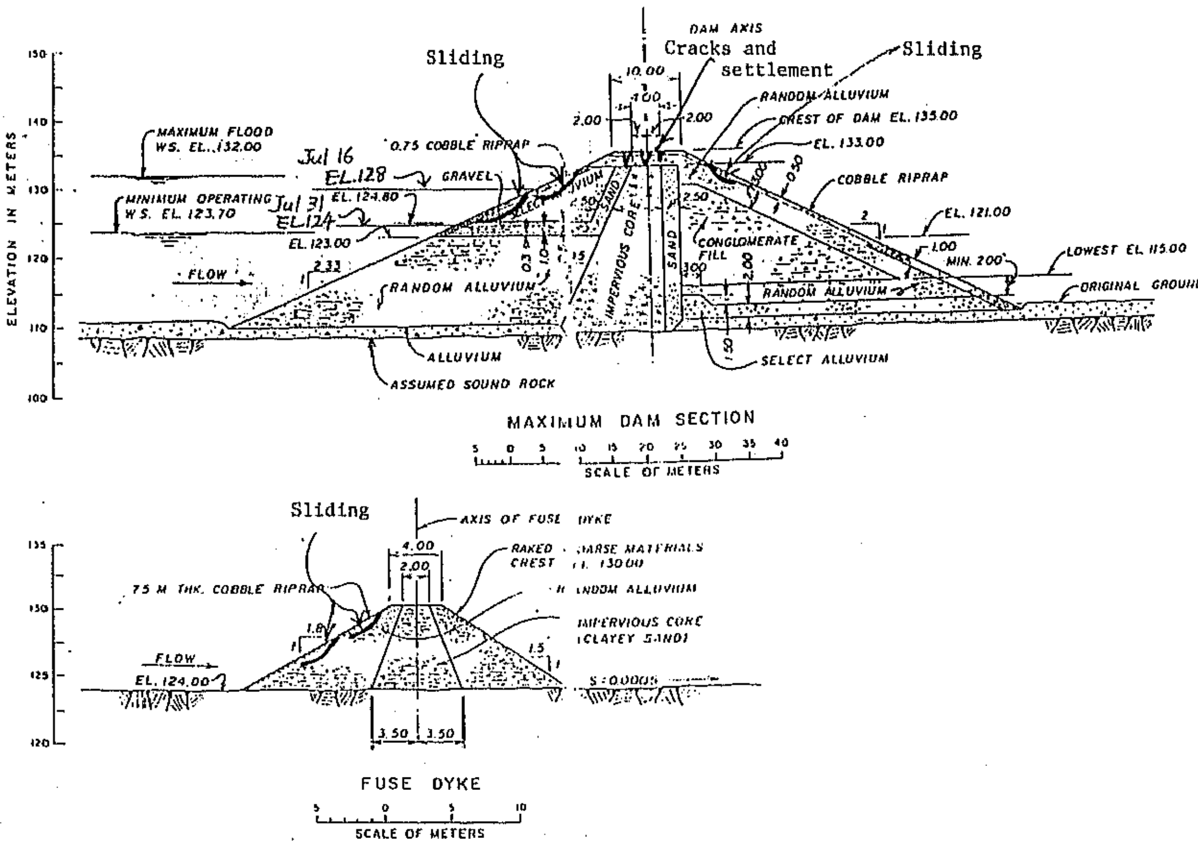


Figure 7.5.14 Standard cross section of Masiway Dam

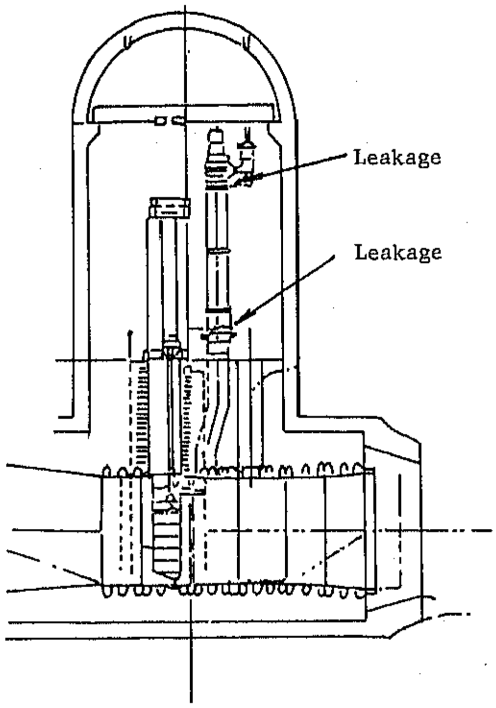


Figure 7.5.15 Leakage from vacuum relief valve and pipe

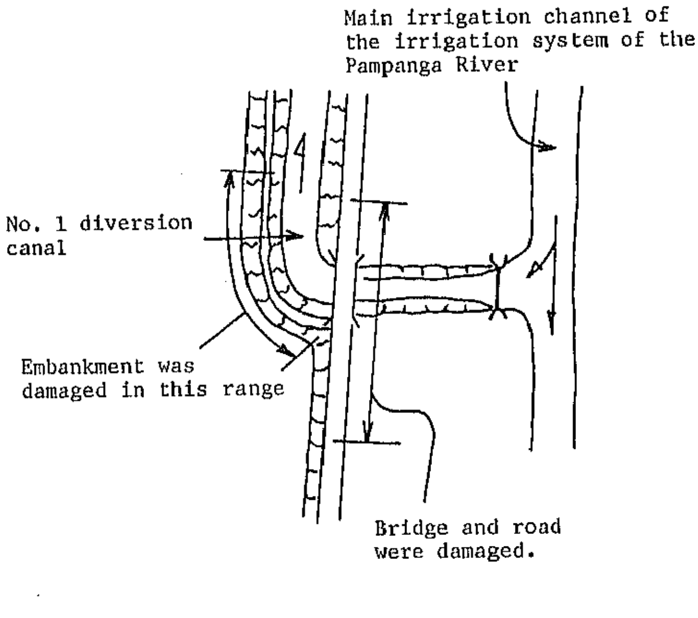


Figure 7.5.16 No. 1 diversion canal

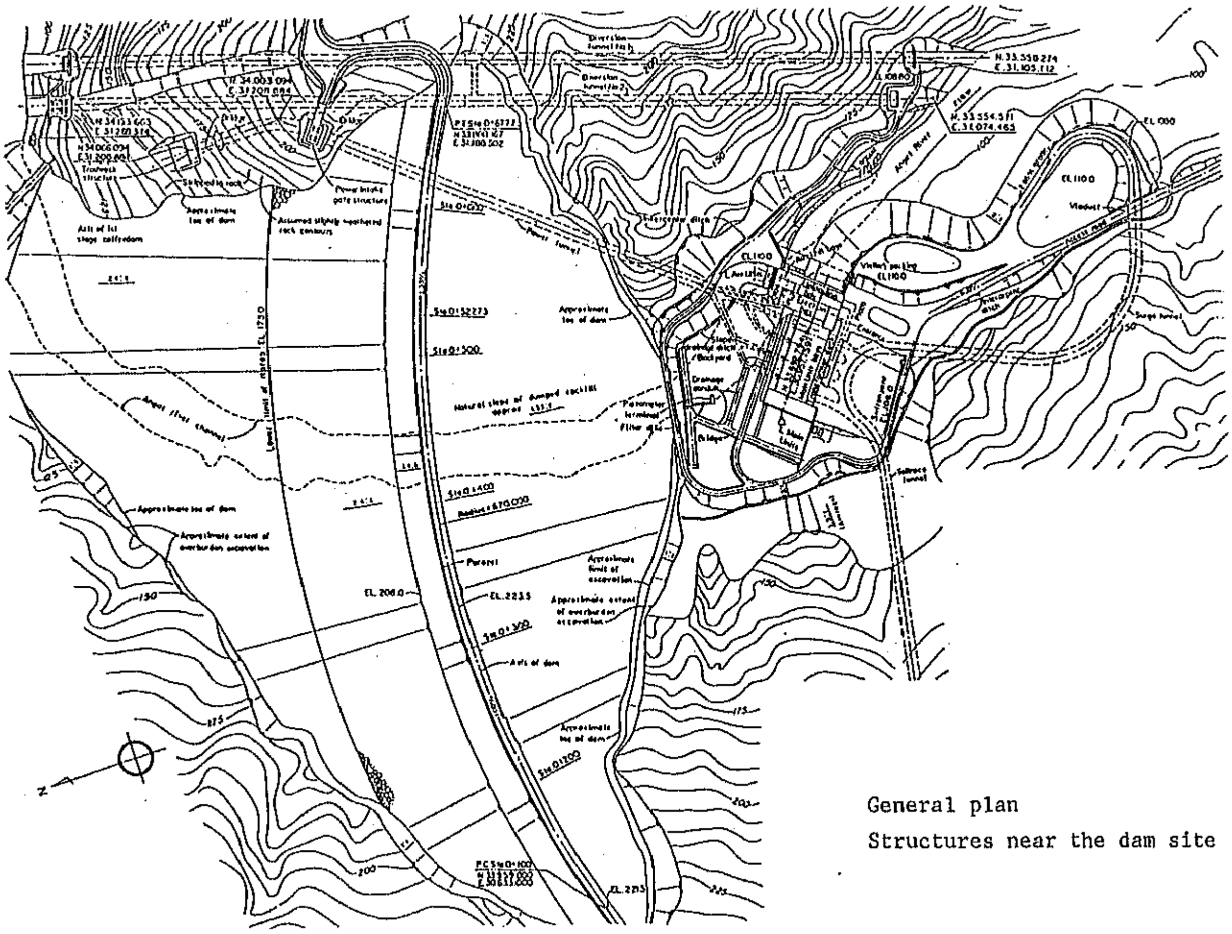


Figure 7.5.17 Plan of Angat Dam

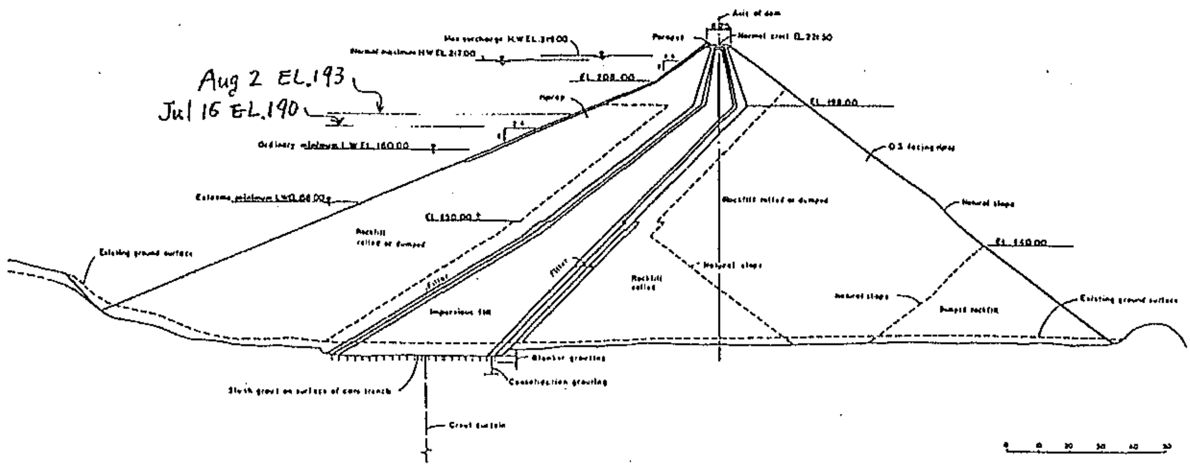


Figure 7.5.18 Standard cross section of Angat Dam

7.5.5 Photographs of rivers and dams

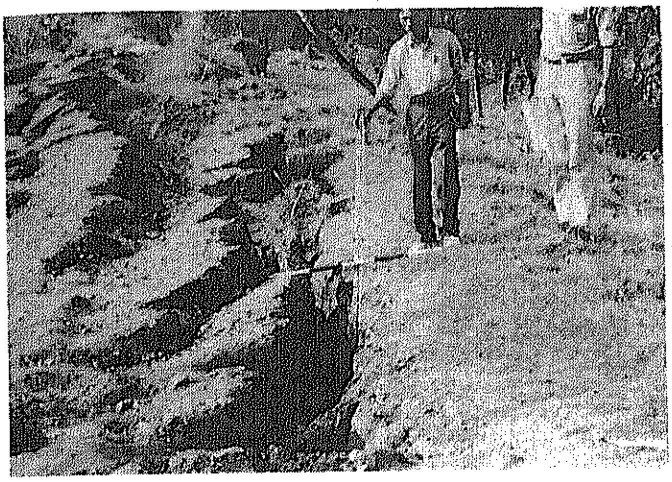


Photo 7.5.1 Damage to a levee of the Tarlac river

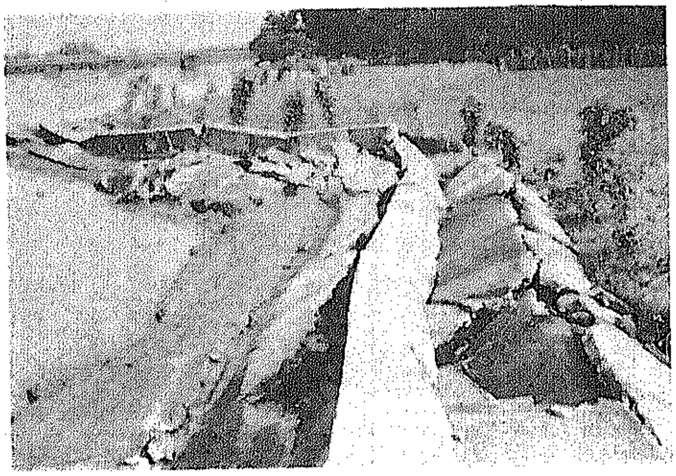


Photo 7.5.2 Damage to a parapet revetment of the Tarlac river

Photo 7.5.3 Damage to a parapet revetment of the Tarlac river

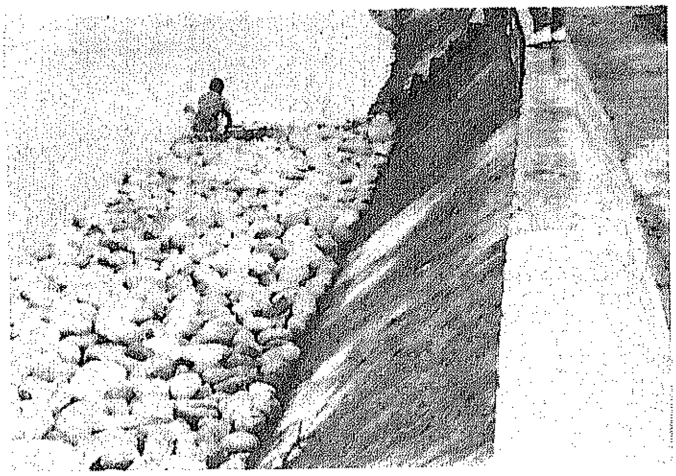


Photo 7.5.4 Parapet revetment with foot protection (no damage)

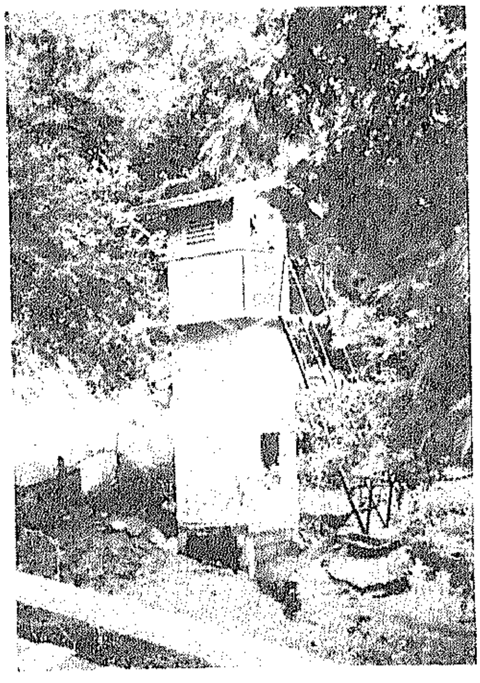


Photo 7.5.5 Damage to the No.6 water level gauging station

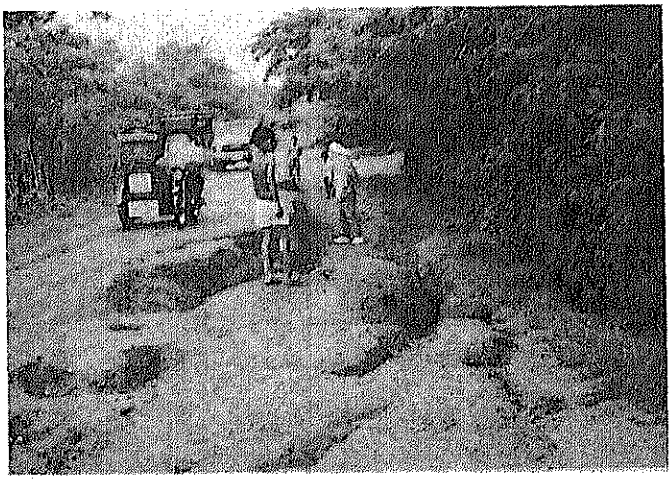


Photo 7.5.6 Damage to a levee of the Agno river

Photo 7.5.7 Damage to a levee of the Agno river

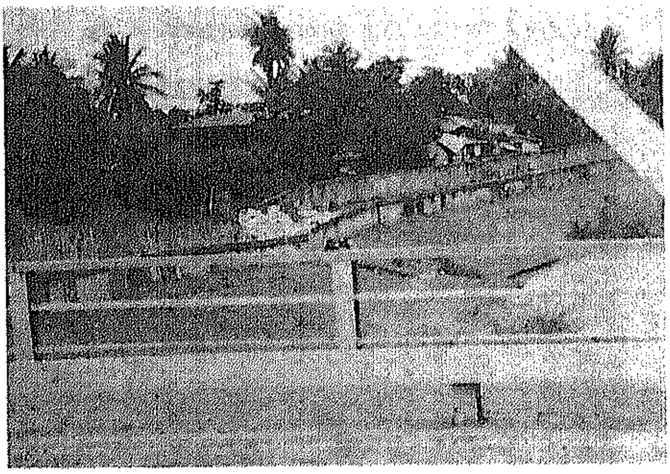


Photo 7.5.8 Damage to a parapet levee of the Agno river

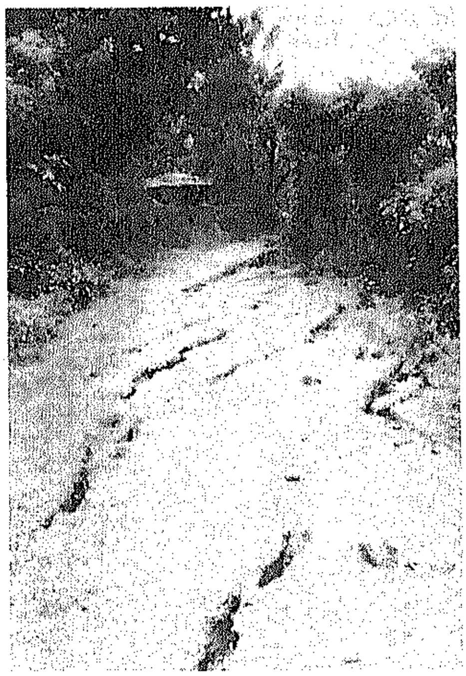


Photo 7.5.9 Damage to a levee of the Agno river

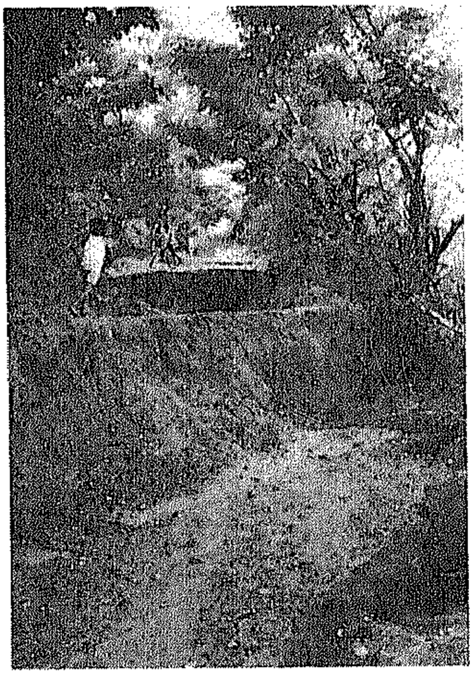


Photo 7.5.10 Damage to a levee of the Agno river

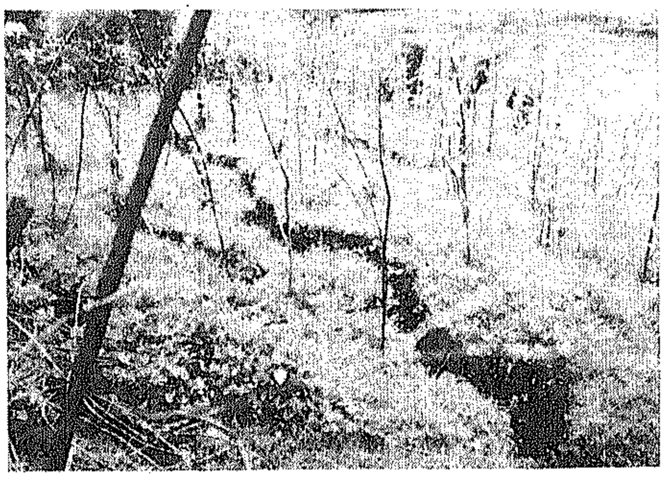


Photo 7.5.11 Damage to the slope-face of a levee of the Agno river

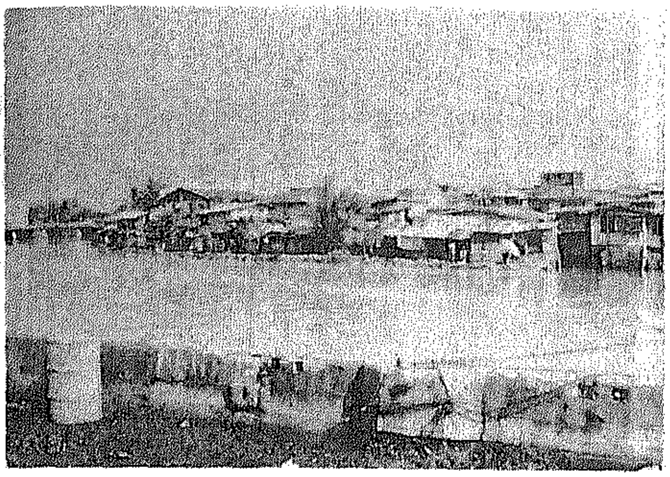


Photo 7.5.12 Damage to a parapet revetment in Dagupan city (on the opposite bank)

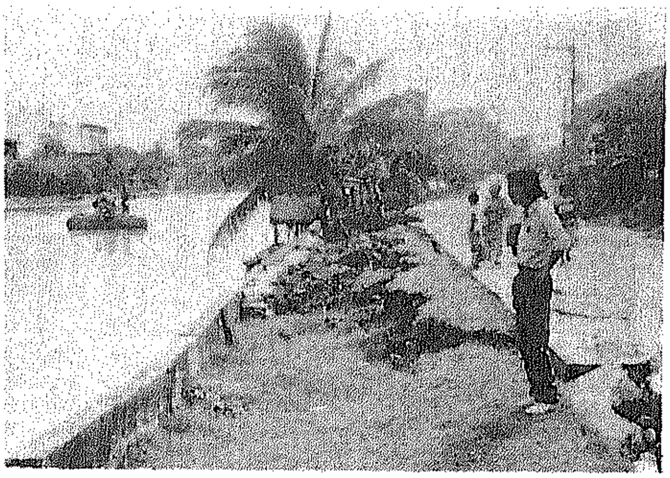


Photo 7.5.13 Damage to a parapet revetment in Dagupan city

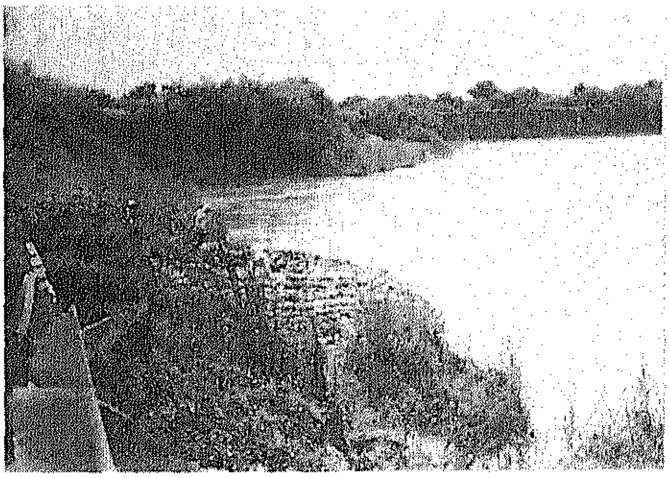


Photo 7.5.14 Damage to a levee of the Pampanga river

Photo 7.5.15 Damage to a levee of the Pampanga river

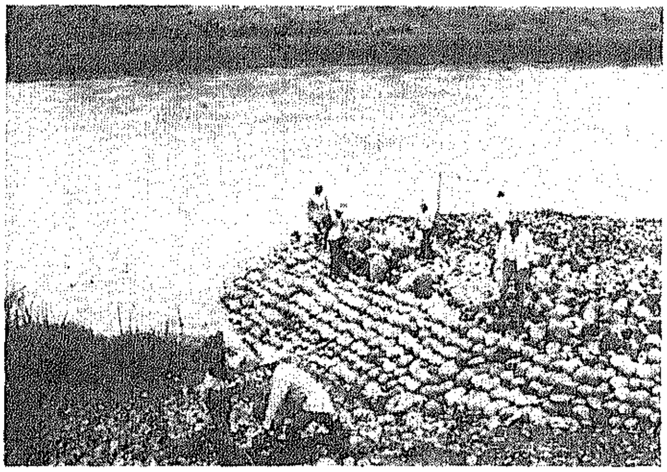


Photo 7.5.16 Groyne work on the Pampanga river (emergency rehabilitation)

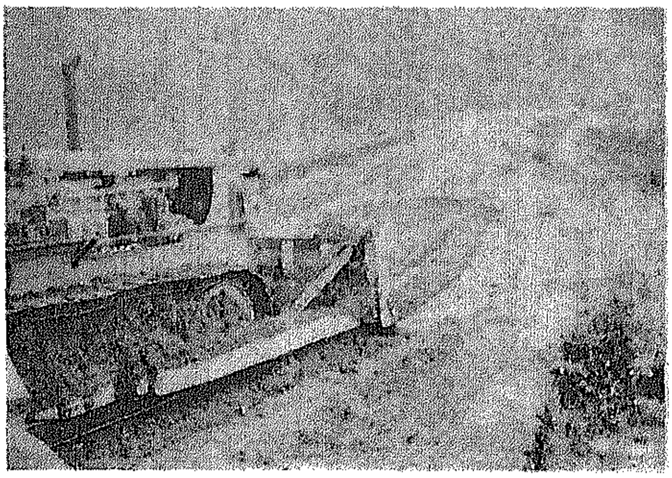


Photo 7.5.17 Repair of the crest of the Ambuklao Dam (temporary rehabilitation)

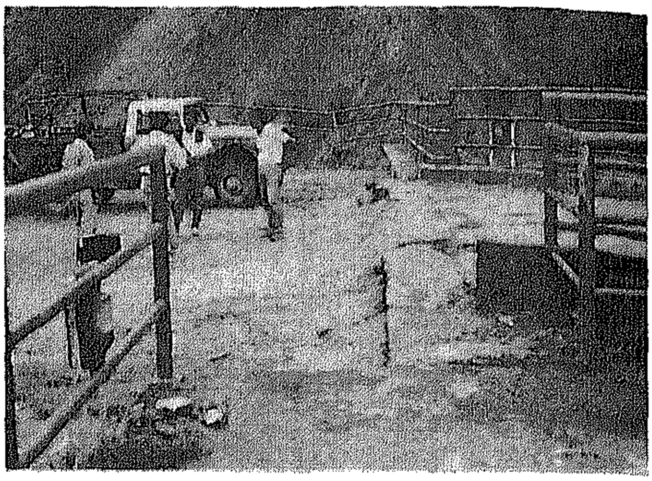


Photo 7.5.18 Settlement of the crest of the Ambuklao Dam (connecting part with the spillway)

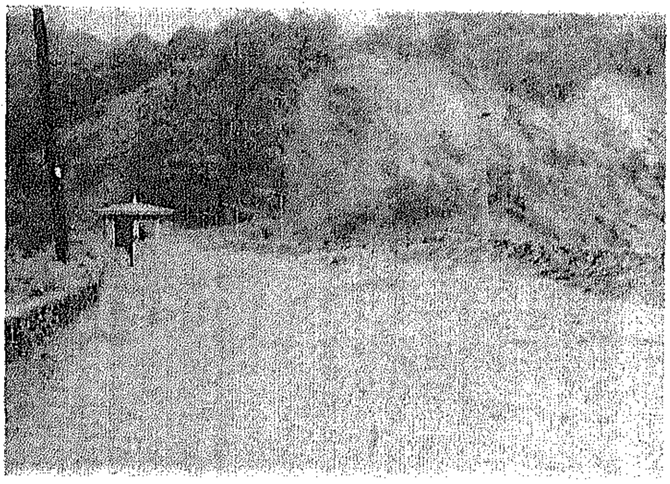


Photo 7.5.19 Differential settlement of the crest of the Ambuklao Dam

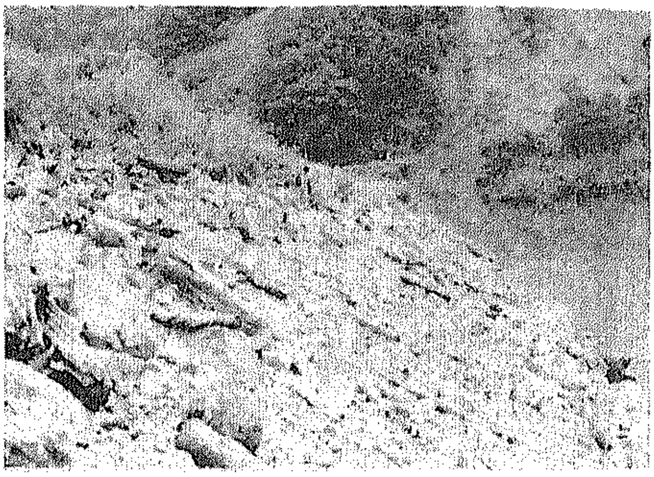


Photo 7.5.20 Conditions of the upstream slope-face of the Ambuklao Dam

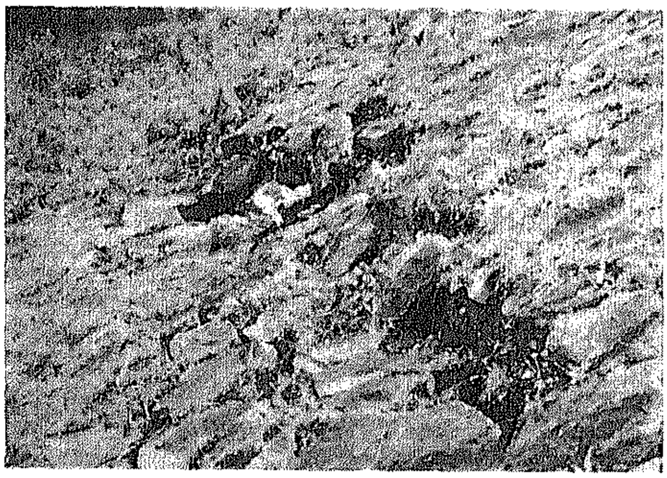


Photo 7.5.21 Sliding of the riprap on the upstream slope-face of the Ambuklao Dam

Photo 7.5.22 Sliding of the upstream slope-face of the Ambuklao Dam

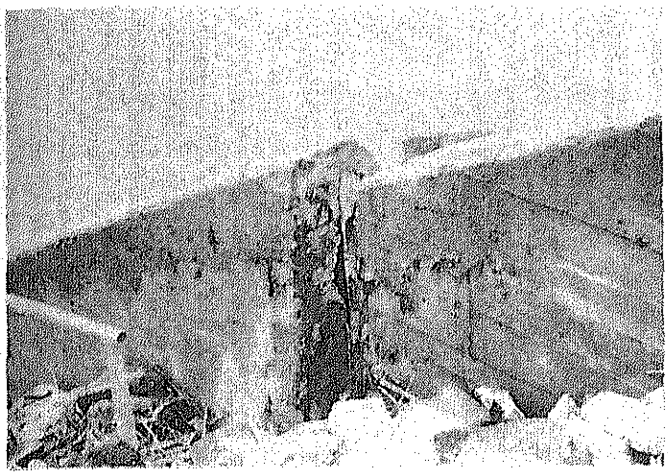


Photo 7.5.23 Damage to the retaining wall of the *Ambuklao Dam*

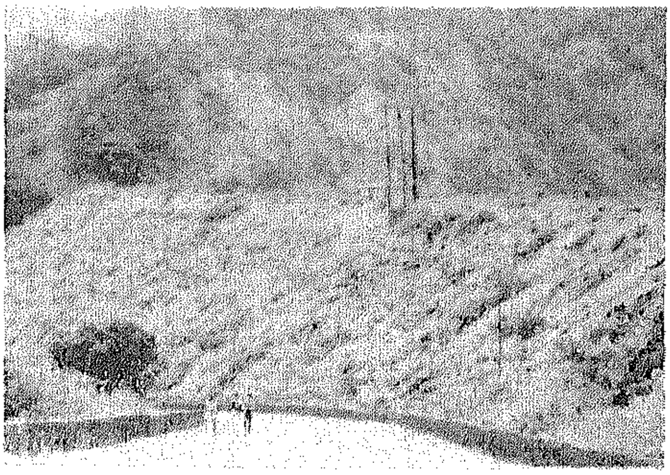


Photo 7.5.24 Conditions of the downstream slope-face of the Ambuklao Dam

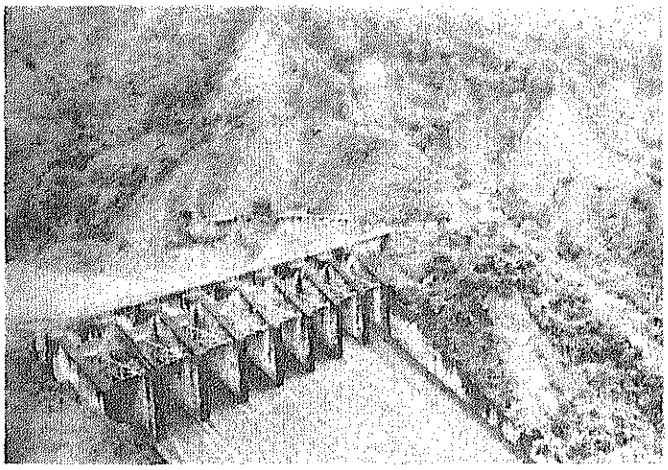


Photo 7.5.25 Sliding of the cutting slope on the spillway of the Ambuklao Dam

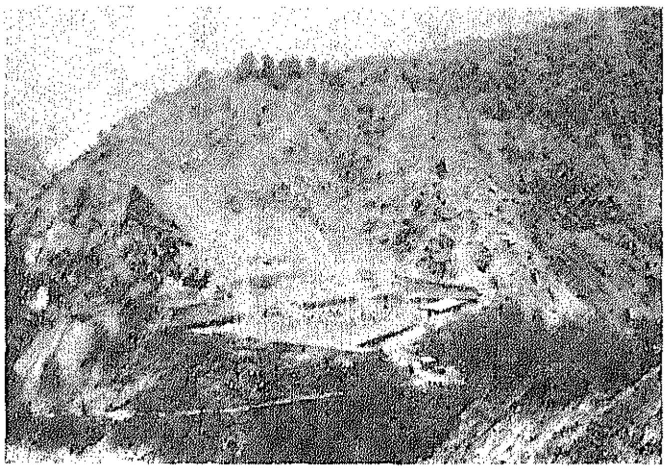


Photo 7.5.26 Sliding near the transmission yard of the Ambuklao Dam

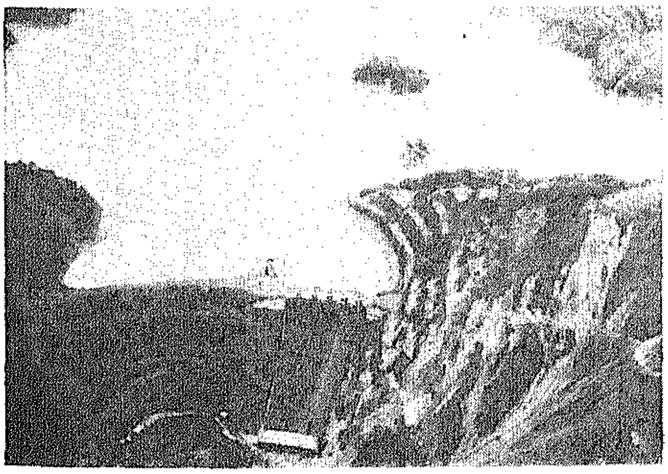


Photo 7.5.27 A general view of the Binga dam

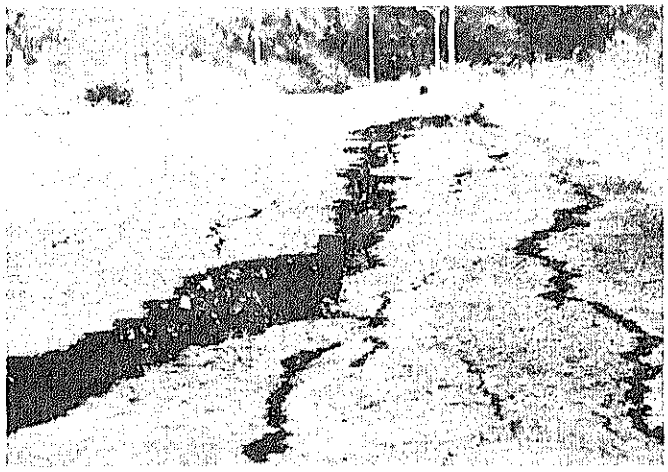


Photo 7.5.28 Cracks on the crest of the Binga Dam

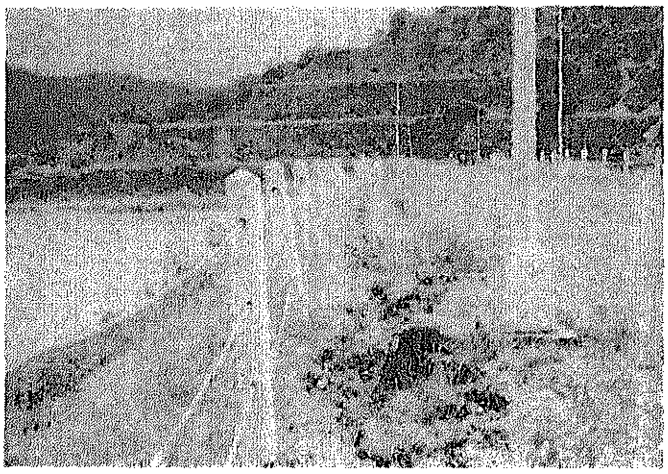


Photo 7.5.29 Cracks on the slope-top of the crest of the Binga Dam

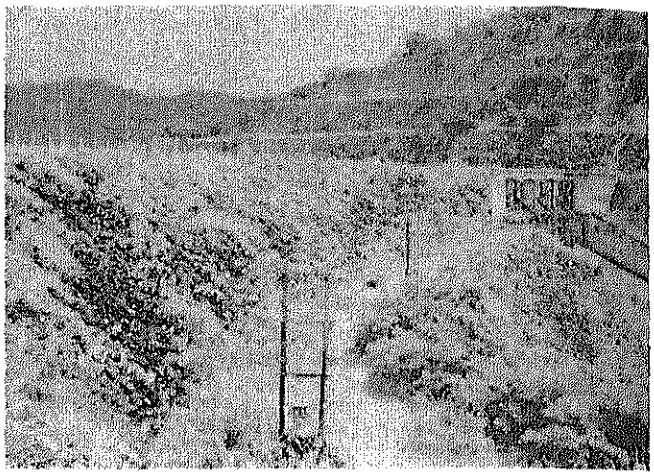


Photo 7.5.30 Conditions of the downstream slope-face of the Binga Dam

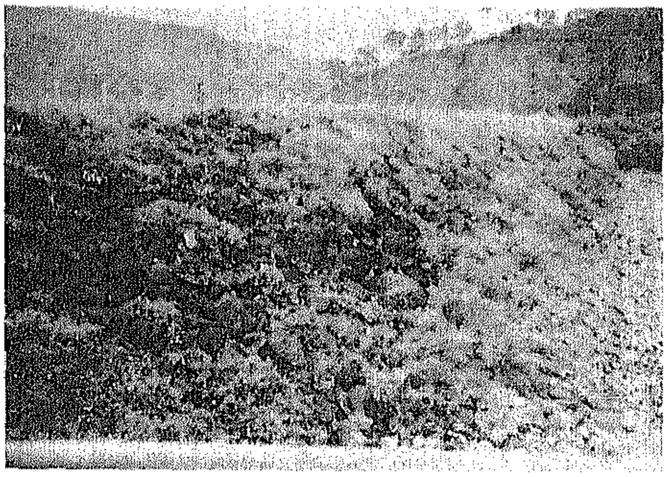


Photo 7.5.31 Conditions of the upstream slope-face of the Binga Dam

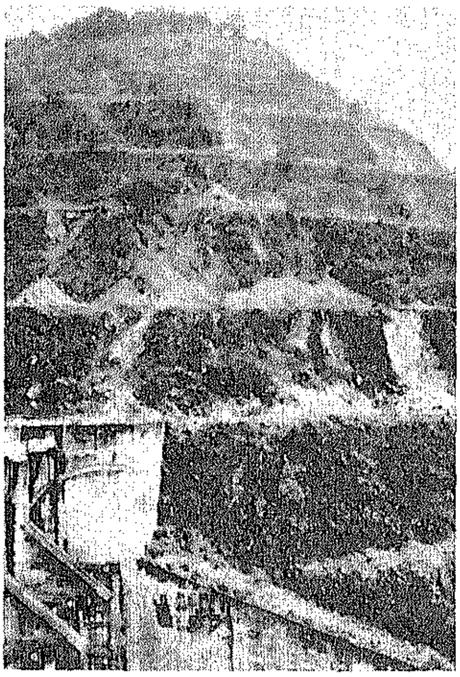


Photo 7.5.32 Collapse of the cutting slope on the spillway of the Binga Dam

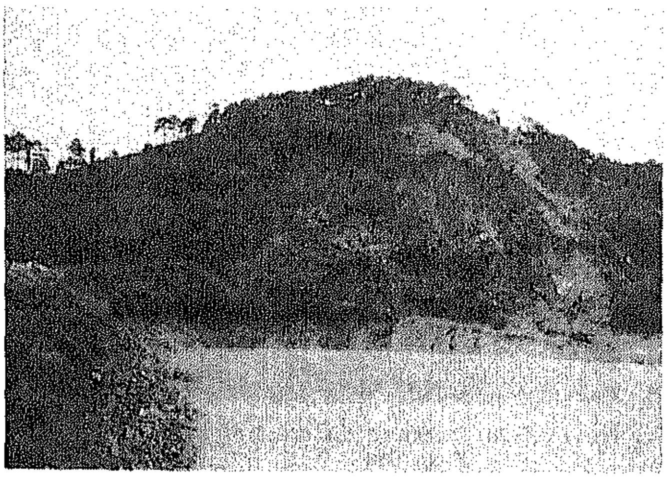


Photo 7.5.33 Sliding of the right bank abutment of the Binga Dam

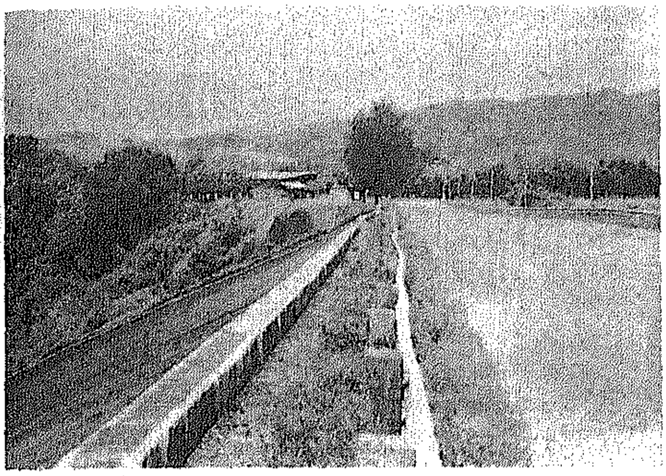


Photo 7.5.34 Settlement of the crest of the Pantabangan Dam

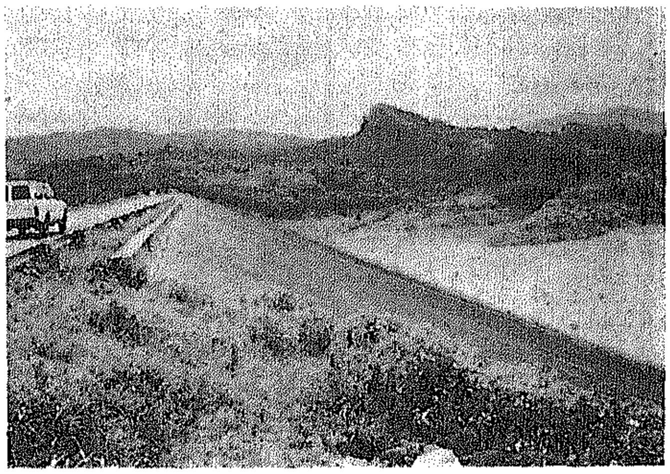


Photo 7.5.35 Conditions of the upstream slope-face of the Pantabangan Dam

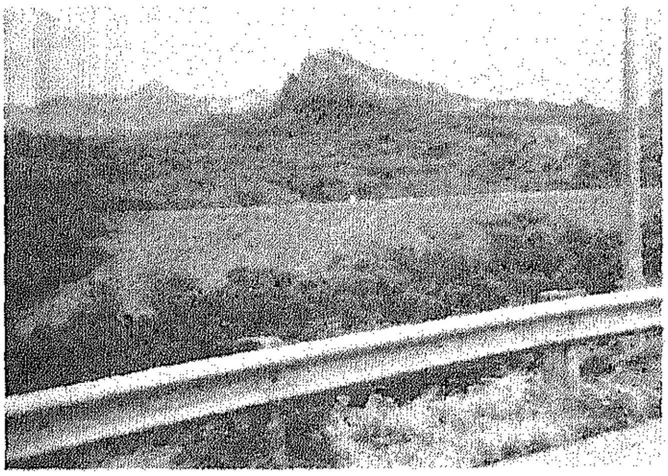


Photo 7.5.36 Conditions of the downstream slope-face of the Pantabangan Dam

Photo 7.5.37 Temporary countermeasure work on the sliding on a road to Pantabangan Dam

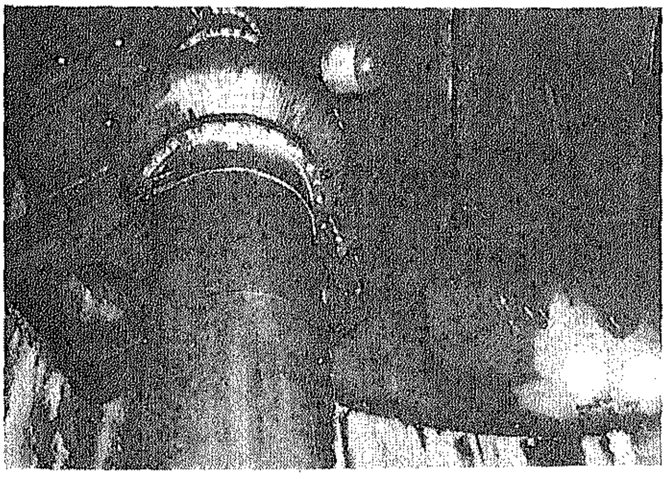


Photo 7.5.38 Leakage from the vacuum relief valves

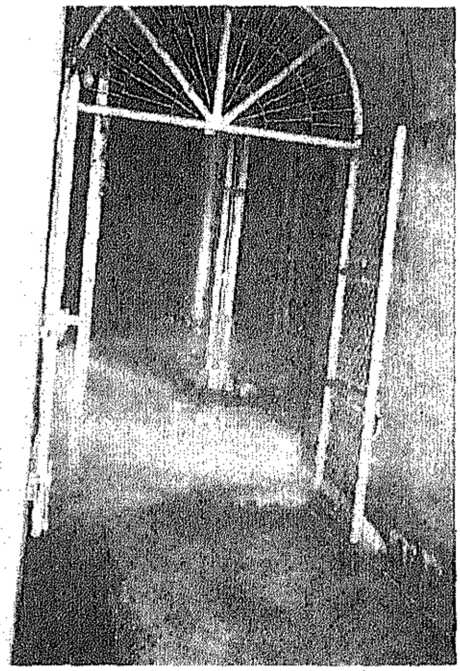


Photo 7.5.39 Leakage from the flange joints of vacuum relief pipes

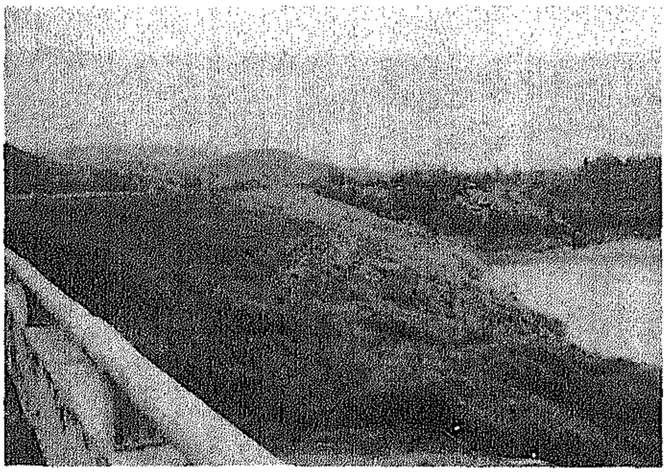


Photo 7.5.40 Conditions of the upstream slope-face of the Aya Dam

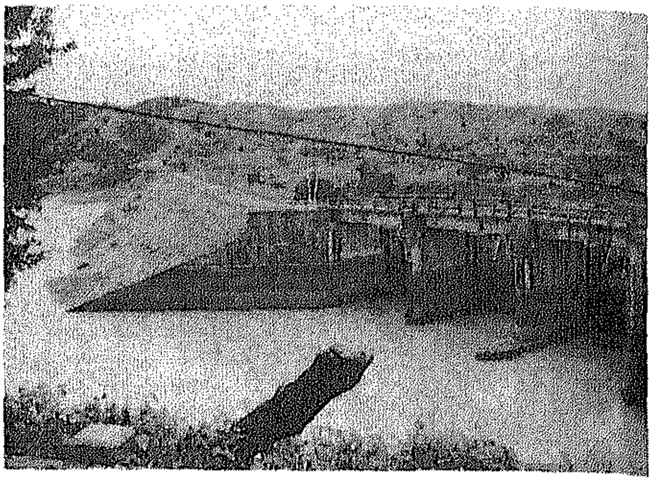


Photo 7.5.41 Conditions of the crest of the Masiway Dam

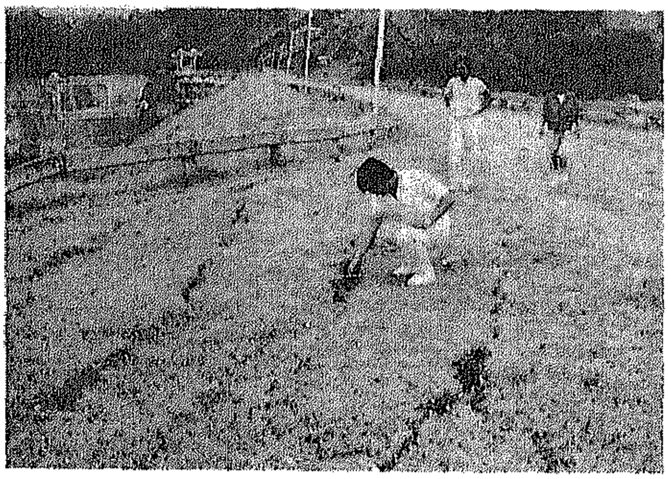


Photo 7.5.42 Cracks on the crest of the Masiway Dam

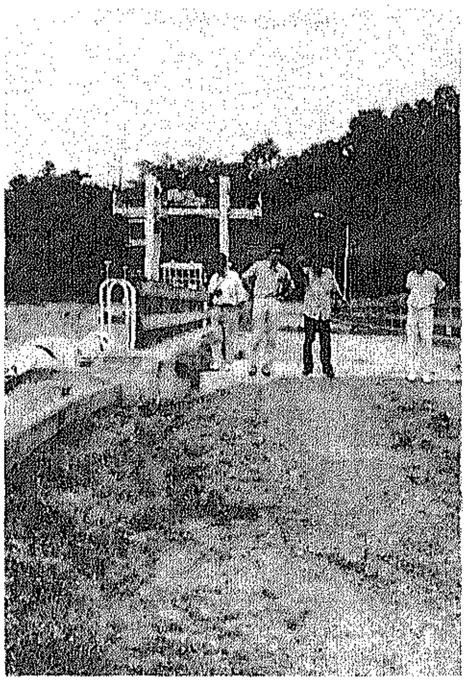


Photo 7.5.43 Settlement of the crest of the Masiway Dam (connecting parts with the spillway)

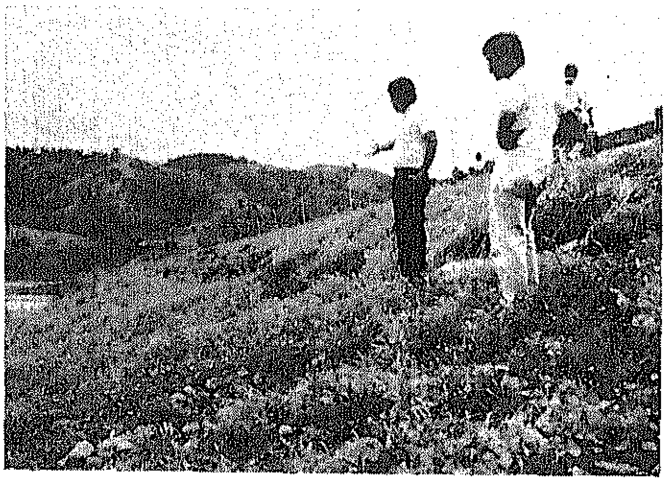


Photo 7.5.44 Sliding of the upstream slope-face of the Masiway Dam

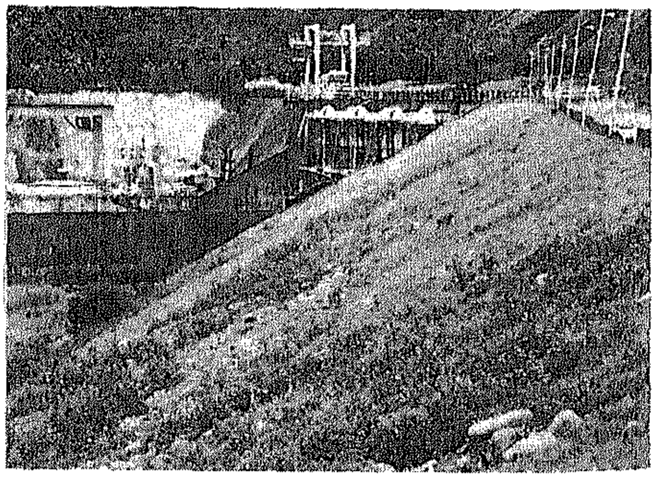


Photo 7.5.45 Conditions of the downstream slope-face of the Masiway Dam

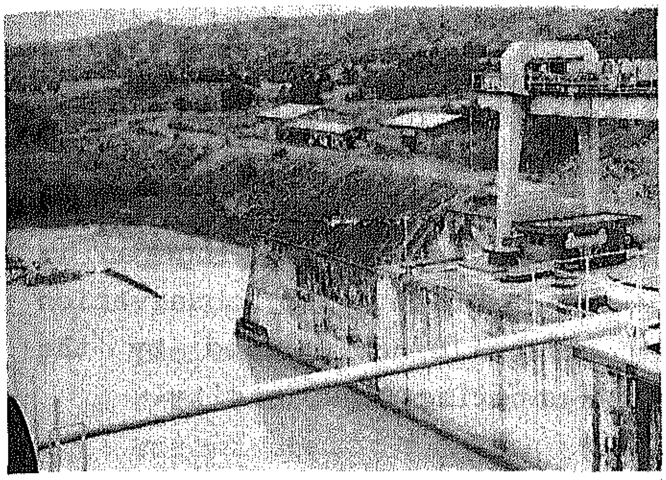


Photo 7.5.46 Cracks on the revetment of the Masiway Dam

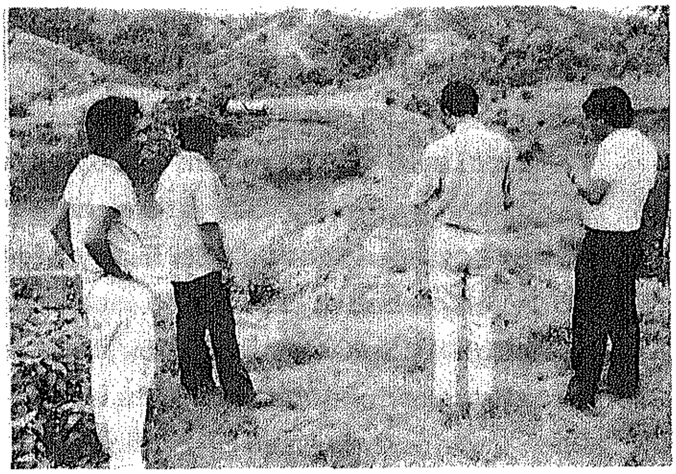


Photo 7.5.47 Damage to the Fuse Dike of the Masiway Dam

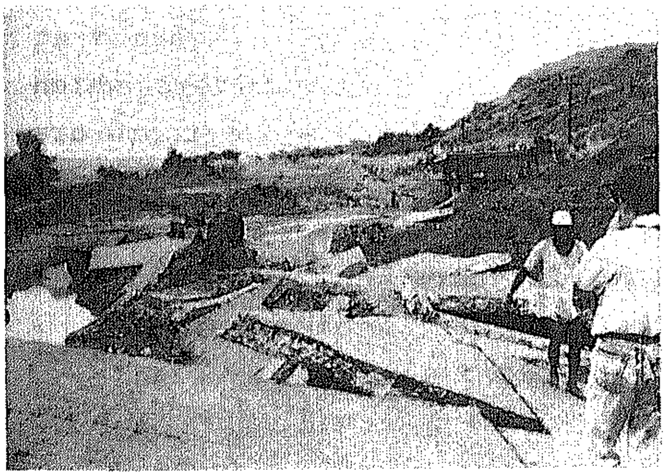


Photo 7.5.48 Damage to the No.1 diversion canal

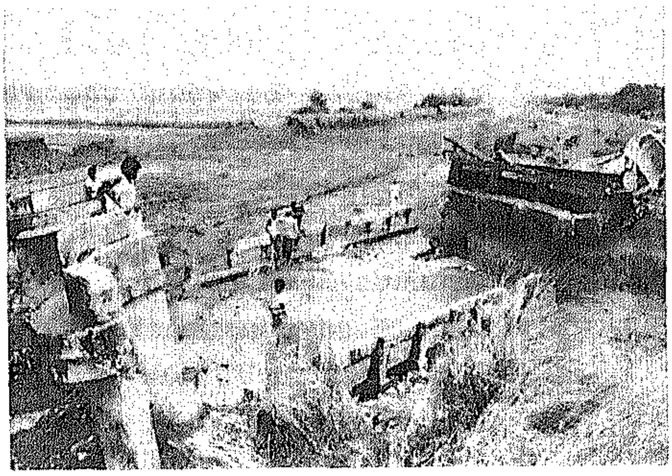


Photo 7.5.49 Damage to the No.1 diversion canal

Photo 7.5.50 A general view of the Angat Dam

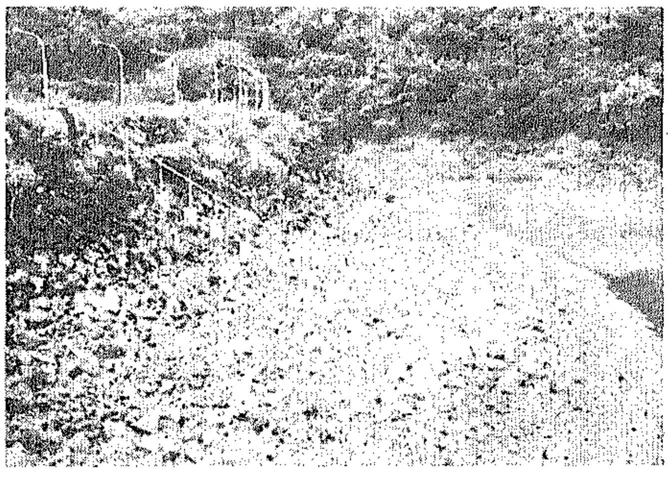


Photo 7.5.51 Conditions of the upstream slope-face of the Angat Dam