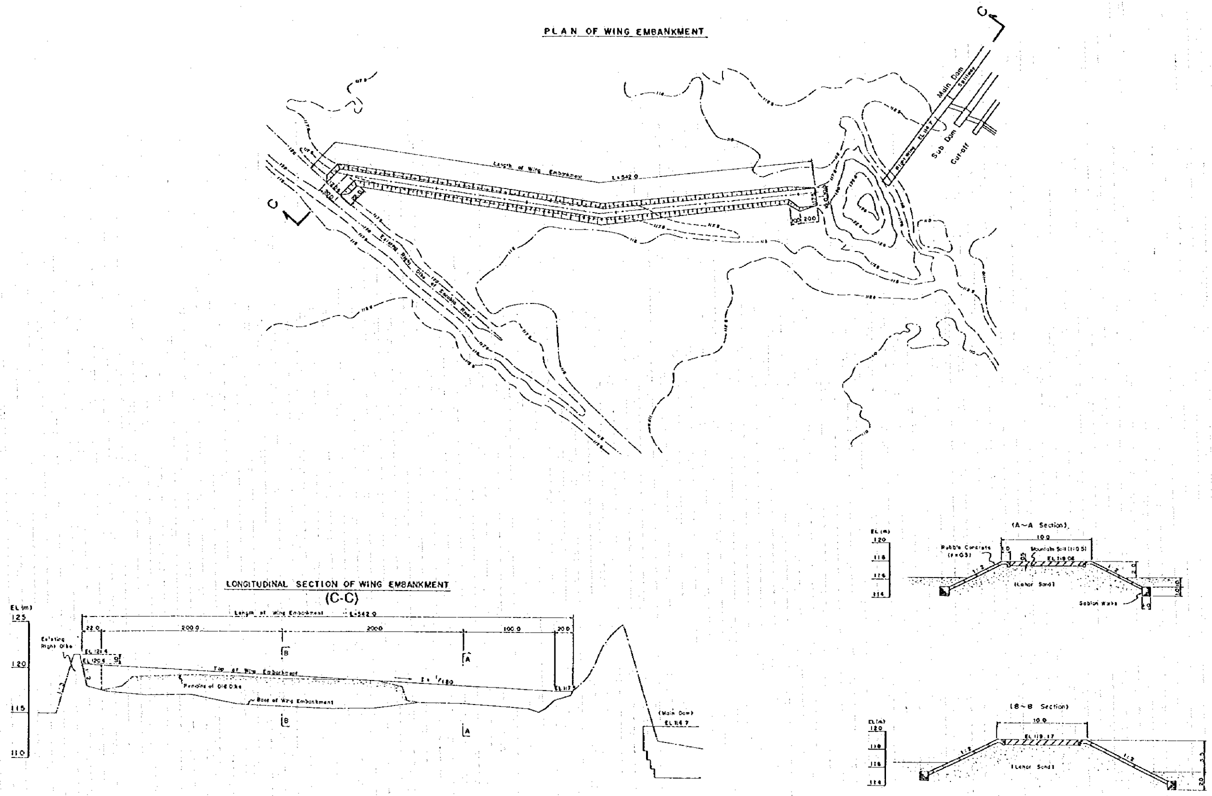


Figure 8.26
Maskup Consolidation Dam (2/2)

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

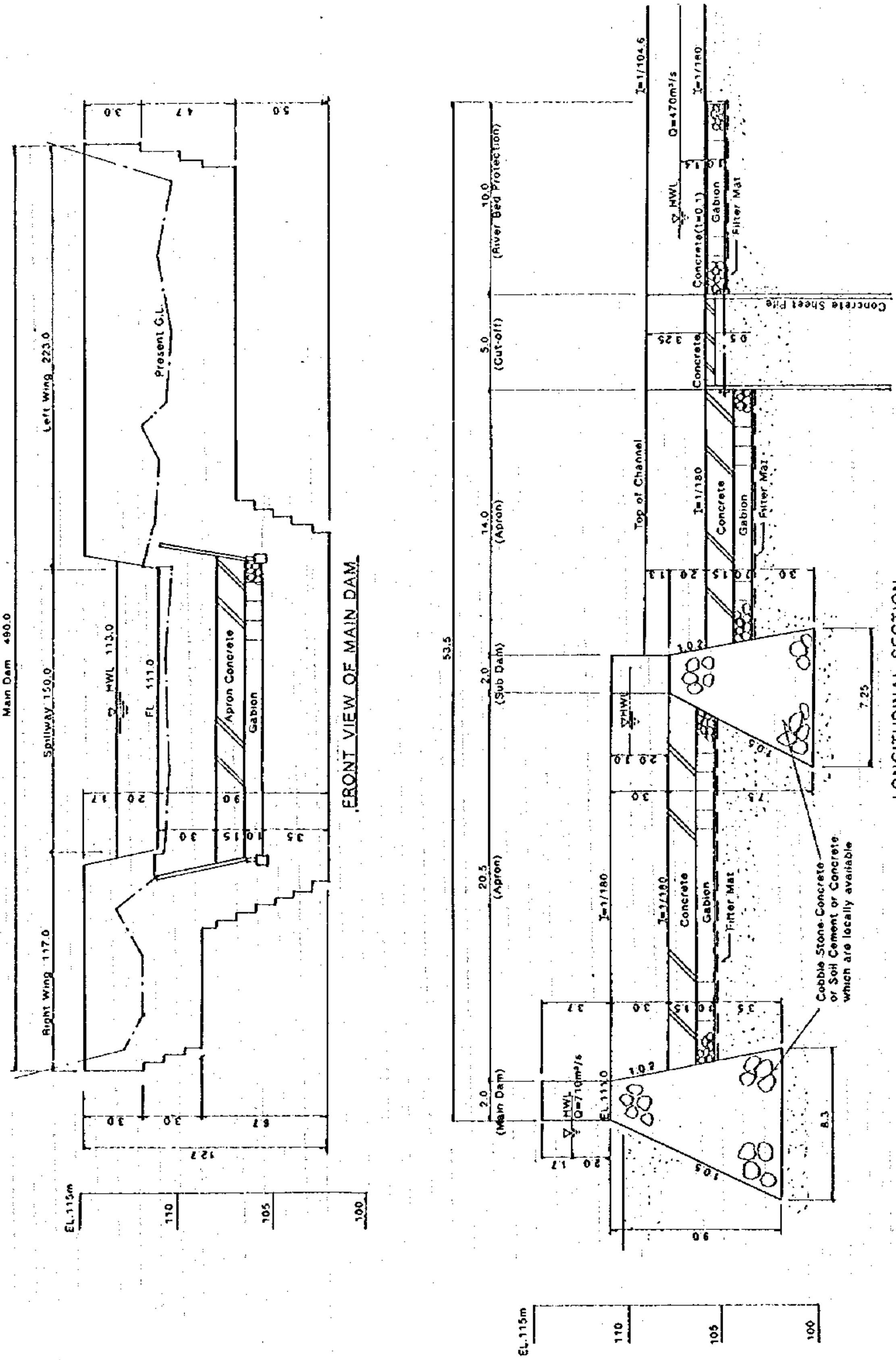


Figure 8.27
Alternative Design for
Maskup Consolidation Dam

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS

THE STUDY ON FLOOD AND MUDFLOW CONTROL
FOR SACOBIA-BAMBAN/ABACAN RIVER
DRAINING FROM MT.PINATUBO

JAPAN INTERNATIONAL COOPERATION AGENCY

PLAN

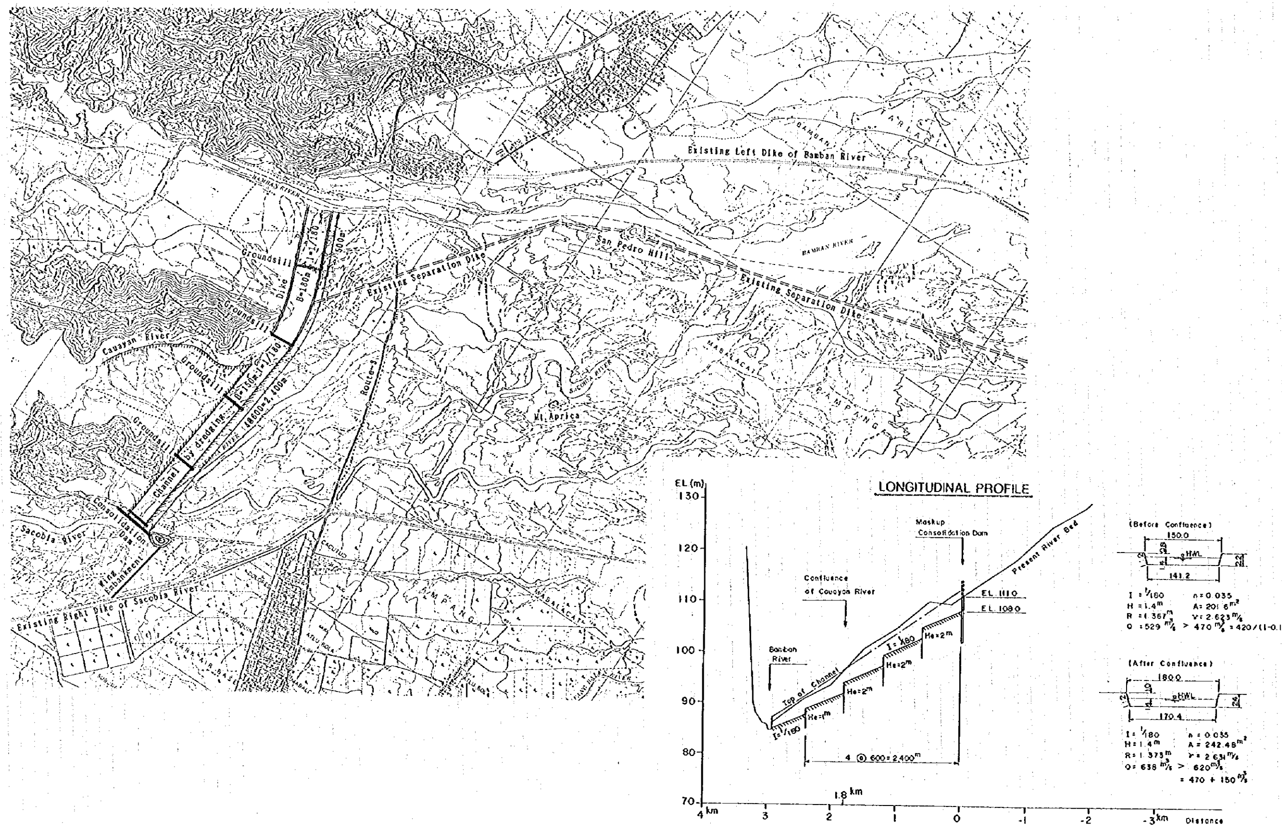


Figure 8.28 Sacobia Training Works Alternative - 1

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

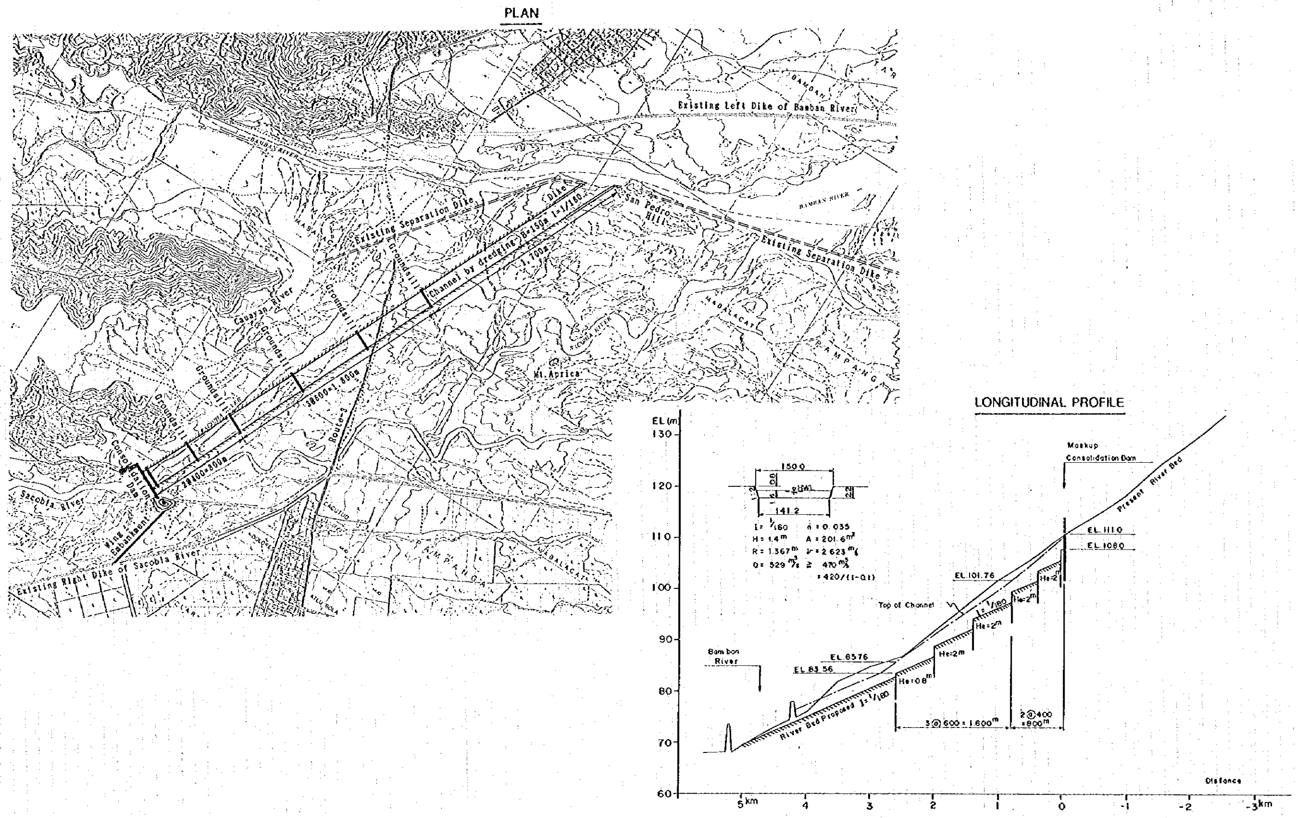


Figure 8.29 Sacobia Training Works Alternative - 2

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

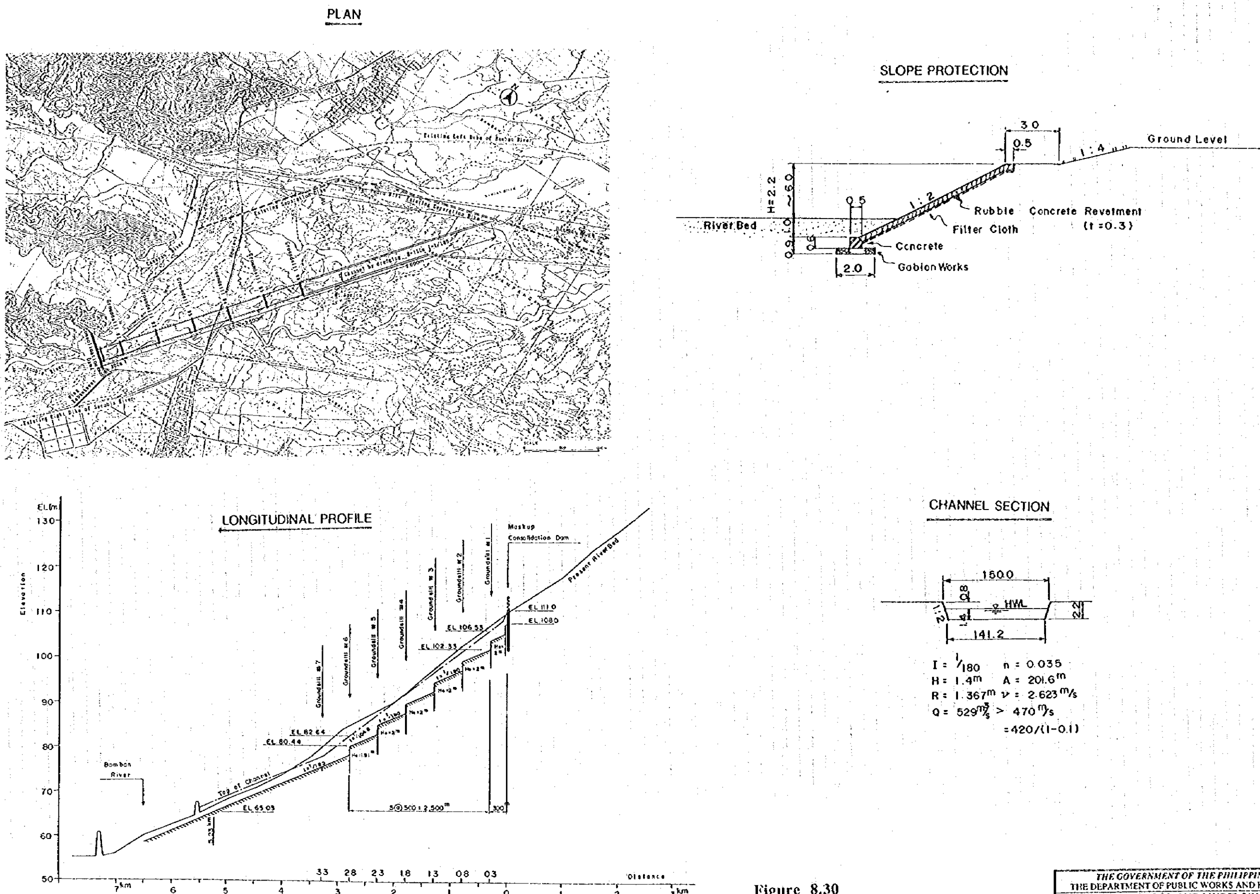


Figure 8.30
Sacobia Training Works Alternative - 3

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

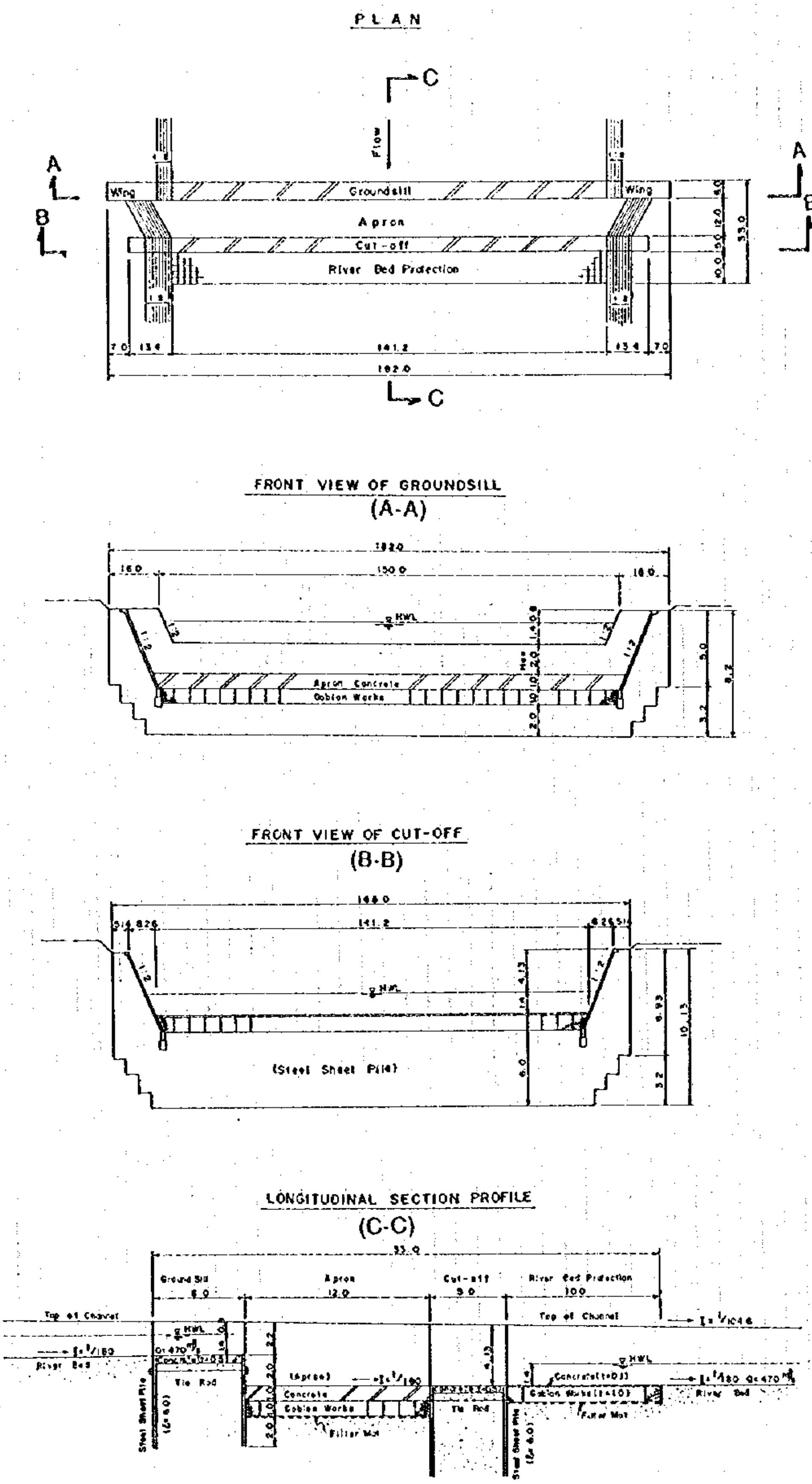
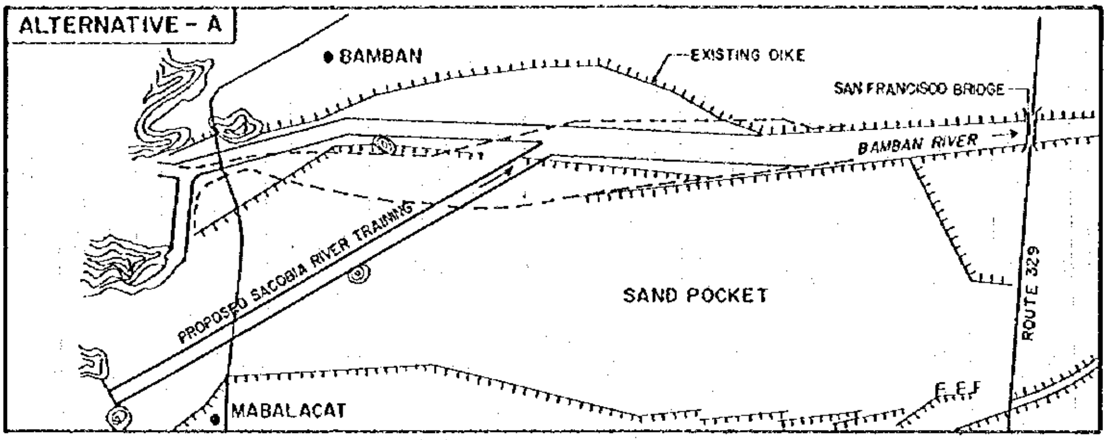
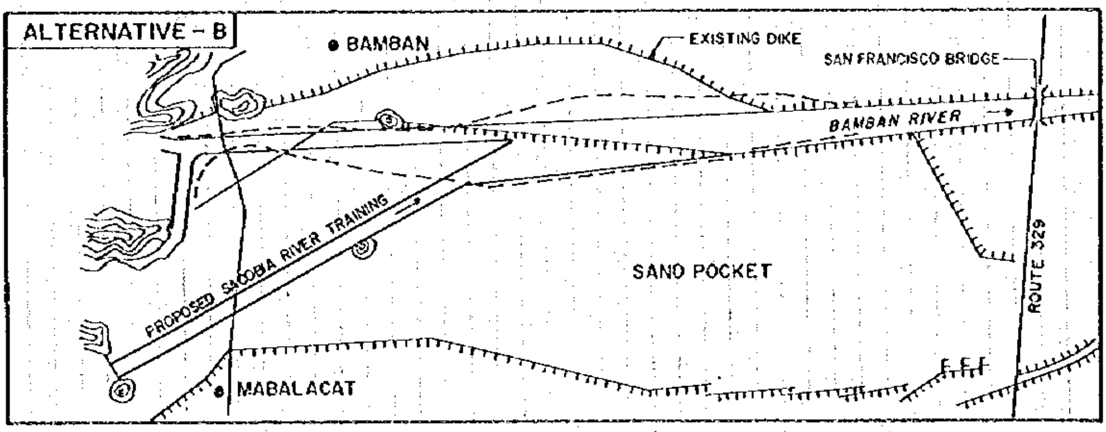


Figure 8.31 Proposed Groundsill

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY





(RECOMMENDED ALIGNMENT)

Figure 8.32 Alternative Alignments of Upper Reach of Bamban River

THE GOVERNMENT OF THE PHILIPPINES THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

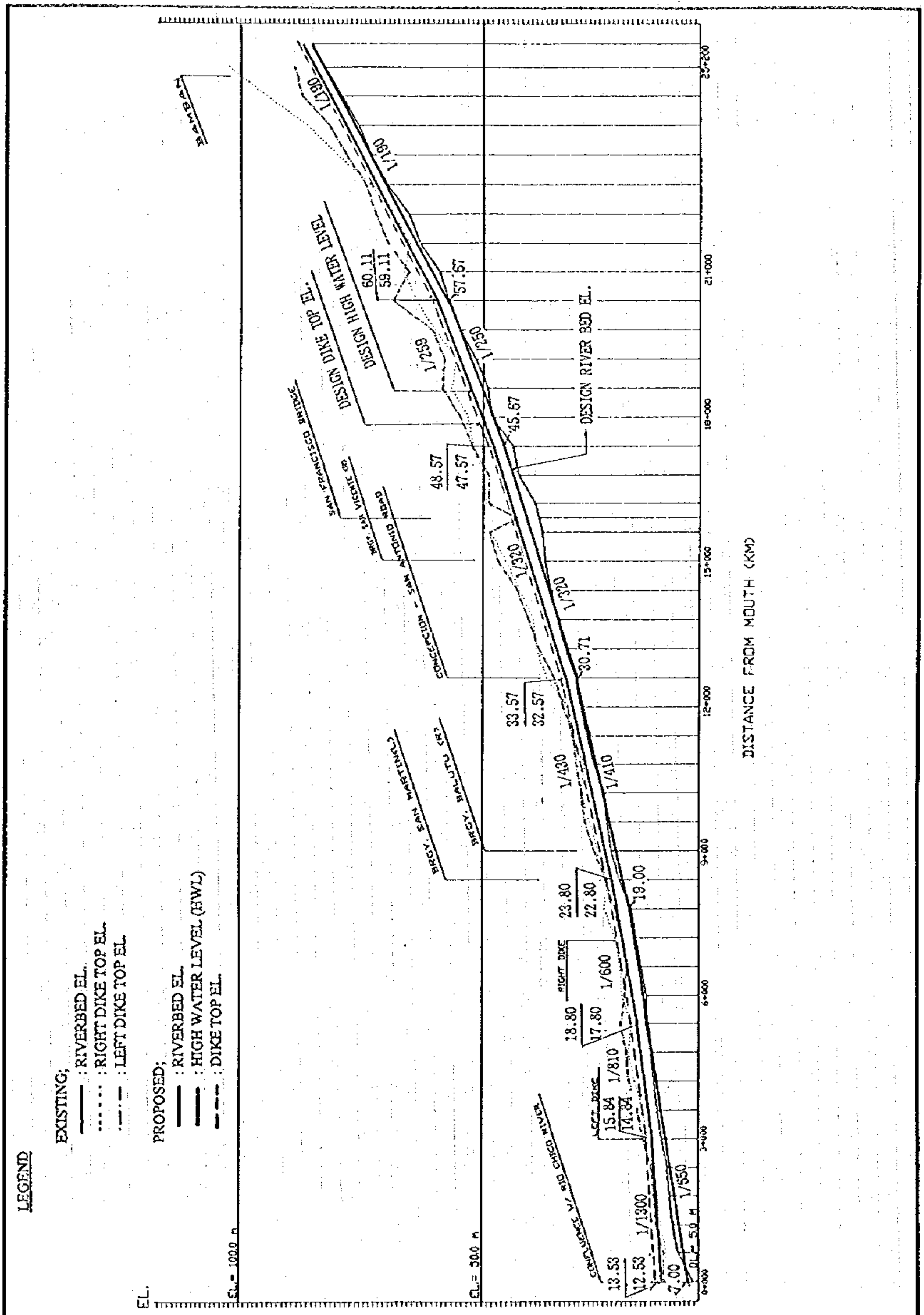


Figure 8.33 Design Longitudinal Profiles of Bamban River

THE GOVERNMENT OF THE PHILIPPINES THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

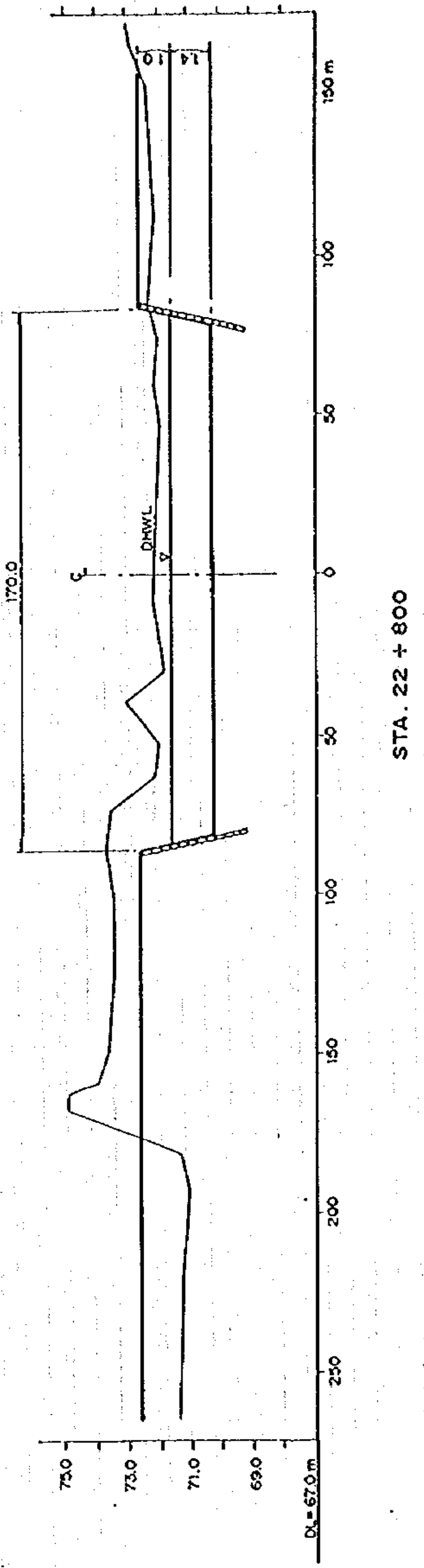


Figure 8.34 Proposed Cross Sections of Upper Bamban River

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS

THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO

JAPAN INTERNATIONAL COOPERATION AGENCY

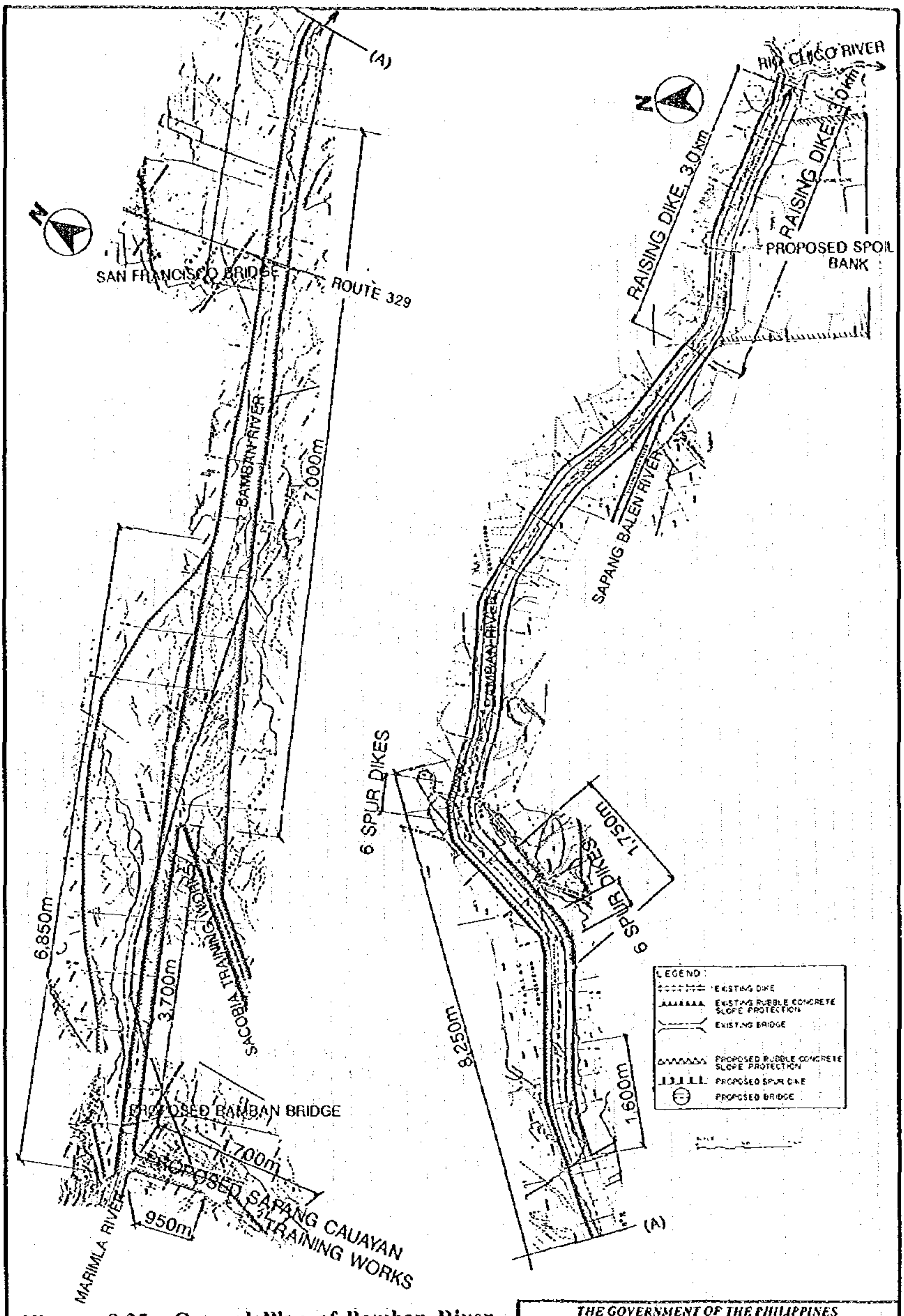
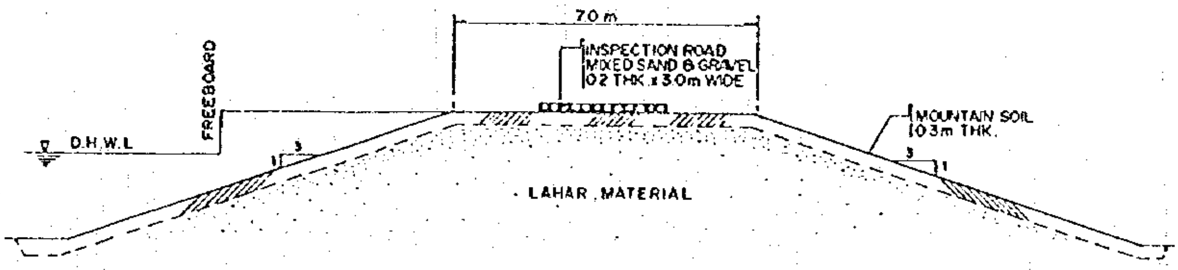
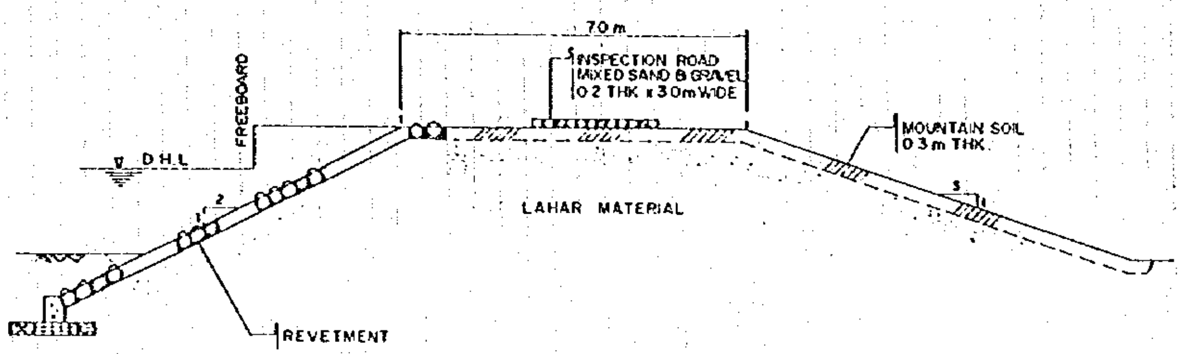


Figure 8.35 General Plan of Bamban River Improvement

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



WITHOUT REVETMENT



WITH REVETMENT

Figure 8.36 Standard Section of Dike

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

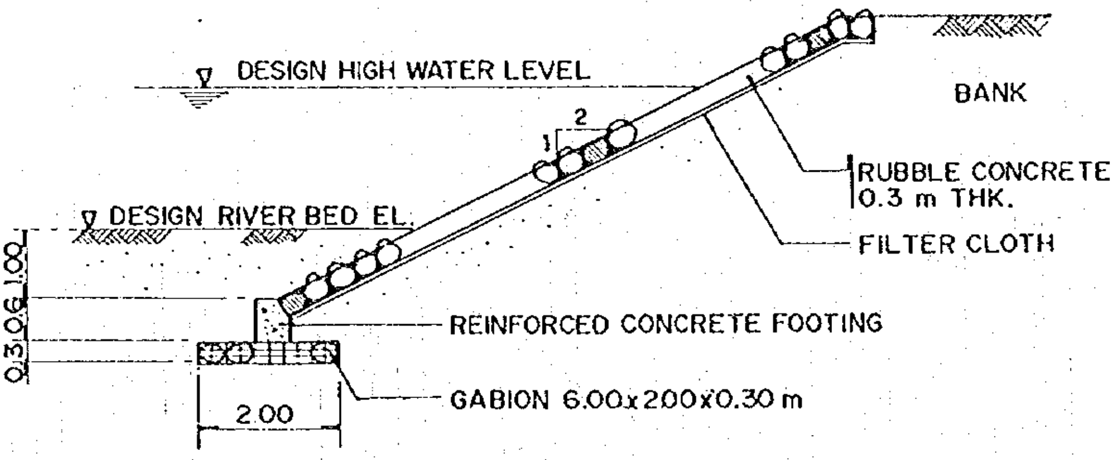


Figure 8.37 Proposed Slope Protection with Rubble Concrete

THE GOVERNMENT OF THE PHILIPPINES THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

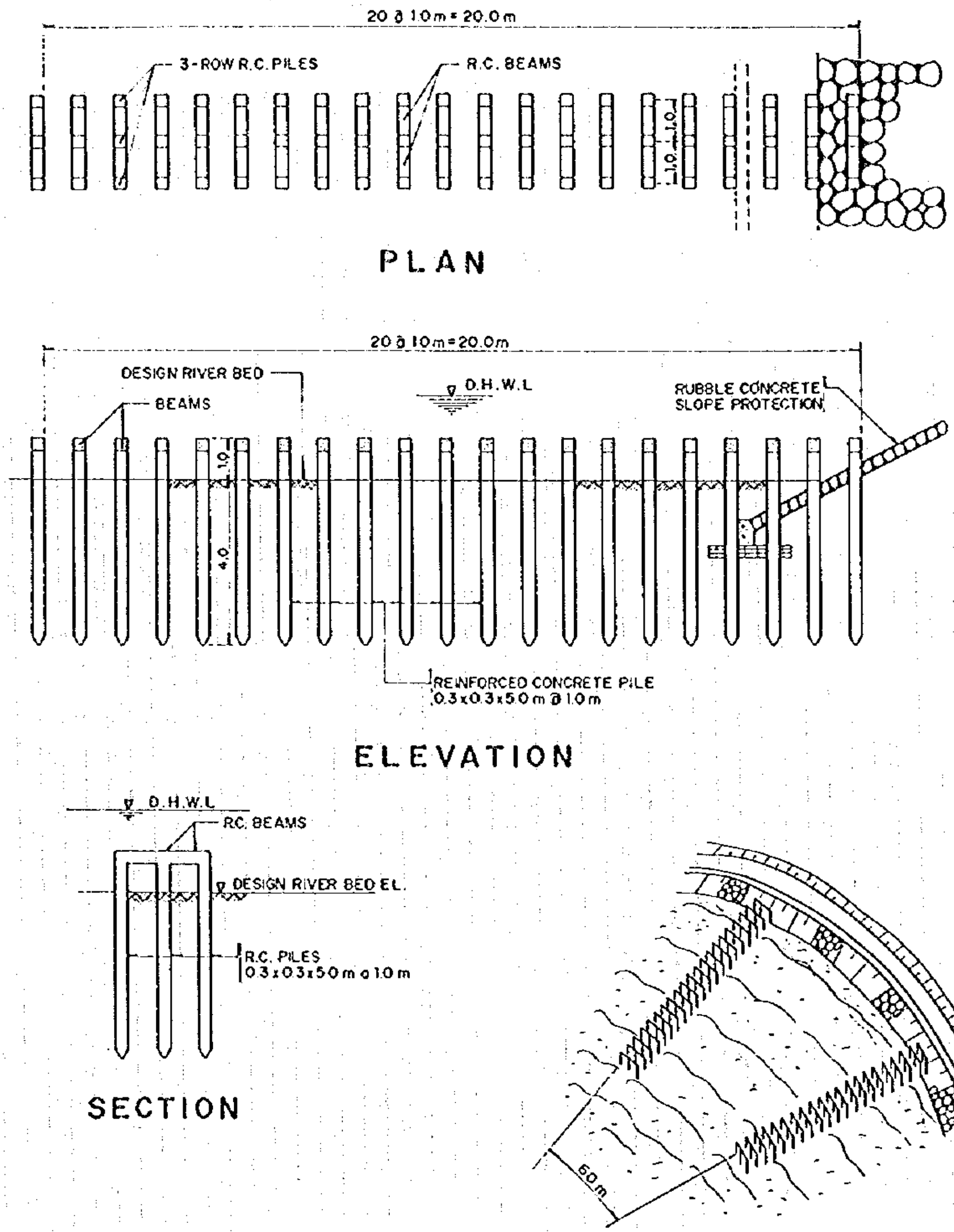


Figure 8.38 Proposed Spur Dike

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

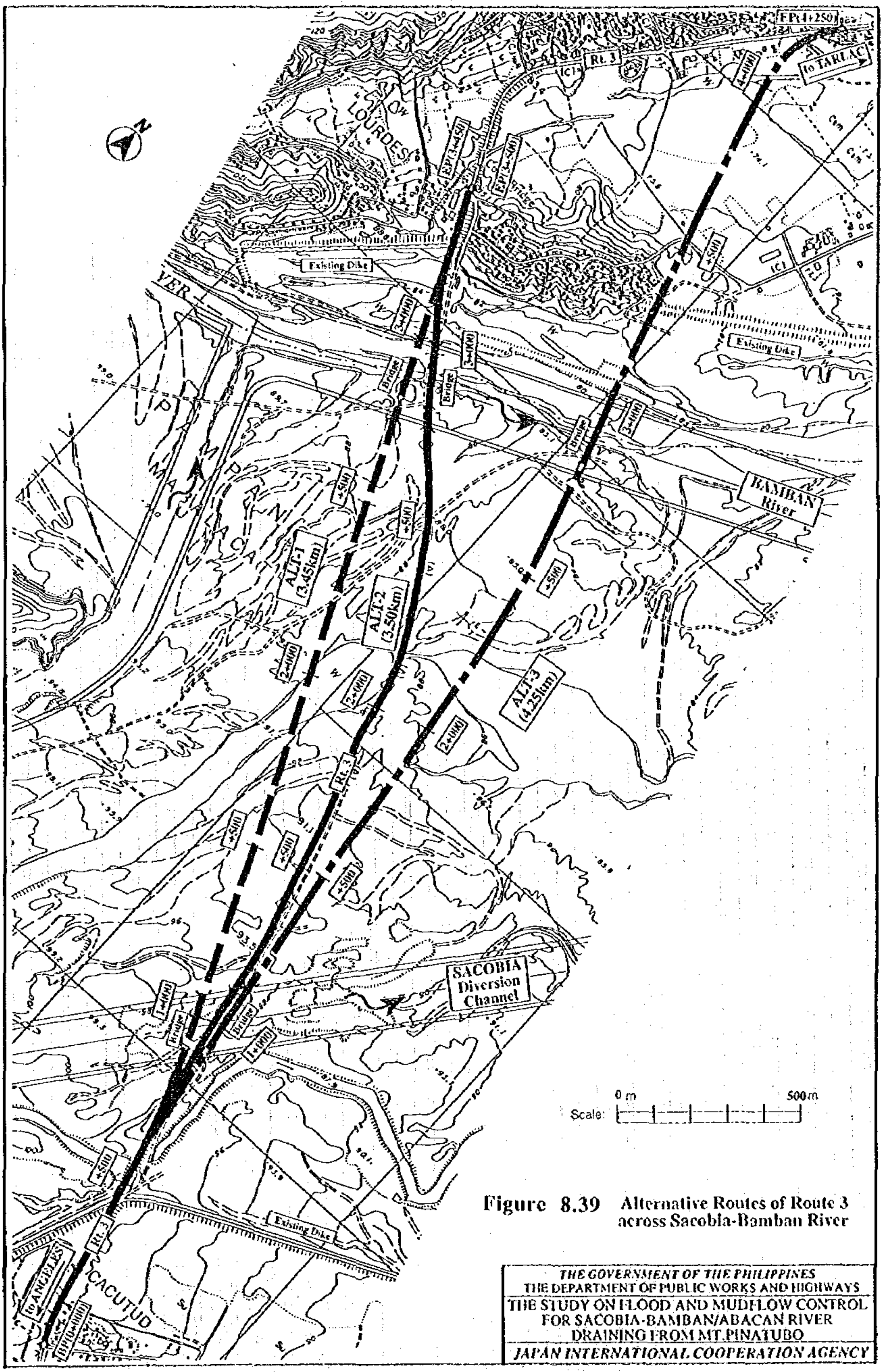


Figure 8.39 Alternative Routes of Route 3 across Sacobia-Bamban River

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

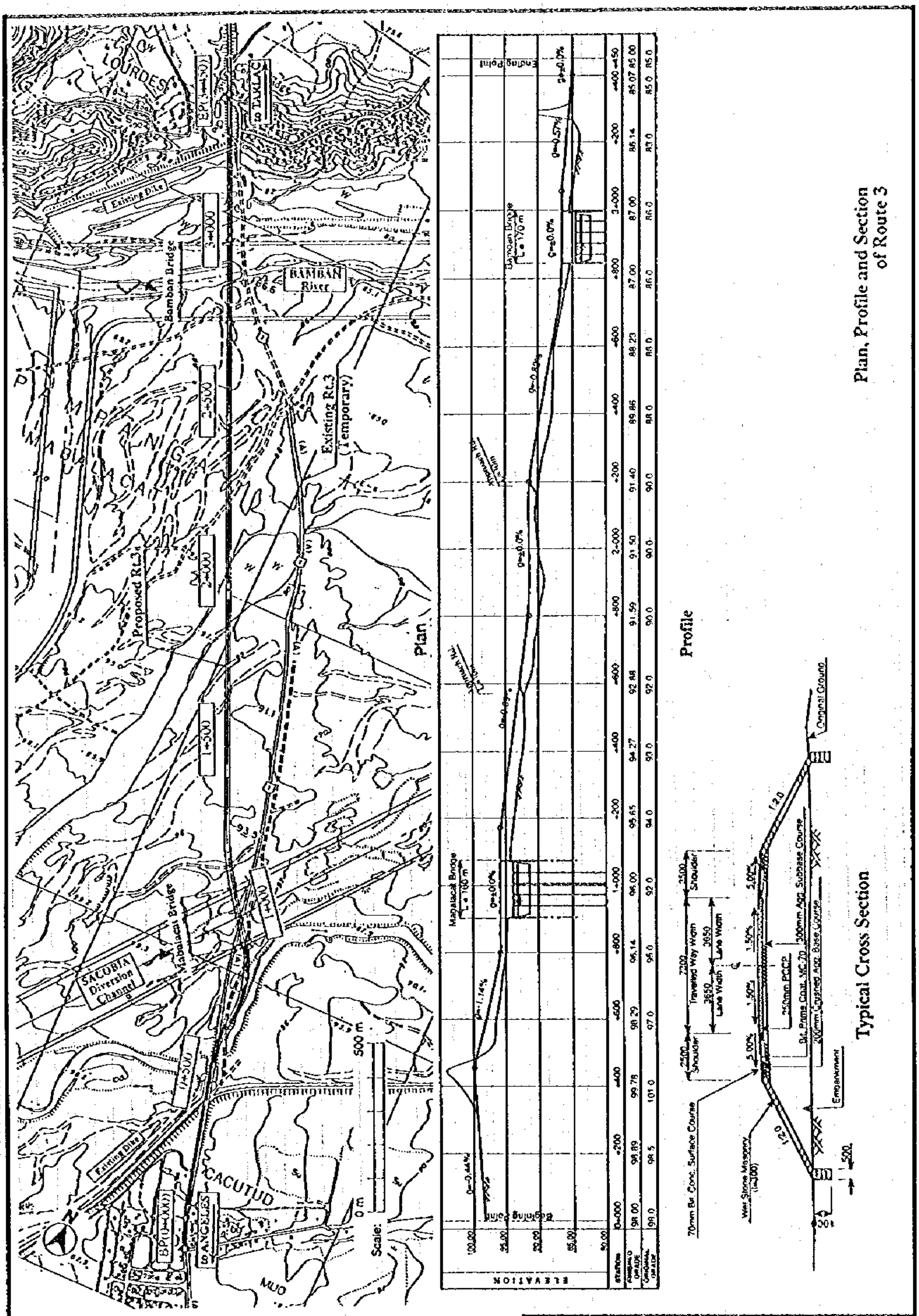


Figure 8.40
Plan, Profile and Section of Route 3

THE GOVERMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN.ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

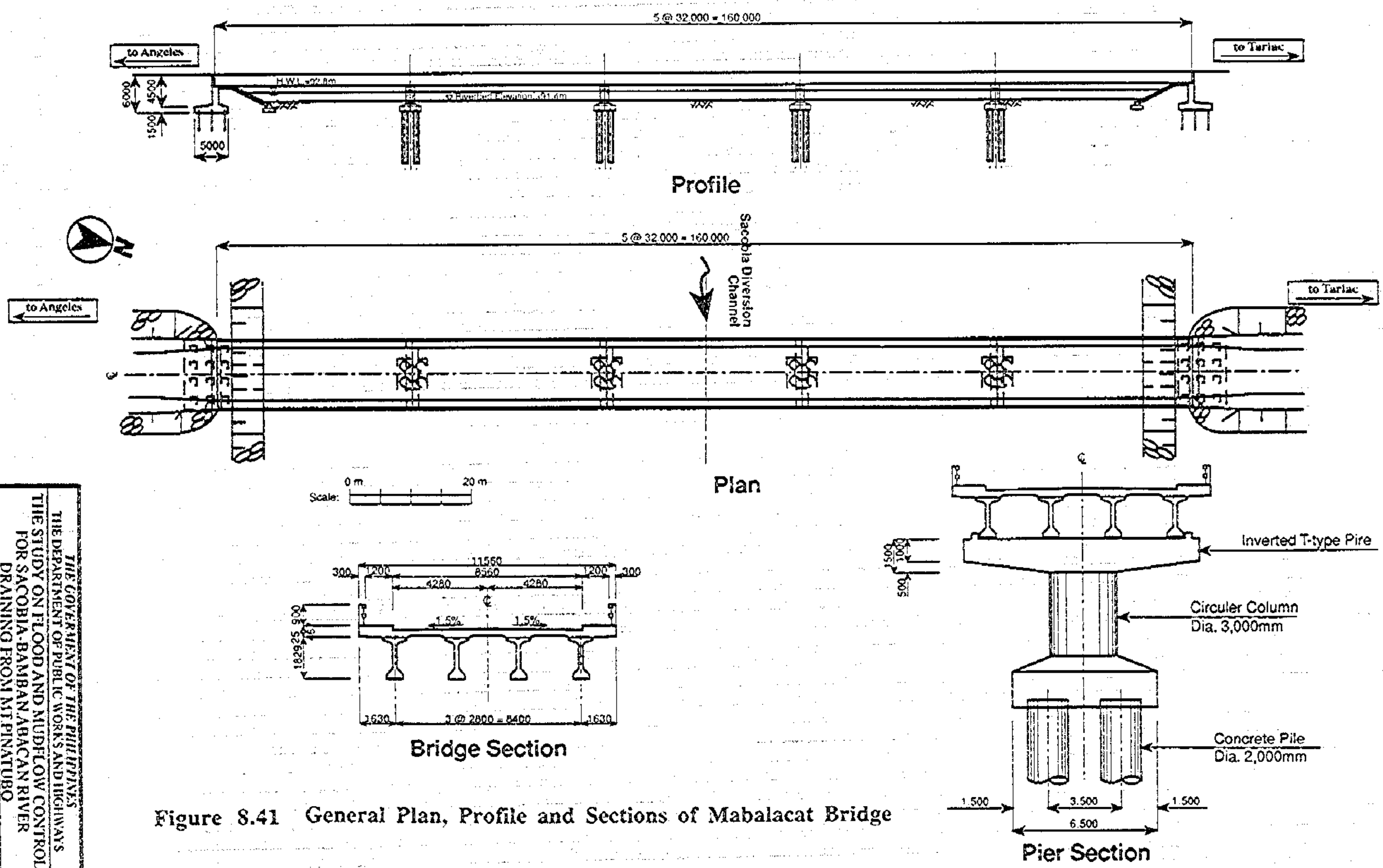
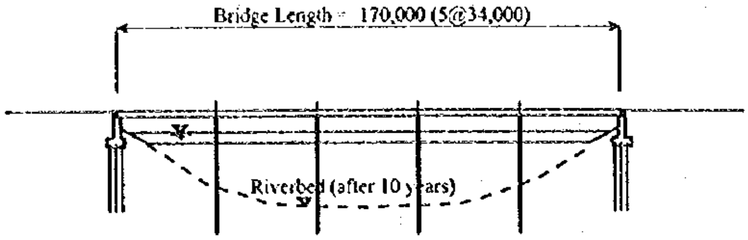
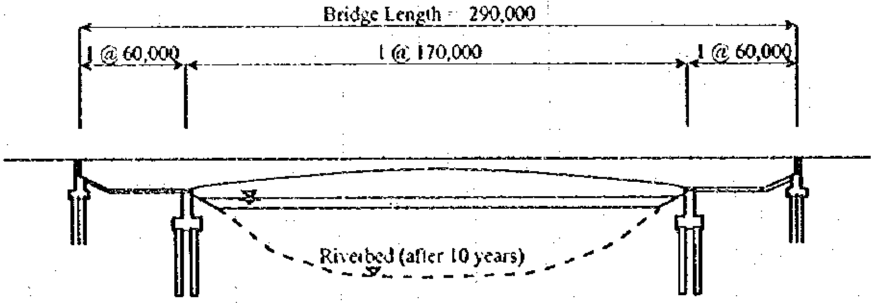


Figure 8.41 General Plan, Profile and Sections of Mabalacat Bridge

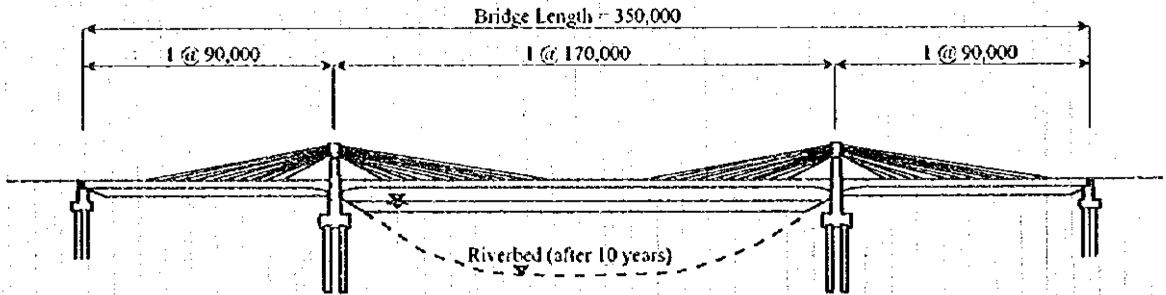
THE GOVERMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN.ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



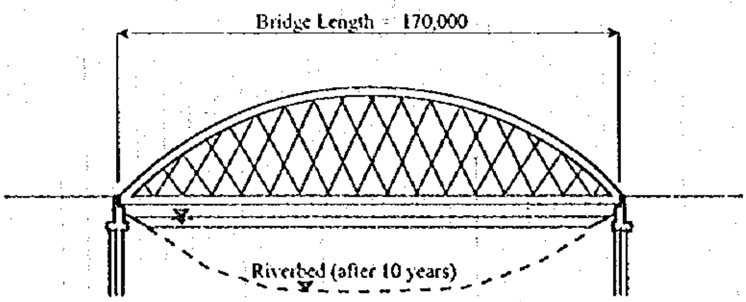
PC I-Girder Bridge



PC Box Girder Bridge



Extra-Dosed Bridge



Nielsen Bridge

Figure 8.42 Altenative Bridge Types of Bamban Bridge

THE GOVERMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN-ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

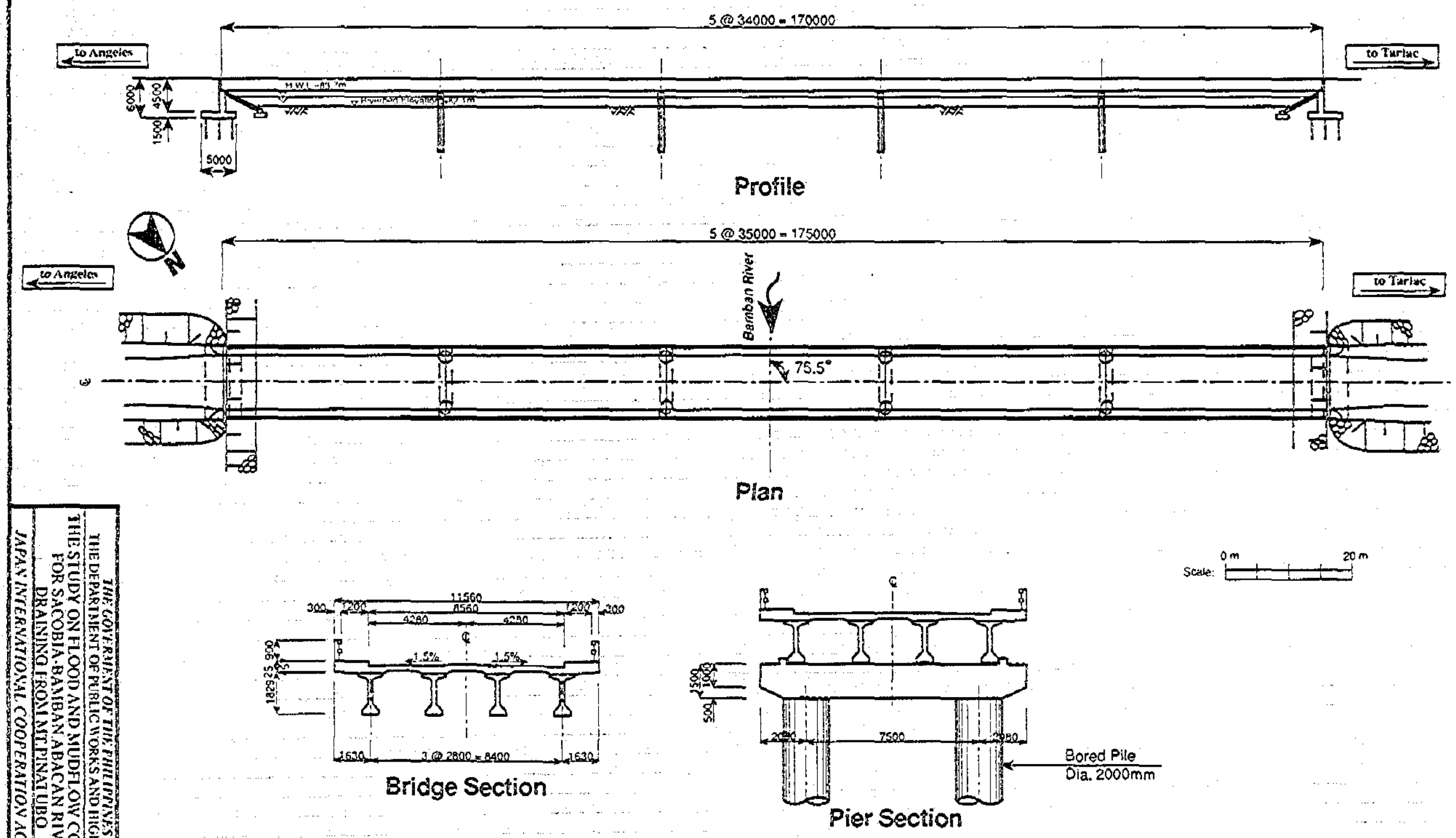


Figure 8.43 General Plan, Profile and Sections of Bamban Bridge

THE GOVERMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN.ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

Work Item	Quantity
1. JICA M/P & F/S	
2. Financial Arrangement	
3. Selection of Consultant	
4. Detailed Design	
5. Selection of Contractors	
6. Construction	
I. Mobilization & Preparatory	l.s.
II. Sacobia River Sediment Control Works	
II.1 Sand Pocket	
(1) Heightening/Closing & Slope Protection of Dikes	7,240 m
a) Mabalacat-Magalang-S/F Bridge Dike	3,050 m
b) San Nicolas Balas Dike	2,100 m
c) Parua River Dike	2,090 m
(2) Lateral Dikes	5,960 m
a) 1st Row	1,110 m
b) 2nd Row	2,130 m
c) 3rd Row	2,720 m
(3) Road Dike	1,650 m
a) Sapang Balen Bridge	38 m
b) Baidbid Box Culvert	15 m
c) San Nicolas Balas Box Culvert	30 m
d) Portland Cement Concrete Pavement	1,567 m
II.2 Sacobia River (Maskup Consolidation Dam and Training Work)	
(1) Driving Sheet Piles	102,140 m
a) Maskup Consolidation Dam	36,920 m
b) Groundsel No.1	10,870 m
c) Groundsel No.2	10,870 m
d) Groundsel No.3	10,870 m
e) Groundsel No.4	10,870 m
f) Groundsel No.5	10,870 m
g) Groundsel No.6	10,870 m
(2) Channel Excavation	2,800,000 m3
(3) Slope Protection of Banks	10,360 m
(4) Gabion Work	25,960 m3
(5) Concrete Work	26,500 m3
(6) Wing Dike	542 m
III. Bamban River Improvement Works	
(1) Dike Reinforcement Work	12,500 m
(2) Channel Excavation (Upper Reach)	2,000,000 m3
(3) Heightening of Dikes (Lower Reaches)	6,000 m
(4) Slope Protection of Dikes	29,150 m
a) Left Dike (Middle Reaches)	8,250 m
b) Left Dike (Upper Reaches)	6,850 m
c) Right Dike (Middle Reaches)	3,350 m
d) Right Dike (Upper Reaches)	10,700 m
(5) Spur Dikes	12 sets
(6) San Francisco Bridge	300 m
IV. Sapang Balen River Improvement	14,000 m
(1) Straightening	2,000 m
(2) Slope Protection	1,200 m
(3) Additional Span for San Antonio Br.	30 m
V. Sapang Cauayan River Training Works	2,650 m
a) Left Bank	950 m
b) Right Bank	1,700 m
VI. Restoration of Highway Route 3	3,400 m
(1) Bamban Bridge	200 m
(2) Mabalacat Bridge	240 m
(3) Portland Cement Concrete Pavement	2,950 m
VII. Maintenance Works (Desilting, up to 2004)	13,500,000 m3

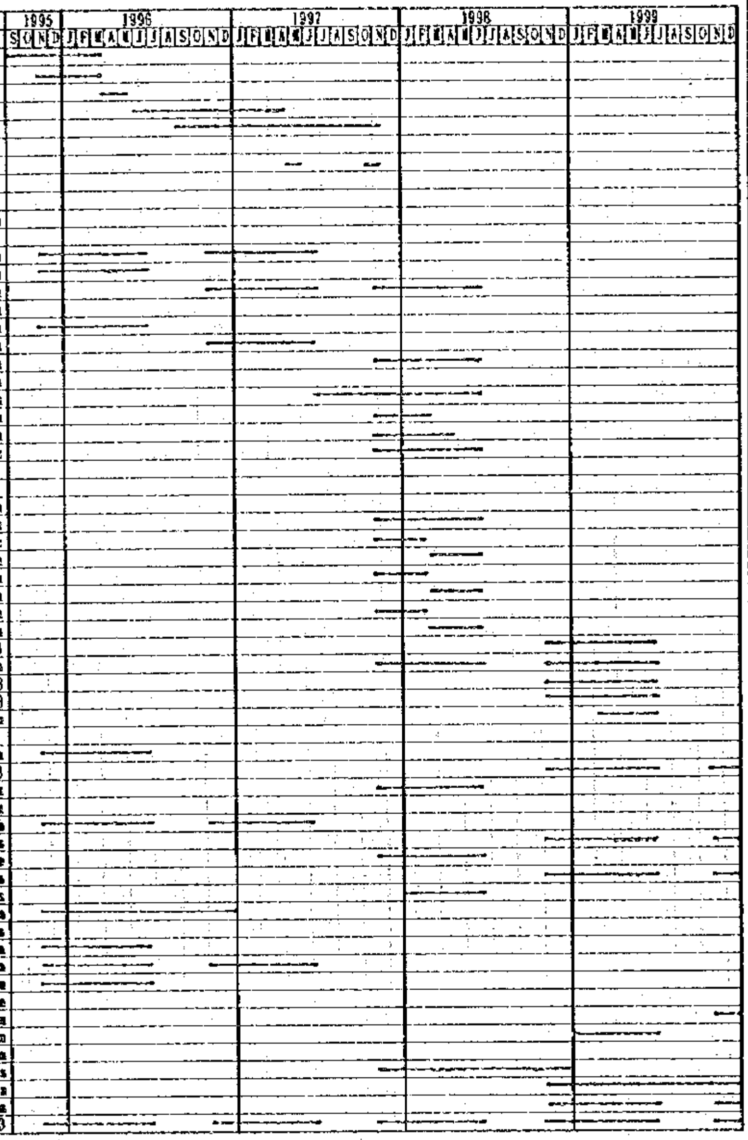


Figure 8.44 Project Implementation Schedule for Sacobia-Bamban River Basin

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

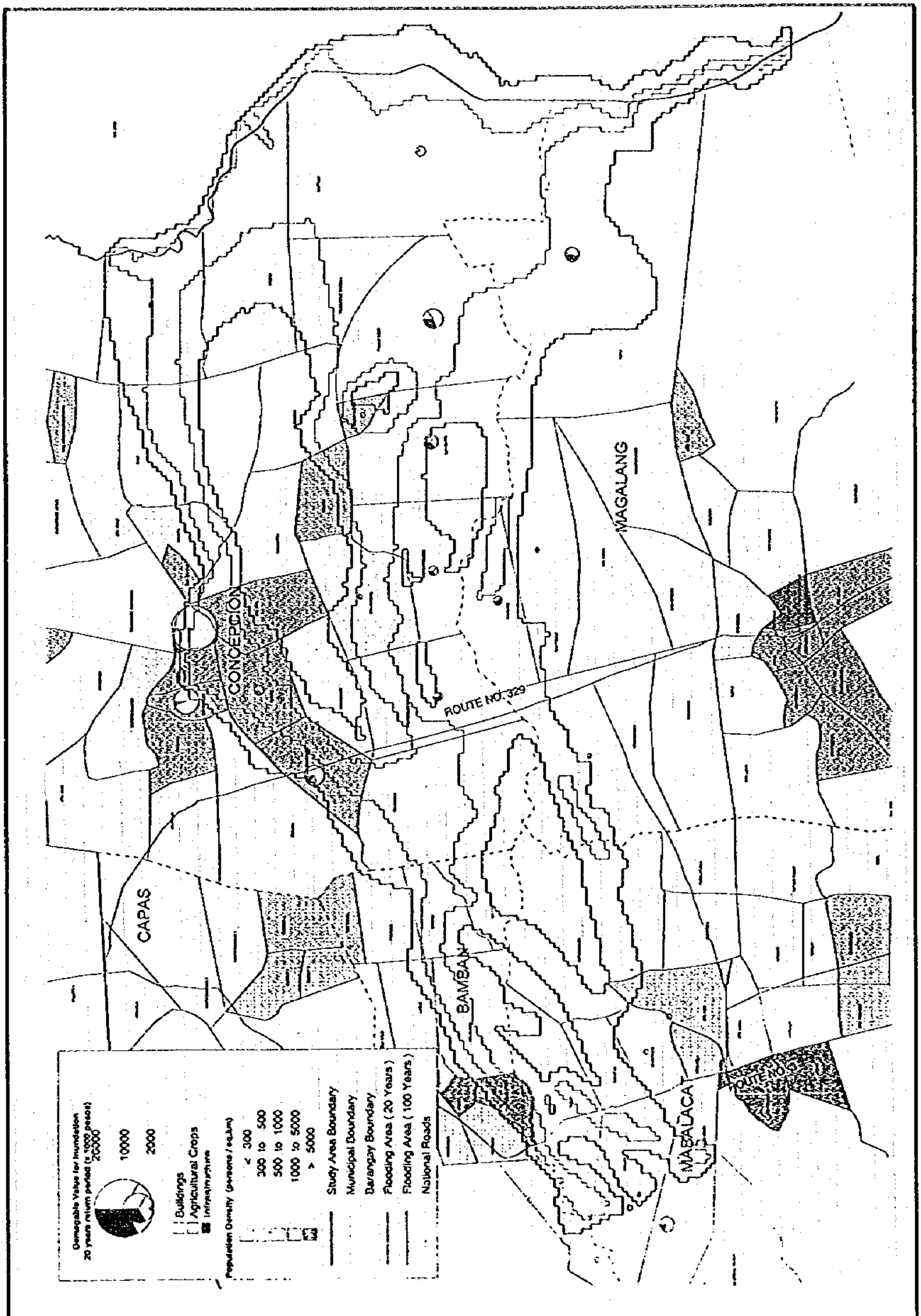


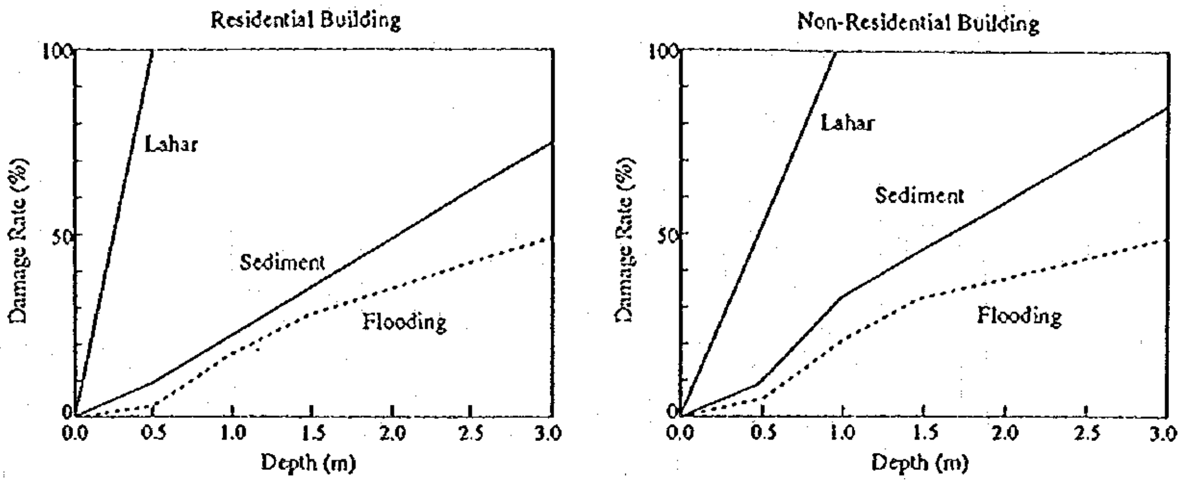
Figure 8.45 Probable Inundation Area in Sacobia/Bamban River Basin

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS

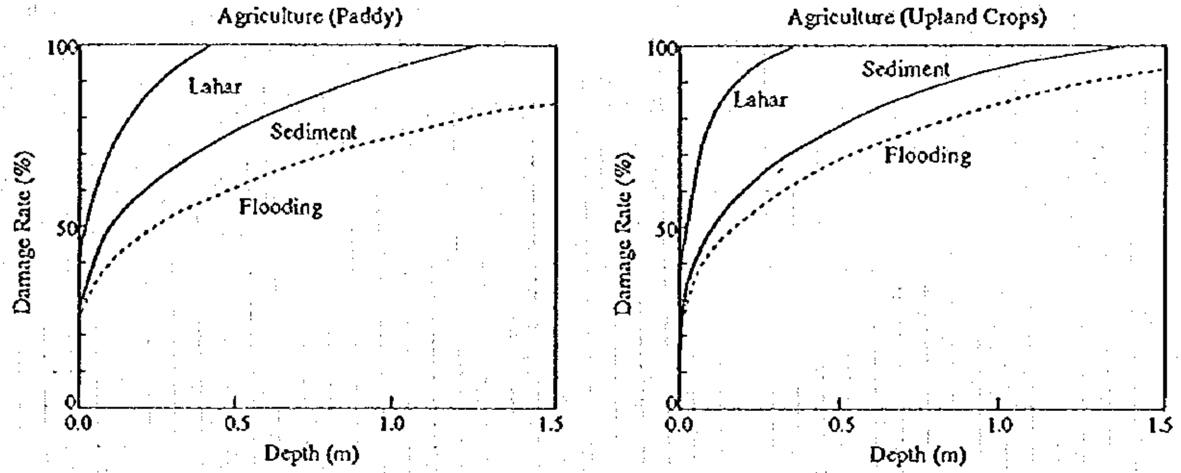
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO

JAPAN INTERNATIONAL COOPERATION AGENCY

Building



Agriculture



Infrastructure

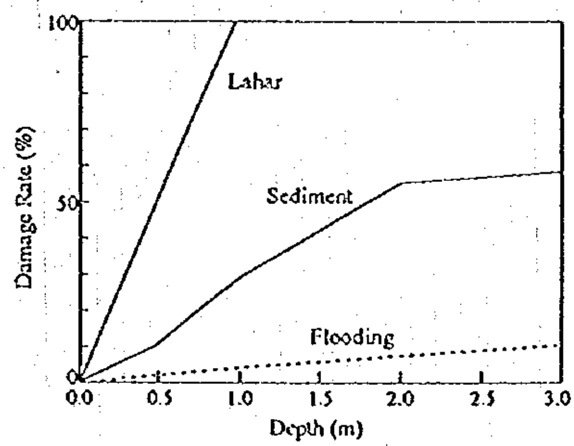


Figure 8.46 Damage Curves for Properties

THE GOVERNMENT OF THE PHILIPPINES THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

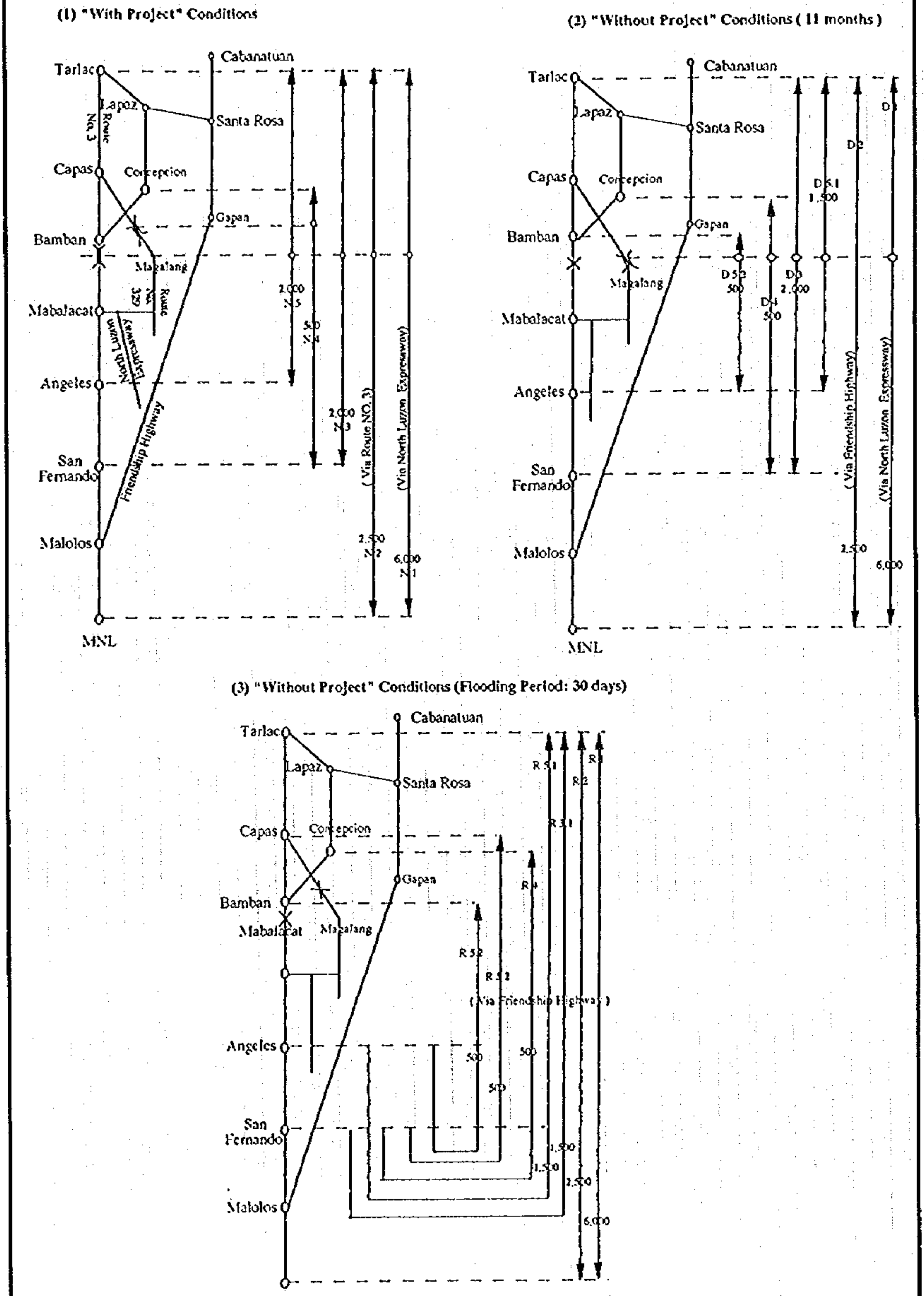


Figure 8.47 Schematics of Detour Alternative Routes

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS

THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO

JAPAN INTERNATIONAL COOPERATION AGENCY

CHAPTER 9

STRUCTURAL MEASURES IN ABACAN RIVER BASIN

CHAPTER 9 STRUCTURAL MEASURE IN ABACAN RIVER BASIN

9.1 FUTURE PROSPECT AND BASIC CONCEPT

9.1.1 UPPER REACH

In 1991 and early 1992, mudflow organized into lahar from pyroclastic flow deposits and ashfall frequently flowed down through the Sapangbato River, while the mudflow in the Taug (Sapangbayo) River was mainly organized into ashfall deposit in the basin. The DPWH constructed ten sabo dams in the tributaries in 1992. When a large secondary explosion had caused the aggradation of about 5 m in the Sapangbato River, sabo dams Nos.1 to 3 was completely buried and sabo dam No.4 was buried partially. These dams were fairly effective in storing unstable sediment. Total volume of unstable sediment is estimated at 3.7 million m^3 in the upper reaches of the Abacan River in 1994, of which 1.5 million m^3 of the unstable sediment is stored by a series of sabo dams.

The mudflow in both rivers caused various problems while it flowed down the river channel such as serious bank erosion destroying residential areas, heavy channel scouring and a remarkable volume of sediment deposition. Although no lahar has observed in the Sapangbato River since April 1992, a remarkable volume of lahar deposits still remains in the river channel.

One of the issues in the headwaters of the Abacan River is to stabilize unstable sediment stored in sabo dams as shown in Figure 9.1. In 1994, some sabo dams were partially or completely collapsed due to deterioration of the materials and local scouring at the front side of the subdams, and the others are likely damaged in 1995.

Another issue is to mitigate the after-effects of lahar events in the upper reach of Abacan river system. Regarding remaining unstable sediment in the upper reaches of the Abacan River, the unstable sediment of 2.2 million m^3 still remains as a form of in-channel deposition in the river channel of tributaries under unstable condition. In 1995, the sediment discharge of about 0.5 million m^3 per year at sabo dam No.9 which is located at downstream end in the upper reach, the remaining unstable sediment would be transported gradually to the lower reaches of the Abacan River for the next several years. However, in case that the unstable sediment stored by sabo dams can be firmly stabilized, sediment discharge from the headwaters of the Abacan River will rapidly diminish to a certain level of some 40,000 m^3 per year.

9.1.2 MIDDLE AND LOWER REACHES

Before the eruption, the Abacan River and its tributaries formed a low-water channel. The residents had utilized the low river bank for farmlands and fishponds beside the stream. At that time the river banks of the Abacan River and its tributaries were relatively safe from lateral erosion during flooding. After the lahar events, however, the former low-water channel was completely buried with sediment or scoured out by mudflow. Even in the 1995 rainy season, bank collapse triggered by lateral erosion occurred during flooding, in particular, at the bend. That is another issue of the Abacan river system.

(1) River Conditions before Eruption

Flooding occasionally occurred downstream of the Capaya Bridge before the Mt. Pinatubo eruption due to overflowing from the river channel of 20 to 30 m wide, while the upstream reaches of the Capaya Bridge hardly experienced flooding.

After the 1972 flood which was the biggest flood recorded in the Central Luzon area, river improvement works were commenced. Until the eruption of Mt. Pinatubo, some shortcut channels, high parallel dikes of 3 m high and 7 km long in a stretch of Barangay San Patrician, Sta.4+000, to Brgy. Malino, Sta.11+000, and dry stone masonry at severe bending portions were completed.

On the other hand, the upper reaches from the Capaya Bridge formed a 200 to 300 m wide valley where the river stream of 30 m wide flowed down and was utilized for paddy and sugarcane fields and fishponds.

Regarding reparian structures, there were many pipe culverts installed for irrigation water, and seven bridges including spillway such a box culvert type bridge, namely; Ninoy Aquino Bridge at Brgy. San Juan, Capaya Bridge of the North Super Highway, Pandan Bridge of Angeles - Magalang Road, Abacan Bridge of National Road Route 3, Abacan Railway Bridge, Friendship Bridge at the uppermost stretch of the Lower Abacan River, and San Francisco Spillway between Abacan Road and the railway bridges.

(2) Present River Conditions

River width in a stretch of the downstream end to Capaya Bridge (Sta.0+600 to Sta.17+700) ranges from 100 to 150 m, where the river channel is confined in a dike system, while the reaches from Capaya Bridge to Friendship Bridge (Sta.17+700 to Sta.25+300) range from 150 to 300 m without a diking system.

At the downstream end of the Abacan River, the river width has gradually reduced from 150 m to 30 m, which corresponds to the width of the San Lorenzo Bridge at the end of the Bungang Guinto River.

Riverbed material consists of sandy lahar including pumice stones in the whole reaches. Remarkable aggradation of riverbed due to reduced sediment transportability is observed at the most downstream reach in the vicinity of Mexico. Severe lateral erosion of 5 to 10 m high bank frequently occurs in the urban area of Angeles City, which accompanies loss of valuable houses and lands.

(3) Existing Structures

The protection/rehabilitation works are being continuously undertaken at present. Dikes, slope protection, spur dikes, bridges, intake pipes have been constructed in the Lower Abacan River.

(a) Diking System

The protection/rehabilitation works by means of diking in the Abacan River started in November 1991. The river channel was confined in a dike system with 3 to 5 m in height and 7 m top width which were built of lahar materials within the reaches from Sabo Dam No. 9 at the Friendship Bridge in Angeles City to the confluence of the San Fernando/Bungang Guinto rivers.

There is a structural problem in that the constructed dikes are weak from lateral erosion and local scouring of flood waters because they are made of sandy lahar material. In early 1994, the breached dikes at several meandering portions in the downstream reaches were rehabilitated and reinforced with wet stone masonry type slope protection.

(b) Channel Excavation

At present, the sediment accumulated in the upper reaches are transported gradually to the downstream end of the river and there is a severe problem of siltation in the vicinity of Mexico in the alluvial plain of the Pampanga Delta. Dredging work for the Bungang Guinto River, downstream of the Abacan River, was executed and is also scheduled in 1995.

(c) Spur Dikes

To protect the Capaya bridge of the North Super Highway from vertical and lateral erosions of river channel, 18 spur dikes of 14 m long, 2 m wide, 3 m high, were built with gabion mattress in an interval of about 50 m in the vicinity of the bridge.

(d) Reconstruction of Bridges

The reconstruction of Abacan Bridge in Angeles City which was washed away by lahar in June 1991 was completed with a span of 300 m long in the following year of 1992, and one bailey bridge of National Road Route 10 in Mexico was constructed in 1994.

(4) Flow Capacity

Present flow capacity of the lower reaches of the Abacan River was examined by means of non-uniform flow calculation using the cross sections of channel at intervals of 600 m newly surveyed in early 1994. The lower reaches from Sta.6+000 have the flow capacity of 500 to 1,000 m^3/s, while the upper reaches from Sta.6+000 have the flow capacity of 2,000 to 4,000 m^3/s.

9.2 STRUCTURAL MEASURE

9.2.1 SEDIMENT RETENTION MEASURE

(1) Possible Structural Measures

The possible structural measures for sediment retention are nominated and preliminary evaluation is done taking into account the site conditions as follows:

1) Sabo Dam

Before the onset of the 1994 rainy season, there were nine sabo dams in the Abacan headwaters as shown in Figure 9.2, of which four sabo dams partially or completely collapsed during the rainy season of 1994. Above all, the key sabo dams, which preserve the important facilities and areas or have relatively large storage among existing sabo dams, are inevitable to be reconstructed as permanent structures.

2) Spur Dike

A spur dike/groin, either permeable or impermeable, is placed at approximately right angle to the riverbank for controlling flow direction towards the center of the channel so as to prevent bank erosion. However, an escarpment of 10 m high with sandy materials was formed along the Sapangbato River, a spur dike is not recommendable for protection measures against bank erosion along the Sapangbato River.

3) Retaining Wall

Retaining wall along the bank would be appropriate against bank erosion. It has a function of protecting bank and training flood water along the wall. Local scouring used to occur along such a structure in case of improper foundations, so that the low-water channel has to be aligned apart from these structures.

(2) Sediment Retention Measure

Some sabo dams have been repaired almost every year due to deterioration of materials and local scouring. Of the sabo dams, No.9 sabo dam plays the most important role among the sediment retention structures in the Abacan River, such as diminishing the exceeding sediment discharge to the lower reaches and sustaining the foundation of the Friendship Bridge. Once No. 9 sabo dam collapses in a heavy rain, enormous retained sediment will be eroded immediately and debris flow forming a high surge will run through the lower reaches with tremendous bank erosion and destroying the riparian structures.

In due consideration of the above-mentioned condition, rehabilitation works for existing sabo dams are inevitable as the Short Term Plan to be executed in 1995-1996. Then, the selected dams with high priority for sediment retention shall be reconstructed as permanent structures in the Medium Term Plan to be executed in 1997-1999. Considering the protected facilities, retained capacity and site availability to be reconstructed, the following sabo dams are nominated to be reconstructed as permanent structures;

- No. 9 sabo dam
- No. 6 sabo dam
- TM-1 sabo dam

Regarding bank erosion along the Sapangbato River, the retaining wall shall also be constructed in the Medium Term Plan, since small-scale spur dikes are now being constructed in the area to be protected with financing by the local government.

9.2.2 *FLOOD CONTROL MEASURES*

(1) Channel Alignment

Alignment planning shall follow the present channel alignment.

(2) Channel Longitudinal Profile

Although the existing bed elevations and slopes are still remarkably fluctuating, design longitudinal profiles will follow the existing riverbed elevations and longitudinal profiles in consideration of the following:

a) According to the longitudinal riverbed survey carried out in early 1994, the present riverbed elevations are slightly lower than the inland ground levels in the whole reaches.

b) As a result of examination of the present flow capacity, the existing dikes have sufficient capacity to drain more than 100-year design flood in most parts of whole reaches.

c) Existing slope protections were designed referring to the riverbed elevations at the time of construction.

Figure 9.3 shows the proposed longitudinal profiles including design high water levels and riverbed elevations.

(3) Channel Cross Section

Although stabilization of low water channel is desirable from the viewpoints of dike protection and irrigation water supply, it is difficult and costly to install and maintain the low water channel because of erodible sandy materials of the riverbed. Thus, a single cross section is designed for river improvement works. In addition, slope protection works are planned at the meandering portions. Figure 9.4 shows the proposed typical cross sections of river channel.

(4) Channeling in the Urban Area of Angeles City

To protect banks from heavy lateral erosion in the valley reach of about 7 km long from the Capaya Bridge to No. 9 sabo dam (Friendship Bridge) in Angeles City, channeling work to stabilize the channel alignment is proposed. Channel is designed as trapezoid-shaped with slope protection of wet stone masonry type as shown in Figure 9.5.

(5) Downstream from the Abacan River (Bungang Guinto River)

It is necessary to continuously dredge the riverbed of the Bungang Guinto River to ensure the sufficient drainage capacity of the downmost Abacan River.

(6) Structure Arrangement

Figure 9.6 shows the arrangement of proposed structures in the Abacan River Improvement Plan.

a) Slope protection for dikes

Slope protection has been constructed in a total of about 4 km long until 1994 and will be continued in 1995. Additional slope protection work is proposed around the severe meandering portions of 13 km long.

b) Slope protection for channeling in Angeles urban area

Channeling work of 7 km long in the urban area of Angeles City is planned with bank protection.

c) Bridges

The following two bridges are scheduled to be constructed as permanent structures.

- Bailey bridge of National Road Route 10 at Mexico
- Hensonville Bridge between Friendship and Abacan bridges

It is noted that the Pandan Bridge in Angeles City is excluded in this development plan since it is designed in 1994 and is scheduled to be constructed after the completion of the San Francisco Bridge in 1997.

d) Channel excavation

To maintain the design riverbed channel excavation work will be necessary. The deposition volume is estimated at some 2 million m^3 for the period of 1996 to 1999.

9.3 SELECTION OF PRIORITY SCHEMES

The combination of engineering intervention measures for the Abacan River was formulated in the Master Plan Study. The structural measures proposed in the Master Plan was approved for the priority scheme proceeded to the Feasibility Study as a result of discussion in the Steering Committee Meeting held on March 25, 1995. The combination of structures are enumerated below:

UPPER REACH : (Upstream Reach from Friendship Bridge)

a) Reconstruction of Sabo Dam
   - sabo dam No.6
   - sabo dam TM-1

b) Bank protection along the tributaries

MIDDLE REACH: (from Friendship Bridge to Capaya Bridge)

a) Reconstruction of Sabo dam No.9

b) River Training Works along Angeles City

c) Restoration of Hensonville Bridge

d) Reconstruction of Pandan Bridge

LOWER REACH (from Capaya Bridge to Mexico Spillway)

a) Reinforcement of Existing Dike System

b) Reconstruction of Mexico Spillway Bridge

c) Maintenance Dredging Works in the Downstream Reach

Overall plan for the combination of flood/mudflow control structures for the Abacan River is shown in Figure 9.7.

9.4 STRUCTURAL DESIGN IN UPPER REACH

9.4.1 RECONSTRUCTION OF SABO DAM

For the purpose of stabilization of sediment retained in the storage areas of the existing sabo dams to prevent of mudflow caused by collapse of the deteriorated sabo dams, the Sabo dam No.6 at Sapangbato River and Sabo dam TM-1 at Taug (Sapangbayo) River shall be reconstructed as permanent structures.

The dimension of sabo dams are propose as follows:

Design Condition	Unit	Sabo Dam TM-1		Sabo Dam No.6	
		Main Dam	Cut-off	Main Dam	Cut-off
Major Construction Material		Sheet Pile	Sheet Pile	Reinf't Bar	Concrete
Effective Height	m	4.3	0.0	3.5	0.0
Depth of Embedment	m	6.2	6.0	2.5	3.5
Length of Dam	m	123.0	91.0	56.0	42.0
Width of Dam	m	9.0	5.0	9.0	2.0
Width of Spillway	m	60.0	60.0	25.0	25.0

Steel double-walled type sabo dam is recommendable as described for the structural measures of the Sacobia River. The embedment depth of the dam base is set at 3 m in consideration of the soft base ground condition at each site. Height of the spillway crest is determined to keep continuous longitudinal profile to the existing sabo dam.

The design discharge of 100-year flood is adopted for flow capacity of the proposed spillway. Sediment concentration of floods is assumed to be 10%, since mudflow and hyper-concentrated flow has not occurred in the Abacan River after piracy at Abacan Gap in April 1992. A set of counter dams, apron, cut-off and riverbed protection works are adopted to prevent heavy scouring around the front side. In addition, the spillway and apron will be covered with concrete to prevent abrasion by sediment collision. The structural plan and typical sections are shown in Figure 9.8 for sabo dam TM-1 and Figure 9.9 for sabo dam No.6. The design condition of spillway and apron is enumerated below:

Design Condition	Unit	Sabo Dam TM-1	Sabo Dam No.6
Catchment Area	km^2	8.3	3.5
Specific Discharge	$m^3/sec/km^2$	20.45	31.63
100-year Flood Peak Discharge	m^3/sec	170	111
Sediment Concentration		0.1	0.1
Mudflow Discharge	m^3/sec	190	125
Width of Spillway	m	60	25
Overflow Depth	m	1.5	2.0
Freeboard	m	0.6	0.6
Height of Non-overflow Section	m	2.1	2.6
Effective Height of Dam	m	4.3	3.5
Length of Apron	m	14	16
Concrete Thickness of Apron	m	1.5	1.5

9.4.2 RIVER BANK PROTECTION

Regarding bank protection works to protect the residential areas against heavy lateral erosion in the upper reaches of the Taug River, the bank protection with concrete facing is required for the stretch of 1,510 m long. The arrangement and typical section of bank protection works is shown in Figure 9.10.

As for the river bank of the Sapang Bato River, the target areas around Sapang Bato, Margot and Anonas Villages are nominated as protective area. A total length of 3,000 m made of gabion with concrete covered of 2.0 m in effective height is proposed for retaining works as shown in Figure 9.11. Backfilling with a gentle slope is also made with sod facing.

9.5 STRUCTURAL DESIGN IN MIDDLE REACH

9.5.1 CONFLUENCE BETWEEN TAUG AND SAPANGBATO RIVERS

Friendship Bridge is located at the confluence between Taug and Sapangbato rivers. Immediately after the eruption of Mt. Pinatubo in 1991, the left approach to Friendship Bridge had badly eroded by lahar. Then, lahar had passed the left approach of the bridge and washed out the riverbanks and houses along the Angeles City. However, the piers and girders of the bridge still remained at original position. DPWH then embanked lahar material at left approach road to the bridge and sabo dam No.9 was constructed to protect the foundation of the bridge in 1992. Since the dam was partially damaged in September 1994 by the rapid currents of flood which was triggered by the moderate scale of thunderstorm, the strengthening of left sidewall of sabo dam has been a source of worry concern to DPWH in 1995. Although the urgent rehabilitation works have been carried out by DPWH to ensure the transportation system through the Friendship Bridge, the dam had been seriously damaged in 1995.

The sabo dam No.9 has been performed its role very well as urgent measure to ensure the transportation through Friendship Bridge. The dam is required not only to store the unstable sediment but also to take a role as the upstream end structure of river improvement works in the middle reach of the Abacan River. However, as far as sabo dam exists at immediately downstream of the bridge, it is expected that the maintenance cost for rehabilitation of the sabo dam will increase annually and the bridge is likely deteriorated. Consequently, the reconstruction of sabo dam No.9 was proposed in the Master Plan Study. The dimension of sabo dam No.9 with steel sheet pile are propose as follows:

Design Condition	Unit	Main Dam	Sub-dam	Cut-off	Bridge Pier Protection
Effective Height	m	3.0	2.92	0.0	1.5
Depth of Embedment	m	6.0	6.0	6.0	4.5
Length of Dam	m	185.0	141.0	126.0	186.0
Width of Dam	m	9.0	9.0	5.0	6.0
Width of Spillway	m	100.0	100.0	100.0	125.0

The structural plan and typical sections are shown in Figure 9.12. The width of spillway is determined to coincide with the river channel width of downstream reach. The surface elevation of sediment deposit in the upstream of sabo dam was estimated at 1.5 m lower that the present one, so that the protection works for bridge piers was proposed to install at 10 m downstream of Friendship Bridge. The left abutment where has been eroded during flood is proposed to be embanked by the excavated materials of low-flow channel in the middle reach of the Abacan River. On the contrary, the bank protection works with backfilling is proposed for the left bank. The design condition of spillway and apron is enumerated below:

Design Condition	Unit	Main Dam	Sub-dam
Catchment Area	km^2	33.3	-
Specific Discharge	$m^3/sec/km^2$	10.14	-
100-year Flood Peak Discharge	m^3/sec	338	-
Sediment Concentration		0.1	-
Mudflow Discharge	m^3/sec	380	380
Width of Spillway	m	100	100
Overflow Depth	m	1.7	1.7
Freeboard	m	0.8	0.8
Height of Non-overflow Section	m	2.5	2.5
Effective Height of Dam	m	3.0	2.92
Length of Apron	m	14	14
Concrete Thickness of Apron	m	1.5	1.5

9.5.2 RIVER TRAINING WORKS ALONG ANGELES CITY

To protect banks from lateral erosion in the valley reach of Angeles City urban area, training work is proposed from Capaya Bridge to No.9 Sabo Dam (Sta. 17+200 to Sta. 25+100, 7.9 km long). Channel is designed to allow a maximum velocity of about 3.0 m/s because of sandy bed materials. Shape of channel is designed as single trapezoid section faced with rubble concrete slope protection. Features of proposed channel computed by uniform flow method are as follows:

Reach	Capaya Bridge - Abacan Bridge	Abacan Bridge - No.9 Sabo Dam
Design discharge (20-year)	$370\ m^3/s$	$370\ m^3/s$
Design longitud. bed slope	1/150	1/115
Design roughness coeff.	0.035	0.035
Design velocity	2.850 m/s	3.105 m/s
Design channel top width	100.0 m	100.0 m
Design channel bed width	91.2 m	91.6 m
Design water depth	1.4 m	1.3 m
Design freeboard	0.8 m	0.8 m
Design side slope	1V : 2H	1V : 2H

Proposed longitudinal slopes follow present profiles and high water level is proposed to be lower than bank levels to avoid lateral erosion of valley. Figure 9.13 shows standard structural section.

9.6 STRUCTURAL DESIGN IN LOWER REACH

9.6.1 DESIGN CONDITION OF RIVER IMPROVEMENT

(1) Protection Level

Design scale of a 20-year return period flood is adopted in accordance with Master Plan.

(2) Design Discharge and Freeboard

River Reach	Design Discharge	Freeboard
Confluence with San Fernando River (Sta.0+000) - Malino (Sta. 11+000)	520 m^3/s	1.0 m
Confluence with Sapang Balen River (Sta. 3+000) - Confluence with Sacobia River (Sta. 21+800)	440 m^3/s	0.8 m

9.6.2 DESIGN OF RIVER CHANNEL

(1) Present River Conditions

The longitudinal profiles of the Abacan River was surveyed in early 1994 and early 1995. According to this survey, no significant movement of riverbed was identified. Dredging work has been done continuously along the Bungang Guinto River, downstream of Abacan River, to remove deposit by bulldozers.

(2) Alignment

The river channel is aligned as that in 1995.

(3) Design Riverbed Elevation

It is proposed to adopt the present longitudinal profiles taking into account present flow capacity and the depth of toe of existing revetment from riverbed except lower reach. Riverbed of lower reach is proposed to be excavated because design riverbed elevation of the Bungang Guinto River is El.2.6 m at connection point with the Abacan River.

Design river bed elevation is shown in Figure 9.14. Design riverbed gradient varies from 1/860 to 1/115. Excavation work of lower reach is estimated at about 0.5 million m^3 on the basis of the cross sectional survey in 1995. Damaged existing 2 spillways at Sta. 0+611 and Sta. 7+800 should be demolished to avoid riverbed scouring downstream face of the structures.

(4) Design High Water Level

The design high water levels as shown in Figure 9.14 are obtained on the following basis:

1) High water levels are computed by non-uniform flow calculation method.
2) High water level at downstream end is obtained by uniform flow calculation method.
3) Roughness coefficient is estimated at 0.035

(5) Cross Sections of Channel

Figure 9.15 shows typical proposed cross sections of river channel.

9.6.3 PROPOSED STRUCTURES

Figure 9.16 shows arrangement of proposed structures for lower/middle Abacan River.

(1) Dike System

Lower reach, 17.2 km long from San Lorenzo Bridge to Capaya Bridge, is confined with parallel dike system made of lahar materials. It is necessary to maintain continuously dikes by covering with mountain soil, provision of gravel inspection road and rubble concrete slope protection works.

(2) Slope Protection Works

Aside from maintenance works for dikes in lower reach, provision of rubble concrete slope protection is urgently needed. At present, slope protection has been constructed in total about 4 km long. Additional slope protection works for 13 km long was proposed at severe meandering parts. The slope protection works are the same as those for Sacobia-Bamban River.

9.7 RECONSTRUCTION OF BRIDGES

9.7.1 GENERAL DESCRIPTION

Before the 1991 eruption of Mt.Pinatubo, there exits five (5) bridges and a spillway bridge; they are, Friendship, Hensonville, Abacan, Pandan and Capaya Bridges and San Juan (Ninoy Aquino) Spillway Bridge. Immediately after the eruption, three (3) bridges, Hensonville, Abacan and Pandan Bridges, were destroyed by rapid current of lahar flow and the access road for Friendship Bridges was washed away. Mexico spillway bridge was constructed across the Abacan River at Mexico on Gapan-San Fernando Road in 1992. Location map is shown in Figure 9.17 and the present condition by bridges are described hereinafter.

(1) Friendship Bridge

Friendship Bridge located at the confluence between Taug and Sapangbato rivers was constructed in 1968. Immediately after the eruption of Mt.Pinatubo in 1991, the left approach to Friendship Bridge had badly eroded by lahar. However, the piers and girders of the bridge still remained at original position. The DPWH then embanked lahar material at left approach road to the bridge and sabo dam No.9 was constructed to protect the foundation of the bridge in 1992. However, the left bank dike of sabo dam No.9 was washed out in spite of continuous rehabilitation works by the DPWH in 1995, so that the surface of sediment deposits in the storage of sabo dam No.9 forms rather steep gradient and the piers were exposed above the surface of sediment deposits.

(2) Hensonville Bridge

Hensonville Bridge connecting between Angeles City and Dau on municipal road was also collapsed immediately after the eruption in 1991. Although the bridge was reconstructed by the municipal office of Angeles City in 1994/1995, the newly constructed bridge was washed away during flood on July 30, 1995.

(3) Abacan Bridge

Abacan Bridge ensures a vital transportation on Route 3. The bridge was collapsed immediately after the eruption of Mt.Pinatubo, and reconstructed with 4-lane highway in 1992. In 1995, the protection works of abutment have been a source of worry concern to DPWH in these years.

(4) Pandan Bridge

Pandan Bridge is located at 500 m downstream from Abacan Bridge on Angeles-Magalang Road, of which the road is utilized as a access road to North Luzon Expressway. The bridge was washed away at the same time of collapse of Abacan Bridge. In 1995, the detailed design of Pandan Bridge has been completed by the DPWH under ADB loan. The DPWH envisages that the design works of bridge would proceed the construction stage.

(5) Capaya Bridge

Capaya Bridge is located at North Luzon Expressway across the middle stream of the Abacan River. Although the abutment of the bridge was damaged during lahar flow, the bank protection works such as spur dike with gabion have been carried out by DPWH. The riverbed degradation of the Abacan River is major have been a source of worry concern to DPWH in these years. The bridge piers for future extension of North Luzon Expressway have already constructed immediately downstream of existing bridge.

Although the slippage of bridge girder and slight tilting of bridge piers were identified, they may occur by the earthquake in 1990.

(6) Ninoy Aquino (San Juan) Bridge

The Abacan River bifurcated into several small creeks in the vicinity of San Juan Bridge and the spillway bridge was maintained by the DPWH on the Magalang-Mexico Road before the eruption. However, the river channel of the Abacan River was improved by 75 m wide with dike system of 5 m high in 1992. The bridge was newly constructed with shortest span. Since the bridge was constructed immediately upstream of previous spillway bridge, the riverbed elevation is fairly stable because that the previous spillway bridge functions as groundsill.

One of the serious problem is a discrepancy of alignment between Magalang-Mexico Road and San Juan Bridge. The Magalang-Mexico Road is aligned on a skew line with the Abacan River, and the bridge is constructed at right angle with the Abacan River. Therefore, the all the vehicles detour on the left dike of 200 m long and connects with Magalang-Mexico Road, although the right abutment of the bridge is coincide with the road. The access road for the bridge is preferable to realign smoothly with Magalang-Mexico Road.

(7) Mexico Spillway Bridge

Mexico spillway bridge across the newly improved river channel with 75 m wide, located at 2 km east of the center of Mexico municipality, was constructed on Gapan-San Fernando Road in April, 1992 and the bridge has already buried with sediment in September 1992. In spite of the continuous desilting works in the vicinity of the bridge by the DPWH, the sediment deposition occurred frequently by 0.5 m in 1993. The DPWH then constructed the Bailey Bridge immediately downstream of spillway bridge. One-way traffic is secured in 1995.

9.7.2 PRESENT CONDITION

Present conditions are shown in Table 9.1 and Figure 9.18.

9.7.3 STRUCTURAL PLAN

Among the bridges, three (3) bridges, Hensonville, Pandan and Mexico Bridges, are inevitable to be reconstructed as early as possible before the year 2000. While, Pandan and Mexico Bridges would proceed to the construction stage under the ADB fund. Therefore, Hensonville Bridge is designed for the Feasibility Study.

Hensonville Bridge is designed as PC girder and balcony type with spiral stairs as shown in Figure 9.19 under the following reasons;

1) PC girder type is standardized by the DPWH and most popular in the Philippines.

2) Material of steel bridge is not domestically produced in Philippines.

3) Maintenance works of steel bridge after completion would be difficult because few Filipino contractors have experienced to construct steel bridges.

4) The wide riverside land scoured out by lahar flow is made use of as a community zone for the residents.

The design return period of flood is determined to be 50-year in accordance with the Design Standard of DPWH. The total length of Hensonville bridge crossing Abacan river is determined to be 150 m, consisting of 6-span of 25 m long girder. The span length is determined to be 25 m by applying the Japanese Structural Standard.

9.8 COTST ESTIMATE

9.8.1 PROJECT COST

Project cost for the Project of Abacan river basin is estimated at 1,005 million pesos in total including physical and price contingencies. The following is a summary of estimated cost, and breakdown of cost is shown in Table 9.2.

Unit: million pesos

	Item	Foreign Currency Portion	Local Currency Portion	Total
1.	Main Construction Cost	407	273	680
1.1	Preparatory Works	18	12	30
1.2	Main Works	354	237	591
1.3	Miscellaneous Works	35	24	59
2.	Land Acquisition	0	8	8
3.	Administration Cost	0	34	34
4.	Engineering Service Cost	61	7	68
5.	Physical Contingency	47	29	76
	Total	515	350	865
6.	Price Contingency	39	100	140
	Grand Total	555	450	1,005

9.8.2 DISBURSEMENT SCHEDULE

The following is a summary of the annual disbursement schedule from 1996 to 1999 based on the Implementation Schedule given in Figure 9.20.

Unit: million pesos

Year	Foreign Portion	Local Portion	Total
1996	55	37	92
1997	83	60	143
1998	238	191	429
1999	178	162	340
Total	555	450	1,005

Table 9.3 shows the Annual Disbursement Schedule in detail.

9.8.3 OPERATION AND MAINTENANCE COST

Annual cost of operation and maintenance (O/M) is estimated at 3.4 million pesos assuming it to be 0.5% of main construction cost from the year of 2000 following completion of project works.

Aside from the O/M cost above, maintenance works (desilting work of channel) should be continued for 4 years from 1996 to 1999. Annual maintenance cost for desilting work is estimated at 30 million pesos.

9.9 ECONOMIC EVALUATION

9.9.1 COST OF THE PROJECT

The investment cost was estimated on the basis of the following preconditions:

1) the base period of cost estimate was set at as of October 1995,
2) the exchange rates were assumed at US$ 1=Peso 25=¥ 100,
3) value added tax and import duties of 7% in total were estimated in the local currency portion,
4) the price contingency for the future were estimated assuming annual inflation rates of 2.5% for foreign currency and 8.7% for local currency portions respectively,
5) the administration cost was estimated in local currency portion at 5% of the total of main construction cost (including F.C. and L.C.) and land acquisition cost,
6) the engineering cost was estimated at 10% of the total main construction cost, of which 90% was assumed to be in foreign currency and 10% in local currency, and
7) the physical contingency was estimated by 10% of the total of main construction cost, land acquisition cost and engineering cost.

The cost for desilting works were treated as the maintenance cost and scheduled to be disbursed in four (4) years for Abacan River starting from the initial stage of the construction.

The Project cost (financial) is estimated at P 1,005 million with foreign currency (F.C.) portion of P 555 million and local currency (L.C.) portion of P 450 million at the price level as of October 1995 as shown below.

Project Cost of Flood/Mudflow Control Works for Abacan River

Unit: Pesos million

	Financial Cost			Economic Cost		
	F.C.	L.C.	Total	F.C.	L.C.	Total
1) Main Construction Cost	407.48	272.52	680.00	407.48	191.80	599.28
2) Land Acquisition Cost	0.00	7.50	7.50	0.00	0.00	0.00
3) Administration Cost	0.00	34.37	34.37	0.00	27.49	27.49
4) Engineering Cost	61.20	6.80	68.00	61.20	5.44	66.64
5) Physical Contingency	46.87	28.68	75.55	46.87	22.94	69.81
6) Price Contingency	39.14	100.50	139.63	-	-	-
7) Total	554.69	450.37	1,005.06	515.55	247.67	763.22

The operation and maintenance costs were estimated based on 0.5% of the main construction cost.

The financial cost shown above was converted into the economic cost to adjust the distorted market price value. Considering the current unemployment situation, the market wage was adjusted by shadow wage rate which was assumed at 60% of the market wage rate. In order to adjust the distortion of the official exchange rate, the standard conversion factor of 0.86 was applied following the recent ADB practice. The economic cost of land acquisition was assumed to be nil based on the fact that the site has been a barren land with no productive use.

9.9.2 *BENEFIT OF THE PROJECT*

(1) Criteria of Benefit

The benefit to be accrued from the implementation of the Project was defined in this Study as the reduction of the direct and indirect damages caused by flood/mudflows. The probable direct and indirect damages were estimated under the current conditions at the end of 1994.

(2) Estimate of Direct Damage

In estimating the damageable value of all the properties in the probable inundation area, a "Barangay Data Base" was established in the GIS. All the data required for the estimate of damage including population, number of household, properties and areas of each barangay were input and arranged in this Data Base.

The probable inundation areas were delineated for the river basin on the basis of a hydrological simulation study for each return period of 2, 5, 10, 20, 50 and 100 years out of which those of 20- and 100-year return period floods are depicted in Figure 9.21.

Damage curves were generated for major items of properties such as residential buildings, non-residential buildings, paddy field, upland crops, and infrastructures including roads and bridges. The damage curves and unit values of properties in Sacobia-Bamban river basin were adopted for each hazard of flooding, sediment and lahar toward the depth and duration of each hazard. The method of identifying and estimating damageable values is also the same as those in Sacobia-Bamban river basin.

The probable flood damage for each property and for each flood return period is summarized in Table 9.4. The average annual direct damage was obtained after aggregating each property damage and is tabulated in Table 9.5.

(3) Estimate of Indirect Damage

In this Study, the indirect damage covers such secondary damages to be stemmed from and induced by the flood/mudflow occurrences as the opportunity loss of product due to the interruption of economic activities caused by flood/mudflow, and the cost of evacuation and clean-up of buildings. The indirect damages were estimated as stated hereunder.

(a) Loss of Production by Interruption of Economic Activities

The loss of production due to the interruption of economic activities caused by flood/mudflows were estimated based on the per capita GRDP of non-agricultural sector (estimated at P33,550 in 1994 at 1994 price) multiplied by the duration (assumed to be ten days in a year) and the number of affected people in urban areas. The loss of production in the agricultural sector was not considered here since it is already included in the direct flood damage of agricultural crops.

(b) Evacuation and Building Clean-up Costs

The evacuation cost and the clean-up cost of buildings to be occurred at the time of disasters were estimated based on the unit cost adopted from a similar study in the past and the assumed duration of the incidence. For the cost of evacuation, the duration of 10 weeks in a year and the unit cost of P216 per week per household were assumed for lahar incidence. For the cost of clean-up of buildings, the duration of 6 days in a year and the unit cost of P150 per day per building were assumed for lahar. No similar costs were considered for flood incidence.

The probable costs of evacuation and building clean-up together with the estimated loss of GRDP are shown for each flood return period in Table 9.6 and their average annual costs are shown in Table 9.7.

9.9.3 COMPARISON OF COST AND BENEFIT

The comparison of cost and benefit is presented in Table 9.8.

The desilting works which are included in the column of maintenance cost were assumed to start from the beginning of the construction for four (4) years.

Benefits were assumed to accrue immediately after the completion of the Project. When the expected rapid economic growth in the Central Luzon Region is considered, the value of properties in the Study Area is also expected to increase rapidly. In this Study, the flood control benefit (reduction of direct damages) was assumed to increase at the same rate as that of GRDP of the Region i.e. 8.23 % p.a.

The estimated foregone of production caused by flood/mudflow incidences together with costs of evacuation and building clean-up was assumed arbitrarily to increase with a rate of growth of population in Region 3 which was estimated at 2.67% per annum for the period of 1990-2010 in JICA CLDP Study.

As the result of benefit-cost comparison, EIRR of 24.1% was derived. The net present value discounted at 12%, which is in this Study considered as the opportunity cost of capital in the Philippines, was computed at P 1,149 million.

A sensitivity analysis was conducted by varying both the benefit and cost of the Project. The result is summarized in Table 9.9. As shown in the table, the Project is justified