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JAPAN INTERNATIONAL COOPERATION AGENCY

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

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

APPENDIX II

FEASIBILITY STUDY

May 1996

NIPPON KOEI Co., Ltd., Tokyo Japan
in association with
CTI ENGINEERING Co., Ltd., Tokyo Japan

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1.1 GENERAL

Alternatives for engineering intervention measures for Sacobia-Bamban River were formulated in the Master Plan Study under the assumption that the San Francisco Bridge is newly in service in 1997. Of the alternatives, Alternative 2 was selected for the priority scheme to proceed to the Feasibility Study. The combination of structures adopted in the Feasibility Study are enumerated below:

(1) Short Term Plan

a) Reinforcement of Sand Pocket Structures
- Reinforcement of Existing Dikes
- Construction of Lateral Dikes

b) River Improvement of the Sapang Balen River

(2) Medium Term Plan

a) Training Works of the Sacobia River
- Consolidation Dam
- River Channeling Work

b) River Improvement of the Bamban River

c) Training Works of the Sapang Cauayan River

1.2 REINFORCEMENT OF SAND POCKET STRUCTURE

1.2.1 Flood/Mudflow Control Effect by Sand Pocket

The expected functions of the sand pocket are protection from remobilization of sediment deposits, retention of sediment inflow and prevention of sediment dispersing in the low-lying area. The effects of flood/mudflow control structures in sand pocket were examined under 1994 topographic conditions against a 20-year flood. As the control structures, Malonzo-San Pedro Hill Dike and the Parua River Dike between Sacobia and Bamban rivers, lateral dikes in lower end of sand pocket, sump, elevated Route 329 and collector channels were considered. According to the observation in the 1995 rainy season, the flood flows in the sand pocket were well drained into the Sapang Balen River and sediment materials were trapped at the lower lateral dike and sump. Most of the sediment deposits were in the upper part of the sand pocket. It means that sediment materials will not only be transported downstream by a single flood event but also be gradually transported by normal flows.

Due to the siltation of collector channels and sump located downstream end of the sand pocket, overflow of the collector channel/river channel occurred in the Sapang Balen River in 1995. The sediment deposit was obvious in the upper half of the sand pocket as well as the north-east corner of the sand pocket. According to these long term changes and flow conditions due to probable floods, major flood flow in the sand pocket would run along the Malonzo-San Pedro Hill Dike and the Parua River Dike between the sand pocket and the Bamban River. Reinforcement of the dikes along the possible waterway should be considered as well as the flood control works in the downstream reaches of the sand pocket.

1.2.2 Reinforcement of Sand Pocket Structure

(1) Existing Structures in the Sand Pocket Area

In 1995, the sand pocket area of around 23 km^2 was enclosed by the Malonzo-San Pedro Hill Dike and the Parua River Dike on the northern boundary, by the San Nicolas Balas Ring Dike and Route 329 on the eastern boundary, and by the Mabalacat-Magalang-San Francisco Bridge Dike on the southern boundary. These closing dike system and lateral dikes which were considerably damaged after the flood on October 1, 1995 are the major structural components in the sand pocket area.

Most of these dikes were built of lahar material without any slope protection works so that they deteriorated due to bank erosion by surface water and gully erosion by heavy raindrops. Although the lateral dike was restored using gabions and sandbags in early September, 1995, some portions were washed away by rapid current during previous floods and lahar events in the sand pocket, or eroded and spread out over the downstream areas of barangays San Bartolome and San Isidro.

To prevent heavy siltation in the low-lying areas downstream of the sand pocket, it is necessary to implement some countermeasures to stabilize the sediment deposits and to trap the sediment transported from the upstream reaches of the Sacobia River.

(2) Concept of Structural Measures

To stabilize the sediment deposits and trap the sediment newly coming from the upstream reaches, the construction of lateral dike system is a likely measure based on the field observation. Sump is also one of the alternatives to attain these purposes; however, the sump which was constructed immediately upstream of Route 329 before the onset of the 1995 rainy season was completely buried by a few small-scale floods in the early 1995 rainy season. After that event the sump could not function any more. On the contrary, after the flood on October 1, 1995, a considerable volume of sediment was found in the stilled flow area created by the lateral dike, even though its construction material such as sandbags was of poor durability against flood water.

The expected functions and required structural elements for the lateral dike system are (1) to stabilize the sediment deposits, the lateral dike system has to cross the sand pocket area with firm foundation against pressure of flood water, (2) to trap the sediment transported from the upstream reaches, the lateral dike system has to have an appropriate body height for sediment retention, (3) to avoid sediment re-entrapment by scouring on the downstream side of the structures, the height of spillway or overflow section should be designed as low as possible with appropriate energy dissipating structures, and (4) to reduce the sediment transport capacity of the active channels, the spillway or overflow section has to disperse flood water with shallow flow depth.

The gabion lateral dike was determined by taking into account the above-mentioned functions and provisional use of the sand pocket until the training works of the Sacobia River are completed to discharge surface water into the Bamban River. To attain sediment containment of about 1 million m^3 per year in addition to the natural containment function of the sand pocket, one row of the lateral dike has to be built every year from the downstream end toward the upstream. According to the construction plan, the Sacobia River channel will be diverted in the dry season of 1998/1999. Thus, three rows of the lateral dike in total will be built during the coming three dry seasons of 1995/1996, 1996/1997, and 1997/1998.

Regarding the closing dike system of the sand pocket, slope protection works of the sand pocket side should be considered on the whole stretch of the target dike system as protection against bank erosion and scouring by braided flood water.

(3) Structural Design

The structures related to the sand pocket are the lateral dikes and closing dike system, as shown in Figure A.1.

a) Lateral Dike

A non-overflow section of the lateral dike of 1 m high is necessary to contain about 1.0 million m^3 of sediment in each storage area. The body of 3 m thick with three gabions (2 m x 1 m x 1 m) and the foundation of 1 m deep, which is the same scale as the body height, are designed to sustain the pressure of flood water and contained sediment.

Flood water of the Sacobia River is flowing down forming two or three main streams of 100 to 200 m in width on the sand pocket area based on the ocular investigation. These braided streams are sometimes shifting over the sand pocket area following its micro-topography. Thus, several overflow sections should be designed along the lateral dike to discharge flood water safely as shown in Figure A.1.

A 2-year flood of 175 m^3/s is adopted as the design discharge for the lateral dike, since the sand pocket is planned as a temporary measure for the coming three rainy seasons, 1996 to 1998. Overflow sections of 150 m wide and 0.5 m high without freeboard are designed to enable release 2-year flood from at least two overflow sections simultaneously.

Front apron of two layers with height difference of 0.5 m is designed for dessipating the energy of overflowing flood water so as to avoid the occurrence of heavy scouring around the front side of the lateral dike.

The structural design of the lateral dike is shown in Figure A.2. Both overflow and non-overflow sections of lateral dikes are designed using gabions. Since strong structure is not necessary for no-overflow sections, economical structure such as soil embankment covered by soil cement bags may be applicable. Detailed comparison will be made in the following detailed design stage.

b) San Nicolas Balas Ring Dike

The proposed road dike of Route 329 will be elevated up to 3 m above the present ground level. The San Nicolas Balas Ring Dike should be at least higher than the road dike, since this dike will directly protect Barangay San Nicolas Balas from flooding. Thus, the height of this dike is set at 3.5 m, and its height should transition to 3.0 m near the junction with the Parua River Dike because the design height of the Parau River Dike is 3.0 m.

The sand pocket area is expected to be raised to 1.0 - 1.5 m higher than the present elevation by sediment confinement of the lateral dike. Slope protection works should be made up to 2 m from the present ground with freeboard of 0.5 - 1.0 m on the sand pocket side to prevent bank erosion by erosive flood water. Furthermore, top of foundation shall be buried 1 m deep under the ground so as to avoid the anticipated collapse of slope protection due to local scouring also by local current of erosive flood water.

The other elements are referred to the existing structures done by DPWH. The structural design of the San Nicolas Balas Ring Dike is presented in Figure A.3.

c) Parau River Dike

The target of the Parua River Dike for reinforcement of the sand pocket is a stretch from the junction with the San Nicolas Balas Dike to the downstream end of the Malonzo-San Pedro Hill Dike, since the effect of sediment confinement by third-row lateral dike would reach up to the downstream end of the Malonzo-San Pedro Hill Dike.

Slope protection works on the sand pocket side shall be made in the same manner as the San Nicolas Balas Ring Dike. According to the Bamban River improvement plan, design height of Parua River Dike is 3 m with slope protection. Thus, dike design on the Bamban River side shall follow the improvement plan. The structural design of the Parua River Dike is shown in Figure A.3.

d) Mabalacat-Magalang-San Francisco Bridge Dike

The target of the Mabalacat-Magalang-San Francisco Bridge Dike for reinforcement of the sand pocket is a stretch from the downstream end of open dike to about 3 km upstream, since the effect of sediment confinement by third-row lateral dike would reach up to this point.

At present the Mabalacat-Magalang-San Francisco Bridge Dike is composed of open dike system in this stretch, and on the opposite side of the sand pocket the dike has suffered from the overbanked flood water of the Sapang Balen River. Thus, the existing dike system should be closed to attain sediment confinement, and then be raised with slope protection on both sides.

The expected function of this dike is to confine sediment safely on the sand pocket side, and to prevent bank erosion and dike breach by the Sapang Balen flood on the other side. Therefore, dike height of 2 m is determined from the viewpoint of minimum requirement for flowing Sapang Balen floods, and the other design elements are the same as the other closing dikes. The structural design of the Mabalacat-Magalang-San Francisco Bridge Dike is shown in Figure A.3.

(4) Construction Schedule

Construction of the closing dike system should proceed in parallel with the progress of construction of the lateral dike so as to create well-functioning circumstances for sediment confinement. The construction schedule until the 1997/1998 dry season is as follows:

a) 1995/1996 Dry Season

- Construction of the front-row lateral dike (1,110 m long)
- Raising and slope protection of the San Nicolas Balas Ring Dike (2,100 m long)
- Raising and closing of the open dike (Mabalacat-Magalang-San Francisco Bridge Dike) and slope protection (1,000 m long)

b) 1996/1997 Dry Season

- Construction of the second-row lateral dike (2,130 m long)
- Raising and slope protection of the Parua River Dike (1,000 m long)
- Raising and closing of the open dike (Mabalacat-Magalang-San Francisco Bridge Dike) and slope protection (1,000 m long)

c) 1997/1998 Dry Season

- Construction of the third-row lateral dike (2,720 m long)
- Raising and slope protection of the Parua River Dike (1,090 m long)
- Raising and closing of the open dike (Mabalacat-Magalang-San Francisco Bridge Dike) and slope protection (1,050 m long)

1.3 CHANNEL IMPROVEMENT OF SAPANG BALEN RIVER

1.3.1 River Improvement Executed in 1995

In 1995, one of the critical conditions in the Sacobia-Bamban river basin was the maintenance work for the design cross section of the Sapang Balen River.

In spite of the river improvement works for widening by 60 m and deepening by 1.5 m of the Sapang Balen River downstream from Route 329 for 13 km long in order to ensure the flow capacity for a 5-year probable flood peak discharge of 380 m^3/sec, the river channel was silted with finer sediment particles.

In August 1995, the river was connected with the Bamban River at 3 km upstream from the confluence with the Rio Chico River, where there was no significant difference in riverbed elevation between Sapang Balen and Bamban/Parua rivers.

As for the alignment of the river, straight alignment of river channel was firstly proposed in 1994 taking advantages from the hydraulic viewpoint into account; however, the plan encountered plenty of opposition because of the right-of-way problem. The alignment was then changed from straight line to a meandering one which followed the pre-eruption condition having several meandering portions. After the flood on October 1, 1995, which was equivalent to the magnitude of a 20-year probable flood peak discharge, the dike collapsed at several portions along the Sapang Balen River. The straightening of river channel started only in October 1995 after the reconciliation between the DPWH and land tillers.

1.3.2 Proposed Reinforcement Plan

Shown in Figure A.4 and ANNEX A2 is the proposed straightening alignment and provision of slope protection works of the Sapang Balen River. The plan includes the following work items to be implemented in the 1995/1996 dry season:

a) To straighten six meandering portions to avoid another breach of dike as much as possible;

b) To provide slope protection works with rubble concrete revetment at the locations, two confluences with collector channels from the sand pocket, the confluence with the Bamban River and the stretches around sand pocket; and

c) To provide an additional bridge span of 30 m long to the existing San Bartolome Bridge between barangays San Antonio and San Bartolome, which is located at 3.5 km downstream from Route 329.

1.3.3 Operation and Maintenance Works

The maintenance work to settle the riverbed elevation of the Sapang Balen River is one of the most important works to release the flood safely from the Sacobia River until the Sacobia River joins with the Bamban River after a few years. Careful monitoring of riverbed aggragation is required for the protection of barangays from flooding.

On the other hand, at the confluence between the Sapang Balen and Bamban/Parua rivers, the riverbed elevation of the Bamban/Parua River tends to aggragate continuously because of the supply of sediment transported from upstream reach. Dredging/excavation work of riverbed materials is required in the Bamban/Parua River.

1.4 TRAINING WORKS OF SACOBIA RIVER

1.4.1 Consolidation Dam

(1) Maskup Consolidation Dam

Maskup narrow path is located at the downstream end of the sediment deposition area in the spindle-shaped valley. The river course of the Sacobia River has shifted frequently in the sediment deposition due to bank erosion and channel clogging. Under such situations, the water course can be stabilized by installation of sediment control structure at the narrow path. Maskup consolidation dam is placed with high priority because of its suitable location for sediment retention.

The restoration work of Route 3 including two bridges across Sacobia and Bamban rivers can be achieved as a permanent structure only when the Maskup consolidation dam fixes the outlet of river channel at the spindle-shaped valley and the river course is trained properly to the downstream of Maskup.

Figure A.5 shows the plan and typical sections of the designed Maskup consolidation dam.

a) Dam Type

In Master Plan study, double wall type was selected for Maskup dam structure from the viewpoints of sub-soil, economical, and construction conditions. The soil boring test carried out in 1995 at proposed site of Maskup dam confirmed that the foundation soil is loose lahar deposits with insufficient bearing capacity.

b) Effective Height of Dam

Since the proposed dam does not aim to store sediment, crest elevation of spillway is set at the same level as the existing terrace. The total effective dam height between spillway crest and apron surface is 5 m as shown in Figure A.5. To avoid damage to apron structure by drop of flow water, effective height of 5 m above is divided into two; 3 m for main dam and 2 m for sub-dam.

c) Hydraulic Design

The following gives the hydraulic design features (refer to ANNEX A1.1):

Items		Main dam	Sub-dam
Catchment area	:	62.5 km^2 (Pre-piracy condition)	
Design discharge	:	568 m^3/s (100-year probable flood)	
Sediment concentration	:	*20%*	*20%*
Mudflow discharge	:	710 m^3/sec	710 m^3/sec
Effective height	:	3.0 m	2.0 m
Overflow depth	:	2.0 m	2.0 m
Spillway width	:	150 m	150 m
Freeboard	:	1.7 m	1.0 m
Height of wing wall	:	3.7 m	3.0 m
Length of apron	:	15 m	14 m
Thickness of concrete at apron	:	1.5 m	1.5 m

On the design of spillway of dams, a 100-year probable discharge and 20% of sediment concentration are applied as table above. Catchment area before eruption is used in consideration of safety even if the headwaters captured by the Pasig-Potrero River would return to the Sacobia River again.

Width of spillway is set at 150 m, the same as the typical section of proposed Sacobia channeling, and overflow depth is given as 2.0 m from the uniform flow calculation. Top height of dam wings is determined considering overflow depth, freeboard and sediment gradient. Length of apron is obtained by formula of bound water in stilling basin. No end sills are provided because they might be hidden by sedimentation.

d) Structural Design

Double wall type dams are constructed using steel sheet piles tied with tie rods. Wall is filled with lahar materials and top of wall is faced by concrete to protect surface from erosion by flow. From the viewpoint of stability of structure, dam needs a width of 9 m. Embedded length of piles are determined from the stability analysis such as balance of earth pressures against structure, circular slip, and piping. Riverbanks between main dam and sub-dam are also protected by steel sheet pile double walls.

e) Main Structural Features

The principal features of consolidation dam are enumerated below:

Design Condition	Unit	Main Dam	Sub-dam	Cut-off	Wing Embankment
Construction Material	-	Sheet Pile	Sheet Pile	Re-bar	Soil
Effective Height	m	3.0	2.0	0.0	3.5
Depth of Embankment	m	6.0	5.5	6.0	2.0
Length of Dam	m	490.0	190.0	173.0	542.0
Width of Dam	m	9.0	7.5	5.0	10.0
Width of Spillway	m	150.0	150.0	150.0	0.0

f) Right Wing Embankment

The wing embankment on the right terrace connected with the right dike of the Sacobia River is also designed as a protective dike with rubble concrete.

(2) Dolores Consolidation Dam

In the Master Plan, Dolores consolidation dam was planned for stabilizing the river course together with Maskup consolidation dam and preventing secondary erosion of sediment deposits so as to make the restoration of Route 3 possible. The results of geotechnical survey carried out in 1995 clarified a very weak sediment depositional layer with N-value (Standard Penetration Test) of less than 5 interbeds at 10 m below sediment depositional surface. In case of construction of Dolores consolidation dam, maleficence such as piping or sliding of dam foundation may occur during flooding. Therefore, a series of groundsills were adopted as effective to ensure the stability of river channel in lieu of Dolores consolidation dam.

1.4.2 Selection of Channel Alignment

(1) Alternative

Sediment in the Sacobia River has remarkably diminished since the river piracy of the Pasig River in 1993. In 1995, a gradation of lahar deposits is developing in the sand pocket area between Highway Routes 3 and 329. It is expected that the Sacobia River will form a braided river system in the sand pocket area in case of no training work of the Sacobia River.

Alternatives for the alignment of the Sacobia River to join with the Bamban River as shown in Figure A.6 to A.8 were evaluated. The alternatives are:

Alternative 1: The Sacobia River is trained to follow the river channel alignment of the pre-eruption period. The Sacobia River changes its flow direction northward at Maskup and joins with the Marimla and Sapang Cauayan rivers at Bamban.

The river channel required is the shortest one among the alternatives. However, the centerline of river channel forms a right angle with the Bamban River due to the rapid current of flood water. In case that unexpected sediment flows down the Sacobia channel, the sediment may block the river flow of the Sapang Cauayan and Marimla rivers.

Alternative 2: The Sacobia River is trained to join with the Bamban River immediately upstream of San Pedro Hill.

This Alternative 2 gives a slightly shorter channel than the others. However, the dam axis of Maskup consolidation dam is required to be bent and the width of dam crest is longer than the others. Furthermore, the angle of confluence between Sacobia and Bamban rivers makes a rather bigger angle compared with Alternative 3.

Alternative 3: The Sacobia River is trained to join with the Bamban River where the Bamban River has the widest river channel.

This alternative ensures the straight flow direction of the Sacobia River down to the confluence with Bamban River. The angle of confluence between the Sacobia and Bamban rivers is rather gentle, and the confluence point is located where the Bamban River has the widest river channel against flooding.

The three alternatives given above are compared from the hydraulic, economical and construction aspects as shown in Table A.1. Although, Alternative 1 shows the most economical cost among the three because the required channel length is the shortest and

Mabalacat Bridge is not needed, Alternative 3 is selected as a suitable plan mainly due to the hydraulic aspect.

According to the results of riverbed fluctuation analysis in the upstream stretch from Barangay Bamban to San Pedro Hill of the Bamban River, the riverbed has a tendency of degradation. In case that the confluence point is set at upstream reach as Alternative 1, continuous embedment of slope protection works is required corresponding to the riverbed degradation, and unexpected sediment supplied from the Sacobia River may result in riverbed aggradation in the upstream reach of the Bamban River which may affect the flow of the Marimla River. Alternative 2 requires the uneven dam axis and flow direction of the Sacobia River is bent.

From the viewpoint of riverbed fluctuation, the location upstream of Malonzo is preferable to the confluence between the Sacobia River and the Bamban River (Alternative 3). Thus, a stretch of 5 km shall be planned as river training works between Maskup consolidation dam and the confluence. The river channel should be trained to join with the Bamban River when the sediment concentration of Sacobia river water is as small as that of the pre-eruption period.

(2) Structural Design

a) River Channel

A 20-year return period of 470 m^3/sec including sediment concentration of 10% is applied for design scale. Riverbed slope of 1/180 with an average water depth of 1.4 m is proposed on the existing topographic condition surveyed in early 1994.

Typical proposed cross section is as given below:

Design cross section shape	: single trapezoid (1.0V:2.0H)
Design discharge	: 470 m^3/sec
Design flow velocity	: 2.6 m/sec
Design depth	: 1.4 m
Freeboard	: 0.8 m
River width	: 150 m
Riverbed width	: 141.2 m
Roughness coefficient	: 0.035

The following are noted on the design of structures:

i) Training channel should be designed as excavated channel considering the possibility of the risks of overflow and damage due to aggradation in channel. Excavated materials will be used for embankment of Bamban area of left bank of the Bamban River and lowest area of Sacobia training channel.

ii) River width of 150 m is proposed based on the existing downstream width (about 300 m of Bamban River), ratio of catchment area between Sacobia River and Bamban River (42%), and width of Maskup narrow path (150 m).

iii) Riverbed gradient of 1/180 is proposed taking into account the existing ground gradient of 1/110 to 1/180 and the gradient of 1/185 of Sacobia River channel before eruption.

iv) Rubble concrete slope protection is proposed for both banks of channel. This is provided up to top of bank slope and embedded into riverbed 1 m in minimum.

b) Groundsill

A series of groundsills is designed as shown in Figure A.9. Groundsills are generally effective in storing sediment in the upstream reach and maintaining riverbed elevation. In Alternative 3 above, a series of groundsills is arranged to adjust the proposed riverbed gradient of 1/180 to the existing ground gradient of 1/110. It is desirable to adopt a lower groundsill from the viewpoint of structural stability and hydraulic safety. Six groundsills of 2.0 m in height are proposed at intervals of 500 m. As a structural type, steel sheet pile double wall is also adopted for the main body and cut-off, while the apron is designed as a thick concrete structure.

1.5 BAMBAN RIVER IMPROVEMENT

1.5.1 Design Conditions

Design flood with a 20-year probability is applied to the Bamban River improvement and the following design discharges computed under the catchment area of pre-eruption conditions are adopted.

River Reach	Design Discharge	Design Freeboard
Confluence with Rio Chico River (Sta. 0+000) to Confluence with Sapang Balen River (Sta. 3+000)	1,260 m^3/s	1.0 m
Confluence with Sapang Balen River (Sta. 3+000) to Confluence with Sacobia River (Sta. 21+800)	1,040 m^3/s	1.0 m
Confluence with Sacobia River (Sta. 21+800) to Confluence with Sapang Cauayan and Marimla Rivers	580 m^3/s	1.0 m

1.5.2 Design of River Improvement

(1) Design of Channel Alignment

a) Lower and Middle Reaches

Alignment of lower and middle reaches of river channel from the confluence with the Rio Chico River to San Francisco Bridge follows the present one considering that parallel dikes exist in the whole reaches.

b) Upper Reach

From San Francisco Bridge to the town of Bamban, the present river channel varies in width from 300 m to 1,000 m and spreads towards the right bank of the pre-eruption condition.

To realize the future land use plan to restore dislocated families to their original settlements, the alignment of river channel should be fixed with the specified width. The following two alignment alternatives are compared to determine the suitable alignment (refer to Figure A.10):

Alternative A : River channel with specified width is aligned within the present river channel of 1995.

Alternative B : River channel with specified width is aligned within the river channel before eruption of Mt. Pinatubo.

Comparative Items	Alternative A	Alternative B
Land Acquisition	0.7 km^2	None
Channel Excavation	Minor	2 million cubic meters
Maintenance of Channel	Easier because of straight channel	Two curvatures to be carefully maintained

Although Alternative B requires an additional excavation work of 2 million m^3 to construct the channel, it is free from the right-of-way problem. Accordingly, it is preferable to adopt Alternative B for smoother construction work. Excavated materials will be used for embankment of Bamban area of the left bank of the Bamban River.

(2) Design of Longitudinal Profile and Cross Section

a) Design Riverbed Elevation

It is preferable to design the riverbed as low as possible from the viewpoint of flood control. Although the riverbed elevations in 1995 are higher than inland elevations, the present longitudinal profiles for Feasibility Design is proposed to be adopted taking the present flow capacity and the stability of existing revetments in the upper and middle reaches into account. While, in the lower reach, river improvement works are crucial to remove sediment deposits down to design riverbed levels for 12.6 km long from Sta. 0+000 to Sta. 12+600 because of insufficient flow capacities.

Design riverbed profiles are shown in Figure A.11. Design riverbed gradient varies from 1/650 at lowest reach to 1/190 at uppermost reach.

b) Design High Water Level

High water levels are computed by non-uniform flow method based on the following:

i) Since 1991, the construction works of the Pampanga Delta Flood Control Project has been carried out by the DPWH. Flood water level with a 20-year probability is defined as the design high water level for the Project above. Thus, the design high water level of EL. 12.53 m at the confluence with the Rio Chico River is adopted to that at downstream end of the Bamban River.

ii) Roughness Coefficient is estimated at 0.035

Figure A.11 also shows the design high water level profiles with slopes from 1/1980 to 1/190.

c) Design of Channel Cross Section

River channel in upper reach from the confluence with Sacobia River is designed using the uniform flow method under the condition that design velocity should be smaller than 3.0 m/s to avoid remarkable riverbed degradation and lateral erosion:

Design discharge	:	580 m^3/s
Design longitudinal bed slope	:	1/190
Design roughness coefficient	:	0.035
Design velocity	:	2.558 m/s
Design shape of section	:	single trapezoid
Design channel top width	:	170.0 m
Design channel bed width	:	160.4 m
Design water depth	:	1.4 m
Design freeboard	:	1.0 m
Design channel side slope	:	1V : 2.0H

Figure A.12 shows the design cross sections.

(3) Proposed Structures

Figure A.13 and ANNEX A2 shows the arrangement of following proposed structures for the Sacobia-Bamban River mudflow/flood control.

a) Dike

At present, existing dikes are eroded by flow river water and damaged by rainwater at some portions. Moreover, dikes of lower reach have insufficient flow capacity. Consequently, raising and repairing works of dikes should be done in accordance with the following design dike dimensions (refer to Figure A.14):

Top width of dike	:	7 m
Side slope	:	1H:3V (without revetment)
	:	1H :2V(with revetment)
Reinforcement of dike surface	:	to be covered with mountain soil and sodding
Provision of inspection road	:	gravel metal on the top of dikes.

Existing dikes are made of lahar sandy materials. According to the site inspection, water seepage through dike body is observed at some locations. Detailed study should be needed in the detailed design.

b) Slope Protection

Slope protection works of about 9 km long in total have been constructed along the Bamban River. Additional provision of rubble concrete slope protection works shall be needed along both dikes of the middle and upper reaches as shown in Figure A.13.

Figure A.15 shows the typical section of slope protection organized into concrete-filled rubble on filter clothing, concrete footing and gabion mattress. Crest elevation of rubble concrete is equivalent to the top of dike/bank. Toe is embedded 1 m deep into the riverbed. Stones should be exposed to reduce flow current of floods.

According to the results of the study on long term forecast, riverbed movement could be serious in the upper reach of the Bamban River in the future. As an example of applicable structural method for this degradation, slope protection works as shown in Figure A.16 should be considered in long term plan.

In addition, there are other structural types to be applicable in the this basin. For example, concrete blocks instead of rubble can be utilized. Slope protection reinforced by concrete beam frames is also another alternative. Detailed study will be done in the following detailed design stage.

c) Spur Dike

Permeable reinforced concrete pile spur dikes of 20 m long and 1 m high, as shown in Figure A.17, are proposed at the four severe meandering portions of the middle reach to avoid erosion of dikes and promote sedimentation. There is no rule of general application for determining the spacing, length and angle. For practical reasons, the following may be applicable based on the experiences in Japan.

Direction	:	right angle to flow
Length	:	less than 10% of river channel width
Spacing	:	1 to 4 times of length
Height	:	as low as 0.5 to 1.0 m above low water level to minimize scouring around spur dikes

1.5.3 Channel Excavation and Spoil Bank

River channel of the lower reach is to be excavated; 1.5 million m^3 yearly for 9 years from 1996 to 2004. The excavated materials are available to reinforce the existing dike system in the lower reach, while the excess material is transported to the spoil bank. A spoil bank of about 350 ha is required at the southwest swampy area of the confluence between Bamban and Rio Chico rivers as shown in Figure A.13.

1.6 TRAINING WORKS FOR SAPANG CAUAYAN RIVER

1.6.1 Treatment of Dammed Lake

A lake formed by damming Sapang Cauayan River with lahar deposit is located at 2.5 km upstream from the confluence with the Marimula and Bamban rivers. This lake will be reserved as it is in the Medium Term Plan. However, the dammed lake may exist temporarily and would become smaller year by year because of the erosion of the lake outlet. If the existence of the lake is desired as it is in the Long Term Plan, a permanent structure such as consolidation weir might be required at the lake outlet to maintain the surface water level of the lake. Land acquisition for land submerged by the lake where many tillers cultivated their farm land before eruption will be required when the permanent structure is constricted to maintain the lake water.

1.6.2 Training Works

At present, water from the lake flows through a channel with a width of 50 to 200 m into the Bamban River. Slope of channel is about 1/250 based on topographic maps surveyed by JICA in April, 1994.

The riverbanks are made of lahar deposits which are easily eroded by flowing/rain water. Accordingly, the construction of bank protection is proposed from the dammed lake to the confluence with the Bamban River, a total length of about 3.6 km (2.6 km for right bank and 1.0 km for left bank, refer to Figure A.13), to ensure restoration of Highway Route 3. Proposed channel section is determined by uniform flow method on the basis of a 20-year flood probability.

The features of proposed training works are listed below and Figure A.15 shows the typical section of proposed bank protection structure consisting of rubble concrete with a slope of 1V:2H and concrete footing on gabion mattress embedded in riverbed at a depth of 1 m.

Design discharge	:	150 m^3/s
Design longitudinal bed slope	:	1/190
Design roughness coefficient	:	0.035
Design velocity	:	2.558 m/s
Design shape of section	:	single trapezoid
Design channel top width	:	170.0 m
Design channel bed width	:	160.4 m
Design water depth	:	1.4 m
Design freeboard	:	1.0 m
Design channel side slope	:	1V : 2.0H

A.2 ABACAN RIVER BASIN

2.1 GENERAL

Alternatives for engineering intervention measures for the Abacan River were formulated in the Master Plan Study. The combination of structures adopted in the Feasibility Study are enumerated below:

(1) Upper Reach (upstream from Friendship Bridge)

a) Reconstruction of Sabo Dam
   - Sabo Dam No. 6
   - Sabo Dam TM-1
b) Bank Protection along two tributaries; Taug and Sapangbato rivers

(2) Middle Reach (from Friendship Bridge to Capaya Bridge)

a) Reconstruction of Sabo Dam No. 9
b) River Training Works in Angeles City

(3) Lower Reach (from Capaya Bridge to Mexico Spillway)

a) Reinforcement of Existing Dike System

2.2 *UPPER REACH*

2.2.1 Present Condition

Although no lahar from the pyroclastic flow field has been observed in the Sapangbato River since April 1992, a remarkable volume of lahar deposits still remain in the river channel. The 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 unstable sediment is stored by sabo dams which were mainly made of gabions constructed from November 1991 to June 1993.

2.2.2 Reconstruction of Sabo Dams No.6 and TM-1

For the purpose of stabilization of sediment retained in the storage areas of the existing sabo dams to prevent 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 (refer to Figure A.18).

The main dimensions of sabo dams are proposed as follows:

Design Condition	Unit	Sabo Dam Main Dam	TM-1 Cut-off	Sabo Dam Main Dam	No.6 Cut-off
Construction Material	m	Sheet Piles	Sheet Piles	Re-bars	Concrete
Effective Height	m	4.3	0.0	3.5	0.0
Embedded Depth	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 in consideration of soft base ground condition at each site. Height of the spillway crest is determined to keep a continuous longitudinal profile with the existing sabo dam.

The peak discharge of 100-year flood is adopted for flow capacity of the proposed spillway. Sediment concentration of floods is assumed to be only 10% of flood peak discharge, 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, aprons, 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 A.19 for Sabo Dam TM-1 and Figure A.20 for Sabo Dam No. 6. The design conditions for spillway and apron are given 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

(1) New TM-1 Sabo Dam

There is no alternative to restore the existing sabo dam because it is severely damaged; therefore, a new sabo dam is proposed 30 m downstream of the existing one. Effective dam height of 4.3 m is proposed to cover the top of the existing dam.

The soil boring test carried out by the JICA Study Team in 1995 shows that sub-soil consists of loose coarse sand. Accordingly, steel sheet piles for double wall type is adopted. Protection works consisting of double walls for banks and concrete apron are provided in front of spillway against scouring by flow water.

(2) New No. 6 Sabo Dam

Although the apron of the existing sabo dam is seriously damaged, the main body is still effective. Therefore, reinforcement of the existing main body is proposed. Additional dam with an effective height of 3.5 m is proposed 10 m downstream of the existing one.

According to the boring test, sub-soil at site consists of sand, gravel and boulder which have sufficient bearing capacity. Based on the soil condition, double wall using reinforced bar mesh is proposed. Boulders to be easily obtained at site are used for filling into walls. Protection works consisting of thick concrete apron and concrete retaining walls are provided in front of spillway to protect banks and main body of dam from scouring by flow water.

2.2.3 Riverbank Protection

Regarding the bank protection works to protect the residential areas against heavy lateral erosion in the upper reaches of the Taug River, bank protection with rubble concrete facing on the gabion mattress and concrete footing is proposed for a stretch of 1,510 m long in total. The arrangement and typical section of bank protection works are shown in Figure A.21.

As for the riverbank of the Sapang Bato River, the target areas around barangays Sapang Bato, Margat and Anonas are nominated as protection areas. A total length of 3,000 m made of gabions with concrete cover is proposed for retaining works of 2.0 m in effective height as shown in Figure A.22. Lahar backfilling with a gentle slope with sodding is also made behind retaining wall.

2.3 *MIDDLE REACH IMPROVEMENT*

2.3.1 Reconstruction of Sabo Dam No.9 and Friendship Bridge

The 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 the Friendship Bridge was destroyed by lahar. Then, lahar washed out the riverbanks and houses along Angeles City. However, the piers and girders of the bridge still remain at their original position. DPWH then embanked lahar material at the 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 a moderate scale of thunderstorm, the strengthening of the left sidewall of the sabo dam has been a source of concern to DPWH in 1995. The dam was seriously damaged in 1995, although urgent rehabilitation works were carried out by DPWH to ensure transportation through the Friendship Bridge.

Sabo Dam No. 9 has performed its role very well as urgent measure to ensure transportation through the Friendship Bridge. The dam is required not only to store the unstable sediment but also to take the role as upstream end structure of channel training works in the middle reach of the Abacan River. However, as long as a sabo dam exists immediately downstream of the bridge, it is expected that maintenance cost for rehabilitation of the sabo dam will increase annually and the bridge is likely to deteriorate. Consequently, the reconstruction of Sabo Dam No. 9 was proposed in the Master Plan Study. The dimensions of Sabo Dam No. 9 are proposed 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
Embedded Depth	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 A.23. The 100 m width of spillway has been determined to coincide with the proposed 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 be installed at 10 m downstream of the Friendship Bridge. The left abutment which has been eroded during floods is proposed to be embanked by the excavated materials of training works in the middle reach of the Abacan River. On the contrary, bank protection works with backfilling is proposed for the left bank. The results of soil boring test show that sub-soil at site consists of loose fine sandy materials which has insufficient bearing capacity. Therefore, the type of double wall using steel sheet piles is proposed, the same as Maskup consolidation dam of the Sacobia River. Effective height of proposed dam is 5.92 m in total consisting of 3.0 m of main dam and 2.92 m of sub-dam. The design flood discharge of 380 m/s for spillway is determined on the basis of a 100-year probable discharge of 338 m^3/s plus 10% of sediment concentration. To protect the front basins of spillways from dropping flow water, thick concrete aprons and double walls of steel sheet piles are provided.

The design conditions of spillway and apron are given 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

2.3.2 River Training Works in Angeles City

Severe lateral erosions of 5 to 10 m high banks frequently occurred and damaged the houses in the urban area of Angeles City. To protect banks, training work is proposed from Capaya Bridge to Sabo Dam No. 9 (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. Soil to be excavated in the construction of the training works will be used for the formation of banks of channel and for the construction of

Sabo Dam No. 9. Features of proposed channel computed by uniform flow method are as follows:

Reach	Capaya Bridge to Abacan Bridge	Abacan Bridge to Sabo Dam No. 9
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 designed to be lower than bank levels to avoid lateral erosion of valley. Figure A.24, A.25, and ANNEX A2 show the concept of training works, design cross sections, typical structural section of slope protection and plans, respectively. From the viewpoint of easy maintenance, rubble concrete facing is adopted.

2.4 *LOWER REACH IMPROVEMENT*

2.4.1 Design Conditions

Design flood with a 20-year probability is applied to the river improvement, and the design discharges and freeboard to be applied are as follows:

River Reach	Design Discharge	Freeboard
Confluence with San Fernando River (Sta.0+000) to Malino (Sta. 11+000)	520 m^3/s	1.0 m
Malino (Sta. 11+000) to Capaya Bridge (Sta.17+200)	440 m^3/s	0.8 m

2.4.2 Design of Alignment and Longitudinal Profiles

(1) Present River Conditions

The longitudinal profiles of the Abacan River have been surveyed in early 1994 and early 1995. No remarkable riverbed fluctuation 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

The present longitudinal profiles are proposed to be adopted, taking the present flow capacity and the embedded depth of the existing revetment into riverbed except lower reach into account. Riverbed of lower reach is proposed to be excavated because design riverbed elevation of the Bungang Guito River is EL. 2.6 m at the confluence with the Abacan River.

Design riverbed elevations are shown in Figure A.26. Design riverbed gradient varies from 1/780 to 1/115. Excavation work of 2.0 million m^3 in total in lower reach should be needed for 4 years from 1996 to 1999 to maintain the design riverbed elevations. Materials to be excavated will be hauled to the proposed spoil bank which is located at left bank near Mexico Bridge. The two damaged existing spillways at Sta. 0+611 and Sta. 7+800 should be demolished to avoid riverbed scouring immediately downstream of these structures.

(4) Design High Water Level

High water levels were obtained on the following basis:

a) High water levels are computed by non-uniform flow calculation method.
b) High water level at downstream end is obtained by uniform flow calculation method.
c) *Roughness coefficient of 0.035 is adopted.*

Design high water level is shown in Figure A.26.

2.4.3 Proposed Structures

Figure A.27 and ANNEX A2 show the arrangement of the following proposed structures for lower/middle Abacan River.

(1) Diking System

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

(2) Slope Protection

At present, a total of 4 km of slope protection has been constructed. Additional slope protection works for 13 km is proposed at severe meandering parts. Figure A.15 shows the typical structure of slope protection which is the same type as the one proposed for Sacobia-Bamban River.

TABLES

Table A.1 Channel Alignment Alternatives of Sacobia Training Works

Comparative Items	Alternative 1	Alternative 2	Alternative 3
Flow Direction	Channel to be severely bent.	Channel to be slightly bent.	Hydraulically Preferable straight channel.
Maskup Consolidation Dam	Unstable left wing of dam.	Longest dam axis.	Preferable dam axis.
Risky Area when overflow of floods	Vast right area to be damaged, when overflow.	Same as Alternative 3.	Limited area along channel because of steep slope.
Risk of River Channel Closure	Danger of S. Cauayan/Bamban river closure.	Less danger of Bamban River closure.	Less danger of Bamban River closure.
Sapang Cauayan River	To be joined.	To be separated.	To be separated.
Forecasted Riverbed Movement at Point of Confluence with Bamban River	Most severest riverbed movement.	More severer riverbed movement.	Some riverbed movement.
Number of Groundsills	2	5	6
Bridges of Route 3	1	2	2
Construction Cost)	460 million pesos.	545 million pesos.	630 million pesos.
Judgment			Recommended (Preferable flow direction, dam axis, less risk of channel clouser, and less risky area)

FIGURES

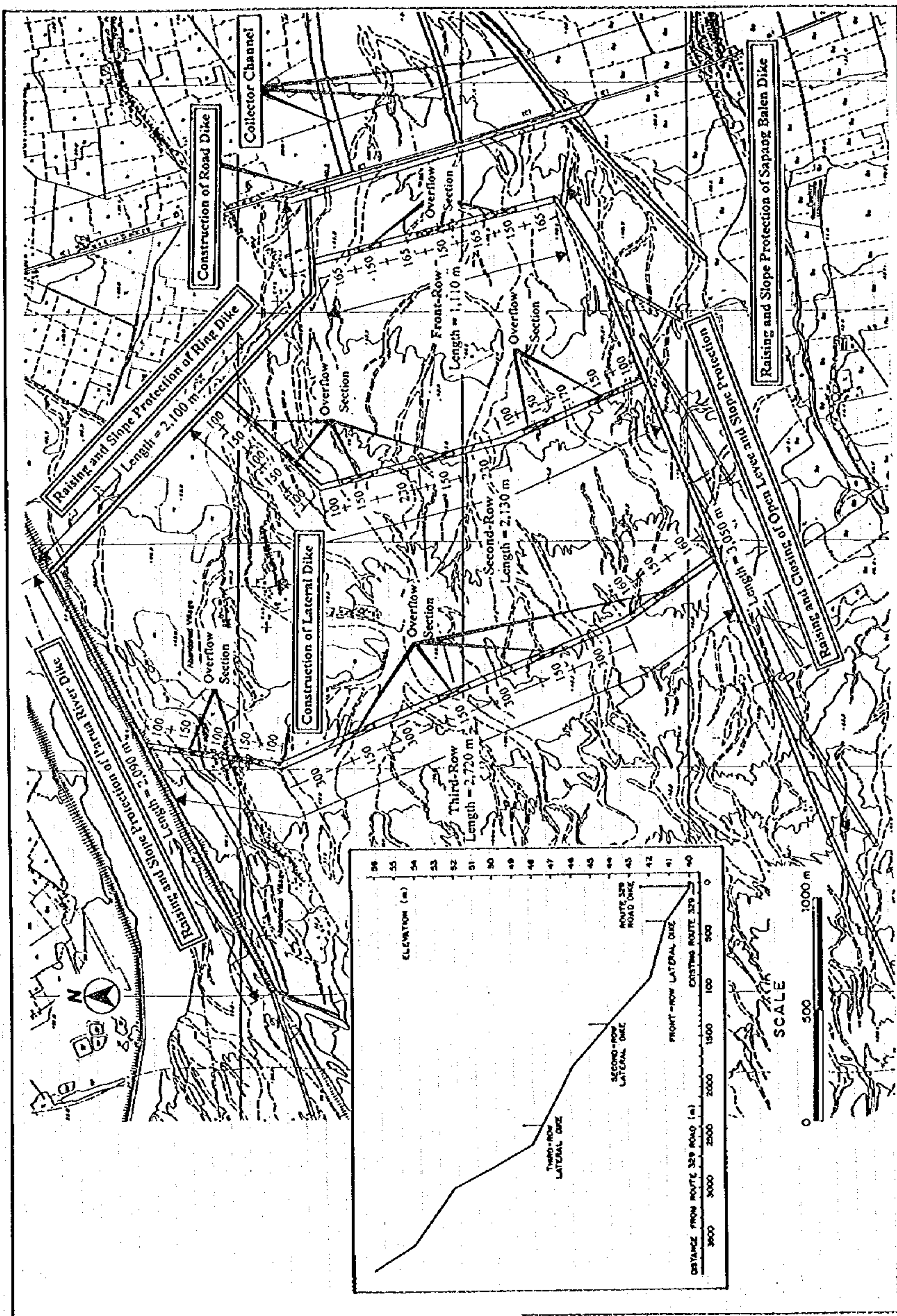

Figure A.1 Sand Pocket Structure

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

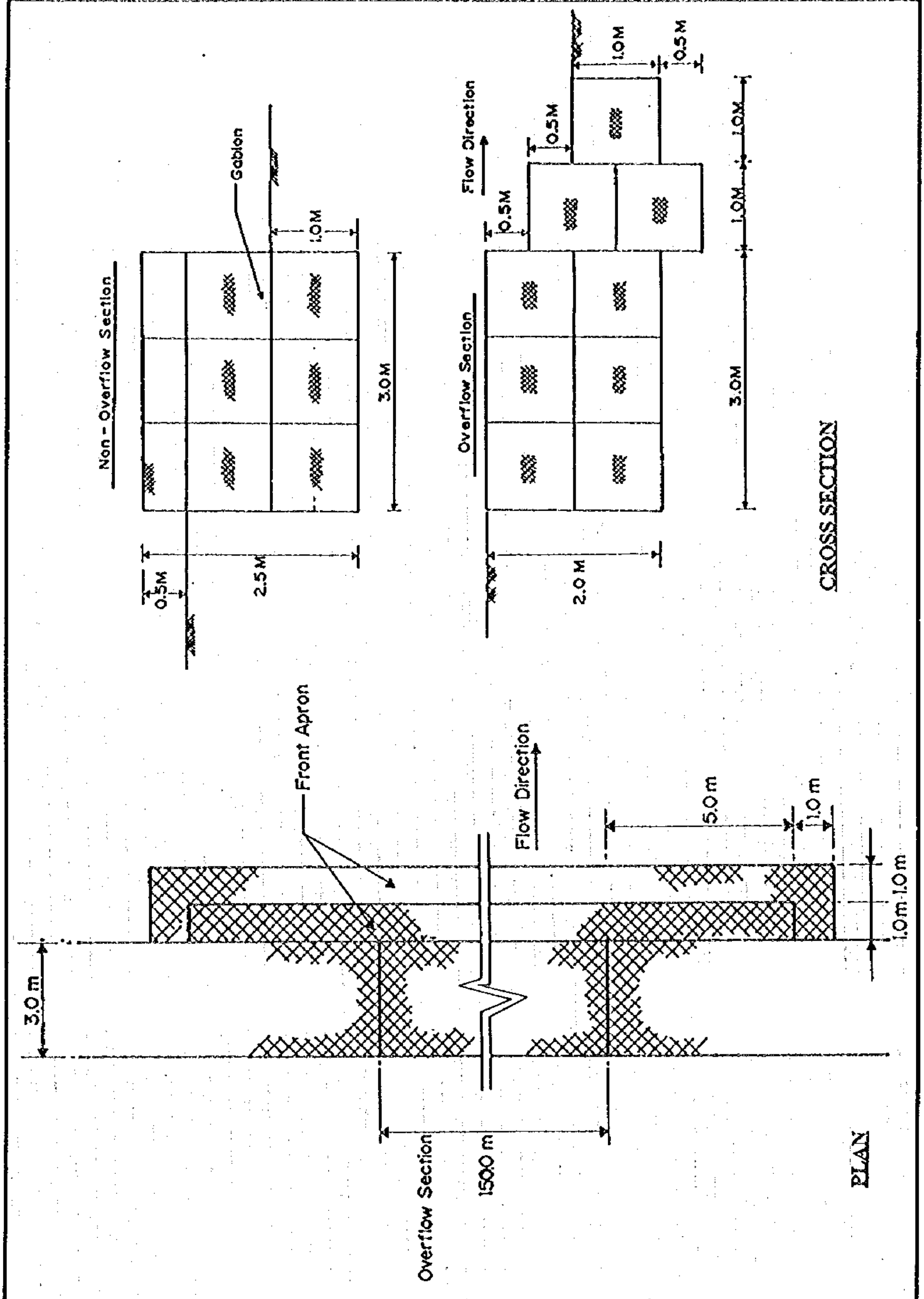

Figure A.2 Proposed Lateral Dike

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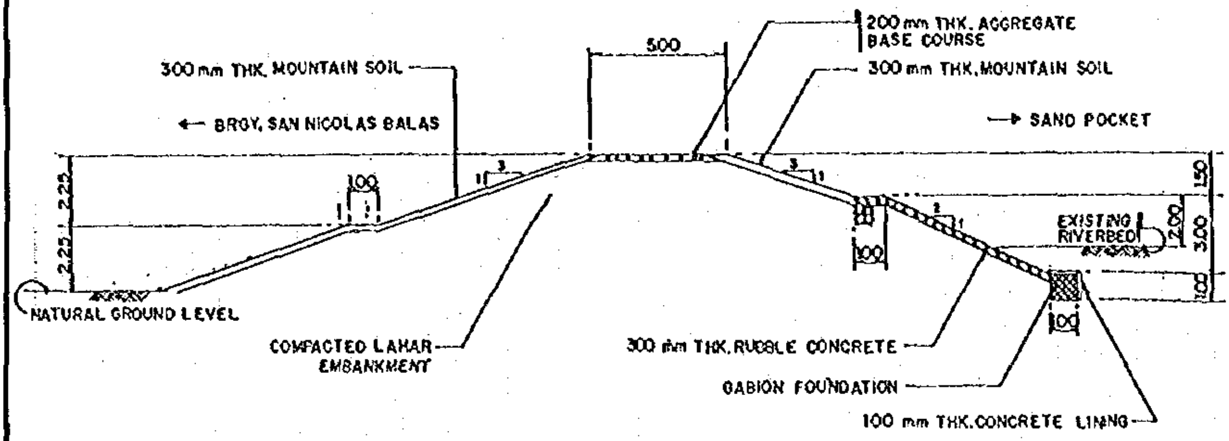
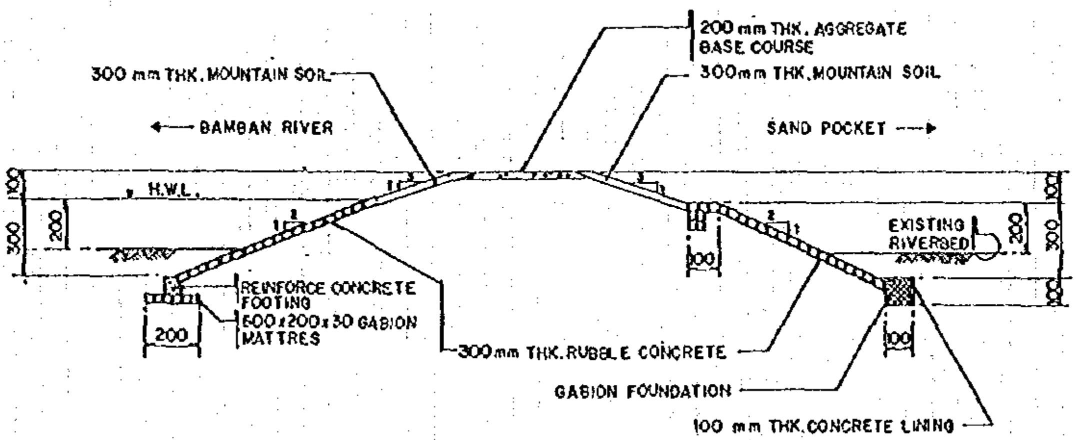
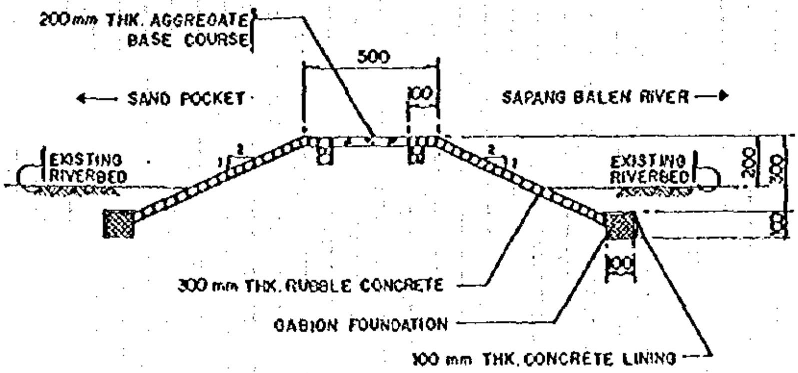


SAN NICOLAS BALAS RING DIKE



PARUA RIVER DIKE



MABALACAT-MAGALANG-SAN FRANCISCO BRIDGE DIKE

Figure A.3 Proposed Closing Dike

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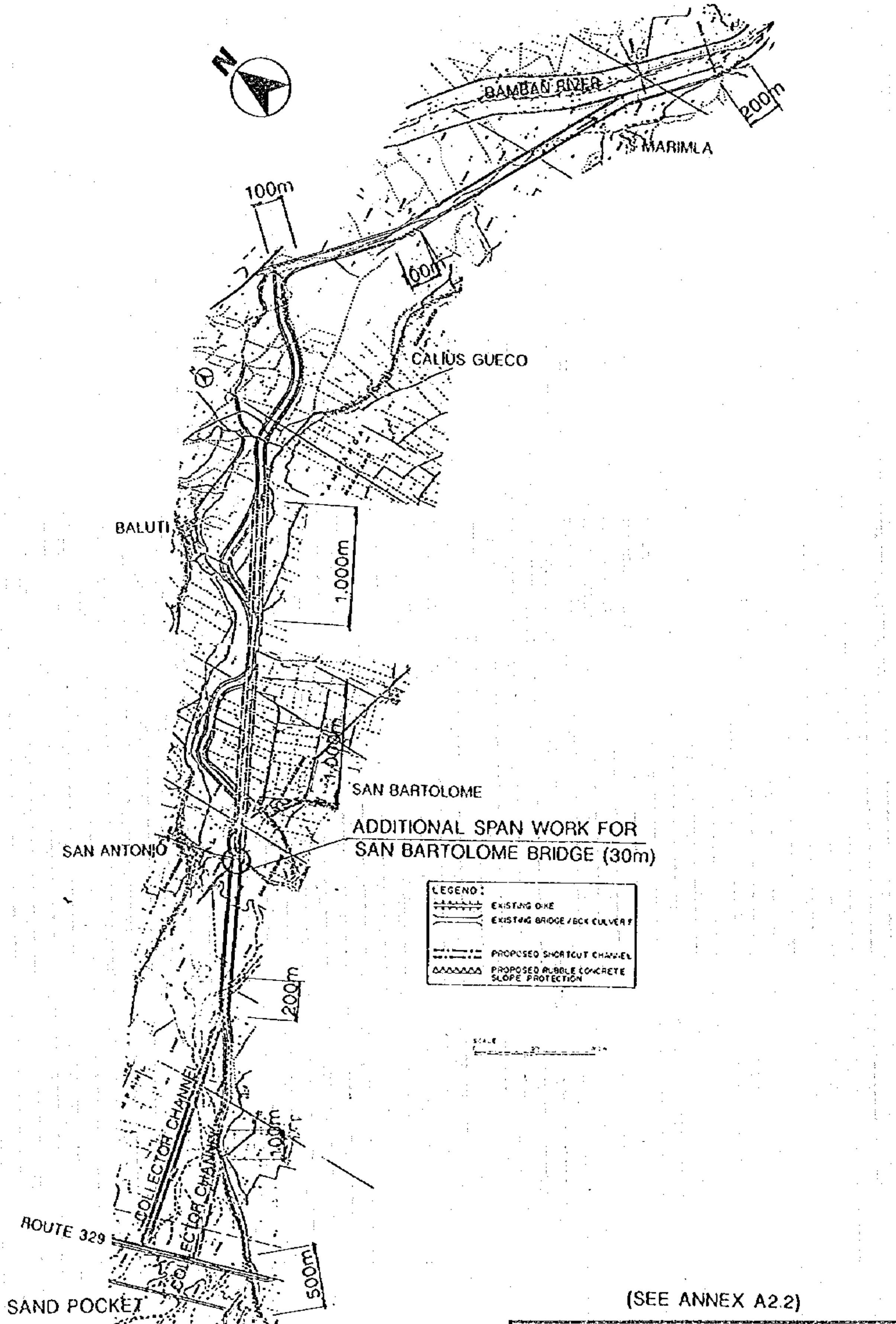

Figure A.4 General Plan of Sapang Balen River Improvement

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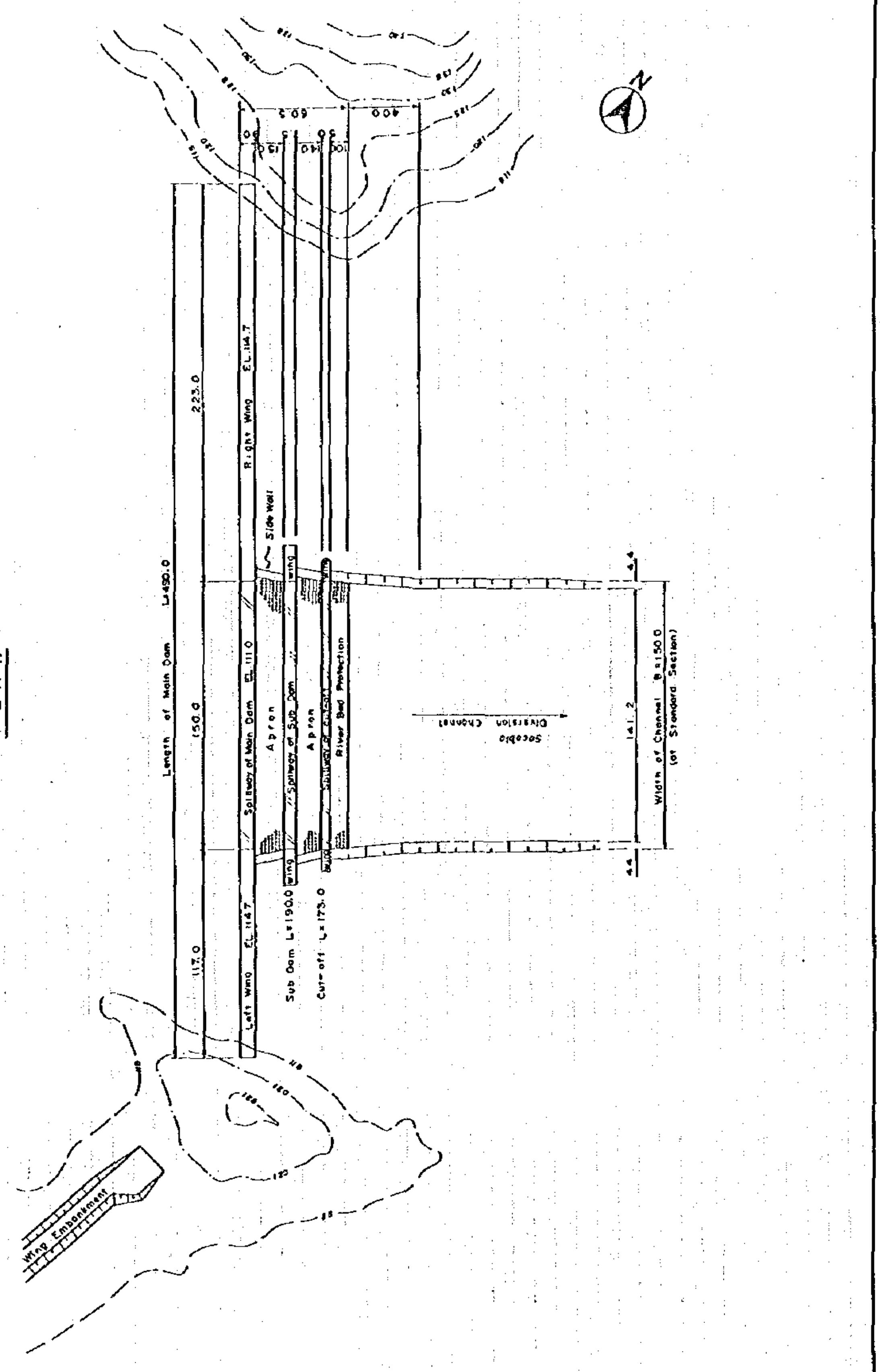

Figure A.5 Proposed Maskup Consolidation Dam (1/8)

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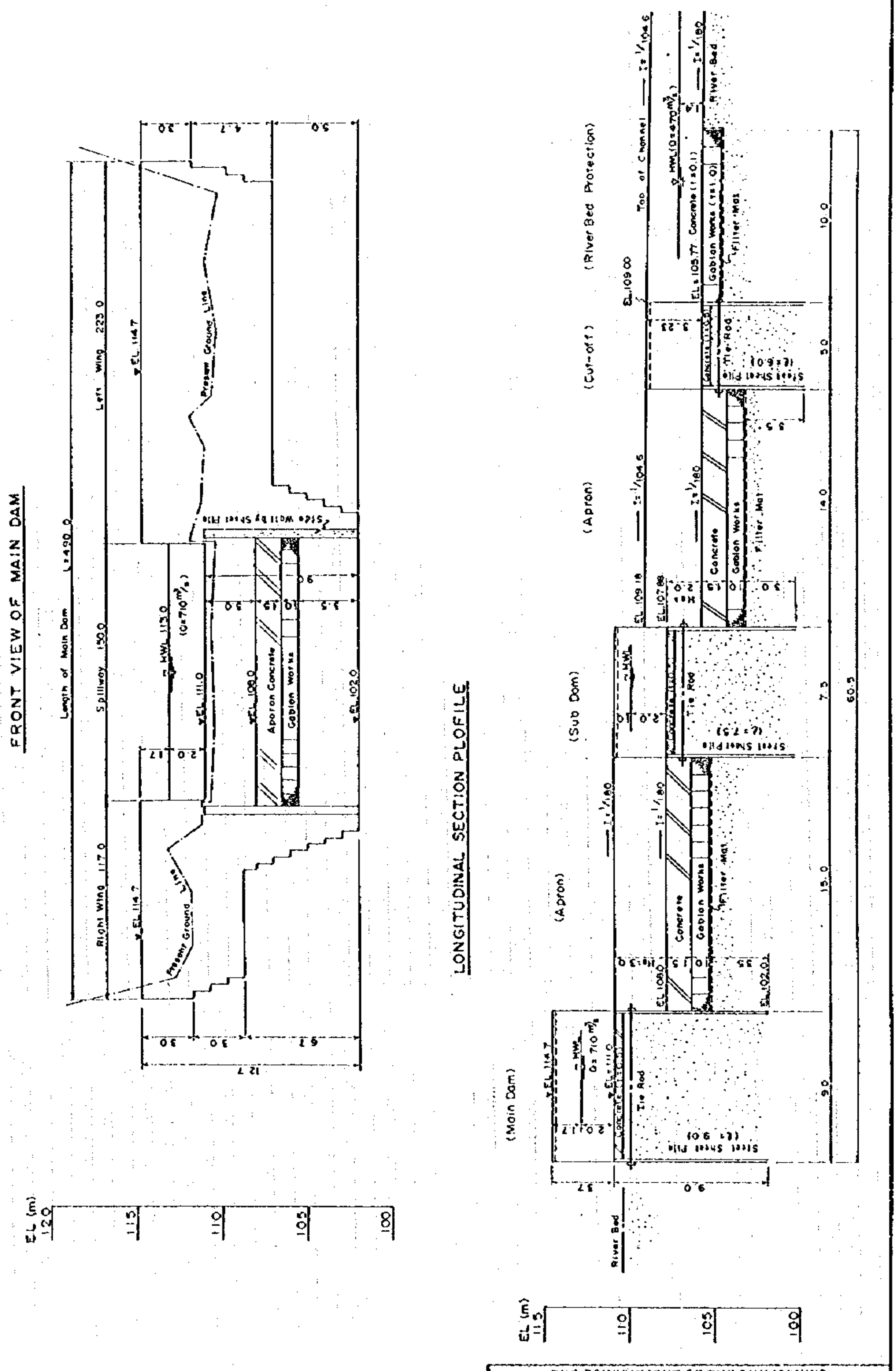

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THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
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Figure A.5 Proposed Maskup Consolidation Dam (2/8)

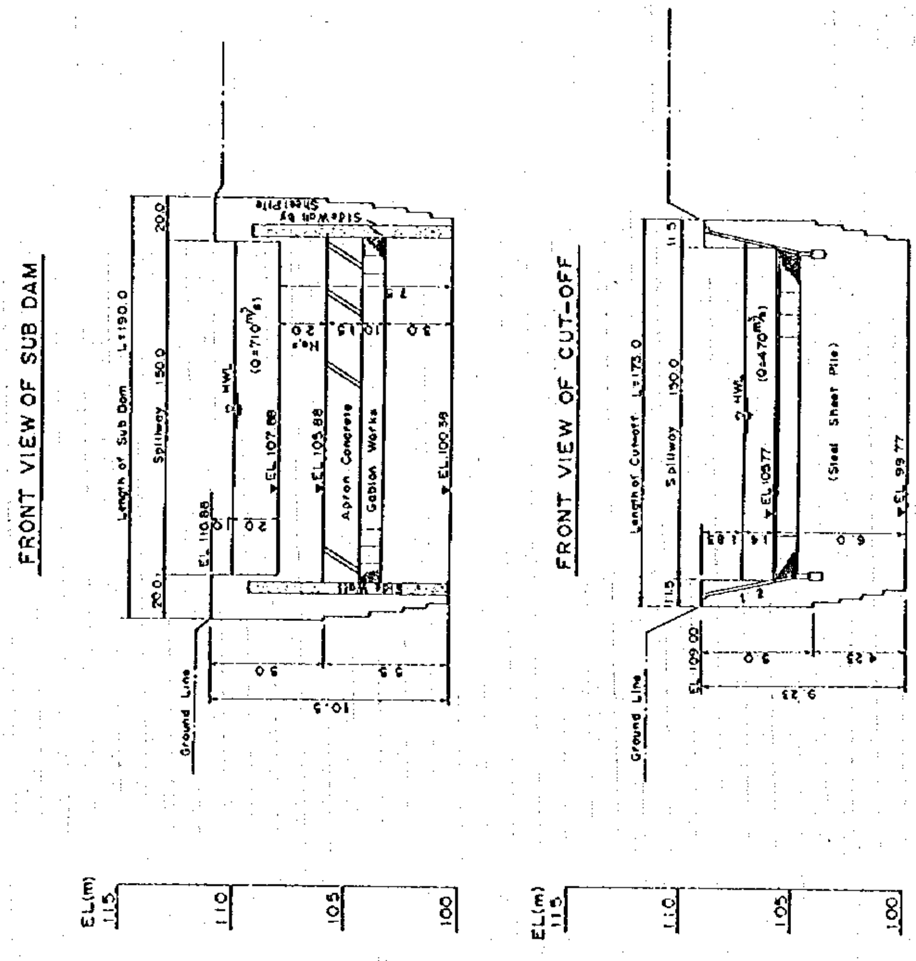

Figure A.5 Proposed Maskup Consolidation Dam (3/8)

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

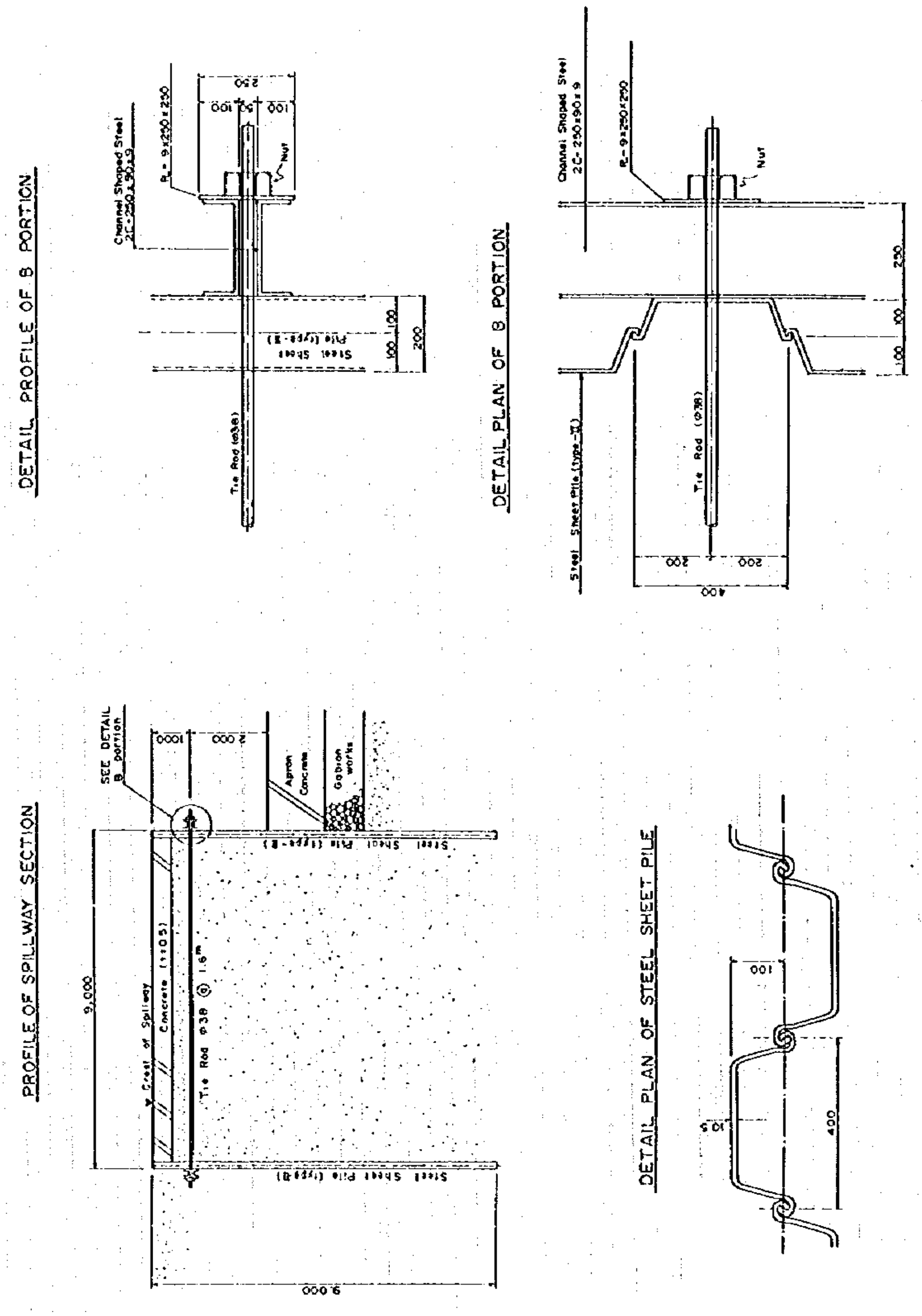

Figure A.5 Proposed Maskup Consolidation Dam (4/8)

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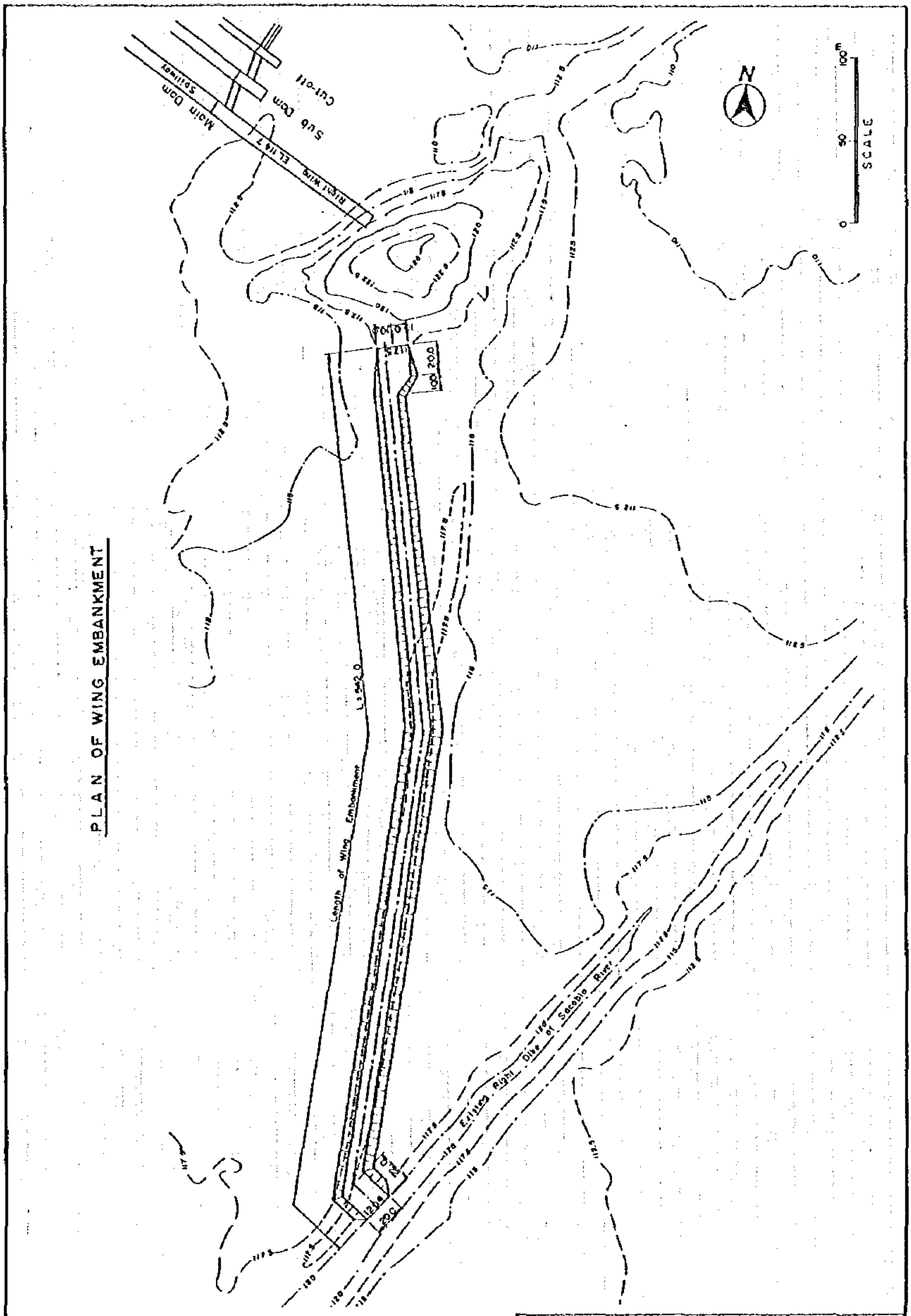

Figure A.5 Proposed Maskup Consolidation Dam (5/8)

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

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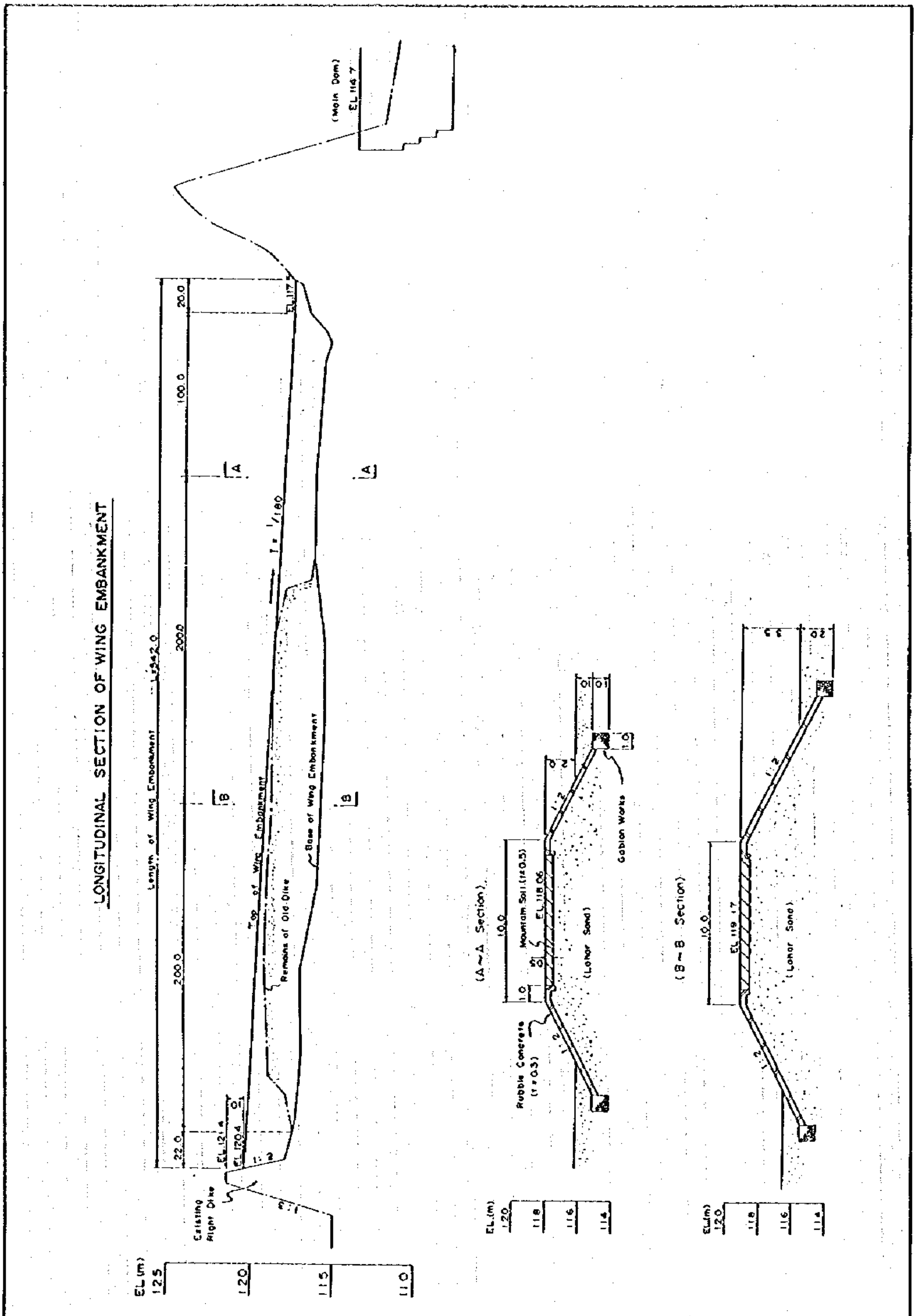

Figure A.5 Proposed Maskup Consolidation Dam (6/8)

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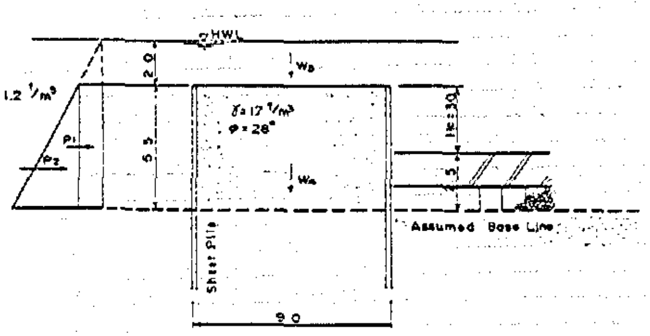
STABILITY OF MAIN DAM



Total Loads

$V = W_s + W_a = 21.6 + 84.15 = 105.75\ t/m$

$M = M_s + M_a - M_1 - M_2 = 97.2 + 378.675 - 36.3 - 33.275 = 406.3\ tm/m$

$H = P_1 + P_2 = 13.2 + 18.15 = 31.35\ t/m$

Safety Factor for Sliding

$n = \tan\phi \times V/H = 0.53 \times 105.75/31.35 = 1.79 > 1.2$ (O.K.)

Middle Third

$e = B/2 - M/V = 9.0/2 - 406.3/105.75 = 0.658^m < B/6 = 1.5^m$ (O.K.)

Stability against Shearing Deformation

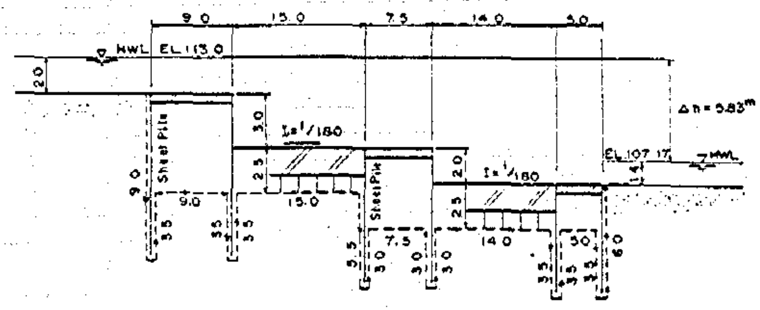
$M_d = M_1 + M_2 = 36.3 + 33.275 = 69.575\ tm/m$

$R_o = (9.0/5.5)^2 (3 - (9.0/5.5)\cos 28°) \sin 28° = 1.955$

$M_r = \gamma R_o h^3/6 = 1.7 \times 1.955 \times 5.5^3/6 = 92.16\ tm/m$

$F = M_r/M_d = 92.16/69.575 = 1.32 > 1.2$ (O.K.)

CREEP RATIO FOR PIPING



(1) Bligh's Method

$L = 9.0 + 3.5 + 9.0 + 3.5 \times 2 + 15.0 + 5.5 + 3.0 + 7.5 + 3.0 \times 2 + 14.0 + 3.5 \times 2$
$+ 5.0 + 3.5 + 6.0 = 101.0^m$

$\Delta h = 5.83^m$

$C_d = L/\Delta h = 101.0/5.83 = 17.3 > 15.0$ (Fine Sand) (O.K.)

(2) Lane's Method

$L = (9.0 + 3.5 \times 3 + 5.5 + 3.0 \times 3 + 3.5 \times 3 + 6.0) + (9.0 + 15.0 + 7.5 + 14.0 + 5.0)/3$
$= 67.3^m$

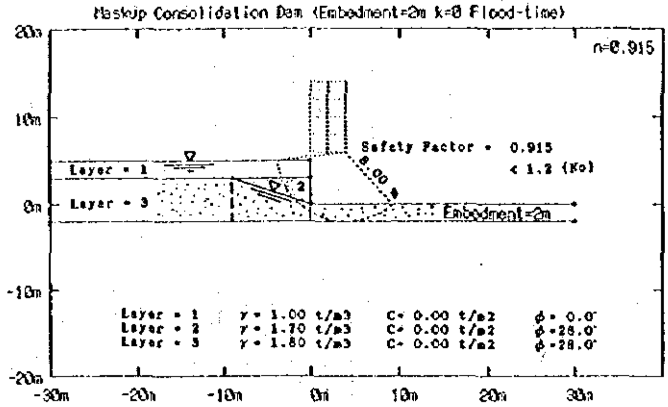
$\Delta h = 5.83^m$

$C_w = L/\Delta h = 67.3/5.83 = 11.5 > 7.0$ (Fine Sand) (O.K.)

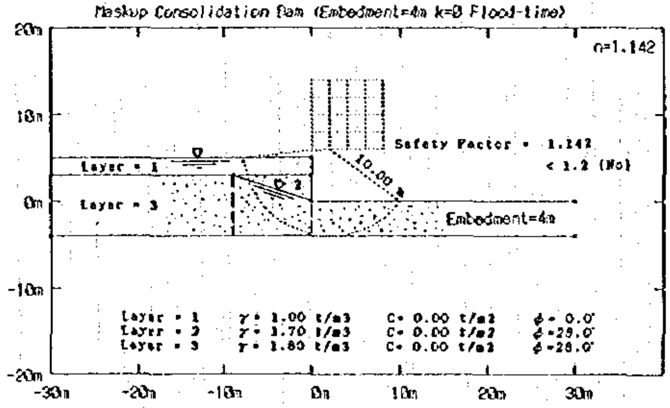
Figure A.5 Proposed Maskup Consolidation Dam (7/8)

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

Maskup Consolidation Dam (Embedment=2m k=0 Flood-time)



Maskup Consolidation Dam (Embedment=4m k=0 Flood-time)



Maskup Consolidation Dam (Embedment=6m k=0 Flood-time)

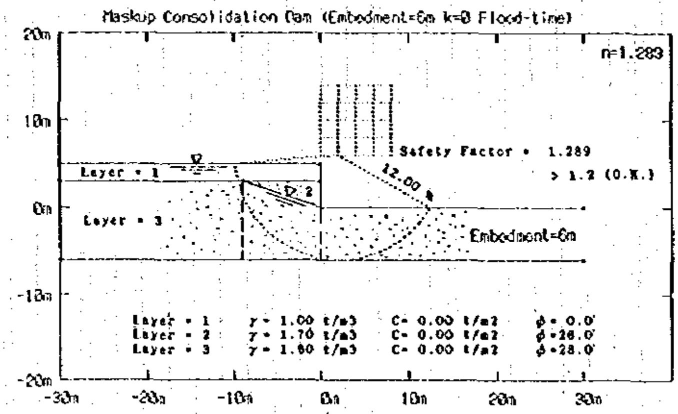


Figure A.5 Proposed Maskup Consolidation Dam (8/8)

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 A.6 Sacobia Training Works
Alternative I (1/2)

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

PROFILE OF SACOBIA TRAINING WORKS (ALTERNATIVE-1)

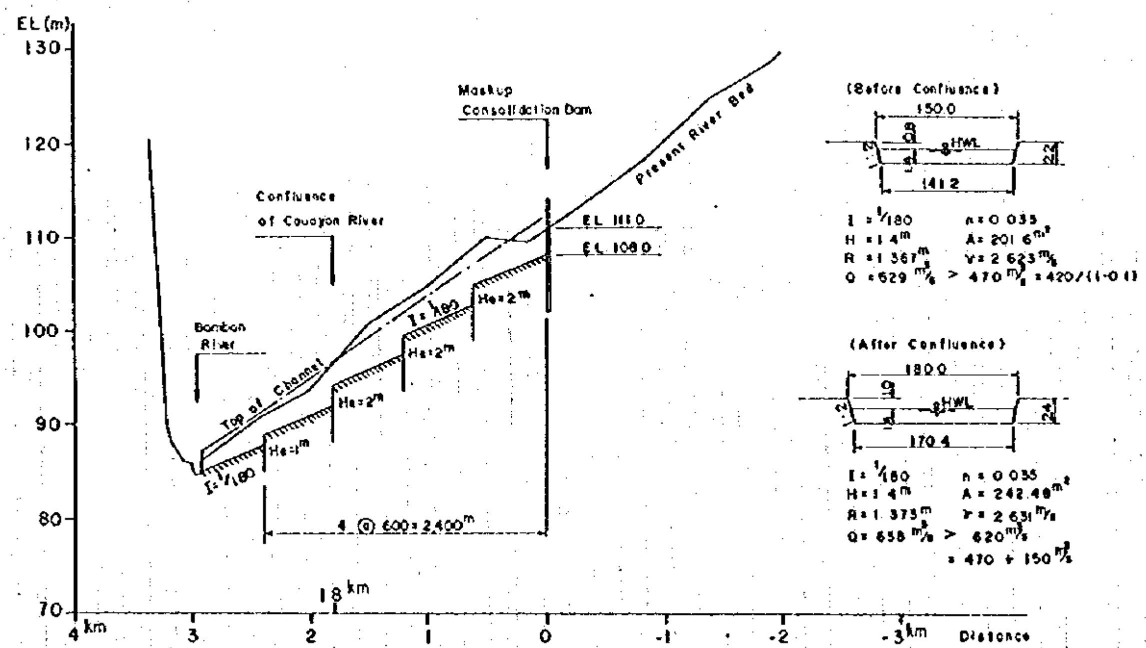


Figure A.6 Sacobia Training Works Alternative 1 (2/2)

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 A.7 Sacobia Training Works
Alternative 2 (1/2)

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

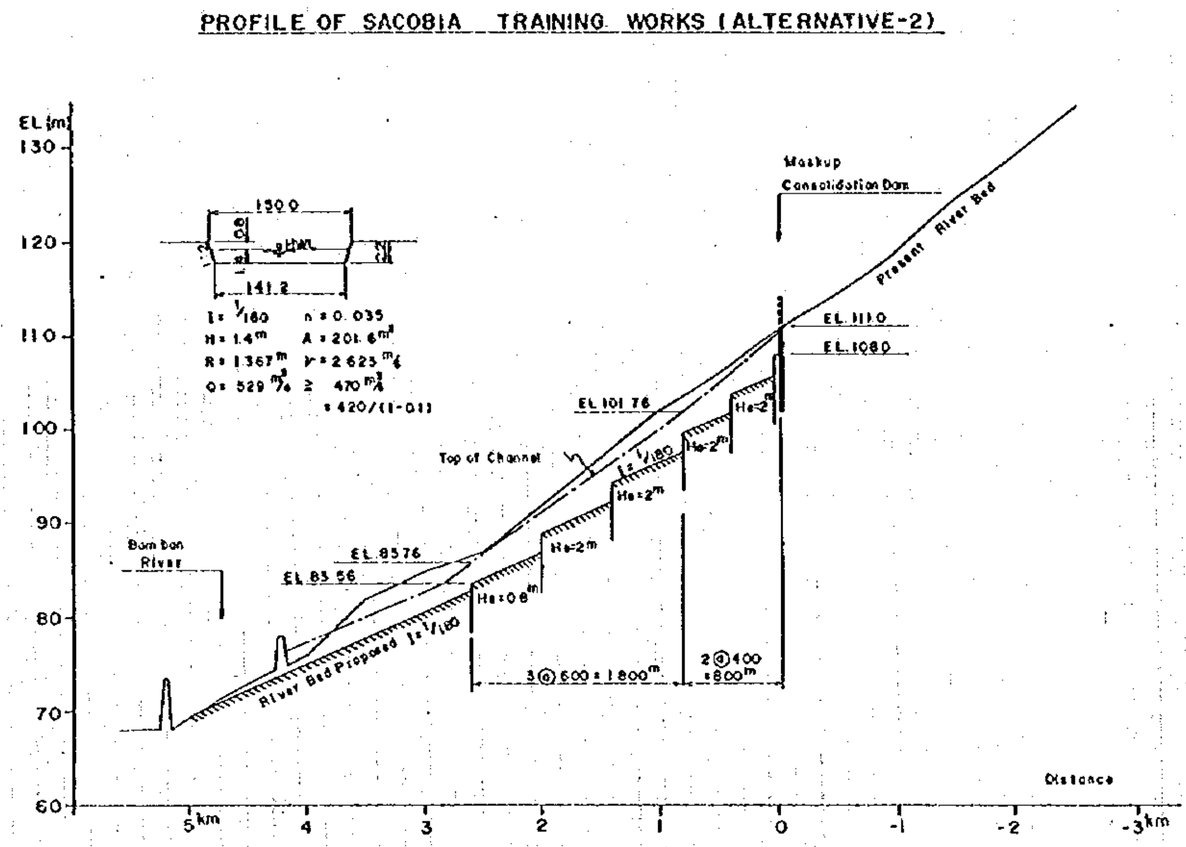


Figure A.7 Sacobia Training Works Alternative 2 (2/2)

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 A.8 Sacobia Training Works Alternative 3 (1/2)

(Recommended Plan)

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

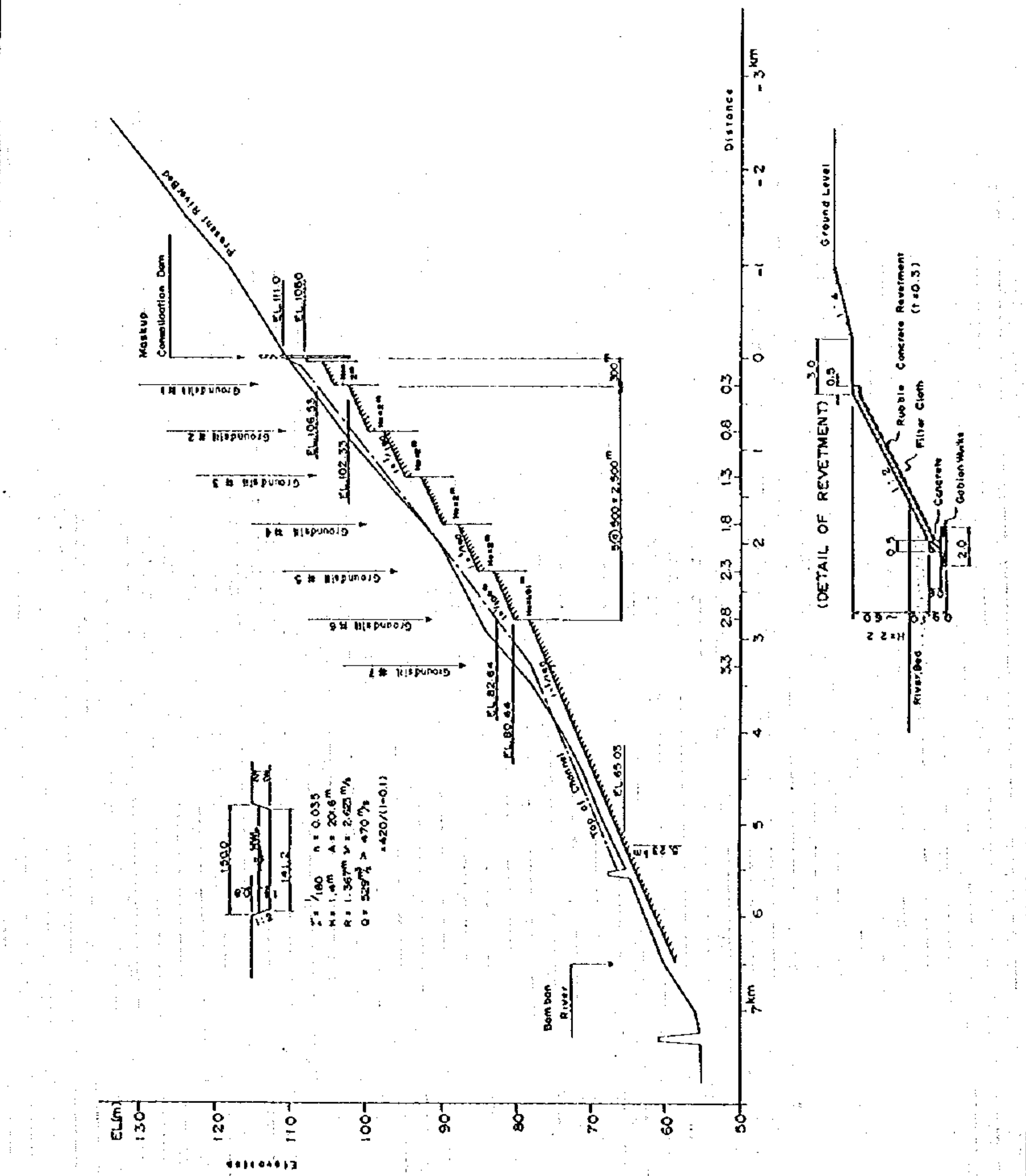


Figure A.8 Sacobia Training Works Alternative 3 (2/2)

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

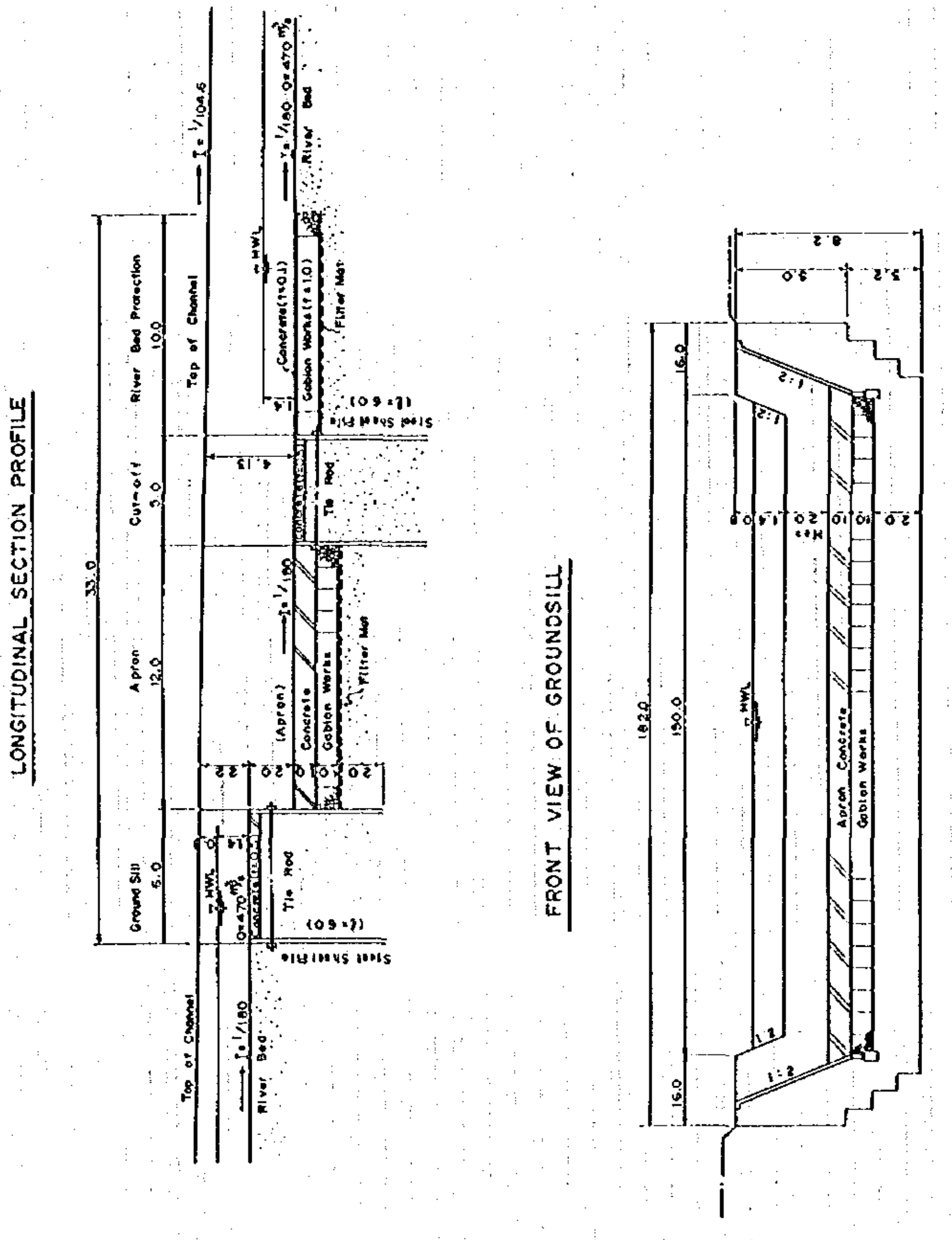


Figure A.9 Proposed Groundsill (1/3)

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

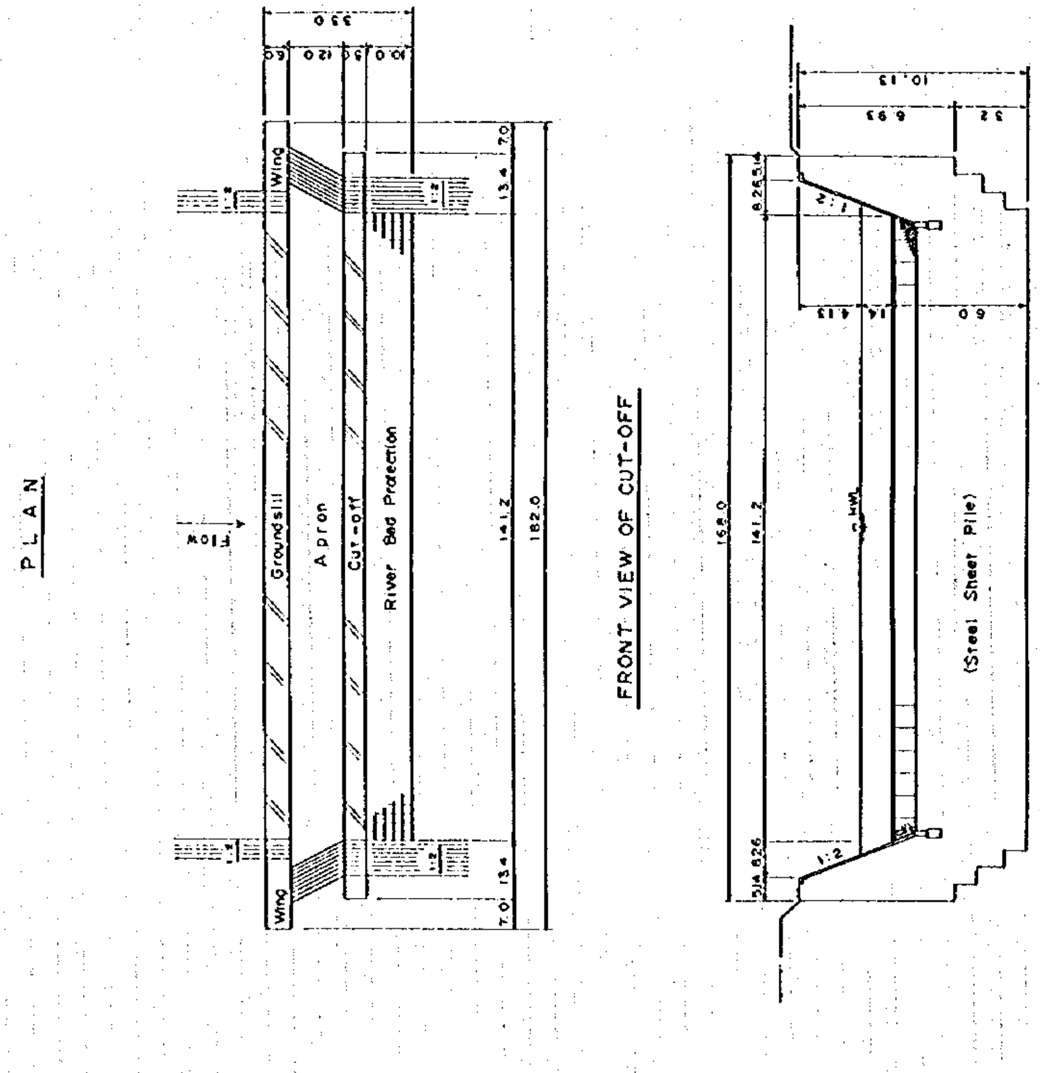
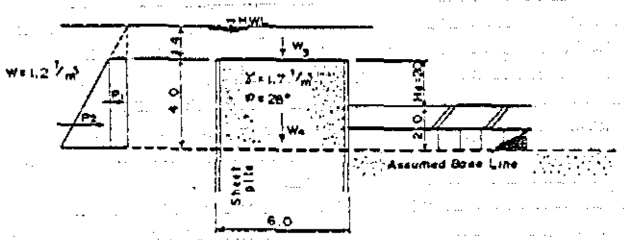


Figure A.9 Proposed Groundsill (2/3)

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

STABILITY OF GROUNDSILL



Total Loads

$V = W_3 + W_4 = 10.08 + 40.8 = 50.88\ ^{t}/_{m}$

$M = M_3 + M_4 - M_1 - M_2 = 30.24 + 122.4 - 13.44 - 12.8 = 126.4\ ^{tm}/_{m}$

$H = P_1 + P_2 = 6.72 + 9.6 = 16.32\ ^{t}/_{m}$

Safety Factor for Sliding

$n = \tan\phi \cdot V/H = 0.53 \times 50.88 / 16.32 = 1.65 > 1.2$ (O.K.)

Middle Third

$e = B/2 - M/V = 6.0/2 - 126.4/50.88 = 0.516^{m} < B/6 = 1.0$ (O.K.)

Stability against Shearing Deformation

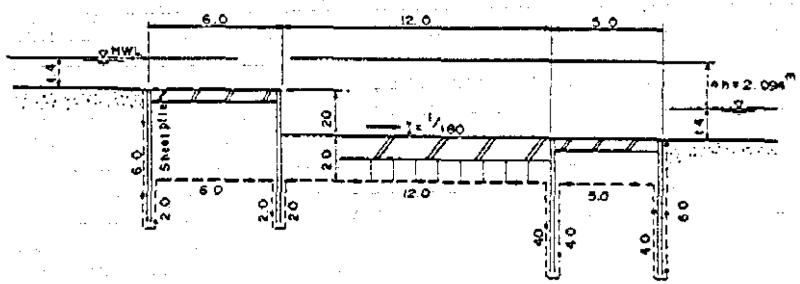
$M_d = M_1 + M_2 = 13.44 + 12.8 = 26.24\ ^{tm}/_{m}$

$R_o = (6.0/4.0)^2\ (3 - (6.0/4.0))\cos 28°)\sin 28° = 1.770$

$M_r = \gamma R_o h^3/6 = 1.7 \times 1.770 \times 4.0^3/6 = 32.10\ ^{tm}/_{m}$

$F = M_r / M_d = 32.10/26.24 = 1.22 > 1.2$ (O.K.)

CREEP RATIO FOR PIPING



(1) Bligh's Method

$L = 6.0 + 2.0 + 6.0 + 2.0 \times 2 + 12.0 + 4.0 \times 2 + 5.0 + 4.0 + 6.0 = 53.0^{m}$

$\Delta h = 2.0 + 17.0/180 = 2.094^{m}$

$C_c = L/\Delta h = 53.0/2.094 = 25.3 > 15.0$ (Fine Sand)(O.K.)

(2) Lane's Method

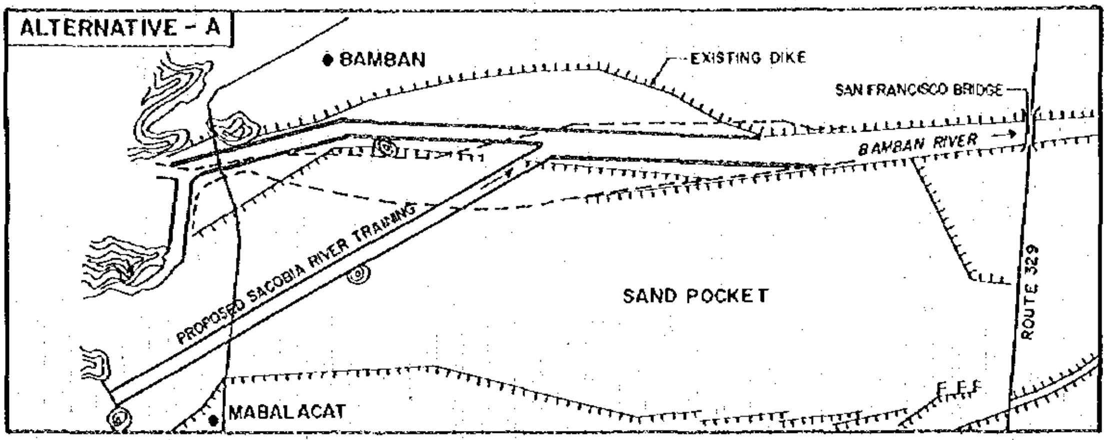
$L = (6.0 + 2.0 \times 3 + 4.0 \times 3 + 6.0) + (6.0 + 12.0 + 5.0)/3 = 37.7^{m}$

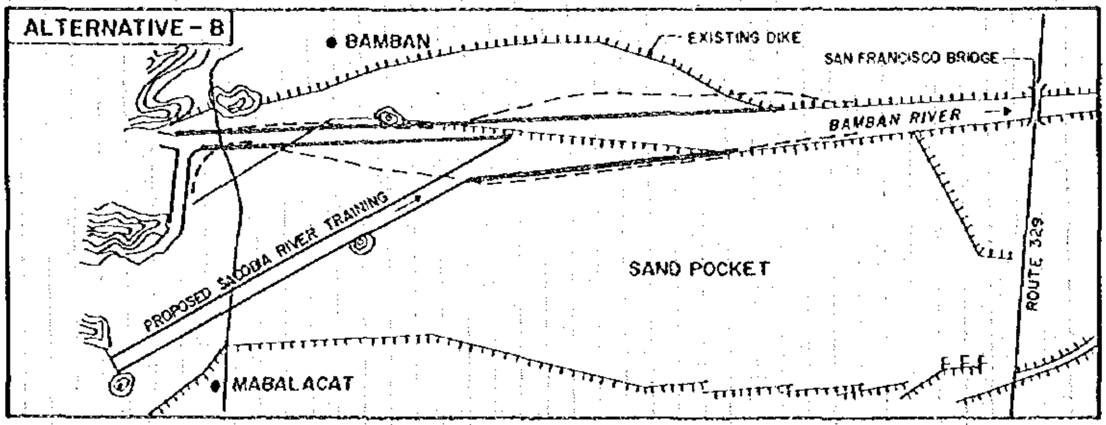
$\Delta h = 2.094^{m}$

$C_w = L/\Delta h = 37.7/2.094 = 18.0 > 7.0$ (Fine Sand)(O.K.)

Figure A.9 Proposed Groundsill (3/3)

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





(Recommended Plan)

Figure A.10 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

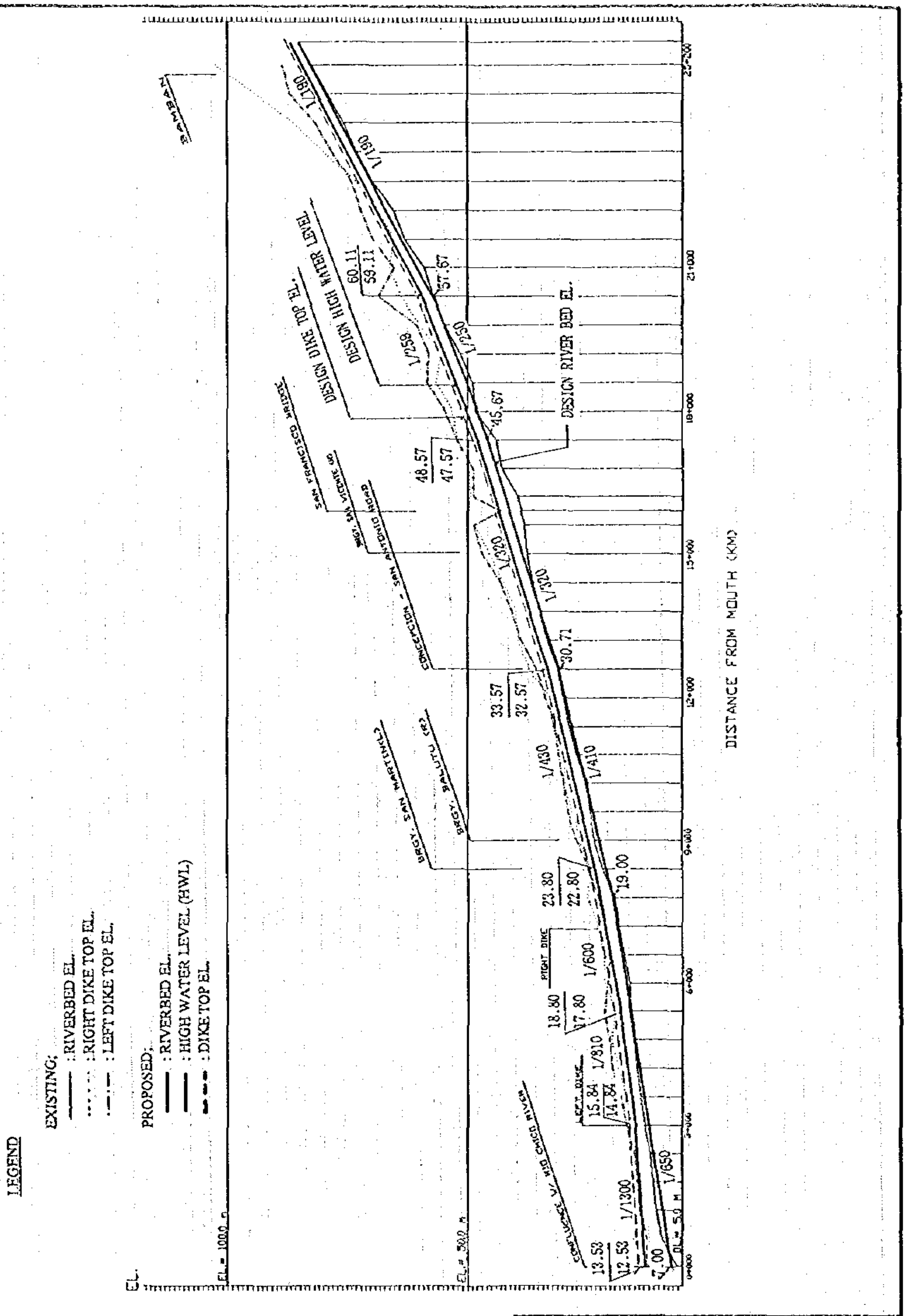


Figure A.11 Design Longitudinal Profiles of Bamban River

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

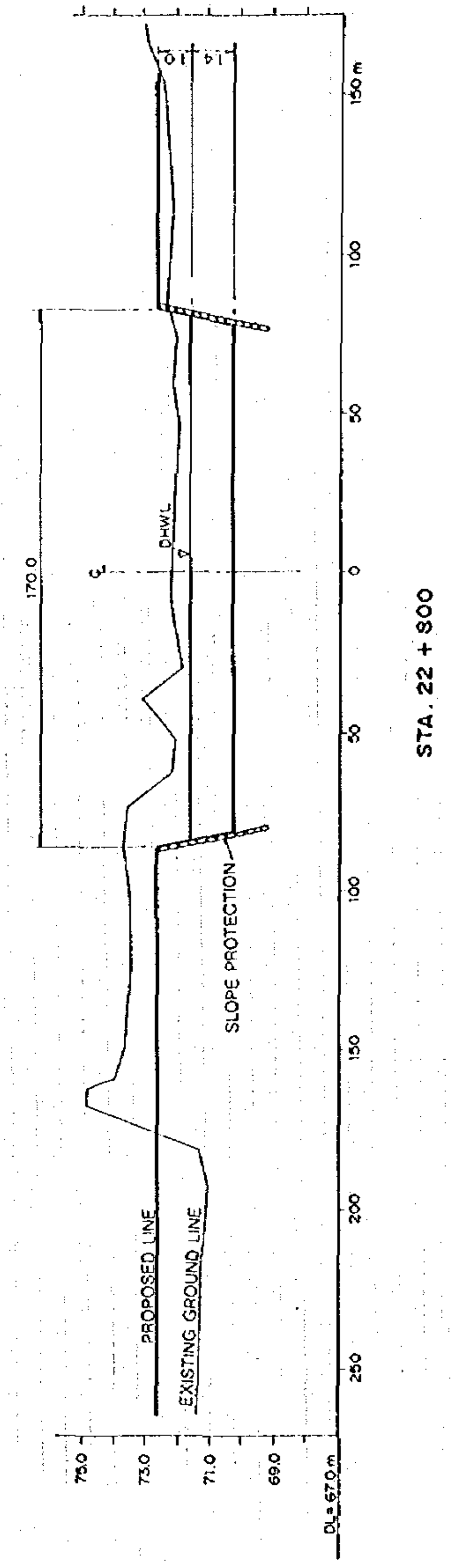


Figure A.12 Proposed Cross Section of Bamban River

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

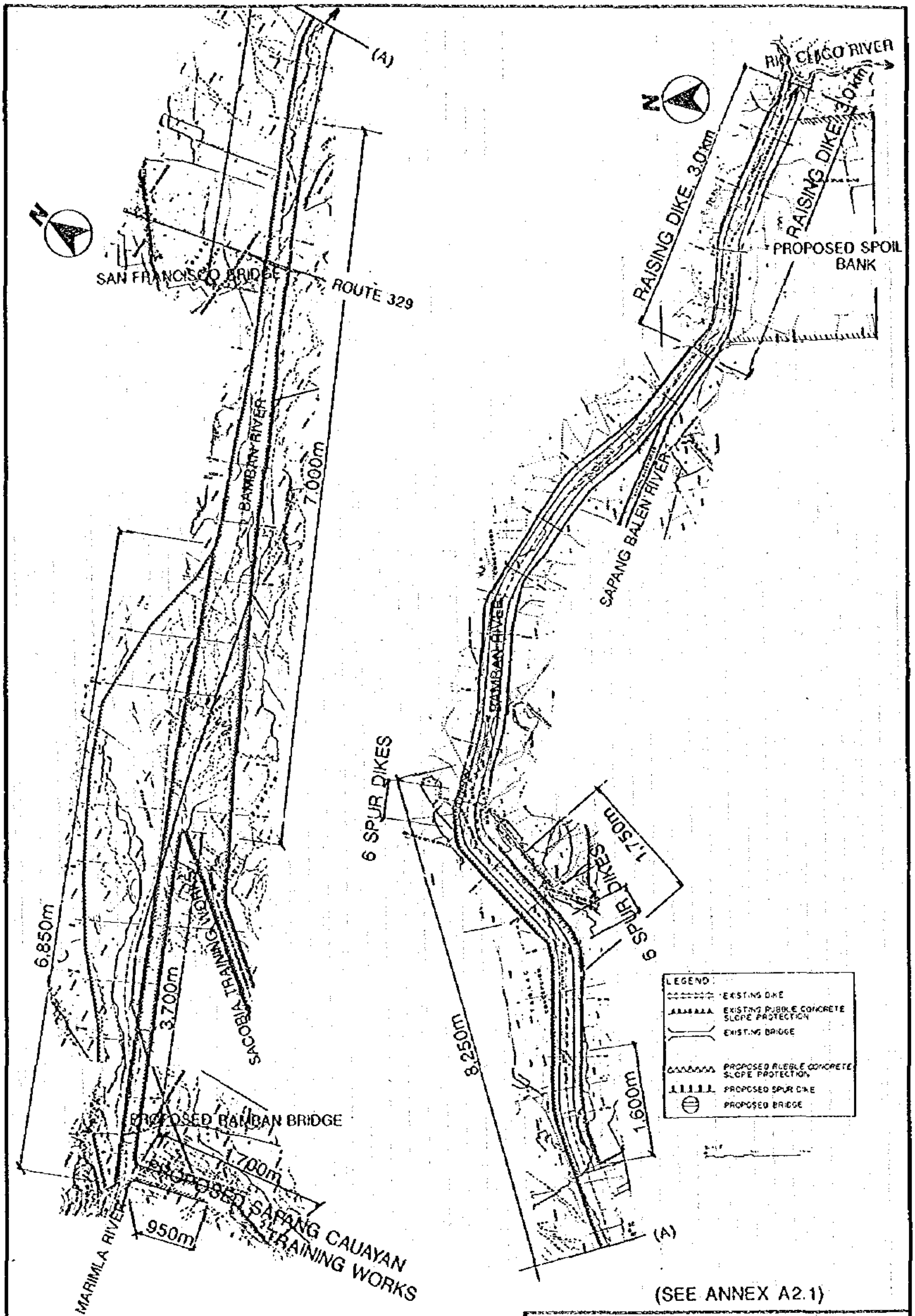
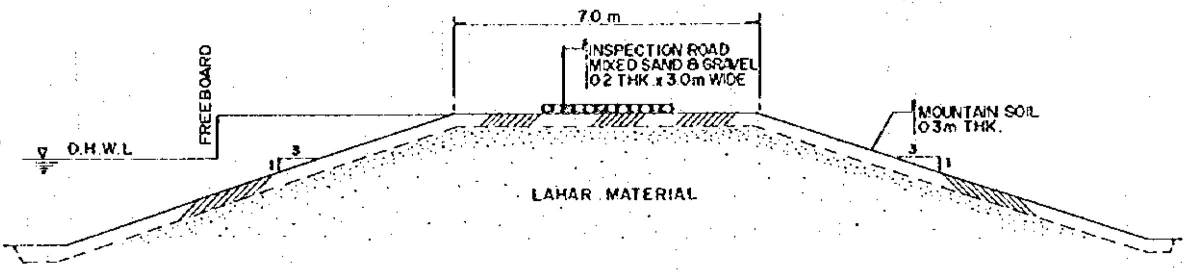
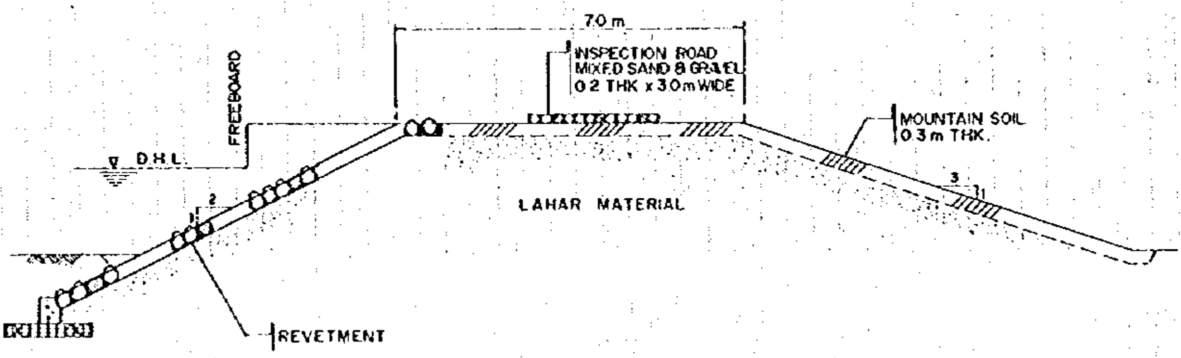


Figure A.13 General Plan of Bamban River Improvement

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 A.14 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

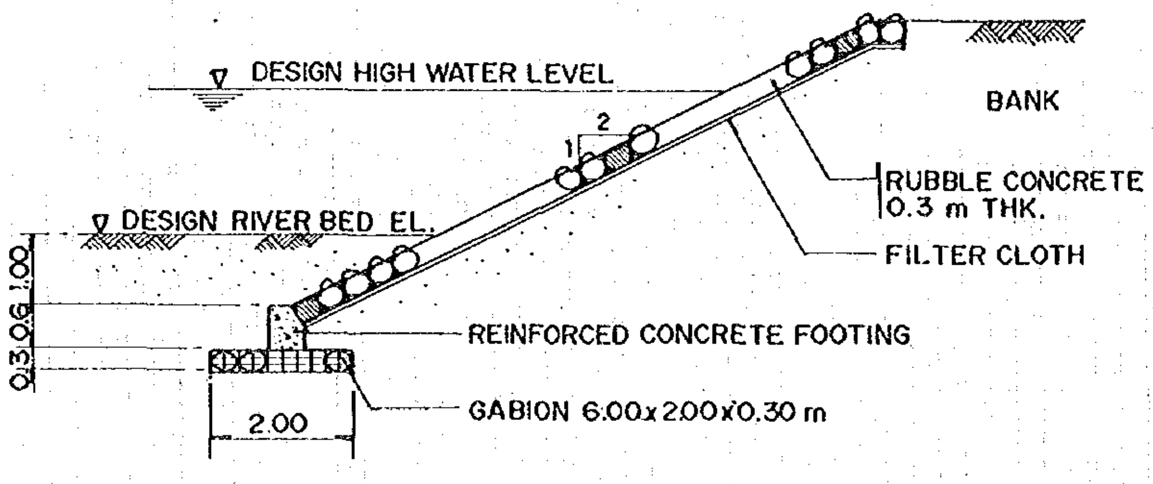


Figure A.15 Proposed Rubble Concrete Slope Protection

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

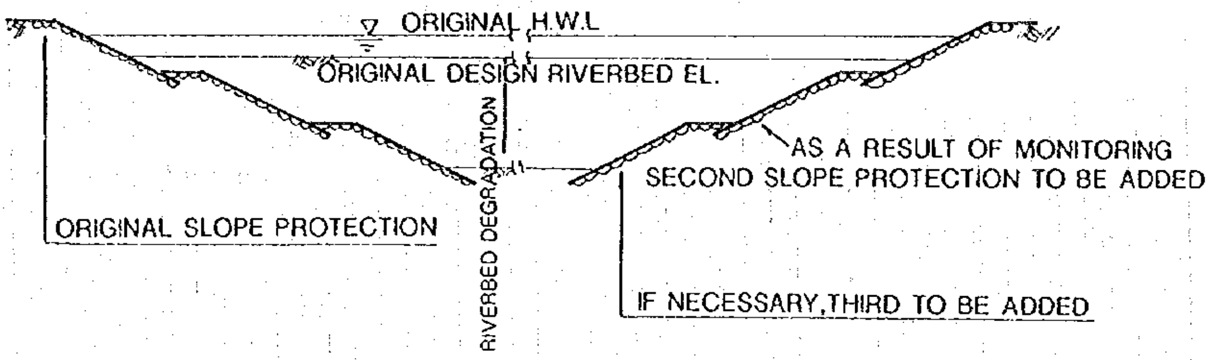
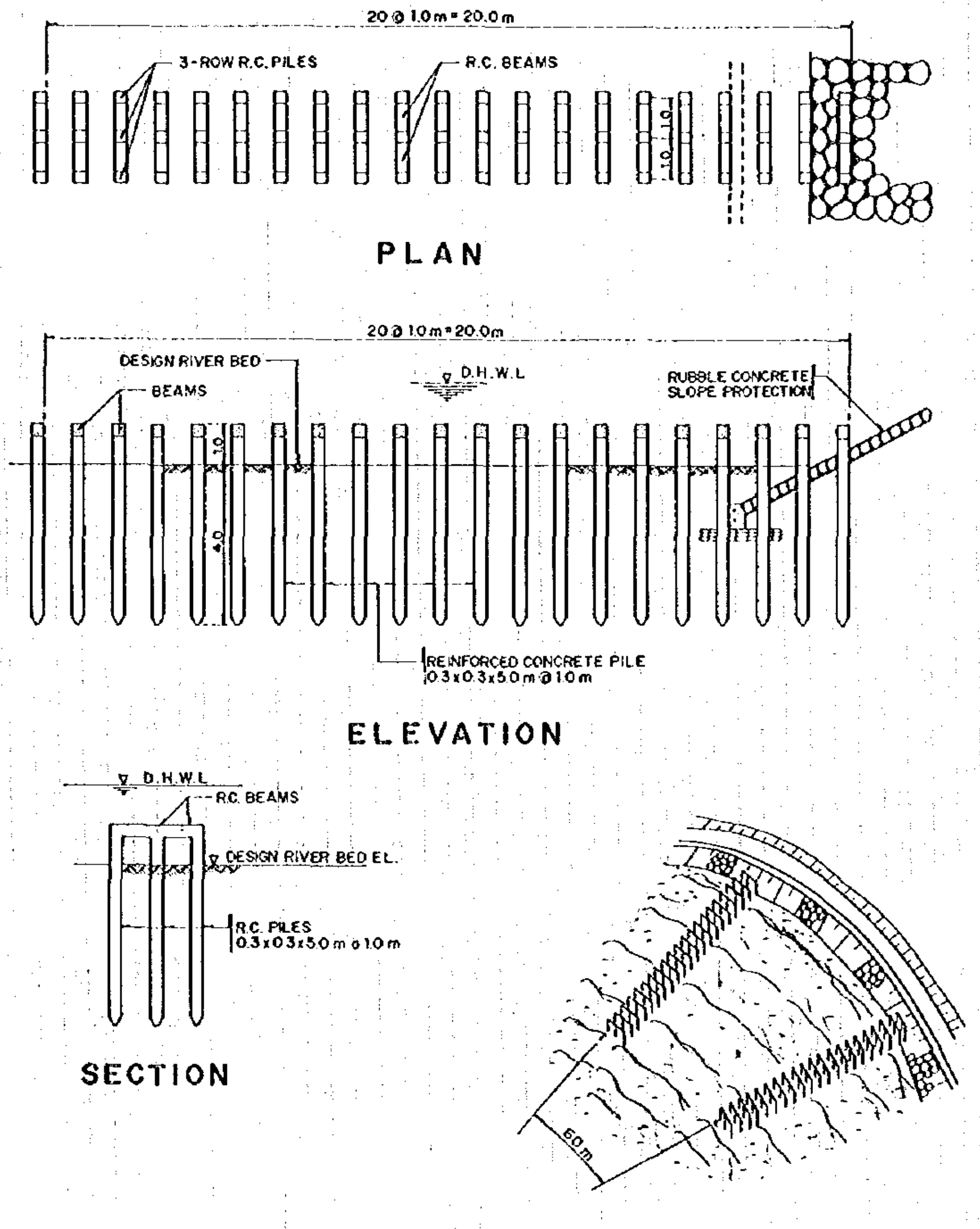


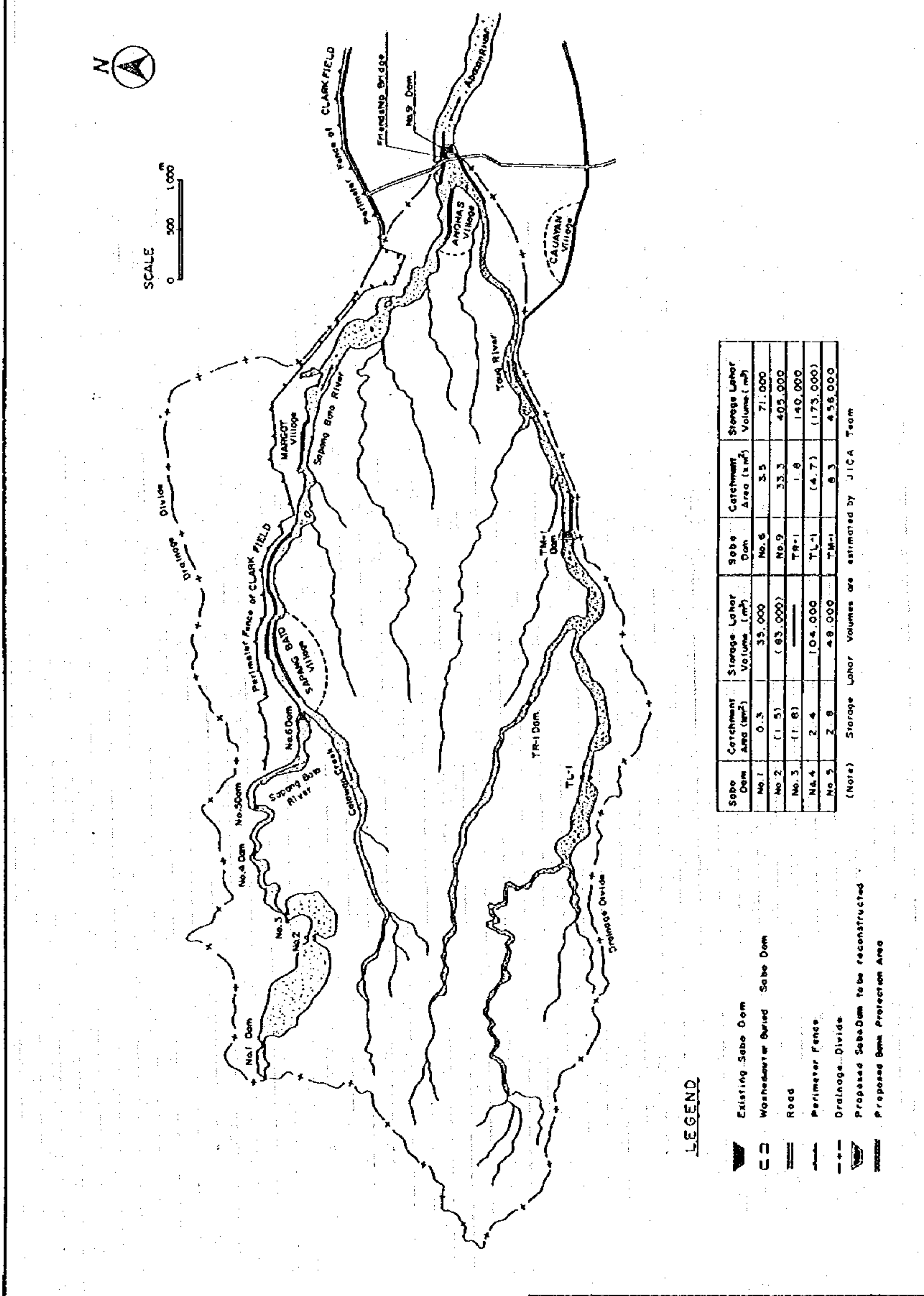
Figure A.16 Concept of Applicable Slope Protection for Channel Degradation

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



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 A.17 Proposed Spur Dike



Sabo Dam	Catchment Area (km²)	Storage Lahar Volume (m³)	Sabo Dam	Catchment Area (km²)	Storage Lahar Volume (m³)
No.1	0.5	35,000	No.6	3.5	71,000
No.2	(1.5)	(83,000)	No.9	33.3	405,000
No.3	(1.8)	—	TR-1	1.8	140,000
No.4	2.4	104,000	TL-1	(4.7)	(173,000)
No.5	2.8	49,000	TM-1	8.3	456,000

(Note) Storage Lahar Volumes are estimated by JICA Team

Figure A.18 Proposed Works for Upper Abacan 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

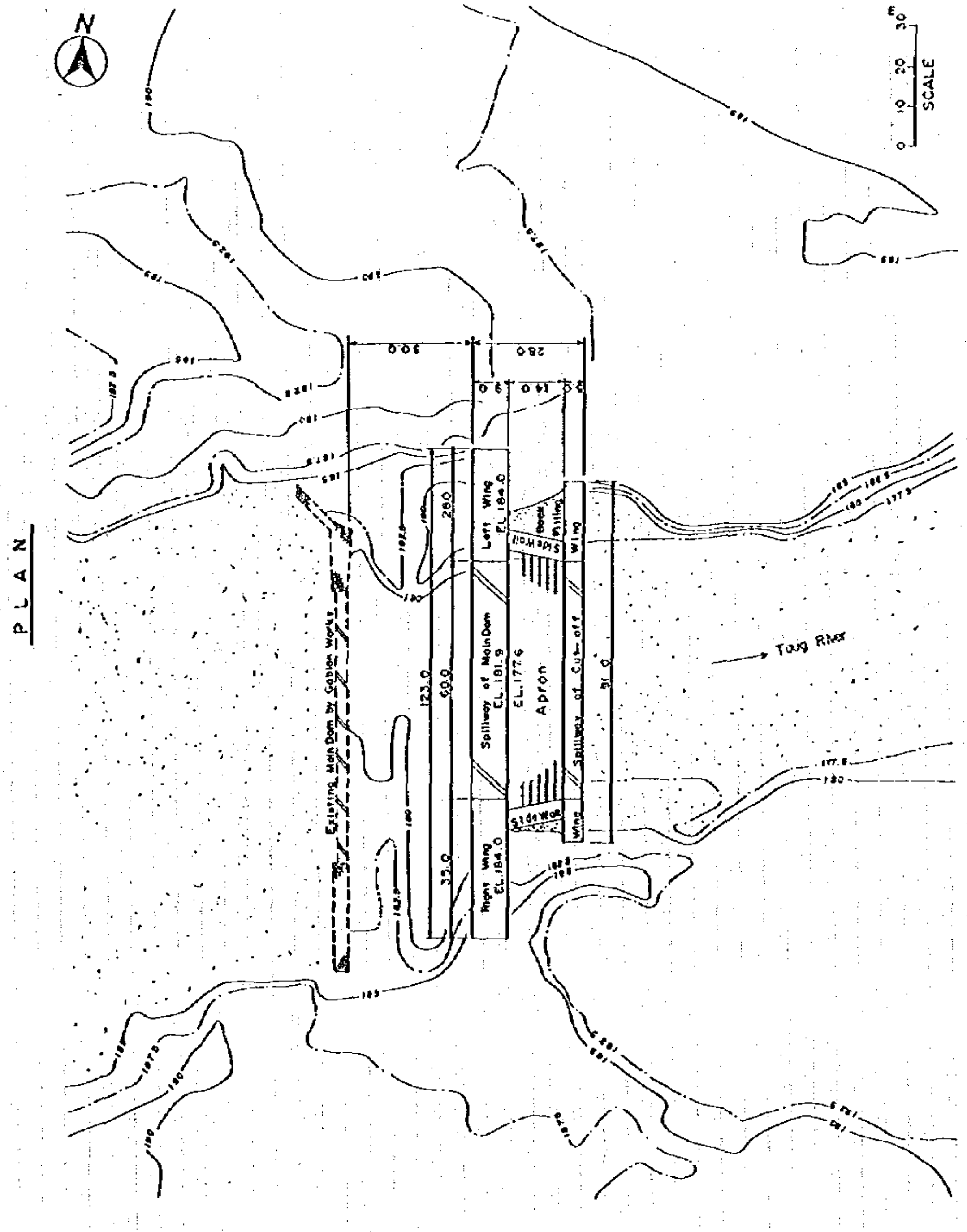


Figure A.19 Reconstruction Plan of Sabo Dam TM-1 (1/3)

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

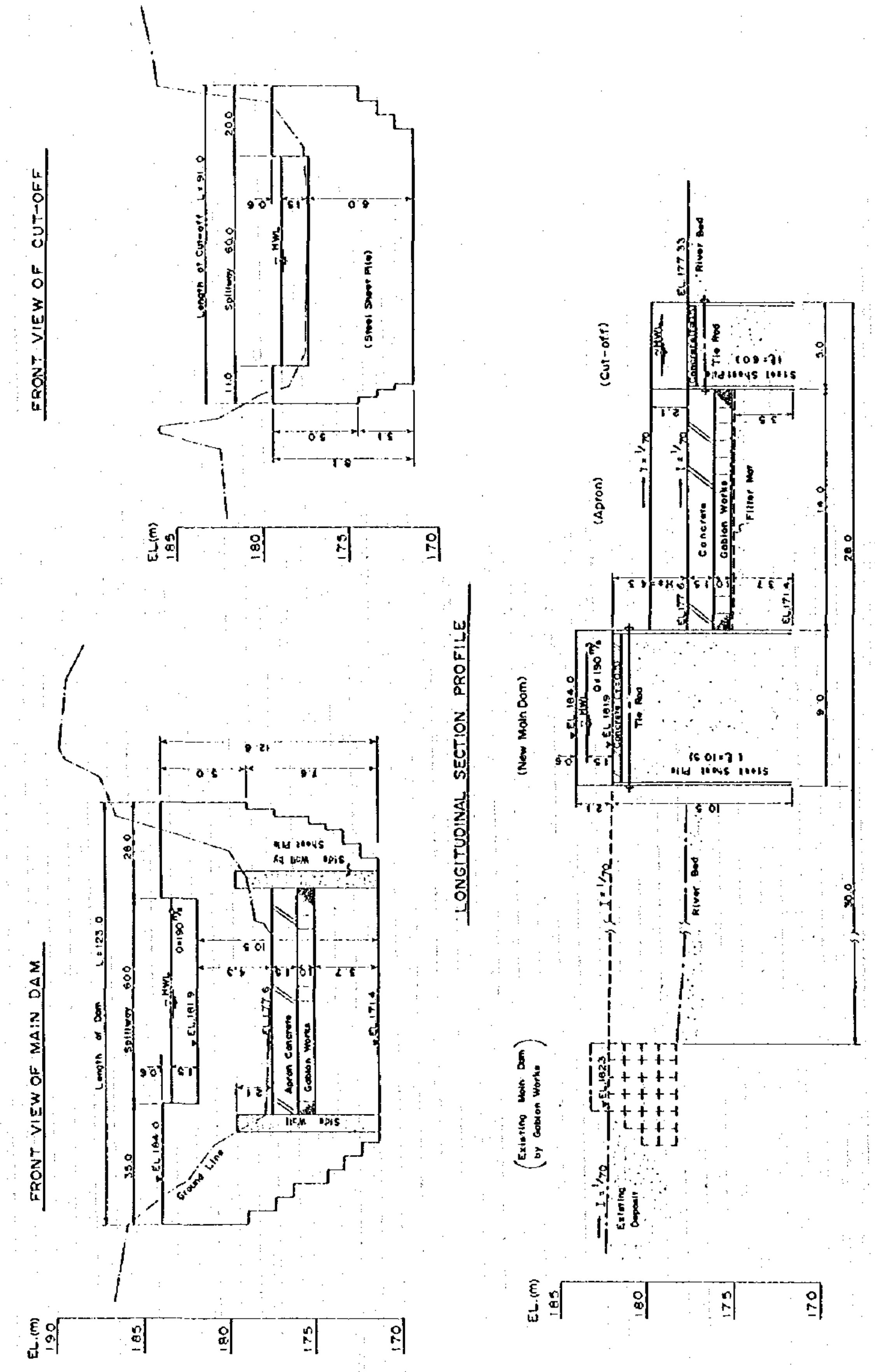
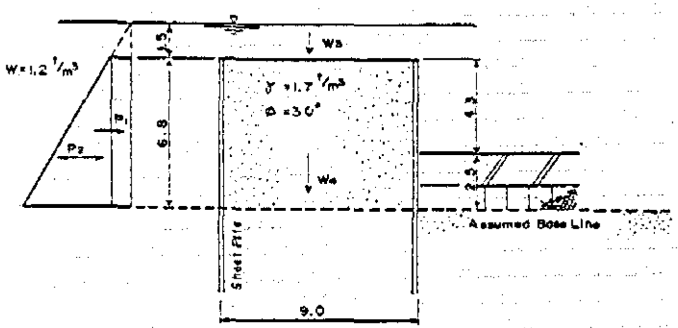


Figure A.19 Reconstruction Plan of Sabo Dam TM-1 (2/3)

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

STABILITY OF MAIN DAM



Total Loads

$V = W_3 + W_4 = 16.2 + 104.04 = 120.24\ t/m$

$M = M_3 + M_4 - M_1 - M_2 = 72.9 + 468.18 - 47.165 - 62.886 = 431.029\ tm/m$

$H = P_1 + P_2 = 13.872 + 27.744 = 41.616\ t/m$

Safety Factor for Sliding

$n = \tan\phi \times V/H = 0.58 \times 120.24/41.616 = 1.68 > 1.2$ (O.K)

Middle Third

$e = B/2 - M/V = 9.0/2 - 431.029/120.24 = 0.915^m < B/6 = 1.5^m$ (O.K.)

Stability against Shearing Deformation

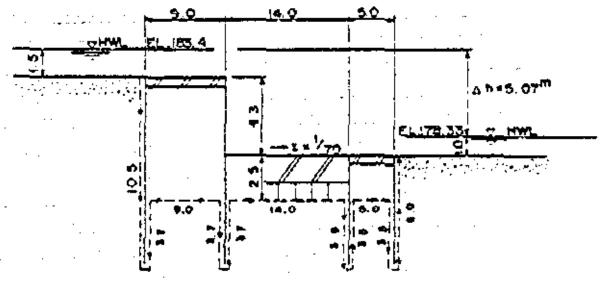
$M_d = M_1 + M_2 = 47.165 + 62.886 = 110.051\ tm/m$

$R_o = (9.0/6.8)^2 (3 - (9.0/6.8)\cos 30^\circ) \sin 30^\circ = 1.624$

$M_r = \delta R_o h^3/6 = 1.7 \times 1.624 \times 6.8^3/6 = 144.68\ tm/m$

$F = M_r/M_d = 144.68/110.051 = 1.31 > 1.2$ (O.K.)

CREEP RATIO FOR PIPING



(1) Bligh's Method

$L = 10.5 + 3.7 + 9.0 + 3.7 \times 2 + 14.0 + 3.5 \times 2 + 5.0 + 3.5 + 6.0 = 66.1^m$

$\Delta h = 5.07^m$

$C_c = L/\Delta h = 66.1/5.07 = 13.0 > 12.0$ (Coarse Sand) (O.K.)

(2) Lane's Method

$L = (10.5 + 3.7 \times 3 + 3.5 \times 3 + 6.0) + (9.0 + 14.0 + 5.0)/3 = 47.4^m$

$\Delta h = 5.07^m$

$C_w = L/\Delta h = 47.4/5.07 = 9.3 > 5.0$ (Coarse Sand) (O.K.)

Figure A.19 Reconstruction Plan of Sabo Dam TM-1 (3/3)

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

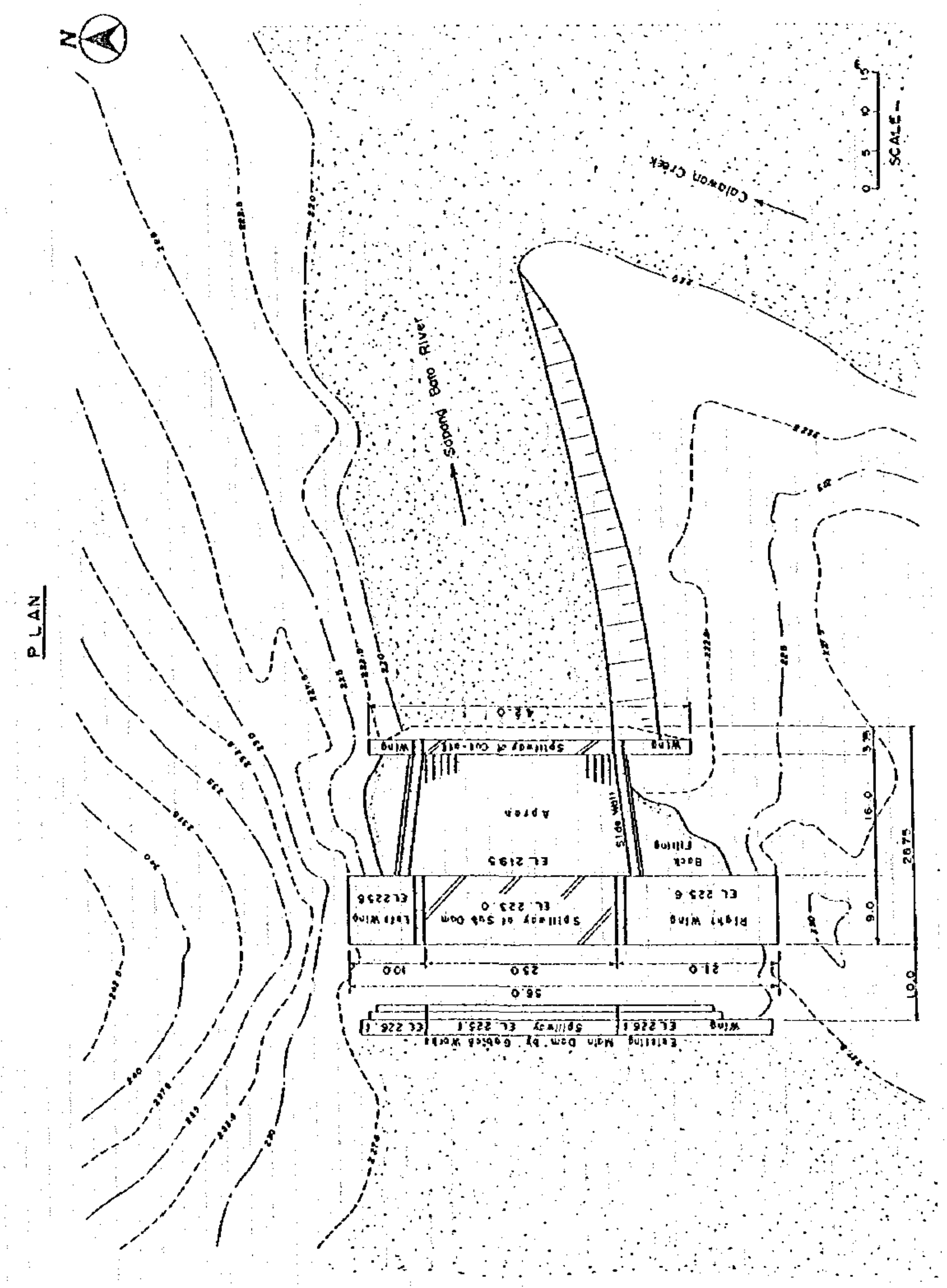


Figure A.20 Reconstruction Plan of Sabo Dam No.6 (1/4)

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

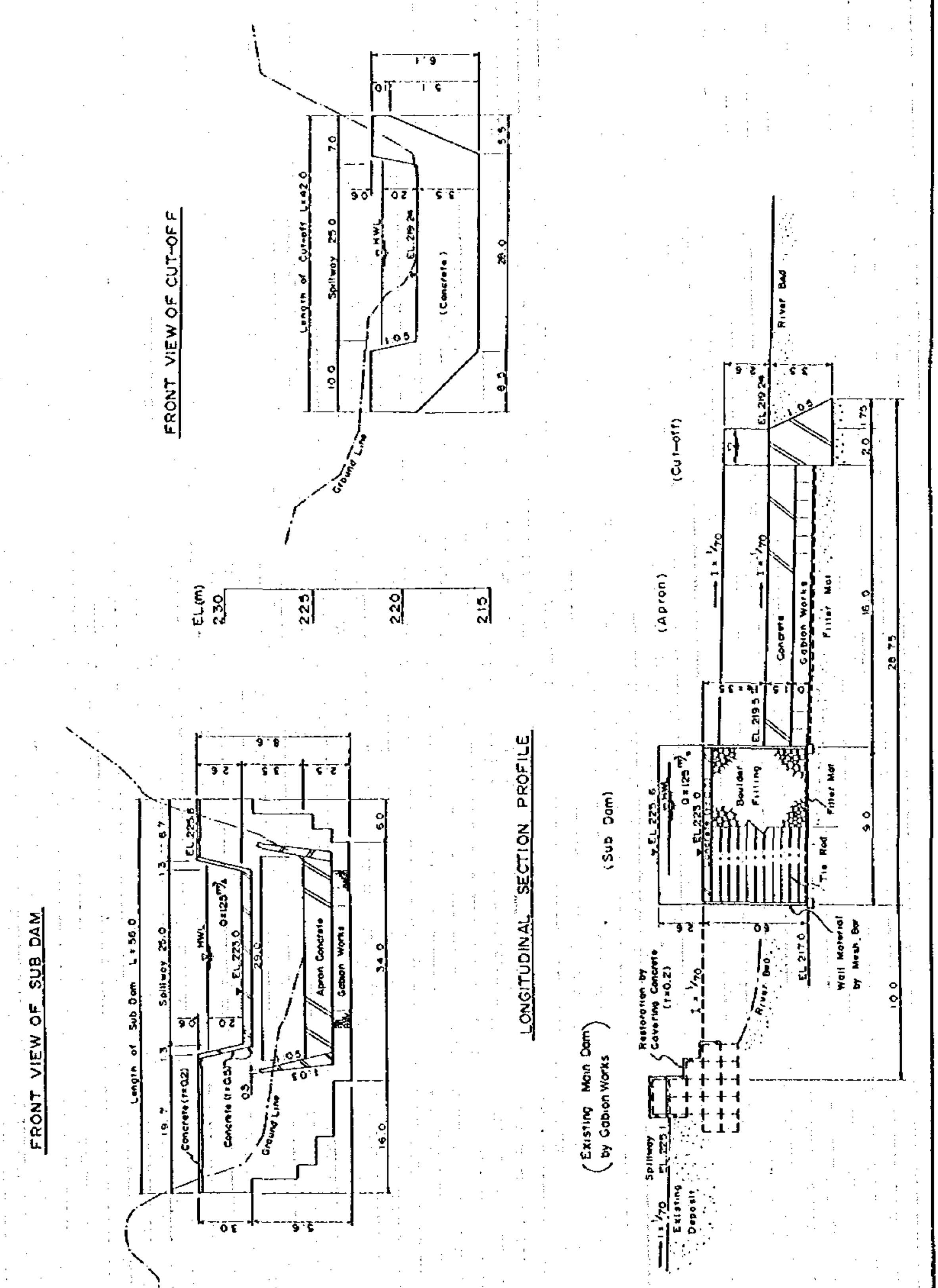
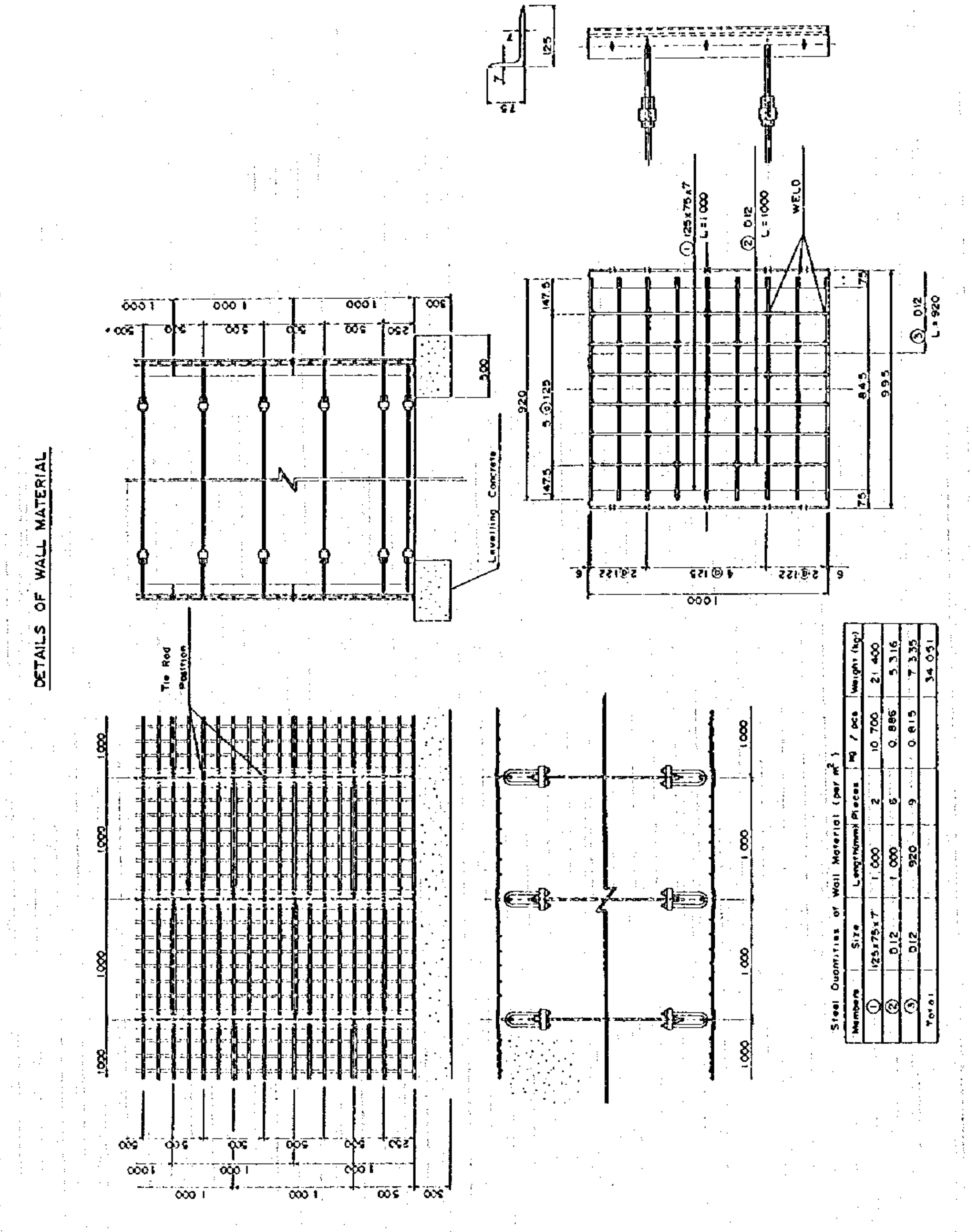


Figure A.20 Reconstruction Plan of Sabo Dam No.6 (2/4)

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



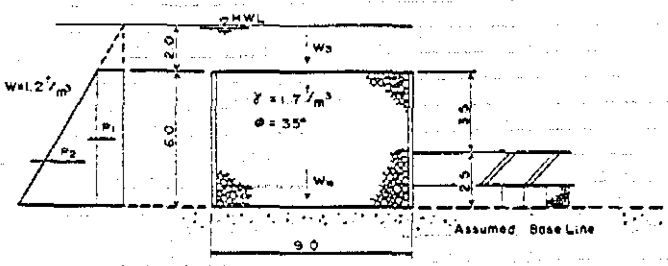
Steel Quantities of Wall Material (per m²)

Members	Size	Length(mm)	Pieces	kg / pcs	Weight (kg)
①	125×75×7	1 000	2	10.700	21.400
②	D12	1 000	6	0.886	5.316
③	D12	920	9	0.815	7.335
Total					34.051

Figure A.20 Reconstruction Plan of Sabo Dam No.6 (3/4)

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

STABILITY OF MAIN DAM



Total Loads

$V = W_3 + W_4 = 21.6 + 91.8 = 113.4\ t/m$

$M = M_3 + M_4 - M_1 - M_2 = 97.2 + 413.1 - 43.2 - 43.2 = 423.9\ tm/m$

$H = P_1 + P_2 = 14.4 + 21.6 = 36.0\ t/m$

Safety Factor for Sliding

$n = \tan\phi \times V/H = 0.70 \times 113.4/36.0 = 2.21 > 1.2$ (O.K)

Middle Third

$e = B/2 - M/V = 9.0/2 - 423.9/113.4 = 0.683^m < B/6 = 1.5^m$ (O.K)

Stability against Shearing Deformation

$Md = M_1 + M_2 = 43.2 + 43.2 = 86.4\ tm/m$

$Ro = (9.0/6.0)^2(3 - (9.0/6.0)\cos 35°)\sin 35° = 2.286$

$Mr = \gamma Ro h^3/6 = 1.7 \times 2.286 \times 6.0^3/6 = 139.9\ tm/m$

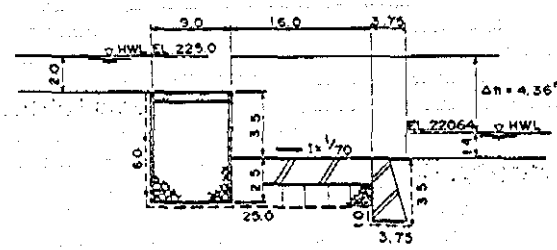
$F = Mr/Md = 139.9/86.4 = 1.62 > 1.2$ (O.K.)

Bearing Capacity of Ground

$q = V/B(1 + 6e/B) = 113.4/9.0 \times (1 + 6 \times 0.683/9.0)$

$= 18.3\ t/m^2 < 20\ t/m^2$ (Gravelly Sand)(O.K.)

CREEP RATIO FOR PIPING



(1) Bligh's Method

$L = 6.0 + 25.0 + 1.0 + 3.75 + 3.5 = 39.25^m$

$\Delta h = 4.36^m$

$Cc = L/\Delta h = 39.25/4.36 = 9.0 \geq 9.0$ (Gravelly Sand)(O.K)

(2) Lane's Method

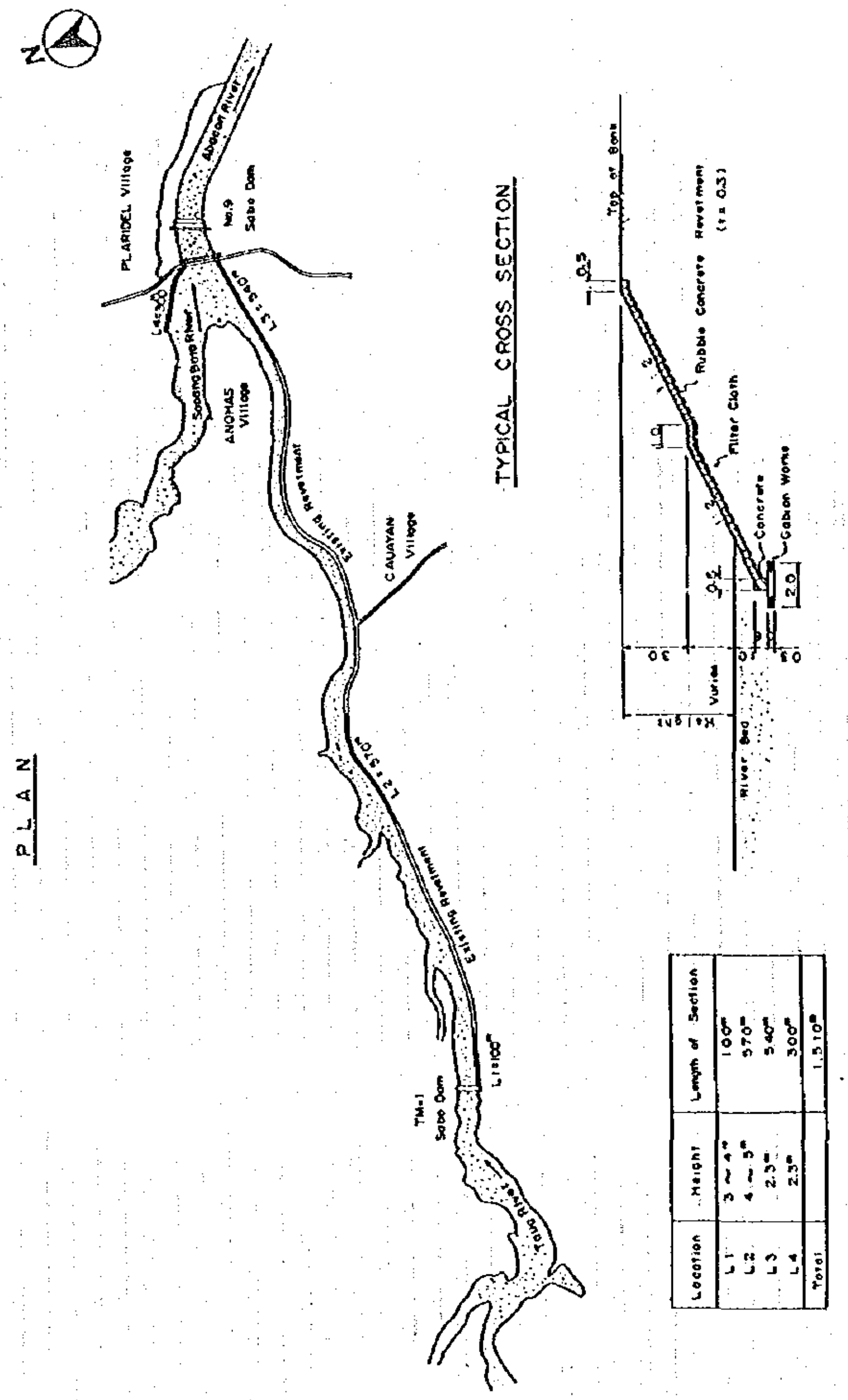
$L = (6.0 + 1.0 + 3.5) + (25.0 + 3.75)/3 = 20.1^m$

$\Delta h = 4.36^m$

$Cw = 20.1/4.36 = 4.6 > 3.5$ (Gravelly Sand)(O.K.)

Figure A.20 Reconstruction Plan of Sabo Dam No.6 (4/4)

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



Location	Height	Length of Section
L1	3 ~ 4m	100m
L2	4 ~ 5m	570m
L3	2.5m	540m
L4	2.5m	300m
Total		1,510m

Figure A.21 Riverbank Protection for Taug River

THE GOVERNMENT OF THE PHILIPPINES
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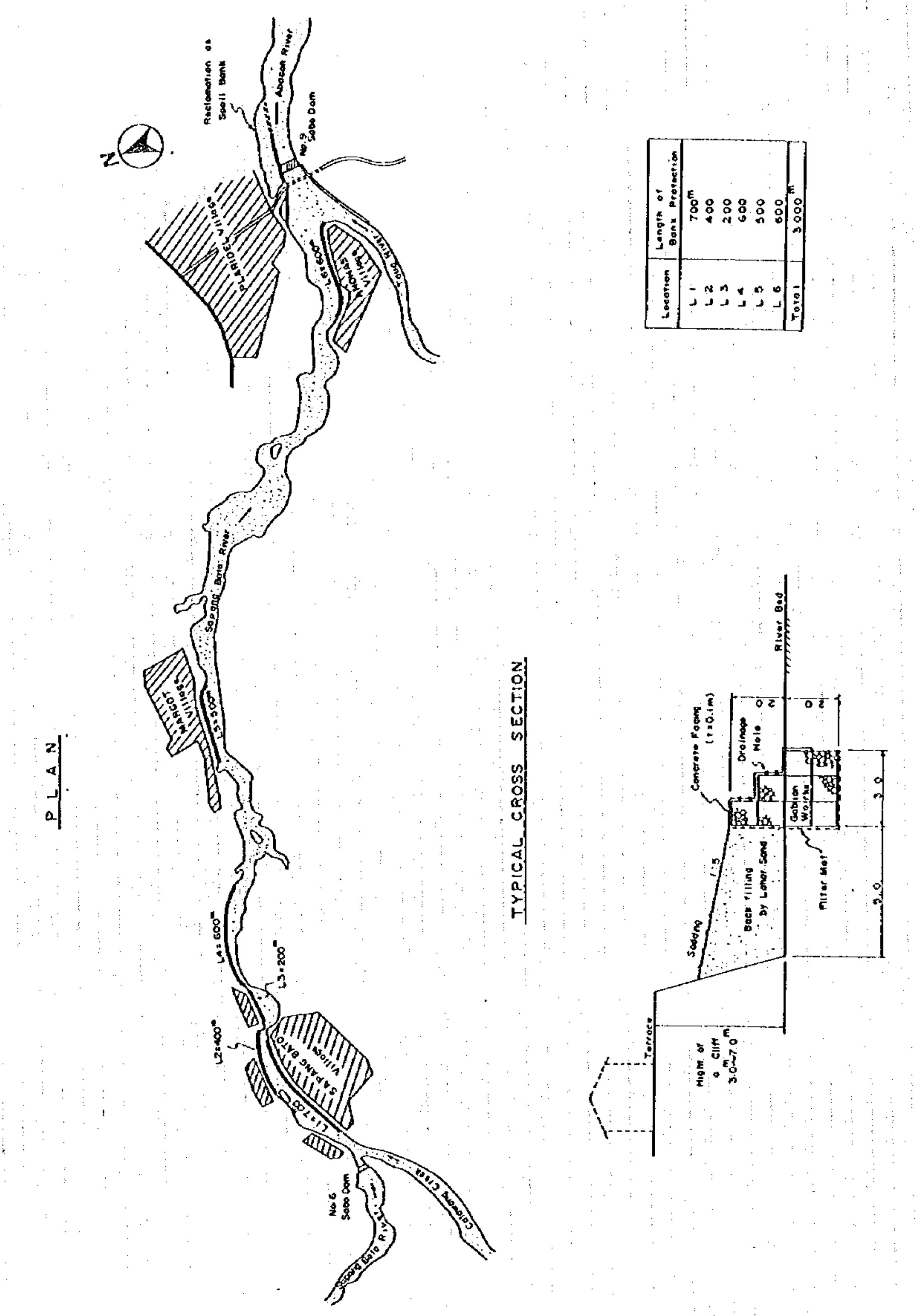

Figure A.22 Riverbank Protection for Sapangbato River

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
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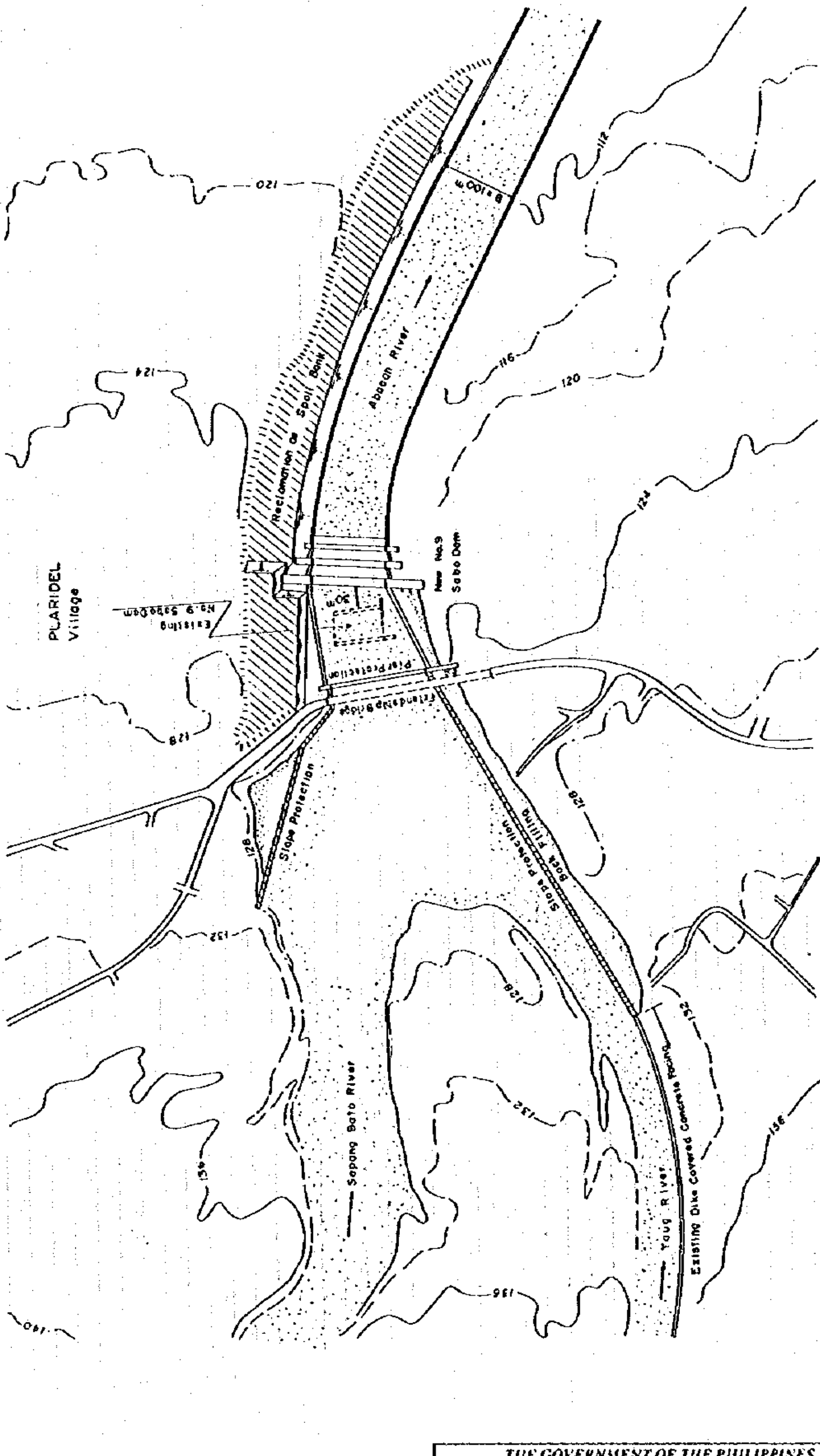
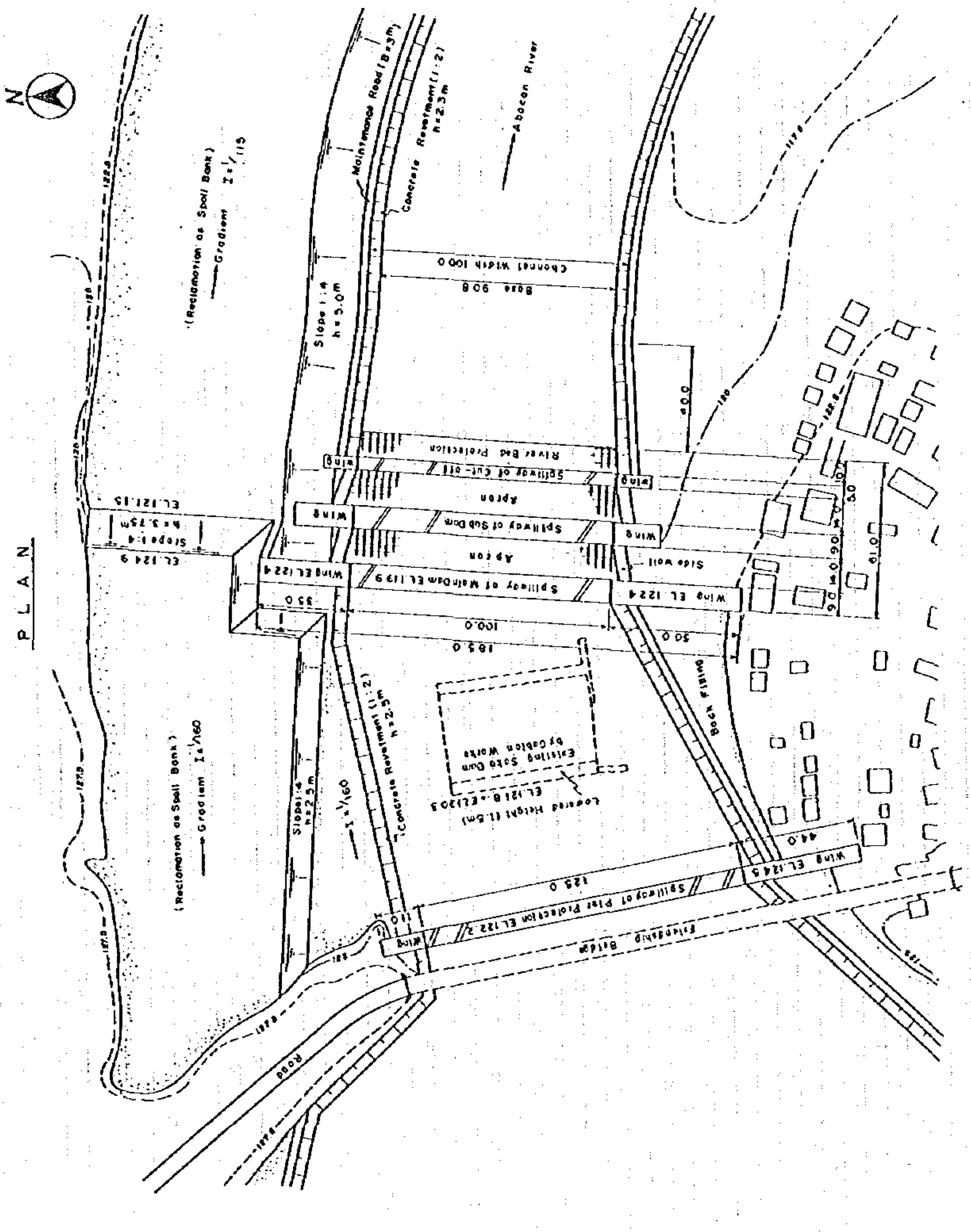


Figure A.23 Reconstruction Plan of Sabo Dam No.9 (1/6)

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



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
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Figure A.23 Reconstruction Plan of Sabo Dam No.9 (2/6)

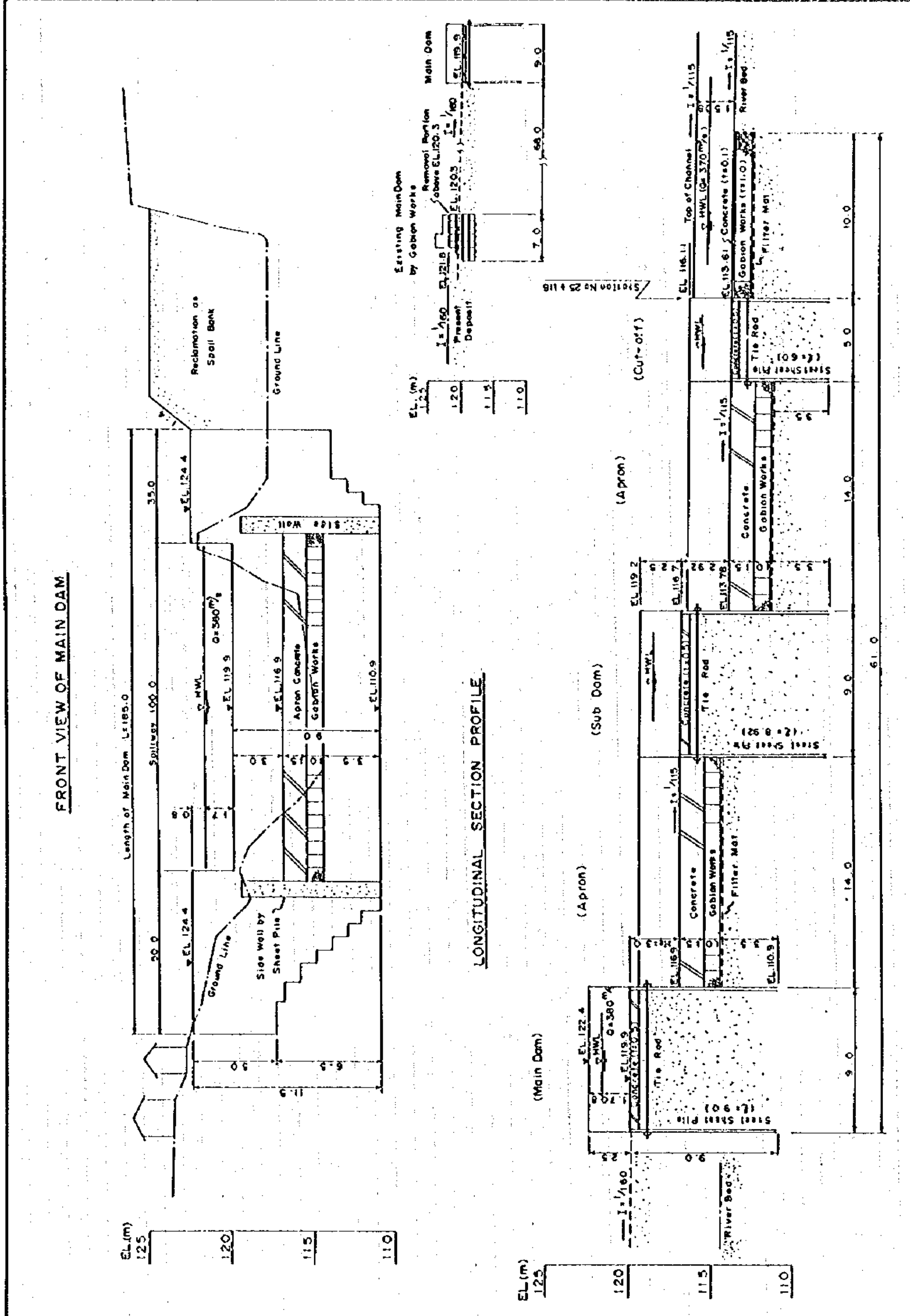

Figure A.23 Reconstruction Plan of Sabo Dam No.9 (3/6)

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

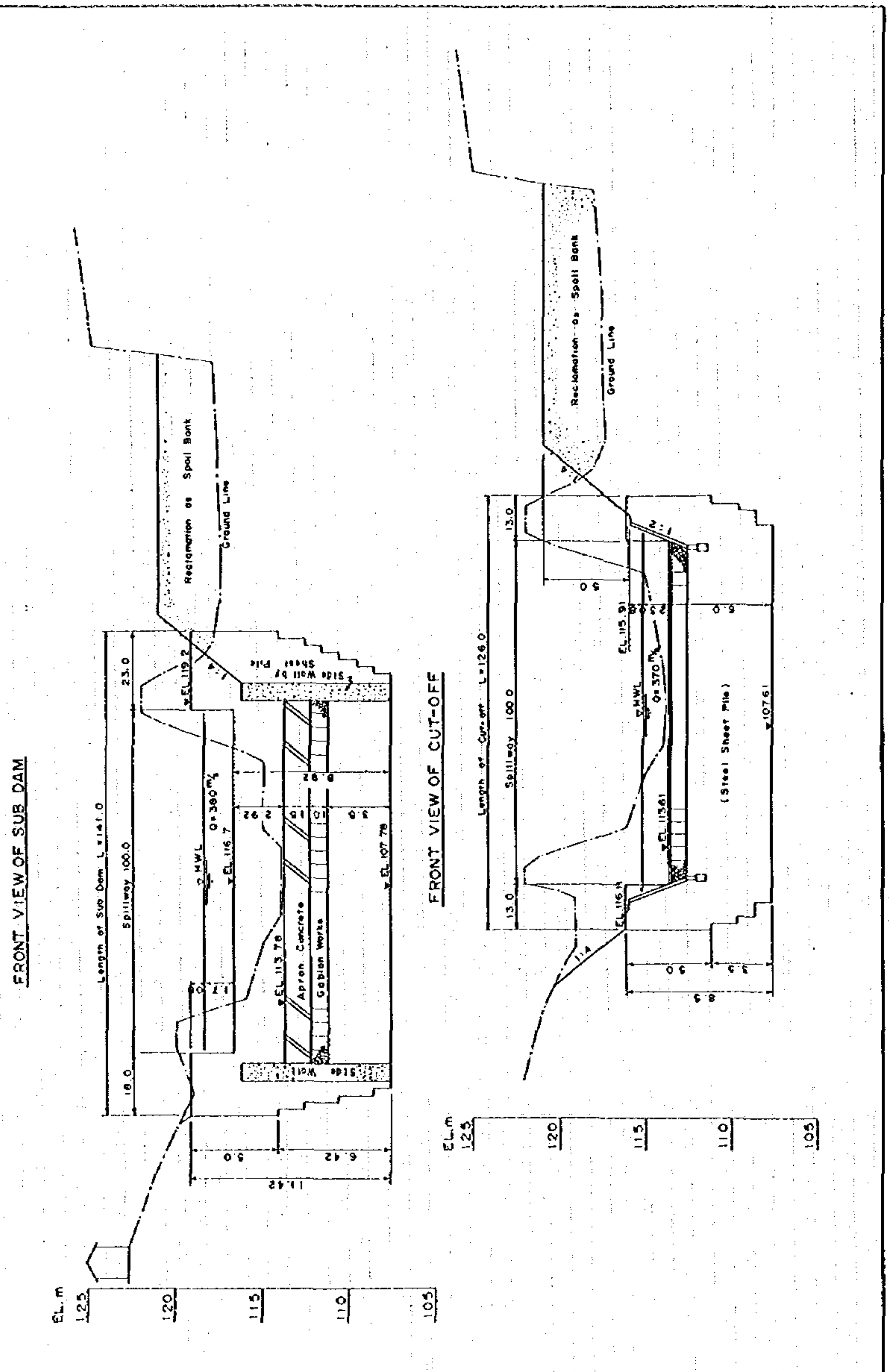

Figure A.23 Reconstruction Plan of Sabo Dam No.9 (4/6)

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
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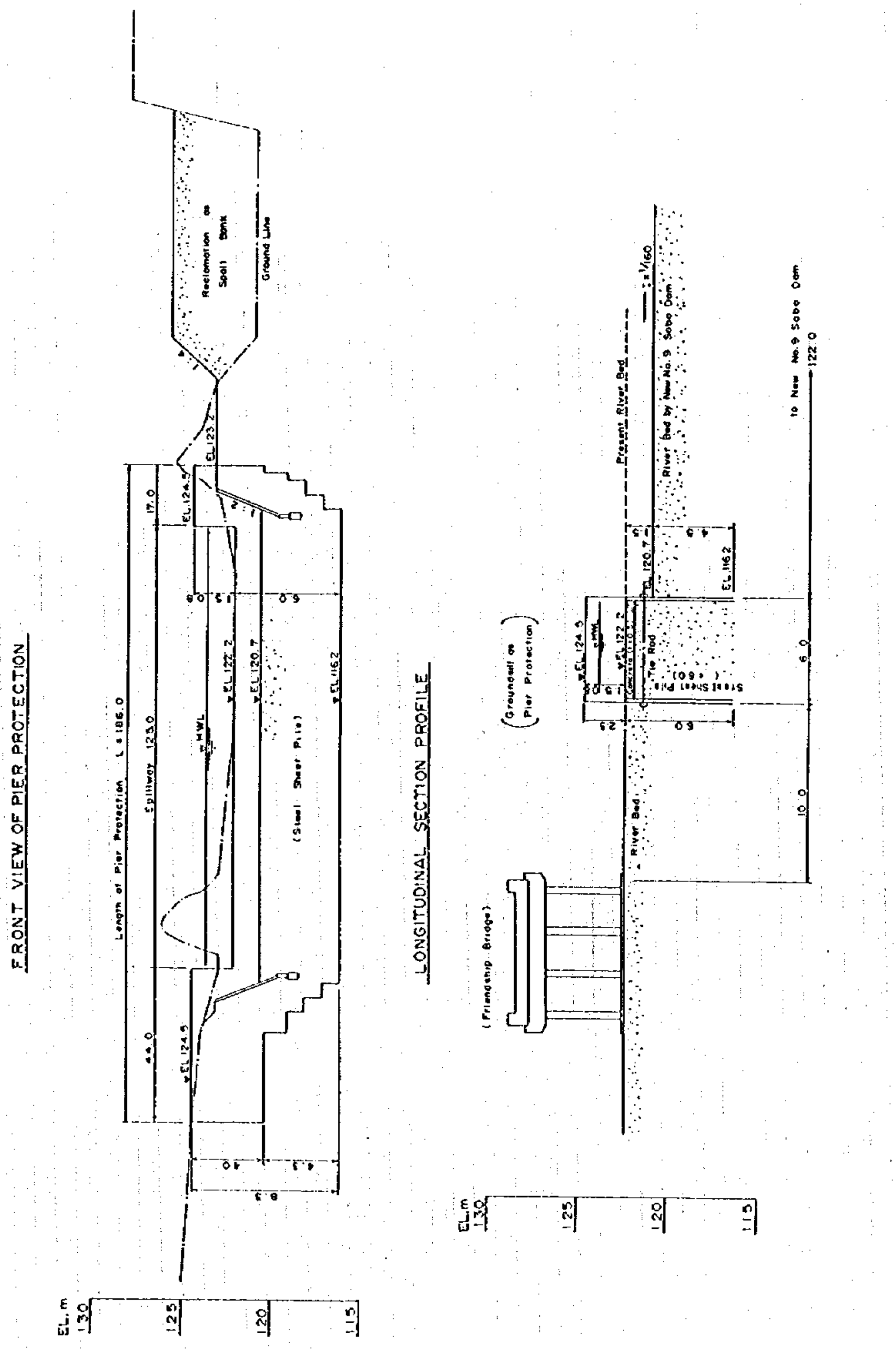

Figure A.23 Reconstruction Plan of Sabo Dam No.9 (5/6)

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
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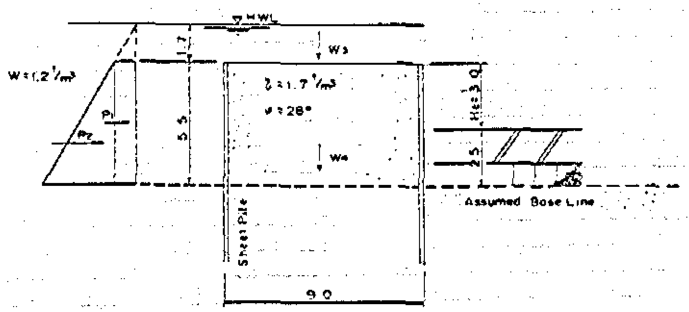
STABILITY OF MAIN DAM



Total Loads

$V = Ws + Wa = 18.36 + 84.15 = 102.51\ t/m$

$M = Ms + Ma - M_1 - M_2 = 82.62 + 378.675 - 30.855 - 33.275 = 397.165\ tm/m$

$H = P_1 + P_2 = 11.22 + 18.15 = 29.37\ t/m$

Safety Factor for Sliding

$n = \tan\phi \times V / H = 0.53 \times 102.51 / 29.37 = 1.85 > 1.2$ (O.K.)

Middle Third

$e = B/2 - M/V = 9.0/2 - 397.165/102.51 = 0.626^m < B/6 = 1.5^m$ (O.K.)

Stability against Shearing Deformation

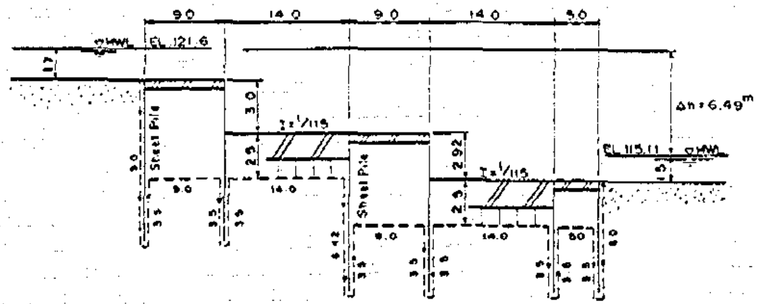
$Md = M_1 + M_2 = 30.855 + 33.275 = 64.13\ tm/m$

$Ro = (9.0/5.5)^2 (3 - (9.0/5.5)\cos 28°) \sin 28° = 1.955$

$Mr = \gamma R o h^3 / 6 = 1.7 \times 1.955 \times 5.5^3 / 6 = 92.16\ t/m$

$F = Mr / Md = 92.16 / 64.13 = 1.44 > 1.2$ (O.K.)

CREEP RATIO FOR PIPING



(1) Bligh's Method

$L = 9.0 + 3.5 + 9.0 + 3.5 \times 2 + 14.0 + 6.42 + 3.5 + 9.0 + 3.5 \times 2 + 14.0 + 3.5 \times 2$
$+ 5.0 + 3.5 + 6.0 = 103.92^m$

$\Delta h = 6.49^m$

$Cc = L / \Delta h = 103.92 / 6.49 = 16.0 > 15.0$ (Fine Sand) (O.K.)

(2) Lane's Method

$L = (9.0 + 3.5 \times 3 + 6.42 + 3.5 \times 6 + 6.0) + (9.0 + 14.0 + 9.0 + 14.0 + 5.0) / 3$
$= 69.92^m$

$\Delta h = 6.49^m$

$Cw = L / \Delta h = 69.92 / 6.49 = 10.8 > 7.0$ (Fine Sand) (O.K.)

Figure A.23 Reconstruction Plan of Sabo Dam No.9 (6/6)

THE GOVERNMENT OF THE PHILIPPINES
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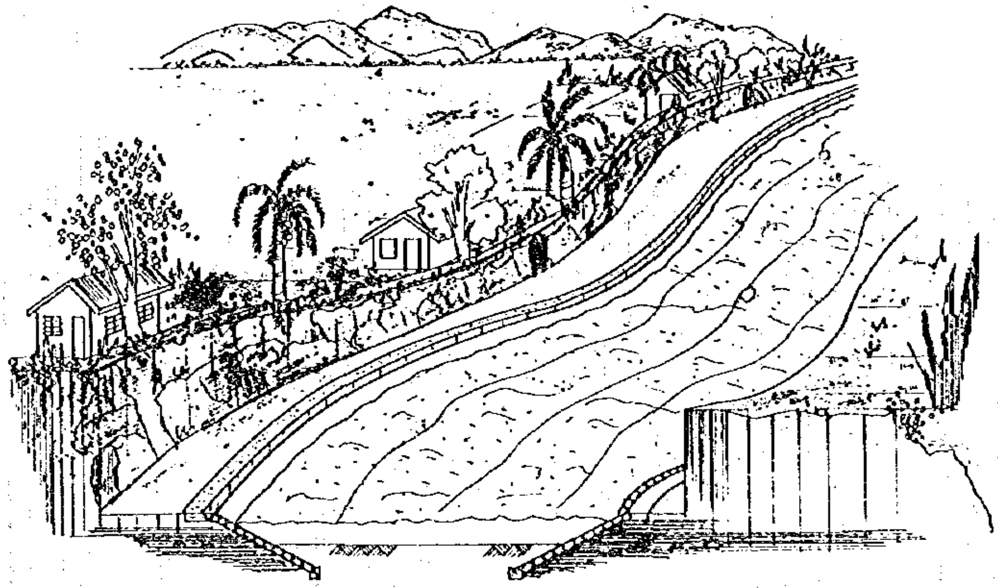
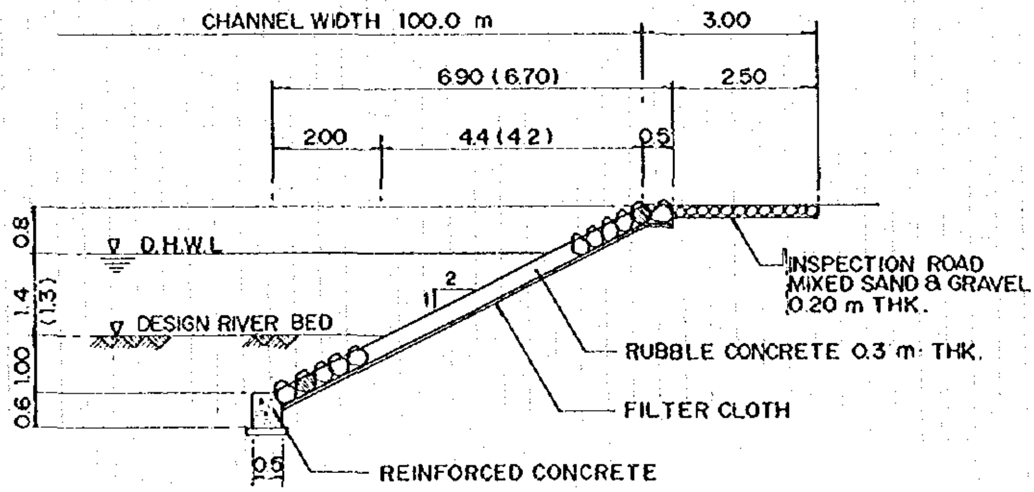


AERIAL VIEW



DETAIL OF SLOPE PROTECTION

NOTE:
WITHOUT ( ) CAPAYA BR. TO ABACAN BR.
WITH ( ) ABACAN BR. TO NO.9 DAM

Figure A.24 Proposed Training Works along Angeles City

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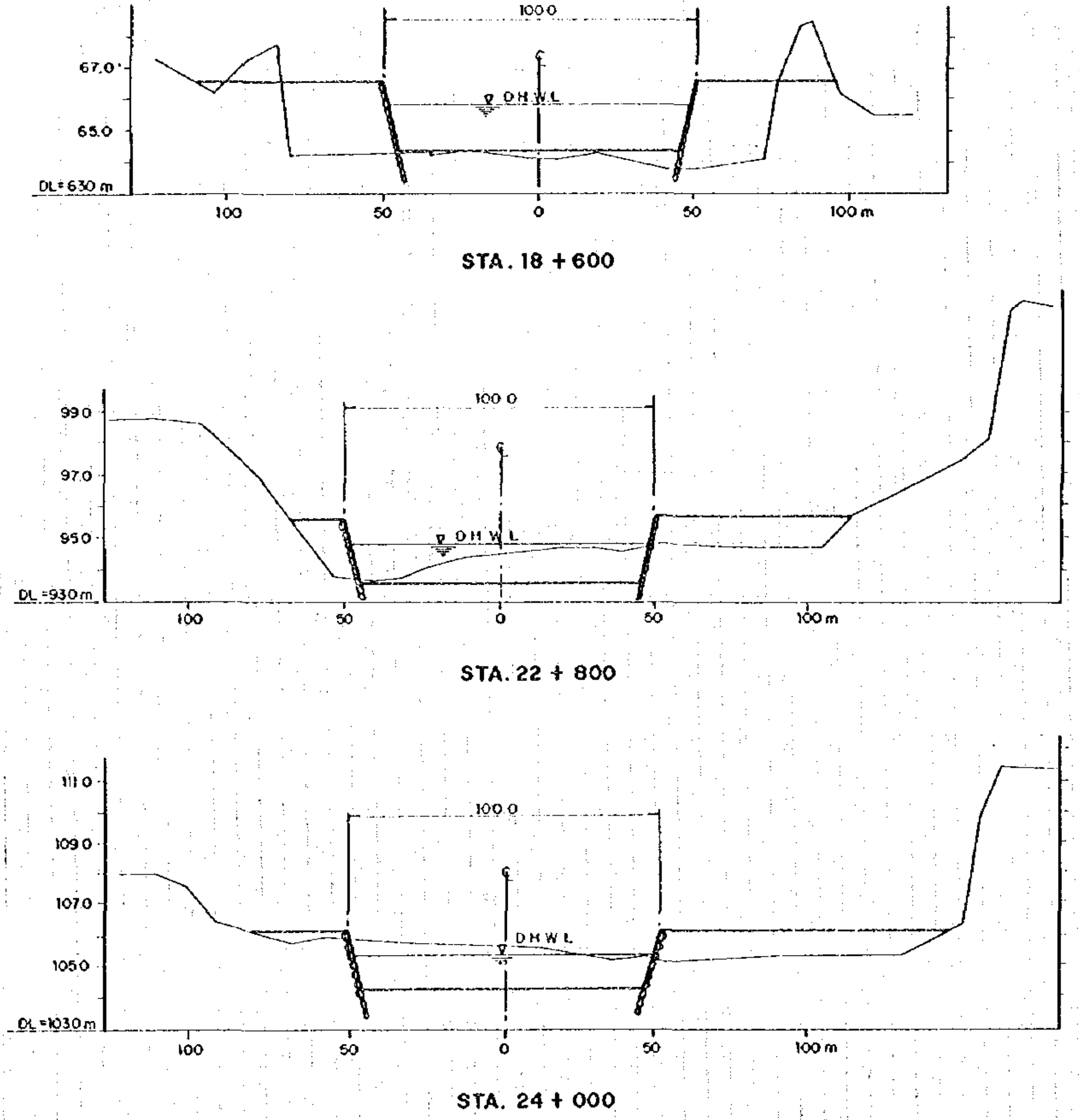

Figure A.25 Proposed Cross Sections of Middle Abacan River

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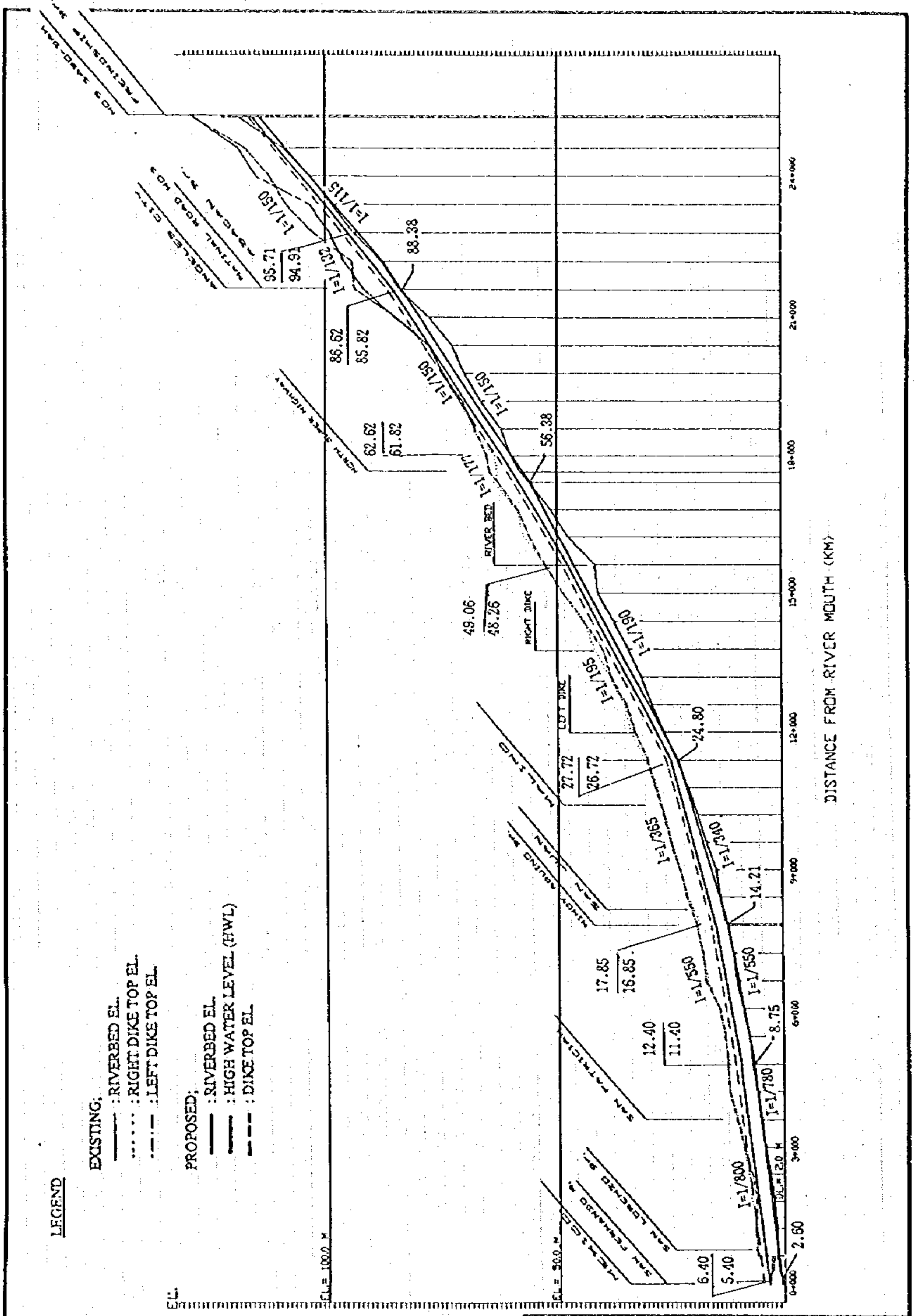

Figure A.26 Design Longitudinal Profiles of Abacan River

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THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
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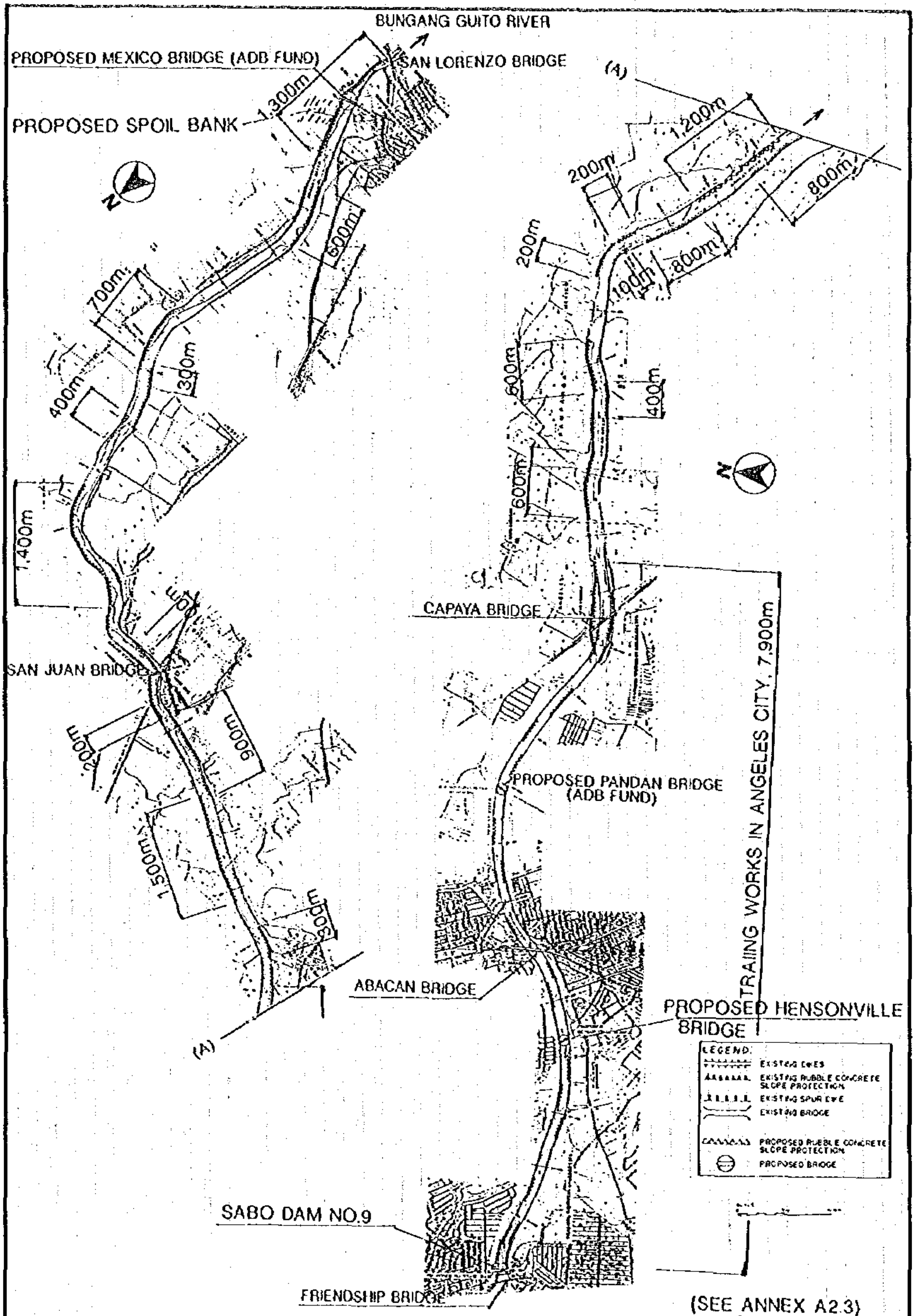


(SEE ANNEX A2.3)

Figure A.27 General Plan of Lower/Middle Abacan 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

ANNEX A1

DESIGN CRITERIA

ANNEX A1 DESIGN CRITERIA

A1.1 SABO STRUCTURE

(1) Flood Discharge (Q)

For spillway of dam	:	Q = 100 year return period discharge.
For channel works	:	Q = 20 year return period discharge.

(2) Design Mudflow Discharge (Qd)

$Qd = Q^* (1-Cs)$

where Cs	:	sediment concentration
Cs=0.1	:	for Sacobia diversion channel
Cs=0.2	:	for Maskup consolidation dam
Cs=0.1	:	for Sabo dam in Abacan river system

(3) Freeboard of wing (dH)

dH=0.6m	:	for $Q < 200\ m^3/s$
dH=0.8m	:	for $200 < Q < 500 m^3/s$
dH=1.0m	:	for $Q > 500 m^3/s$

(4) Hydraulics formula for apron of dam

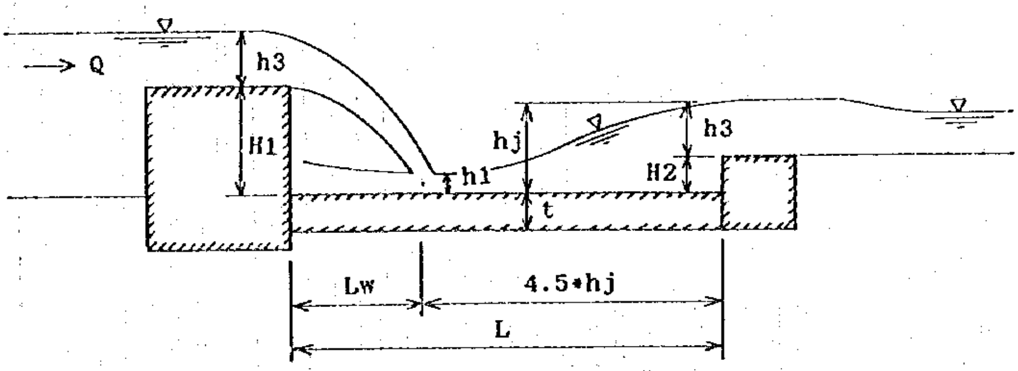
as shown in Figure 1.1

(5) Stability analysis method for double wall type dam

as shown in Figure 1.2

(6) Creeping ratio for piping of base ground

as shown in Figure 1.3



Discharge	Q
Width	B
Overflow Depth	h3=(Q/1.77/B)^(2/3)
Length of Top	Lw=(Q/B/h3)(2(H1+h3/2)/9.8)^0.5
Shooting Flow Depth	h1=Q/B/(19.8(H1+h3))^0.5
Froude Number	F1=(19.8(H1+h3))^0.5/(9.8*h1)^0.5
Length of Jump	hj=((1+8F1^2)^0.5-1)h1/2
Length of Apron	L=Lw+4.5*hj
Thickness of Apron	t=0.1(0.6*H1+3*h3-1.0) when H2=hj-h3 t=0.2(0.6*H1+3*h3-1.0) when H2=0

Figure 1.1 Hydraulic Formula for Apron of Dam

THE GOVERNMENT OF THE PHILIPPINES
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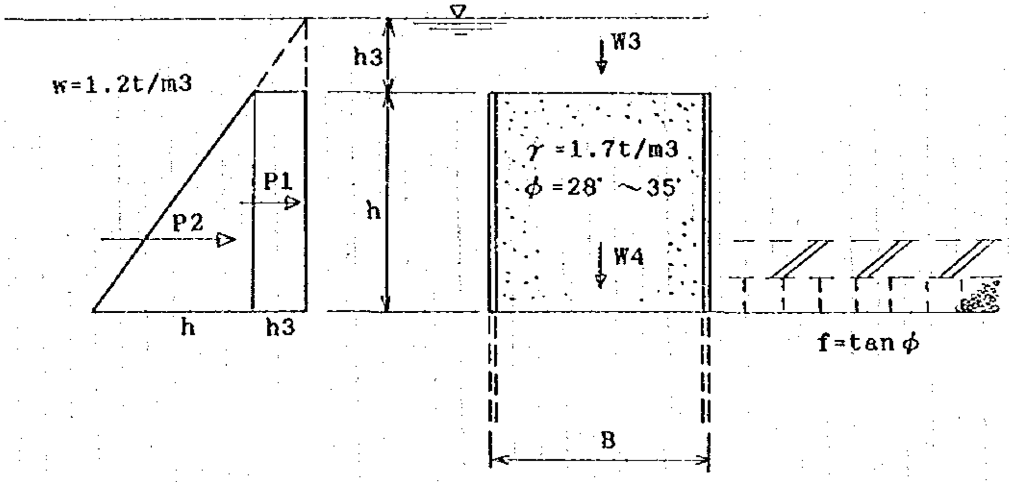


Water Pressure

P1=h*h3*w   a1=h/2   M1=P1*a1

P2=h^2*w/2   a2=h/3   M2=P2*a2

Water Weight

W3=h3*B*w   a3=B/2   M3=W3*a3

Own Weight

W4=h*B*γ   a4=B/2   M4=W4*a4

Total Loads

V=W3+W4

M=M3+M4-M1-M2

H=P1+P2

Safety Factor for Sliding

n=f*V/H > 1.2

Middle Third

e=B/2-M/V < B/6

Deformation Moment

Md=M1+M2=e*V

Resisting Moment

Mr=γ*RO*h^3/6

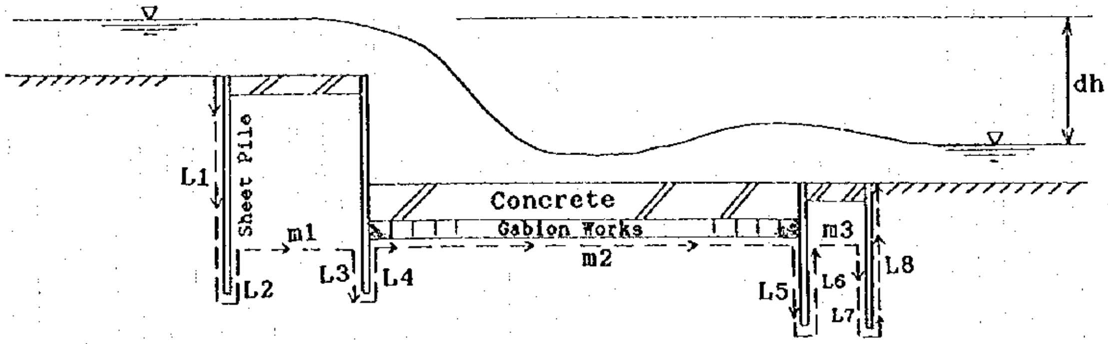
RO=(B/h)^2*(3-(B/h)cos φ)sin φ

Safety Factor for Shearing Deformation

F=Mr/Md > 1.2

Figure 1.2 Stability Analysis Method for Double Wall Type 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



(1) Bligh's Method

$$Cc \leqq (L1+L2+L3+L4+L5+L6+L7+L8+m1+m2+m3) / dh$$

Cc = 15 (for Fine Sand)

= 12 (for Coarse Sand)

= 9 (for Gravelly Sand)

(2) Lane's Method

$$Cw \leqq ((L1+L2+L3+L4+L5+L6+L7+L8)+(m1+m2+m3)/3) / dh$$

Cw = 7.0 (for Fine Sand)

= 5.0 (for Coarse Sand)

= 3.5 (for Gravelly Sand)

Figure 1.3 Creep Ratio for Piping of Base Ground

AI.2 RIVER STRUCTURE

To design the flood control works for the Sacobia/Bamban and Abacan rivers, the following design criteria are applied.

(1) Basic Guidelines, Standards and Criteria

1) Design Guidelines, Criteria and Standards for Public Works and Highways, DPWH, Philippines

2) Technical Standard for River and Sabo Works (Draft), Ministry of Construction of Japan.

(2) Flood Protection Level

1) A 20-year return period flood in Medium Term Plan.

2) A 5-year return period for Sapang Balen River joining together with Sacobia River.

(3) Design Discharge

1) Sacobia-Bamban River Basin

River	Reach	Design Discharge (m^3/s)
Bamban River (20-yr.)	No.9	1,260
	No.6	1,040
	No.5	580
Sapang Balen River w/ Sacobia River (5-yr.)	No.6	380
Sapang Balen River only (20-yr.)	No.8	310

Note: Design discharges computed under the basin of pre-eruption conditions are applied for Bamban River

2) Abacan River Basin

River	Reach	Design Discharge (m^3/s)
Abacan River (20-yr.)	No.3	370
	No.4	440
	No.6	520

(4) Freeboard

Design Discharge Q (m^3/s)	Freeboard (m)
$Q < 200$	0.6 m
$200 <= Q < 500$	0.8 m
$500 <= Q < 2,000$	1.0 m

(5) Design River Bed Slopes

A ratio of adjacent slopes should be less than 2.0 ($I_1/I_2 < 2.0$) considering stability of river bed.

(6) Design Flow Velocity

Maximum design flow velocity of 3.0 m/s is applied considering sandy bed materials.

(7) Water Level Computation Methods

1) Uniform Channel Sections

Manning's equation.

2) Non-uniform Channel Sections

Non-uniform flow calculation method.

(8) Roughness Coefficient

Roughness coefficient of 0.035.