The Study on Comprehensive Disaster Prevention
around Mayon Volcano

SUPPORTING REPORT (1)

(Part I : Master Plan)

III : Facility Design

SUPPORTING REPORT (1)-III
FACILITY DESIGN

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FACILITY DESIGN

1. THE CONDITION AND DESIGN PROBLEM OF THE EXISTING FACILITIES

1.1 The Distribution and the Present Condition of the Existing Facilities

The distribution map and cross section of the existing facilities is shown in figures as a data book.

Based on the existing data collection survey, the aerial photograph interpretation and the field survey, the distribution and the present condition of the existing facilities are summarised.

And based on the existing data from 1984 to 1992, the year of completion and the dimension of the existing facilities are summarised and shown in Tables III 1.1 to 1.7 as a data book.

The location of the broken and the vanished facilities have not been determined from the field survey and the aerial photographs. But these facilities have been listed in the inventory in Tables III 1.1 to 1.7 as a data book.

1.2 The Damaged Condition of the Existing Facilities

The damage condition of the existing facilities to be verified by the field survey is shown in Tables III 1.1 to 1.7 as a data book. The summary of the damage condition for the existing facilities is as follows::

(1) Consolidation Dam

The Whole overflow portion of the consolidation dam in the Basud River failed to function properly and was destroyed. In addition, owing to erosion of foundation along left bank on the Pawa-Burabod River, the consolidation dams in this river was broken away and also failed to function properly.

(2) Spur Dike, Training Dike

A part of spur dikes and training dikes were observed to be damaged or destroyed. In case of failure of spur dikes and training dikes, plenty of foundations for training dikes with stone pitching structure may be considered to be damaged or destroyed by erosion of basement or bump of boulders.

Especially many damaged and destroyed portions were observed in the Basud River, the Padang River, the Budio River, the Pawa-Burabod River, and the Anoling River, situated from the southeast area to the southwest area.

1.3 The Cause of Damage of the Existing Facilities

The causes of damage of the existing facilities to be supposed from the damage condition are as follows:

(1) Consolidation Dam

The cause of failure of the consolidation dam is considered as follows:

- the failure of the front apron from being hit by boulders as they rolled over the dam
- after the front apron was destroyed, a part of the foundation of the dam was eroded away

The conditions of the failed consolidation dam are shown in the figure “Situation of Failure of Consolidation Dam in Basud River” and explained as follows:

- The base of the consolidation dam consists of a loose fresh sediment material, so that the downstream part of the facilities is easy eroded.
- It is considered that the apron length of the existing consolidation dam, which is been induced by the field empiric is too short to protect the piping of sand and gravel base.
- There are lots of large boulders, 1.0m to 1.5m in diameter, along the channel downstream of the dam site, which are considered to be transported with mudflows. Although the large boulder probably bumped the wing section of the consolidation work, both sides of it were not destroyed.
- The traces of sedimentation soils along both sides of the five upstream of the dam show the consolidation work that consolidation work itself was in a state full of sands.
- It is considered that the failure of the consolidation dam was caused by the destruction of the front apron by the erosion under vertical wall and impact of large boulders.

A process of failure of the consolidation dam in the Basud River can be explained as follows and the figure “Process of Failure of Consolidation Dam in Basud River”:

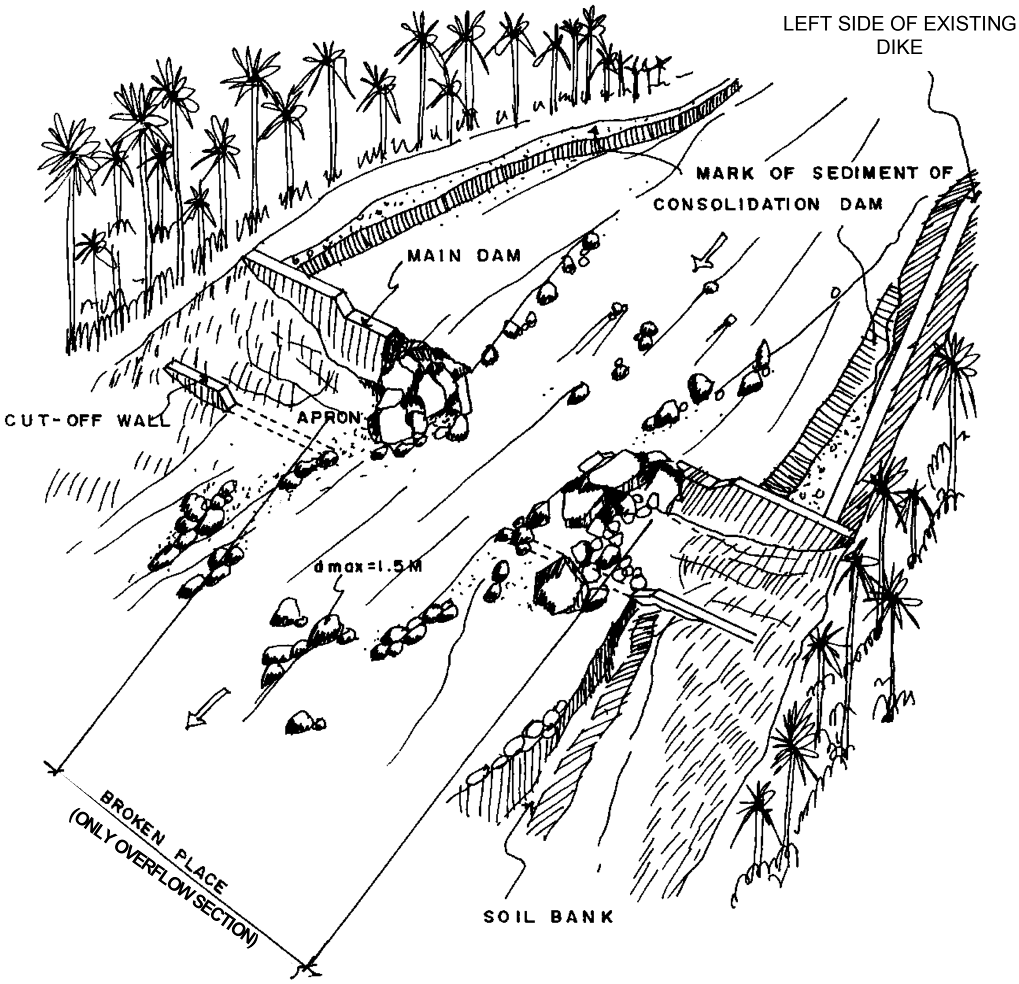
a) Since large boulders had fallen on to the main consolidation work, the front apron was under abrasion. At the same time, the vertical wall downstream of the body was broken away.
b) A part of the front apron was destroyed by the impact of boulders. Then a large part of the foundation with the apron was scoured off, and the apron became unsteady.
c) After both the front apron and the vertical wall were destroyed, the foundation of the body was eroded away.
d) Owing to enlarged erosion on the foundation, loose boulder concrete inside the dam body was flowed out.

NO.1-(1)

BASUD RIVER

1. BROKEN CONDITION OF CONSOLIDATION DAM (H = 5.0M)

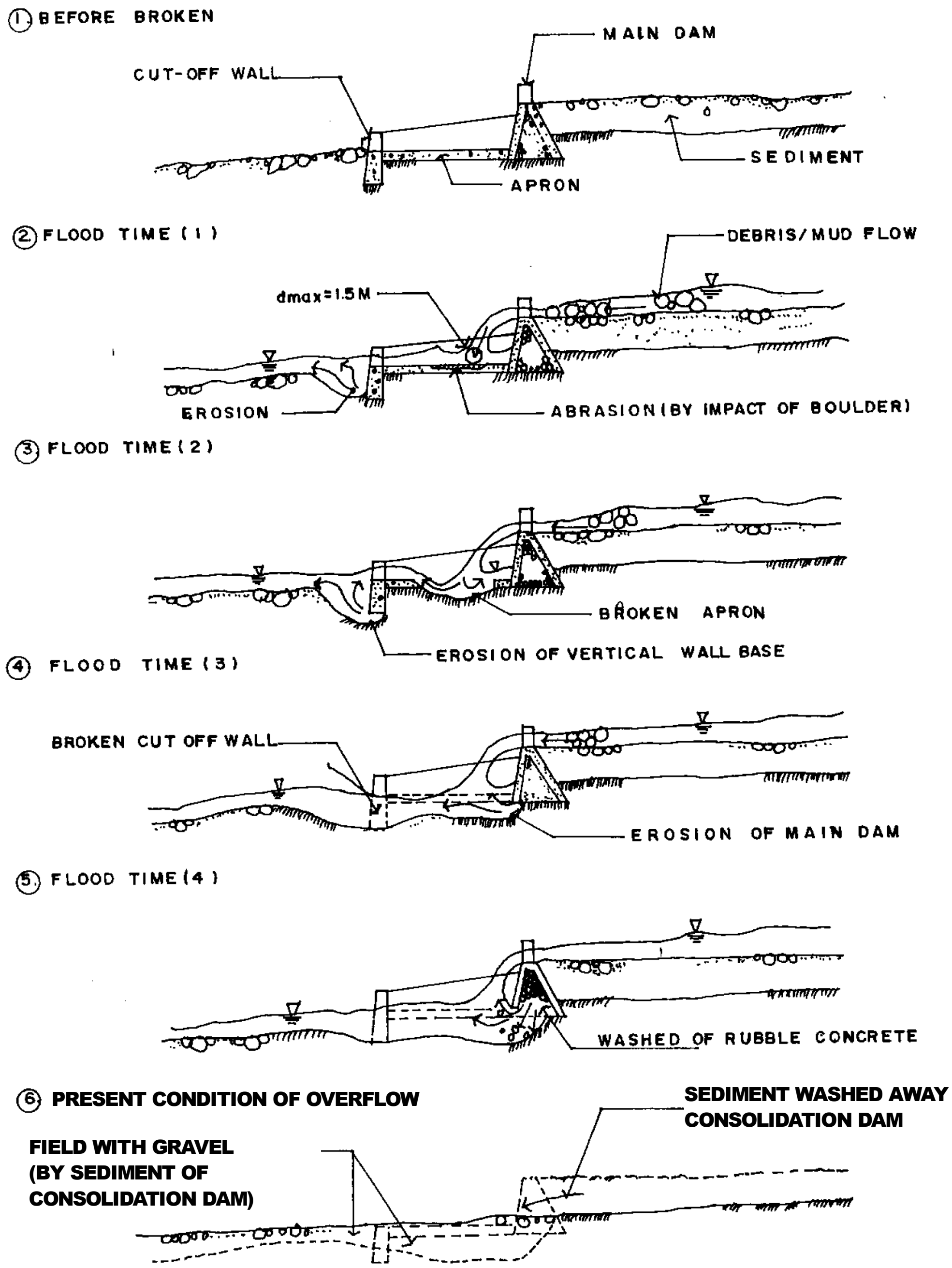
(600M UPSTREAM FR. NATIONAL ROAD)



Situation of Failure of Consolidation Dam in Basud River

NO.1-(2) = BASUD RIVER

2. PROCESS OF BROKEN CONSOLIDATION DAM (OVERFLOW SECTION)



Process of Failure of Consolidation Dam in Basud River

(2) Spur Dike, Training Dike

The cause of failure of the spur dike and the training dike is as follows:

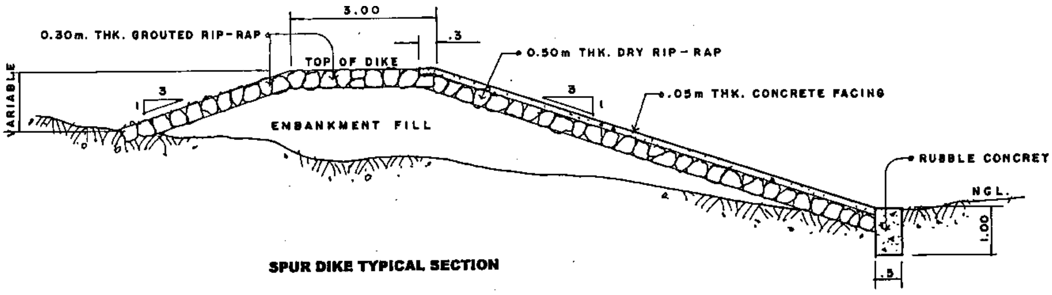
- Some cracks on the facing wall of dike have occurred by impact of boulders flowing down the river.
- The foundation of the dike has been eroded because of a short penetration, and the fill material has been washed away.

It is considered that these two combined causes resulted in failure of the dikes, for the following reasons:

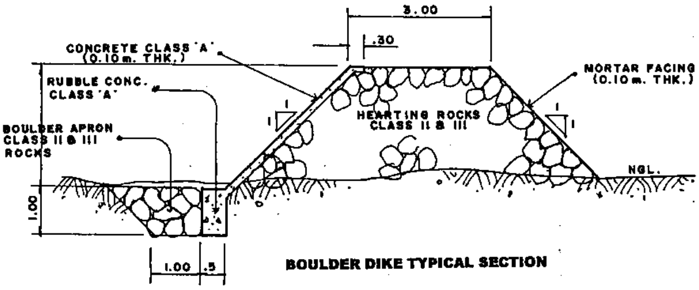
- The fill material in dikes has used loose and porous sand and gravel in-situ. Therefore the concrete facing and the boulder facing could be broken under impact of boulder.
- Gaps or openings were observed between the facing of the dike and fill material in the dike, and there are floating portions of the levee crown relative to setting of the fill material in dikes.
- Gaps or openings between the facing of the dike and a material for stuff in the dike have extended furthermore by the inside materials being washed away because of settling, flowing, and eroding.
- The slope gradient of embankment in the existing dikes is very gentle in 1:2.5. This proves that the material for filling is not strong in compaction.
- The location of failure of dikes is on the undercut slope banks which were attacked directly by debris flow and boulders with a diameter of 1.0 - 2.0m.
- It is recognized that a scouring of the downstream to the cross dikes and channel bank where spur dikes are situated reveals a short of foundation depth of facilities.

The example of failure of the spur dike in the Bulawan River, Anoling River, and the Padang River is shown in the following figures.

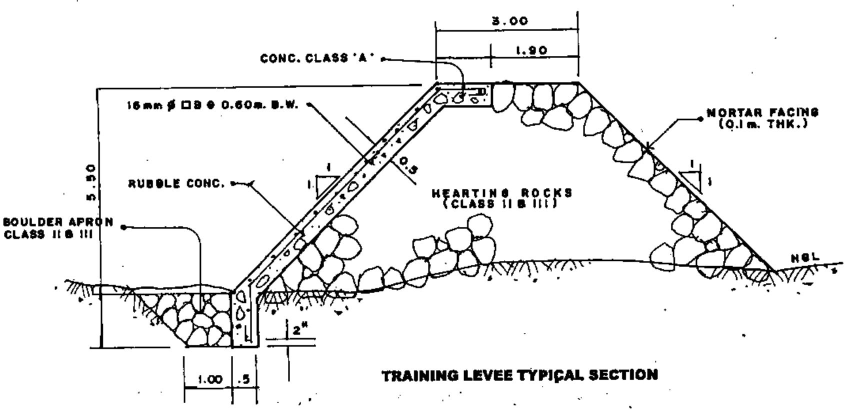
- The main cause of failure of the spur dike in the Bulawan River is considered to be from being bumped by boulders.
- The main cause of failure of the spur dike in the Anolin River is considered to be from both the erosion of the basement and being bumped by boulders.
- The cause of failure of the spur dike in the Padang River is considered that a part of the foundation of the dam eroded away and was mainly destroyed, so fill material in dike was washed away, and the broken portion was expanded more by impact of boulders.



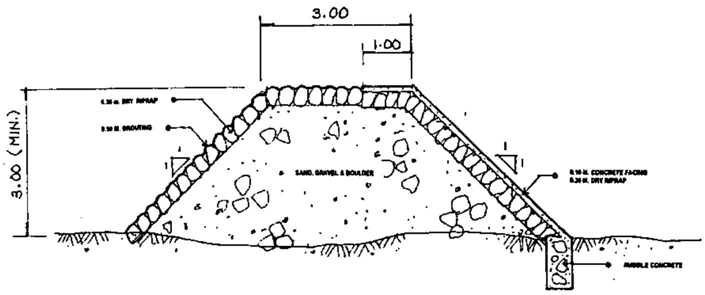
SPUR DIKE TYPICAL SECTION



BOULDER DIKE TYPICAL SECTION



TRAINING LEVEE TYPICAL SECTION

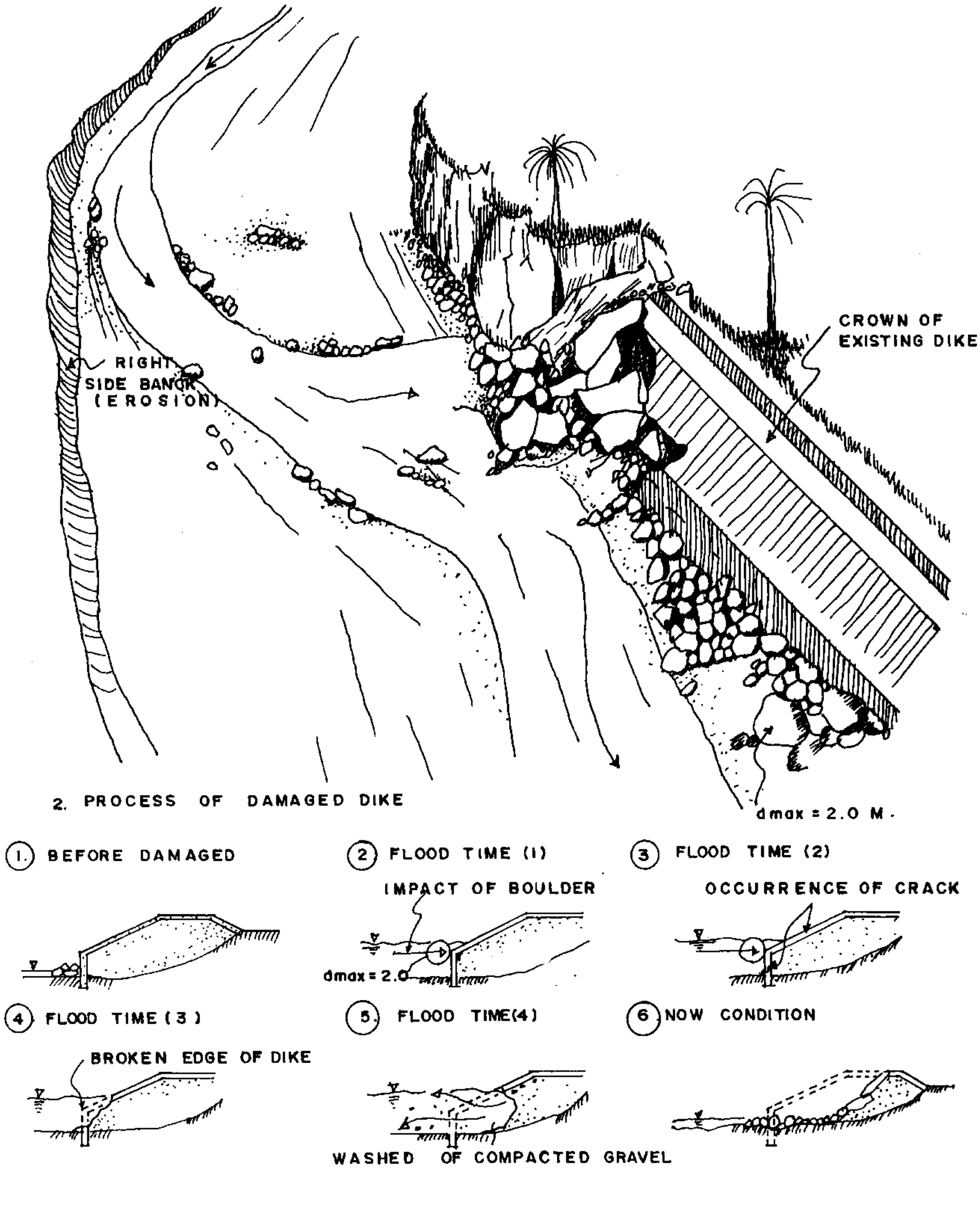


TYPICAL SECTION OF REVETMENT

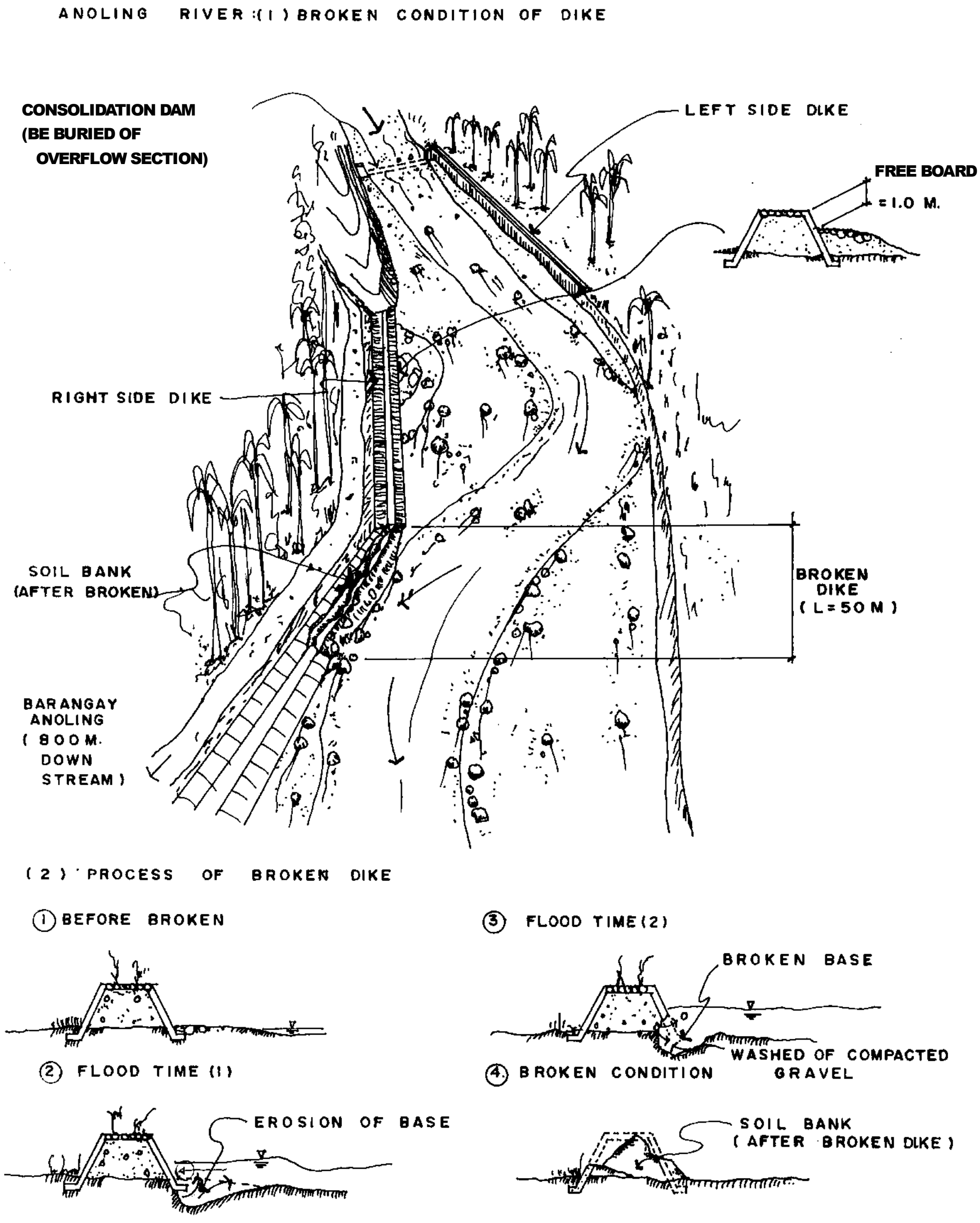
Typical Section of Dike

BULAWAN RIVER = DIKE

1. DAMAGE CONDITION OF LEFT SIDE DIKE (UPSTREAM FROM N.R.)



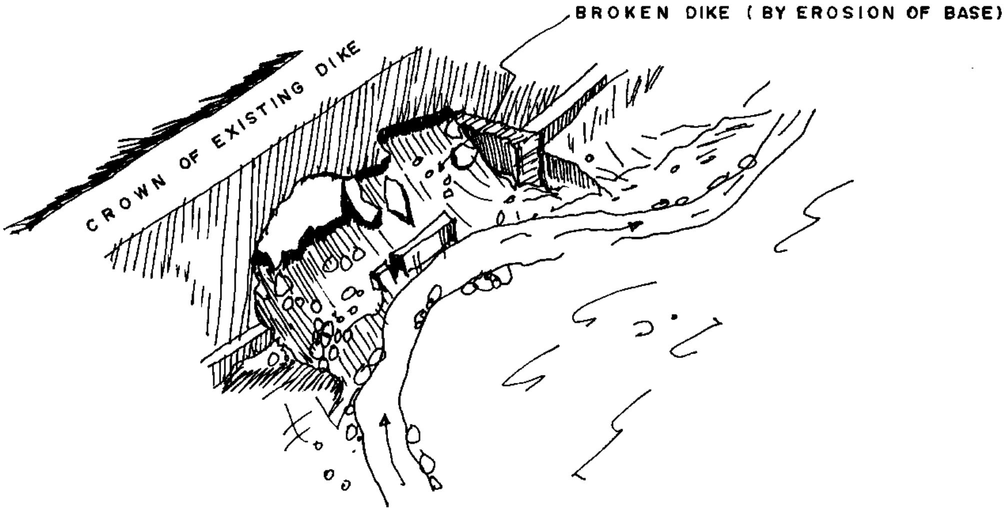
Situation of Failure of Spur Dike in Bulawan River



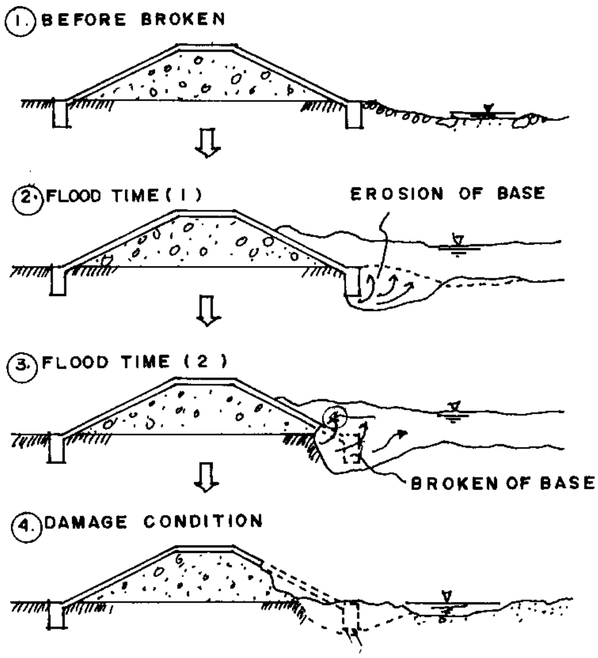
Situation of Failure of Spur Dike in Anoling River

PADANG RIVER

1. DAMAGE CONDITION OF LEFT SIDE DIKE



2. PROCESS OF DAMAGED DIKE



Situation of Failure of Spur Dike in Padang River

2. THE BASIC CONDITION OF FACILITY DESIGN

2.1 Phenomenon and Magnitude to be Treated by the Sabo Facilities

(1) Phenomenon to be Treated by the Sabo Facility

Phenomenon to be treated by the Sabo facility is assumed to be debris flow and mud flow which is triggered by rainfall accompanied with the Mayon Volcano eruption soon and after.

(2) Probable One Day Rainfall

Probable one-day rainfall as design magnitude will be examined as follows:

- 10 year
- 20 year
- 50year

2.2 Life Period of Facility

A 30-year life was set for the facilities. O&M work must keep the facilities functioning after they are built.

2.3 Functions of Sabo Facilities to be Required

Based on the condition of failure of the existing facilities, functions of proposed Sabo facilities will be required as follows.

(1) Consolidation Dam

- The front apron of dam must be protected from itself failing.
- Control of abrasion of apron and erosion under vertical wall.
- If the apron of dam break, consolidation dam must be designed not to spread an effect of failure to the main dam body.
- Proposed facility must resolve the problem of piping and low allowable bearing capacity.

(2) Spur Dike

It is desirable to be used the inside material with the following conditions:

- Fill material in dike must not be setting and flowing away.
- Facing wall and inside material must strengthen to be protected from impact of boulder.
- If the foundation of dike is eroded, whole dike body must be strong enough to prevent the failure spreading to the main body.

- Easy construction work, low cost, and high local content
- The foundation depth of the existing spur dike is 1m. These foundations have been scoured by debris flow in some location. The foundation will be the depth of 2m, which is commonly used on sand and gravel area in Japan.

CSG (Cemented Sand and Gravel) method satisfies the above condition.

2.4 CSG（Cemented Sand and Gravel）Method

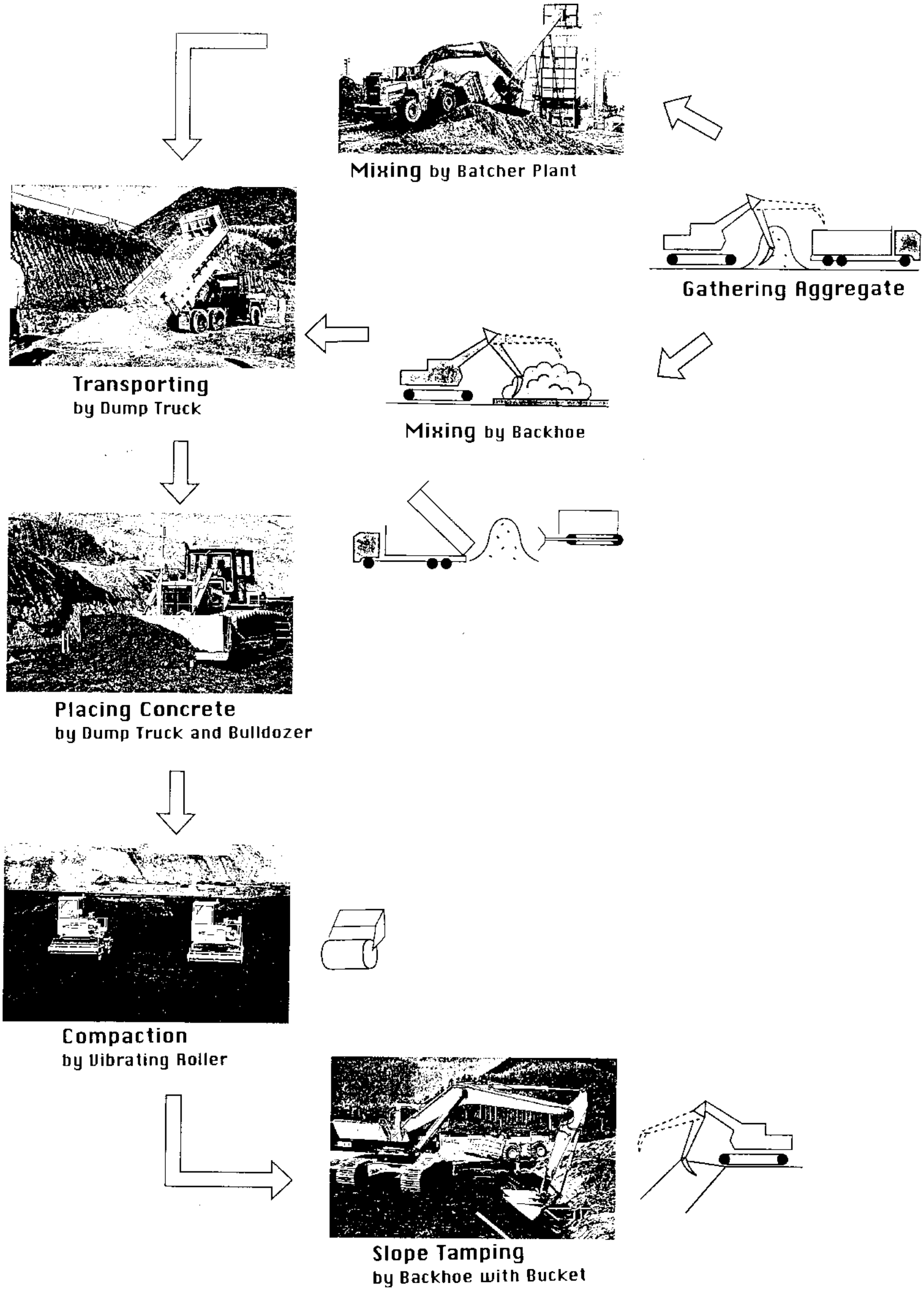
CSG method is a kind of aggregate as the filling material for created embankment of spur dike and construction dam. That is a mixture of sand-gravel in site, ordinary cement, and water. CSG method has taken the following making process.

1) Composition of CSG
2) Mixing by batcher plant of cemented sand and gravel
3) Transporting cemented sand and gravel
4) Placing concrete by dump truck and bulldozer for cemented sand and gravel
5) Compaction of cemented sand and gravel
6) Expansion joints, curing

The feature of CSG method is as follows:

- CSG is useful for local content in site
- CSG can slim down the material volume for facility to strengthen materials compared to the fill method.
- Although construction sequence of CSG is almost same as the fill dam type, construction period can expect to be reduced, so that it is possible to work what it is raining.
- Advantage of CSG method is easy construction work, low cost, and high local content.

Sabo works in Unzen in Japan and Pinatubo have already used CSG and have shown its advantage. Construction procedure of CSG. Method is shown in the following figure.



Construction Procedure for CSG Method

3. STRUCTURE OF FACILITY

3.1 Consolidation Dam

(1) Consolidation Dam with Effective Height of 3.0 - 5.0m

The proposed consolidation dam with effective height of 3.0 - 5.0m will be designed with the following structural conditions (see the following figure):

- The slope is designed with gentle gradient to protect from abrasion and failure on the apron.
- The cross sectional design of the overflow portion uses slit dam type with single section to protect the scoring accident to the facility.
- The concrete facing material is made of concrete. The inside material is made of CSG.
- The width of main body is designed wider than the concrete dam to protect piping and impact from debris flow.
- The width of crown is 5m, considering the regulation of construction for CSG.
- Boulders are placed on the downstream from facility to protect degradation of river bed as the occasions demands.

Concrete facing of overflow portion is thicker than non-overflow portion because of impact pressure against boulder attacking.

Advantage of using the CSG for the inside material is summarized as follows:

- The CSG can use the spoil material, which is excavated for the facility construction work and the dredging work.
- The structure for the CSG has enough strength to withstand the attack of the debris flow. If the concrete facing of facility is broken on a portion by debris flow, the critical damage does not affect the inside material made of CSG.
- The formwork for the CSG dam is not needed because of being gentle gradient to the facing slope.
- There is enough construction yard for constructing CSG facility.
- The surface of crown made by CSG method can be designed wider than the concrete dam. Therefore, the top surface of the facility can be used for multi-purposes.
- It is easy to obtain the equipment for CSG construction locally such as dump truck, bulldozer, and vibration roller.

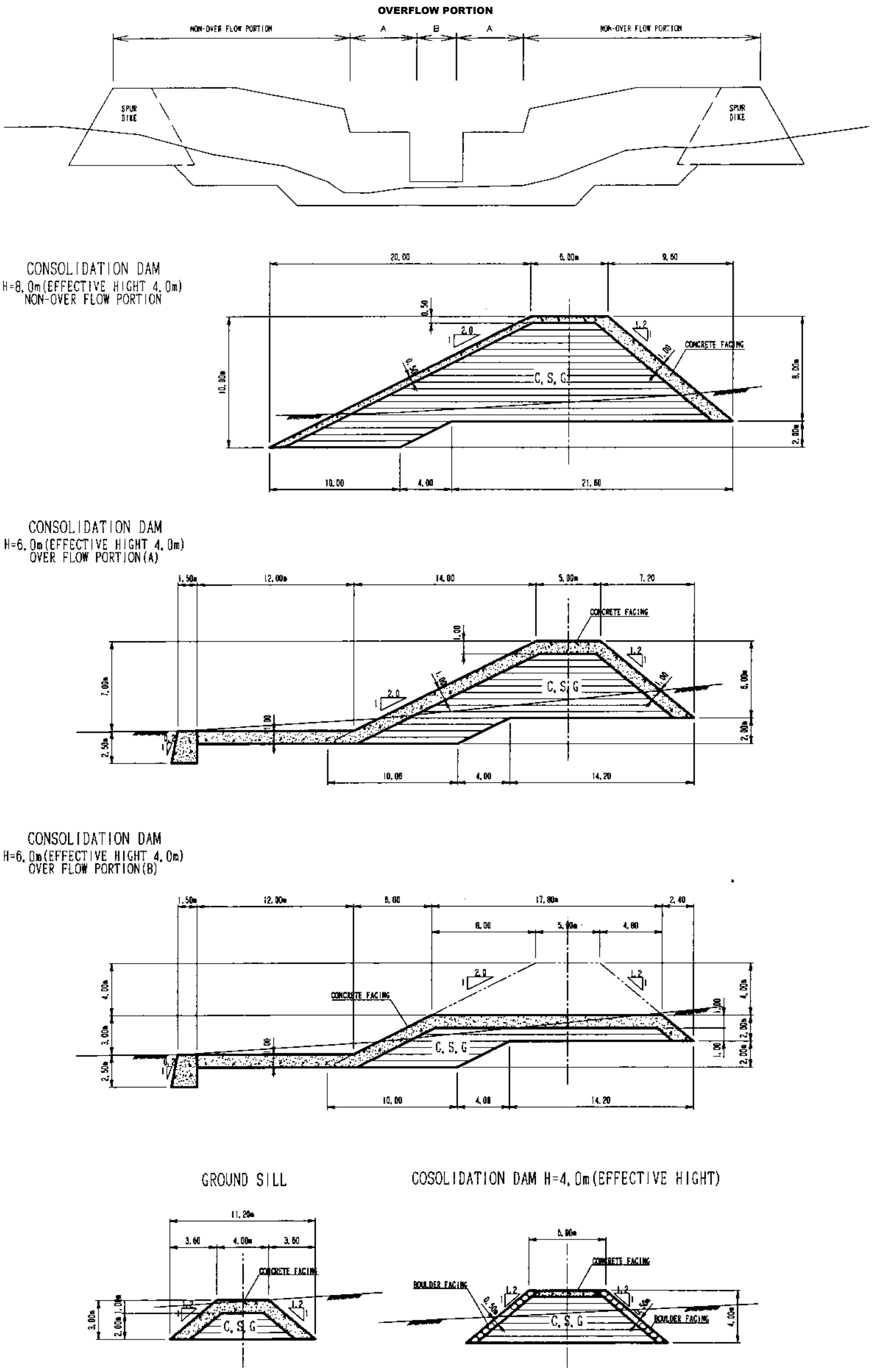
The following table, which compared with the concrete dam and the CSG dam demonstrate of the value of using the CSG method. According to the comparison between the concrete dam and the CSG dam, the CSG dam has high advantage in cost performance and simplicity of construction.

(2) Consolidation Dam with Effective Height of 1.0 - 1.5m

The proposed consolidation dam with low effective height of 1.0 - 1.5m will have a 6.0m wide crown, which is used to combine with the barangay road.

(3) Ground Sill

The proposed groundsill will have 4.0m wide crown, which is a minimum value in considering with CSG construction work.



Consolidation Dam Type

Comparison between Concrete Dam and CSG Dam

Item	Concrete	Cemented Sand and Gravel
	Effective Hight: 3.0m, Hight: 5.5m Length of Apron: 18.0m Upstream Slope 1: 0.2 Downstream Slope 1: 0.2 Slope: stability analysis, water depth 2.0m Length of Apron: emprocal formula and Bligh's formula	Effective Hight: 3.0m, Hight: 5.5m Cutoff: 1.0m, Length of Apron: 10.0m Upstream Slope 1: 1.2 Downstream Slope 1: 2.0 Slope: from construction way Length of Apron: emprocal formula and Bligh's formula
Strength	Enough strength for impact pressure, erosion and over flow	No problem for debris flow by concrete facing
	O	O
Cost per 100m	Concrete for Dam: 2,260	Concrete Facing: 2,600
	Apron: 2,770	Apron: 1,340
		CSG: 4,900
	Cost (peso): 12,575,000	Cost (peso): 11,810,000
	Δ	O
Period of Construction by Mizunasi Instance	1.2 month (per 100m)	1.5 month (per 100m)
	Concrete Volume/250m³/day	CSG Volume/600m³/day
	17 day/month	15 day/month
	O There is very little difference between two type.	O
Simplicity of Construction	Not easier than CSG	Main works are by machines Easy construction work
	Δ	O
Local Supplement	Low local Supplement	High local supplement
	×	O
Total Decision	It is not better than CSG. High cost, not easy construction work.	It is better than Concrete dam. Low cost, easy construction work, high local supplement.
	Δ	O

Notes: Performance Grade

O: Good

Δ: Average

×: Failing

3.2 Spur Dike and Training Dike

(1) Spur Dike

Four types of structures are considered for the design of the spur dike according to the topographical and hydrological condition (see the following figure).

1) Type A (all CSG)

Type A consists of all CSG as material for stuff in dike. Type A will install the section with high possibility for an attack and an overtopping of debris flow.

2) Type B (CSG + Embankment)

Type B consists of CSG in half of the outside and embankment in half of the inside. Type B will install the section with the low possibility for an attack and an overtopping of debris flow.

3) Type C (Embankment)

Type C consists of embankment only. Type C will install the downstream section with small size of river bed material and the low possibility for attack of debris flow. Material for stuff in dike will use the sand and gravel as usual.

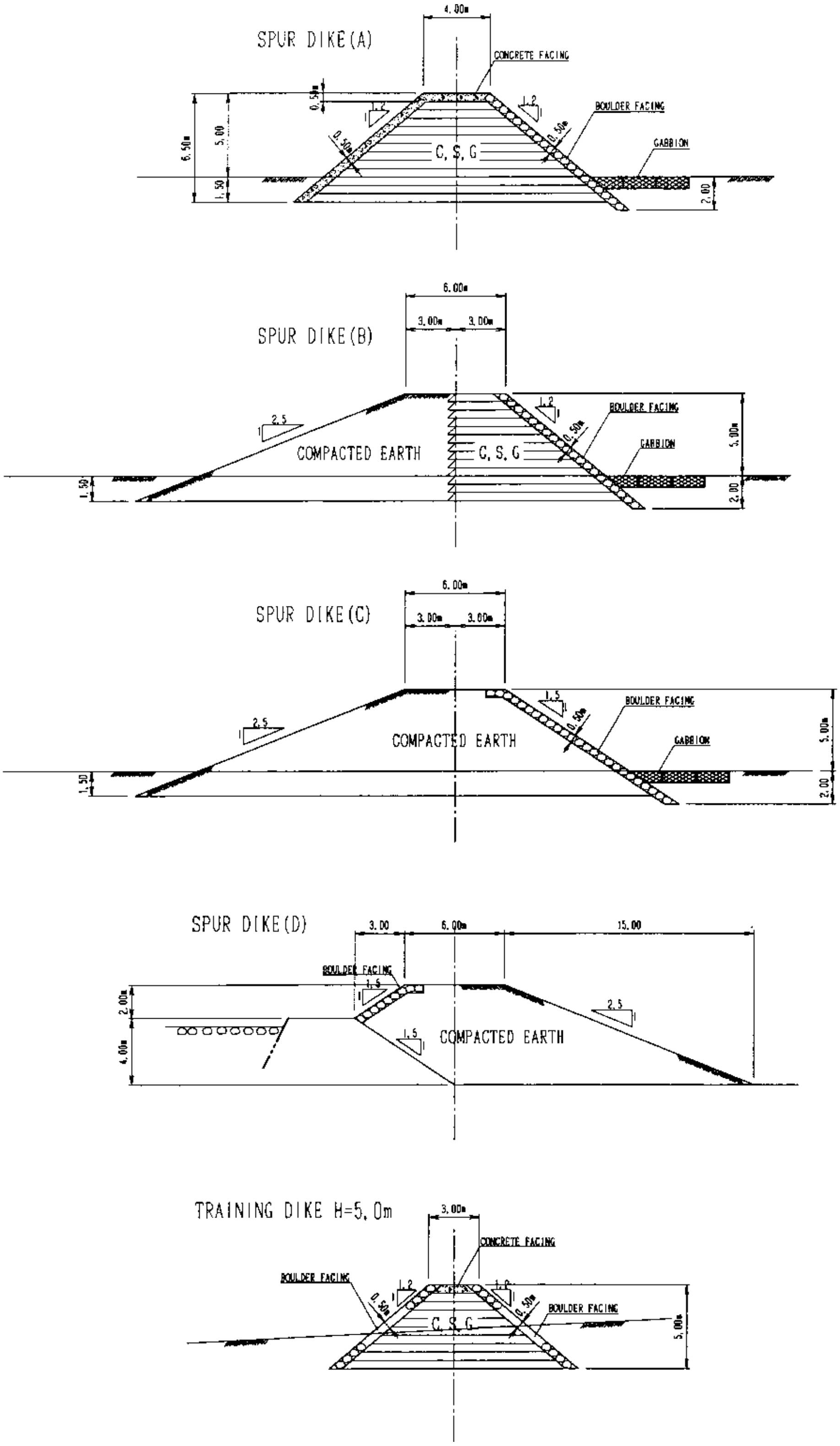
4) Type Ｄ (Raising)

Type D is the raising work for spur dike. Material for stuff in dike will use the sand and gravel as usual.

The following table which compared with the concrete, the CSG and the embankment demonstrate of the value of using CSG method. According to the comparison between three kinds of material, CSG type has high advantage in the section which is required the strength to debris flow attach. On the other hand, embankment type has advantage in the section, which is not required, so much to debris attack.

(2) Training Dike

The proposed training dike is made of CSG method to reduce the construction land as much as possible for effective utilization in the paddy field.



Spur Dike Type

Comparison between Materials of Dike

Item	Concrete	Cemented Sand and Gravel	Embankment
Strength	Enough strength for impact pressure, erosion and over flow.	No problem for debris flow by concrete facing.	Existing facilities are broken. It is problem for debris flow.
	O	O	Δ
Cost per 100m	Concrete: 4,160	Concrete Facing: 660	Concrete Facing:
	Boulder Facing: 390	Boulder Facing: 550	Boulder Facing: 630
	Formwork: 1,570	CSG: 6,500	Embankment: 11,760
	Cost (peso): 11,965,000	Cost (peso): 5,350,000	Cost (peso): 3,612,000
	Δ	O	O
Period of Construction by Mizunasi Instance	1.0 month (per 100m)	0.7 month (per 100m)	0.6 month (per 100m)
	Concrete Volume/250m^3/day	CSG Volume/600m^3/day	Embankment/1,300m^3/day
	17 day/month	15 day/month	15 day/month
	Δ	O	O
Simplicity of Construction	Not easier than other types.	Main works are operated by machines. Easy construction work.	Main works are operated by machines Easy construction work
	Δ	O	O
Local Supplement	Low local Supplement	High local supplement	High local supplement
	×	O	O
Total Decision	It is not better than other type. High cost, not easy construction work.	It is better than other types. Low cost, easy construction work, high local supplement.	It is better than other types, when it does not need strength for debris flow.
	×	O	△

Notes: Performance Grade

O: Good

Δ: Average

×: Failing

4. ALTERNATIVE PLANS

The basic components of each alternative plan for sabo planning are given below:

4.1 Sand Pocket

The proposed sand pocket alignment is composes of the long spur dikes and the consolidation dam. This alignment is designed to trap sediment material, and to protect houses and cultivated area widely.

4.2 Spur Dike and Training Dike

The proposed spur dike and the training dike converge debris flows into the one channel, and flow the debris out to the downstream safely and directly.

4.3 Protection Dike

The proposed protection dike is designed to protect only houses. The debris can flow over the cultivated area except protected area.

5. STRUCTURE AND DIMENSION ON EACH ALTERNATIVE PLANS

5.1 Structure and Dimension

The type of facility is shown in below. The structure of facility is shown in the previous figures.

(1) Consolidation Dam and Ground Sill

1) Consolidation dam (with notch portion in low water channel)

Effective Height (m)	Probable One-day Rainfall (year)	Height (m)	Crown Width (m)	Remarks
5.0	1/50	7.0	5.0	2.0m
4.0	1/20	6.0	5.0	2.0m
3.0	1/10	5.0	5.0	1.0m

2) Consolidation dam（combined with road）

Effective Height (m)	Probable One-day Rainfall (year)	Height (m)	Crown Width (m)	Remarks
1.5	1/10 - 1/50	5.0	6.0	Without apron

3) Ground sill

Effective Height (m)	Probable One-day Rainfall (year)	Height (m)	Crown Width (m)	Remarks
0	1/10 - 1/50	3.0	4.0	Without apron

(2) Spur Dike

1) Type A

Effective Height (m)	Probable One-day Rainfall (year)	Height (m)	Crown Width (m)	Remarks
6.0	1/50	8.0	4.0	CSG Type
5.0	1/20	7.0	4.0	CSG Type
4.0	1/10	6.0	4.0	CSG Type

2) Type B

Effective Height (m)	Probable One-day Rainfall (year)	Height (m)	Crown Width (m)	Remarks
6.0	1/50	7.5	6.0	CSG + Embankment Type
5.0	1/20	6.5	6.0	CSG + Embankment Type
4.0	1/10	5.5	6.0	CSG + Embankment Type

3) Type C

Effective Height (m)	Probable One-day Rainfall (year)	Height (m)	Crown Width (m)	Remarks
6.0	1/50	7.5	6.0	Embankment Type
5.0	1/20	6.5	6.0	Embankment Type
4.0	1/10	5.5	6.0	Embankment Type

4) Type D

Effective Height (m)	Probable One-day Rainfall (year)	Height (m)	Crown Width (m)	Remarks
6.0	1/50	7.0	6.0	Embankment Type
5.0	1/20	6.0	6.0	Embankment Type
4.0	1/10	5.0	6.0	Embankment Type

5) Training dike

The dimension of training dike is designed due to water depth (see the table “Size of Dike in Padang River”). Present channel is assumed low water channel. The foundation of proposed training dike will be constructed on the ground out of riverbank.

Effective Height (m)	Height (m)	Crown Width (m)	Remarks
2.0 - 2.6	4.0	3.0	Embankment Type

Size of Planning Facilities

	Year	Effective Hight	Hight	Width of Crown	Cutoff	Length of Apron	Slope of Upstrem Flow Side	Slope of Downstrem Nonflow Side	Material	Facing	Notice
Consolidation Dam	1/50	5.0	7.0	5.0	2.0	14.0	1.2	2.0	CSG Concrete	Concrete	Sand Pocket
	1/20	4.0	6.0	5.0	2.0	12.0	1.2	2.0			
	1/10	3.0	5.0	5.0	1.0	10.0	1.2	2.0			
Consolidation Dam	1/50	1.5	4.0	6.0	--	--	1.2	1.2	CSG	Concrete & Boulder	Used as road
	1/20	1.5	4.0	6.0	--	--	1.2	1.2			
	1/10	1.5	4.0	6.0	--	--	1.2	1.2			
Ground Sill	1/50	0.0	3.0	4.0	--	--	1.2	1.2	CSG	Concrete	
	1/20	0.0	3.0	4.0	--	--	1.2	1.2			
	1/10	0.0	3.0	4.0	--	--	1.2	1.2			
Spur Dike type (A)	1/50	6.0	8.0	6.0	--	--	1.2	1.2	CSG	Concrete & Boulder	
	1/20	5.0	7.0	6.0	--	--	1.2	1.2			
	1/10	4.0	6.0	6.0	--	--	1.2	1.2			
Spur Dike type (B)	1/50	6.0	7.5	6.0	--	--	1.2	2.5	CSG Compacted Earth	Boulder	
	1/20	5.0	6.5	6.0	--	--	1.2	2.5			
	1/10	4.0	5.5	6.0	--	--	1.2	2.5			
Spur Dike type (C)	1/50	6.0	7.5	6.0	--	--	1.5	2.5	Compacted Earth	Boulder	
	1/20	5.0	6.5	6.0	--	--	1.5	2.5			
	1/10	4.0	5.5	6.0	--	--	1.5	2.5			
Spur Dike type (D)	1/50	3.0	7.0	6.0	--	--	1.5	2.5	Compacted Earth	Boulder	
	1/20	2.0	6.0	6.0	--	--	1.5	2.5			
	1/10	1.0	5.0	6.0	--	--	1.5	2.5			
Training Dike	1/50	2.0-2.3	4.0-4.3	3.0	--	--	1.2	1.2	CSG	Concrete & Boulder	
	1/20	2.1-2.5	4.1-4.5	3.0	--	--	1.2	1.2			
	1/10	2.2-2.6	4.2-4.6	3.0	--	--	1.2	1.2			

Size of Training Dike

River Name	Year	Discharge (/s)		River Width	Bed Slope	Sidewall Slope	Rough-ness	Water Depth	Sectional Area	Wetted Perimeter	Hydraulic Radius	Velocity	Water Depth h_2 (m)		Allowable Hight	Effective Hight	Hight
		Static	Sediment	(m)	1/n	1:m	*n*	h_1 (m)	A (m^2)	P (m)	R (m)	V_1 (m/s)	Calculated	Accepted	(m)	(m)	(m)
Anoling	10year	237.0	260	40.0	1/40.0	1:1.2	0.040	1.348	56.112	44.212	1.269	4.634	1.348	1.4	0.8	2.2	4.2
Anoling	20year	274.0	300	40.0	1/40.0	1:1.2	0.040	1.469	61.351	44.589	1.376	4.890	1.469	1.5	0.8	2.3	4.3
Anoling	50year	322.0	350	40.0	1/40.0	1:1.2	0.040	1.611	67.563	45.034	1.500	5.180	1.611	1.7	0.8	2.5	4.5
Pawa-Burabod	10year	181.0	200	30.0	1/40.0	1:1.2	0.040	1.368	43.297	34.275	1.263	4.619	1.368	1.4	0.6	2.0	4.0
Pawa-Burabod	20year	210.0	230	30.0	1/40.0	1:1.2	0.040	1.488	47.289	34.648	1.365	4.864	1.488	1.5	0.8	2.3	4.3
Pawa-Burabod	50year	247.0	270	30.0	1/40.0	1:1.2	0.040	1.638	52.345	35.116	1.491	5.158	1.638	1.7	0.8	2.5	4.5
Quirangay	10year	219.0	240	30.0	1/30.0	1:1.2	0.040	1.400	44.360	34.375	1.290	5.410	1.400	1.5	0.8	2.3	4.3
Quirangay	20year	248.0	270	30.0	1/30.0	1:1.2	0.040	1.503	47.785	34.694	1.377	5.650	1.503	1.6	0.8	2.4	4.4
Quirangay	50year	284.0	310	30.0	1/30.0	1:1.2	0.040	1.632	52.156	35.099	1.486	5.944	1.632	1.7	0.8	2.5	4.5
Tumpa	10year	157.0	170	20.0	1/30.0	1:1.2	0.040	1.450	31.515	24.529	1.285	5.394	1.450	1.5	0.6	2.1	4.1
Tumpa	20year	177.0	190	20.0	1/30.0	1:1.2	0.040	1.549	33.859	24.839	1.363	5.611	1.549	1.6	0.6	2.2	4.2
Tumpa	50year	203.0	220	20.0	1/30.0	1:1.2	0.040	1.690	37.234	25.281	1.473	5.909	1.690	1.7	0.8	2.5	4.5
No name	10year	113.0	120	15.0	1/25.0	1:1.2	0.040	1.321	21.918	19.128	1.146	5.475	1.321	1.4	0.6	2.0	4.0
No name	20year	128.0	140	15.0	1/25.0	1:1.2	0.040	1.448	24.240	19.524	1.242	5.776	1.448	1.5	0.6	2.1	4.1
No name	50year	146.0	160	15.0	1/25.0	1:1.2	0.040	1.567	26.461	19.897	1.330	6.047	1.567	1.6	0.6	2.2	4.2
Maninila	10year	113.0	120	15.0	1/35.0	1:1.2	0.040	1.460	24.464	19.562	1.251	4.905	1.460	1.5	0.6	2.1	4.1
Maninila	20year	128.0	140	15.0	1/35.0	1:1.2	0.040	1.600	27.073	19.999	1.354	5.171	1.600	1.7	0.6	2.3	4.3
Maninila	50year	148.0	160	15.0	1/35.0	1:1.2	0.040	1.732	29.571	20.409	1.449	5.411	1.732	1.8	0.6	2.4	4.4
Masarawag	10year	215.0	240	30.0	1/37.5	1:1.2	0.040	1.497	47.598	34.677	1.373	5.042	1.497	1.5	0.8	2.3	4.3
Masarawag	20year	244.0	270	30.0	1/37.5	1:1.2	0.040	1.606	51.284	35.018	1.464	5.265	1.606	1.7	0.8	2.5	4.5
Masarawag	50year	280.0	310	30.0	1/37.5	1:1.2	0.040	1.745	55.990	35.450	1.579	5.537	1.745	1.8	0.8	2.6	4.6
Padang	10year	177.0	190	20.0	1/25.0	1:1.2	0.040	1.467	31.925	24.583	1.299	5.952	1.467	1.5	0.6	2.1	4.1
Padang	20year	198.0	220	20.0	1/25.0	1:1.2	0.040	1.601	35.096	25.002	1.404	6.268	1.601	1.7	0.8	2.5	4.5
Padang	50year	225.0	250	20.0	1/25.0	1:1.2	0.040	1.728	38.133	25.397	1.501	6.556	1.728	1.8	0.8	2.6	4.6

Sediment Concentration 0.1

Size of Dike in Padang River

Station	Year	Discharge Qp (/s)	Sediment Con-centration Cd 0.3	Debris-flow Discharge Qsp (/s)	Discharge for Plan (/s)	Bed Slope		Width of Resume Bc	Width of River B (m)	Depth of Debris-flow h_1 (m)	Allowable Hight h' (m)	Effective Hight h (m)
Sto Domingo	10	177.0	0.30	354.0	360.0	1/35.00	1.64	56.9	60	2.14	0.8	3.00
	20	198.0	0.30	396.0	400.0	1/35.00	1.64	60.0	60	2.28	0.8	3.10
	50	225.0	0.30	450.0	450.0	1/35.00	1.64	63.6	60	2.44	0.8	3.30

5.2 Material

The material of the construction is examined as the below.

Concrete .... Apron and Apron Wall of Consolidation Dam

Facing for Consolidation Dam, Ground Sill, Crown of Dike

Boulder..................................... Facing for Dike

Cemented Sand and Gravel....... Material for stuff in Consolidation Dam and Dike

Embankment.............................. Material for stuff in Dike

Gabion .... Foundation Works of Dike for erosion

It is defined that the material of CSG can utilize the local supplement and the spoil materials in accompany with construction work. But the detail specification of CSG work needs the experimental construction and the laboratory test to determine whether the used of CSG in the field is applicable or not.

5.3 Construction Sequence

The items of construction sequence in all facilities are as follows:

Concrete Deposing.................... Apron and Apron Wall of Consolidation Dam

Concrete Facing......................... Consolidation Dam, Ground Sill, Crown of Dike

Boulder Faicing......................... Dike

Cemented Sand and Gravel....... Material for stuff in Consolidation Dam and Dike

Embankment.............................. Material for stuff in Dike

Excavation................................. All facilities

Gabion .... Dike

The process of construction sequence of CSG is summarized as follows:

(1) Composition of CSG

The composition of CSG is estimated by the past case study that quantity of the cement material is around 80kg/m^3, moisture ration for cement is around 10%. For example, the composition of CLG (Cemented Lahar and Gravel) in case of Pinatubo is summarized below.

Composition and Strength of CLG

	Minimum Cement Content per m^3 kg (bag)*	Maximum Water/Cement Ratio kg/kg	Designated Size of Coarse Aggregate Square Opening Std. (mm)	Minimum Compressive Strength of 150 x 300mm Concrete Cylinder Speciment at 28 days, MN/m^2 (psi)
Cement Lahar and Gravel (CLG)	80 (2 bags)	2.43	Max. 150mm	3.5 (508)

* Based on 40 kg/bag

Water content after mixing shall be between 8% and 12%, and minimum dry density shall be 1.85tf/m^3.

(2) Mixing by Batcher Plant of Cemented Sand and Gravel

The mixing of cemented sand and gravel is done at the batcher plant. The advantage of the batcher plant is easy construction work, good for strength of CSG and low cost in case of large quantity production.

(3) Transporting Cemented Sand and Gravel by dump truck

CSG material must be transported to the construction site by dump truck quickly.

(4) Placing Concrete by Bulldozer for Cemented Sand and Gravel

The placing concrete work at the construction site is constructed by bulldozer.

(5) Compaction of Cemented Sand and Gravel by Vibrating Roller

The optimum condition of the compaction work, in thickness and revolution number in the roller is needed to examine sufficiently before construction.

(6) Slope Tamping by Backhoe with Bucket

The slope tamping work is done by backhoe with bucket.

Table III 1.1 Inventory of Existing Facilities Condition in the Study Area (1)

River System	River Name & Location	Facility Name	Facility Size		Date Constructed	Expected Effect	Existing Condition	Cause of Failure
			Height(m)	Length(m)				
YAWA River system	1.YAWA Legaspi city	a.Boulder dike	(4.00)	320	2-14-89	Fix flood flows course		
		b.Boulder dike	(4.00)	1,200	6-02-91	-do-		
		c.Concreting of boulder dike	(4.00)	1,250	11-01-89	-do-		
		d.Dike No.1,2,3,4	4.00	308	ongoing	-do-	Broken part of structure damaged (about 50m)	Erosion on foundation of dike
		Dredging	45000cu.m		1991			
	2.PAWA-BURABOD Legaspi city	a.Training levee	3.00	160	2-17-91	Control of Mud flow course	Missing structure in the field	
		b.Consolidation dam No.1	(2-3.00)	60	11-25-89	Prevent erosion of river bed	Partially left side bank eroded	Meander of flood flows
		c.Spur dike No.2	3.00	140	11-29-88	Control of Mud flow course	Structure of down stream damaged or destroyed	Erosion on foundation of dike
		d.Spur dike No.3	4.00	300	11-29-88	-do-	All structure destroyed	-do-
		e.Spur dike No.4	3.00	186	9-26-88	-do-		
		f.Spur dike No.5	4.00	280	12-24-83	-do-		
		g.Spur dike No.6	3.00	280	1-11-84	-do-		
		h.Spur dike No.7	3.00	350	9-26-88	-do-		
		i.Revetmen down stream	3.00	275	12-20-92	Prevent erosion of river bank		
		j.Road dike	3.00	260	12-20-92	Road		
		Dredging	34929cu.m		1991			

* ( ) = imaginary value by field survey

Table III 1.2 Inventory of Existing Facilities Condition in the Study Area (2)

River System	River Name & Location	Facility Name	Facility Size Height(m)	Facility Size Length(m)	**Date** Constructed	Expected Effect	Existing Condition	Cause of Failure
YAWA River system	3.BUDIAO	a.Boulder dike (stone pitching)	3.00	640	1990	Control Mud flow course	All structure destroyed	Erosion on foundation of dike or impact of boulders
		Boulder dike No.2	(3.00)	200	4-5-91	-do-	-do-	
		Boulder dike No.3	(3.00)	240	4-5-91	-do-	-do-	
		b.Spur dike No.1	(down stream 3.00 up stream 5.00)	1,155	1986~1990	-do-		
		c.Spur dike No.2	(-do-)	2,380	1986~1989	-do-		
		d.Training levee (stone pitching)	(3.00)	520	1988?1989	-do-	All structure destroyed	Erosion on foundation of dike or impact of boulders
		e.Spur dike (down stream)	(3.00)		1989	-do-		
		Channelization	5125cu.m		6-2-91			
	4.ANOLING Anoling Camalig Albay	a.Spur dike No.1	3.00	(200)		Control Mud flow course		
		b.Boulder dike 1-B	3.00	250	10-28-87	-do-		
		c.Boulder dike 1-A	3.00	280	10-28-87	-do-		
		d.Spur dike No.4	3.00	200		-do-		
		e.Spur dike with conc.cribs	(3.00)	230	6-18-88	-do-		
		f.Training levee	3.00	600	5-10-88 6-14-88	-do-	Failure at 3 sites (total L 500m)	Erosion on foundation of levee
		g.Ground sill No.2	(2.00)	80	1-13-89	Prevent erosion of river bed		
		h.Spur dike	(3.00)	90	1-13-89	Control Mud flow course		

* ( ) = imaginary value by field survey

Table III 1.3 Inventory of Existing Facilities Condition in the Study Area (3)

River System	River Name & Location	Facility Name	Facility Size Height(m)	Facility Size Length(m)	**Date** Constructed	Expected Effect	Existing Condition	Cause of Failure
QUINALI(A) River system	5.QUIRANGAY Camalig Albay	a.Boulder dike No.3-B	2.60	655	12-27-89	Control of Mud flow course		
		b.Boulder dike No.3-A	2.60	440	12-27-89	-do-		
		c.Earth dike	2.60	400	12-27-89	-do-		
		d.Spur dike No.3-A	2.60	520	6-15-87	-do-		
		e.Spur dike No.2-A	2.60	(200)	11-30-84	-do-		
		f.Spur dike No.1-A	2.60	180	8-6-87	-do-		
		g.Training levee	2.60	400	2-22-88	-do-		
		h.Spur dike No.1-B	2.60	120	3-6-89	-do-	Missing structure in the field	
		i.Consolidation dam No.1	2.60	170	3-6-89	Prevent erosion of river bed	-do-	
		j.Boulder dike No.2-B	(2.60)	300	1990	Control Mud flow course		
		k.Boulder dike No.3-B	(2.60)	90	1990	-do-		
		Dredging	13977+8818cu.m		1990			
	6.TUMPA							
	7.MANINILA							
	8.MASARAWAG Guinobatan Albay	a.Spur dike No.8A	(5.00)	280	4-18-89	Control Mud flow course		
		b.Spur dike No.7A	(5.00)	280	4-18-89	-do-		
		c.Spur dike No.6A	(5.00)	280	4-18-89	-do-		
		d.Spur dike No.5A	(5.00)	220	4-18-89	-do-		

*( )=imaginary value by field survey

Table III 1.4 Inventory of Existing Facilities Condition in the Study Area (4)

River System	River Name & Location	Facility Name	Facility Size		Date Constructed	Expected Effect	Existing Condition	Cause of Failure
			Height(m)	Length(m)				
QUINALI(A) River system	8.MASARAWAG Guinobatan Aibay	e.Boulder dike No.1A	(3.00)	280	2-25-91	-do-		
		f.Training levee	5.50	160	2-25-91	-do-		
		g.Boulder dike No.1	(3.00)	130	2-25-91	-do-		
		h.Spur dike	unknown	60+10	1992			
		Channelization	109938cu.m		4-23-91			
	9.OGSONG	Spur Dike NO.7	unknown	40	1992			
		Spur Dike NO.8	unknown	40	1992			
	10.NASISI	a.Consolidation dam No.1	5.00	88	8-16-83	Prevent erosion of river bed	Base of dam eroded	Erosion of down stream river bed from dam
		b.Ground sill No.1	3.00	180	3-7-89	-do-		
		c.Ground sill No.2	3.00	(180)	11-11-89	-do-		
		d.Ground sill No.3	3.00	205	2-4-91	-do-		
		e.Consolidation dam No.2	5.00	150	4-15-88	-do-	Missing structure in the field	
		Spur dike	unknown	194	1992			
QUINALI(B) River system	11.BUANG							
	12.QUINALI(B)							
	13.SAN VICENTE	a.Boulder dike No.1	(4.00)	115	12-22-90	Fix flood flows course		
		b.Boulder dike No.2	(4.00)	115	12-22-90	-do-		
		c.Boulder dike No.3	(4.00)	60	3-10-92	-do-		
		d.Boulder dike No.4	(4.00)	unknown	3-10-92	-do-		

*( )=imaginary value by field survey

Table III 1.5 Inventory of Existing Facilities Condition in the Study Area (5)

River System	River Name & Location	Facility Name	Facility Size		**Date** Constructed	Expected Effect	Existing Condition	Cause of Failure
			Height(m)	Length(m)				
QUINALI(B) River system	13.SAN-VICENTE	e.Spur dike No.1	(4.00)	240	unknown	-do-		
		f.Spur dike No.2	(4.00)	240	unknown	-do-		
		Dredging	5488cu.m		1991			
ARIMBAY River system	14.ARIMBAY	a.Concrete rivetment	(2.50)	60	2-15-88	Prevent erosion of river bank		
		b.Spur dike No.1	(3.00)	420	12-18-90	Control MUD flow course		
		c.Spur dike No.2	(3.00)	300	12-18-90	-do-		
		d.Spur dike No.4	(3.00)	400	11-19-88	-do-		
		e.Spur dike No.5	(3.00)	250	88	-do-		
		f.Spur dike No.7	(3.00)	450	11-30-89	Control MUD flow course		
		g.Spur dike No.8	(3.00)	360	4-18-89	-do-		
			(3.00)	80	7-26-92	-do-		
		h.Spur dike No.9	(3.00)	(360)	4-18-89	-do-		
		i.Consolidation dam	unknown	70	4-18-89	Barangay road		
PADANG River system	15.PADANG	a.Spur dike No.1	(3.00)	(1,100)	1990	Control MUD flow course		
		b.Spur dike No.2	(3.00)	(800)	1991	-do-	Part of structure damaged (about 20m)	Erosion on foundation of dike
		c.Spur dike No.3	(3.00)	(420)	1987~1989	-do-	All structure destroyed	-do-
		d.Spur dike No.4	(3.00)	(760)	1987~1989	-do-	-do-	-do-
		e.Spur dike No.5	(3.00)	(560)	1987~1990	-do-		
		f.Spur dike No.6	(3.00)	160	7-24-89	-do-		
		g.Spur dike No.7	(3.00)	(540)	1987~1990	-do-		

*( )=imaginary value by field survey

Table III 1.6 Inventory of Existing Facilities Condition in the Study Area (6)

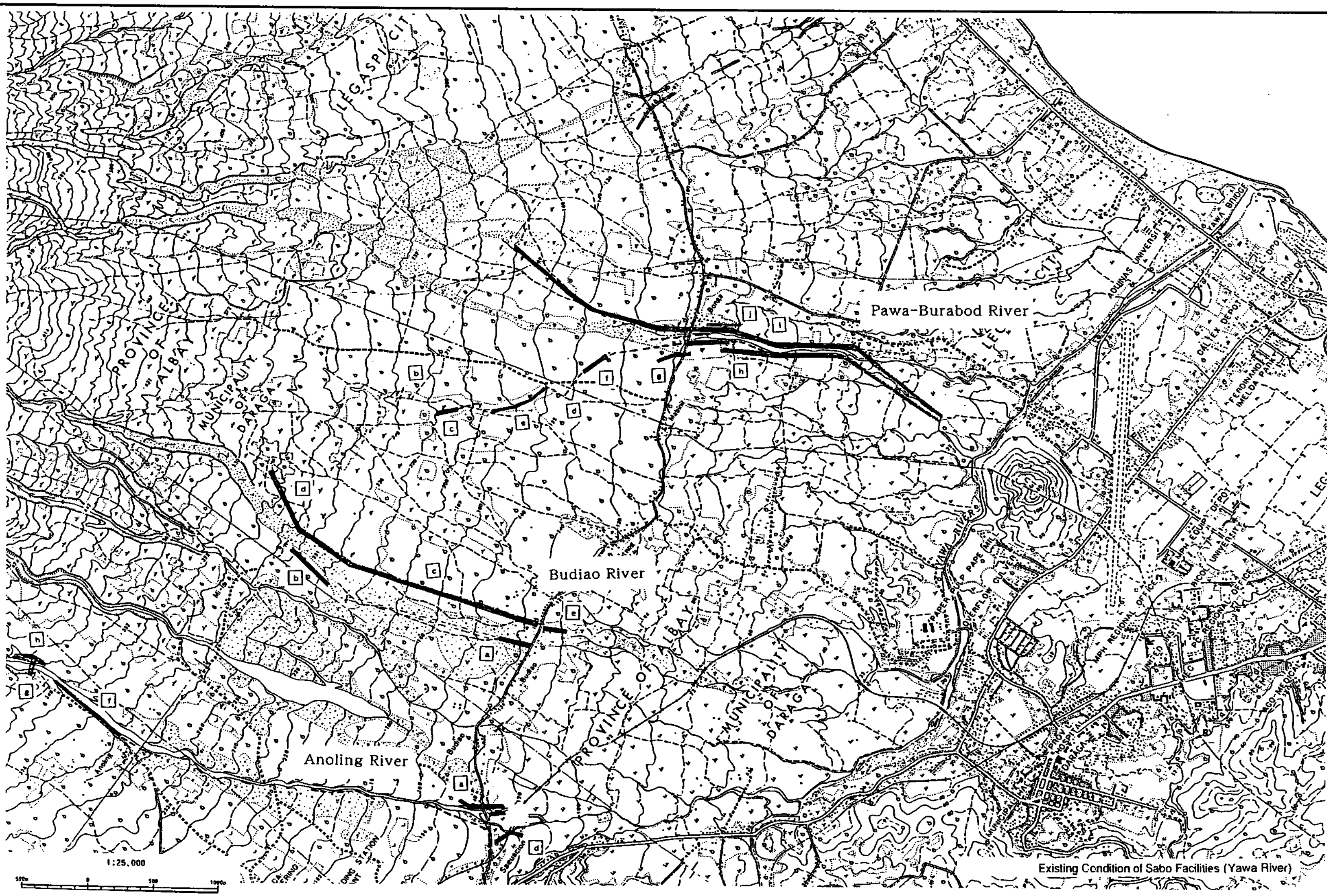
River System	River Name & Location	Facility Name	Facility Size		Date Constructed	Expected Effect	Existing Condition	Cause of Failure
			Height(m)	Length(m)				
PADANG River system	15.PADANG	h.Spur dike No.8	(3.00)	(200)	1988?1990	-do-		
		i.Spur dike No.9	(3.00)	(200)	7-24-89	-do-		
		j.Consolidation Dam	unknown	55	7-24-89			
		Dredging	6280cu.m		12-29-90			
		Dredging	6814cu.m		2-10-92			
BASUD River system	16.BASUD	a.Spur dike No.2	(4.00)	132	1985	Control Mud flow course		
		〃	〃	400	8-22-89	〃		
		b.Boulder dike No.1 (stone pitching)	(2.00)	170	1985	-do-	All structure destroyed	Erosion on foundation of dike or impact of boulders
		〃 (upstream)	〃	50	8-17-89	〃	〃	〃
		c.Boulder dike No.2 (stone pitching)	(2.00)	200	1985	-do-	-do-	-do-
		〃	〃	132	8-17-89	〃	〃	〃
		d.Boulder spur dike No.1	(3.00)	84	1985	-do-		
		e.Boulder dike No.5	(3.00)	55	1992	Control Mud flow course	All structure destroyed	Erosion on foundation of dike or impact of boulders
		f.Boulder dike No.6	(3.00)	65	1992	-do-	-do-	-do-
		g.Boulder dike No.8	(3.00)	100	1986	-do-	-do-	-do-
		h.Spur dike No.1	(4.00)	370	6-2-88	-do-		
		i.Spur dike No.4	(4.00)	180	6-2-88	-do-		
		j.Spur dike No.5	(4.00)	55	1992	-do-		
		〃	〃	200	6-2-88	〃		
		k.Spur dike No.6	(4.00)	65	1992	-do-		
		〃	〃	100	6-2-88	〃		
		l.Spur dike No.9	(4.00)	(100)	unknown	-do-		
		m.Consolidation dan	(5.00)	(50)	4-17-91	Prevent erosion of river bed	Over-flow section of dam destroyed	Apron damaged by impact of boulders and erosion down stream

*( )=imaginary value by field survey

Table III 1.7 Inventory of Existing Facilities Condition in the Study Area (7)

River System	River Name & Location	Facility Name	Facility Size Height(m)	Facility Size Length(m)	Date Constructed	Expected Effect	Existing Condition	Cause of Failure
BASUD River system	16.BASUD	n.Spur dike of up stream from dam(Right bank)	(5.00)	(100)	4-17-91	Control Mud flow course		
		o.Spur dike of down stream from dam(Left bank)	(5.00)	(210)	4-17-91	-do-		
		p.Spur dike of1.5km up stream from dam(Left bank)	(3.00)	(100)	unknown	-do-	All structure destroyed	Impact of boulders
		dredging	11327cu.m		1991			
		channel zation (upstream)	9797cu.m		1992			
BULAWAN River system	17.BULAWAN	a.Spur dike No.1	(5.00)	(900)	1990	Control Mud flow course	Part of up stream damaged or destroyed	Impact of boulder
		b.Spur dike No.2	(5.00)	(1,300)	1991	-do-		
		i.Consolidation dam	(2.00)	(55)	7-10-89	Prevent erosion of river bed	Foundation of dam eroded	erosion of down stream river bed from dam
		j.Revetment	(3.00~4.00)	(100)	unknown	Prevent erosion of river bed		
		e.Spur dike No.3	unknown	(370)	1989~1991			
		f.Spur dike No.4	unknown	(240)	1987~1990			
		g.Spur dike No.5	unknown	(260)	1991			
		h.Spur dike No.6	unknown	(203)	1987~1992			
		k.boulder dike	unknown	80	7-10-89			
		l.boulder dike No.3		40	11-5-92			

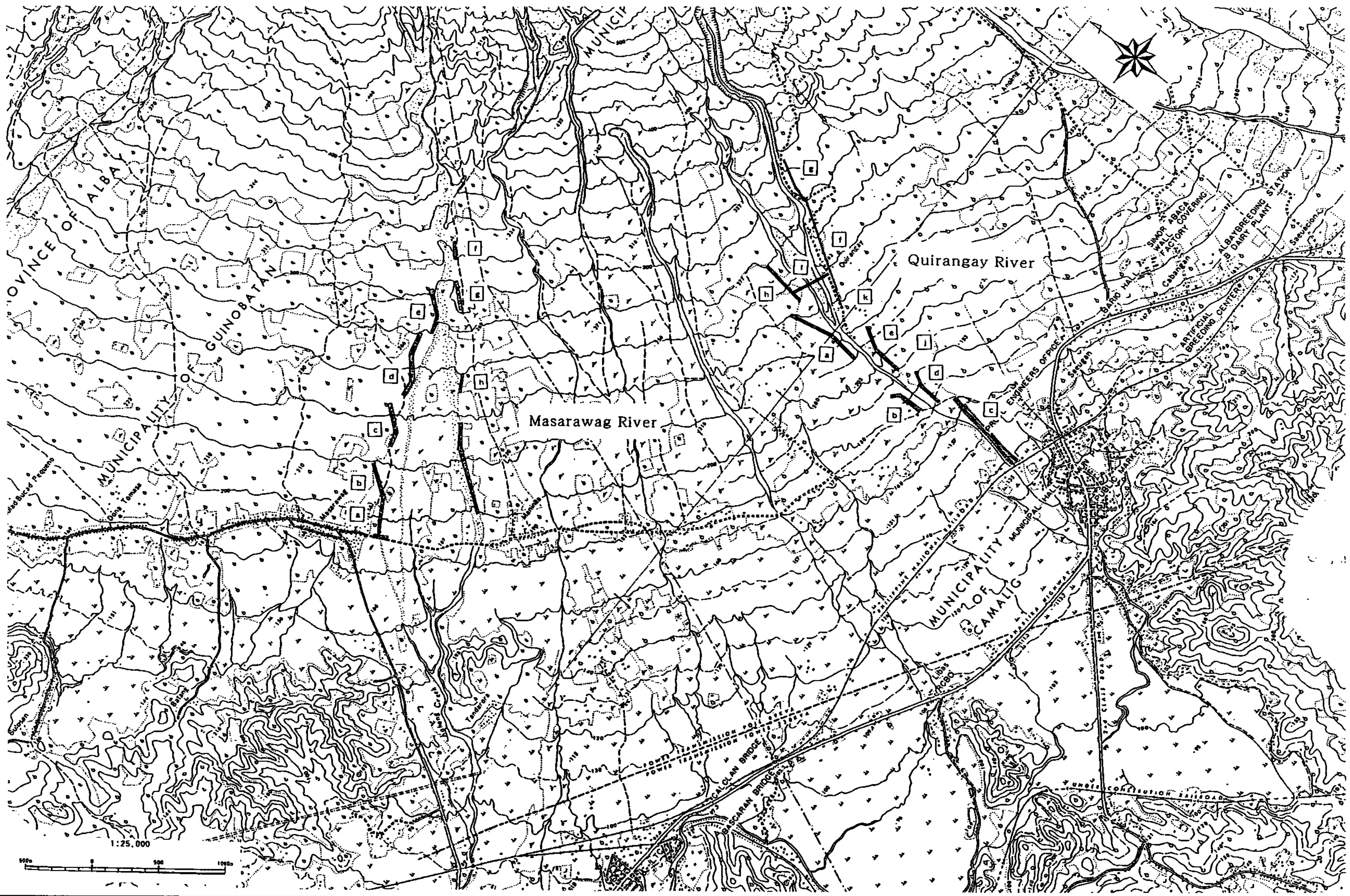
*( )=imaginary value by field survey



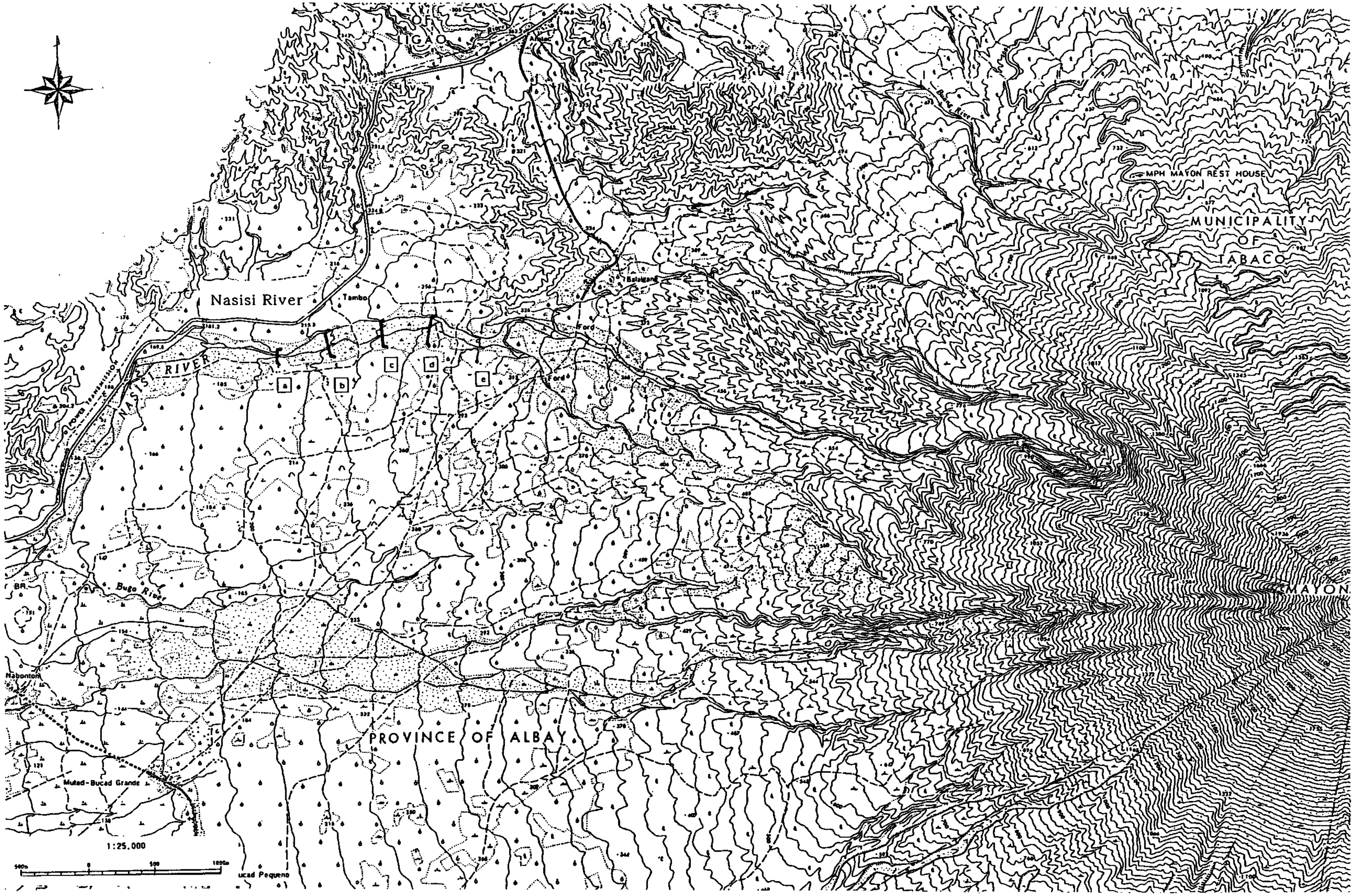
COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

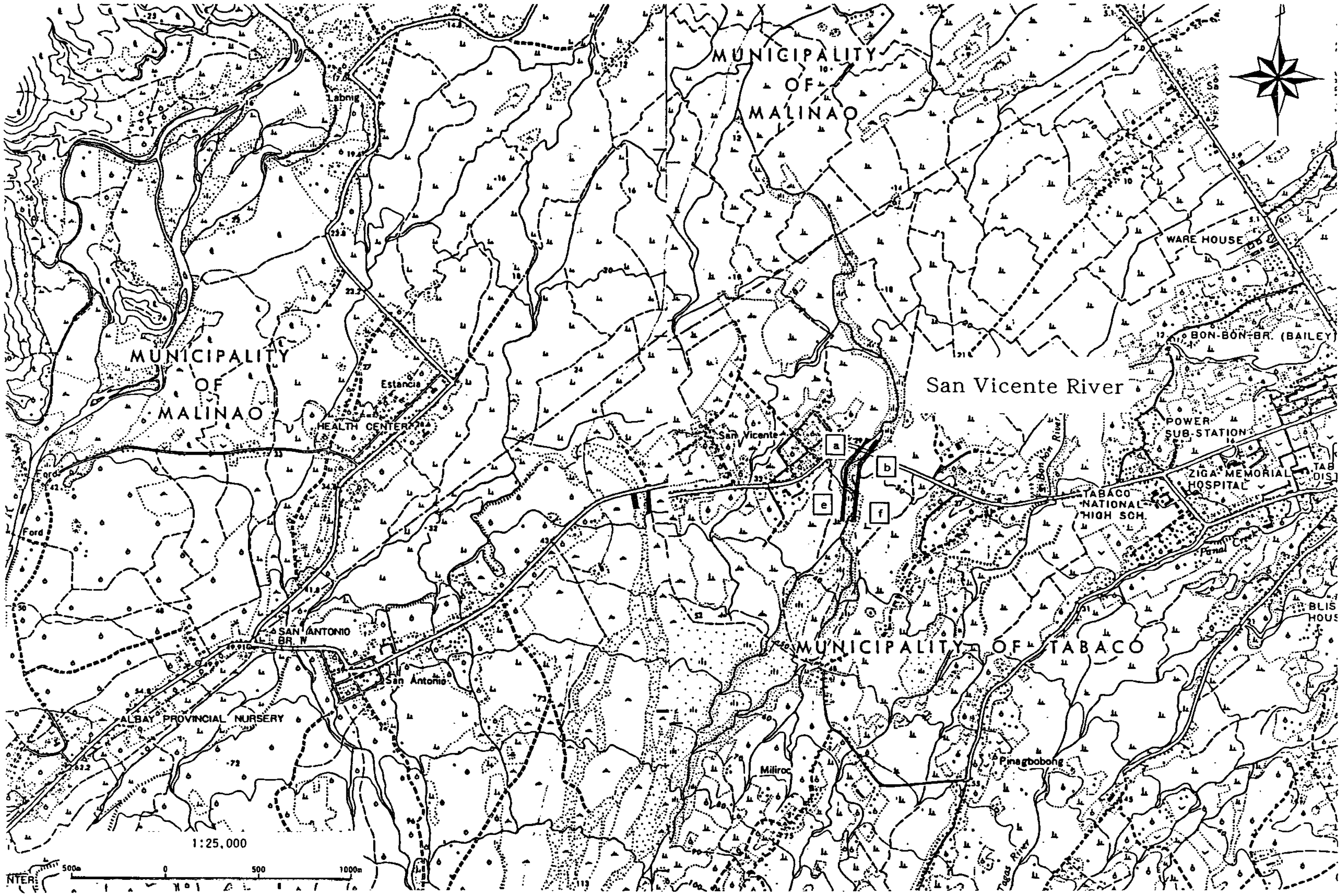
Figure III 1.1
Existing Condition of Sabo Facilities (Yawa River)



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	Figure III 1.2 Existing Condition of Sabo Facilities (Quirangay River, Masarawag River
JAPAN INTERNATIONAL COOPERATION AGENCY	



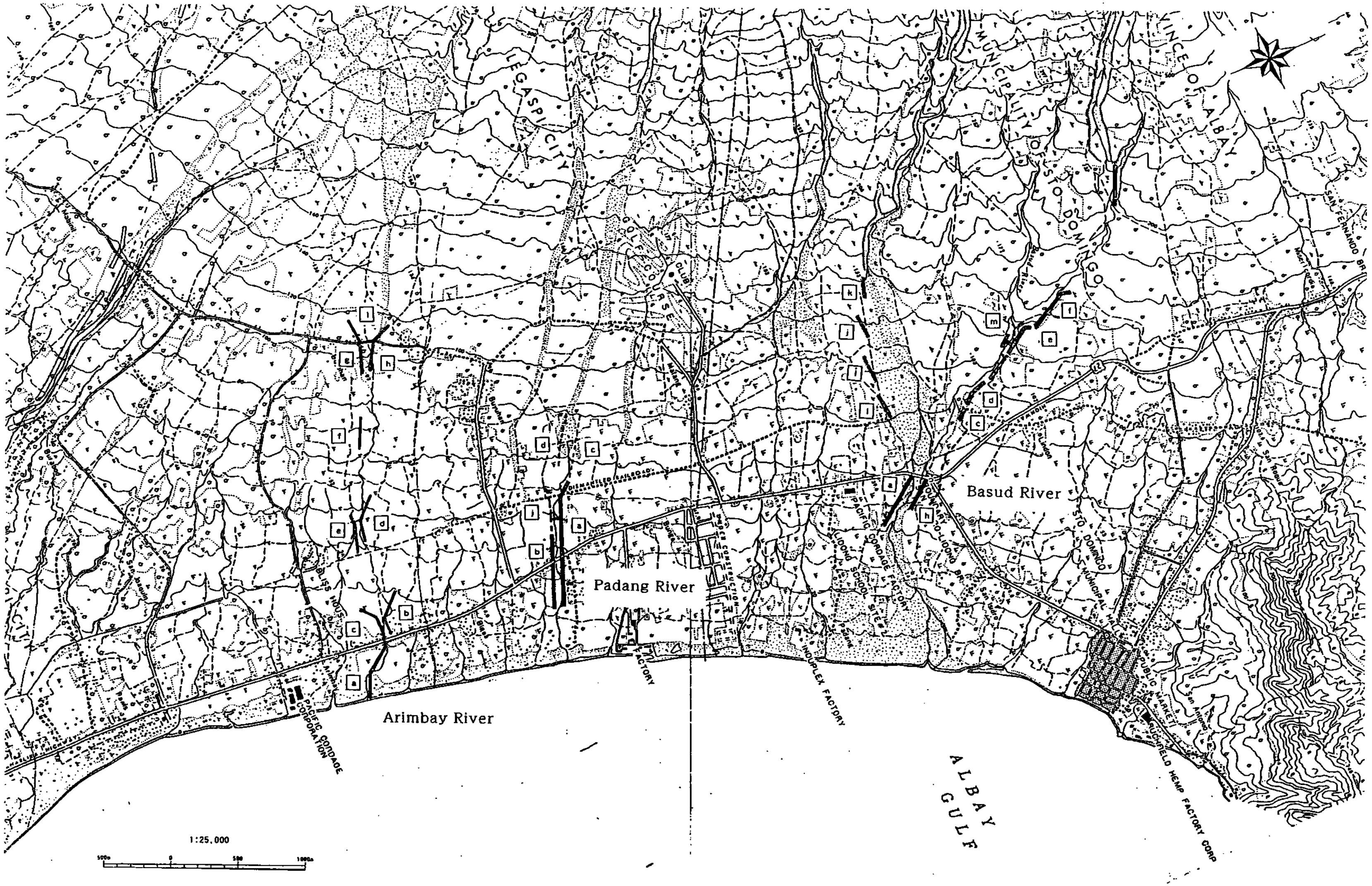
COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	Figure III 1.3 Existing Condition of Sabo Facilities (Nasisi River)
JAPAN INTERNATIONAL COOPERATION AGENCY	



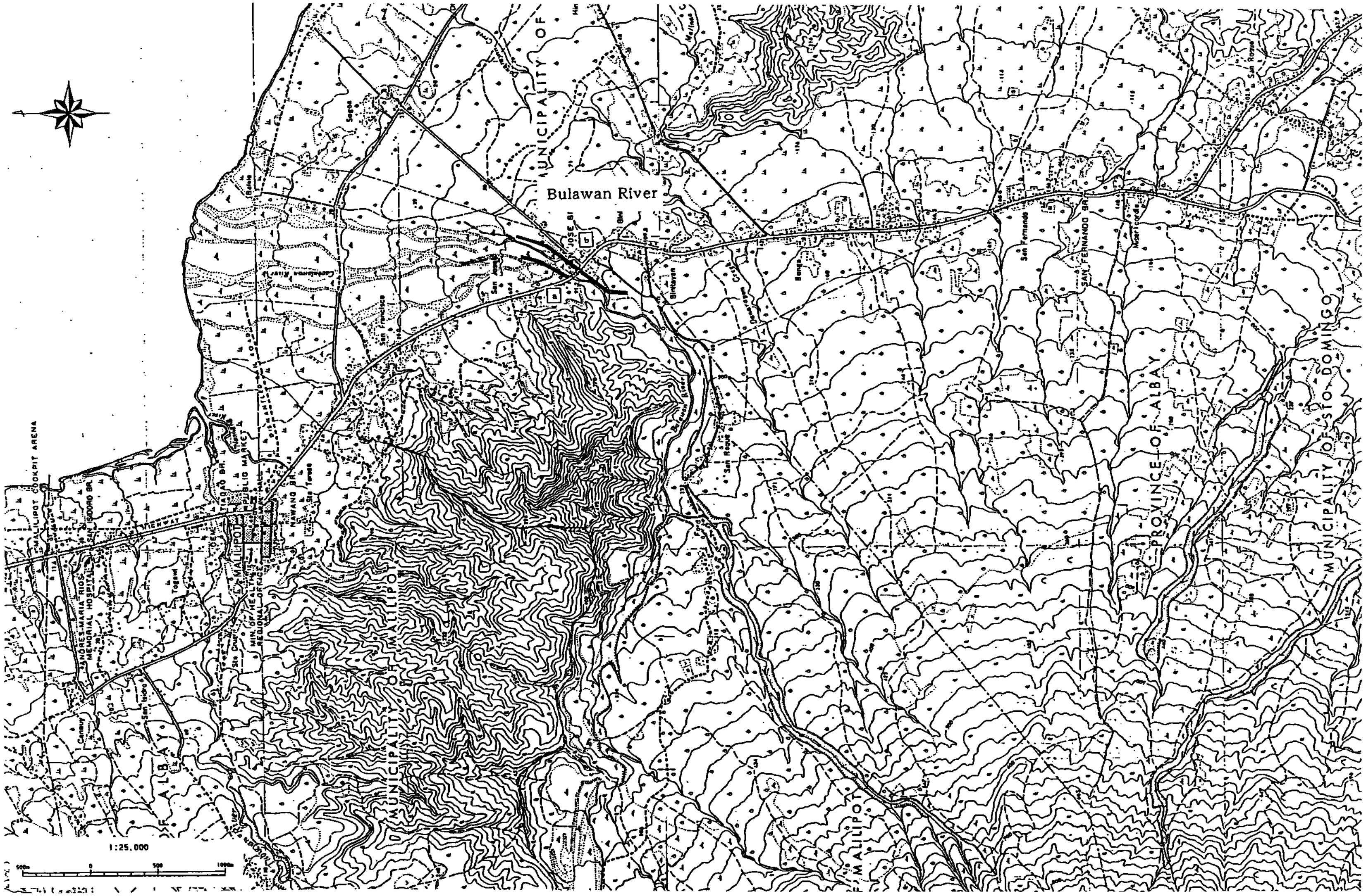
COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure III 1.4
Existing Condition of Sabo Facilities (San Vicente River)



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure III 1.5** **Existing Condition of Sabo Facilities (Arimbay River, Padang River, Basud River)**
JAPAN INTERNATIONAL COOPERATION AGENCY	



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	Figure III 1.6 Existing Condition of Sabo Facilities (Bulawan River)
JAPAN INTERNATIONAL COOPERATION AGENCY	