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THE REPUBLIC OF THE PHILIPPINES

MASTER PLAN FOR MAYON VOLCANO SABO AND FLOOD CONTROL PROJECT

MAIN REPORT

MARCH 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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This report is published in two (2) volumes under the following titles:

1. MAIN REPORT

2. SUPPORTING REPORT

PREFACE

In response to the request of the Government of the Republic of the Philippines, the Japanese Government decided to conduct a survey on the Master Plan for Mayon Volcano Sabo and Flood Control Project and entrusted the Japan International Cooperation Agency with the survey. The JICA sent to the Philippines a survey team headed by Mr. Teruo Yoshimatsu from June 23 to August 30, 1980.

The team had discussions with the officials concerned of the Government of the Republic of the Philippines and conducted a field survey in Albay Province and Legaspi City, the Philippines. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Republic of the Philippines and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of the Philippines for their close cooperation extended to the team.

March 1981

Keisuke Arita
President
Japan International Cooperation Agency

SUMMARY

A. General

1. Mayon Volcano with an elevation of 2,469 m which is located in the southeast of Luzon has erupted periodically about once every 10 years. The surrounding area of Mayon Volcano and the Quinali (A) River basin have been suffering from the sediment and flood damages directly or indirectly resulting from the eruption. Sabo and flood control project against the above damages have been a long-cherished desire of the inhabitant in this district. The recent typhoon "Pepang" in 1979 caused flood damage of approximately P 13.4 million.

2. The Philippine Government requested the Japanese Government to study the Project in 1977. In response to the request, the Japanese Government despatched experts twice in 1978. They confirmed the urgent necessity of the proper study of the Project. With this confirmation, the Japanese Government sent the study team to the Philippines through the Japan International Cooperation Agency (JICA). The study was made in two phases. The first phase was dealt with detailed design of Sabo facilities in Pawa-Burabod River, a tributary of the Yawa River according to the request of the Philippine Government in 1979 and 1980. The second phase, this time in 1980 and 1981, was to establish the Master Plan of Sabo and flood control.

3. This report presents a Master Plan for Sabo and Flood Control Project established for three major rivers of the Quinali (A) River including the Talisay River, the Quinali (B) River and the Yawa River.

4. All the Sabo and river plans are established against 50-year probable flood considering importance of the region and design discharge of other rivers in the Philippines and the Japanese Standard of river planning.

5. In both of the Quinali (A) River basin and the Quinali (B) River basin, an agricultural development scheme is also established aiming at land enhancement resulting from the Sabo and flood control project.

6. Regarding the warning and evacuation system for the area, it is proposed to use the existing Calamities and Disaster Preparedness Plan formulated by Department of National Defence, Office of Civil Defence on September 6, 1976, adding a meteo-hydrological monitoring and forecasting system.

7. Construction cost is estimated on the basis of the Government estimate procedure, in considering local conditions of the Philippines, available equipments and materials, suitability of construction method, working rules, etc..

8. Implementation program includes necessary future studies and design, and a proposed construction time schedule for each component work of the Master Plan.

B. Master Plan for The Quinali (A) River

1. Sabo plan is established for such six (6) torrents as the Quirangay, the Tumpa, the Maninila, the Masarawag, the Ogsong (Nabonton Creek) and the Nasisi which have been seriously devastated. Also, the Sabo works are planned to check and control the sediment runoff or debris flow against 50-year probable flood, and to take account of the importance of the affected area. (see FIG.-4.3.1 and FIG.-4.3.2)

1) For the Quirangay River, six (6) spur dikes and three (3) jetties are arranged in order to promote a sand retarding. The sediment runoff at base point reduces from 260,100 m^3 to 78,200 m^3 with these facilities for 50-year probable flood.

2) For the Tumpa River, fifteen (15) consolidation works with coconut trunk fences are planned to mitigate the river bed and side erosion. The sediment runoff at base point reduces from 43,700 m^3 to 26,900 m^3.

3) For the Maninila River, nine (9) consolidation works with cribs are planned to mitigate the river bed and side erosion. The sediment runoff at base point reduces from 94,000 m^3 to 36,700 m^3.

4) For the Masarawag River, thirteen (13) spur dikes and three (3) jetties are arranged in the upper reaches to enlarge the function of existing natural sand retarding basin and also nine (9) consolidation works are planned in the lower reaches to stabilize the river bed. The sediment runoff at base point reduces from 276,800 m^3 to 65,300 m^3.

5) For the Ogsong River (Nabonton Creek), six (6) spur dikes and nine (9) jetties are arranged in the upper reach to enlarge the function of existing natural sand retarding basin, and two (2) consolidation dams and three (3) ground-sills planned in the lower reaches to stabilize the river bed. The sediment runoff at base point reduces from 140,500 m^3 to 28,500 m^3.

6) For the Nasisi River, two (2) consolidation dams are proposed in the upper reach to check and control the sediment runoff and in the lower reaches of the dams, three (3) spur dikes, twenty-three (23) groins and levee of 2,350 m long are arranged to form a big artificial sand retarding basin in the river course. Then, the reconstruction of overflow type culvert of the Ligao-Tabaco National Highway is proposed together with four (4) groins & ground-sills to stabilize the lower river channel and increase a sand retarding capacity. With these structures, the sediment runoff at base point reduces from 1,128,700 m^3 to 107,400 m^3.

2. The river reaches to be improved for flood control are selected as follows considering the discharge capacity of the present river channel and importance of the affected area. (see FIG.-4.3.17 and FIG.-4.3.18)

(i) Main course - Lake Bato to Sta. 27+500 (reach of 27.5 km)
(ii) Talisay River - Junction with the main course to Sta. 13+700 (reach of 13.7 km)
(iii) Nasisi River - Junction with the main course to the Ligao-Tabaco National Highway bridge (reach of 7.6 km)

1) At the alignment design of river channel, two (2) alternative schemes are studied to find out an economical route. Alternative I is to improve mostly the present river course and alternative II is a scheme of Bobonsuran diversion to the Talisay River. As a result, the alternative I is selected to be the recommendable scheme mainly due to the construction cost which is estimated at P 656 million for alternative I and P 832 million for alternative II. (see FIG.-4.3.15)

2) In the proposed scheme (Alternative I), 50-year probable flood peak run-off is taken as the design discharge which ranges from 1,730 m^3/sec to 4,260 m^3/sec for the main course, from 1,970 m^3/sec to 1,980 m^3/sec for the Talisay River and from 920 m^3/sec to 1,660 m^3/sec for the Nasisi River. (see FIG.-4.3.14)

3) Alignment of river channel is made so as to follow the present river channel as much as possible except Oas where the new river channel is proposed to be constructed at the outskirts of Oas to avoid the densely populated area.

4) River profile is principally designed to retain the present river bed slope as much as possible to keep the equilibrium river bed slope. The proposed river bed slope ranges from 1/1,550 to 1/550 for the main course, from 1/1,100 to 1/800 for the Talisay River and from 1/400 to 1/130 for the Nasisi River. (see FIG.-4.3.19 to FIG.-4.3.21)

5) River cross section is designed as a compound section except the Nasisi River, for which a simple section was designed due to the limited formation height of PNR and also a transition to Sabo work section. The proposed river width ranges from 200 m to 450 m for the main course, from 180 m to 200 m for the Talisay River and from 80 m to 160 m for the Nasisi River. (see FIG.-4.3.22)

6) Levees are designed to have a slope of 1:2, freeboard of 1.2 m to 1.0 m and top width of 5 m to 4 m with sod facing.

7) As for the river drainage facilities, three (3) sites for box culvert type sluiceways with a dimension of 2 m high and 2 m wide will be provided for the main course, three (3) sites for the Talisay River and one (1) site for the Nasisi River.

3. In connection with the proposed Sabo and flood control plan, an agricultural development scheme is proposed, which has the basic strategies of expanding of irrigated double cropping of rice through integration of the existing irrigation systems and increase of agricultural inputs such as fertilizer.

1) As an irrigation development plan, three (3) new irrigation systems integrating the existing nineteen (19) irrigation systems are proposed. With this scheme, the irrigation area increases from 3,640 ha to 6,350 ha. (see FIG.-4.3.23)

2) Out of the existing four (4) headworks, one (1) is used with some rehabilitation of the intake facilities. In addition two (2) new headworks with movable weirs are proposed to be constructed.

3) In order to establish the complete canal networks for the new irrigation systems, the main and secondary canals with a total length of 76 km will be newly constructed combining with the existing main and secondary canals. Also, the existing main and secondary canals with a total length of 49 km and related structures are to be rehabilitated. As for the tertiary and quaternary canals, the existing canals will be left untouched as much as possible.

4) As for a drainage system, the natural rivers and streams will be used as the drainage channal and the main and secondary drains with total length of 12 km are to be newly constructed. In addition, the field and collector drains with a total length of approximately 254 km (40 m/ha) will be arranged for the rice field.

5) As for an agricultural development plan, the irrigated rice cultivation of double cropping is introduced to the whole schemed area of 6,350 ha including 2,710 ha of converted area from rainfed to irrigated condition and also the fertilization of nitrogen is increased from around 70 kg N/ha to 100 kg N/ha for the dry season and 80 kg N/ha for the wet season.

6) With this agricultural development scheme, palay yield is expected to increase from about 3.8 tons/ha to 5.0 tons/ha in the dry season and from about 3.5 tons/ha to 4.5 tons/ha in the wet season.

4. The whole construction period is assumed to be 10 years. The respective construction periods are 10 years for sabo works, 10 years for river improvement works and 4 years for irrigation works. (see FIG.-5.2.1)

5. The total construction cost including price escalation and contingency is estimated at P 1,087.5 million, which comprises P 81.7 million for sabo works, P 923.2 million for river improvement works and P 82.6 million for irrigation works. (Foreign portion P 388.7 million, Local portion P 698.8 million)

6. The direct economic benefit is annually expected to be P 45.6 million consisting of the flood reduction benefit of P 16.0 millions and the land enhancement benefit of P 29.6 million.

7. The economic internal rate of return of the project is calculated at 6.9%. The economic viability of the project is not so much enough. However, the project shall be executed because the project will bring about such indirect and intangible benefits as increase in the employment opportunity, promotion of the regional economy, elimination of the social unrest, stabilization of the national life, etc. and also making several dense-populated municipalities free from the flood.

C. Master Plan for The Quinali (B) River

1. Sabo plan is established for the Buang River and the upper reaches of main course which has been affected by the Buang River. Also, the Sabo works are planned to check and control the sediment runoff or debris flow against 50-year probable flood, to take account of the affected area. (see FIG.-4.4.1)

1) For the Buang River, four (4) consolidation works and two (2) spur dikes which are attached to the consolidation works are planned to mitigate the erosion and to stabilize the river bed. The sediment runoff at base point reduces from 211,800 m^3 to 67,800 m^3 with these facilities for 50-year probable flood.

2) For the upper reaches of main course, one (1) Sabo dam with an effective height of 8 m is planned to check and control the sediment runoff. The sediment runoff at dam site will reduces from 319,700 m^3 to 119,700 m^3 with above consolidation works and Sabo dam.

2. The river reaches to be improved for flood control are selected as follows considering the discharge capacity of the present river channel and importance of the affected area. (see FIG.-4.4.5)

(i) Main course - River mouth to Ogob (reach of 11.3 km)

(ii) San Francisco River - Junction with the main course to the Ligao - Tabaco National Highway bridge at San Antonio (reach of 6.5 km)

(iii) San Vicente River - River mouth to the Ligao - Tabaco National Highway bridge at San Vicente (reach of 4.0 km)

1) Fifty (50) year probable flood is taken as the design discharge which ranges from 2,420 m^3/sec to 1,930 m^3/sec for the main course and is 460 m^3/sec for the San Francisco River and 270 m^3/sec for the San Vicente River. (see FIG.-4.4.4)

2) Alignment of river channel is made so as to follow the present river channel as much as possible.

3) River profile is designed to retain the present river bed slope as much as possible to keep the equilibrium river bed slope. The proposed river bed slope ranges from 1/1,200 to 1/80 for the main course and is 1/190 for the San Francisco River and 1/100 for the San Vicente River. (see FIG.-4.4.6)

4) River cross section is designed as a compound section for the main course and a simple section for the San Francisco River and the San Vicente River. The proposed river width ranges from 150 m to 270 m for the main course and is 64 m for the San Francisco River and 42 m for the San Vicente River.

5) Levees are designed to have a slope of 1:2, top width of 5 m to 4 m, freeboard of 1.2 m to 1.0 m with sod facing.

3. In connection with the Sabo and flood control plan, an agricultural development scheme is proposed, which has the basic strategies of expanding of irrigated double cropping of rice through integration of the existing irrigation systems and increase of agricultural inputs such as fertilizer.

1) As an irrigation development plan, one (1) new irrigation system integrating the existing nine (9) irrigation systems is proposed. With this scheme, the irrigation area increases from about 560 ha to 2,400 ha. (see FIG.-4.3.23)

2) One (1) headwork with movable weir is planned to be newly constructed on the main course about 2 km downstream from confluence of the main course and the Soa River coming from Mt. Malinao.

3) The main and secondary canals with a total length of 28 km are to be newly constructed combining with the existing canal networks, and the existing canal networks are used as the terminal irrigation canal networks as much as possible.

4) As for a drainage system, the natural rivers and streams are used as a drainage channel and the main and secondary drains with a total length of 2 km are proposed to be newly constructed. In addition, the field and collector drains with a total length of approximately 96 km (40 m/ha) are arranged for the rice field.

5) As for an agricultural development plan, the irrigated rice cultivation of double cropping are introduced to the whole schemed area of 2,400 ha including 1,030 ha of converted area from rainfed to irrigated condition and also the fertilization of nitrogen is increased from around 70 kg N/ha to 100 kg N/ha for the dry season and 80 kg N/ha for the wet season.

6) With this agricultural development scheme, palay yield is expected to increase from about 3.8 tons/ha to 5.0 tons/ha in the dry season and from about 3.5 tons/ha to 4.5 tons/ha in the wet season.

4. The whole construction period is assumed to be 8 years. The respective construction periods are 1 year for sabo works, 8 years for river improvement works and 3 years for irrigation works. (see FIG.-5.2.1)

5. The total construction cost including price escalation and contingency is estimated at P 338.6 million, which comprises P 3.2 million for sabo works, P 302.0 million for river improvement works and P 33.4 million for irrigation works. (Foreign portion P 130.0 million, Local portion P 208.6 million)

6. The direct economic benefit is annually expected to be P 13.0 million consisting of the flood reduction benefit of P 1.6 million and the land enhancement benefit of P 11.4 million.

7. The economic internal rate of return of the project is calculated at 4.5%. The economic viability of the project is not enough. However, the project shall be executed because the project will bring about such indirect and intangible benefits as increase in the employment oppotunity, promotion of the regional economy, elimination of the social unrest, stabilization of the national life, etc. and also making Malinao City free from the flood.

D. Master Plan for The Yawa River

1. Sabo plan is established for three rivers of the Anuling River, the Budiao River and the Pawa-Burabod River. Also, the Sabo works are planned to check and control the sediment runoff or debris flow against 50-year probable flood, and to take account of the importance of the affected area. (see FIG.-4.5.1)

1) For the Anuling River, five (5) consolidation works are planned to check and control the debris production and sediment runoff. The sediment runoff at base point reduces from 415,600 m^3 to 68,600 m^3 with these facilities for 50-year probable flood.

2) For the Budiao River, eight (8) spur dikes and six (6) jetties are arranged to make the best use of the vast existing natural sand retarding basin. The sediment runoff at base point reduces from 234,600 m^3 to 51,800 m^3.

3) For the Pawa-Burabod River, the Sabo works were designed by the first phase Study Team in 1979, i.e. one (1) Sabo dam for the upper reaches to check and control the debris runoff and seven (7) consolidation works for the just lower reach to stabilize the river bed. In the next downstream reaches, seven (7) spur dikes are arranged to check and control the sediment flowing into the existing canal and the lower river channel. The sediment runoff at base point reduces from 440,900 m^3 to 58,800 m^3 with the above facilities.

2. The river to be improved for flood control is the reach of 2.3 km from river mouth to just the downstream reach of junction with the Pawa-Burabod River. (see FIG.-4.5.7)

1) Fifty (50) year probable flood is taken as the design discharge which is 2,150 m^3/sec for the whole reach improved. (see FIG.-4.5.6)

2) Alignment of river channel is designed so as to follow the present river channel as much as possible.

3) Present river bed will be left as it is. The river bed slope ranges from 1/1,000 to 1/300. (see FIG.-4.5.8)

4) River cross section is designed as a compound section and the present river channel is to be used as a low water channel and a high water channel is formed by constructing new levees. The proposed river width ranges from 150 m to 190 m. (see FIG.-4.5.9)

5) Levees are designed to have a slope of 1:2, top width of 5 m, freeboard of 1.2 m and sod facing.

3. The whole construction period is assumed to be 8 years. The respective construction periods are 6 years for sabo works and 4 years for river improvement works. (see FIG.-5.2.1)

4. The total construction cost including price escalation and contingency is estimated at P 80.7 million, which comprises P 34.9 million for sabo works and P 45.8 million for river improvement works. (Foreign portion P 24.5 million, Local portion P 56.2 million)

5. The direct economic benefit is annually expected to be P 2.6 million of the flood reduction benefit.

6. The economic internal rate of return of the project is calculated at 3.8%. The economic viability of the project is not enough. However, the project shall be executed because the project will bring about such indirect and intangible benefits as increase in the employment oppotunity, promotion of the regional economy, elimination of the social unrest, stabilization of the national life, etc. and also Legaspi City in the area is a politically important city, that is, the city capital of Albay Province.

E. Conclusions and Recommendations

The economic internal rate of return of the whole Project is calculated at 5.4%. The economic viability of the Project is not enough. However, it can be expected to a large extent that the project will bring about such indirect and intangible benefits as increase in the employment opportunity, promotion of the regional economy, elimination of the social unrest, stabilization of the national life etc. In conclusion, the project shall be immediately executed to highten the standard of living of the Bicol Region, which is lower than the national standard.

For the successful implementation of the Project, the following are particularly recommended:

(1) Use of local materials and simple structures

(2) Collection of sufficient meteo-hydrological data

(3) Watershed management to conserve the water sources area and to promote reforestation

(4) Selection and control of quarry sites

(5) Assistence of engineering experts

(6) Model test

(7) Pilot project

F. Principal Features of The Project

1. Hydrology and Geomophology

Item	River Basin		
	Quinali (A)	Quinali (B)	Yawa
Drainage Area at River Mouth	524 km^2	158 km^2	74 km^2
River Length at River Mouth	57 km (at Lake Bato)	31 km	17 km
Average Annual Rainfall	2,400 mm (at Guinobatan)	4,200 mm (at Malinao)	3,300 mm (at Legaspi)

2. Sabo Facilities

Facility	River Basin		
	Quinali (A)	Quinali (B)	Yawa
Sabo Dam	-	1 nos.	1 nos.
Spur Dike	28 nos.	-	15 nos.
Jetty	15 nos.	-	-
Consolidation (fence works)	15 nos.	-	-
Consolidation (crib works)	18 nos.	-	-
Consolidation (masonry)	1 nos.	-	-
Consolidation Dam	4 nos.	-	-
Consolidation & Spur Dike	-	4 nos.	-
Consolidation Wing: Spur Dike Body: Crib Works	-	-	12 nos.
Revetment Works	260 m	-	-
Ground-Sill	3 nos.	-	-
Groin	23 nos.	-	-
Groin & Ground-Sill	4 nos.	-	-
Levee	2,350 m	-	-
Excavation	800 m	-	-

3. Sediment Volume for Sabo Plan

(Unit: $10^3 m^3$)

Item	River Basin		
	Quinali (A)	Quinali (B)	Yawa
Sediment Run-off Volume at Base Point (without facilities)	1,943.8	319.7	1,091.1
Allowable Sediment Volume	350.7	143.7	213.4
Excess Sediment Volume	1,593.1	176.0	877.7
Sediment Run-off Volume at Base Point (with facilities)	321.5	119.7	179.2
Sediment Volume Controlled (Reduction Rate)	1,622.3 (83%)	200.0 (63%)	911.9 (84%)

4. River Improvement Works

Item	River Basin		
	Quinali (A)	Quinali (B)	Yawa
Improvement Length	48.8 km	24.9 km	2.3 km
Design Discharge	920 - 4,260 m^3/sec	270 - 2,420 m^3/sec	2,150 m^3/sec
Proposed Riverbed Slope	1/130 - 1/1,550	1/80 - 1/1,200	1/300 - 1/1,000
Proposed River Width	80 - 450 m	42 - 270 m	150 - 190 m
Proposed Levee			
Slope	1 : 2	1 : 2	1 : 2
Top Width	4 - 5 m	4 - 5 m	5 m
Freeboard	1.0 - 1.2 m	1.0 - 1.2 m	1.2 m
Proposed River Cross Section	Simple and Compound	Simple and Compound	Compound
Sluiceway	7 sites (2m x 2m x 26 nos.)	-	-

5. Agricultural Development Scheme

Item	River Basin	
	Quinali (A)	Quinali (B)
Irrigation Area		
Existing (Net)	3,640 ha	1,370 ha
Proposed (Net)	6,350 ha	2,400 ha
Weir (New)	2	1
Intake (New)	3	1
Irrigation Canal		
Main	45 km	11 km
Secondary	80 km	41 km
Drainage Canal		
Main & Secondary	71 km	45 km
Field Drain	238 km	95 km
Sluiceway	7	4
Fertilization		
Existing	70 kg N/ha	70 kg N/ha
Proposed		
Dry Season	100 kg N/ha	100 kg N/ha
Wet Season	80 kg N/ha	80 kg N/ha
Palay Yield		
Present		
Dry Season	3.8 tons/ha	3.8 tons/ha
Wet Season	3.5 tons/ha	3.5 tons/ha
Proposed		
Dry Season	5.0 tons/ha	5.0 tons/ha
Wet Season	4.5 tons/ha	4.5 tons/ha

6. Construction Cost

(Unit: Million Pesos)

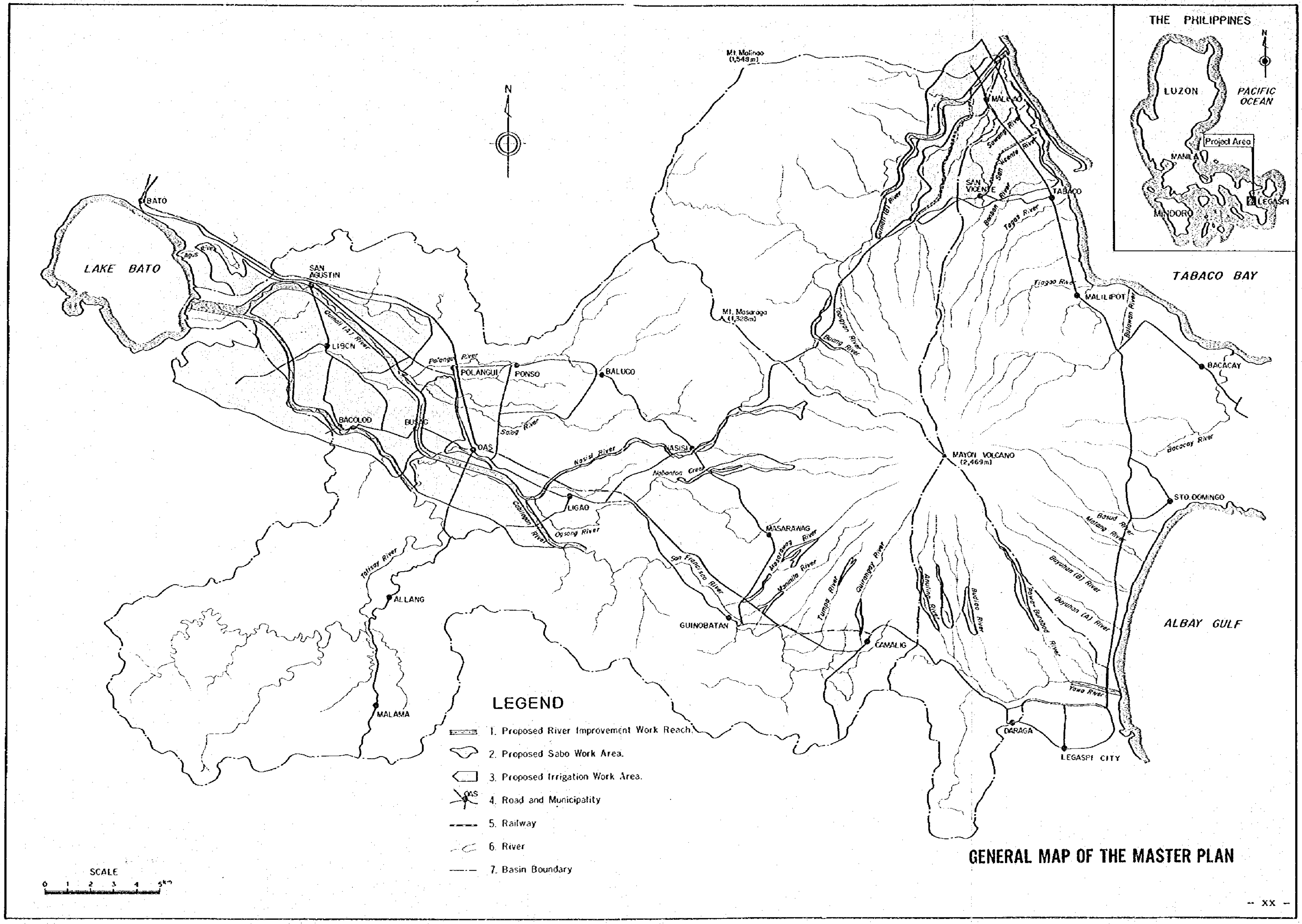
Item	River Basin			
	Quinali (A)	Quinali (B)	Yawa	Total
1. Contract Cost				
Direct Cost	429.7	146.6	35.7	612.0
General	43.0	14.7	3.6	61.3
Contractor's Profit	47.2	16.1	3.9	67.2
Contractor's Tax	14.2	4.8	1.2	20.2
Surcharges	23.6	8.1	2.0	33.7
Sub Total	557.7	190.3	46.4	794.4
2. Acquisition	14.5	3.0	0.3	17.8
3. Resettlement	16.8	0.6	0.8	18.2
4. Engineering	55.8	19.0	4.6	79.4
5. Administration	27.9	9.5	2.3	39.7
6. Contingency				
Physical	111.5	38.1	9.3	158.9
Price Escalation	303.3	78.1	17.0	398.4
Total	1,087.5	338.6	80.7	1,506.8

Notes: 1) Interest during construction period is not included.

2) Foreign currency portion is roughly estimated at P 543.2 million. Local currency portion is roughly estimated at P 963.6 million.

7. Economic Cost and Benefit

Item	River Basin			
	Quinali (A)	Quinali (B)	Yawa	Total
Whole Construction Period (years)	10	8	8	10
Sabo Works (million pesos)	44.8	2.2	20.2	67.2
River Improvement Works (million pesos)	522.2	181.9	29.1	733.2
Irrigation Works (million pesos)	53.2	21.0	-	74.2
Total Cost (million pesos)	620.2	205.1	49.3	874.6
Flood Reduction Benefit (million pesos)	16.0	1.6	2.6	20.2
Land Enhancement Benefit (million pesos)	29.6	11.4	-	41.0
Total Beneift (million pesos)	45.6	13.0	2.6	61.2
Internal Rate of Return (%)	6.9	4.5	3.8	5.4
Benefit Cost Ratio				
Discount Rate				
4%	1.4	1.1	1.0	1.2
6%	1.1	0.8	0.7	0.9



GENERAL MAP OF THE MASTER PLAN

MASTER PLAN

FOR

MAYON VOLCANO SABO AND FLOOD CONTROL PROJECT

MAIN REPORT

CONTENTS

Page

Page

Page

V. IMPLEMENTATION PROGRAM

VI. PROJECT EVALUATION

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

BAEcon	Bureau of Agricultural Economics
BAEx	Bureau of Agricultural Extension
BFCD	Bureau of Flood Control and Drainage
BPI	Bureau of Plant Industry
BRBDP	Bicol River Basin Development Program
COWS	Committee on Warning System
FAO	Food and Agriculture of the United Nations
JICA	Japan International Cooperation Agency
MPW	Ministry of Public Works
NSCO	National Census and Statistics Office
NEDA	National Economic and Development Authority
NIA	National Irrigation Administration
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PNR	Philippine National Railway
mm	milimeter
cm	centimeter
m	meter
km	kilometer
m^2	square meter
km^2	square kilometer
ha	hectare
$mile^2$	square mile
m^3	cubic meter
m/sec	meter per second
l/sec	liter per second
m^3/sec	cubic meter per second

m^3/sec/km^2	cubic meter per second per square kilometer
m^3/year/km^2	cubic meter per year per square kilometer
mm/hr	milimeter per hour
lit/sec/ha	liter per second per hectare
m/ha	meter per hectare
kg/ha	kilogram per hectare
kgN/ha	kilogram nitrogen per hectare
kgP_2O_2/ha	kilogram phosphate per hectare
kgK_2O/ha	kilogram patassium per hectare
mg/l	miligram per liter
yr	year
%	percent
°C	degree centigrade
EL.	elevation above mean sea level
Mt.	Mount
GNP	Gross National Product
GRDP	Gross Regional Domestic Product
FOB	Free on Board
PD#390	President Decree No.390
P	Philippine peso
US$	United States dollar
FY	Fiscal Year

I. INTRODUCTION

1.1 Historical Background

Mayon Volcano with an elevation of 2,469 m which is located in the southeast of Luzon, the Republic of the Philippines, has erupted periodically about once every 10 years. In the surrounding area of Mayon Volcano and the Quinali (A) River basin, the ejecta as lava, volcanic ashes, etc. from the volcano has run out as an avalanche of earth and rocks or a debris flow with heavy rain and thus has caused such serious damages as burying houses, paddy field, and washing away of railway, road, etc. In the plain area of the Quinali (A) River basin, flooding has brought about much sediment deposition and thus caused a serious damage due to flood inundation. Sabo works against the surrounding area of the volcano have been a long-cherished desire of the inhabitants in this district and also an outstanding problem of the Philippines Government.

In 1977, the Philippine Government requested the Study Team for the Pasig Potrero River Flood Control and Sabo Project located in the central Luzon, which was undertaken by the Japanese Government at that time, to study the Mayon Volcano Sabo Project.

In August, 1977, the Philippine Government officially requested the Japanese Government to study the Project. In response to the request of the Philippine Government, the Japanese Government despatched three experts during the period from January 16 to January 19 in 1978. They examined a course of cooperation by the Japanese Government, necessity of preliminary study, and possibility of the project implementation. As a conclusion, they convinced the necessity of countermeasures against debris extrusion and recommended the urgent despatch of a preliminary study team.

In response to the above recommendation and the request of the Philippine Government, a preliminary study team consisting of six experts was despatched to the field during the period from May 29 to June 17 in 1978. The Team confirmed the urgent necessity of the proper study and possibility of the project implementation based upon the results of site reconnaissance and its examination, hearing of the situation from and the consultation with the Philippine Government. The Team then proposed the basic principle, work items and work schedule of the study of the Project.

The Project is studied by two (2) phases. The study team for the first phase was despatched to the field during the period from September 17 to December 18 in 1979, and performed detailed design of Sabo facilities in Pawa-Burabod River, a tributary of the Yawa River according to the request of the Philippine Government. And it submitted the Design Report to the Philippine Government in March 1980.

The study team for the second phase was despatched to the field during the period from June 23 to August 30 in 1980, and established the Master Plan of the Project after further study in Japan.

1.2 Objectives of the Study and Scope of Work

The objectives of the study are to establish the Master Plan of Sabo and Flood Control covering the subject area and to make a study of a warning and evacuation system.

The study covers the area of Mayon Volcano and its surrounding area which is directly or indirectly affected by the eruption of Mayon Volcano. The rivers which originate in Mayon Volcano are taken up including their tributaries and distributaries. They are;

(1) The Quinali (A) River including the Talisay and the Polangui Rivers, both of which are the tributaries of the Quinali (A) River.

(2) The Quinali (B) River including its tributaries originating in Mt. Malinao.

(3) The Yawa River including its tributaries.

(4) Eleven (11) streams originating in the east and north-east slope of Mayon Volcano. (East and North-East Streams)

Lake Bato, rivers flowing into it other than the above rivers, and rivers downstream from Lake Bato are out of the subject area. A dam project which is planned in the Talisay River is also out of the formulation of the Project Master Plan.

Study of Sabo Plan is made for the slope of Mayon Volcano only. The mountainous areas of the Talisay, the Polangui, the Quinali (B) Rivers, etc. other than Mayon Volcano are not be taken into consideration for Sabo Plan.

As for Flood Control Plan (River Planning), the middle and lower reaches of the rivers subject are studied.

The Master Plan for Sabo and Flood Control is established for the Quinali (A), the Quinali (B) and the Yawa Rivers, but as for the East and North-East Streams, their present conditions, problems encountered and necessities of sabo and river improvement works are presented without establishing Sabo and Flood Control Plan.

1.3 Acknowledgement

Throughout the period of this investigation, the Study Team has maintained close cooperation with the Philippine Government for all engineering and administrative matters. Many data and informations required for the study were provided by the Philippine Government.

The Study Team takes this opportunity to express its sincere thanks to the Bureau of Flood Control and Drainage, Ministry of Public Works, MPW Region V Office in Legaspi City and all other authorities concerned for their kind cooperation and assistance to the Study Team during its stay in the Philippines. The Study Team feels it particularly happy to be able to contribute with this study to the development of the Philippines.

II. NATIONAL AND REGIONAL SOCIO-ECONOMIC BACKGROUND

2.1 National Socio-Economic Condition

2.1.1 Economic Indices

The Republic of the Philippines consists of 7,107 islands with the total land of 300,000 km^2. In 1975, the population was 42.0 million, indicating an average annual increase of 2.7% from 1970 to 1975. This is a marked slowdown from the 3.1% average annual growth in population for the period 1960-1970. The population density was 140 persons per km^2 in 1975.

The economy of the Philippines has grown very steadily during the last decade and the Gross National Product (GNP) in 1977 attained around P 77,961 million at constant 1972 prices. The GNP grew at an annual rate of 5.1% during 1966-1971, 6.6% during 1971-1976 and 6.3% for the last 1976-1977. Per-capita GNP was P 1,747 at constant 1972 prices.

Agricultural sector shares 26.5% of GNP. Industrial sector including mining and quarrying, manufacturing, construction, electricity, gas and water shares 34.3%, in which manufacturing is the largest, while service sector shares 39.2% of GNP. In terms of the employment structure, about 53% of the labor force is absorbed in agricultural sector, while 15% of the labor force in industrial sector. About 32% of the labor force is working in service sector. Unemployment rate is estimated at 4-6% of the working population. But the ratio would become higher if taking into account the existence of the under-employment in agricultural sector.

In the agricultural sector, agricultural crops including food and commercial, palay, corn, banana, coconut, sugar cane, abaca and other crops, produced P 20.2 billion in 1976. Rice is the most important crop in the agricultural crops produced in the country. Total production of palay was 6,160 thousand tons in 1976. The production has been increasing steadily during the past 10 years except the stagnation period around 1972-1973. Despite the steady increase of the palay production, it is not yet sufficient for domestic consumption.

Production of coconut was fluctuating affected partly by world market price and partly by natural conditions. Most of the products were for foreign consumption. In 1976, out of the total production of about 3.4 million tons, the coconut products share 24% in 1977 of export commodity. Sugar cane is another important crop for export. Its total production increased from about 2.2 million tons in 1970 to 3.6 million tons in 1976.

Total exports of the commodity were US$ 2,574 million in 1976 and US$ 3,151 million in 1977 and US$ 3,425 million in 1978. It grew at an annual growth rate of 12.2% for 1975-1976 and 8.7% for 1977-1978. They consist of agricultural products, mineral products, manufactures and others. In 1976, US$ 1,502 million or nearly 60% of the total export value came from agricultural products, while the export value of the same commodity was US$ 1,677 million or nearly 50% of total export value in 1978.

Total imports of the commodity in 1976 were US$ 3,634 million. It increased at an average growth rate of 31% during 1972-1976 period. Main components of the imports were raw materials and capital goods. In 1976, raw materials including mineral and fuels account for about 60% of the total imports in value. Capital goods share 30%, while consumer goods share the residual 10%. In 1977 and 1978, consumer goods increased around 16% of the total imports.

Exports and imports were roughly in balance in value during 1970-1072 period. In 1973, trade balance recorded a surplus. Since 1974, however, it was deteriorated and a deficit attained US$1,176 million in 1978. The balance of payments recorded a surplus during 1970 to 1974. It turned to a deficit from 1975 despite the huge non-monetary capital surplus. In 1975, a deficit of the balance of payment attained US$521 million.

All the indices indicate steady price increase during 1972 to 1977. Wholesale price increased by 14.9% annually on the average including the extraordinary period of 1972-1974, while it increased by 9.5% annually from 1975 to 1977.

Revenue of the national government increased at an annual rate of 12.3% and attained P 21.7 billion in 1977. Current expenditure grew up at an annual rate of 7.3% and reached P 17.4 billion in 1977. The current surplus which is the amount of the revenue minus the expenditure recorded for the past three years ranging from about P 2 to P 4 billion. The surplus was spent on the infrastructure investment which strengthened the economic base of the country.

2.1.2 Long-term Development Plan

In the Republic of the Philippines, there are three Development Plan including Five-Year Development Plan (1978-1982), Ten-Year Development Plan (1978-1987) and Long-Term Development Plan up to the year 2000. According to the Long-Term Plan, GNP will be growing at an average annual rate of approximately 8%, reaching close to P500 billion (at constant 1972 prices) by 2000.

The share of agriculture, fishery and forestry to total net domestic product will drop by 14.2% points in the next development decades, i.e. from 30.9% in 1976 to 16.7% in the year 2000. However, agricultural production will still be expanding at the rate of 5.6% between now and 2000. By the year 2000, Philippine population could be approximately 83 million from a Level of 42 million in 1975.

There will be 52 million Philippine people of working age of over 15 years old in 2000. The labor force will be more than double within the next quarter of the century, reaching around 33 million. Therefore, some 32 million jobs will have to be provided in order to reduce the unemployment rate down to 4%.

2.2 Regional Socio-Economic Condition

2.2.1 General

The Bicol Region is located at the southeastern tip of Luzon lying between latitudes 12 N and 14 N degrees and longitudes 122 E and 124 E north, consisting of six provinces (Albay, Camarines Norte, Camarines Sur, Catanduanes, Masbate and Sorsogon), three cities (Iriga, Legazpi and Naga) and 113 municipalities. It has the total area of 17,633 km^2 and the total population of 3,194 thousand (in 1975) comprised 7.6% of total national population. The population density was 168 persons per km^2 in 1970 and slightly rose to 180 persons per km^2 by 1975.

2.2.2 Gross Regional Domestic Product and Regional Economic Structure

Gross regional domestio product (GRDP) of the Bicol Region between 1971 and 1975 grew by 7.8%, or, in absolute terms, from P 2,032 million in 1971 to P 2,750 million in 1975 at constant at 1972 prices. Per-capita GRDP was P 861 in 1975, which was lower than the national level.

Agriculture sector including fishery and forestry is the region's largest economic sector, producing about 50% of the total regional product. Industrial sector including mining and quarrying, manufacturing and electricity, gas and water is about 16%, which is lower than commerce and service sector of 31% of total regional product. Characteristics of the economic structure are also represented by the labor force absorption by the various sectors of the economy. In 1975, there were 1,059 thousand persons employed compared to 911 thousand in 1970 and the employment has increased by 3.1%. Agriculture remains to be the main source of livelihood as indicated by about 655 thousand workers, or 61.8% in agriculture activities, industry's share was approximately 154 thousand or 14.5%, while the rest of the economy accounted for 251 thousand or 23.7% of total employed in 1975.

All the consumer price indices in the Bicol Region indicate price increase during 1972 to 1979 and especially higher price increase during 1972 to 1974 were caused due to quadruple increase in oil price. The consumer price increased by 12.1% annually on the average from 1975 to 1979.

2.2.3 Five-Year Regional Development Plan

To contend with the problems of the region, the development plan for 1978-1982 is formulated. For the years from 1978 to 1982, an average growth rate of 8.3% is aimed to lift the GRDP from P 3,262 million in 1978 to P 4,502 million by 1982 for an increase of 51% over the five-year span. Among subsectors, agriculture will be increasing production by 5.2% yearly, industry by 11.4%, and services by 12.9%. Valued at 1972 prices, output-per-person in the region will be increasing from P 873 in 1977 to P 1,219 by 1982 and further to P 1,662 by 1987.

According to the Long-Term Development Plan, for the next 25 years, the development strategy of the Bicol Region will emphasize a structural shift in its economy from a predominantly agricultural base to a more balanced and interdependent agroindustrial setup. Other major sectors will give equally important contributions to support the requirements of agro-based and mineral-based industries. Growth will largely be propelled through physical infrastructure initiated by the government. To attain self-sufficiencies in rice, the main thrust of the agricultural strategy will be to reduce damages from typhoons through flood control and drainage works. The rehabilitation of the abaca industry is envisioned to provide expanded rural development opportunities in handicrafts and raw materials for paper production and cordage products.

III. PRESENT CONDITIONS OF THE PROJECT AREA

3.1 Geomorphology and Geology

3.1.1 Geomorphology

An environment of Mayon Volcano in Albay Province in southeastern Luzon and the Quinali (A) River basin between Mayon Volcano and Lake Bato are studied for the project area. Mayon Volcano is one of the world famous mountains for its picturesque conical form of symmetry. It is an active volcano of typical konide stratovolcano with an elevation of 2,469 m. There are an extinct volcano of Masaraga (EL. 1,328 m) in the west side and a dormant volcano of Malinao (EL. 1,548 m) and northwest side of Mayon Volcano.

A low hill area lower than EL. 400 m is extending in the south of the project area, comprising sandstone, shale, limestone and volcanic rocks of Pleistocene and Tertiary.

The surveyed area can be divided into two geomorphological provinces, Mayon Volcano and alluvial plain.

(1) Mayon Volcano

Mayon Volcano is a typical stratovolcano consisted of alternation of lava and pyroclastic materials, showing younger stage of geomorphic cycle. Contour line is concentric around its crator. Characteristic drainage pattern is radial and consequent valleys are formed. Rivers above EL. 200 m - 300 m are intermittent streams which flow only in heavy rainfall time or in rainy season, because most of the ground is covered with well-permeable pyroclastic flow deposits. Between summit and mid slope of EL. 1,500 m, the Mayon slope is extending barren ground with talus covers and grass land of Cogon dissected with dry gullies. These gullies develop into V-shaped at EL. 1,500 m down to 600 m, into U-shaped at lower than EL. 600 m, and finally diverge into unsettled shallow channels over the alluvial fan at EL. of 200 m - 300 m. River deposits below EL. 600 m are mostly debris flow deposit in recent age and gravelly, accompanying big blocks. Especially, between EL. 200 m and 300 m, debris flow deposits are covering on the gentle slope. The riverbed of the lower Basid River is raised up close to the girder of the San Isidro-Lideng Bridge on the eastern slope. On the other hand, at the Buang Bridge on the lower Buang River on the western slope. The riverbed is scored and bridge pier is exposed at the foot. Slope gradient of Mayon Volcano can be classified at clear transition points as follows.

	Slope section		Gradient
Below	elevation of	200 m - 300 m	less than 3°
	"	500 m - 600 m	around 5°
	"	900 m - 1,000 m	15° - 20°
	"	1,600 m - 1,700 m	25° - 27°
above	"	1,600 m - 1,700 m	30° - 42°

Thus, difference of slope gradient is more than 10° around EL. 600 m, where very sharp transition of gradient appears. It shows that the upper slope of the transition point is covered with debris and volcanic ejecta on the surface and lava flow underneath, and that the lower slope is mostly comprised with pyroclastic materials. It means that debris flow comes into existence and runs on the upper slope and runs through or deposits on the lower slope.

There are several small hills of cinder cone, dacitic volcanic spine with an elevation of less than 300 m, such as Tagontong Hill of Kilicao, Mt. Quituinan of Bublusan and Tancalao Hill in the southwest of Malinao.

(2) Alluvial Plain

There are developing alluvial plains around Legaspi City, south of the Yawa River and along the Albay Gulf, and plain along the Quinali (B) River, which is rising on Malinao volcano and Masaraga Volcano and debouches into the Tabaco Bay. These alluvial plains are extension of alluvial fans on the skirt of Mayon Volcano. North of the plain along the Quinali (A) River, debouched to Lake Bato is abutted on the skirt of Masaraga volcano with an elevation of 1,328 m. South of the plain is abutted on the foot of hills with an elevation of about 400 m of sedimentary and volcanic rocks of Pleistoceue - Tertiary period. The plain extends with a width of 6 km.

An active fault (San Vicente-Ligao Fault) is running along the boundary between the hills and the plain, showing very clear line extending WNW - ESE direction.

Lake Bato where the Quinali (A) River debouches, is very shallow. Its bottom is about 1.5 m above mean sea level, its surface is 6 m in elevation and its surface area is 20 km^2, having low flat plain around the lake.

3.1.2 Geology

The Philippine Archipelago is located in the Circum-Pacific Islands arc or in the Circum-Pacific Active Zone, where volcanic and earthquake activities are concentrated. Bicol peninsula is located in a graben between Philippine Deep on the east and Philippine Fault Zone on the west. A big active fault (San Visente-Ligao Fault) of WNW-ESE is running in the south of Mayon Volcano.

A series of characateristic andesitic volcanic rocks has been developed around the Mayon volcanic group during the period from Tertiary to the Recent. According to the plate-techtonic theory, when the oceanic plate (Philippine Plate) thrusts underneath the Philippine archipelago to the depth of 100 - 200 km, the plate is metamorphosed and emitted hot fluid causes melting of mantle material to form andesitic magma which extrudes as volcanism.

Geology of Mayon Volcano and its surroundings is classified as follows:

(1) Volcanic rocks of andesite and dacite (partly including phyolite) and sedimentary formations of sandstone, shale and conglomerate of Oligocene to Miocene Tertiary.

(2) Andesitic volcanic rocks of upper Miocene Tertiary to Pleistocene Quaternary (partly including phyolitic volcanic spine and cinder cone).

(3) Limestone and limestone-bearing sandstone, mudstone and conglomerate of Pliocene Tertiary to Pleistocene Quaternary.

(4) Lava, ash fall deposits, pyroclastic rocks, debris flow deposits, and mud flow deposits formed directly from Mayon activity during the period of Pleistocene Quaterrary to the Recent.

(5) Alluvium consisting of gravel, sand and silt deposited in Holocene (partly including littoral deposits).

Items (1) - (3) are developing around Mayon Volcano and hilly area on both sides of the Quinali River Plain.

No sedimentary rock formations such as limestone, sandstone, conglomerate and mudstone is developing on the north side of the San Vicente-Ligao Fault, but all covered with volcanic rocks. Sedimentary rocks and volcanic rocks that formed before Mayon activity are rather hard and compact, resistive against corrosion and sound enough for basement rocks of heavy structures, though their distribution is very limited.

There are several low hills in the skirt of Mayon Volcano, which is throughly or partly covered with volcanic ejecta from Mayon Volcano. Most of them are andesitic and dacitic lava dome, volcanic spine and cinder cone as mentioned above, item (2). Volcanic rocks on a hill, north of Sto Domingo and Mt. Bulakawan, south of Malilipot, is the same series of andesitic and dacitic lava, intercalated with agglomerate, and both belong to the volcanic rock in item (1). There are many exposures of hard andesitic rocks along the Bulawan River and the Tabigyan River around Mt. Bulakawan. Exposures of andesitic rock of item (2) are also found on Tankalao hill, north of Bantayan on the Quinali River and in southwest area of Tabiguian.

The first explosion of Mayon Volcano, ever recorded in history is in the year 1616. The active volcano has been errupted periodically about onece a 10-year since the year 1928. Magma in Mayon Volcano is andesite or andesitic basalt with lower viscosity. Destructive explosion as in the case of dacite or rhyolitic magma could not be taken place in the Mayon Volcano. But drastic damages caused by mud and pyroclastic flow will be a matter of deep concerns.

Slope forming materials of Mayon Volcano are classified into: (a) debris flow, (b) ash fall deposits, (c) pyroclastic flow, (d) mud flow, and (e) lava flow. Items (a) - (d) are unconsolidated to some extent and may have enough bearing strength for foundation of small sabo structure but they are less resistive against erosion.

Alluvium is developed on the plain of less than EL. 100 m and composed of gravel, sand and silt. Most of the alluvium is extending along the Quinali (A), the Quinali (B) and the Yawa Rivers and littoral sediment of gravel and sand is deposited along coast of the Albay Gulf and Tabaco Bay.

3.1.3 Eruptions of Mayon Volcano and Their Recorded Calamities

Mayon Volcano is a stratovolcano of augite-hypersthene andesite accompanied with olivin-augite-hypersthene basalt. Its eruptions are not so violent but subsequent pyroclastic flows and mud flow often cause calamities. The oldest eruption ever recorded in history is that of 1616; eruption records since then are as follows.

July 1766, Feb. 1814, June 1897, Mar. 1900, 1902, June 1928, 1938, Aug. 1939, Sep. 1941, Jan. 1947, Apr. 1968 and Jan. 1978.

Bigger eruptions among them are in 1814, 1897, 1928 and 1968.

Causes of eruption calamities are generally classified as follows.

	Activities	Outcoming calamities
(a)	hot blast (nuees ordentes)	glowing cloud
(b)	rolling incandescent material	pyroclastic flow
(c)	earthquake	earthquake
(d)	mud flow	mud flow
(e)	lava flow	lava flow
(f)	ash shower	ash fall

In the case of Mayon's activity, no big calamity of (a), (c), (e), and (f) occurs. Bigger calamities with a loss of life are in the case of pyroclastic flow (b) and mud flow (d). According to past records, big calamities in Mayon eruption has been limited in eastern, southern and southwestern slopes. Pyroclastic flow occurs at the time of eruption, but mud flow usually occurs after eruption and spread over wide area. Several records on bigger eruption and its calamities are described in the following paragraphs.

(1) Oct. 1766

An eruption was taken place in July, 1766, and mud flow occurs in Oct., 1966 due to heavy rain caused by big typhoon. Malinao was throughly destroyed, coconut trees were burried in the mud flow up to their top. Nearby villages of Cagsaua, Budiao, Guinobatan, Ligao and Polangui were heavily damaged. The 30 deads in Malinao and the 16 deads in Legaspi were reported.

(2) Feb. 1814

Heavy cloud accompanied with a big eruption caused torrential rainfall and mud flow attacked on the village of Bubulusan, Cagsawa and Budiao with the depth of 10 - 12 m. The total deads in these villages reached to 1200.

(3) 1875's disaster

No eruption occured in this year. But mud flow was taken place by heavy rainfall, being recorded the 1500 deads.

(4) 1897's disaster

A big-scale eruption was taken place. Pyroclastic flow attacked Libog town, 212 lives were lost in a day. Hot mud flow also flowed down along the Basud River, just after the eruption.

(5) 1915's disaster

There was no eruption happened in the year 1915. Nevertheless, big mud flow was occurred by heavy rain, attacking most of the town of Camalig, Bongabong and Tabaco. No life was lost in the mud flow, but Railroad between Legaspi and Libog was burried.

(6) Jan. - Aug. 1928

A big-scale eruption was taken place. A lava flow reached down to an elevation of 300 m on the Libog side. Glowing cloud was occured. The one dead was reported in the town San Antonio.

(7) Apr. and May 1968

Large scale eruption was taken place. Lava flow reached down to an elevation on Camalig side slope. Flowing cloud and mud flow occurred but no big damage.

3.2 Land Evaluation

3.2.1 General

Based on existing documents, aerial photo interpretation, topographic analysis and field survey, basic data for land evaluation are developed in the form of the land classification map, land use map, devastation map and topographic analysis map.

The land classification map shows the features of terrains formed by internal forces of the earth such as volcanic activities and crustal movements as well as by external forces such as weathering, erosion, sedimentation. Terrains are classified in terms of causes and stages of formation. This map is useful for the purpose of predicting possible future topographic change.

The land use map shows the existing land use in the project area. It displays populated areas (settlements), cultivated lands and other specified land uses. This map is useful for agricultural development scheme, Sabo and river planning.

The devastation map shows debris in the production, transportation and sedimentation of the major streams coming from Mayon Volcano. It provides basic information for sabo planning.

The topographic analysis map shows the terrain features such as slope, aspect, river order in the project area.

3.2.2 Land classification

In FIG.-3.2.1 the land classification map is shown.

The land in the project area is largely classified into the mountainous area and lowland.

The mountainous area is classified into three types, i.e. lava flow, volcanic fan and Tertiary mountain.

Lava flow is subdivided into new and old ones, which is distributed around Mayon Volcano and consists mainly of andesite lava flow and pyroclastics. Volcanic fan is distributed in the skirt of Mayon Volcano, consisting mainly of unconsolidated sediments. Tertiary mountain is distributed in the surrounding area of Mayon Volcano and subdivided into Volcanics, limestone - sandstone - volcanics and diorite.

Lowland is classified into high terrace plain, natural levee, alluvial plain, fan-like lowland, bar, old river trace, existing river and lake.

High terrace plain is distributed in northeast of Lake Bato. Natural levee is distributed in such major cities and municipalities as Legaspi City, Ligao, Libon and Oas. Alluvial plain is subdivided into low and high fan. It is widely distributed in the lowland. Fan-like lowland has a slight slope. Bar is distributed in Albay Gulf and Tabaco Bay. Old river trace is partly swampy. Existing river and lake indicate the main river such as Quinali River, Yawa River, Lake Bato, etc.

The land classification in the project area is summarized as follows:

1) The land form in the project area is largely classified into two types, i.e. mountainous area and lowland.

2) In the mountainous area, volcanic fan is distributed on the foot of Mayon Volcano. Indicating the transportation and sedimentation of a large volume of sediment. Lava flow is distributed in the upper half of Mayon Volcano.

3) In the lowland, Alluvial plain has an extensive distribution, which is generally susceptible to flood.

3.2.3 Land use

In FIG-3.2.2 the land use map is shown.

The land use is largely classified into populated area, public facility, cultivated and, forest and others.

Populated areas are classified into the concentrated and scattered ones. The former represents the major cities and municipalities such as Legazpi City, Tabaco, Ligao and Libon. The latter indicates barangays, etc. Public facilities are classified into school, church, airport and golf course. Cultivated lands are classified into rice field, field (Soy beans, cassva, corn, sweet potato, etc.), coconuts, abaca, citron and fish farms. Coconut farms are subdivided into dense and sparse ones. Forests are classified into natural tree schrub (Dipterocarp, Vitex parviflora) and nipa. Other land uses represented are glassland (Cogon, Parang), bare land, developed land and waters.

The land use in the project area is summarized as follows:

1) The lowland is almost used for rice field. Such major cities and municipalities as Legaspi City, Tabaco, Ligao and Libon are located in the lowland.

2) The lower half of Mayon Volcano is used for coconut plantation. In this plantation, the villages are scattered. The higher area than coconut plantation is covered with natural forest. Natural forest is well preserved rather on the northern side than southern side. From summit down to the 1,600 m level, the slope of Mayon Volcano remains bare.

3.2.4 Devastation

In FIG-3.2.3 the devastation map is shown.

The devastation area is classified into three zones of the productive, transport and sedimentation ones.

The productive zone is classified into three categories according to the type of productive area, i.e. collapse, bare land and lava flow.

Collapse is subdivided into the productive and less productive ones. It is distributed on the upper slope of Mayon Volcano. Bare land is also distributed near the summit of Mayon Volcano. Lava flow occurred on the southwest slope of Mayon Volcano by 1978's activity.

The transport zone is classified into the unstable, moderately stable and stable zones according to the degree of stability of sediments.

The sedimentation zone is classified into the unstable, moderately stable and stable zones according to the grade of stability of sediments. Debris flow is classified into the old and new ones based on the period of sedimentation.

The devastation in the project area is summarized as follows:

1) The extremely devastated areas are extending from west to southwest and in southeast of Mayon Volcano. The upper streams of the Nasiri River, the Nabonton Creek, the Masarawag River, the Tumpa River, the Quirangay River and the Pawa-Burabod River are included in this area.

2) The rivers on the northern slope of Mayon Volcano are not so devastated with the exception of the Buang River. Also the Basud River on the eastern slope is fairly devastated.

3.2.5 Topographic analysis

The topographic analysis comprises the slope, aspect and river order classification.

3.2.5.1 Slope

The slope is one of the important environmental variables in relation to land collapse and land use.

Slopes are defined by a total of 10 ranks with 6 ranks for the 11 - 100% range, 3 ranks for the 0 - 10% range and one rank for 101% or more.

The slope map is shown in FIG.-3.2.4.

The slope in the project area is summarized as follows:

1) The lowland in the west of Mayon Volcano has no slope or a gentle slope of 0 - 2%

2) The slope changes gradually from 6% at the foot to 100% near the summit of Mayon Volcano. The area with a slope of more than 100% is limited near the summit of Mayon Volcano.

3.2.5.2 Aspect

The aspect is another important environmental variable concerned with land collapse and land use. Aspects are defined by a total of 8 directions plus pit, flat and peak.

The aspect map is shown in FIG.-3.2.5.

The aspect in the project area is summarized as follows:

1) The lowland is almost pit and flat with exception of the partial topographical change.

2) The aspects of Mayon Volcano has all directions. It indicates that Mayon Volcano is the typical cone.

3.2.5.3 River Order

In sabo planning, it is important to understand the river order. The river order map is produced by picking out major river systems from 1/25,000 scale topographic map referring aerial photos and classifying them according to Horton-Strahler order.

The river order map is shown in FIG.-3.2.6.

The river order in the project area is summarized as follows:

The maximum order in the area is sixth. Most of the streams in the slope of Mayon Volcano have third or fourth order in maximum.

3.3 Meteorology and Hydrology

3.3.1 Meteorology

3.3.1.1 Climate

The climate around the project area is tropical and it is affected by two air stream systems which produce distinctive variation in the climate. These air stream systems are monsoons and Pacific Trade Winds.

The Northeast Monsoon associated with the Northern Hemisphere winter extends from October to March, bringing significant amount of rain to the southern Luzon where the project area is located. The Southwest Monsoon originating in the Indian Ocean affects the area during the Northern Hemisphere summer from May to October. During this period the area is warm and very humid with increasing rates of rainfall.

The North Pacific Trade Wind prevails during April and May, raising the temperature significantly. The South Pacific Trade Wind coincides with the Southwest Monsoon from May to July.

The tropical cyclones affecting the Philippines orginate in the eastern ocean and generally travel on a westerly or northwesterly course over the Philippines. They strike any month of the year, but most occur from June through December. The highest frequency is in July and August. The tropical cyclones affecting the district around the project area have also the same characteristics.

The climatic divisions in the Philippines are classified into four types depending on the rainfall pattern. Much of the area belong to Type II climate with no significant dry season and with a very pronounced maximum rainfall from November to January.

3.3.1.2 Rainfall

The observation network of rainfall is shown in FIG.-3.3.2. Eleven stations exist in the project area. All stations are located along the major roads and at low elevations of less than 130 m. The observation has been conducted on a daily basis with the ordinary collector-type rain gages. No hourly record is available within the area.

The mean annual rainfall in the project area ranges from 2,000 mm to 4,000 mm. Dividing the area by Mayon Volcano, the western part located in the inland area has lower amount of rainfall than the eastern part facing to the sea. This may be due to sheltering effect of the hills and mountains surrounding it.

On the mean monthly rainfall, the period from May to January is generally a rainy season and the large amount of rainfall occurs during the period from November to January. The relatively dry season appears from February through April.

The recorded maximum rainfalls for the duration of 1-day, 1-month and 1-year are 484.8 mm at Legaspi in 1967, 1,528.8 mm at Legaspi in 1975 and 5,128.1 mm at Malinao in 1976 respectively.

3.3.1.3 Temperature and Relative Humidity

Mean temperature fluctuates monotonously within a small range from 25°C to 28°C throughout the year. The temperature rises during the period from January to May and after that goes down gradually until January. The highest temperature occurs in May or June. The extreme temperature within the area ranges from 21°C in January to 33°C in June.

The relative humidity within the area is generally high and its fluctuation is very slight throughout the year. The driest period of the year occurs in May. The extreme relative humidity within the area ranges from 79% to 91%.

3.3.2 Hydrology

3.3.2.1 Streamflow Runoff

There are many streams in the project area originating in Mayon Volcano and other mountains. The largest river is the Quinali (A) River with a drainage area of 331 km^2 and a river length of 55 km. The second-largest one is the Talisay River with a drainage area of 194 km^2 and a river length of 50 km, and then the Quinali (B) and the Yawa Rivers are next.

The streamflow observation network in the area is poor. Only two rivers of the Quinali (A) and the Talisay Rivers have gaging stations, but other rivers do not. Seven stations are located in the Quinali (A) River basin and one in the Talisay River basin as shown in FIG.-3.3.2. Measurement has been conducted on a daily basis by staff gage.

The specific annual mean runoff ranges from 0.04 $m^3/sec/km^2$ to 0.1 $m^3/sec/km^2$. The runoff increases significantly in June and July and continues to increase until Deccember. The draught period appears from February to May. Especially, the draught of the Talisay River is severe due to low flow for its drainage area size. On the other hand, the runoff of the Nasisi River is stable throughout the year. Annual runoff coefficient is estimated at about 0.6 to 0.7 based on the mean annual runoff at the San Francisco River gaging station and the mean annual rainfall at Guinobatan.

Floods are produced by typhoons and tropical cyclones frequenting the area every year. The flash floods coming down from the mountains have been somewhat controlled in recent years by construction of dike system in the Quinali (A) River basin. The area however is often flooded due to a failure of river dikes with the inadequate dishcarge capacities. For this, the major floods have never been recorded accurately due to flooding as well as the poor measurement method such as no self-recording, no flood mark investigation, etc.

3.3.2.2 Sediment

Many streams originate in the slope of Mayon Volcano, and some of them run down with plenty debris. A portion of debris carried deposits along the low hills and the remainings are transported downstream through river channels. The sediment deposition in the middle and lower reaches causes the river bed rising which results in the lack of discharge capacity of the river channel and thus flooding. The quantitative analysis of debris production and sediment deposition over the area has not yet been made at present.

According to the feasibility report prepared by TAMS-TAE in 1978 and subsequent study by ASIATIC in 1980, sediment inflow into Lake Bato, which is the outlet of the Quinali (A) River including the Talisay River, was estimated 400,000 m^3 per year employing the sediment load of the Talisay River at Allang as a representative of sediment inflow into Lake Bato. Assuming the sediment flowing into the lake settled equally over the entire lake area of 20 km^2, the average lake bottom rising is estimated at about 2 cm per year.

3.3.2.3 Hydrology of Lake Bato

Lake Bato is a natural reservoir having a drainage area of 874 km^2. The Quinali (A) River basin including the Talisay River occupies 60% of the above drainage area. The water surface area of Lake Bato changes from about 40 km^2 during rainy season to 6 km^2 during dry months. The recorded maximum water level is 10.48 m in October 1980 and the minimum is 3.37 m in May 1969. The mean water level is 6 m, which corresponds to the water surface area of 20 km^2. During flood time, the water level rises immediately within a few day and goes down very slowly extending more than a month. It is because the only outlet of Lake Bato is the Bicol River. According to the discharge measurement data at Sto. Domingo, the Bicol River, the lake discharges about 38 m^3/sec in average. The discharge may range from 12 m^3/sec to 64 m^3/sec depending upon the season.

3.4 Present River Conditions

3.4.1 Rivers in The Scope of Study

The rivers to be studied, divide of Sabo work section and flood control work section and records on tide at Legazpi and water level of Lake Bato are summarized below.

The rivers to be studied are the following three (3) major rivers and eleven (11) small streams which originate in the Mayon Volcano in accordance with the Inception Report submitted in June 1980.

(i) Quinali (A) River including its tributaries.
(ii) Quinali (B) River including its tributaries.
(iii) Yawa River including its tributaries.
(iv) East and North-East Streams

But only for East and North-East Streams necessity of sabo and flood control works are also explained in this section.

Divides of sabo work section and flood control work section are plotted off the following spots, where the river bed slope is approximately 1/100.

(i) Quinali (A) River - Bridges of National Highway for eastern tributaries upto the Ogsong River
- The overflow culvert type bridge of Ligao-Tabaco National Highway for the Nasisi River

(ii) Quinali (B) River - The contraction at Bantayan
(iii) Yawa River - Banag Railway Bridge
(iv) East and North-East Streams
- Legaspi-Malinao National Highway bridges

The Quinali (A) River is affected by the water level of Lake Bato, and the highest recorded water level is about EL. 10.80 m. Whereas, the Quinali (B) River and the Yawa River is affected by the tide. The highest tide recorded at Legaspi during the period between Jan.'79 and Apr.'80, is about 1.3 m high from the mean sea level. No tidal records in Tabaco Bay exist.

3.4.2 Quinali (A) River

3.4.2.1 General

The Quinali (A) River gathering many streams originating on the southern to western slope of the Mayon Volcano flows generally in a westerly or northwesterly direction and finally pours into Lake Bato. It is the biggest river among the above rivers to be studied in the Project Area. The total length of the river is about 150 km and its drainage area is about 365 km^2. The catchment area is mostly cultivated lands. Most of them are rice fields. But along the main Quinali, there are such densely populated municipalities as Camalig, Guinobatan, Ligao, Oas, Polangui and Libon and many other properties that can hardly be removed.

3.4.2.2 Sabo Work Section

Most of the upstream tributaries are devastated. They are the Quirangay River which pass across Camalig, the Tumpa River which pass across, National highway between Camalig and Guinobatan, the Maninila River, the Masarawag River, the Ogsong River (the Nabonton Creek and Bublusan Creek upstream) and the Nasisi River which pass across the Ligao-Tabaco National highway. The western to southwestern slope of Mayon Volcano that ranges about 20° is well stabilized, and no wild and devastated tributaries exist.

1) Quirangay River

The Quirangay River is the most upstream and most devastated tributary. It forms a deep gorge between EL. 600 m and EL. 400 m. Together with the Maninila River, it forms a large alluvial fan between EL. 350 m and EL. 160 m, which also contains the Maninila River. It is a wide area occupied by cogon grass. Below EL. 160 m it flows at a gentle bed slope and the river course becomes a ditch of several meters in width. Sandy soil dike is existing upstream the Philippine National Railway bridge. Sediment yield at the gorge does not seem to be notable, since vegetation is well renovated. Source of sediment is the secondary erosion above the fan.

2) Tumpa River

The Tumpa River does not have an erosive gorge upstream. A large alluvial fan exists on the mountain skirt, which proves a vast amount of sediment yield in the past. Secondary erosion at the upstream of the fan seems to be the sediment source, but it is not violent. Below EL. 200 m, the river course becomes gentle, and below EL. 170 m it disappears into rice fields.

3) Maninila River

At the east of Maninila, the Maninila River passes across the Provincial road, where the river course is not violent. But below EL. 150 m, new secondary erosion has started and the downstream river course flows down to Travesia. As far as the history of the formation of the river course, it seems that the river course is unstable and will be more unstable.

4) Masarawag River

The Masarawag River bifurcates two (2) courses at the confluence elevating EL. 270 m and combines at about 1 km downstream the Provincial road at EL. 160 m. The spindle-shape between two (2) courses is 1 km in the maximum width and 3 km in length, and is functioning as a natural sand retarding basin. Along the left course, left bank is constructed with excavated sediment for 500 m in length. At present, left course has appearance of the main course, but there is a trace of a vast amount of debris in the past along the right course. The debris reached further than the contraction upto Maipon. It has much debris production downstream.

5) Nabonton Creek

The upstream reach of the Nabonton Creek is neighbouring with the Buga River, a left tributary of the Nasisi River. The border of the catchment of the Nabonton Creek and that of the Buga River around EL. 300 m is not clear. Therefore, sediment discharge flows into both of the rivers depending on the amount and feature of sediment.

The River bed slope upstream the Provincial road is steep. One irrigation intake is existing which is now under repair. But the river bed slope downstream is about 1/40 and there exist deposit terrace of 2 - 3 m in height. The river course is winding, and secondary erosion of river bed is due to sand sediment discharge. About 1.6 km upstream the Paulog Bridge, the Bublusan Creek joins and along the 1 km reach of upstream the bridge, there exists a natural sand retarding basin.

6) Nasisi River

The Nasisi River is a downreach of the Baligan River, which originates from Mayon Volcano running down on the western slope and which is very much devastated and erosive. It is the largest tributary of the Quinali (A) River. Along the Nasisi River, there are such important structures as a Provincial Road bridge, Nasisi Dam and the overflow culvert type bridge of Ligao - Tabaco National Highway. These structures are more or less suffered from flood damages due to erosion and sediment deposition. Near Nasisi, the river course forms a contraction confined between hill foots. The contraction functions as a natural sand retarding basin. Five hundred (500) m downstream Nasisi, there is the Nasisi Dam of the National Irrigation Department, which is an overflow type fixed weir with a small sand flush, which also functions as consolidation works. The bed slope changes from 1/70 to 1/40 at the dam due to scoring. But as the bed material is composed of big gravels, lowering of river bed does not seem to occur further. About five hundred (500) m downstream the dam, there is the Ligao - Tabaco National Highway bridge. Just downstream the bridge, scoring is notable, and the bed was lowered by 3 m for these several years. Eight hundred (800) m downstream the bridge, the river bed slope is 1/200, and there exists a natural sand retarding basin of 100 m in width and 1,500 m in length. It is noted that the dam, a vast amount of excavation of river bed materials for highway constructions upstream the Ligao - Tabaco National Highway bridge, and the bridge itself offers adverse effects or sediment balance.

3.4.2.3 River Work Section

Along the middle and the lower reach of the main course, major tributaries are the Nasisi River from Mayon Volcano, the Polangui River and the Talisay River. And no good sites for flood control dams and retarding basins are found.

1) Upstream reach of the main course

Along the main course, Guinobatan suffers from flood inundation due to the limited discharge capacity of the present river channel. Hightening and extensioning of the present dike will be effective. Along the Salong River, the Iraya River which goes by the name of the Camalig River, the Sua River and the Maninila River, flood inundation occurs in the limited area in the middle or downstream reaches mostly due to poor drainage.

2) Cabilogan River

After the Banao Bridge, the Cabilogan River flows in a deep valley receiving two (2) left tributaries. After passing this valley it is meandering, especially at Tagpo-Cavaci. The left dike of grouted riprap was partly destroyed there. A short cut should properly be made there.

3) Ogsong River

The Ogsong River seems rather stable in its middle and lower reach.

4) Nasisi River

Along the Nasisi River, there are such important structures as a National Railway bridge and a National Highway bridge. These structures are hightening the river bed with sedimentation.

5) Polangui River

Along the Polangui River, there exists Quinali Left and Right Dam, which is an overflow type fixed weir with a small sand flush. As the dam height is about 3 m, and as it is hightening the bed, it is one of the reasons of flood inundation of Polangui.

6) Talisay River

The Talisay River course up to the upstream the Bacolod Bridge has a wide and deep channel for passage of a large flood, but suddenly becomes shallow after the bridge. And it causes flood inundation in the area near the Talisay River. It receives the Libon River before the Bailey Bridge, and joins the main course about 2 km before Lake Bato.

7) Quinali (A) River

The middle and lower reaches of the main course which is called the Quinali (A) River are considerably mingled with the Talisay River, the Polangui River and other tributaries, all of which flow down from the surrounding mountains and hills other than Mayon Volcano. These tributaries have flushy nature of discharge and contain much more suspended materials due to surface soil erosion than the rivers coming from Mayon Volcano. About two-thirds of the Quinali (A) River course in length is provided by levees. However, the levees are often destroyed in many places. This is mainly because of lack of discharge capacity of the river course. It is found that the left bank levees intentionally constructed lower than the right bank. Four permanent irrigation intake dams, such as Libod Bariw, South Quinali, San Agustin and Agos-Sta. Cruz dams are existing in the main course, all of which are overflow type fixed weirs with a small sand flush. These dams offer adverse effects from the viewpoints of flood control of the river, since they not only reduce discharge capacity during floods, but also highten the river bed with sedimentation. There are at present three (3) connecting canals between the Quinali (A) River and the Talisay River; at Bobonsuran upstream reach of Oas, at South Quinali Dam downstream reach of Oas and the Libon River downstream the Busac Bridge. First two (2) canals join each other before entering into the Talisay River. Presently a part of the ordinary discharge of the Quinali (A) River is diverted through these canals into the Talisay River. And it seems that they also function as flood ways, but the inundation in the area between the two rivers does not seem to be avoided.

8) Lake Bato

Presently, Lake Bato is utilized as a flood retarding basin. The flood inundation in the downstream reaches near Lake Bato, some 2,000 ha is mainly due to Lake Bato so far as it functions as a natural retarding basin. It is a different phenomenon from the flooding pattern of the middle reaches of the Quinali (A) River. This implies that the area near Lake Bato of about 2,000 ha could not be improved by the flood control works of the Quinali (A) River unless such artificial regulation of Lake Bato as is considered the presently contemplated Lake Bato-Pantao Bay Diversion Scheme.

3.4.3 Quinali (B) River

3.4.3.1 General

The Quinali (B) River originates on the western to northwestern slope of Mayon Volcano and gathers several tributaries both from Mayon Volcano, the Mt. Masaraga and the Mt. Malinao. The affected area covers the Malinao plain, Tabaco, Malinao and a large tract of rice field. It passes across the National Highway bridge near the river mouth.

3.4.3.2 Sabo Plan Section

Such tributaries as the Parapoto River, the Namotnga River, the Tabigiyan, Buang are from Mayon Volcano, and some other tributaries are from the Mt. Masaraga and Mt. Malinao. They are well stabilized except the Buang River.

1) The upstream reach of the main course above Bantayan is a deep valley. There is a contraction at EL. 155 m near Bantayan. The river width there is only 25 m, and the river bed slope is about 1/40, heap of boulders especially from the Buang River exists. Other tributaries from Mayon Volcano are well covered with dense forest. And further sediment discharge is not expected at present.

2) Buang River

The Buang River is the most violent ravine which flows in northeastern slope of Mayon Volcano and then joins the main course at Buang. Three hundred (300) m upstream of Buang, it passes across the Buang Bridge of the Ligao - Tabaco National Highway. The bridge piers were attacked and the concrete suffered abrasion. And foundation of piers is scored and exposed. This is due to deposition by debris flow and scoring by flood. It seems that fluctuations of river bed is 4 - 5 m or more.

It causes devastation in the reach between the junction with the main course and 500 - 1,000 m downstream. The debris terrace of 1 - 5 m high is ready to suffer from secondary erosion.

3.4.3.3 River Work Section

Along the middle and the lower reaches of the main course, the San Francisco River from Mayon Volcano from the right and the Taki River from Malinao from the left join the main course. The tributaries from Mayon Volcano has less discharge while the tributaries from Mt. Malinao has flushy nature and its discharge is great.

Among the tributaries from Mt. Malinao the Plansa River and the Taki River particularly which join the main course in the lower reach often cause flood damages to rice fields of Malinao. The San Francisco River is the major tributary coming from Mayon Volcano, and it meanders in the lower reaches and the river course is not stable. Along the main course, due to contractions by fords near Ogob, the river bed is hightened with sedimentation. Flood protection dikes were constructed several years ago on the right bank of the main course and the San Francisco River respectively to protect the Malinao Plain from flooding. However, these dikes are often destroyed due to flood caused by typhoons. Either the reinforcement and extension of these protection or new construction of dikes will be required. The main course meanders in the middle reaches, but it forms a natural retarding basin in rather a wider channel. The sand spit due to coastal sedimentation developes at the river mouth. But it has been observed that it is flushed out during the flood.