3.4.4 Yawa River

3.4.4.1 General

The Yawa River gathers three (3) streams on the southern to southeastern slope of Mayon Volcano and other small tributaries from the southern hills which is outside of the Project Area, where the biggest one is the Busay River, and it flows mostly in easterly direction along the Legaspi Airport passing across the National Highway bridge and pouring finally into Poliqui Bay of Albay Gulf, just north of Legaspi City. The three streams are the Anuling River, the Budiao River and the Pawa-Burabod River from the west to the east.

3.4.4.2 Sabo Work Section

The Anuling River, the Budiao River and Pawa-Burabod River are less devatated than the Nasisi River.

1) Anuling River

Two (2) parallel torrents which originate at EL. 1,100 m on the southern slope flow together and form the uppermost reach of the Yawa River, near Cagsawa Ruin. The slope between EL. 1,200 m down to EL. 400 m is covered with natural forest. And the slope of gorge between EL. 600 m down to EL. 350 m is covered with vegetation, and no violent debris is yielded at present. Banks of right torrent are heigher than those of left torrent.

The river channel below the Provincial Road at EL. 140 m is scattered into many ditches in a large tract of rice field and most of water infiltrates into the underground.

2) Budiao River

The Budiao River originates in southern active and steep collapse on southern slope of the Mayon Volcano. And it changes its course to southeastern direction. There must have occured a land slide of a big scale in the uppermost reach of the basin, previously. And still, there occurs an active sediment yield. It, however, will not directly menace the lower reaches because upstream the water fall at EL. 600 m, the river bed slope is rather gentle and the river course is functioning well as a control and a storage of debris. Between EL. 500 m and EL. 300 m, a gorge in 20 m in depth is formed. It passes debris, and lateral erosion in small scale is occuring. Between EL. 300 m and EL. 100 m, along the reach of 3 km, the river width varies between 100 m and 200 m, and the width of deposition of debris is 1.5 km in maximum. The bed slope there is about 1/15. The swelled convex deposit on both sides of the river course proves a vast amount of debris flow in the past. The debris and sand flow suddenly stop at EL.180 m. Most of the water infiltrates into the underground. This phenomenon is common in Mayon Volcano. But this is the most typical. Immediately after the above sand and debris deposition, there exists a large tract of rice field.

3) Pawa-Burabod River

The Pawa-Burabod River is the most active and violent stream all the tributaries of the Yawa River. It has a plenty of debris production in its upstream reach. It originates in collapses on the southeastern slope of Mayon Volcano. Two (2) deep gorges join at EL.500 m and flow down to EL.340 at a steep slope. It puts a right tributary together at EL.300 m. As the present river course does not have banks high enough, debris gushes out with heavy rain and easily overflows the left bank between EL.270 and 230 m. Bonga can be attacked from behind. There is a clear trace of debris dispersed toward this direction. Debris is dispersed and deposited in the middle reach, and the alluvial fan formed has really a wide area. Bottom length along Provincial Road at EL.100 m is as long as 3 km between Mabinit and Matang. From 300 m upstream of Bonga down to Pawa training levee, of grouted riprap was constructed for 1.6 km on left bank and 0.3 km on right bank. It is to protect Bonga, Burabod and Pawa and a tract of rice field from flooding. Extensioning of levee is now under way by Legaspi City Engineering Office under the control of the Ministry of Public Works. In the lower reach after Pawa most of water infiltrates into the under ground and river channel becomes gentler and narrower and joins finally the main course at Bagtang.

For this River, the detailed Sabo and River Training Works was designed by the previous JICA Study Team, as one of the pilot projects in the Mayon Volcano Sabo and Flood Control Project.

3.4.4.3 River Work Section

The main course of the Yawa River has gravels and boulders in its middle reaches. However, the river channel seems stable.

The bank erosion is seen in the middle reaches for which some bank protection work is required. The bridge cum intake dam for industrial water for paper mills at Quilicao hinders the passage of flood flow. This should be replaced by an intake structure with a movable weir. From Quilicao to the point near the Legaspi airport, the banks are provided on both sides. However, about 2.5 km of the lowermost reaches of the Yawa River causes sometimes inundation with 0.5 m deep during high flood. This section will require the construction of dikes to protect the densely populated Legaspi City and its suburbs. It is noted that such rivers as the San Roque River should be improved for drainage. Sand spit due to coastal sedimentation is formed at the river mouth. But it has been observed that it is flushed out during the flood.

3.4.5 East and North-East Streams

3.4.5.1 General

There are many independent streams originating in Mayon Volcano and flowing into Albay Gulf and Tabaco Bay between the Yawa River and the Quinali (B) River. Among these, eleven (11) streams were selected to be the ones within the scope of study in this project. They are numbered one (1) to eleven (11) from south to north as seen in "LOCATION MAP". One of the important features of this area is that careful consideration should be made for Sabo works and flood control works should mainly for Malilipot, Tabaco, Balading and Malinao. Another is that among these, number four (4), six (6) and ten (10) are relatively important than the others. Eleven (11) streams are basically divided into two (2) groups. Those in the first group (No.1 to 6) are located between the Yawa River and the Pre Mayon Volcano. And the river bed slope of them is kept steep until they form alluvial fans just before pouring into the sea except No.5 which has relatively longer river course than the others. Among these, number (3), four (4) and (6) are devastated. Those in the 2nd group (No.7 to 11) are located between the Pre Mayon Volcano and the Quinali (B) River. They flow north-east to north and change their courses to east at around EL. 100 m. Sediment deposition is notable around here, and some form big alluvial fans. After changing their courses, river bed slope of them becomes gentler, and they flow into Tabaco Bay. Among these only number ten (10) is devastated.

3.4.5.2 Present River Condition of Each Stream and Its Future Design

1) No.1 Stream (Buyuhan (A) River)

The upstream course forms a small gorge, and it approaches very near to the Pawa-Burabod River, a tributary of the Yawa River. After the gorge, it forms a big alluvial fan together with the Pawa-Burabod River. At the junction with National Highway, sediment load is not notable and river bed seems to be stable.

For Sabo works, necessity of construction of a sand retarding basin at the fan must be checked.

2) No.2 Stream (Buyuhan (B) River)

This stream is composed of two (2) tributaries flowing parallel along the southern side of Mayon golf course. The upstream gorge is relatively deep. The northern tributary is flowing along the southern edge of the golf course, but it does not seem to be that a debris flow enters the golf course. Along the southern tributary there grow coconut trees and bushes. No damage downstream due to a debris flow is expected.

For Sabo works, necessity of construction of spur dikes and consolidation works must be checked. For flood control works, revetment by boulders to avoid erosion of left bank at the southern edge of the golf course is necessary in case that further erosion is expected.

3) No.3 Stream (Matang River)

There exists a relatively new lava flow at EL. 500 m. Invading of vegetation covers reddish-brown surface of lava partially. Erosion at the upstream portion below lava is not notably recognized. Due to the influence of lava, poor vegetation is revealed around there. But it is still probable that the river course becomes devastated due to further erosion. Sediment deposition exists down to EL. 80 m followed by rice fields downstream.

For flood control works, canalization to protect newly developed area for housing and factories seems to be necessary.

4) No.4 Stream (Basud River)

This stream is one of the most devastated. And right tributary comes from the left side of the same lava flow as No.3 stream. And left tributary is relatively stable. Right tributary formed an alluvial fan between EL. 230 m and EL. 120 m, and during the flood in 1968, a mass movement of sediment occurred, and sediment was deposited at the junction with the left tributary at the National Highway bridge.

For Sabo works, several low Sabo dams should be constructed at around the top of an alluvial fan to control sediment transportation. For flood control works, protection of bridge pier and having an adequate discharge capacity of both flood and sediment is required at the bridge. And revetment of banks by boulders to avoid further erosion of rice field downstream seems effective.

5) No.5 Stream (Bacacay River)

Invading of vegetation is revealed at a higher elevation than the other streams. And gully erosion is in small scale. Consequently, the river course is in a stable state. Five (5) tributaries are passing across National Highway, but the discharge capacity does not seem to be adequate. The 4th tributary from south seems to be the largest in ordinary discharge, and a notable amount of sediment transport is expected during a flood. Judging from a mountaneous mass and the form of the basin seen at the downstream the National Highway, it seems that the river course could be devastated in old days. But the basin at present is used as rice fields and is in a stable state.

No Sabo and flood control works seem to be necessary.

6) No.6 Stream (Bulawan River)

It flows through a narrow course in its middle reach, and forms a flat plain. And sediment is deposited there. The river course changes toward east, and then toward north-east after National Highway and flows into Tabaco Bay at a steep river bed slope. The top of an alluvial fan exists at the highway, and a vast amount of boulders and a notable ordinary flow exist there. But the water infiltrates afterwards. As no vegetation is revealed at the flat plain upstream, a notable amount of sediment load can be assumed.

No Sabo and flood control works seem to be necessary, since no damage downstream is expected.

7) No.7 Stream (Tiagao River)

From the Mayon Volcano, it flows north-east and changes its course to east at El. 100 m and it flows along the northern side of Malilipot being joined by several small tributaries from the Pre Mayon Volcano. The river bed is now in a stable state. As far as the ordinary discharge is concerned, one eastern most tributary from the Pre Mayon Volcano that flow along the southern side of Malilipot is largest.

No Sabo work and flood control works seem to be necessary.

8) No.8 Stream (Tagas River)

The origin of this stream is very near to that of No.7 stream, but it flows north and flows along the southern side of Tabaco. As rice fields exist at a higher elevation than the others, it seems that the river course became stable in old days. Profile of the river course seems to be quite smooth.

For flood control works, construction of retaining wall under planning by the district office of MPW at the eroded portions of existing dike on left bank to protect Tabaco seems reasonable.

9) No.9 Stream (Bonbon River)

The origin of this stream is an underground aquifer at EL. 100 m. Around the origin, a gully erosion in small scale can be observed. But sediment yield seems to be small, and the effect towards downstream is negligibly small. Even though the water comes from the underground aquifer, ordinary discharge is comparatively large. And as the river bed slope is gentle, the river course is meandering and causing right bank erosion just upstream from the National Highway bridge.

For flood control works, revetment of right bank by boulders just upstream from the bridge seems to be effective to avoid further erosion and meadering.

10) No.10 Stream (San Vicente River)

The upstream river course is most devastated among the eleven (11) streams. The upstream most portion forms the deepest gorge. And there is a trace that the river course ran to No.8 stream previously. A vast alluvial cone starts at around EL. 180 to 160 m, and a debris flow of a big scale, flowed along the left side of the cone and overflowed Provincial Road between San Vicente and San Antonio. After deposition of mud and debris. The river course becomes narrower and it flows into the San Francisco River. And at the same time, most of the runoff flows with erosion along the right side of the cone. And it mainly flows into No.11 stream and partly into No.10 stream. The downstream reach is the old river course from San Vicente. Therefore, it is quite probable that a flood flows from San Vicente to the downstream reach of this stream. The present river course is used for irrigation. And the discharge capacity for flood does not seem to be adequate.

For Sabo works, it is necessary to prevent a debris flow and a flood to San Vicente. Therefore, spur dikes should be constructed to form a sand retarding basin for controlling sediment, and consequently to prevent a debris flow from reaching San Vicente. They also aim at controlling the flood flow along the right side of the cone. Reforestation should be accomplished by a contour trench method. For flood control works, canalization of river course is vitally necessry to divert a flood. Construction of dikes on both banks is required and a wider river course is also required. A further consideration should be given to coastal sedimentation that might effect Tabaco Port due to this diversion work, since the dominant direction of littoral sand drift there seems to be from north-northwest to south-southwest.

The district office of MPW has a plan to excavate a cut-off channel and construct dikes along the river.

11) No.11 Stream (Sawang River)

This is the present river course from San Vicente. And it is used as an irrigation canal.

No flood control works seem to be necessary.

3.5 Present Conditions of Agriculture

3.5.1 Natural Condition for Agriculture

The alluvial plains in the project area are mostly well suited for rice cultivation from the viewpoint of soil condition. The soils of alluvial plains are derived from recent alluviums with soil texture of silty clay to loam and natural fertility of moderate to high. Surface soils are silty loam to clay in soil texture and are easily puddled.

The water resources of existing irrigations systems of which net irrigatiin area totals 9,400 ha almost depend on surface water of the major rivers and their tributaries in the project area. The average seasonal stream flow at the middle reach of the Quinali (A) River is estimated at 8.30 m^3/sec in the wet season and 5.75 m^3/sec in the dry season, while the estimated flow of the Quinali (B) River is 1.78 m^3/sec in the wet season and 1.03 m^3/sec in the dry season. The water quality of river flow does no farm on the irrigated farming.

3.5.2 Socio-economic Background

According to the sensus in 1980, the total number of household in the project area is 73,400 into which 39,200 farm households are included. The average farm size is about 1.2 ha, while about 60% of the total farm household has an farm land of less than 0.9 ha.

Only 18% of the farm household is owner cultivator. The remaining 17% is amortizing farmer, 45% is leaseholder, 16% is sharetenants and 4% is mixed tenure. The share-cropping arrangement or rent for rice cultivation consists of sharing system and leaseholder system. In the former, tenants share normally about 50 - 60% of the total farm products and 100% of the production costs. The latter has the fixed rent which is assessed according to the law at less than 25% of the average normal net income for the previous three crop years.

3.5.3 Land Use

The project area covers 70,000 ha among which agricultural land occupies 44,800 ha comprising 21,700 ha of rice field, 1,900 ha of upland field, 20,950 ha of coconut field, 130 ha of abaca field and 120 ha of citrus field. Out of the whole rice field, the existing irrigated area is 13,000 ha in gross and 9,900 ha in net. The rainfed area is 6,600 ha in net among 8,700 ha in gross.

The non-agricultural land amounts to 25,200 ha in total including 10,200 ha of forest and 7,700 ha of grass land. Due to such limitations as slope and soils, however, these areas are mostly not suitable for further reclamation to agricultural land.

3.5.4 Agricultural Production

The predominant cropping pattern of rice in the project area is restricted by the rainfall pattern and also influenced by typhoon and flood seasons. In the Quinali (A) River basin, double cropping of rice is practiced on irrigated field. The wet season rice cultivation starts in April to June and ends in August to October. The dry season rice is sown from November to January and harvested from March to May. In the Quinali (B) River basin, the cropping pattern starts nearly one month earlier than that in the Quinali (A) River basin. The both cropping patterns are illustrated in FIG.-3.5.1 and FIG.-3.5.2.

Farming practices have partially been mechanized by introducing hand-tractor but still carabao is used for most cases. For spraying and threshing works, compressed air-type sprayers and threshers are used.

Improving high-yeilding rice varieties such as IR-36 and IR-42 are the majority in the project area. The fertilizer application is the common agricultural practices for rice cultivation. Based on the farm survey carried out, the average uses of fertilizers in the Quinali (A) River basin are 76 kg N/ha, 16 kg P_2O_5/ha and 8 kg K_2O/ha, and those in the Quinali (B) River basin are 67 kg N/ha, 19 kg P_2O_5/ha and 6 kg K_2/O/ha. As damages to rice by pests and diseases are slight, farmers apply insecticides normally 3 to 4 times for a preventive measure.

According to the sample survey on rice yield through interviews, the average yield of irrigated rice in the sample surveyed area is estimated at 3.2 tons/ha as palay in the wet season and 3.5 tons/ha in the dry season. These yields are considered to be obtained under the flood-free condition and through well extension services. The actual yield estimated in the whole project area averages 3.0 tons/ha for the wet season irrigated palay, 3.2 tons/ha for the dry season irrigated palay and 1.6 tons/ha for the rainfed palay. The annual production of palay is estimated at 70,900 tons being equivalent to 1.3 times of the estimated local consumption of palay in the project area.

Coconut is also the most important crops and major upland crops are maize, cassava, sweet potato, vegetables, banana and citrus in the project area. About 20,000 tons of copra are annually produced from 21,200 ha of coconut field. The planted area of abaca and maize has not incresed due to prevalence of diseases.

3.5.5 Market, Price and Agricultural Support System

The production and distribution of improved seeds and plant materials are the responsibility of the Bureau of Plant Industry (BPI). The farm gate price of ordinary palay has fluctuated between 0.88 and 1.00 P/kg since 1975, while the price of urea raised from 1.44 to 1.93 P/kg, the hired labour charge became 2.4 times and the *consumer's price index increased by 90% during the same period.*

BPI has two research stations in Bicol regions. It is conducting rice and corn experiments at the Bicol Rice and Corn Experiment Station in Pili, and research works for vegetables, rootcrops and cereal crops at the Albay Experiment Station in Tabaco. Since 1975, the Food and Agricultural Organization (FAO) and the United Nations Development Programme (UNDP) have been carrying out the fertilizer field trials at 560 trial plots established on farmers' fields in the project area. The results show the high yield potentiality of the project area at the experimental level under which the wet season palay yield is 5.6 tons/ha and the dry season yield is 6.9 tons/ha at the treatment of 105 kg N/ha, 20 kg P_2O_5/ha and 20 kg K_2O/kg.

The Bureau of Agricultural Extension (BAEx) and BPI promote comprehensive agricultural extension programs relating to crop production, poultry and livestock, farm organization, credits, etc. Among the programs, the supervision of credit schemes such as the *Masagana 99 and the Masagana Maizan plays an important part in the* extension work. The number of extension worker as of 1980 for the Albay Province is 118 in BAEx and 56 in BPI.

The Masagana 99 program is an agricultural credit for rice production, the Masagana Maizan program is for maize, sorghum and soybean production, and the Gulayan Sa Kalusugan program is for vegetables. The average amount of loan provided to one farmer was about 2,600 pesos and repayment rate was 85% in 1979.

3.6 Present Condition of Irrigation and Drainage Systems

3.6.1 General View of Irrigated Condition in the Project Area

Out of 44,700 ha of agricultural land in the project area, rice field occupies approximately 21,700 ha and extend over three major river basin, namely, the Quinali (A), the Quinali (B) and the Yawa River basins, and the East and North-East areas of Mayon Volcano. At present, total 13,000 ha of rice field is irrigated under existing irrigation systems.

There are 4 National Irrigation Systems covering approximately 2,400 ha, and 65 Communal Irrigation Systems covering about 10,600 ha in the project area. TABLE-3.6.1 shows the net irrigable area of existing irrigation systems. FIG.-3.6.1 shows location of each irrigation system.

The National Irrigation System is implemented from planning stage to construction stage by the National Irrigation Administration (NIA). Operation and maintenance works after accomplishment of the project are continuously carried out by NIA.

The Communal Irrigation System is also implemented from planning stage to construction stage by NIA, but operation and maintenance works are handed over to associated farmers' organization after accomplishment of the project. Some Communal Irrigation Systems have systematical irrigation canal networks with major permanent facilities such as headworks and related structures. However, the other Communal Irrigation Systems have only temporary brush dams and simple irrigation canal networks which are operated individually by farmers themselves.

Canals of the existing irrigation systems are almost unlined and trapezoidal. The irrigation facilities and canal networks are kept in good condition.

Drainage canal networks in the existing irrigation systems are not completely established yet. A number of natural rivers and streams in the project area are utilized as the drainage canal networks. Therefore, a local inundation often occurs just after heavy rain.

3.6.2 Existing Irrigation System in the Quinali (A) River Basin

Total rice field in the Quinali (A) River basin is 12,400 ha among which 8,530 ha is irrigated under 31 existing irrigation systems consisting of 4 National Irrigation Systems and 27 Communal Irrigation Systems. The net area benefiting from these existing irrigation systems is 6,320 ha.

Water sources for these irrigation areas are mainly surface water from the Quinali (A) River and its tributaries. In addition, there is abundant spring water in the slope area of Mayon Volcano, which is also used as irrigation water.

The 4 National Irrigation Systems, namely, Nasisi, Ogsong, Mahaba, and Hibiga, are located on the right bank of the Quinali (A) River and cover 2,400 ha of rice field. There are 9 permanent headworks built therein. Total length of the existing main and secondary canals is about 75 km, and these canals are almost unlined and trapezoidal. Canal networks of the irrigation systems are maintained in good condition by associated farmers.

The 27 Communal Irrigation Systems provide with irrigation water to 6,130 ha of rice field. At present, there are 5 permanent headworks built on the Quinali (A) River and its tributaries, while other intake facilities consist of temporary brush dams and free intakes. Main and secondary canals are almost unlined and trapezoidal.

3.6.3 Existing Irrigation System in the Quinali (B) River Basin

Total rice field in the Quinali (B) River basin amounts to 3,950 ha among which 1,990 ha is irrigated under 8 Communal Irrigation Systems. These are scattered along the lower reach of the river from San Antonio to Malinao. The net area benefiting from the irrigation systems are 1,370 ha.

The intake facilities in of the irrigation systems, except Tuliw-Pawa Communal Irrigation System which is provided with permanent headworks, are temporary brush dams or washable boulder dams. Main and secondary canals are almost unlined and trapezoidal, and are of dual purposes of irrigation and drainage.

3.6.4 Existing Irrigation System in the Yawa River Basin

Total rice field is 550 ha among which 380 ha is irrigated under 3 Communal Irrigation Systems. The net area irrigated amounts to 310 ha. Major facilities in the existing irrigation systems are only temporary brush dams. The canal networks are of dual purposes of irrigation and drainage, and are kept in good condition by associated farmers.

3.6.5 Existing Irrigation System in the East and North-East Area of Mayon Volcano

Total rice field area is 4,800 ha, among which 2,100 ha is commanded by 27 Communal Irrigation Systems. The net irrigation areas are 1,900 ha. These 29 Systems are scattered in the East and North-East area of Mayon Volcano with the elevations between EL. 20 m and EL. 120 m.

The existing irrigation systems have many temporary brush dams and simple canal networks. Canal networks are not fully developed yet, and some existing irrigation systems are of dual purposes of irrigation and drainage.

3.6.6 Governmental Irrigation Development Plan

Five-year Communal Irrigation Development Program (1981-1985) in Albay Province has been established by NIA. The program includes rehabilitation of existing Communal Irrigation Systems and new development of irrigation system in the project area. The implementation of plan is scheduled from 1981.

The rehabilitation program aims at integration of 3 existing irrigation systems with a total area of 1,664 ha in the Quinali (A) River basin and 2 systems totalling 585 ha in the Quinali (B) River basin.

As for the new development program, 4 schemes are contemplated in the project area. Among them, 3 schemes are located in the Quinali (A) River basin and cover 1,030 ha. The remaining new scheme is located in the East and North-East area of Mayon Volcano and its total area amounts to 312 ha.

3.7 Present Condition of Infrastructure

3.7.1 Population and Labor Structure

Present condition of infrastructure in the project area describes as follows on the basis of socio-economic and physical profile of Albay Province and of twelve municipalities and Legazpi City. Total population of the project area was 419 thousand in 1980, 377 thousand in 1975 and about 52% of the total population of Albay Province. According to the population census, it increased by 2.2% and 2.7% per annum during 1970 to 1975 and 1975 to 1980 respectively. The population density was 599 persons per km^2 at present and the population was concentrated in the project area referring the average density of 286 persons per km^2 in Albay Province. The project area is predominantly rural and only about 20% of the total population lives in the urban area. The number of barangays are 307 and about 50% of the total barangays is located in the project area.

Total households were 73,400 in 1980 in the project area and an average family size was 5.7 persons. The households increased at 17% during 1975 to 1980.

With respect to age composition, about 47% of total population belongs to younger age group, 0-14 years, while about 50% to working age group from 15 to 64 years and the remaining 3% to older age group.

Out of the persons of Albay Province, aged ten years and over in 1975, 43.1% are engaged in gainful occupation and 53.8% in non-gainful occupations such as students, housekeepers. Agriculture, forestry and fishing were engaged in by 53.8% of the gainful workers. On the other hand, the proportions of gainful workers such as manufacturing, construction and commerce were 18.5%, 3.1% and 6.0% respectively.

3.7.2 Infrastructure

3.7.2.1 Roads

The barangays, the mucinipalities and the growth centers in the project area are interconnected to each other by national, provincial, municipal, city and barangay roads. The national road has 21 road rinks of 171.63 km, and especially the Daan Maharika Highway (Manila South Road) serves as the main arterial road traversing Albay Province and leading to the external zones of Camarines Sur and Sorsogon.

The project area has 138.96 km of provincial road, 139.77 km of municipality/city road and 238.37 km of barangay road. All barangays within project area are with road connection.

Presently, the project area has 688.73 km of road and indicates at 44.7% of the total length in Albay Province. With respect to the road classification of surface material, gravel and earth surfacing road is estimated at 60.5% of total length in the project area and at 76.3% of the road length except national road.

Bridges of the road network is composed that concrete type is at approximately 12% and the rest are timber, bailey, foot, suspension bridges and spillways. Out of them, some bridges were constructed during the Spanish era.

3.7.2.2 Railway

The railway southline of 474.05 km links Manila and Albay. This line passes through 4 municipalities of Albay Province, namely, Polangui, Oas, Ligao, Guinobatan, and ended down to the terminal point at Camalig. The original terminal at Legazpi City was cut-off when the 1975 flood washed away the steel bridge at Daraga.

The railway length between Bato station and Camalig station is 40.06 km and 13.63 km between Camalig and Legazpi was dismantled from 1975. New railway Line (Deviation Line Project, Guinobatan-Camalig-Daraga) is under-construction from 1977 and will be completed in December 1981. This Line is 18.8 km length and is located at southern area of Mahalika Highway to avoid the influence of debris flow and flood from Mayon Volcano.

There is train service available in Albay Province; three a day service of north bound and south bound respectively between Albay Province and Manila.

The railway in the project area has 41 railway bridges and these bridges are mainly made of I-beam and wooden pile bridge. The bridges located over the tributary of the Quinali (A) River between Ligao and Camalig were constructed as temporary bridge, since these bridges are affected by the flood and debris flow.

3.7.2.3 Flood Control

Some part of project area is annually inundated at present during rainy season by the flood of the Quinali (A) River and the Quinali (B) River and the area around Mayon Vocano is affected by the inundation and sand sedimentation. Also the government infrastructure such as road structures, railway structures and river facilities are damaged by the flood water. Therefore, the ministry of public works has 17 river control projects and City Engineering Office has 4 river control project in the project area.

In 1977, the ministry of Public Works undertook a flood control construction of 10,951 m and 10,762 m repairs of dike and continued the construction at present. However, some levee and dikes are damaged every year by the flood and the dsamaged portion are reconstructed after flood. Total amount of P 4.74 million was spent for the Quinali (A) River and Quinali (B) River and total amount of P 1.49 million was spent for the Yawa River during 1975 to 1979.

3.7.2.4 Communication

The Mayon Telephone Cooperation (MATELCO) operates the telephone system in Legazpi City, Daraga and Tabaco. Albay Province accounts for 29.8 percent of the total number of telephone connection in the Bicol Region and the number of 1,320 subscribers indicates a low density of 0.17/100 population in 1977.

All municipalities and one city in Albay Province are equipped with telegraph service operated by the Bureau of Telecommunications. Also six private telegraph companies complement the telegraph service.

Postal service in Albay Province is provided mainly by the government post offices to the municipalities and city and 1.6 percent of all barangay are served by postael agencies. This yields an average ratio of 0.04 post officer per 100,000 population.

3.7.2.5. Waterworks System

The water supply comes from mainly from springs, artesian wells, shallow pump wells and open wells. All the poblacions and city are served with a piped waterworks system, however, this system is far from adequate.

3.7.2.6 Power

The electrification of Albay Province covers Legazpi City and the poblacion of 13 municipalities of project area. The electrification supplied by the Albay Electric cooperative affected 18,300 household which is about 16 percent of the total household, 2,500 commercial consumers and 69 industrial consumers.

3.8 Flood and Sediment Damage

3.8.1 General

The flood and sediment damages are classified into tangible damages and intangible damages in general. The tangible damages consist of direct physical damages and indirect damage such as loss of income, wages, interruption of services, utilities, and transportation; perturbation of markets; temporary rentals; unsual expenditures; and special damages. The intangible damages consist, for example, of loss of life, personal injury and sickness.

The first field inventory survey on the flood and sediment damages in the project area was carried out in 1979, and the second field inventry survey for the master plan study which is a follow-up of the first survey was made in 1980 by using topographic maps on the scale of 1/25,000. Data of the flood and sediment damages in the project area were mainly collected for the following three aspects: infrastructures, agro-economy, and irrigation facilities to be studied.

Data of the flood and sediment damages are available for 5 years since 1975 to 1979, of which the data of the flood and sediment damages due to Typhoon "Pepang" in 1979 are mainly used for this study.

As a result of these field inventory surveys and studies, primary causes of flood are considered to be as follows.

1) There are local sediment of sand debris at individual river structures such as bridges, culverts, headworks, etc., in the Quinali (A) and the Quinali (B) Rivers. The local sediment decreases the stream flow capacities of individual river section against flood.

2) Drainage structures such as culverts and small bridges constructed on the tributaries of the major rivers have not enough flow capacities compared with drainage water flowing out from rice fields. Therefore, the flood flows over rice fields and in many Barangays and some municipalities scattered along the Quinali (A) and the Quinali (B) Rivers and their tributaries. And inundation due to the flood lasts from 2 days to a few weeks in the individual area.

3.8.2 Damaged Area

According to the results of field inventory surveys and studies, it can be said that the damages are mainly caused by the inundation due to flood. The inundation area is delineated by counterchecking the data of the field inventory surveys and the reseults of hydrological and hydraulic analysis, expecially, in view of inundation depth and inundation period. As the result, the damaged area due to Typhoon "Pepang" is approximately 113 km^2 in the project area as shown in FIG.-3.8.1. The damaged areas of individual river basins are summarized as follows.

1) The Quinali (A) River basin

The lower part of the Quinali (A) river basin; the vicinity of Lake Bato, is inundated annually for more than one week by backwater from the lake during the rainy season. According to water level record of Lake Bato which has been observed since 1974, the high water level rises annually up to more than 8.30 m above mean sea level as shown in TABLE-3.8.2. One of the main causes of the backwater is surely shortage of drainage capacity of the Bicol River which originates from Lake Bato and functions as the outlet of the lake. The middle part of the basin is also inundated by the floods from the streams crossing the area due to their less flow capacities and breach of river dikes by flood. The inundation depth varies from 0.3 m to 0.5 m and the inundation period lasts for 2 days to one week. Since a lot of Municipalities, Barangays, road network and infrastructures concentrates in this area, the damages to these facilities are serious.

Flood in the areas along the upper reach of the Quinali (A) River and its tributaries is of torrential nature involving sand debris. The causes of flood are mainly their limited flow capacities and obstructions such as bridges and road culverts constructed on the rivers. There are only local damages in this area such as erosion of river bank and sedimentation of sand debris in rice field and river structures and on the roads.

2) The Quinali (B) River basin and the Yawa River basin

Flood occurs almost in lower parts of both rivers mainly due to limited flow capacity of the rivers, especially at river structures. The flood often flows in the Municipalities, Barangays and rice fields along Provincial road, but the inundation period is not so long; one day at most.

3) The East and North-East Area of Mayon Volcano

The flood is mainly of torrential nature involving sand debris, which causes only local damages such as erosion of river bank and deposition of sand debris in rice field and river structures and on the roads.

3.8.3 Damage to Crops

Flood damages to crops were caused for most cases by typhoons, whose damages to crop were surveyed by the extension workers of BAEx municipal offices whenever typoon attacked the project area. According to the information of extension workers, typhoon damages to upland crops such as coconut and abaca mainly consist of damages by strong wind and those damages caused by flood are negligibly small. The typhoon damages to palay in the project area are mostly flood damages and in some cases include strong wind damages resulting in shattering of rice grain and sterility of grain. Only the information on the flood damages to palay by typhoon "Pepang" in 1979 is available in BAEx offices. This information as summarized in TABLE-3.8.3 shows that 4,100 ha of rice field was affected by flood and 9,130 tons of palay was lost in the Quinali (A) River basin, while affected area was 1,410 ha and production loss was 480 tons in the Quinali (B) River basin.

3.8.4 Damage to Irrigation Facilities

Available data of damages to irrigation facilities caused by flood of each typhoon and monsoon for 5 years from 1975 to 1979 were collected in the project area. These data were prepared by NIA staff based on the investigation carried out immediately after the flood of each typhoon and monsoon. The damages investigated include not only those on National Irrigation Systems but also those on Communal Irrigation Systems. TABLE-3.8.4 presents the flood damages to the irrigation facilities during the period from 1975 to 1979.

The damages investigated in the Quinali (A) river basin include; (1) erosion of fore apron of the existing permanent headworks and scouring of protection wall: (2) sedimentation of sand and gravel in front of every intake gate: (3) complete breach of temporary brush dams: (4) local erosion at foundation of the river structures: (5) erosion and scouring of canal embankment: (6) local sedimentation of sand and gravel in canal networks: (7) sedimentation of sand and debris in rice field along the Quinali (A) River: and (8) local erosion of rice field along the upper reach of the Quinali (A) River.

The damages observed in the Quinali (B) river basin consist of ; (1) erosion of fore apron of existing permanent headworks; (2) complete breach of temporary brush dams: (3) local erosion and sedimentation of sand and gravel around the river structures: (4) erosion and scouring of canal embankment: (5) local sedimentation of sand and debris in canal networks: and (6) local erosion of rice field along the steep streams.

The damages occured in the East and North-East area of Mayon Volcano include; (1) breach of temporary brush dams: (2) local sedimentation of sand in canal network and in rice field: and (3) local erosion of rice field along the steep streams.

3.8.5 Damage to Infrastructure

In this study, the damage to infrastructure consists of the damages such as those to houses and buildings, national roads, provincial roads, municipal roads, barangay roads, railways and river facilities. These damage data are collected by the field survey between July and August in 1980.

The field data for the damages to houses and buildings were collected after first identifying those barangays suffering from the greatest damage in the past and inundated every year. This information was obtained from the Ministry of Public Works, the District Engineering Office, the City Engineering Office, the Provincial Development Staff, the Municipality, etc.

The damages to government infrastructure were collected as the estimated damage costs due to flood caused by typhoon and heavy rain in Albay Province. These damage costs were obtained from the Ministry of Public Works, the Ministry of Public Highway, the Provincial Engineering Office, the Municipality, the City Engineering Office, the District Engineering Office, the Philippine National Railways, etc.

3.8.5.1 Damage to Houses and Buildings

(1) Flood Damage Survey

The 1979 Flood Damage Survey

In an effect to determine the flood damages caused by Typhoon "Pepang" in September 1979 in the project area, the Study Team conducted a survey of 13 municipalities and Legazpi City. The survey collected data on damages to houses and buildsings and out the social impact of the flood.

During the survey, the flood damage data was obtained especially from interview with barangay captains and staffs of each municipality on random sample basis. The establishments and buildings damage data was obtained from the Provincial Development Staff. This data, however, was damage cost of only four municipalities such as Libon, Oas, Polangui and Ligao and consisted of a few data of barangays.

The data of buildings damage for elementary schools and governmental buildings was obtained from only Legazpi City and these damages, however, were not caused by flood but caused by the wind and rain of typhoon.

The Past Flood Damage Survey

In the past records of the flood damages before 1979, it was confirmed that the greatest flood damage was occurred in 1969-1970 and the next serious flood damage was occured in 1975 (Typhoon Sisang), by the field survey in the project area. However, the data and information for the past flood damage except the government infrastructure were not collected completely in this survey.

Damage to Houses and Buildings

During the field survey in the project area, the flood situation, inundation depth, inundation area and damage caused by flood were collected by interview with about 50 barangay captains.

The inundated barangays caused by typhoon Pepang in 1979 are more than 50 in the project area. Especially, the barangays near the Quinali (A) River of Polangui, Libon, Oas, Ligao, Guinobatan and Comalig, are inundated every year due to overflow on levee and flushing water from the destroyed dike.

The damage to houses and buildings are estimated on the basis of flood analysis and data of field interview.

3.8.5.2 Damage to Government Infrastructure

(1) Damage to Road Structures

The damage data to road structures were collected during the period of 1975 - 1979. This damage is classified into the national, provincial, municipal, city and barangay roads.

The road structures were damaged by flood and heavy rain every year. Filling and surfacing materials were eroded, scoured and washed out. The grouted riprap was scoured and washed out. The concrete and asphalt pavement were cracked. The related structures such as box culvert and concrete pipe were washed out and timber bridges were washed out.

The damage to bridges and roads can be approximately measured by the estimated damage costs, since these damage costs due to each typhoon and heavy rain were submitted as the calamity fund to the Government by the Ministry of Public Highway, the Provincial Engineering Office, the City Engineering Office and the Municipalities.

These estimated damage costs in the past records are revalued at 1979 price level by using an average inflation rate of 12.1% per annum considering the consumer price indices in Bicol Region of P 3.16 million, P 1.06 million, P 3.91 million, P 1.57 million and P 2.10 million for the floods in 1975, 1976, 1977, 1978 and 1979 respectively in the whole project area. Also, the revalued damages for each river basin are listed in TABLE-3.8.5.

(2) Damage to Railway Structures

Railway from Legazpi City to Tabaco was destroyed and dismantled by the eruption in 1938. The railway from Daraga to Camaling was damaged by debris flow in 1969 after the eruption of 1968 and many bridges were damaged heavily in 1975 by flood water and debris flow from Mayon Volcano. The railway system in Albay Province has been dismantled between Camalig and Legazpi City at present. The latest damage due to flood was caused by typhoon "Pepang" in 1979 and this damage was occurred at ST.8881-8882 (Oas-Ligao, the Nasisi River).

The damage to railway trucks and bridges were obtained from the Philippine National Railway. These estimated damage costs in TABLE-3.8.6 are revalued at 1979 price level, which are P 6.11 million and P 0.32 million for the floods in 1975 and 1979 respectively.

(3) Damage to River Facilities

In the project area, flooding of such main rivers including various tributaries as the Quinali (A) River, the Yawa River and the Quinali (B) River, has done damages to river structures caused by washing out and eroding dikes and by scouring boulder riprap. In the East and North-East Area, flooding of 11 small streams has not caused serious damage after eruption of Mayon Volcano in 1968.

The damage costs were measured by the estimated damage costs submitted as the calamity fund to the Government by the Ministry of Public Works and the City Engineering Office. These estimated damage costs are revalued at 1979 price level, which are P 0.88 million, P 0.07 million, P 0.15 million, P 0.63 million and P 0.97 million for the flood of 1975, 1976, 1977, 1978 and 1979 respectively in the whole project area. Also, the revalued damage costs for each river basin are listed in TABLE-3.8.7.

(4) Damage to Government Infrastructure

Flood damage to government infrastructure from 1975 to 1979 are listed in TABLE-3.8.9. These estimated damage costs are devided into four river basins and are estimated including the indirect damages.

The indirect damages are assumed to be 15 percent of the direct estimated damage costs. This value is used by the Bureau of Public Works in their damage estimates of the past flood damage costs.

The estimated damage costs at 1979 price level are P 11.67 million, P 1.30 million, P 4.66 million, P 2.53 million and P 3.90 million for the flood of 1975, 1976, 1977, 1978 and 1979 respectively as shown in TABLE-3.8.9.

3.8.6 Total Damage

The damages due to the flood of the Typhoon "Pepang" in 1979 are evaluated in monetary terms at the 1979 price level using the inflation rate of Bicol region shown in TABLE-3.8.1. The evaluated results are shown in TABLE-3.8.10.

IV. MASTER PLAN FOR SABO AND FLOOD CONTROL

4.1 Hydrological Analysis

4.1.1 General

Hydrological study is made to provide the basic data for sabo, river and irrigation planning. The study mainly consists of flood analysis, runoff analysis and sediment analysis.

The area subject to the study covers all the rivers originating in Mayon Volcano and those tributaries which originate in Mt. Malinao, Mt. Masaraga and other surrounding mountains. The total drainage area comes to about 1,000 km^2.

4.1.2 Flood Analysis

4.1.2.1 Basic Principle

Analysis is made for the estimation of only probable flood peak runoff from probable rainfall for the reasons described hereinafter.

No hourly record of both rainfall and streamflow and no flood peak runoff record is available within the area. Thus, the flood hydrograph analysis is obliged to be given up. Also, the flood hydrograph analysis is not always needed for the present sabo and flood control master plan. Accordingly, the estimation of only probable flood peak runoff based on the probable rainfall is satisfactorily acceptable.

In order to estimate the probable flood peak runoff, Rational formula is employed, which is commonly used for that purpose. It is expressed in the form of

$$Q = \frac{1}{3.6} A . I . f$$

where, Q is flood peak runoff in m^3/sec, A is drainage area in km^2, I is average rainfall intensity over the basin for a given duration equal to flood concentration time in mm/hr and f is runoff coefficient.

4.1.2.2 Probable Rainfall

The annual maximum point rainfall and areal rainfall within the area are statistically analyzed employing three methods of Gumbel's, Hazen's and Iwai's ones.

TABLE-4.1.1 and TABLE-4.1.2 list the probable point rainfall with different return periods of the stations in the area and the probable basin average rainfall for the Quinali (A) River basin with a drainage area of 523 km^2 including the Talisay River basin.

4.1.2.3 Depth - Area - Duration Analysis

In order to estimate the average rainfall intensity in Rational formula, the rainfall depth-area-duration relation is analyzed.

The depth-area relation is defined by Horton's formula because of no existence of isohyetal map which is the essential data for construction of the actual depth-area relation in the area. Horton's formula is represented by

$$P = Po \cdot \exp(-kA^n)$$

where, P is average depth of rainfall for a given duration over a certain area in inches, Po is the largest rainfall amount in the area in inches, A is area in square miles and k and n are constants.

Po is estimated at an increase of 50 percent of the point rainfall at a station selected as a representative one based on the actual data. The constants, k and n, are empirically taken as 0.1 and 0.2 respectively for 24-hour rainfall in the United States according to Horton. In this study, n is determined as 0.3 letting k be 0.1 constantly based on the probable basin average 1-day rainfall of the Quinali (A) River basin including the Talisay River basin as mentioned before.

FIG.-4.1.1 shows the depth-area relation after Horton.

Then, the depth-duration relation is studied for Legaspi station which has rainfall records of 6-hour intervals. Since the flood concentration time for the subject basins may be less than 6 hours, the depth-duration relation should be defined by the proper formula to estimate the rainfall intensity for the duration of less than 6 hours. Talbot's formula was employed in this study. It is experessed in the form of

$$I = \frac{b}{t + a}$$

Where, I is rainfall intensity (i.e. depth) in mm/hr, t is duration in hours and a and b are constants. The constants, a and b, were determined by the least square method for the probable rainfalls of Legaspi with the duration of 6-, 12-, 18- and 24-hour.

FIG.-4.1.2 shows the probable rainfall intensity - duration curves for Legaspi generated. This relation is applied to all the basins proportionally depending on the rainfall magnitude.

4.1.2.4 Runoff Coefficient

Runoff coefficient in Rational formula is taken as 0.7 uniformly over the area applying Japanese standard because of no available data in the area and no definite instruction on that matter in the Philippines. The value of 0.7 is given for the mountainous area and paddy field which occupy almost of the area.

4.1.2.5 Flood Concentration Time

Flood concentration time is estimated by employing Kraven's formula which is applicable for both estimates of the time required for flood to flow out into the river course from the farthest point in the basin and the time required for flood to run down through the river course up to the point in question.

Kraven gave the following empirical values on the flood velocity depending on the river bed slope.

FLOOD VELOCITY AFTER KRAVEN

River Bed Slope	1/100	1/100 - 1/200	1/200
Flood Velocity (m/sec)	3.5	3.0	2.1

4.1.2.6 Probable Flood Peak Runoff

The base points are selected taking into account the relation with sabo planning, river planning, etc. and then the representative stations are selected based on the record length and reliability of the record.

The probable flood peak runoff at each base point can be calculated by substituting the drainage area, runoff coefficient and the probable average rainfall intensity during the flood concentration time which is given by the probable depth-area-duration relation analyzed before to Rational formula.

The reseults are summarized in TABLE-4.1.4.

The results are examined with the specific discharge diagram of the recorded maximum flood peak runoffs in the whole Philippines. It is consequently noted that the results are reasonable.

4.1.3 Draught and Low Flow Analysis

Draught and low flow analysis is essential for the irrigation development scheme. In this study, low rainfall amount and low flow are statistically analyzed by Weibull's extreme value frequency analysis method which is commonly used for the statistical analysis of annual minimum events.

TABLE-4.1.5 and TABLE-4.1.6 show the probable draught annual rainfall and the probable annual minimum monthly rainfall. TABLE-4.1.7 shows the probable annual minimum monthly mean runoff.

In addition, the regional draught frequency analysis is made in order to estimate the draught runoff in the ungaged basin. The variation of mean annual draught runoff with drainage area is analyzed and the regional draught frequency curve is prepared for selected stations in the Quinali (A) River basin. By combination use of the above two figures, the draught runoff with different return periods in the ungaged basin can be estimated easily.

Then, the drainage area-runoff relation is analyzed on the annual mean runoff. The ordinary runoff at ungaged site can be estimated from that at gaged site through this relation.

4.1.4 Sediment Analysis

In order to grasp the situation of sedimentation under the present river conditions, the suspended load amount is estimated based on the actual measurement records and also the bed load amount is estimated by Einstein's formula using the sieve analysis results of river bed materials.

Mean annual suspended load amount is estimated at 86,400 m^3 for the Quinali River at Busac with a drainage area of 232 km^2 and 131,000 m^3 for the Talisay River at Allang with a drainage area of 90 km^2 based on the daily runoff and the suspended load rating curves. The specific annual suspended loads are calculated as 370 $m^3/year/km^2$ and 1,460 $m^3/year/km^2$ respectively. The difference between both values is large. This may be because the rating curve for Allang was often used beyond the valid range and the sediment load amount was estimated with a large error. The estimated suspended load amount for Busac is expected to be reasonable compared with other rivers in Luzon.

On the other hand, mean annual bed load is estimated at 16,600 m^3 for the Quinali River at Busac, 1,800 m^3 for the San Augstin River at San Augstin and 1,100 m^3 for the Talisay River at Bacolod in the same manner as the suspended load based on the daily runoff and the bed load rating curves which is made by Einstein's formula under the present river conditions. The calculation result is very influenced with the mean grain size of river bed materials. The grain sizes for 65 percent by weight at San Augstin and at Bacolod are rather larger than that at Busac. Considering the balance with the estimated amount of suspended load, the amount for Busac seems to be reasonable. Because, the bed load amount is empirically taken as 10 to 20 percent of suspended load amount for the river with no data.

Finally, the annual sediment load is roughly estimated at 100,000 m^3 for the Quinali River at Busac, which is equivalent to 440 $m^3/year/km^2$ in specific sediment load.

The sediment load for other rivers are not estimated because of no measurement record of runoff and sediment load.

4.2 Evaluation of Disaster Potential and Sediment Yield

4.2.1 General

A series of evaluation maps are developed by overlaying the topographic analysis data on the basic data such as land classification, land use, devastation, etc. mentioned in Chapter III.

4.2.2 Debris Flow Potential Evaluation

As environmental variables concerned with debris flow potentials, the river order, devastation, land classification and slope are considered. Debris flows are easy to occur in the stream with the first and second orders and do not occur in the stream with fifth or sixth order. In land classification, they are likely to occur in lava area and Tertiary mountain. From the viewpoint of devastation, they are most likely to occur in productive collapse, unsatable transport zone and unstable sedimentation zone, which are followed by bare land, moderately unstable transport zone, moderately unstable sedimentation zone and then less productive collapse, lava flow and stable transport zone. No debris flow has occurred in slopes of less than 9% (5^o).

FIG.-4.2.1 shows the debris flow potential evaluation map.

The debris flow potential in the Project area is summarized as follows:

1) In the lowland the west of Mayon Volcano, the occurrence probability of the debris flow is very low.

2) Most of torrents round Mayon Volcano have a high occurrence probability of debris flow.

3) The occurrence probability of the debris flow is low in the mountainous area which surrounds Mayon Volcano.

4.2.3 Debris Flow Damage Potential Evaluation

River order, devastation, land classification and slopes are considered as environmental variables related to debris flow damage potentials. Damages by debris flow are easy to occur in the streams with the first and second orders. No damage by debris flow has occurred in the streams with the fifth and sixth river orders.

In land classification, damages are hard to occur in lava area, volcanic fan and then in Tertiary mountain and Alluvial fan. The high terrace plain, natural levee and fan-like lowland have almost no damages. From the viewpoint of devastation, damages are easy to occur in productive collapse, unstable transport zone, unstable sedimentation zone and debris flow. Bare land, moderately unstable transport zone, moderately unstable sedimentation zone less productive collapse, lava flow, stable transport zone and stable sediment zone have a less damage potential in the order.

FIG.-4.2.2 shows the debris flow damage potential evaluation map.

The debris flow damage potential in the project area is summarized as follows:

1) The lowland in the western side of Mayon Volcano has little debris flow damage potential.

2) Most of the torrents originating in Mayon Volcano have debris flow damage potential. The damaged areas extend from 1,600 m down to 100 m in elevation.

3) The mountains other than Mayon Volcano have a very few debris flow damage potential.

4.2.4 Flood Potential Evaluation

As environmental variables related to the flood potential, the river order, land classification and slope are considered. Flood is more likely to occur in the streams with the sixth and fifth river order than the fourth and the third order. No flood occurs for the second and first orders. In land classification, low Alluvial plain, old river trace, marsh, existing river and lake are the most prone to floods, which are followed by volcanic fan Alluvial fan, Alluvial plain-high, fan-like lowland and further by natural levee and bar in proveness. High terrace plain, lava flow and tertiary mountain have almost no floods. With regard to slopes, those of 0 - 2% are the most susceptible to floods. Slopes of more than 6% are the least likely to be affected by flood.

FIG.-4.2.3 shows the flood potential evaluation map.

The flood potential in the project area is summarized as follows:

1) The area round Mayon Volcano has a low flood potential.
2) The lowland along rivers in the west of Mayon has a high flood potential Volcano and alluvial plain is next.
3) It is noticeable that Legazpi City, Camalig and Tabaco have areas with a high flood potential.

4.2.5 Sediment Yield Evaluation

From devastation map, the sediment yield is calculated for each major drainage area. The sediments yield is defined as the amount of sediment expected to runoff from collapse plus the amount of unstable sediments in the stream.

The depth of collapse and sediment are estimated from the field survey and aerial photo interpretation. Sediment yield is estimated in terms of the amounts to be produced during a period of 50 years. The result is listed in TABLE-4.2.1.

The sediment yield calculated above is a potential sediment discharge, and thus it is not directly used for the Sabo plan. But it is a good check on degree of devastation.

The sediment yield evaluation in the project area is summarized as follows:

The rivers with large sediment yield are the Nasisi River, the Nabonton Creek, the Masarawag River, the Quirangay River, the Pawa-Burabod River, the Basud River and the Bulawan River.

4.3 Master Plan for the Quinali (A) River

4.3.1 General

The flooded area in the Quinali (A) River basin is mainly utilized as rice field at present and, out of 10,400 ha of the whole rice field in the basin, 8,580 ha or 83% extends over the flooded area. The objective and basic strategy of this master plan are therefore to improve land productivity and land use intensification aiming at increase in farmer's income and stabilization of regional economy through enforcement of flood control measures.

Although climate and soils in the Quinali (A) River basin are well suitable for rice cultivation, large investment in equipment of irrigation facilities has not been made, resulting in that the irrigated double cropping area presently covers 43% of the whole rice field and the palay yield is 4.6 tons/ha a year.

With provision of the irrigation and drainage facilities prior to the implementation of flood control measures for the Quinali (A) River, it is expected that the whole rice field becomes the irrigated double cropping area and the palay yield increases to 8.5 tons/ha a year. In this case, the increment of the palay yield is theoretically 3.9 tons/ha a year.

Under the condition of without river improvement for the Quinali (A) River, however, the irrigated rice field is always inundated by flooding whenever flood occurs. In addition, no improvement of fertilization beyond the present level is expected so that the increase in the palay yield is only 2.7 tons/ha a year. The repairing cost of irrigation facilities damaged by flooding is estimated at P 76/ha for every flood besides P 250/ha for the annual operation and maintenance costs of irrigation facilities. As a result, less benefit attributable to the irrigation development prior to the river improvement can be expected for the Quinali (A) River basin. Farmers are also considered to be not so much favourable to carrying out of intensive agriculture under such circumstances.

If the levees are constructed for protecting a flood with a return period of 10-year in combination with provision of the irrigation facilities, the yield increase is expected to be 4.9 tons/ha a year. But it is pointed out from the viewpoint of river improvement construction planning that alternative construction methods are limited by the topographic condition of the Quinali (A) River basin and the river improvement cost cannot be saved by the method to diminish the levee scale.

As the loss of life and damages to house by flood in the Quinali (A) River basin increase rapidly when the magnitude of flood exceeds 10-year probability, the flood control measures should have enough capacity which can guarantee local people against the said loss and damages. Accordingly, the master plan for the improvement of the Quinali (A) River is made to prevent the flood with the return period of 50-year in due consideration of the discussions above-mentioned.

No measures for excess sediments in the Quinali (A) River basin causes continuous decline of the capacity of irrigation water intake facilities resulting in the annual cost of P 500 thousand which is required for dredging cost. To save such additional dredging cost and to maintain well function of intake facilities, Sabo plan is combined with the river improvement plan.

4.3.2 Sabo Plan

4.3.2.1 Subject Rivers

Among the rivers in the Quinali (A) River basin, the Nasisi River is the most important river for Sabo planning, and the Masarawag and the Quirangay Rivers are next in importance.

The Nasisi River is along Ligao-Tabaco National Highway in the middle reach and also two big municipalities of Ligao and Oas in the downstream. The Masarawag and the Quirangay Rivers are closed to municipalities of Guinobatan and Camalig having a menace of debris and sediment damages in the lower reaches.

The Nabonton Creek in the upstream of the Ogsong River, the Maninila River and the Tumpa River also need some proper countermeasures for Sabo.

The Nabonton Creek has destroyed the provincial road between Nasisi and Masarawag and is threatening the irrigation facilities of NIA in the downstream. The Maninila and the Tumpa Rivers have a source of secondary debris production.

4.3.2.2 Base Point

For the above six rivers, the base points for sabo planning are set at the locations as shown in FIG.-4.3.1 and FIG.-4.3.2. The sediment control plan and the Sabo facility arrangement plan are established estimating the quantity of sediment passing through those base points.

4.3.2.3 Sediment Run-off Volume

In Sabo planning, it is important to grasp the sediment amount transported as debris flow or dense sediment flow caused by a major flood. Whereas no sediment observation and survey record usuful for Sabo planning is available within the area and even in the Philippines.

Therefore, the empirical formula proposed by Dr. Ashida and Dr. Okumura is employed in order to estimate the sediment amount said above, namely, the sediment run-off volume. The sediment run-off volume at base points shown in FIG.-4.3.1 and FIG.-4.3.2 are estimated for the design flood with a return period of 50-year as follows.

SEDIMENT RUN-OFF VOLUME (50-yr Probable Flood)

Name of River	Drainage Area (km2)	Sediment Run-off Volume (m3)	Specific Sediment Run-off (m3/km2)
Quirangay	10.0	260,100	26,000
Tumpa	5.7	43,700	7,700
Maninila	4.9	94,000	19,200
Masarawag	9.7	276,800	28,500
Ogson	8.3	140,500	16,900
Nasisi	35.7	1,128,700	31,600

4.3.2.4 Excess Sediment Volume

Excess sediment volume is defined as the sediment amount given by subtracting allowable sediment volume from sediment run-off volume. The excess sediment volume is just the objective sediment volume for Sabo planning.

The allowable sediment volume is very closely concerned to river planning and conditions in the lower reaches and controlled by the complicated factors. In this study, the bed load under the present river conditions for the design flood with a return period of 50-yr is taken as the allowable sediment volume supposing that the said bed load is nearly equal to the allowable sediment volume for the downstream river. This means that the sand deposition in the lower reaches is not so serious and also the natural regulation in the river channel can be expected. The bed load is calculated by employing Dr. Ashida, Takahashi and Mizuyama's formula.

Finally, the excess and allowable sediment volume estimated are listed as follows.

Name of River	Sediment Run-off Volume (m3)	Allowable Sediment Volume (m3)	Excess Sediment Volume (m3)
Quirangay	260,100	82,600	177,500
Tumpa	43,700	35,200	8,500
Maninila	94,000	36,700	57,300
Masarawag	276,800	77,600	199,200
Ogson	140,500	32,700	107,800
Nasisi	1,128,700	85,900	1,042,800

4.3.2.5 Sediment Control Plan

The type and location of sabo facilities should be determined so that the excess sediment volume may be nearly equal to zero by reducting the sediment yield and run-off by the various Sabo facilities. The Sabo facilities planned for the respective rivers are as follows.

1) Quirangay River

The capacity of natural sand retarding basin is increased with the construction of six (6) spur dikes and three (3) jetties as shown in FIG.-4.3.1 and the sediment run-off volume at base point is planned so as to be reduced from 260,100 m^3 to 78,200 m^3. The sediment run-off volume at base point after construction will become less than the allowable sediment volume of 82,600 m^3.

In addition, the spur dikes located at the left bank side not only form the sand returding basin, but also function effectively to protect Camalig from debris flow and sediment flow.

2) Tumpa River

The consolidation works with coconut trunks are planned at fifteen (15) sites shown in FIG.-4.3.1 in order to mitigate the river bed and side erosion. The sediment discharge at base point will be reduced from 43,700 m^3 to 26,900 m^3 with the works and lower than the allowable sediment volume of 35,200 m^3.

3) Maninila River

As shown in FIG-4.3.1, the consolidation works with cribs are planned at nine (9) sites to mitigate the river bed and side erosion. The sediment discharge at base point will be reduced from 94,000 m^3 to 36,700 m^3 with the works and become equal to the allowable sediment volume of 36,700 m^3.

4) Masarawag River

In the upper reach, the twelve (12) spur dikes and three (3) jetties are arranged so as to enlarge the function of existing natural sand retarding basin. In the lower reach, the consolidation works with cribs are planned at nine (9) sites to stabilize the river bed. In addition, the spur dikes in the upstream will effectively function to defend two barangays of Masarawag and Maninila against the attack of debris flow and sediment flow. The sediment discharge at base point will be reduced from 276,800 m^3 to 65,300 m^3 which is less than the allowable sediment volume of 77,600 m^3.

5) Ogsong River (Nabonton Creek)

As shown in FIG.-4.3.2, the six (6) spur dikes and nine (9) jetties are arranged in the upstream reach to enlarge the function of existing natural sand retarding basin. The consolidation works with cribs are planned at two (2) sites and the ground-sills at three (3) sites in the lower reach to stabilize the river bed.

Beside, the spur dikes and jetties will protect the adjacent barrangays from debris flow and also the consolidation works make possible the restoration of destroyed provincial road bridge with the partial revetment.

The sediment run-off volume at base point will be reduced from 140,500 m^3 to 28,500 m^3 which is allowable.

6) Nasisi River

In order to check the debris flow at the uppermost reach, two (2) combined consolidation works of consolidation dam and spur dikes are planned on the Baligang River. Also, the three (3) spur dikes and ten (10) groins are arranged in the river channel between Alimbubyog Bridge and Nasisi Balley Bridge and the levee of 2,350 m long is constructed at the right bank side, making a big artificial sand retarding basin with an area of more than 400,000 m^2.

The overflow type culvert of Ligao-Tabaco National Highway across the Nasisi River is reconstructed into the consolidation dam. The sediment volume at base point may be sharply reduced from 1,128,700 m^3 to 107,400 m^3. Though the sediment run-off of 107,400 m^3 is a little over the allowable limit of 85,900 m^3. However, the excess can be checked by the consolidation works with crib as a body and groin as a wing located just downstream from base point.

In this plan, the construction of groins and levee at the right bank side of the Nasisi River results in raising the elevation of existing road and the traffic will be secured more easily for flooding. Also, the Nasisi Balley Bridge at which the traffic has been suspended at present can be reconstructed and that maintained easily. In addition, the irrigation intake weir of NIA, which is located about 500 m downstream from the Nasisi Balley Bridge, may be protected from sediment damage.

The principal features of proposed Sabo facilities are summarized as show in the next table.

PRINCIPAL FEATURES OF PROPOSED SABO FACILITIES

Name of River	Proposed Works	Scale of Works	Remarks
Quirangay	Spur dike (masonry)	At six (6) sites Total length: 300m	On the left bank
	Jetty (masonry)	At three (3) sites Total length: 450m	On the right bank
Tumpa	Consolidation (fence works)	At fifteen (15) sites Total length: 350 m	Drop: 1.0-1.5 m
Maninila	Consolidation (crib works)	At nine (9) sites Total length: 450 m	Drop: 1.0-2.0 m
Masarawag	Spur dike (masonry)	At six (6) sites Total length: 380 m	On the left bank
	Jetty (masonry)	At two (2) sites Total length: 300 m	In the river course
	Spur dike (masonry)	At three (3) sites Total length: 150 m	On the left bank
	Jetty (masonry)	At one (1) site Total length: 250 m	In the river course
	Spur dike (masonry)	At four (4) sites Total length: 600 m	On the right bank
	Consolidation (crib works)	At five (5) sites Total length: 300 m	Drop: 1.0-2.0 m
	Consolidation (crib works)	At four (4) sites Total length: 400 m	Drop: 1.0-1.5 m
Ogsong	Jetty (masonry)	At nine (9) sites Total length: 900 m	In the uppermost reach of the stream
	Spur dike (masonry)	At six (6) sites Total length: 360 m	
	Consolidation dam (masonry)	Height: 3 m	In the previous main course of the stream
	Revetment works	Length: 160 m	

Name of River	Proposed Works	Scale of Works	Remarks
Ogsong	Consolidation dam (masonry)	Height: 2 m	In the tributary
	Revetment works	Length: 100 m	
	Ground-sill (crib works)	At three (3) sites Total length: 220 m	
Nasisi	Consolidation dam (masonry)	Effective height: 5 m Crest length: 240 m	On the right bank Spur dike attached
	Consolidation dam (masonry)	Effective height: 3 m Crest length: 300 m	On the left bank Spur dike attached
	Spur dike (masonry)	At three (3) sites Total length: 420 m	
	Groin (masonry)	At ten (10) sites Total length: 180 m	A-type
	Levee (dry masonry)	Length: 1,650 m	
	Groin (masonry)	At thirteen (13) sites Total length: 310 m	A-type
	Levee (dry masonry)	Length: 700 m	
	Excavation	Length: 800 m	50-100 m in width 1-3 m in depth
	Consolidation (masonry)	Effective height: 5 m Crest length: 75 m	At the site of existing overflow culvert bridge
	Groin (masonry) & Ground-sill (crib works)	At four (4) sites Total length of groin: 220 m Total length of ground-sill: 400 m	B-type

4.3.3 River Improvement Plan

4.3.3.1 General

As stated in Subsection 3.4.1, divides of Sabo work section and flood control work section are plotted off as follows.

For the Nasisi River

(a) The overflow culvert type bridge of Ligao-Tabaco National Highway

For the eastern tributaries upto the Ogsong River

(b) Bridges of National Highway

4.3.3.2 River Width and Discharge Capacity of The Present River Channel

Using the profiles and cross sections of the present river channel, river width and discharge capacity is computed as shown in FIG.-4.3.11 to FIG.-4.3.13. For the calculation of discharge capacity, Manning's Formula is used assuming uniform flow. The roughness coefficient is selected to be 0.035.

4.3.3.3 Design Discharge

The design discharge is selected to be 50-year probable flood, considering importance of the region, design discharge of other rivers in the Philippines and the Japanese Standard of river planning (hereinafter called the Standard). From the results of hydrological analyses, design discharge distribution diagram is established as shown in FIG.-4.3.14.

4.3.3.4 River Reaches for Improvement

Comparing FIG.-4.3.11 to FIG.-4.3.13 and FIG.4.3.14, it can be said that the present river course has not sufficient discharge capacity and it results in flood inundation. Thus, damage is caused to human lives, crops, houses, railways, highways, river structures and irrigation facilities, especially in the affected area including six (6) important municipalities of Camalig, Guinobatan, Ligao, Oas, Polangui and Libon. Consequently, it is necessary to establish a flood control plan to avoid this damage by improving the river channel. The river reaches for improvement are selected as follows considering the discharge capacity of the present river and importance of the affected area.

(a) Main course - Lake Bato to Sta. 27+500 (reach of 27.5 km)

(b) Talisay River - Junction with the main course to Sta. 13+700 (reach of 13.7 km)

(c) Nasisi River - Junction with the main course to the Ligao-Tabaco National Highway bridge (reach of 7.6 km)

But, as the downstream area from junction of the main course and the Talisay River has been affected by backwater from Lake Bato as far as the lake functions as a retarding basin, the most downstream reach of 2 km near the lake should be improved after completion of Lake Bato regulation works such as Lake Bato - Pantao Bay Diversion, etc.

The said reach is shown by dotted line in the figure.

4.3.3.5 River Improvement Plan

(1) Route Selection

In fact, along the main course, there are densely populated municipalities especially Oas and many other properties that can hardly be removed due to necessary river improvement. Basically the route should be selected along the present river course, considering topography, land use and difficulties of land acquisition, but for such an important municipality of Oas, a diversion of Oas and a diversion to the Talisay River (a flood way) are considered. Two (2) alternatives as shown in FIG.-4.3.15 and as explained below are established and compared. Alternative I is the Oas Diversion Scheme, the route of which is selected along the present river course except Oas. And alternative II is the Bobonsuran Diversion Scheme constructing a newly excavated flood way from Bobonsuran to the Talisay River. And alternative I is selected as a recommendable scheme, comparing the construction cost (Alternative II is about 27% more costly than Alternative I), environmental problems and maintenance after improvement.

(i) Alternative I (Oas Diversion Scheme, Proposed Scheme)

As shown in FIG.-4.3.15, it is basically a plan to improve the main course along the present river course except the river course near the city of Oas. Existing levees are entirely replaced by newly constructed ones. The Oas diversion scheme is considered due to difficulties of land acquisition. The three (3) present fixed weir type dams (South Quinali, San Agustin and Aguz-Sta. Cruz) for irrigation are integrated to proposed Agus Sta Cruz-South Quinali Dam, which is of a movable weir type. Generally speaking, any weir type structures across the main course of rivers shall be of a movable type. And Cabilogan Dam is also a movable weir type and proposed for integration of irrigation systems together with proposed Agus Sta Cruz-South Quinali Dam. The cross section is designed as a compound section except the Nasisi River, which is designed as a simple trapezoidal section. Total construction cost for Alternative I Scheme is estimated at about P 656 million.

(ii) Alternative II (Bobonsuran Diversion Scheme)

As shown in FIG.-4.3.15, it is a plan to divert all of the flood water from Bobonsuran directly to the Talisay River with a concrete made fixed weir of 220 m in length 2.5 m in height and 3 m in top width with horizontal apron type stilling basin of 20 m in length and 220 m in width and a diversion channel newly excavated of 170 m in width and 4.4 km in length. The bed slope is selected to be 1/800 in conformity with the Talisay River. (It is about 1/320 according to the height difference between the main course and the Talisay River.)

The river channel of 10.5 km reach between Bobonsuran to the junction with the Polangui River through Oas leaves as it is including existing levees, South Quinali Dam and the Spillway just upsteam. And it functions as a low water channel. To avoid flood inundation from the existing channel during flood, a gate at the upstream end of the existing channel is installed. (Hightening of the levees of 10.5 km reach without a gate to avoid inundation results in being more costly than the installation of a gate.) The cross section is designed as a compound section except the Nasisi River, which is designed as a simple trapezoidal section. To obtain design discharge, specific discharge of the Quinali (A) River basin is used. And the design discharge distribution diagram is shown in FIG.-4.3.16. Total construction cost for Alternative II Scheme is estimated at about P 832 million.

(2) Alignment of River Channel

The alignment of river channel is designed with the following consideration:

(i) The alignment will follow the course of the present river channel to the extent possible.

(ii) The radius of curve of river channel should be as large as possible.

(iii) Existing levees are entirely replaced by the newly constructed ones.

(iv) The alignment should not be selected to involve such existing important infrastructures as railways, highways etc. in the river channel.

(v) The alignment should not be selected to involve the land occupied by houses, etc. as much as possible.

Final alignment of levees of proposed scheme is shown in FIG.-4.3.17 and FIG.-4.3.18.

(3) River profile

River profile should principally be designed to meet the present river bed slope as much as possible to keep the equilibrium river bed slope and minimize the construction cost for the present. Thus, the river bed slope is designed ranging from 1/1,550 to 1/550 for the main course as shown in FIG.-4.3.19 to FIG.-4.3.21 and from 1/1,000 to 1/800 for the Talisay River and from 1/400 to 1/130 for the Nasisi River.

(4) River Cross Section

As the design discharge is over 300 m^3/sec, the river cross section is designed as a compound section except the Nasisi River, which is quite limited by the formation height of the Philippine National Railway (For a design criterion, 1.0 m of clearance is taken in accordance with the plan underway of a permanent bridge by the Philippine National Railway.), and which is also a transition to Sabo work section. Considering the river bed depth measured from the ground level of inland, formation height of side sections are designed to be 2.5 m higher than the main section except the Talisay River upstream Sta. 8+000. The width of the main section is so designed that the side sections are used for passage of flood water 1 to 3 times a year. As there is not much densely populated area except Oas, land aquisition is not very difficult, therefore, river width is selected as wide as possible within the range specified in the Standard.

The dimension of cross section is determined by Manning's Formula assuming uniform flow. The levees are basically designed in conformity with the Standard. The freeboard is set at 1.2 m to 1.0 m and the top width is 5 m to 4 m depending on the design discharge. The slope of levee is selected to be 1:2. The berm of inland side of 3 m in width is constructed at every 3 m height in case total height of the levee is over 4 m. And the one of riverside of the same width is constructed at every 4 m height in case total height of the levee is over 6 m. The maximum height of levee will be about 6.5 m near Lake Bato and about 5.3 m at the junction with the Talisay River. The river width will be about 450 m at Lake Bato, and 360 m at the junction with the Talisay River. The formation height of levee at Lake Bato is EL. 12 m, which leaves 1.2 m of freeboard on the highest recorded water level of the lake. It is necessary to take some measures for drainage. The typical cross sections are shown in FIG.-4.3.22.

(5) Major River Structures

Relating to the above-mentioned river improvement, the necessary river structures are summarily listed as follows:

(i) Levees with sod facing
(ii) Foot protection and wet masonry for levees
(iii) Sluiceways for river drainage

Only gravity drainage is considered. And box culvert type sluiceways will be constructed as follows, calculated by an empirical formula depending on topographic conditions and drainage areas.

The main course	
Junction with the Sugtad Creek	2 m x 2 m x 4 nos.
Junction to Oas diversion	2 m x 2 m x 5 nos.
Junction with Oas diversion	2 m x 2 m x 5 nos.
The Talisay River	
Junction with the right tributary from the Spillway	2 m x 2 m x 3 nos.
Junction with the Libon River	2 m x 2 m x 2 nos.
Junction with the right creek just upstream the junction with the main course	2 m x 2 m x 2 nos.
The Ogsong River	
Junction with the Nasisi River	2 m x 2 m x 5 nos.

4.3.4 Agricultural Development Scheme

4.3.4.1 Agricultural Development Plan

(1) Basic Strategy

In connection with the Sabo and river improvement works, the proposed agricultural development schemes were contemplated in view of the land use intensification of the flooded agricultural land in the Quinali (A) River basin.

In the present situation, the flood not only causes much crop damage but also hinders the development of the intensive agriculture, although climatic and soil conditions are well suitable for rice cultivation. Investment by farmers themselves in the cropping such as fertilization is discourged by the flood, because once the heavy flood occurs the investment so far made is in vain. The irrigation water management for the rice cultivation in the project area is also hampered by the flood. The intake weirs for the existing irrigation systems are in most cases made of brushes and earth bags which are easily destroyed by the flood. When such temporary facilities destroyed, the irrigation water shortage is observed in the beneficial rice fields in the next dry season. No investment in construction of permanent intake structures however has been made, because the risk by the flood is considerably serious under the present river circumstances. In addition, poor drainage system makes inundation in lower part of rice field after heavy rainfall, resulting in crop production losses.

In the above context, the following basic agricultural development strategies are formulated in accordance with the national policy of equitable distribution of farm income and social welfare, national stability and economic growth:

- expansion of irrigated cropping area,
- integration of the existing irrigation systems, and
- increase of agricultural inputs such as fertilizer

(2) Delineation of Development Area

In the Quinali (A) River basin, 10,500 ha is cultivated with rice at present, but the lower part of rice field near the Lake Bato suffers from inundation annually for more than one week and its water level rises up to more than EL. 8.3 m in the rainy season. This hydrological condition will not be much improved under this project before the completion of river improvement works which is being carried out along the Quinali (A) River downstream from the Lake Bato. Considering that the height of rice in the ripening stage is 0.8 m on an average, 1,000 ha with an elevation below EL. 7.5 m is excluded from the development area under the project.

Among the existing irrigation systems, the Nasisi-Hibiga scheme has already been taken up under the NISIP Program of NIA with financial assistance from the World Bank. Thus, the irrigation development area under this project totals 6,350 ha in net, comprising Agos Sta. Cruz-South Quinali scheme (4,350 ha), Cabilogan scheme (1,400 ha) and Quinali scheme (600 ha), as portrayed in FIG.-4.3.23.

(3) Future Land Use and Proposed Cropping Pattern

The gross development area covers 6,900 ha consisting of 6,720 ha of flooded area and 180 ha of flood-free area. The flooded area includes 3,640 ha of irrigated rice field and 3,080 ha of rainfed one, while the whole flood-free area is coconut field. Through the implementation of the proposed river improvement works, 520 ha of irrigated rice field and 30 ha of rainfed one which are distributed in the flooded area at present will be converted to the new river bed. On the other hand, 180 ha of coconut field will be reclaimed as irrigated rice field. Accordingly, the irrigated rice field will be expanded from 3,640 ha to 6,350 ha under the proposed agricultural development plan.

The proposed cropping pattern is the irrigated double cropping of rice as illustrated in FIG.-4.3.24, which is established by modifying of the present cropping pattern predominant in the Project area. The proposed cropping pattern is technically sound from the view point of the farm labour requirement. Also, it has no problem in farm operations in due consideration of the availability of workable carabao per hectare and its work capability.

(4) Farm Input and Farming Practices

The farm input and farming practices of rice cultivation in the present condition have no weak points except for the amount of the nitrogen applied. The present application of about 70 kg N/ha is not sufficient considering the yield obtained through the fertilizer field trials which are conducted by FAO/UNDP. It can be increased to 100 kg N/ha for the dry season and 80 kg N/ha for the wet season under flood-free condition.

4.3.4.2 Irrigation Development Plan

The Cabilogan Scheme area extends over the both sides of the upper Quinali (A) River. There is no notable irrigation system in the area at present except for some small areas which are irrigated with water led from the temporary brush dams. For the future irrigation development in this area, a new headworks will be constructed on the Cabilogan River; around 1.5 km upstream Sta. Cruz, Ligao. In addition, 2 main canals with a total length of 12 km and 6 secondary canals with a total length of 19 km are required for the development. For the surface drainage in the area, around 10 km of main drains and 40 km of secondary drains are excavated along the depressed lands so as to finally flow into the Quinali (A) River.

The Quinali Scheme area is located along the right bank of the upper Quinali (A) River and its north end is bounded by the national railway. The irrigation water required in this area is taken from the existing Quinali headworks and several brush dams and distributed to the area through earth canals. The said Quinali headworks are still functioning well and will not hamper the proposed river improvement plan. The headworks are therefore be incorporated in the proposed irrigation system. All the temporary brush dams will be removed and their existing canal systems will be integrated into the new Quinali system. The new canal system will require 2 new main canals with a total length of around 6 km and 3 secondary canals with a total length of 7 km. Around 12 km of main and secondary drains will also be required for the surface drainage in the area.

The Agos Sta. Cruz - South Quinali Scheme area extends over the left bank of the most downstream reach of the Quinali (A) River. This area is largely bisected by the Talisay River which runs north-westwards through the scheme area. At present, this area is served by 5 headworks for irrigation, i.e. South Quinali, Quinali, San Agustin, Agos Sta. Cruz and Del Rosario headworks. All headworks are well functioning but will be removed because their weir lengths are not enough for the proposed flood control plan. Instead, the new headwork, which will integrate the existing 4 irrigation systems into one, will be constructed 50 m upstream the existing South Quinali headworks. In addition to the existing canal system, 2 main canals with a total length of 27 km and 26 secondary canals will be required for the irrigation development in this area. Around 49 km of main and secondary drains will newly be excavated and drain the excess rain water to the Talisay River or directly to Lake Bato.

The design discharge is 2.34 m^3/sec for the Cabilogan scheme, 1.00 m^3/sec for the Quinali scheme and 5.57 m^3/sec for the Agos Sta. Cruz-South Quinali scheme.

4.3.4.3 Anticipated Yield and Production Increase

With the increase of the nitrogen fertilizer amount applied and the improvement of irrigation facilities, the palay yield is expected to increase to 5.0 tons/ha for the dry season rice cultivation and 4.5 tons/ha for the wet season. The palay production will increase by 23,700 tons from the present production level of 34,300 tons. This increment is attributable to the proposed irrigation development scheme when commenced after implementation of the proposed flood control plan.

4.3.5 Flood Damage Analysis

4.3.5.1 General

In order to justify the effect of the proposed river improvement and sabo plans, the flood damage reduction amount is estimated for the Quinali (A) River basin. The proposed improvement plan of the Quinali (A) River can also reduce the flood damage occuring in the World Bank project area (Nasisi-Hibaga National Irrigation System Scheme). Therefore, the flood damage reduction amount expected in the World Bank project area is combined into that expected through this project.

The flood damages are estimated for the infrastructure, houses, crops and irrigation facilities under different flood magnitude with a return period of 2-, 10-, 20-, 50- and 100-year.

4.3.5.2 Damage to Infrastructure

(1) Damage to Houses

In estimating the flood damages caused by typhoon and heavy rain, only the damage to private houses is taken into consideration, since the damage data for the public buildings such as schools, churches, government building and factories were not obtained. For the estimation of the flood damages, effect of the wind and rainfall is not included and the damages to household effects are not taken into account. Inundation area and inundation depth caused by Typhoon Pepang in 1979 were obtained from the field survey in 1980 and those of the other magnitude of flood are based on the flood analysis.

The damage to houses is estimated by multiplying the number of houses by the value of house and flood damage rate based on inundation depth. The damage to commercial establishments is estimated at about 10 percent of the damage on houses.

The damage is estimated at P 10.93 million, P 18.58 million, P 22.30 million and P 27.36 million and P32.49 million for the flood magnitude of 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively as shown in TABLE-4.3.3.

(2) Damage to Government Infrastructure

(a) Damage to Road Structure

Damage to road structure can be approximately measured by the estimated damage cost (calamity fund) of each typhoon between 1975 and 1979. The damage revalued at 1979 price level is estimated at P 2.06 million, P 0.31 million, P 2.67 million, P 0.76 million and P 0.83 million for the flood of 1975, 1976, 1977, 1978 and 1979 respectively as shown in TABLE-4.3.4.

(b) Damage to Railway Structure

Damage to railway structure can be measured by the estimated damage costs (calamity fund) of 1975 and 1979 as shown in TABLE-4.3.4. The damage revalued at 1979 price level is estimated at P 0.89 million for the 1975 flood and P 0.32 million for the 1979 flood.

(c) Damage to River Facilities

Damage to river facilities can be measured by the estimated damage cost of each typhoon between 1975 and 1979. The damage revalued at 1979 price level is estimated at P 0.72 million, P 0.15 million, P 0.37 million and P 0.80 million for the flood of 1975, 1977, 1978 and 1979 respectively as shown in TABLE-4.3.4.

(d) Damage to Government Infrastructure

Flood damage to government infrastructure between 1975 and 1979 is listed in TABLE-4.3.4. Indirect damage is estimated at 15 percent of total direct damage.

The damage revalued at 1979 price level is estimated at P 4.16 million. P 0.36 million, P 0.32 million, P 1.30 million and P 2.25 million for the flood of 1975, 1976, 1977, 1978 and 1979 respectively as shown in TABLE-4.3.4.

(3) Total Damage to Infrastructure

The total damage to infrastructure are calculated for the five flood cases of 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively by aggregating the damages in the preceeding clauses. These damages are estimated on the following assumption:

i) Damage to infrastructure is the actual estimated damage for 2-year and 20-year probable flood. The damage for 2-year probable flood is taken as the greatest damage cost between 1976 and 1979, since the damage of the period between 1976 and 1979 is assumed to be 2-year probable flood from the flood analysis. 20-year damage is used the damage due to typhoon Sisang in 1975.

ii) The damage to infrastructure for 10-year, 20-years, 50-year and 100-year probable flood is estimated on the assumption that the damages will be affected mainly by the inundation depth obtained from the flood analysis. Therefore, these damages are estimated by multiplying the actual flood damage of 2-year by the flood damage rate of 1.2 for 10-year, 1.28 for 20-year, 1.3 for 50-year and 1.4 for 100-year respectively.

They are P 14.17 million, P 22.47 million, P 26.45 million, P 31.58 million and P 37.03 million at 1979 price level for 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively as shown in TABLE-4.3.5.

4.3.5.3 Damage to Crops

The annual record of flood damage to crops in the project area is not kept systematically in the relevant offices. The flood damage to rice is therefore estimated by applying the standard for the estimation of inundation damages prepared by the Ministry of Agriculture, Forestry and Fisheries in Japan. The obtained amount of flood damages to rice is regarded as the crop damages taking into account the present land use condition in the flooded area.

The rice field in the project area is classified based on the inundation area by flood of Typhoon "Pepang" as illustrated in FIG.-3.8.1 and the inundation depth and period for different return period as shown in TABLE-4.3.6. The result of classification is summarized in TABLE-4.3.7. Out of 9,400 ha of the existing rice field in the Quinali (A) River basin, 7,500 ha is flooded. The flooded rice field consists of 6,320 ha of irrigated area and 3,080 ha of rainfed area.

The flood damage to crops varies with the time of flood occurrence even the magnitude of flood is quite the same. From this viewpoint, the ratio of planted area during the growing period, the distribution of Typhoon and the damage rate of rice are monthly established. The monthly flood damage is calculated by multiplying these factors by monthly production cost already spent and net income of each crop season respectively. The sum of the monthly flood damage obtained is considered as the annual flood damage to crop. As given in TABLE-4.3.8, the annual flood damage is estimated at P 3.32 million and P 5.03 million for the flood of 2-year and 10-year to 100-year respectively.

4.3.5.4 Damage to Irrigation Facilities

The estimation method of flood damage to irrigation facilities is considered to be the same as that to infrastructure. Therefore, the biggest amount among the damages by Typoon between 1975 and 1979 is picked up and is regarded as the flood damage caused by the probable flood with a return period of 2-year. By applying the same flood damage rate as the infrastructure, the damage for 2-year, 10-year, 20-year, 50-year and 100-year probable flood is estimated at P 0.43 million, P 0.52 million, P 0.55 million, P 0.56 million and P 0.61 million respectively as shown in TABLE-4.3.9.

4.3.6 Cost Estimate

4.3.6.1 Estimated Construction Cost

Construction costs for the Sabo Works including six tributaries, the river improvement works of the Quinali (A) River including the Nasisi River and the Talisay River, and the irrigation works are estimated in considering local conditions of the Philippines, available equipments and materials, suitability of construction method, working rules, etc. These costs are estimated on the following conditions and on the basis of the Government estimate procedure.

(1) Construction cost comprises contract cost and indirect cost. Contract cost includes direct cost of material, labor, PD#390 and equipment, general, Contractor's profit, Contractor's tax and surcharges. Indirect cost includes land acquisition and resettlement, Engineering cost, Administration cost and contingencies.

(2) General cost for this estimate includes mobilization and demobilization, vehiecles, field offices and other temporary works. General cost is taken as 10 percent of direct cost.

(3) Contractor's profit and Contractor's tax are the cost of 10 percent and 3 percent respectively of the sum of direct cost plus general cost. Surcharges are the cost of 5 percent of the sum of direct cost plus general cost.

(4) Engineering cost which is 10 percent of the contract cost includes topographic surveys, design, soil testing prior to and during construction, construction surveys and construction management.

(5) Administration cost is the cost of 5 percent of the contract cost.

(6) Physical contingency is included in the cost estimate which is 20 percent of the contract cost. The rate of price escalation contingency varies with inflation in the Philippines. On the assumption that the annual escalation rate is 7 percent and the cost of price escalation is basis of disbursement schedule.

(7) Construction cost is estimated on the basis of the previous study report of the Mayon Volcano Sabo and Flood Control Project in February 1980. All unit price and summary cost are in local currency, pesos and centavos.

The estimated construction cost including physical and price escalation contingencies in the Quinali (A) River is P 1,087.5 million which comprises P 81.7 million for the Sabo works, P 923.2 million for the river improvement works and P 82.6 million for the irrigation works as shown in TABLE-4.3.12.

4.3.6.2 Operation and Maintenance Cost

Annual operation and maintenance cost for the Sabo works and the river improvement is taken as 0.5 percent of the construction cost uniformly in this study. Annual O & M cost for the irrigation works is estimated at P 250 per hectare.

The estimated annual O/M cost is P 292 thousand, P 3,278 thousand and P 1,588 thousand for the Sabo works, the river improvement works and the irrigation works respectively after completion of all the project works.

4.4 Master Plan for The Quinali (B) River

4.4.1 General

There are many upstream tributaries originating on the western to northwestern slope of Mayon Volcano. They are mostly devastated by debris and sediment flow. A basic strategy of Sabo plan is presented to control debris and sediment for the protection of the potential irrigation development area extending over the middle and lower reaches areas of the Quinali (B) River basin.

Along the middle reache, between Tuliw and Labnig, severe erosion is observed. Several large flood damages were recored in Malinao city and 6 villages. The strategy of flood control plan for the Quinali (B) River is to maintain public peace in the region through reducing damages to human lives, crops, houses, highways, river structures and irrigation facilities.

4.4.2 Sabo Plan

4.4.2.1 Subject Rivers

In the Quinali (B) River basin, the Buang River is to be treated from the view point of sabo planning.

The main course of the Quinali (B) River in the vicinity of barangay Tabigyan has been affected by the devastation of the Buang River, so that this reach is taken up for sabo planning.

The rivers other than the above are not taken up because they have no serious sabo problems.

4.4.2.2 Base Point

The base point for Sabo planning is set at the location shown in FIG.-4.4.1.

4.4.2.3 Sediment Run-off Volume

The sediment run-off volume at base point is calculated by employing the same formula proposed by Dr. Ashida and Dr. Okumura as the Quinali (A) River basin.

The sediment run-off volume at base point is estimated for the design flood with a return period of 50-year as follows.

SEDIMENT RUN-OFF VOLUME (50-yr Probable Flood)

Name of River	Drainage Area (km2)	Sediment Run-off Volume (m3)	Specific Sediment Run-off (m3/km2)
Quinali (B)	19.2	319,700	16,600
Buang	4.7	211,800	45,100

4.4.2.4 Excess Sediment

Based on the same principle as the Quinali (A) River basin, the excess sediment volume is defined as the sediment amount given by subtracting the allowable sediment amount from sediment run-off volume. The allowable sediment volume is taken as the bed load amount under the present river conditions for the 50-yr design flood.

Name of River	Sediment Run-off Volume (km2)	Allowable Sediment Volume (m3)	Excess Sediment Volume (m3)
Quinali (B)	319,700	143,700	176,000

4.4.2.5 Sediment Control Plan

The sediment control plan is established mainly for the Buang River. Four (4) consolidation works are planned on the Buang River just upstream from Ligao-Tabaco National Highway Bridge. The sediment of 144,000 m^3 will be controlled with these facilities and the sediment run-off volume at highway bridge on the Buang River will be reduced from 211,800 m^3 to 67,800 m^3.

Then, the Sabo dam with a height of about 8 m is planned on the Quinali (B) River main course in the vicinity of Tabigyan near base point. The sediment of 56,000 m^3 will be controlled with this dam.

Finally, the sediment run-off volume at base point will be reduced from 319,700 m^3 to 119,700 m^3 which is lower than the allowable sediment volume of 176,000 m^3.

PRINCIPAL FEATURES OF PROPOSED SABO FACILITIES

Name of River	Proposed Works	Scale of Works	Remarks
Buang	Consolidation (masonry) &	At four (4) sites Total length: 300 m	Two of them: 100m long Two of them: 40m long
	Spur dike (masonry)	At two (2) sites Total length: 100 m	Attached to two of the above consolidation works
Quinali (B)	Sabo dam (masonry)	Height of non-overflow section: 10 m Height of overflow section: 8 m Crest length: 55 m	At the site of EL. 155 m in river bed

4.4.3 River improvement plan

4.4.3.1 General

As stated in subsection 3.4.1, divide of Sabo work section and flood control work section is plotted off at contraction at Bantayan.

4.4.3.2 River Width and Discharge Capacity of The Present River Channel

Using the profiles and cross sections of the present river channel, river width and discharge capacity is computed as shown in FIG.-4.4.3. For the calculation of discharge capacity, Manning's Formula is used assuming uniform flow. The roughness coefficient is selected to be 0.035.

4.4.3.3 Design Discharge

The design discharge is selected to be 50-year probable flood, considering importance of the region, design discharge of other rivers in the Philippines and the Standard. From the results of hydrological analyses, design discharge distribution diagram is established as shown in FIG.-4.4.4. The design discharge for the San Vicente River is 270 m^3/sec.

4.4.3.4 River Reaches for Improvement

From FIG.-4.4.3 and FIG.-4.4.4, it can be said that the present river course has not sufficient discharge capacity, and it results in flood inundation. Thus, damage is caused on a smaller scale than the Quinali (A) River to human lives, crops, houses, highways, river structures and irrigation facilities, especially in the affected area including two (2) important municipalities of Tabaco and Malinao. Consequently, it is necessary to establish a flood control plan to avoid this damage by improving the river channel. The river reaches for improvement are selected as follows considering the discharge capacity of the present river and importance of the affected area.

(a) The main course - River mouth to Ogob 2 km downstream the contraction at Bantayan

(reach of 11.3 km)

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

(c) The San Vicente River* - The river mouth to Ligao-Tabaco National Bridge at San Vicente (reach of 4.0 km)

* This river is out of scope of the Master Plan.

4.4.3.5 River Improvement Plan

(1) Alignment of river channel

The alignment of river channel is designed with the following consideration:

(i) The alignment will follow the present course of the river channel to the extent possible.

(ii) The radius of curve of river channel should be as large as possible.

(iii) Existing levees are entirely replaced by the newly constructed ones.

(iv) The alignment should not be selected to involved the land occupied by houses, etc. as much as possible.

Final alignment of levees of proposed scheme is shown in FIG.-4.4.5. The ones for the San Francisco River and the San Vicente River are also shown by dotted lines in the same figure because of no river survey.

(2) River profile

River profile should principally be designed to maintaining the present river bed slope as much as possible to keep the equilibrium river bed slope and minimize and the construction cost for the present. Thus, the river bed slope is designed ranging from 1/1,200 to 1/80 as shown in FIG.-4.4.6. The average river bed slope of 1/190 and 1/100 for the San Francisco River and the San Vicente River is used respectively for computation.

(3) River cross section

As the design discharge is over 300 m^3/sec, the river cross section along the main course is designed as a compound section. And the ones for the San Francisco River and the San Vincente River are designed as simple trapezoidal sections. Considering the river bed depth measured from the ground level of inland, formation height of side sections are designed to be 2.5 m higher than the main section. The width of the main section is so designed that the side sections are used for passage of flood water 1 to 3 times a year. As there is not much densely populated area, land acquisition is not very difficult, therefore, river width is selected within the range specified in the Standard.

The dimension of cross section is determined by Manning's Formula assuming uniform flow. The levees are basically designed in conformity with the Standard. The freeboard is set at 1.2 m to 1.0 m and the top width is 5 m to 4 m depending on the design discharge. The slope of levee is selected to be 1:2. The berm of inland side of 3 m in width is constructed at every 3 m height in case total height of the levee is over 4 m. The maximum height of levee becomes about 4.0 m near the river mouth. The river width becomes about 270 m there. As the high water level of EL. 5.1 m at the river mouth is higher than the highest tide of 1.3 m recorded during the period between Jan. '79 and Apr. '80, no special consideration is given to tidal effect. It is necessary to take some measures for drainage. The typical cross sections are shown in FIG.-4.4.7.

(4) Major river structures

Relating to the above-mentioned river improvement, the necessary river structures are summarily listed as follows:

(i) Levees with sod facing

(ii) Foot protection and wet masonry for levees

4.4.4 Agricultural Development Scheme

4.4.4.1 Agricultural Development Plan

Agricultural development plan proposed for the Quinali (B) River basin is formulated in the same manner as that in the Quinali (A) River basin.

Out of the present rice field of 3,950 ha in the Quinali (B) River basin, 1,370 ha is irrigated, but not satisfactorily because of temporary nature of intake facilities and imcomplete canal networks. The proposed development plan covers 2,400 ha along the middle and lower reach of the Quinali (B) River, including 810 ha of flooded area and 1,590 ha of flood-free area. The whole flooded area is the existing irrigated rice field, while the flood-free area consists of 560 ha of the existing irrigation scheme area and 1,030 ha of rainfed rice field. Thus, the irrigated rice field will increase from 1,370 ha to 2,400 ha under the proposed agricultural development plan.

The proposed cropping pattern is the same as that of the Quinali (A) River basin as illustrated in FIG.-4.3.25. Farm inputs and farming practices are also the same as that of the Quinali (A) River basin.

4.4.4.2 Irrigation Development Plan

The present water sources for the proposed development area depend on the Sawang and the San Francisco Rivers which almost dry up in the dry season. For the future irrigation development in this area, therefore, the Quinali (B) River is selected as irrigation water source. The new headworks with movable weir will be constructed 2 km downstream the confluence of the Quinali (B) River with the Soa River. From the headworks, main canal of 11 km will be constructed along the southern boundary of the area. Seven secondary canals with a total length of around 30 km will be branched off from the main canal. The existing canal networks are combined with the said proposed canal network as terminal irrigation canal networks. In addition to the natural drainage canals with a total length of 28 km, about 17 km of main and secondary drainage canals and 95 km of field drains will be excavated for the surface drainage in the area.

4.4.4.3 Anticipated Yield and Production Increase

With the increase in the amount of nitrogen fertilizer applied and the improvement of irrigation facilities, the palay yield is expected to increase to 5.0 tons/ha for the dry season rice cultivation and 4.5 tons/ha for the wet season. The production of palay will increase by 10,200 tons from the present production level of 12,600 tons. This increment is attributable to the proposed irrigation development scheme when commenced after implementation of the proposed river improvement plan.

4.4.5 Flood Damage Analysis

4.4.5.1 Damage to Infrastructure

(1) Damage to Houses

The damage to houses in the Quinali (B) River basin is estimated by the same method of the previous Clause 4.3.5.

The damage is estimated at P 0.75 million, P 1.54 million, P 1.88 million, P 3.65 million and P 4.22 million for 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively as shown in TABLE-4.4.1.

(2) Damage to Government Infrastructure

Damage to government infrastructure such as roads and river facilities is estimated at P 0.31 million, P 0.14 million, P 0.49 million, P 0.43 million and P 0.54 million for the flood of 1975, 1976, 1977, 1978 and 1979 respectively as shown in TABLE-4.4.2.

(3) Damage to Infrastructure

The estimated damage to infrastructure is calculated for five flood cases by aggregating the damages and on the same assumption as the previous clause 4.3.5.

The damage revalued at 1979 price level is estimated at P 1.29 million, P 2.19 million, P 2.55 million, P 4.35 million and P 4.97 million for 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively as shown in TABLE-4.4.3.