CHAPTER 8 PLANNING AND PRELIMINARY DESIGN OF SUBPROJECTS

8.1 Yawa River System Sabo Project

8.1.1 Yawa River System

(1) Rivers to be studied

The Master Plan study, completed prior to this feasibility study, assessed the priorities of the preliminary Sabo plans for the targeted 17 rivers in the Study Area to select a priority project as the objective of the feasibility study. The enumerated items are economic viability, number of beneficiaries, social impact, each proposed priority core projects and supporting project/programs. The assessment concluded that the Yawa River System Sabo Project has the highest economic internal rate of return and the largest number of beneficiaries. It might bring about a certain social impact. However, the conceivable impacts are to be driven away by the supporting programs proposed in this report. It also revealed that the Yawa River System Sabo Project could be a pilot project for other proposed Sabo projects from administrative and technical points of view. In light of this, the Master Plan Study proposed that the Yawa River Sabo Project should be included for the feasibility study. The proposal was duly approved by both the JICA and the Steering Committee of the Study held on August 23, 1999 in Manila. The committee concluded that a sand pocket is the basic option or the most appropriate facility to protect life and property of the people in conformity to the geomorphologic conditions of the Study Area

The selected Yawa River Sabo Project comprises sand pockets and related structures for three tributaries, the Pawa- Burabod river, the Budiao river, and the Anoling river.

1) Revision in Sabo plan from one proposed in the Master Plan

The Sabo plans for three tributaries proposed in the Master Plan were reviewed on the basis of the results of additional surveys conducted in this period and the elaboration of the obtained data. Such in-depth study attested the appropriateness of the proposed plan in general. The magnitude of hazard or design mud and debris flow and the major features of proposed facility or the alignments, heights and materials of dam and dike for sand pocket are confirmed to be adopted in the feasibility study as proposed in the Master Plan.

The major revisions adopted in this Study are as follows:

- The proposed open dike is revised to a continuous dike in order to use the dike as a reliable road especially for the inspection and the maintenance of the Sabo facility.
- The proposed training dike on the right bank of downstream reach of the Pawa- Burabod sand pocket was deleted because the road provided along the river was confirmed to be functioning as a dike as well. And the paddy fields of around 30 ha which extend along the river is included in the existing protected area.
- A more in depth study was carried out for the maintenance works of the proposed sand pocket.
- A preliminary study on stage wise development was carried out for the period until the facility is provided.
- A preliminary study on the buffer zone was carried out.
- A more in-depth study on the structural design was carried out as follows:
  - Stability of dams
  - Dimensions of slit in the proposed spillway

8.1.2 Present Condition in the Project Area

(1) Explanation of rivers

The Yawa river system is situated on the southeast slope of Mt.Mayon. The Yawa river gathers three tributaries from the Mayon volcano slope side, namely, the Anoling river, the Budiao river and the Pawa- Burabod river.

1) Anoling river

The Anoling river drains the water from three tributaries in its upstream reach. Tentatively the tributaries are named as, the Anoling (A), (B), (C) rivers dissect deeply on the pyroclastic plateau in the upper reach. The channels of the Anoling (A), (B), (C) river have rather straight courses on the alluvial fan area. The Anoling (A), (B) rivers meander slightly at the elevation of 160m (the Anoling (A) river) and 240m (the Anoling (B) river). The Anoling (C) river absorbs the most part of the catchment area ($4.1km^2$) of the Budiao river. Therefore, volume of sediment materials had increased since the piracy event. There is no evidence of large scale debris movement so far in the Anoling tributaries. Scouring of riverbed occurred in the Anoling (A) river channel in the fan area on the 1998 typhoon Loleng. But the landform change was small.

2) Budiao river

Catchment area of the Budiao river was pillaged by the Anoling (C) river at the elevation of 600m between 1990 and 1994. As a result, catchment area of the Budiao river was reduced from $10km^2$ to $5.1km^2$. There is no occurrence of debris flow movement since.

3) Pawa-Burabod river

Pyroclastic flow, which was ejected by the eruption in 1984, widely covered the drainage area of the middle reach of the Pawa Burabod river. New channel had formed along the west edge of a pyroclastic flow deposit area. Consequently, new channel had run with a large and smooth curve through the alluvial fan area. In the process of making a new channel, the Pawa Burabod river totally carried sediment material of $1,250,000m^3$ to the lower reach after the 1984 eruption. When the 1993 eruption occurred, pyroclastic flow deposited on the same place again. After the 1993 eruption, the downstream area of the Pawa Burabod river has been devastated by several debris flows. However, remarkable debris flow has not occurred recently in the Pawa Burabod river since the last disaster which was caused by the 1996 Typhoon Akang.

(2) Delineation of Danger Zone

A disaster prevention plan should focus on the mud and debris flow that occurs after an eruption.

The mud and debris flows that occurred in 1984 and 1993 were highlighted in the Study as they had the largest magnitude of those recently occurring and their records are satisfactory.

Hazard map prepared reflects the date of the mud and debris flow that occurred in 1984 and 1993.

(3) Economic and Social Condition

1) Population and Number of Houses

The population of the protected area is 14,282 and the number of households is 2,621 in 1999. This area includes Legazpi City, two municipalities of Daraga and Camalig. Legazpi City has 64.9% of total population in the protected area followed by Daraga municipality, (31.8%) and Camalig (3.2%).

2) Family Income and Poverty Level

According to the People's Intention Survey carried out by the JICA Study Team in September- October 1999, the average income levels of the households of resettlers and candidate resettlers living around Mayon Volcano was estimated as 42,075 pesos per year or 3,506 pesos per month.

3) Present Land Use

The area of the Yawa River System Sabo Project (the Yawa Project Area, 2,658.55ha) and surroundings show clear classification of present land use along its slope over the skirt of Mayon volcano. (Figure 8.1.1)

4) Road Traffic

The main barangay road running horizontally in the middle of the area between Salvacion, Daraga, and Padang, Legazpi, is the core for residents in this area. Yawa River dividing the Yawa Project Area and the city proper. Also, there is a national road running from Salvacion into the center of the City of Legazpi.

5) Agriculture

The Yawa Project Area has about 70% of the share of agricultural use. The major crop in this area is coconut and paddy. The main barangay road mentioned above is running between these two major crop area and looks like if devides them as upper area and lower area. Upper area is mostly occupied by coconut and intercropping. Vegetables are also harvested on the paddy area along the barangay road as semiannual crops with rice in the lower area.

6) Bush and Forestry

Some bush area show their share in the upper part of the Project Area toward into the PDZ. Forestry, mostly "agoho", has its share along the gully and among the sand and gravel area.

7) Vacant Area- Sand and Gravel Area

The pyrocrastic materials were deposited at the upper portions due to the eruption of Mayon Volcano. These materials were carried down during flash floods along gullies to tributary rivers like Budiao, Banadero, Mabinit, Matanag and Pawa-Brabod down to the main Yawa River. The quarrying activity can be seen along these rivers.

8) Residential

Twenty barangays are in this Yawa Project Area. Most of the settlement is along the barangay road and in the paddy field. Not so much settlement can be seen in the upper area except Anoling.

8.1.3 Basic Sabo Planning

(1) Background of the Plan

Mayon Volcano is an active strata volcano which ejects voluminous ashfall, lava and pyroclastic flow with debris and thereby changes the land form of its slopes still now. Ejecta, once parched on the steep slope with a gradient less than 1/10 tends to move downward by the traction force of water which is sustained by torrential rainfall with a high intensity. The average volume of ejecta is estimated to be 20 million cubic meters per eruption. The estimated average annual precipitation is about 4,000mm on the slope with a high elevation and 3,000mm on the flat low land. The estimated average annual rainy day in Legazpi City is 210 days out of 365 days a year.

The moved mud and debris mostly deposit on the slopes with heights of 400m to 100m above mean sea level because the gradient of the slopes decrease to around 1/20. Mud and debris spread wide at this area of the slope and form an alluvial fan. The mud and debris flow from the upstream reaches from the alluvial fan spreads wide and leave behind mud and debris while it passes fan. Small scale mud and debris flow deposit at the upper portion of a fan. While a large scale one is strong enough to pass through the fan and deposits at the lower slope from the existing fan. Thus, the fan extends its lower portion incidentally. For more than some thousand years, the alluvial fan has played the role of a saucer for the volcanic ejecta. Consequently to trap a mud and debris flow in a fan is the unique method adaptable to this overwhelming natural hazard and is to be adopted to mitigate the hazard around Mayon Volcano. In the light of this, the Steering Committee meeting concluded to adopt the plan, which proposes the development of sand pocket in the Master Plan.

As stated in the Interim Report, the alternative study carried out by the Study concluded that the 20-year probable mud and debris flow should be adopted as the design value for the feasibility study. The Steering Committee meeting accepted the conclusion as well.

(2) Design Debris Flow

1) Probable rainfall and design rainfall

The crater of the volcano is open to southwest exposing the dome to this direction. Accordingly, the possibility that lava flow and pyroclastic flow take this direction is high once the volcano erupts. Furthermore, the recent geomorphologic activities have developed prominent gullies on the slopes of southeast, south, and southwest. They are Basud gully on the southeast slope, Bonga gully on the south slope and Anoling gully on the southwest. These ruptures are liable to induce lava flow and pyroclastic flow. In fact, lava flow and pyroclastic flow went down along Bonga gully at the eruption occurred in 1993. The photograph shot at the explosion in June 22,1999 shows a trace of a kind of pyroclastic flow along Bonga gully. All these are contemplated to select the priority project among several candidates at the Steering Committee meeting held on August 23, 1999 in Manila as mentioned before. The meeting accepted the Yawa river Sabo project as the priority project as proposed in the Interim Report.

Mud and debris flow is triggered by flood caused by a torrential rainfall with a high intensity as discussed before. Accordingly the probable rainfall is imperative to designate the probable design mud and debris flow.

PAGASA has kept daily rainfall records at five gauging stations in the Study Area and made the data available since 1980. They are Legazpi City, Sto. Domingo, Tabaco, Buang and Guinobatan. Hydrologic study estimated the probable daily rainfalls for each river basin relating gauging station to the corresponding river basin. The following is a list of the estimated probable daily rainfall for each river basin.

Table of Estimated Probable Daily Rainfalls

Basin	Whole Area	Eroding Area of Whole Area	Bed Slope of Whole Area	Pyroclastic Area in Eroding Area	Bed Slope of Pyroclastic Area	Design Rainfall (mm/day)						
	(km²)	(km²)	(1/n)	(km²)	(1/n)	Station	2year	5year	10year	20year	50year	100year
Yawa River System												
Pawa-Burabod	20.835	7.257	1/14.0	5.098	1/10.6	Legazpi	229	326	394	463	554	626
Budiao	10.475	2.985	1/15.1	1.613	1/7.5	Legazpi	229	327	394	463	554	626
Anoling A	10.251	5.433	1/18.9	4.313	1/15.7	Legazpi	227	323	390	458	548	619
Anoling B	4.317	3.358	1/14.1	2.876	1/13.1	Legazpi	227	323	390	458	548	619
Anoling C	6.438	3.150	1/15.0	3.055	1/14.9	Legazpi	227	323	390	458	548	619
Quinali A River System												
Quirangay	11.844	5.081	1/12.0	3.641	1/9.1	Ligao	209	296	353	407	474	524
Tumpa	6.890	0.948	1/12.9	0.000		Ligao	213	303	361	416	485	536
Maninira	12.687	5.389	1/17.9	3.812	1/14.6	Ligao	215	305	363	419	488	540
Masarrawag	24.868	6.504	1/16.4	4.702	1/10.5	Ligao	207	294	351	404	471	521
Ogsong	9.820	3.785	1/15.4	3.179	1/12.7	Ligao	191	271	322	372	433	479
Nasisi	16.630	6.731	1/14.0	8.640	1/19.0	Buang	177	252	300	346	403	445
Quinali B River System												
Buang	28.602	11.446	1/17.1	19.645	1/16.1	Buang	172	297	400	515	696	865
San Vicente	52.382	11.348	1/14.3	15.089	1/16.2	Buang	141	213	267	324	406	474
Arimbay	5.778	0.676	1/12.7			St.Doming	236	308	356	403	467	514
Padang	17.258	9.501	1/16.0	5.996	1/8.5	St.Doming	226	295	341	386	447	493
Basud	22.862	11.3288	1/17.9	5.366	1/11.7	Tabaco	219	286	330	374	433	477
Bulawan	22.579	13.214	1/14.7	15.771	1/20.0	Tabaco	218	284	328	372	431	475

Note: Pyroclastic Area distributes in eroding area of whole catchment basin.

The consequent 20-year probable rainfalls of the target river basins to be adopted as design rainfalls are as follows:

Pawa – Burabod River	463mm
Budiao River	463mm
Anoling River	458mm

2) The probable runoff and design runoff of mud and debris flow

The probable runoff volume formula as the estimation model (Technical Standard for the Measures against Debris Flow (Draft), 1988, Ministry of Construction)

The Quantitative relationship between rainfall and the magnitude of mud and debris flow is not available in the Study Area since no measurement of mud and debris flow had been conducted.

The empirical probable runoff volume formula is applicable to estimate the magnitude of mud and debris flow on the basis of a rainfall depth.

The formula reflects the topographic and geologic conditions of the site and have yielded satisfactory results in Japan. The following explain the formula:

$$Vec = (10^3 \times R \times A) / (1-\lambda) \times (Cd/(1-Cd)) \times fr \quad \text{..........} \quad (1)$$

Where;

Vec : Sediment Flow Volume (m^3)
Rt : Provable one day rainfall (mm)
A : Catchment area (km^2)
λ : Void ratio of unstable material
C* : Sediment concentration of stable sediment material (0.6)
Cd : Sediment concentration of flowing debris material
In case of Cd>0.9 C*; Cd = 0.9 C*
In case of Cd<0.3 C*; Cd = 0.3
fr : Calibration coefficient runoff
$A<0.1km^2$; fr = 0.50
$1km^2 \quad A \times 10.0km^2$; fr = 0.05 (logA × 2.0) + 0.05
$A>10.0km^2$; fr =0.10

The concentration of following debris material is obtained by the following equation:

$$Cd = (\rho \times \tan\theta) / \{(\sigma - \rho) \times (\tan\phi - \tan\theta)\} \quad \text{..........} \quad (2)$$

Where;

Cd : Sediment concentration of flowing debris material
σ : Density of gravel ($2.6t/m^3$)
ρ : density of water ($1.2t/m^3$)
ϕ : Angle of internal friction in sediment material (30°)
θ : Slope gradient (from base point to 200m upstream)

The probable runoff volume formula was adopted to estimate sediment runoff.

3) Estimation of sediment runoff soon after eruption

The probable runoff volume formula was developed analysing the sediment runoff of volcanic material. Most of materials analyzed were ones ejected several years before and fresh debris of ejecta are very few. Fresh debris of ejecta is easy to flow because it is not consolidated and have a higher λ of formula (1) as compared with those old debris. Another reason of this might be the smaller cohesion as compared with an old debris. Void ratio of unstable material (λ) has had gradual and continuous increase after deposition of pyroclastic flow. As the result of that, λ changes in the formula (1) is accompanied with passing of time. In this connection a special consideration is necessary for the estimation of sediment runoff for the fresh debris because the Mayon Volcano have erupted with an interval of approximately 10 years.

The deposit of mud and debris flow at October 18, 1985 was 260,000m^3 according to the measurement carried out in the Pawa-Burabod river. The daily rainfall of this occasion was 59.8mm of which is recorded at the Buang rain gauge station on October 18, 1985 and correspond to under the 2-year design rainfall. The estimated sediment runoff the proposed model is 28,308m^3 assuming the following parameters:

Basin area	:	5.1km^2
River bed slope	:	1/10.6
Internal friction angle	:	30.0 degree
Specific gravity	:	2.60 (t/m^3)
C*	:	0.17
Cd	:	0.30
fr	:	0.13

This big difference between the measured and the estimated might be due to the eruption that just occurred one year before on October 6, 1984. In this accord, it is concluded that the multiplier of 9.19 or rate of 260,000m^3 is to be applied to the estimation of the sediment runoff within one year

4) Expectation of sediment runoff within the design flow

The expectation of sediment runoff due to the probable (n) year rainfall in a year is obtained by the product of sediment run off be estimated and the probability density. Where the probability density for (n) year event is approximated by following formula:

$$Pd\ (n) = 1/(n-1)(n+1) \quad \cdots\cdots (3)$$

Where :

Pd : Probability density for n-year event
n : Return period of exceedence in year

Meanwhile the probability of a year to fall on the period within 10 year is 0.1 because the eruption takes place once 10 years. On the contrary the probability not to fall on the critical period is 0.9 because 9 years out of 10 there is no eruption.

Pe = 0.1 for erupted year and 0.9 for not erupted year

Since the 20-year mud and debris flow was adopted as the design flow, the expectation of sediment run off not exceeding the design flow for a year is given by the following formula:

$$V = \sum_{n-1}^{20} (k.V(n).Pd(n).Pe)$$

Where :

V : Expectation of sediment runoff in m^3
(n) : Index for return period of exceedence
K : Amplifier, 9.19 for erupted year, 1.0 for not erupted year
V(n) : Sediment runoff corresponding to (n)-year rainfall obtained by formula (1)
Pd : Probability density, obtained by formula (2)
Pe : Probability density, obtained by formula (3)

The expectation of the total sediment volume within the assumed life period for the proposed disaster prevention facility of 30 years is the simply 30 times the expectation for a year. Below is a listing up of the 30 year total sediment volume for each river.

Estimated Total Sediment Volume in 30 year

River	Volume of 30 years		
	Usually Period	After Eruption	Total
Yawa			
Pawa-Burrabod	3,096,000	3,161,400	6,257,400
Budiao	1,583,700	1,617,300	3,201,000
Anoling A	2,794,800	2,853,900	5,648,700
Anoling B	2,263,500	2,311,200	4,574,700
Anoling C	2,263,500	2,311,200	4,574,700
Anoling Total	8,9005,500	9,093,600	17,999,100

(3) Planning of sand pocket

1) Basic Conditions for Planning

Basic conditions contemplated in sand pocket planning are as belows:

- Eruptive magnitude to be referred to is the one occurred in 1984.
- Existing structure and alignment of Sabo facility shall be utilized in this planning after the availability thereof is confirmed.
- Natural undulation on slope landform shall be considered. For example, lava flow mound can be utilized as natural barrier like a large dike.
- Sabo planning shall adapt to changeable river course, landform changes and Increase of runoff volume by the future eruption.
- Changeable channel course will develop on fan surface.
- New channel will be formed from time to time by deposition of pyroclastic flow or lava flow in a gully portion.

2) Hazard area

Hazard area of mud and debris flow is identified on the basis of the following assumptions:

- mud and debris is to flow along the channel developed in a gully until it reaches the intersection point which is situated at the rivet of a fan.
- the flow direction of mud and debris flow has possibility to fluctuate 25 degree to the left and 30 degree to the right at the intersection point according to the topographic conditions of the fan and the geomorphologic interpretation of the fan.
- the results of preliminary mud and debris flow analysis and interpretation of geography indicate that a mud and debris flow with a scale of 20-year return period flows down the fan to the area which has the slope gradient of less than 1/35.

The identified hazard areas thus delineated for the Pawa-Burabod river and Anoling-Budiao rivers are shown in Figure 8.1.2 and Figure 8.1.3.

3) Locations, alignment and height of the facilities

In the Master Plan Study, the locations of sand pockets for the Pawa-Burabod, Budiao and Anoling rivers are studied considering the following:

- a sand pocket is provided in a fan area to trap mud debris:
- a sand pocket is provided to protect area within the estimated hazard area as much as possible:

- existing structures are availed to the maximum extent:
- take advantage of natural topography to the maximum extent:
- observe the existing land use and the area to be occupied by the proposed sand pocket should be the devastated land by the recent disaster:
- angle of incidence of mud and debris flow to the proposed training dike of more than 30 degree is preferable:
- the preliminary hydraulic analysis on the mud and debris flow concluded that the peak water levels of mud and debris flow of about $320m^3/s$ for the Pawa-Burabod river and $284m^3/s$ for Anoling-Budiao rivers with a return period of 20-year are 2m at the site where the slope is 1 to 15, 2.2m at 1 to 20 and 3m at 1to 30:
- the deposit caused by mud and debris in 1984 is 4m at the maximum.

Consequently the height of 4m was adopted for the proposed training dike a part of which is provided at the site with a slope of less than 1 to 30.

Several alternative sites for a proposed dam were studied for each river. The contemplated heights of dam are 3, 4, and 5m in accordance with the incoming water levels of 320 and $284m^3/s$ for the Pawa-Burabod and Anoling-Budiao rivers, respectively. The results of the Study concluded that the dams with height of 4m are the optimum as the least costly alternative because the beneficial areas do not vary among the contemplated alternatives. Thus, the proposed sites for dam axis corresponding to the height of 4m are adopted. The feature of each sand pocket is described below.

(The Pawa-Burabod river)

The river diversified three branches just upstream from the provincial road crossing. The training dikes are provided along the left bank of left branch and the right bank of right branch. The area extending on both sides are well cultivated and populated in the downstream reach from the road and the dike is extended to protect these area down to near the confluence with the Yawa River where a Sabo dam is proposed to trap debris before it flows into the Yawa River. The dam is so planned to trap the debris discharged from the neighboring river on the right bank.

(The Anoling-Budiao rivers)

The Anoling river consists of three tributatries at the crossing of the provincial road. The proposed sand pocket traps all the debris from these four rivers including the Budiao River. In order to protect Barangay Budiao, the dams with a height of 4m are proposed at the upper reach of the rivers sacrifying the storage capacity. The existing dike on the left bank of the Budiao river is available and a training dike is proposed on the right bank of the Anoling river.

The proposed plans are shown in Figure 8.1.4 and Figure 8.1.5.

(4) Stage Wise Development

It takes time and requires a considerable amount of investment to construct a sand pocket. The development of a proposed sand pocket might take 5 years at the earliest including detailed design of 1.5 year, contracting procedure of 1 year and construction of 2.5 years. The budget required for the construction of a sand pocket might be 1,000 to 2,000 million pesos including indirect cost. Staging of construction is one of the most realistic ways to solve the budgetary constraint. In this case, the latter stages might be implemented more than 10 years after from today.

In order to deal with the issue, provision of a temporary simple structure to protect the area will be effective. The structure should be easy to construct and cheap in its nature to be afforded by the budget of the communities.

In this conformity, a wooden beam structure, a concrete beam structure, and CSG structure without concrete facing works were studied. However, preliminary study on the stability of these proposed structures concluded that such facilities are not effective because the hazard is overwhelming. There is a possibility that such temporary structures turn to debris once it is broken by mud and debris flow.

Consequently, it is recommended to construct only limited parts of the proposed training dike which is located at just upstream from residential areas if the budget can afford it. That part of the dike is to be constructed to save life of residents in emergency case as the partial implementation of the plans proposed in the Master plan. Evacuation is the substantial prevention measure of a disaster in this area.

(5) Buffer Zone

The areas to be protected by proposed sand pocket should be developed to the maximum extent to enhance the regional economy and environment. A considerable amount of capital investment would be imposed for the development. Thus, needs for protection increase in the areas. However, any structure has possibility of having defects which might hamper the structure to function well. Accordingly, complimentary measures should be provided to secure higher security.

The proposed Sabo dam and training dike will protect the land side areas against the mud and debris flow with a return period less than 20-year. A mud and debris flow with a magnitude more than 20-year can overtop the dike and attack the land side areas although the hazard may have its energy dissipated to some extent when it overtop the provided dike. Accordingly, any measure to mitigate the destructive energy is necessary.

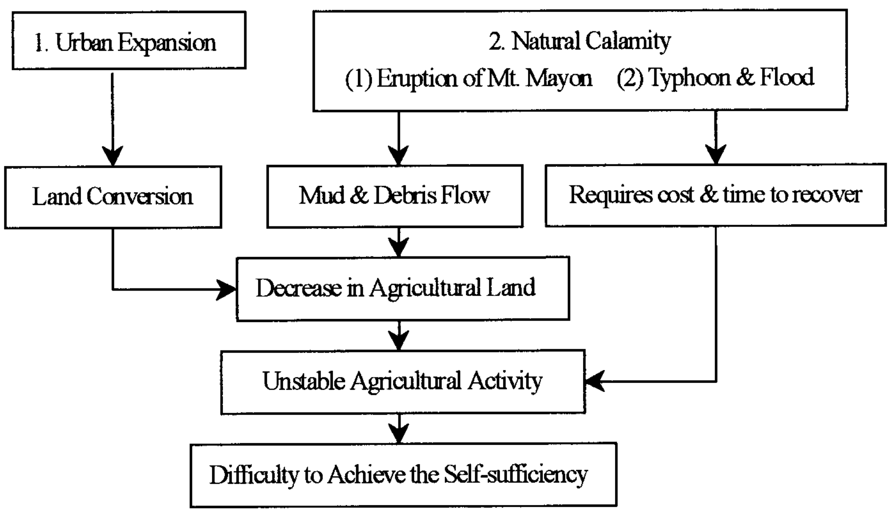
In this connection, it is proposed to provide a buffer zone between the proposed dike and the areas to be developed in order to keep people from living in the area adjacent area to the proposed sand pocket . The width of the zone should be 150m at minimum. Cropping tree should be planted to use the zone as productive land. If trees are planted with an interval of 10m, 16 rows of trees is accommodated. A tree with a trunk diameter of 30cm might have some effects to raise the coefficient of roughness. No scientific study report is available to assess the resistance of tree against mud and debris flow so far. However, there are certain effects to mitigate the energy of mud and debris flow. Another possibility is that the uprooted trees become a kind of screen to dehydrate mud and debris flow. Planning of buffer zone should take account of the fact that mud and debris mostly deposit at the slope with a gradient of less than 3°.

8.1.4 Study on Alternative Plans

(1) Basic Concept of Alternative Plans

1) Problems and Issues over Land Use in Yawa Protected Area

The Yawa Protected Area has two major problems and issues over the land: (a) urban expansion and (b) natural calamity. The following figure indicates the problem structure to explain that these problems and issues lead to a decrease of agricultural land and to the low standard of living.



Problem Structure over the Land in Yawa Project Area

a. Low Productivity – Low Self Sufficiency in Albay Province

The agriculture is a primary sector in the area economy. According to the Provincial Food Security Plan 1999-2002, Province of Albay has 158,311.63ha, accounting for 65.40% of agricultural land in the total area in 1996. However, the sufficiency level of the Province of Albay is 44.60% on average.

One of the factors to make the productivity increase difficult is the high cost of the agricultural inputs like fertilizers and pesticides. According to the "Provincial Food Security Plan (1999-2002)", Province of Albay, the appropriate amount of the fertilizers and pesticides is three to four times more than what is used now (refer to Agricultural Development Plan).

Self Sufficiency Level in Albay Province 1998

Commodity	Sufficiency Level (%)
Rice	43.65
White Corn	0.38
Root crop/Tuber	34.92
Vegetables	36.68
Fruit	32.44
Chicken Meat	11.00
Egg(Layers)	41.00
Beef	106.00
Carabeef	67.00
Pork	57.00
Fish	61.50

Source: "Provincial Food Security Plan 1999-2002", Province of Albay

b. Urban Expansion - Land Conversion

Regulations and Rules over the Land Conversion

"Revised Rule and Regulations on the Conversion of Agricultural Lands to Non-Agricultural Uses, 1999", the criteria of the land which can be subject to the land conversion is as follows:

- Not the irrigated area
- Not the Protected Area - NIPAS (described in Master Plan)
- Not classified as the Agricultural Land in the LGU's land use plan
  * 500m from the National Rd. can not be classified as Agricultural Land.

Present Situation

The Yawa Project Area is adjacent to the center of the Legazpi City. According to the aerial photograph, about 100ha of the palay area, has been changing into residential in last 20 years and classified as residential area on the land use map of Legazpi City in 1990. Now the area has changed to be a large sub-division residential area.

Irrigation System

According to NIA and "Provincial Food Security Plan (1999-2002)", Province of Albay, the province has a total potential irrigation area of 50,046ha in 1996. The existing system has a service area of 23,741ha, while its potential development area is 26,305ha.

In the Yawa Project Area, there are 12 irrigation schemes in operations: 11 private systems and 1 irrigation system assisted by other agency.

Irrigation System in Yawa Project Area, 1996

Irrigation System	Area (ha)
1. Private Irrigation System	
Alcala	119
Bagong Abre	41.5
Banadero	49
Budiao	35
Malobago	22
Matanag	17.30
Quilicao	65
Salvacion	22
Tagas	13.25
Mabinit	15
Matanag	44
Tamayoan	24.40
Subtotal	423.89
2. Other Agency Assisted System	
Pawa CIS*	200
Total	623.89

Note: * CIS =: Community Irrigation System
Source : NIA and CENRO

c. Natural Calamity – Eruption of Mayon Volcano, Typhoon and Floods

Environmental degradation due to soil erosion, flash floods, and mudflow by the eruption of Mayon Volcano is the major factor for reduction of agricultural production in the area. There are areas, especially the uplands, which are considered prone to erosion under intensive cultivation and floods. In the lowland, according to the aerial photographs over Yawa Project area in 1999 and 1982, about 17% of the agricultural area (mostly coconut and paddy) had been covered by mudflow by the eruptions of 1993 and 1984. No rehabilitation is has yet been done over the land covered by mud and sand, because of the financial problems of the LGUs concerned.

d. Land Rehabilitation

According to the interview surveys at DENR, relevant municipalities and based on the aerial photographs (1982 & 1999), the land once covered by mudflow is classified as idle and vacant land. However, on these areas, some farmers started growing vegetables. There is no financial or physical assistance to the disaster-stricken land.

2) Concept of Land Use Plan for the Yawa River System Sabo Project

To solve or improve these problems and issues, two major concepts are proposed: (a) improvement of the area productivity and (b) prevention of agricultural land decrease. For each concept, the plan stated below is proposed.

a. Improvement of the Productivity

- Agricultural and Livelihood Development Plan (refer to the Agricultural and Livelihood Development Plans for more detailed information)

b. Prevention of Agricultural Land Decrease

- Sabo Project (refer to the Sabo Planning) with Resettlement Plan

For these plans, three concepts (options) of the land use had been proposed in the Master Plan. The final plan was selected by the economic evaluation of these options.

3) Land Use Options

a. Options

Three options were proposed as the possible plan. These options can be assessed by economic evaluation to choose as the final plan.

Option I: Without Sabo project + Resettlement of all residents.

This is the option without the Sabo Facility.

In this option, all residents in the hazard area of the mudflow must be resettled and the hazard area will not be utilized for any purpose. The number of residents who should be resettled is the largest among the three options and a new resettlement site must be provided.

Option II: Sabo Project + Intensive Agricultural Plan + Resettlement Plan;

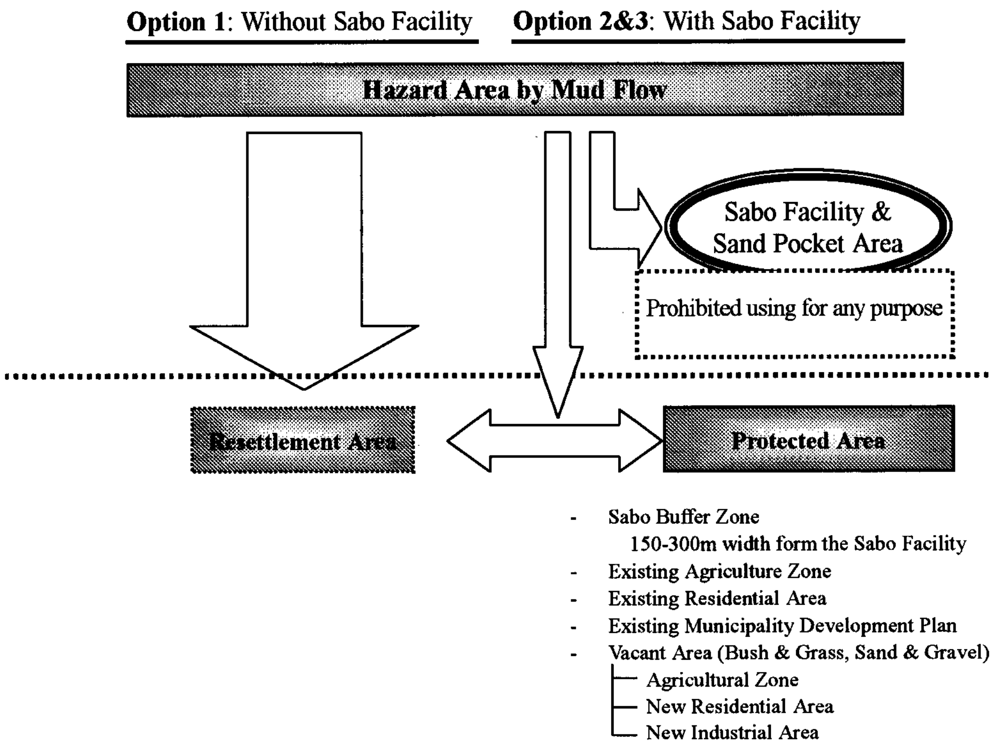
Enhancement of the productivity with maintaining present land use.

In the protected area by the Sabo project the agricultural productivity will be enhanced but the present land use should be maintained. The residents under the Sabo facility and the sedimentation area must be resettled in the resettlement area.

Option III: Sabo Project + Agricultural Plan + Agro-industrial Plan + Resettlement Plan:

Enhancement of the productivity with the intensification of land use.

In this option, the land use of the Protected Area will be enhanced by agro-industrial usage as well as agricultural. The residents under the Sabo facility and the sedimentation area must be resettled in the resettlement area.



Structure of Land Use Classification

8.1.5 Preliminary Structural Design

(1) The Cemented Sand and Gravel (CSG) method for the Sabo works

Based on the Study Team Proposal, Steering Committee agreed to apply the CSG for the material of Sabo works recognizing the following:

- The CSG method claims less investment in general as compared with regular concrete and soil embankment for the design load.
- The CSG method does not require special heavy equipment and plant.
- The CSG method avails sand and gravel to be borrowed at the site to the maximum extent.
- The CSG method could be applied to the existing structure through consolidation of the filled material.
- The site is suitable for roller compaction.

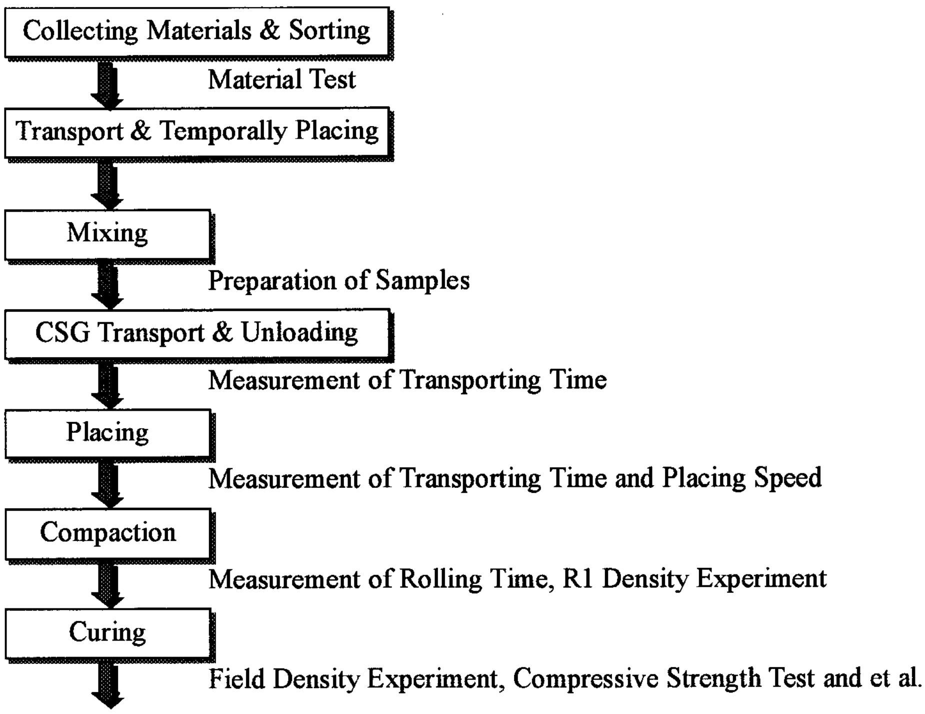
(2) The outline of the CSG method

1) Material : Cement, sand and gravel
No specification of aggregate size
Volume of cement 60~160Kg/m^3 with water content around 10%

The specifications vary in wide range and yet the constructed structures proved the sufficient performances. In the Study Area the specific gravity is as large as 2.65 and the fine aggregate ratio is in between 30 and 45. The specification of sand and gravel in the Study Area is listed below:

2) Construction Procedure

Mixing	:	Batcher plant or backhoe
Transportation	:	Dump truck
Placing	:	Bulldozer every 25cm depth
Compaction	:	Vibrating roller every 50cm depth layer
Treatment of edge	:	Bucket of backhoe 3~4 times
Expansion joint	:	Cleaning and moisturing are necessary
Curing	:	Avoid drying up by sheet covering



Construction Procedure of the CSG Method

(3) Sand pocketing works

1) Component of Structure

Training dike and sabo dam with a reservoir constitute a sand pocketing facility. The training dike control mud and debris flow do not go beyond downstream reach and flow direction to the center of the reservoir. The sabo dam retain mud and debris in the upstream reach therefrom. A spillway with slit is provided to sabo dam so that water can pass through to flow down. The reservoir stores the mud and debris which are guided by the training wall and the sabo dam should have sufficient strength against the attack of mud and debris flow.

2) Sabo Dam

A comparative study on the unit cost (pesos/m^3) showed that a dam constructed by the CSG method is economically advantageous over a concrete dam. The following table presents the results of the comparative study for the case of the Anoling dam.

Comparative Study on the Construction Cost

Item	Concrete		Cemented Sand and Gravel	
	Effective Height: 4.0m, Height: 7.0m Length of Apron: 22.5m Upstream Slope 1:0.4 Downstream Slope 1:0.2		Effective Height: 4.0m, Height: 6.0m Cutoff: 1.0m, Length of Apron: 23.5m Upstream Slope 1:1.2 Downstream Slope 1:2.0	
Volume (m^3/m)	Body	35.7	Concrete facing	27.8
	Apron	35.1	Apron	14.3
	Vertical wall	7.5	Vertical wall	5.4
			CSG	66.8
Cost per m	Body	89,250	Concrete facing	69,500
	Apron	87,750	Apron	35,750
	Vertical wall	18,750	Vertical wall	13,500
			CSG	26,720
	Cost (peso/m)	**198,250**	Cost (peso)	**145,984**
	△		O	
Simplicity of Construction	△		O	
Local Supplement	△		O	
Total Decision	△		O	
Unit Price (peso/m^3)	Concrete	2,500	CSG	400

Notes: O Good, △ Average, × Failure

Proposed Dam Features

Dam Name	Dam Height (m)	Dam Length (m)	Crown Width (m)	Waterway Width (m)
Pawa Sabo Dam	6.0	450.0	5.0	55.0
Anoling L Sabo dam	6.0	375.0	5.0	50.0
Anoling R Sabo dam	6.0	300.0	5.0	70.0

<u>Design Discharge</u>

The fundamental condition to design dam and the relate structure is design discharge for mud and debris flow.

The following procedures were applied to designate the design discharges. The adopted values of parameter reflect the experiences in the similar cases in Japan.

The results of computation to estimate necessary height above spillway crest are summarized below:

Elevation of Flow Surfaces above Spillway Crest

		Discharge	Width of Waterway	Slope of Waterway	Overflow Depth	Free Board	Height of Waterway
Pawa-Burabod	Sabo Dam	321	55.0	1.2	2.19	0.80	3.00
Budiao	Sabo Dam	284	50.0	1.2	2.15	0.80	3.00
Anoling	Sabo Dam	360	70.0	1.2	2.02	0.80	3.00

The Master Plan Study adopted an effective height of 4m for all the proposed sabo dams of the Yawa river sabo plan as the optimum height in connection to the available reservoir arca as the result of the alternative study for 3, 4, and 5m. Since spill out of water depths of three dams are 3.0m including freeboard of 0.80m, the necessary spillway heights are 9m as follows:

Effective height	4.0 m
Foundation depth	2.0 m
Spillout water depth	3.0 m
Total	9.0 m

The designed slope gradient of upstream is 1:1.2 considering the convenience of the compaction works and finishing concrete works without using frame works. Meanwhile, an abrasion counter measure is necessary to protect the structure on the downstream surface of the spillway. For this purpose, a boulder concrete is proposed. In order to secure the apron in the downstream, the gradient of surface of 1:2.0 is proposed referring the experiences in Japan for the construction of consolidation dam.

The proposed spillways have slits to supply sand in normal flow. The provided slits will contribute to avoid degrading of river channel in the downstream reach from the dam. The slits protect silting in the channel in the upstream reach from the dam as well during low flow period and maintain the flow courses. The slits are designed as to discharge 2-year flood. The provided slits are as follows:

Height and Width of the Dams

Name of Dam	Height (m)	Width (m)	No.	Total Width (m)
Pawa-Burabod	4.0	5.0	2	10.0
Budiao	4.0	4.0	2	8.0
Anolign	4.0	4.0	3	12.0

Dam Body

The following are the conditions to be regarded in the preliminary design dam:

- The CSG method without frame works is adopted
- Vibrating roller is used for compaction

In this respect the following dimensions were adopted:

- Width of dam crest : Requisite width is 5m for compaction works using vibrating roller
- Gradient of Slope : Gradient of 1:1.2 is convenient for compaction works and finishing concrete works without frame works.

The average river channel slopes of the Pawa-Burabod river and the Anoling river are 0.035 and 0.055 for about 2000m upstream from the proposed dam sites. The free boards for mud and debris flow are assumed to be 1.0m for the dam on the Pawa-Burabod river and 2.0m for ones on the Anoling river taking account of silting.

The stability analysis of dam applied the following design load:

List of Design Loads

	Ordinary Times	Debris Flow	Flood
Dam Height is less than 15m		Hydrostatic Pressure, Pressure of Sedimentation Pressure of Debris flow	Hydrostatic Pressure

Apron

The comparative study on the empirical formula and the Brigh's formula gave the necessary length of apron as follows.

Comparative Study on the Length of Apron

	Brigh's Formula				Empirical Formula					Length of front apron
	Q $m^3/s/m$	D (m)	W (m)	L (m)	H (m)	H3 (m)	H1 (m)	t (m)	L (m)	
Pawa-Burrabod	5.84	5.0	8.0	21.7	6.5	2.20	5.0	1.5	21.60	22.0
Budiao	5.68	5.5	8.4	22.5	7.0	2.20	5.5	1.5	23.10	23.5
Anoling	5.51	5.5	8.4	22.1	7.0	2.20	5.5	1.5	23.10	23.5

Cutoff

The apron is placed horizontally and the downstream edge thereof is fitted at the ground surface of the river channel. The height of cutoff is obtained as the difference in the elevations between the original ground at the upper most edge of the apron. The figure shown above present the height of apron.

The profiles of the proposed dam are shown in Figure 8.1.6 and 8.1.7 and typical sections in Figure 8.1.8 and 8.1.9.

Type of Dike

Training dike encloses the proposed sand pocket so that mud and debris flow flushed from the gully situated at the upstream reach from the fan is trapped in the sand pocket. There are 3 types of training dike which are adopted in this plan. They are,

- Type A : whole body is constructed by the CSG method
- Type B : combined dike of CSG (river side) and cobble stone embankment (land side)
- Type C : whole body is constructed by cobble stone embankment

Type A is applied to the portion where the slope of the fan is more than 1/30 and there is a slight possibility of overtopping. Type B is applied to the portion where the slope of the fan is more than 1/30 but overtopping is unconceivable. Type C is applied to the portion where the slope of the fan is less than 1/30.

Structural Details

The width of the crest of 4.0m is adopted for the convenience of compaction works by the bucket of backhoe. In case of cobble stone embankment, additional 1.0m is provided for each end. The crest of dike will provide a road for the local residents.

The deposition depth of 2.0m was assumed to define the height of dike. The assumed water depth is 2.2m and the adopted freeboard is 0.8m and the standard height of 5.0m was adopted for the training dike.

The recorded depth of erosion is in between 1.0m and 2.0m in the fan area. Accordingly the embedded depth of 2.0m was adopted for a dike.

The slope gradient of 1:1.2 is adopted for the CSG method so that compaction and finishing works could be done without frame works. Since the embankment material is cobble stone, the slope gradient of 1:20 is adopted for the embanked dike.

Riprap with boulder is to be provided to control erosion at the foot of the slope in riverside. Land side slope should be protected by means of such as sod facing for the embanked dike.

3) Channeling works

Channeling works are to be provided to maintain the river channel in the downstream reach from the sabo dam. Channeling works comprises the provision of new dike and the provision of revetment work to the existing riverbanks. New dike is to be provided to the river with a bed slope of 1/30 or less and stable river channel is established. Following methods are to be applied:

New Dike : The Budiao and the Anoling river upstream reaches from the confluence.

Revetment works : The Pawa-Burabod river and the Anoling river downstream reach from the confluence of the Budiao and Anoling rivers.

The crest width of 3.0m is adopted for new dike. The dike should be embedded for 2.0m. The adopted gradient of the slope is 1:1.2.

The wet masonry works is to be applied to the revetment works. The gradient slope is according to the existing channel but 1:0.5 is adopted as the standard. The depth of the masonry is 0.5m or more and concrete foundation with a depth of 1.0m is provided.

The heights of this revetment works are summarized in the following table:

The Height of Revetment Works

River Name	Year	Discharge (m^3/s)		River Width (m)	Bed Slope 1/n	Sidewall Slope 1:m	Rough -ness n	Water Depth h1(m)	Sectional Area $A(m^2)$	Wetted Perimeter P(m)	Hydraulic Raidus R(m)	Velocity V1(m/s)
		Flood	Sediment									
Pawa-Burabod	20	216.0	240	30.0	1/40.0	1:0.5	0.040	1.555	47.849	33.476	1.429	5.016
Anoling L	20	209.0	230	30.0	1/30.0	1:1.2	0.040	1.365	43.186	34.264	1.260	5.326
Anoling R	20	240.0	260	30.0	1/30.0	1:1.2	0.040	1.469	46.659	24.589	1.349	5.572
Anoling D	20	427.0	470	40.0	1/40.0	1:0.5	0.040	1.956	80.161	44.374	1.806	5.863

River Name	Year	Discharge (m^3/s)		River Width (m)	Bed Slope 1/n	Sidewall Slope 1:m	Water Depth h^2(m)		Allowable Height (m)	Effective Height (m)	Height (m)
		Flood	Sediment				Calculated	Accepted			
Pawa-Burabod	20	216.0	240	30.0	1/40.0	1:0.5	1.555	1.6	0.8	2.4	4.4
Anoling L	20	209.0	230	30.0	1/30.0	1:1.2	1.365	1.4	0.8	2.2	4.2
Anoling R	20	240.0	260	30.0	1/30.0	1:1.2	1.469	1.5	0.8	2.3	4.3
Anoling D	20	427.0	470	40.0	1/40.0	1:0.5	1.956	2.0	0.8	2.8	4.8

8.1.6 Maintenance and Monitoring Works

(1) Present situation of maintenance works

DPWH region V has constructed various infrastructures and is mandated for the maintenance.

The total number of employee is 2290 including casual and temporary. About 35% belong to the regional office and remaining to the district engineers office. The number of staff that belong to the maintenance division is 122 including casual. The number of permanent staff of RES is 133. One of the substantial resources of RES is heavy equipment for construction works as follows:

- Bulldozer
- Backhoe
- Shovel
- Pump
- Generator
- Others

The budget allocated to maintenance works in 1998 are as follows:

Budget Allocation in 1998

(unit: 1000 pesos)

Item	amount
River structure	43,144
Road and bridge	245,066
Urban infrastructure	656
Total	288,866

* Source : DPWH 1998

The largest scale of maintenance works was conducted in 1990. The dredged volume was 84,000 cubic meter and the allocated budget was 3,291,000 pesos.

The monitoring works of infrastructure are carried out by planning and design division and relevant district engineers office. Once any defect is detected, the division formulate a rehabilitation plan. The plan is released to the maintenance division after the approval of the regional office.

There are cases that local people detect defects. The request to repair the defects is to be raised to the provincial governor. The provincial governor request district engineer to take action for repair.

(2) OMR works related to the proposed Sabo works

1) Maintenance of sand pocket

The ejecta from Mayon Volcano move downward and deposit on the fan. The proposed sand pocket in the fan will trap these ejecta in the pocket in a controlled manner. Sand pocket confines the area for mud and debris flow to the deposit. If the provided sand pocket area cannot accommodate the debris for the life period of 30 years, removal of deposit by means of dredging is necessary to maintain space to secure the function during the life period. The limitation of area, on the other hand, results in the higher piling up of debris. This will entail the followings:

- The rivet of fan climb up the mountain slope to upstream reach and it will grant wider option of flow direction to the mud and debris flow. The mud and debris flow tend to flow to arbitrary directions other than to concentrate to the channel.
- The slope of the river channel become gentle in the fan area and it will deprive of the sufficient traction force of the flow to supply sand and gravel to maintain river channel in the down stream reach from the fan.

The DPWH should conduct maintenance works to avoid such situation through dredging works.

2) Dredging works as maintenance works

There are two types of dredging works in view of the objectives discussed in the previous paragraph. The first one is to secure available storage of the proposed sand pocket. The other is to maintain a channel within the proposed sand pocket.

The balance of the debris inflow and storage capacity is summarized in the following table:

Balance of Sediment

Sand Pocket	A Sand pocket Capacity (m^3)	B Sediment Flow Deposit in 30 year (m^3)	(B-A) Total Excess Material Volume (m^3)	(B-A)/30Annual Dredged Material (m^3)
Pawa-Burabod	14,960,000	6,257,400	-8,702,600	-
Anoling Budiao	13,600,000	17,999,100	4,399,100	146,637
Total	28,560,000	24,256,500		

According to the balance, the estimated necessary dredging volume is 146,637m^3/y for the Anoling-Budiao sand pocket and none for the Pawa-Burabod sand pocket.

The remove of deposited materials in the original river channel is the second type of dredging works. The following figure designates the length of deposit of each river:

Length of Deposit

Sand pocket	Deposit At dam (m)	Original gradient	After deposit gradient
Pawa-Burabod	4	1/20	1/60
Anoling-Budiao	4	1/18	1/54

The obtained lengths are 120m for both sand pockets. Applying the channel width of 55m for the Pawa-Burabod and 120m for the Anoling-Budiao channels, the required dredging volumes are estimated as follows:

Pawa-Burabod : 13,200 m^3/y
Anoling-Budiao : 28,800 m^3/y

However, the Type 1 dredging volume of Anoling-Budiao of 146,600m^3/y cover the type 2 dredging and consequent dredging volumes are given below:

Pawa-Burabod : 13,200 m^3/y
Anoling-Budiao : 146,600 m^3/y

The dredged materials are suitable for aggregate of concrete and the river bed materials have been exploited by private enterprises. In this connection the dredged material should be stockpiled at appropriate places as material for aggregate industry. The dredged materials are stockpiled with a height of 5m and a slope of 1:20. The areas required to deposit materials of one year dredging, are 0.5 ha for the Pawa-Burabod and 3.5 ha for Anoling. The distances between the dredging sites and spoil bank yards for the proposed Pawa-Burabod sand pocket and Anoling sand pockets are 1,800m and 800m, respectively. A typical screen dam as free maintenance facility in Japan is shown in Figure 8.1.10.

3) Other maintenance and monitoring works

One of the most frequent damages to a structure is scouring of foundations. The traction force of mud and debris flow is overwhelming and loose soil are to be scoured easily. Back filling of scoured foundation and riprap works should be provided as maintenance works.

With this respect, monitoring and inspection will be one of the most significant tasks of DPWH region V. Monitoring and inspection are to be conducted in the following items:

- Surface of dike and revetment works of channel works
- Foundation of dike and revetment work of channel works
- Fluctuation of riverbed and riprap at the cutoff wall of apron
- Deposition on apron
- Abrasion on spillway surface
- Clogging of slit
- Deposition at immediately upstream from dam
- Surfaces of training dike of both rivers
- Riprap of spur dike
- Silting along the channel in the sand pocket
- Deposition in the sand pocket
- Channel upstream from the rivet of fan

4) Inhabitant-level Measures against Disasters

Since the measures by the inhabitants against disasters such as debris flow are limited, it would be important to establish the policy in the direction that the damage by debris flow, if happened, is unavoidable and therefore, minimum property should be secured.

Moreover, in order to prevent increasing disaster potential and inundation district by the debris flow, the policy should be in accordance with the natural flow of the disaster as much as possible. To fulfill this goal, it would be necessary to enlighten the inhabitants about soil disaster and soil transportation.

On the other hand, it would be necessary to make use of the existing structures as much as possible and to maintain their functions. The concrete policies are as follows:

- To construct embankment around the residential district in order to prevent the soil and water from entering,
- To protect the damaged parts of the existing training dike with soil or boulder,
- To implement planning works on the land between the training dike and the residential district in order to reduce the energy of the debris flow, and
- To construct bamboo hedges and/or sandbags as simple training dikes in order to distract the debris flow from important properties.
- Finally, since the measures against the damage at the inhabitant-level tend to be a smaller scale, the policies against disasters such as debris flow would be examined from various viewpoints such as gravel extraction.

8.1.7 Land Development Plan

(1) Basic Plan of Land Use

1) Zoning I : Sabo Facility Area (Table 8.1.1 and Figure 8.1.11 and 8.1.12)

In the Yawa Protected Area two Sabo Facilities are proposed: Anoling and Pawa-Burabod. In addition to the construction sites of sabo structures, their circumferential areas, which are 7m from the respective structures and sand pockets are subject to the land acquisition.

a. Sabo Structure

The total construction area amounts to 27.28ha: 11.59ha in Anoling and 15.69ha in Pawa-Burabod. The total circumferential area is 6.81ha: 2.92ha in Anoling and 3.89ha in Pawa-Burabod.

b. Sand Pocket

The total sand pocket area totals to 553.13ha. This area will be categorized as two areas: (a) sand sedimentation area and (b) its upper portion.

2) Zoning II: Protected Area

a. Buffer Zone

The sabo-buffer zone is proposed along the sabo facility. This area is 150m from the facility. The purpose of this sabo buffer zone is to prohibit the new dwelling in future for the further safety. For this buffer zone, agro-forestry plan is proposed under the Agricultural Development Plan.

b. Agricultural Area

Agricultural Development Plan is proposed for the Project Area and its surroundings. The purpose is to improve the productivity and to encourage the water retention in its upland as well.

Considering the productivity and cost for the agricultural land development, the area with less than 4% of slope shall be the rice paddy, and more than 4% shall be the intercropping of coconut, banana or abaca. In the area under 4% slope, the paddy field can be developed without land formation for the terrace paddy. These criteria will support the concept of NPAAD and food security.

c. Industrial Area

The small agri-business has been developed in places as a home or cottage industry. In parallel with the agri-business development in the resettlement sites the small and medium-scale industrial development for the first processed goods will be proposed in the protected area. Also Mayon Volcano has produced sand and gravel of a good quality. In this Project Area, two industries are proposed: (a) agro-industry, and (b) sand and gravel industry.

Agro-Industry

For this industry, several products from coco tree and abaca and others are proposed. For the convenience of their processing and marketing, the area for the industry is proposed between barangays of Matanag and Mabinit (about 3ha).

Sand & Gravel

The area for sand and gravel exploitation is proposed at the west side of the dike of Mabinit.

Criteria:

- Lot: 3ha at least per a factory & research center
- Road traffic: 6m width road for traffic circulation and a parking lot, which is 10% of the total area.
- Buffer zone & utility zone: five times of the facility area, traffic circulation and buffer zone & utility area.

d. Residential Area

New settlement area is proposed in Matnog, around the junction of the barangay roads between Salvacion and Sto. Domingo and Mabinit and Daraga. This area is to be the nucleus of this protected area as a junction area of residential, agro-industrial and research and commercial.

Criteria:

- Lot: 200 m^2 at least per a lot per a household
- Road traffic: 6m wide road for the community circulation
- Residential buffer zone & utility zone: 10% of the total residential and circulation area.
- Park amenity zone

e. Service and Commercial

In view of the new development of industrial and residential areas, the service and commercial areas are also proposed. These areas will contribute to activate the area economy and assume the main function to connect between areas of residential, industrial, and park & amenity.

f. Road Traffic

The new main barangay road (about 2 km) is proposed from the junction in Matnog to the upper area development center. Also, the construction of the other secondary road is recommended to connect the center and the pilot farm, nursery and sabo dikes to be used as the evacuation road.

<u>Land Area by Category</u>

(2) Land Acquisition

The total area to be expropriated amount to 587.21 ha (see the following table and Figure 8.1.11).

The area to be expropriated for the Sabo facility is 34.09 ha. The site needed for the facility is 27.28 ha and the circumferential area, which is 7m from the facility, is 6.81 ha.

The total area to be expropriated for the sand sedimentation is 553.13 ha: 318.13 ha in Anoling area and 235.00 ha in Pawa-Burabod area.

Land Acquisition Area for Sabo Facility

Type of Dike	Length (m)	Width (m)	Total Area to be Expropriated for Facility (ha)	Circum-ferential Area (ha)	Total Area to be Expropriated (ha)
Anoling					
Sabo Dam	650.00	37.00	2.41	0.46	2.86
Spur Dike (Type A)	1,725.00	24.00	4.14	1.21	5.35
Spur Dike (Type B)	1,800.00	28.00	5.04	1.26	6.30
Subtotal	4,175.00	89.00	11.59	2.92	14.51
Sand Sedimentation Area (ha)					318.13
Total					332.64
Pawa-Burabod					
Sabo Dam	450.00	35.00	1.58	0.32	1.89
Spur Dike (Type A)	600.00	24.00	1.44	0.42	1.86
Spur Dike (Type B-1)	3,375.00	28.00	9.45	2.36	11.81
Spur Dike (Type B-2)	750.00	28.00	2.10	0.53	2.63
Spur Dike (Type C)	375.00	30.00	1.13	0.26	1.39
Subtotal Area	5,550.00	145.00	15.69	3.89	19.58
Sand Sedimentation Area (ha)					235.00
Total					254.58
Grand Total (ha)	9,725.00	234.00	27.28	6.81	587.21
Total Sand Pocket Area (ha)					553.13

Note: * The area does not include the sand sedimentation area side.

(3) Compensation

Criteria for Compensation

a. Landowner

The compensation for landowners will be done with the official purchase price.

b. Tenant: Disturbance Compensation

The compensation for tenants will be equivalent to the amount of five times the average gross harvest in the last five years.

(4) Criteria for Compensating the Resettlers

As for resettlers, the following countermeasures will be considered.

a. Both the Residence and Livelihood (Farmland) are in the Protected Area

In this case, there is no major concern about the residents and livelihood. Therefore, there is no need to consider about the resettlement.

b. Residence is in the Protected Area and Livelihood in the Construction Area

In this case, the residence will be protected from the mudflow, but their livelihood will be damaged. To solve this, two options will be conceived.

Resettlement

As it is not the option in this Study to leave or resettle the residents without livelihood, it is recommended to resettle all dwellers who lost the farmlands or livelihood due to the construction of sabo facilities.

New livelihood in a community

It is proposed to provide the new livelihood opportunities to the resettlers who lost the farmlands or livelihood due to the construction of sabo facilities.

c. Livelihood of the resettlers is in the protected area, but their residences are located at the construction sites

In this case, the livelihood (farmland) of the resettlers will be protected from the mudflow, but their residences will be damaged. In this case, there are the following two options.

Resettlement

In this case, the matter will be solved just by moving the resident to another part of their own farmland.

New housing zone in a community

It is proposed to create the new housing zone in the area for the resettlers who lost the housing because of the construction of sabo facility.

d. Both Residence and Livelihood are situated in the Construction Area

In this case, there is no option to take other than the resettlement with a new livelihood.

8.2 Legazpi City Urban Drainage Project

8.2.1 Legazpi City

Legazpi City is situated at approximately 123°45' Longitude East and 13°19' Latitude North, approximately 554km (road distance) southeast of Manila. Legazpi City has an area of 20,420 ha (204 km^2). The area spans 29km from north to south and 19.5km east to west. The present land use of Legazpi City is divided into urban area and rural area as shown below.

Land Use of Legazpi City

Total Area of Legazpi City	20,420 ha	100%
Urban Area	1,382 ha	6.8%
Rural Area	19,038 ha	93.2%

Note : Urban Area is defined as an area of Legazpi Port and Albay Districts, and Rural Area is defined as an area of Rural North and South Districts of four Districts in Legazpi City.

The urban area consists of Albay District and Legazpi Port District. The Albay District is an area of provincial and city government administrative centers and other institutional facilities. The Legazpi Port District is a hub of business and trade and center of financial and commercial activities in the region.

8.2.2 Present Condition and Problems

(1) Flood Damage

1) Hazard Area

According to the Engineer's Office of Legazpi City, flooded areas shown in Figure 8.2.1 are roughly defined as follows.

a. Areas regularly flooded : Approx. 70 ha
Floods occur 3-5 times per year by 1-day storm rainfall (Approx. 60 mm/day estimated by JICA Study)

b. Areas occasionally flooded : Approx. 180 ha
Flood occurs once in year by 3-day storm rainfall (Approx. 200 mm/3-day estimated by JICA Study)

Rainfall amounts for these defined floods are not mentioned by Engineer's Office. The flood prone areas defined by Engineer's Office of Legazpi City are briefed below.

a. Low-lying area along the Macabalo River
b. Low-lying area along the TibuRiver
c. Low-lying area along the Panal River
d. City center in the Legazpi Port District

Legazpi Port District is situated in the low-lying area and some areas in the central commercial area of Port District are at below the sea water level. The central area of Albay District is not affected by flood inundation.

2) Hazard Map

The flood hazard map of Legazpi City is preliminarily prepared with the following assumptions. The recorded flood inundation area by Typhoon "Daling" in 1981 as shown in Figure 8.2.2 is measured to be one caused by 5 year probable rainfall. The Study Team also observed that almost the same area was inundated by Typhoon "Loleng" in 1998. The inundation area is assumed to be one caused by 2-year probable rainfall.

The comparison between two flood inundation events is tabulated below.

Comparison of Flood Events in 1981 and 1998 in Legazpi

Flood Event	Flood Inundation Area (ha)	Storm Rainfall Amount at Legazpi (mm)	Duration and Depth of Inundation
Typhoon "Daling" in 1981	450	220 mm (1 day rainfall) Approx. 5 year probable rainfall	One to two days 50 cm (maximum)
Typhoon "Loleng" in 1998	450 (almost the same as above area)	266 mm (3 day rainfall) Approx. 2 year probable rainfall	One day 30 cm (maximum)

Figure 8.2.2 indicates that the flood inundation areas caused by Typhoon "Daling" are confined within the low-lying areas east of Washington Drive in Albay District which is laid between the Legazpi Airport and Legazpi City Hall.

On the other hand, 10-year probable 1-day rainfall at Legazpi is estimated to be around 300 mm which is as 1.2 times as that of 5-year probable 1-day rainfall. Therefore, it is preliminarily assumed for the purpose of urban drainage plan that flood hazard area caused by 10-year probable 1-day rainfall in Legazpi City will also be confined within the low-lying areas east of Washington Drive in Albay District. Figure 8.2.3 shows the hazard map of 10-year probable flood in Legazpi City.

3) Historical Flood Damages

According to the Planning Office of Legazpi City, no official data of historical flood damages was compiled in Legazpi City.

JICA Study Team investigated the historical flood damages of Legazpi City in collaboration with the Planning Office of Legazpi City. The results of this survey are used for economic evaluation of the proposed urban drainage project.

(2) Physical Settings in the Project Area

Two rivers serve as main storm drainage outlets, namely, Macabalo River for storm water coming from the Albay District and Tibu River for the Legazpi Port District. Macabalo River collects storm water from its upstream branch rivers such as Ruran, Sagumayon and Panal Rivers in the Albay District.

The catchment area of Macabalo and Tibu Rivers is briefed below:

Catchment Area of Macabalo and Tibu Rivers

River	Subbasin	Catchment Area (km^2)
Macabalo	Ruran	3.5
	Sagumayon	3.6
	Panal	3.0
	Macabalo	2.8
	Total	12.9
Tibu	Tibu	2.4

Note: Tentatively measured by Legazpi City Map of NAMRIA (Scale: 1/10,000, Contour Line: 10m). This map is only available for the Study.

The river length and river slope of Macabalo and Tibu rivers are summarized below:

River Length and River Slope of Macabalo and Tibu Rivers

River	Subbasin	River Length (m)	River Slope
Macabalo	Ruran	4,500	0.0037
	Sagumayon	5,250	0.0032
	Panal	3,312	0.0051
	Macabalo	2,000	0.0015
Tibu	Tibu	1,700	0.0018

Note: Tentatively measured by Legazpi City Map of NAMRIA (Scale: 1:10,000, Contour Line: 10m). This map is only available for the Study.

The drainage capacity of the existing river channels is preliminarily estimated by site surveys as follows. Present river system diagram of Macabalo and Tibu rivers with flow capacity of each section is shown in Figure 8.2.4. Back data for calculation of flow capacity of existing river channel in Macabalo and Tibu rivers are tabulated in Data Book.

Drainage Capacity of Macabalo River

River	Location of Section	Drainage Capacity (m^3/s)
Ruran	65 m upstream of National Road	3.7
Sagumayon	Upstream of confluence with Ruran River	5.7
Sagumayon	Downstream of confluence with Ruran River	18.9
Panal	100 m upstream of confluence to Macabalo River	19.6
Macabalo	Downstream of confluence with Panal River	17.0
Macabalo	1,600 m upstream of river mouth	3.8
Macabalo	1,000 m upstream of river mouth	149.6

Drainage Capacity of Tibu River

Distance from River Mouth (m)	Drainage Capacity (m^3/s)
125	263.0
203	33.2
440	20.2
510	20.2
696	9.5
786	9.5
834	30.0

The present conditions of the existing river channels in the Macabalo and Tibu rivers are summarized below.

Present Condition of Existing River Channels

River	Dike Condition	Dike Height	Channel Width
Macabalo and its tributaries	Heavily damaged. Needs to be newly reconstructed for all sections.	Suitable for 10-year flood peak only for section (1000 m from river mouth). Other sections are to be raised.	Suitable for 10-year flood peak only for section (1000 m from river mouth). Other sections are to be widened.
Tibu	Heavily damaged. Needs to be newly reconstructed for all sections.	Suitable for 10-year flood peak, except for section (696 to 786 m from river mouth).	Suitable for 10-year flood peak for all sections (0 to 834 m from river mouth.

8.2.3 Alternative Study

(1) Conceivable Alternatives

1) Basic Concept

Basic concepts for urban drainage plan in Legazpi City are:

a. to mitigate flood damage in the flood prone areas,
b. to upgrade the function of river as an estero in urban district,
c. to take into consideration social and environmental aspects such as land use, land acquisition, water quality and garbage disposal, etc.,
d. to protect the low-lying areas from the intrusion of tidal flood,
e. to facilitate the operation and maintenance of drainage system, and
f. to propose technically sound and economically viable urban drainage plan.

2) Conceivable Alternative Solutions

Conceivable alternative solutions for Legazpi Urban Drainage are composed of the structural measures such as river improvement, pump station and retention pond to mitigate flooding and inundation in Legazpi City.

a. River improvement of main river channels (Macabalo and Tibu Rivers) to enlarge river flow capacity suitable for 10-year probable flood
b. Installation of pumping station to compulsorily drain interior flood inundation
c. Installation of floodgate to protect tidal flood into the rivers
d. Installation of retention pond to regulate flood peak discharge

3) Alternatives

The alternative is selected as the combination of all components such as river improvement, pump station, and retention pond for each river. All three components are indispensable for the purpose of flood and inundation mitigation in each river basin.

(2) Case Study on Alternative

1) Definition of Alternative

The Alternative is composed of river improvement works for the Macabalo and Tibu rivers and an integration of a pump station and a retention pond to regulate flood water, also operated with a floodgate at a river mouth. Installation of a retention pond will reduce the pumping capacity of a pump station if the required area for a retention pond is available in those rivers.

2) Preliminary Facility Plan and Design for Alternatives

The alignment and hydraulic design of the proposed river improvement for Alternative Plan for the Macabalo and Tibu rives are briefly described below.

a. Alignment

The alignment of the proposed dike for Alternative in the Macabalo and Tibu rivers is shown in Figures 8.2.5 and 8.2.6.

The length of the dike for each river is summarized below.

Length of Dike for Macabalo River and Tibu River and Its Tributaries

River Name	Length of Dike (m)	Location
Macabalo	1,700	From the river mouth
Ruran	95	From the confluence to the Sagumayon
Sagumayon	50	From the confluence with the Ruran
Sagumayon after Ruran	70	From the confluence with the Panal to the confluence with the Ruran
Panal	100	From the confluence to the Macabalo
Tibu	834	From the river mouth

b. Hydraulic Design

The proposed river section is a single trapezoid for the Macabalo and Tibu rivers so as to flash out debris and garbage being stuck in the rivers. The typical cross section of the proposed dike is shown in Figure 8.2.7. The riverside slope is set at 1v:1.2h and protected by grouted riprap.

The common hydraulic design of the dike for each river is summarized below.

Hydraulic Design Standard for Urban Drainage Plan

Free Board	1.0 m
Channel gradient	0.001
Roughness coefficient	0.030

Design discharge, design depth and channel width for each river are summarized below. Back data for determination of design depth and channel width are tabulated in Supporting Report (2), Chapter XIV.

List of Hydraulic Design Parameters

River Name	River Length to be Improved (m)	Design Discharge (m^3/s)	Design Water Depth (m)	Design River Width (m)	River Width to be Widen (m)
Macabalo	1,700	105	2.00-2.50	26.0-32.0	0.0-28.0
Ruran	95	34	2.00	10.5	6.5-7.0
Sagumayon	50	35	2.00	11.0	5.0
Sagumayon after Ruran	70	70	2.50	15.0	10.0
Panal	100	39	2.00	12.0	2.0
Tibu	834	17	1.10-4.00	4.8-39.0	-

Note : Design peak discharge is 10-year probable flood, which occurs at a time of concentration.

The alignment and hydraulic design of the proposed pump drainage for the Macabalo and Tibu rives are briefly described below.

a. Alignment

The pump drainage is composed of a pump station, retention pond and floodgates at the river mouth of each river. The pump station is installed in the existing river channel without an inlet to the pump station. The floodgate is installed at the other side of the river channel separated from the pump station with an island revetment.

b. Hydraulic Design

The design pumping capacity for each river is equivalent to the estimated design flood peak for pump drainage facilities with retention pond condition, derived from 10-year return period rainfall as described below. Design flood peak is also calculated by Modified Rational Method as follows.

Design Flood Peak for Pumping Station

River Name	tc (min)	Q (m^3/s)
Macabalo	58	105
Tibu	14	17

Steel gates are furnished in the floodgate for each river to prevent the design high water sea level (EL. + 1.61 m) from intruding into the drainage areas. Design discharge for the floodgate and its number of gates for each river are briefed below.

Design Discharge of Floodgate and No. of Gates

River Name	Design Flood Discharge (m^3/s)	No. of Gates
Macabalo	105	5
Tibu	17	3

The floodgates will drain the design flood of each river. The freeboard of 1.00 m is set above HWL of river channel. Several combinations of a pump station and a retention pond are prepared for those rivers. The physically maximum land available for a retention pond in the Macabalo and Tibu river is firstly checked and shown below.

Available Area for Retention Pond

River Name	Available Areas for Retention Pond
Macabalo	(1) 3.0 ha at river mouth (2) 6.3 ha at Lap-Lap Barangay (500m upstream of the river mouth, left bank) (3) 12 ha between Macabalo and Bagumbayan Bridges (1.5 km upstream from river mouth)
Tibu	(1) 0.5 ha at river mouth (2) No other available areas along river channel

Note : The area is measured by 1:5,000 City Map.

The relationship between a pump capacity and required retention pond volume is calculated by simulation of flood inflow hydrograph, outflow by pump station and required retention pond volume. Results of calculation are shown below.

Relationship between Pump Capacity and Required Retention Pond Volume

For Macabalo River

Pump Capacity (m^3/s)	Pump Operation Time (hr)	Required Retention Pond Volume (m^3)	Depth of Retention Pond (m)	Area of Retention Pond (ha)
20	7.9	367,200	3.1	12
15	10.5	405,000	3.4	12
10	15.8	444,600	3.7	12

Note : Total flood volume is estimated to be 567,000 m^3.

Relationship between Pump Capacity and Required Retention Pond Volume

For Tibu River

Pump Capacity (m^3/s)	Pump Operation Time (hr)	Required Retention Pond Volume (m^3)	Depth of Retention Pond (m)	Area of Retention Pond (ha)
3	1.4	10,800	2.0	0.5
2	2.1	11,880	2.4	0.5
1	4.3	13,536	2.7	0.5

Note : Total flood volume is estimated to be 15,300 m^3.

3) Cost Estimate

The preliminary cost estimate is made for Cases 1, 2 and 3 conceived for the Macabalo and Tibu rivers as follows. The estimate is based on the direct construction cost of each case.

Preliminary Cost Estimate among Cases for Macabalo River

Case	River Improvement	Pump Station	Flood Gate	Retention Pond
1 (Qmax=20m^3/s) Grand Total PHP294.3 million	Excavation : 36,400 m^3 x PHP120/m^3 = PHP4.4 million Embankment : 4,840 m^3 x PHP200/m^3 = PHP1.0 million Riprapping : 23,750 m^2 x PHP330 /m^2 = PHPPHP7.8 million Total : PHP13.2 million	Conventional Type 5 (m^3/s) x 4 = 20 (m^3/s) Total : PHP211.7 million	5 units (3 m x 3 m) Total : PHP24.0 million	Area : 12 ha Depth : 3.1 m Excavation : 340,760 m^3 x PHP120/m^3 = PHP43.6 million Embankment : 4,022 m^3 x PHP200/m^3 = PHP0.9 million Riprapping : 2,508 m^2 x PHP330/m^2 = PHP0.9 million Total : PHP45.4 million
2 (Qmax=15m^3/s) Grand Total PHP266.9 million	(same as Case1) Total : PHP13.2 million	Conventional Type 4 (m3/s) x 3 = 12 (m^3/s) 3 (m3/s) x 1 = 3 (m^3/s) Total : PHP180. 3 million	5 units (3 m x 3m) Total : PHP24.0 million	Area : 12 ha Depth : 3.4 m Excavation : 395,721 m^3 x PHP120 /m^3 = PHP47.5 million Embankment : 4,671 m^3 x PHP200 /m^3 = PHP0.9 million Riprapping : 2,913 m^2 x PHP330 /m^2 = PHP1.0 million Total : PHP49.4 million
3 (Qmax=10m^3/s) Grand Total PHP240.5 million	(same as Alt 1) Total : PHP13.2 million	Conventional Type 3 (m3/s) x 2 = 6 (m^3/s) 2 (m3/s) x 2 = 4 (m^3/s) Total : PHP149.1 million	5 units (3 m x 3m) Total : PHP24.0 million	Area : 12 ha Depth : 3.6 m Excavation : 434,413 m^3 x PHP120 /m^3 = 52.1 million Embankment : 5,127 m^3 x PHP200 /m^3 = 1.0 million Riprapping : 3,198 m^2 x PHP330 /m^2 = 1.1 million Total : PHP54.2 million

The least cost alternative is Case 3, composing river improvement of the Macabalo river and pump drainage (Pumping Capacity = 10 m^3/s) with a retention pond with grand total direct cost of 240.5 Million pesos.

Preliminary Cost Estimate for Alternative for Tibu River

Case	River Improvement	Pump Station	Flood Gate	Retention Pond
1 (Qmax=3m^3/s) Grand Total PHP84.84 million	Excavation : 1,500 m^3 x PHP120 /m^3 = PHP0.2 million Embankment : 437 m^3 x PHP200 /m^3 = PHP0.1 million Riprapping : 9,180 m^2 x PHP330 /m^2 = PHP3.0 million Total : PHP3.3 million	Submersible Type 1 (m^3/s) x 1 = 1 (m^3/s) 2 (m^3/s) x 1 = 2 (m^3/s) Total : PHP65.3 million	3 units (3 m x 3m) Total : PHP15.0 million	Area : 0.5 ha Depth : 2.0 m Excavation : 10,056 m^3 x PHP120 /m^3 = PHP1.2 million Embankment : 119 m^3 x PHP200 /m^3 = PHP0.02 million Riprapping : 74 m^2 x PHP330 /m^2 = PHP0.02 million Total : PHP1.24 million
2 (Qmax=2m^3/s) Grand Total PHP76.08 million	(same as Case 1) Total : PHP3.3 million	Submersible Type 1 (m^3/s) x 1 = 1 (m^3/s) 1 (m^3/s) x 1 = 1 (m^3/s) Total : PHP56.2 million	3 units (3 m x 3m) Total : PHP15.0 million	Area : 0.5 ha Depth : 2.4 m Excavation : 12,067 m^3 x PHP120 /m^3 = PHP1.5 million Embankment : 239 m^3 x PHP200 /m^3 = PHP0.05 million Riprapping : 89 m^2 x PHP330 /m^2 = PHP0.03 million Total : PHP1.58 million
3 (Qmax=1m^3/s) Grand Total PHP67.16 million	(same as Case 1) Total : PHP3.3 million	Submersible Type 0.5 (m^3/s) x 1 = 1 (m^3/s) 0.5 (m^3/s) x 1 = 1 (m^3/s) Total : PHP47.2 million	3 units (3 m x 3m) Total : PHP15.0 million	Area : 0.5 ha Depth : 2.0 m Excavation : 13,576 m^3 x PHP120 /m^3 = PHP1.6 million Embankment : 161 m^3 x PHP200 /m^3 = PHP0.03 million Riprapping : 100 m^2 x PHP330 /m^2 = PHP0.03 million Total : PHP1.66 million

The least cost alternative is Case 3, composing river improvement of the Tibu river and pump drainage (Pumping Capacity = 1 m^3/s) with a retention pond with grand total direct cost of PHP67.2 million pesos.

4) Selection of Optimum Scheme

a. Selection Criteria

Since related project evaluations based on environmental and social surveys for the alternative plan of urban drainage are presently under investigation, the optimum scheme can be selected by the least cost alternative method.

b. Optimum Scheme

Cases 1, 2 and 3 will similarly reduce flood damage in the flood prone area and inundation damage in the low-lying areas in the Port District with the same reducibility.

Expected land acquisition and resettlement costs of Cases 1, 2 and 3 will be the same since the equivalent area will be used for a retention pond.

Therefore, Case 3 is economically more feasible than Cases 1 and 2, with the least cost and the same reducibility of flood and inundation damages.

8.2.4 Basic Plan of Urban Drainage

(1) Purpose of the Project

The purpose of the Project is to control or mitigate flooding and inundation in Legazpi City through effective river structural measures that will result in reduction of losses due to flood.

The Feasibility Study aims to confirm the economic and technical viability of the priority structural projects identified in the master plan, to assess their social and environmental impact, and to come up with final recommendations on the most appropriate type of structure to be constructed.

(2) Design Flood

1) Probable Rainfall

Considering that two rivers are located in the vicinity of Legazpi City, Legazpi rainfall station was selected as a representative rainfall station to estimate probable storm rainfall. The following probable rainfall intensity-duration relationships estimated by PAGASA were adopted not only to the runoff study for river improvement plan but also for urban drainage plan.

Adopted Probable Rainfall Intensity-Duration Relation at Legazpi

(unit : mm/hr)

Return Period (yr)	10 (min)	20 (min)	30 (min)	60 (min)	120 (min)	3 (hr)	6 (hr)	12 (hr)	24 (hr)
2	129.6	95.1	78.4	52.4	36.8	29.2	19.2	11.7	6.8
5	186.0	136.8	113.2	76.6	55.3	44.4	31.1	19.0	10.6
10	223.8	164.4	136.2	92.7	67.6	54.5	38.9	23.8	13.2
20	259.8	191.1	158.2	108.1	79.3	64.2	46.5	28.4	15.6
50	306.0	225.3	186.8	128.0	94.6	76.7	56.2	34.4	18.7
100	341.4	251.1	208.2	143.0	106.0	86.1	63.5	38.8	21.1

Note : Obtained from PAGASA.

2) Probable Design Flood

The design flood protection level of 10-year return period was adopted as a protection level of each river, based on the recommendation by BOD of DPWH as a design criteria for urban drainage plan in the Philippines. The runoff formula adopted for determination of flood peak discharge is explained below :

$$Q = 1/3.6\ Cs\ C\ I\ A$$

where,
- Q = Peak discharge (m^3/s)
- I = Intensity of rainfall (mm/hr)
- A = Catchment area (km^2)
- C = Runoff coefficient
- Cs = Storage coefficient

  $Cs = 2\ tc / (2\ tc + td)$

  where,

  tc = Time of concentration

  td = Time of flow in the main drain

The application of a rational formula modified by a storage coefficient is preferable in the project area which mainly consists of flat and low-lying areas. Results of calculation for 10-year probable flood peaks in the Macabalo and Tibu Rivers are tabulated below.

Results of Flood Peak Calculation (10-Year)

River Name	Catchment Area (km^2)	River Length (m)	Tc (min)	Td (min)	Cs	C	Q (m^3/s)
Macabalo	12.9	7,250	58	117	0.44	0.70	105
Ruran	3.5	4,500	36	117	0.40	0.70	34
Sagumayon	3.6	5,250	42	105	0.44	0.70	35
Panal	3.0	3,312	26	60	0.46	0.70	39
Tibu	2.4	1,700	14	123	0.19	0.70	17

Note: Ruran, Sagumayon and Panal are upstream branch rivers of Macabalo River.

3) Tide Levels in the Albay Gulf

The design tidal levels at Port of Legazpi are obtained from "Design Manual for Port and Harbour Facilities in the Philippine Ports Authority (1995)" as summarized below.

List of Tides at Port of Legazpi

(unit : m)

HHWL	HWL	MHHW	MHW	MTL	MLW	LWL	DLT	LLWL
Highest High Water Level	High Water Level	Mean Higher High Water	Mean High Water	Mean Tide Level	Mean Low Water	Low Water Level	Design Low Tide Level	Lowest Low Water Level
-	+1.61	+1.40	+1.33	+0.75	+0.17	-0.25	-0.35	-0.70

Note: HHWL is not available at Port of Legazpi.

The deviation between HWL and LWL at Port of Legazpi is approximately 1.9 m. High Water Level (HWL) of 1.61 m observed at Port of Legazpi is adopted to the design high tide level.

(4) Alignment of Drainage System

1) Basic Plan

Basic Plan of Urban Drainage for Legazpi City is selected as the least cost alternative plan (Case 3) by case study as described in Section 8.2.3.

The selected alternative plan has the following subprojects.

Basic Plan of Legazpi City Urban Drainage

Sub-Project	River	Composition of Structural Measures
River Improvement	Macabalo	1. Construction of new dike (L=1,700 m) 2. Raising dike height (L=616 m) 3. Widening river channel (L=616 m)
	Ruran	1. Construction of new dike (L=95 m) 2. Raising dike height (L=95 m) 3. Widening river channel (L=95 m)
	Sagumayon	1. Construction of new dike (L=50 m) 2. Raising dike height (L=50 m) 3. Widening river channel (L=50 m)
	Sagumayon after Ruran	1. Construction of new dike (L=70 m) 2. Widening river channel (L=70 m)
	Panal	1. Construction of new dike (L=100 m) 2. Raising dike height (L=100 m) 3. Widening river channel (L=100 m)
	Tibu	1. Construction of new dike (L=834 m) 2. Raising dike height (L=277 m)
Pump Drainage	Macabalo	1. Pump station (2 units) 2. Floodgate (3 units) 3. Retention Pond (12 ha)
	Tibu	1. Pump station (4 units) 2. Floodgate (5 units) 3. Retention Pond (0.5 ha)

Dimensions of composition of river improvement for Macabalo and Tibu rivers are tabulated in Data Book.

2) Design Capacity of River Channels

Design capacity of river channels of Macabalo and Tibu and its tributaries to be improved to reduce the flood and inundation damages in those river basins is calculated as shown below.

Design Capacity of River Channels (10-Year)

River Name	River Length To be Improved (m)	Design Capacity (m^3/s)	Present Capacity (m^3/s)
Macabalo	1,700	105	4 - 150
Ruran	95	34	4
Sagumayon	50	35	6
Sagumayon after Ruran	70	70	19
Panal	100	39	20
Tibu	834	17	10 - 263

3) Design Capacity of Pumping Station

a. Design flood

Design flood for the determination of a pumping capacity is derived from 10-year return period rainfall as described in Section 8.2.3.

Design Flood Peak for Pumping Capacity

River Name	Q (m^3/s)
Macabalo	105
Tibu	17

b. Design capacity

Design capacity of pump station is determined as follows.

Design Pump Capacity

River Name	Design Pumping Capacity (m^3/s)
Macabalo	10
Tibu	1

4) Design Capacity of Retention Pond

a. Design flood

Design flood for the determination of a retention is also derived from 10-year return period rainfall as described in Section 8.2.3.

Design Flood Peak for Retention Pond

River Name	Q (m^3/s)
Macabalo	105
Tibu	17

b. Design capacity

Design capacity of retention pond is determined as follows.

Design Retention Pond Capacity

River Name	Design Retention Pond Capacity (m^3)	Design Retention Pond Area (ha)	Design Retention Pond Depth (m)
Macabalo	444,600	12	3.7
Tibu	13,536	0.5	2.7

8.2.5 Preliminary Structural Design of Selected Scheme

(1) Channel Improvement

1) Constitution of Works

The constitution of channel improvement works is composed of the following works.

a. Channel works
b. Dikes and revetments

2) Alignment and Profile

The alignment of river channel is based on the following design considerations.

a. The channel alignment generally follow the existing ones to minimize land acquisition.
b. In case of widening of the existing channels, the optimum design alignment is determined in order to minimize house evacuation and consequently, reduce cost.
c. The design alignment should be as smooth as possible to attain uniform channel flow.

The alignment of the proposed river channel improvement works is shown in Figures 8.2.5 and 8.2.6.

The profile of the river channels is designed on the following aspects.

a. The design gradient of the channel bed approximately follows the slope of the ground line.
b. The design channel bed is determined to start from the channel mouth which has the same elevation as that of the sea.
c. The slope of the design high water level also approximately follows the adjacent ground and as much as possible not higher than the predominant elevation of the adjoining ground.

3) Drainage Capacity

The design discharge capacity of the proposed river channel for the Macabalo and Tibu rivers is summarized below.

Drainage Capacity of Proposed River Channels

River Name	River Length to be Improved (m)	Design Discharge (m^3/s)	Design Water Depth (m)	Design River Width (m)	River Width to be Widen (m)
Macabalo	1,700	105	2.00-2.50	26.0-32.0	0.0-28.0
Ruran	95	34	2.00	10.5	6.5-7.0
Sagumayon	50	35	2.00	11.0	5.0
Sagumayon after Ruran	70	70	2.50	15.0	10.0
Panal	100	39	2.00	12.0	2.0
Tibu	834	17	1.10-4.00	4.8-39.0	-

Note: Design peak discharge is 10-year probable flood.

4) Preliminary Design

a. Channel works

A single trapezoid section for the river channels is adopted with a single slope of 1v:1.2h for all the sections to be improved in the Macabalo and Tibu rivers, considering highly congested land use along those rivers as shown in Figure 8.2.7.

The dimensions of the adopted cross-section of the channels are tabulated in Supporting Report (2), Chapter XIV.

b. Dikes and revetments

The dikes are designed to have several functions/uses such as for maintenance and repair works, flood defense activities during high water stage of the river channels. The channel revetments are provided for all the sections to be improved with a side slope of 1v:1.2h to prevent the channel banks from being eroded and widened, hence, protecting the houses from possible damages.

The type of revetment is selected on the basis of the channel design requirement and conditions in the area in relation to the side slope. The selected type of revetment is shown below.

a. Side slope : Single section

b. Revetment : Grouted wet masonry

5) Construction Work Volume

The construction work volume for the proposed river improvement of the Macabalo and Tibu rivers is tabulated below.

Construction Work Volume for Proposed River Improvement

River Name	Excavation (m^3)	Embankment (m^3)	Riprapping (m^2)
Macabalo	36,400	4,840	23,750
Tibu	1,500	437	9,180

(2) Pump Drainage

1) Constitution of Works

The constitution of pump drainage works is composed of the following works.

a. Pump stations
b. Floodgates
c. Operation building and appurtenances

2) Alignment

The alignment of the proposed pump drainage in the Macabalo and Tibu rivers is shown in Figures 8.2.5 and 8.2.6.

3) Pump Capacity

The design pump capacity of the proposed pump drainage in the Macabalo and Tibu rivers is summarized below.

Design Pump Capacity

River Name	Design Flood Peak (m^3/s)	Design Pumping Capacity (m^3/s)
Macabalo	105	10
Tibu	17	1

4) Preliminary Design

a. Pump stations

The selection of a suitable pump type for the proposed pumping stations in the Macabalo and Tibu rivers is made for the Study.

Pump Type

The basic conditions for the selection of a pump type are as follows.

- The required pump capacity for future extension is not considered.
- Total pump head is approximately 1.5 m.
- Actual pump head is variable.

Generally, the following two types of pumps, consisting totally of six kinds, are applicable for use in storm water drainage considering the basic conditions given above:

- Conventional type
  - Horizontal shaft axial flow pump
  - Horizontal shaft mixed flow pump
  - Vertical shaft axial flow pump
  - Vertical shaft mixed flow pump
  - Screw pump
- Submersible type
  - Submersible motor pump

Among these pump types, the following are chosen on preliminary selection.

Selected Pump Type for Pump Stations

River Name	Pump Type	Reasons
Macabalo	Horizontal shaft axial flow pump	Most economical among conventional types of pump for large pumping capacity (= 10.0 m^3/s) required for Macabalo river.
Tibu	Submersible motor pump	Most suitable for small pumping capacity (= 1.0 m^3/s) required for Tibu river.

Unit Capacity and Number of Pumps

The unit capacity and number of pumps are generally determined on the basis of the following premises.

- At least two units shall be installed in each pumping station against breakdown of a pump unit
- For easy maintenance, variations of a pump size and number of pump units shall be kept to a minimum
- The ON-OFF operation shall be as rare as possible

Taking into consideration the these premises, the following unit capacity and number of pumps are proposed.

Unit Capacity and Number of Pumps

River Name	Unit Capacity	No. of Pumps
Macabalo	3.0	2
	2.0	2
Tibu	0.5	2

Design of Pumping Station

The main structure of a pumping station is typically composed of the following as shown in Figures 8.2.8 and 8.2.9.

- Sand basin
- Intake canal
- Pump pit
- Surge tank

Structural Features of Pumping Station

River Name	No of Bay	Total Width (m)	Total Length (m)	Maximum Height (m)	Width of Surge Tank (m)
Macabalo	4	35	105	7.0	19.0
Tibu	2	22	105	7.0	9.0

b. Floodgates

Type and Basic Structure

The type and basic structure of the floodgates are determined in accordance with the following concepts.

In common practices, two types of floodgates are properly used in compliance with the site condition: namely, the open channel type and box culvert type.

Since there is nearly 0.7 m difference of the design high water levels between the sea side and river side, the box culvert type requires smaller gate height resulting in less construction cost.

Moreover, no navigation of large vessels is expected through the floodgates. It is, therefore, recommended to apply to the sites the box culvert type of floodgate for the Project.

Dimensions of Opening

The opening of a box culvert in each floodgate is designed so that the flow velocity can be around 1.0 m/s to avoid both sedimentation and abrasion through the culvert.

The dimensions of opening is presented below.

Dimensions of Floodgates

River Name	Design Discharge (m^3/s)	Gate Height (m)	Gate Width (m)	No. of Gates
Macabalo	105	3.5	3.0	5
Tibu	17	3.5	3.0	3

Design of Floodgates

The Macabalo and Tibu Floodgates have the structural components as shown in Figures 8.2.8 and 8.2.9.

Operation building and appurtenances

The proposed pumping station and floodgate shall be arranged together in the layout of facilities, particularly such as:

- Main structure comprising intake canals, pump pits, pump bay, surge tank, etc.
- Operation building
- Pavement and parking lot
- Walled-in area with an entrance/exit gate

The required lot for each pumping stations in the Macabalo and Tibu rivers is briefed below.

Required Lot for Pumping Station

River Name	Required Lot (m^2)
Macabalo	3,700
Tibu	2,300

5) Construction Work Volume

The construction work volume for the proposed pump drainage of the Macabalo and Tibu rivers is tabulated below.

Construction Work Volume for Proposed Pump Drainage

Work Item	Macabalo	Tibu
Embankment	16,000 m^3	4,600 m^3
Reinforced Concrete	6,700 m^3	3,200 m^3
R C Pile	3,900 m^3	560 m^3
Pump	Horizontal Shaft Pump 4 sets	Submersible Pump 2 sets
Diesel Engine	4 sets 325ps-1,000rpm	
Mechanical Rake	1 set	1 set
Electrical Facilities for Auxiliary	L.S.	
Diesel Engine for Auxiliary Equipment	2 sets	
Low-tension Distribution Panel		3 sets
Auxiliary Pump and Auxiliary Facilities	L.S.	L.S.
Cable and Miscellaneous Materials	L.S.	L.S.
Diesel Generator		1 set
Control Panel	1 set	1 set
Day Oil Tank	2.0 ton	1.5 ton
Track Crane	1 set	1 set
Gate	5 sets	3 sets

(3) Retention Pond

1) Constitution of Works

The constitution of retention pond works is composed of the following works.

a. Excavation works
b. Embankment works
c. Riprapping works

2) Alignment

The alignment of retention pond is selected, based on the following design considerations.

a. Unused open space or paddy fields is used for retention pond to minimize land acquisition.
b. Design alignment is determined in order to minimize house evacuation and consequently, reduce cost.

The alignment of the proposed retention pond works is shown in Figures 8.2.5 and 8.2.6.

3) Design Capacity

The design capacity of the proposed retention pond for the Macabalo and Tibu rivers is summarized below.

Design Retention Pond Capacity

River Name	Design Retention Pond Capacity (m^3)	Design Retention Pond Area (ha)	Design Water Depth (m)
Macabalo	444,600	12	3.7
Tibu	13,536	0.5	2.7

4) Preliminary Design

a. Excavation works

A single trapezoid section for the slope of retention pond is adopted with a single slope of 1v:1.5h for all the sections

The dimensions of the adopted cross-section of the slope are tabulated below.

Dimensions of Adopted Cross Section of Retention Pond

River Name	Length of Retention Pond (m)	Width of Retention Pond (m)	Free Board (m)	Water Depth (m)
Macabalo	400	300	1.0	3.7
Tibu	100	50	1.0	2.7

b. Dikes and revetment

The dikes are designed to have several functions/uses such as for maintenance and repair works, flood defense activities during high water stage of the river channels.

The revetments are provided for all the slopes with a side slope of 1v:1.5h to prevent the banks from being eroded.

The type of revetment is selected on the basis of the design requirement and conditions in the area in relation to the side slope. The selected type of revetment is shown below.

a. Side slope : Single section
b. Revetment : Grouted wet masonry

5) Construction Work Volume

The construction work volume for the proposed retention pond of the Macabalo and Tibu rivers is tabulated below.

Construction Work Volume for Proposed Retention Pond

River Name	Excavation (m^3)	Embankment (m^3)	Riprapping (m^2)
Macabalo	434,413	5,127	3,198
Tibu	13,576	161	100