(2) Calculation Procedure

(a) Determination of Cross Section Characteristics

Tables of water level H and the corresponding values A and R are prepared by using the cross sections.

(b) Determination of Water Level at Downstream End

Water level at the downstream end is determined taking into consideration the discharge to be used and the conditions at the downstream end such as tide level and main river stage.

(c) Non-Uniform Flow Calculation

Based on the foregoing conditions and by Eqs. (1) and (2), the successive calculation of non-uniform flow is started from the downstream cross section and successively up to the upstream ones to calculate the inundation water level and areas.

Calculation Results

The calculation results are shown in Figs. VII-10 and VII-11. It is presumed from these figures that the bankfull flow capacity of the Chama River which is obtainable in comparison between bank height and calculation water stage is about 100 m^3/s in the stretch without embankment and about 1,000 m^3/s in the stretch with embankment.

The flow capacity in the stretch with embankment, however, reduces to about 300 m^3/s when the embankment is broken, as noted from the fact that the flood in 1988 with the discharge of about 700 m^3/s had inundation in this stretch when the dike was broken.

3.3.3 Flood Inundation Analysis

The procedure of flood inundation analysis is as follows:

- Selection of methodology for flood inundation analysis;
- Formulation of flood inundation simulation model;
- Determination of the constants of the model; and

- Calculation of the flood inundation discharge and water level.

Selection of Method for Flood Inundation Analysis

The inundation area in the lower reaches is on the relatively steep slope with the gradient of more than 1/1,000. Inundation water flows down the slope along the river course up to the Maracaibo Lake.

Among the flood inundation types which are broadly classified into the storage type and the diffusion type, inundation condition in this area may belong to the storage type judging from the aforementioned topographic condition in the inundation area.

In consideration of the flood inundation type and the topography of the flood prone area, the storage function model was selected over the other inundation models such as Muskingum Model, the Simplified Unsteady Flow Model, the Two-Dimensional Unsteady Flow, etc., for consistency with the method of runoff analysis.

Formulation of Flood Inundation Simulation Model

On the basis of the recorded inundation area in 1972, 1982 and 1988, as well as the topographic map, the probable inundation area which can be subdivided into five stretches was presumed (refer to Fig. 3.3-2). To reflect these flood inundation conditions, the simulation model was featured with the subdivided stretches of the lower reaches.

Determination of Constants of the Model

In the storage function model, the following exponential equation was used to express the relation between flood discharge (Q) and storage volume (S) of the inundation area including the river channel.

$$S = KQ^p$$

where,

S : storage volume ($m^3/s \cdot hr$)

Q : discharge (m^3/s)

K, p: constants

The relation between Q and S largely changes when flood discharge is over the flow capacity of the river channel, because the storage volume for flood discharge below the flow capacity is counted only for that of the river channel, while the storage volume above the flow capacity includes that of the inundation area and that of the river channel.

Thus, the relation between Q and S is generally assumed with a two-step exponential function. The constants "K" and "p" of the storage function model were determined on the basis of the hydrological relation between flood discharge and its corresponding storage volume of the river channel and the inundation area.

Calculation of Flood Inundation Discharge and Water Level

Calculation of flood inundation discharge was made on the basis of the following conditions. The calculation results are shown in Table 3.3-1.

- Six study cases with the probability of 2, 5, 10, 30, 50 and 100-year return period are employed.
- One week is applied as the calculation duration to evaluate the flood damage on agricultural products, since the magnitude of the damage depend on not only inundation water depth but also inundation duration.
- Calculated flood discharge is converted into water level by rating curve based on the non-uniform calculation.

CHAPTER 4. PRINCIPLES OF PROJECT FORMULATION

4.1 Identification of Target Assets

Sediment and flood disasters occur at different locations and affect the social and economic activities in the Chama River Basin. The disasters are classified into four according to type and magnitude as follows:

- Inundation disasters that spread over a wide area and cause extensive damage to agriculture, infrastructures and the small urban areas in the lower reaches;

- Disasters due to slope failure, debris flow and other causes that occur at spot sites but affect the social and economic activities to a great extent through the interruption of traffic on the arterial roads such as Route 2 and Route 7;

- Inundation disasters which are not so serious at present but expected to increase in the future due to urban development such as those occurring at the urban areas of Mérida and Ejido cities; and

- Sediment and flood disasters that occur at spot sites and do not spread to adjoining areas such as those on the rural roads, houses in small villages, small agricultural areas and others.

Since damage to assets under the first three categories will have a serious influence on the social and economic activities in the Chama River Basin, the assets covered by these three categories were selected as the target assets for this basin conservation project.

4.2 Manner of Project Formulation

Master Plan and Action Plan

The master plan for river basin conservation consisting of sediment and flood control works is firstly formulated with its target year set at 2020. Within the framework of the master plan, an action plan is also formulated for the selected urgent projects with the target year at 2000.

Basin-wide Project and Local Project

The planning area for disaster prevention works depends on the target assets, as described hereafter.

(1) Agricultural and Residential Areas in the Lower Reaches

Disasters are basically caused by sediment and flood discharge from the upper and middle reaches and inundation in the lower reaches. Therefore, the planning area shall cover the whole Chama River Basin.

(2) Arterial Road Route 2 and Route 7

Disasters due to slope failure, debris flow, landslide and other causes occur at spots on the road independently from each other. The planning area for each disaster is, therefore, limited to a relatively small area.

(3) Urban Areas of Mérida and Ejido

The urban areas in the cities of Mérida and Ejido belong to the small river basins of the Albarregas, Milla and Portuguesa rivers. Accordingly, the planning area is also limited to the small area of the basins.

Since there is much difference in size among the planning areas mentioned above, it is difficult to formulate the disaster prevention plan for each planning area at the same level. For a more objective approach, the river basin conservation project is divided into two sub-projects, namely basin-wide project and local project, as presented in the following table. The master and action plans for the sub-projects are formulated separately, but project evaluation is done for both projects as a whole.

Sub-Project	Target Asset	Planning Area	Objective
1. Basin-wide Project	Agricultural and residential area	Whole River Basin	Flood and Sediment Control
2. Local Project	Routes 2 & 7 of arterial road	Stream and Slope	Sediment Control
	Urban areas of Mérida and Ejido cities	Stream	Flood Control

4.3 Concept of Project Formulation

4.3.1 Basin-wide Project

Objective

The objective of the basin-wide project is to mitigate flood inundation damage in the lower reaches. To achieve this objective, flood will be controlled in the lower reaches and sediment will be controlled in the upper/middle reaches to prevent sediment deposition and the resulting decrease in flow capacity of the river course in the lower reaches.

Project Scale

(1) Project Scale for Sediment Control

The project scale for sediment control under the basin-wide project is set to control all harmful sediment, which may decrease the flow capacity, by the master plan target year of 2020.

(2) Project Scale for Flood Control

The project scale for the master plan of flood control is determined in terms of occurrence probability considering the technical, social, economical and financial aspects, with special emphasis on the social aspect. Project scales employed in similar projects were examined and taken into consideration as an index of social requirements.

The project scale of the action plan is decided within the framework of the master plan, considering the technical, economical and financial aspects.

Alternative Study Cases

Alternative study cases of structural measures for the master plan of sediment and flood control are selected among realistic ones in view of natural conditions of the basin, e.g., topography, geology, meteorology, hydrology, etc. Alternative study on structural measures for formulation of the action plan, on the other hand, is made putting emphasis on more detailed points, e.g., structural type, applied materials, etc., of individual structures.

As for the non-structural measures that can supplement the structural ones at a lesser cost, the optimum measures are examined in conjunction with the formulation of the action plan.

Selection of the Optimum Plan

Among the alternative study cases, the optimum combination of structural measures is selected from the technical and economical aspects and, accordingly, the sediment and flood control plan is formulated. The adequacy of the formulated plan is confirmed in consideration of economic viability and financial capability.

4.3.2 Local Project

Objective

The local project aims at the protection of roads and urban areas from sediment flow, slope failure, landslide and flood inundation. The project objectives for sediment disaster prevention are Route No. 2 and No. 7 of the arterial road and those for flood damage prevention are the urban areas of Mérida and Ejido.

Project Scale

The project scale for formulation of the master plan of the local project for both sediment disaster and flood damage prevention is determined in terms of occurrence probability considering the technical and social viewpoints.

Applicable Method

The applicable structural measures are listed up in consideration of those commonly used in Venezuela and in other countries, as well as from the topographic, geologic and hydrologic conditions, and other aspects. As in the basin-wide project, non-structural measures were considered only in the action plan.

Optimum Method

The optimum method for both sediment disaster and flood damage prevention is selected through a conceptual study on the applicable methods judging from the features of the sites such as topography, geology, etc.

The optimum plan of non-structural measures is selected in consideration of the capability and availability of personnel and facilities of agencies concerned.

CHAPTER 5. MASTER PLAN

5.1 Basin-wide Project

5.1.1 Sediment Control

Project Scale

The master plan is designed to control all harmful sediment in the Chama River Basin by the target year 2020. As the project scale to determine the most appropriate plan, either one of two target design features has to be selected; namely, (1) the annual sediment discharge, or (2) the sediment discharge during an extraordinary flood. For the basin-wide project, the annual sediment discharge was selected as the target design feature for the formulation of the sediment control plan. The selection was based on the following considerations.

- The sequence of sediment movement; namely, production, transportation and deposition, will take a long time in the Chama River Basin with large catchment area of over 3,500 km^2.

- Sediment movement which is to be taken into account in the sediment control plan, occurs several times a year even during ordinary floods.

Applicable Method

In consideration of the three sediment movements mentioned above, the applicable methods for sediment control were selected as follows.

(1) Sediment Production

Sediment is produced by slope erosion, slope failure and torrent erosion, as well as the erosion of main river channels. The applicable methods to control erosion in slopes or torrents are afforestation, hillside works, torrent control works and groundsills, while those for slope failure are afforestation and retaining wall. Sabo dam and groundsill are applicable for main channel erosion.

(2) Sediment Transportation

Sediment is transported along the main channels of tributaries and the Chama River. The applicable methods to control sediment transportation and to regulate sediment discharge are sabo dam and groundsill.

(3) Sediment Deposition

Sediment is deposited on the alluvial fan downstream of El Vigía. To prevent sediment deposition, channeling works, debris basin and diversion channel are applicable.

Alternative Study Cases

From the applicable methods mentioned above, a study on alternative cases of production control, discharge regulation and deposition reduction was carried out with the following conclusions.

(1) Production Control

Among the applicable methods, afforestation, hillside works and torrent control works were selected for production control. Afforestation shall be done in two steps; seeding on the denuded land and planting of the pulse family seedlings. Required seeds are 10 kg/ha, and seedlings are 10,000 tree/ha.

Hillside works shall be of masonry installed at the end of gullies. This work is economical because of the abundant boulders and gravels around the project sites. Torrent control works are of low dams constructed continuously at more or less 10 sites along the devastated torrent.

(2) Discharge Regulation

Sabo dam was selected as a measure for sediment transportation regulation along main channels in the upper/middle reaches. A high and large-capacity sabo dam is effective for regulating sediment transportation. Sabo dam has also a sieving function to allow the sediment be transported without deposition in the river channel.

(3) Deposition Reduction

Channeling works were selected as a most realistic approach among the applicable methods for sediment deposition reduction in the channels downstream of El Vigía. Channeling works are usually made with a concrete lining to increase the sediment transport capacity of rivers and a continuous groundsill to stabilize the channel bed. Those for the Chama main channel from El Vigía to the river mouth consist of a concrete-lined 100 m wide channel and continuous groundsills at intervals of approx. 50 m which may be able to transport all the sediment discharge from the upstream area.

The required investment rate which is defined as the investment cost divided by the controllable sediment discharge was estimated for the respective methods as follows.

Control Method	Features		Investment Rate
Afforestation	Seeding of Eragrostis	: 10 kg/ha	820 Bs/m^3
	Planting of Acacia	: 10,000 trees/ha	
Hillside/torrent works	Retaining Wall	: wet masonry 5 sites/gully	237 Bs/m^3
	Continuous Low Dam	: 1 site/120 m	
Sabo dam	Rubble Concrete		145 Bs/m^3
Channeling works	Concrete Lining	: 100 m wide single section	669 Bs/m^3
	Groundsill	: 50 m interval	

The following considerations have to be taken into account in the formulation of the basin-wide sediment control plan applying the control methods enumerated above.

- Afforestation or hillside/torrent works may control only sediment production, so that sabo dams or groundsills are additionally required to control channel erosion.

- Sabo dam has the function of regulating sediment discharge in addition to preventing channel erosion. Accordingly, with 10 sabo dams, 2,580,000 m^3/year out of the surplus sediment inflow of a 3,730,000 m^3/year will be regulated and 3,750,000 m^3/year of channel erosion will be controlled. The remaining volume of 1,150,000 m^3/year will have to be controlled by employing some other additional methods.

- With the channeling works, the whole project sediment discharge of a 9,600,000 m^3/year shall be conveyed to the Maracaibo Lake.

Judging from the investment rates shown in the foregoing table, afforestation and channeling works are much costlier than the other works. Together with the above considerations, it was concluded that a combination of hillside/torrent works for production control and sabo dam for discharge regulation is more appropriate for the basin-wide sediment control plan.

Selection of Optimum Method

Out of the harmful sediment discharge of 7,480,000 m^3/year, channel erosion of 3,750,000 m^3/year will be primarily controlled by erosion control works consisting of sabo dam or groundsill. The remaining 3,730,000 m^3/year will be treated by either sabo dam or hillside/torrent works, or a combination of both methods.

To cope with these circumstances, the sediment control plan consisting of a combination of sediment discharge regulation and production control by means of sabo dams and hillside/torrent works mentioned above has three alternatives, as follows:

Alternative A : Groundsill + Hillside/Torrent control works
Alternative B : Sabo dam
Alternative C : Sabo dam + Hillside/Torrent control works

Erosion control works shall be constructed on the eroded portions of two river stretches; namely, from El Vigía to the confluence with the Mocotíes River and from Estánquez to the confluence with the Nuestra Señora River. A comparative study on the unit costs of a sabo dam and groundsills to control erosion on a river stretch of 2,000 m long shows that the sabo dam is cheaper than the groundsill by 71% with the cost of 58,800,000 and 100,800,000 bolívares, respectively. Moreover, the sabo dam has the additional function of regulating sediment discharge.

In view of the above considerations, Alternative A is dropped from the plan. As for Alternative B, the suitable sabo dam sites are limited in the Chama mainstream and major tributaries which have a wide river width, making it impossible to construct a sabo dam in all the channels where erosion occurs.

To fulfill both functions of discharge regulation and erosion control, the most effective sites for sabo dams have been selected. Correspondingly, Alternative C is selected as the optimum sediment control plan. A total of 10 sabo dam sites were selected, and the heights and lengths were determined as presented in Table 5.1-1 and Fig. 5.1-1.

With 10 sabo dams, the annual sediment discharge of 2,580,000 m^3 will be regulated and sieved for safe transportation through the downstream channel. The remaining 1,150,000 m^3 will be controlled by hillside works and torrent works. A schematic diagram of the sediment control plan and the sediment discharge to be treated by the preventive works are presented in Fig. 5.1-2.

Considering the ratio of sediment production volume between torrent erosion and slope erosion that was estimated at 8:9, the design sediment volumes for torrent and hillside works were evaluated at 530,000 m^3/year and 620,000 m^3/year, respectively. All torrent and hillside works are to be employed for the area where sediment production is dominant; namely, sub-basins 8, 9, 12, 13, 14, 15 and 16, as presented in

Table 5.1-2. The optimum method for the basin-wide sediment control plan, together with the controllable sediment discharges, is schematically presented in Fig. 5.1-3.

Structural Layout

(1) Sabo Dam

Additional field survey, topographic survey and geological reconnaissance were carried out to determine the most suitable dam sites. The structural dimensions of the sabo dams were determined and their functional efficiencies were expressed by the ratio of sediment capacity to dam volume, as presented in Table 5.1-1.

(2) Torrent Works

For torrents, continuous low dams will be employed on a torrent length of 12,600 m in the denuded area. A total of 110 sites are required because the effective distance of a 4-m high low dam was calculated at only 90 to 120 m.

Among the sub-basins, the Nuestra Señora River Basin brings the largest sediment discharge of 1,746,000 m^3/year and the San Pablo River Basin does the second of 1,456,000 m^3/year. Sub-basin 15 (La Joya and others), Sub-basin 12 (Arbolote and others), Sub-basin 14 (Maruchi, El Molino, El Anís and others), and Sub-basin 13 (La Vizcaína) follow the first two sub-basins (refer to Table 5.1-3).

The required number of low dam sites was estimated in proportion to the sediment production volumes of sub-basins. Among the major sub-basins of sediment production, Sub-basin 16 (San Pablo) should have the largest number of low dams at 30 sites, as shown in the following table.

Sub-basin Number	Name of Tributaries	Number of Low Dam Sites
8	Upper Nuestra Señora	18
9	Lower Nuestra Señora	9
12	Arbolote, etc.	15
13	La Vizcaína	6
14	Maruchi, El Molino, El Anís	14
15	La Joya, etc.	18
16	San Pablo	30
Total		110

(3) Hillside Works

Hillside works are employed only for the sediment productive sub-basins with a total area of 1,345.8 km^2, specifically, for gullies in the denuded area of 147.0 km^2. A retaining wall of wet masonry is adopted for the works in consideration of the availability of materials around the job sites, construction efficiency and cost. Provided that five retaining walls are constructed for a gully of 5 m wide and 325 m long on an average, 1,400 sites of retaining walls will be required for 280 gullies to control the sediment volume of 620,000 m^3/year from the slope erosion.

The required number of retaining walls was estimated in proportion to the sediment production volumes of sub-basins as made for the torrent works. The number of retaining walls for each sub-basin is shown in the following table.

Sub-basin Number	Name of Tributaries	Number of Retaining Wall
8	Upper Nuestra Señora	230
9	Lower Nuestra Señora	110
12	Arbolote, etc.	190
13	La Vizcaína	80
14	Maruchi, El Molino, El Anís	180
15	La Joya, etc.	230
16	San Pablo	380
Total		1,400

5.1.2 Flood Control

Project Scale

In consideration of the optimum flood control measures, the project scale is first selected on the basis of that employed on similar projects. Examples of these projects are the Zulia River Improvement, the Catatumbo River Improvement and the Escalante Diversion Channel which are all located south of the Maracaibo Lake and which were executed with the probability of between 50 and 100-year return period. Another project is the Mucujepe Diversion Channel which was proposed with the probability of 100-year return period.

Since land use and living conditions in the lower reaches of the Chama River Basin are quite similar to those in the vicinity of the projects mentioned above, the social requirements in the Chama River Basin are supposed to be at the same level as these project areas. Therefore, a probability of 100-year return period was applied as project scale. The 100-year period probable discharge of the Chama River at El Vigía is 2,300 m^3/s.

Applicable Method

For the basin-wide project, several methods are applicable; namely, (1) river channel improvement, (2) diversion channel, (3) retarding basin, and (4) dam and reservoir. In view of the topographic condition, the retarding basin is virtually eliminated.

By the comparative studies conducted since the 1960's on the other three methods, it was concluded that the diversion channel had an economical advantage over the other two methods. However, there was not much difference in cost between the river diversion channel and the river channel improvement, while dams and reservoirs are very costly compared with the river channel improvement and diversion channel. The economical advantage of the diversion channel over the river channel improvement may be reduced due to the recent land development.

In view of the above, the diversion channel and the channel improvement of Chama River was studied to determine the optimum method of flood control.

Alternative Study Cases

(1) Possible Study Cases

River improvement and diversion channel plans were identified as the applicable methods for flood control. To select the optimum method, the following items were studied: (a) design of alignment, (b) design of longitudinal profile, and (c) design of cross section.

(a) Case of Chama River Improvement

The present channel of the Chama River has the following features:

- As mentioned before, the river course has not drastically changed in the past 20 years except for a minor change in meandering points.
- The flow capacity of around 100 m^3/s is very poor compared with the expected design discharge of 2,300 m^3/s, and it is

presumed that the flood discharge flows down along the center line of the meandering course of the river channel (refer to Fig. 5.1-4).

- The riverbed gradient is still steep even in the lowland as shown in Fig. 5.1-5; the flow velocity of the design discharge is very swift.

Under the above features, the river channel will be designed on the following principles:

- New alignment will be designed along the center line of meandering of the present river course, since the flood discharge flows down along this course of center line which has been stable for the past 20 years. As a result, the river length from the river mouth to El Vigía is measured at 53 km, although it is 73 km when measured along the course of meandering.

- Longitudinal profile is designed on the basis of the new alignment.

- For selection of the appropriate cross section based on economical and technical aspects, the following cases were examined:

  CASE 1: For easier maintenance, single cross section with sufficient river width is proposed, so that the channel meandering can be developed without erosion on embankment.

  CASE 2: To save on land acquisition cost, single cross section with a narrower river width than Case 1 is proposed, so that revetment may have to be provided to the embankment portion of water colliding front.

  CASE 3: To assure the stability of the river channel and safety of the embankment, a complex cross section with a much narrowed river width is proposed, which can also save on land acquisition cost.

(b) Case of Diversion Channel

The diversion channel is designed under the same principles as river channel improvement in consideration of the previous study results on diversion channel, as follows:

- Design alignment is adopted from the previous study results.
- Longitudinal profile is designed by taking into account the ground height along the design alignment.
- For the selection of the appropriate cross section, the same alternative cases are examined.

In accordance with the above principles, the following study cases were considered:

Alternative Plan	Alignment	Longitudinal Profile	Cross Section	Total
Chama River Channel Improvement	1 case	1 case	3 cases	3 cases
Diversion Channel	1 case	1 case	3 cases	3 cases

In these study cases, the optimum cross section of the diversion channel will coincide with that of the Chama River channel improvement, because of the similarity of channel characteristics such as river gradient, meandering, soil condition, land use condition, etc. For convenience, the optimum cross section of the Chama River improvement is first selected and a comparative study between river improvement and diversion channel will be examined by using the optimum cross section among the three cases.

(2) Outline of the Design Features of Study Cases

The design features with the discharge of 2,300 m^3/s for the study cases on Chama river improvement are in Table 5.1-4. In this table, river width and the necessary structures are designed under the following considerations:

(a) Case 1

Since the amplitude of meandering of the present river channel is mostly within 600 m as shown in Fig. 5.1-6, the river width of 1,400 m including some allowance is adopted (refer to Fig. 5.1-7). Groins are provided in the stretch where water velocity is over 2 m/s and the revetment is provided at the water colliding front of meandering point to protect the dike from erosion. Groundsill is provided at the section of the Pan-American Highway Bridge to prevent degradation of the riverbed.

(b) Case 2

Floodmarks in an aerial photograph of the El Vigía area show that the width of the Chama River had extended to about 600 m on an average, and a natural levee had been formed. Therefore, 600 m is adopted as the design width because it is possible to confine the flood discharge within this river width by means of embankment, and the velocity of flood discharge can be kept at around 2 m/s (refer to Fig. 5.1-8). Groins, revetment and a groundsill are provided in the same manner as Case 1.

(c) Case 3

In this complex cross section, the low water channel is designed with a flow capacity corresponding to a discharge of 2 to 3-year probability. The high water channel is designed not to exceed the velocity of 2 m/s and thus a river width of 150 to 290 m is applied to the design. Revetment is provided to the low water channel to assure stability of the meandering section of the river course. Groins and a groundsill are provided in the same manner as Case 1. (Refer to Fig. 5.1-9.)

Selection of the Optimum Method

(1) Selection of Optimum Cross Section of Chama River Improvement

The cost comparison is shown in Table 5.1-5. Judging from the table, the following features are pointed out:

- Among the three study cases, Case 3 with a complex cross section is too costly compared with the other cases due to a large excavation volume.

- There is not much cost difference between Case 1 and Case 2; however, a wide tract of cultivated land of approx. 3,000 ha which is equivalent to 60% of the annual average inundation area of about 5,000 ha will be lost for the river area in Case 1.

  Here, Case 1 is not realistic since the purpose of this project is to mitigate the flood damage on the flood prone area to secure agricultural production. Case 2 is then selected as the optimum cross section of the Chama River improvement.

(2) Selection of Optimum Flood Control Plan

In accordance with the results of the optimum cross section of the Chama River improvement, the diversion channel plan is designed in the same manner as the Chama river improvement (refer to Fig. 5.1-10).

Table 5.1-6 shows the cost comparison between Chama River improvement and the diversion channel. Judging from this table, the following features are pointed out:

- The diversion channel plan has an advantage in land acquisition cost compared with the river channel improvement plan due to the difference of land use conditions. However, the difference is not so large, since the land has to be acquired for the whole stretch in case of the diversion channel plan, while the present river area is not needed to acquire and therefore excluded from the whole stretch in case of the river channel improvement plan.

- As for the low water channel, it is necessary to excavate only a small portion for river channel improvement. On the other hand, a new low water channel has to be excavated in the case of diversion and thus the excavation cost is higher.

As a conclusion, the diversion channel plan has no advantage over the river channel improvement in economical aspects.

(3) Consideration on the Other Aspects

The following differences are pointed out in the other aspects:

- In connection with the stability of the river channel, the Chama River has changed its course only in minor portions, therefore, it may not be difficult to confine the flood discharge within the proposed channel along the present river course. On the other hand, it is difficult to predict how the new diversion channel will meander, therefore, it may require more maintenance work to confine the flood discharge safely.

- From the environmental aspect, a diversion channel project may adversely affect the living conditions of the people along the Chama river course due to the lowering of ground water level. Besides, a diversion channel will hamper the smooth communication between the inhabitants on both sides of the channel.

- From the economic efficiency of investment, the Chama river channel improvement has an advantage since project benefit is expected at once in proportion to investment cost, while the diversion project expects the project benefit only after completion of the diversion channel.

From the above considerations, it is desirable to select the Chama river channel improvement plan as the optimum case. The design alignment, longitudinal profile and typical cross sections of the Chama river channel improvement plan are shown in Figs. 5.1-11, 5.1-12 and 5.1-13.

5.1.3 Preliminary Design

Preliminary designs of structures such as sabo dam, continuous low dam and retaining wall for sediment control, and dike, revetment, groin, groundsill and bridge for flood control were prepared from the viewpoint of availability of construction materials near the project sites, economy, construction efficiency, structural stability, and so on.

Sediment Control

(1) Sabo Dam

For the sediment discharge regulation and erosion control, ten sabo dams are proposed in the master plan; nine dams (C-1 to C-9) on the Chama River and one dam (N-1) on the Nuestra Señora River.

Among several kinds of dam types, gravity dam type which is commonly used because of its technical advantage is applied to that for C-1, C-2 and N-1 dam with the height of 22 m.

On the other hand, for the remaining dams from C-3 to C-9, dams with the height of between 9 and 11 m proposed at the sites on the active Bocono fault, steel frame dam type is adopted to cope with the transformation of topography by the fault.

The preliminary design of these sabo dams are based on the following conditions and assumptions.

- Topographic maps on the scale of 1/25,000 and contour interval of 20 m are available for the preliminary design.

- A 100-year return period flood is employed in the determination of dimensions of the overflow section, subdam, apron and sidewall.

- The structure of each sabo dam consists of a main dam, subdam, apron and sidewall. The major dimensions of the main dam are 3.0 m of dam crest width and a downstream slope of 1:0.2. The upstream slope is determined by the structure stability analysis. The dam body is embedded 2.0 m below the existing riverbed.

- To prevent overturn of the main dam caused by scouring through the impact of dropping water from the main dam, the subdam and the apron of rubble concrete are provided. The design of the subdam is made in the same manner as the main dam. The sidewall is constructed of wet masonry to stabilize the river bank.

Fig. 5.1-14 shows the typical structure of sabo dam and the principal dimensions of each proposed dam such as height, upstream slope of main dam, volume of structure, etc.

(2) Continuous Low Dam

Continuous low dams 110 in number and 4 m high are provided in the small river basin situated in the area between Estánquez and the junction of the Chama River with the Nuestra Señora River, and in the Nuestra Señora River Basin. The continuous low dams with rubble concrete is designed in the same manner as the sabo dam. The typical sections of design features are shown in Fig. 5.1-15.

(3) Retaining Wall

Retaining wall of rubble concrete using stone available at the site is useful for the prevention of gully erosion and it will not be swept away by a tumultuous rush of water. Fig. 5.1-16 shows the typical sections.

Flood Control

(1) Excavation of Riverbed

Riverbed excavation is proposed to increase the flow capacity of the low water channel and obtain the construction materials for the dike.

(2) Dike

Dike is constructed of earth which is obtainable through the excavations from the existing river channel at a relatively low cost.

The typical cross section of dike is shown in Fig. 5.1-17. Dike slopes are 1:2 from the viewpoint of stability of soil. It is necessary to sod the slopes of the dike to prevent erosion by rainfall or river water.

Gravel-paved road 3 m in width is constructed on top of the dike to permit movement of maintenance equipment.

(3) Revetment

Revetment which is used for protecting the dike at the water colliding front from erosion by river water, is of wet masonry using cobblestones available at the project sites. In front of the revetment, pieces of gabion mattress are placed to protect the revetment foot from scouring. Fig. 5.1-18 shows the standard drawing of revetment.

(4) Groin

Groins are used for deflecting strong currents of more than 2 m/s in the downstream of the Chama River. Accordingly, short semi-permeable groins built of gabion cylinder are employed and they are set at right angles with the axis of the current.

The standard cross section of the groin is shown in Fig. 5.1-19. The spacing between groins was determined as two times the groin length.

(5) Groundsill

A rubble concrete groundsill is placed to prevent the foundation of Chama Bridge from scouring caused by flow water. The crest elevation is equal to the riverbed elevation. Concrete revetment at right and left sides of groundsill and apron of gabion mattress are placed in the lower reaches for protection against scouring. The structural profile is shown in Fig. 5.1-20.

(6) Extension of Puerto Chama Bridge

The existing Puerto Chama Bridge 10.9 m wide and 137 m long consists of 1 steel span and 2 concrete spans. In consonance with the construction of dike along each side of the river, it is necessary to extend the existing bridge by 480 m. The extended portion is of 16 concrete spans, each of which is 30 m long. The profile of the proposed bridge extension is shown in Fig. 5.1-21.

5.1.4 Cost Estimates

Project Cost

The project cost, consisting of direct construction cost, compensation cost, engineering services cost, government administration cost, and physical contingency, is estimated on the following conditions and assumptions, and are expressed in bolivar (Bs), the Venezuelan currency.

- Cost for all works is estimated on the price level of January 1989.

- Currency conversion rates are US$1.00 = Bs 40 = ¥130.

- Project works are to be done by contract.

- Cost is estimated on unit cost basis, which consists of direct and indirect costs. Direct cost consists of the cost of labor, materials, and construction equipment and plant. Indirect cost consists of field administration and supervision, corporate overhead and profit, security and safety control, and other incidental costs of the contractor. 30% of the direct cost was assumed as the indirect cost.

- Labor wage, listed in Table 5.1-7, was prepared on the basis of data collected from government offices and contractors.

- Prices of construction materials shown in Table 5.1-8 were obtained from suppliers and contractors.

- Direct construction cost is estimated by multiplying the work quantities by the unit cost.

- Government administration cost is assumed at 5% of the direct construction cost and land acquisition cost, and engineering services cost for detailed design and construction supervision is assumed at 10% of the direct construction cost.

- Physical contingency is estimated at 10% of the total cost.

The overall cost of the proposed basin-wide project is estimated at 3,503 million bolivares as tabulated below. The detailed estimation is shown in Table 5.1-9.

	Cost Item	Sediment Control	Flood Control	Total
I.	Direct Cost	1,014	1,657	2,671
II.	Land Acquisition	-	108	108
III.	Engineering Services, Administration Cost and Physical Contingency	269	455	724
	Total	1,283	2,220	3,503

OMR Cost

Annual OMR cost is divided into four major components; namely, (1) administrative expenses for personnel; (2) owner cost of equipment, including operator wage, fuel charges and equipment expenses;

(3) construction and maintenance costs for office buildings; and (4) materials cost of structures requiring replacement.

As a result, annual OMR cost was estimated at 7.4 million bolivares after completion of the whole project. This amount is equivalent to 0.21% of the overall project cost.

5.2 Local Project

5.2.1 Sediment Control

The object of local project for sediment control is to protect roads and houses from debris/sediment flow, slope failure and bank erosion. The project area has been specified as Route No. 2 and No. 7 of the arterial road.

<u>Project Scale</u>

With regard to the project scale of master plan, the return period of a 100-year was adopted in consonance with that for the flood control plan of both basin-wide and local disaster preventions, that was determined from social and technical aspects.

<u>Prevention Methods</u>

Depending on the types of sediment disaster, the prevention works were selected as follows:

(1) Debris/Sediment flow

All debris/sediment flows have taken place in small rivers running out to the arterial roads. Steep-sloped riverbeds accelerate the flow velocity resulting in the erosion of the river bank and the bed. The prevention method is to be a check dam which may stabilize the river bank and the bed, as well as control the sediment discharge.

(2) Slope Failure

All the cut slopes along the arterial road Route No. 7 have been well treated with sodding, shotcreting or wire sheeting, but the natural slopes along Route No. 2 have been left without any protection works. Retaining walls are proposed to stabilize the slopes.

(3) Bank Erosion

Some portions of the arterial road have been eroded by water flow. Serious ones were observed along the Chama mainstream at its meandering points. Since the eroded portions are located along the boundary of river terraces, the revetment is suitable as protection works.

5.2.2 Flood Control

Project Scale

The flood of a 100-year return period is adopted as the project scale for the Albarregas and the Portuguesa rivers, with consideration on the social requirement as done in the basin-wide flood control project. As for the Milla River where the river improvement project is going on, a 50-year return period flood is applied in consonance with the ongoing project scale.

Selection of Optimum Method

The local project shall consist of flood control measures to protect the urban areas from flood disasters. River improvement was considered because the diversion channel, retarding basin and reservoir are not realistic due to the topographic and flood damage conditions of the basin.

(1) River Improvement Section

The section for river improvement to mitigate inundation damage in the cities of Mérida and Ejido were decided from the inundation conditions as follows.

- Albarregas River : Between 11.9 km to 12.9 km from the confluence with the Chama River.

- Milla River : Between 0.0 km to 3.04 km from the confluence with the Albarregas River.

- Portuguesa River : Between 2.0 km and 3.4 km from the confluence with the Chama River.

(2) Flow Capacity of the Rivers

The average flow capacity at the sections of Albarregas and Portuguesa rivers were calculated by the uniform flow calculation method at 150 m^3/s and 70 m^3/s, respectively. At the Milla River, the flow capacity was estimated at 30 to 60 m^3/s on the basis of the study results in 1986 (refer to the sector on Flood Control of the Supporting Report).

(3) Design Conditions for River Improvement

The features of the river improvement plan are as follows (refer to Figs. 5.2-1 and 5.2-2).

(a) Albarregas River

Design Discharge	:	180 m^3/s (100-year return period)
Improvement Stretch	:	1,000 m
Standard Cross Section	:	Width of 6 m and depth of 3.5 m
Manner of Improvement	:	Embankment

(b) Milla River

Design Discharge	:	60 m^3/s (50-year return period)
Improvement Stretch	:	3,040 m
Manner of Improvement	:	Excavation

(c) Portuguesa River

Design Discharge	:	130 m^3/s (100-year return period)
Improvement Stretch	:	1,400 m
Standard Cross Section	:	Width of 5 m and depth of 2.5 m
Manner of Improvement	:	Widening of river channel and excavation

5.2.3 Preliminary Design

Sediment Control

Check dam, retaining wall and revetment are proposed. Their typical cross sections are shown in Figs. 5.2-3 and 5.2-5, respectively.

A check dam consisting of dam, apron and sidewall is basically designed in the same manner as the sabo dam described in Subsection 5.1.3. In general, the height of the check dam is less than 5 m. The retaining wall is made of concrete.

Revetment of wet masonry is proposed. The design height shall be 1 m above the design flood level at the river section where the revetment is to be constructed. The length shall be twice the eroded portion.

Flood Control

River improvement works such as excavation of existing channel and additional concrete parapet are proposed for flood control. The additional concrete parapet, 1 m high, is to be built on the existing parapet.

5.2.4 Cost Estimates

The overall project cost of the local project was estimated in the same manner as Subsection 5.1.4 at 48 million bolivares as shown in the following table. The breakdown of the cost is shown in Table 5.2-1.

(Unit: Million Bs)

	Cost Item	Sediment Control	Flood Control	Total
I.	Direct Cost	19	19	38
II.	Engineering Services, Administration Cost and Physical Contingency	5	5	10
	Total	24	24	48

5.3 Construction Schedule

The construction schedule for the master plan was determined in consideration of the priority of project components, work volume, capability of contractors and so on.

5.3.1 Project Components and Prioritization

Project Components

The components of the master plan are as follows:

Sub-Project	Target Asset	Objective	Component	Quantity
Basin-wide Project	Agricultural and Residential Areas in the lower reaches	Sediment Control	Sabo Dam	10 sites
			Continuous Low Dams	110 sites
			Retaining Wall	1,400 sites
		Flood Control	River Channel Improvement	53.4 km
Local Project	Routes 2 & 7 of Arterial	Sediment Control	Check Dam	88 sites

Road		Retaining Wall	6 sites
		Revetment	6 sites
Urban Area of Mérida and Ejido cities	Flood Control	River Channel Improvement	5.44 km

Priority between Basin-wide and Local Projects

The mitigation of disasters is very essential in the whole Chama River Basin; hence, both the basin-wide and the local projects will be implemented simultaneously without giving any priority against each other.

Prioritization of Components of Basin-wide Project

Prevention of flood disasters in the lower reaches can be achieved by both river channel improvement and sediment control. Therefore, sediment control structures are to be constructed together with the river channel improvement works.

(1) Sediment Control

The priority of sediment control plan is designated, focusing on the components of the master plan that will be implemented in every 10-year period. The required work volume in each period is generally determined to be one-third of the master plan, while the works themselves shall be selected from the viewpoints of economic superiority.

On the other hand, the sediment control works in the basin-wide project is to prevent river channel aggradation downstream of El Vigía, so that the lower Chama River will not bring any flood inundation over the lower reaches. Therefore, the work volume of sediment control in every 10-year period shall be determined on how the downstream channel will be improved in the master plan of flood control.

From the above, the required volume of sediment control works shall be determined to minimize the channel aggradation based on the following conditions.

- The channel section to be improved in the first 10-year period is about 25 km with one-side embankment that corresponds to 25% of the total embankment length. Then the lower reaches of 31 km will be improved in the second 10-year period. In the last 10-year period, the remaining portion of the embankment will be carried out.
- The sediment discharge, which has been deposited on the flood-plain, is assumed to be confined in the river channel in proportion to the progress of river improvement.

In accordance with the above conditions, more than the sediment discharge which will be confined due to the river improvement shall be controlled by the sediment control works in every 10-year period. From this, the required volume of sediment control works in every 10-year period was determined to be one-third of the master plan.

(a) Sabo Dam

With reference to the efficiency of 10 sabo dams as discussed in the foregoing (refer to Table 5.1-1), the C-1 dam is the most efficient and the C-5 comes second. The capacity of both the C-1 and the C-5 are insufficient for the required capacity. To assure one-third of the total function of the 10 sabo dams such as sediment regulation and erosion control, the N-1 shall be included in the first 10-year period since this sabo dam will be effective for not only regulation and control but also retention of sediment from the Nuestra Señora River.

Therefore, the C-1, C-5 and N-1 sabo dams shall be constructed in the first 10-year period, and accordingly three dams of

C-2, C-3 and C-4 in the second 10-year period and the remaining C-6, C-7, C-8 and C-9 will be implemented in the last 10-year period.

(b) Torrent Works

Among 7 sub-basins, Sub-basin 16 (San Pablo River) has the heaviest sediment production and Sub-basin 8 (Upper Nuestra Señora) has the second heaviest, although the latter is more devastated than the former. This is due to rainfall which is heavier in Sub-basin 16.

Since Sabo Dam C-5 will play a role in retaining the sediment discharge from Sub-basin 16, Sub-basin 8 shall be the priority area for the torrent control works in the master plan. Therefore, the total number of 18 continuous low dams will be constructed in the first 10-year period along three torrents, namely Mucusás with 10 sites, Mucusurú with 5 sites and Mucusós with 3 sites. Then, the 44 low dams on the lower Nuestra Señora, Arbolote, Maruchi La Víscaina, El Molino, El Anís, etc., will be constructed in the second 10-year period and the remaining 48 dams will be in the last 10-year period.

(c) Hillside Works

As discussed for the torrent control works, priority shall be given to Sub-basin 8 (Upper Nuestra Señora River), together with Sub-basin 9 (Lower Nuestra Señora River). Therefore, the retaining walls of 340 sites, i.e., 230 sites in Sub-basin 8 and 110 sites in Sub-basin 9, will be constructed in the first 10-year period. In the second 10-year period, 450 sites of retaining walls in the Arbolote, La Víscaina, Maruchi, El Molino, El Anís, etc., will be constructed and the remaining 610 sites will be in the last 10-year period.

(2) Flood Control

From the technical and economical aspects, priorities for river channel improvement were made in accordance with the following considerations. The priorities of construction based on these considerations are shown in Fig. 5.3-1.

- Embankment should be provided for the stretch where the flood damage is serious. Since the flood damage is emphasized with that on the plantain, high priority will be given to the area where plantain plantation is dominant in land use.

- High priority is also given to the area where the residential area may be widely involved in the probable inundation area such as El Vigía and La Fortuna.

- In the other areas, priority is given in the order of the stretch form the upper part to the lower part, as generally promoted, in the embankment works. Since the flood water is hardly confined in the river channel by only embankment in the lower part.

- However, the embankment of the uppermost area should be carefully provided, since the sediment from the upper reaches will adversely affect the maintenance of the design riverbed, unless the sediment control structures are completed in the upper reaches.

Local Project

(1) Protection of Road (Route 2 & 7)

Although the work sites of the local project for sediment control are scattered over the basin, the total volume of the project is rather small compared with the basin-wide project. Therefore, all the sediment control works for the local project can be implemented in the first 10-year period, namely until the year 2000.

Among the works such as check dams for 88 small streams, retaining walls for 6 unstable slopes and revetments for 6 erodable river banks, the priority of construction should firstly be given to the retaining wall and secondarily to the check dam in consideration of the urgency and danger to human life and property.

(2) Protection of Urban Area of Mérida and Ejido Cities

The priority for protection of the urban areas will be given according to the magnitude of expected damage. In this context, protection of Mérida City will have a higher priority in view of the existing land use.

5.3.2 Construction Schedule

Work Items

The objectives and work items of the basin-wide and local projects are summarized according to priority in the following table.

Sub-Project	Objective	Items of Work
Basin-wide Project	Sediment Control	(1) Sabo dams C-1, C-5 and N-1; torrent works of 18 sites; hillside works of 340 sites.
		(2) Sabo dams C-2 to C-4; torrent works of 44 sites; hillside works of 450 sites.
		(3) Sabo dams C-6 to C-9; torrent works of 48 sites; hillside works of 610 sites.
	Flood Control (Fig. 5.3-1)	(1) Reinforcement of existing dike (10.4 km), embankment for the plantain plantation in a stretch of 24.7 km, and construction of groundsill.
		(2) Embankment for the other area including plantain plantation in the stretch of 31.4 km and extension of Puerto Chama Bridge.
		(3) Embankment for the remaining area including the uppermost open area.
Local Project	Sediment Control for protection of arterial road	(1) Check dams of 88 sites; retaining walls of 6 sites, revetments of 6 sites.
	Flood Control for protection of Mérida and Ejido cities	(1) River improvement of 1.0 km of the Albarregas and 3.04 km of the Milla River in Merida and 1.4 km of Portuguesa River in Ejido.

Construction Time Schedule

In accordance with the items of work mentioned above, the construction time schedule of the whole project shown in Fig. 5.3-2 was prepared in consideration of the following:

- Implementation period is 30 years.
- Daily working hours is set at 8 hours, Mondays to Fridays, and annual working days for construction is assumed at 220 days for concrete and stone works, 190 days for excavation works, and 165 days for embankment works, excluding Saturdays and Sundays, holidays and rainy days.

Although the flood control plan of the master plan is formulated at the project scale of 100-year return period, the action plan corresponding to the first 10-year period work volume is proposed at the project scale of 10-year return period as mentioned in Chapter 6. In this connection, the enhancement work for the dike from a 10-year return period to a 100-year return period will be executed in the last 10 years between 2011 and 2020.

5.3.3 Disbursement Schedule

In accordance with the construction time schedule shown in Fig. 5.3-2, 10-year disbursement schedules for Phase 1, 2 and 3 were obtained as follows:

(Unit: million Bs)

Cost Item	Phase 1	Phase 2	Phase 3	Total
Basin-wide Project				
I. Direct Cost				
A. Sediment Control	410	283	321	1,014
B. Flood Control	394	810	452	1,656
Sub-Total	804	1,093	773	2,670
II. Land Acquisition	33	28	47	108
III. Administration Cost, Engineering Services Cost and Physical Contingency	218	294	213	725
Total	1,055	1,415	1,033	3,503
Local Project				
I. Direct Cost				
A. Sediment Control	19	-	-	19
B. Flood Control	19	-	-	19
Sub-Total	38	-	-	38
II. Administrative Cost, Engineering Services Cost and Physical Contingency	10	-	-	10
Total	48	-	-	48

As for the operation, maintenance and replacement cost, the following were obtained.

(Unit: 10^3 Bs)

Year	Personnel Expenditures	Machinery	Office	Materials	Total
2001-2010	1,300	800	100	1,300	3,500
2011-2020	1,500	1,600	100	2,200	5,400
2021-2050	1,700	2,500	100	3,100	7,400

5.4 Project Evaluation

Economic and financial studies were carried out for the Master Plan that was formulated with the design period of 2020 to solve the major problems caused by flooding water and sediment flow. The basic conditions for the studies are mentioned in the following subsections, and all the calculations in monetary terms are based on the price level of January 1989. The project life (for economic evaluation) is fixed at 60 years considering the life of structures to be constructed for the project.

5.4.1 Economic Viability of the Master Plan

Project benefit is defined as the difference in damage by flooding water and sediment flow between the with- and the without-the-project situations. Hence, the damage in both situations have to be estimated to quantify the project benefit in monetary terms in consideration of the future change of land use in the probable inundation areas and the increase of traffic volume, though the estimates may be uncertain to some extent.

Damage in the Chama River Basin can be classified into three categories, as discussed hereafter.

(1) Damage Due to Submergence by Floodwaters

Damage due to submergence by floodwaters mainly affects the cultivated land, mostly plantain plantations, in the lower reaches and some properties consisting of houses and household effects in Mérida and Ejido in the upper reaches. A vast pasture land and small patches of vegetable plantations lie in the lower reaches, but the former is far from vulnerable to flood damage and the area of the latter is so small that the damage cannot be figured out.

The damage rates for plantain were estimated according to inundation depth and duration, based on a 20 cm inundation depth and a 3-day flood duration (see Table 5.4-1). The forecast of cultivated land in the lower reaches is in Table 5.4-2.

(2) Damage Due to Traffic Interruption by Sediment Disaster

Damage due to traffic interruption by sediment from slope failure, debris flow, etc., includes the augmentation of operation cost of vehicles affected by detouring and speed-down, as well as loss of productivity of people who may lose their time for economic activities. This takes place in the upper/middle reaches.

Table 5.4-3 presents the estimated traffic volume at the years 2000, 2010 and 2020 in the 28 probable disaster points, the estimated damage by traffic interruption and the detailed figures used for calculation.

(3) Indirect Damage

Indirect damage includes loss of income and sales of the affected people, adverse economic influence to the nation, deterioration of sanitary conditions, etc.

The indirect damage is assumed to correspond to 20% of the total of the damages mentioned above.

Annual Average Benefit

The damages due to flooding water and traffic interruption are estimated for several probable rainfalls or discharges by applying the calculation conditions set forth in Table 5.4-4. The annual average benefit is figured out from the following formula.

$$B = \sum_{i=1}^{n} 1/2\,[D(Q_{i-1}) + D(Q_i)] \times [P(Q_{i-1}) - P(Q_i)]$$

where,

B	:	Annual average benefit
$D(Q_{i-1}), D(Q_i)$	:	Flood damage caused by the floods with Q_{i-1} and Q_i discharges, respectively
$P(Q_{i-1}), P(Q_i)$	:	Probabilities of occurrence of Q_{i-1} and Q_i discharges, respectively
n	:	Number of floods applied

The master plan has been formulated on the scale of a 100-year return period flood and its annual average benefit is expected to increase to 126, 170 and 231 million bolivares at the years 2000, 2010 and 2020, respectively, assuming that the project will be completed by the year 2020. The breakdown of annual average benefit in 2020 is shown in Table 5.4-5.

Economic Project Cost

The economic costs of the project are nominal figures that duly reflect the true economic value of goods and services involved. These costs were used only for the economic evaluation of the project.

Transfer items such as taxes and duties imposed on construction materials and equipment, including government subsidy and contractor's profit, should be excluded from the elements of financial cost. It is assumed that about 20% of the financial construction cost is involved in the transfer items.

Land has to be acquired for project implementation, and its economic value is considered to correspond to the productivity foregone by the project, which is reflected by the price.

The economic project costs for the master plan is estimated at 2,866 million bolivares.

Economic Viability of the Master Plan

The economic viability of the master plan was assessed using three indicators: internal rate of return (IRR), cost-benefit ratio (B/C) and net present value (NPV). Calculations were made in consideration of the annual cash flow prepared from the economic project cost and the annual average benefit previously discussed. The economic viability of the master plan is as shown below and its annual cash flow is shown in Table 5.4-6.

IRR : 10.7%
B/C : 1.22
NPV : 244.20 million bolivares
(Note: Discount rate is 8% for B/C and NPV.)

5.4.2 Financial Consideration

The annual growth rate of GDP in the recent years resulted in 3.3% on an average, which is almost equivalent to the rate projected in the Seventh National Development Plan. On the average, about 22% of the GDP has been earmarked for the national budget in these five years, 3% of which is allocated to the MARNR. This rate of allocation is growing at about 10% annually on the average. Public investment for development and/or conservation projects in the State of Mérida and the region south of Maracaibo Lake is made mainly by MARNR Zone Office No. 16 and the MARNR regional office for the region south of the Maracaibo Lake. The public investment of these offices accounts for about 2% of the total budget. (See Table 5.4-7.)

To forecast the available fund for public investment in these areas, two cases are examined under the different combinations between the growth rate of GDP and the ratio of budget allocation to the MARNR. One is 3% and 3% as the minimum case, and the other is 4% and 4% as the maximum case, respectively. The public investment thus examined for the 1991-2020 period ranges from 5,100 million bolivares to 8,300 million bolivares. (See Table 5.4-8.)

The total cost of the master plan is estimated at 3,551 million bolivares. In case that the master plan is implemented under the

MARNR's budget, the allocation rate of public investment will amount to as much as 70% in the above-said minimum case, as shown in Table 5.4-8. Under these circumstances, the MARNR's budget may not be able to handle all the funds for the project.

Assuming that 50% of the required cost is funded by an international financing agency on the conditions of 8% annual interest and 20-year repayment period including a 5-year grace period, the annual disbursement for the master plan was calculated as shown in Table 5.4-9.

5.4.3 Socioeconomic Impacts

Project implementation could exert favorable influence on not only the Chama River Basin but also the whole nation. The favorable impacts are summarized as follows:

- The national roads leading to the other major cities will be released from traffic interruption caused to sediment flow. Nationwide circulation of commodities will be secured resulting in the stabilization of the people's living condition in the whole country.

- Due to non-flooding in the lower reaches where fertile lands exist, it becomes possible to produce more plantain or other crops with a higher productivity than the pasture land, even in the present flood risk areas.

- A number of engineers, technicians, laborers, etc., will be required for project implementation, so that increase of employment opportunities is expected, at least during the construction period.

Environmental influence by project implementation is generally assessed from the water quality, fauna/flora and aesthetic scenery. The proposed structures will not have any adverse effect on these items, and may even improve water quality.

5.4.4 Project Justification

For infrastructure projects such as power generation, transportation and water supply works, project justification is generally based on economic viability. The IRR of the master plan is 10.7%, and other indicators also show high values. From the economic viewpoint, therefore, the master plan which was formulated on the project scale of a 100-year return period flood is justifiably viable for implementation.

CHAPTER 6. ACTION PLAN

6.1 Basin-wide Project

In accordance with Chapter 4, Principles of Project Formulation, the action plan was formulated with the projects included in the first 10-year construction schedule of the master plan.

6.1.1 Sediment Control

Project Scale

The action plan for basin-wide sediment control adopts the annual average sediment discharge in consonance with the project scale of the master plan.

Alternative Study Cases

The sabo dam, continuous low dam and retaining wall were selected as the optimum methods for the basin-wide sediment control works in the master plan through the study on alternatives. As a result, 3 sabo dams, 18 continuous low dams and 340 retaining walls were included in the optimum method for the action plan. The study on alternatives was made to select the most suitable structure type and materials to be employed for the said structures. The study cases are shown in Table 6.1-1 and the manner of selection of the optimum cases is described hereinafter.

Selection of Optimum Case

(1) Sabo Dam

(a) Structure Type

Among the five types of sabo dam, namely gravity, fill, arch, steel frame and concrete block, the following considerations were taken into account in the selection of the optimum structure type for the three sabo dams at sites C-1, C-5 and N-1.

- Judging from the topographic and geological conditions of the sites, an arch dam may not be feasible.

- A fill dam is not suitable since the river width is too narrow to construct a spillway for the big design discharge and it is difficult to divert floods by means of a diversion channel or tunnel.

- A gravity dam has technical advantages over the other types like the steel frame and concrete block if a high dam of more than 15 m is required. However, it is not applicable to the sites on the Bocono fault which has been reported to have a transformation of 1 cm per year on an average.

- Both the steel frame type and the concrete block type are applicable at the sites on the fault because of flexibility against transformation. From the economical aspect, however, the former type has an advantage over the latter.

From the above considerations, the optimum types of sabo dam were selected as follows:

- Gravity type is selected for the C-1 and N-1 dams whose sites are far from the Bocono fault.

- Steel frame type with the height of 9 m is selected for the C-5 dam which is situated on the Bocono fault.

For the gravity type of C-1 and N-1 dams, the construction costs according to material are as shown in the following table. The comparison of cost leads to the selection of the rubble concrete as the most suitable type.

Sabo Dam	Material	Construction Cost (million Bs)
C-1	Concrete	202
	Rubble Concrete	149
	Masonry	159
N-1	Concrete	196
	Rubble Concrete	135
	Masonry	163

(2) Torrent Works

Torrent works consisting of 18 continuous low dams are provided at the three torrents; 10 at Mucusás, 3 at Mucusós and 5 at Mucusurú.

(a) Structure Type

There are three applicable types of torrent works; gravity, steel frame and concrete block. The comparative study has selected the gravity type of dam from the economical aspect, since no geological condition requiring a sustainable type of dam against weak foundation was identified at the proposed construction sites.

(b) Materials

The riverbed materials in the three torrents are mostly composed of slate which is easy to weather. Therefore, these riverbed materials are not applicable as concrete aggregate but only as rubble aggregate inside the dam body. The wet masonry with rubble inside of the dam body was then selected as the optimum material for the continuous low dam, although the hard materials must be brought from the other sites of wet masonry.

(3) Hillside Works

(a) Structure Type

As shown in Table 6.1-1, the gravity and anchor types of hillside works are applicable for retaining walls. The gravity type which has economical advantages over the anchor type was selected as the optimum structure type.

(b) Materials

Among the materials applicable for retaining walls of the gravity type, the wet masonry was employed due to availability in the structure sites and at the steep slopes of gullies.

6.1.2 Flood Control

In the action plan for flood control, river embankments are provided on a total stretch of 24.7 km, as shown in Fig. 6.1-1, in accordance with the first 10-year schedule of the master plan.

Project Scale

For the basin-wide action plan of flood control where the river embankments mentioned above are to be urgently provided for the protection of high priority areas, a 10-year return period flood is employed as the project scale. This scale of the urgent project was determined under the following considerations. Table 6.1-2 shows the design features of the dike.

- To facilitate project realization, the project scale of 5 to 10-year return period is generally applied to action plans for flood control.

- Economic efficiency in the Chama River Basin tends to increase in proportion to design flood probability of up to 30-year return period, as discussed in Chapter 5; thus, a higher economic efficiency is expected with a larger project scale.

- Even if the embankments are provided under the action plan, inundation by flood will still occur in the stretch where a dike is not provided. However, the peak discharge of 2,300 m^3/s of a 100-year return period flood is expected to be reduced to less than discharge of a 10-year return period flood by the retarding function of the inundation area.

Alternative Study Cases

The main structures applied for flood control include dike, revetment, groin, and groundsill. For selection of the optimum structure type and suitable materials, alternative studies were made with the following conditions. The study cases are shown in Table 6.1-3.

- In the case of dike construction, the study has to be made only to confirm the applicability of the earth materials obtainable at the construction sites, since earth material is the only material applicable from the technical and economical points of view.

- For the protection of dike against erosion, two kinds of structures are applicable; namely, revetment and groin, depending on the section of dike to be protected, i.e, the section with water colliding front, and the section with high current velocity. In this flood control plan, the revetment is applied to the former and groin is to the latter, and then a study was made to select the most suitable material for each kind of structure.

- As for the groundsill, a study was made for the selection of the suitable materials.

Selection of Optimum Case

(1) Dike

In accordance with the conditions set for the selection of optimum structure type and materials discussed above, the availability of earth materials obtainable at the construction site was confirmed putting emphasis on the following aspects.

- The material can withstand changes in weather conditions.
- The material does not contain organic matter.

- The material is easily compacted.

The Chama River downstream of El Vigía can be broadly divided into two stretches separated by the alluvial fan. The riverbed of the upper stretch is composed of sand and gravel, while that of the lower stretch is mainly silty clay. Through the field investigation, it was identified that both materials can be used for embankment by themselves or adding a small amount of sand or clay.

(2) Revetment

Among the five cases of applicable materials for revetment, comparison was made from the technical and economical aspects as shown in Table 6.1-4. Judging from this table, the wet masonry which has a high reliability for the protection of the dike and economical advantages, was selected as the most suitable material.

(3) Groin

A comparison to select the suitable materials for groin was also made among the three materials, as shown in Table 6.1-5. The gabion was selected because of economical advantages, since there is not much difference in function according to material.

(4) Groundsill

Rubble concrete is selected as the applicable material for groundsill due to its economical advantage, as shown in the following table.

Material	Cost (million Bs)
Rubble Concrete	22.1
Concrete	25.4
Concrete Block	25.4
Textile Form Concrete	23.5

6.1.3 Preliminary Design

Sediment Control

(1) Sabo Dam

(a) Seismic Condition

Since the Chama River Basin was formed by the active Bocono fault, the construction sites of the proposed sabo dams are located at the most probable earthquake disaster zone in Venezuela. In this connection, seismic force is essential to the dam design. Therefore, a bigger seismic coefficient of K = 0.18 is employed with reference to "Propuesta de Normas para el Diseño Sismorresite de Puentes" (Proposal for Design Standards Against Seismic Force for Bridges), as well as the results of the analysis on seismic data from 1910 to 1970.

(b) Overflow Section

An overflow section is provided at such position and direction that overflow water may easily concentrate to the center of the downstream to assure river channel stabilization. The bottom width of the overflow section is the same as the river width to minimize the water depth over the dam crest. The overflow depths estimated for each sabo dam site are as follows.

Dam Site	Design Discharge (m^2/s)	Bottom Width (m)	Top Width (m)	Overflow Depth (m)
C-1	2,300	100	105.4	5.4
C-5	1,950	75	80.9	5.9
N-1	610	100	102.3	2.3

(c) Main Dam

For the crest width of the main dam, 3 m is employed from the viewpoint of stability of the dam crest and safety against erosion by sediment. For the down slope, the gradient of 1:0.2 is employed and not to be steeper than the nap of sediment flow from the overflow section so as not to be damaged by sediment. The gradients of the upstream slopes; namely, 1:1.1 for C-1 dam, 1:0.7 for C-5 dam and 1:1.1 for N-1 dam, were obtained by Stability Analysis. The dam body is to be embedded more than 2.0 m below the existing riverbed.

Since the dam foundation is composed of alluvial deposit, it is necessary to estimate safety against piping. A study was made by Justin's critical velocity and as a result, no piping is anticipated at any of the dam sites.

(d) Subdam and Apron

Since the riverbed is formed by deep alluvial deposit, it is necessary to provide a subdam, apron, sidewall at the downstream of the main dam, so that the riverbed will not be scoured by the impact of water dropped from the overflow section. The major dimensions of the subdam and apron were estimated for each sabo dam as shown in the following table. The plan, front view and standard cross section of each dam are shown in Figs. 6.1-2 to 6.1-4.

Dam Site	Apron Length L (m)	Sidewall Height H (m)	Subdam Height D (m)	Apron Thickness t (m)
C-1	53	10	4.5	2.5
C-5	46	9	2.7	2.0
N-1	29	5	2.7	2.0

(2) Continuous Low Dam

The major dimensions and layout of continuous low dams are shown in Figs. 6.1-5 to 6.1-7. In the action plan, three sites for the continuous low dams were selected, the Mucusurú River (5 dams), the Mucusás River (10 dams), and the Mucusós River (3 dams). As in sabo dams, the continuous low dams are composed of main dam, overflow section, apron and subdam. These are designed on the same conditions as the sabo dams. All dams are 4 m in height and their overflow sections have a flow capacity corresponding to a 100-year return period flood. The body of the main dam is embedded 1 m below the existing riverbed.

(3) Retaining Wall

The retaining wall is designed of wet masonry type by using stone available at the site. The height of retaining wall is 2 m and, it is embedded 1 m below the base of the gully. The typical section is shown in Fig. 5.1-18.

Flood Control

(1) Dike

The standard cross-section of the dike for the basin-wide action plan for flood control is the same as the master plan, but the design height corresponds to a 10-year return period, so that the bottom width of the dike is reduced by about 2.5 m from that of the master plan. The dike for the action plan will be constructed along the footline of the front slope of the dike for the master plan to avoid the double investment for revetment and groin when the dike is enhanced and widened to the design height and width of the master plan. (Refer to Fig. 6.1-8.)

(2) Revetment

Wet masonry is employed for revetment at the water colliding front. The revetment structure consists of a revetment and a foot protection.

Foot protection of gabion is provided at the base to protect the revetment from riverbed erosion. As for the height of revetment, the design height of the master plan is adopted in the action plan to avoid double investment in case the dike height is enhanced to the master plan. The structural details are shown in Fig. 5.1-20.

(3) Groin

Groin of gabion cylinder is provided at the portion where the flow velocity is over 2 m/s. The right-angled groin is employed for arresting sediment and accelerating their deposit. The height, length and interval of groins shown below were calculated by empirical formulas, and their structural details are shown in Fig. 5.1-21.

Height of Groin	:	1.57 m
Interval of Groin	:	20 m
Length of Groin	:	10 m

(4) Groundsill

Groundsill is proposed over the full width of the river 10 m downstream of the Chama Bridge to prevent scouring of the riverbed in the vicinity of its foundation. The structural profile is shown in Fig. 5.1-22.

The crest elevation of the groundsill is equal to the design riverbed elevation and it is embedded 3 m from the riverbed. Concrete revetments are provided at both sides of the groundsill to prevent scouring.

Aprons of gabion mattress are constructed upstream of the groundsill at a length of 7 m and downstream at a length of 20 m for protection against scouring. Gabion mattress is also placed around the pier of the bridge to prevent local scouring.

6.2 Local Project

6.2.1 Sediment Control

There are 88 small streams, 6 unstable slopes and 6 river bank portions along the arterial road routes No. 2 and No. 7 which may have debris flow, slope failure and bank erosion with a downpour of a 100-year return period. As mentioned in Subsection 5.3.1, all the prevention works such as check dam, retaining wall and revetment for the disaster sites can be implemented in 10 years, because the work volumes are small. Therefore, all sediment control works of the local project will be incorporated in the action plan for early implementation.

Check Dam

The check dam to control debris/sediment flow from small streams was selected from among the materials for gravity dam type such as concrete, rubble concrete, masonry and gabion. Since topographic and geologic conditions are similar among the construction sites, there is no difference in design conditions to distinguish the dam materials. The optimum materials were selected from the viewpoint of construction cost.

Comparing construction costs, the wet masonry was selected as the optimum one as shown in the following table.

Materials	Unit Construction Cost (Bs/dam)
Concrete	117,000
Rubble Concrete	75,000
Wet Masonry	61,000
Gabion	63,000

Retaining Wall

The retaining wall for the local project is of a leaning-to-slope type made of concrete. This wall shall be extended longer than the contacting distance between the collapsing slope and road. The leaning type is more economical than the self-supporting type due to the required volume of concrete. The height of retaining wall is set at 2 m above the road surface. The dimensions of the proposed retaining walls are presented in Table 6.2-1.

Revetment

As discussed in Subsection 6.1.2, Flood Control, four materials applicable for revetment to protect river banks from erosion caused by flood discharge were studied. They are of concrete, wet masonry, gabion and textile form concrete.

The gabion requires some stronger plastering or cover of concrete to protect the gabion from colliding boulders and cobbles. In consideration of this additional protection works, the construction costs for the said four materials of revetment were compared as shown in the following table, resulting in the selection of the wet masonry which shows the lowest cost. The location and dimensions of the works at 6 sites are presented in Table 6.2-2.

Material	Construction Cost (Bs/m)
Concrete	18,300
Wet Masonry	8,350
Gabion	9,330
Textile Form Concrete	11,820

6.2.2 Flood Control

For the formulation of the flood control works for the local project, the following considerations were made.

- As noted from the construction cost and work volume for the master plan, those of the local flood control projects is less than 1% of those of the basin-wide project. Thus, all the flood control works of the local project formulated under the master plan may be put into execution in the action plan stage, since they will not affect the feasibility of the Chama River Basin Conservation Project.

- Although the project scale of the basin-wide flood control project is reduced to a 10-year return period to facilitate project execution, the project cost for local projects will not affect the total cost. Thus, it is recommendable to apply the project scale of the master plan to the action plan to ensure safety against flood disasters and to avoid double investment.

- Since the data available for project formulation was used for the study on the master plan, further modification of the contents of the plan is not necessary when the same project scale and river improvement stretch are applied to the action plan.

In view of the above considerations, the flood control plan of the local project under the master plan is applied to the action plan. In accordance with the contents of the master plan, the project features of the action plan are summarized as follows.

(a) Albarregas River

Design Discharge	:	180 m^3/s (100-year return period
Improvement Stretch	:	1,000 m
Standard Cross-Section	:	6 m wide x 3.5 m deep
Improvement Type	:	Embankment

(b) Milla River

Design Discharge	:	60 m^3/s (50-year return period)
Improvement Stretch	:	3,040 m
Improvement Type	:	Excavation

(c) Portuguesa River

Design Discharge	:	130 m^3 (100-year return period)
Improvement Stretch	:	1,400 m
Standard Cross-Section	:	5 m wide x 2.5 m deep
Improvement Type	:	Channel widening and excavation

6.2.3 Preliminary Design

Reference is made to Figs. 5.1-1 to 5.1-5, since the local project of the action plan is the same as the master plan and the preliminary design is also the same as the master plan.

6.3 Construction Schedule and Cost Estimates

In this section, the construction schedule and cost estimates for the action plan are studied considering the prioritization of project components, work quantities, construction methods and so on.

6.3.1 Project Components and Prioritization

<u>Project Components</u>

The components of the action plan are as follows.

Sub-Project	Objective	Component	Quantity
Basin-wide Project	Sediment Control	Sabo Dam	3 sites
		Continuous Dams	18 sites
		Retaining Wall	350 sites
	Flood Control	River Channel Improvement	24.7 km
		Reinforcement of Existing Dike	10.4 km
		Groundsill	1 in number
Local Project	Sediment Control	Check Dam	88 sites
		Retaining Wall	6 sites
		Revetment/Wall	6 sites
	Flood Control	River Channel Improvement	5.44 km

Basin-wide Project

Although flood disasters can be prevented by river channel improvement, sediment control is indispensable to assure the capacity of the river channel to convey floods safely to the Maracaibo Lake. Hence, sediment facilities are to be provided simultaneously with the river channel improvement works.

(1) Sediment Control

Sediment control structures including sabo dams, hillside works, etc., are provided to control the discharge of excess sediment at the river channel. The prioritization of facilities was decided as follows.

(a) Sabo Dam

Among the three sabo dams, namely C-1, C-5 and N-1, the first priority of construction shall be given to C-1 whose site is nearest to the target area and it most efficient in controlling sediment discharge. The second priority shall be given to C-5 which is the second most efficient and effective in controlling channel erosion along the middle stream. N-1 at the Nuestra Señora River shall have the third priority since it is the biggest source of sediment flowing into the target area.

(b) Torrent Works

Among the three torrents, namely the Mucusás, the Mucusurú and the Mucusós, priority of construction shall be given to the most devastated torrent, the Mucusás, with 10 continuous low dams. The Mucusurú will be the second, followed by the Mucusós, with five and three low dams, respectively.

(c) Hillside Works

Between Sub-basin 8 and Sub-basin 9 in the Nuestra Señora River Basin, higher priority shall be given to Sub-basin 8 (upper basin) which has a sediment production volume bigger than Sub-basin 9 (lower basin). Therefore, the retaining walls at 230 sites will first be constructed, followed by the retaining walls at 110 sites.

(2) Flood Control

According to the study results on the master plan, the cost and project benefit expected by river embankment with the project scale of a 10-year return period flood are as follows.

Embankment Stretch	Benefit (1) (10^9 Bs)	Cost (2) (10^9 Bs)	(1)/(2)
No. 3km - 9km	51.0	80.5	0.63
No. 10.4km - 16.7 km	16.2	80.3	0.20
No. 17.9km - 22.3 km	12.4	56.7	0.22
No. 35.0km - 43.0 km	4.4	103.8	0.04
No. 43.0km - 53.4 km	4.9	48.3	0.10

Judging from the above table, the economic efficiency expressed by the ratio between the direct cost and the benefit show the tendency to be higher at the lower stretches, except the stretch between 43.0 km and 53.4 km where the existing dike is reinforced. The priority of river improvement will then be put on the basis of this economic efficiency.

As to the construction of groundsill, high priority will be given to the construction of groundsill near the Chama Bridge which is proposed to prevent erosion of the riverbed, since such erosion may promptly appear with the construction of sediment control structures in the middle and upper reaches.

Although the economic efficiency of the reinforcement of the existing dike is not high compared with the river improvement in the lower reaches, high priority should be given to ensure the safety of the existing dike, so that the urban area of El Vigía City can be released from the menace of flood disasters.

The order of construction of flood control structures are as follows.

- Embankment for the stretch between 3,0 km and 9.0 km and construction of groundsill.

- Embankment for the stretch between 10.4 km and 16.7 km and reinforcement of existing dike between 43.0 km and 53.4 km.

- Embankment for the stretch between 18.2 km and 22.3 km.

- Embankment for the stretch between 35.0 km and 43.0 km.

Local Disaster Prevention Project

(1) Sediment Control

The first priority of protection works shall be given to the construction of retaining wall at the unstable slope. Slope failure occurs rather suddenly and may be more dangerous to human life. The second priority will be given to the check dam to control debris/sediment flow, and the third is the portion of the river bank which may be eroded by flood flow.

(2) Flood Control

The prioritization of flood control projects will follow that of the master plan; namely, river improvement of the Albarregas River as first priority, the Milla River as second priority, and the Portuguesa River as the third priority.

6.3.2 Construction Schedule

The construction schedule of the action plan was determined in accordance with the prioritization of project components, taking into account the following considerations (see Fig. 6.3-1).

- Project implementation is 10 years.
- In accordance with rainfall condition, the following are adopted as the workable days: between 138 and 214 days for earth works; between 220 and 243 days for rock works; and, between 216 and 243 days for concrete works.
- Daily working hours are fundamentally 8 hours for Mondays to Fridays. Total working hours per week is not more than 48 hours by the Labor Law.

6.3.3 Construction Cost

As in the master plan, the project cost for the action plan was estimated considering direct construction cost, compensation cost, engineering cost, government administration cost, and physical contingency. Unit prices were based on the price level of January 1989; currency conversion rate is US$1.00 = Bs40 = ¥130.

The total costs for the proposed basin-wide and local projects were estimated at 1,103 million bolivares as shown in the following table. The details of estimation are shown in Tables 6.3-1 and 6.3-2.

(Unit: Million Bs)

Sub-Project/Cost Item	Sediment Control	Flood Control	Total
Basin-wide Project			
I. Direct Cost	409.6	393.9	803.6
II. Land Acquisition	0	33.0	33.0
III. Engineering Services	20.5	21.3	41.8
IV. Administration Cost	41.0	39.4	80.4
V. Physical Contingency	47.1	48.8	95.9
Sub-Total	518.2	536.5	1,054.7
Local Project			
I. Direct Cost	19.3	18.5	37.8
II. Land Acquisition	0	0	0
III. Engineering Services	1.0	0.9	1.9
IV. Administration Cost	1.9	1.9	3.8
V. Physical Contingency	2.2	2.1	4.3
Sub-Total	24.4	23.4	47.8
Grand Total	542.6	559.9	1,102.5

Note: Figures may not add up to totals due to rounding.

6.3.4 Operation, Maintenance and Replacement Cost

Annual operation, maintenance and replacement (OMR) cost, required after completion of the Project, is divided into four major cost components; namely, (a) administrative expenses for government personnel; (b) owner cost of equipment, including operator wage, fuel charges and equipment expenses; (c) construction and maintenance costs for office building; and, (d) materials cost of structures requiring replacement. The annual OMR cost is equivalent to 0.3% of the cost for the action plan, as shown in the following table.

(Unit: 1,000 Bs)

Year	Personal Expenditure	Machinery	Office	Materials	Total
After Completion of Action Plan	1,300	800	100	1,300	3,500

[Note] (1) Necessary personnel for this work is assumed to be one director, one chief engineer, five technicians, two drivers, one typist, and one secretary.

(2) Necessary machinery is assumed to be one bulldozer, one backhoe, one wheel loader, two dump trucks, two station wagons, one pick-up truck, one concrete mixer, and one vibrating roller.

6.3.5 Disbursement Schedule

In accordance with the construction schedule of the basin-wide and local disaster prevention projects of the action plan shown in Fig. 6.3-1, the annual disbursement schedules were determined as shown in Tables 6.3-3 and 6.3-4.

6.4 Evaluation of the Action Plan

The action plan for sediment and flood disasters is formulated at the target year 2000. The basic conditions for the economic and financial studies are the same as the master plan. For the economic evaluation, project life is fixed at 30 years after construction.

6.4.1 Economic Viability of the Action Plan

Project benefit is defined as the difference in damage by flooding water and sediment flow between the with- and the without-the-project situations. Therefore, the damage in both situations has to be estimated to quantify the project benefit in monetary terms in consideration of the future change of land use in the probable inundation areas and the increase of traffic volume in the year of 2000. In view of this consideration, damage in the Chama River Basin can be classified into three categories, as discussed hereafter.

(1) Damage Due to Submergence by Floodwaters

The assets vulnerable to damage due to submergence by floodwaters are the cultivated land, mostly plantain plantations, in the lower reaches and houses/household effects in Mérida and Ejido in the upper reaches. The damage rates for plantain were estimated according to inundation depth and duration as presented in Table 5.4-1, and the cultivated land in the lower reaches at the year 2000 is shown in Table 5.4-2.

(2) Damage Due to Traffic Interruption by Sediment Disaster

Damage due to traffic interruption by sediment discharge, slope failure, debris flow, etc., includes the augmentation of operation cost of vehicles affected by detouring and speed-down, as well as loss of productivity of people who may lose their time for economic activities. This takes place in the upper/middle reaches. The traffic volume in the year 2000 at the 28 probable disaster points was estimated, as shown in Table 5.4-3 together with the estimated damage by traffic interruption and the detailed figures used for calculation.

(3) Indirect Damage

Indirect damage includes adverse economic influence to the nation, deterioration of sanitary conditions, negative aesthetic effects of flood/debris flow, etc. The indirect damage is assumed to correspond to 20% of the total of the damages mentioned above.

Annual Average Benefit

The damage due to flooding water and traffic interruption is estimated for several probable rainfalls or discharges by applying the calculation conditions in Table 5.4-4. The annual average benefit was figured out from the same formula used in the master plan.

The annual average benefit of the action plan is estimated at 126 million bolivares at the year of 2000. The breakdown is shown in Table 6.4-1.

Economic Project Cost

The economic costs of the project are nominal figures that duly reflect the true economic value of goods and services involved. These costs are used only for the economic evaluation of the project. Transfer items such as taxes and duties imposed on construction materials and equipment, as well as government subsidy, are excluded from the elements of financial cost, and shadow wage rates should also be applied to unskilled labor.

The CORDIPLAN conducted a study on conversion factors from the financial cost to the economic cost and also on the shadow wage rate for unskilled labor. In this connection, the construction cost for the action plan was classified as presented in Table 6.4-2, and the following rates were applied for the calculation of economic cost. Foreign currency and other labor items were taken into account as estimated.

- Common Labor (unskilled labor) : 0.55
- Light Oil (diesel oil) : 4.06
- Lubricant : 1.46
- Concrete : 0.76
- Other Materials : 0.80
- Construction Equipment : 0.73

Land has to be acquired for project implementation, and its economic value is considered to correspond to the productivity foregone by the project, which is reflected by the price.

The economic project costs for the action plan is estimated at 907 million bolivares, and the breakdown is presented in Table 6.4-3.

Economic Viability of the Action Plan

The economic viability of the action plan was assessed using three indicators; internal rate of return (IRR), cost-benefit ratio (B/C) and net present value (NPV). Calculations were made in consideration of the annual cash flow prepared from the economic project cost and the annual average benefit previously discussed. The economic viability of the action plan is as shown below and its annual cash flow is shown in Table 6.4-4.

IRR : 13.2%
B/C : 1.58
NPV : 346.52 million bolivares
(Note: Discount rate is 8% for B/C and NPV.)

6.4.2 Financial Consideration

The MARNR's available fund for public investment is forecast in two cases as discussed in Subsection 5.4.2, ranging from 1,230 to 1,780 million bolivares for the 1991-2000 as given in Table 5.4-7.

The MTC of Mérida State expends a considerable amount of its budget to maintain roads and highways, which shares about 8% of its budget for all the projects on an average for these five years. A large part of this maintenance cost will be saved through the implementation of the action plan, so that the MTC can also be a source for financing the plan.

Assuming that 50% of the road maintenance cost can be allocated to this plan, the available fund is estimated to be in a range of from 200 million to 220 million bolivares as presented in Table 6.4-5. The total available fund is, therefore, the sum of those from the MARNR and the MTC, which is from 1,480 million to 1,980 million bolivares. The total cost of the action plan is estimated at 1,103 million bolivares. The MARNR has to allocate its budget for public investment by as much as 50% to 70%, as shown in Table 5.4-7. Under these circumstances, the MARNR's budget may not be able to handle all the funds for the project.

Assuming that 50% of the required cost is funded by an international financing agency on the conditions of 8% annual interest and 20-year repayment period including a 5-year grace period, the annual disbursement for the action plan was calculated as shown in Table 6.4-6.

6.4.3 Socioeconomic and Environmental Impacts

Project implementation could exert favorable influence on not only the Chama River Basin but also the whole nation. The favorable impacts are summarized as follows.

- The national roads leading to the other major cities will be released from traffic interruption caused by sediment flow. Nationwide circulation of commodities will be ensured resulting in the stabilization of the people's living condition in the whole country.

- Due to non-flooding in the lower reaches where fertile lands exist, it becomes possible to produce more plantain with a higher productivity than the pasture land, even in the present flood risk areas.

- A number of engineers, technicians, laborers, etc., will be required for project implementation, so that increase of employment opportunities is expected, at least during the construction period.

Environmental influence by project implementation is generally assessed from the water quality, fauna/flora and aesthetic scenery. Turbidity of river water may be decreased by preventing sediment from flowing into the lower reaches. In constructing some structures in a river channel, the matter of most concern from the environmental viewpoint is the life of fishes going up and down the streams.

The Chama River is rich in trouts, but they are raised in man-made fishponds that take in water from the river. Therefore, the structures to be constructed will not deteriorate the present situation. Sediment control structures which restrain the development of land erosion, may contribute to the growth of vegetation. Under this situation, they will not give any adverse influence on the fauna and will give a favorable influence on the flora in the basin.

6.4.4 Project Justification

For infrastructure projects such as power generation, transportation and water supply works, project justification is generally based on economic viability. The IRR of the action plan is 13.2%, and the other indicators also show high values; 1.58 of B/C and 347 million bolivares of NPV. From the economic viewpoint, therefore, the action plan which is formulated on the project scale of a 10-year return period flood is justifiably viable for implementation.

6.5 Organization for Project Execution

Several agencies are concerned in the Chama River Basin Conservation Project, and it may be difficult to adopt the existing organization to realize this project due to staff and technical limitations. Therefore, it is desirable to establish a new project office that will exclusively cater to its realization.

The following points are considered in the establishment of the project office.

- Like in other project offices for this kind of project, the project office shall have the following functions: (1) planning and design, (2) construction, (3) equipment and materials, and (4) operation and maintenance.

- The project shall be divided into two sub-projects: (1) the basin-wide project and (2) the local project. Both projects shall cover sediment control and flood control, although the latter is for the sediment control on roads and flood control on urban areas.

- A coordinating committee shall be established to ensure the funds and budget for prioritization and to coordinate the activities of the agencies concerned such as the MARNR, MTC and MAC.

From the above considerations, two kinds of organizations are proposed. One is putting emphases on the functions of planning, design, construction, etc., and the other is on the engineering field such as flood control and sediment control as shown in Figs. 6.5-1 and 6.5-2. The former kind is recommendable because the staff engage in the same engineering field can be shared in one function, although there may be some difficulty in coordination of the same engineering field such as the local project for road protection, the basin-wide project for sediment control, etc.

6.6 Non-Structural Measures

The structural measures to be applied in the river basin conservation project were studied in the preceding section. Since it may take a long time to complete the structural measures, while the river basin suffers continuously from disasters, it is necessary to provide certain measures to mitigate the disaster until the time when the structural measures are completed.

In this sense, study is made on non-structural measures to cope with this situation and also, to be used as supplementary measures for disaster prevention even after completion of the proposed structural measures.

6.6.1 Basin-wide Project

Sediment Control

Structural measures for the basin-wide sediment disaster prevention to control sediment discharge to the downstream area of El Vigía are provided only to reduce sediment production in the upstream area. Since road construction and agricultural development have accelerated slope erosions, these activities shall be regulated so as not to aggravate the sediment problem. A useful non-structural measure is to have a land use regulation in areas expected to cause more sediment production.

As described in the Supporting Report on Socioeconomy, a watershed management has been conducted with some legislations on land use but they are applied only to the upper reaches from Mérida City. Therefore, it is recommended that the legislations be expanded to include other areas upstream of El Vigía.

Flood Control

Among several non-structural measures which include flood forecasting and warning, flood fighting, relocation of assets, flood proofing, land use regulation, public investment policy, etc., the following measures were basically considered as the applicable measures judging from the disaster conditions in the lower reaches.

- Land use regulation;
- Flood forecasting and warning; and
- Consolidation of river structure management and flood fighting.

In this basin, the non-structural measures will be applied in the following manner:

(1) Land Use Regulation

The flood prone area in the lower reaches is classified into three categories: river area, probable inundation area, and other areas. Among them, land use in the river area and the probable inundation area should be regulated as follows:

(a) River Area

In this study, the river area was proposed as discussed in Chapter 5, and this proposed river area should be acquired and delineated from private use.

(b) Probable Inundation Area

The recorded flood inundation area has been clarified in this study and this area is currently used for plantain plantation, pastures, etc. Among them, the plantain plantation covering more than 50% of the land use in the flood inundation area is not so durable against flood inundation damage. Therefore, it is desirable to control the land use for plantain plantation and to promote the diversification of crops to the more sturdy ones like tree crops.

In case of urbanization and construction of public facilities, they should be provided on the ground above the presumed inundation water level which may require land reclamation.

(2) Flood Forecasting and Warning

To establish an updated overall flood forecasting and warning system, it is desirable to provide a number of hydrological observation stations together with a telemetering system. However, an enormous fund is required to install new facilities and to carry out a precise study which will require an abundance of hydrological data, and such an updated system may not be realistic in this basin.

A convenient system that can be realized with a lesser investment with the use of existing facilities is recommendable. In this connection, the following principles will be considered for its formulation:

- The water stage in the lower reaches is predicted on the basis of correlation of water stage with that of the upper reaches.

- As the hydrological observation network, a new water stage gauging station with an observer at the confluence point of the Chama River with the Mocotíes River and another station at the Mocotíes River Basin are required. (Refer to Fig. 6.6-1.)

- Water stage in the upper reaches is informed to Zone Office No. 5 by telephone.

- Zone Office No. 5 after data processing for prediction of water stage based on the observed data disseminates the information to the Civil Defense Department by telephone, if necessary.

(3) Consolidation of River Management and Flood Fighting

(a) River Management

The main purpose of river management is to maintain the structures and river channel under normal condition, so that they can fulfill their function of disaster prevention when needed.

The maintenance works will involve the following items: (1) restoration of dike, (2) dredging of river channel, (3) regulation on construction of structures in the riverine, and (4) land use regulation in the river area.

Although Zone Office No. 5 is trying its best to cover all these works, its capability is maybe insufficient as noted from the fact that the bank failure in September 1988 has been left for a long time without restoration due to lack of financing, and the river area is illegally used for planting crops resulting in the reduction of flow capacity and increment of flood damage. It is then necessary to consolidate the maintenance works through the allocation of sufficient funds and putting additional personnel.

(b) Flood Fighting

The inhabitants expect public agencies to take some action in preventing the spread of flooding to the urban area, which have never been carried out up to the present. It is then desirable to consolidate flood fighting works through the MARNR in cooperation with the Civil Defense Department.

Organization for Operation

(1) Land Use Regulation

The agencies concerned in land use management in this country are as follows:

- River Area : MARNR

- Flood Prone Areas

  Agricultural Area : MAC, IAN, MARNR
  Urban Area : MINDUR

- Public Facilities : MARNR, MTC, State Governments

Regarding the management of flood prone areas, exchange of information is made but not periodically through the activities of the agencies concerned, and the coordinating committee does not convene periodically for the regulation of land use in the flood prone area. In this connection, it is recommended that a coordinating committee consisting of representatives of these agencies be established to monitor any disorder in land development and to give instructions on appropriate land use.

(2) Flood Forecasting and Warning

Although flood forecasting and warning were never executed in the Chama River Basin, hydrological information has been collected by the MARNR, and the Civil Defense Department of the Ministry of Interior has the responsibility of flood fighting and rescue works. In this connection, it is possible to cope with the flood forecasting and warning works by these existing agencies through the consolidation of organization and flood warning efforts.

(3) Flood Fighting

As in flood forecasting and warning works, flood fighting is tasked with the MARNR and the Civil Defense Department, and it is necessary to consolidate the present organization for flood fighting.

6.6.2 Local Project

Protection of Road

The local disaster prevention plan is, as described in the foregoing structural measures, mainly put on the sediment disaster along arterial Route 2 and Route 7. Until the completion of the prevention works, the potential disaster sites of 171 locations will always be under the menace of damage by debris/sediment flow, slope failure and bank erosion, which may bring not only damage on the road itself but also loss of human life and injuries as experienced before.

From this situation, some non-structural measures shall be provided, firstly, to avoid dangers on human life which are exposed in the transportation along the road. Through the experience and accomplishment of such non-structural disaster prevention projects in Japan, there are two measures applicable to local disaster prevention along the arterial road. One is a warning system to disseminate information on traffic condition, and the other is to establish rules and regulations on structures of roads and houses.

(1) Warning System

The objective of a warning system is to provide the information of impending sediment disaster along the arterial roads and to allow the responsible agencies prepare the necessary actions such as temporary preventive works and traffic control.

The system is to be installed as an integrated network consisting of weather observation system, data transmission system, dissemination system and a warning center.

The weather observation system is mainly composed of rainfall stations equipped with data transmission system. The stations transmit rainfall data of short interval such as hourly and 3-hourly.

The data transmission system includes the linkages between observation stations and the warning center, and between warning devices/stations and the warning center.

The dissemination system consists of devices or stations to disseminate warning/information directly to people and the agencies concerned with the road traffic.

The warning center which is to be located in the Chama River Basin shall collect data, analyze the danger degree and disseminate warning/information to people and the agencies concerned.

As the warning system shall be immediately installed to ensure safe traffic along the arterial road, as the first step, a rather simple and low cost system is proposed as follows (Fig. 6.6-2).

- Warning Center : To be located in Zone Office No. 16 of MARNR.

- Observation System : 10 rainfall stations equipped with transmission devices.

- Transmission System : Simplex telemetering between the center and rainfall stations; existing telephone line between the center and warning station.

- Dissemination System : Four manned traffic control stations shall be installed under MTC.

(2) Rules and Regulations for Structures

Most of the damageable portions of the arterial road Route No. 2 crossing small rivers are not provided with culverts or bridges designed to allow sediment flows passing through. Sometimes, houses are constructed on or around steep and unstable slopes which are always under the menace of failures and slides with strong rainfall.

Some rules and regulations shall be established for all the structures to be constructed in the potential sediment disaster area, i.e., a certain structural code for road bridges and culverts to clear sediment damage shall be prepared, and zoning and public announcement regarding potential sediment disaster areas shall be carried out for achieving safe housing development.

Land use regulation shall also be applied to areas which have a high possibility of sediment disasters. Particularly, houses in such areas will be relocated under this regulation.

Protection for Mérida and Ejido Cities

(1) Applicable Measures and Their Application

The measures applicable for flood disasters in the cities of Mérida and Ejido are land use regulation, flood warning system, and evacuation of inhabitants. These measures are proposed to be employed as follows.

(a) Land Use Regulation

A land use map for the year 2000 covering Mérida and Ejido cities has been prepared by the MINDUR and the municipalities. The areas to be protected from urbanization such as forests, potential landslide areas and river areas have been delineated. Even these areas, however, are urbanized resulting in the increment of flood disasters. In this connection, the consolidation of inspection by the agencies concerned is necessary.

(b) Flood Warning System

In addition to the warning system for sediment disaster along national road routes 2 and 7, a flood warning system should be installed to mitigate damage on household effects and prevent loss of human life. The warning system consisting of rainfall observation system, data transmission system, dissemination system and warning system is featured as follows (refer to Fig. 6.6-1):

- Three rainfall stations equipped with transmission devices are proposed to be installed as the rainfall observation system in the upper reaches of the Albarregas, Milla and Portuguesa river basins.

- Data is transmitted by simplex telemetering to Zone Office No. 16 of the MARNR.
- Data is disseminated to the Civil Defense Department of the Ministry of Interior as the warning center.
- Flood warning is issued by the warning center to the inhabitants by siren based on the magnitude of rainfall.

(c) Evacuation of Inhabitants

Since the flood damage area is not so large, it may be possible to avoid flood damage on household effects and loss of human life through evacuation to higher places adjoining the possible flood damage area. In this connection, it is recommended that the evacuation system in the flood damage area be established by setting up the rules, route and place of evacuation.

(2) Organization for Operations

The agencies concerned in the above tasks are as follows:

- Land Use Regulation	:	MINDUR and municipality
- Flood Warning System	:	MARNR and Civil Defense Department
- Evacuation of Inhabitants	:	Civil Defense Department

To accomplish the tasks, a new organization is not necessary, but augmentation of the staff of the existing organization is needed.

CHAPTER 7. CONCLUSION AND RECOMMENDATIONS

1. The master plan for the Chama River Basin Conservation Project consisting of sediment and flood control was formulated with its target year set at 2020. Within the framework of the master plan, the action plan for urgent projects selected from the components of the master plan was formulated aiming at early realization of the projects with the target year at 2000.

   The results of the study show that the action plan is technically sound, financially viable and economically feasible with the internal rate of return (IRR) of 13.2%, and the implementation of the project will give favorable impacts to society. Therefore, it is strongly recommended that the project be promoted to the detailed design stage at the earliest possible opportunity.

   Since it may be difficult to implement the action plan with only the currently allocated budget of the MARNR, a special fund or a loan from an international financing agency is needed. In this connection, it is recommended that a committee be established to make the necessary arrangements for this purpose.

2. The optimum plan of non-structural measures was proposed in the action plan to mitigate disasters until such time that the structural measures are completed. These non-structural measures can serve as supplementary measures for disaster prevention even after completion of the proposed structural measures. Since the non-structural measures can be introduced at a lesser financial burden and a shorter time, it is recommended that they are provided at an early stage of project implementation.

3. As a result of the alternative study for the applicable methods, afforestation in the basin is not proposed from the economical point of view. Instead, it is recommended that forest areas be maintained not only to prevent sediment disasters but also to ensure favorable environmental conditions. In this connection, it

is desirable to promote afforestation in less vegetated areas in the Chama River Basin through an environmental conservation project.

4. The design sediment discharge for the formulation of the sediment control plan was estimated from experimental formulas commonly used in other countries, since the observed data on sediment discharge which is essential for future studies is not sufficient to determine the specific formula or coefficient in this basin. In this connection, it is desirable to provide an experimental basin in the upper basins of the Nuestra Señora River such as the Mucusurú, the Mucusás and the Mucusós to collect the observed data on sediment production and discharge, together with the hydrological data.

5. Hydrological data, e.g., rainfall, water stage, flood inundation, etc., are also insufficient. It is, therefore, necessary to install hydrological stations and collect data for use in analysis and design in the next stage.

6. At present, some lands in the riverine are illegally used resulting in the increment of flood damage. This illegal land use should be discouraged through daily inspections. In this connection, the organization for maintenance and inspection should be consolidated for the smooth implementation of the action plan and reduction of flood damage. Besides, future land use and regional development programs should be defined taking into account the location of the flood plain that was clarified through the study.

7. In case the action plan is executed, river improvement in the lower reaches from El Vigía has to be promoted confirming the effect and influence of the sediment control works in the upper/middle reaches. It is also important to know the influence of the groin and revetment for dike protection. In this connection, it is recommended that periodical observations on river condition such as meandering of the river course and aggradation of the riverbed be conducted.

8. Wet masonry was selected through the comparative study for revetment of the dike in view of its reliability. However, other materials which are less reliable or less durable but locally available can be employed in the action plan should there be a financial restraint or difficulty in procurement of the proposed materials for the wet masonry.

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TABLES

Table 2.1-1(1/2) SLOPE FAILURES AND DEBRIS FLOW RECORDS IN THE CHAMA RIVER BASIN

No.	Location	Type of Failure	Year/ Month/ Date	Scale of Collapse and Debris Flow L*W*D (m)	V(m3)	Geological Condition
1.	Cacute	Slope failure	1988	(1) 30*15*3	1,350	talus deposit
				(2) 40*15*3	1,800	seems to be still active
		Bank erosion	1988	(1) 80*10*4	3,200	talus deposit
				(2) 30*2*10	600	damage to road
2.	Tabay	Debris flow	1988 Sep.	50(?)*2*2	200(?)	talus deposit with boulders of 1 m in max.
		Bank erosion		28*6*7	1,176	alluvial deposit damage to road
3.	Mesa de la Virgen	Slope failure		(1) 150*5*0.5	375	granite
				(2) 50*100*0.8	4,000	seems to de still active
4.	Qda. Los Higuerones	Debris flow	1988 Aug.	1,500*8*4	48,000	granite, fan deposit with boulders of 2 m in max
5.	Confluence of R.Chama & R.Nuestra Senora	Slope failure	1987	(1) 100*100*1.5	15,000	mica schist, quartz schist bedding:N50E/40N, joint:N60E/45S
				(2) 100*100*1.5	15,000	seems to be still active
6.	Qda. Los Limos	Debris flow		1,500*10*1.5	22,500	green schist; damage to bridge with boulders of 2 m in max.
7.	Qda. Maciqual	Debris flow		(1) 100*4*1.5	600	green schist; damage to bride & road
				(2) 60*4*1.5	360	with boulders of 1.5 to 2 m
8.	Arraquares	Debris flow		30*5*3	450	green schist with boulders of 2 m in max.
9.	Qda. La Jaya	Debris flow		1,000*12*1	12,000	green schist with boulders of 2 m in max.
10.	Qda. El Diablo	Bank erosion		5*10*1	50	sandstone and shale
11.	La Honda	Slope failure	1988	100*20*8	16,000	sandstone damage to road
12.	La Palmita	Slope failure	1989 Jan.6	90*20*5	9,000	sandstone damage to road
13.	La Providencia	Slope failure	1988 Dec.	10*40*1	400	sandstone damage to road
14.	Carabanchel	Debris flow		20*5*2	200	sandstone damage to road
15.	Qda. Romero	Slope failure	1988 Sep.	15*4*1	60	crystalline schist damage to road

Table 2.1-1(2/2) SLOPE FAILURES AND DEBRIS FLOW RECORDS IN THE CHAMA RIVER BASIN

No.	Location	Type of Failure	Date	Scale of Collapse and Debris Flow L*W*D (m)	V(m3)	Geological Condition
16.	Qda. Cubalibre	Debris flow	1988 Sep.	(1) 30*10*1 (2) 100*8*1	300 800	crystalline schist damage to road
17.	Qda. Tabacal	Debris flow		200*15*2	6,000	crystalline schist damage to road
18.	Qda. Silencio	Debris flow	1988 Sep.	(1) 150*15*2 (2) 50*10*1	4,500 500	granite damage to road
19.	Qda. Caciquito	Debris flow		1,000*20*1	20,000	granite damage to road
20.	Qda. Penon II	Debris flow	1988 Sep.	100*9*1	900	granite damage to road & check dams

Table 2.2-1 MONTHLY METEOROLOGICAL RECORDS

Area/Station	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave./ Total
Upper Reaches	3112 Mucuchies (Alt. 3,100m)													
Temperature	C.Deg.	11.0	11.3	11.6	11.7	11.7	11.4	11.0	11.2	11.3	11.4	11.2	11.1	11.3
Middle Reaches I	3047 Merida Aeropuerto (Alt. 1,470m)													
Temperature	C.Deg.	18.0	18.4	19.1	19.2	19.5	19.3	19.1	19.4	19.4	19.0	18.8	18.3	19.0
Relative Humidity	%	78	77	77	81	82	81	79	78	78	82	83	81	79.8
Middle Reaches II	3170 San Juan de Lagunillas (Alt. 1,050m)													
Temperature	C.Deg.	22.1	22.4	22.7	22.7	22.3	22.5	22.4	22.8	23.1	22.5	22.4	21.9	22.5
Evaporation	mm	183	176	186	164	160	153	167	170	163	157	161	167	2,007
Middle Reaches III	3141 Tovar (Alt. 952m)													
Temperature	C.Deg.	20.9	21.1	21.7	22.1	22.7	22.6	22.4	22.5	22.3	22.0	21.6	20.9	21.9
Relative Humidity	%	77	74	73	75	75	73	69	71	71	74	75	74	73.4
Evaporation	mm	97	90	103	95	109	111	120	127	112	99	93	93	1,249
Lower Reaches	3035 El Vigia (Alt. 130m)													
Temperature	C.Deg.	26.6	27.1	27.8	27.8	28.5	28.9	28.1	28.9	28.5	27.9	27.6	26.9	27.9
Evaporation	mm	113	112	130	117	136	130	141	150	148	137	118	109	1,541

Note: The figures of temperature and relative humidity present the daily mean.

Table 2.3-1 RESULTS OF SAMPLING SURVEY FOR TORRENTS

No.	Name	River C.A. (km2)	River Slope (Deg.)	River Width (m)	River Length (m)	Geology Rock	Geology Condition	Sediment Volume (m2/section) Ero-ded	Sediment Volume Resi-dual	Sediment Volume Sum	Grain Size (cm) Max.	Grain Size (cm) Mean
1.	Mucujun	57.90	5.7	30	11,900	Gneiss	Debris Deposits	15	300	315	200	30
2.	Mucuy	71.90	6.5	40	12,800	Gneiss	Debris-flow Deposits	32	316	348	200	30
3.	Desbarran-cadero (Mucuy)	17.60	13.2	50	8,900	Quartz and Sand Schist	Debris-flow Deposits	1,270	500	1,770	300	30
4.	N. Senora I	266.20	0.94	17	40,000	Meta-black Shale	Debris Deposits	14	20	34	150	40
5.	Mucusuru I (N. Senora)	60.60	3.7	24	14,000	Meta-black Shale	Debris Deposits	8	40	48	100	30
6.	Mucusuru II (N. Senora)	91.00	3.7	15	14,200	Meta-black Shale	Debris Deposits	11	19	30	200	40
7.	N. Senora II	604.50	2.0	50	49,300	Sand Schist	Debris Deposits	4	56	60	100	30
8.	Gonzalez II	90.30	7.0	15	24,500	Sandstone	Terrace Deposits	15	300	315	100	20
9.	Gonzalez I	108.50	3.0	5	31,500	Sandstone Shale	Debris Deposits	25	450	475	300	50
10.	Tabacal (Mocoties)	2.55	6.0	4	2,250	Sandstone	Debris-flow Deposits	12	8	20	30	10
11.	Casiguito (Mocoties)	4.20	10.0	10	3,150	Sandstone	Debris-flow Deposits	10	10	20	50	10

Table 2.3-2 RESULTS OF SAMPLING SURVEY FOR MASS WASTING

No.	Location of Sampling Pt.	Slope (Deg.)	Depth of Top Soil (m)	Geology	Vegetation	Mass Wasting (m) Type	Depth	Length	Sediment Volume (m3) Total	Resi-dual	Ex-panded
1.	Qd. Portuguesa	35	1.0	Granite sand stone	High forest Dense	Slide	38	300	28,500	10,000	25,000
2.	S. Onofre (Chama R.)	35	0.2	Debris deposits	Bare land	Debris flow	50	200	8,400	4,000	20,000
3.	Higuerones (Chama R.)	45	0.2	Debris deposits	Low forest Sparse	Debris flow	12	500	50,000	24,000	26,000
4.	Rio Negro (Chama R.)	50	0.2	Debris deposits	Glass land Sparse	Glide	40	200	400,000	4,000	25,000
5.	Gonzalez (Chama R.)	20	0.2	Debris deposits	Bare land	Debris flow	40	400	48,000	36,000	54,000
6.	Qd. Agua Caliente (Gonzalez R.)	25	1.0	Granite Sand stone	High forest Dense	Slide Glide	90	20	4,500	900	2,500
7.	Pte. Real (Chama R.)	40	0.2	Debris deposits	Glassland Sparse	Glide	40	50	20,000	5,000	5,000
8.	Pte. Viejo (Chama R.)	35	0.2	Debris deposits	Glassland Sparse	Debris flow	40	200	319,500	21,300	290,000
9.	Pte. Chama 3 (Chama R.)	50	0.2	Debris deposits	Glassland Sparse	Glide	5	300	150,000	1,500	10,000
10.	El Guamo (Sucia R.)	15	0.3	Meta-black shale	High forest Dense	Slide	8	300	144,000	100,000	100,000
11.	Qd. Delicious (Sucia R.)	20	0.2	Meta-black shale	High forest Dense	Slide	20	500	750,000	370,000	200,000

Table 2.5-1 PAST DISASTERS IN THE CHAMA RIVER BASIN

No	Place	River	Date	Cause	Situation of Disaster
1.	Cacute	Chama	1988	Land Failure & Bank Erosion Debris Flow	1-day interception of Route 7
2.	Tabay	Qd.La Pueblo	1979	Debris	1 week interception of Route 7; Destruction of 1 gas station, 4 houses and graveyard;
3.	Ivega Farm	Chama	1988	Flood	2 day inundation of 15 ha farm; 2 day interception of domestic water and electricity; 0.5 m inundation of 15 houses.
4.	Capilla del Carmen	Chama	1987 & 88	Slope Faillure	3 hours interception of Route 7
5.	Andres Eloy Milla	Chama	1975	Flood	0.5 m inundation of 5 houses
6.	El Rincon	El Rincon	1987 & 88	Flood	1 m inundation of 5 houses
7.	San Jacinto	Qd La Fria	1987 & 88	Flood	0.5 m inundation of 3 houses
8.	La Pedregosa	Qd La Resbalosa		Flood	0.5 m inundation of 10 houses 1 day inundation of 3 ha farm 3 houses interception of electricity
9.	Urbanizacion Carabobo	La Gavidia	1987 & 88	Flood	1.3 m inundation of houses
10.	Ejido	Portuguesa	1988	Flood	0.3 m inundation of 1 houses and 1 gas station
11.	San Onofre	Chama	1987	Slope Failure	1 day interception of Route 7; 1 hour interception of electricity; Destruction of 2 houses.
12.	Rio Negro	Chama	1988	Bank Erosion	Half day interception of Route 7
13.	La Gonzalez	Chama	1988	Slope Failure	Half day interception of Route 7
14.	Chichy	Chama	1988	Flood	One day inundation of 4 ha farm 0.5 m inundation of 2 houses
15.	La Honda	Chama	1987 & 88	Slope Failure	Mud inundation of 12 ha pasture 3 hours interception of Route 2
16.	La Providencia	Chama	1988	Slope Failure	2 to 3 hours interception of Route 2
17.	Carabanchel	Chama	1988	Slope Failire	2 to 3 hours interception of Route 7
18.	Qd. Romero	Mocoties	1988	Slope Failire	2 to 3 hours interception of Route 7
19.	Tabacal	Qd.Cubalibre	1988	Debris Flow	2 to 3 hours interception of Route 7
20.	Tabacal		1988	Debris Flow	2 to 3 hours interception of Route 7
21.	Balero	Qd.Silencio	1988	Debris Flow	2 to 3 hours interception of Route 7
22.	Tovar	Penon II	1988	Debris Flow	2 to 3 hours interception of Route 7

Table 2.5-2 SEDIMENT DISASTER PREVENTION WORKS (1984-1988)

No.	Work Item	Work Volume	Total Cost (Bs)	Location
1.	Sediment Control Works -Check Dam -Groundsill	470 ha	5,243,840	Mamon Romero, Granates, Barro, Chorro
2.	Retaining Works -Retaining Wall -Embankment	3.95 km	11,779,544	Albarregas, Milla, Resbalosa
3.	Channeling Works -Excavation -Embankment	---	4,590,000	Mocoties, La Sucia
4.	Reforestation and Maintenance	10 ha	150,000	San Juan De Lagunillas
5.	Tree Nursery	---	---	---
6.	Soil Conservation	---	---	---
Total			21,763,384	

Table 2.7-1 PRINCIPAL ECONOMIC INDICES OF THE SEVENTH NATIONAL DEVELOPMENT PLAN

ITEM	1984	1985	1986	1987	1988
1. Annual Growth Rate of GDP (%) *	-1.5	4.3	5.3	4.4	4.0
2. Unemployment Ratio (%)	14.5	12.3	10.8	9.9	9.3
3. Increase Rate of Living Cost (%)	15.0	13.0	12.0	11.0	10.0
4. Operating Reserve (thousand million US$)	3.5	2.5	1.9	2.1	2.7
5. Foreign Exchange Reserve (thousand million US$)	12.2	11.4	12.2	12.4	13.0
6. Public Debts (thousand million US$)	26.0	24.5	24.0	23.2	22.3

NOTE *: Excluding the sector of Central Government.
SOURCE: VII PLAN DE LA NACION, 1984-1988

Table 2.7-2 DEMOGRAPHIC CHARACTERISTICS OF THE CHAMA-MOCOTIES RIVER BASIN

COVERAGE	AREA (km2)	POPULATION (Thousand) 1981	1984	1988	ANNUAL GROWTH RATE	POPULATION DENSITY IN 1988
1. Venezuela	921,050	15,484.7	16,851.2	18,757.4	2.8%	20
2. Merida State	11,300	498.0	538.6	594.4	2.6%	53
3. Upper & Middle Reaches (Merida State)	4,480 *	366.1	401.5	451.2	3.0%	101
- Alberto Adriani Dist.	561	50.1	57.1	67.5	4.4%	120
- Pinto Salinas Dist.	392	18.8	19.6	20.6	1.3%	53
- Campo Elias Dist.	798	40.3	42.1	44.4	1.4%	56
- Libertador Dist.	1,086 *	176.7	198.0	228.1	3.7%	210
- Miranda Dist.	381 *	18.7	19.9	21.6	2.1%	57
- Rangel Dist.	837	19.8	20.8	22.0	1.5%	26
- Rivas Davila Dist.	137 *	9.0	9.5	10.2	1.8%	74
- Tovar Dist.	288	32.7	34.5	36.8	1.7%	128
4. Lower Reaches (Zulia State)						
- Uribarre Municipality	965	18.6	19.5	20.8	1.6%	22

NOTE *: Total areas of the municipalities in which the Chama-Mocoties River basin is located.
SOURCE: "Proyecctiones de Poblacion, 1980-2000", OCEI
"Conversion de la Division Politico Territorial de los Estados de la Region de Los Andes", CORPOANDES

Table 2.7-3 GROSS REGIONAL PRODUCT OF MERIDA STATE AND DISTRIBUTION BY SECTOR

Unit: million Bs. at 1963 constant price

SECTOR/ACTIVITIES	1970	(%)	1973	(%)	1976	(%)	1979	(%)	Annual Growth
1. PRIMARY SECTOR	113.1	18.6%	102.3	16.8%	105.4	14.5%	121.2	12.3%	0.8%
- Agricurture	112.7	18.6%	101.7	16.7%	104.7	14.4%	118.3	12.0%	0.5%
- Mining	0.5	0.1%	0.6	0.1%	0.8	0.1%	2.9	0.3%	21.6%
2. SECONDARY SECTOR	128.1	21.1%	178.2	29.3%	199.8	27.4%	301.4	30.5%	10.0%
- Manufacturing	55.4	9.1%	69.7	11.5%	84.4	11.6%	107.3	10.9%	7.6%
- Construction	64.7	10.7%	104.0	17.1%	84.1	11.5%	147.7	15.0%	9.6%
- Electricity & Water Supply	8.0	1.3%	4.4	0.7%	31.2	4.3%	46.4	4.7%	21.6%
3. TERTIARY	365.9	60.3%	327.9	53.9%	424.2	58.2%	565.3	57.2%	5.0%
- Commerce	78.6	12.9%	76.7	12.6%	82.3	11.3%	122.0	12.3%	5.0%
- Transport & Communication	45.2	7.4%	61.0	10.0%	80.8	11.1%	145.0	14.7%	13.8%
- Services	242.1	39.9%	190.2	31.3%	261.1	35.8%	298.2	30.2%	2.3%
T O T A L	607.1	100.0%	608.4	100.0%	729.4	100.0%	987.9	100.0%	5.6%

NOTE: Figures may not add up to totals due to rounding.
SOURCE: CORPOANDES,"Estadisticas del Edo.Merida",1984

Table 2.7-4 AGRICULTURAL PRODUCTS AND THEIR DISTRIBUTION IN THE STATES OF MERIDA, ZULIA AND TACHIRA

Agricultural Products	National Production (TM)	* States' Production (TM)	Contribution to the National (%)	Distribution Volume (TM)	Distribution Ratio (%)
Vegetables	114,610	21,200	18.5	15,703	74.1
Tubers	596,230	26,100	4.4	14,571	55.8
Fuits					
- Plantain	448,570	208,100	46.4	180,000	86.5
- Bananas	1,003,980	153,100	15.2	5,856	3.8
- Other Fruits	---	32,000	---	25,000	78.1

NOTE *: Including the states of Merida, Zulia and Tachira.
SOURCE: CORPOANDES

Table 2.7-5 DISTRIBUTION RATIOS OF AGRICULTURAL PRODUCTS BY THE REGION

Unit: %

Region	Plantain	Banana	Other Fruits	Vegetables	Tubers
Maracaibo	20	14	9	3	---
Caracas	29	28	16	2	32
Centro	17	10	20	23	4
Barquisimeto	9	40	9	5	24
Oriente	10	1	---	---	---
Region los Andes	15	7	46	67	40
T o t a l	100	100	100	100	100

Source: CORPOANDES

Table 2.7-6 INTERANNUAL PRICE ESCALATION RATES IN MAJOR CITIES

Unit: %

MAJOR CITIES	INTERANNUAL PRICE ESCALATION RATES				
	1983-1984	1984-1985	1985-1986	1986-1987	AVERAGE
METRO CARACAS AREA	---	11.4	11.6	28.1	16.8
BARINAS	15.6	14.1	11.3	35.2	19.7
BARQUISIMETO	10.3	10.8	11.0	21.3	14.3
COIDAD GIAUAMA	---	12.1	10.6	36.9	19.3
MARACAIBO	13.9	15.2	11.4	21.1	15.8
MERIDA	12.7	15.4	11.9	25.9	17.6
PUERTO LA CRUZ-BARCELONA	12.4	14.3	11.5	25.0	16.8
SAN CRISTOBAL	12.6	12.7	12.7	27.1	17.3
VALENCIA	12.8	13.2	11.8	26.9	17.1
VALERA	14.8	14.9	12.3	26.5	17.7
AVERAGE	13.1	13.4	11.6	27.4	17.2

SOURCE : ANUARIO ESTADISTICO DE VENEZUELA 1987, OCEI

Table 2.7-7 LAND USE IN MERIDA STATE IN 1983

CATEGORY	Area*(ha)	Ratio(%)
1. Agriculture & Cattle Raising	264,663	24.4%
- Vegetal Agriculture	47,443	4.4%
- Cultivated & Natural Pasture	145,898	13.4%
- Agriculture & Livestock Raising (for the residents living)	71,322	6.6%
2. Natural Vegetation (including forests & bleak plains)	812,697	74.8%
3. Urban & Industrial	7,859	0.7%
4. Infrastructure	1,033	0.1%
TOTAL	1,086,252	100.0%

Note *: The total area does not include 43,748 ha of rivers, lakes, etc.
Source: Comision de Ordenacion del Territorio "Plan de Ordenacion del Territorio del Estado Merida", 1988.

Table 2.7-8 MONETARY ALLOCATION OF THE NATIONAL BUDGET, 1984-1988

(Unit: thousand million Bs. at current price)

BRANCH/MINISTRY	1984	1985	1986	1987	1988	ANNUAL GROWTH
1. EXECUTIVE	75.74	101.59	120.68	156.17	180.75	24.3%
Presidential Secretary Office	1.08	1.01	1.67	1.81	3.1	30.2%
Interior Relations	11.56	16.13	18.45	21.31	26.3	22.8%
Exterior Relations	0.46	0.76	0.74	1.33	1.63	37.2%
Finance	24.67	41.17	42.56	59.9	56.21	22.9%
Defense	4.95	6.08	6.61	8.72	12.31	25.6%
Promotion	0.22	0.17	1.08	3.29	2.63	85.9%
Education	14.01	15.71	16.86	19.85	28.08	19.0%
Sanitary & Social Assistance	4.72	5.24	6.47	8.99	12.64	27.9%
Agriculture & Animal Husbandry	3.44	3.01	5.35	7.19	7.75	22.5%
Labor	0.14	0.87	0.87	1.2	1.65	85.3%
Transport & Communications	3.89	4.22	8.42	8.76	10.99	29.6%
Justice	0.71	0.76	0.83	1.12	1.49	20.4%
Energy & Mining	0.16	0.2	0.21	0.27	0.34	20.7%
Environment & Natural Resources Conservation	1.83	1.89	4.35	4.6	6.35	36.5%
Urban Development	2.85	3.27	5.45	6.86	9.2	34.0%
Information & Tourism	0.15	0.22	---	---	---	---
Juvenile	0.9	0.88	0.76	0.97	0.08	-45.4%
2. LEGISLATIVE	0.66	0.55	0.66	0.79	1.54	23.6%
3. JUDICIAL	0.65	0.71	0.94	1.06	2.83	44.5%
T O T A L	77.04	102.84	122.28	158.02	185.12	24.5%

NOTE: Figures may not add up to totals due to rounding.
SOURCE: National Budgetary Office

Table 2.7-9 PERCENTAGE ALLOCATION OF THE NATIONAL BUDGET, 1984-1988

(Unit: %)

BRANCH/MINISTRY	1984	1985	1986	1987	1988	ANNUAL GROWTH
1. EXECUTIVE	98.31%	98.78%	98.69%	98.83%	97.64%	98.45%
Presidential Secretary Office	1.40%	0.98%	1.37%	1.15%	1.67%	1.31%
Interior Relations	15.01%	15.68%	15.09%	13.49%	14.21%	14.69%
Exterior Relations	0.60%	0.74%	0.61%	0.84%	0.88%	0.73%
Finance	32.02%	40.03%	34.81%	37.91%	30.36%	35.03%
Defense	6.43%	5.91%	5.41%	5.52%	6.65%	5.98%
Promotion	0.29%	0.17%	0.88%	2.08%	1.42%	0.97%
Education	18.19%	15.28%	13.79%	12.56%	15.17%	15.00%
Sanitary & Social Assistance	6.13%	5.10%	5.29%	5.69%	6.83%	5.81%
Agriculture & Animal Husbandry	4.47%	2.93%	4.38%	4.55%	4.19%	4.10%
Labor	0.18%	0.85%	0.71%	0.76%	0.89%	0.68%
Transport & Communications	5.05%	4.10%	6.89%	5.54%	5.94%	5.50%
Justice	0.92%	0.74%	0.68%	0.71%	0.80%	0.77%
Energy & Mining	0.21%	0.19%	0.17%	0.17%	0.18%	0.19%
Environment & Natural Resources Conservation	2.38%	1.84%	3.56%	2.91%	3.43%	2.82%
Urban Development	3.70%	3.18%	4.46%	4.34%	4.97%	4.13%
Information & Tourism	0.19%	0.21%	---	---	---	---
Juvenile	1.17%	0.86%	0.62%	0.61%	0.04%	0.66%
2. LEGISLATIVE	0.86%	0.53%	0.54%	0.50%	0.83%	0.65%
3. JUDICIAL	0.84%	0.69%	0.77%	0.67%	1.53%	0.90%
T O T A L	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

NOTE: Figures may not add up to totals due to rounding.
SOURCE: National Budgetary Office

Table 2.7-10 NATIONAL BUDGETARY EXPENDITURES AND PUBLIC INVESTMENT OF MARNR

ITEM	UNIT	1984	1985	1986	1987	1988	AVERAGE
1. Gross Domestic Product (GDP)	million Bs.	409,487	464,620	493,765	719,423	---	521,824
- Real Growth Rate	%	---	1.8	-4.7	13.8	---	3.3
2. National Budget	million Bs.	77,041	102,844	122,283	158,018	185,122	129,062
- Proportion to GDP	%	18.8	22.1	24.8	22.0	---	21.9
3. Budget of MARNR		1,835	1,894	4,353	4,596	6,350	3,806
- Public Investment	million Bs.	313	320	1,014	803	1,237	737
- Population of the Nation	thousand persons	16,851	17,317	17,791	18,272	18,757	17,798
- Per Capita Investment	Bs.	19	18	57	44	66	41
3.1 Zone 16 Office							
- Public Investment	million Bs.	10	12	9	22	31	17
- Population of Merida State	thousand persons	539	552	566	580	594	566
- Per Capita Investment	Bs.	19	22	16	38	52	29
3.2 Office for the South Region of Maracaibo Lake							
- Public Investment	million Bs.	4	73	75	72	63	57
- Population of the Region	thousand persons	145	147	148	150	151	148
- Per Capita Investment	Bs.	28	497	507	480	417	386

SOURCE: Central Budgetary Office, OCEI, MARNR, Zone 16 Office and Office for the South Region of Maracaibo Lake of MARNR

Table 3.1-1 SUMMARY OF CONATANTS OF STORAGE FUNCTION MODEL FOR UPPER/MIDDLE REACHES

No.	Sub-Basin	A (km2)	L (km)	h (m)	1/i	K	p	Tl (hr)	f
1.	Upper Mucuruba	365.0	3.33	2,160	15.4	11.0	0.333	1.01	0.60
2.	Chama Mucuruba-Merida	134.2	9.5	2,240	4.2	16.3	0.245	0	0.60
3.	La Mucuy	102.4	18.0	2,400	7.5	13.7	0.281	0.29	0.60
4.	Mucujun	205.7	30.3	3,040	10.0	12.5	0.301	0.86	0.60
5.	Tabay-La Penta Left Bank	192.7	12.0	2,960	4.1	16.4	0.244	0	0.60
6.	Albarregas	130.0	28.0	3,200	8.8	13.0	0.292	0.76	0.60
7.	Chama Lower Ejido	98.0	12.0	2,720	4.4	16.0	0.248	0	0.61
8.	Upper Nuestra Senora	304.8	32.0 (52.0)	3,280	9.8	12.6	0.299	1.88	0.60
9.	Lower Nuestra Senora	338.0	28.0	3,200	8.8	13.0	0.292	0.76	0.61
10.	Las Gonzales	118.6	30.5	3,200	9.5	12.7	0.297	0.87	0.61
11.	La Sucia	63.2	15.5	2,000	7.8	13.5	0.284	0.17	0.61
12.	Upper Laguillas Left Bank	58.8	8.8	2,040	4.3	16.1	0.247	0	0.65
13.	Vizcanina	136.6	23.8	2,760	8.6	13.1	0.290	0.56	0.61
14.	Laguillas-Chiguara Right Bank	191.5	15.0	1,760	8.5	13.2	0.289	0.15	0.68
15.	Lower Laguillas Left Bank	45.4	10.5	2,200	4.8	15.6	0.253	0	0.67
16.	San Pablo	270.7	25.5	2,640	9.7	12.6	0.298	0.64	0.61
17.	Santo Domingo	74.7	16.3	2,120	7.7	13.6	0.283	0.21	0.62
18.	Upper Mocoties	241.0	25.0	2,640	9.5	12.7	0.297	0.62	0.60
19.	Lower Mocoties	173.5	8.8	2,800	3.1	17.8	0.228	0	0.60
20.	Mejias	119.9	19.3	3,040	6.3	14.4	0.270	0.35	0.60
21.	Upstream of El Vigia	152.3	13.0	1,800	7.2	13.8	0.278	0.05	0.60
Total		3,517.0							

River Channel	K	p	Tl	Tlz
A Upper Chama	0	0.5	0	0.56
B Middle Chama I	0	0.5	0	0.69
C Middle Chama II	36.4	0.6	0.189	0.83
D Mocoties	0	0.5	0	0.82

Table 3.1-2 MONTHLY AVERAGE DAILY DISCHARGE BY SUB-BASIN

(Unit: m3/s)

Sub-basin	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
BASIN- 1	2.1	1.2	1.4	7.8	13.0	8.5	4.6	5.9	10.4	15.4	15.8	7.3	7.8
BASIN- 2	0.8	0.4	0.5	2.9	4.8	3.1	1.7	2.2	3.8	5.7	5.8	2.7	2.9
BASIN- 3	0.6	0.3	0.4	2.2	3.7	2.4	1.3	1.7	2.9	4.3	4.4	2.1	2.2
BASIN- 4	1.2	0.7	0.8	4.4	7.3	4.8	2.6	3.3	5.8	8.7	8.9	4.1	4.4
BASIN- 5	1.1	0.6	0.7	4.1	6.9	4.5	2.4	3.1	5.5	8.1	8.3	3.9	4.1
BASIN- 6	0.7	0.4	0.5	2.8	4.6	3.0	1.6	2.1	3.7	5.5	5.6	2.6	2.8
BASIN- 7	0.6	0.3	0.4	2.1	3.5	2.3	1.2	1.6	2.8	4.1	4.2	2.0	2.1
BASIN- 8	1.0	0.6	0.6	3.6	6.0	3.9	2.1	2.7	4.8	7.1	7.3	3.4	3.6
BASIN- 9	1.1	0.6	0.7	4.0	6.6	4.3	2.4	3.0	5.3	7.9	8.0	3.7	4.0
BASIN-10	0.7	0.4	0.5	2.5	4.2	2.8	1.5	1.9	3.4	5.0	5.1	2.4	2.5
BASIN-11	0.4	0.2	0.2	1.4	2.3	1.5	0.8	1.0	1.8	2.7	2.7	1.3	1.4
BASIN-12	0.2	0.1	0.1	0.7	1.2	0.8	0.4	0.5	0.9	1.4	1.4	0.6	0.7
BASIN-13	0.4	0.2	0.3	1.6	2.7	1.8	1.0	1.2	2.1	3.2	3.2	1.5	1.6
BASIN-14	0.6	0.3	0.4	2.3	3.8	2.5	1.3	1.7	3.0	4.4	4.6	2.1	2.3
BASIN-15	0.1	0.1	0.1	0.5	0.9	0.6	0.3	0.4	0.7	1.1	1.1	0.5	0.5
BASIN-16	2.6	1.5	1.5	6.0	9.7	6.6	3.8	4.6	7.7	11.2	11.9	6.2	6.1
BASIN-17	0.7	0.4	0.4	1.6	2.7	1.8	1.0	1.3	2.1	3.1	3.3	1.7	1.7
BASIN-18	2.3	1.4	1.4	5.3	8.6	5.9	3.4	4.1	6.8	10.0	10.6	5.5	5.4
BASIN-19	1.7	1.0	1.0	3.8	6.2	4.2	2.4	2.9	4.9	7.2	7.6	3.9	3.9
BASIN-20	1.2	0.7	0.7	2.6	4.3	2.9	1.7	2.0	3.4	5.0	5.3	2.7	2.7
BASIN-21	1.5	0.9	0.9	3.4	5.5	3.7	2.1	2.6	4.3	6.3	6.7	3.5	3.4
Total	21.6	12.3	13.5	65.6	108.5	71.9	39.6	49.8	86.1	127.4	131.8	63.7	66.1

Table 3.2-1 ANNUAL SEDIMENT PRODUCTION

Year	Rainfall (mm)		Sediment Production (1000 m3)		
	Annual Total	Maximum Daily	Annual Total *	Coarse Material	Maximum Daily
1967	1,129.7	17.1	25,282	5,596	772
1968	1,246.6	21.4	40,026	8,611	1,540
1969	1,432.4	31.6	69,372	14,579	2,674
1970	1,165.4	8.7	21,408	4,826	572
1971	1,327.8	22.5	24,650	5,434	1,135
1972	1,172.5	19.4	27,690	6,094	889
1973	1,165.0	19.1	21,037	4,707	650
1974	1,125.6	16.2	11,554	2,642	510
1975	1,287.7	11.1	17,267	3,849	782
1976	1,124.0	24.3	21,768	4,722	1,202
1977	923.6	22.7	17,901	3,932	1,074
1978	1,208.7	16.8	14,379	3,256	491
1979	1,337.7	10.6	34,734	7,782	957
1980	875.4	10.8	11,525	2,599	491
1981	1,436.9	17.7	47,366	10,036	1,339
1982	1,184.4	19.6	19,238	4,248	582
1983	986.4	14.8	19,962	4,403	721
1984	1,082.2	8.0	32,097	2,713	680
1985	1,227.8	10.5	16,442	3,703	656
1986	1,159.1	16.4	14,004	3,178	451
1987	941.8	26.5	28,985	3,174	1,446
Total	24,540.7	---	536,687	110,084	---
Maximum	1,436.9	31.6	69,372	14,579	2,674
Average	1,168.6	17.4	25,557	5,242	934

Note *: Including fine and coarse materials.

Table 3.2-2 CONSTANTS FOR BED LOAD RATING CURVE BY BASE POINT

Base Point	Constants A	Constants B	Base Point	Constants A	Constants B
BP-1	1,395	1.05	BP-18	2,829	0.96
BP-2	2,113	1.01	BP-19	2,878	0.88
BP-3	1,315	1.01	BP-20	575	1.00
BP-4	2,113	1.01	BP-21	559	1.13
BP-5	1,304	0.99	BP-22	2,878	0.88
BP-6	845	1.06	BP-23	2,878	0.88
BP-7	2,113	1.01	BP-24	746	0.96
BP-8	674	1.07	BP-25	844	1.00
BP-9	497	1.03	BP-26	1,277	0.97
BP-10	1,232	0.98	BP-27	714	1.01
BP-11	2,905	0.90	BP-28	169	1.07
BP-12	1,640	0.99	BP-29	2,961	0.90
BP-13	1,128	1.05	BP-30	501	1.00
BP-14	662	1.01	BP-31	224	1.04
BP-15	559	1.13	BP-32	1,243	1.07
BP-16	559	1.13	BP-33	379	1.01
BP-17	575	1.00			

Note: Qs=A*Q^B

where; Qs : Sediment discharge (m3/day)
Q : Water discharge (m3/s)

Table 3.2-3 CRITICAL TRACTIVE FORCE AND CRITICAL DISCHARGE AT BASE POINT

Base Point	dm (mm)	U*c (cm/s)	hc (m)	n	I	Qc (m3/s)
BP-1	210	41	0.26	0.04	1/15	11.6
BP-2	200	40	0.17	0.04	1/10	4.2
BP-3	150	35	0.25	0.04	1/20	7.6
BP-4	300	49	0.25	0.04	1/10	15.2
BP-5	130	32	0.27	0.04	1/25	7.9
BP-6	190	39	0.39	0.04	1/25	26.9
BP-7	200	40	0.17	0.04	1/10	4.2
BP-8	190	39	0.47	0.04	1/30	41.8
BP-9	120	31	0.50	0.04	1/50	30.9
BP-10	200	40	0.50	0.04	1/30	51.4
BP-11	200	40	0.17	0.04	1/10	4.2
BP-12	140	34	0.24	0.04	1/20	6.6
BP-13	190	39	0.31	0.04	1/20	15.6
BP-14	110	30	0.45	0.04	1/50	21.7
BP-15	230	43	0.47	0.04	1/25	50.2
BP-16	200	40	0.41	0.04	1/25	31.8
BP-17	90	27	0.59	0.04	1/66	3.9
BP-18	200	40	0.13	0.04	1/8	2.1
BP-19	200	40	0.08	0.04	1/5	0.7
BP-20	84	26	0.69	0.04	1/66	3.9
BP-21	200	40	0.41	0.04	1/25	31.8
BP-22	230	43	0.10	0.04	1/5	1.5
BP-23	230	43	0.10	0.04	1/5	1.5
BP-24	40	18	0.33	0.04	1/66	3.9
BP-25	150	35	0.43	0.04	1/44	26.6
BP-26	120	31	0.30	0.04	1/30	9.3
BP-27	100	28	0.41	0.04	1/50	15.9
BP-28	130	32	0.64	0.04	1/150	58.7
BP-29	130	32	0.11	0.04	1/10	1.0
BP-30	100	28	0.83	0.04	1/100	83.9
BP-31	25	14	0.31	0.04	1/80	2.1
BP-32	120	31	0.15	0.04	1/150	1.8
BP-33	25	14	0.31	0.04	1/100	2.1

Note; dm : Mean diameter of armor coat materials
U*c: Critical tractive force
hc : Critical water depth
n : Manning's roughness coefficient of riverbed
I : Riverbed slope
Qc : Critical discharge

Table 3.2-4 ANNUAL SEDIMENT DISCHARGE AND BALANCE

(Unit: 1000m3)

Year	Inflow	Outflow	Balance	River Runoff
1967	5,596	7,846	-2,250	1,712,405
1968	8,611	13,938	-5,327	3,021,149
1969	14,579	13,558	1,021	2,939,155
1970	4,826	13,331	-8,505	2,891,851
1971	5,434	8,606	-3,172	1,879,546
1972	6,094	7,237	-1,143	1,576,800
1973	4,707	7,117	-2,410	1,551,571
1974	2,642	6,267	-3,625	1,368,662
1975	3,849	8,462	-4,613	1,844,856
Total	56,338	86,362	-30,024	18,785,995
Average	6,260	9,596	-3,336	2,087,333

Table 3.3-1(1/2) CALCULATION RESULTS OF FLOOD INUNDATION
(PRESENT CONDITION)

DAY	STRETCH 1			STRETCH 2			STRETCH 3			STRETCH 4			STRETCH 5		
	Q. (m3/s)	I.D. (cm)	F.D. (hr)	Q. (m3/s)	I.D. (cm)	F.D. (hr)	Q. (m3/s)	I.D. (cm)	F.D. (hr)	Q. (m3/s)	I.D. (cm)	F.D. (hr)	Q. (m3/s)	I.D. (cm)	F.D. (hr)
(2-yr. return peirod)															
1st	---	0	0	---	0	0	---	0	0	210	8	1	149	5	16
2nd	---	0	0	---	0	0	---	0	0	210	10	5	152	5	24
3rd	682	20	5	394	7	18	370	11	19	359	14	20	330	23	24
4th	723	23	6	412	8	19	395	12	22	379	14	24	354	25	24
5th	682	20	5	395	7	18	372	11	19	364	14	20	333	24	24
6th	---	0	0	---	0	0	---	0	0	215	10	5	160	6	24
7th	---	0	0	---	0	0	---	0	0	211	8	1	151	5	20
(5-yr. return peirod)															
1st	310	2	1	230	4	1	220	5	2	215	8	2	202	10	16
2nd	311	2	3	231	5	6	222	8	10	217	10	10	209	11	24
3rd	851	32	7	470	10	19	450	15	18	424	16	16	388	29	24
4th	1,170	47	8	622	12	20	583	16	22	552	20	24	504	40	24
5th	851	32	7	470	10	19	451	15	20	430	16	24	406	31	24
6th	311	2	3	231	5	6	222	8	11	210	11	20	222	12	24
7th	310	2	1	230	4	1	220	5	2	210	8	2	209	11	24
(10-yr. return peirod)															
1st	445	5	2	292	8	2	281	8	3	270	10	3	249	15	16
2nd	448	7	7	295	10	10	282	11	14	273	12	17	260	16	24
3rd	969	40	8	524	12	19	495	14	21	470	16	23	430	33	24
4th	1,443	74	9	762	15	20	704	20	22	660	25	24	598	43	24
5th	969	40	8	524	12	19	495	16	22	476	20	24	449	35	24
6th	448	7	7	295	10	10	290	13	17	366	16	24	271	17	24
7th	445	5	2	292	8	2	288	8	3	362	10	3	261	16	24
(30-yr. return peirod)															
1st	668	15	3	387	8	3	330	10	5	311	11	4	302	22	16
2nd	668	20	13	387	10	19	361	13	22	358	16	24	337	24	24
3rd	1,182	55	14	629	15	20	580	18	22	556	20	24	504	40	24
4th	1,845	80	17	980	20	24	893	26	24	831	32	24	742	46	24
5th	1,182	55	14	629	15	20	580	18	22	561	20	24	526	41	24
6th	668	20	13	390	10	19	360	13	22	350	16	24	346	25	24
7th	667	15	3	387	8	3	328	10	5	305	11	4	296	25	24
(50-yr. return peirod)															
1st	780	8	3	415	8	4	350	10	8	340	14	15	333	24	16
2nd	781	10	13	418	10	19	401	13	22	385	16	24	358	26	24
3rd	1,288	59	14	678	16	20	632	19	22	595	22	24	540	41	24
4th	2,012	101	17	1,061	25	24	970	31	24	901	36	24	802	48	24
5th	1,288	59	16	678	16	23	630	19	24	601	22	24	563	42	24
6th	781	10	14	441	10	20	410	15	22	388	20	24	386	29	24
7th	781	8	3	438	8	4	350	10	8	342	18	24	331	28	24
(100-yr. return peirod)															
1st	969	20	4	524	10	5	480	13	10	465	16	15	417	32	16
2nd	969	27	13	524	12	19	490	15	22	474	17	24	440	34	24
3rd	1,423	72	14	749	18	20	705	21	23	651	24	24	590	42	24
4th	2,239	110	16	1,173	34	23	1,072	37	24	995	40	24	883	50	24
5th	1,423	72	14	749	18	24	705	22	23	658	25	24	613	43	24
6th	969	27	14	524	12	20	490	15	22	476	17	24	448	35	24
7th	969	20	4	524	10	5	480	13	10	474	17	24	440	34	24

NOTE: Q.= discharge D.= depth P.= period (flood duration)
"---" in the column of Q. means no overtopping river water.

Table 3.3-1(2/2) CALCULATION RESULTS OF FLOOD INUNDATION
(AFTER COMPLETION OF ACTION PLAN)

Return Period (Year)	STRETCH 1	STRETCH 2	STRETCH 3	STRETCH 4	STRETCH 5
	Q. (m3/s)	Q. (m3/s)	Q. (m3/s)	Q. (m3/s)	Q. (m3/s)
100	2,239	1,393	1,220	1,096	1,057
50	2,012	1,260	1,094	984	953
30	1,845	1,161	1,000	903	876
10	1,443	922	788	713	692
5	1,170	759	648	590	574
2	723	490	436	398	391

Table 5.1-1 FEATURES OF SABO DAM

No.	Dam Name	Height (m)	Length(m)		Dam Volume (m3)	Capacity (10^3m3)	Efficiency (Ca/Dv)
			Top	Bottom			
1	C-1	22	170	100	62,500	6,825	109
2	C-2	22	120	60	40,500	3,520	87
3	C-3	11	150	80	17,100	1,620	95
4	C-4	11	200	150	27,000	2,540	94
5	C-5	9	230	70	14,600	1,510	103
6	C-6	11	200	130	25,100	2,330	93
7	C-7	11	200	100	22,000	2,190	100
8	C-8	11	150	80	17,100	1,510	88
9	C-9	11	250	120	27,200	2,090	77
10	N-1	22	180	120	65,000	1,344	21
Total					318,100	25,479	

Note: Efficiency is expressed in the following equation.

Efficiency = Capacity / Dam Volume