4. FLOOD CONDITION AND FLOOD DAMAGE

CHAPTER 4. FLOOD CONDITION AND FLOOD DAMAGE

4.1 Flood Condition

4.1.1 Flood Prone Areas in El Salvador

According to "Regiones Criticas De Desastres Naturales De El Salvador (Critical Regions of Natural Disaster in El Salvador)", flood prone areas in the country amount to 2,573 km^2 in total and about one third of the whole area, 870 km^2, is located in the Study Area as follows:

(Flood prone Areas in El Salvador and Study Area)

Department	Flood Prone Area (km^2)	
	Whole Country	Study Area
San Miguel	773	725
La Union	459	133
Usulutan	169	12
La Paz	290	-
San Vicente	495	-
Sonsonate	169	-
Ahuachapan	218	-
(Total)	2,573	870

Information on the past floods was collected from various sources and summarized in Table 4.1. Major floods occurred in the Study Area are in 1961, 1966, 1969, 1974, 1988, 1989, 1991, 1992 and 1995.

4.1.2 Inundation Survey

Inundation survey, mainly of 1995 flood, was conducted by the Study Team in 1996. The results are as follows:

The inundated areas were classified into the following three categories:

- Inundated areas in 1995 flood
- Maximum inundated areas which have experienced any flooding in the past (regard as potential flood area)
- Frequently inundated areas, once in 2 years or more (regard as frequent flood area)

(1) Maximum Flood

The floods remembered by the residents as the maximum events are those occurred in 1969, 1988, 1989, 1991 and 1992. The number of interviewees suffered from these floods and its conditions are shown in Table 4.2. The 1988 flood was, judging from inundated depth and duration, the most disastrous one in the Jocotal and Usulutan areas among four floods after 1988. The depth and the duration of 1988 flood in San Miguel, Olomega, Jocotal and Usulutan areas were, 1.2 m/0.8 day, 1.0 m/23 days, 2.1 m/19 days and 2.7 m/27 days respectively.

(2) Frequent Flood

199 houses out of the 421 houses have experienced the inundation. And 31 houses among them have experienced frequent inundation, once or more per 2 years.

(Frequency of Inundation Experience)

	San Miguel	Olomega	Jocotal	Usulutan	Total
Total interviewee	99	168	76	78	421
Once or more till now	43	71	30	55	199
Once/2 yrs or more	5	9	9	8	31

The inundated areas are Usulutan, Jocotal, Olomega and San Miguel as shown in Fig.4.1. Inundated areas for respective cases and inundation water volumes of 1995-flood are shown below:

(Inundated Areas)

Inundated area (km^2)	San Miguel	Olomega	Jocotal	Usulutan	Total
1995-flood (km^2)	2.8	88.5	35.8	6.6	133.7
(Volume in million m^3)	(3.4)	(57)	(54)	(7.6)	(116)
Maximum flood (km^2)	7.0	98.4	44.4	31.3	181.1
Frequent flood (km^2)	0.64	44.4	29.6	0.9	75.5

(3) 1995 Flood

The number of interviewees who had suffered from inundation in 1995 and its conditions are summarized in Table 4.2. In 1995, the inundation area was the largest in September having a total area of 133.7 km^2. The depth and the duration of 1995 flood in San Miguel, Olomega, Jocotal and Usulutan areas were, 0.5 m/2 days, 0.17 m/1 week, 1.5 m/11 days and 0.9 m/1 month, respectively.

Flood mark survey was conducted to obtain actual flood stage profile of the 1995 flood.
Flood stage profile of the 1995 flood, together with the river profile, is shown in Fig.4.2.

4.2. Flood Characteristics

4.2.1 Methodology of Flood Simulation

Runoff analysis was first carried out using a runoff simulation model, and then flood flow analysis was conducted using the flood flow simulation model incorporating the results of runoff analysis.

(1) Runoff Simulation Model

Runoff simulation model was formulated in order to evaluate the runoff under various different rainfall and basin conditions. The Storage Function Method was adopted in simulation.

The San Miguel River Basin and its river channels were divided into 18 sub-basins and 12 channels respectively. Sub-basins and river channels are presented as a runoff system diagram in Fig. 4.3. Basin areas and their overall slopes are shown in Table 4.3.

Runoff from the sub-basin was simulated by storage functions expressed by the following equations:

$$S_l = k \cdot Q_l^p$$
$$dS_l/dt = (1/3.6) \cdot f \cdot r \cdot A - Q_l$$
$$Q_l(t) = Q(t + T_l)$$

where,

- S_l : Basin storage (m^3)
- Q_l : Runoff from sub-basin (m^3/sec) in consideration of lag time(T_l)
- k, p : Basin constants
- t : Time in seconds
- f : Runoff coefficient
- r : Basin mean rainfall (mm/hr)
- A : Catchment area (km^2)
- T_l : Lag time

Principally, same fundamental equations as that of the basin runoff were applied to the channel as follows:

$$S_l = k \cdot Q_l^P$$
$$dS_l/dt = sum(f_i \cdot I_i) - Q_l$$

where,

f_i : Inflow rate

I_i : Inflow

sum ($f_i \cdot I_i$) : Total of effective inflows

Basin constants (K) in the storage functions were derived from the following equation:

$$K = 7.35\ (N \times L/I^{0.5})^{0.6}$$

where,

N : Equivalent roughness of basin

L : Slope length (km)

I : Basin slope

Equivalent roughness (N) for each sub-basin was initially assumed referring to the standard values used in Japan shown in the table below:

(Standard Equivalent Roughness)

Land use	N	Land use	N
Paved road	0.05	Secondary forest	0.7
Gravel/dirt roads	0.07	Shrub	1
Town	0.1	Lava	5
River	2	Coffee	0.3
Lake and Pond	2	Cultivated area and Pasture	
Swamp	2		0.3

Relationship between the total runoff and corresponding basin rainfall at Villerias was studied. The results are shown in Fig. 4.4. Runoff coefficient of the upper basin ranges from 0.3 to 0.4.

The following two (2) floods were selected for simulation considering the magnitude of flood and availability of discharge and rainfall records.

- 1995-flood (July-September): The latest flood with relatively many data. This flood is a flood surveyed in detail by the Study Team.
- 1980-flood (June): At Las Conchas, the maximum discharge was recorded.

Available rainfall data of respective floods for calibration are listed in Supporting Report. Since the flood events and data available were quite limited, the following procedures were taken for calibrating the runoff simulation model.

1) The upper basin consisting of sub-basin No.1 through 8 was calibrated based on 1995-flood using discharge record at Villerias Station.
2) The lower basin consisting of sub-basin No.16 through 18 was calibrated based on 1980-flood using runoff records at Vado Marin and Las Conchas stations.
3) At the station where only daily rainfall records were available, the hourly rainfall distribution at the nearest station was assumed.

Results of runoff simulation for 1995 and 1980 floods are shown in Fig. 4.5. Basin and channel constants calibrated are shown in Table 4.4. These constants are assumed to be under the present basin and channel conditions. In some portions of the runoff hydrograph, calculated and measured runoffs did not agree well. This would largely depend on the lack of hourly rainfall records.

(2) Flow Simulation Model

A simulation model of a one-dimensional unsteady flood flow was formulated as shown in Fig. 4.6. The simulation was made by dividing the basin into two, Middle and Lower, because there is a supercritical flow at El Delirio. The boundary conditions for the calculation were set as follows:

1) Middle Basin:
    - Channel inflow: Discharge at Villerias
    - Sub-basin inflow: Sub-basin No.9 through 14
    - Water level at lower end: At El Delirio, assuming critical flow at section No.103

2) Lower Basin:
    - Channel inflow: Outflow from the middle basin at El Delirio
    - Sub-basin inflow: Sub-basin No.15 through 18
    - Water level at lower end: At river mouth, assuming constant water level of 1.39 m above MSL

The flood flow simulation was made under the following conditions:

1) Initial water level of Lake Olomega of 64.7 m above MSL, taking the average water level of July from the year 1970 to 1978.
2) The results of the topographic surveys made by the Study Team were used for river channel and the floodplain sections.
3) Manning's coefficient of roughness of 0.035 for the river channel and n = 0.7 to 1.0 for the floodplain were adopted.

The results of the flood flow simulation are shown in Fig. 4.7.

4.2.2 Rainfall Analysis

Rainfall analysis to determine the design discharge was made in terms of the following:

- Magnitude of a rainfall
- Duration of a rainfall
- Rainfall distribution in catchment
- Pattern of hyetograph

Six (6) rain-gauge stations which were functioning in September, 1988 are San Francisco Gotera, Beneficio El Papalon, Santiago de Maria, El Sitio, Puerto Parada and Corinto. Among them, San Francisco Gotera, El Papalon and Santiago de Maria have continuous daily data for more than 30 years. Probability analysis was made for these stations.

The annual maximum rainfall depths at San Francisco Gotera, El Papalon and the basin mean values, during 31 years from 1964 to 1995 are listed below:

ANNUAL MAXIMUM RAINFALL 1)1-DAY, 3)3-DAY, 7)7-DAY DEPTH

Name of Station	Largest Value (mm)	Smallest Value (mm)
S.F. Gotera	1) 181, 3) 215, 7) 388	1) 59, 3) 86, 7)152
El Papalon	1) 222, 3) 293, 7) 340	1) 50, 3) 81, 7) 128
Basin Mean	1) 185, 3) 259, 7) 281	1) 33, 3) 43, 7) 63

Point rainfall depths are in the order of 200 mm for 1-day, 250 mm for 3-day and 350 mm for 7-day consecutive duration.

Probable basin mean rainfall was calculated as shown in Fig. 4.8 based on the point rainfalls at these 3 stations applying Thiessen ratios of 0.300 for San Francisco Gotera, 0.509 for El Papalon and 0.191 for Santiago de Maria. Results are summarized as follows:

(Probable Basin Mean 7-day Rainfall)

Return period (yr.)	Basin mean rainfall (mm)	Return period (yr.)	Basin mean rainfall (mm)
100	362.2	5	240.9
50	335.5	2	191.4
20	299.9	1.05	120.0
10	271.7		

The rainfall distribution in the basin was studied for annual maximum 1-day and 7-day rainfalls of past floods in the basin. A reduction curve of point rainfall along area axis is shown in Fig. 4.9.

Peak runoffs by same 7-day rainfall depth were calculated for 10-year and 100-year return periods using rainfall patterns of the biggest three floods of 1988, 1992 and 1982. Rainfall pattern of the 1988-flood gives the largest runoff at all points as shown below:

(Peak Runoffs for Different Rainfall Patterns)

Location	Runoff for 10-yr. rainfall (m^3/s)			Runoff for 100-yr. Rainfall (m^3/s)		
	Sep1988	Sep.1992	Sep.1982	Sep1988	Sep.1992	Sep.1982
Villerias	910	690	670	1,410	970	990
Moscoso	1,020	710	710	1,600	990	1,050
El Delirio	1,230	690	880	2,010	1,220	1,420
Vado Marin	1,320	740	950	2,190	1,310	1,580
Las Conchas	1,470	790	1,120	2,470	1,370	1,900
River mouth	1,480	790	1,130	2,480	1,370	1,910

4.2.3 Flood Characteristics

Characteristics of flooding of the San Miguel Basin are summarized as follows:

(1) Rainfall

- Hourly rainfall intensity is high, in the order of 70 mm for large storms.
- Annual maximum daily rainfall during large storm is about 200 mm and it increases to about 250 mm for 3 consecutive days and 350 mm for 7 consecutive days.
- Rainfall occurs, in general, in the afternoon and in the night.

(2) Run-off

- Flood discharge from the Upper Basin affected by approximately 6-hour rainfall.
- Flooding of the Lower Basin is affected by about 7-day rainfall.

- Run-off coefficient of the Upper Basin is 0.3 to 0.4.

(3) Flooding

- Floodwater volume at the peak stage of 1995 flood was about 50 million cu.m in each of Olomega area and Jocotal area. Effects of flooding, including in the lakes, on the flood discharge are large. The discharge at Vado Marin during large flood is estimated to be reduced from about 1000 cu.m / sec. to 200 cu.m.

4.3 Flood Damage

4.3.1 General Features of Flood Area

The potential flood area of 18,108 ha shares 8.1 % of the Study Area, and is located along the Middle and Lower reaches of the San Miguel River. Land of the potential flood area is used for agriculture and livestock of low production rate. The area is spreading over 30 Cantons in the Departments of San Miguel and Usulutan, with a population of 33 thousand.

The lands are flat with fertile soils. Class I to III shares 20 % of that of the Study Area. 13.5 % of the arable land is distributed in the flood area, and shares 39 % of the flood area, as shown in Table 4.3. This means that the lands in the potential flood area have a potential for high agricultural production. The area of arable land can be increased by 57 % from 5,892 ha to 9,239 ha, because there is a Class IV land of 3,357 ha. The lands are located in the areas of Olomega (2,379 ha) and Jocotal (965 ha), and can be improved to be arable lands by mitigating the flooding.

Land use maps of the potential flood areas have been prepared by the Study Team, based on field reconnaissance and the aerial photographs taken in 1996, as shown in Fig. 4.10 and Tables 4.5 and 4.6. According to the maps, pasture occupies about 60 % and is distributed in the areas of un-arable land. The second is sugar cane, which is characterized as a water-tolerant crop. The main annual crop is maize distributed in the less flooding areas.

4.3.2 Flood Damage

COEN, DGEA and CEPRODE are related to the evaluation of flood damage. However, reports and data published by them cover specific areas and items, and they can not be applied to evaluate flood damage in the Study Area. However, an extent of the damage can be found in agricultural statistics.

Due to its fertile soil, the Study Area enjoys maize production, which is the most dominant crop in the area. The maize production in Region IV shares about 15 % of that of the whole country.

According to the table below, the production in 1995 and 1992, when severe flooding occurred, was decreased remarkably. Especially, the yield in the rainy season of these years showed about a half of the previous year, which might be affected by flood. The production loss during the rainy seasons of 1995 and 1992, therefore, could be estimated at 1,695,800 QQ (76,311ton) and 1,678,500 QQ (76,208 ton) respectively, which account for more than 50 % of the total production in each year, if the yield were the same as the previous year.

(Maize Production and Yield in Region IV)

	95/94	94/93	93/92	92/91	91/90	90/89	89/88	88/87
Yield(QQ/Mz)								
Rainy Season	13	27	34	14	29	27	2	26
Average	18	27	30	17	28	26	27	21
Production								
(1,000QQ)	3,307	4,540	5,553	2,891	3,972	3,226	3,169	2,596

Source: MAG

4.3.3 Flood Damage Survey

Flood damage survey consists of two kinds of surveys as follows:

- Property survey by height from the ground surface such as construction cost of the house, and cost of furniture and clothes etc.
- Flood damage of agricultural production in 1992 and 1995.

Total number of interview survey by area is shown in the following table.

(Number of Interview Survey by Area)

	San Miguel	Olmega	Jocotal	Total
Housing Property	69	93	65	227
Agricultural Damage	8	124	39	171

4.3.4 Farmer's Desire

The interview survey also included the farmer's desire after flood control. The contents of the question is "What type of agriculture will you want after flood control ?"

The results are shown in the table below .

According to the survey, land use for crop cultivation in Olomega and Jocotal area shares 50 % and 14 %, respectively. The farmers want to expand crop cultivation rather than grazing and the results are in accordance with the agricultural development policy of the country.

(Farmer's Desire; %)

	Maize	Sorghum	Sesame	Veg.	Sugarcane	Rice
Olomega	30.5	14.5	15.0	13.5	12.5	-
Jocotal	35.5	9.7	24.5	11.3	-	12.9

4.3.5 Existing Flood Fighting

There is a flood forecasting / warning system by COEN and no special organization by the residents for flood fighting. During the large flood event, flood fighting activities are to be coordinated by COEN. Flood forecasting is to be made by STAR4, as an organization in COEN.

5. FLOOD CONTROL MASTER PLAN

CHAPTER 5. FLOOD CONTROL MASTER PLAN

5.1 Basis of Planning

5.1.1 Target Year

The flood control master plan is to be prepared to meet the socio-economic conditions of the Study Area when time reaches a target year. Main items related to the master plan are,

- National and regional development policies
- Land use of the San Miguel River Basin for the design discharge calculation, and
- Land use, population, assets, etc. in the potential flood area for flood damage estimation which will be used for project evaluation.

The target year is proposed to be 2020 by the reasons below :

- National development plan was prepared up to the year 1999. Future population is projected up to 2020.
- Urban development plan of San Miguel City, proposed in 1992, targeted for the period of about 20 years.
- Since a flood control project would take a long time, program for a period of about 20 years would be required.

5.1.2 Socio-economic Framework

(1) Population of the Study Area

Population of the Study Area in 1992 was 474,000 and projected to be 1,041,000 in 2020 as shown in Table 2.4.

(2) Gross Regional Domestic Product (GRDP) in the Study Area

Projected GDP of El Salvador in 2020 is US$32,254 Million. The per capita GRDP in the Study Area in 1993 for the agriculture sector was 2,340 Colons and proposed to be increased to 3,987 Colons in the target year of 2020. The proposed flood control projects will contribute to such economic growth.

(3) Land Use Plan

Land use of the Study Area in 2020 is proposed mainly based on the standard of land classification, existing land use plan and Watershed Management Plan as presented in Sub-section 5.5.2 (Watershed Management).

A part of the inundated area will be upgraded in land classification and will be cultivated for more valuable crops after it becomes free from flooding.

Land use of the Study Area in 2020 is proposed as follows:

- The urban area will be increased according to the increase in population
- About a half of the potential production forest area will become forest. Future land use of the Study Area is shown in Fig. 5.18.

Future land use of the potential flood area is set that an area of 4,900 ha out of the existing pasture area will become agricultural area as desired by the farmers.

5.1.3 Area to be Protected

The areas to be protected by the proposed flood control project are to be located within the potential flood area (the past maximum flooded areas). In some areas, it is difficult to make them flood free by the project due to the depressed topography. Such areas were studied and identified using the topographic maps prepared by the Study Team. The result is shown in Fig. 5.1. Some areas around Lake Jocotal, Lake Olomega, and Lake San Juan are proposed to be excluded from the areas to be protected. The area to be protected, as a result of the Study, is 162 sq.km.

5.1.4 Design Return Period of Flood

The design return period of flood for the master plan is proposed to be 10 years taking the following into account :

- Though the potential flood area is an agricultural area and expected to be improved by flood control project in the future, it is still a rural area except the area near San Miguel City. Therefore, flood damage potential is low compared to that of urban area.

- The size of the San Miguel River is a medium one, and the damage caused by flood larger than the designed one will not be serious except for the area protected by dike.

- Therefore, large scale investment to cope with a large flood will not be economical.

The height of dike shall have safety against 10-year flood with freeboard of 1.2 m.

5.1.5 Design Rainfall

The design discharge is evaluated by a design rainfall consisting of rainfall distributions in the catchment and along time, and magnitude of rainfall depth in a duration. The design rainfall is proposed as follows:

- The total consecutive rainfall depth for the duration of 7 days is adopted based on the time lag between rainfall and flood in the downstream reach (Las Conchas), and rainfall depths of the past major floods.
- For the upstream reach (Moscoso), the duration of about 6 hours affects the peak flood discharge. Therefore, 6-hour rainfall depth is adopted, and the total 7-day rainfall depth is same as the depth mentioned above.
- For the rainfall distribution in the basin and along time, actual rainfall distributions of 1988 flood at five stations were used as a design rainfall pattern.

The design rainfalls (10-year return period) at four stations are shown in Fig. 5.2.

5.1.6 Land Use of the Basin for Design Discharge Calculation

Future land use of the Study Area is assumed as follows :

- The existing land use map prepared by MAG in 1996 is basically used
- The urban areas are expanded for the year 2020 based on the proposed economic frame work
- Areas for reforestation are not taken into account in order to be on the safety side of the design discharge

5.1.7 Design Discharge Distribution

The design discharge distribution for 10-year flood is to be finalized after decision of the proposed flood control method under the following conditions:

- Future land use of the basin,
- With floodwater storage by proposed facilities, and
- Improved river channels.

Calculation of the design discharge distribution along the river is made by applying the Storage Function Method using the design rainfall and the simulated coefficients. The results are shown in latter Section 5.2.

5.2 Alternative Flood Control Measures

5.2.1 Conceivable Measures

Flood control measures in general, which cover the structural and non-structural measures, are shown in Table 5.1.

Conceivable flood control measures for the San Miguel River are as follows:

The non-structural measures, as well as the structural measures, were introduced for the San Miguel River in order to cope with deforestation in the upper catchment, water related problems in the flood prone areas, etc.

(1) Structural Measures

1) River Improvement

- Dredging/excavation of the existing river including cut-off, for the reaches with small discharge capacities, such as around Olomega, around Jocotal, etc.
- Diking for the reaches, where it is difficult to make the design high water levels low, such as river mouth delta area, reaches for floodwater diversion to a retarding basin, etc.

2) Floodway/Diversion Channel, etc.

- A floodway proposed in the Olomega Project in 1967 to divert floodwater from the San Miguel River to Lake Olomega
- A floodway to make the San Miguel River short at San Felipe

3) Floodwater Storage

- Dam at San Esteban proposed by MAG for irrigation and by CEL for hydro-power in 1975 and 1995 respectively
- Group of small dams in the upper basin
- Retarding basin by using the lakes, namely, Olomega and Jocotal
- Retarding basin in the areas of Olomega and Jocotal

(2) Non-structural Measures

1) Floodplain Management

Floodplain management methods applicable to the San Miguel River Basin area as follows:

(a) To allow an area to be flooded:
There will be some areas which are difficult to make flood-free by the structural measures to be proposed.

(b) Land use regulation:
Land use regulation as well as flood proofing is necessary to reduce the flood damage by a larger flood than the designed one.

(c) Flood proofing, such as elevated house, embankment, etc.:
This will reduce the flood damage

(d) Flood forecasting and warning and flood fighting:
Flood forecasting/warning and flood fighting have been conducted by the existing system of COEN, however, it is necessary to strengthen the data/information transmission system.

(e) Public education:
This can be done MAG and COEN by using a flood risk map.

In this Master Plan, land use regulation, flood proofing, flood forecasting/warning and public education are adopted for the floodplain management measures.

(2) Watershed Management

Watershed management, as a flood control measure, reforestation, land use regulation, infiltration of stormwater, etc. are effective to reduce flood and sediment runoffs. In the Study Area, there are lands which are not properly used from the viewpoints of topography, geology, soil and water, resulting in an increase in flood runoff and soil erosion.

Reforestation and erosion/storm runoff control are adopted in the Master Plan.

A concept of the conceivable flood control measures for the San Miguel River is shown in Fig. 5.3.

5.2.2 Structural Measures

(1) River Improvement

River improvement is a primary measure for flood control. River improvement by means of diking system, channel excavation, and cut-off channel were considered for the San Miguel River. Merits and demerits of the diking method and excavation method are explained in Fig. 5.4.

Principally it is favorable to set the design high water level as low as possible, so that the rain water in the surrounding area could be drained by gravity.

The channel excavation is effective to lower the design flood level. Even for the floods exceeding the designed one, the excavated channel could alleviate the flooding in the riverine lands. However, the river improvement by channel excavation sometimes requires a large amount of earth work, and the excavated channel might bring about difficulties in taking river water and sedimentation problems.

In the meanwhile, improvement by the diking system require less earth work, especially for big rivers, and could avoid the inconvenience of water intake problem. The diking system, however, may cause the drainage problems in the areas protected by the dike and tributaries. The dike can not cope with the abnormal flood exceeding the designed one.

The cut-off channel enables smooth passage of floodwater by shortening the channel length, steepening the slope, and smoothering the alignment. For the San Miguel River, both of diking and excavation methods can be applied. Since one of the important proposes of the river improvement is to fix its course, some revetments for both methods will be required.

(2) Floodway

Two floodway schemes, Olomega and San Felipe floodways, have been studied previously.

The Olomega floodway scheme has been studied as a component of the Olomega Project proposed in 1967. The floodway aims to divert floodwater of the San Miguel River to Lake Olomega and store it there to alleviate flooding in the Lower Basin. Principal features of the floodway scheme are as follows:

- Most of floodwater of the San Miguel River is diverted at a section near Lake Aramuaca toward Lake Olomega by a new floodway
- Floodwater exceeding the design discharge of floodway is spilled into the existing San Miguel River.
- The lake water level will be raised by the confining dike around the lake in order to store the floodwater.

However, the Olomega floodway is not recommended mainly by the following reasons:

- Drainage of the areas located in the north of the lake becomes difficult due to high lake water raised by confining dike.
- Large amount of sediment will flow into the lake and shorten its life span.
- The lake's ecology will be aggravated due to the sediment and polluted water flowing into the lake.
- The project was planned about 30 years ago and social condition in the basin has changed.

The San Felipe floodway scheme has been studied in 1990 by MAG as an alternative scheme to alleviate flooding in the lower Usultan area. The floodway scheme aims to divert floodwater of the San Miguel River to the estuary area by cutting off the hill. This floodway scheme is not recommended by the following reasons:

1) The scheme requires a large amount of excavation amounting to about 2 million m^3 or more, of which greater part are rock materials.
2) Cost of the work will be higher than the improvement cost of the existing river channel.
3) The floodway will change the water and sediment flow conditions and may cause adverse effects on the downstream reaches.
4) The floodway section will have a high river bank-slopes with the height of about 35 m.

Problems of water use and maintenance after completion of the floodway are anticipated.

The Olomega and San Felipe floodways are, therefore, not incorporated in the alternative flood control schemes of the San Miguel River.

(3) Detention of Floodwater

Multi-purpose dam proposed at San Esteban (San Esteban Dam) has a catchment area of 825 km^2 and is deemed to be effective for flood control as well as for hydroelectric power generation and irrigation. There are some other possible dam sites in the Upper Basin. These dams have small catchment areas, less than 80 km^2 each and are not effective for flood control.

A group of fourteen small dams with a total catchment area of 363 sq. km was studied as a measure of flood control. This is not recommended for flood control because of the following:

- Total cost of the small dams is higher than that of San Esteban Dam, while flood control effect of the small dams is approximately one third of San Esteban's one.
- Maintenance and operation of the 14 dams are complicated and costly.

Lake Olomega has been serving naturally for floodwater storage in the Middle Basin. The storage would lighten the flood control burden in the downstream reaches. Lake Olomega has an area of 20 km^2 and is possible to store the floodwater of 20 million m^3 per effective depth of 1.0 m. Use of the existing Lake Olomega enables to get rid of the problems such as site selection and land acquisition. Effects on fishery should be avoided as much as possible.
Lake Jocotal and its surrounding areas in the Lower Basin have been reserved to protect its ecological environment. There is an extensive depressed area along the San Miguel River near the lake and it would be difficult to make the area free from flooding. In order to protect the ecology, it is not recommended to use Lake Jocotal positively for flood detention. However, the lake has been serving naturally for floodwater storage.

Retarding basin to store floodwater of 50 million m^3 will require a land of about 1,700 ha, assuming effective depth of 3 m. It is difficult to acquire such a vast land for making flood free land in the downstream. Artificial retarding basin is not recommended.

Therefore, San Esteban Dam and Lake Olomega are studied as alternative flood control measures of the San Miguel River. The floodwater storage function of the existing Lake Jocotal is reserved for flood control of the San Miguel River.

5.2.3 Non-structural Measures

(1) Floodplain Management

1) Objectives

There are four potential flood areas for floodplain management.

- Flat area adjacent to Lake Olomega
- Flat and depressed area around Lake Jocotal
- Low and flat area in the river mouth delta
- Flood area near San Miguel City

The objectives of the floodplain management are the following :

- Effective usage of Lake Olomega for floodwater storage
- Well balanced operation of the lake water level for flood damage mitigation, fishery, and lake ecology
- Prevention of increase in potential flood damage due to uncontrolled expansion of the San Miguel urban areas
- Avoidance of the unfavorable effects of embankment construction on flooding
- Prevention of increase in potential flood damage in the delta areas due to agricultural and fishery developments

2) Floodplain Management Measures

- Area Near San Miguel City -

The urban areas of San Miguel City are expanding to the flood prone areas along the San Miguel River. The existing urban areas along the river are not functioning well due to flooding. The urban areas should be located outside the river area required for flood control. A land use regulation is to be proposed.

- Lake Olomega And Its Surrounding Areas -

It is necessary to establish an operation rule of the lake water level taking the following into account :

- To keep the minimum water level during the dry season for fishery
- To maintain the maximum water level during the flood season for floodwater storage
- To monitor the river and lake water levels for minimizing the damage caused by flood including larger than the designed one

Land use regulation, flood proofing, flood forecasting/warning and education to the residents are to be proposed.

- *Lake Jocotal And Its Surrounding Areas* -

Land use regulation, flood proofing, flood forecasting/warning and education to the residents are to be proposed for this area.

- *Estuary Delta Area* -

Land use regulation flood proofing and education to the residents are to be proposed.

(2) Watershed Management

1) Objectives

The objectives of the watershed management are, to

- reduce the soil erosion volume,
- increase the river discharge in the dry season,
- reduce the peak flood discharge, and
- maintain the river water clean,

in addition to the protection of agricultural lands and preservation of nature.

2) Watershed Management Measures

The watershed management is proposed, taking topography, geology, soil and water conditions into account, for sustainable and effective land use of the watershed. The soil classification map made by MAG is basically used for planning. Major points of the plan for each sub-basin are as described below.

- *Upper Basin* -

The upper basin is an important area for water resources as well as for floodwater storage. The vast pasture areas are located even in the steep mountain slopes. Such areas should be changed into forest by reforestation.

There are mud-flow deposit areas in the upper part of the San Esteban River basin which produce much sediment discharge. Reforestation of these areas is needed.

- *Middle Basin* -

The reserved forest area in the slope of San Miguel Volcano should be kept as forest. The mountain slopes of Lake Olomega catchment should be reforested to reduce sediment and pollutant flow into the lake.

- Lower Basin -

The large mud-flow area between San Miguel and Usulutan volcanoes produces much sediments and affects the river-bed stability. The steep sloped mud-flow areas should be reforested.

Lake Jocotal water is depending on the groundwater from catchment with high permeability. Such condition should be preserved.

5.2.4 Establishment of Alternative Schemes

Flood control for the San Miguel River consists of the following components:

1) River improvement
2) Flood retention by San Esteban Dam
3) Flood retention by Lake Olomega
4) Floodplain management
5) Watershed management

By combining the structural measures, four cases of alternative schemes were established for selection of the optimum flood control master plan:

Case-1: River improvement with no dam and no storage in Lake Olomega
Case-2: River improvement with no dam and with storage in Lake Olomega
Case-3: River improvement with dam and storage in Lake Olomega
Case-4: River improvement with dam and no storage in Lake Olomega

The river improvement is a basic flood control measure and is considered necessary for every case. Design discharge distributions for the above four alternative schemes are shown in Fig. 5.5.

The non-structural measures of floodplain management and watershed management are to be adopted complementary to any of the selected scheme.

5.2.5 Facility Planning

(1) River Improvement

The San Miguel River was divided into a lot of stretches of different conditions and the channel improvement concept was discussed by each stretch. Stretch codes in the Lower and Middle basins are denoted, respectively, by the initial L and M. The concept of channel improvement is shown in Table 5.2. Layout plan of the channel improvement is shown in the Fig. 5.14.

From Sta. Rita R. to Ereguayquin R. (stretches L1 and L2): The existing channel sections are markedly small especially in L1 due to bifurcation into the Limon and the Cinco rivers. The channel is to be excavated up to L1-2 and dikes are to be constructed up to L1-3.

From Ereguayquin R. to Vado Marin (stretch L3): The existing river channel has relatively large cross section in this stretch. The channel is to be excavated and dikes are to be constructed locally.

From Vado Marin to La Canoa (stretches L4-1 through L4-4): Considering the drainage of surrounding areas, dikes are not proposed. The existing river meanders severely and channel cross section is small in these stretches. Channel excavation and making smooth alignment by cut-off channels are the principal measures. The design high water level (DHWL) was set lower than the ground except for stretch L4-2. Ground elevation along the stretch L4-2 is too low to set DHWL lower than the ground. Inundation would remain in this stretch, though the flood conditions will be improved much than ever.

From La Canoa to Sect. SM-103 (stretches L4-5): This stretch forms rapids which run between hilly lands. No work is necessary except at the upper portion of this stretch.

From Sect. SM-103 to Pelota R. (stretches M1, O1-1, COC and M2): Dike is not to be constructed in these stretches except for M2-3 setting the DHWL lower than the ground for the drainage of surrounding areas. Stretch M2-1 (sect. SM105 to SM113) of the existing San Miguel River will serve only for local drainage, because the floodwater of the San Miguel River is partly led to Lake Olomega by the proposed diversion channel and the remaining by new cut-off channel. No work is planned for the stretch M2-1, since the existing channel has enough capacity to convey runoff from its own basin.

Olomega drainage and Pelota R. (stretches O1, P1 and P2): Dike is not proposed for Olomega drainage (stretch O1) setting the DHWL lower than the ground to drain water in the surrounding areas. The Pelota River (stretches P1 and P2) is planned as a diversion channel to lead floodwater of the San Miguel River to Lake Olomega. The diversion channel is provided with dikes.

From Pelota R. to Urbina bridge (stretches M3 through M6-1): The existing river channel has relatively large cross sections. The channel is to be excavated locally. Dikes are necessary only up to Lake Aramuaca (stretch M3).

(2) San Esteban Dam

1) General

The sectors which may be concerned with the multi-purpose San Esteban Dam are hydro-electric generation, irrigation and flood control. San Esteban Dam for multi-purposes was planned based on the following assumptions:

- Sedimentation volume in the reservoir is estimated as an accumulated sediment volume for 100 years assuming the sediment yield of 1,000 m^3/year/km^2 in the dam catchment.
- Reservoir operation proposed by CEL is assumed for the required storage volume calculation for hydro-electric generation.
- Required storage volume for irrigation is obtained by assuming that the agricultural area of 11,000 ha will be irrigated as proposed by MAG.
- Flood control effect of the reservoir is calculated assuming free overflow from the spillway. The design flood hydrograph of 10-year return period is assumed for the inflow to the reservoir.
- The total cost of multi-purpose dam is allocated to each sector assuming that the allocated costs are proportional to the costs of corresponding single purpose dam.

According to the report on Hydro-electric Projects of the Lempa River and the San Miguel River prepared in 1995 by CEL, the unit power generation cost of the San Esteban Dam has been evaluated to be the highest among seven dams. The unit cost of the San Esteban Dam is five times higher than the 1st ranked Tigre Dam. Priority of the San Esteban dam for power generation is not high.

2) Hydraulic Effect of San Esteban Dam

Flood discharges were calculated based on the design rainfall hyetograph under the conditions without and with San Esteban Dam

- Without dam: No inundation along the river and no floodwater detention by the lakes of Olomega and Jocotal are considered (referred to as discharge without inundation)
- With dam: Detention effect of San Esteban Dam is considered

Calculated runoff hydrographs at the major points of the San Miguel River for 10-year flood are shown in Fig. 5.6. Discharge distribution along the San Miguel River for various probable rainfalls are shown in Fig. 5.7.

The calculated discharge distributions without inundation were compared with the existing channel capacity in Fig. 5.8. The existing channel capacity is markedly low in the reaches below Las Conchas, from Vado Marin to El Delirio, and just upstream of El Delirio.

Effect of the dam is less than 50 % in the lower reaches of El Delirio.

Section	(1) Without dam (m^3/s)	(2) With dam (m^3/s)	(2)/(1) (%)
Villerias	930	270	29
Moscoso	1,050	340	32
El Delirio	1,380	760	55
Vado Marin	1,490	880	59
Las Conchas	1,530	960	63

(3) Lake Olomega

There are two opposing issues on the use of Lake Olomega. The farmers want to develop the flood prone areas and lake for agriculture, and the fishermen want to keep the lake water level high for fishery.

According to the past records and the latest survey result, the lake water level during dry season is getting higher. This is probably due to filling up of the outlet channel of the lake implemented as a countermeasure against decrease in lake area in the past extreme dry year (refer to Fig. 5.9).
A study was made on the relation between the amount of fish catch and water level of Lake Olomega based on the statistic data by MAG. According to the result of study shown in Fig. 5.9, bigger fish catch happen to be during the water levels ranging from 64.0 m to 65.5 m above mean sea level. In other words, as far as the lake water level is kept within this range, substantial damage to fishery may not be brought about.

Considering those mentioned above, the use of Lake Olomega for flood detention was planned as follows:

- To ensure the fishery, the lake water level should be kept above 64.0 m. And to mitigate the flood damage in the surrounding agricultural lands, the lake water level should be kept below 65.5 m.

- The lake water level is to be kept at 64.5 m preparing for the coming flood. Floodwater of the San Miguel River led through the Pelota River is to be stored in the lake to the maximum water level of 65.5 m. The effective storage volume is about 20 million m^3 for the storage depth of 1.0 m (Fig. 5.10).
- Stabilizing the variations of lake water level by the operation mentioned above, the flood damage of the area around the lake and fish catch reduction due to large variation of lake water level would be avoided.

In order to detain the floodwater of the San Miguel River, the Pelota River is to be improved as a channel to divert the water to Lake Olomega.

For the calculation with storage in Lake Olomega, diversion of floodwater by diversion weir was assumed. Control by the weir is shown in Fig. 5.11.

At the inlet to the diversion channel, a diversion weir is to be constructed. For the effective use of the storage volume, a control gate is to be provided at the outlet of the lake.

The existing Olomega drainage is also to be improved for drainage of the lake water.

(4) Jocotal Area

The area around Lake Jocotal is depressed and difficult to make flood-free. Some extremely low lands would still remain flood-prone even after the completion of works. The following positive effects of the river improvement works are expected:

- Reduction of flood damage in the agricultural areas
- Reduction of floodwater inflow into the lake. This will diminish the ecological degradation and stabilize the fishery production.

5.3 Selection of the Optimum Measures

The four alternative flood control schemes were compared from technical, economic, financial, and social and natural environmental viewpoints. The cases are as follows:

Case-1 : River improvement only
Case-2 : River improvement and Storage in Olomega
Case-3 : River improvement and Storage in San Esteban Dam and Olomega
Case-4 : River improvement and Storage in San Esteban Dam

Quantities of works for respective cases are summarized in Table 5.3.

(1) Technical Aspects

There is no technical difficulty except for the multi-purpose dam, that is included in Case-3 and Case-4. As for the multi-purpose dam, some large dams have been constructed in El Salvador without any serious technical problem.

(2) Financial Aspects

The cost of the project was compared. Case-2 (0.69) is the lowest, followed by Case-3 (0.83) and Case-4 (0.89), assuming Case-1 is 1.0.

(3) Economic Aspects

All cases have the same economic effect, flood damage reduction and a regional development. Case-2 and Case-3 are expected to contribute to a stable production of fishery in Lake Olomega.

(4) Environmental Aspects

Land acquisition of 3,500 ha and resettlement of 1,300 homes are required for Case-3 and Case-4 due to the multi-purpose dam, while for Case-1 and Case-2 it is only about 400 ha and 20 homes.
All cases can improve the ecology of Lake Jocotal by reducing the floodwater inflow to the lake. Case-2 and Case-3 will stabilize the water level of Lake Olomega.

(5) Overall Evaluation

Comparison of the alternatives is shown in Table 5.4.

In conclusion, alternative scheme of Case-2 was selected as the most suitable for flood control master plan by the following reasons:

1) The total cost of flood control is the lowest and economical.
2) Negative social impact is small.

3) Positive impacts on environment are large.
4) Technically, there is no remarkable difficulty.
5) Flood damage in the greater parts of the flood prone areas will be mitigated and can be developed mainly for agricultural purpose (refer to Fig. 5.12).

5.4 Proposed Structural Measures

The proposed Flood Control Master Plan is composed of the following components (projects):

- Improvement of the San Miguel River from the river mouth to the Urbina Bridge, and
- Floodwater Storage in Lake Olomega, as structural measures,

- Watershed Management by reforestation and sediment / storm runoff control, and
- Floodplain Management of the potential flood areas, as non-structural measures.

Concept of the Master Plan is shown in Fig. 5.13.

General features of the proposed structural measures in the Master Plan are as follows:

(1) Improvement of the San Miguel River

- Total length 109 km of the existing river from the Santa Rita Canal confluence to the Urbina Bridge is to be improved and shortened to 92 km by the cut-off channels,
- Dikes along right bank side and some parts of left bank side in the river mouth delta area and small parts in the downstream of Vado Marin,
- Dikes from the Pelota River junction to downstream of Lake Aaramuaca on both sides to prevent flooding and to raise the river flood level for diversion,
- Dredging and excavation of the river channel for whole improvement reaches. Reaches between, Lake Aramuaca and the Urbina Bridge, and upstream of the Ereguayquin River confluence are to be excavated partially. The rapids at El Delirio are not to be dredged.

(2) Olomega Diversion / Retarding

- Floodwater of the San Miguel River is to be diverted into Lake Olomega through improved Pelota River.
- At the diversion point, a weir to overflow peak parts of the floods was proposed.
- The downstream reach of the diversion weir was proposed to have narrow cross section in order to keep a certain level of flood required for diversion.

- Shallow portion of the lake is to be dredged as a part of the diversion channel.
- Outlet of the lake is to be dredged to drain the lake water during flood season.
- At the outlet of the lake, a gate to control the lake water level was proposed.

General layout of the proposed facilities is shown in Fig. 5.14. Principal features of the San Miguel River improvement are presented in Table 5.5 and proposed longitudinal profile and typical cross sections are shown in Figs. 5.15 and 5.16 respectively.

Main features of the works of the project are summarized below.

Dredging / Excavation	: L = 89 km, 15.0 million m^3
Dike	: L = 48 km, 1.8 million m^3
Revetment	: L = 6,000 m
Drainage Sluice	: 15 places
Groundsill	: 4 places L = 348 m
Diversion Weir	: L = 62 m, 1 place
Olomega Control Gate	: Effective Span = 20 m, 1 place
Bridge	: 5 places

5.5 Proposed Non-structural Measures

5.5.1 Floodplain Management

(1) Objectives

- Effective use of Lake Olomega for floodwater retarding,
- Well balanced operation of the lake water level for flood damage mitigation, fishery and ecology of the lakes of Olomega and Jocotal,
- Prevention of increase in potential flood damage due to uncontrolled expansion of the San Miguel urban area,
- Avoidance of unfavorable effects of embankment construction on flooding, and
- Prevention of increase in potential flood damage in the river mouth delta area due to agricultural and forestry developments.

Proposed floodplain management covers the flood forecasting/warning, land use regulation, flood proofing and public education, for the four areas of San Miguel, Olomega, Jocotal and Usulutan.

(2) Contents of Floodplain Management Project

Proposed floodplain management project is as follows;

① flood forecsting/warning (five water level stations and warning to the residents)
② land use regulation
③ flood proofing, like elevated floor housing, etc.
④ education to the residents

The contents by area are as follows;

- Area Near San Miguel City -

The urban areas of San Miguel City are expanding to the flood prone areas along the San Miguel River. The existing urban areas along the river are not functioning well due to flooding. The urban areas should be located outside the river area required for flood control. A land use regulation is proposed.

- Lake Olomega And Its Surrounding Areas -

It is necessary to establish an operation rule of the lake water level taking the following into account :

- To keep the water level high during the dry season for fishery
- To maintain the water level low during the flood season for floodwater storage
- To monitor the river and lake water levels for minimizing the damage caused by flood including larger than the designed one

Flood forecasting/warning, land use regulation and flood proofing are proposed. For smooth implementation of the project, education of the project to the residents is required for their understanding.

- Lake Jocotal And Its Surrounding Areas -

Flood forecasting/warning, land use regulation and flood proofing are proposed for this area.

- Estuary Delta Area (Usulutan)-

Land use regulation and flood proofing are proposed.

Proposed Floodplain Management (Master Plan) is shown in Fig. 5.17.

5.5.2. Watershed Management

(1) Objectives

- To reduce the soil erosion volume,
- To increase the river discharge in the dry season,
- To reduce the peak flood discharge,
- To maintain the river-water clean, and
- To protect the agricultural land from erosion and preservation of nature.

(2) Basic Concept

1) Topography, geology, soil and water conditions are taken into account for sustainable development. The soil classification map made by MAG is basically used for planning.

2) An ideal land use plan, as a long-term program, was proposed by the Study Team by using the map made by MAG (refer to Fig. 2.9).
3) For the Master Plan, the areas of reforestation and erosion control are to be selected from the ideal land use plan considering the work volume possible to complete until the target year of 2020.

Major points of the watershed management plan for each sub-basin are as described below:

<u>Upper Basin</u>
The Upper Basin is an important area for water resources as well as for floodwater storage. The vast pasture areas are located even in the steep mountain slopes. Such areas should be changed into forest by reforestation. There are mud-flow deposit areas in the San Esteban River basin which produce much sediments. Reforestation for steep slope areas or erosion control for gentle slope areas will be needed.

<u>Middle Basin</u>
The reserve forest area in the slope of San Miguel Volcano should be kept as forest. The mountain slopes of Lake Olomega catchment should be reforested to reduce sediments and pollutants flow into the lake.

<u>Lower Basin</u>
The large mud-flow deposit area between San Miguel and Usulutan volcanoes produces much sediments and affects the river-bed stability. The steep sloped mud-flow deposit areas should be reforested, and erosion control be made in the gentle sloped areas. Lake Jocotal water is supplied by the springs originated from the catchment with high permeability, and such condition should be preserved.

(3) Contents

1) Reforestation : 300 km^2

- Protection forest area of about 70 km^2 out of the total area of 207 km^2, excluding existing forest and the areas where it is difficult to reforest
- Potential production forest area of 74 km^2 located in the mud-flow deposit area
- Upstream steep slope area of 156 km^2, which is used for pasture

2) Erosion Control : 200 km^2

- Potential agricultural area of 200 km^2 located in the mud-flow deposit areas having relatively steep slopes. Drainage and stormwater retention are applied.
- Ground sills of 30 places in the rivers located in the mud-flow deposit areas

The proposed watershed management is shown in Fig. 5.18.

5.6 Operation and Maintenance Plan

Operation and maintenance of the flood control facilities, after construction, will be conducted by MAG as described below:

- Operation and maintenance of the facilities, such as river banks, dikes, revetments, diversion structures, gauging stations, will be carried out by MAG.
- The Project Office in San Miguel provided during the construction stage will carry out the management of the facilities.
- For maintenance and management of facilities, a staff of ten will be required in the Project Office to be constructed in the construction stage.
- For maintenance and operation of facilities at Lake Olomega, a staff of five will be required in the Olomega Site Office to be constructed in the construction stage.

Management of the non-structural measures will be conducted by MAG and COEN as follows;

- Emergency activities during the flood will be made by COEN.
- Watershed management including reforestation and erosion control will be carried out by MAG. CENTA in Morazan will be involved in execution of the field work of the project. Five more employees would be required for the activities such as research, education, nursery, etc.
- For watershed management, five employees will be required in the Project Office in San Miguel. Close contact with CENTA in Morazan will be required.
- For Floodplain Management, the same personnel for Structural Measures will also hold the post of Floodplain Management in the Project Office in San Miguel and in the Olomega Site Office.

5.7 Organization and Institution Plan

5.7.1 Structural Measures

The project is proposed to be implemented with the following method:

- Detailed design and construction supervision will be made by the government with the assistance of selected consultant(s).

- Construction works will be carried out by contractor(s), selected through international competitive tendering, under supervision of the government.

At present, MAG is in charge of flood control for all stages of planning, design, construction and operation/maintenance except for large scaled construction works. Therefore, MAG will be the executing agency for the project. Hence the project includes large scale earth work volume and bridge construction, involvement of MOP during the construction stage will be required.

The proposed organization for construction stage activities, which include the preparatory work, detailed design, tendering, land acquisition/compensation, construction supervision and coordination with agencies concerned, consists of the following (refer to Fig. 5.19) :

- Central Office of MAG and MOP in San Salvador
- Project Office in San Miguel
- Consultant(s)

5.7.2 Non-structural Measures

Organization in charge of the floodplain management will be the MAG San Miguel Office and the existing system of COEN including STAR 4.

MAG will undertake the execution of the watershed management project. The San Miguel Office together with the CENTA Morazon Office will execute the project. Reforestation and the ground sill works of the erosion control are to be executed directly by MAG. The erosion control of the flat pasture areas for upland field will basically be carried out by the land owners under the guidance of MAG and applying the incentives given to them as planned in the Environmental Program of El Salvador (PAES).

5.8 Project Cost

5.8.1 Basis of Cost Estimate

The project cost consists of the costs for:

1) Construction works,
2) Land acquisition / compensation,
3) Administration,
4) Engineering services,
5) Physical Contingency, and
6) Price Contingency.

The project cost was estimated based on the following conditions and assumptions:

1) All the costs are expressed based on the fixed price as of December 1996.

2) The exchange rate of currencies is assumed according to the prevailing exchange rate during the study period as follows:

    - US$ 1.00 = Colons 8.75

3) Administration cost is assumed at 5 % of the total costs of construction works and land acquisition / compensation.

4) Engineering services cost is assumed at 15 % of the total costs of construction works and land acquisition.

5) A physical contingency is assumed to be 10 % of the total costs of construction works, land acquisition / compensation, administration, and engineering services.

6) Annual price escalation rates during the construction period are assumed at 3 % for foreign currency portion and 6 % for local currency portion.

7) The construction cost in principle is estimated on the basis of unit costs supported by unit prices of labor, materials, cost for operation of equipment and indirect cost. The cost is estimated for the local and foreign currency components.

5.8.2 Structural Measures

(1) Unit Prices and Unit Costs

- The unit prices of materials, labor and equipment are based on the data prepared by MAG, MOP, CEL, etc.
- The construction cost, consisting of mobilization / demobilization, preparatory works and main civil works, is estimated by adopting a unit cost which is then multiplied by the corresponding work quantity.
- The unit cost is estimated based on the conventional construction method.
- The costs of land acquisition and compensation are based on the properties affected by the river improvement and diversion works and estimated based on the unit costs prepared by MAG.

(2) Project Cost

The project costs for the Master Plan were estimated as follows:

1) Construction works	:	807.5 million colons
2) Land Acquisition / Compensation	:	23.8 million colons
3) Administration	:	41.6 million colons
4) Engineering Services	:	124.7 million colons
5) Physical Contingency	:	99.8 million colons
Sub-total	:	(1097.4 million colons)
6) Price Contingency	:	480.2 million colons
Total	:	1,577.6 million colons

Breakdown of the project cost is shown in Table 5.6.

Annual disbursement schedule was also estimated based on the assumed implementation schedule as shown in Table 5.7.

5.8.3 Non-structural Measures

(1) Floodplain Management

The cost of Floodplain Management is estimated at Colons 8.1 Million for telemetering system and office. This is closely relate to the operation of Lake Olomega water level and the cost was included in the cost of structural measures. The cost of land use regulation and flood proofing is not included as it would be a separate project executed by the government by applying subsidy, etc.. The cost of education to the residents is included in the cost of administration in the structural measure costs. The O/M cost is estimated at Colons 0.72 Million per year. Breakdown of the project cost is shown in Table 5.8.

(2) Watershed Management

The cost of Watershed Management consists of the costs for reforestation including saplings and planting, erosion control works of upland fields and the groundsill works. The total cost is estimated at Colons 208.0 Million as shown in Table 5.8. Reforestation of the protection areas of 7,000 ha. (21 Million Colons), the steep slope areas of 23,000 ha, and the ground sill works of the erosion control area to be executed by MAG as public works. The erosion control of the flat pasture areas for upland field of 20,000 ha. (100 Million Colons) will basically be carried out by the land owners under the guidance of MAG and applying the incentives given to them, such as loan, technology transfer, etc.

5.9 Project Evaluation

5.9.1 Structural Measures

(1) General

The Study Area covers 2,247 km^2 spreading over the four Departments; Usulutan, San Miguel, Morazan and La Union in the Region IV. The potential flood area, in the Study Area, covers approximately 180 km^2 in the Departments of San Miguel, Usulutan and small part of La Union.

In the present Master Plan, the project is aiming to reduce the flood damage for the 10-year flood, and its effect is evaluated from the economic, financial and environmental points of view.

The economic evaluation would be described in detail in the succeeding section. The financial aspect would be discussed about raising and refund of the construction fund of the project. The financial evaluation of the project would not be carried out in the present study, because the project have no financial revenue.

(2) Economic Evaluation

1) Economic Benefit

Benefit of the flood control project is generally defined as an economic difference between "with-project" and "without-project" situations.

Of the economic benefit, direct/tangible benefit of the flood control project is evaluated as a reduction in damage to assets such as building, household effects, livestock, agricultural field crops, infrastructure and other facilities. On the other hand, indirect/tangible benefit is evaluated by an effective land use of the flood prone area, for urban, agriculture, etc., after completion of the project. However, the indirect/tangible benefit is not included in the project evaluation of this study.

Based on a difference of two inundation areas between without-project and with-project situations, number and area of assets to be saved from flood damage are obtained by category of assets, return period of flood and water depth, as listed in Table 5.9 based on the conditions given in Tables 5.10, 5.11 and 5.12.

The following tables give reduction amount of damage expected by implementing the project for the Master Plan.

Reduction in Flood Damage (Cols. Million)

Return Period (Year)	Reduction
1	46.46
2	112.45
5	145.54
10	170.72
20	196.03
50	173.95
100	116.60

Using the reduction in flood damage above, an expected Average Annual Benefit would be estimated at Colons 156.87 Million.

2) Economic Cost

For the purpose of the economic evaluation, the project cost is converted into the economic cost which excludes portions of inflation and transfer payments such as taxes and duties. Besides these exclusion portions, the economic cost is estimated taking shadow prices into account. The shadow prices are based on the standard conversion rate (SCR) and the opportunity costs of items such as land acquisition and wage of unskilled labor. The annual flows of the economic costs calculated for the years from 1999 to 2010 are shown in Table 5.13. The total amount of the economic and financial costs are listed below:

Construction Cost		Annual OM Cost	
Financial	Economic	Financial	Economic
1,577.56	998.29	10.04	4.03

3) Economic Evaluation

EIRR of the project for the master plan indicates 14.6 %, supporting that the project is economically feasible, in view of the opportunity cost of capital (approximately 12 %) in El Salvador. In addition, NPV of Cols. 99.51 Million and B/C of 1.2 at a discount rate of 12 % support the economic feasibility of the project (refer to Table 5.14).

(3) Financial Aspects

The project cost (except the OM cost) is estimated at US$ 146.037 Million, consisting of US$ 116.646 Million for the F.C. portion and US$ 29.391 Million for the L.C. portion at the 1996 price level. These amounts are scheduled to be disbursed over a period of 10 years.

Considering that the project will require a vast fund for short period , as an example, the project cost is assumed to be financed with a loan, under the terms of (1) an interest rate of 6 % per annum, (2) a repayment period of 30 years including a grace period of 10 years, and (3) paying only the interest of debt every year for the construction period, and the capital amount with interest in years after the construction period.

Table 5.15 gives examples of annual requirement of fund and repayment schedule for two scenarios of loans for (1) the whole project cost and (2) only the F.C. portion. The total refund with interest will amount to US$ 212,353 Million in the scenario (1) and US$ 169.649 Million in the scenario (2). The maximum amount of annual repayment will be US$ 11.683 Million in the scenario (1) and US$ 9.332 Million in the scenario (2) in the 11th year. The annual repayment amount above will be less than 10 % of the total amount of the annual international payment of El Salvador, judging from that an average repayment amount of official debt was US$ 130 Million per annum during the period 1991-1994:

The government national budget for 1996 is Colons 14,815 Million, as a result of annual increase by 24.4% during two years from 1994 to 1996. The government estimated the budget at Colons 198.5 Million for the San Miguel Flood Control Project in the Development Plan. About 90 % of the budget was expected to be financed by foreign aids.

A project of this nature, non-profit and public, would require financial assistance by an international funding agency.

(4) Initial Environmental Examination (IEE)

The results of IEE are presented in Table 5.16. Major impacts of the Project are as follows :

1) Social Impacts

- Land acquisition, for the San Miguel River improvement, of 676 ha. (-)
- Compensation of 20 houses (-)
- Disturbance of the communities during the construction work (-)
- Improvement of sanitation due to decrease in flooding (+)

2) Natural Environmental Impacts

- Mitigation of polluted floodwater of the San Miguel River flow into Lake Jocotal (+)
- Stabilization of fishery production in Lake Olomega (+)

(5) Socio-economic Effects

- Contribute to development and stability of the region,
- Increase in employment opportunity by execution of the project, and works
- Improvement of the environment for socio-economic activities in the communities.

(6) Evaluation of Structural Measures

The proposed project of the structural measure is viable from the following viewpoints:

- Economically feasible (EIRR = 14.6 %),
- Negative environmental impacts of land acquisition / compensation and disturbance by construction work are not large,
- Positive environmental impacts on lake ecology, sanitation, etc. are large, and
- Contribute to the development and stability of the region.

5.9.2 Non-structural Measures

(1) Floodplain Management

1) General impacts on all flood prone areas are,

- Decrease in flood damage potential including danger,
- Decrease in flood control cost in the future, and
- Saving of the flood control project cost

2) Specific impacts on each flood prone area are,

- Stabilization of fishery production in Lake Olomega, (fishery related people of about 10,000)
- Improvement in ecology of Lake Jocotal, and
- Smooth development of the San Miguel urban area

The floodplain management is important to support the structural measure project.

(2) Watershed Management

1) Reforestation of Steep Slope Areas (30,000 ha)

- Decrease in runoffs of flood, sediments and nourishment,
- Increase in river water in dry season and improvement in water quality,
- Decrease in sediment runoff especially from mud flow deposit areas of 74 km^2, which will contribute to flood control,
- Increase in forestry production/employment opportunity, and
- Improvement in natural environment.

2) Erosion Control of Potential Upland Field Areas (20,000 ha)

- Increase in agricultural production/employment opportunity,
- Decrease in runoffs of sediments and nourishment,
- Improvements in river channel stability and river water quality, and
- Increase in agricultural production/employment opportunity.

The watershed management will contribute to development and stability of the region.

5.10 Implementation Schedule

The project implementation time schedule is prepared as follows: (refer to Fig. 5.20).

(1) The project is planned to be completed by the year 2020 .

(2) River improvement works of the Master Plan Project is subdivided into two stages, "Priority Project" to cope with 2-year flood and "The Rest" to cope with 10-year flood for effective implementation. Whole construction works is proposed to be completed within 10 years. Construction of the Priority Project is planned to be completed within 5 years. The area allowed to be flooded by 10-year flood is 19 sq. km for the Master Plan Project and it would be about 42 sq. km for the Priority Project.

(3) The works for floodwater storage in Lake Olomega shall be completed prior to the river improvement works of the upstream reaches.

(4) For other reaches of the San Miguel River, river improvement works shall be implemented, in principle, from the downstream toward the upstream to avoid the effects on the flooding downstream area.

(5) Floodplain Management and Watershed Management projects are scheduled to be implemented in early stage independent of the structural measures.

(6) The water level stations required for the flood forecasting/warning of the floodplain management are to be provided by the year 2005.

5.11 Water Resources Development Scenario

The Study Area has a long dry season, and therefore, the flood control scenario would be more attractive if water resources problem is solved.
The results of water resources development study are summarized as follows:

- Group of small dams is not efficient compared to the San Esteban Dam for flood control. The small dams will be considered mainly for irrigation.
- The San Esteban Dam for multi-purpose is not included because of large social impact, low economic efficiency, etc. The value of EIRR is not so low of 10.6 % and it is desirable to have a further study for the final judgement.
- Water of the San Miguel River is being polluted mainly due to wastewater effluent from the urban areas. Wastewater treatment would be required.
- Groundwater level in the San Miguel City area has been lowered due to concentrated locations of intake wells for water supply. The wells should be distributed moderately in the areas along the skirt of San Miguel Volcano.

Taking account of the above results, a scenario for water resources development of the San Miguel River Basin is proposed as follows:

For short-term program,

- Usage of the river water and groundwater for irrigation of the areas, which will become flood-free by the flood control project,
- Study and redistribute the locations of intake wells for water supply of San Miguel City,
- Treatment of the wastewater from San Miguel City, and
- Further study of water resources development method by dams, such as the San Esteban Multi-purpose Dam, the Taisihuat Dam, selection of small dams for irrigation, etc.

and for long-term program,

- Construction of the selected dams based on the above study, and
- Use of groundwater

6. FEASIBILITY STUDY OF PRIORITY PROJECTS

CHAPTER 6. FEASIBILITY STUDY FOR PRIORITY PROJECTS

6.1 Priority of Projects

6.1.1 Criteria for Selection

The criteria for selection of the priority project(s) are as follows:

Economic Target;	EIRR is larger than that of Master Plan value of 14.6%
Financial Target;	The total cost is less than 800 Million Colons
	The construction period can be less than 5 years
Social Target;	The negative impact is small and acceptable, and positive impact (beneficial area) is large
Environment Target;	The negative environment impact is small
Technical Target;	No remarkable difficulty in engineering and construction

6.1.2 Selection of Priority Projects

(1) Structural Measures

A phased implementation with at first a small scaled project and the rest to cope with 10-year flood as second phase was studied, since the cost of the project covered by the Master Plan is high. As the first-phase project, river improvements to cope with 2-year flood, 5-year flood and 10-year flood were compared. The EIRRs are 18.1 %, 15.9 % and 15.2 % respectively. The 2-year flood was selected in view of the size of the project cost and efficiency of flood area reduction as compared in Fig. 6.1.

Thus, the Master Plan project is divided into the following projects.

San Miguel River Improvement, Lower Reach (River mouth - El Delirio)
  Improvement to cope with 2-year flood
  The Rest of Improvement to cope with 10-year flood
San Miguel River Improvement, Middle Reach (El Delirio - Aramuaca)
  Improvement to cope with 2-year flood
  The Rest of Improvement to cope with 10-year flood
San Miguel River Improvement, Reach around San Miguel City
  (Aramuaca -Urbina Bridge)
Olomega Diversion / Retarding

Flood area reduction by each river improvement project against 10-year flood is summarized below:

Project	Flood Area Reduction
Lower Reach 1 (to cope with 2-year flood)	26.6 km^2 (25.9 %)
Middle Reach 1 including Olomega Diversion / Retarding (to cope with 2-year flood)	53.9 km^2 (51.8 %)
Sub-total	80.5 km^2 (77.7 %)
Lower Reach 2, The rest (to cope with 10-year flood)	15.2 km^2 (14.6 %)
Middle Reach 2, The rest (to cope with 10-year flood)	7.9 km^2 (7.6 %)
Upper Reach (to cope with, 10-year flood)	0.4 km^2 (0.3 %)
Total	104.0 km^2 (100 %)

The rates of flood area reduction of the Lower and the Middle reaches river improvement projects are large and can cover 78 % of the Master Plan value. As shown in Table 6.1, socio-economic, environmental positive impacts of these projects are high while the negative impacts are low.

The River Improvement of the Lower and the Middle reaches and Floodwater Storage in Olomega to cope with 2-year flood are recommended to be priority projects of the structural measures.

(2) Non-structural Measures

Non-strutural Measure projects in the Master Plan are as follows;

Watershed Management

Watershed Management, Upper Basin (Reforestation)
Watershed Management, Middle Basin (Reforestation / Erosion Control)
Watershed Management, Lower Basin (Reforestation / Erosion Control)

Floodplain Management

Floodplain Management, Estuary Area
Floodplain Management, Jocotal Area
Floodplain Management, Olomega Area
Floodplain Management, San Miguel City Area

For the non-structural measures, watershed management projects were not selected as priority project for the Feasibility Study because of the following:

- Projects will be executed mainly by land owners with the assistance of the government and would take long period,
- Detailed plan of the reforestation and erosion control can be done by MAG, because he has experienced some projects and studied how to implement. CEL has conducted a reforestation project in the dam basin. and
- Not pure flood control project but mostly for forestry, agriculture and environmental improvement though it is derivable for flood control also.

The reforestation and erosion control projects, however, will be required for development and stability of the region. The projects should be started in early stage and continued steadily.

Floodplain management for the areas around Olomega, around Jocotal and near San Miguel City were selected as priority project with the following reasons:

- For the estuary area, floodplain management can be done without feasibility study,
- For the area near San Miguel City, urbanization is rapid and it is urgently required to study, how to regulate the urbanization in relation to the river improvement, and
- For the areas around Olomega and Jocotal lakes, it is necessary to establish a rule of flood control and usage of the lakes by the feasibility study.

Selected priority projects for non-structural measures are as follows:

Floodplain Management, Jocotal Area
Floodplain Management, Olomega Area
Floodplain Management, San Miguel City Area

6.1.4 Selected Priority Projects

Selected priority project based on the discussions between the El Salvador side and JICA Study Team, the following projects were selected as the Priority Projects for the Feasibility Study.

- San Miguel River Improvements of Lower and Upper Reaches and Olomega Diversion / Retarding to cope with 2-year flood for structural measures, and

- Floodplain Management of the areas near San Miguel City, around Olomega and around Jocotal for non-structural measures

Main features of the priority projects are summarized in Fig. 6.2.

6.1.5 Planning Conditions

Study Area	:	Rio Grande de San Miguel Basin in the East Region (2,247 sq. km)
Target Year	:	2020 for the Master Plan and 2005 for the Priority Project
Target Area to be Protected	:	162 km^2 out of flood prone area of 181 km^2 excluding extremely low areas around the lakes
Design Flood	:	10-year flood for the Master Plan and 2-year flood for the Priority Project (refer to Fig. 6.3)

The Feasibility Study has been conducted by collecting supplementary data / information, supplementary river survey, reconnaissance on geology and soil along the San Miguel River and studying in more detail.

6.2 Floodwater Retarding Plan

6.2.1 Diversion Plan

(1) Flood Discharge Distribution

The basic idea of the flood discharge at the diversion point is that the San Miguel River is to take more than half of the peak discharge of the flood, while less than half is to be diverted to the lake. This is because too much dependence on a storage will be dangerous in case of a flood of a larger scale than the design one. The hydrographs at the Olomega Diversion for the Master Plan and the Priority Project are shown in Fig. 6.4. The crest elevation and the weir length are 66.1 m above mean sea level (MSL), 62 m for the Priority Project and 67.3 m above MSL, 62 m for the Master Plan respectively.

For the Master Plan (10-year flood), the discharge diverted into the lake is 490 m^3/s, out of the peak discharge of 1,150 m^3. The volume of storage in the lake for this design flood is 19 million m^3/s, in which 13 million m^3 are from the San Miguel River and 6 million m^3 from the lake catchment.

For the Priority Project (2-year flood), the discharge into the lake is 290 m^3/s, out of the peak discharge of 660 m^3/s. The total volume of storage in the lake for this design flood is 14 million m^3, in which 9 million m^3 are from the San Miguel River and 5 million m^3 from the lake catchment.

The calculated relationship of the elevation, the surface area and the water volume is shown in Fig. 5.10. The bottom elevation of the lake is 62 m and the storage volume below 64 m is 23 million m^3. The storage volume between the elevation 64.5 m and 65.5 m is 29 million m^3.

In planning of storage allocation, following factors were taken into account;

(1) Estimated sedimentation in 100 years (20 million m^3)
(2) Optimum water level for fishery (EL 64.0m～EL 65.5m)
(3) Required flood storage volume (19 million m^3)

Consequently, the planned storage allocation of Lake Olomega is as follows;

Dead Capacity	23,000 m^3	(EL 62m～EL 64.5 m)
Flood Control Capacity	29,000 m^3	(EL 64.5m～EL 65.5 m)

(2) Simulation

1) Flood Simulation

In order to see the behavior of the lake during a flood larger than the design flood, a mathematical simulation was performed. The conditions for simulation are as follows;

River Improvement	Priority project level (2-year flood)
Return Period of Design Flood;	10 years
Initial Lake Water Level;	64.5m
Inflow from the own catchment;	considered
Outflow from the Olomega Control Gate;	0 m^3/s

According to this simulation, when the design flood comes, the maximum water level of the lake reaches 65.6m, only 0.1m above the Design High Water Level and will give no serious damage to the surrounding area.

2) Drought Simulation

The behavior of the lake during an extreme drought was simulated. The conditions for simulation are as follows.

Data duration	:	Between 1970 and 1979
Inflow	:	Based on the discharge data of Moscoso converted by using specific discharge.
Evaporation	:	Estimated by multiplying 0.7 to the pan evaporation at El Papalon.

The lake water level can be maintained above 65.0 m even in 1978, the driest year in ten years, by the implementation of the project. Without the project, the lake water level went down to 63.4m and caused damage to the fishery.

6.2.2 Facility Plan

(1) Diversion Weir

For this type of structure, three different ideas were compared, namely a concrete monolith type, a concrete paved embankment type and a gabion type. The comparison is shown in Table 6.2. Finally a concrete monolith type was selected mainly because of maintenance reason. The diversion weir should be planned so as to cope with both the two-year flood and the ten-year flood. Therefore, the structure was planned for two-year flood first for the priority project and its modification in the final stage for the Master Plan.

(2) Olomega Control Gate

The width and the depth of the proposed channel were determined to have larger capacity than the existing outlet channel. Proposed width and bed elevation of the channel are 25 m and 63.0m, respectively. As the gates are to be operated to cope with the small change of inflow and to maintain the lake water level during the wet season, the gate system should be composed of many number of small gates. The width of each gate is proposed to be two meters. The gates are planned to cope with the 10-year flood and the same structures are to be applied for 2-year flood.

Operation of the Gates:

<u>During the wet season</u>

- To maintain the lake water level at 64.5m before a flood overflows the diversion weir

- When the flood overflows the diversion weir, the gates are controlled so that the flood is stored in the lake effectively

- After the flood is over and the danger of inundation downstream eliminated, the stored water is released by controlling the gates, and the flood storage volume is recovered

- At the end of the wet season, the gates are operated so that the lake water level is raised up to 65.0m and maintained as it is

<u>During the dry season</u>

- The lake water level is maintained at 65.0m by closing the gates completely

- The total evaporation depth during the dry season is estimated as 80 to 90 cm, and as there is still inflow from the own catchment, the lake water level is maintained above 64.0m

6.3 River Facility Plan

6.3.1 Improvement Concept

The San Miguel River improvement for the Priority Project is proposed as follows:

- Design tide level at the river mouth is the mean high spring tide of 1.4 m above mean sea level
- The downstream flood area in Usulutan will be protected by the dikes.

- The flood area around Lake Jocotal will be reduced by dredging / excavation which lowers the river flood level.

- The flood area around Lake Olomega will be reduced by dredging / excavation for the downstream area and by the dikes for the upstream area. The dikes in the upstream reach is proposed also for floodwater diversion to Lake Olomega.

- The flood area near San Miguel City will be improved in the Master Plan stage. Flood damage in this area before the Master Plan stage will be reduced by means of the floodplain management.

- The dikes are proposed to have a freeboard of 1.2 m above 10-year flood level.

- River channel cross sections are proposed to be compound sections for the channel stability. Low water channel sections are planned to have similar capacities as the existing ones to discharge frequent flooding after flood control.

- Concave sides of the bending sections are protected by revetments.

- Double investment in the future river improvement is to be minimized.

6.3.2 River Alignment

Alternative studies of the river alignment for two reaches, near estuary and around Lake Olomega, have been made.

Near Estuary

Three alternatives, as shown in Fig. 6.5, were compared from viewpoints of the river improvement cost, effects on mangrove forest and flood area reduction. The alternatives are the following:

Alt.1 : Dike up to Cerro El Encantado (same location as the existing dike), and dredging of the River for the farm land section

Alt. 2 : Dike up to the end of the farm land section

Alt. 3 : Dike up to the end of the farm land section and cutting the mangrove trees

Comparison of the Alternatives is shown in Table 6.3.

The Alt. 1 was recommended because of the following reasons:

- Flooding of the cultivated area ,where it was mangrove forest before, will be reduced by the river dredging,
- Effects of river improvement on mangrove during the large flood is small due to dispersion of floodwater over the cultivated areas,
- Construction cost is low, and
- Cutting of the mangrove trees avoided

Around Olomega

Three alternative alignments, as shown in Fig. 6.6, were compared (refer to Table 6.4).

Alt. 1 : Same alignment as existing the San Miguel River. Improve the Pelota River and its use as a diversion channel.

Alt. 2 : Same as ALT. 1 except a cut-off before El Delirio

Alt. 3 : Improve the Pelota River and Olomega Drainage as a new San Miguel River

Alt. 1 is recommended because of,

- the construction cost is the lowest,
- no serious social impact, and
- effects on river water use can be avoided.

Layout of the river improvement plan is shown in Fig. 6.7.

6.3.3 Longitudinal and Cross Sectional Plan

Longitudinal profile and cross sections of the San Miguel River for the Priority Project have been proposed as follows:

- Longitudinal profiles of the design high water level and the river-bed are, in principle, proposed approximately parallel to the ground level line or the past flood level line in the flood prone areas.
- No improvement for about 10 km from the river-mouth (Canal Santa Rita)
- Cross sections of the low-water channels are well balanced sizes from the upstream to the downstream.

Proposed longitudinal profiles and representative cross sections of the San Miguel River are shown in Figs. 6.8 and 6.9 respectively.

6.3.4 Facility Plan

(1) River Channel

Concept of channel improvement of the San Miguel River is shown in Table 6.5.

River Stretches for Channel Design

The San Miguel River and its related channels were divided into 20 stretches for channel design purposes, i.e., stretches L0 through L3 for the lower reach, M1 through M6 for the middle reach, U1 through U6 for the upper reach, FW and O1 for Olomega Drainage, and P2 for the Pelota River.

Channel Alignment

Channel alignment is generally the same for Master Plan and Priority Project. Especially the dike alignments of the Priority Project are designed on the same alignments as those of the Master Plan. The channel alignment was principally designed on the existing river course except the following:

1) Local sharp bends of the existing river: Alignment to be smoothened

2) Meandering river reaches in Jocotal area (stretches M2 through M5): Improved by cut-off channels.

3) Olomega diversion channel along the Pelota River (stretch P2): Channel was realigned to reduce the house compensation

4) New cut off downstream from SM113 (stretch FW)

Channel Profile

Design high water level (DHWL) was set considering the past flood water level and ground elevation to be drained. The DHWL of the Priority Project was set at the same elevation as that of the Master Plan. The DHWL was set lower than the 1995-flood water level as a whole except the stretches L1 through L3 and U3 where floodwater bifurcated or over-topped the dike.

Design river-bed elevation was set principally at the lowest river bed or higher. However, in the Jocotal area (stretches M3 through M5), the design river bed was set lower than the existing bed, since the existing channel section is too small to convey the design discharge. Channel slopes were designed approximately same as those of the existing channels.

Channel Section

For the Priority Project, the channel section with dike was designed based on 10-year flood discharge and the channel section without dike on 2-year design discharge, while the channel section for the Master Plan was designed based on 10-year design discharge. Side slope of the excavated channel is 1 on 2 and a berm is provided at 3 m above the design bed.

(2) Preliminary Design of Other Facilities

Dike: Standard dike section is shown in Fig. 6.10 which is applied for both the Priority Project and the Master Plan.

Revetment: Revetment of low water channel was proposed at the sharp bends where flood flows would hit the banks directly.

Drainage Sluice: Drainage sluice was proposed crossing the dike for inland drainage where the land side ground elevation is lower than DHWL for the drainage of surrounding areas.

Groundsill: Groundsill works are necessary at the drop of river bed in order to consolidate and stabilize the river-bed.

Intake Gate: At the head of new cut off at SM113, the existing San Miguel River is to be closed, however, the existing river needs to supply irrigation water during dry season. An intake gate was proposed across the dike of the existing San Miguel River. Design discharge of the intake gate was assumed at 3.0 m^3/s based on the average flow during the driest four months.

Bridge: The existing bridges at Moropala and Vado Marin need to be reconstructed for the Master Plan, since Moropala Bridge has not enough length and Vado Marin Bridge not enough length nor elevation. However, these bridges will not be reconstructed for the Priority Project stage. New bridges were proposed across the New Cut Off (CF), Olomega diversion channel (P2) and Olomega drainage (O1). Prestressed concrete bridge, 8 m wide, was proposed.

Rural Road: The existing rural roads need to be relocated in some places because of the channel excavation and dike embankment works.

Preliminary design of the major facilities are shown in Fig. 6.11.

(3) Land Acquisition and House Compensation

The land within the designed river area will be acquired for the works, and the houses are to be compensated.

(4) Quantities of Works

Quantities of works for the Priority Project estimated based on the results of preliminary facility design are shown in Table 6.6 and summarized below:

River Improvement (from estuary to Aramuaca)

- Dredging / excavation	:	$7{,}444 \times 10^3\ m^3$ (L = 70 km)
- Dike	:	$1{,}173 \times 10^3\ m^3$ (L = 29 km)
- Revetment	:	6,000 m
- Groundsill	:	4 places, 229 m
- Bridge	:	3 places
- Sluice	:	1 place

Diversion / Retarding in L. Olomega

- Excavation / dredging	:	$591 \times 10^3\ m^3$
- Diversion weir	:	1 place
- Control gate	:	1 place, effective span 20 m

6.4 Floodplain Management Plan

The non-structural measure as Priority Projects is the floodplain management for the areas of San Miguel, Olomega and Jocotal, which includes flood forecasting/warning, land use regulation, flood proofing, and education to the residents.

6.4.1 Flood Risk Map

A flood risk map covering the potential flood areas of Near San Miguel City, Olomega and Jocotal have been prepared for the following purposes:

(1) As a basic information for detailed planning of the land use regulation / flood proofing and flood warning,

(2) To inform the residents and authorities related to development about the floodplain management plan, and discuss, covering the following contents :

- Background and purposes of the whole flood control project and implementation schedule,

- Contents of the flood risk areas depending on the implementation stage,
- How to use the lands and methodology of flood proofing.

The flood risk maps showing flood areas caused by several magnitudes of floods in each stage of the river improvement have been analyzed. The maps of the potential flood areas are characterized as follows:

Flood Areas (in sq. km), Near San Miguel City

Magnitude of Flood	Existing River	After 2-year Improvement (Priority Project)	After 10-year Improvement (Master Plan)
2-year Flood	1.6	1.6	0.0
5-year Flood	2.0	2.0	0.0
10-year Flood	2.5	2.5	0.0
20-year Flood	3.0	3.0	0.0
50-year Flood	3.5	3.5	0.0

Flood Areas (in sq. km), Around Lake Olomega

Magnitude of Flood	Existing River	After 2-year Improvement (Priority Project)	After 10-year Improvement (Master Plan)
2-year Flood	41.5	9.2	0
5-year Flood	54.5	14.0	4.6
10-year Flood	69.4	15.5	9.6
20-year Flood	78.0	17.5	10.0
50-year Flood	83.7	55.4	55.4

Flood Areas (in sq. km), Around Lake Jocotal

Magnitude of Flood	Existing River	After 2-year Improvement (Priority Project)	After 10-year Improvement (Master Plan)
2-year Flood	25.6	9.0	5.2
5-year Flood	29.7	26.0	5.9
10-year Flood	31.0	27.7	10.0
20-year Flood	32.0	29.0	15.4
50-year Flood	33.0	29.3	9.0

The flood risk maps are shown in Fig. 6.12.

6.4.2 Flood Forecasting and Warning Plan

A real time water level data of the River and Lake Olomega are proposed to be added for reinforcement of the existing flood forecasting/warning system.

(1) Proposed System

Proposed flood forecasting/warning system consists of the following five (5) automatic water level gauging stations with telemeters at,

- Moscoso (inflow to the flood risk area),
- Diversion point (San Miguel River flood level at Olomega Diversion Weir),
- El Delirio (downstream end of the flood area around Olomega),
- Vado Marin (San Miguel River flood level at flood area around Jocotal), and
- Lake Olomega (fishery and flood water retarding).

(2) Flood Forecasting and Warning Method

1) Target Areas

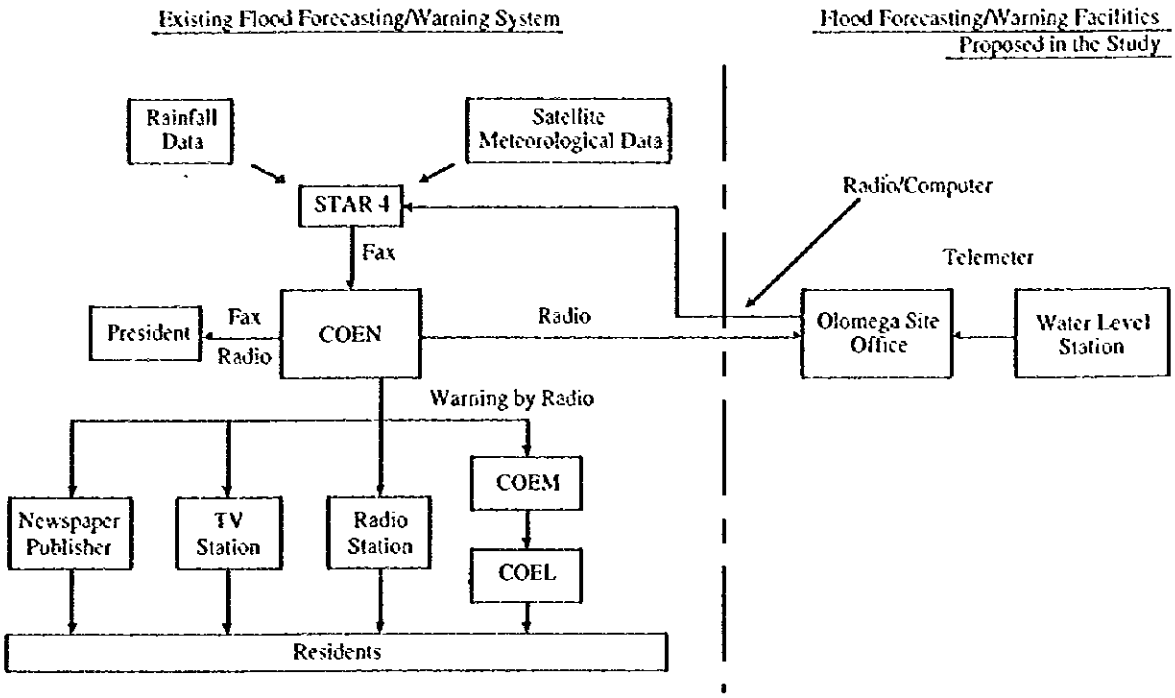
The flood forecasting / warning is proposed for the potential flood areas of Olomega and Jocotal. The flood forecasting / warning system is proposed to be completed by 2005 when the river improvement to cope with 2-year flood is completed. Therefore, the flood warning will be targeted to the areas anticipated to be flooded by 10-year flood after completion of the river improvement.

2) Flood Forecasting Method

Flood forecasting is proposed to be made by change in water level (or discharge) at Moscoso. For preparation of the flood warning, existing weather forecasting station, STAR 4 in Ilopango, will be used. STAR 4 has hourly base satellite image data and some rainfall data. The water level data sent from the Site Office will also be used for forecasting at STAR 4.

3) Flood Warning Method

All water level data collected and analyzed in the Olomega Site Office shall be informed to COEN through STAR 4 and used for warning. The homes in the potential flood areas are scattered in wide areas having a density of about 0.5 families /ha at present and 1.0 families / ha. in 2020. Therefore, transmission of information to all residents by telephone, siren, transceiver, etc. will not be practical. These method will be applicable to the limited number of persons like community chiefs. Usage of the radio and television is recommended for the data transmission method as presently done by COEN. Existing system for flood warning and evacuation is basically applied in this plan.



6.4.3 Land Use Regulation

(1) Area near San Miguel City

Present land use of the potential flood area consists of grazing 31.5%, urban 23.5%, sugarcane 23.3%, annual crop 8.6%, etc. with a total area of 700 ha.. This narrow and long flood prone area is mostly formed by old river courses and even a large flood will not expand the area so much due to steep topography.

Land use of this area is recommended as follows:

- Area required for the river improvement works to cope with 50-year flood shall be kept, considering the required width and future land use. The required width of the river is 100 m to 110 m.
- Outside the river area within the risk area should not be developed for commercial, industrial and residential purposes, unless embankment or other flood proofing method is applied. It can be used for the areas with low damage potential such as agriculture, park, etc..

(2) Areas around Lake Olomega and Lake Jocotal

A guideline on the land use for this area is proposed, from the viewpoint of flood control, as follows:

- The areas anticipated to be flooded by 2-year flood should not be developed for any purpose,
- The area not flooded by 10- year flood can be developed for any purposes,
- The areas flooded by 10-year flood but not flooded by 2- year flood can be used for low potential damage purposes,

Recommended floodplain management is presented in Fig. 6.13.

(3) Education to the Residents

This is intended for the residents in the flood area under 10-year flood. The contents are briefing of the whole project, flood area as for with/without project, concept of land use regulation and flood proofing, method of flood forecasting/warning and evacuation.

6.5 Cost Estimate

6.5.1 Basic Concept

(1) Construction Works

The major construction works for the project are dredging / excavation of the river channel and related structures including revetments, bridges, diversion weir, control gate, etc.

(2) Assumptions

The construction plan and cost estimate are based on the following assumptions:

1) The funds required for the construction works are proposed to be financed by the Government national budget and the supporting loan from an international funding agencie(s).
2) The construction works will be undertaken by the selected contractor(s) upon international competitive bidding.
3) The construction works will be supervised and administrated by MAG

6.5.2 Construction Plan

The major quantities of works estimated based on the preliminary facility design are as presented below respectively for the Priority Projects.

	Priority Projects (m^3)
Earth excavation	7,883,000
Excavation of rock layer	152,000
Embankment	1,173,000

Construction method of major works are planned as follows :

1) The excavation is planned to be carried out by bulldozer and backhoe.
2) Materials excavated are to be used for reclamation of low-lying area near river course in Jocotal area, and in other areas, are hauled to spoil bank area by dump truck.
3) The excavation of rock layer is planned to be carried out by blasting in combination with ripper bulldozer and backhoe with ripper.
4) The embankment is planned to be carried out by bulldozer, backhoe and roller.
5) Bank protection of 6 km long for the priority project is planned to be executed by man power.

6.5.3 Cost Estimate

(1) Basis of Cost Estimate

The project cost consists of the costs for the following items:

1) Construction works;

- Channel works (earth excavation, rock excavation, embankment and revetment)
- Structure works (diversion weir, control gate, drainage sluice and groundsill)
- Appurtenant works (intake gate, bridge, rural road and telemetering system)

2) Land acquisition and house compensation;
3) Administration;
4) Engineering services; and
5) Physical contingency
6) Price contingency

The project cost is estimated based on the following conditions and assumptions:

1) Administration cost is assumed at 5 % of the total costs of construction works and land acquisition/compensation.
2) Engineering services cost is assumed at 15 % of the total costs of construction works and land acquisition/compensation.

3) A physical contingency is assumed to be 10 % of the total costs of construction works, land acquisition/compensation, administration and engineering services.
4) Annual price escalation rate is assumed at 3 % for foreign currency portion and 6 % for local currency portion.

Within the above unit costs, 22 % of the indirect cost such as site expenses, contractor's overhead, profit and tax are included.

(2) Project Cost

The cost of the structural Priority Project, at the price level of December 1996, was estimated as summarized below:

Unit : Million Colons

Cost Item	L / C	F / C	Total
1. Construction	210.3	223.4	433.7
2. Land acquisition / Compensation	19.2	0	19.2
3. Administration	22.6	0	22.6
4. Engineering Services	25.1	42.8	67.9
5. Physical Contingency	27.7	26.6	54.3
(Sub-total)	(304.9)	(292.8)	(597.7)
6. Price Escalation	123.4	54.8	178.2
Total	428.3	347.6	775.9

Breakdown of the project cost is shown in Table 6.7.

The project cost for non-structural measures of 8.1 Million Colons including five water level stations, telemeter system and Lake Olomega site office is included in the above project cost.

(3) Disbursement Schedule

Disbursement schedule for the Priority Project is prepared according to the implementation schedule which is prepared based on the following assumptions (refer to Fig. 6.14).

1) Loan agreement will be completed by December 1998.
2) Detailed design including topographic and geologic surveys for the Priority Project will be commenced in January 1999 and completed by December 1999.
3) Tendering of the main civil works will be started in January 2000, and completed by December 2000.

4) Main civil works will be commenced in January 2001 and completed by December 2005 with a construction period of five (5) years.

5) Prior to the execution of construction works, land acquisition and house compensation will be started in January 2000 and completed by December 2003.

The disbursement schedule is shown in Table 6.8. The total funds required for the implementation of the works are estimated as follows:

Foreign currency portion	347.8 Million Colons
Local currency portion	428.1 Million Colons
Total	775.9 Million Colons

(4) Operation and Maintenance Cost

The operation and maintenance cost at full operation stage of facilities, after completion of the construction works, is assumed to be annually 0.5 % of the cost of construction works and land acquisition.

(5) Cost of Floodplain Management

The cost of Floodplain Management is estimated at Colons 8.1 Million for flood forecasting and warning system. This is closely related to the operation of Lake Olomega water level and the cost was included in the cost of structural measures. The cost of land use regulation and flood proofing is not included as it would be a separate project executed by the government by applying subsidy, etc.. The cost of education to the residents is included in the cost of administration in the structural measure costs.

6.6 Operation and Maintenance Plan

Operation and maintenance (O/M) of the flood control facilities, such as river channel, revetment, groundsill, sluice, diversion weir, control gate, etc. are the same as proposed in the Master Plan and summarized below.

- New Project Office in San Miguel of MAG will undertake the O / M work after completion of the facilities. Therefore, the Office shall be equipped with required machines and equipment for O / M work.

- Participation of the residents in the O / M work is recommended. COEL and MAG will prepare an organization.

- Olomega Site Office will undertake the O / M work of the Control Gate, water level stations and the Diversion Weir.

6.7 Proposed Organization and Institution

6.7.1 River Improvement and Floodwater Retarding

Proposed organization for the river improvement and floodwater retarding project is based on that of the Master Plan. Organization proposed for the stages of design / construction stage and operation / maintenance stage are shown in Fig. 5.19. Major points are summarized below:

MAG central office will arrange the general matter such as finance, coordination, etc. for all stages.

(1) Design / Construction Stage

- DGRNR in San Salvador will manage the detailed design. The design work will be carried out by the consultant(s) selected upon international competitive bidding.
- The construction works will be executed by the contractor(s) selected upon international competitive bidding.
- Project Office in San Miguel will undertake all the management work for the construction, with the assistance of the consultant(s), under the support by MAG central office.
- MOP will participate in the management of the detailed design and construction works.

(2) Operation and Maintenance Stage

- MAG Central Office for general arrangement,
- Project Office in San Miguel and the residents for O/M work of the river facilities, and
- Olomega Site Office for O/M of the Olomega Control Gate and the Diversion Weir

6.7.2 Floodplain Management

Organization for flood fighting, including forecasting, warning, evacuation, etc. is proposed as follows (refer to Fig. 5.19):

- MAG central office for general arrangement,
- MAG Project Office in San Miguel for public relation, education and coordination with the related agencies,
- Site Office at Olomega for collection and analysis of the water level data, O / M of Control Gate and the water level gauging stations,

- STAR 4 for weather (flood) forecasting,
- COEN for warning, evacuation and other necessary coordination in emergency period, and
- PNC, local government, local authority, residents, and other related organizations for flood fighting activities, coordinated by COEN.

6.8 Project Evaluation

6.8.1 Economic Evaluation

(1) Economic Benefit

The major direct economic benefit of the flood control project could be presented as an expected reduction effect in flood damage by implementing the project. The main flood damage to be reduced is composed of the damage to assets and the damage to economic activities.

In the present study, the assets are represented by building, household effects, livestock public facilities and agricultural field crops. The buildings and household effects are called the "general assets" herein. The general assets consist of residences (three kinds of medium, low and poor classes), stores and other houses. Each household in the residence keeps some livestock such as pigs and chickens.

The public facilities are facilities of transport, agriculture, electricity, water supply, drainage, etc.. The agricultural field crops are limited to major crops such as annual crops, sugar cane and pasture, where the annual crops are represented by maize.

Based on a difference of two inundation areas between without-project and with-project situations, number and area of assets to be saved from flood damage are given the Priority Project as shown in Table 6.9.

The flood area caused by 10-year flood, for example, is expected to be reduced by the project by 8,100 ha, and the depth and duration of flooding in the area still flooded will be reduced. The damage reduced by implementing the project is estimated for each return period by using the tables above, under the same conditions and assumptions as shown in Chapter 2. The results are summarized as follows:

Reduction in Flood Damage (Colons. Million)	
Return Period (Year)	Reduction
1	38.50
2	76.14
5	65.48
10	88.25
20	109.45
50	107.83
100	116.52

Using the reduction in flood damage above, an expected Average Annual Benefit would be estimated as Colons 105.42 Million.

(2) Economic Cost

For the purpose of the economic evaluation, the project cost is converted into the economic cost which excludes portions of inflation and transfer payments such as taxes and duties. Besides these exclusion portions, the economic cost is estimated taking shadow prices into account. The shadow prices are based on the standard conversion rate (SCR) and the opportunity costs of items such as land acquisition and wage of unskilled labor. The annual flows of the economic costs are transferred to Table 6.10, and the total amount of the economic and financial costs are summarized below:

	Construction Cost		Annual OM Cost	
	Financial	Economic	Financial	Economic
Priority Project	775.98	540.15	4.03	2.15

(3) Economic Evaluation

1) Direct Effects

The economic feasibility of the project is examined using cash flows of the economic cost and benefit shown in Table 6.11. As a result, EIRR of the projects is estimated at 18.1 %.

These percentage show that all alternative projects are economically feasible, in view of the opportunity cost of capital (approximately 12 %) in El Salvador. NPV and B/C at a discount rate of 12 % are summarized below:

	EIRR (%)	NPV (Cols. Million)	B/C
Priority Project	18.11	161.31	1.49

An EIRR sensitivity on the priority project would be tested under the conditions of the increase in 5 % and 10 % of the economic cost and the decrease in 5 % and 10 % of the economic benefit. As a result, the priority project would have a feasibility economically, maintaining the EIRR of 14.6 %, even in the unfavorable case where the increase in cost and the decrease in benefit are both 10 %.

2) Indirect Tangible Effects

After completion of the flood control project, the most expected indirect effect will be an utilization of an unused land. It is expected that an unused land caused by flood will be converted into an effective land such as agricultural land and residential area.

For example, in case it is used as an agricultural land, it is expected that the project will produce an agricultural land area of approximately 3,300 ha, consisting of 1,500 ha for the maize plantation and 1,800 ha for the sugar cane plantation, based on the land classification maps in the flood prone area.

Net economic benefit produced by these lands would be estimated at Colons. 6.5 Million per annum, i.e. it would be to rise by approximately 0.5 % as to the EIRR of the project.

6.8.2 Financial Aspects

(1) Raising of the Project Fund

In the present section, a consideration would be given on raising the construction fund, in order to examine a financial viability of the project.

The construction cost of the priority project is estimated at Colons. 775.9 Million (equivalent to US$ 88.67 Million) in total. This construction fund is assumed to be raised from two sources of self-fund and external debt, under conditions as follows:

1) The external debt is assumed to be 75 % of the project cost, and the remaining 25 % would come from a self-fund;

2) A repayment schedule for the external debt is assumed to take the loan terms of 30 years including the grace period of 10 years, and the interest rate of 6 % per annum, based on the actual condition of the external debt of El Salvador.

3) During the grace period, only the interest is paid, and repayment of the debt with the interest is made after the grace period.

Under the conditions above, the total fund required, US$ 88.67 Million, is composed of US$ 66.50 Million for the external debt and US$ 22.17 Million for the self-fund. In accordance with the construction schedule, the fund required every year during the period from 1999 to 2005 is estimated as follows:

	Total	Annual Disbursement						
	Fund	1999	2000	2001	2002	2003	2004	2005
Self-fund	22.17	0.70	0.38	3.93	4.11	4.31	4.27	4.47
External Debt	66.50	2.08	1.14	11.80	12.35	12.92	12.82	13.39
Total	88.67	2.78	1.52	15.73	14.46	17.23	17.09	17.86

Unit : US$ Million

Of the annual disbursement, the maximum disbursement would come to US$ 17.86 Million in total and US$ 4.47 Million for the self-fund in 2005. The respective amounts correspond to 3.1 % and 0.8 % of the expected average annual public investment of the Central Government for the period from 1995 to 1999. These rates appear not to be such a large share from the governmental finance.

(2) Repayment of External Debt

Table 6.14 gives a tentative schedule of repayment for the external debt. The annual maximum repayment would amount to US$ 7.32 Million in 2009 (the eleventh year from the commencement of the project).

According to the repayment statistics of the external debt of El Salvador, the average annual repayment amounted to US$ 263.7 Million for the period 1990-1995, and it was trending toward increase at an annual rate of 6.3 %. The annual maximum repayment amount of US$ 7.32 Million in 2009 for the present project will be less than 3 % of the total annual repayment of El Salvador for the said period.

In conclusion, if the fund schedule is executed under the said conditions, raising of the construction fund and repayment of the external debt seem to be possible, judging that the maximum annual disbursement is nearly 3 % of the average annual disbursement of public investment expected for the period 1995-1999, and the maximum annual repayment of the external debt is less than 3 % of the annual debt service of the Government for the period 1990-1995.

The government national budget for 1996 is Colons 14,815 Million, as a result of an annual increase by 24.4 % during two years from 1994 to 1996. The government has estimated the budget at Colons 198.5 Million for the San Miguel Flood Control Project in the Development Plan. About 90 % of the budget was expected to be financed by foreign aids.

A project of this nature, non-profit and public, the project cost is to be funded by the government's national budget and would require financial assistance by a funding agency.

6.8.3 Socio-economic Effects

- Enhancement of regional development and stability of the region
- Increase in employment opportunity by the project works
- Improvement of environment for socio-economic activities in the communities

6.8.4 Environmental Impact Assessment (EIA)

1) Social Impacts (Negative)

- Land acquisition, for the San Miguel River improvement, of 676 ha.
- Compensation of 20 houses
- Disturbance of the communities during the construction work

2) Natural Environmental Impacts (Positive)

- Mitigation of polluted floodwater of the San Miguel River flow into Lake Jocotal
- Stabilization of fishery production in Lake Olomega (fishery related people of about

10,000)
Negative impact is low while positive impact is high.

6.8.5 Evaluation of Structural Measures

The proposed project of the structural measure is viable from the viewpoints of the following:

- Economically feasible (EIRR = 18.1 %),
- Negative environmental effects of land acquisition / compensation and disturbance by construction work are not large,
- Positive environmental impacts on lake ecology, sanitation, etc. are large, and
- Contribute to the development and stability of the region.

6.8.6 Evaluation of Floodplain Management

(1) Floodplain Management

1) General effects on all flood prone areas are,

- Decrease in flood damage potential including danger,
- Decrease in flood control cost in the future, and
- Saving of the flood control project cost

2) Specific effects on each flood prone area are,

- Stabilization of fishery production in Lake Olomega,
- Improvement in ecology of Lake Jocotal, and
- Smooth development of the San Miguel urban area

6.9 Implementation Schedule

The project implementation time schedule is prepared based on the following assumptions (refer to Fig. 6.14).

(1) The project is completed by the year 2005.
(2) One year for loan process and two years for detail design and tendering are allocated.
(3) The construction term is five years.

(4) The work for floodwater storage in Lake Olomega shall be completed prior to the river improvement works of the upstream reaches.

(5) For other reaches of the San Miguel River, river improvement works shall be implemented, in principle, from the downstream toward the upstream to avoid the effects on the flooding downstream area.

(6) Flood forecasting and warning system are installed so that it is applicable when the structures are completed.

7. CONCLUSION AND RECOMMENDATION

CHAPTER 7. CONCLUSION AND RECOMMENDATION

(1) The Priority Project of the structural measure is, from technical, economic, social and natural environmental viewpoints, justified. Immediate implementation of the Project is recommended for the reduction in flood damage and smooth development of the region.

(2) The flood forecasting/warning system is recommended to be established for solving the problems of fishery and flood in the Olomega area, and ecology and flood in the Jocotal area. Land use regulation, to reduce the flood damage potential, can be done by using the proposed floodplain management.

(3) The floodplain management, including land use regulation, flood forecasting/warning and education to the residents, for the flood prone areas of San Miguel City, Olomega and Jocotal is urgent and effective to reduce the potential flood damage. Immediate implementation of the project is recommended.

(4) The basins of Lake Jocotal and Lake Olomega are recommended to be preserved as areas of water sources which support their ecology.

(5) The wastewater of San Miguel City should be treated as soon as possible.

(6) Study of water resources development should be conducted.