社会開発調査部報告書

No. 38

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF AGRICULTURE AND LIVESTOCK
REPUBLIC OF EL SALVADOR

THE STUDY ON COMPREHENSIVE FLOOD CONTROL FOR THE RIO GRANDE DE SAN MIGUEL IN THE REPUBLIC OF EL SALVADOR

EXECUTIVE SUMMARY

SEPTEMBER 1997

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO
YACHIYO ENGINEERING CO., LTD., TOKYO
PASCO CORPORATION, TOKYO

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The Project costs were estimated based on
the price level of December 1996.
The exchange rates are:

Colons 1.00 = US$ 0.114

PREFACE

In response to a request from the Government of the Republic of El Salvador, the Government of Japan decided to conduct a master plan and feasibility study on Comprehensive Flood Control for the Rio Grande de San Miguel and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Republic of El Salvador a study team headed by Mr. Hiroyuki SHIRAIWA, Pacific Consultants International (PCI) and composed of staff members of PCI, Nikken Consultants Inc. and PASCO International Inc. three times between March 1996 to July 1997.

The team held discussions with the officials concerned of the Government of the Republic of El Salvador, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of El Salvador for their close cooperation extended to the team.

September 1997

Kimio Fujita
President
Japan International Cooperation Agency

THE STUDY
ON
COMPREHENSIVE FLOOD CONTROL
FOR
THE RIO GRANDE DE SAN MIGUEL
IN
THE REPUBLIC OF EL SALVADOR

September, 1997

Mr. Kimio FUJITA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit the final report entitled the "The Study on Comprehensive Flood Control for the Rio Grande de San Miguel in the Republic of El Salvador." This report has been prepared by the Study Team in accordance with the contract signed on February 20, 1996, November 29, 1996 and May 15, 1997 between the Japan International Cooperation Agency and Pacific Consultants International in associate with Nikken Consultants Inc. and PASCO International Inc.

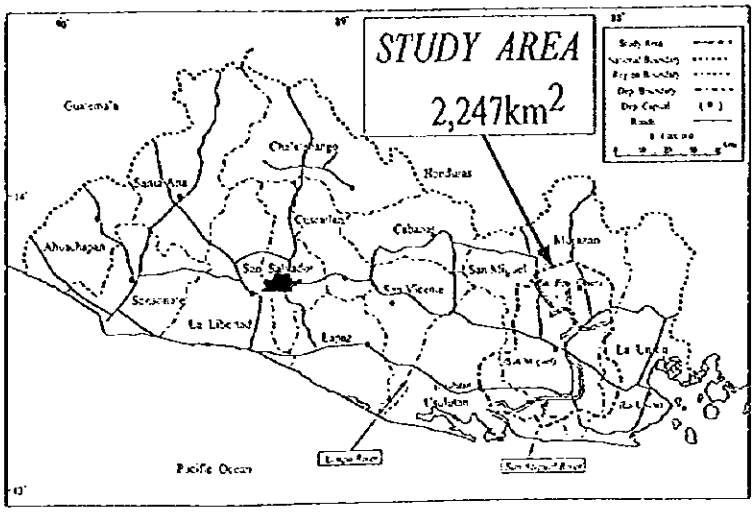
The report consists of the Summary, Main Report, Supporting Report and Data Book. The Summary summarizes the results of all studies. The Main Report presents the results of the whole study including analysis of existing conditions, study of alternative flood control measures, selection of the optimum measures, formulation of the flood control master plan and the feasibility study for the priority projects. The Supporting Report describes in detail the technical aspects of the entire study. In addition, the Data Book has been prepared and submitted herewith.

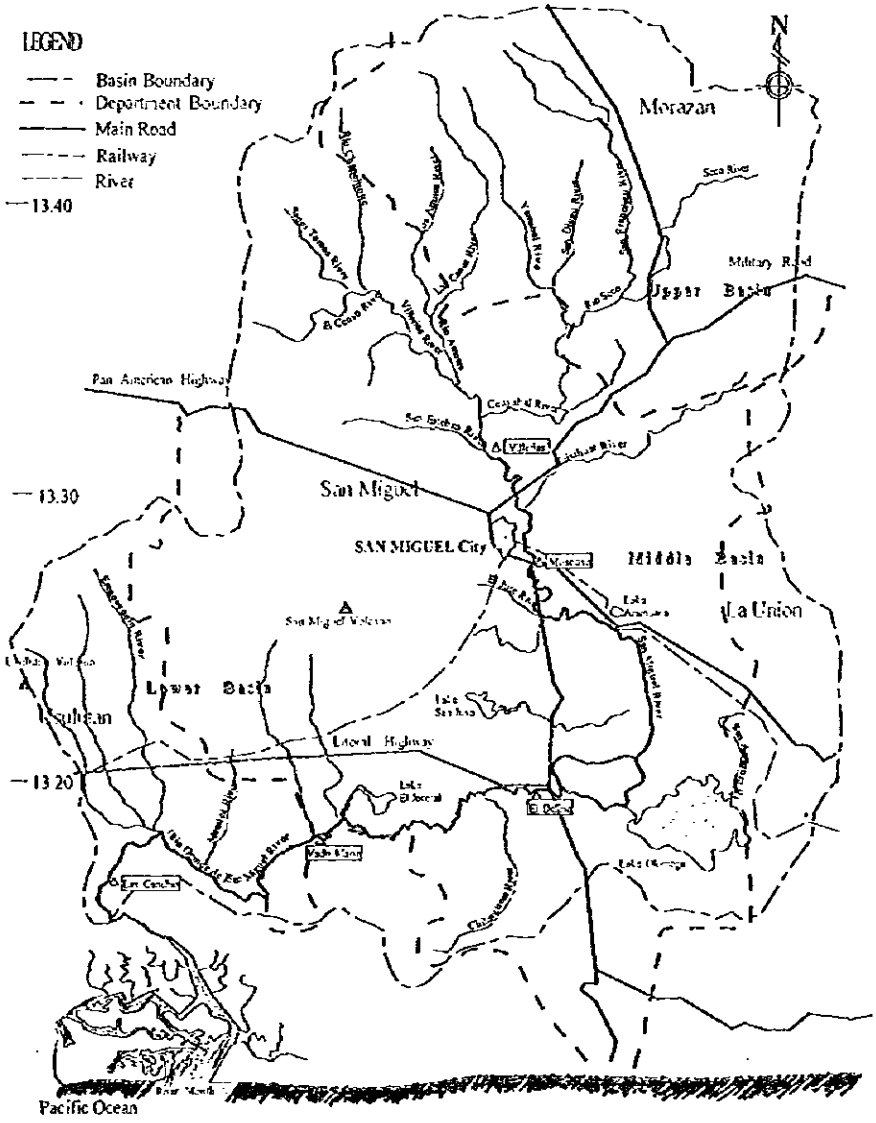
All members of the Study Team wish to express sincere appreciation to the personnel of your Agency, Advisory Committee, and Embassy of Japan in El Salvador, and also to the officials and individuals of the Government of the Republic of El Salvador for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the flood control and the socio-economic development in the Grande de San Miguel River basin.

Yours Faithfully

白岩弘行

Hiroyuki SHIRAIWA
Team Leader of the Study Team





LOCATION OF STUDY AREA

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DIGEST

I SOCIO-ECONOMIC FRAMEWORK

(1) Study Area; Rio Grande de San Miguel Basin in the East Region (2,247 km^2)

(2) Target Year; 2020

(3) Socio-economic Condition

	(1996)	(2020)
Basin Population	474 thousand	1,041 thousand
Economy	(1994)	(2020)
GDP (whole country)	$ 8,070 million	$ 36,410 million
Average Growth Rate	6 %/year (1994~2020)	
Land Use of Study Area		
Urban Area	29km^2 (1.3%)	58km^2 (2.6%)
Farm Land	359km^2 (16.0%)	530km^2 (23.6%)
Pasture/Crop Land	1,464km^2 (65.1%)	964km^2 (42.9%)
Forest	331km^2 (14.7%)	631km^2 (28.1%)
Others	64 km^2 (2.8%)	64 km^2 (2.8%)

Land Use of the Flood Prone Area (unit: km^2(ha))

	Urban	Farmland	Pasture	Forest	Others	Total
Present (1996)	1.65 (165)	47.68 (4,768)	103.17 (10,317)	6.05 (605)	22.74 (2,274)	181.08 (18,108)
%	0.9	26.2	57.0	3.3	12.6	100.0
Future (2020)	1.65 (165)	90.52 (9,052)	54.17 (5,417)	12.00 (1,200)	22.74 (2,274)	181.08 (18,108)
%	0.9	50.0	29.9	6.6	12.6	100.0

II MASTER PLAN

(1) Target Area to be Protected : 162 km^2 (16,200 ha) out of flood prone area of 181 km^2 (18,100 ha) excluding extremely low areas around the lakes

(2) Design Flood : 10-year flood
(Execution of the project with a staged small scale project with large benefit was recommended)

(3) Outline of the Projects

1) Structural Measures

The structural measure project is proposed to implement by two stages, to cope with 2-year flood for the first stage and the rest of the Master Plan project to cope with 10-year flood for the second stage.

Project:	San Miguel River Improvement (100.7 km) and Floodwater Storage in Lake Olomega
Project Cost:	1,578 Million Colons (1,097 Million Colons excluding price escalation).
Flood Area Reduction:	104 km^2 (10,400 ha) against 10-year flood (Estimated population in 2020 is 47,000)
Economic Effect:	EIRR = 14.6 %, B/C = 1.23 (discount rate 12 %)
Socio-economic Effect:	• Effective land use, • Stable fishery in Lake Olomega, • Increase in employment opportunity, • Sanitary improvement and • Increase in development potential
Environmental Effect:	• Reduction in floodwater flow into Lake Jocotal
Negative Effect:	• Land Acquisition; 779ha • Compensation; 20 houses • Noise, etc. during construction
Evaluation	• Positive effect is large and the project will contribute to the development and stability of the region.

2) Non-structural Measures

- San Miguel River Floodplain Management Project:
  Flood forecasting/warning, Land use regulation, Flood proofing and Education to the residents for four flood prone areas of San Miguel, Olomega, Jocotal and Usulutan

Project Cost	8.1 Million Colons for flood forecasting/warning system (This is included in the cost of structural measures.)
Social Effect	• Smooth development of San Miguel City • Reduction in flood damage, and • Improvement of safety

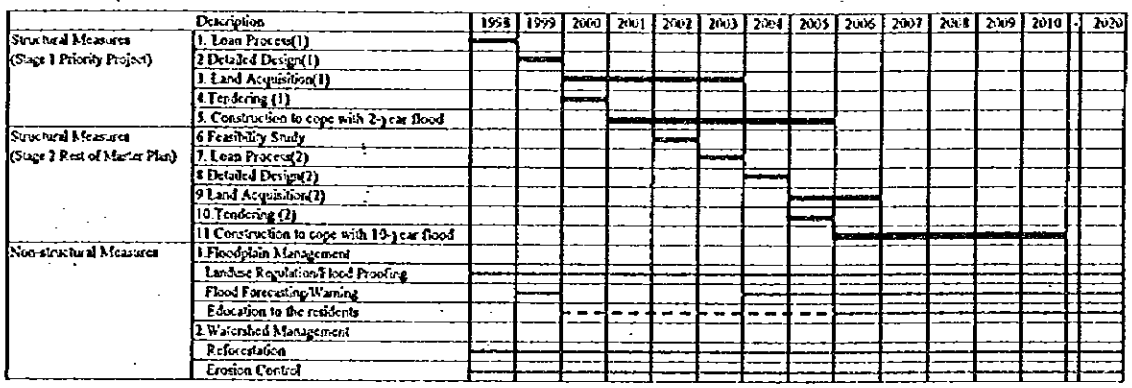
- San Miguel River Watershed Management Project:
  Reforestation of 30,000 ha, Erosion Control of 20,000 ha and ground sill 30 places

Project Cost	208 Million Colons
Socio-economic Effect	Increase in agricultural production
Environmental Effect	• Reduction in erosion • Stability of stream flow • Stability of river course

- Evaluation — It is necessary for development and stability of the region.

(4) Implementation Schedule for Master Plan Projects

The structural measure project is proposed to implement by two stages, to cope with 2-year flood for the first stage and the rest of the Master Plan project to cope with 10-year flood for the second stage.



III. FEASIBILITY STUDY OF PRIORITY PROJECTS

(1) Criteria for Selection of Priority Projects

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

(2) Selection Process

Structure Measures

- River improvement by excavation / dredging and floodwater storage in Lake Olomega

The ratios of protected area and the project cost for different scale river improvements of 2-year, 5-year and 10-year floods were compared. The 2-year flood river improvement can reduce the flood area by 8,050 ha against 10-year flood (80 % of the Master Plan). It is economically the most effective and adopted for the priority projects for early implementation.

For the reaches with dikes, the river channels are to be improved to cope with 10-year flood to have a certain level of safety against overtopping of floodwater.

Non-structural Measures

- Among floodplain management projects, urgent flood forecasting/warning, land use regulation and flood proofing in San Miguel City area, Olomega area and Jocotal area, and education to the residents were selected.
- Erosion control for protection of agricultural area and reforestation projects of the watershed management were not selected as priority project for the feasibility study. These have been planned mainly by MAG and experienced by CEL in Lempa River Basin. Though these projects are desirable for flood control, greater part of the purposes are forestry, agriculture and nature preservation. The watershed management projects, however, are required for development and stabilization of the region. The projects should be started in early stage and continued to implement.

(3) Outline of Priority Projects

1) Structural Measure Project

Contents of Project	:	River Improvement (74.3 km) and floodwater storage in Lake Olomega to cope with 2-year flood (10-year flood for the sections with dikes)
Project Cost	:	776 Million Colons (598 Million Colons excluding price escalation

2) Non-structural Measure Project

Contents of Project : Floodplain Management in Jocotal, Olomega and San Miguel City Areas

	San Miguel Area	Olomega Area	Jocotal Area
1. Flood Forecasting/Warning	-	Five (5) Waterlevel Gauging Stations and Alert to the residents	
2. Land Use Regulation/Flood Proofing	Keep river areas, regulation of urbanization	Land use regulation and Flood proofing taking into account flood frequency	
3. Education to the Residents (by MAG San Miguel Office)	For the residents in the flood area under 10-year flood The contents are briefing of the whole project, flood areas for with/without project, concept of land use regulation and flood proofing, method of flood forecasting/warning and evacuation.		

Land use regulation and flood proofing will be done by MAG Central Office soon by using the flood risk maps and succeeded inducing education to the residents by the San Miguel Project Office after its provision.

The project cost for non-structural measures is 8.1 Million Colons including five waterlevel stations, telemeter system and Lake Olomega site office. This cost is already included in the cost for the structural measure project, 776 Million Colons.

3) Project Evaluation

Flood Area Reduction : 81 km^2 (8,100 ha) against 10-year flood (population in 2020 estimated as 36,000)

Economic Effect : EIRR = 18.1 %, B/C = 1.49 (discount rate of 12 %)

Socio-economic Effect : Effective use of lands
Stable fishery in Lake Olomega (about 10,000 persons related)
Increase in employment opportunity
Improvement in sanitation
Increase in development potential

Environmental Effect : Reduction of floodwater flow into Lake Jocotal

Negative Effect : Land acquisition of 676 ha
Compensation of 20 houses
Noise etc. during construction

Project Evaluation : Positive economic and social effects are large and the project will contribute to the development of the basin and stability of the region.

(4) Implementation Schedule for Priority Project

Description		1998	1999	2000	2001	2002	2003	2004	2005
Structural Measures	1. Loan Process								
	2.Detailed Design								
	3. Land Acquisition								
	4.Tendering								
	5. Construction to cope with 2-year flood								
Non-structural Measures, (Floodplain Management)	1.Land Use Regulation/Flood Proofing								
	2.Flood Forecasting/Warning								
	3.Education to the residents								

IV. CONCLUSION AND RECOMMENDATION

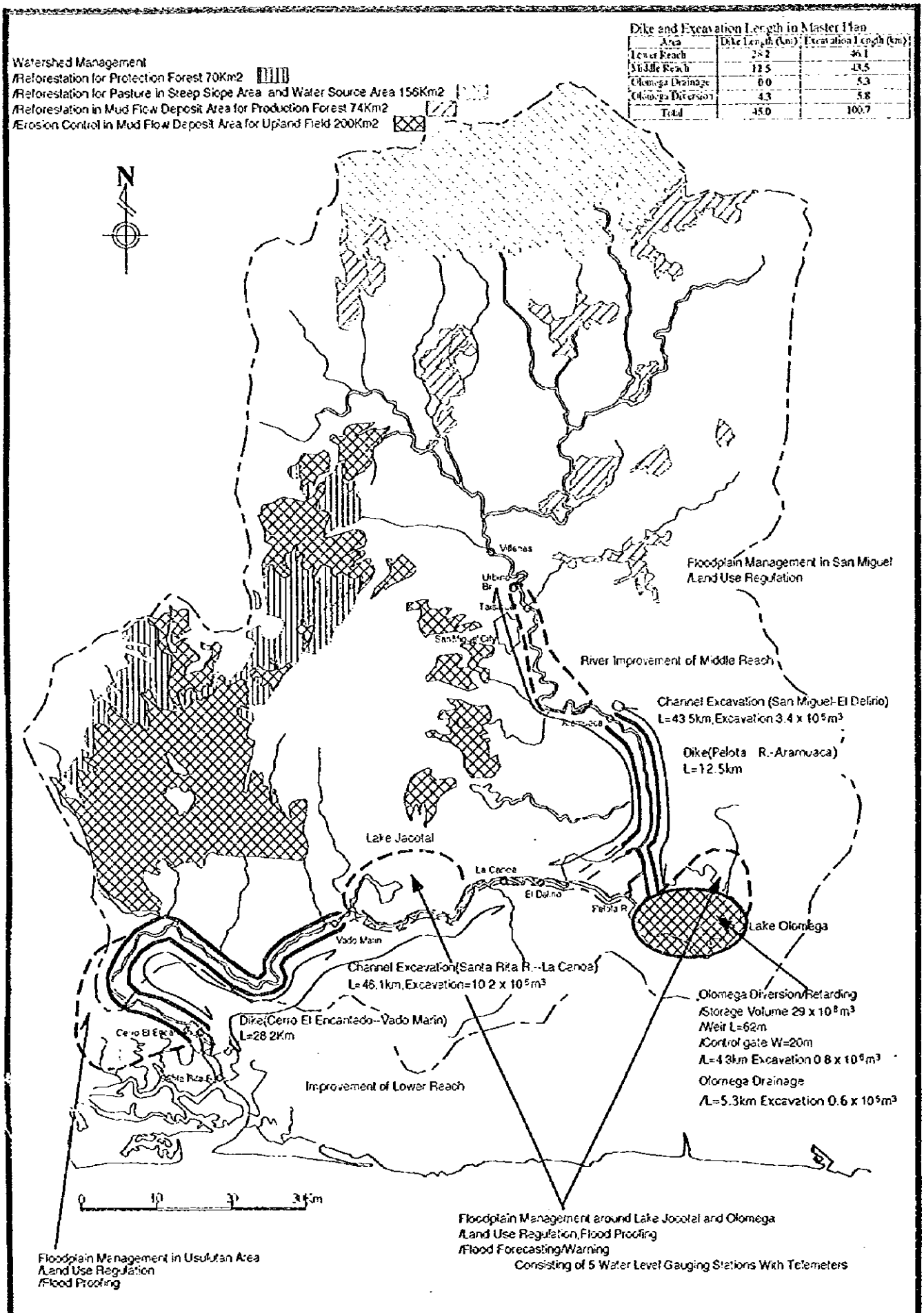
(1) The Priority Project of the structural measures is, from technical, economic, social and natural environmental viewpoints, justified. Immediate implementation of the Project is recommended for reduction in flood damage and smooth development of the region.

(2) The floodplain management, including land use regulation / flood proofing, 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.

(3) Reforestation and erosion control have been studied and planned by the Government and should be applied to the San Miguel River Basin. The proposed watershed management is recommended to be implemented immediately for flood control / water resources development, increase in forestry / agricultural production, recovering of nature, etc.

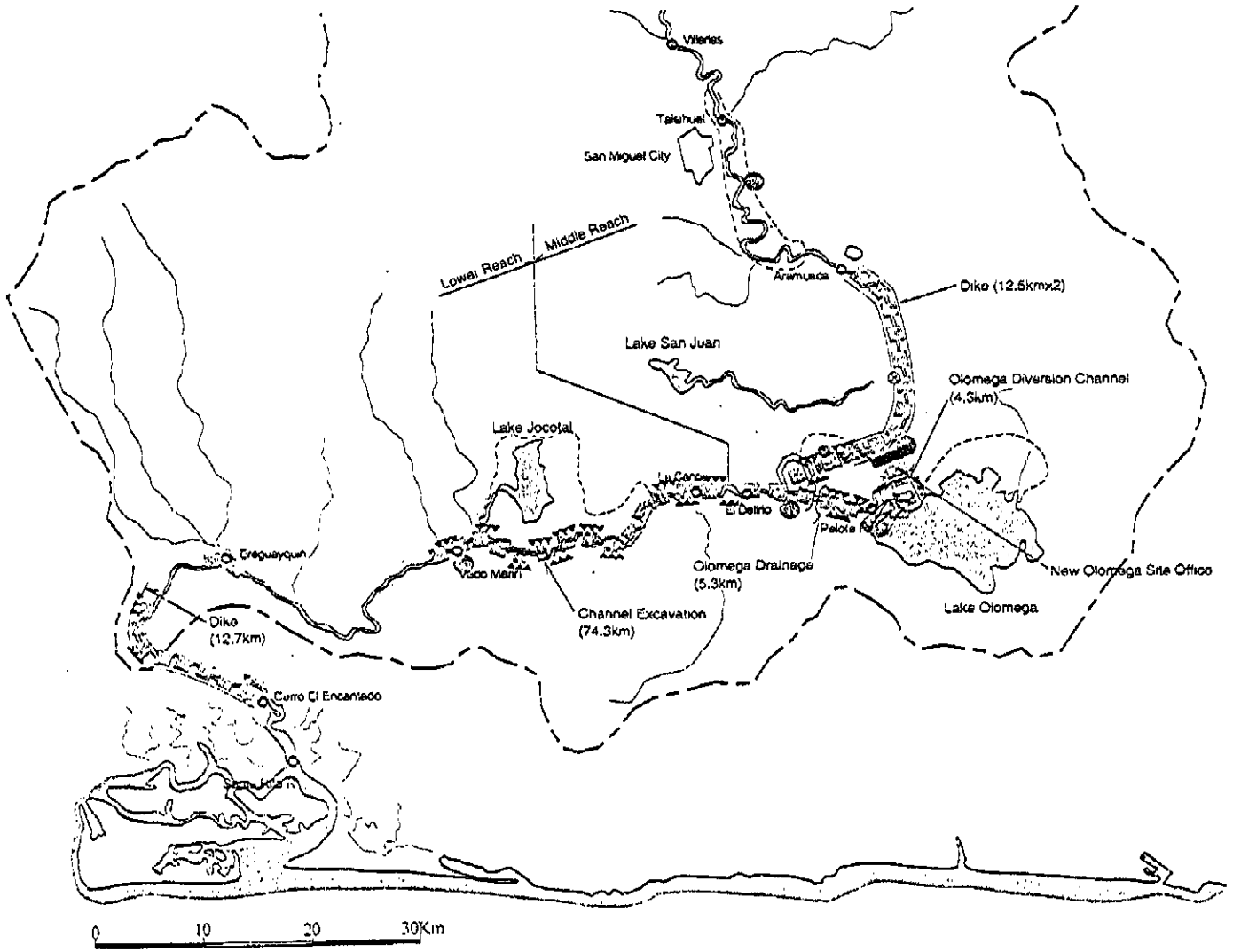
FEATURES OF MASTER PLAN AND PRIORITY PROJECT

DESCRIPTION		MASTER PLAN River improvement to cope with 10-year flood	PRIORITY PROJECT River improvement with reduced channel excavation (to cope with 2-year flood)	REST OF MASTER PLAN PROJECT Projects other than the Priority Project
RIVER IMPROVEMENT				
Project Cost(¢ million): Fixed cost as of Dec. 1996		1,097.4	597.7	499.7
Fund Required(¢ million): Including price escalation		1,577.6	775.9	801.7
Construction Works	Construction Period	10 years from 2001 to 2010	5 years from 2001 to 2005	5 years from 2006 to 2010
	Excavation(m^3):	14,956,000	8,035,000	6,921,000
	Embankment(m^3):	1,843,000	1,173,000	670,000
	Revetment(m^3):	6,000	6,000	-
	Ground sill(site)	4	4	4 (renovation)
	Weir/gate(site):	2	2	1(renovation)
	Sluice(site):	15	1	14
	Bridge(site):	5	3	2
Reduction of Flooded Area : 5 For 10-yr. flood (km^2)	San Miguel:	0.4	0.0	0.4
	Olomega:	61.8	53.9	7.9
	Jocotal:	28.2	13.0	15.2
	Usulutan:	13.6	13.6	0.0
	Total:	104.0	80.5	23.5
Beneficiary in the Protected Area: 5 For 10-yr. flood in 2020 (persons)	San Miguel:	200	0	200
	Olomega:	27,900	24,400	3,500
	Jocotal:	12,700	5,900	6,800
	Usulutan:	6,100	6,100	0
	Total:	46,900	36,400	10,500
Social Impact	Positive Impact:	- To enable effective land use and development of the basin, - To ensure the people's livelihood in the basin, - To ensure stable fishery in lakes of Olomega and Jocotal, - To create employment opportunities during construction, and - To improve sanitary conditions.		
	Negative Impact: - Land acquisition: - House comp.:	779 ha 20 houses	676 ha 20 houses	103 ha None
		- Disturbance of communities during construction		
Environmental Impact		- Mitigation of inflow of polluted and sediment contained water of the San Miguel River - Stabilization of water level in lakes of Olomega and Jocotal		
Economic Viability: EIRR (%)		14.6	18.1	10.1
FLOODPLAIN MANAGEMENT				
Estuary Area		Land use regulation and flood proofing	Not adopted	Land use regulation and flood proofing
Jocotal Area		Land use regulation, flood proofing and flood forecasting/warning to mitigate damage in non-dike reaches		
Olomega Area				
Near S. Miguel City		Land use regulation to mitigate damage in urban area		
WATERSHED MANAGEMENT				
Lower Basin		Reforestation, erosion control and ground sill works	Not included	Reforestation, erosion control and ground sill works
Middle Basin				
Upper Basin				
Project Cost		¢ 208,000,000	None	¢ 208,000,000



GENERAL LAYOUT OF FLOOD CONTROL MASTER PLAN

Proposed Priority Project



Dike and Excavation Length

Area	Dike Length(km)	Excavation Length(km)
Lower Reach	12.7	46.1
Middle Reach	12.5	18.6
Olomega Drainage	0.0	5.3
Olomega Diversion	4.3	4.3
Total	29.5	74.3

Proposed Project Works

ITEM	AMOUNT
1. Structural Measures	
Earth Excavation	7,803,000 m³
Rock Excavation	152,000 m³
Embankment	1,173,000 m³
Revetment	6,000 m
Diversion Weir	1 place
Control Gate	1 place
Drainage Sluice	1 place
Ground Sill	229 m
Intake Gate	1 place
Bridge	3 places
Rural Road	2,640 m
Land Acquisition	0.76 km2
Compensation	20 houses
2. Non-structural Measures	
Automatic Water Level Station	5 places
Telemetering System	1 unit
Floodplain Management	3 places

Legend

- San Miguel River
- Catchment Boundary
- Maximum Flooded Area
- Dike
- Channel Excavation
- Revetment
- Olomega Diversion Weir
- Olomega Control Gate
- Automatic Water Level Station
- New Olomega Site Office
- Area for Floodplain Management
- Bridge
- Ground Sill
- Drainage Sluice
- Intake Gate

SUMMARY

CONTENTS

List of Tables

List of Figures

ABRREVIATIONS

ALCALDIA	Municipal Office
ANDA	National Administration of Water Supply and Sewage
B/C	Benifit-Cost Ratio
BOD	Biochemical Oxigen Demand
CEL	Hydroelectric Executive Commission for the Lempa River
CENTA	National Center of Agricultural Technology
COEN	National Emergency Committee
COED	Department Emergency Committee
COEM	Municiplal Emergency Committee
COEL	Local Emergency Committee
DGRNR	General Directorate of Renewable Natural Resources
EIA	Environmental Impact Assesment
EIRR	Economic Interanl Rate of Return
GDP	Gross Domestic Product
IEE	Initial Environmental Examination
MAG	Ministry of Agriculture and Livestock
MIPLAN	Ministry of Planning and Coordination for Economic and Social Development
MOI (or MI)	Ministry of Internal Affairs
MOP	Ministry of Public Works
NGO	Non Governmental Organization
NPV	Net Present Value
SCR	Standard Conversion Rate
SEMA	Executive Secretariate of Environment
STAR 4	Satelite Transmission Association Region 4

1. INTRODUCTION

1. INTRODUCTION

The Rio Grande de San Miguel (hereinafter referred to as "the San Miguel River"), the second largest river in the Republic of El Salvador, is located in the eastern part of the country having a catchment area of 2,247 km^2 (the Study Area, refer to Fig. 1.1). The river basin, in its center, has San Miguel City which is ranked as the center of Region IV (the East Region).

In the middle and the lower basins, there is a vast area of land with a potential mainly for agricultural development. Such a flat area is valuable in this country, where mountainous areas prevail. The above mentioned large area has been suffering from severe floods with long duration due to large rainfall depth, flat topography, and small river discharge capacity.

The basin has problems with water resources such as a difficulty in water use due to the long dry season from November to April, the water pollution of the rivers and lakes, sediment run-off from the mountain areas, decrease in groundwater pressure, etc. The Government of El Salvador has proposed a "Social and Economic Development Plan, 1994 - '99" in 1995. The Plan includes the development of the flood prone areas in the San Miguel River basin by means of flood control and drainage project based on the following national development policies:

- Reduction of the poor, especially extremely poor ones
- Decentralization of the population
- Strengthening of the rural area development
- Preservation of natural resources and sustainable economic development

Thus, the flood control taking into account water resources is urgent and essential for the development and stabilization of the region.

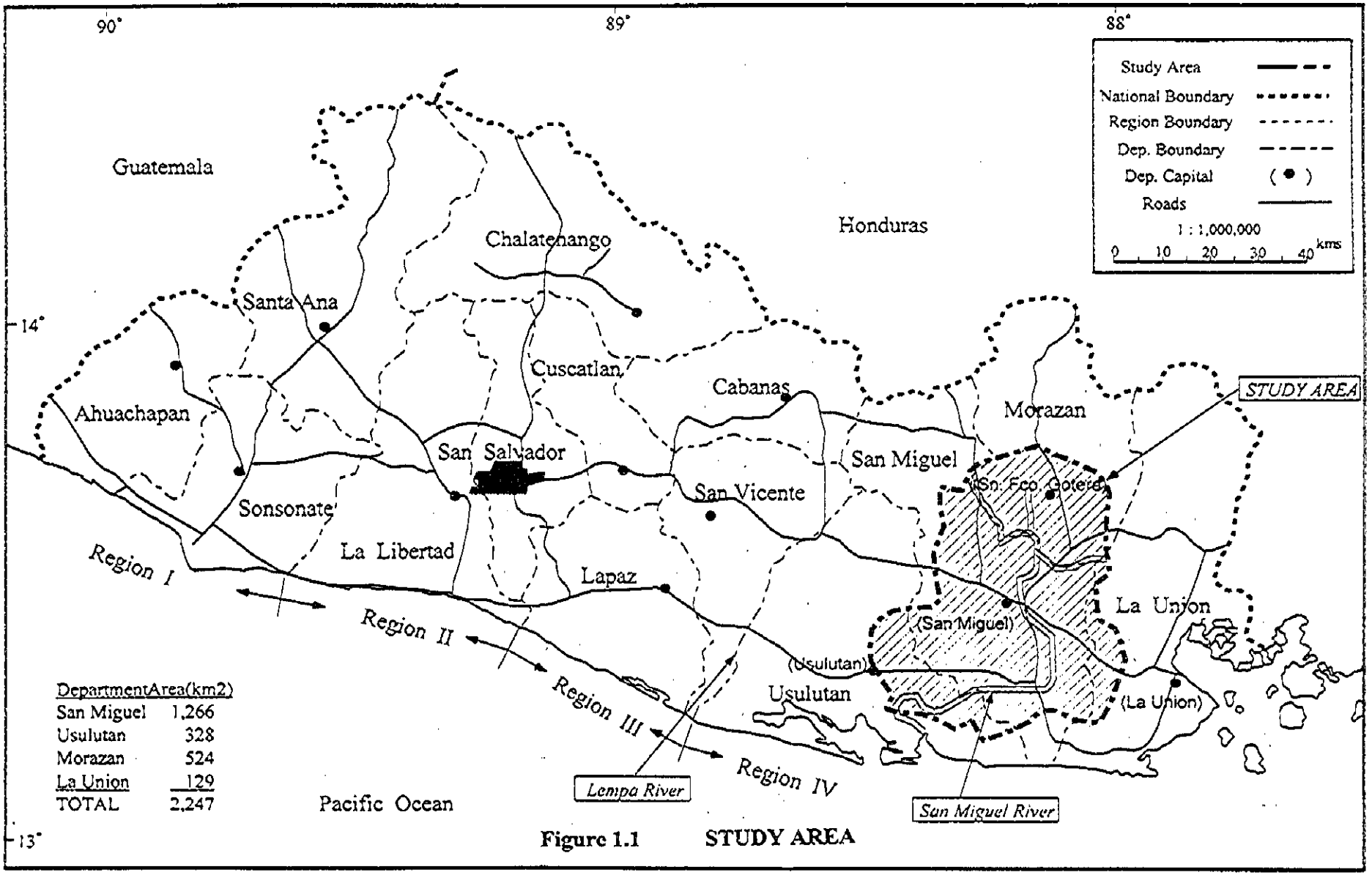


Figure 1.1 STUDY AREA

2. EXISTING CONDITIONS OF THE STUDY AREA

2. EXISTING CONDITION OF THE STUDY AREA

2.1 Natural Condition

The San Miguel River Basin occupies 10.7 % of the territory surrounded by mountain ridges with altitudes of 300 m to 2,000 m, having a catchment area of 2,247 km^2 as shown in Fig. 2.1. There are two large volcanoes, San Miguel and Usulutan, located in the western part of the basin. The areas along the middle and the lower reaches of the San Miguel River are flat and flood prone.

The geology of the basin is characterized by the volcanic layers consisting of pyroclastic rocks, mud flow deposit, lava, alluvial deposit, etc. as shown in Fig. 2.2. Therefore, the Study Area has been affected by eruptions and earthquakes due to volcanic activities. The mud flow deposit areas are easily eroded and produce much sediment discharge into the rivers but not so much flood discharge because they are high in permeability.

The average monthly temperature at San Miguel ranges from 26 ℃ in January to 29 ℃ in April with an annual average value of 26.9 ℃. The average monthly humidity at San Miguel ranges from 58 % in February to 82 % in September.

The annual average rainfall depth of the Study Area is about 2,000 mm in the northern mountainous area and about 1,500 mm in the southern flat area with an average value of 1,673 mm. About 93 % of the annual depth occurs in the wet season from May to October (refer to Fig. 2.3) .

2.2 Socio-economic Condition

The country consists of four regions I to IV, and the Study Area is located in the Region IV (East Region) which covers four departments. The Study Area spreads over parts of San Miguel, Usulutan, Morazan and La Union departments. Flood prone areas are located in the departments of San Miguel and Usulutan.

The total population of the East Region in 1992 was 1,129,484 which shared 22.1 % of the whole country (5,118,599). The population of the Study Area in 1992 is estimated as 473,956 (9.23 % of the national population), 46 % of which was the urban population and 54 % was the rural population, respectively. (Table 2.1)

The present land use of the Study Area consists of urban 29 km^2 (1.3 %), agriculture 359 km^2 (16.0 %), pasture and basic grains 1,464 km^2 (65.2 %), natural forest 331 km^2 (14.7 %), and others 64 km^2 (2.8 %), as shown in Table 2.2 and Fig. 2.4.

The population of the Study Area in 1992 was only 9.2 % of the national one, while its area shares 10.7 % of the whole country. Employees in the Study Area in 1992 were 140,900 persons, 8.5 % of whole country, consisting of 46.8 % for agriculture, 14.5 % for commerce, 10.2 % for manufacturing industry, and the rest for other sectors. The Study Area is developing compared with other regions.
In addition, agricultural GRDP per capita in the Study Area in 1993 was 2,340 Colons while the national average value was much higher of 2,766 Colons. This is due to unsuitable use of land, flooding, low technological level, etc.

During the civil conflict, a great number of people emigrated and, at least, 1 million Salvadorians are living and working in the USA. Many of the emigrants were from Region IV, and will return to their own country. Therefore, it is necessary to facilitate the conditions for their return.

2.3 River Condition

The river system of the San Miguel River basin and the longitudinal profile of the River are shown in Fig. 2.5 and Fig. 2.6, respectively.

The Basin is subdivided into the following three parts for convenience of the Study.

Upper Basin : Upstream of San Miguel City . Mountain areas for main sources of water

Middle Basin : San Miguel - Olomega . Large flood area with potential for agricultural and urban developments

Lower Basin : Jocotal - Estuary . Large flood area with agricultural development potential

The characteristics of the Basin are summarized as follows:

- Major tributaries are concentrated in the Upper Basin.
- The vegetation of the Basin is poor consisting mainly of pasture and upland field areas.
- Land erosion is remarkable in the mud flow deposit areas. The erosion in other areas is not so serious, though sediment run-off would be larger than that of the forest area.

The characteristics of the San Miguel River are as follows:

- There is a rapid with 30 m drop of the ground elevation at the boundary (El Delirio) between the Upper and the Lower basins.

- At about 10 km from the river mouth to the beginning of the San Miguel River (Canal Santa Rita), the riverbed is lower than the mean sea level. The mean high spring tide is 1.4 m above mean sea level.

- The riverbed slopes of the flood prone areas near the lakes of Jocotal and Olomega are 1 / 2,300 and 1 / 1,700, respectively. The discharge capacities of the channels are very small compared to the flood discharge.

- Due to the storage of water by flooding, the peak discharge in the upstream decreases as it goes toward the downstream even though run-off from the downstream catchment is added.

- The dikes, one on the right bank in the Lower reach by the government and others in the flood prone areas by private entities have been constructed.

- There is no dam in the Basin. There is one irrigation intake pump operating in the Middle reach.

- The river water is polluted due to the domestic and industrial wastewater effluent. The values of BOD at Moscoso and Villerias during the dry season in 1981 recorded high concentrations of 15.2 and 6.6 PPM, respectively. The values of BOD during the wet season were less than 3.0 PPM. The BOD values in May 1996 at Moscoso and Urbina were 4.7 and 9.3 PPM respectively.

- The sources of water supply for the cities of San Miguel and Usulutan are groundwater and spring. The pressure of the groundwater in San Miguel has dropped due to concentrated locations of intake wells.

2.4 Flood Condition and Flood Damage

The flooded areas in the past are located along the San Miguel River at around Lake Olomega, around Lake Jocotal, near San Miguel City, and the river mouth delta area as shown in Fig. 2.7. Those are considered to be a potential flood area and the total area is 181 km^2, excluding the lake areas of Olomega and Jocotal. The estimated population in the potential flood area in 1992 was 32,700.
There are frequent flood areas around Olomega and Jocotal with the total area of 75 km^2 where flooding occurs almost every year.

The past major floods have occurred in 1969, 1975, 1980, 1988, 1989, 1991, 1992, and 1995. The floods have occurred mainly from August to October. Among those, the 1988 flood was the largest.

The 1995 flood inundated the areas of San Miguel (2.8 km^2), around Olomega (88.5 km^2), around Jocotal (35.8 km^2) and Usulutan (6.6 km^2) with the total area of 133.7 km^2 excluding the lake areas.
The maximum depth and duration of the 1995 flood are 0.5m and 4 days in San Miguel area, 0.2 m and 8 days in the area around Olomega, 1.5 m and 11 days in the area around Jocotal and 0.9 m and 46 days in Usulutan area within the points of the interviews made by the Study Team. The longitudinal profile of the 1995 flood stage is shown in Fig. 2.8.

The present land use of the potential flood area consists of grazing (57 %), sugar cane field (16 %), annual crops field (10 %), etc. as shown in Table 2.3. The lands are good for agriculture, if there is no flood.

2.5 Environmental Condition

There are four major environmental issues related to the flood control and water resources development, namely, (1) deforestation, (2) Lake Olomega, (3) Lake Jocotal, and (4) mangrove forest.

(1) Deforestation

The deforestation of the Republic has been a big problem for a long time and is still continuing. It has been caused by the human activities such as agriculture, livestock, and extraction of fuel

supply. According to the past measurement data of streams in other countries, the forest stores stormwater, makes river low-flow stable, diminishes sediment run-off and absorbs narishments in the rainwater. Therefore, the Study Area, due to deforestation, has lost such functions of the forest.
Forest area in the Study Area is only 331 km^2 (15 % of the total area).

The forest area in the whole country had been decreased from 1903 km^2 in 1978 to 1290 km^2 in 1990 with an annual rate of 51 km^2. The trees cut had been used mainly for firewood.

The annual average erosion depth in the Upper Basin is in the order of 1.0 mm/year and it is not so large. But the value of deforested mud flow deposit areas is much higher and a large volume of sediments is discharged into the rivers .
The river discharge, both of flood and low-flow, is considered to be affected by deforestation.

(2) Lake Olomega

Lake Olomega is now used mainly for fishery purpose. The most common species for fishery are Guapote Tigre, Tilapia, Bagre, Mojarra, etc., and the annual production ranges from 760 to 56 tons depending on the lake water level and other reasons. The area and the water depth of the lake are about 20 km^2 and 2m, respectively.

(3) Lake Jocotal

Lake Jocotal has an area of about 5 km^2 with a depth of 1.5 m.
The lake is used for fishery and, at the same time, is a precious area for flora and fauna such as migratory birds, fishes, and other wetland animals. The lake and the surrounding area (18.8 km^2) is designated as an Environmental Conservation Area of the Republic. Kinds of fishes for fishery are similar to those of Olomega. During the dry season, the migratory birds stay in and around the lake. In the flood season, the San Miguel River carries much sediments and polluted water into the lake giving negative impact on its ecology.

(4) Mangrove Forest

Mangrove forest is located along the Canal Santa Rita (downstream portion of the San Miguel River). Trees with the height of 10 to 20 m are common.

2.6 Organization and Institution

The existing organizations related to the flood control and water resources development, based mainly on the Forest Law and the Water Law, are,

- Ministry of Agriculture and Livestock (MAG) in charge of the watershed management,
- Ministry of Public Works (MOP) in charge of construction,
- Ministry of Internal Affairs (MOI) in charge of resettlement,
- National Emergency Committee (COEN) in charge of emergency activities to cope with natural and other disasters,
- National Administration of Water Supply and Sewage (ANDA) in charge of water supply and sewerage,
- Hydroelectric Executive Commission for the Lempa River (CEL) in charge of hydro-power generation, and
- Executive Secretariat of Environment (SEMA) in charge of environment.

2.7. Related Projects and Plans

Major projects, studies and plans related to the flood control and water resources development are as follows:

(1) Economic and Social Development Plan of El Salvador, 1994 - 1999, MIPLAN, 1995 (Revised in 1996 by the National Government)
(2) Usulutan and San Miguel Irrigation Project, MAG, 1975
(3) Hydro-electric Projects of the Lempa River and the San Miguel River, CEL, 1995
(4) Olomega Project, MAG, 1967
(5) Water Supply Master Plan of San Miguel City, ANDA, under study
(6) National Environmental Strategy and Action Plan, SEMA, 1994

2.8 Existing Problems

Existing problems related to the flood control and water resources are summarized as follows :

(1) There are vast flood prone areas with a total area of 18,100 ha.
(2) The flood prone lands are used mainly for grazing (57 %) with low productivity.
(3) The areas are flat and fertile, and have potential for development, if there is no flood.
(4) Flooding has occurred frequently with long duration resulting the following negative effects:

- Damage in houses and properties,
- Damage in agriculture and livestock production,
- Obstruction to traffic and other socio-economic activities,
- Worsening in sanitation, and
- Other disturbance of the community life

Though the farmers who live in the flood prone area desire to produce basic grains, which are currently imported from other countries, it is not possible due to flooding.
The government intends to develop the east region based on the national policy. Flooding mentioned above, however, is a constraint for the development and stabilization of the region.

Table 2.1 POPULATION CENSUS AND PROJECTION (THE STUDY AREA)

Study Area(2,247km2)

	Census Population		Projected Population		
Year	1971	1992	2000	2010	2020
Population(person)	376,623	473,956	775,948	909,137	1,041,477
Density(person/km2)	-	211	345	405	464

Average Annual Growth Rate(%)

Year	1971-1992	1992-2000	2000-2010	2010-2020
Growth Rate	1.1	6.4	1.6	1.3

source: Censos Nacionales de Pobacion y Vivienda,1971 y 1972
Proyeccion de la Poblacion de El Salvador 2025,DIGESTYC

Table 2.2 PRESENT LAND USE IN THE STUDY AREA

	Urban	Agriculture								Forest	lake & River	Lave	Total
		Basic Grain	Pasture &	Coffee	Sugar cane	Henequen	Fruits	Veg.	Sub-Total				
Area (1,000ha)	2.9	11.0	146.4	14.0	3.9	5.2	0.8	1.0	182.3	33.1	3.6	2.8	224.7
Ratio (%)	1.3	4.9	65.2	6.2	1.7	2.3	0.4	0.4	81.1	14.7	1.6	1.2	100.0

Source : MAG

Table 2.3 PRESENT LAND USE IN POTENTIAL FLOOD AREA

Land use / Area		Annual Crop	Sugarcane	Grazing	Bush & Forest	Urban	Other	Total
San Miguel	(ha)	22.9	169.3	251.6	41.2	164.7	50.4	700.1
	(%)	3.3	24.2	35.9	5.9	23.5	7.2	100.0
Olomega	(ha)	896.7	1,687.0	6,095.8	109.5	0.0	1,050.9	9,839.9
	(%)	9.1	17.1	61.9	1.1	0.0	10.7	100.0
Jocotal	(ha)	479.7	701.6	2,446.7	36.0	0.0	774.1	4,438.1
	(%)	10.8	15.8	55.1	0.8	0.0	17.4	100.0
Usulutan	(ha)	465.3	325.6	1,522.7	417.8	0.0	398.6	3,130.0
	(%)	14.9	10.4	48.6	13.3	0.0	12.7	100.0
Total	(ha)	1,864.6	2,883.5	10,316.8	604.5	164.7	2,274.0	18,108.1
	(%)	10.3	15.9	57.0	3.3	0.9	12.6	100.0

Source : Study Team

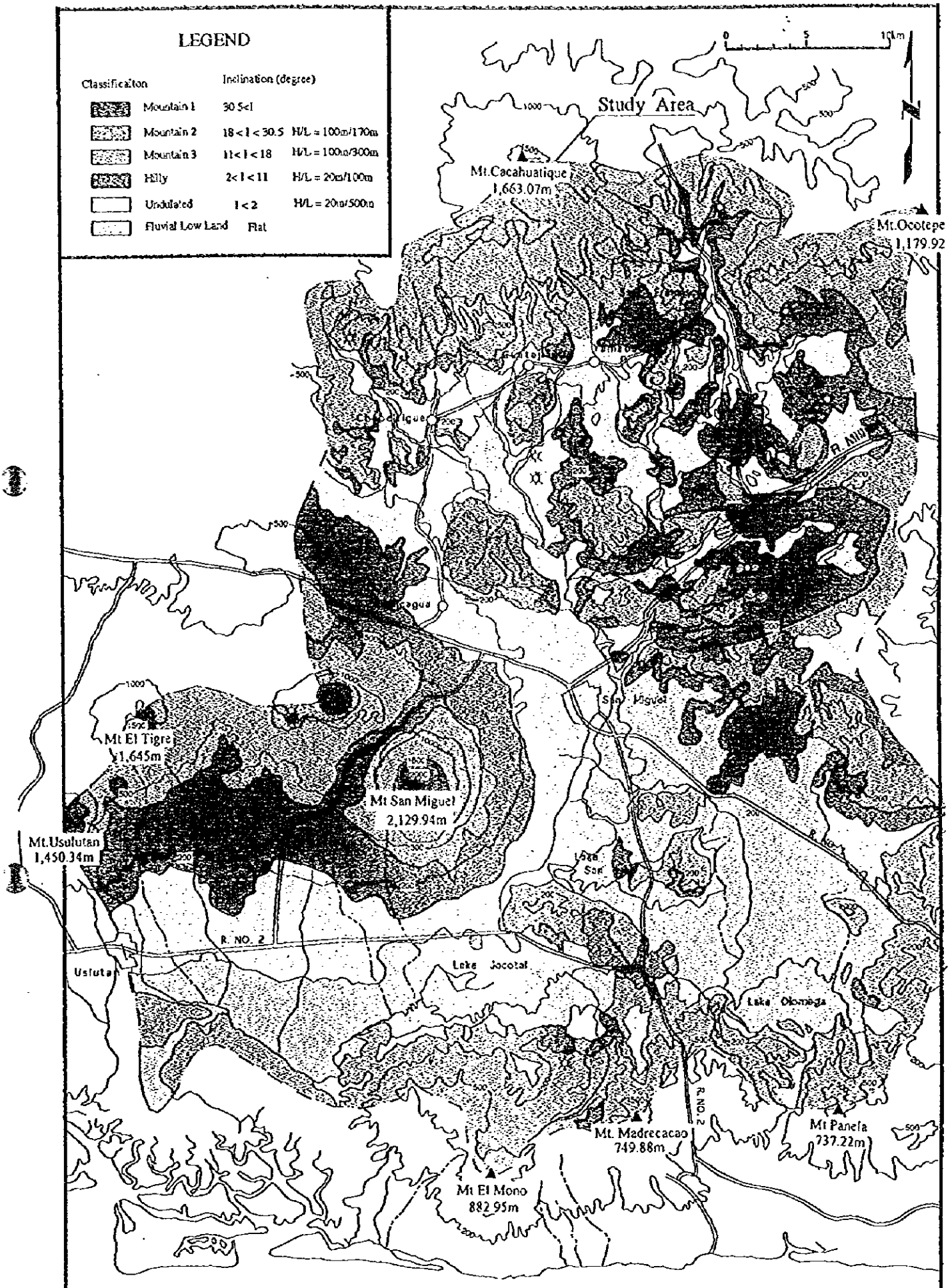


Figure.2.1 TOPOGRAPHY OF STUDY AREA

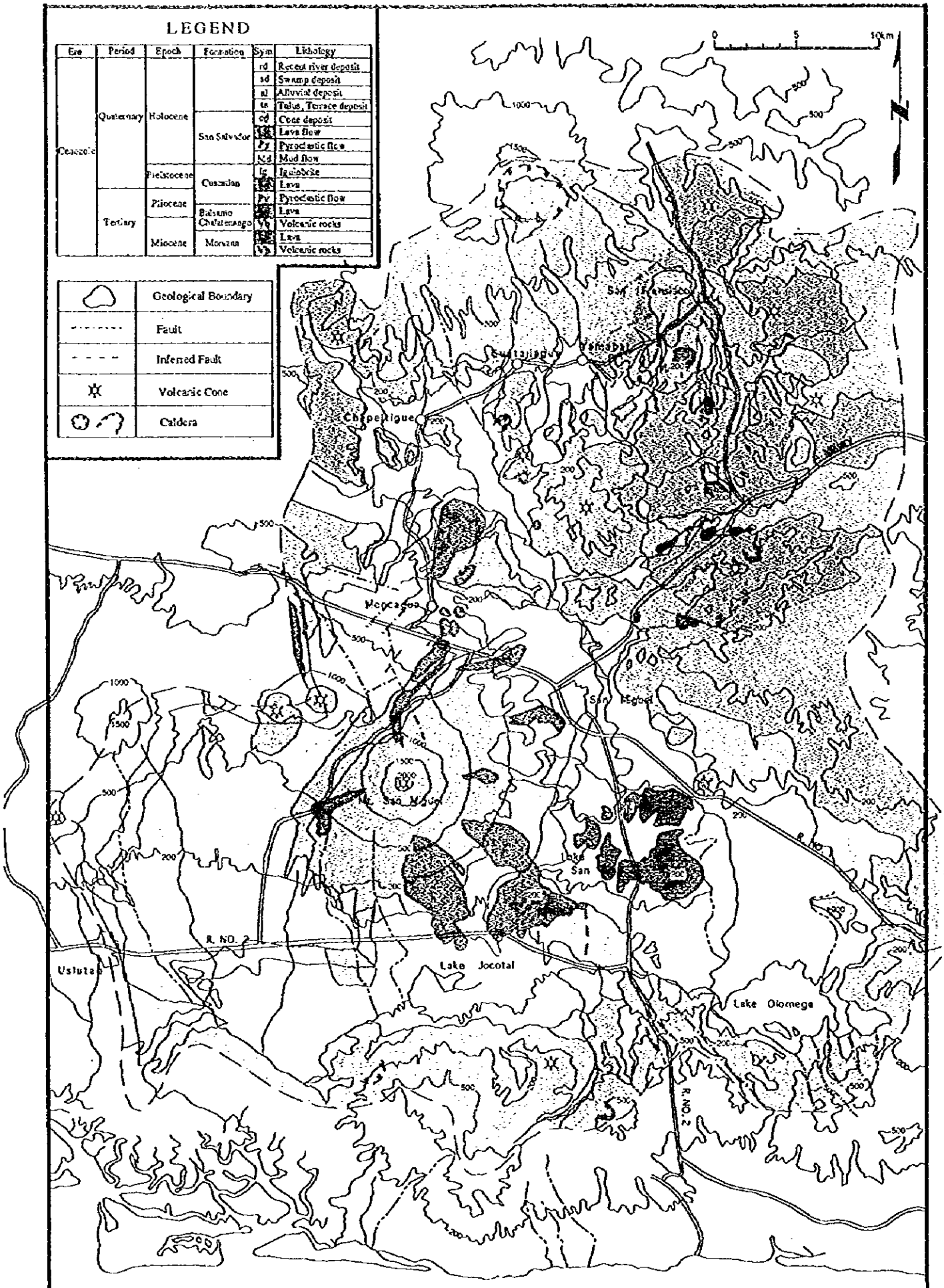
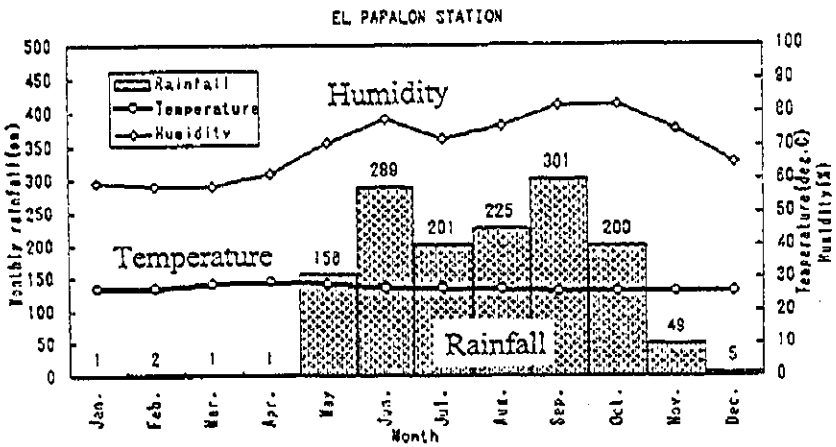
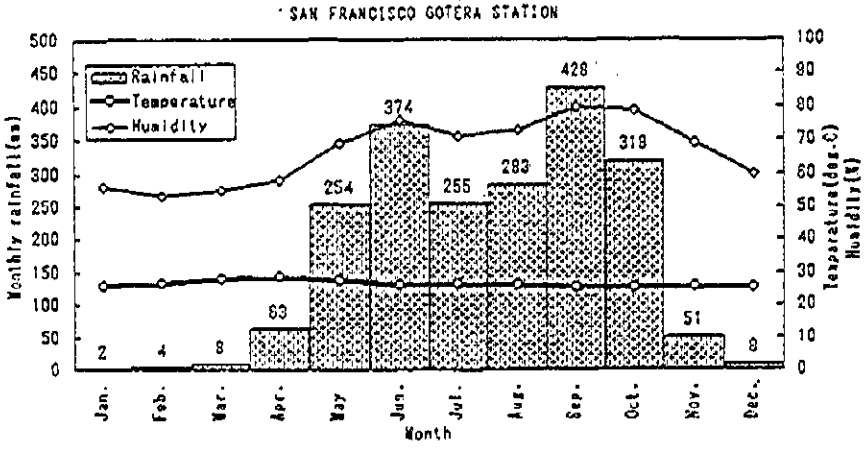


Figure.2.2 GEOLOGICAL MAP





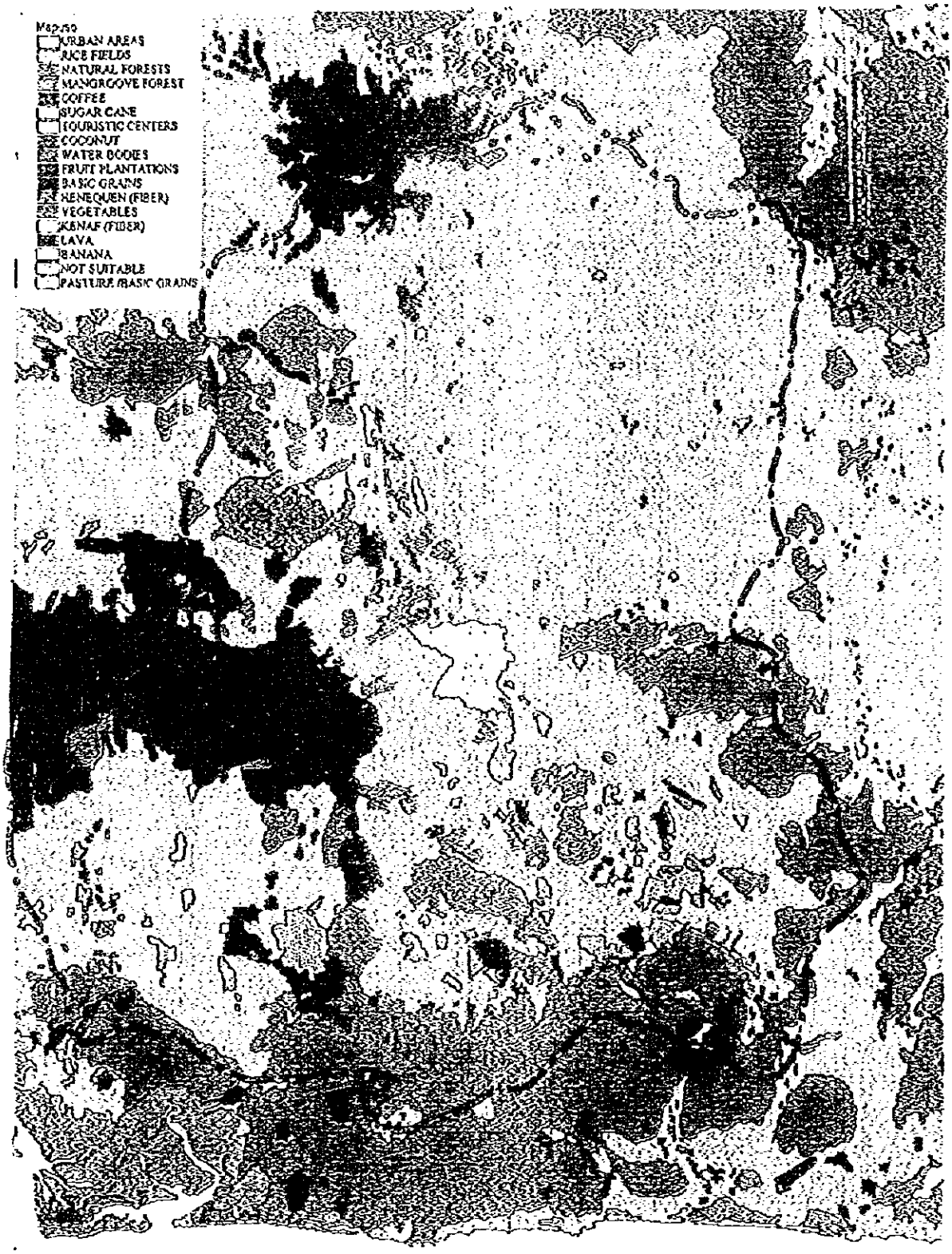
EL PAPALON STATION

Month	Rainfall (mm)	Tempera-ture (deg.C)	Humidity (%)	Wind velocity (km/h)	Wind direction
Jan.	1	26.9	59	5.0	N
Feb.	2	27	58	5.0	N
Mar.	1	28.3	58	5.0	S
Apr.	1	29	62	5.0	S
May	156	28.2	71	3.0	S
Jun.	289	26.9	78	1.0	SE
Jul.	201	26.8	72	5.0	N
Aug.	225	26.7	76	5.0	N
Sep.	301	25.9	82	5.0	S
Oct.	200	25.8	82	1.0	S
Nov.	49	25.8	75	5.0	N
Dec	5	25.8	65	5.0	N
For rainfall:					For temp./humid.
Annual total(1)	1431	26.9	70		Mean
Total(May-Oct)(2)	1372	29.0	82		Max.
(2)/(1) (%)	96	25.8	58		Min.

SAN FRANCISCO GOTERA STATION

Month	Rainfall (mm)	Tempera-ture (deg.C)	Humidity (%)	Wind velocity (km/h)	Wind direction
Jan.	2	25.8	56	3.6	N
Feb.	4	26.5	53	3	N
Mar.	8	27.9	55	3	N
Apr.	63	28.6	58	3	N
May	254	27.4	69	3	N
Jun.	374	26	76	3	N
Jul.	255	26.3	71	3	N
Aug.	283	25.9	73	3	N
Sep.	428	25.3	80	3	N
Oct.	318	25.4	79	3	N
Nov.	51	25.6	69	3	N
Dec.	8	25.5	60	3	N
For rainfall:					For temp./humid.
Annual total(1)	2048	26.4	67		Mean
Total(May-Oct)(2)	1912	28.6	80		Max.
(2)/(1) (%)	93	25.3	53		Min.

Figure 2.3 CLIMATE CONDITIONS OF STUDY AREA



Source:MAG

	Urban	Agriculture								Forest	lake & River	Lave	Total
		Basic Grain	Pasture &	Coffee	Sugar cane	Heneq-uen	Fruits	Veg.	Sub-Total				
Area (1,000ha)	2.9	11.0	146.4	14.0	3.9	5.2	0.8	1.0	182.3	33.1	3.6	2.8	224.7
Ratio (%)	1.3	4.9	65.2	6.2	1.7	2.3	0.4	0.4	81.1	14.7	1.6	1.2	100.0

Source : MAG

Figure 2.4 PRESENT LAND USE OF STUDY AREA

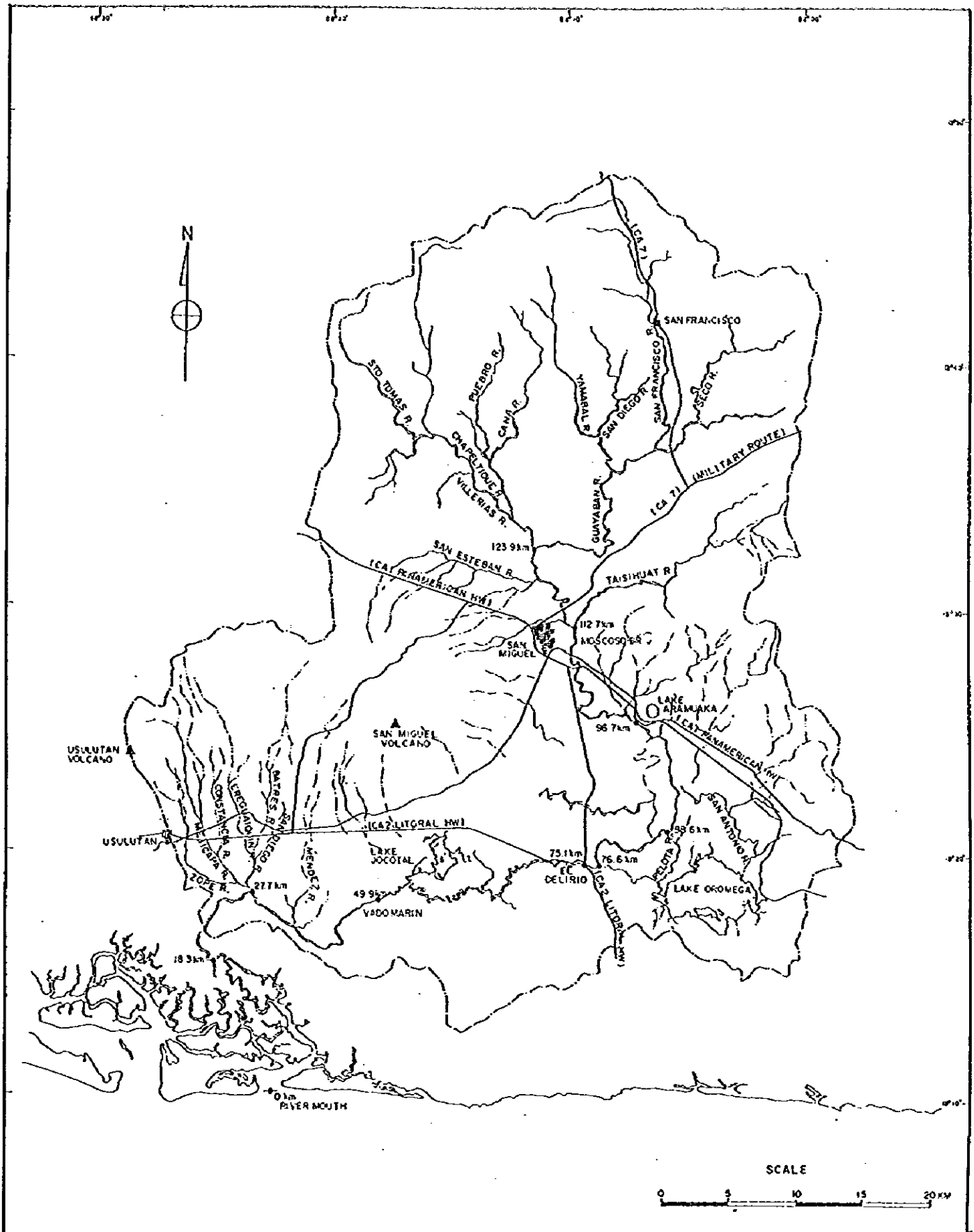


Figure 2.5 **SAN MIGUEL RIVER SYSTEM**

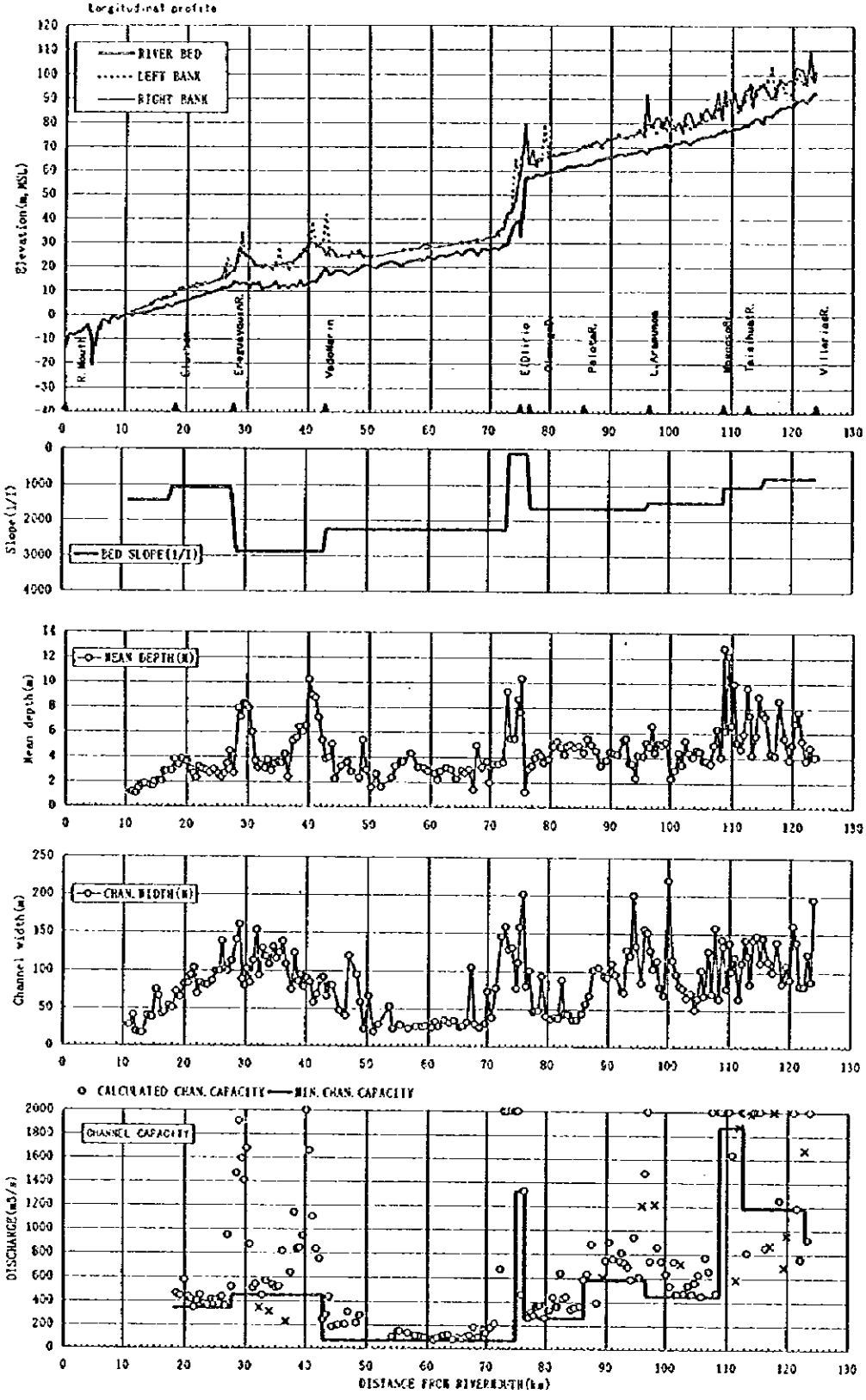
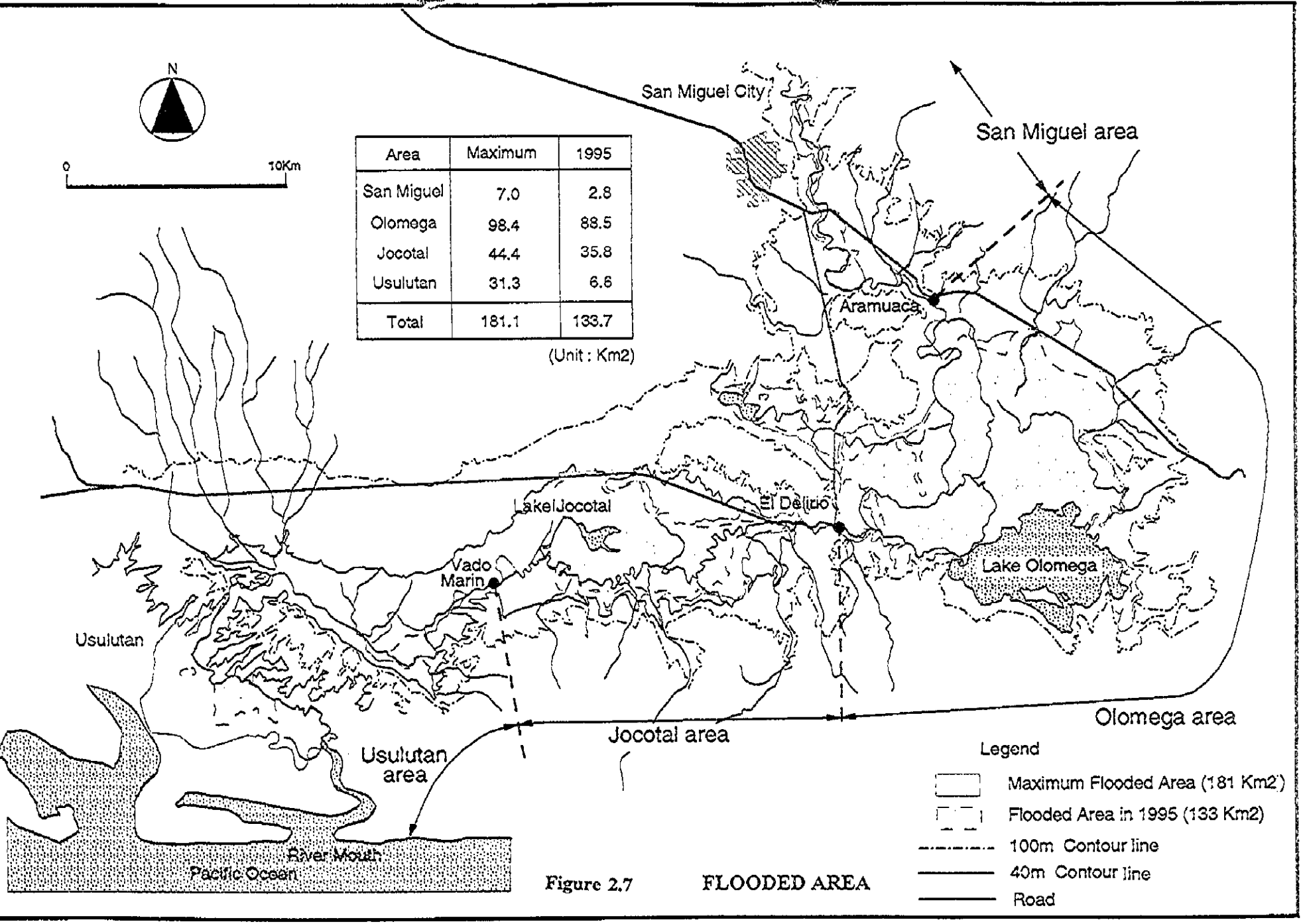


Figure 2.6 **LONGITUDINAL PROFILES OF EXISTING SAN MIGUEL RIVER**



Area	Maximum	1995
San Miguel	7.0	2.8
Olomega	98.4	88.5
Jocotal	44.4	35.8
Usulutan	31.3	6.6
Total	181.1	133.7

(Unit : Km2)

Figure 2.7 FLOODED AREA

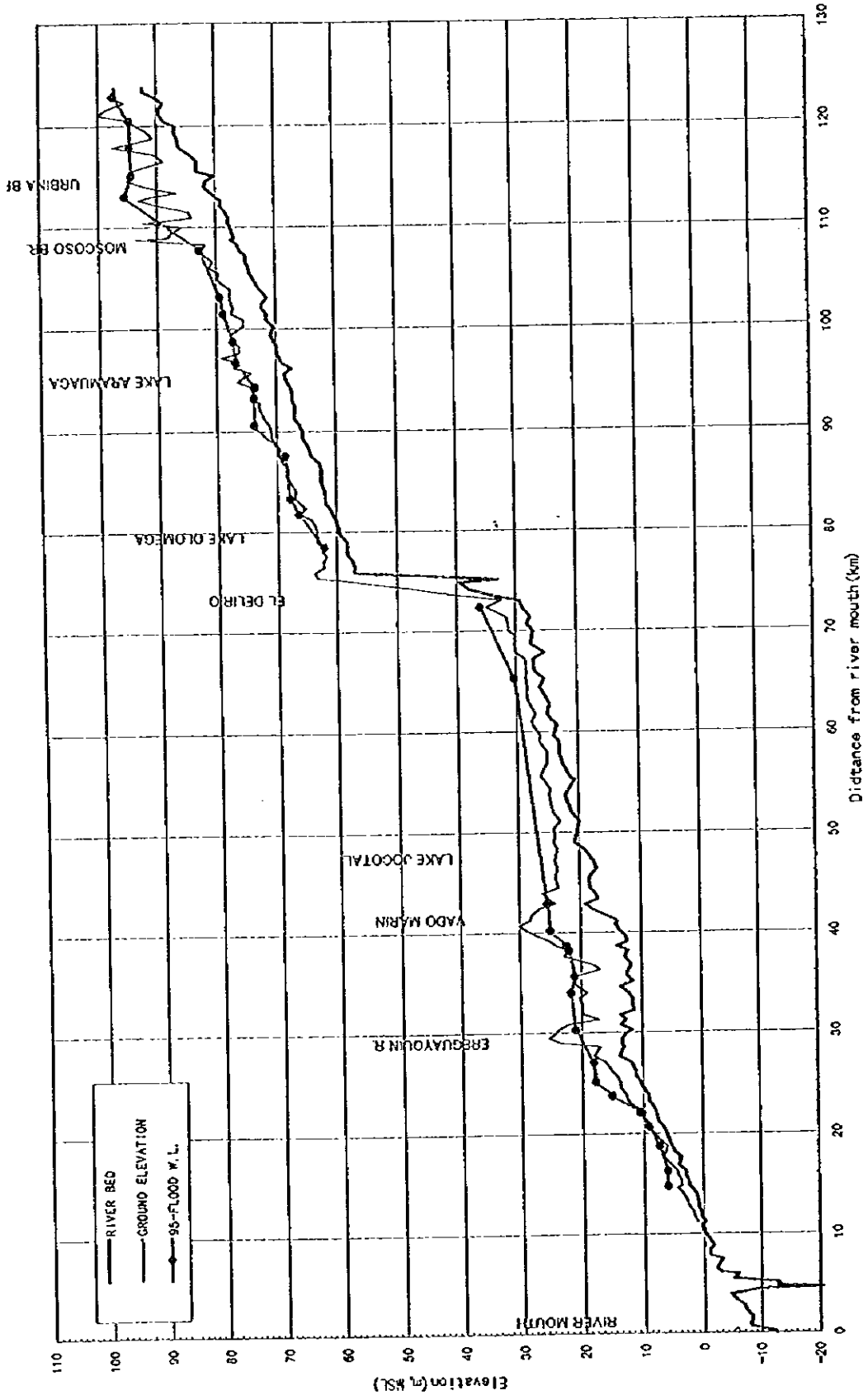


Figure 2.8 MAXIMUM WATER LEVEL OF 1995-FLOOD

3. FLOOD CONTROL MASTER PLAN

3. FLOOD CONTROL MASTER PLAN

3.1 Basis of Planning

3.1.1 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.

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.

3.1.2 Socio-economic Framework

(1) Population of the Study Area

Population of the Study Area in 1992 is 474,000 and is projected to be 1,041,000 in 2020.

(2) GRDP in the Study Area

The per capita GRDP in the Study Area in 1993 for the agriculture sector was 2,340 Colons and is 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 as follows:

- The urban areas will be expanded according to the population projected in 2020.
- Fifty (50)% of the potential production forest area is proposed to be reforested.

Future land use of the Study Area is shown in Fig. 3.9.

Future land use of the flood area is set assuming that the pasture area of 4,900 ha will be used for agriculture as desired by the farmers.

3.1.3 Areas to be Protected

The areas to be protected by the proposed flood control project are proposed to be located within the potential flood area (the past maximum flooded areas: 181 km^2). In some areas, it is difficult and uneconomical 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. 3.1. Some areas around Lake Jocotal, Lake Olomega, and Lake San Juan (totally 19 km^2) are proposed to be excluded from the areas to be protected. Thus the area to be protected is 162 km^2.

3.1.4 Design Flood

(1) 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 in the future, it is still a rural area except for the area near San Miguel City. Therefore, flood damage potential is low compared to that of urban area.
- The size of the river is a medium one, and the damage caused by flood larger than the designed one will not be serious except for the case of dike.
- Therefore, large scale investment to cope with a large flood like 100-year flood would not be economical.

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

(2) 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 was 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 is adopted as the time unit in design rainfall.

- For the rainfall distribution in the basin and along time, actual rainfall distributions of 1988 flood were used as a design rainfall pattern.

(3) Land Use of the Basin for Design Discharge Calculation

Future land use of the Study Area for design discharge calculation 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 framework
- Effects of reforestation on flood runoff are not taken into account for safety side of the design discharge

(4) Design Discharge Distribution

The design discharge distributions for several probabilities under conditions that, the basin land use is the proposed one for the future, the rivers are improved and no floodwater storage by inundation or reservoir. This is defined to be a "basic design discharge".

Distributions of the basic design discharges are shown in Fig. 3. 2.

3.2 Alternative Flood Control Measures

The alternative flood control measures applicable to the San Miguel River are river improvement, dams, floodways and retarding basins for structural measures and watershed management and floodplain management for non-structural measures as shown in Fig. 3.3. For the San Miguel River, the non - structural measures are essential in addition to the structural measures, because of deforestation in the Upper catchment, water related problems in the flood prone areas, etc.

3.2.1 Structural Measures

(1) Study of Alternatives

1) River Improvement

River improvement is a basic method of flood control, and there are two methods, namely,

- dredging / excavation method, and
- diking method.

The former is effective to lower the flood level and even when a larger flood than the designed one comes, damage would not be so serious. The demerits of this method are , river mouth sedimentation problem and inconvenience for water intake due to lowered river-bed.
The latter is convenient for water intake and river mouth sedimentation is not such a problem. However, drainage of inner water or tributary is difficult and dangerous when the flood exceeds the designed one.

Dredging / excavation is costly for the large scale rivers in general and therefore, the former is applicable to small or medium scale rivers. Both methods mentioned above will be applicable to the San Miguel River.

There are two types of river cross sections as shown below (refer to Fig. 3.4):

- Single cross section type
- Compound cross section type

The compound type is recommended taking account of the river-bed stability. The single type would be silted again. Since an important role of the river improvement is to fix its course, some bank protections will be required for both types.

2) San Felipe Floodway

An alternative method, to divert the floodwater from the river to other point of the river, is considered at San Felipe located in the downstream reach. This floodway construction will

require the excavation volume of about 2 million m^3 including in greater part rock materials, and therefore, the cost will be much higher than the cost of river improvement along the existing river. In addition, the floodway will change the existing river flow condition, and it will have a large height river bank slope of about 35m. After construction, problems of water use and maintenance are anticipated.
Therefore, the floodway is not recommended.

3) Olomega Floodway

The Olomega Floodway, proposed in 1967, is not recommended in this Master Plan by the following reasons:

- To divert almost all of the San Miguel River water into the lake will cause pollution and sedimentation of the lake
- Drainage of the Olomega catchment is difficult due to the dike proposed along shore line of the lake

4) San Esteban Multi-purpose Dam

The multi-purpose dam at San Esteban has a catchment area of 825 km^2 and is considered to be effective for the flood control, in addition to hydroelectric power generation and irrigation. Other dams proposed for irrigation have small catchment areas, less than 80 km^2, and are not effective for flood control.
Therefore, the San Esteban Dam is studied as an alternative flood control measure.

The multi-purpose dam at San Esteban for the purposes of hydro-electric power generation, irrigation and flood control is assumed as follows:

- Reservoir operation proposed by CEL is assumed in required storage volume calculation for hydropower 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 by the difference between inflow and outflow from the spillway. The design flood hydrograph of 10-year return period is assumed for the inflow to the reservoir.

- Sedimentation volume is calculated by assuming that 1,000 m^3/year/km^2 of sediments from the dam catchment for 100 years are to be accumulated.

- The total cost of multi-purpose dam is distributed (allocated) to each purpose assuming that the cost for each purpose is proportional to the cost of each single purpose dam.

5) Floodwater Storage in Lake Olomega

Lake Olomega has an area of 20 km^2 and it is possible to store the floodwater with a storage volume of 20 million m^3 per 1.0 m effective depth. Floodwater storage by a retarding basin requires land acquisition of large agricultural land and is difficult to find out the suitable site in other areas.
The usage of Lake Olomega is studied as an alternative measure.

In the area of the lake and its surroundings, the farmers want to develop the flood prone areas for agriculture, on the other hand, the fishermen want to keep the lake water level high for fishery. Water level of Olomega during the dry season is higher than before due to filling up of the outlet channel. This was a countermeasure against expansion of agricultural area to the lake area during the last extremely dry year.

Idea of the usage of Lake Olomega for flood control is as follows:

- To mitigate the flood damage of agricultural land by river improvement

- To store floodwater of the San Miguel River in Lake Olomega, when the river water level becomes high, by diverting.

- The lake water level is to be kept low during flood season for floodwater storage, and maintained at a certain level during dry season for fishery. The lake water level is to be controlled by a small gate at the outlet of the lake.

- The lake level variation will be kept within a certain amount to reduce flood damage and fishery damage. Such water level ranges within 64.0 m to 65.5m above mean sea level (refer to Figs. 3.5 and 3.6).

6) Floodwater Storage in Lake Jocotal

The floodwater storage in Lake Jocotal is not recommended, because the area is designated as an environmental protection area. However it would be difficult to make the area flood free as there are depressed areas along the San Miguel River near the lake. As the effect of flood storage extends only to its downstream, a storage in the lower basin gives effect to only limited areas. Retarding basin in this area is not recommended either.

(2) Selection of Alternatives

Alternative cases of the structural measures to be studied in more detail are combinations of river improvements with and without floodwater storage by San Esteban multi-purpose dam and/or by usage of Lake Olomega.

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

Comparison of the alternative cases, from economic, financial, social, technical and environmental view points, is shown in Table 3.1.

Case -2 is recommended from view point of flood control based on the following:

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.

3.2.2 Non-structural Measures

(1) Floodplain Management

The floodplain management projects which are applicable to the San Miguel River Basin are as follows;

① designation of areas allowed to be inundated
② land use regulation
③ flood proofing such as embankment or elevated floor housing
④ flood forecasting and warning
⑤ flood fighting
⑥ education to the residents

① : the area allowed to be inundated after the completion of structure measures
② and ③ : necessary against flood larger than the designed one
④ and ⑤ : on-going by COEN
⑥ : applicable by COEN and MAG using flood risk maps

Here, land use regulation flood proofing, flood forecasting/warning and education to the residents are selected as floodplain management measures in the basin.

(2) Watershed Management

General measures of watershed management are forest reserve, erosion and run-off control by land use regulation, storm water infiltration and land treatment.

In this Master Plan, reforestation and erosion/run-off control are adapted as some areas are improperly utilized from the view points of topography, geology, soil type and water, resulting in the increase in flood and sediment run-off.

3.3 Proposed Flood Control Master Plan

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

- River improvement of the San Miguel River from the river mouth to the Urbina Bridge (L=89 km)

- Floodwater storage in Lake Olomega
- Floodplain management of the potential flood areas including land use regulation, flood proofing, flood forecasting/warning and education to the residents
- Watershed management including sediment and storm runoff control

The Master Plan is presented in Fig. 3.7. Main features of the projects are described below (refer to Table 3.2).

(1) River Improvement / Floodwater Storage in Lake Olomega

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
Ground sill	: 4 places, L= 348 m
Deversoir (diversion weir)	: L= 62 m, 1 place
Olomega Control Gate	: Effective Span = 20m, 1 place
Bridge reconstruction	: 5 places

(2) Floodplain Management

1) Objectives

- 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
- Prevention of increase in potential flood damage in the delta areas due to agricultural and fishery developments

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 -

Land use regulation and flood proofing are proposed.

Proposed floodplain management is presented in Fig. 3.8.

(3) 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, and
- to maintain the river water clean,
  in addition to the protection of agricultural lands and the conservation of nature.

2) Contents of Watershed Managment Project

Proposed watershed management project is as follows;

①	reforestation	:	30,000 ha
②	erosion and run-off control	:	20,000 ha
③	debris control	:	ground sill 30 places

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 slope 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 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 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 deposit areas should be reforested. For the potential agricultural areas, erosion and runoff control should be done.

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

Proposed watershed management is shown in Fig. 3.6.

3.4 Project Cost

3.4.1 Structural Measures

The total cost of the Master Plan Project at December 1997 price is 1,097 Million Colons and with price escalation is 1,578 Million Colons. (Table 3.3)

The structural measures consists of river improvement of the San Miguel River and floodwater diversion and retarding in Lake Olomega, and the costs were estimated as follows:

(1) Construction Cost : estimated based on the data obtained from MAG, MOP, CEL and related agencies
(2) Land Acquisition / Compensation Cost : estimated based on the unit price data obtained from MAG
(3) Administration Cost : assumed to be 5% of the total of (1) and (2)
(4) Engineering Services Cost : assumed to be 15 % of the total of (1) and (2)
(5) Contingency : 10 % of the total of (1) to (4) is assumed for the physical contingency
(6) Price Contingency : estimated assuming an annual price escalation for foreign currency of 3 % and for local currency of 6%

3.4.2 Non-structural Measures

(1) 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.

(2) Watershed Management

The cost of Watershed Management consists in the costs for reforestation including saplings and planting, erosion control works of upland fields and debris control (sabo) works. The total cost is estimated at Colons 208 Million. 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 are 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..

3.5 Operation and Maintenance Plan/Organization and Institution

3.5.1 Operation and Maintenance Plan

The flood control facilities constructed according to the Master Plan are to be operated and maintained by the San Miguel Project Office together with the Olomega Site Office which have been provided during the construction stage. COEN will carry out emergency activities of floodplain management.

3.5.2 Organization and Institution

1) Structure Measures

Organization in charge during the construction stage is MAG. The San Miguel Project Office consisting of MAG and MOP staff will execute the project. Operation and maintenance of the facilities will be done by the San Miguel Project Office including Olomega Site Office provided during the construction stage.

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 Morazan 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).

3.6 Project Evaluation

3.6.1 Structural Measures

(1) 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 project evaluation of this study.

Average annual economic benefit is estimated at Colons 156.9 Million.

2) Economic Cost

As the result, the economic cost of the project is estimated at Colons 998.3 Million for the construction cost and Colons 4.03 Million for the annual operation and maintenance cost (O/M cost).

3) Economic Evaluation

The economic evaluation of the project is made in terms of Economic Internal Rate of Return (EIRR), Net Present Value (NPV) and Benefit-Cost Ratio (B/C). The results are as follows :

EIRR = 14.6 %,
NPV = Colons 99.5 Million (at the discount rate of 12%),and
B / C = 1.20 (at the discount rate of 12%)

The values above indicate that the structural measures are economically feasible.

(2) Financial Aspects

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.

(3) Initial Environmental Examination (IEE)

The results of IEE are presented in Table 3.4. Major impacts of the structural measures are as follows :

1) Social Impacts

- Land acquisition, for the San Miguel River improvement, of 779 ha. (-)
- Compensation of 20 houses (-)
- Disturbance of the communities during the construction work (-)
- Improvement of sanitation due to decrease in flooding (+)

2) Natural Environmental Effects

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

(4) 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

(5) Evaluation

The structural measures are evaluated to be feasible because of,

- Economically viable,
- Technically no difficulty,
- Large positive environmental effects and small negative impacts, and
- Large socio-economic effects such as contribution to the regional development owing to effective land use, improvement in environment of local communities, increase in employment opportunity, etc.

3.6.2 Project Evaluation of Non-structural Measures

(1) Floodplain Management

Social effects of the project are as follows:

- Smooth development of San Miguel City
- Decrease in flood damage
- Raising of safety
- Optimization of Lake Olomega usage

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

(2) Watershed Management

Major impacts are,

- Increase in agricultural production,
- Decrease in soil erosion,
- Stabilization of river flow, and
- Stabilization of riverbed.

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

3.7 Implementation Schedule

The implementation time schedule of Master Plan project is prepared as follows. (refer to Fig. 3.14).

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

(2) The structural measure project is proposed to be divided into two stages for effective implementation of the project.
To cope with 2-year flood for the first stage and the rest of the Master Plan project to cope with 10-year flood for the second stage were scheduled.

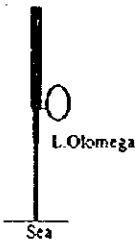
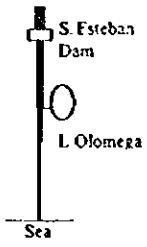
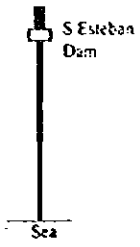
(3) Floodplain Management and Watershed Management projects are scheduled to be implemented in early stage independent of the structural measures.

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

Implementation Schedule of San Miguel River Basin Flood Control Master Plan

	Description	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2020
Structural Measures (Stage 1 Priority Project)	1. Loan Process(1)														
	2 Detailed Design(1)														
	3. Land Acquisition(1)														
	4.Tendering (1)														
	5. Construction to cope with 2-year flood														
Structural Measures (Stage 2 Rest of Master Plan)	6 Feasibility Study														
	7. Loan Process(2)														
	8 Detailed Design(2)														
	9 Land Acquisition(2)														
	10.Tendering (2)														
	11.Construction to cope with 10-year flood														
Non-structural Measures	1.Floodplain Management														
	Landuse Regulation/Flood Proofing														
	Flood Forecasting/Warning														
	Education to the residents														
	2.Watershed Management														
	Reforestation														
	Erosion Control														

Table 3.1 COMPARISON OF FLOOD CONTROL ALTERNATIVES

Description	Case 1	Case 2	Case 3	Case 4
SCHEMATIC DESCRIPTION OF ALTERNATIVE SCHEMES				
	Channel improvement only	Channel improvement + L.Olomega	Channel improvement + L.Olomega + San Esteban dam	Channel improvement + San Esteban dam
TECHNICAL ASPECTS				
• Difficulty	• Easier: Mainly channel improvement works	• Easier: Mainly channel improvement works	• More difficult: Dam construction and channel improvement works	• More difficult: Dam construction and channel improvement works
• Construction period	• Approx. 5 years	• Approx. 5 years	• Approx. 10 years	• Approx. 10 years
• Ranking (Wt=0.15)	• 1	• 1	• 3	• 3
FINANCIAL ASPECTS				
• Project cost(Ratio to Case-1)	• 1.00	• 0.69	• 0.83(multi-purpose)	• 0.89(multi-purpose)
• Ranking (Wt=0.40)	• 4	• 1	• 2	• 3
ECONOMIC ASPECTS				
• Benefit	• Reduction of flood damage • Enhancement of production	• Reduction of flood damage • Enhancement of production • Stable fishery in Lake Olomega	• Reduction of flood damage • Enhancement of production • Stable fishery in Lake Olomega	• Reduction of flood damage • Enhancement of production
• Ranking (Wt=0.15)	• 1	• 1	• 1	• 1
SOCIAL IMPACT				
• Land acquisition	• 3.7 km^2	• 4.5 km^2	• 35.5 km^2	• 34.7 km^2
• Re-settlement	• 18 houses	• 20 houses	• 1,301 houses	• 1,299 houses
• Ranking (Wt=0.15)	• 1	• 1	• 3	• 3
ENVIRONMENTAL ASPECTS				
• Positive effects	• Stabilization of water level in Lake Jocotal	• Stabilization of water level in Lake Jocotal and Lake Olomega	• Stabilization of water level in Lake Jocotal and Lake Olomega	• Stabilization of water level in Lake Jocotal
• Negative effects			• Ecological changes in reservoir area	• Ecological changes in reservoir area
• Ranking (Wt=0.15)	• 2	• 1	• 3	• 4
OVERALL EVALUATION				
• Summary of ranking	• 1x0.15+4x0.4+1x0.15+1x0.15+2x0.15=2.35	• 1x0.15+1x0.4+1x0.15+1x0.15+1x0.15=1.00	• 3x0.15+2x0.4+1x0.15+3x0.15+3x0.15=2.30	• 3x0.15+3x0.4+1x0.15+3x0.15+4x0.15=2.85
• Overall ranking	• 3	• 1	• 2	• 4

REMARKS:

1) Quantities presented in this table are for the facility plan based on 10-year provable flood.
2) Wt: Weight for overall evaluation
3) F.C: Flood control

Table 3.2 PRINCIPAL FEATURES OF MASTER PLAN

RIVER IMPROVEMENT

Project Cost(¢ million): (Including price escalation)		1,577.6
Construction Works	Construction Period	10 years from 2001 to 2010
	Excavation(m^3):	14,956,000
	Embankment(m^3):	1,843,000
	Revetment(m^3):	6,000
	Ground sill(site)	4
	Weir/gate(site):	2
	Sluice(site):	15
	Bridge(site):	5
Reduction of Flooded Area: for 10-yr. flood (km^2)	San Miguel:	0.4
	Olomega:	61.8
	Jocotal:	28.2
	Usulutan:	13.6
	Total:	104.0
Beneficiary in the Protected Area: for 10-yr. flood in 2020 (persons)	San Miguel:	200
	Olomega:	27,900
	Jocotal:	12,700
	Usulutan:	6,100
	Total:	46,900
Social Impact	Positive Impact:	- To enable effective land use and development of the basin, - To ensure the people's livelihood in the basin, - To ensure stable fishery in lakes of Olomega and Jocotal, - To create employment opportunities during construction, and - To improve sanitary conditions.
	Negative Impact: - Land acquisition: - House comp.:	779 ha 20 houses
		- Disturbance of communities during construction
Environmental Impact		- Mitigation of inflow of polluted and sediment contained water of the San Miguel River - Stabilization of water level in lakes of Olomega and Jocotal
Economic Viability: EIRR (%)		14.6

FLOODPLAIN MANAGEMENT

Estuary Area	Land use regulation and flood proofing
Jocotal Area	Land use regulation, flood proofing and flood forecasting/warning to mitigate damage in non-dike reaches
Olomega Area	
Near S. Miguel City	Land use regulation to mitigate damage in urban area
Project Cost	- Office and equipment: ¢ 8,100,000 - Operation and maintenance: ¢ 720,000/yr.

WATERSHED MANAGEMENT

Lower Basin	Reforestation, erosion control and ground sill works
Middle Basin	
Upper Basin	
Project Cost	¢ 208,000,000

Table 3.3 PROJECT COST FOR MASTER PLAN

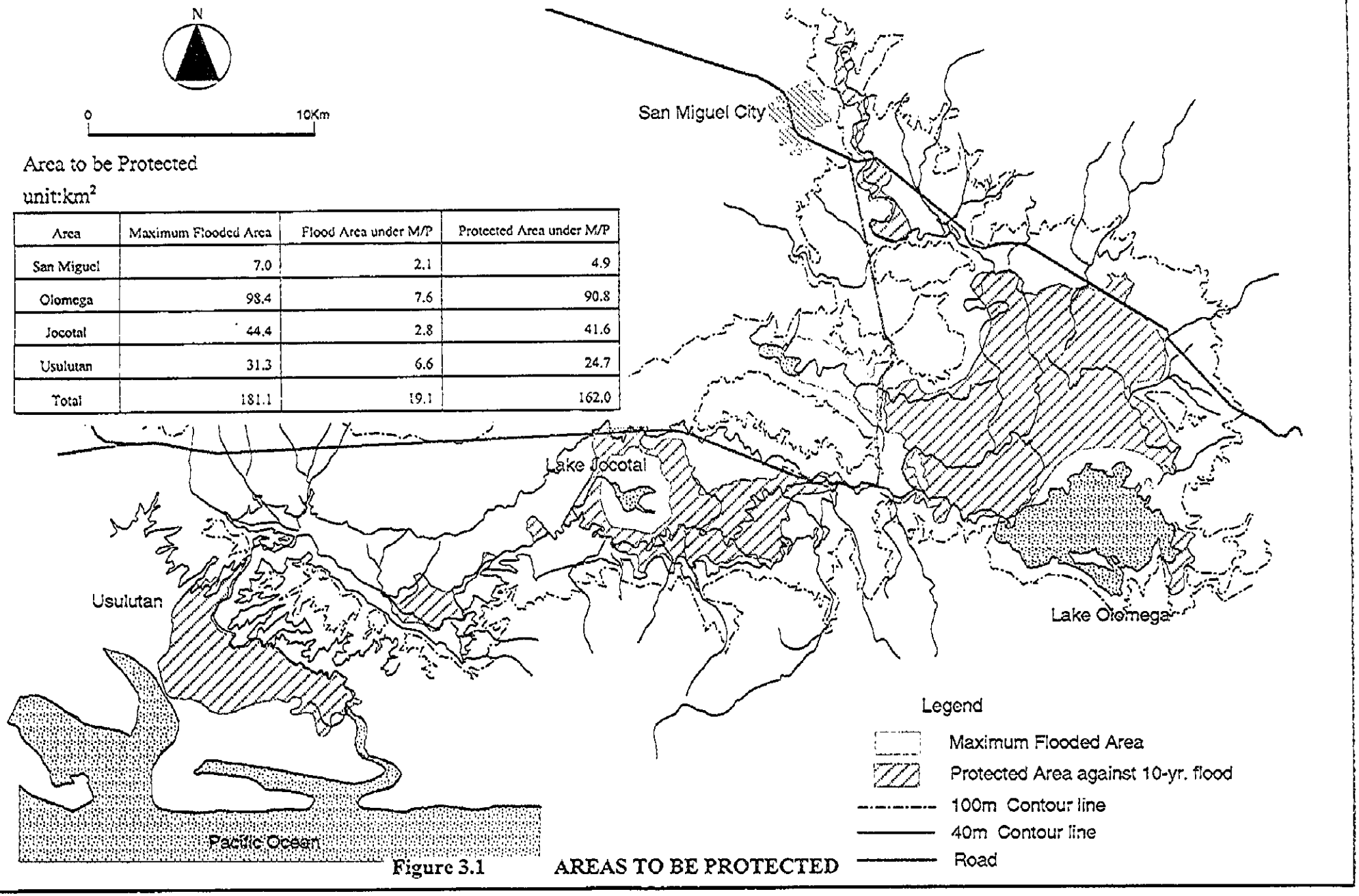
Items	Unit		Quantity	Amount(¢ million)		
	Unit	Cost(¢)		Total	L.C.	F.C.
1. Construction works						
1.1 Channel works				705.1	306.2	398.9
Earth excavation(1)	m^3	45	8,087,000	363.9	149.2	214.7
Earth excavation(2)	m^3	20	6,266,000	125.3	51.4	73.9
Rock excavation	m^3	173	603,000	104.3	42.8	61.5
Embankment	m^3	42	1,843,000	77.4	31.7	45.7
Revetment	m	5,700	6,000	34.2	31.1	3.1
1.2 Structure works				34.7	25.6	9.1
Diversion weir	l.s.			10.9	9.4	1.5
Control gate	l.s.			9.4	5.8	3.6
Drainage sluice				8.0	5.0	3.0
Type-A	nos	426,000	7	3.0	1.9	1.1
Type-B	nos	586,000	6	3.5	2.2	1.3
Type-C	nos	754,000	2	1.5	0.9	0.6
Ground sill	m	18,269	348	6.4	5.4	1.0
1.3 Appurtenant works				67.7	37.5	30.2
Intake gate(Type-B)	nos	586,000	1	0.6	0.4	0.2
Bridge				58.2	30.3	27.9
Bridge(105m)	nos	13,400,000	1	13.4	7.0	6.4
Bridge(90m)	nos	12,600,000	3	37.8	19.7	18.1
Bridge(40m)	nos	7,000,000	1	7.0	3.6	3.4
Rural road	m	160	5,140	0.8	0.8	0.0
Telemetering system	l.s.			8.1	6.1	2.0
(Sub-total : 1.1+1.2+1.3)				807.5	369.3	438.2
2. Land and house				23.8	23.8	0.0
Land acquisit.(1)	10^3m^2	2,150	728	1.6	1.6	0.0
Land acquisit.(2)	10^3m^2	5,720	845	4.8	4.8	0.0
Land acquisit.(3)	10^3m^2	2,570	1,067	2.7	2.7	0.0
Land acquisit.(4)	10^3m^2	720	1,695	1.2	1.2	0.0
Land acquisit.(5)	10^3m^2	3,580	3,181	11.4	11.4	0.0
Land acquisit.(6)	10^3m^2	7,150	270	1.9	1.9	0.0
House compensat.	house	12,000	20	0.2	0.2	0.0
3. Administration	l.s.	-		41.6	41.6	0.0
4. Engineering service	l.s.	-		124.7	46.1	78.6
5. Physical contingency	l.s.	-		99.8	48.1	51.7
(Sub-total : 1+2+3+4+5)				1,097.4	528.9	568.5
6. Price contingency	l.s.	-		480.2	321.3	158.9
Total				1,577.6	850.2	727.4

Table 3.4 RESULTS OF IEE

No	Environmental Item	Discretion	Activity				Remarks
Social Environment			1	2	3	4	
a	Resettlement	Resettlement by land occupation (Transfer of rights of residence, land ownership)	D	B	D	A	(2) Land acquisition for the water way (4) Resettlement of about 7,000 persons in the area
b	Economic Activities	Loss of production base (land , etc) and change of economic structure.	D	D	D	B	(4) Loss of farmland
c	Traffic and Public Facilities	Impacts on existing traffic, schools, hospitals, etc. (e.g., traffic jam, accidents)	D	D	D	B	(4) School, road in the submerged area
d	Split of Communities	Separation of regional communities by hindrance of regional traffic	D	D	D	B	
e	Cultural Property	Loss or deterioration of cultural properties such as temples, shrines, archaeological assets, etc.	D	D	D	D	
f	Water Rights and Right of Common	Obstruction of fishing rights, irrigation and water rights	D	B	D	D	(2) Fishing rights of about 2,000 fishermen
g	Public Health Condition	Worsening of health and sanitary condition due to generation of garbage and appearance of harmful insects, increasing of agricultural chemicals	D	D	D	D	
h	Waste	Generation of construction waste, surplus soil, sludge, domestic waste, etc.	A	B	D	A	Generation of debris and soil
i	Hazards(Risk)	Increase in risk of cave-ins, ground failure and accident	D	D	D	D	
Natural Environment							
a	Topography and Geology	Change of valuable topography and geology due to excavation and earthfill	D	D	D	D	
b	Soil and land	Topsoil erosion by rainfall after land reclamation or deforestation, salt accumulation by irrigation, degradation of soil fertility	D	D	D	D	
c	Groundwater	Lowering of groundwater table due to overdraft and turbid water caused by construction work	B	D	D	B	(1) Lowering of groundwater table
d	Hydrological Situation	Change of discharge and water quality due to reclamation and drainage	A	A	D	A	(1),(2) Impact on fishery and change of channel form
e	Fauna and Flora	Interruption of reproduction or extinction of species due to change of habitat condition	D	B	D	D	(2) Effect on water level
f	Meteorology	Change of micro-climate, such as temperature, wind, etc., due to large scale reclamation, and construction	D	D	D	D	
g	Landscape	Deterioration of aesthetic harmony by structures and topographic change by reclamation	B	B	D	A	Damage to landscape due to construction of dike, waterway and dam
Pollution							
a	Air Pollution	Pollution caused by exhaust gas or toxic gas from vehicles and factories	D	D	D	D	
b	Water Pollution	Water pollution of river and groundwater caused by drilling mud and oil	D	B	D	D	(2) Inflow of sediment into the lake
c	Soil Contamination	Contamination caused by discharge or diffusion of sewage or toxic substances	D	D	D	D	
d	Noise and Vibration	Generation of noise and vibration due to drilling and operation of pumping machines	D	D	D	B	(4) Noise by operation of construction equipment
e	Land Subsidence	Deformation of the land and land subsidence due to lowering of groundwater table	D	D	D	D	
f	Offensive Odor	Generation of offensive odor and exhaust gases	D	D	D	D	
Overall Evaluation :		EIA is necessary for the project implementation					

Activities :
(1) Improvement of river channel
(2) Flood water storage in Lake Olomega
(3) Watershed management
(4) San Esteban Dam

Mark classification : A: Important Impact, B: Some impact, C: Unknown , D: No Impact

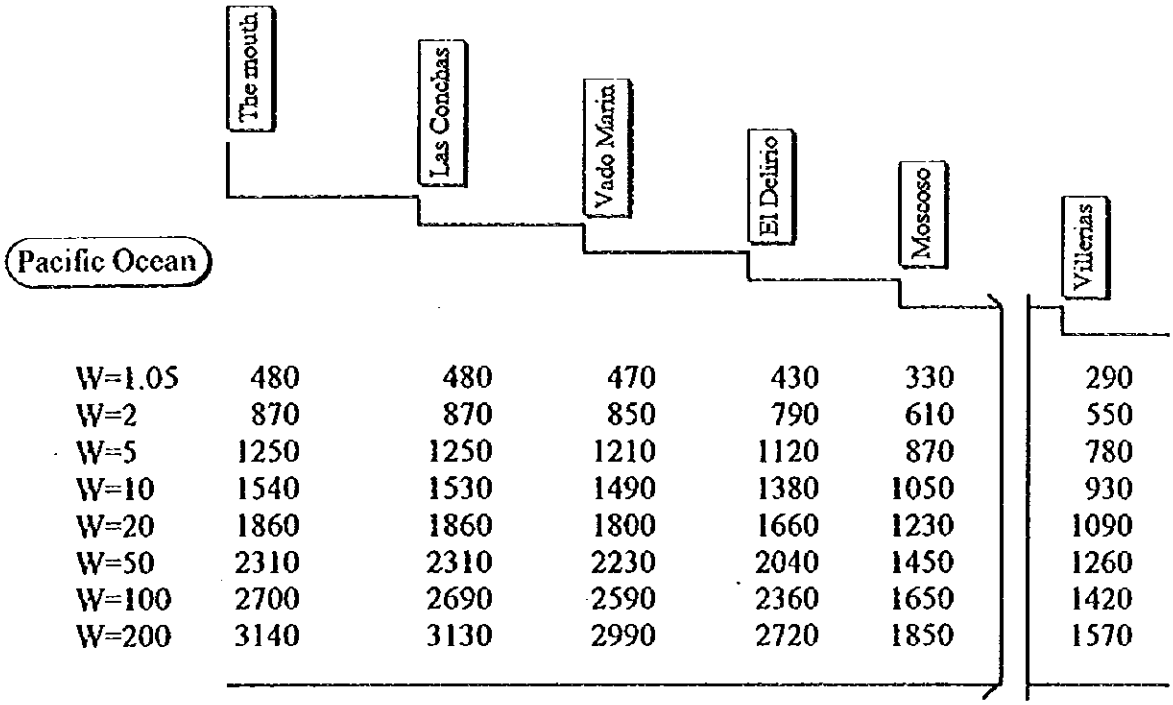


Area to be Protected

unit:km^2

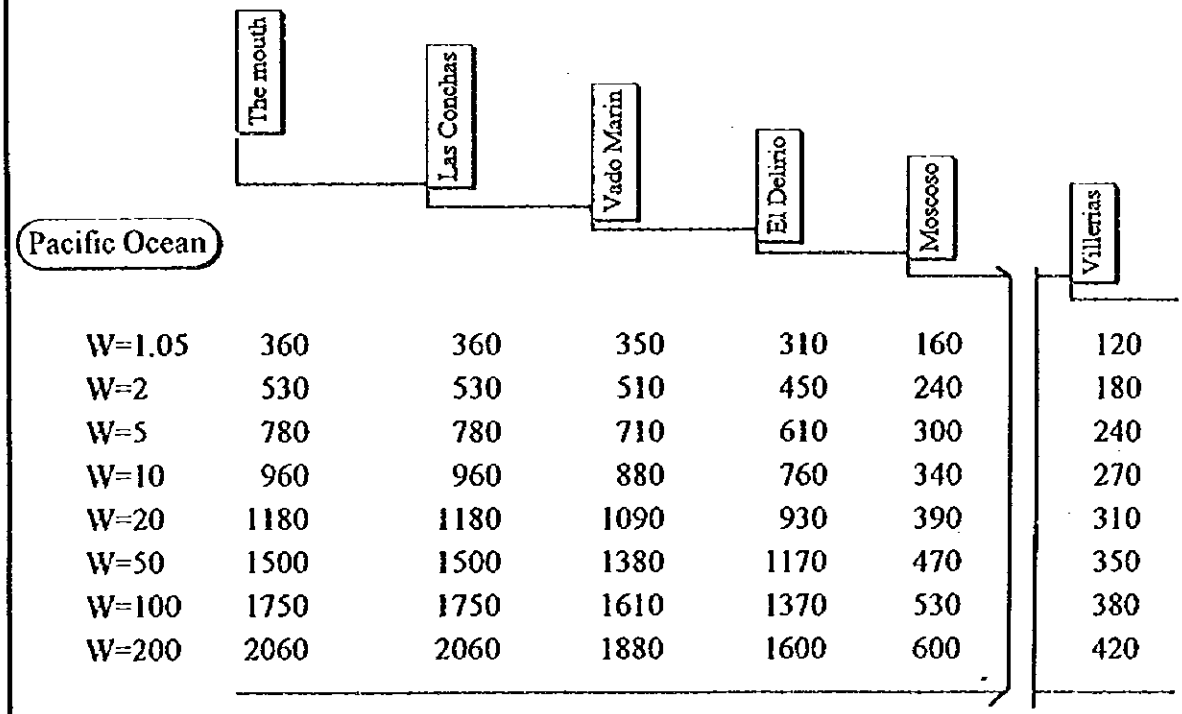
Area	Maximum Flooded Area	Flood Area under M/P	Protected Area under M/P
San Miguel	7.0	2.1	4.9
Olomega	98.4	7.6	90.8
Jocotal	44.4	2.8	41.6
Usulutan	31.3	6.6	24.7
Total	181.1	19.1	162.0

Figure 3.1 AREAS TO BE PROTECTED



W=1.05	480	480	470	430	330	290
W=2	870	870	850	790	610	550
W=5	1250	1250	1210	1120	870	780
W=10	1540	1530	1490	1380	1050	930
W=20	1860	1860	1800	1660	1230	1090
W=50	2310	2310	2230	2040	1450	1260
W=100	2700	2690	2590	2360	1650	1420
W=200	3140	3130	2990	2720	1850	1570

Discharge Distribution without inundation(unit; m3/s)



W=1.05	360	360	350	310	160	120
W=2	530	530	510	450	240	180
W=5	780	780	710	610	300	240
W=10	960	960	880	760	340	270
W=20	1180	1180	1090	930	390	310
W=50	1500	1500	1380	1170	470	350
W=100	1750	1750	1610	1370	530	380
W=200	2060	2060	1880	1600	600	420

Discharge Distribution with Dam (unit; m^3/s)

Figure 3.2 PROBABLE DISCHARGE DISTRIBUTION

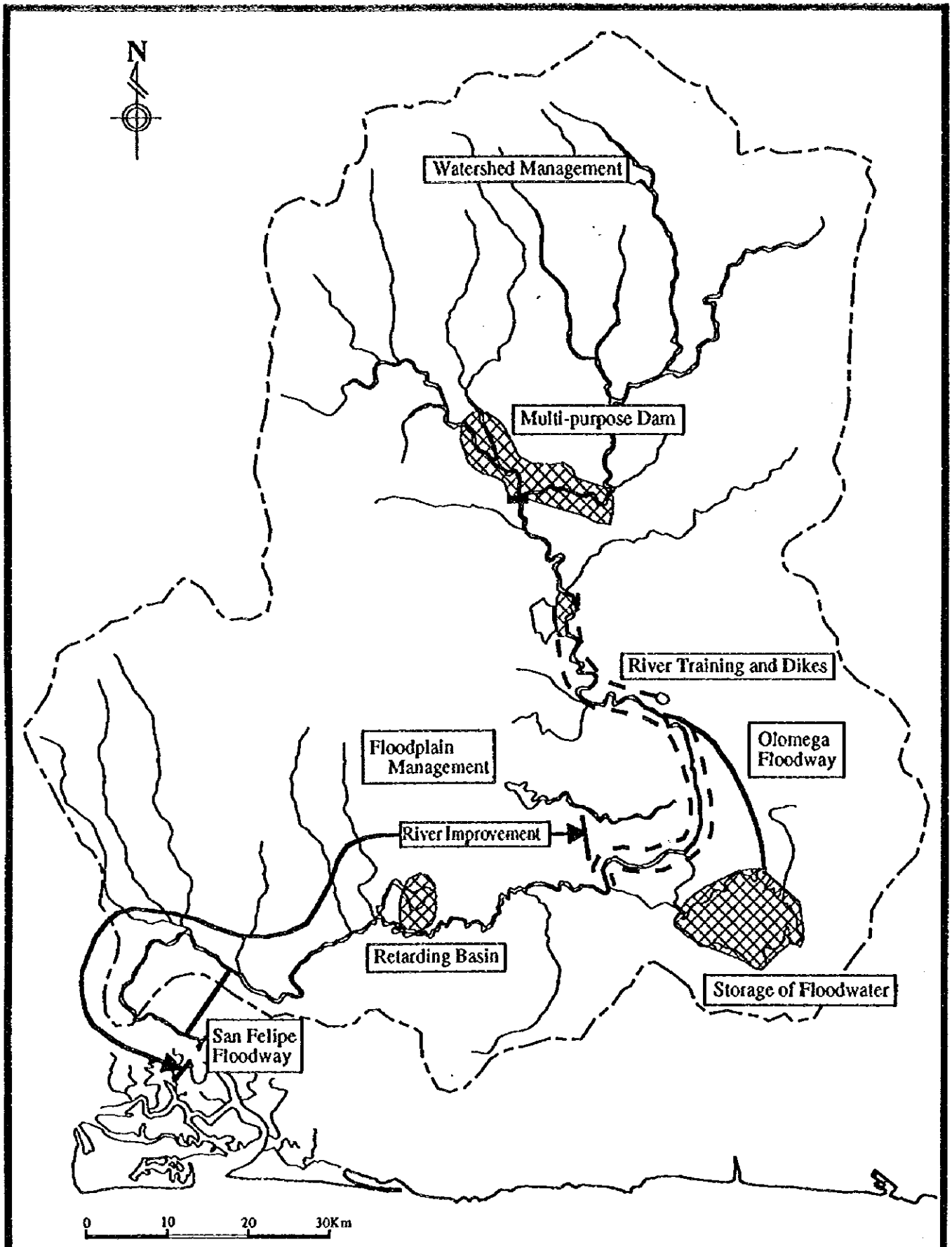


Figure 3.3 CONCEIVABLE FLOOD CONTROL MEASURES

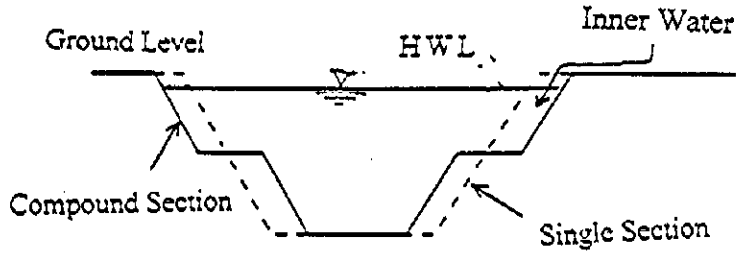
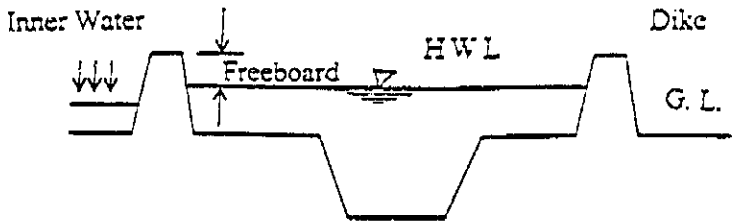
Dredging / Excavation Method	Diking Method
 ※ H W L (Design Flood Level) shall be lower than the ground level	 ※ H W L+Freeboard is required
1. Inner water can be drained by gravity flow. 2. Damage by flood larger than the designed one would not increase so much. 3. Construction cost is high but width of land acquisition cost is small. 4. Inconvenient for water intake due to low river-bed. 5. River mouth sedimentation is problem if dredged deeply.	1. Inner water cannot be drained by gravity. Dike for tributary or pumping station would be required. 2. Dangerous when larger flood comes. 3. Small in construction cost and large in land acquisition cost 4. Convenient for water intake 5. No problem with river mouth sedimentation

Figure 3.4 COMPARISON OF RIVER IMPROVEMENT METHOD

Figure 3.5 LAKE WATER LEVEL AND FISH CATCH (LAKE OLOMEGA)

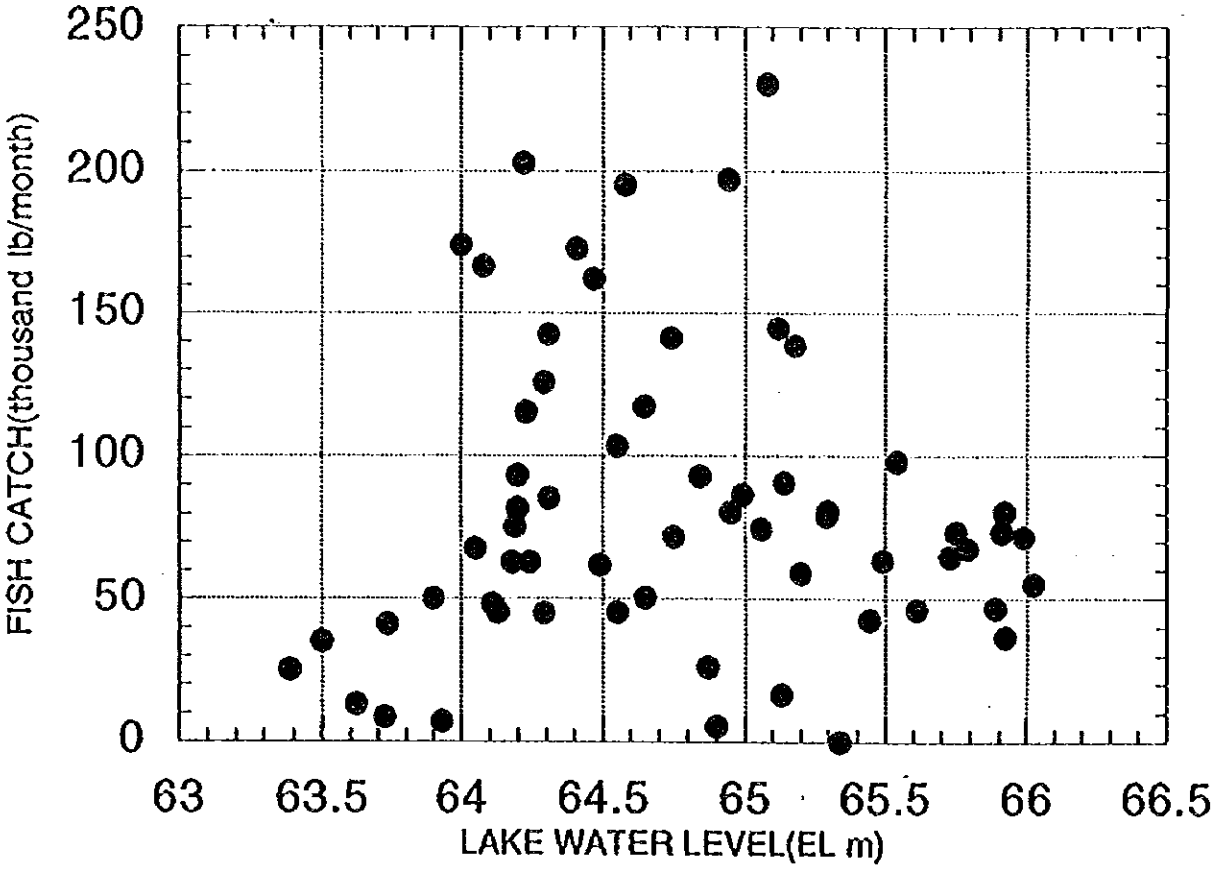
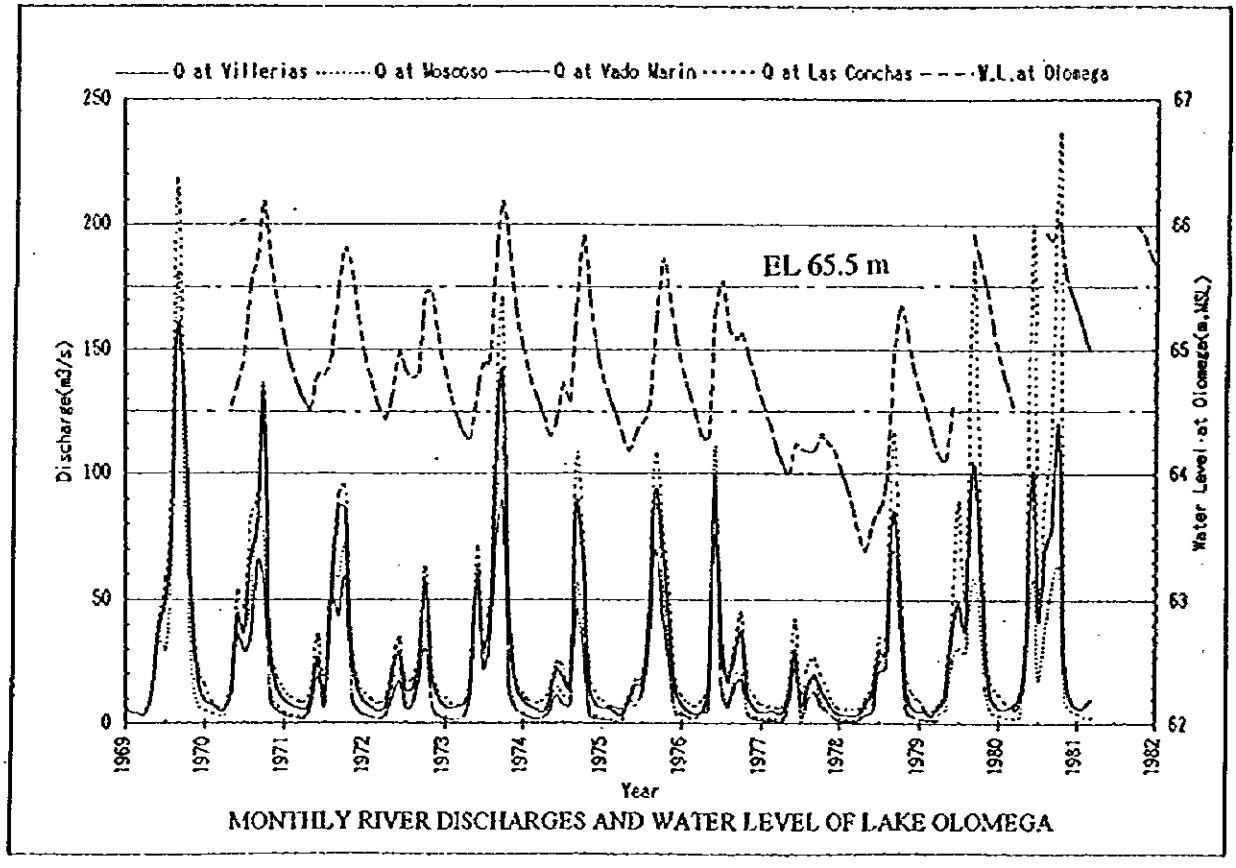


Figure 3.6 MONTHLY RIVER DISCHARGES AND WATER LEVEL OF LAKE OLOMEGA



MONTHLY RIVER DISCHARGES AND WATER LEVEL OF LAKE OLOMEGA

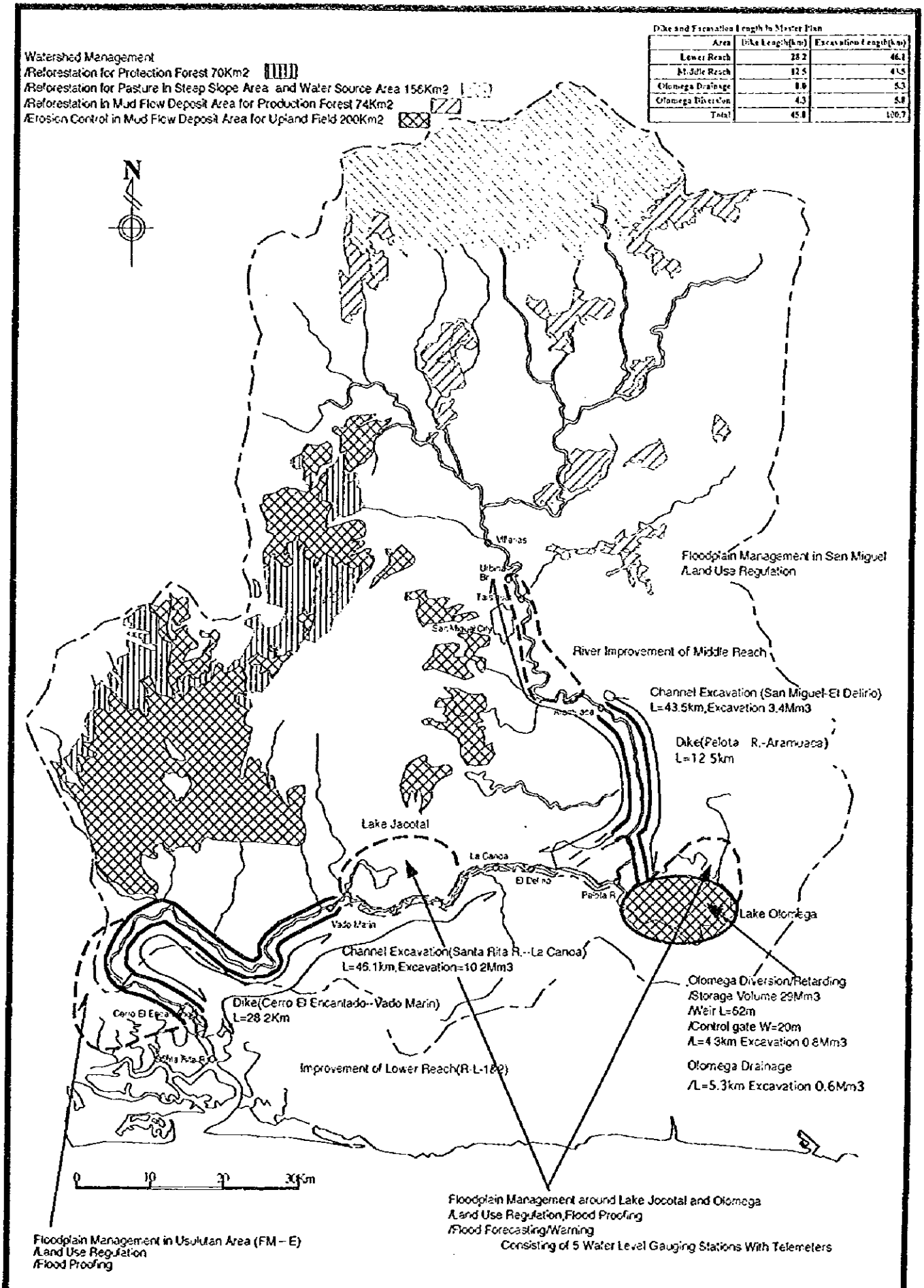


Figure 3.7 **GENERAL LAYOUT OF FLOOD CONTROL MASTER PLAN**

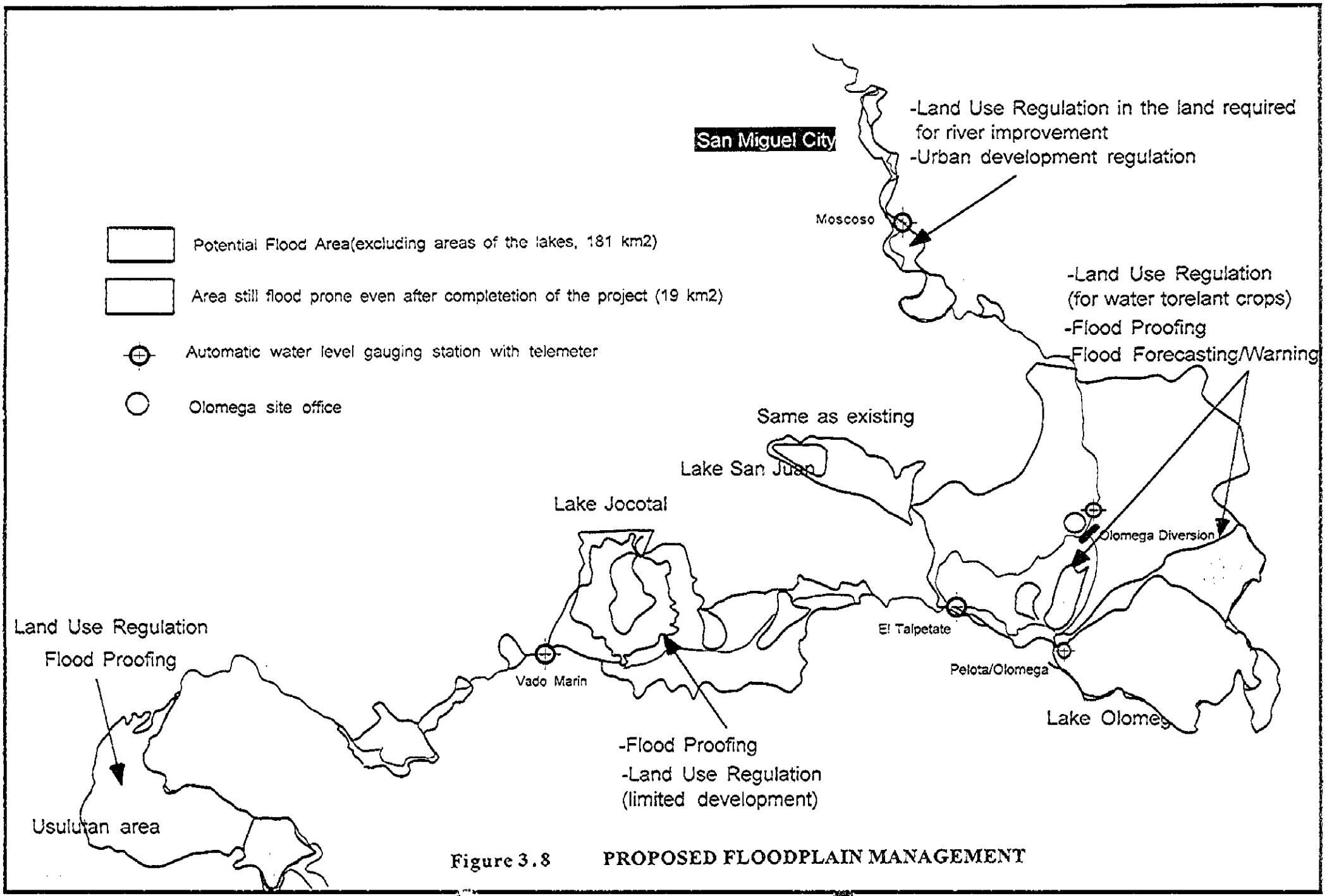
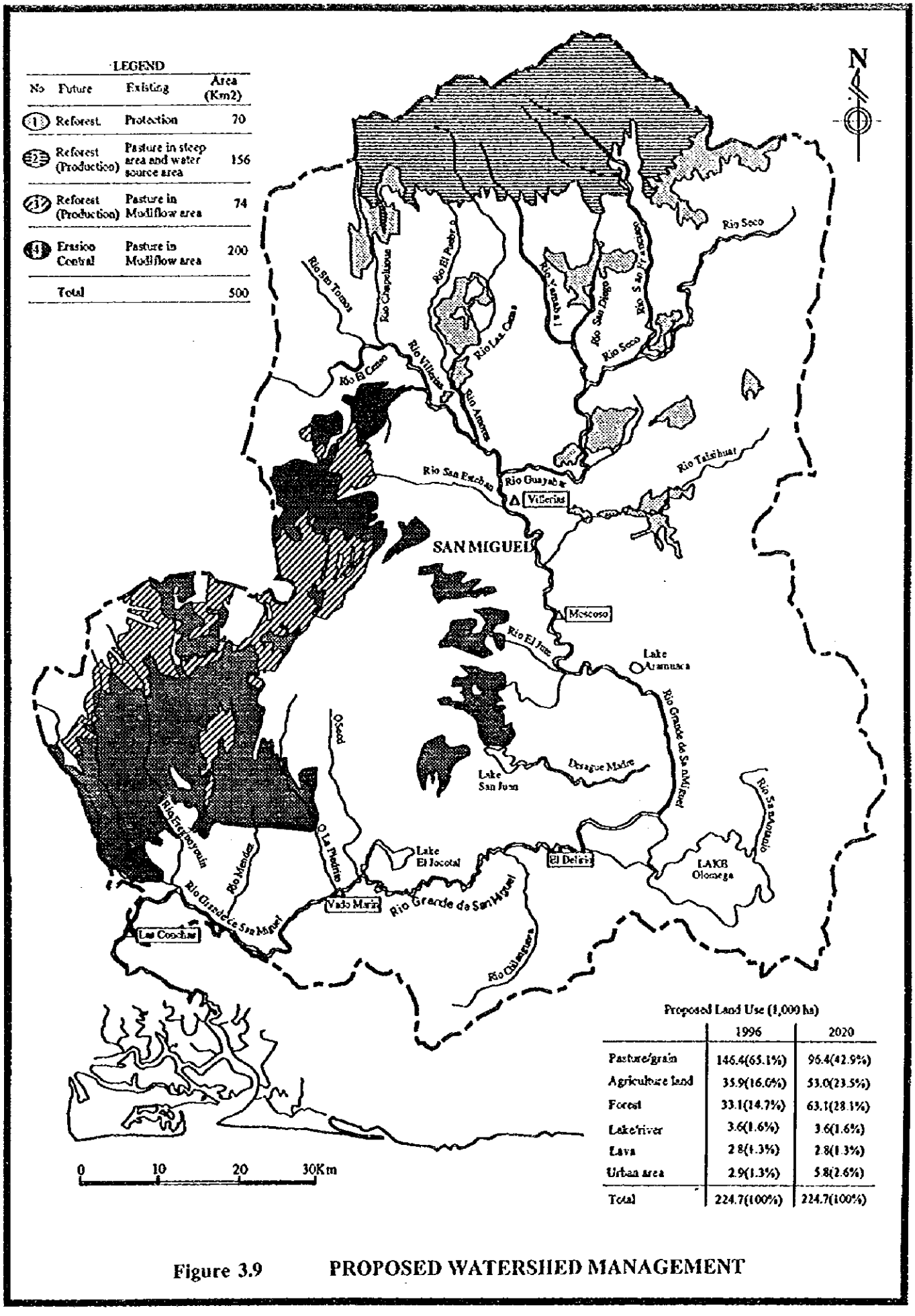


Figure 3.8 PROPOSED FLOODPLAIN MANAGEMENT



Proposed Land Use (1,000 ha)

	1996	2020
Pasture/grain	146.4(65.1%)	96.4(42.9%)
Agriculture land	35.9(16.0%)	53.0(23.5%)
Forest	33.1(14.7%)	63.1(28.1%)
Lake/river	3.6(1.6%)	3.6(1.6%)
Lava	2.8(1.3%)	2.8(1.3%)
Urban area	2.9(1.3%)	5.8(2.6%)
Total	224.7(100%)	224.7(100%)

Figure 3.9 PROPOSED WATERSHED MANAGEMENT