No. 13

REPUBLIC OF GUATEMALA

FLOOD CONTROL PROJECT

(ACHIGUATE AND PANTALEON RIVERS)

MAIN REPORT

JANUARY 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

REPUBLIC OF GUATEMALA

FLOOD CONTROL PROJECT

(ACHIGUATE AND PANTALEON RIVERS)

MAIN REPORT

JANUARY 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Republic of Guatemala, the Government of Japan decided to conduct a study on Flood Control Project in the Achiguate and Pantaleon River Basins and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Guatemala a team headed by Mr. Mitsuo Igarashi of the CTI Engineering Co., Ltd. from August, 1983 to March, 1984 and from June to November, 1984.

The team had discussions on the Project with the officials concerned of the Government of Guatemala and conducted a field survey in the Achiguate and Pantaleon River Basins in the Department of Escuintla. After the team returned to Japan, further studies were made and the present report has been prepared.

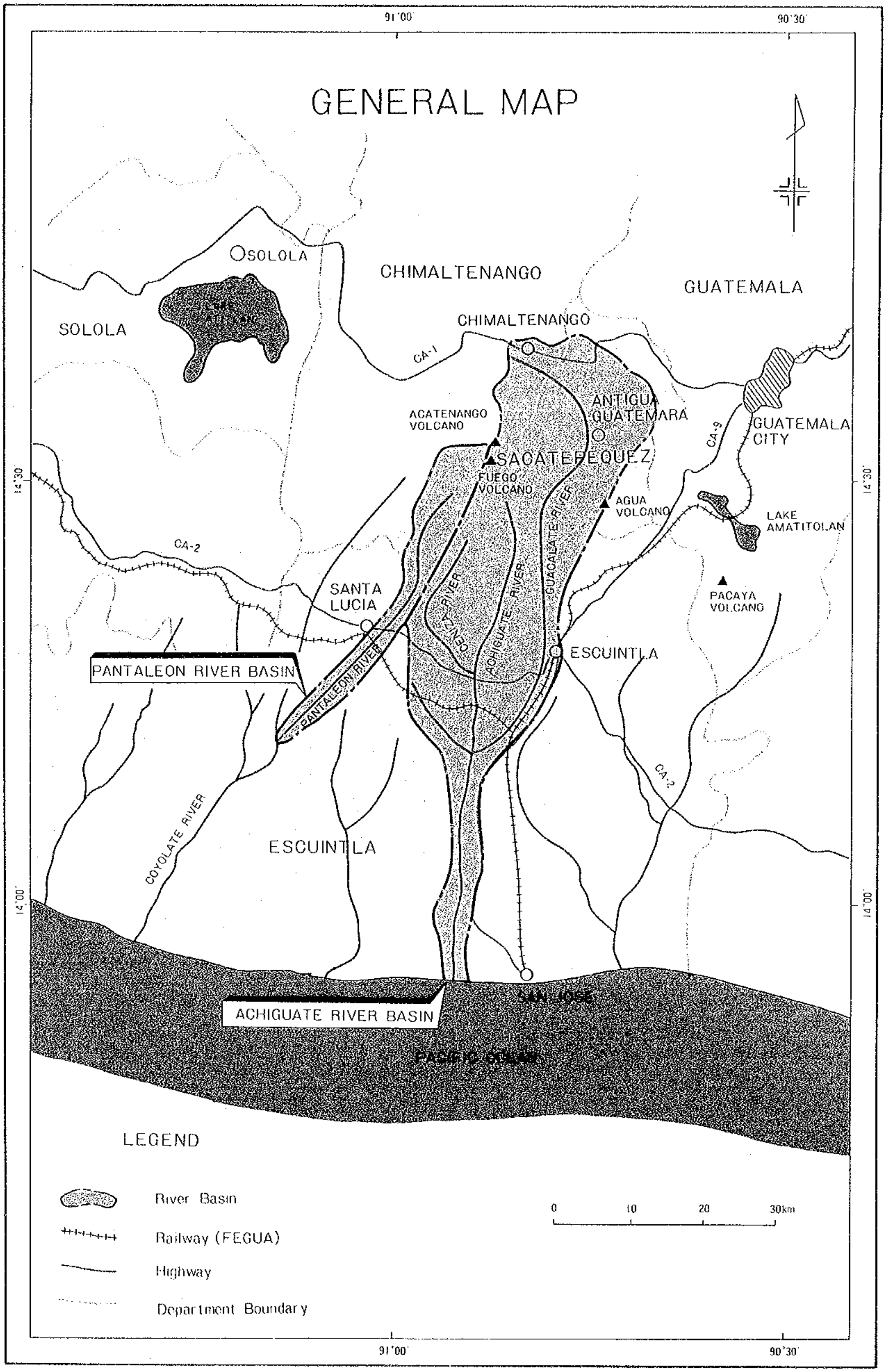
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Guatemala for their close cooperation extended to the team.

January, 1985

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency



GENERAL MAP
91°00'
90°30'
14°30'
14°00'
SOLOLA
CHIMALTENANGO
GUATEMALA
CHIMALTENANGO
CA-1
ACATENANGO VOLCANO
ANTIGUA GUATEMARA
GUATEMALA CITY
SACATEPEQUEZ
FUEGO VOLCANO
AGUA VOLCANO
LAKE AMATITOLAN
CA-9
CA-2
SANTA LUCIA
PACAYA VOLCANO
ESCUINTLA
PANTALEON RIVER BASIN
PANTALEON RIVER
CENIZA RIVER
ACHIGUATE RIVER
GUACALATE RIVER
COYOLATE RIVER
ESCUINTLA
ACHIGUATE RIVER BASIN
LEGEND
River Basin
Railway (FEGUA)
Highway
Department Boundary
0 10 20 30km

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

Page

LIST OF FIGURES

Page

Page

GLOSSARY OF TERMS AND ABBREVIATIONS

1. Organizations

AID	=	International Development Agency
BANVI	=	National Bank of House
BID	=	Inter-American Development Bank
CACM	=	Centeral American Common Market
CAMINOS (DGC)	=	General Direction of Roads
CONE	=	National Emergency Committee
CRN	=	Committee of National Reconstruction
DGOP	=	General Direction of Public Works
DGSS	=	General Direction of Health Service
DICABI	=	Direction of Land Ledger and Real Property Appraisal
DIGESA	=	General Direction of Agricultural Services
DIRYA	=	Technical Direction of Irrigation and Drainage
DSM	=	Division of Environmental Sanitation
EEGSA	=	Guatemalan Electric Company
FEGUA	=	National Railway of Guatemala
IGM	=	Military Geographic Institute
INFOM	=	National Institute of Municipal Development
INTA	=	Natinal Institute of Agrarian Transformation
INSIVUMEH	=	National Institute of Sismology, Volcanology, Meteorology and Hydrology
INDE	=	National Institute of Electrification
JICA	=	Japan International Cooperation Agency
PHCA	=	Central America Hydrometeorologic Project
SEGEPLAN	=	General Secretary of Planning
UNECPA	=	Executor Unit of the Harbor Complex on the Pacific Coast
WMO	=	World Meteorological Organization

2. Length

m	=	meter
cm	=	centimeter
km	=	kilometer

3. Area, Volume and Weight

m^2	=	square meter
ha	=	hectare = 10^4 m^2
km^2	=	square kilometer = 10^6 m^2
l	=	liter = 1,000 cm^3
m^3	=	cubic meter
cm^2	=	square centimeter
kg	=	kilogram
t	=	ton = 1,000 kg
lb	=	pound = 453.6 g
Mz	=	manzana = 0.7 ha
qq	=	quintal = 100 lb = 45.36 kg

4. Derived Measures based on the Sam Symbols

m^3/s, m^3/sec	=	cubic meter per second
t/ha, ton/ha	=	ton per hectare
m^3/km^2	=	cubic meter per squre kilometer
mm/day	=	millimeter per day
$m^3/km^2/year$	=	cubic meter per square kilometer per year
l/s, l/sec	=	liter per second
m/s, m/sec	=	meter per second
qq/Mz	=	quital per manzana
Q/qq	=	quetzales per quintal
Q/kg	=	quetzales per kilogram

5. Electric Measures

KW	=	kilowatt
KV	=	kilovolt
MW	=	megawatt
KWH	=	kilowatt-hour
GWH	=	gigawatt-hour

6. Currency

US$	=	United States Dollar
Q.	=	Guatemalan Quetzales
¥	=	Japanese Yen

7. Temperature, Height, etc.

°C	=	degrees in Centigrate
M.S.L.	=	mean sea level
DL	=	datum line
EL.	=	elevation
qc	=	resistance of cone penetration test
PS	=	horse power
%	=	percentage
No.	=	number
Nos.	=	numbers

8. Others

B/C	=	Benefit-Cost Ratio
CA	=	American Highway
CIF	=	Cost, Insurance and Freight
EIRR	=	Economic Internal Rate of Return
FOB	=	Free on Board
GDP	=	Gross Domestic Product
NPV	=	Net Present Value

CHAPTER I. INTRODUCTION

1.1 History of the Study

The areas along the Achiguate and the Pantaleon rivers have long been suffering from serious flood and sediment discharge damages on private and public properties and utilities. This prompted the Government of Guatemala to request technical assistance from the Government of Japan for the control of flood and sediment discharge in the said areas to solve or at least alleviate the people's sufferings.

In response to the request, the Government of Japan, through JICA, dispatched preliminary study teams to Guatemala on two occasions, in November 1982 and in April 1983, to evaluate the realization of the technical cooperation program, wherein the Government of Guatemala proposed a feasibility study on a flood control project in the Achiguate and the Pantaleon river basins. Eventually, on August 2, 1983, JICA dispatched a study team to undertake this Study.

1.2 Outline of the Study

1.2.1 Study Area

The Study Area basically covers the Achiguate and the Pantaleon river basins which have catchment areas of 1,080 km^2 and 150 km^2, respectively, as presented in Fig. 1-1. The surrounding area which also suffers from serious damage by floods from the rivers was included in the study.

1.2.2 Objectives

The objectives of the study are as follows:

(1) to formulate a long-term comprehensive flood control project in the Study Area; and

(2) to conduct a feasibility study with respect to the identified and priority works to be formulated through the above-mentioned study as an urgent flood control project for immediate implementation.

1.2.3 Scope of the Study

The scope of the study agreed upon by and between JICA and the Government of Guatemala covers the following items:

(1) Data Collection and Analysis

(a) Meteorology

(b) Hydrology

(c) Existing facilities for flood control and other relevant facilities

(d) Future plan and project for flood control and river basin development

(e) Regional economy and sociology

(f) Geology

(g) Agriculture

(2) Formulation of Long-Term Comprehensive Flood Control Project

(a) Hydrological and hydraulic study

(b) Geological and geomorphologic study

(c) Flood control study

(d) Planning, design and cost estimation

(e) Identification for optimum river administration system

(3) Feasibility Study

(a) Geological and soil mechanics investigations for necessary sites

(b) Material survey for construction works

(c) Preparation of preliminary engineering design for the project

(d) Construction plan for the project

(e) Estimation of construction cost

(f) Estimation of benefits of the project from the economic and social viewpoints

(g) Evaluation of the cost and benefits of the project from the economic and social viewpoints

1.3 Study Procedure

The study has been carried out in accordance with the study procedure shown in Fig. 1-2 which contains the flow of analyses and project formulation. The basic data used for this study is listed in Table 1-1.

The results of studies were presented in the report of the following three separate volumes:

(1) Executive summary

(2) Main report

(3) Supporting report

    (a) Socio-economy

    (b) Hydrology

    (c) Sediment control plan

    (d) River improvement plan

    (e) Construction plan and cost estimates

    (f) Project Evaluation

    (g) River administration system

CHAPTER II. PROJECT BACKGROUND

2.1 Economic Background

The Republic of Guatemala is located in the tropic zone and extends from 13°44' to 18°30' north latitude and from 87°24' to 92°14' west longitude. The country, which is situated in the northern part of Central America, is bounded by Mexico to the North and West, by El Salvador to the Southeast and by Honduras to the Northeast. It faces the Caribbean Sea to the Northeast and the Pacific Ocean to the Southwest.

In view of geographical and economic situations, the central american countries (Guatemala, El Salvador, Honduras, Nicaragua and Costa Rica) established the Central American Common Market (CACM) in 1951 and have mutually cooperated in the aspects of trade, industry and transportation. Especially, the Central American Road and the Pan American Road have greatly contributed to the development of industry and communications in the respective countries.

The countries have something in common on the social and economic aspects. That is, all of them became independent in 1821 and their mainstay is agriculture which has the staple products of maize, sugarcane, cotton, coffee, banana and beef in the stock farming. Export places main reliance on these agricultural products, excepting maize for self-supply, which are exported to the United States of America and other advanced countries.

From 1971 to 1982, the Government of Guatemala had implemented three (3) economic development plans; namely, the Five-Year Plan from 1971 to 1975, the Five-Year Plan from 1975 to 1979, and the Four-Year Plan from 1979 to 1982.

Based on these development plans and by translating the plans into action, Guatemala had an average annual economic growth of 5.2 per cent in the first and second five-year plans for the period from 1971 to 1979. However, since 1980 the economic growth has shown a rather downward trend.

As for a new long-term economic development plan, the government has not made any declaration of its political views and since 1982, the government's policy has been carried out on the basis of the short-term development plan with the following major objectives:

(1) to correct the imbalance of trade;

(2) to establish sound national finance;

(3) to promote development of the agricultural, manufacturing-industrial and construction sectors;

(4) to build housing for the working class;

(5) to provide greater employment opportunities for the people;

(6) to correct the social and economic imbalance among people; and

(7) to strive for the activation of the Central American Common Market.

In principle, this short-term plan is almost the same as the preceding four-year plan (1979-1982).

The country can be roughly classified into three (3) regions by its geographical feature; the middle highlands region, the south coastal region and the north lowlands region.

The middle highlands region consists of the Sierra Madre mountains and the basin among the mountains which extends from east to west in the southern part of the country. This region has a mild climate owing to its high altitude in the tropic zone. The greater number of the population of Guatemala has concentrated on the basin among the mountains because of the suitable climate for living conditions. Guatemala City, the capital, lies in this region, and the slope south of the mountains is a central area for the cultivation of coffee.

The south coastal region, which lies parallel to the coastline of the Pacific Ocean, is generally flat and has fertile soil. Owing to such good natural condition, agriculture is extensively done and cattle-raising is practiced on a large scale. This region is, therefore, valuable to Guatemala which is an agricultural country.

Many rivers that originate from the Sierra Madre mountains flow into the Pacific Ocean passing through this plain region. River water has been used mainly for the people's daily necessities and a part of it, for agriculture. On the other hand, the river basins have frequently suffered from damage caused by floods from the rivers in every rainy season.

The north lowlands region has tropical rain forest and is the most undeveloped among the three regions. The immigration of farmers from other regions has been practiced since the 1950's based on the agricultural development program of the government; however, it is said that agricultural development does not warrant any optimism because of strongly acidic soil and thin topsoil. On the other hand, petroleum and other mineral products have been developed for several years in the area near the central mountains and owing to their development, roads in this region have been fairly maintained.

According to the 1981 census, the population of Guatemala was 6,054,000, consisting of Indigena (Indians) of 56%, Mestizo (mixed Hispanic-Indian origin) of 36%, and Blanco (whites) of

8%. More than half of the population is within the agricultural sector. Of primary importance is the fact that most of the Indians depend on agriculture for their livelihood and they form a society of their own by respective tribes isolated from the civilized community.

Transportation in Guatemala depends mainly on the road traffic. The roads are classified into four (4) categories; Pan American Road, Central American Road, National Road and Departmental Road. In 1980, the total length of these roads was 14,591 km, consisting of the paved road of 2,887 km and the earth road of 11,704 km. In 1978, the total number of motor vehicles in use in Guatemala was some 134,000, consisting of the passenger cars of 90,000 and the commercial vehicles of 44,000.

The National Railway of Guatemala was established by a private company in the 1890's. At present, it is operated by FEGUA, Ministry of Communications, Transportation and Public Works.

The railway consists of a main line and three branch lines. The main line extends from Puerto Barrios to Tecun Uman near the Mexico boundary. The total length of railways is 778.9 km, including 176.1 km of branch lines. The rail in use is single-track with a narrow gauge.

Guatemala has four (4) ports; Santo Tomas and Puerto Barrios on the Atlantic Ocean side, and San Jose and Champerico on the Pacific Ocean side. In 1981, cargoes handled amounted to some 2,120,000 tons.

At present, Guatemala has 31 power plants, consisting of 12 hydraulic plants and 19 thermal plants. In 1981, the capacity, production and consumption of electric power were 446.2 kW, 1,437.6 GWH, and 1,210.4 GWH, respectively.

The number of telephone subscribers in Guatemala in 1983 was about 108,000, corresponding to 70% of the capacity (158,000) of the telephone facility. This number is in the ratio of one set to 60 persons, and 85% of it is in Guatemala City. The telephone facility that is presently in use is the non-automatic operating type.

Agriculture is the mainstay of the country and majority of the Guatemalan people are engaged in this sector. The major agricultural products are coffee, cotton, sugarcane, maize, beans, banana and beef in the stock-farming. In 1979/80, the production of coffee, cotton and sugar were 156,000 tons, 148,000 tons and 432,000 tons, respectively, as shown in Table 2-1.

Agricultural land area is 40,000 km^2, corresponding to about 37% of the total area of the country. It consists of the cultivated area of 12,000 km^2, the cultivated area and pasture of 15,000 km^2, and the pasture of 13,000 km^2.

Farms are divided into five (5) categories by operation scale; micro-farm (1 manzana[1/] and below), sub-familiar farm (over 1 to 10 manzanas), familiar farm (over 10 to 64 manzanas), middle multi-familiar farm (over 64 to 1,280 manzanas), and large multi-familiar farm (over 1,280 manzanas).

Farms of over 10 to 64 manzanas are 10% in number and occupy 19% of the total area of farms, and farms of over 64 manzanas (45 ha) are less than 3% in number but their total area amounts to over 60% of the whole farm area. On the other hand, farms of 10 manzanas and be low in area are more than 85% in number but their total area is only about 15% of the whole farm area. Such an intensive structure of farms is characteristic of the Guatemalan agriculture.

In 1980, trade amounted to some Q3,032 million, comprising Q1,473 million for the export and Q1,559 million for the import (see Table 2-2). Every year from 1975 to 1980, except in 1977, the amount of exports was a little less than that of imports.

1/ 1 manzana = 0.7 ha

The main export items are coffee, cotton, sugar, beef and banana.

The national budget, which had been increased in proportion to the Gross Domestic Product (GDP), amounted to Q1,480 million in 1982. However, in 1983, the budget was Q1,310 million, decreasing by some 10% of that of the previous year.

The GDP of Guatemala was about Q7,809 million in 1980 at current prices (see Table 2-3). During the period from 1971 to 1980, the average annual growth rate of GDP has been estimated at 16.9%. The per capita GDP reached Q1,060 in 1980 and its average growth rate showed 13.2% a year for the same period. However, the real growth of GDP for the same period has been estimated at 5.2% a year on the average and it was 2.0% in 1980.

Table 2-4 shows the share in GDP by the industrial sector for 1971-1980. Among the industrial sectors, commercial services and agriculture occupied large percentages in the GDP, i.e., in 1980, they were 27.0% and 24.9%, respectively. However, the share of the agricultural sector shows the decreasing tendency.

In Guatemala, the growth in the agricultural sector has considerable effect on the growth in GDP. Although the decreasing trend seems to be common to most countries in the world, agriculture is the major source of revenue for Guatemala; hence, it is necessary for the government to exert more effort to increase agricultural production and promote the development of the national economy.

2.2 Project Identification

2.2.1 Significance of Achiguate and Pantaleon River Basins

In Guatemala exists a chain of volcanoes running in parallel with the Pacific Coast from Mexico to El Salvador and forming the southern range of the Sierra Madre. Among them are Santiaguito, Fuego and Pacaya, which are always active and thus, bring about tremendous flood and sediment discharge damages compounded by the tropical cyclones which frequently hit the country. Damage caused by cyclones had been very severe so that the World Meteorological Organization (WMO) had declared the southwestern part of the Caribbean Sea, including Guatemala, as Disastrous Zone. Under such situation, the Achiguate and the Pantaleon river basins, to which serious damages had been inflicted in recent years, are justified as the project area for the following reasons:

(1) The Achiguate and the Pantaleon river basins have an agricultural land better developed than the other areas, especially on the production of sugarcane, cotton and cattle which are ranked first in the whole country. Goods manufactured from these products are sent abroad and earn the foreign currency.

(2) The central american roads CA-2 and CA-9, and the national railways going in parallel with the roads, run through these two river basins and lead to the international ports of San Jose and Champerico. Interruption of these transportation lines has an adverse effect on not only regional but also national economic activities.

(3) In every flood time, flood and sediment discharge cause much more serious damage in these river basins than in the other river basins in Guatemala. Living conditions in these two river basins are inferior to the national average. In this connection, sediment and flood control works in these areas are significant to compensate for the gap in the extent of regional development.

(4) Transfer of technical knowledge concerning sabo and river engineering is one of the most important aspects of the study. A study on the Achiguate and the Pantaleon rivers is suitable for the transfer of knowledge because these

rivers, having the average size and standard terrains in Guatemala, can be considered as model rivers.

2.2.2 Other Serious Sediment Discharge and Flood Damages in Guatemala

Information revealed that the recent serious sediment discharge and flood damages occurred in other river basins such as Samala and Urayara, besides the Achiguate and the Pantaleon river basins. Their locations are shown in Fig. 2-1.

Samala River Basin

Santiaguito Volcano erupted on June 20, 1983. The ejecta deposited on the volcanic piedmont area flowed down with the river water of Samala River, went along Nima II River, and directly hit the residential area of El Palmar. (Refer to Fig. 2-2.)

Sediment discharge brought damage to an area of about 15 km^2 and 150 houses were either partially or totally destroyed. Consequently, 2,100 people corresponding to 35% of the total population in El Palmar were evacuated. Damages on croplands of maize and beans due to sediment discharge, which piled up to 8.0 m, were also reported.

Urayara River Basin

The debris flow from Tecuanburo Volcano rushed down along Urayara River, the tributary of Paso Hondo River which pours into the Pacific Ocean, to Chiquimulilla in the Department of Santa Rosa. This occurred on September 12, 1982 due to Hurricane Paul, causing 280 deaths in the western part of Chiquimulilla and damaging a tremendous number of properties. So far, such a serious debris damage with a great number of deaths has never been experienced in Guatemala. (Refer to Fig. 2-3.)

CHAPTER III. PRESENT CONDITIONS

3.1 Socio-Economy

3.1.1 Administration

The Republic of Guatemala consists of some twenty departments. Each department has several municipalities as administrative substructures and the municipalities number about three hundred.

The Study Area is almost all located in the Department of Escuintla, except for some portions in the mountain regions of the departments of Sacatepequez and Chimaltenango. The Department of Escuintla consists of thirteen (13) municipalities of 4,384 km^2 and the Study Area covers seven (7) of these municipalities; Escuintla, Santa Lucia Cotzumalguapa, La Democracia, Siquinala, Masagua, La Gomera and San Jose. Among them, the Municipality of Escuintla is the administrative center of the department.

3.1.2 Population and Labor Force

Population

Population census in Guatemala were taken four (4) times; in the years of 1950, 1964, 1973 and 1981. Table 3-1 shows the population by department in the whole country.

The Department of Escuintla had the population of some 335,000 in 1981, as shown in Table 3-2. For the period from 1950 to 1964, it had the average annual population growth rate of 5.74% which was the highest among the departments. However, after that period, the rate of population growth has remarkably declined and showed low rates such as 1.17% on the average per year for the period from 1964 to 1973 and 1.37% for the period from 1973 to 1981. The population density of the Department of Escuintla was 76 persons/km^2 in 1981.

The Study Area stretches to the seven (7) municipalities, as described in Subsection 3.1.1. In 1981, the seven municipalities had the population of some 217,000 corresponding to two-thirds (2/3) of that of the Department of Escuintla. As shown in Table 3-2, this population consists of some 141,000 in the five (5) municipalities in the Achiguate river basin and some 76,000 in the two (2) municipalities in the Pantaleon river basin.

The population of 10 years and over of age in 1981 was about 4,100,000 in the whole country and about 270,000 in the Department of Escuintla, as shown in Table 3-3. These figures correspond to 68% of the respective total population.

Labor Force

The working population in the Department of Escuintla was 96,000, comprising 88,000 males and 8,000 females. Ratios of working population to the respective populations were 29% for the total population, 51% for the males and 5% for the females. These ratios are nearly equal to those of the whole country. In the whole country, the working population was 1,700,000, consisting of 1,450,000 males and 250,000 females.

3.1.3 Sediment Discharge and Flood Damage

Through the interview-survey with inhabitants and the review of records in documents, newspapers and other publications, it was determined that both the Achiguate and the Pantaleon river basins have long been suffering from sediment discharge and flood damages. The protection of assets from sediment discharge and flood damage has been increasingly urged after Fuego Volcano erupted on September 14, 1971.

Sediment discharge with a large amount of volcanic ejecta had raised riverbeds resulting in the reduction of flow capacity and the shift of river courses to the area where houses and farms are located.

Due to the above situation, the Achiguate and the Pantaleon rivers have, in every rainy season, brought sediment discharge and flood damage on buildings, farms, and especially, on public utilities, such as the bridges of the national road and the railway crossing the two rivers. The sediment discharge and flood damage in the Achiguate and the Pantaleon river basins in the last 15 years are tabulated in Table 3-4.

Serious damages in both the Achiguate and the Pantaleon river basins occurred in 1969, 1971, 1974 and 1982. Among the floods, the 1969 flood is so far recorded as the biggest. (Refer to Fig. 3-1.)

3.1.4 Infrastructures

Road

Among the national roads, the central american roads CA-2 and CA-9 run through the Study Area with the former running from east to west in parallel with the pan american road CA-1 and extending from the boundary of El Salvador to the boundary of Mexico, and the latter, running from south to north and connecting between both the Pacific and the Atlantic oceans. Besides these roads, national roads (feeders of CA-2) and several departmental roads support the transportation system in the Study Area.

The total length of roads in the Department of Escuintla was 1,321 km in 1980, consisting of the paved road of 399 km and the earth road of 922 km. The length of paved roads corresponds to 30.2% of the total length of roads in the department. This percentage of paved road is higher by 19.8%

than that in the Department of Guatemala, and the roads in the Department of Escuintla are comparatively in better condition.

The average daily traffic volume on CA-2 was some 4,300 vehicles in 1982 at Sta. 200 (kilopost situated 78 km away from Guatemala City), as shown in Table 3-5.

The average annual increase in rate of the traffic volume on major roads was in the range of from 1 to 8% during the decade from 1972 to 1982. The increase in traffic volume on major roads is comparatively low and since 1977, it remained on the same level. During the period from 1978 to 1982, the traffic volume showed no marked fluctuation and as for the feeder roads of CA-2, it showed the decreasing tendency.

Railway

In the Study Area, the railway runs the section of nearly 74 km, comprising 49 km for the section of Escuintla-San Jose and 25 km for the section of Santa Maria-Santa Lucia. Trains run one round trip every day along these sections.

According to the report of FEGUA, the railway transported 950,000 tons of cargo and 600,000 passengers a year on the average for the period from 1978 to 1982. Among them, 200,000 tons of cargo and 150,000 passengers a year were transported through the Study Area, i.e., 560 tons of cargo and 400 passengers a day, respectively. Although the transportation volume by railway is not so much, the railway still plays an important role in the transportation system of Guatemala.

Harbor

The Port of San Jose, which is located in the Study Area, has a superannuated pier jutting out into the sea. Cargoes handled in this port amounted to 100,000 tons in 1981.

Ships of about 200 a year come from Japan, Colombia, Liberia, the United States of America and other countries. Among them, Japanese ships abound in number with tonnage of 5,000 on the average. The main goods handled are cotton and coffee for the export, and metal goods, industrial raw materials and fertilizer for the import.

Electric Power Supply

At present, electric power in Guatemala is supplied by two corporations; Instituto Nacional de Electrificacion (INDE) and Empresa Electrico de Guatemala (EEGSA), on the ratio of 7:3. Among the 31 power plants, 4 hydraulic plants and 4 thermal plants lie in the Department of Escuintla. The power produced in the Department of Escuintla, aside from local consumption, is mainly sent to the Department of Guatemala.

In the Department of Escuintla and in the seven (7) municipalities mentioned in Subsection 3.1.1, electric power was supplied to 27,500 households (or 42% of the whole) and 20,000 households (or 47%) in 1981, respectively. In the whole country, it was supplied to 430,000 households corresponding to 37% of the whole.

Water Supply

Water supply systems in Guatemala are operated by the respective municipal governments under the control of INFOM, and the other authorities concerned in the central government. Water sources depend chiefly upon the well.

In 1981, the water supply systems supplied water to 600,000 households, corresponding to only 50% of the whole, and it remains at a low level. In the Department of Escuintla and the said seven municipalities, 29,000 households (44% of the whole) and 21,000 households (or 49%) were supplied with domestic water in the same year. Among the seven municipalities, households of around 80% of the whole in the Municipality of Escuintla was supplied with domestic water by its system.

Telecommunications

In Guatemala, telecommunications, such as the telephone, radio, television and communications satellite, are operated by GUATEL.

In 1983, telephone subscribers in Guatemala were about 108,000 in number, corresponding to 70% of the capacity of 158,000 of the telephone facility. This number is in the ratio of one set to 60 persons.

In the Department of Escuintla, telephone subscribers numbered about 1,050 in the same year. This is in the ratio of one set to 320 persons and corresponds to 40% of the capacity of 2,600 of the telephone facility in the department. Nearly 70% of the subscribers are in the Municipality of Escuintla.

3.1.5 Agriculture and Other Industries

Agriculture

The Department of Escuintla had farms of some 660,000 manzanas in 1979. This area increased by about 30,000 manzanas (or 5%) over that of 1964. The number of farms with over 64 manzanas in area is about 4.5% and their total area corresponds to 85% of the whole area of farms; whereas, farms of 10 manzanas and below are nearly 80% in number and their total area is only about 5% of the whole area of farms. These figures show that intensive farming is highly developed in the Department of Escuintla.

The Department of Escuintla is one of the most developed areas for agriculture in the country. Especially, the productions of sugarcane, cotton and cattle are ranked first in the whole country, i.e., they amount to 73%, 44% and 25% of the productions in the whole country, respectively. These products occupy a great portion of the exportable goods and contribute to the country's foreign currency earnings.

Other Industries

There are no manufacturing industries to be specially mentioned, except refining factories for sugar, petroleum and cotton. Articles of folkcraft for tourists such as textiles and carvings are slightly made in small factories. The sugar refineries process the sugarcane harvested in the Department of Escuintla and the manufactured goods are exported through the Port of San Jose.

3.1.6 Land Use and Assets

Land use in the Study Area has been studied using land use maps with the scale of 1:50,000 and aerophotographs with the scale of 1:20,000. The study has been carried out by the mesh of 1 km^2 on the maps. The result is summarized in Table 3-7 and shown in Fig. 3-2.

The greater part of the Department of Escuintla is used for agriculture, i.e., the area of cultivated land and pasture covers nearly 3,800 km^2, corresponding to 87% of the whole area. Areas of cultivated land and pasture are in the ratio of 5:3 (see Table 3-6).

The Study Area extends to about 130,200 ha. Pasture has an area of nearly 53,000 ha, corresponding to 40% of the Study Area and occupies the largest share. Besides the pasture, the area of cultivated land is about 34,000 ha or a quarter (1/4) of the Study Area, and much sugarcane, cotton, fruits and other agricultural crops such as maize, coffee and beans are produced. The area of uncultivated land is estimated at 8,700 ha or 7% of the Study Area, except areas of town, road, railway and 29,000 ha of forest land which is of little utility value. The town area is estimated at about 1,600 ha in total.

According to the housing census in 1981, houses in the Department of Escuintla numbered some 71,000, consisting of 21,000 in the urban area and 50,000 in the rural area (see Table 3-2). Based on these figures, the average number per square kilometer has been estimated at 16 houses for the whole area of the department, 383 houses for the urban area and 12 houses for the rural area.

The seven (7) municipalities which contain the Study Area have about 46,000 houses in total in 1981, comprising 29,000 houses in the Achiguate river basin and 17,000 houses in the Pantaleon river basin.

3.1.7 On-Going Projects

Table 3-8 shows the major public works projects presently in progress in the Study Area.

In San Jose, the construction of a new port with water depth of 12 m is presently in progress and is expected to be completed in 1986 at the cost of about 300 million Quetzales. After completion of the new port, it is expected that the quantity of cargo handled will increase to around 1,000,000 tons in the completion year and reach about 2,000,000 tons in the year 2000.

In connection with the construction of the new port, the construction of a new road has been planned by CAMINOS in the section of 50 km from Escuintla to San Jose in CA-9 to augment the carrying capacity and to maintain the flow of transportation. Construction works are scheduled from 1984 to 1985 at the cost of 17 million Quetzales. The route is located east of the present road.

3.2 Physical Resources

3.2.1 Location and Topography

The Achiguate and the Pantaleon river basins are located at approximately 13°50' to 14°40' north latitude and 90°45' to 91°10' west longitude in the southern part of Guatemala, as shown in the General Map. Most of the basins administratively belong to the Department of Escuintla.

Achiguate River

Achiguate River originates in Fuego Volcano and has a total catchment area of 1,080 km^2, including those of the tributaries. Its main stream, however, has only a catchment area of 216 km^2 with a river length of 55 km. This catchment area is topographically divided into two portions; the mountainous area of 92 km^2 and the alluvial fan area of 124 km^2. The transition section of both areas is located at around 40 km of the river length from the estuary.

The river flows down on the steep slope of the mountainous area with the gradient of 1:10 and after joining some tributaries pours into the North Pacific Ocean through the fan area with the gradient of 1:400.

The main tributaries are Guacalate River, Ceniza River and Mazate River. Among these tributaries, Guacalate River which has the largest catchment basin of 629 km^2 originates in Mt. El Saco and flows down a relatively flat valley in which some towns such as Antigua Guatemala, Escuintla, and so on, are situated. Guacalate River joins with Achiguate River in the stretch of 33 km from the estuary. Ceniza and Mazate rivers which have catchment basins of 113 km^2 and 36 km^2, respectively, originate in Fuego Volcano and flow down on the steep slope of the mountainside with the gradient of 1:10 to join Achiguate River in the alluvial fan area.

In the mountainside upper reaches of the rivers, much volcanic debris had been deposited on which assorted trees have grown and where land use has been developed. Most of the alluvial fan area in the lower reaches are utilized for livestock farming and the cultivation of sugarcane, maize and cotton. Only a small portion of the coastal area still remains as swamp area.

Along the river course, some villages are scattered. Finca La Trinidad and Finca La Barrita are the densely populated areas in the Study Area.

Pantaleon River

Pantaleon River, the tributary of Cristobal River which joins Coyolate River, also originates in Fuego Volcano, and the catchment area and river length are 150 km^2 and 40 km, respectively. It runs down at some distance in the mountainside with the gradient of 1:10 and then joins Cristobal River, passing through the alluvial fan area in the stretch of 20 km with the gradient of 1:100. Then, it changes its course to the south drawing a gentle curve, and the shape of the basin may be compared to a long and slender rectangle.

The upper reaches of Pantaleon River are also covered with volcanic debris with assorted trees, and the lower reaches have also been relatively developed for the cultivation of sugarcane, maize and cotton. Only a small area is utilized for livestock farming.

3.2.2 Climate

The climate in the Study Area is divided into two seasons; a rainy season with 90% of the annual rainfall, from May to October, and a dry season, from November to April, as shown in Table 3-9.

The mean annual rainfall at San Jose (4 m MSL) which is located in the low plain land is 1,100 mm. Rainfall amount increases with a rise in altitude and reaches to 4,400 mm a year at the skirts of Fuego Volcano (1,100 m MSL). In the highlands located behind the volcanoes Fuego, Acatenango and Agua, rainfall decreases because of the loss of humidity on the slopes of the volcanoes facing the Pacific Ocean. Therefore, rainfall at Antigua Guatemala (1,530 m MSL) is merely 970 mm a year.

Owing to such rainfall characteristics, the average annual rainfall in the upstream area (upstream of CA-2) of Achiguate River amounts to 3,500 mm, and the Guacalate river basin receives only 1,830 mm a year. On the entire river basins of the Achiguate and the Pantaleon, the average annual rainfall are 2,300 mm and 3,300 mm, respectively.

The mean annual temperatures at San Jose and at the skirts of Fuego Volcano (760 m MSL) are 27°C and 24°C, respectively (see Table 3-10). The hottest and coldest months are April to May and December to February, respectively, and both the rise and fall from the mean annual temperature are within 2°C. The highest and lowest daily temperatures are 34°C and 18°C at San Jose.

The mean monthly relative humidity is about 83% in the rainy season and about 73% in the dry season (see Table 3-11). The mean annual evaporation is from 1,250 mm to 1,600 mm in the skirts of Fuego Volcano (see Table 3-12).

The sunshine hour per day is 6.5 in the rainy season and 9.2 in the dry season.

3.2.3 Geology and Geomorphology

The Study Area is roughly divided into three; namely, (1) the mountainous area around Fuego Volcano, (2) the very wide alluvial fan at the foot of Fuego Volcano, and (3) the very flat alluvial plain spreading from the fan area to the seacoast. As to the process on the earth surface, erosion is distinguished in Area (1), both of transportation and deposition of materials are distinguished in Area (2), and sedimentation is eminent in Area (3).

Basement rock in the mountainous area is tertiary miocene volcanic rocks which do not form into a volcano yet, consisting mainly of tuffs, lava flows (andesite and dasite), laharic deposits, volcanic conglomerates, etc., and has rough stratifications, as shown in Fig. 3-3.

The volcanic body of Fuego Volcano is divided into two parts; (1) the old volcanic body and (2) the new main volcanic body. The old Fuego Volcano is the part lower than 2,200 m in elevation, and the new Fuego Volcano was established after explosion or expression of the ancient central cone forming a kind of cardera. The recent Fuego Volcano is a typical conide type strato-volcano with a small lava dome at the top.

3.2.4 Flood, Runoff and Tide

Flood

The recent biggest flood in both the Achiguate and the Pantaleon rivers occurred on September 5, 1969 due to the heavy rainfall caused by Hurricane Francelia.

The flood peak discharge in Achiguate River was estimated at 1,200 m^3/s from the flood mark at the national railway bridge[1/], while that in Pantaleon River was presumed to have

---

1/ The flood mark is shown in the design drawing of the railway bridge which was prepared in 1970.

reached 1,050 m^3/s[1/]. Although both rivers brought floods almost every year, no flood discharge has been recorded.

Runoff

The annual runoff ratio was estimated at 0.5 by taking the average of those in the neighboring river basins.

The mean annual runoff volumes for the last 20 years were estimated at $0.359 \times 10^9\ m^3$, $1.147 \times 10^9\ m^3$, and $0.248 \times 10^9\ m^3$ in the basin area upstream of the CA-2 road bridge, at the confluence with Guacalate River in the Achiguate river basin, and in the Pantaleon river basin, respectively.

Tide

The mean high and low tides at the estuary of Achiguate River are 0.8 m and -0.78 m MSL, respectively, which were estimated from the tide records at La Union, El Salvador, by SMB Method (INSIVUMEH, 1979).

3.2.5 Volcanic Activities and Sedimentation

Past Activities of Fuego Volcano

Fuego Volcano, which is presently in the active stage, had erupted sixty times since the record began in 1524. The eruption is of very violent nature typical to vulcanian eruptions with a duration ranging from a few hours to a few days usually accompanied by pyroclastic flow (ash flow or lahar). The activity is marked by predominance of volcanic ash and ash flows.

1/ The existing water level gauging station in Coyolate River, i.e., Cerro Colorado, was installed in 1971. The flood peak discharge was roughly calculated from the ratio of catchment area and basin rainfall between Achiguate and Pantaleon river basins.

The review of the recorded history reveals four outstanding periods of activity each lasting twenty to fifty years (refer to Table 3-13). As can be seen from the table, it is now in the fourth period of activity, a violent and intermittent one which started in the 1950's. It can be reasoned from the past activity records that the present activity will last for ten or twenty more years.

The recent biggest vulcanian eruption occurred on September 14, 1971. Tremendous amount of ejecta were deposited on the slope of the mountain.

Sedimentation

Due to the volcanic activities of Fuego Volcano, sediment in the Study Area is mostly produced from the volcanic ejecta and by gully erosion. Debris is usually deposited on the slope of Fuego Volcano and washed down the gullies and rivers by heavy rainfall.

In the Achiguate river basin, many gullies were formed on the southern slope of Fuego Volcano. The large amount of sediment along the lower reaches of gullies have originated from the volcanic ejecta. They have piled up in the elevation of 700 m MSL along the Achiguate main stream and of 1,000 m MSL along Ceniza River. Sediment was plentifully observed below these elevations up to the confluence with Ceniza River (150 m MSL), and sedimentation in the riverbed was likewise observed up to the confluence with Guacalate River (80 m MSL). The lower reaches after the confluence with Guacalate River is considered to be the sediment transportation section.

In the Pantaleon river basin, debris deposits were also observed on the southern and southwestern slopes of Fuego Volcano. Sediment from the gullies cover the fan area of Taniluya River and reach up to the CA-2 road bridge and the railway bridge.

In the reach after 5 km downstream of the railway bridge, sediment was seen piling up to the volcanic fan's surface and flowing down along the river. This reach is considered as the temporary sediment deposition zone.

The total sediment runoff volumes from 1971 to 1983 were estimated at $47,143 \times 10^3$ m^3 in the Achiguate river basin and $50,365 \times 10^3$ m^3 in the Pantaleon river basin.

3.2.6 River Feature

Transition of the River Course

Fig. 3-4 shows the transition of the Achiguate and the Pantaleon river courses, extracted from the aerophotographs in 1956, 1958, 1967 and 1983, and from the topographic map editted in 1960.

As can be seen from this figure, the rivers have changed their courses in a wide range, especially Achiguate River which shifted its main course at the stretch of 16 km from the estuary from year to year. The maximum range of the transition at the stretch is estimated at approximately 2.0 km. On the other hand, the stretch of the upper reaches from 16 km to the road bridge was comparatively stable before the 1950's, although the course has now become unstable due to the increase of sediment load after the eruption of Fuego Volcano in 1971. The river course in the upper reaches from the road bridge is forming a steep valley; hence, has been stable.

In Fig. 3-5, the transition of the river mouth shows that the coastline at the estuary has been shifting towards offshore. During the period from 1954 to 1983, the stretch had extended to about 150 m.

As to the closing of the estuary, it is sometimes closed by sand transported by the current, wave, tide, and so on, causing inundation problem to the area around the estuary. To cope with this situation, inhabitants around the area excavate the sand closing the estuary once a year so that the river will remain open during the flood season.

Riverbed Fluctuation

Although the data are not sufficient to precisely investigate riverbed fluctuations, they show that the riverbed at the railway bridge in Achiguate River had not remarkably changed during the period from 1895 to 1969, and the river had kept a narrow but deep course. The riverbed, however, has risen to the present level due to the abundant sediment load by the sediment discharge since the eruption of Fuego Volcano in 1971 (refer to Fig. 3-6). The bank height in the downstream about 20 km from the estuary is only 0.3 to 0.5 m above the riverbed; once, it had been more than 2.0 m.

Similar conditions as mentioned above for the railway bridge and the riverbed in Achiguate River were observed through the field investigation at the other bridge sites in Pantaleon River. Besides the above, bank erosion can be seen in some places as emphasized in the cross section of Pantaleon River at the CA-2 road shown in Fig. 3-7.

Flow Capacity

Fig. 3-8 shows the flow capacity of each section along the Achiguate and Pantaleon rivers, together with the longitudinal profile, river width, and so on. Evidently, the flow capacities of these rivers are very poor in consideration of their catchment areas, and these rivers can safely flow down only the low water discharge.

The sections of Achiguate River with very poor flow capacities of only 50 m^3/s and 25 m^3/s are those at 30 km and 16 km. As for Pantaleon River, these have been observed at 16 km with a flow capacity of 200 m^3/s, and at 4 km with a flow capacity of 70 m^3/s.

River Utilization

River water in Achiguate and Pantaleon are being utilized only for the drinking water of livestocks, watering of some fruit trees and washing clothes; while, people obtain drinking water from shallow wells.

Besides, inhabitants along the river course are engaged in small fishery such as catching fish or fresh water shrimps for local consumption only. Navigation is limited to the canal connecting Achiguate River to the sea, passing by San Jose, for the transport of local products by some small wooden boats.

Riparian Facilities

Intake facilities were constructed in the 1960's to take in river water for use in livestock farming and the cultivation of fruit trees. Due to the rise of riverbeds, however, the efficiency of the intake systems had been reduced and now, the intake facilities are not effectively operated for the purpose.

Gabion mattresses which are used as the only facility for flood protection in this area have come into use since the 1960's to protect bridges and/or some areas. Some of the gabion mattresses have had effects on flood damage protection, but the others were not installed effectively and some of them had been washed away by floods.

The local ring levees had been privately constructed to protect livestock farms from flood waters.

CHAPTER IV. BASIC CONCEPTS FOR PLANNING

4.1 General

Long-term and urgent sediment and flood control plans were formulated in this study. The long-term plan aims at accomplishment of the desirable sediment and flood control system under the prospects of the future development of the Study Area; while, the urgent plan focuses on the immediate protection of the present assets being seriously damaged.

In this connection, the suitable sediment and flood control method for the formulation of the said plans was selected in due consideration of the river features, such as sediment discharge, flood discharge and inundation water stage, under various flood magnitudes.

An evaluation method for each plan is, therefore, established to select the optimum long-term and urgent plans among the suggested plans from the aspects of economic viability, social requirement and financial capability.

4.2 Fundamentals of the Plan

4.2.1 Sediment Discharge

<u>Sediment Reference Point</u>

Sediment reference points should be set up to be able to quantitatively estimate the sediment discharge volume and evaluate the damage potential, as well as the efficiency of sediment control works.

The sediment reference points in the Achiguate and Pantaleon river basins were established as follows, in consideration of the sediment discharge conditions. (Refer to Fig. 4-1.)

Achiguate Reference Point:	CA-2 Road Bridge (Catchment Area:	 205.0 km^2)
Pantaleon Reference Point:	CA-2 Road Bridge (Catchment Area:	 115.0 km^2)

Probable Sediment Discharge

The formulation of the long-term plan was based on the estimated sediment deposits that had accumulated immediately after the eruption of Fuego Volcano in September 1971, because it is the largest one experienced in the recent past. The urgent plan was formulated to control the sediment discharge which may be produced from the sediment deposits existing as of 1983.

Sediment discharge is directly attributed to the accumulated sediments and the rainfall in the river basin. The total sediment volume since 1967 was estimated by comparing two aerophotographs taken in 1967 and in 1983. The probability of sediment discharge has been calculated from the relation between the rainfall probability and the total sediment volume. Probable sediment discharges thus obtained are tabulated in Table 4-1.

Allowable Sediment Discharge

Allowable sediment discharge is defined as the discharge that flows down through rivers without inflicting any damage on the areas and structures along the rivers.

The allowable sediment discharges of the rivers were estimated on each probable flood discharge by using the sediment transportation equation, Brown's Formula, and the model hydrograph.

Sediment Discharge to be Controlled

The sediment discharge to be controlled is defined as the difference between the allowable and the total sediment discharges. In other words, the sediment discharge exceeding the allowable sediment discharge will have to be controlled by sediment control works. (Refer to Table 4-1.)

4.2.2 Flood Discharge

Flood Reference Point

To provide the fundamental factors necessary for the formulation of a flood control plan, hydrological conditions regarding the recorded past floods and design floods should be identified and analyzed at a certain point, called Flood Reference Point, in a river channel.

For the Achiguate and Pantaleon river basins, their flood reference points were selected in consideration of hydrological conditions, location of flood plains and especially, a conformity with their sediment control plans, as follows:

- Achiguate River Basin

  Reference Point I : CA-2 Road Bridge
  (Catchment Area: 205.0 km^2)

  Reference Point II: Immediate downstream point of the confluence with Mazate River
  (Catchment Area: 956.0 km^2)

- Pantaleon River Basin

  Reference Point : Confluence with Cristobal River
  (Catchment Area: 150.0 km^2)

The locations of the flood reference points are shown in Fig. 4-1.

Probable Flood Discharge

Since the hydrological data of the Achiguate and the Pantaleon rivers are insufficient in quantity to directly calculate the probable flood discharges, reference has to be made to other well-arranged data in the neighboring river basins that are topographically and geologically similar to the Achiguate river basin. In this connection, the Nahualate river basin was chosen as the most similar basin.

From the hydrological relation between Nahualate and Achiguate/Pantaleon river basins, as shown in Fig. 4-2, the probable flood discharges at the flood reference points in the Achiguate and the Pantaleon river basins were estimated, and the results are tabulated in Table 4-2.

The flood discharges of a 30-year return period which corresponds to the recorded biggest flood are 1,190 m^3/s at Achiguate Reference Point I; 1,670 m^3/s at Achiguate Reference Point II; and 1,110 m^3/s at Pantaleon Reference Point.

Model Hydrograph

The model hydrograph at each reference point was as well prepared by taking the similarity to the flood hydrographs of Nahualate River.

The model hydrographs at the Montecristo and the San Miguel Moca gauging stations located in Nahualate River were applied to Achiguate Reference Point I/Pantaleon Reference Point and Achiguate Reference Point II, respectively. The model hydrographs at the respective reference points are illustrated in Fig. 4-3.

4.2.3 Flood Simulation

Simulation Model

Only a few big floods have been recorded in the Achiguate and the Pantaleon river basins as mentioned in the previous chapter. Consequently, data on flood and sediment transport are insufficient in quantity to assume the inundation water stages of floods of various scales which are needed for the estimation of sediment discharge and flood damages. Therefore, a simulation model for the analysis of sediment transport and flood behaviors needs to be drawn in order to identify the inundation water stage of a flood in a river basin.

(1) Achiguate River Basin

The simulation model in the Achiguate river basin was drawn based on the flood and inundation data in 1969 and 1982 and the topographical condition of the basin. The model shows the following features:

(a) Since the river section at the CA-2 road bridge has a sufficient flow capacity, the flow of river water and sediment discharge are confined in the river channel.

(b) In the stretch from 42 km to 28 km, the flood discharge temporarily overflows the river banks at flood time, and flows down along the river course without spreading out.

As for the sediment discharge, sedimentation on the riverbed depends upon the balance between the inflow and the outflow sediment volumes that are subject to the tractive force in the stretch. Downstream of the stretch, sediment transport is too small due to poor transportation capacity so that the sediment behavior thereabout may be neglected.

(c) The overflow river water at 28 km goes down into the Naranjo and the Suquite rivers on the left.

(d) In the river stretch from 28 km to 20 km, the behavior of river water is same as (b).

(e) The overflow river water below 20 km inundates the right and left banks, and the overflow water on the left bank spreads down on the plain area between Achiguate River and the town of San Jose.

(f) All the inundation water are drained into the sea through the estuary of Achiguate River.

(2) Pantaleon River Basin

Big floods occurred in the Pantaleon river basin in 1969, 1971, and 1974. The simulation model for this basin was prepared with reference to all the data of the aforementioned floods, and its features are described as follows:

(a) In the upper stream of 16.0 km from the confluence point with Cristobal River, river water temporarily inundates both the right and left sides of the river at flood time, and flows down along the river course without spreading out.

Sedimentation on the riverbed depends upon the balance between the inflow and the outflow sediment volumes in the same manner as that in Achiguate River.

(b) Flood discharge is diverted at 16 km to Pataya River and brings about inundation on both sides along the Pataya river course.

(c) The overflow water at 6.0 km from the confluence flows into Jute River with inundation on both sides along the river.

(d) In the stretch from 6 km to the confluence with Cristobal River, the behavior of river water is same as (a).

Inundation Water Stage

Inundation water stage is used for the estimation of the effect of the flood control facilities.

The inundation water stage of each probable flood at the present conditions were calculated by applying the probable discharge to the simulation model. Table 4-3 shows the results of the calculation.

4.3 Sediment and Flood Control Method

4.3.1 Sediment Control

Applicable Methods

There are four (4) major methods to control sediment discharge in areas along rivers, as follows:

(1) Sediment control dam;
(2) Training levees and channel works1/;
(3) Hillside works; and
(4) Groundsill1/

1/ Application of these methods will be discussed under river channel improvement, since this method is mainly used with emphasis on the control of flood water in this study.

Judging from the features of each method as described in the following paragraphs, sediment discharge in the Study Area should be controlled by the combination of methods (1), (2) and (4).

Heavy sediment output into river channels is most effectively stopped by constructing sediment control dams at the source of sediment.

Training levees and channel works would guide the flood waters, and sediment spreading out of the river course is prevented.

Hillside works are not to be employed when they are meant to control erosion on slopes of volcanoes, such as the Fuego Volcano, because they are practically ineffective in the presence of heavy persistent erosion.

Groundsills are effective for riverbed stabilization.

Concepts for the Sediment Control Plan

Sediment control dams are to be so planned as to effectively regulate the sediment discharge during a flood. Planning of sediment control dams is based on the following considerations:

(1) Dam sites are primarily selected on the basis of topographical conditions and areal sediment deposit distribution so that the dam will have a large storage capacity and regulation effect.

(2) The site nearest to the target protection area may assure the highest regulation effect among the proposed sites.

Priority should be given to the adoption of the suggested dams on the basis of the above concepts.

4.3.2 Flood Control

Applicable Methods

The following methods are commonly employed for flood control works:

(1) River channel improvement;
(2) Ring levee;
(3) Impounding reservoir;
(4) Floodway; and
(5) Retarding basin.

Among the above methods, improvement of the existing river channel and the provision of ring levees are considered to be the most applicable in the Study Area, judging from the ineffectiveness of the other methods as described hereunder.

The Study Area, which is dominated by hillside slopes, is devoid of appropriate places for an impounding reservoir. An impounding reservoir, even if installed, will be made ineffective by heavy sediment output.

The present river course, when simplified, forms a right angle to the ocean where it pours. Construction of a floodway will not be an effective shortcut under such circumstance.

Flood control by a retarding basin alone will be very difficult where the river basin has a steep gradient.

Concepts for River Channel Improvement Plan

The river channel improvement plan is basically featured by the following factors:

(1) The proposed alignment in principle follows the present river course, since the river channels may smoothly flow down runoff discharge because of slight meandering.

(2) The longitudinal profile is so designed as to assure the stability of the river channel by fixing the riverbed gradient to become steeper gradually in proportion to the distance from the estuary.

(3) The design high water level should be kept as low as possible in order to avoid the aggravation of flood damage potential in case of overtopping.

(4) The river width will be taken to the technically and socially maximum extent, regardless of the volume of design flood discharge, since the land along the river course can be acquired easily at a low cost.

(5) With regard to the cross section, an excavated channel should be provided for the stretches with a steep riverbed gradient where river water flows down at a high velocity.

The compound cross section consisting of high and low water channels will be applied to the stretches with a low velocity of water flow.

(6) Countermeasures against closing of a river mouth can be proposed in two methods; construction of a jetty together with excavation works, and provision of a pilot channel in the sand bar. The latter method is not appropriate for the treatment of the Achiguate river mouth for the reason that the areas near the river mouth would be in a dangerous situation when the river water level rapidly rises due to river improvement works in the upper stream. Jetty together with excavation works, though much more costly, will be installed to stabilize the river mouth without bringing such dangerous situation upon the neigboring areas.

4.4 Project Evaluation Method

Target Assets

One of the primary purposes of a flood control project is to alleviate flood damage to not only the currently existing assets in the river basin but also the increased assets in the future. It is, therefore, necessary to set up the target assets that currently exist or will be situated at a certain point of time in the future when a flood control project is implemented.

(1) Long-Term Plan

The long-term plan may be put into execution in the distant future to protect the possibly increased assets from flood damage.

Based on the relative data showing the future economic development in the nation and regions up to the year 2010, the target assets in the study area are fixed at the estimated value in 2010, the most distant future year having reliable data.

(2) Urgent Plan

An urgent flood control project is literally required to be put into implementation in the near future. In this sense, the project should be planned on the basis of the present situation of assets in the basin.

Classification of Assets

Assets in the Study Area were classified into four (4) categories and given priority according to their socio-economic significance in order to make a study on the stretch and size of flood control works, as follows:

Priority	Assets
A	Community in a dangerous zone[1/]
B	Infrastructure and Urban Area
C	Cultivated Lands
D	Pastures

The highest priority was placed on the community where an abrupt attack of flood could bring about casualties. The second priority was on infrastructures such as the railways and roads, and also on the urban areas, considering the nationwide influence if damaged and importance of stabilitization of the inhabitants' livelihood. Cultivated lands and pastures are in the third and fourth orders of priority, respectively, according to their productivity.

Evaluation Method

The plan will be assessed on the basis of social requirement and/or economic viability in accordance with the priority of the assets.

The plan of protection for the assets designated as A was evaluated only from the viewpoint of social requirement. Evaluation of both social requirement and economic viability was made for assets designated as B. As for the assets recognized to be C and D, only economic viability was assessed.

To justify the optimum plan of the long-term and the urgent projects, evaluation was based on the following concepts:

(1) Long-Term Plan

The recorded maximum flood should be the basis for the determination of the sediment and flood control facilities

1/ Assets A are not seen in the study area.

in a concept that damage equivalent to the maximum damage in the past be at least released as social requirements. Economic evaluation was made in combination of assets such as B + C + D, B + C, or only B by means of the economic internal rate of return (EIRR). The standard of economic evaluation (percentage of EIRR) is 6.5%, which is equivalent to the average of interest rates of applicable loans in Guatemala (refer to Table 4-4).

(2) Urgent Plan

The social requirements for the urgent plan are defined as the enhancement of living conditions up to the national average, while its economic viability is assessed in reference to the same standard as the long-term plan.

CHAPTER V. LONG-TERM PLAN

5.1 General

For the improvement of the regional economy, alleviation of sediment and flood damages in the Study Area where they are inflicted much more than in the other regions of the country is deemed very necessary. Most especially, the vital links of the national highway and the railroads which are crucial to the economies of the regions contiguous to the Study Area should be secured by means of sediment and flood control works.

The river channel improvement which is employed for the flood control plan may be broadly categorized into two types based on the stretch covered; namely, channel improvement of the entire river course and partial river channel improvement.

The former aims at the establishment of a flood control system on the precept that all assets along river courses be equally protected from sediment and flood damage. It is superior in technical and social viewpoints to the latter which may cause adverse effects to the downstream of the improved section, though the former may require an enormous fund and takes a long period of construction.

However, in case that the execution of channel improvement of the entire river course has less possibility due to economic or financial constraint, the partial river channel improvement may be employed in order to release specific areas and assets from sediment and flood damage as early as possible. It is also one step to reach the channel improvement of the entire river course.

The possibility of river channel improvement works covering the entire river course has been studied, and it was clarified that this plan has a low economic viability and needs an enormous fund, and that it is more practical to implement the plan in the mode of partial improvement. A long-term plan, therefore, has been formulated for the protection of the main transportation system and the urban areas that were recognized to be socially important, by providing partial river improvement together with sediment control works in the upper stream.

5.2 Design Sediment and Flood Discharge

Design Sediment Discharge

The design scale for flood control was decided to be equivalent to the biggest recorded flood that corresponds to a 30-year return period in both the Achiguate and the Pantaleon rivers based on the basic concepts for planning in Chapter IV. The design sediment discharge at the sediment reference points in both rivers were estimated as follows:

Achiguate Reference Point : $1,940 \times 10^3$ m^3
Pantaleon Reference Point : $3,246 \times 10^3$ m^3

Design Flood Discharge

The design flood discharges that correspond to a 30-year return period were estimated at the flood reference points as follows:

Achiguate Reference Point I : 1,200 m^3/s
Achiguate Reference Point II: 1,700 m^3/s
pantaleon Reference Point : 1,150 m^3/s

The design discharge distribution in both the Achiguate and the Pantaleon rivers are shown in Fig. 5-1.

5.3 Comparative Study

5.3.1 Sediment Control Dams

It is of predominant importance to completely regulate the sediment discharge during a flood. In due consideration of the sediment discharge and topographic conditions, three (3) sediment control dams in Achiguate River, one (1) in Ceniza River, a tributary of Achiguate River, and six (6) in Pantaleon River were considered for the selection of the suitable dams to regulate the design sediment discharge. In Taniluya River where enormous sediment transport was observed, no suitable dam site can be seen. (Refer to Fig. 5-3.)

The following combination of dams are eventually proposed to regulate the design sediment discharge to the optimum.

River	Dam Name	Effective Height (m)	Regulation Volume (10^3 m^3)
Achiguate	A-1	8.0	990
	A-2	18.0	562
	C-1	7.0	338
Pantaleon	P-1	5.0	60
	P-2	9.0	976
	P-3	11.0	235
	P-4	9.0	315
	P-5	18.0	1,370

5.3.2 Channel Improvement of Entire River Course

Channel improvement of the entire river course to totally protect all the assets along a river from sediment and flood damage is essential to the river improvement plan. (Refer to Fig. 5-2.) This method may be called as the comprehensive river improvement plan.

The major features of the comprehensive plan are summarized as follows:

Achiguate River

(1) River Channel

(a) Location and Extent

River improvement works for Achiguate River will cover all the stretch of 43.8 km from the river mouth. The upper end of the improvement works is the site of the sediment control dam.

(b) Alignment

New alignment of Achiguate River with a width of approximately 250 m which corresponds to the average width of the present river course is drawn from the river mouth to 33.24 km, the confluence point with Guacalate River, while the stretch from 33.24 km to 43.8 km will be drawn with a width of approximately 100 m. (Refer to Fig. 5-3.)

(c) Longitudinal Profile

The excavation depth is within 3.5 m and the design high water level is within 2.0 m above the average ground height which coincides with the recorded maximum water level. Likewise, the height of the dike is within 3.0 m above the ground height including the 1.0 m freeboard. The riverbed gradient gradually varies from 1:500 to 1:110 in proportion to the distance from the river mouth, as shown in Fig. 5-4.

(d) Cross Section

A compound cross section is applied to the downstream stretch from the confluence at 33.24 km where the low water channel can confine a discharge of 450 m^3/s, corresponding to the probable discharge of a 1.5-year return period flood. Bank gradients for high and low water channels are fixed at 1:2.

A single cross section is applied to the stretch above the confluence point. The slope of channel is 1:2 in the stretch between 33.24 km and 39.6 km, and 1:0.5 in the stretch from 39.6 km to 43.8 km. The standard cross section is shown in Fig. 5-3.

(2) Riparian Facilities

Riparian facilities required for the comprehensive plan consist of revetment, groundsill, groyne, drainage ditch and sluice. Revetment of approximately 21.5 km will be provided for both high and low water channels of the compound cross section. Revetment in a total length of 21.12 km will be applied to the channel of the single cross section.

Aside from 30 groundsills, 2 sections of groyne in a total length of 5,600 m, drainage ditch of 66.48 km and 17 sluices will be installed in and/or along the river channel.

(3) River Mouth Treatment

Jetties of 280 m and 380 m long are proposed on the left and right banks so that drift sand caused mainly by waves may not enter the river mouth from the southeast and southwest directions, respectively.

Pantaleon River

(1) River Channel

(a) Location and Extent

River improvement works for Pantaleon River will cover the whole stretch from the confluence with Cristobal River to 22 km where most of the downstream sediment control dams will be constructed.

(b) Alignment

New alignment of Pantaleon River is proposed with a width of approximately 80 m which corresponds to the average river width and to the maximum possible width for expansion at the location of the railway bridge.

(c) Longitudinal Profile

The average excavation depth is within 3.0 m and the design high water level is so designed to remain below the average ground height. The riverbed gradient gradually varies from 1:105 to 1:38 in proportion to the distance from the confluence point with Cristobal River. (Refer to Fig. 5-4.)

(d) Cross Section

A single cross section is applied to the whole stretch with a bank slope of 1:0.5. The standard cross section is presented in Fig. 5-3.

(2) Riparian Facilities

Riparian facilities of revetment and groundsills will be provided for Pantaleon River. The whole river stretch of

22.0 km will be revetted, and 293 groundsills will be installed.

Evaluation

The sediment and flood control plan of improving the entire river course for the protection of all the assets in the Study Area has a very low economic viability and needs such an enormous fund for its implementation, as described below, so that it is impractical to put this plan into implementation from the present point of view.

(1) Construction Cost

The construction cost required for this plan is estimated to be as much as US$192 million, comprising US$27 million for sediment control works and US$165 million for flood control works.

(2) Economic Viability

The annual average benefit that will accrue after completion of this plan is estimated at US$8.6 million. The economic internal rate of return (EIRR) is estimated at 2% based on the disbursement schedule with a 10-year construction period.

5.3.3 Partial River Improvement (Case I)

Judging from the evaluation and findings for the comprehensive river improvement plan described in the preceding subsection, partial river improvement may have to be applied to the Achiguate and the Pantaleon rivers to provide protection to specific assets from floods.

In this connection, partial river improvement for the protection of Assets B and C which spread out over a large area has been studied and the results are summarized as follows:

Achiguate River

(1) River Channel

River channel improvement works cover two (2) stretches; from the estuary to 16 km and from 28 km to 43.8 km, where new alignment, longitudinal profile and cross section are drawn in the same manner as that of the comprehensive river improvement of the entire river course.

(2) Riparian Facilities

The shortening of the stretch for improvement leads to the reduction in length and quantity of the required riparian facilities; namely, revetment of a total of 33.12 km, 30 groundsills, one section of groyne, drainage ditch of 42.48 km, and 12 sluices.

(3) River Mouth Treatment

A jetty is designed as countermeasure against closing of the river mouth in the same manner as that of the comprehensive river improvement.

Pantaleon River

(1) River Channel

The stretch from 6 km to 22 km will be improved on the basis of new alignment, longitudinal profile and cross section, which have been designed in the same manner as that of the comprehensive river improvement.

(2) Riparian Facilities

The riparian facilities required for the improvement of Pantaleon River are likewise modified to revetment of a total of 32 km and 241 groundsills.

Evaluation

This partial river improvement plan (Case I) for the protection of Assets B and C has a very low economic viability and requires an enormous fund for its implementation, same as the comprehensive river improvement plan. Accordingly, this plan can be hardly considered to be practicable at present. The construction cost and economic viability are briefly assessed as follows:

(1) Construction Cost

The total construction cost required for this plan is estimated to be as much as US$143 million, US$27 million of which is for sediment control works and US$116 million for flood control works.

(2) Economic Viability

The annual average benefit which will accrue after completion of this plan is estimated at US$8.0 million. The economic internal rate of return (EIRR) is calculated at 3% based on the disbursement schedule with a 10-year construction period.

5.3.4 Partial River Improvement (Case II)

This plan is discussed for the protection of only Assets B which are enumerated as follows:

River	Target Assets
Achiguate	CA-2 road bridge and railway bridge; urban areas in Finca La Trinidad on the left side and in Finca La Barrita on the right side
Pantaleon	CA-2 road bridge and railway bridge

Not only the river channel improvement but several methods to release Assets B from flood damage were evaluated as follows:

Achiguate River

(1) Road and Railway Bridges

Damage at the CA-2 road bridge is mainly caused by severe bank erosion and/or scouring of the riverbed around the piers, while that at the railway bridge is due to the insufficient flow capacity in the stretch downstream of 41.7 km.

Judging from the cause of damage, the following three (3) methods can be suggested for the protection of the CA-2 road bridge and the railway bridge (refer to Fig. 5-5):

Method I-1	:	River channel improvement
Method I-2	:	River channel improvement together with training levee
Method I-3	:	Heightening of the railway bridge including embankment of its approach portions and revetment works of the main channel near the road bridge

Method I-1 needs the least cost among the three methods as far as the cost required throughout the project life is concerned. Though the initial investment of Method I-2 is limited to a small amount in comparison with that of Method I-1, the training levee contained in Method I-2 requires a high replacement cost in every 10 years due to low durability. Method I-3 has a disadvantage in that the damage potential cannot be lowered due to no increment of flow capacity of the river. Accordingly, Method I-1 is employed for the improvement section.

The costs required for the three methods are tabulated in Table 5-1.

(2) Urban Area, Finca La Trinidad

The flood damage on the area is mainly attributed to overtopping flood water in the stretch from 28 km to 30 km. Therefore, following methods are suggested for the protection of the urban area in Finca La Trinidad, as illustrated in Fig. 5-5.

Method II-1 : River channel improvement
Method II-2 : Raising CA-9 road
Method II-3 : Ring levee

Method II-1 can be recommended, though economically inferior to Method II-2, on the ground that this method can equally protect the assets on both sides of the river, thereby causing no social problem derived from one-sided protection which may be caused by the implementation of Method II-2. Method II-3 is the most costly of the three. (Refer to Table 5-1.)

(3) Urban Area, Finca La Barrita

The flood damage on this area is mainly due to the insufficient flow capacity of the river in the stretch below 9 km. The following two methods may be suggested to protect the urban area in Finca La Barrita. (Refer to Fig. 5-5.)

Method III-1: River channel improvement and training levee

Method III-2: Ring levee with drainage facilities

The flow capacity of the river channel is so small that the lower reaches are widely inundated by flooding water. Protection of this urban area by means of Method III-1 will be much more costly because a long stretch of river channel will have to be improved. From the economic viewpoint, therefore, Method III-2 is much superior to Method III-1, as shown in Table 5-1.

Pantaleon River

The CA-2 road bridge and the railway bridge which are under the same situation as those in Achiguate River may be protected by the following two methods:

Method IV-1 : River channel improvement
Method IV-2 : River channel improvement with a training levee

Method IV-1 does not require so much construction cost as Method IV-2. Moreover, the training levee in Method IV-2 needs to be replaced at a high cost in every 10 years. Method IV-1 is, therefore, employed for the improvement section.

The location of these works is plotted in Fig. 5-5 and the results of their comparative economic study are shown in Table 5-1.

Evaluation

The sediment and flood control plan for the protection of Asset B should be carried out by Methods I-1, II-1, III-2 and IV-1 which have been determined through the comparative study under this subsection. Though this Case II plan still shows an EIRR slightly below the economic standard defined in Chapter IV, Asset B should be protected in view of social requirements.

5.4 Proposed Long-Term Plan

5.4.1 Features of the Plan

The outline of the proposed long-term plan for both the Achiguate and the Pantaleon rivers is summarized as follows:

Achiguate River

(1) Sediment Control

The sediment control works for Achiguate River are composed of three (3) dams of cobble stone concrete type whose features are summarized in the following table. (Refer to Fig. 5-6.)

Dam Name	Catchment Area (km^2)	Effective Height (m)	Crest Length (m)	Dam Body Volume (m^3)	Regulation Volume (10^3 m^3)
A-1	92.0	8.0	460	21,000	990
A-2	39.0	18.0	135	24,000	562
C-1	112.0	7.0	455	19,000	338

(2) Flood Control

The flood control works consist of river channel improve-ment works in two stretches, one for the CA-2 road and railway bridges and the other for the urban area in Finca La Trinidad, and a ring levee around the urban area in Finca La Barrita. (Refer to Fig. 5-6.)

(a) CA-2 Road and Railway Bridges

The upper improvement stretch is 5.0 km long from 38 km to 43 km (the point of 180 m above the CA-2 road bridge), covering the road bridge and the railway bridge. This includes a transition section of 1.6 km in its lower stream.

The proposed alignment with a width of about 100 m has been arranged as smoothly as possible in line with the existing one. The riverbed gradient is 1:110 in the stretch from 39.6 km to 43 km. The gradient of the transition section is 1:170. The design high water level is set at 2.45 m above the riverbed in this stretch and the depth of channel includes a freeboard of 1.0 m.

A single cross section with a gradient of 1:0.5 is applied to the whole stretch. The cross section of the transition portion is gradually adjusted to follow the present cross section from the standard design cross section.

The required riparian facilities are revetment for both sides of the channel slope with a total length of 2.3 km and 17 groundsills with a breadth of approximately 100 m to be installed at intervals of 150 m.

(b) Urban Area, Finca La Trinidad

The improvement stretch extends for 6.0 km from 25.5 km to 31.5 km, including transition sections of 1.5 km in the upper stream and 2.5 km in the lower stream.

The proposed alignment with a width of about 250 m is drawn in a smooth line in consonance with the existing one. The gradient of riverbed is set at 1:300 and gradients of 1:250 and 1:340 are applied to the transition portions above and below the improvement stretch, respectively. The design high water level is fixed at 1.7 m above the ground height and a freeboard of 1.0 m is included in the height of the embankment.

A compound cross section with a gradient of 1:2 is applied to the whole stretch. The cross section of the transition portion is adjusted in the same manner as that in the river improvement for the stretch from 38 km to 43 km.

(c) Urban Area, Finca La Barrita

A ring levee will be constructed in a length of 5.0 km around the urban area named La Barrita. This ring levee is designed with a gradient of 1:2, and revetment of 3.0 km will be provided for the outer side of the levee.

Drainage facilities will be provided to drain inland water in the area surrounded by the ring levee.

Pantaleon River

(1) Sediment Control

The sediment control works are composed of five (5) sediment control dams of cobblestone concrete type (refer to Fig. 5-6). The features of these dams are summarized in the following table.

Dam Name	Catchment Area (km^2)	Effective Height (m)	Crest Length (m)	Dam Body Volume (m^3)	Regulation Volume (10^3 m^3)
P-1	115.0	5.0	210	7,000	60
P-2	107.0	9.0	392	17,000	976
P-3	62.0	11.0	160	17,000	235
P-4	61.0	9.0	190	12,000	315
P-5	60.0	18.0	230	44,000	1,370

(2) Flood Control

The flood control works for this river are composed of river channel improvement works including revetment of the river channel in the vicinity of the CA-2 road bridge, as shown in Fig. 5-6. The improve-ment stretch is 3.4 km starting from 18.0 km to 21.4 km.

The proposed alignment with a width of 80 m has been arranged in the same way as that of Achiguate River.

The gradient of riverbed is fixed at 1:38. The design high water level is set at 2.0 m above the riverbed, and a freeboard of 1.0 m has been considered in setting the bank height.

A single cross section with a gradient of 1:0.5 is applied to the whole stretch. The cross section of the transition portion is gradually adjusted to follow the present cross section.

The required riparian facilities are revetment for both sides of the channel slope for a stretch of 2.3 km and 47 groundsills with a breadth of about 80 m to be installed at intervals of 50 m.

5.4.2 Construction Schedule and Cost

Construction Schedule

The works for the sediment control dam construction consist of excavation and cobble stone concrete works. The river improvement works include excavation, embankment, and the installation of riparian facilities such as revetment, groundsill, and so on.

The proposed period of construction works is seven (7) years, including detailed design engineering services of two (2) years, as follows:

Work Stage		Year
(1)	Detailed Design Engineering Services	1st to 2nd
(2)	Construction Works	
(a)	Sediment Control Dam Construction in Achiguate	3rd to 6th
(b)	Sediment Control Dam construction in Pantaleon	3rd to 7th
(c)	River Improvement Works in Achiguate	4th to 7th
(d)	River Improvement Works in Pantaleon	6th to 7th

The construction schedule covering all the stages of this plan is shown in Fig. 5-7.

Cost Estimates

(1) Construction Cost

The base construction cost, which was estimated based on the contract basis and the prices as of August 1984, comprises direct construction cost for the sediment control dams and river improvement works, land acquisition cost, engineering service cost and administration cost, plus 10% physical contingencies.

Taking price contingency based on the annual escalation rate of 6% for both the foreign and local currency portions into consideration, the total financial construction cost is estimated at US$63.2 million of which US$36.2 million 57% is in foreign currency and US$27.0 million or 43% in local currency.

The breakdown of the base construction cost and the annual disbursement of the financial construction cost are presented in Tables 5-2 and 5-3, respectively.

(2) Operation, Maintenance and Replacement Cost

The operation, maintenance and replacement cost (OMR cost) comprise sediment removal cost, personnel cost, machinery and equipment cost, administrative cost and miscellaneous costs.

The annual OMR cost is estimated at US$0.56 million. Replacement costs of the groyne in every five years, the gabion mattress for saddle dam in every ten years and the drainage facilities for the ring levee in every twenty years have been accounted for.

CHAPTER VI. URGENT PLAN

6.1 General

The long-term sediment and flood control plan has been formulated to protect the assets in the Study Area which were recognized to be socially important. In order to release the Study Area from sediment and flood damage as soon as possible, an urgent sediment and flood control plan was formulated on a practical basis by narrowing down the target assets to those that would adversely affect, if seriously damaged, the socio-economic activities in a large area.

At first, an proposed urgent plan was formulated based on the precept that economic viability may be maximized in due consideration of the social requirement in the area.

In the formulation of the proposed plan, various kinds of study on the optimum sediment and flood control methods and on the optimum project scale have been made. The proposed plan has been projected under the condition that the project will be implemented with financial assistance from an eligible source country.

In the event that financial constraints arise resulting in the difficulty to implement the proposed plan, an alternative plan whose construction can be more stepwisely executed under only local finance was prepared under the same conditions, such as target assets, design sediment and flood discharges, etc., as those of the proposed plan.

6.2 Target Assets

In the long-term plan, the proposed plan was formulated to protect the CA-2 road bridge, the national railway bridge, and the urban areas in Finca La Trinidad and Finca La Barrita from flood damage.

With regard to the urgent plan, the target assets are narrowed down to the CA-2 road bridge and the national railway bridge spanning the Achiguate and the Pantaleon rivers for the reasons stated below.

(1) CA-2 is the national road linking the country to Mexico and El Salvador. From the viewpoint of regional economy, it is one of the vital traffic systems of the nation interconnecting Guatemala City, San Jose Port and the important agricultural production area. Any damage resulting in the interruption of the traffic system will produce an extensive adverse effect over a large area in the region.

(2) Since flood waters spread widely over the urban areas in Finca La Trinidad and Finca La Barrita having a population of about 4,000 each, inundation water depth is not so high; only below 0.5 m which corresponds to a 10-year return period flood. This will not generate such a serious inconvenience to the inhabitants in both areas that should be urgently resolved.

(3) The project cost was squeezed down to the possible minimum to facilitate the construction of the proposed project.

6.3 Comparative Study

6.3.1 Sediment Control Works

It is firstly necessary, same as the long-term plan, to regulate completely the sediment discharge during flood time by sediment control dams. Possible dam sites are suggested to regulate the sediment discharge that may be produced from the accumulated sediment deposit existing as of 1983. Selection of the sites is based upon their economic efficiency which is represented by the ratio of the construction cost to the regulation volume, in the same manner as the long-term plan.

Two (2) sediment control dam sites are required in Achiguate River to regulate the probable sediment discharge of 5-, 10-, and 30-year return periods, while one (1) dam site for 5- and 10-year return periods and two (2) dam sites for a 30-year return period are needed for Pantaleon River.

Dam names, effective heights and regulation volumes are tabulated in the following table and the dam locations are plotted in Fig. 6-1.

River	Return Period	Dam Name	Effective Height (m)	Regulation Volume (10^3 m^3)
Achiguate	5 years	A-1	6.0	431
		C-1	4.0	94
	10 years	A-1	6.5	551
		C-1	4.5	119
	30 years	A-1	7.0	755
		C-1	5.5	165
Pantaleon	5 years	P-2	8.0	767
	10 years	P-2	9.0	976
	30 years	P-2	9.0	976
		P-6	8.0	357

The return period applied for sediment control dams has to be always the same as that applied for river improvement works. In other words, the appropriate scale of a sediment control dam can only be determined in combination with river improvement works at the same return period.

6.3.2 Flood Control Works

Improvement Stretch

Flood control works are required in the following stretches to protect the road and railway bridges. (Refer to Fig. 6-1.)

Achiguate River	From 38.0 km to 43.0 km (transition section: from 38.0 km to 39.75 km)
Pantaleon River	From 18.0 km to 21.4 km (transition section: from 18.0 km to 18.45 km)

Applicable Methods

The above-mentioned stretches are subdivided into the following sections on account of their minimum flow capacities:

River	Section	Minimum Flow Capacity (m^3/s)
Achiguate	39.75 km to 40.4 km	150
	40.4 km to 41.7 km	1,000
	41.7 km to 43.0 km	1,400
Pantaleon	18.45 km to 19.5 km	550
	19.5 km to 20.5 km	1,000
	20.5 km to 21.4 km	1,300

In general, several methods are considered to improve a river channel, but the applicable methods for the above-mentioned sections are limited to only one or two due to their existing situations as described hereunder.

(1) Achiguate River, 39.75 km to 40.4 km

In this section, there exists the railway bridge which makes it difficult to widen or embank the river channel, so that excavation of the channel is solely applicable.

(2) Achiguate River, 40.4 km to 41.7 km

There are two methods applicable for this section; excavation of the channel and provision of a training levee on the left side. The former is suitable in view of keeping a consistency with its lower section, while the latter can make use of the ponding function of the existing non-use area.

(3) Achiguate River, 41.7 km to 43.0 km

This section has sufficient flow capacity so that works are not needed for the increment of flow capacity. Only protection works are proposed in the immediate upper and lower streams of the road bridge to protect it from damage possibly derived from bank erosion and riverbed scouring.

(4) Pantaleon River, 18.45 km to 19.5 km

The situation of this section is almost equal to that of Section 39.75 km to 40.4 km of Achiguate River, but in addition to channel excavation, embankment (provision of a training levee) can also be applicable for this section, because there is a sufficient clearance below the bridge girder.

(5) Pantaleon River, 19.5 km to 20.5 km

Excavation of the channel and embankment (provision of a training levee) are applicable for this section to keep a conformity with the lower section.

(6) Pantaleon River, 20.5 km to 21.4 km

Protection works are solely needed to secure the road bridge for the same reason as for Section 41.7 km to 43.0 km of Achiguate River.

Selection of Methods

A study on the combination of the applicable methods for each section which have been discussed above were carried out for the probable discharges of 5-, 10- and 30-year return periods to select the optimum method.

The possible combinations of the applicable methods were considered in the following four (4) cases:

River	Case	Section	Combination of Methods
Achiguate	Case A-E	39.75 km to 40.4 km	Channel excavation
		40.4 km to 41.7 km	Channel excavation
		41.7 km to 43.0 km	Protection works
	Case A-T	39.75 km to 40.4 km	Channel excavation
		40.4 km to 41.7 km	Training levee
		41.7 km to 43.0 km	Protection works
Pantaleon	Case P-E	18.45 km to 19.5 km	Channel excavation
		19.5 km to 20.5 km	Channel excavation
		20.5 km to 21.4 km	Protection works
	Case P-T	18.45 km to 19.5 km	Training levee
		19.5 km to 20.5 km	Training levee
		20.5 km to 21.4 km	Protection works

The comparative study on the above cases has been conducted in consideration of the construction cost, and concluded as follows (refer to Table 6-1 and Fig. 6-2):

(1) Achiguate River

The combination in Case A-T can be recommended for the floods of 5- and 10-year return periods, while the combination in Case A-E is suitable for the control of a 30-year return period flood.

(2) Pantaleon River

The combination in Case P-E proves to be the optimum for any probable discharge.

Selection of the Optimum Scale

The urgent works should be proposed in such a scale that the sediment and flood discharges of 10-year return period may be controlled in due consideration of economic and social viewpoints as mentioned below.

(1) Viewpoint of Economic Viability

Economic Internal Rate of Return (EIRR) of such project scales as 5-, 10- and 30-year return periods were estimated and given in Table 6-2 and Fig. 6-3. As verified by Fig. 6-3, the urgent plan with a project scale of 10-year return period is economically the most viable, having an EIRR of 7% which is above the standard EIRR for economic evaluation defined in Chapter IV (refer to Table 4-4).

(2) Viewpoint of Social Requirement

The project scale against the flood of a 10-year return period can be said to reach the national level in comparison with the social situations concerning flood damage in other river basins that had experienced flood damage with a frequency ranging from every 3 to 10 years, though a few other river basins are in a safer condition. (Refer to Fig. 6-4.)

6.4 Design Sediment and Flood Discharge

Design sediment and flood discharge of a 10-year return period is employed for the urgent flood control plan.

The design sediment discharges were estimated at 710 x 10^3 m^3 and 1,206 x 10^3 m^3, and the design flood discharges were also fixed at 950 m^3/s and 900 m^3/s for the Achiguate and the Pantaleon rivers, respectively.

6.5 Proposed Plan

The proposed plan of the urgent project has been formulated as follows:

6.5.1 Features of the Plan

The urgent flood control plan is designed to cope with the design discharge of a 10-year return period. As regards the river improvement works, however, the revetment and groundsills of this plan may have to be removed and reconstructed when the long-term plan is put into implementation.

A study has been made on the idea of providing the structures at the scale of the long-term plan, i.e., a 30-year return period (refer to the Supporting Report for details), and it was concluded that the said structures should be constructed in this urgent plan at the scale of the long-term plan to avoid duplication of construction and double investment.

The features of the urgent plan in which the above-mentioned idea has been considered are described as follows:

Achiguate River

(1) Sediment Control

Sediment control works are composed of two (2) sediment control dams of cobble stone concrete type at A-1 and C-1, whose detailed features are as follows (refer to Fig. 6-5):

Dam Name	Catchment Area (km^2)	Effective Height (m)	Crest Length (m)	Dam Body Volume (m^3)	Regulation Volume (10^3 m^3)
A-1	92	6.5	409	14,000	551
C-1	112	4.5	425	10,000	119

(2) Flood Control

(a) Location and Extent

River improvement works for Achiguate River cover the stretch from 38.0 km to 43.0 km where the road bridge and the railway bridge exist.

(b) Alignment

New alignment is in principle drawn along the present river course. The river width is fixed at 100 m as shown in Fig. 6-6.

(c) Longitudinal Profile

The longitudinal profile is designed at 1:110 in the proximity of the existing riverbed gradient. The design high water level is fixed below the landside ground height as shown in Fig. 6-7.

(d) Cross Section

Single cross section is applied to all the river improvement stretches (refer to Fig. 6-7).

(e) Riparian Facilities

The required riparian facilities are revetment and groundsills at intervals of 150 m (39.75 km to 40.4 km and 42.8 km to 43.0 km), and foot protection groyne on the left side (40.4 km to 41.7 km).

Pantaleon River

(1) Sediment Control

One sediment control dam of cobble stone concrete type is proposed at P-2, which has the following features (refer to Fig. 6-5):

Dam Name	Catchment Area (km^2)	Effective Height (m)	Crest Length (m)	Dam Body Volume (m^3)	Regulation Volume (10^3 m^3)
P-2	107	9.0	392	17,000	976

(2) Flood Control

(a) Location and Extent

River improvement works cover the stretch from 18.0 km to 21.4 km where the road bridge and the railway bridge exist.

(b) Alignment

New alignment is drawn along the present river course, and the river width is fixed at approximately 80 m as shown in Fig. 6-6.

(c) Longitudinal Profile

The longitudinal profile is designed at 1:38 in consonance with the existing riverbed gradient. The design high water level is fixed below the landside ground height. (Refer to Fig. 6-7.)

(d) Cross Section

Single cross section is applied to all the river improvement stretch. (Refer to Fig. 6-7.)

(e) Riparian Facilities

The riparian facilities consist of revetment and groundsills at intervals of 50 m which will be both provided in the stretches from 18.45 km to 19.5 km and from 21.3 km to 21.4 km.

6.5.2 Preliminary Design

<u>Sediment Control Dam</u>

The sediment control facilities are structurally composed of the main dam, overflow section, subdam and apron, as shown in Fig. 6-8.

(1) Main Dam Type and Feature

The dam types generally applicable for sediment control dams are concrete, cobble stone concrete, steel frame, concrete block, and gabion mattress. The cobble stone concrete type has been selected for the proposed plan on account of least construction cost. (Refer to Table 6-3.)

The dam foundation is embedded down to 1.5 m below the existing riverbed to assure the stability of the dam body. The depth of 1.5 m is arrived at from the present situation of the unstable sediments. The crest width is designed at 2.0 m.

The dam slope in the downstream is fixed at 1:0.2 to avoid damage from the impact of falling overflow stones. In the upstream, the slope is set in the range of from 1:0.45 to 1:0.65 to provide endurance against any possible pressure.

The detailed dimension of each dam, together with the overflow sections, are shown in Table 6-4.

(2) Overflow Section

The overflow section is designed at such a position and direction that overflow water may easily concentrate to the center of the downstream in order to promote river channel stabilization. The size of this section is equally designed for all the dams so that a discharge of 1,250 m^3/s corresponding to a 100-year return period flood may flow down safely.

(3) Subdam and Apron

The subdam and apron, including the side walls, made of cobble stone concrete and wet masonry, respectively, are designed in the downstream of the dam, and they will function as scouring prevention facilities.

Riparian Facilities

The riparian facilities are revetment, groyne and groundsill. Revetment and groyne have the function of river bank protection against erosion, while groundsill is needed for the stabilization of the riverbed. Each structure has several types according to the construction materials involved.

(1) Applicable Structural Types

Each structure may be divided into four (4) types, which are further grouped into permanent and semi-permanent types according to durability. A comparative study on the types has been conducted in view of the construction and replacement costs to select the optimum type in each group for each structure as tabulated in Table 6-5. The applicable structural types are summarized as follows:

Structure	Type	Durability
Revetment	Wet Masonry	Permanent
	Gabion Cylinder	Semi-permanent
Groyne	Concrete	Permanent
	Crib	Semi-permanent
Groundsill	Concrete	Permanent
	Gabion Mattress	Semi-permanent

The suitable structural types for the respective river improvement sections were selected as follows:

(a) Achiguate River, 39.75 km to 40.4 km and 42.8 km to 43.0 km

Protection works are required for both the right and left banks in these sections where the road bridge and the railway bridge are located. Revetment and/or groyne can be suggested for the bank protection, but a groyne is not recommendable considering that a concrete groyne needs a higher construction cost compared to a revetment and that the water flow with a high velocity may destroy or wash away the crib groyne. A permanent structure of wet masonry is selected for the revetment.

Riverbed stabilization is also required for this section to secure the bridges against the damage that may be caused possibly by riverbed scouring. Concrete type (permanent structure) of groundsill is adopted for this plan.

(b) Achiguate River, 40.4 km to 41.7 km

Bank protection works should be provided on only the left side because on the right side bank lies a hilly land adjacent to the river course. Also, a wide high water channel having a maximum width of 600 m extends along the left side bank, so that revetment is not necessary. Even semi-permanent groynes are durable enough to protect the bank.

The permeable foot protection groyne made of cribs is employed for this section. No groundsill is provided.

(c) Pantaleon River, 18.45 km to 19.5 km and 21.3 km to 21.4 km

Bank protection and riverbed stabilization works are required for these sections to protect the road bridge and the railway bridge.

The wet masonry type of revetment is proposed because of the water flow of high velocity. As regards the groundsill, the concrete type is applied for the riverbed stabilization.

(2) Proposed Riparian Facilities

The riparian facilities necessary for the proposed plan, together with their objective river sections, is summarized in the following table and shown in Fig. 6-9.

Structure	Type	River	Section
Revetment	Wet Masonry	Achiguate	39.75 km to 40.4 km 42.8 km to 43.0 km
		Pantaleon	18.45 km to 19.5 km 21.3 km to 21.4 km
Groyne	Crib	Achiguate	40.4 km to 41.7 km
Groundsill	Concrete	Achiguate	39.75 km to 40.4 km 42.8 km to 43.0 km
		Pantaleon	18.45 km to 19.5 km 21.3 km to 21.4 km

(a) Revetment

The revetment of wet masonry type has a steep slope of 1:0.5 to suffer as little as possible from the damage caused by falling stones. The crest height is designed to coincide with the design bank crown. The foundation is embedded by 1.0 m below the design riverbed, and base concrete is placed thereunder to support the revetment. Gabion mattress is placed for the foot protection in a width of 3.0 m to prevent riverbed scouring at the foot of the revetment.

(b) Groyne

Groynes made of cone-shaped cribs in which gabion cylinders are placed for its stabilization are distributed along the bank line at intervals of 20 m.

(c) Groundsill

The crest width of the main body is designed at 1.0 m, and the foundation is embedded by 2.0 m below the design riverbed, i.e., the elevation of the foundation bottom is a little deeper than that of the crest of another groundsill installed in the downstream. Gabion mattresses are also placed on the downstream riverbed in a width of 6.0 m for the purpose of scouring prevention thereabout.

6.5.3 Construction Schedule and Cost

Construction Schedule

The construction works are broadly divided into construction of sediment control dams and construction of river improvement works.

In the proposed plan, major work items of sediment control dams include excavation, cobble stone concreting, and provision of wet masonry. Those of river improvement works consist of excavation, provision of wet masonry, concrete placing, and installation of gabion cylinder/mattress and groyne.

The construction works are executed in a period of five (5) years, including an engineering service period of one (1) year for the detailed design, which has been decided from the work volume of each work item. Fig. 6-10 shows the construction schedule which is briefly summarized as follows:

Work Stage	Year
(1) Detailed Design	1st
(2) Construction Works	
(a) Construction of A-1 Dam	2nd to 4th
(b) Construction of C-1 Dam	2nd to 4th
(c) Construction of P-2 Dam	2nd to 5th
(d) River improvement works in Achiguate	3rd to 5th
(e) River improvement works in Pantaleon	3rd to 5th

Cost Estimate

(1) Construction Cost

The total financial construction cost is estimated in foreign and local currency portions based on the contract basis at the price level of August 1984. The work quantities were estimated on the basis of the preliminary design which has been prepared during the study period. Unit prices related to the project implementation are in line with the recent bid prices for similar works. Physical contingencies of 10% have been applied to all the work items. Price contingencies are also taken into account at an annual escalation rate of 6% for both foreign and local currency components.

The estimated financial construction costs of the proposed plan are summarized in the following table, together with the percentages of the foreign and local currency components.

Foreign Currency	:	US$11.5 million	(56%)
Local Currency	:	US$ 9.0 million	(44%)
T o t a l	:	US$20.5 million	(100%)

The breakdown and the annual disbursement of the financial construction cost are shown in Tables 6-6 and 6-7, respectively.

(2) Operation, Maintenance and Replacement Cost

The operation, maintenance and replacement cost (OMR cost) will comprise personnel cost, machinery cost (sediment removal cost), replacement cost for the groyne and gabion mattress in every ten years, administration cost, and other miscellaneous costs.

The annual OMR cost is estimated at US$0.30 million.

6.6 Alternative Plan

The construction works of the alternative plan for the urgent sediment and flood control project is expected to be implemented subject to the limitation of the annual appropriation for the project. Therefore, the alternative plan has been formulated in consideration of (1) the possibility of stepwise construction, (2) easier construction method, and (3) availability of materials in the proximity of the construction site.

With regard to the sediment control plan for the Achiguate and the Pantaleon rivers, dam sites may be selected from two different ideas concerning the dam height; namely, to construct high dams which have the highest sediment regulation efficiency at a limited number of sites, or to provide low dams at several sites which may spread out in a wide area. The latter has been employed for the alternative plan on the ground that this can be stepwisely implemented by using the materials existing in the proximity of the sites.

6.6.1 Features of the Plan

Achiguate River

(1) Sediment Control

In compliance with the planning concept for the alternatives, the sediment control works are composed of four (4) dams, i.e., three for the Achiguate main stream and one for Ceniza River, whose detailed features are as follows (refer to Fig. 6-11):

Dam Name	Catchment Area (km^2)	Effective Height (m)	Crest Length (m)	Dam Body Volume (m^3)	Regulation Volume (10^3 m^3)
A-1	92.0	5.0	404	38,000	350
A-1'	87.0	3.5	401	21,000	111
A-2	39.0	5.0	101	9,000	90
C-1	112.0	4.5	424	35,000	119

(2) Flood Control

The location and extent of river improvement works, their alignment, longitudinal profile and cross section are the same as in the proposed plan, except the required riparian facilities.

The required riparian facilities are revetment and groundsills at an interval of 150 m (39.75 km to 40.4 km and 42.8 km to 43.0 km), foot protection groyne on the left side (40.4 km to 41.7 km).

Pantaleon River

(1) Sediment Control

Five (5) sediment control dams are proposed at P-2, P-2', P-3, P-4 and P-5, which have the following features (refer to Fig. 6-11):

Dam Name	Catchment Area (km^2)	Effective Height (m)	Crest Length (m)	Dam Body Volume (m^3)	Regulation Volume (10^3 m^3)
P-2	107.0	5.0	276	23,000	370
P-2'	64.0	4.0	308	21,000	101
P-3	62.0	5.0	167	16,000	105
P-4	61.0	5.0	170	14,000	180
P-5	60.0	5.0	158	18,000	220

(2) Flood Control

The location and extent of river improvement works, their alignment, longitudinal profile and cross section are the same as those in the proposed plan, except the required riparian facilities.

The riparian facilities consist of revetment and groundsills at intervals of 50 m (18.45 km to 19.5 km and 21.3 km to 21.4 km).

6.6.2 Preliminary Design

Sediment Control Facilities

The gabion mattress type is employed for the alternative plan, because only this type can be constructed with technically less difficulties and by using the available materials in the proximity of the construction sites.

The gabion mattress dam consists of main dam, overflow section, and apron as shown in Fig. 6-12.

(1) Main Dam

The riverbed for the foundation is only levelled off, and gabion mattresses are just placed thereon, because the gabion mattress dam has a relatively wide bottom in proportion to its height, and does not require a big bearing capacity. The dam has a crest width of 2.0 m, a downstream slope of 1:0.2 and an upstream slope of 1:1. The down-stream slope is designed steep for the same reason as that of the proposed plan. The dimensions are summarized in Table 6-4.

(2) Overflow Section

The design of the overflow section was prepared in the same way as in the proposed plan.

(3) Apron

Apron will be prepared by placing gabion mattress in a width of 12.0 m in the downstream of the dam to prevent riverbed scouring thereat caused by overflow water.

Riparian Facilities

The riparian facilities applied for the alternative plan are presented together with their objective river sections in the following table (refer to Fig. 6-13):

Structure	Type	River	Section
Revetment	Gabion Cylinder	Achiguate	39.75 km to 40.4 km 42.8 km to 43.0 km
		Pantaleon	18.45 km to 19.5 km 21.3 km to 21.4 km
Groyne	Crib	Achiguate	40.4 km to 41.7 km
Groundsill	Gabion Mattress	Achiguate	39.75 km to 40.4 km 42.8 km to 43.0 km
		Pantaleon	18.45 km to 19.5 km 21.3 km to 21.4 km

(1) Revetment

As for the revetment of gabion cylinder type, the slope is fixed at 1:1.5 for easier construction. The crest height is designed at the same elevation as the design bank crown. Cylinders are also placed on the riverbed in a width of 3.0 m from the toe of slope so that riverbed lowering may not directly affect the gabion cylinder on the slope.

(2) Groyne

The groyne of crib type is designed in the same precept as those for the proposed plan.

(3) Groundsill

Gabion mattresses are embedded by 1.0 m below the design riverbed. Three (3) units of mattress of 3.0 m wide each are placed adjacent to each other in a total length of 9.0 m to cope with the riverbed fluctuation.

6.6.3 Construction Schedule and Cost

Construction Schedule

The alternative plan has major work items such as excavation and installation of gabion mattress for the construction of sediment control dams, and excavation, installation of gabion cylinder/mattress and groyne for the river improvement works.

The schedule of construction works has been decided in this study as five (5) years, same as in the proposed plan, for comparison of their economic viabilities, as summarized hereunder. It may be necessary to make amendments or alterations by following the expected annual budget allocation at the time of actual implementation. (Refer to Fig. 6-14.)

Work Stage	Year
(1) Detailed Design	1st
(2) Construction Works	
(a) Construction of dams in Achiguate	2nd to 3rd
(b) Construction of dams in Pantaleon	4th to 5th
(c) River improvement works in Achiguate	3rd to 5th
(d) River improvement works in Pantaleon	4th to 5th

Cost Estimates

(1) Construction Cost

The total financial construction cost of the alternative plan is summarized hereunder, together with the percentages of the foreign and local currency components:

Foreign Currency:	US$10.7 million	(49%)
Local Currency :	US$11.1 million	(51%)
T o t a l :	US$21.8 million	(100%)

The breakdown and annual disbursement of the financial construction cost are shown in Tables 6-8 and 6-9, respectively.

(2) Operation, Maintenance and Replacement Cost

The operation, maintenance and replacement cost (OMR cost) will comprise the same items as the proposed plan. The annual OMR cost is estimated at US$0.64 million.

CHAPTER VII. PROJECT EVALUATION

7.1 General

The proposed plan for the long-term sediment and flood control project has been formulated, as described in Chapter V, on the basis of social requirement in due consideration of financial, economic and technical aspects. The proposed and alternative plans for the urgent project with a smaller scale than the long-term project were also formulated, as described in Chapter VI, based on economic, financial, social and technical aspects.

In the present chapter, the project is evaluated from a purely economic standpoint with respect to the above three (3) plans.

The economic evaluation is carried out in order to ascertain the economic viability, by comparing the economic cost to be invested for the project and the economic benefit that will accrue by implementing the project. The economic viability is evaluated by Economic Internal Rate of Return (EIRR), Net Present Value (NPV) and Benefit-Cost Ratio (B/C), and the sensitivity test for EIRR of the optimum urgent plan is made with respect to variations in cost and/or benefit.

The evaluation is based on the following assumptions:

(1) Economic Life

The economic life of the project is taken as 30 years after completion of the construction works.

(2) Direct Tangible Benefits

Mainly, direct tangible benefits are counted in the evaluation, and indirect and/or intangible benefits are described as socio-economic impacts of the project in Section 7.5.

(3) Implementation Period

The implementation period of the project is seven (7) years for the long-term plan and five (5) years for the urgent plan, including the detailed engineering service periods of two (2) years and one (1) year, respectively.

7.2 Conditions and Methodology for Estimation of Economic Cost and Benefit

7.2.1 Prices

In estimating the economic cost and benefit, the economic prices are assumed to be as follows:

(1) Foreign exchange rate is set at Q1.00 to US$1.00 on the basis of the following situations:

(a) Official exchange rate is Q1.00 to US$1.00 at present.

(b) Shadow exchange rate (SER) is nearly equal to 1.00 in recent years, as shown in Table 7-1.

(2) Economic prices of locally hired unskilled laborers is assumed to be 70% of the actual market prices in consideration of the unemployment situation in the country in recent years.

(3) As for transfer payment such as tax and duty, it is assumed that locally procured goods and services would include the transfer payment of 10% of their prices and those imported from abroad would exclude any transfer payment.

(4) The cost and benefit estimates are made on the basis of the price level in August 1984.

7.2.2 Costs

The financial construction costs, as described in Chapter V and Chapter VI, consist of the following items:

(1) direct construction cost;
(2) land acquisition cost and compensation;
(3) government administration expenses;
(4) engineering service charges;
(5) physical contingencies; and
(6) price contingencies.

Among the above costs, price contingencies are not included in the economic construction cost. Other costs are given as the economic cost by making adjustments on the aforementioned economic prices.

Annual operation, maintenance and replacement cost (OMR cost) is required during the period of economic life of the project after the construction work is completed. The OMR cost for the construction period is estimated by assuming that the cost would be increased in proportion to the progress of the construction works. The economic OMR cost is also given by making adjustments on the said economic prices.

7.2.3 Benefits

Direct tangible benefits of the project are given as the economic effects of reduction in sediment and flood damage to assets around and in the flooded area.

The benefits will accrue immediately after the construction works are completed. Partial benefits that will accrue during the construction period are estimated in the same way as in the

OMR cost, assuming that the benefits would be increased in proportion to the progress of the construction works.

Assets to be Bnefitted

The major assets to be benefitted by this project are:

(1) Road and railway bridges;
(2) Transportation system;
(3) Houses and household effects;
(4) Agricultural products;
(5) Business activities; and
(6) Public facilities, except (1) above.

Based on collected information and results of field surveys, the assets are appraised as follows:

(1) Road and Railway Bridges

The road bridge and the railway bridge over the Achiguate and the Pantaleon rivers are appraised at the 1984 prices based on the information from CAMINOS and FEGUA, as follows:

Bridge	Appraisement (US$$10^3$)
Achiguate Road Bridge	1,000
Pantaleon Road Bridge	750
Achiguate Railway Bridge	230
Pantaleon Railway Bridge	420

(2) Transportation System

The average daily traffic volume at Sta. 200[1/] on CA-2 is estimated at 4,500 vehicles in 1984 and 6,000 vehicles in

1/ Kilopost which is 78 km away from the Municiaplity of Guatemala.

2010 on the basis of the traffic statistics by CAMINOS. The former is applied to the estimation of benefit for the urgent plan and the latter, for the long-term plan.

The volume of goods and number of passengers transported by railway are assumed to be 5% of those by the road, according to the information from FEGUA.

(3) Houses and Household Effects

Based on the 1981 housing census, the number of houses in the Study Area is estimated at 405 houses per square kilometer in the urban area and 13 houses per square kilometer in the rural area in 1984, and its average annual growth rate was 2.81% for the period from 1973 to 1981.

By assuming that such a growth will be maintained, the number of houses in the urban and rural areas in the year 2010 is estimated to be 810 houses and 26 houses per square kilometer, respectively. These figures were used for the estimation of the project benefit for the long-term plan.

As for the urgent plan, it is, on the basis of the present study, estimated that 28 farmhouses in the Study Area will be submerged due to flood discharges of over 2-year return period.

The Study Area contains various types of buildings, such as residential, farmhouse, shop, factory, office, church, etc., and their appraisements are also multifarious. Since it is difficult to appraise these buildings individually, in the present study, the farmhouse, which occupies the greater part of buildings in the Study Area, is adopted as the object of asset evaluation. For convenience, all buildings are described as houses in this report.

Based on the site study, the appraisement of houses is set at Q3,750 per house on the average. The appraisement of household effects is estimated at one-third (1/3) of that of houses in conformity to the studies of similar projects in Guatemala.

(4) Agricultural Products

The unit yields of agricultural products were estimated on the basis of production and cultivated area of each crop in recent years in the Department of Escuintla. The values were used not only for the urgent plan but also for the long-term plan, because the unit yields of major crops in the Department of Escuintla remain almost unchanged since 1973. The unit yields of the major crops, together with their economic prices, are shown in Table 7-2.

Rates of Damage to Assets

(1) Road and Railway Bridges

It is assumed that two (2) bridges on the railway will be washed away by floods with discharges of over 2-year return period, based on the study result on the past floods. In this case, the damage is given as loss in appraisement of the railway bridge shown in (2) of the present subsection.

As for the two (2) road bridges on CA-2, it is assumed that a part of the bridge structure will be damaged by floods with discharges of over 2-year return period, and the damage amount is given as the repairing cost, which corresponds to 5% of the appraisement of the road bridges shown in (2) of the present subsection.

(2) *Transportation System*

The flood damage to transportation system was mainly studied on the road traffic, because the transportation volume by railway is very little.

Traffic on CA-2 is presumed to be interrrupted by floods with discharges of over 2-year return period, based on the study on floods of the Achiguate and the Pantaleon rivers in the past. During the period of the traffic interruption, the concern of passengers and offices will be to select from either waiting or making detours using other roads. Based on the origin and destination survey on CA-2 and conditions of roads connecting to CA-2, it was estimated that;

(a) About 90% of the number of vehicles running on CA-2 in the Study Area will come from or go to Guatemala City, Escuintla, or their surrounding areas.

(b) Due to the interruption of traffic on CA-2, the above-mentioned vehicles will select the CA-1 route through Cocales and Godinez from the economical viewpoint.

In this case, the damage will be given as the increase in running distance and time of vehicles. The damage to the waiting vehicles will be estimated as the loss due to suspension of business activities.

Goods and passengers to be transported by railway will also select either waiting or making the conversion from railway into road until the damaged bridges are restored.

In the present study, the flood damage to railway transportation is simply assumed to be 5% of the damage to road transportation, in proportion to the transportation volume by either road or railway.

(3) Houses, Household Effects and Agricultural Products

The damage rate of the assets submerged will be given as a function of the water depth and duration of submergence. However, since there are no available data in this country, the damage rate used in the tropic zone has been applied to this study.

Table 7-3 shows the damage rate of the assets, such as houses, household effects and agricultural products.

(4) Business Activities

Some aspects of the business activities of inhabitants and offices around and in the inundated area will be suspended during the period of inundation. Since it is, however, very difficult to clearly estimate such a loss in the present study, the loss is assumed to be 6% of the total damage to houses and household effects, with reference to similar projects in the tropic zone.

(5) Public Facilities

Public facilities in the Study Area, such as electric power system, water supply system, agricultural facilities and roads, except the bridges on the CA-2 road and the railway mentioned earlier, will be damage due to the inundation. However, it is also difficult to clearly estimate the damage. In the present study, the damage is therefore assumed to be 60% of the total damage to houses and household effects, in the light of similar projects in the tropic zone.

Economic Benefit

Sediment and flood damage has been estimated for the respective probable discharges.

The average annual sediment and flood damage can be estimated by integrating the product of the damage caused by sediment and flood discharges and the probability of occurrence of the same sediment and flood discharges from the innocuous discharge to the infinitely large discharge.

The project benefit is given as the difference between both damages with and without the project, and it is expressed as the effect of reduction in the average annual sediment and flood damage.

7.3 Evaluation of the Long-Term Plan

7.3.1 Economic Cost

The economic construction cost of the project under the proposed long-term plan is estimated at US$46.6 million, consisting of the foreign currency portion of US$28.6 million and the local currency portion of US$18.1 million. The annual disbursement of economic construction cost is shown in Table 7-4.

The economic operation, maintenance and replacement cost (OMR cost) is estimated at US$500 thousand a year throughout the period of economic life of the project after the construction work is completed. The annual flow of O & M cost including those for the construction period is also given in Table 7-4.

7.3.2 Economic Benefit

The total area inundated due to floods of the Achiguate and the Pantaleon rivers is estimated at about 14,300 ha. Water depths were estimated for the respective probable flood discharges, as shown in Table 4-3. Out of the inundated area, the area of 3,271 ha including 2,054 houses may be saved from inundation by a flood of less than 30-year return period by implementing the long-term plan. The breakdown of the inundation area is shown in Table 6-7 of Sector 6 of the Supporting Report.

The benefits, which accrue by the reduction in the sediment and flood damage to assets such as houses, household effects and agricultural products, were estimated by using the above inundation area and water depths, together with the appraisement of houses and household effects, and unit yields and prices of agricultural products described in Subsection 7.2.3.

The economic annual benefit under the proposed long-term plan, which will accrue during the period of economic life of the project, is estimated at US$3,478 thousand, consisting of the following items:

	Item	Annual Benefit (US$$10^3$)
(1)	Railway Bridges	465
(2)	Road Bridges	126
(3)	Transportation System	1,179
(4)	Houses and Household Effects[1/]	651
(5)	Agricultural Products	1,057
	T o t a l	3,478

The annual flow of benefit, including partial annual benefits that accrue for the construction period, is also given in Table 7-4.

7.3.3 Economic Evaluation

EIRR, together with B/C and NPV in cases discounted at the rates of 5% and 6%, is summarized as follows:

Item	EIRR (%)	B/C Discount Rate (5%)	B/C Discount Rate (6%)	NPV (US$$10^3$) Discount Rate (5%)	NPV (US$$10^3$) Discount Rate (6%)
Proposed Long-Term Plan	5.1	1.01	0.92	446	-3,411

1/ Includes benefits for business activities.

The result shows that the project under the proposed long-term plan is relatively of a low economic viability.

This result gives a general evaluation of the long-term plan from the economic viewpoint. Further study on the economic evaluation will be carried out for the urgent plan, as described in the succeeding section.

7.4 Economic Evaluation for the Urgent Plan

7.4.1 Economic Cost

The economic construction cost of the project under the urgent plan has been estimated as follows:

Plan	Foreign Currency (US$$10^6$)	Local Currency (US$$10^6$)	Total (US$$10^6$)
Proposed Plan	8.8	5.8	14.6
Alternative Plan	8.3	7.3	15.6

The annual disbursements of the economic construction costs are shown in Tables 7-5 and 7-6.

The annual OMR cost is estimated at US$260 thousand for the Proposed Plan and US$540 thousand for the Alternative Plan during the period of economic life of the project after the construction works are completed. The annual flows of OMR costs, including those for the construction period, are also given in Table 7-5 and 7-6.

7.4.2 Economic Benefit

The area which may be saved from the inundation by floods of less than 10-year return period by implementing the urgent plan is estimated at 291 ha together with 28 houses, as shown in Table 6-10 of Sector 6 of the Supporting Report.

The benefits, which accrue by the reduction in the sediment and flood damage to assets such as houses, household effects and agricultural products, are estimated by using the above figures together with the appraisements of houses and household effects, and the unit yields and prices of agricultural products described in Subsection 7.2.3.

The economic annual benefit of the project under the urgent plan is estimated at US$1,465 thousand each for the proposed and alternative plans, consisting of the following items:

	Item	Annual Benefit ($US\$10^3$)
(1)	Railway Bridges	422
(2)	Road Bridges	114
(3)	Transportation System	802
(4)	Houses and Household Effects1/	38
(5)	Agricultural Products	89
	T o t a l	1,465

The benefits will accrue during the period of economic life of the project. The annual flows of benefit, including partial benefit which will accrue for the construction period, are shown in Tables 7-5 and 7-6.

7.4.3 Economic Evaluation

EIRR of the project under the urgent plan is estimated at 7.3% for the Proposed Plan and 4.4% for the Alternative Plan,

1/ Includes benefit for business activities and public facilities such as electric power and water supply systems, agricultural facilities and roads in the inundation area.

as shown in the following table together with B/C and NPV in cases discounted at the rates of 6% and 7% a year.

Plan	EIRR (%)	B/C Discount Rate (6%)	(7%)	NPV (US$$10^3$) Discount Rate (6%)	(7%)
Proposed Plan	7.3	1.12	1.06	1,779	774
Alternative Plan	4.4	0.93	0.87	-1,211	-2,152

EIRR of the project is not so high for either of the two plans, but EIRR for the proposed plan exceeds somewhat the standard rate of 6.5% mentioned in Chapter IV; therefore, it has been identified to be economically viable.

In addition to the above, it must be emphasized that the project has the social needs more seriously, and its implementation will generate great socio-economic impacts, as described in the succeeding section.

The economic viability of the project is further discussed under Sensitivity Test.

7.4.4 Sensitivity Test

Sensitivity tests were made for the variations in cost and/or benefit by 5% for the EIRR of the proposed urgent plan, and the results are summarized as follows:

Case	EIRR (%)
5% decrease in benefit	6.7
5% increase in cost	6.8

In the cases of 5% decrease in benefit and 5% increase in cost, EIRR still holds a higher rate than the standard rate of 6.5%, and it is identified to be economically viable.