REPUBLIC OF COSTA RICA
SERVICIO NACIONAL DE AGUAS SUBTERRANEAS
RIEGO Y AVENAMIENTO (SENARA)

LIMON INTEGRATED AGRICULTURAL DEVELOPMENT PROJECT

(THE FEASIBILITY STUDY)

VOLUME I

MAIN REPORT

OCTOBER 1988

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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PREFACE

In response to the request of the Government of the Republic of Costa Rica, the Japanese Government decided to conduct a survey on the Limon Integrated Agricultural Development Project and entrusted the survey to the Japan International Cooperation Agency (JICA). JICA sent to Costa Rica a survey team headed by Mr. Yasuo Maeda, Naigai Engineering Co., Ltd., from February 1987 to March 1988.

The team exchanged views with the officials concerned of the Government of Costa Rica. 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.

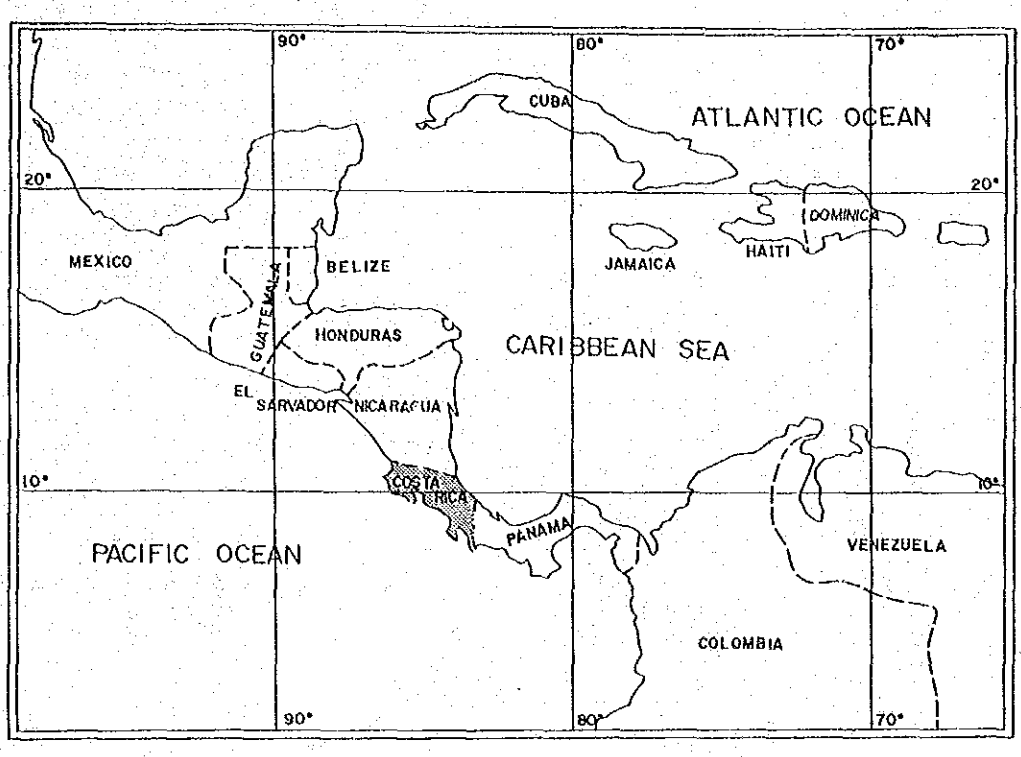
I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Costa Rica for their close cooperation extended to the team.

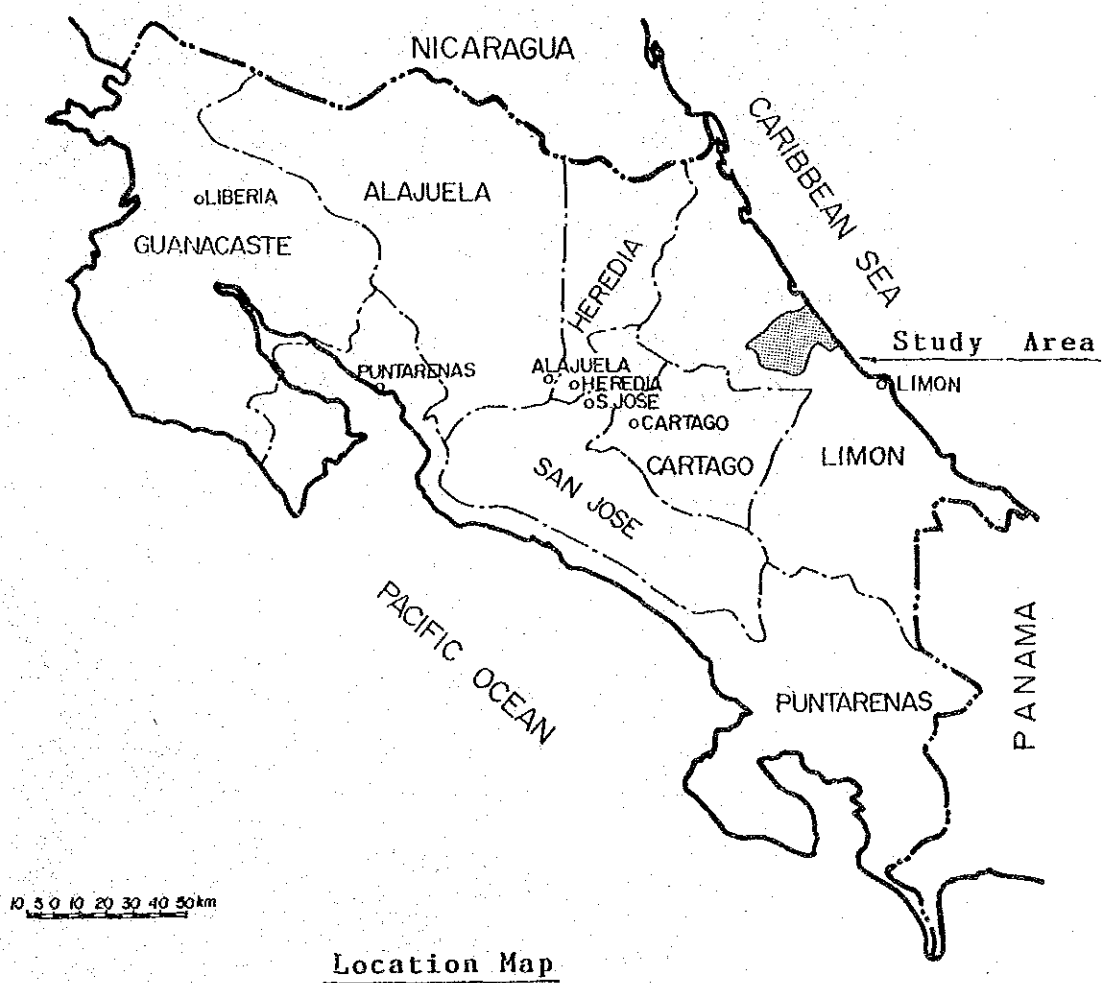
October 1988

Kensuke Yanagiya

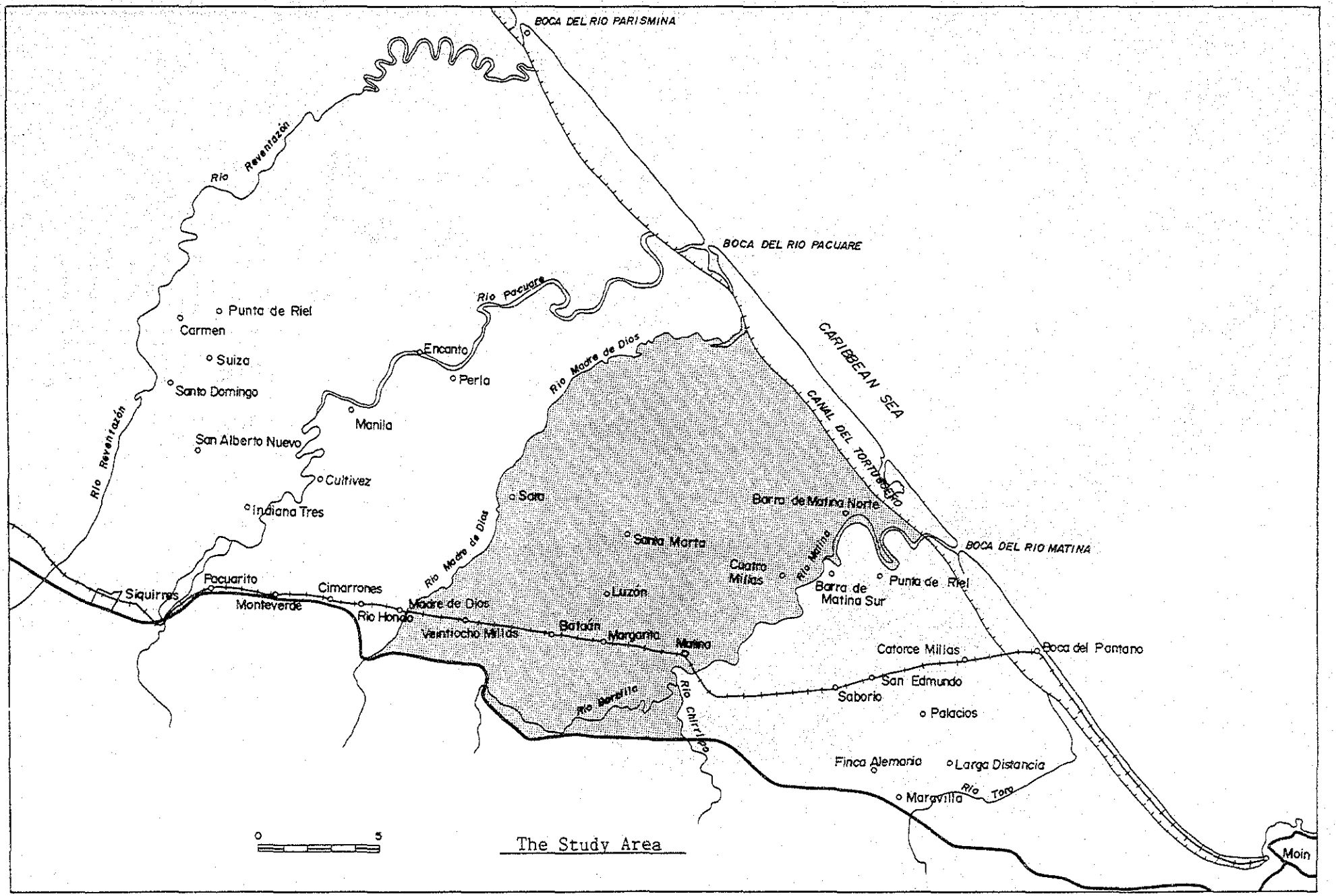
President

Japan International Cooperation Agency





Location Map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Perla
Manila
San Alberto Nuevo
Cultivez
Indiana Tres
Rio Reventazón
Rio Madre de Dios
CARIBBEAN SEA
CANAL DEL TORTUGUERO
Sara
Barra de Matina Norte
Santa Marta
Cuatro Millas
Rio Matina
BOCA DEL RIO MATINA
Barra de Matina Sur
Punta de Riel
Siquirres
Pacuarito
Cimarrones
Monteverde
Rio Hondo
Madre de Dios
Luzón
Veintiocho Millas
Batán
Margarita
Matina
Catorce Millas
Boca del Pantano
San Edmundo
Saborio
Palacios
Rio Bonilla
Rio Chirripo
Finca Alemania
Larga Distancia
Rio Toro
Margvilla
Moin
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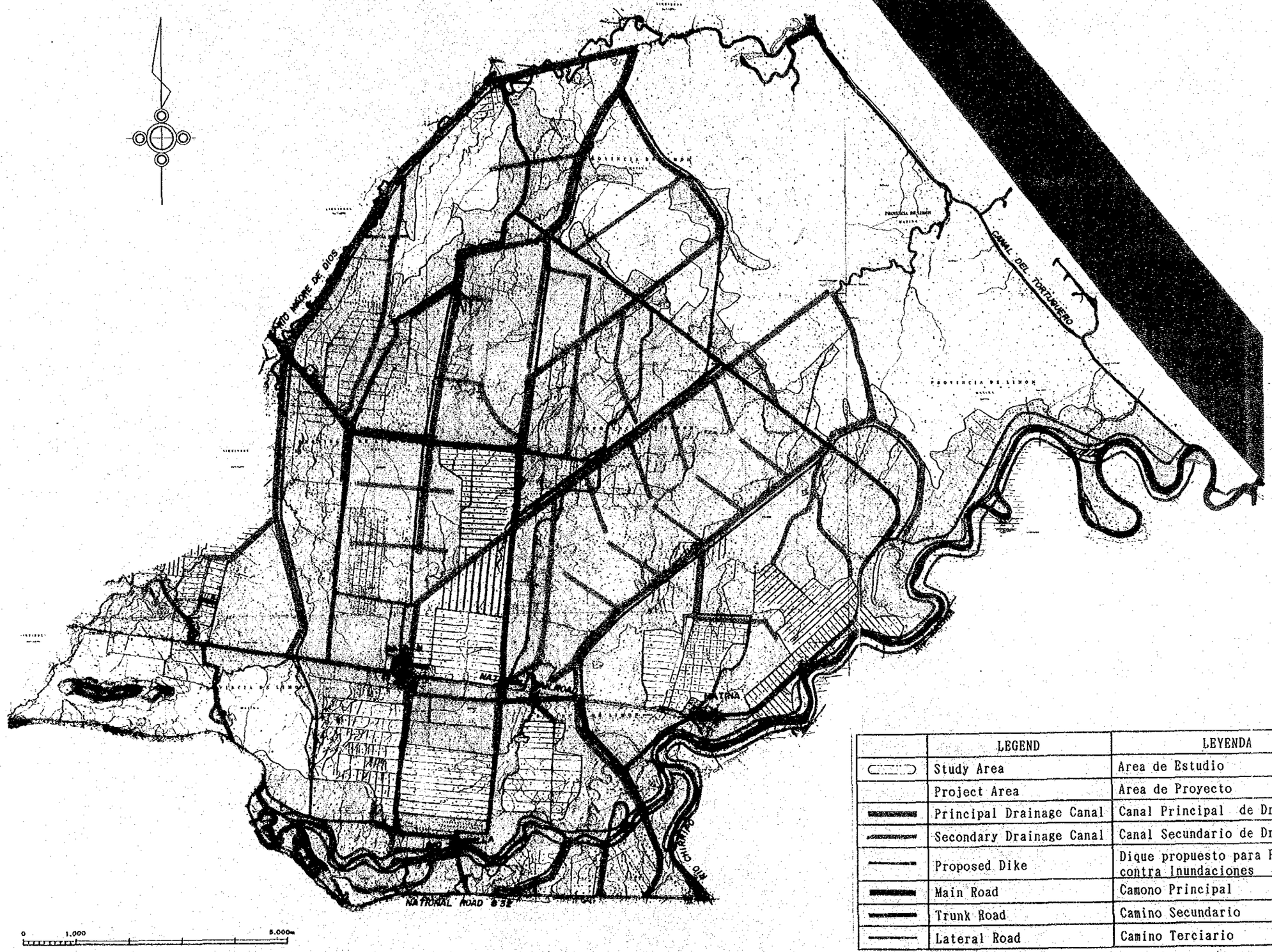
The Study Area

GENERAL PLAN
PLANO GENERAL



	LEGEND	LEYENDA
	Study Area	Area de Estudio
	Project Area	Area de Proyecto
	Principal Drainage Canal	Canal Principal de Drenaje
	Secondary Drainage Canal	Canal Secundario de Drenaje
	Proposed Dike	Dique propuesto para Proteccions contra Inundaciones
	Main Road	Camono Principal
	Trunk Road	Camino Secundario
	Lateral Road	Camino Terciario

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ABBREVIATIONS

Institutions and Organizations

ASBANA	Asociación Bananera Nacional	National Banana Association
BAC	Banco Anglo Costarricense	Anglo Bank of Costa Rican
BCAC	Banco Crédito Agrícola de Cartago	Agricultural Credit Bank of Cartago
BCCR	Banco Central de Costa Rica	Central Bank of Costa Rica
BCR	Banco de Costa Rica	Bank of Costa Rica
BID	Banco Interamericano de Desarrollo	Interamerican Development Bank
CATIE	Centro Agronomico Tropical de Investigación y Enseñanza	Investigation and Education Center for Tropical Agriculture
CNP	Consejo Nacional de Producción	National Production Council
FAO	Organización de las Naciones Unidas para la Agricultura y la Alimentación	Food and Agriculture Organization of the United Nations
ICCA	Instituto Costarricense de Acuaductos y Alcantarillado	Water Supply and Sewerage Institute of Costa Rica
ICE	Instituto Costarricense de Electricidad	Electric Institute of Costa Rica
IDA	Instituto de Desarrollo Agrario	Agrarian Development Institute
INFOCOOP	Instituto Nacional de Fomento Cooperativos	National Cooperative Fomentation Institute
INS	Instituto Nacional de Seguros	National Insurance Institute
JAPDEVA	Junta de Administración Portuaria de Desarrollo Económico de la Vertiente Atlántica	Board for Administration of Ports and Development of the Atlantic Basin
MAG	Ministerio de Agricultura y Ganadería	Ministry of Agriculture and Livestock

MIDEPLAN	Ministerio de Planificación Nacional y Política Económica	Ministry of National Planning and Economy Policy
MOPT	Ministerio de Obras Públicas y Transportes	Ministry of Public Construction and Transport
SENARA	Servicio Nacional de Aguas Subterraneas Riego y Avenamiento	National Ground Water, Irrigation and Drainage Service

Monetary Unit

¢	Colon Costarricense	Costa Rican Colon
US $	Dolar Americano	United States Dollar

Economic Term

B/C	Razon Entre Beneficio y Costo	Benefit-cost Ratio
CIF	Costo de Seguro y Flete	Cost, Insurance and Freight
EIRR	Tasa Interna Económica de Retorno	Economic Internal Rate of Return
ENPV	Valor Económico Actual Neto	Economic Net Present Value
FIRR	Tasa Interna Financiera de Retorno	Financial Internal Rate of Return

Others

BOD(DOB)	Demanda Bioquímica de Oxigeno	Biochemical Oxygen Demand
DO (OD)	Oxigeno Disuelto	Dissolved Oxigen
EC (CE)	Conductividad Eléctrica	Electric Conductivity
pH	Concentración de ion hidrogeno	Hydrogen-ion Concentration
D.A.	Area de Drenaje	Drainage Area
EL.	Sobre nivel del mar	Elevation Above Mean Sea Level
MSL	Principal Nivel de mar	Mean Sea Level
GL.	Nivel de Tierra	Ground Level

SUMMARY

Summary

1. Introduction

1) Limon Integrated Agricultural Development Project was initiated in accordance with the Scope of Work agreed between the Japan International Cooperation Agency (JICA) and the Government of Costa Rica in August 1986.

2) A study team of eleven experts headed by Mr. Yasuo Maeda was sent by JICA and conducted field studies on three occasions from February 1987. The first two studies were made to draw up a master plan covering the whole Limon area, and the last study was a feasibility study conducted on the Zone B which had been given top priority as the result of the surveys based on the Master Plan.

3) The study covered an area of 19,500 ha located along the Atlantic Coast in Limon Province in the eastern part of Costa Rica.

The Area covered, in spite of the heavy annual rainfall, is burdened with basic agricultural problems including stagnant water and inferior drainage, mainly due to poor drainage facilities. As a result, the agricultural development in this Area has progressed very slowly, but the planting of the perennial crops such as banana, cacao and etc. has been conducted by business enterprises.

4) The objectives of the Study are to provide comprehensive agricultural development in this Area, to form agricultural development plan and implementation programs in line with the Master Plan, and to study their technical and economic viability.

2. Background of the Project

1) The Study Area, having the heavy annual rainfall, is laden with the problems on agricultural foundation such as poor drainage and inundation damage which are mainly caused by lack of drainage facilities. Hence this Area is backward in agricultural development except for the cultivation of perennial crops such as

bananas and cacao by private enterprises.

2) Under this situation, the Government of Costa Rica requested the Japanese Government a technical cooperation in formulating the Limon Integrated agricultural Development Project in November 1980.

3) In response to this request, JICA started a field study in February 1987. As a result, a master plan of the Project was formulated in October 1987, and the Zone B, as an area having the highest priority in implementation of the Project, was selected simultaneously.

3 Present Situation in the Area

3.1 General

1) Location

The feasibility study covered an area located along the Caribbean Sea in Limon Province in the eastern part of Costa Rica. Almost at the center of the Study Area covered by the Master Plan, it measures about 22 km by 16 km for a total area of 19,500 ha. It is about 160 km from San Jose, the capital of the country.

2) Topography

The highest point in the Area is 110m and the lowest about zero m. The area by elevation above sea level is as follows:

Area by Elevation

Elevation	Area (ha)	Ratio (%)
110 to 80 m	45	0.2%
80 to 60 m	80	0.4%
60 to 20 m	1,030	5.3%
20 to 10 m	4,925	25.2%
10 to 2 m	10,310	52.9%
2 m or less	3,110	16.0%
Total	19,500	100.0%

3) Climate

The Area belongs to the tropical rainforest climate zone with an annual rainfall of 3,520 mm. February, March, September and October have light rainfall, while the other months have much rain. Rainfall is the least in March at about 140 mm, and greatest in December at about 460 mm. The average annual temperature is of 25.3°C. The lowest temperature is of 19.6°C registered in January.

4) Population

The Area belongs to the administrative jurisdiction of Matina and Bataan districts, Matina County, Limon Province. The population of the two districts is 3,964 and 6,712 respectively according to the census conducted in 1984. About 70% of the population reside in farmlands and are engaged in agriculture. Many of them are part-time farmers.

3.2 Soil Condition

The soils in this Area, roughly classified, comprise alluvial soil which is superior in chemical properties and is fertile. It is therefore suitable for planting. Nevertheless, this advantage is not fully utilized due to the unsatisfactory drainage facilities.

Soil Classification

Order	Area (ha)	Ratio (%)
Entisol	7,808	36.3
Inceptisol	12,130	62.2
Ultisol	290	1.5
Total	19,500	100.0

According to the USDA method used in Costa Rica, the land was classified as follows, taking the drainage conditions into consideration.

Land Classification

Classification	Suitability for Field Crop	Area (ha)	(%)
I	Highly suitable	-	-
II	Moderately suitable	9,925	50.9
III	Suitable	620	3.2
IV	Marginally suitable	4,080	20.9
V	Suitable for pasture & forests	-	-
VI	Only available for forests	290	1.5
VII	Only available for pasture & forests	4,585	23.5
Total		19,500	100.0

This shows that land which could be effectively used for agriculture in this Area measures about 14,625 ha. Class VI and VII are not included in the total.

3.3 Drainage Conditions

No drainage canals are found in the Area except those constructed for banana plantations. Drainage is discharged into rivers, but owing to the absence of drainage canals leading from fields to rivers, rainwater collecting in low-lying areas and hollow land cannot be discharged quickly and often causes inundation. Inundation of such low-lying areas and hollow land occurs 3 - 4 times a year, in a depth of about 30 - 50 cm and lasts for 3 - 4 days. From the results of the survey, the poor drainage area is of 11,670 ha, and including the permanent swamp area of 3,380 ha along Canal del Tortuguero, the total inundation area is as large as 15,050 ha.

In the greater part of the farmland area, therefore, the drainage condition is poor and the groundwater table is high through the year. The groundwater table averages as high as 0.3 to 0.5 m below the ground surface, which makes the soil moisture in the farmland too large.

3.4 Flood Situation

Rivers flowing through the Area do not have a cross-section area large enough to ensure a smooth downflow of flood discharge in their midstream and downstream sections. When there is a heavy rainfall, flood overflows and causes damage to crops. In particular, large rivers have a

very large flood discharge because they have mountainous watershed areas where the rainfall reaches an annual average of as high as 3,700 mm. The estimated flood yield discharge ranges from 1.6 to 2.0 $m^3/s/km^2$ with the probability of 5 years.

3.5 Land Use

92% of the whole area is privately owned. The present land use in the Area is as follows.

Present Land Use

Classification	Area (ha)	Ratio (%)	Remarks
Annual Crop Land	4,340	22.3	Including 810 ha of fallow land
Bananas	1,960	10.1	Enterprise, Cooperative
Cacao	1,540	7.9	
Plantains, Coconuts	620	3.2	
Pasture	3,510	18.0	
Virgin forests	3,380	17.3	Along the Canal del Tortuguero
General forests	1,740	8.9	
Abandoned plantations	1,550	7.9	Banana, Cacao
Others	860	4.4	
Total	19,500	100.0	

(Note) Others include urban areas, roads, canals and institutes' lots.

3.6 Agriculture

There are 1,822 farm households in the Area of which 1,127 are settled farmers. Plants cultivated include such perennial crops as bananas, cacao, coconuts and plantain (edible banana) and such annual crops as rice, corn, kidney beans and tuber crops. The perennial crops are intended mainly for export. The annual crops, on the other hand, are for domestic consumption and are mostly self-supplied except for rice.

The current cropping area, as shown in the table below, covers 6,870 ha, representing 57% of the total farmland including the pasture. Crops excepting bananas are mainly produced on small scale by small-scale farmers with holdings of less than 12 ha. In the farmlands excluding banana plantations, frequent flood and insufficient drainage facilities

become a stumbling block to an increase in planting area and improved productivity.

The agricultural productivity except for banana, as shown in the table below, is lower than the national average. This low productivity in spite of favorable climate conditions is primarily attributable to the insufficient drainage facilities and the low planting techniques.

Cropping Area and Production

Crop	Area (ha)	%	Yield (ton/ha)		Production (ton)
1. Perennial:				1/	
Bananas	1,180	16.8	43.3	(43.4)	51,100
Cacao	1,540	24.4	0.25	(0.3)	390
Coconuts	320	4.4	2.2	(3.6)	700
Plantains	300	4.3	5.5	(10.5)	1,650
Sub-total	3,340	49.9	-	-	-
2. Annual:					2/
Rice	2,900	41.1	3.0	(3.3)	17,400
Maize	350	5.0	1.2	(1.7)	420
Kidney beans	40	0.6	0.5	(0.7)	20
Tuber crops	240	3.4	6.0	(6.8)	1,440
Sub-total	3,530	50.1	-	-	-
Total	6,870	100.0	-	-	-

Note: 1/ National average yield, 2/ Double cropping

3.7 Agricultural Economy, Marketing and Extension Services

1) Agricultural Economy

According to the results of a farm management survey, the small-scale farmers making up 80% of all farm households find it difficult to make ends meet with only agricultural income. Many farmers, therefore, take jobs on banana plantations, etc. Their non-agricultural income accounts for about 50% of their total income.

2) Agricultural Extension Services

Agricultural extension services are offered by the Ministry of Agriculture and Livestock (MAG) to the existing farm households, and by the Agricultural Land Development Institute (IDA) to new

settlers, but authorities are unable to provide services to all farm households because of the shortage of extension workers. It can be said, however, that farmers in the new settlement areas are given more intensive extension services than those in the existing farmland areas.

3) Agricultural Marketing

Bananas are exported to the U.S. and Europe through an exclusive marketing route. Tuber crops, on the other hand, are exported to the U.S. by trading companies operating in the Area. The export volume of tuber crops, though negligible at the present time, is steadily increasing every year. Considering the number of Spanish immigrants in the U.S., the demand for tuber crops is expected to increase considerably. The other crops are generally collected by brokers and sent mainly to San José because no large markets or processing facilities are found in or near the Area.

4) Farmers' Organization

Two farmers' cooperatives exist in the Area. These cooperatives handle the production and management of banana plantations, including processing for grading, washing and packing. Moreover, other cooperatives take charge of the production and sale of plantains, cacao and fruits.

On the other hand, the three (3) consumers' cooperatives are involved in supermarket activities at the center of the town.

There are additional groups committed to the improvement of the local environment in each village, but their activities are not significant.

3.8 Settlement and Land Consolidation

1) Settlement

Settlement in the Area has been promoted by IDA since 1965. By 1984, farmers had completely settled on an area of 9,930 ha (1,127 farm households). Each household has purchased 8.8 ha of farmland on the average. No other settlement is planned at present in the Area.

2) Farm Villages

The villages in the Area are of street-side type (10%), colony type (25%) or scattered type (65%). The reason for the greater portion making up the scattered type is that settled farmers are obligated to live on or near their respective farmland.
Subsequently no utilities are available to the scattered type villages. Each farmhouse depends on a shallow well for its drinking water, which is considerably polluted according to tests conducted at the site. This water is, therefore, dangerous to drink without boiling. Sewerage systems are also lacking, adversely affecting the quality of the water in the wells.

3) Land Consolidation

The farmland in the Area is not substantially equipped with drainage canals or farm roads except in the banana plantations. In the latest settlement areas, however, roads are constructed by IDA and the farmlands are arranged to face these roads, but such areas are only about 700 ha in total according to the field survey.

3.9 Social Infrastructure

The social infrastructure in the Area is not yet established. Roads leading to the banana plantations, though unpaved, are in comparatively good condition. Other roads, however, are left in such bad conditions that many of them are blocked by rainfall. The road conditions get worse further away from the national routes. There are substantially no farm roads in general farmlands except the banana plantations and some

settlements.

Schools, though not in short supply, are understaffed. The medical facilities are small public health centers built in major communities. The extension of telephone service to farming areas is very low, although a plan is under way for a telephone network. Electricity is the most-widely extended item of social infrastructure, and is distributed to almost all farm households in all settlements.

4. Development Plan

4.1 Basic Concept

The Area has low agricultural productivity and is underdeveloped mainly due to insufficient drainage facilities. Nevertheless, some banana plantations fully equipped with drainage systems achieve the highest productivity in Costa Rica. There are also areas where the rice yield is as high as 3.0 t/ha in spite of damage suffered from stagnant water. All these facts tell of a high potential for agricultural productivity in the Area. One of the main factors retarding agricultural development in this Area is the low agricultural productivity stemming from insufficient drainage facilities and the shortage of roads. The unsatisfactory extension of agricultural techniques and insufficient farmers' organizations are also other factors affecting to the delayed development.

Based on the study and analysis of the present situations, the following development plans are proposed for a feasibility study.

Outline of Development Plan

1. Drainage Improvement Plan:

Principal drainage canals		
	New construction	32.10 km
	Rehabilitation	25.95 km
Secondary drainage canals		
	New construction	42.40 km
	Rehabilitation	24.70 km

2. Flood Protection Plan:

Embankment	
Rio Matina	32.80 km
Rio Chirripo	4.10 km
Rio Barbilla	19.20 km

3. Agricultural Production Plan: Main crops to be introduced bananas, cacao, coconuts, plantains, pepper, rice, maize kidney beans, tuber crops and beef cattle

4. Road Network Plan:

Main and trunk roads		
	New construction	13.60 km
	Rehabilitation	46.00 km
Lateral roads		
	New construction	58.80 km
	Rehabilitation	19.70 km

5. Land Consolidation Plan:
   New construction of tertiary and lateral drainage canals
   New construction of farm roads

6. Rural Infrastructure Plan: Water supply facilities 5 villages

7. Agricultural Promotion Plan:
   a. Strengthening of agricultural supporting organizations,
   b. Improvement of farmers' organizations,
   c. Establishment of two agricultural machinery centers,
   d. Establishment of six post-harvest facilities,

4.2 Drainage Improvement Plan

The objective of this plan is to drain water from farmlands quickly to prevent water stagnation, while at the same time reducing the level of groundwater to secure unhampered plant growth. For this purpose, the construction of principal and secondary drainage canals are needed to drain water out of the farmland quickly by gravity drainage.

The earth type canals are adopted considering the economy of construction cost.

In principle, a "principal drainage canal" is defined as one having a drainage area of 10 km^2 or more and a "secondary drainage canal" as one with a drainage basin of less than 10 km^2. The layout of the planned drainage canals was determined by considering the topographical condition and the arrangement of the farmlands. The dimensions of the proposed drainage canals are 3 m to 5 m deep with the bottom width of 1.0 m to 50 m for principal canals, and 2 m to 3 m deep with the bottom width of 1.0 m to 8.5 m for secondary drainage canals. A service road is built along each drainage canal according to the size.

4.3 Flood Protection Plan

Flood protection facilities are proposed for Rio Matina, Rio Chirripo and Rio Barbilla which often overflow during major floodings. There are two types of flood protection facilities, embankment type and excavation type. After alternative studies of these two choices, the embankment type was selected.

The scope of the protection facility was determined by a hydraulic calculation using the result of a field survey, river and other surveys.

The specifications are shown as follows;

Outline of Flood Protection Facilities

River	Expansion of Embankment (km)	River Width (m)	Height of Embankment (m)
Rio Matina	32.8	300 - 640	1.0 - 4.0
Rio Barbilla	19.2	120 - 160	0.5 - 3.6
Rio Chirripo	4.1	130	2.2 - 3.6
Total	56.1		

4.4 Land Use Plan

It was decided that a land use plan would be provided for the presently cultivated lands with emphasis placed basically on the current crop items unless these crops are unsuitable under soil conditions or land classification.

The land less than 2.0 m in height will be excluded because the gravity drainage is difficult and the utility as a farmland is low. Such lands in the Area are mostly covered by virgin forests.

If any plan has already been provided for land use, such existing plan will be adopted unless it has an adverse effect on the Project.

The virgin forests along Canal del Tortuguero provide a valuable natural environment. Since the elevation of this Area is very low and the area does not allow efficient drainage, the forests should be left unexploited.

The large forest areas in the Area also should be left intact from the viewpoint of providing a precious natural environment. In addition, they are not suitable for farmland since their gradients are sharp.

As a result, the area for development will measure 11,150 ha excluding the following areas:

Farmland with elevation of less than 2.0 m	:	410 ha
Virgin forest along Canal del Tortuguero	:	3,380 ha
Large scale forests	:	1,740 ha
Banana plantations	:	1,960 ha
Urban areas, etc.	:	860 ha
Total		8,350 ha

Referring to the result of selecting the types of crops suitable for classes of land and the agricultural production plan, the land use plan for the Study Area is determined as shown below.

Proposed Land Use

Unit: ha

Classification	Present Area	Proposed Area	Increase or Decrease
Annual crops	4,340	4,490	150
Bananas	1,960	4,000	2,040
Cacao	1,540	2,880	1,340
Plantains, Coconuts	620	1,000	380
Pepper	0	180	180
Pasture	3,510	560	-2,950
Virgin forests	3,380	3,380	0
General forests	1,740	1,740	0
Abandoned plantations	1,550	0	-1,550
Others	860	1,270	410
Total	19,500	19,500	0

(Note) Others include urban areas roads, canals, institutes' lots and farmland with an elevation of less than 2.0 m.

4.5 Agricultural Production Plan

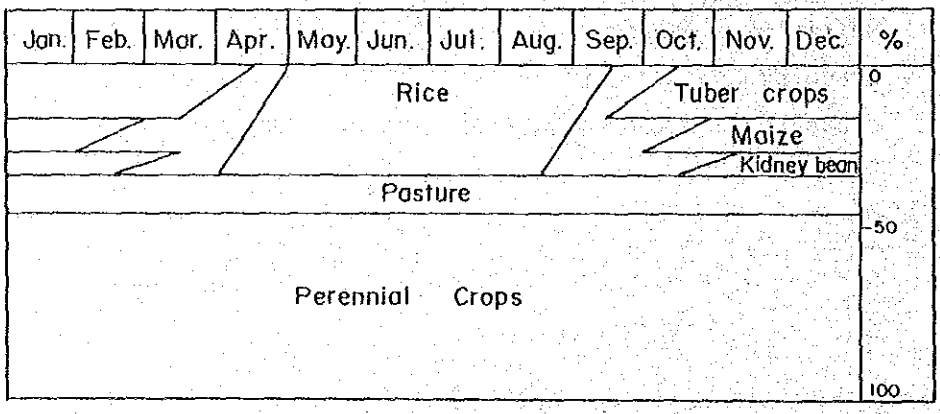
1) Proposed Crops and Cropping Pattern

Proposed crops and the cropping area were determined in consideration of the soil adaptability, agricultural and planting techniques, market trend and the desire of farmers in the Area while ensuring coordination with the production promotion plan conducted by the Government. On the other hand, those lands of lower class where planting of general crops is difficult will be more advantageously used as pasture. For this purpose the introduction of beef cattle is planned. The crops to be introduced and the projected cropping areas are shown below. The total cropping area will increase by about 80% over the current level.

Selected Crops and Cropping Area

Unit: ha

Crops	Cropping Area	Increased Area
1. Perennial crops:		
Bananas	2,040	2,040
Cacao	2,880	1,340
Coconuts	500	180
Plantains	500	200
Black pepper	180	180
Sub-total	6,100	3,940
2. Annual crops:		
Rice	2,900	0
Maize	540	190
Kidney beans	330	290
Tuber crops	720	480
Sub-total	4,490	960
3. Pasture	560	560
Total	11,150	5,460



Proposed Cropping Pattern

2) Proposed Yield and Production

The proposed yield and the production were calculated on the basis of the result of tests and research into plant cultivation conducted in experimental stations in and adjacent to the Area.

Proposed Yield and Production

Crops	Yield (ton/ha)	Production (ton)
1. Perennial crops:		
Bananas	49.0	117,600
Cacao	1.0	2,880
Coconuts	10.0	5,000
Plantains	17.0	8,500
Black pepper	2.2	400
2. Annual crops:		
Rice	4.5	26,100
Maize	2.5	1,350
Kidney beans	1.5	500
Tuber crops	11.0	7,920
3. Beef cattle	0.35	196

3) Proposed Farm Input Requirement

In order to achieve the planned yield, it is necessary to improve the input charge of production equipment centered on fertilization and to establish the agricultural work system in line with it. For this purpose, the variety of crops, sowing density, fertilizer and insecticide and herbicide were studied.

4) Production Cost and Producer's Price

The production cost and the producer's price were calculated. The gross production value and net production value per unit area calculated on the basis of the planned yield, production cost and the producer's price are shown in the table below.

Expected Production Values

Crop	Production Cost (₵/ha)	Producer's Price (₵/ton)	Gross Production Values (₵/ha)	Net Production Values (₵/ha)
1. Perennial crops;				
Bananas	462,235	13,200	646,800	184,565
Cacao	44,171	95,000	95,000	50,829
Coconuts	61,737	8,600	86,000	24,263
Plantains	94,082	8,500	144,500	50,418
Black pepper	134,800	220,000	440,000	305,000
2. Annual crops;				
Rice	41,800	14,200	63,900	22,100
Maize	23,139	13,669	34,173	11,034
Kidney bean	36,659	35,788	53,682	16,932
Tuber crops	94,659	14,000	154,000	59,341
3. Beef cattle	10,080	50,000	17,500	7,420

4.6 Farm Household Economy Plan

1) Farm Scale and Farming Type

Once this project is implemented, the average cropping area per farm household will almost double in 6.5 ha, and seven (7) farming types are proposed for this Area.

2) Labor Force Requirement

According to the plan, an increased cropping area and the conversion of the cropping pattern will increase the demand for agricultural labor. For this reason, agricultural machines will be introduced and the cropping patterns which could be realized within the home workforce will be established.

The latest unemployment in this Area and the surrounding areas is considerably high(8.8%, about 4,700 persons). This extra labor may be utilized to meet a further increase in demand for agricultural labor.

3) Household Incomes

The farm household income as calculated by farming type is forecast as indicated below.

As a result of implementation of the project, the income of each farm household is expected to increase from 1.8 to 2.0 times the level before implementation, greatly improving the economic conditions of the farmers.

Farm Household Incomes

Unit: ¢/farm household

Farming Type	Agricultural Gross Income	Production Cost	Income of Farm Household
A: Cacao + Annual Crops	796,741	410,918	385,823
B: Plantains + Annual Crops	1,062,836	681,716	381,120
C: Coconuts + Annual Crops	888,750	588,095	300,655
D: Black Pepper + Annual Crops	803,963	447,920	356,043
E: Rotation of Annual Crops	991,381	635,894	355,487
F: Cattle Annual Crops	875,000	504,000	371,000
G: Bananas	116,424,000	83,202,300	33,221,700

(Note) - Management area for livestock-farmer is 50 ha.
- Bananas are cultivated by farmers' cooperatives, and the management area per cooperative is 300 ha.

4.7 Road Network Plan

The road network system will be improved, taking into account the flow of agricultural products in the Area, transportation of agricultural equipment and the living conditions of the residents in the Area. The road layout was studied to match the road network program for the whole Limon area suggested in the Master Plan. The plan was formed to minimize the construction cost by utilizing the existing roads and the service roads for drainage canals.

4.8 Land Consolidation Plan

This plan improves drainage channels, small drainage channel and branch drainage channel, and farm roads in the farmland. Model design is provided for an unimproved area (290 ha), a slightly improved area (256 ha), and a location for a banana plantation (220 ha).

4.9 Rural Infrastructure Plan

As a result of well water quality inspection on the spot, it is judged that a simplified water-supply is needed, so the corresponding planning was created.

The simplified water-supply is to be installed in five places: Goschen, Davao, Cuatro Millas, Balumont Oeste, and a part of Bataán. The Cuatro Millas district (approx. sixty houses) has been selected from the above places for model design.

4.10 Agricultural Promotion Plan

1) Agricultural Supporting Organization Reinforcement Plan

If an agricultural development plan based on a drainage improvement is to be implemented to improve the agricultural production in the Area, it is important to strengthen the extension of agricultural techniques. This program is formulated.

2) Farmers' Organization Improvement Plan

Establishment of the agricultural organization by farmers themselves is planned for producing agricultural products of good quality. The agricultural organization consists of six producers' cooperatives producing cacao as a main product and one producing tuber crops as a main product.

3) Agricultural Machinery Center Plan

The agricultural machinery rental center is planned to promote agricultural mechanization and raise agricultural productivity. Sara and Bataan are provided with one center respectively.

4) Establishment Plan for Post-harvest Facilities

These facilities will be operated by farmers' groups and include:
(1) One processing plant for washing, drying, sorting, packing and

shipping tuber crops and coconuts.

(2) Six facilities for processing cacao after harvest.

5. Project Implementation Plan

1) Organization for Project Implementation

This Project is preferably implemented in coordination among SENARA, IDA, MAG and JAPDEVA. For this purpose, these organizations should set up a joint committee. SENARA will take the direct responsibility for the implementation of the Project. SENARA is an organization established for planning and implementing irrigation and drainage projects in Costa Rica, and has experiences in implementation of irrigation and drainage projects.

2) Site Office

A site office will be installed in Bataán at the center of the Area, and will be controlled by the project office.

The staff requirements of the site office will be as follows:

Job	Number of personnel
Director	1
Secretary	1
Engineer	1
Technicians	2
Staff members	2
Clerks	2
Drivers	2
Guards	2
Servant	1

3) Project Implementation Plan

Rio Matina and Rio Madre de Dios provide the boundary of the Area. If only the Area side of these rivers is covered, the construction work will not be effective. Therefore, the other side must also be included in the work at the same time.

4) Implementation Schedule

The work will be implemented according to the schedule described below.

Work Item			Preparation Period		Work Period		
			1st	2nd	3rd	4th	5th
Preparation of Loan Agreement							
Preparation Work	Detailed Design and Preparation of Tender Documents						
	Tender and Tender Evaluation						
Construction Work	Flood Protection Work						
	Drainage Improvement Work	Principal Canal Work					
		Secondary, Tertiary and Lateral Canal Works					
	Road Construction Work	Main and Trunk Road Works					
		Lateral and Farm Road Works					

6. Operation and Maintenance Plan

1) Basic Policy

The constructed facilities will be maintained and controlled by the following organizations;

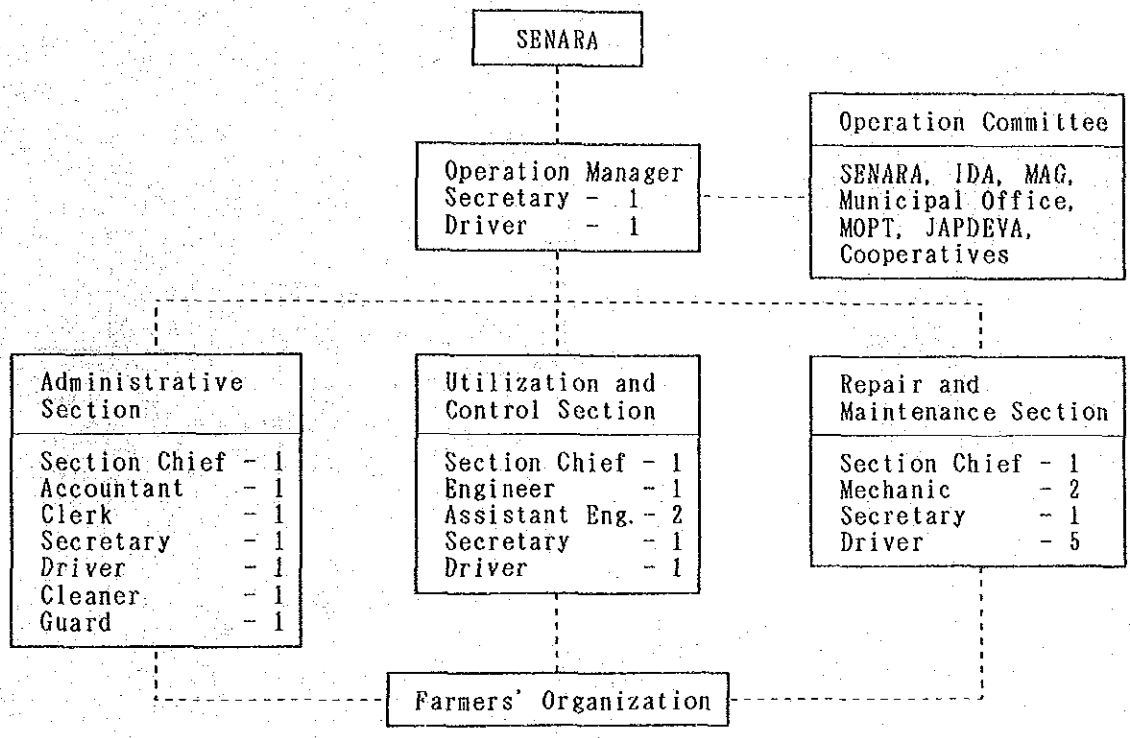
Organization for Operation and Maintenance of Facilities

Facilities		Operation Organization
Rivers	:	MOPT
Principal and Secondary drainage canals	:	SENARA
Trunk roads in the area	:	MOPT
Lateral road	:	Matina Municipality
Lateral drainage canal	:	Farmers' management association

2) Organization of Operation and Maintenance

For the purpose of operation and maintenance of the facilities, SENARA will institute an operation and maintenance (O/M) office.

This O/M office will be responsible for not only the operation and maintenance of the facilities taken charge by SENARA but also to provide consultation and give instructions on the facilities under the control of other organizations and associations. The organization of this office is shown below.



The building used as the site office will be used as an office building with attached facilities. The operational fund for the office will be provided by contributions from beneficiary farmers.

The management association organized by farmers for each drainage canal system will have a branch in each village and settlement.

3) Operation and Maintenance Cost

The operation and maintenance for the facilities is considered to require an estimated ₡16,811,000 per year, on the assumption that the equipment and vehicles are to be replaced with new ones upon expiry of their useful life.

All the costs required for this purpose will be paid by beneficiary farm households, each of which will assume a yearly charge of ₡1,282 per ha.

7. Estimate of Project Cost

The total project cost is estimated at ₡3,706,680,000 (US$53,915,350) as shown below.

Project Cost

Unit: ¢ 1,000

Item of Works		Foreign Currency	Domestic Currency	Total	Remarks
Inside Area	Drainage Improvement	779,509	176,595	956,104	
	Flood Protection	449,163	74,006	523,169	
	Roads and Bridges	223,685	64,932	288,617	
	Land Consolidation	232,046	89,374	321,420	
	Sub-total	1,684,403	404,907	2,089,310	
	Small Scale Water Supply System	782	7,217	7,999	
	Agricultural Processing Facilities	110,682	12,298	122,980	
	Agricultural Machinery Centers	79,310	0	79,310	
	Sub-total	190,774	19,515	210,289	
	Land Acquisitions Cost	0	82,497	82,497	
	Consulting Fee	192,314	21,368	213,682	
	Administration Cost	649	10,145	10,794	
	Sub-total	192,963	114,010	306,973	
	Price Contingency	283,363	74,192	357,555	
	Total	2,351,503	612,624	2,964,127	
Outside Area	Drainage Improvement	225,617	43,998	269,615	Rio Madre de Dios
	Flood Protection	231,703	38,712	270,415	
	Roads and Bridges	7,390	3,651	11,041	
	Sub-total	464,710	86,361	551,071	
	Land Acquisition Cost	0	43,988	43,988	
	Consulting Fee	49,596	5,510	55,106	
	Administration Cost	199	3,116	3,315	
	Sub-total	49,795	52,614	102,409	
	Price Contingency	70,460	18,613	89,073	
	Total	584,965	157,588	742,553	
Grand Total		2,936,468	770,212	3,706,680	

(Note) Outside area works means works on the opposite sides of Rio Madre de Dios and Rio Matina

8. Project Evaluation

1) Method of Economic Evaluation

(1) The evaluation period is assumed to be 50 years from the initiation of the construction.

(2) The exchange rate is set to the official rate of ₡68.75 per U.S. dollar as of December 24, 1987.

(3) Project Benefit

The expected benefit by the implementation of the project is the increased yield of agricultural products and the saving of transportation cost and the reduction of banana's damage loss attributable to construction and improvement of roads.

Project Benefit

Benefit	Amount (₡1,000/Year)
Benefit by agricultural production	1,001,037
Benefit by saving in transportation cost	16,473
Benefit by reduction of banana's damage loss	110,603
Total	1,128,113

(4) Annual Outlay of Project Cost

The annual outlay of these costs is determined as shown below in accordance with the project implementation schedule.

Annual Outlay of Project Cost

Year	1st	2nd	3rd	4th	5th
Amount (₡1,000)	20,446	153,602	363,775	981,084	637,754

(5) Operation and Maintenance Cost

The annual operation and maintenance cost is as follows:

Annual Operation and Maintenance Cost

Item	Amount (₱1,000)
Personnel cost	4,997
Operation of control vehicles	237
Office supplies	100
O/M machine control cost	6,923
Reserve	368
Total	12,625

(6) The replacement cost of the O/M equipment is shown below.

Replacement Cost of Equipment

Equipment	Spec.	Useful life (years)	Unit replacement cost (₱1,000)
Backhoe	0.7m^3	15	10,048
Motor grader	180 ps	15	6,161
Dragline	1.2m^3	15	28,135
Dump truck	11 t	8	2,036
Bulldozer	13.5 t	15	5,606
Pick-up	1 t	5	2,550
Motor cycles	125 cc	3	275

2) Economic Internal Rate of Return (EIRR) and Benefit Cost Ratio (B/C)

The economic internal rate of return (EIRR) is estimated at 23.0%.

On the other hand, the benefit-cost ratio (B/C) and the net present value (NPV) as calculated on the basis of the discount rates of 8%, 10% and 18% respectively are as follows.

Economic Evaluation

Description	Original (%)	Discount rate 8%	10%	18%
EIRR (%)	23.00	-	-	-
B/C (%)		1.50	1.40	1.07
NPV (₡1,000)		170,270,461	111,496,743	10,632,413

This shows that the Project has a high EIRR value as well as NPV. This Project is thus considered economically feasible.

3) Sensitivity Analysis

The sensitivity analysis was conducted for each of various cases including fluctuation in the project cost, drop in the price of agricultural products, decrease in yield and a given combination of these cases. The results shown below were obtained.

		EIRR (%)
CASE I :	20% increase in project cost	20.7
CASE II :	10% reduction in price or yield of agricultural products	20.0
CASE III:	Combination of CASE I and CASE II	18.0

4) Repayment of Foreign Loan

The repayment schedule of foreign loan was drawn up on the assumption that the loan period extends over 25 years (following a grace period of five years) with the interest per annum of 4% and repayment to be made in two annual installments of equal amount. As a result, the maximum amount of foreign currency to be repaid at a time, including interest, is of US$ 3,466,000.

5) Financial Analysis of Model Farm Household

On the results of financial analysis of the model farmers in the target year, it is clear that a remarkable improvement of farm household economy can be expected for every farmer after completion of the Project. The annual withdrawal cost counted as a burden of the beneficiaries is estimated at ₡1,167 per ha.

The cost calculated based on the operation and maintenance plan is ₡1,282 per ha annually. This is considered that this amount can be borne since the 4th year after completion of the Project.

6) Social Evaluation

After completion of the Project, various results are expected including improved agricultural productivity, creation of job opportunities, and stabilized agricultural management. Their direct advantages will be as follows:

(1) The agricultural production will increase by 97,000 tons in all from the current level.

(2) The farmer's family labor will be absorbed by the increase in cropping area, hence the work opportunities for farmer will increase by 240 persons annually.

(3) An appropriate land improvement and introduction of high-profit crops will enable to operate a stable farming. An average farm household is thus expected to increase its income by about ₡180,000 - ₡200,000 per year.

Indirectly on the other hand, the Project is expected to improve the living standards due to a stabilized farm household economy, activate the economy of the regions around the Area due to increased distribution of farming-related equipment and materials, and thus contribute to local development, leading to the further development of the country of Costa Rica.

9. Conclusions

In conducting a feasibility study of the Area, a development plan in an area of 19,500 ha (including 11,150 ha actually to be developed), has been formulated and the plan has been studied from technical, economic and social standpoints. As a result the following conclusions are obtained:

1) Factors hampering current agricultural production are insufficient drainage facilities, flooding of rivers, an insufficient road network, and lack of arrangement of farmlands, resulting in a low land use rate and low productivity.

In addition, there are also such problems as insufficient organization of extension services for agricultural management techniques, and a shortage of agricultural financing. However, it is confirmed that the execution of the development plan proposed by this Project would remove these obstructive factors and help to develop the agriculture in the Project Area while improving the welfare of local residents.

It is thus of urgent necessity to implement the Project.

2) From the technical and economic viewpoints, the following plans are proposed to be implemented:

Drainage Improvement Plan:

Principal drainage canals		
	New construction	32.10 km
	Rehabilitation	25.95 km
Secondary drainage canals		
	New construction	42.40 km
	Rehabilitation	24.70 km

Flood Protection Plan:

	Embankment	56.10 km

Agricultural Production Plan:

Main crops to be introduced

bananas, cacao, coconuts, plantains, pepper, rice, maize kidney beans, tuber crops and beef cattle

Road Network Plan:

Main and trunk roads		
	New construction	13.60 km
	Rehabilitation	46.00 km

Lateral roads

New construction	58.80 km
Rehabilitation	19.70 km

Land Consolidation Plan:

New construction of tertiary and lateral drainage canals

New construction of farm roads construction

Rural Infrastructure Plan:

Water supply facilities 5 villages

Agricultural Promotion Plan:

a. Strengthening of agricultural supporting organizations,
b. Improvement of farmers' organizations,
c. Establishment of two agricultural machinery centers,
d. Establishment of six post-harvest facilities

3) The estimated project cost for the implementation, in U.S. dollar equivalent is as follows:

Foreign currency	:	US$ 42,712,000
Local currency	:	US$ 11,203,000
Total	:	US$ 53,915,000

4) The period for implementation of the Project is reasonably set at 4.25 years including the period of detailed design.

5) If the Project is implemented successfully as planned, the benefits expected to be obtained by increased production of agricultural products, saved transportation costs and reduced banana's damage loss will be equivalent to ₡1,128,113,000 per year.

6) The internal rate of return (IRR) as estimated from the expenses and benefit of the project will be 23.0% on the assumption that the project life of 50 years. Further, this figure may vary between 20.7% and 18.0% according to the results of sensitivity analysis taking future conditions charges into account.

These results, with a higher economic evaluation than for other

similar projects in the country of Costa Rica, indicate the superiority of this Project.

7) In this development plan, virgin forests and large scale forests are excluded from the area to be developed in order to environmental reservation. As a result of examination on the impact to environment of the Area, it is confirmed that the impact does not cause problems in particular. It also can be confirmed that the sedimentation will not change from the present state though the sediment transportation from the river may increase slightly.

10. Recommendations

1) The implementation of this Project will not only benefit the residents in the Area directly but also have a socio-economic impact on the country as well as the Area. The Government of Costa Rica is requested to take measures for the implementation of this Project based on this feasibility study.

2) Further, preparations should be made for the following items at the same time:

(1) Establishment of an implementation organization based on the project implementation plan proposed.
(2) Explanation of the Project to the residents in the Area.
(3) Acquisition of the necessary land according to the plan.

3) If the Project under consideration is to be successful, the following items are also important and should be stressed during the progress of the Project:

(1) Establishment of an organization for operation and maintenance of the facilities.
(2) Strengthening and enlargement of the proposed agricultural supporting organization.
(3) Instructions on the establishment of the proposed farmers' organization.
(4) Construction of an agricultural equipment center commensurate with the increase in the cultivated area.

(5) Construction of post-harvest facilities commensurate with the increase in production volume.

4) Rio Matina and Rio Madre de Dios are located on the boundary of the Study Area. The construction related to these rivers, therefore, should cover both the locations included in the Area and those of the opposite side, outside of the Area.

5) There are forests including virgin forests. Especially, the virgin forests extending in low swampy land along Canal del Tortuguero are inhabited by valuable animals and are also an important tourism resource. The plan takes special care for environmental conservation of these forests, and the above area is excluded from the proposed Project Area to be developed. Under the circumstances, however, efforts must be made to protect this environment from unauthorized entry or other adverse factors.

11. Reports

The reports on the Feasibility Study are comprised of the following:

Volume I	Main report	(English)
Volume II	Annex	(English)
Volume III	Summary	(Spanish)
Volume IV	Drawings	(English)

With regard to the Master Plan Study, the following reports are prepared separately and should be referred to as required:

Volume I	Main report	(English)
Volume II	Annex	(English)
Volume III	Summary	(Spanish)

CHAPTER 1 INTRODUCTION

Chapter 1. Introduction

1.1 Background of the Study

The study of the Limon Integrated Agricultural Development Project, commenced in compliance with the request of the Government of Costa Rica, was divided roughly into two phases: Phase I for a master plan study and Phase II for a feasibility study of an area which was judged to have the highest priority for the project implementation based on the master plan study.

Phase I: The study was carried out during the period from February to October 1987, and the master plan on the Limon Integrated Development Project was formulated to cover the entire area of 67,000 ha. The results of this study have been drawn up as the master plan report.

Phase II: The feasibility study for Zone B (19,500 ha), evaluated to have the highest priority for implementation of the Project, was carried out during the period from January to July 1988.

1.2 Scope of the Study

The contents of the feasibility study are as follows:

1) Design of outline for the project planning
2) Project implementation plan
3) Cost estimation of the Project
4) Estimation of the project benefits
5) Project evaluation

1.3 Contents of the Study

1.3.1 Objectives of the Study

The objectives of this Study are to formulate an agricultural development project corresponding to a master plan after comprehension and analysis of present conditions in this Area in order to

promote the integrated agricultural development in the Project Area and to examine its technical feasibility and economical viability.

Specifically, the following items can be enumerated.

1) To grasp present conditions of the whole project area (19,500 ha).
2) To ascertain the possibility of drainage improvement to pinpoint an area having a potential for development.
3) To establish the agricultural development plan, and project plan and to examine its technical feasibility and economic viability.
4) To transfer the techniques for counterparts of Costa Rica through the Study.

1.3.2 Contents of the Study

This feasibility study consists of a field study in Costa Rica and a detailed analysis at the home office. The field study and the detailed analysis were commenced from January and June 1988, respectively. The contents of this study are as follows:

1) Field study (Jan. 16, 1988 to Mar. 30, 1988)

Basic data and information were collected for an agricultural development plan. The contents are as follows;

(1) Reconnaissance survey of the Project Area and surroundings, and collection of data and information on: meteorology and hydrology, soil, land use, irrigation and drainage, agriculture, agro-economy, agricultural land consolidation, settlement and rural development, cost estimation and project evaluation.

(2) Cross and longitudinal leveling of Rio Matina which is a main river in the Area.

(3) Cross-section leveling of small and medium rivers in the Area.

(4) Consultation with the authorities concerned with the Project.

2) Home office work (Detailed analysis)

Based on the results of the consultation with the Costa Rican side and data and information obtained by the field study, work was done on drainage plan, flood protection plan, agricultural production plan, agricultural promotion plan, cost estimation of the Project, economic evaluation and project evaluation. Further, recommendations for the development and project plans were also prepared.

The results of the Study and the project examination have been drawn up in the feasibility report, as follows;

(1) Main report: English
(2) Annex : English
(3) Summary : Spanish
(4) Drawings : English

CHAPTER 2 PRESENT CONDITION OF THE STUDY AREA

Chapter 2. Present Condition of the Study Area

2.1 General

The Study Area of the feasibility study is Zone B, which was evaluated to have the highest priority for implementation of the Project among four divided zones in the master plan study. This zone is situated virtually in the center of 67,000 ha where the master plan study was carried out, and the total area is 19,500 ha.

The Study Area lies in the eastern part of Costa Rica at $10^{o}02'$-$10^{o}10'$ north latitude and $83^{o}10'$ - $83^{o}25'$ west longitude, and has an area of about 16 Km from south to north and about 22 Km form east to west. The Area is located about 160 Km to the east of the country's capital, San José.

This Area is flatland downstream of the rivers originated in the mountainous area of the Central Costa Rica. It lies between Rio Matina to the southeast and Rio Madre de Dios to the northwest, and is bounded by the Canal del Tortuguero, which runs parallel to the Caribbean Sea, to the northeast and National Route 32 to the south. The area consists of 3,100 ha of swampy lowland with an elevation of 2 m or less, 10,300 ha of alluvial area with an elevation of 2 m and 10 m and 6,100 ha of hilly area with an elevation of 10 m and over. Moreover, 3,400 ha of virgin forest extends along the Canal del Tortuguero.

The main agricultural products are bananas, cacao, rice, maize, kidney beans and tuber crops.

As the characteristics in agricultural production, bananas are produced only by private enterprises, never by individual farmers. Although this Area is favored with a good climate, agriculture has problems due to poor drainage, flooding and the lack of agricultural supporting organizations.

The Area is in a tropical rain forest zone. The average annual rainfall reaches 3,520 mm, with especially heavy rainfall from June to August and November to December; even in the relatively dry month of

March, the average rainfall is 140 mm. The average annual temperature is 25.3°C.

Administratively the Study Area belongs to the Districts of Matina and Bataán, of Matina Canton in Limon Province. According to the 1986 Census, the population for these districts was of 3,964 and of 6,712 respectively.

The settlement project in this Area has been conducted by IDA since 1965, and 1,127 farm households, over an area of 9,300 ha, have been settled as of 1984. IDA has scheduled no new settlement project in the Area for the future.

The roads are poor in quality and in quantity, with a route density of 6.3 m/ha. Most of the roads are near National Route 32, and the area along the coast has scarcely any roads. The maintenance for these roads is bad, so that many become impassable due to rainfall. However, the roads running to banana plantations are relatively well surfaced because they are properly maintained by the banana companies.

The social infrastructure remains backward. Waterworks are not provided except the urban area of Bataan, and the farm households in the rural area use the water of the wells or rainwater as domestic water. A plan is a foot to construct sewerage works in the urban area of Bataan; however, no sewerage is provided in the rural area at all. Though educational and medical facilities are sufficient in number, these lack materials, equipment and personnel.

The administrative organizations in the Area are the Bataán offices of IDA and MAG, the Bataán branch of BNCR and Matina Municipal Office. The offices of IDA and MAG are in charge of assistance and extension services of farming techniques for the settlers and the farmers respectively.

2.2 Meteorology and Hydrology

2.2.1 Meteorology

The Study Area is located in the eastern part of Costa Rica facing the Caribbean Sea, and has a humid tropical rain forest climate with a high temperature and heavy rainfall throughout the year. The average annual temperature is 25.3°C and the average annual rainfall is 3,520 mm. There is no clear distinction between the dry season and the wet season.

1) Observatories

In and near the Area, there are two synoptic meteorological stations (La Lola, Limon) and four rainfall stations (Boston, ASBANA, Perla and Agrodisa). (See Fig. 2.2.1) For the following reasons, the rainfall at La Lola synoptic meteorological station is used to estimate flooding inside the Study Area:

(1) The rainfall inside the Study Area can be estimated from data at ASBANA, Perla and Agrodisa rainfall stations, which were newly established by the Study Team in March, 1987; however, records of these stations are short. The rainfall data of these stations and the one at La Lola are similar (Annex B Table B.1.1).

(2) La Lola meteorological station is located in the Study Area and has a reliable record over the period from 1949 to 1985.

(3) The period of observation, from 1978 to 1985, at Boston rainfall station was too short and was interrupted, so its data are not used.

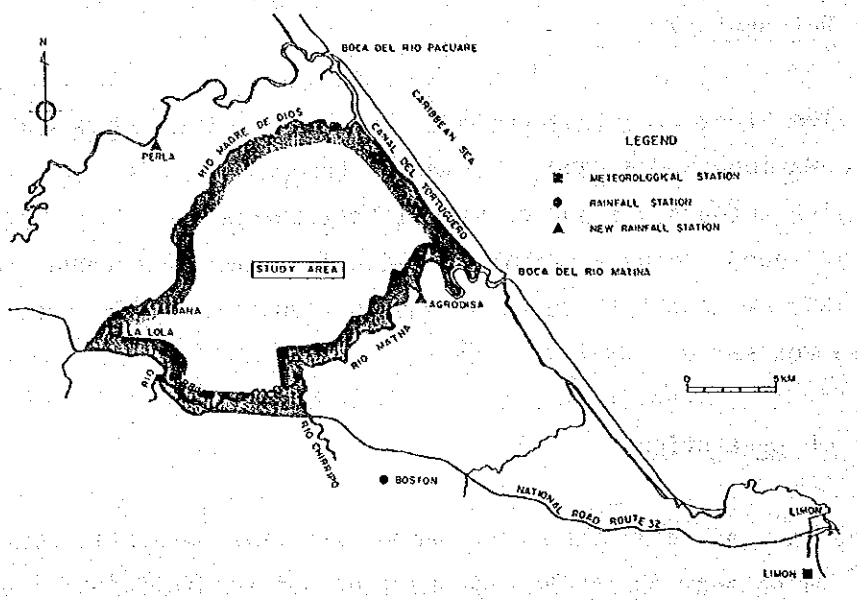


Fig. 2.2.1 Location of Meteorological Station

2) General Climate

According to the data at La Lola, the annual average rainfall is 3,520 mm, and there are no distinct dry periods during the year. The monthly rainfall peaks in July and December, at 420 mm and 460 mm, and is lowest in March, at 140 mm (Fig. 2.2.2).

The general climate in the Study Area is shown in Fig. 2.2.2 and Table 2.2.1. The climate has no monthly fluctuations. The climate is shown in more detail in Annex B Table B.1.2.

3) Probable Rainfall

The probable rainfall over short periods and rainfall intensity are shown in Table 2.2.2.

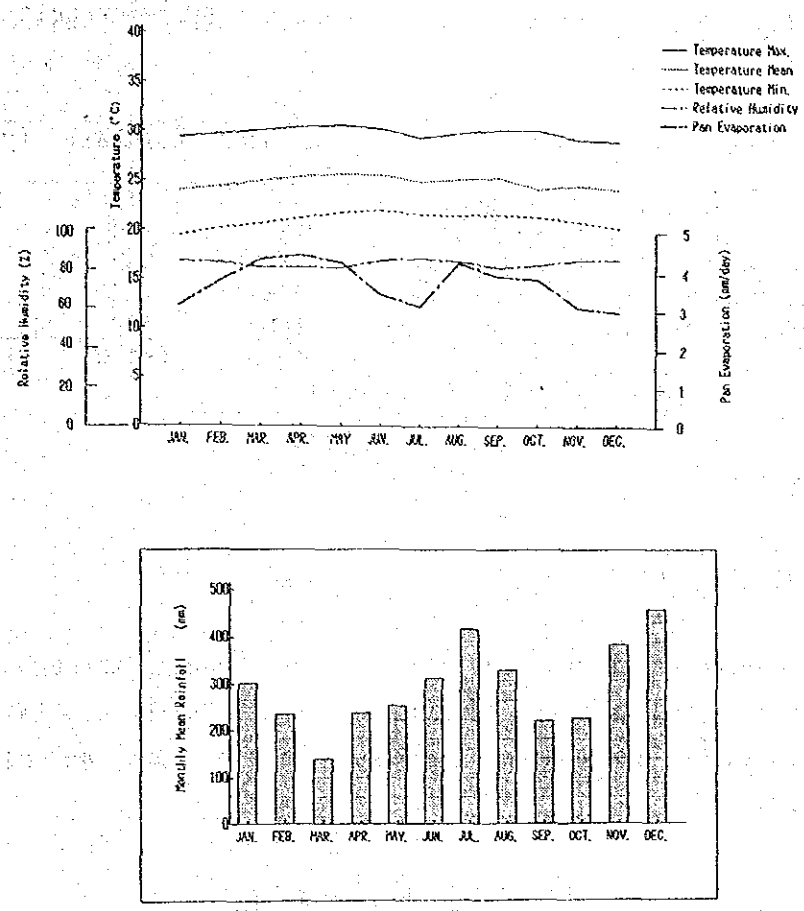


Fig. 2.2.2 General Climate of the Study Area

Table 2.2.1 Monthly Mean Climatical Data

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total (Mean)
Precipitation * (mm)	301	235	139	238	255	313	418	330	221	229	384	461	3,524
Temperature **													
Max (°C)	29.7	30.0	30.5	30.8	31.1	30.7	29.9	30.4	30.8	30.8	29.9	29.7	(30.4)
Min (°C)	19.6	20.4	20.9	21.5	22.1	22.3	22.0	21.9	22.1	21.8	21.4	20.7	(21.4)
Mean (°C)	24.3	24.6	25.3	25.7	26.1	26.0	25.4	25.6	25.9	24.7	25.1	24.7	(25.3)
Relative Humidity (%) *	85	84	82	82	82	86	87	86	83	84	87	87	(84)
Wind Velocity ** (km/hr)	6.6	6.5	7.0	7.2	6.3	5.7	6.1	5.9	6.1	5.9	6.5	6.7	(6.5)

(Note) * : La Lola meteorological Station
** : Limon Synoptic meteorological Station

Table 2.2.2 Probable Rainfall and Rainfall Intensity

Description	Probable Rainfall (year) 2	5	10
Hourly rainfall mm/hr	37	46	51
1- day max. rainfall mm/1-day	155	196	224
2- day max. rainfall mm/2 days	212	282	331
3- day max. rainfall mm/3-days	245	325	382
Rainfall intensity mm/hr	180	229	262
	t+3.9	t+4.0	t+4.1

(Note) t: duration of rainfall (hours)

2.2.2 Hydrology

1) Watershed Area

The entire watershed area of the rivers running through the Study Area is 1,654 km^2, and is composed of Rio Matina - a large river - and, small and medium rivers such as Rio Madre de Dios (Table 2.2.3).

Table 2.2.3 Watershed Area

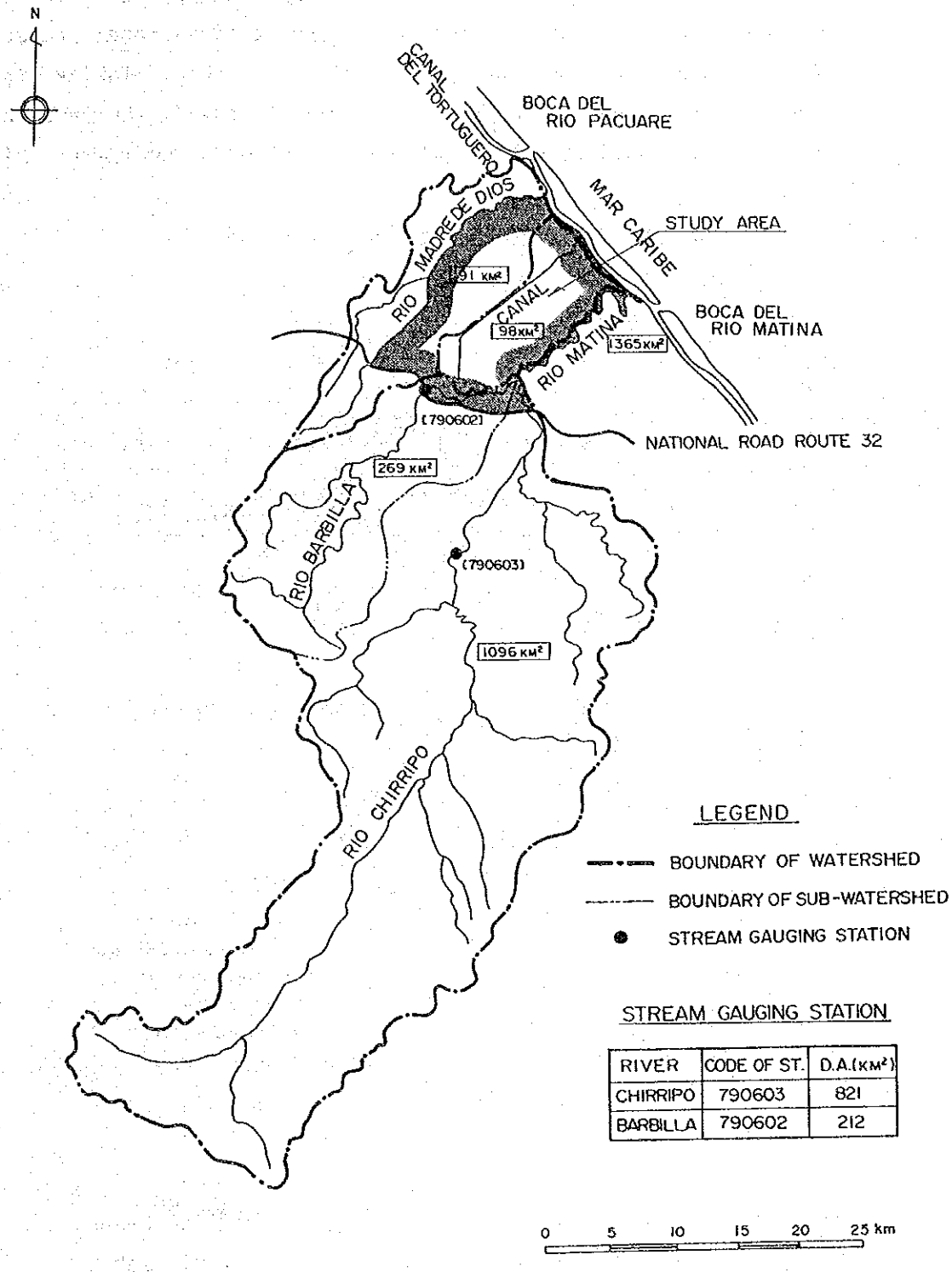
Unit : Km^2

River	Inside Study Area	Outside Study Area	Total
Rio Matina	15	1,350	1,365
Rio Chirripo*	(1)	(1,095)	(1,096)
Rio Barbilla*	(14)	(255)	(269)
Rio Madre de Dios	82	109	191
Others	98	-	98
Total	195	1,459	1,654
(%)	(12)	(88)	(100)

* Rio Chirripo and Barbilla are tributaries of Rio Matina

2) Flood Discharge of River

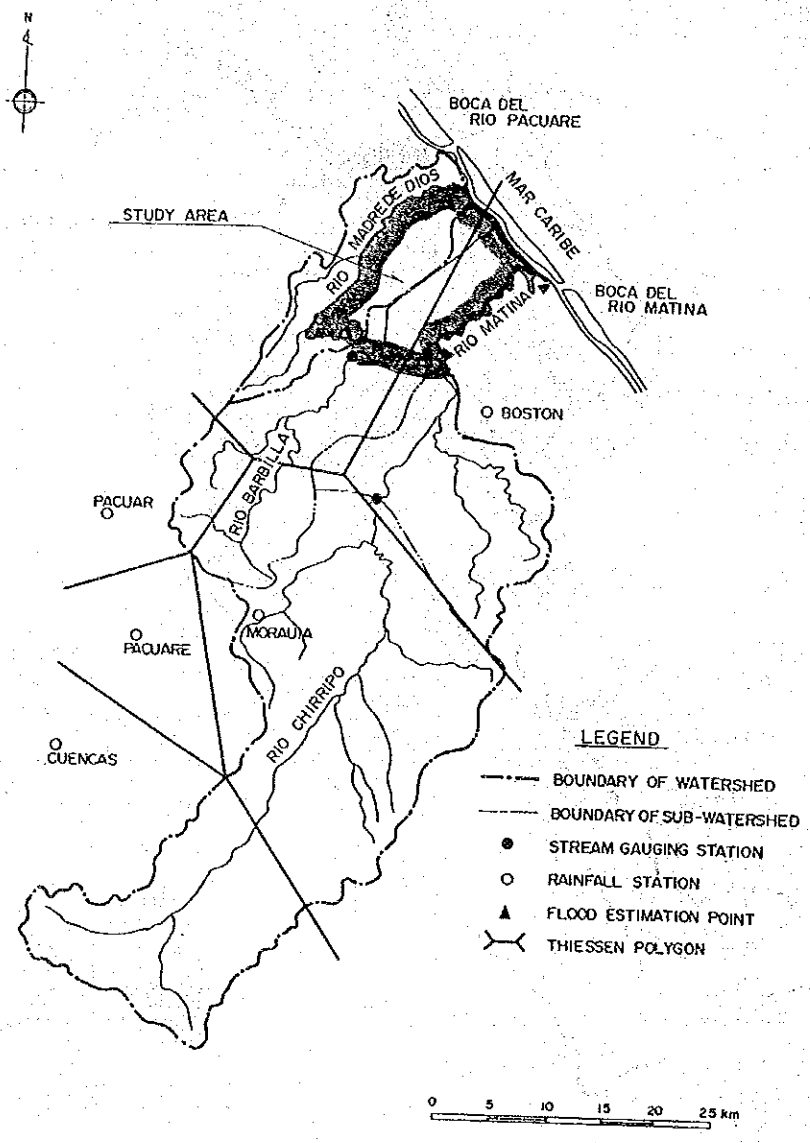
ICE (Instituto Costarricense de Electricidad) operates two steam gauging stations on these rivers (See Fig. 2.2.3).



RIVER	CODE OF ST.	D.A.(KM²)
CHIRRIPO	790603	821
BARBILLA	790602	212

Fig. 2.2.3 Watershed

The probable flood is estimated by unit-hydrograph, which is established by using observed data at these stations, and probable area rainfall computed through the Thiessen method. Taking into consideration the characteristics of the watershed, the unit-hydrograph is derived using the runoff function method (see Fig. 2.2.4).



Figs. 2.2.4 Thiessen Polygon over Watershed

As a design rainfall, an annual maximum three days' consecutive rainfall is adopted, because inundation analysis with long term rainfall is needed for the Study Area and the frequency of flooding caused by three days' consecutive rainfall is relatively high.

Rainfall with the probability of 5 years return period is adopted according to the result of the Master Plan Study.

The flood discharges at major points are estimated and the obtained result is shown in Table 2.2.4.

Table 2.2.4 Design Peak Flood Discharge

River	Location	D.A. (Km^2)	Estimated Peak Discharge (m^3/s)
Rio Matina	River-mouth	1,365	2,248
Rio chirripo	Confluence with Rio Matina	1,096	1,760
Rio Barbilla	Confluence with Rio Matina	269	528
Rio Madre de Dios	Confluence with Canal del Tortuguero	191	341

Flooding estimation for large rivers is shown in more detail in Annex B B.2.1, and for small and medium rivers in Section 2.4.

3) Sedimentation of Canal del Tortuguero

Canal del Tortuguero is supplied with sediment from the drainage canals and rivers.

The sediment flowing into the Canal del Tortuguero through the drainage canals is composed of small soil particles such as silt and clay. Though this sediment is dumped temporarily when the velocity of Canal del Tortuguero is very low, most of the sediment drains by tractive force to the Caribbean Sea when the sea level at the river mouth lowers and the water level of Canal del Tortuguero rises due to rainfall.

Based on the record of daily water level of Canal del Tortuguero W-No. 10 station which is located 1.3 km northwest from the confluence with Rio Matina, (see Master Plan Report) the velocity of Canal del Tortuguero is about 0.1 - 0.6 m/s. This velocity enables the dumped sediment with soil particle of less than 2 mm to be flushed out to the sea.

However, there are deposits in the 1 km section of Canal del Tor-

tuguero near the confluence with Rio Matina. The cause of deposit is that a part of the discharge from Rio Matina flows into Canal del Tortuguero which has a river-bed with a gradient opposite to the flow direction, so the contained sediment settles as deposits. JAPDEVA, operating Canal del Tortuguero, dredges this section of the canal every several years. According to the survey of a cross-section of the canal carried out in August 1987, the volume of deposited sand for the last four years reached 17,500 m^3.

With the completion of flood protection work on Rio Matina, the flooding that flows into farmland in the Study Area will run downstream, but without overflowing the river banks. This means the increase of flood discharge and inflow sand in the confluence of the canal will occur.

The daily discharge data for the three years from 1982 to 1984 show that the deposited sand after completion of the Project will become 1.03 times as much as at present.

Accordingly, the change in the volume of sedimentation will be only slight, after completion of the Project.

2.2.3 Analysis of Well-Water Quality

Most inhabitants in the Study Area depend on well-water for drinking water. To establish if the quality of well-water is suitable for drinking use, well-water was sampled at 14 places - eight shallow wells, four deep wells and two spring wells - and analyzed. (See Annex B Table B.3.1 and Fig. B.3.1)

According to the results, only three wells (No. 1, 9 and 10) among these 14 places are suitable as a water resource of drinking; the rest are not suitable because they have substantial coliform bacteria. (See Annex B Table B.3.2) The cause seems to be pollutant such as domestic sewage and raw sewage seeping into the groundwater zone. This well-water will have to be sterilized by chlorination and boiling if used for public and/or private drinking water.

2.3 Soil

2.3.1 General

To identify the characteristics of the soil and its distribution in the Study Area and to gather information on land use for the development of agriculture, a soil survey was conducted in the field work with pit and boring examinations and in the laboratory with physical and chemical estimates of the soil samples taken from the field.

Although the soil has generally good chemical properties, being rich in the 2:1 type clay and the exchangeable bases such as Ca and Mg, its physical properties possess major problems for cultivating common upland crops: excess water but very low air content caused by the low-land topography and the high rainfall all year round.

These facts prove the necessity of artificial drainage to improve the land.

1) Topography

Most of the Study Area is an alluvial plain gradually descending toward the Caribbean Sea, from the north-north east to the south-south west, with a few gentle undulations formed by the deposits transported by the three main rivers, Rio Madre de Dios, Rio Barbilla and Rio Matina, and their many branches; a few parts in the south-west are hilly (about 60 m to 110 m in elevation).

The elevation rates of the Area are 16% for 0 m to 2 m, 53% for 2 m to 10 m, 25% for 10 m to 20 m and a little less than 6% for land with more than 20 m elevation.

2) Soil Formation

The tropical rain-forest climate, shallow groundwater table and imperfect drainage mean that the main processes for soil formation seem to be grayzation and gleyzation resulting from the excess

water and oxygen deficiency in the soil, besides leaching. However, since the parent materials are newly deposited, the effect of the above processes on the soil profiles (differentiation of soil horizon) seems to be at the relatively early stages in the development of the horizons.

Namely, having young or underdeveloped soil formation, the minerals in the soils have not been weathered so much and can supply many of plant nutrients with the exception of just a few elements. Moreover, in many places the limestone debris and volcanic ash transported from the river basins seem to have remarkable affects on the physical and chemical properties of the soil in the Area.

3) Physical and Chemical Properties of the Soils

Among the many factors affecting agricultural land use in the Study Area, the physical properties of the soil seem to be the most important. As shown in Table 2.3.1, as much as about 80% of the soil samples examined had fine to very fine textures, being rich in clay. These samples were taken from soil layers (the available depth for common crops) at about one meter in depth. The imperfect gravity drainage in the Area seem to be promoted because of these clayey textures.

Table 2.3.1 Distribution of Soil Texture

Soil texture	Soil family	a (%)	b (%)	c (%)	d.e (%)	Total (%)
Course	(S, LS)	1	0	0	0	1
Medium	(SL, L, SiL)	17	28	17	5	17
Fine	(CL, SiCL)	46	58	52	34	49
Very fine	(SC, LiC, SiC, HC)	36	16	31	61	33
Total		100	100	100	100	100

(Note) Surface soil + sub-soil

The measured values of the three phases of soil are shown in Table 2.3.2.

With more than 50% moisture and less than 10% air, over 90% of the porosity in both upper and lower soils is saturated by moisture with only a few exceptions. The soil has very little capacity to supply oxygen to common upland crop roots for normal

growth. All this results from the excess water in the soil.

Thus, the soil texture and the values of the three phases of soil are closely related to the characteristic profiles of the moisture conditions in the soil, as shown in the differences between the soil series groups classified below.

Table 2.3.2 Soil Family and Three Phase

Soil family	Soil layer	Solid (%)	Liquid (%)	Air (%)	Moisture ratio (%)	Degree of water saturation (%)
a	U	39	53	8	53	88
	S	41	55	5	51	92
b	U	37	57	6	60	91
	S	40	55	5	50	91
c	U	36	59	5	64	93
	S	43	54	4	47	94
d	U	35	63	2	68	96
	S	N.D.	N.D.	N.D.	N.D.	N.D.
e	U	35	62	3	69	96
	S	N.D.	N.D.	N.D.	N.D.	N.D.

U: Surface soil S: Sub-soil N.D.: No data

With a few exceptions, obstacles preventing the growth of roots of crops and trees, such as sand and stone layers or bed-rock are not observed in depths of less than one meter. The hardness (compactness) of the soil is suitable for the easy growing of big trees, regardless of the wet conditions.

As for the soil fertility, the chemical properties of the soil in the Area are arranged in Table 2.3.3 according to MAG's standard for soil fertility (Annex C Table C.6.5).

The table indicates that soil with high content of exchangeable bases, especially Ca and Mg, occupies 86% and 68% of all the soil in the Area, respectively, and about 65% of the soil is ranked in the optimum range in pH, while the soil that indicate high acidity and alkalinity is less than about 20%.