No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

REGIONAL AUTONOMOUS CORPORATION OF CUNDINAMARCA (CAR)
THE REPUBLIC OF COLOMBIA

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE

FINAL REPORT

Vol. 2 : MAIN REPORT

MAY 2000

CTI ENGINEERING INTERNATIONAL CO., LTD.

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EXCHANGE RATES

The exchange rates used in this Study are:

US Dollar (US$)1.00 = Japanese Yen (¥) 106

= Colombian Pesos (Col$) 1,920

As of October 1999

PREFACE

In response to a request from the Government of the Republic of Colombia, the Government of Japan decided to conduct the Study on Regional Environmental Improvement Plan for the Basin of Lake Fuquene and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Naohito Murata, CTI Engineering International Co., Ltd. to the Republic of Colombia three times between February 1999 to May 2000. In addition, JICA set up an advisory committee headed by Dr. Hiroshi Kidono, Senior Advisor of JICA, between February 1999 and May 2000, which examined the Study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of the Republic of Colombia and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

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

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

May, 2000

Kimio Fujita
President
Japan International Cooperation Agency

May, 2000

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Sir:

LETTER OF TRANSMITTAL

We are pleased to submit herewith the Final Report for the Study on Regional Environmental Improvement Plan for the Basin of Lake Fuquene, the Republic of Colombia. The report contains the advice and suggestions of authorities concerned of the Government of Japan and the Japan International Cooperation Agency (JICA), as well as the formulation of the environmental improvement plan for the Basin. Also included are the comments made by the Regional Autonomous Corporation of Cundinamarca (CAR), the Republic of Colombia during the technical discussions on the Draft Final Report.

The Final Report presents the Master Plan of the Environmental Improvement for the Basin of Lake Fuquene. In view of the urgency and necessity of the environmental improvement in the Basin, it is recommended that the Government of Colombia should proceed with implementation of the priority projects selected in the master plan at the earliest possible time.

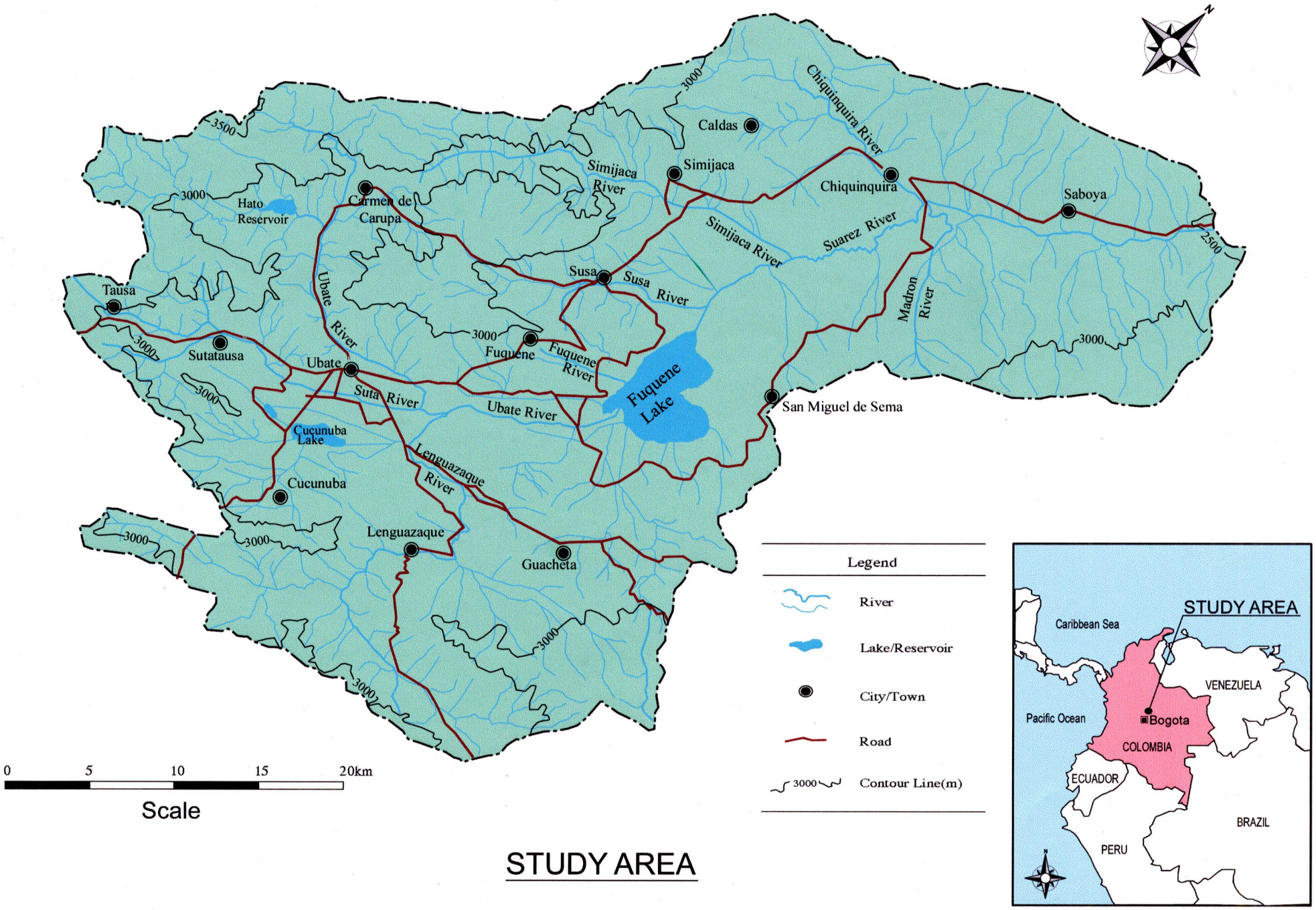
Finally, we wish to take this opportunity to express our sincere gratitude to the Government of Japan, particularly, JICA, the Ministry of Foreign Affairs, the Environment Agency and other offices concerned. We also wish to express our deep appreciation to CAR, the Ministry of Environment, the Colombian Agency of International Cooperation and other authorities concerned of the Government of Colombia for their close cooperation and assistance extended to the JICA Study Team during the Study.

Very truly yours,

村田直人

Naohito Murata
Leader
JICA Study Team

Encl. : a/s


N
Caldas
Chiquinquira River
Simijaca
Simijaca River
Chiquinquira
Saboya
Hato Reservoir
Carmen de Carupa
Suarez River
Simijaca River
Susa
Susa River
Madron River
Tausa
Ubate River
Sutatausa
Ubate
Fuquene
Fuquene River
Fuquene Lake
San Miguel de Sema
Suta River
Ubate River
Cucunuba Lake
Lenguazaque River
Cucunuba
Lenguazaque
Guacheta
3500
3000
2500
0 5 10 15 20km
Scale
Legend
River
Lake/Reservoir
City/Town
Road
3000 Contour Line(m)
STUDY AREA
Caribbean Sea
VENEZUELA
Pacific Ocean
Bogota
COLOMBIA
ECUADOR
BRAZIL
PERU

STUDY AREA

COMPOSITION OF FINAL REPORT

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ABSTRACT

1. INTRODUCTION

The Study Area covers 1,752 km^2 of the Ubate - Chiquinquira valley located 100 km northeast of Bogota City, the capital of Colombia. Lake Fuquene with a surface area of 30 km^2 is situated in the center of the valley. The existing population of the Study Area is 181,000. The largest economic activity is livestock industry, raising 171,000 cattle for meat and dairy production.

The water resources in the valley is not used effectively due to insufficient water intake and distribution system. Livestock, domestic and industrial wastewater cause pollution of the surface water. Lake Fuquene is suffering from excessive aquatic plants, resulting in reduction of water surface area and storage capacity, deterioration of water quality, and damage to aquatic life. Alleviation of these environmental problems is essentially necessary to sustain the economic development of the valley.

In response to the request of the Government of Colombia, the Japan International Cooperation Agency conducted the "Study on Regional Environmental Improvement Plan for the Basin of Lake Fuquene" from February 1999 to May 2000. The objectives of the Study are:

(1) To formulate a master plan for regional environmental improvement for the Basin of the Lake, targeting the year 2010; and,

(2) To pursue technology transfer to the counterpart personnel in the course of the Study.

2. WATER RESOURCES AND USE MANAGEMENT

2.1 Water Demand and Supply Balance

The major water use in the Study Area is irrigation. The other water uses such as municipal and livestock water are small in quantity, compared to the irrigation water. The existing irrigation areas of 20,337 ha extend on the flat plane of the valley and are mostly used for pastures. For the location, see Fig. 1. The irrigation area will be extended to 24,849 ha by 2010.

There are one (1) reservoir, three (3) lakes and three (3) gates in the Study Area. They are operated for irrigation and municipal water supply, and flood control. For the location, see Fig. 1.

At present, irrigation suffers from water deficit in some areas due to not only the shortage of water resources but also the lack of irrigation facilities. In fact, the Hato Dam is not fully used due to the lack of irrigation facilities in the downstream areas. Full operation of Hato Dam and construction of additional irrigation facilities at proper locations will maximize the available surface water and mitigate the irrigation water deficit. The existing and future water demand and supply balances in a 5-year drought are compared as follows.

Item	Present	Future
Irrigation Area (ha)	20,337	24,849
Annual Water Demand (million m^3/year)	97.76	125.77
Annual Water Deficit (million m^3/year)	15.85	14.07
Deficit Ratio (%)	16.2	11.2

2.2 Optimum Operation of Hato Dam and Lake Fuquene

The optimum operation rules of Hato Dam and Lake Fuquene are proposed as shown below for the existing and future water use conditions in the Study Area.

(1) Hato Dam

The optimum monthly water release of the dam under the existing and future water use conditions is shown below.

(unit: m^3/s)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Existing Release	0.10	0.10	0.10	0.00	0.05	0.05	0.10	0.10	0.00	0.00	0.00	0.10
Future Release	1.50	0.95	0.50	0.00	0.05	0.05	0.50	0.80	0.35	0.00	0.00	0.60

The optimum flood release - water level curve under the existing and future optimum operation rules for irrigation water supply is shown below.

Dam Water Level (m)*	42.7	42.8	42.9	43.0	43.1	43.2	43.3	43.4	43.5	43.6	43.7
Existing Release (m^3/s)	0.0	0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00
Future Release (m^3/s)	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50

*: Base of water level is 2,800 m.

(2) Lake Fuquene

Tolon Gate should be opened immediately when the lake water level exceeds the operation water level and be closed without delay when the lake water level lowers below the operation water level. The target water level and operation water level under the conditions of the existing and future water uses with the optimum Hato Dam operation are proposed as shown below.

Water Level	Existing Condition (m)	Future Condition (m)
High Water Level (2-year Return Period)	2,539.46	2,539.41
Low Water Level (2-year Return Period)	2,538.52	2,538.56
Operation Water Level (Dry Season)	2,539.1	2,539.1
Operation Water Level (Rainy Season)	2,538.9	2,538.9

2.3 Improvement of Water Resources and Use Management

To cope with the water deficit in the irrigation area of approximately 7,000 ha, such irrigation facilities as canal (152 km), gate (14 places), etc. will be constructed along with the optimum operation of Hato Dam and Lake Fuquene.

The low pasturelands around Lake Fuquene are habitually inundated. These flooding problems will be mitigated by clearing the Suarez River and the optimum operation of the Lake.

The existing intake pumps and water purification plant of the Chiquinquira water supply system will be improved to supply stable and clean water.

The investment and annual O&M costs for the proposed projects are estimated as shown below.

Item	Investment Cost (million Col$)	Annual O&M Cost (million Col$/year)
Irrigation	15,049.0	162.3
Drainage	-	38.5
Municipal Water Supply	780.1	Negligible
Total	15,829.1	200.8
Total (million US$ or million US$/year)	(8.25)	(0.10)

3. WATER QUALITY AND POLLUTION CONTROL

3.1 Water Quality of Lake Fuquene

The existing lake water quality is characterized as follows.

(1) The water temperature is nearly constant (17 ^{o}C) throughout the year.

(2) DO content is low due to the decomposition of withered aquatic plants. A wide lake area where aquatic plants densely grow is colored black, emitting a highly concentrated toxic substance of sulfide (H_2S).

(3) The lake water is highly eutrophic, and contains a high content of T-N, T-P, COD, NH_4 and Coliforms. However, the population of plankton is small throughout the year.

(4) The lake deposits are under a high anaerobic condition. No benthos are identified.

(5) Neither heavy metals nor pesticides are detected in the water and deposits.

3.2 Pollution Load Runoff

(1) Pollutant Sources

There are 15 sewerage systems in 14 municipalities, serving almost all the urban population of 75,800 in the Study Area. However, only five (5) sewerage systems are provided with treatment plant.

There are 14 slaughterhouses and 50 dairy factories in the Study Area. Among them, all the slaughterhouses have treatment plant, however, only eight (8) dairy factories are provided with treatment plant.

The non-point pollution loads are generated from livestock, lands and rural households. The load from livestock is extremely larger than the other point and non-point loads.

(2) Pollution Load Runoff to the Lake

A considerable portion of the pollution loads generated from the above pollutant sources run off to Lake Fuquene. The largest source is livestock followed by sewerage. The existing pollution load runoff to the Lake are shown below.

Pollutant Parameter	BOD	COD	T-N	T-P
Pollution Load Runoff (kg/d)	2,899	11,472	1,036	131
Ratio of Source (%)				
Point (sewerage)	29.2	12.3	22.9	21.4
Point (industry)	1.1	0.4	0.8	1.5
Non-point (livestock)	65.2	80.6	60.5	75.5
Non-point (land)	4.2	6.5	15.7	1.6
Non-point (household)	0.3	0.2	0.1	0.0

(3) Target Treatment Level of Wastewater

CAR stipulated the target river water quality in the Study Area by categorizing river sections into four (4) classes. To satisfy this target water quality, all the sewerage will be treated to 40 mg/l in BOD and all the industrial wastewater (slaughterhouse, dairy factory) will be treated in compliance with CAR standards.

(4) Simulated River and Lake Water Quality

The river water quality at the principal river stations was simulated for the existing condition, and future conditions without and with project in 2010. For location of the principal river stations, see Fig. 1.

River	Location	BOD (mg/l)			
		Present	Future without Project	Future with Project	CAR Target Quality
Ubate	Colorado	5.3	7.9	3.9	< 5.0
Suarez	Tolon	3.2	3.5	2.8	< 5.0
Suarez	After Chiquinquira City	17.7	20.6	5.3	< 10.0

The simulated future lake water quality under the conditions of without and with project in 2010 are shown below, compared with the existing one.

Item	Existing	Future without Project	Future with Project
COD (mg/l)	31.40	33.40	31.97
T-N (mg/l)	1.83	2.02	1.79
T-P (mg/l)	0.07	0.09	0.07

3.3 Improvement of Wastewater Treatment System

Among the existing five (5) treatment plants, four (4) plants will be improved and new treatment plants will be installed for the 10 sewerage systems that have no treatment plant at present.

Among the existing 14 slaughterhouse treatment plants, two (2) plants will be improved. New

treatment plants will be constructed for the 42 factories that have no treatment plant at present.

The investment and annual O&M costs for the proposed projects are estimated, as shown below.

Item	Investment Cost (million Col$)	Annual O&M Cost (million Col$/year)
Sewerage Treatment	7,561.0	831.0
Industrial Wastewater Treatment	231.0	27.0
Total	7,792.0	858.0
Total (million US$ or million US$/year)	(4.06)	(0.45)

4. AQUATIC PLANT CONTROL OF THE LAKE

4.1 Aquatic Plant Area

The most prevailing aquatic plants of Lake Fuquene are *Egeria densa* (Brazilian Elodea) of submerged plant, *Eichornia crassipes* (Water Hyacinth) of floating plant, and *Scirpus californicus* (Bulrush) and *Typha angustifolia* (Cattail) of emergent plant.

The aquatic plant area is propagating at a high speed. It is expected to increase as shown below in the future if no control measures are taken.

Classification	1999		2010		2020	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Emergent Plant	899	30.4	1,284	43.4	1,596	53.9
Floating Plant	697	23.6	867	29.3	1,058	35.8
Submerged Plant	1,204	40.7	649	21.9	146	4.9
Pure Water Area	159	5.3	159	5.4	159	5.4
Total	2,959	100.0	2,959	100.0	2,959	100.0

4.2 Problems Caused by Excessive Aquatic Plants

The following major problems will be caused by the above mentioned excessive growth of aquatic plants in the future.

(1) Reduction of Storage Capacity of the Lake: Aquatic plants reduce the storage capacity of the Lake. The reduced effective storage capacities are estimated to be 0.74 million m^3 at present and 0.98 million m^3 in the future (2020).

(2) Deterioration of Lake Water Quality: Excessive aquatic plants make the lake water anaerobic, resulting in emission of a toxic substances of H_2S. Such deteriorated lake water may not allow benthos, fishes and other aquatic lives at all. Groundwater recharged from the Lake may decay roots of the pastures around the Lake.

(3) Blocking of Water Flow: Excessive aquatic plants in the Lake block the outlet of the Lake. This blocking may result in flood damages on the surrounding low areas of the Lake and damages on the water uses in the downstream of the Suarez River.

4.3 Aquatic Plant Control

(1) Proposed Control Plan

(a) Dredging of the Lake Bed: Dredging of the front-zone of Bulrush is proposed to stop the expansion of Bulrush area toward the lake center. The required dredging volume is estimated at 480,000 m^3. A pilot project will be executed prior to the full scale project to confirm the effectiveness of the dredging.

(b) Harvesting/Removal and Composting of Aquatic Plants: Elodea will be controlled by a combination of machine harvesting and grass carp feeding. Approximately 20% of the existing biomass or 38,000 ton (in wet weight) will be harvested by machine and the remaining one will be controlled by grass carp every year.

Water hyacinth will be decreased to approximately 50% of the existing one by 2010 and nearly zero in 2015. For this purpose, 75,000 ton (in wet weight) will be mechanically removed annually.

Annually, 16,100 ton of compost will be produced from the harvested Elodea and removed Water hyacinth for the use of flower farming. A pilot project will be executed prior to the full scale project to confirm the effectiveness of the compost use for flower farming.

(c) Control by Grass Carp: For control of Elodea along with mechanical harvesting, 44,000 fingerlings of sterile triploid grass carp will be released into the Lake.

(2) Controlled Aquatic Plant Area

The aquatic plant area in the Lake will be controlled by the proposed projects as below.

Aquatic Plant	1999	2010	2020
Bulrush (ha)	899	1,284	1,284
Water hyacinth (ha)	697	376	0
Elodea (ha)	1,204	Negligible	272
Total (ha)	2,800	1,660	1,556

(3) Project Cost

The investment and annual O&M costs for the proposed projects are estimated as below.

Item	Investment Cost (million Col$)	Annual O&M Cost (million Col$/year)
Dredging of Lake Bed	17,196.1	-
Harvesting/Removal and Composting	11,688.2	1,009.6
Control by Grass Carp	2,054.0	50.0
Total	30,938.3	1,059.6
Total (million US$ or million US$/year)	(16.11)	(0.55)

5. PROJECT EVALUATION

5.1 Economic Evaluation

The proposed master plan will generate the following major economic benefits.

Project	Benefits
Irrigation and Drainage	Increase of milk production of livestock on the beneficial pastureland
Municipal Water Supply	Improvement of the public health of the users in Chiquinquira City
Sewerage Treatment	Improvement of the environments of the public water body and Conservation of the water resources.
Aquatic Plant Control	Compost production, Reduction of water pollution and flood damages on the pasturelands around the Lake, Reduction of water pollution damage on the municipal water supply of Chiquinquira, Conservation of lake storage capacity, Improvement of landscape, and Improvement of aquatic life habitat.

The economic efficiency of the proposed projects is evaluated in terms of economic internal rate of return (EIRR) as follows.

Project	EIRR (%)
Water Resources and Use Management	26
Wastewater Treatment (Sewerage Treatment)	-
Aquatic Plant Control	5
Master Plan (Total Project)	10

5.2 Financial Analysis

(1) Irrigation

The existing water charge system can cover the all O&M cost but can not cover the construction cost at all. The existing water charge should be raised to cover a certain portion of the investment cost.

(2) Sewerage Treatment

The sewerage treatment charge for which the people in the Study Area are willing to pay at present is estimated to be 0.12% of the average monthly household income. The sewerage treatment charge should be raised to 0.25% of the household income to cover the O&M cost at least.

(3) Compost Production

The required cost should be borne by both government and private sector in a proper allocation. This project may be attractive for the participation of private sector when the government shoulders a considerable portion of the investment cost.

5.3 Environmental Impact Assessment

In the overall assessment, the positive impacts of the projects will overweigh the negative ones. The most important positive impact is the recovery of the Lake. The possible negative impacts could be prevented or minimized by the proposed control measures. Then, the proposed

projects could be implemented with no significant adverse impacts on the environment.

6. RECOMMENDATIONS

6.1 Project Implementation

(1) The irrigation areas to be served by Hato Dam should be implemented at the earliest time.

(2) The water intake and purification facilities of Chiquinquira water supply system should be immediately improved to supply stable and clean water.

(3) Improvement of the sewerage treatment system of Chiquinquira and Ubate cities should be started at the earliest time.

(4) The excessive aquatic plants should be controlled by an integral method of dredging, harvesting/composting and grass carp. The harvested aquatic plants should be reused to the maximum extent to sustain the proposed aquatic plant control project. Then, the harvesting, compost production and marketing should be implemented as a package under joint operation of both public and private sectors.

(5) Effectiveness of the dredging and applicability of the produced compost should be confirmed through a pilot project prior to the full scale implementation. The pilot projects should be commenced at the earliest time.

(6) The ongoing experiments of grass carp and growth rate of Elodea should be further continued to reach a final conclusion.

(7) Rational irrigation water use is necessary along with the proposed improvement of irrigation system to mitigate the drought problems in the irrigation service areas. For this purpose, investigation on the most efficient way of irrigation water use should be conducted.

6.2 Monitoring and Optimum Operation of Dam/Lake

(1) For successful implementation of the proposed projects, the existing monitoring system of hydrology and water quality should be improved. Further, the effects of the proposed aquatic plant control project should be monitored.

(2) Hato Dam and Lake Fuquene should be operated in accordance with the proposed optimum operation rules. Aquatic plants in the Lake outlet and Suarez River should be well controlled to obtain the expected results of the proposed operation rule of the Lake.

6.3 Environmental Education

Significance of the environmental conservation of the Study Area must be well understood by the people to attain a smooth implementation of the proposed projects. For this purpose, CAR should promote environmental education at various levels.

THE SYUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE

FINAL REPORT

MAIN REPORT

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ABBREVIATIONS AND ACRONYMS

AGENCIES/ORGANIZATIONS

CAR	:	Regional Autonomous Corporation of Cundinamarca
DANE	:	National Administrative Department of Stastistics
FAO	:	Food and Agriculture Organization of the United Nations
GTZ	:	Deutsche Gesellschaft für Technische Zusammenarbeit
IDEAM	:	Hydrology, Meteorology and Environmental Studies Institute
IGAC	:	Geographic Institute “Agustin Codazzi”
INPA	:	National Agricultural and Livestock Planning Institute
JICA	:	Japan International Cooperation Agency
KfW	:	Kreditanstalt für Wiederaufbau
MINERCOL	:	Minerals of Colombia which belong to the Ministry of Mining
SENA	:	National Service for Learning
SINA	:	National Environmental System
UMATA	:	Municipal Unit for Technical Assistance on Livestock and Agriculture
URPA	:	Regional Unit for Agriculture/Livestock Planning
USA	:	United States of America

ACRONYMS

Ave.	:	Average
B/C	:	Benefit Cost ratio
BOD	:	Biochemical Oxygen Demand
CAD	:	Computer-aided Design
COD	:	Chemical Oxygen Demand
D	:	Depth
D/D	:	Detailed Design
DO	:	Dissolved Oxgen
EC	:	Elictro Conductivity
EIRR	:	Economic Internal Rate of Return
EL.	:	Elevation
Fig.	:	Figure
FIRR	:	Financial Internal Rate of Return
GDP	:	Gross Domestic Product
GIS	:	Geographic Information System
GNP	:	Gross National Product
GoC	:	Government of Colombia
GoJ	:	Government of Japan
Has	:	Hectare
Hr	:	hour
IVA	:	Value-added Tax
L	:	Length
max.	:	Maximum
min.	:	Minimum
MPN	:	Most Probable Number

N°	:	Number
N.D.	:	Non Detected
NPV	:	Net Present Value
NGO(s)	:	Non Governmental Organization(s)
O&M	:	Operation and Maintenance
S.T.	:	Study Team
SS	:	Suspended Solid
W	:	Width

MEASUREMENTS/SYMBOLS

%	:	Percent
℃	:	Celsius
cal	:	Calorie
Cells/ml	:	Cells per milliliter
cm	:	Centimeter
cm^2	:	Square centimeter
g/ m^2.d	:	gram per square meter per day
ha	:	Hectare(100m x 100m)
kg/d	:	kilogram per day
kg/sq.m	:	kilogram per square meter
km	:	kilometer
km^2	:	Square kilometer
L/c/d	:	Liter per capita per day
lt/d	:	liter per day
m	:	meter
m.s.n.m	:	mean sea level meter
m/s	:	Meter per second
m/sec, m^3/s	:	Meter per second
m^3	:	Cubic meter
mg/l	:	milligram per liter
mg/ m^2/d	:	milligram per square meter per day
mg/ m^3	:	milligram per cubic meter
mm	:	Milimeter
MP	:	Million Pesos
MPN/100ml	:	Most Probable Number per 100 milliliter
₱/kWh	:	Pesos per kilo watt hour
ps/day	:	Pounds per day
t/y	:	ton per year
US$	:	United States Dollar
µS/cm	:	Micro Siemens per centimeter