APPENDIX E

WATER QUALITY AND POLLUTION MECHANISM

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Table of Contents

List of Tables

List of Figures

APPENDIX E WATER QUALITY AND POLLUTION MECHANISM

CHAPTER I EXISTING RIVER AND LAKE WATER QUALITY

1.1 Available Water Quality Data

1.1.1 Sampling Location and Frequency

CAR has analyzed the river and lake water quality of the Study Area since 1993 only on ad hoc basis. The analysis has been done under the direct management only when abnormal water quality was noticed and its analysis was requested from the local people. Apart from this, CAR entrusted a local consultant to analyze the water quality one (1) time in May, 1997. However, the sampling locations and frequency are not sufficient and then, existing available data are limited.

The sampling locations and frequency in the past are shown below.

No.	River	Location	Frequency	Sampling Date
	Ubate River			
1	Main	Lower End	4	Aug. 96, July 97, Dec. 98, Mar. 99
2	Lenguazaque	Before Prodeco	1	Jan., 93
	Other Inflow Rivers			
3	Q. Honda	Lower End	2	Dec. 98, Mar. 99
4	Q. Monroy	Lower End	1	May 97
5	Q. Tagusa	Lower End	1	May 97
6	Q. Calaboza	Lower End	1	May 97
7	Q. Cucunuba	Lower End	1	May 97
8	Q. Malvinas	Lower End	1	May 97
	Suarez River			
9	Main	Before Tolon Gate	4	Dec. 93, Oct.96,Dec. 98, Mar. 99
10	Main	Balsa Bridge	1	Dec. 93
11	Simijaca	Lower End	1	Oct. 96
12	Susa	Lower End	1	Oct. 96
	Lake Fuquene			
13		Near Port	1	Dec. 96,
14		Near Ubate Mouth	5	Dec. 96, May 97, July 97, Dec. 98, Mar. 99
15		Center	3	Dec. 96, May 97, July 97
16		Island	3	May 97, Dec. 98, Mar. 99
17		Near Suarez Outlet	5	Dec. 96, May 97, July 97, Dec. 98, , Mar. 99

The above sampling locations are shown in Fig. E.1.1.

1.1.2 Water Quality in the Past

The analyzed water quality parameters are as follows.

Water Temperature, EC, pH, DO (Dissolved O_2), BOD (DBO), COD (DQO), SS, Heavy Metals (Cd, Pb, Cr, Zn, Hg), NH_4, NO_3, NO_2, Kje-N, T-N, PO_4, T-P, T-Fe, Mg, Hardness ($CaCO_3$), Fecal Coli.

The water quality data at the above 17 sampling locations during 1993-1999 are shown in

Table E.1.1.

Among the above 17 locations, Ubate River (lower end), Suarez River (before Tolon Gate) and Lake Fuquene are the key locations for evaluation of the water quality in the Study Area. The average water quality of the three (3) key locations in the past are shown in Table E.1.1. The average water quality in major parameters are summarized as shown below.

Parameter	Ubate River (Lower End)	Suarez River (Before Tolon)	Lake Fuquene
Water Temp.(^oC)	16.3	17.5	17.7
PH	7.1	6.7	7.2
DO (O_2)	4.1	3.9	6.4
BOD (DBO)	3.8	2.0	2.5
COD (DQO)	31.1	46.0	25.6
NH_4	0.76	0.58	0.52
T-N	3.11	3.68	1.98
T-P	0.18	0.18	0.10
T-Fe	1.45	2.73	0.75
Heavy Metals	N.D. or Negligible	N.D. or Negligible	N.D. or Negligible

As shown in the above table, the water quality are characterized as follows.

(1) The water temperature is moderate and little varies throughout the year

(2) T-Fe is considerably high.

(3) COD (DQO) is also high.

(4) NH_4 is very high. It is considered mainly due to the large wastewater of cattle raising.

(5) Lake Fuquene is considered highly eutrophic, judging from that T-N and T-P much exceed the ordinary criteria of lake eutrophication (T-N>0.2 mg/l, T-P>0.02 mg/l).

1.2 Supplementary Water Quality Observation in Rainy Season

Observations of the river/lake water quality, deposit quality in the river/lake, biological features in the Lake, transparency/releasing/production/settling rates in the Lake and wastewater quality of sewerage and factories in rainy season were conducted during April to May, 1999 to supplement the existing available data. The observed locations, parameters and frequency are described below.

1.2.1 Water Quality Observation

(1) Water Quality Observation in the Lake

The water quality of the Lake was observed at the four (4) locations for 34 quality parameters. The observation was done at both fine and rainy weathers one (1) time each. The observed locations are as follows.

Sampling Location	Code No.
Near Ubate River Mouth	QL-1
Near Port	QL-2
Center	QL-3
Near Suarez Outlet	QL-4

For locations, see Fig. E 1.2

The observed parameters are shown below.

Classification	Parameter	Remarks
General Item	Color, Odor, EC, Turbidity, pH, DO (O_2), Temperature	
Organic Substances	COD (DQO)	
Eutrophication	T-N, NH_4, NO_3, NO_2, T-P, PO_4	
Suspended Solid	SS, Particle Size Distribution, V-SS	
Toxic Substances	Phenol, As, Cd, CN, Cr, Cu, Hg, Ni, Pb, Zn, Pesticides (3 kinds)	Fine weather only
General Metal	Fe, Mn	Fine weather only
Coliform Bacillus	Total, Fecal	Fine weather only

The observed water quality is shown in Table E.1.2.

(2) Water Quality Observation at the Principal River Stations

The river water quality at the seven (7) principal stations was observed for 36 quality parameters. The observation was done at fine weather one (1) time and rainy weather two (2) times.

The observed locations are as follows.

River	Sampling Location	Code No.
Hato River	Outlet of Hato Dam	QS-4
Ubate Main River	Before Meeting of Lenguazaque River	QR-1
Lenguazaque River	Vereda Punta Gande	QR-2
Ubate Main River	Colorado (Lower End)	QR-3
Suarez Main River	Before Meeting of Simijaca River	QR-4
Chiquinquira River	Upstream of Chiquiquira City	QR-5
Suarez Main River	Before Tolong Gate	QR-6

For locations, see Fig. E 1.2.

The observed parameters are shown below.

Classification	Parameter	Remarks
General Item	Discharge, Color, Odor, EC, Turbidity, pH, DO (O_2)*, Temperature	*: Fine weather only
Organic Substances	BOD (DBO), COD (DQO)	
Eutrophication	T-N, NH_4,* NO_3,* NO_2,* T-P, PO_4*	*: Fine weather only
Suspended Solid	SS, Particle Size Distribution,* V-SS	*: Fine weather only
Toxic Substances	Phenol, As, Cd, CN, Cr, Cu, Hg, Ni, Pb, Zn, Pesticides (3 kinds)	Fine weather only
General Metal	Fe, Mn	Fine weather only
Coliform Bacillus	Total, Fecal	Fine weather only

The observed water quality is shown in Table E.1.3.

(3) Water Quality Observation at the Secondary River Stations

The river water quality at 10 secondary river stations was observed for 13 quality parameters to analyze non-point pollution load runoff. The observation was done at rainy weather two (2) times.

The observed locations are as follows.

River	Sampling Location	Code No.
Leanguazaque River	Lower End	AD-1
Q. Obejeras	Lower End	AD-2
Q. Mojica	Lower End	AD-3
Suta River	Lower End	AD-4
Q. La Playa	La Malilla	AD-6
Fuquene River	Chinzaque	AD-8
Q. Honda	Virgen Punta Pena	AD-9
Q. Mina	Tica. Munaz	AD-10
Ubate River	La Bayera	AD-11
Vallado Madre Norte	Vereda Taquila	QS-3

For locations, see Fig. E.1.2.

The observed parameters are shown below.

Classification	Parameter
General Item	Discharge, Color, Odor, EC, Turbidity, pH, Temperature
Organic Substances	BOD (DBO), COD (DQO)
Eutrophication	T-N, T-P
Suspended Solid	SS, V-SS

The observed water quality is shown in Table E.1.4

(4) Continuous Water Quality Observation at Ubate River

The river water quality at Colorado (lower end) of the Ubate River was continuously observed during a flood to analyze the relationship between river discharge and pollution load inflow to the Lake. For locations, see Fig. E.1.2.

The observed parameters are shown below.

Classification	Parameter
General Item	Discharge, *EC
Organic Substances	COD (DQO)
Eutrophication	T-N, T-P
Suspended Solid	SS, Particle Size Distribution, V-SS

*: EC observation was carried out for one (1) month by an automatic recorder every one (1) hour .

The observed water quality is shown in Table E.1.5.

1.2.2 Deposit Quality Observation

The deposit quality in the lake bed was observed at the same locations as water quality observation. The deposit quality in the river was also observed at the principal stations of water quality observation (excluding the outlet of Hato Dam). The observation was done in a fine weather. The observed parameters are 26 ones as shown below.

Classification	Parameter
General Item	Color, Odor, pH
Organic Substances	COD (DQO)
Eutrophication	T-N, T-P
Toxic Substances	Phenol, As, Cd, CN, Cr, Cu, Hg, Ni, Pb, Zn, Pesticides (3 kinds)
General Metal	Fe, Mn
Others	Moisture Content, Sulfide, Oxygen Reproduction Potential, Particle Size Distribution, V-SS

The observed deposit quality is shown in Table E.1.6

1.2.3 Biological Observation in the Lake

The biological observation was done at the same locations as water quality observation in the Lake at a fine weather. The observation includes the following sampling/analyses.

Sampling/Analysis	Chlorophyl-a, Phytoplankton, Zooplankton, Benthos

The observation results are shown in Table E 1.7

1.2.4 Transparency, Releasing, Production and Settling Test

(1) Transparency Test

The transparency test of the lake water was done at the same locations as water quality observation in a fine weather. The observation results are shown in Fig E.1.3

(2) Releasing Test

The releasing test of substances from the lake bed was done at a location near the Port. The tested substances are as follows.

Tested Substances	COD (DQO), T-N, NH_4, NO_3, NO_2, T-P, PO_4

The observation results are shown in Table E.1.8.

(3) Production Test

Primary production of phytoplankton (absorption and emission of oxygen) was observed at the same locations as water quality observation in the Lake.

The observation results are shown in Table E 1.9.

(4) Settling Test

Settling of detritus (including inorganic particles) was observed at the same locations as water quality observation in the Lake. Analyzed parameters are shown below.

Analyzed Parameters	SS, Particle Size Distribution, V-SS

The observation results are shown in Table E.1.10

1.2.5 Wastewater Quality Observation of Sewerage and Factories

The wastewater quality of sewerage and factories was observed at 13 locations for 17 quality parameters. The observation was done at fine weather one (1) time each. The sampling locations, factory activities and wastewater receiving body are as follows.

Municipality	Sampling Location	Activities	Receiving Body
Ubate	Lacteos San Andres	Dairy Processing	Irrigation
Ubate	Lacteos Ubate	Dairy Processing	Sewerage
Ubate	Ubate Slaughterhouse	Slaughterhouse	Sewerage
Ubate	Parmalat	Milk Cooling	Sewerage
Ubate	Dona Leche	Dairy Processing	Ubate River
Ubate	Ubate Sewerage after Treatment	Sewerage	Suta River
Ubate	Ubate Sewerage before Treatment	Sewerage	Suta River
Fuquene	Colfrance	Dairy Processing	Irrigation
Simijaca	Alpina	Milk Cooling	Sewerage
Simijaca	Delay	Milk Cooling	Q. Capitplio
Simijaca	Simijaca Slaughterhouse	Slaughterhouse	Sewerage
Cucunuba	Cucunuba Sewerage after Treatment	Sewerage	Q.Buida
Saboya	Saboya Sewerage after Treatment	Sewerage	Suarez River

The observed parameters are shown below.

Classification	Parameter	Remarks
General Item	Discharge, Color, Odor, EC, Turbidity, pH, Temperature	
Organic Substances	BOD (DBO), COD (DQO)	
Eutrophication	T-N, NH_4, NO_3, NO_2, T-P, PO_4	
Suspended Solid	SS	
Coliform Bacillus	Total, Fecal	Sewerage System only

The observed water quality is shown in Table E.1.11.

1.3 Supplementary Water Quality Observation in Dry Season

Observations of the river/lake/groundwater water quality, biological features in the Lake, transparency/production/settling rates in the Lake and wastewater quality of sewerage and factories in dry season were conducted during July to September, 1999 to supplement the existing available data. The observed locations, parameters and frequency are described below.

1.3.1 Water Quality Observation

(1) Water Quality Observation in the Lake

The water quality of the Lake was observed at the four (4) locations for 37 quality parameters. The observation was done at fine weathers one (1) time. The observed locations are as follows.

Sampling Location	Code No.
Near Ubate River Mouth	QL-1
Near Port	QL-2
Center	QL-3
Near Suarez Outlet	QL-4

For locations, see Fig. E 1.2

The observed parameters are shown below.

Classification	Parameter	Remarks
General Item	Color, Odor, EC, Turbidity, pH, DO (O_2), Temperature	
Organic Substances	COD (DQO),COD(Mn),TOC,Humic acid	
Eutrophication	T-N, NH_4, NO_3, NO_2, T-P, PO_4	
Suspended Solid	SS, Particle Size Distribution, V-SS	
Toxic Substances	Phenol, As, Cd, CN, Cr, Cu, Hg, Ni, Pb, Zn, Pesticides (3 kinds)	
General Metal	Fe, Mn	
Coliform Bacillus	Total, Fecal	

The observed water quality is shown in Table E.1.12.

(2) Water Quality Observation at the Principal River Stations and Groundwater Stations

The river water quality at the ten (10) principal river stations and the groundwater quality at the two (2) stations were observed for 39 quality parameters. The observation was done at fine weather two (2) times.

The observed locations are as follows.

River	Sampling Location	Code No.
Hato River	Outlet of Hato Dam	QS-4
Ubate Main River	Before Meeting of Lenguazaque River	QR-1
Lenguazaque River	Vereda Punta Gande	QR-2
Ubate Main River	Colorado (Lower End)	QR-3
Suarez Main River	Before Meeting of Simijaca River	QR-4
Chiquinquira River	Upstream of Chiquiquira City	QR-5
Suarez Main River	Before Tolong Gate	QR-6
Suarez Main River	After Sewerage Effluent of Chiquinquira City	QR-7
Susa River	Lower End	QR-8
Simjaca River	Lower End	QR-9
Groundwater-1	Ubate River Basin (Near Colorado)	QU-1
Groundwater-2	Suarez River Basin (Saboya)	QU-2

For locations, see Fig. E 1.2.

The observed parameters are shown below.

Classification	Parameter	Remarks
General Item	Discharge, Color, Odor, EC, Turbidity, pH, DO (O_2)*, Temperature	
Organic Substances	BOD (DBO), COD (DQO) ,COD(Mn),TOC,Humic acid	
Eutrophication	T-N, NH_4, NO_3, NO_2, T-P, PO_4	
Suspended Solid	SS, *Particle Size Distribution, V-SS	* Main points only
Toxic Substances	Phenol, As, Cd, CN, Cr, Cu, Hg, Ni, Pb, Zn, Pesticides (3 kinds)	Main points only
General Metal	Fe, Mn	
Coliform Bacillus	Total, Fecal	

The observed water quality is shown in Table E.1.13.

(3) Water Quality Observation at the Secondary River Stations

The river water quality at 10 secondary river stations was observed for 13 quality parameters to analyze non-point pollution load runoff. The observation was done at fine weather two (2) times.

The observed locations are as follows.

River	Sampling Location	Code No.
Leanguazaque River	Lower End	AD-1
Q. Obejeras	Lower End	AD-2
Q. Mojica	Lower End	AD-3
Suta River	Lower End	AD-4
Q. La Playa	La Malilla	AD-6
Fuquene River	Chinzaque	AD-8
Q. Honda	Virgen Punta Pena	AD-9
Q. Mina	Tica. Munaz	AD-10
Ubate River	La Bayera	AD-11
Vallado Madre Norte	Vereda Taquila	QS-3

For locations, see Fig. E.1.2.

The observed parameters are shown below.

Classification	Parameter
General Item	Discharge, Color, Odor, EC, Turbidity, pH, Temperature
Organic Substances	BOD (DBO), COD (DQO)
Eutrophication	T-N, T-P
Suspended Solid	SS, V-SS

The observed water quality is shown in Table E.1.14

(4) Water Quality Observation in relation to the Sewerage Effluent

The river water quality at 5 stations was observed for 5 quality parameters to know the effect of sewerage effluent. The observation was done at fine weather one (1) time.

The observed locations are as follows.

River	Sampling Location	Remarks
Ubate River	Before Meeting Suta River	
Suta River	Lower End	
Ubaete River	After Meeting of Suta River	
Ubaete River	Before Cubio Gate	
Suarez River	After Chiquinquira City	

The observed parameters are shown below.

Classification	Parameter
General Item	Discharge,
Organic Substances	BOD (DBO), COD (DQO)
Eutrophication	T-N, T-P
Reduction substance	H_2S*

*: only observed at Suta River

The observed water quality is shown in Chapter I Sub-section 1.4.1.

1.3.2 Biological Observation in the Lake

The biological observation was done at the same locations as water quality observation in the Lake at a fine weather. The observation includes the following sampling/analyses.

Sampling/Analysis	Chlorophyl-a, Phytoplankton, Zooplankton, Benthos

The observation results are shown in Table E 1.15

1.3.3 Transparency, Production and Settling Test

(1) Transparency Test

The transparency test of the lake water was done at the same locations as water quality observation in a fine weather. The observation results are shown in Fig E.1.4

(2) Production Test

Primary production of phytoplankton (absorption and emission of oxygen) was observed at the same locations as water quality observation in the Lake.

The observation results are shown in Table E 1.16.

(3) Settling Test

Settling of detritus (including inorganic particles) was observed at the same locations as water quality observation in the Lake. Analyzed parameters are shown below.

Analyzed Parameters	SS, Particle Size Distribution, V-SS

The observation results are shown in Table E.1.17

1.3.4 Wastewater Quality Observation of Sewerage and Factories

The wastewater quality of sewerage and factories was observed at 13 locations for 17 quality parameters. The observation was done at fine weather one (1) time each. The sampling locations, factory activities and wastewater receiving body are as follows.

Municipality	Sampling Location	Activities	Receiving Body
Ubate	Lacteos San Andres	Dairy Processing	Irrigation
Ubate	Lacteos Ubate	Dairy Processing	Sewerage
Ubate	Ubate Slaughterhouse	Slaughterhouse	Sewerage
Ubate	Parmalat	Milk Cooling	Sewerage
Ubate	Dona Leche	Dairy Processing	Ubate River
Ubate	Ubate Sewerage after Treatment	Sewerage	Suta River
Ubate	Ubate Sewerage before Treatment	Sewerage	Suta River
Fuquene	Colfrance	Dairy Processing	Irrigation
Simijaca	Alpina	Milk Cooling	Sewerage
Simijaca	Delay	Milk Cooling	Q. Capitplio
Simijaca	Simijaca Slaughterhouse	Slaughterhouse	Sewerage
Cucunuba	Cucunuba Sewerage after Treatment	Sewerage	Q.Buida
Saboya	Saboya Sewerage after Treatment	Sewerage	Suarez River

The observed parameters are shown below.

Classification	Parameter	Remarks
General Item	Discharge, Color, Odor, EC, Turbidity, pH, Temperature	
Organic Substances	BOD (DBO), COD (DQO)	
Eutrophication	T-N, NH_4, NO_3, NO_2, T-P, PO_4	
Suspended Solid	SS	
Coliform Bacillus	Total, Fecal	Sewerage System only

The observed water quality is shown in Table E.1.18.

1.4 Evaluation of Supplementary Observation Results

1.4.1 River and Lake Water Quality

(1) Average Water Quality

The average water quality at the major river stations (Hato Dam Outlet, Pte Colorado in Ubate River and Tolon Gate in Suarez River) and the Lake Fuquene (average at 4 locations) in the rainy season and dry season of 1999 are summarized below. These summarized data can be further compared to the existing raw water quality standards of CAR which are mentioned in pages E-16,17 and Table E 1.20.

Item	Unit	Rainy Saeson				Dry Season			
		Average Lake Water	Hato Dam Outlet	Ubate River Pte Colorado	Suarez River Tolon Gate	Average Lake Water	Hato Dam Outlet	Ubate River Pte Colorado	Suarez River Tolon Gate
PH	-	6.68	7.04	7.00	6.90	6.74	7.60	6.95	6.70
DO	mg/l	3.3	6.0	6.3	0.3	4.5	6.2	0.7	2.3
BOD_5 (DBO_5)	mg/l	-	2.5	3.5	1.5	-	1.0	6.2	2.3
COD (DQO)	mg/l	34.3	17.7	22.70	51.7	28.5	21.5	64.0	41.1
T-N	mg/l	2.10	1.12	2.18	2.44	1.55	3.25	6.9	2.5
T-P	mg/l	0.10	0.08	0.30	0.12	0.04	0.14	0.78	0.07
NH_4^+	mg/l	0.88	0.77	0.32	1.24	0.54	0.43	2.34	0.53
NO_3^-	mg/l	0.25	0.16	0.32	0.33	0.04	0.25	0.40	0.25
NO_2^-	mg/l	0.01	0.05	0.00	0.00	0.00	0.007	0.001	0.001
Turbidity	UJT	20.0	39	43.8	117.3	4.6	7.1	5.7	31.0
Fe	mg/l	1.46	1.68	3.46	18.3	1.72	1.46	2.84	5.89
Total coli.	MPN	37×10^2	70	$>24\times10^6$	15×10^2	29×10	$<20\times10^2$	16×10^4	17×10^2
Fecal coli.	MPN	37×10^2	70	93×10^5	9×10^2	12×10	$<30\times10^2$	11×10^4	16×10^2

As shown from the above table, the river and lake water quality are characterized as follows.

(a) pH of both river and lake water is normal in both seasons.

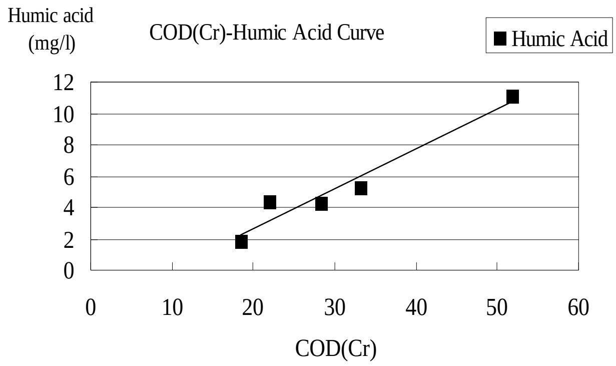
(b) Both the river and lake water are highly turbid and the turbidity exceeds the raw water standard of CAR for drinking in rainy season. On the other hand ,turbidity in dry season becomes lower than in rainy season, and the river water does not exceed the water standard of CAR for drinking, only Suarez River turbidity exceeds CAR standards.

(c) DO (O_2) in the Lake and Tolon Gate is low and do not satisfy the raw water CAR standard for drinking at any season. DO in the Lake excluding the central area is even lower (2.8mg/l). This low DO is probably caused mainly to the fact that decomposition of the withered aquatic plants (especially Elodia) and detritus consumes a lot of the dissolved oxygen in the lake water. DO (O_2) in Ubate River Pte Colorado is very low in dry season. DO before Cubio Gate becomes much lower. It is due to sewerage inflow of Ubate City and low river discharge.

(d) BOD (DBO) in the river water is comparably low. However, COD (DQO) in both river and lake water is very high. It is probably due to a high content of humic acid in the water. The cause of this high COD (DQO) content is confirmed as below with analysis results in dry season. Generally COD (DQO) value is multiplying 2.5-2.8 by COD(Mn) value. The relation of COD (DQO) and COD(Mn) is calculated about 5 times by the analysis results at dry season, it is probably due to the presence of many acid resistant organic compounds. On the other hand, TOC and humic acid are relative high concentration. These data indicates that high COD (DQO) value is due to high humic acid concentration. These relation of COD (DQO), COD(Mn) and Humic acid are shown below.

Ordinary humic acid is not detected in colorless river water and indicated nearly zero (0). Humic acid is not toxic substance, and it is not necessary to consider it regarding water use in Suarez River.

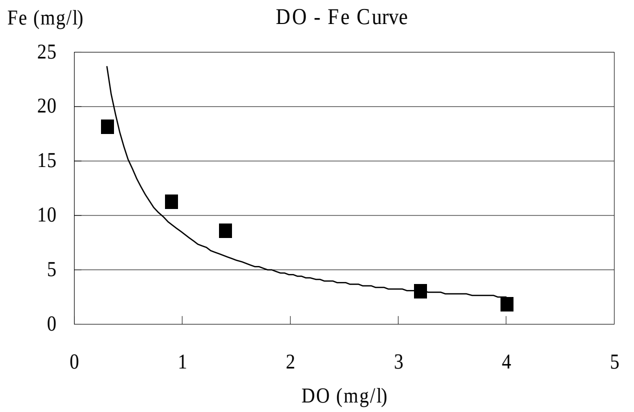
River	Point	COD (DQO) (mg/l)	Humic acid (mg/l)
Hato Dam	Outlet of Dam	22.0	4.4
Ubate River	Downstream of Ubate City	15.0	7.0
Lenguazaque River	Vereda Punta Gande	28.3	4.3
Ubate River	Pte Colorado	33.2	6.3
Suarez River	Balsa Bridge	50.0	3.3
Chiquinquira River	Upstream of Chiquinquira City	18.5	1.9
Suarez River	Tolon Gate	51.8	11.1



(e) Fe concentration in both river and lake water is also high. It is probably due to that the geology of the Study Area contains a high degree of Iron. This can be proved from the fact that groundwater in the Study Area shows a high concentration of Fe as shown below.

No.	Location	Well Name	Ave. Fe (mg/l)
QU-1	Near Colorado	Albaida II (Pozo No.4)	94.0
QU-2	Saboya	Sugamuxi Pozo	66.9

Fe in the rivers of Ubate, Lenguazaque, Susa, Simijaca and Chiquinquira shows a comparatively small variation of 0.59 - 3.46 mg/l (average: 1.99 mg/l). It is considered to be due to the comparatively high content of DO (average: 5.1 mg/l) in the rivers. However, Fe in the Suarez River (lake outlet - Tolon gate) considerably varies ranging from 1.75 mg/l to 18.30 mg/l (average: 7.50 mg/l). The Fe value indicates a sudden increase according to the decrease of DO as shown



It is considered due to that the deposits in the River are under a high anaerobic condition.

(f) High contents of NH_4 and Coliforms are observed in both river and lake water at both seasons. It is considered to be mainly due to the large wastewater of livestock in the Study Area.

(g) T-N and T-P in the Lake exceed by far the ordinary criteria of lake eutrophication (T-N>0.2 mg/l, T-P>0.02 mg/l) despite season. Especially in dry season, T-N and T-P in the river highly increase at Ubate River Pte Colorodo.

(h) T-N, NH_4-N, and T-P concentration in groundwater are high at Ubate River sub-basin. The average water quality analysis data of groundwater are summarized below.

Item	Unit	Ubate River sub-basin ALBAIDA-II	Suarez River sub-basin SUGAMXI
PH	-	6.4	6.9
DO	mg/l	0.0	1.7
BOD	mg/l	23.7	1.6
COD	mg/l	260	44.0
T-N	mg/l	36.1	2.85
NH_4-N	mg/l	29.8	2.23
NO_3-N	mg/l	0.5	0.2
NO_2-N	mg/l	ND	ND
T-P	mg/l	3.02	0.40

(2) Specific Water Quality Problem

(a) The wastewater from the sewerage systems of Ubate and Chiquinquira cities considerably affects the water quality in the downstream river sections at a drought time. The observed water quality at a drought time is summarized below. The water in the river sections immediately after the sewerage effluents of Ubate and Chiquinquira cities is highly polluted with black color and bad odor, then emitting a toxic substance (H_2S).

Location	Q (m^3/s)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	H_2S (mg/l)
Ubate River before Suta River Confluence	0.47	6.3	2.0	5.8	
Suta River after Ubate Sewerage Effluent	0.08	0.9	183.0	403.0	3.00
Ubate River after Suta River Confluence	0.55	5.3	24.1	44.1	
Ubate River after Lenguazaque River Confluence		4.5	3.1	24.5	
Suarez River after Chiquinquira Sewerage Effluent	0.68		137.0	399.0	

(b) Decomposition of the withered aquatic plants and detritus consumes a lot of oxygen in the lake water, resulting in making the water anaerobic. A wide water area is anaerobic in the Lake at present. In such area, the lake water is colored black, emitting a highly concentrated toxic substance (H_2S) as shown below.

Location	Lake Surface		Lake Bottom	
	DO (mg/l)	H_2S (mg/l)	DO (mg/l)	H_2S (mg/l)
St-1	0.0	1.20		
St-2	0.4	0.40	0.0	0.50
Near Suarez Outlet	1.9	0.01	0.0	2.60

(3) Relationship between Water Quality and Water Depth in the Lake

The relationship between the water quality and water depth in the Lake Fuquene is summarized below.

(a) Temperature of the lake water is nearly constant (16-18 ^oC) regardless of water depth and season.

(b) In rainy season, turbidity of the lake water is 20 mg/l regardless of water depth except near the Ubate river mouth. The surface water near the Ubate river mouth is as turbid as 60 mg/l, however, it decreases to less than 30 mg/l at a depth of 2.0 m

(c) Transparency of the lake water decreases at a high rate according as the water depth increases. The relative illumination rate decreases to 1.0% of the surface one at approximately 1.0 m depth. However, transparency of the lake water in dry season was relative different with rainy season, decreasing at a high rate as the water depth increased. The relative illumination rate decreases to 1.0% of the surface one at approximately 1.5-3.5 m depth.

(d) DO (O_2) at the locations of near Port and center is constant at 4-5 mg/l regardless of water depth. However, near Ubate river mouth and Suarez outlet, it suddenly decreases as water depth increases and becomes nearly zero at 2.0 m depth.

(e) DO (O_2) values in the daytime and at night were compared in a location near the Port. The DO in the daytime was constant regardless of water depth. On the other hand, the DO at night decreased at a high rate according to the increase of water depth and it became zero at 2.5 m depth. It is probably due to the respiration effects of Elodea at night.

For the above, see Fig E.1.3 and Fig E 1.4.

1.4.2 Deposit Quality

The deposit quality of the river and lake beds at the principal river stations (Ubate River at Pte Colorado and Suarez River at Tolon Gate) and the Lake (average at 4 locations) are summarized below.

Item	Unit	Average Lake Deposit	Ubate River Pte Colorado	Suarez River Tolon Gate
Color	-	Black/Dark Gray	Dark Brown	Dark gray
COD (DQO)	mg/dry-g	87,1	208.2	99.4
T-N	mg/dry-g	4.60	1.01	3.80
T-P	mg/dry-g	0.148	0.454	0.037
Ignition Loss	%	16.4	45.2	17.8
Sulfide.	mg/dry-g	0.98	0.84	1.24
ORP*	MV	-132	-95	-142

* ORP: Oxidation- Reduction Potential

(1) Ignition loss of both river and lake deposits are more than 15%. It means that the deposits contain a high content of organic substances. It is also confirmed by the high contents of COD, T-N and T-P in the deposits.

(2) Oxidation-Reduction Potential (ORP) of the river and lake deposits is as low as - 95 to - 100 mV. It indicates a high anaerobic condition of the deposits. The deposits contain much sulfide (H_2S) and are colored black or dark gray.

(3) Among the nine (9) major heavy metals (As,Cd,CN,Cr^{6+},Cu,Hg,Ni,Pb,and Zn), Cd, CN, Cr^{6+} and Hg are not detected in the river and lake deposits, while a certain concentration level of As, Cu, Ni, Pb and Zn are identified. However, this concentration level is as low as that of ordinary soils, causing no problems on the water environments.

(4) No pesticides are detected in both river and lake deposits.

1.4.3 Plankton and Benthos

(1) Plankton

(a) The existing phytoplankton in the Lake counts 32 species in rainy season and 28 species in dry season with an average population density (number of cells) of 6,525 cells/ml in rainy season and 4,290 cells/ml in dry season. Each species and average population are very similar despite of the seasons. The average concentration of Chlorophyll-a is estimated to be 0.75 mg/m^3 in rainy season and 1.08 mg/m^3 in dry season. The population density and Chlorophyll-a concentration at the respective stations at both seasons are shown below.

Observation Station	Rainy Season		Dry Season	
	Population Density (cells/ml)	Chlorophyll-a (mg/m^3)	Population Density (cells/ml)	Chlorophyll-a (mg/m^3)
QL-1	3,470	0.31	2,110	0.41
QL-2	1,825	0.07	2,175	0.31
QL-3	11,025	0.30	1,650	0.26
QL-4	9,775	2.30	11,225	3.35
Average	6,525	0.75	4,290	1.08

(f) Population of the existing zooplankton is very small in both seasons. It counts only four (4) species with an average population density of 4 cells/ml in rainy season, and only three (3) species with an average population density of 0.01cells/ml in dry season,

(g) The phytoplankton population and Chlorophyll-a concentration in the Lake Fuquene are compared with those in the typical eutrophic lakes in Japan as shown below. The population in the Lake Fuquene is very few compared to those in the lakes of Japan although the Lake Fuquene contains more nutrients. This is considered due to that the water temperature of the Lake Fuquene stays around 17℃ throughout the year and it never reaches 20℃.

Lake	Phytoplankton Cell Number	Chlorophyll-a (mg/m^3)	Water Temperature (℃)	Average T-N (mg/l)	Average T-P (mg/l)
Lake Fuquene	6525	0.75	16.8	1.83	0.07
South Biwa Lake in Japan-1)	650-79,000	3.6-30.3	5.0-30.2	0.40	0.02
Kasumigaura Lake in Japan-2)	10,000-270,000	56-110	4.5-30.2	0.86	0.08

The monthly change of phytoplankton in South Biwa Lake and Kasumigaura Lake, Japan are shown in Fig E.1.5. As shown in this figure, warm water temperature causes an explosive increase of population when it exceeds 20℃ in summer season and the population returns to the original level when the water temperature lowers in winter season.

(2) Benthos

Through both seasons, no benthos is identified in the deposits of the Lake since even the surface layer of the lake bed is under an anaerobic condition. This anaerobic condition may be caused by decomposition of the deposited aquatic plants and detritus on the lake bed. Generally, clean lakes contain oxygen in the surface layer of the bed where shellfish and various species of benthos live.

1.4.4 Settling, Releasing and Production Rate

(1) Settling Rate of Particles

The settling rate of particles in the Lake is considered especially large near the river mouth of Ubate (QL-1 station). However, neither QL-1 station could be observed during the first and second field survey, not Near Port (Ql-2 station) in dry season. The average settling rate at the remaining stations in the Lake is calculated as shown below.

Parameter	Rainy Season	Dry Season
SS ($g/m^2/d$)	2.32	1.09
Ratio of Organic Substances((%)	34	22

(2) Releasing Rate of COD, T-N and T-P

The deposited chemical elements on the lake bed dissolve in the water again. The releasing rate of COD, T-N and T-P from the lake bed was observed at the station (QL-2). From these observation results, the releasing rates of COD, T-N and T-P in the Lake through both seasons are estimated as follows.

Parameter	Releasing Rate
COD	900 $mg/m^2/d$
T-N	60 $mg/m^2/d$
T-P	0.55 $mg/m^2/d$

(3) Production Rate of Phytoplanton

The production rates of phytoplankton through both seasons were estimated by the field tests at the four (4) stations of the Lake as shown below.

Observation Station	Daily Primary Production ($Cg/m^2/d$)		
	Rainy Season	Dry Season	Average
QL-1	3.16	2.35	2.76
QL-2	2.73	1.04	1.89
QL-3	0.95	2.80	1.88
QL-4	3.42	1.56	2.49
Average	2.57	1.94	2.23

1.4.5 Wastewater Quality

The effluent wastewater quality and pollutant load were observed at the representative milk processing factories (7 factories), slaughterhouses (2 houses) and sewerage systems (4 systems) in the Study Area. The average pollutant concentration and load through both seasons of the factories, slaughterhouse and sewerage are summarized below.

Item	Parameter	Unit	Milk Factory*	Slaughterhouse	Sewerage**
Effluent Wastewater Quality	BOD	mg/l	522.7	402.8	49.3
	COD	mg/l	943.9	647.0	116.3
	T-N	mg/l	44.4	61.4	20.2
	T-P	mg/l	22.0	7.1	2.5
Effluent Pollutant Load	BOD	kg/d	8.8	3.7	175.3
	COD	kg/d	16.4	8.0	427.9
	T-N	kg/d	0.7	0.6	82.7
	T-P	kg/d	0.4	0.1	10.9

*: Excluding the observed data of Colfrance factory since the factory produces different products from the other ones.

**: Excluding the observed data of Ubate sewerage treatment system in dry season since the treatment system stopped Effluent Pollutant Load is calculated only for rainy season.

1.5 Standards of Surface Water Quality and Wastewater Effluents

1.5.1 National Standards

The Government of Colombia stipulated the national standards of surface water quality (permissive water quality concentration for domestic, agriculture, stockbreeding and recreation uses) and wastewater effluents (permissible wastewater concentration into river and sewerage) through the Decree 1594/84 The national standards give the minimum values to be conformed nationwide. They are shown in Table E.1.19.

1.5.2 CAR Standards

CAR stipulated the standards of surface water and wastewater effluents to be applied for their administration region through the Agreement 58/87, based on national standard. They are shown in Table E.1.20. Further, CAR categorized the target river water quality into four (4) classes of A,B,C,D in accordance with the water use level of rivers and designated the class of the rivers under their jurisdiction through the Agreement 58/87. The target water quality of each class is shown below. The river section in the Study Area are classified as shown in Fig E 1.6.

No.	Parameter	Unit	Permissible Concentration (mg/l)				Remarks
			Class-A	Class-B	Class-C	Class-D	
1	pH	(-)	6.5-8.5	5.0-9.0	4.5-9.0	4.5-9.0	
2	DO	O_2 mg/l	6.0	5.0	2.0	-	
3	BOD_5 (OBO_5)	O_2 mg/l	5.0	10.0	30.0	100.0	
4	Cobalt	Co mg/l	0.05	0.05	0.05	0.05	
5	Total Cyanide	CN mg/l	0.2	-	-	-	
6	Molybdenum	Mo mg/l	0.01	0.01	0.01	0.01	
7	Vanadium	V mg/l	0.1	0.1	0.1	0.1	
8	Boron	B mg/l	0.3-4.0	0.3-4.0	0.3-4.0	0.3-4.0	
9	Fluorine	F mg/l	1.0	1.0	1.0	1.0	
10	Phenol	C_6H_5OH mg/l	0.002	-	-	-	
11	Diphenyl	mg/l	0.0001	0.0001	-	-	
12	Chlorophenol	C_6H_5OHClmg/l	0.5	0.5	-	-	
13	Hydrogen Sulfide	H_2S mg/l	0.002	0.002	-	-	
14	Lithium	Li mg/l	2.5	2.5	2.5	2.5	
15	Aluminum	Al mg/l	5.0	5.0	5.0	5.0	
16	Magnesium	Mg mg/l	0.2	-	-	-	
17	Nitrate	NO_3-N mg/l	10.0	-	-	-	
18	Nitrite	NO_2-N mg/l	1.0	10.0	10	-	
19	Nitrate + Nitrite	N mg/l	-	100	100	-	
20	Chloride	Cl^-mg/l	250.0	-	-	-	
21	Color	Real Color	75	-	-	-	
22	Total Substance	mg/l	500.0	500.0	1,000	-	
23	Turbidity	UJT	2.0	-	-	-	
24	Total coliform	NMP	5,000	5,000	10,000	-	
25	Fecal coliform	NMP	1,000	1,000			

However, other heavy metals (Pb,Hg,Cr,As,Cd,Se) and toxic organic compounds (Organic mercury compounds, Trichloroethylene, etc) are not included in table above, because these parameters are regulated as toxic methodology.

CHAPTER II EXISTING POINT POLLUTION LOAD GENERATION

2.1 Inventory of Existing Point Pollution Sources

2.1.1 Sewerage System

The study Area covers totally or partially 17 municipalities, namely, Carmen de Carupa, Ubate, Tausa, Sutatausa, Suesca, Villapinzon, Lenguazaque, Guacheta, San Miguel de Sema, Raquira, Fuquene, Susa, Simijaca, Caldas, Chiquinquira, and Saboya as shown in Fig. E.2.1.

Out of those municipalities, the urban centers of 14 municipalities, excluding Suesca, Villapinzon and Raquira are located in the Study Area and are equipped with the sewerage system. Inventory of the existing sewerage systems of these municipalities in the Study Area was prepared through questionnaire and interviews (conducted in April, 1999) with the related personnel of each municipality and available data in the CAR. The results are tabulated in Table E.2.1 and shown below.

(1) Carmen de Carupa

The population of Carmen de Carupa urban area is 1,320 (305 households) and no industries exist in the urban area. The sewerage with combined collection system is located in the urban area and domestic wastewater of 1,300 persons (300 households) and slaughterhouse are combined and discharged into Q. Suchinica without treatment. The remaining five (5) households of 20 persons have their own septic tanks. The Carmen de Carupa municipality has no data of total pipe length of the sewerage system but diameters of the system are 30.5 cm (max.) and 15.2 cm (min.). Sewerage charge is not collected.

(2) Ubate

16,750 persons of 3,350 households live in the urban area of Ubate Municipality. The sewerage with combined collection system covers all the persons in the urban area and receives also 88 industrial establishments. The length of pipe is 36 km in total and pipe diameter is 61.0 cm in max. and 20.3 cm in min.

The treatment plant was completed in 1995 beside the Suta River. The wastewater from the households and industrial establishments are treated through anaerobic process (R.A.P) and discharged into the Suta River. Designed service population is 18,000. Design discharge and BOD concentration for the treatment plant are 45 L/s and 290 mg/L. However, due to inflow of wastewater from the dairy industry, which exceeds the design condition, the treatment plant is operated under an overloading condition.

The sewerage charge of Ubate is collected based on water use volume and unit charge is different for households (42.58 peso/m^3) and factories (64.11 peso/m^3). The average charge per household is 1,700 peso/month.

The following table tabulates average water quality observation results in 1998 (Sep.22, Oct.30 and Nov. 20) and in 1999 (Feb. 04 and Feb. 18).

Year	Location	Volume (l/s)	pH	BOD_5 (mg/l)	$COD_{(Cr)}$ (mg/l)	SS (mg/l)	Coliforms (MPN/100ml)	
							Total	Fecal
1998	Influent	42.7	6.8	285	645	257	11×10^8	24×10^7
	Effluent	39.7	6.7	107	241	88	11×10^7	93×10^5
1999	Influent	54.8	6.9	776	1,018	282	46×10^7	46×10^7
	Effluent	49.5	7.3	122	565	103	75×10^6	31×10^5
Ave.	Influent	47.5	6.8	481	7,942	267	11×10^8	46×10^7
	Effluent	43.6	7.0	113	370.	94	11×10^7	93×10^5

(3) Tausa

Urban area of Tausa is 10 ha where 955 persons of 191 families live and no industry is located. Tausa has sewerage system in its urban area with diameter of 40.6 cm to 20.3 cm. The Tausa sewerage system receives wastewater of 955 persons and discharges into the Suta River without treatment and collection system is separate. In Tausa, sewerage charge of 400 peso/month is collected at present.

(4) Sutatausa

The sewerage with combined collection system of Sutatausa urban area receives wastewater from 582 persons (155 households) but receives no industrial wastewater. Total pipe length of the system is 3.5 km. Max. diameter of the pipe is 25.4 cm, while min. diameter is 15.2 cm. The collected wastewater is discharged into the Suta River without treatment. The sewerage charge is 900 peso/month.

(5) Cucunuba

Sewerage with combined collection system is installed in urban area of Cucunuba municipality. Service population is 1,153 (310 households) and in its service area, no industry exists. The pipe length is 13.5 km with max. diameter of 25.4 cm and min. diameter of 15.2 cm. Stabilization ponds to treat wastewater from households and slaughterhouse was completed in 1992 which discharges effluent into the San Isidro River. No charge is collected from households at present.

(6) Lenguazaque

In Lenguazaque, the sewerage system covers urban area of 49 km^2 with pipe length of 5.1 km (max. diameter 25.4 cm and min. diameter 20.3 cm). Collection system is separate and service population is 1,800 (410 households). Domestic wastewater is discharged into Lenguazaque River after treating with activated sludge plant. This plant was constructed in 1998, financed with 280 million peso. The system receives no wastewater from industry. In Lenguazaque, no sewerage charge is collected form households connecting to the sewerage system.

(7) Guacheta

Urban area of Guacheta is 43 ha where 3,366 persons of 625 families live and five (5) dairy industries are located. Guacheta has sewerage with combined collection system and pipe length of 6.0 km and diameter varies from 61.0 cm to 20.3 cm. The Guacheta sewerage system, which receives wastewater of 3,366 persons and slaughterhouse, discharges into the Q. Gualacia without treatment. In Guacheta, sewerage charge of 450 peso/month is collected from each household at present

(8) San Miguel de Sema

The sewerage system installed in the urban area of San Miguel de Sema receives wastewater from approx. 500 persons (116 households) and one (1) dairy factory. The total pipe length of the system is approx. 2.8 km with max. diameter of 25.4 cm and min. diameter of 20.3 cm. In 1994, stabilization ponds, which treat the wastewater, were completed. The effluent is discharged into the Q. Santa Ana. The sewerage charge is 240 peso/month both for a household and a dairy factory.

The following table tabulates average water quality observation results of the San Miguel de Sema Treatment Plant conducted in 1998 (Sep. 02, Sep. 30, Nov.05 and Nov.26) and in 1999 (Jan.26 and Feb.09).

Year	Location	Volume (l/s)	pH	BOD_5 (mg/l)	$COD_{(Cr)}$ (mg/l)	SS (mg/l)	Coliforms (MPN/100ml)	
							Total	Fecal
1998	Influent	2.47	7.3	970	1,985	706	11×10^9	24×10^8
	Effluent	3.10	7.2	89	249	125	15×10^6	43×10^6
1999	Influent	1.35	6.6	89	245	45	24×10^6	36×10^5
	Effluent	1.40	7.0	47	160	57	93×10^6	43×10^6
Ave.	Influent	2.10	7.0	676	1,404	486	11×10^9	24×10^8
	Effluent	2.53	7.1	75	219	103	93×10^6	43×10^6

(9) Fuquene

In this municipality, there are two (2) sewerage with separate collection system; one is in the urban area of Capellania and the other is in the urban area of Fuquene. The Capellania system has service population of 500 (150 households). Its total pipe length is 4.0 km with max. diameter of 30.5 cm and min. diameter of 20.3 cm. The Capellania system discharges the collected water to the Q. Bautista without treatment. The Fuquene system receives wastewater of 300 persons (45 households) with total pipe length of 1.5 km (max. diameter: 30.5 cm and min. diameter: 20.3 cm). The collected wastewater of the Fuquene system is utilized for irrigation water of pastureland. Both systems receive no industrial wastewater. Sewerage charge is not collected in both systems.

The following table summarizes the water quality observation results of the center of Fuquene and Capellania conducted in 1997.2.3 and 2.4, respectively.

Locaation	BOD_5 (mg/l)	$COD_{(Cr)}$ (mg/l)	Oil (mg/l)	TS (mg/l)	TSS (mg/l)	VSS (mg/l)	Coliforms (MPN/100ml)	
							Total	Fecal
Fuquene	255	397	93.1	331	124	100	$>24 \times 10^6$	$>24 \times 10^6$
Capellania	348	607	128.4	671	165	135	$>24 \times 10^6$	$>24 \times 10^6$

(10) Susa

The sewerage system of Susa urban area receives wastewater from 400 households and one factory and collection system is separate. Total pipe length of the system is 2.5 km. Max, diameter of the pipe is 40.6 cm, while min. diameter is 20.3 cm. The collected wastewater is discharged into the Susa River without treatment. 800 peso is collected from each household every two (2) months. In urban area of Susa, 100 households have septic tanks to treat their wastewater.

(11) Simijaca

Urban area of 62 ha. is covered by the sewerage system with combined collection system, which receives wastewater of 4,500 persons (1,340 households) and five (5) dairy factories. Total pipe length of the system is 19.0 km (max. diameter of 40.6 cm and min. diameter of 20.3 cm). The collected wastewater is discharged into the Simijaca River without treatment. The wastewater quality is tabulated below.

PH	BOD_5 (mg/l)	$COD_{(Cr)}$ (mg/l)	TSS (mg/l)	SS (mg/l)	Oil (mg/l)	Total Coliform (MPN/100ml)
6.9	210	320	522	172	49	$>24 \times 10^6$

The sewerage charge in residential area is different from that in industrial area. The average charge of each area is 275 peso/month and 8,125 peso/month, respectively.

(12) Caldas

Urban area of Cardas is 4 ha where 100 persons of 50 families live and no industry is located. Cardas has sewerage system with pipe length of 1.0 km and diameter of 30.5 cm to 20.3 cm and collection system is combined. The Cardas sewerage system receives wastewater of 86 persons (43 households) and discharges into the Q. La Playa without treatment. Out of 7 households, which are not connected to the sewerage system, two (2) households have septic tank and others are latrines. In Cardas, no sewerage charge is collected at present.

(13) Chiquinquira

In Chiquinquira, the sewerage system covers a service area of 20 km^2 with pipe length of 60 km (max. diameter 147 cm and min. diameter 25.4 cm). Collection system is combined. Service population is 42,000 (8,400 households) and the system receives wastewater of 12 dairy industries. Domestic wastewater is discharged into Suárez River without treatment. The sewerage charge depended on the quantity and unit charge is 105 peso/m3/month. The average charge of household is 5,405 peso/month.

Average quality of wastewater is as follows.

(unit: mg/l)

PH	BOD_5	$COD_{(Cr)}$	TSS	T-N	T-P	Oil	Pesticide (Cl)	Pesticide (P)
6.77	415	850	702	13	10	18	116	5.0

(14) Saboya

Saboya has sewerage system with service population of 1,098 (183 households) with pipe length of 12.0 km (max. diameter of 40.6 cm and min. diameter of 20.3 cm). Collection system is separate and the collected waster water from households is treated by the stabilization ponds and then discharged into the Q. La Ruda. The treatment plant was constructed in 1991. The sewerage charge for the connection to the system is 2,125 peso/month.

2.1.2 Slaughterhouse

There are 14 urban centers located in the Study Area and all the urban centers have their own slaughterhouses.

Inventory of the existing sewerage systems of these wastewater treatment of the 14 urban centers mentioned above was prepared through questionnaire and interviews (conducted in April and September, 1999) with the related personnel of each municipality/slaughterhouse and also data provided by the CAR. The results are tabulated in the following table.

No.	Name of Municipality	Animal	Number of Animals (Head/Week)	Water Use Volume	Treatment Plant*	Discharging Point
1	Carmen de Carupa	Cow	15		Bl + Sc + Gr + Se	Sewerage
2	Ubate	Cow Pig Sheep	150 72 72	650 m^3/M	Bl + Sc + Se + An	Sewerage
3	Tausa	Cow	18		Bl + Sc + Gr + Se	Sewerage
4	Sutatausa	Cow	11		Bl + Sc + Gr + Se	Q. Chiritoque
5	Cucunuba	Cow	5		Bl + Sc + Gr + Se	Sewerage
6	Lenguazaque	Cow	24	27 m^3/W	Bl + Sc + Gr + Se	Sewerage
7	Guacheta	Cow	21		Bl + Sc + Gr + Se	Sewerage
8	San Miguel de Sema	Cow	2		Bl + Sc + Gr + Se	Q. Los Cerezos
9	Fuquene	Cow	21		Bl + Sc	Fuquene
10	Susa	Cow	22		Bl + Sc + Gr + Se	Sewerage
11	Simijaca	Cow	35	180 m^3/M	Bl + Sc + Gr + Se	Q. El Capitodio
12	Caldas	Cow	4		Bl + Sc	Q. La Praya
13		Cow	115		Bl + Sc + Gr + Se	Rio.Chiquinquira
14	Saboya	Cow	21		Bl + Sc + Gr + Se	Q.El Cantoco

Note: Bl: Blood Well, Sc: Screen, Gr: Grease Remover, Se: Septic tank, An: Anaerobic Treatment Process.

2.1.3 Industrial Establishment

Table E.2.2 tabulates industrial establishments in the Study Area, composing of (1) dairy processing, (2) milk cooling, (3) gas stations and (4) others consisting of taxi, beverage production and flowers listed by the CAR. Number of establishments according to activities is tabulated below.

Dairy Processing	Milk Cooling	Gas Station	Others	Total
44	6	8	5	63

In addition to the industrial establishments mentioned above, there are approx. 280 mining industries in the Study Area. Out of the above industrial establishments, only dairy processing and milk cooling factories are considered to discharge a significant amount of pollution load, which may affect water quality of the Fuquene Lake and rivers in the Study Area.

In order to estimate pollution load from these two (2) kinds of industrial activities, questionnaire survey was made. First, dairy processing and milk cooling factories in the Study Area are classified into large, medium and small from the size of factories as indicated in Table E.2.2. Then 14 factories from dairy processing and 4 factories from milk cooling are selected, covering all the large and medium-sized factories. They are also tabulated in Table E.2.2.

Followings are the summary of answers of the questionnaires from the dairy processing and the milk cooling factories.

(1) Dona Leche

Activity	:	Dairy Processing	
Size	:	Large	
Municipality	:	Ubate	
Milk Processed (l/day)	:	60,000	
Production		Cheese (kg/day)	: 100 (including Yogurt)
		Yogurt (kg/day)	:
		Others	: Milk Cooling 40,000 l/day
Water Use Volume	:	650 m^3/month (Municipal Water)	
Treatment Plant	:	3 grease Traps	
Discharging Point	:	Ubate Sewerage System	

(2) Fabrica de Quesos San Jose

Activity	:	Dairy Processing	
Size	:	Small	
Municipality	:	Ubate	
Milk Processed (l/day)	:	250	
Production		Cheese (kg/day)	: 31.8
		Yogurt (kg/day)	:
		Others	:
Water Use Volume	:	0.2 m^3 /day (Municipal Water)	
Treatment Plant	:	None	
Discharging Point	:	Ubate Sewerage System	

(3) La Gran Vaquita

Activity	:	Dairy Processing	
Size	:	Small	
Municipality	:	Ubate	
Milk Processed (l/day)	:	400	
Production		Cheese (kg/day)	: 31.8
		Yogurt (kg/day)	:
		Others	:
Water Use Volume	:	0.2 m^3/day	
Treatment Plant	:	None	
Discharging Point	:	Ubate Sewerage System	

(4) Lacteos Don Luis

Activity	:	Dairy Processing	
Size	:	Small	
Municipality	:	Ubate	
Milk Processed (l/day)	:	800	
Production		Cheese (kg/day)	: 13.6
		Yogurt (kg/day)	:
		Others	: Light cheese 200 ps/day
Water Use Volume	:	0.2 m^3/day	
Treatment Plant		None	
Discharging Point	:	Ubate Sewerage System	

(5) Lacteos el Manatial

Activity	:	Dairy Processing	
Size	:	Small	
Municipality	:	Ubate	
Milk Processed (l/day)	:	800	
Production		Cheese (kg/day)	: 72.6
		Yogurt (l/day)	: 40
		Others	:
Water Use Volume	:	6 m^3/day	
Treatment Plant		2 Grease Traps + 1 Anaerobic Pond	
Discharging Point	:	Irrigation	

(6) Lacteos Hato Chips

Activity	:	Dairy Processing	
Size	:	Small	
Municipality	:	Ubate	
Milk Processed (l/day)	:	600	
Production		Cheese (kg/day)	: 47.6
		Yogurt (l/day)	: 80
		Others	:
Water Use Volume	:	85 m^3/month (Municipal Water	
Treatment Plant		None	
Discharging Point	:	Ubate Sewerage System	

(7) Lacteos La Pirinola

Activity	:	Dairy Processing	
Size	:	Small	
Municipality	:	Ubate	
Milk Processed (l/day)	:	250	
Production		Cheese (kg/day)	: 15.9
		Yogurt (kg/day)	:
		Others	:
Water Use Volume	:	0.2 m^3/day (Municipal Water)	
Treatment Plant		None	
Discharging Point	:	Ubate Sewerage System	

(8) Lacteos San Andres

Activity	:	Dairy Processing	
Size	:	Medium	
Municipality	:	Ubate	
Milk Processed (l/day)	:	2,800	
Production		Cheese (kg/day)	: 63.5
		Yogurt (kg/day)	:
		Others	: Butter 18.1 kg/week
Water Use Volume	:	1.125 m^3/day (Municipal Water)	
Treatment Plant		5 Grease Traps	
Discharging Point	:	Irrigation	

(9) Lacteos Ubate

Activity	:	Dairy Processing	
Size	:	Medium	
Municipality	:	Ubate	
Milk Processed (l/day)	:	4,000	
Production		Cheese (kg/day)	: 200
		Yogurt (L/week)	: 600
		Others	:
Water Use Volume	:	160 m^3/month (Municipal Water)	
Treatment Plant		1 Grease Trap + 1 Sedimentation Tank	
Discharging Point	:	Ubate Sewerage System	

(10) Quesos el Candad

Activity	:	Dairy Processing	
Size	:	Small	
Municipality	:	Ubate	
Milk Processed (l/day)	:	800	
Production		Cheese (kg/day)	: 68.0
		Yogurt	:
		Others	:
Water Use Volume	:	0.2 m^3/day (Municipal Water)	
Treatment Plant		None	
Discharging Point	:	Ubate Sewerage System	

(11) Quesos los Alpes

Activity	:	Dairy Processing	
Size	:	Small	
Municipality	:	Ubate	
Milk Processed (l/day)	:	400	
Production		Cheese (kg/day)	: 36.3
		Yogurt (kg/day) :	:
		Others	:
Water Use Volume	:	0.3 m^3/day	
Treatment Plant		None	
Discharging Point	:	Ubate Sewerage System	

(12) Quesos Villa Ubate

Activity	:	Dairy Processing
Size	:	Small
Municipality	:	Ubate
Milk Processed (l/day)	:	1,500
Production		Cheese (kg/day) : 122.5
		Yogurt (kg/day) :
		Others :
Water Use Volume	:	3,500 m^3/year (Groundwater)
Treatment Plant		None
Discharging Point	:	Irrigation Water

(13) Colfrance

Activity	:	Dairy Processing
Size	:	Large
Municipality	:	Fuquene
Milk Processed (l/day)	:	8,000
Production		Cheese (t/year) : 690
		Yogurt (t/year) : 576
		Others :
Water Use Volume	:	1,200 m^3/year (Groundwater)
Treatment Plant		2 Grease Traps + 1 Sedimentation Tank + 1 Anaerobic Pond
Discharging Point	:	Irrigation

(14) Incolacteos

Activity	:	Dairy Processing
Size	:	Large
Municipality	:	Simijaca
Milk Processed (l/day)	:	180,000
Production		Cheese (kg/day) :
		Yogurt (kg/day) :
		Others : Milk 100,000 /day, Jam, Juice, etc.
Water Use Volume	:	1,800 m^3/month (Municipal Water), 3,000 m^3/month (Groundwater)
Treatment Plant		3 Grease Traps + 2 Stabilization Ponds
Discharging Point	:	Irrigation

(15) Alqueria

Activity	:	Milk Cooling
Size	:	Small
Municipality	:	Ubate
Milk Processed (l/day)	:	80,000
Water Use Volume	:	450 m^3/month
Treatment Plant		None
Discharging Point	:	Ubate Sewerage System

(16) Parmalat (Ubate)

Activity	:	Milk Cooling
Size	:	Medium
Municipality	:	Ubate
Milk Processed (l/day)	:	38,500
Water Use Volume	:	500 m^3/month
Treatment Plant		2 Grease Traps + 1 Sedimentation Tank
Discharging Point	:	Ubate Sewerage System

(17) Alpina

Activity	:	Milk Cooling
Size	:	Large
Municipality	:	Simijaca
Milk Processed (l/day)	:	80,000
Water Use Volume	:	286 m^3/year (Municipal Water) 10,950 m^3/year (Groundwater)
Treatment Plant		3 Grease Traps
Discharging Point	:	Simijaca Sewerage System

(18) Delay

Activity	:	Milk Cooling
Size	:	Large
Municipality	:	Simijaca
Milk Processed (l/day)	:	37,000
Water Use Volume	:	3,000 m^3/year (Municipal Water), 6,000 m^3/year (Groundwater)
Treatment Plant		None
Discharging Point	:	Q. Capitolio

2.2 Existing Pollution Load Generation/Effluent

Point pollution sources in the Study Area can be classified into (a) sewerage system, (b) slaughterhouse, and (c) industrial establishments in the urban centers of 14 municipalities. The sewerage system equipped in all the urban centers receive not only domestic wastewater but also accept the effluent from some of slaughterhouses and industrial establishments.

In this section, firstly the pollution load generated/effluent of domestic wastewater, slaughterhouse wastewater and industrial wastewater covered by sewerage system is estimated. Then, pollution load flowing directly into rivers/channels (sewerage and slaughterhouse /industrial wastewater not covered by sewerage system) is obtained to estimate water quality of the selected rivers and the Fuquene Lake together with pollution load from non-point source explained in Chapter 3.

2.2.1 Generated/Effluent Pollution Load

(1) Domestic Wastewater

Domestic wastewater in each urban center is obtained from the per capita unit wastewater discharge and per capita unit load (BOD_5), which were applied to design the existing sewerage systems in the Study Area. As for per capita unit load for COD, T-N and T-P, those used in Japan are applied after modification.

Per capita unit water consumption or wastewater discharge and per capita unit BOD_5 used for design of the existing sewerage systems are explained below.

(a) San Miguel de Sema (1992)

The following per capita water consumption, which varies by years as tabulated below was applied.

(unit: l/day)

Year	Water Consumption
1991	100
1996	105
2001	110
2006	115
2010	120

Regarding BOD_5, 50 g/day/person was applied.

(b) Simijaca (1998)

Per capita domestic water consumption used for the design of Simijaca sewerage system is 173 l/day for the target year based on the present per capita domestic water consumption of 153 l/day. Per capita BOD_5 load is not used for the design.

(c) Chiquinquira (1993)

Followings are unit pollution generation load applied for the Chiquinquira.

Domestic Water Consumption	200 l/day (1995 and 2035)
BOD	50 g/day

(d) Ubate

Domestic Discharge	250 l/day (1990 and 2010)
BOD	60 g/day

Based on the above, the following unit discharge and unit pollution load (BOD_5) is applied, classifying the urban centers into 'large', 'medium' and 'small' from the point of their present population.

In the design of sewerage systems, return factor of 0.7 (Chiquinquira), 0.8 (Simijaca) and 0.85 (Ubate) were used to convert water consumption to wastewater. In this study, return factor of 0.8 is used to estimate the per capita wastewater.

Name of Town	Water	Wastewater	BOD_5
Ubate & Chiquinquira	225 l/day	180 l/day	50 g/day
Lenguazaque, Guacheta & Simijaca	170 l/day	136 l/day	50 g/day
Other 9 municipalities	110 l/day	88 l/day	50 g/day

Regarding the per capita pollution load of $COD_{(Cr)}$, T-N and T-P, following values are applied from the standards used in Japan, adjusting from the BOD value.

(unit: mg/L)

	BOD_5	$COD_{(Cr)}$	T-N	T-P
Japan	58	73	11	1.2
Fuquene Lake Basin	50	63	9.5	1.0

Table E.2.3 tabulates the domestic pollution load generation in the urban centers in the Study Area.

(1) Slaughterhouse

Considering lack of quality and quantity data of slaughterhouse wastewater, the unit generation load used in the CAR jurisdiction is applied for this study (see, Table E.2.4). Wastewater quantity data were obtained from some of slaughterhouses, while for those with no available water consumption data, unit wastewater volume shown in Table E.2.4 is also applied.

Effluent quality of BOD, COD, T-N and T-P are obtained based on the analysis result conducted by CAR in eight (8) municipalities near Bogota, and supplementary observation by the Study Team (See, Table E.2.5). The adopted concentration of BOD, COD, T-N, T-P are as follows;

(unit: mg/l)

Parameter	Average Result By CAR	Supplementary Observation by Study Team	Adopted Concentration
BOD_5	2,755	605	2,500
COD	4,667	900	4,000
T-N	577.4	98.3	500
T-P	9.07	9.78	10

Table E.2.6 tabulates pollution load effluent from 14 slaughterhouses in the Study Area.

(3) Industrial Wastewater

The major industrial pollutant sources in the Study Area are dairy industry such as milk processing and milk cooling industries. The water quality data are scarce and therefore, the unit generation load shown in Table E.2.4 is applied for all of the factories with no available wastewater volume data, the unit wastewater volume in this table is used as well.

Following tables tabulate the unit wastewater volume and unit pollution generation load for milk processing and milk cooling industries.

Activities	Wastewater Volume	BOD_5
Milk Processing	5.0 l/l of milk	2,700 mg/l
Milk Cooling	2.5 l/l of milk	800 mg/l

Table E.2.7 tabulates pollution load effluent from each dairy factory. BOD removal ratio of 0.4 is applied for the factories with treatment plant. Effluent COD, T-N and T-P loads are estimated from BOD - COD, BOD - T-N, and BOD - T-P relationship (Fig. E.2.2) based on the supplementary water quality observation made by the Study Team.

2.2.2 Point Pollution Load Effluent to Rivers

Point pollution load effluent flowing into rivers includes the wastewater form (a) sewerage system, (b) slaughterhouse not covered by sewerage system and (c) industrial establishment not covered by sewerage system.

(1) Sewerage System

Table E.2.8 tabulates domestic, slaughterhouses and industrial pollution load flowing into the sewerage systems of 14 municipalities in the Study Area which finally pour into rivers.

Table E.2.9 shows pollution load effluent flowing into rivers from 14 sewerage systems mentioned above. For sewerage system without treatment plant, effluent pollution load is equal to influent pollution load, while effluent load with treatment plant is obtained as follows.

The effluent BOD concentration after treatment in the sewerage systems of Ubate, Cucunuba, San Miguel de Sema and Saboya are supposed to be the average effluent BOD concentration observed by the Study Team and the CAR.

COD, T-N and T-P concentration after treatment is estimated from obtained the effluent BOD concentration of each sewerage system based on the relationship of BOD to COD, T-N and T-P, which are estimated from supplementary observation by the Study Team (See Fig.E.2.3).

(2) Slaughterhouse

Effluent of slaughterhouses in Statausa, San Miguel de Sema, Fuquene, Simijaca, Caldas, Chinquinquira and Saboya is considered to flow directly into the rivers.

(3) Dairy Industry

Effluent of dairy industry located in Tausa, Guacheta, Fuquene and Simijaca is considered to flow into the rivers.

Table E.2.10 summarizes point pollution load effluent from three (3) categories mentioned above and their total in 14 urban centers.

2.3 Future Pollution Load Generation/Effluent

2.3.1 Domestic Pollution

(1) Served Population in the Study Area

The existing sewerage system of municipalities covers almost all the urban area. Hence, it is assumed that the future service of the sewerage system will cover all the urban area.

Projection of the population in municipalities in the Study Area is shown in Table A.2.1.

(2) Wastewater Quantity

Per capita unit water consumption, return factor is assumed to be the same as those of the existing ones. Consequently, the wastewater quantity per capita is also the same as the existing one.

(3) Wastewater Quality

BOD load and ratio of COD, T-N and T-P to BOD is same.

(4) Domestic Pollution Load Generation

Based on the assumption above, the domestic pollution load generation is shown in Table E.2.11.

2.3.2 Slaughterhouse

(1) The number of animals to be slaughtered

The number of animals to be slaughtered will increase in proportion to the population growth on the assumption that meet consumption weight per capita will be constant.

(2) The Wastewater Quantity

The wastewater quantity per unit described in Table E.2.4 is also applied. Consequently, the wastewater in the target year will increase in proportion to the population growth.

(3) The Wastewater Quality

The generated BOD concentration and the ratio of COD, T-N and T-P to BOD is assumed to be the same as the existing ones. At present, every municipality installs the pre-treatment plant based on their circumstance. The removal rate will be constant in spite of the increasing of wastewater. The discharge point will not change.

(4) Slaughterhouse Pollution Load Effluent

Based on the assumption above, the slaughterhouse pollution load effluent is shown in Table E.2.12.

2.3.3 Industry

(1) The Number of Factory

With regard to the dairy factory, the number of factory that discharges the effluent into sewerage system, river and irrigation are 41, 4 and 5, respectively. In this study, it is assumed that neither additional industrial establishments will be located in the Study Area nor the discharge point will be changed.

(2) The Wastewater Quantity

Based on the assumption in Section A.2.5.(1), milk industry sector will increases in proportion to the number of cows for milk. It is concluded that the milk production will increase by 4 % from the year 1998 to the target year. Per unit wastewater quantity for cooling/bottling/processing is assumed to be the same. Consequently, the wastewater in the target year will be 1.04 times of one in 1998.

(3) The Wastewater Quality

The future generated BOD concentration and the ratio of COD, T-N and T-P to BOD is assumed to be the same as the existing ones. At present, few factories install the pre-treatment. It is assumed that in the target year, the removal rate will be the same as that of existing one though the wastewater quantity will be 1.04 times as mentioned above.

On the other hand, no more factories will install the pre-treatment plant in case of “without project” and pre-treatment plant will be installed in every factory in case of “with project”.

(4) Industrial Pollution Load Effluent

Based on the assumption above, the industrial pollution load effluent with and without project is summarized in Table E.2.13.

2.3.4 Future Point Pollution Load to Rivers

(1) Sewerage System

Domestic, slaughterhouse and industrial pollution load flowing into the sewerage system of 14 municipalities in the Study Area “ without project” and “with project” is tabulated in Table E.2.14 (1) and Table E.2.14 (2).

In case of “with project”, every municipality will install the treatment plant till the target year. The effluent quality is assumed to be 40 mg/l, which will be proposed in Appendix F, Section 2.2.2 due to the improvement/development of sewerage treatment plant. T-N and T-P to BOD concentration after treatment is estimated by the relationship between them. The Study Team estimates the relationship from the supplementary observation. (See Fig. E.2.3).

In case of “without project”, the efficiency of the existing treatment plant will become worse due to the increase of sewerage discharge. If sewerage discharge will become μ times of existing one in the future, the future retention time becomes $1/\mu$.

The future BOD concentration of sewerage effluent is calculated from the following relationship.

$$Ce'/Ci' = \mu/(\mu - 1 + Ci/Ce)$$

Where Ci: Existing influent BOD concentration
Ce: Existing effluent BOD concentration
Ci’: Future influent BOD concentration
Ce’: Future effluent BOD concentration
μ: the ratio of future sewerage discharge to existing one

The BOD of sewerage discharge of effluent without treatment plant is equal to that of influent.

The Table E.2.15 tabulates future pollution load effluent.

(2) Other Pollutant Source

The discharging point of each pollution source will be same.

(a) Slaughterhouse

Effluent of slaughterhouses in Statausa, San Miguel de Sema, Fuquene, Simijaca, Caldas, Chinquinquira and Saboya will flow into the rivers.

(b) Industry

Effluent of dairy industry located in Tausa, Guacheta, Fuquene and Simijaca will flow into the rivers.

(3) Future Point Pollution Load to Rivers

Table E.2.16 (1) and Table E.2.16 (2) summarize the total future point load which will be discharged from sewerage, slaughterhouse and industry above in the Study Area in case of "without project" and "with project", respectively.

CHAPTER Ⅲ WATER POLLUTION MECHANISM

3.1 Pollution Load Runoff Mechanism

3.1.1 General

The pollutant sources in the Study Area are classified into point sources and non-point sources. The point sources consist of sewerage wastewater and industrial wastewater (slaughterhouses and milk processing factories). The non-point sources include livestock wastewater, wastewater from lands (farmland, pasture and shrub/forest) and household wastewater in rural area. The wastewater from urban lands is neglected since the urban are is small.

The non-point pollution loads run off on lands or through small channels/ditches to the tributaries. On the other hands, the point pollution loads are directly discharged into the tributaries or main rivers with treatment or without treatment. Thereafter, both point and non-point pollution loads run off through the tributaries to enter the main river. Finally, they flow down the main river.

In the first runoff stage, the non-point pollution load is decreased to a large extent by the natural purification effects on lands and small channels. The runoff coefficient (R_1) is generally constant for each land use category. In the second runoff stage, the point and non-point pollution loads are reduced by the natural purification effects in the tributaries. The runoff coefficient (R_2) varies according to the tributary length. In this Study, pollution load effluent is defined as the pollution load runoff to the main river. Then, the pollution load effluent is calculated by multiplying the runoff coefficients by the generated pollution load as follows:

Pollution Load Effluent = Generated Pollution Load x R_1 x R_2

In this Study, the pollution load generation and effluent are estimated in parameters of BOD, COD, T-N and T-P.

3.1.2 Modeling of the Basin

In this Study, the pollution load generation and effluent are estimated for the entire upstream basin of the confluence with the Chiquinquira River (1,462 km^2). The objective basin is divided into nine (9) sub-basins as shown Fig E.3.1. Both point and non-point pollution load runoffs are simulated at the downstream end of the respective sub-basins. The river water quality is simulated at the three (3) principal locations: Ubate River at Pte Colorado (A), Suarez River at Tolon Gate (C) and Suarez River immediately after the confluence of Chiquinquira River (hereafter called Downstream of Chiquinquira City, (D). Further, the water quality of the Lake (B) will be simulated apart from the river water simulation.

The schematic diagram for the simulation of pollution load runoff and water quality is shown in Fig E. 3.2.

3.2 Existing Pollution Load Generation and Runoff

3.2.1 Existing Pollution Load Generation

(1) Point Pollution Load Generation

The existing generated pollution loads of sewerage and industrial wastewater are estimated in Chapter II, Subsections 2.2.1 and 2.2.2. They are directly discharged into the tributaries or main river except a very few sources.

Most of the industrial pollutant sources are discharged into the municipal sewerage and the remaining sources are directly discharged into the public water body. In this simulation study, the industrial sources covered by the sewerage are categorized into sewerage wastewater and only the remaining sources are categorized into industrial wastewater.

(2) Non-point Pollution Load Generation

The non-point pollutants are generated from livestock, land (farmland, pastureland and shrub/forest) and household in rural area.

The number of livestock, rural population and land use in each sub-basin are estimated as shown in Table E.3.1. The unit pollution load generation (BOD, COD, T-N and T-P) of each non-point source category are assumed as shown in Table E.3.2, based on the various previous studies and reports. In the above table, unit population load of household is defined as the load after septic tank treatment.

The non-point pollution load generation of BOD, COD, T-N and T-P in each sub-basin are calculated as the products of the values in Table E 3.1 and Table E 3.2.

(3) Total Existing Pollution Load Generation

The total existing pollution load generation of BOD, COD, T-N and T-P in the Study Area (simulation objective area: 1,462 km^2) are summarized below.

(unit: kg/d)

Pollution Load Parameter	Upper Basin of the Lake	Suarez River Basin	Total
BOD	68,541	44,026	112,567
COD	166,791	95,705	262,496
T-N	48,123	29,502	77,624
T-P	6,165	3,858	10,023

The total existing pollution load generation of BOD, COD, T-N and T-P by each point and non-point sources are shown below.

(a) BOD

(unit: kg/day)

Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
Point (sewerage)	846	2,619	3,464	3.08
Point (industry)*	34	140	174	0.15
Sub-total	880	2,759	3,638	3.23
Non-point (household)	266	100	366	0.33
Non-point (livestock)	62,857	38,767	101,624	90.28
Non-point (land)	4,539	2,400	6,939	6.16
Sub-total	67,661	41,267	108,929	96.77
Total	68,541	44,026	112,567	100.00

*: Only the industrial wastewater discharging into river

(b) COD

(unit: kg/day)

Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
Point (sewerage)	1,410	3,284	4,694	1.79
Point (industry)*	46	196	242	0.09
Sub-total	1,456	3,480	4,936	1.88
Non-point (household)	432	160	592	0.23
Non-point (livestock)	152,592	85,841	238,433	90.83
Non-point (land)	12,311	6,224	18,535	7.06
Sub-total	165,334	92,225	257,560	98.12
Total	166,790	95,705	262,496	100.00

*: Only the industrial wastewater discharging into river

(c) T-N

(unit: kg/day)

Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
Point (sewerage)	238	511	748	0.96
Point (industry)*	8	32	40	0.05
Sub-total	246	543	788	1.02
Non-point (household)	45	17	61	0.08
Non-point (livestock)	37,939	23,711	61,650	79.42
Non-point (land)	9,894	5,232	15,125	19.49
Sub-total	47,877	28,959	76,836	98.98
Total	48,123	29,502	77,624	100.00

*: Only the industrial wastewater discharging into river

(d) T-P

(unit: kg/day)

Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
Point (sewerage)	28	72	100	0.99
Point (industry)*	2	9	11	0.12
Sub-total	29	81	111	1.11
Non-point (household)	7	3	10	0.10
Non-point (livestock)	5,982	3,700	9,682	96.69
Non-point (land)	147	74	220	2.20
Sub-total	6,136	3,776	9,912	98.89
Total	6,165	3,858	10,023	100.00

*: Only the industrial wastewater discharging into river

The total existing pollution load generation of BOD, COD, T-N and T-P by source and by sub-basin are shown in Table E 3.3 and illustrated in Fig E 3.3.

Existing pollution load generation ratio of each source in the upper basin of the Lake Fuquene is shown in Fig E 3.4. Livestock generates the largest pollution load in the basin as follows: BOD: 92%, COD: 91%, T-N: 79% and T-P: 97%.

3.2.2 Existing Pollution Load Runoff

(1) General

The pollution load effluent to the main river or Lake is estimated by multiplying the above generated pollution load by runoff coefficients of R_1 an R_2. Here, R_1 is the runoff ratio of pollutants generated from each sub-basin to its discharging tributary. R_2 is the self-purification ratio of pollutants in the tributary.

Among the four (4) pollutants of BOD, COD, T-N and T-P, BOD is decomposed in the streams to a considerable extent while it flows down. On the other hand, decomposition of COD, T-N and T-P in the ordinary streams is not significant. Therefore, the self-purification ratio in the tributary is evaluated for only BOD.

Among nine (9) sub-basins, seven (7) sub-basins are discharged to the main river through each discharging tributary. Those tributaries are Ubate (upstream portion), Suta, Cucunuba, Lenguazaque, Susa, Simijaca and Chiquinquira rivers. However, the Lake Fuquene sub-basin and Suarez residual sub-basin are assumed to directly be discharged into the Lake and the Suarez main river respectively. Therefore, the self purification ratio (R_2) of BOD is evaluated only for the above seven (7) rivers.

(2) Estimation of Runoff Coefficients

The runoff ratio of pollutant loads from the sub-basins generally vary depending on the topographical, geological and other environmental conditions. In this Study, the runoff coefficients R_1 and R_2 are determined so that the simulated pollution loads may coincide with the observed ones at Pte Colorado station of Ubate River (after confluence of the Suta, Cucunuba and Lenguazaque rivers).

As mentioned before, the self purification effect of the tributary on COD, T-N and T-P in the tributary is negligible, namely, $R_2 = 1.0$. Hence, the runoff coefficient of the sub-basin (R_1) of COD, T-N and T-P is determined to coincide with the measured values at Pte

Colorado station.

On the other hand, the self-purification effect of the tributaries on BOD concentration is significant. The self-purification rate of BOD in the tributaries can be estimated by the following equation.

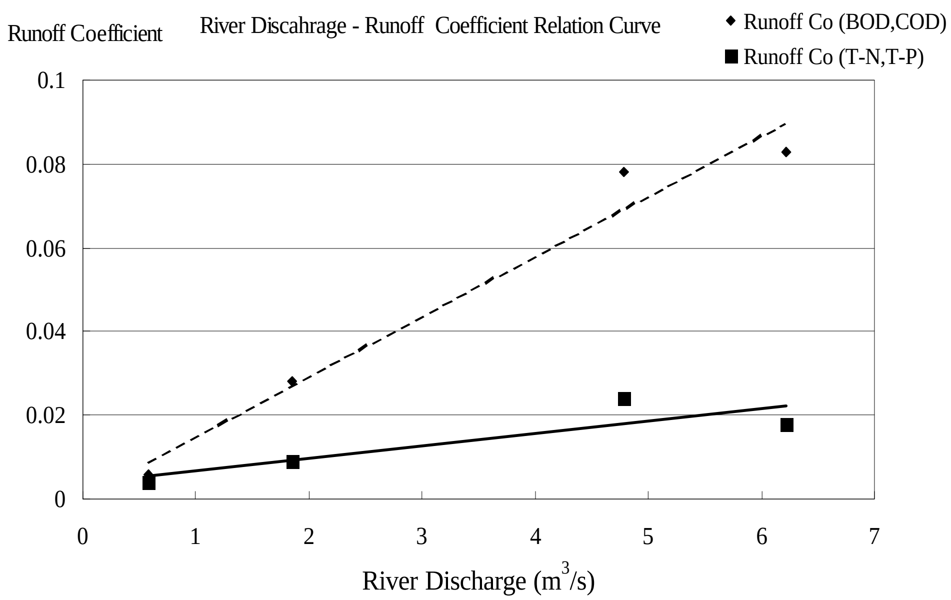
$dL/dt = - K \cdot L$, where, L: BOD load (kg), K: self-purification constant (1/day)

The above self-purification constant K is assumed at 1.2 (1/day), considering the river conditions of the tributaries. From the above equation, the average reduction rate of R_2 in the tributaries is estimated to be 3% per km.

The runoff coefficient (R_1) of BOD in the sub-basins is obtained through comparison of the calculated pollution load runoff with the observed one at Colorado station. In this comparison, the pollution load reduction in the tributary by the self-purification effect is duly considered.

The generated non-point pollution loads (BOD, COD, T-N and T-P) in the sub-basins easily run off to the tributaries at a rainy time, while they stay more on the lands at a dry time. There is a certain relationship between the runoff coefficients (R_1) of non-point pollution loads and the river discharge. Generally, the runoff coefficients (R_1) proportionally increase according to the river discharge. Further, BOD and COD run off more easily than T-N and T-P.

The relationship between the runoff coefficients (R_1) of non-point pollution loads (BOD, COD, T-N and T-P) and river discharge at Colorado of the Ubate River is established, based on the field observation of four (4) times as shown below.



The average river discharges at Colorado during the rainy and dry seasons are estimated at 6.21 m^3/s and 2.27 m^3/s respectively. Accordingly, the average runoff coefficients (R_1) of non-point pollution loads are estimated as follows

Non-point Load	Rainy Season	Dry season
BOD/COD	0.090	0.031
T-N/T-P	0.023	0.010

The estimated runoff coefficients of the sub-basin (R_1) and tributary (R_2) by point and non-point loads are summarized below.

Pollution Load	BOD	COD	T-N	T-P
Point Load (whole year)				
R_1	1.0	1.0	1.0	1.0
R_2	3% reduction per km	1.0	1.0	1.0
Non-Point Load (rainy season)				
R_1	0.090	0.090	0.023	0.023
R_2	3% reduction per km	1.0	1.0	1.0
Non-Point Load (dry season)				
R_1	0.031	0.031	0.010	0.010
R_2	3% reduction per km	1.0	1.0	1.0

The above runoff coefficients are applied for all the sub-basins and tributaries in the Study Area (simulation objective area).

(3) Total Existing Pollution Load Runoff

The total existing pollution runoff of BOD, COD, T-N and T-P in the Study Area (simulation objective area: 1,462 km^2) through both seasons are summarized below.

(unit: kg/d)

Season	Pollution Load Parameter	Upper Basin of the Lake	Suarez River Basin	Total
Rainy Season	BOD	3,877	4,853	8,730
	COD	16,336	12,523	28,859
	T-N	1,347	1,188	2,535
	T-P	171	168	339
Dry Season	BOD	1,915	3,480	5,395
	COD	6,581	6,595	13,176
	T-N	725	832	1,557
	T-P	91	119	210

The total existing pollution load runoff of BOD, COD, T-N and T-P by each point and non-point sources through both seasons are shown below.

(a) BOD

(unit: kg/day)

Season	Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
Rainy Season	Point (sewerage)	846	2,619	3,464	39.68
	Point (industry)*	34	140	174	1.99
	Sub-total	880	2,759	3,638	41.68
	Non-point (household)	11	5	16	0.18
	Non-point (livestock)	2,808	1,949	4,757	54.49
	Non-point (land)	179	140	319	3.65
	Sub-total	2,997	2,094	5,092	58.32
	Total	3,877	4,853	8,730	100.0
Dry Season	Point (sewerage)	846	2,619	3,464	64.21
	Point (industry)*	34	140	174	3.23
	Sub-total	880	2,759	3,638	67.44
	Non-point (household)	4	2	6	0.10
	Non-point (livestock)	967	672	1,639	30.37
	Non-point (land)	65	48	113	2.09
	Sub-total	1,035	722	1,757	32.56
	Total	1,915	3,480	5,395	100.0

*: Only the industrial wastewater discharging into river

(b) COD

(unit: kg/day)

Season	Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
Rainy Season	Point (sewerage)	1,410	3,284	4,694	16.26
	Point (industry)*	46	196	242	0.84
	Sub-total	1,456	3,480	4,936	17.10
	Non-point (household)	39	15	54	0.19
	Non-point (livestock)	13,733	8,525	22,258	77.13
	Non-point (land)	1,108	503	1,611	5.58
	Sub-total	14,880	9,043	23,923	82.90
	Total	16,336	12,522	28,859	100.0
Dry Season	Point (sewerage)	1,410	3,284	4,694	35.62
	Point (industry)*	46	196	242	1.84
	Sub-total	1,456	3,480	4,936	37.46
	Non-point (household)	13	5	18	0.14
	Non-point (livestock)	4,730	2,936	7,667	58.19
	Non-point (land)	382	173	555	4.21
	Sub-total	5,125	3,115	8,240	62.54
	Total	6,581	6,595	13,176	100.0

*: Only the industrial wastewater discharging into river

(c) T-N

(unit: kg/day)

Season	Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
Rainy Season	Point (sewerage)	238	510	748	29.49
	Point (industry)*	8	32	40	1.60
	Sub-total	246	542	788	31.09
	Non-point (household)	1	0	1	0.06
	Non-point (livestock)	873	525	1,398	55.13
	Non-point (land)	227	120	347	13.72
	Sub-total	1,101	645	1,746	68.91
	Total	1,347	1,187	2,534	100.0
Dry Season	Point (sewerage)	238	510	748	48.03
	Point (industry)*	8	32	40	2.60
	Sub-total	246	542	788	50.63
	Non-point (household)	0	0	0	0.04
	Non-point (livestock)	379	237	616	39.61
	Non-point (land)	99	52	151	9.72
	Sub-total	479	289	767	49.37
	Total	725	832	1,557	100.0

*: Only the industrial wastewater discharging into river

(d) T-P

(unit: kg/day)

Season	Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
Rainy Season	Point (sewerage)	28	72	100	29.35
	Point (industry)*	2	9	11	3.36
	Sub-total	30	81	111	32.71
	Non-point (household)	0	0	0	0.07
	Non-point (livestock)	138	85	223	65.73
	Non-point (land)	3	2	5	1.50
	Sub-total	141	87	228	67.29
	Total	171	168	339	100.0
Dry Season	Point (sewerage)	28	72	100	47.62
	Point (industry)*	2	9	11	5.23
	Sub-total	30	81	111	52.86
	Non-point (household)	0	0	0	0.05
	Non-point (livestock)	60	37	97	46.19
	Non-point (land)	1	1	2	1.05
	Sub-total	61	38	99	47.14
	Total	91	119	210	100.0

*: Only the industrial wastewater discharging into river

The total existing pollution load runoff of BOD, COD, T-N and T-P by source and by sub-basin are shown in Table E 3.4 (rainy season)-Table E 3.5 (rainy season), and illustrated in Fig E 3.5 (rainy season)-Fig E 3.6 (dry season).

Pollution load runoff ratio of each source in the upper basin of the Lake Fuquene is shown in Fig E 3.7 (rainy season) and Fig E 3.8 (dry season). Livestock shares the largest pollution load runoff in the basin as follows: BOD: 70%, COD: 83%, T-N: 63% and T-P: 80% (rainy season) and BOD: 52%, COD: 74%, T-N: 53% and T-P: 67% (dry season).

Annual pollution load runoff of each source in the upper basin of the Lake Fuquene is shown below. It is considered rainy season includes 185 days and dry season includes 182 days a year.

(unit: ton/y)

Item	BOD		COD		T-N		T-P	
	Pollution Runoff	Ratio (%)	Pollution Runoff	Ratio (%)	Pollution Runoff	Ratio (%)	Pollution Runoff	Ratio (%)
Point (sewerage)	308.8	29.19	514.7	12.29	86.9	22.95	10.2	21.36
Point (industry)*	12.4	1.17	16.8	0.40	2.9	0.77	0.8	1.53
Sub-total	321.2	30.36	531.4	12.69	89.8	23.73	11.0	22.88
Non-point (household)	2.7	0.26	9.5	0.23	0.2	0.05	0.0	0.00
Non-point (livestock)	689.9	65.20	3374.0	80.58	228.7	60.44	36.2	75.59
Non-point (land)	44.6	4.21	272.3	6.50	59.6	15.74	0.7	1.53
Sub-total	736.8	69.64	3655.8	87.31	288.7	76.27	36.9	77.12
Total	1058.0	100.00	4187.2	100.00	378.5	100.00	47.9	100.00

*: Only the industrial wastewater directly discharging into river

3.3 Future Pollution Load Generation and Runoff

3.3.1 Future Pollution Load Generation

The future generated non-point pollution loads of livestock, land and household are estimated under the future socioeconomic conditions with the increased number of livestock and rural population projected in Appendix A, Chapter II, Subsections 2.2-2.3. The future generated point pollution loads of sewerage and industrial wastewater are estimated in Chapter II, Subsections 2.3. The total future pollution load generation of BOD, COD, T-N and T-P in the Study Area (Simulation object area: 1,462 km^2) is summarized below.

(unit: kg/d)

Project	Pollution Load Parameter	Upper Basin of The Lake	Suarez River Basin	Total
Without Project	BOD	77,214	49,604	126,818
	COD	187,970	117,869	305,838
	T-N	53,415	32,823	86,238
	T-P	6,947	4,315	11,262
With Project	BOD	76,041	46,958	122,999
	COD	185,907	114,888	300,796
	T-N	53,065	32,380	85,445
	T-P	6,904	4,251	11,155

In the above table, with project is the case where sewerage and industry waste are treated as shown in Appendix F. The future point and non-point pollution load generation of BOD, COD, T-N and T-P are shown below.

(unit: kg/day)

Parameter	Project	Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
BOD	Without Project	Point	1,469	3,187	4,656	3.67
		Non-Point	75,745	46,416	122,162	96.33
		Total	77,214	49,603	126,818	100.00
	With Project	Point	296	541	837	0.68
		Non-Point	75,745	45,516	122,162	99.32
		Total	76,041	46,057	122,999	100.0
COD	Without Project	Point	2,696	4,037	6,732	2.20
		Non-Point	185,274	113,832	299,106	97.80
		Total	187,970	117,869	305,838	100.00
	With Project	Point	633	1,056	1,690	0.56
		Non-Point	185,274	113,832	299,106	99.44
		Total	185,907	114,888	300,796	100.00
T-N	Without Project	Point	462	625	1,087	1.26
		Non-Point	52,953	32,198	85,150	98.74
		Total	53,415	32,823	86,237	100.00
	With Project	Point	112	162	294	0.34
		Non-Point	52,953	32,198	85,150	99.66
		Total	53,065	32,360	85,444	100.00
T-P	Without Project	Point	58	90	148	1.31
		Non-Point	6,889	4,225	11,114	98.69
		Total	6,947	4,315	11,262	100.00
	With Project	Point	15	26	41	0.37
		Non-Point	6,889	4,225	11,114	99.63
		Total	6,904	4,251	11,155	100.00

The above table is broken down by sub-basin and by source as shown in Table E 3.6 (Without Project) and Table E. 3.7 (With Project).

Livestock is the largest source of pollution load generation in the Study Area. It shows an extremely large percentage in the upper basin of the Lake Fuquene as shown below.

Project	Pollution Load Parameter	Ratio of Livestock (%)
Without Project	BOD	92
	COD	93
	T-N	80
	T-P	97
With Project	BOD	94
	COD	94
	T-N	81
	T-P	98

3.3.2 Future Pollution Load Runoff

The total future pollution load runoff of BOD, COD, T-N and T-P in the Study Area (simulation objective area: 1,462 km^2) in both seasons are summarized below. The runoff coefficients are assumed to be the same values as the existing ones.

(unit: kg/d)

Project	Season	Pollution Load Parameter	Upper Basin of The Lake	Suarez River Basin	Total
Without Project	Rainy Season	BOD	4,840	5,538	10,378
		COD	19,370	14,282	33,652
		T-N	1,680	1,366	3,046
		T-P	216	187	403
	Dry Season	BOD	2,630	3,998	6,628
		COD	8,439	7,565	16,004
		T-N	992	947	1,939
		T-P	127	132	259
With Project	Rainy Season	BOD	3,667	2,892	6,559
		COD	17,308	11,301	28,609
		T-N	1,330	922	2,252
		T-P	174	123	297
	Dry Season	BOD	1,457	1,351	2,808
		COD	6,377	4,585	10,962
		T-N	642	504	1,146
		T-P	84	68	152

The total future pollution load runoff of BOD, COD, T-N and T-P by each point and non-point sources in both seasons are shown below. For details of each pollution load runoff, see Table E.3.8 -Table E 3.11.

(unit: kg/day)

Parameter	Project	Season	Source	Upper Area of the Lake	Suarez River Basin	Total	(%)
BOD	Without Project	Rainy Season	Point	1,469	3,187	4,656	44.87
			Non-point	3,371	2,351	5,722	55.13
			Total	4,840	5,538	10,378	100.00
		Dry Season	Point	1,469	3,187	4,653	70.25
			Non-point	1,161	811	1,972	29.75
			Total	2,630	3,998	6,628	100.00
	With Project	Rainy Season	Point	296	541	837	12.77
			Non-point	3,371	2,351	5,722	87.23
			Total	3,667	2,892	6,559	100.00
		Dry Season	Point	296	541	837	29.82
			Non-point	1,161	810	1,971	70.18
			Total	1,457	1,351	2,808	100.00
COD	Without Project	Rainy Season	Point	2,696	4,037	6,732	20.01
			Non-point	16,675	10,245	26,920	79.99
			Total	19,370	14,282	33,652	100.00
		Dry Season	Point	2,696	4,037	6,732	42.06
			Non-point	5,743	3,529	9.272	57.94
			Total	8,439	7,565	16,004	100.00
	With Project	Rainy Season	Point	633	1,056	1,690	5.91
			Non-point	16,675	10,245	26,920	94.09
			Total	17,308	11,301	28,609	100.00
		Dry Season	Point	633	1,056	1,690	15.41
			Non-point	5,743	3,529	9.272	84.59
			Total	6,377	4,585	10,962	100.00
T-N	Without Project	Rainy Season	Point	462	625	1,087	35.70
			Non-point	1,218	741	1,958	64.30
			Total	1,680	1,366	3,046	100.00
		Dry Season	Point	462	625	1,087	56.08
			Non-point	530	321	852	43.92
			Total	992	947	1,939	100.00
	With Project	Rainy Season	Point	112	182	294	13.06
			Non-point	1,218	740	1,958	86.94
			Total	1,330	922	2,252	100.00
		Dry Season	Point	112	182	294	25.68
			Non-point	530	322	852	74.32
			Total	642	503	1,146	100.00
T-P	Without Project	Rainy Season	Point	58	90	148	36.60
			Non-point	158	97	255	63.40
			Total	216	187	403	100.00
		Dry Season	Point	58	90	148	57.04
			Non-point	69	42	111	42.96
			Total	127	132	259	100.00
	With Project	Rainy Season	Point	15	26	41	13.77
			Non-point	158	97	256	86.23
			Total	174	123	297	100.00
		Dry Season	Point	15	26	41	26.87
			Non-point	69	42	111	73.13
			Total	84	68	152	100.00

Livestock is the largest source of pollution load runoff in the Study Area. It shows a large percentage in the upper basin of the Lake Fuquene as shown below.

Project	Season	Pollution Load Parameter	Ratio of Livestock (%)
Without Project	Rainy Season	BOD	66
		COD	80
		T-N	59
		T-P	73
	Dry Season	BOD	42
		COD	63
		T-N	43
		T-P	54
With Project	Rainy Season	BOD	87
		COD	91
		T-N	75
		T-P	89
	Dry Season	BOD	76
		COD	84
		T-N	67
		T-P	80

Annual future pollution load runoff of each source in the upper basin of the Lake Fuquene is shown below. In the above estimation, It is assumed that rainy season covers 185 days and dry season 182 days a year.

(unit: ton/y)

Project	Item	BOD		COD		T-N		T-P	
		Pollution Runoff	Ratio (%)	Pollution Runoff	Ratio (%)	Pollution Runoff	Ratio (%)	Pollution Runoff	Ratio (%)
Without Project	Point (sewerage)	522.7	38.31	965.8	19.01	165.3	33.88	20.1	32.05
	Point (industry)*	13.1	0.96	18.3	0.36	3.3	0.67	1.1	1.75
	Sub-total	536.2	39.30	984.0	19.37	168.6	34.56	21.2	33.80
	Non-point (household)	2.7	0.20	10.1	0.20	0.2	0.04	0.0	0.00
	Non-point (livestock)	779.4	57.12	3,814.4	75.08	259.2	53.13	40.6	64.75
	Non-point (land)	46.1	3.38	272.3	5.36	59.7	12.24	0.7	1.17
	Sub-total	828.2	60.70	4,096.8	80.64	319.4	65.44	41.5	66.20
	Total	1,364.4	100.0	5,080.6	100.0	488.0	100.0	62.6	100.0
With Project	Point (sewerage)	98.2	10.49	217.5	5.03	38.7	10.74	4.7	10.07
	Point (industry)*	9.9	1.05	13.5	0.31	2.2	0.61	0.7	1.55
	Sub-total	108.0	11.54	231.0	5.34	40.9	11.35	5.5	11.62
	Non-point (household)	2.7	0.29	10.1	0.23	0.2	0.05	0.0	0.00
	Non-point (livestock)	779.4	83.25	3,814.4	88.13	259.2	71.97	40.6	86.06
	Non-point (land)	45.9	4.90	272.3	6.29	59.7	16.58	0.7	1.55
	Sub-total	828.2	88.46	4,096.8	94.66	319.4	88.65	41.5	87.99
	Total	936.2	100.0	4,328.0	100.0	360.2	100.0	47.1	100.0

*: Only the industrial wastewater directly discharging into river

3.4 Water Quality Simulation

3.4.1 Methodology

(1) General

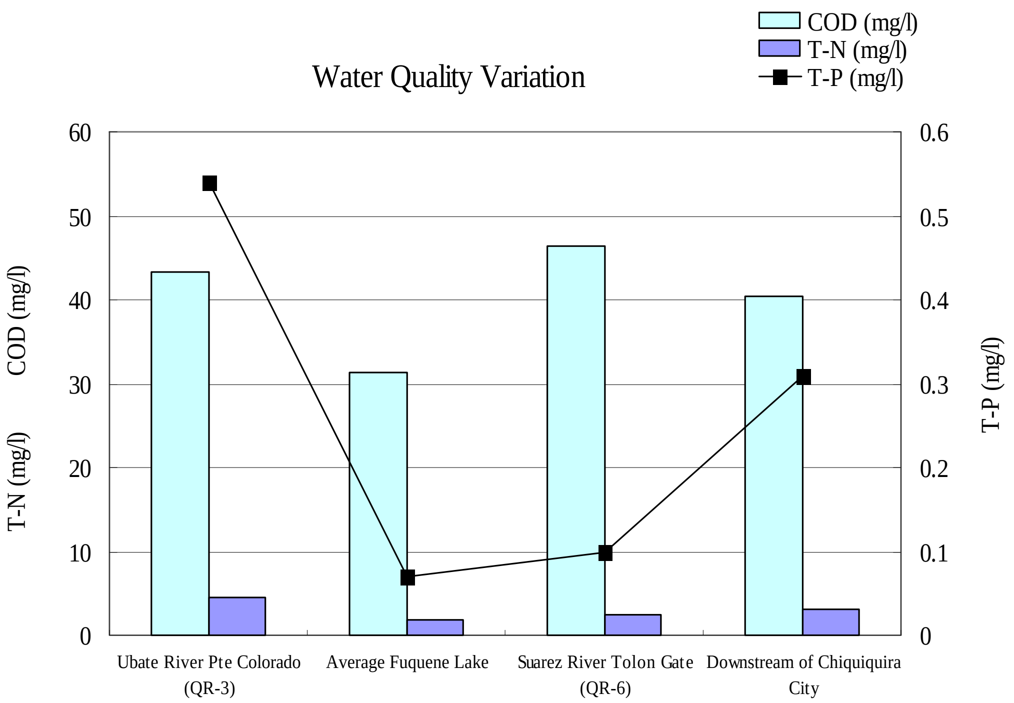
The pollution load generated in the four (4) sub-basins of Upper Ubate, Suta, Cucunuba and Lenguazaque runoff to the Pte Colorado through the respective tributaries. Thereafter, they flow down the Ubate River (lower portion) to enter the Lake Fuquene. On the other hand, the pollution loads in the Lake Fuquene sub-basin is directly discharged into the Lake.

The pollution load entered the Lake are drained to the Suarez River after they are affected by the metabolic effects of the Lake.

The pollution load effluents from the Lake flow down the Suarez River to the Lower Downstream of Chiquinquira City through the Tolon Gate. On the way to the Downstream of Chiquinquira City, the pollution load generated in the sub-basins of Susa, Simijaca, Chiquinquira and Suarez residual are discharged into the Suarez River.

For the schematic diagram of the above pollution load runoff, see Fig. E 3.2.

The water quality shows complicated variations in the river course between Pte Colorado and Downstream of Chiquinquira City as shown below (Pte Colorado, Average Fuquene Lake and Tolon Gate: average observed value, Downstream of Chiquinquira City: estimated value). This mechanism is analyzed in the following Section. In this Section, the concept and methodology for the water quality simulation are presented.



(2) Water Quality Simulation of Main River

The Ubate River (Pte Colorado – Entrance to the Lake) is only 2 km in distance, therefore, no water quality change is assumed in this reach. The river water quality simulation will be made for the Suarez River (Lake Fuquene outlet – Downstream of Chiquinquira City) with a river distance of 20 km.

In the Suarez River, BOD considerably decreases, while COD increases to a significant extent between the Lake outlet and Tolong Gate. However, T-N and T-P scarcely varies.

Hence, BOD concentration is simulated at the objective point based on the following equations.

Variation speed of BOD concentration: $dC/dt = \pm K \cdot C$

BOD concentration at objective point (i): $Ci = Li/Qi$

Where,

C: BOD concentration (mg/l)
Ci: BOD concentration at objective point (i) (mg/l)
K: Variation speed coefficient (1/day)
Li: Pollution load at objective point (i) (kg/day)
Qi: River flow rate at objective point (i) (m^3/s)

COD, T-N and T-P concentration at the objective point (i) is simply simulated by the following equation:

COD/T-N/T-P concentration at objective point (i): $Ci = Li/Qi$

Where,

Ci: COD/T-N/T-P concentration at objective point (i) (mg/l)
Li: Pollution load at objective point (i) (kg/day)
Qi: River flow rate at objective point (i) (m^3/s)

(3) Lake Water Simulation

(a) General

The water quality of the Lake will be evaluated in the parameters of COD, T-N and T-P. COD, T-N and T-P load enter the Lake from the Ubate River and Lake Fuquene sub-basin. They are drained into the Suarez River through the metabolic process of the Lake including decomposition, settling on the bed, absorption by aquatic plants and releasing from the bed.

Such metabolic process is shown in Fig.E.3.9. In this simulation, water quality variation due to the production and decomposition of plankton is not considered since the existing plankton population is small.

The water quality of COD, T-N and T-P will be estimated by calculating the balance of inflow, outflow, decomposition, settling (sedimentation), absorption and releasing loads respectively.

(b) Adopted Lake Water Quality Simulation Formula

The Vollenweider Model was adopted for simulation of the lake water pollution in terms of COD, T-N, and T-P. The adopted formula for the lake water quality simulation is as follows.

C_N =L(N)/((ρ w+ σ N) × V)

C_P = L(N)/((ρ w+ σ P) × V)

C_{COD} = L(COD)/((ρ w+ σ COD) × V)

Where;

C_N : Concentration of Nitrogen of lake (mg/l)

C_P : Concentration of Phosphate of lake (mg/l)

C_{COD}: Concentration of COD of lake (mg/l)

L(N): T-N quantity of inflow into lake and releasing from lake bed sediment (g/day)

L(P): T-P quantity of inflow into lake and releasing from lake bed sediment (g/day)

L(COD): COD quantity of inflow into lake and releasing from lake bed sediment (g/day)

ρ w: Change rate of lake water (annual inflow/lake volume or 1/retention time)

σ N: T-N self-purification (reduction) or production coefficient

σ P: T-P self-purification (reduction) or production coefficient

σ COD: COD self-purification (reduction) or production coefficient

V: Volume of lake

The following assumptions are made in the application of the above formula.

(i) Lake water temperature is constant at 17℃ throughout the year.

(ii) The lake water quality is completely mixed.

(iii) The lake water is under a steady hydraulic condition.

3.4.2 Simulated River Water Quality

(1) Existing River Water Quality

The water quality of the main river at the time of 75% probable discharge is calculated as below. Runoff coefficient (R_1) of non-point pollution loads at the time of 75% probable discharge are BOD/COD: 0.017, T-N/T-P: 0.007.

Item	Unit	Ubate River			Suarez River*	
		After Confluence of Suta River	Pte. Colorado	Tolon Gate	After Chiquinquira City	After Chiquinquira City*
Discharge	m^3/s	0.60	1.14	1.15	1.50	0.35
BOD	mg/l	13.6	5.27	3.22	17.7	69.8
COD	mg/l	37.3	31.1	63.6	72.9	103.6
T-N	mg/l	5.50	4.37	5.26	7.66	15.6
T-P	mg/l	0.69	0.54	0.62	0.90	1.85

*: When Tolon Gate is closed.

(2) Future River Water Quality

The future water quality of the main river at the time of 75% probable discharge is calculated as below. Runoff coefficient (R_1) of non-point pollution loads at the time of 75% probable discharge are the same values as existing case.

Project	Item	Unit	Ubate River			Suarez River*	
			After Confluence of Suta River	Pte. Colorado	Tolon Gate	After Chiquinquira City	After Chiquinquira City*
Without Project	Discharge	M^3/s	0.60	1.14	1.15	1.50	0.35
	BOD	Mg/l	20.9	7.89	3.47	20.6	82.0
	COD	Mg/l	53.2	44.6	68.5	81.0	122.0
	T-N	Mg/l	8.49	6.59	5.77	8.67	18.2
	T-P	Mg/l	1.07	0.78	0.69	1.02	2.10
With Project	Discharge	M^3/s	0.60	1.14	1.15	1.50	0.35
	BOD	Mg/l	9.59	3.94	2.77	5.31	16.0
	COD	Mg/l	27,4	27.3	60.8	56.2	41.1
	T-N	Mg/l	4.02	3.58	4.56	5.01	6.51
	T-P	Mg/l	0.52	0.47	0.42	0.50	0.77

*: When Tolon Gate is closed.

As shown in the above table, the future water quality with project will satisfy the standards of CAR (class-A BOD 5mg/l) at Pte Colorado and Tolon Gate. However, immediately after confluence of Suta River and after Chiquinquira City, it will not meet class-A, but meet class-B (BOD 10mg/l).

3.4.3 Simulated Lake Water Quality

(1) Existing Lake Condition

The pollution analysis of the lake was conducted under following condition.

(a) Hydrological features

Hydrological features of the Fuquene Lake are calculated blow.

Item	Value
Average Discharge at Ubate River Pte Colorado (m^3/s)	4.24
Annual Water Inflow to the Fuquene Lake ($10^6 m^3/y$)	183.6
Lake Water Volume at Average Water Level ($10^6 m^3$)	50.0
Lake Surface Area (km^2)	29.8

(b) Average Water Quality

Average water quality at Ubate River Pte Colorado and Fuquene Lake are shown below.

Parameter	Average River Water Quality at Ubate River Pte Colorado (QR-3)	Average Lake Water Quality in the Fuquene Lake	Remarks
COD(mg/l)	43.4	31.4	
T-N (mg/l)	4.54	1.83	
T-P (mg/l)	0.54	0.07	

As shown above, T-N and T-P concentrations are much lower than those in the Ubate River. It is considered due to that reduction by primary/secondary sedimentation, decomposition by denitrfication of nitrogen, and absorption of the aquatic plants are all large.

(c) Pollution Load Inflow and Outflow

Annual pollution load inflow and outflow are estimated blow. Those pollution loads are obtained from the annual flow rate and average river/lake water quality.

Parameter	Annual Pollution Load Inflow (t/y)	Annual Pollution Load Outflow (t/y)	Remarks
COD	4,187	5,765	
T-N	378.5	336.0	
T-P	47.9	12.9	

(2) Pollution Load Balance

Annual pollution load balance in the lake is summarized below.

Item		COD (t/y)	T-N (t/y)	T-P (t/y)
Production	Pollution Load Inflow	4,187	369.7	47.9
	Releasing Pollution Load	9,789	652.6	6.0
	Total Production of Pollutants	13,976	1,031	53.9
Reduction	Pollution Load Outflow	5,765	336.0	12.9
	Nutrient Absorption by Aquatic Plants	-	25.6	1.8
	Primary Sedimentation in the Ubate River Mouth	619	179.3	36.0
	Secondary Sedimentation in the Lake	1,621	85.9	2.8
	Decomposition in the Lake	5,928	367.9	-
	Total Reduction of Pollutants	13,933	995	53.5

(a) Releasing Pollution Load from Lake Bed Sediment

Releasing rate of COD, T-N, and T-P from the lake bed sediment is calculated in Appendix E Sub-section 1.1.4. Annual releasing pollution load is estimated below.

Parameter	Deposit Quality (mg/dry g)	Releasing Rate ($mg/m^2/d$)	Annual Releasing Pollution Load(t/y)
COD	87.1	900	9,789
T-N	4.60	60	652.6
T-P	0.15	0.55	6.0

As shown above, the releasing pollution loads of COD and T-N from the lake bed sediment are larger than the pollution load inflow. However, the releasing pollution load of T-P is smaller than the pollution load inflow.

(b) Nutrients Content of Aquatic Plants

The nutrients content of aquatic plants in the lake were analyzed by the Study Team as shown below.

No.	Aquatic Plants	Water Content(%)	Ash Content(%)	N (%)	P (%)
1	Elodea	92.2	20.8	2.85	0.23
2	Water hyacinth	91.0	16.8	1.84	0.13
3	Bulrush	76.9	7.4	1.03	0.05

%: Dry Weight

In this lake water quality simulation, the nutrients content analyzed by Study Team are employed.

(c) Nutrients Absorption by Aquatic Plants

The major aquatic plants in the Lake are Water hyacinth, Elodea and Bulrush. Bulrush absorbs nutrients only from the lake bed sediments, Elodea uptakes from both the sediments and lake water, and Water hyacinth absorbs only from the lake water. In this report, only pollution load balance in the lake water is simulated. Then, Bulrush and Elodea are excluded from the simulation. Because;

(i) Bulrush does not uptake nutrients from the lake water.

(ii) The annual growth and death rates of Elodea are considered balanced. Then the releasing and absorption of nutrients to/from the lake water are balanced.

Water hyacinth is estimated to increase at a rate of 2 % of the existing area every year, see Appendix G Chapter IV Sub-section 4.2.1. The annual increasing area of Water Hyacinth at present is calculated to be 697 ha $\times$ 0.02 =13.9 ha. Water content of Water Hyacinth is assumed as 90%.

Then, the increasing Water Hyacinth of the Fuquene Lake will consume the following N and P quantities per year.

N = 100 kg/m^2 $\times$13.9 ha $\times$10% $\times$ 1.84% = 25.6 ton/year

P = 100 kg/m^2 $\times$13.9 ha $\times$10% $\times$ 0.13% = 1.8 ton/year

(d) Primary Sedimentation in the Ubate River Mouth

Primary sedimentation is defined as the sedimentation in the Ubate River mouth. Generally, primary sedimentation rate of pollutants is relatively high in the river mouth. It is considered due to the sedimentation of particles (suspended solid) contained in the river water. Most of the large size particles are removed by sedimentation before inflow to the lake, because of the low current velocity in the river mouth. This phenomenon is observed in the typical eutrophic lakes in Japan, for instance Lake Teganuma and Lake Kasumigaura [–3)]. Especially, primary sedimentation of T-P is expected to be higher than other parameters.

In this Study, primary sedimentation ratio is estimated by the comparison between the average water quality at Uabte River Pte Colorado and Fuquene Lake Ubate Mouth. Primary sedimentation ratio of pollutants is calculated below.

Parameter	Average Pollutants Concentration		Primary Sedimentation Ratio (%)	Annual Primary Sedimentation Quantity (t/y)
	Ubate River at Pte. Colorado QR-3 (mg/l)	Fuquene Lake at Ubate Mouth QL-1 (mg/l)		
COD	39.2	33.3	15.0	618.9
T-N	4.55	2.34	48.5	179.3
T-P	0.49	0.12	76.2	36.0

(e) Secondary Sedimentation in the Lake

Secondary sedimentation is defined as the sedimentation in the lake. Pollution load reduction by secondary sedimentation in the lake is estimated based on the results of settling test and deposit quality observation. Annual secondary sedimentation quantity is calculated below.

Item	Average Settling Rate of Particles		Average Deposit Quality (mg/dry g)	Secondary Sedimentation Rate(t/y)
	Daily Rate($g/m^2/d$)	Annual Rate ($g/m^2/y$)		
SS	1.71	624	-	-
COD	-	-	87.1	1,621
T-N	-	-	4.60	85.9
T-P	-	-	0.15	2.8

(f) Decomposition in the Lake

Organic substance concentration (COD) will be reduced by biological decomposition in the lake water. On the other hand, nitrate (NO_3) and nitrite (NO_2) concentration will be also reduced by denitrification on interface between the lake bed and the lake water. Decomposition of phosphorus is considered negligible.

(i) COD

Generally, the organic substances in the eutrophic lake are hardly biodegradable. Biological decomposition rate of COD(Mn) in the eutrophic lake is reported at 0.007 (1/day) at 20℃ of water temperature based on the experimental analysis [-4)]. On the other hand, the COD decomposition rate varies depending on water temperature as shown below.

$$K=K_{20}\times\theta^{T-20}$$

Where

K : COD decomposition rate at T℃

K_{20}:COD decomposition rate at 20℃

θ : Thermal coefficient

Thermal coefficient θ is in the range of 1.047-1.103 (average value 1.077) according to a previous study [-5)]. Therefore, COD (Cr) decomposition rate in the Fuquene Lake is assumed as 0.0056 (1/day) at 17℃. The annual decomposition quantity of COD (Cr) is calculated as 5,928 ton.

(ii) Nitrogen

T-N concentration in the lake water gradually decreases to outlet because of its denitrification. Generally, denitrification rate in the lake depends on the lake water temperature, the lake water quality, hydraulic features, and so on.

Denitrofication ratio in the Fuquene Lake is assumed as 36% referring to the case of Lake Teganuma, Japan [–3)]. Using this value, annual denitrofication quantity in the Fuquene Lake is estimated at 367.9t/y.

(3) Self-Purification Coefficient in the Fuquene Lake

Based on the Vollenweider Model given in Subsection 3.4.1 (3), self-purification coefficients for each parameter are calculated below. These coefficient values are adopted for projection of the future lake water quality.

Item	Unit	Self-purification Coefficient	Remarks
COD	(1/day)	0.014	
T-N	(1/day)	0.021	
T-P	(1/day)	0.032	

(4) Future Lake Water Quality and Pollution Load Balance

(a) Future Lake Water Quality

Future lake water quality is simulated based on the future total production of pollutants. The future total pollutant production are shown below. In this table, releasing pollution loads are assumed to be the same quantity as the existing ones.

Item	Without Project			With Project		
	COD (t/y)	T-N (t/y)	T-P (t/y)	COD (t/y)	T-N (t/y)	T-P (t/y)
Pollution Load Inflow	5,081	488.0	62.6	4,328	360.2	47.1
Releasing Pollution Load	9,789	652.6	6.0	9,789	652.6	6.0
Total Production of Pollutants	14,870	1,141	68.6	14,117	1,013	53.1

The future average water quality of the Lake is calculated below.

Item	Unit	Existing Water Quality	Future Water Quality (Without Project)	Future Water Quality (With Project)
COD	mg/l	31.4	33.4	31.7
T-N	mg/l	1.83	2.02	1.79
T-P	mg/l	0.07	0.09	0.07

In this calculation, the future self-purification coefficient are assumed to be the same as the existing ones.

As shown above, the future lake water quality will be still highly eutrophic regardless the wastewater treatment of point sources. It is due to that a large pollution load of non-point sources is left untreated even in the future.

(b) Future Pollution Load Balance

Balance of the future annual pollution load in the lake is summarized blow. In this table, the future nutrient absorption by aquatic plants and secondary sedimentation in the lake are assumed to be the same as the existing ones.

	Item	Without Project COD (t/y)	Without Project T-N (t/y)	Without Project T-P (t/y)	With Project COD (t/y)	With Project T-N (t/y)	With Project T-P (t/y)
Production	Pollution Load Inflow	5,081	488.0	62.6	4,328	360.2	47.1
	Releasing Pollution Load	9,789	652.6	6.0	9,789	652.6	6.0
	Total Production of Pollutants	14,870	1,141	68.6	14,117	1,013	53.1
Reduction	Pollution Load Outflow	6,132	370.9	16.5	5,820	328.6	12.9
	Nutrient Absorption by Aquatic Plants	-	25.6	1.8	-	25.6	1.8
	Primary Sedimentation in the Ubate River Mouth	762	236.7	47.7	649	174.7	35.9
	Secondary Sedimentation in the Lake	1,621	85.9	2.8	1,621	85.9	2.8
	Decomposition in the Lake	6,335	410.8	-	6,014	364.7	-
	Total Reduction of Pollutants	14,850	1,130	68.8	14,101	980	53.4

REFERENCES

1) Toshiko Nakamura et al, Seasonal Variation of Phitoplankton in South Biwa Lake, Journal of Water and Waste, Vol. 39 No.11 (1997)

2) Report of Water Quality in Kasumigaura Lake, Japan, (1995).

3) Masaaki Hosomi and Ryuichi Sudo, A three-year Water, Nitrogen, and Phosphorus Budget for Lake Teganuma, Journal of Japan Society on Water Environment Vol. 15 No.2 105-112 (1992)

4) Shigeo Fujii, Isao Somiya, and Yoshihiro Kokura, Quantitification of Bacterial Decomposition Activity in Eutrophicated Water, Journal of Japan Society on Water Environment Vol. 14 No.5 335-342 (1991)

5) Shigeo Fujii, Isao Somiya, and Toshiyuki Shiraki, Studies on Effect of Phytoplankton and Zooplankton on Self-Purification in Eutrophicated Water, Journal of Japan Society on Water Environment Vol. 14 No.7 469-478 (1991)

Table E.1.1 Existing Data of Water Quality Analysis (Fuquene Lake)-1/4

Year	1994			1996					1997					
Sampling Site	Center	Near Suarez Outlet	Average	Near Port	Near Ubate Mouth	Center	Near Suarez Outlet	Average	Near Ubate Mouth	Island	Near Suarez Outlet	Center	Near Ubate Mouth	Island
Sampling Date	1994.5.25	1994.5.25		1996.8.20	1996.8.20	1996.8.20	1996.8.20		1997.5.23	1997.5.23	1997.5.23	1997.5.23	1997.7.25	1997.7.25
Sampling Time	10:30	10:40		15:00	15:00	13:50	14:00							
Sampling Depth (m)	Superficial	Superficial		Superficial	Superficial	Superficial	Superficial		Superficial	Superficial	Superficial	Superficial	Superficial	Superficial
WaterTemperature(℃)	17.0	17.0	17.0	14.5	15.7	16.4	16.2	15.7	16.2	15.4	15.3	16.3		
pH	7.0	6.8	6.9	7.7	7.8	7.5	7.4	7.6	7.9	7.6	6.8	7.9	6.8	7.0
DO(Disolved O_2) (mg/l)	7.50	8.30	7.90	8.3	2.6	7.6	8.0	6.6	6.5	6.3	6.8	6.6		
BOD_5(DBO) (mg/l)				2.0	6.2	4.2	3.0	3.9	2.0	4.0	1.0	2.0		
COD(DQO) (mg/l)				19.0	31.1	50.0	47.3	36.8	18.0	17.0	18.0	23.0		
SS(mg/l)				4.0	10.0	2.0	0.0	4.0	2.0	2.0	1.0	4.0	44.0	16.0
Pb (mg/l)				0.03	0.02	0.03	0.03	0.03	0.00	0.00	0.00	0.00		
Zn (mg/l)				0.04	0.02	0.03	0.0	0.0						
Hg (mg/l)									0.0000	0.0000	0.0000	0.0000		
Cr (mg/l)									0.00	0.00	0.00	0.00		
Phenol (mg/l)									0.000	0.000	0.000	0.000		
NH4 (mg/l)				0.87	0.7	0.98	0.69	0.81	0.81	0.84	0.6	0.79	0.41	0.00
NO3(mg/l)				0.1	0.3	0.1	0.2	0.2	0.02	0.00	0.91	0.03	0.009	0.009
NO2 (mg/l)				0.004	0.003	0.005	0.008	0.005	0.00	0.00	0.00	0.00		
Kje-N (mg/l)				3.23	1.09	2.80	4.20	2.83						
Org-N (mg/l)														
T-N (mg/l)				3.33	1.39	2.91	4.41	3.01	0.90	1.20	1.90	1.30		
PO43- (mg/l)				0.04	0.01	0.03	0.03	0.03	0.02	0.00	0.00	0.00	0.09	0.00
T-P(mg/l)				0.07	0.04	0.09	0.05	0.06	0.16	0.13	0.15	0.12	0.19	0.007
T-Fe (mg/l)	1.96	2.17	2.07	1.02	0.94	1.35	0.67	1.00	0.72	0.59	0.42	0.48	1.96	0.62
Mg (mg/l)				1.98	1.90	2.41	2.42	2.18						
Mn (mg/l)													0.09	0.41
T-S (mg/l)				36	136	128	120	105.0	88	87	88	92	94	90
D-S (mg/l)				32	126	126	120	101.0	86	85	87	88		
Al (mg/l)				0.27	0.09	0.44	0.36	0.29						
Oil/Grease(mg/l)									3.7	12.6	5.6	3.1		
Sulfate (mg/l)									3.5	7.9	12.2	6.5		
Detergent (mg/l)	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.01						
Pesticide(mg/m^3)									0.000	0.000	0.000	0.000		
Total acidity($CaCO_3$mg/l)				2.4	5.7	3.8	1.0	3.2					4.1	1.5
Total alkalinity($CaCO_3$mg/				29.1	25.0	30.4	26.7	27.8	27.0	26.0	27.0	27.0	14.8	34.9
EC(mS/cm)	50.0	50.0	50.0	125.0	89.0	137.0	123.0	118.5					70.6	109.3
Chloride (mg/l)				13.4	13.9	15.6	17.5	15.1					73.2	557.1
Chlorophyil (mg/m^3)													2.3	6.0
Turbidity (NTU)	17.0	15.0	16.0	10.0	10.0	10.0	10.0	10.0					45.0	5.4
Total hardness (mg$CaCO_3$/l)				67.4	73.2	72.6	74.4	71.9	44.0	50.0	48.0	50.0	20.4	56.3
Total Coliform(MPN/100ml)				$<30\times10^4$	$<30\times10^4$	$<30\times10^4$	$<30\times10^2$						93×10^2	93×10^2
Facal Coliform(MPN/100ml)				$<30\times10^4$	$<30\times10^4$	$<30\times10^2$	$<30\times10^2$						93×10^2	<30

Table E.1.1 Existing Data of Water Quality Analysis (Fuquene Lake)-2/4

Year	1997		1998				1999				1994-1999		
Sampling Site	Near Suarez Outlet	Average	Near Ubate Mouth	Island	Near Suarez Outlet	Average	Near Ubate Mouth	Island	Near Suarez Outlet	Average	Average	Maximum	Minimum
Sampling Date	1997.7.25		1998.12.3	1998.12.3	1998.12.3		1999.3.25	1999.3.25	1999.3.25				
Sampling Time			9:40	9:55	10:05		11:25	11:50	11:40				
Sampling Depth (m)	Superficial		Superficial	Superficial	Superficial		Superficial	Superficial	Superficial				
WaterTemperature(°C)			19.0	19.0	19.0	19.0	20.0	18.0	20.0	19.3	17.7	20.0	15.3
pH	6.7	7.2	7.3	7.2	6.6	7.0	7.4	7.1	6.9	7.1	7.2	7.9	6.6
DO(Disolved O_2) (mg/l)		6.6	5.2	7.2	6.6	6.3	12.1	4.8	0.9	5.9	6.4	12.1	0.9
BOD_5(DBO) (mg/l)		2.3	1.8	5.5	1.2	2.8	2.8	2.1	1.1	2.0	2.5	5.5	1.0
COD(DQO) (mg/l)		19.0									25.6	47.3	17.0
SS(mg/l)	0.0	9.9	4.0	8.0	4.0	5.3	17.0	5.0	6.0	9.3	7.9	44.0	0.0
Pb (mg/l)		0.00									0.01	0.03	0.00
Zn (mg/l)											0.03	0.03	0.03
Hg (mg/l)		0.0000									0.0000	0.0000	0.0000
Cr (mg/l)		0.00									0.00	0.00	0.00
Phenol (mg/l)		0.000									0.000	0.000	0.00
NH4 (mg/l)	0.65	0.59	0.18	0.27	0.20	0.22	0.59	0.31	0.78	0.56	0.52	0.84	0.00
NO3(mg/l)	0.002	0.140	1.30	5.10	3.40	3.27	0.00	0.10	0.10	0.07	0.8	5.1	0.0
NO2 (mg/l)		0.000	0.000	0.000	0.000	0.000	0.003	0.002	0.003	0.003	0.002	0.008	0.000
Kjc-N (mg/l)			1.3	1.6	1.0	1.3	2.2	1.9	1.5	1.9	2.0	4.2	1.0
Org-N (mg/l)							1.6	1.6	0.7	1.3	1.3	1.6	0.7
T-N (mg/l)		1.33					2.20	2.00	1.60	1.94	1.98	4.41	0.90
PO43- (mg/l)	0.00	0.02	0..01	0.01	0.02	0.015	0.03	0.00	0.00	0.01	0.02	0.09	0.00
T-P(mg/l)	0.00	0.11	0.06	0.04	0.07	0.06	0.18	0.20	0.06	0.15	0.10	0.20	0.00
T-Fe (mg/l)	0.31	0.73									0.75	1.96	0.31
Mg (mg/l)											2.30	2.42	2.18
Mn (mg/l)	0.14	0.21									0.21	0.41	0.09
T-S (mg/l)	64	86									91	120	64
D-S (mg/l)		87									93	120	85
Al (mg/l)											0.33	0.36	0.29
Oil/Grease(mg/l)		6.3									6.3	12.6	3.1
Sulfate (mg/l)		7.53									7.5	12.2	3.5
Detergent (mg/l)											0.0	0.0	0.0
Pesticide(mg/m^3)		0.000									0.0	0.0	0.0
Total acidity($CaCO_3$mg/l)	3.9	3.2									2.8	4.1	1.0
Total alkalinity($CaCO_3$mg/	31.1	26.8									26.9	34.9	14.8
EC(mS/cm)	103.0	94.3	93.0	85.0	100.0	92.7	207	119	174	167	118.3	207.0	70.6
Chloride (mg/l)	296.1	308.8									211.3	557.1	15.1
Chlorophyil (mg/m^3)	0.87	3.1					14.763	8.606	1.846	8.405	5.731	14.763	0.870
Turbidity (NTU)	1.3	17.2	6.7	13.0	17.0	12.2	32.0	14.0	11.0	19.0	15.3	45.0	1.3
Total hardness (mg$CaCO_3$/l)	29.8	42.6	62.0	46.6	61.2	56.6	89.6	63.8	87.8	80.4	57.5	89.6	20.4
Total Coliform(MPN/100ml)	45×10^2		43×10^2	36×10	46×10^2		91×10^2	36×10^2	$<30\times10^2$				
Facal Coliform(MPN/100ml)	91×10		$<30\times10$	$<30\times10$	$<30\times10$		$<30\times10^2$	$<30\times10^2$	$<30\times10^2$				

Table E.1.1 Existing Data of Water Quality Analysis (River)-3/4

Basin	Ubate								Other Inflow Rivers						
River Name	Ubate							Lenguazaque	Q.Honda		Q.Monroy	Q.Tagusa	Q.Calaboza	Q.Cucunuba	Q.Malvinas
Sampling Site	Lower End	Lower End	Lower End	Lower End	Average	Maximum	Minimum	Before Prodeco	Lower End	Lower End	Lower End	Lower End	Lower End	Lower End	Lower End
Sampling Date	1996.8.20	1997.7.25	1998.12.3	1999.3.25				1993.1.14	1999.3.25	1998.12.3	1997.5.8	1997.5.8	1997.5.8	1997.5.8	1997.5.8
Sampling Time			9:45	14:30				10:00	14:40	9:20					
Sampling Depth (m)	Superficial	Superficial	Superficial	Superficial				Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial
WaterTemperature(°C)	15.7	14.0	18.5	17.0	16.3	18.5	14.0	16.0	15.0	17.7					
pH	7.8	6.8	6.9	6.8	7.1	7.8	6.8	6.4	7.0	6.8					
DO(Disolved O_2) (mg/l)	2.6	3.6	3.0	7.3	4.1	7.3	2.6	4.1	9.1	7.1					
BOD_5(DBO) (mg/l)	6.2		3.3	2.0	3.8	6.2	2.0	5.0	1.0	1.2	1.0	1.0	2.0	1.0	1.0
COD(DQO) (mg/l)	31.1				31.1	31.1	31.1	18.0			2.0	17.0	18.0	9.0	13.0
SS(mg/l)	10.0	44.0	4.0	21.0	19.8	44.0	4.0	22.0	10.0	6.0	15.0	1.0	18.0	5.0	2.0
Pb (mg/l)	0.02				0.02	0.02	0.02				0.00	0.00	0.00	0.00	0.00
Zn (mg/l)	0.02				0.02	0.02	0.02								
Hg (mg/l)											0.0000	0.0000	0.0000	0.0000	0.0000
Cr (mg/l)											0.00	0.00	0.00	0.00	0.00
Phenol (mg/l)								0.000			0.000	0.000	0.000	0.000	0.000
NH4 (mg/l)	0.70	0.41	1.08	0.85	0.76	1.08	0.41		0.63	0.34	0.87	1.00	1.59	1.24	0.76
NO3(mg/l)	0.30		3.20	0.20	1.23	3.20	0.20		0.00	5.30	0.04	0.22	0.00	0.22	0.01
NO2 (mg/l)	0.003	0.008	0.023	0.019	0.013	0.023	0.003		0.005	0.007	0.000	0.000	0.000	0.010	0.000
Kje-N (mg/l)	1.09	1.50	2.50	2.00	1.77	2.50	1.09		1.30	1.0					
Org-N (mg/l)		0.7		1.2	1.0	1.2	0.7		0.70						
T-N (mg/l)	1.39		5.72	2.22	3.11	5.72	1.39				1.00	1.50	1.70	1.90	1.00
PO43- (mg/l)	0.01	0.09	0.13	0.11	0.09	0.13	0.01		0.00	0.03	0.06	0.00	0.00	0.00	0.00
T-P(mg/l)	0.04	0.19	0.24	0.25	0.18	0.25	0.04		0.15	0.05	0.45	0.13	0.22	0.39	0.40
T-Fe (mg/l)	0.94	1.96			1.45	1.96	0.94	1.00			2.79	2.25	2.49	2.35	2.53
Mg (mg/l)	1.9	1.22			1.56	1.90	1.22								
Mn (mg/l)		0.09			0.09	0.09	0.09								
T-S (mg/l)	136	94			115	136	94	96			69	90	94	41	108
D-S (mg/l)	126				126	126	126	70			54	89	76	36	106
Al (mg/l)	0.09				0.09	0.09	0.09	22.5							
Oil/Grease(mg/l)											2.2	0.0	2.0	1.8	1.9
Sulfate (mg/l)	0.00				0.00	0.00	0.00	8.9			0.00	0.30	0.40	0.20	9.30
Detergent (mg/l)															
Pesticide(mg/m^3)											0.000	0.000	0.000	0.000	0.000
Total acidity($CaCO_3$mg/l)	5.7	4.1			4.9	5.7	4.1	3.4			14.0	27.0	16.0	7.0	36.0
Total alkalinity($CaCO_3$mg/	25.0	14.8			19.9	25.0	14.8	20.9							
EC(mS/cm)	89.0	70.6	106	227	123.2	227.0	70.6	90.0	69.0	62.0					
Chloride (mg/l)	13.9				13.9	13.9	13.9								
Chlorophyil (mg/m^3)		2.3			2.3	2.3	2.3								
Turbidity (NTU)	<10	45.0	15.0	32.0	30.7	45.0	15.0	6.7	10.0	17.0					
Total hardness ($mgCaCO_3$/l)	73.2	20.4	50.4	81.8	56.5	81.8	20.4	30.2	49.0	36.0	30.0	42.0	31.0	22.0	54.0
Total Coliform(MPN/100ml)	$<30\times10^4$	93×10^2	24×10^2	15×10^4				11×10^4	93×10	23×10^2					
Facal Coliform(MPN/100ml)	$<30\times10^4$	93×10^2	35×10^2	91×10^2				11×10^4	73	$<30\times10$					

Table E.1.1 Existing Data of Water Quality Analysis (River)-4/4

Basin	Suarez												
River Name	Susa	Simijaca	Suarez										
Sampling Site	Lower End	Lower End	Before Tolon Gate	Before Tolon Gate	Before Tolon Gate	Before Tolon Gate	Balsa Bridge	Average	Maximum	Minimum			
Sampling Date	1996.10.4	1996.10.4	1993.12.2	1996.10.4	1998.12.3	1999.3.25	1993.12.2						
Sampling Time	15:00	13:30	14:45	12:00	10:40	13:05	14:40						
Sampling Depth (m)	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial						
WaterTemperature(℃)	21.0	21.0	16.0	19.7	18.2	16.0	16.0	17.5	19.7	16.0			
pH	7.7	7.3	5.4	7.8	6.8	6.8	5.2	6.7	7.8	5.4			
DO(Disolved O_2) (mg/l)	1.7	0.0		5.4	5.3	1.0		3.9	5.4	1.0			
BOD_5(DBO) (mg/l)	5.0	3.0	3.0	2.0	1.5	1.6	1.0	2.0	3.0	1.5			
COD(DQO) (mg/l)	12.0	30.0	45.0	47.0			41.0	46.0	47.0	45.0			
SS(mg/l)	10.0	22.0	242.0	0.0	8.0	9.0	234.0	64.8	242.0	0.0			
Pb (mg/l)													
Zn (mg/l)													
Hg (mg/l)													
Cr (mg/l)													
Phenol (mg/l)													
NH4 (mg/l)	4.04	1.08	0.48	0.50	1.03	0.32	0.48	0.58	1.03	0.32			
NO3(mg/l)	0.44	0.50		0.73	4.30	0.10		1.71	4.30	0.10			
NO2 (mg/l)	0.000	0.000		0.000	0.000	0.004		0.001	0.004	0.000			
Kjc-N (mg/l)	5.47	2.75	1.32	2.42	1.80	1.70	1.92	1.81	2.42	1.32			
Org-N (mg/l)						1.4		1.4	1.4	1.4			
T-N (mg/l)	5.91	3.25		3.15	6.10	1.80		3.68	6.10	1.80			
PO43- (mg/l)			0.07		0.03	0.35	0.05	0.15	0.35	0.03			
T-P(mg/l)	0.70	0.37	0.06	0.06	0.06	0.52	0.05	0.18	0.52	0.06			
T-Fe (mg/l)	3.48	5.78	2.88	2.57			3.65	2.73	2.88	2.57			
Mg (mg/l)													
Mn (mg/l)													
T-S (mg/l)	110	108	258	136			260	197	258	136			
D-S (mg/l)	100	86	16	136			26	76	136	16			
Al (mg/l)													
Oil/Grease(mg/l)			26.7	7.4			2.1	17.1	26.7	7.4			
Sulfate (mg/l)													
Detergent (mg/l)	0.46	0.07		0.00				0.00	0.00	0.00			
Pesticide(mg/m^3)													
Total acidity($CaCO_3$mg/l)	9.1	8.1	19.0				12.2	19.0	19.0	19.0			
Total alkalinity($CaCO_3$mg/			33.0				15.3	33.0	33.0	33.0			
EC(mS/cm)	245.0	220.0		257.0	116.0	172.0		181.7	257.0	116.0			
Chloride (mg/l)	56.5	56.6		39.1				39.1	39.1	39.1			
Chlorophyil (mg/m^3)													
Turbidity (NTU)					28.0	22.0		25.0	28.0	22.0			
Total hardness ($mgCaCO_3$/l)	49.8	111.8		46.0	66.0	82.0		64.7	82.0	46.0			
Total Coliform(MPN/100ml)	94×10^2	36×10^3	$<36\times10^3$	36×10^2	464×10^2	11×10^3	$<36\times10^3$						
Facal Coliform(MPN/100ml)	$<30\times10^2$	$<36\times10^3$	$<36\times10^3$	$<36\times10^2$	73×10	36	$<36\times10^3$						

Table E.1.2 Results of Water Quality Observation in the Lake in Rainy Season -1/2

Sample No.	1	2	3	4	5	6	7	8
Lake Name	Fuquene Lake		Fuquene Lake		Fuquene Lake		Fuquene Lake	
Sampling Site	Near Ubate Mouth		Near Port		Center		Near Suarez Outlet	
Remarks								
Code No.	QL-1		QL-2		QL-3		QL-4	
Sampling Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer
Sampling Date	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15
Sampling Time	10:40	10:42	13:15	13:18	11:40	11:45	14:10	14:15
Climate	Clear		Clear		Clear		Clear	
Point Depth (m)	2.10		4.20		5.10		2.20	
Clearance (m)	0.36		0.84		0.58		1.10	
Sampling Depth (m)	0.50	1.60	0.50	3.20	0.50	4.00	0.50	1.70
WaterTemperature(°C)	17.4	17.4	17.2	17.2	17.2	17.0	18.5	15.6
Color	Light Yellow	Light Yellow	Light Yellow	Light Yellow	Light Yellow	Light Yellow	Colorless	Colorless
Odor	Odorless	Odorless	Sulfur	Sulfur	Odorless	Odorless	Odorless	Odorless
EC(mS/cm)	18.1	18.0	14.2	14.0	8.8	8.6	13.5	13.6
Turbidity	60.5	54.1	16.2	16.0	19.0	19.8	5.7	13.6
pH	6.80	6.82	6.90	6.90	6.90	6.90	6.90	6.92
Dissolved O_2 (mg/l)	3.80	0.30	4.50	4.20	4.70	4.60	7.70	0.50
COD(Cr) (mg/l)	28.0	41.0	23.0	23.0	25.0	25.0	25.0	48.0
T-N(mg/l)	3.08	2.67	1.08	2.77	1.28	1.08	1.39	2.41
NH_4^+ -N (mg/l)	1.31	1.28	0.64	0.92	0.92	0.72	0.73	0.48
NO_3^- -N(mg/l)	0.22	0.19	0.39	0.30	0.25	0.28	0.02	0.06
NO_2^- -N(mg/l)	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
T-P(mg/l)	0.20	0.29	0.36	0.00	0.04	0.00	0.06	0.25
PO_4^{3-} -P(mg/l)	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.02
SS (mg/l)	23	176	11	3	10	5	37	105
Particle size distribution(% 400-38micron)	92.0	76.6	82.2	100	100	100	85.3	98.8
V-SS (mg/l)	7	36	4	1	1	3	18	32
Phenol (mg/l)	0.000	-	0.000	-	0.000	-	0.000	-
Arsenic (mg/l)	0.000	-	0.000	-	0.000	-	0.000	-
Cadmium (mg/l)	0.00	-	0.00	-	0.00	-	0.00	-
Cyanide (mg/l)	0.0	-	0.0	-	0.0	-	0.0	-
Cr6+ (mg/l)	0.00	-	0.00	-	0.00	-	0.00	-
Copper (mg/l)	0.00	-	0.00	-	0.00	-	0.00	-
Hg (mg/l)	0.0000	-	0.0000	-	0.0000	-	0.0000	-
Ni2+ (mg/l)	0.00	-	0.00	-	0.00	-	0.00	-
Lead (mg/l)	0.00	-	0.00	-	0.00	-	0.00	-
Zinc (mg/l)	0.00	-	0.00	-	0.00	-	0.00	-
Iron(mg/l)	1.92	-	0.72	-	3.08	-	0.13	-
Manganese(mg/l)	0.03	-	0.08	-	0.09	-	0.00	-
Organo-chlorine Pesticide (mg/l)	0.000	-	0.000	-	0.000	-	0.000	-
Organo-phosphorus Pesticide (mg/l)	0.000	-	0.000	-	0.000	-	0.000	-
Organo-carbonate Pesticide (mg/l)	0.000	-	0.000	-	0.000	-	0.000	-
Total Coliform (MPN)	15×10^2	23×10^2	70	40	40	23×10^3	40	23×10^2
Facal Coliform (MPN)	15×10^2	23×10^2	70	40	40	23×10^3	40	23×10^2

Table E.1.2 Results of Water Quality Observation in the Lake in Rainy Season -2/2

Sample No.	1	2	3	4	5	6	7	8
Lake Name	Fuquene Lake		Fuquene Lake		Fuquene Lake		Fuquene Lake	
Sampling Site	Near Ubate Mouth		Near Port		Center		Near Suarez Outlet	
Remarks								
Code No.	QL-1		QL-2		QL-3		QL-4	
Sampling Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer
Sampling Date	1999/5/14	1999/5/14	1999/5/14	1999/5/14	1999/5/14	1999/5/14	1999/5/14	1999/5/14
Sampling Time	13:00	13:10	14:30	14:35	13:50	14:00	14:50	15:00
Climate								
Point Depth (m)	2.05		3.50		4.50		2.00	
Clearance (m)	0.45		0.96		1.20		0.55	
Sampling Depth (m)	0.50	1.50	0.50	3.20	0.50	4.00	0.50	1.50
WaterTemperature(°C)	16.8	16.2	16.1	15.7	16.9	15.3	15.0	15.3
Color	Light Yellow	Light Yellow	Green Yellow	Green Yellow	Light Yellow	Light Yellow	Yellow	Yellow
Odor	Odorless	Odorless	Soft fishy	Soft fishy	Odorless	Odorless	Fishy	Fishy
EC(mS/cm)	170.0	200.0	140.0	140.0	90.0	90.0	170.0	170.0
Turbidity	26.0	33.0	5.8	4.1	5.3	4.8	17.0	19.0
pH	6.20	6.40	6.60	6.70	6.50	6.50	6.50	6.40
Dissolved O_2 (mg/l)	3.5	1.0	3.8	2.4	5.1	4.7	1.4	1.0
COD(Cr) (mg/l)	35.0	47.0	30.0	46.0	25.0	48.0	28.0	52.0
T-N(mg/l)	2.62	2.94	2.25	2.02	2.07	2.33	1.65	1.97
NH_4^+ -N (mg/l)	1.31	1.36	0.69	0.71	0.79	1.08	0.68	0.64
NO_3^- -N(mg/l)	0.31	0.45	0.54	0.23	0.27	0.24	0.06	0.13
NO_2^- -N(mg/l)	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.00
T-P(mg/l)	0.08	0.05	0.05	0.04	0.04	0.02	0.06	0.04
PO_4^{3-} -P(mg/l)	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
SS (mg/l)	8	17	7	3	9	3	13	16
Particle size distribution(% 400-	100	99.5	100	100	100	100	100	99.0
V-SS (mg/l)	4	7	3	2	7	2	9	9
Phenol (mg/l)	-	-	-	-	-	-	-	-
Arsenic (mg/l)	-	-	-	-	-	-	-	-
Cadmium (mg/l)	-	-	-	-	-	-	-	-
Cyanide (mg/l)	-	-	-	-	-	-	-	-
Cr6+ (mg/l)	-	-	-	-	-	-	-	-
Copper (mg/l)	-	-	-	-	-	-	-	-
Hg (mg/l)	-	-	-	-	-	-	-	-
Ni2+ (mg/l)	-	-	-	-	-	-	-	-
Lead (mg/l)	-	-	-	-	-	-	-	-
Zinc (mg/l)	-	-	-	-	-	-	-	-
Iron(mg/l)	-	-	-	-	-	-	-	-
Manganese(mg/l)	-	-	-	-	-	-	-	-
Organo-chlorine Pesticide (mg/l)	0.000	-	0.000	-	0.000	-	0.000	-
Organo-phosphorus Pesticide (mg/l)	0.000	-	0.000	-	0.000	-	0.000	-
Organo-carbonate Pesticide (mg/l)	0.000	-	0.000	-	0.000	-	0.000	-
Total Coliform (MPN)	-	-	-	-	-	-	-	-
Facal Coliform (MPN)	-	-	-	-	-	-	-	-

Table E.1.3 Results of Water Quality Observation at the Principal River Stations in Rainy Season 1/3

Sample No.	1	2	3	4	5	6	7
River Name	Hato Dam	Ubate River	Lenguazaque River	Ubate River	Suarez River	Chiquinquira River	Suarez River
Sampling Site	Outlet of Dam	Downstream of Ubate City	Verda Punta Gande	Colorado	Balsa Bridge	Upstream of Chiquinquira City	Before Tolon Gate
Remarks							
Code No.	QS-4	QR-1	QR-2	QR-3	QR-4	QR-5	QR-6
Sampling Date	1999/4/16	1999/4/16	1999/4/16	1999/4/16	1999/4/16	1999/4/16	1999/4/16
Sampling Time	15:15	14:36	14:05	13:32	9:55	9:20	8:25
Climate	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Discharge(m^3/s)	1.60	2.62	0.62	6.22	3.88	3.11	4.02
Water Level (m)	-	0.84	0.49	-	-	-	39.30
Water Depth (m)	0.50	0.90	0.30	2.10	3.45	1.10	2.50
WaterTemperature(°C)	14.8	15.6	15.3	15.6	16.6	15.5	17.4
Color	Light Yellow	Light Yellow	Light Yellow	Light Beige	Light Brown	Light Yellow	Light Yellow
Odor	Sulfur	Odorless	Fish	Odorless	Light Anaerobic	Odorless	Odorless
EC(ms/m)	5.90	8.03	8.62	18.50	24.40	7.70	33.60
Turbidity	39.0	71.4	26.2	43.8	149.4	34.3	117.3
pH	7.08	7.04	7.03	7.02	7.02	7.01	6.99
Dissolved O_2 (mg/l)	4.3	7.5	7.9	7.0	0.9	7.8	0.3
BOD (mg/l)	4.0	2.0	2.0	3.0	1.0	2.0	1.0
COD(Kr) (mg/l)	16.0	13.0	8.0	15.0	45.0	17.0	62.0
T-N(mg/l)	1.23	1.31	1.09	1.51	2.09	0.78	2.87
NH_4^+ -N (mg/l)	0.77	0.30	0.32	0.68	0.65	0.27	1.24
NO_3^- -N(mg/l)	0.16	0.48	0.26	0.32	0.18	0.17	0.33
NO_2^- -N(mg/l)	0.05	0.02	0.00	0.00	0.00	0.00	0.00
T-P(mg/l)	0.10	0.14	0.10	0.17	0.15	0.18	0.17
PO_4^{3-} -P(mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SS (mg/l)	15	44	14	29	113	39	83
Particle size distribution(% 400-38micron)	98.5	68.5	100	2.1	37.2	75.5	88.4
V-SS (mg/l)	2.0	3.0	2.0	3.0	21.0	8.0	32.0
Phenol (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arsenic (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cadmium (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyanide (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr6+ (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Copper (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hg (mg/l)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ni2+ (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lead (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zinc (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron(mg/l)	1.68	1.56	1.57	3.46	11.3	2.88	18.3
Manganese(mg/l)	0.00	0.00	0.09	0.08	0.19	0.00	0.28
Organo-chlorine Pesticide (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Organo-phosphorus Pesticide (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Organo-carbonate Pesticide (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total Cloakroom (MAN)	70	11×10^3	11×10^3	$>24\times10^6$	23×10^2	11×10^3	15×10^2
Facial Cloakroom (MAN)	70	11×10^3	11×10^3	93×10^5	4×10^2	11×10^3	9×10^2

Table E.1.3 Results of Water Quality Observation at the Principal River Stations in Rainy Season 2/3

Sample No.	1	2	3	4	5	6	7
River Name	Hato Dam	Ubate River	Lenguazaque River	Ubate River	Suarez River	Chiquinquira River	Suarez River
Sampling Site	Outlet of Dam	Downstream of Ubate City	Verda Punta Gande	Colorado	Balsa Bridge	Upstream of Chiquinquira City	Before Tolon Gate
Remarks							
Code No.	QS-4	QR-1	QR-2	QR-3	QR-4	QR-5	QR-6
Sampling Date	1999/5/13	1999/5/12	1999/5/12	1999/5/13	1999/5/13	1999/5/13	1999/5/13
Sampling Time	15:00	17:42	15:51	14:04	9:42	8:49	8:30
Climate							
Discharge(m^3/s)	0.601	1.24	0.890	4.78	3.37	2.74	4.24
Water Level (m)	-	0.62	0.520	1.86	1.68	2.70	3.28
Water Depth (m)	0.22	0.75	0.25	1.90	3.34	1.03	2.50
WaterTemperature(°C)	13.7	16.6	16.3	15.5	19.3	16.6	14.0
Color	Light Yellow	Light Yellow	Light Beige	Beige	Light Brown	Dark Beige	Light Yellow
Odor	Sulfur	Soft Anaerobic	Mud	Odorless	Odorless	Odorless	Odorless
EC(mS/cm)	60	120	120	18	360	90	180
Turbidity	11	23	100	43	31	84	34
pH	7.02	6.87	6.85	6.99	6.86	6.85	6.86
Dissolved O_2 (mg/l)	7.7			5.6	4.3		
BOD (mg/l)	1.0	2.0	3.0	4.0	3.0	6.0	2.0
COD(Cr) (mg/l)	22.0	18.0	33.0	27.0	48.0	84.0	62.0
T-N(mg/l)	1.00	1.54	1.16	2.87	2.70	2.27	2.00
NH_4^+ -N (mg/l)	—	—	—	—	—	—	—
NO_3^- -N(mg/l)	—	—	—	—	—	—	—
NO_2^- -N(mg/l)	—	—	—	—	—	—	—
T-P(mg/l)	0.08	0.07	0.21	0.33	0.12	0.34	0.12
PO_4^{3-} -P(mg/l)	—	—	—	—	—	—	—
SS (mg/l)	9	36	83	46	25	197	26
Particle size distribution(% 400-38micron)	—	—	—	—	—	—	—
V-SS (mg/l)	4	7	10	7	12	39	3
Phenol (mg/l)	—	—	—	—	—	—	—
Arsenic (mg/l)	—	—	—	—	—	—	—
Cadmium (mg/l)	—	—	—	—	—	—	—
Cyanide (mg/l)	—	—	—	—	—	—	—
Cr6+ (mg/l)	—	—	—	—	—	—	—
Copper (mg/l)	—	—	—	—	—	—	—
Hg (mg/l)	—	—	—	—	—	—	—
Ni2+ (mg/l)	—	—	—	—	—	—	—
Lead (mg/l)	—	—	—	—	—	—	—
Zinc (mg/l)	—	—	—	—	—	—	—
Iron(mg/l)	—	—	—	—	—	—	—
Manganese(mg/l)	—	—	—	—	—	—	—
Organo-chlorine Pesticide (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Organo-phosphorus Pesticide (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Organo-carbonate Pesticide (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total Coliform (MPN)	—	—	—	—	—	—	—
Facal Coliform (MPN)	—	—	—	—	—	—	—

Table E.1.3 Results of Water Quality Observation at the Principal River Stations in Rainy Season 3/3

Sample No.	1	2	3	4	5	6	7
River Name	Hato Dam	Ubate River	Lenguazaque River	Ubate River	Suarez River	Chiquinquira River	Suarez River
Sampling Site	Outlet of Dam	Downstream of Ubate City	Verda Punta Gande	Colorado	Balsa Bridge	Upstream of Chiquinquira City	Before Tolon Gate
Remarks							
Code No.	QS-4	QR-1	QR-2	QR-3	QR-4	QR-5	QR-6
Sampling Date	1999/5/14	1999/5/14	1999/5/14	1999/5/14	1999/5/14	1999/5/14	1999/5/14
Sampling Time	18:45	17:20	17:45	16:10	11:20	10:30	8:35
Climate							
Discharge(m^3/s)	0.55	1.01	0.780	1.85		1.59	5.05
Water Level (m)	-	0.61	0.490	1.82	1.69	-	3.29
WaterTemperature(℃)	13.4	15.2	13.7	16.9	16.8	15.6	16.8
Color	Green Yellow	Grey	Dark Beige	Brown	Honey	Beige	Light Browm
Odor	Soft Sulfur	Soft Anaerobic	Odorless	Odorless	Fish	Odorless	Odorless
EC(mS/cm)	60	120	120	18	360	90	180
Turbidity	5.8	13	34	30	50	31	34
pH	7.02	6.87	6.85	6.99	6.86	6.85	6.86
Dissolved O_2 (mg/l)	-	-	-	-	-	-	-
BOD (mg/l)	—	—	—	—	—	—	—
COD(Cr) (mg/l)	15.0	11.0	22.0	26.0	74.0	8.0	31.0
T-N(mg/l)	—	—	—	—	—	—	—
NH_4^+ -N (mg/l)	—	—	—	—	—	—	—
NO_3^- -N(mg/l)	—	—	—	—	—	—	—
NO_2^- -N(mg/l)	—	—	—	—	—	—	—
T-P(mg/l)	0.06	0.05	0.20	0.40	0.07	0.09	0.08
PO_4^{3-} -P(mg/l)	—	—	—	—	—	—	—
SS (mg/l)	11	14	34	51	27	33	35
Particle size distributio	7	4	8	12	12	5	18
V-SS (mg/l)	—	—	—	—	—	—	—
Phenol (mg/l)	—	—	—	—	—	—	—
Arsenic (mg/l)	—	—	—	—	—	—	—
Cadmium (mg/l)	—	—	—	—	—	—	—
Cyanide (mg/l)	—	—	—	—	—	—	—
Cr6+ (mg/l)	—	—	—	—	—	—	—
Copper (mg/l)	—	—	—	—	—	—	—
Hg (mg/l)	—	—	—	—	—	—	—
Ni2+ (mg/l)	—	—	—	—	—	—	—
Lead (mg/l)	—	—	—	—	—	—	—
Zinc (mg/l)	—	—	—	—	—	—	—
Iron(mg/l)	—	—	—	—	—	—	—
Manganese(mg/l)	—	—	—	—	—	—	—
Organo-chlorine Pesticide (mg/l)	—	—	—	—	—	—	—
Organo-phosphorus Pesticide (mg/l)	—	—	—	—	—	—	—
Organo-carbonate Pesticide (mg/l)	—	—	—	—	—	—	—
Total Coliform (MPN)	—	—	—	—	—	—	—
Facal Coliform (MPN)	—	—	—	—	—	—	—

Table E 1.4 Results of Water Quality Observation at the Secondary River Stations in Rainy Season-1/2

Sample No.	1	2	3	4	5	6	7	8	9	10
River Name	Lenguazaque	Q. Obejeras	Q. Mojica	Suta	Q. La Playa	Fuquene	Q. Honda	Q. Mina	Ubate	Vallado Madre Norte
Sampling Site	Lowest	Lowest	Lowest	Lowest	La Malilla	Chinzaque	Fuquene	Tica.Muna	La.Baiero	Vereda Taquila
Remarks										
Code No.	AD-1	AD-2	AD-3	AD-4	AD-6	AD-8	AD-9	AD-10	AD-11	QS-3
Sampling Date	1999/5/5	1999/5/5	1999/5/5	1999/5/5	1999/5/6	1999/5/6	1999/5/5	1999/5/5	1999/5/6	1999/4/16
Sampling Time	17:18	17:00	16:25	15:57	11:26	9:45	14:46	15:01	10:51	10:18
Climate										
Discharge(m^3/s)	0.188	0.013	0.012	0.102	0.367	0.062	0.112	0.073	1.43	0.138
Water Level (m)										
Water Depth (m)	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial
WaterTemperature(℃)	14.7	14.4	14.4	14.8	14.2	14.3	14.5	14.6	14.3	16.0
Color	Beige	Light Gray	Light Beige	Light Yellow	Light Gray	Light Gray	Colorless	Colorless	Grayish Yellow	LightYellow
Odor	Odorless	Soft Anaerobic	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Light Fish
EC(mS/m)	7.37	16.70	1.66	23.50	7.37	4.63	6.98	41.9	4.63	11.99
Turbidity	70.0	150.0	15.0	1950.0	65.0	40.0	50.0	380.0	21.0	12.9
pH	6.40	6.80	6.30	6.20	7.20	6.70	6.60	7.40	7.30	7.02
BOD (mg/l)	1.0	3.0	2.0	3.0	2.0	1.0	2.0	5.0	3.0	1.0
COD(Cr) (mg/l)	11.0	18.0	19.0	75.0	18.0	11.0	18.0	27.0	21.0	15.0
T-N(mg/l)	0.15	0.71	0.28	1.00	0.78	0.38	0.40	1.21	1.54	1.23
T-P(mg/l)	0.09	0.06	0.03	0.09	0.11	0.04	0.06	0.29	0.12	0.34
SS (mg/l)	8	8	8	157	12	6	37	42	58	23
V-SS (mg/l)										

Table E 1.4 Results of Water Quality Observation at the Secondary River Stations in Rainy Season-2/2

Sample No.	1	2	3	4	5	6	7	8	9	10
River Name	Lenguazaque	Q. Obejeras	Q. Mojica	Suta	Q. La Playa	Fuquene	Q. Honda	Q. Mina	Ubate	Vallado Madre Norte
Sampling Site	Lowest	Lowest	Lowest	Lowest	La Malilla	Chinzaque	Fuquene	Tica.Muna	La.Baiero	Vereda Taquila
Remarks										
Code No.	AD-1	AD-2	AD-3	AD-4	AD-6	AD-8	AD-9	AD-10	AD-11	QS-3
Sampling Date	1999/5/12	1999/5/12	1999/5/12	1999/5/12	1999/5/13	1999/5/13	1999/5/13	1999/5/13	1999/5/13	1999/5/13
Sampling Time	17:06	16:50	16:27	15:30	15:25	9:40	13:40	13:23	14:53	11:26
Climate										
Discharge(m^3/s)	0.360	0.089	0.147	0.190	0.439	0.052	0.323	0.014	0.740	0.025
Water Level (m)						0.10				
Water Depth (m)	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial	Superficial
WaterTemperature(℃)	15.7	16.6	16.8	18.3	13.7	17.0	18.5	18.7	14.4	
Color	Light Yellow	Colorless	Light Brown	Honey	Light Gray	Light Yellow	Light Gray	Light Gray	Grayish Yellow	LightYellow
Odor	Odorless	Soft Anaerobic	Odorless	Iron odor	Odorless	Odorless	Odorless	Odorless	Odorless	Light Fish
EC(mS/m)	7.37	16.70	1.66	23.50	7.37	4.63	6.98	41.9	4.63	11.99
Turbidity	140.0	160.0	270.0	20.0	95.0	22.0	9.0	10.0	12.0	12.9
pH	6.80	6.70	6.60	7.00	7.40	7.10	6.70	7.70	7.50	7.02
BOD (mg/l)	3.0	2.0	2.0	2.0	2.0	1.0	1.0	2.0	3.0	1.0
COD(Cr) (mg/l)	26.0	41.0	34.0	21.0	9.0	10.0	34.0	15.0	10.0	15.0
T-N(mg/l)	0.90	1.03	1.79	0.60	0.68	0.65	0.13	1.84	1.64	1.23
T-P(mg/l)	0.18	0.35	0.33	0.07	0.09	0.07	0.03	0.25	0.05	0.34
SS (mg/l)	42	165	388	20	14	17	8	13	12	23
V-SS (mg/l)										

Table E.1.5 Results of Continuous Water Quality Observation in Ubate River -1/2

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sampling Site	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado	Colorado
Remarks															
Sampling Date	1999/5/12	1999/5/12	1999/5/12	1999/5/12	1999/5/12	1999/5/12	1999/5/13	1999/5/13	1999/5/13	1999/5/13	1999/5/13	1999/5/13	1999/5/13	1999/5/13	1999/7/6
Discharge(m^3/s)															
Sampling Time (:)	13:10	15:20	18:07	19:07	20:07	21:07	5:00	7:00	9:00	11:00	13:00	14:20	15:46	16:11	14:44
Water Level (m)															
Climate															
WaterTemperature(°C)															
COD(Cr) (mg/l)	15.0	16.0	16.0	16.0	14.0	21.0	20.0	28.0	22.0	42.0	27.0	18.0	23.0	10.0	25.0
T-N(mg/l)	1.00	0.83	1.13	1.89	0.60	0.96	1.26	2.65	3.40	2.90	1.54	2.12	2.22	1.94	4.00
T-P(mg/l)	0.26	0.25	0.23	0.11	0.18	0.14	0.14	0.36	0.34	0.26	0.16	0.30	0.13	0.30	0.60
SS (mg/l)	20	22	21	22	24	19	37	37	38	33	47	14	47	32	6
Particle size distribution(% 400-38micron)				100		100	15.1		26.3						
V-SS (mg/l)				5		4	7		13						5

Table E.1.5 Results of Continuous Water Quality Observation in Ubate River -2/2

Sample No.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Sampling Site	Colorado	Colorado	Colorado	Colorado											
Remarks															
Sampling Date	1999/7/7	1999/7/7	1999/7/7	1999/7/6											
Discharge(m^3/s)	13:18	15:14	15:48												
Sampling Time (:)															
Water Level (m)															
Climate															
WaterTemperature(°C)															
COD(Cr) (mg/l)	25.0	28.0	16.0	14.0											
T-N(mg/l)	3.50	1.90	2.00	2.20											
T-P(mg/l)	0.57	0.48	0.35	0.42											
SS (mg/l)	19	51	48	20											
Particle size distribution(% 400-38micron)															
V-SS (mg/l)	14	19	24	10											

Table E.1.6 Results of River/Lake Deposit Quality Observation

Sample No.	1	2	3	4	5	6	7	8	9	10
Lake or River Name	Fuquene Lake	Fuquene Lake	Fuquene Lake	Fuquene Lake	Ubate River	Lenguazaque River	Ubate River	Suarez River	Chiquinquira River	Suarez River
Sampling Site	Near Ubate Mouth	Near Port	Center	Near Suarez Outlet	Downstream of Ubate City	Verda Punta Gande	Colorado	Balsa Bridge	Upstream of Chiquinquira City	Before Tolon Gate
Remarks										
Code No.	QL-1	QL-2	QL-3	QL-4	QR-1	QR-2	QR-3	QR-4	QR-5	QR-6
Sampling Date	1999/4/21	1999/4/21	1999/4/21	1999/4/21	1999/4/22	1999/4/22	1999/4/22	1999/4/22	1999/4/22	1999/4/22
Point Depth (m)	2.20	4.00	5.30	2.20	1.20	0.75	3.35	3.45	0.90	1.60
Color	Black	Dark Gray	Dark Gray	Black	Dark Gray	Beige	Dark Brown	Dark Gray	Dark Brown	Dark Gray
Odor	Anaerobic	Anaerobic	Anaerobic	Anaerobic	Anaerobic	Fish	Anaerobic	Soft Anaerobic	Fish	Anaerobic
pH	6.30	6.30	6.50	6.10	6.20	5.70	6.20	6.20	6.70	6.70
COD(Cr) (mg/dry)	98.6	59.8	97.5	92.6	32.3	4.8	208.2	139.3	99.4	103.0
T-N(mg/dryg)	4.30	3.60	5.30	5.20	1.30	0.50	1.01	6.80	3.80	5.20
T-P(mg/dryg)	0.196	0.094	0.019	0.282	0.045	0.019	0.454	0.408	0.037	0.010
Particle size distribution (% 40micron)	88.4	90.8	82.8	74.6	68.2	93.0	61.0	74.6	78.9	90.6
Ignition Loss (%)	16.2	13.5	15.8	20.1	8.2	4.7	45.2	25.4	15.7	17.8
Phenol (mgdrykgl)	1.28	0.65	0.63	1.43	0.11	0.03	0.15	0.67	0.25	0.48
Arsenic (mg/drykg)	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2
Cadmium (mg/drykg)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyanide (mg/drykg)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr^{6+} (mg/drykg)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copper (mg/drykgl)	84.3	76.0	78.3	72.7	63.4	67.9	70.0	66.9	64.2	59.9
Hg (mg/drykg)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ni^{2+} (mg/drykg)	37,7	28.2	32.6	33.2	27.5	17.2	24.1	15.1	32.1	18.6
Lead (mg/drykgl)	59.9	67.3	54.4	68.5	52.8	20.5	30.6	45.3	53.5	41.3
Zinc (mg/drykg)	90.9	68.9	138.9	566.7	287.7	159.9	112	121.2	275.9	195.0
Iron(mg/dryg)	34.5	43.8	61.3	49.0	37.5	20.1	27.3	46.7	37.7	48.7
Manganese (mg/dryg)	0.212	0.667	0.750	0.667	0.,294	0.192	0.143	0.500	0.299	0.101
Organo-chlorine Pesticide (mg/drykg)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Organo-phosphorus Pesticide (mg/dryk)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Organo-carbonate Pesticide (mg/drykg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moisture Content (%)	74.6	75.8	85.4	83.7	34.5	23.7	78.5	75.8	68.4	72.0
Sulfide (mg/dryg)	1.21	0.65	0.63	1.43	0.10	0.03	0.84	0.36	0.61	1.24
Oxidation Reduction Potential (mV)	-123	-129	-154	-120	-114	328	-95	-134	-51	-142

Table E.1.7 Results of Biological Observation in the Lake in Rainy Season (Phytoplankton)-1/4

Sample No.	1	2	3	4	5	6	7	8
Lake Name	Fuquene Lake		Fuquene Lake		Fuquene Lake		Fuquene Lake	
Sampling Site	Near Ubate Mouth		Near Port		Center		Near Suarez Outlet	
Remarks								
Code No.	QL-1		QL-2		QL-3		QL-4	
Sampling Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer
Sampling Date	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15
Sampling Time	10:40	10:42	13:15	13:18	11:40	11:45	14:10	14:15
Chlorophill-a (mg/m^3)	0.39	0.23	0.11	0.03	0.49	0.11	1.2	3.4
Density (Cells/ml)	900	6050	500	3150	7800	14250	8700	10850
Taxonomy Description	*Microspora sp 1,*	*Nitzschia sp,*	*Nitzschia sp,*	*Navicula plantula,*	*Oscillatoria sp 1,*	*Peridinium sp,*	*Tabellaria fenestrata.,*	*Cymbella sp,*
(Genera,speces)	*Spyrogyra sp,*	*Tabelleria.*	*Navicula sp 1,*	*Closterium sp,*	*Anabaena sp,*	*Oscillatoria sp 1,*	*Cymbella sp,*	*Synedre ilne,*
	Trachetomona.	*fenestrata,Synedra,*	*Penium sp,*	*Peridium sp,*	*Trachetomona*	*Anabaena sp,*	*Gomphoriema*	*Gomphoriema*
	volvocina,	*ulna,Microspora sp1,*		*Spirulina sp,*	*volvocina,*		*acuminatum,*	*acuminatum,*
		Closterium acutum.					*Microspora sp 2,*	*Gomphoriema sp,*
							Cosmarium sp 1,	*Navicula plantula,*
							Cosmarium sp 2,	*Microspora sp 2,*
							Sccendesmus econis.,	*Sccendesmus econis.,*
							Ulothrix sp,	*Ulothrix sp,*
							Lingbya sp,	*Anabaena sp,*
							Oscillatoria sp 1,	*Phacus sp,*
							Oscillatoria sp 2,	

Table E.1.7 Results of Biological Observation in the Lake in Rainy Season (Zooplankton)-2/4

Sample No.	1	2	3	4	5	6	7	8
Lake Name	Fuquene Lake		Fuquene Lake		Fuquene Lake		Fuquene Lake	
Sampling Site	Near Ubate Mouth		Near Port		Center		Near Suarez Outlet	
Remarks								
Code No.	QL-1		QL-2		QL-3		QL-4	
Sampling Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer
Sampling Date	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15	1999/4/15
Sampling Time	10:40	10:42	13:15	13:18	11:40	11:45	14:10	14:15
Density (Cells/ml)	0.8	4.0	4.0	1.2	2.0	20.0	0.0	0.0
Texanomy Description (Genera,speces)	Lionotus	Lionotus, Euchlanis,	Moina, Rotaria,	Moina, Lionotus,	Moina, Lionotus,	Moina,	-	-

Table E.1.7 Results of Biological Observation in the Lake in Rainy Season (Macrobenthos) -3/4

Sample No.	1	2	3	4
Code No.	QL-1	QL-2	QL-3	QL-4
Sampling Date	1999/4/15	1999/4/15	1999/4/15	1999/4/15
Sampling Time	10:40	10:42	13:15	13:18
Specimen Numbers	0.0	0.0	0.0	0.0

Table E.1.7 Results of Biological Observation in the Lake in Rainy Season (Microbenthos) -4/4

Sample No.	1	2	3	4
Code No.	QL-1	QL-2	QL-3	QL-4
Sampling Date	1999/4/15	1999/4/15	1999/4/15	1999/4/15
Sampling Time	10:40	10:42	13:15	13:18
Specimen Numbers	0.0	0.0	0.0	0.0

Table E 1.8 Results of Releasing Test in the Lake (Point (Code No. : QL-2))

Sample No.	1	2	3	4	5	6	7
Day from Start	0	1	2	4	6	9	13
Sampling ate	1999/5/11	1999/5/12	1999/5/13	1999/5/15	1999/5/17	1999/5/20	1999/5/24
COD(Cr) (mg/l)	1.8	12.6	13.7	16.2	19.7	22.8	24.0
T-N(mg/l)	0.61	1.21	1.32	1.51	1.66	1.775	1.91
$NH4^{+}$ -N (mg/l)	0.14	0.52	0.60	0.82	1.00	1.06	1.18
NO^{3-} -N(mg/l)	0.07	0.08	0.10	0.11	0.05	0.08	0.07
NO^{2-} -N(mg/l)	0.05	0.05	0.04	0.03	0.04	0.04	0.04
T-P(mg/l)	0.009	0.010	0.012	0.015	0.014	0.018	0.021
PO_4^{3-} -P(mg/l)	0.002	0.005	0.009	0.010	0.009	0.011	0.012

Table E.1.9 Results of Production Test in Rainy Season-1/4 (Code No.:QL-1)

Sample No.	1	2	3	4	5	6	Remarks
Sampling Time	10:50		16:53		16:53		
Time from Start (hour)	0.00		6.05		6.05		
Dark or Light Bottle	Dark Bottle	Light Bottle	Dark Bottle-1	Dark Bottle-2	Light Bottle-1	Light Bottle-2	
Upper Layer DO(mg/l)	3.5	3.9	1.6	1.4	2.8	2.5	
Deep Layer DO(mg/l)	2.5	2.2	2.0	1.5	3.0	3.2	

Table E.1.9 Results of Production Test in Rainy Season -2/4 (Code No.:QL-2)

Sample No.	1	2	3	4	5	6	Remarks
Sampling Time	13:15		17:15		17:15		
Time from Start (hour)	0.00		4.00		4.00		
Dark or Light Bottle	Dark Bottle	Light Bottle	Dark Bottle-1	Dark Bottle-2	Light Bottle-1	Light Bottle-2	
Upper Layer DO(mg/l)	4.0	4.2	4.1	4.0	7.0	6.6	
Deep Layer DO(mg/l)	4.5	4.4	4.1	3.6	4.1	3.9	

Table E.1.9 Results of Production Test in Rainy Season-3/4 (Code No.:QL-3)

Sample No.	1	2	3	4	5	6	Remarks
Sampling Time	11:40		17:07		17:07		
Time from Start (hour)	0.00		5.78		5.78		
Dark or Light Bottle	Dark Bottle	Light Bottle	Dark Bottle-1	Dark Bottle-2	Light Bottle-1	Light Bottle-2	
Upper Layer DO(mg/l)	5.2	5.3	4.5	4.1	6.6	6.2	
Deep Layer DO(mg/l)	5.0	4.9	4.9	4.1	4.3	4.8	

Table E.1.9 Results of Production Test in Rainy Season-4/4 (Code No.:QL-4)

Sample No.	1	2	3	4	5	6	Remarks
Sampling Time	14:10		17:25		17:25		
Time from Start (hour)	0.00		3.25		3.25		
Dark or Light Bottle	Dark Bottle	Light Bottle	Dark Bottle-1	Dark Bottle-2	Light Bottle-1	Light Bottle-2	
Upper Layer DO(mg/l)	6.0	5.6	3.8	3.5	8.2	7.8	
Deep Layer DO(mg/l)	4.0	3.8	3.6	2.9	3.5	3.2	

Table E.1.10 Results of Settling Test in the Lake in Rainy Season

Sample No.	1		2		3		4	
Lake Name	Fuquene Lake		Fuquene Lake		Fuquene Lake		Fuquene Lake	
Sampling Site	Near Ubate Mouth		Near Port		Center		Near Suarez Outlet	
Remarks								
Code No.	QL-1		QL-2		QL-3		QL-4	
Setting Date	1999/4/15		1999/4/15		1999/4/15		1999/4/22	
Sampling Date	1999/5/14		1999/5/14		1999/5/14		1999/5/14	
Test Period (d)	29		29		29		22	
Point Depth (m)	2.10		4.20		5.10		2.20	
Setting Depth (m)	0.50	1.60	0.50	3.20	0.50	4.00	0.50	1.70
SS (mg/l)	Not Observed		1630		125		593	
Particle size distribution(% 400-38micron)	Not Observed		74.8		99.0		12.0	
V-SS (mg/l)	Not Observed		550		58		202	
SS (g/m^2.d)	Not Observed		4.48		0.34		2.15	
V-SS (g/m^2.d)	Not Observed		1.51		0.16		0.73	

Table E.1.11 Results of Wastewater Quality Observation of Sewerage and Factories in Rainy Season-1/2

Sample No.	1	2	3	4	5	6	7	8	9	10
Name of Factory or Sewerage	Lacteos San Andres	Lacteos Ubate		Ubate Slaughterhouse	Parmalat	Dona Leche	Ubate Sewerage System		Colfrance	
Sampling Site	Effluent Point	Affluent Point	Effluent Point	Outlet	Outlet	Outlet	Affluent Point	Effluent Point	Affluent Point	Effluent Point
Code No.	QW-1	QW-2	QW-2	QW-3	QW-4	QW-5	QW-6	QW-6	QW-7	QW-7
Sampling Date	1999/5/7	1999/5/7	1999/5/7	1999/5/6	1999/4/30	1999/4/30	1999/4/30	1999/4/30	1999/4/30	1999/4/30
Sampling Time	9:30	10:30	10:40	16:30	13:30	14:30	15:20	15:25	12:00	12:10
Climate										
Discharge(m3/s)	30*	160*		650*	500*	650*	0.047		100*	
WaterTemperature	17.1	23.1	18.8	19.7	18.2	18.8	17.5	18.5	23.2	17.8
Color	Milky Gray	Colorless	Gray	Greenish	White	white	Milky Gray	Black	white	white Graish
Odor	Anaerobic	Rancid	Anaerobic	Dung	Rancid milk	Milky	Waste	Strong Anaerobic	Rancid Milk	Anaerobic
EC(mS/m)	1500	800	125	1000.00	45.3	0.33	71.8	71.4	145.80	0.44
Turbidity (UNT)	120.0	15.0	5.0	120.0	320	25	28	25	350	510
pH	5.10	6.91	6.95	6.95	6.86	5.50	7.10	7.00	5.50	4.90
BOD (mg/l)	360	56.0	18.0	480.0	372	766	285	60.0	3420	399
COD(Cr) (mg/l)	1537	78.0	24.0	1195.0	862.0	1509	431	149	3890	5720
T-N(mg/l)	107.6	13.3	2.50	43.50	42.1	107.8	41.1	38.0	103	342
NH_4^+-N (mg/l)	11.6	5.77	0.69	5.95	9.88	5.60	28.9	30.90	33.7	321.1
NO^{3-}-N(mg/l)	2.0	0.71	0.13	0.00	0.40	0.35	0.38	0.32	0.26	3.01
NO^{2-}-N(mg/l)	0.0	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T-P(mg/l)	26.7	6.73	0.29	8.4	6.68	91.5	6.47	5.02	14.75	132.5
PO_4^{3-}-P(mg/l)	18.4	4.58	0.11	5.68	2.89	22.9	0.25	0.16	9.13	86.48
SS (mg/l)	3208	104.0	24	398	236	295	277	95	1087	1277
VSS (mg/l)	2784	68.0	16	375	236	293	211	70	983	1207
Total Coliform (MPN)								93×10[illegible]		
Facal Coliform (MPN)								93×10[illegible]		

Table E.1.11 Results of Wastewater Quality Observation of Sewerage and Factories in Rainy Season -2/2

Sample No.	11	12	13	14	15	16	17	18	19	
Name of Factory or Sewerage	Alpina	Delay	Simijaca Slaughterhouse		Cucunuba Sewerage System		Saboya Sewerage System		Ubate Sewerage System	
Sampling Site	Outlet	Outlet	Affluent Point	Effluent Point	Affluent Point	Effluent Point	Affluent Point	Effluent Point	Effluent Point	
Code No.	QW-8	QW-9	QW-10	QW-10	QW-11	QW-11	QW-12	QW-12	QW-13	
Sampling Date	1999/4/30	1999/4/30	1999/4/30	1999/4/30	1999/4/30	1999/4/30	1999/4/30	1999/4/30	1999/4/30	
Sampling Time	10:40	11:40	10:05	10:10	16:40	17:00	8:30	8:40	15:05	
Climate										
Discharge(m3/s)	936*	750*	180*		0.035		0.001		0.033	
WaterTemperature	18.6	22.1	16.5	17.4	17.5	18.3	15.4	15.8	17.5	
Color	White	Colorless	Red	Dark red	Milky Gray	Black	Light Gray	Light Green	Milky Gray	
Odor	Rancid Milk	Odorless	Blood	Fetid	Waste	Anaerobic	Waste	Odorless	Strong Waste	
EC(mS/m)	0.28	45.3	25.70	123.3	59.20	57.2	48.3	14.6	71.5	
Turbidity (UNT)	120	130	46	45	75	18	45	22	25	
pH	11.9	7.60	6.50	6.90	6.80	7.00	6.60	6.30	6.80	
BOD (mg/l)	288	84.0	645	690.0	258	93.0	136	12.0	240.0	
COD(Cr) (mg/l)	419	227	792	713	336	223	243	51	298	
T-N(mg/l)	39.0	13.4	107.8	143.7	30.8	30.8	43.1	8.20	35.90	
NH_4^+-N (mg/l)	37.98	12.55	77.0	28.4	23.2	21.2	35.1	2.45	5.65	
NO^{3-}-N(mg/l)	1.95	0.27	1.12	2.78	0.65	0.33	0.48	0.32	0.35	
NO^{2-}-N(mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	
T-P(mg/l)	5.85	16.2	6.44	9.78	3.96	4.04	5.34	0.47	8.74	
PO_4^{3-}-P(mg/l)	2.18	9.06	0.03	5.50	0.42	0.13	0.96	0.00	3.66	
SS (mg/l)	238	159	277	376	75	123	384	61	173	
Total Coliform (MPN)						15×10^6		43		
Facal Coliform (MPN)						75×10[illegible]		43		

* :m^3/month

Table E.1.12 Results of Water Quality Observation in the Lake in Dry Season

Sample No.	1	2	3	4	5	6	7	8
Lake Name	Fuquene Lake		Fuquene Lake		Fuquene Lake		Fuquene Lake	
Sampling Site	Near Ubate Mouth		Near Port		Center		Near Suarez Outlet	
Remarks								
Code No.	QL-1		QL-2		QL-3		QL-4	
Sampling Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer	Upper Layer	Deep Layer
Sampling Date	1999/8/26	1999/8/26	1999/8/26	1999/8/26	1999/8/26	1999/8/26	1999/8/26	1999/8/26
Sampling Time	13:30	13:35	14:05	14:10	15:05	15:10	16:40	16:45
Climate	Clear		Clear		Clear		Clear	
Point Depth (m)	1.90		2.00		4.30		1.80	
Clearance (m)	0.96		1.10		1.81		0.33	
Sampling Depth (m)	0.50	1.60	0.50	1.50	0.50	4.00	0.50	1.70
WaterTemperature(℃)	17.4	17.4	17.2	17.2	17.2	17.0	18.5	15.6
Color	Light Yellow	Light Yellow	Light Yellow	Light Yellow	Light Yellow	Light Yellow	Colorless	Colorless
Odor	Odorless	Odorless	Sulfur	Sulfur	Odorless	Odorless	Odorless	Odorless
EC(mS/cm)	120.0	120.0	120.0	130.0	110.0	110.0	140.0	140.0
Turbidity	4.5	7.8	2.0	4.7	2.2	3.0	6.0	6.5
pH	6.60	6.70	6.80	6.60	6.90	7.00	6.70	6.60
Dissolved O_2 (mg/l)	6.0	5.7	5.8	4.0	6.2	6.5	1.9	0.0
COD(Cr) (mg/l)	24.0	25.0	28.0	31.0	27.0	25.0	28.0	40.0
COD(Mn) (mg/l)	10.3	10.7	10.7	12.5	9.5	10.9	12.3	13.3
TOC (mg/l)	9.3	3.0	4.2	10.3	1.8	15.3	3.1	3.1
Humic acid (mg/l)	5.9	1.7	1.6	4.6	1.6	3.6	5.3	7.6
T-N(mg/l)	1.40	1.31	1.38	2.17	1.38	1.70	1.12	1.96
NH_4^+ -N (mg/l)	0.73	0.73	0.79	0.85	0.76	0.82	0.79	0.82
NO_3^- -N(mg/l)	0.30	0.45	0.53	0.69	0.61	0.77	0.30	0.69
NO_2^- -N(mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T-P(mg/l)	0.02	0.03	0.02	0.16	0.00	0.00	0.04	0.07
PO_4^{3-} -P(mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SS (mg/l)	6	9	4	15	2	4	13	44
Particle size distribution(% 400-38micron)	100	100	100	100	100	100	100	100
V-SS (mg/l)	4	4	2	9	1	3	7	27
Phenol (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arsenic (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cadmium (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyanide (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr6+ (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Copper (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hg (mg/l)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ni2+ (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lead (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zinc (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron(mg/l)	1.51	3.23	0.74	2.54	0.23	0.21	2.70	2.61
Manganese(mg/l)	0.03	0.12	0.05	0.17	0.00	0.00	0.08	0.12
Organo-chlorine Pesticide (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Organo-phosphorus Pesticide (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Organo-carbonate Pesticide (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total Coliform (MPN)	230	-	<2	-	230	-	430	-
Facal Coliform (MPN)	230	-	<2	-	40	-	90	-