APPENDIX F

WASTEWATER TREATMENT

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CHAPTER I EXISTING WASTEWATER TREATMENT SYSTEM

1.1 Sewerage Treatment

1.1.1 Existing Facilities

At present, five (5) municipalities have the sewerage treatment plant. The outlines of each treatment plant are as follows:

Municipality	Treatment Process	Completion Year	Cost ($\times 10^3$ Col$)	
			Construction	Annual Maintenance
Ubate	Reactor of Anaerobic Piston	1995	419,000	90,636
Cucunuba	Stabilization Pond	1992	10,000	-
Lenguazaque	Activated Sludge	1998	280,000	17,964
San Miguel de Sema	Stabilization Pond	1995	29,000	4,200
Saboya	Stabilization Pond	1992	81,000	3,300

The area and size of main facilities are as follows:

Municipality	Area	Facilities	Size
Ubate	1.76ha	Reactor	L13.8m×W20m×D2.8m×2
		Sedimentation	L13.8m×W8m×D2.4m×2
		Total	L28.6m×W31m×D3.3m
Cucunuba	0.19ha	Facultative Pond	L28.3m×W19.1m×D2.5m
			L15.1m×W14.9m×D2.0m
			L40.7m×W21.9m×D2.0m
Lenguazaque	0.89ha	Aeration Tank	L9.2m×W5m×D3.6m + L5m×W3.7m×D3.6m
		Sedimentation Tank	L3.6m×W1.4m×D3.6m+ L3.6m×W1.7m×D3.6m
		Total	L11.0m×W9.9m×D4.0m
San Miguel de Sema	3.84ha	Facultative Pond	L51.6m×W16.6m×D1.4m
Saboya	2.00ha	Facultative Pond	L84m×W36.5m×D2.0m
			L79m×W43m×D2.0m

1.1.2 Effluent Quality

The average effluent quality of Ubate, San Miguel de Sema and Saboya in 1999 is shown below. The analysis was conducted by CAR. The detailed ones are shown in from Table F.1.1 to Table T.1.4. The data of effluent quality data in Cucunuba and Lenguazaque were not obtained.

Parameter	Unit	Ubate	San Miguel de Sema	Saboya
pH	-	7.1	7.0	8.8
BOD	mg/l	132.8	73.9	24.9
COD	mg/l	410.5	319.2	103.4
SS	mg/l	88.7	115.8	46.2
DO	mg/l	0.0	4.4	5.7
Total Coliforms	MPN/100ml	33×10^{6}	46×10^{6}	30×10^{4}
Fecal Coliforms	MPN/100ml	19×10^{6}	32×10^{5}	32×10^{3}

1.2 Slaughterhouse

1.2.1 The Characteristics of Wastewater

The characteristics of wastewater in slaughterhouse are as follows:

(1) The fluctuation of quantity and quality are very large, depending on the slaughtering process. The major pollutant is blood.

(2) The wastewater includes a lot of organic matter of protein, blood, grease, which are easily decomposed and the cause of bad smell. It requires quick treatment. The concentration of fibber and suspended solid from undigested matter in the stomach, are also high.

(3) The blood and other internal organs should be collected for any other use like feed or fertilizer and not discharged into wastewater as much as possible.

The average effluent quality in the eight (8) municipalities near Bogotá by CAR and Ubate and Simijaca by JICA Study Team are shown below.

Parameter	Unit	8 Municipalities*	Ubate	Simiaca
pH	-	7.4	7.0	7.9
BOD	mg/l	2,755.4	270	357
COD	mg/l	4,667.4	672	408
SS	mg/l	661.0	247	26

Note´* Chocontá, El Colegio, Cachipay, Agua de Dios, Sesquilé, Suesca, Gacancipá, Tocancipá

1.2.2 Treatment Process

Every municipality has the pre-treatment plant in varying degree as mentioned in Appendix E. 2.1.2. The pre-treatment in most municipalities consists of blood well, grease trap, screen and septic tank. The anaerobic tank is installed after sedimentation in Ubate. On the other hand, only blood well and screen are installed in Fuquene and Caldas. The quality of wastewater depends on the daily cleaning and desluding of each tank.

1.3 Industrial Wastewater

1.3.1 Location and Size

Milk cooling/processing factories are distributed mainly in municipalities of Ubate, Chiquinquira and Simijaca. The number of milk factories of each size and those which has the pre-treatment plant are as follows, according to the questionnaire and observation conducted by the Study Team. The installation rate is very low, especially in small size factory.

1.3.2 The Characteristics of Wastewater

The wastewater quality depends on the operation of equipments for processing, lost quantity of milk and by-products from cheese/yogurt. It is necessary to collect them as much as possible because these products will be utilized as feeder etc.,.

The characteristics of wastewater from milk factory are as follows:

(1) The fluctuation of quality and quantity is large due to the milk collection schedules.

(2) The color of wastewater in cooling factory are usually white and turbid, caused by loss of milk.

(3) The solvent including NaOH or other alkalis, which are periodically used for cleaning container and manufacturing equipment, cause the high pH. On the other hand, long detention time or poor maintenance rots the solids in the tank, resulting in low pH by acid-forming bacteria under the anaerobic condition.

The data of supplementary observation by JICA Study Team in 30th April and 30th September are shown below. The fluctuation is very large, especially in milk processing. pH is slightly low, resulting from anaerobic condition.

(1) Milk Processing

(Unit: mgl/)

Parameter	Influent			Effluent		
	Minimum	Average	Maximum	Minimum	Average	Maximum
PH	4	5.3	6.9	4.5	5.5	7.0
BOD	560	5,495	15,000	18	854	2,520
COD	780	14,096	34,600	24	2,026	5,720
SS	850	1,652	3,440	24	600	2,100

Note: Sampling number of influent and effluent is 8 and 4, respectively.

(2) Milk Cooling

(Unit: mgl/)

Parameter	Influent			Effluent		
	Minimum	Average	Maximum	Minimum	Average	Maximum
PH	5.5	6.6	7.6	5.3	9.2	12.6
BOD	84	492	900	5	343	710
COD	227	867	1,507	319	606	862
SS	477	499	520	236	267	325

Note: Sampling number of influent and effluent is 4 and 2, respectively.

1.3.3 Treatment Process

The treatment process except Incolacteos is only composed of grit chamber, screen, grease trap and sedimentation. Incolateos in Simijaca has the oxidation ditch and treated effluent is used for irrigation. Out of 50 factories, five (5) factories including Incolateos use the effluent for irrigation.

1.4 Solid Waste

1.4.1 Inventory

Most municipalities except San Miguel de Sema and Guacheta provide the collection service. The inventory is summarized in Table F.1.5. In Guacheta, the disposal site was operated until 1996, but currently the solid is burned in different private farming place.

1.4.2 Dumping and Leachate Treatment

The collected solid waste is dumped in the disposal site. The way of dumping is usually open dumping. In some municipalities such as Simijaca, Saboya, there is an idea to execute a regional plan for the solid waste management.

Some respondents are anxious of a possibility of contaminating watercourses by leachate. Lechate from solid waste are not treated except Chiquinquira. The treatment process in Chiquinquira is composed of outer channel, treatment plant and devolution of leachate to the landfill site. However, the plant doesn’t work due to the damage of pump at present.

Cucunumba recently constructed a landfill site, applying membrane to avoid infiltration. Its span life will be 25 years. This project is co-financed by Cundinamarca Prefecture and the Municipality. Sutatausa also has the projection of covering with synthetic membrane of low permeability. San Miguel de Sema wants to implement the sanitary landfill in the near future. In Fuquene, recycling of bottles, carbons, plastics is performed and sold to buyers in Bogota.

CHAPTER II WASTEWATER TREATMENT SYSTEM DEVELOPMENT

2.1 Regulation of Effluent

Regulation of effluent into water body and/or sewerage was stipulated by CAR in 1987 (Acuerdo No.58 de 1987). Any discharge into sewerage or water body must comply with, at least, this regulation. The characteristics of this regulation are that the removal rate in load is stipulated instead of concentration with regard to BOD, SS, and Oil.

On the other hand, CAR is able to extend or make more restrictive regulation, according to the characteristics and quality objectives of the receiving body, sewerage system and the drainage. Furthermore, when the users, even complying with the dumping regulation, produce concentrations on the receiving body, CAR is able to require more restrictive values on the drainage for the user or assigned uses to the resource.

At the same time, the municipalities or public enterprises can, under CAR authorization, include new substances of sanitary interest and materials subject to special control for the purposes of sewerage net protection.

The regulation of major parameter of sewerage effluent is shown below. Table F.2.1 shows the regulation in detail.

Parameter		Water Body		Sewerage System	
		Current User	New User	Current User	New User
pH		5.0-9.0	5.0-9.0	5.0-9.0	5.0-9.0
Temperature		≦40℃	≦40℃	≦40℃	≦40℃
Floating Material		Absent	Absent	-	-
Fats and Oils		Removal≧80%	Removal≧80%	-	-
Acid, Base (explosive or flamma-ble substances)		-	-	Absent	Absent
Settling Solids		-	-	≦10	≦10
Hexane Subtracted Substances		-	-	≦100	≦100
Suspended Solid	Domestic	Removal≧50%	Removal≧80%	Removal≧50%	Removal≧80%
	Industrial (>500mg/l)			Removal≧50%	Removal≧80%
BOD(>500mg/l)	Domestic	Removal≧30%	Removal≧80%	Removal≧30%	Removal ≧80%
	Industrial	Removal≧20%	Removal≧80%	Removal≧20%	Removal≧80%

2.2 Sewerage Treatment Development

2.2.1 Objectives

Sewerage is the wastewater of a community. This is mainly composed of human wastes (faces and urine) and sullage resulting from personal washing, laundry, food preparations and the cleaning of kitchen utensils. Sometimes wastewater from small factory and other facilities are discharged together. The discharge of raw wastewater yields massive pollution and oxygen depletion in the river. The sewerage system is installed in order to reduce the organic load and control the pollution in the watercourses.

2.2.2 Required Quality of Effluent

It is clear that effluent quality of the sewerage treatment plant has to meet the quality mentioned above. In addition, the river water where the effluent is discharged does not exceed the water criteria. The quality of each river is classified into A, B, C and D. The classification of each river is already shown in Fig.E.1.6.

The effluent of the municipality of Ubate and Chiquinquira, which are the major pollutant in the Study Area, is discharged into the Ubate River and Suarez River. The water criteria of BOD in each river are 5 mg/l and 10 mg/l, respectively. The required quality effluent has to be decided based on the quality in Ubate River because the water criteria in Ubate River is more critical than that in Suarez River. The river water quality after receiving the effluent from sewerage plant is calculated by averaging both quantity and quality of the river and effluent.

After the confluence of Ubate and Suta River, the low flow rate is about 0.60 m^3/sec, on the other hand, BOD concentration before receiving effluent is nearly 2 mg/l. The result of the calculation shows that river water quality will meet the water criteria if the effluent is less than 30 mg/l. The same calculation at the point of Colorado, where low flow rate is about 1.14 m^3/sec, shows the allowable quality is 50 mg/l.

It is proposed that the effluent quality from the sewerage treatment plant be required to be less than 40 mg/l based on the average of both calculation results.

2.2.3 Proposed Treatment Process

(1) Treatment Evaluation

Various treatment processes were developed to reduce the suspended load, the oxygen demand of the discharged wastewater and pathogenic microorganisms.

For evaluating the alternatives, it is necessary to take the consideration into the following aspects.

(a) Technical Aspect

- ✓ To clear the target of effluent level and make effluent not hazardous
- ✓ To be able to cope with fluctuation of both influent quantity and quality
- ✓ Easy operation and maintenance
- ✓ Easy disposal of generated sludge

(b) Economical Aspect

- ✓ To secure the necessary space
- ✓ Low construction cost
- ✓ Low operation and maintenance cost

(c) Hygienic Aspect

- ✓ Easy and effective removal of pathogenic microorganism

(2) Alternative Treatment Process

A lot of kind of treatment and its variation were developed until now. The characteristics, advantage and disadvantage of five (5) treatment processes, namely, stabilization pond (SP), aerated lagoon (AL), Piston Flow Anaerobic Reactor (RAP), oxidation ditch (OD) and activated sludge (AS) are dealt with in this section. As mentioned above, five (5) municipalities already adopted ST, RAP and AS.

(a) Stabilization Pond (SP)

Stabilization pond consists of large and shallow basins enclosed by earthen embankments in which raw sewage is treated by entirely natural processes involving both algae and bacteria. The anaerobic ponds, the facultative ponds and the maturation ponds are allocated individually or combined. Sludge treatment facilities are not needed.

The advantage of this process is as follows:

(i) BOD and pathogens can be removed from sewage at least capital and operating cost. The removal of pathogens is considerably greater than that of other sewage treatment plant.

(ii) Maintenance can be carried out by unskilled labor under minimal supervision. The main tasks are to cut grass of embankments regularly and to ensure the absence of floating solids, dead spots, emergent vegetation on the sides of the pond to prevent the nuisance of mosquito and other insects.

(iii) Sludge handling is minimal

Other process requires regular sludge removal, resulting in a demand for large area of drying beds or sophisticated and expensive sludge disposal facilities for dewatering, digesting and incineration. On the other hand, anaerobic ponds will only require desludging every 2 or 3 years, and facultative and maturation pond are generally capable of functioning satisfactorily for over 20 years before sludge buildup reaches a level that necessitates its removal.

(iv) They are able to withdraw both organic and hydraulic shock loads well.

(v) They can easily be designed so that the degree of treatment is readily altered.

The major disadvantage of this process is as follows:

(i) It requires much larger space than other treatment processes.

The reason why the extremely long retention time and large facilities are required is that natural wave and photosynthesis of algae supply oxygen in reactor tanks.

(ii) Final effluent may also contain highly suspended solids resulting from algae growth. This process sometimes requires the sedimentation facilities like maturation pond prior to discharge.

(iii) Odor nuisance and the risks of insect breeding are the probable problem, which will occur due to poor maintenance. It is preferable to install the plant apart from a dwelling house, especially in case of anaerobic pond.

(b) Aerated Lagoon (AL)

Aerated lagoons are activated sludge units operated without sludge return. Historically, they were developed from stabilization ponds in temperate climates where mechanical aeration was used to supplement the algae oxygen supply in winter. This process is now usually designed as mixed non-return activated sludge units.

Oxygen is usually supplied by means of surface aerator or diffused air units for bio-oxygen. The turbulence created by the aeration devices with sufficient power is used to mix the lagoon contents, to maintain them in suspension and to keep a dissolved oxygen level at 1-2 mg/l at all times of the year. This process is adequate and efficient in case where load increases, space is strictly limited and a high quality of effluent is required. Since oxygen supply in reactor tank is done by compulsive oxidation, retention time is shorter than that of stabilization pond. Sludge treatment facilities is not necessary.

The advantages of this process are as follows:

(i) System is not sensitive to shock load.

(ii) Construction cost is relatively low compared to conventional activated sludge process.

(iii) The operation is easy.

(iv) This process is applicable to increase capacity of sewerage treatment plant originally constructed as the stabilization pond, where facultative ponds become overloaded they could, with careful design, be converted into aerated lagoons by the installation of mechanical aerators.

(c) Piston Flow Anaerobic Reactor (RAP)

The anaerobic treatment including piston flow anaerobic reactor is to degrade organic matter by the coordinated action of microorganisms in the absence of oxygen. Gas is obtained as a by-product, usually called bio-gas composed of methane and carbon dioxide. Traditionally, the anaerobic process has been considered to be cheap but low efficient. Piston flow anaerobic reactor is modified to contact the water surface with the atmosphere directly so that the low concentration of methane in it causes an important gradient inside the wastewater, saturated with gas and the air. This allows a physical evacuation of part of methane from the wastewater and also helps the methanogenesis thermodynamically.

The advantage of this process is as follows:

(i) It produces less sludge for final disposition.

(ii) It requires fewer nutrients.

(iii) Operation cost is cheap because it requires no oxygen and less quantities of sludge process.

(iv) It takes high hydraulic and organic load.

(v) Byproduct production (methane) is potentially useful.

The disadvantage of this process is as follows:

(i) Its operation is difficult due to the instability and starting process is lazy and sensible.

(ii) The settlement and thickening is difficult because the sludge is methane-genetic.

(iii) Since it is less efficient, it often requires anaerobic process such as oxidation ditch or facultative pond as after-treatment process.

(iv) It has the possibility of generating more undesirable odor.

(d) Oxidation Ditch (OD)

This is a special adaptation of the activated sludge process. It consists of a ring-or oval-shaped channel and is equipped with mechanical aeration devices. Screened wastewater enters the ditch, is aerated, and circulates at about 0.3 m/s. The sewage in the ditch circulates together with activated sludge and contained organic substance is absorbed and assimilated by activated sludge.

While primary sedimentation tank is not necessary, secondary sedimentation tanks are used for most applications. Sludge treatment facilities are also needed. Oxidation ditch is adopted in many municipalities because of its high efficiency and compact area. Sludge handling is not so complicated.

The advantages in comparison with activated sludge process are as follows:

(i) It is flexible to the fluctuation of influent quantity and quality by its long retention time in reactor tank.

(ii) It requires less mechanical equipment.

(iii) It requires less demand for skilled operators due to simple operation.

(iv) The construction cost is cheaper.

(v) It produces much less sludge resulting from normally stabilization or a high degree of mineralization in the ditch itself.

One disadvantage is that this process requires more land than activated sludge process.

(e) Activated Sludge (AS)

This process is composed of two stages. The first stage comprises physical settling of solids in the first sedimentation tank. The second stage is normally a biological process. Settled wastewater and recycled activated sludge enter the head of the aeration tank and are mixed with diffuser-air or mechanical aeration. The supernatant is discharged after separation in the secondary sedimentation tank.

Retention time in a reactor is the shortest (about six (6) hours) and load is highest. Thus, primary sedimentation tank is needed to cope with the fluctuation in sewage quantity and quality to equalize/mitigate the load. Sludge from the primary and secondary treatment stage is normally stabilized in separate anaerobic digester and requires either dewatering machine or drying bed.

Activated sludge process is not available except large city and tourist resorts where land acquisition cost is extremely high.

The advantages of this process are as follows:

(i) It requires low land space.

(ii) The scale is considerably economical, therefore suitable for large sewage flows.

(iii) The removal efficiency of BOD_5 is the highest.

The disadvantages are as follows:

(i) The treatment process is mechanical rather than labor intensive, requires high foreign cost, high energy consumption because this process relies heavily on electrical machinery such as pumps, sludge scrapers, blower, etc.,

(ii) These facilities require considerable skill in installation, operation and maintenance. This skill, particularly, in maintenance, is not readily available.

(iii) The biological process is sensitive to toxic substances in the wastewater and to shock load.

(f) The characteristics of each treatment process

The table below shows the some of advantages and disadvantages of the most widely used sewage treatment processes.

Items		SP	AL	RAP	OD	AS
BOD Removal		B	B	C	A	A
SS Removal		C*	B	C	A	A
Cost	Construction	A	B	B	B	C
	Maintenance	A	B	B	C	C
Design for Construction		A	B	B	B	C
Energy Demand		A	B	A	C	C
Sludge Removal		A	A	B	B	C
Required Area		C	B	A	A	A

Note: A: Good, B: Fair, C: Poor, *: due to algae

(3) Comparison of Each Process

In order to make a comparison between each process except RAP and activated sludge, construction cost, operation and maintenance cost and required area are estimated under the same design condition.

The reason why RAP is excluded is as follows:

(a) This system usually requires aerobic post-treatment process such as oxidation ditch or facultative pond.

(b) The analysis data in Ubate shows that the removal rate is inferior to the other treatment process.

On the other hand, activated sludge process is also excluded because it is usually adopted in the high population area, it require high energy consumption and considerable skill in installation, operation and maintenance as mentioned above.

The design conditions are as follows:

(a) The influent quantity is 1,000 m^3/day; BOD in influent and effluent is 250 mg/l and 40 mg/l, respectively.

(b) With regard to stabilization pond, two type, namely, the combination of anaerobic and facultative pond and facultative pond individually are adopted because anaerobic pond is very effective in saving retention time and pond area. Maturation pond is not considered because its main function is to destruct pathogens, to produce an effluent with a BOD less than 25 mg/l and to reduce highly suspended solids resulting from algae growth.

(c) The pump for lifting influent is installed in every case.

(d) The candidate site is nearly flat, the permeability is medium. Unit real estate purchase cost is supposed to be approximately 2,500 Col$/$m^2$, which is the average price of pastureland in the 14 municipalities.

(e) Unit cost in September 1999 is adopted.

(f) Construction cost is only direct one, not including indirect cost like administration cost, incidental expense, profit, IVA, and intervention.

(g) Maintenance and operation cost is composed of electricity charge and personnel expense. 151 Col$/kwh is adopted as the electricity charge. Repair, supply of parts of machinery etc., is not included.

The comparison is summarized below:

Items		Stabilization Pond		Aerated Lagoon	Oxidation Ditch
		FA	AN+FA		
Required Area (m^2)		22,700	16,000	6,800	5,000
Construction Cost (M Col$)	Civil	167.7	191.4	122.2	123.6
	Machinery	15.3	15.3	189.4	343.9
	Sub-Total	183.0	206.6	311.5	467.5
Real Estate Purchase (M Col$)		56.7	39.9	16.9	12.5
Total Cost (M Col$)		239.6	246.5	328.4	480.0
Annual O & M Cost (M Col$)		14.4	14.4	44.2	57.9

Note: FA: Facultative Pond, AN: Anaerobic Pond,

(4) Conclusion and Recommendation

The table above shows that the most preferable treatment process is stabilization pond with facultative pond if sufficient land is available at reasonable cost and proximity for sewerage treatment plant. The second one is stabilization with combination of anaerobic and facultative pond because anaerobic pond sometimes causes the complaint of bad smell due to poor maintenance although it has the advantage of saving land area. Another process will be adopted in consideration of the restriction of area or existing facilities.

2.2.4 Sewerage Treatment Plant in Each Municipality

(1) Quantity and Quality of Influent

The quantity and quality of influent from major pollutant sources into the treatment plant is calculated based on Table E.2.13.

The quantity of groundwater is infiltrated into sewer pipe unavoidably. This volume depends on soil conditions, groundwater level, materials of sewer pipe, type of pipe joint, local construction skill and method. Treatment capacity must include some allowance for infiltration of groundwater.

While there is no quantitative data to draw a conclusion, it might not be unreasonable to assume an allowance of 0.1 l/ha/s, adopted in designing Ubate treatment plant.

The quantity and quality of each municipality is summarized below:

Name of Municipality		Served Area (ha)*	Quantity (m^3/day)	Quality of BOD	
				Load (kg/d)	Concentration(mg/l)
Carmen de Carupa		37	515	115.5	224
Ubate		158	6,212	1,995.7	321
Tausa		11	192	60.4	314
Sutatausa		12	234	73.8	316
Cucunuba		21	363	104.6	288
Lenguazaque		33	670	149.3	223
Guacheta		41	983	238.4	242
San Miguel de Sema		16	303	84.5	279
Fuquene	Fuquene	15	184	30.7	167
	Capellania	12	149	25.9	173
Susa		37	478	96.6	202
Simijaca		75	1,551	365.9	236
Caldas		10	141	31.1	220
Chiquinquira		391	12,298	2,777.9	226
Saboya		40	488	80.8	166

Note: * Informacion Catastral de 1998, Subdireccion de Catastro, Institute Geografico ‘Agustin Cozazzi’, Ministerio de Hacienda y Credito Publico

(2) The Candidate Site for Treatment Plant

The location and the area of candidate site for treatment plant are the most important factor in designing the treatment plant. Some municipalities have already required a site, other has no treatment plan or site area. The following table shows the situation of acquiring the site for the treatment plant. The average cost of pastureland in each municipality is also shown below.

Name of Municipality		Treatment Process	Plan	Site of Treatment Plant		Land Cost ($Col\$/m^2$)
				Area(m^2)	Price(M Col$)	
Carmen de Carupa		-	None	-	-	800
Ubate		RAP	-	17,600	Unknown	4,700
Tausa		-	Confirmed	-	-	1,600
Sutatausa		-	None	(12,000)	-	2,300
Cucunuba		SP	-	1,900	-	3,100
Lenguazaque		AS	-	8,900	Unknown	2,800
Guacheta		-	None	-	-	3,100
San Miguel de Sema		SP	-	38,400	78	2,300
Fuquene	Fuquene	-	None	-	-	3,100
	Capellania	-	Confirmed	1,700	13.84	
Susa		-	None	19,200	54	2,800
Simijaca		-	Confirmed	60,000	-	3,900
Caldas		-	None	-	-	1,300
Chiquinquira		-	Confirmed	116,444	282	3,900
Saboya		SP	-	20,000	20	3,700

Note: The figures in parenthesis show the fixed but not yet purchased.

(3) Improvement of Existing Treatment Plant

(a) Ubate

Ubate is the second city in the Study Area. The treatment plant (RAP) has already been operated since 1995. The target year of this plant is 2010, and there is a plan of constructing new treatment plant near the existing one.

The average effluent of BOD in 1998 and 1999 is 100 mg/l and 133 mg/l, respectively and removal rate is about 65 % (See Table F.1.1and 1.2). Almost every data shows that DO concentration is 0 mg/l because the effluent from sedimentation tank is discharged directly into the river. It is afraid that the effluent with insufficient treatment causes the water pollution of Ubate River. Aerobic treatment process is necessary, following by the existing plant. The staff also wants to adopt the different treatment system in case of construction of next treatment plant.

The total area of treatment site is about 17,600 m^2 including the existing plant of 1,000 m^2. The available area for new treatment plant is not enough to install stabilization pond.

Aerated lagoon or oxidation ditch is available within the range of the remaining area. The comparison result of each process is as follows:

Items		Aerated Lagoon	Oxidation Ditch
Construction Cost (M Col$)	Civil	179.6	254.4
	Machinery	407.2	790.2
	Total	586.8	1,044.6
Annual O & M Cost (M Col$)		89.4	144.8
Required Land Area (m^2)		15,000	11,000

Based on the comparison above, aerated lagoon is recommendable. The major facilities of proposed plant are as follows. The location map and layout of each facilities are shown in Fig. F.2.1.

Facilities	Size
Aerated Pond	L55 (53)m×W32(30)m×D4.5(4)m×1
	L68(66)m×W27(25)m×D4.5(4)m×1
Facultative Pond	L77(75)m×W32(30)m×D2.5 (2.0)m×2
Aerator	5.5 kw×6, Floating Type

Note: The figures in parenthesis show the net length of each facilities.

(b) Cucunuba

Three ponds have treated wastewater since 1992. The municipality recognizes the necessity of constructing the additional ponds in future because the pond capacity is too small. However, the owner of the land does not want to sell the land next to the pond. Due to lack of area, the total volume is too small to treat the influent efficiently. The treatment plant is surrounded by vast pastureland and owner uses the effluent for irrigation. The irrigation time is at night to prevent the complaint of bad smell from the neighbor because the effluent quality is poor.

The stabilization pond with anaerobic and facultative pond is recommended to save the land area. The first pond will be dredged for functioning as an anaerobic pond and required surface area of new pond will be calculated by subtracting the required area from the existing ones. The new pond is installed at a adequate site between the second and third pond.

The major facilities required for new construction are as follows. The location map and layout of each facilities are shown in Fig. F.2.2.

Facilities	Size
Anaerobic Pond (Improvement of Existing Pond)	L28(27)m×W19(18)m×D4.5(4.0)m×1
Facultative Pond	L58(56)m×W58(56)m×D2.5(2.0)m×1
Required Land Area	4,700 m^2

Note: The figures in parenthesis show the net length of each facilities.

(c) Lenguazaque

CAR proposed the treatment plant with the stabilization pond, which consists of four (4) facultative pond in 1998. The target year is 2020, served population is 2,400 and total cost is 486 M Col$.

However, treatment plant with activated sludge process was completed in October 1998 financed by governor of Cundinamarca. All the machinery is made in America. However, the pump and sewer pipe of about 1,200 m, which send the wastewater in urban area to treatment plant, have not been constructed yet. Recently governor of Cundinamarca promised to provide the improvement fund of installing pumping station. At present, the treatment plant only treats the circulated wastewater discharged by the temporary pump in order to protect the plant concrete wall.

This plant does not have primary sedimentation tank and the overflow rate of secondary sedimentation tank is too large to separate the supernatant from the sludge-mixed effluent. There are no facilities of handling sludge like thickener or drying bed. There is no data of effluent, but removal rate is supposed to less than 30 %. It requires another treatment plant to meet the effluent BOD of 40 mg/l.

The municipality has the area of 10,500 m^2 as the treatment site. At present existing plant occupies about 150 m^2 and new slaughterhouse of 1,600 m^2 is under construction in this site. About 9,300 m^2 is left for new treatment site.

Since it is impossible to install the stabilization pond within the range of the above area, the next selection is aerated lagoon or oxidation ditch. Aerated lagoon is preferable in consideration of construction and maintenance cost, simple operation and maintenance.

The major facilities of proposed plant are as follows. The location map and layout of each facilities are shown in Fig. F.2.3.

Facilities	Size
Aerated Pond	L30(28)m×W30(28)m×D4.5(4.0)m×1
Facultative Pond	L48(46)m×W30(28)m×D2.5(2.0)m×1
Aerator	2.2 kw×4, Floating Type
Required Land Area	5,200 m^2

Note: The figures in parenthesis show the net length of each facilities.

(d) San Miguel de Sema

This plant has only one pond, which functions as anaerobic and facultative pond. The average quantity of effluent in 1999 is 74 mg/l, which exceeds 40 mg/l.

The municipality has total area of 38,400 m^2 including the existing plant as a treatment plant. The existing pond, which has the surface area of 700 m^2, is used as facultative pond because the depth is 1.4 m. A new stabilization pond is proposed to be constructed over the existing pond, where the student plants vegetable patch.

The major facilities of proposed plant are as follows. The location map and layout of each facilities are shown in Fig.F.2.4.

Facilities	Size
Facultative Pond	L68(66)m×W35(33)m×D2.5(2.0)m×2
Required Land Area	9,000 m^2

Note: The figures in parenthesis show the net length of each facilities.

(e) Saboya

The treatment plant is composed of facultative and maturation pond and completed in 1992. Dredging of the sludge has not been conducted since then. The total surface area of two ponds is 6,600 m^2, which is enough even if the quantity will increase till 2010. The average quantity of effluent in 1999 is 25 mg/l, which meets 40 mg/l. There is no need to improve this treatment plant.

(4) Development of Treatment plant

(a) Carmen de Carupa

This municipality has neither plan nor candidate site of the treatment plant. Above the discharging point to the river, there is a barley field. It is proposed to install the stabilization pond in this site with the agreement of landowner.

The major facilities of proposed plant are as follows. The location map and layout of each facilities are shown in Fig. F.2.5.

Facilities	Size
Facultative Pond	L86(84)m×W44(42)m×D2.5(2.0)m×2
Required Land Area	12,500 m^2

Note: The figures in parenthesis show the net length of each facilities.

(b) Tausa

This municipality has already the design of treatment plant with activated sludge process, and wants to construct next year. Total cost is approximately 80 M Col$, which will be financed by Cundicamarca. The candidate site is fixed near the discharging point but not purchased yet. This area is very small and flat space is little. However, it is possible to install the stabilization pond with anaerobic and facultative pond by devising the layout of each facilities.

The major facilities of proposed plant are as follows. The location map and layout of each facilities are shown in Fig. F.2.6.

Facilities	Size
Anaerobic Pond	L15-22(14-21)m×W20(19)m×D4.5(4.0)m×1
Facultative Pond	L23-25(21-23)m×W55(53)m×D2.5(2.0)m×1
	L45(43)m×W15(13)m×D2.5(2.0)m×1
Required Land Area	3,600 m^2

Note: The figures in parenthesis show the net length of each facilities.

(c) Sutatausa

While the candidate site is fixed with the recommendation by CAR, the area is not purchased yet. The location is along the river and the pipe of about 200 m should be extended because the location is at the downstream of the discharging point. The owner posses the total 100,000 m^2 including the candidate site of 12,000 m^2. The treatment process is not decided yet, but RAP like Ubate is considered. The boundary of 12,000 m^2 is not clear, but flat area of candidate site of approximately 4,800 m^2 is enough to install the stabilization pond with anaerobic and facultative pond. If 12,000 m^2 is available, facultative pond only will be more preferable.

The major facilities in both cases are as follows:

(i) Anaerobic and Facultative Pond

Facilities	Size
Anaerobic Pond	L25-15(24-14)m×W20(19)m×D4.5(4.0).m×1
Facultative Pond	L35-27(33-25)m×W25(24)m×D2.5(2.0)m×1
	L33-15(31-13)m×W55(53)m×D2.5(2.0)m×1
Required Land Area	4,800 m^2

Note: The figures in parenthesis show the net length of each facilities.

(ii) Facultative Pond

Facilities	Size
Facultative Pond	L68(66)m×W35(33)m×D2.5(2.0)m×2
Required Land Area	6,600 m^2

Note: The figures in parenthesis show the net length of each facilities.

The location map and layout of each facilities with the combination of anaerobic and facultative pond are shown in Fig. F.2.7.

(d) Guacheta

This municipality has neither plan nor candidate site of the treatment plant. The adjoining site of the discharging point is flat and used as a pastureland. It is proposed to install the stabilization pond along the river with the agreement of the landowner. The pump is required to lift the influent to the facultative pond.

The major facilities of proposed plant are as follows. The location map and layout of each facilities are shown in Fig. F.2.8.

Facilities	Size
Pumping Station	1.5 kw×3(plus 1 for spare)
Facultative Pond	L122(120)m×W62(60)m×D2.5(2.0)m×2
Required Land Area	22,500 m^2

Note: The figures in parenthesis show the net length of each facilities.

(e) Fuquene

Since there are two districts with high population, treatment plant is to be constructed in each district, namely urban area and Capellania.

With regard to the urban area, CAR proposed the treatment plant with the stabilization pond composed of two facultative and maturation ponds in 1997. Target year is 2016, served person number is 284 and total cost is 141 M Col$. However, there is neither outlook for construction nor land acquisition. There are four (4) discharging points, and the neighboring site on the lowest river has a gentle slope. At present the land is privately owned and used for no purpose.

It is proposed to install the stabilization pond along the river with the agreement of the landowner. The major facilities of proposed plant are as follows:

Facilities	Size
Facultative Pond	L46(44)m×W24(22)m×D2.5(2.0)m×2
Required Land Area	5,200 m^2

Note: The figures in parenthesis show the net length of each facilities.

The location map and layout of each facilities are shown in Fig. F.2.9.

With regard to Capellania, the land of about 1,700 m^2 was purchased six month ago as the treatment plant site. CAR also proposed the treatment plant of stabilization pond with stabilization pond composed of one facultative pond and maturation pond. Target year is 2016, served person is 557 and total cost is 225 M Col$. However, on the 24th August 1999, the request for investment of the treatment plant was submitted to the governor in the department of Cundinamarca by the municipality of Fuquene. In this document, the treatment plant is projected for 240 families and activated sludge process is adopted. The total construction cost is 504 M Col$.

Some complaints of bad smell from the neighbor of discharging point are sometimes taken to the municipality in the dry season. The purchased area is insufficient to install the stabilization pond. While it is possible to install aerated lagoon or oxidation ditch within the range of the purchased area, it requires higher construction cost and energy consumption and more skill in operation and maintenance after completion. It is recommended to install the stabilization pond by purchasing more area of 1,100 m^2 near by.

The major facilities of proposed plant are as follows. The location map and layout of each facilities are shown in Fig. F.2.10.

Facilities	Size
Anaerobic Pond	L21(20)m×W21(20)m×D4.5(4.0)m×1
Facultative Pond	L37(35)m×W22(20)m×D2.5(2.0)m×1
Required Land Area	2,800 m^2

Note: The figures in parenthesis show the net length of each facilities.

(f) Susa

The municipality has the plan of constructing the sport ground, slaughterhouse and other facilities and candidate site is also included in this plan. The municipality has already purchased the land for this purpose and 19,200 m^2 is allocated as treatment plant although the exact boundary is not clear. The candidate site is nearly flat and now used as a pastureland.

The area of 19,200 m^2 is enough to construct the stabilization pond. The pump to lift the influent is required in consideration of elevation of inlet and discharging point.

The major facilities of proposed plant are as follows. The location map and layout of each facilities are shown in Fig. F.2.11.

Facilities	Size
Pumping Station	0.4 kw×2 (plus 1for spare)
Facultative Pond	L56(54)m×W56(54)m×D2.5(2.0)m×2
Required Land Area	10,800 m^2

Note: The figures in parenthesis show the net length of each facilities.

(g) Simijaca

CAR proposed the design of treatment plant with the combination of facultative and maturation pond in 1998. Target year is 2010, served population is 2,400 and total cost is 485 M Col$. This design requires the area of 60,000 m^2, but the candidate site is still privately owned.

The stabilization pond is available to be installed within the candidate site. It is necessary to install the interceptor pipe because there are seven (7) discharging points. The pump is also required to lift the influent to the facultative pond

The major facilities are proposed as follows. The location map and layout of each facilities are shown in Fig. F.2.12.

Facilities	Size
Pumping Station	0.75 kw×4 (Plus 1 for spare)
Facultative Pond	L135-132(133-130)m×W112-90(110-88)m×D2.5(2.0)m×1
	L154-116(152-114)m×W112-90(110-88)m×D2.5(2.0)m×1
Required Land Area	41,000 m^2

Note: The figures in parenthesis show the net length of each facilities.

(h) Caldas

There is neither plan nor candidate site for the treatment plant although a vague plan was proposed by GTZ in Germany before. Near the discharging point to the river, there is a vast field. It is proposed to install the stabilization pond in this area. The pond will be terraced because the site has a gentle slope.

The major facilities of proposed plant are as follows. The location map and layout of each facilities are shown in Fig. F.2.13.

Facilities	Size
Facultative Pond	L46(44)m×W24(22)m×D2.5(2.0)m×2
Required Land Area	5,200 m^2

Note: The figures in parenthesis show the net length of each facilities.

(i) Chiquinquira

Chiquinquira is the largest city in the Study Area. Almost all effluent is discharged into the Suarez River without treatment, which might cause the pollution of the downstream of the river. To install the treatment plant is the most urgent subject to control the water pollution in the Suarez River.

The municipality has already purchased the land of 116,444 m^2 and CAR conducted the design of treatment plant.

This area is barely enough to install the stabilization pond with the combination of anaerobic and facultative pond. There is another choice of construction of oxidation ditch or aerated lagoon. The comparison of each treatment plant is as follows:

Items		Stabilization Pond	Aerated Lagoon	Oxidation Ditch
Construction Cost (M Col$)	Civil	774.6	455.3	1,095.9
	Machinery	52.3	1,279.7	1,728.6
	Total	826.8	1,734.4	2,824.5
Annual O & M Cost (M Col$)		71.0	272.4	452.7
Required Land Area (m^2)		107,000	59,000	43,000

Note: The figures in parenthesis show the net length of each facilities.

In consideration of the table above, the stabilization pond is the most preferable from every point of view.

The major facilities of proposed plant are as follows. The pump for lifting wastewater is required. The location map and each facilities are shown in Fig. F.2.14.

Facilities	Size
Pumping Station	3.7 kw×4 (plus 1 for spare)
Anaerobic Pond	L72(70)m×W62(60)m×D4.5(4.0)m×2
Facultative Pond	L302(300)m×W72(70)m×D2.5(2.0)m×4

Note: The figures in parenthesis show the net length of each facilities.

2.2.5 Cost Estimate

(1) General

The improvement/development plan of the sewerage treatment projects was planned in the previous section in consideration of the design pollution load to be reduced till 2010.

(2) Condition of estimation

The basic assumptions of constructing each treatment facilities are as follows:

(a) Topographic and geologic site conditions are fairly good

(b) It is no problem to access from the existing trunk road.

(c) Transportation of materials and equipment is easy.

(3) Unit Cost

All unit cost applied in this chapter is mostly estimated based on prevailing market prices during this study period.

(4) Materials and Equipments

Most materials and equipments to be used at the foreseeable construction stage are expected to be manufactured and/or available in Columbia because all components of existing sewerage plant such as pumping station and various equipment are genuine domestic products.

(5) Construction Cost

Construction cost is composed of direct cost, land acquisition cost, indirect cost and physical contingency. The indirect cost consists of engineering service and administration cost. Physical contingency is added to the direct cost. Value added tax (IVA) is not included in this cost estimate.

Exchange rate of currency is assumed to be 1 US $=106 Yen = 1920 Col$ (Columbian peso) prevailing as of October of 1999.

(6) Operation and Maintenance Cost

The effluent quality depends on the operation and maintenance considerably. The main works of each treatment process is already described in Section 2.2.3.

It is very important to cut grass of embankments regularly and to ensure the absence of floating solids, dead spots and emergent vegetation on the side of the pond in case of stabilization pond system. It is also necessary to check the dissolved oxygen demand to keep the dissolved oxygen level at 1-2 mg/l by controlling the working time of aerator. Cleaning screen and grit chamber is also very necessary and cleaned periodically.

Operation and maintenance cost mainly consists of electricity charge and personnel expenses for guard and plant operation. The electricity charge is calculated by multiplying the electric power of each equipment such as pump and aerator by its operation time and a unit cost. Other expense such as water quality analysis, maintenance and repair cost, water/fuel/telephone charge, etc., are calculated based on actual result of the working plant near Bogota. Operation and maintenance cost in the municipality, which has already the treatment plant, is estimated by adding the supplementary cost for improvement /development to the present one.

The cost of construction and operation/maintenance are shown below. Direct cost and land acquisition cost are broken down in Table F.2.2 and F.2.3, respectively.

(Unit: M Col$)

Name of Municipality	Construction Cost						Annual O & M Cost				
	Direct Cost	Land Acqui.	Indirect Cost	Physical Contin.	Total MCol$	Total (10^3US$)	Electri. Charge	Person. Expense	Others	Total MCol$	Total (10^3US$)
Ubate	1,203.4	0.0	240.7	120.3	1,564.4	(814.8)	69.8	55.0	19.3	144.1	(75.0)
Cucunuba	131.5	14.7	29.2	14.6	190.0	(99.0)	-	32.9	10.9	43.8	(22.8)
Lenguazaque	450.2	0.0	90.0	45.0	585.2	(304.8)	29.6	38.1	12.3	80.0	(41.7)
San Miguel de Sema	144.7	0.0	28.9	14.5	188.1	(98.0)	-	32.9	10.5	43.4	(22.6)
Carmen de Carupa	194.2	9.8	40.8	20.4	265.2	(138.1)	-	32.9	11.7	44.6	(23.2)
Tausa	335.9	5.6	68.3	34.2	444.0	(231.2)	-	26.3	9.6	35.9	(18.7)
Statausa	112.6	11.3	24.8	12.4	161.0	(83.9)	-	26.3	10.0	36.3	(18.9)
Guacheta	407.6	70.3	95.6	47.8	621.3	(323.6)	6.0	38.1	13.3	57.4	(29.9)
Fuquene	96.3	16.3	22.5	11.3	146.4	(76.2)	-	26.3	9.5	35.8	(18.7)
Capellania	94.1	3.4	19.5	9.8	126.8	(66.0)	-	26.3	9.1	35.4	(18.5)
Susa	241.5	0.0	48.3	24.1	313.9	(163.5)	1.1	32.9	11.5	45.5	(23.7)
Simijaca	562.9	160.2	144.6	72.3	939.9	(490.0)	4.0	38.1	14.6	56.7	(29.5)
Caldas	91.3	6.5	19.6	9.8	127.1	(66.2)	-	26.3	9.0	35.3	(18.4)
Chiquinquira	1,452.0	0.0	290.4	145.2	1,887.7	(983.2)	19.6	60.1	22.1	101.8	(53.0)
Saboya	-	-	-	-	-	-	-	26.3	8.4	34.7	(18.1)
Total	5,518.2	298.0	1,163.2	581.6	7,561.0	(3,938.0)	130.1	518.8	182.1	831.0	(432.8)

Note: Cost estimate: as of 1999 October. 1US$=1,920 Col$
Indirect Cost =(Direct Cost + Real Estate)× 20 %
Physical Contingency = (Direct Cost + Real Estate) × 10 %

2.2.6 Implementation Schedule

(1) Phasing of Sewerage System Development

The target term is divided into two phases, namely, for the short-term plan year (2005) as the first phase and the master plan year (2010) as the second phase. All the sewerage system development plans are prioritized as follows, taking into consideration of the effectiveness of each project, the current condition of each municipality and relatively uniform investment during two phases.

(a) First Phase (2001-2005)

The treatment plant in Ubate and Chiquinquira should be improved/developed as the following reasons.

(i) The treatment efficiency of the present treatment plant in Ubate is not sufficient and the effluent from the treatment plant causes one of the most serious water pollution in Ubate River and Fuquene Lake.

(ii) Chiquinquira is the biggest municipality in the Fuquene River. Though the point pollution load effluent from this municipality flowing into river is approximately 2,167 kg/d are about 60 % of total effluent pollution load, the wastewater is discharged directly without any treatment into the river at present.

(iii) The land for treatment plant is already acquired.

(iv) The total construction cost of Ubate and Chiquinquirea treatment plant is 3,452 M Col$ and about 50 % of total investment cost.

(b) Second Phase (2006-2010)

The remains other than the above mentioned projects are expected to be implemented i the second phase until the master plan target year of 2010.

(2) Phased Program of Reduction

With the implementation of sewerage treatment development as discussed above, an average wastewater reduction (BOD: mg/l) in the whole objective area by each phase can be estimated and summarized in the following table. The reduction processes compared to the case of "without project" in each municipality are tabulated in Table F.2.4.

Phase	Without Project		With Project	
	Q (m^3/day)	Load (kg/day)	Load (kg/day)	Cut Load (kg/day)
Existing	13,670.0	3,465.3	-	-
First Phase	15,402.9	2,009.6	1,310.7	698.9
Second Phase	16,737.7	4,472.9	666.3	3,630.5

(3) Investment Program of Sewerage Development

Phasing and investment program of each sewerage treatment plant is summarized on the phased program basis in Table F.2.5 and Table F.2.6, respectively.

2.3 Slaughterhouse

2.3.1 Proposed Treatment System

Every municipality has a pre-treatment plant in varying degrees before discharging into the sewer/river. Effluent regulation by CAR is that the removal rate of BOD and SS should be more than 20 % and 50 %.

Due to the lack of influent quality, it is very difficult to calculate the removal rate. Generally speaking about BOD, the influent quality before pre-treatment plant is supposed to be 7,500 mg/l as shown in Table E.2.4, while the effluent quality of BOD is less than 2,500 mg/l as mentioned in Section 1.2.1. Consequently the removal rate meets the regulation by CAR. Since SS removal rate is assumed to be the same, it might be no need to install the additional treatment plant except Fuquene and Caldas, which has only the blood well and screen. It might be impossible to meet the regulation by CAR.

It is proposed to install the grease trap and septic tank after blood well and screen, which is usually adopted in most municipalities. The structure of each is shown in Fig. F.2.15.

The grease trap must be properly operated and regularly cleaned in order to prevent considerable grease quantity leakage and undesirable odor generation. The influent quality might be worse due to the long retention time in the pre-treatment tank, especially in the small town where the number of animal to be slaughtered is few. The most important for the effluent to clear the regulation is to collect the blood or other internal organs as much as possible and prevent them from discharging and keep the functioning of tank in good condition by removing scum, grease and sludge.

2.3.2 Cost Estimate

The wastewater quantity in Fuquene and Caldas will be 3.3 m^3/day and 0.6 m^3/day in 2010, respectively. The construction cost of each municipality including indirect cost and physical contingency is 7.8 M Col$ and 2.6 M Col$, respectively.

2.4 Industrial Wastewater

2.4.1 Proposed Treatment System

As mentioned in section 1.3.1, the installation rate of pre-treatment plant is only 16 %, especially that in the small factory is only 2.5 %. Almost all the small size factory discharges the wastewater without treatment directly into the sewer/river.

The removal rate of milk processing and milk cooling activity by JICA Study Team is shown below. While the removal rate of BOD in both activities meet the regulation by CAR of 20 %, that of SS in milk cooling exceeds the regulation by CAR of 50 %. However, good maintenance of pre-treatment plant will result in meeting this regulation.

Parameter	Milk Processing			Milk Cooling		
	Influent	Effluent	Removal Rate	Influent	Effluent	Removal Rate
PH	5.3	5.3	-	6.6	9.2	-
BOD	5,495	854	84.5 %	492	343	30.1 %
COD	14,096	2,026	85.6 %	867	606	30.1 %
SS	1,652	600	63.6 %	499	267	46.5 %

The regulation of BOD and SS will be achieved by the combination of grit chamber, screen, grease trap and sedimentation tank, which has been already installed in the major factories. Every factory has to install the above pre-treatment plant until the 2010. With regard to pH, it is necessary to add the neutralization equipment when pH is still out of range of regulation in spite of good maintenance in the tank.

The size of pre-treatment plant depends on the quantity and quality of wastewater. The average retention time of sedimentation tank is about 4 - 6 hours.

When more strict regulation is applied to the dairy factory by the authorization of CAR, the introduction of high - developed technology into the existing plant will be required. The treatment process will be shown in Fig. F.2.16 as a reference.

2.4.2 Cost Estimate

42 factories have to install the pre-treatment plant as mentioned above. The direct construction cost of installing pre-treatment plant is approximately 170 M Col$. The total cost including 20 % of indirect cost and 10 % of physical contingency is about 221 M Col$.

2.5 Solid Waste Disposal System

2.5.1 Improvement Measures

Solid waste is only disposed into the hole or open dumping in most municipalities. The dumping location is far from the urban area and little problem has occurred till now.

The sanitary level of landfill system can be classified into four (4) and tabulated below.

Classification	Component
Level 1	Controlled Tipping
Level 2	With a Bound and Daily Cover Soil
Level 3	Effluent Control of Leachate
Level 4	Leachate Treatment System

A complete landfill system requires a large amount of capital investment. Taking into the consideration of annual budget and its financial situation, various problems will be expected to ensue.

The leachate is composed of the moisture of the food waste and the rain after contacting with solid waste. It has the possibility of contaminating surface and groundwater. With regard to the leachate control, only Cucunuba and Chiquinquira take the counter measurement for preventing the groundwater from contamination. While Cucunuba has installed the membrane filter and tank recently, Chiquinquira operates the leachate treatment plant. Operation and maintenance cost per month is about 6 M Col$ although the required cost is about 17 M Col$.

The leachate control consists of collection facilities and the gas exhaustion equipment, which function is as follows:

(1) To supply air into the garbage layer to facilitate aerobic decomposition.

(2) To discharge gaseous substances in the garbage layer.

(3) To collect and take out leachate from the garbage layer to the reservoir by the horizontal and vertical network.

To perform these functions, vertical exhaust equipment and horizontal underdrains will be installed beside the network. The gas exhaust equipment and underdrains are composed of porous materials such as crushed stone and porous PVC pipes. In this case, the gas exhaust equipment consists of crushed stone in wire baskets.

The municipality in Ubate collects the solid waste from more than 16,000 persons, and disposed them by open dumping system. The area of dumping site is about 5.5 ha, including the future compost plant of 1.5 ha. According to the trial calculation, this area is available for more than 20 years.

In Ubate, the leachate treatment system as same as that in Chiquinquira should be adopted to solve the leachate problem.

The treatment system consists of gas exhaustion pipe, drainage for collecting leachate, and leachate treatment plant. Leachate is collected by drainage and treated by passing through primary sedimentation tank, anaerobic filter and secondary sedimentation tank. The treatment system is shown in Fig. F.2.17.

2.5.2 Cost Estimate

The volume of leacate depends on the solid waste quantity, area of the dumping site and the difference between participation and evaporation. On the assumption that the area of disposal site of 5.5 ha and the solid waste per capita/the composition of food waste are constant till 2010, leachate from rain and food waste is projected to be 2.4 m^3/day and 4.3 m^3/day, respectively. Total quantity of leachate to be treated will be 6.7 m^3/day.

The direct construction cost of each facilities are as follows: The total cost including 20 % of indirect cost and 10 % of physical contingency is about 86.6 M Col$.

(Unit: M Col$)

Facilities	Cost
Gas Exhaustion Pipe and Accessory	7.1
Drainage for Collecting Leachate	14.6
Leachate Treatment Plant	32.4
Others	12.5
Total	66.6

Note: Cost estimate: as of 1999 October.

Reference:

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7): " Chiquinquira Alcantarillado y Tratamiento de Aguas Negras", Santiago Escallon Angel, Bogota, Julio, 1980

8): " Diseño del Sistema de Tratamiento de Aguas Negras para le Municipio de San Miguel de Sema (Boyaca)", Universidad Santo Tomas, Facultad de Ingenieria Civil, Santafé de Bogotá, D.C., 1992

9): " Analisis Technico y Economico de las Alternativas para el Diseño de la Planta de Tratamiento de Aguas Residuales para el Municipio de Ubate", Universidad de Los Andes, Departmento de Ingenieria Civil, Bogota, Septiembre de 1990

10): " Operación y Maintenance ´Manual nen Augas Residuales para el Municipio de Ubate", 1994

11): "Acuerdo NO.58 de 1987", CAR, Diciembre de 1987

12): "´Provincia,Ubate 1998", Departamento de Cundinamarca, Gerencia para la Infraestructura, Direccion de Agua Potable y Saneamiento Basico,

Table F.1.1 Water Quality of Treatment Plant in Ubate in 1998

Parameter	Unit	1998.1.5		1998.2.12		1998.3.26		1998.6.25		1998.7.23	
		Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
flow	l/s	47.2	11.1	37.9	13.5	28	22.5			42	18.8
Water Temperature	℃	19.1	21.1	18.2	18.2	18.5	18.9	13	14	17.4	17.4
Air Temperature	℃	17	17	18	19	19	20	14	15	20	20
Conductivity	μ S/cm	716	724	565	445	495	300	425	495	432	425
Oil and Grease	mg/l	30.3	7.5	25.5	3.7	62.1	15.2	117	52.7		
COD	mg/l	235.2	177	709	317	538	240	540	242	588	259
BOD_5	mg/l	145.8	52.5	365	135	356	95.2	233	137	368	124
SS	mg/l	172	54	228	137	265	84	410	285	100	94
Turbidity	NTU	113	148	546	335	495	300	260	186	216	70
DO	mg/l	0	0	0.17	0	0	0	0	0	0.7	0
pH		6.03	6.63	7.2	6.5	7.5	6.8	5.97	5.79	6.1	5.9
NH_4-N	mg/l	27.62	38.45	39.03	22.37	41.8	11.85	18.58	27.55		
NO_3-N	mg/l	1.66	0.69	1.1	2	1.6	1.6	2	1		
NO_2-N	mg/l	ND	0.01	0.003	0.006	0.001	0.001	0.003	0.001		
Organic N	mg/l	4.58	4.35	29.47	13.03	3.7	29.75	7.75	10.52		
Kjeldahl N	mg/l	32.2	42.8	68.5	35.4	45.5	41.6	26.33	38.07		
Orto-P	mg/l	1.33	5.25	5.26	4.04	4.2	4.65	2.46	5.14		
Organic P	mg/l	0.54	0.26	0.76	0.91	2.19	1.24	3.95	1.21		
T-P	mg/l	1.87	5.51	6.02	4.95	6.39	5.89	6.41	6.35		
SO_4^{2-}	mg/l	155.2	147	124	107	544	57.4	106	144		
S^{2-}	mg/l	0.32	ND	0.21	0.37	0.77	0.29	4.57	5.67		
Hg	mg/l	0.003		0.001		0.002		ND			
Pb	mg/l	0.07		0.07		0.1		0.08			
Total Coliforms	MPN/100ml	43×10^7	36×10^5	46×10^8	11×10^7			24×10^7	12×10^8	36×10^6	21×10^6
Fecal Coliforms	MPN/100ml	15×10^7	36×10^5	15×10^8	11×10^7			72×10^5	61×10^6	36×10^6	15×10^6

Parameter	Unit	1998.8.27		1998.9.22		1998.10.30		1998.11.20		Average	
		Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
flow	l/s	32	12.6	39	36	52	48	37	35	39.4	24.7
Water Temperature	℃	17.2	17.7	17.9	18.2	16.1	16.7	17.8	18.6	17.2	17.9
Air Temperature	℃	18	18	22	22	16	16	17	17	17.9	18.2
Conductivity	μ S/cm	460	487	520	515	454	387	757	695	536.0	497.0
Oil and Grease	mg/l									58.7	19.8
COD	mg/l	624	197	780	264	253	146	903	312	574.5	239.3
BOD_5	mg/l	249	42.6	410	99.8	111	44	334	178	285.8	100.9
SS	mg/l	230	46	387	150	120	50	265	65	241.9	107.2
Turbidity	NTU	280	47	409	68	140	75	320	108	308.8	148.6
DO	mg/l	0	0.5	0	0	0.2	0.1	0	0	0.119	0.067
pH		6.6	6.2	6.71	6.55	7	6.8	6.8	6.8	6.7	6.4
NH_4-N	mg/l									31.8	25.1
NO_3-N	mg/l									1.6	1.3
NO_2-N	mg/l									0.002	0.005
Organic N	mg/l									11.4	14.4
Kjeldahl N	mg/l									43.1	39.5
Orto-P	mg/l									3.3	4.8
Organic P	mg/l									1.9	0.9
T-P	mg/l									5.2	5.7
SO_4^{2-}	mg/l									232.3	113.9
S^{2-}	mg/l									1.5	1.6
Hg	mg/l									0.002	
Pb	mg/l									0.080	
Total Coliforms	MPN/100ml	43×10^6	15×10^6	93×10^6	11×10^7	11×10^8	29×10^6	43×10^6	15×10^6	82×10^7	19×10^7
Fecal Coliforms	MPN/100ml	43×10^6	36×10^5	93×10^6	93×10^5	24×10^7	23×10^4	43×10^6	36×10^5	26×10^7	26×10^6

Table F.1.2 Water Quality of Treatment Plant in Ubate in 1999

Parameter	Unit	1999.1		1999.2		1999.3		1999.4	
		Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Flow	l/s	63.6	60	46	39	46.5	41	46.5	46
Conductivity	μ S/cm	842	911	773	641	796	657	475	785
COD	mg/l	1200	315	835	815	432	277	193	347
BOD	mg/l	840	110	711	134	182	124	110	195
SS	mg/l	253	89	310	117	152	100	40	46
Turbidity	NTU	320	200	276	142	126	117	77	166
DO	mg/l	0	0	0	0	0	0	0	0
pH		6.8	7.4	6.9	7.2	7	6.9	6.5	6.8
Total Coliforms	MPN/100ml	46×10^7	75×10^5	46×10^7	24×10^4			43×10^6	43×10^6
Fecal Coliforms	MPN/100ml	43×10^6	31×10^5					43×10^6	43×10^6

Parameter	Unit	1999.6		1999.7		Average	
		Influent	Effluent	Influent	Effluent	Influent	Effluent
Flow	l/s	26	25	26	25	42.4	39.3
Conductivity	μ S/cm	745	489	638	720	711.5	700.5
COD	mg/l	424	396	556	313	606.7	410.5
BOD	mg/l	169	129	263	105	379.2	132.8
SS	mg/l	223	90	300	90	213.0	88.7
Turbidity	NTU	78	150	84	138	160.2	152.2
DO	mg/l	0	0	0	0	0	0
pH		7.1	7	7	7	6.9	7.1
Total Coliforms	MPN/100ml	24×10^6	43×10^5	43×10^6	11×10^7	20×10^7	33×10^6
Fecal Coliforms	MPN/100ml	24×10^6	91×10^4	91×10^5	46×10^6	30×10^6	19×10^6

Table F.1.3 Water Quality of Treatment Plant in San Miguel de Sema

Parameter	Unit	1999.1		1999.2		1999.3	
		Influent	Effluent	Influent	Effluent	Influent	Effluent
Flow	l/s	1.5	2	1.2	0.8	1.5	2
Conductiviy	μ S/cm	300	358	502	347	763	391
COD	mg/l	277	157	212	163	1311	373
BOD	mg/l	111	44.1	66	49.1	886	104
SS	mg/l	10	43	80	71	540	35
Turbidity	NTU	39	47	57	56	49	57
DO	mg/l	3.5	1.5	1.5	4.6	1.6	5.5
pH		6.5	7.1	6.7	6.8	6.6	7
Total Coliforms	MPN/100ml	11×10^8	93×10^6	93×10^8	43×10^6		
Fecal Coliforms	MPN/100ml	$<30\times10^5$	$<30\times10^5$	$<36\times10^5$	$<30\times10^5$		

Parameter	Unit	1999.4		1999.6		Average	
		Influent	Effluent	Influent	Effluent	Influent	Effluent
Flow	l/s	2.3	2.5	1.5	3	1.6	2.1
Conductivity	μ S/cm	539	385	639	518	548.6	399.8
COD	mg/l	539	385	639	518	595.6	319.2
BOD	mg/l	216	77.3	447	95.1	345.2	73.9
SS	mg/l	145	140	356	290	226.2	115.8
Turbidity	mg/l	84	42	210	76	87.8	55.6
DO	mg/l	0	5.4		4.9	1.3	4.4
pH	mg/l	7.2	7.1	6.6	7	6.7	7.0
Total Coliforms	MPN/100ml	46×10^7	24×10^7	43×10^6	24×10^6	27×10^8	46×10^6
Fecal Coliforms	MPN/100ml	39×10^6	91×10^5	91×10^5	91×10^4	10×10^6	32×10^5

Table F.1.4 Water Quality of Treatment Plant in Saboya

Parameter	Unit	1999.1		1999.2		1999.3		1999.4	
		Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Flow	l/s	0.2	0.5	1.2	1.1	1.5	1.5	4.4	3
COD	mg/l	229	83.1	150	67	97.8	138	256	104
BOD	mg/l	82	14.6	38	14	48.8	25.8	74.5	23.9
SS	mg/l	22	11	46	30	29	70	69	44
DO	mg/l	0	3.5	1.3	3.6	2.6	6.8	0.7	6.5
pH		6.7	6.7	6.6	6.7	6.9	10.7	6.8	10.1
Total Coliforms	MPN/100ml	46×10^6	73×10^3	93×10^6	93×10^4			43×10^6	43×10^4
Fecal Coliforms	MPN/100ml	15×10^6	73×10^3	93×10^6	$<30 \times 10^3$			23×10^6	$<30 \times 10^3$

Parameter	Unit	1999.5		1999.6		Average	
		Influent	Effluent	Influent	Effluent	Influent	Effluent
Flow	l/s	0.8	0.5	1.3	2	1.6	1.4
COD	mg/l	273	125	257	102	210.5	103.2
BOD	mg/l	113	52	68	19.1	70.7	24.9
SS	mg/l	60	54	110	68	56.0	46.2
DO	mg/l	0.3	6.7	2.2	6.8	1.2	5.7
pH		6.7	10.2	6.8	8.6	6.8	8.8
Total Coliforms	MPN/100ml	91×10^5	$<30 \times 10^3$	23×10^5	15×10^2	39×10^6	30×10^4
Fecal Coliforms	MPN/100ml	36×10^5	$<30 \times 10^3$	91×10^4	$<30 \times 10$	27×10^6	32×10^3

Table F.1.5 Solid Waste Disposal System in Study Area

No.	Name of Municipality	Service		Domestic Waste	Dumping Site				Leachate Treatment	Future Plan
		Area (ha)	Population		Location	Area (ha)	Type	Remaining Year		
1	Carmen de Carupa	43	1,300	8m^3/week	High place, not Watercourses near	2.6	Hole and Ditch	>10	No	Cooperation with Cucunuba, Site is not decided
2	Ubate			Hopital waste is not included		5.5	Hole and Ditch	>20	No	OM 7M.Peso/year, Compost Plan (1.5ha)
3	Tausa				Private Land, borrowed by the owner in codition of providing the feces in slaughterhouse	0.5	Hole			Cooperation with Cucunuba, Chibaquira, Statausa
4	Sutatausa			3.5 t/week, 168t/year, Hospital waste is not included	Private Land, Owner does not want to contitue to use	2	Open Dumping	unknown	No	Covering with Synthetic Membrane of Low Permeability, Cooperation with Cucunuba or alone
5	Cucunuba	100	1,153	6 t/week	Vereda Aposentos, 4km from the Centre	1	Open Dumping	25	Membrane Filter and Tank	
6	Lenguazaque			6 t/week		2	Hole			
7	Guacheta	No collection since 1996								Cooperaiton with Ubate
8	San Miguel de Sema	No collection								New Site at Veredas Arboledas
9	Fuquene	19	800	3 t/week	5km from the Urban Centre in Vereda Taravita	2	Hole	100	No	
10	Susa	130	2,500	30 m^3/week	Private land, back to owner till the end of 1999, to2km from Vereda Cascada	3	Open Dumping		No	No site,
11	Simijaca	62	4,500	55 m^3/week(dom.) 10 m^3/week(indust.)	High Place, not Watercourses near	1.9	Hole	<2	No	Regional Plan
12	Caldas	4	100	3m^3/week	1km from the Urban Centre	1	Open Dumping		No	
13	Chiquinquira	2,000	50,000	10,000 t/year 20,000 m^3/year		25	Hole		Leachate Treatment,	Facilities for using bio-gas
14	Saboya	400	1,200	4 t/week	Vereda Merchan, 4km from the Centre	2	Hole	25	No data	Cooperate with Chinquinquira

Table F.2.1 Effluent Regulation

(unit: mg/l)

<table>
<tr><th colspan="2" rowspan="2">Parameter</th><th colspan="2">Water Body</th><th colspan="2">Sewerage System</th></tr>
<tr><th>Current User</th><th>New User</th><th>Current User</th><th>New User</th></tr>
<tr><td colspan="2">pH</td><td>5.0-9.0</td><td>5.0-9.0</td><td>5.0-9.0</td><td>5.0-9.0</td></tr>
<tr><td colspan="2">Temperature</td><td>≦40℃</td><td>≦40℃</td><td>≦40℃</td><td>≦40℃</td></tr>
<tr><td colspan="2">Floating Material</td><td>Absent</td><td>Absent</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Fats and Oils</td><td>Removal≧80%</td><td>Removal≧80%</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Acid, Base (explosive or flammable substances)</td><td>-</td><td>-</td><td>Absent</td><td>Absent</td></tr>
<tr><td colspan="2">Settling Solids</td><td>-</td><td>-</td><td>≦10</td><td>≦10</td></tr>
<tr><td colspan="2">Hexane Substracted Substances</td><td>-</td><td>-</td><td>≦100</td><td>≦100</td></tr>
<tr><td rowspan="2">Suspended Solid</td><td>Domestic</td><td rowspan="2">Removal≧50%</td><td rowspan="2">Removal≧80%</td><td>Removal≧50%</td><td>Removal≧80%</td></tr>
<tr><td>Industrial (>500mg/l)</td><td>Removal≧50%</td><td>Removal≧80%</td></tr>
<tr><td rowspan="2">BOD(>500mg/l)</td><td>Domestic</td><td>Removal≧30%</td><td>Removal≧80%</td><td>Removal≧30%</td><td>Removal ≧80%</td></tr>
<tr><td>Industrial</td><td>Removal≧20%</td><td>Removal≧80%</td><td>Removal≧20%</td><td>Removal≧80%</td></tr>
<tr><td colspan="2">Maximum Volume of Flow</td><td>-</td><td>-</td><td colspan="2">1.5 times of the hour average flow</td></tr>
<tr><td colspan="2">Sb</td><td colspan="2">0.5</td><td colspan="2">0.5</td></tr>
<tr><td colspan="2">As</td><td colspan="2">0.5</td><td colspan="2">0.5</td></tr>
<tr><td colspan="2">Ba</td><td colspan="2">5.0</td><td colspan="2">5.0</td></tr>
<tr><td colspan="2">Be</td><td colspan="2">10.0</td><td colspan="2">10.0</td></tr>
<tr><td colspan="2">B</td><td colspan="2">10.0</td><td colspan="2">10.0</td></tr>
<tr><td colspan="2">Cd</td><td colspan="2">0.1</td><td colspan="2">0.1</td></tr>
<tr><td colspan="2">Carbamate</td><td colspan="2">0.1</td><td colspan="2">0.1</td></tr>
<tr><td colspan="2">CN^-</td><td colspan="2">1.0</td><td colspan="2">1.0</td></tr>
<tr><td colspan="2">Chloroform</td><td colspan="2">1.0</td><td colspan="2">1.0</td></tr>
<tr><td colspan="2">Cu</td><td colspan="2">3.0</td><td colspan="2">3.0</td></tr>
<tr><td colspan="2">Cr^{6+}</td><td colspan="2">0.5</td><td colspan="2">0.5</td></tr>
<tr><td colspan="2">Total Cr</td><td colspan="2">5.0</td><td colspan="2">5.0</td></tr>
<tr><td colspan="2">Organic Compound</td><td colspan="2">0.05</td><td colspan="2">0.05</td></tr>
<tr><td colspan="2">Phenols</td><td colspan="2">0.2</td><td colspan="2">0.2</td></tr>
<tr><td colspan="2">Organic Phosphorous Compound</td><td colspan="2">0.1</td><td colspan="2">0.1</td></tr>
<tr><td colspan="2">Dichlor-ethylene</td><td colspan="2">1.0</td><td colspan="2">1.0</td></tr>
<tr><td colspan="2">Diphenyl-polychloride</td><td colspan="2">ND</td><td colspan="2">ND</td></tr>
<tr><td colspan="2">Fe</td><td colspan="2">15.0</td><td colspan="2">15.0</td></tr>
<tr><td colspan="2">Hg</td><td colspan="2">0.02</td><td colspan="2">0.02</td></tr>
<tr><td colspan="2">Organic Hg</td><td colspan="2">ND</td><td colspan="2">ND</td></tr>
<tr><td colspan="2">Ni</td><td colspan="2">2.0</td><td colspan="2">2.0</td></tr>
<tr><td colspan="2">Pb</td><td colspan="2">0.5</td><td colspan="2">0.5</td></tr>
<tr><td colspan="2">Ag</td><td colspan="2">0.5</td><td colspan="2">0.5</td></tr>
<tr><td colspan="2">Se</td><td colspan="2">0.5</td><td colspan="2">0.5</td></tr>
<tr><td colspan="2">Carbonic Surfide</td><td colspan="2">1.0</td><td colspan="2">1.0</td></tr>
<tr><td colspan="2">Tetrachlor-carbonate</td><td colspan="2">1.0</td><td colspan="2">1.0</td></tr>
<tr><td colspan="2">Trichlor-ethylene</td><td colspan="2">1.0</td><td colspan="2">1.0</td></tr>
<tr><td colspan="2">Zn</td><td colspan="2">3.0</td><td colspan="2">3.0</td></tr>
</table>

Table F.2.2 Direct Construction Cost of Sewerage Treatment Plant in Each Municipality

(unit: M Col$)

Municipality	Civil Works								Machinery			Electricity	Total
	Prepara-tion*1	Excava-tion	Embank-ment	Preliminary Treatment*2	Building *3	In & Out Structure*4	Exterior *5	Sub-total	Pump	Aerator	Sub-total		
Carmen de Carupa	14.7	88.6	0.0	1.9	0.8	63.6	17.9	187.5	0.0	0.0	0.0	6.7	194.2
Ubate	17.7	133.8	64.0	8.9	0.8	86.3	20.8	332.3	0.0	544.4	544.4	326.7	1,203.4
Tausa	237.7	21.5	20.3	1.9	0.8	35.2	11.9	329.2	0.0	0.0	0.0	6.7	335.9
Statausa	5.7	22.0	22.4	1.9	0.8	39.6	13.7	105.9	0.0	0.0	0.0	6.7	112.6
Cucunuba	5.5	34.1	26.6	1.9	0.8	42.4	13.5	124.8	0.0	0.0	0.0	6.7	131.5
Lenguazaque	6.1	41.9	35.6	3.7	0.8	61.3	14.3	163.7	0.0	179.0	179.0	107.4	450.2
Guacheta	26.5	140.6	0.0	3.7	14.2	93.7	17.7	296.3	24.3	45.3	69.6	41.7	407.6
San Miguel de Sema	10.6	67.6	0.0	1.9	0.8	38.1	19.1	138.0	0.0	0.0	0.0	6.7	144.7
Fuquene	6.1	32.7	0.0	1.9	0.8	34.3	13.9	89.6	0.0	0.0	0.0	6.7	96.3
Capellania	3.3	16.3	23.1	1.9	0.8	30.2	11.9	87.4	0.0	0.0	0.0	6.7	94.1
Susa	12.7	73.8	0.0	1.9	14.2	60.8	17.6	181.0	9.9	27.9	37.8	22.7	241.5
Simijaca	48.3	231.2	0.0	3.7	20.9	123.2	19.5	446.7	22.0	50.5	72.6	43.5	562.9
Caldas	6.1	32.7	0.0	1.9	0.8	29.2	13.9	84.6	0.0	0.0	0.0	6.7	91.3
Chiquinquira	126.0	392.7	162.2	12.6	27.6	426.8	33.5	1,181.3	46.2	123.0	169.2	101.5	1,452.0
Total	527.0	1,329.3	3,54.0	49.2	85.1	1,164.8	238.9	3,748.5	102.4	970.2	1,072.6	697.2	5,518.2

*1: Dismantling, Cleaning, Leveling, Retaining Wall, etc.,

*2: Screening, Grease Trap, Grit Chamber, Flow Meter such as notch

*3: Pumping Station, Security Cabin

*4: Structure of Inlet, Outlet and Discharge into River

*5: Entrance Gate, Entrance Way Fence, etc.

Table F.2.3 Land Acquisition Cost

Municipality	Total Area (m^2)	Acquired Area (m^2)	Required Area (m^2)	Unit Cost (Pesos/m^2)	Total Cost (M Col$)
Carmen de Carupa	12,500	0	12,500	781.3	9.8
Ubate	15,000	15,000	0	4,687.5	0.0
Tausa	3,600	0	3,600	1,562.5	5.6
Statausa	4,800	0	4,800	2,343.8	11.3
Cucunuba	4,700	0	4,700	3,125.0	14.7
Lenguazaque	5,200	5,200	0	2,812.5	0.0
Guacheta	22,500	0	22,500	3,125.0	70.3
San Miguel de Sema	9,000	9,000	0	2,343.8	0.0
Fuquene	5,200	0	5,200	3,125.0	16.3
Capellania	2,800	1,700	1,100	3,125.0	3.4
Susa	10,800	10,800	0	2,812.5	0.0
Simijaca	41,000	0	41,000	3,906.3	160.2
Caldas	5,200	0	5,200	1,250.0	6.5
Chiquinquira	107,000	107,000	0	3,906.3	0.0
Total	249,300	148,700	100,600		298.0

Table F.2.4 Phased Program of Sewerage Wastewater Reduction (BOD Load)

Name of Municipality	Existing		First Phase (2005)				Second Phase (2010)			
			Without Project		With Project		Without Project		With Project	
	Q (m^3/d)	Load (kg/d)	Q (m^3/d)	Load (kg/d)	Load (kg/d)	Cut Load	Q (m^3/d)	Load (kg/d)	Load (kg/d)	Cut Load
Carmen de Carupa	116.5	70.4	170.3	101.2	101.2	-	195.3	115.5	7.8	107.7
Ubate	3,710.6	357.5	4,379.9	449.4	175.2	274.2	4,846.9	676.4	193.9	334.0
Tausa	86.6	54.1	80.3	50.7	50.7	-	97.2	60.4	3.9	56.6
Sutatausa	51.2	29.1	116.5	66.2	66.2	-	129.9	73.8	5.2	68.6
Cucunuba	102.2	9.5	148.9	17.8	17.8	-	181.1	52.8	7.2	14.4
Lenguazaque	248.2	98.6	348.5	135.8	135.8	-	384.5	132.9	15.4	133.9
Guacheta	460.8	175.8	576.8	218.9	218.9	-	629.2	238.4	25.2	213.3
San Miguel de Sema	140.3	10.5	154.8	12.3	12.3	-	164.3	25.5	6.6	6.5
Fuquene	70.4	40.0	79.2	45.0	45.0	-	99.6	56.6	4.0	52.6
Susa	171.9	103.8	144.1	88.2	88.2	-	158.7	96.6	6.3	90.3
Simijaca	820.1	342.9	856.1	356.9	356.9	-	903.0	375.0	36.1	338.9
Caldas	7.6	4.3	40.8	23.2	23.2	-	54.6	31.1	2.2	28.9
Chiquinquira	7,587.0	2,167.8	8,187.9	442.4	17.7	424.7	8,751.2	2,535.1	350.0	2,185.0
Saboya	96.6	1.2	118.6	1.7	1.7	-	142.2	2.5	2.5	-
Total	13,670.0	3,465.3	15,402.9	2,009.6	1,310.7	698.9	16,737.7	4,472.9	666.3	3,630.5

Table F.2.5 Phasing of Implementation of Each Sewerage System Development

(Unit: M Col$)

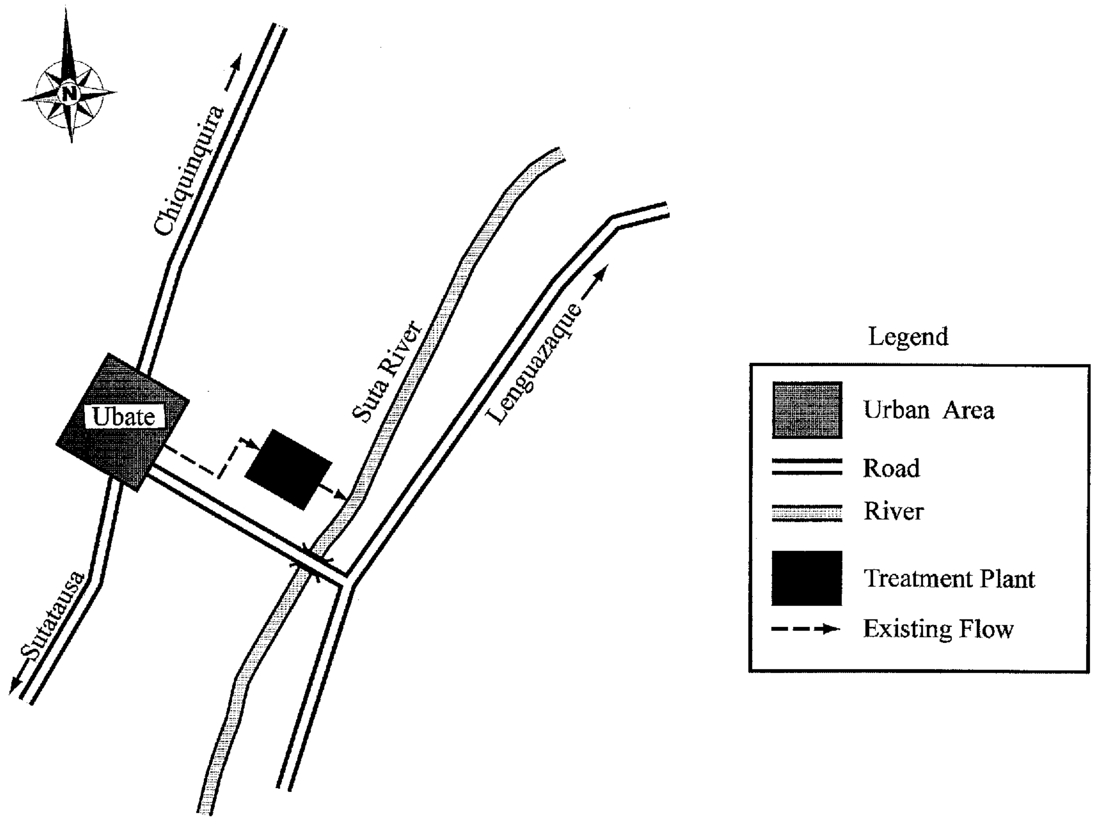
Municipality	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total: Direct C/C	Total: Land Acquisition
Carmen de Carupa							9.8	84.2	129.5		213.6	9.8
Ubate	120.3			601.7	601.7						1,323.7	0.0
Tausa					5.6				145.6	223.9	369.5	5.6
Statausa					11.3			48.8	75.1		123.9	11.3
Cucunuba							14.7	57.0	87.7		144.7	14.7
Lenguazaque						195.1	300.1				495.2	0.0
Guacheta					70.3	176.6	271.7				448.4	70.3
San Miguel de Sema									62.7	96.5	159.2	0.0
Fuquene								16.3	41.7	64.2	105.9	16.3
Capellania								3.4	40.8	62.7	103.5	3.4
Susa								104.7	161.0		265.7	0.0
Simijaca						160.2	243.9	375.3			619.7	160.2
Caldas								6.5	39.6	60.9	100.4	6.5
Chiquinquira	435.6	580.8	580.8								1,597.2	0.0
Saboya											0.0	0.0
Total	555.9	580.8	580.8	601.7	688.9	531.9	840.3	696.0	783.5	508.2	6,070.0	298.1
Construction Cost: Direct C/C	555.9	580.8	580.8	601.7	601.7	371.7	815.8	669.8	783.5	508.2	6,070.0	
Construction Cost: Land Acquisition	0.0	0.0	0.0	0.0	87.2	160.2	24.5	26.2	0.0	0.0	298.1	
Construction Cost: Engin. and Admi. Cost	29.0	58.1	58.1	60.2	77.6	60.6	80.9	65.4	70.7	50.8	611.4	
Construction Cost: Physical Contingency	29.0	58.1	58.1	60.2	68.9	44.6	78.4	62.8	70.8	50.8	581.7	
Construction Cost: Total	614.0	697.0	697.0	722.0	835.4	637.2	999.5	824.3	925.0	609.8	7,561.2	
Annual O & M Cost: Existing Facilities	233.6	233.6	233.6	233.6	233.6	233.6	233.6	233.6	233.6	233.6	2,335.6	
Annual O & M Cost: Development Facilities	0.0	0.0	0.0	101.8	101.8	157.4	157.4	235.0	291.7	447.4	1,492.6	
Annual O & M Cost: Total	233.6	233.6	233.6	335.4	335.4	391.0	391.0	468.6	525.3	681.0	3,828.2	

Note: ▓: Deseño de Detalles ▧: Adquisicíon de Tierra ░: Construcción Directo

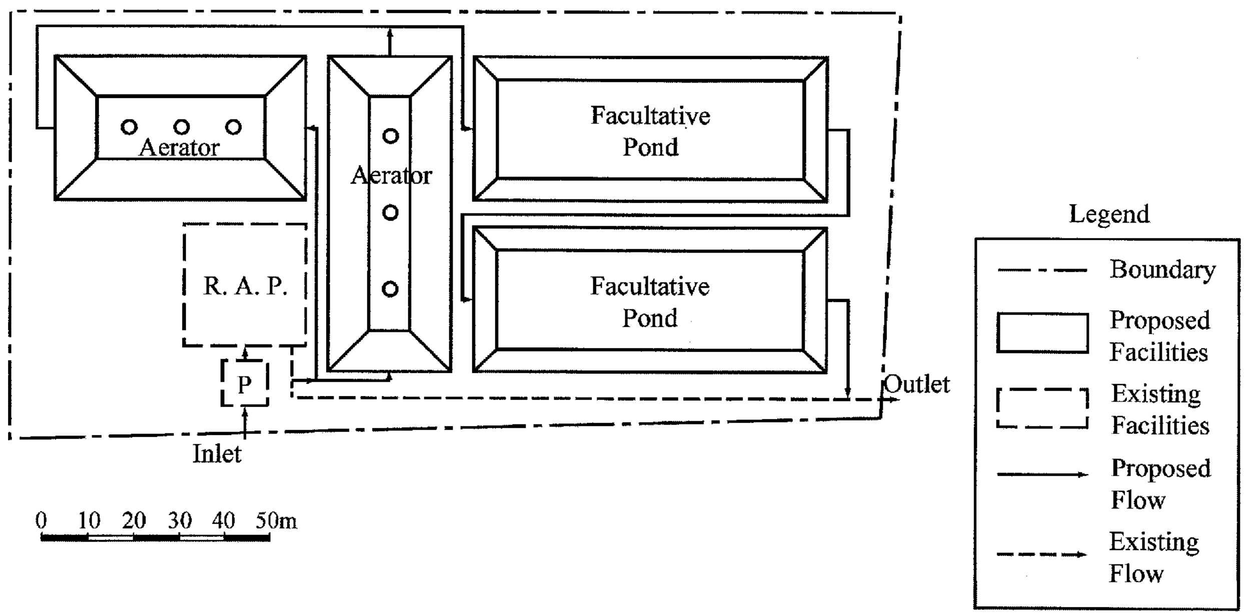
Table F.2.6 Investment Program of Sewerage Treatment Plant

(unit: M Col$)

Municipality	First Phase (2001-2005)				Second Phase (2006-2010)				Total (2001-2010)				2011-
	Construction Cost	Annual O & M Cost			Construction Cost	Annual O & M Cost			Construction Cost	Annual O & M Cost			Annual O & M Cost
		Existing	Develop.	Total		Existing	Develop.	Total		Existing	Develop.	Total	
Carmen de Carupa	0.0	0.0	0.0	0.0	265.2	0.0	44.6	44.6	265.2	0.0	44.6	44.6	44.6
Ubate	1,564.4	442.3	0.0	442.3	0.0	442.3	278.1	720.4	1,564.4	884.6	278.1	1,162.7	144.1
Tausa	7.3	0.0	0.0	0.0	436.7	0.0	0.0	0.0	444.0	0.0	0.0	0.0	35.9
Statausa	14.7	0.0	0.0	0.0	146.4	0.0	36.3	36.3	161.1	0.0	36.3	36.3	36.3
Cucunuba	0.0	72.8	0.0	72.8	190.1	72.3	29.3	102.1	190.1	145.6	29.3	174.9	43.8
Lenguazaque	0.0	299.3	0.0	299.3	585.3	299.3	60.6	359.9	585.3	598.6	60.6	659.2	80.0
Guacheta	91.4	0.0	0.0	0.0	529.9	0.0	172.3	172.3	621.3	0.0	172.3	172.3	57.4
San Miguel de Sema	0.0	179.9	0.0	179.9	188.1	179.9	0.0	179.9	188.1	359.8	0.0	359.8	43.4
Fuquene	0.0	0.0	0.0	0.0	146.4	0.0	0.0	0.0	146.4	0.0	0.0	0.0	35.8
Capellania	0.0	0.0	0.0	0.0	126.8	0.0	0.0	0.0	126.8	0.0	0.0	0.0	35.4
Susa	0.0	0.0	0.0	0.0	314.0	0.0	45.5	45.5	314.0	0.0	45.5	45.5	45.5
Simijaca	0.0	0.0	0.0	0.0	940.0	0.0	113.4	113.4	940.0	0.0	113.4	113.4	56.7
Caldas	0.0	0.0	0.0	0.0	127.1	0.0	0.0	0.0	127.1	0.0	0.0	0.0	35.3
Chiquinquira	1,887.6	0.0	203.6	203.6	0.0	0.0	509.0	509.0	1,887.6	0.0	712.6	712.6	101.8
Saboya	0.0	173.5	0.0	0.0	0.0	173.5	0.0	173.5	0.0	347.0	0.0	347.0	34.7
Total	3,565.4	1,167.8	203.6	1,371.4	3,995.8	1,167.8	1,289.0	2,456.8	7,561.2	2,335.6	1,492.6	3,828.3	831.0

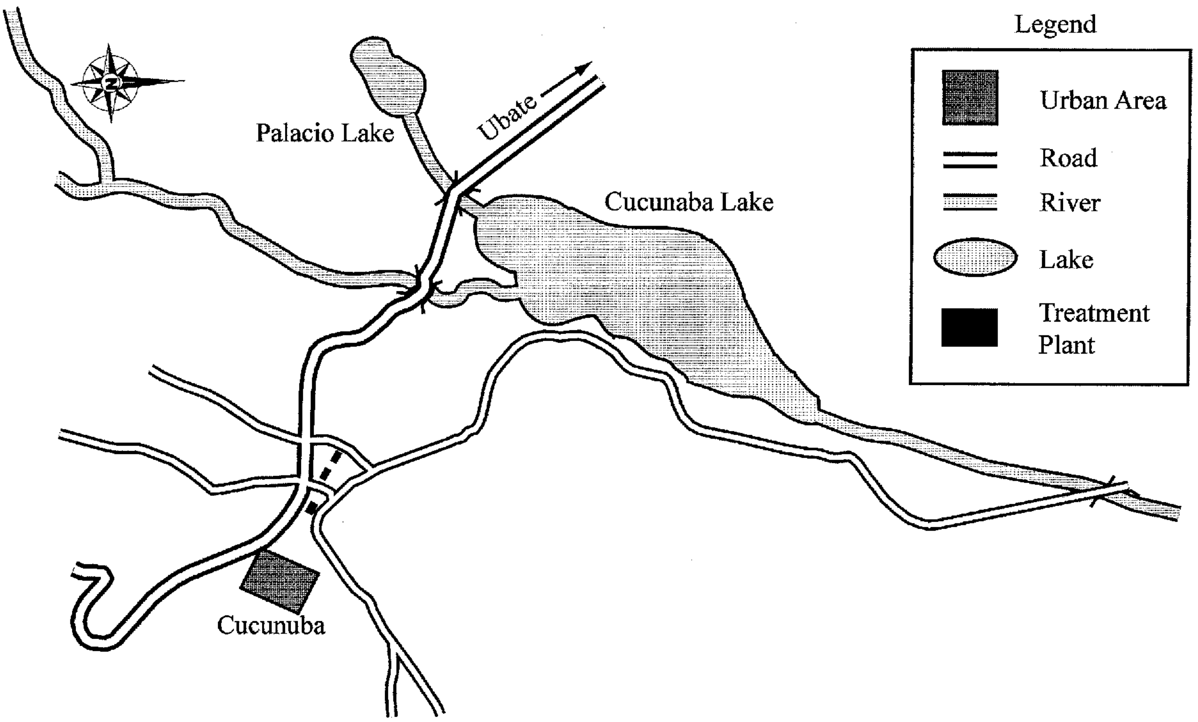


Location Map



Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.1 Sewerage Treatment Plant in Ubate
JAPAN INTERNATIONAL COOPERATION AGENCY	



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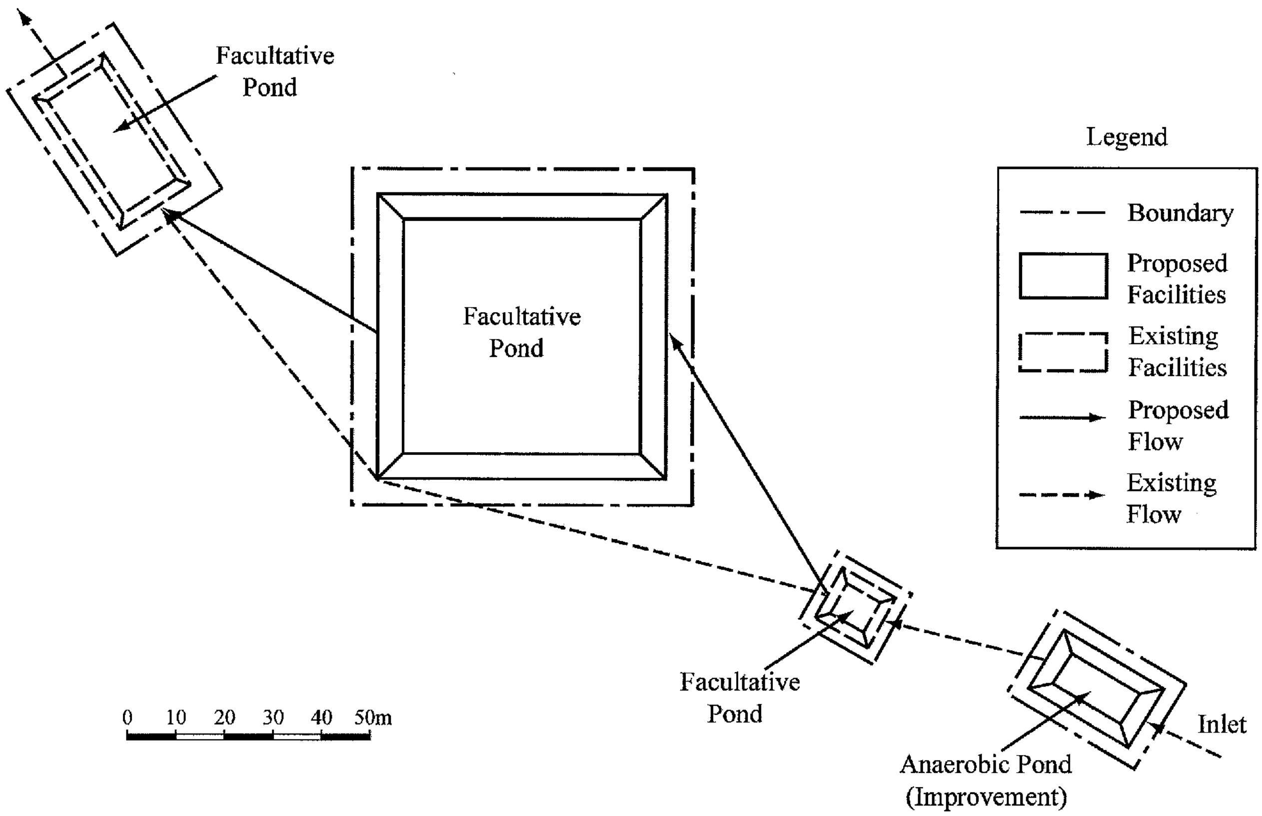
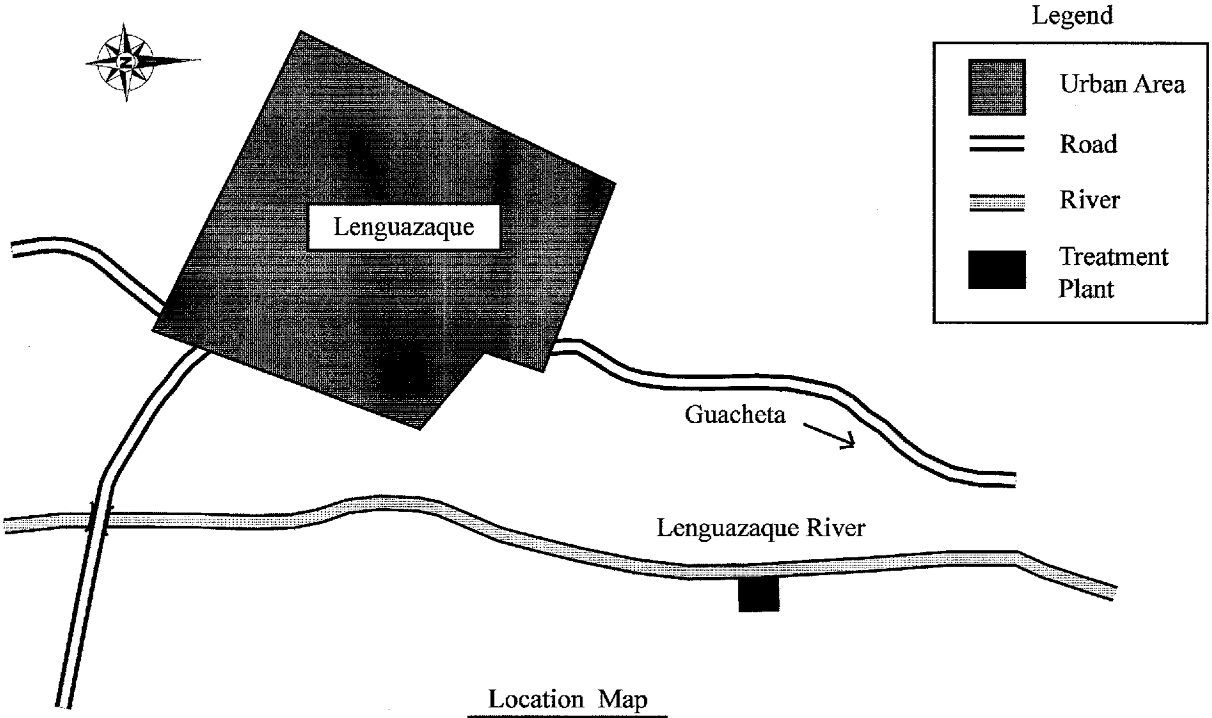
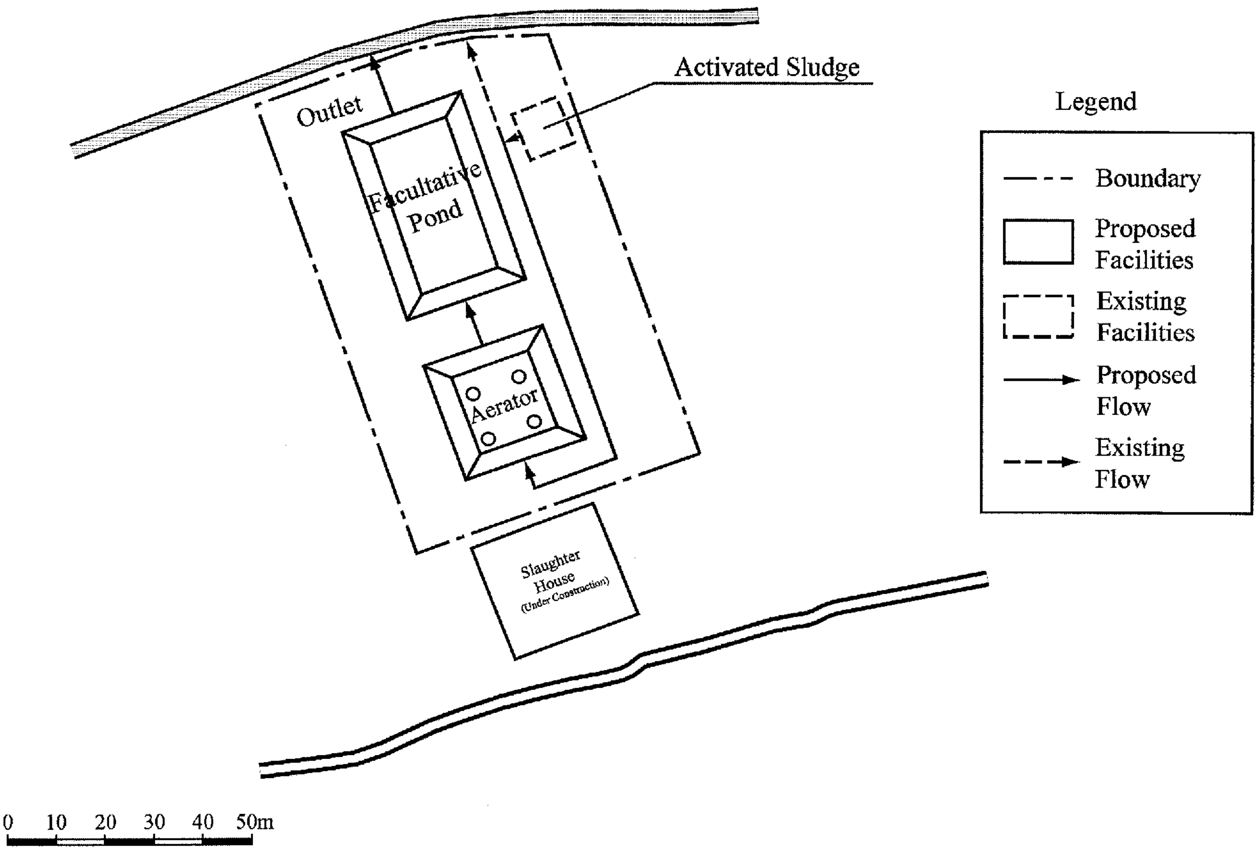


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.2 Sewerage Treatment Plant in Cucunuba
JAPAN INTERNATIONAL COOPERATION AGENCY	

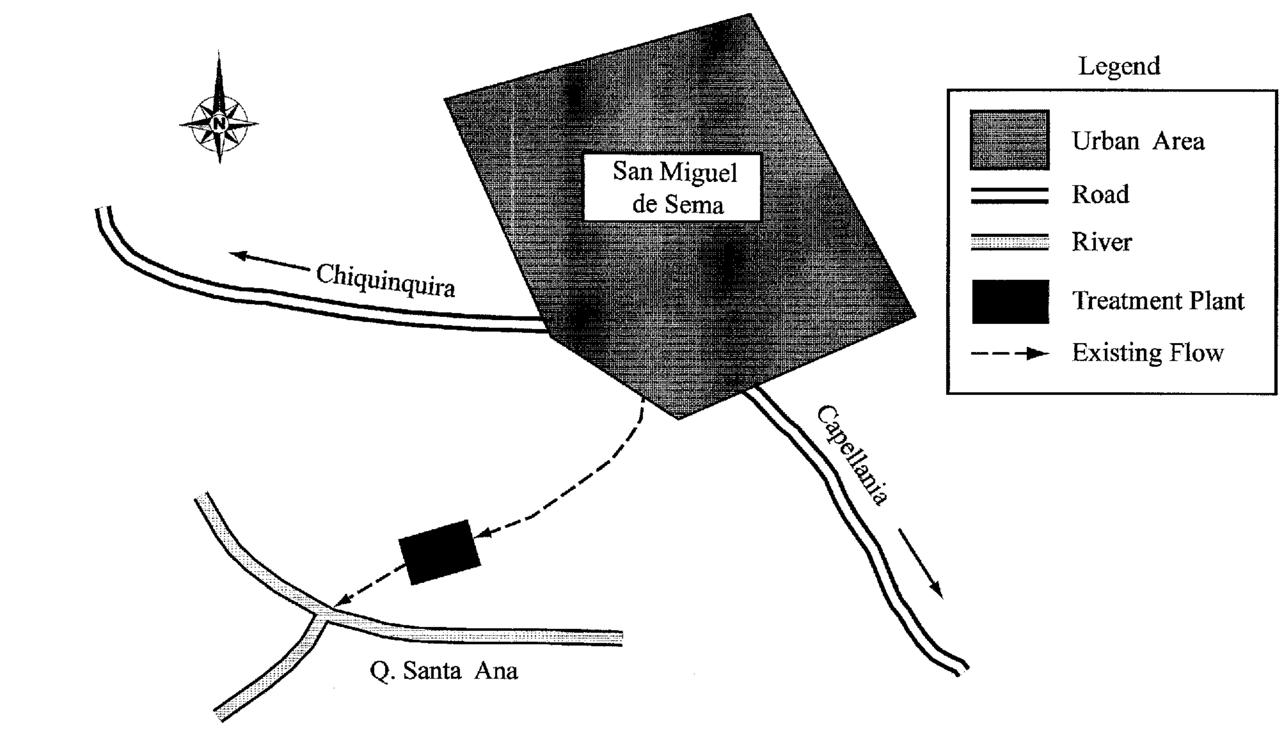


Location Map

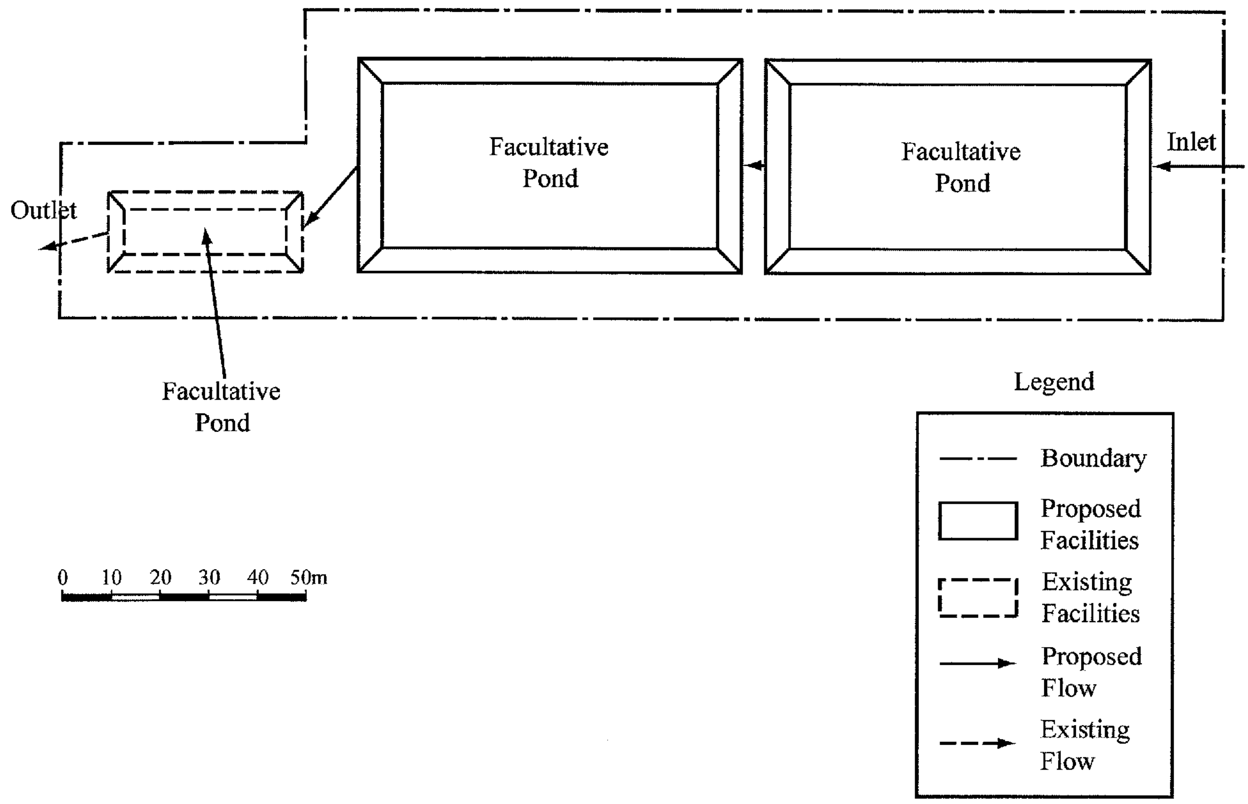


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.3 Sewerage Treatment Plant in Lenguazaque
JAPAN INTERNATIONAL COOPERATION AGENCY	

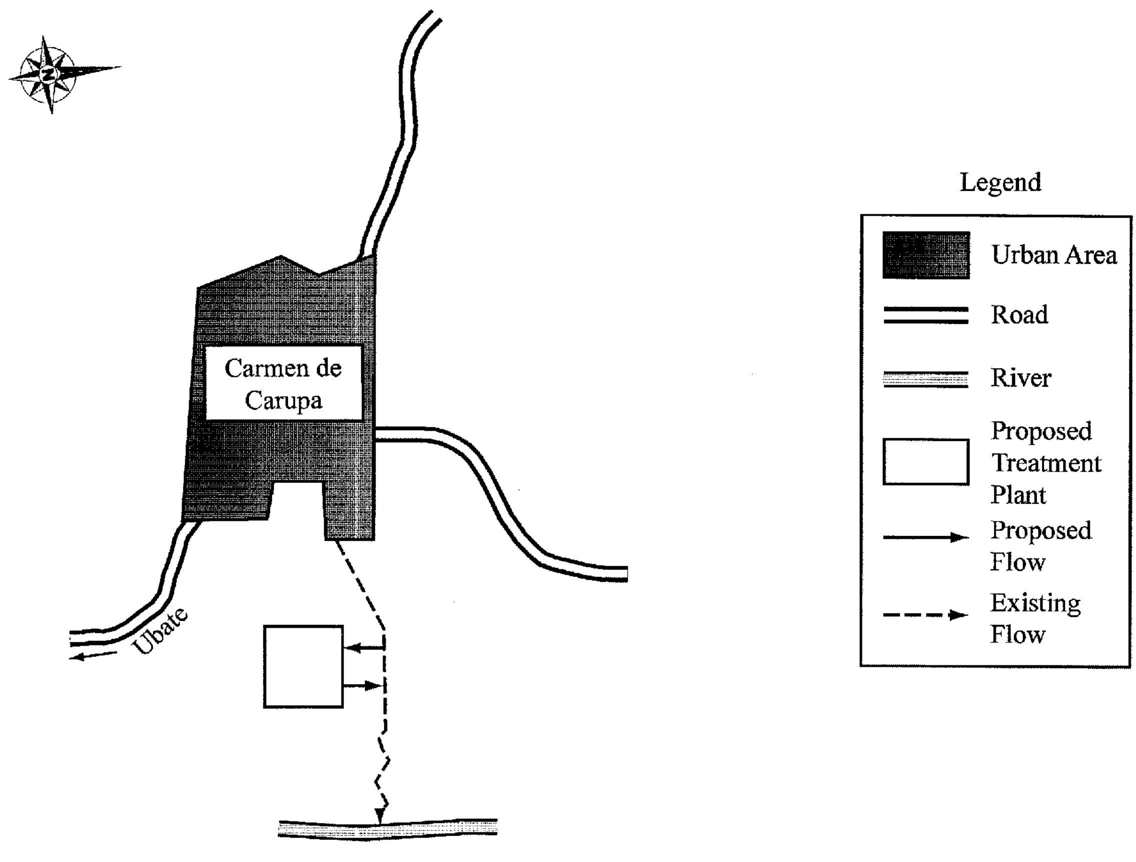


Location Map



Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.4 Sewerage Treatment Plant in San Miguel de Sema
JAPAN INTERNATIONAL COOPERATION AGENCY	



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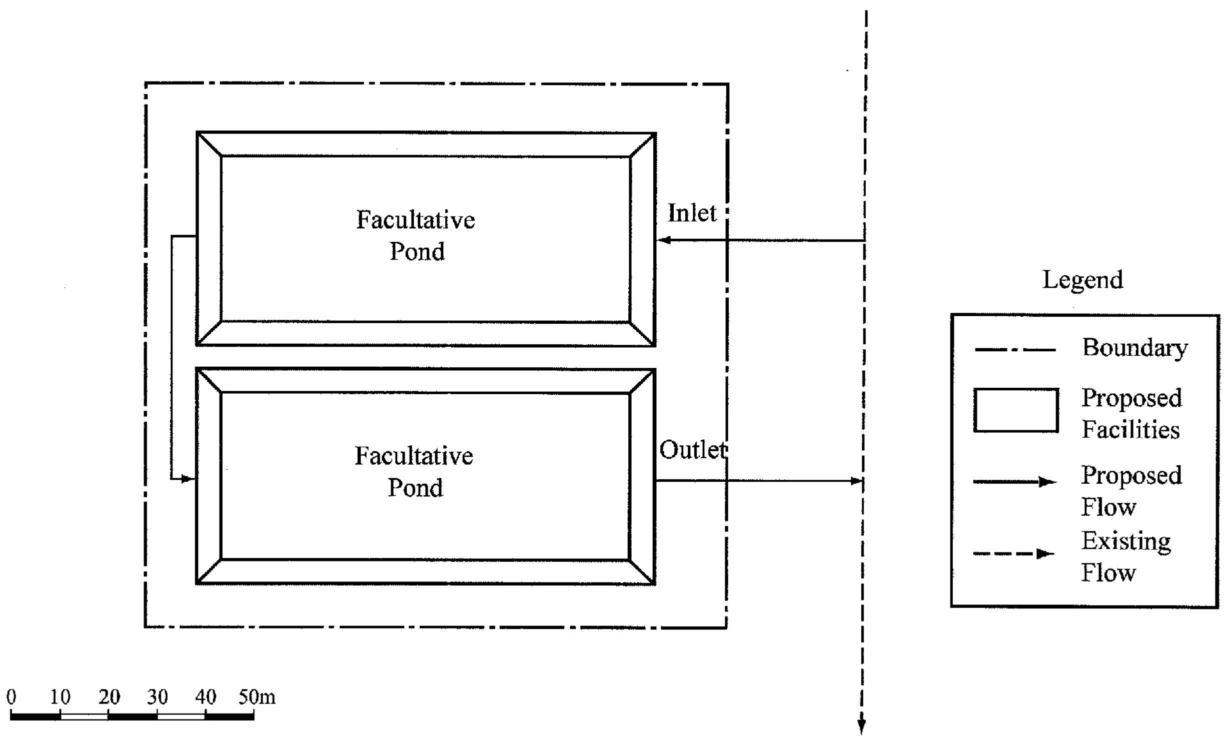
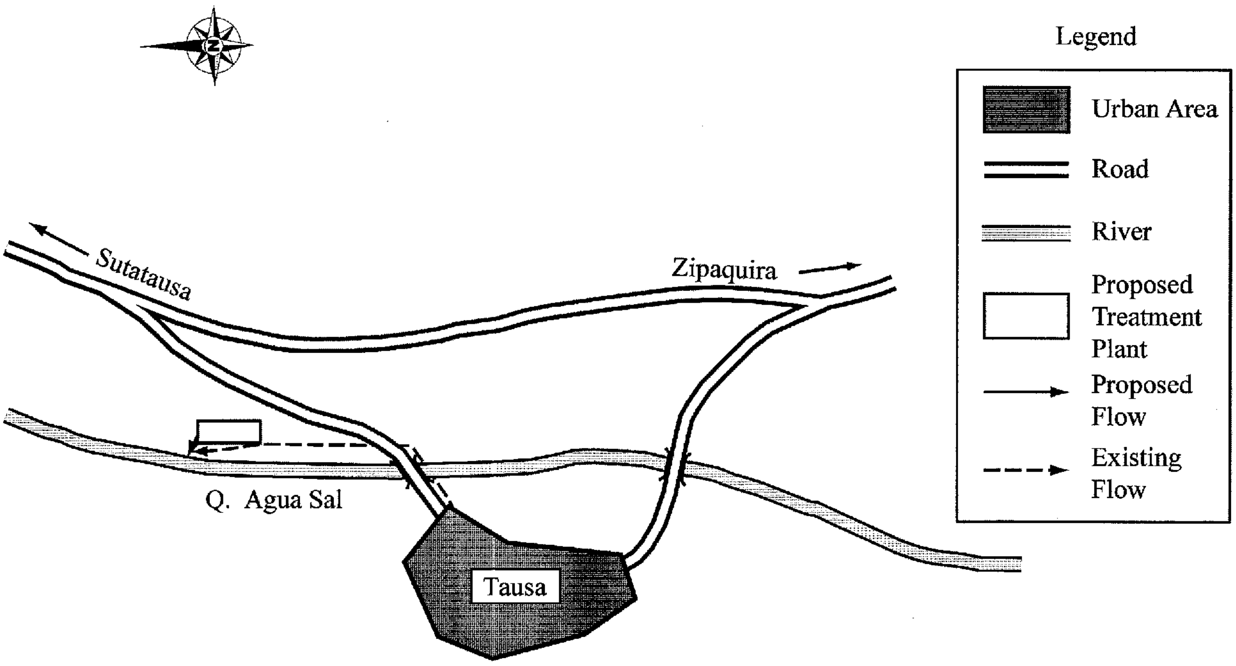
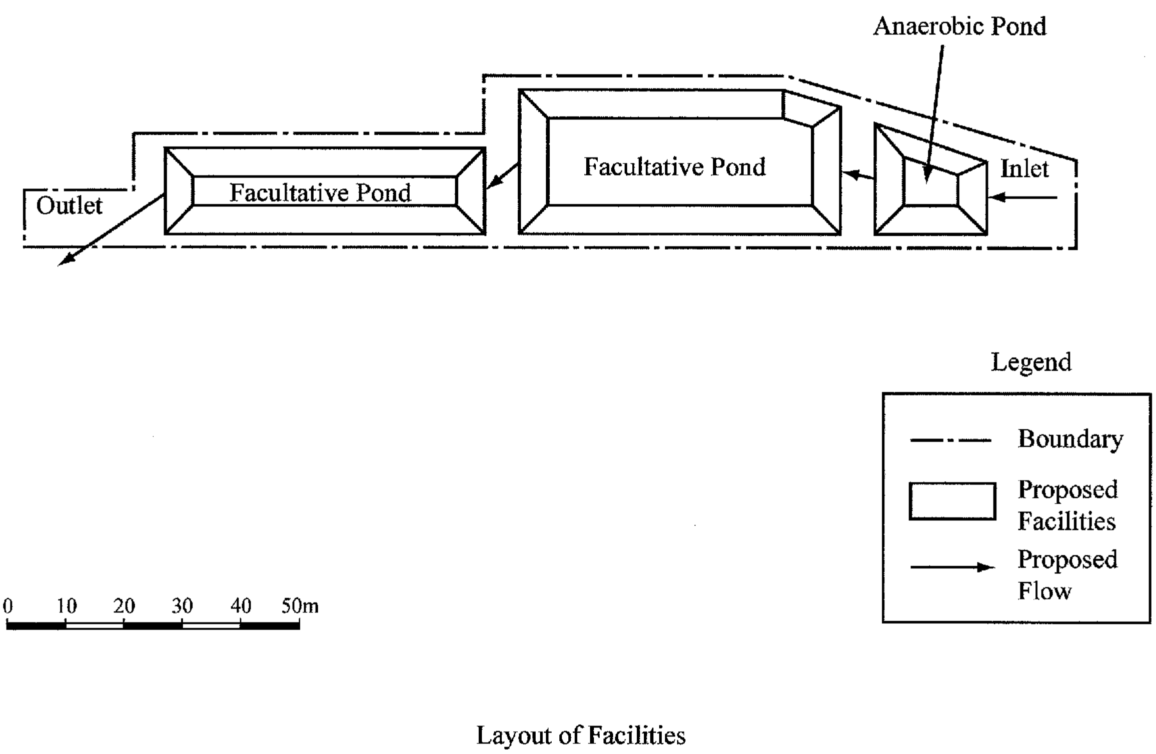


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.5 Sewerage Treatment Plant in Carmen de Carupa
JAPAN INTERNATIONAL COOPERATION AGENCY	

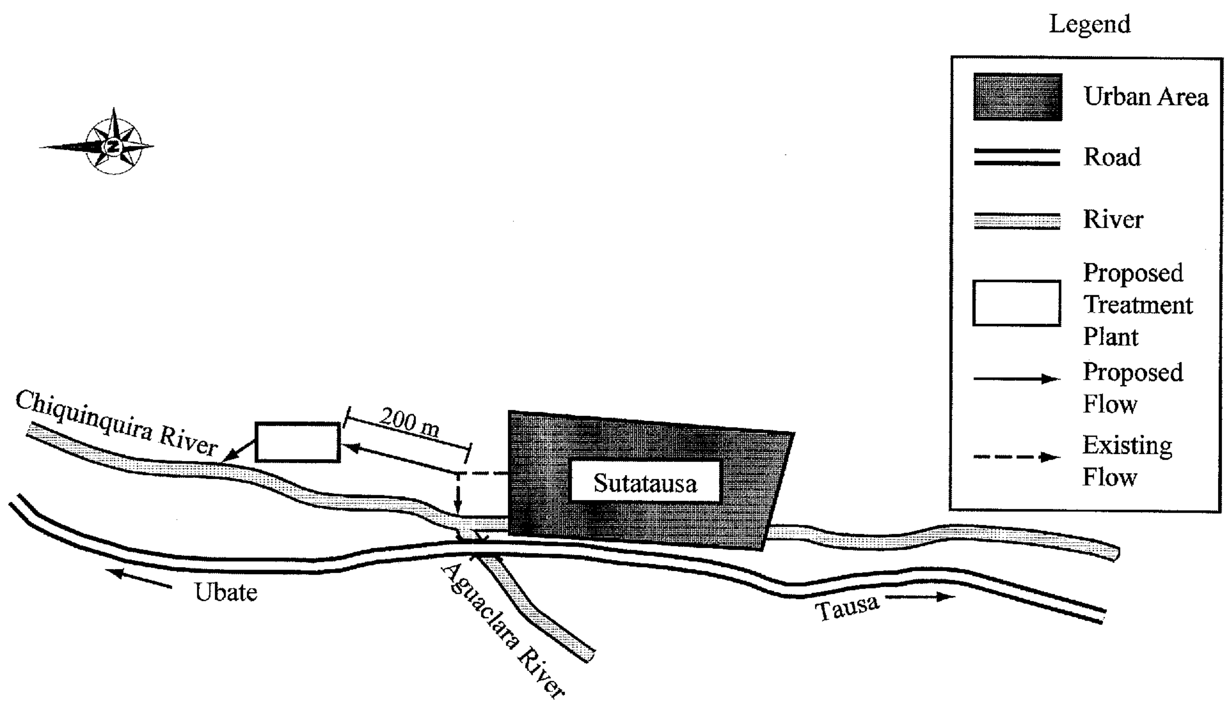


Location Map

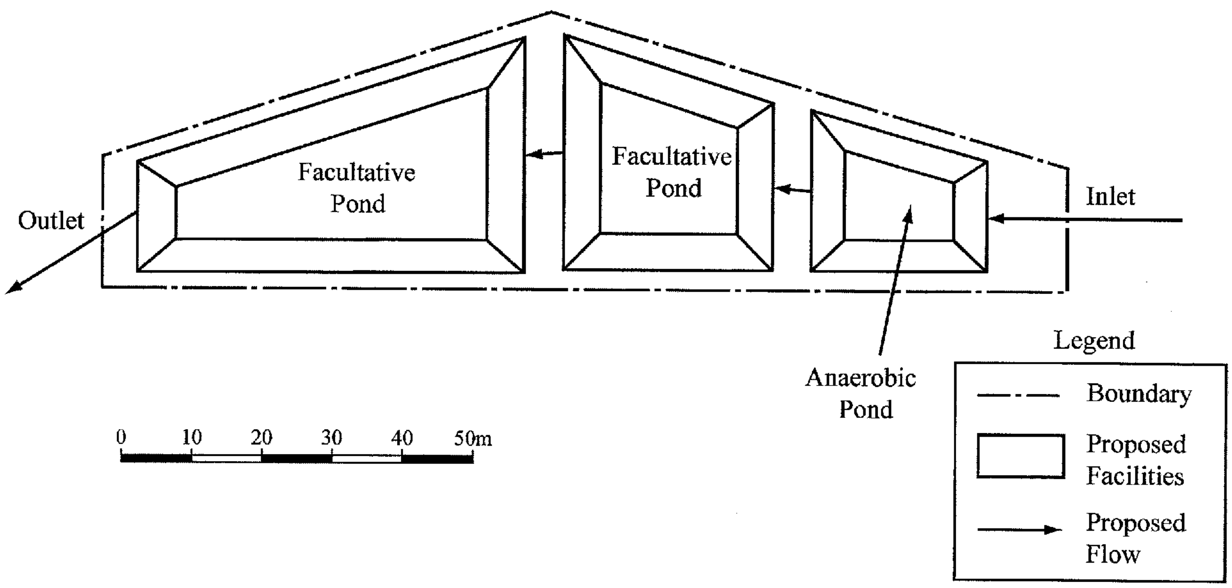


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.6 Sewerage Treatment Plant in Tausa
JAPAN INTERNATIONAL COOPERATION AGENCY	

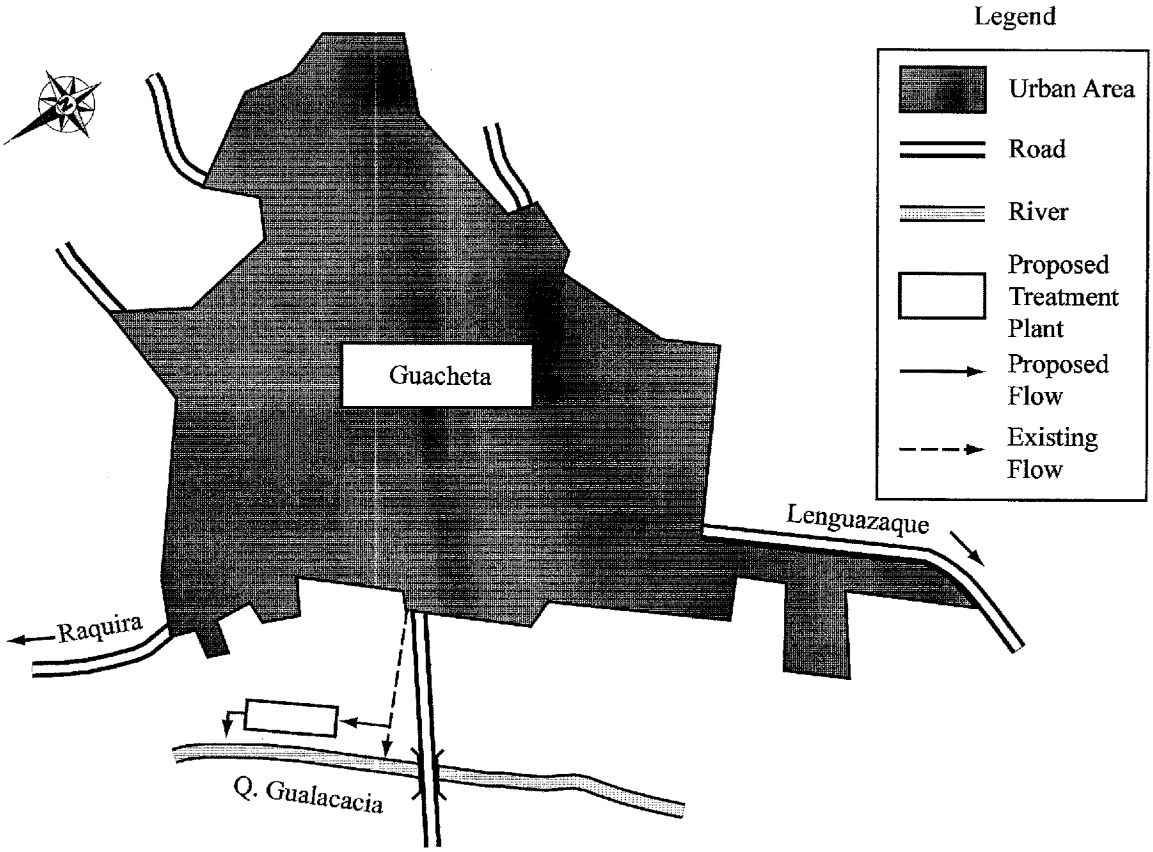


Location Map

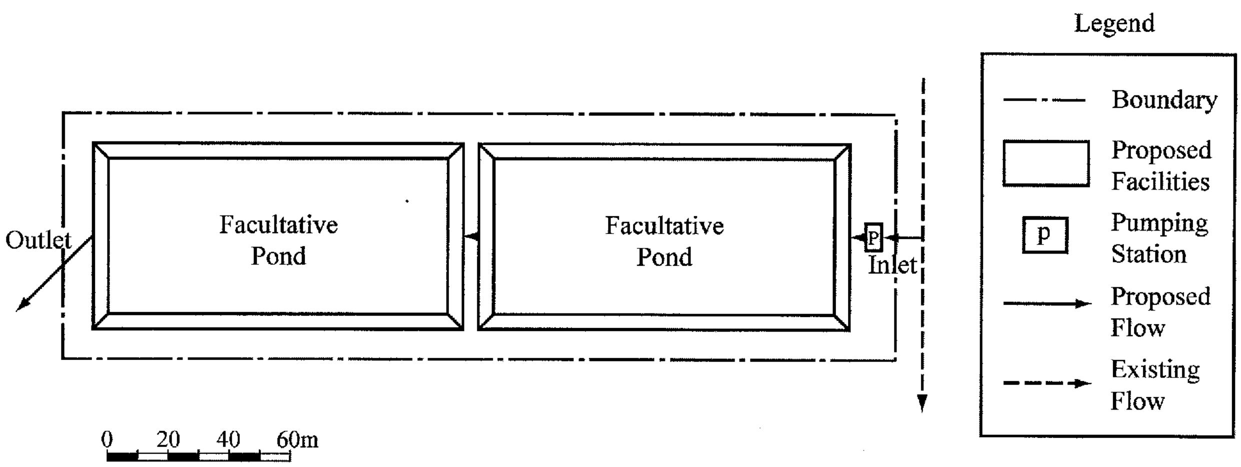


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.7 Sewerage Treatment Plant in Sutatusa
JAPAN INTERNATIONAL COOPERATION AGENCY	

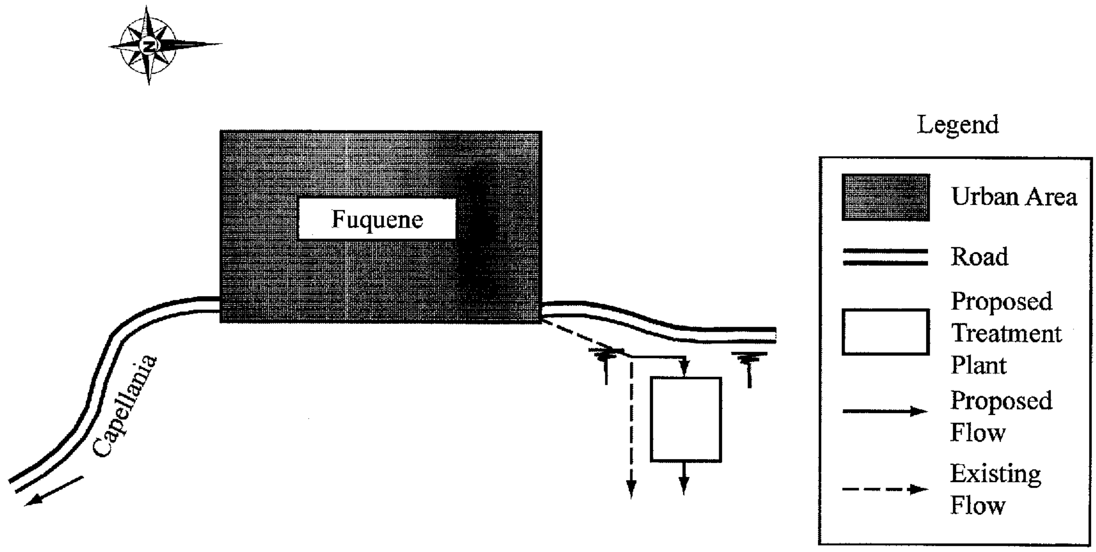


Location Map

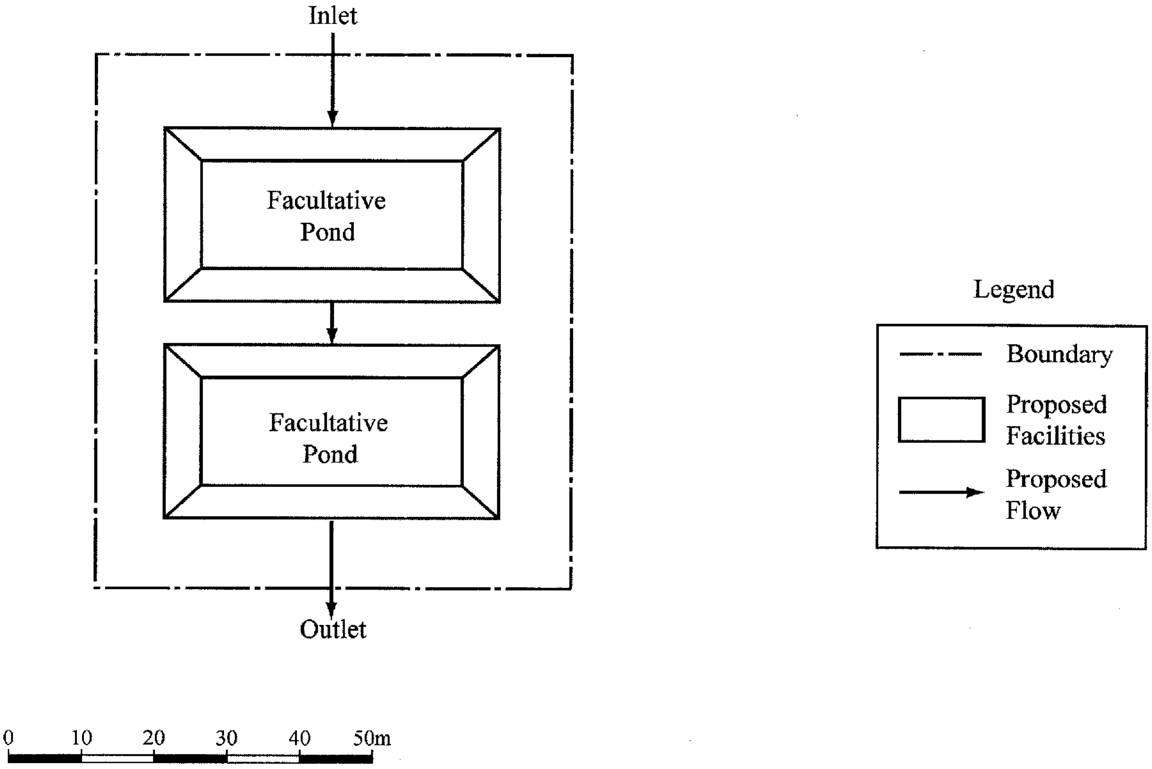


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.8 Sewerage Treatment Plant in Guacheta
JAPAN INTERNATIONAL COOPERATION AGENCY	

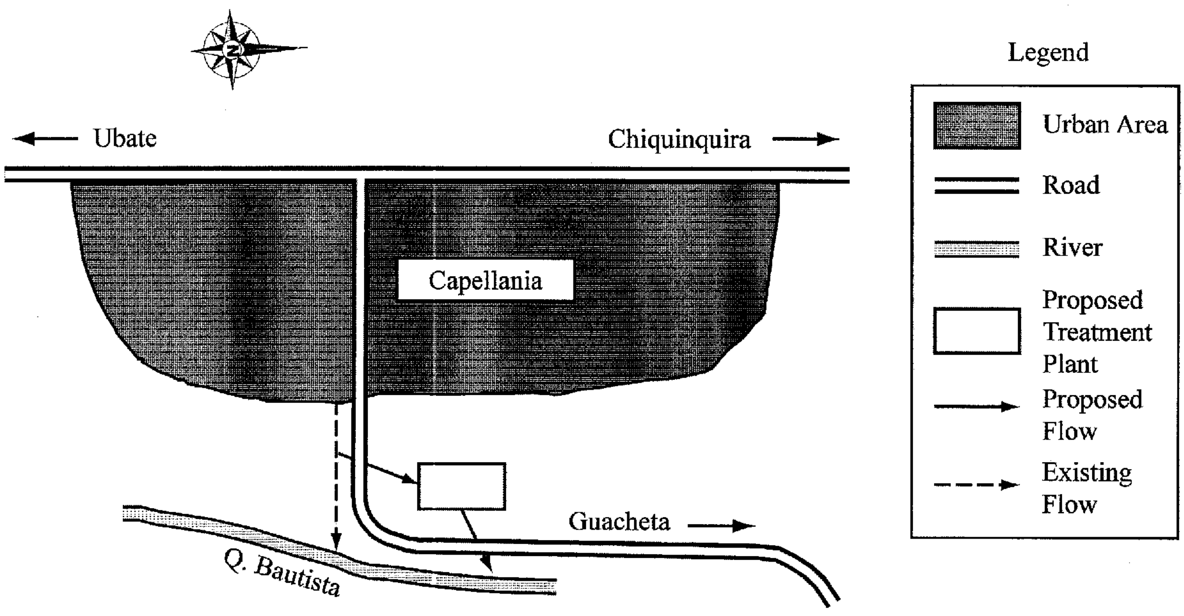


Location Map

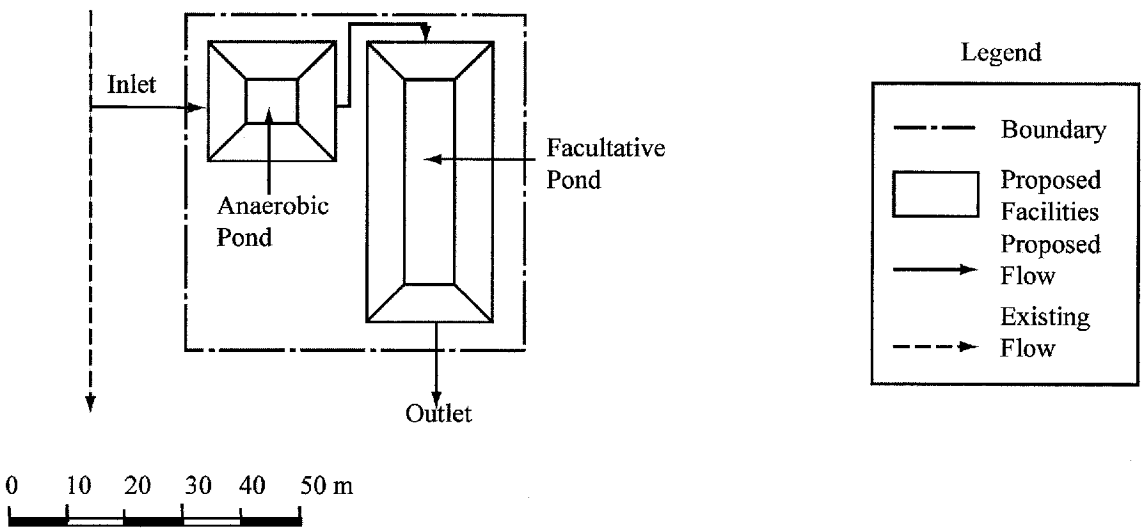


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.9 Sewerage Treatment Plant in Urban Area in Fuquene
JAPAN INTERNATIONAL COOPERATION AGENCY	

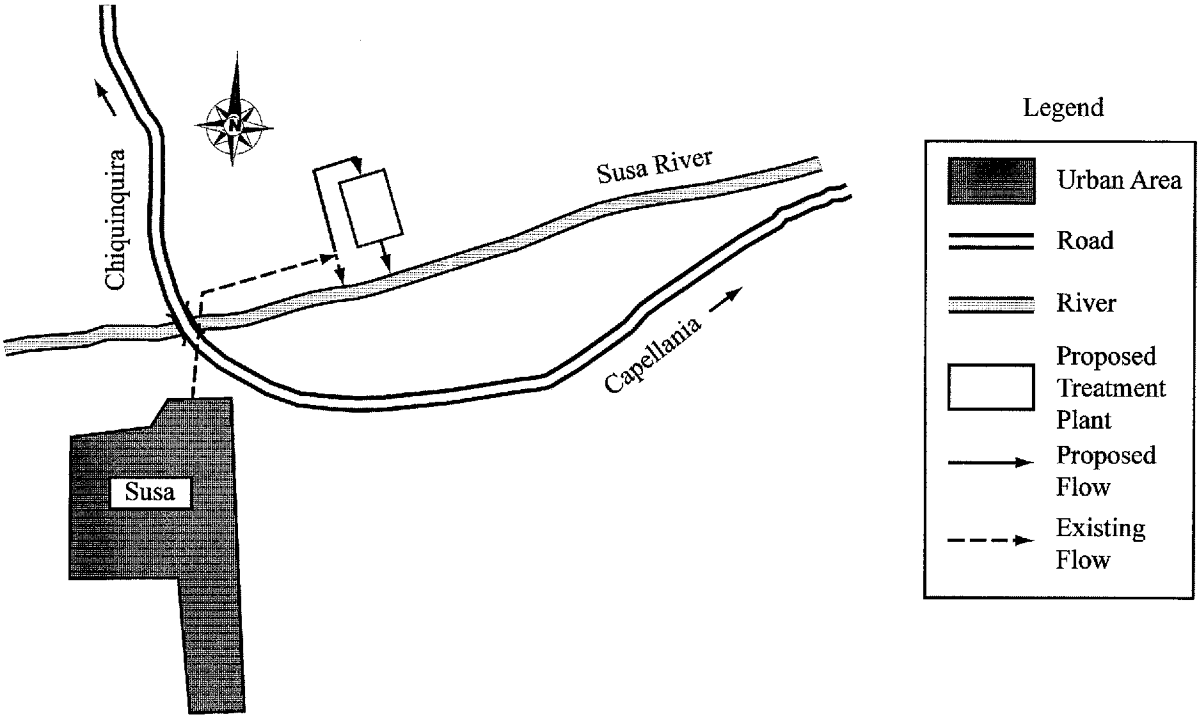


Location Map

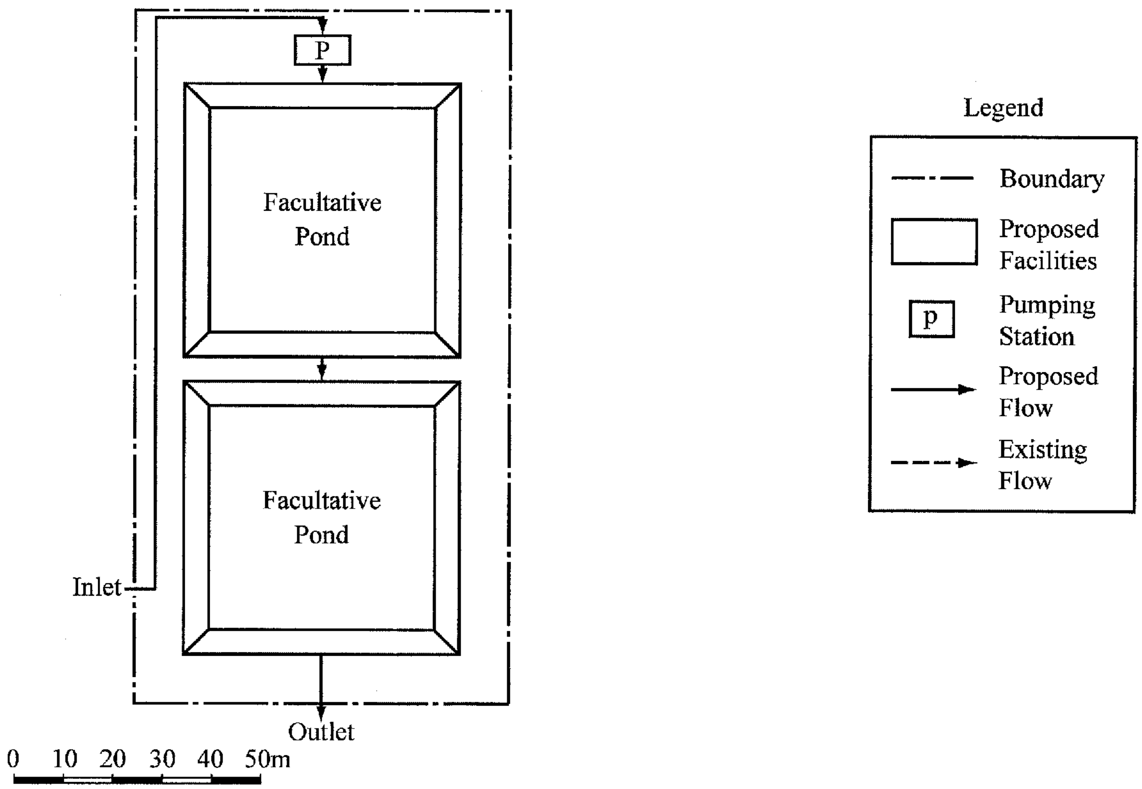


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.10 Sewerage Treatment Plant in Capellania in Fuquene
JAPAN INTERNATIONAL COOPERATION AGENCY	

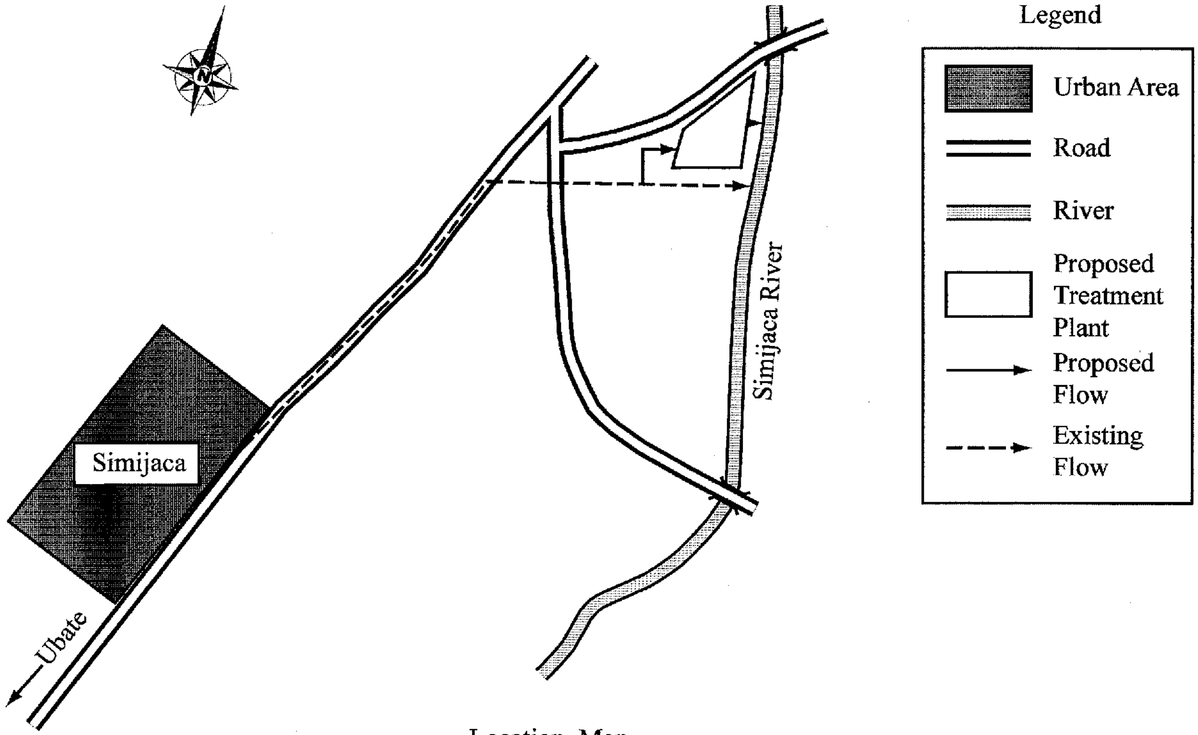


Location Map

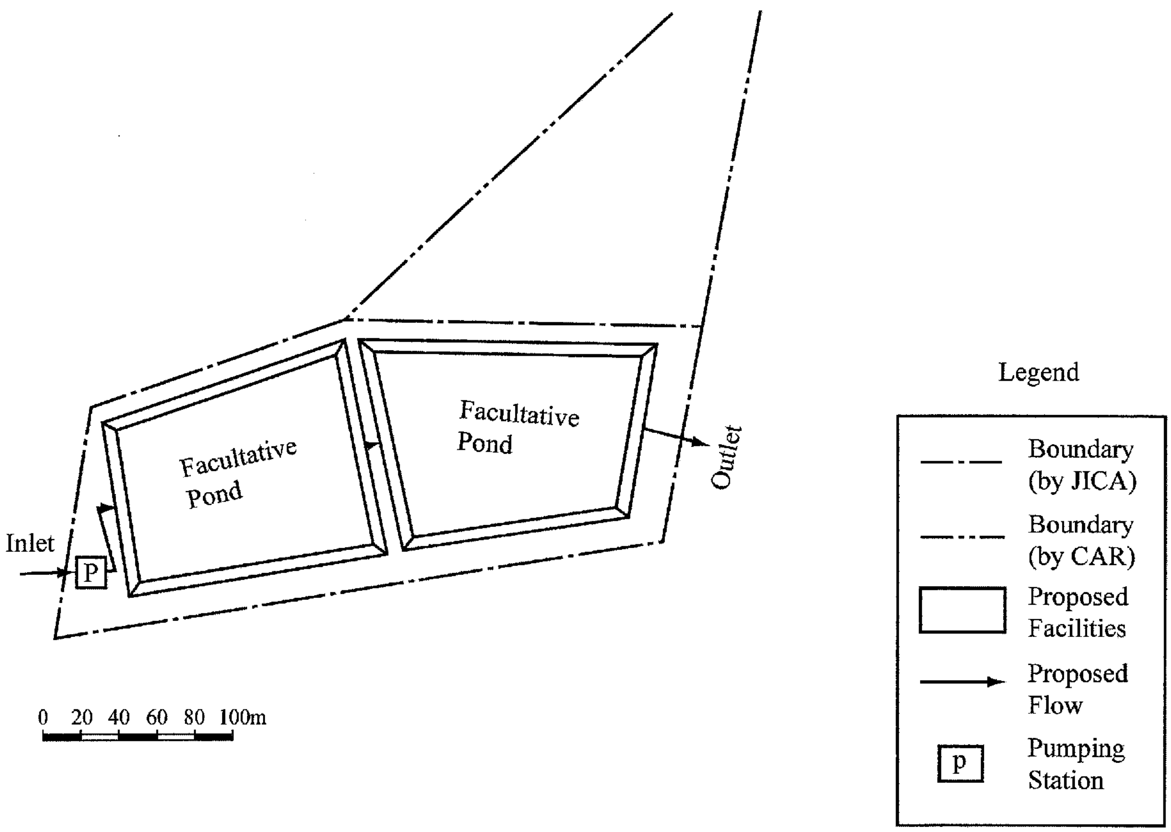


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.11 Sewerage Treatment Plant in Susa
JAPAN INTERNATIONAL COOPERATION AGENCY	

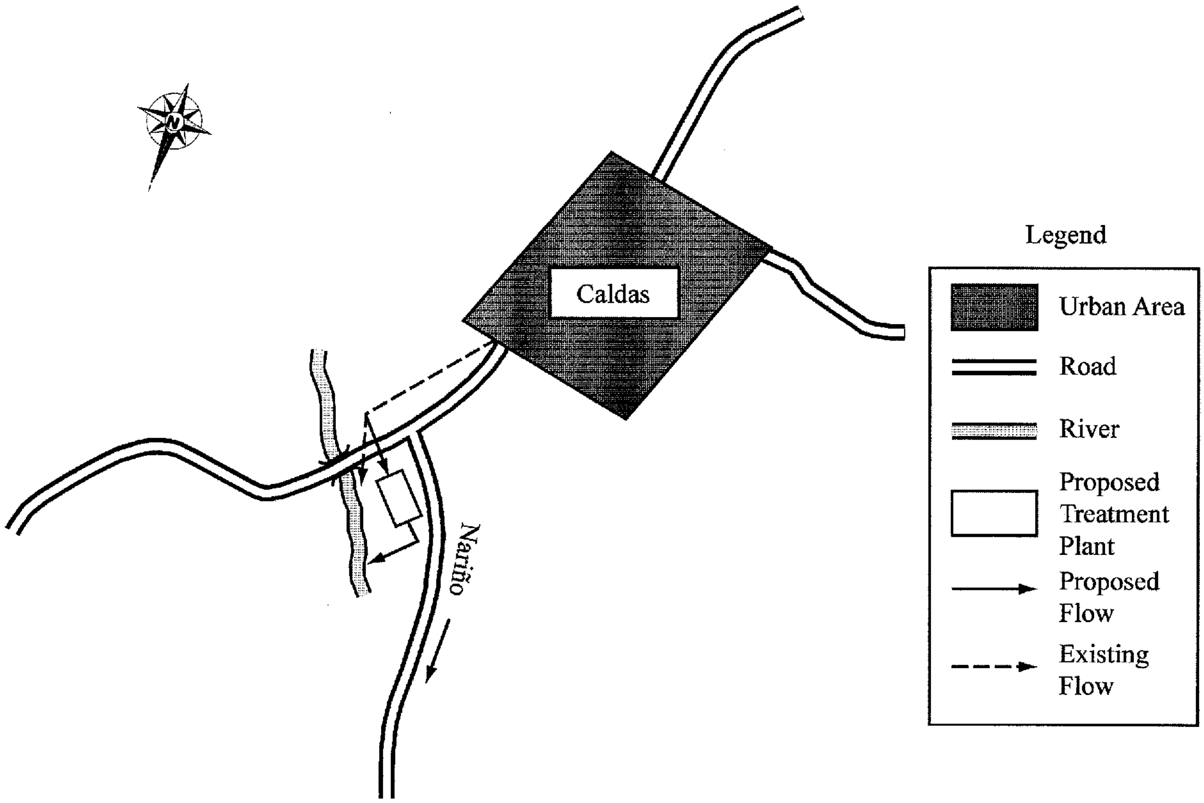


Location Map

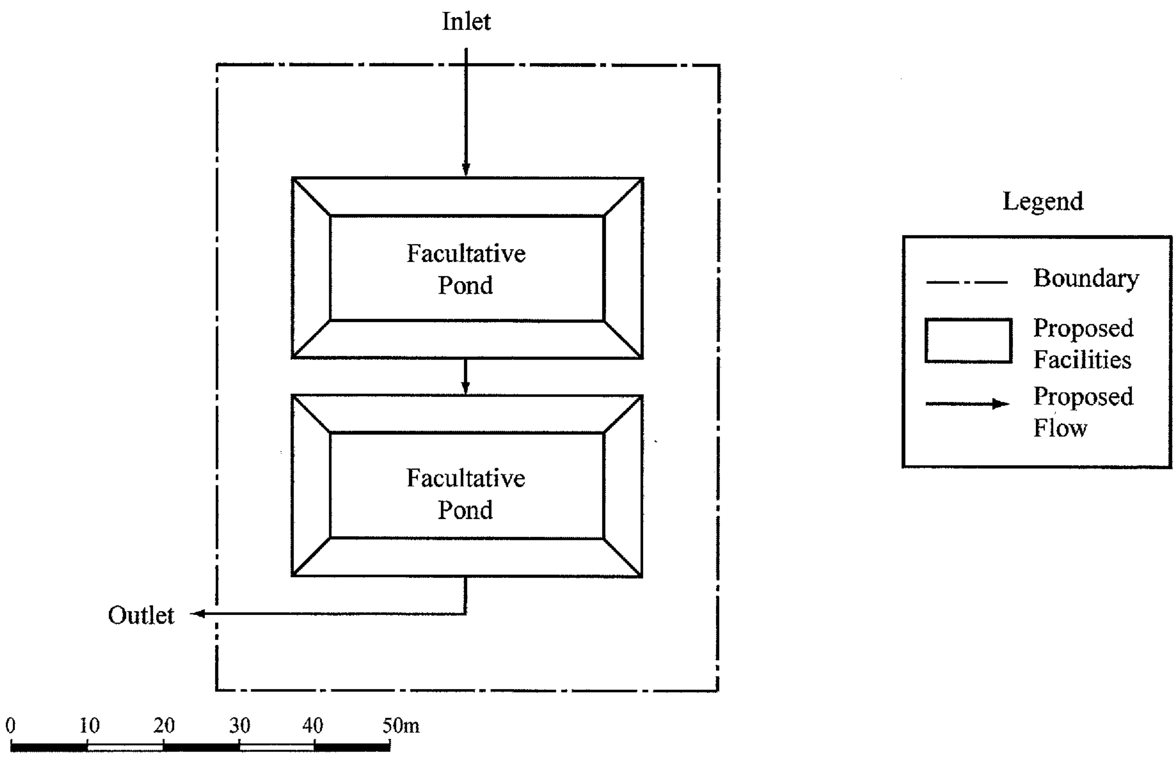


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.12 Sewerage Treatment Plant in Simijaca
JAPAN INTERNATIONAL COOPERATION AGENCY	

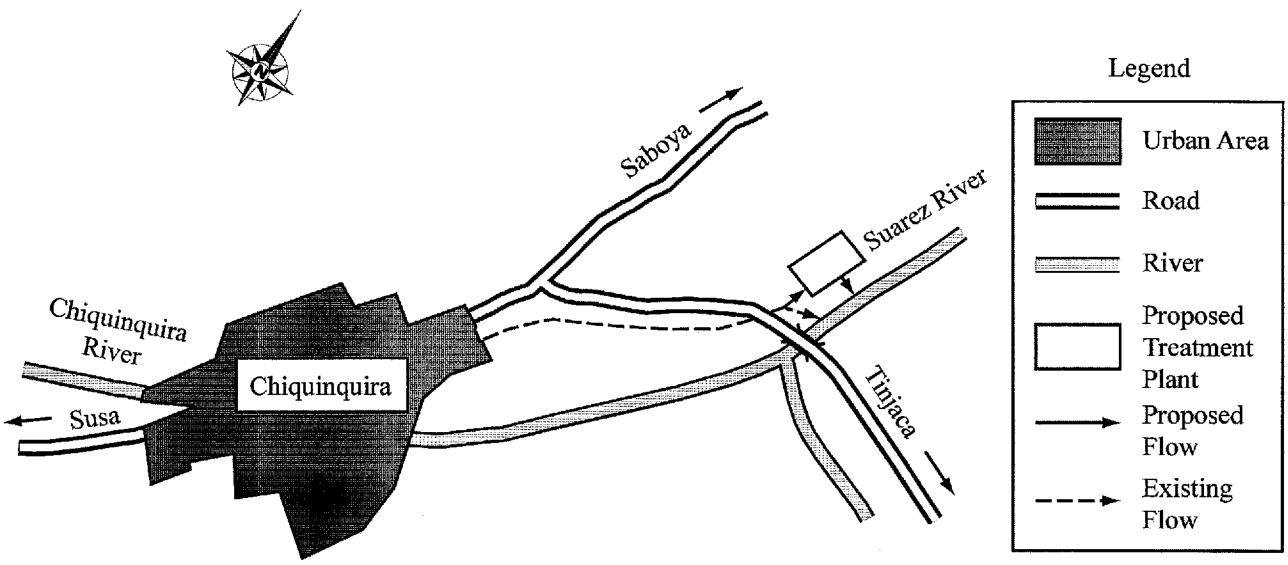


Location Map

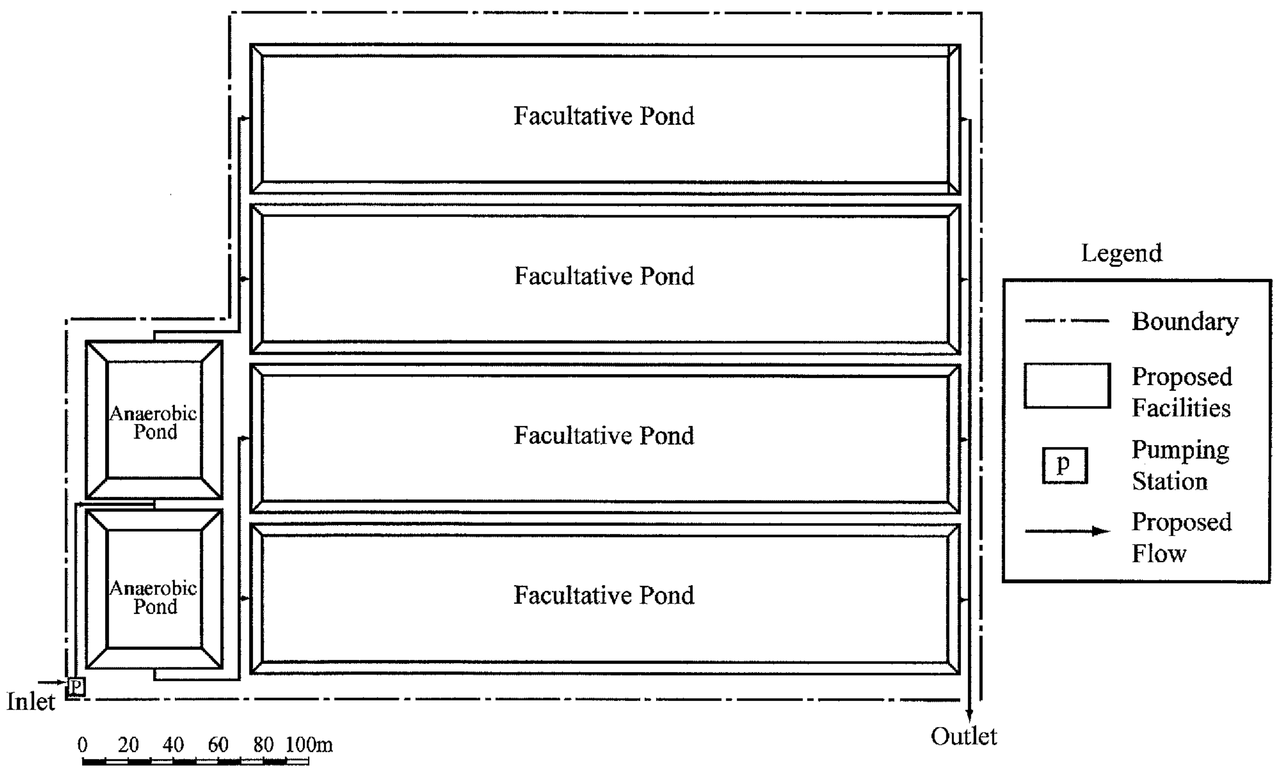


Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.13 Sewerage Treatment Plant in Caldas
JAPAN INTERNATIONAL COOPERATION AGENCY	

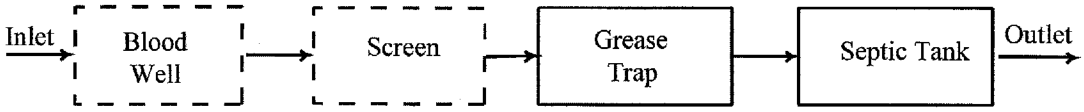


Location Map



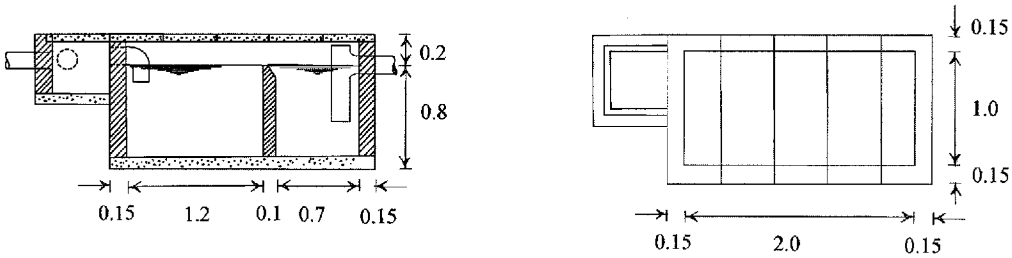
Layout of Facilities

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.14 Sewerage Treatment Plant in Chiquinquira
JAPAN INTERNATIONAL COOPERATION AGENCY	

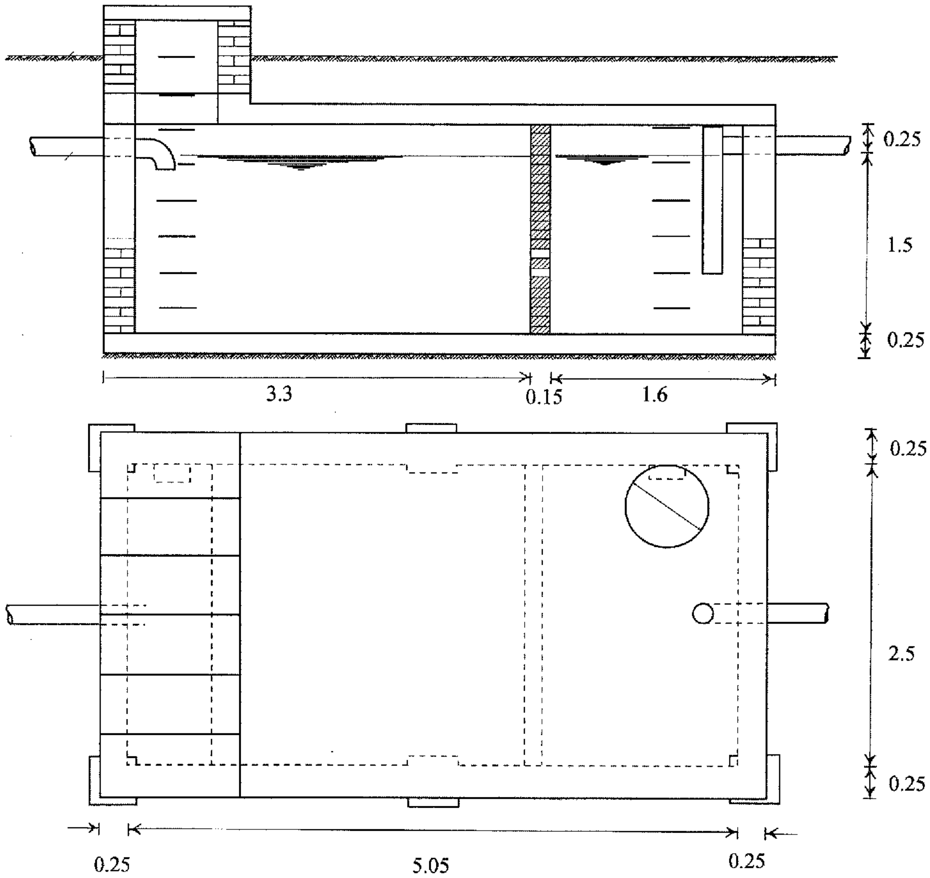


Flow

(Q = 5m^3/day)



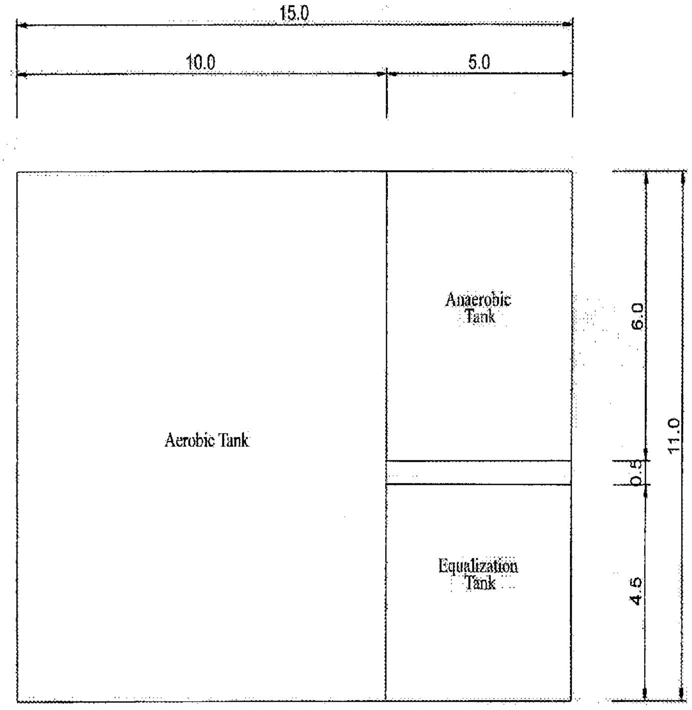
Grease Trap
(unit: m)



Septic Tank
(unit: m)

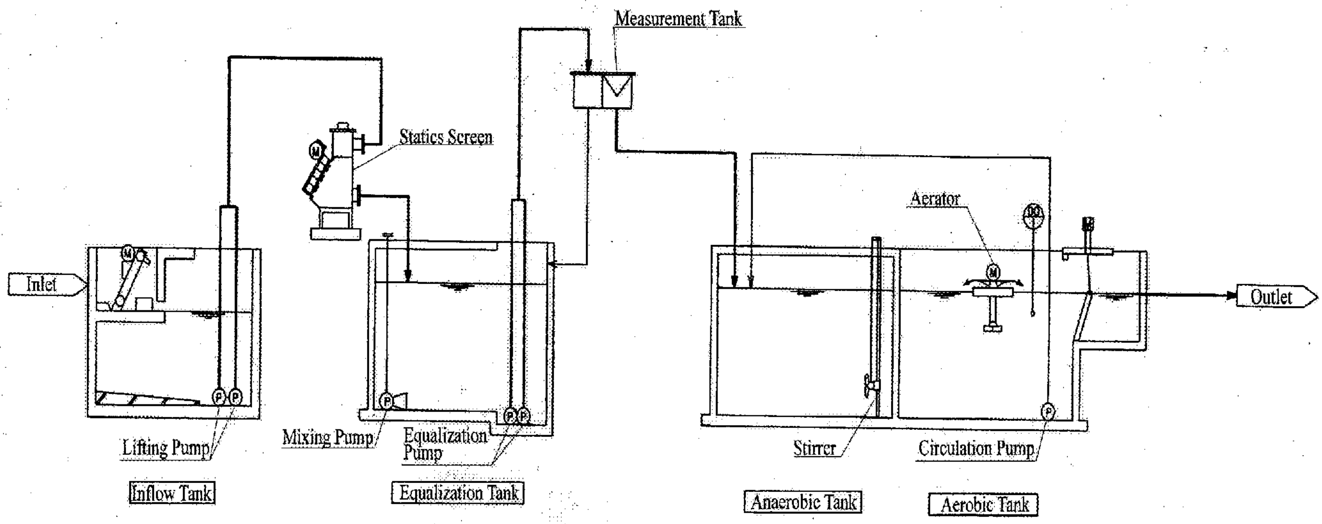
THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.15 Pre-treatment Plant of Slanghterhouse
JAPAN INTERNATIONAL COOPERATION AGENCY	

Q=42m³/day



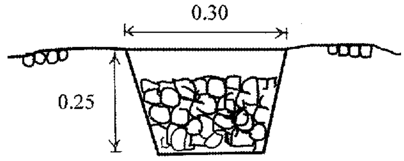
Horizontal Section

(unit : m)

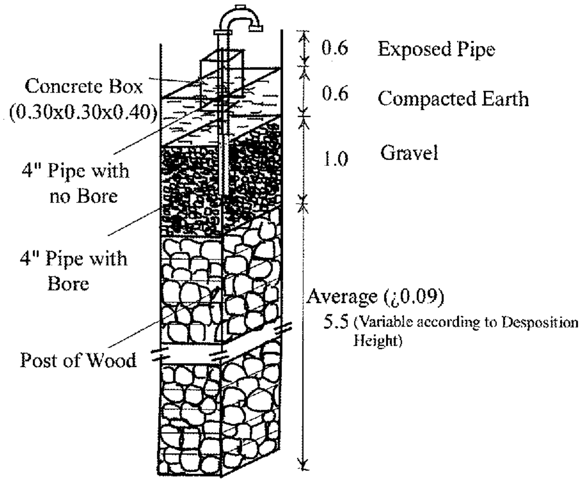


Cross Section

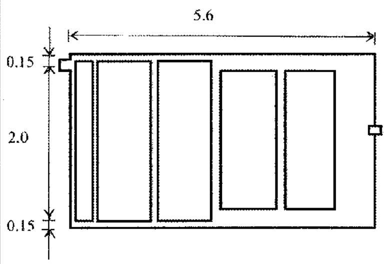
THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.16 Advanced Pre-Treatment Plant of Milk Processing Factory
JAPAN INTERNATIONAL COOPERATION AGENCY	



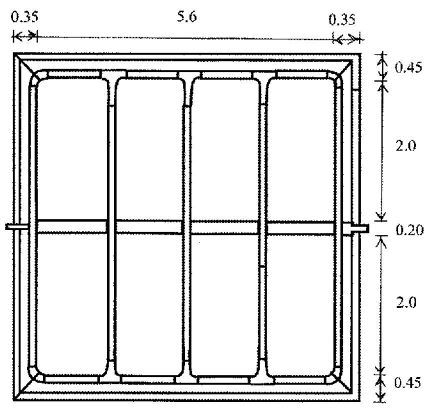
Drainage for Collecting Leachate
(unit: m)



Gas Exhaustion Pipe
(unit: m)



Primary Sedimentation Tank



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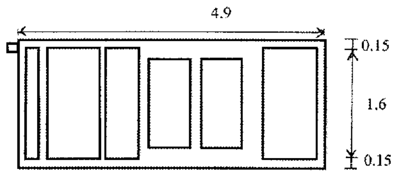
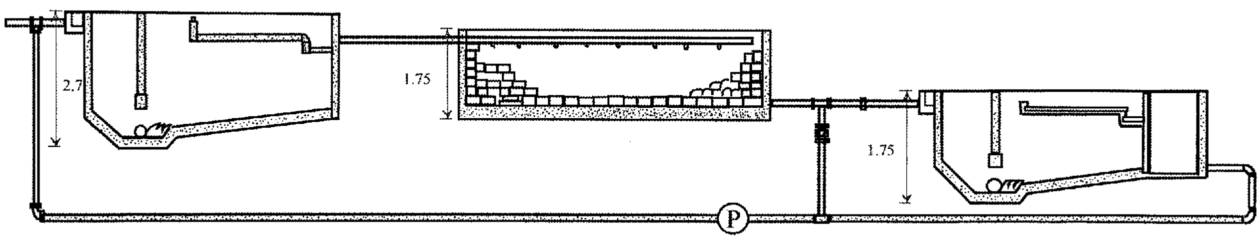


Secondary Sedimentation Tank



Leachate Treatment Plant
(unit: m)

THE STUDY ON REGIONAL ENVIRONMENTAL IMPROVEMENT PLAN FOR THE BASIN OF LAKE FUQUENE	Fig. F.2.17 Treatment System of Leachate
JAPAN INTERNATIONAL COOPERATION AGENCY	