Table 2.3-5 (2/3) Effluent Pollution Load Projection (BOD)

(Low : 2000)

Basin No.	Name of Main Area	Industrial Wastewater (kg/day)	Livestock Wastewater (kg/day)	Domestic Wastewater (kg/day)	Total (kg/day)	Rate (%)
1	Tovar	26	0	166	191	0.3
2	El Consejo	20,212	0	1,359	21,571	36.5
3	Las Tejerias	3,846	2,286	2,219	8,350	14.1
4	Qda.Guayas	815	936	271	2,022	3.4
5	Paracotos	655	0	1,519	2,174	3.7
6	R.Guare	0	1,134	102	1,236	2.1
7	Cua	73	15	1,059	1,146	1.9
8	Charallave	3,993	729	9,366	14,088	23.8
9	Ocumare del Tuy	2,593	0	5,749	8,342	14.1
	Total	32,212	5,100	21,809	59,121	100.0

(Low : 2005)

Basin No.	Name of Main Area	Industrial Wastewater (kg/day)	Livestock Wastewater (kg/day)	Domestic Wastewater (kg/day)	Total (kg/day)	Rate (%)
1	Tovar	33	0	165	197	0.3
2	El Consejo	33,311	0	1,433	34,744	44.2
3	Las Tejerias	4,793	2,286	2,302	9,381	11.9
4	Qda.Guayas	1,038	936	279	2,253	2.9
5	Paracotos	865	0	1,570	2,435	3.1
6	R.Guare	0	1,134	102	1,236	1.6
7	Cua	88	15	1,275	1,378	1.8
8	Charallave	4,897	729	11,445	17,071	21.7
9	Ocumare del Tuy	3,374	0	6,492	9,866	12.6
	Total	48,400	5,100	25,063	78,562	100.0

(Low : 2010

Basin No.	Name of Main Area	Industrial Wastewater (kg/day)	Livestock Wastewater (kg/day)	Domestic Wastewater (kg/day)	Total (kg/day)	Rate (%)
1	Tovar	41	0	165	205	0.2
2	El Consejo	48,496	0	1,507	50,003	49.4
3	Las Tejerias	5,891	2,286	2,376	10,552	10.4
4	Qda.Guayas	1,297	936	284	2,518	2.5
5	Paracotos	1,108	0	1,618	2,727	2.7
6	R.Guare	0	1,134	103	1,237	1.2
7	Cua	106	15	1,534	1,655	1.6
8	Charallave	5,945	729	13,993	20,667	20.4
9	Ocumare del Tuy	4,279	0	7,335	11,614	11.5
	Total	67,164	5,100	28,914	101,178	100.0

Table 3.1-1 (1/2) Summary of Key Issues for Water Quality

Major Problem

Organic Pollution	Toxicant	Turbidity

- Destruction of original function (place of aquatic life) of the river
- Problem on water supply
  - Suspension of intake
  - Use of much chlorine (effect to human health)
  - High treatment cost for color, odor, etc.
	- Potential damage to human health
	- Problem on water supply
	  - Suspension of intake
	  - Effect to human health
		- Destruction of esthetic environment of the river
		- Problem on water supply
		  - Suspension of intake
		  - High pre-treatment cost to remove sediment

Indicator

Organic Pollution	Toxicant	Turbidity
- BOD (coliform is represented by BOD)	- Heavy metals (Pb, Cr, Cu, Zn)	- SS

Pollution Source

Organic Pollution	Toxicant	Turbidity
Factory: Alcohol, Food, Textile, Others Piggery Residence	Factory: Metal plating, Tannery, Others	Factory: Sand quarry, organic pollution Basin: Basin erosion

Ongoing Pollution Control Efforts (Technical Measure)

Organic Pollution	Toxicant	Turbidity
<u>Factories and Piggeries</u> - Most of the factories have plans to install treatment plants prepared with the assistance of a consultant - There are also studies by GTZ for the installation of treatment plants of several representative factories and for improvement in production process <u>Domestic Wastewater</u> - Sewerage networks (could be used in the future) have been established in major urban centers	<u>Factories</u> - Treatment is basically conducted	<u>Factory (Sand Quarry)</u> - Some are installed with sand settling ponds, and in these factories, turbidity of effluent is less <u>Other Factories</u> - Same with the items in the column of factories for organic pollution <u>Countermeasure for use</u> - Hidrocapital uses pre-treatment for removal of turbidity <u>Basins erosion</u> - No countermeasures are conducted

Present Problems (Technical Aspect)

Organic Pollution	Toxicant	Turbidity
<u>Factories and Piggeries</u> - Only 50% of the factories have treatment plant and actual installation of treatment plants is not progressing well due to lack of funds - In addition, necessity of	<u>Factory</u> - Due to bad maintenance, toxicant flows from some factories. - Factories lack in technical staff for maintaining treatment plants and O&M is not properly conducted - Necessity of treatment to	<u>Factory (Sand Quarry)</u> - Actual installation of the plants is not in good progress due to lack of funds - Necessity of treatment to meet the water quality standard is not well recognized by owners, thus education is necessary <u>Other Factories</u>

(to be continued)

Table 3.1-1 (2/2) Summary of Key Issues for Water Quality

(continued from the previous page)

treatment to meet the water quality standards is not well recognized by owners, thus education is necessary - Factories lack in technical staff for maintaining treatment plants and O&M is not properly conducted <u>Domestic Wastewater</u> - Treatment plants are either not installed or inoperable except in some residential complexes and the overall treatment rate is very low	meet the water quality standard is not well recognized by owners, thus education is necessary	- The same with the items in the column of factories and piggeries for organic pollution <u>Countermeasure for use</u> - Cost for pre-treatment is high for the removal of sediment <u>Basins erosion</u> - No countermeasures are being conducted

Institutional Measures already Undertaken and Present Problems

Organic Pollution	Toxicant	Turbidity

<u>Laws and Regulations</u>

Laws and regulations are sufficient to a large extent.

Current water quality standards Decree No.883 do not include a limit for BOD; it should be included

- Installation of treatment plants by factories is not progressing well; provision of necessary laws and regulations for a support system is needed

<u>Enforcement of Laws</u>

- Enforcement of these laws and regulations are not adequately conducted.
- Application of punitive action is necessary in combination with a strong support system.
- Monitoring is conducted with the assistance of GTZ; strengthening of the monitoring system is necessary for the enforcement of the laws.

<u>Organization and Operational Management</u>

- Training in environmental aspect is needed for the technical personnel of ACRT
- Strengthening of function of ACRT is needed
- Budget of ACRT is not sufficient

<u>Public Awareness of the Environment</u>

- Environmental education is performed by ACRT; it should be strengthened
- Seminars focusing on manufacturers have been conducted by the program of GTZ; it should be strengthened
- Appropriate countermeasures should be taken for forest fire that cause devastation of the basin and resultant erosion and sediment discharge

Table 3.1-2 BOD Production and Effluent Load by Sub-basin (1995)

Area Name	Category	Production			Discharge			Area
		Load (kg/day)	Rate(1) (%)	Rate(2) (%)	Load (kg/day)	Rate(1) (%)	Rate(2) (%)	(km2)
Tovar and other	Industrial	38	11.7		19	10.1		
	Livestock	0	0.0		0	0.0		
	Domestic	285	88.3		168	89.9		
	Sub total	323	100.0	0.3	187	100.0	0.4	240.7
El Consejo C.Tiquirito and other	Industrial	51,949	97.2		7,792	84.0		
	Livestock	0	0.0		0	0.0		
	Domestic	1,482	2.8		1,482	16.0		
	Sub total	53,431	100.0	54.1	9,275	100.0	22.4	46.0
Las Tejerias Q.Morocopo and other	Industrial	5,083	37.7		2,948	39.3		
	Livestock	6,140	45.5		2,286	30.5		
	Domestic	2,262	16.8		2,262	30.2		
	Sub total	13,485	100.0	13.7	7,496	100.0	18.1	132.8
Q.Guayas and other	Industrial	1,173	30.5		603	33.5		
	Livestock	2,414	62.7		936	52.0		
	Domestic	261	6.8		261	14.5		
	Sub total	3,848	100.0	3.9	1,800	100.0	4.3	106.9
Paracotos Q.Maitana and other	Industrial	570	26.6		456	22.5		
	Livestock	0	0.0		0	0.0		
	Domestic	1,571	73.4		1,571	77.5		
	Sub total	2,141	100.0	2.2	2,027	100.0	4.9	284.8
R.Guare (including Tacata)	Industrial	0	0.0		0	0.0		
	Livestock	0	0.0		0	0.0		
	Domestic	96	100.0		96	100.0		
	Sub total	96	100.0	0.1	96	100.0	0.2	181.6
Tacata-Tazon (Sabaneta)	Industrial	0	0.0		0	0.0		
	Livestock	1,134	96.5		1,134	97.9		
	Domestic	41	3.5		24	2.1		
	Sub total	1,175	100.0	1.2	1,158	100.0	2.8	55.8
R.Tarma part of Cua and other	Industrial	74	7.5		59	6.2		
	Livestock	49	4.9		15	1.5		
	Domestic	874	87.7		874	92.3		
	Sub total	997	100.0	1.0	947	100.0	2.3	218.0
Charallave, part of Cua and other	Industrial	4,572	33.2		3,135	27.2		
	Livestock	1,458	10.6		729	6.3		
	Domestic	7,732	56.2		7,654	66.4		
	Sub total	13,762	100.0	13.9	11,518	100.0	27.8	357.4
Ocumare del Tuy S.F de Yare and other	Industrial	3,213	33.9		1,853	26.6		
	Livestock	1,118	11.8		0	0.0		
	Domestic	5,152	54.3		5,117	73.4		
	Sub total	9,483	100.0	9.6	6,970	100.0	16.8	226.8
TOTAL		98,740	-	100.0	41,474	-	100.0	1,850.8

Note : Rate(1) is against each areas
Rate(2) is against whole areas

Table 3.1-3 Present Removal Rate by Pollution Source

Factory (mg/l)

Category		BOD			COD			SS		
		before	after	rate (%)	before	after	rate (%)	before	after	rate (%)
Food	F-1	67,200	2,220	96.7	110,361	11,496	89.6	14,700	2,453	83.3
	F-3	4,320	14	99.7	2,131	73	96.6	1,630	3	99.8
	F-4	1,920	34	98.2	4,133	32	99.2	1,063	216	79.7
	F-8	300	14	95.3	376	143	62.0	288	188	34.7
	F-9	288	5	98.3	413	58	86.0	256	228	10.9
	F-10	315	185	41.3	765	335	56.2	179	68	62.0
	Ave			88.2			81.6			61.7
Non-Food	N-26	10	4	60.0	58	10	82.8	214	92	57.0
	N-18	20	20	0.0	166	100	39.8	190	316	-66.3
	N-41		192		4,035	3,242	19.7	456	324	28.9
	N-42				184	376	-104.3	192	224	-16.7
	N-27	150			428	317	25.9	92	280	-204.3
	N-34	16	2	87.5	754	6,110	-710.3	522	1,768	-238.7
	N-35	635	177	72.1	714	547	23.4	40	224	-460.0
	N-40	42	54	0.0	120	280	-133.3	8	8	0.0
	Ave			43.9			-94.6			-112.5

Piggery (mg/l)

	BOD			COD			SS		
	before	after	rate (%)	before	after	rate (%)	before	after	rate (%)
P-8	8,976	47	99.5	20,800	640	96.9	22,625	81	99.6
P-5	3,100	116	96.3	13,705	896	93.5	5,870	146	97.5
P-13	14,500	1,170	91.9	11,049	1,832	83.4	5,900	333	94.4
Ave			95.9			91.3			97.2

Household (mg/l)

	BOD			COD			SS		
	before	after	rate (%)	before	after	rate (%)	before	after	rate (%)
D-7	101	56	44.6	60	119	-98.3	48	32	33.3

Table3.1-4 Decrease of Pollution Load by Removing of Solid for Piggery

Removal rate of solids			0%	50%	70%	90%
BOD	feces	(g)	183	92	55	18
	urine	(g)	15	15	15	15
	total	(g)	198	107	70	33
	Treatment rate	(%)	-	54	35	17
	Concentration	(mg/*l*)	33,000	24,000	18,000	10,000
SS	feces	(g)	669	335	200	67
	urine	(g)	14	14	14	14
	total	(g)	683	349	214	81
	Treatment rate	(%)	-	51	31	12
	Concentration	(mg/*l*)	117,000	78,000	54,000	25,000

Source: A Guide of Treatment in Livestock Wastewater(1978)

Table 3.1-5 Removal Rate of Heavy Metals at Factoies

(μg/l)

Category		Pb (SD=50)			Cr (SD=50)			Cu (SD=1000)		
		before	after	rate	before	after	rate	before	after	rate
Non-Food	N-26	<250	<250	-	333	<50	15	168	64	38
	N-18	<250	<250	-	<50	<50	-	63	<50	79
	N-41	<250	<250	-	200	<50	25	<50	100	200
	N-42	<250	<250	-	150	150	100	<50	100	200
	N-27	<250	<250	-	<50	90	180	100	80	80
	N-34	7270	3450	47	1100	2100	191	3900	1100	28
	N-35	<250	<250	-	<50	400	800	70	<50	71
	N-40	<250	<250	-	<50	177	354	<50	<50	-
	Ave			53			-138			0

Category		Zn (SD=5000)			Ni			Hg (SD=5)		
		before	after	rate	before	after	rate	before	after	rate
Non-Food	N-26	83	65	22	465	<50	89	1.7	1.4	18
	N-18	1915	90	95	20837	255	99	3.8	3.3	13
	N-41	248	83	67	80	98	-23	2.5	2.5	-12
	N-42	40	2228	-5470	139	100	28	2.7	2.6	4
	N-27	48	48	0	<50	<50	-	1	5	-400
	N-34	2543	229	91	697	1230	-76	9.9	2	80
	N-35	200	7300	-3550	<50	<50	-	1.9	-	-
	N-40	500	400	20	<50	<50	-	2.9	-	-
	Ave			-1091			23			-50

Category		As (SD=50)			Cd (SD=10)			Se (SD=10)		
		before	after	rate	before	after	rate	before	after	rate
Non-Food	N-26	BLD	BLD	-	BLD	BLD	-	BLD	BLD	-
	N-18	BLD	10	-	BLD	BLD	-	BLD	BLD	-
	N-41	BLD	BLD	-	BLD	BLD	-	BLD	0.5	-
	N-42	11	BLD	-	ND	BLD	-	BLD	BLD	-
	N-27	11	BLD	-	BLD	BLD	-	BLD	BLD	-
	N-34	29	13	45	BLD	BLD	-	BLD	BLD	-
	N-35	BLD	10	-	BLD	41	-	BLD	BLD	-
	N-40	11	BLD	-	BLD	BLD	-	BLD	BLD	-
	Ave			55			0			0

(SD=) : Standard for effluent to river

Table 5.5-1 Equipment Required of the Monitoring System

For continuous monitoring

Equipment required	Quantity
Rrecording device	2
Cabinet for snsing equipment measurement with underwater pump	2
Sensors (Temp., EC, DO, pH, Turb.)	2
Sensor (water level)	2
Pump	2
Personal computer with modem	1
Voltage regulator	3
Electric power unit	3

For field measurement

Equipment required	Quantity
Current meter	2
EC meter	1
pH meter	1
DO meter	1
Turbidity meter	2
Simple water analyzer	1
Transportation (4WD vehicle)	1

For the central laboratory

Equipment required	Quantity
TOC analyzer	1
A A spectrophotometer	1
ISE	1
Spectrophotometer (UV-visible)	1
Refrigerator	2
Freezer	1
Water distillation apparatus	2
BOD gauge	3
Incubator (BOD)	2
Incubator (37 C)	2
Chemical balance (0.1 mg - 200 g)	2
Chemical balance (0.01 mg - 45 g)	2
Concentrator	2
Autoclave	2
Ultrasonic bath	2
Distillation unit	2
Water filtering set	5

Table 5.6-1 Operation Plan and Cost of the Monitoring System

Personnel Schedule

Work	Supervising	Field measurement and sample collection	Continuous monitoring	Data storage and arrangement	Laboratory work	Total
Engineer	1#	2*				3
Technician		5*	1*#			6
Operator				2#		2
Professional analyst					4	4
Technician					3	3

*: 6 personnel shall be involved each time of 2 field work teams.
#: One of operators, one engineer and technician are additional personnel.

Expenses for the Additional Personnel

	Salary/ month ($)	Number	Total/year ($)
Engineer	500	1	6,000
Technician	400	1	4,800
Operator	400	1	4,800
Total/year ($)			15,600

Consumption articles in the central laboratory

	Cost/year ($)
Reagent	18000
Gas (acetylene, nitrogen, etc.)	8000
Glass ware	4000
Lamp for AA	2000
Electrodes	1500
Others	7000
Electricity	16000
Telephone	3500
Total	60000

Total Operation Cost		
	Personal expenses	15.600
	Consumption articles	60.000
Total cost ($)		75.600

Table 5.6-2 Maintenance Plan and Cost of Monitoring System

Continuous monitoring system

Equipment required	Unit cost ($)	Ratio (%)	Maintenenc cost/year ($)	Quantity	Total cost per year ($)	Useful life (year)
Recording device	7000	5	350	2	700	3
Cabinet for sensing equipment	5000	3	150	2	300	5
Sensor (Temp., EC)	2300	5	115	2	230	3
Sensor (DO)	2600	5	130	2	260	2
Sensor (water level)	2500	5	125	2	250	3
Voltage regulator	900	5	45	3	135	5
Personal computer with modem	3850	5	192.5	1	192.5	3
Building	260	10	26	20	520	15
Sub-total					2588	

Continuous monitoring system

	Unit cost ($)	Ratio (%)	Maintenance cost/year ($)	Quantity	Total cost per year ($)	Useful life (year)
Current meter	4000	5	200	2	400	5
EC meter	2000	5	100	1	100	5
pH meter	2000	5	100	1	100	5
DO meter	2000	5	100	1	100	3
Turbidity meter	4500	10	450	2	900	5
Simple water analyzer	10000	5	500	1	500	5
Transportation (4WD vehicle)	27500	10	2750	1	2,750	7
Sub-total					4,850	

Additional Equipment for the Central Laboratory

Equipment required	Unit cost ($)	Ratio (%)	Maintenance cost/year ($)	Quantity	Total cost ($)	Useful life (year)
TOC analyzer	30.000	10	3.000	1	3000	7
A A spectrometer	110.000	5	5.500	1	5500	7
ISE (10 electrodes)	9000	5	450	1	450	3
Spectrophotometer (UV-visible)	17.000	10	1.700	1	1700	7
Refrigerator	3.000	5	150	2	300	10
Freezer	5.000	5	250	1	250	10
Water distillation apparatus	2.500	5	125	2	250	7
BOD gauge	4.500	5	225	3	675	5
Incubator (BOD)	5.000	5	250	2	500	10
Incubator (37 C)	5.000	5	250	2	500	10
Chemical balance (0.1 mg - 200 g)	2.000	5	100	2	200	5
Chemical balance (0.01 mg - 45 g)	4.000	5	200	2	400	5
Concentrator	5.000	5	250	2	500	5
Autoclave	4.000	5	200	2	400	10
Ultrasonic bath	2.500	5	125	2	250	7
Distillation unit	1.500	5	75	2	150	7
Water filtering set	800	5	40	5	200	7
Sub-total					15225	

Existing Equipment in the Central Laboratory

Equipment	Unit cost ($)	Ratio* (%)	Maintenenc cost/year ($)	Quantity	Total cost ($)	Remaining year
AA Spectrometer with flame	100.000	5	5000	1	5000	5
Spectrophotometer (UV - visible)	9.000	10	900	1	900	5
Gas chromatography	60.000	5	3000	1	3000	5
Gas chromatography	80.000	5	4000	1	4000	5
Balance	2.000	5	100	1	100	3
Analytical balance	4.000	5	200	2	400	5
Conductivity meter	2.000	5	100	1	100	3
Turbidometer	3.000	5	150	1	150	3
Digestion unit (COD)	3.000	5	150	1	150	5
Ion analyzer	7.000	5	350	2	700	5
Water deionization unit	3.000	5	150	1	150	5
Distillation apparaturs	1.500	5	75	1	75	3
Oven (180 C)	5.000	5	250	1	250	7
Oven (105 C)	3.500	5	175	1	175	7
Compressor	500	5	250	1	250	5
Sub-total					15400	

Total maintenance cost ($)	38.638	

Table 5.6-3 Replacement Plan of Equipment

New equipment

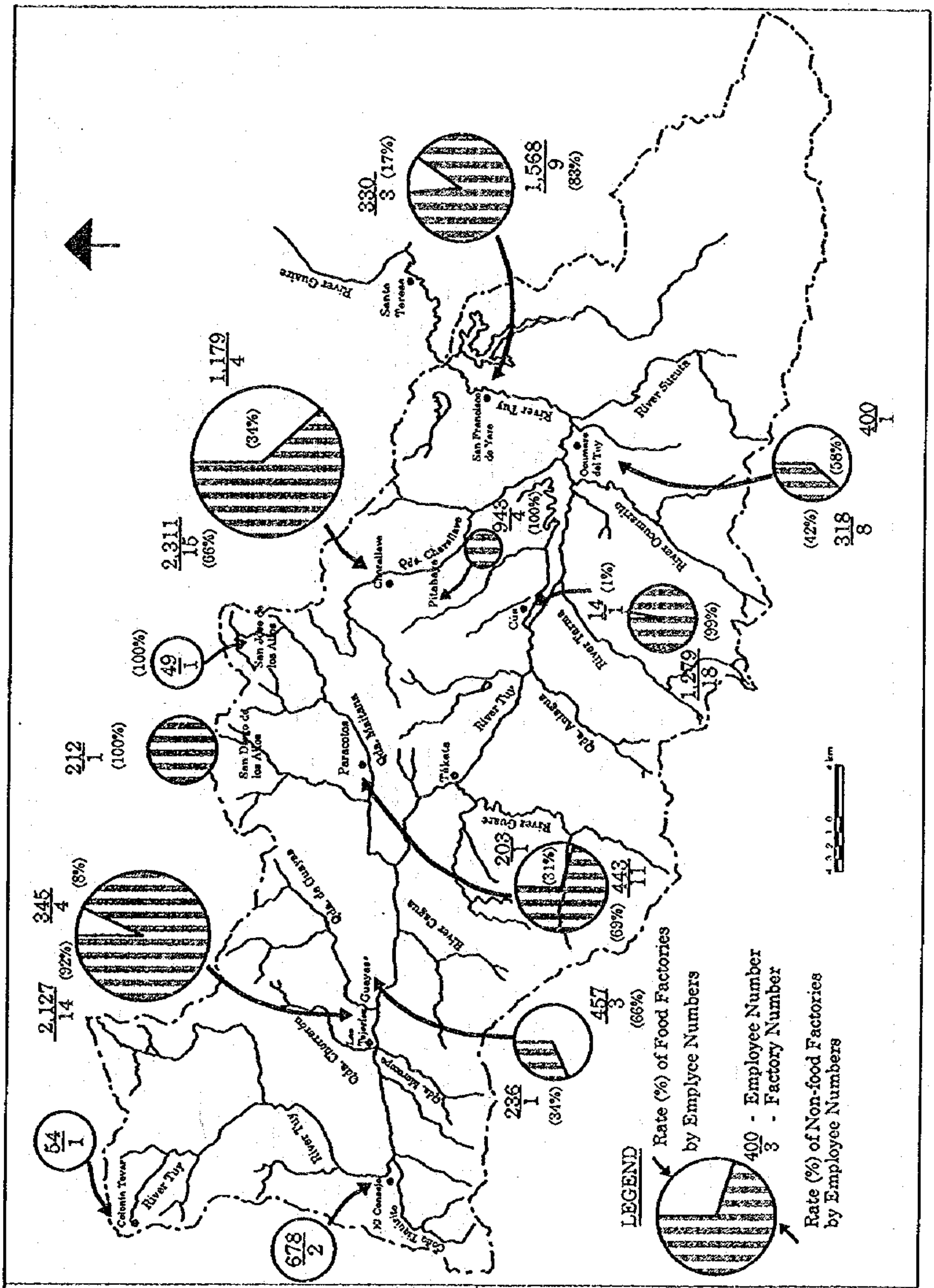
Equipment year	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th
Underwater pump (2)	7700	3850	3850	3850	3850	3850	3850	3850	3850	3850	3850	3850	3850
pH sensor (2)	5000	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Turbidity sensor (2)	13500	6750	6750	6750	6750	6750	6750	6750	6750	6750	6750	6750	6750
Recording device (2)	14000			14000			14000			14000			14000
Temp. and EC sensor(2)	4600			4600			4600			4600			4600
water level sensor(2)	5000			5000			5000			5000			5000
personal computer	3850			5000			5000			5000			5000
DO sensor(2)	5200		5200		5200		5200		5200		5200		5200
DO meter (field)	2000			1500			1500			1500			1500
Simple water analyzer	10000					10000					10000		
Building for monitoring	5200												
Current meter(2)	8000					8000					8000		
pH meter	2000					1000					1000		
Turbidity meter(2)	9000					18000					18000		
BOD gauge(3)	13500					10000					10000		
Distillation unit(2)	3000					3000					3000		
TOC analyzer	30000							30000					
ISE (electrods)	90000			9000			9000			9000			9000
Water distillation apparatus	5000							5000					
Chemical balance (0.1 mg	4000							4000					
Chemical balance (0.01 mg	8000							8000					
Concentrator(2)	10000							10000					
Ultrasonic bath(2)	5000							5000					
Water filtering set(5)	4000							4000					
Transformer	2700							2700					
Electric power	2700							2700					
4WD vehicle	2750							2750					
AA spectrotometer	110000							1E+05					
Spectrophotometer	17000										17000		
Incubator(BOD)(2)	10000										10000		
Incubator(37 C) (2)	10000										10000		
Autoclave (2)	8000										8000		
Refrigerator(2)	6000										6000		
Freezer	5000										5000		
Sub-total ($)	441700	13100	18300	52200	18300	63100	57400	2E+05	18300	52200	1E+05	13100	57400

Existing equipment

Balance			2000			2000			2000			2000	
Conductivity meter			2000			2000			2000			2000	
Turbidometer			3000			3000			3000			3000	
Distillation apparatus			1500			1500			1500			1500	
AA spectrophotometer					1E+05					1E+05			
Spectrophotometer(UV-visible)					9000					9000			
Gas chromatography					60000					60000			
Gas chromatography					80000					80000			
Analytical balance					4000					4000			
Digestion unit					3000					3000			
Ion analyzer					14000					14000			
Water deionizing unit					3000					3000			
Compressor					500					500			
Oven (180 C)							5000						
Oven (105 C)							3500						
Sub-total($)	0	0	8500	0	3E+05	8500	8500	0	8500	3E+05	0	8500	0
Total (x1000)($)	441.7	13.1	26.8	52.2	291.8	71.6	65.9	197.3	26.8	325.7	124.3	21.6	57.4

SECTOR A

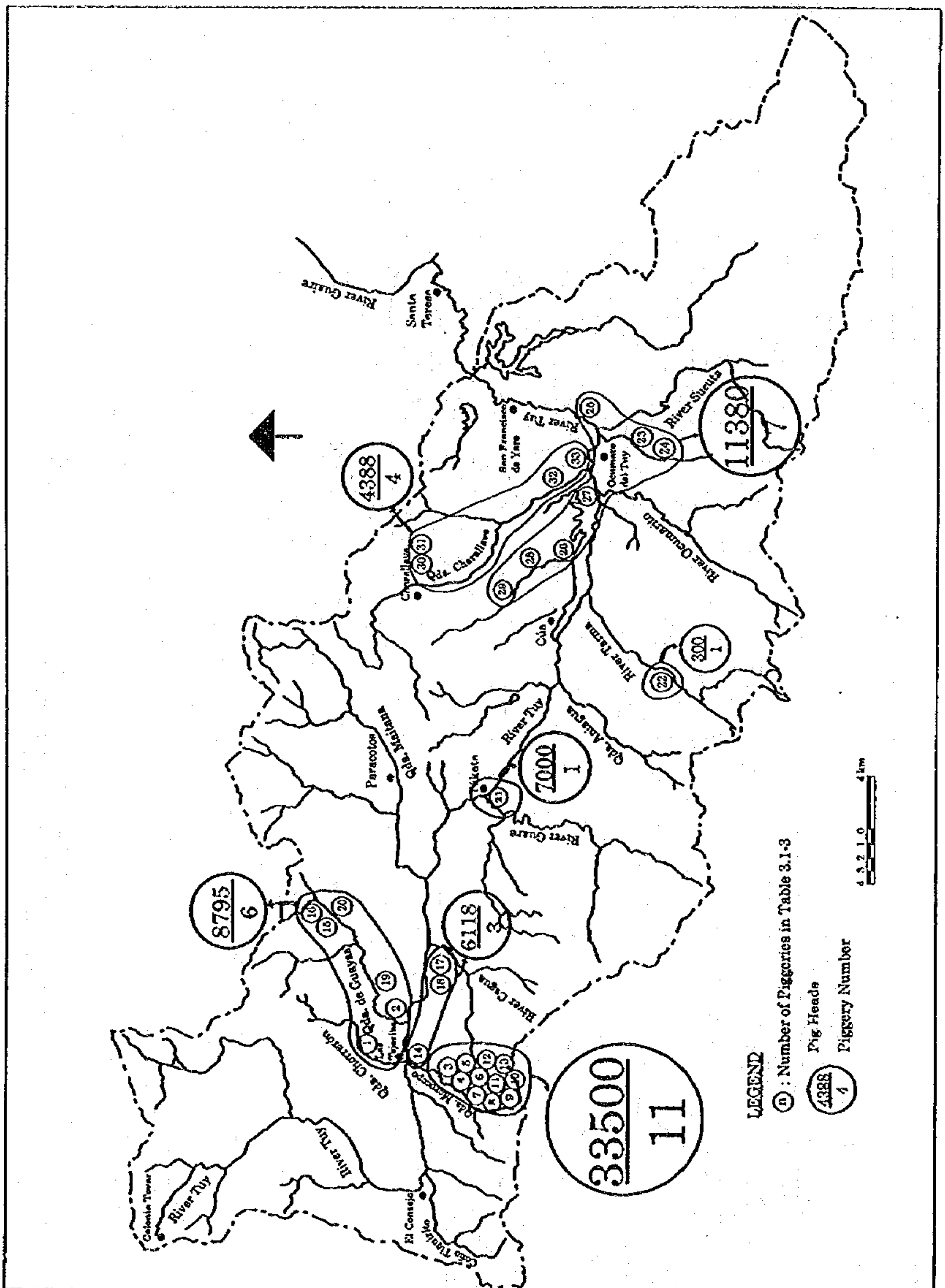
FIGURES



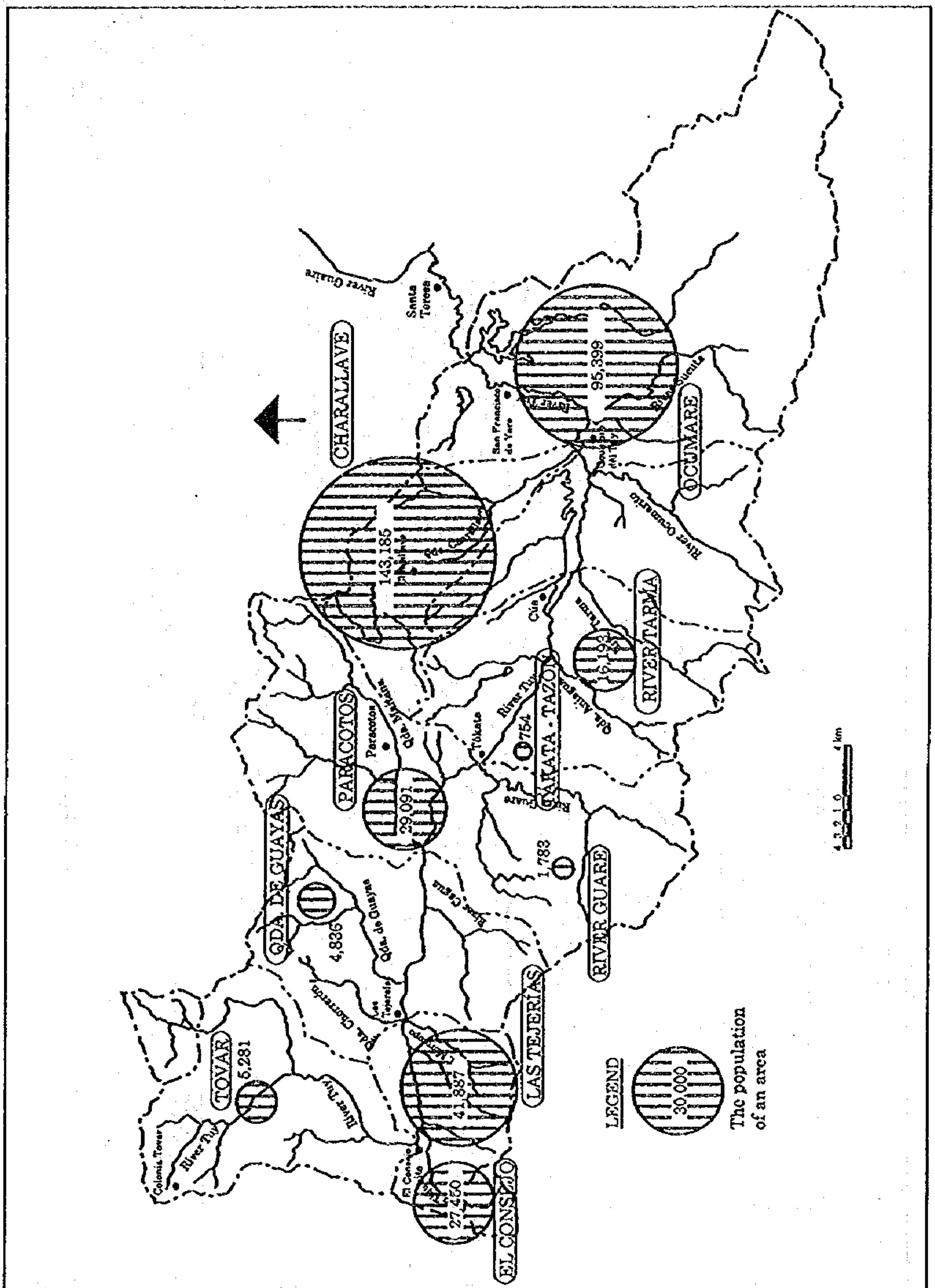
THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

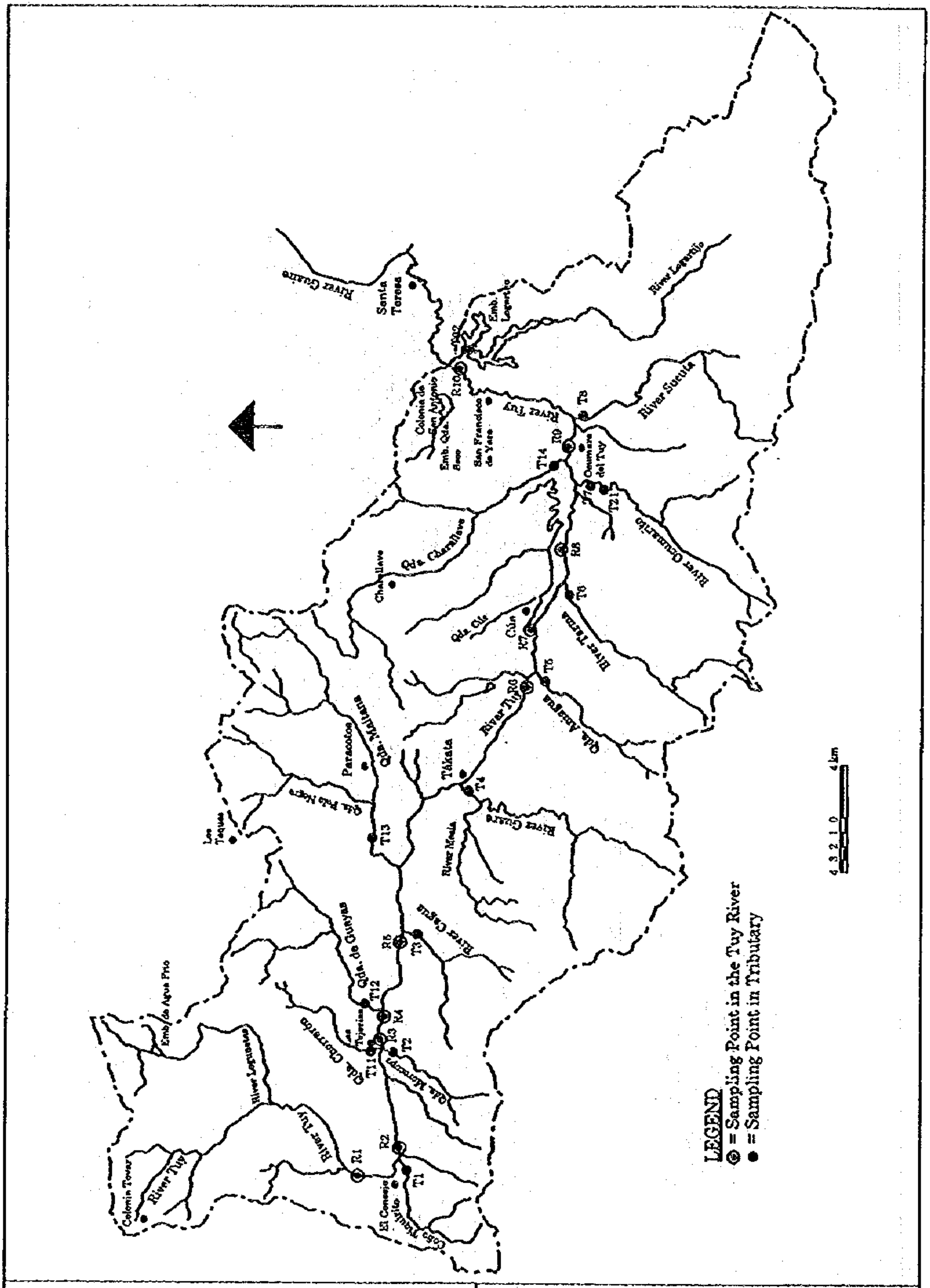
Fig. 1.1-1 Distribution of Factory and Employee Numbers by Food and Non-food Factories



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.1-2 Distribution of Piggeries and Pig Heads
JAPAN INTERNATIONAL COOPERATION AGENCY	



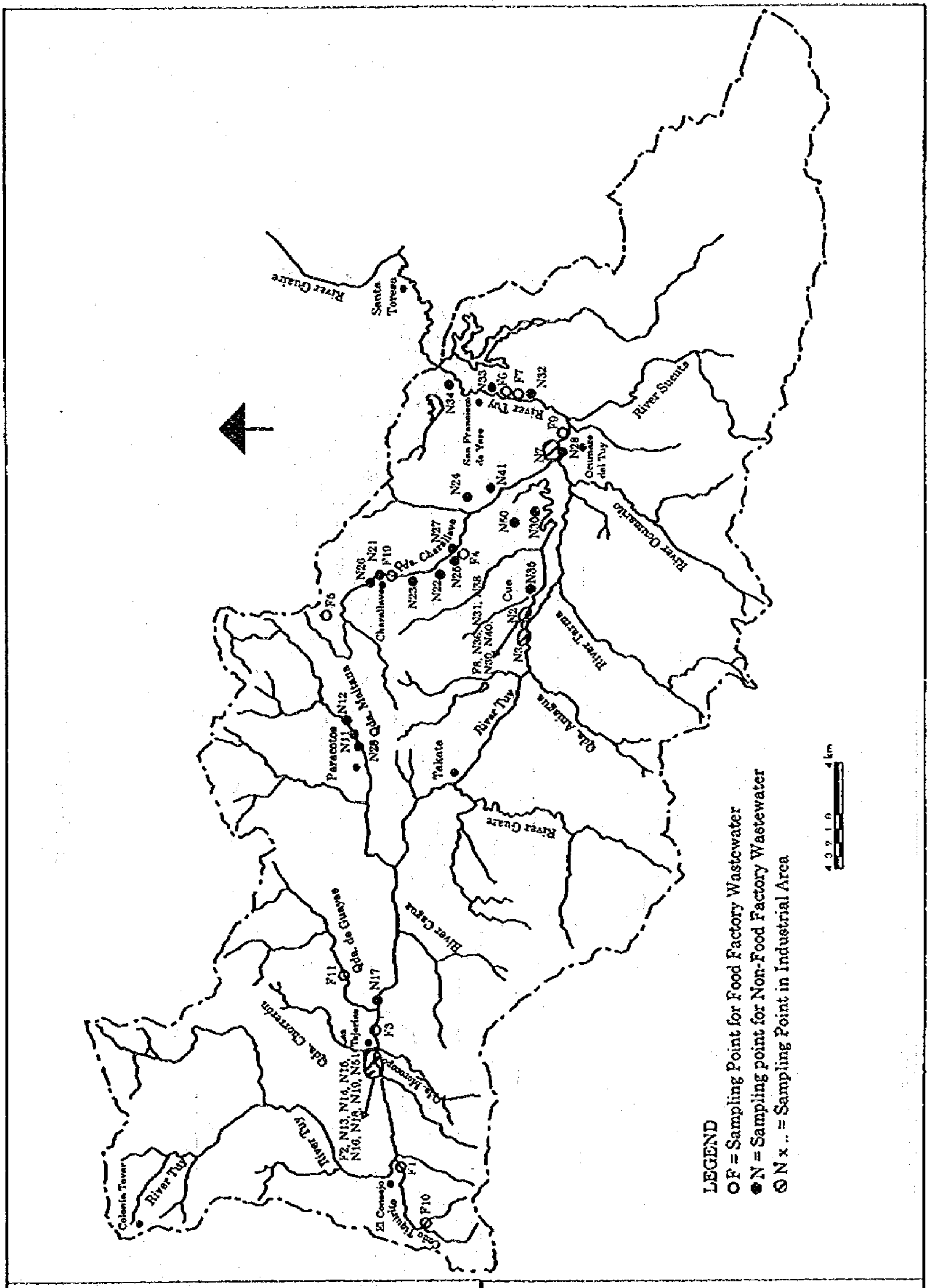
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.1-3 Human Population in Area



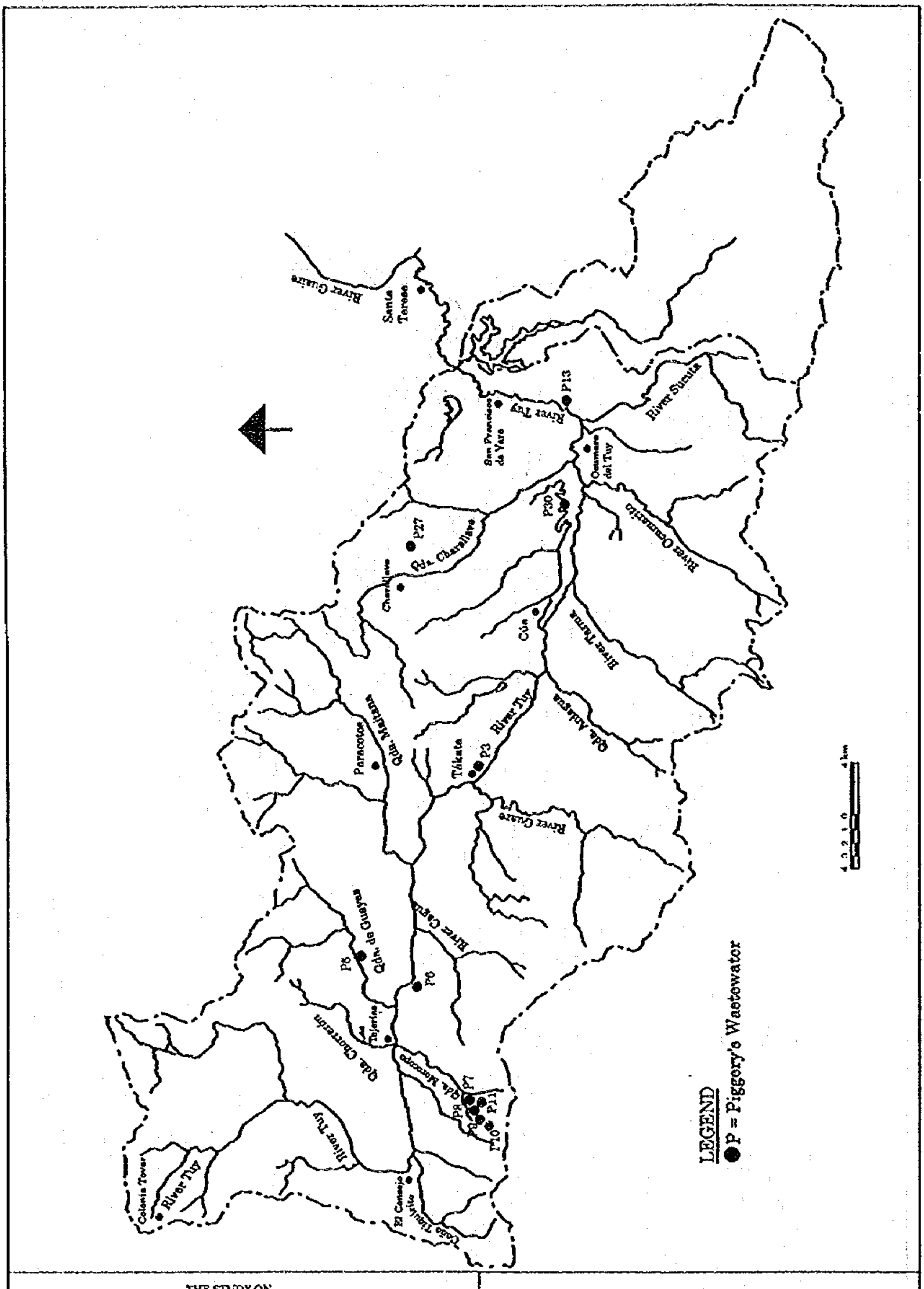
THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

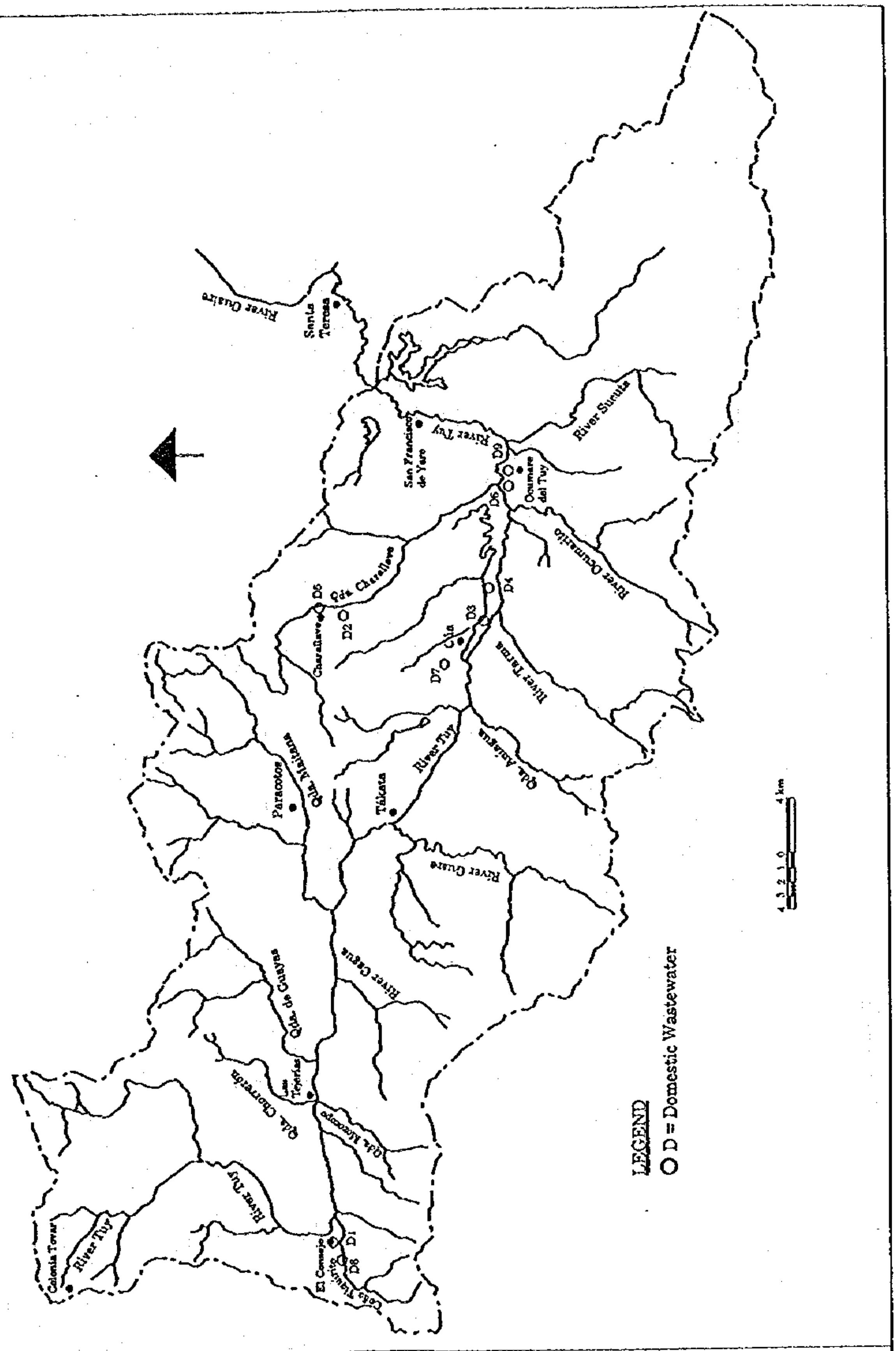
Fig. 1.2-1 (1/4) Sampling Points on the Tuy River and Tributaries



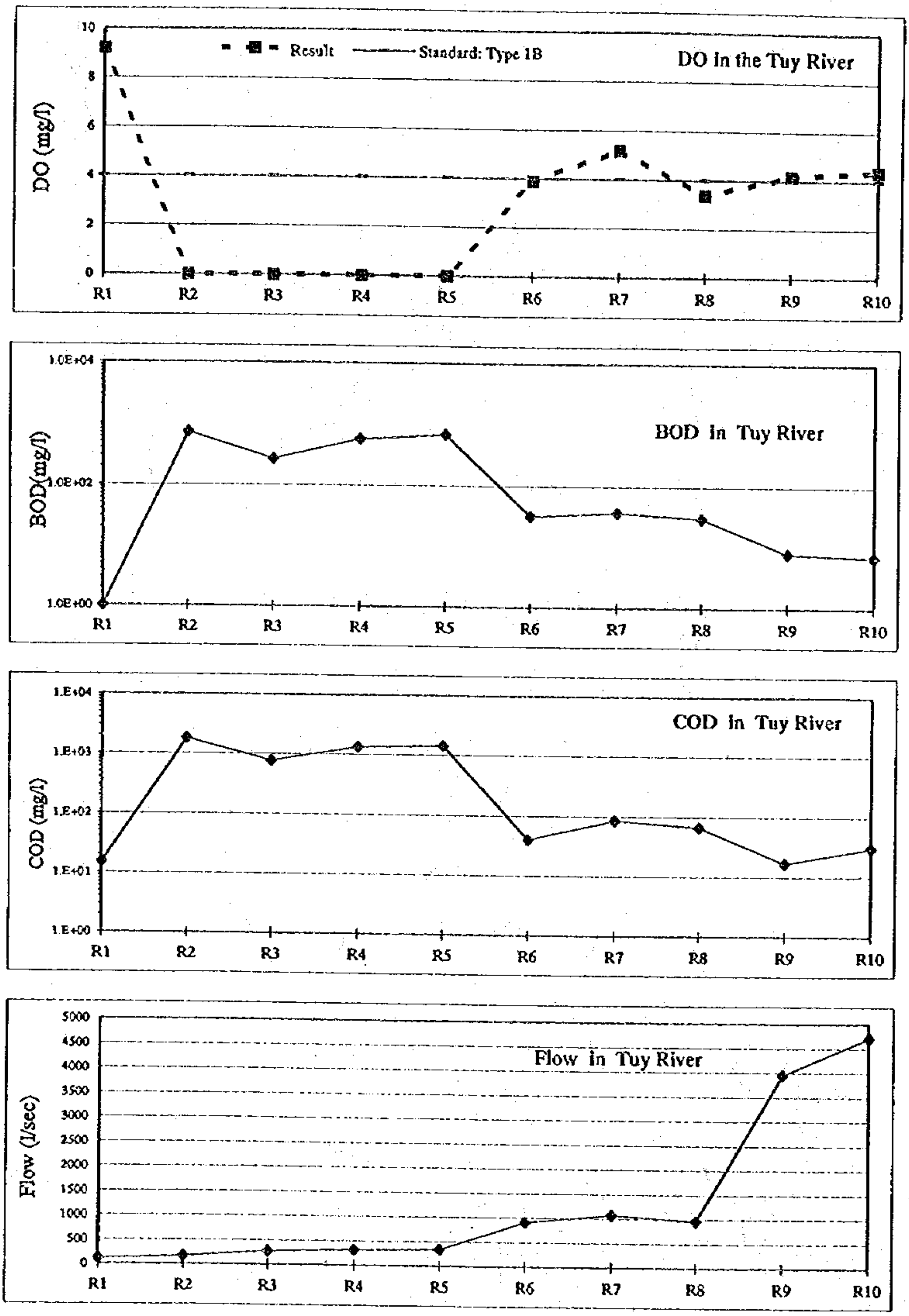
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-1 (2/4) Sampling Points on the Tuy River and Tributaries
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-1 (3/4) Sampling Points on the Tuy River and Tributaries
JAPAN INTERNATIONAL COOPERATION AGENCY	



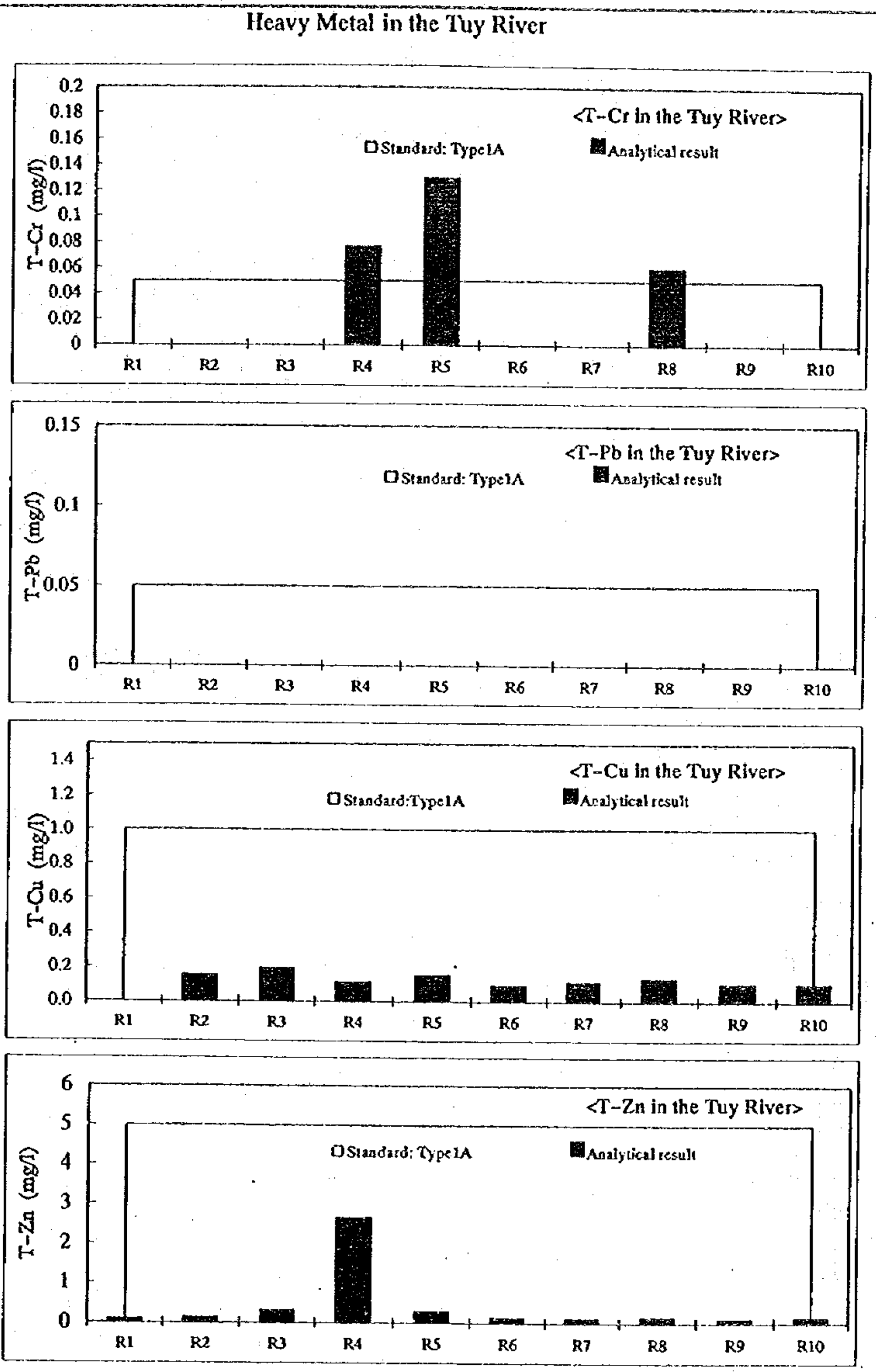
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-1 (4/4) Sampling Points on the Tuy River and Tributaries
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 1.2-2 Organic Pollution in the Tuy River

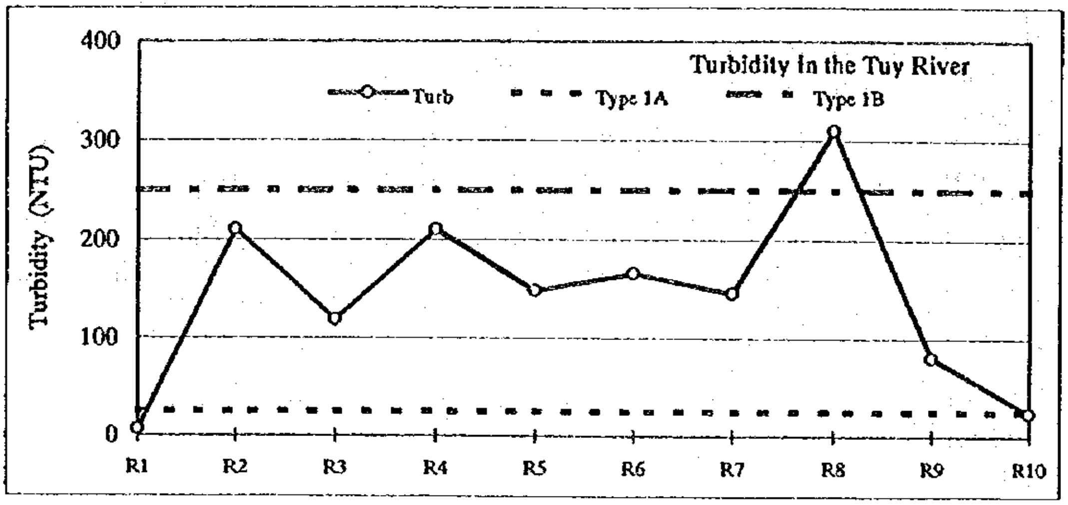


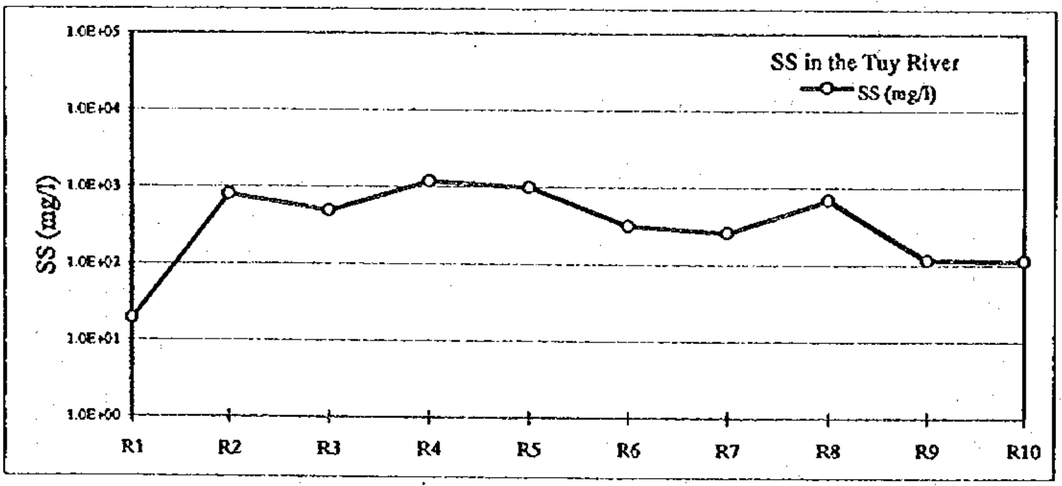
THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 1.2-3 Heavy Metals in the Tuy River

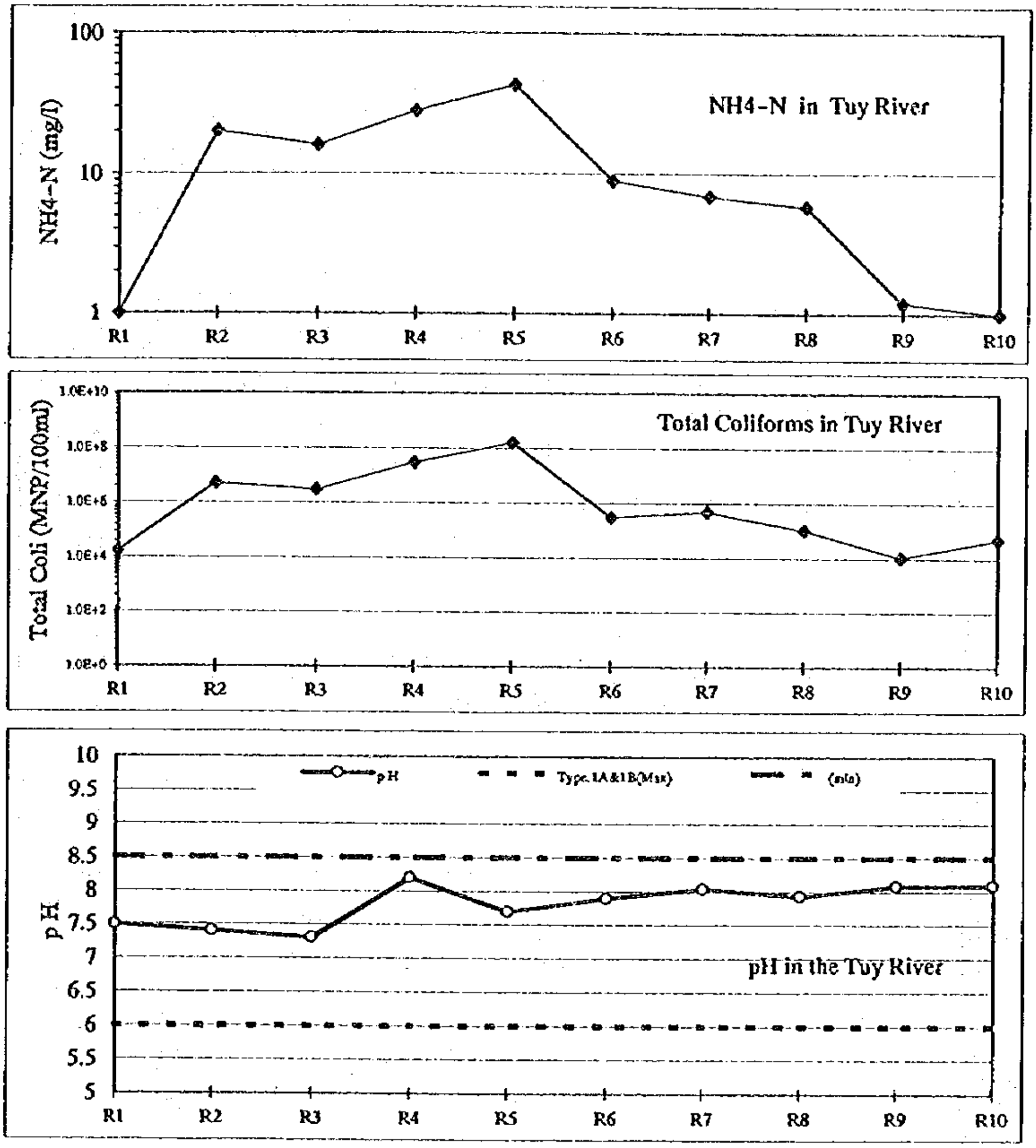
Turbidity & SS in the Tuy River





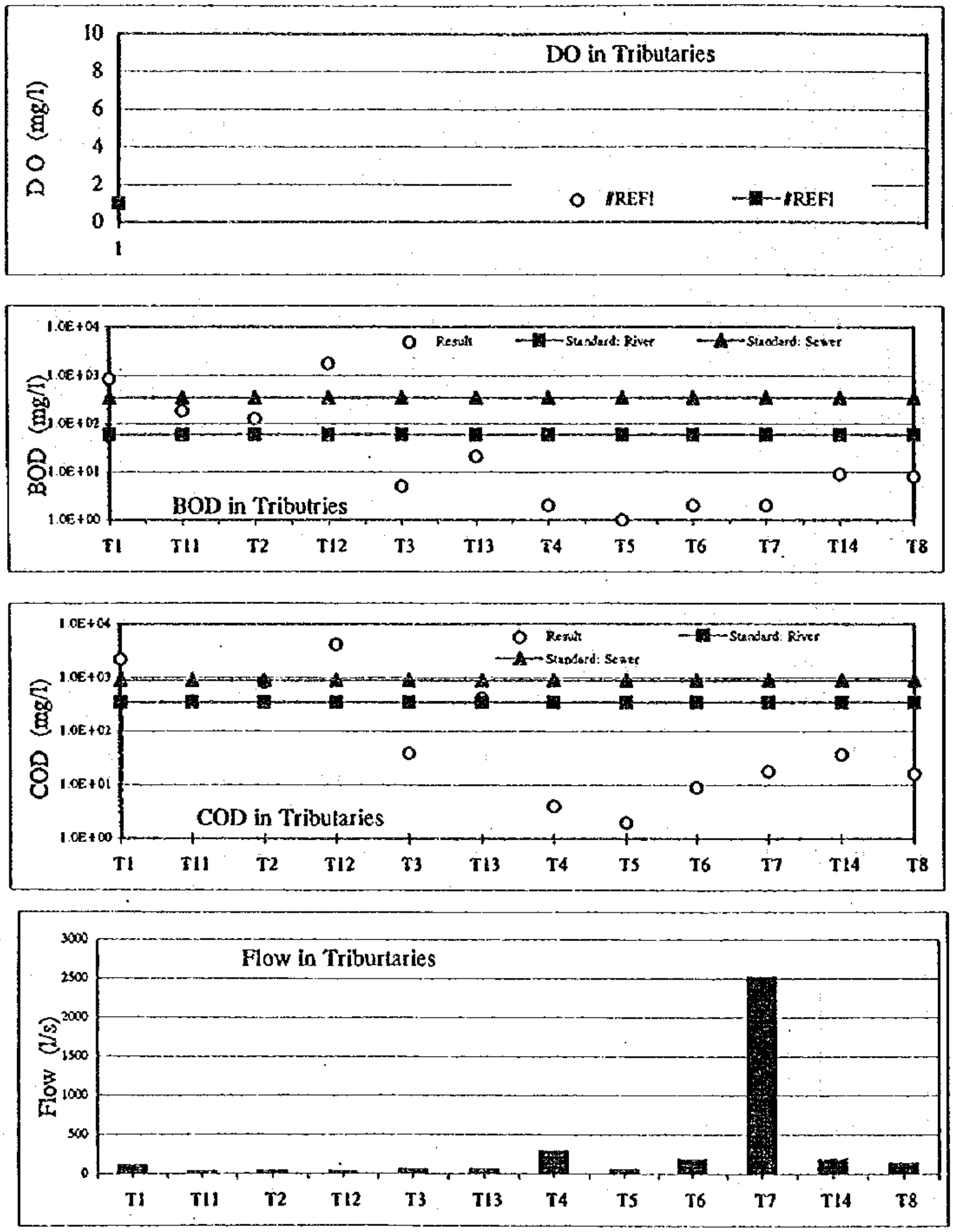
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.2-4 Turbidity and SS of the Tuy River

Other Qualities in the Tuy River

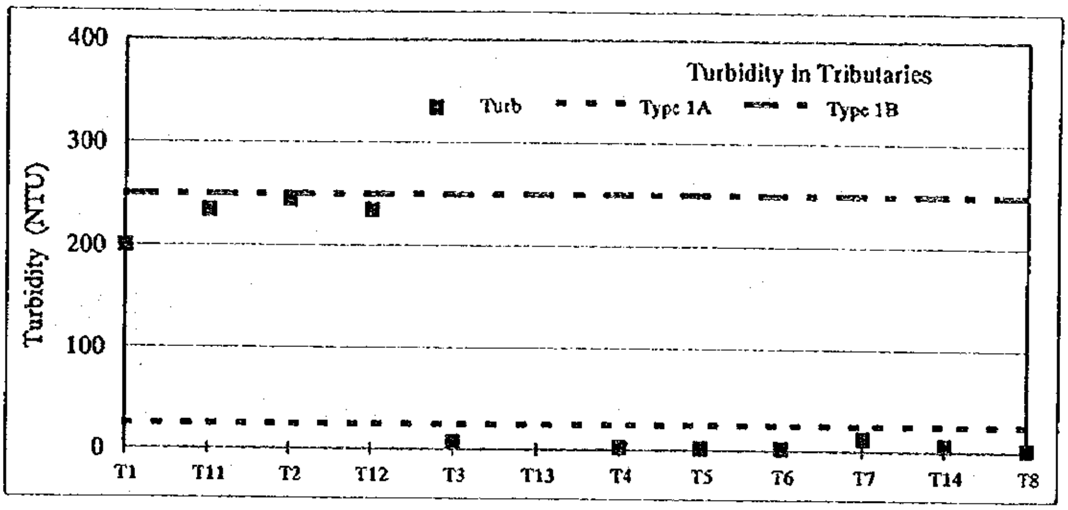


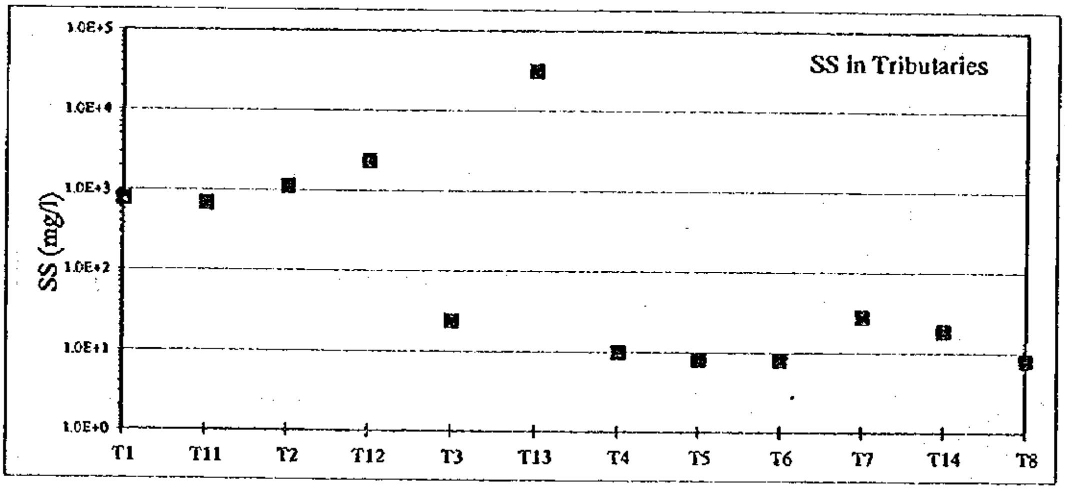
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.2-5 Other Water Qualities of the Tuy River

Organic Pollution in the Tributries



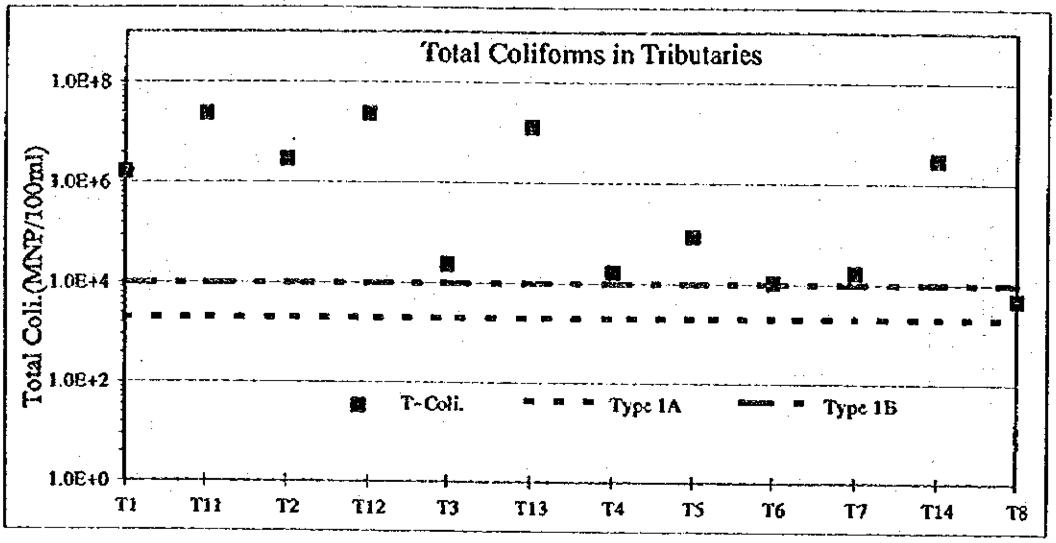
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.2-6 Organic Pollution in the Tributaries

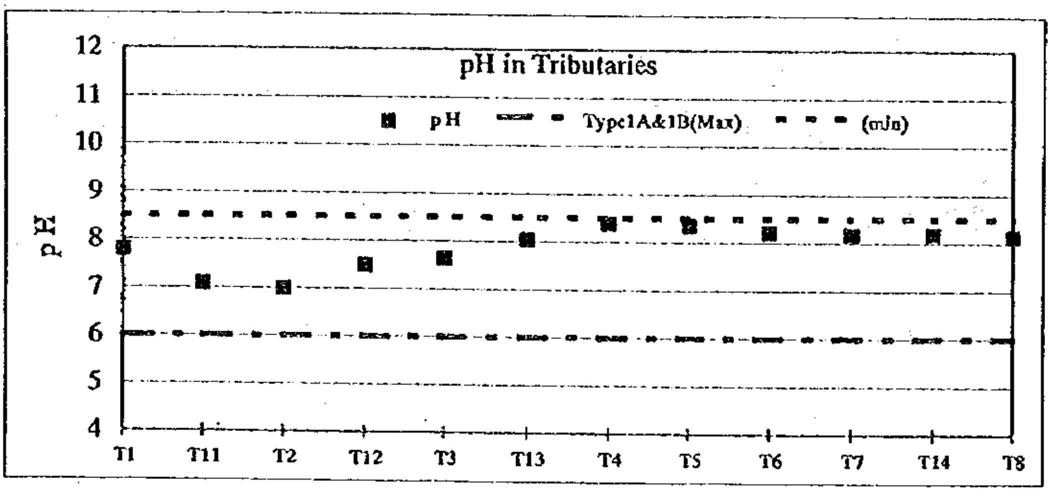




THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-7 Turbidity and SS of the Tributaries
JAPAN INTERNATIONAL COOPERATION AGENCY	

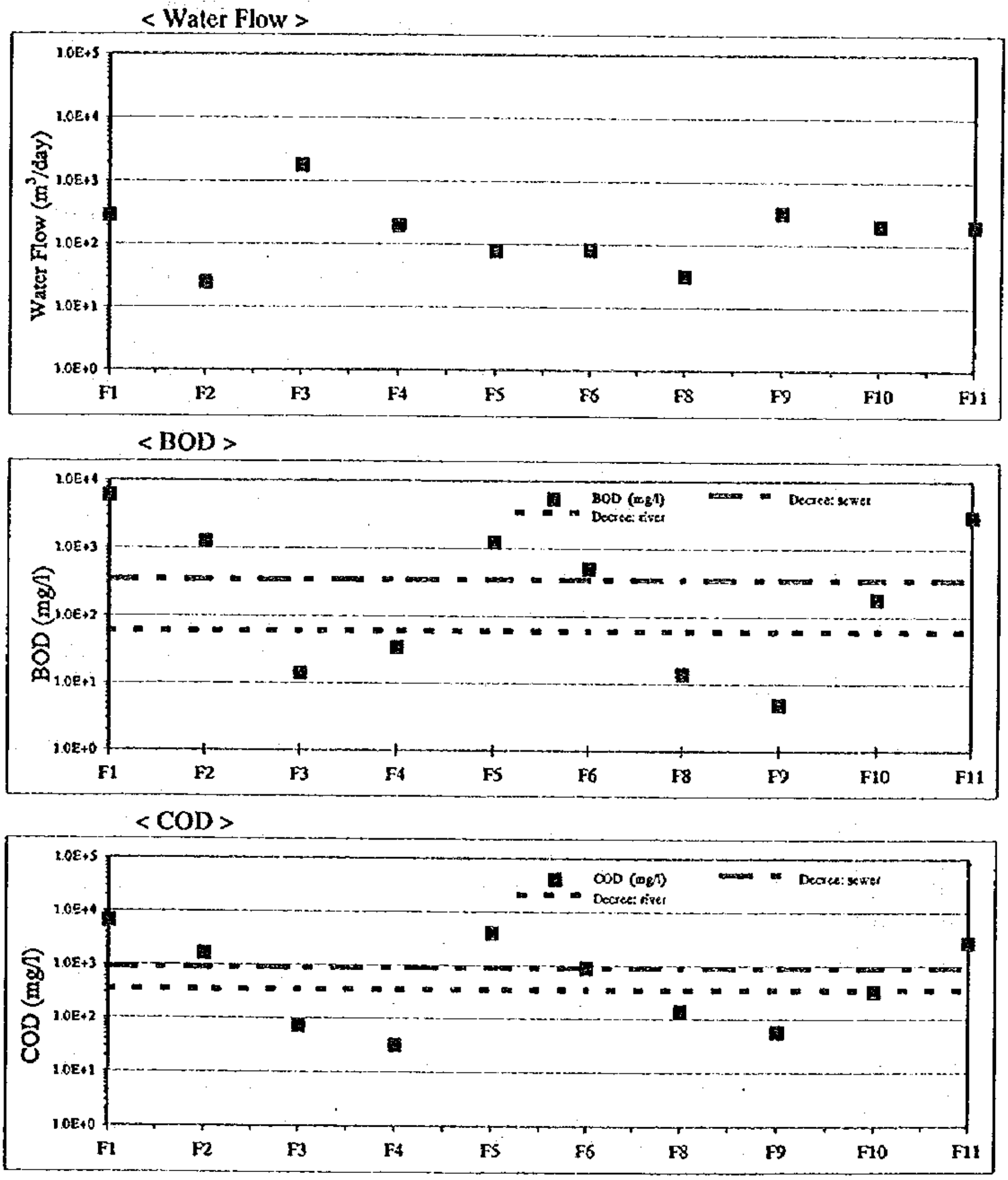
Other Qualities in Triburtaries





THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-8 Other Water Qualities of the Tributaries
JAPAN INTERNATIONAL COOPERATION AGENCY	

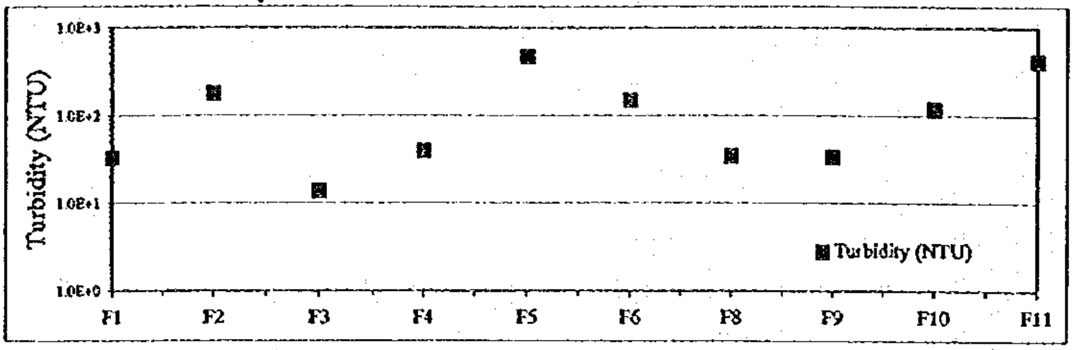
Water Quality in Food Factory Wastewater



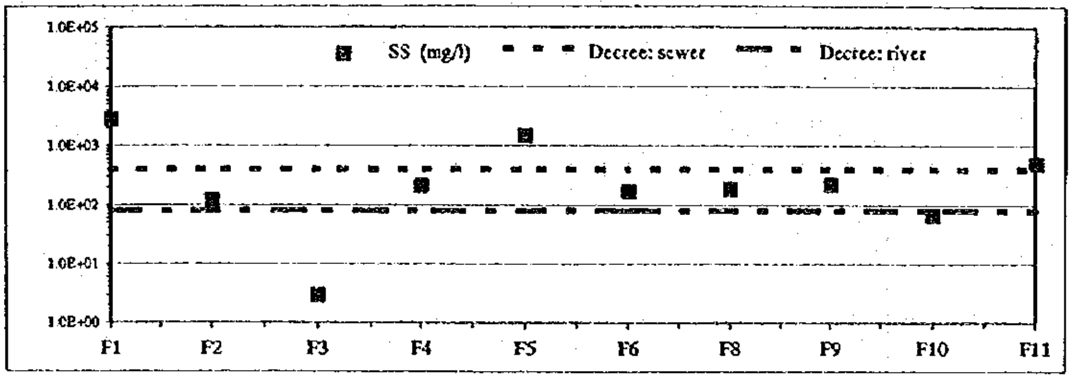
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-9 Pollution from Food Factories (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	

Water Quality in Food Factory Wastewater

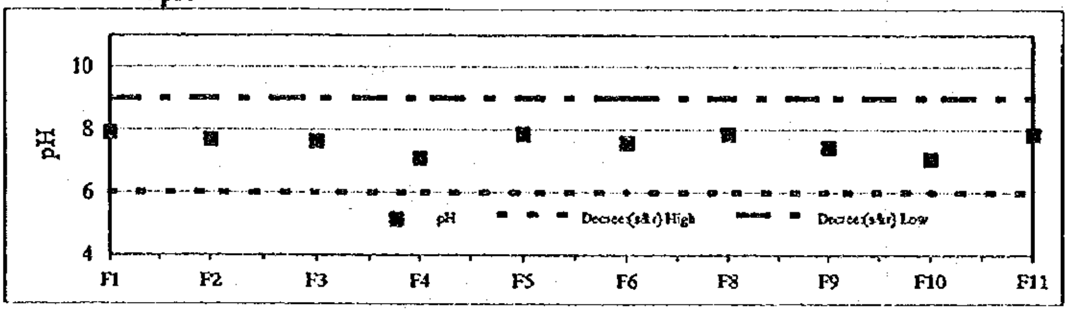
< Turbidity >



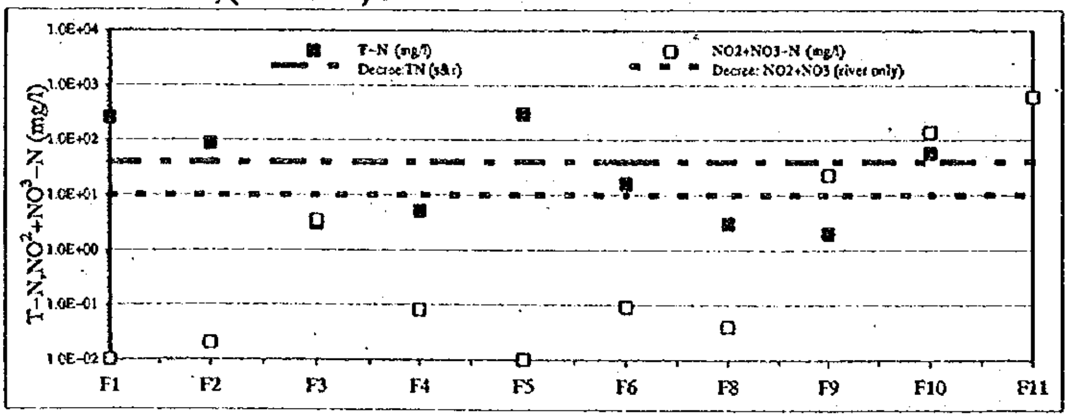
< SS >



< pH >



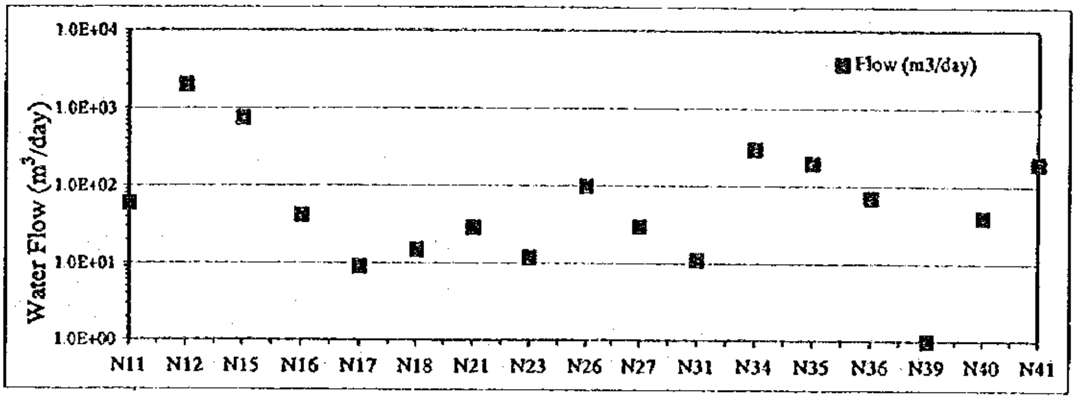
< T-N , (NO^2+NO^3)-N >



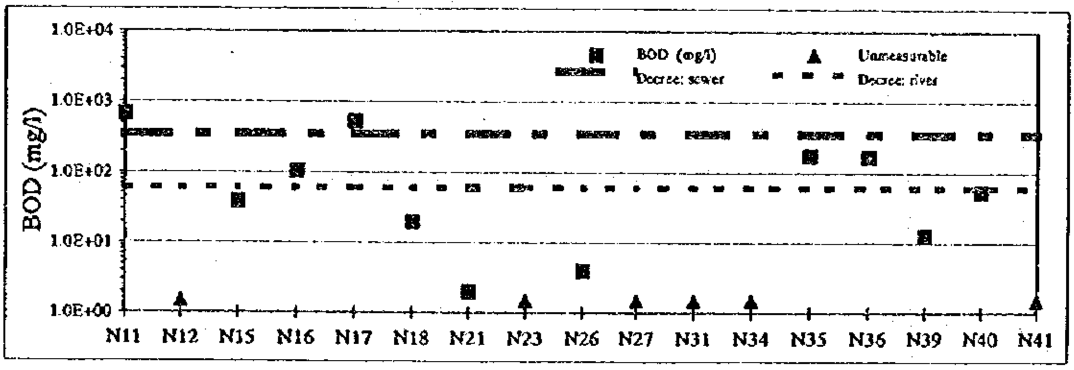
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.2-9 Pollution from Food Factories (2/2)

Water Quality in Non-food Factory Wastewater

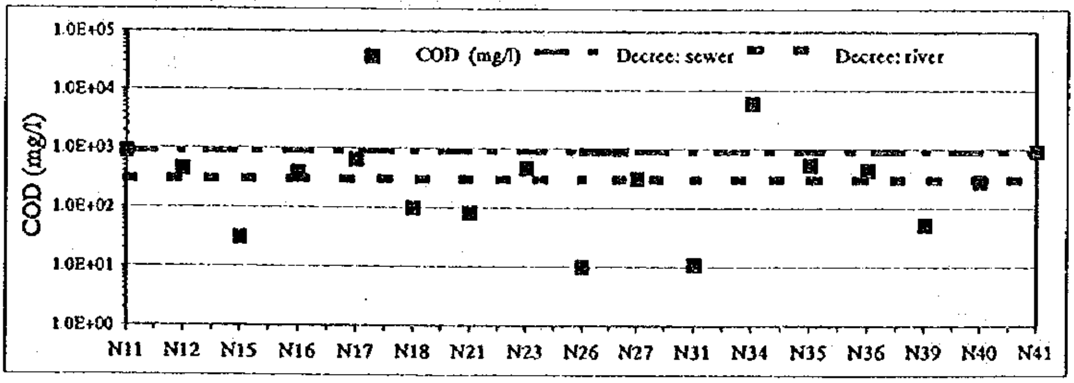
< Water Flow >



< BOD >



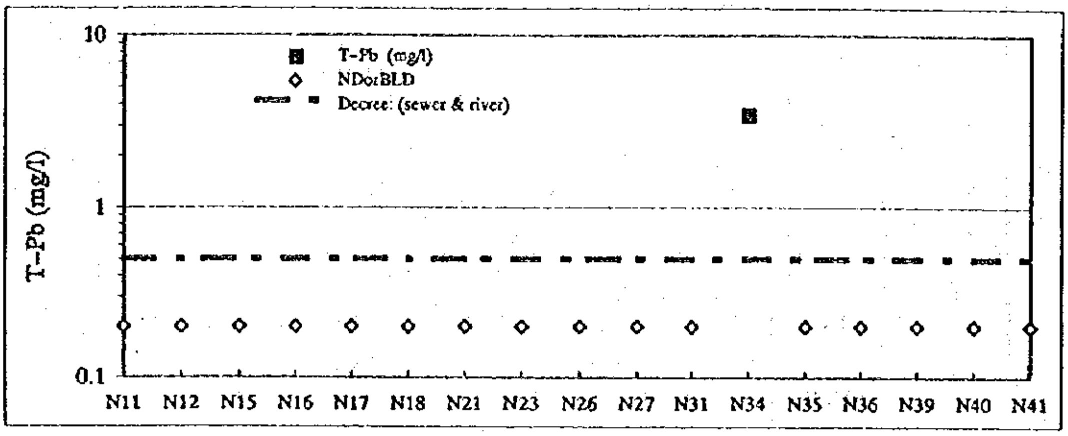
< COD >



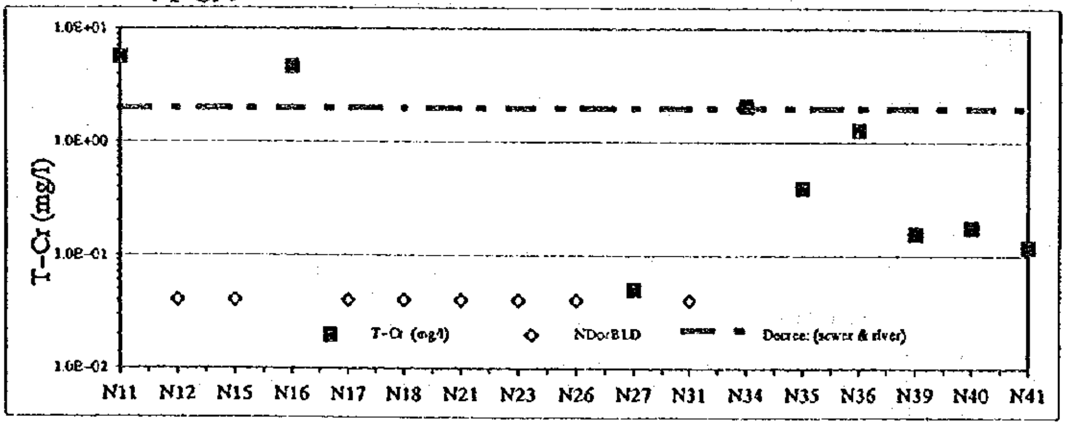
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-10 Pollution from Non-food Factories (1/4)
JAPAN INTERNATIONAL COOPERATION AGENCY	

Water Quality in Non-food Factory Wastewater

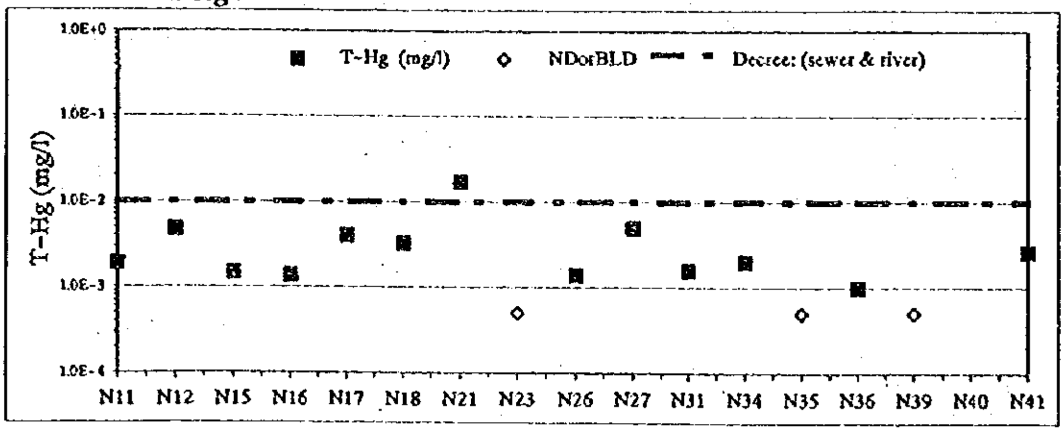
< T-Pb >



< T-Cr >



< T-Hg >



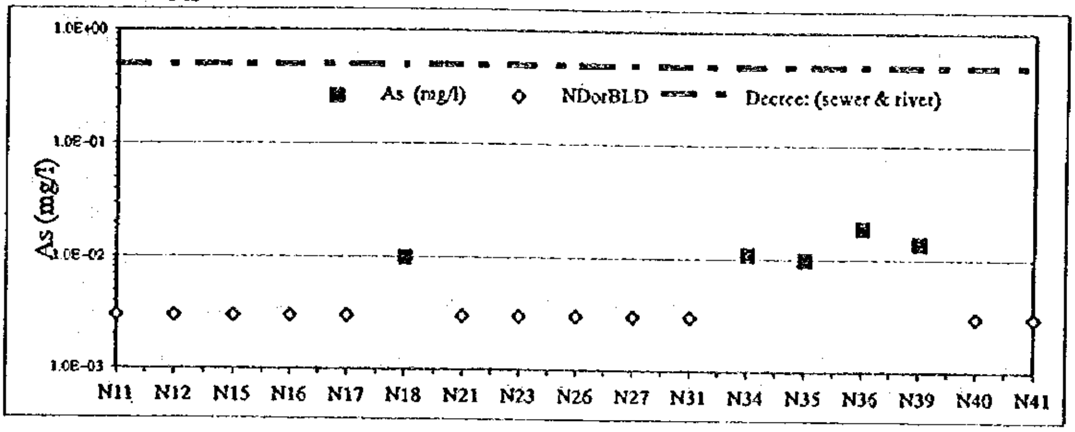
THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

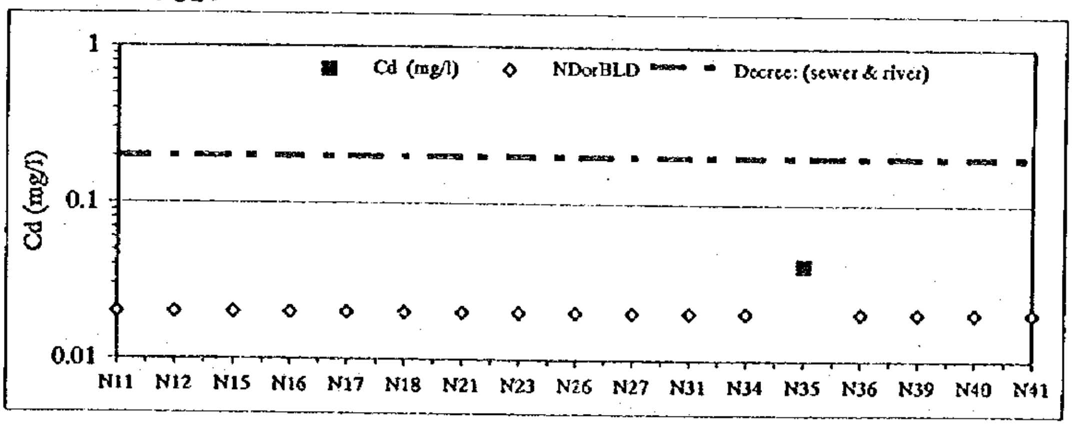
Fig. 1.2-10 Pollution from Non-food Factories (2/4)

Water Quality in Non-food Factory Wastewater

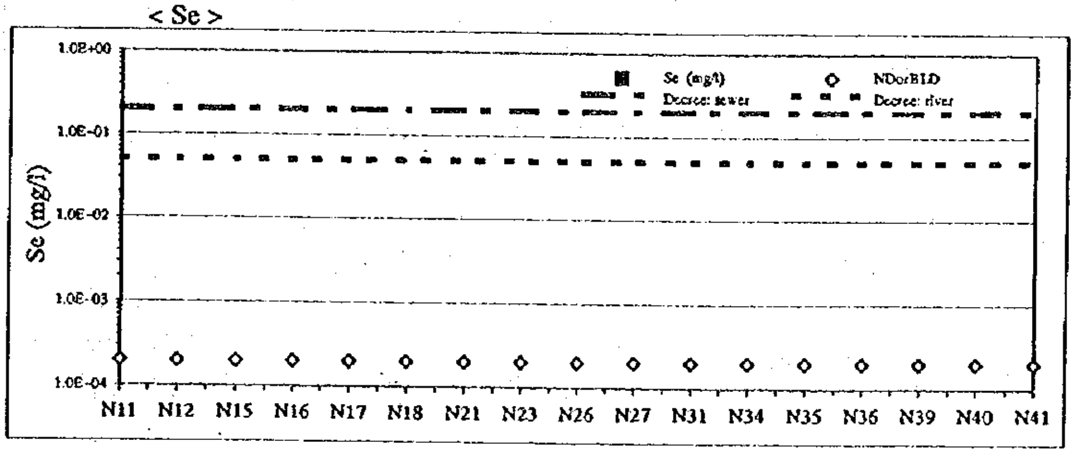
< As >



< Cd >



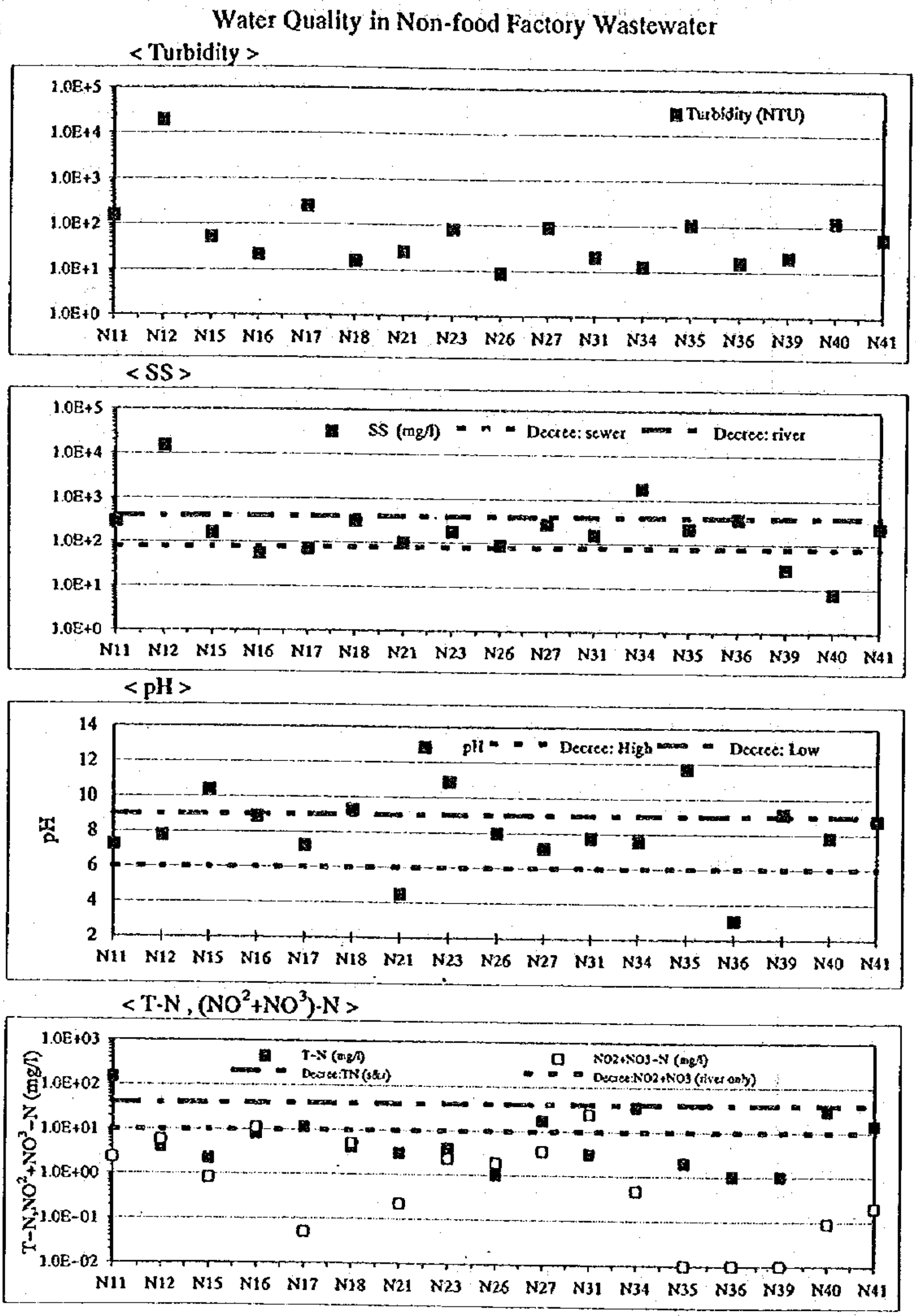
< Se >



THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

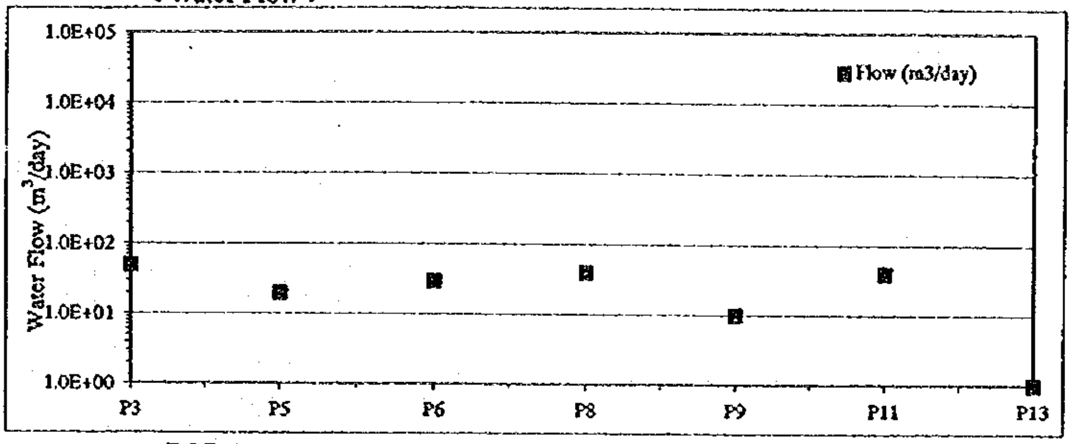
Fig. 1.2-10 Pollution from Non-food Factories (3/4)



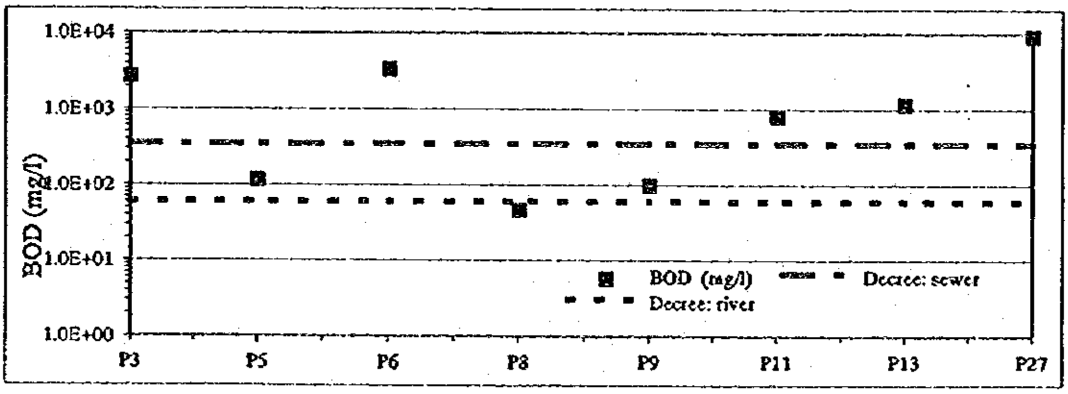
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-10 Pollution from Non-food Factories (4/4)
JAPAN INTERNATIONAL COOPERATION AGENCY	

Water Quality in Piggery Wastewater

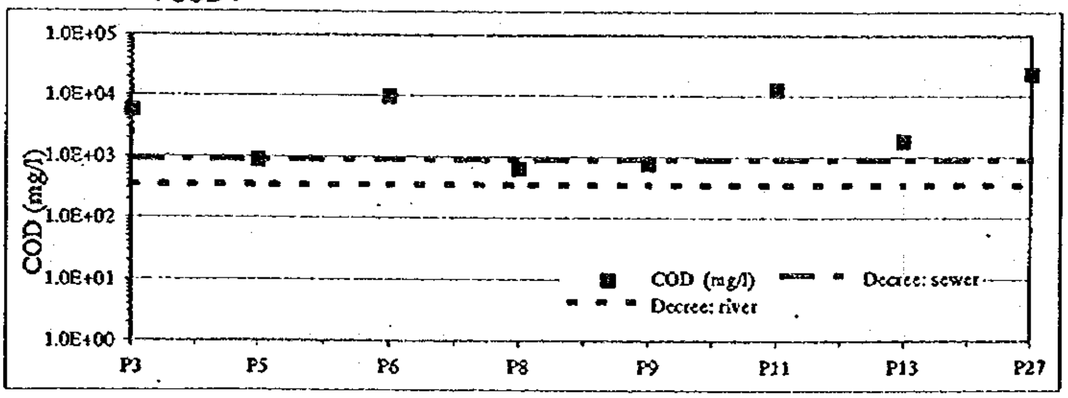
< Water Flow >



< BOD >

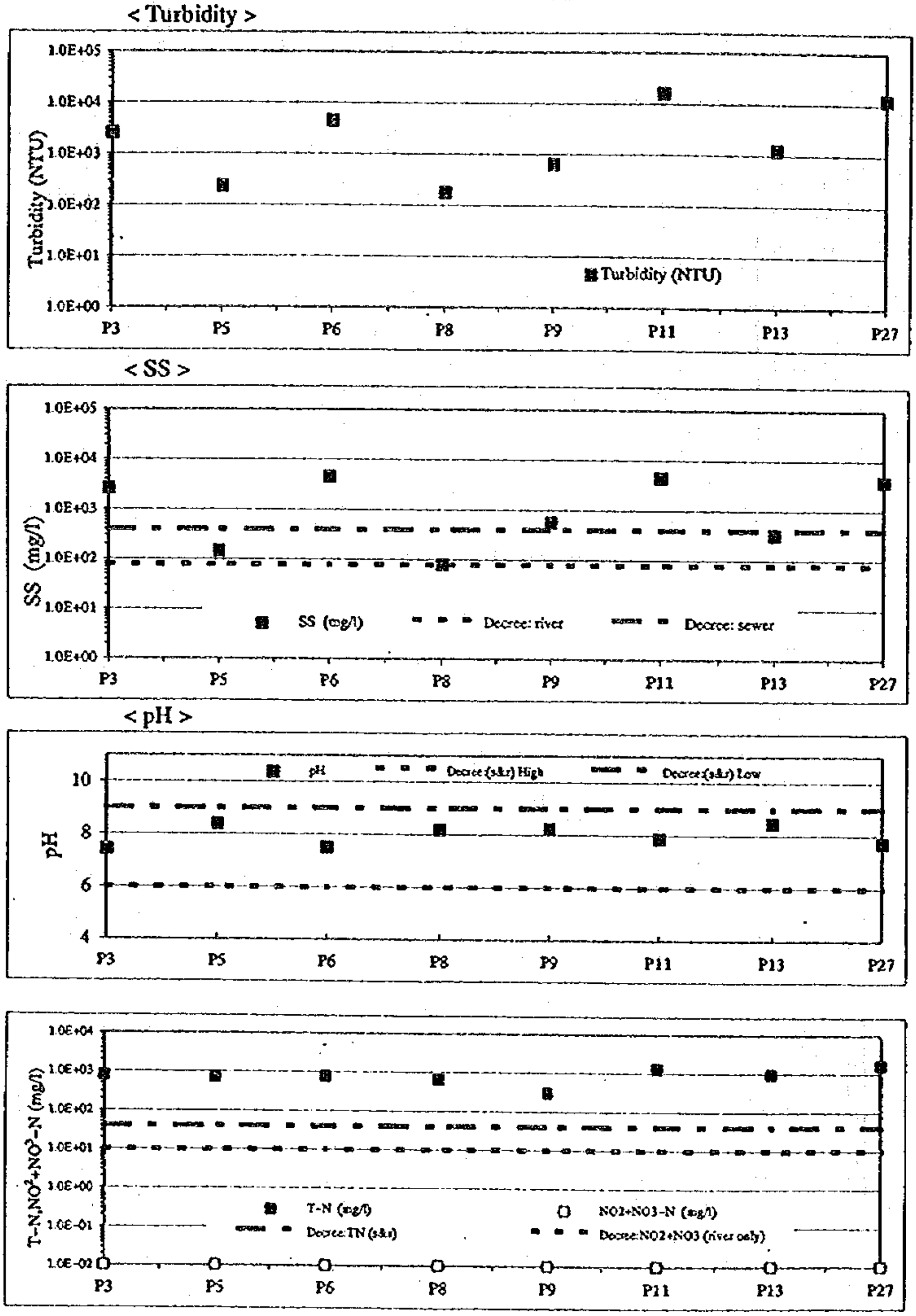


< COD >



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-11 Pollution from Piggeries (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	

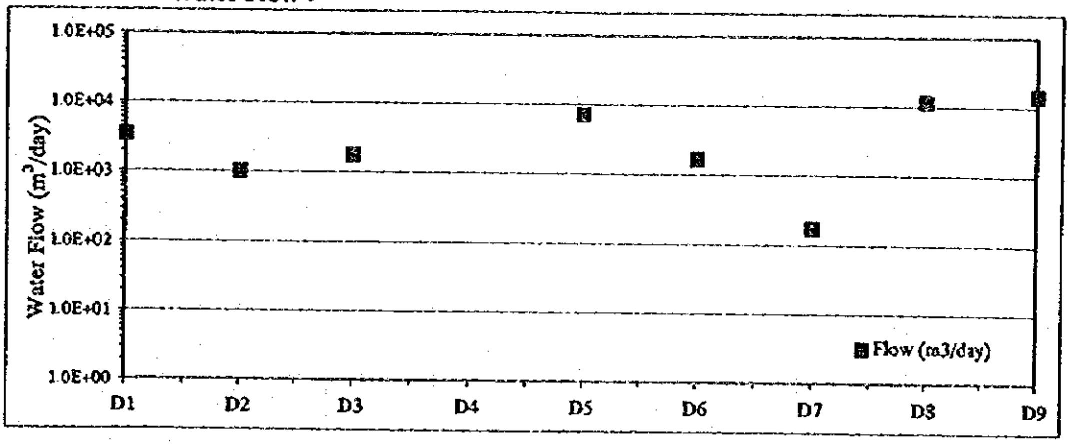
Water Quality in Piggery Wastewater



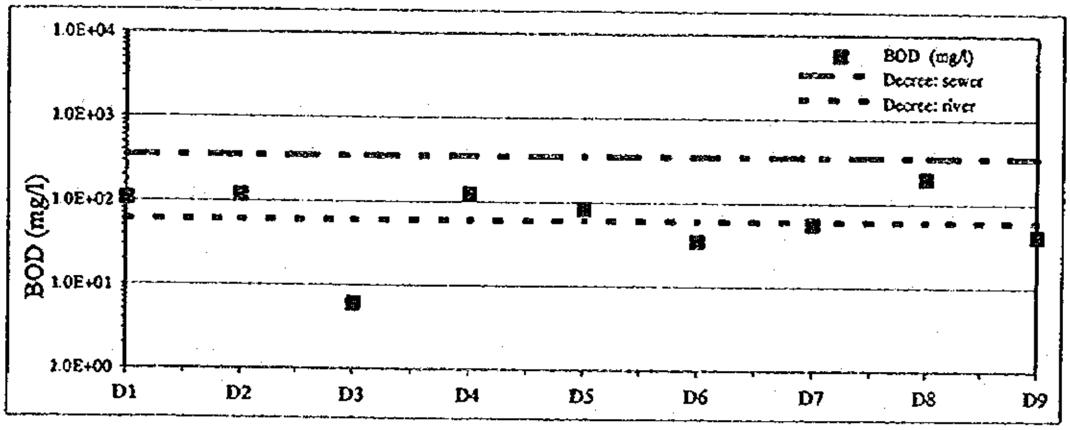
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-11 Pollution from Piggeries (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	

Water Quality in Domestic Wastewater

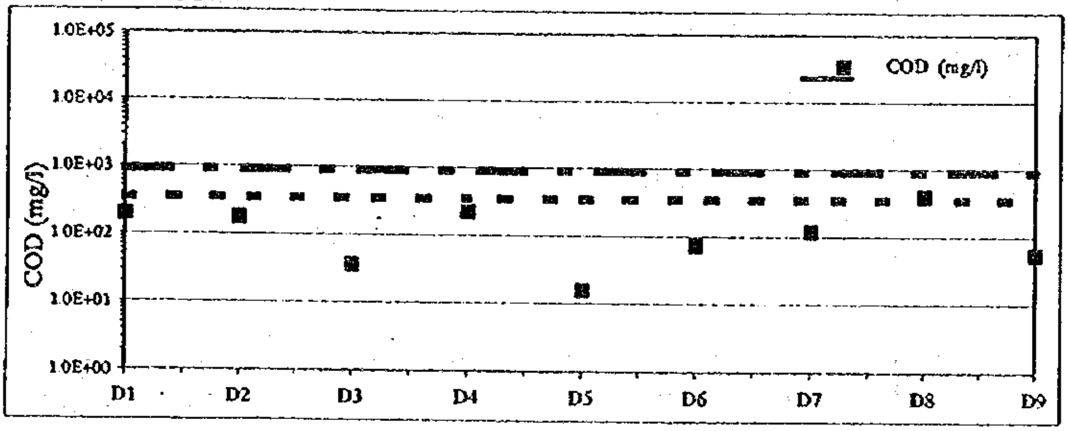
< Water Flow >



< BOD >



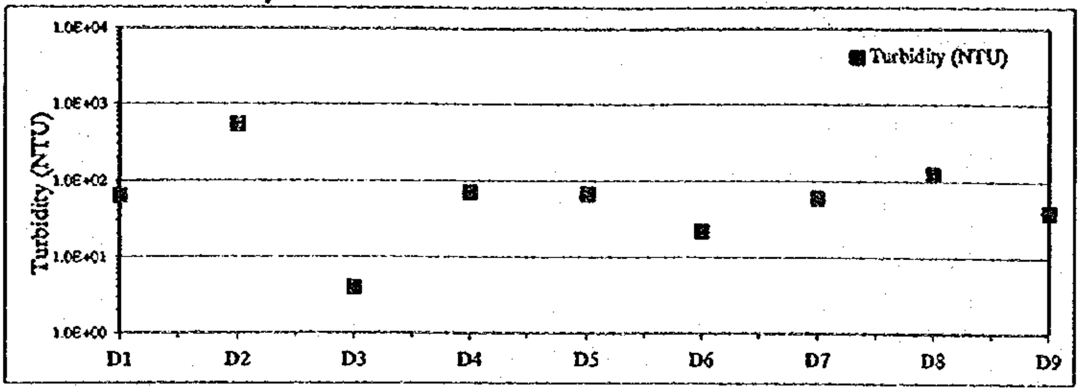
< COD >



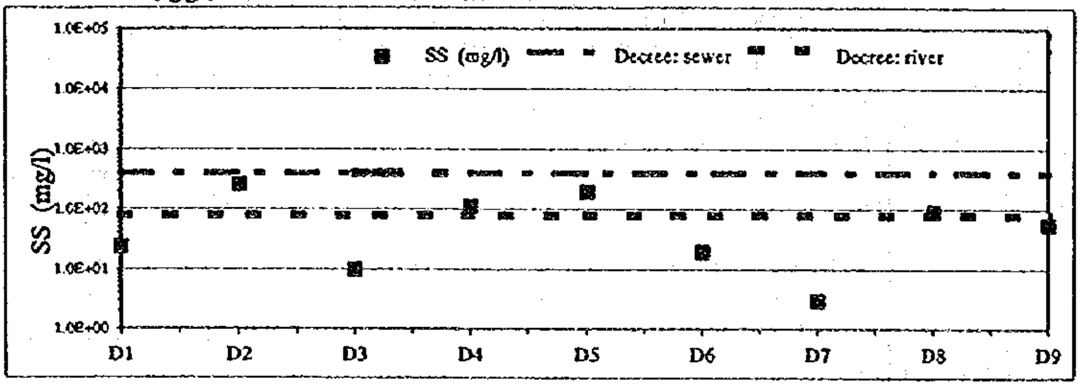
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-12 Pollution of Domestic Wastewater (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	

Water Quality in Food Factory Wastewater

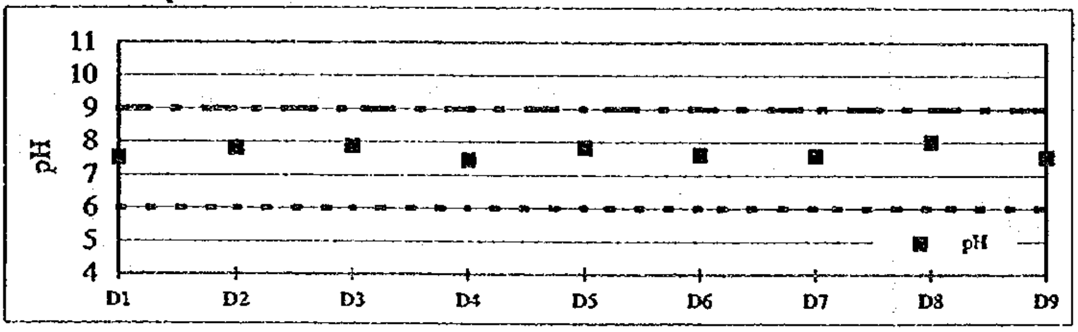
< Turbidity >



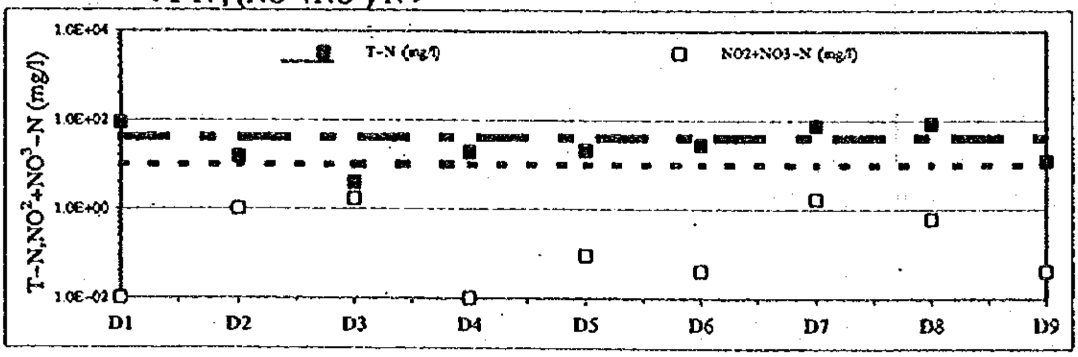
< SS >



< pH >

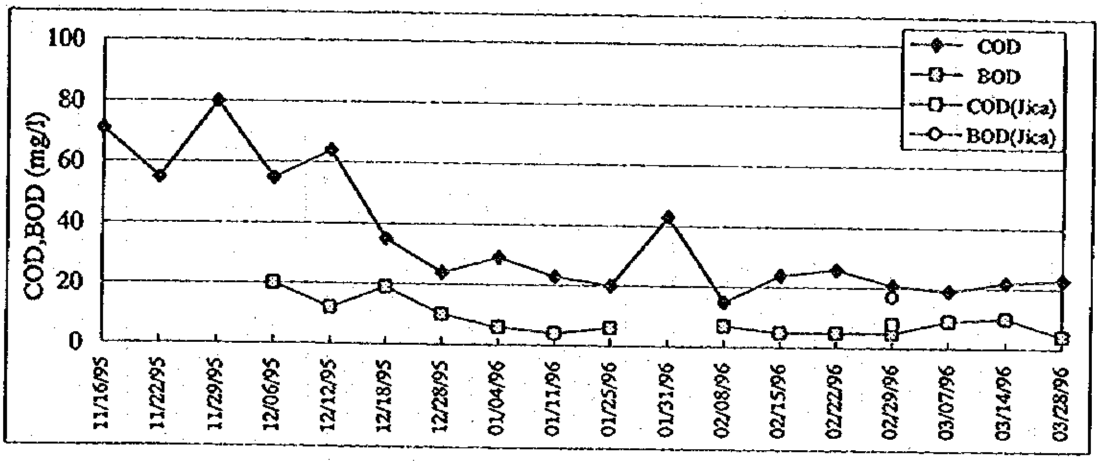


< T-N , (NO^2+NO^3)-N >

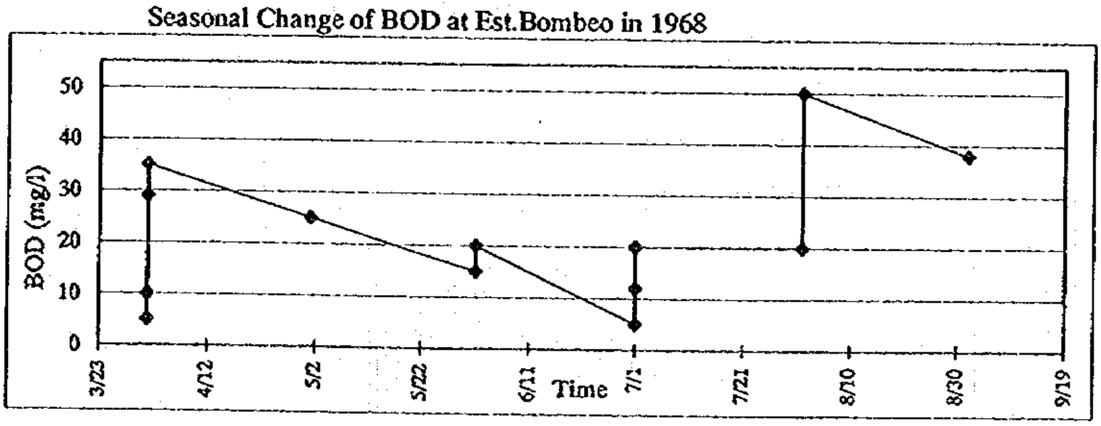


THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-12 Pollution of Domestic Wastewater (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	

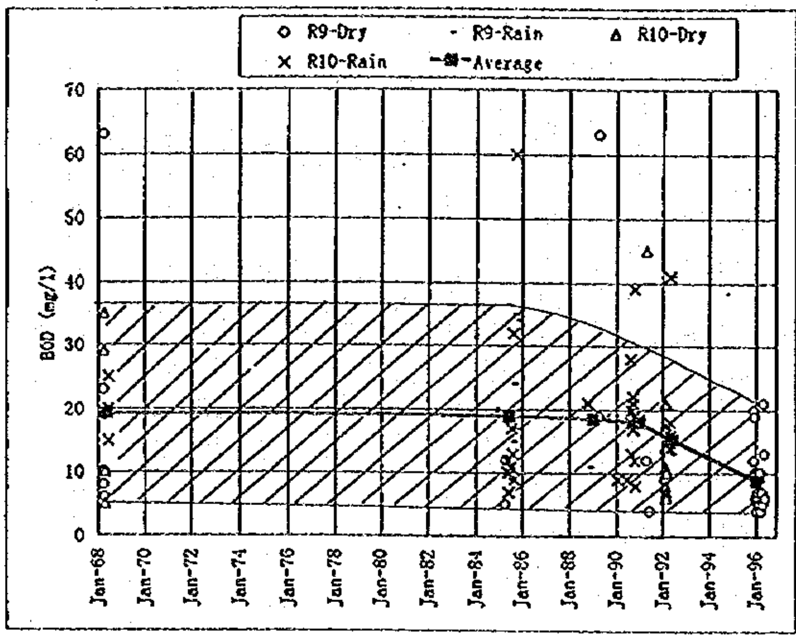
Water Quality in Tuy River (Puente Ocumare) from GTZ Data

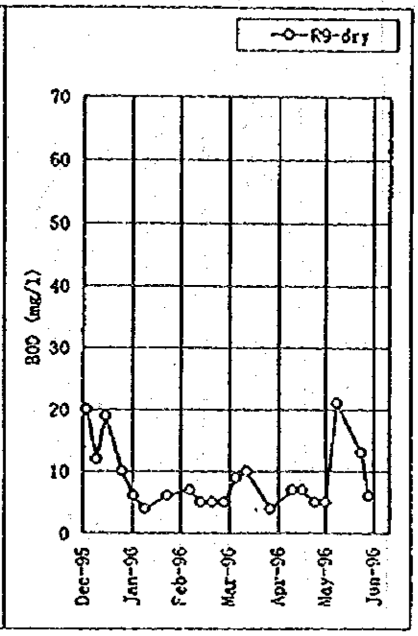


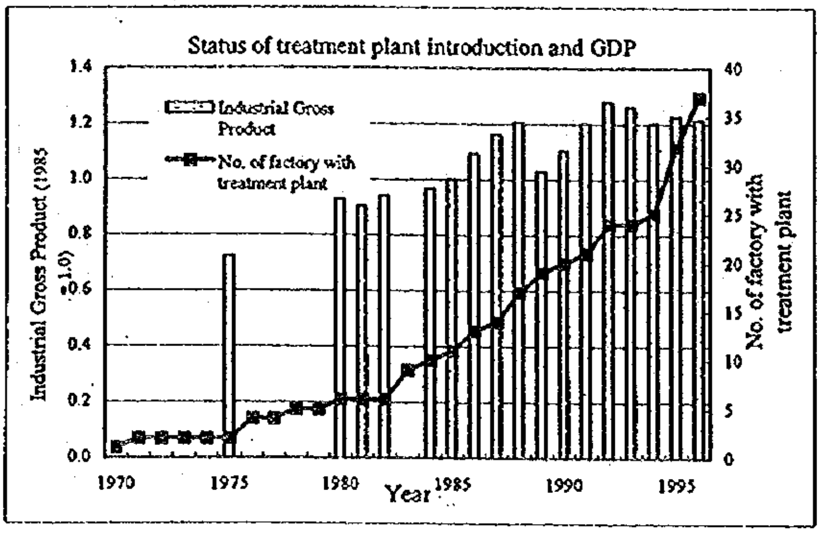
Seasonal Change of BOD at Est.Bombeo in 1968



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.2-13 Water Qualities from Past Observations

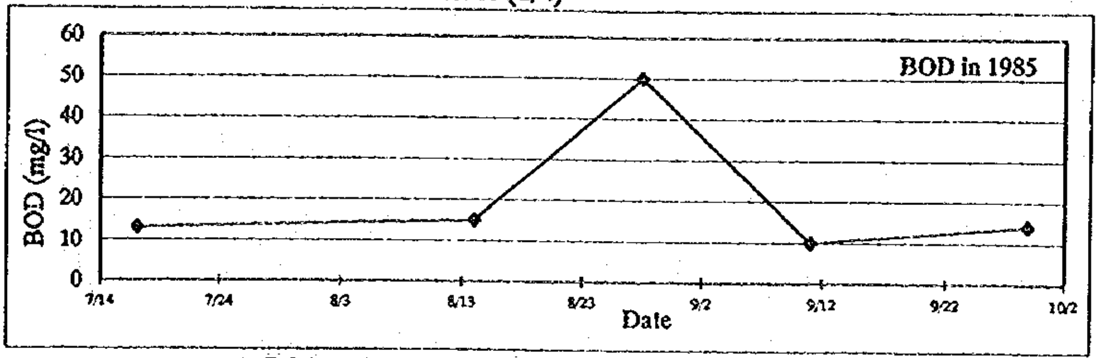




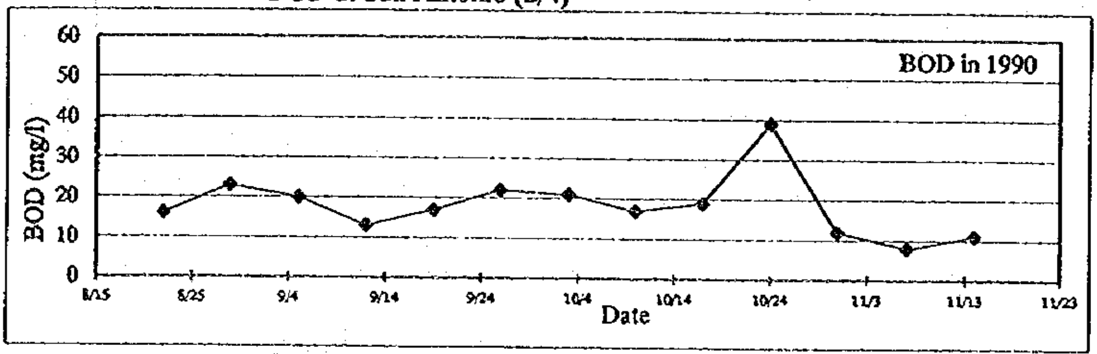


THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-14 (1/2) Historical and Seasonal Change of BOD in the Tuy River
JAPAN INTERNATIONAL COOPERATION AGENCY	

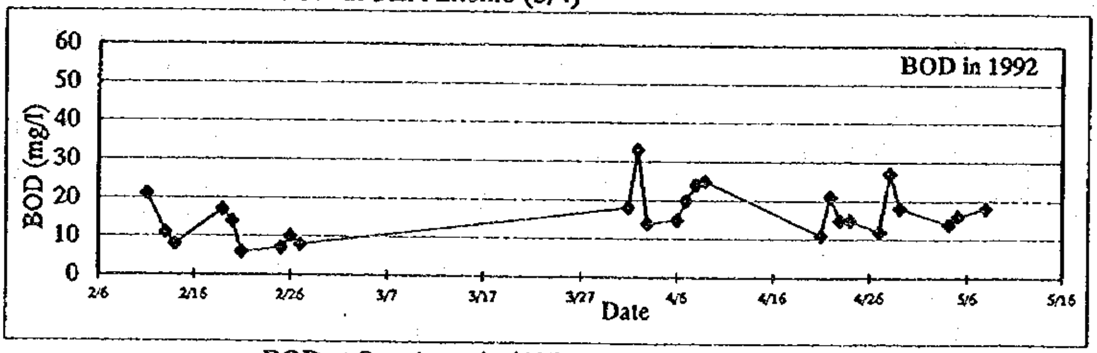
BOD at San Antonio (1/4)



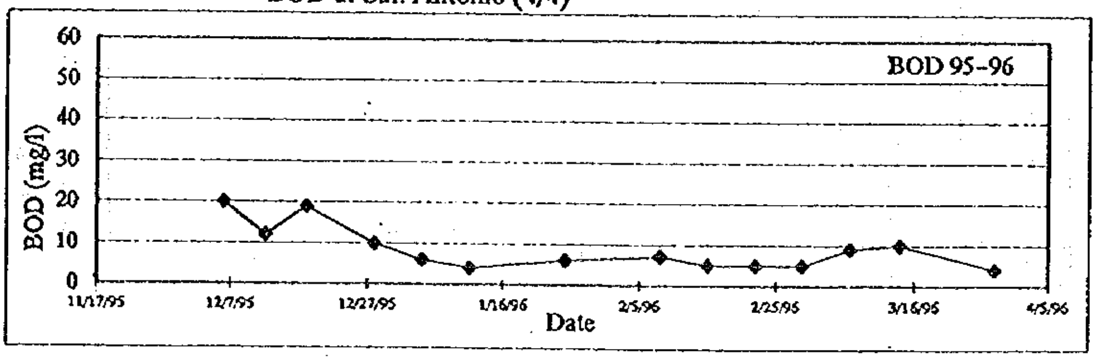
BOD at San Antonio (2/4)



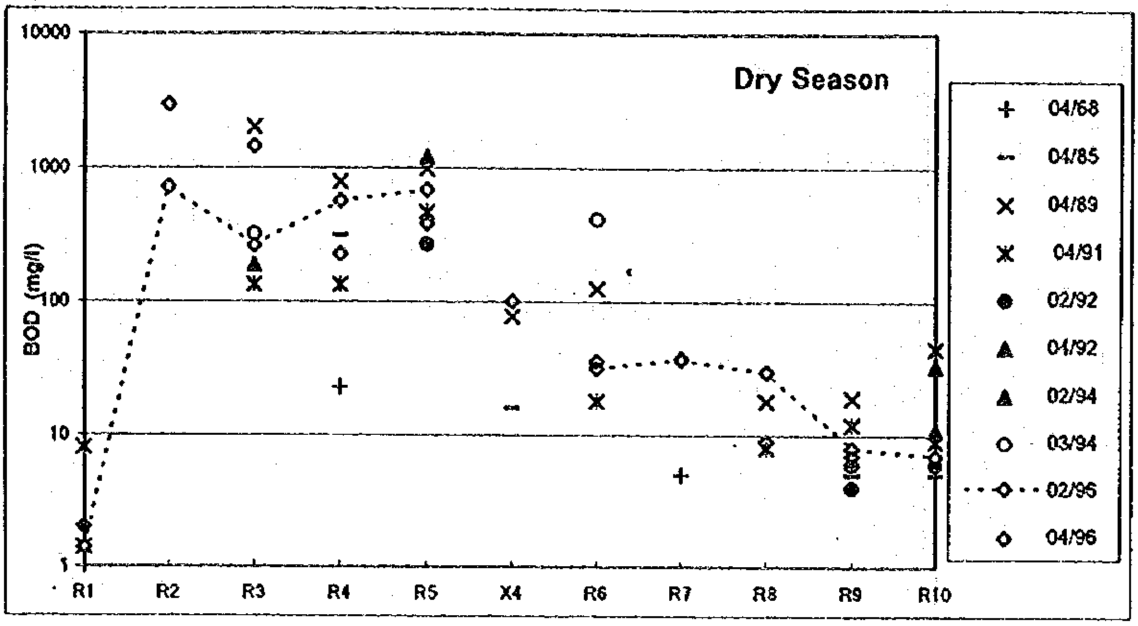
BOD at San Antonio (3/4)

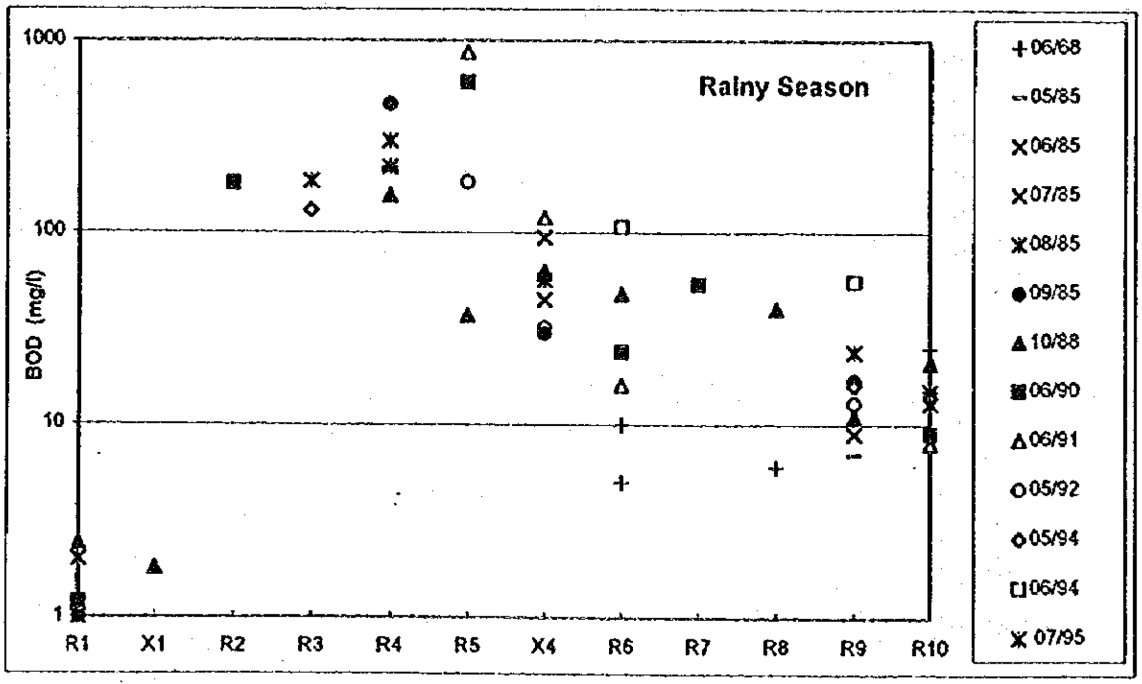


BOD at San Antonio (4/4)

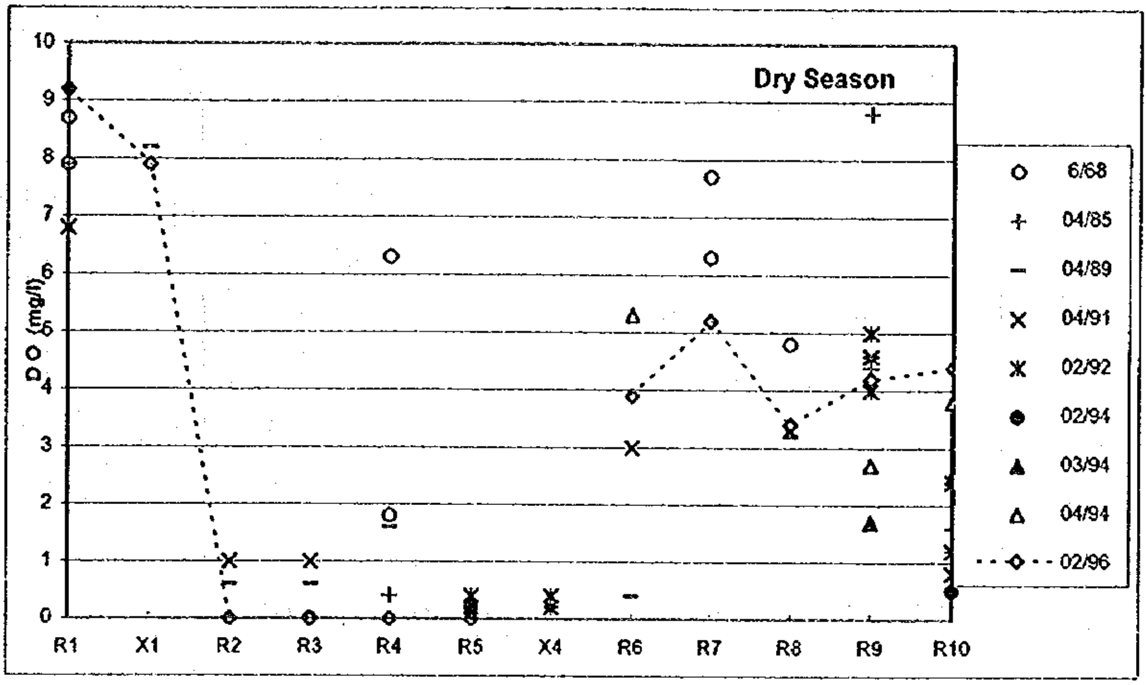


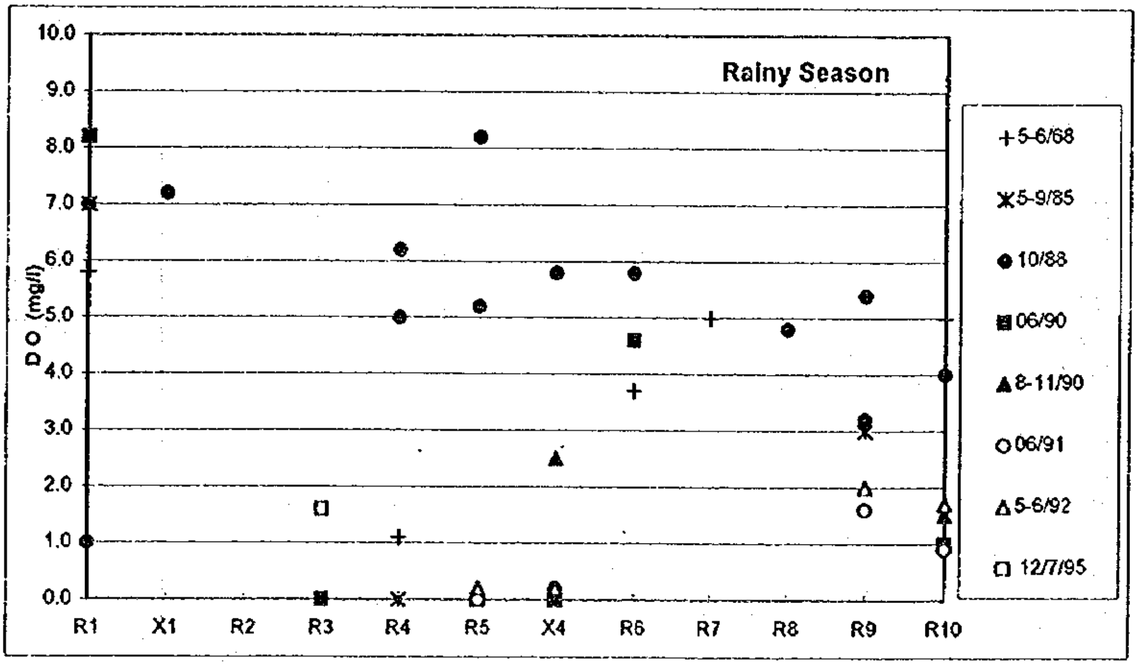
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-14 (2/2) Historical and Seasonal Change of BOD in the Tuy River
JAPAN INTERNATIONAL COOPERATION AGENCY	



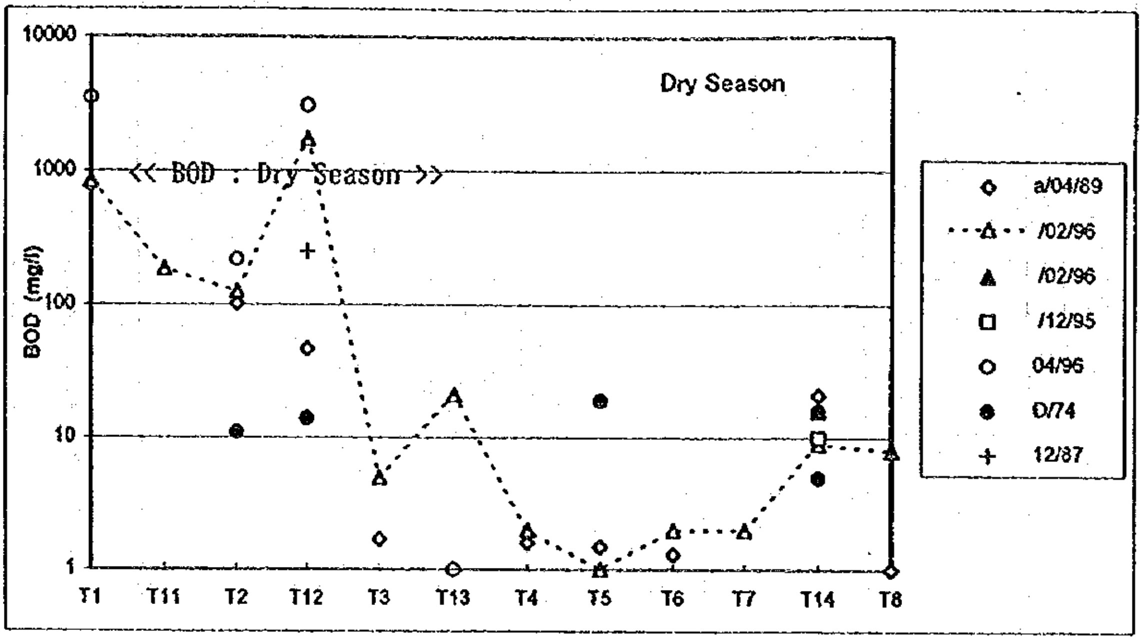


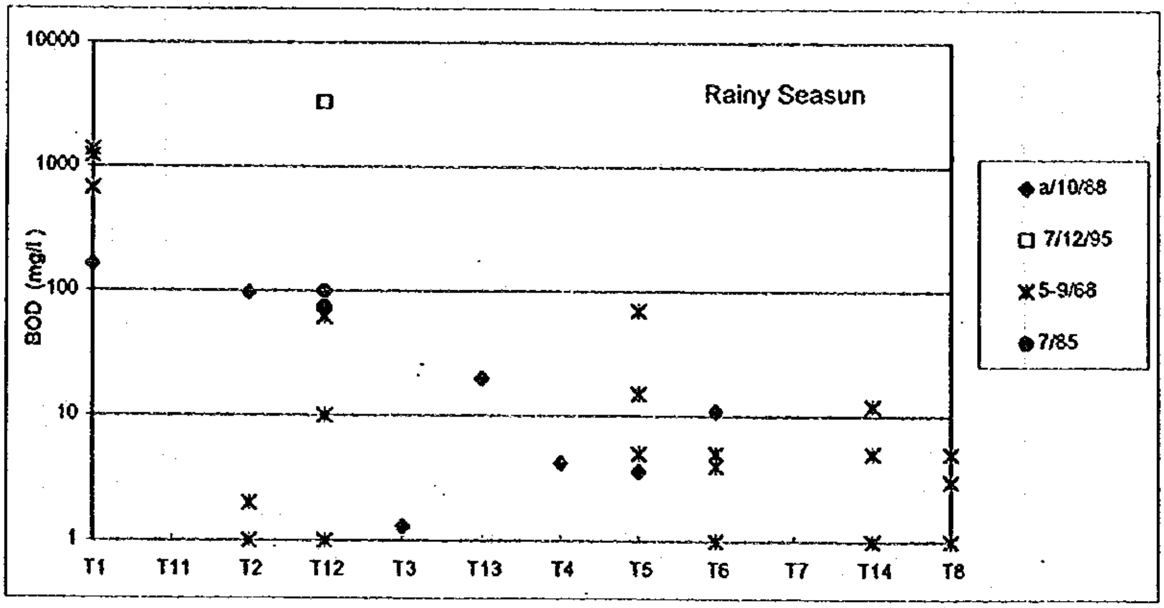
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.2-15 (1/2) Seasonal Changes of BOD and DO in the Tuy River



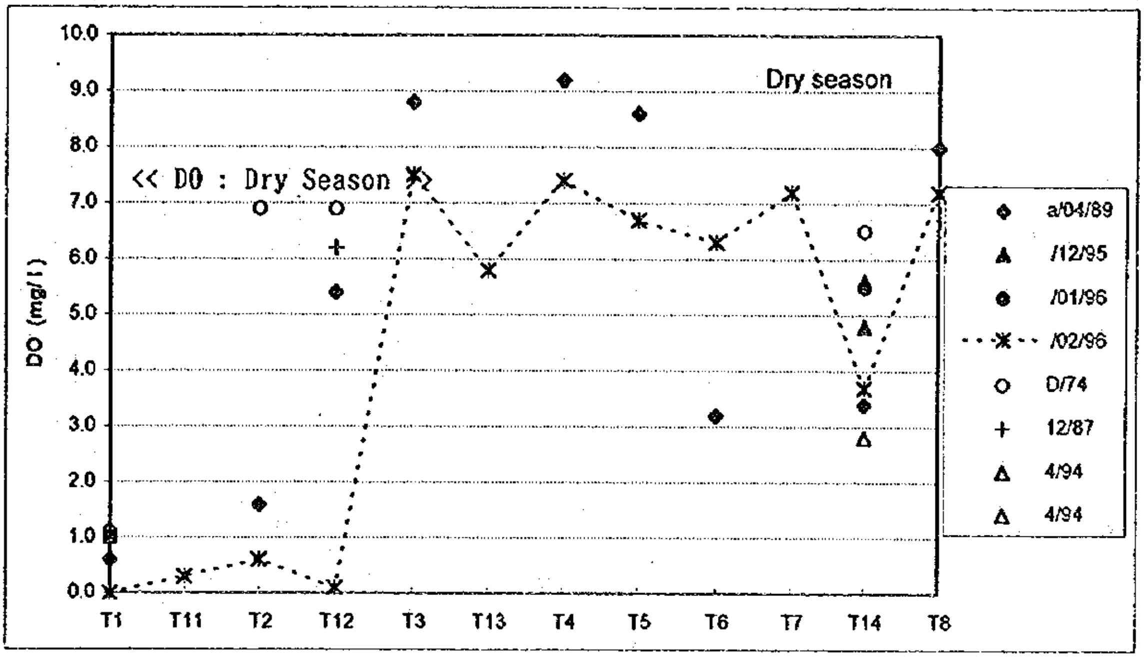


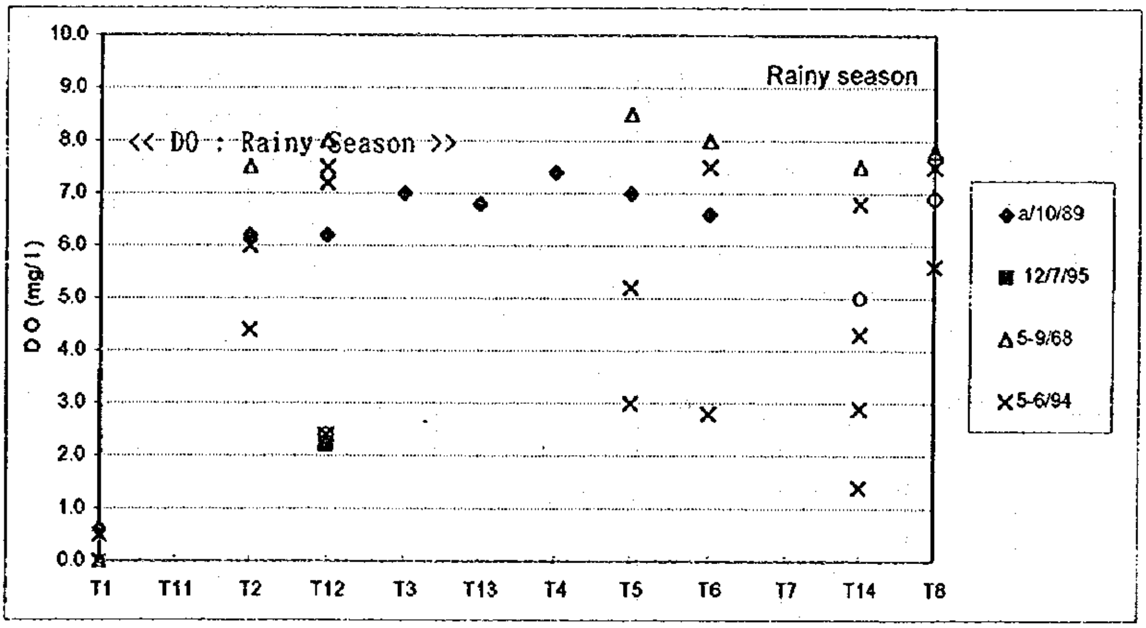
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-15 (2/2) Seasonal Changes of BOD and DO in the Tuy River
JAPAN INTERNATIONAL COOPERATION AGENCY	



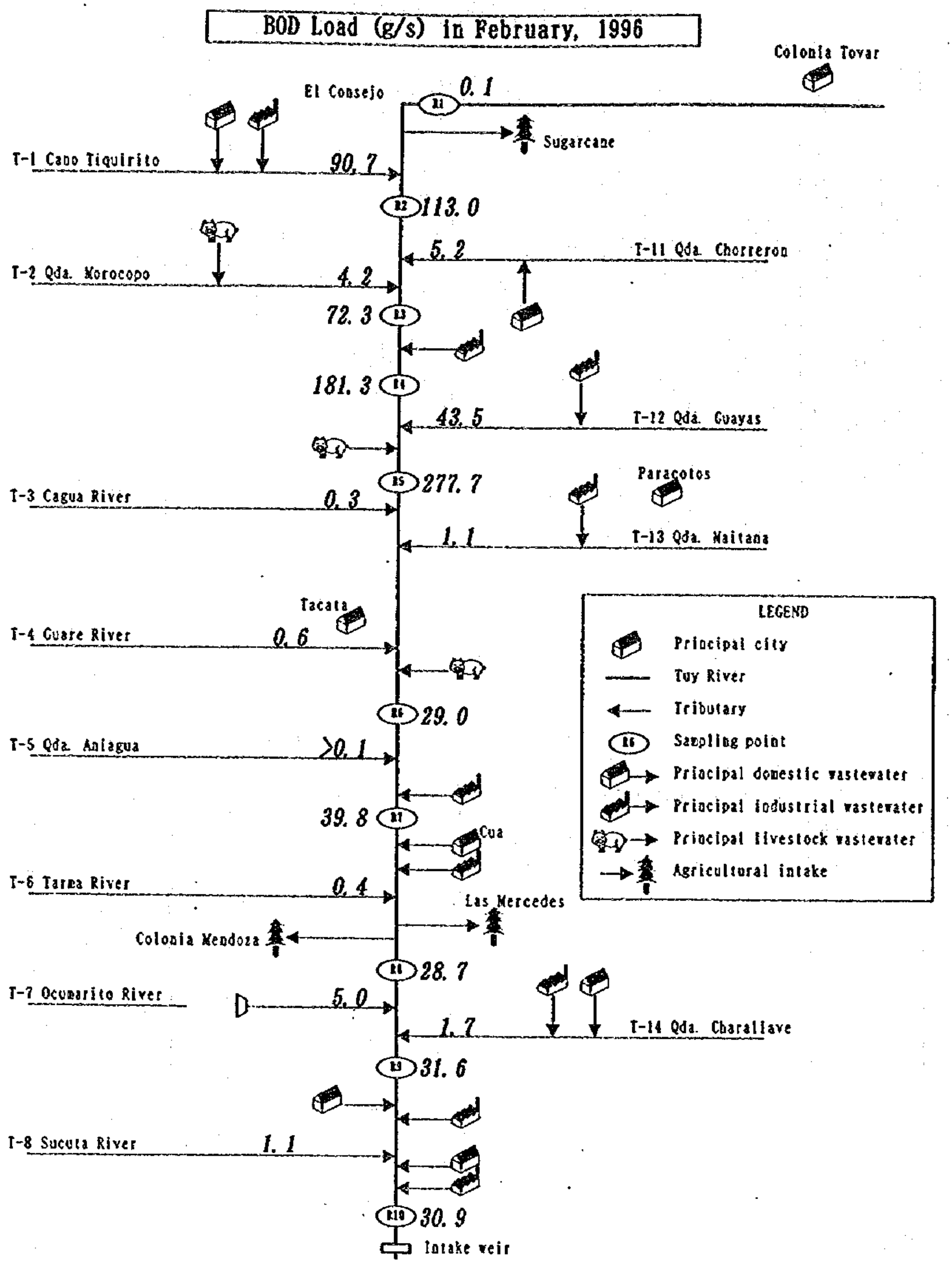


THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-16 Seasonal Changes of BOD and DO in Tributaries (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	





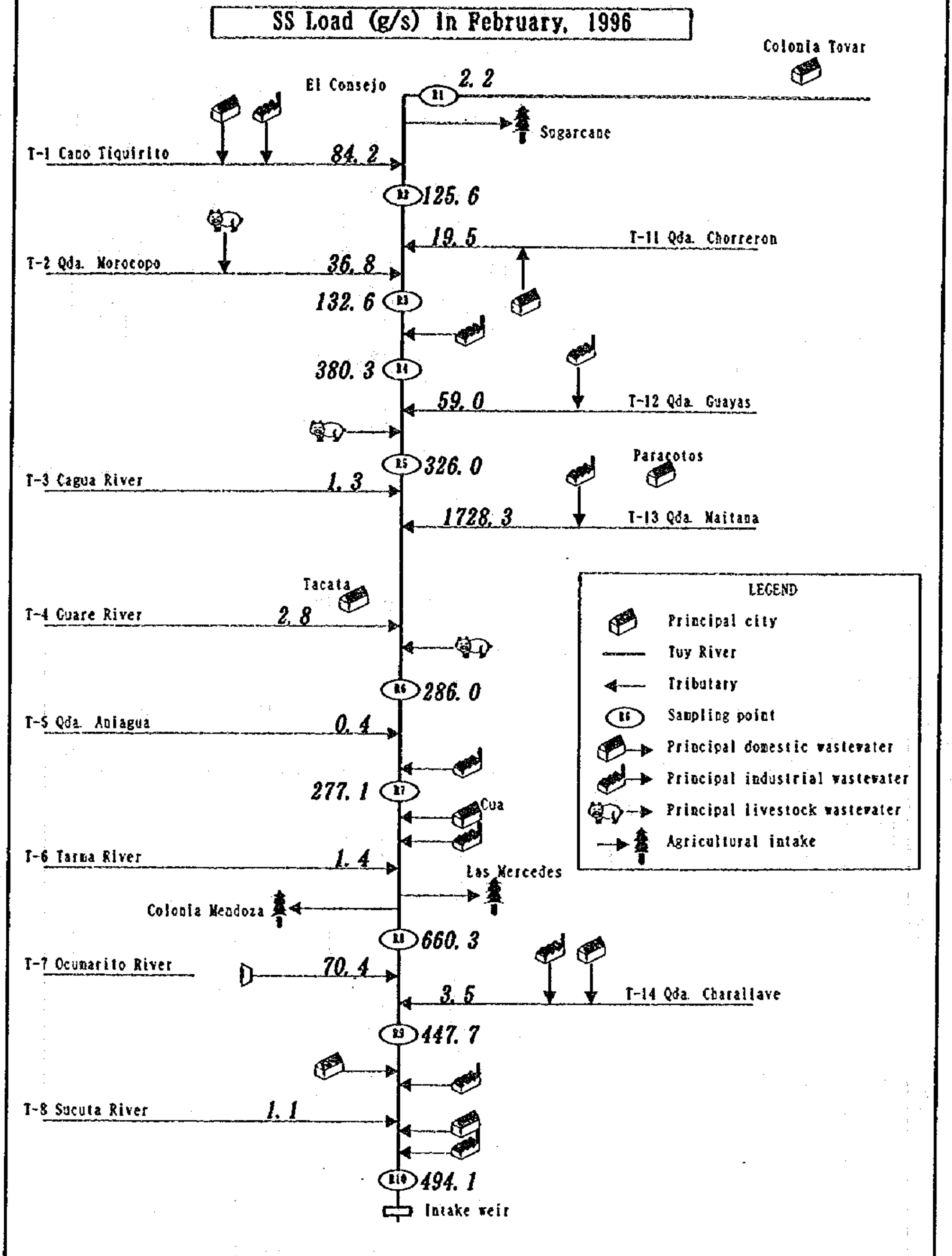
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 1.2-16 Seasonal Changes of BOD and DO (2/2) in Tributaries
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

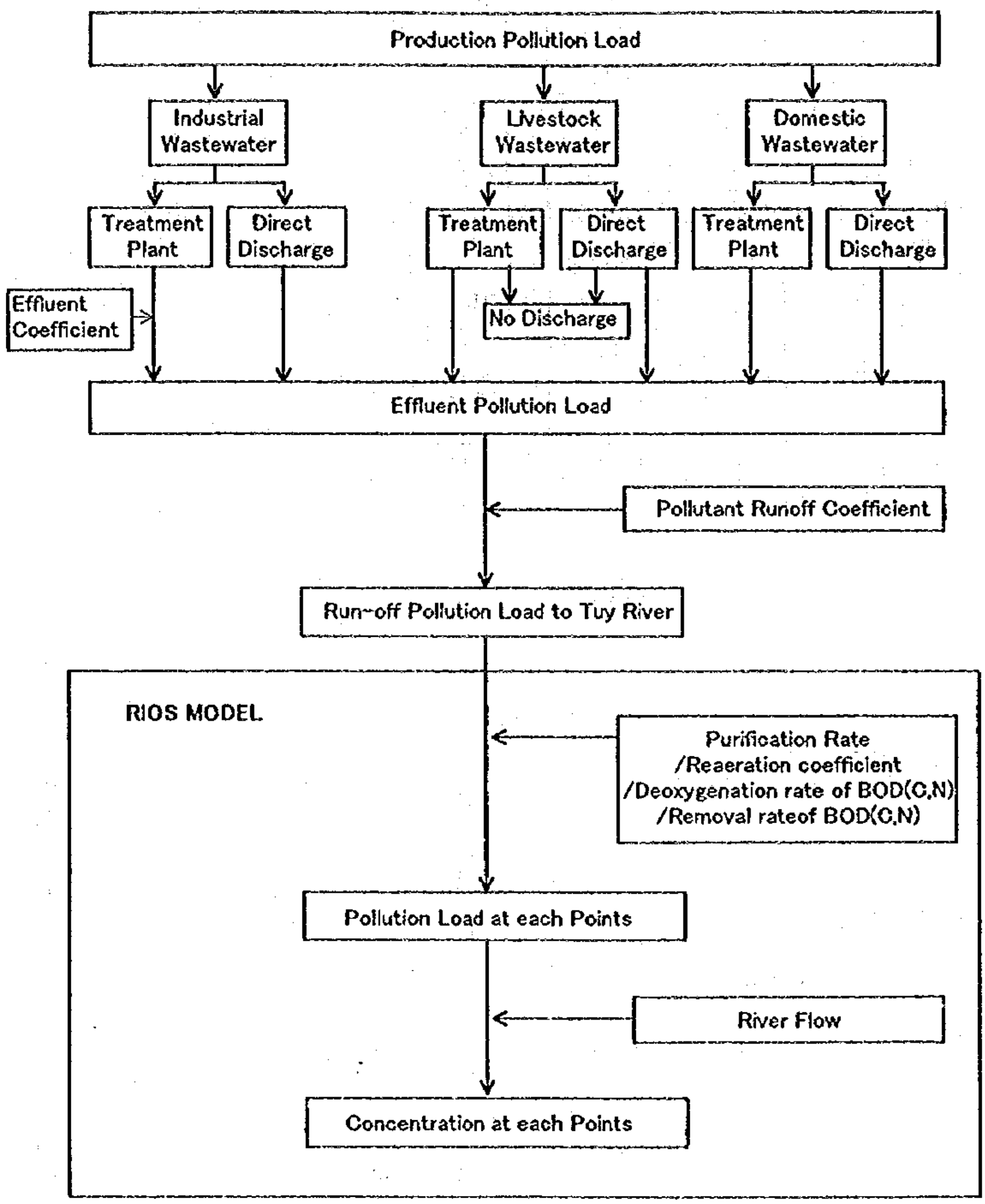
Fig. 1.3-1 BOD Load before Intake Weir



THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

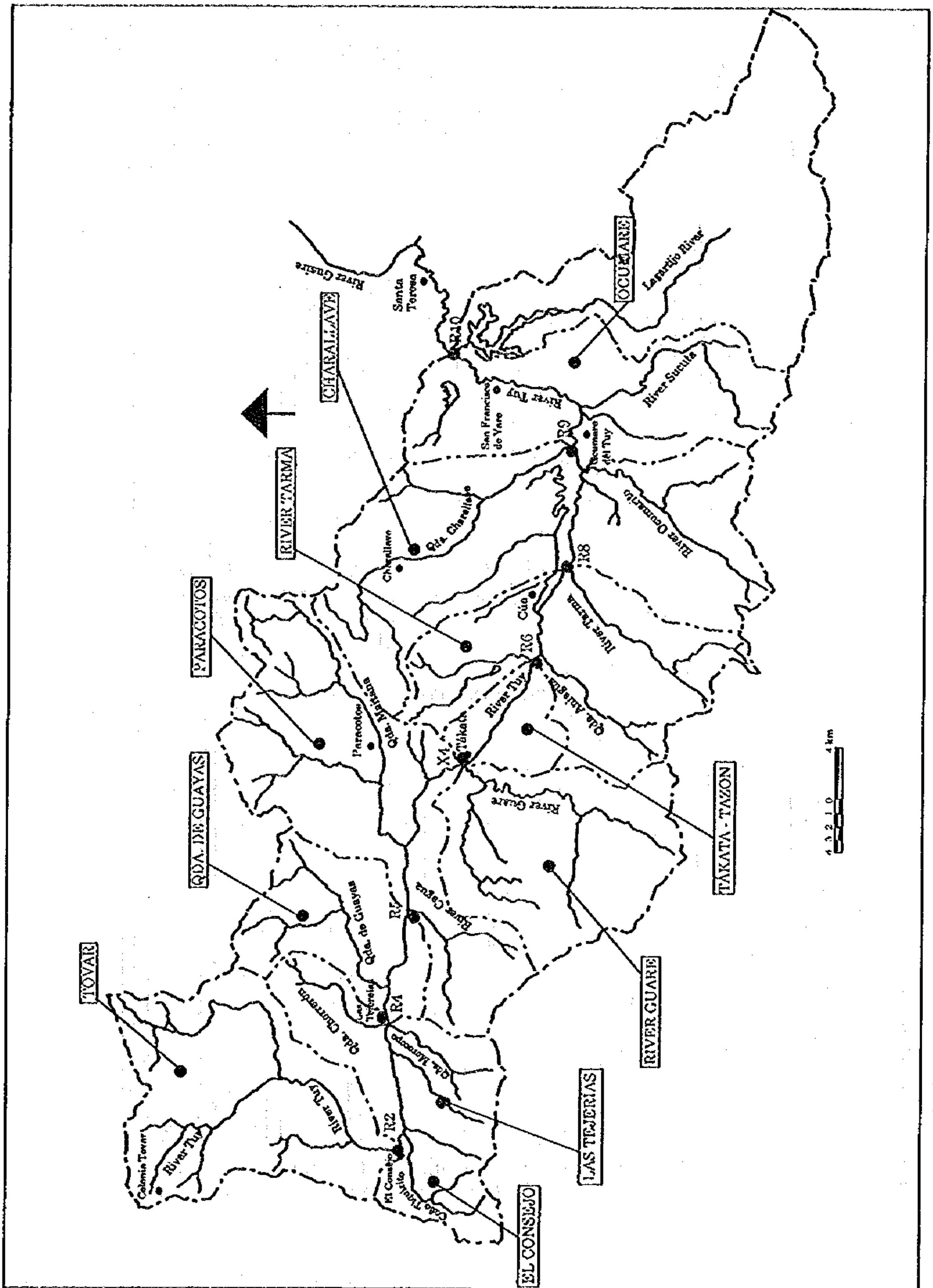
Fig. 1.3-2 SS Load before Intake Weir



THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

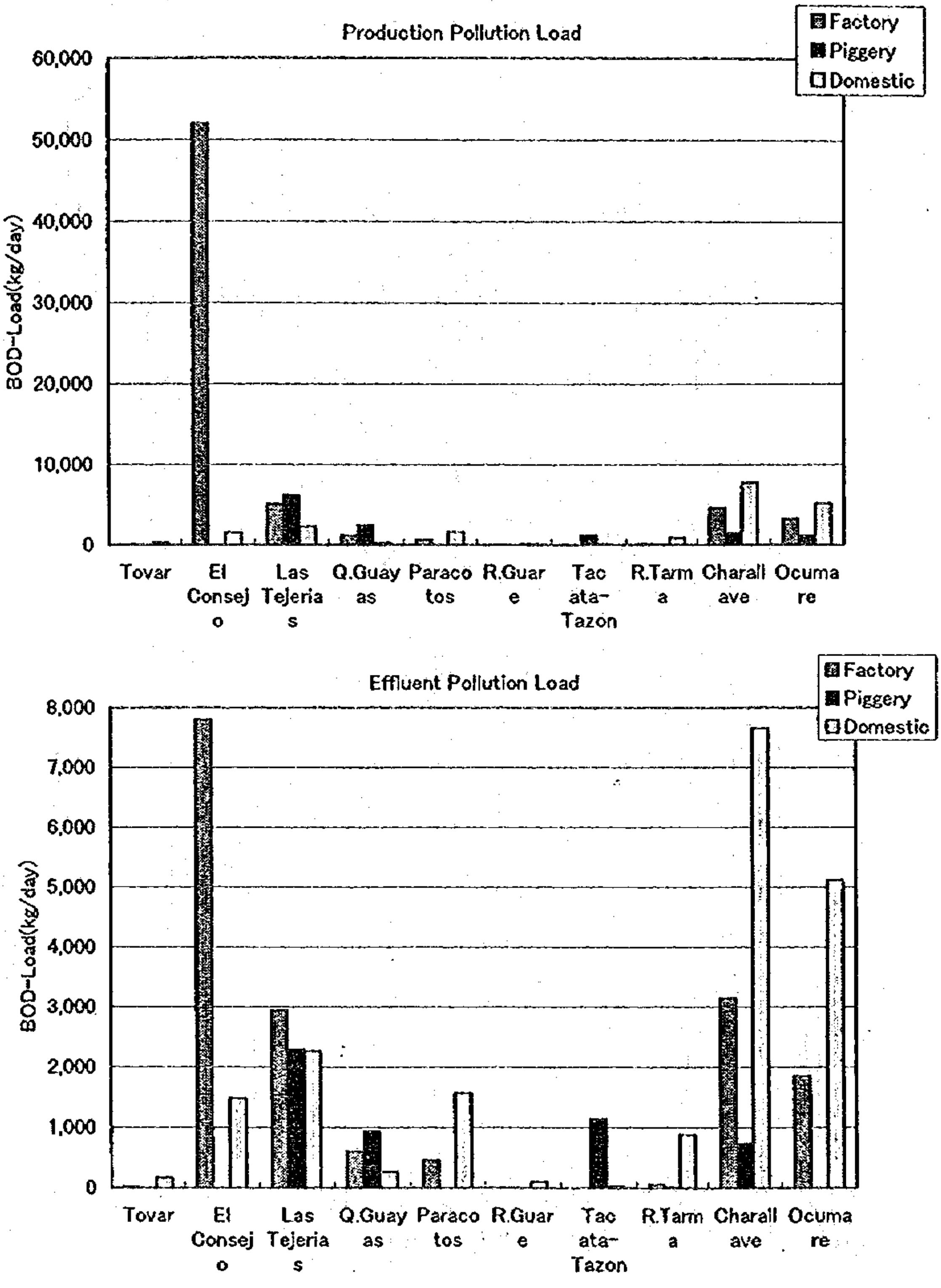
Fig. 1.3-3 Flow Chart of Pollution Analysis



THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE
STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 1.3-4 Sub Basin for Pollution - Discharge Analysis



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.3-5 Production and Effluent Pollution Load

Weighted average of effluent coefficient → Runoff coefficient →

Tovar (effluent coefficient 57.8 (%); runoff coefficient 20 (%) → R-2)

	Production load	Effluent load
F	38	19
P	0	0
D	285	168
T	323	187

El Consejo (effluent coefficient 17.4 (%); runoff coefficient 100 (%))

	Production load	Effluent load
F	51,949	7,792
P	0	0
D	1,482	1,482
T	53,431	9,275

R-2

Load	9,312	(kg/day)
Flow	13,565	(m3/day)
Conc	686	(mg/l)

−592

Las Tejerias (effluent coefficient 55.6 (%); runoff coefficient 90 (%))

	Production load	Effluent load
F	5,083	2,948
P	6,140	2,286
D	2,262	2,262
T	13,485	7,496

R-4

Load	15,465	(kg/day)
Flow	27,475	(m3/day)
Conc	563	(mg/l)

−30

Q.Guayas (effluent coefficient 46.8 (%); runoff coefficient 90 (%))

	Production load	Effluent load
F	1,173	603
P	2,414	936
D	261	261
T	3,848	1,800

R-5

Load	17,055	(kg/day)
Flow	28,512	(m3/day)
Conc	598	(mg/l)

−15,984

Paracotos (effluent coefficient 94.7 (%); runoff coefficient 20 (%))

	Production load	Effluent load
F	570	456
P	0	0
D	1,571	1,571
T	2,141	2,027

X-4

Load	1,477	(kg/day)
Flow	43,632	(m3/day)
Conc	34	(mg/l)

−79

R.Guare+Tazon (effluent coefficient 98.7 (%); runoff coefficient 90 (%))

	Production load	Effluent load
F	0	0
P	1,134	1,134
D	137	121
T	1,271	1,255

R-6

Load	2,528	(kg/day)
Flow	78,192	(m3/day)
Conc	32	(mg/l)

−919

R.Tarma (effluent coefficient 95.0 (%); runoff coefficient 90 (%))

	Production load	Effluent load
F	74	59
P	49	15
D	874	874
T	997	947

R-8

Load	2,461	(kg/day)
Flow	82,685	(m3/day)
Conc	30	(mg/l)

−1,916

Charallave (effluent coefficient 83.7 (%); runoff coefficient 20 (%))

	Production load	Effluent load
F	4,572	3,135
P	1,458	729
D	7,732	7,654
T	13,762	11,518

R-9

Load	2,849	(kg/day)
Flow	340,848	(m3/day)
Conc	8	(mg/l)

−6,264

Ocumare (effluent coefficient 73.5 (%); runoff coefficient 90 (%))

	Production load	Effluent load
F	3,213	1,853
P	1,118	0
D	5,152	5,117
T	9,483	6,970

R-10

Load	2,858	(kg/day)
Flow	381,197	(m3/day)
Conc	7	(mg/l)

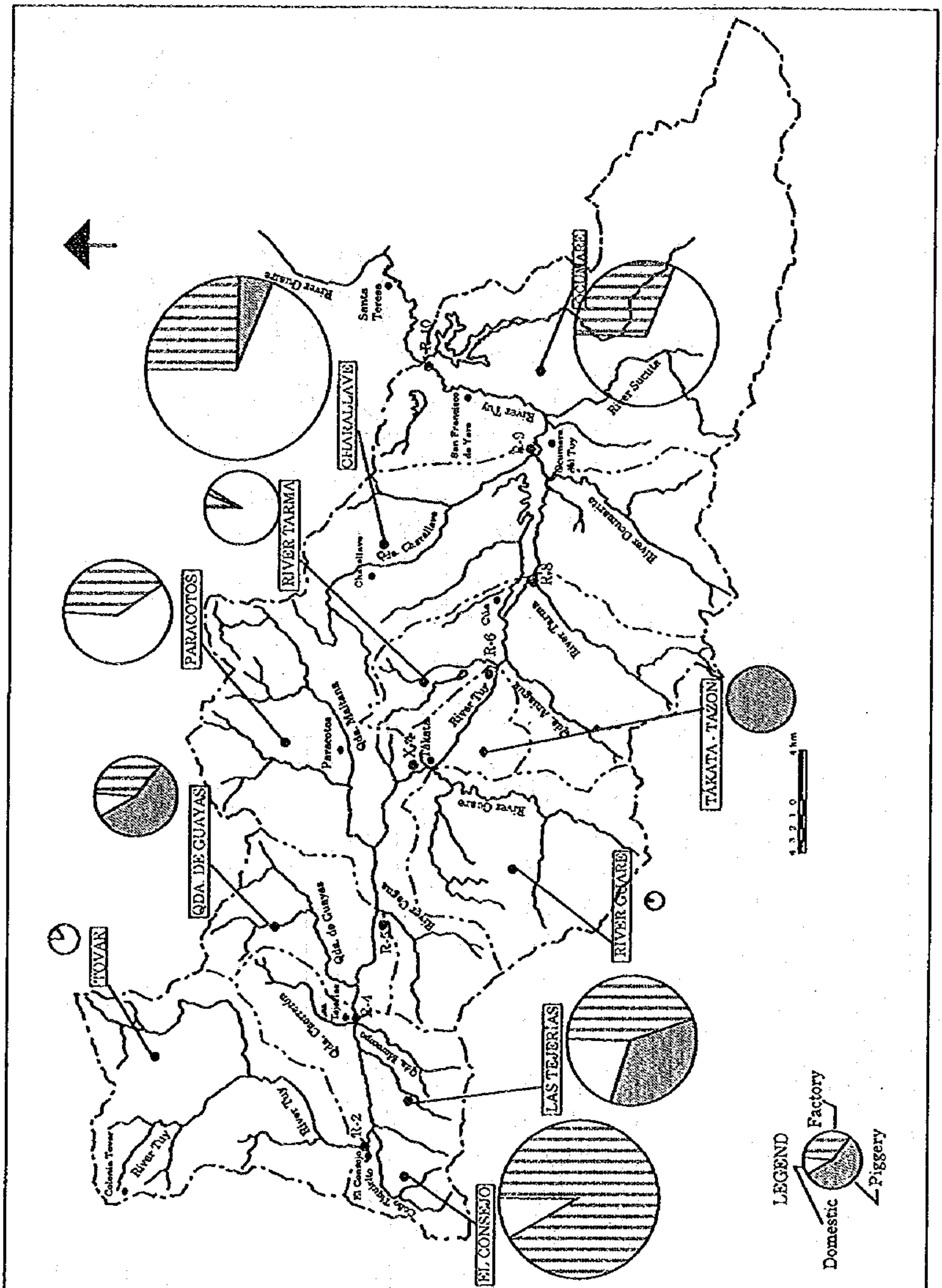
Fig. 1.3-6 Balance of BOD Load in the Tuy River

Pattern	Station	BOD (mg/l)	SS (mg/l)
1 High	El Consejo	6,523	
	Boca de Cagua	2,776	
	Tacata	119	
	Toma de Agua	16	1,170
2 Standard	El Consejo	5,335	
	Boca de Cagua	2,440	
	Tacata	97	
	Toma de Agua	14	1,080
3 Low	El Consejo	3,468	
	Boca de Cagua	1,794	
	Tacata	70	
	Toma de Agua	11	1,020

THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE
STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

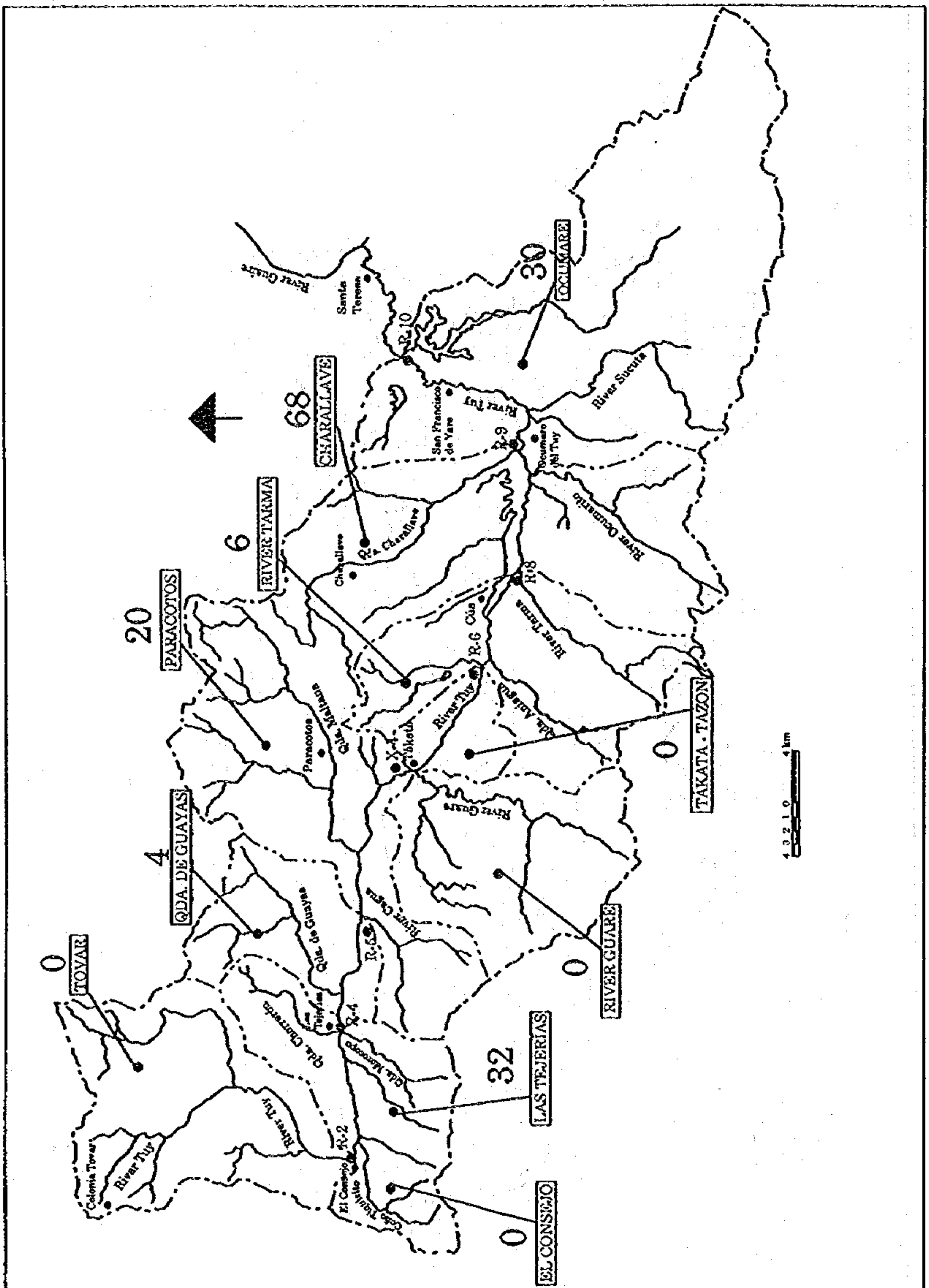
Fig. 2.3-1 Baseline Pollution Projection (BOD and SS Concentrations in 2010)



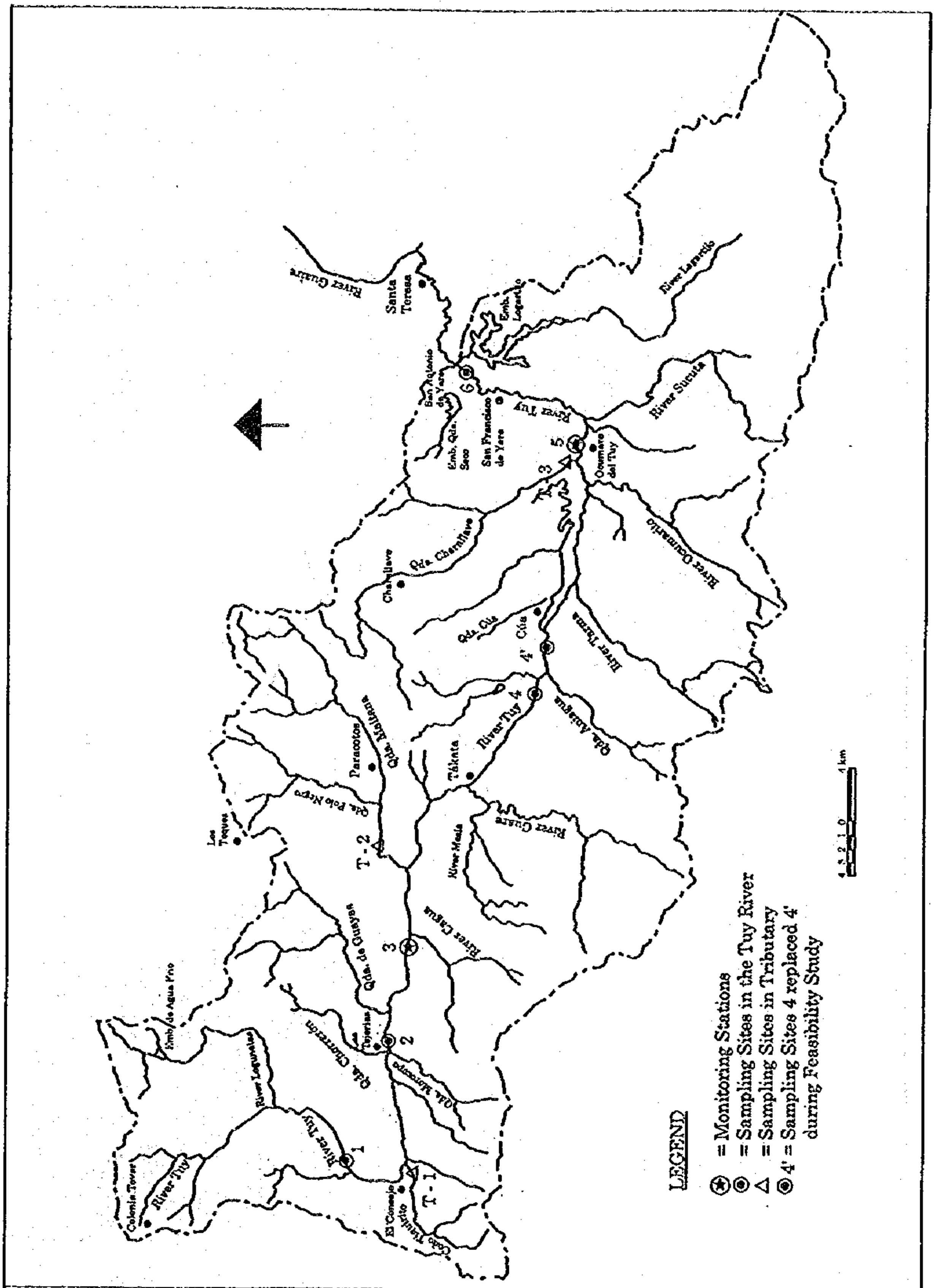
THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

JAPAN INTERNATIONAL COOPERATION AGENCY

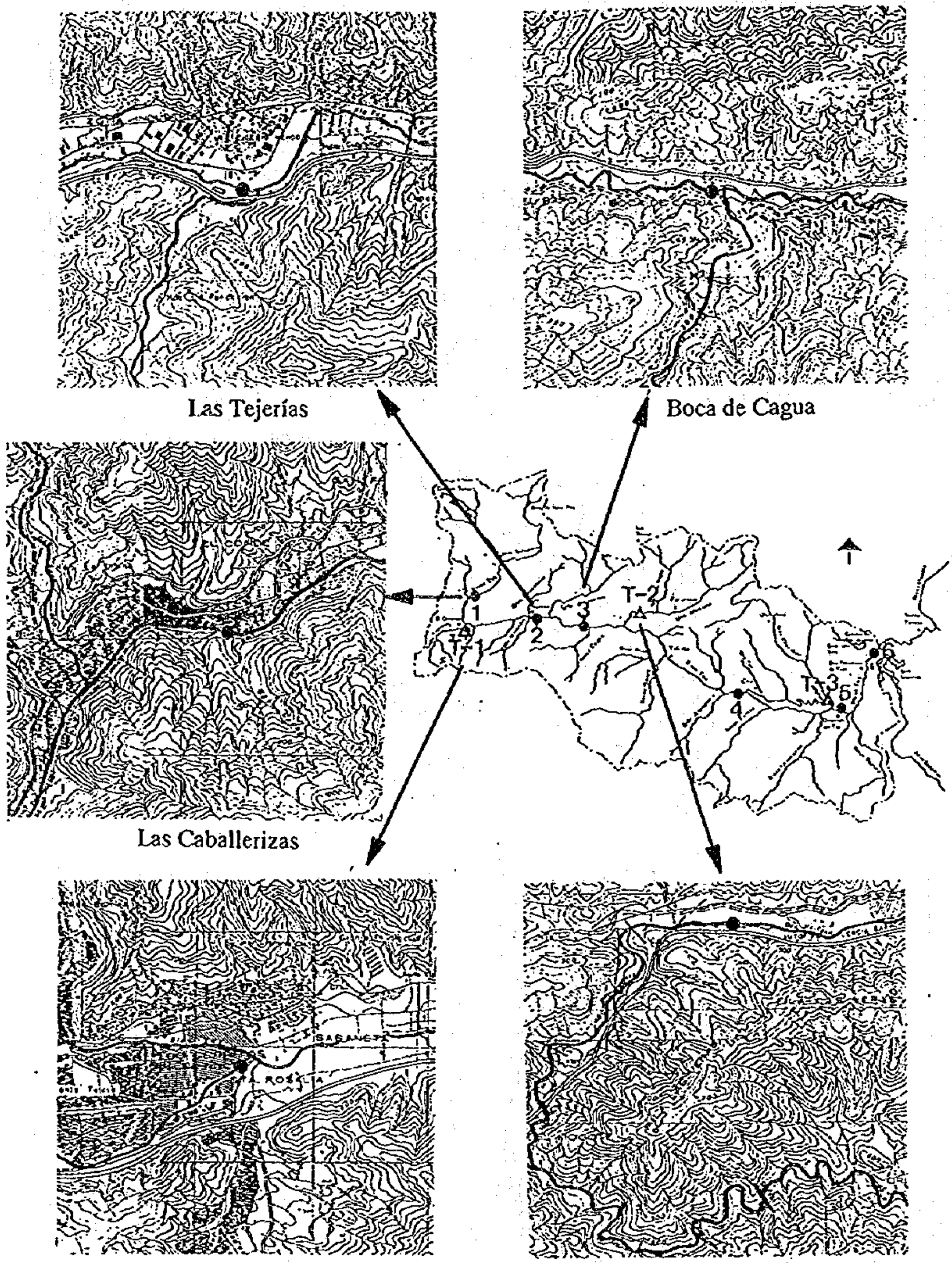
Fig. 3.1-1 Spatial Distribution of BOD Effluent Load



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 3.1-2 Spatial Distribution of Non-food Factory Number
JAPAN INTERNATIONAL COOPERATION AGENCY	



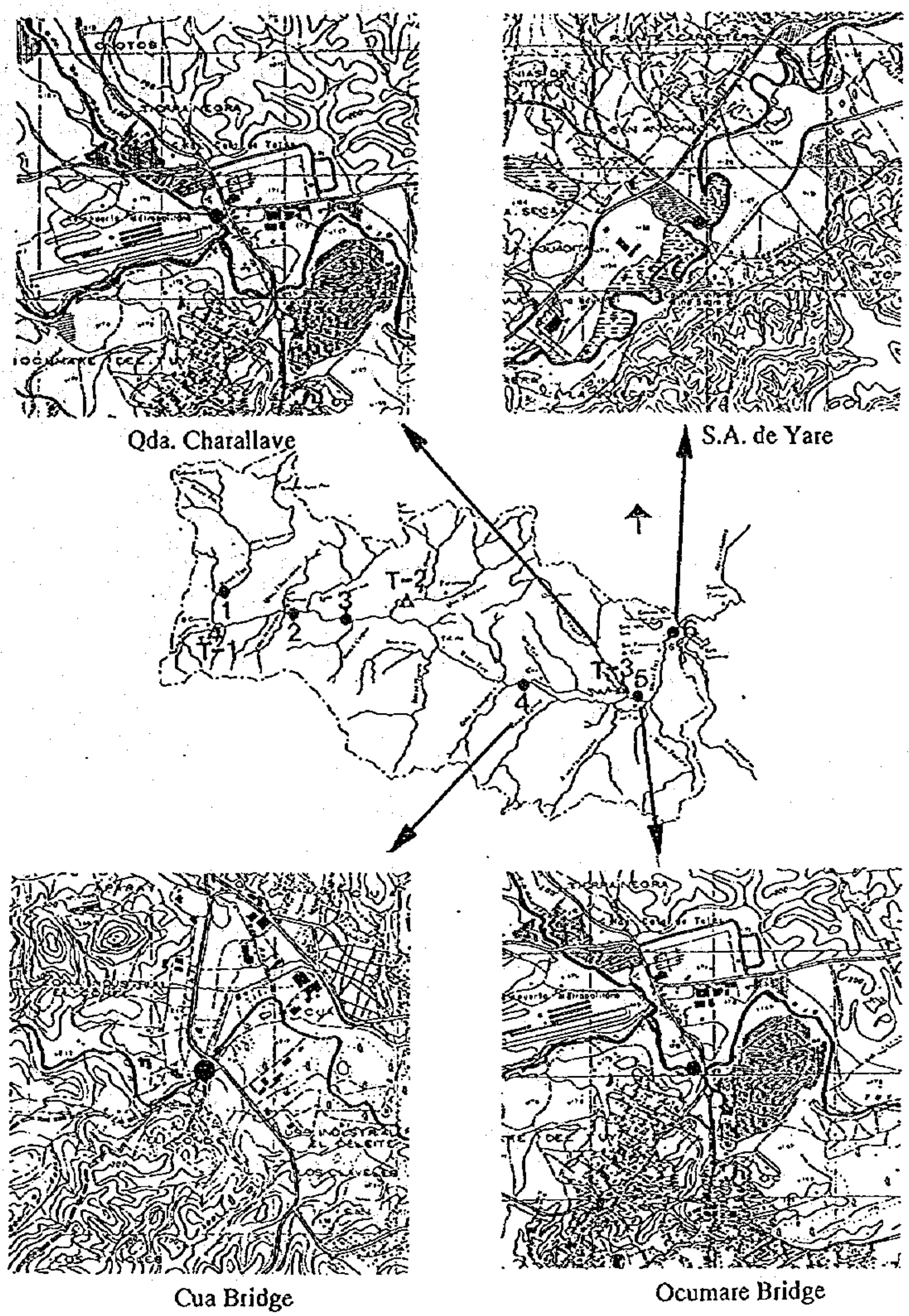
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 4.2-1 Proposed Monitoring Stations and Sampling Sites
JAPAN INTERNATIONAL COOPERATION AGENCY	



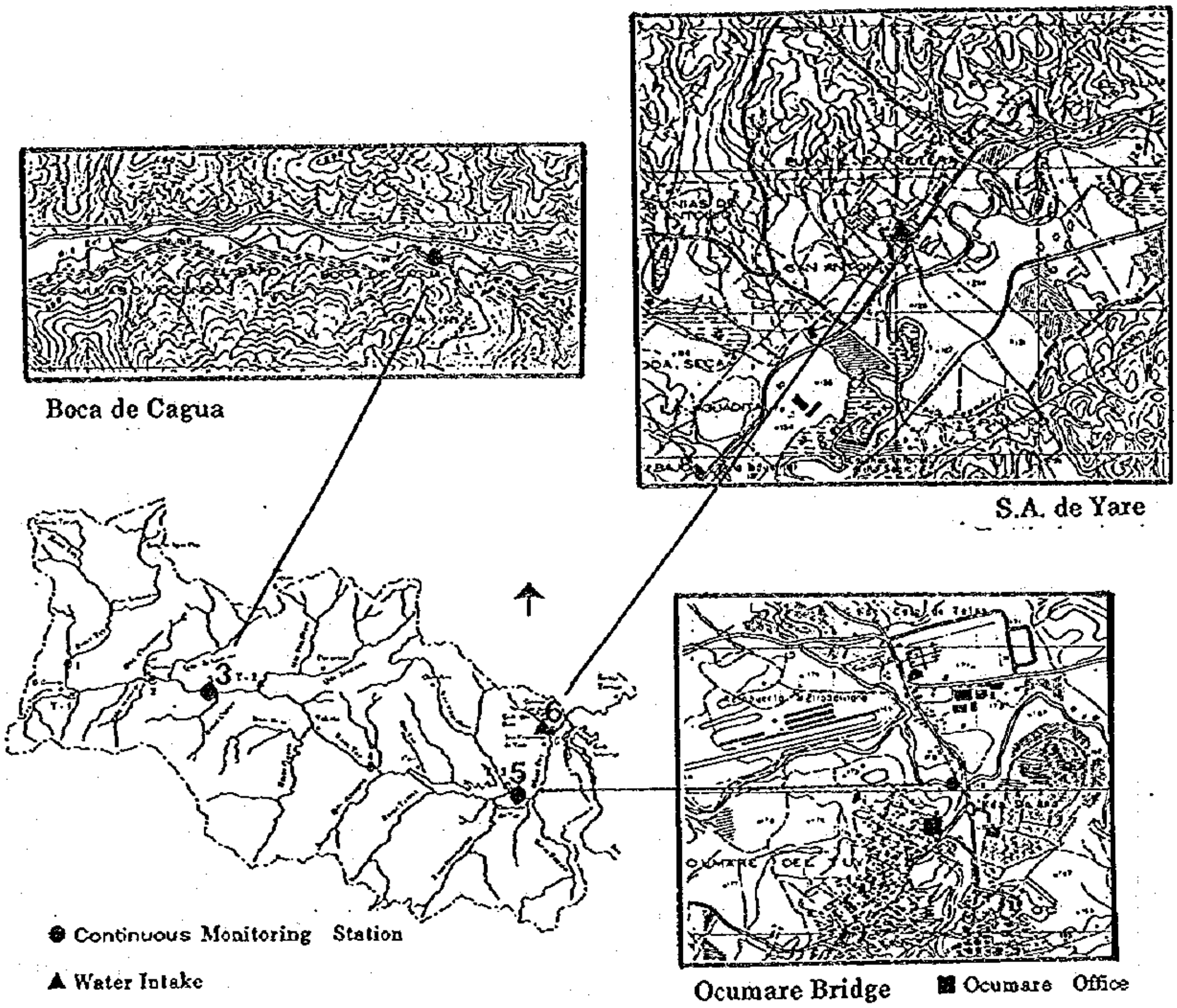
THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE
STREAM OF THE TUY RIVER BASIN
IN THE REPUBLIC OF VENEZUELA

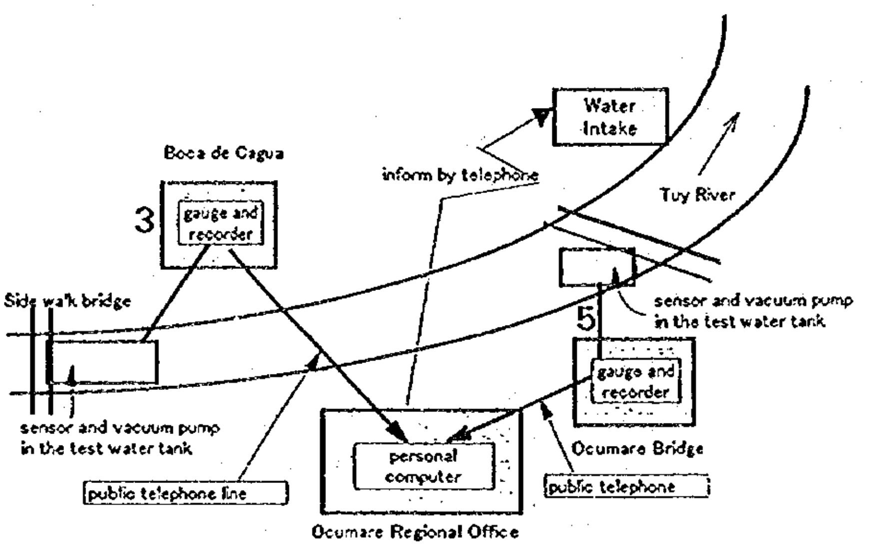
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 5.2-1 Location of Sampling Sites (1/2)



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 5.2-1 Location of Sampling Sites (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	





Continuous Monitoring System

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 5.2-2 Location of Continuous Monitoring Stations
JAPAN INTERNATIONAL COOPERATION AGENCY	

SECTOR B

EXISTING WATER SUPPLY SYSTEM

F.48'

THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF
THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN

SECTOR B: EXISTING WATER SUPPLY SYSTEM

TABLE OF CONTENTS

LIST OF TABLES

. LIST OF FIGURES

SECTOR B: EXISTING WATER SUPPLY SYSTEM

1. Outline of the Water Supply System

Figs 1-1 and 1-2 show the Metropolitan Caracas Water Supply Map and Water Supply System Diagram. The current conditions of the water supply system are discussed hereunder:

Development of the Water Supply System

The Metropolitan Caracas water supply system was established in 1950 using groundwater resources of the adjacent area. The increase in the population and demand for water supply led to the gradual development of other water resources, namely the Tuy River and reservoirs in the surrounding area. Table 1-1 shows the progress in the development of the water supply system of Metropolitan Caracas.

Agency Responsible for Water Supply

"Hidrocapital", a public organization, is responsible for the construction, operation and maintenance of the water supply system in Metropolitan Caracas. The Tuy River Basin Agency supervises the use of the Tuy River as a water resource. Both organizations are under the jurisdiction of MARNR.

Characteristics of the Metropolitan Caracas Water Supply System

The characteristics of the Metropolitan Caracas water supply system are generally as follows:

- Water resources in the Caracas valley are limited and must be found outside the metropolitan area. Production costs are high due to the disparity between the water resources elevations (100 to 200 meters) and the service area elevation (900 m), as well as the long distances from 35 to 40 km between these areas.
- Production costs considerably exceed the amount of money collected from the water consumers because of the low water fee structure set by the government. The collected water fees only cover 44% of the production costs. The operation of the water supply is therefore precarious.

2. Water Sources

Currently, the water sources of Caracas are the Tuy River and the Lagartijo, Taguacita and Camatagua reservoirs. Average intake in 1995 were as follows:

Water resource	Intake (m^3/s)
Tuy River	3.56
Lagartijo reservoir	2.05
Taguacita reservoir	1.86
Camatagua reservoir	11.94
Total	19.41

The respective intake volumes from these water sources are as shown in Table 2-1and Fig. 2-1 (for detail, see Annex).

The intake ratios from these water sources are shown below:

	Tuy River	Lagartijo	Taguacita	Camatagua
Dry Season	14.8%	14.7%	7.8%	62.7%
Rainy Season	20.5%	7.6%	10.6%	61.3%
Average	18.3%	10.6%	9.6%	61.5%

Currently, the dependence on Camatagua is the greatest, at over 60% in all seasons. As the intake volume of $11.94m^3/s$ is close to the system limit of station No. 31, it is currently impossible to increase the transmission capacity from the Camatagua Reservoir, whatever its water level. If we compare with other sources, the second water source after Camatagua in terms of intake volume is Tuy River at $3.56m^3/s$, which is only 46% of the intake capacity at Toma de Agua. Accordingly, it is possible to increase the total intake volume, depending on Tuy River level.

Each water source is described hereunder.

(1) Tuy River

Water from the Tuy River is collected from the intake weir in San Antonio, and is collected by pumps Toma II and III. The average intake volume in 1995 was $3.56m^3/s$. The collected water is conveyed to the pre-treatment plant to remove mud and sand. It then merges with water from the Lagartijo Reservoir and is conveyed to station No. 11 of the Tuy I System and station No. 21 of the Tuy II System.

The details of the intake pumps are as follows:

Station	Number of Pumps	Capacity/pump	Head/pump	Power/pump
Toma II	7	600 l/s	25 m	350 kW
Toma III	2	1,750 l/s	35 m	950 kW

There used to be a Toma I Pump System to collect the water from the Tuy River by diverting the flow with a channel. However, it is not used anymore.

(2) Lagartijo Reservoir

Water from the Lagartijo Reservoir is conveyed by gravity to pumping stations No. 11 & No.21. The water intake volume is controlled by the opening and closing of a valve. The average intake in 1995 was 2.05m^3/s. The conveyed water then merges with water from the Tuy River that was treated at pre-treatment plant. Surplus water is conveyed to Quebrada Seca Reservoir for storage. Conveyance to Quebrada Seca is carried out by gravity when the water level in the Lagartijo Reservoir is high, and by pumping when the water level is low.

(3) Taguacita Reservoir

Water collected at the Taguacita Reservoir is pumped up at the Taguacita pumping station to Toma de Agua. The average intake volume in 1995 was 1.86m^3/s. The water then merges with the water in the Tuy II System conveyance pipe before it reaches station No.21.

The details of the pumps at the Taguacita pump station are as follows:

Station	Number of Pumps	Capacity/pump	Head/pump	Power/pump
Taguacita	4	1,000 l/s	287 m	3,850 kW

(4) Camatagua Reservoir

Water from the Camatagua Reservoir is collected by an intake tower, pumped up at stations No. 31 and Mamonal, and conveyed to Caicita. It then flows by gravity to the Caujarito treatment plant. The average intake volume in 1995 was 11.94m^3/s.

3. Composition of the System

The water transmission system to the Caracas Metropolitan Area is composed of Tuy I, Tuy II and Tuy III systems. The composition of the system is outlined in Table 3-1 and Fig. 1-2. The monthly transmission of each system is shown in Table 3-2 and Fig. 3-1.

(1) Tuy I System

The Tuy I System was commissioned in 1965, and is currently the oldest of Caracas' three water transmission systems. Repair work in 1988 to counteract the deteriorating condition of the system has made it the most reliable system. However, compared to the other systems, it has a low supply capacity of 4.0 m^3/s.

The main water resources of the system are the Tuy River and Lagartijo

Reservoir, but when their water level is low, water is collected from the Quebrada Seca Reservoir or Camatagua Reservoir. Water from the Camatagua Reservoir can be diverted into the Tuy I system if necessary.

Water from the Tuy River and Lagartijo Reservoir is distributed to station No. 11 of the Tuy I System and station No. 21 of the Tuy II System. Water conveyed to station No. 11 is pumped up to stations No. 12, 13, and 14, flows into the Yalle River, and is stored at La Mariposa Reservoir. Water from La Mariposa Reservoir is conveyed to La Mariposa treatment plant then distributed to Caracas.

The distance between the water source and Caracas is 32.0 km, which is the shortest of the three systems. The total pump head is very high at 1,074m, but as it is relayed by 4 pump stations, the actual pump head per pump station is low compared to the other systems. Therefore the Tuy I System puts less strain on the pumps in view of the low pump head and minimal transmission volume.

The details of each Tuy I pumping station are as follows:

Station	Number of pumps	Capacity/pump	Head/pump	Power/pump
No. 11	5	1,032 l/s	271.6 m	3,720 kW
No. 12	4	1,000 l/s	51.3 m	3,850 kW
No. 13	4	1,000 l/s	287.0 m	3,850 kW
No. 14	4	1,000 l/s	287.0 m	3,850 kW

(2) Tuy II System

The Tuy II water transmission system started in 1968. Like the Tuy I System, it has progressively deteriorated, and is scheduled to undergo repair in 1997.

Like Tuy I, station No. 21 of the Tuy II System pumps up water from the Tuy River and Lagartijo Reservoir. The system also receives water from the Taguacita Reservoir which merges with the water from the two sources before station No. 21.

Water conveyed to station No. 21 is pumped up to stations No. 22 and 23, purified at La Guairita treatment plant, and distributed to Caracas. Any surplus water is pumped up at station No. 24 and stored in La Pereza Reservoir as an emergency water supply.

The details of each Tuy II pumping station are as follows:

Station	Number of pumps	Capacity/pump	Head/pump	Power/pump
No. 21	4	1,500 l/s	150.00m	5,950 kW
No. 22	4	1,500 l/s	364.29 m	8,000 kW
No. 23	4	1,500 l/s	364.29 m	8,000 kW
No. 24	4	1,000 l/s	100.00m	1,440 kW

(3) Tuy III System

The Tuy III water transmission system started operation in 1981, and since then new facilities have been added. The most recent was the construction of Mamonal Station between station No. 31 and Toma de Caicita in 1994. This addition has increased the water transmission capacity on average by 1.5 m^3/s.

Before the completion of the Tuy III System in 1981, water was conveyed from the Camatagua Reservoir to the Ocumarito Reservoir by the Camatuy System built in 1968. Water from the Camatagua Reservoir was pumped up at station No. 31 to Toma de Caicita. From Tom de Caicita the water flowed down the Ocumarito River to the Ocumarito Reservoir. Water from the Ocumarito Reservoir was then discharged into the Ocumarito River, and merged with the Tuy River. It was then collected at Toma de Agua and conveyed to Caracas by the Tuy I and Tuy II Systems. In the Camatuy System, the Ocumarito and Tuy rivers were used as means to transmit water.

In the current Tuy III System, water is collected from the Camatagua Reservoir, pumped up at station No. 31 and Mamonal Station, then released at Caicita. From there, water is conveyed by gravity in an 85" pipe to the Caujarito treatment plant. After treatment, it is pumped up at stations No. 32 and 33, conveyed to the Baruta distribution reservoir, then distributed to Caracas. The distance between the water resource and Caracas is 80.3 km. The total pump head is 1,028m, and the pump head per pump station is large. Compared to the other systems, this system applies a huge strain on the pumps. However, as stations No. 32 and 33 pump up purified water treated at the Caujarito treatment plant, pump damage is comparatively less than the other stations.

Because, unlike other systems, it does not have a reservoir, interruptions in operation due to breakdown and such significantly affect Caracas, as this system provides approximately 60% of its water supply.

The details of each Tuy III pumping station are as follows:

Station	Number of pumps	Capacity/pump	Head/pump	Power/pump
No. 31	5	2,333 l/s	217.5 m	8,000 kW
Mamonal	5	2,800 l/s	71.0 m	2,700 kW
No. 32	5	3,040 l/s	420.0 m	15,000 kW
No. 33	5	3,040 l/s	420.0 m	15,000 kW

(4) Pre-treatment Plant

Water is currently pumped from the intake to a pre-mixing facility where aluminum sulfate, organic polymers, and activated carbon are added. After such treatment the water flows into sedimentation ponds. At the discharge point chlorine is added.

The pre-treatment plants are currently installed with settling tanks, six in total, rectangular in shape, 24.0 meters wide, 82.0 meters long, and 3.25 meters deep. Each of these settling tanks is equipped with a carriage type sludge collector. These sludge collectors are, however, broken down and have been for some time.

If turbidity of the intake water is 5,000 NTU, it is estimated that the sludge depth will be 5 meters, and thus the tanks would be inoperative. Accordingly the following limitations were set.

The maximum inflow turbidity should be less than 2,000 NTU

Sludge operations such as the periodical removal and cleaning of the tanks should be done manually.

Careful attention should be paid to inflow turbidity and sludge sedimentation as they increase personnel expenses in operation and maintenance.

Every two hours, samples are taken at the intake point A, as shown in Fig. 3-2, and tested for turbidity, color, odor, alkalinity, hardness, pH, and T12 (chlorine demand). Although not always strictly adhered to, water quality limits are as stated in the following table.

Water Quality Limits are as follows:

Item	Point A	Point B
Turbidity	< 2000 NTU	< 600 NTU
Color		< 1200
T_{12}		< 12 mg/ℓ
Alkalinity		> 80 mg/ℓ
Oil	not included	

Note: Point A is at the intake and Point B is at the outlet of the pre-treatment

Hidrocapital has recently, since 1995, started monitoring heavy metals at the water intake once a month. This, however, is not sufficient considering the substantial possibility of toxicant contamination in the Tuy River water.

The apparent color and the turbidity of the water is removed to a considerable degree during the pre-treatment process (see Fig. 3-3). Treated water, however, still maintains color beyond the set limit for drinking water and it is considerably difficult to remove such color from the water. Removal of color from the industrial effluent is thus deemed important.

When water quality is judged extremely poor, water is pumped to either Qda. Seca Reservoir or Lagartijo Reservoir; water already in the system is re-routed to the La Pereza Reservoir.

(5) Treatment Plants

Water taken from the Tuy River undergoes further treatment. Water from the Tuy I system is treated at the Mariposa Treatment Plant, while intake from the Tuy II system is treated at the Gairita Treatment Plant. The choice of treatment system depends on the flow conditions and the quality of the water of the Tuy River. The plan for the Tuy III system entails the treatment of the water from Camatagua Reservoir at the Caujarito treatment plant (see Fig. 1-2).

The three treatment plants practice conventional treatment methods, namely coagulation, filtration, and chlorination. These plants treat water in accordance with the drinking water guidelines of the Government of Venezuela.

Fig. 3-4 shows the actual condition of the turbidity and color of water before and after treatment at the Guairita Treatment Plant and the Mariposa Treatment Plant in 1995.

The outline of the facilities of each treatment plant is as follows:

<u>Mariposa Treatment Plant</u>

Treatment Capacity		
Normal :	$4.0\ m^3/s$	
Maximum :	$4.5\ m^3/s$	
Distribution Pond Volume	$82.5\ m^3$	
Flocculation Ponds	Line "A"	Line "B"
Number of Units :	2 units	3 units
Volume :	$1{,}260\ m^3$	$1{,}279\ m^3$
Retention Time :	30 minutes	30 minutes
Sedimentation Ponds	Line "A"	Line "B"
Number of Units :	2 units	3 units
Volume :	$5{,}243\ m^3$	$5{,}266\ m^3$
Retention Time :	120 minutes	120 minutes
Filtration Ponds		
Number of Units :	6 double	12 double
Area :	$58.50\ m^2$	$117.05\ m^2$

<u>Gairita Treatment Plant</u>

Treatment Capacity

Normal :	6.0 m^3/s
Maximum :	7.2 m^3/s
Distribution Pond Volume :	190.0 m^3
Flocculation Ponds	
Number of Units :	6 units
Volume :	7,570 m^3
Retention Time :	30 minutes
Sedimentation Ponds	
Number of Units :	6 units
Volume :	7,570 m^3
Retention Time :	120 minutes
Filtration Ponds	
Number of Units :	24 units
Area :	128.88 m^2

Caujarito Treatment Plant

Treatment Capacity	
Normal :	9.0 m^3/s
Maximum :	15.0 m^3/s
Distribution Pond Volume :	240.0 m^3
Flocculation Ponds	
Number of Units :	7 units
Volume :	2,560 m^3
Retention Time :	20 minutes
Sedimentation Ponds	
Volume :	11,670 m^3
Retention Time :	90 minutes
Filtration Ponds	
Number of Units :	24 units
Area :	57.88 m^2

4. Problems of the System

4.1 Daily Intake Fluctuations and Causes of Intake Suspensions at Toma de Agua

Fig. 4-1 illustrates daily intake volume at Toma de Agua in 1995. Fig. 4-2 presents the percentages by cause of intake suspension, while Table 4-1 and Fig. 4-3 depicts the percentages by cause for the case of intake suspension due to water quality. The following discussion is made based on these figures.

Causes of Intake Suspension at Toma de Agua, 1995

	Quality	L.W.L	Maint.	Mechanical	Electrical	Other	Total
Dry season	10	9	3	3	0	0	25
Rainy Season	13	1	1	7	2	1	28
Total	23	10	10	10	2	1	53

As seen in Fig. 4-1, the conditions of intake suspension in the dry season and the wet season seem similar. The causes of suspension, however, are different:

(1) Suspension Causes (All Reasons)

According to actual Hidrocapital records of intake suspension in 1995, total suspensions in the dry season and rainy season are similar, at 25 times and 28 times, respectively (see Fig. 4-2). However, the causes of suspension are different; water quality and low water levels make up 40% and 36% (total 76%) of the suspensions in the dry season, respectively, but 46% and 4% (total 50%) in the rainy season.

(2) Suspension Causes (Water Quality)

On the basis of the data for three years from 1993-95, suspension of water intake at Toma de Agua occurred 14 times (39%) in the dry season and 22 times (61%) in the rainy season (see Fig. 4-3).

Suspension of water intake due to organic pollution, namely color, odor, and chlorine residual totals 18 times (50%) in 1995. Whereas suspensions due to high turbidity occurred 10 times (28%).

The average duration of suspension was 8 hours. Although suspensions occur more often in the rainy season, water shortages are more critical in the dry season. Suspension of water intake operations in the rainy season is offset by the availability of other water resources.

4.2 Failures in the Transmission System

The following shows the failures in the transmission operation of the Tuy systems (for detail see Annex).

System / Items	Tuy I	Tuy II	Tuy III
Frequency of failure	22	26	30
Failure duration (total)	166 hrs.	155 hrs.	202 hrs.
Average failure period	452 min.	404 min.	404 min.
Volume not transmitted per failure	73,365 m^3	138,040 m^3	174,138 m^3

Failure in transmission is attributed to the following factors:

System Factors	Tuy I	Tuy II	Tuy III
Electrical Failure	14	14	16
Mechanical Failure	5	9	7
Others	3	3	7
Total	22	26	30

Suspension of Tuy III has the largest impact on the overall system. Compared to the other systems, Tuy III has the highest failure frequency, and each Tuy III operation interruption comparatively affects the biggest water volume. Moreover, whereas Tuy I and II systems have a reservoir which water can be used in case of operation failure, Tuy II has no reservoir and any operation failure means water supply is stopped. Therefore, compared to Tuy I and II Systems, operation failure of Tuy III has a larger impact.

As for the causes of failure, we can guess from the daily operation time and the transmission volume that the pumps of the Tuy III System operate everyday at full power without interruption, which increases the chance of failures. Moreover, the system does not by multiplying the pump capacity by pump operation hours. Also, the water volume is calculated based on the degree to which the valves are opened and closed. Hence, the actual intake volume, water volume distributed to Caracas and other municipalities, and leakage during conveyance are unknown. Because knowledge of these values is vital to operation and maintenance, an actual water volume survey should be carried out at all stations.