JAPAN INTERNATIONAL COOPERATION AGENCY

STATE SECRETARIAT OF PLANNING, SCIENCE AND TECHNOLOGY
THE STATE OF SERGIPE, THE FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY
ON
WATER RESOURCES DEVELOPMENT
IN THE STATE OF SERGIPE
IN
THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT
SUPPORTING
(VOLUME I)
MASTER PLAN STUDY

[D]. WATER QUALITY

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THE STUDY ON WATER RESOURCES DEVELOPMENT IN THE STATE OF SERGIPE IN THE FEDERATIVE REPUBLIC OF BRAZIL

SUPPORTING REPORT (D) WATER QUALITY

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CHAPTER 1 CURRENT CONDITIONS OF WATER QUALITY

Effluent from industries and municipalities are considered as major pollution sources in Sergipe. Potential BOD loads from main municipalities are shown in Table-1.1 and 5% of those potential loads, except from Aracaju, are estimated to reach rivers. Regarding industrial effluent, there is no data available.

Locations of main industries and municipalities are shown in Figure-1.1 with potential BOD loads.

Table-1.1 Potential BOD Loads of Main Municipalities

Municipality (Area > 10,000 ha)	Population in 1998 (persons)	BOD Loads (kg/day)
Aracaju	451,048	20,297
Boquim	15,174	683
Capela	15,816	718
Estancia	46,340	2,085
Itabaiana	51,404	2,313
Itabaianinha	14,226	640
Lagarto	36,929	1,662
Laranjeiras	20,710	932
Maruim	10,789	486
N. Sr. do Socorro	112,801	5,076
N. Sr. da Gloria	16,220	730
N. Sr. das Dores	12,884	580
Neopolis	10,754	484
Propria	23,201	1,044
Simao Dias	16,061	723
Tobias Barreto	26,612	1,198

Monitoring of water quality in Sergipe has been conducted by DESO, COHIDRO and ADEMA. Specific task of each agency is described below.

1) DESO (Companhia de Agua e Esgoto de Sergipe)
   DESO has been carrying out drinking water monitoring at about 90 sampling points, distributed over all available tributaries in the State of Sergipe, since 1995. Sampling of water is conducted once every 6 months with occasional discharge measurement.
   Approximately 80% of the sampling stations have acceptable water quality for public supply purposes. High salinity contents are observed in the upper reaches of Sergipe, Vaza Barris and Japaratuba rivers, resulting difficulty in their use as drinking waters.
2) COHIDRO (Companhia de Desenvolvimento de Recursos Hidricos do Estado de Sergipe)
   COHIDRO has conducted surface water monitoring at points strategically important for multiple use of water. Twelve parameters of water quality were selected for the monitoring of the reservoirs of Jabiberi, Jacarecica and Piaui rivers, and sampling has been done occasionally. Other 22 sites are selected for observation of electrical conductivity and discharge.
3) ADEMA (Administracoes Estadual do Meio Ambiente)
   ADEMA carried out water monitoring in the Sergipe, Piaui and Japaratuba basins during 1982-1984. 13 parameters of water quality were analyzed and 9 of them were used for calculation of the Water Quality Index (IQA). The results of the water survey indicate very low organic population and the IQA values suggest, generally, good water quality in all the basins studied.

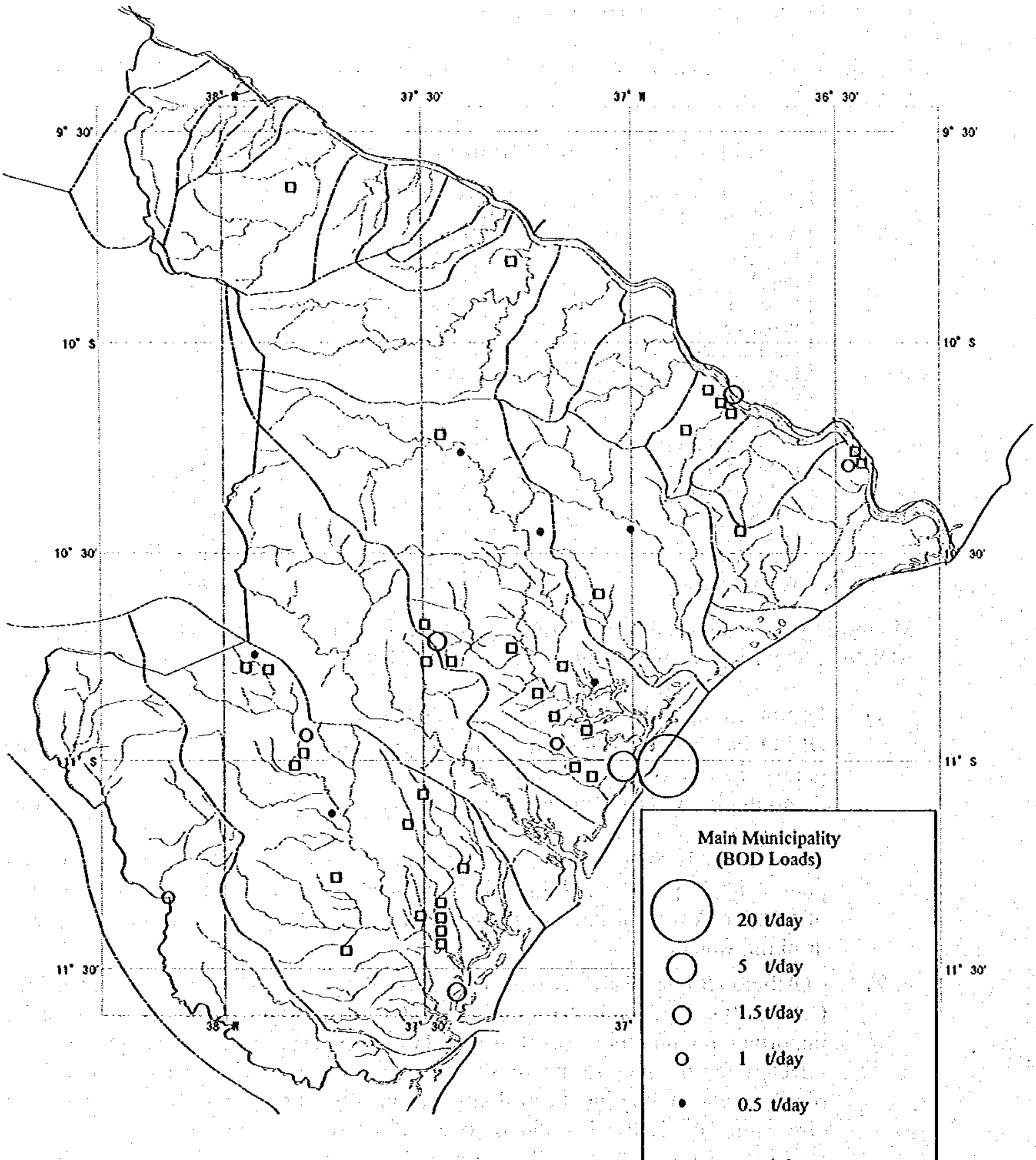

Figure-1.1 Locations of Main Municipal and Industrial Pollution Loads

CHAPTER 2 WATER QUALITY SURVEY

Since there is a lack of water quality data for the Master Plan Study, the JICA Study Team conducted water quality survey to provide basic information concerning current conditions of surface water and groundwater quality in Sergipe State.

2.1 Methodology

For the monitoring of the surface water, two sampling surveys were conducted in 1998, one in August, representing a rainy season and another in October, corresponding to a dry season. The monitoring of groundwater was also completed in September of the same year.

50 stations were selected for the surface water survey based on the existing monitoring points managed by DESO, ADEMA and COHIDRO, (organizations responsible for water resources management), the location of flow gauging stations, and current/future use of water, soil, etc. For the groundwater survey, 50 sampling stations were also selected, based on the information previously obtained by DESO and COHIDRO.

At each sampling point, 24 previously established water quality parameters were analyzed. Electric conductivity, turbidity, DO, salinity and pH were determined on site using portable analyzers, and other parameters were determined from samples sent to IPTS (Instituto de Pesquisa e Tecnologia de Sergipe).

Figure-2.1 indicates the location of the surface water and groundwater sampling points.

2.2 Water Quality Standards

The Standards established by CONAMA 20 Resolution (Conselho Nacional do Meio Ambiente) in 1986 for raw water quality according to the classification of river basins are considered to be appropriate for the present study. As there is no classification of the river basins established in Sergipe State, the CONAMA 20 Standard for Class 2 rivers has been adopted for all basins in this Study.

In addition to the CONAMA 20 standards, the criteria recommended by WHO were also introduced in order to perform a more comprehensive interpretation of the water quality results. It must be mentioned, however, that these water quality standards are aimed at drinking water, that is final treated water, and not at raw river water.

With regards to water use for irrigation, the guidelines published by FAO (Food and Agricultural Organization of the United Nations - 1985) have been adopted in this Study. These guidelines indicate the suitability of water use by dividing water quality parameters into three categories of restriction for use, as indicated in Table-2.1. For industrial use, the Japan Industrial Standards (JIS) for water boilers only were adopted in the Study, since each industry usually has its own specific criteria for the industrial processes concerned.

Table-2.2 shows the upper limit or range of limits adopted by the four organizations mentioned above for the water quality parameters analyzed in this Study.

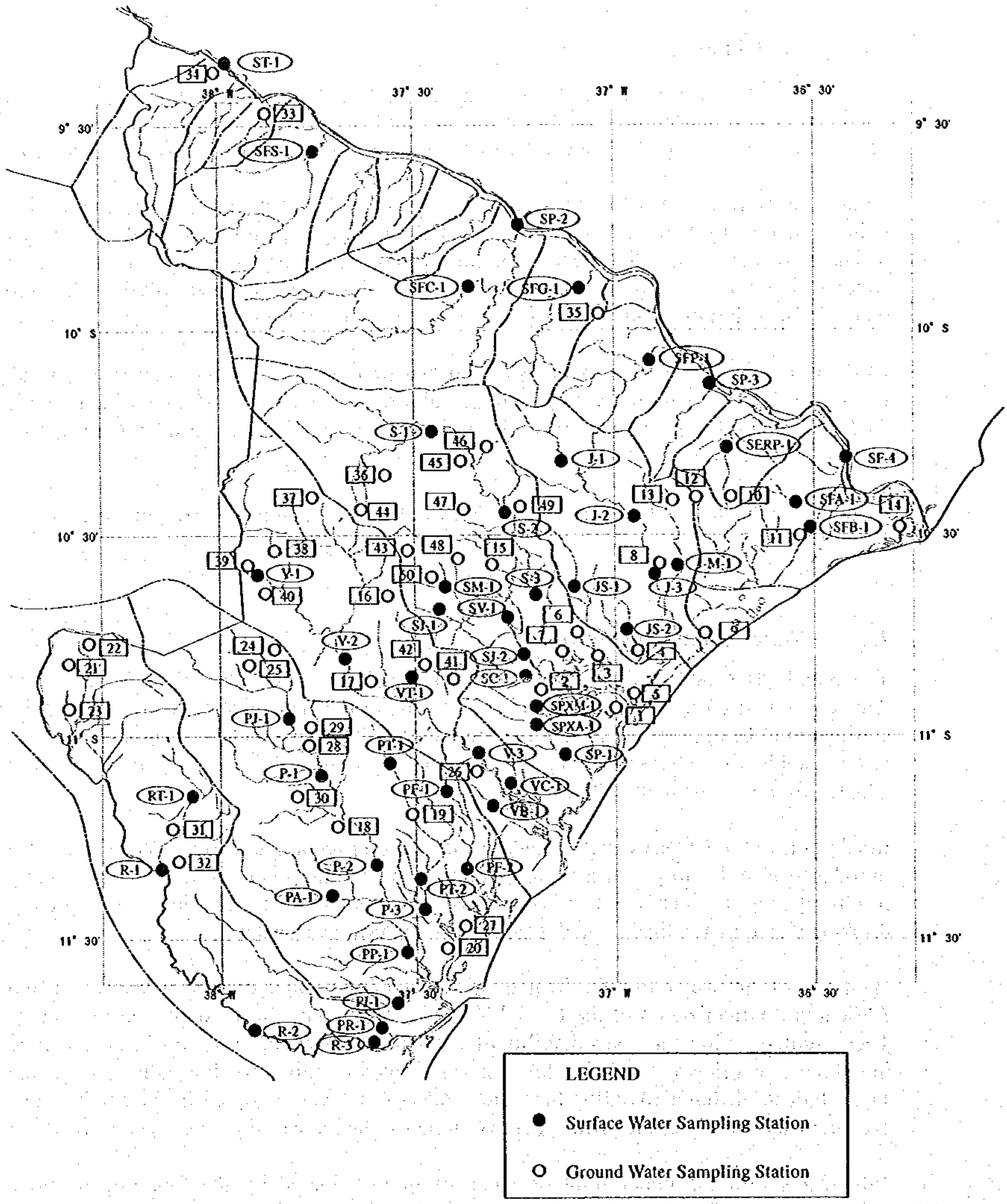

Figure-2.1 Location of the Surface Water and Groundwater Sampling Points

Table-2.1 Guidelines for Interpretation of Water Quality for Irrigation

Potential Irrigation Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Salinity (*affects crop water availability*)[1]				
ECw	dS/m	< 0.7	0.7 - 3.0	> 3.0
(or)				
TDS	mg/L	< 450	450 - 2000	> 2000
Infiltration (*affects infiltration rate of water into the soil. Evaluate using ECw and SAR together*)[2]				
SAR = 0 - 3 and ECw =		> 0.7	0.7 - 0.2	< 0.2
= 3 - 6 =		> 1.2	1.2 - 0.3	< 0.3
= 6 - 12 =		> 1.9	1.9 - 0.5	< 0.5
= 12 - 20 =		> 2.9	2.9 - 1.3	< 1.3
= 20 - 40 =		> 5.0	5.0 - 2.9	< 2.9
Specific Ion Toxicity (*affects sensitive crops*)				
Sodium (Na)				
surface irrigation	SAR	< 3	3 - 9	> 9
sprinkler irrigation	me/L	< 3	> 3	
Chloride (Cl)				
surface irrigation	me/L	< 4	4 - 10	> 10
sprinkler irrigation	me/L	< 3	> 3	
Boron (B)	mg/L	< 0.7	0.7 - 3.0	> 3.0
Trace Elements (see Table 3.1)				
Miscellaneous Effects (*affects susceptible crops*)				
Nitrogen (NO_3 - N)	mg/L	< 5	5 - 30	> 30
Bicarbonate (HCO_3) (*overhead sprinkling only*)	me/L	< 1.5	1.5 - 8.5	> 8.5
pH			Normal Range: 6.5 - 8.4	

[1] ECw means electrical conductivity, a measure of the water salinity, reported in deci Siemens per metre at 25° C (dS/m) or in units millimhos per centimetre (mmho/cm). Both are equivalent. TDS means total dissolved solids, reported in milligrams per liter (mg/L).

[2] SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol Rna. See Figure 1 for the SAR calculation procedure. At a given SAR, infiltration rate increases as water salinity increases. Evaluate the potential infiltration problem by SAR as modified by ECw. Adapted from Rhoades 1977, and Oster and Schroer 1979.

Source : FAO Irrigation and Drainage Paper 29, "Water Quality for Agriculture"

Table-2.2 Water Quality Standards Recommended by Different Organizations

ORGANIZATION		W. H. O.	FAO	CONAMA	JIS
PARAMETER \ WATER USE		DRINKING	IRRIGATION	MULTIPLE USE - Class 2 -	INDUSTRY USE
pH		6.5 - 9.5	6.5 - 8.4	6.00 - 9.00	7 - 9
DO	(mg/L)	NO REC.	NO REC.	> 4.0	< 0.5
BOD	(mg/L)	NO REC.	NO REC.	< 5.0	NO REC.
Turbidity	(UNT)	5.0	NO REC.	100 UNT	NO REC.
Conductivity	(μS/cm)	NO REC.	< 700	NO LIMIT	< 1000
Alkalinity Met.	(mg/L)	NO REC.	NO REC.	NO LIMIT	< 150
Hardness $CaCo_3$	(mg/L)	500	NO REC.	NO LIMIT	0
Cl.	(mg/L)	250	142.0	250	< 100
Na	(mg/L)	200	69.0	NO LIMIT	-
Fe	(mg/L)	1 - 3	5.0	0.3 (sol.)	0.03
Mn	(mg/L)	0.1	0.2	0.1	-
SO_4	(mg/L)	500	NO REC.	250	-
Tot. diss. solids	(mg/L)	600	450	500	< 700
Fecal coli	(NMP/100mL)	ABSENCE	NO REC.	1000	-
Total coli	(NMP/100mL)	ABSENCE	NO REC.	5000	-
NO_3	(mg/L)	50.0	< 90	10.0 (N)	-
Al	(mg/L)	0.2	5.6	0.1	-
Ba	(mg/L)	0.7	NO REC.	1.0	-
B	(mg/L)	0.3	7.6	0.75	-
Cd	(mg/L)	0.003	0.01	0.001	-
Pb	(mg/L)	0.01	5.0	0.03	-
Zn	(mg/L)	3.0 - 5.0	2.0	5.0	-
Cu	(mg/L)	2.0	0.20	0.02	-
Cr	(mg/L)	0.05	0.10	Cr^6 0.05 Cr^3 0.5	-
Sn	(mg/L)	0.24	NO REC.	2.0	-
SO_3	(mg/L)	NO REC.	NO REC.	NO LIMIT	5 - 10
F	(mg/L)	1.5 (provisory)	1.0	1.4	-
Hg	(mg/L)	0.001	0.0002	0.0002	-
Ni	(mg/L)	0.02	0.2	0.025	-
PO_4	(mg/L)	NO REC.	NO REC.	0.25 (P)	5 - 15
Ar	(mg/L)	0.01	NO REC.	0.05	-
CN	(mg/L)	0.07	NO REC.	0.01	-
HCO_3	(mg/L)	NO REC.	< 92	NO LIMIT	-

W. H. O. : World Health Organization
FAO : Food Agriculture Organization of the United Nation
CONAMA : Conselho Nacional do Meio Ambiente. Resolucao nº 20, de 18 de Junho de 1986.
JIS : Japan Industrial Standards

2.3 Results of Analysis

All analytical results obtained from the first sampling series in August and from the second series in October are presented graphically in Figure-2.2, Figure-2.3, Figure-2.4 and Figure-2.5 to provide easier understanding of the variations in water quality.

Figure-2.2 refers to rivers (according to CONAMA 20 standards), which do not contain fecal coliform, and rivers with and without fecal coliform contamination are plotted in Figure-2.3. Figure-2.4 shows three different river categories according to FAO classification of water for irrigation purposes. Figure-2.5 indicates the location of groundwater sampling stations and the compatibility with water quality standards.

2.3.1 Surface Water

From the data obtained, it could be observed that most of the monitored sites showed low BOD levels of about 1 mg/liter, and satisfactory DO concentrations, indicating a low organic pollution level in the surface waters of Sergipe State. The exceptions were some sites on Sergipe River where some organic contamination, as expressed by BOD, was registered in the second survey.

pH values at most of the sampling stations ranged from 6.0 to 8.2 and were, therefore, in accordance with standards. NO_3, Mn and Fe were also acceptable in both sampling periods. Metallic ion concentrations were always lower than the established standards.

Large variations were observed for electric conductivity (ECw) values, indicating the presence of chlorides, sodium ions, and carbonate compounds, which could interfere with conductivity measurements. Over about 70% of the length of Real River, ECw values were higher than 1000 µm/cm and chloride values were above standards. Bacteria contamination was checked on all monitoring sites during the second survey. Jabiberi reservoir, however, was not checked.

Salinity parameters were within standards for most of the Piaui river basin, except for Araua River, during the first survey. The second survey showed chloride values above standards in the upper stretch of Piaui River and Jacare River. Fecal coliform contamination was observed in several tributaries, although other control parameters were within standards of CONAMA 20 and WHO.

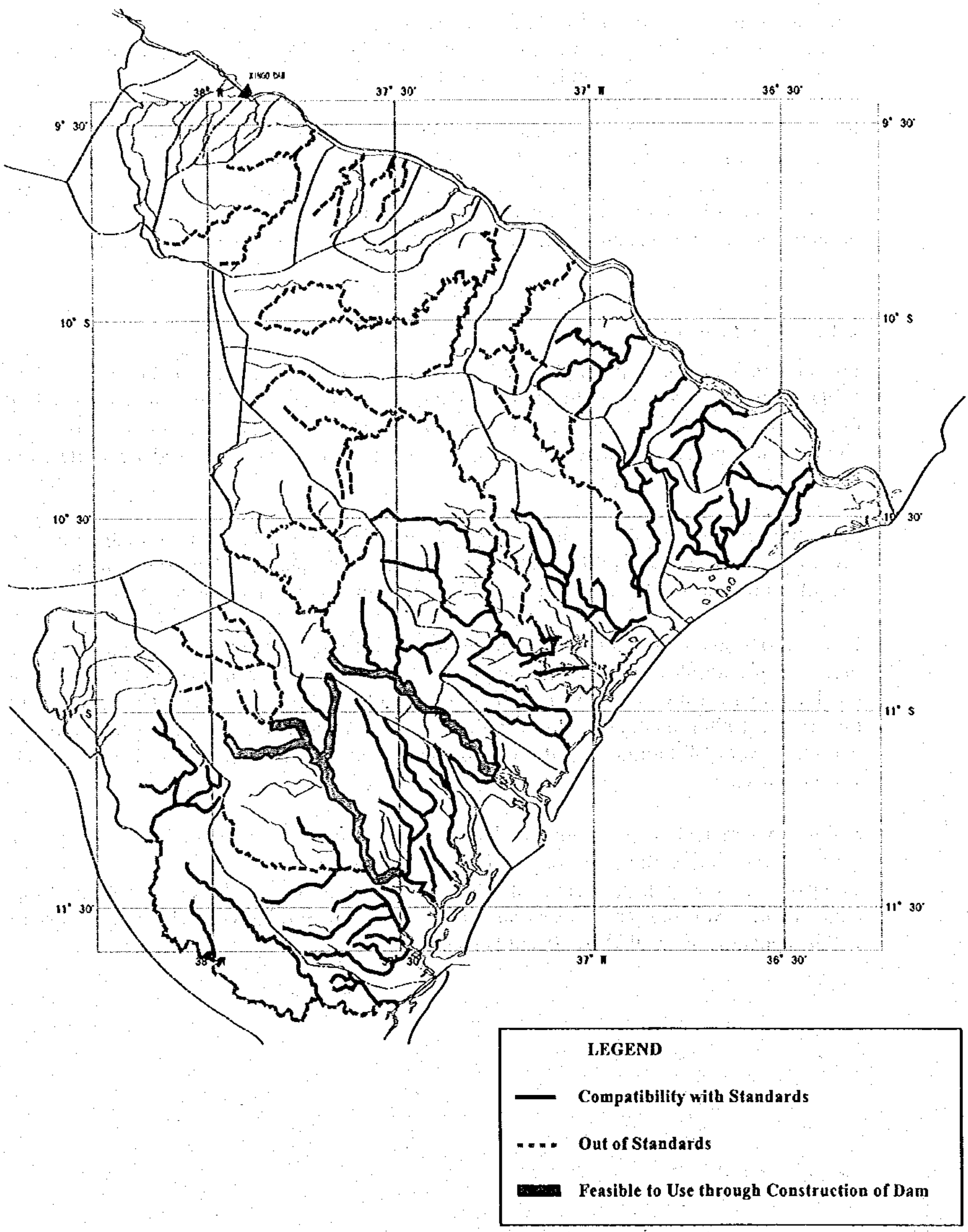

Figure-2.2 Classification of Rivers according to CONAMA 20 and W.H.O. Water Quality Standards

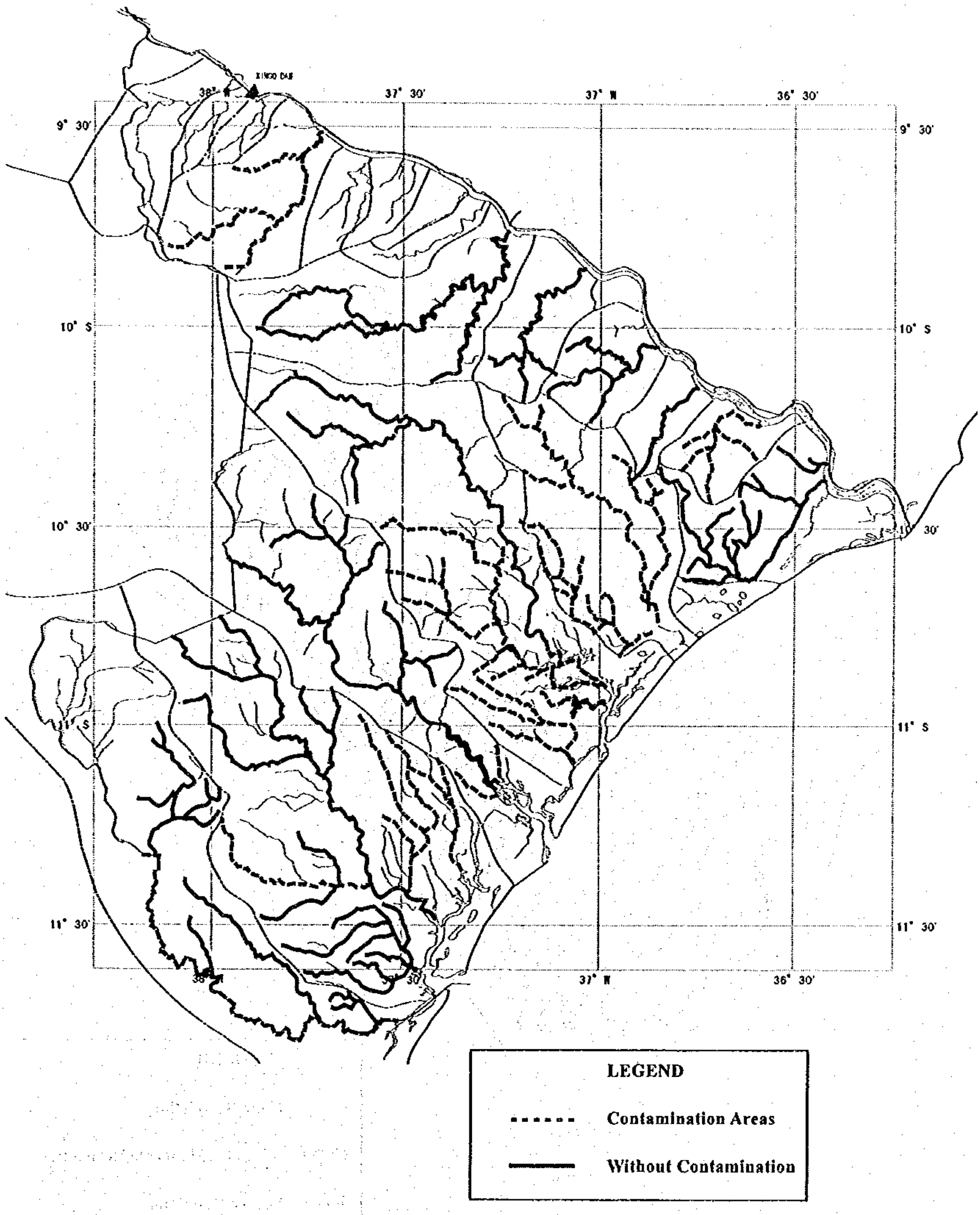

Figure-2.3　　Fecal Coliform Contamination Areas

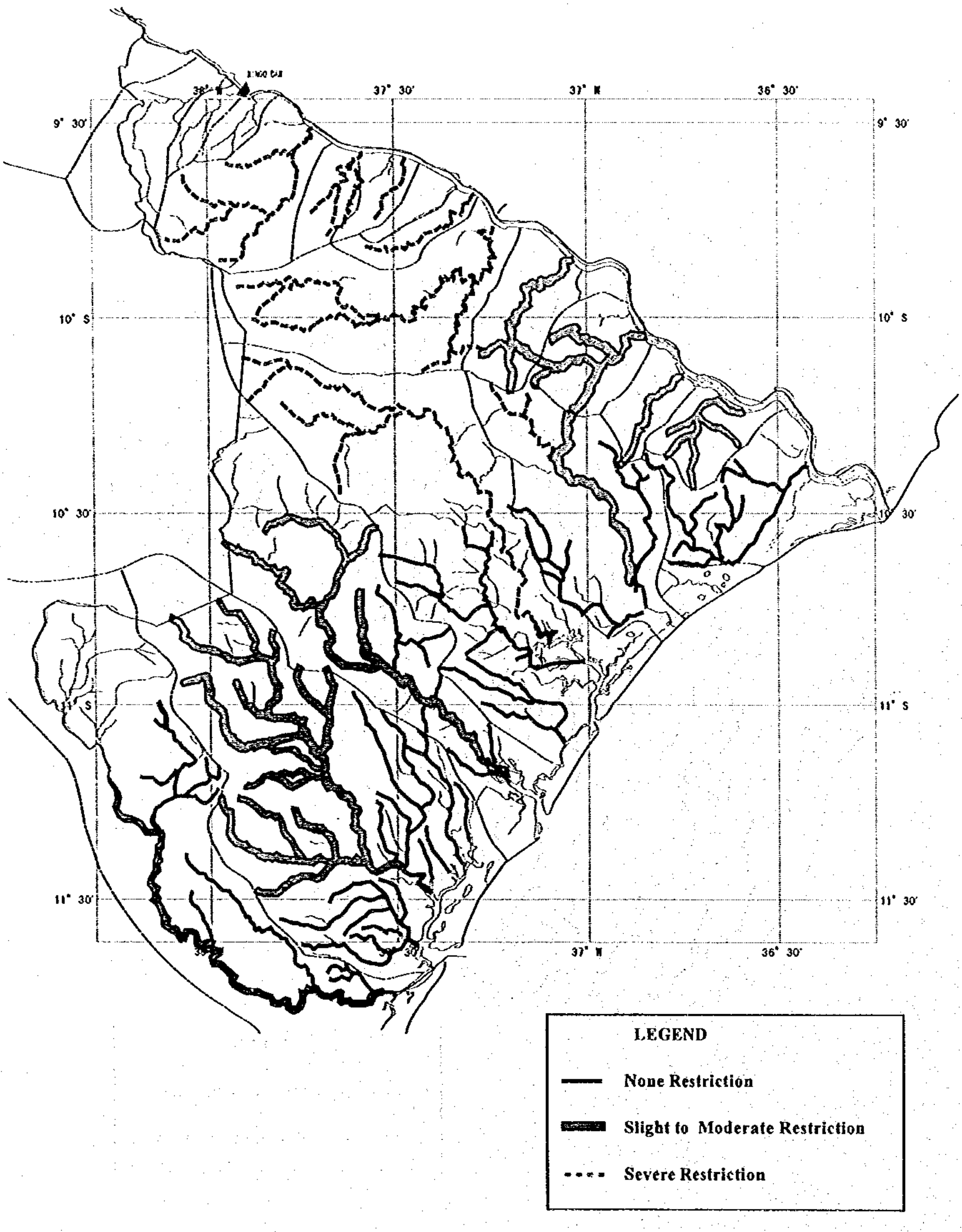

Figure-2.4 Classification of Water Quality for Irrigation Use according to the F.A.O Criteria

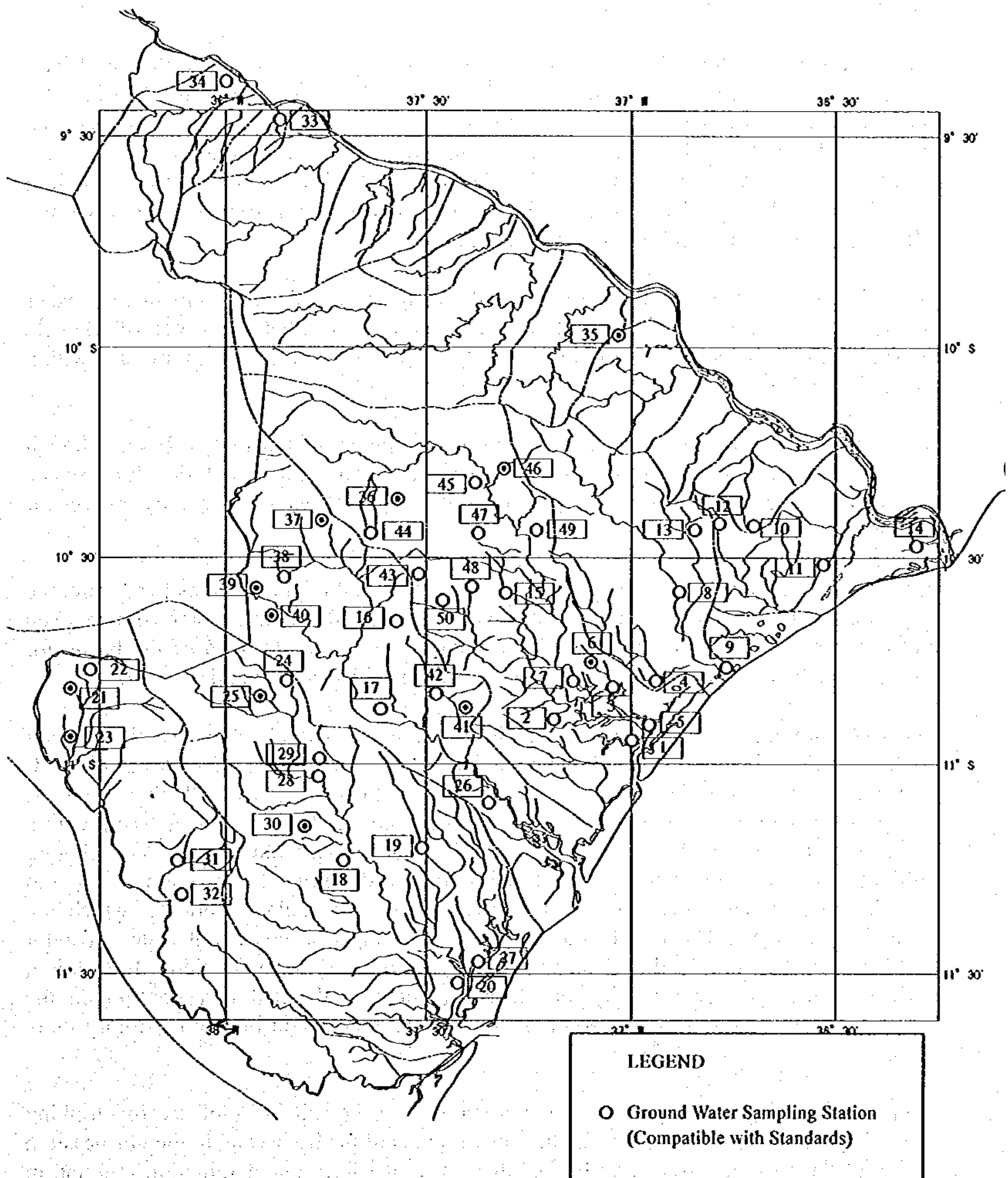

Figure-2.5 Classification of Groundwater according to W.H.O and CONAMA 20 Water Quality Standards

In Vaza Barris river basin, chloride concentrations in the upper stretches of the river reached 2,800 mg/liter during the first and second surveys, in addition to high values of ECw, Na and hardness. However these parameters decrease in downstream sections, due to the contribution of runoff water within the basin. Consequently, tributaries of the lower basin, such as the Trairas and Tejupeba show satisfactory water quality, although fecal coliform in excess of the criterion can be found.

The highest water salinity level was registered in the upper section of the Sergipe River, where 9,263 mg/liter of chloride was found in the first sampling series and 9,084 mg/liter in the second. High values for sulfate and for hardness were also observed in excess of the limits established by WHO. These concentrations were also high in downstream stretches of this river and always above the established standards. High values observed at sampling point No.4 of Sergipe River during the second survey, are assumed to indicate the influence of seawater reaching this sampling point.

Jacarecica, Cotinguiba, Poxim, Vermelho and Pitanga rivers all show satisfactory water quality, except for fecal coliform. It should be pointed out that the water of Marcela reservoir shows characteristics of slight salinity, although chloride values are still within the established standards.

High salinity levels could also be observed in most stretches of Japaratuba River, although much lower than those observed in Sergipe River. The downstream tributaries, for instance the Siriri and the Japaratuba Mirim, presented quite satisfactory water quality, except for fecal coliform.

In the Sao Francisco river basin, the rivers of the northwest region, such as the Jacare, the Capivara and the Pocao, presented greater salinity level and also low water volume, even during the rainy season in August. Other tributaries in the coastal area of the basin, for instance, the Poxim and the Santo Antonio, meet the established standards.

The four sampling stations along the main Sao Francisco River show excellent water quality for multiple use. It should be remarked, however, that fairly high values of pH (7.8-8.2) detected in both sampling surveys are not likely to be caused by alkaline elements. The possibility of an eutrophication process exists. The Sao Francisco river basin, with a drainage area of 640,000 km^2, includes several cities and agricultural areas contributing nutrients, which easily cause algae proliferation in the several reservoirs along Sao Francisco River. The great hazard of nutrients is their cumulative effects, which are difficult to mitigate. The proliferation of blue-green algae brings about taste and odor problems, thus the use for domestic water supply becomes seriously difficult. In addition, toxic substances are released by the algae. Therefore a detailed investigation on the eutrophication conditions in the Sao Francisco is recommended during the feasibility study phase.

Figure-2.2 and Figure-2.3 presented earlier summarize the suitability of use for drinking water. Higher salinity levels occur in the upper regions of the basins and in the northeastern region of the Sao Francisco river basin, whereas fecal bacteria contamination is found in the coastal areas, where population density is higher. It should be pointed out that Vaza Barris and Piaui rivers show potentiality to be used for multiple purposes if low quality flows in the dry season could be well integrated with higher flows in the rainy season.

With regards to the suitability of the water for irrigation purposes, Figure-2.4 presents three distinct zones according to the restriction level. The restriction free zone is situated in the coastal area and the most restrictive zone in the northwest area, while the intermediate area is a zone of moderate restriction. This distribution shows almost the same pattern as rainfall distribution in the state, indicating that climate conditions definitely influence the water quality of these regions.

For use as industrial supply, the type of industrial process will be important. Even for the use in boilers only, industrial water standards will be specific for each type and capacity of boiler. However, it can be concluded that water suitable for irrigation use without restriction will be of acceptable quality for use in boiler operation.

2.3.2 Groundwater Quality

According to the results obtained at 50 sampling stations (Figure-2.5) distributed over the entire State of Sergipe, in general, high alkalinity and low level fecal coliform contamination were observed in many locations. Ferric ion, which causes color in water, and nitrates, which cause diseases related to blood circulation, showed lower concentrations than standards at all stations. Heavy metals analyzed were always less than the relevant standards and no organic pollution was observed.

However, chloride, sodium and hardness contents were above WHO and CONAMA standards at various locations. For instance, the DESO water supply station at No. 6 Santa Rosa de Lima, and COHIDRO wells at No. 23 Povoado Saco de Camisa, No. 24 Povoado Aroeira, No. 30 Povoado Bonfim, No. 35 Povoado Lagoa dos Porcos(1), No. 36 Povoado Retoro, No. 37 Lagoa dos Porcos(2), No. 39 Povoado Laja, No. 40 Povoado Diogo and No. 45 Lagoa do Croa are not considered entirely adequate for drinking water purposes. At station No. 47 high concentrations of fecal coliform were observed, requiring urgent application of disinfecting procedures.

From the results of the groundwater sampling analysis, it is clear that water quality is closely related with geology. All the deep wells where values of Cl, Na and hardness exceed water quality standards are located in the Pre-Cambrian formation. On the other hand, all the deep wells in the Cretaceous area satisfy water quality standards.

Values of Cl, Na and hardness exceed the standard in 30% of the deep wells in the Pre-Cambrian area. A great number of deep wells were drilled in the Pre-Cambrian area in the past; however, many of these wells have already been abandoned due to poor water quality. Water samples of this survey were taken from deep wells that are still used now because of better water quality than others. However, from the result of this analysis, it is concluded that there are still water quality problems in 30% of deep wells in the Pre-Cambrian area.

CHAPTER 3 PROPOSED VAZA BARRIS DAM PROJECT

3.1 Discharge

Vaza Barris River has its source in the municipality of Uaua in the State of Bahia and its basin extends over 15,700 km^2, 15% of which is situated in Sergipe State. Although most of its basin is located in the semi-arid region, the flow in Vaza Barris is not negligible, due to its large drainage area and to the intense rainfall that occurs sporadically. This rainfall contributes both to the conservation of its water flow and to the dilution of the high salt concentrations resulting from evaporation. In Chapter 5, it is proposed to plan a dam on Vaza Barris River, in order to store an adequate volume of water of appropriate quality for multiple use.

The flow measured in Vaza Barris River at the ANEEL flow station of Ponte SE-302 in the municipality of Ponte SE-302, situated at the border with Bahia State, during the period of 1985-1993, shows average monthly variations of 1.41 m^3/s in November to 9.64 m^3/s in April, and an annual average of 4.45 m^3/s.

The ANEEL station at Faz. Belem in the municipality of Itaporanga, 86 km downstream of the previous station, shows monthly average variations of 3.14 m^3/s in November to 23.04 m^3/s in July, and an annual average value of 12.31 m^3/s. The basin area of this stretch is 1,305 km^2 and the specific discharge may be estimated as 6.1 liter/sec/km^2. This is not a great contribution when compared to the catchment area of the basin under normal climate conditions, but it is still an appreciable water volume to be integrated in the proposed dam.

3.2 Water Quality Estimation

Table-3.1 presents weighted average concentrations for the most critical parameters for Vaza Barris River with respect to public supply and irrigation water use. These calculations were based on eight sampling series carried out from 1995 to 1998 by DESO and JICA at three points along the Vaza Barris River. The flow data obtained by ANEEL on the same sampling dates at the stations of Ponte SE-302 and Faz. Belem was used in the calculation.

Table-3.1 Weighted Average Concentration for the Most Critical Water Quality Parameters of Vaza Barris River

Quality Parameter		Station		
		Ponte SE-302	Sao Domingos	Faz. Belem
CL	(mg/l)	574.0	302.1	125.4
Na	(mg/l)	165.6	106.6	47.4
Con.	(um/cm)	1,832.7	531.6	471.9
Hardness	(mg/l)	1,400.82	286.8	145.7
Ca	(mg/l)	109.4	70.4	42.3
Mg	(mg/l)	68.0	34.3	12.9
HCO_3	(mg/l)	159.2	119.6	95.6

Figure-3.1 illustrates changes in chloride concentrations along the length of Vaza Barris. The chloride concentration level of 574 mg/liter registered at the first station (Ponte SE-302), decreases linearly to 302 mg/liter at the second station (Sao Domingos) and to 125 mg/liter at the third station (Faz. Belem), 86 km downstream of the first station. Considering the low activity of the chloride ion in the solution, this reduction in chloride concentration can be interpreted as the effect of proportional dilution produced by surface runoff through the Vaza Barris basin within Sergipe State.

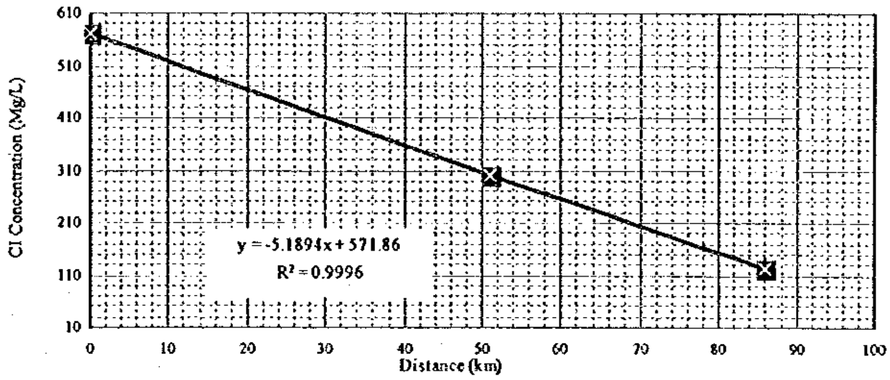

Figure-3.1 Variation of Cl Concentration – Vaza Barris River

The Standards established by the CONAMA 20 Resolution and by WHO are 250 mg/liter for chloride. Therefore, the Vaza Barris River meets the referred standards from a point 10 km downstream of the Sao Domingos station.

With regard to water use for irrigation purposes, Table-3.2 presents calculations determining the restriction of water use following the guidelines published by FAO. The moderate restriction level obtained at Ponte SE-302 and Sao Domingos stations change to no restriction at Fazenda Belem station. This suggests the possibility of agricultural water use in this river stretch.

Table-3.2 Evaluation of Vaza Barris River for Irrigation Use

Parameter	Sampling Station		
	V-1 Ponte SE-302	V-2 Sao Domingos	V-3 Faz. Belem
ECw (ds/m)	1.8 (M)	1.1 (M)	0.47 (N)
SAR	6.1 (M)	5.4 (M)	2.4 (M)
Na (me/liter)	7.2 (M)	5.0 (M)	2.1 (N)
CL (me/liter)	11.1 (S)	8.6 (M)	3.5 (N)
HCO_3 (me/liter)	2.6 (M)	1.2 (N)	1.6 (M)
Water quality tendency	(M)*	(M)*	(N)*

* (N) No restriction, (M) Slight to moderate restriction, (S) Severe restriction

It should be emphasized, however, that a greater number of analytical results and simultaneous flow measurements are essential to confirm the above possibility. A further water quality survey is recommended as outlined.

1) Frequency of sampling: once a week, with corresponding staff gauge readings at ANEEL flow gauging stations at Ponte SE-302 and Faz. Belem.
2) Sampling stations: Ponte SE-302, Sao Domingos and Fazenda Belem
3) Parameters to be determined: chloride, sodium, total hardness, calcium, magnesium, bicarbonates, electric conductivity, total solids, suspended solids, total nitrogen and total phosphorus. Total nitrogen and total phosphorus may be done only once a month.

APPENDIX-1

Results of Water Quality Analyses

Appendix-1 RESULTS OF WATER QUALITY ANALYSES

Table-1

BASIN - REAL RIVER	SAMPLING PERIOD	UNIT	STATION				
			R - 1	R - 2	R - 3	RP - 1	RJ - 1
PARAMETER			R. REAL	R. REAL	R. REAL	R. PARIPE	R. JABIBERI
pH	1ª	-	7..3	8.1	8.1	7.3	7.2
	2ª	-	8.0	8.4	8.0	7.6	8.1
DO	1ª	mg/L	4.50	6.50	7.10	5.70	5.30
	2ª	mg/L	6.10	6.10	6.00	5.50	6.30
BOD	1ª	mg/L	2.40	1.00	0.60	0.40	1.40
	2ª	mg/L	0.40	1.00	0.80	1.60	0.60
Turbidity	1ª	UNT	21	16	16	10	35
	2ª	UNT	186	8	5	14	7
Elect. Condutivity	1ª	µmho/cm	1 398	1 219	840	210	302
	2ª	µmho/cm	2 147	1 631	589		524
Salinity	1ª	%	0.062	0.046	0.042	0.010	0.015
	2ª	%	0.107	0.082	0.030	0.101	0.026
Alcal. Fen. $CaCO_3$	1ª	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
	2ª	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	1ª	mg/L	109.20	138.00	95.20	43.20	37.20
	2ª	mg/L	125.60	170.40	81.60	62.80	50.80
Bicarb. HCO_3	1ª	mg/L	133.22	168.36	116.14	52.70	45.38
	2ª	mg/L	153.23	207.89	99.55	76.62	61.98
Chloride	1ª	mg/L	346.91	267.52	174.89	31.83	51.50
	2ª	mg/L	578.99	385.40	115.44	577.23	70.04
SO_4	1ª	mg/L	30.66	20.58	10.70	3.70	6.17
	2ª	mg/L	38.68	37.24	8.64	73.45	18.31
Ca	1ª	mg/L	48.22	38.58	22.84	7.36	9.64
	2ª	mg/L	39.90	47.38	22.94	27.43	14.96
Mg	1ª	mg/L	23.84	27.56	17.69	5.39	4.47
	2ª	mg/L	32.17	46.91	11.60	39.73	6.06
Fe	1ª	mg/L	2.00	1.26	1.34	1.89	2.58
	2ª	mg/L	2.65	0.75	0.60	0.93	1.65
Mn	1ª	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
	2ª	mg/L	0.27	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	1ª	mg/L	218.51	209.76	129.85	40.58	42.45
	2ª	mg/L	232.01	311.38	105.01	232.01	62.28
Fecal Coli.	1ª	NMP/100mL	240	900	≥ 1 600	500	2
	2ª	NMP/100mL	1 600	1 600	≥ 1 600	≥ 1 600	2
Total Coli.	1ª	NMP/100mL	240	900	≥ 1 600	900	4
	2ª	NMP/100mL	1 600	1 600	≥ 1 600	≥ 1 600	4
$N-NO_3$	1ª	mg/L	0.38	0.28	0.30	0.42	0.79
	2ª	mg/L	2.46	0.28	0.37	0.85	0.21
Na	1ª	mg/L	165.00	293.00	192.00	20.80	55.70
	2ª	mg/L	291.00	161.00	53.90	99.20	71.40
K	1ª	mg/L	4.41	3.91	2.99	1.94	2.60
	2ª	mg/L	12.30	5.83	1.84	5.83	2.51
Pb	1ª	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
	2ª	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	1ª	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
	2ª	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cd	1ª	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	2ª	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	1ª	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
	2ª	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	1ª	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	2ª	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	1ª	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
	2ª	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp.	1ª	°C	28.0	31.0	30.0	30.0	27.5
	2ª	°C	31.0	29.0	31.0	31.0	31.0
Water Temp.	1ª	°C	27.2	30.0	27.6	27.5	27.3
	2ª	°C	29.3	32.5	29.4	31.2	29.9
Sampling Date	1ª	mm/dd/yy	08/18/98	08/18/98	08/18/98	08/18/98	08/18/98
	2ª	mm/dd/yy	11/05/98	11/05/98	11/05/98	11/05/98	11/05/98
Weather	1ª	-	Good	Good	Good	Good	Good
	2ª	-	-	-	-	-	-

Table-2

BASIN - PIAUI RIVER	UNIT	STATION										
		P - 1	P - 2	P - 3	PT - 1	PT - 2	PF - 1	PF - 2	PJ - 1	PI - 1	PA - 1	PP - 1
PARAMETER		PIAUI RIVER	PIAUI RIVER	PIAUI RIVER	PIAUITINGA RIVER	PIAUITINGA RIVER	FUNDO RIVER	FUNDO RIVER	JACARE RIVER	INDIAROBA RIVER	ARAUA RIVER	PAGÃO RIVER
pH	-	8.0	7.8	7.9	6.7	7.3	6.8	6.8	8.0	7.1	8.2	7.1
DO	mg/L	6.50	6.20	6.60	6.50	6.80	6.40	6.80	7.70	6.40	7.10	6.60
BOD	mg/L	0.60	0.40	0.40	0.60	0.60	1.00	0.20	0.80	0.40	0.80	0.40
Turbidity	UNT	14	10	10	17	21	33	25	21	12	10	14
Elect. Condutiv.	µmho/cm	745	897	902	155	228	127	126	753	168	1,160	155
Salinity	%	0.037	0.045	0.046	0.008	0.011	0.006	0.006	0.037	0.008	0.083	0.008
Alcal. Fen. $CaCO_3$	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	mg/L	123.60	116.80	115.20	12.80	42.80	17.20	11.20	91.20	27.60	196.40	36.40
Bicarb. HCO_3	mg/L	150.79	142.50	140.54	15.62	52.22	20.98	13.66	111.26	33.67	239.61	44.41
Chloride	mg/L	210.29	181.68	188.84	35.41	35.41	37.19	24.68	160.22	26.46	391.62	31.83
SO_4	mg/L	13.58	17.49	19.13	5.14	4.73	6.79	6.17	12.55	6.38	19.13	7.20
Ca	mg/L	36.55	32.49	28.43	2.03	8.63	2.54	2.03	28.43	4.06	53.50	5.33
Mg	mg/L	25.15	20.94	20.37	2.86	6.44	2.86	1.95	18.55	3.30	38.96	4.20
Fe	mg/L	1.83	1.81	2.06	2.93	2.92	3.24	2.62	2.39	2.33	0.97	2.25
Mn	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	mg/L	194.78	167.31	154.83	16.86	48.07	18.10	13.11	147.33	23.72	293.42	30.59
Fecal Coli	NMP/100mL	170	170	130	1,600	1,600	500	> 1,600	14	300	240	34
Total Coli	NMP/100mL	900	900	300	1,600	1,600	900	> 1,600	110	900	1,600	900
$N\text{-}NO_3$	mg/L	0.95	0.87	0.80	0.97	1.00	0.87	0.57	0.57	0.69	0.65	0.71
Na	mg/L	202.00	184.00	202.00	19.50	16.50	21.20	15.20	159.00	17.50	218.00	20.80
K	mg/L	3.78	3.13	3.13	1.11	0.88	1.17	0.71	2.34	1.45	3.52	1.40
Pb	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cd	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp	°C	26.0	26.0	24.0	27.0	29.0	26.0	28.0	28.0	29.0	29.0	29.0
Water Temp	°C	26.9	26.1	25.9	22.9	25.3	23.8	24.7	27.8	26.4	26.2	28.5
Sampling Date		08/12/98	08/12/98	08/12/98	08/13/98	08/13/98	08/13/98	08/13/98	08/12/98	08/12/98	08/12/98	08/12/98
Weather		Rain	Rain	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Good	Cloudy	Cloudy	Cloudy
pH	-	8.5	8.2	8.5	7.5	8.1	7.0	6.9	8.3		7.5	7.2
DO	mg/L	7.50	6.80	5.40	5.70	6.60	6.20	6.50	6.70	6.90	5.30	5.80
BOD	mg/L	1.40	1.20	1.20	0.40	1.60	0.20	1.00	1.60	0.80	0.60	0.80
Turbidity	UNT	5	6	16	13	18	14	33	1		30	16
Elect. Condutiv.	µmho/cm	1,287	1,324	222	174	259	184	128	1,474		848	223
Salinity	%	0.064	0.013	0.033	0.009	0.013	0.009	0.006	0.074	0.010	0.042	0.011
Alcal. Fen. $CaCO_3$	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	mg/L	169.20	164.00	105.60	14.40	54.80	14.00	13.20	158.40	40.80	91.20	36.00
Bicarb. HCO_3	mg/L	206.42	200.08	128.83	17.57	66.86	17.08	16.10	193.25	49.78	111.26	43.92
Chloride	mg/L	293.27	302.21	124.60	37.19	38.98	41.88	26.04	341.91	29.56	185.84	36.60
SO_4	mg/L	23.87	31.89	14.61	26.13	24.90	4.53	5.35	22.84	19.96	24.69	4.73
Ca	mg/L	47.38	43.64	22.94	2.99	12.22	2.99	3.24	46.88	6.23	20.95	5.24
Mg	mg/L	31.34	32.12	13.38	2.49	6.98	3.08	1.89	34.46	3.34	15.18	3.65
Fe	mg/L	0.33	0.42	0.91	1.62	1.46	1.61	1.22	0.34	1.74	2.13	1.46
Mn	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	mg/L	247.27	241.17	112.34	17.71	59.22	20.15	15.87	258.87	29.31	114.78	28.09
Fecal Coli	NMP/100mL	300	80	> 1,600	300	> 1,600	900	1,600	23	> 1,600	> 1,600	1,600
Total Coli	NMP/100mL	900	130	> 1,600	900	> 1,600	> 1,600	> 1,600	80	> 1,600	> 1,600	> 1,600
$N\text{-}NO_3$	mg/L	0.30	0.29	0.75	0.43	0.69	0.56	1.60	0.25	0.39	0.83	0.83
Na	mg/L	151.00	148.00	72.20	11.80	18.40	24.30	16.40	168.00	17.60	105.00	23.70
K	mg/L	4.01	3.12	2.68	1.93	1.86	1.51	0.97	3.27	2.11	2.68	2.38
Pb	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cd	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp	°C	31.0	30.0	29.0	30.0	30.0	31.0	31.0	31.0	300	28.0	29.0
Water Temp.	°C	31.2	29.9	29.0	26.4	29.4	26.1	26.1	29.0	29.0	26.0	26.9
Sampling Date		10/15/98	10/15/98	10/21/98	10/15/98	10/15/98	10/21/98	10/21/98	10/21/98	11/05/98	10/21/98	10/21/98
Weather		-	-	-	-	-	-	-	-	-	-	-

Table-3

BASIN - VAZA-BARRIS RIVER	SAMPLING PERIOD	UNIT	STATION					
			V - 1	V - 2	V - 3	VB - 1	VC - 1	VT - 1
PARAMETER			R. VAZA BARRIS	R. VAZA BARRIS	R. VAZA BARRIS	R. TEJU PEBA	R. COMPRIDO	R. TRAEIRAS
pH	1ª	-	8.3	8.4	7.9	6.8	7.4	8.0
	2ª	-	8.2	8.1	7.7	7.6	7.7	7.5
DO	1ª	mg/L	7.00	6.00	6.10	6.60	6.40	7.04
	2ª	mg/L	7.30	7.30	6.10	7.00	4.80	5.90
BOD	1ª	mg/L	0.20	0.20	0.40	0.40	0.60	0.60
	2ª	mg/L	2.40	1.80	0.80	0.20	0.60	1.40
Turbidity	1ª	UNT	19	10	10	19	10	18
	2ª	UNT	2	1	5	8	5	6
Elect. Condutivity	1ª	µmho/cm	6 200	2 280	864	215	362	306
	2ª	µmho/cm	6 600	3 500	398	147	398	350
Salinity	1ª	%	-	-	0..055	0.011	0.018	0.015
	2ª	%	0.350	0.180	0.090	0.007	0.020	0.018
Alcal. Fen. $CaCO_3$	1ª	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
	2ª	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	1ª	mg/L	108.40	144.80	120.00	18.40	152.40	60.80
	2ª	mg/L	90.80	108.00	112.80	14.80	175.60	98.00
Bicarb. HCO_3	1ª	mg/L	132.25	176.66	146.40	22.45	185.93	74.18
	2ª	mg/L	110.78	131.71	137.62	18.06	214.32	119.56
Chloride	1ª	mg/L	2 843.27	886.96	302.21	28.25	19.31	56.86
	2ª	mg/L	2 031.42	1 280.36	382.68	28.25	19.31	72.96
SO_4	1ª	mg/L	410.27	124.68	39.30	5.35	6.79	7.00
	2ª	mg/L	401.62	189.29	27.36	8.23	4.20	11.73
Ca	1ª	mg/L	342.63	137.05	63.45	2.79	48.48	9.64
	2ª	mg/L	336.62	184.52	82.28	3.24	59.34	14.96
Mg	1ª	mg/L	277.53	80.67	29.76	2.55	4.56	9.93
	2ª	mg/L	225.99	113.54	31.67	2.34	3.75	14.36
Fe	1ª	mg/L	0.09	0.16	1.08	2.14	1.00	1.25
	2ª	mg/L	0.15	0.14	0.40	1.08	0.34	0.36
Mn	1ª	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
	2ª	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	1ª	mg/L	1 997.76	674.24	280.94	17.48	139.84	64.93
	2ª	mg/L	1 770.59	928.04	335.80	17.71	163.63	96.47
Fecal Coli	1ª	NMP/100mL	170	170	170	≥ 1 600	240	23
	2ª	NMP/100mL	23	17	90	≥ 1 600	≥ 1 600	500
Total Coli	1ª	NMP/100mL	300	≥ 1 600	300	≥ 1 600	≥ 1 600	110
	2ª	NMP/100mL	170	27	140	≥ 1 600	≥ 1 600	1 600
$N\text{-}NO_3$	1ª	mg/L	0.77	0.36	0.87	0.93	0.60	1.06
	2ª	mg/L	1.49	1.12	0.53	0.62	0.51	0.50
Na	1ª	mg/L	110.00	328.00	111.00	17.60	9..37	31.30
	2ª	mg/L	611.00	436.00	162.00	17.70	13.90	41.90
K	1ª	mg/L	15.20	5.37	4.36	1.07	0.59	3.71
	2ª	mg/L	14.00	7.68	4.24	0.79	0.82	4.39
Pb	1ª	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
	2ª	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	1ª	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
	2ª	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cd	1ª	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	2ª	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	1ª	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
	2ª	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	1ª	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	2ª	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	1ª	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
	2ª	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp.	1ª	°C	30.0	29.0	27.0	29.0	25.0	30.0
	2ª	°C	30.0	30.0	29.0	28.0	28.0	29.0
Water Temp.	1ª	°C	26.5	27.0	28.4	25.0	27.0	26.5
	2ª	°C	28.1	28.3	31.6	25.0	28.0	29.9
Sampling Date	1ª	mm/dd/yy	08/04/98	05/08/98	08/04/98	08/04/98	08/04/98	08/04/98
	2ª	mm/dd/yy	10/06/98	10/06/98	10/06/98	10/07/98	10/06/98	10/06/98
Weather	1ª	-	Good	Rain	Good	Good	Good	Good
	2ª	-	-	-	-	-	-	-

Table-4

BASIN - SERGIPE RIVER		STATION											
PARAMETER	UNIT	S - 1	S - 2	S - 3	S - 4	SC - 1	SJ - 1	SJ - 2	SP - 1	SPXA - 1	SPXM - 1	SM - 1	SV - 1
		SERGIPE RIVER	SERGIPE RIVER	SERGIPE RIVER	SERGIPE RIVER	COTINGUIBA RIVER	JACARECICA RIVER	JACARECICA RIVER	PITANGA RIVER	POXIMAÇU RIVER	P.MIRIM RIVER	MARCELA WEIR	V.DANGRA RIVER
pH	-		8.2	8.1	7.4	7.5	7.6	7.7	6.2	7.6	7.5	7.4	4.6
DO	mg/L	9.70	7.50	8.00	4.90	6.50	5.90	6.00	5.80	6.40	5.50	2.90	5.90
BOD	mg/L	0.40	1.00	0.60	2.00	0.80	0.60	1.00	1.00	0.80	1.00	0.80	1.80
Turbidity	UNT	9	9	17	25	12	19	65	11	37	39	10	25
Elect. Condutiv.	μmho/cm	21,100	5,770	2,750	1,580	246	315	416	61	161	360	900	57
Salinity	%	-	-	0.138	0.129	-	0.016	0.021	0.030	0.080	0.016	0.045	0.003
Alcal. Fen. $CaCO_3$	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	mg/L	252.00	234.40	172.00	154.80	66.00	66.80	92.80	8.40	43.60	140.40	192.00	ABSENCE
Bicarb. HCO_3	mg/L	307.44	285.97	209.84	188.86	80.52	81.50	113.22	10.25	53.19	171.29	234.24	ABSENCE
Chloride	mg/L	9,262.98	2,281.77	815.43	886.96	47.92	46.14	97.99	15.74	21.10	28.25	213.87	10.37
SO_4	mg/L	523.43	126.95	37.86	80.04	17.69	4.32	8.64	3.29	1.65	2.88	38.06	1.44
Ca	mg/L	685.26	228.42	96.44	81.22	17.26	13.45	14.21	1.52	14.47	42.38	35.53	1.78
Mg	mg/L	1,025.33	263.40	87.11	66.01	6.37	6.86	13.83	1.20	1.99	3.87	30.02	0.29
Fe	mg/L	0.27	0.81	1.14	2.35	2.92	3.76	2.93	3.16	3.01	2.45	0.65	NO LIMIT
Mn	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	mg/L	5,930.85	1,654.40	599.33	474.47	69.30	61.81	92.40	8.74	44.33	121.74	212.26	5.62
Fecal Coli	NMP/100mL	300	140	240	1,600	>1,600	≥1,600	≥1,600	≥1,600	≥ 1,600	>1,600	≥1,600	> 1,600
Total Coli	NMP/100mL	>1,600	≥1,600	>1,600	>1,600	>1,600	>1,600	>1,600	>1,600	≥ 1,600	≥1,600	>1,600	> 1,600
N-NO_3	mg/L	062	0.62	0.66	1.11	0.95	0.80	1.27	1.04	0.94	0.74	1.28	0.56
Na	mg/L	360.00	862.00	301.00	420.00	28.60	30.10	7.05	7.05	11.40	22.00	131.00	5.42
K	mg/L	31.70	8.01	4.64	13.20	3.06	3.78	1.30	1.30	0.93	0.81	11.30	0.41
Pb	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cd	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.0004	< 0.05	< 0.05
Hg	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp.	°C	27.5	29.0	28.0	29.0	27.0	25.0	26.0	26.0	27.0	29.0	25.0	30.0
Water Temp.	°C	29.0	28.7	27.0	26.0	24.9	25.6	25.2	24.7	26.0	25.8	26.8	25.5
Sampling Date		08/06/98	08/06/98	08/06/98	08/06/98	08/05/98	08/05/98	08/05/98	08/05/98	08/05/98	08/05/98	08/05/98	08/11/98
Weather		-	Good	Good	Good	Rain	Rain	Rain	Rain	Rain	Rain	Rain	Good
pH	-	8.0	8.2	7.8	7.4	7.9	8.0	8.1	7.4	7.4	7.5	7.3	6.1
DO	mg/L	5.70	7.70	5.90	3.20	4.90	5.30	5.80	5.00	6.70	5.20	1.00	3.90
BOD	mg/L	1.00	2.40	0.60	2.80	1.00	2.00	1.60	0.20	0.80	0.60	3.20	0.80
Turbidity	UNT	14	17	3	1,010	28	29	30	45	25	18	6	31
Elect. Condutiv.	μmho/cm	23,900	8,500	2,253	3,310	204	462	872	80	283	348	1,123	55
Salinity	%	1.390	0.460	0.113	1.990	0.010	0.023	0.044	0.004	0.016	0.017	0.056	0.003
Alcal. Fen. $CaCO_3$	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	mg/L	242.80	213.60	172.00	164.40	33.60	100.00	145.60	8.80	42.80	153.20	268.80	9.60
Bicarb. HCO_3	mg/L	296.22	260.59	209.84	200.57	40.99	122.00	177.63	10.74	52.22	186.90	327.94	11.71
Chloride	mg/L	9,084.16	3,183.03	636.61	11,587.66	31.83	71.77	178.11	19.01	21.10	37.19	285.40	12.16
SO_4	mg/L	532.89	144.02	32.51	1,493.95	8.85	11.11	9.05	2.26	8.64	4.32	48.56	2.67
Ca	mg/L	648.31	274.29	74.81	349.09	10.22	20.95	19.45	1.99	14.46	29.17	46.88	2.24
Mg	mg/L	1,001.21	323.16	82.20	782.20	4.18	9.84	21.73	1.61	2.35	15.09	41.58	1.01
Fe	mg/L	0.37	0.78	0.26	0.52	1.40	1.24	1.47	1.75	1.31	0.98	0.08	0.34
Mn	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	mg/L	5,739.17	2,014.82	525.07	4,090.69	42.74	92.80	137.98	11.60	45.79	134.93	288.18	9.77
Fecal Coli	NMP/100mL	170	220	500	170	1,600	1,600	≥1,600	240	240	>1,600	26	≥1,600
Total Coli	NMP/100mL	900	220	500	170	1,600	>1,600	>1,600	300	500	>1,600	280	>1,600
N-NO_3	mg/L	0.43	4.19	0.53	0.69	0.71	0.78	0.50	0.67	0.65	0.60	0.43	0.41
Na	mg/L	3,464.00	1,402.00	215.00	6,757.00	18.20	50.80	106.00	9.53	15.10	22.20	172.00	25.00
K	mg/L	39.60	12.10	4.62	242.00	1.15	3.08	3.93	0.83	0.57	0.98	11.90	< 0.20
Pb	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cd	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp.	°C	28.0	30.0	30.0	27.0	27.0	27.0	28.0	31.0	30.0	30.0	28.0	31.0
Water Temp.	°C	27.7	29.3	30.8	28.7	25.1	27.8	29.2	26.4	25.0	25.1	26.0	27.2
Sampling Date		10/08/98	10/13/98	10/08/98	10/07/98	10/07/98	10/07/98	10/07/98	10/21/98	10/08/98	10/08/98	10/07/98	10/08/98
Weather		-	-	-	-	-	-	-	-	-	-	-	-

Table-5

BASIN - JAPARATUBA R. / PARAMETER	SAMPLING PERIOD	UNIT	STATION J - 1 R. JAPARATUBA	J - 2 R. JAPARATUBA	J - 3 R. JAPARATUBA	JS - 1 R. SIRIRI	JS - 2 R. SIRIRI	JM - 1 R. J. MIRIM
pH	1ª	-	8.1	7.4	7.6	7.3	7.2	7.5
	2ª	-	7.8	8.2	7.8	7.7	7.7	7.6
DO	1ª	mg/L	8.10	6.80	6.30	6.80	6.00	6.40
	2ª	mg/L	5.50	5.90	6.20	5.40	5.80	5.60
BOD	1ª	mg/L	0.80	0.20	0.20	0.20	0.60	0.80
	2ª	mg/L	0.40	2.60	0.80	1.40	1.00	0.60
Turbidity	1ª	UNT	12	7	9	12	12	37
	2ª	UNT	5	19	4	29	17	48
Elect. Condutivity	1ª	µmho/cm	5 660	1 644	1 110	280	344	350
	2ª	µmho/cm	10 600	8 500	949	445	860	315
Salinity	1ª	%	-	0.084	0.056	0.014	0.017	0.017
	2ª	%	0.580	0.058	0.050	0.022	0.043	0.016
Alcal. Fen. $CaCO_3$	1ª	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
	2ª	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	1ª	mg/L	331.60	150.00	130.80	42.80	60.40	60.40
	2ª	mg/L	246.80	103.60	102.80	42.80	50.00	44.40
Bicarb. HCO_3	1ª	mg/L	404.55	183.00	159.58	52.22	73.69	73.69
	2ª	mg/L	301.10	126.39	125.42	52.22	61.00	54.17
Chloride	1ª	mg/L	2 485.62	425.60	248.56	50.00	89.05	92.63
	2ª	mg/L	3 605.05	313.30	210.29	81.90	74.75	60.44
SO_4	1ª	mg/L	55.96	19.34	26.54	3.50	11.32	5.56
	2ª	mg/L	67.90	11.73	11.11	5.97	5.76	4.53
Ca	1ª	mg/L	203.04	40.61	32.99	7.11	14.22	8.63
	2ª	mg/L	286.75	19.95	24.94	11.97	11.47	8.23
Mg	1ª	mg/L	256.04	45.14	26.25	4.48	7.45	10.24
	2ª	mg/L	367.52	33.59	22.25	5.50	5.65	5.98
Fe	1ª	mg/L	0.37	1.24	1.52	2.36	3.22	3.42
	2ª	mg/L	0.23	0.69	0.64	2.21	1.31	2.60
Mn	1ª	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
	2ª	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	1ª	mg/L	1 560.75	287.18	190.41	36.21	66.18	63.68
	2ª	mg/L	2 228.51	188.05	153.86	52.51	51.90	45.18
Fecal Coli	1ª	NMP/100mL	≥ 1 600	1 600	130	1 600	1 600	≥ 1 600
	2ª	NMP/100mL	130	170	280	1 600	≥ 1 600	≥ 1 600
Total Coli	1ª	NMP/100mL	≥ 1 600	≥ 1 600	500	≥ 1 600	≥ 1 600	≥ 1 600
	2ª	NMP/100mL	300	300	900	≥ 1 600	≥ 1 600	≥ 1 600
N-NO_3	1ª	mg/L	1.27	1.24	1.32	0.85	0.71	0.84
	2ª	mg/L	0.49	0.44	0.55	0.36	0.45	0.45
Na	1ª	mg/L	918.00	200.00	129.00	32.50	51.20	55.20
	2ª	mg/L	1,517.00	148.00	105.00	81.70	85.70	34.90
K	1ª	mg/L	9.12	5.08	4.28	2.62	2.62	3.64
	2ª	mg/L	9.98	5.35	4.16	2.53	2.53	2.97
Pb	1ª	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
	2ª	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	1ª	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
	2ª	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cd	1ª	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	2ª	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	1ª	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
	2ª	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	1ª	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	2ª	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	1ª	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
	2ª	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp.	1ª	°C	27.0	28.0	30.0	30.5	28.0	30.0
	2ª	°C	30.0	31.0	29.0	30.0	30.0	29.0
Water Temp.	1ª	°C	27.0	25.4	26.0	24.9	24.6	25.0
	2ª	°C	27.2	26.7	26.7	26.0	25.7	27.6
Sampling Date	1ª	mm/dd/yy	08/11/98	08/11/98	08/11/98	08/11/98	08/11/98	08/11/98
	2ª	mm/dd/yy	10/13/98	10/15/98	10/13/98	10/13/98	10/13/98	10/13/98
Weather	1ª	-	Good	Good	Good	Good	Good	Good
	2ª	-	-	-	-	-	-	-

Table-6

BACIN SÃO FRANCISCO RIVER		STATION										
		SF -1	SF -2	SF -3	SF -4	SFB -1	SFA -1	SFRP -1	SFG -1	SFP -1	SFC -1	SFJ -1
PARAMETER	UNIT	S.FRANCISCO RIVER	S.FRANCISCO RIVER	S.FRANCISCO RIVER	S.FRANCISCO RIVER	BETUME RIVER	ST. ANTÔNIO RIVER	PILÕES RIVER	GARARU RIVER	POÇÃO RIVER	CAPIVARA RIVER	JACARÉ RIVER
pH	-	7.8	8.1	8.2	8.0	6.2	5.5	8.0	8.2	8.4	8.2	8.3
DO	mg/L	6.60	6.90	6.90	7.00	4.80	5.60	7.50	7.50	6.70	7.50	9.00
BOD	mg/L	0.20	0.20	0.80	0.60	1.00	0.80	0.40	0.40	0.60	1.60	3.80
Turbidity	UNT	10	5	4	5	5	7	9	2	7	7	160
Elect. Condutiv	umho/cm	8.1	20.4	10.0	7.3	13.7	7.3	127.7	174	600.0	11,600	7,750
Salinity	%	0.074	0.008	0.005	0.004	0.070	0.004	0.064	0.094	0.320	0.040	0.410
Alcal. Fen. $CaCO_3$	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	mg/L	29.20	28.80	30.00	28.80	11.20	6.00	163.60	37.60	297.60	305.60	616.40
Bicarb. HCO_3	mg/L	35.62	35.14	36.60	35.14	13.66	7.32	199.59	45.87	363.07	372.83	752.01
Chloride	mg/L	8.58	6.79	6.79	6.79	30.04	17.52	238.91	30.04	1,924.12	4,273.84	2,281.77
SO_4	mg/L	3.91	2.67	1.44	3.70	12.14	11.11	73.45	6.17	167.07	359.03	261.30
Ca	mg/L	8.63	8.12	8.38	8.38	3.55	2.03	59.90	9.39	203.04	380.70	241.11
Mg	mg/L	1.13	1.75	2.04	1.74	1.79	1.35	26.76	3.71	127.10	421.30	187.43
Fe	mg/L	0.30	0.05	0.12	0.09	0.88	0.59	0.72	0.24	0.69	1.58	0.49
Mn	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	mg/L	26.22	27.47	29.34	28.09	16.23	10.61	259.71	38.71	1,030.09	2,684.49	1,373.46
Fecal Coli	NMP/100mL	13	1,600	900	> 1,600	70	17	1,600	80	9	12	1,600
Total Coli	NMP/100mL	50	1,600	900	> 1,600	> 1,600	> 1,600	1,600	1,600	900	240	> 1,600
N-NO_3	mg/L	0.46	0.40	0.43	0.47	0.36	0.41	0.50	0.28	0.45	0.23	0.41
Na	mg/L	2.21	2.79	3.17	2.17	14.20	8.83	121.00	11.40	77.90	1,510.00	988.00
K	mg/L	1.83	1.76	1.83	1.47	1.03	0.22	5.02	1.98	16.00	1.10	66.70
Pb	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cd	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp	°C	30.0	28.0	28.0	30.0	28.0	27.5	27.0	26.0	25.0	27.5	30.0
Water Temp	°C	25.7	25.6	25.8	25.7	27.0	26.4	27.8	26.0	27.8	26.0	26.6
Sampling Date		08/19/98	08/19/98	08/20/98	08/20/98	08/20/98	08/20/98	08/20/98	08/19/98	08/19/98	08/19/98	08/19/98
Weather		Good	Good	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Good	Good
pH	-	6.6	7.8	8.3	8.4	6.6	6.6	7.7	8.5	8.6		
DO	mg/L	6.70	7.20	7.00	7.10	3.10	5.40	5.90	6.30	6.80		
BOD	mg/L	0.20	0.60	0.40	0.80	1.40	1.20	0.80	2.40	2.60		
Turbidity	UNT	2	2	2	7	14	4	15	5	33		
Elect. Condutiv	μmho/cm	73	67	67	72	147	106	1,048	83	7,800		
Salinity	%	0.004	0.003	0.003	0.004	0.007	0.005	0.052	0.004	0.420		
Alcal. Fen. $CaCO_3$	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	15.60		
Alcal. Met. $CaCO_3$	mg/L	38.00	27.60	32.40	28.80	19.20	5.60	120.00	33.60	392.40		
Bicarb. HCO_3	mg/L	46.36	33.67	39.53	35.14	23.42	6.83	146.40	40.99	440.66		
Chloride	mg/L	6.69	6.69	8.45	4.93	26.05	17.25	199.92	10.21	2,456.74		
SO_4	mg/L	16.05	6.38	5.35	2.47	8.23	5.14	72.42	10.29	182.50		
Ca	mg/L	9.48	7.98	8.73	8.23	4.74	2.74	46.88	8.23	187.01		
Mg	mg/L	1.96	1.39	1.82	1.53	2.76	1.16	19.62	1.68	190.67		
Fe	mg/L	0.03	0.23	0.22	0.60	2.28	0.49	0.71	0.31	1.24		
Mn	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.12		
Hardness $CaCO_3$	mg/L	31.75	25.64	29.31	26.86	23.20	11.60	197.82	27.47	1,251.63		
Fecal Coli	NMP/100mL	8	50	280	900	1,600	>1,600	240	>1,600	500		
Total Coli	NMP/100mL	8	80	900	900	>1,600	>1,600	300	>1,600	500		
N-NO_3	mg/L	0.11	0.32	0.40	0.21	0.29	0.32	0.17	0.17	0.29		
Na	mg/L	2.44	2.23	3.33	2.31	17.70	7.88	105.00	3.93	1,125.00		
K	mg/L	1.20	1.20	1.86	2.07	1.43	0.27	6.84	1.20	21.10		
Pb	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03		
Cu	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		
Cd	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001		
Cr	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05		
Hg	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002		
As	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005		
Air Temp	°C	32.0	32.0	30.0	30.0	30.0	31.0	31.0	32.0	30.0		
Water Temp	°C	26.5	27.4	27.4	28.1	28.7	27.9	26.5	29.4	30.9		
Sampling Date		11/04/98	11/04/98	10/22/98	10/22/98	10/22/98	10/22/98	10/22/98	11/04/98	11/04/98		
Weather		-	-	-	-	-	-	-	-	-		

Table-7

GROUNDWATER																		
PARAMETER	UNIT	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
pH	-	6.8	6.7	7.6	7.0	7.5	5.8	4.4	7.1	5.6	7.1	7.0	6.4	5.8	7.2	6.8	6.6	6.7
DO	mg/L	2.00	4.10	5.10	2.00	2.80	4.40	3.30	3.40	1.00	5.90	6.70	2.50	4.80	5.00	6.90	5.40	4.90
BOD	mg/L	0.20	2.20	0.20	0.20	0.40	0.20	1.00	0.60	0.20	0.20	0.60	2.40	0.20	0.20	0.20	0.20	0.60
Turbidity	UNT	42	1	1	0	2	0	1	1	1	16	34	0	0	1	0	0	0
Elect. Condutiv.	μmho/cm	107.2	85.8	55.7	95.4	65.4	26.8	32.5	39.6	18.4	28.9	26.8	95.3	17.5	45.2	42.1	91.9	47.5
Salinity	%	0.042	0.043	0.028	0.048	0.033	0.013	0.016	0.020	0.009	0.014	0.013	0.048	0.011	0.023	0.021	0.060	0.024
Alcal. Fen. $CaCO_3$	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	mg/L	376.80	348.80	359.60	420.40	194.40	28.00	ABSENCE	233.60	28.40	38.40	96.00	140.00	19.60	191.20	144.00	156.40	96.00
Bicarb. HCO_3	mg/L	459.69	425.54	438.71	512.89	237.17	34.16	ABSENCE	284.99	34.65	46.85	117.12	170.80	23.91	233.26	175.68	190.81	117.12
Chloride	mg/L	99.78	55.08	26.46	65.81	78.32	51.50	64.02	24.68	40.77	80.11	21.10	195.99	38.98	64.02	56.86	260.36	67.59
SO_4	mg/L	39.50	20.78	7.82	19.55	11.52	3.50	2.47	4.32	4.32	3.70	5.97	23.45	10.29	7.41	9.26	13.17	7.00
Ca	mg/L	129.44	124.36	93.91	90.35	53.81	8.88	2.54	68.02	2.28	8.63	17.77	32.49	4.57	24.36	46.70	68.02	22.33
Mg	mg/L	9.44	4.94	23.42	38.62	12.86	6.44	4.22	11.82	1.65	5.99	6.66	26.40	2.38	10.70	5.95	43.07	13.45
Fe	mg/L	2.86	0.11	NOLIMIT	NOLIMIT	0.03	0.04	0.10	NOLIMIT	2.94	1.33	2.96	0.22	NOLIMIT	3.08	0.04	NOLIMIT	0.02
Mn	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.30	<0.11	<0.10	0.10	<0.10	<0.10	<0.10
Hardness $CaCO_3$	mg/L	362.09	330.88	330.88	384.57	187.29	48.70	23.72	218.51	12.49	46.20	71.79	189.79	21.23	104.88	141.09	347.11	111.13
Fecal Coli	NMP/100mL	30	50	<2	<2	7	7	13	4	<2	8	<2	11	<2	<2	<2	<2	<2
Total Coli	NMP/100mL	30	50	<2	<2	17	11	240	30	<2	8	<2	11	<2	<2	<2	<2	<2
N-NO_3	mg/L	1.31	6.09	1.13	4.87	1.09	2.32	9.05	1.62	0.82	2.64	2.21	5.78	2.81	1.70	2.98	9.11	4.62
Na	mg/L	20.00	57.70	14.00	57.70	49.20	258.00	33.20	10.30	18.00	40.80	13.60	108.00	11.90	65.40	36.90	123.00	35.40
K	mg/L	2.04	0.96	1.27	2.20	3.27	5.88	0.80	0.88	0.96	3.58	2.35	12.10	2.81	7.10	2.81	2.81	2.50
Pb	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cu	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cd	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hg	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
As	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Air Temp.	°C	27.0	27.0	25.0	28.0	30.0	27.0	24.0	28.0	28.0	30.0	27.0	31.0	30.0	28.0	30.0	30.0	30.0
Water Temp.	°C	25.4	27.1	26.2	27.0	31.6	26.2	25.5	28.5	29.5	27.0	26.8	28.1	28.6	29.7	27.3	26.8	26.7
Sampling Date		08/26/98	08/26/98	08/26/98	08/26/98	08/26/98	08/26/98	08/26/98	08/27/98	08/27/98	08/27/98	08/27/98	08/27/98	08/27/98	08/27/98	09/01/98	09/01/98	09/01/98

Table-8

GROUNDWATER																		
PARAMETER	UNIT	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
pH	-	7.0	7.3	6.7	7.7	7.5	7.3	7.0	7.3	7.1	6.8	6.0	6.0	7.2	6.3	6.4	7.4	7.8
DO	mg/L	2.10	2.8	1.7	4.4	4.6	5.2	4.2	4.5	5.0	6.0	5.0	4.3	3.4	5.1	4.8	6.5	5.5
BOD	mg/L	1.80	0.40	1.20	0.20	0.80	0.20	0.20	0.20	0.40	0.20	0.20	0.40	0.20	0.20	0.20	0.20	0.20
Turbidity	UNT	7	0	0	0	3	0	8	2	0	9	0	0	2	0	2	0	1
Elect. Condutiv.	µmho/cm	88.4	49.0	84.8	90.7	82.9	261.7	234.0	194.1	27.7	20.7	61.6	68.6	222.7	32.3	24.3	121.9	7.3
Salinity	%	0.044	0.025	0.042	0.04	0.042	0.130	0.092	0.097	0.014	0.010	0.029	0.034	0.111	0.016	0.012	0.061	0.004
Alcal. Fen. $CaCO_3$	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	mg/L	326.40	224.80	287.60	300.08	262.40	482.40	512.40	576.80	76.00	31.60	15.60	26.40	449.60	26.40	17.60	254.00	34.80
Bicarb. HCO_3	mg/L	298.21	274.26	350.87	366.98	320.13	588.53	625.13	703.70	92.72	38.55	19.03	32.21	548.51	32.21	21.47	309.88	42.46
Chloride	mg/L	85.48	26.46	76.53	97.99	178.11	507.85	570.44	382.68	19.31	31.83	163.80	231.75	624.09	55.08	51.50	249.63	5.01
SO_4	mg/L	22.84	11.52	28.80	22.02	19.34	126.74	101.02	261.92	5.56	12.96	6.17	6.17	112.96	8.85	1.23	44.24	8.64
Ca	mg/L	81.22	51.78	62.94	42.39	59.84	201.97	199.48	127.17	12.97	6.23	16.96	19.95	187.01	1.25	1.75	94.75	8.48
Mg	mg/L	22.01	21.07	32.80	30.66	45.59	73.28	92.60	44.49	5.19	5.57	17.60	22.31	52.69	0.73	0.72	17.87	0.94
Fe	mg/L	0.51	NO LIMT	0.01	0.01	0.49	0.01	0.76	0.02	0.04	1.40	0.08	0.09	0.04	0.05	0.08	0.03	0.29
Mn	mg/L	0.53	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.48	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	mg/L	293.42	216.01	292.17	232.01	337.02	805.93	879.19	500.65	53.73	38.46	114.78	141.65	683.82	6.10	7.33	310.16	25.03
Fecal Coli	NMP/100mL	4	< 2	< 2	2	4	50	80	240	< 2	< 2	< 2	30	< 2	< 2	< 2	8	21
Total Coli	NMP/100mL	9	< 2	2	4	30	1,600	220	≥ 1,600	900	< 2	< 2	50	500	< 2	80	220	1,600
N-NO_3	mg/L	2.01	2.72	4.43	2.54	2.81	12.74	9.74	6.65	1.23	3.03	7.73	13.74	13.99	3.17	5.87	3.36	1.04
Na	mg/L	73.10	16.90	67.30	92.30	75.40	308.00	219.00	577.00	20.80	16.90	82.70	96.20	354.00	43.80	53.80	138.00	2.28
K	mg/L	1.19	1.35	4.34	12.10	18.80	2.04	1.43	1.58	2.35	0.96	3.73	5.26	5.26	0.29	0.30	8.48	0.88
Pb	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cd	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp.	°C	30.0	29.0	29.0	28.0	29.0	30.0	30.0	29.0	27.0	29.0	29.0	29.0	28.0	27.0	26.0	31.0	31.0
Water Temp.	°C	26.8	28.7	26.6	28.0	25.6	25.8	24.9	25.0	26.7	25.0	27.4	26.0	26.4	25.4	28.4	30.1	28.4
Sampling Date		09/01/98	09/01/98	09/01/98	09/02/98	09/02/98	09/02/98	09/02/98	09/02/98	09/02/98	09/03/98	09/03/98	09/03/98	09/03/98	09/03/98	09/03/98	09/08/98	09/08/98

JAPAN INTERNATIONAL COOPERATION AGENCY

STATE SECRETARIAT OF PLANNING, SCIENCE AND TECHNOLOGY
THE STATE OF SERGIPE, THE FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY
ON
WATER RESOURCES DEVELOPMENT
IN THE STATE OF SERGIPE
IN
THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT
SUPPORTING
(VOLUME I)
MASTER PLAN STUDY

[E] AGRICULTURE AND IRRIGATION

MARCH 2000

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**THE STUDY ON WATER RESOURCES DEVELOPMENT
IN THE STATE OF SERGIPE
IN THE FEDERATIVE REPUBLIC OF BRAZIL**

**SUPPORTING REPORT(E)
AGRICULTURE AND IRRIGATION**

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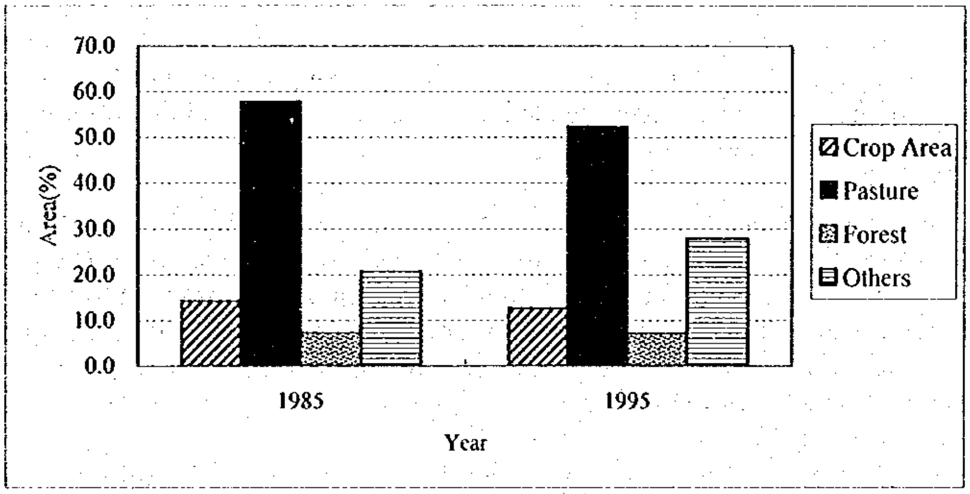
CHAPTER 1 CURRENT AGRICULTURE AND IRRIGATION

Agriculture in Sergipe was examined to assess whether the further water resources development is necessary for agriculture sector. Inland fish culture has been recently promoted by CODEVASF; however, its extension is still negligibly small compared to other agriculture practices. Besides, its water consumption is expected to be not significant because it will be practiced in reservoirs and ponds for other purposes, such as hydropower and irrigation. Therefore, inland fish culture was excluded from the study.

1.1 General Characteristics of Agriculture

1.1.1 State Agricultural Area

As shown in Figure-1.1, approximately 14 % and 58 % of state land (2,205,030 ha) was cropland and pasture respectively in 1985, while both decreased to 13 % and 52 % in 1995. The reduction of agricultural areas is probably due to limited market and unfavorable prices. Urbanization also stipulates conversion of agricultural areas to other usage, such as residential areas and industrial areas.



Source: IBGE ("Census of Agriculture 1995-1996", 1996)

Figure-1.1 Agricultural Area

1.1.2 Crop Cultivation

Primary crops in Sergipe are corn, beans, cassava, sugarcane, cotton, coconut and orange. Variation of yields and harvested areas of those crops in the last 20 years are shown in Table-1.1. Significant change is decrease in cultivation of traditional field crops, such as cotton and sugarcane, and increase in fruit cultivation. The harvested area of cotton dropped from 33,800 ha in 1985 to 1,900 ha in 1996. Harvested area of sugarcane reached to the maximum in 1990 (38,100 ha) but it decreased to 22,400 ha in 1996. Cultivation of other field crops has fluctuated depending on market. Beans have the similar tendency of corn because they are normally secondary crops of corn in Sergipe.

In the contrast to the field crops, fruit culture has increased steadily. Harvested areas of coconut and orange have increased at the rate of 1.6 % and 4.0 %, respectively. As a result, production of orange is classified second in Brazil after Sao Paulo state.

Since beans and cassava are staple food in Brazil, those crops are cultivated in approximately 35 % of the state cropland. Considering the self-sufficiency of framers, areas of those crops will not decrease like cotton and sugarcane. At least, some areas for self-sufficiency will be maintained.

Table-1.1 Change in Harvested Areas of Primary Crops

Crop	Yield (ton/ha)				Harvested Area (1,000 ha)			
	1981	1985	1990	1996	1981	1985	1990	1996
Corn	0.3	1.0	0.6	1.4	54.9	98.5	29.8	81.6
Beans	0.2	0.2	0.4	0.5	47.6	50.1	36.9	67.0
Cassava	13.1	13.1	14.9	15.0	28.8	35.2	34.2	39.8
Sugarcane	57.5	60.6	57.3	59.9	22.7	26.5	38.1	22.4
Cotton	0.1	0.4	0.3	0.4	19.7	33.8	2.7	1.9
Coconut 1)	1.9	1.9	2.0	1.9	39.3	42.6	43.1	50.2
Orange 1)	106.1	103.2	106.9	100.8	22.8	28.3	34.4	41.4

1): number of 1,000 fruits per hectare
Source: "Municipal Agricultural Production, 1981 – 1996" (IBGE) and EMDAGRO for Modification

Table-1.2 shows main production sites of primary crops and fruits in 1996 by micro-region and river basin. Since cotton is no longer a primary crop, it is excluded from the table. Expansion of fruit culture is recent tendency. Therefore, some minor fruits in terms of harvested area are also shown in the table.

Beans, one of the staple foods, are cultivated in the semi-arid and tropical sub-humid climates, especially the upper reaches of Sao Francisco and Real rivers (Sergipana do Sertao do Sao Francisco and Tobias Barreto micro-regions). Beans are cultivated in same sites of corn because beans are secondary crops of corn. Main production site for cassava, another staple food, is Agreste de Lagarto micro-region located in the tropical sub-humid climate (middle reaches of Piaui River).

Sugarcane which was introduced in 17 century, immigration era, is still one of primary crops and mainly cultivated along coast in the north of Aracaju, Japaratuba micro-region. Since the climate class is the tropical humid, rain-fed agriculture satisfies sugarcane cultivation in the region.

Dominant fruit culture in Sergipe consists of orange, coconut, passion fruit and banana. Coconut farms are located along the coast, while banana is cultivated in most of state, except semi-arid area. More than 65 % of orange farms are located in Boquim micro-region, and Agreste de Lagarto is the main region for passion fruit.

Other fruits, such as mango, lemon, watermelon and pineapple, are cultivated still in the small area. As mentioned before, the state agriculture in the last 20 years shows decrease in cultivation of traditional field crops and increase in cultivation of fruits. This tendency implies diversification of crops and extension of cash crop cultivation. Therefore, fruit culture will be more significant.

Main consumption of water in association with crop cultivation is irrigation. Irrigation is discussed in the section 1.2.

Table-1.2 Main Production Sites of Primary Crops and Fruits in 1996

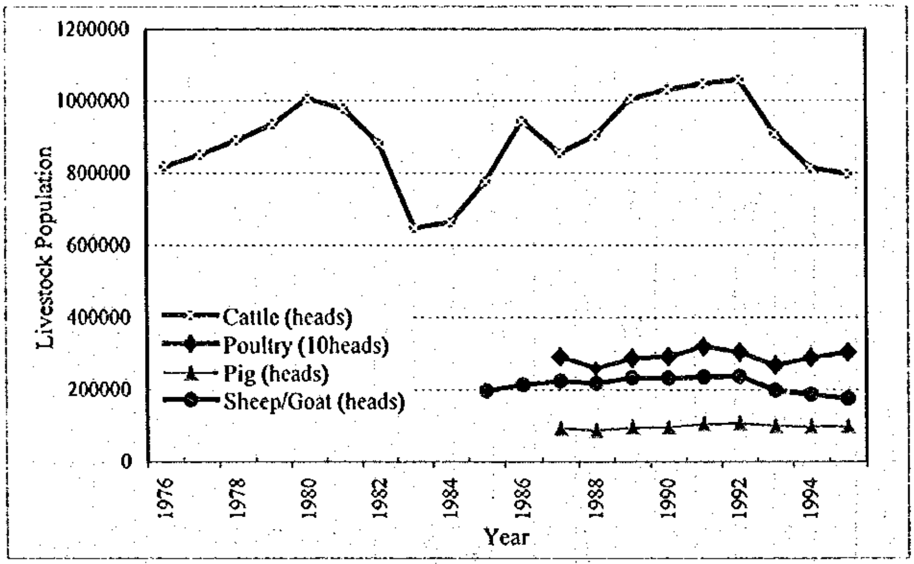
Unit: ha

	Micro-region	Corn	Beans	Cassava	Sugarcane	Coconut	Orange	Passion Fruit	Banana	Mango	Lemon	Water Melon	Pineapple
Micro-region	Sergipana do Sertao do Sao Francisco	30,250	25,440	0	0	0	0	0	0	0	0	70	60
	Carira	14,000	6,655	750	0	0	0	0	0	0	0	0	0
	Nossa Senhora das Dores	2,000	0	2,500	700	0	0	0	107	44	0	0	50
	Agreste de Itabaiana	1,500	1,050	5,200	620	0	0	0	387	66	0	320	0
	Tobias Barreto	18,000	18,250	3,117	0	0	0	145	170	0	0	0	0
	Agreste de Lagarto	2,900	3,410	13,850	0	0	9,030	3,271	295	0	23	0	70
	Propria	0	0	550	0	2,800	0	0	246	40	0	0	0
	Cotinguiba	0	0	600	1,950	0	0	0	244	65	0	0	0
	Japaratuba	0	0	1,800	10,150	7,830	0	200	210	0	0	0	70
	Baixo Cotinguiba	0	0	0	6,550	6,000	0	0	105	132	0	0	0
	Aracaju	0	0	0	0	9,200	0	0	60	170	0	0	0
	Boquim	0	0	1,520	0	0	25,877	481	490	0	528	0	0
	Estancia	0	0	2,625	0	16,679	4,459	478	404	49	0	0	74
River Basin	Sao Francisco	27437	23,912	3,084	6,861	10,630	0	168	435	48	0	70	128
	Japaratuba	140	0	1,387	5,826	2,346	0	32	249	125	0	0	52
	Sergipe	12,033	6,037	4,179	7,078	10,450	0	4	655	280	0	185	0
	Vaza Barris	10,194	5,484	6,310	205	4,532	1,242	719	153	64	0	135	0
	Piaui	7,944	8,592	15,579	0	13,235	30,041	3,371	1,043	43	325	0	106
	Real	10,902	10,781	1,973	0	1,317	8,083	281	183	7	226	0	38
Total		68,650	54,805	32,512	19,970	42,509	39,366	4,575	2,718	566	551	390	324
% to State Total		84%	82%	82%	89%	85%	95%	91%	81%	79%	94%	89%	77%
State Total		81,649	67,016	39,833	22,412	50,193	41,445	5,016	3,346	718	589	437	421

Source : "Municipal Agriculture Production, 1996" (IBGE) and EMDAGRO for Modification
Figures by river basin were calculated by JICA Study Team.

1.1.3 Livestock

Figure-1.2 shows state population of main livestock from 1976 to 1995. Main factors to fluctuate livestock population are price, climate and disease. According to "Brazil in Figures (IBGE, 1997)", sharp decline of cattle population in middle of 1980s is due to anti-inflationary price-control policies, while the local information explains that it is due to the severe drought.



Source: Municipality Livestock Population, 1976 ~ 1995 (IBGE)
Modified by EMDAGRO

Figure-1.2 Livestock Population (1976 ~ 1995)

Since cattle raising in Sergipe mainly rely on pasture without irrigation system, unfavorable climate to pasture directly affects on cattle population. Recent decline of cattle population is probably explained by low precipitation.

Populations of pigs and poultry maintain almost constant at 0.1 million and 3 million heads, respectively. Total population of sheep and goats has slightly decreased since 1992.

Livestock is raised in all over the state as shown in Table-1.3. Sergipana do Sertao do Sao Francisco micro-region is one of dominant regions for cattle, poultry and pig raising, contributing to 16 %, 10 % and 14 % (highest) of total population, respectively. Estancia micro-region is ranked as the highest population in poultry, while Tobias Barreto micro-region has the highest population in sheep and goats.

Since irrigation has not been applied to pasture, water required for livestock is mainly consumption by animals, and water supply relies on local water resources, such as spring, small stream, well water and so on. Unlike irrigation, water resources development in large scale has not been applied.

Table-1.3 Livestock Population by Region (1995)

Unit: 1,000 heads

	Division	Cattle (1995)	Poultry (1995)	Pigs (1995)	Sheep/Goat (1995)
Micro-region	Sergipana do Sertao do Sao Francisco	131	384	13	12
	Carira	51	70	3	3
	Nossa Senhora das Dores	66	83	2	2
	Agreste de Itabaiana	37	329	5	4
	Tobias Barreto	75	336	24	86
	Agreste de Lagarto	95	364	28	36
	Propria	33	46	4	2
	Cotinguiba	53	143	1	1
	Japaratuba	40	78	1	3
	Baixo Cotinguiba	35	175	1	1
	Aracaju	15	276	1	1
	Boquim	104	200	10	18
	Estancia	64	558	3	4
River Basin	Sao Francisco	187	446	16	15
	Japaratuba	95	168	3	4
	Sergipe	125	672	9	7
	Vaza Barris	80	530	12	13
	Piaui	211	961	39	60
	Real	99	264	20	76
	Sate Total	797	3,041	99	175

Source: "Production by Municipal Livestock, 1995" (IBGE)
Figures by river basin were calculated by JICA Study Team.

1.2 Irrigation

Main execution agencies to study and implement irrigation projects in Sergipe are CODEVASF and COHIDRO. CODEVASF promotes irrigation in Sao Francisco River Basin only, while COHIDRO promotes it in all state area.

Based on data and information collected from relative government agencies, technical specifications of existing irrigation projects in Sergipe were studied and summarized in Table-1.4. Since Jacare-Curituba and Jacarecica II projects are still under the construction, those projects are included in the future projects discussed in Chapter 2.

Total irrigation area of 9 existing projects is approximately 17,000 ha; however, this area is not fully irrigated because settlement of farmers has not been completed in some projects. Problems associated with the settlement are mainly, 1) inadequate selection of crops due to fluctuation of market price, and 2) fail in formulating farmers' association for water management and market.

Existing irrigation projects are mostly located near Xingo dam, Propria and Neopolis where water intake from Sao Francisco River is available. 8 % and 79 % of the total irrigation area is located near Xingo dam and river mouth of Sao Francisco River (Propria and Neopolis), respectively. This is mainly due to surface water quality (see Supporting Report D). The surface water quality along the coast (tropical humid climate) is generally suitable for irrigation; however, quality of inland rivers in Sergipe, except Sao Francisco River, is mostly classified from slight to severe salinity.

Irrigation in Sergipe has been applied to cash crops because prices of staple food are not high enough for application of irrigation. CODEVASF projects was initially designed for paddy rice; however, they have encountered difficulty in keeping rice cultivation due to low price (approximately R$0.25/kg of rice in the husk). Fruit culture, such as citrus, pineapple, mango, papaya etc., and vegetable culture, such as tomato, okra, lettuce, etc., are commonly cultivated in irrigation projects as cash crops.

Application of irrigation to orange culture is rare. Orange is mainly produced in Boquim and Agreste de Lagarto micro-regions. Since climate in these regions does not require irrigation and orange requires some water stress, irrigation has not been practiced for orange culture.

Project water requirement is a function of climate, altitude, latitude, crops to be irrigated, irrigation method, water distribution method, water quality and so on. Figures in Table-1.4 were adopted from reports concerned, except Cotinguiba project whose water requirement was estimated by data from Propria project. Since Propria, Cotinguiba and Betume projects were initially designed for paddy rice fully or partially, their annual requirements are twice or three times as much as that of Neopolis project, whose conditions are almost same as the former 3 projects, except crops (fruit culture) and irrigation method. Irrigation method (surface irrigation, such as furrow) and distribution system (open channel) of Jabiberi project result in the highest project water requirement per hectare.

Crops irrigated depend on market. For example, diversification of crops has been extended in the projects for paddy rice. Even inland fish culture has been promoted in those projects. Therefore, current water consumption of each project vary from project water requirement; however, since water supply system was designed for project water requirement, it is considered as maximum volume of irrigation water. This is a reason to adopt the original figurers from reports.

Projects in Sao Francisco river basin conduct water by direct intake, while projects in other river basins require dam due to insufficient river discharge for direct intake. Since high cost of dam construction is one of factors to limit application of irrigation, project scales in those basins are relatively small compared to projects along Sao Francisco River.

Method of irrigation depends on crops, topography, availability of water resources and so on. Paddy rice cultivated in flat alluvial plain requires surface irrigation (basin irrigation), while vegetable and fruit cultures on undulating land require sprinkle or trickle irrigation system. Propria, Cotinguiba and Betume projects employ both surface and sprinkle irrigation because designed crops are paddy rice, field crops and fruits. Sprinkle irrigation is applied to other projects for fruits, field crops and vegetable crops, except Jabiberi, which was designed for gravity irrigation instead of pressurized irrigation.

According to EMDAGRO ("Irrigated Agriculture in Sergipe State, Material for JICA Workshop", Jodemir, 1998), there are approximately 6,000 ha of private irrigation projects conducted by farmers themselves using mainly groundwater. These projects are small scale and located mostly in Itabaiana and Lagarto micro-regions. Since their exact locations and project specifications are unknown, they are excluded from Table-1.4.

Table-1.4 Existing Irrigation Projects

No.			1	2	3	4	5	6	7	8	9
Project Name			California	Propria	Cotinguiba	Neopolis	Betume	Jacarecica	Pocao da Ribeira	Piaui	Jabiberi
Execution Agency			COHIDRO	CODEVASF	CODEVASF	COHIDRO	CODEVASF	COHIDRO	COHIDRO	COHIDRO	COHIDRO
Completed Year of Construction			1987	1975	1980	1994	1977	1987	1987	1987	1987
Area of Irrigation (ha)			1,360	1,177	2,215	7,230	2,861	252	1,100	703	225
Watershed			Sao Francisco	Sao Francisco	Sao Francisco	Sao Francisco	Sao Francisco	Sergipe	Vaza Barris	Piaui	Real
Water Resources			Sao Francisco River	Sao Francisco River	Sao Francisco River	Sao Francisco River	Sao Francisco River	Jacarecica River	Trairas River	Piaui River	Jabiberi
Intake	Dam	Type	none	none	none	none	none	Concrete	Earth	Rock Fill	Concrete
		Height (m)						20	26	20	21.5
		Crest Length (m)						420	500	465	290
		Storage Volume (million m³)						4.71	16.50	15.00	4.30
	Pump	Total Capacity (m³/s)	1.50	5.76	7.80	3.74	8.80	0.33	1.00	0.55	none
		Pump Head (m)	170	NA	NA	123	NA	84	60	75	
Distribution			Pipelines & Open Channels	Open Channels	Pipelines & Open Channels	Pipelines & Open Channels	Open Channels	Pipelines	Pipelines	Pipelines	Open Channels
Irrigation Method			Sprinkle	Surface & Sprinkle	Surface & Sprinkle	Sprinkle & Trickle	Surface	Sprinkle	Sprinkle	Sprinkle	Surface
Overall Irrigation Efficiency for Design			0.70	0.63	0.62	NA	0.60	0.70	0.70	0.70	0.60
Designed Crops			Fruits, Field & Vegetable Crops	Paddy Rice & Field Crops	Paddy Rice, Fruits & Field Crops	Fruits	Paddy Rice & Field Crops	Vegetable Crops	Vegetable Crops	Vegetable Crops	Fruits & Vegetable Crops
Soil Class			NC	Ae	Ae	PV	PV	PLe	LVd, PV	PV	Ae
Project Water Requirement (m³/ha/month)											
	January		1,150	2,624	1,810	990	2,350	3,210	690	720	2,800
	February		970	2,368	1,640	850	1,300	2,590	810	760	2,540
	March		1,400		240	570	550	2,520	1,420	1,220	3,390
	April		1,460	1,568	810	120	950	1,580	870	720	2,770
	May		1,100	880	450		1,700	90	180	190	810
	June		710	1,008	500		1,500				400
	July		590	1,104	550	100	1,000				310
	August		700	1,696	940	340	750		80	120	650
	September		1,070		220	330	550	530	310	1,200	1,970
	October		1,680	2,448	1,440	790	1,000	1,680	1,650	2,460	4,310
	November		1,800	2,448	1,470	910	2,550	2,650	2,960	2,090	5,530
	December		1,670	2,592	1,640	1,000	2,900	3,160	2,020	1,620	4,970
Total Requirement (million m³/year)			19.4	22.1	25.9	43.4	48.9	4.5	12.1	7.8	6.9
Maximum Requirement (million m³/month)			2.4	3.1	4.0	7.2	8.3	0.8	3.3	1.7	1.2

NC: Non Calcic Brown Soil, Ae: Eutrophic Alluvial Soil, PV: Red Yellow Podzolic Soil, PLe: Planosol, LVd: Red Yellow Latosol

Source: COHIDRO & CODEVASF (report of each project)

Project water requirements were adopted from the reports, except Cotinguiba whose requirement was calculated by Propria and Cotinguiba meteorological data.

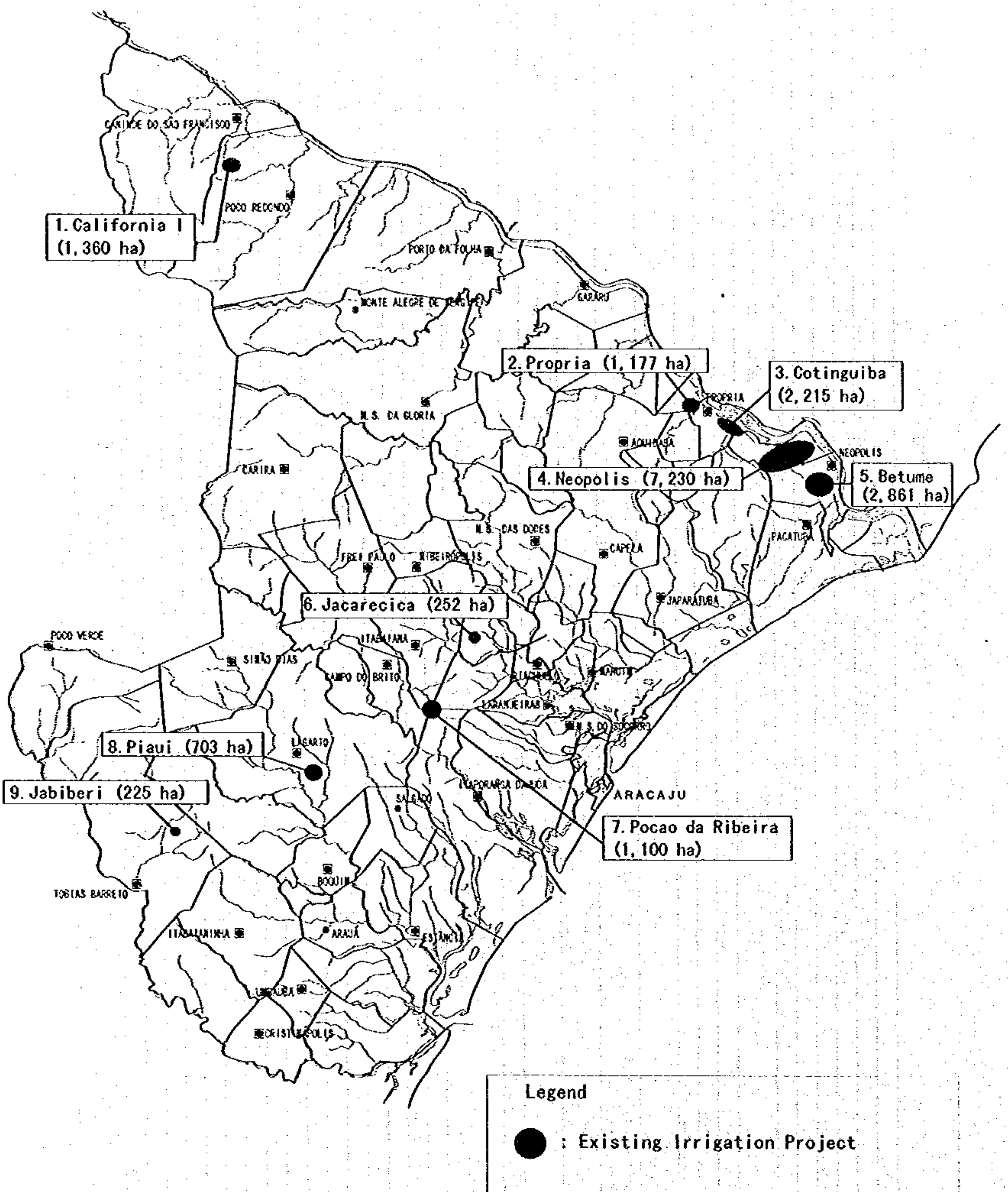


Figure-1.3 Existing Irrigation Projects

CHAPTER 2 AGRICULTURAL WATER DEMAND WATER PROJECTION

In general, agricultural waters to be evaluated for water resources development are irrigation, water consumption by livestock and fish culture. Since water consumption by fish culture itself will be negligibly small, only irrigation and water for livestock were examined to estimate future water demand.

2.1 Projection of Future Agriculture

To estimate water demand until the target year, 2020, it is necessary to project future agriculture in Sergipe. Based on analysis of agriculture statistics, the following projection and assumptions were made.

As discussed in Chapter 1, areas of cropland and pasture tend to decrease. In the last decade (1985 ~ 1995), 11 % of cropland and 9 % of pasture were changed to other uses. Labor force involved in agriculture also decreased from 161,000 in 1970 to 149,700 in 1980; however, it maintained almost constant between 1980 and 1991. Industrialization and urbanization will affect the further decrease of agricultural area and labor force.

1) Since crops are diversified depending on market, production of traditional field crops will be decreased. However, state self sufficiency of staple food, such as beans and cassava, will be maintained.
2) Production of fruits will be increased.
3) Cultivation of vegetables, such as tomato, cabbage, lettuce and so on, for the supply to urban areas will expand.
4) Irrigation will be applied to cash crops, such as fruits and vegetables, rather than traditional field crops (beans, sugarcane, etc.).
5) Production of livestock will fluctuate depending on the market; however, at least average figures in the last 10 years will be maintained.
6) Irrigation will not be applied to pasture due to its high cost in Sergipe, unless new breeds with good profit are introduced.
7) Increase of future GRDP will be achieved by expansion of irrigation projects.

2.2 Future Irrigation Areas

Irrigation potential areas were examined in terms of soil properties and topography, and successively future irrigation areas were determined for water demand projection in terms of climate, water quality and future agriculture projected.

2.2.1 Soil Properties and Topography

EMBRAPA ("Evaluation of Land Potential for Irrigation in Northeast Brazil", 1994) evaluated irrigation potential areas in the northeast Brazil, based on criteria and classification suggested by U. S. Bureau of Reclamation. Soils are categorized in 6 classes from 1 for the most suitable soils for irrigation to 6 for soils which irrigation is not applicable. Since the result of evaluation is shown in a 1/2,000,000 scale map, it is too rough to identify the irrigation potential areas in Sergipe for the Master Plan Study. Therefore, based on soil data and a soil map (1/400,000) available in "Exploratory Research – Recognition of Soils in Sergipe State" (EMBRAPA and SUDENE, 1975), irrigation potential of soils in Sergipe were examined in cooperation with EMBRAPA, Recife. The soil map with scale of 1/400,000 is good enough for only initial identification of irrigable soils. Therefore, soil investigation in more detail is required for the further study.

The results are shown in Table-2.1 and Figure-2.1. In general, soils extended in the tropical humid region (near coast) show characteristics of low fertility and low salinity, while soils in the semi-arid region is fertile but their salinity ranges from medium to high. Table-2.1 shows that 15 % of the state land, 330,800 ha, is possible to be irrigated; however, Ce, BV, V, Ae and NC class soils require special management for salinity, such as leaching, selection of crops by salinity tolerance and so on. Existing irrigation projects are located mainly on PV, LV, PE and NC class soils. Projects on NC class are susceptible to saline problem.

Table-2.1 Soils Suitable for Irrigation

Soil Class	Name	Potential Area (ha)	Soil Depth	Drainage	Fertility	Salinity	Irrigation Class
Ce	Eutrophic Cambisol	16,000	M	G	H	M~H	3s, 2s, 4s
BV	Reddish Brunizem	4,600	M	M~G	H	M	3st, 2s, 4s
V	Vertisol	4,700	D	P	H	M~H	2s, 4s
Ae	Eutrophic Alluvial Soil	8,200	D	P	H	M~H	2s, 3s, 4s
PE	Eutrophic Red Yellow Podzolic Soil	106,100	D	G	M	L	2s, 2st, 3s, 3st, 4s
LV	Red Yellow Latosol	44,700	D	G	L	VL	3s
PV	Red Yellow Podzolic Soil	74,900	D	G	L	VL	3s, 3st
NC	Non Calcic Brown Soil	37,200	M	M	H	M~H	4s
RE	Regosol	34,400	D	E	L	VL	4s
Total		330,800					
Ratio to State Area (%)		15					

H: high, M: medium, L: low, D: deep, G: good, P: poor, E: excessive, VL: very low
Irrigation Class was determined based on criteria of U. S. Bureau of Reclamation. 1: most suitable ~ 6: not applicable
Subscripts of irrigation classes denote deficiency. s: soil, t: topography
Source: evaluated by EMBRAPA, Recife, based on "Exploratory Research - Recognition of Sergipe Soil"

As shown in Figure-2.1, lands in the middle reaches (defined within Sergipe State) of Sao Francisco River and the upper reaches of Vaza Barris, Piaui and Real Rivers are non-arable due to hilly and rocky relief with very shallow soils (Lithosol). Soils with impermeable layer at shallow depth and high salt contents, such as Planosol, are also spread in those areas.

Eutrophic Red Yellow Podzolic Soil spread in the middle and upper reaches of Jacarecica River and in the upper reaches of Japaratuba River has wide range of irrigation potential from class 2 to 4, due to large variation of soil properties and relief. In general, main characteristics of this soil are low salinity, good drainage and medium fertility.

Most of Red Yellow Podzolic Soil (PV) spread in the lower reaches, except Piaui and Real Rivers, is non-irrigable due to hilly relief with high susceptibility to soil erosion. PV on level or gently undulating lands is irrigable.

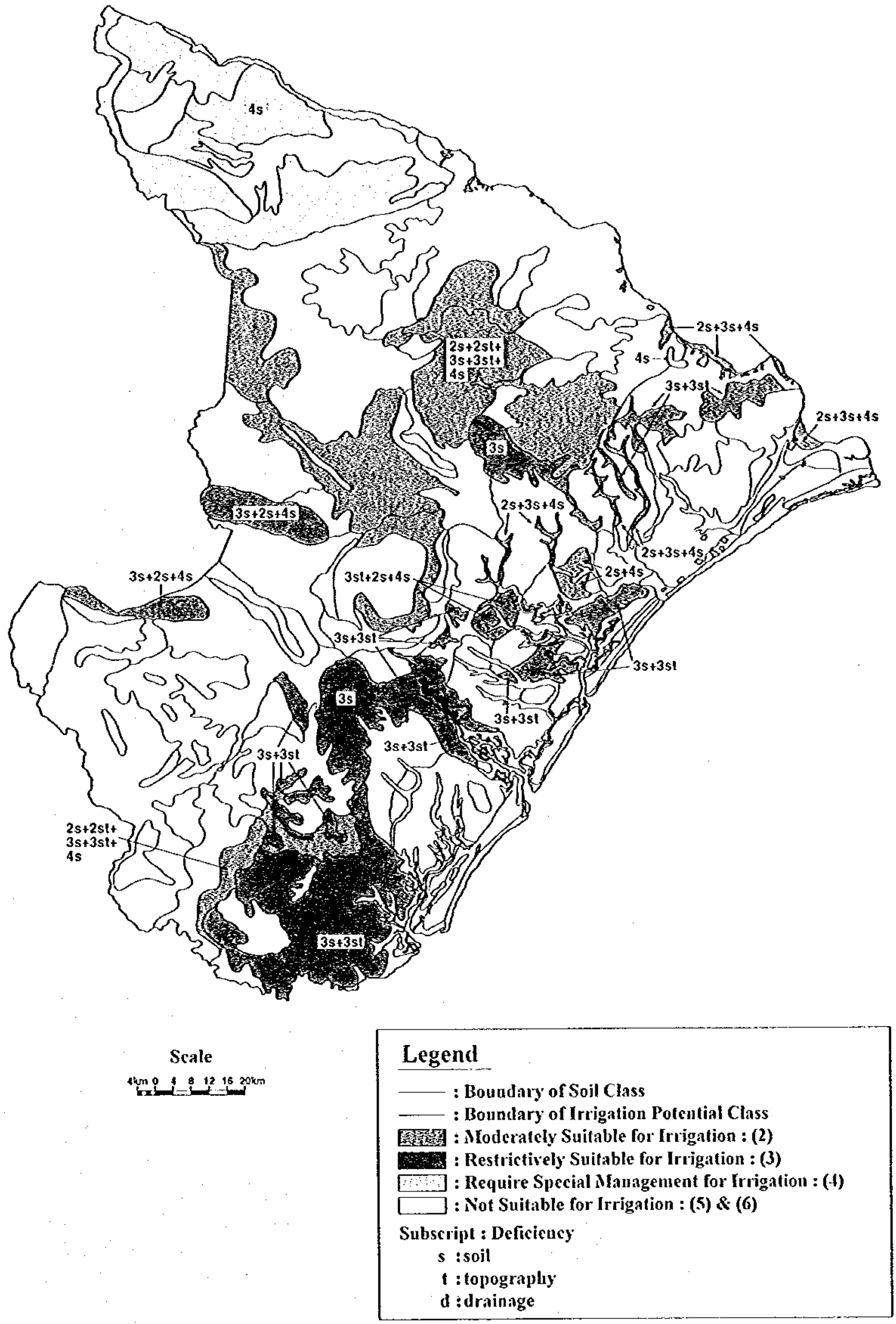


Figure-2.1 Irrigable Lands by Soil Properties and Topography