2.3 Climate and Hydrology

2.3.1 Climate of Vaza Barris River Basin

The climate of the Vaza Barris River basin varies widely across the river basin from the tropical humid Leste region at the coast, through the drier intermediate Agreste region, to the semi-arid interior and finally to the arid regions around the source of the Vaza Barris River near Uaua in Bahia.

Average temperatures vary only slightly from 25° C at the coast to 23° C in Uaua at the upstream of Vaza Barris River. The daily range of temperature is, however, higher in the upper part of the basin. Evaporation is also high varying from 1,200mm at the coast to 500mm in the arid interior.

Rainfall shows an uneven distribution and can clearly be divided into two regions; namely, the humid/semi-humid region parallel to the coast with annual rainfall between 1,800mm and 800mm, and the semi-arid/arid interior with annual rainfall of between 800mm and 500mm. The majority of the Vaza Barris River basin within Bahia State has an average annual rainfall of about 600mm/year. The isohyetal map of the Vaza Barris river basin is shown in).

2.3.2 Rainfall in Sergipe State

Within the Vaza Barris River basin in Sergipe State, there are five rainfall gauges that have a reasonable level of data availability. These are Carira, Frei Paulo, Campo do Brito, Belem and Sao Cristovao, of which data availability is ranged 23 to 30 yeas to date. It can be seen that average annual rainfall varies from over 1,500 mm/year for the stations at Fazenda Belem and Sao Cristovao in the coastal Leste region, to less than 800 mm/year for Carira in the semi-arid interior near to the border with Bahia State.

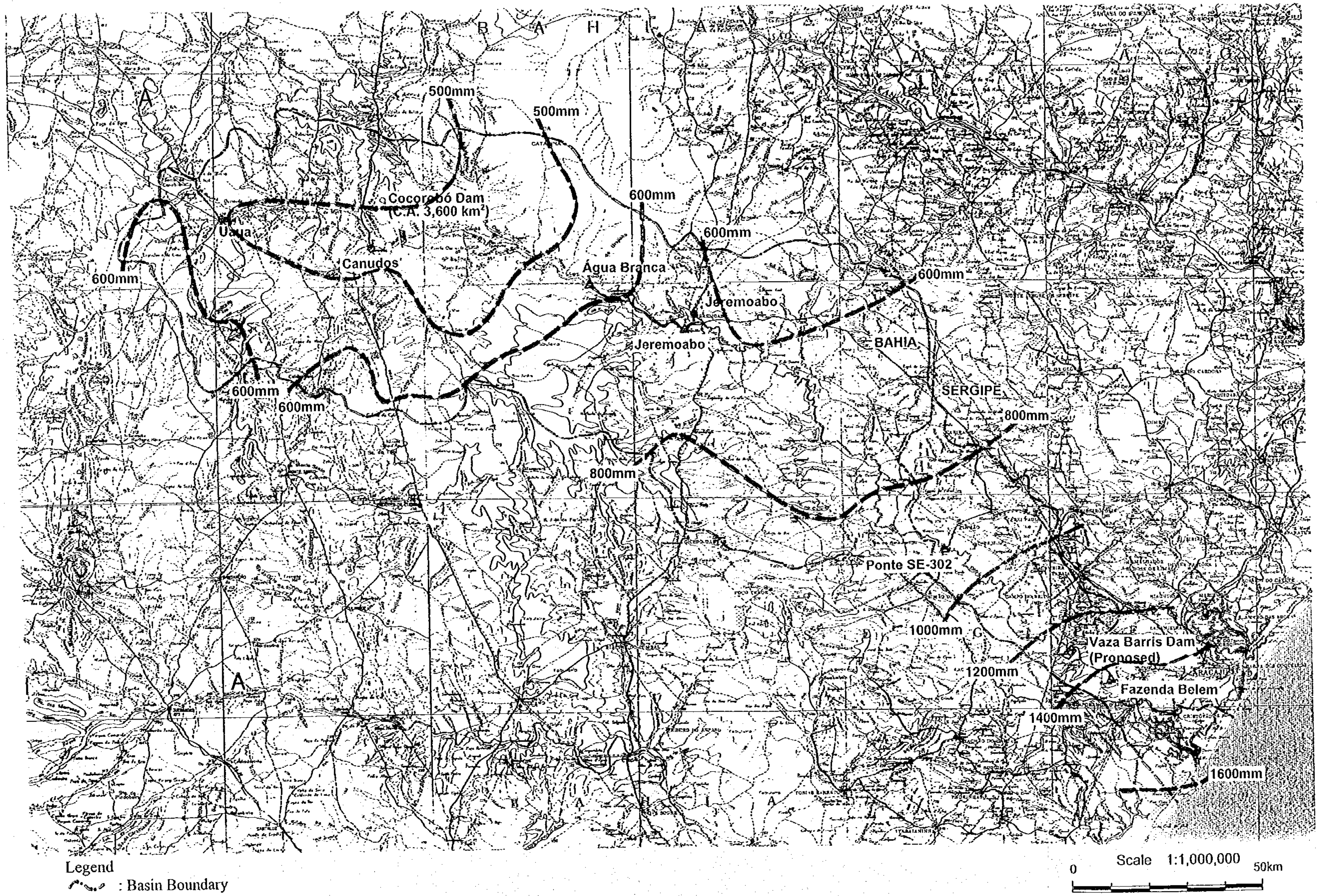
The variation in monthly average rainfall for four of the five rainfall stations is shown in Figure-2.2. It can be seen that the year is clearly divided into a rainy winter season (April to July) and a dry summer season (October to January) in Sergipe.

Probable annual rainfall was calculated using the 30-year data period for a range of return periods assuming a normal probability distribution. Both minimum and maximum probable annual rainfall was calculated for the five rainfall stations and the results are shown in Table-2.10.

Table-2.10 Minimum and Maximum Probable Annual Rainfall

Unit: mm

Station	Carira		Frei Paulo		Campo do Brito		Belem		Sao Cristovao	
Ave.	769.2		940.5		1250.5		1539.4		1485.3	
Return Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	676.7	861.6	833.9	1047.1	1084.4	1416.6	1382.2	1696.6	1312.5	1658.1
5	588.5	949.8	732.2	1148.8	925.9	1575.2	1232.2	1846.6	1147.6	1823.0
10	494.0	1044.3	623.3	1257.7	756.2	1744.9	1071.6	2007.2	971.0	1999.6
15	446.9	1091.4	569.0	1312.0	671.5	1829.5	991.5	2087.3	882.9	2087.7
20	416.1	1122.3	533.4	1347.6	616.0	1885.0	939.0	2139.8	825.2	2145.4
30	375.4	1162.9	486.5	1394.5	542.9	1958.1	869.9	2208.9	749.1	2221.4
40	348.4	1189.9	455.4	1425.6	494.5	2006.6	824.0	2254.8	698.7	2271.8
50	328.3	1210.0	432.2	1448.8	458.3	2042.7	789.8	2289.0	661.1	2309.5
100	269.8	1268.6	364.8	1516.2	353.1	2147.9	690.3	2388.5	551.7	2418.9



Legend
: Basin Boundary
o : City
Δ : Hydrological Observation Station
: Dam

Figure-2.1 Isohyetal Map of Vaza Barris River Basin

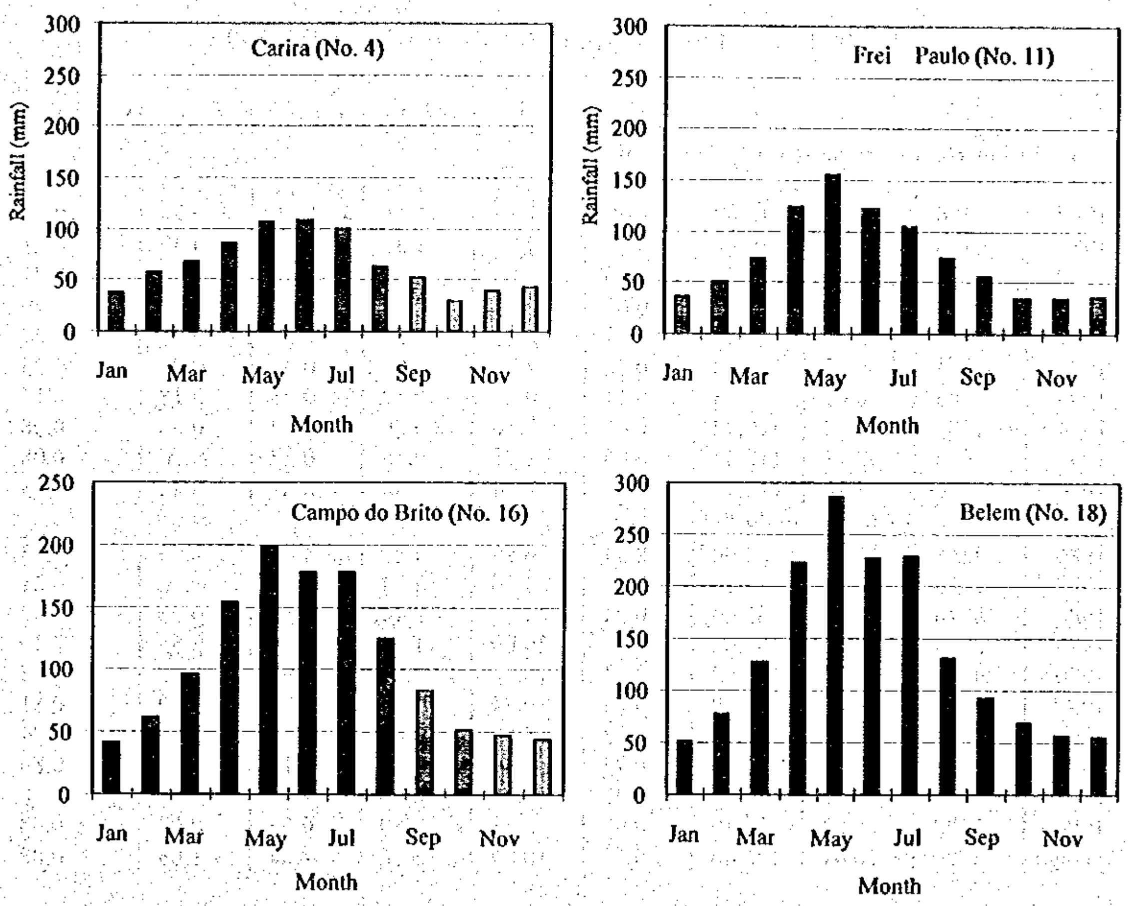


Figure-2.2 Variation of Monthly Rainfall in Vaza Barris Basin

2.3.3 River Flow

(1) Monthly Average Flow and Flow Regime

Vaza Barris River originates in the municipality of Uaua in the State of Bahia at an elevation of over 500 m. It has a total length of around 410 km, of which only 125 km is within Sergipe State. The total basin area is 16,229 km^2, the majority of which lies in Bahia State with only 16% or 2,559 km^2 lying within Sergipe making up 11.6% of the state area. In spite of its significant basin area, the discharge in Bahia is intermittent and it is only within Sergipe State that Vaza Barris River becomes a perennial river. The main tributaries in Sergipe are the Salgado and Trairas rivers, both of which join the main Vaza Barris River from the left bank.

There are two flow-gauging stations in Sergipe State in the Vaza Barris River basin, namely Ponte SE-302 and Fazenda Belem. Flow regime and monthly average flow during recent 10 years (1986-1995) are presented in Table-2.11 and Table-2.12.

In addition to these two ANEEL flow-gauging stations, there are also another two stations further upstream in the Vaza Barris basin at Agua Branca and Jeremoabo in Bahia. The results of the flow regime analysis for these two additional stations and for the revised data at Ponte SE-302 and Fazenda Belem are given in Table-2.13. The variation in monthly discharge for the four ANEEL stations on Vaza Barris River is shown in Figure-2.3.

Table-2.11 Flow Regime Results during 1986-1995

Units: m³/s

Year	Total	Ave	Max	Min	95-day	185-day	275-day	355-day	Min.7day Ave
Revised Flow Regime Results for Ponte SE-302									
1986	746	2.04	17.07	0.97	2.09	1.77	1.52	1.09	1.00
1987	506	1.39	17.07	0.22	1.37	1.16	0.70	0.24	0.24
1988	2168	5.92	179.82	0.18	4.71	2.39	1.44	0.42	0.21
1989	1593	4.44	115.43	0.70	2.99	2.31	1.16	0.70	0.71
1990	1079	2.96	48.17	0.65	2.16	1.95	1.16	0.80	0.79
1991	737	2.02	48.17	0.27	2.47	0.85	0.61	0.27	0.27
1992	1951	5.33	104.78	0.22	2.72	0.97	0.65	0.27	0.25
1993	245	0.67	2.55	0.11	0.80	0.57	0.45	0.18	0.14
1994	1583	4.34	510.72	0.06	2.16	0.70	0.22	0.08	0.08
1995	954	2.71	115.43	0.06	1.95	0.75	0.22	N.A.	0.08
Average	1156	3.18	115.92	0.34	2.34	1.34	0.81	0.45	0.38
Flow Regime Results for Fazenda Belem									
1986	2261	6.20	64.00	2.34	6.90	4.80	4.00	2.60	2.43
1987	1215	3.73	27.50	0.15	3.86	2.74	1.00	N.A.	0.21
1988	8818	24.09	285.00	0.24	24.70	9.74	6.15	0.43	0.32
1989	8772	24.03	309.00	2.10	26.00	11.30	5.88	2.55	2.40
1990	4108	11.26	101.00	0.24	10.90	7.78	3.90	0.72	0.62
1991	2955	8.09	66.10	0.62	9.74	3.54	1.80	1.00	0.81
1992	4591	12.54	174.00	0.53	12.50	6.69	2.55	1.00	0.74
1993	778	2.13	10.90	0.72	2.40	1.35	1.15	0.81	0.86
1994	2929	8.03	132.00	0.23	5.85	2.90	1.47	0.53	0.30
1995	1472	4.03	95.10	0.00	2.58	0.80	0.53	0.08	0.08
Average	3790	10.41	126.46	0.72	10.54	5.16	2.84	1.08	0.88

Table-2.12 Monthly Average Flows during 1986-1995

Units : m³/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Revised Monthly Average Flows for Ponte SE-302												
1986	3.54	1.92	2.77	2.33	2.04	1.65	1.91	1.54	1.18	2.27	1.48	1.83
1987	1.03	1.27	1.67	3.55	2.21	1.05	1.91	1.56	1.16	0.30	0.26	0.68
1988	1.25	1.81	6.18	7.95	18.08	16.24	6.87	2.39	2.30	1.69	1.31	4.88
1989	1.25	0.90	3.69	2.23	8.64	3.28	5.89	2.76	2.16	0.97	2.09	22.23
1990	15.33	3.14	2.35	1.98	1.98	1.73	1.69	1.60	1.00	0.96	1.52	2.05
1991	0.98	1.57	3.07	2.96	7.28	2.74	2.55	0.71	0.83	0.44	0.53	0.48
1992	11.40	38.75	3.94	2.96	0.93	0.74	0.87	1.04	0.86	0.60	0.75	2.77
1993	0.87	0.57	0.44	0.68	0.53	0.91	0.67	1.01	0.51	0.61	0.70	0.54
1994	0.14	3.20	31.19	4.33	1.27	4.39	4.43	1.30	0.68	0.45	0.19	0.10
1995	0.45	1.38	1.40	16.62	2.04	1.09	1.33	0.91	0.47	0.20	5.87	2.64
Ave.	3.62	5.45	5.67	4.56	4.50	3.38	2.81	1.48	1.12	0.85	1.47	3.82
Monthly Average Flows for Fazenda Belem												
1986	6.43	2.85	12.12	7.40	8.87	9.06	4.43	4.54	3.87	5.63	3.93	4.88
1987	2.38	2.11	4.45	7.36	6.78	4.63	5.36	4.22	N.A.	N.A.	0.60	1.07
1988	3.78	4.77	25.60	11.60	45.90	65.95	69.49	18.86	12.35	10.62	4.41	14.49
1989	4.27	3.01	9.11	28.25	40.80	24.49	49.90	24.53	13.00	13.38	8.20	66.68
1990	21.99	11.68	4.62	5.00	8.56	10.14	28.74	23.36	8.96	5.22	3.32	2.95
1991	1.96	2.57	4.60	3.40	20.64	19.59	17.28	10.39	9.66	1.80	2.65	2.17
1992	18.76	49.02	19.16	10.79	2.78	11.57	11.62	6.90	5.56	5.67	1.75	8.61
1993	1.70	1.21	0.97	1.10	1.31	5.12	4.78	2.95	2.46	1.54	1.12	1.28
1994	1.52	3.91	19.94	7.09	5.37	17.12	32.79	3.12	1.88	1.59	0.85	0.55
1995	0.58	4.01	2.07	11.38	1.77	3.60	14.19	3.12	1.43	0.36	3.91	2.12
Ave.	6.34	8.51	10.26	9.34	14.28	17.13	23.86	10.20	6.57	5.09	3.07	10.48

Table-2.13 Results of Flow Regime Analysis for Vaza Barris River

Station Name / Catchment Area	Agua Branca 7,110 km²	Jeremoabo 8,685 km²	Ponte SE-302 14,435 km²	Fazenda Belem 15,740 km²
Data Availability	1985 - 1993	1972 - 1993	1985 - 1996	1971 - 1995
Flows (m^3/s)				
Average	0.95	2.91	4.19	11.86
Q-95 day (25%)	0.50	1.71	2.92	10.35
Q-185 day (50%)	0.38	0.82	1.53	4.95
Q-275 day (75%)	0.32	0.60	0.88	2.77
Q-355 day (95%)	0.20	0.36	0.47	1.33
Minimum Q 7-day	0.24	0.34	0.40	1.18
Average Specific Q ($l/s/km^2$)	0.13	0.34	0.29	0.75

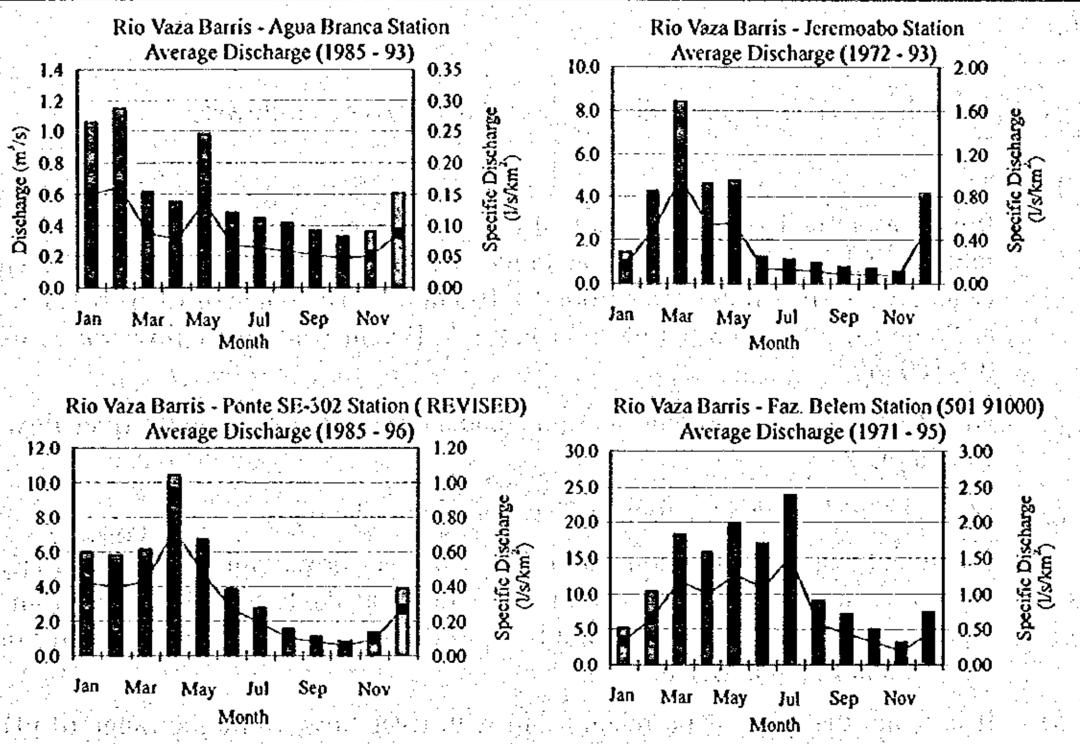


Figure-2.3 Variation of Monthly Discharge for Vaza Barris River

(2) Probable Discharge at Fazenda Belem

The daily discharges at Fazenda Belem are the consequence of the water level measuring twice a day. It means that the annual maximum daily discharges are not always the maximum in that day. Introducing the assumption that actual maximum discharge in that day is 1.2 times of measured maximum daily discharge, probable flood discharge at Fazenda Belem is estimated and is given in Table-2.14.

Table-2.14 Probable Flood Discharge at Fazenda Belem - Thomas (Moment) Method

Return Period (year)	Probable Flood Discharge (m^3/s)	Return Period (year)	Probable Flood Discharge (m^3/s)	Return Period (year)	Probable Flood Discharge (m^3/s)
50,000	4,857	80	1,134	8	484
20,000	4,101	70	1,089	7	454
10,000	3,588	60	1,038	6	420
5,000	3,121	50	979	5	380
1,000	2,198	40	910	4	334
500	1,863	30	825	3	276
200	1,471	20	712	2	197
150	1,360	15	636		
100	1,211	10	536		

2.4 Water Quality

In the parameters that were observed in Vaza Barris River, Chlorine (Cl) concentration is high and critical for potable water, as well as Electric Conductivity (EC), Sodium (Na), Magnesium (Mg), Calcium (Ca), Carbonic Acid (HCO_3) and pH Value (pH) are important for irrigation planning. The relationship between river flow and the said water quality parameters were established at Ponte SE-302 and Fazenda Belem, showing in Figure-2.4 and Figure-2.5. Besides, the correlation between EC and Na/Mg/Ca/Cl were studied, based on the water quality data at the both observation stations and are shown in Figure-2.6.

These figures characterize water quality in Vaza Barris River as follows:

1) The most important parameters of Cl and EC have strong relationship with river flow, presenting less concentration of Cl and EC while the larger river flow. The range of Cl is 2,000-300 mg/l at Ponte SE-302 and 1,000-80 mg/l at Fazenda Belem while river flow varies from 0.1-100 m^3/s. The range of EC is 6-1.3 dS/m at Ponte SE-302 and 3-0.4 dS/m at Fazenda Belem while river flow varies from 0.1-100 m^3/s.
2) Na, Mg and Ca also present the same tendency of relationship with river flow as Cl and EC.
3) EC and Na/Mg/Ca/Cl are found to have good correlation.
4) It is found that HCO_3 has no relationship with river flow, while the range of HCO_3 is from 26 mg/l to 184 mg/l (average: 103mg/l) at Ponte SE-302 and is from 51 mg/l to 146 mg/l (average: 109mg/l). No differences are found between Ponte SE-302 and Fazenda Belem.
5) It is found that pH has no relationship with river flow, while the range of pH is from 6.9 to 8.3 (average: 7.5) at Ponte SE-302 and is from 7.2 to 8.4 (average: 7.6). No differences are found between Ponte SE-302 and Fazenda Belem.

However, it is noted that water quality data in Vaza Barris River is not yet enough to understand the water quality behavior. It is needed to continue observation of water quality such as the said parameters not only at the existing observation stations but also at the proposed dam site and the check dam site.

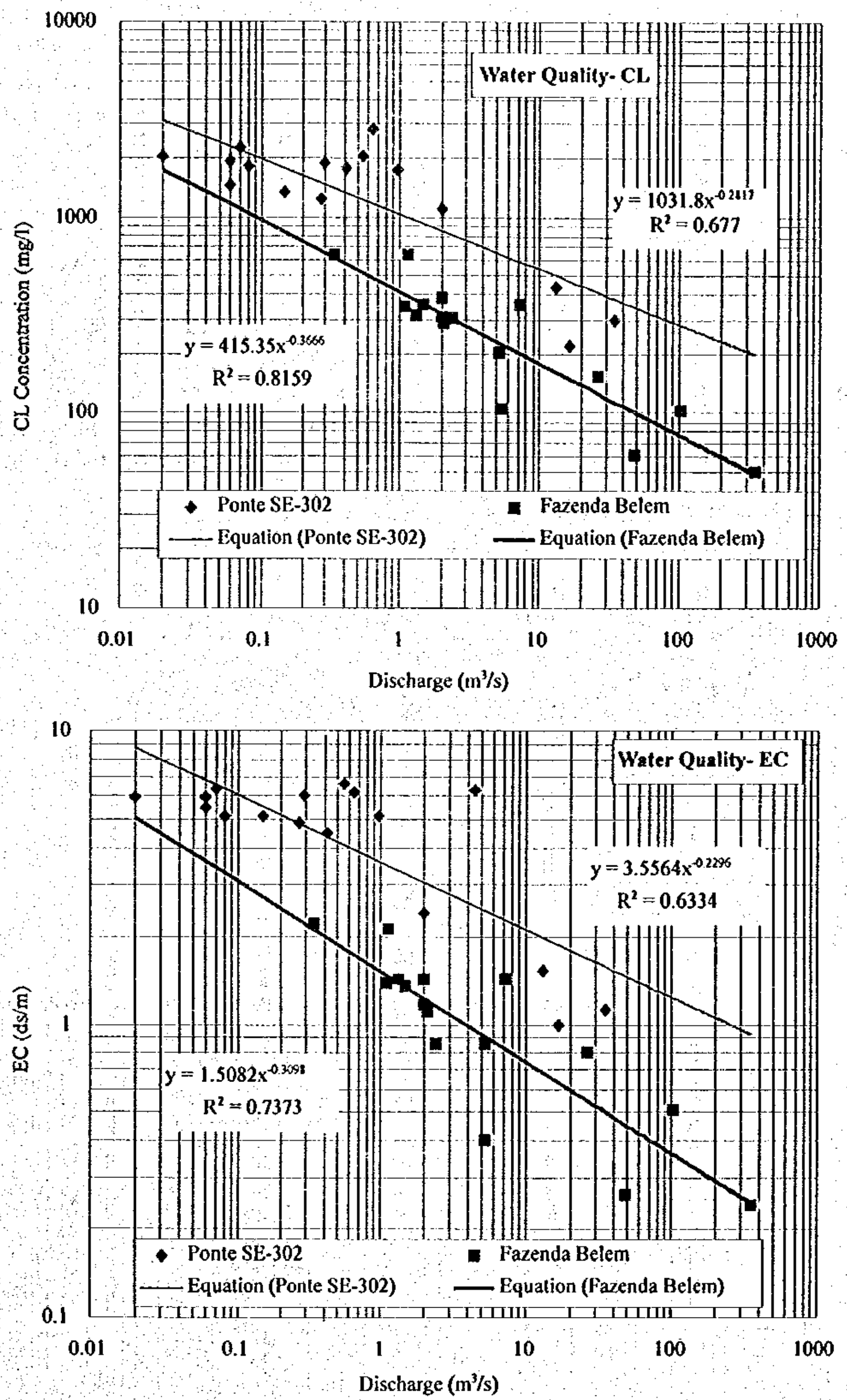


Figure-2.4 Relationship between Cl Concentration / EC and River Flow

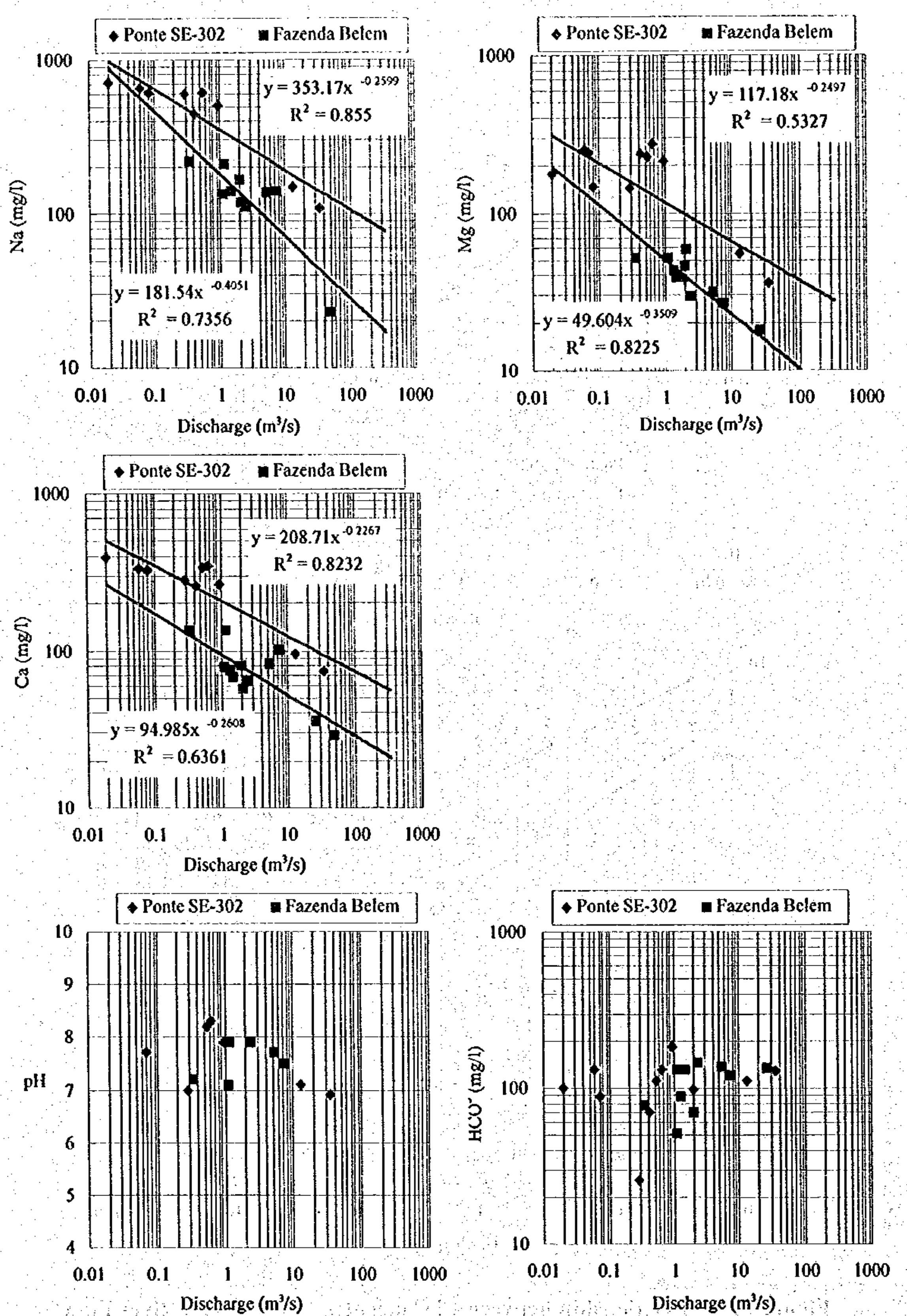


Figure-2.5 Relationship between Na/Mg/Ca/HCO_3/pH and River Flow

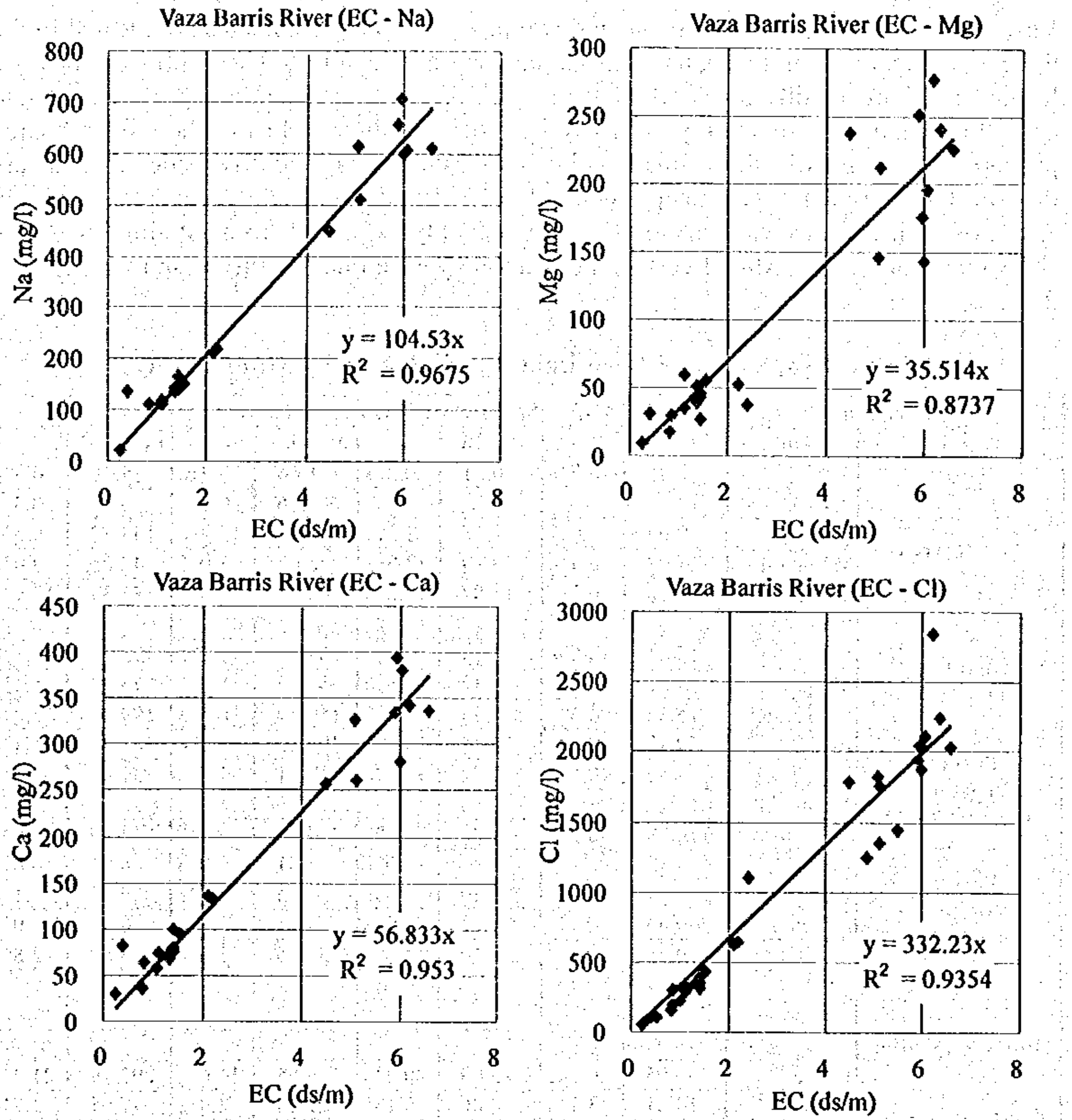


Figure-2.6 Correlation between EC and Na/Mg/Ca/Cl

2.5 Social and Natural Environment

2.5.1 Social Environment

Vaza Barris dam site, check dam site and two pipeline construction sites are located in the three municipalities of Itabaiana, Sao Domingos and Lagarto. These project sites are located in plain or hilly areas where agriculture is the only economic activity. These agricultural activities are mainly extensive livestock farming. Most of the project area is pastureland or grassland. Small cultivated-pasturelands and riverside forests are dispersed in the area. The steep slopes of the riverside are mainly covered by shrub. Areas of each land use category by each municipality estimated from satellite image are shown in Table-2.15. Main livestock population by each municipality is shown in Table-2.16.

Table-2.15 Area of Each Land Use Category by Municipality

Municipality		ITABAIANA		SAO DOMINGOS		LAGARTO		TOTAL	
Area	km²	338.40		102.30		962.5		1403.20	
Town		2.35	0.7%	0.21	0.2%	1.64	0.2%	4.20	0.3%
Forest Area	Plain					5.86	0.6%	5.86	0.4%
	Hill	0.02	0.0%	1.58	1.5%	131.82	13.7%	133.42	9.5%
	Mountain	1.08	0.3%	12.29	12.0%	28.68	3.0%	42.05	3.0%
	Sub-total	1.10	0.3%	13.87	13.6%	166.36	17.3%	181.33	12.9%
Wood Land	Plain								
	Hill	15.34	4.5%	0.03	0.0%	107.77	11.2%	123.14	8.8%
	Mountain			24.32	23.8%	51.62	5.4%	75.94	5.4%
	Sub-total	15.34	4.5%	24.35	23.8%	159.39	16.6%	199.08	14.2%
Pasture (Vegetation Density>20%)	Plain	169.13	50.0%	15.28	14.9%	396.89	41.2%	581.30	41.4%
	Hill	1.86	0.5%	11.72	11.5%	17.51	1.8%	31.09	2.2%
	Mountain								
	Sub-total	170.99	50.5%	27.00	26.4%	414.4	43.1%	612.39	43.6%
Pasture (Vegetation Density<20%)	Plain				0.0%	8.91	0.9%	8.91	0.6%
	Hill			3.40	3.3%	25.84	2.7%	29.24	2.1%
	Mountain	0.45	0.1%		0.0%			0.45	0.0%
	Sub-total	0.45	0.1%	3.40	3.3%	34.75	3.6%	38.60	2.8%
Mangrove									
Salt Marsh									
Dunes Vegetation									
Cultivation Area	Dense	135.95	40.2%	20.69	20.2%	140.55	14.6%	297.19	21.2%
	Plain	10.41	3.1%	0.06	0.1%	27.48	2.9%	37.95	2.7%
	Hill				0.0%	14.83	1.5%	14.83	1.1%
	Sub-total	146.36	43.3%	20.75	20.3%	182.86	19.0%	349.97	24.9%
Exposed Rock/Soil				12.72	12.4%	1.13	0.1%	13.85	1.0%
Water		1.81	0.5%			1.97	0.2%	3.78	0.3%

Table-2.16 Livestock Population by Municipality

(Heads)

Municipality	ITABAIANA	SAO DOMINGOS	LAGARTO	Total
Cattle	19,200	5,200	68,130	92,530
Sheep	1,360	600	11,800	13,760
Goat	280	260	4,250	4,790
House	1,440	455	19,530	21,425

Source: Production by Municipal Livestock (IBGE)

State road (SE-110) crosses Vaza Barris River at about 20 km upstream of the Vaza Barris dam site. Electric wires exist near check dam site. In and around the Vaza Barris dam site, there are only farm roads that are only possible by tractors and jeeps. There are no other infrastructure facilities around the reservoir area as well as no towns and cultural properties in the inundated area. The nearest residence from the Vaza Barris dam site is located 4 km upstream. In Sao Domingos town located near the reservoir, groundwater is the main source of water supply. The outlet of wastewater from Sao Domingos town is located 3 km away from the river.

In the downstream area of Vaza Barris dam, there are no irrigation areas and intake facilities from Vaza Barris River. In the estuary, fishery has been flourishing. In Sao Cristovao, registered fisher persons were 1,401 in 1998. The total including unregistered reaches approximately 6,000 people in a season. Most of the fishery activities use canoes with oar or sail, and a day trip in accordance with the tide. In recent years, however, the catch has been decreasing. Annual catch for 1987-88 in Sao Cristovao was more than 400 ton, but the catch in 1998 has dropped by 13 ton. Main reason for the decease is over fishing including the catch of juveniles. The catch for 1996-98 in Sao Cristovao is shown in Table-2.17.

Table-2.17 Catch of Fish for 1996-98 in Sao Cristovao

Area	1996	1997	1998
Sao Cristovao	229.1 tons	176.8 tons	13.0 tons
Total of Sergipe State	3,401.5 tons	3,193.8 tons	3,692.6 tons

Source: "Preliminary Ecological Evaluation of Vaza Barris River Estuary" by Federal University of Sergipe

2.5.2 Natural Environment

Most of the project area is extensive pastureland or grassland, where the vegetation is monotonous biologically. Small forest areas are scattered along the riverside. These riverside forests provide habitats of wildlife such as birds, small mammals and insects. Steep slopes of the riverside are mainly covered by shrub forests. The riverside and shrub forests consist of several species and have no precise dominant species.

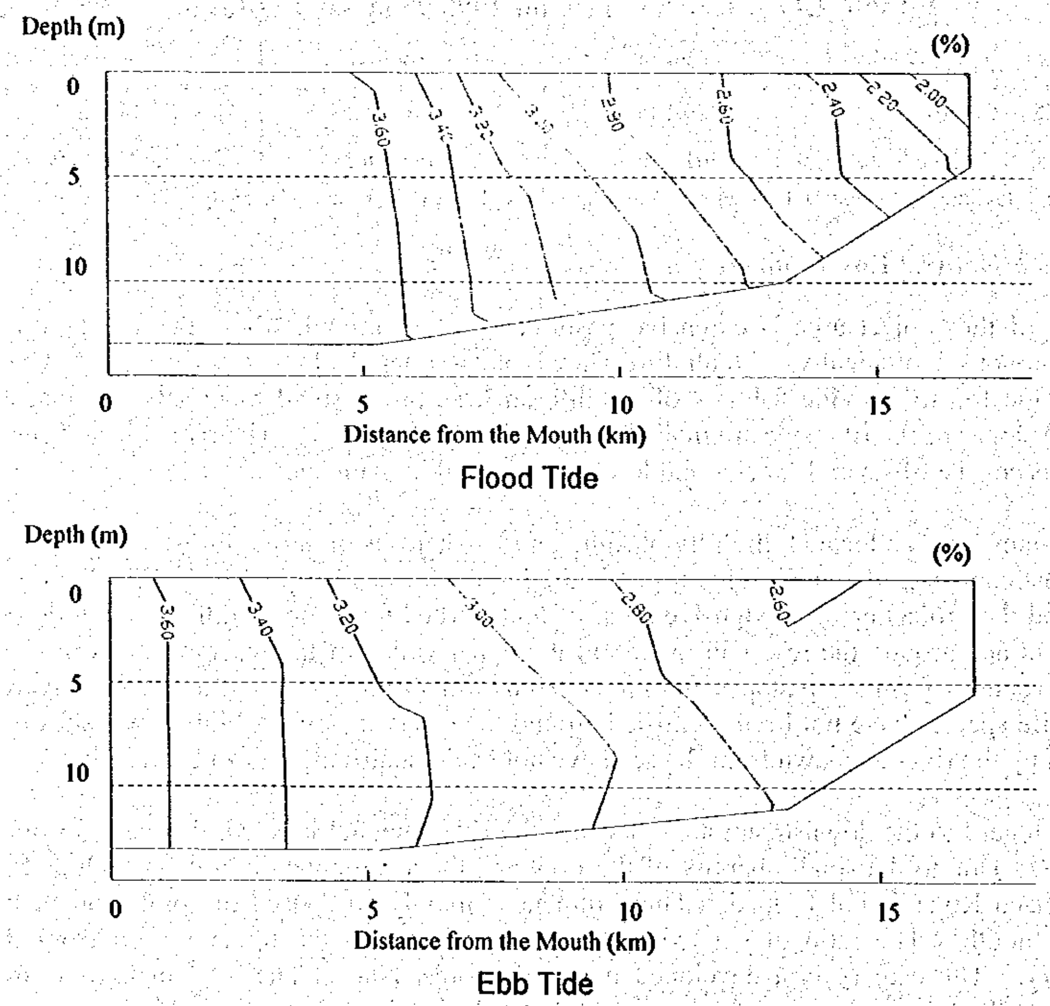
The dam site is located in hilly pastureland. There is a large forest area 1.5 km downstream from the site. This forest is the largest forest identified by the field surveys around the project area. Extensive areas of undisturbed forest and wildlife habitat do not exist in and around the reservoir area. In the upper valley of the reservoir area, most of the riversides form steep slopes and are covered with shrub forests. Rare or endangered wildlife species have not been identified around the reservoir area. Migratory fishes that swim up the river to spawn from the sea have not been identified in Vaza Barris River.

With regard to the downstream area, because the river channel is fixed, there are no flood plains. Due to the small quantity of the flow and the sedimentation, a delta such as Sao Francisco River is not formed. The sediment is mainly composed of coral sand in the river mouth. The ratio of silt existence rises gradually to the upper stream from the estuary. The estuary is a developed mangrove forest zone. The total mangrove area reaches 60.56 km^2. The mangrove areas trap the fine sediment transported in suspension, and progressively colonize the estuary. *Rhizophora mangle* is the dominant species and grows in the estuary margins, the islands and the shoals, up to the salt intrusion limit. About 70 % of the mangrove area are formed on the coral sand.

Salinity level of the estuary ranges from 1.78 % to 3.69% according to water quality analysis by Federal University of Sergipe. The high salinity water goes up close to the confluence with Paramopama River. The saltwater intrusion reaches approximately 20 km upstream at the spring tide. Oceanic fish species dominate up to the confluence with Paramopama River. In the more upper stream, demersal species dominate. Distribution of salinity in July 1999 (the rainy season) in the estuary is shown in Figure-2.7.

There is a state protected-area in the estuary. This protected-area consists of Paraiso Island located at the river mouth and Paz Island located in front of Mosqueiro Village. However, Paraiso Island is a momentary island and has no biological importance. Paz Island is covered with old growth mangroves. All of mangrove areas in Sergipe State are objects of State Mangrove Protection Law.

The land use is shown in Figure-2.8. The typical land use patterns (cross section) are shown in Figure-2.9. The environmental condition of the downstream area is shown in Figure-2.10.



Original Data: from Federal University of Sergipe

Figure-2.7 Distribution of Salinity Level in Vaza Barris River Estuary

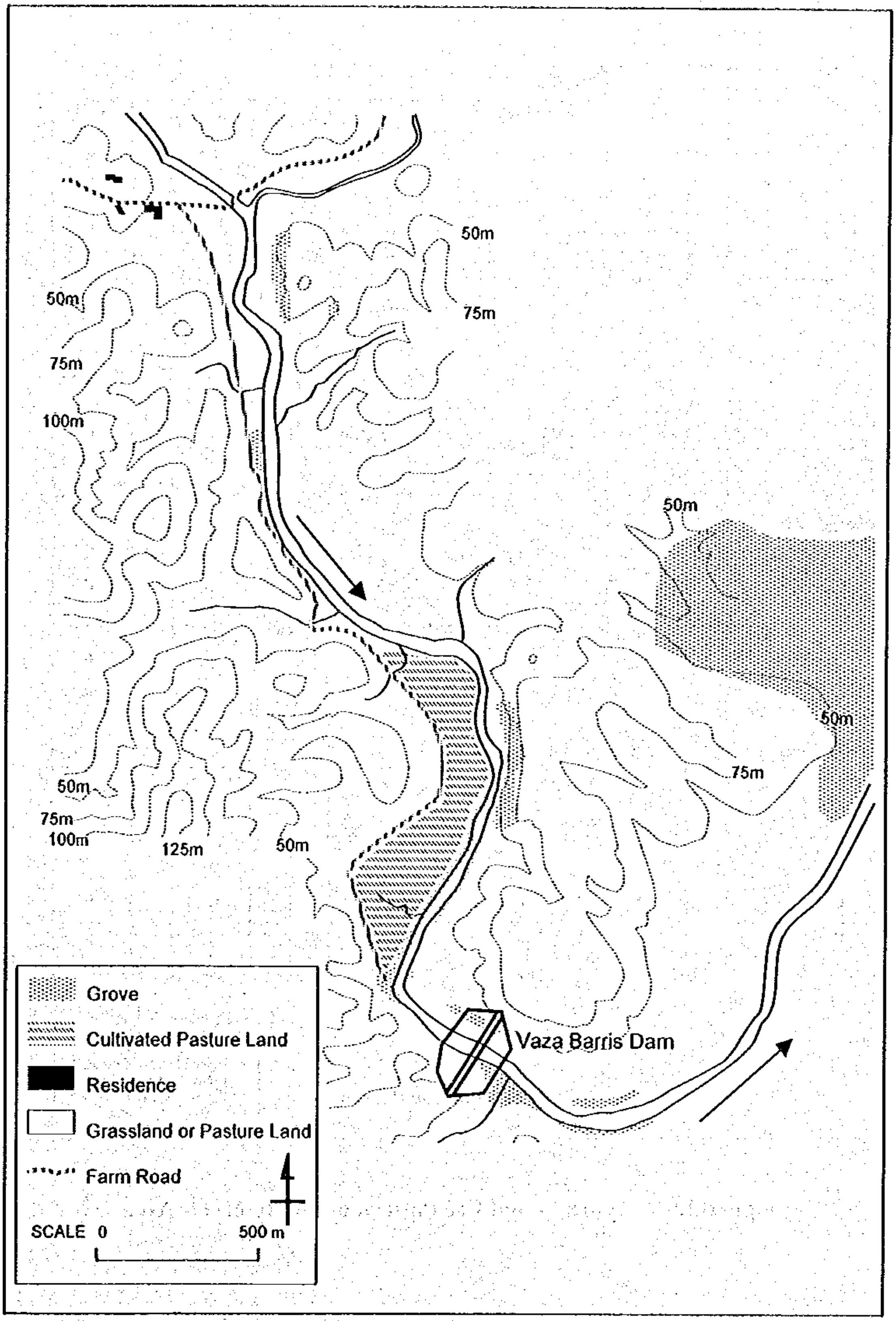


Figure-2.8 Land Use of Vaza Barris Dam Site

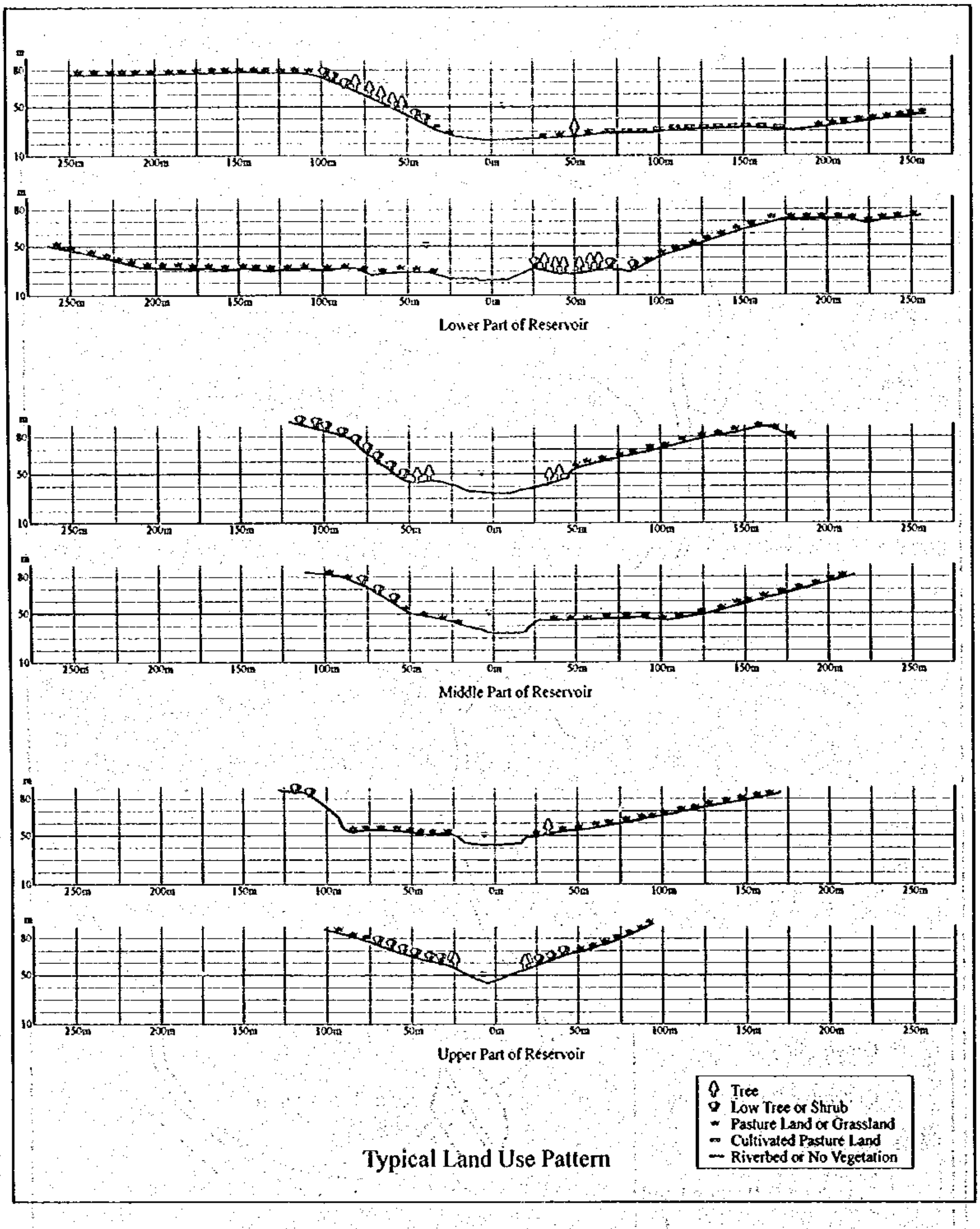


Figure-2.9 Typical Land Use Pattern of the Reservoir Area

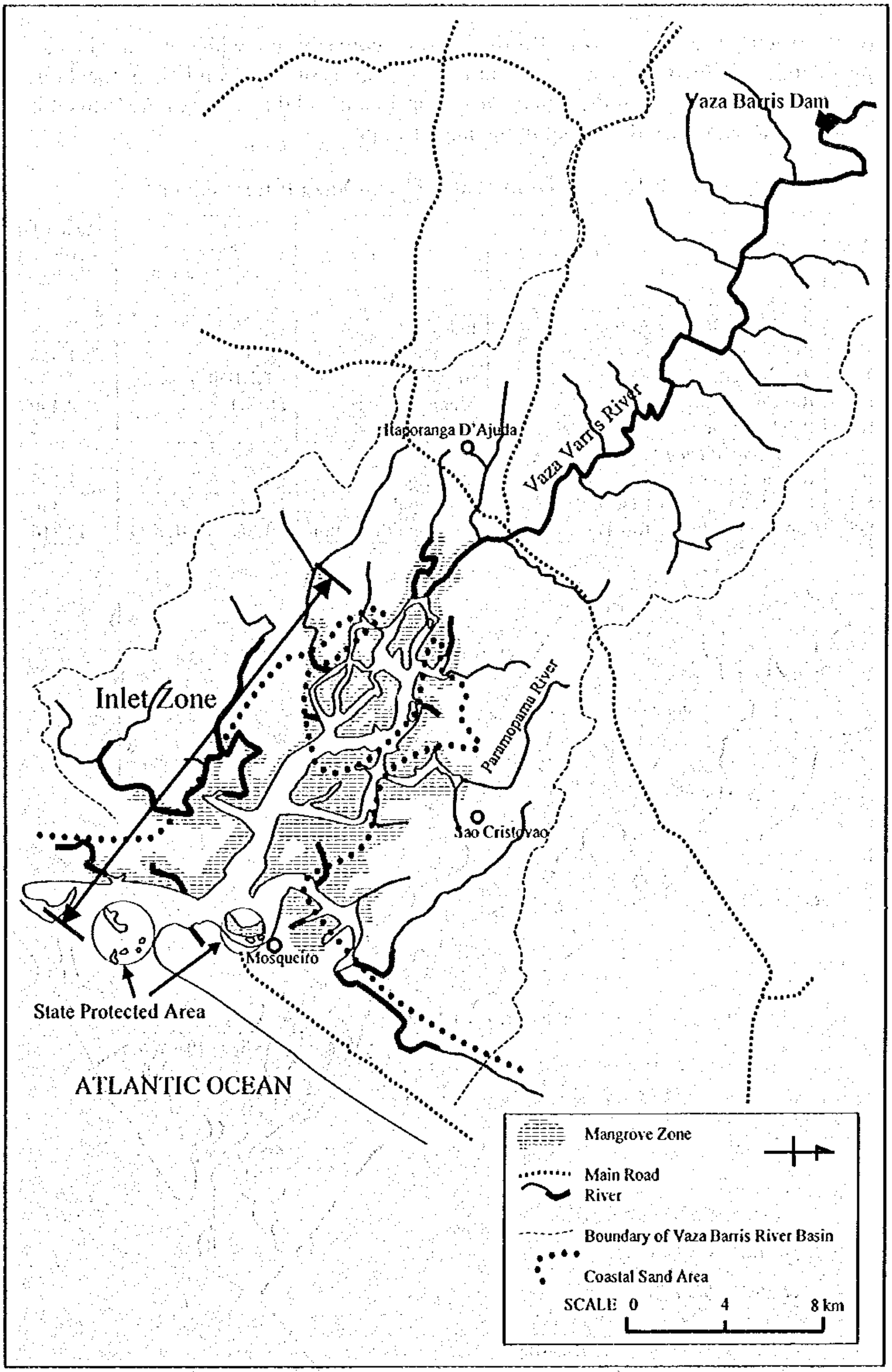


Figure- 2.10 Lower Part of Vaza Barris River

2.6 Current Water Use in Vaza Barris River in Sergipe State

Current water use in Vaza Barris River concerning with water intake on domestic/industrial/irrigation water is summarized in Table-2.18 and their locations are pointed in Figure-2.11. All the intakes in the upstream and downstream are located in the tributaries of Vaza Barris River, not in the main stream.

Table-2.18 Current Water Use in Vaza Barris River

Station No.	River	Location	Objective	Operation Organization	Water Use Amount (m^3/day)
	Downstream of Dam Site				
02	Rio Chinduba	Antiga Intake	Industry	-	-
06	Riacho Taboca	Pov. Sape	Municipal	DESO	1,356
08	Riacho Pedras	Faz. Riacho Doce	Irrigation	COHIDRO	-
11	Rio Comprido	Intake SAAE	Municipal	DESO	2,400
12	Riacho Pindoba	Fonte Indaiá	Industry	-	-
	Upstream of Dam Site				
10	Riacho Taboca	Pov. Genipapo	Municipal	DESO	1,199
18-1	Rio Trairas	Riacho Ribeira	Municipal	DESO	346
18-3	Rio Trairas	Rio Trairas	Municipal/Irrigation	DESO/COHIDRO	12,216

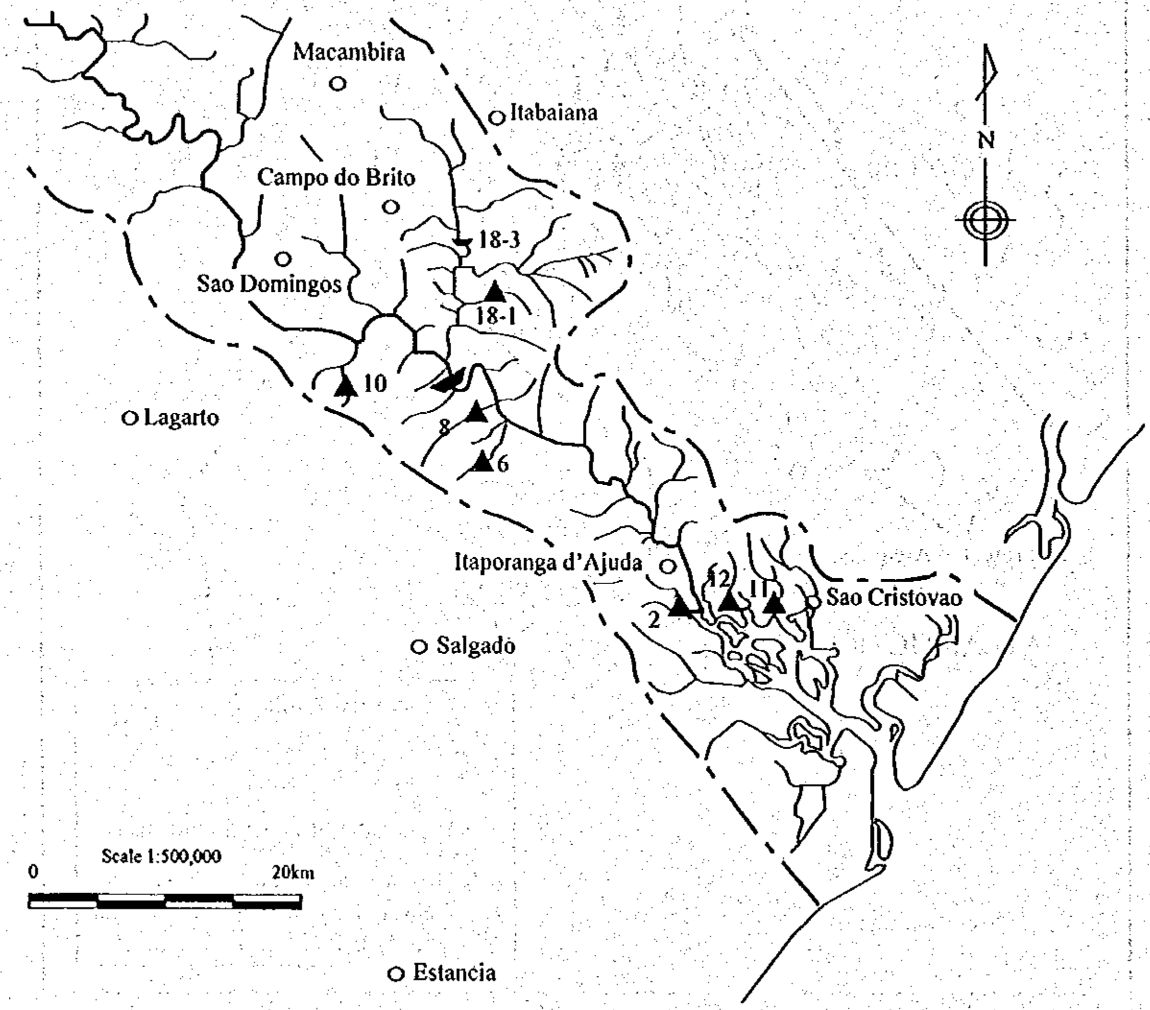


Figure-2.11 Location of Current Water Use in Vaza Barris River

CHAPTER 3 WATER DEMAND AND SUPPLY PLAN

3.1 Domestic and Industrial Water

3.1.1 Water Supply Areas

This project, Water Resources Development and Supply in Vaza Barris River – Sergipe, is planned to supply water to Itabaiana and Lagarto Water Supply areas. Water demand and shortage conditions in these areas in the year of 2020 are described in Table-3.1. Water supply shortage by municipalities in 2020 is presented in Table-3.2. The location of these areas is shown in Figure-3.1.

Table-3.1 Water Demand and Shortage in 2020

Items	Itabaiana Water Supply Area	Lagarto Water Supply Area	Total
Water Demand (m³/day)			
Private-tap System	67,545	88,411	155,956
- Industrial Water	22,296	57,518	79,814
- Domestic Water: Urban Area	40,467	24,427	64,894
- Domestic Water: Large Rural Area	4,782	6,466	11,248
Public-tap System (Small Rural Area)	1,196	1,617	2,813
Total	68,741	90,028	158,769
Necessary Supply Water (m³/day)			
Private Industrial Water	11,148	27,739	38,887
Private-tap System	74,286	79,664	153,950
- Industrial Water	14,864	39,704	54,568
- Domestic Water: Urban Area	53,957	32,570	86,527
- Domestic Water: Large Rural Area	5,465	7,390	12,855
Public-tap System (Small Rural Area)	1,107	1,497	2,604
Total (Except self-supplied ind.)	75,393	81,161	156,554
Current Water Supply Capacity (m³/day)			
Private-tap System (Urban & Large Rural Area)	12,810	12,130	24,940
Public-tap System (Small Rural Area)	150	225	375
Total	12,960	12,355	25,315
Supply Water Shortage (m³/day)			
Private-tap System (Urban & Large Rural Area)	61,476	67,534	129,010
Public-tap System (Small Rural Area)	957	1,272	2,229
Total	62,433	68,806	131,239

Table-3.2 Supply Water Shortage in 2020 by Municipalities

Areas	Municipalities	Supply Water Shortage (m³/day)	Areas	Municipalities	Supply Water Shortage (m³/day)
Itabaiana Water Supply Area Agreste Pipeline System	Total	61,476	Lagarto Water Supply Area Piauitinga Pipeline System	Total	67,534
	Areia Branca	13,462		Poco Verde	2,226
	Campo do Brito	6,148		Simao Dias	9,102
	Itabaiana	38,432		Lagarto	53,891
	Macambira	1,149		Riachao do Dantes	2,315
	Sao Domingos	2,285			

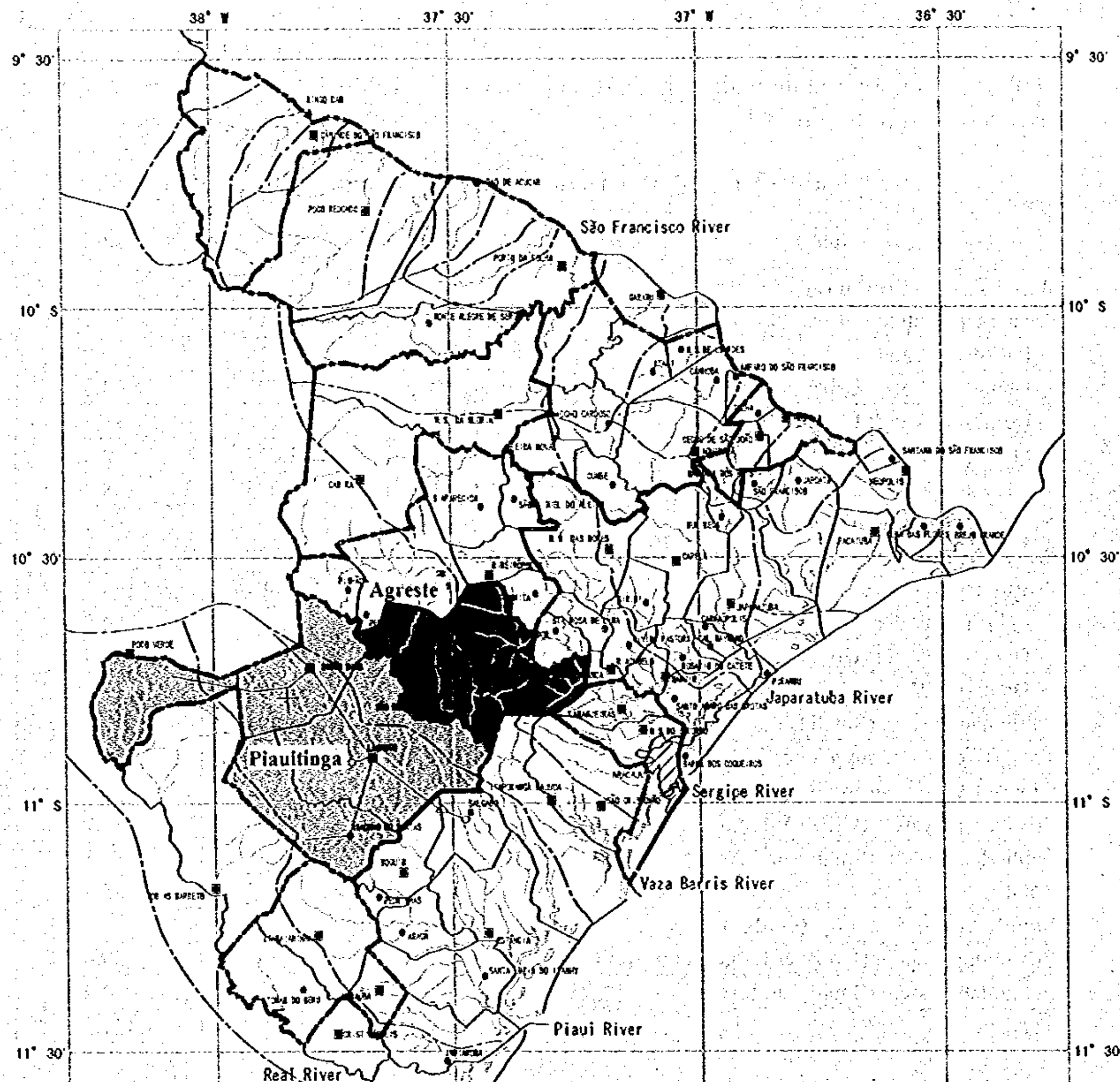


Figure-3.1 Water Supply of the Study

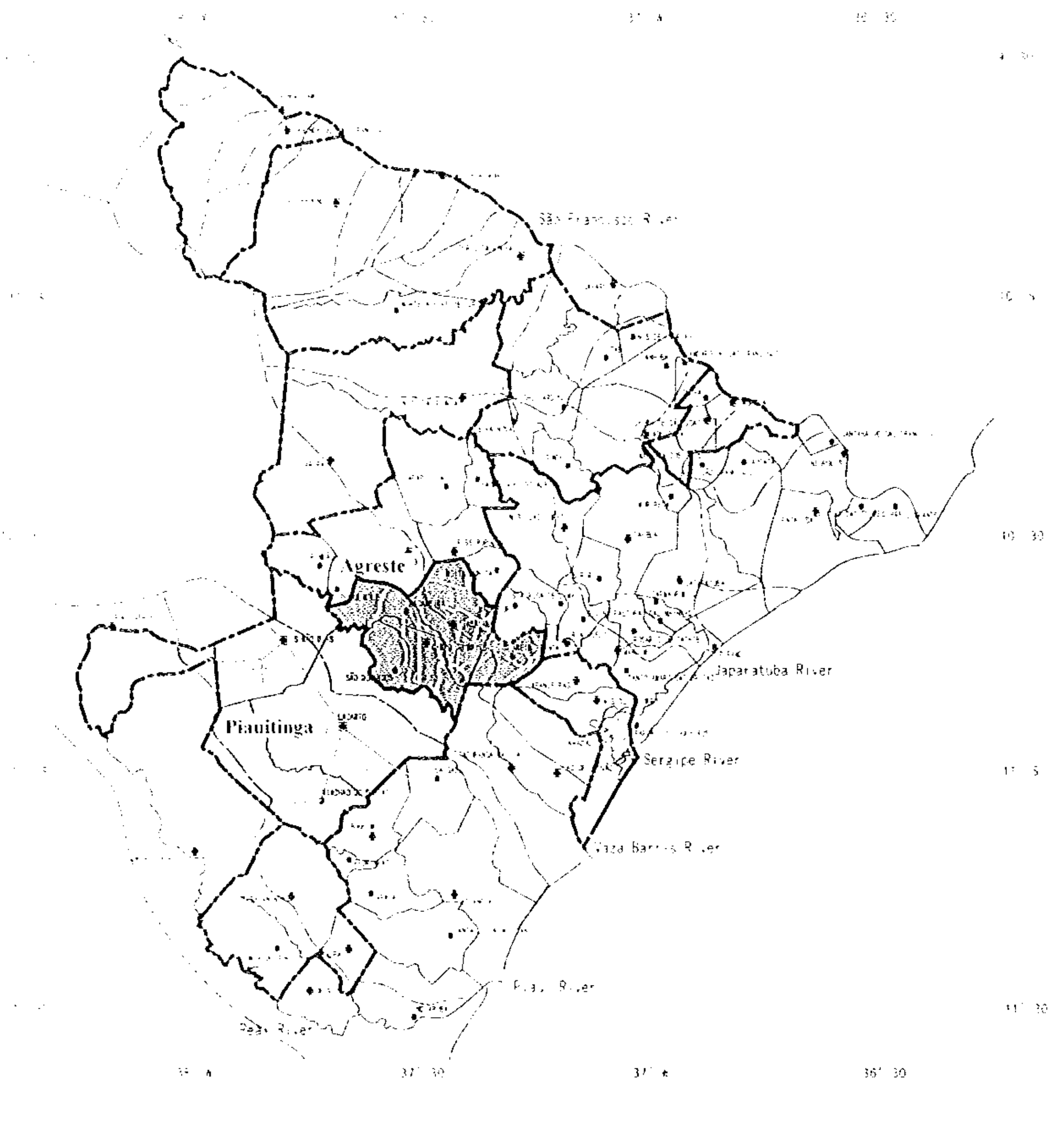


Figure-3.1 Water Supply of the Study

3.1.2 Domestic and Industrial Water Supply Plan

For the water supply to this urban and large rural area, two projects as shown below are being proposed as water resources development and supply in the Study Area, in order to meet the water demand.

- Project of Water Resources Development and Supply in Vaza Barris River-Sergipe
- Expansion project proposed to PROAGUA

Water supply for urban and large rural area was planned as shown in Table-3.3.

Table-3.3 Domestic and Industrial Water Supply in Agreste and Piauitinga Areas

Area Covered	Agreste Integrated Pipeline System		Piauitinga Integrated Pipeline System		Total Supply	
	(m^3/day)	(m^3/s)	(m^3/day)	(m^3/s)	(m^3/day)	(m^3/s)
Water amount necessary to be supplied in 2020	74,286	0.860	79,664	0.922	153,950	1.782
Present Capacity	12,810	0.148	12,130	0.141	24,940	0.289
Expansion project to be proposed to PROAGUA	22,200	0.257	30,200	0.349	52,400	0.606
Required development water amount in this project	39,276	0.455	37,334	0.432	76,610	0.887

As for small rural areas, following deep wells and desalinizer were proposed to meet the residential water demand in 2020.

- 126 deep wells and 71 desalinizers to develop 957 m^3/day for Itabaiana Area
- 166 deep wells and 88 desalinizers to develop 1,272 m^3/day for Lagarto Area

Besides, private industrial water, which is supplied not through public water supply system, is assumed that individual factories will develop water through groundwater development. Total required water, which is 11,148 m^3/s for Itabaiana area and 27,793 m^3/s for Lagarto area in 2020, is far lower than the groundwater potential in these areas. Supply/Potential ratio shows less than 1% in most areas except 14% in Itabaiana municipality and 18% in Lagarto municipality.

3.2 Irrigation

Since the irrigation was out of the scope of the JICA Feasibility Study (Study on Vaza Barris Dam Project), SEPLANTEC conducted the pre-feasibility study on irrigation through the contract with a local consultant so that the Vaza Barris Dam Project can be evaluated from all sectors concerned. The result of the pre-feasibility study (SEPLANTEC, "Pre-Feasibility Study of Vaza Barris Irrigation Project/Sergipe, Volume I - III", 1999) is summarized below.

3.2.1 Project Specifications

Proposed site for the Vaza Barris Irrigation Project is located on the right bank of Vaza Barris River in Lagarto municipality. The site expands to Sape town in the east, Jenipapo town in the north and Brasilia town in the west with the total irrigation area of 4,519 ha. Soil in the site is categorized mainly Yellow Podzolic Soil which has the potential for irrigation as long as soil fertility is maintained properly.

The project site is currently utilized as agricultural land in full. Considering current landuse and scale of farmers, the project consists of 6 types in terms of area as shown in Table-3.4. Recommended crops were determined through the agricultural market analysis in order to select the most profitable crops for the internal market. As a result, vegetable and fruit cultures are recommended. Area of each type, recommended crops and irrigation methods depending on crops are summarized in Table-3.4.

Table-3.4 Irrigation Models

Model	Culture	Lot Area (ha)	Lot Number	Total Area (ha)	Irrigation Method
A	Vegetables	3	268	804	Conventional Sprinkling
B1	Vegetables, Papaya, Lemon	5	113	565	Conventional Sprinkling for Vegetables and Micro-sprinkling for Fruit
B2	Acerola, Papaya, Lemon	5	98	490	Micro-sprinkling
C	Orange, Lemon, Pineapple, Passion Fruit	10	148	1,480	Micro-sprinkling, except Pineapple (Conventional Sprinkling)
D	Orange, Tangerine, Pineapple, Acerola, Passion Fruit	20	24	480	Micro-sprinkling, except Pineapple (Conventional Sprinkling)
E	Orange, Tangerine, Pineapple, Acerola, Passion Fruit	50	14	700	Micro-sprinkling, except Pineapple (Conventional Sprinkling)
Total Irrigation Area of Project (ha)				4,519	

Source: SEPLANTEC, "Pre-Feasibility Study of Vaza Barris Irrigation Project/Sergipe, Volume I - III", 1999

Reference crop evapotranspiration was calculated by Penman-Monteith equation and 75 % probability rainfall was adopted as dependable rainfall. Application efficiencies of conventional sprinkling and micro-sprinkling were assumed to be 70 % and 85 %, respectively, while distribution and conveyance efficiencies were assumed to be 90 %. Leaching factor is concluded not necessary because the leaching fractions calculated by crop tolerance to salinity and irrigation water salinity are within the range of 0.008 ~ 0.150.

The result of project water requirement at intake (Vaza Barris dam) is shown in Table-3.5. The maximum project water requirement is 2.912 m^3/s in January.

Table-3.5 Source Water Requirement of Vaza Barris Irrigation Project

Unit: m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water Requirement at Intake	2.912	2.469	2.022	0.717	0.273	0.000	0.033	0.542	1.344	2.484	2.463	2.820

Source: SEPLANTEC, "Pre-Feasibility Study of Vaza Barris Irrigation Project/Sergipe, Volume I - III", 1999

3.2.2 Construction Cost and Benefit

Construction cost of the Vaza Barris Irrigation Project was estimated at 52.269 million Real ("Pre-Feasibility Study of Vaza Barris Irrigation Project/Sergipe", Volume II). The cost includes all facilities associated with irrigation (from intake to irrigation application) but excludes the dam. Total construction cost of the irrigation project integrating both irrigation facilities and the dam is discussed in the chapter 8 (Cost Estimate).

To assess benefit of the irrigation project, productivities of the recommended crops were determined by analyzing IBGE Information/Agri-annual 99 and Agricultural-Livestock Budgets (Banco do Nordeste). The result is shown in Table-3.6. The figures adopted for fruit cultures are quite high compared to average figures of advanced countries in respective culture, especially orange, lemon and pineapple.

Table-3.6 Productivity of Recommended Crops with Irrigation

Vegetables		Fruits	
Item	Productivity (ton/ha)	Item	Productivity (ton/ha)
Tomato	40.0	Orange	55.0
Pimento	15.0	Lemon	45.0
Cabbage	30.0	Passion Fruit	12.0 ~ 16.0
Carrot	25.0	Acerola	20.0
Watermelon	25.0	Pineapple	50.0
Melon	15.0	Tangerine	45.0
Bean	1.6	Papaya	20.0 ~ 40.0

Source: SEPLANTEC, "Pre-Feasibility Study of Vaza Barris Irrigation Project/Sergipe, Volume I - III", 1999

CHAPTER 4 WATER RESOURCES DEVELOPMENT PLAN

4.1 Criteria for Plan and Design

4.1.1 Planning Criteria

(1) Compensation Discharge

The "compensation discharge" Q_{CM} could be defined as the discharge necessary to maintain the normal function of a river, and consists of maintenance discharge and water-use discharge. Maintenance discharge has been stipulated to maintain river function even at the times of low flow, with overall consideration to the following: 1) fisheries, 2) scenery, 3) sea water intrusion, 4) preservation of fauna and flora, 5) preservation of cleanliness of river flow, 6) prevention of river-mouth clogging, 7) protection of river works, 8) groundwater level maintenance, 9) boat transportation. Water-use discharge is the flow necessary for the exclusive use of the river water at all points downstream.

After the following consideration, compensation discharge was set as the 100% of the 10-year return period 7-day flow (Q7, 10).

Maintenance Discharge: In this Study, the 100% of the 10-year return period 7-day flow (Q7, 10) is applied as maintenance discharge for dam planning. The (Q7, 10) refers to the mean annual minimum 7-day flow with 10-year return period, and this is secure as compensation discharge to the downstream when developing new water resources of river flow. As this value is not an absolute one, the above items to be considered should be studied in detailed environmental study.

Water Use Discharge: Based on the survey of current water use in Vaza Barris River in the Sergipe State, exclusive water use in the main stream could not be found. Consequently, no water use discharge is taken into account for compensation discharge. Refer to the following investigation of current water use.

(2) Reservoir Reliability (Security Level of Water Supply)

Low flow security in the plan has been set to ensure the intake of newly developed discharge even in the worst drought in ten years for domestic/industrial and irrigation water supply.

(3) Design Discharges

(a) Design Flood Discharge of Dam

A spillway is the safety valve for a dam. It must have the capacity to discharge major floods without damage to the dam or any appurtenant structures, at the same time keeping the reservoir level below some predetermined maximum level.

The selection of design flood discharge is related to the degree of protection that ought to be provided to the dam that depends on the type of dam, its location, and consequences of failure of the dam. A high dam storing a large volume of water located upstream of an inhabited area should have a much higher degree of protection than a low dam storing a small quantity of water whose downstream reach is uninhabited. The probable maximum flood is commonly used for the former while a smaller flood based on frequency analysis is suitable for the latter.

According to the "Criteria of Civil Design of Hydro-electric Plant, 1994 May, Preliminary Edition, CEMIG (Energy Company of Minas Gerais)", design flood discharge of a dam is set as follows:

1) For dams whose collapse involves loss risk of human lives (if permanent habitation exists downstream), the design flood discharge should be the Probable Maximum Flood.
2) For dams with the height less than 30 m or with the volume less than 50,000,000 m^3, and when there is not loss risk of human lives (if permanent habitation exists downstream), the design flood discharge should be defined as minimum return period of 1,000 years by probability analysis.

The proposed dam is categorized in 1) above and the design flood discharge should be the probable maximum discharge.

(b) Other Design Discharges

As the scale of the following design discharges are not defined in the criteria mentioned above, the Japanese standard for dam design are referred.

- Design discharge for energy dissipater of a dam
- Design discharge of diversion channel during construction
- Design discharge for spillway of a check dam

4.1.2 Design Criteria

Dam should be carefully designed to minimize the construction cost, holding necessary functions of each facility. Dam and related structures are designed according to reasonable balance between construction cost and safety level. A large safety level of structures requires a large scale of structures and complicated construction procedures. Consequently, the construction costs increase. Design Criteria are standards to decide a balance between construction cost and safety level.

Dam Design Criteria used in Brazil are as follows:

1) For almost existing dams, dam design standards of USBR (US, Dep. of the Interior, Bureau of Reclamation) and USCE (US Army, Corps of Engineer) were employed.
2) Sao Francisco Electricity Corporation (CHESF) recently uses the standard "Civil Works Criteria for Hydropower Generation" which was complied by Mina Gerais Power Company (CEMIG) on the basis of standards of USBR and USCE. This standard was used in designing Xingo Dam.

Considering the above situation, CEMIG standard is employed basically in design of Vaza Barris Dam and other related structures. If necessary, the Japanese Standards for dam design of "Manual of River Works, Ministry of Public Works, Japan" are referred.

4.2 Site Selection of Dam and Spillway

Candidates of dam site were selected in Vaza Barris River in Sergipe around Lagarto and Itabaiana on the basis of following viewpoints of topography, geology hydrology and water quality:

1) Large drainage area
2) Good Water Quality
3) Narrow river valley
4) Appropriately steep valley slope
5) No lying over large lineament or fault line

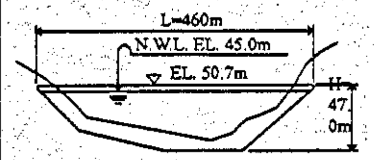
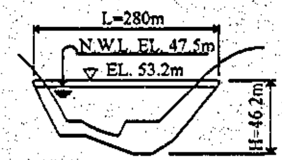
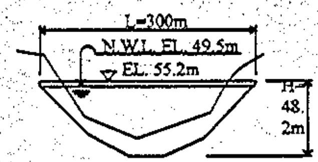
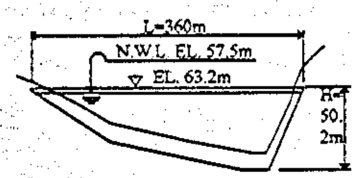
At first the area suitable for a dam site was supposed to be between around the observation station of Fazenda Belem and 10 km downstream of Sao Domingos Town, based on the following considerations:

- From the upstream of the point 10km downstream of Sao Domingos Town, the valley of Vaza Barris River is quite narrow with steep valley walls and is having no wide portion suitable for the reservoir. Moreover, water quality seems not to be suitable in the main river upstream from there.
- From the downstream of around the observation station of Fazenda Belem, as the Vaza Barris River forms a wide valley and a thick alluvial deposit, no good dam site was found.

In the range set based on the above considerations, four (4) locations of dam site candidates were selected based on the study on topographical map and the site reconnaissance and are shown in Figure-4.1. These four (4) alternatives are studied in the viewpoints of hydrology, water quality, topography and geology as well as economic condition. The comparison was summarized in Table-4.1.

As the results of engineering comparison, the proposed site was selected as the site of Vaza Barris Dam.

Table-4.1 Comparison of Dam Site Candidates

Item	Alternative A	Proposed Site	Alternative B	Alternative C
Dam Site Cross Section				
Aspects on Hydrological and Water Quality	Additionally to Trairas River, high potential right tributary is confluent from the right side. it has the best advantage in the viewpoint of water quality and quantity.	As located at the downstream of Trairas River that has rich surface water potential, it is advantage in the viewpoint of water quality.	As located at the downstream of Trairas River that has rich surface water potential, it is advantage in the viewpoint of water quality.	As located at the upstream of Trairas River that has rich surface water potential, it is disadvantage in the viewpoint of water quality.
Aspects on Topography and Geology	This site is located near the lowest part of the set area. A distinct sheared zone is supposed to be lying on the section of south-north direction. Hence this site is judged to be insufficient for the dam site.	This site has rather narrow ridge in its right slope, but a clear lineament is not found. Recent river deposit is rather thickly accumulated near the riverbed and conceals almost all the features of geological conditions. However, some rock outcrops are still visible at some brinks, which suggests an irregularity of underground rock surface.	This site has a fair good landform, but a distinct lineament overlies, which suggests a large structural accident meaning a existence of fractured zones. Thus, this site must be avoided.	This site is on the almost same circumstance as the alternative B.
Normal Water Level	EL. 45.0 m	EL. 47.5 m	EL. 49.5 m	EL. 57.5 m
Reservoir Area (N.W.L)	10.5 km^2	9.5 km^2	9.2 km^2	6.9 km^2
Dam Top Level	EL. 50.7 m	EL. 53.2 m	EL. 55.2 m	EL. 63.2 m
Dam Height	47.0 m	48.2 m	48.2 m	50.2 m
Crest Length of Dam	460 m	280 m	300 m	360 m
Dam Volume	322,000,000 m^3	219,000,000 m^3	205,000,000 m^3	283,000,000 m^3
Total Evaluation	×	◎	△	×

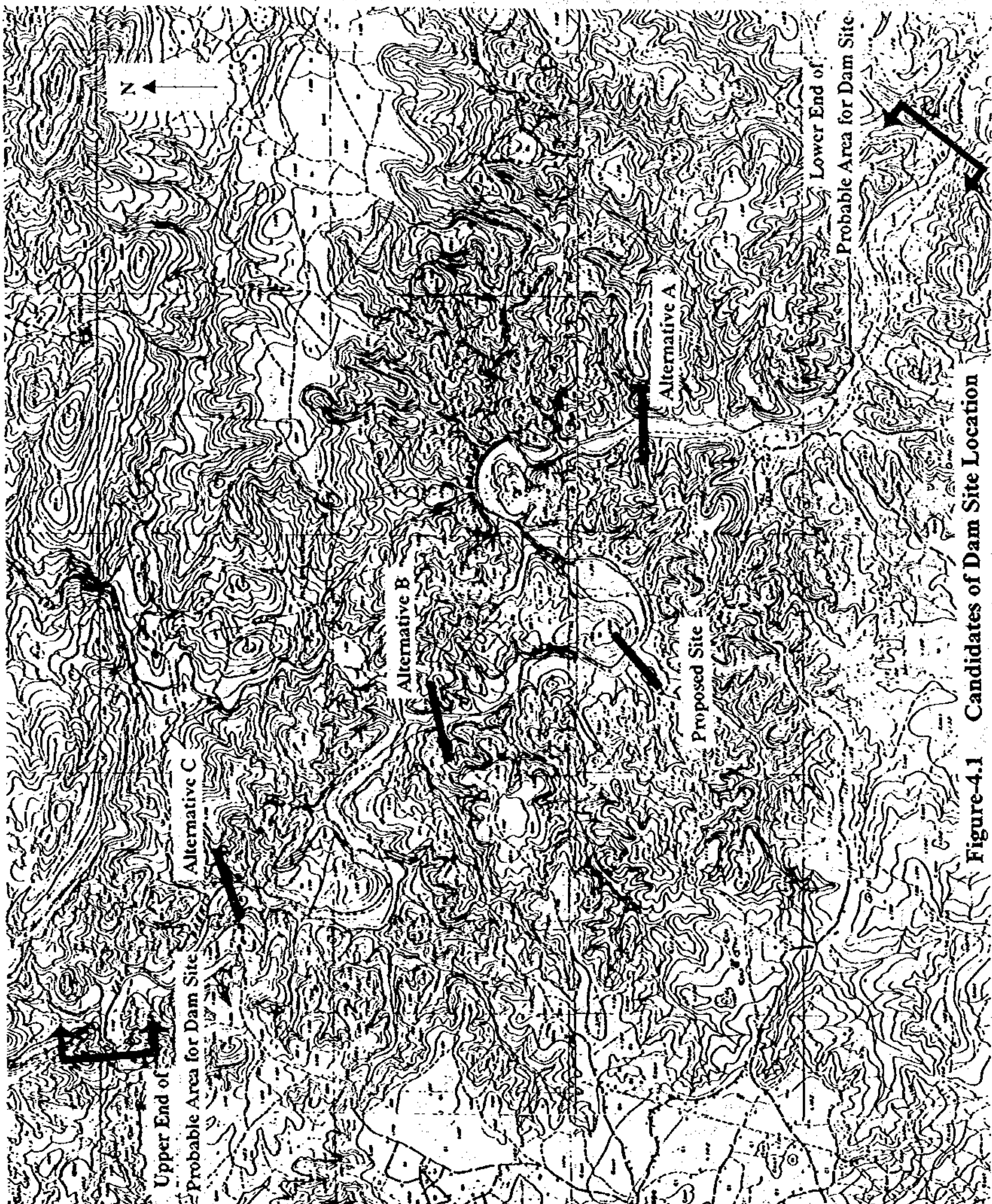


Figure-4.1 Candidates of Dam Site Location

4.3 Planning Condition of Dam

4.3.1 Required Development Water Amount

Vaza Barris Dam is planned for development of domestic/industrial water and irrigation water. Domestic and industrial water is to be supplied for the area covered by Agreste and Piauitinga Integrated Pipeline Systems. Required water amount developed by Vaza Barris Dam is set as follows:

- Municipal and industrial water supply: 0.887 m^3/s
- Irrigation water supply: 2.912 m^3/s in maximum
  1.507 m^3/s in average
- Total required development amount: 3.799 m^3/s in maximum
  2.394 m^3/s in average

4.3.2 Reservoir Sedimentation

There are two dams existing in the Vaza Barris River basin, namely Cocorobo Dam (C.A.=3,600 km^2) and Cajaiba Dam (C.A.=195 km^2). As the hydrographic basin of the Vaza Barris dam is 15,560 km^2, sediment catchment area becomes 11,765km^2, subtracting the catchment areas of the existing dams.

Planned sediment capacities of the dams with the catchment area of over 100 km^2 in Sergipe State are shown in Table-4.2. The specific sediment capacities (m^3/km^2/year) of the above dams with the catchment area between 118-1,350 km^2 are ranged from 14-53 m^3/km^2/year. Taking into account of the catchment area size and the deference of basin elevation, the specific sediment capacity of the Vaza Barris Dam is set at 10 m^3/km^2/year. Then, securing 100-year sediment for the dam reservoir, the sediment capacity for the Vaza Barris Dam is necessary to be 12,000,000 m^3.

Table-4.2 Sediment Capacities of Dams in Sergipe State

Dam Name	River Name	Catch-ment Area (km^2)	Deference of Basin Elevation (m)	Reservoir Area (ha)	Reservoir Volume Vt (m^3)	Sediment Capacity Vs (m^3)	Specific Sediment Capacity (m^3/km^2/year)	Vs/Vt (%)
Vaza Barris	Vaza Barris	15,560 (11,765)	600	948	93,000,000	12,000,000	10	12.9%
Piaiu	Piaui	1,350	400	367	15,000,000	2,000,000	15	13.3%
Jabiberi	Jabiberi/Real	118	200	61	4,300,000	540,000	46	12.6%
Jacarecica I	Jac./Sergipe	221	200	115	4,700,000	300,000	14	6.4%
Cajaiba	Trairas/V.B.	195	200	250	16,500,000	1,032,000	53	6.3%

Note: () shows sediment catchment area

4.3.3 Determination of Design Discharges

(1) Design Flood Discharge of Dam

According to the planning criteria, the design flood discharge should be the probable maximum discharge, which is assumed to be the discharge with 10,000-year return period in this report. Based on annual maximum daily discharge for the 24-year data series (1971-1995) at Fazenda Belem (C.A.=15,740km^2), the discharge with 10,000-year return period was calculated to be 3,588 m^3/s. Taking into account of the ration of the catchment areas at Fazenda Belem and that at the dam site, the design flood discharge was set at 3,600 m^3/s.

- Design Flood Discharge: 3,600 m^3/s
- Specific Discharge: 0.23 $m^3/s/km^2$ (Dam C.A.= 15,560 km^2)

Figure-4.2 illustrates the range of specific discharge of the maximum flow for rivers in the world. As the design flood discharge of Vaza Barris Dam is pointed in the figure, it corresponds to the maximum discharge of the upper range in a plain area or the lower range in a mountain area. It seems to be reasonable studying the topographical condition of this basin.

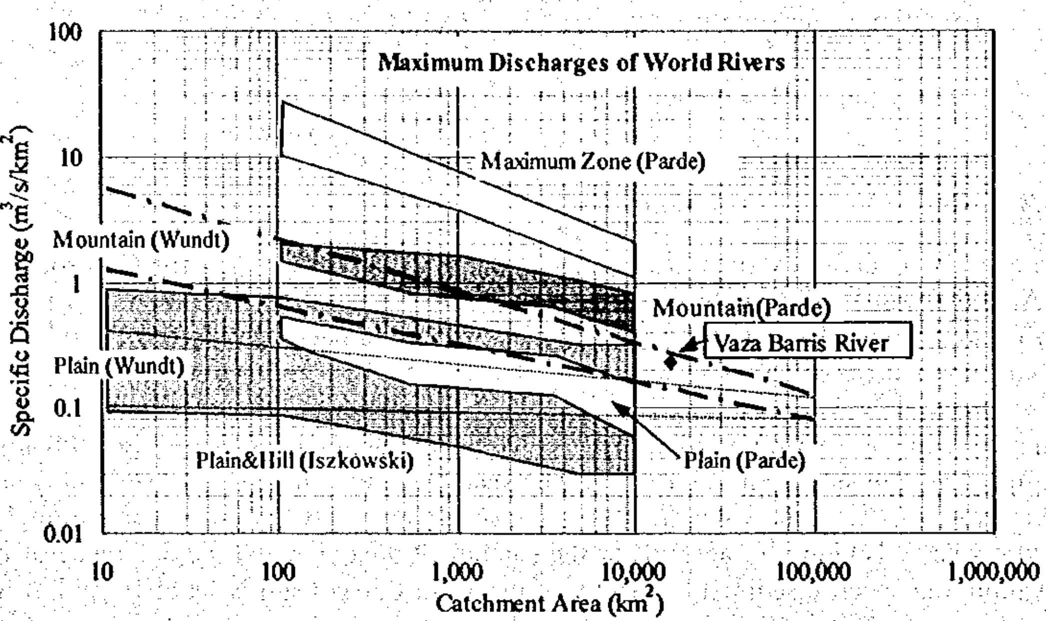


Figure-4.2 Specific Maximum Discharges of Rivers in the World

Table-4.3 Design Flood Discharge of Existing Dams in Sergipe State

Dam Name	Piaui	Jabiberi	Jacarecica I	Cajaiba	Xingo
River Name	Piaui	Jabiberi	Jacarecica	Trairas	S. Francisco
Responsible Organization	COHIDRO	COHIDRO	COHIDRO	COHIDRO	CODEVASF
Purpose	Irrigation	Irrigation	Irrigation	Irrigation/ Domestic	Power generation
Catchment Area (km^2)	1,350	118	221	195	633,000
Spillway Design Discharge (m^3/s) (Probable year)	2,238 (1,000)	331.5 (1,000)	738 (1,000)	1,621 (10,000)	33,000
Specific Discharge ($m^3/s/km^2$)	1.66	2.81	3.34	8.31	0.052

(2) Design Discharge for Energy Dissipater of Dam

The design discharge of the dam energy dissipater is adopted as the discharge with 100-year return period, according to "Manual of River Works, Ministry of Public Works, Japan".

The probable discharge with 100-year return period at Fazenda Belem (C.A.=15,740km^2) is 1,211 m^3/s, and that at the dam site is 1,197 m^3/s taking into account of the basin areas' ratio. Then the design discharge of 1,200 m^3/s was taken for the design discharge.

(3) Design Discharge of Diversion Channel during Construction

A design discharge of a diversion channel is defined, as the frequency resulting from probable analysis, comparing the expected value of losses cost resultant from respective floods. According to the degree of flood damage by a dam type, in this report, a design discharge of a diversion channel during construction is set as the following criteria:

- Concrete dam: Discharge with 2-year return period
- Earth-fill dam or Rock-fill dam: Discharge with 20-year return period

Therefore, the design discharge of the diversion channel during construction is set as follows:

- Concrete dam: 200 m^3/s (0.013 $m^3/s/km^2$)
- Earth-fill or rock-fill dam: 720 m^3/s (0.048 $m^3/s/km^2$)

(4) Design Discharge for the Spillway of a Check Dam

The larger one of the following two discharges is adopted as a design discharge for the spillway of a check dam, according to "Manual of River Works, Ministry of Public Works, Japan".

- Discharge with 100-year return period
- Experienced maximum discharge

The probable discharge with 100-year return period at Fazenda Belem (C.A.=15,740km^2) is 1,211 m^3/s, and that at the dam site is 1,170 m^3/s taking into account of the basin areas' ratio. On the other hand, the experienced maximum discharge at Fazenda Belem is 647 m^3/s in 1975 during 25-year data series from 1971 to 1995. Then the design discharge with 100-year return period should be taken for the design discharge.

However, the proposed check dam has the function not only as a sand sedimentation facility but also as an intake facility. For the dam reservoir operation, this intake is inevitable for improvement of reservoir water quality. Therefore, adding 20 % of discharge due to its importance, the design discharge of the spillway for the check dam is set at 1,400 m^3/s.

- Design discharge: 1,400 m^3/s
- Specific Discharge: 0.09 $m^3/s/km^2$ (Check Dam C.A.= 15,030 km^2)