1.3.4 Rainfall Observation Network

SUDENE took over operation of most of the rainfall gauges (59 stations) in Sergipe in 1963 as part of the Northeast Basic Hydro-Meteorological Network. Since 1991, SUDENE has not collected the rainfall data but instead relies on data provided by EMDAGRO. EMDAGRO operates or collects data from 44 rainfall stations located near to its regional offices located across the state. ANEEL operates 8 rainfall gauges in Sergipe in conjunction with its network of river flow gauging stations.

As described above, daily data for 59 stations is available on the SUDENE database for the period from 1963 to 1984. Monthly data for some of the stations is available until 1991. Recent data across the state is available from EMDAGRO for the period 1985 to 1997, but only as monthly totals. Daily data for 6 of the ANEEL stations is available for periods of over 40 years. The availability of monthly rainfall data is shown in Table-1.15.

In order to study the variation of rainfall across Sergipe, the SUDENE and EMDAGRO data was combined to give a 30 year period (1968-1997) of available monthly rainfall data. In addition, the ANEEL stations were included as the only current source of daily rainfall data. These stations are listed in Table-1.15. The availability of data and the annual average of the raw data for each station are also shown.

Table-1.15 Availability of Monthly Rainfall Data (1968 – 1997)

Poly No.	SUDENE Post No.	Station Name	Average 1968 - 97 mm/yr	Average 1968 - 97 No. Years	Poly No.	SUDENE Post No.	Station Name	Average 1968 - 97 mm/yr	Average 1968 - 97 No. Years
1	389 4341	Caninde do S. Francisco	541.8	28	16	481 5501	Campo do Brito	1267.7	23
*	389 4666	Poco Redondo	559.0	23	17	ANEEL	Santa Rosa de Lima	1196.7	30
2	389 5848	Porto da Folha	583.3	26	*	481 5667	Laranjeiras	1277.5	23
3	480 4093	Monte Alegre de Sergipe	814.8	20	18	ANEEL	Belem	1539.4	30
4	480 4761	Carira	784.2	28	19	481 5891	Aracaju (inc. Airport)	1574.7	27
5	480 5282	Itabi	962.2	29	20	481 6211	Japaratuba	1497.1	28
6	480 5418	Nossa Senhora da Gloria	807.2	30	*	482 4155	Riacho do Dantas	1075.2	20
7	480 5595	Aquidaba	997.3	26	21	482 4303	Tobias Barreto	868.6	21
8	ANEEL	Propria	813.0	29	22	482 4467	Pedrinhas	1571.5	28
9	480 6971	Pacatuba	1318.8	28	23	482 4545	Itabaianinha	1070.0	28
10	481 3462	Poco Verde	696.7	25	24	482 4574	Araua	987.0	28
11	481 4194	Frei Paulo	944.8	29	*	482 4732	Tomar do Geru	1123.7	14
12	481 4443	Simao Dias	989.8	29	25	482 4768	Umbauba	1280.9	25
13	481 4868	Lagarto	1164.8	29	*	482 4949	Cristinapolis	1349.2	21
*	481 5016	Ribeirópolis	928.5	29	26	482 5062	Sao Cristovao	1515.1	28
14	481 5057	Nossa Senhoras das Dores	1093.5	29	27	ANEEL	Salgado	1396.8	28
15	ANEEL	Capela	1301.2	30	28	ANEEL	Estancia	1651.8	30
*	481 5319	Itabaiana	896.6	28	29	483 4098	Indiaroba	1602.5	24
*	481 5342	Malhador	1397.9	25					

Notes: *: not included for Thiessen Polygons, No. Years : number of years with complete data

1.3.5 Rainfall Characteristics

(1) Variation of Annual Rainfall

Annual average rainfall was calculated for the 29 selected rainfall stations. The annual average isohyetal map based on the available rainfall data for the 30-year period from 1968 to 1997 is shown in Figure-1.5. The location of the 29 stations is also indicated.

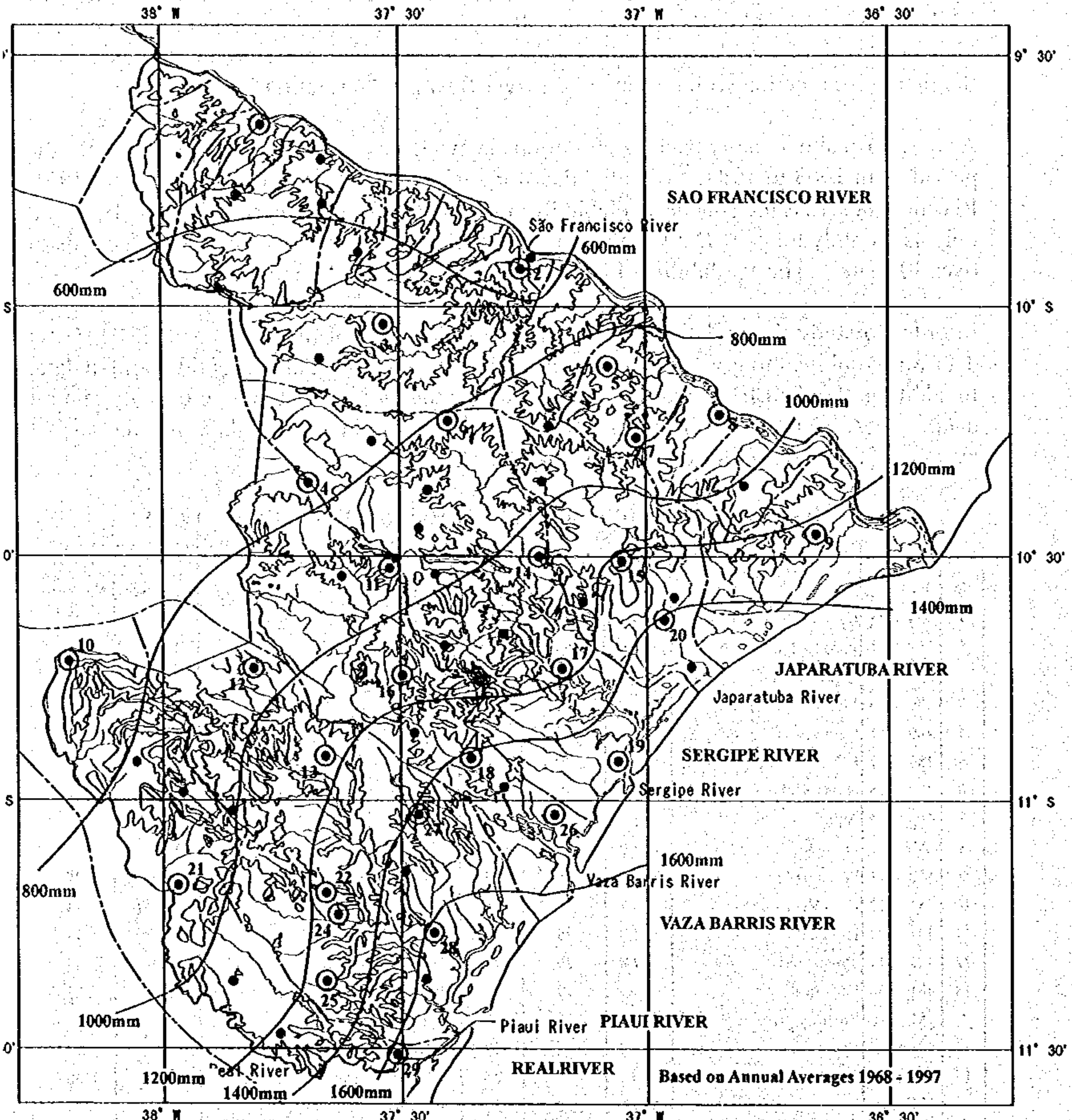


Figure-1.5 Annual Average Isohyetal Map and Location of Rainfall Stations

The variation in annual rainfall for four typical rainfall stations is shown in Figure-1.6. The four stations selected illustrate the different climate regions described previously; namely Caninde do Sao Francisco in the Semi-Arido region (annual average rainfall = 538 mm/year), Nossa Senhora das Dores in the Agreste region (1,098 mm/year), and Aracaju (1,514 mm/year) and Estancia (1,652 mm/year) in the Leste region. From Figure-1.6, it can be seen that there is considerable variation in total annual rainfall from one year to the next – for example at Caninde, some years have as little as 200 mm of rainfall (less than 40% of the long term average) whereas others have 800-900 mm. This trend is particularly noticeable in the Sertao region but can also be seen in the Agreste and Leste regions where the rainfall in dry years is around 50-60% of the long-term average.

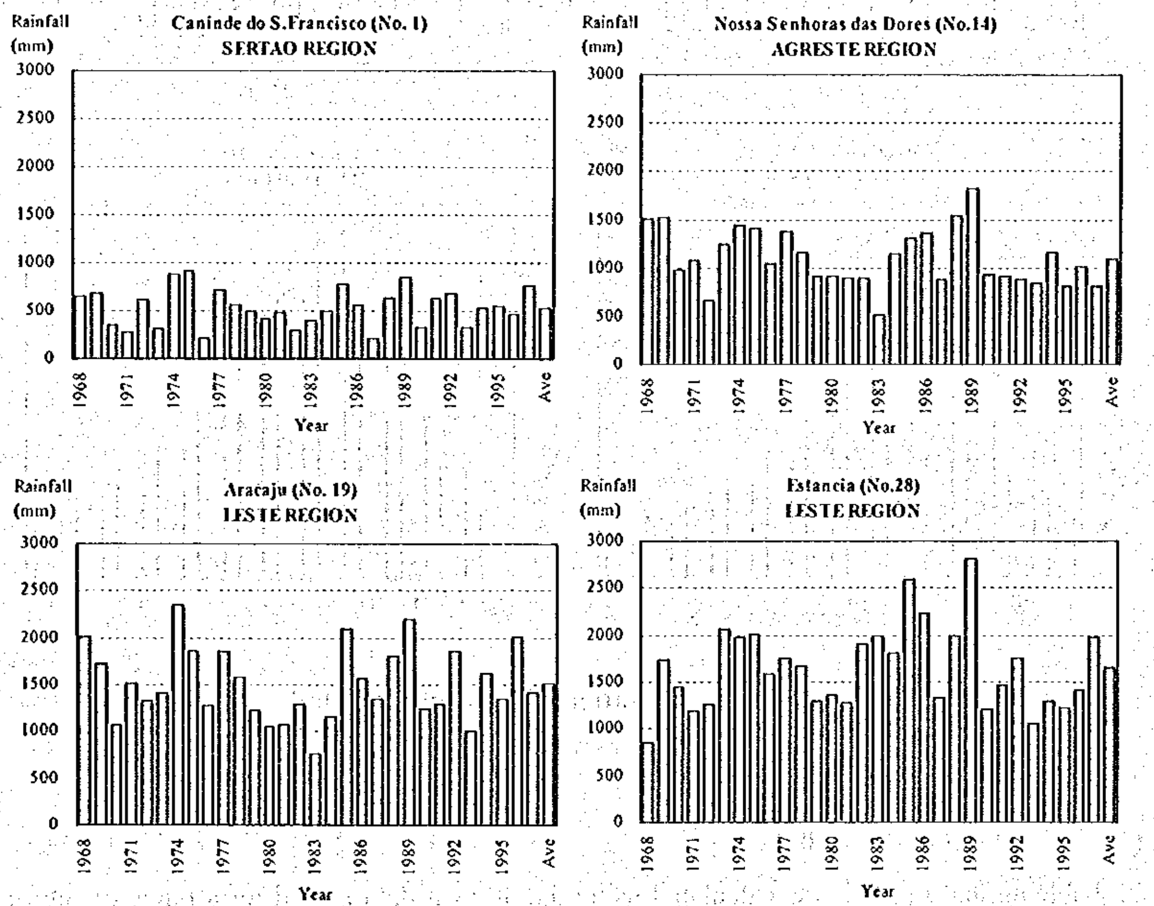


Figure-1.6 Variation of Annual Rainfall

(2) Variation of Monthly Rainfall

The variation in monthly average rainfall for the four typical rainfall stations is shown in Figure-1.7. As described in the section on meteorological data, the year is clearly divided into a rainy winter season (April to July) and a dry summer season (October to January) in Sergipe. This seasonal variation is observed at all the rainfall stations across Sergipe and is clearly shown in Figure-1.7.

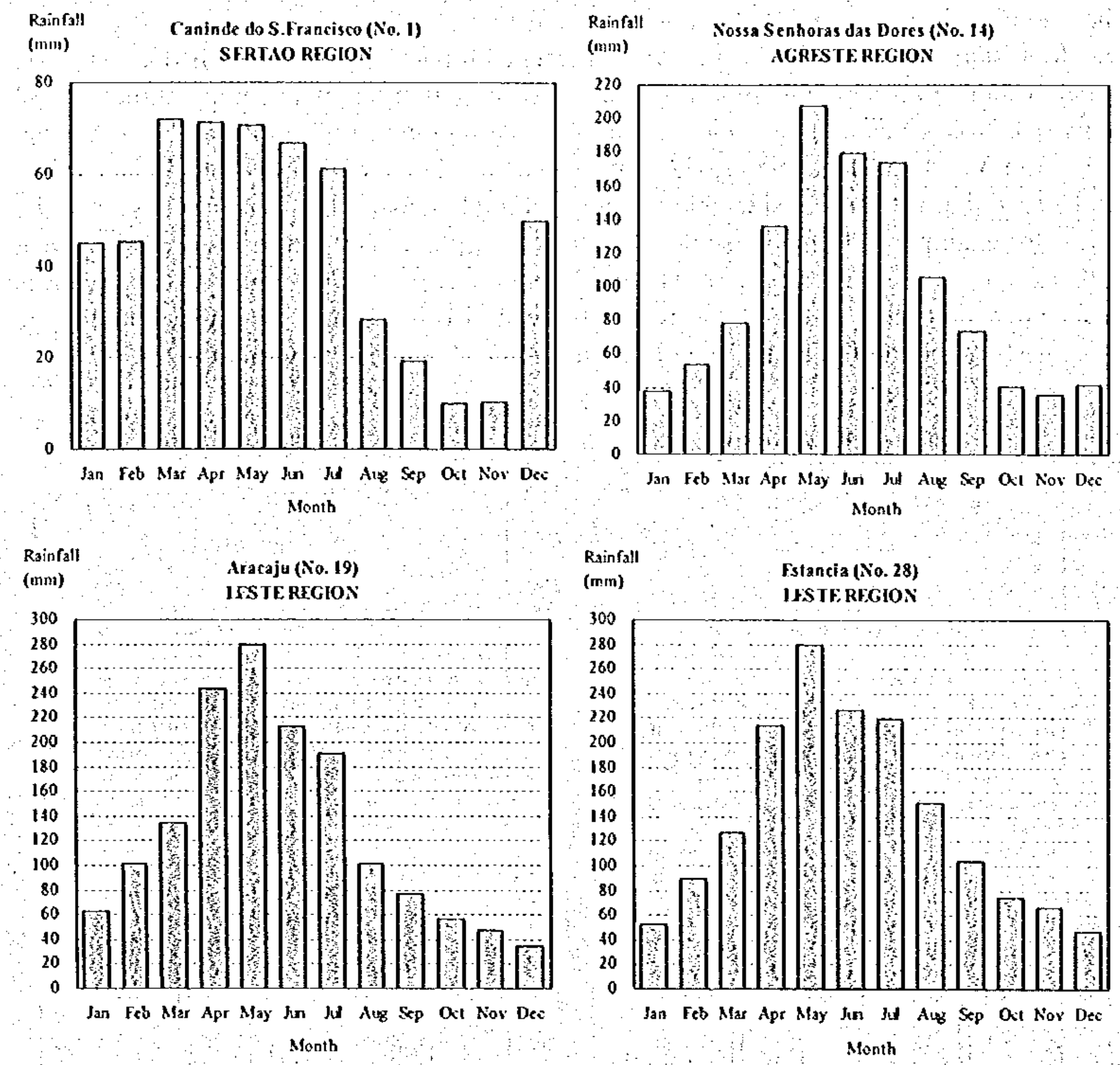


Figure-1.7 Variation of Monthly Rainfall

(3) Probable Rainfall

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 and those for all 29 stations are shown in Table-1.16.

Table-1.16 Minimum and Maximum Probable Annual Rainfall

Unit: mm/year

No.	1		2		3		4		5		6		7		8	
Station Name	Caninde do S. Francisco		Porto da Folha		Monte Alegre de Sergipe		Carira		Itabi		Nossa Senhora da Gloria		Aquidaba		Propria	
Ann. Ave.	538.0		588.0		814.9		769.2		966.2		807.2		1061.7		813.0	
Rtn Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	454.3	621.7	498.0	678.0	680.5	949.4	676.7	861.6	838.9	1093.5	713.5	900.8	910.0	1213.4	689.8	930.3
4	406.9	669.1	447.0	729.0	604.4	1025.5	624.4	913.9	766.9	1165.5	660.5	953.8	824.1	1299.3	621.7	998.4
5	374.5	701.5	412.1	764.0	552.2	1077.7	588.5	949.8	717.5	1214.9	624.2	990.1	765.2	1358.2	575.0	1045.1
10	289.0	787.0	320.1	855.9	414.9	1215.0	494.0	1044.3	587.5	1344.9	528.6	1085.8	610.2	1513.2	452.1	1167.9
15	246.3	829.7	274.2	901.8	346.3	1283.5	446.9	1091.4	522.6	1409.8	480.8	1133.5	532.9	1590.5	390.8	1229.2
20	218.4	857.6	244.1	931.9	301.4	1328.4	416.1	1122.3	480.1	1452.3	449.6	1164.8	482.3	1641.1	350.7	1269.4
25	197.8	878.2	222.0	954.0	268.4	1361.5	393.3	1145.0	448.8	1483.6	426.6	1187.8	445.0	1678.4	321.1	1298.9
30	181.6	894.4	204.5	971.5	242.3	1387.6	375.4	1162.9	424.1	1508.3	408.4	1206.0	415.5	1707.9	297.7	1322.3
40	157.2	918.8	178.2	997.8	203.1	1426.8	348.4	1189.9	387.0	1545.4	381.1	1233.3	371.3	1752.1	262.7	1357.4
50	138.9	937.1	158.6	1017.4	173.8	1456.1	328.3	1210.0	359.3	1573.1	360.7	1253.6	338.2	1785.2	236.5	1383.6
100	86.0	990.0	101.6	1074.4	88.7	1541.2	269.8	1268.6	278.7	1653.7	301.4	1312.9	242.2	1881.2	160.3	1459.7

No.	9		10		11		12		13		14		15		16	
Station Name	Pacatuba / Neopolis		Poco Verde		Frei Paulo		Simao Dias		Lagarto		Nossa Senhoras das Dores		Capela		Campo do Brito	
Ann. Ave.	1312.9		675.7		940.5		976.1		1157.0		1098.4		1301.2		1250.5	
Rtn Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	1176.8	1449.0	588.0	763.3	833.9	1047.1	872.6	1079.6	962.6	1351.4	972.2	1224.7	1148.1	1454.2	1084.4	1416.6
4	1099.7	1526.0	538.4	813.0	773.6	1107.4	814.0	1138.1	852.6	1461.4	900.7	1296.2	1061.5	1540.9	990.3	1510.7
5	1046.9	1578.8	504.4	847.0	732.2	1148.8	773.9	1178.3	777.2	1536.9	851.7	1345.2	1002.0	1600.3	925.9	1575.2
10	907.8	1717.9	414.8	936.6	623.3	1257.7	668.2	1284.0	578.6	1735.4	722.7	1474.2	845.7	1756.7	756.2	1744.9
15	838.5	1787.2	370.1	981.2	569.0	1312.0	615.4	1336.8	479.5	1834.5	658.3	1538.5	767.7	1834.7	671.5	1829.5
20	793.0	1832.7	340.8	1010.5	533.4	1347.6	580.9	1371.3	414.6	1899.4	616.2	1580.7	716.5	1885.8	616.0	1885.0
25	759.6	1866.1	319.3	1032.1	507.2	1373.8	555.5	1396.7	366.9	1947.1	585.2	1611.7	679.0	1923.4	575.2	1925.8
30	733.1	1892.6	302.3	1049.1	486.5	1394.5	535.3	1416.9	329.1	1984.9	560.6	1636.2	649.2	1953.1	542.9	1958.1
40	693.4	1932.3	276.7	1074.7	455.4	1425.6	505.2	1447.0	272.4	2041.6	523.8	1673.1	604.6	1997.8	494.5	2006.6
50	663.8	1961.9	257.6	1093.8	432.2	1448.8	482.6	1469.6	230.1	2083.9	496.3	1700.5	571.2	2031.1	458.3	2042.7
100	577.6	2048.1	202.1	1149.3	364.8	1516.2	417.1	1535.1	107.0	2207.0	416.4	1780.5	474.3	2128.0	353.1	2147.9

No.	17		18		19		20		21		22		23		24	
Station Name	Santa Rosa de Lima		Belem		Aracaju (inc. Airport)		Japaratuba		Tobias Barreto		Pedrinhas		Itabaianinha		Araua	
Ann. Ave.	1196.7		1539.4		1514.0		1526.3		830.1		1548.9		1053.2		991.3	
Rtn Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	1046.0	1347.4	1382.2	1696.6	1347.6	1680.4	1347.3	1705.2	673.3	986.9	1343.0	1754.8	923.7	1182.6	855.0	1127.7
4	960.7	1432.7	1293.2	1785.6	1253.4	1774.6	1246.0	1806.5	584.5	1075.7	1226.5	1871.3	850.4	1255.9	777.8	1204.9
5	902.2	1491.2	1232.2	1846.6	1188.8	1839.1	1176.5	1876.0	523.6	1136.5	1146.6	1951.2	800.2	1306.1	724.9	1257.8
10	748.3	1645.1	1071.6	2007.2	1018.8	2009.1	993.7	2058.8	363.4	1296.8	936.3	2161.5	668.0	1438.4	585.5	1397.2
15	671.5	1721.9	991.5	2087.3	934.0	2093.9	902.5	2150.0	283.5	1376.7	831.3	2266.5	602.0	1504.4	516.0	1466.7
20	621.2	1772.3	939.0	2139.8	878.5	2149.5	842.7	2209.8	231.1	1429.1	762.6	2335.2	558.8	1547.6	470.5	1512.2
25	584.1	1809.3	900.4	2178.4	837.6	2190.4	798.8	2253.8	192.6	1467.6	712.0	2385.8	527.0	1579.4	437.0	1545.7
30	554.8	1838.6	869.9	2208.9	805.2	2222.7	764.0	2288.5	162.1	1498.1	672.0	2425.8	501.8	1604.6	410.5	1572.2
40	510.9	1882.5	824.0	2254.8	756.7	2271.2	711.8	2340.7	116.4	1543.8	612.0	2485.8	464.0	1642.3	370.7	1612.0
50	478.1	1915.3	789.8	2289.0	720.5	2307.5	672.8	2379.7	82.2	1577.9	567.2	2530.7	435.9	1670.5	341.0	1641.7
100	382.7	2010.7	690.3	2388.5	615.1	2412.8	559.5	2493.0		1677.2	436.8	2661.0	353.9	1752.4	254.7	1728.0

No.	25		26		27		28		29	
Station Name	Umbauba		Sao Cristovao		Salgado		Estancia		Indiaroba	
Ann. Ave.	1234.0		1485.3		1396.8		1651.8		1612.1	
Rtn Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	1097.3	1370.8	1312.5	1658.1	1238.4	1563.6	1461.4	1842.2	1427.1	1797.2
4	1019.8	1448.2	1214.6	1756.0	1146.4	1655.7	1353.6	1950.0	1322.3	1901.9
5	966.8	1501.3	1147.6	1823.0	1083.2	1718.8	1279.7	2023.9	1250.5	1973.8
10	827.0	1641.0	971.0	1999.6	917.1	1885.0	1085.1	2218.4	1061.4	2162.8
15	757.3	1710.7	882.9	2087.7	834.2	1967.8	988.1	2315.5	967.1	2257.2
20	711.6	1756.4	825.2	2145.4	779.9	2022.1	924.5	2379.1	905.3	2319.0
25	678.1	1790.0	782.7	2187.8	740.0	2062.1	877.7	2425.8	859.8	2364.4
30	651.5	1816.6	749.1	2221.4	708.4	2093.7	840.7	2462.8	823.9	2400.4
40	611.6	1856.5	698.7	2271.8	660.9	2141.1	785.2	2518.4	769.9	2454.4
50	581.8	1886.3	661.1	2309.5	625.5	2176.5	743.7	2559.8	729.6	2494.6
100	495.2	1972.9	551.7	2418.9	522.6	2279.5	623.2	2680.4	612.4	2611.8

1.4 Hydrology

1.4.1 River Systems

There are six main river systems draining the State of Sergipe; namely, from north to south, Sao Francisco, Japaratuba, Sergipe, Vaza Barris, Piaui and Real rivers, of which basin areas are shown in Table-1.17. The six river systems are shown in Figure-1.8 and are described below:

Table-1.17 River Basin Areas in Sergipe State

River Basin	Total	Sao Francisco	Japaratuba	Sergipe	Vaza Barris	Piaui	Real
Basin Areas (km^2)	22,050	7,276	1,722	3,673	2,559	4,262	2,558
Percentage of Sergipe State	100.0 %	33.0 %	7.8 %	16.7 %	11.6 %	19.3 %	11.6 %
Total River Length (km)	3,734	2,700	124	210	410	150	140

< Sao Francisco River >
Sao Francisco River is the longest entirely national river in Brazil and is the main source of surface water in the Northeast region. Its basin covers a total area of 640,000 km^2. It forms the boundary between the states of Sergipe and Alagoas before flowing into the Atlantic Ocean. The principal tributaries within Sergipe include the Curituba, Jacare, Capivara, Gararu, Canhoba and Betume rivers.

< Japaratuba River >
Japaratuba River is the smallest of the rivers in Sergipe, covering 15 municipalities. Its source is in Feira Nova, about 10 km from the municipality of Gracho Cardoso. The main tributaries are the Japaratuba Mirim on the left and the Siriri on the right.

< Sergipe River >
Sergipe River originates in the State of Bahia, near the border with Sergipe and flows the Atlantic Ocean at Atalaia Nova beach near Aracaju city. The main tributaries are the Socavao, Jacarecica, Cotinguiba and Poxim rivers, all of which are on the right bank of the main Sergipe River.

< Vaza Barris River >
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 152 km is within Sergipe State. The total basin area is 16,229 km^2, the majority of which lies in Bahia State with only 15% or 2,559 km^2 lying within Sergipe State 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.

< Piaui River >
Like Sergipe River, Piaui River also originates in Bahia State close to the border with Sergipe State, at an elevation of about 460 m where it is known as Jacare River. The main tributaries are the Araua on the right bank and the Piauitinga on the left bank.

< Real River >
Real River forms the western border between the states of Sergipe and Bahia flowing for about 140 km from near the municipality of Poco Verde to the Atlantic Ocean at the Piaui river mouth. The total basin area is approximately 4,800 km^2, of which 2,558 km^2 is located in Sergipe. The main tributaries within Sergipe are the Jabiberi and Itamirim rivers.

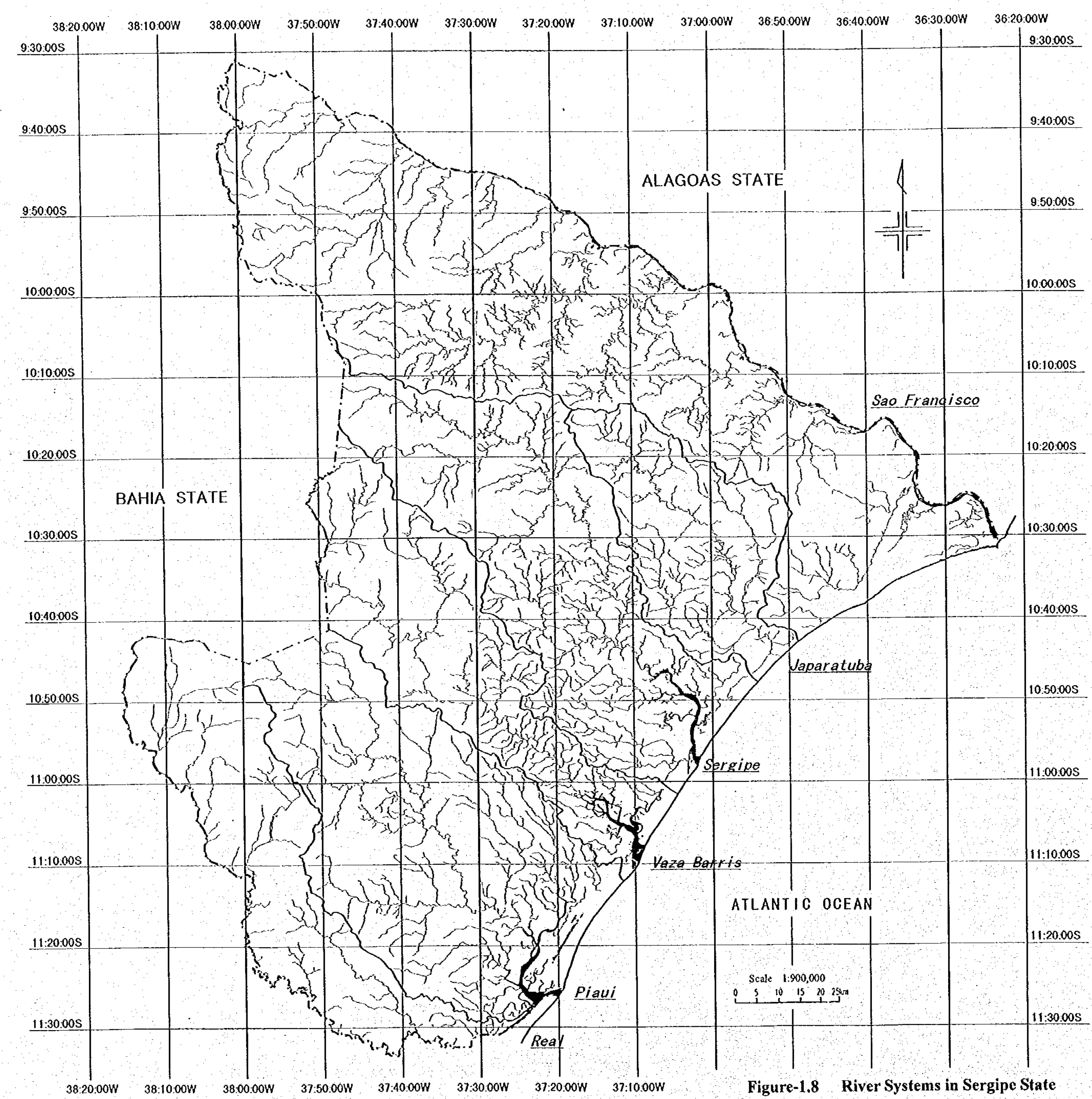


Figure-1.8 River Systems in Sergipe State

1.4.2 Hydrometric Observation Network

The main organization responsible for the collection of river flow data throughout Brazil is ANEEL, the federal electricity generator. Within Sergipe State, ANEEL has 12 operational flow gauging stations. The location of the ANEEL and CHESF flow gauging stations are shown in Figure-1.9.

In addition to these main rivers, both COHIDRO and DESO undertake river flow measurement on an intermittent basis on smaller basins throughout Sergipe. DESO carry out flow gauging at 89 points, mainly in the Leste-Sergipano region. COHIDRO started a program of flow measurement at 44 points between 1995 and 1997 including some non-perennial rivers in the north of the state, but this program has now been suspended due to lack of funds. Neither of these organizations have staff gauges at the flow measurement points so there is no record of daily water level

The availability of daily discharge data at the 12 ANEEL flow gauging stations and the 4 CHESF flow stations on Sao Francisco River is indicated in Table-1.18 below.

Table-1.18 Availability of Discharge Data

No.	CHESF	Station	River	Basin	Period	No. Years	Comments	
1	-	Piranhas	S. Francisco	S. Francisco	1960 – 1997	32	5 years missing	
2	-	P. de Acucar	S. Francisco	S. Francisco	1927 – 1997	70		
3	-	Traipu	S. Francisco	S. Francisco	1986 – 1997	12		
4	-	Propria	S. Francisco	S. Francisco	1927 – 1997	31	Since 1965	
No.	ANEEL	Station	River	Basin	Period	No. Years	H/Q Eqn	Qm
5	497 05000	Propria	Sao Francisco	Sao Francisco	1977 – 1995	19	6	157
6	500 40000	Japaratuba	Japaratuba	Japaratuba	1969 – 1993	25	3	232
7	500 42000	Faz. Pao de Acucar	Japaratuba Mirim	Japaratuba	1973 – 1993	19	1	388
8	500 43000	Faz. Cajueiro	Japaratuba Mirim	Japaratuba	1973 – 1993	19	1	394
9	500 46000	Siriri	Siriri	Japaratuba	1973 – 1993	19	2	421
10	500 47000	Rosario do Catete	Siriri	Japaratuba	1973 – 1993	19	1	425
11	500 80000	Santa Rosa de Lima	Sergipe	Sergipe	1972 – 1993	13	1	227
12	501 69000	Ponte SE-302	Vaza Barris	Vaza Barris	1985 – 1993	9	1	55
13	501 91000	Faz. Belem	Vaza Barris	Vaza Barris	1971 – 1993	23	3	296
14	502 30000	Estancia	Piauitinga	Piaui	1950 – 1993	44	1	240
15	502 50000	Faz. Tourao	Real	Real	1978 – 1993	16	2	83
16	502 90000	Itanhi (Bahia)	Real	Real	1966 – 1993	26	1	164

Notes: No. Years: number of years complete daily data
H/Q Eqn: number of H/Q equations
Qm: number of discharge measurements

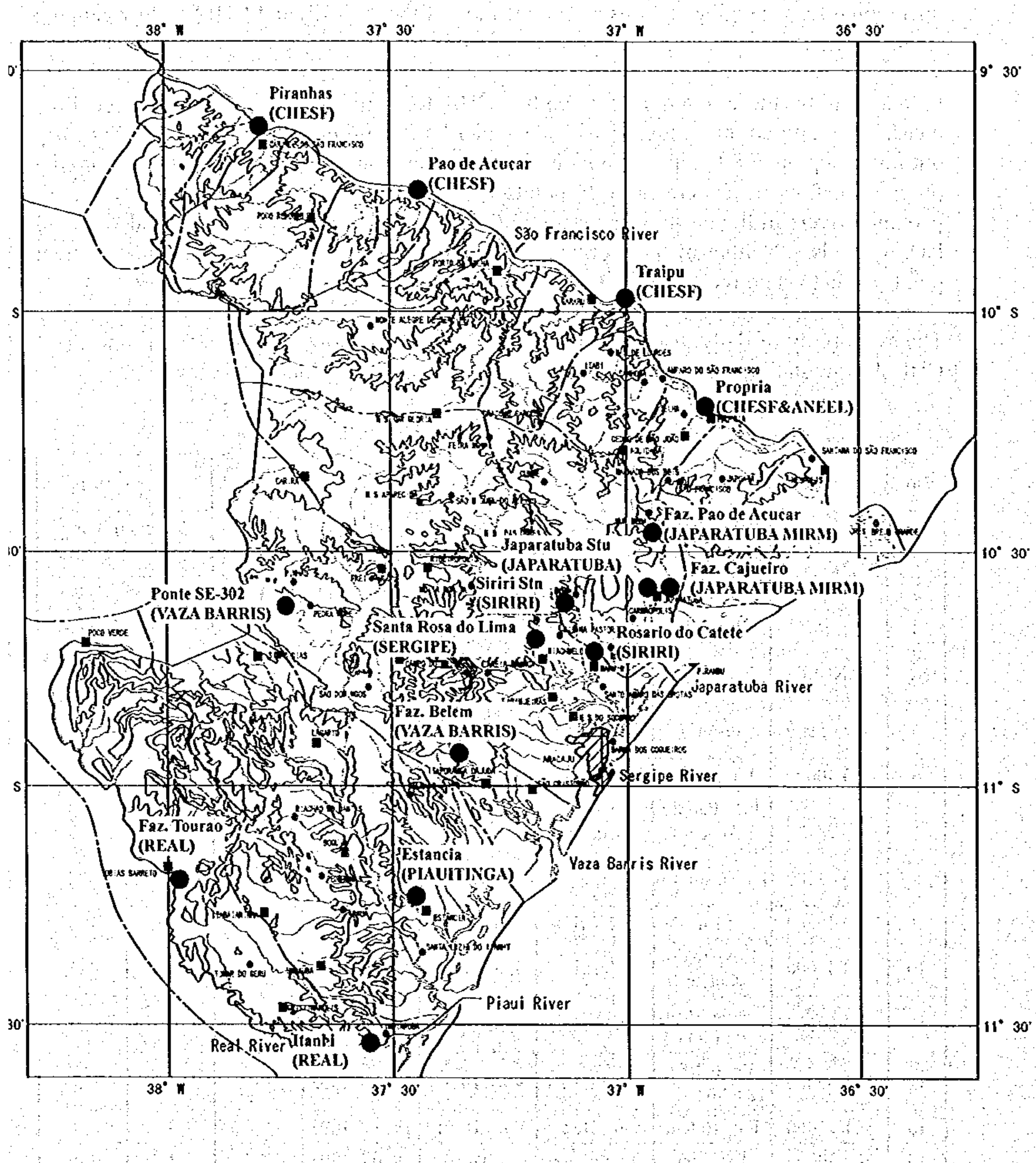


Figure-1.9 Location of River Flow Gauging Stations

1.4.3 River Flow Conditions

(1) Variation of Monthly Discharge

The annual variation of discharge and specific discharge for each of the six main river systems is shown in Figure-1.10. The ratio of maximum to minimum discharge (or coefficient of river regime) for the five rivers except Sao Francisco River can be seen to vary from 4.88 for Piauitinga River, which has a high base flow from groundwater springs, to 12.50 for Real River which has most of its upper catchment in the semi-arid interior. The values of coefficient of river regime for the other rivers are 7.62 for Vaza Barris River at Fazenda Belem, 9.54 for Japaratuba River and 11.25 for Sergipe River. The variation of discharge in Sao Francisco River is almost the opposite of the other five rivers, presumably because of the regulatory effects of the dams and reservoirs constructed in the upstream. Also the ratio of maximum to minimum discharge is much lower at 2.13.

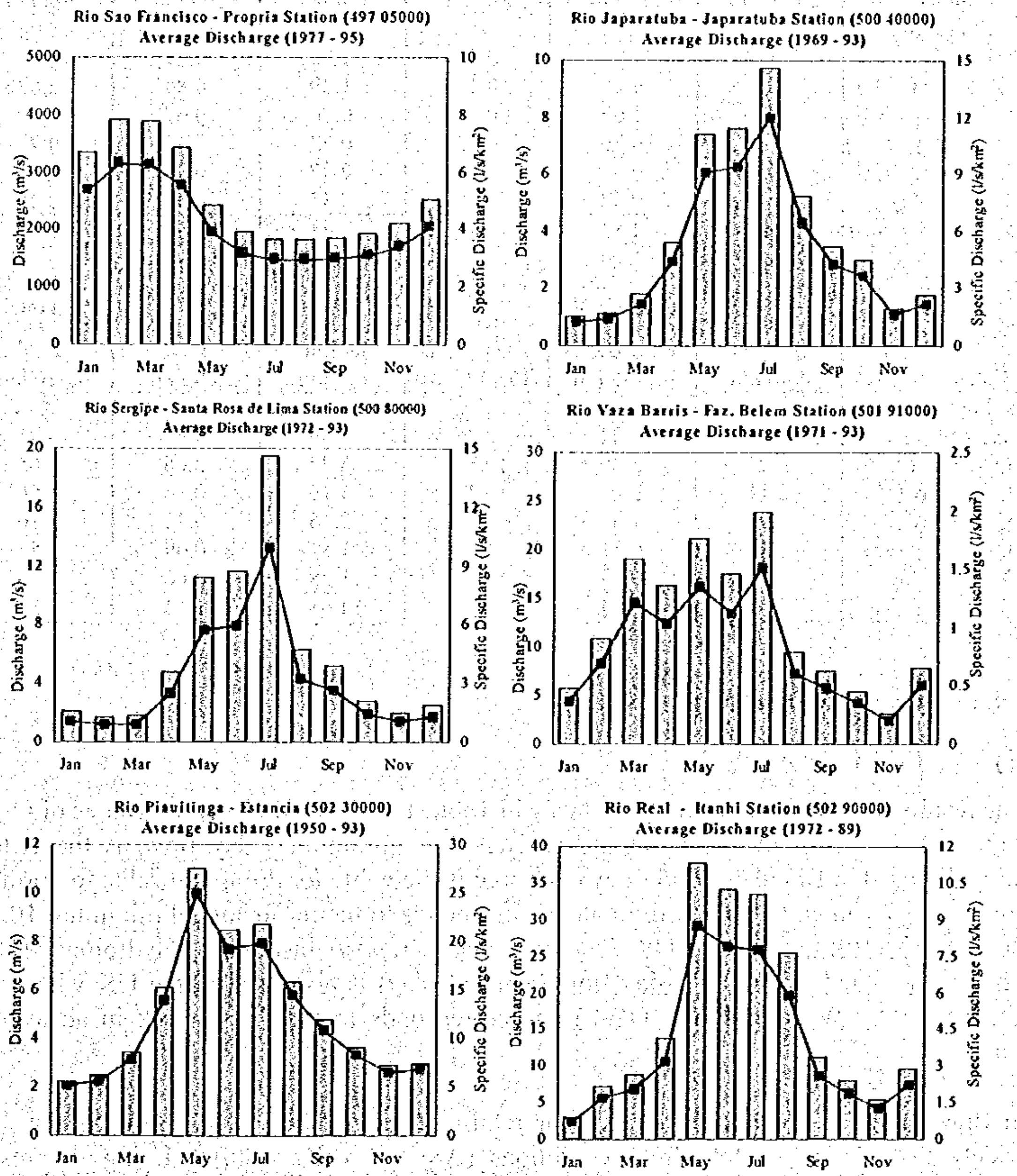


Figure-1.10 Monthly Average Discharge at ANEEL Stations

(2) Flow Regime Analysis

Daily discharge data from the ANEEL stations was used for flow regime analysis in the study hydrological database. The average results are summarized in Table-1.19 for the six river basins in Sergipe State. In addition to the flow regime, mean annual minimum 7-day flow (Min. Q 7-day) was also calculated as this is the normal measure of low flow for rivers in Brazil – refer to low flow analysis later.

Table-1.19 Results of Flow Regime Analysis

River Basin	Sao Francisco	Japaratuba				
Station Name	Propria	Japaratuba	Fazenda Acucar	Fazenda Cajueiro	Siriri	Rosario do Catete
River Name	Sao Francisco	Japaratuba	Japaratuba Mirim	Japaratuba Mirim	Siriri	Siriri
Catchment Area	623,500 km²	815 km²	201 km²	315 km²	160 km²	302 km²
Flows (m³/s)						
Average	2,574	3.94	0.66	1.70	0.81	3.29
Q-95 day (25%)	2,801	4.28	0.47	1.29	0.84	2.83
Q-185 day (50%)	1,990	1.62	0.23	0.76	0.67	1.49
Q-275 day (75%)	1,743	0.79	0.13	0.52	0.42	0.77
Q-355 day (95%)	1,650	0.43	0.06	0.37	0.34	0.54
Min. Q7-day	1,643	0.42	0.06	0.33	0.33	0.45
Spec. Q (l/s/km²)	4.13	4.83	3.30	5.41	5.08	10.89
River Basin	Sergipe	Vaza Barris		Piaui	Real	
Station Name	Santa Rosa de Lima	Ponte SE-302	Fazenda Belem	Estancia	Fazenda Tourao	Itanhi (Bahia)
River Name	Sergipe	Vaza Barris	Vaza Barris	Piauitinga	Real	Real
Catchment Area	1960 km²	14,435 km²	15,740 km²	440 km²	2,895 km²	4,320 km²
Flows (m³/s)						
Average	5.83	4.44	12.36	5.46	3.27	16.41
Q-95 day (25%)	4.94	3.49	10.88	5.27	2.06	12.65
Q-185 day (50%)	2.11	2.02	5.22	3.19	0.36	5.56
Q-275 day (75%)	0.92	1.34	2.92	2.15	0.22	3.16
Q-355 day (95%)	0.48	0.86	1.43	1.54	0.09	1.55
Min. Q7-day	0.52	0.82	1.26	1.28	0.06	1.46
Spec. Q (l/s/km²)	2.97	0.31	0.79	14.65	1.13	3.80

Note : Vaza Barris - Spec. Q for Basin in Sergipe = 3.96 l/s/km²

1.4.4 Probable Discharge

(1) Low Flow Analysis

The results for low flow shown previously in Table-1.19 show the average values of Q-355 day discharge from the flow regime analysis and minimum 7-day flow as the criteria normally used in Brazil. Q-355 day discharge is the value for drought discharge normally adopted in Japan and also approximately corresponds to the mean annual minimum 10-day flow, MAM(10), used in the UK *Low flow studies report* (Institute of Hydrology, 1980). The mean annual minimum 7-day flow (Min.Q 7-day) is also used in the UK where it is known as Dry Weather Flow (DWF) and corresponds to the driest week in an average summer.

In Brazil (and in the USA), the 10-year return period 7-day flow (Q7, 10) is the most widely used index of low flow conditions (ASCE-TASK, 1980). Using the results obtained from the database analysis, the 10-year return period 7-day flow was calculated for each of the 12 ANEEL stations. The results are given in Table-1.20.

Table-1.20 Results of Low Flow Analysis

Unit: m^3/s

River Basin	Sao Francisco	Japaratuba				
Station Name	Propria	Japaratuba	Fazenda Acucar	Fazenda Cajueiro	Siriri	Rosario do Catete
Q-355 day (95%)	1,650	0.43	0.06	0.37	0.34	0.54
Min. Q7-day	1,643	0.42	0.06	0.33	0.33	0.45
(Q7, 10)	1,279	0.08	0.02	0.21	0.14	0.09
River Basin	Sergipe	Vaza Barris		Piaui	Real	
Station Name	Santa Rosa de Lima	Ponte SE-302	Fazenda Belem	Estancia	Fazenda Tourao	Itanhi (Bahia)
Q-355 day (95%)	0.48	0.86	1.43	1.54	0.09	1.55
Min. Q7-day	0.52	0.82	1.26	1.28	0.06	1.46
(Q7, 10)	0.09	0.38	0.46	0.86	0.00	0.34

(2) Flood Flow Analysis - Vaza Barris Dam

Annual maximum daily discharges for the 23-year data series at Fazenda Belem gauging station was used in the flood flow analysis, the results of which are shown in Table-1.21 below. Probable discharge was calculated from the Thomas using four different methods – the least squares and moment methods (Thomas), the Iwai method (commonly used in Japan) and the Gumbel method. The best fit or the maximum was obtained using the recognized Thomas (Moment) method and these results were adopted in the design of the dam spillway.

Table-1.21 Probable Flood Discharge – Vaza Barris: Fazenda Belem

Year	Max Daily Discharge (m^3/s)	Rank	Year	Sorted Data	Thomas Plot	Return Period (Year)	Probable Discharge (m^3/s)
1971	139.0	1	1975	647.0	0.955	1000	1554.6
1972	154.0	2	1974	437.0	0.909	500	1343.8
1973	426.0	3	1973	426.0	0.864	200	1091.6
1974	437.0	4	1981	340.0	0.818	150	1018.3
1975	647.0	5	1989	309.0	0.773	100	919.6
1976	102.0	6	1988	285.0	0.727	80	867.4
1977	274.0	7	1977	274.0	0.682	70	836.9
1978	266.0	8	1978	266.0	0.636	60	802.4
1979	138.0	9	1985	183.0	0.591	50	762.4
1980	121.0	10	1984	176.0	0.545	40	714.8
1981	340.0	11	1992	174.0	0.500	30	655.5
1982	137.0	12	1972	154.0	0.455	20	575.6
1983	141.0	13	1983	141.0	0.409	10	448.3
1984	176.0	14	1971	139.0	0.364	8	409.6
1985	183.0	15	1979	138.0	0.318	7	386.9
1986	64.0	16	1982	137.0	0.273	6	361.2
1988	285.0	17	1980	121.0	0.227	5	331.2
1989	309.0	18	1976	102.0	0.182	4	295.2
1990	101.0	19	1990	101.0	0.136	3	249.7
1991	66.1	20	1991	66.1	0.091	2	185.7
1992	174.0	21	1986	64.0	0.045		

1.5 Hydrogeology

1.5.1 Hydrogeological Classification

Hydrogeological feature of the study area is dominated by geological condition. Hydrogeological classification should follow the geological classification. Table-1.22 shows hydrogeological classification and Figure-1.11 shows its distribution.

Table-1.22 Hydrogeological Unit the Study Area

Age		Stratigraphy	Rock Faces	Hydraulic Characteristics
Cenozoic	Quaternary	Alluvium	Clay, silt, sand, gravel	Unconfined stratum water
	Tertiary	Barreiras Formation	Claystone, siltstone, sandstone, conglomerate	Unconfined / confined stratum water
Mesozoic |	Cretaceous |	Tucano Basin	Limestone, sandstone, shale	Unconfined / confined stratum water
Palaeozoic	Silurian	Sergipe Basin	Limestone, sandstone, shale	Unconfined / confined stratum water
Late Proterozoic		Caninde Domain	Gabbro, amphibolite, metavolcanic rock, ultramafic rock	Unconfined fissure water
		Poco Redondo Domain	Granites, migmatite, gneiss	Unconfined fissure water
		Maranco Domain	Granites, metaconglomerate, phyllite	Unconfined fissure water
		Macurure Domain	Micaschist, quartzite, gabbro	Unconfined fissure water
Middle Proterozoic - late Proterozoic		Vaza-Barris Domain	Carbonate, phyllite, argillaceous rock	Unconfined fissure water
		Estancia Domain	Sandstone, argillaceous rock Conglomerate.	Unconfined fissure water
Archaean - early Proterozoic		Sao Francisco Craton	Gneiss, migmatite, granodiorite.	Unconfined fissure water
		Itabaiana Dome Craton	Migmatite.	Unconfined fissure water

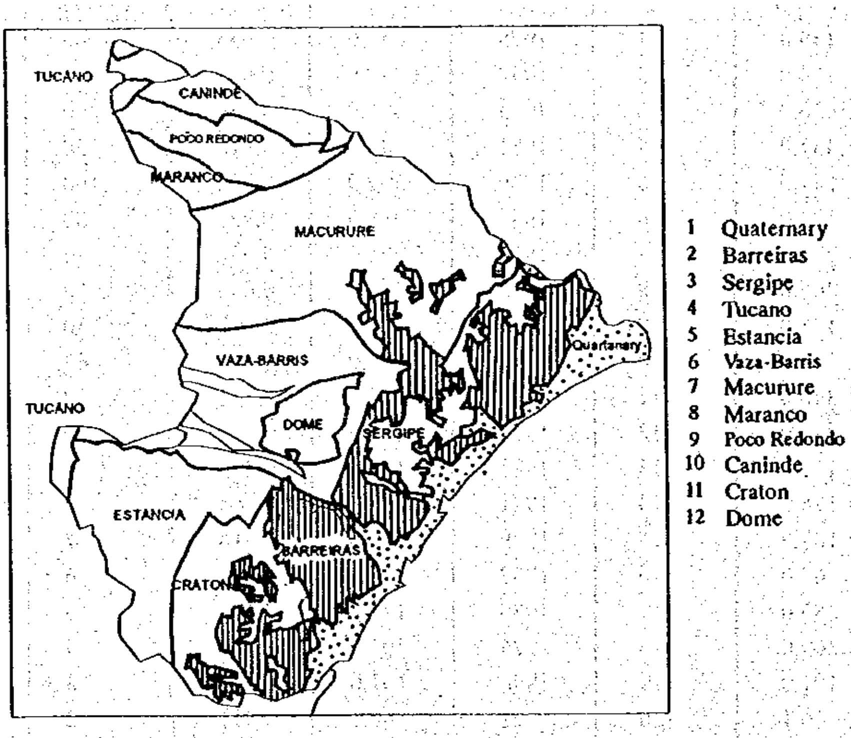


Figure-1.11 Hydrogeological Unit

1.5.2 Current Groundwater Use and Hydrogeological Information

Groundwater development has been carried out mainly by means of drilling deep wells in Sergipe State. More than 4,000 deep wells and great number of shallow wells were drilled so far. Other than wells, groundwater is used from springs. Characteristics of deep wells are described below based on the result of existing data analysis.

< Distribution of deep wells by municipality >
The number of existing deep wells is different by municipality. Some municipalities have many deep wells but others not. It is notable that tremendous numbers of deep wells were drilled in the past in Itabaiana municipality (758 wells) and Lagarto municipality (289 wells). However, the number of deep wells is usually less than 50 in most of municipalities. The number of deep wells depends on water demand and water quality by municipality.

< Basic capacity of deep well >
Yield, specific capacity, success rate and water quality are the most important parameters of deep well. Representative values of these parameters are shown in Table-1.23. It is clear that well capacity is different by each geological unit, and also groundwater development potential seems to be different by each geological unit. Especially difference in water quality is dominant. Generally in terms of water quality, deep wells in sedimentary rock area (Cretaceous and Quaternary) is more excellent than deep wells in crystalline rock area in quality and quantity. Barreiras formation that distributes in wide area of the Study area, is out of Table-1.23 because of its poor capacity for deep wells.

Table-1.23 Basic Capacity of Deep Well

Aquifer	Yield (m^3/day)	Specific Capacity (m^3/day/m)	Success rate (%)	Rate of fresh water (%)
Alluvium covering Sergipe Basin Alluvium covering Craton	600	140	95	100
Tucano Basin	100	4	60	60
Sergipe Basin covering Barreiras	140	17	80	85
Sergipe Basin outcropping	140	13	70	60
Caninde Domain	40	2	45	10
Poco Redondo Domain	40	2	45	10
Maranco Domain	40	2	45	10
Macurure Domain	40	2	60	15
Vaza-Barris Domain	80	4	75	40
Estancia Domain	50	3	70	50
Sao Francisco Craton covered by Barreiras	70	4	85	90
Sao Francisco Craton outcropping	40	2	75	30
Itabaiana Dome Craton	70	4	75	35

< Groundwater quality >
It is notable that groundwater in Precambrian rock usually contains high salinity in the study area. Especially chlorine (Cl) concentration is high, usually more than 250 mg/l. Groundwater in Maranco Domain and Macurure Domain, which belong to Precambrian rock, shows especially high Cl with more than 250 mg/l in most of deep wells. On the other hand, groundwater in Itabaiana Dome, which also belongs to Precambrian rock, shows less Cl concentration, but some wells show Cl of less than 250 mg/l. Compared with Precambrian rock, sedimentary rock (Cretaceous, Tertiary and Quaternary) in the Study area has groundwater of lower Cl concentration of usually less than 250 mg/l.

< Depth and diameter of deep wells >

The depth of most wells ranges 40 m to 80 m and 60 m in average. Diameter of deep wells is 6 inch (15 cm).

< Groundwater static level >

Groundwater static level is usually less than 15 m from ground surface, and the average is 10 m.

< Number of deep wells drilled by aquifer >

The number of deep wells by aquifer is shown in Table-1.24. In the past, many deep wells were drilled in the area covered by Barreiras Formation, and in the area of Itabaiana Dome, Estancia Belt and Vaza-Barris Belt.

Table-1.24 Number of Deep Wells Drilled by Aquifer

Hydrogeological unit	Number	Hydrogeological unit	Number
Quaternary	13	Vaza-Barris Domain	599
Area covered by Barreiras Formation	1,078	Macurure Domain	247
Sergipe Basin	272	Maranco Domain	108
Tucano Basin	97	Sao Francisco Craton	25
Estancia Domain	603	Itabaiana Dome Craton	950

1.5.3 Groundwater Field Survey

Groundwater level and water quality were observed for all Sergipe State by the Study Team. The observation was carried out twice, the first observation was in September 1998, and the second one was in November 1998. Observed items were below;

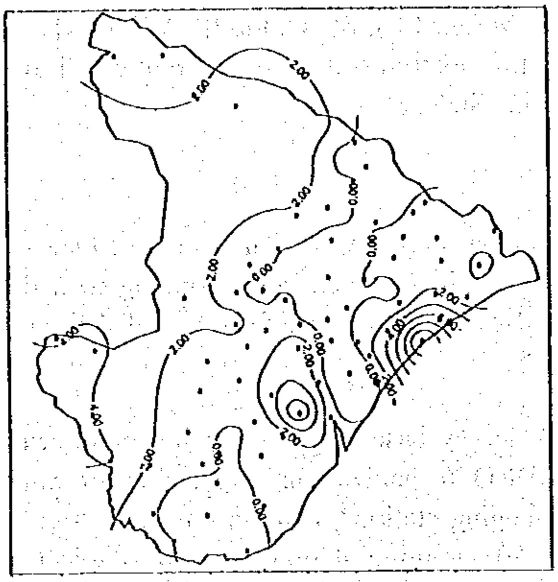
- Groundwater level
- Water quality: pH, temperature, electric conductivity, dissolved oxygen

< Groundwater level >

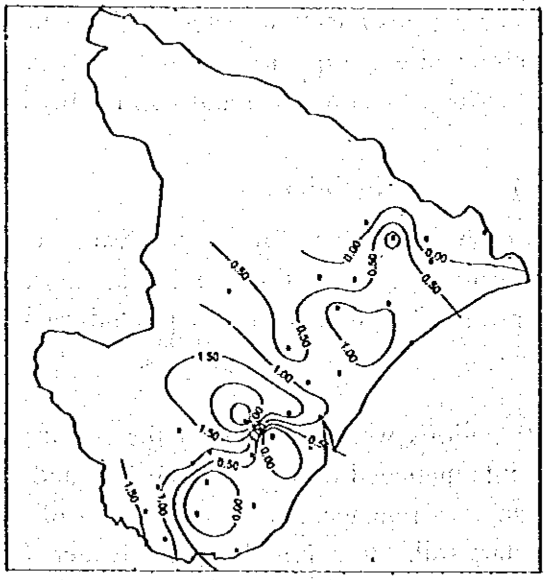
The twice observation in different season was done in order to obtain groundwater level fluctuation. Groundwater level was measured for 70 deep wells and 30 shallow wells. The result is shown in Figure-1.12. As shown in this figure, groundwater level fluctuation is about 1m to 2 m in whole Sergipe State during observation period.

< Water quality >

Measured electric conductivity is shown in Figure-1.13. Electric conductivity has strong relationship with salinity. The relationship is approximated as Conductivity (μS/cm) = 0.5 x Cl (mg/l). As shown in this figure, electric conductivity, namely salinity, becomes gradually higher from the coastal area to the inland area.

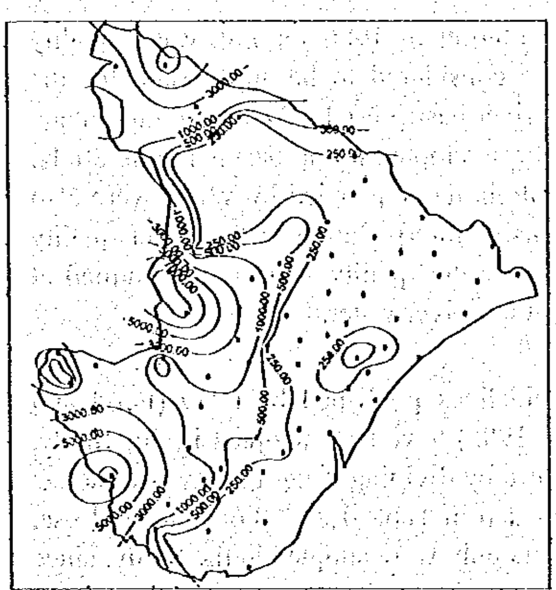


Groundwater Level Draw Down of Deep Wells during Sep. and Nov. 1998 (m)

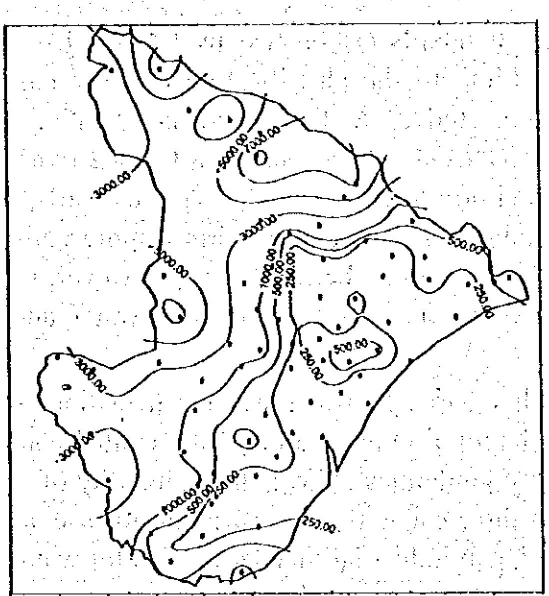


Groundwater Level Draw Down of Shallow Wells during Sep. and Nov. 1998 (m)

Figure-1.12 Groundwater Level Draw Down



Electric Conductivity of Groundwater in September 1998 (μS/cm)



Electric Conductivity of Groundwater in November 1998 (μS/cm)

Figure-1.13 Result of Field Groundwater Survey

1.6 Water Quality

1.6.1 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.

(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. Figure-1.14 indicates the location of the surface water and groundwater sampling points.

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.

(2) Water Quality Standards

The Standards established by CONAMA 20 Resolution 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-1.25. 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-1.26 shows the upper limit or range of limits adopted by the four organizations mentioned above for the water quality parameters analyzed in this Study.

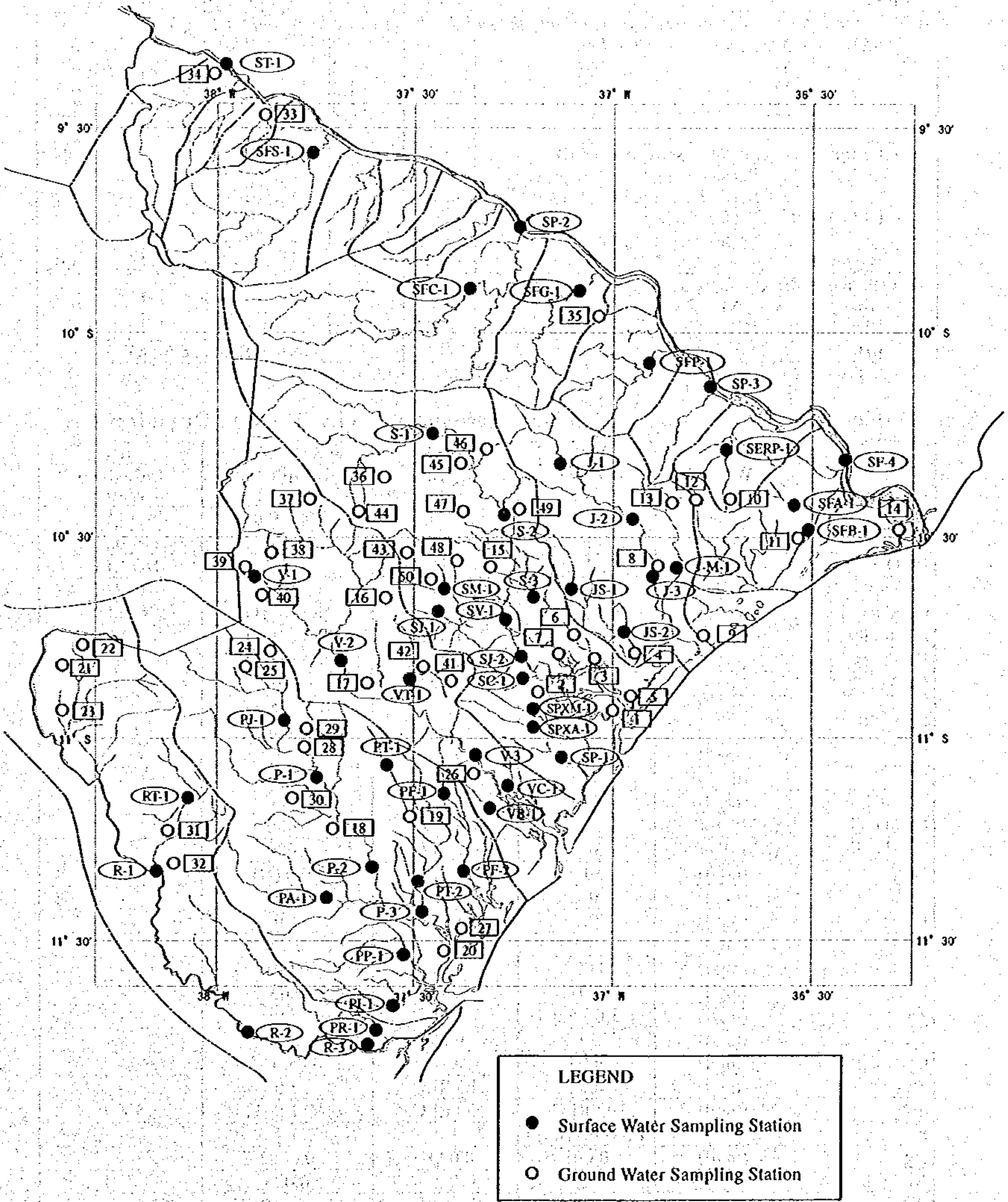


Figure-1.14 Location of the Surface Water and Groundwater Sampling Points

Table-1.25 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*)				
EC_w	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*)				
SAR = 0 – 3 (*Sodium Absorption Rate*)		> 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
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		

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

Table-1.26 Water Quality Standards Recommended by Different Organizations

Organization / Water Use / Parameter		WHO. Drinking Water	FAO Irrigation Water	CONAMA Multiple Use - Class 2 -	JIS Industrial Water
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	-

(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-1.15, Figure-1.16, Figure-1.17 and Figure-1.18 to provide easier understanding of the variations in water quality. Figure-1.15 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-1.16. Figure-1.17 shows three different river categories according to FAO classification of water for irrigation purposes. Figure-1.18 indicates the location of groundwater sampling stations and the compatibility with water quality standards.

(a) 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 μS/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.

In Vaza Barris river basin, chloride concentrations in the upper stretches of the river reached 2,800 mg/ 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/l 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 the most downstream sampling point of Sergipe River during the second survey, are assumed to indicate the influence of seawater reaching this sampling point.

Jacarecica, Cotinguiba, Poxim, Vermelha 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 uses. 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, the algae release toxic substances. Therefore a detailed investigation on the eutrophication conditions in the Sao Francisco River is recommended.

Figure-1.15 and Figure-1.16 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-1.17 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.

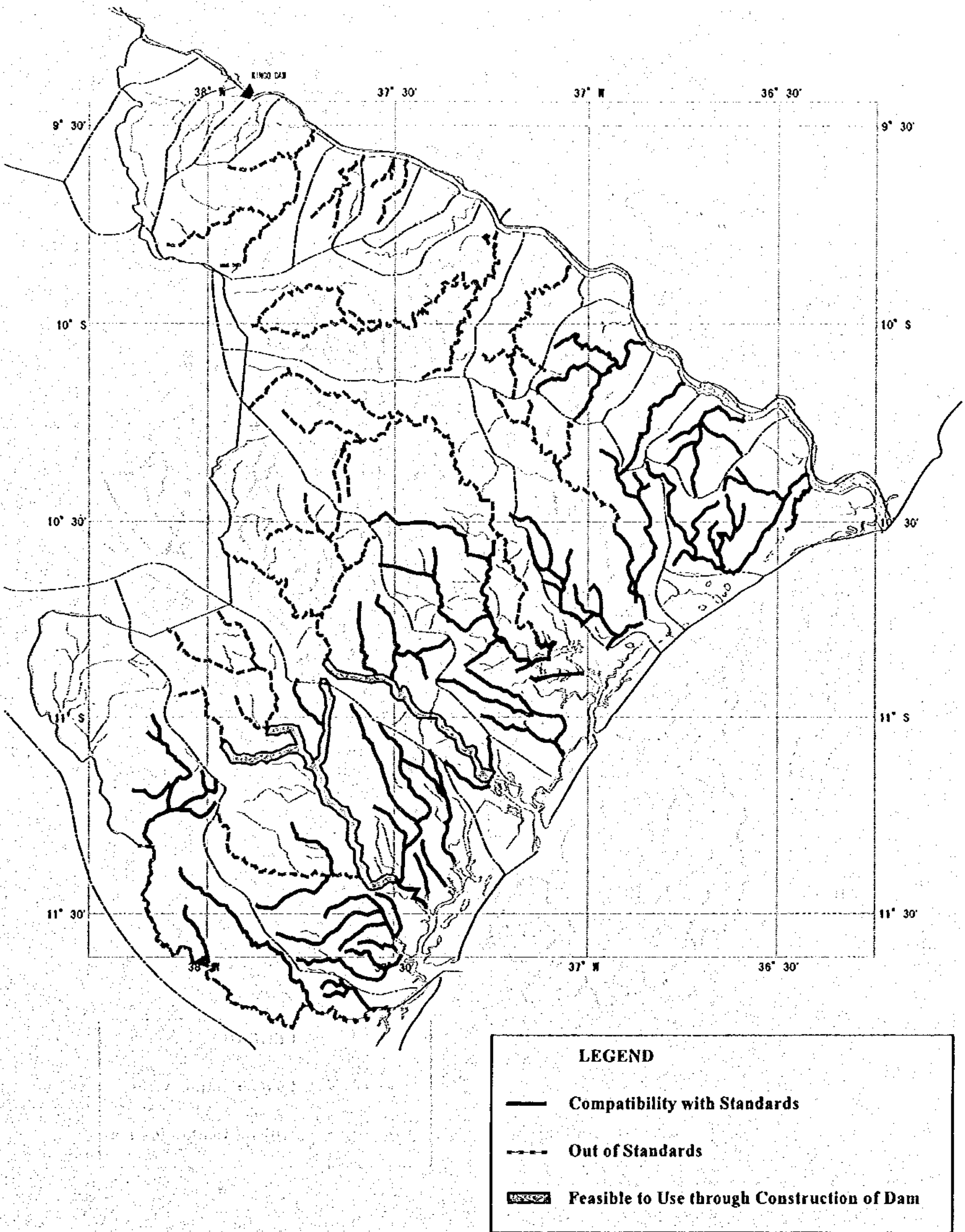


Figure-1.15 Classification of Rivers according to CONAMA 20 and W.H.O. Water Quality Standards

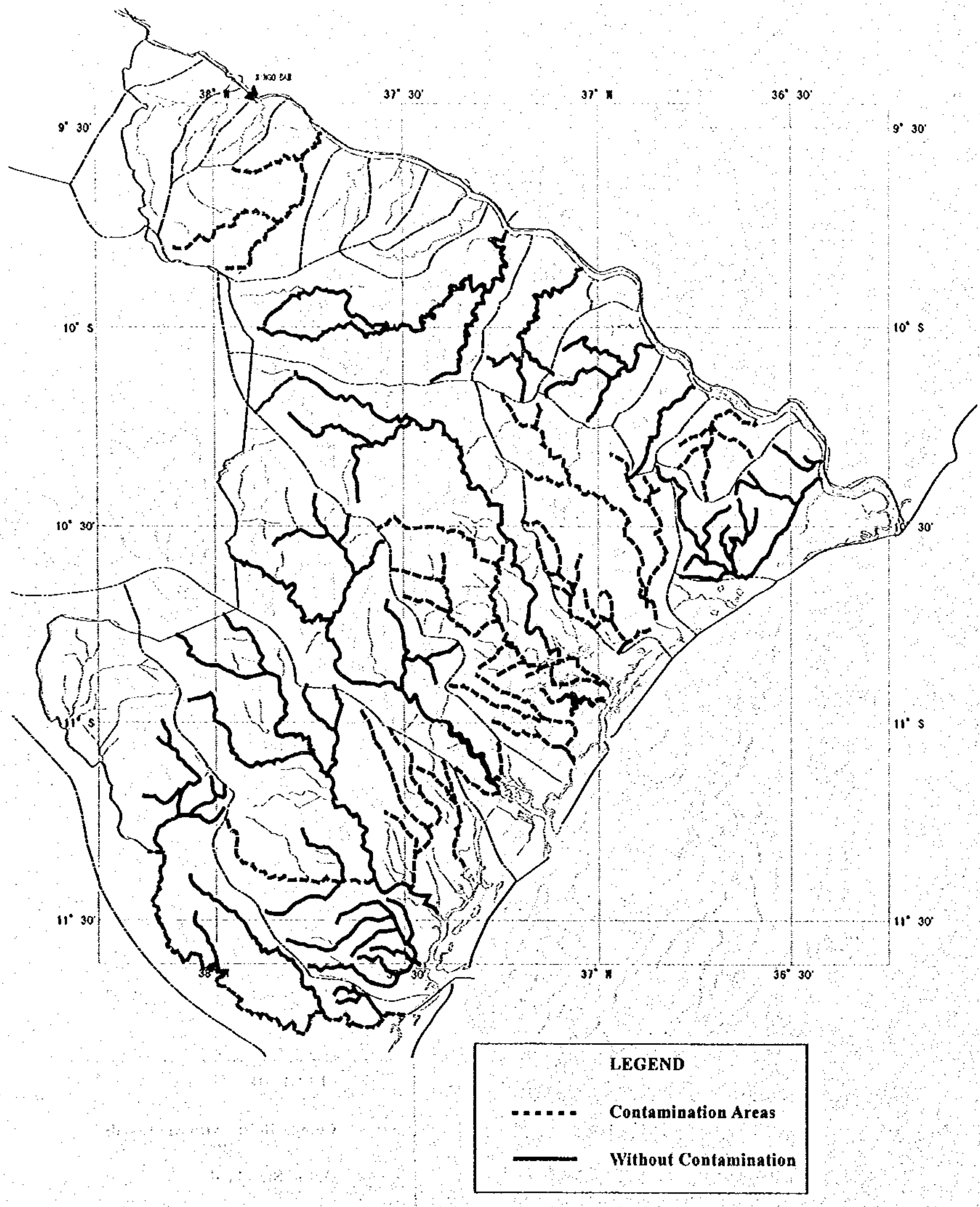


Figure-1.16 Fecal Coliform Contamination Areas

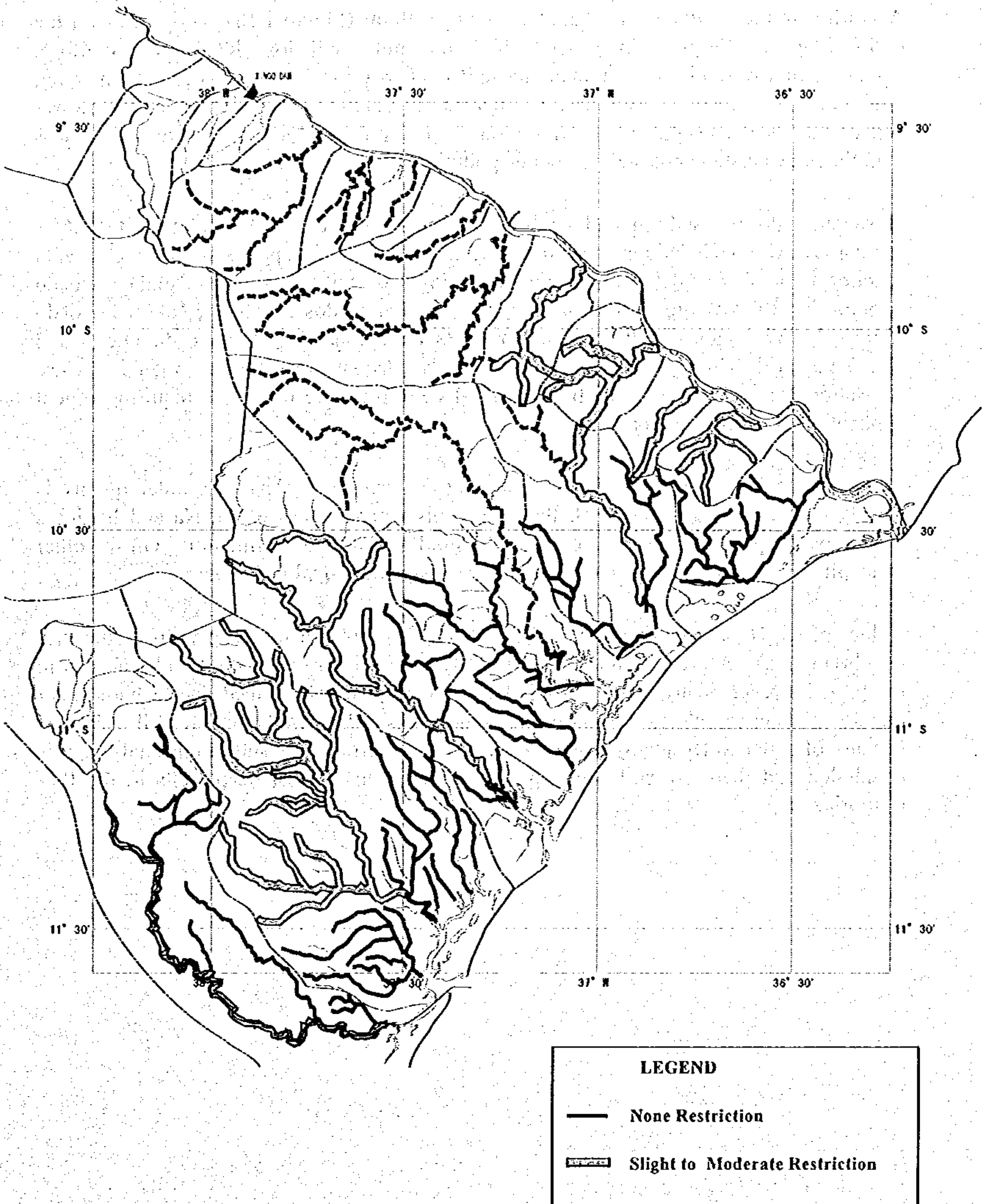


Figure-1.17 Classification of Water Quality for Irrigation Use according to the F.A.O Criteria

(b) Groundwater Quality

According to the results obtained at 50 sampling stations (Figure-1.18) 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.

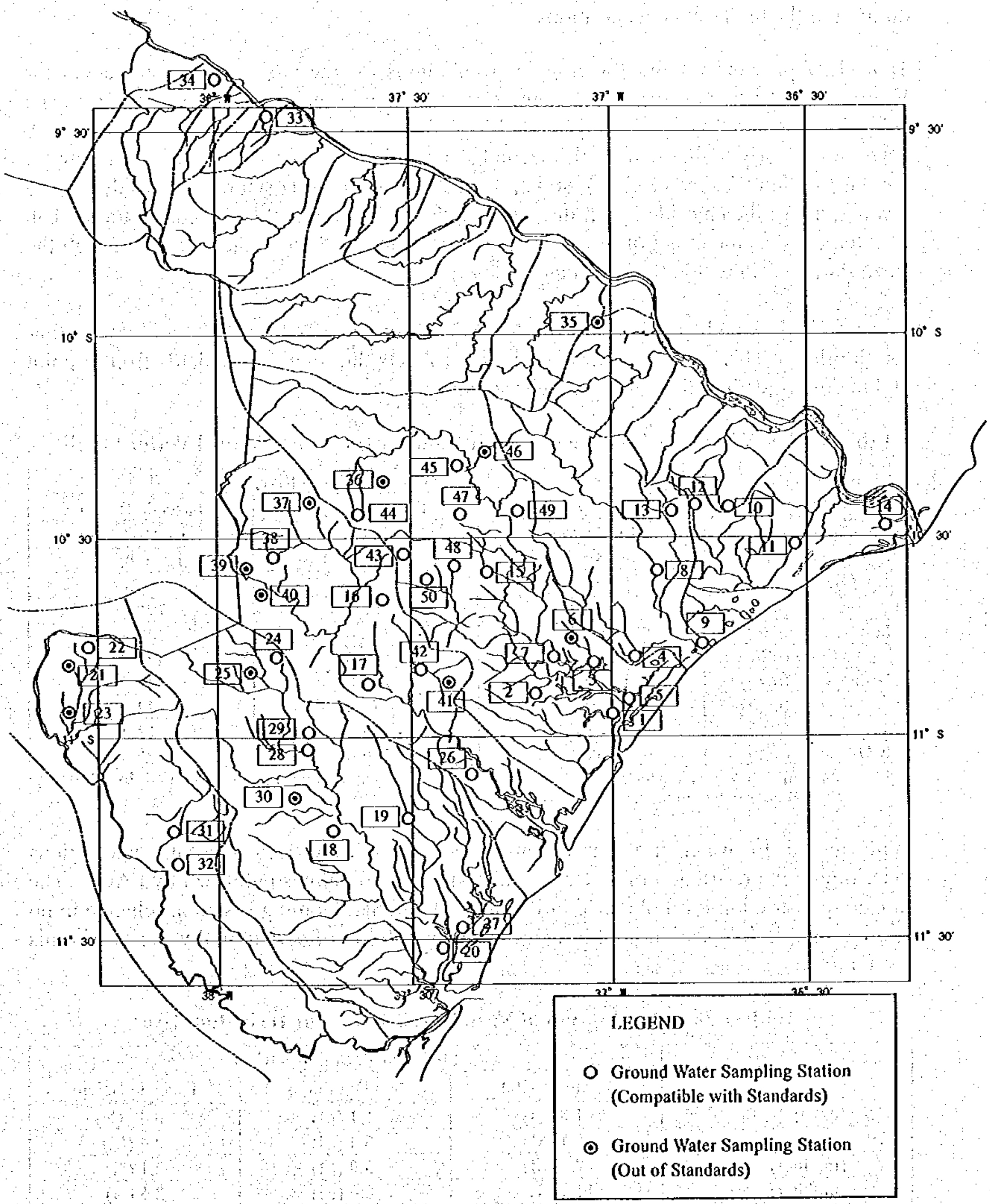


Figure-1.18 Classification of Groundwater according to W.H.O and CONAMA 20 Water Quality Standards

1.6.2 Water Quality Behavior in Vaza Barris River

Although most of its basin is located in the semi-arid region, the flow in Vaza Barris River 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.

Table-1.27 presents weighted average concentrations for the most critical parameters for Vaza Barris River with respect to domestic water supply and irrigation water use. The chloride concentration level of 574 mg/l registered at the first station (Ponte SE-302), decreases linearly to 302 mg/l at the second station (Sao Domingos) and to 125 mg/liter at the third station (Fazenda 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.

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

Table-1.27 Weighted Average Concentration for the Most Critical Water Quality

Water Quality Parameter	Station in Vaza Barris River		
	Ponte SE-302	Sao Domingos	Fazenda Belem
Catchment Area	14,435 km^2	-	15,740 km^2
Average Discharge	4.44 m^3/s	-	12.36 m^3/s
Min. Q7-day	0.82 m^3/s	-	1.26 m^3/s
CL (mg/l)	574.0	302.1	125.4
Na (mg/l)	165.6	106.6	47.4
Conductivity (μS/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

Note. Water qualities were calculated based on eight sampling series carried out from 1995 to 1998 by DESO and JICA at three points along the Vaza Barris River.

With regard to water use for irrigation purposes, Table-1.28 presents calculations determining the restriction of water use following the guidelines published by FAO. The moderate restriction level obtained at Pedra Mole and Sao Domingos stations change to no restriction at Belem station. This suggests the possibility of agricultural water use in this river stretch.

Table-1.28 Evaluation of Vaza Barris River for Irrigation Use

Parameter	Station in Vaza Barris River		
	Ponte SE-302	Sao Domingos	Fazenda 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

1.7 Environment

1.7.1 Land-use

Dominant land use in Sergipe State is pasture land. Intensive agricultural lands are only small areas. The natural vegetation of inland area is thicket or shrub, which are called Cerrado or Caatinga. Undisturbed Cerrado or Caatinga remain only in limited areas such as mountainous district or hill area because of grazing and/or agricultural activity. The natural vegetation of coastal areas is characterized by mangrove, or evergreen forest called Mata Atlantica. The mangrove forests have thrived well. Small old growth forests are scattered from the coastal area to the middle east part. There are no major inland wetlands and deserts.

A major built-up area is located only in Aracaju urban area. The agricultural land is dominated by sugarcane plantation and small plots cultivated for fruits, cassava, corn, bean and vegetables. Irrigated farmlands are mainly located near Xingo dam and Sao Francisco River mouth because of intake from Sao Francisco River. The stock farming is mostly extensive in semi-arid or arid zone.

Areas of each land use category estimated from satellite image by each drainage basin are shown in Table-1.29. Land use map by satellite image analysis is shown in Figure-1.19.

Table-1.29 Area of Each Land Use Category by Each Drainage Basin

Drainage Basin	Sao Francisco		Japaratuba		Sergipe		Vaza Barris	
Total Area (km^2)	7,276		1,722		3,673		2,559	
Town	5.7	0.1%	4.2	0.2%	74.4	2.0%	5.0	0.2%
Forest Area	510.8	7.0%	123.7	7.2%	186.6	5.1%	188.6	7.4%
Wood Land	1,698.9	23.3%	328.1	19.1%	830.5	22.6%	596.1	23.3%
Pasture (Vegetation density > 20%)	2,909.2	40.0%	802.1	46.6%	1,487.4	40.5%	874.6	34.2%
Pasture (Vegetation density < 20%)	748.6	10.3%	8.0	0.5%	203.1	5.5%	186.9	7.3%
Mangrove	36.2	0.5%	13.8	0.8%	81.1	2.2%	73.2	2.9%
Salt Marsh	48.3	0.7%	20.7	1.2%	0.5	0.0%	2.5	0.1%
Dunes Vegetation	11.4	0.2%	0.1	0.0%	57.8	1.6%	46.3	1.8%
Cultivation Area	1,067.9	14.7%	412.1	23.9%	678.0	18.5%	515.7	20.2%
Exposed Rock and Soil	95.4	1.3%	8.2	0.5%	27.0	0.7%	21.9	0.9%
Water	143.8	2.0%	1.1	0.1%	46.6	1.3%	48.2	1.9%

Drainage Basin	Piaui		Real		Total	
Total Area (km^2)	4,262		2,558		22,050	
Town	8.9	0.2%	3.0	0.1%	101.2	0.5%
Forest Area	997.7	23.4%	553.2	21.6%	2,560.6	11.6%
Wood Land	226.3	5.3%	155.2	6.1%	3,835.1	17.4%
Pasture (Vegetation density > 20%)	1,224.1	28.7%	1,293.9	50.6%	8,591.3	39.0%
Pasture (Vegetation density < 20%)	183.6	4.3%	43.4	1.7%	1,373.6	6.2%
Mangrove	99.8	2.3%	9.8	0.4%	313.8	1.4%
Salt Marsh	11.5	0.3%	0.0	0.0%	83.4	0.4%
Dunes Vegetation	67.5	1.6%	0.0	0.0%	183.1	0.8%
Cultivation Area	1,350.3	31.7%	486.0	19.0%	4,510.1	20.5%
Exposed Rock and Soil	37.7	0.9%	4.8	0.2%	195.0	0.9%
Water	54.8	1.3%	8.7	0.3%	303.2	1.4%

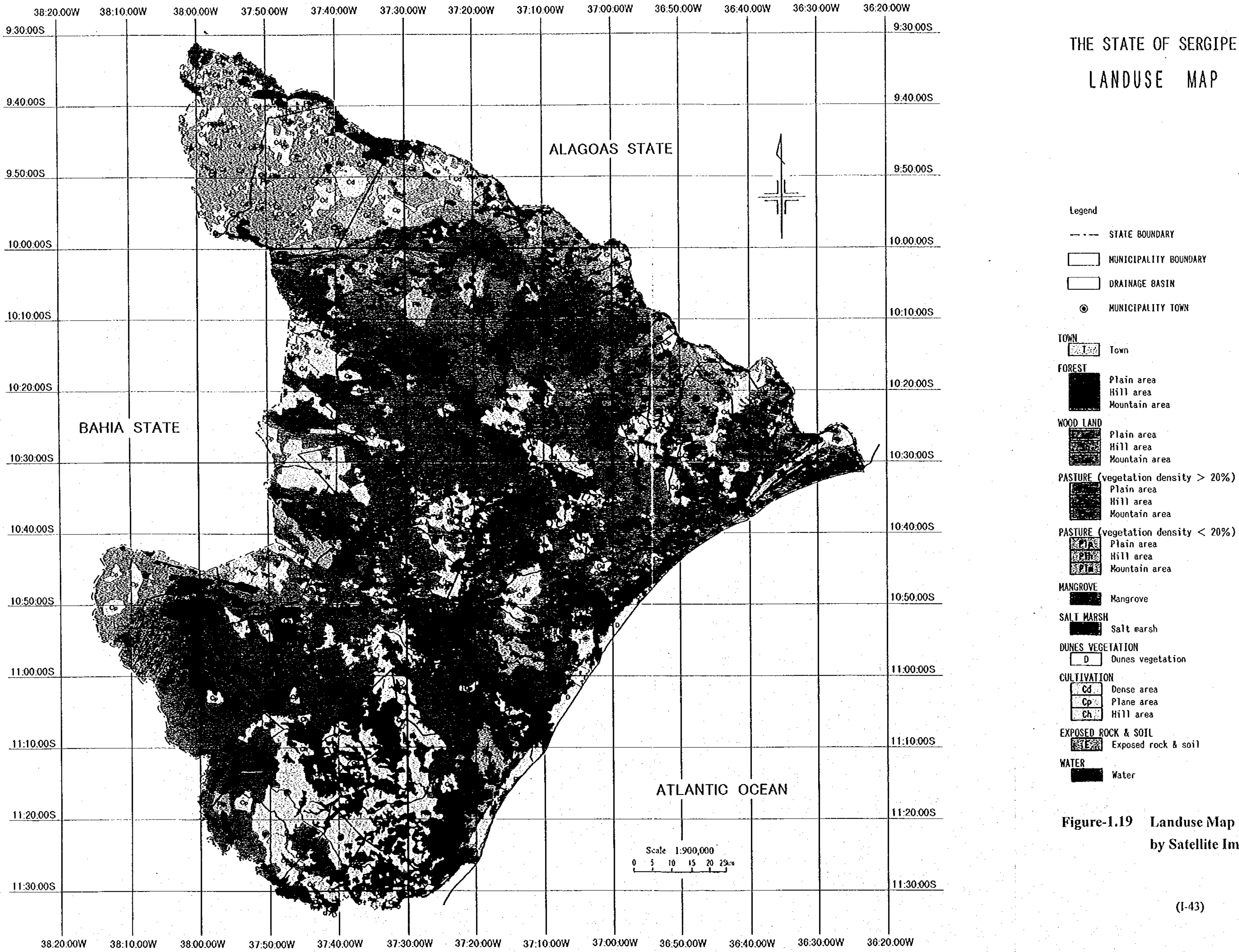


Figure-1.19 Landuse Map in Sergipe State by Satellite Image Analysis

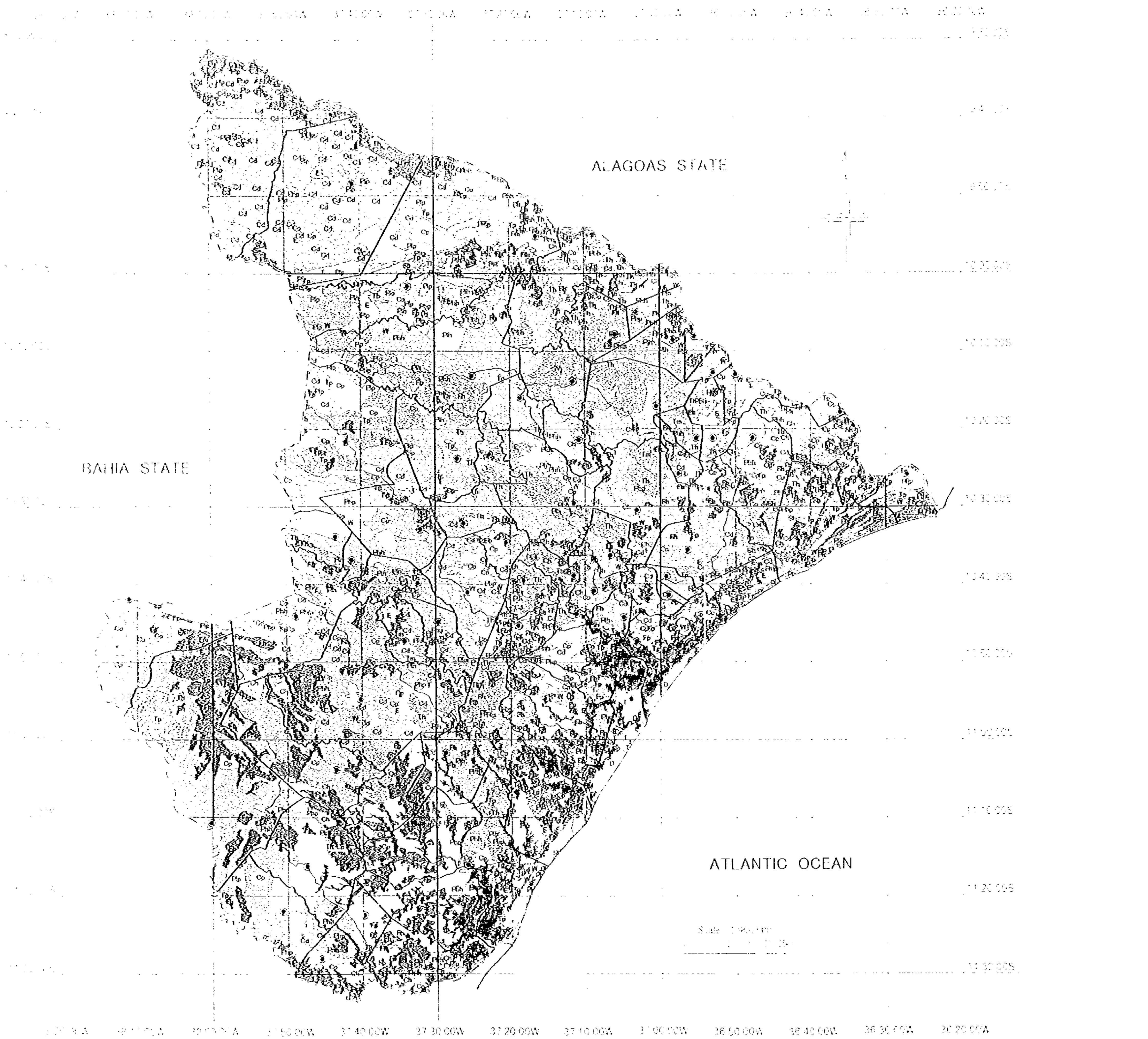


Figure-1.19 Landuse Map in Sergipe State by Satellite Image Analysis