2.4 Agricultural Water Demand Projection

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

2.4.1 Projection of Future Agriculture

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

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

2.4.2 Future Irrigation Areas

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

(1) Soil Properties and Topography

Based on soil data and a soil map (1/400,000) available in "Exploratory Research – Recognition of Soils in Sergipe State" (EMBRAPA and SUDENE, 1975), irrigation potential of soils in Sergipe were examined in cooperation with EMBRAPA, Recife. The soil map with scale of 1/400,000 is good enough for only initial identification of irrigable soils. Therefore, soil investigation in more detail is required for the further study.

The results are shown in Figure-2.1 and Table-2.11. In general, soils extended in the tropical humid region (near coast) show characteristics of low fertility and low salinity, while soils in the semi-arid region is fertile but their salinity ranges from medium to high. Table-2.11 shows that 15 % of the state land, 330,800 ha, is possible to be irrigated; however, Ce, BV, V, Ae and NC class soils require special management for salinity, such as leaching, selection of crops by salinity tolerance and so on. Existing irrigation projects are located mainly on PV, LV, PE and NC class soils. Projects on NC class are susceptible to saline problem.

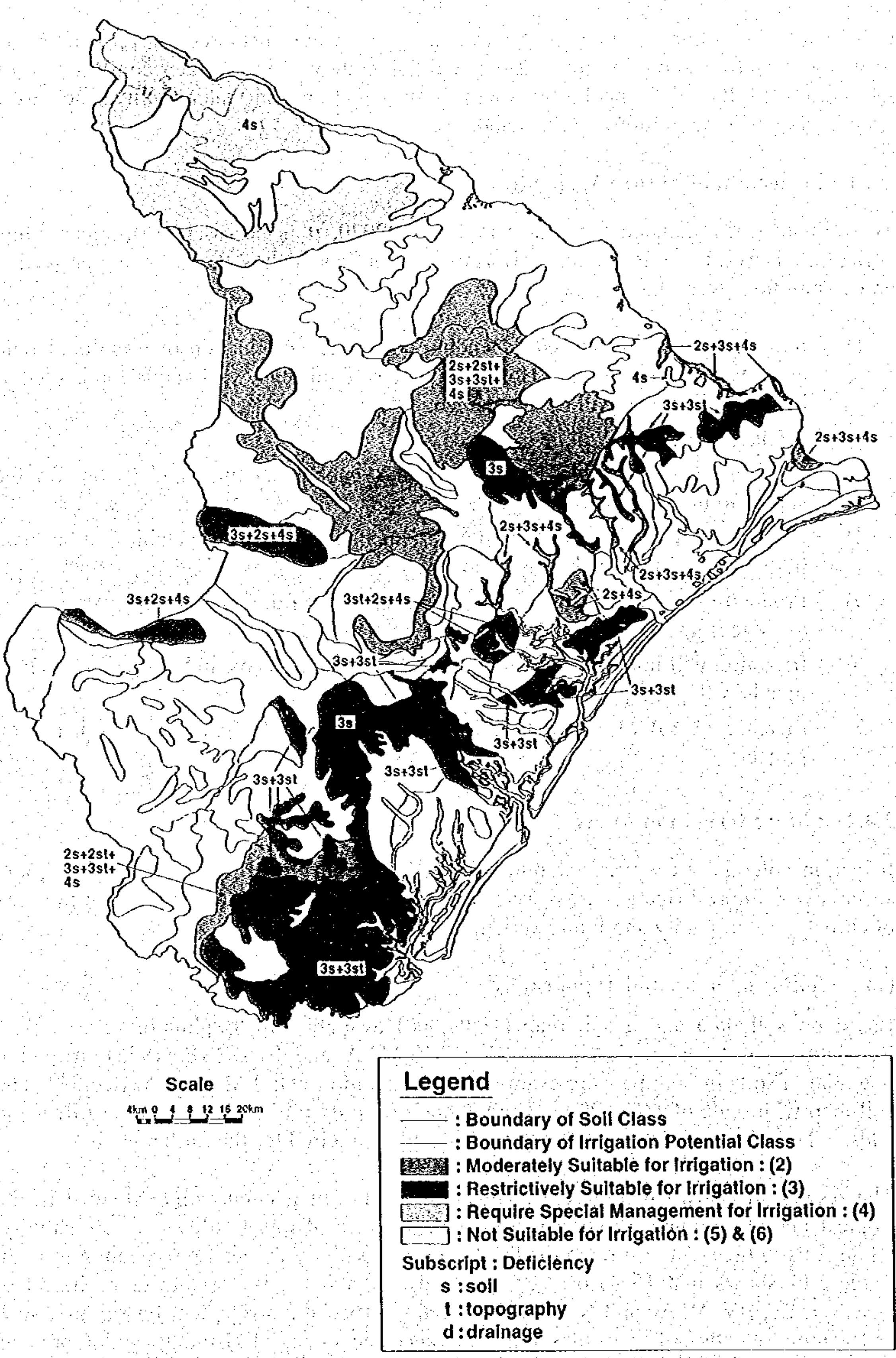


Figure-2.1 Irrigable Lands by Soil Properties and Topography

Table-2.11 Soils Suitable for Irrigation

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

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

(2) Climate

In general, climate factors in Sergipe, except rainfall, are suitable for agricultural practices. Seasonal and spatial variations of rainfall require proper selection of crops and cropping calendar for rain-fed agriculture in the tropical humid (Leste) and tropical sub-humid (Agreste) regions, while irrigation is necessary to grow most of crops in the semi-arid (Sertao) region. If annual fluctuation of rainfall is considered, irrigation should be promoted to ensure and increase productivity even in the Leste and Agreste regions.

Potential evapotranspiration or reference crop evapotranspiration (ETp) is another climate factor to examine necessity of irrigation. ETp was estimated by Penman-Monteith equation, using meteorological data from 7 stations (see section 1.4) as shown in Table-2.12.

Table-2.12 Potential Evapotranspiration

	Station Name	California	Cotinguiba	Jacarecica	Piaui	Boquim	Jabiberi	Airport
	Altitude (EL. m)	207.0	7.1	161.0	160.0	164.0	177.0	9.5
	Latitude (degree)	9.70	10.27	10.73	10.93	11.14	11.08	10.98
	Longitude (degree)	37.82	36.85	37.33	37.65	37.62	37.95	37.07
	Data Available Year	89-97	90-95	89-97	90-97	75-97	89-97	85-97
		Potential Evapotranspiration (mm/month)						
Month	January	185	170	180	162	150	169	159
	February	169	150	159	143	127	151	143
	March	175	162	166	150	142	160	153
	April	135	127	122	118	108	120	126
	May	113	102	102	100	95	101	116
	June	92	87	85	80	82	81	104
	July	96	94	90	86	85	89	112
	August	120	104	104	97	96	101	117
	September	147	120	120	116	111	122	124
	October	186	144	158	149	136	160	144
	November	186	143	164	153	137	159	147
	December	187	165	178	170	145	173	150
	Total	1,791	1,568	1,628	1,524	1,414	1,586	1,595

Penman-Monteith equation was used in Potential Evapotranspiration calculations with the following values.
for Angstrom's Coefficients: a = 0.25 b = 0.5
degree: degree south for latitude and degree west for longitude
EL.: elevation above mean sea level, Data Available Year: year available for meteorological data
Notice: Sunshine duration was estimated by a relation between barometric pressure and temperature due to no data available for Cotinguiba and Airport.

Annual ETp in semi-arid, tropical sub-humid and tropical humid regions, are approximately 1,800 mm/year, 1,600 mm/year and 1,400 mm/year, respectively. Those figures are consistent with characteristics of climate. ETp decreases in the direction to the sea. ETp at the airport is an exception because high wind speed along sea governs drying power of the air. Seasonal variation of ETp is distinct, high in December and January (a dry summer season), and low in June and July (a rainy winter season). This characteristic is applicable regardless of location.

(3) Water Resources Quality

The Study Team conducted quality analysis of surface water and groundwater as discussed in section 1.6. Based on the analysis, available water resources for irrigation in terms of quality are summarized as follows.

1) Semi-Arid Region

Surface water, except Sao Francisco River, is contaminated by salt. FAO criteria classify surface water quality in this region as severe hazard in terms of salinity and specific iron toxicity. Groundwater is also not available due to salinity (refer to Chapter 3). Therefore, water resource available for irrigation is only Sao Francisco River.

2) Tropical Sub-Humid Region

Surface water quality is mostly classified as moderate to severe hazard; however, good quality was observed in several rivers, such as Jabiberi, Fundo, Jacarecica and Vermelha rivers. Meanwhile, groundwater is not available due to quality, except some in the upper reaches of Vaza Barris and Piaui rivers and Boquim Micro-Region, where fresh water rate is roughly 30 %.

3) Tropical Humid Region

Both surface water and groundwater have no restriction on use.

(4) Sites for Future Irrigation Projects

330,800 ha of the state land have potential for irrigation in terms of soil properties and topographical features. Those areas were re-evaluated by climate and water quality discussed above to determine future irrigation sites by the year of 2020. The result is described in the following section.

1) Semi-Arid Region

One of crucial issues to determine irrigation sites is water resources. Since only Sao Francisco River is available, feasibility of irrigation projects depends on distance between project site and the river. Considering cost for conveyance of water and crop prices, future project sites should be near Xingo dam that has two conduits available for water supply of 20 m^3/s.

2) Tropical Sub-Humid Region

Propria Micro-region has 12,300 ha of irrigable land in terms of soil properties and topography; however, there are already 4 projects implemented and total area of the 4 projects (13,480 ha) exceeds the potential area. Therefore, it can be assumed that there is no area remained for new projects in the lower reaches of

Sao Francisco River. Surface water is available for irrigation only in several rivers, such as Jabiberi, Fundo, Jacarecica and Vermelha rivers, excluding Sao Francisco River. Soils in the upstream of those rivers, Red Yellow Podzolic Soil (PV) and Red Yellow Latosol (LV), have irrigation potential with low salinity, too. Therefore, irrigation is possible by means of water resources development near project sites, such as dam and weir, but area of irrigation is limited by cost of those structures and undulating land. Meanwhile, some of groundwater with satisfactory quality is suitable for irrigation by individual farmers rather than project scale due to low expected yield.

3) Tropical Humid Region

Rainfall in this region is considered sufficient to grow crops currently cultivated, such as sugarcane, coconut, orange and banana. Orange out of those crops is possible to be irrigated because of higher price compared to other primary crops; however, research results show that orange production in this region can be improved by denser planting but not by irrigation. Therefore, irrigation will not be required as long as crops do not vary.

Irrigation is expected to play an important role in future agriculture in Sergipe; however, since irrigation is intensive agriculture, it requires large investment in facilities and materials. On the other hand, markets require competitive crop prices. Therefore, future project sites were selected from the potential sites by 1) minimizing investment especially water resources development and 2) considering applicability of profitable crops.

Since Xingo dam has two conduits available and the Study Team has proposed Vaza Barris dam for domestic and industrial waters, cost of water resources development can be minimized if irrigation water is conducted from those sources. Therefore, the Study Team proposes two projects, São Francisco and Vaza Barris irrigation projects. As a result of water requirement estimate, roughly 16,000 ha and 2,500 ha of lands are irrigable by intake from Xingo dam and Vaza Barris dam respectively.

Fruits for not only raw consumption but also agro-industry should be cultivated in Sao Francisco project because of favorable climate for fruits. Since Vaza Barris project has a good access to Aracaju, which is the largest consumer of agricultural products in Sergipe, cultivation of vegetables in most of land and fruits in steep land is recommended.

Proposed projects by COHIDRO and CODEVASF were also examined and Quixabeira, Ladeirinhas, Jacarecica II, Entre Rios and Estancinha were adopted as future irrigation projects. Factors considered for selection are soil, climate, water quality and possibility of water resources development. Although the study phase varies depending on the project, the further study is required to realize the projects.

Locations of future and existing irrigation projects are shown in Figure-2.2.

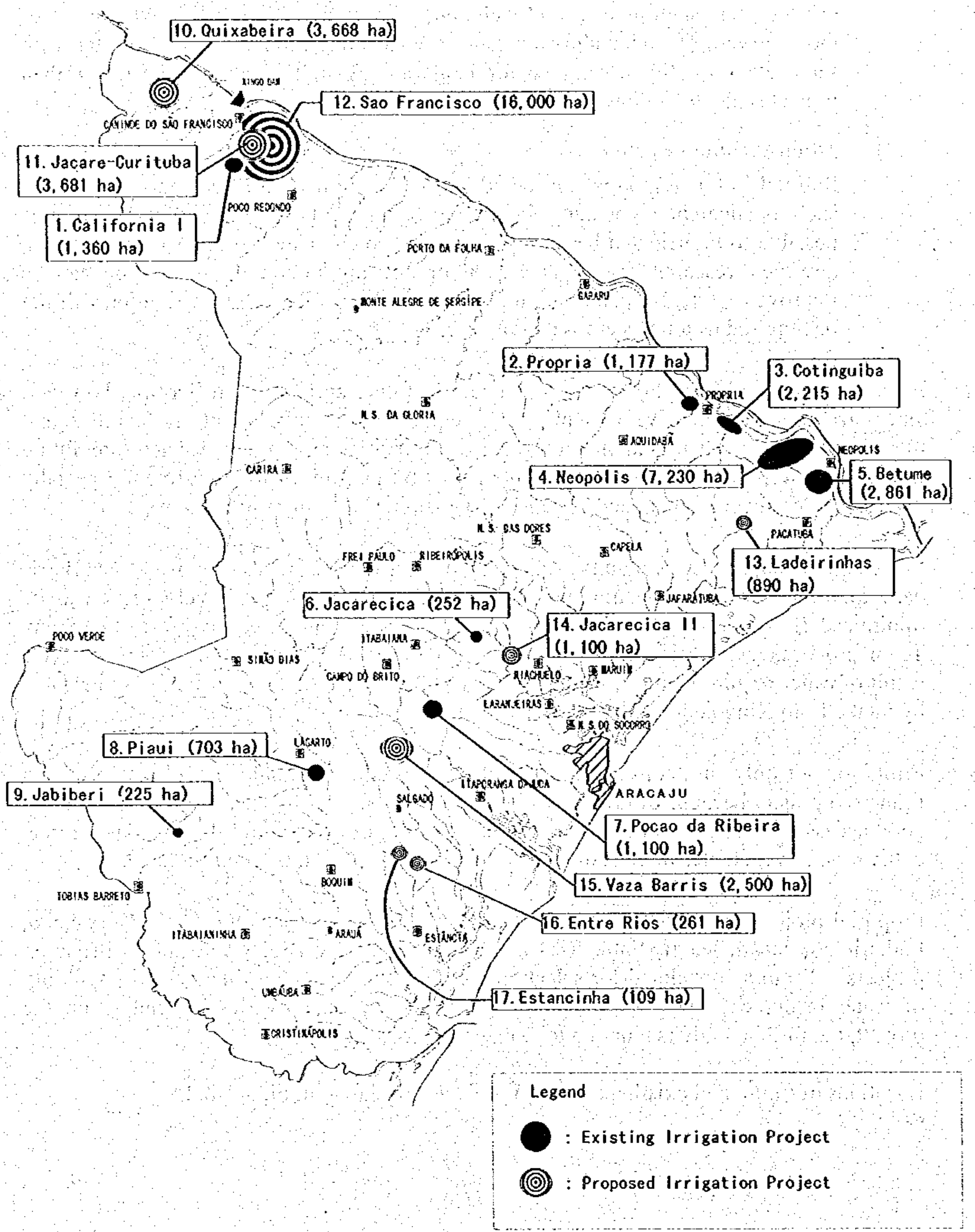


Figure-2.2 Existing and Future Irrigation Projects

2.4.3 Water Demand for Irrigation

Conditions to calculate water demand for irrigation are as follows:

1) Crop water requirement (ETcrop) = potential evapotranspiration (ETp) x crop coefficient (kc), where Penman-Monteith equation for ETp and kc available from "FAO Irrigation and Drainage Paper 24"
2) 75 % probability rainfall is adopted as dependable rainfall and is determined, based on monthly rainfall for 30 years (1968 ~ 1997).
3) Effective rainfall (water stored in the root zone) is estimated by the relation between ETcrop and rainfall ("FAO Irrigation and Drainage Paper 24").
4) Since some of soils and waters in Sergipe have salinity problems, leaching requirement is examined.
5) Overall irrigation efficiencies, that are integrated values of conveyance efficiency, field canal efficiency and application efficiency, are 0.6 for a project consisting of conventional sprinkler and trickle irrigation, and 0.75 for a project of trickle irrigation.

Project water requirement is integrated value of net irrigation requirement, leaching requirement and irrigation efficiency. Project water requirements were estimated for proposed projects and results are shown in Table-2.13.

Hargreaves table (1985) is common to estimate irrigation requirement in Sergipe due to lack of meteorological data. Since the Study Team conducted meteorological analysis using the latest data, irrigation requirements of projects proposed by COHIDRO and CODEVAF were also estimated, based on JICA Study Team analysis. For the existing projects, original figures were adopted as project water requirement because irrigation facilities were already installed in accordance with those figures.

2.4.4 Water Demand for Livestock

As mentioned in projection of future agriculture, livestock population depends on market but average population will be maintained. With this assumption, livestock population in 2020 was estimated as follows, and successively water demand for livestock was calculated. Since the latest year of livestock population data is 1995, it was assumed that the current population (1997) is equal to that in 1995. Cattle, poultry, pig, sheep and goats are major water consumers in Sergipe.

	1997	2020
Cattle	797,000 heads	1,000,000 heads
Poultry	3,041,000 heads	3,100,000 heads
Pig	99,000 heads	100,000 heads
Sheep & Goats	175,000 heads	200,000 heads

Table-2.13 Water Demand of Existing and Future Irrigation Projects

Phase of Project	River Basin	No.	Project Name	Irrigation Area (ha)	Main Crops	Project Water Requirement at Source (m^3/ha/month)												Peak Requirement (million m^3/month)
						Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Existing	SF	1	California	1,360	fruit & vegetable culture	1,150	970	1,400	1,460	1,100	710	590	700	1,070	1,680	1,800	1,670	2.4
	SF	2	Propria	1,177	paddy rice (2 harvests)	2,624	2,368		1,568	880	1,008	1,104	1,696		2,448	2,448	2,592	3.1
	SF	3	Cotinguiba	2,215	paddy rice & vegetables	1,810	1,640	240	810	450	500	550	940	220	1,440	1,470	1,640	4.0
	SF	4	Neopolis	7,230	fruit culture	990	850	570	120			100	340	330	790	910	1,000	7.2
	SF	5	Betume	2,861	paddy rice	2,350	1,300	550	950	1,700	1,500	1,000	750	550	1,000	2,550	2,900	8.3
	Jac	6	Jacarecica	252	Vegetable culture	3,210	2,590	2,520	1,580	90				530	1,680	2,650	3,160	0.8
	VB	7	Pocao da Ribeira	1,100	Vegetable culture	690	810	1,420	870	180			80	310	1,650	2,960	2,020	3.3
	Piaui	8	Piaui	703	Vegetable culture	720	760	1,220	720	190			120	1,200	2,460	2,090	1,620	1.7
	Real	9	Jabiberi	225	fruit & vegetable culture	2,800	2,540	3,390	2,770	810	400	310	650	1,970	4,310	5,530	4,970	1.2
Propose	SF	10	Quixabeira	3,668	fruit & vegetable culture	1,550	730	550	250	750	0	0	0	480	1,300	1,730	2,150	7.9
	SF	11	Jacare-Curituba	3,681	fruit & vegetable culture	1,770	1,130	900	430	730	0	0	0	730	1,480	1,870	2,220	8.2
	SF	12	Sao Francisco	16,000	fruit culture	1,730	1,470	1,150	570	310	0	0	0	490	1,120	1,490	1,750	28.0
	SF	13	Ladeirinhas	890	fruit & vegetable culture	1,930	1,960	1,630	350	150	0	70	630	950	1,630	1,490	1,230	1.7
	Jac	14	Jacarecica II	1,100	fruit & vegetable culture	1,900	1,700	2,300	1,530	700	0	0	0	830	2,180	2,470	2,670	2.9
	VB	15	Vaza Barris	2,500	Vegetable culture	1,400	1,030	1,630	830	470	0	1,520	0	430	2,070	2,630	3,120	7.8
	Piaui	16	Entre Rios	261	fruit & vegetable culture	1,850	1,470	780	0	30	630	0	150	450	730	1,300	1,770	0.5
	Piaui	17	Estancinha	109	fruit & vegetable culture	1,320	930	780	270	0	900	0	430	1,180	1,530	1,150	1,400	0.2

SF: Sao Francisco River, Jac: Jacarecica River, VB: Vaza Barris River
Figures for existing projects: adopted from individual report
Figures for proposed projects: estimated by JICA Study Team
Sao Francisco and Vaza Barris projects: proposed by JICA Study Team
Other proposed projects: adopted from COHIDRO and CODEVASF proposals

It is necessary to consider water intake by means of pasture to estimate water demand of herbivores, such as cattle, sheep and goats. Since pigs and poultry are not herbivores, it was assumed that there is no water intake by means of food. For the calculation sake, the following figures were adopted.

Cattle:	25 liter/day
Pigs:	5 liter/day
Sheep and Goats:	1.5 liter/day
Poultry:	0.2 liter/day

Current and future water consumption of livestock was estimated by multiplying population by the above rates. As shown in Table-2.14, total water consumption by livestock in 1997 is approximately 21,290 m^3/day and it will increase to 26,430 m^3/day in 2020. Increment is about 24 %.

Table-2.14 Water Demand of Livestock

Unit : 1,000m^3/day

Division		Cattle (1995)	Poultry (1995)	Pigs (1995)	Sheep/ Goat (1995)	Cattle (2020)	Poultry (2020)	Pigs (2020)	Sheep/ Goat (2020)
Micro-region	Sergipana do Sertao do Sao Francisco	3.275	0.078	0.067	0.019	4.100	0.079	0.070	0.023
	Carira	1.263	0.014	0.016	0.006	1.575	0.014	0.015	0.008
	Nossa Senhora das Dores	1.653	0.018	0.009	0.004	2.075	0.018	0.010	0.006
	Agreste de Itabaiana	0.918	0.065	0.027	0.005	1.150	0.066	0.030	0.006
	Tobias Barreto	1.863	0.067	0.122	0.130	2.350	0.068	0.125	0.149
	Agreste de Lagarto	2.367	0.072	0.141	0.055	2.975	0.074	0.145	0.064
	Propria	0.824	0.008	0.023	0.002	1.025	0.008	0.020	0.004
	Cotinguiba	1.320	0.028	0.006	0.001	1.650	0.028	0.005	0.002
	Japaratuba	1.013	0.015	0.006	0.004	1.275	0.015	0.005	0.005
	Baixo Cotinguiba	0.868	0.034	0.006	0.001	1.100	0.035	0.005	0.004
	Aracaju	0.386	0.055	0.005	0.002	0.475	0.056	0.005	0.002
	Boquim	2.588	0.040	0.049	0.028	3.250	0.040	0.050	0.034
	Estancia	1.590	0.111	0.016	0.006	2.000	0.113	0.015	0.008
River basin	Sao Francisco	4.667	0.087	0.084	0.021	5.834	0.090	0.089	0.028
	Japaratuba	2.379	0.034	0.012	0.002	3.003	0.033	0.011	0.009
	Sergipe	3.128	0.134	0.042	0.008	3.914	0.136	0.034	0.015
	Vaza Barris	2.003	0.105	0.058	0.021	2.501	0.108	0.064	0.023
	Piaui	5.290	0.192	0.194	0.092	6.656	0.194	0.199	0.108
	Real	2.462	0.053	0.103	0.115	3.101	0.053	0.105	0.134
State Total		**19.93**	**0.61**	**0.49**	**0.26**	**25.00**	**0.61**	**0.50**	**0.32**

(1995): Figures denote year

CHAPTER 3 WATER RESOURCES POTENTIAL

3.1 Surface Water Potential

3.1.1 Discharge Analysis

(1) Discharge at Reference Points

Reference points were chosen within each river basin and the basins sub-divided as shown in Figure-3.1. In general, reference points were chosen at the confluence of major tributaries or at easily identifiable locations such as bridges. The catchment area of each sub-basin was measured from the available 1:100,000 SUDENE maps. The river basin sub-division is shown schematically in Figure-3.2.

Based on Thiessen polygons drawn for the 29 selected rainfall stations, basin mean rainfall was calculated for the sub-basins using the annual average rainfall data for the 30 year period 1968-1997.

In principal, the discharge at each reference point is estimated from the known discharge at the ANEEL discharge observation station by using the catchment area ratio and the basin mean rainfall ratio, in accordance with the following equation:

$$Q_2 = Q_1 \times (A_2 / A_1) \times (R_2 / R_1)$$

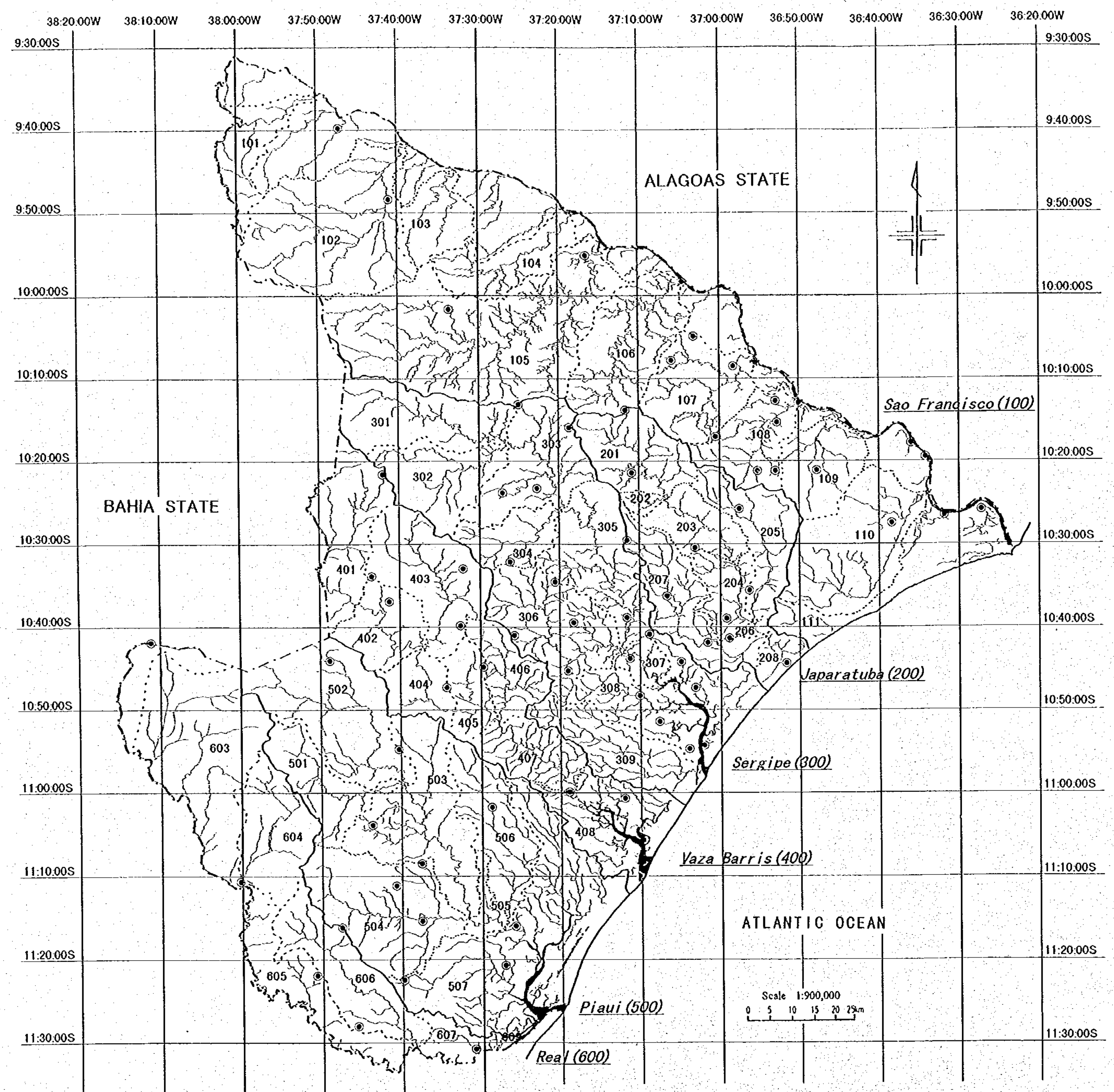
where,

Q_1 : known discharge at Flow Measurement Point
Q_2 : required discharge at Reference Point
A_1 , A_2 : catchment area at Flow Measurement Point and at Reference Point
R_1 , R_2 : basin mean rainfall at Flow Measurement Point and at Reference Point

With regards to Vaza Barris river, the difference between the flow regime at Fazenda Belem and that at Ponte SE-302 near the border with Bahia state has been used to evaluate the water resources generated within Sergipe state. Although Vaza Barris has a considerable catchment outside Sergipe state, the flows generated are low as can be seen from the discharge data at Ponte SE-302 (average specific discharge of only 0.31 l/sec/km^2 from a catchment area of 14,435 km^2). For this reason, the difference in flow between the upstream and downstream stations has been used in the above equation to calculate the flow conditions at the reference points in Vaza Barris basin.

The same method was employed for the Real river basin, because of the lack of rainfall data in the upstream and Bahia parts of the basin, and because of the fact that flow in the river is intermittent upstream of Tobias Barreto. In this case, the difference between the flow regime at Itanhi station and that at Faz. Tourao was used to calculate the discharge at the Real river reference points.

The results of the discharge analysis at the reference points are given in Table-3.1.



THE STATE OF SERGIPE

DRAINAGE SYSTEM MAP

Legend

- RIVER
- DRAINAGE BASIN
- SUB DRAINAGE BASIN
- STATE BOUNDARY
- MUNICIPALITY TOWN

No.	DRAINAGE BASIN	No.	SUB DRAINAGE BASIN
100	São Francisco	101	Rio Curituba
		102	Rio Jacaré (Poco Redondo)
		103	Rch do Cururu
		104	Rio Campos Novos
		105	Rio Capivara
		106	Rio Gararu
		107	Rch Canhoba
		108	Rch Jacaré (Propria)
		109	Rch dos Pilões
		110	Rio Betume
		111	Rio Sapucaia
200	Japaratuba	201	Upper Japaratuba
		202	Un-named Tributary
		203	Tributary to BR-101 Road Bridge
		204	BR-101 to Japaratuba Mirim
		205	Rio Japaratuba Mirim
		206	Japaratuba Mirim to Siriri
		207	Rio Siriri
		208	Siriri to River Mouth
300	Sergipe	301	Upper Sergipe
		302	Rio Socavão
		303	Sergipe to Jacoca
		304	Rio Jacoca
		305	Jacoca to Jacarecica
		306	Rio Jacarecica
		307	Jacarecica to BR-101 Road Bridge
		308	BR-101 to Poxim
		309	Rio Poxim
400	Vaza Barris	401	Upstream SE-302 Road Bridge
		402	SE-302 Bridge to Salgado
		403	Rio Salgado
		404	Salgado to SE-110 Road Bridge
		405	SE-110 to Rch. das Trairas
		406	Rch. das Trairas
		407	Trairas to BR-101 Road Bridge
		408	BR-101 to River Mouth
500	Piauì	501	Upper Piauì
		502	Rio Jacaré
		503	Jacaré to Arauá
		504	Rio Arauá
		505	Arauá to Piauitinga
		506	Piauitinga
		507	Piauitinga to River Mouth
600	Real	601	Upper Real
		603	Baxia do Tubarão to Jabiberi
		604	Rio Jabiberi
		605	Jabiberi to Itamirim
		606	Rio Itamirim
		607	Itamirim to Tabatinga
		609	Tabatinga to River Mouth

Figure-3.1 Sub-Division of River Basins and Location of Reference Points

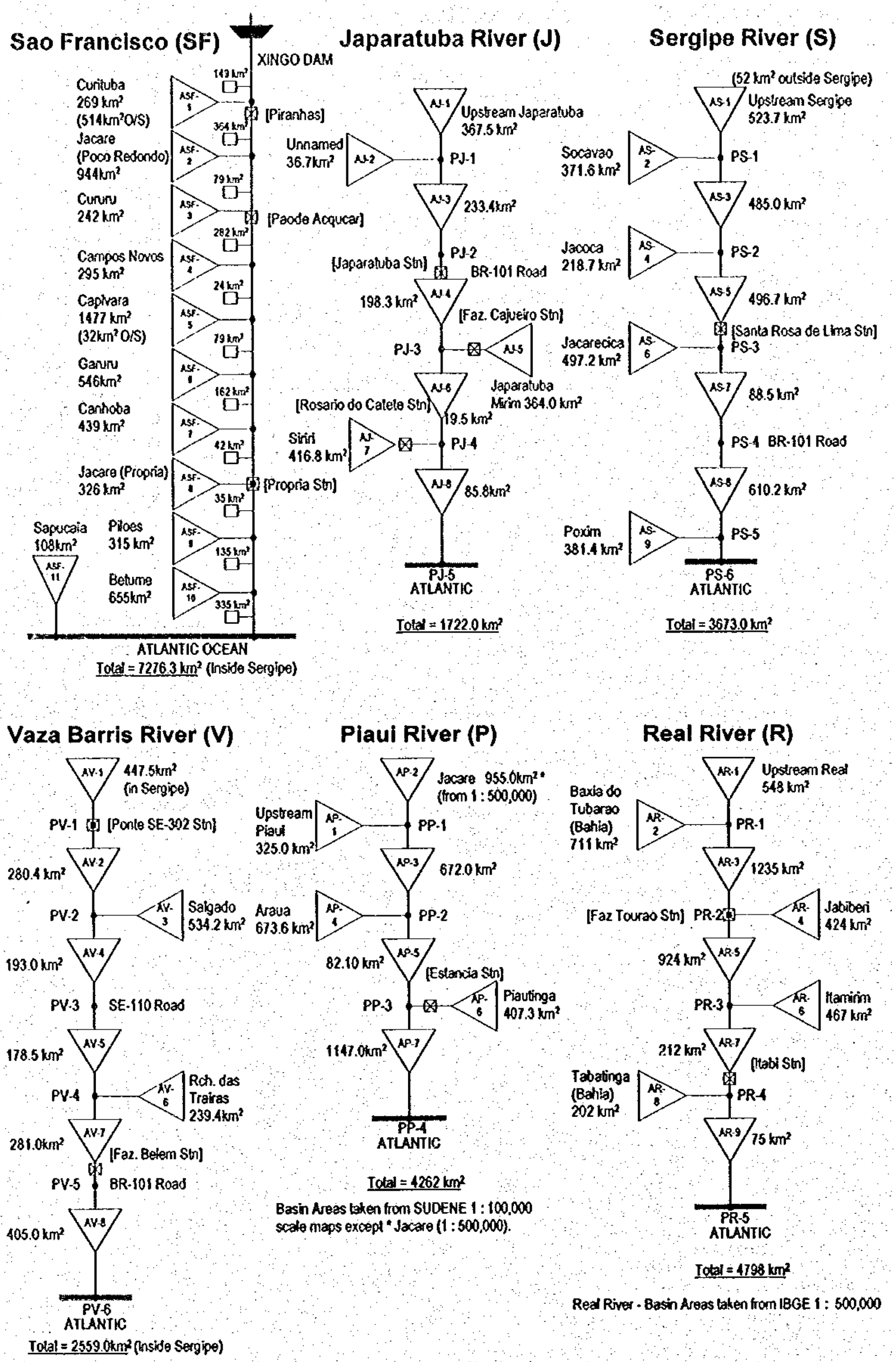


Figure-3.2 Schematic of River Basin Sub-Division

Table-3.1 (1/2) Calculated Flow Regime at Reference Points

Ref Pt	Sub-Basin	Basin Area (km²)	Basin Rain (mm/yr)	Annual Rain (10^6 m³)	Flow Regime (m³/s) Ave.	Q-95 (25%)	Q-185 (50%)	Q-275 (75%)	Q-355 (95%)	Q 7-day Average (m³/s)	Q 7-day 1 in 10 yr (m³/s)	Average Monthly Flow (m³/s) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
SAO FRANCISCO BASIN *																							
Piranhas Stn.		604000	-	-	2692	3181	2131	1825	1600	1606	-	3628	3974	4040	3533	2409	1919	1833	1852	1866	1954	2308	3012
Acucal Stn.		608900	-	-	2568	2986	2066	1775	1589	1600	-	3439	3713	3811	3392	2383	1908	1785	1778	1777	1862	2187	2851
Propria Stn.		623500	-	-	2473	2870	1979	1682	1563	1444	-	3268	3537	3631	3273	2302	1847	1737	1701	1735	1762	2073	2697
JAPARATUBA BASIN																							
	AJ-1	367.5	1006.0	369.7	1.78	1.93	0.73	0.36	0.19	0.189	0.036	0.46	0.50	0.81	1.62	3.34	3.44	4.39	2.37	1.57	1.35	0.59	0.79
	AJ-2	36.7	1093.5	40.1	0.19	0.21	0.08	0.04	0.02	0.021	0.004	0.05	0.05	0.09	0.18	0.36	0.37	0.48	0.26	0.17	0.15	0.06	0.09
PJ-1		404.2	1013.9	409.8	1.97	2.14	0.81	0.39	0.21	0.210	0.040	0.51	0.56	0.90	1.80	3.70	3.81	4.86	2.63	1.74	1.50	0.65	0.88
	AJ-3	233.4	1332.5	311.0	1.49	1.62	0.61	0.30	0.16	0.159	0.030	0.39	0.42	0.68	1.36	2.81	2.89	3.69	1.99	1.32	1.14	0.50	0.67
PJ-2		637.6	1130.6	720.8	3.46	3.76	1.42	0.69	0.38	0.369	0.070	0.90	0.98	1.58	3.16	6.50	6.70	8.55	4.62	3.06	2.64	1.15	1.55
	AJ-4	198.3	1470.3	291.6	1.40	1.52	0.58	0.28	0.15	0.149	0.028	0.36	0.40	0.64	1.28	2.63	2.71	3.46	1.87	1.24	1.07	0.47	0.63
	AJ-5	364.0	1348.3	490.8	2.36	2.56	0.97	0.47	0.26	0.251	0.048	0.61	0.67	1.08	2.15	4.43	4.56	5.82	3.15	2.08	1.79	0.78	1.05
PJ-3		1199.9	1252.8	1503.2	7.22	7.84	2.97	1.45	0.79	0.770	0.147	1.87	2.05	3.30	6.60	13.56	13.98	17.83	9.64	6.38	5.50	2.40	3.23
	AJ-6	19.5	1497.1	29.2	0.14	0.15	0.06	0.03	0.02	0.015	0.003	0.04	0.04	0.06	0.13	0.26	0.27	0.35	0.19	0.12	0.11	0.05	0.06
	AJ-7	416.8	1307.7	545.0	2.62	2.84	1.08	0.52	0.29	0.279	0.053	0.68	0.74	1.20	2.39	4.92	5.07	6.47	3.50	2.31	1.99	0.87	1.17
PJ-4		1636.2	1269.7	2077.4	9.98	10.84	4.10	2.00	1.09	1.064	0.203	2.58	2.84	4.56	9.12	18.74	19.32	24.64	13.32	8.81	7.60	3.32	4.46
	AJ-8	85.8	1497.1	128.5	0.62	0.67	0.25	0.12	0.07	0.066	0.013	0.16	0.18	0.28	0.56	1.16	1.19	1.52	0.82	0.54	0.47	0.21	0.28
PJ-5		1722.0	1281.0	2205.9	10.60	11.51	4.36	2.12	1.16	1.129	0.215	2.74	3.01	4.84	9.68	19.90	20.52	26.17	14.14	9.36	8.07	3.52	4.73
Japaratuba Stn		706.0	1161.9	820.3	3.94	4.28	1.62	0.79	0.43	0.420	0.080	1.02	1.12	1.80	3.60	7.40	7.63	9.73	5.26	3.48	3.00	1.31	1.76
SERGIPE BASIN																							
	AS-1	523.7	791.3	421.8	1.40	1.19	0.51	0.22	0.12	0.123	0.021	0.49	0.41	0.42	1.15	2.66	2.76	4.61	1.50	1.23	0.67	0.48	0.58
	AS-2	371.6	822.1	310.9	1.04	0.88	0.37	0.16	0.09	0.091	0.016	0.36	0.30	0.31	0.85	1.96	2.03	3.40	1.10	0.90	0.50	0.35	0.43
PS-1		895.3	804.1	732.7	2.44	2.07	0.88	0.39	0.20	0.214	0.037	0.85	0.71	0.72	2.00	4.63	4.79	8.00	2.60	2.13	1.17	0.83	1.01
	AS-3	485.0	870.6	429.7	1.43	1.21	0.52	0.23	0.12	0.125	0.022	0.50	0.42	0.42	1.17	2.71	2.81	4.69	1.53	1.25	0.68	0.49	0.59
	AS-4	218.7	967.1	215.3	0.72	0.61	0.26	0.11	0.06	0.063	0.011	0.25	0.21	0.21	0.59	1.36	1.41	2.35	0.76	0.63	0.34	0.25	0.30
PS-2		1599.0	846.6	1377.7	4.59	3.89	1.66	0.72	0.38	0.402	0.070	1.60	1.34	1.36	3.76	8.70	9.00	15.05	4.89	4.01	2.20	1.57	1.90
	AS-5	496.7	1123.4	567.9	1.89	1.60	0.68	0.30	0.16	0.166	0.029	0.66	0.55	0.56	1.55	3.59	3.71	6.20	2.02	1.65	0.91	0.65	0.78
	AS-6	497.2	1156.2	585.1	1.95	1.65	0.71	0.31	0.16	0.171	0.030	0.68	0.57	0.58	1.60	3.69	3.82	6.39	2.08	1.70	0.93	0.67	0.81
PS-3		2592.9	959.0	2530.7	8.43	7.14	3.05	1.33	0.69	0.739	0.128	2.94	2.46	2.50	6.90	15.98	16.53	27.64	8.99	7.36	4.03	2.88	3.49
	AS-7	88.5	1196.7	107.8	0.36	0.30	0.13	0.06	0.03	0.031	0.005	0.13	0.10	0.11	0.29	0.68	0.70	1.18	0.38	0.31	0.17	0.12	0.15
PS-4		2681.4	966.8	2638.5	8.79	7.45	3.18	1.39	0.72	0.770	0.133	3.07	2.56	2.61	7.20	16.66	17.24	28.82	9.37	7.67	4.21	3.01	3.64
	AS-8	610.2	1480.5	919.4	3.06	2.59	1.11	0.48	0.25	0.268	0.046	1.07	0.89	0.91	2.51	5.81	6.01	10.04	3.27	2.67	1.47	1.05	1.27
	AS-9	381.4	1538.7	597.4	1.99	1.69	0.72	0.31	0.16	0.174	0.030	0.69	0.58	0.59	1.63	3.77	3.90	6.52	2.12	1.74	0.95	0.68	0.82
PS-5		3673.0	1111.5	4155.2	13.84	11.73	5.01	2.18	1.14	1.213	0.210	4.83	4.03	4.10	11.33	26.24	27.15	45.38	14.76	12.08	6.62	4.73	5.74
S.R. de Lima		1960.0	893.2	1750.7	5.83	4.94	2.11	0.92	0.48	0.520	0.090	2.07	1.73	1.76	4.86	11.25	11.64	19.46	6.33	5.18	2.84	2.03	2.46
VAZA BARRIS BASIN																							
	AV-1	447.5	835.6	373.9																			
PV-1 *		447.5	835.6	373.9	4.44	3.49	2.02	1.34	0.86	0.820	0.380	4.89	7.24	4.58	9.51	8.47	4.09	3.02	1.76	1.32	1.06	1.20	4.86
	AV-2	280.4	1009.5	283.1	1.22	1.45	0.72	0.35	0.08	0.062	0.012	0.42	0.50	1.02	0.88	1.72	2.20	2.98	1.55	1.10	0.75	0.32	1.27
	AV-3	534.2	957.9	511.7	2.20	2.62	1.30	0.63	0.15	0.113	0.022	0.76	0.91	1.85	1.58	3.11	3.98	5.39	2.81	1.98	1.35	0.58	2.30
PV-2		1262.1	975.7	794.8	7.86	7.55	4.04	2.32	1.09	0.995	0.414	6.07	8.66	7.45	11.97	13.30	10.27	11.39	6.12	4.40	3.16	2.10	8.44
	AV-4	193.0	1193.6	230.4	0.99	1.18	0.59	0.28	0.07	0.051	0.010	0.34	0.41	0.83	0.71	1.40	1.79	2.43	1.26	0.89	0.61	0.26	1.04
PV-3		1455.1	1017.4	1025.1	8.85	8.73	4.63	2.60	1.16	1.045	0.424	6.41	9.07	8.28	12.68	14.70	12.06	13.82	7.38	5.30	3.77	2.37	9.47
	AV-5	178.5	1266.4	226.1	0.97	1.16	0.57	0.28	0.07	0.050	0.010	0.34	0.40	0.82	0.70	1.37	1.76	2.38	1.24	0.88	0.60	0.26	1.02
	AV-6	239.4	1311.2	313.9	1.35	1.60	0.80	0.39	0.09	0.069	0.013	0.47	0.56	1.13	0.97	1.91	2.44	3.31	1.72	1.22	0.83	0.36	1.41
PV-4		1873.0	1097.9	1565.1	11.17	11.49	6.00	3.27	1.31	1.164	0.447	7.22	10.03	10.23	14.35	17.98	16.26	19.50	10.34	7.39	5.20	2.98	11.90
	AV-7	281.0	1513.7	425.3	1.83	2.17	1.08	0.52	0.12	0.094	0.018	0.63	0.76	1.54	1.32	2.59	3.31	4.48	2.33	1.65	1.12	0.48	1.91
PV-5		2154.0	1166.4	1990.4	13.00	13.67	7.08	3.80	1.44	1.258	0.465	7.85	10.79	11.77	15.67	20.57	19.57	23.98	12.67	9.04	6.32	3.46	13.82
	AV-8	405.0	1515.1	613.6	2.64	3.14	1.56	0.76	0.18	0.135	0.026	0.91	1.09	2.22	1.90	3.73	4.77	6.46	3.36	2.38	1.62	0.70	2.76
PV-6		2559.0	1233.3	2604.1	15.64	16.80	8.64	4.55	1.61	1.393	0.492	8.76	11.88	13.98	17.57	24.30	24.35	30.44	16.04	11.42	7.95	4.16	16.58
Faz. Belem Stn		15740	-	-	12.46	13.02	6.76	3.64	1.40	1.230	0.460	7.66	10.56	11.31	15.28	19.80	18.59	22.65	11.98	8.55	5.99	3.32	13.25
Ponte SE-302*		14122	-	-	4.44	3.49	2.02	1.34	0.86	0.820	0.380	4.89	7.24	4.58	9.51	8.47	4.09	3.02	1.76	1.32	1.06	1.20	4.86
Difference		1618.0	1148.5	1858.3	8.02	9.53	4.74	2.30	0.54	0.410	0.080	2.77	3.32	6.73	5.77	11.33	14.50	19.63	10.22	7.23	4.93	2.12	8.39

Note: Sao Francisco River – Average values for 1968 – 1997 (30 years)
Vaza Barris – difference between Faz. Belem and Ponte SE-302 taken as flow generated in Sergipe
Average values for same period 1985-93 used for both Faz. Belem and Ponte SE-302
Catchment area measured from 1:100,000 scale maps – different from ANEEL values

Table-3.1 (2/2) Calculated Flow Regime at Reference Points

Ref Pt	Sub-Basin	Basin Area (km²)	Basin Rain (mm/yr)	Annual Rain (10^6 m³)	Flow Regime (m³/s) Ave.	Q-95 (25%)	Q-185 (50%)	Q-275 (75%)	Q-355 (95%)	Q 7-day Average (m³/s)	Q 7-day 1 in 10 yr (m³/s)	Average Monthly Flow (m³/s) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
PIAUI BASIN																							
	AP-1	325.0	1180.3	383.6	1.34	1.56	0.77	0.35	0.09	0.061	0.036	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
	AP-2	955.0	1023.0	977.0	3.41	3.97	1.95	0.90	0.22	0.155	0.093	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
PP-1		1280.0	1062.9	1360.6	4.75	5.52	2.72	1.25	0.30	0.216	0.129	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75
	AP-3	672.0	1374.3	923.5	3.22	3.75	1.84	0.85	0.20	0.146	0.088	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22
	AP-4	673.6	1219.1	821.2	2.86	3.33	1.64	0.76	0.18	0.130	0.078	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86
PP-2		2625.6	1182.7	3105.3	10.83	12.60	6.20	2.86	0.69	0.492	0.295	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83
	AP-5	82.1	1651.8	135.6	0.47	0.55	0.27	0.12	0.03	0.022	0.013	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
	AP-6 *	407.3	1470.8	599.1	5.46	5.27	3.19	2.15	1.54	1.280	0.860	2.26	2.48	3.46	6.13	11.02	8.46	8.75	6.38	4.81	3.65	2.89	2.97
PP-3		3115.0	1232.7	3839.9	16.76	18.42	9.66	5.13	2.26	1.794	1.168	13.56	13.78	14.76	17.43	22.32	19.76	20.05	17.68	16.11	14.95	14.19	14.27
	AP-7	1147.0	1538.8	1765.0	6.16	7.16	3.53	1.62	0.39	0.280	0.168	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16
PP-4		4262.0	1315.1	5605.0	22.92	25.59	13.19	6.75	2.65	2.074	1.336	19.72	19.94	20.92	23.59	28.48	25.92	26.21	23.84	22.27	21.11	20.35	20.43
REAL BASIN																							
	AR-1	548.0	696.7	381.8	0.69	0.44	0.07	0.04	0.02	0.009	0.000	0.12	0.44	0.64	0.92	1.42	1.21	1.78	0.91	0.20	0.07	0.28	0.80
	AR-2	711.0	696.7	495.4	0.89	0.57	0.09	0.05	0.02	0.011	0.000	0.15	0.58	0.83	1.19	1.84	1.58	2.30	1.18	0.26	0.09	0.37	1.03
PR-1		1259.0	696.7	877.1	1.58	1.01	0.15	0.10	0.04	0.020	0.000	0.27	1.02	1.47	2.11	3.25	2.79	4.08	2.09	0.46	0.17	0.65	1.83
	AR-3	1235.0	779.1	962.2	1.73	1.11	0.17	0.10	0.04	0.022	0.000	0.30	1.12	1.61	2.31	3.57	3.06	4.48	2.30	0.50	0.18	0.71	2.00
	AR-4	424.0	868.6	368.3	0.66	0.42	0.07	0.04	0.02	0.008	0.000	0.12	0.43	0.62	0.89	1.37	1.17	1.71	0.88	0.19	0.07	0.27	0.77
PR-2 *		2918.0	756.6	2207.6	3.98	2.54	0.39	0.24	0.09	0.050	0.000	0.69	2.57	3.69	5.31	8.19	7.02	10.27	5.27	1.15	0.42	1.63	4.60
	AR-5	924.0	1079.0	997.0	7.06	5.85	3.06	1.70	0.84	0.870	0.187	1.40	3.55	4.21	6.28	17.55	14.90	4.64	2.38	0.52	0.19	0.74	2.08
	AR-6	467.0	1167.0	545.0	3.86	3.20	1.67	0.93	0.46	0.476	0.102	0.76	1.94	2.30	3.43	9.60	8.14	2.54	1.30	0.28	0.10	0.40	1.14
PR-3		4309.0	1108.5	1542.0	14.90	11.59	5.12	2.87	1.39	1.346	0.290	2.85	8.06	10.20	15.02	35.34	30.06	28.03	23.31	7.75	5.58	4.58	11.29
	AR-7	212.0	1602.5	339.7	2.41	1.99	1.04	0.58	0.29	0.297	0.064	0.48	1.21	1.43	2.14	5.98	5.08	1.58	0.81	0.18	0.06	0.25	0.71
	AR-8	202.0	1602.5	323.7	2.29	1.90	0.99	0.55	0.27	0.283	0.061	0.45	1.15	1.37	2.04	5.70	4.84	1.51	0.77	0.17	0.06	0.24	0.67
PR-4		4723.0	1221.8	2205.4	19.60	15.48	7.15	4.01	1.94	1.926	0.414	3.79	10.42	13.00	19.19	47.02	39.97	35.67	31.07	10.58	7.81	5.85	14.17
	AR-9	75.0	1602.5	120.2	0.85	0.71	0.37	0.21	0.10	0.105	0.023	0.17	0.43	0.51	0.76	2.12	1.80	0.56	0.29	0.06	0.02	0.09	0.25
PR-5		4798.0	1237.0	2325.6	20.46	16.19	7.52	4.21	2.04	2.031	0.437	3.95	10.85	13.51	19.95	49.13	41.77	37.05	32.48	11.10	8.21	6.08	14.69
Itanhi Stn		4320.0	-	-	16.80	13.16	5.94	3.33	1.61	1.630	0.340	3.23	9.01	11.33	16.70	40.05	34.06	31.11	26.44	8.89	6.48	5.09	12.45
Faz. Tourao*		2895.0	-	-	3.98	2.54	0.39	0.24	0.09	0.050	0.000	0.69	2.57	3.69	5.31	8.19	7.02	10.27	5.27	1.15	0.42	1.63	4.60
Difference		1558.0	1161.5	1809.6	12.82	10.62	5.55	3.09	1.52	1.580	0.340	2.54	6.44	7.64	11.39	31.86	27.04	20.84	21.17	7.74	6.06	3.46	7.85

Note: Real river – difference between Itanhi and Faz. Tourao taken as flow generated
Catchment area measured from 1:500,000 scale maps – different from ANEEL values

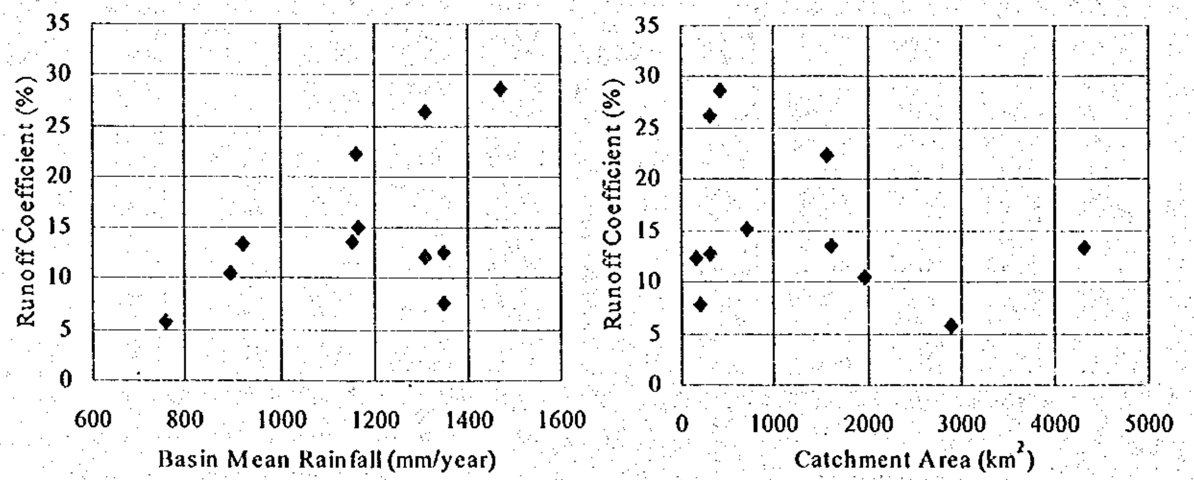


Figure-3.3 Variation of Annual Runoff Coefficient

Table-3.2 Annual Runoff Coefficients

	ANEEL Station	River Name	Basin Area (km²)	Basin Mean Rainfall (mm/yr)	Total Annual Rainfall (mill. m³)	Annual Average Discharge (m³/s)	Total Annual Flow (mill. m³)	Annual Runoff Coefft (%)
a	Japaratuba	Japaratuba	706.0	1161.9	820.3	3.94	124.3	15.1
b	Faz. Pao de Acucar	Japaratuba-Mirim	201.0	1348.3	271.0	0.66	20.8	7.7
c	Faz. Cajueiro	Japaratuba-Mirim	315.0	1348.3	424.7	1.70	53.6	12.6
d	Siriri	Siriri	160.0	1307.7	209.2	0.81	25.5	12.2
e	Rosario do Catete	Siriri	302.0	1307.7	394.9	3.29	103.8	26.3
f	Santa Rosa de Lima	Sergipe	1960.0	893.2	1750.7	5.83	183.9	10.5
g	Faz. Belem *1	Vaza Barris	1618.0	1148.5	1858.3	8.02	252.9	13.6
h	Estancia	Piauitinga	409.0	1470.8	601.6	5.46	172.2	28.6
i	Faz. Tourao	Real	2895.0	756.6	2190.4	3.98	125.5	5.7
j	Itanhi	Real	4320.0	920.7	3977.4	16.80	529.8	13.3
k	Itanhi *2	Real	1558.0	1161.5	1809.6	12.82	404.3	22.3

Notes: *1 Area downstream of Ponte-SE302
*2 Area downstream of Faz. Tourao

(2) Runoff Analysis

Total annual rainfall volume was calculated for each of discharge observation stations using the basin mean rainfall and catchment area. This volume was then compared to the average annual flow volume to give a preliminary estimation of the annual runoff coefficient. The results are given in Table-3.2 and shown graphically in Figure-3.3. From the annual data, it appears that there is no correlation between runoff coefficient and either basin mean rainfall or catchment area.

3.1.2 Surface Water Potential in Rivers

(1) Surface Water Potential on Main River Basins

The water resource potential is assumed to be the available flow in excess of the Q-7day minimum average flow. In Brazil, the Q(7,10) indicator is used as an assessment of low flow – that is, the 1 in 10 year probability continuous minimum 7day average. It has been decided to adopt 20% of the Q(7,10) flow as the maintenance discharge to be secured downstream for free intakes. In the case of dam development, 100% of the Q(7,10) flow will be provided as the environmental maintenance discharge.

The maximum surface water resources potential is estimated for each river basin from the average annual flow at the most downstream reference point (river mouth). The potential that can be realized without the construction of storage facilities, ie the free intake potential, is calculated from 80% of Q(7,10), where 20% of Q(7,10) is allowed to flow downstream as the maintenance discharge.

The surface water potential is shown for the six river basins in Table-3.3. In the case of Sao Francisco River, potential is estimated at Propria based on the ANEEL flow data. Average flow is taken as the annual average since the start of operation of Xingo Dam; 7-day average minimum flow is based on historical data.

Table-3.3 Surface Water Potential on Main River Basin

River Basin	Average Flow (m^3/s)	Annual Potential (MCM/yr)	Ave Min 7-day Flow (m^3/s)	Annual Potential (MCM/yr)	10-yr Min. 7-day Flow (m^3/s)	Annual Potential (MCM/yr)
S. Francisco	1780	56,134	1640	51,719	1279	40,335
Japaratuba	10.60	334.3	1.129	35.6	0.215	6.8
Sergipe	13.84	436.5	1.213	38.3	0.210	6.6
Vaza Barris	15.64	493.2	1.393	43.9	0.492	15.5
Piaui	22.92	722.8	2.074	65.4	1.336	42.1
Real	20.46	645.2	2.031	64.0	0.437	13.8

Notes : Sao Francisco at Propria ANEEL gauging station, Other basins at downstream Reference Point at River Mouth

(2) Surface Water Potential on Small River Basins

The surface water resources potential of the small perennial rivers used by DESO for water supply was assessed from an analysis of the DESO river flow data as described below.

< Minimum Discharge in Perennial Rivers >

DESO carries out discharge measurement at a total of 89 flow measuring points, of which 83 stations (93%) are located in the coastal Leste Sergipano and the remainder on the Leste side of the Agreste and Sertao regions. In principal, flow measurement is undertaken on a monthly basis but in fact, the observation periods of the 89 stations vary from only one month to 59 months over the last ten years, with an average value of 14 readings. From the available data, the minimum observed discharges (Q_{min}) were picked up and used to estimate the ten-year return period minimum 7-day flow Q(7,10).

< Small River Basin Potential >

The water resource potential of the small river basins was assessed as follows. The annual rainfall at the time of the minimum observed discharges identified above was compared to the ten-year return period minimum annual rainfall for the rainfall station closest to each of the flow measuring points. The ratio of ten-year return period rainfall to Q_{min} rainfall was then used as the Q(7,10) ratio and the ten-year return period minimum 7-day flow estimated from:

$$Q(7,10)\ flow = Q_{min} \times Q(7,10)\ ratio$$

In addition, the Q(7,10) specific discharge was calculated by dividing the Q(7,10) flow by the catchment area at the flow measuring point. The results of this assessment are shown in Table-3.4 and the variation of ten-year return period minimum discharge with catchment area for each of the six main river systems are plotted in Figure-3.4. The water resource potential for each small basin was then ranked for both Q(7,10) flow and specific discharge according to the criteria given in Table-3.4. The results of the potential ranking are also given as follows:

Potential Rank		A	B	C	D
Q(7,10) Flow	(m^3/day)	Q>3000	Q>2000	Q>1000	Q<1000
Q(7,10) Spec. Q	(m^3/day/km^2)	Q>200	Q>100	Q>30	Q<30

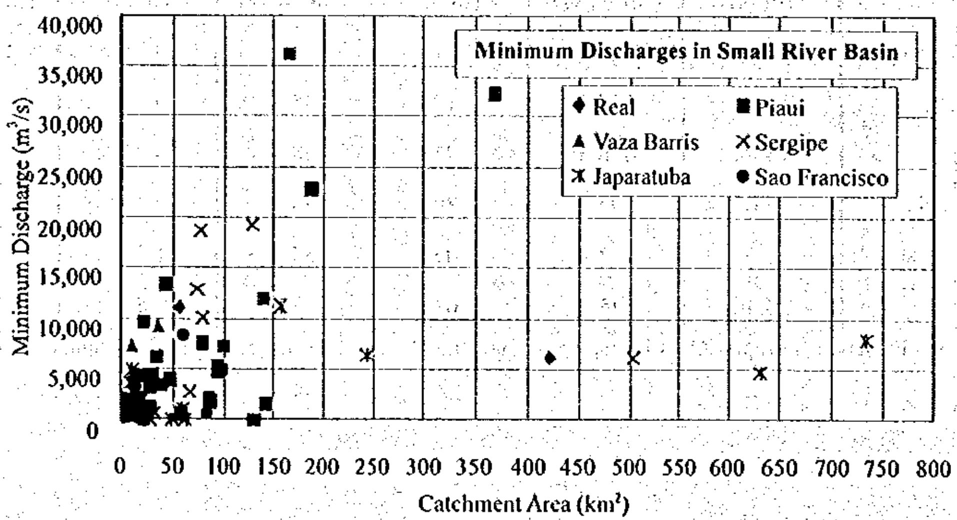


Figure-3.4 Specific and Minimum Discharge in Small River Basins

Table-3.4 Potential at DESO Flow Measuring Points

No	Station Name	River	Basin	Micro-Region	Municipality	Catch. Area (km²)	Number of Data	Date	Ratio of Q(7,10)	Minimum Flow (lit/s)	Q(7,10) Flow (m³/day)	Q(7,10) Specific Q m³/day/km²	Potential Rank Q	Potential Rank Spec Q
1	BR - 101	Real	Real	12	Cristinapolis		4	Aug-96	0.61	85	4,480			
2	Faz. Cruzeiro	Real	Real	12	Cristinapolis		4	Feb-96	0.61	98	5,165			
3	Col. Retiro	Real	Real	13	Indiaroba		4	Apr-96	0.61	260	13,703			
4	DESO/Cristinapolis	Rch. Brejo	Real	12	Cristinapolis	9.21	27	Jan-96	0.61	31	1,634	177.4	C	B
5	Faz. B. Hora	Itamirim	Real	12	Umbauba	421.40	12	Jan-96	0.61	118	6,219	14.8	A	D
6	DESO/Indiaroba	Paripe	Real	13	Indiaroba	54.54	21	Mar-96	0.66	194	11,063	202.8	A	A
7	DESO/Itabaianinha	Guararema	Piaui	12	Umbauba	18.75	26	Jan-96	0.61	9	474	25.3	D	D
8	Faz. Cedro	Guararema	Piaui	13	Sta. L. Itanhy	93.11	18	Jan-96	0.61	103	5,429	58.3	A	C
9	Faz. Antas	Guararema	Piaui	13	Sta. L. Itanhy	138.19	12	Apr-96	0.61	225	11,858	85.8	A	C
10	DESO/Itabaianinha	Rch. Riachão	Piaui	12	Umbauba	10.10	29	Mar-96	0.61	3	158	15.7	D	D
11	DESO/Umbauba	Rch. Imbe	Piaui	12	Umbauba	7.14	20	Feb-95	0.76	5	328	46.0	D	C
12	Faz. Antas	Sapucaia	Piaui	13	Sta. L. Itanhy	38.13	10	Jan-96	0.61	65	3,426	89.8	A	C
13	Faz. Castelo	Ariquitiba	Piaui	13	Sta. L. Itanhy	46.13	19	Apr-96	0.76	62	4,071	88.3	A	C
14	BR - 101	João Dias	Piaui	13	Sta. L. Itanhy	34.67	7	Apr-96	0.76	52	3,415	98.5	A	C
15	Faz. Pilar	Indiaroba	Piaui	13	Indiaroba	77.67	11	Jan-96	0.66	133	7,584	97.6	A	C
16	Faz. Saguim	Saguim	Piaui	13	Sta. L. Itanhy	26.44	9	Apr-96	0.66	22	1,255	47.4	C	C
17	Rod. SE-318	Priapu	Piaui	13	Sta. L. Itanhy	15.43	15	Apr-96	0.66	14	798	51.7	D	C
18	Pov. Casa Caiada	Garangau	Piaui	12	Araua	92.57	11	Jan-96	0.79	69	4,710	50.9	A	C
19	DESO/Araua	Doce	Piaui	12	Araua	7.47	18	Nov-95	0.66	10	570	76.3	D	C
20	DESO/Pedrinhas	Rch. Areias	Piaui	12	Pedrinhas	4.27	9	Mar-95	0.74	5	320	74.9	D	C
21	Faz. Soledade	Rch. Cabugu	Piaui	13	Sta. L. Itanhy	85.55	12	Jan-96	0.61	33	1,739	20.3	C	D
22	Faz. Tuim	Camboata	Piaui	12	Araua	140.67	11	Jan-96	0.50	36	1,555	11.1	C	D
23	Faz. Alecrim	Cassungue	Piaui	13	Estancia	29.47	12	Mar-95	0.89	60	4,614	156.6	A	B
24	Faz. Biriba	Biriba	Piaui	13	Estancia	14.56	11	Jan-96	0.76	32	2,101	144.3	B	B
25	Pov. Mancambira	Muculunduba	Piaui	13	Estancia	18.81	10	Jan-96	0.76	66	4,334	230.4	A	A
26	Gasod. Petrobras	Macaco	Piaui	13	Estancia	12.03	1	Dec-95	0.83	51	3,657	304.0	A	A
27	Faz. S. Jose	Aguas Claras	Piaui	13	Estancia	129.94			-					
28	Col. Bela Vista	Rch. Riachao	Piaui	13	Estancia	21.72			-					
29	DESO/Itaporanga	Fundo	Piaui	13	Itaporanga	42.54	23	Mar-95	0.83	188	13,482	316.9	A	A
30	Faz. Jurema	Fundo	Piaui	13	Estancia	163.98	23	Mar-95	0.83	506	36,286	221.3	A	A
31	Pov. S. Bento	Pau Grande	Piaui	12	Salgado	56.20	39	Mar-96	0.69	8	477	8.5	D	D
32	Pov. Agua Fria	Agua Fria	Piaui	12	Salgado	6.45	38	Apr-96	0.69	34	2,027	314.3	B	A
33	DESO - S.I.P	Piauitinga	Piaui	12	Salgado	82.96	59	Apr-96	0.69	36	2,146	25.9	B	D
34	Faz. Boa Vista	Piauitinga	Piaui	12	Salgado	100.43	49	Feb-96	0.69	120	7,154	71.2	A	C
35	Faz. Cupira	Piauitinga	Piaui	12	Salgado	187.46	19	Feb-95	0.83	319	22,876	122.0	A	B
36	Estancia	Piauitinga	Piaui	13	Estancia	366.49	13	Jan-96	0.69	539	32,133	87.7	A	C
37	DESO/Boquim	Grilo	Piaui	12	Salgado	26.45	26	Mar-95	0.83	46	3,299	124.7	A	B
38	Col. Entre Rios	Quebradas	Piaui	13	Estancia	96.35	10	Jan-95	0.83	69	4,948	51.4	A	C
39	Faz. Vertentes	Capivara	Piaui	13	Estancia	21.68	9	Mar-95	0.89	125	9,612	443.4	A	A
40	Faz. Riachao	Riachao	Piaui	13	Estancia	33.62	15	Mar-95	0.83	85	6,096	181.3	A	B
41	SAEE/S. Cristovao	Comprido	Vaza Barris	11	S. Cristovao	10.10	25	Feb-95	0.84	99	7,185	711.4	A	A
42	Faz. Colegio	Tejupeba	Vaza Barris	13	Itaporanga	35.01	7	Apr-95	0.84	126	9,145	261.2	A	A
43	BR - 101	Chinduba	Vaza Barris	13	Itaporanga	21.11	6	Jan-96	0.63	26	1,415	67.0	C	C
44	Pov. Sape	Tabocas	Vaza Barris	13	Itaporanga	11.68	15	Jan-96	0.69	25	1,490	127.6	C	B
45	Pov. Ribeira	Ribeira	Vaza Barris	13	Itaporanga	11.60	10	Jan-96	0.67	19	1,100	94.8	C	C
46	SAEE/S. Cristovao	DA Besta	Vaza Barris	11	S. Cristovao	11.80	8	Oct-85	0.49	26	1,101	93.3	C	C
47	Boa Terra	Ribeira	Vaza Barris	4	Itabaiana	5.42	20	Feb-95	0.87	29	2,180	402.2	B	A
48	Faz. Escurial	Bica	Vaza Barris	11	S. Cristovao	29.46	13	Apr-95	0.87	49	3,683	125.0	A	B
49	Faz. Itaperoa	Pindoba	Vaza Barris	11	S. Cristovao	11.63	15	Mar-95	0.87	12	902	77.6	D	C
50	Faz. Panema	Pe de Serra	Vaza Barris	13	Itaporanga	11.60	11	Apr-95	0.87	48	3,608	311.0	A	A
51	Faz. Dira	DA Mata	Vaza Barris	13	Itaporanga	9.34	11	Jan-96	0.67	20	1,158	124.0	C	B
52	Faz. Dira	R. da Mata	Vaza Barris	13	Itaporanga	14.93	8	Jan-96	0.67	18	1,042	69.8	C	C
53	Morena	Campos	Vaza Barris	13	Itaporanga	6.64	8	Apr-95	0.87	2	150	22.6	D	D
54	Faz. Camocule	Quirino	Vaza Barris	13	Itaporanga	15.75	8	Apr-95	0.87	24	1,804	114.5	C	B
55	Genipapo	Tabocas	Vaza Barris	6	Lagarto		5	Oct-96	0.51	4	176			
56	Faz. R. Alegre	Ipanema	Vaza Barris	13	Itaporanga		1	Jul-94	-	241			D	D
57	Pov. Campos	Tinga	Vaza Barris	13	Itaporanga	8.98	7	Jan-96	0.67	20	1,158	128.9	C	B
58	Pedra Mole	Vaza Barris	Vaza Barris	2	Pedra Mole		6	Nov-95	-	75				
59	Faz. Passagem	Vaza Barris	Vaza Barris	4	S. Domingos		4	Nov-95	-	281				
60	Faz. Dira	Vaza Barris	Vaza Barris	13	Itaporanga		4	Jan-96	-	710				
61	Colegio Agricola	Poxim Acu	Sergipe	11	S. Cristovao	127.72	26	Mar-95	0.87	256	19,243	150.7	A	B
62	Faz. Cumbe	Poxim Acu	Sergipe	11	S. Cristovao	73.82	22	Mar-95	0.87	170	12,779	173.1	A	B
63	Pov. Timbo	Timbo	Sergipe	11	S. Cristovao	7.13	9	Mar-96	0.67	38	2,200	308.5	B	A
64	Tabua	Poxim Mirim	Sergipe	11	S. Cristovao	32.75	18	Jan-96	0.67	14	810	24.7	D	D
65	Quissama	Poxim Mirim	Sergipe	11	S. Cristovao	57.81	15	Jan-96	0.67	14	810	14.0	D	D
66	BR - 101	Pitanga	Sergipe	11	S. Cristovao	27.19			-					
67	Cabrita	Pitanga	Sergipe	11	S. Cristovao	77.93	23	Feb-95	0.87	136	10,223	131.2	A	B
68	Faz. Treme	Cotinguiba	Sergipe	10	Laranjeiras	77.02	5	Oct-95	0.64	336	18,579	241.2	A	A
69	Central	Jacarecica	Sergipe	10	Riachuelo	504.79	11	Jul-90	0.60	118	6,117	12.1	A	D
70	DESO/A. Branca	Coqueiro	Sergipe	4	Areia Branca	19.05	25	Apr-92	0.58	41	2,055	107.9	B	B
71	DESO/Malhador	C. do Veado	Sergipe	4	Malhador	12.71	19	Apr-94	0.64	19	1,051	82.7	C	C
72	DESO/Riachuelo	Dangra	Sergipe	10	Riachuelo	65.65	5	Jan-95	0.64	48	2,654	40.4	B	C
73	DESO/N.S.Dores	Siriri Vivo	Japaratuba	8	Siriri	9.87	33	Jan-84	0.52	108	4,852	491.6	A	A
74	Gado Bravo	Aldeia	Japaratuba	8	Capela	9.71	12	Apr-96	0.59	70	3,568	367.5	A	A
75	SAEE/Capela	Lagartixo	Japaratuba	8	Capela	3.68	10	Jan-96	0.59	37	1,886	512.5	C	A
76	Faz. Sta. Tereza	Lagartixo	Japaratuba	9	Japaratuba	48.03			-					
77	Pov. Curral Bois	Japat. Mirim	Japaratuba	9	Japaratuba	243.21	8	Nov-83	1.54	47	6,254	25.7	A	D
78	Usina Stá. Clara	Japaratuba	Japaratuba	9	Japaratuba	633.24	4	Jan-96	0.59	94	4,792	7.6	A	D
79	Rod. SE - 206	Cancelo	Japaratuba	8	Siriri	58.76	7	Apr-95	0.75	18	1,166	19.9	C	D
80	Rod. SE - 206	Japaratuba	Japaratuba	9	Japaratuba	734.67	4	Jan-96	0.59	157	8,003	10.9	A	D
81	Rod. SE - 206	Siriri	Japaratuba	8	Siriri	155.96	5	Dec-95	0.75	173	11,210	71.9	A	C
82	Pov. L. Redonda	Sapucaia	Sapucaia	9	Pirambu	62.30			-					
83	Estiva do Raposo	E. Raposo	S. Francisco	9	Pacatuba	12.00	10	Nov-94	0.51	75	3,305	275.4	A	A
84	DESO/Japoata	N. Senhora	S. Francisco	9	Japoata	23.71	21	Mar-95	0.60	21	1,089	45.9	C	C
85	Faz. Praia	Sto. Antonio	S. Francisco	9	Pacatuba	58.00	8	Mar-96	0.58	166	8,319	143.4	A	B
86	Faz. Estancinha	Piloies	S. Francisco	9	Japoata	81.15	9	Mar-96	0.58	16	802	9.9	D	D
87	Atalho	Atalho	S. Francisco	9	Pacatuba				-					
88	Badajos	Papagaio	S. Francisco	9	Japaratuba		3	Jan-96	0.66	20	1,140			
89	Faz. Papagaio	Papagaio	S. Francisco	9	Japaratuba		1	Nov-95	0.87	224	16,838			

Potential Rank Q A:Q>3000 B:Q>2000 C:Q>1000 D:Q<1000 m³/day
Potential Rank Spec Q A:Q>200 B:Q>100 C:Q>30 D:Q<30 m³/day/km²

3.2 Groundwater Potential

Groundwater exists in whole Sergipe State, though its quantity and quality is different in each site. Groundwater development is possible in any place in Sergipe State depending on groundwater development potential of each place. Groundwater development potential is dominated by three factors shown below:

1) Groundwater recharge 2) Well capacity 3) Groundwater quality

3.2.1 Groundwater Recharge

Groundwater recharge is analyzed using two methods of; 1) Method-(I): Analysis of groundwater level fluctuation and 2) Method-(II):Numerical simulation.

(1) Method-(I) : Analysis of groundwater level fluctuation

< Principle of Method-(I) >

Principle of Method-(I) is shown in Figure-3.5. Groundwater recharge can be calculated by following formula:

$$R = u \times dh \times F$$

Where, R : Annual groundwater recharge (m^3/year) u :Specific yield of aquifer
dh : Annual groundwater level fluctuation (m) F :Area of aquifer (m^2)

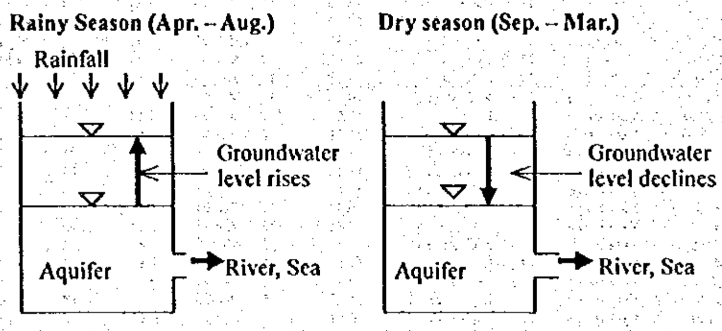


Figure-3.5 Principle of Method-(I)

< Specific yield (u) >

There are no data showing representative values of specific yield in the Study area. Therefore, the values are assumed using general values by each geology, and the result is shown in Table-3.5.

Table-3.5 Specific Yield of Aquifer

Aquifer	Specific yield	Aquifer	Specific yield
Alluvium covering Sergipe	0.15 - 0.20	Maranco Domain	0.005 - 0.01
Alluvium covering Craton	0.10 - 0.20	Macurure Domain	0.005 - 0.01
Tucano	0.05 - 0.10	Vaza-Barris Domain	0.03 - 0.05
Sergipe covered by Barreiras	0.05 - 0.15	Estancia Domain	0.01 - 0.02
Sergipe outcropping	0.10 - 0.15	Craton covered by Barreiras	0.05 - 0.15
Caninde Domain	0.005 - 0.01	Sao Francisco Craton outcropping	0.03 - 0.05
Poco Redondo Domain	0.005 - 0.01	Itabaiana Dome	0.03 - 0.05

< Annual groundwater level fluctuation (dh) >

Annual groundwater level fluctuation (dh) is estimated using result of groundwater level survey carried out by the Study Team. However, groundwater level fluctuation was observed for only 3 month between September and November 1998. Therefore, the observed groundwater level fluctuation was modified in order to obtain annual groundwater level fluctuation. Annual groundwater level fluctuation was assumed as shown in Table-3.6.

Table-3.6 Assumed Annual Groundwater Level Fluctuation

Hydrogeological Unit	Observed groundwater level fluctuation during Sep. to Nov.	Assumed annual groundwater level fluctuation
Sedimentary Rock Area	0.7m	1.4m – 2.1m
Crystalline Rock Area	0.8m	1.6m – 2.4m

<Result of Analysis by Method-(I)>
Based on the deep well data-base established by SRH, hydrogeological classification for the Master Plan formulation was made, taking account of effective utilization of the data-base. Annual groundwater recharge was analyzed, and the result is shown in Table-3.7.

Table-3.7 Annual Groundwater Recharge by Method-(I)

Hydrogeological Unit	Area	Rainfall	Annual Recharge			
	km²	mm/yea	mm/y	lit/s/km²	m³/s	% of annual rainfall
Alluvium covering Sergipe	1,061	1,398	210 - 420	6.7 - 13.3	7.1 - 14.1	15.0 - 30.1
Alluvium covering Craton	434	1,672	140 - 420	4.4 - 13.3	1.9 - 5.8	8.4 - 25.1
Tucano Basin	310	613	70 - 210	2.2 - 6.7	0.7 - 2.1	11.4 - 34.3
Sergipe covered by Barreiras	2,688	1,271	70 - 315	2.2 - 9.9	6.0 - 26.8	5.5 - 24.8
Sergipe outcropping	962	1,160	140 - 315	4.4 - 9.9	4.3 - 9.6	12.1 - 27.2
Caninde Domain	854	521	8 - 24	0.25 - 0.76	0.2 - 0.6	1.5 - 4.6
Poco Redondo Domain	1,050	570	8 - 24	0.25 - 0.76	0.3 - 0.8	1.4 - 4.2
Maranco Domain	569	639	8 - 24	0.25 - 0.76	0.1 - 0.4	1.3 - 3.8
Macurure Domain	4,909	785	8 - 24	0.25 - 0.76	1.2 - 3.7	1.0 - 3.1
Vaza-Barris Domain	2,656	972	48 - 120	1.52 - 3.81	4.0 - 10.1	4.9 - 12.3
Estancia Domain	2,391	921	16 - 48	0.51 - 1.52	1.2 - 3.6	1.7 - 5.2
Craton covered by Barreiras	2,092	1,425	70 - 315	2.2 - 9.9	4.6 - 20.9	4.9 - 22.1
Craton outcropping	1,435	1,205	48 - 120	1.52 – 3.81	2.2 - 5.5	4.0 - 10.0
Itabaiana Dome	639	1,082	48 - 120	1.52 - 3.81	1.0 - 2.4	4.4 - 11.1
Total	22,050	1,015	-	-	34.8 - 107	4.9 - 15.0

(2) Method-(II) : Numerical Simulation

< Principal of Method-(II) >
Simplified hydrogeological model was formulated for the whole Sergipe State, and boundary condition was given to this model. Simulation was repeated with different groundwater recharge until simulated groundwater level fitted with observed data. Simulation program used for this analysis is three dimensional simulation model, namely USGS-MODFLOW. Procedure of the simulation is flow-charted as follows;

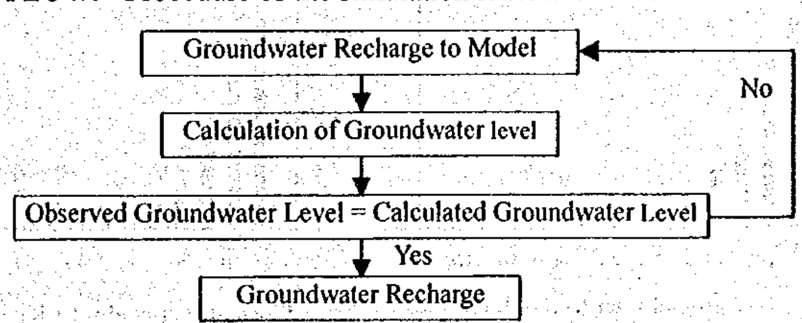


Figure-3.6 Procedure of Simulation

< Aquifer Model >

Groundwater aquifer was modeled as shown in Table-3.8.

Table-3.8 Simplified Aquifer Model

Item	Content
Aquifer model	4 layer model: Permeability of layers gradually reduces from the 1st layer to the 4th layer.
Boundary condition	There are three types of boundary conditions. - Sea : Constant groundwater level boundary - Water shed : No groundwater flow boundary - River : Groundwater discharge boundary
Conductivity	Conductivity is examined for each aquifer from transsimisivity of existing boreholes using borehole data-base which stores 4,000 borehole data

< Result of Method-(II) >

The simulation was completed when simulated groundwater level fitted with observed one, and groundwater recharge at this time was considered to be the most likely groundwater recharge, which is shown in Table-3.9. Histogram of observed groundwater levels and simulated ones is shown in Figure-3.7. Both of the histograms look to correspond enough to each other. Histogram of observed groundwater level is obtained from borehole data-base which shows actual groundwater level during drilling.

Table-3.9 Groundwater Recharge by Method-(II)

Hydrogeological Unit	Area	Rainfall	Annual groundwater recharge			
	km^2	mm/yea	mm/y	$lit/s/km^2$	m^3/s	% of Annual Rainfall
Alluvium covering Sergipe	1,061	1,398	360	11.42	12.11	25.8
Alluvium covering Craton	434	1,672	170	5.39	2.34	10.2
Tucano Basin	310	613	110	3.49	1.08	18.0
Sergipe covered by Barreiras	2,688	1,271	250	7.93	21.31	19.7
Sergipe outcropping	962	1,160	280	8.88	8.54	24.1
Caninde Domain	854	521	10	0.32	0.27	1.9
Poco Redondo Domain	1,050	570	10	0.32	0.33	1.8
Maranco Domain	569	639	10	0.32	0.18	1.6
Macurure Domain	4,909	785	15	0.48	2.34	1.9
Vaza-Barris Domain	2,656	972	60	1.90	5.05	6.2
Estancia Domain	2,391	921	30	0.95	2.27	3.3
Craton covered by Barreiras	2,092	1,425	90	2.85	5.97	6.3
Craton outcropping	1,435	1,205	60	1.90	2.73	5.0
Itabaiana Dome Craton	639	1,082	80	2.54	1.62	7.4
Total	22,050	1,015	95	3.00	66.15	9.3

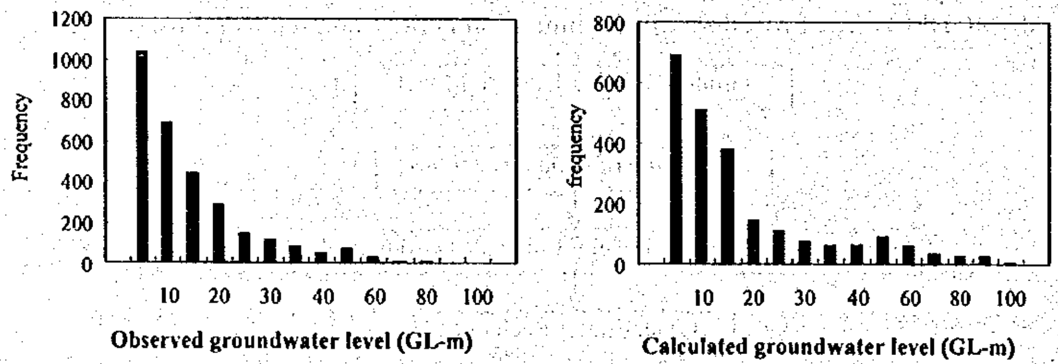


Figure-3.7 Histogram of Groundwater Level

(3) Examination of Groundwater Recharge

Groundwater recharge was estimated by two methods as explained before. The result of the method-(I) shows a wide range of values, the annual groundwater recharge of 34.8m^3/s – 107.0 m^3/s with the average of 70.9m^3/s, as shown in Table-3.7. On the other hand, the result of the method-(II) has a single value, the annual groundwater recharge of 66.15 m^3/s, as shown in Table-3.9. Comparing the two results, the method-(I) result is, if its average is taken, almost the same as the method-(II) result with negligible difference between them. Consequently, the method-(II) result is finally applied as the value of groundwater recharge, though the actual groundwater recharge is considered to be between 34.8m^3/s – 107.0 m^3/s.

3.2.2 Well Capacity and Water Quality

Well capacity and water quality were analyzed using the existing data-base. The result is shown in Table-3.10.

Table-3.10 Well Capacity and Water Quality by Aquifer

Hydrogeological Unit	Expected yield (m^3/day)	Specific capacity (m^3/day/m)	Success rate (%)	Rate of fresh water (%)
Alluvium covering Sergipe Basin Alluvium covering Craton Basin	600	140	95	100
Tucano Basin	100	4	60	60
Sergipe Basin covered by 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
Craton covered by Barreiras	70	4	85	90
Sao Francisco Craton outcropping	40	2	75	30
Itabaiana Dome	70	4	75	35

Note: Fresh water means chlorine (Cl) is less than 250 ppm.

3.2.3 Groundwater Development Potential

Groundwater development potential is shown in brief by basin in Table-3.11, and in detail by municipality in Table-3.12.

Table-3.11 Groundwater Potential by River Basin

Basin	Area (km^2)	Total amount without water quality consideration		Total amount with water quality consideration (Cl<250mg/L)	
		mm/year	mil m^3/year	mm/year	mil m^3/year
Sao Francisco	7,276.3	84	611	61	444
Japaratuba	1,722.0	152	262	113	195
Sergipe	3,673.0	131	481	91	334
Vaza Barris	2,559.0	99	253	64	164
Piaui	4,262.0	80	341	56	239
Real	2,558.0	54	138	30	77
Total	22,050.3	95	2,086	66	1,453

Table-3.12 Groundwater Development Potential by Municipality

Code	Municipality	Main aquifer	Area	Annual Groundwater Recharge		Expected Yield	Specific Capacity	Success Rate	Rate of Fresh Water	Rank
			(km2)	(mm/y)	(lit/s)	(m^3/day)	(m^3/day/m)	(%)	(%)	
01-0120	CANIDÉ DO SÃO SANCISCO	Caninde	908	27	776	40	3	50	15	D
01-0220	FEIRA NOVA	Macurure	189	15	92	40	2	60	15	D
01-0240	GARARU	Macurure	640	15	313	35	2	60	15	D
01-0260	GRACCHO CARDOSO	Macurure	236	15	115	40	2	60	15	D
01-0310	ITABI	Macurure	202	15	99	40	2	60	15	D
01-0420	MONTE ALEGRE	Macurure	418	15	204	40	2	60	15	D
01-0450	NOSSA SENHORA DA GLÓRIA	Macurure	745	15	364	40	2	60	15	D
01-0540	POÇO REDONDO	Poco Redondo	1,220	14	533	40	2	45	10	D
01-0560	PORTO DA FOLHA	Poco Redondo	895	20	555	40	3	50	10	D
02-0140	CARIRA	Macurure	634	32	642	50	4	60	20	D
02-0230	FREI PAULO	Vaza-Barris	406	67	860	75	8	75	35	C
02-0445	NOSSA SENHORA APARECIDA	Macurure	347	39	430	60	5	70	25	D
02-0500	PEDRA MOLE	Vaza-Barris	79	62	154	80	7	75	40	C
02-0520	PINHÃO	Vaza-Barris	152	62	298	80	7	75	40	C
02-0600	RIBEIRÓPOLIS	Vaza-Barris	263	61	507	75	7	75	40	C
03-0020	AQUIDABÃ	Macurure	370	15	181	40	2	60	15	D
03-0190	CUMBE	Macurure	131	15	64	40	2	60	15	D
03-0380	MALHADA DOS BOIS	Macurure	59	70	132	60	4	65	25	D
03-0430	MURIBECA	Sergipe	82	150	369	90	9	65	40	C
03-0460	NOSSA SENHORA DAS DORES	Macurure	482	32	489	50	4	65	25	D
03-0700	SÃO MIGUEL DO ALEIXO	Vaza-Barris	143	45	206	65	5	70	30	D
04-0050	AREIA BRANCA	Vaza-Barris	129	209	857	150	17	75	65	A-B
04-0100	CAMPO DO BRITO	Dome	200	75	476	70	5	75	35	C
04-0290	ITABAIANA	Dome	338	80	854	70	5	75	35	C
04-0370	MACAMBIRA	Vaza-Barris	137	65	285	75	6	75	40	C
04-0390	MALHADOR	Vaza-Barris	102	95	308	85	9	75	45	C
04-0410	MOITA BONITA	Dome	95	74	223	70	5	75	35	C
04-0680	SÃO DOMINGOS	Vaza-Barris	102	75	243	75	5	80	50	C
05-0550	POÇO VERDE	Tucano	380	81	982	60	8	65	55	C
05-0710	SIMÃO DIAS	Vaza-Barris	560	55	978	70	6	75	40	D
05-0740	TOBIAS BARRETO	Estancia	1119	33	1,170	50	3	70	50	D
06-0350	LAGARTO	Estancia	962	57	1,740	60	4	75	55	C
06-0580	RIACHÃO DO DANTAS	Estancia	528	46	776	45	3	75	40	D
07-0010	AMPARO DE SAO FRANCISCO	Macurure	39	15	19	40	2	60	15	D
07-0070	BREJO GRANDE	Q/S	149	369	1,747	600	90	95	100	A
07-0110	CANHOBA	Macurure	165	15	81	40	2	60	15	D
07-0160	CEDRO DE SÃO JOÃO	Macurure	73	89	207	65	6	65	25	D
07-0270	ILHA DAS FLORES	Q/S	57	369	675	600	90	95	100	A
07-0440	NEÓPOLIS	Sergipe	249	288	2,281	250	34	80	85	A-B
07-0470	NOSSA SENHORA DE LOURDES	Macurure	80	15	39	40	2	60	15	D
07-0570	PROPRIÁ	Sergipe	95	262	794	300	42	75	65	A-B
07-0730	TELHA	Macurure	56	37	67	45	4	60	15	D
07-0999	SANTANA DO SAO FRANCISCO	Sergipe	47	273	406	180	23	80	85	A-B
08-0130	CAPELA	Macurure	431	45	615	50	4	60	20	D
08-0200	DIVINA PASTORA	Sergipe	93	273	806	170	19	75	70	A-B
08-0650	SANTA ROSA DE LIMA	Vaza-Barris	66	122	256	95	10	75	50	C
08-0720	SIRIRI	Sergipe	167	238	1,262	175	23	80	80	A-B
09-0330	JAPARATUBA	Sergipe	374	278	3,299	215	29	80	85	A
09-0340	JAPOATÃ	Sergipe	397	269	3,391	160	19	80	80	A-B
09-0490	PACATUBA	Sergipe	407	323	4,167	405	59	90	90	A
09-0530	PIRAMBU	Sergipe	199	317	2,000	385	56	85	90	A
09-0690	SÃO FRANCISCO	Sergipe	86	275	758	140	15	75	70	A-B
10-0150	CARMÓPOLIS	Sergipe	40	305	386	295	41	80	85	A
10-0250	GENERAL MAYNARD	Sergipe	18	289	166	180	21	75	70	A
10-0360	LARANJEIRAS	Sergipe	163	302	1,564	235	30	75	70	A
10-0400	MARUIM	Sergipe	95	292	882	195	23	75	70	A-B
10-0590	RIACHUELO	Sergipe	78	293	731	180	20	75	65	A-B
10-0610	ROSÁRIO DO CATETE	Sergipe	103	302	993	260	34	80	75	A-B
10-0660	SANTO AMARO DAS BROTAS	Sergipe	237	323	2,434	395	57	85	90	A
11-0030	ARACAJU	Sergipe	181	330	1,904	440	65	90	95	A
11-0060	BARRA DOS COQUEIROS	Q/S	87	369	1,030	600	90	95	100	A
11-0480	NOSSA SENHORA DO SOCORRO	Sergipe	157	305	1,518	285	39	80	80	A-B
11-0670	SÃO CRISTOVÃO	Sergipe	432	276	3,790	215	29	80	85	A
12-0040	ARAUÁ	Craton	194	72	444	50	3	80	50	C
12-0067	BOQUIM	Craton	213	76	514	50	3	80	60	C
12-0170	CRISTINÁPOLIS	Craton	251	71	564	50	3	80	60	C
12-0300	ITABAIANINHA	Craton	480	65	991	45	2	80	40	C
12-0510	PEDRINHAS	Craton	39	82	103	60	3	80	70	B
12-0620	SALGADO	Craton	255	88	716	65	4	80	85	B
12-0750	TOMAR DO GERU	Estancia	337	50	535	45	3	75	45	D
12-0760	UMBAÚBA	Craton	124	81	319	55	3	80	70	B
13-0210	ESTÂNCIA	Craton	649	114	2,347	70	9	80	85	B
13-0280	INDIAROBA	Craton	311	108	1,067	70	8	80	80	B
13-0320	ITAPORANGA D' AJUDA	Craton	757	110	2,638	75	9	80	85	B
13-0630	SANTA LUZIA DO ITANHY	Craton	336	110	1,172	70	8	80	85	B

Note: 1) Main aquifer: Q/S- Quaternary covering Sergipe Basin, 2) Rate of fresh water: Fresh water means Cl is less than 250mg/L. 3) Success rate is the success rate of well with yield of more than 8 m^3/day.

3.2.4 Total Evaluation of Groundwater Development Potential

Groundwater development potential was evaluated based on three factors, groundwater recharge, well capacity and water quality. Taking the three factors into the consideration, rank of groundwater potential by aquifer was evaluated, and the results is shown in Table-3.13 and Figure-3.8. The total evaluation gives important criteria on possibility of new groundwater development in the future.

Table-3.13 Evaluation of Groundwater Potential by Aquifer

Hydrogeological Unit	Groundwater Recharge	Well Capacity	Water Quality	Total Evaluation
Alluvium covering Sergipe	A	A - B	A	A - B
Alluvium covering Craton	B	B	A	B
Tucano Basin	B	B	B	B
Sergipe covered by Barreiras	A	A - B	A	A - B
Sergipe outcropping	A	A - B	B	A - B
Caninde Domain	D	D	D	D
Poco Redondo Domain	D	D	D	D
Maranco Domain	D	D	D	D
Macurure Domain	D	D	D	D
Vaza-Barris Domain	C	C	C	C
Estancia Domain	D	D	C	D
Craton covered by Barreiras	C	C	A	B
Sao Francisco Craton outcropping	C	D	C	C
Itabaiana Dome Craton	C	C	C	C

Note 1) A - High, B - Medium, C – Low, D – Very low
2) Barreiras Formation is excluded from Table above because of its poor capacity for deep wells

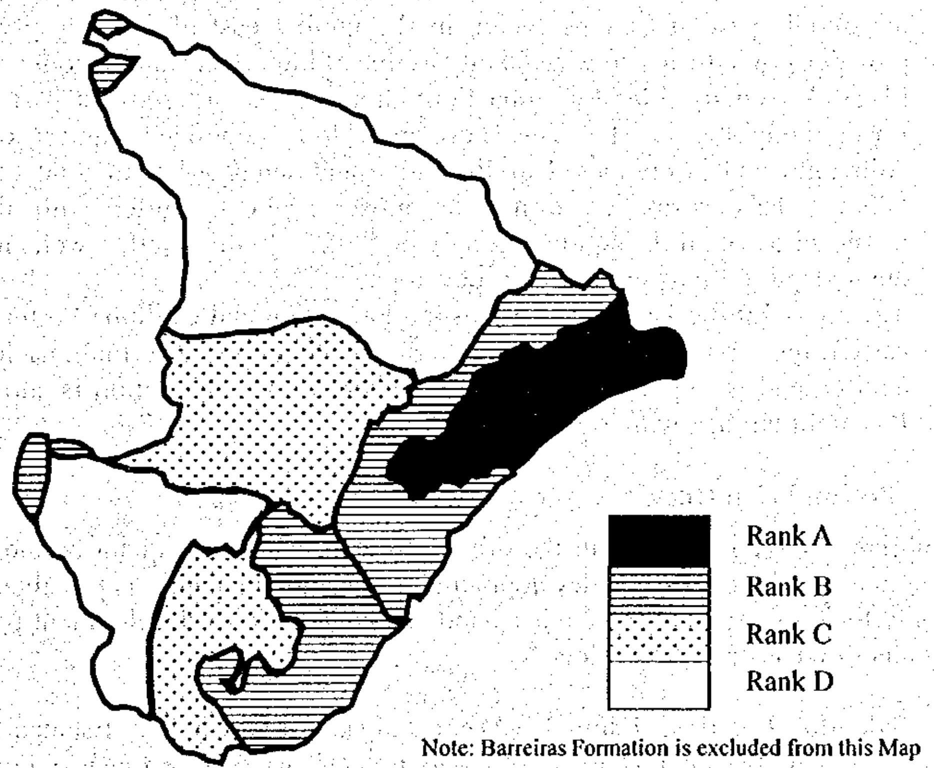


Figure-3.8 Rank of Groundwater Development Potential

3.2.5 Promising Groundwater Development Site

(1) Alluvial Basin Aquifer

Alluvial aquifer is located in the coastal area. This aquifer has high permeability, and great deal of groundwater is possible to be pumped up from this aquifer. As thickness of the Alluvium, however, is not great, over-pumping and consequent sea water intrudes into the aquifer are worried. Therefore, proper well location / yield must be designed.

(2) Sergipe Basin Aquifer

Sergipe Basin aquifer is the most promising aquifer in State. Although this aquifer expands in large area with high permeability and good water quality, this aquifer has not yet highly developed so far. Therefore, this aquifer is the most promising for new groundwater development. Figure-3.10 shows regional geological section including this aquifer. This aquifer sometimes locates deep in the ground, and drilling length must be 100 to 200m, which is longer than the existing wells. There is a possibility that groundwater discharge by pumping exceeds groundwater recharge, because the aquifer has high permeability. Sergipe Basin aquifer is divided into some formations, and promising ones are described below:

- **Penedo Formation and Serraia Formation:** Sandstone forms good aquifer in Penedo Formation and Serraia Formation. These aquifers locate in the northern part of Sergipe Basin. Muribeca, Malhada dos Bois and Japoata municipalities are located in this area.
- **Sapucari Formation, Angico Formation, Maruim Formation and Agulhada Formation:** Limestone of Sapucari Formation, Angico Formation, Maruim Formation and Agulhada Formation form good aquifers. These aquifers locate in the middle part of Sergipe Basin, in the north - east of Aracaju city, and now provides groundwater to Aracaju city as one of important water resources.
- **Marituba Formation:** Marituba Formation locates eastern-most part of Sergipe Basin along the coast. This Formation forms confined aquifer covered by Alluvium, and is composed of limestone and sandstone with total thickness of 500m. This Formation forms the most excellent aquifer with the highest permeability of all the aquifers in Sergipe State. In this aquifer, wells need 100 to 200m depth for new groundwater development.
- **Tucano – Jatoba Basin:** Sao Sebastiao Formation and Curituba Formation locate eastern-most part of Sergipe State. Sandstone of these formations forms good aquifer, and is important water resource because this formation is surrounded by Precambrian rock with low yield.

(3) Precambrian Rock

Precambrian aquifer is inferior to the other aquifers in terms of quantity and quality in Sergipe States, and groundwater development in Precambrian aquifer is possible on a small scale only for rural area. On the other hand, areas with higher development potential are locally identified as described below.

- **Salgado, Lagarto, Estancia Area:** Salgado, Lagarto and Estancia areas are located in Estancia Domain and Sao Francisco Craton. Lagarto Formation of Estancia Domain has boundary with gneiss of Sao Francisco Craton, and the boundary with many fissures sometimes forms good aquifer. However, Barreiras Formation covers this area wide, and the boundary is usually difficult to be found.

- **Itabaiana Dome and Vaza-Barris Area:** Gneiss of Itabaiana Dome forms good aquifers, and Frei Paulo Formation and Ribeiropolis Formation of Vaza-Barris Domain also form good aquifers.

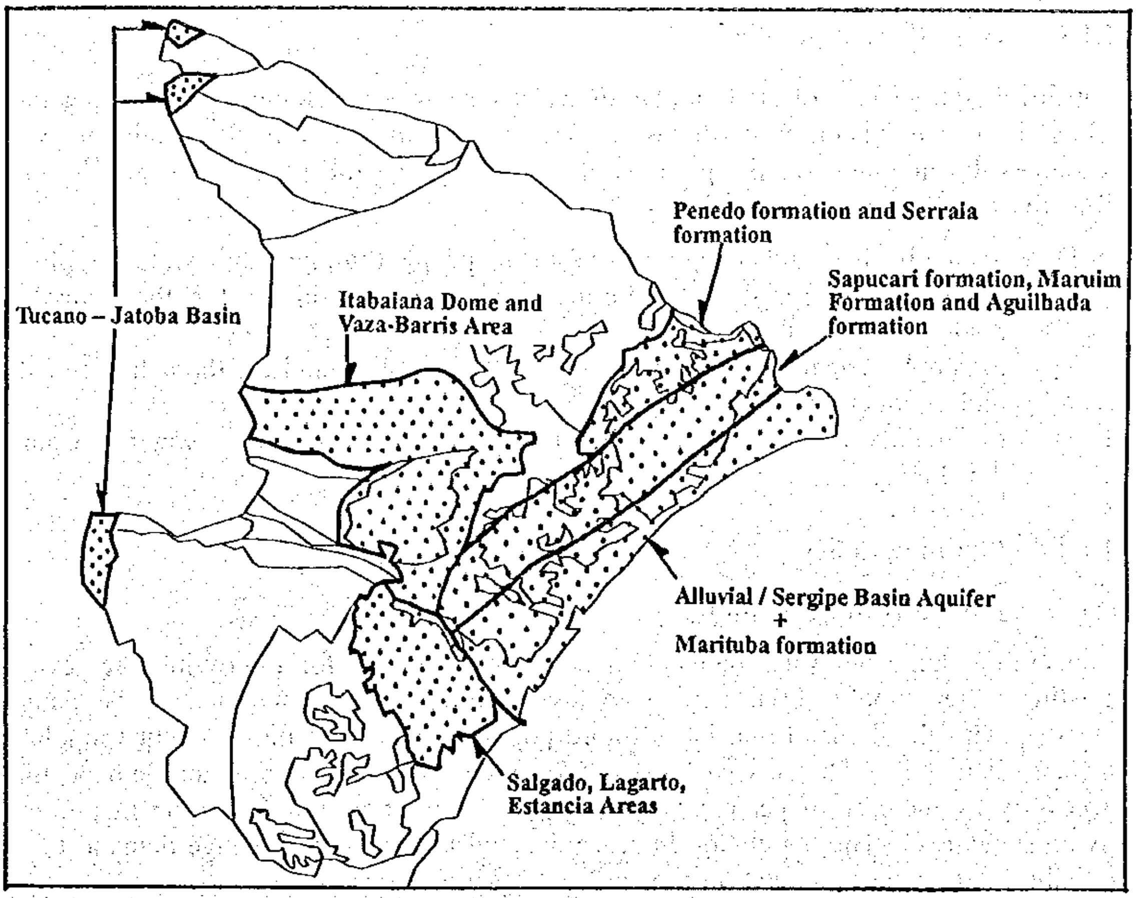


Figure-3.9 Promising Groundwater Development Site

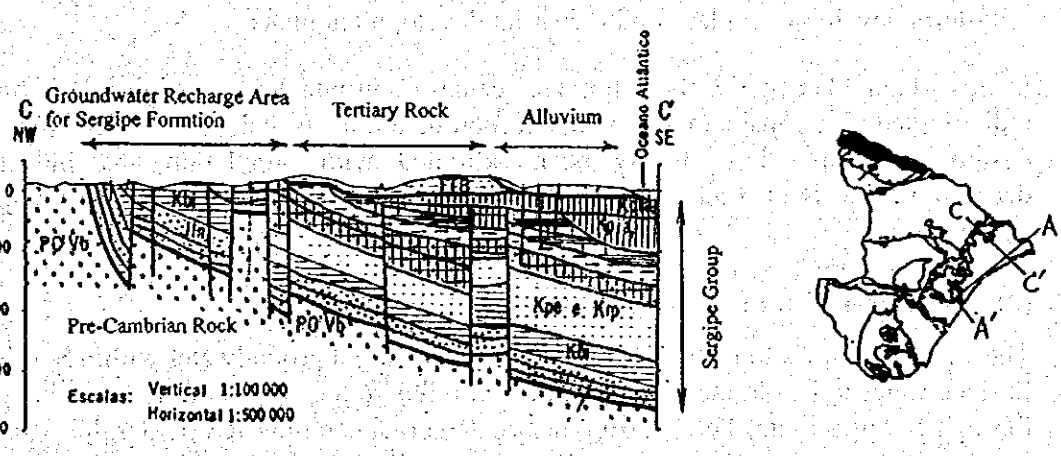


Figure-3.10 Regional Geological Section

CHAPTER 4 WATER RESOURCES DEVELOPMENT PLAN

4.1 Objectives, Policy and Goal

4.1.1 Objectives of the Plan

Toward the target year of 2020, a plan of water resources development and management, which is a state vision from the water sector, is proposed through sustainable water resources development for the purpose of securing stable life of the state people. The objectives of the plan is set as follows:

1) to supply clean and enough water for state people through public water supply.
2) to supply industrial water through public water supply for the growth of manufacturing industries.
3) to supply irrigation water to agriculturally potential land for the achievement of high productivity.
4) to maintain environmental quality through sustainable water resources development.

4.1.2 Planning Policy

(1) Future Water Demand

Concerning domestic water demand, the demand required for improving the level of existing water supply services (service level improvement demand) shall be gauged, together with the demand that takes future population increase into account (population increase demand). The service level improvement demand refers to the demand made necessary by increase of per capita consumption and supply rate, resulting in improved living standards. The population increase demand is necessary to gauge demand for the possible cases where population movement from rural areas to the cities continues and urban population concentration reaches a peak.

Industrial water demand and agricultural water demand are strategic water demands concerned with economic vitalization. Since this is demand for water needed to achieve the correction of regional disparities in the state and the mitigation of poverty (important issues in water resources development projects), it is necessary to strike a balance with the long-term development plans and industrial development plans.

In this Mater Plan Study, the "strategic scenario", in which population and industry was redistributed in consideration with decentralization, is adopted, since the Aracaju cosmopolitan area has already been saturated with population and industry, and decentralization is also advisable in the view point of water supply and development in Sergipe State.

(2) Water Resources Development

The water resources to be targeted are surface water and groundwater within Sergipe State. Surface water to be targeted for development refers to the waters of the six rivers that flow through Sergipe State, i.e. Sao Francisco River, Japaratuba River, Sergipe River, Vaza Barris River, Piaui River and Real River. Sao Francisco River, which is a major river flowing through seven states, is the most stable water resource of the said rivers. Water quality, especially saline contamination, shall be taken into account for water resources development.

Although groundwater can not be expected to provide as much water potential as surface water, it is more economical and convenient water source. Groundwater sources could be made use as the domestic water for small and medium towns, and moreover it could complement surface water sources of urban and large rural cities.

In the western and northern semi-arid districts in the state, rainwater is commonly used as water resources by directly collecting and storing rainwater. However, as its reliability is relatively low and water truck must assist to supply water in a dry year, rainwater source is not applied in this plan.

(3) Water Supply

Concerning surface water development facilities, examination shall first be carried out on the plan for water conveyance from Sao Francisco River, which possesses the most stable and abundant potential. Xingo Dam, located in the northern tip of the state, is a promising intake point that allows water to be supplied over the widest possible area. Regarding the other rivers, intakes weirs, dams, reservoirs and other development facilities shall be examined.

In districts which cannot be covered by the above water conveyance plan or intake weir, dam and reservoir plans, the appropriateness of groundwater use shall be ascertained. Concerning groundwater that possesses high salt concentration, the feasibility of using desalination to improve water quality shall be examined.

(4) Implementation of Project

The construction of facilities contained in the Master Plan should be implemented step by step in line with increasing water demand. Facilities for domestic water supply shall be constructed in line with population increase. In the case of industrial water and agricultural water, since plans also exist for the construction of basic infrastructure not related to water supply, facilities shall be constructed in accordance with plans laid down by the state for long-term industrial development. The project for water conveyance from Sao Francisco River should be a multi-purpose project intended to supply municipal and irrigation water to the semi-arid belt and other districts.

(5) Institutional Plan and Operation & Maintenance Plan

An important factor in water resources development and management is the achievement of an appropriate distribution of limited water resources to each consumer sector and the proper operation of the distribution system. In view of this, the following measures are required:

- Setting up of a system for coordinating the interests of each consumer sector (public water supply, power generation, industry, tourism, environment, etc.)
- Cost recovery and demand control through pricing
- Participation of users and residents, and decentralization in the area of water resources management and development
- Institutional development for the implementation of multi-purpose projects

4.1.3 Goal of Water Resources Development and Supply

The goals of water resources development and supply as well as river basin management are set as follows:

(1) Target Year

Target year for the Master Plan was set at the year of 2020.

(2) Domestic Water Supply

(a) Water Supply Rate

The goal of domestic water supply rate is set to provide clean water to urban and rural population in the following manners:

- **For urban areas:** to continue and achieve complete coverage (100%) in 75 municipality capitals.
- **For rural areas:** to provide water for 60% of the rural population with the private-tap system and for 25 % with the public-tap system by 2020. Total 85% of rural population will be supplied with clean water.
- **Replacing public-tap to private-tap:** Half of the present public-tap systems in the small rural areas are to be replaced with the private-tap system by 2020.

Table-4.1 Domestic Water Supply Rate

Year		1997	1998	2000	2005	2010	2015	2020
Urban Water Supply Rate		100%	100%	100%	100%	100%	100%	100%
Rural Water Supply Rate	Large Rural Area	21%	22.7%	26.1%	34.6%	43.0%	51.5%	60%
	Small Rural Area	14%	14.5%	15.4%	17.8%	20.2%	22.6%	25%
	Total	35%	37.2%	41.5%	52.4%	63.2%	74.4%	85%

Note: Rural water supply rate was set by municipalities based on the present supply rate. But the rate in 2020 is same in whole the Sergipe State.

(b) Water Supply Loss Rate

The total supply amount of water required is obtained by adding the margin for losses and leakage to total water demand to be consumed. The margin should cover losses and leakage, which occur at intake, conveyance, treatment, distribution etc. For private-tap system, present water loss rate is set at 42% and the goal of the future improvement program is set at 25% in 2020. For public-tap system, 10% is employed as water loss rate. Thus the design water supply loss rates are set as follows.

Table-4.2 Water Supply Loss Rate

Year		1997	1998	2000	2005	2010	2015	2020
Water Loss Rate	Private-tap System	42%	41.33%	40.00%	36.25%	32.50%	28.75%	25%
	Public-tap System	10%	10%	10%	10%	10%	10%	10%

(3) Industrial Water Supply

Industrial water supply rate is defined to be a ratio of total industrial water demand to public industrial water supply (by private-tap system). The industrial water supply rates were set by micro-regions as shown in Table-4.3, in accordance with the current rate of DESO's water supply to industries, as well as industrial development strategy and water resources potential.

The rest of industrial water to be not supplied by public water supply system, namely private industrial water, shall be obtained individually by means of deep wells development at the near site of factories.

Table-4.3 Industrial Water Supply Rate through Public Water Supply

Year	1997	1998	2000	2005	2010	2015	2020
Sergipe State	5%	5%	5%	10%	15%	20%	28%
01- Sergipana do Sertao do Sao Francisco	9%	9%	9%	25%	42%	58%	75%
02- Carira	7%	7%	7%	3%	53%	77%	100%
03- Nossa Senhora das Dores	3%	3%	3%	15%	26%	38%	50%
04- Agreste de Itabaiana	10%	10%	1%	14%	26%	38%	50%
05- Tobias Barreto	30%	30%	3%	21%	39%	57%	75%
06- Agreste de Lagarto	0%	0%	0%	13%	25%	38%	50%
07- Propria	2%	2%	2%	8%	14%	19%	25%
08- Cotinguiba	0%	0%	0%	6%	13%	19%	25%
09- Japaratuba	2%	2%	2%	8%	13%	19%	25%
10- Baixo Cotinguiba	0%	0%	0%	6%	13%	19%	25%
11- Aracaju	14%	14%	14%	17%	19%	22%	25%
12- Boquim	3%	3%	3%	15%	26%	38%	50%
13- Estancia	0%	0%	0%	6%	13%	19%	25%

(4) Agricultural Water Supply

Irrigation projects are planned so as to contribute 1 % in the 5 % of projected GRDP growth. Thus water resources development for irrigation is planned to satisfy the water demand of those irrigation projects.

(5) Water Resources Management

Institutional and juridical proposal and plan is made in order to maintain sustainable water resources development and conservation, and to properly implement proposed projects for water resources development and supply.