CHAPTER 3 WATER BALANCE AND WATER SHORTAGE

3.1 Balance between Water Demand and Potential

(1) Water Demand

The current and future domestic/industrial and irrigation water demands were combined to give the total water demand for each of the six river basins. From Table-3.1, it can be seen that the total water demand for Sergipe state will increase from 356.3 million cubic meters (MCM) / year in 1997 to 900.4 MCM/year, an increase of over 150% in just over 20 years.

(2) Water Resources

The available water resources to meet this demand were estimated and the results are also combined in Table-3.1. The total groundwater potential, after considering water quality implications, is estimated as 1,453 MCM/year. Surface water potential was calculated for average flow, low flow and 10-year return period drought flow conditions. The total surface water potential based on average flow is over 58,700 MCM/year; and, based on low flow conditions, almost 52,000 MCM in an average year but only 40,400 MCM in a drought year. However, if the contribution from Sao Francisco river is excluded, the corresponding values for the remaining five river basins are 2632 MCM/year based on average flows, and based on 7-day minimum flows only 247 MCM in an average year falling to 85 MCM in a drought year.

(3) Water Balance

The balance between current and forecast water demands and calculated water resources potential was made for both average and drought years. As shown in Table-3.1, when both surface and groundwater resources are considered, the available potential is sufficient to meet the demands in all six river basins.

However, if groundwater potential is excluded, it can be seen that surface water resources only are insufficient to meet the demand. This is particularly noticeable in Sergipe river basin where there is a deficit between demand and potential even in the average dry season at current demand levels. This fact illustrates the necessity to transfer water resources from basins with high potential but low demand to basins with low potential and high demand, as is currently the case with the existing Sao Francisco Pipeline System serving Aracaju city. By the target year of 2020, the deficit is also noticed in Vaza Barris basin in an average year and in all five river basins in a drought year.

(4) Water Quality

The above water balance does not consider water quality implications in the assessment of surface water potential. As described previously, there are serious salinity problems on the main streams of Sergipe, Vaza Barris and Real river basins, although the lower tributaries have acceptable water quality. In order to develop the surface water potential it is necessary to fully consider the water quality aspects and propose remedial measures in any water resources development plan.

(5) Conclusions

From the above balance, the following conclusions and recommendations can be made:

1) It is necessary to transfer water resources from basins with a surplus potential to those with a deficit, for example from Sao Francisco river basin to Sergipe river basin.

2) It is necessary to develop groundwater resources where feasible, in order to reduce the necessity for transfer between river basins.

3) Over reliance on one water resource, namely Sao Francisco river, should be avoided. For this reason it is recommended to develop alternative water resources, such as dams on tributaries and groundwater development, within Sergipe state.

Table-3.1 Balance between Water Demand and Potential

Units: million cubic meters (MCM)/year

	Sao Francisco	Japaratuba	Sergipe	Vaza Barris	Piaui	Real	TOTAL
CURRENT DEMAND (1997)							
Municipal / Industrial	13.5	10.4	99.7	14.5	21.5	5.7	165.3
Irrigation	164.2	---	---	12.1	7.8	6.9	191.0
TOTAL	177.7	10.4	99.7	26.6	29.3	12.6	356.3
FUTURE DEMAND (2020)							
Municipal / Industrial	36.8	29.6	232.2	37.2	56.8	9.4	402.0
Irrigation	412.4	---	17.9	49.9	11.3	6.9	498.4
TOTAL	449.2	29.6	250.1	87.1	68.1	16.3	900.4
WATER RESOURCES POTENTIAL							
Groundwater	444.0	195.0	334.0	164.0	239.0	77.0	1,453.0
Surface Water (Average)	56,134.0	334.3	436.5	493.2	722.8	645.2	58,766.0
Surface Water (Low Flow)	51,719.0	35.6	38.3	43.9	65.4	64.0	51,966.2
Surface Water (Drought)	40,335.0	6.8	6.6	15.5	42.1	13.8	40,419.8
TOTAL (Average Flow)	56,578.0	529.3	770.5	657.2	961.8	722.2	60,219.0
TOTAL (Ave. Low Flow)	52,163.0	230.6	372.3	207.9	304.4	141.0	53,419.2
TOTAL (Drought Flow)	40,779.0	201.8	340.6	179.5	281.1	90.8	41,872.8
CURRENT BALANCE (1997)							
Balance (Average Flow)	56,400.3	518.9	670.8	630.6	932.5	709.6	59,862.7
Balance (Ave. Low Flow)	51,985.3	220.2	272.6	181.3	275.1	128.4	53,062.9
Balance (Drought Flow)	40,601.3	191.4	240.9	152.9	251.8	78.2	41,516.5
FUTURE BALANCE (2020)							
Balance (Average Flow)	56,128.8	499.7	520.4	570.1	893.7	705.9	59,318.6
Balance (Ave. Low Flow)	51,713.8	201.0	122.2	120.8	236.3	124.7	52,518.8
Balance (Drought Flow)	40,329.8	172.2	90.5	92.4	213.0	74.5	40,972.4
CURRENT BALANCE (1997) - Surface Water Resources ONLY							
Balance (Average Flow)	55,956.3	323.9	336.8	466.6	693.5	632.6	58,409.7
Balance (Ave. Low Flow)	51,541.3	25.2	-61.4	17.3	36.1	51.4	51,609.9
Balance (Drought Flow)	40,157.3	-3.6	-93.1	-11.1	12.8	1.2	40,063.5
FUTURE BALANCE (2020) - Surface Water Resources ONLY							
Balance (Average Flow)	55,684.8	304.7	186.4	406.1	654.7	628.9	57,865.6
Balance (Ave. Low Flow)	51,269.8	6.0	-211.8	-43.2	-2.7	47.7	51,065.8
Balance (Drought Flow)	39,885.8	-22.8	-243.5	-71.6	-26.0	-2.5	39,519.4

Note: Surface Water Potential
Average Flow — Annual average flow at downstream Ref. Pt. (river mouth)
Ave. Low Flow — Average 7-day minimum flow at downstream Ref. Pt. (river mouth)
Drought Flow — 10-yr. return period 7-day minimum flow at downstream Ref. Pt. (river mouth)
(except Sao Francisco data at Propria ANEEL gauging station)

3.2 Water Demand, Supply and Shortage

3.2.1 Domestic and Industrial Water

Total water supply and shortage in the Sergipe State is summarized in Table-3.2 and Figure-3.1. According to the planned goal of water supply rate, water amount of 829,600 m^3/day (9.6 m^3/s) is necessary to be supplied in 2020 for the whole Sergipe State. Industrial water accounts for 32 %, and domestic water accounts for 68 %. As for domestic water, urban, large rural and small rural areas hold 60%, 6% and 1% respectively. Subtracting current water supply, 547,100 m^3/day (6.3 m^3/s) is necessary to be newly produced, accounting for 98% to urban and large rural area, and for 2% to small rural area.

Water supply and shortage by river basins is shown is Table-3.3, Table-3.4 and Figure-3.3. Supply water shortage by river basins is summarized as follows:

River Basin	Urban and Large Rural Area Supply Water Shortage		Rate	Small Rural Area Supply Water Shortage		Rate
(Sergipe State)	537,682	m^3/day	100 %	9,353	m^3/day	100 %
Sao Francisco River Basin	69,175	m^3/day	13 %	1,612	m^3/day	17 %
Japaratuba River Basin	34,862	m^3/day	6 %	720	m^3/day	8 %
Sergipe River Basin	259,352	m^3/day	48 %	2,184	m^3/day	23 %
Vaza Barris River basin	47,744	m^3/day	9 %	1,051	m^3/day	11 %
Piaui River basin	106,577	m^3/day	20 %	2,529	m^3/day	27 %
Real River Basin	19,972	m^3/day	4 %	1,257	m^3/day	14 %

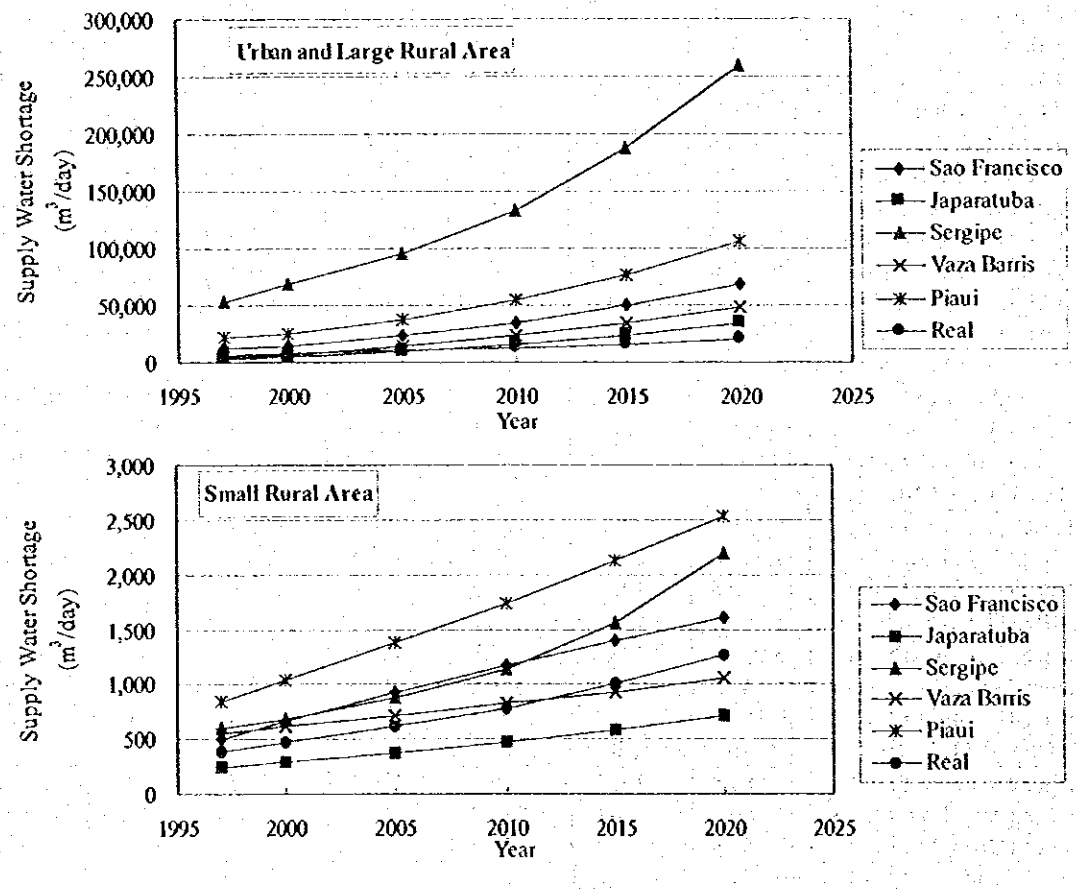


Figure-3.1 Supply Water Shortage by River Basins

Table-3.2 Water Demand and Shortage in Sergipe State

Year	1997	1998	2000	2005	2010	2015	2020
Water Demand (m^3/day)							
Private-tap System	442,952	460,283	494,946	596,653	724,629	886,097	1,089,991
- Industrial Water	201,869	213,706	237,380	309,090	400,763	518,259	668,514
- Domestic Water: Urban Area	200,510	206,018	217,036	246,738	282,221	324,718	376,029
- Domestic Water: Large Rural Area	40,574	40,559	40,530	40,824	41,646	43,120	45,447
Public-tap System (Residential Water: Small Rural Area)	10,143	10,140	10,132	10,206	10,411	10,780	11,362
Total	453,096	470,423	505,078	606,859	735,040	896,877	1,101,353
Water Supply Rate (%)							
Industrial Water	5	5	5	11	17	22	28
Urban Area (Private-tap)	100	100	100	100	100	100	100
Rural Area	35	37	41	53	63	75	85
- Large Rural Area (Private-tap)	21	23	26	35	43	52	60
- Small Rural Area (Public-tap)	14	14	15	18	20	23	25
Water Loss and Seasonal Fluctuation (%)							
Water Loss Rate: Private-tap System	42	41	40	36	33	29	25
Water Loss Rate: Public-tap System	10	10	10	10	10	10	10
Seasonal Fluctuation Coefficient	120	120	120	120	120	120	120
Necessary Supply Water (m^3/day)							
Private Industrial Water	191,262	202,478	224,908	275,712	333,069	397,976	469,158
Private-tap System	385,153	392,663	407,684	470,797	555,999	668,823	819,120
- Industrial Water	18,287	19,120	20,787	52,359	100,287	168,818	265,808
- Domestic Water: Urban Area	345,706	351,046	361,727	387,040	418,104	455,744	501,373
- Domestic Water: Large Rural Area	21,160	22,497	25,170	31,398	37,607	44,260	51,940
Public-tap System (Residential Water: Small Rural Area)	5,458	5,618	5,936	6,798	7,791	8,991	10,520
Total (Except self-supplied ind.)	390,611	398,281	413,620	477,595	563,789	677,814	829,640
Current Water Supply Capacity (m^3/day)							
Private-tap System	281,438	281,438	281,438	281,438	281,438	281,438	281,438
Public-tap System	2,333	2,283	2,181	1,928	1,674	1,420	1,167
Total	283,772	283,721	283,620	283,366	283,112	282,859	282,605
Supply Water Shortage (m^3/day)							
Private-tap System	103,714	111,225	126,245	189,358	274,560	387,384	537,682
Public-tap System	3,125	3,335	3,755	4,871	6,117	7,571	9,353
Total	106,840	114,560	130,000	194,229	280,677	394,955	547,035
Supply Water Shortage Rate (%)							
Private-tap System	37	40	45	67	98	138	191
Public-tap System	134	146	172	253	365	533	802
Total	38	40	46	69	99	140	194

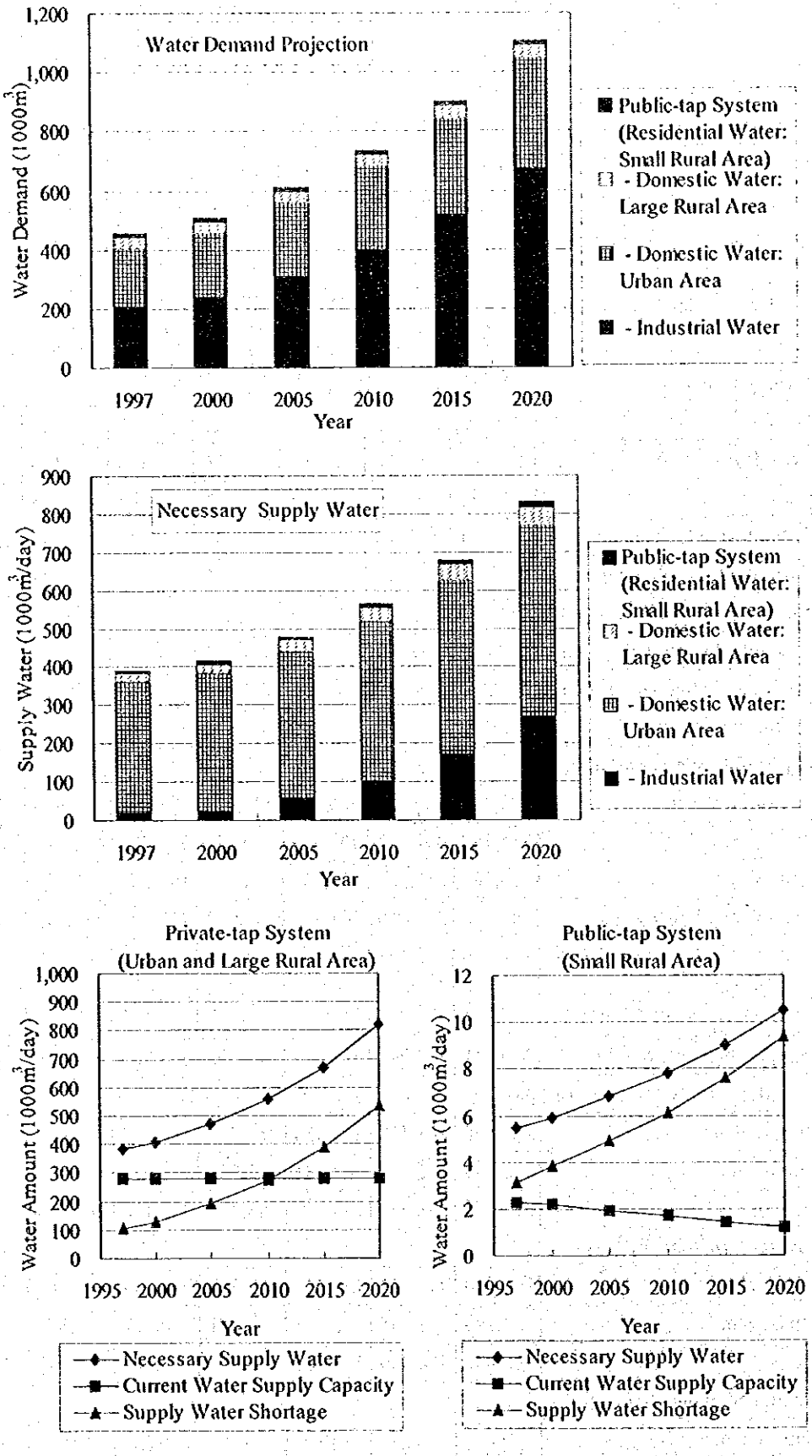


Figure-3.2 Water Demand and Shortage in Sergipe State

Table-3.3(1/2) Supply Water Shortage for Private-tap System by River Basin

River	Year	1997	2000	2005	2010	2015	2020
Sao Francisco River Basin	Water Demand (m^3/day)	34,679	37,150	47,808	60,945	77,542	98,762
	- Industrial Water	6,988	8,217	13,219	20,146	29,637	42,493
	- Domestic Water: Urban Area	18,363	19,913	26,002	32,558	39,936	48,506
	- Domestic Water: Large Rural Area	9,328	9,020	8,587	8,241	7,969	7,762
	Private Industrial Water (m^3/day)	6,773	7,964	11,620	15,725	20,240	24,418
	Necessary Supply Water (m^3/day)	40,744	42,395	52,108	63,609	78,080	97,646
	- Industrial Water	370	421	2,508	6,549	13,189	24,100
	- Domestic Water: Urban Area	31,660	33,188	40,788	48,234	56,050	64,675
	- Domestic Water: Large Rural Area	8,714	8,786	8,813	8,825	8,840	8,871
	Current Water Supply Capacity (m^3/day)	28,472	28,472	28,472	28,472	28,472	28,472
	Supply Water Shortage (m^3/day)	12,273	13,923	23,637	35,137	49,608	69,175
	Supply Water Shortage Rate (%)	43	49	83	123	174	243
Japaratuba River Basin	Water Demand (m^3/day)	27,816	31,313	39,583	50,018	63,303	80,271
	- Industrial Water	15,794	18,572	24,830	32,967	43,554	57,278
	- Domestic Water: Urban Area	9,005	9,712	11,683	13,900	16,465	19,498
	- Domestic Water: Large Rural Area	3,017	3,029	3,071	3,150	3,283	3,494
	Private Industrial Water (m^3/day)	15,791	18,569	23,324	28,660	35,239	42,891
	Necessary Supply Water (m^3/day)	18,140	18,935	23,645	30,183	38,316	49,174
	- Industrial Water	4	5	2,362	6,381	11,670	19,183
	- Domestic Water: Urban Area	15,525	16,186	18,326	20,593	23,109	25,998
	- Domestic Water: Large Rural Area	2,611	2,744	2,958	3,210	3,537	3,993
	Current Water Supply Capacity (m^3/day)	14,312	14,312	14,312	14,312	14,312	14,312
	Supply Water Shortage (m^3/day)	3,828	4,623	9,333	15,871	24,004	34,862
	Supply Water Shortage Rate (%)	27	32	65	111	168	244
Sergipe River Basin	Water Demand (m^3/day)	271,523	307,127	363,208	433,888	522,545	633,454
	- Industrial Water	139,932	164,547	207,636	261,313	328,499	412,543
	- Domestic Water: Urban Area	124,782	135,683	148,349	164,742	185,208	210,510
	- Domestic Water: Large Rural Area	6,809	6,897	7,222	7,834	8,838	10,401
	Private Industrial Water (m^3/day)	129,772	152,601	183,363	218,398	258,066	302,250
	Necessary Supply Water (m^3/day)	233,993	248,424	274,895	313,711	367,323	439,623
	- Industrial Water	17,516	19,911	38,076	63,578	98,854	147,057
	- Domestic Water: Urban Area	215,141	226,138	232,705	244,062	259,941	280,679
	- Domestic Water: Large Rural Area	1,336	2,375	4,114	6,071	8,528	11,887
	Current Water Supply Capacity (m^3/day)	180,272	180,272	180,272	180,272	180,272	180,272
	Supply Water Shortage (m^3/day)	53,722	68,152	94,624	133,439	187,051	259,352
	Supply Water Shortage Rate (%)	30	38	52	74	104	144
Vaza Barris River Basin	Water Demand (m^3/day)	38,414	42,822	52,753	65,156	80,796	100,597
	- Industrial Water	17,607	20,704	27,533	36,387	47,873	62,728
	- Domestic Water: Urban Area	15,505	16,818	19,910	23,434	27,544	32,427
	- Domestic Water: Large Rural Area	5,302	5,301	5,310	5,335	5,379	5,442
	Private Industrial Water (m^3/day)	17,458	20,529	25,602	31,280	38,204	46,204
	Necessary Supply Water (m^3/day)	28,542	30,612	37,663	46,692	57,567	71,488
	- Industrial Water	256	291	3,030	7,566	13,571	22,032
	- Domestic Water: Urban Area	26,733	28,030	31,231	34,717	38,658	43,236
	- Domestic Water: Large Rural Area	1,553	2,291	3,402	4,408	5,338	6,220
	Current Water Supply Capacity (m^3/day)	23,744	23,744	23,744	23,744	23,744	23,744
	Supply Water Shortage (m^3/day)	4,798	6,868	13,920	22,948	33,823	47,744
	Supply Water Shortage Rate (%)	20	29	59	97	142	201
Piaui River Basin	Water Demand (m^3/day)	56,118	61,222	76,388	95,727	120,580	152,577
	- Industrial Water	20,850	24,517	34,801	48,561	66,900	91,155
	- Domestic Water: Urban Area	23,993	25,353	30,076	35,451	41,711	49,144
	- Domestic Water: Large Rural Area	11,275	11,351	11,510	11,715	11,969	12,278
	Private Industrial Water (m^3/day)	20,789	24,446	30,902	38,006	45,167	52,327
	Necessary Supply Water (m^3/day)	47,198	49,403	62,282	78,936	101,493	131,329
	- Industrial Water	104	118	6,116	15,637	30,502	51,771
	- Domestic Water: Urban Area	41,368	42,256	47,178	52,520	58,542	65,526
	- Domestic Water: Large Rural Area	5,727	7,029	8,988	10,780	12,449	14,032
	Current Water Supply Capacity (m^3/day)	24,752	24,752	24,752	24,752	24,752	24,752
	Supply Water Shortage (m^3/day)	22,447	24,651	37,530	54,185	76,741	106,577
	Supply Water Shortage Rate (%)	91	100	152	219	310	431

Table-3.3(2/2) Supply Water Shortage for Private-tap System by River Basin

River	Year	1997	2000	2005	2010	2015	2020
Real River Basin	Water Demand (m^3/day)	14,402	15,312	16,912	18,895	21,332	24,330
	- Industrial Water	699	823	1,071	1,389	1,796	2,316
	- Domestic Water: Urban Area	8,862	9,557	10,718	12,135	13,854	15,944
	- Domestic Water: Large Rural Area	4,841	4,932	5,124	5,371	5,682	6,070
	Private Industrial Water (m^3/day)	679	798	900	999	1,060	1,068
	Necessary Supply Water (m^3/day)	16,535	17,916	20,202	22,868	26,044	29,860
	- Industrial Water	36	41	268	577	1,032	1,665
	- Domestic Water: Urban Area	15,279	15,929	16,812	17,978	19,444	21,258
	- Domestic Water: Large Rural Area	1,220	1,946	3,123	4,314	5,568	6,937
	Current Water Supply Capacity (m^3/day)	9,888	9,888	9,888	9,888	9,888	9,888
	Supply Water Shortage (m^3/day)	6,648	8,028	10,315	12,981	16,156	19,972
	Supply Water Shortage Rate (%)	67	81	104	131	163	202

Table-3.4 Supply Water Shortage for Public-tap System by River Basin

River	Year	1997	2000	2005	2010	2015	2020
Sao Francisco River Basin	Water Demand (m^3/day)	2,332	2,255	2,147	2,060	1,992	1,941
	Necessary Supply Water (m^3/day)	866	1,010	1,231	1,432	1,619	1,797
	Current Water Supply Capacity (m^3/day)	369	345	305	265	225	185
	Supply Water Shortage (m^3/day)	496	665	926	1,167	1,394	1,612
	Supply Water Shortage Rate (%)	134	193	303	440	620	873
Japaratuba River Basin	Water Demand (m^3/day)	754	757	768	788	821	873
	Necessary Supply Water (m^3/day)	415	451	516	592	685	809
	Current Water Supply Capacity (m^3/day)	177	165	146	127	108	89
	Supply Water Shortage (m^3/day)	238	285	370	465	578	720
	Supply Water Shortage Rate (%)	134	173	253	366	536	814
Sergipe River Basin	Water Demand (m^3/day)	1,702	1,724	1,806	1,958	2,209	2,600
	Necessary Supply Water (m^3/day)	1,047	1,104	1,242	1,463	1,822	2,408
	Current Water Supply Capacity (m^3/day)	448	418	370	321	272	224
	Supply Water Shortage (m^3/day)	600	686	872	1,142	1,550	2,184
	Supply Water Shortage Rate (%)	134	164	236	356	569	976
Vaza Barris River Basin	Water Demand (m^3/day)	1,326	1,325	1,327	1,334	1,345	1,361
	Necessary Supply Water (m^3/day)	974	1,004	1,058	1,118	1,185	1,260
	Current Water Supply Capacity (m^3/day)	417	389	344	299	254	208
	Supply Water Shortage (m^3/day)	558	615	714	819	931	1,051
	Supply Water Shortage Rate (%)	134	158	208	274	367	505
Piaui River Basin	Water Demand (m^3/day)	2,819	2,838	2,878	2,929	2,992	3,069
	Necessary Supply Water (m^3/day)	1,473	1,627	1,897	2,188	2,501	2,842
	Current Water Supply Capacity (m^3/day)	626	585	517	449	381	313
	Supply Water Shortage (m^3/day)	847	1,042	1,380	1,738	2,120	2,529
	Supply Water Shortage Rate (%)	135	178	267	387	556	808
Real River Basin	Water Demand (m^3/day)	1,210	1,233	1,281	1,343	1,421	1,518
	Necessary Supply Water (m^3/day)	684	740	854	998	1,179	1,405
	Current Water Supply Capacity (m^3/day)	297	277	245	213	181	148
	Supply Water Shortage (m^3/day)	387	462	609	785	998	1,257
	Supply Water Shortage Rate (%)	131	167	248	369	553	848
Sergipe State	Water Demand (m^3/day)	10,143	10,132	10,206	10,411	10,780	11,362
	Necessary Supply Water (m^3/day)	5,458	5,936	6,798	7,791	8,991	10,520
	Current Water Supply Capacity (m^3/day)	2,333	2,181	1,928	1,674	1,420	1,167
	Supply Water Shortage (m^3/day)	3,125	3,755	4,871	6,117	7,571	9,353
	Supply Water Shortage Rate (%)	134	172	253	365	533	802

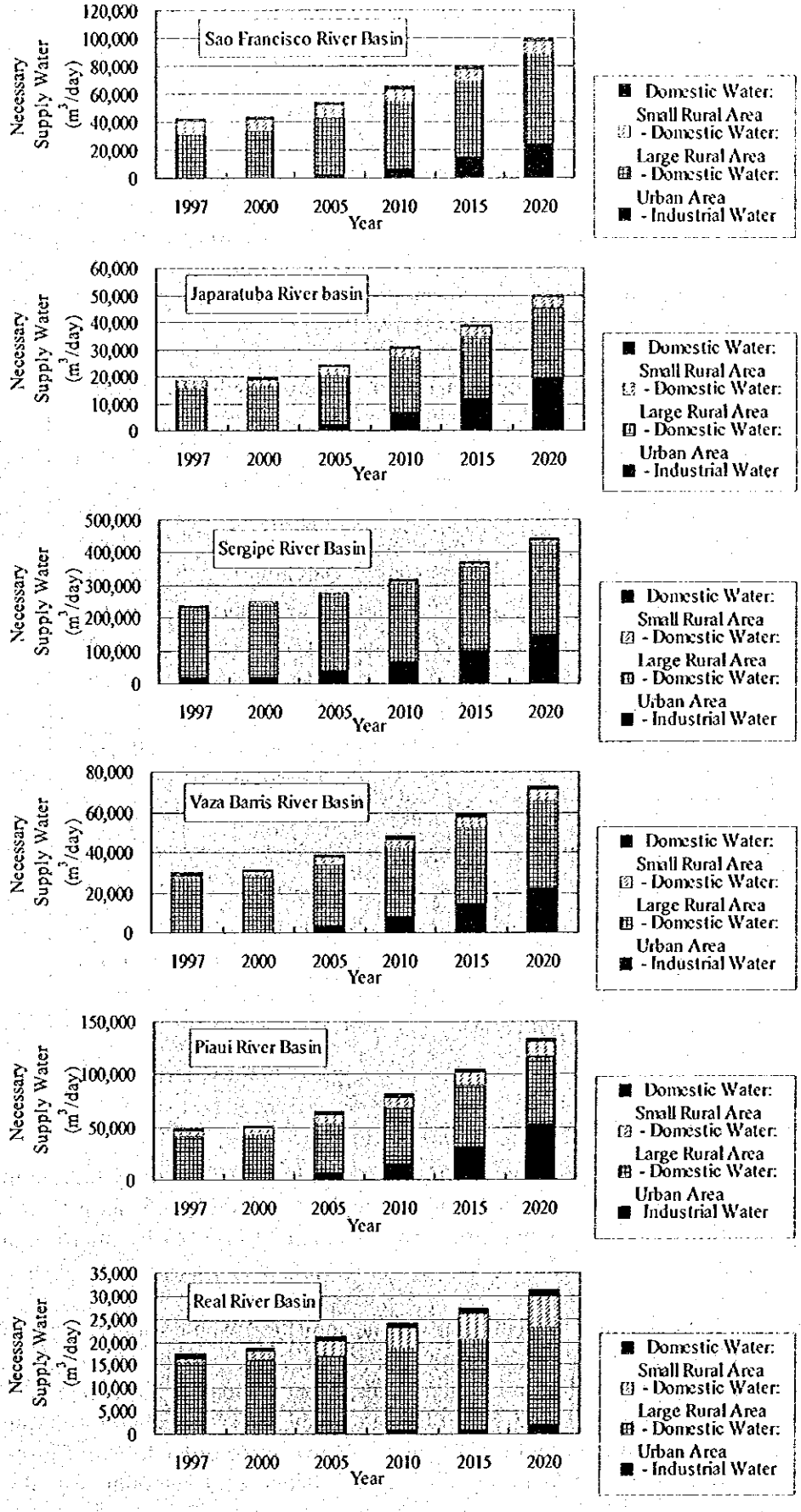


Figure-3.3 Necessary Supply Water by River Basin

3.2.2 Irrigation Water

Presently 9 irrigation projects have been operated in Sergipe State. Total irrigation water (peak requirement) for these existing projects reaches 12.08 m^3/s (1,043,310 m^3/day). Of this irrigation water, 78% depends on Sao Francisco River.

The 6 irrigation projects planned by COHIDRO were employed to the Master Plan. Of these projects, Jacare-Curituba and Jacarecica II projects are under construction. Two irrigation projects, namely Sao Francisco and Vaza Barris, were newly proposed in this Study. Total irrigation water necessary to be developed for 8 proposed projects reaches 21.42 m^3/s (1,850,838 m^3/day). The 80 % of new planned irrigation water depends on Sao Francisco River and the 14 % on Vaza Barris River.

Table-3.5 Irrigation Water Demand by River Basin

River Basin	Existing Project		Planned Project		Total Irrigation Water (m^3/day)
	Irrigation Project	Irrigation Water (m^3/day)	Irrigation Project	Irrigation Water (m^3/day)	
Sergipe State (Total)	-	1,043,310	-	1,850,838	2,894,148
Sao Francisco River	- California	81,600	- Quixabeira	254,394	
	- Propria	99,627	- Jacare-Curituba	263,607	
	- Cotinguiba	129,327	- Sao Francisco	903,226	
	- Neopolis	233,226	- Ladeirinhas	62,300	
	- Betume	267,642			
	Total	811,422	Total	1,483,527	2,294,949
Japaratuba River	-	-	-	-	-
Sergipe River	- Jacarecica	26,094	- Jacarecica II	94,742	120,836
Vaza Barris River	- Pocao da Ribeira	108,533	- Vaza Barris	251,613	360,146
Piaui River	- Piaui	55,786	- Entre Rios	15,576	
			- Estancinha	5,380	
			Total	20,956	76,742
Real River	- Jabiberi	41,475	-	-	41,475

Note: Irrigation water shows maximum amount.

3.3 Private Industrial Water

The industrial water not supplied by public water supply system, namely private industrial water, is recommend to be developed by groundwater. Table-3.6 shows the balance between industrial water supply and groundwater potential in 2020 by micro-regions and main river basins.

According to the table, the ratio between private industrial water supply to groundwater potential (supply/potential ratio) varies from 0 % to 32 % and 8.2 % on the average. Checking the supply/potential ratio by municipalities, municipalities less than 10 % of the ratio occupy 87 %, and those below 5% of the ratio occupy 84 %. Therefore groundwater potential is enough for private industrial water. However in order to avoid groundwater disaster, the following consideration should be taken into account for deep well development:

- Deep wells should be developed at interval of more than 100-200m.
- Safe yield should be kept at water abstraction, avoiding groundwater disaster such as sea water intrusion, regional groundwater level decline and so on.

Of the municipalities, Laranjeiras, Aracaju and Rosario do Catete indicating high supply/potential ratio, groundwater development should be carefully carried out.

Table-3.6 Balance between Private Industrial Water Supply and Groundwater Potential in 2020

Micro-Region / River Basin	Private Industrial Water Supply (m^3/day)	Groundwater Potential (m^3/day)	Supply/Potential Ratio
Sergipe State	469,158	5,700,067	8.2%
Micro-Region			
01- Sergipana do Sertao do Sao Francisco	4,489	263,606	1.7%
02- Carira	0	249,782	0.0%
03- Nossa Senhora das Dores	585	126,230	0.5%
04- Agreste de Itabaiana	11,302	280,454	4.0%
05- Tobias Barreto	1,108	270,432	0.4%
06- Agreste de Lagarto	26,720	217,382	12.3%
07- Propria	14,929	545,702	2.7%
08- Cotinguiba	6,228	253,930	2.5%
09- Japaratuba	6,710	1,176,336	0.6%
10- Baixo Cotinguiba	196,411	618,278	31.8%
11- Aracaju	131,703	712,109	18.5%
12- Boquim	2,266	361,670	0.6%
13- Estancia	66,707	624,154	10.7%
River Basin			
Sao Francisco River	24,418	1,526,213	2.8%
Japaratuba River	42,891	822,701	7.0%
Sergipe River	302,250	1,294,488	31.9%
Vaza Barris River	46,204	810,950	7.7%
Piaui River Real River	52,327	829,829	11.0%
Real River	1,068	415,886	0.6%

CHAPTER 4 WATER SUPPLY FOR URBAN AND LARGE RURAL AREA

4.1 Independent Water Supply

4.1.1 Alternative Water Resources

Present water sources and capacities, water supply shortage and alternative water resources (Surface Water Development, Groundwater Development and other development) are compiled by municipalities in the Sergipe State as shown in Table-4.1.

The integrated system continues to supply water to the areas supplied presently by the integrated systems. Additionally, it is decided that integrated system supplies water to the municipalities of Caninde do Sao Francisco, Ribeiropolis, Moita Bonita, Sao Domingos and Poco Verde, because of no good potential for surface water and groundwater in these areas. Note that Gararu is divided into two districts, which are 1) independent system for urban and half of large rural area and 2) integrated system for half of large rural area.

Therefore, Independent systems are to supply water to the 35 municipalities as shown in Table-4.1.

4.1.2 Plan of Independent Water Supply

The 35 municipalities to be planned are shown in Table-4.2, which describes water shortage, source water developed amount, beneficiaries, etc. by municipalities/systems.

In general, the nearer the water resource, the cheaper the water development cost. The first alternative is groundwater development if there exists good groundwater potential aquifer. In case of no good groundwater potential and much developed water requested, surface water development by weirs and intake pumps is adopted. Water resources development plans for independent water supply systems are summarized in Table-4.3 and graphically shown in Figure-4.1.

4.2 Integrated Water Supply for Urban and Large Rural Area

4.2.1 District Covered by Integrated Water Supply

Based on the study of independent water supply in the previous section, the district to be covered by integrated water supply is set as shown in Table-4.4 and Figure-4.4. The area includes the existing seven systems of integrated water supply and California I System for Caninde, accounting for 41 municipalities out of 75 municipalities in Sergipe State. This area is divided into 10 blocks, dividing the area of Sertaneja Pipeline System into 3 blocks, according to the water supply area of the existing systems and the study of independent water supply.

Table-4.1 Alternative Water Resources for Urban and Large Rural Area

Municipality		Planning Condition				Alternative Water Resources							
		Present Water Supply			Water	Surface Water Development			Groundwater Development				
		System	Water Sources	Water Supply Capacity (m^3/day)	Supply Shortage in 2020 (m^3/day)	Potable Water Quality	River	Intake Potential Rank	Yield per Well (m^3/day)	Success Rate of Yield (%)	Fresh Water Rate (%)	Water Potential Rank	Other Development
01-0120	Canindé do São Francisco	Independent	SFR	1.552	18.484	Good	SFR	A	80	50	15	D	Xingo Dam Pipeline
01-0220	Feira Nova	Integrated	Sertaneja Pipeline	629	1.891	Good	SFR	A	80	60	15	D	
01-0240	Gararu	Independent	SFR	648	645	Good	SFR	A	35	60	15	D	
01-0260	Gracho Cardoso	Integrated	Sertaneja Pipeline	501	416	Good	SFR	A	80	60	15	D	
01-0310	Itabi	Integrated	Sertaneja Pipeline	755	387	Good	SFR	A	80	60	15	D	
01-0320	Monte Alegre de Sergipe	Integrated	Alto Sertao Pipeline	1.543	2.507	Good	SFR	A	80	60	15	D	
01-0430	Nossa Senhora da Gloria	Integrated	Sertaneja Pipeline	3.040	13.473	Good	SFR	A	80	60	15	D	
01-0540	Poco Redondo	Integrated	Alto Sertao Pipeline	2.370	1.808	Good	SFR	A	80	45	10	D	
01-0560	Porto da Folha	Integrated	Alto Sertao Pipeline	2.801	2.180	Good	SFR	A	80	50	10	D	
02-0140	Carira	Integrated	Sertaneja Pipeline	1.706	3.033	Good	SFR	A	50	60	20	D	
02-0230	Frei Paulo	Integrated	Sertaneja Pipeline	1.439	3.031	Good	SFR	A	75	75	35	C	
02-0445	Nossa Senhora Aparecida	Integrated	Sertaneja Pipeline	712	831	Good	SFR	A	60	70	25	D	
02-0500	Pedra Mole	Integrated	Sertaneja Pipeline	325	186	Good	SFR	A	80	75	40	C	
02-0520	Pinhao	Integrated	Sertaneja Pipeline	529	797	Good	SFR	A	80	75	40	C	
02-0600	Ribeiropolis	Independent	Well	1.784	2.064	Unknown	Jacoca R/SR	Unknown	75	75	40	C	Xingo Dam Pipeline 11km from Frei Paulo
03-0020	Aquidaba	Integrated	Sertaneja Pipeline	2.537	2.202	Good	SFR	A	80	60	15	D	
03-0190	Cumbe	Integrated	Sertaneja Pipeline	672	287	Good	SFR	A	80	60	15	D	
03-0380	Malhada dos Bois	Integrated	Sao Francisco Pipeline	263	830	Good	SFR	A	60	65	25	D	
03-0430	Marubeca	Independent	Well	864	365	Good	Japaratuba Mirim R/JR	B	90	65	40	C	Sao Francisco Pipeline 25km from Pipe
03-0460	Nossa Senhora das Dores	Independent	Sirirí R/JR	1.905	3.202	Good JR	Sirirí R/JR, Piauí R/JR	A	50	65	25	D	-
03-0700	São Miguel do Aleixo	Integrated	Sertaneja Pipeline	252	226	Good	SFR	A	65	70	30	D	
04-0050	Areia Branca	Integrated	Itabaiana Pipeline	1.094	13.462	Good	Jacarecica R/SR	B	150	75	65	A-B	
04-0100	Campo do Brito	Integrated	Itabaiana Pipeline	1.148	6.148	Unknown	Lombada R/VR	Unknown	70	75	35	C	
04-0290	Itabaiana	Integrated	Itabaiana Pipeline	9.685	38.432	Good	Jacarecica R/SR	B	70	75	35	C	
04-0370	Macambira	Integrated	Itabaiana Pipeline	365	1.149	-	-	-	75	75	40	C	
04-0390	Malhador	Independent	Vermelho R/SR	1.038	1.377	Good	Vermelho R/SR	C	85	75	45	C	-
04-0410	Moita Bonita	Independent	Well	547	1.875	Good	Jacarecica R/SR	Unknown	70	75	35	C	Xingo Dam Pipeline 11km from Ribeiropolis
04-0680	São Domingos	Independent	Well	518	2.285	Unknown	Lombada R/VR	Unknown	75	80	50	C	Piauitinga Pipeline 10 km from Campo do Brito
05-0550	Poco Verde	Independent	Well	1.672	2.226	-	-	-	60	65	55	C	Piauitinga Pipeline
05-0710	Simao Dias	Integrated	Piauitinga Pipeline	2.964	9.102	-	-	-	70	75	40	D	
05-0740	Tobias Barreto	Independent	RR Bahia	4.570	7.727	Good	Jabiberi R.	Unknown	50	70	50	D	Jabiberi Dam Raising
06-0350	Lagarto	Integrated	Piauitinga Pipeline	6.669	53.891	Unknown	Cotinguiba R/PR	Unknown	60	75	55	C	
06-0580	Riachuelo do Dantas	Integrated	Piauitinga Pipeline	825	2.315	-	-	-	45	75	30	D	
07-0010	Amparo de São Francisco	Integrated	Sertaneja Pipeline	315	126	Good	SFR	A	40	60	35	D	
07-0070	Brejo Grande	Independent	Well	724	722	Unknown	SFR	A	600	95	100	A	
07-0110	Canhoba	Integrated	Sertaneja Pipeline	704	0	Good	SFR	A	80	60	15	D	
07-0160	Cedro de São João	Integrated	Propria Pipeline	844	155	Good	SFR	A	65	65	25	D	
07-0270	Ilha das Flores	Independent	SFR	872	788	Good	SFR	A	600	95	100	A	
07-0180	Neopolis	Independent	SFR	1.850	16.916	Good	SFR	A	250	85	85	A-B	
07-0470	Nossa Senhora de Lourdes	Integrated	Sertaneja Pipeline	712	1.050	Good	SFR	A	80	60	15	D	
07-0570	Propri	Integrated	Propria Pipeline	4.908	5.097	Good	SFR	A	300	75	65	A-B	
07-0730	Telha	Integrated	Propria Pipeline	447	197	Good	SFR	A	45	60	15	D	
07-0999	Santana do São Francisco	Independent	Well	707	3.841	Good	SFR	A	180	90	85	A-B	
08-0130	*Capela*	Independent	*Lagarixo R./JR*	*3.359*	*6.694*	*Good*	*Sirirí R./JR, Oleo R./JR*	*A*	*50*	*60*	*20*	*D*	
08-0200	Divina Pastora	Independent	Well/Spring	320	479	Good	Guararoba R/SR	Unknown	170	75	70	A-B	
08-0650	Santa Rosa de Lima	Independent	Well	428	306	Good	Small Tributaries/SE	Unknown	95	75	50	C	
09-0720	*Sirirí*	Independent	*Sirirí R./JR*	*958*	*607*	*Good*	*Sirirí R./JR*	*B*	*175*	*80*	*50*	*A-B*	
09-0330	Japaratiba	Independent	Well/Spring	1.819	2.791	Good	JR, J-Mirim R/JR	B	215	80	85	A	
09-0340	Japoata	Independent	Poncaria R/SFR	1.057	471	Good	Poncaria R/SFR	B	160	80	80	A-B	
09-0400	Pacatuba	Independent	Well	629	4.298	Good	Santo Antonio R/ Butume R/SFR	A	405	90	90	A	
09-0530	Pirambu	Independent	Well	940	2.165	Bad	JR	A	385	85	90	A	
09-0600	Sao Francisco	Independent	Well/Spring	427	373	Good	Sapo R/SFR	D	180	75	70	A-B	
10-0150	*Carmopolis*	Independent	*Diogo R./JR Well/Spring*	*2.951*	*691*	*Good*	*JR, Rio Joao R./JR*	*B*	*295*	*80*	*85*	*A*	
10-0250	General Maynard	Independent	Well	262	388	*Good*	*JR, Rio Joao*	*B*	180	75	70	A	
10-0360	Laranjeiras	Independent	Well	1.861	70.476	Good	Cotinguiba R/SR	A	235	75	70	A	Sao Francisco Pipeline 5km from Pipe
10-0400	Maruim	Independent	Well	2.015	2.990	Good	Guararoba R/SR	B	195	75	70	A-B	
10-0530	Riachuelo	Independent	Jacarecica R/SR	883	2.765	Good	Jacarecica R/SR	A	180	75	65	A-B	
10-0610	Rosario do Catete	Independent	Well	880	17.531	Good	Sirirí R./JR	A	260	80	75	A-B	
10-0660	Santo Amaro das Brotas	Independent	Well	1.003	807	-	-	-	395	85	90	A	
11-0030	Arauju	Integrated	Sao Francisco Pipeline	124.677	73.001	Good	SFR	A	430	90	95	A	
11-0060	Barra dos Coqueiros	Independent	Well	2.243	6.277	-	-	-	600	95	100	A	
11-0480	Nossa Senhora do Socorro	Integrated	Sao Francisco Pipeline	28.777	30.815	Good	SFR	A	285	85	80	A-B	
11-0670	*Sao Cristovao*	Independent	*Tributaries/JR*	*15.832*	*4.529*	*Good*	*Tributaries/JR*	*C*	*215*	*80*	*55*	*A*	
12-0040	Araua	Independent	Araua R/PR	697	1.680	Feasible Good	Caribeira R/ Araua R/PR	C	50	80	50	C	
12-0067	Boquim	Independent	Piauí R.	2.800	2.929	Feasible Good	Cotinguiba R/Araua R/PR	B	50	80	60	C	
12-0170	Cristinapolis	Independent	Jiboia R/RR	1.064	2.656	Good	Itamirim R/PR	B	50	80	60	C	
12-0300	Itabaianinha	Integrated	Itabaianinha Pipeline	2.449	6.235	Good	Itamirim R/PR	Unknown	45	80	40	C	
12-0510	Pedrinhas	Independent	Araua R/PR	689	1.647	Feasible Good	Tributaries/ Araua R/PR	C	60	90	70	B	
12-0620	Salgado	Independent	Spring/Well	1.245	2.906	Good	Gelo R/ Piauitinga R/PR	B	65	80	85	B	
12-0750	Tomar do Geru	Integrated	Itabaianinha Pipeline	569	2.646	Good	Itamirim R/PR	Unknown	45	75	45	D	
12-0760	Umbauba	Integrated	Itabaianinha Pipeline	983	3.940	Good	Guararema R/PR	D	55	80	70	B	
13-0210	*Estancia*	Independent	*Piauí R.*	*6.360*	*23.358*	*Good*	*Piauitinga R./PR*	*A*	*70*	*90*	*85*	*B*	
13-0280	Indiaroba	Independent	Paripe R/RR	841	1.105	Good	Paripe R/ RR	A	70	90	80	B	
13-0320	Itaporanga D'Ajuda	Independent	Fundo R/PR	1.773	24.640	Good	Tejupeba R/VR, Fundo R/PR	A	75	80	85	B	Vaza Barris Dam Pipeline 21km Boca Dam
13-0630	Santa Luzia do Itanhy	Independent	Well	455	1.917	Good	Guararema R/PR	B	70	80	85	B	

Table-4.2 Water Supply Plan for Independent Water Supply System in 2020

Municipality / System		Population		Supply Water				Source Water
		Total (person)	Beneficiaries (person)	Present Capacity (m^3/day)	Total (m^3/day)	Shortage (m^3/day)	Shortage Rate	Develop. Amount (m^3/day)
Total		793,141	455,588	65,019	223,370	158,351	244%	190,035
01-0240	Gararu (Urban and Half of Large Rural)	5,220	2,391	485	994	510	105%	612
03-0430	Muribeca	7,115	2,193	864	1,329	465	54%	558
03-0460	Nossa Senhora das Dores	25,331	15,818	1,905	5,207	3,302	173%	3,963
04-0390	Malhador	12,740	6,635	1,038	2,415	1,377	133%	1,653
05-0740	Tobias Barreto	59,735	36,473	4,570	12,297	7,727	169%	9,273
07-0070	Brejo Grande	7,283	3,326	724	1,447	722	100%	867
07-0270	Ilha das Flores	8,935	3,994	872	1,661	788	90%	946
07-0440	Neopolis	64,545	55,947	1,850	18,766	16,916	914%	20,300
07-0999	Santana do Sao Francisco	21,352	17,905	707	4,548	3,841	544%	4,610
08-0130	*Capela*	37,518	19,975	3,389	10,083	6,694	198%	8,033
08-0200	Divina Pastora	3,515	1,869	320	799	479	150%	575
08-0650	Santa Rosa de Lima	3,586	1,396	428	734	306	71%	368
08-0720	*Siriri*	8,572	3,207	988	1,595	607	61%	729
09-0330	Japaratuba	20,880	11,036	1,819	4,613	2,794	154%	3,353
09-0340	Japoata	8,597	2,531	1,057	1,529	471	45%	566
09-0490	Pacatuba	13,474	9,831	629	4,928	4,298	683%	5,158
09-0530	Pirambu	15,697	10,719	940	3,105	2,165	230%	2,598
09-0690	Sao Francisco	3,967	1,878	427	801	373	87%	448
10-0150	*Carmopolis*	16,404	2,172	2,981	3,872	891	30%	1,070
10-0250	General Maynard	3,328	1,987	262	650	388	148%	466
10-0400	Maruim	12,536	2,706	2,015	5,005	2,990	148%	3,588
10-0590	Riachuelo	10,430	6,223	883	8,648	7,765	880%	9,318
10-0610	Rosario do Catete	14,447	10,213	880	18,411	17,531	1991%	21,038
10-0660	Santo Amaro das Brotas	8,590	3,519	1,061	1,868	807	76%	968
11-0060	Barra dos Coqueiros	53,637	37,472	2,243	8,520	6,277	280%	7,533
11-0670	*Sao Cristovao*	91,990	18,427	15,832	20,430	4,599	29%	5,519
12-0040	Araua	10,304	6,260	697	2,377	1,680	241%	2,016
12-0067	Boquim	28,465	14,264	2,800	5,730	2,929	105%	3,515
12-0170	Cristianopolis	22,283	15,216	1,064	3,721	2,656	250%	3,188
12-0510	Pedrinhas	11,538	7,917	689	2,337	1,647	239%	1,977
12-0620	Salgado	22,501	15,024	1,245	4,151	2,906	233%	3,488
13-0210	*Estancia*	97,749	64,292	6,280	30,038	23,758	378%	28,510
13-0280	Indiaroba	11,136	6,083	844	1,949	1,105	131%	1,326
13-0320	Itaporanga D'Ajuda	35,337	25,950	1,773	26,413	24,640	1390%	29,568
13-0630	Santa Luzia do Itanhy	14,403	10,738	455	2,402	1,947	428%	2,337

Table-4.3 (1/2) Water Resources Development Plan for Independent Water Supply System

Municipality / System	Source Water Shortage (m^3/day)	Surface Water Development							Groundwater Development			
		Weir and Intake					Pump and Pipeline		Deep Well and Pump			
		River Name	Catch-ment Area (km^2)	Q(7,10) (m^3/day/ km^2)	Potential Developed Discharge (m^3/day)	Developed Discharge (m^3/day)	Pipeline Length (km)	Lifting Head [Elevation] (m)	River Basin	Yield per Well (m^3/day)	Number of Well	Developed Discharge (m^3/day)
Gararu (Urban and Half of Large Rural)	612	SFR (Direct Intake): Expansion	-	-	-	612	-	-	-	-	-	-
Muribeca	558	-	-	-	-	-	-	-	SFR	90	7	558
Nossa Senhora das Dores	3,963	Pinol R./ Siriri R./ JR	14	360	4,032	3,963	4	10 [190-210]	-	-	-	-
Malhador	1,653	Vermelho R./ SR	43 (13)	70	2,408	1,162 (1,246)	6	170 [90-260]	SR	85	6	491
Tobias Barreto	9,273	Jabiberi R./ RR (Jabiberi Dam)	118	-	-	9,273	17	20 [180-160]	-	-	-	-
Brejo Grande	867	-	-	-	-	-	-	-	SFR	600	2	867
Ilha das Flores	946	-	-	-	-	-	-	-	SFR	600	2	946
Neopolis	20,300	SFR (Direct Intake): Expansion	-	-	-	20,300	-	-	-	-	-	-
Santana do Sao Francisco	4,610	SFR (Direct Intake): New	-	-	-	4,610	-	-	-	-	-	-
Capela	8,033	Siriri R./ JR	96 (24)	70	7,680	5,396 (2,286)	8	70 [100-170]	-	-	-	-
		Adeira R./ JR	16	350	4,480	2,637	9	60 [110-170]				
Divina Pastora	575	-	-	-	-	-	-	-	SR	170	4	575
Santa Rosa de Lima	368	-	-	-	-	-	-	-	SR	95	4	368
Siriri	729	-	-	-	-	-	-	-	JR/SR	175	5	729
Japaratuba	3,353	-	-	-	-	-	-	-	JR	215	16	3,353
Japoata	566	-	-	-	-	-	-	-	SFR	160	4	566
Pacatuba	5,158	Santo Antonio R./ Betume R./ SFR	74	140	8,288	5,158	2	85 [90-5]	-	-	-	-
Pirambu	2,598	-	-	-	-	-	-	-	JR/SFR	385	7	2,598
Sao Francisco	448	-	-	-	-	-	-	-	SFR	140	4	448
Carmopolis	1,070	-	-	-	-	-	-	-	JR	295	4	1,070
General Maynard	466	-	-	-	-	-	-	-	JR	180	3	466
Maruim	3,588	-	-	-	-	-	-	-	SR	195	19	3,588

Note: SFR: Sao Francisco River JR: Japaratuba River SR: Sergipe River VR: Vaza Barris River PR: Piaui River RR: Real River
( ) shows intake in the upstream of the site.

Table-4.3 (2/2) Water Resources Development Plan for Independent Water Supply System

Municipality / System	Source Water Shortage (m^3/day)	Surface Water Development							Groundwater Development			
		Weir and Intake					Pump and Pipeline		Deep Well and Pump			
		River Name	Catch-ment Area (km^2)	Q(7,10) (m^3/day/km^2)	Potential Developed Discharge (m^3/day)	Developed Discharge (m^3/day)	Pipeline Length (km)	Lifting Head [Elevation] (m)	River Basin	Yield per Well (m^3/day)	Number of Well	Developed Discharge (m^3/day)
Riachuelo	9,318	Jacarecica R./SR	516 (372)	40	16,512	4,608 (11,904)	1	20 [30-50]	SR	180	27	4,710
Rosario do Catete	21,038	Siriri R./ JR	303 (96)	50	12,120	8,280 (3,840)	1	30 [10-40]	JR	260	50	12,758
Santo Amaro das Brotas	968	-	-	-	-	-	-	-	SR	395	3	968
Barra dos Coqueiros	7,533	-	-	-	-	-	-	-	SR/JR	600	13	7,533
Sao Cristovao	5,519	-	-	-	-	-	-	-	VR/SR	215	26	5,519
Araua	2,016	Camboata R./ Araua R./ PR	141	10	1,128	1,128	2	40 [80-120]	PR	50	18	888
Boquim	3,515	Gaiangal R./ Araua R./ PR	93 (5)	50	3,720	3,515 (200)	9	50 [80-130]	-	-	-	-
Cristianopolis	3,186	Itamirim R./ PR	414	14	4,637	3,186	9	60 [70-130]	-	-	-	-
Pedrinhas	1,977	Tributary/ Araua R./ PR	37	50	1,480	1,480	6	50 [130-180]	PR	60	9	497
Salgado	3,488	Grilo R./ Piauitinga R./ PR	26	120	2,496	2,496	4	40 [70-110]	PR	65	16	992
Estancia	28,510	Piauitinga R./ PR	405 (283)	102 (Ave.)	33,084 (19,244)	13,840	3	40 [20-60]	PR	70	50	3,500
		Sub-1: Capivara R./ Piauitinga R./ PR	22	400	7,040	7,040	-	-				
		Sub-2: Piauitinga R./ PR	383 (283)	85	26,044 (19,244)	6,800	-	-				
		PR (Main River): Expansion	4,262	27	115,074	11,170	2	55 [5-60]				
Indiaroba	1,326	Paripe R./ RR: Expansion	55	200	8,800	1,326	2	15 [5-20]	-	-	-	-
Itaporanga	29,568	Tejupeba R./ VR	35	260	7,280	7,280	10	60 [10-70]	-	-	-	-
D'Ajuda		Fundo R./ PR	164	220	28,864	22,288	23	65 [5-70]				
Santa Luzia do Itanhy	2,337	Ariquitiba R./ Guararema R./ PR	46	85	3,128	2,337	2	20 [20-40]	-	-	-	-

Note: SFR: Sao Francisco River JR: Japaratuba River SR: Sergipe River VR: Vaza Barris River PR: Piaui River RR: Real River
( ) shows intake in the upstream of the site.

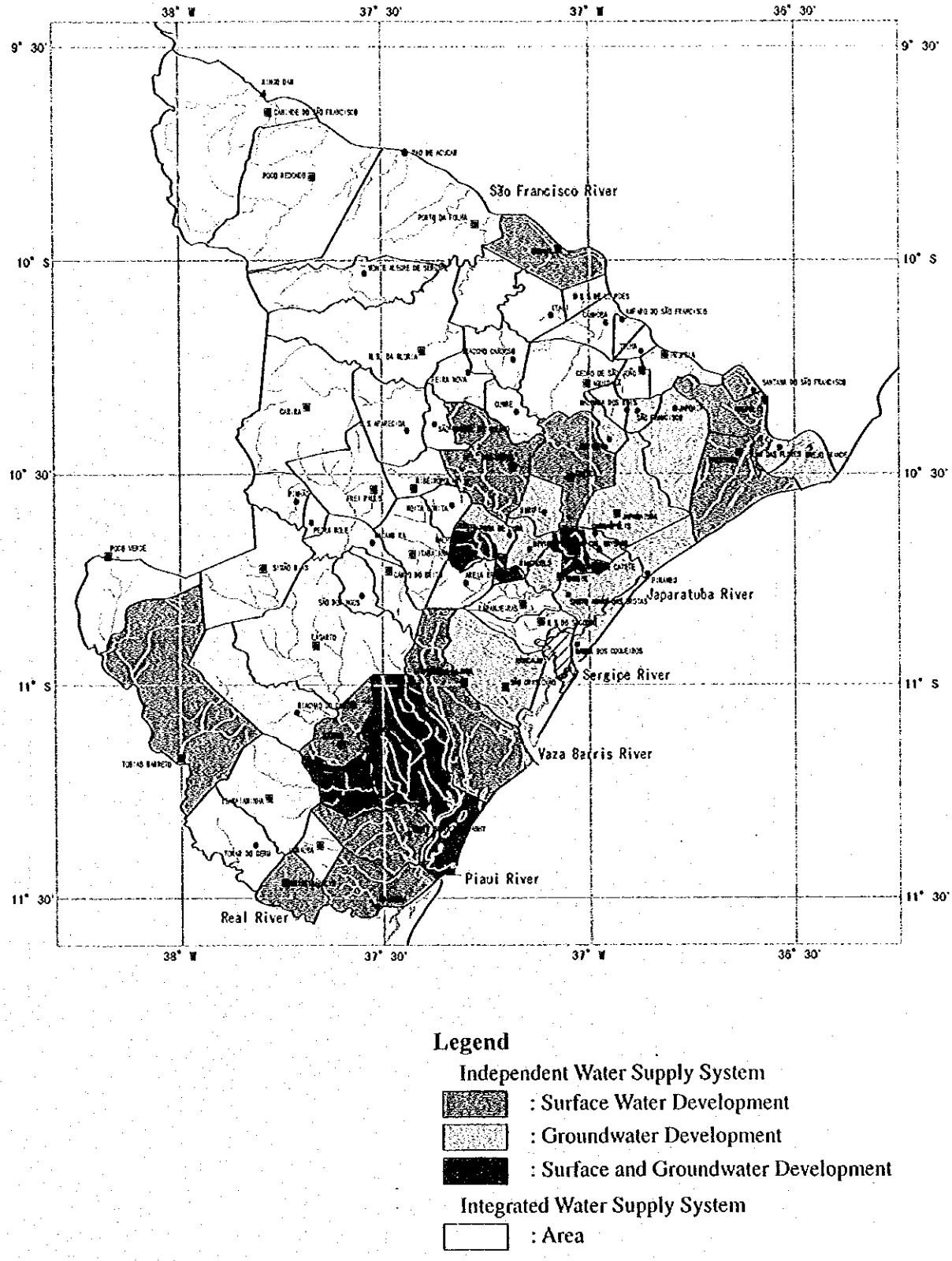


Figure-4.1 Water Resources Development Plan for Independent Water Supply System

Figure-4.2 Block Division of Integrated Water Supply Area

Table-4.4 Block Division and Supply Water Shortage in 2020

Block Name of Integrated Pipeline System	Central City of Block	Municipalities	Supply Water Shortage (m^3/day)
Aracaju Pipeline System	Aracaju	Total (3 municipalities)	174,892
		Laranjeiras	70,476
		Aracaju	73,601
		N.S. do Socorro	30,815
Agreste Pipeline System	Itabaiana	Total (5 municipalities)	61,476
		Areia Branca	13,462
		Campo do Brito	6,148
		Itabaiana	38,432
		Macambira	1,149
		Sao Domingos	2,285
Piauitinga Pipeline System	Lagarto	Total (4 municipalities)	67,534
		Poco Verde	2,226
		Simao Dias	9,102
		Lagarto	53,891
		Riachao do Dantes	2,315
Itabaianinha Pipeline System	Itabaianinha	Total (3 municipalities)	13,321
		Itabaianinha	6,735
		Tomar do Geru	2,646
		Umbauba	3,940
Propria Pipeline System	Propria	Total (4 municipalities)	6,189
		Malhada dos Bois	830
		Cedro de Sao Joao	155
		Propria	5,097
		Telha	107
Alto Sertao Pipeline System	Monte Alegre de Sergipe	Total (3 municipalities)	5,495
		Monte Alegre de Sergipe	2,507
		Poco Redondo	1,808
		Porto da Folha	1,180
Sertaneja Pipeline System		Total (18 municipalities)	32,051
Sertaneja [1]	Gracho Cardoso	Sub-Total (9 municipalities)	6,494
		Feira Nova	1,891
		Gararu (Half of Large Rural)*	135
		Gracho Cardoso	416
		Itabi	387
		Aquidaba	2,202
		Cumbe	287
		Amparo de Sao Francisco	126
		Canhoba	0
		Nossa Senhora de Lourdes	1,050
Sertaneja [2]	N. S. da Gloria	Sub-Total (2 municipalities)	16,505
		Nossa Senhora da Gloria	13,473
		Carira	3,033
Sertaneja [3]	Frei Paulo	Sub-Total (7 municipalities)	9,010
		Frei Paulo	3,031
		Nossa Senhora Aparecida	831
		Pedra Mole	186
		Pinhao	797
		Ribeiropolis	2,064
		Sao Miguel do Aleixo	226
		Moita Bonita	1,875
California I	Caninde do Sao Francisco	Caninde do Sao Francisco	18,484

Note: * : Gararu municipality is divided into independent system and integrated system.

4.2.2 Alternative Plans

(1) Proposal of Alternative Plans

(a) On-going and Existing Planned Projects

As for integrated water supply system to be planned, existing plans under construction and the projects being proposed to PROAGUA are listed below, and their respective developed supply water volumes are also indicated. These projects are to be included in the Master Plan.

1) Project Expansion of Sao Francisco Pipeline System: 151,600 m^3/day
(Some works are under construction.)
2) Project Expansion of Agreste Pipeline System: 22,200 m^3/day
(PROAGUA project being proposed)
3) Project Expansion of Piauitinga Pipeline System: 30,200 m^3/day
(PROAGUA project being proposed)

(b) Alternative Projects by Blocks

Table-4.5 shows alternative projects of integrated water supply by blocks. These projects are conceptually explained as follows:

< Project Expansion of Existing System >

1) **Aracaju Well Development Project (Aracaju Block):** As Aracaju metropolitan area has one of the largest groundwater potential aquifer, well development is proposed as one of the alternatives. Required water development volume is set at 23,292m^3/day, subtracting water amount by Project Expansion of Sao Francisco Pipeline System (151,600 m^3/day) from supply water shortage (174,892m^3/day) in 2020.
2) **Additional Project Expansion of Sao Francisco Pipeline System (Aracaju Block):** Project expansion to double the pipelines is on-going for Aracaju metropolitan area. For the purpose of supplying water to Agreste and Piauitinga blocks, an additional expansion project is proposed to develop water of 76,610m^3/day.
3) **Project Expansion of Itabaianinha Pipeline System (Itabaianinha Block):** As the block is located far south-west side of Sergipe State, water resources from Sao Francisco River and Vaza Barris Dam can not be utilized. However, the south-east of this block has large potential of surface and groundwater, and project expansion is reasonable to develop 13,321m^3/day of supply water.
4) **Project Expansion of Propria Pipeline System (Propria Block):** Project expansion is the only alternative in this block, because Sao Francisco River has plenty water resources and the required development water amount (6,494m^3/day) is relatively small for this block.
5) **Project Expansion of Alto Sertao Pipeline System (Alto Sertao Block):** As Sao Francisco River has plenty water resources, project expansion is the one of the alternatives.
6) **Project Expansion of Sertaneja Pipeline System (Sertaneja Block):** Same as above

Table-4.5 Individual Project Proposed as Alternatives for Integrated Water Supply Systems

Block	Present System	Present* Water Supply Capacity (m^3/day)	Supply* Water Shortage in 2020 (m^3/day)	Alternative Projects	Water Resources
Aracaju	Sao Francisco Pipeline System and Well/Weir Supply System	155,315 (306,915)	174,900 (23,291)	Project Expansion of Sao Francisco Pipeline System: 151,600m^3/day (Some works are under construction.)	Direct Intake from Sao Francisco River
				Aracaju Well Development Project	Deep Wells near Aracaju
Itabaiana	Agreste Pipeline System	12,810 (35,010)	61,476 (39,276)	Project Expansion of Itabaiana Pipeline System: 22,200m^3/day (Proposed PROAGUA Project)	Jacarecica II Dam, weirs and wells
				Additional Project Expansion of Sao Francisco Pipeline System	Direct Intake from Sao Francisco River
				Xingo Dam Pipeline Project	Xingo Dam Conduit
				(4) Vaza Barris Dam Project	Vaza Barris Dam
Piauitinga	Piauitinga Pipeline System	12,130 (42,330)	67,534 (37,334)	Project Expansion of Piauitinga Pipeline System: 30,200m^3/day (Proposed PROAGUA Project)	Piaui Dam, weirs and wells
				Additional Project Expansion of Sao Francisco Pipeline System	Direct Intake from Sao Francisco River
				Vaza Barris Dam Project	Vaza Barris Dam
Itabaianinha	Itabaianinha Pipeline System	4,002	13,321	(1) Project Expansion of Itabaianinha Pipeline System	Weirs and Wells
Propria	Propria Pipeline System	6,462	6,189	(1) Project Expansion of Propria Pipeline System	Direct Intake from Sao Francisco River
Alto Sertao	Alto Sertao Pipeline System	6,716	5,495	(1) Project Expansion of Alto Sertao Pipeline System	Direct Intake from Sao Francisco River
				(2) Xingo Dam Pipeline Project	Xingo Dam Conduit
Sertaneja [1]	Sertaneja Pipeline System	7,079	6,494	(1) Project Expansion of Sertaneja Pipeline System	Direct Intake from Sao Francisco River
				(2) Xingo Dam Pipeline Project	Xingo Dam Conduit
Sertaneja [2]		4,746	16,505	(1) Project Expansion of Sertaneja Pipeline System	Direct Intake from Sao Francisco River
				(2) Xingo Dam Pipeline Project	Xingo Dam Conduit
Sertaneja [3]		5,608	9,010	(1) Project Expansion of Sertaneja Pipeline System	Direct Intake from Sao Francisco River
				(2) Xingo Dam Pipeline Project	Xingo Dam Conduit
California I	California I Pipeline System	1,552	18,484	(1) Xingo Dam Pipeline Project	Xingo Dam Conduit

Note: * ( ) shows the figures after the completion of the projects under construction and proposed to PROAGUA

< Xingo Dam Pipeline Project >

Xingo Dam, which has two intake conduits, has been ready for the available discharge of 20 m^3/s (10 m^3/s each) to be distributed to Sergipe State. Jacare-Curituba Project is to use 5.1 m^3/s, using one conduit intake with the capacity of 10m^3/s. Thus presently 14.9 m^3/s (1,287,400 m^3/day) is available to new projects. Xingo Dam Pipeline Project utilizing this water source is proposed. This pipeline has the possibility to be connected to the pipeline systems of Alto Sertao and/or Sertaneja, further into the pipeline systems of Agreste and Piauitinga. This project is also able to supply water to the municipality of Caninde do Sao Francisco in addition to California I Pipeline System.

Irrigation water of 10.454 m^3/s in maximum could also be supplied to Sao Francisco Irrigation Project near Caninde do Sao Francisco. Further, Irrigation water directly drawn out from the Xingo Dam reservoir can be utilized for Quixabeira Irrigation Project, requiring 2.944 m^3/s of irrigation water in maximum. Therefore the total necessary water amount for irrigation in this project accounts for 13.398 m^3/s. These figures include all the pipe losses.

< Vaza Barris Dam Project>

Vaza Barris Dam, which is planned at 40 km upstream from the mouth of Vaza Barris River, is proposed. The dam has potential development discharge of about 4.5 m^3/s with the maximum dam height of 40-50m. The development discharge by the dam can be supplied to the blocks of Piauitinga and Agreste.

Irrigation water of 2.912 m^3/s in maximum can also be supplied to Vaza Barris Irrigation Project by this project.

(c) Proposal of Alternative Plans for Integrated Water Supply Systems

Combining the on-going, on-planned and newly proposed projects, ten cases of alternative plans for the area of integrated water supply are proposed as shown in Table-4.7 and Figure-4.3. Required development water by cases and projects are described in Table-4.6.

Table-4.6 Required Development Water by Cases and Projects

Unit: 1,000m^3/day

Project \ Case	XX1	XX2	XX3	XV1	XV2	XV3	VV1	VV2	VV3	SS1
Project Expansion of Sao Francisco Pipeline System	151.6	151.6	151.6	151.6	151.6	151.6	151.6	151.6	151.6	151.6
Project Expansion of Agreste Pipeline System	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
Project Expansion of Piauitinga Pipeline System	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2
Aracaju Well Development Project	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3
Additional Project Expansion of Sao Francisco Pipeline System	-	-	-	-	-	-	-	-	-	76.6
Project Expansion of Itabaianinha Pipeline System	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
Project Expansion of Propria Pipeline System	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Project Expansion of Alto Sertao Pipeline System	18.2	5.5	-	18.2	5.5	-	18.2	5.5	-	18.2
Project Expansion of Sertaneja Pipeline System	19.3	6.5	6.5	19.3	6.5	6.5	19.3	6.5	6.5	19.3
Xingo Dam Pipeline Project	95.1	120.6	126.1	57.8	83.3	88.8	18.5	44.0	49.5	18.5
Vaza Barris Dam Project	-	-	-	37.3	37.3	37.3	76.6	76.6	76.6	-
Total of Required Development Water Amount	379.4									

Table-4.7 Alternative Plans for Integrated Water Supply

Water Supply Block	Required Development Water Amount	Case-XX1	Case-XX2	Case-XX3	Case-XV1	Case-XV2	Case-XV3
Aracaju	174,892 m³/day	- *Project Expansion of Sao Francisco Pipeline System (151,600)* - Aracaju Well Development Project (23,292)					
Agreste	61,476 m³/day	- *Project Expansion (22,200)* - Xingo Dam Pipeline Project (39,276)					
Piauitinga	67,534 m³/day	- *Project Expansion (30,200)* - Xingo Dam Pipeline Project (37,334)			- *Project Expansion (30,200)* - Vaza Barris Dam Project (37,334)		
Itabaianinha	13,321 m³/day	- Project Expansion (13,321)					
Propria	6,189 m³/day	- Project Expansion (6,189)					
Alto Sertao	5,495 m³/day	- Project Expansion (18,253)*1	- Project Expansion (5,495)	- Xingo Dam Pipeline Project (5,495)	- Project Expansion (18,253)*1	- Project Expansion (5,495)	- Xingo Dam Pipeline Project (5,495)
Sertaneja [1]	6,494 m³/day	- Project Expansion (19,251)*1	- Project Expansion (6,494)*2	- Project Expansion(6,494)*2	- Project Expansion (19,251)*1	- Project Expansion (6,494)*2	- Project Expansion (6,494)*2
Sertaneja [2]	16,505 m³/day		- Xingo Dam Pipeline Project (25,515)	- Xingo Dam Pipeline Project (25,515)		- Xingo Dam Pipeline Project (25,515)	- Xingo Dam Pipeline Project (25,515)
Sertaneja [3]	9,010 m³/day						
California I	18,484 m³/day	- Xingo Dam Pipeline Project (18,484)					

Water Supply Block	Required Development Water Amount	Case-VV1	Case-VV2	Case-VV3	Case-SS1
Aracaju	174,892 m³/day	- ***Project Expansion of Sao Francisco Pipeline System (151,600)*** - **Well Development Project (23,292)**			
Agreste	61,476 m³/day	- ***Project Expansion (22,200)*** - **Vaza Barris Dam Project (39,276)**			- *Project Expansion (22,200)* - Additional Project Expansion of Sao Francisco Pipeline System (39,334)
Piauitinga	67,534 m³/day	- **Project Expansion (30,200)** - **Vaza Barris Dam Project (37,334)**			- *Project Expansion (30,200)* - Additional Project Expansion of Sao Francisco Pipeline System (37,334)
Itabaianinha	13,321 m³/day	- **Project Expansion (13,321)**			
Propria	6,189 m³/day	- **Project Expansion (6,189)**			
Alto Sertao	5,495 m³/day	- Project Expansion (18,253)*1	- **Project Expansion (5,495)**	- Xingo Dam Pipeline Project (5,495)	- Project Expansion (18,253)*1
Sertaneja [1]	6,494 m³/day	- Project Expansion (19,251)*1	- **Project Expansion (6,494)*2**	- Project Expansion (6,494)*2	- Project Expansion (19,251)*1
Sertaneja [2]	16,505 m³/day		- **Xingo Dam Pipeline Project (25,515)**	- Xingo Dam Pipeline Project (25,515)	
Sertaneja [3]	9,010 m³/day				
California I	18,484 m³/day	- **Xingo Dam Pipeline Project (18,484)**			

Note: ( ) shows water supply amount in m³/day

*1 Project Expansions of the both Alto Sertao and Sertaneja is assumed to develop water for the both blocks of Sertaneja [2] and [3] with 50% each.

*2 In the Case-XX3, XV3 and VV3, Sertaneja System is to supply water to Sertaneja [1] only, and Xingo Dam Pipeline Project is to supply water to Sertaneja [2] and [3].

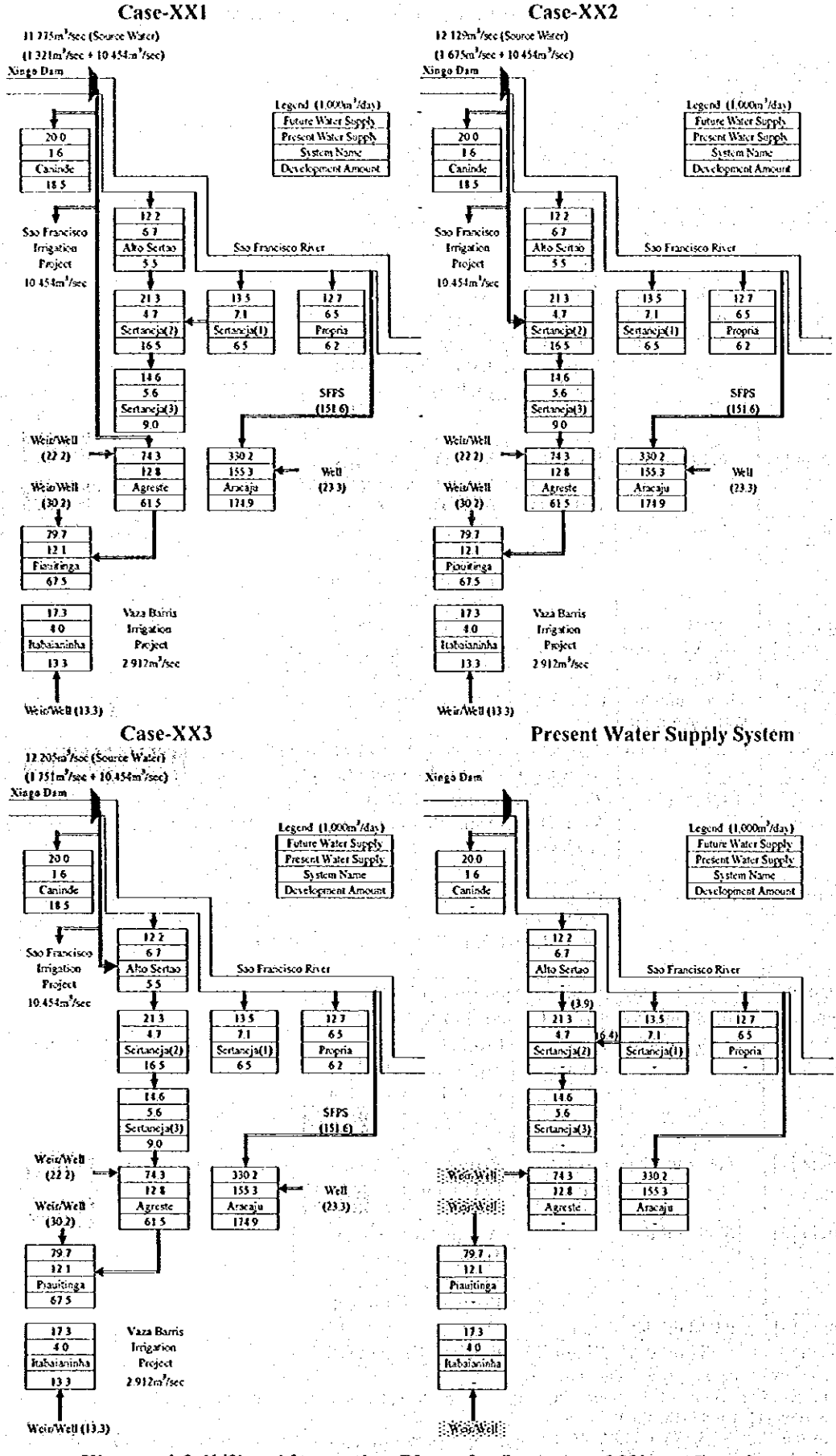


Figure-4.3 (1/3) Alternative Plans for Integrated Water Supply

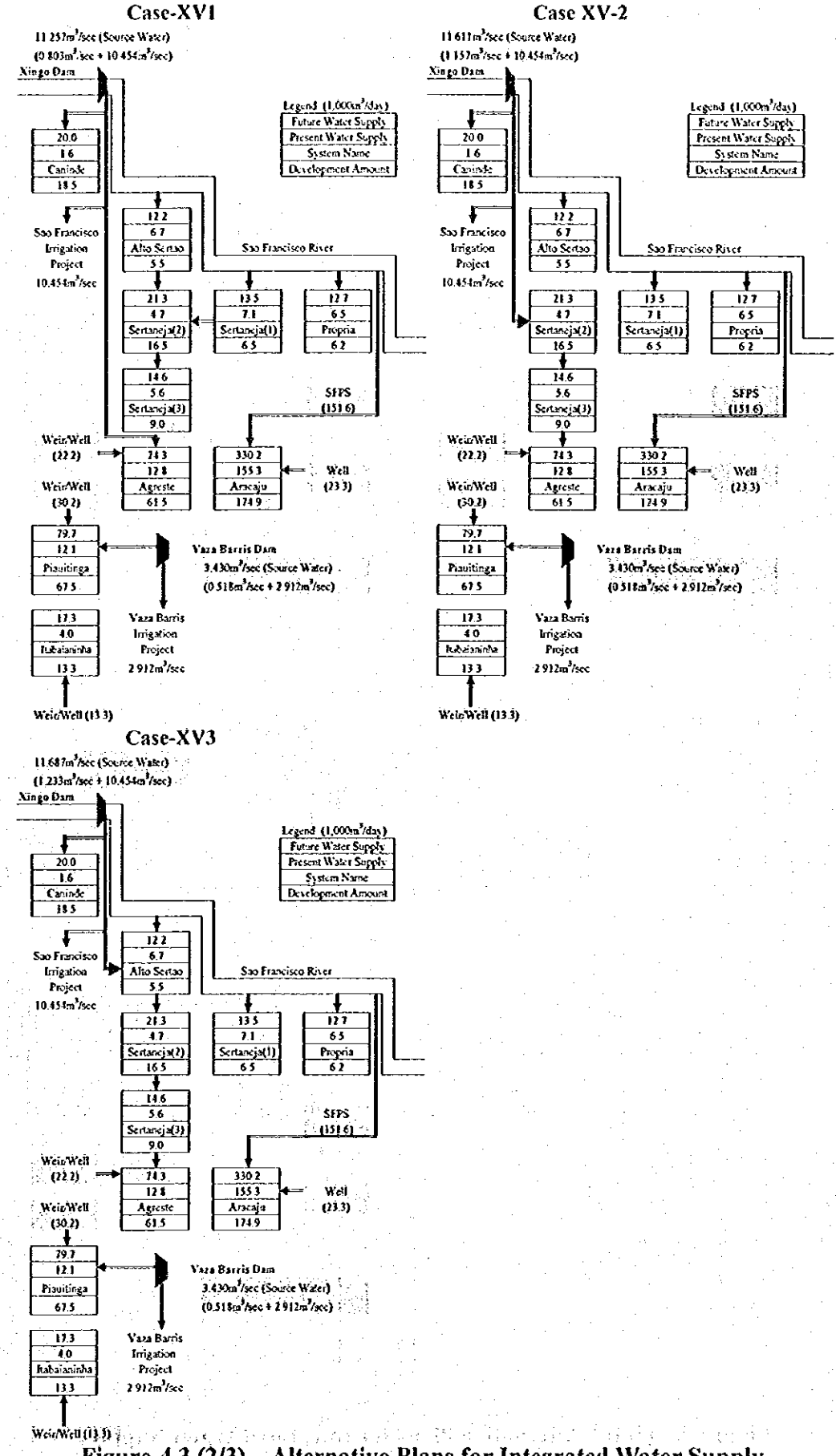


Figure-4.3 (2/3) Alternative Plans for Integrated Water Supply

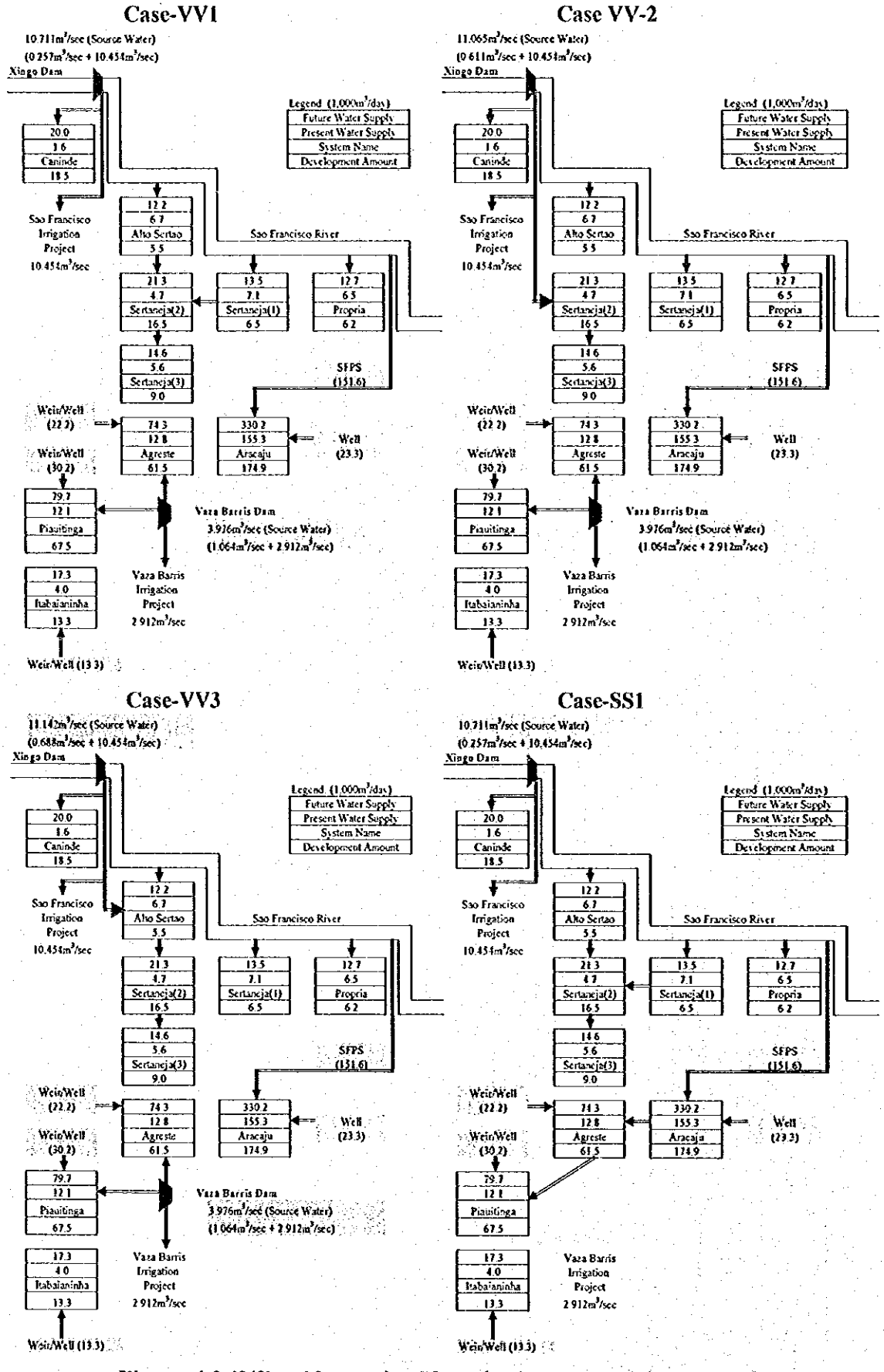


Figure-4.3 (3/3) Alternative Plans for Integrated Water Supply

(2) Selection of Optimum Plans

The optimum plan is selected by evaluating each alternative plan based on the results of rough design and cost estimation of component projects. The concept of Annual Expense is introduced for economic evaluation of alternative plans. The annual expense for each alternative project is evaluated and it was concluded that the alternative project VV2 is the most economical than any other projects in their annual expense basis.

Detailed analysis is presented in the Supporting Report (H) FACILITY DESIGN AND COST ESTIMATE.

4.2.3 Plan of Vaza Barris Dam Project

(1) Planning Conditions

(a) Location of Dam Site

The dam is planned on Vaza Barris River approximately 2 km downstream of the confluence with Trairas tributary and 6 km upstream from Fazenda Belem in Itaporanga d'Ajuda municipality. The dam location is roughly 22 km south from Itabaiana city and 24 km east from Lagarto city.

(b) Required Development Water Amount

Vaza Barris Dam is planned for development of domestic/industrial water and irrigation water. Planned water supply amount is as follows:

- Domestic and industrial water supply: 1.064 m^3/s (1.2 times of 0.887m^3/s considering seasonal fluctuation) for the area covered by Agreste and Piauitinga Integrated Pipeline Systems.
- Irrigation water supply: Average of 1.20 m^3/s (1.88 m^3/s in dry season (Oct.-Mar.), maximum 2.912 m^3/s in December) for Vaza Barris Irrigation Project - refer to Table-4.8.

Table-4.8 Water Requirement for Vaza Barris Irrigation Project

Item	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
Irrigation Water Demand (m^3/ha/month)	1,400	1,030	1,630	830	470	0	1,520	0	430	2,070	2,630	3,120	1,260
Project Water Requirement (million m^3/month)	3.5	2.6	4.1	2.1	1.2	0.0	3.8	0.0	1.1	5.2	6.6	7.8	3.15
Water Requirement (m^3/s)	1.31	1.06	1.52	0.80	0.44	0.00	1.42	0.00	0.41	1.93	2.54	2.91	1.20

Note: Irrigation Area: 2,500 ha

(c) Hydrological Conditions

< River Flow >

Daily discharge data is available at the ANEEL Fazenda Belem gauging station for the 23 year period from 1971 to 1993. Based on the results of the flow regime analysis, the discharge at the dam site and at the intake point of the low flow bypass was estimated. Using the calculated discharge at the Vaza Barris reference points and the ratio of catchment areas, the discharges were estimated in relation to the Fazenda Belem daily data Q_B for normal and low flow conditions as follows:

Discharge at Dam Site = 89.8% Q_B (normal flows) & 94.6% Q_B (low flows)
Discharge at Intake = 64.6% Q_B (normal flows) & 81.2% Q_B (low flows)

< Compensation Discharge >

Compensation discharge could be shown in the following equation:

[Compensation discharge] = [Maintenance Discharge] + [Water-use Discharge]

Water-use discharge is assumed to be zero based on the present water use conditions in the downstream of Vaza Barris River. The maintenance or environmental discharge to be allowed to flow to the downstream of the dam was taken as the 10-year return period 7-day flow (Q7,10) calculated from the available data at Fazenda Belem gauging station as 0.46 m^3/s. This is the discharge to be maintained for environmental protection purposes only as there is currently no other water use from Vaza Barris River.

< River Water Quality >

Water quality data is available for the Fazenda Belem flow gauging station based on sampling undertaken between 1995 and 1998 by DESO and JICA. By comparing the chloride concentration data with the river flow data measured by ANEEL, the relationship between Cl concentration (C_{Cl}) and discharge (Q) can be estimated from the following equation:

Chloride concentration at Fazenda Belem : $C_{Cl} = 500\ Q^{-0.5}$

The sampling data and above-mentioned relationship is shown in Figure-4.4. Based on the flow regime analysis and a "chloride balance", the chloride concentration at the dam site and at the inlet of the reservoir (low flow bypass intake) are assumed as:

Chloride concentration at Dam Site : $C_{Cl} = 600\ Q^{-0.5}$
Chloride concentration at Bypass Intake : $C_{Cl} = 700\ Q^{-0.5}$

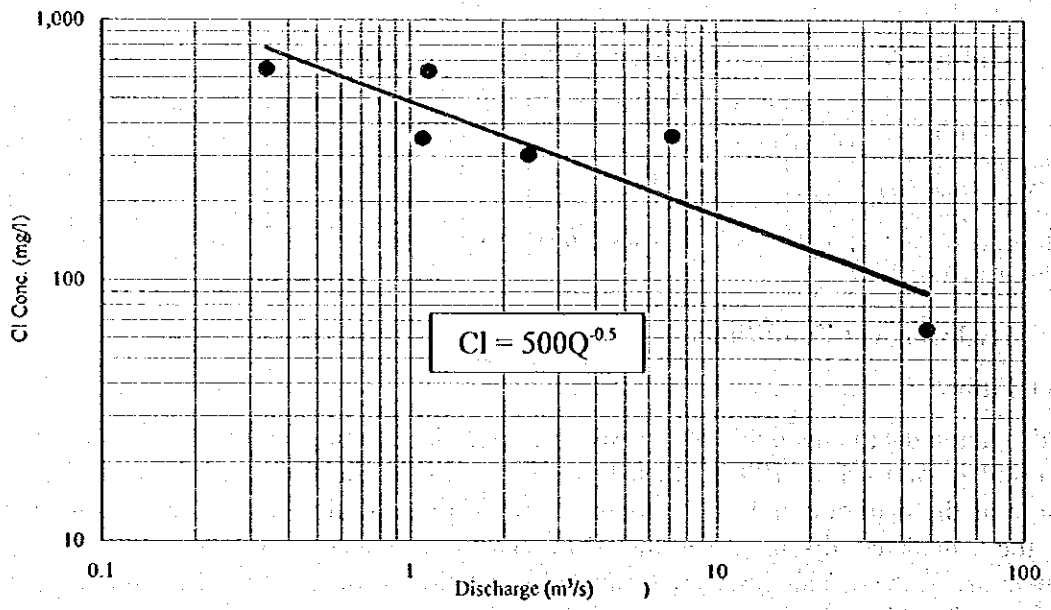


Figure-4.4 Relationship between Cl Concentration and Discharge at Fazenda Belem

(d) Reservoir Security Level

The reservoir security level was considered from both the quantity and quality viewpoints. The maximum chloride concentration of reservoir water should be less than 250 mg/l for safe drinking water in accordance with the CONAMA 20 Resolution and WHO water quality standards. The security level for dam reservoir use is set at 10-year frequency, so as to ensure sufficient water quantity and potable water quality even in a severe drought year with 10-year return period.

(2) Required Reservoir Capacity

(a) Reservoir Water Use Model

The reservoir capacity necessary to meet the required development water volume described above is calculated as follows:

< Daily Discharge Data >

Daily discharge data from Fazenda Belem flow gauging station for the 10 year period from Jan. 1980 to Dec. 1989 was used in the calculation. After studying all the available flow data, this period was chosen as the worst case scenario in preference to the latest 10 years data in order to incorporate the very dry year of 1983.

< Measurement of Reservoir Area and Volume >

The reservoir area upstream of the dam site was measured from available 1:25,000 scale maps (10m contours) for a range of possible normal water level (NWL) elevations between 30m and 60m. The measured areas were used to calculate the corresponding reservoir volumes and the results plotted as the H/V and H/A curves shown in Figure-4.5.

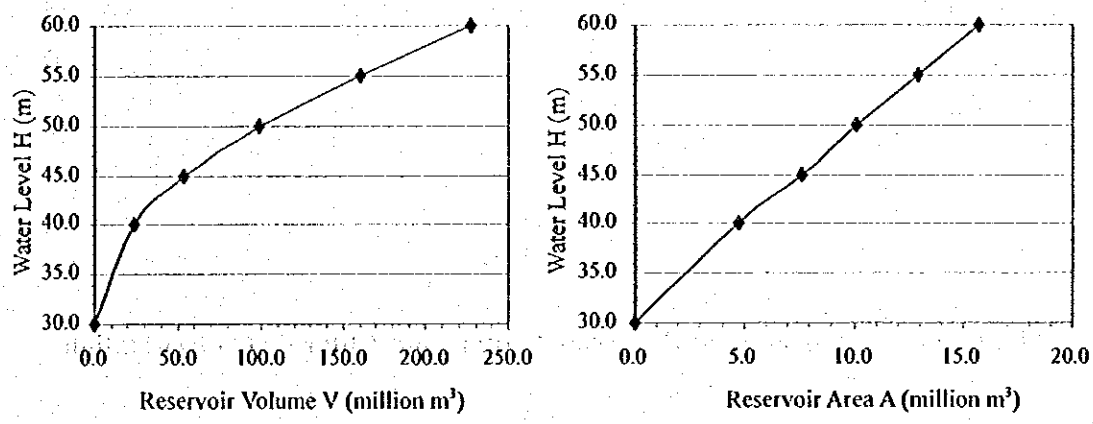


Figure-4.5 Vaza Barris Dam – H/V and H/A Curves

< Variation in Reservoir Volume >

Inflow to the reservoir was calculated as a percentage of the available daily discharge data at Fazenda Belem. Abstraction from the reservoir was taken as the sum of the planned water supply amounts for domestic and industrial water supply and irrigation water supply. Variation in reservoir volume, inflow and chloride concentration for 10 year period is shown in Figure-4.6.

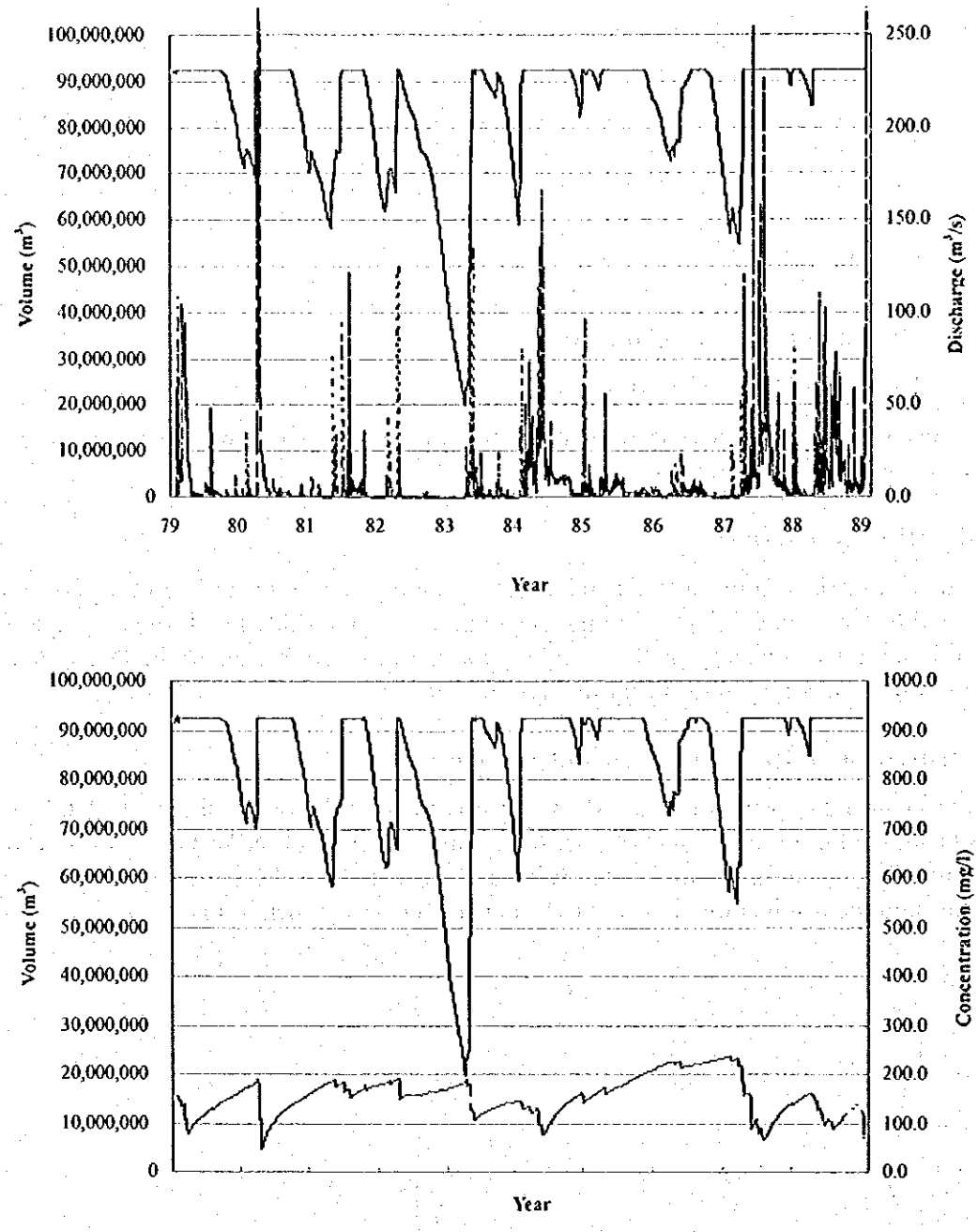


Figure-4.6 Variation of Reservoir Volume and Chloride Concentration

< Evaporation Losses >

Evaporation losses from the reservoir surface were converted to an equivalent daily volume loss using the following equation:

$$Eloss = 0.7 \cdot Ep \cdot Ar / t$$

where Eloss : Evaporation loss from reservoir (m^3/day),
Ep : Monthly pan evaporation (m),
Ar : Reservoir area (m^2),
t : Unit time conversion = number of days in month,
0.7 : Pan coefficient (Class A evaporation pan).

Monthly pan evaporation was taken as the average of the measured values at the COHIDRO Piaui and Jacarecica stations. Reservoir area was calculated on a daily basis from the H/V and H/A curves described above.

(b) Operation Study for Water Use

In order to ensure that the reservoir water quality remains within the acceptable limit of 250 mg/l chloride concentration, it is necessary to divert the high salinity flows which occur during the dry season. For this reason, a low flow bypass is to be provided.

The optimum discharge to be diverted via this bypass channel was studied in the water use model. The necessary reservoir capacity was calculated assuming different values of bypass discharge. At the same time, the maximum and average chloride concentration in the reservoir and the number of days when the concentration exceeds 250 mg/l were calculated. The results are shown in Table-4.9 below.

Table-4.9 Results of Dam Operation Study

Case	Bypass Discharge	Res. Vol. (Mm^3)		Res. Conc. (mg/l)		No. Days	Comments
		Input	Calc	Max.	Ave	> 250 mg/l	
1	0.0	62.0	61.93	742.0	220.2	1321	
		70.0	62.96	540.2	217.1	1279	
		75.0	63.51	498.3	215.2	1244	
		85.0	64.50	449.3	211.8	1176	
2	0.5	63.5	63.44	567.8	192.9	849	
		70.0	64.29	305.7	191.0	750	
		75.0	64.85	302.8	189.6	683	
		85.0	65.86	297.4	187.1	578	
3	1.0	69.2	69.14	454.4	168.1	112	
		75.0	69.90	259.1	166.9	74	
		80.0	70.46	257.6	165.9	62	
		85.0	70.98	256.1	165.0	49	
		90.0	71.47	254.4	164.0	37	
4	1.1	70.0	69.81	316.7	163.4	20	
		75.0	70.47	251.6	162.5	10	
		80.0	71.04	250.2	161.5	2	
		85.0	71.56	248.8	160.6	0	
		90.0	72.05	247.4	159.8	0	
5	1.2	70.5	70.38	324.4	158.9	1	Sed. Vol. = 19,690,000
		75.0	70.97	243.9	158.1	0	
		80.0	71.55	242.7	157.3	0	Maint. Vol. = 5,912,000
		85.0	72.08	241.4	156.4	0	Irrigation = 34,832,000
		90.0	72.57	240.1	155.6	0	Mun. & Ind. = 32,066,000
		92.5	72.81	239.4	155.2	0	Total Vol. = 92,500,000
6	1.5	75.0	72.05	219.6	145.4	0	
		80.0	72.64	218.9	144.7	0	
		85.0	73.18	218.0	144.0	0	
		95.0	74.15	216.1	142.7	0	

(c) Water Use Storage

From the above analysis, the bypass discharge was fixed as 1.2 m^3/s, giving a total reservoir volume of 92.5 million m^3. This total storage volume comprises:

Sediment Volume	= 19,690,000 m^3
Maintenance Volume	= 5,912,000 m^3
Irrigation Volume	= 34,832,000 m^3
Domestic & Industrial Volume	= 32,066,000 m^3
Total Storage Volume	= 92,500,000 m^3

(d) Sedimentation Storage (Dead Storage)

The anticipated sedimentation volume shown above was calculated from the suspended sediment discharge Q_s according to the following equation:

$$Q_s = 10^{-6} Q^3$$

where Q is the discharge flowing into the reservoir. Daily discharge data for the same ten year period as the water use model was used to calculate the sediment volume. The reservoir design life was taken as 100 years and the total sediment volume during that period estimated as 19.69 million m^3.

(3) Dam Design

(a) Geological and Topographical Condition

The geological formation of dam site is river terrace developed at the both sides of the river over the bedrock of phyllite. The bedrock is considered to have sufficient strength for the dam construction. Vaza Barris River was formed as valley or ravine which river flow has been eroded the platform. The depth from the top of river terrace to the shoulder of platform is approximately 40m to 50 m. Width of river at the shoulder of platform is about 300 m to 400 m.

(b) Dam Type

Dam was designed as rock-fill dam in this Master Plan because no sufficient geological information available at the dam site. Borrow pit for rock material will be the spillway construction site. Excavated rock of spillway will be used for construction of dam filling.

(c) Spillway

< Design Discharge of Spillway >

Probability of spillway design discharge is set at 1,000-year frequency according to the standard in Brazil. Using daily flow data at Fazenda Belem probable discharge with 1,000-year return period is estimated to be 1,600 m^3/s.

< Type of Spillway >

The type of spillway was designed as free overflow type in concrete open channel.

< Location of Spillway >

The following two locations of spillway were planned as alternatives and were compared:

1) Location-I : Spillway at the left side of dam
2) Location-II : Spillway apart from the dam site taking the river alignment into account.

As the result of cost estimation of spillway in both locations using quantity of materials as shown in Table-4.10, it was found that Location-II was more economical than Location-I.

(d) Low Flow Bypass and Check Dam

< Low Flow Bypass Channel >

The low flow bypass channel is designed to have the inverted-trapezoidal section with 10 cm thick plain concrete lining. It is planned to construct on the river terrace of Vaza Barris River from the check dam, located at approximately 30 km upstream of the Vaza Barris Dam, to the Vaza Barris Dam. The bed elevation of the channel is planned to be EL. 59.0m at intake point and EL. 50.0m at the Vaza Barris Dam Axis, resulting in the average gradient of channel as 0.000263 (1/3800) with total length of channel of 34.2 km. Hydraulic calculation shows that the average flow velocity is 0.7m/s incase of bypass flow 1.2 m^3/s with the cross section shown in Figure-4.10. Where the channel has to pass deep inside of gully, gorge or ravine, siphon pipe of prefabricated concrete pipe is provided to make short cut and to reduce channel length and friction head loss. Diameter of the siphon pipe is designed to be 2.0m to pass the flow volume more than 1.2 m^3/s within total head loss of 9m (59.0m - 50.0m).

< Check Dam >

Because of the low gradient of the natural river bed of Vaza Barris River as I = 0.000917 (1/1,090), when the water level of the reservoir rises up to about EL. 50m as the result of construction of Vaza Barris Dam, it is very difficult to keep required gradient of the channel to enable the high salinity water flow of 1.2m^3/s without providing countermeasures. Check dam is planned to cope with this difficulty by raising intake water level of the channel to acceptable limit. The check dam is designed as a concrete type with dam height of 14m and its crest elevation of EL. 59.0m. Over flow section is designed to have the width of 50m by overflow depth of 7m, thus allowing flood discharge of 1,600m^3/s. The check dam is also expected to provide the reduction in sedimentation to the Vaza Barris Dam Reservoir. General profile of the check dam is shown in Figure-4.11.

(e) Specification of the Proposed Dam

Specifications of the proposed dams with two types of spillways are summarized in Table-4.10. The capacity distribution of the reservoir is schematically shown in Figure-4.7.

Table-4.10 Specification of Proposed Vaza Barris Dam

Items		Unit	Specification		Remarks
			Type-I	Type-II	
Development Discharge	Municipal and Industrial Water	m^3/s	1.064		
	Irrigation Water	m^3/s	2.912		Vaza Barris Irr. Project
	Total	m^3/s	3.976		
Reservoir	Catchment Area	km^2	15,560		
	Reservoir Area	km^2	16.0		
	Total Storage Capacity	M. m^3	92.50		
	Effective Storage Capacity	M. m^3	72.81		
	Water Utilization Capacity	M. m^3	72.81		
	Municipal / Industrial	M. m^3	32.07		
	Irrigation	M. m^3	34.83		
	Maintenance	M. m^3	5.91		Maintenance discharge: 0.46 m^3/s
	Sediment Capacity	M. m^3	19.69		12.7 m^3/km^2/year
	Design High Water Level (H.W.L.)	EL. m	53.40		4 m Flood Capacity
	Normal Water Level (N.W.L.)	EL. m	49.40		
	Low Water Level (L.W.L.)	EL. m	39.10		
Dam	Dam Type	-	Rock Fill		
	Dam Top Level	EL. m	56.00		2.6 m Freeboard
	Dam Foundation Level	EL. m	20.00		
	Dam Height	m	36.00		
	Dam Crest Width	m	260	285	
Spillway	Type	-	Free Overflow		
	Design Discharge	m^3/s	1,600		1,000-yr. return period
	Structure : Width	m	105		
	: Height	m	4		
Check Dam	Dam Type	-	Concrete Sabo Dam		
	Dam Top Level	EL. m	59.00		
	Dam Foundation Level	EL. m	45.00		
	Dam Height	m	14.00		
	Dam Crest Width (Over flow sec.)	m	50.00		
	Design High Water Level	EL. m	66.00		
Low Flow Diversion Channel	Type Channel Portion	-	Open channel		
	Siphon Portion	-	Concrete pipe		
	Section Channel Portion	-	Inverted-Trapezoidal		
	Siphon Portion	-	Diameter 2.0m		
	Total Length	km	34.23		
	Channel Portion	km	31.73		
	Siphon Portion	km	2.5 km		25 places
	Average Gradient	m/m	0.000263 (1/3,800)		
	Nominal discharge volume	m^3/s	1.23		
Construction Quantity	Dam Embankment Volume	m^3	617,000	633,000	
	Dam Excavation	m^3	72,000	72,000	
	Spillway Excavation	m^3	153,000	690,000	
	Spillway Concrete	m^3	52,000	5,000	
	Stripping of Spillway Course	m^2	-	90,000	

Notes: Type I: Spillway at the left side of dam
Type II: Spillway apart from the dam site

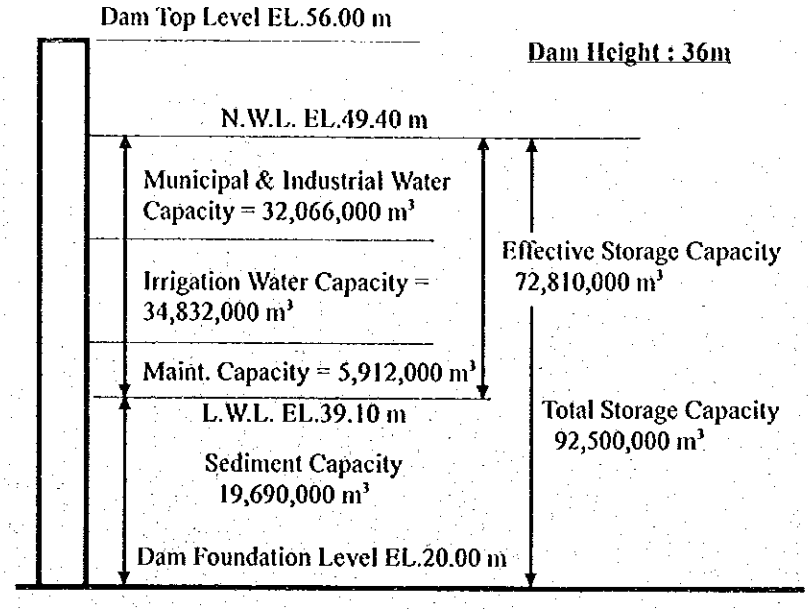


Figure-4.7 Schematic Description of Capacity of Vaza Barris Dam

(f) Profiles of Dam

The general profiles of the Vaza Barris Dam is attached in Figure-4.8 to Figure-4.11.

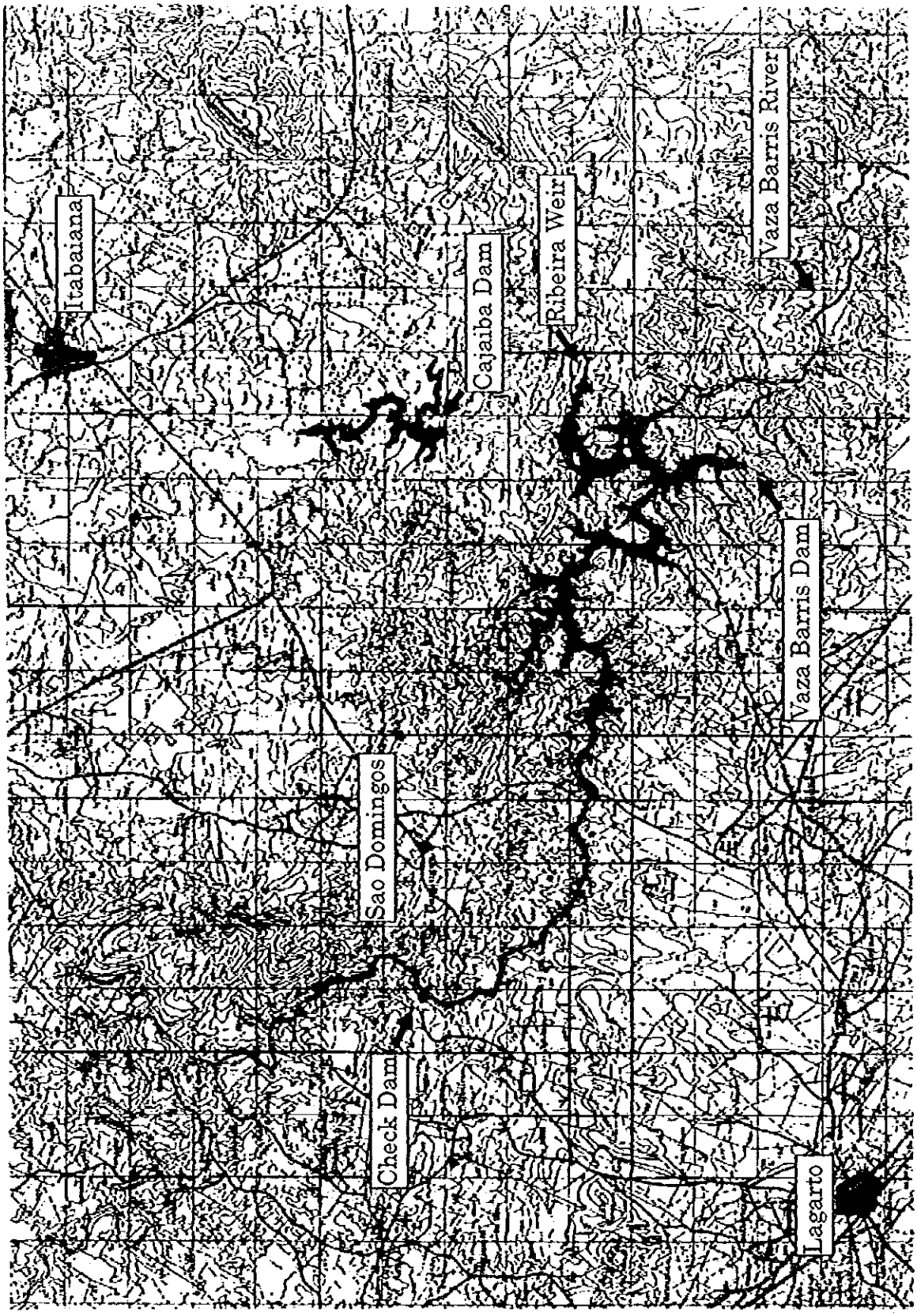


Figure-4.8 Location map of Vaza Barris Dam

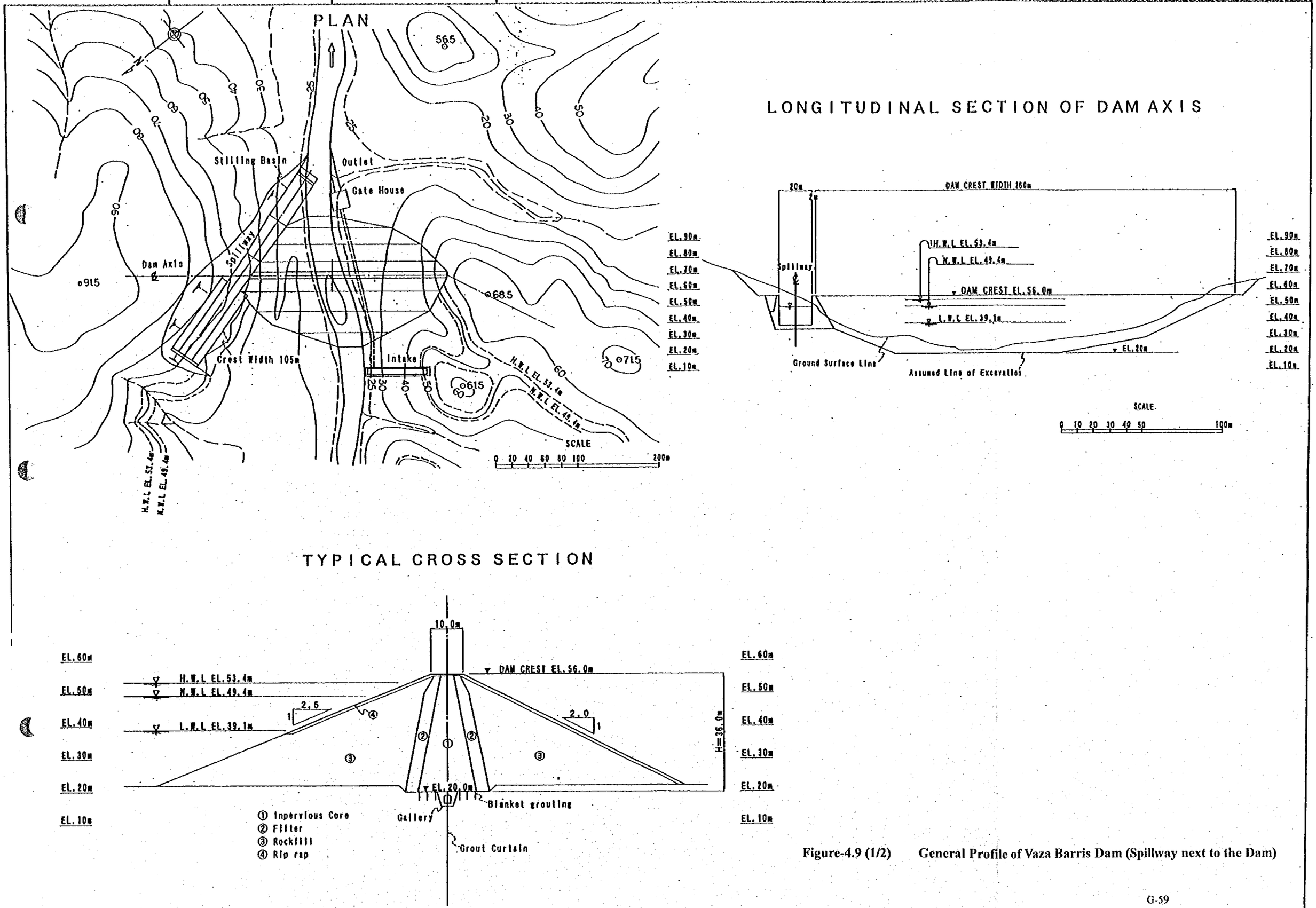
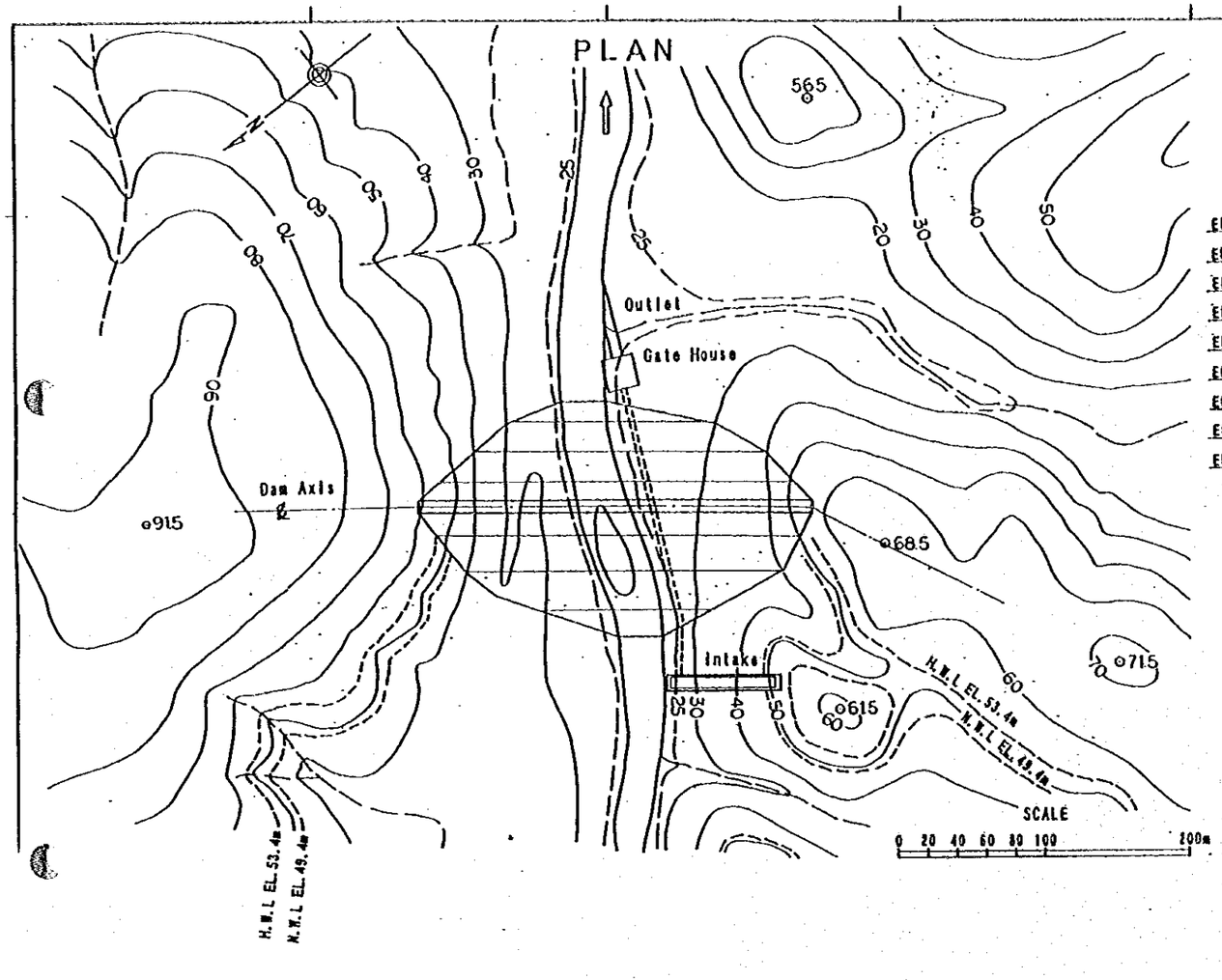
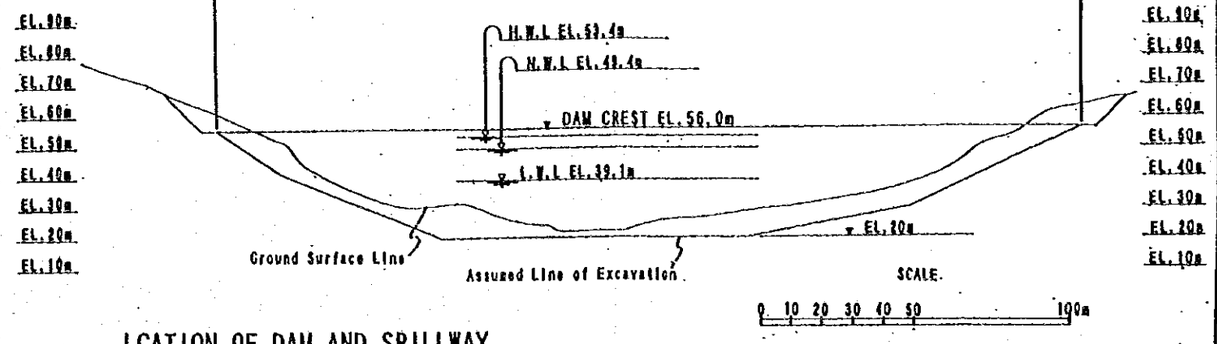
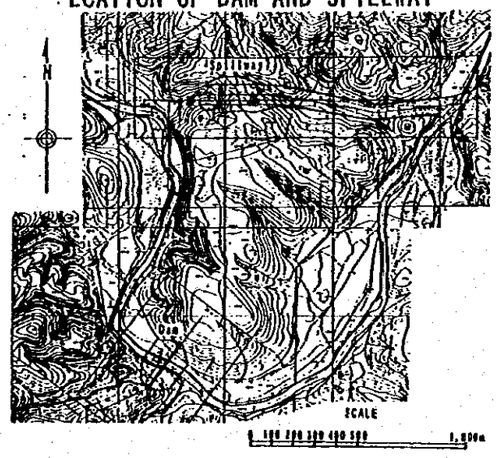
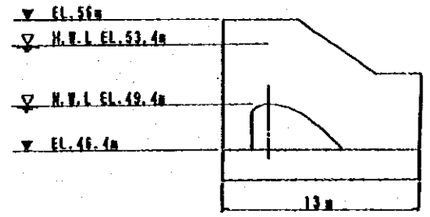


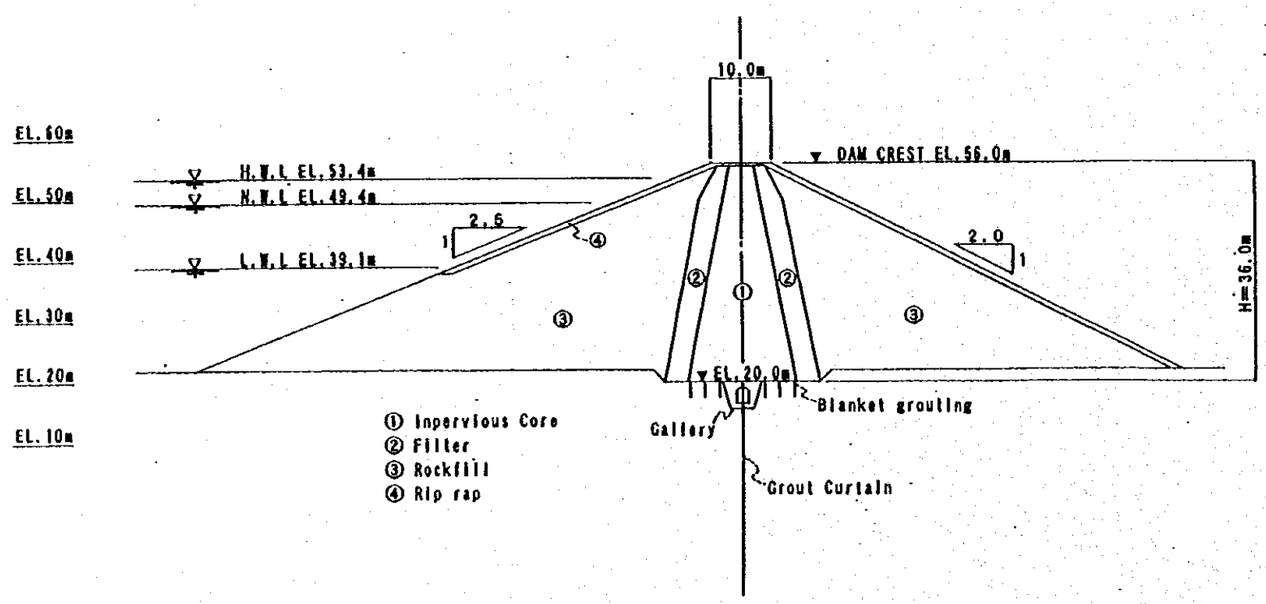
Figure-4.9 (1/2) General Profile of Vaza Barris Dam (Spillway next to the Dam)

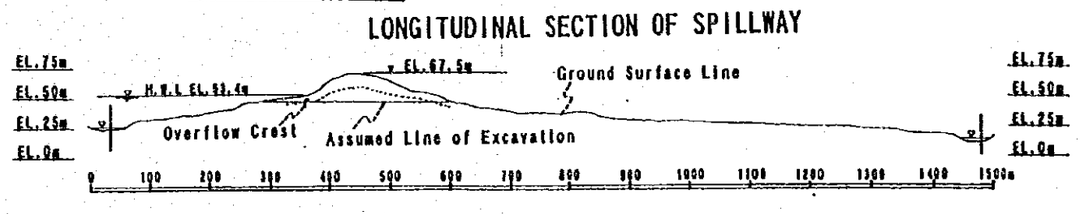












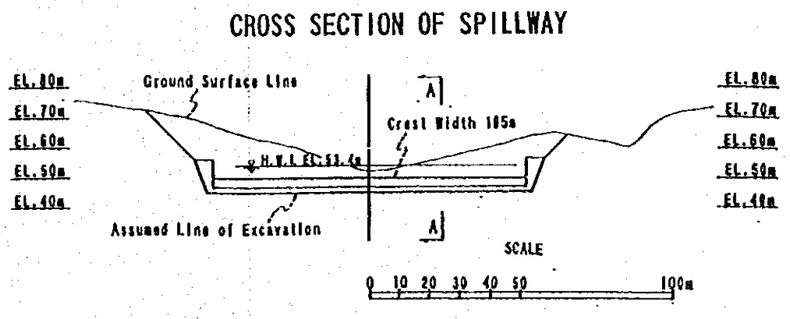
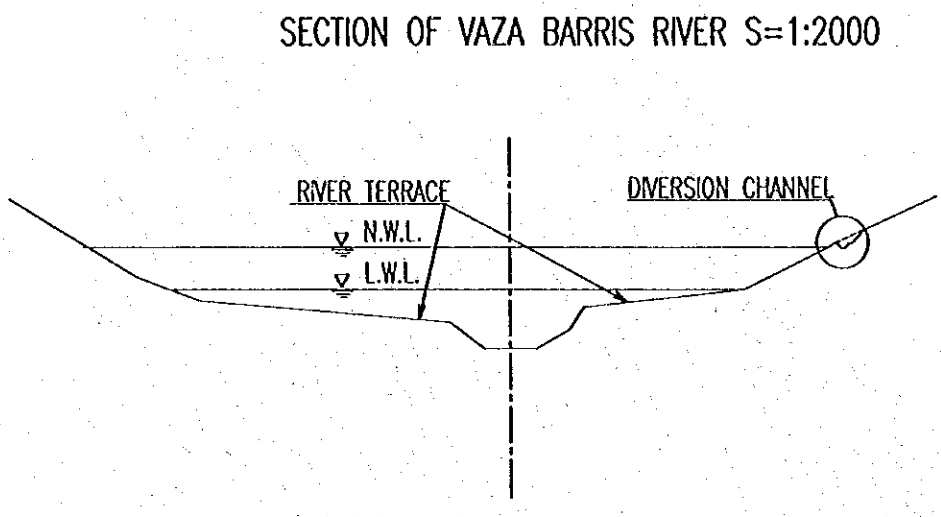


Figure-4.9 (2/2) General Profile of Vaza Barris Dam (Spillway apart from the Dam)



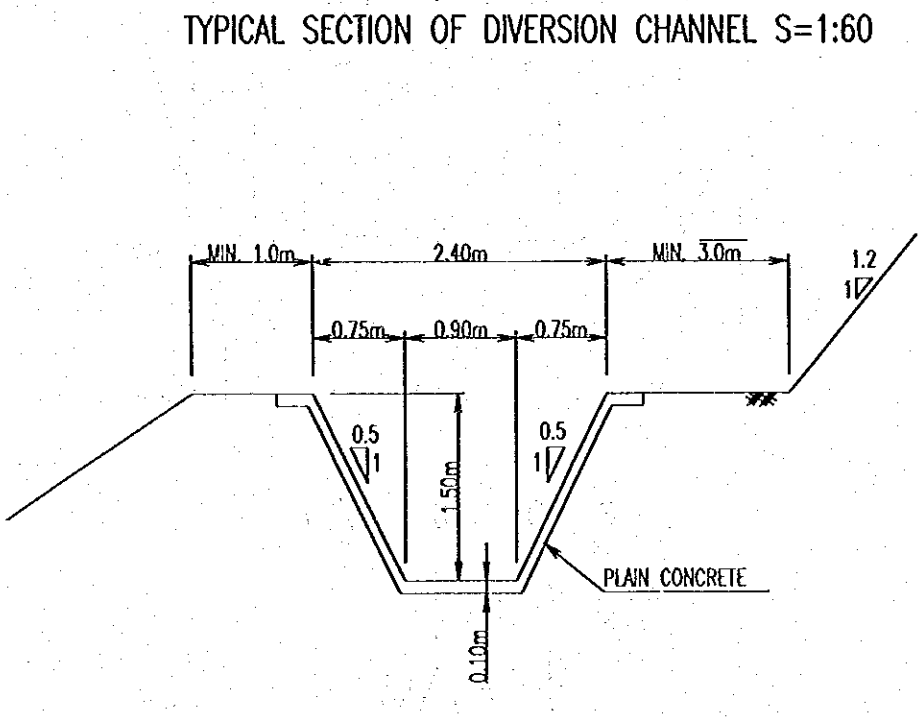
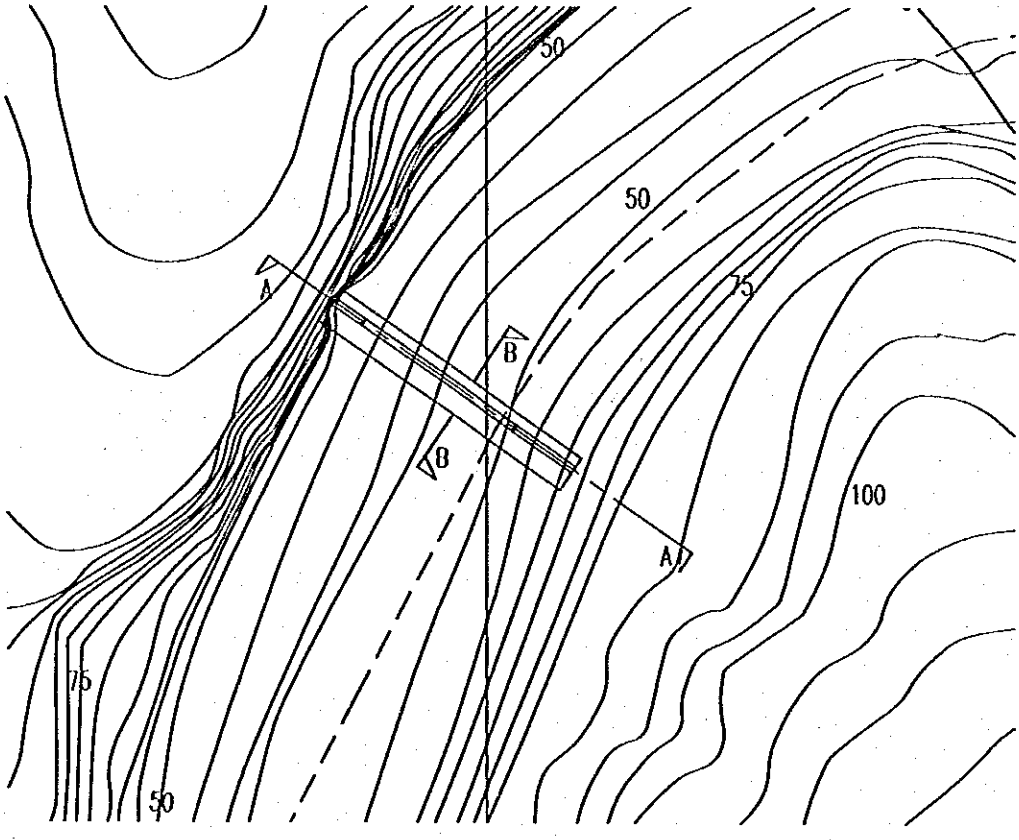
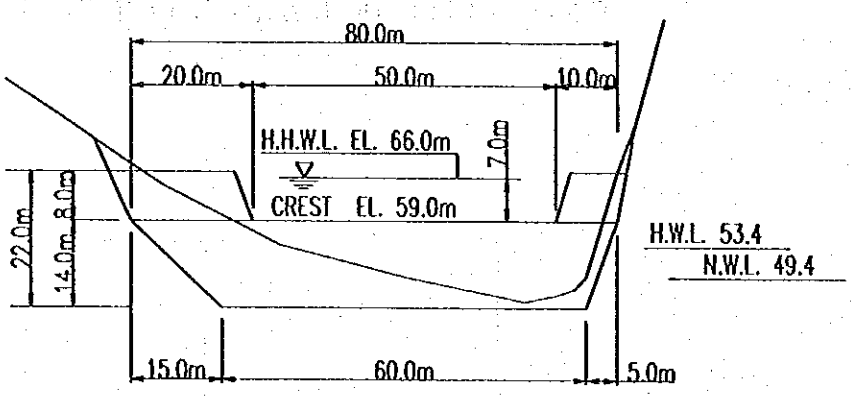


Figure-4.10 Typical Section of Low Flow Diversion Channel

PLAN S=1:50



SECTION A-A S=1:60



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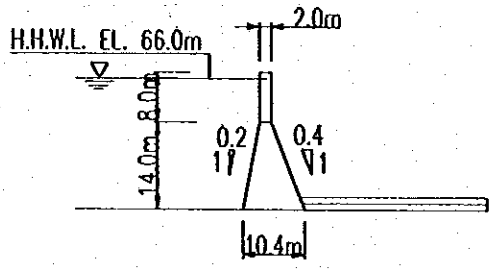


Figure-4.11 General Profile of Check Dam

4.2.4 Plan of Integrated Pipeline Projects

(1) Plan of Water Supply and Development

Water supply and development plan of following integrated pipeline systems are shown in Table-4.12 with the explanation below.

- Sao Francisco Pipeline Project (On-going)
- Aracaju Well Development Project (On-going)
- Project Expansion of Agreste Pipeline System (PROAGUA)
- Project Expansion of Piauitinga Pipeline System (PROAGUA)
- Xingo Dam Pipeline Project
- Vaza Barris Dam Pipeline Project
- Project Expansion of Itabaianinha Pipeline System
- Project Expansion of Propria Pipeline System
- Project Expansion of Alto Sertao Pipeline System
- Project Expansion of Sertaneja Pipeline System

(a) Sao Francisco Pipeline Project (On-going)

This project is currently on-going. Source water is taken from Sao Francisco River and is supplied to Aracaju metropolitan area, such as the municipalities of Laranjeiras, Aracaju and N. S. do Socorro. Total water supply amount is 151,600 m^3/day.

(b) Aracaju Well Development Project (On-going)

In 1998, large potential wells were found around Aracaju, of which yield was reported to be 200 m^3/hr. DESO has a plan to construct nine wells. Assuming 16 hours operation of well pumps per day, water flow volume of 28,800 m^3/day can be developed by these nine wells.

(c) Project Expansion of Agreste Pipeline System (PROAGUA)

This project was proposed for application to PROAGUA and is in procedure. Water resources are 0.140m^3/s from Cajaiba Dam, 0.046m^3/s from Ribeira weir and 0.220 m^3/s from Jacarecica II Dam. This project is planned to supply water of 22,200m^3/day, which is equivalent to 36% of supply water shortage for the Agreste block in 2020.

(d) Project Expansion of Piauitinga Pipeline System (PROAGUA)

This project was proposed for application to PROAGUA and is in procedure. Water resources are 0.240m^3/s from Piaui Dam, 0.110m^3/s from Piaui River direct intake and 0.130 m^3/s from deep wells near Salgado and Pe da Serra. This project is planned to supply water of 30,200m^3/day, which is equivalent to 45% of supply water shortage for the Piauitinga block in 2020.

(e) Xingo Dam Pipeline Project

Source water is drawn out from the conduits of Xingo Dam and 43,999 m^3/day of water is planned to be supplied to the blocks of California I (Caninde do Sao Francisco), Sertaneja[2] and Sertaneja[3]. This project is planned as multi-purpose project with domestic/industrial water supply and irrigation water supply for Sao Francisco irrigation project.

(f) Vaza Barris Dam Pipeline Project

Vaza Barris Dam is planned in the main stream of Vaza Barris River. This project supplies 39,276m^3/day of water to Agreste block and 37,334 m^3/day to Piauitinga block, which are equivalent to 64% and 55% of supply water shortage for each block in 2020. This project is planned as multi-purpose project with domestic/industrial water supply and irrigation water supply for Vaza Barris irrigation project.

(g) Project Expansion of Itabaianinha Pipeline System

Weir and intake systems were planned at Piaui River and the facility plan of the systems are shown in Table-4.11. 13,321 m^3/day of water is planned to be supplied for Itabaianinha block.

Table-4.11 Facility Plan of Project Expansion of Itabaianinha Pipeline System

System Name	Weir and Intake					Pump and Pipeline *2	
	River Name	Catch-ment Area (km^2)	Q[7,10] (m^3/day)	Potential Developed Discharge (m^3/day)	Source Developed Discharge (m^3/day)	Pipeline Length (km)	Lifting Head (Elevation) (m)
Guararema I	Guararema R./ PR	176	85	11,968	11,327 (641) *1	21	110 (20-130)
Guararema II	Indiaroba R./ PR	78	95	5,928	4,658	21	110 (20-130)

Note: *1 Existing system takes 262m^3/day and 379m^3/day of water from Pagao R. (7km^2,) and Sapcaia R. (19km^2) respectively. Then 641m^3/day is subtracted from potential development discharge.
*2 Pipeline shall set from weirs to Umbauba City.

(h) Project Expansion of Propria Pipeline System

Water resource is Sao Francisco River and 6,189 m^3/day of water is planned to be supplied to Propria block, expanding present integrated system.

(i) Project Expansion of Alto Sertao and Sertaneja Pipeline System

Although the Alto Sertao and Sertaneja Pipeline Systems currently supply water to the blocks of Sertaneja [2] and [3], Xingo Dam Pipeline Project is planned to supply water to these blocks. Thus 10,354 m^3/day of water that is being supplied to these blocks is available for the both blocks of Alto Sertao and Sertaneja [1], accounting for 3,929 m^3/day and 6,425 m^3/day respectively.

Alto Sertao System is planned to newly develop source water of 1,879 m^3/day from Sao Francisco River and to additionally supply water of 5,495 m^3/day.

Sertaneja System is planned to newly develop source water of 68 m^3/day from Sao Francisco River and to additionally supply water of 6,493 m^3/day.

Table-4.12 (1/2) Plan of Water Supply and Development for Integrated System

Beneficial Block and Municipality		Population		Supply Water				Source Water
		Total (person)	Benefici-aries (person)	Present Capacity (m^3/day)	Total (m^3/day)	Shortage (m^3/day)	Shortage Rate (%)	Develop. Amount (m^3/day)
Sao Francisco Pipeline Project		**874,290**	**268,263**	**134,630**	**286,230**	**151,600**	**113%**	**181,919**
Aracaju Block	Laranjeiras	46,688	32,874	1,613	62,703	61,090	3787%	73,308
	Aracaju	602,002	142,680	108,073	171,871	63,799	59%	76,558
	N. S. do Socorro	225,600	92,709	24,944	51,655	26,711	107%	32,053
Aracaju Well Development Project		**874,290**	**41,217**	**20,685**	**43,977**	**23,292**	**113%**	**27,950**
Aracaju Block	Laranjeiras	46,688	5,051	248	9,634	9,386	3787%	11,263
	Aracaju	602,002	21,922	16,605	26,407	9,802	59%	11,763
	N. S. do Socorro	225,600	14,244	3,832	7,936	4,104	107%	4,925
Expansion of Agreste Pipeline S.		**292,774**	**81,802**	**4,626**	**26,826**	**22,200**	**480%**	**26,640**
Agreste Block	Areia Branca	72,136	23,587	395	5,257	4,861	1231%	5,834
	Campo do Brito	34,123	10,130	415	2,635	2,220	535%	2,664
	Itabaiana	165,664	42,358	3,497	17,376	13,878	397%	16,654
	Macambira	7,945	2,088	132	547	415	315%	498
	Sao Domingos	12,907	3,640	187	1,012	825	441%	990
Expansion of Piauitinga Pipeline S.		**198,857**	**62,639**	**5,424**	**35,624**	**30,200**	**557%**	**36,240**
Piauitinga Block	Poco Verde	18,959	4,975	748	1,743	995	133%	1,195
	Simao Dias	39,948	11,784	1,325	5,396	4,070	307%	4,884
	Lagarto	122,919	40,207	2,982	27,081	24,099	808%	28,919
	Riachao do Dantas	17,031	5,674	369	1,404	1,035	281%	1,242
Xingo Dam Pipeline Project		**194,370**	**131,584**	**11,906**	**55,905**	**43,999**	**370%**	**52,799**
Sub-total of California I Block		53,986	45,279	1,552	20,036	18,484	1191%	22,180
Sub-total of Sertaneja [2] Block		69,765	45,674	4,746	21,251	16,505	348%	19,806
Sub-total of Sertaneja [3] Block		70,620	40,631	5,608	14,618	9,010	161%	10,812
California I	Caninde do Sao Francisco	53,986	45,279	1,552	20,036	18,484	1191%	22,180
Sertaneja [2] Block	Nossa Senhora da Gloria	46,437	31,750	3,040	16,513	13,473	443%	16,167
	Carira	23,328	13,923	1,706	4,738	3,033	178%	3,639
Sertaneja [3] Block	Frei Paulo	18,411	10,612	1,439	4,470	3,031	211%	3,638
	Nossa Senhora Aparecida	8,033	3,893	732	1,563	831	113%	997
	Pedra Mole	2,865	1,005	325	511	186	57%	223
	Pinhao	6,635	3,989	529	1,326	797	151%	957
	Ribeiropolis	18,760	9,968	1,784	3,848	2,064	116%	2,476
	Sao Miguel do Aleixo	2,575	1,246	252	479	226	90%	272
	Moita Bonita	13,341	9,918	547	2,422	1,875	343%	2,250
Vaza Barris Dam Pipeline Project		**485,938**	**223,212**	**14,890**	**91,500**	**76,610**	**515%**	**91,932**
Sub-total of Agreste Block		292,774	144,721	8,184	47,460	39,276	480%	47,131
Sub-total of Piauitinga Block		198,857	77,437	6,706	44,040	37,334	557%	44,801
Agreste Block	Areia Branca	72,136	41,729	699	9,300	8,601	1,231%	10,321
	Campo do Brito	34,123	17,921	734	4,662	3,928	535%	4,713
	Itabaiana	165,664	74,938	6,188	30,741	24,553	397%	29,464
	Macambira	7,945	3,694	233	967	734	315%	881
	Sao Domingos	12,907	6,440	331	1,791	1,460	441%	1,752
Piauitinga Block	Poco Verde	18,959	6,038	6,150	2,155	1,231	133%	1,477
	Simao Dias	39,948	14,295	14,567	6,671	5,032	307%	6,038
	Lagarto	122,919	50,433	49,705	33,479	29,792	808%	35,750
	Riachao do Dantas	17,031	7,081	7,015	1,736	1,280	281%	1,536

Table-4.12 (2/2) Plan of Water Supply and Development for Integrated System

Beneficial Block and Municipality		Population		Supply Water				Source Water
		Total (person)	Benefic i-aries (person)	Present Capacity (m^3/day)	Total (m^3/day)	Shortage (m^3/day)	Shorta ge Rate (%)	Develop. Amount (m^3/day)
Expansion of Itabaianinha P. S.		**80,848**	**57,529**	**4,002**	**17,323**	**13,321**	**333%**	**15,985**
Itabaianinha Block	Itabaianinha	37,389	23,778	2,449	9,184	6,735	275%	8,082
	Tomar do Geru	17,547	13,693	569	3,215	2,646	465%	3,175
	Umbauba	25,912	20,059	983	4,923	3,940	401%	4,728
Expansion of Propria Pipeline S.		**54,574**	**22,968**	**6,462**	**12,651**	**6,189**	**96%**	**7,427**
Propria Block	Malhada dos Bois	5,531	4,137	263	1,093	830	316%	996
	Cedro de Sao Joao	4,992	846	844	999	155	18%	186
	Propria	40,826	17,513	4,908	10,005	5,097	104%	6,116
	Telha	3,225	472	447	555	107	24%	129
Expansion of Alto Sertao P. S. *1		**54,241**	**18,052**	**6,716**	**12,211**	**5,495**	**82%**	**6,594**
						(1,566)		**(1,879)**
Alto Sertao	Monte Alegre de Sergipe	12,818	4,972	1,545	4,052	2,507	162%	3,008
	Poco Redondo	20,658	8,208	2,370	4,179	1,808	76%	2,170
	Porto da Folha	20,766	4,873	2,801	3,980	1,180	42%	1,416
Expansion of Sertaneja P. S. *2		**65,241**	**26,940**	**7,079**	**13,504**	**6,493**	**92%**	**7,792**
						(68)		**(82)**
Sertaneja [1] Block	Feira Nova	11,972	8,832	629	2,520	1,891	300%	2,269
	Gararu: Half Large Rural	2,178	845	163	299	135	83%	162
	Gracho Cardoso	5,198	2,141	561	977	416	74%	499
	Itabi	4,663	768	755	1,142	387	51%	464
	Aquidaba	21,763	7,918	2,537	4,739	2,202	87%	2,643
	Cumbe	4,276	795	672	959	287	43%	345
	Amparo de Sao Francisco	2,307	638	315	441	126	40%	151
	Canhoba	3,513	0	704	636	0	0%	0
	N. S. de Lourdes	9,371	5,003	742	1,791	1,050	142%	1,260

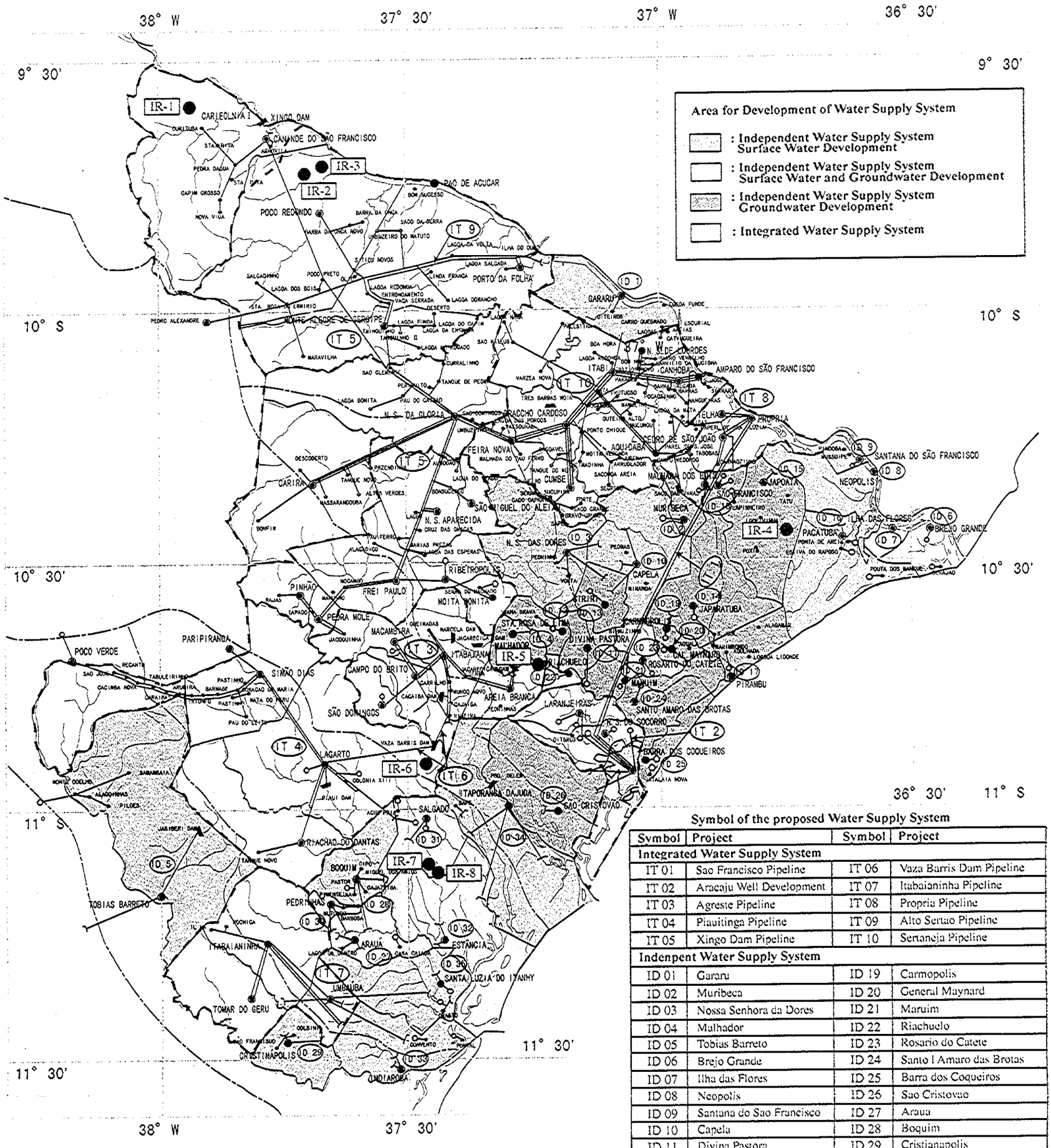
Note: *1 3,929 m^3/day of supply water to Sertaneja [2] and [3] could be used in Alto Sertao Block, because of no more water supply to Sertaneja [2] and [3].

*2 6,425 m^3/day of supply water to Sertaneja [2] and [3] could be used in Sertaneja Block, because of no more water supply to Sertaneja [2] and [3]. This project is planned to supply water to the area of the half of large rural in Gararu Municipality

(2) Facility Plan

The design concept of this water supply system is exactly the same as for Independent Water Supply System, except that most of the system do not require construction of new dams or weirs.

The location of the Independent Water Supply System and the Integrated Water Supply System is shown in Figure-4.12.



Symbol of the proposed Water Supply System

Symbol	Project	Symbol	Project
Integrated Water Supply System			
IT 01	Sao Francisco Pipeline	IT 06	Vaza Barris Dam Pipeline
IT 02	Aracaju Well Development	IT 07	Itabaianinha Pipeline
IT 03	Agreste Pipeline	IT 08	Propria Pipeline
IT 04	Piauitinga Pipeline	IT 09	Alto Sertao Pipeline
IT 05	Xingo Dam Pipeline	IT 10	Sertaneja Pipeline
Indenpent Water Supply System			
ID 01	Gararu	ID 19	Carmopolis
ID 02	Muribeca	ID 20	General Maynard
ID 03	Nossa Senhora da Dores	ID 21	Maruim
ID 04	Malhador	ID 22	Riachuelo
ID 05	Tobias Barreto	ID 23	Rosario do Catete
ID 06	Brejo Grande	ID 24	Santo I Amaro das Brotas
ID 07	Ilha das Flores	ID 25	Barra dos Coqueiros
ID 08	Neopolis	ID 26	Sao Cristovao
ID 09	Santana do Sao Francisco	ID 27	Araua
ID 10	Capela	ID 28	Boquim
ID 11	Divina Pastora	ID 29	Cristianapolis
ID 12	Santa Rosa de Lima	ID 30	Pedrinhas
ID 13	Siriri	ID 31	Salgado
ID 14	Japaratuba	ID 32	Estancia
ID 15	Japoata	ID 33	Indiabora
ID 16	Pacatuba	ID 34	Itaporanga D'Ajuda
ID 17	Pirambu	ID 35	Santa Luzia do Itanhy
ID 18	Sao Francisco		
Irrigation Project			
IR 01	Quixabeira	IR 05	Jacarecica II
IR 02	Jacare-Curituba	IR 06	Vaza Barris
IR 03	Sao Francisco	IR 07	Entre Rios
IR 04	Ladeirinhas	IR 08	Estancinha

Figure - 4.12 Plan of Integrated and Independent Water Supply System