4.2 Criteria for Plan and Design

4.2.1 Planning Criteria

(1) Domestic and Industrial Water Resources Development and Supply

(a) Water Supply System

Domestic water supply systems are divided into following two categories according to present condition of water supply system in Sergipe State.

- Urban and large rural area: Private-tap water supply system
- Small rural area: Public-tap water supply system

Another water supply means, such as rainfall collecting system and watering pond are not discussed in this study because of their unreliability. Water-truck delivery system is not situated as a water supply system but as an emergency activity.

(b) Urban and Large Rural Area

In urban and large rural area, domestic and industrial water is supplied by private-tap system, which is divided into integrated system and independent system. The areas supplied with water presently by the integrated systems are planned to be supplied by the integrated system in general, because of no good potential of surface water and groundwater in these areas.

In general, the nearer water resources are the economical development. The areas supplied with water presently by the independent systems are planned as following rules:

- Except areas with water supply potential of Sao Francisco River, the first alternative is groundwater development if there is good potential groundwater aquifer.
- In the case of no good groundwater potential and much developed water requested, following alternatives are studied, such as 1) surface water development by weirs and intake pumps, and 2) connecting integrated systems.

(c) Small Rural Area

In small rural area, residential water is supplied by public-tap system, which is named "Single Well System", by means of groundwater development. Desalinizer is also planned if necessary.

(d) Industrial Water Supply

Industrial water is assumed to be consumed in urban and large rural area but not in small rural area. Then industrial water is supplied by private-tap system with the supply rate mentioned in Table-4.3. The rest of industrial water not supplied by private-tap system is assumed to be developed by means of groundwater near the site by individual industries.

(2) Agricultural Water Resources Development

The criteria for water resources development in agricultural sector are set as follows:

- Agricultural water are classified as: 1) Irrigation water, 2) Livestock water and 3) Aquaculture water. Water sources of livestock breeding depend mainly on watering ponds (aguadas) or wells near farms because the livestock water demand is regionally scattered and the volume of individual demand is small. The project scale of aquaculture in Sergipe State is very small and its necessary water amount is considered to be negligible. Thus, irrigation water development plan is mainly discussed in this study.

– Water sources for irrigation are to be mainly surface water of Sao Francisco River and large dam reservoirs. Groundwater and direct intake from a river are applied only for small scale irrigation projects.

(3) Surface Water Development

(a) Security Level of Water Supply

Low flow security in plans of weirs and direct intakes has been set to ensure the abstraction of new development discharge even in the worst drought in ten years for domestic and industrial water supply, and in five years for irrigation water supply. In the case of dam development, both cases of single and multi-purpose, low flow security is set against the worst drought in ten years as determined for water supply projects for domestic and industrial use.

(b) Level of Compensation Discharge

In Brazil, the 10-year return period 7-day flow (Q7,10) has recently come to be used in low water management. The (Q7,10) refers to the mean annual minimum 7-day flow with 10-year return period, and this is secure as compensation discharge to the downstream when developing new water resources of river flow. The "compensation discharge" Q_{CM} could be defined as the discharge necessary to maintain the normal function of a river, and consists of maintenance discharge and water-use discharge. Maintenance discharge has been stipulated to be maintained even at times of low flow, with overall consideration to the follows: 1) boat transportation, 2) fishing, 3) scenery, 4) groundwater level maintenance, 5) preservation of plants and animals, 6) preservation of cleanliness of river flow. Water-use discharge is the flow necessary for the consumptive use of the river water at all points downstream.

How many percents of (Q7,10) should be secured varies according to the states, namely 100% in Sao Paulo State, 50% in Parana State and 30% in Minas Gerais State. Although the rate has not been stipulated yet in Sergipe State, in this Study, the detail setup of compensation discharge (Q_{CM}) and available discharge (Q_{AV}) in perennial river is as follows:

<u>Weir Intake or Direct Intake</u>

Q_{CM} =20% of (Q7,10) (Security Level: 10 years return period)
Q_{AV} =80% of (Q7,10) (Security Level: 10 years return period for human use)
Q_{AV} =100% of (Q7,5) – Q_{CM} (Security Level: 5 years return period for irrigation use)

<u>Dam and Reservoir</u>

Q_{CM} =100% of (Q7,10) (Security Level: 10 years return period)
Q_{AV} = Newly developed discharge (Security Level: 10 years return period)

(4) Groundwater - Deep Well Development

The required number of deep wells to meet the regional demands is estimated for the formulation of the groundwater development plan. Deep wells provide a more stable source of water with better quantity and quality than shallow wells, which are affected by droughts and are not a reliable source for sustainable development. The following criteria are applied for the groundwater development plans:

- **Urban and Large Rural Water Supply:** Water supply in urban areas requires large volume of water. Pumped water from one borehole is determined based on the assessment of safe yield according to the hydrogeological characteristics of the area. Standard size of boreholes is 15cm in diameter and 100m in depth. Desalinizer is not installed and pure water wells should be developed. A well, if saline water is found, should be abandoned and a new pure water well should be developed because of much development water volume required in urban and large rural areas.
- **Rural Water Supply:** Standard size of boreholes is 15cm in diameter and 60m in depth. A deep well is assumed to cover an area with 100 people. A desalinizer should be installed if saline water is appeared.

Groundwater development is carried out through drilling boreholes. Yields of boreholes are limited and over pumping causes adverse effects, not only to groundwater environment around the borehole, but also to the borehole itself. Therefore, the safe yield should be determined for each borehole for sustainable groundwater use. Success rates in quantity and in quality are also taken into account for deep well development. The safe yield, success rates in quantity and quality depend on main aquifer and the best aquifers in Sergipe are Alluvium, Barreiras/Sergipe and Sergipe formation. Refer toTable-4.4. These yields and rates are compiled by municipalities and vary as follows:

- Expected Yield : 40-600 m^3/day
- Success rate in quantity : 45-90 %
- Success rate in quality : 10-100 %

Table-4.4 Well Capacity and Water Quality by Aquifer

Aquifer	Expected yield (m^3/day)	Specific capacity (m^3/day/m)	Success rate in quantity (%)	Success rate in quality (%)
Alluvium	600	140	95	100
Barreiras/Sergipe	140	17	80	85
Barreiras/Craton	70	4	85	90
Tucano	100	4	60	60
Sergipe	140	13	70	60
Dominio Caninde	40	2	45	10
Dominio Poco Redondo	40	2	45	10
Dominio Maranco	40	2	45	10
Dominio Macurure	40	2	60	15
Dominio Vaza-Barris	80	7	75	40
Dominio Estancia	50	3	70	50
Craton do Sao Francisco	40	2	75	30
Domos de Itabaiana	70	4	75	35

Note: 'Fresh water' means chlorine (Cl) is less than 250 mg/L

4.2.2 Design Criteria

(1) General

(a) Codes and Standards

Facilities to be required in the Master Plan Study is designed in accordance with the Codes and Standards published and authorized by federal, regional, state, municipal and/or any other public organizations or authorities in Brazil. When applicable Codes and Standards are not specified by the related organizations mentioned above, the Codes, Standards and Regulations in Japan are used with some adjustment in accordance with the local conditions in the State of Sergipe.

(b) Units of Measurements

Units of measurements in design are in SI/MKS metric system.

(c) Design Method of Facilities

In principle, allowable stress design method is applied for all structural design of the facilities.

(d) Materials to be Used

All materials to be used for construction of facilities required in the Master Plan are in accordance with Brazilian Technical Standards (ABNT) or equivalent Japanese Industrial Standards (JIS) or other internationally accepted standards.

(2) Design of Dams

(a) Codes and Standards

Unless otherwise specified by the related organizations, the following codes and standards are used for the design of dams:

- Design Criteria for Dams, Japanese National Committee on Large Dams, Japan
- Manual for river works in Japan, River Bureau, Ministry of Construction, Japan
- Manual of small dam, SUDENE, Brazil

(b) Loads to be Considered

In principle, the loads to be considered in the design of dams are dead weight of dam, hydrostatic pressure, pore pressure, sediment pressure and uplift pressure. Seismic loads such as seismic body force and hydrodynamic pressure will not be taken into account because of no earthquake in Brazil.

(c) Selection of Dam Type

The full consideration is given to various requirements such as topographical, geological and hydrological conditions of the dam site, dam materials and others in the selection of dam type.

(d) Determination of Dam Size

The dam size is determined on the basis of the design flood run-off for dam, water levels used for design of dam such as normal water level, surcharge water level and design flood level. Consideration is also given to the structural aspects of dam body and its base ground in order to determine the dam size.

(e) Spillway and Other Discharge Installations

The concrete dam is equipped with the following discharge installations:

- Spillway to let flood discharge flow down
- Low flow outlet to flow compensation discharge maintaining normal river functions

Fill dam is equipped with a discharge installation which can lower the water level of the reservoir in addition to the above.

(f) Safety Requirements

< Fill Dams >

- Safety against sliding failure
- Safety against seepage

< Concrete Dams >

- Safety against shear failure of the contact plane between dam body and bedrock as well as that of the weak zone within the bedrock
- Safety on stress in concrete
- Stability of bedrock

(3) Design of Water Supply Facility

(a) Codes and Standards

Unless otherwise specified by the related organizations, the following codes and standards are used for the design of water supply facilities:

- Brazilian Norms (NBR), Brazilian Association of Technical Norms (ABNT)
- Japan Water Works Association (JWWA)
- American Water Works Association (AWWA)
- Japanese Industrial Standard (JIS)
- American Standard of Testing Materials (ASTM)

(b) Loads to be Considered

In principle, the loads to be considered in the design of structures in Water Supply Systems are dead Weight, floor loads, live loads, equipment loads, earth pressure, groundwater pressure, hydrostatic pressure, uplift pressure and wind loads. Seismic loads such as seismic body force and hydrodynamic pressure are not considered because of no earthquake in Brazil.

(c) Design Parameters and Water Supply Volume

- Estimated population at the target year, P (person)
- Design daily water supply volume per capita, q (litter/day)
- Coefficient of daily maximum consumption : k_1 = 1.2
- Coefficient of hourly maximum consumption : k_2 = 1.5
- Water loss rate : r_L = 42% in 1998
  = 25% in 2020

- Daily maximum water supply volume, Q_{DM} (litter/day)

$$Q_{DM} = \frac{P \times q \times k_1}{1 - r_L}$$

- Hourly maximum water supply volume, Q_{HM} (litter/day)

$$Q_{HM} = Q_{DM} \times k_2 = \frac{P \times q \times k_1 \times k_2}{1 - r_L}$$

(d) Design of Water Supply System

< Raw Water Pump Station >

The required capacity of raw water pump to be installed in raw water pump station, RWPS, is determined based on Q_{DM} when a water storage tank elevated (ET) or on the ground (AT) is installed in the system. The pump is selected using head-discharge curves of pump and system. Actual suction head is the difference in water levels between suction (intake) side and discharge side in meters. Fluctuation of water levels and siphon effect is also considered in determining the actual suction head. Although item 5.7.3 of Norm NBR1218 in July 1994 recommends to use Colebrook-White formula for calculation of head loss in pipeline, head loss in pipeline shall be calculated using Hazen-Williams formula because of the simplicity in calculation to deal with tremendous cases of water pipeline systems and because of the standard method in Japan for calculation of head loss. Materials of pipe are cast-iron or PVC.

< Water Main >

The water main from RWPS to the Water Treatment Station, WTS is capable of transfer of pumped-up water to WTS. Materials of pipe is steel or cast-iron.

< Water Treatment Station >

Water treatment station, WTS, is a conventional type and have the capacity to meet Q_{HM}. The treated water distribution pump in treated water pump station, TWPS, has the capacity to meet Q_{HM}. Filter is direct ascending type. Desalinizer is portable REVERSE OSMOSIS type installed where pumped-up water is saline, especially in rural area in the State of Sergipe. The required capacity of storage tank is determined as one third of Q_{DM}.

< Distribution Main >

The distribution main from WTPS or ET to the distribution network is capable of transfer of water to meet Q_{HM}. Materials of pipe is steel or cast-iron.

< Distribution Network >

The distribution network is sufficient enough to supply water to each user.

4.3 Water Balance and Water Shortage

4.3.1 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-4.5, 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-4.5. 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-4.5, 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-4.5 Balance between Water Demand and Potential

Units: million cubic meters (MCM)/year

River System	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)	55684.8	304.7	186.4	406.1	654.7	628.9	57865.6
Balance (Ave. Low Flow)	51269.8	6.0	-211.8	-43.2	-2.7	47.7	51065.8
Balance (Drought Flow)	39885.8	-22.8	-243.5	-71.6	-26.0	-2.5	39519.4

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)

4.3.2 Water Demand, Supply and Shortage

(1) Domestic and Industrial Water

Total water supply and shortage in the Sergipe State is summarized in Table-4.6 and Figure-4.1. 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-4.7, Table-4.8 and Figure-4.1. Supply water shortage by river basins is summarized as follows:

	Urban and Large Rural Area		Small Rural Area	
River Basin	Supply Water Shortage	Rate	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 %

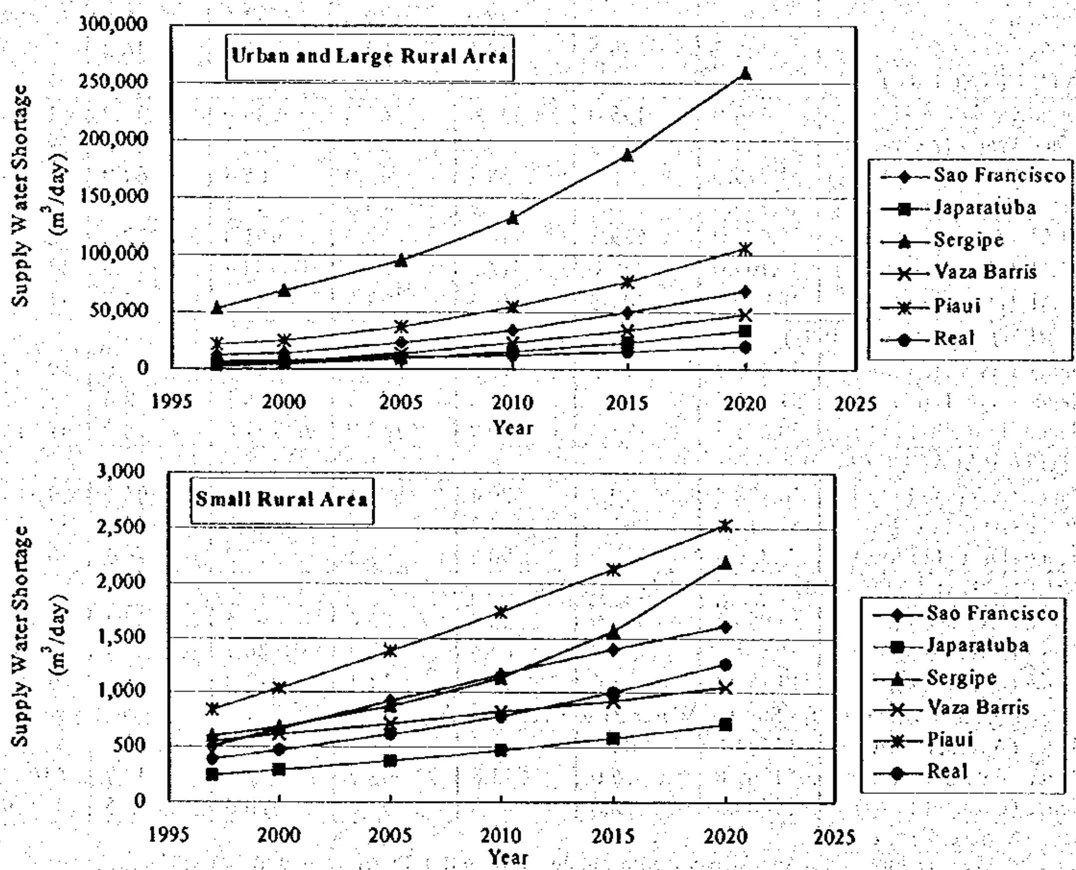


Figure-4.1 Supply Water Shortage by River Basins

Table-4.6 Water Demand and Shortage in Sergipe State

Year	1997	1998	2000	2005	2010	2015	2020
Water Demand (m³/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 (m³/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 (m³/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 (m³/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

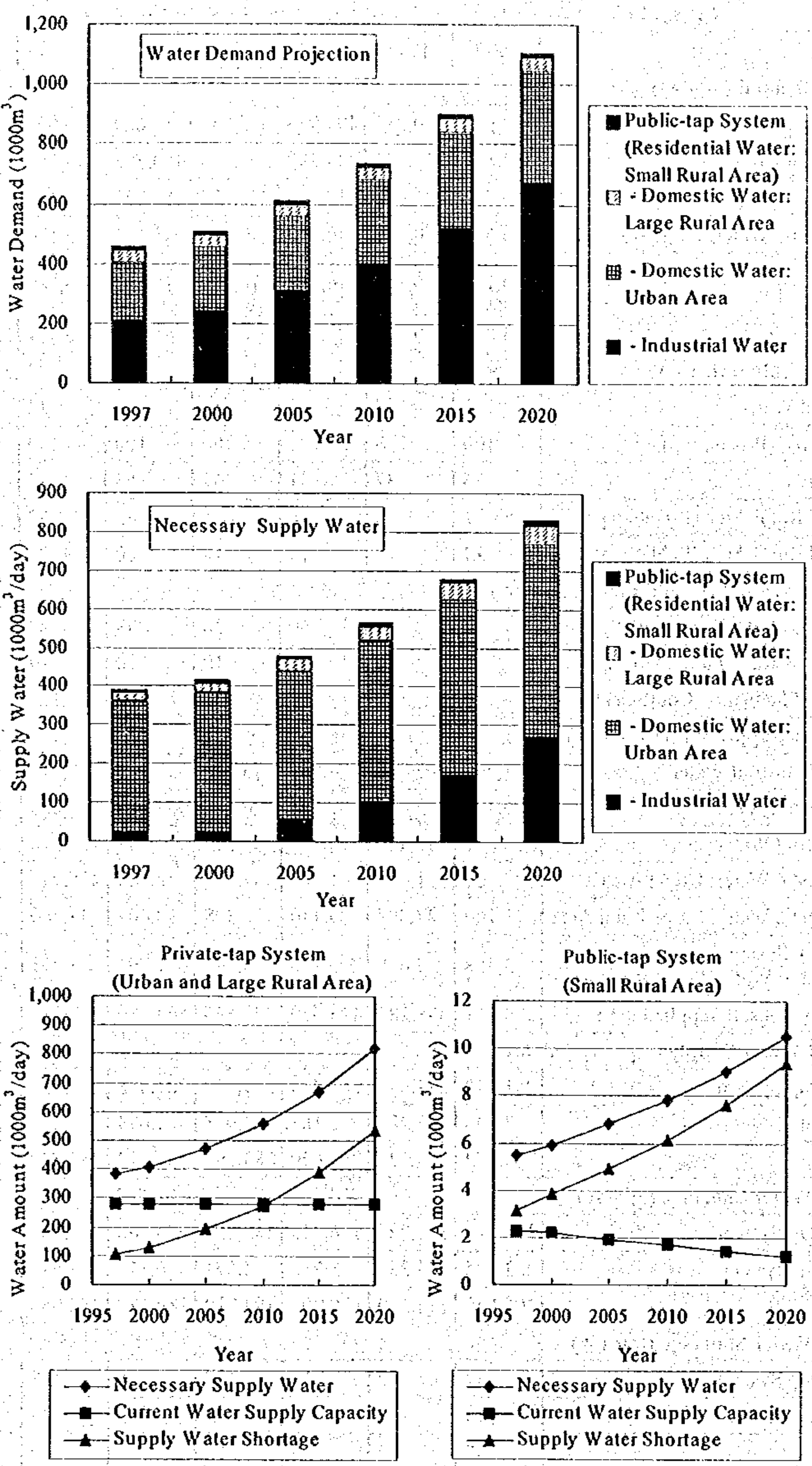


Figure-4.2 Water Demand and Shortage in Sergipe State

Table-4.7 (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 (m³/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 (m³/day)	6,773	7,964	11,620	15,725	20,240	24,418
	Necessary Supply Water (m³/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 (m³/day)	28,472	28,472	28,472	28,472	28,472	28,472
	Supply Water Shortage (m³/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 (m³/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 (m³/day)	15,791	18,569	23,324	28,660	35,239	42,891
	Necessary Supply Water (m³/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 (m³/day)	14,312	14,312	14,312	14,312	14,312	14,312
	Supply Water Shortage (m³/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 (m³/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 (m³/day)	129,772	152,601	183,363	218,398	258,066	302,250
	Necessary Supply Water (m³/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 (m³/day)	180,272	180,272	180,272	180,272	180,272	180,272
	Supply Water Shortage (m³/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 (m³/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 (m³/day)	17,458	20,529	25,602	31,280	38,204	46,204
	Necessary Supply Water (m³/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 (m³/day)	23,744	23,744	23,744	23,744	23,744	23,744
	Supply Water Shortage (m³/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 (m³/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 (m³/day)	20,789	24,446	30,902	38,006	45,167	52,327
	Necessary Supply Water (m³/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 (m³/day)	24,752	24,752	24,752	24,752	24,752	24,752
	Supply Water Shortage (m³/day)	22,447	24,651	37,530	54,185	76,741	106,577
	Supply Water Shortage Rate (%)	91	100	152	219	310	431

Table-4.7 (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 (m³/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 (m³/day)	679	798	900	999	1,060	1,068
	Necessary Supply Water (m³/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 (m³/day)	9,888	9,888	9,888	9,888	9,888	9,888
	Supply Water Shortage (m³/day)	6,648	8,028	10,315	12,981	16,156	19,972
	Supply Water Shortage Rate (%)	67	81	104	131	163	202

Table-4.8 Supply Water Shortage for Public-tap System by River Basin

River	Year	1997	2000	2005	2010	2015	2020
Sao Francisco River Basin	Water Demand (m³/day)	2,332	2,255	2,147	2,060	1,992	1,941
	Necessary Supply Water (m³/day)	866	1,010	1,231	1,432	1,619	1,797
	Current Water Supply Capacity (m³/day)	369	345	305	265	225	185
	Supply Water Shortage (m³/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 (m³/day)	754	757	768	788	821	873
	Necessary Supply Water (m³/day)	415	451	516	592	685	809
	Current Water Supply Capacity (m³/day)	177	165	146	127	108	89
	Supply Water Shortage (m³/day)	238	285	370	465	578	720
	Supply Water Shortage Rate (%)	134	173	253	366	536	814
Sergipe River Basin	Water Demand (m³/day)	1,702	1,724	1,806	1,958	2,209	2,600
	Necessary Supply Water (m³/day)	1,047	1,104	1,242	1,463	1,822	2,408
	Current Water Supply Capacity (m³/day)	448	418	370	321	272	224
	Supply Water Shortage (m³/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 (m³/day)	1,326	1,325	1,327	1,334	1,345	1,361
	Necessary Supply Water (m³/day)	974	1,004	1,058	1,118	1,185	1,260
	Current Water Supply Capacity (m³/day)	417	389	344	299	254	208
	Supply Water Shortage (m³/day)	558	615	714	819	931	1,051
	Supply Water Shortage Rate (%)	134	158	208	274	367	505
Piaui River Basin	Water Demand (m³/day)	2,819	2,838	2,878	2,929	2,992	3,069
	Necessary Supply Water (m³/day)	1,473	1,627	1,897	2,188	2,501	2,842
	Current Water Supply Capacity (m³/day)	626	585	517	449	381	313
	Supply Water Shortage (m³/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 (m³/day)	1,210	1,233	1,281	1,343	1,421	1,518
	Necessary Supply Water (m³/day)	684	740	854	998	1,179	1,405
	Current Water Supply Capacity (m³/day)	297	277	245	213	181	148
	Supply Water Shortage (m³/day)	387	462	609	785	998	1,257
	Supply Water Shortage Rate (%)	131	167	248	369	553	848
Sergipe State	Water Demand (m³/day)	10,143	10,132	10,206	10,411	10,780	11,362
	Necessary Supply Water (m³/day)	5,458	5,936	6,798	7,791	8,991	10,520
	Current Water Supply Capacity (m³/day)	2,333	2,181	1,928	1,674	1,420	1,167
	Supply Water Shortage (m³/day)	3,125	3,755	4,871	6,117	7,571	9,353
	Supply Water Shortage Rate (%)	134	172	253	365	533	802

(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-4.9 Irrigation Water Demand by River Basin

River Basin	Existing Project		Planned Project		Total
	Irrigation Project	Irrigation Water (m^3/day)	Irrigation Project	Irrigation Water (m^3/day)	Irrigation Water (m^3/day)
Sergipe State (Total)	-	1,043,310	-	1,850,838	2,894,148
São Francisco River	- California	81,600	- Quixabeira	254,394	
	- Propria	99,627	- Jacare-Curituba	263,607	
	- Cotinguiba	129,327	- São 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) Private Industrial Water

The industrial water not supplied by public water supply system, namely private industrial water, is recommend to be developed by groundwater. According to the analysis, 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.

4.4 Independent Water Supply for Urban and Large Rural Area

4.4.1 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-4.11.

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-4.10.

4.4.2 Plan of Independent Water Supply

The 35 municipalities to be planned are shown in Table-4.10, which describes water shortage, source water developed amount, beneficiaries, etc. by municipalities/systems. In general, the nearer the water resource, the economical 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-4.12 and graphically shown in Figure-4.3. Development water amount at water source is set 1.2 times of supply water shortage for seasonal fluctuation

Table-4.10 Water Supply Plan for Independent Water Supply System in 2020

Municipalities	Present Capacity (m^3/day)	Total (m^3/day)	Shortage (m^3/day)	Develop. Amount (m^3/day)	Municipalities	Present Capacity (m^3/day)	Total (m^3/day)	Shortage (m^3/day)	Develop. Amount (m^3/day)
Total	**65,019**	**223,370**	**158,351**	**190,035**	Sao Francisco	427	801	373	448
Gararu (Urban and Half Large Rural)	485	994	510	612	Carmopolis	2,981	3,872	891	1,070
Muribeca	864	1,329	465	558	General Maynard	262	650	388	466
N. S. das Dores	1,905	5,207	3,302	3,963	Maruim	2,015	5,005	2,990	3,588
Malhador	1,038	2,415	1,377	1,653	Riachuelo	883	8,648	7,765	9,318
Tobias Barreto	4,570	12,297	7,727	9,273	Rosario do Catete	880	18,411	17,531	21,038
Brejo Grande	724	1,447	722	867	S. Amaro das Brotas	1,061	1,868	807	968
Ilha das Flores	872	1,661	788	946	Barra dos Coqueiros	2,243	8,520	6,277	7,533
Neopolis	1,850	18,766	16,916	20,300	*Sao Cristovao*	15,832	20,430	4,599	5,519
S. do Sao Francisco	707	4,548	3,841	4,610	Araua	697	2,377	1,680	2,016
Capela	3,389	10,083	6,694	8,033	Boquim	2,800	5,730	2,929	3,515
Divina Pastora	320	799	479	575	Cristianopolis	1,064	3,721	2,656	3,188
Santa Rosa de Lima	428	734	306	368	Pedrinhas	689	2,337	1,647	1,977
Siriri	988	1,595	607	729	Salgado	1,245	4,151	2,906	3,488
Japaratuba	1,819	4,613	2,794	3,353	*Estancia*	6,280	30,038	23,758	28,510
Japoata	1,057	1,529	471	566	Indiaroba	844	1,949	1,105	1,326
Pacatuba	629	4,928	4,298	5,158	Itaporanga D'Ajuda	1,773	26,413	24,640	29,568
Pirambu	940	3,105	2,165	2,598	S. Luzia do Itanhy	455	2,402	1,947	2,337

Note: Italics show the municipalities of which water supply systems is being managed by FNS.
The remainders are managed by DESO.

Table-4.11 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 (m³/day)		Supply Shortage in 2020 (m³/day)	Potable Water Quality	River	Intake Potential Rank	Yield per Well (m³/day)	Success Rate of Yield (%)	Fresh Water Rate (%)	Water Potential Rank	Other Development
01-0120	Caninde do Sao Francisco	Independent	S.F.R.	1,552	18,454	Good	S.F.R.	A	40	50	15	D	Xingo Dam Pipeline
01-0220	Fora Nova	Integrated	Sertaneja Pipeline	629	1,891	Good	S.F.R.	A	40	60	15	D	
01-0240	Gararu	Independent	S.F.R.	648	645	Good	S.F.R.	A	35	60	15	D	-
01-0260	Gracho Cardoso	Integrated	Sertaneja Pipeline	561	416	Good	S.F.R.	A	40	60	15	D	
01-0310	Itabi	Integrated	Sertaneja Pipeline	755	387	Good	S.F.R.	A	40	60	15	D	
01-0420	Monte Alegre de Sergipe	Integrated	Alto Sertao Pipeline	1,515	2,507	Good	S.F.R.	A	40	60	15	D	
01-0450	Nossa Senhora da Gloria	Integrated	Sertaneja Pipeline	3,040	13,473	Good	S.F.R.	A	40	60	15	D	
01-0540	Poco Redondo	Integrated	Alto Sertao Pipeline	2,330	1,806	Good	S.F.R.	A	40	45	10	D	
01-0560	Porto da Folha	Integrated	Alto Sertao Pipeline	2,801	1,190	Good	S.F.R.	A	40	50	10	D	
02-0140	Carira	Integrated	Sertaneja Pipeline	1,706	3,033	Good	S.F.R.	A	50	60	20	D	
02-0230	Frei Paulo	Integrated	Sertaneja Pipeline	1,439	3,031	Good	S.F.R.	A	75	75	33	C	
02-0445	Nossa Senhora Aparecida	Integrated	Sertaneja Pipeline	732	831	Good	S.F.R.	A	60	70	25	D	
02-0500	Pedra Mole	Integrated	Sertaneja Pipeline	325	186	Good	S.F.R.	A	80	75	40	C	
02-0520	Pinhao	Integrated	Sertaneja Pipeline	529	797	Good	S.F.R.	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, 11 km from Frei Paulo
03-0020	Aquidaba	Integrated	Sertaneja Pipeline	2,537	2,202	Good	S.F.R.	A	40	60	15	D	
03-0190	Cumbe	Integrated	Sertaneja Pipeline	672	287	Good	S.F.R.	A	40	60	15	D	
03-0380	Malhada dos Bois	Integrated	Sao Francisco Pipeline	263	800	Good	S.F.R.	A	60	65	25	D	
03-0430	Muribeca	Independent	Well	864	465	Good	Japaratuba-Miriam R/JR	B	90	65	40	C	Sao Francisco Pipeline, 2.5 km from Pipe
03-0460	Nossa Senhora das Dores	Independent	Siriri R/JR	1,905	3,302	Good JR	Siriri R/JR, Pintor R/JR	A	50	65	25	D	-
03-0700	Sao Miguel do Aleixo	Integrated	Sertaneja Pipeline	252	226	Good	S.F.R.	A	65	70	30	D	
04-0050	Areia Branca	Integrated	Itabaiana Pipeline	1,094	11,462	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, 11 km from Ribeiropolis
04-0680	Sao 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	Caboclo R/PR	Unknown	60	75	55	C	
06-0580	Riachao do Dantas	Integrated	Piauitinga Pipeline	825	2,315	-	-	-	45	75	40	D	
07-0010	Amparo de Sao Francisco	Integrated	Sertaneja Pipeline	315	126	Good	S.F.R.	A	40	60	15	D	
07-0070	Brejo Grande	Independent	Well	724	722	Unknown	S.F.R.	A	600	95	100	A	
07-0110	Canhoba	Integrated	Sertaneja Pipeline	704	0	Good	S.F.R.	A	40	60	15	D	
07-0160	Cedro de Sao Joao	Integrated	Propria Pipeline	844	155	Good	S.F.R.	A	65	65	25	D	
07-0270	Ilha das Flores	Independent	S.F.R.	872	788	Good	S.F.R.	A	600	95	100	A	
07-0440	Neopolis	Independent	S.F.R.	1,850	16,916	Good	S.F.R.	A	250	80	85	A-B	
07-0470	Nossa Senhora de Lourdes	Integrated	Sertaneja Pipeline	742	1,050	Good	S.F.R.	A	40	60	15	D	
07-0570	Propri	Integrated	Propria Pipeline	4,908	5,097	Good	S.F.R.	A	300	75	65	A-B	
07-0730	Telha	Integrated	Propria Pipeline	447	107	Good	S.F.R.	A	45	60	15	D	
07-0999	Santana do Sao Francisco	Independent	Well	707	3,841	Good	S.F.R.	A	180	80	85	A-B	
08-0130	*Capela*	Independent	*Lagartixo R/JR*	*3,339*	*6,694*	*Good*	*Siriri R/JR, Alvira R/JR*	*A*	*50*	*60*	*20*	*D*	
08-0200	Divina Pastora	Independent	Well/Spring	320	479	Good	Gramarba 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	*Sriri*	Independent	*Siriri R/JR*	*988*	*607*	*Good*	*Siriri R/JR*	*B*	*175*	*80*	*80*	*A-B*	
09-0330	Japaratuba	Independent	Well/Spring	1,819	2,794	Good	JR, J-Miriam 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	
09-0490	Pacatuba	Independent	Well	629	4,298	Good	Santo Antonio R/ Betume R/SFR	A	405	90	90	A	
09-0530	Pirambu	Independent	Well	940	2,165	Bad	JR	A	385	85	90	A	
09-0690	Sao Francisco	Independent	Well/Spring	427	373	Good	Sapo R/SFR	D	140	75	70	A-B	
10-0150	*Carmopolis*	Independent	*Diego R/JR Well Spring*	*2,951*	*891*	*Good*	*JR, Riachao R/JR*	*B*	*295*	*80*	*85*	*A*	
10-0250	General Maynard	Independent	Well	262	388	*Good*	*JR, Riachao*	*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, 5 km from Pipe
10-0400	Maruim	Independent	Well	2,015	2,990	Good	Gramarba R/SR	B	195	75	70	A-B	
10-0590	Riachuelo	Independent	Jacarecica R/SR	883	7,765	Good	Jacarecica R/SR	A	180	75	65	A-B	
10-0610	Rosario do Catete	Independent	Well	880	17,531	Good	Siriri R/JR	A	260	80	75	A-B	
10-0660	Santo Amaro das Brotas	Independent	Well	1,061	807	-	-	-	395	85	90	A	
11-0030	Aracaju	Integrated	Sao Francisco Pipeline	124,677	73,601	Good	S.F.R.	A	440	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	S.F.R.	A	285	80	80	A-B	
11-0670	*Sao Cristovao*	Independent	*Tributaries VR*	*13,832*	*4,579*	*Good*	*Tributaries VR*	*C*	*215*	*80*	*85*	*A*	
12-0040	Araua	Independent	Araua R/PR	697	1,680	Feasible, Good	Camboata R/ Araua R/ PR	C	50	80	50	C	
12-0063	Boquim	Independent	Piaui R.	2,800	2,929	Feasible, Good	Quiongui 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	6,735	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	80	70	B	
12-0620	Salgado	Independent	Spring/Well	1,245	2,906	Good	Grilo 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	*Piaui R.*	*6,290*	*23,755*	*Good*	*Piauitinga R/ PR*	*A*	*70*	*80*	*85*	*B*	
13-0280	Indiaroba	Independent	Piripe R/RR	844	1,105	Good	Piripe R/ RR	A	70	80	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, 21 km from Dam
13-0630	Santa Luzia do Itanhy	Independent	Well	455	1,947	Good	Guararema R/PR	B	70	80	85	B	

Table-4.12 (1/2) Water Resources Development Plan for Independent Water Supply System

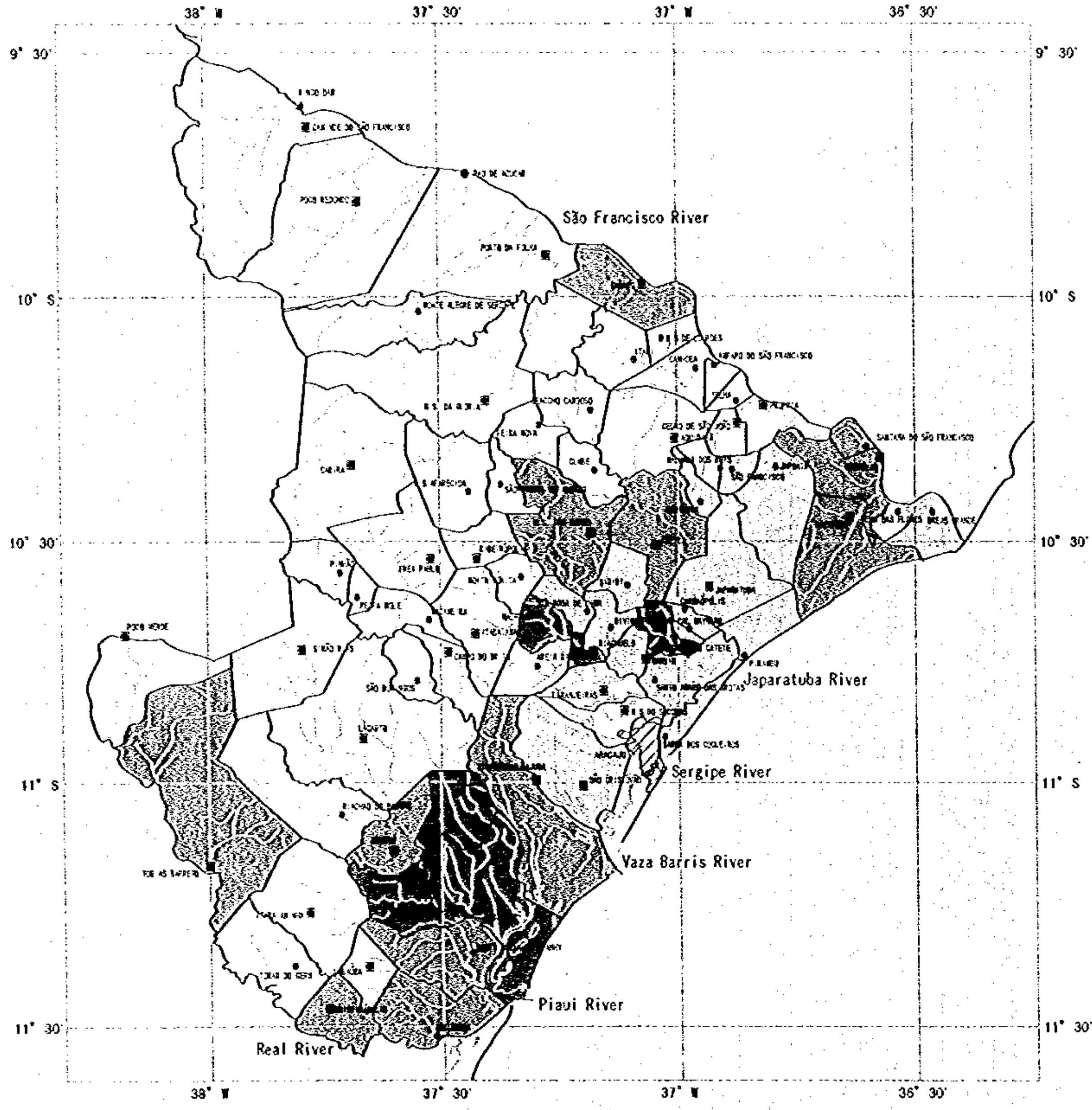
Municipality / System	Source	Surface Water Development							Groundwater Development			
		Weir and Intake					Pump and Pipeline		Deep Well and Pump			
	Water Shortage (m^3/day)	River Name	Catch-ment Area (km^2)	Q(7,10) (m^3/day/km^2)	Potential Developed Discharge (m^3/day)	Developed Discharge (m^3/day)	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 RiverRR: Real River
( ) shows intake in the upstream of the site.

Table-4.12 (2/2) Water Resources Development Plan for Independent Water Supply System

Municipality / System	Source	Surface Water Development							Groundwater Development			
		Weir and Intake					Pump and Pipeline		Deep Well and Pump			
	Water Shortage (m^3/day)	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 D'Ajuda	29,568	Tejupeba R./ VR	35	260	7,280	7,280	10	60 [10-70]	-	-	-	-
		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 RiverRR: Real River
( ) shows intake in the upstream of the site.



Legend

Independent Water Supply System

: Surface Water Development

: Groundwater Development

: Surface and Groundwater Development

Integrated Water Supply System

: Area

Figure-4.3 Water Resources Development Plan for Independent Water Supply System

4.4.3 Design of Independent Water Supply System

(1) Design Concept

(a) Independent Surface Water Supply Systems

The components included in the Surface Water Supply Systems are as follows:

- Dam or weir where required
- Intake and Raw Water Pump Station, RWPS
- Pipelines (From Raw water intake to water treatment station)
- Water treatment station, WTS, composed of chemical house, filters, auxiliary water storage tank, AT, elevated water storage tank, ET, and treated water pumps, TWP
- Distribution pipeline and network

Conceptual sketch of the system is as shown in Figure-4.4.

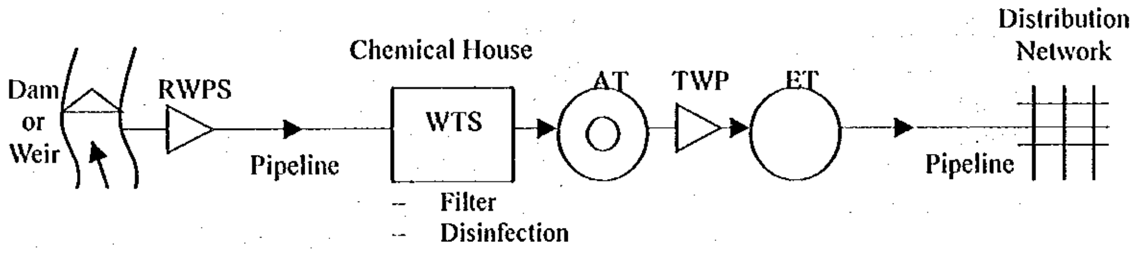


Figure-4.4 Conceptual Sketch of Integrated Surface Water Supply System

(b) Independent Groundwater Supply Systems

< Components Included >

The components included in the Groundwater Supply Systems are as follows:

- Wells
- Raw Water Pump, RWP
- Pipelines (From Raw water pump to water treatment station)
- Water treatment station, WTS, composed of disinfections unit, DIU, auxiliary water storage tank, AT, elevated water storage tank, ET, and treated water pumps, TWP
- Distribution pipeline and network

Conceptual sketch of the system is as shown in Figure-4.5.

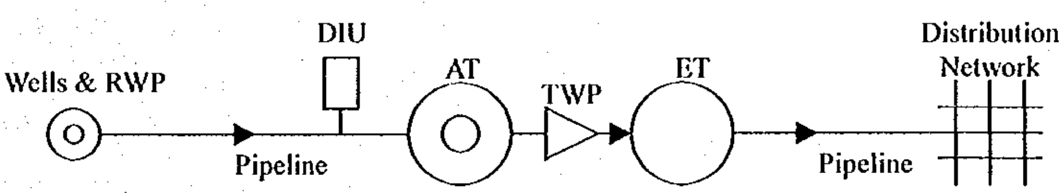


Figure-4.5 Conceptual Sketch of Integrated Groundwater Supply System

< Design Conditions >

Design conditions are summarized as follows:

- Depth of well to be 100 m
- Number of drilling to be the required number of wells divided by expected success rate and fresh rate of groundwater
- Desalination unit not to be provided even if water in the drilled well contains high salinity. Additional drilling to be performed until to find acceptable well.

(2) Jabiberi Dam Raising Project for the Municipality of Tobias Barreto

Jabiberi Dam was constructed in 1986 as a concrete gravity dam for the purpose of irrigation water supply. The main specifications are shown as follows:

– Catchment Area:	118km^2
– Development Discharge:	0.2 m^3/s
– Dam Height:	21.5m
– Dam Length:	290m
– Reservoir Volume:	4,300,000m^3
– Reservoir Area:	605,000m^2

To meet the future source water shortage (9,273 m^3/day) toward the year 2,020 for the municipality of Tobias Barreto, Jabiberi Dam Raising Project is proposed. Raise in 3 m of dam height can develop 1.8 million m^3 of additional reservoir volume, providing approximately 10,000 m^3/day of water supply during 6 months of drought period in each year. General profile of raise of dam height is shown in Figure-4.6.

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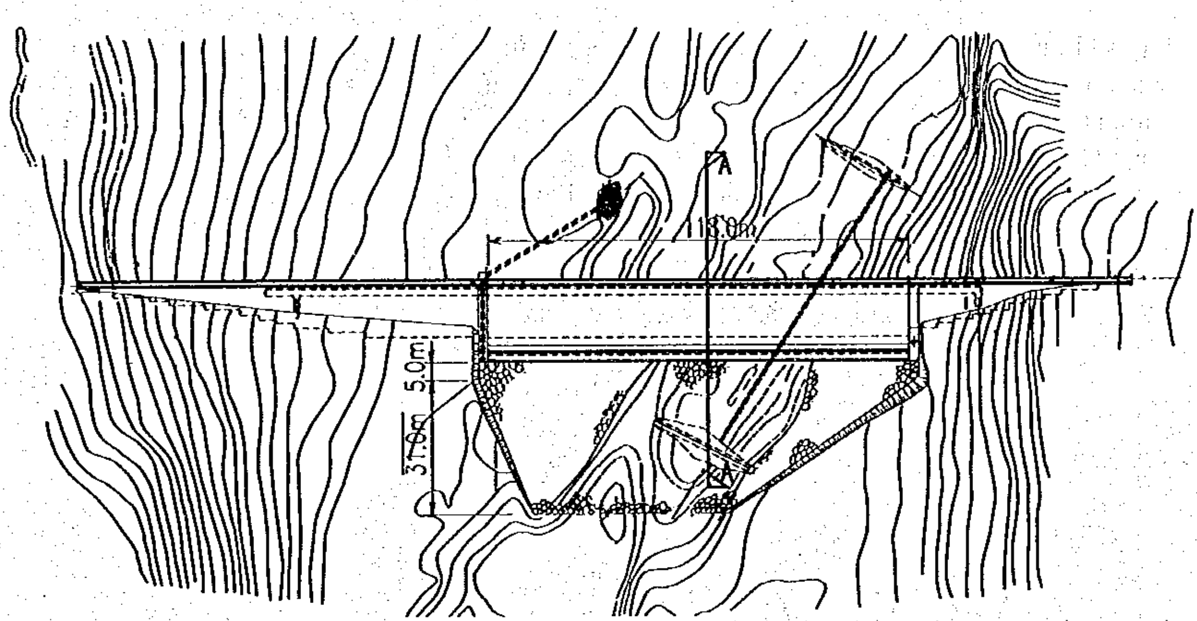

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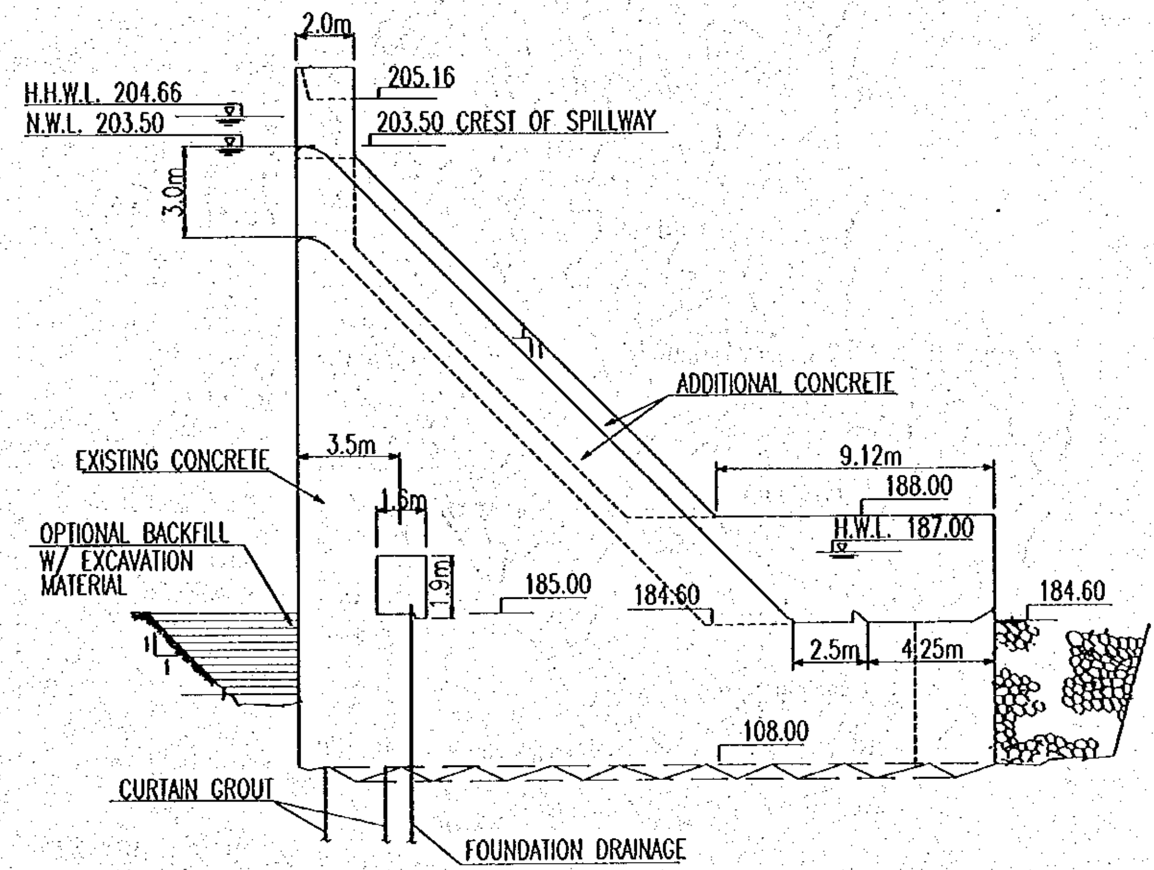


Figure-4.6 General Profile of Jabiberi Dam Raising

4.5 Integrated Water Supply for Urban and Large Rural Area

4.5.1 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-4.13 and Figure-4.7. 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.

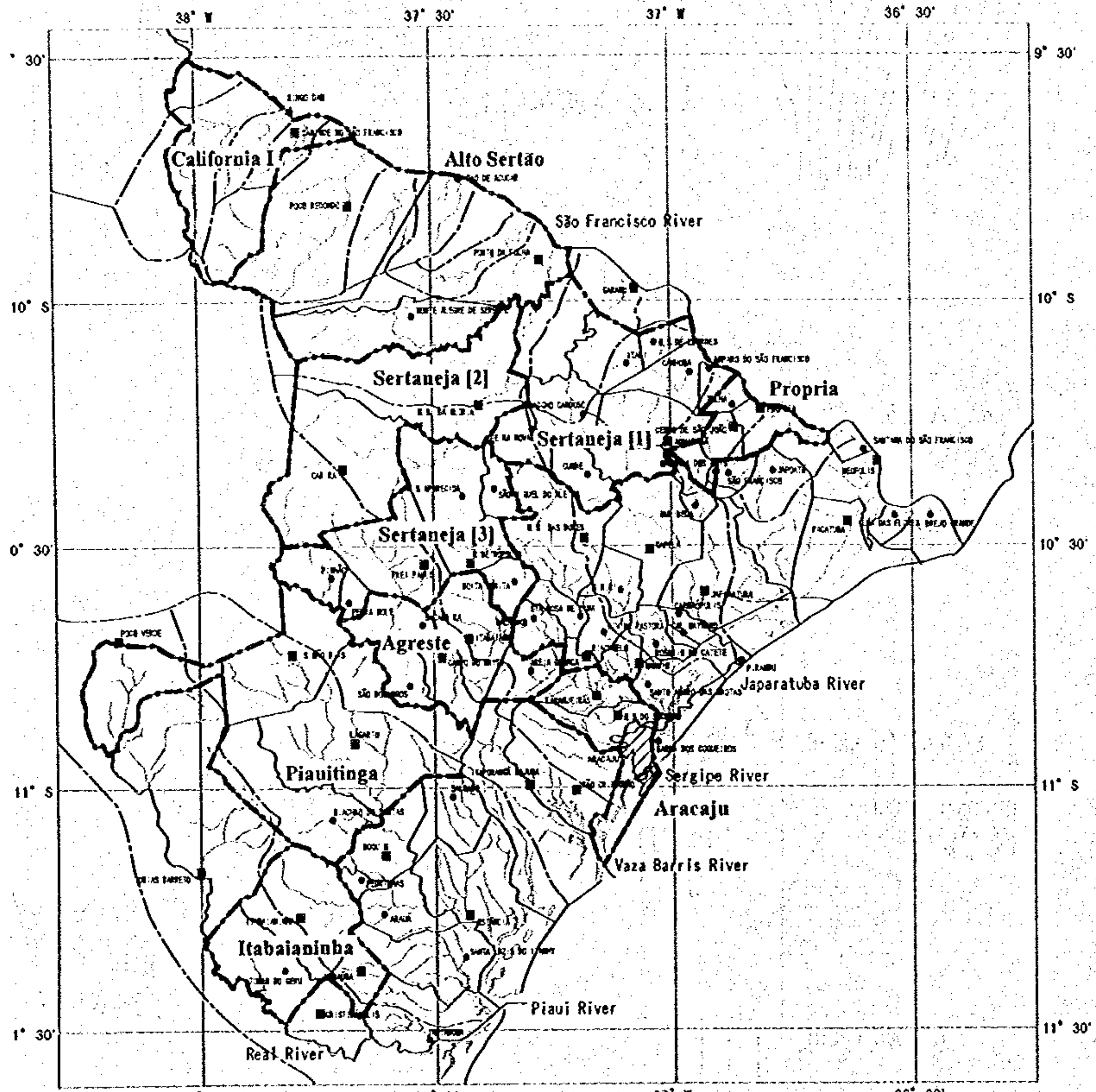


Figure-4.7 Block Division of Integrated Water Supply Area

Table-4.13 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
Piaultinga 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
		Ribeirapolis	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.

4.5.2 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-4.14 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-4.14 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
				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

* ( ) 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 Canindc 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 Canindc 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/sec 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-4.16 and Figure-4.8. Required development water by cases and projects are described in Table-4.15.

Table-4.15 Required Development Water by Cases and Projects

Unit: 1,000m^3/day

Case / Project	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-4.16 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 m^3/day	- *Project Expansion of Sao Francisco Pipeline System (151,600)* - Aracaju Well Development Project (23,292)					
Agreste	61,476 m^3/day	- *Project Expansion (22,200)* - Xingo Dam Pipeline Project (39,276)					
Piauitinga	67,534 m^3/day	- *Project Expansion (30,200)* - Xingo Dam Pipeline Project (37,334)			- *Project Expansion (30,200)* - Vaza Barris Dam Project (37,334)		
Itabaianinha	13,321 m^3/day	- Project Expansion (13,321)					
Propria	6,189 m^3/day	- Project Expansion (6,189)					
Alto Sertao	5,495 m^3/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 m^3/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 m^3/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 m^3/day						
California I	18,484 m^3/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 m^3/day	***- Project Expansion of Sao Francisco Pipeline System (151,600)*** **- Well Development Project (23,292)**			
Agreste	61,476 m^3/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 m^3/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 m^3/day	**- Project Expansion (13,321)**			
Propria	6,189 m^3/day	**- Project Expansion (6,189)**			
Alto Sertao	5,495 m^3/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 m^3/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 m^3/day		**- Xingo Dam Pipeline Project (25,515)**	- Xingo Dam Pipeline Project (25,515)	
Sertaneja [3]	9,010 m^3/day				
California I	18,484 m^3/day	**- Xingo Dam Pipeline Project (18,484)**			

Note: ( ) shows water supply amount in m^3/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].

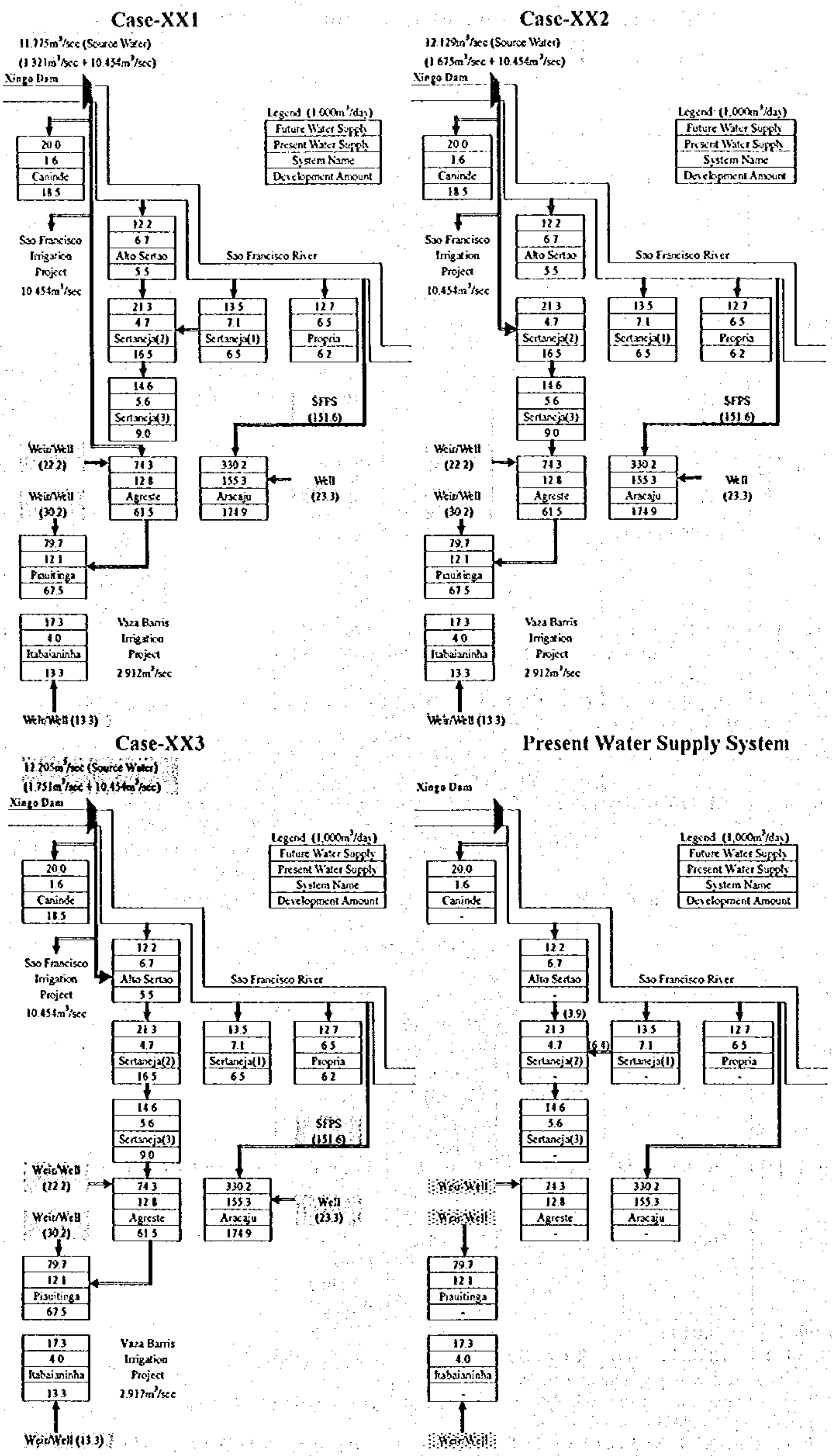
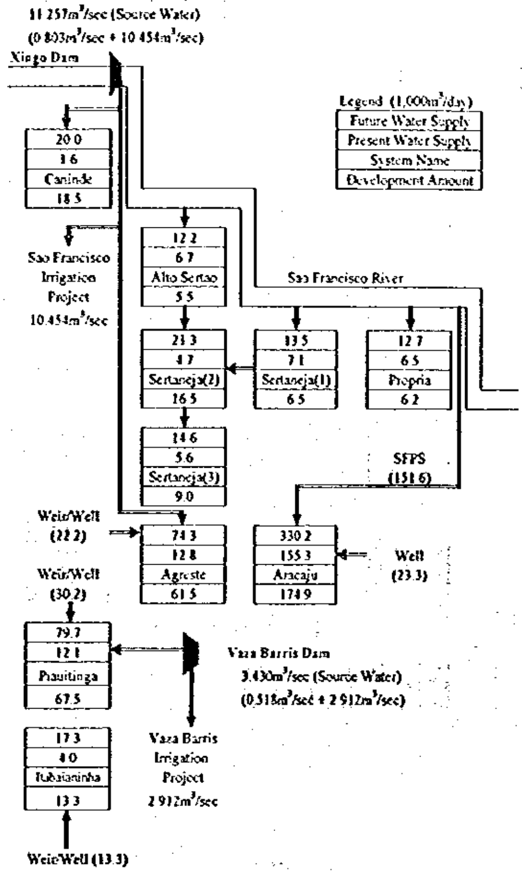
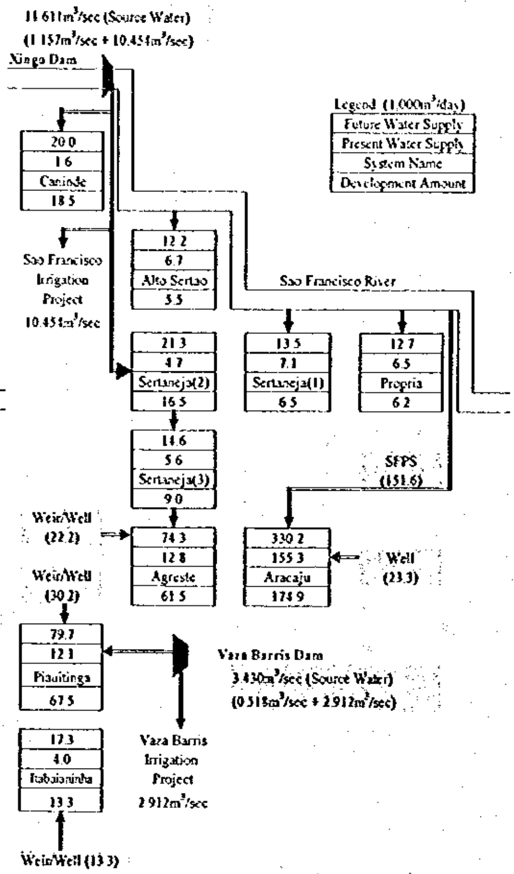


Figure-4.8 (1/3) Alternative Plans for Integrated Water Supply

Case-XV1



Case XV-2



Case-XV3

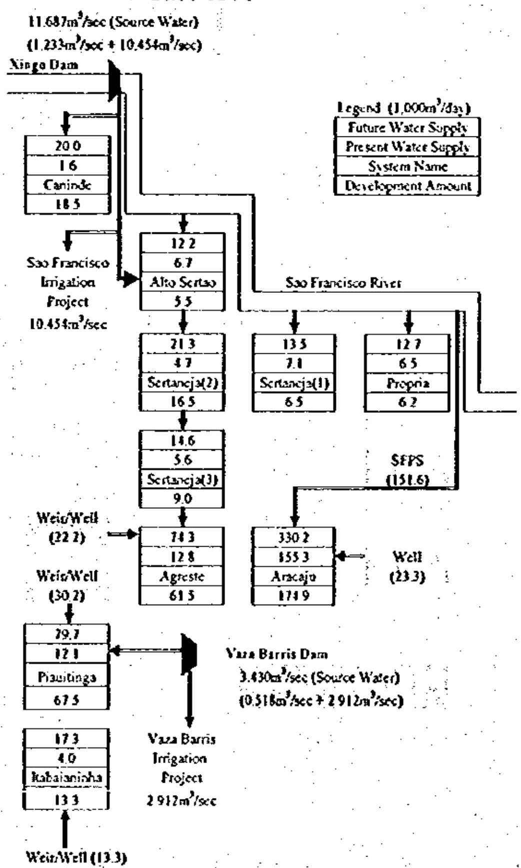


Figure-4.8 (2/3) Alternative Plans for Integrated Water Supply

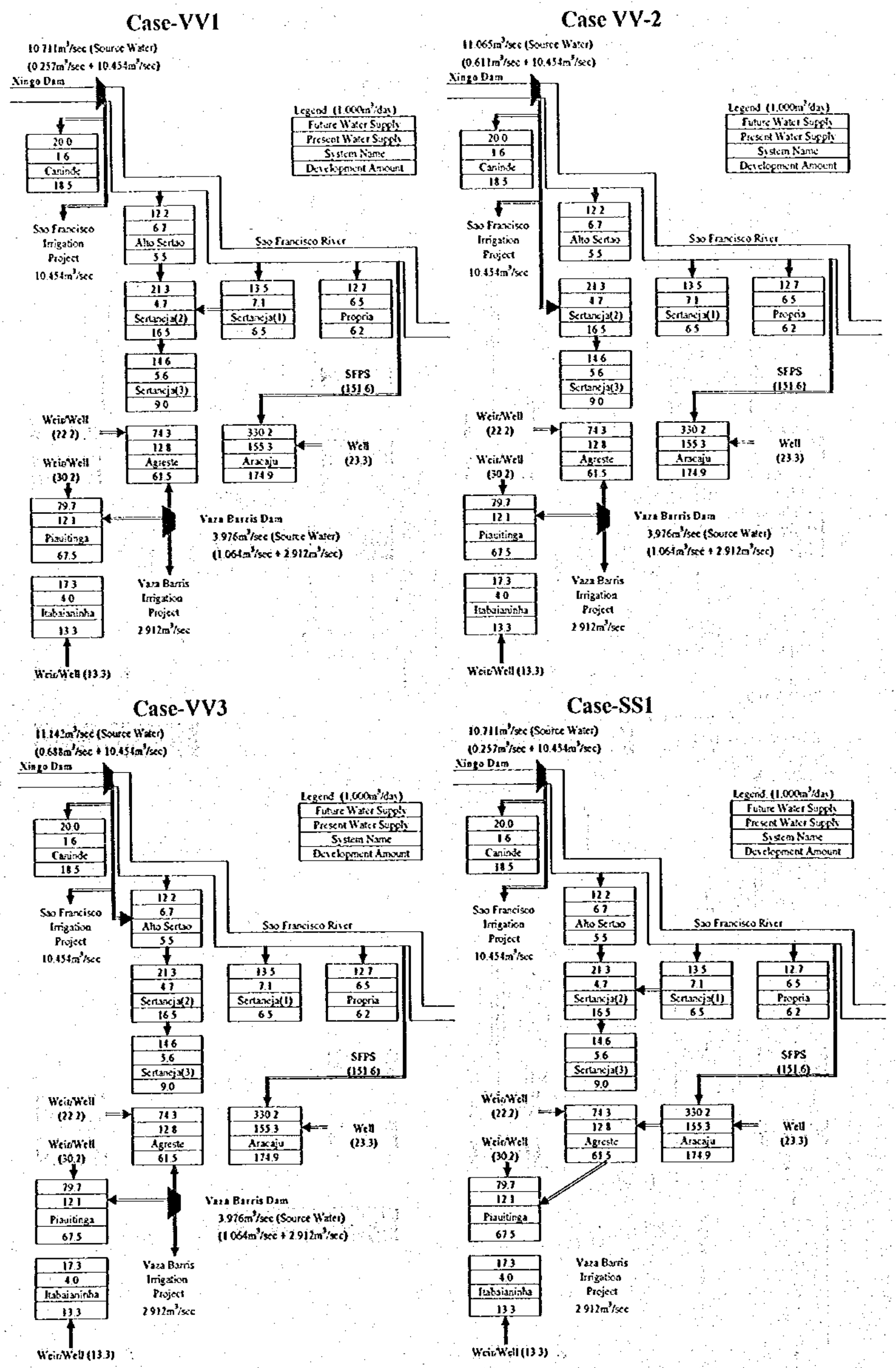


Figure-4.8 (3/3) Alternative Plans for Integrated Water Supply

(2) Selection of Optimum Plans

(a) Selection Method

Optimum plan is selected by evaluating each alternative plan based on the results of design and cost estimation of component projects. The concept of Annual Expense is introduced for economical evaluation of alternative plans.

(b) Definition of Annual Expense

Annual expense is defined as the expense expected annually, after completion of construction of integrated water supply system and during operational period. It consists of the follows;

< Expense for Reimbursement, Aec >

- expense for reimbursement of loans for construction of the system
- depreciation of constructed facilities in the system

< Expense for Operation and Maintenance of the System, Aco >

- expenses for operation and maintenance of the facilities in the system, including expenses for personnel, consumable materials, electricity and other expenses required for operation and maintenance of the system

(c) Basic Cost Parameters

The basic cost parameters required for evaluation of annual expense for the water supply systems are as follows;

< Construction Cost for Dam, Cd (R$) >

C_d is made up of the construction cost of dam, spillway, check dam, low flow diversion channel and other auxiliary facilities.

< Construction Cost of Pipeline, Cpl (R$) >

C_{pl} can be given by multiplication of unit cost for construction of pipeline per linear meter(R$/m) and length of pipeline (m).

< Construction Cost of Pump Stations >

This cost can be divided into the construction cost for civil works, C_{pfc} (R$) and for electrical and mechanical works, C_{pfe} (R$).

< Construction Cost of Common Projects and Other Required Facility >

The construction cost for additional water treatment facility, water storage facility and water distribution facility are not considered in evaluation of the alternative plans, because these costs are nothing to do with the route of proposed pipelines and are the same for every alternative project. Land acquisition cost is also disregarded because depreciation of land is not necessary to be counted.

The following enlargement or improvement projects are common in all alternative plans and are not covered in this evaluation because the enlargement or expansion of each system involved can be done within its system and does not affect the costs of proposed alternative projects.

- Enlargement Project of Propria Pipeline System
- Enlargement Project of Itabaianinha Pipeline System
- Jabiberi Dam Raising Project near Tobias Barreto
- Independent Water Resources Development Project in Leste Sergipano
- Water Resources Development Plan for Small Rural Area
- Irrigation Water Supply Projects

< Interest And Depreciation Rate of Constructed Facility >

The following items are the rates of interest and depreciation considered in this evaluation:

- Interest for loan, r: 0.025
- Depreciation rate

1)	for civil works,	m_1	dam	: 0.0125 (80 years)
		m_2	RC structures	: 0.0250 (40 years)
		m_3	steel pipeline	: 0.0667 (15 years)
2)	for electrical and mechanical works,	m_4	pump facility	: 0.0667 (15 years)

< Cost for Electricity, fe (US$/kWh) >

Operation cost of pump facility is evaluated as cost for energy consumption of pump, and unit cost of electricity is given as 0.0499 R$/kWh determined from the data presented by ENERGIPE.

< Unit Cost For Operation And Maintenance, fo (R$/m³) >

Unit cost for operation and maintenance, except for electricity and depreciation, is given by the following expression obtained by analysis of O & M cost presented by DESO:

$$f_o = 9{,}075.74 \times e^{2.08655E\text{-}05Q} \times \text{R\$ } 1.18/\text{US\$}$$

where, Q : Daily production capacity of pump station (m^3/day).

(d) Annual Expense

< Annual expense Aec >

$$AEc = AEc_d + AEc_{pfc} + AEc_{pl} + AEc_{pfe}$$
$$AEc_d = C_d \times (r + m1)$$
$$AEc_{pfc} = C_{pfc} \times (r + m2)$$
$$AEc_{pl} = C_{pl} \times (r + m3)$$
$$AEc_{pfe} = C_{pfe} \times (r + m4)$$

< Annual expense Aeo >

$$AEo = AEoe + AEoo$$
$$AEoe = fe \times P \times 24 \times 365$$
$$AEoo = fo \times Q \times 365$$

where, P : Power of pump units (kW).

(e) Construction Cost of Dam

< Facilities Included >

The dam includes dam body, spillway, check dam, low flow diversion channel and other auxiliary facilities.

- Dam : Rock fill dam.
- Spillway : Free overflow reinforced concrete open channel. To be constructed apart from dam body. Design flood discharge to be 1,600m^3/s.
- Check dam : Concrete dam. To be constructed for regulation of water level at water inflow for low flow diversion channel. To be located 30km upstream of main dam.
- Low flow diversion channel : Open channel of inverted-trapezoidal section with concrete lining. To be constructed for prevention of high salinity river flow go into the reservoir. To be constructed on river terrace.

< Development Discharge, Dam Specification and Construction Cost >

Among all alternative plans, construction of dam is included in the Cases-XV1, XV2, XV3, VV1, VV2 and VV3. Development discharge and dam specification for each case is shown in Table-4.17.

Construction costs and allocated costs are also shown in Table-4.17. The construction cost of multi-purpose dam for water supply and irrigation purposes can be allocated in proportion to the following dam construction cost;

- Construction cost of dam developed solely for water supply purpose
- Construction cost of dam developed solely for irrigation purpose

Cost allocation of construction of dam for irrigation and domestic water supply is taken as 51% for irrigation and 49% for domestic water supply for Cases-XV1 to XV3 and as 50% for each water supply for Cases-VV1 to VV3.

Table-4.17 Development Discharge and Dam Specification

Case		Unit	Case XV1-3	Case VV1-3	Single Purpose		
					Water Supply		Irrigation
					Case A	Case B	
Development Discharge	Domestic	m^3/s	0.518	1.064	0.518	1.064	-
	Irrigation	m^3/s	2.912	2.912	-	-	2.912
	Total	m^3/s	3.430	3.976	0.518	1.064	2.912
Dam Specification	N.W.L.	EL.m	47.6	49.4	43.0	45.6	45.8
	Crest Elevation	EL.m	54.0	56.0	49.0	52.0	52.0
	Dam Height	m	34.0	36.0	29.0	32.0	32.0
	Reservoir. Area	km^2	15.0	16.0	12.4	14.0	14.0
	Dam Material Volume	$x10^3m^3$	533	633	331	445	445
Construction Cost	Dam Body	M.R$	12.18	16.63	6.30	8.26	8.26
	Spillway	M.R$	35.55	35.55	35.55	35.55	35.55
	Low Flow Diver. Channel	M.R$	6.51	6.51	6.51	6.51	6.51
	Check Dam	M.R$	2.21	2.21	2.21	2.21	2.21
	Land Acquisition	M.R$	1.06	1.13	0.87	0.99	0.99
	Total	M.R$	57.51	62.03	51.45	53.52	53.52
Cost Allocation	For water supply system	M.R$	28.19	31.02	51.45	53.52	0.00
	For irrigation system	M.R$	29.32	31.02	0.00	0.00	53.52

Note:
1) N.W.L.: Normal Water Level
2) Cases-XX1, XX2 and XX3 is for water supply to Vaza Barris Irrigation Project only.
3) Cases-XV1, XV2 and XV3 is for domestic water supply to Lagarto only and for irrigation water supply to Vaza Barris Project.
4) Cases-VV1, VV2 and VV3 is for domestic water supply to Itabaiana and Lagarto in addition to irrigation water supply to Vaza Barris Project.
5) Ratio of allocation of dam construction cost for water supply and irrigation for Cases XV1 to XV3 is given by the ratio of dam construction cost for single purpose of water supply in Case A and dam construction cost for single purpose of irrigation..
6) Ratio of allocation of dam construction cost for water supply and irrigation for Cases VV1 to VV3 is given by the ratio of dam construction cost for single purpose of water supply in Case B and dam construction cost for single purpose of irrigation..

(f) Conditions for Design and Cost Estimation of Water Supply Pipelines

The following conditions are applied to the economic evaluation of water supply system;

1) The total water demand and supply for each water supply block is concentrated at the center of each block and distribution of water from the center of block to any other place of consumption in the block is neglected.
2) Full capacity of existing water supply facility is used for current water supply. Additional water supply facility shall be provided for additional supply of water in any blocks of consumption.
3) A segment of pipelines is composed of single continuous pipe with single diameter, starting from a water intake point or a center of block to another center of block. Material of pipe is steel. Most economical diameter for each segment is selected based on the results of annual expenses for different diameters in 10cm pitch.
4) Water intake points and centers of blocks are shown in Figure-4.9 later.
5) Flow volume, Q (m^3/s), to be transported through a segment of pipeline is determined by the volume of demand in future minus current water supply capacity.
6) One pump station for one segment of pipeline.
7) Actual suction head and friction head loss, hf, are considered for calculation of total head loss, H, and other miscellaneous head losses are neglected.
8) Construction cost of a pump station is proportional to the potential of pump.
9) Potential of pump, P (kW)
   Potential of pump can be obtained with flow volume and total head.
   Friction head loss can be calculated by Hazen･Williams formula.

(g) Description of Alternative Projects

1) Case-XX1
   - The pipeline from Xingo dam, WIP1, led directly to Agreste and went to Piauitinga
   - The pipeline from Porto da Folha, WIP2, to Alto Sertao along the existing Alto Sertao pipeline
   - The pipeline from Amparo do Sao Francisco, WIP3, to Sertaneja[3] via Sertaneja[1] and Sertaneja[2] along the existing Sertaneja pipeline.

2) Case-XX2
   - The pipeline from Xingo dam, WIP1, led directly to Sertaneja[2] and went to Piauitinga
   - The pipeline from Porto da Folha, WIP2, to Alto Sertao along the existing Alto Sertao pipeline

3) Case-XX3
   - The pipeline from WIP1 led Poco Profundo to Piauitinga via Alto Sertao, Sertaneja[2], Sertaneja[3] and Agreste along the existing pipelines.

4) Case-XV1

- The pipeline from WIP1 led directly to Agreste
- The pipeline from WIP2 to Alto Sertao along the existing Alto Sertao pipeline
- The pipeline from WIP3 to Sertaneja3 via Sertaneja1 and Sertaneja[2] along the existing Sertaneja pipeline.
- The pipeline from Vaza Barris Dam, WIP5, to Piauitinga.

5) Case-XV2

- The pipeline from WIP1 led directly to Sertaneja[2] and went to Agreste via Sertaneja[3] along the existing pipelines.
- The pipeline from WIP2 to Alto Sertao along the existing Alto Sertao pipeline
- The pipeline from WIP5 to Piauitinga.

6) Case-XV3

- The pipeline from WIP1 led Poco Profundo to Agreste via Alto Sertao, Sertaneja[2] and Sertaneja[3] along the existing pipelines.
- The pipeline from WIP5 to Piauitinga.

7) Case-VV1

- The pipeline from WIP2 to Alto Sertao along the existing Alto Sertao pipeline
- The pipeline from WIP3 to Sertaneja3 via Sertaneja1 and Sertaneja[2] along the existing Sertaneja pipeline.
- The pipeline from WIP5 to Agreste.
- The pipeline from WIP5 to Piauitinga.

8) Case-VV2

- The pipeline from WIP1 led directly to Sertaneja[2] and went to Sertaneja[3].
- The pipeline from WIP2 to Alto Sertao along the existing Alto Sertao pipeline
- The pipeline from WIP5 to Agreste.
- The pipeline from WIP5 to Piauitinga.

9) Case-VV3

- The pipeline from WIP1 led to Sertaneja3 via Poco Profundo, Alto Sertao and Sertaneja[2].
- The pipeline from WIP5 to Agreste.
- The pipeline from WIP5 to Piauitinga.

10) Case-SS1

- The pipeline from WIP2 to Alto Sertao along the existing Alto Sertao pipeline
- The pipeline from WIP3 to Sertaneja[3] via Sertaneja1 and Sertaneja[2] along the existing Sertaneja pipeline.
- The pipeline from Propria, WIP4, to Piauitinga via Aracaju and Agreste along the existing Sao Francisco Pipeline.

(h) Results of calculation of annual expenses for each alternative plan

Calculation results of annual expense for each alternative project are summarized in Table-4.18 and follows:

1) Construction costs and annual expenses for alternative plans with dam, Cases-XV1, XV2, XV3, VV1, VV2 and VV3 are lower than those for alternative plans without dam, Cases-XX1, XX2, XX3 and SS1. This result means that the cost for water transportation from any places of Sao Francisco River down to Itabaiana and Lagarto is quite high compared with the cost for water development in the vicinity of Itabaiana and Lagarto. It suggests that, in the economical point of view, the water development in central and south eastern regions in Sergipe State shall be conducted in their respective river basin.
2) In case of long distance water transportation by pipeline from Xingo dam to Itabaiana and Lagarto, annual expense for Case-XX1 is lower than those for Cases-XX2 and XX3. This is because the pipelines in Cases-XX2 and XX3 pass through the existing water supply facilities located in high land cities and villages.
3) In comparison of Cases-VV1, VV2 and VV3, water transportation from Xingo dam to Frei Paulo, the center of block of Sertaneja3, without passing through the existing high land water supply facilities, is lower than from Amparo do Sao Francisco to Frei Paulo along the existing pipeline route. The pipeline route from Xingo dam is advantageous for water transportation to Frei Paulo
4) Comparison of the results of Cases-XV1, XV2, XV3, VV1, VV2 and VV3 shows that if Vaza Barris Dam is constructed, the water to Itabaiana shall be supplied from the Vaza Barris Dam as well and not from Sao Francisco River.

Table-4.18 Summary of Construction Cost and Annual Expense for Alternative Plans

Unit : Million R$

Alternative Plan	Construction Cost					Annual Expense		
	Dam	Pipeline	Civil Works	Equipm't	Total	AEc	AEo	Total
XX1	0.0	129.8	4.1	15.9	149.9	13.6	5.9	19.5
XX2	0.0	135.5	4.1	16.5	156.1	14.1	8.8	22.9
XX3	0.0	138.1	5.2	21.5	164.7	14.9	12.1	27.0
XV1	28.8	97.8	3.2	12.3	142.1	11.3	4.7	16.0
XV2	28.8	96.5	2.8	11.2	139.4	11.1	4.8	15.9
XV3	28.8	97.9	3.5	14.2	144.4	11.5	6.0	17.5
VV1	31.6	45.5	3.1	11.7	91.9	6.6	4.3	10.9
VV2	31.6	51.9	2.6	10.3	96.4	7.0	3.7	10.7
VV3	31.6	61.4	2.5	10.3	105.7	7.9	4.0	11.9
SS1	0.0	137.2	4.4	17.0	158.6	10.6	6.2	16.8

(i) Conclusion of Evaluation of Alternative Plans

It is concluded that the alternative plan VV2 is most economical than any other projects in their annual expense basis, and then it was adopted as the integrated water supply plan.

The project plan adopted (alternative plan VV2) is shown in Figure-4.9.