CHAPTER 5 FUTURE SOCIO-ECONOMIC FRAMEWORK

5.1 Population

5.1.1 Population Projection per River Basin

A population projection for the years of 2000, 2005 and 2015 with separated figures for urban and rural areas, was provided by IPARDES as a preliminary population projection per River Basin (shown in Table-5.1). According to this projection, population of Paraná State in 2005 will reach 8,350,200 of urban inhabitants, 1,558,700 of rural inhabitants performing a total of 9,908,900 inhabitants. For the year of 2015, urban population, rural population and total population were estimated at 9,969,300, 1,161,100 and 11,130,400 people, respectively.

It means that:

- Urban population will increase in approximately 3,500,000 inhabitants from now to 2015. In other words, there will be an increase of urban area larger than approximately two times the area equivalent to the present urban area of Curitiba.
- Approximately one million inhabitants will migrate from rural areas to urban areas from now until the year of 2015.

In terms of projected population per river basin, Iguaçu river basin, Tibagi river basin and Ivaí river basin will occupy approximately 40%, 15% and 12% of the total population in 2015, respectively.

5.1.2 Population Projection per MRH

In addition to the results of the census of 1970, 1980 and 1991, projected population per MRH for 1993, 1995 and 2000 was provided by IPARDES as preliminary projection. The population projection for the target years 2005 and 2015 per MRH was made by JICA Team based on the results of the census of 1970, 1980 and 1991 and on IPARDES' projection for the years of 1995 and 2000.

Estimated population (urban, rural and total) per MRH in the years of 1993, 2005 and 2015 is shown in Table-5.2. The results of graphic works for population projection per MRH (urban, rural and total) and the average annual growth rate per MRH (urban, rural and total) for the periods of 1970-1980, 1980-1991, 1991-2005 and 2005-2015 are shown in Section-1.2.1 of the Sectoral Report Vol. A.

According to the estimated population by JICA Team, the urban population in MRH 268/Curitiba will reach approximately 3,113,000 inhabitants and will share about 31% of the total urban population of the State in 2015. This means that Curitiba region will have an increase of more than one million inhabitants in urban area from 1993 to 2015.

In terms of urban population of the other four large MRH (MRH 273/Campos de Ponta Grossa, MRH 281/N.N. Londrina, MRH 282/N.N. Maringá and MRH 288/Extr. Oeste Parananese (Cascavel, Foz do Iguaçu, etc.)) will increase not only in figures but also in share. The urban population of these four large MRH is estimated in approximately 3,608,000 inhabitants, sharing 36% of the urban population of Paraná State in 2015.

Table-5.1 Projected Population in Paraná State per River Basins in the years 2000,2005 and 2015

		2000						2005						2015					
No.	Name of Basin	Urban Population	%	Rural Population	%	Total Population	%	Urban Population	%	Rural Population	%	Total Population	%	Urban Population	%	Rural Population	%	Total Population	%
1	Cinzas	197,966	2.63	83,541	4.63	281,507	3.02	218,417	2.62	69,003	4.43	287,420	2.9	259,287	2.6	49,093	4.23	308,380	2.77
2	Iguaçu	3,043,306	40.44	654,514	36.24	3,697,820	39.63	3,367,428	40.33	601,351	38.58	3,968,779	40.05	4,009,226	40.22	475,112	40.92	4,484,338	40.29
3	Itararé	100,705	1.34	31,211	1.73	131,916	1.41	120,433	1.44	26,064	1.67	146,497	1.48	154,165	1.55	18,764	1.62	172,929	1.55
4	Ivai	869,286	11.55	315,440	17.47	1,184,726	12.7	948,009	11.35	257,638	16.53	1,205,647	12.17	1,112,099	11.16	181,034	15.59	1,293,133	11.62
5	Litorânea	167,275	2.22	42,123	2.33	209,398	2.24	182,859	2.19	41,064	2.63	223,923	2.26	215,038	2.16	34,097	2.94	249,135	2.24
6	Paraná 1	7,202	0.1	7,092	0.39	14,294	0.15	7,666	0.09	5,674	0.36	13,340	0.13	8,763	0.09	3,894	0.34	12,657	0.11
7	Paraná 2	18,728	0.25	21,675	1.2	40,403	0.43	19,858	0.24	16,402	1.05	36,260	0.37	22,606	0.23	10,500	0.9	33,106	0.3
8	Paraná 3	615,212	8.17	81,405	4.51	696,617	7.47	720,267	8.63	63,457	4.07	783,724	7.91	904,871	9.08	42,204	3.63	947,075	8.51
9	Paranapanema 1	77,878	1.03	12,717	0.7	90,595	0.97	82,141	0.98	10,330	0.66	92,471	0.93	92,971	0.93	7,214	0.62	100,185	0.9
10	Paranapanema 2	17,841	0.24	4,485	0.25	22,326	0.24	19,108	0.23	3,777	0.24	22,885	0.23	21,991	0.22	2,744	0.24	24,735	0.22
11	Paranapanema 3	157,497	2.09	23,438	1.3	180,935	1.94	168,129	2.01	17,426	1.12	185,555	1.87	192,820	1.93	10,893	0.94	203,713	1.83
12	Paranapanema 4	64,165	0.85	17,315	0.96	81,480	0.87	67,388	0.81	12,712	0.82	80,100	0.81	75,909	0.76	7,806	0.67	83,715	0.75
13	Piquiri	478,263	6.36	215,634	11.94	693,897	7.44	517,018	6.19	175,686	11.27	692,704	6.99	600,973	6.03	123,106	10.6	724,079	6.51
14	Pirapó	439,909	5.85	34,784	1.93	474,693	5.09	503,395	6.03	26,586	1.71	529,981	5.35	619,252	6.21	17,246	1.49	636,498	5.72
15	Ribeira	71,731	0.95	82,412	4.56	154,143	1.65	90,117	1.08	76,687	4.92	166,804	1.68	120,159	1.21	61,266	5.28	181,425	1.63
16	Tibagi	1,198,609	15.93	178,155	9.86	1,376,764	14.75	1,317,932	15.78	154,838	9.93	1,472,770	14.86	1,559,141	15.64	116,144	10.00	1,675,285	15.05
	TOTAL	7,525,573	100.00	1,805,941	100.00	9,331,514	100.00	8,350,165	100.00	1,558,695	100.00	9,908,860	100.00	9,969,271	100.00	1,161,117	100.00	11,130,388	100.00

Source: Projeção da População do Paraná Segundo as Bacias Hidrográficas do Estado para os anos de 2005 e 2015 (Projection of the Population of Paraná According to the River Basins of the State for the years 2005 and 2015)-IPARDES

Table-5.2 Projected Population in Paraná State per MRH-1993, 2005 and 2015

	1993						2005						2015					
No of the MRH/Name of Region	Urban	%	Rural	%	Total	%	Urban	%	Rural	%	Total	%	Urban	%	Rural	%	Total	%
01. MRH 268/CURITIBA	1,949,779	30.33	126,226	5.88	2,076,005	24.21	2,582,200	30.92	113,700	7.29	2,695,900	27.21	3,112,700	31.22	96,700	8.33	3,209,400	28.83
02. MRH 269/L. PARANAENSE	145,826	2.27	33,639	1.57	179,465	2.09	180,500	2.16	32,700	2.10	213,200	2.15	210,000	2.11	30,100	2.59	240,100	2.16
03. MRH 270/ALTO RIBEIRA	5,478	0.09	24,430	1.14	29,908	0.35	7,300	0.09	21,600	1.39	28,900	0.29	8,800	0.09	18,400	1.58	27,200	0.24
04. MRH 271/A. RIO NEGRO	6,350	0.10	33,468	1.56	39,818	0.46	9,100	0.11	36,200	2.32	45,300	0.46	11,200	0.11	36,100	3.11	47,300	0.42
05. MRH 272/ C. LAPA	60,616	0.94	46,044	2.15	106,660	1.24	73,600	0.88	46,400	2.98	120,000	1.21	84,800	0.85	44,100	3.80	128,900	1.16
06. MRH 273/C.PONTA GROSSA	349,228	5.43	65,327	3.04	414,555	4.84	441,200	5.28	55,400	3.55	496,600	5.01	519,800	5.21	44,800	3.86	564,600	5.07
07. MRH 274/C.JAGUARIAIVA	43,660	0.68	20,975	0.98	64,635	0.75	69,300	0.83	15,600	1.00	84,900	0.86	87,400	0.88	10,700	0.92	98,100	0.88
08. MRH 275/S. MAT. do SUL	20,122	0.31	34,552	1.61	54,674	0.64	26,300	0.31	35,000	2.25	61,300	0.62	31,500	0.32	33,100	2.85	64,600	0.58
09. MRH 276/Col. IRATI	71,821	1.12	103,597	4.83	175,418	2.05	90,400	1.08	103,300	6.63	193,700	1.95	105,900	1.06	97,300	8.38	203,200	1.83
10. MRH 277/ALTO IVAI	23,934	0.37	72,182	3.36	96,116	1.12	32,600	0.39	59,500	3.82	92,100	0.93	39,700	0.40	46,600	4.01	86,300	0.78
11. MRH 278/N. V. WENCESLAU BRAZ	96,440	1.50	71,394	3.33	167,834	1.96	123,300	1.48	45,000	2.89	168,300	1.70	145,700	1.46	28,900	2.49	174,600	1.57
12. MRH 279/N. V. JACAREZINHO	220,756	3.43	86,480	4.03	307,236	3.58	262,100	3.14	50,900	3.27	313,000	3.16	298,200	2.99	30,600	2.64	328,800	2.95
13. MRH 280/Alg. ASSAI	49,386	0.77	28,412	1.32	77,798	0.91	60,200	0.72	15,900	1.02	76,100	0.77	69,500	0.70	9,200	0.79	78,700	0.71
14. MRH 281/N. N. LONDRINA	738,500	11.49	94,994	4.43	833,494	9.72	935,700	11.21	48,600	3.12	984,300	9.93	1,103,700	11.07	26,000	2.24	1,129,700	10.15
15. MRH 282/N. N. MARINGA	404,731	6.30	35,651	1.66	440,382	5.14	548,500	6.57	16,800	1.08	565,300	5.70	664,200	6.66	8,400	0.72	672,600	6.04
16. MRH 283/N. Novis. PARANAVAI	205,603	3.20	65,124	3.03	270,727	3.16	240,200	2.88	35,000	2.25	275,200	2.78	271,500	2.72	19,500	1.68	291,000	2.61
17. MRH 284/N. N. APUCARANA	214,052	3.33	104,770	4.88	318,822	3.72	257,900	3.09	53,900	3.46	311,800	3.15	297,300	2.98	29,200	2.51	326,500	2.93
18. MRH 285/N. Novis. UMUARAMA	260,680	4.06	137,751	6.42	398,431	4.65	312,000	3.74	68,500	4.39	380,500	3.84	357,800	3.59	35,900	3.09	393,700	3.54
19. MRH 286/C. MOURAO	241,901	3.76	132,508	6.18	374,409	4.37	310,400	3.72	72,000	4.62	382,400	3.86	368,600	3.70	40,600	3.50	409,200	3.68
20. MRH 287/PITANGA	33,770	0.53	91,821	4.28	125,591	1.46	50,600	0.61	79,400	5.09	130,000	1.31	63,400	0.64	65,900	5.68	129,300	1.16
21. MRH 288/Extr. Oeste PARANAENSE	765,866	11.91	264,671	12.33	1,030,537	12.02	1,069,000	12.80	160,800	10.32	1,229,800	12.41	1,320,500	13.25	100,300	8.64	1,420,800	12.77
22. MRH 289/Sudoeste PARANAENSE	235,122	3.66	238,203	11.10	473,325	5.52	305,400	3.66	162,100	10.40	467,500	4.72	366,300	3.67	93,500	8.05	459,800	4.13
23. MRH 290/ C. GUARAPUAVA	179,566	2.79	157,625	7.35	337,191	3.93	230,700	2.76	159,500	10.23	390,200	3.94	276,000	2.77	152,100	13.10	428,100	3.85
24. MRH 291/ MEDIO IGUACU	105,048	1.63	75,963	3.54	181,011	2.11	131,700	1.58	70,900	4.55	202,600	2.04	154,800	1.55	63,100	5.43	217,900	1.96
TOTAL OF PARANA STATE	6,428,235	100.00	2,145,807	100.00	8,574,042	100.00	8,350,200	100.00	1,558,700	100.00	9,908,900	100.00	9,969,300	100.00	1,161,100	100.00	11,130,400	100.00

Source: Population of 1993 is Preliminary Projection by IPARDES

Remark: Population of 2005 and 2015 was projected by JICA Team

5.2 Gross Domestic Product (GDP)

5.2.1 GDP of Paraná State

Based on the GDP's past tendency during the years of 1980 to 1991, provided by IPARDES, GDP of Paraná State for the years of 1993, 2005 and 2015 was estimated by JICA Team as 27,111 million US$, 49,945 million US$ and 81,354 million US$, respectively, with growth rate of 5 %/year.

5.2.2 GDP of Paraná State per Sector

GDP of Paraná per Sector: Primary Sector/Agriculture, Livestock and Fishery, Second Sector/Industry and Tertiary Sector/Commerce and Services, in 1993, was estimated by JICA Team based on the percentage of participation of each Sector in the total value added of Paraná State, provided by SEFA and IPARDES - *Municipalities' Participation Fund-Preliminary Indexes-95 (Fundo de Participação dos Municípios-Índices Preliminares-95-SEFA)*. GDP of Paraná per Sector for the target year, for the Primary Sector, Secondary Sector and Tertiary Sector was estimated as shown in Table-5.3, with growth rate of approximately 2.00%/year, 5.35%/year and 5.25%/year, respectively. However, it should be noted that the participation of the service sector in the Tertiary Sector was considered, for each year, the same portion of the year of 1989 (37.71% of the total value added of Paraná State) because there was not available data.

Table-5.3 Estimated GDP-Paraná by Sector - 1993, 2005 and 2015

Year	Primary Sector		Secondary Sector		Tertiary Sector		GDP - Paraná	
	Million US$	%	Million US$	%	Million US$	%	Million US$	%
1993	3,149	11.32	9,295	33.42	15,367	55.26	27,811	100.00
2005	3,831	7.67	17,446	34.93	28,668	57.40	49,945	100.00
2015	4,874	5.99	29,110	35.78	47,370	58.23	81,354	100.00

Source : Fundo de Participação dos Municípios-Índices Provisórios/95 (Municipalities' Participation Fund-Preliminary Indexes/95)-SEFA
Remark : Values in US$ were estimated by JICA Team

5.2.3 Gross Regional Domestic Product (GRDP) per MRH

GRDP per MRH in 1993 was estimated by using the same method mentioned above, and GRDP per MRH in 2005 and 2015 was estimated based on the past trend of the GRDP of each MRH from 1980 to 1993.

According to this estimation, there are some remarkable points, as follows:

- GRDP of MRH 268/Curitiba will increase from approximately 10,540.00 million US$ to 34,330.00 million US$ until the target year of 2015 (more than three times the value of 1993) and will share almost 42% of GDP-Paraná.
- GRDP of the other four large MRH (MRH 273/Campos de Ponta Grossa, MRH 281/N.N. Londrina, MRH 282/N.N. Maringá and MRH 288/Extr. Oeste Paranaense (Cascavel, Foz do Iguaçu, etc.)) will increase approximately 185% and will account for 32% of GDP-Paraná in 2015.

However, it should be noted that:

1) the contribution, as energy production, of Hydroelectric Power Stations was calculated as value added of the Secondary Sector to GDP-Paraná and to GRDP of some MRH that have municipalities influenced by this contribution, from 1989 on;

2) estimation of GRDP per MRH based on the past trend and estimation of the expansion planning of the Electric Sector should be considered separately, and

3) Therefore, GDP-Paraná and GDP-Paraná by Sector were estimated including this contribution, but GRDP per MRH, GRDP of Secondary Sector per MRH and GRDP per Capita per MRH (mentioned in next section) were estimated excluding this contribution.

This estimated GRDP per MRH is shown in Table-5.9.

5.2.4 GRDP by Sector per MRH

GRDP by Sector (Primary and Secondary) per MRH in 1993 was estimated in the same manner mentioned before, and the GRDP by Sector per MRH in 2005 and 2015 was also estimated by using the same method of GRDP per MRH, while the Tertiary Sector per MRH could not be estimated because data concerning the participation of the service sector per MRH, which composes the Tertiary Sector together with the commercial sector, was not available. Estimated GRDP by Sector (Primary and Secondary) are shown in Table-5.10.

5.2.5 GDP per Capita and GRDP per Capita

Based on the estimated population (shown in Table-5.2) and the estimated GDP-Paraná (shown in Table-5.4), GDP per Capita of Paraná State in 1993, 2005 and 2015 was estimated in about 3,200 US$, 5,000 US$ and 7,300 US$, respectively. In terms of GRDP per Capita per MRH, it can be seen that there is a great difference, in terms of regional productivity, between developed regions such as MRH 268/Curitiba and undeveloped regions such as MRH 272/Alto Ivaí and MRH 287/Pitanga and that this difference will decrease in percentage (from approximately 1,200% to 900%) increasing ,however, in value added (from about 4,500 US$ to 9,500 US$).

Estimated GDP per Capita of Paraná State and estimated GRDP per Capita per MRH are also shown in Table-5.9.

5.2.6 Future Socio-Economic Framework

From a general point of view, in 2015:

- approximately ten million people will live in urban areas and only one million people will live in rural areas;
- Primary Sector, Secondary Sector and Tertiary Sector will share approximately 6%, 36% and 58% of GDP-Paraná, respectively;
- GDP-Paraná will increase in about 200% and GDP per Capita in Paraná will increase in approximately 125%.

The future socio-economic structure of Paraná State can be estimated by classifying the 24 MRH into four categories in terms of urban population, GRDP and GRDP per Capita, and future socio-economic framework for the four categories in 2005 and 2015 can be drawn as shown in Table-5.4 and Table-5.5, respectively.

However, it should be noted that 1) the number of municipalities that compose each MRH varies considerably. For example, MRH 273/Campos de Ponta Grossa is composed only of five municipalities, while MRH 288/Extr. Oeste Paranaense is composed of 49 municipalities, 2) the land area, the number of medium urban centers and the degree of concentration of population in urban areas, for example, are also variable for each MRH.

Table-5.4 Socio-Economic Framework of Paraná State in 2005

Classification	No. and Name of MRH	Urban Population		GRDP		GRDP per Capita
		Population	%	million US$	%	US$
1st	MRH 268/Curitiba	2,582,200	30.90	20,210.00	42.50	7,500.00
2nd	MRH 273/C. Ponta Grossa	441,200	5.30	2,870.00	6.00	5,780.00
	MRH 281/N.N. Londrina	935,700	11.20	3,860.00	8.10	3,920.00
	MRH 282/N.N. Maringá	548,500	6.60	2,930.00	6.20	5,180.00
	MRH 288/Extr. Oeste Paranaense	1,069,000	12.80	5,710.00	12.00	5,130.00
	Subtotal/Average	2,994,400	35.90	15,370.00	32.30	4,690.00
3rd	MRH 279/284/285/286/289/290	1,678,500	20.10	7,300.00	15.30	3,250.00
4th	MRH 269/270/271/272/274/ 275/276/277/278/280/ 283/287/291	1,095,100	13.10	4,710.00	9.90	2,780.00
TOTAL of MRH / Average		8,350,200	100.00	47,590.00	100.00	4,800.00

Remark: Total population per 1st, 2nd, 3rd and 4th Categories are 2,695,900, 3,276,000, 2,245,400 and 1,691,600, respectively.
: GRDP and GRDP per Capita per MRH do not include contribution of Hydroelectric Power Stations.

Table-5.5 Socio-Economic Framework of Paraná State in 2015

Classification	No. and Name of MRH	Urban Population		GRDP		GRDP per Capita
		Population	%	million US$	%	US$
1st	MRH 268/Curitiba	3,112,700	31.20	34,330.00	44.30	10,700.00
2nd	MRH 273/C. de Ponta Grossa	519,800	5.20	4,630.00	6.00	8,200.00
	MRH 281/N.N. Londrina	1,103,700	11.10	5,990.00	7.70	5,300.00
	MRH 282/N.N. Maringá	664,200	6.70	4,920.00	6.30	7,310.00
	MRH 288/Extr. Oeste Paranaense	1,320,500	13.30	9,050.00	11.70	6,370.00
	Subtotal/Average	3,608,200	36.30	24,590.00	31.70	6,490.00
3rd	MRH 279/284/285/286/289/290	1,964,200	19.70	11,110.00	14.30	4,740.00
4th	MRH 269/270/271/272/274/ 275/276/277/278/280/ 283/287/291	1,284,200	12.80	7,490.00	9.70	4,190.00
TOTAL of MRH / Average		9,969,300	100.00	77,520.00	100.00	6,960.00

Remark: Total population per 1st, 2nd, 3rd and 4th Categories are 3,209,400, 3,787,700, 2,346,100 and 1,787,200, respectively.

: GRDP and GRDP per Capita per MRH do not include contribution of Hydroelectric Power Stations.

5.3 Alternative

5.3.1 Future Socio-Economic Framework in Curitiba Metropolitan Area

Based on the study, concerning the water development in the Metropolitan Area of Curitiba, the balance between water demand and water supply will be very tight. In addition to that, problems in water quality, solid waste and other environmental issues will be enlarged to the extent of threatening human life.

As mentioned in the previous Section, it is estimated that in the year of 2015 MRH 268/Curitiba will need a great amount of additional social infrastructure on which more than one million people live. It is also foreseeable that large areas of useful land and basic infrastructure will be required to enable this MRH to cope with the several problems that will be caused by the increase in economic activities, by three times, up to 2015.

5.3.2 Alternative Regional Development Plan

To solve the problems above, or to avoid the foreseeable problems mentioned above, JICA Team proposes an alternative regional development plan, as a Strategy, with a concept of decentralization of socio-economic activities. It will be necessary to restrict the number of emigrants to Curitiba metropolitan area and to distribute them to the big MRH which have medium local urban centers, such as MRH 281/N. N. Londrina, MRH 288/Extr. Oeste Paranaense, MRH 282/N. N. Maringá, MRH 273/Campos de Ponta Grossa and others, which have the capacity and possibility to accept these immigrants.

(1) Outline of the Alternative Plan

Considering the concept mentioned above as well as the present regional economic activities, an outline of the alternative plan is composed as follows:

Composition of Three Urban Complexes.

a) MRH 281/Londrina and MRH 282/Maringá

To compose the urban axis /Londrina - Maringá/ with the neighboring municipalities, including part of MRH 284/Apucarana, as center of the north region in the State of Paraná.

b) MRH 288/Extr. Oeste Paranaense (Cascavel)

To compose the urban axis /Toledo-Cascavel-Foz do Iguaçu/ as the center of the west region in Paraná State.

c) MRH 273/Ponta Grossa

To compose the urban axis /Ponta Grossa-Castro/ as a new development region near the metropolitan area of Curitiba.

It is needless to say, however, that this plan is still in a level of strategy and it is necessary to study this plan further on from the political and administrative point of view.

5.3.3 Alternative Socio-Economic Framework

(1) Restriction and Distribution of the Number of Emigrants

According to Table-5.2, the increase of urban population in MRH 268/Curitiba is estimated in approximately 1,163,000 people, with an annual growth rate of 2.15% from the year of 1993 to the year of 2015. In order to find the reasonable ratio of restriction, the ratios of 30%, 40% and 50% were studied, respectively, relating to the growth rate of the four main MRH and the State of Paraná.

As a result of this study, the ratio of 40%, which is equivalent to 253,000 emigrants in 2005, and 465,000 emigrants in 2015, and to about 15% of the estimated urban population of each year, is considered reasonable to be distributed to the four large MRH (MRH 273/Campos de Ponta Grossa, MRH 281/N. N. Londrina, MRH 282/N. N. Maringá and MRH 288/Extr. Oeste Paranaense - Cascavel, Foz do Iguaçu, etc.), according to the proportion of each urban population in 2005 and 2015.

(2) Distribution of GRDP/Secondary Sector and Tertiary Sector in MRH 268/Curitiba

Consequently, 15% of the amount of the GRDP by Secondary Sector and Tertiary Sector in MRH 268, equivalent to 1,950 million US$ and 750,000 million US$ in 2005 and 5,100 million US$ and 1,900 million US$ in 2015, would be distributed to the same four large MRH, according to the same method mentioned above.

The restriction of MRH 268 and distribution for the four large MRH in 2005 and 2015 are shown below in Table-5.6.

(3) Alternative Socio-Economic Framework

According to the restriction of the emigrants and economic activities (GRDP of Secondary Sector and Tertiary Sector) in MRH 268, and the distribution of these matters to the four large MRH, the alternative socio-economic framework in 2005 and 2015 can be estimated as shown in Table-5.7 and Table-5.8, respectively.

Table-5.6 Urban population, GRDP (2nd & 3rd Sector) and GRDP (2nd Sector) (2005 & 2015)

No. and Name of MRH	2005				2015			
	%	Urban Population	GRDP (2nd and 3rd Sector) million US$	GRDP of 2nd Sector million US$	%	Urban Population	GRDP (2nd and 3rd Sector) million US$	GRDP of 2nd Sector million US$
MRH 268/Curitiba	100.00	(253,000)	(1,950.00)	(750.00)	100.00	(465,000)	(5,100.00)	(1,900.00)
MRH 271/C. Ponta Grossa	14.70	37,200	285.00	110.00	14.40	67,000	735.00	275.00
MRH 281/N.N. Londrina	31.30	79,200	610.00	235.00	30.60	142,200	1,560.00	580.00
MRH 282/N.N. Maringá	18.30	46,300	355.00	140.00	18.40	85,600	935.00	350.00
MRH 288/Extr. Oeste Paranaense	35.70	90,300	700.00	265.00	36.60	170,200	1,870.00	695.00

Remark : % is percentage of distribution per MRH.
: The values of GRDP of Secondary Sector and Tertiary Sector are in million US$.

Table-5.7 Socio-Economic framework of Paraná State in 2005/Alternative Case

Classification	No. and Name of MRH	Urban Population		GRDP 2nd and 3rd Sectors		GRDP 2nd sector	
		Population	%	million US$	%	million US$	%
1st	MRH 268/Curitiba	2,329,200	27.90	18,260.00	38.40	6,990.00	46.30
2nd	MRH 273/C. Ponta Grossa	478,400	5.70	3,150.00	6.60	1,190.00	7.90
	MRH 281/N.N. Londrina	1,014,900	12.20	4,470.00	9.40	1,470.00	9.80
	MRH 282/N.N. Maringá	594,800	7.10	3,290.00	6.90	1,270.00	8.40
	MRH 288/Extr. Oeste Paranaense	1,159,300	13.90	6,410.00	13.50	890.00	5.90
	Subtotal/Average	3,247,400	38.90	17,320.00	36.40	4,820.00	32.00
3rd	MRH 279/284/285/286/289/290	1,678,500	20.10	7,300.00	15.30	1,890.00	12.50
4th	MRH 269/270/271/272/274/275/276 277/278/280/283/287/291	1,095,100	13.10	4,710.00	9.90	1,390.00	9.20
TOTAL of MRH / Average		8,350,200	100.00	47,590.00	100.00	15,090.00	100.00

Remark : GRDP and GRDP per Capita per MRH do not include contribution of Hydroelectric Power Stations.

Table-5.8 Socio-Economic Framework of Paraná State in 2015/Alternative Case

Classification	No. and Name of MRH	Urban Population		GRDP 2nd and 3rd Sectors		GRDP 2nd Sector	
		Population	%	million US$	%	million US$	%
1st	MRH 268/Curitiba	2,647,700	26.60	29,230.00	37.70	10,940.00	43.30
2nd	MRH 273/C. de Ponta Grossa	586,800	5.90	5,360.00	6.90	2,030.00	8.00
	MRH 281/N.N. Londrina	1,245,900	12.50	7,550.00	9.70	2,640.00	10.50
	MRH 282/N.N. Maringá	749,800	7.50	5,860.00	7.60	2,410.00	9.50
	MRH 288/Extr. Oeste Paranaense	1,490,700	15.00	10,920.00	14.10	1,540.00	6.10
	Subtotal/Average	4,073,200	40.90	29,690.00	38.30	8,620.00	34.10
3rd	MRH 279/284/285/286/289/290	1,964,200	19.70	11,110.00	14.30	3,370.00	13.30
4th	MRH 269/270/271/272/274/275/276/ 277/278289/283/287/291	1,284,200	12.80	7,490.00	9.70	2,340.00	9.30
TOTAL of MRH / Average		9,969,300	100.00	77,520.00	100.00	25,270.00	100.00

Remark : GRDP and GRDP per Capita per MRH do not include contribution of Hydroelectric Power Stations.

Table - 5.9 Estimated GRDP per MRH and GRDP per Capita per MRH in 1993, 2005 and 2015

No. and Name of MRH	GRDP / MRH (US$ Million)						GRDP per Capita (US$)					
	1993	%	2005	%	2015	%	1993	%	2005	%	2015	%
1. MRH 268/CURITIBA	10,538.30	39.63	20,213.73	42.47	34,326.41	44.28	5,080.00	163.87	7,500.00	156.25	10,700.00	153.74
2. MRH 269/L. PARANAENSE	442.86	1.67	732.61	1.54	1,088.63	1.40	2,470.00	79.68	3,430.00	71.46	4,530.00	65.09
3. MRH 270/ALTO RIBEIRA	44.18	0.17	77.41	0.16	133.11	0.17	1,480.00	47.74	2,680.00	55.83	4,890.00	70.26
4. MRH 271/A. RIO NEGRO	32.22	0.12	61.37	0.13	105.60	0.14	810.00	26.13	1,350.00	28.13	2,230.00	32.04
5. MRH 272/ C.da LAPA	362.82	1.36	667.94	1.40	1,163.22	1.50	3,400.00	109.68	5,570.00	116.04	9,020.00	129.60
6. MRH 273/C. de PONTA GROSSA	1545.3	5.81	2,870.83	6.03	4,632.53	5.98	3,730.00	120.32	5,780.00	120.42	8,200.00	117.82
7. MRH 274/C. de JAGUARIAIVA	294.55	1.11	660.63	1.39	1,055.69	1.36	4,560.00	147.10	7,780.00	162.08	10,760.00	154.60
8. MRH 275/S. MATEUS do SUL	85.74	0.32	160.89	0.34	282.33	0.36	1,570.00	50.65	2,620.00	54.58	4,370.00	62.79
9. MRH 276/Col. de IRATI	200.53	0.75	383.82	0.81	637.75	0.82	1,140.00	36.77	1,980.00	41.25	3,140.00	45.11
10. MRH 277/ALTO IVAI	42.78	0.16	69.22	0.15	104.06	0.13	450.00	14.52	750.00	15.63	1,210.00	17.39
11. MRH 278/N. V. DE WENCESLAU B.	149.02	0.56	216.28	0.45	332.69	0.43	890.00	28.71	1,290.00	26.88	1,910.00	27.44
12. MRH 279/N. V. JACAREZINHO	664.9	2.50	1,013.13	2.13	1,436.03	1.85	2,160.00	69.68	3,240.00	67.50	4,370.00	62.79
13. MRH 280/ALG. de ASSAI	135.06	0.51	171.29	0.36	191.06	0.25	1,740.00	56.13	2,250.00	46.88	2,430.00	34.91
14. MRH 281/N. N. LONDRINA	2,344.76	8.82	3,862.85	8.12	5,990.97	7.73	2,810.00	90.65	3,920.00	81.67	5,300.00	76.15
15. MRH 282/N. N. MARINGA	1,510.93	5.68	2,931.00	6.16	4,915.47	6.34	3,430.00	110.65	5,180.00	107.92	7,310.00	105.03
16. MRH 283/N. Noviss. PARANAVAI	375.86	1.41	515.05	1.08	654.40	0.84	1,390.00	44.84	1,870.00	38.96	2,250.00	32.33
17. MRH 284/N. N. APUCARANA	556.79	2.09	857.07	1.80	1,253.83	1.62	1,750.00	56.45	2,750.00	57.29	3,840.00	55.17
18. MRH 285/N. Noviss. UMUARAMA	594.16	2.23	626.05	1.32	686.23	0.89	1,490.00	48.06	1,650.00	34.38	1,740.00	25.00
19. MRH 286/C. MOURAO	850.96	3.20	1,252.64	2.63	1,817.18	2.34	2,270.00	73.23	3,280.00	68.33	4,440.00	63.79
20. MRH 287/PITANGA	101.33	0.38	198.64	0.42	335.22	0.43	810.00	26.13	1,530.00	31.88	2,590.00	37.21
21. MRH 288/Ext. OESTE PARANAENSE	3,234.55	12.17	5,711.90	12.00	9,048.13	11.67	3,140.00	101.29	4,640.00	96.67	6,370.00	91.52
22. MRH 289/SUDOESTE PARANAENSE	1,006.21	3.78	1,545.04	3.25	2,428.76	3.13	2,130.00	68.71	3,300.00	68.75	5,280.00	75.86
23. MRH 290/ C. de GUARAPUAVA	1,022.30	3.84	2,000.58	4.20	3,480.28	4.49	3,030.00	97.74	5,130.00	106.88	8,130.00	116.81
24. MRH291/ MEDIO IGUACU	452.69	1.70	790.96	1.66	1,416.72	1.83	2,500.00	80.65	3,900.00	81.25	6,500.00	93.39
Subtotal of MRH/Average of MRH	26,588.80	100.00	47,590.93	100.00	77,516.30	100.00	3,100.00	100.00	4,800.00	100.00	6,960.00	100.00
Contribution of Hydroelectric Power Stations	1,222.20	—	2,354.07	—	3,837.70	—	—	—	—	—	—	—
Total of the STATE/Average of the STATE	27,811.00		49,945.00		81,354.00	—	3,240.00	—	5,040.00	—	7,310.00	—

Source: Estatística Economico-Financeira (Finance Economic Statistics) 74/85, 86/87, 88/89 and 91/93 - SEFA; Fundo de Participação dos Municípios - Índices Provisórios - 95 (Municipalities' Participation Fund - Preliminary Indexes - 95) - SEFA

Remark: Values in 2005 and 2015 were projected by JICA Team

: % of GRDP per Capita means ratio from average of Paraná State

Table -5.10 GRDP per MRH/Primary Sector and Secondary Sector in 1993, 2005 and 2015

	PRIMARY SECTOR						SECONDARY SECTOR					
	GRDP / MRH (US$ Million)						GRDP / MRH (US$ Million)					
No. and Name of MRH	1993	%	2005	%	2015	%	1993	%	2005	%	2015	%
1. MRH 268/CURITIBA	55.82	1.77	75.77	1.98	102.35	2.10	4,261.84	52.79	7,743.53	51.31	12,844.63	50.82
2. MRH 269/L. PARANAENSE	4.33	0.14	6.11	0.16	7.80	0.16	42.92	0.53	17.01	0.11	8.75	0.03
3. MRH 270/ALTO RIBEIRA	7.12	0.23	12.29	0.32	19.98	0.41	14.89	0.18	22.65	0.15	35.03	0.14
4. MRH 271/A. RIO NEGRO	10.14	0.32	12.19	0.32	15.11	0.31	6.77	0.08	12.89	0.09	24.16	0.10
5. MRH 272/ C.da LAPA	75.47	2.40	110.70	2.89	163.77	3.36	144.48	1.79	259.40	1.72	461.01	1.82
6. MRH 273/C. de PONTA GROSSA	171.57	5.45	262.20	6.84	362.14	7.43	530.69	6.57	1,076.90	7.14	1,753.81	6.94
7. MRH 274/C. de JAGUARIAIVA	58.20	1.85	89.57	2.34	129.16	2.65	147.34	1.83	371.52	2.46	714.92	2.83
8. MRH 275/S. MATEUS do SUL	22.69	0.72	29.51	0.77	40.94	0.84	30.25	0.37	48.95	0.32	91.88	0.36
9. MRH 276/Col. de IRATI	49.17	1.56	76.48	2.00	109.67	2.25	53.75	0.67	102.17	0.68	179.22	0.71
10. MRH 277/ALTO IVAI	19.03	0.60	22.60	0.59	27.29	0.56	4.78	0.06	8.30	0.05	14.90	0.06
11. MRH 278/N. V. DE WENCESLAU B.	58.67	1.86	53.63	1.40	56.54	1.16	10.44	0.13	29.97	0.20	61.21	0.24
12. MRH 279/N. V. JACAREZINHO	180.86	5.74	215.88	5.64	259.30	5.32	147.34	1.83	289.03	1.92	472.99	1.87
13. MRH 280/ALG. de ASSAI	61.62	1.96	69.10	1.80	71.65	1.47	32.52	0.40	40.37	0.27	49.03	0.19
14. MRH 281/N. N. LONDRINA	311.08	9.88	383.33	10.01	486.43	9.98	654.41	8.11	1,235.39	8.19	2,060.31	8.15
15. MRH 282/N. N. MARINGA	199.17	6.32	310.59	8.11	442.07	9.07	532.35	6.59	1,132.77	7.51	2,059.37	8.15
16. MRH 283/N. Noviss. PARANAVAI	108.97	3.46	93.05	2.43	84.81	1.74	98.39	1.22	198.55	1.32	353.60	1.40
17. MRH 284/N. N. APUCARANA	122.17	3.88	125.62	3.28	139.88	2.87	152.55	1.89	359.04	2.38	632.91	2.50
18. MRH 285/N. Noviss. UMUARAMA	154.68	4.91	89.03	2.32	55.56	1.14	128.48	1.59	241.83	1.60	418.13	1.65
19. MRH 286/C. MOURAO	282.36	8.97	309.39	8.08	366.04	7.51	152.11	1.88	286.98	1.90	496.73	1.97
20. MRH 287/PITANGA	39.16	1.24	56.90	1.49	79.45	1.63	5.59	0.07	11.27	0.07	20.06	0.08
21. MRH 288/Ext. OESTE PARANAENSE	675.86	21.46	860.00	22.45	1,116.14	22.90	424.10	5.25	626.89	4.15	850.15	3.36
22. MRH 289/SUDOESTE PARANAENSE	239.34	7.60	234.31	6.12	272.46	5.59	168.98	2.09	400.32	2.65	746.02	2.95
23. MRH 290/ C. de GUARAPUAVA	165.60	5.26	231.38	6.04	329.48	6.76	180.50	2.24	315.38	2.09	600.43	2.38
24. MRH291/ MEDIO IGUACU	75.92	2.41	101.37	2.65	135.98	2.79	147.33	1.83	260.82	1.73	323.05	1.28
Subtotal of MRH	3,149.00	100.00	3,831.00	100.00	4,874.00	100.00	8,072.80	100.00	15,091.93	100.00	25,272.30	100.00
Contribution of Hydroelectric Power Stations	—	—	—	—	—	—	1,222.20	—	2,354.07	—	3,837.70	—
TOTAL OF THE STATE	3,149.00	—	3,831.00	—	4,874.00	—	9,295.00	—	17,446.00	—	29,110.00	—

Source: Estatística Economico-Financeira (Finance Economic Statistics) 74/85, 86/87, 88/89 and 91/93 - SEFA; Fundo de Participação dos Municípios - Indices Provisórios - 95 (Municipalities' Participation Fund - Preliminary Indexes - 95) - SEFA

Remark: Values in 2005 and 2015 were projected by JICA Team

CHAPTER 6 PRESENT SITUATION AND WATER DEMAND PROJECTION FOR 2005 AND 2015

6.1 Domestic Water

6.1.1 Present Situation of Domestic Water Consumption

The domestic water supply service (including sewage services in Paraná State) is provided by three (3) undertakers; SANEPAR-Sanitation Company of the State of Paraná (Companhia de Saneamento do Paraná), F. N. S.-National Health Foundation (Fundação Nacional de Saúde) and Other Organs-Autonomous Municipalities, (Municípios Autônomos).

According to a report by the Pan-American Health Organization and World Health Organization - "Sector Analysis of Water Supply and Sanitary Sewage", the number of municipalities served by SANEPAR was gradually increasing. The number of municipalities served by SANEPAR reached 316 in 1993. It means that SANEPAR has nowadays a predominant participation in water supply service. In terms of number of municipalities and target service population, the share of SANEPAR is approximately 85% of the State's total number of municipalities and 92% of the State's total population, respectively. Therefore, information and data related to water supply service, provided by SANEPAR, were used for the Study.

6.1.2 Present Water Consumption Volume

(1) Average Water Consumption Volume

Present water consumption volume is one of the most fundamental information for water demand studies. The main information and data related to water consumption in Paraná State was provided by SANEPAR's Commercial Division and APC/SANEPAR (Section of Planning and Coordination Assistance - Sanepar).

According to the information and data mentioned above, an essential item concerning present unit consumption volume was arranged, by dividing the consumption in two categories: 1) residential water and 2) non-residential water (commercial use and public use), as presented in Table-6.1.

Table-6.1 Present Situation of Water Supply of SANEPAR, Estimated Unit Consumption Volume per MRH and GRDP per Capita per MRH - 1993

No. and Name of MRH	Target Water Service Population by SANEPAR	Water Service Population by SANEPAR	Service Percentage by SANEPAR %	Unit Consumption Volume (l/person . day)		GRDP per Capita US$
				Residential Water	Non-Residential Water	
01. MRH 268/Curitiba	2,047,710	1,869,347	91.29	95.91	23.43	5,080.00
02. MRH 269/L. Paranaense	52,240	35,598	68.14	-----	36.42	2,470.00
03. MRH 270/Alto Ribeira	24,873	6,930	27.86	66.18	17.24	1,480.00
04. MRH 271/A. Rio Negro	39,818	10,746	26.99	-----	15.18	810.00
05. MRH 272/C. Lapa	106,660	63,303	59.35	68.22	14.05	3,400.00
06. MRH 273/C. Ponta Grossa	414,555	342,204	82.55	79.47	16.59	3,730.00
07. MRH 274/C. Jaguariaíva	37,188	20,640	55.50	78.81	16.40	4,560.00
08. MRH 275/S. Mateus do Sul	54,674	20,240	37.02	76.86	21.44	1,570.00
09. MRH 276/Col. Irati	175,418	73,856	42.10	64.91	11.37	1,140.00
10. MRH 277/Alto Ivaí	96,116	24,870	25.87	61.07	12.03	450.00
11. MRH 278/N.V. Wenceslau Braz	167,834	97,614	58.16	72.99	31.30	890.00
12. MRH 279/N.V. Jacarezinho	223,982	182,576	81.51	94.99	24.06	2,160.00
13. MRH 280/Alg. Assaí	45,839	27,790	60.63	-----	44.16	1,740.00
14. MRH 281/N.N. Londrina	717,311	675,642	94.19	101.83	21.13	2,810.00
15. MRH 282/N.N. Maringá	357,982	356,347	99.54	103.40	41.46	3,430.00
16. MRH 283/N. Novis. Paranavaí	237,684	199,165	83.79	94.67	-----	1,390.00
17. MRH 284/N.N. Apucarana	307,705	254,080	82.57	70.18	13.11	1,750.00
18. MRH 285/N. Novis. Umuarama	384,374	258,668	67.30	84.78	-----	1,490.00
19. MRH 286/Campo Mourão	305,677	226,599	74.13	81.09	-----	2,270.00
20. MRH 287/Pitanga	119,572	29,832	24.95	65.96	16.15	810.00
21. MRH 288/Extr. Oeste Paranaense	974,483	698,071	71.64	88.57	27.45	3,140.00
22. MRH 289/Sudoeste Paranaense	450,505	236,683	52.54	71.20	16.35	2,130.00
23. MRH 290/Guarapuava	337,191	162,579	48.22	71.92	14.81	3,030.00
24. MRH 291/Médio Iguaçu	181,011	121,285	67.00	76.93	15.43	2,500.00
TOTAL of the State	7,860,402	5,994,665	-----	-----	-----	-----
Average of MRH	-----	-----	76.26	89.44	23.11	3,100.00

Source : APC/SANEPAR - Water Service Population and Consumption Volume per MRH, Table-5.9 - GRDP per Capita per MRH

Remark: Target Water Service Population was estimated based on IPARDES' estimation in 1993 but does not include figures of other water supply undertakers;
: Water Service Population in MRH 269 does not include floating population;
: Unit Consumption Volume without figures was collected but not reliable;
: Water service population per MRH by SANEPAR was calculated as residential unit by SANEPAR x Average inhabitant per residence estimated by SANEPAR;
: Unit Consumption Volume was calculated by Average Consumption Volume per MRH, shown in Sectorial Report Vol. D., divided by Water Service Population per MRH.

6.1.3 Present Unit Consumption Rate

(1) Average Unit Consumption Rate of Paraná State

Based on Table-6.1, average unit consumption rate for urban population, divided in residential water and non-residential water was estimated as shown in Table-6.2.

For the residential water for a part of people who live in rural areas of Paraná State, figures for estimation of unit consumption rate, such as water consumption volume and water service population, were not available.

Therefore, regarding the unit consumption rate for rural population, it was decided to use the following criteria for the Study:

- unit consumption rate of residential water is the same figure of the MRH of the 3rd category shown in Table-6.3.

– unit consumption rate of non-residential water is zero.

The estimated average unit consumption rate for rural population is also shown in Table-6.2.

Table-6.2 Average Unit Consumption Volume and Average Unit Consumption Rate of Paraná State - 1993

Urban Population				Rural Population			
Residential Water		Non-Residential Water		Residential Water		Non-Residential Water	
Average Consumption Volume (l/person . day)	Average Consumption Rate (l/person . day)	Average Consumption Volume (l/person . day)	Average Consumption Rate (l/person . day)	Average Consumption Volume (l/person . day)	Average Consumption Rate (l/person . day)	Average Consumption Volume (l/person . day)	Average Consumption Rate (l/person . day)
89.44	90.00	23.11	25.00	no data	70.00	no data	0.00

(2) Unit Consumption Rate per Region (MRH)

1) Unit Consumption Rate per MRH of Residential Water for Urban Population

According to the arranged data of unit consumption volume per MRH, shown in Table-6.1, considering service percentage of water supply by SANEPAR per MRH, GRDP per Capita per MRH and the degrees of concentration of population for urban areas (shown in Table-5.2) the unit consumption rate per MRH was estimated by classifying the 24 MRH into three categories, as presented in Table-6.3.

2) Unit Consumption Rate per MRH of Non-Residential Water for Urban Population

This unit rate was estimated for each category mentioned above, approximately in the same proportion of the average unit consumption rate of residential water.

3) Unit Consumption Rate of Residential Water per MRH for Rural Population

The unit rate was assumed as the same rate as the MRH classified in the 3rd category for all MRH, as shown in Table-6.3.

Table-6.3 Present Unit Water Consumption Rate per Region (MRH) - 1993

	Classification	No. of MRH	Unit Consumption Rate (l / person . day)		
			Residential Water	Non-Residential Water	Total Domestic Water
Urban Population	1st Category	MRH 268, MRH 281, MRH 282	100.00	30.00	130.00
	2nd Category	MRH 269, MRH 270, MRH 272 to MRH 276, MRH 279 to MRH 286, MRH 288 to MRH 291	85.00	20.00	105.00
	3rd Category	MRH 271, MRH 277, MRH 278, MRH 287	70.00	15.00	85.00
	Average of Paraná State		90.00	25.00	115.00
Rural Population		All MRH	70.00	0.00	70.00

Source : APC/SANEPAR

6.1.4 Future Unit Consumption Rate

(1) Average Unit Consumption Rate of Paraná State

1) Average Unit Consumption Rate of Residential Water for Urban Population

It can be considered that the unit water consumption rate of residential water is mainly influenced by the living standards and life style of the society such as, the household income and the place where the people live.

In this study, the recent trend of the household income, or personal income, in the State of Paraná could not be collected, therefore the GDP (or GRDP) per Capita has been used as a parameter for the analysis of water demand projection.

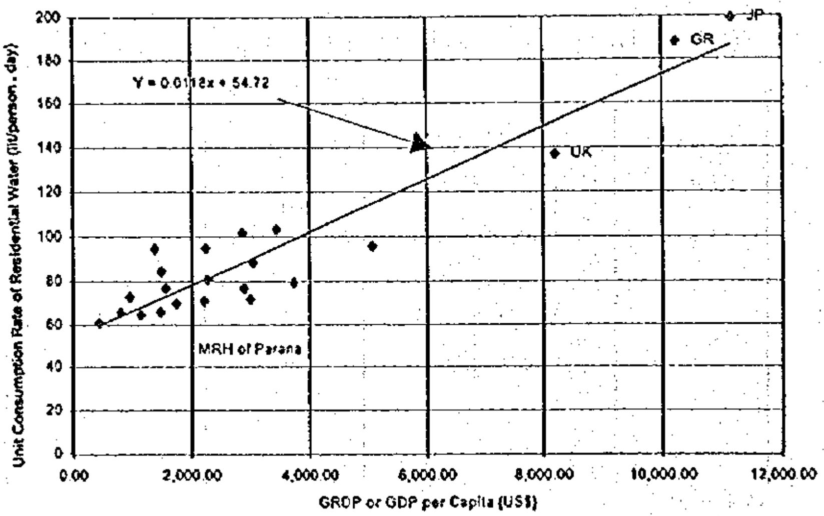
GDP per Capita of Paraná State was estimated at approximately 7,000.00 US$ in 2015, excluding the contribution of hydroelectric power stations (shown in Table-5.9). As this value is very high, there are no data at present in Paraná State to achieve a precise projection, therefore, data of unit consumption volume and GRDP per Capita in developed countries were also collected for this study, as shown in Table-6.4.

Table-6.4 Relation between the Unit Water Consumption Volume of Residential Water and GDP per Capita of Developed Countries in 1985

Name of the Country	Unit Consumption Volume (l / person . day)	GDP per Capita (US$)
Japan	199.00	11,155.00
United Kingdom	137.00	8,210.00
Germany	188.00	10,237.00

Source : Present Situation of Major Water Utilities in the World/Japan Water Works Association and World Statistics/Div. Statistics of Management & Coordination Agency Japan

Remark : Data of Japan is the Average Volume of the Country, data of UK is the Average Volume of the Cities of Northwest, North Umbrian, Southwest, Thames Welsh and Yorkshire, and data of Germany is the same Volume of the cities of Frankfurt and Hamburg.



JP: Japan, UK: United Kingdom, GR: Germany Source: APC/SANEPAR

Figure-6.1 Trend of Correlation between Unit Consumption Volume and GDP (or GRDP) per Capita

In order to estimate the trend of the future unit consumption rate, the correlation between unit consumption volume and GDP (or GRDP) per Capita was figured as Figure-6.1, using the unit consumption volume and GRDP per Capita (Table-6.2) of 19 MRH, and the same data of three developed countries mentioned above.

Based on Figure-6.1 (Trend of the Correlation Between Unit Consumption Volume and GDP (or GRDP) per Capita), and estimated GDP per Capita of Paraná State in 2005 and 2015 (shown in Table-5.9) the average unit consumption rate in Paraná State for urban population in 2005 and 2015 was estimated as shown in Table-6.5.

2) Average Unit Consumption Rate of Non-Residential Water for Urban Population

This unit rate was considered to increase in the same proportion of non-residential water to residential water in 1993, and is also presented in Table-6.5.

3) Average Unit Consumption Rate for Rural Population

This unit rate was estimated according to the criterion for present average unit consumption rate for rural population, and is shown in Table-6.5.

However, it shall be pointed out that future administrative changes in the policies of water supply and water charge were not considered for this estimation.

Table-6.5 Average Unit Consumption Rate of Paraná State - 2005 and 2015

2005				2015			
Urban Population		Rural Population		Urban Population		Rural Population	
Residential Water (l/person . day)	Non-Residential Water (l/person . day)	Residential Water (l/person . day)	Non-Residential Water (l/person . day)	Residential Water (l/person . day)	Non-Residential Water (l/person . day)	Residential Water (l/person . day)	Non-Residential Water (l/person . day)
115	30	75	0	140	40	80	0

(2) Unit Consumption Rate per Region (MRH) - 2005 and 2015

1) Unit Consumption Rate per MRH of Residential Water for Urban Population

This unit consumption rate was estimated per category (shown in Table-6.3) (not per each MRH) by using Figure-6.1. The unit consumption rate of these three categories was adjusted tentatively to the total water demand calculated by multiplying the average unit consumption rate (shown in Table-6.5) by the total urban population.

2) Unit Consumption Rate per MRH of Non-Residential Water for Urban Population

This unit consumption rate was estimated using the same method of estimation of the present unit consumption rate of non-residential water (Section - 6.1.3 (2).2)).

3) Unit Consumption Rate per MRH of Residential Water for Rural Population

As in the case of the present unit consumption rate per MRH, this unit rate was estimated considering the same figure of the MRH classified in the 3rd category for all the MRH.

Unit consumption rate of residential water and of non-residential water for urban population and unit consumption rate of residential water for rural population in 2005 and 2015 are summarized in Table-6.6.

Table-6.6 Unit Consumption Rate per Region (MRH) - 2005 and 2015

			2005			2015		
			Residential Water	Non Residential Water	Total Domestic Water	Residential Water	Non Residential Water	Total Domestic Water
	Classification	No. and Name of the MRH	Unit Rate (l/p . d)	Unit Rate (l/p . d)	Unit Rate (l/p . d)	Unit Rate (l/p . d)	Unit Rate (l/p . d)	Unit Rate (l/p . d)
Urban Population	1st Category	MRH 268/CURITIBA						
		MRH 281/N.N. LONDRINA						
		MRH 282/N.N. MARINGÁ						
		MRH 288/Extr.Oeste PARANAENSE	125	35	160	155	45	200
	2nd Category	MRH 269/L. PARANAENSE						
		MRH 270/ALTO RIBEIRA						
		MRH 272/C. LAPA						
		MRH 273/C. PONTA GROSSA						
		MRH 274/C. JAGUARIAÍVA						
		MRH 275/S. MATEUS do SUL						
		MRH 276/Col. IRATI						
		MRH 279/N. V. JACAREZINHO						
		MRH 280/Alg. ASSAÍ						
		MRH 283/N. Novis. PARANAVAÍ						
		MRH 284/N. N. APUCARANA						
		MRH 286/CAMPO MOURÃO						
		MRH 289/Sudoeste PARANAENSE						
		MRH 290/GUARAPUAVA						
		MRH 291/MÉDIO IGUAÇU	100	30	130	125	35	160
	3rd Category	MRH 271/A. RIO NEGRO						
		MRH 277/ALTO IVAÍ						
		MRH 278/N. V. WENCESLAU BRAZ						
		MRH 285/N. Novis. UMUARAMA						
		MRH 287/PITANGA	75	20	95	80	25	105
	AVERAGE OF PARANÁ STATE		115	30	145	140	40	180
RURAL POPULATION			75	0	75	80	0	80

Remark : (l/p . d) = liter/person . day

6.1.5 Water Demand Projection in 1993, 2005 and 2015

The water demand for the target years was estimated by multiplying the estimated urban and rural population per MRH of each year by the unit consumption rate per MRH of the corresponding year, and is presented in Section-6.6.

6.2 Industrial Water

6.2.1 Present Situation of Industrial Water Consumption

(1) Basic Data Concerning Industrial Water Consumption

The industrial demand is generally to be estimated by using the following information:

- Present water consumption volume and water recovery rate of factories by industrial type
- Value added of factories by industrial type
- GDP (GRDP) of Secondary Sector (Industrial Sector)

Unfortunately, the Team obtained very little information about present industrial water consumption except for the information shown below:

- SANEPAR: approximately 7,900 factories with consumption volume are listed by consumption volume per month;
- IAP: 563 factories with application of consumption volume are listed as granted for water use by river basin and by municipality;

  932 factories with present water consumption volume and effluent volume were listed by river basin and by municipality in the inventory of water resources in Paraná State but the inventory is incomplete;
- SEIC: the number of factories in Paraná State in 1993 (approximately 25,600 units) are listed by MRH and by industrial type.

Therefore, in the Study the present industrial water consumption can be roughly estimated.

(2) Water Consumption

For the time being, the following results could be obtained according to the analysis of the information mentioned above:

- 563 factories granted for water use: approximately 476,000 m^3/day is estimated, as intake volume;
- 932 factories listed in the inventory of water resources in Paraná State: approximately 900 factories use 362,000 m^3/day, which is estimated by the sewage discharge volume or 8 hours/day of average operating time of the water pumps, and by adding drinking water (5%), the total volume was estimated 401,000 m^3/day, approximately;
- data from water service undertakers (SANEPAR): 7,900 factories use 960,000 m^3/month (41,000 m^3/day). Among these factories, 216 factories (2.60%) use more than 500 m^3/month (average consumption is 153 m^3/day), other 7,680 factories (97.40%) have small consumption of 1.65 m^3/day in average.

Present water consumption volume was estimated by classifying the total number of factories (25,600 units-listed by SEIC) into three categories, as follows:

- Large Consumer: 900 factories with total consumption volume of 401,000 m^3/day, which are listed in the inventory of IAP.
- Medium Consumer: 8,800 factories supplied by water service undertakers with total consumption volume of 46,000 m^3/day (7,900 factories supplied by SANEPAR + 900 factories supplied by other water service undertakers).
- Small Consumer: 15,900 factories with total consumption volume of 27,000 m^3/day (approximately 1.65 m^3/day).

The present water consumption is summarized as shown in Table-6.7.

Table-6.7 Present Industrial Water Consumption Volume - 1993

	Large Consumer	Medium Consumer	Small Consumer	Total
Number of Establishments	900	8,800	15,900	25,600
Consumption Volume (m^3/day)	401,000	46,000	27,000	474,000

6.2.2 Present Average Unit Consumption Rate per Value Added (V.A.)

Based on the estimated present industrial consumption volume and on the estimated value added of Secondary Sector, excluding the contribution of hydroelectric power stations (shown in table-5.9), the present unit consumption rate was estimated below:

474,000 m^3/day ÷ 8,072.80 million US$ = 0.059 m^3/day/1,000.00 US$ (V.A.)

6.2.3 Future Average Unit Consumption Rate per Value Added (V.A.)

For the estimation of future unit consumption rate, one of the most fundamental information is the water recovery rate of industrial water. However, this information is not available presently. Therefore, this unit rate for the target year 2015 was estimated applying 50% of the industrial water recovery rate (75%) of Japan in 1993. In other words, future average water recovery rate of industrial water in Paraná State was estimated by an increase of 19% in 2005 and 37.5% in 2015, respectively. The estimated average unit consumption rate is shown below in Table-6.8.

Table-6.8 Average Unit Consumption Rate per Value Added - 1993, 2005 and 2015

Unit Rate - 1993 Unit Rate with Present Recovery Rate m^3/day . US$ 1,000.00 (V.A.)	Unit Rate - 2005 Increase of Water Recovery Rate: 19% m^3/day . US$ 1,000.00 (V.A.)	Unit Rate - 2015 Increase of water Recovery Rate: 37.50% m^3/day . US$ 1,000.00 (V.A.)
0.059	0.048	0.037

6.2.4 Water Demand Projection in 1993, 2005 and 2015

Based on the GRDP by Secondary Sector per MRH (Shown in Table-5.10) and unit consumption rate per Value Added of each year mentioned above, the estimated water demands for the target years are presented in Section-6.6.

6.3 Agricultural Water inclusive of Livestock and Fishery

Since the area of Paraná state is quite large, approximately 200 thousand km², agriculture in Paraná varies with region due to different climatic, topographic and market conditions. EMATER divides Paraná in 20 regions as shown in Figure-6.2 and has conducted agriculture extension services. Based on agriculture statistics with EMATER division wise, current agriculture and its water consumption were identified, and future agriculture and its water demand were projected.

6.3.1 Current Agriculture in Paraná

(1) Paraná Participation in Brazilian Agriculture

According to the Cropping Calendar in Paraná (DERAL, SEAB and CEPA, 1990), the participation of Paraná agriculture in Brazil is very high. As shown in Table-6.9, Paraná is one of the leading state in agriculture.

Table-6.9 Paraná Participation in Brazil Agriculture

	Participation in Brazil (%)		production rank
	area	production	in Brazil
cotton	17.0	37.0	1
rice	3.1	3.0	9
potato	27.3	26.7	3
coffee	16.3	16.8	4
sugarcane	3.8	4.5	5
beans	19.5	21.1	1
cassava	5.0	8.0	4
maize	18.5	25.7	1
soybean	19.7	21.0	2
wheat	56.0	61.0	1
	Participation in Brazil (%)		production rank
	heads	production	in Brazil
cattle (meat)	6.1	10.4	4
cattle (milk)		8.3	5
chicken (meat)	13.1	15.6	2
chicken (egg)		9.7	3

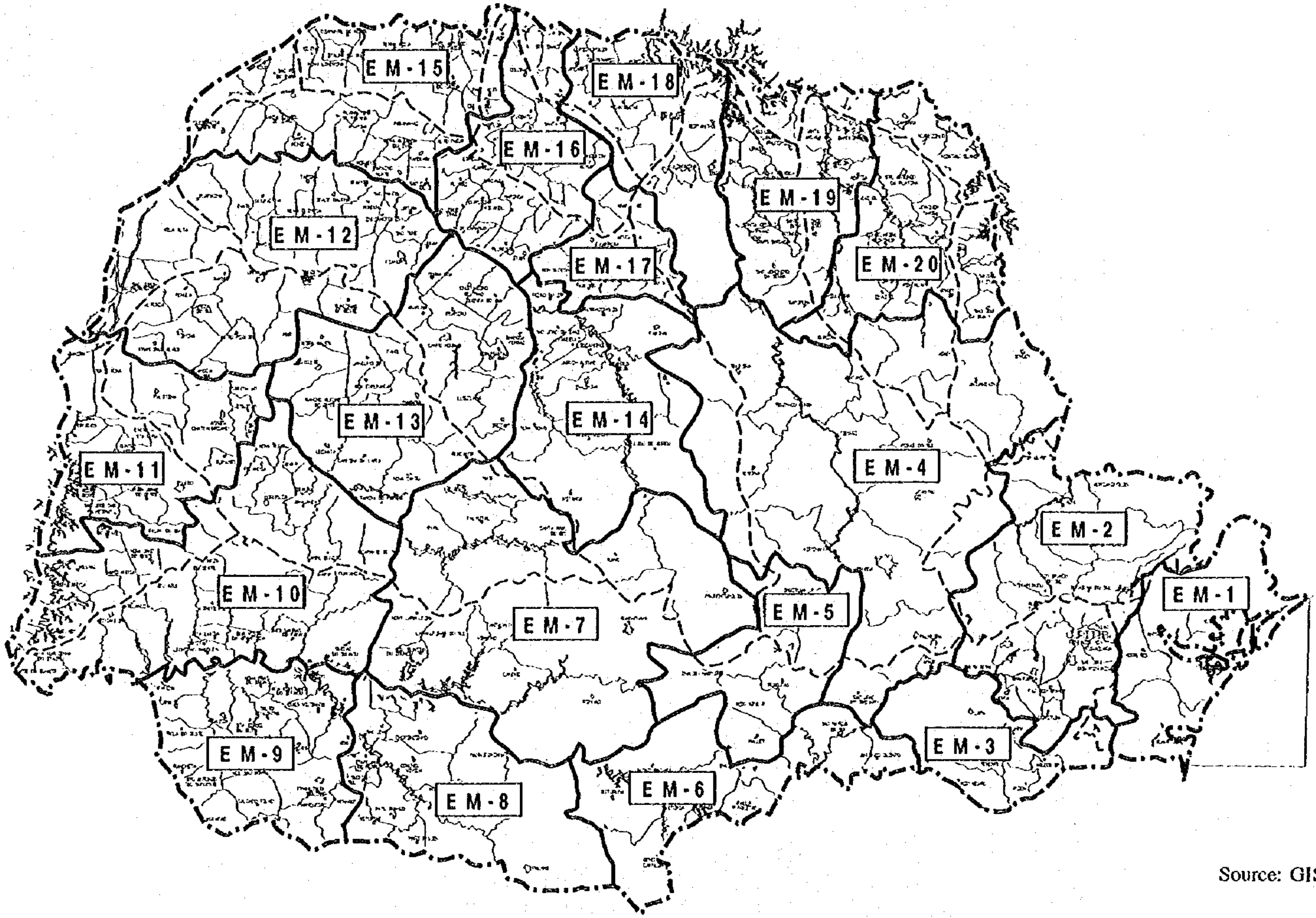
Source: DERAL/SEAB, and CEPA (1990)

(2) Regional Variation of Agriculture

The primary crops in Paraná are cotton, rice (paddy and upland), potato, sugarcane, beans, cassava, coffee, maize, soybean and wheat. As shown in Table-6.10, there are clear regional distinctions of crop cultivation.

Regional characteristics of livestock raising and inland fish culture are also shown in Table-6.10. Pig raising is limited due to its low price, while cattle raising and poultry farming (chicken) are the dominant livestock industry for Paraná state.

One of the significant features is that agriculture inclusive of livestock and inland fish culture is not dominant in the Paranagua region (EM-1).



EMATER Division

E M - 1	Paranagua
E M - 2	Curitiba
E M - 3	Lapa
E M - 4	Ponta Grossa
E M - 5	Irati
E M - 6	Uniao da Vitoria
E M - 7	Guarapuava
E M - 8	Pato Branco
E M - 9	Francisco Beltrao
E M - 10	Cascavel
E M - 11	Toledo
E M - 12	Umuarama
E M - 13	Campo Mourao
E M - 14	Ivaipora
E M - 15	Paranavai
E M - 16	Maringa
E M - 17	Apucarana
E M - 18	Londrina
E M - 19	Cornelio Procopio
E M - 20	Jacarezinho

Legend

Boundary of River Basin

Boundary of EMATER Division

Scale 1:2,500,000

Source: GIS Digitization by SANEPAR (1994)

Figure-6.2 EMATER Division

Table-6.10 Agricultural Characteristics with EMATER Division

No.	Division	Beans A (%)	Beans P (%)	Beans (winter) A (%)	Beans (winter) P (%)	Cassava A (%)	Cassava P (%)	Coffee A (%)	Coffee P (%)	Cotton A (%)	Cotton P (%)	Maize A (%)	Maize P (%)	Maize (Saf) A (%)	Maize (Saf) P (%)
1	Paranagua					1	1								
2	Curitiba	6	5	6	3	2	2					3	2		
3	Lapa	5	6									2	2		
4	Ponta Grossa	12	13	15	28	2	2					10	10	2	2
5	Irati	11	11	2	2							4	3		
6	Uniao da Vitoria	7	8	2	1	1	1					2	2		
7	Guarapuava	13	11	4	3							14	13	1	1
8	Pato Branco	4	6	1	1	2	2					7	7	3	3
9	Francisco Beltrao	12	13	8	6	9	11	1	1			12	10	16	15
10	Cascavel	3	4			12	15			8	9	10	14	13	11
11	Toledo	1	1			14	16	3	7	12	12	6	9	23	25
12	Umuarama	2	1	4	2	18	17	22	9	14	15	1	1	1	1
13	Campo Mourao	3	2			10	9	10	9	25	27	6	6	5	5
14	Ivaipora	15	12	7	4	2	1	7	8	10	10	9	7	5	5
15	Paranavai			10	7	20	18	11	12	6	7				
16	Maringa			3	1	4	3	5	5	6	5	1	1	8	8
17	Apucarana	1	1					7	5	3	3	3	3		
18	Londrina			5	4	2	1	11	10	4	4	2	2	10	11
19	Cornelio Procopio			11	9			9	15	11	7	3	4	9	10
20	Jacarezinho	5	6	22	29	1	1	14	19	1	1	5	4	4	3
	Total (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Total*	522	431	74	63	153	3,343	222	169	316	455	2,236	7,133	513	1,158

No.	Division	Potato A (%)	Potato P (%)	Potato(winter) A (%)	Potato(winter) P (%)	Rice A (%)	Rice P (%)	Rice(paddy) A (%)	Rice(paddy) P (%)	Soybean A (%)	Soybean P (%)	Soybean(saf) A (%)	Soybean(saf) P (%)	Sugarcane A (%)	Sugarcane P (%)	Wheat A (%)	Wheat P (%)
1	Paranagua																
2	Curitiba	55	52	73	61	1	1										
3	Lapa	23	22			1	1										
4	Ponta Grossa	5	6			9	12			7	8	2	4			6	9
5	Irati	6	7			7	6			1	1						
6	Uniao da Vitoria	5	6			7	6										
7	Guarapuava	4	5	27	39	12	15			4	5					2	3
8	Pato Branco	1	1			4	4			6	5					3	3
9	Francisco Beltrao	1	1			9	10			5	5			2	1	5	6
10	Cascavel					8	10			14	14	9	7	1	1	12	10
11	Toledo					1	1	13	14	16	15	77	76			17	12
12	Umuarama					2	1	17	13	1	1			15	12	1	1
13	Campo Mourao					6	5			17	17	4	3	8	8	22	20
14	Ivaipora					12	9			3	3			3	3	4	3
15	Paranavai					1	1	25	20					9	11		
16	Maringa					2	1			8	8	1	1	15	16	9	7
17	Apucarana					3	3			2	2			3	1	2	2
18	Londrina					3	3	9	13	8	8	2	3	16	17	6	8
19	Cornelio Procopio					1	2	22	23	7	7	5	6	12	13	9	14
20	Jacarezinho					11	9	14	17	1	1			16	17	2	2
	Total (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Total*	25	368	11	137	88	126	13	54	1,944	4,525	76	72	249	17,327	934	1,358

A: Area, P: Production, Saf: Second Cropping in Summer (Safrinha) *: Unit of Total A: 1000 ha, P: 1000 ton

Source: adopted and enlarged from EMATER (1993)

No.	Division	Pig H (%)	Cattle H (%)	Chicken H (%)	Fish Pond A (%)
1	Paranagua		0.1		0.5
2	Curitiba	3.4	1.3	5.0	4.2
3	Lapa	1.9	0.8	2.8	2.3
4	Ponta Grossa	6.0	5.2	11.0	8.5
5	Irati	3.6	0.9	1.4	3.7
6	Uniao da Vitoria	3.0	1.0	1.2	2.7
7	Guarapuava	8.1	5.0	2.8	4.4
8	Pato Branco	7.3	3.5	8.7	16.2
9	Francisco Beltrao	12.4	3.9	16.6	19.6
10	Cascavel	10.5	6.8	8.0	10.8
11	Toledo	15.0	4.6	15.2	9.4
12	Umuarama	4.4	16.7	2.2	0.1
13	Campo Mourao	4.2	8.1	2.5	1.3
14	Ivaipora	4.9	5.3	1.8	5.5
15	Paranavai	1.4	12.7	2.2	0.3
16	Maringa	3.1	6.9	4.5	1.0
17	Apucarana	1.8	2.2	0.7	1.2
18	Londrina	3.0	5.5	6.0	2.0
19	Cornelio Procopio	2.0	3.3	2.4	3.2
20	Jacarezinho	4.0	6.2	5.0	3.1
	Total (%)	100	100	100	100
	Total*	2,815	9,736	60,744	3,756

H: Head, A: Area *: Unit of Total H:1,000 head, A: ha

Source: Livestock, IBGE for Population, Cropping Calendar of Parana (DERAL/SEAB and CEPA, 1990) for Region Participation
DEPEC/SEAB for Fish Pond

6.3.2 Water Consumption

In general, agricultural water consists of irrigation, livestock and inland fish culture. Since the data regarding irrigation is not available in Paraná state, the necessity of irrigation was examined by means of comparison between crop water requirement assessed and precipitation data observed. 11 primary crops, cotton, rice (paddy and upland), potato, coffee, sugarcane, beans, cassava, maize, soybean and wheat, were selected for this examination. Considering the spatial variation of climate and crop cultivation, crop water requirement was computed and compared with effective rainfall, 80 % of rainfall for upland crops and 90 % of rainfall for paddy rice, as shown in Table-6.11.

Table-6.11 Comparison between ETcrop and ER for Primary Crops

Crop	Meteorological Station	ET/ Rainfall (mm/month)	Month 1	2	3	4	5	6	7	8	9	10	11	12	Total
Cotton	Bandeirantes Cfa(h)*	ETcrop	137	85								89	128	137	575
		ER	144	124								98	133	169	668
		Difference	7	39	0	0	0	0	0	0	0	9	5	32	
	Nova Cantu Cfa*	ETcrop	146	89								91	128	154	607
		ER	133	137								159	148	176	752
		Difference	-13	49	0	0	0	0	0	0	0	67	21	22	
Rice (paddy)	Apucarana Cfa(h)*	ETcrop	131	110	99								138	139	616
		ER	171	139	136								143	190	780
		Difference	41	29	38	0	0	0	0	0	0	0	5	51	
	Palotina Cfa*	ETcrop	135	129								122	149	151	686
		ER	138	127								153	149	161	727
		Difference	3	-2	0	0	0	0	0	0	0	31	0	10	
Rice (upland)	Apucarana Cfa(h)*	ETcrop	131	110	99								110	139	588
		ER	152	124	121								127	169	693
		Difference	22	14	23	0	0	0	0	0	0	0	17	30	
	Cascavel Cfa*	ETcrop	144	107								97	137	144	628
		ER	142	138								164	158	142	745
		Difference	-2	32	0	0	0	0	0	0	0	67	21	-2	
	Guarapuava Cfb*	ETcrop	135	112	98								107	139	590
		ER	164	132	132								157	166	751
		Difference	29	20	35	0	0	0	0	0	0	0	50	27	
Potato Aguas (summer)	Lapa Cfb*	ETcrop								42	63	107	124	74	410
		ER								79	96	117	102	94	488
		Difference	0	0	0	0	0	0	0	37	33	10	-22	21	
Potato Seca (winter)	Lapa Cfb*	ETcrop		76	84	72	51	27							311
		ER		110	97	69	114	72							462
		Difference	0	34	13	-3	63	45	0	0	0	0	0	0	
Coffee	Umuarama Cfa(h)*	ETcrop	128	110	108	80	55	42	49	67	78	109	124	129	1078
		ER	132	101	100	109	126	86	55	61	113	123	135	153	1294
		Difference	4	-8	-8	29	71	45	6	-5	35	14	11	24	
Sugarcane	Londrina Cfa(h)*	ETcrop	142	123	118	93	65	49	44	46	50	99	130	133	1090
		ER	152	132	126	97	94	72	50	43	95	109	143	194	1308
		Difference	10	10	9	4	30	24	6	-3	45	10	14	61	
Beans Aguas (summer)	Francisco Beltrao Cfa*	ETcrop									31	94	117	56	298
		ER									61	168	155	59	444
		Difference	0	0	0	0	0	0	0	0	30	74	38	3	
	Guarapuava Cfb*	ETcrop	49									43	102	121	315
		ER	61									71	140	147	419
		Difference	13	0	0	0	0	0	0	0	0	28	37	27	
Beans Seca (winter)	Joaquim Tavora Cfa*	ETcrop	96	106	103										304
		ER	143	113	113										369
		Difference	48	7	10	0	0	0	0	0	0	0	0	0	
Maize	Cascavel Cfa*	ETcrop	144	115	74							104	122	142	699
		ER	142	138	106							164	158	142	851
		Difference	-2	24	32	0	0	0	0	0	0	61	37	0	
	Guarapuava Cfb*	ETcrop	135	109	70							85	105	129	631
		ER	146	118	110							147	140	147	807
		Difference	11	9	40	0	0	0	0	0	0	62	35	19	
Soybean	Cascavel Cfa*	ETcrop	137	84									116	137	473
		ER	142	138									158	142	581
		Difference	5	55	0	0	0	0	0	0	0	0	42	6	
Wheat	Cascavel Cfa*	ETcrop					53	41	47	26					167
		ER					175	103	92	65					435
		Difference	0	0	0	0	122	62	44	39	0	0	0	0	

ETcrop: Crop Water Requirement
ER: Effective Rainfall Upland Crops = 0.8 x rainfall, Paddy Rice = 0.9 x rainfall
*: Koeppen Classification

The result shows that the rain-fed agriculture is practically adequate in Paraná state and therefore there is no water consumption in terms of irrigation as long as the favorable weather and cropping pattern does not vary. If irrigation was applied, high production would be secured even during the drought but it would depend on cost and benefit evaluation.

Since the rain-fed agriculture is adequate in Paraná state, water requirements for livestock and fish pond were considered as agricultural water. Their rates were examined as follows.

(1) Livestock

Cattle, pig and chicken were selected as the primary livestock in Paraná state. Water requirement per head of each kind of livestock was estimated and the total water requirement was determined by multiplying population with the rate per head.

In Paraná state, it is said that an livestock of 100 kg live weight requires 4 - 12 liter/day. For the calculation sake, 10 liter/day was adopted as the total water requirement.

Natural pasture contains as much as 80 % of water during the growth period. Therefore, amount of water actually supplied to cattle is a part of total water requirement which cannot be provided by moisture content of forage. It was assumed that the actual water supply to cattle is 33 % of total water requirement.

Since pigs and chickens are not herbivores, it was assumed that there is no water intake by means of food. Therefore, their water requirements depend on an average live weight. Consequently, the rates of water requirement of each livestock were determined as shown in Table-6.12.

Table-6.12 Water Requirement of Livestock

Livestock	Average Live Weight (kg)	Total Water Requirement (liter/head/day)	Actual Water Supply (liter/head/day)
Pig	40	4.0	4.0
Cattle	300	30.0	10.0
Chicken	2	0.2	0.2

Total water requirement includes water intake by forage.
Actual water supply is a supply in liquid phase.

(2) Inland Fish Culture

Main species of fish raising in Paraná are mainly carp and tilapia. There are 3,756 ha of fish ponds in 1993 with an average water depth of 1 m according to DEPEC. The productivity is approximately 1.5 ton/ha/year.

In general, water consumption from fish ponds consists of evaporation from free water surface, seepage and change of water due to contamination. To estimate water consumption, the following assumptions were made; 1) There is no change of water. 2) The bottom of a pond is well coated with clay. Therefore, no seepage occurs or seepage ceases after a long use. 3) 60 % of annual rainfall is stored in a pond and 40 % is overflowed.

An average rainfall and evaporation in 33 selected meteorological stations are 1700 mm and 1300 mm, respectively. Applying these average values, annual water loss from a fish pond is approximately 300 mm (= 1300 - 1700 x 0.6). This water loss is compensated by the water intake from either surface water or groundwater. 300 mm/year is equivalent to 1 mm/day. Ignoring the spatial variation, this 1 mm/day was adopted to estimate water consumption.

6.3.3 Future Agriculture Plan and Water Demand

Agricultural potential in Paraná state was examined from the point of view of climate, soil properties and topography. After the identification of agricultural potential, future agriculture in Paraná was projected in terms of food demand in Paraná, cropping area and productivity of primary crops, livestock population and area of fish ponds. Finally, water demand of agricultural sector in the year of 2005 and 2015 were assessed. Although the details of the result is discussed in Sectoral Report E " Agriculture", the conclusion is that future agriculture in Paraná will be promising and Paraná state will keep a current position as one of the leading sates of Brazilian agriculture.

Since the water demand of agriculture in Paraná depends on the livestock population and fish pond area, the way of projection is explained briefly below. The future livestock population and fish pond area projected are shown in Table-6.13 with related water demand.

Livestock population in future, except pig raising, was estimated by means of linear regression in the last 20 years, 1973 to 1993, using the data available from IBGE. Regarding pig raising, this method could not apply due to the recent sharp decline in its population. Considering the past trend before the decline, it was assumed that its population will be stabilized at 4 million by the year of 2000.

Cattle (1,000 head) = 174.256 x Year - 337839

Chicken (million head) = 1.83697 x Year - 3591.68

The gross income of inland fish culture is limited compared to crop cultivation and livestock raising. Considering the data availability, it was assumed that the inland fish culture in Paraná will expand proportional to the increase of agricultural gross income, 2 % per year.

Literature Cited

DERAL, SEAB., and CEPA. (1990). Calendário agrícola do Paraná (Cropping Calendar in Paraná). Curitiba.

Table-6.13 Current Water Consumption and Water Demand Projection for Agriculture

NO.	EMATER	Population (1,000 head)									Fish Pond Area (ha)		
		Pig			Cattle			Chicken					
	Region	1993	2005	2015	1993	2005	2015	1993	2005	2015	1993	2005	2015
EM-1	Paranagua	0.0	0.0	0.0	9.7	11.5	13.3	0.0	0.0	0.0	17	24	29
EM-2	Curitiba	95.7	136.0	136.0	126.6	150.1	172.7	3,037.2	4,572.2	5,490.7	156	202	244
EM-3	Lapa	53.5	76.0	76.0	77.9	92.4	106.3	1,700.8	2,560.4	3,074.8	87	110	133
EM-4	Ponta Grossa	168.9	240.0	240.0	506.3	600.3	690.9	6,681.9	10,058.7	12,079.4	320	408	493
EM-5	Irati	101.3	144.0	144.0	87.6	103.9	119.6	850.4	1,280.2	1,537.4	139	178	215
EM-6	Uniao da Vitoria	84.5	120.0	120.0	97.4	115.5	132.9	728.9	1,097.3	1,317.8	103	130	157
EM-7	Guarapuava	228.0	324.0	324.0	486.8	577.3	664.4	1,700.8	2,560.4	3,074.8	165	211	255
EM-8	Pato Branco	205.5	292.0	292.0	340.8	404.1	465.0	5,284.8	7,955.5	9,553.7	611	778	940
EM-9	Francisco Beltrao	349.1	496.0	496.0	379.7	450.3	518.2	10,083.6	15,179.5	18,229.0	736	940	1136
EM-10	Cascavel	295.6	420.0	420.0	662.1	785.1	903.5	4,859.5	7,315.4	8,785.0	405	518	626
EM-11	Toledo	422.3	600.0	600.0	447.9	531.1	611.2	9,233.1	13,899.3	16,691.6	354	451	545
EM-12	Umuarama	123.9	176.0	176.0	1,625.9	1,928.0	2,218.9	1,336.4	2,011.7	2,415.9	4	5	6
EM-13	Campo Mourao	118.2	168.0	168.0	788.6	935.1	1,076.2	1,518.6	2,286.1	2,745.3	47	62	75
EM-14	Ivaipora	137.9	196.0	196.0	516.0	611.9	704.2	1,093.4	1,646.0	1,976.6	209	264	319
EM-15	Paranavai	39.4	56.0	56.0	1,236.5	1,466.2	1,687.4	1,336.4	2,011.7	2,415.9	11	14	17
EM-16	Maringa	87.3	124.0	124.0	671.8	796.6	916.8	2,733.5	4,114.9	4,941.6	36	48	58
EM-17	Apucarana	50.7	72.0	72.0	214.2	254.0	292.3	425.2	640.1	768.7	46	58	70
EM-18	Londrina	84.5	120.0	120.0	535.5	635.0	730.8	3,644.7	5,486.6	6,588.8	75	96	116
EM-19	Cornelio Procopio	56.3	80.0	80.0	321.3	381.0	438.5	1,457.9	2,194.6	2,635.5	119	154	186
EM-20	Jacarezinho	112.6	160.0	160.0	603.6	715.8	823.8	3,037.2	4,572.2	5,490.7	116	149	180
	Total	2,815.0	4,000.0	4,000.0	9,736.0	11,545.0	13,287.0	60,744.0	91,443.0	109,813.0	3756	4800	5800

Source: IBGE for Livestock Population in 1993, adapted and enlarged from DEPEC/SEAB for Fish Pond Area in 1993

NO.	EMATER	Water Demand (1,000 m3/day)														
		1993					2005					2015				
	Region	pig	cattle	chicken	fish	total	pig	cattle	chicken	fish	total	pig	cattle	chicken	fish	total
EM-1	Paranagua	0.000	0.097	0.000	0.170	0.267	0.000	0.115	0.000	0.240	0.355	0.000	0.133	0.000	0.290	0.423
EM-2	Curitiba	0.383	1.266	0.607	1.560	3.816	0.544	1.501	0.914	2.020	4.979	0.544	1.727	1.098	2.440	5.809
EM-3	Lapa	0.214	0.779	0.340	0.870	2.203	0.304	0.924	0.512	1.100	2.840	0.304	1.063	0.615	1.330	3.312
EM-4	Ponta Grossa	0.676	5.063	1.336	3.200	10.275	0.960	6.003	2.012	4.080	13.055	0.960	6.909	2.416	4.930	15.215
EM-5	Irati	0.405	0.876	0.170	1.390	2.841	0.576	1.039	0.256	1.780	3.651	0.576	1.196	0.307	2.150	4.229
EM-6	Uniao da Vitoria	0.338	0.974	0.146	1.030	2.488	0.480	1.155	0.219	1.300	3.154	0.480	1.329	0.264	1.570	3.643
EM-7	Guarapuava	0.912	4.868	0.340	1.650	7.770	1.296	5.773	0.512	2.110	9.691	1.296	6.644	0.615	2.550	11.105
EM-8	Pato Branco	0.822	3.408	1.057	6.110	11.397	1.168	4.041	1.591	7.780	14.580	1.168	4.650	1.911	9.400	17.129
EM-9	Francisco Beltrao	1.396	3.797	2.017	7.360	14.570	1.984	4.503	3.036	9.400	18.923	1.984	5.182	3.646	11.360	22.172
EM-10	Cascavel	1.182	6.621	0.972	4.050	12.825	1.680	7.851	1.463	5.180	16.174	1.680	9.035	1.757	6.260	18.732
EM-11	Toledo	1.689	4.479	1.847	3.540	11.555	2.400	5.311	2.780	4.510	15.001	2.400	6.112	3.338	5.450	17.300
EM-12	Umuarama	0.496	16.259	0.267	0.040	17.062	0.704	19.280	0.402	0.050	20.436	0.706	22.189	0.483	0.060	23.436
EM-13	Campo Mourao	0.473	7.886	0.304	0.470	9.133	0.672	9.351	0.457	0.620	11.100	0.672	10.762	0.549	0.750	12.733
EM-14	Ivaipora	0.552	5.160	0.219	2.090	8.021	0.784	6.119	0.329	2.640	9.872	0.784	7.042	0.395	3.190	11.411
EM-15	Paranavai	0.158	12.365	0.267	0.110	12.900	0.224	14.662	0.402	0.140	15.428	0.224	16.874	0.483	0.170	17.751
EM-16	Maringa	0.349	6.718	0.547	0.360	7.974	0.496	7.966	0.823	0.480	9.765	0.496	9.168	0.988	0.580	11.232
EM-17	Apucarana	0.203	2.142	0.085	0.460	2.890	0.288	2.540	0.128	0.580	3.536	0.288	2.923	0.154	0.700	4.065
EM-18	Londrina	0.338	5.355	0.729	0.750	7.172	0.480	6.350	1.097	0.960	8.887	0.480	7.308	1.318	1.160	10.266
EM-19	Cornelio Procopio	0.225	3.213	0.292	1.190	4.920	0.320	3.810	0.439	1.540	6.109	0.320	4.385	0.527	1.860	7.092
EM-20	Jacarezinho	0.450	6.036	0.607	1.160	8.253	0.640	7.158	0.914	1.490	10.202	0.640	8.238	1.098	1.800	11.776
	Total	11.261	97.362	12.149	37.560	158.332	16.000	115.452	18.286	48.000	197.738	16.000	132.869	21.962	58.000	228.831

6.4 Hydropower

6.4.1 Existing Power Supply System

(1) Whole Brazil

Power system in Brazil is composed of four major regional systems; north, northeast, southeast and south systems, and other several small isolated systems in the north regions. The regional systems are presently interconnected between the north and northeast systems and between the southeast and south systems.

DNAEE, which belongs to the Ministry of Mines and Energy (MME), is a competent authority on power sector in Brazil and is responsible for framing national electric power policy. Eletrobras, which is a partly government-owned corporation under jurisdiction of MME, is responsible for implementing the national electric power policy. Eletrobras operates the power systems in Brazil via four regional subsidiary companies; Eletronrte for the north system, Chesf for the northeast system, Furnas for southeast system and Eletrosul for the south system. These companies operate major power plants and trunk transmission lines in the respective regions.

In addition to the regional power companies, most of states have their own electric power companies to distribute electricity in respective states. Those state companies also have the right to develop and operate generating plants mainly for their own consumption. Further to those federal and state power companies, there are many small power companies for local power supply and other industrial companies which possess generation plant for their own use.

(2) State of Paraná

The power system in the state of Paraná belongs to the South System which is under control of Eletrosul and covers four states; Paraná, Santa Catarina, Rio Grande do Sul and Mato Grosso do Sul. The south system is interconnected with the adjoining Southeast System which covers the five states and one federal district such as Sao Paulo, Rio de Janeiro and Brazilia.

Power supply/distribution in the Paraná state is made mainly by COPEL (Companhia Paranaense de Energia); state-owned power company of the state. In addition, some small companies handle power distribution for local areas and also some industrial companies generate power for use by themselves.

On the western border of the state formed by the Paraná river, Itaipu hydropower station (12.6 GW) is under operation from 1985 by the Brazil/Paraguay binational company. On the northern border of the state formed by the Paranapanema river, four hydropower plants of CESP (Sao Paulo state's power company) are in service. Power generation within the territory of the Paraná state excepting on the state border rivers is made mainly by the two power companies; COPEL and Eletrosul.

Total installed capacity of generating plants in the Paraná state (except the border rivers) and their energy production in 1993, according to COPEL's year book 1993 (ref.2), are 5,958 MW and 23,738 GWh, respectively as shown in Table-6.14.

Table-6.14 Electric Sources in Paraná State (except border rivers) 1993

	Installed Capacity (MW)			Energy Production (GWh)		
Producers	Hydro	Thermal	Total	Hydro	Thermal	Total
COPEL	3,319	20	3,339	11,029	36	11,065
Eletrosul	2,382	0	2,382	11,689	0	11,689
Self-producers & others	72	166	238	438	543	981
Total	5,773	187	5,959	23,156	579	23,735
	(96.9%)	(3.1%)	(100%)	(97.6%)	(2.4%)	(100%)

As seen in this table, hydropower shares about 97 % of total power generation in the Paraná state in both generation capacity and energy.

On the other hand, electric energy consumed in the Paraná state in 1993 was only 13,387 GWh. This corresponds to 56 % of total energy production in the state. The remaining surplus, 44 % of energy generated, was supplied to neighboring states through the Eletrosul's transmission network.

The Paraná state is broadly divided into 5 river basins; i.e., 4 basins of Iguaçu, Piquiri, Ivai and Tibagi rivers which are primary or secondary tributaries of the Paraná river and another basin composed of Litoranea coastal rivers. At present, major source of electric power in the Paraná state is the Iguaçu river. In view of the generation capacity in 1993, the Iguaçu river has 4 power stations with an aggregate capacity of 5,318 MW and it shares 89 % of the total capacity in the state.

Major hydropower stations (> 5 MW) in service in 1993 in the state are listed in Table-6.15 and their locations are shown in Figure-6.3.

6.4.2 Power Demand Projection

In Brazil, official forecast of future growth of electric power demand as well as strategic planning of national power supply expansion is worked out by GCPS (Coordination Group of Planning of Electric System) formed under Eletrobras. GCPS elaborates two forecasts for different time ranges; short term (10 years) and long/medium term (20 to 30 years). The short term forecast is worked out every year for a succeeding 10 years range and the long term forecast is renewed at an interval of about 5 years.

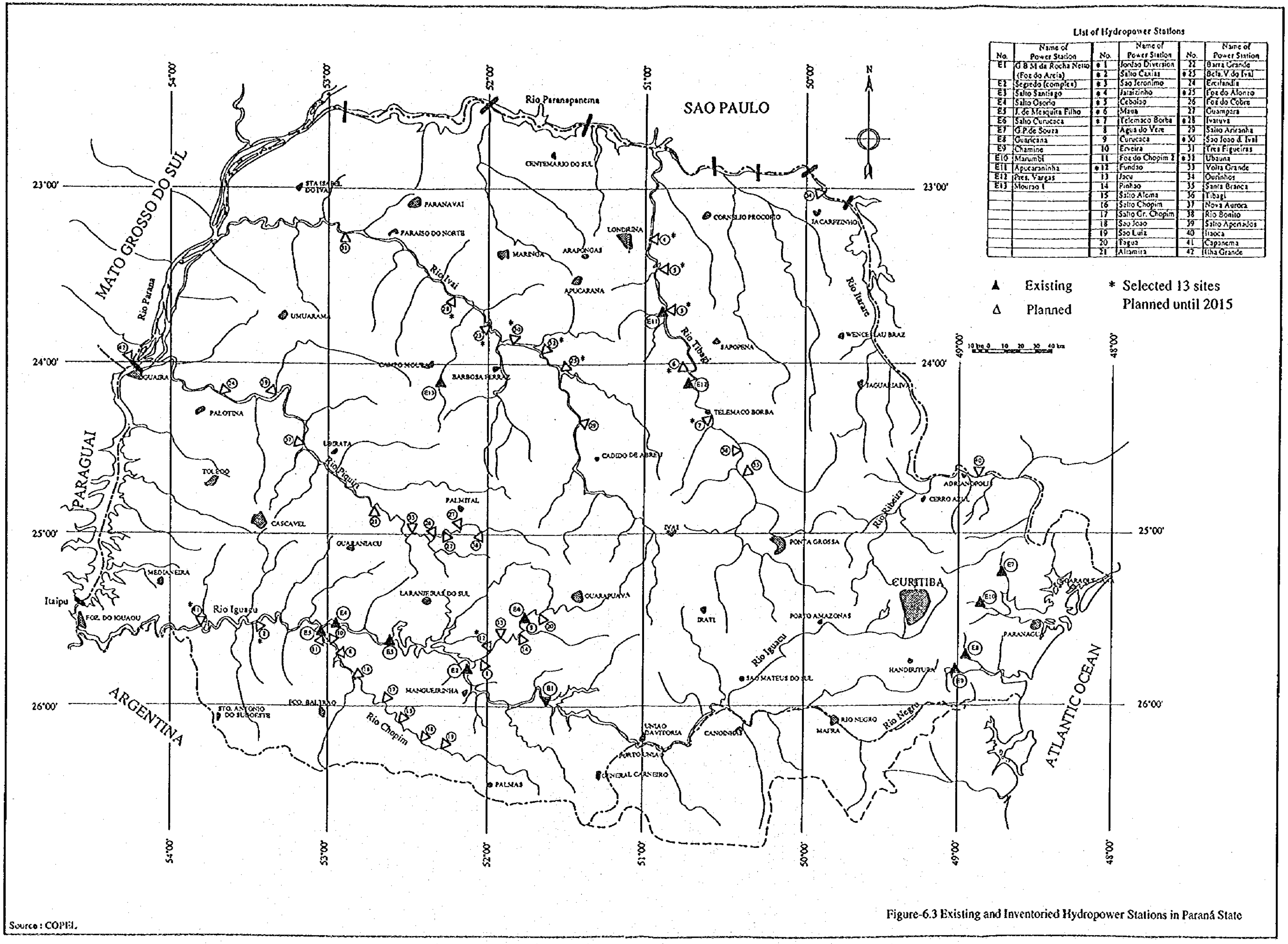
The latest short term forecast is given in "10-Year Expansion Plan 1994-2003" (herein referred to as the 10-year plan) issued in December 1993. The latest formal long term plan is "Plano 2010" which was issued in 1987 for the years up to 2010. However, a next new plan "Plano 2015" is presently under preparation by GCPS and likely to be formalized in 1994 or 1995. Fundamental data for the new plan is presented in a COPEL's seminar document prepared in July 1993. JICA's forecast refers to those GCPS's data; the 10-year plan and the Plano 2015 seminar document.

According to the 10-year plan, population of Brazil increased to 1.6 times for the period from 1970 to 1992 at an average annual rate of 2.1 %. In the same period, the gross domestic product (GDP) and electric energy consumption increased at an average rate of 4.2 % and 8.4 %, respectively. As for the future growth, the 10-year plan envisions that GDP increases at an annual rate of 4.4 % for the period of 1993-1998 and at a 5.0 % annual rate for the period of 1998-2003, i.e. at the 10-year average rate of 4.7 %. This average rate is close to the JICA team's estimate (5 %) of the GDP growth.

Table-6.15 Existing Major Hydropower Stations in Paraná State

Name of Station	Basin	Installed Capacity (MW)	Owner	Commis-sioned in
G.B.M da Rocha Netto (Foz do Areia)	Iguacu	1,676	COPEL	1980
Segredo	Iguacu	1,260	COPEL	1992
Salto Santiago	Iguacu	1,332	Eletrosul	1980
Salto Osorio	Iguacu	1,050	Eletrosul	1975
J. de Mesquita Filho	Iguacu	50	COPEL	1970
Salto Curucaca	Iguacu	7.4	Sta. Maria	1982
G.P.de Souza	Litoranea	252	COPEL	1970
Guaricana	Litoranea	36	COPEL	1957
Chamine	Litoranea	18	COPEL	1931
Marumbi	Litoranea	9.6	RFFSA	1961
Apucaraninha	Tibagi	9.5	COPEL	1949
Pres. Vargas	Tibagi	22.5	Klabin	1947
Mourao 1	Ivai	7.5	COPEL	1964
Total		5,731		

Source: COPEL/GTIB/SIPOT



List of Hydropower Stations

No.	Name of Power Station	No.	Name of Power Station	No.	Name of Power Station
E1	G.B.M da Rocha Netto (Foz do Areia)	*1	Jordao Diversion	22	Barra Grande
		*2	Salto Caxias	*23	Bela.V.do Ival
E2	Segredo (complex)	*3	Sao Jeronimo	24	Ercilandia
E3	Salto Santiago	*4	Jataizinho	*25	Foz do Alonzo
E4	Salto Osorio	*5	Cebolao	26	Foz do Cobre
E5	J. de Mesquita Filho	*6	Maua	27	Guampara
E6	Salto Curucaca	*7	Telemaco Borba	*28	Ivatuva
E7	G.P.de Souza	8	Agua do Vere	29	Salto Ariranha
E8	Guaricana	9	Curucaca	*30	Sao Joao d. Ival
E9	Chamine	10	Erveira	31	Tres Figueiras
E10	Marumbi	11	Foz do Chopim 2	*32	Ubauna
E11	Apucaraninha	*12	Fundao	33	Volta Grande
E12	Pres. Vargas	13	Jacu	34	Ourinhos
E13	Mourao I	14	Pinhao	35	Santa Branca
		15	Salto Alema	36	Tibagi
		16	Salto Chopim	37	Nova Aurora
		17	Salto Gr. Chopim	38	Rio Bonito
		18	Sao Joao	39	Salto Apertados
		19	Sao Luiz	40	Itaoca
		20	Tagua	41	Capanema
		21	Altamira	42	Ilha Grande

▲ Existing
Δ Planned

* Selected 13 sites Planned until 2015

Figure-6.3 Existing and Inventoried Hydropower Stations in Paraná State

Source : COPEL

In respect of power demand growth in Brazil, the JICA team considers that estimations in the 10-year plan for the near future and the scenario II for the remote future give most realistic figures. Accordingly, this JICA team's power demand study refers to the demand projections in the 10-year plan for the period up to 2003 and in the scenario II of the Plano 2015 for the period from 2005 to 2015. For the demand growth between 2003 and 2005, it is estimated on the assumption that the demand increases linearly from the value of 2003 in the 10-year plan to the value of 2005 in the Plano 2015.

As the power system of the Paraná state is interconnected to the south/southeast regional network, amount of electric energy to be produced in the Paraná state depends not only on the demand in the state but also on the whole demand of the interconnected system. In the 10-year plan and the Plano-2015, energy demands are projected region by region applying various increasing rates different by regions. The demand increasing rates averaged for Brazil and for the regions covered by the south/southeast system are as shown in Table-6.16.

Table-6.16 Annual Increase Rate of Energy Demand (%)

	1993-98	1998-03	2003-05	2005-10	2010-15
South/Southeast System	4.0	4.6	7.4	3.5	3.2
Whole Brazil	4.3	5.1	8.7	4.0	3.8

Yearly electric energy demands projected on the basis of the above increasing rates are shown in Table-6.19. Actual energy consumption in 1992 and projected demands in 2005 and 2015 are summarized in Table-6.17.

Table-6.17 Energy Demand (Twh)

	Actual	Projected	
	1992	2005	2015
South/southeast system	176.5	319.0	444.3
Whole Brazil	224.0	430.6	631.3

On the other hand, in the GCPS's data, estimation of peak power demand growth is not clearly indicated. Its reason would be that majority of power sources in Brazil is hydropower and most of major hydropower stations have large reservoirs suitable for peaking operation. Installed capacities of those stations are determined at sufficiently high level taking into account of extreme draught years and regional variation in availability of river water.

Load factors of Brazil's power system estimated in Plano-2015 were 0.69 for 1990 and 0.75 for the years after 2000. In this JICA team's study, peak power demands are estimated applying the load factors of 0.7 for 1992 and 0.75 for 2005 and 2015. The result is tabulated below.

Table-6.18 Peak Power Demand (GW)

	Estimated	Projected	
	1992	2005	2015
South/southeast system	28.8	48.6	67.6
Whole Brazil	36.6	65.5	96.1

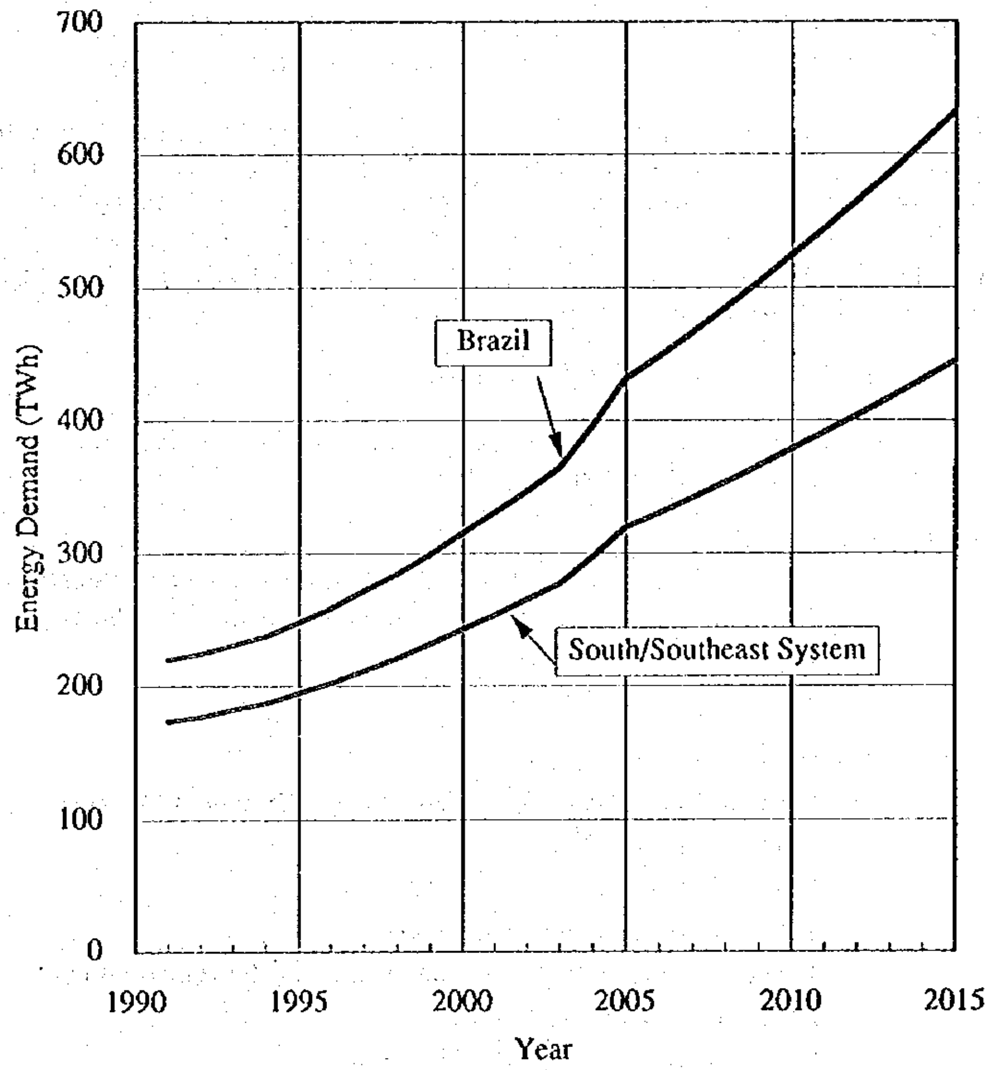
6.4.3 Water Demand Projection for Hydropower in Paraná State

The water demand for hydropower plant is defined here as the rate of discharge required for generating the firm energy designated for the plant.

Approximate water demand of each plant for continuous generation of power equivalent to average hourly firm energy which is given by dividing the value of the firm energy (GWh) by 8760 hours is calculated in the Sectoral Report vol.F. Hydroelectric Power Generation.

On the other hand, the DNAEE's regulation stipulates the minimum water discharge to be released downstream from the power station, i.e. 80 % of monthly average minimum discharge in the historical series of natural discharge. Any hydropower plant is controlled so as to follow this regulation.

The water demand for hydropower plants has different characteristics to the other water demands for such as domestic water, industrial water and agricultural water. The water used for hydropower plants only passes through water turbine for generation and is not consumed. Therefore, the water demand for hydropower plants does not affect downstream water consumption significantly.



Source: 10-Year Plan 1994-2003 and data for Plano-2015

Table-6.19 Energy Demand Projection 1993-2015

6.5 Inland Navigation

Basically the inland navigation activity in Paraná began in the Paraná river in the region between Foz do Iguaçu (Paraná State) and Tres Lagoas (Sao Paulo State) with the extraction and transportation of the wood in the west of the state of Paraná in the fifties.

Although there were approximately 30 inland navigation companies at that time, these companies were disappeared by expansion of other methods of transportation such as railway transportation and trucking. Based on a hearing from related agencies, only a few navigation companies are operated to transport the agriculture products and vehicles at present. Based on discussions with these companies and SETR, the following commercial waterways are known to be operating;

6.5.1 Present Commercial Waterways

The following navigation companies are operating in Paraná river for carrying either agriculture products or vehicles. (Refer to Figure-6.4)

1) MECA Navigation Company
- Between Hemandarias (Paraguai) and Presidente Epitacio (Sao Paulo State)
- 6 convoys (about 2,100 ton/time) or 7 convoys (about 2,400 ton/time)
- Frequency : 3 times/week
- Type of Cargo : Soybeans

2) F.Andreis Transportation Company
- a) Between Guaira (Paraná) and Salto Guaira (Paraguai) (3.5 km)
  2 Ferry Boats and 2 Tag Boats
  Operation Time : 8:00 a.m. - 19:00 p.m.
  Type of Cargo : Vehicles and Tracks
- b) Between Ilha Grande (Paraná) and Itaquirai (Mato Grosso do Sul)
  2 Ferry Boats and 2 Tag Boats
  Operation Time : 6:00 a.m. - 23:00 p.m.
  Type of Cargo : Vehicles and Tracks
- c) Between Guaira (Paraná) and Mundo Novo (Mato Grosso do Sul) (6 km)
  2 Ferry Boats, 3 Tag Boats
  24 hours operation
  Type of Cargo : Vehicles and Tracks
- d) Between Sao Pedro do Paraná (Paraná) and Bataipora (Mato Grosso do Sul)
  3 Ferry Boats and 3 Tag Boats
  Operation Time : 6:00 a.m. - 19:00 p.m.
  Type of Cargo : Vehicles and Tracks
- e) Between Guaratuba and Matinhos (Paraná) (2 km), Coast Area
  3 Ferry Boats and 3 Tag Boats
  24 hours operation
  Type of Cargo : Vehicles and Tracks

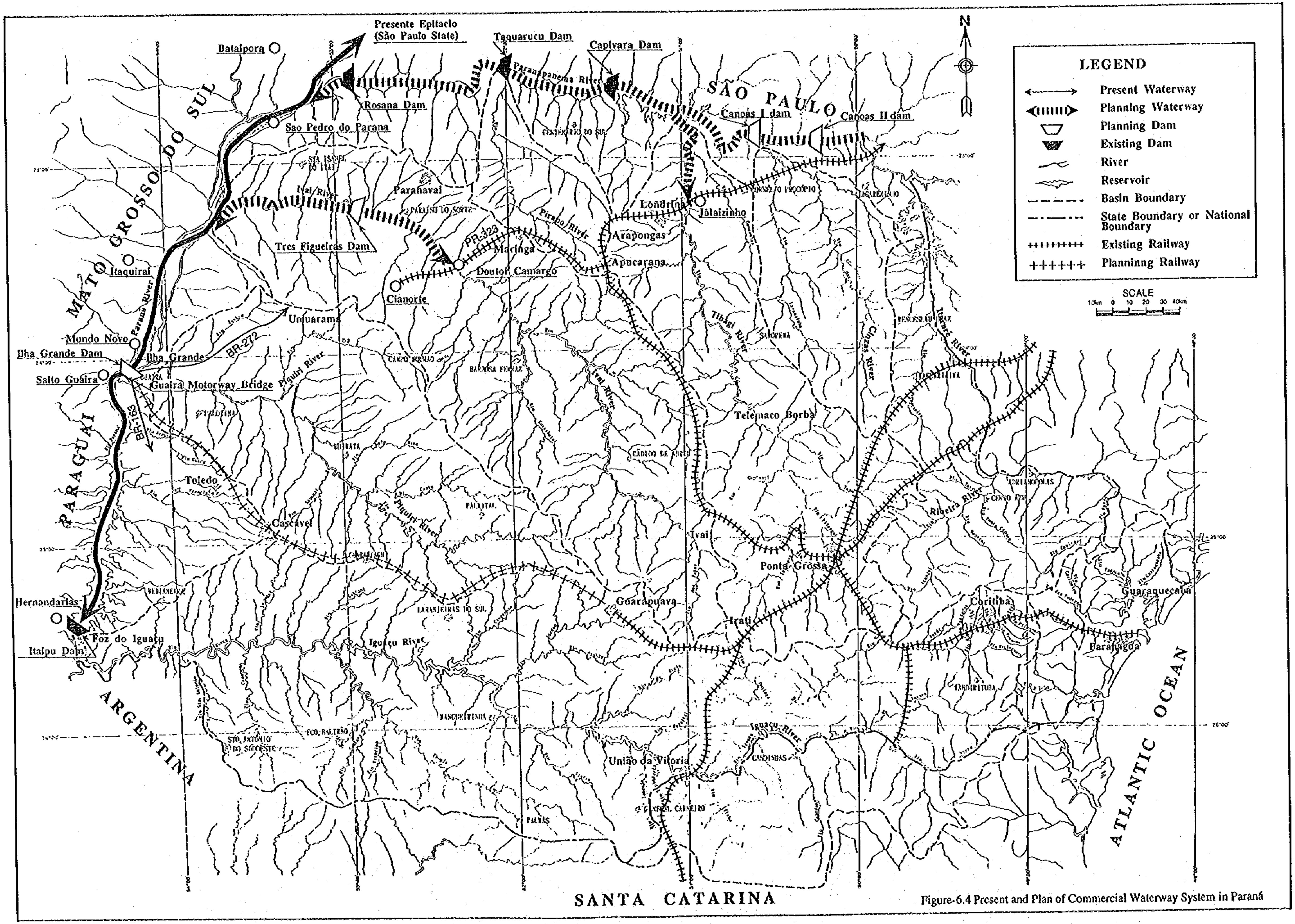


Figure-6.4 Present and Plan of Commercial Waterway System in Paraná

3) Upper Paraná Waterway

Upper Paraná Waterway is composed of the following rivers, and located among four states such as Paraná, Sao Paulo, Mato Grosso do Sul and Minas Gerais. (Refer to Figure-6.5)

<Paraná River>

From Itaipu dam to Sao Simao dam in Paranaiba river and Agua Vermaiha dam in Grande river of about 800 km distance. Today, the width of channel in Paraná river has already sufficient conditions, and locks are being projected with 17.0 m width for future 16.0 m width convoys, but the draught is limited to 1.70 m due to restrictive condition of depth in a few parts.

<Tiete River>

Tiete river mouth to an upstream point of Bonita Barra dam in Sao Paulo State with an extension of 575 km. Tiete river is totally dammed with lock facilities.

<Ivinhema River>

Ivinhema river mouth to Nova Andradina city in Mato Grosso do Sul, with an extension of 110 km. This waterway will be considered with the influence of backwater level by the planned Ilha Grande dam at downstream.

6.5.2 Other Transportation Methods

1) Extension of Motorway

At present, a bridge with a span of about 3.5 km linking Paraná State to Mato Grosso do Sul State over the Paraná river at Guaira to connect with existing BR-272 and BR-163 highways is being constructed since year of 1990, and the target of completion will be December 1995. If the bridge has been operating, 2,000 vehicles shall be crossing daily. It means that above existing mentioned waterways such as from Guaira to Salto Guaira and from Guaira to Itaquirai may reduce/ or stop their ferry operation.

2) Extension of Railway

At present, a railway with an extension of about 220 km has been constructing parallel with existing roadway between Cascavel and Guarapuava, and also further extension of between Guarapuava and Guaira with extension of about 130 km has been planned. If the extension of railway to Guaira has been completed, routes from Guaira to Ponta Grossa, Curitiba and other stations will be connected in the future.

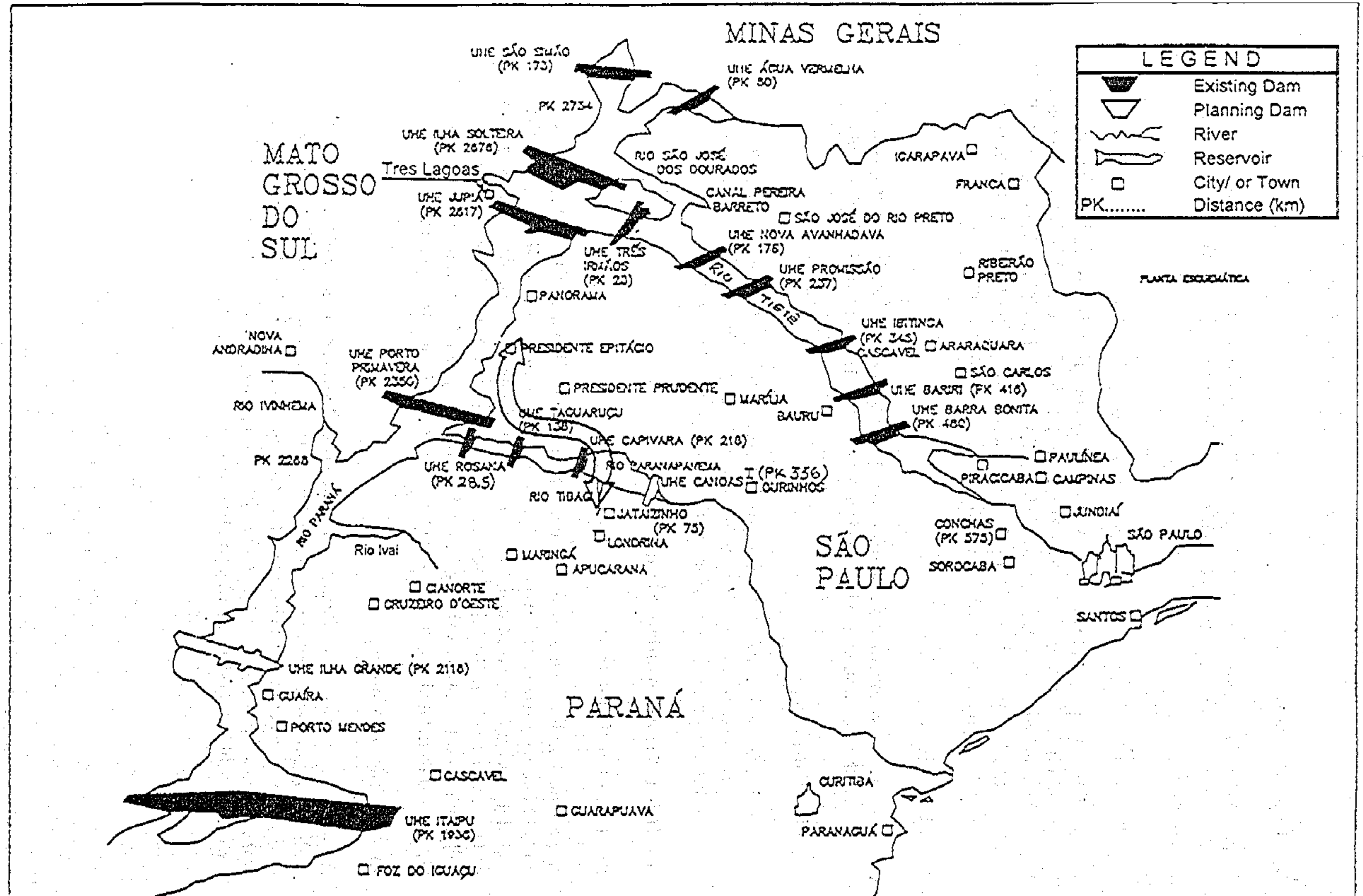


Figure-6.5 Upper Paraná Waterway System

6.6 Water Demand Projection by Sector and by Region

6.6.1. Zoning for Demand Projection

The state of Paraná, which is composed of 371 municipalities as of 1993, is divided into several regions based on the micro-zoning established by the state government. The zoning number and boundary vary among the institutions on their purpose.

There are two kinds of micro-zoning adopted in the Study. One is Homogeneous Micro Region (Micro Regiões Homogeneas: MRH) and the other is EMATER's regional zoning, both of which are composed of municipality units.

There are 24 MRHs, from MRH - 268 to MRH 291, in the Paraná state and they are the units for socio-economic statistics such as population, value added for each industrial sectors, GDP, etc. The demand for domestic water and industrial water were projected based on MRH. unit.

There are 20 of EMATER's regional zonings, and they are the units for agricultural statistics and policy making. The agricultural water demand was projected based on EMATER's units.

6.6.2 Demand Distribution to River Basin

In order to estimate the balance between demand and supply, demand is to be distributed to each river basin.

Domestic and industrial water demand were distributed from MRH unit to river basins.

The agricultural water demand which is composed of livestock water and aquaculture water was estimated based on the EMATER's regional unit. The EMATER's zone is composed of municipality units and the water demand is assumed to be homogeneous in each zone. Therefore, the water demand is distributed to each municipality at first and then summed up by MRH unit and by river basin. The relation between MRH units and river basins are shown in the Figure-6.6.

6.6.3 Water Demand Projection by Sector and by Region

The water demand projection by sector and by region was calculated for the base case as shown in Table-6.20 and 6.21.

6.7 Environmental Sanitation Program for Curitiba Metropolitan Region (PROSAM)

PROSAM is an environmental sanitation project for Curitiba Metropolitan region including water supply, flood control and urban drainage, sewerage system, environment conservation etc. It includes construction of Irai dam for water supply of 2.0 m^3/sec, drainage channel excavation with a length of 15 km along left bank of the Iguaçu River, development river park, sewer pipe line with a length of 1,300 km, 8 sewerage treatment plants, solid waste disposal, bridges, and environmental education, etc. The total project cost amounts to US$ 233 x 10^6, 52% of which is to be financed by the World Bank. The project is scheduled to be implemented from 1992 to 1997. However, the progress rate as of June 1995 is estimated less than 20%.

Table-6.20 Water Demand by Sector and by River Basin (Base Case)

Basin	1993				2005				2015			
	Urban		Rural		Urban		Rural		Urban		Rural	
	Domestic	Industrial	Domestic	Agricultural	Domestic	Industrial	Domestic	Agricultural	Domestic	Industrial	Domestic	Agricultural
Cinzas	17,090	6,390	7,260	7,820	25,340	11,060	4,850	9,690	35,140	14,790	3,260	11,240
Iguacu	319,610	285,860	49,660	44,900	523,030	424,940	44,920	57,570	784,610	545,680	38,830	67,130
Itarare	6,990	7,600	2,740	3,300	12,080	15,660	1,960	4,120	17,660	23,280	1,380	4,770
Ivai	83,200	33,140	27,900	30,900	124,170	56,300	19,680	37,800	177,990	77,310	14,830	43,380
Litoranea	15,320	2,530	2,870	450	23,470	820	2,990	570	33,600	320	2,940	690
Parana 1	710	190	680	1,980	1,020	310	390	2,370	1,420	430	230	2,730
Parana 2	1,810	500	2,170	3,780	1,960	770	1,160	4,500	2,490	1,020	650	5,190
Parana 3	52,740	16,410	7,750	10,200	112,170	19,730	5,050	13,030	173,190	20,630	3,360	15,070
ParanaPanema1	7,380	2,770	1,120	1,050	10,850	4,420	710	1,300	15,190	5,570	450	1,510
ParanaPanema 2	1,680	630	400	370	2,480	1,010	250	460	3,470	1,270	160	540
ParanaPanema 3	17,780	7,150	2,290	3,760	27,730	10,980	1,260	4,650	40,880	14,120	720	5,370
ParanaPanema4	6,270	1,690	1,660	4,790	9,070	2,770	950	5,730	12,620	3,800	570	6,610
Piquiri	42,710	13,200	19,490	21,560	71,030	18,440	13,500	26,650	104,170	22,690	9,830	30,710
Pirapo	46,410	24,270	3,390	5,880	75,250	41,210	1,820	7,210	112,500	56,730	1,020	8,320
Ribeira	7,710	7,960	5,810	2,870	12,580	11,550	5,540	3,710	18,930	14,670	5,000	4,320
Tibagi	121,670	66,000	15,010	14,600	188,930	104,450	11,910	18,260	275,340	132,760	9,670	21,190
Total	749,080	476,290	150,200	158,210	1,221,160	724,420	116,940	197,620	1,809,200	935,070	92,900	228,770

Table-6.21 Water Demand by Sector and by MRH (Base Case)

MRH	1993				2005				2015			
	Urban		Rural		Urban		Rural		Urban		Rural	
	Domestic	Industrial	Domestic	Agricultural	Domestic	Industrial	Domestic	Agricultural	Domestic	Industrial	Domestic	Agricultural
MRH 268	253,470	251,450	8,840	2,920	413,160	371,690	8,530	3,800	622,540	475,250	7,740	4,400
MRH 269	15,320	2,530	2,350	270	23,470	820	2,450	340	33,600	320	2,410	420
MRH 270	580	880	1,710	910	950	1,090	1,620	1,190	1,410	1,300	1,470	1,390
MRH 271	540	400	2,340	730	860	620	2,720	940	1,180	890	2,890	1,110
MRH 272	6,360	8,520	3,220	2,160	9,570	12,450	3,480	2,770	13,570	17,060	3,530	3,230
MRH 273	36,660	31,310	4,570	5,000	57,360	51,690	4,160	6,310	83,170	64,890	3,580	7,370
MRH 274	4,580	8,690	1,470	1,900	9,010	17,830	1,170	2,400	13,990	26,450	860	2,800
MRH 275	2,110	1,790	2,420	920	3,420	2,350	2,630	1,160	5,040	3,400	2,650	1,340
MRH 276	7,540	3,170	7,250	3,340	11,750	4,900	7,750	4,250	16,950	6,630	7,780	4,920
MRH 277	2,040	280	5,050	3,690	3,100	400	4,460	4,640	4,170	550	3,730	5,400
MRH 278	8,200	620	5,000	6,000	11,720	1,440	3,380	7,430	15,300	2,270	2,310	8,570
MRH 279	23,180	8,690	6,050	5,690	34,070	13,870	3,820	7,020	47,720	17,500	2,450	8,180
MRH 280	5,190	1,920	1,990	1,460	7,830	1,940	1,190	1,820	11,120	1,810	740	2,110
MRH 281	96,010	38,610	6,650	10,950	149,710	59,300	3,650	13,530	220,740	76,230	2,080	15,630
MRH 282	52,610	31,410	2,500	4,340	87,760	54,370	1,260	5,310	132,840	76,200	670	6,130
MRH 283	21,590	5,810	4,560	13,210	31,230	9,530	2,630	15,830	43,440	13,080	1,560	18,240
MRH 284	22,470	9,000	7,330	6,410	33,530	17,230	4,040	7,910	47,570	23,420	2,340	9,100
MRH 285	27,370	7,580	9,640	16,810	29,640	11,610	5,140	20,170	37,570	15,470	2,870	23,080
MRH 286	25,400	8,970	9,280	9,050	40,350	13,780	5,400	11,020	58,980	18,380	3,250	12,650
MRH 287	2,870	330	6,430	4,010	4,810	540	5,960	4,930	6,660	740	5,270	5,700
MRH 288	80,420	25,020	18,530	24,390	171,050	30,090	12,060	31,140	264,100	31,460	8,020	36,020
MRH 289	24,690	9,970	16,670	19,270	39,700	19,220	12,160	24,990	58,610	27,600	7,480	29,250
MRH 290	18,850	10,650	11,030	6,220	29,990	15,140	11,960	7,800	44,160	22,220	12,170	8,940
MRH 291	11,030	8,690	5,320	8,560	17,120	12,520	5,320	10,920	24,770	11,950	5,050	12,790
Total	749,080	476,290	150,200	158,210	1,221,160	724,420	116,940	197,620	1,809,200	935,070	92,900	228,770

CHAPTER 7 WATER RESOURCES DEVELOPMENT

7.1 Surface Water Potential

7.1.1 Current Water Use

(1) Present Water Supply in Paraná State

Domestic water for urban area is supplied to 98% of urban population. SANEPAR supplies water to 89% of urban population and other organizations, including municipalities, supply the rest.

Water source depends on surface water in 85%, and groundwater in 15%. The areas where the percentage of surface water is high are Iguaçu, Tibagi, Cinzas and Litoranea river basins, and use of groundwater prevails in Paraná residual basins and Paranapanema residual basins.

(2) Current Water Use Survey

Information and data on water use are scattered among related organizations and types of registration form are also different. To understand the present situation of water use, the following investigations were carried out.

a) Collection of Registered Data

IAP	Water Right Registration	1,680
	Application of Factory Construction	1,299
SANEPAR	Water Use in Systems	1,820
COPEL	Hydroelectric Water Use	113
EMATER	Agricultural Water Use	1,484

b) Questionnaire survey for branch offices of IAP, EMATER and SANEPAR, and municipalities.

c) Interview survey of branch offices of IAP, EMATER and municipalities.

After processing the collected data, the database system was prepared.

7.1.2 Criteria for Surface Water Development

Main points of the Criteria in the Paraná State are as follows:

1) Allowable direct intake water should be less than 50% of $Q_{10,7}$.

   Q_7 ; Annual minimum of average discharge of continuous 7 days.

   $Q_{10,7}$; Q_7 discharge with occurrence probability of once in 10 years.

2) Minimum discharge to downstream of intake point should be more than 50% of $Q_{10,7}$

3) Allowable intake for public supply shall be more than 10% of $Q_{10,7}$ due to imposed restrictions for potential pollutant above intake point (State Law number : 8935/89)

4) Permission of water intake shall be given, in the case that intended use will be compatible to the water quality standard established in CONAMA Resolution number : 20/86 and State Law number: 8935/89.

In addition to the above, DNAEE stipulates that the discharge from dams for hydroelectric power should be more than 80% of the monthly average minimum discharge in the historical series of natural discharge of the river.

7.1.3 Surface Water Potential for Each Basin

Applying the mentioned water development and maintenance discharge criteria, an amount of surface water potential by discharge reference point was computed as follows;

(1) Discharge Reference Point

Each river basin was divided into maximum 5 blocks as shown in Figure-7.1 for convenience of surface water development study mentioned later in the Section-7.4. The boundary of each block crossing the river basin was determined along the boundary of the municipality as similar as possible to the natural boundary of tributary basins.

30 discharge reference points were determined downstream of each block. Surface water potential is to be calculated at discharge reference points.

(2) Surface Water Potential

Surface water potential was calculated by deducting maintenance discharge (0.5 $Q_{10,7}$) from the low water flow ($Q_{10,7}$; obtained using the maps of HG52 from CEHPAR (1982)) at each reference point. The water use of the upstream was not considered in the above calculation. The results are shown in Table-7.1 and Figure-7.1.

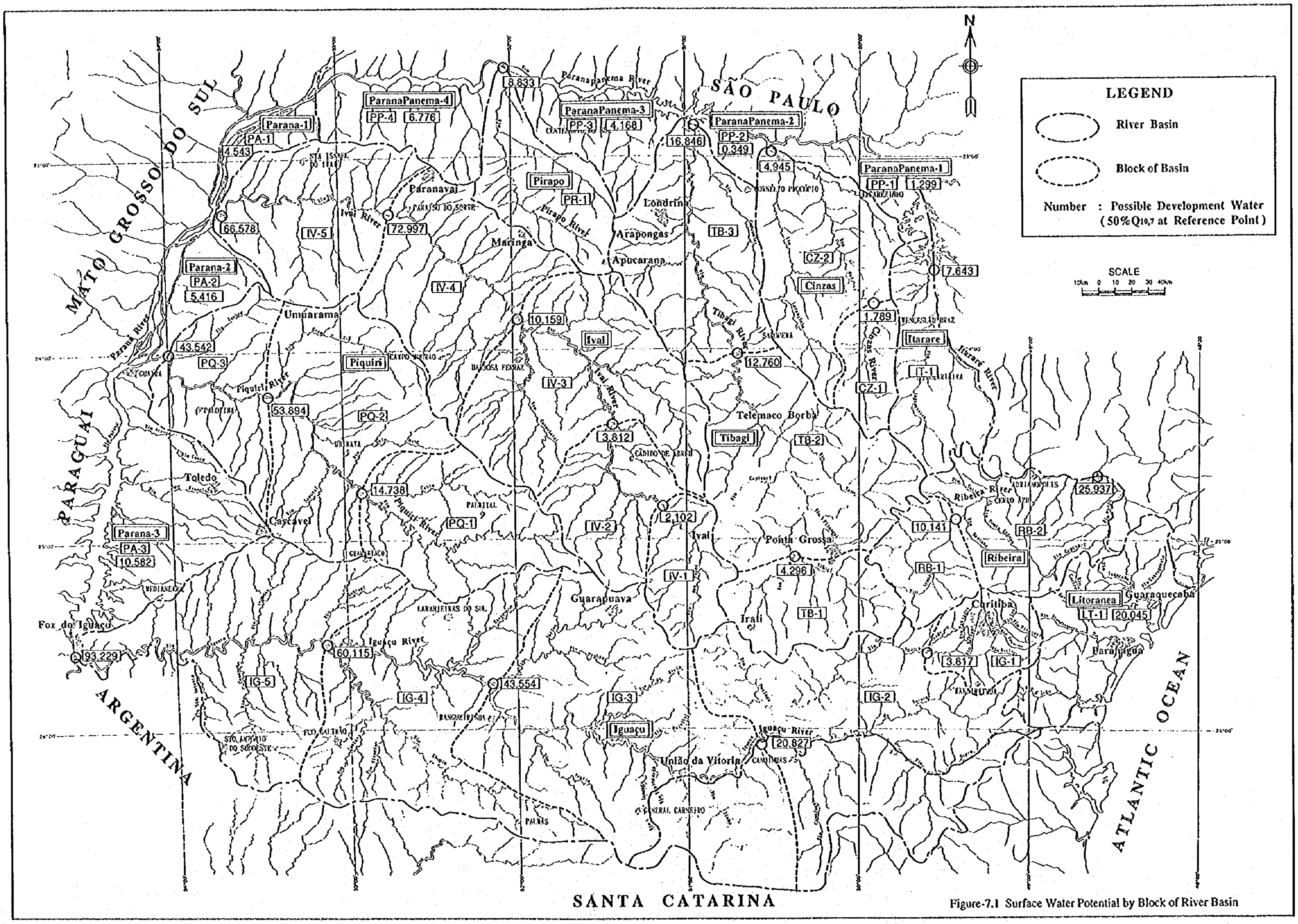


Figure-7.1 Surface Water Potential by Block of River Basin

Table-7.1 Surface Water Potential at Each Reference Point

No.	Basin	Block	Area [km²]	Potential [m³/s]
[1]	Cinzas	CZ-1	1,970	1.789
[2]		CZ-2	9,291	4.945
[3]	Iguaçu	IG-1	3,590	3.817
[4]		IG-2	18,300	20.827
[5]		IG-3	38,670	43.554
[6]		IG-4	57,000	60.115
[7]		IG-5	68,700	93.229
[8]	Itarare	IT-1	5,198	7.643
[9]	Ivai	IV-1	3,170	2.102
[10]		IV-2	8,442	3.812
[11]		IV-3	19,992	10.159
[12]		IV-4	29,206	72.997
[13]		IV-5	35,879	66.578
[14]	Litoranea	LT-1	5,766	20.045
[15]	Paraná-1	PA-1	1,332	4.543
[16]	Paraná-2	PA-2	3,157	5.416
[17]	Paraná-3	PA-3	8,668	10.582
[18]	Paraná Panema-1	PP-1	1,246	1.299
[19]	Paraná Panema-2	PP-2	695	0.349
[20]	Paraná Panema-3	PP-3	3,712	4.168
[21]	Paraná Panema-4	PP4	4,144	6.776
[22]	Piquiri	PQ-1	8,745	14.738
[23]		PQ-2	18,969	53.894
[24]		PQ-3	24,708	43.542
[25]	Pirapo	PR-1	5,006	8.833
[26]	Ribeira	RB-1	4,016	10.141
[27]		RB-2	9,129	25.937
[28]	Tibagi	TB-1	5,148	4.296
[29]		TB-2	16,475	12.760
[30]		TB-3	24,635	16.846

7.2 Groundwater Potential

7.2.1 Methodology

For sustainable development, assessment of groundwater potential is necessary to be carried out on the basis of water balance between surface water and groundwater in addition to the borehole yield analysis by pumping test considered with drawdown of groundwater table.

The following three ways of assessing groundwater potential were adopted in consideration of available data :

- Borehole yield analysis by pumping test considered with drawdown of groundwater table.
- Interference area analysis during pumping test.
- Baseflow analysis on the basis of water balance between the river discharge and circulating groundwater such as transitional recharge.

7.2.2 Estimation of Groundwater Potential on the Basis of Borehole Yield Analysis by Pumping Test Data

The estimation of groundwater potential on the basis of pumping test data can be roughly calculated by the following formula:

$$GR = A \times Qc \,/\, (3.14 \times r_{wi}^2)$$

GR. ; Groundwater Resources of Respective Aquifer, A; Area of Aquifer

Qc ; Critical Yield of Respective Aquifer, r_{wi} ; Radius of Well Interference

However, the above formula is presented for a part of groundwater resources which is a "Critical Pumping Yield" and not total volume of groundwater resources. The calculation results on the basis of the above formula are shown in Table-7.2.

In consequence of the above results, the high potential aquifers in Paraná State are as follows :

1) Botucatu Formation and Serra Geral Formation

2) the "Karst"

3) Caiua Formation

The groundwater potential of Botucatu Formation is assessed to be extremely large due to large aquifer distribution and porosity. It's productivity is also high because the aquifer is highly confined.

However, the above result doesn't mean the groundwater potential for the sustainable development, but it means productivity's of boreholes in the yield.

Table-7.2 Assessment of Groundwater Resources on the Basis of Pumping Tests

No.	Aquifer	Subarea	Aquifer Type: porous	Aquifer Type: fracture	Area A (km2)	Well Depth in general (m)	Diameter of Well Bottom in general (mm)	Critical Yield in general (m3/h)	Spacific Capacity in general (m3/h/m)	Radius of Well Interference in general (m)	Estimation of Groundwater Resources by the Radius of the Well Interference (m3/h/km2)	Estimation of Groundwater Resources by the Radius of the Well Interference (l/s/km2)	Estimation of Groundwater Resources Resources in Groundwater Basins (million*m3/d)	Estimation of Groundwater Resources Resources in Groundwater Basins (m3/s)	Principal Cities
1	(the Karst) in Acungui & Setuva G.		A	AAA (CAVE)	5,740 (3,480)	80	250	160	70	400	320	89	27 (X 3480 km2)	313 *3	Curitiba, Campo Largo, (Metropolitan Curitiba)
2	Crystalline rocks in Pre-Ordovician		X	b~c	17,500	120	150	20	1	500	25	6.9	11	121	Pirai do Sul, Doutor Ulysses Mandirituba, Campo do Tenente
3	Early Paleozoic / Castro/Parana Group		X	b~c	7,150				0.7	500	13	3.6	2.2	25.7	Ponta Grossa, Tibagi, Pirai do Sul
4	Middle-Late Paleoz. Itarare/Guata Group		C	b~c	17,400	150	150	10	1	400	20	5.6	8.4	97.4	Tomazina, Telemaco Barba, Ipiranga Teixeira Soares, Lapa
5	Late Paleozoic Passa Dois Group		X	b~c	15,700				0.5	500	13	3.6	4.9	56.5	Joaquim Tavora, Sapopema, Ival, Irati, Sao Mateus do Sul
6/7	Botucatu & Serra Geral Fm.												2000	28000	
6~7	Botucatu F. / recharge zone		AA	X	12,560	100	200	50	3	200	398	110	120	1400	Ponta Grossa, Castro, Pirai do Sul, Tibagi
6~7	Botucatu & Serra Geral Fm. / confined aquifer zone		AAA	A	24,080	200	250	150	5	300	531	150	300	3600	Tomazina, Telmaca Barba, Ipiranga, Texeira Sores, Lapa
6~7	Botucatu & Serra Geral Fm. ; deep sheeted & confined aquifer zone		AAA	-	105,480	1,100	200	200	12	300	708	200	1800	21100	Joaquim Tavora, Sapopema, Curiuva, Reserva, Ival, Irati, Sao Mateus do Sul
6	Serra Geral F.	Norte	X	AA	59,050	120	200	40	2	400	80	22	110	1300	Londrina, Cornelio Procopio, Apucarana Maringa, Cascavel, Camp Mourao, Toredo
7		Sulu	X	A	42,060	180	150	12	0.8	500	15	4.2	15	180	Guarapuava, Palmas, Laranjeiras do sul Foz do Iguacu, Pato Branco
8	Caiua Formation		A	X	30,450	120	200	30	1.5	300	110	31	80	51	Paranavai, Loanda, Tapira, Icaraima, Umuarama, Cianorte,
9	(Metropolitan Curitiba Area)				1,130								>0.25		Metropolitan Curitiba
10	Guabirotuba F. sd bed		B	X	950 (300) *2	60	100	12	2	500	15	4.2	0.11	1.26	
11	Aluvium System in Flood Plane		AA	X	180				-	-					
12	Granitic rocks		X	C	(300)	120	100	15	1	500	19	5.3	0.14	0.11	
13	(Quaternary Sys. in Coastal Range)				1,950 *1								>2.5		Paranaval, Guaraquecaba, Matinhos, Guaratuba,
14	Quat. River Bed (Delta/River Bed)		AA	X	380	8	40	20	20	150	280	80	2.6	190	Antonina, Alexandra, Serra Negra,
15	Marine Terrace Deposit		A	X	1,570	8	150	1	3	200	8.0	2.2	0.30	3.50	Praia de Leste, Ilha do Mel, Ipanema

Legend in terms of Aquifer Type : AAA; very high potencial, AA; higher potential, A; high potential, B; moderate potential, C; low potential, X; no potential, b-c; partial potencial(moderate~ low potential)

*1 : Aquifer in Quat. River Bed is recharged by upper streams in area of Crystalline rocks.

*2 : Aquifer of Guabirituba F. is composed of sd. layers underlain in about 1/3 area in the exposured area of Guabirituba F.

*3 : Area of cabonate rocks in the "Karst"

7.2.3 Estimation of Aquifer Potential on the Basis of Interference Area of Pumping and Geological Setting of Aquifers

The total volume of aquifer's groundwater potential is estimated on the basis of following formula and data summarized by the well inventory database and geology as shown in Table-7.3.

$$GR = (A / Ai) \times Sc \times D \times (3.14 \times Ir^2)$$

GR: Total Groundwater Potential of respective aquifers

A: Area of aquifer, Ai : Area of pumping interference ($Ai = 3.14 \times Ir^2$),

D : Tickness of each aquifer (assumed by conceptional aquifer model),

Sc: Coefficient of storage (= effective permeability), $Sc = Qt / (3.14 \times ds \times Ir^2)$,

Qt: Total volume of discharge from pumping start time to being time of critical yield,

ds: Drawdown of groundwater table during pumping,

Ir : Interference radius of groundwater table during pumping,

This table indicates that large amount of groundwater resources is stored in the aquifer areas in Paraná State. The order of stored volume is ranked as follows:

1) Botucatu Formation

2) Serra Geral Formation north

3) Caiua Formation

4) "Karst"

5) Serra Geral Formation south

However, this result does not necessarily mean that groundwater development potential of these aquifers is extremely high from standpoint of the sustainable use.

7.2.4 Estimation of Groundwater Potential on the Basis of Relationship between Baseflow of River Discharge and Transitional Recharge of Groundwater

Generally, the groundwater resources are composed of circulating parts and stored parts. Their circulating parts, in their turn, are composed of two parts: transitory recharge and deep recharge, but deep recharge is considered very small in the mean for long period such as 20 years.

Some of the circulating groundwater resources are utilized for domestic, industrial and agricultural water. Besides they supply baseflow as transitory recharge into river and maintain the minimum discharge in drought seasons for preservation of water environment in natural. Therefore, the sustainable development can not allow totally the use of the circulating groundwater for the above social and natural convenience. The part of it is defined as Permissive Yield. Thus concept of Permissive Yield is very important for the assessment of groundwater potential under consideration of sustainable development of groundwater resources.

Table-7.3 Assessment of Aquifer Potential on the Basis of Interference Areas during Pumping Test

[1]	[2] Aquifer	[3]	[4] Aquifer Type porous	[5] Aquifer Type fracture	[6] Area km2	[7] Borehole Depth m	[8] Diameter of Borehole mm	[9] Critical Yield m3/h	[10] Specific Capacity m3/h/m	[11] Radius of Interference m	[12] Groundwater Potential in 1 km 2 m3/h/km2	[13] Groundwater Potential in 1 km 2 l/s/km2	[14] Total Groundwater Potential for Respective Aquifer million m3/h/km2	[15] Total Groundwater Potential for Respective Aquifer m3/km2	[16] Principal Municipalities
1	(the Karst) in Acungui & Setuva G.		A	AAA (CAVE)	3,740 (3,480)	80	250	160	70	400	320	89	27 (3,480km2 of the area) *3	313 (3,480km2 of the area) *3	Curitiba, Campo Largo, (Metropolitan Curitiba)
2	Crystalline rocks in Pre-Ordovician		X	b~c	17,500	120	150	20	1	500	25	6.9	11	121	Pira do Sul, Doutor Ulysses Mandirituba, Campo do Tenente
3	Early Paleozoic; Castro/Parana Group		X	b~c	7,150				0.7	500	13	3.6	2.2	25.7	Ponta Grossa, Tibagi, Pira do Sul
4	Middle-Late Paleozoic Itarare/Guata Group		X	b~c	17,400	150	150	10	1	400	20	5.6	8.4	97.4	Texaira Soares, Lapa
5	Late Paleozoic Passa Dois Group		X	b~c	15,700				0.5	500	13	3.6	4.9	56.5	Joaquim Tavora, Sapopema, Ivai, Irati, Sao Madeus do Sul
6/7	Botucatu & Serra Geral Fs.							(124 L/s) Deep Botucatu					2,000	28,000	
6~7	Botucatu F. : recharge zone		AA	X	12,560	100	200	50	3	200	398	110	120	1400	Ponta Grossa, Castro, Pira do Sul, Tibagi
6~7	Botucatu & Serra Geral Fs. : confined aquifer zone		AAA	A	24,080	200	250	150	5	300	531	150	300	3,600	Tomazina, Telmaco Borba, Ipiranga, Texaira Soares, Lapa
6~7	Botucatu & Serra Geral Fs. : deep sheeted & confined a.zone		AAA	-	105,480	1,100	200	200	12	300	708	200	1,800	21,100	Joaquim Tavora, Saponema, Curiuva, Reserva, Ivai, Irati, Sao Mateus do Sul
6	Serra Geral F.	Norte	X	AA	59,050	150	200	40	2	400	80	22	110	1,300	Londrina, Cornelio Procopio, Apucarana Maringa, Cascavel, Camp Mourao, Toredo
7		Sula	X	A	42,060	180	150	12	0.8	500	15	4.2	15	180	Guarapuava, Palmas, Laranjeiras do sul Foz do Iguacu, Pato Branco
8	Caiua Formation		A	X	30,450	120	200	30	1.5	300	110	31	80	51	Paranavai, Loanda, Tapira, Icarama, Umuarama, Cianorte,
9	(Metropolitan Curitiba Area)				1,130								>0.25		Metropolitan Curitiba
10	Guabirotuba F. sd bed		B	X	950(300)*2	60	100	12	2	500	15	4.2	0.1	1.3	
11	Aluvium System in Flood Plane		AA	X	180				-	-					
12	Granitic rocks		X	C	(300)	120	100	15	1	500	19	5.3	0.1	0.1	
13	(Quaternary Sys. in Coastal Range)				1,950 *1								>2.9		Paranavai, Guaraquecaba, Matinhos, Guaratuba,
14	Quat. River Bed (Delta/River B.		AA	X	380	8	40	20	20	150	280	80	2.6	190	Antonina, Alexandra, Serra Negra,
15	Marine Terrace Deposit		A	X	1,570	8	150	1	3	200	8	2.2	0.3	3.5	Praia de Leste, Ilha do Mel, Ipanema

Legend in Items of Aquifer Type : AAA; very high potencial, AA; higher potential, A; high potential, B; moderate potential, C; low potential, X; no potential, b~c; partial

*1 : Aquifer in Quat. River Bed is recharged by upper streams in area of Crystalline rocks.

*2 : Aquifer of Guabirotuba F. is composed of sd. layers underlain in about 1/3 area in the exposured area of Guabirotuba F.

*3 : Area of cabonate rocks in the "Karst"

[11]; Interfernce radius of drawdown during pumping test

In the determination of Permissive Yield for respective aquifers, the ratio of sustainable development/estimated circulating groundwater resources is assumed on the basis of experimental presumptions and consideration of reservoir structures. The Permissive Yield for respective aquifers is shown in Table-7.4.

In addition, the amount of groundwater potential was calculated on the assumption that amount of deep recharge is negligible, so that the data of meteorological and river discharge are used in the average of about twenty (17 ~ 20) years for the analysis.

The transitory recharge of groundwater resources can be estimated by the analysis of baseflow, because baseflow of river comes from the discharge from groundwater.

In the view of the above baseflow, the partial estimation of transitory groundwater resources for each aquifers and groundwater basins were studied using the low discharge data of Q_7 by IAP and the low discharge data of 355 day's discharge in "Flow Regime" by JICA Team. The mean baseflow in respective exposure units of aquifers were decided by the relationship between the above mentioned low discharges (Q_7 and 355 day's discharge data) and the catchment areas corresponding to the discharge shown in Figure-7.2. Therefore, the average of Q_7 for long years like as 17 years in a catchment areas was assumed almost same as baseflow analyzed by hydrograph. Furthermore, the mean Q_7 and 355 day's discharges were adopted as the baseflow in this study. The assessment result of the groundwater potential on the basis of the water balance is shown in Table-7.4.

The baseflow of Metropolitan Curitiba in Table-7.4 is smaller than average. This evidences can be explained to be that the circulating parts of groundwater resources in Metropolitan Curitiba are not discharged to the Iguaçu basin but they are discharged to the Coastal range and the "Karst" area. In addition to the above, the discharge mechanism can be caused by the following two reasons :

1) The geographical situation of Curitiba Metropolitan Area is much higher than that of the Coastal Range and the "Karst" area.
2) The fracture reservoirs developed in Pre-Cambrian are connecting their different geographical situation over the river basins (the Upper Iguaçu River Basin, the Coastal range and the "Karst" area).

Therefore, the baseflow analysis shows high potential of transitory groundwater resources for the following aquifers :

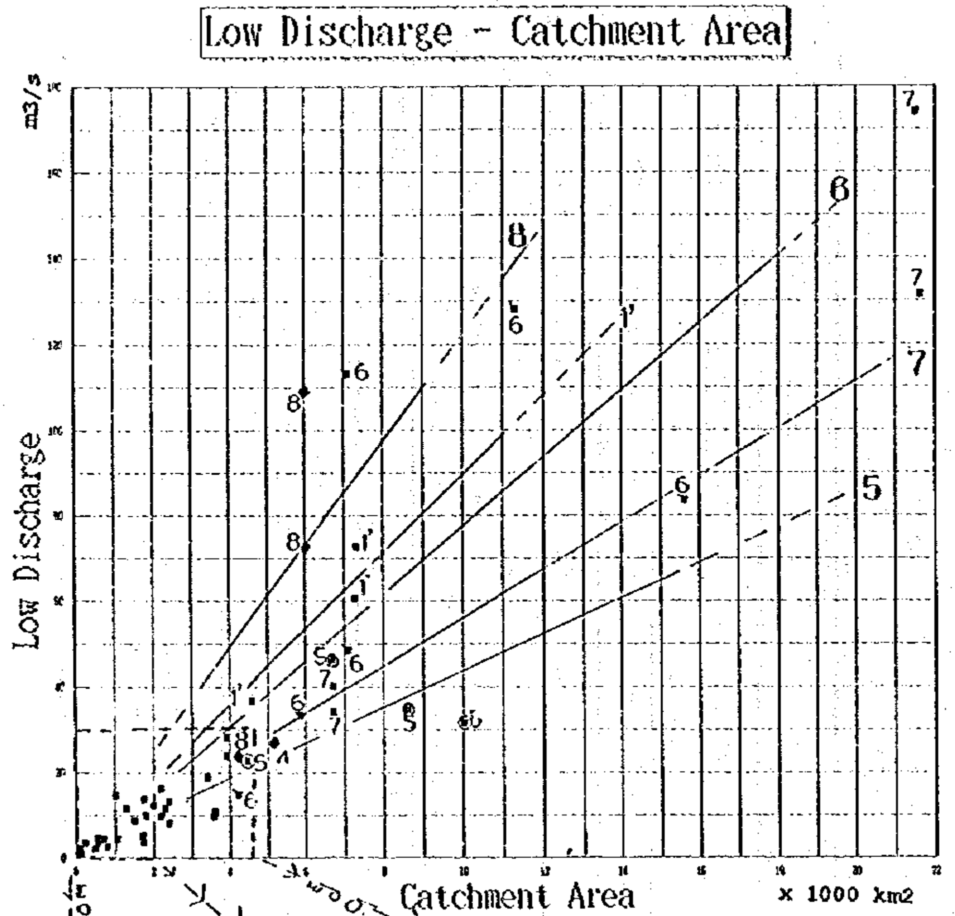
1) the area of Caiua Formation -------------------------------- 1,056 $m^3/d/km^2$
2) the "Karst" area -------------------------------- 785 $m^3/d/km^2$
3) the northern area of Botucatu and Serra Geral Formations ---- 672 $m^3/d/km^2$

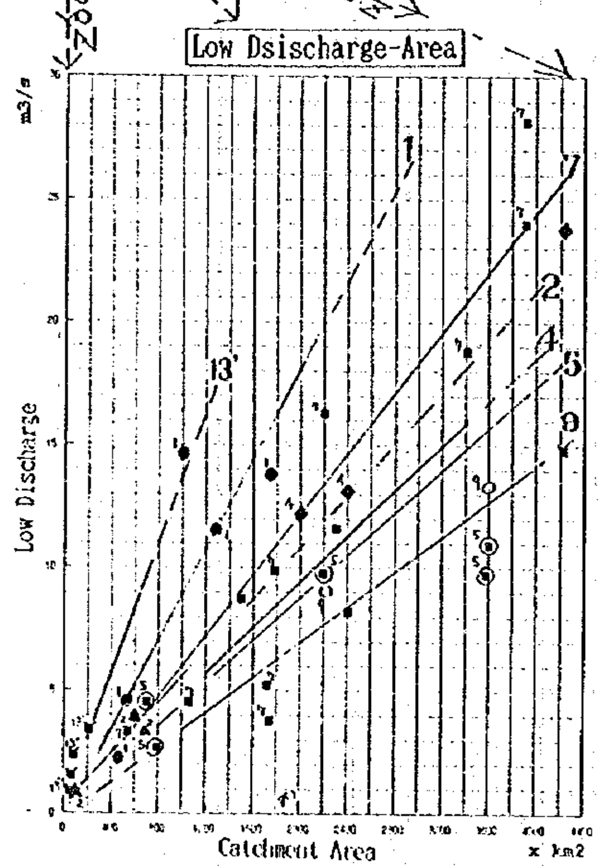
Furthermore, the estimated results of circulating groundwater resources present the total yields of a circulating groundwater, and the spatial permissive yield of appears to be about 10 % of the yield from experimental estimation. However, the permissive percentages of aquifers in the "Karst" and Serra Geral Formation (consists two parts; the northern part and the southern part) can be estimated much higher by approximately 30 %, 20% and 15%. That is because, their aquifers structures are very suitable for transposition of groundwater resources and the critical yield of boreholes in the above areas is bigger.

Table-7.4 Potential of Groundwater Resources on the Basis of Water Balance

No.	Aquifer	Subarea	Area A	Mean Discharge	Rtgw	Transitory Recharge=Baseflow Rtgw		Permissive Yield of Recharge			Productivity of Well	Principal Cities
			km2	m3/s	m3/d/km2	l/s/km2	million*m3/d	%	l/s/km2	million*m3/d		
							Baseflow * A			% * Rtgw		
1	(the Karst) in Acungui & Setuva G.		5,740	125	785	9.1	4.5	30	3	1.4	AAA	Curitiba, Campo Largo, (Metropolitan Curitiba)
2	Granitic rocks in Pre-Ordovician		7,540	136	550	6.4	3.9	10	1	0.4	CC	Pirai do Sul, Doutor Ulysses Mandirituba, Campo do Tenente
3	Early Paleozoic ; Castro/Parana Group		7,150	153	350 +-	4.1 +-	3 +-	10	0.41 +-	0.3	C	Ponta Grossa, Tibagi, Pirai do Sul
4	Middle-Late Paleoz. Itarare/Guata Group		17,400	331	405	4.7	7	10	0	0.7	B	Tomazina, Telemaco Barba, Ipiranga Texeira Soares, Lapa
5	Late Paleozoic Passa Dois Group		15,700	345	403	4.7	6	10	0	0.6	B	Joaquim Tavora, Sapopema, Ivai, Irati, Sao Madeus do Sul
	Botucatu & Serra Geral F.	Total	101,000				60			11	A	
6		Norte	59,050	1,490	672	7.8	40	20	2	8.00	AA	Londrina, Cornelio Procopio, Apucarama Maringa, Cascavel, Camp Mourao, Toredo
7		Sulu	42,060	1,640	480	5.6	20	15	1	3	BB	Guarapuava, Palamas, Laranjeiras do sul Foz do Iguacu, Pato Branco
8	Caiua Formation		30,450	609	1,056	12	3	10	1	0.3	BB	Paranavai, Loanda, Tapira, Icaraima, Umuarama, Cianorte,
9	(Metropolitan Curitiba Area)		1,130	9	305	3.5	0.34	10	0.35	0.03		Metropolitan Curitiba
10	Guabirotuba F.		950	-	-	-	-	-	-	-	BB	
11	Aluvium System in Flood Plane		180	-	-	-	-	-	-	-	A	
12	Granitic rocks		(300)	-	-	-	-	-	-	-	B	
13	(Quaternary Sys. in Coastal Range) *1		1,950	175	-	-	-	-	-	-		Paranavai, Guaraquecaba, Matinhos, Guaratuba,
14	Quat. River Bed (Delta/River B.		380	- -	1,166	13	1.11	30	3.9	0.3	A	Antonina,Alexandra, Serra Negra,
15	Marine Terrace Deposit		1,570	-	-	-	-	-	-	-	C	Praia de Leste, Ilha do Mel, Ipanema

*1 : the richarge to Quat.River Bed in the Coastal Range is estimated to be equal to the baseflow of rivers in





No	Aquifor	Low Discharge
1: (filled circle)	the Karast in Acungui & Setuva G.	785 m3/d/km2 9.09 l/s/km2
2: (triangle)	the Granitics in Pre-Ordovicien	550 m3/d/km2 6.37 l/s/km2
4: (diamond)	Mid-Late Paleozoic Itarete/Guata G.	405 m3/d/km2 4.69 l/s/km2
5: (circled square)	Late Paleozoic Passa dois G.	403 m3/d/km2 4.66 l/s/km2
6: (square)	Northern part of Botucatu & Serra Geral F.	672 m3/d/km2 7.78 l/s/km2
7: (square/diamond)	Southern part of Botucatu & Serra Geral F.	480 m3/d/km2 5.56 l/s/km2
8: (diamond)	Caiua Formation	1056 m3/d/km2 12.22 l/s/km2
9: (open circle)	(Metropolitan Curitiba Area :)	305 m3/d/km2 3.53 l/s/km2
13': (marker)	the Crystalline rocks in the Coarstal Range	1166 m3/d/km2 13.5 l/s/km2
1': (dot)	(RIBEIRA BASIN : the Karst and Granitics)	778 m3/d/km2 9 l/s/km2

Figure-7.2 Relationship between Low Discharge and Catchment Area

7.3 Required Water Supply Amount

7.3.1 Water Demands and Sources

Water demands are estimated for urban domestic water, rural domestic water, industrial water and agricultural water (refer to Chapter 6). Water source appropriate for each water demand seems to be basically as shown in Table-7.5, from the view point of developed amount, economy, technology, realization, etc.

Table-7.5 Water Demands and Sources

Water Demands	Region	Main Water Sources	Sub Water Sources
Domestic	Urban	Surface Water	Groundwater
	Rural	Groundwater	Surface Water
Industrial	Urban	Surface Water	Groundwater
Agricultural	Rural	Surface Water	Groundwater

Surface water is better to be developed than groundwater for such concentrated and large amount of water demands as urban domestic water and industrial water. On the other hand, groundwater is better for scattered water demand of rural domestic water. Agricultural water demand, composed of livestock and aquacultural water, is also scattered in rural area, can be developed by surface water from small tributaries nearby. However, as the actual water development method depends on the topographical, hydrological and hydrogeological conditions of the place, the use of combined surface and groundwater is also to be considered in some cases.

7.3.2 Water Losses

Required water supply amount is calculated by adding various losses to each water demand. Percentage of total water loss which includes losses for intake, conveyance , treatment, distribution of water, etc, is assumed as shown in Table-7.6 taking into consideration present loss percentage, future improvement, and type of water development.

Table-7.6 Percentage of Water Losses

Purpose of Water Use	Region	1993 (%)	2005 (%)	2015 (%)
Domestic	Urban	40	30	25
	Rural	15	10	10
Industry	Urban	15	10	10
Agriculture	Rural	20	20	20

7.3.3 Required Water Supply

Assuming water loss percentage as shown in Table-7.6, based on water demand estimated in the Section-6.6, required water supply by sector, by MRH and by basin is calculated as shown in Table-7.7 and 7.8, respectively.

Table-7.7 Required Water Supply by Sector and by MRH

MRH	1993				2005				2015			
	Urban		Rural		Urban		Rural		Urban		Rural	
	Domestic	Industrial	Domestic	Agricultural	Domestic	Industrial	Domestic	Agricultural	Domestic	Industrial	Domestic	Agricultural
MRH 268	4.889	3.424	0.120	0.042	6.831	4.780	0.110	0.055	9.607	6.112	0.100	0.064
MRH 269	0.296	0.034	0.032	0.004	0.388	0.011	0.032	0.005	0.519	0.004	0.031	0.006
MRH 270	0.011	0.012	0.023	0.013	0.016	0.014	0.021	0.017	0.022	0.017	0.019	0.020
MRH 271	0.010	0.005	0.032	0.011	0.014	0.008	0.035	0.014	0.018	0.011	0.037	0.016
MRH 272	0.123	0.116	0.044	0.031	0.158	0.160	0.045	0.040	0.209	0.219	0.045	0.047
MRH 273	0.707	0.426	0.062	0.072	0.948	0.665	0.053	0.091	1.283	0.834	0.046	0.107
MRH 274	0.088	0.118	0.020	0.027	0.149	0.229	0.015	0.035	0.216	0.340	0.011	0.041
MRH 275	0.041	0.024	0.033	0.013	0.057	0.030	0.034	0.017	0.078	0.044	0.034	0.019
MRH 276	0.145	0.043	0.099	0.048	0.194	0.063	0.100	0.061	0.262	0.085	0.100	0.071
MRH 277	0.039	0.004	0.069	0.053	0.051	0.005	0.057	0.067	0.064	0.007	0.048	0.078
MRH 278	0.158	0.008	0.068	0.087	0.194	0.019	0.043	0.107	0.236	0.029	0.030	0.124
MRH 279	0.447	0.118	0.082	0.082	0.563	0.178	0.049	0.102	0.736	0.225	0.032	0.118
MRH 280	0.100	0.026	0.027	0.021	0.129	0.025	0.015	0.026	0.172	0.023	0.010	0.031
MRH 281	1.852	0.526	0.091	0.158	2.475	0.763	0.047	0.196	3.406	0.980	0.027	0.226
MRH 282	1.015	0.428	0.034	0.063	1.451	0.699	0.016	0.077	2.050	0.980	0.009	0.089
MRH 283	0.416	0.079	0.062	0.191	0.516	0.123	0.034	0.229	0.670	0.168	0.020	0.264
MRH 284	0.433	0.123	0.100	0.093	0.554	0.222	0.052	0.114	0.734	0.301	0.030	0.132
MRH 285	0.528	0.103	0.131	0.243	0.490	0.149	0.066	0.292	0.580	0.199	0.037	0.334
MRH 286	0.490	0.122	0.126	0.131	0.667	0.177	0.069	0.159	0.910	0.236	0.042	0.183
MRH 287	0.055	0.004	0.088	0.058	0.080	0.007	0.077	0.071	0.103	0.010	0.068	0.082
MRH 288	1.551	0.341	0.252	0.353	2.828	0.387	0.155	0.451	4.076	0.405	0.103	0.521
MRH 289	0.476	0.136	0.227	0.279	0.656	0.247	0.156	0.362	0.904	0.355	0.096	0.423
MRH 290	0.364	0.145	0.150	0.090	0.496	0.195	0.154	0.113	0.681	0.286	0.157	0.129
MRH 291	0.213	0.118	0.072	0.124	0.283	0.161	0.068	0.158	0.382	0.154	0.065	0.185
Total	14.45	6.48	2.04	2.29	20.19	9.32	1.50	2.86	28.92	12.02	1.20	3.31

Table-7.8 Required Water Supply by Sector and by Basin

Basin	1993				2005				2015			
	Urban		Rural		Urban		Rural		Urban		Rural	
	Domestic	Industrial	Domestic	Agricultural	Domestic	Industrial	Domestic	Agricultural	Domestic	Industrial	Domestic	Agricultural
Cinzas	0.330	0.087	0.099	0.113	0.419	0.142	0.062	0.140	0.542	0.190	0.042	0.163
Iguacu	6.165	3.893	0.677	0.649	8.648	5.465	0.578	0.834	12.108	7.018	0.500	0.971
Itarare	0.135	0.103	0.037	0.048	0.200	0.201	0.025	0.060	0.272	0.299	0.018	0.069
Ivai	1.605	0.451	0.380	0.447	2.053	0.724	0.253	0.545	2.747	0.994	0.191	0.628
Litoranea	0.296	0.034	0.039	0.007	0.388	0.011	0.038	0.008	0.519	0.004	0.038	0.010
Parana 1	0.014	0.003	0.009	0.029	0.017	0.004	0.005	0.034	0.022	0.005	0.003	0.040
Parana 2	0.035	0.007	0.030	0.055	0.032	0.010	0.015	0.066	0.038	0.013	0.008	0.075
Parana 3	1.017	0.223	0.106	0.148	1.855	0.254	0.065	0.188	2.673	0.265	0.043	0.218
ParanaPanema1	0.142	0.038	0.015	0.015	0.179	0.057	0.009	0.019	0.234	0.072	0.006	0.022
ParanaPanema 2	0.032	0.009	0.005	0.005	0.041	0.013	0.003	0.007	0.053	0.016	0.002	0.008
ParanaPanema 3	0.343	0.097	0.031	0.054	0.458	0.141	0.016	0.067	0.631	0.182	0.009	0.078
ParanaPanema4	0.121	0.023	0.023	0.069	0.150	0.036	0.012	0.083	0.195	0.049	0.007	0.096
Piquiri	0.824	0.180	0.265	0.312	1.174	0.237	0.174	0.386	1.608	0.292	0.126	0.444
Pirapo	0.895	0.330	0.046	0.085	1.244	0.530	0.023	0.104	1.736	0.730	0.013	0.120
Ribeira	0.149	0.108	0.079	0.042	0.208	0.149	0.071	0.054	0.292	0.189	0.064	0.062
Tibagi	2.347	0.899	0.204	0.211	3.124	1.343	0.153	0.264	4.249	1.707	0.124	0.307
Total	14.45	6.48	2.04	2.29	20.19	9.32	1.50	2.86	28.92	12.02	1.20	3.31

7.4 Surface Water Development

7.4.1 Process of Water Development Study

Process of water development study is as shown below:

1) Possibility of water development by direct intake of surface water is examined for required supply amount in several block of each river basin. And water shortage areas are identified. For such water shortage areas, development by dam or groundwater is studied in the latter sections.
2) Demand and supply in Curitiba metropolitan area are studied for surface water development by dams and groundwater development.
3) Demand and supply in the large urban areas such as Ponta Grossa, Londrina, Maringá, Cascavel, etc are studied.
4) Demand and supply in the other urban areas are studied.
5) Demand and supply in the rural domestic areas are studied.
6) Demand and supply for the agricultural water in the rural area are studied.

7.4.2 Surface Water Development

(1) Required Water Supply by Block of River Basin.

In order to compare required water supply with surface water potential in each block of basin, the required water supply is distributed to each block of each river basin by applying the same method as distributing water demand of MRH to each river basin. The required water supply by block of river basin is calculated as shown in Table-7.9.

(2) Method of Assessment

The following equations are applied to assess the potential water development by direct intake of surface water.

$$Q_{e,N} = Q_{p,N} - Q_{s,N}$$

$$Q_{p,N} = 0.5Q_{10,7,N} - \sum_{i=1}^{N-1} (Q_{s,i} : \text{when } Q_{s,i} \le Q_{p,i}, \text{or } Q_{p,i} : \text{when } Q_{p,i} < Q_{s,i})$$

$$R_N = \frac{Q_{p,N}}{Q_{s,N}}$$

Where:

$Q_{e,N}$: Excess water after intake at N-point.

$Q_{p,N}$: Possible development water at N-point.

$Q_{s,N}$: Required supply water at N-point.

$Q_{10,7,N}$: Low water flow once in 10-years and last 7 days at N-point

R_N : Ratio of $Q_{p,N}$ to $Q_{s,N}$ at N-point.

Table-7.9 Required Water Supply by Block of River Basin

[1993]

Name of BASIN	BLOCK	Domestic Urban	Domestic Rural	Industrial	Agricult.	Total
		m3/s	m3/s	m3/s	m3/s	m3/s
Cinzas	CZ-1	0.017	0.013	0.005	0.015	0.050
	CZ-2	0.312	0.086	0.005	0.098	0.501
Iguacu	IG-1	4.540	0.081	2.866	0.078	7.566
	IG-2	0.207	0.138	0.131	0.133	0.608
	IG-3	0.481	0.103	0.304	0.099	0.986
	IG-4	0.574	0.214	0.363	0.205	1.355
	IG-5	0.363	0.140	0.229	0.135	0.868
Itarare	IT-1	0.135	0.037	0.103	0.048	0.323
Ivai	IV-1	0.032	0.063	0.009	0.074	0.178
	IV-2	0.074	0.069	0.021	0.081	0.244
	IV-3	0.361	0.136	0.101	0.159	0.757
	IV-4	0.984	0.078	0.277	0.092	1.432
	IV-5	0.154	0.035	0.043	0.041	0.273
Litoranea	LT-1	0.296	0.039	0.034	0.007	0.376
Parana-1	PA-1	0.014	0.009	0.003	0.029	0.054
Parana-2	PA-2	0.035	0.030	0.007	0.055	0.126
Parana-3	PA-3	1.017	0.106	0.223	0.148	1.494
P.Panema-1	PP-1	0.142	0.015	0.038	0.015	0.210
P.Panema-2	PP-2	0.032	0.005	0.009	0.005	0.052
P.Panema-3	PP-3	0.343	0.031	0.097	0.054	0.526
P.Panema-4	PP-4	0.121	0.023	0.023	0.069	0.236
Piquiri	PQ-1	0.085	0.110	0.019	0.129	0.343
	PQ-2	0.543	0.101	0.119	0.119	0.881
	PQ-3	0.195	0.055	0.043	0.064	0.356
Pirapo	PR-1	0.895	0.046	0.330	0.085	1.357
Ribeira	RB-1	0.052	0.039	0.038	0.020	0.150
	RB-2	0.097	0.076	0.097	0.076	0.344
Tibagi	TB-1	0.627	0.054	0.240	0.056	0.978
	TB-2	0.324	0.073	0.124	0.075	0.597
	TB-3	1.396	0.077	0.534	0.080	2.087
Total		14.450	2.081	6.434	2.343	25.308

[2015]

Name of BASIN	BLOCK	Domestic Urban	Domestic Urban	Industrial	Agricult.	Total
		m3/s	m3/s	m3/s	m3/s	m3/s
Cinzas	CZ-1	0.028	0.006	0.010	0.022	0.066
	CZ-2	0.514	0.036	0.010	0.141	0.701
Iguacu	IG-1	8.916	0.060	5.168	0.117	14.261
	IG-2	0.406	0.102	0.235	0.198	0.942
	IG-3	0.944	0.076	0.547	0.148	1.715
	IG-4	1.128	0.158	0.654	0.307	2.246
	IG-5	0.714	0.104	0.414	0.202	1.433
Itarare	IT-1	0.272	0.018	0.299	0.069	0.659
Ivai	IV-1	0.054	0.032	0.020	0.104	0.210
	IV-2	0.126	0.034	0.046	0.113	0.319
	IV-3	0.618	0.068	0.224	0.224	1.133
	IV-4	1.685	0.039	0.610	0.129	2.463
	IV-5	0.264	0.017	0.096	0.057	0.434
Litoranea	LT-1	0.519	0.038	0.004	0.010	0.570
Parana-1	PA-1	0.022	0.003	0.005	0.040	0.070
Parana-2	PA-2	0.038	0.008	0.013	0.075	0.135
Parana-3	PA-3	2.673	0.043	0.265	0.218	3.199
P.Panema-1	PP-1	0.234	0.006	0.072	0.022	0.334
P.Panema-2	PP-2	0.053	0.002	0.016	0.008	0.080
P.Panema-3	PP-3	0.631	0.009	0.182	0.078	0.899
P.Panema-4	PP-4	0.195	0.007	0.049	0.096	0.346
Piquiri	PQ-1	0.167	0.052	0.030	0.184	0.433
	PQ-2	1.060	0.048	0.192	0.169	1.469
	PQ-3	0.381	0.026	0.069	0.091	0.567
Pirapo	PR-1	1.736	0.013	0.730	0.120	2.599
Ribeira	RB-1	0.103	0.032	0.066	0.031	0.231
	RB-2	0.190	0.149	0.190	0.149	0.676
Tibagi	TB-1	1.135	0.033	0.456	0.082	1.706
	TB-2	0.587	0.044	0.236	0.110	0.976
	TB-3	2.527	0.047	1.015	0.115	3.705
Total		27.920	1.311	11.922	3.427	44.579

[2015-1993]

Name of BASIN	BLOCK	Domestic Urban	Domestic Urban	Industrial	Agricult.	Total
		m3/s	m3/s	m3/s	m3/s	m3/s
Cinzas	CZ-1	0.011	0.055	0.005	0.007	0.016
	CZ-2	0.201	0.231	0.005	0.043	0.200
Iguacu	IG-1	4.377	5.181	2.301	0.039	6.695
	IG-2	0.199	0.176	0.105	0.066	0.334
	IG-3	0.464	0.392	0.244	0.049	0.729
	IG-4	0.554	0.441	0.291	0.102	0.890
	IG-5	0.350	0.321	0.184	0.067	0.565
Itarare	IT-1	0.138	0.359	0.196	0.021	0.335
Ivai	IV-1	0.023	0.026	0.011	0.030	0.032
	IV-2	0.052	0.128	0.025	0.033	0.076
	IV-3	0.257	0.255	0.122	0.064	0.376
	IV-4	0.700	0.759	0.333	0.037	1.031
	IV-5	0.110	0.105	0.052	0.016	0.161
Litoranea	LT-1	0.223	0.237	-0.030	0.004	0.195
Parana-1	PA-1	0.008	0.008	0.003	0.011	0.016
Parana-2	PA-2	0.003	0.021	0.006	0.020	0.009
Parana-3	PA-3	1.655	1.146	0.042	0.070	1.705
P.Panema-1	PP-1	0.092	0.089	0.034	0.007	0.123
P.Panema-2	PP-2	0.021	0.020	0.008	0.002	0.028
P.Panema-3	PP-3	0.288	0.235	0.084	0.023	0.373
P.Panema-4	PP-4	0.074	0.071	0.026	0.026	0.111
Piquiri	PQ-1	0.081	0.103	0.012	0.055	0.090
	PQ-2	0.517	0.481	0.074	0.050	0.588
	PQ-3	0.186	0.182	0.027	0.027	0.211
Pirapo	PR-1	0.841	0.702	0.399	0.035	1.242
Ribeira	RB-1	0.050	0.072	0.028	0.010	0.081
	RB-2	0.093	0.094	0.093	0.073	0.332
Tibagi	TB-1	0.508	0.483	0.216	0.025	0.728
	TB-2	0.263	0.250	0.112	0.034	0.380
	TB-3	1.131	1.026	0.481	0.036	1.618
Total		13.470	13.649	5.488	1.083	19.271

The possibility of surface water development by direct intake is judged as follows:

$Q_{e,N} \geq 0$, or $R_N \geq 1.0$: Surface water development by direct intake is possible.

$Q_{e,N} < 0$ or $R_N < 1.0$: Surface water development by direct intake is impossible and other facilities such as dam, weir etc, are required for regulating discharge.

(3) Possibility of Surface Water Development.

In accordance with the equations above, the possibility of surface water development by direct intake was assessed for each block of each river basin for the Base case as shown in Figure-7.3.

Based on Figure-7.3, severe shortage of water is found at the upstream of Iguaçu river, block IG-1 which includes Curitiba metropolitan area, and considerable tight condition of water supply is found at the upstream of Tibagi river, block TB-1 which includes Ponta Grossa area though the potential is more than the requirement. Except for those two blocks, surface water development by direct intake seems to be generally possible for the other blocks. This means that most of urban areas scattered in the river basins could develop their urban domestic water by direct intake from nearby rivers. As to the Curitiba metropolitan area, other water development methods such as by dam and by ground water are required and as to other large urban areas such as Cascavel, Ponta Grossa, Londrina, Maringa, etc., which are located at the extreme upstream of main stream or tributaries, sufficient study should be carried out.

2015	Sub-basin	Required Supply Water [A] Urban	Required Supply Water [A] Rural	Required Supply Water [A] Total	Possible Development [B]	[B]-[A]	[B]/[A]
Cinzas	CZ-1	0.038	0.027	0.066	1.788	1.722	27.3
Cinzas	CZ-2	0.524	0.177	0.701	4.878	4.177	7.0
Iguacu	IG-1	14.084	0.177	14.261	3.816	-10.445	0.268
Iguacu	IG-2	0.641	0.300	0.942	17.011	16.069	18.1
Iguacu	IG-3	1.492	0.224	1.715	38.795	37.080	22.6
Iguacu	IG-4	1.781	0.464	2.246	53.642	51.396	23.9
Iguacu	IG-5	1.127	0.305	1.433	84.509	83.076	59.0
Itarare	IT-1	0.572	0.087	0.659	7.643	6.984	11.6
Ivai	IV-1	0.074	0.136	0.210	2.102	1.892	10.0
Ivai	IV-2	0.172	0.148	0.319	3.601	3.282	11.3
Ivai	IV-3	0.841	0.292	1.133	9.630	8.497	8.5
Ivai	IV-4	2.294	0.169	2.463	71.335	68.872	29.0
Ivai	IV-5	0.360	0.075	0.434	62.453	62.019	143.9
Litoranea	LT-1	0.523	0.048	0.570	20.044	19.474	35.1
Parana-1	PA-1	0.027	0.043	0.070	4.542	4.472	65.0
Parana-2	PA-2	0.052	0.083	0.135	5.415	5.280	40.1
Parana-3	PA-3	2.938	0.261	3.199	10.581	7.382	3.3
P.Panema-1	PP-1	0.306	0.028	0.334	1.299	0.965	3.9
P.Panema-2	PP-2	0.070	0.010	0.080	0.348	0.268	4.4
P.Panema-3	PP-3	0.812	0.087	0.899	4.168	3.269	4.6
P.Panema-4	PP-4	0.244	0.103	0.346	6.775	6.429	19.6
Piquiri	PQ-1	0.197	0.236	0.433	14.737	14.304	34.0
Piquiri	PQ-2	1.252	0.217	1.469	53.461	51.991	36.4
Piquiri	PQ-3	0.450	0.117	0.567	41.639	41.072	73.4
Pirapo	PR-1	2.466	0.134	2.599	8.832	6.233	3.4
Ribeira	RB-1	0.169	0.062	0.231	10.140	9.909	43.9
Ribeira	RB-2	0.379	0.297	0.676	25.706	25.030	38.0
Tibagi	TB-1	1.591	0.115	1.706	4.295	2.589	2.5
Tibagi	TB-2	0.822	0.154	0.976	11.054	10.078	11.3
Tibagi	TB-3	3.543	0.162	3.705	14.163	10.458	3.8

Figure-7.3 Possibility of Surface Water Development by Direct Intake

7.5 Groundwater Development

(1) Policy of Groundwater Development

The following three bases are to be considered for the groundwater development:

a) Sustainable development,

b) Good use in quantity and quality,

c) Alternative development between the surface water and groundwater by cost performance.

The concept of sustainable groundwater development is to use only a part of circulating groundwater resources (=rechargeable groundwater resources) in consideration of both of environmental and socioeconomic aspects.

The concept of permissive yield is introduced in Section-7.2 to achieve sustainable development.

Good use in quantity and quality is to make development plan of effective use in quantity and chemistry such as pH, hardness and temperature. For example the characteristics of the groundwater in Curitiba Metropolitan Area is summarized as follows :

"Karst"; – High hardness in chemistry and not suitable for industry use such as boilers.

- The other chemistry is very suitable for drinking water in actually to be bottled for mineral water for Curitiba Metropolitan Area.
- High productivity of borehole and high potential of groundwater resources.

Guabirotuba Formation; - Low hardness and suitable for industry use in chemistry,

- Low productivity of borehole for big municipality, but suitable for local use.
- Development possibility at any places within the distribution area of lower horizon of Guabirotuba Formation as same area as Curitiba City.

Alternative development between the surface water and groundwater is described in Section-7.6 and 7.7.

(2) Methodology of Groundwater Resources Development

The required area of development, borehole number and site selection were planned by the following method. The assumed parameters to make a groundwater development plan for each aquifer are listed in Table-7.10.

a) Required Area of Development

The required area of development (Ar) is calculated by the following formula :

$$Ar = Dr / Qpr \quad \text{or} \quad Ar = Dr / (Qr \times k)$$

Dr ; Demand of required water supply (m^3/s),

Qpr ; Permissive recharge of groundwater resources ($m^3/s/km^2$, represented ; $Qpr=Qr \times k$), Qr ; Recharge of groundwater resources per spatial unit ($m^3/s/km^2$),

k ; Ratio of spatial permissive yield (%).

b) Required Borehole Number ;

The required borehole number (N) is calculated by the following formula :

$$N = Dr / Yp$$

Dr ; same as the above

Yp ; Spatial Permissive yield of borehole (= Critical yield, m^3/h)

c) Site selection of boreholes

The site selection of boreholes is studied based on the geology, topography and pipeline design in respective sites of groundwater development.

The study results of the large urban areas are presented in Section-7.6 and 7.7, while the development for the rural domestic water is presented in the Section-7.8.

Table-7.10 Parameters to Make Development Plan of Groundwater Resources for Each Aquifer

Aquifer	Area (km2)	Recharge of Groundwater Resources per Areal Unit	Ratio of Areal Permissive Yield %	Permissive Recharge of Groundwater Resources per Areal Unit (Qpr = Qr * Yp)	Required Area of Groundwater Supply by Permissive Recharge of 1m3/sec (Aru = 1 / Qrt)	Possible Yield of Well in Data of Pumping Test
No Name	A	Qr	k	Qpr	Aru	Yp
1. The Karst in Acungui & Setuva G.	5,740	0.0092 m3/s/km2	30 %	0.0028 m3/s/km2	360 km2 / m3/s	0.044 m3/s
2. Granitic Rock in Pre-Oldovician	7,540	0.0061 m3/s/km2	10 %	0.00061 m3/s/km2	1,640 km2 / m3/s	0.0056 m3/S
3. Early Paleozoic Castro/Parana G.	7,150	0.0045 m3/s/km2	10 %	0.00045 m3/s/km2	2,220 km2 / m3/s	0.0028 m3/s
4. Middle - Late Paleozoic Itarare/Guata G.	17,400	0.0047 m3/s/km2	10 %	0.00047 m3/s/km2	2,130 km2 / m3/s	0.0028 m3/s
5. Late Paleozoic Passa Dois Group	15,700	0.0044 m3/s/km2	10 %	0.00044 m3/s/km2	2,270 km2 / m3/s	0.0028 m3/s
6. Botucatu & Serra Geral Formation (Norte)	59,050	0.0078 m3/s/km2	20 %	0.0016 m3/s/km2	625 km2 / m3/s	0.011 m3/s
7. Botucatu & Serra Geral Formation (Sulu)	42,060	0.0055 m3/s/km2	15 %	0.00083 m3/s/km2	1,200 km2 / m3/s	0.0033 m3/s
8. Caiua Formation	30,450	0.0011 m3/s/km2	10 %	0.00011 m3/s/km2	9100 km2 / m3/s	0.0083 m3/s
9. Metropolotan Curitiba	1,130	0.0035 m3/s/km2	10 %	0.00035 m3/s	2860 km2 / m3/s	0.0038 m3/s

7.6 Water Development in Curitiba Metropolitan Area

(1) Population and Water Requirement

Municipalities which are included in Curitiba metropolitan area were assumed to be the following 9 municipalities: Curitiba, Almirante Tamandaré, Colombo, Piraquara, São José dos Pinhais, Araucária, Campo Largo, Pinhais, Fazenda Rio Grande.

Urban population of Curitiba metropolitan area was estimated based on population of municipalities in 2,000 which were the most up-to-date data projected by IPARDES as shown below:

$$\textit{Urban Population in Curitiba metropolitan area in } 2015$$
$$= \frac{\textit{Total urban population of 9 Municipalities in } 2000}{\textit{Urban population of MRH–268 in } 2000} \times \textit{Urban population of MRH–268 in } 2015$$
$$= \frac{2.207\times 10^6}{2.306\times 10^6}\times 3.280\times 10^6 = 0.957\times 3.280\times 10^6 = 3.14\times 10^6 \textit{ inhabitants}$$

Water requirement for urban area is mainly composed of urban domestic water and industrial water. Required water supply in 2015 and in 1993 were calculated by the same method as used in population estimation as shown in Table-7.11.

Table-7.11 Required Water Supply in Curitiba Metropolitan Area

(m^3/sec)

Year	Urban Domestic Water			Industrial Water			Total
	Demand	Loss	Intake	Demand	Loss	Intake	
2015	6.898	2.298	9.194	5.264	0.585	5.849	15.043
1993	2.808	1.872	4.679	2.785	0.491	3.277	7.956
Water to be newly developed			4.515			2.572	7.087

(2) Surface Water Development by Dam

As studied in the Section-7.4, there is no room for direct intake from river due to shortage of natural discharge in the upstream of Iguaçu river, therefore development of new water resources has to depend on construction of dam-reservoirs.

Water development in proposed 10 dams, planned by SANEPAR around Curitiba at the upstream tributaries of Iguaçu river (refer to Figure-7.4) was studied.

The water development calculation is made based on the following conditions.

a) Assuming the daily discharge at proposed dam sites are inflow to the reservoir, daily water balance in the reservoir is simulated for 20 years.

b) Maintenance discharge from the reservoir is assumed to be 50% of $Q_{10,7}$ and daily discharge from the reservoir is to be more than the maintenance discharge.

c) i) When inflow is less than the sum of proposed development water and maintenace discharge, deference is supplied from reservoir water.

ii) When inflow is more than the sum of proposed development water and maintenance discharge, excess of inflow is recharged to the reservoir. If the reservoir is full at that time, excess water is discharged to the downstream of dam.

d) Evaporation from reservoir is also counted by applying average monthly evaporation data for 20 years at Piraquara observation station.

e) Seepage or infiltration from reservoir is neglected.

f) The maximum period of recovery is about 5 years.

Several cases of proposed water development volume ranging from 0.10 m^3/sec to 1.40 m^3/sec were assumed at each proposed dam. Simulation of daily water balance in reservoir was carried out for 20 years. The results of simulation are shown in Table-7.12. For example, judging from required recovery period of reservoir capacity, an appropriate water development volume by Pequeno dam (No.3) seems to be 0.9 m^3/sec.

The water development volume by dams around Curitiba is as shown in Table-7.13.

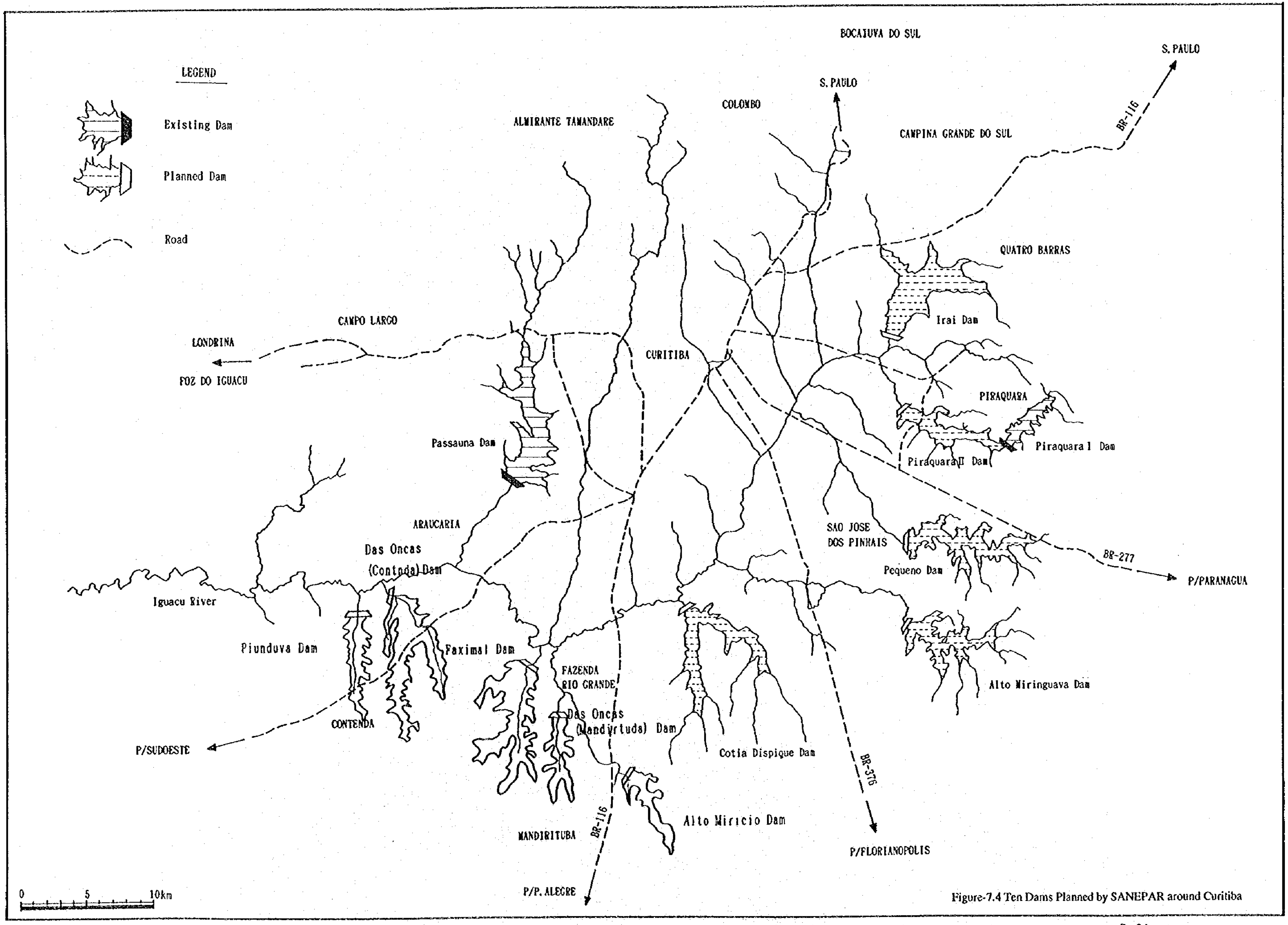


Figure-7.4 Ten Dams Planned by SANEPAR around Curitiba

Table-7.12 Developed Water and Required Reservoir Capacity by Planned Dam

Name of Dam		Development Water (m^3/sec)	Reservoir Capacity ($x 10^6 m^3$)	Period of Recovery (Year)
1	Irai	0.90	24.3	2.0
		1.00	29.1	4.5
		1.10	35.0	5.5
		1.20	41.4	9.0
		1.30	54.6	-
2	Piraquara II	0.50	10.1	2.0
		0.60	14.7	3.0
		0.70	19.8	5.5
		0.80	28.2	-
		0.90		-
3	Pequeno	0.70	15.3	2.0
		0.80	19.9	4.0
		0.90	31.3	5.5
		1.00	32.3	-
		1.10		-
4	Alto Miringuava	0.80	18.3	2.0
		0.90	23.0	4.5
		1.00	28.7	6.0
		1.10	39.0	-
		1.20		-
5	Cotia Despique	1.00	27.6	3.0
		1.10	32.9	4.5
		1.20	38.9	5.5
		1.30	47.2	-
		1.40		-
6	Alto Mauricio	0.15	3.0	1.5
		0.20	5.3	2.0
		0.25	7.8	5.0
		0.30	11.6	-
		0.36		-
7	Das Onças (Mandirituba)	0.10	1.7	1.5
		0.15	3.5	2.0
		0.20	5.8	4.5
		0.25	9.7	-
		0.30		-
8	Faxinal	0.30	5.2	1.5
		0.40	9.8	2.0
		0.50	14.9	5.5
		0.60	25.0	-
		0.70		-
9	Das Onças (Contenda)	0.40	7.2	2.0
		0.50	11.8	2.5
		0.60	16.8	5.0
		0.70	25.3	-
		0.80		-
10	Piunduva	0.10	1.8	1.5
		0.15	4.0	2.0
		0.20	6.7	5.5
		0.25		-
		0.30		-

[Note] "-": It means that capacity is not recovery.

Table-7.13 Water Development Volume by Dams around Curitiba

Name of Dam (River)		Catchment Area (: C.A). (km^2)	Reservoir Area (km^2)	$q_{10,7}$ ($m^3/sec/100\ km^2$)	$Q_{10,7}$	$Q_{10,7} \times 50\%$	Development Volume (m^3/sec)	Effective Reservoir Capacity ($10^6/m^3$)	Correction Coefficient (: α)
1	Iraí	112.6	13.80	0.355	0.40	0.200	1.10	35.0	0.781
2	Piraquara II	58.0	5.54	0.397	0.23	0.115	0.70	19.8	0.450
3	Pequeno	62.3	6.17	0.465	0.29	0.145	0.90	31.3	0.566
4	Alto Miringuava	71.9	5.78	0.417	0.30	0.150	1.00	28.7	0.586
5	Cotia Despique	154.7	14.17	0.271	0.42	0.210	1.20	38.9	0.820
6	Alto Maurício	36.0	3.76	0.277	0.10	0.050	0.25	7.8	0.195
7	Das Onças (Mandirituba)	29.0	2.79	0.276	0.08	0.040	0.20	5.8	0.156
8	Faxinal	63.3	4.86	0.269	0.17	0.085	0.50	14.9	0.333
9	Das Onças (Contenda)	75.6	4.86	0.265	0.20	0.100	0.60	16.8	0.392
10	Piunduva	25.4	2.50	0.276	0.07	0.035	0.20	6.7	0.137
Total		688.8	-	-			6.55	205.7	-

[Note] : Daily discharge at each dam site is calculated by multiplying daily discharge at Fazendinha station by correction coefficient.

Correction Coefficient : $\alpha = C.A/110.0 \times q_{10,7}/0.465$

110.0 : C.A. of Fazendinha

0.465 : q10,7 of Pequeno

$q_{10,7}$ value was calculated by the HG64.

(3) Groundwater Development in Curitiba Metropolitan Area.

There is the Karst aquifer about 10 to 50 km north of Curitiba which has large potential to be developed.

As mentioned above, the Karst aquifer has large potential, therefore, groundwater development might cover theoretically all required water. However, more economical well field near Curitiba in the Karst aquifer should be developed in early stage.

The stage development with 1.0 m^3/sec of groundwater development was considered. Number of required boreholes per each stage was calculated as follows.

Number of Boreholes per Stage = 1.0 m^3/sec ÷ 0.044 $m^3/sec/well$ = 23 wells

The optimization of water supply system between surface water and groundwater should be studied.

(4) Optimization of Water Supply System

The combination of 10 dams mentioned above and wells was optimized for the water supply. Construction cost of each dam and well field was estimated as shown in Table-7.14.

Table-7.14 Construction Cost of Dams and Wells

Name of Dam (River) Well Field		Development Volume (m^3/sec)	Construction Cost (10^6 US$)	Unit Cost (10^6 US$/ m^3/sec)
Surface Water				
1	Iraí	1.10	39.8	36.2
2	Piraquara II	0.70	18.0	25.7
3	Pequeno	0.90	30.6	34.0
4	Alto Miringuava	1.00	30.5	30.0
5	Cotia Despique	1.20	36.0	30.0
6	Alto Maurício	0.25	12.5	50.0
7	Das Onças (Mandirituba)	0.20	19.4	97.0
8	Faxinal	0.50	21.5	43.0
9	Das Onças (Contenda)	0.60	18.6	31.0
10	Piunduva	0.20	16.7	83.5
Total		6.55	243.6	37.2
Groundwater				
1	Wells (Stage I), 23 wells	1.00	30.0	30.0
2	Wells (Stage II), 23 wells	1.00	43.8	43.8
3	Wells (Stage III), 23 wells	1.00	62.7	62.7
Total		3.00	136.5	45.5

Since surface water development is generally more economical than groundwater development for the large scale water resources development, the ratio of surface water development and groundwater development was assumed 7 : 3 at the Strategy study. Detailed optimization will be carried out in the Master Plan study. The required water supply in Curitiba metropolitan area is 7.09 m^3/s, therefore surface water development amount is to be 5.00 m^3/s and groundwater development amount is to be 2.09 m^3/s. The construction cost was estimated by the multiplication of water development amount and average unit cost by water source wise.

The cost for dam construction and well field is shown in Table-7.18 and 7.17.

(5) Balance of Demand and Supply

Balance of demand and supply in Curitiba metropolitan area is estimated to be as shown below:

	Q (m^3/s)
– Required Supply Water	7.09
– Possible Supply Water	
by dams	5.00
by wells	2.09
Total	7.09