7.7 Water Development in Other Areas

(1) Large Urban Areas

As studied in the Section-7.4, generally speaking, there is no water shortage area, except for block IG-1, upstream of Iguaçu river. However, large urban areas located at extremely upstream of main stream or tributaries will be sometimes problematic areas for water development. Generally, they are suffering from large amount of water demand, shortage of surface water, long distance and high head for water conveyance, low productivity of well, etc.

Required water supplies for large urban areas in both base and alternative cases were summarized in Table-7.15.

Water supply systems for large urban areas were also determined in terms of the lowest cost. The cost of dams, conveyance pipes and wells are shown in Table-7.18 and Table-7.17, respectively, and the locations of surface water development points are shown in Figure-7.5. Table-7.18 denotes the construction cost from intake to purification of water.

This study was executed depending on mainly topographical maps and available hydrological data, therefore, they are on very rough basis and will require further detailed studies for realization.

1) Cascavel

Construction of a dam at D-C5 is enough to satisfy the required supply, 0.611 m^3/s, and its cost, US$ 29.0 million (US$ 42.0 million/m^3/s), is the lowest among alternatives. Groundwater development to meet the required supply costs US$ 35.1 million and it is approximately twice as much as the dam construction.

From the economical point of view, water supply by the D-C5 is optimum; however, it takes time to complete its construction and thus water is not available until the completion. Therefore, it is necessary to consider the groundwater development depending on the actual trend of water demand. Besides D-C5, construction of a dam at D-C3 (US$ 31.4 million) is also worth to be considered as an alternative.

2) Ponta Grossa

The most economical way to satisfy the required water supply, 0.615 m^3/s, is the direct intake from Tibagi river at S-P1 by means of weir and it costs US$ 7.4 million (US$ 12.3 million/m^3/s). If dam was applied, it would require two dams and the total cost would be approximately US$ 50 million. Since there is no suitable aquifer for water supply around Ponta Grossa, its development would cost comparatively high, US$ 70 million. Consequently, the direct intake from Tibagi river is optimum.

3) Londrina

The optimum water supply to Londrina is the direct intake from Tibagi river at S-L1 by means of weir to satisfy the requirement, 1.045 m^3/s, and its cost is US$ 11.6 million (US$ 13.3 million/m^3/s). There are only two sites suitable for dam construction around Londrina; however, the water supply from two dams would not meet the requirement and further it would cost US$ 120 million/m^3/s. Groundwater development would cost approximately five times as much as the cost of the direct intake, US$ 53.2 million. Therefore, neither dam nor groundwater is suitable for the water supply.

4) Apucarana

There are only two sites for dam development and the water supply from the two dams would be 0.030 m^3/s, which is much less than the requirement, 0.202 m^3/s. And further, it would cost high, US$ 400 million/m^3/s. On the other hand, groundwater is available to meet the requirement and its cost of development is US$ 8.9 million (US$ 46.4 million/m^3/s), which is much less than dam development. In conclusion, the required water supply in Apucarana should be satisfied by the groundwater. There is one alternative that water is conducted from Londrina to Apucarana because of the low cost of surface water development in Londrina.

5) Maringa

The optimum water supply to Maringa is the direct intake from Pirapo river at S-M1 and its cost to meet the water requirement, 0.906 m^3/s, is US$ 8.9 million (US$ 12.1 million/m^3/s). It needs two dams to satisfy the water requirement and it would cost more than US$ 60 million. Groundwater is not suitable due to its high cost (US$ 32.3 million), four times more than the cost of the direct intake.

6) Umuarama

Compared to other large urban areas, the unit cost of water development in Umuarama is high. The cost of dam to satisfy the water requirement, 0.04 m^3/s, is US$ 11.3 million (US$ 94.2 million/m^3/s) at D-U1 and US$ 11.5 million (US$ 95.8 million/m^3/s) at D-U2, while the cost of groundwater development to meet the requirement is US$ 19.6 million (US$ 163.3 million/m^3/s). From the economical point of view, the water supply by a dam, either D-U1 or D-U2, is appropriate; however, the combination of dam and groundwater might be an alternative because of small difference in their cost.

In conclusion, the most desirable water development facilities for each large urban area is tentatively assumed as shown in Table-7.19.

Table-7.15 Required Water Supply Amount in Urban Areas

No.	Municipality	MRH	Population Ratio in 2000 [Mun./MRH]%	Year	Required Supply in MRH		Required Supply in Municipality		Remark
					Base Case	Alternative Case	Base Case	Alternative Case	
			1000/1000		m3/s	m3/s	m3/s	m3/s	
-	Urban Area in Parana		-	1993	-	-	20.953	20.953	
				2015			39.945	39.903	
				2015-1993			18.992	18.950	
1	Curitiba MEtropollitan	268	2207.4	1993	8.313	8.313	7.956	7.956	
			/2306.2=	2015	15.719	13.380	15.043	12.805	
			95.7	2015-1993	7.406	5.067	7.088	4.849	
2	Cascavel	288	221.1	1993	1.892	1.892	0.447	0.447	
			/938.3=	2015	4.480	5.336	1.057	1.259	
			23.6	2015-1993	2.588	3.444	0.611	0.813	
3	Ponta Grossa	273	250.9	1993	1.134	1.134	0.709	0.709	
			/401.3=	2015	2.118	2.414	1.324	1.509	
			62.5	2015-1993	0.984	1.280	0.615	0.800	
4	Londrina	281	442.4	1993	2.378	2.378	1.237	1.237	
			/851.2=	2015	4.387	5.102	2.281	2.653	
			52.0	2015-1993	2.009	2.724	1.045	1.416	
5	Apucarana	284	98.1	1993	0.556	0.556	0.234	0.234	
			/232.8=	2015	1.035	1.035	0.436	0.436	
			42.1	2015-1993	0.479	0.479	0.202	0.202	
6	Maringa	282	288.7	1993	1.443	1.443	0.824	0.824	
			/505.7=	2015	3.030	3.461	1.730	1.976	
			57.1	2015-1993	1.587	2.018	0.906	1.152	
7	Umuarama	285	84.0	1993	0.631	0.631	0.187	0.187	
			/283.9=	2015	0.779	0.779	0.231	0.231	
			29.6	2015-1993	0.148	0.148	0.044	0.044	

Table-7.16 Alternative Solutions for Water Development in Particular Area

Location	Required Supply Amount	River	Specific Drought Discharge q10.7	Coordinates X	Coordinates Y	Catchment Area	Direct Intake from River: Developed Water	Direct Intake from River: Pipe Line Length	Direct Intake from River: PumpHead	Development by Dam: Developed Water	Development by Dam: Effective Capacity	Development by Dam: Pipe Line Length	Development by Dam: PumpHead	Development from Groundwater: Aquifer No.	Development from Groundwater: Required Well Num.	Development from Groundwater: Required Well Field	Remark
	m3/s		m3/s/100km2			km2	m3/s	km	m	m3/s	million m3	km	m			km2	
	0.611	:Base Case															
Cascavel	(0.813)	:Alternative Case															
[1] D-C1		Barreiro	0.411	264	7,244	38.6				0.55	14.5	15.0	160				
[2] D-C2		Tesouro	0.410	266	7,243	24.2				0.35	9.3	17.0	150				
[3] D-C3		Barreiro	0.445	266	7,247	83.0				1.30	35.7	21.0	170				
[4] D-C4		Aroeira	0.339	258	7,248	47.8				0.60	15.2	12.0	160				
[5] D-C5		Antos	0.365	244	7,244	68.9				0.90	23.0	8.0	160				
[6] D-C6		C.S.Salvador	0.351	259	7,230	17.5				0.20	4.2	10.0	160				
[7] Wells														[6]	55	382	for 0.611m3/s
														[6]	(73)	(508)	:Alternative Case
Ponta	0.615	:Base Case															
Grossa	(0.800)	:Alternative Case															
[1] S-P1		Tibagi	0.214	586	7,214	1,520.0	1.63	11.0	160								
[2] D-P1		Pitangui	0.214	590	7,231	70.9				0.55	15.0	8.5	90				
[3] D-P2		Verde	0.221	594	7,226	32.4				0.25	6.1	10.0	30				
[4] Wells														[3]	221	1,367	for 0.615m3/s
														[3]	(288)	(1,778)	:Alternative Case
	1.045	:Base Case															
Londrina	(1.416)	:Alternative Case															
[1] S-L1		Tibagi	0.088	501	7,429	21,955.0	9.66	15.0	250								St.64-507-011
									150 or 200								Using COPEL dam
[2] D-L1		Cafezal	0.072	482	7,416	157.8				0.40	9.6	7.0	150				
[3] D-L2		Jacutinga	0.091	491	7,428	96.7				0.25	6.5	10.0	200				
[4] Wells														[6]	97	653	for 1.045m3/s
														[6]	(127)	(885)	:Alternative Case
Apucarana	0.202	:Base Case															
[1] D-A1		Pirapo	0.082	450	7,398	20.9				0.02	1.3	4.5	160				
[2] D-A2		Bara Nova	0.056	451	7,391	15.6				0.01	0.5	6.0	120				
[3] Wells														[6]	19	126	for 0.202m3/s
	0.906	:Base Case															
Maringa	(1.152)	:Alternative Case															
[1] S-M1		Pirapo	0.269	414	7,420	1,252.0	1.68	13.0	190								
[2] D-M1		Ribeirao Sarandi	0.224	414	7,412	59.7				0.50	12.9	8.0	120				
[3] D-M2		Ribeirao Pinguim	0.191	403	7,402	81.6				0.55	13.4	8.0	160				
[4] Wells														[6]	77	566	for 0.906m3/s
														[6]	(104)	(720)	:Alternative Case
Umuarama	0.044	:Base Case															
[1] D-U1		Corregio Pinaizinho	0.503	270	7,368	44.2				0.70	20.4	6.0	120				
[2] D-U2		Riberao Verde	0.524	259	7,372	28.4				0.40	12.7	6.0	160				
[3] Wells														[8]	6	398	for 0.044m3/s

Note : D ; dam, S ; direct intake from river, C1,P1 etc. ; Location of Site
Aquifer Classification ;
[3]:Early Paleozoic;Castro/Parana Group
[6]:Botucatu & Serra Geral F.(Norte)
[8]:Caiua Formation

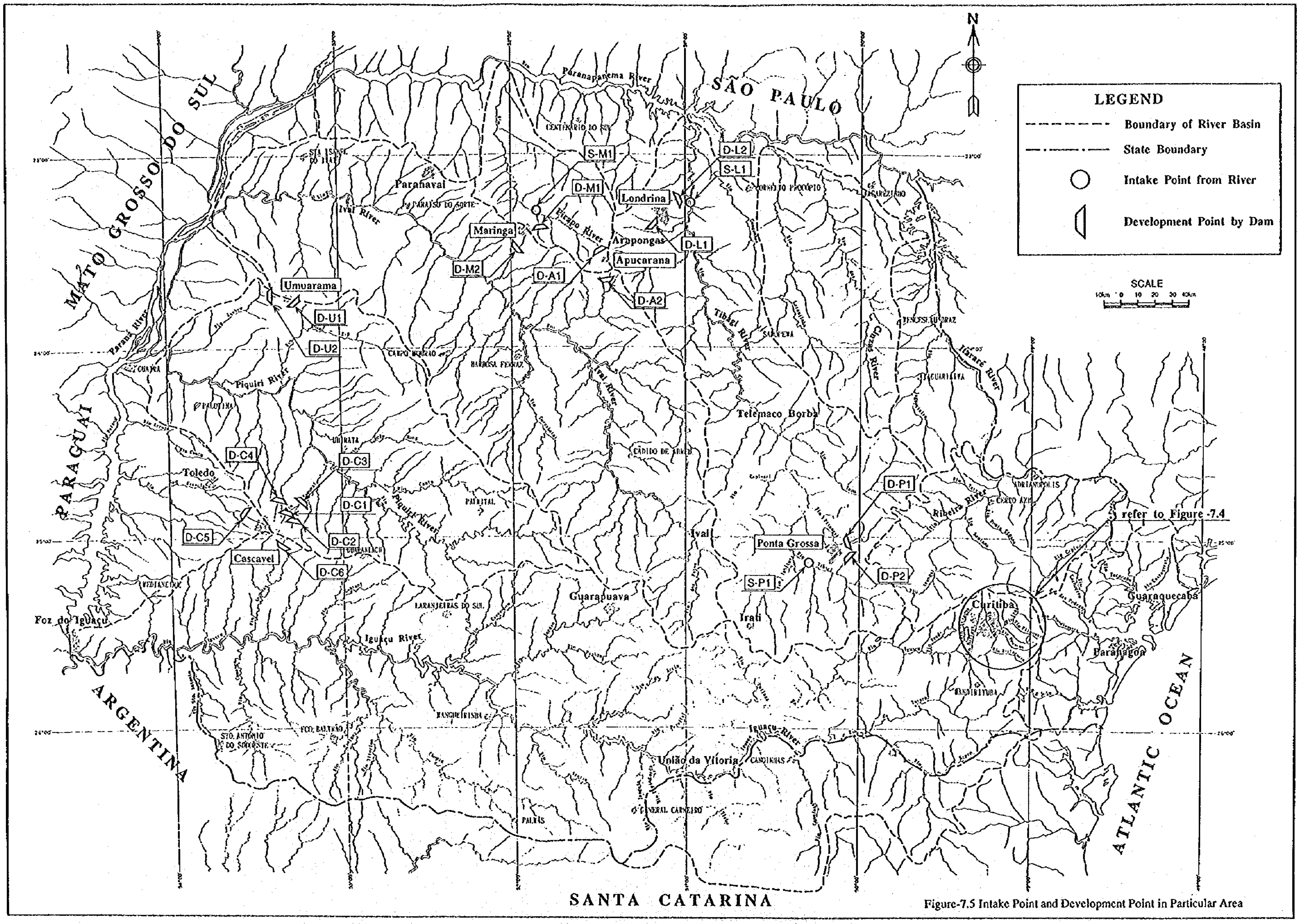

Figure-7.5 Intake Point and Development Point in Particular Area

Table-7.17 Groundwater Development Cost by Development Volume

Site No.	Development Volume (m^3/s)	Diameter of Conduit (mm)	Unit Cost US＄／m	Distance (m)	Number of Pipeline	Cost x10^{6}US＄ (1)	Boring number	Depth ／Well (m)	Cost／m US＄	Cost x10^{6}US＄ (2)	Pumping Cost x10^{6}US＄ (3)	Access Read (km)	Cost x10^{6}US＄ (4)	Total	Accumulate
1-1 (23)	1.00	φ400	290	12,000	4	13.9	23 (31)	80	880	2.2	2.6	16	5.0	30.0	30.0
1-2 (22)	1.00	φ400	290	20,000	4	23.2	22 (30)	80	880	2.2	4.2	16	5.0	43.8	73.8
1-3 (23)	1.00	φ400	290	30,000	4	34.8	23 (31)	80	880	2.2	6.4	20	6.2	62.7	136.5
2-1 (7)	0.08	φ300	160	1,000	1	0.16	7 (10)	120	490	0.59	0.05	5	1.7	2.9	2.9
2-2 (8)	0.09	φ300	160	2,000	1	0.32	8 (11)	120	490	0.65	0.08	4	1.4	2.9	5.8
2-3 (8)	0.09	φ300	160	4,000	1	0.64	8 (11)	120	490	0.65	0.13	3	1.1	3.0	8.8
2-4 (8)	0.09	φ300	160	6,000	1	0.96	8 (11)	120	490	0.65	0.19	3	1.1	3.4	12.2
2-5 (7)	0.08	φ300	160	4,000	1	0.64	7 (10)	120	490	0.59	0.13	7	2.3	4.4	16.6
2-6 (8)	0.09	φ300	160	9,000	1	1.44	8 (11)	120	490	0.65	0.28	4	1.4	4.5	21.1
2-7 (8)	0.09	φ300	160	15,000	1	2.40	8 (11)	120	490	0.65	0.45	4	1.4	6.0	27.1
2-8 (8)	0.09	φ300	160	22,000	1	3.52	8 (11)	120	490	0.65	0.65	5	1.7	8.0	35.1
3-1 (30)	0.08	φ300	160	5,000	1	0.80	30 (40)	150	370	2.22	0.21	5	1.7	6.2	6.2
3-2 (30)	0.08	φ300	160	5,000	1	0.80	30 (40)	150	370	2.22	0.21	5	1.7	6.2	12.4
3-3 (30)	0.08	φ300	160	10,000	1	1.60	30 (40)	150	370	2.22	0.35	6	2.0	7.8	20.2
3-4 (30)	0.08	φ300	160	10,000	1	1.60	30 (40)	150	370	2.22	0.35	6	2.0	7.8	28.0
3-5 (30)	0.08	φ300	160	15,000	1	2.40	30 (40)	150	370	2.22	0.50	7	2.3	9.4	37.4
3-6 (30)	0.08	φ300	160	15,000	1	2.40	30 (40)	150	370	2.22	0.50	8	2.6	9.8	47.2
3-7 (30)	0.08	φ300	160	20,000	1	3.20	30 (40)	150	370	2.22	0.64	11	3.5	12.1	59.3
3-8 (7)	0.08	φ300	160	20,000	1	3.20	7 (10)	150	370	0.56	0.59	12	3.8	10.3	69.6
4-1 (7)	0.08	φ300	160	8,000	1	1.28	7 (10)	120	490	0.59	0.25	5	1.7	4.9	4.9
4-2 (6)	0.07	φ300	160	7,000	1	1.12	6 (8)	120	490	0.47	0.21	4	1.4	4.1	9.0
4-3 (6)	0.07	φ300	160	12,000	1	1.92	6 (8)	120	490	0.47	0.36	3	1.1	4.9	13.9
4-4 (7)	0.08	φ300	160	3,000	1	0.48	7 (10)	120	490	0.59	0.10	3	1.1	2.9	16.8
4-5 (8)	0.09	φ300	160	5,000	1	0.80	8 (11)	120	490	0.65	0.16	7	2.3	4.9	21.7
4-6 (7)	0.08	φ300	160	4,000	1	0.64	7 (10)	120	490	0.59	0.13	4	1.4	3.5	25.2
4-7 (8)	0.09	φ300	160	2,000	1	0.32	8 (11)	120	490	0.65	0.08	4	1.4	3.1	28.3
4-8 (8)	0.09	φ300	160	7,000	1	1.12	8 (11)	120	490	0.65	0.22	5	1.7	4.7	33.0
4-9 (6)	0.07	φ300	160	8,000	1	1.28	6 (8)	120	490	0.47	0.24	4	1.4	4.3	37.3
4-10(7)	0.08	φ300	160	10,000	1	1.60	7 (10)	120	490	0.59	0.30	4	1.4	4.9	42.2
4-11(6)	0.07	φ300	160	11,000	1	1.76	6 (8)	120	490	0.47	0.33	4	1.4	5.0	47.2
4-12(6)	0.07	φ300	160	15,000	1	2.40	6 (8)	120	490	0.47	0.45	4	1.4	6.0	53.2
5-1 (6)	0.07	φ300	160	2,000	1	0.32	6 (8)	120	490	0.47	0.07	3	1.1	2.5	2.5
5-2 (6)	0.07	φ300	160	2,000	1	0.32	6 (8)	120	490	0.47	0.07	4	1.4	2.9	5.4
5-3 (6)	0.07	φ300	160	3,000	1	0.48	6 (8)	120	490	0.47	0.10	5	1.7	3.5	8.9
6-1 (13)	0.07	φ300	160	2,000	2	0.64	13 (18)	120	490	1.06	0.14	4	1.4	4.1	4.1
6-2 (12)	0.07	φ300	160	3,000	2	0.96	12 (16)	120	490	0.94	0.20	4	1.4	4.4	8.5
6-3 (12)	0.07	φ300	160	6,000	2	1.92	12 (16)	120	490	0.94	0.37	6	2.0	6.6	15.1
6-4 (12)	0.07	φ300	160	8,000	2	2.56	12 (16)	120	490	0.94	0.49	5	1.7	7.2	22.3
6-5 (12)	0.07	φ300	160	12,000	2	3.84	13 (18)	120	490	1.06	0.72	7	2.3	10.0	32.3
7-1 (3)	0.025	φ200	110	7,000	1	0.77	3 (4)	120	490	0.24	0.15	4	1.4	3.2	3.2
7-2 (3)	0.025	φ200	110	4,000	1	0.44	3 (4)	120	490	0.24	0.09	4	1.4	2.7	5.9
7-3 (3)	0.025	φ200	110	7,000	1	0.77	3 (4)	120	490	0.24	0.15	6	2.0	4.0	9.9
7-4 (3)	0.025	φ200	110	11,000	1	1.21	3 (4)	120	490	0.24	0.22	5	1.7	4.3	14.2
7-5 (3)	0.025	φ200	110	13,000	1	1.43	3 (4)	120	490	0.24	0.26	7	2.3	5.4	19.6

(1) Access Road 300,000US＄/km, 200,000US＄/site Contigency : 15%, Engineering Service 10%
(2) Pumping Cost is 18% of Pipeline cost . Pumping cost of well 3,100US＄/site (KARST) 2,200US＄/site (others)
(3) The unit cost of Pipeline includes price change (1.571times)
(4) Site No. 1- : Curitiba, 2- : Cascavel, 3- : Ponta Grossa, 4- : Londrina, 5- : Apucarana, 6- : Maringa, 7- : Umuarama

Table-7.18 Estimated Construction Cost of Planned Dams and Pipeline

Site NO.	Name	Location	Construction Cost of Dam ($\times 10^6$ US$)	Convenyance Facility Cost ($\times 10^6$ US$)	($\times 10^6$ US$)	Development Volume (m^3/s)	($\times 10^6$ US$)
1	Irai	near Curitiba	33.1	6.7	39.8	1.10	36.2
2	Piraquara II	do	13.7	4.3	18.0	0.70	25.7
3	Pequeno	do	25.1	5.5	30.6	0.90	34.0
4	Alto Miringuava	do	24.4	6.1	30.5	1.00	30.5
5	Cotia Despique	do	28.7	7.3	36.0	1.20	30.0
6	Alto Mauricio	do	11.0	1.5	12.5	0.25	50.0
7	Das Oncas(Mandirituba)	do	17.9	1.5	19.4	0.25	77.6
8	Faxinal	do	18.4	3.1	21.5	0.50	43.0
9	Das Oncas(Contenda)	do	14.9	3.7	18.6	0.60	31.0
10	Piunduva	do	15.5	1.2	16.7	0.20	83.5
①	Well Field	do			30.0	1.00	30.0
②	Well Field	do			73.8	2.00	36.9
③	Well Field	do			136.5	3.00	45.5
C_1	Baneiro(I)	near Cascavel	36.0	8.2	44.2	0.55	80.4
C_2	Tesovro	do	27.8	7.5	35.3	0.35	100.9
C_3	Baneiro(II)	do	17.5	13.9	31.4	0.69	45.5
C_4	Aroeira	do	45.1	8.2	53.3	0.60	88.8
C_5	Antos	do	23.4	5.6	29.0	0.69	42.0
C_6	C.S.Salvaror	do	22.1	2.0	24.1	0.20	120.5
①	Well Field	do			35.1	0.69	50.9
P_1-S		near Ponta Grossa		7.4	7.4	0.602	12.3
P_1	Pitangui	do	41.0	4.7	45.7	0.55	83.1
P_2	Verde	do	27.1	3.3	30.4	0.25	121.6
①	Well Field	do			69.6	0.602	115.6
L_1-S		near Londrina		11.6	11.6	0.874	13.3
L_1	Catezai	do	45.1	3.3	48.4	0.40	121.0
L_2	Jacutinga	do	15.1	3.5	18.6	0.25	74.4
①	Well Field	do			53.2	0.874	60.9
A_1	Pirapo	Apucarana	7.3	0.8	8.1	0.02	405.0
A_2	Bara Nova	do	6.3	0.9	7.2	0.01	720.0
①	Well Field	do			8.9	0.192	46.4
M_1-S		Maringa		8.9	16.3	0.737	12.0
M_1	Ribeirao Sarandi	do	41.6	4.6	46.2	0.50	92.4
M_2	Ribeirao Pinguim	do	39.7	4.6	44.3	0.55	80.5
①	Well Field	do			32.3	0.737	43.8
U_1	Conegio Pinaizinho	Umuarama	7.3	4.0	11.3	0.12	94.2
U_2	Ribeirao Verde	do	7.5	4.0	11.5	0.12	95.8
①	Well Field	do			19.6	0.120	163.3

Table-7.19 Specifications and Cost of Desirable Water Development Facilities for Large Urban Areas

Urban Name	Location or Construction Name	Development Volume (m^3/s)	Embankment Volume ($1000m^3$)	Pumping Head (m)	Well Numbers	Well Depth (m)	Pipeline (mm)*(m)	Cost (million us$)
Curitiba	Dams	5.000						186.0
Metropolitan	Wells	2.090						95.1
Cascavel	D-C5 Dam	0.611	473	200			800* 8,000	29.0
Ponta Grossa	S-P1 Direct Intake	0.615		200			700*11,000	7.4
Londrina	S-L1 Direct Intake	1.045		310			800*15,000	11.6
Apucarana	Wells	0.202			18	120	300* 2,000	8.9
Maringa	S-M1 Direct Intake	0.906		260			700*13,000	8.9
Umuarama	D-U1 Dam	0.044	54	140			400* 6,000	11.3

(2) Other Urban Areas

There are 356 municipalities except for above large urban areas in Paraná State. The required water for both domestic and industrial uses was described in Table-7.20. An amount of required water by each urban area depends on the scale of municipality, and required water volume at the target year of 2015 ranges from 0.001 in minimum to 0.795 m^3/sec in maximum at Foz do Iguaçu, with a mean of 0.024 m^3/sec.

Although a recommendable method of water development in this scale of urban areas is a direct intake method, such as using a pipeline or an open channel which leads water from weir/reservoir, pumping the water from river is necessary for an area located on the top of mountain ridge.

The cost estimation of the water supply system for other urban areas follows the procedure below.

1) Identification of the relationship between the water requirement and its development cost at the range of 0.01 m^3/s to 0.90 m^3/s based on the cost estimation of 24 municipalities selected

2) Cost estimation of all municipalities applying the above relationship to the water requirement of each municipality, except ones selected in (1).

The cost of water development of each municipality was summarized in MRH wise as shown below.

The total cost of water development of urban areas, except Curitiba metropolitan area and large urban areas, is US$ 306.3 million as shwon Table-7.21.

Table-7.20 Required Water Supply Amount in Each Municipality Urban Area

Municipality Name	1993 m3/s	2015 m3/s	2015-93 m3/s	Municipality Name	1993 m3/s	2015 m3/s	2015-93 m3/s	Municipality Name	1993 m3/s	2015 m3/s	2015-93 m3/s	Municipality Name	1993 m3/s	2015 m3/s	2015-93 m3/s	Municipality Name	1993 m3/s	2015 m3/s	2015-93 m3/s
Mandirituba	0.038	0.072	0.034	Jacarezinho	0.078	0.132	0.054	Presidente Castero Branco	0.007	0.011	0.004	Campo Mourao	0.199	0.373	0.174	Chopinzinho	0.021	0.042	0.021
Rio Blanco do Sul	0.091	0.172	0.081	Ribeirao Claro	0.016	0.027	0.011	Nova Esperanca	0.041	0.070	0.029	Ara Una	0.014	0.027	0.013	Coronal	0.030	0.062	0.032
Bocaiuva do Sul	0.010	0.020	0.010	Santo Antonio da Planita	0.071	0.120	0.049	Cruzeiro do Sul	0.008	0.014	0.006	Peabiru	0.021	0.039	0.018	Sao Joao	0.012	0.025	0.013
Campinha Grande do Sul	0.107	0.202	0.095	Barra do Jacare	0.004	0.006	0.002	Paranacity	0.014	0.023	0.009	Engenheiro Beltrao	0.023	0.043	0.020	Itapejara D'Oeste	0.010	0.020	0.010
Quatro Barras	0.052	0.098	0.046	Cambara	0.042	0.072	0.030	Inaja	0.005	0.009	0.004	Quinta do Sol	0.008	0.015	0.007	Pato Branco	0.113	0.233	0.120
Contenda	0.020	0.038	0.018	Andira	0.044	0.075	0.031	Paranapoema	0.006	0.010	0.004	Fenix	0.009	0.017	0.008	Mariopolis	0.007	0.014	0.007
Balsa Nova	0.013	0.025	0.012	Itambaraca	0.020	0.034	0.014	Jardim Olinda	0.003	0.005	0.002	Barbora Ferraz	0.024	0.046	0.022	Vitorino	0.007	0.013	0.006
Tunas do Parana	0.003	0.006	0.003	Bandeirantes	0.064	0.109	0.045	Alto Parana	0.020	0.034	0.014	Iretama	0.018	0.034	0.016	Renascenca	0.005	0.009	0.004
Itaperucu	0.023	0.044	0.021	Santa Amelia	0.006	0.010	0.004	Sao Joao do Caiua	0.011	0.019	0.008	Roncador	0.019	0.035	0.016	Marmeleiro	0.019	0.038	0.019
MRH-268	0.357	0.677	0.320	Abatia	0.016	0.028	0.012	Santo Antonio do Caiua	0.004	0.006	0.002	Nova Cantu	0.012	0.022	0.010	Francisco Beltrao	0.138	0.283	0.145
Guaraquesaba	0.004	0.007	0.003	Ribeirao do Pinhal	0.022	0.037	0.015	Tambora	0.007	0.012	0.005	Campina da Lagoa	0.030	0.057	0.027	Vere	0.007	0.015	0.008
Antonina	0.027	0.043	0.016	Jundiai do Sul	0.005	0.009	0.004	Paraiso do Norte	0.019	0.033	0.014	Ubirata	0.046	0.087	0.041	Dois Vizinhos	0.065	0.135	0.070
Morretes	0.012	0.018	0.006	Congonhinhas	0.012	0.020	0.008	Nova Alianca do Ivai	0.002	0.003	0.001	Mambore	0.022	0.040	0.018	Sao Jorge D'Oeste	0.008	0.016	0.008
Paranagua	0.210	0.332	0.122	Santo Antonio do Paraiso	0.003	0.005	0.002	Mirador	0.005	0.008	0.003	Boa Esperanca	0.007	0.012	0.005	Salgado Filho	0.005	0.009	0.004
Guaratuba	0.039	0.063	0.024	Nova Fatima	0.015	0.026	0.011	Paranavai	0.153	0.259	0.106	Janiopolis	0.010	0.020	0.010	Barracao	0.014	0.029	0.015
Matinhos	0.038	0.060	0.022	Nova America do Colina	0.005	0.009	0.004	Amapora	0.010	0.016	0.006	Goio-Ere	0.071	0.133	0.062	Santo Antonio do Sudoeste	0.021	0.042	0.021
MRH-269	0.330	0.523	0.193	Cornelio Procopio	0.104	0.177	0.073	Planaltina do Parana	0.005	0.008	0.003	Moreira Sies	0.026	0.049	0.023	Eneas Marques	0.003	0.007	0.004
Cerro Azul	0.014	0.024	0.010	Santa Mariana	0.020	0.033	0.013	Guairaca	0.007	0.012	0.005	Mariluz	0.018	0.033	0.015	Salto do Lontra	0.013	0.026	0.013
Adrianopolis	0.007	0.012	0.005	Leopolis	0.007	0.011	0.004	Terra Rica	0.027	0.045	0.018	Rancho Alegre do Oeste	0.005	0.009	0.004	Santa Izabel do Oeste	0.010	0.021	0.011
Doutor Ulysses	0.002	0.003	0.001	Sertaneja	0.012	0.020	0.008	Diamante de Norte	0.013	0.021	0.008	Farol	0.005	0.009	0.004	Ampere	0.014	0.029	0.015
MRH-270	0.023	0.039	0.016	MRH-279	0.566	0.960	0.394	Itauna do Sul	0.010	0.017	0.007	Luiziana	0.010	0.019	0.009	Realeza	0.020	0.041	0.021
Tijucas do Sul	0.002	0.004	0.002	Urai	0.023	0.036	0.013	Nova Londrina	0.026	0.044	0.018	Corumbatai do Sul	0.004	0.008	0.004	Perolaza	0.007	0.015	0.008
Agudos do Sul	0.001	0.002	0.001	Rancho Alegre	0.009	0.013	0.004	Loanda	0.033	0.056	0.023	Juranda	0.010	0.019	0.009	Planalto	0.009	0.019	0.010
Pien	0.008	0.014	0.006	Jataizinho	0.021	0.033	0.012	Santa Izabel do Ivai	0.011	0.018	0.007	MRH-286	0.611	1.146	0.535	Capanema	0.017	0.034	0.017
Quitandinha	0.005	0.009	0.004	Assai	0.033	0.051	0.018	Santa Cruz do Monte Castelo	0.016	0.027	0.011	Pitanga	0.030	0.056	0.026	Saudade do Iguacu	0.005	0.010	0.005
MRH-271	0.016	0.029	0.013	Sao Sebastioo da Amoreira	0.014	0.022	0.008	Querencia do Norte	0.017	0.028	0.011	Palmital	0.008	0.015	0.007	Pinhal do Sao Bento	0.001	0.003	0.002
Campo de Tenente	0.011	0.020	0.009	Santa Cecilia do Pavao	0.006	0.009	0.003	Sao Pedro do Parana	0.003	0.005	0.002	Manoel Ribas	0.008	0.016	0.008	Nova Esperanca do Sudoeste	0.002	0.004	0.002
Rio Negro	0.079	0.143	0.064	Sao Jeronimo da Serra	0.015	0.023	0.008	Porto Rico	0.004	0.006	0.002	Santa Moria D'Oeste	0.002	0.004	0.002	Flor da Serra do Sul	0.001	0.001	0.000
Lapa	0.080	0.144	0.064	Nova Santa Barbara	0.005	0.008	0.003	Marilena	0.009	0.016	0.007	Mato Rico	0.001	0.001	0.000	Cruzeiro do Iguacu	0.006	0.013	0.007
Palmeira	0.059	0.106	0.047	MRH-280	0.126	0.195	0.069	Santa Monica	0.001	0.002	0.001	Laranjal	0.001	0.003	0.002	Bom Sucesso do Sul	0.003	0.006	0.003
Porto Amazonas	0.009	0.017	0.008	Primeiro de Maio	0.030	0.055	0.025	MRH-283	0.497	0.837	0.340	Nova Tebas	0.006	0.012	0.006	Boa Esperanca do Iguacu	0.002	0.003	0.001
MRH-272	0.238	0.430	0.192	Sertanopolis	0.031	0.058	0.027	Grandes Rios	0.012	0.022	0.010	Altamira do Parana	0.003	0.005	0.002	Sulina	0.002	0.004	0.002
Castro	0.142	0.266	0.124	Ibipora	0.112	0.206	0.094	California	0.012	0.023	0.011	MRH-287	0.059	0.112	0.053	Pranchita	0.007	0.015	0.008
Pirai do Sul	0.040	0.074	0.034	Cambe	0.238	0.439	0.201	Rio Bom	0.004	0.008	0.004	Guaraniacu	0.018	0.042	0.024	Nova Prata do Iguacu	0.009	0.019	0.010
Tibagi	0.030	0.056	0.026	Bela Vista do Paraiso	0.038	0.070	0.032	Marilandia do Sul	0.013	0.025	0.012	Catanduvas	0.011	0.027	0.016	MRH-289	0.613	1.255	0.642
Telemaco Borba	0.200	0.373	0.173	Alvorada do Sul	0.017	0.032	0.015	Faxinal	0.029	0.054	0.025	Corbelia	0.023	0.055	0.032	Guarapuava	0.335	0.636	0.301
Ventania	0.014	0.026	0.012	Miraselva	0.011	0.020	0.009	Borrazopolis	0.013	0.024	0.011	Capitao Leonidas Marques	0.011	0.027	0.016	Inacio Martins	0.007	0.013	0.006
MRH-273	0.426	0.795	0.369	Florestopolis	0.028	0.053	0.025	Cambira	0.009	0.016	0.007	Formosa do Oeste	0.011	0.026	0.015	Pinhao	0.021	0.040	0.019
Jaguariaiva	0.103	0.276	0.173	Porecatu	0.029	0.054	0.025	Jandaia do Sul	0.040	0.074	0.034	Assis Chateaubriand	0.061	0.144	0.083	Laranjeiras do Sul	0.049	0.092	0.043
Senges	0.041	0.110	0.069	Jaguapita	0.026	0.048	0.022	Bom Sucesso	0.013	0.024	0.011	Palotina	0.045	0.105	0.060	Quedas do Iguacu	0.044	0.084	0.040
Arapoti	0.063	0.170	0.107	Centenario do Sul	0.032	0.058	0.026	Sao Pedro do Ivai	0.021	0.038	0.017	Terra Roxa	0.023	0.055	0.032	Virmond	0.002	0.003	0.001
MRH-274	0.207	0.556	0.349	Guaraci	0.012	0.023	0.011	Marumbi	0.008	0.014	0.006	Guaira	0.045	0.110	0.064	Rio Bonito do Iguacu	0.002	0.003	0.001
Antonio Olinto	0.002	0.005	0.003	Nossa Senhora dos Gracas	0.007	0.013	0.006	Kalore	0.007	0.014	0.007	Marechal Candido Rondon	0.042	0.098	0.056	Nova Laranjeiras	0.001	0.001	0.000
Sao Mateus do Sul	0.053	0.099	0.046	Cafera	0.005	0.010	0.005	Sao Joao do Ivai	0.026	0.048	0.022	Toledo	0.203	0.482	0.279	Candoi	0.005	0.010	0.005
Sao Joao do Triunfo	0.010	0.019	0.009	Lupionopolis	0.011	0.020	0.009	Jardim Alegre	0.016	0.030	0.014	Matelandia	0.018	0.043	0.025	Turvo	0.010	0.020	0.010
MRH-275	0.065	0.123	0.058	Colorado	0.057	0.105	0.048	Ivaipora	0.066	0.124	0.058	Medianeira	0.067	0.160	0.093	Cantagalo	0.034	0.064	0.030
Prudentopolis	0.030	0.055	0.025	Santo Inacio	0.013	0.025	0.012	Novo Itacolomi	0.002	0.004	0.002	Sao Miguel do Iguacu	0.024	0.056	0.032	MRH-290	0.510	0.966	0.456
Imbituba	0.021	0.038	0.017	Santa Ines	0.003	0.005	0.002	Maua da Serra	0.008	0.015	0.007	Foz do Iguacu	0.581	1.376	0.795	Uniao da Vitoria	0.112	0.182	0.070
Teixeira Soares	0.013	0.024	0.011	Itaguaje	0.010	0.019	0.009	Lidianopolis	0.005	0.008	0.003	Ceu Azul	0.012	0.029	0.017	Paula Freitas	0.007	0.011	0.004
Irati	0.085	0.156	0.071	Rolandia	0.109	0.201	0.092	Godoy Moreira	0.003	0.005	0.002	Nova Aurora	0.019	0.045	0.026	Paulo Frontin	0.006	0.009	0.003
Reboucas	0.015	0.027	0.012	Arapongas	0.185	0.342	0.157	Rosario do Ivai	0.006	0.012	0.006	Santa Helena	0.013	0.032	0.019	Cruz Mavhado	0.008	0.013	0.005
Rio Azul	0.008	0.015	0.007	Sabaudia	0.011	0.021	0.010	Lunardelli	0.008	0.015	0.007	Nova Santa Rosa	0.009	0.021	0.012	Bituruna	0.020	0.033	0.013
Mallet	0.018	0.033	0.015	Astorega	0.059	0.110	0.051	MRH-284	0.321	0.597	0.276	Sao Pedro do Iguacu	0.007	0.016	0.009	Porto Vitoria	0.006	0.009	0.003
MRH-276	0.190	0.348	0.158	Munhoz de Melo	0.006	0.011	0.005	Alto Piquiri	0.020	0.025	0.005	Santa Lucia	0.004	0.009	0.005	General Carneiro	0.026	0.043	0.017
Ortigueira	0.008	0.014	0.006	Iguaracu	0.011	0.020	0.009	Ipora	0.030	0.037	0.007	Ramilandia	0.004	0.010	0.006	Palmas	0.086	0.139	0.053
Reserva	0.015	0.025	0.010	Santa Fe	0.021	0.039	0.018	Xambre	0.006	0.007	0.001	Quatro Pontes	0.002	0.005	0.003	Mangueirinha	0.020	0.033	0.013
Candido de Abreu	0.008	0.013	0.005	Florida	0.006	0.011	0.005	Icaraima	0.015	0.019	0.004	Pato Bragado	0.003	0.006	0.003	Clevelandia	0.037	0.060	0.023
Ivai	0.006	0.010	0.004	Lobato	0.011	0.020	0.009	Maria Helena	0.006	0.008	0.002	Mercedes	0.001	0.003	0.002	Honorio Serpa	0.003	0.005	0.002
Ipiranga	0.006	0.010	0.004	Pitangueiras	0.004	0.007	0.003	Cidade Gaucha	0.019	0.023	0.004	Maripa	0.005	0.012	0.007	MRH-291	0.331	0.537	0.206
MRH-277	0.043	0.072	0.029	Angulo	0.007	0.012	0.005	Cruzeiro do Oeste	0.037	0.046	0.009	Itaipulandia	0.002	0.005	0.003				
Carlopolis	0.010	0.017	0.007	MRH-281	1.140	2.107	0.967	Gauporema	0.003	0.003	0.000	Iracema do Oeste	0.005	0.011	0.006				
Salto do Itarare	0.005	0.008	0.003	Mandaguari	0.073	0.154	0.081	Rondon	0.011	0.013	0.002	Iguatu	0.002	0.005	0.003				
Santana do Itarare	0.005	0.007	0.002	Marialva	0.055	0.116	0.061	Tapejara	0.023	0.028	0.005	Entre Rios do Oeste	0.002	0.005	0.003				
Sao Jose da Boa Vista	0.006	0.010	0.004	Itambe	0.016	0.034	0.018	Tuneiras do Oeste	0.013	0.016	0.003	Diamante so Sul	0.002	0.004	0.002				
Wenceslau Braz	0.023	0.036	0.013	Floresta	0.013	0.028	0.015	Japura	0.011	0.013	0.002	Anahy	0.003	0.007	0.004				
Siqueira Campos	0.014	0.022	0.008	Ivatuba	0.006	0.012	0.006	Sao Tome	0.006	0.008	0.002	Santa Tereza do Oeste	0.007	0.017	0.010				
Tomazina	0.007	0.011	0.004	Doutor Camargo	0.014	0.030	0.016	Cianorte	0.097	0.119	0.022	Ouro Verde do Oeste	0.007	0.017	0.010				
Quatigua	0.008	0.013	0.005	Paicandu	0.107	0.225	0.118	Jussara	0.014	0.018	0.004	Lindoeste	0.001	0.003	0.002				
Joaquim Tavora	0.010	0.016	0.006	Ourizona	0.009	0.019	0.010	Terra Boa	0.022	0.027	0.005	Ibema	0.015	0.036	0.021				
Guapirama	0.005	0.009	0.004	Mandaguacu	0.041	0.086	0.045	Altonia	0.030	0.037	0.007	Sao Jose des Palmeiras	0.005	0.012	0.007				
Conselheiro Mairink	0.004	0.007	0.003	Sao Jorge do Ivai	0.013	0.028	0.015	Perola	0.017	0.021	0.004	Diamante D'Oeste	0.009	0.021	0.012				
Jaboti	0.003	0.005	0.002	Florai	0.012	0.025	0.013	Indianapolis	0.004	0.005	0.001	Campo Bonito	0.004	0.009	0.005				
Japira	0.003	0.005	0.002	Atalaia	0.010	0.020	0.010	Tapira	0.007	0.008	0.001	Boa Vista da Aparecida	0.006	0.014	0.008				
Ibaiti	0.024	0.039	0.015	Uniflor	0.005	0.011	0.006	Nova Olimpia	0.008	0.010	0.002	Missal	0.010	0.025	0.015				
Pinhalao	0.005	0.007	0.002	Sao Carlos do Ivai	0.012	0.025	0.013	Francisco Alves	0.008	0.010	0.002	Santa Terezinhodo do Itaipu	0.029	0.069	0.040				
Curiuva	0.009	0.014	0.005	Sarandi	0.232	0.489	0.257	Vila Alta	0.005	0.006	0.001	Jesuitas	0.012	0.028	0.016				
Sapopema	0.006	0.010	0.004	MRH-282	0.618	1.302	0.684	Sao Manoel do Parana	0.002	0.002	0.000	Braganey	0.007	0.017	0.010				
Figueira	0.019	0.030	0.011					Cafezal do Sul	0.005	0.006	0.001	Vera Cruz d Oeate	0.011	0.026	0.015				
MRH-278	0.166	0.266	0.100					Brasilandia do Sul	0.006	0.007	0.001	Tres Barras do Parana	0.008	0.019	0.011				
								Ivate	0.005	0.007	0.002	Catelandia	0.020	0.048	0.028				
								Douradina	0.007	0.008	0.001	Tupassi	0.011	0.026	0.015				
								Sao Jorge do Patrocinio	0.007	0.008	0.001	MRH-288	1.441	3.418	1.977	Total Required Water	9.338	17.835	8.497
								MRH-285	0.444	0.545	0.101					Average Required Water	0.026	0.050	0.024

Table-7.21 The Cost of Water Development in MRH [Surface Water]/Domestic & Industrial

MRH Name	1993 m3/s	2015 m3/s	2015-'93 m3/s	Cost million US$
MRH-268	0.357	0.677	0.320	9.80
MRH-269	0.330	0.523	0.193	6.06
MRH-270	0.023	0.039	0.016	1.77
MRH-271	0.016	0.029	0.013	2.22
MRH-272	0.238	0.430	0.192	5.68
MRH-273	0.426	0.795	0.369	8.05
MRH-274	0.207	0.556	0.349	6.82
MRH-275	0.065	0.123	0.058	2.46
MRH-276	0.190	0.348	0.158	6.11
MRH-277	0.043	0.072	0.029	2.99
MRH-278	0.166	0.266	0.100	10.65
MRH-279	0.566	0.960	0.394	16.50
MRH-280	0.126	0.195	0.069	5.14
MRH-281	1.140	2.107	0.967	30.09
MRH-282	0.618	1.302	0.684	17.75
MRH-283	0.497	0.837	0.340	20.60
MRH-284	0.321	0.597	0.276	15.07
MRH-285	0.444	0.545	0.101	16.36
MRH-286	0.611	1.146	0.535	19.94
MRH-287	0.059	0.112	0.053	4.90
MRH-288	1.441	3.418	1.977	49.39
MRH-289	0.613	1.255	0.642	27.30
MRH-290	0.510	0.966	0.456	11.80
MRH-291	0.331	0.537	0.206	8.89
Total	9.338	17.835	8.497	306.34

7.8 Water Development in Rural Areas

In rural areas, it is difficult to supply the water requirement by surface water systematically, because demand of domestic water is scattered due to topographic condition. Therefore, supply for domestic water will be done by groundwater development.

The demand of domestic water in rural areas tends to decrease in Paraná state. As a result, the development of rural water will not be necessary and only improvement of maintenance of existing wells is enough to satisfy the future water demand.

7.9 Water Development for Agricultural Water

Supply method of agricultural water at rural areas is generally a pipeline method with a direct intake using a pipeline and head works.

According to hearing and field reconnaissance, an average of intake volume was less than 0.001 m^3/s , and average length of pipeline was 3 km.

The total water requirement for agricultural sector is 1.02 m^3/s. The total cost of its development was estimated applying the cost of unit water development determined during the cost estimation for large urban areas and thus the total cost is US$ 12.2 million.

7.10 Total Cost for Water Development

The cost estimated in the previous sections covers from intake to purification of water. In this section, the total cost including from intake to water supply to house/industry was estimated and summarized in Table-7.22.

Table-7.22 Total Cost for Water Development

	Q (m^3/s)	Cost (10^6US$)	Unit Cost (10^6 US$/$m^3$/s)	Water Supply System
(1) Domestic and Industrial Water Development (Urban Area)				
1) Curitiba	7.088(2.572)	759.7	107.2	dams & groundwater
2) Cascavel	0.611(0.145)	78.4	128.3	1 dam
3) Ponta Grossa	0.615(0.283)	20.0	32.5	direct intake
4) Londrina	1.045(0.300)	31.4	30.0	direct intake
5) Apucarana	0.202(0.058)	24.1	119.3	groundwater
6) Maringa	0.906(0.339)	24.1	26.6	direct intake
7) Umuarama	0.044(0.010)	30.5	693.2	1 dam
8) Other urban area	8.497(1.603)	827.9	97.4	direct intake
Sub-total	19.008(5.310)	1,796.1	94.5	
(2) Agricultural Water Development (Rural Area)				
	1.018	12.2	12.0	direct intake
Total	20.026	1,808.3	90.3	

Note: ( )shows industrial water.

7.11 Hydropower Development

7.11.1 Power Supply Expansion Program

(1) Whole Brazil

National plan on power supply expansion including generation expansion and transmission expansion is studied by Eletrobras/GCPS to meet the future electricity demand growth. The results are presented in the 10-year plan and the long term national plan for electric energy. According to the latest plans in the 10-year plan (1994-2003) and the Plano-2015 (Scenario II), the total generation capacities at present and envisioned for 2005 and 2015 are shown in Table-7.23.

Table-7.23 Total Generation Capacity

	Generation Capacity (GW)			Firm Energy (TWh)		
	Actual	Projected		Estimated		
	1992	2005	2015	1992	2005	2015
South/Southeast System	38.32	71.50	80.40	191	354	402
Whole Brazil	51.32	94.80	140.10	257	478	703

The firm energy shown in this table is the energy which can be supplied firmly by whole of generation plants including present ones. These figures were estimated by the JICA team from the envisioned generation capacity applying the capacity factor of 0.57 which is the factor of present system.

(2) Paraná State

Paraná state has 42 candidates of hydropower projects on the rivers in the state as listed in Table-7.24. Those candidate projects are located on the rivers of Iguaçu and its tributaries, Tibagi, Ivai, Piquiri, Paranapanema and Paraná as well as on the rivers in coastal basin. Out of these, 13 projects are tentatively planned to be commissioned up to 2015. Location of those power stations are indicated on map in Figure-6.3. Total hydropower generation capacity of 13 projects is 8,868 MW as shown in Table-7.25.

Table-7.24 List of Inventoried Hydropower Stations in Paraná State

No.	Name of Power Station	Basin	River System	Intalled Capacity MW	Firm Energy GWh	Planned Start-up Year
1	Jordao Diversion	Iguacu	Jordao	6.5	526 *	Mar. 96
2	Salto Caxias	Iguacu	Iguacu	1,240	4,853	Dec. 98
3	Jataizinho	Tibagi	Tibagi	156	758	2002
4	Cebolao	Tibagi	Tibagi	156	757	2003
	Total (up to 2005)			1,559	6,894	
5	Sao Jeronimo	Tibagi	Tibagi	284	1,386	2006
6	Maua	Tibagi	Tibagi	388	1,617	2007
7	Telemaco Borba	Tibagi	Tibagi	112	541	2008
8	Agua do Vere	Iguacu	Chopim	96	411	
9	Curucaca	Iguacu	Jordao	52	225	
10	Erveira	Iguacu	Chopim	96	398	
11	Foz do Chopim 2	Iguacu	Chopim	60	252	
12	Fundao	Iguacu	Jordao	154	640	2006-15
13	Jacu	Iguacu	Jordao	122	527	
14	Pinhao	Iguacu	Jordao	42	184	
15	Salto Alema	Iguacu	Chopim	70	281	
16	Salto Chopim	Iguacu	Chopim	98	410	
17	Salto Gr. Chopim	Iguacu	Chopim	52	200	
18	Sao Joao	Iguacu	Chopim	68	265	
19	Sao Luiz	Iguacu	Chopim	42	158	
20	Tagua	Iguacu	Jordao	36	136	
21	Altamira	Piquiri	Piquiri	116	412	
22	Barra Grande	Piquiri	Piquiri	34	140	
23	Bela.V.do Ivai	Ivai	Ivai	96	412	2006-15
24	Ercilandia	Piquiri	Piquiri	102	403	
25	Foz do Alonzo	Ivai	Ivai	138	587	2006-15
26	Foz do Cobre	Piquiri	Piquiri	18	79	
27	Guampara	Piquiri	Piquiri	32	123	
28	Ivatuva	Ivai	Ivai	144	622	2006-15
29	Salto Ariranha	Ivai	Ivai	168	604	
30	Sao Joao do Ivai	Ivai	Ivai	98	420	2006-15
31	Tres Figueiras	Ivai	Ivai	120	526	
32	Ubauna	Ivai	Ivai	122	508	2006-15
33	Volta Grande	Piquiri	Piquiri	34	131	
34	Ourinhos	Paranapanema	Paranapanema	48	201	
35	Santa Branca	Tibagi	Tibagi	67	302	
36	Tibagi	Tibagi	Tibagi	47	222	
37	Nova Aurora	Piquiri	Piquiri	172	639	
38	Rio Bonito	Piquiri	Piquiri	16	53	
39	Salto Apertados	Piquiri	Piquiri	156	604	
40	Itaoca	Ribeira	Ribeira	40	237	
41	Capanema	Iguacu	Iguacu	1,200	3,653	
42	Ilha Grande	Parana	Parana	1,320	9,408	
	Total (2006 to 2015)			1,536	6,733	
	Grand Total (1996 - 2015)			3,095	13,627	

Remarks : * denotes increment of energy in the existing Segredo plant and Jordao small plant.

Table-7.25 Hydropower Generation Capacity in Paraná State

	River		Total Installed Capacity (MW)
Existing (1993)			5,773
Up to 2005	Jordao	6.5	
	Iguaçu	1,240	
	Tibagi	312	
	Total	1,559	
	Accumulated		7,332
Up to 2015	Iguaçu, Jordao	154	
	Tibagi	784	
	Ivai	598	
	Total	1,536	
	Accumulated		8,868

7.11.2 Construction Cost of Planned Hydropower Stations in Paraná State

According to data presented by COPEL, construction costs of the selected 13 plants are as shown in Table-7.26. The cost in the COPEL's data expressed in Brazilian currency was converted to US$ using a conversion rate table (reference 3) given by COPEL.

Literature Cited

1. Eletrobras/GCPS. (Dec. 1993). Plano Decenal de Expansao 1994-2003.

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Table-7.26 Construction Cost of Planned Hydropower Stations in Paraná State

No.	Name of Power Station	Basin	Installed Capacity MW	Construction Cost in Original Estimate Million US$	Construction Cost in Original Estimate Estimated Date	Price Conver. Coeff.	Construction Cost Converted to Current Price by JICA (Dec.93) Mill'n US$	US$/kW	US$/MWh *
1	Jordao Diversion	Iguacu	6.5	** 92.3	Dec.92	1.0	92.3	14,200	203.4
2	Salto Caxias	Iguacu	1,240	887.6	Dec.92	1.0	887.6	715.8	19.2
3	Sao Jeronimo	Tibagi	284	268.6	Dec.93	N.A.	281.6	1,025	21.7
4	Jataizinho	Tibagi	156	183.2	Dec.93	N.A.	177.4	1,137	24.9
5	Cebolao	Tibagi	156	180.6	Dec.93	N.A.	174.8	1,120	24.6
6	Maua	Tibagi	388	367.8	Dec.93	N.A.	385.6	1,054	25.4
7	Telemaco Borba	Tibagi	112	132.1	Dec.93	N.A.	127.9	1,142	25.4
8	Fundao	Iguacu	154	126	Jul.81	1.697	214	1,393	34
9	Bela.V.do Ivai	Ivai	96	106	Jul.81	1.697	180	1,875	44
10	Foz do Alonzo	Ivai	138	132	Jul.81	1.697	224	1,620	38
11	Ivatuva	Ivai	144	135	Jul.81	1.697	229	1,593	37
12	Sao Joao do Ivai	Ivai	98	104	Jul.81	1.697	176	1,799	42
13	Ubauna	Ivai	122	136	Jul.81	1.697	231	1,894	46

* : Unit cost of firm energy = (Construction cost x CRF)/Annual firm energy
CRF = capital recovery factor = 0.10086 at 10 % discount rate and 50 years life

** : including cost for facility to divert water to existing Segredo reservoir.

N.A.: data not available ( ) : assumed value

7.12 Inland Navigation Development

7.12.1 Review of Feasibility Study for Inland Navigation

SETR has been studying the following commercial waterways at both Ivai river and Tibagi river on 1985 and 1991 respectively. Both waterway systems aim to link with the existing railway system in Paraná.

(1) Paraná - Ivai Waterway System (between Doutor Camargo and Paraná River)

According to a report of "Best Usage of the Lower Course of the Ivai River for Transportation and Generation of Energy, October 1985" issued by COPEL and SETR, This study aims at analyzing the feasibility of necessary investments, focusing the characterization of the many alternative implementation works, and destining the best usage of the lower course of Ivai river.

This waterway system is characterized as combination of a waterway in the Ivai river (from its mouth until the surroundings of Doutor Camargo Municipality, about 237 km), and the existing rail-motorway (PR-323) from Cianorte to Maringa.

At present, especially from river mouth to 149 km at upstream of Ivai river, the river presents four sub-streams and depth problem at some points. To increase the sufficient depth for navigability, Tres Figueiras dam with lock facility should be provided in Ivai river.

1) Type of Vessels

The total length of convoy of both types are same as 137.5 m, and maximum cargo capacity are 1,200 ton (3 barges) for 9 m width type and 5,000 ton (2 barges) for 16 m width.

2) Type of Cargoes

Type of cargoes are expected both agricultural products (soybean, wheat, corn, rice and others) and industrial product (limestone, fuels and others), and it depends on the regional characteristics.

3) Necessary Works

The alternatives of transport systems were considered as follows, and evaluated the best transportation system by a comparative economical analysis;

Alternative I	waterway system
Alternative II	Cianorte-Guaira railway
Alternative III	Guarapuava-Guaira railway
Alternative IV	rail-waterway

The conclusion was that the best transport alternative for regional interest is the combined water-railway, using the Ivai river in all the extension of its lower course, inter-linking the Dr. Camargo existing railway system.

The necessary works to be done are as follows;

- Tres Figueiras dam with lock facility
- Improvement of downstream river course in Ivai river
- Terminal port of water-railway in Dr. Camargo

4) Cost Estimation

The cost to actualize the Ivai waterway system , Tres Figueiras hydroelectric dam with lock was estimated to be US$ 239 million (prices in September 1983) in maximum, and Doutor Camargo port facility and other works were estimated to be US$ 10.9 million, therefore total cost was estimated to be US$ 249.9 million. (prices in September 1983)

(2) Tibagi - Paranapanema Waterway System (between Jataizinho and Paraná river)

According to a report of "Navigation Study in Paranapanema and Tibagi River, September 1991", issued by SETR, this study aimed to analyze the feasibility of navigability between Tibagi and Paranapanema rivers, and destining the useful waterway by linking to the existing railway.

This waterway system is characterized from the confluence of Paraná river to the end of Capivara dam reservoir, and also towards Canoas I dam and Tibagi river. The route of waterway will be utilized the backwater in reservoirs.

The distance of waterway from river mouth to the existing Capirava dam in Paranapanema river is estimated 217.2 km, and waterway in Tibagi is 75 km. There exist three dams such as Rosana dam, Taquarucu dam and Capivara dam through the planned waterway system, but none of these existing dams have lock facilities at present.

1) Type of Vessels

Type of vessels are considered as two types such as a Tiete convoy type and a Paranapanema convoy type. The differences between them are mainly total length of convoy (138 - 256 m/convoy), gross loading capacity (2,000 - 3,300 ton/time), and width of barge (8 - 11 m). Especially, two types of lock facility are considered at 12 m width lock and 17 m width lock for Tiete convoy type and Paranapanema convoy type, respectively. The draught of the vessel adapted as 2.5 m for both types.

2) Type of Cargoes

Type of cargoes are expected both agricultural products (soybean, wheat, corn, rice and others) and industrial product (soybean bran, cement, fertilizers and others), and it depends on the regional characteristics.

3) Necessary Works

The following work items are listed to be necessary to approach the future waterway of Paranapanema and Tibagi rivers.

<Level Transition Works>

Lock facilities at the existing dams such as Rosana (different water level : 22.5 m), Taquarucu (different water level : 28.9 m) and Capivara dams (different water level : 52.4 m).

<Other Necessary Works>

Besides the works mentioned above, the following works will be necessary;

- Improvement at Foz Jataizinho trajectory course

- Improvement in the backwater trajectory course of Capivara reservoir
- Trans-shipment Terminal and rail-highway accesses

4) Cost Estimation

The cost was estimated to install new lock facilities in the existing dams at least US$ 210 million (prices in September 1991), and with an extension of waterway in Tibagi river (between Capivara dam reservoir and Jataizinho city) was estimated to be US$ 40 million (prices in September 1991), therefore total cost was estimated to be about US$ 250 million (prices in September 1991).

7.12.2 Necessity for Updating of Feasibility Studies

The implementation of the mentioned waterway plans has to satisfy the following conditions respectively;

< Paraná-Ivai Waterway >

It is clear that a required water depth for smooth navigability will be kept by the future reservoir of Ilha Grande dam and Tres Figueiras dam with a lock facility. According to the plan of hydropower stations in Paraná State by COPEL, Ilha Grande dam and Tres Figueiras dam are planned to be operated in year of 2010 - 2015 and 2005 - 2009 respectively.

< Tibagi-Paranapanema Waterway >

From the extension of 760 km in Paraná river, about 510 km belong to seven existing hydropower stations with lock facilities and sufficient depth kept by each reservoir such as Rosana, Taquaracu, Capivara, Salto Grande, Xavantes, Piraju and Santa Cruz e Jurumim. Paranapanema river is already canalized more than two-thirds of a target waterway, it mean that adequate waterway conditions are already provided. The demand of navigability with the extension of Tibagi-Paranapanema waterway depends on the implementation of installation of lock facilities and other related works for continuous of long waterway investments.

The implementation of the future waterway system require long period and huge cost. As long period elapses, transport environment surrounding the inland navigation will be changed. Generally speaking, road and railway transportation net-works will be developed more than expected. Therefore, the feasibility study for the inland navigation will be necessary to be updated in near future.

7.12.3 Effect of Inland Navigation on Water Environment

The Team considered that even if the above mentioned project is implemented in the future, it will not have an important effect upon water environment in terms of water consumption for inland navigation, because required depth of waterway will be kept by dam reservoirs. Of course, construction of dams and reservoirs involved in the project, of which primary purpose is hydroelectric power generation, will affect water environment such as ecosystem, sedimentation, flooding and others, and therefore have to be carefully assessed for their environmental impact.

CHAPTER 8 ENVIRONMENTAL CONSERVATION AND IMPROVEMENT

8.1 Flood

8.1.1 Historic Flood Records in Paraná State

(1) General

Record of monetary damage, detailed description of social, economic and structural damage, and maps of flood inundation areas are not available in Paraná State, except for some fraction of information kept in several municipal offices and states institutions. The National Department of Sanitation Works (DNOS) was in charge of the flood control management at national level. The DNOS had a function of flood investigation, study and keeping flood damage record. The historic record and investigation reports made by DNOS seems to be disappeared. After DNOS was abolished in 1990, the Civil Defense (CD) is the only institution that has officially kept historic record of floods in Paraná State. However, the record of CD is limited to number of persons, houses, buildings and bridges that suffered flood damage, since it takes charges of security of people and rescue activities, instead of flood control management.

The National Department of Water and Electric Energy (DNAEE) keeps a few secondary information about flood obtained from other organizations including photographs and newspaper articles. The Superintendency of Erosion Control and Environmental Sanitation (SUCEAM) has been taken over the management of flood control in Paraná State and Curitiba Metropolitan area after reorganization in February, 1995. SUCEAM keeps some information on flood which are related to the Environmental Sanitation Program of Curitiba Metropolitan Region (PROSAM), but those information do not include monetary damage. The Coordination of the Metropolitan Area of Curitiba (COMEC) assesses flood control projects in terms of change in land value, since there is not available record of monetary damage caused by floods. The Institute of Investigation and Planning of Urban Curitiba (IPPUC) made a partial survey of the damage caused by major floods in Curitiba city.

(2) Flood Records by Civil Defense

The historic record of flood damage kept by the Civil Defense covers number of people dislodged, injured and dead, number of houses damaged or destroyed, and damage to bridges and roads. Table-8.1 summarizes the historic distribution of damage caused by floods in Paraná State in terms of number of affected people (total number of people dislodged, injured, and dead) in the period from 1980 to 1993. The 1983 and 1992 floods are the two largest floods in Paraná State since 1931. It is difficult to make a precise assessment of the magnitude of floods that occurred in a year other than 1983, 1992 and 1995 because of the scarcity of damage data.

(3) Flood Prone Areas in Paraná State

The location distributions of municipalities which suffered the floods of 1983 and 1992, the two major floods in Paraná State during the last two decades, are shown in Figure-8.1 and Figure-8.2 respectively. The location distribution of municipalities affected by floods in a year other than 1983 and 1992 are shown in Figure-8.3. From Figures-8.1, 8.2 and 8.3 it can be seen that the majority of urban flood prone areas of Paraná State are located within the

Iguaçu river basin.

Since flood inundation maps are not available in the institutions of Paraná State, JICA Study Team conducted a reconnaissance survey in the flood susceptible areas listed below.

Iguaçu river basin

Region-1: Curitiba metropolitan area
Region-2: Porto Amazonas, São Mateus do Sul
Region-3: Reboucas, Guarapuava, Irati (Tibagi river basin)
Region-4: União da Vitoria, Porto União (Santa Catarina State), Porto Vitoria
Region-5: Rio Negro, Mafra (Santa Catarina state)
Region-8: Capanema

Paraná river basin

Region-6: Foz do Iguaçu, Del Este city (Paraguay), Upstream of Itaipu dam

Coastal basin (Litoranea region)

Region-7: Morretes

Ipiranga and Ivai cities were investigated as a part of the Tibagi river basin. The location map of these regions is shown in Figure-8.4.

(4) Flood Inundation and Maps

The available records of flood in Paraná State indicate that flood inundation causing significant economic and social damage occurred generally in urban or semi-urban flood prone areas. Those urban flood prone lands are of relatively small size. In many cases the flood prone areas in Paraná State are occupied by low income families. Most of the urban flood prone areas are located within the Iguaçu river basin. Interview with the authority from the Department of Agriculture confirmed that there was not significant flood inundation affecting large agricultural land area in Paraná State. There are only verbal reports of relatively small and scattered flood inundation damage to agriculture and livestock.

Further flood inundation information and maps of the regions 1 to 8 are presented in the Sectoral Report vol.H, Flood Control.

(5) Estimation of Flood Damage

Comprehensive evaluation of tangible flood damage, specially monetary damage, has not been done yet in Paraná state. Probable flood damage was roughly estimated with reference to the data and information gathered during the field survey done during Phase II and III of the Flood Control Study. The results of estimated probable flood inundation damage are simply notional to get a general idea of the magnitude of probable flood inundation damage for different flood level at each selected flood prone area.

Table-8.1 Number of people Affected by Historic Flood in Paraná State

Municipality	1980	1981	1982	1983	1984	1986	1987	1988	1989	1990	1991	1992	1993
Uniao da Vitoria	1151		*3572	30003	140		815					14129	1378
São Mateus do Sul				5800			50		55			970	70
Rio Negro				5502	800				50			5001	
Curitiba	2000	2000	547	5000				500				281	405
Francisco Beltrao				4000								60	
Ivai				3200									
Porto Vitória				3150								130	
Itapejara do Oeste				3000									
Ipiranga				3000									
Irati		4		2892		160	90					700	
Coronel Vivida				2001								50	
São Jose dos Pinhais	1000	1000	4000	2062									300
Piraquara	1000	1000	2038	2000									
Paula Freitas				1500								240	
Porto Amazonas				1301			80		20			352	130
Capanema				1200								400	
Tres Barras do Parana				1200								150	
Ortigueira				1002									
Bituruna				1000								18	
Palmas				700									
Vitorino				600									
Chopinzinho				600								197	
Sao Joao				600									
São Jorge do Oeste				502									
Mangueirinha				500								120	
General Carneiro				500								12	
Cruz Machado				500								1140	
Araucaria				500									
Candido de Abreu				400									
Reboucas				350								450	
Dois Vezinhos				340								305	
Quitandinha				300								228	
Alto Piquiri				250									
Imbituva				252									
Balsa Nova				241									
Veré				240								120	
Campo Tenente				200								240	
Castro				200									
Paulo Frontim				200								42	
Pien				200									
Mariópolis				102									
Mallet				50								278	
Colombo	400	400											600
Santa Mariana										7660			
Cambará											2000		
Foz do Iguacu												830	
Altonia.		80											
Marilena		200											
Sao Pedro de Parana		230									75		
Porto Rico		350											
Laranjeiras do Sul							100						
Capitao L. Marques												239	
Guarapuava												587	
Sulina												90	
Rio Azul												50	
Lapa												200	
N. Prata Iguacu												150	
Pinhais													400
Salto do Lontra												10	
Realeza												12	

Source: CIVIL DEFENSE.

Note: The data represent the total number of people affected by floods (total of dislodged, injured, and dead).

* In two flood events, June and November 1982

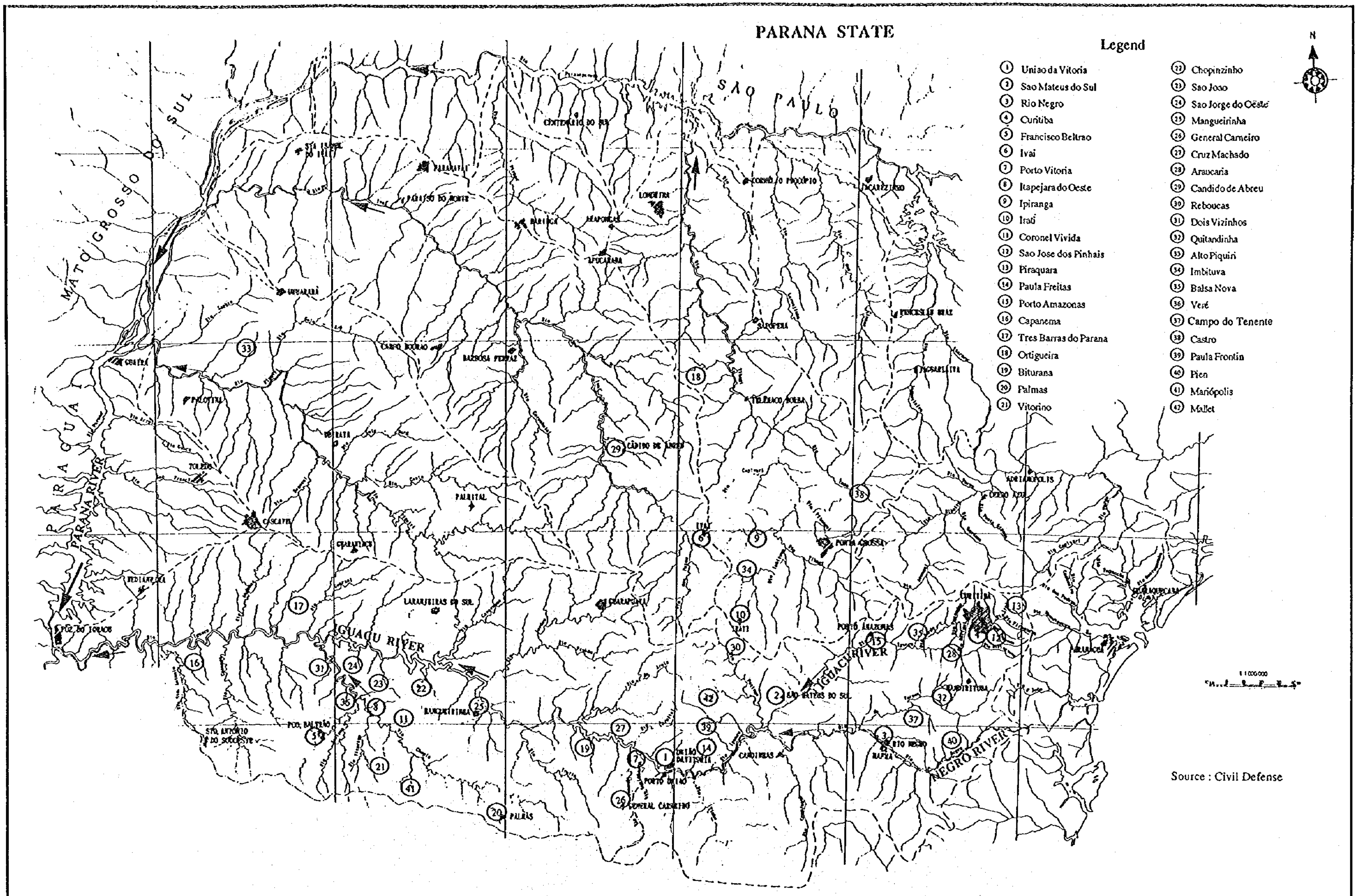

Figure-8.1 Location Distribution of Municipalities Which Suffered Flood in 1983

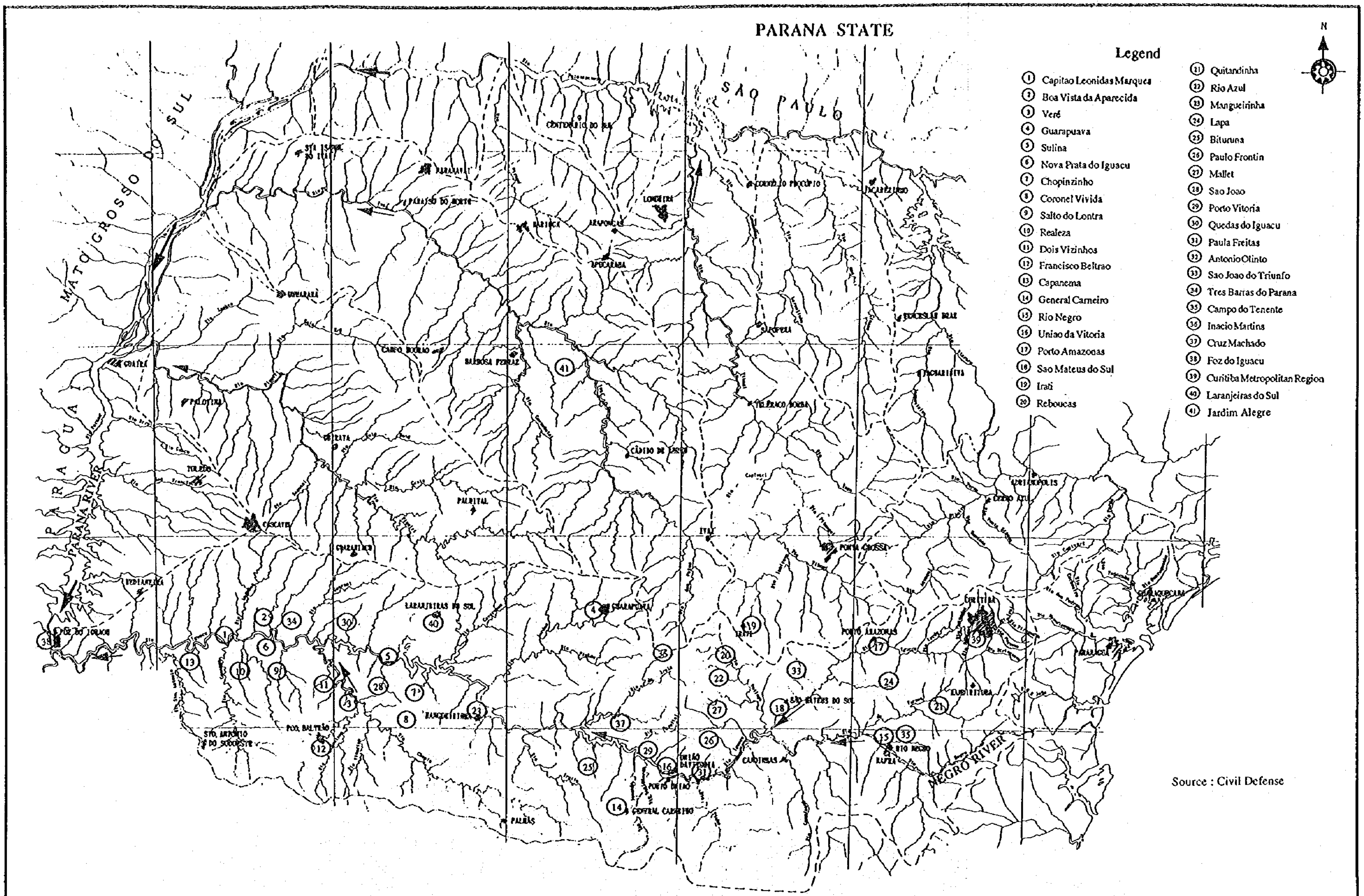

Figure-8.2 Location Distribution of Municipalities Which Suffered Flood in 1992

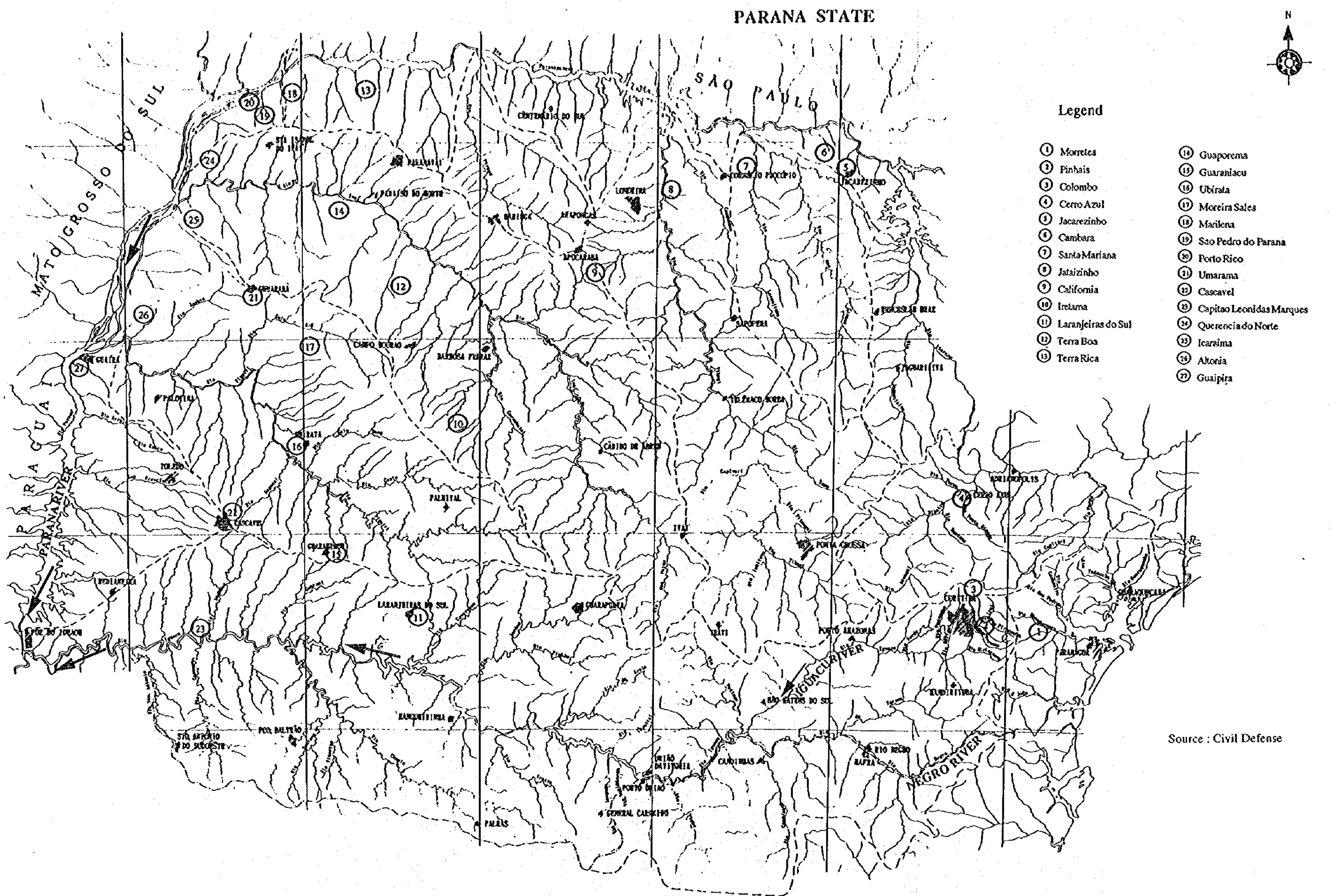

Figure-8.3 Location Distribution of Municipalities Which Suffered Flood in a Year Other than 1983 and 1992

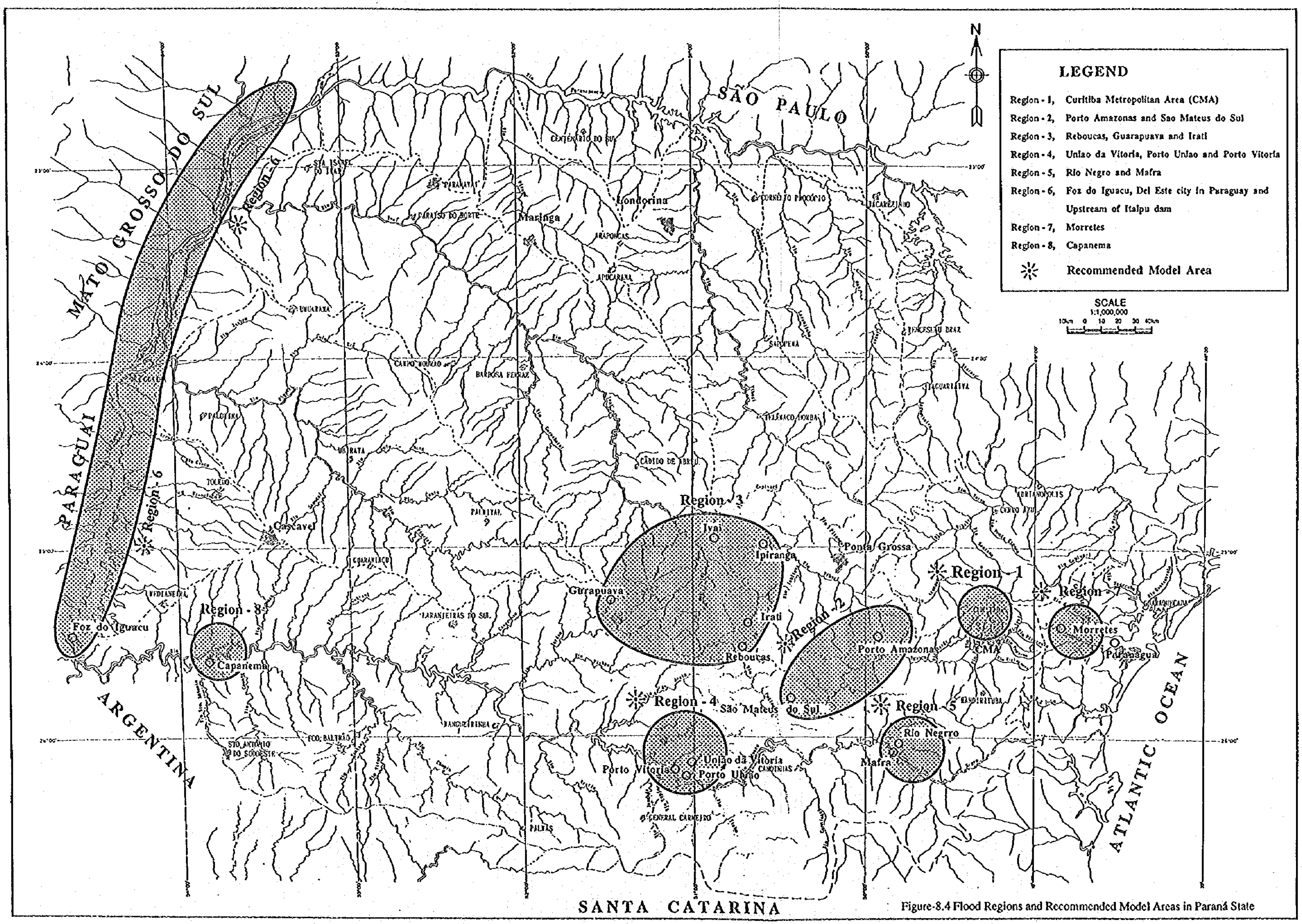

Figure-8.4 Flood Regions and Recommended Model Areas in Paraná State

For Curitiba metropolitan area the estimated probable flood damage is as high as US $ 20 million for a flood similar to that of 1993, and some US $ 44 million for a large flood similar to that of January 1995. For União da Vitoria-Porto União area the estimated probable flood damage is in the range of US $ 10 million for a flood inundation event similar to that of 1982 to US $ 78 million for a flood event similar to that of 1983. For Rio Negro-Mafra area the range of estimated probable flood damage is US $ 3 million for a flood event similar to that of 1984 and US $ 17 million for a large flood event similar to that of 1983. For São Mateus do Sul the estimated range of probable flood damage is US $ 0.1 million for a small flood event similar to that of 1993 and US $ 9 million for large flood event similar to that of 1983. For Porto Amazonas area the estimated flood damage are in the range between US $ 0.2 million for a relatively small flood similar to that of 1993, to some US $ 2 million for a relatively large flood similar to that of 1983. For Foz do Iguaçu area the estimated probable flood damage are in the range between US $ 0.02 million for relatively small flood of maximum water level reaching the 119 meter counter and some US $ 3 million if relatively large flood occur, up to the 130 meter level. For Morretes area the estimated probable flood damage are in the range between US $ 5 million if relatively small floods occur, and some US $ 10 million for a large flood similar to that of February 1995.

8.1.2 Design Flood Discharge

(1) Probable Peak Flood Discharge

The frequency analysis of the maximum daily mean discharge was made for the selected stream flow gauging stations in the Sectoral Report, Vol. B, Hydrology. The 100 year probable peak flood discharges of the selected stations are plotted on Figure-8.5. Further information of the flood discharges are presented in the Sectoral Report, Vol. H, Flood Control.

(2) Design Flood Discharge

It is practically difficult to apply the recorded maximum flood as the design flood discharge in Paraná State. Practical flood control level is to be determined based on damage level, social significance, regional development policy, etc. The recurrence interval of the design flood for the urban areas in the major municipalities is assumed tentatively to be 100 years as a target for the future.

8.1.3 Problems and Needs in Water Excess Management

(1) General

Flood control is referred to as the management of water excess. Flood control deals with water excess that endangers lives, causes economic damage and disrupt the normal socioeconomic human activities. Concept of water excess management is broadly divided into Flood Plain management and Urban Storm Water management. Flood plain management considers the integrated views of all structural and non-structural measures for minimizing the damage caused by floods on a comprehensive scale. Urban storm water management, besides the above framework of flood plain management, also considers the integrated view on urban sewage and storm drainage management. For the purpose of Strategy study, the flood prone areas of Paraná state were divided into eight regions as previously described. Flood plain management issues were identified in all the eight regions. At present urban storm water management issues are identified only in Region 1, specifically in Curitiba metropolitan area.

Curitiba metropolitan area has experimented an exponential growth of the urban population and expansion of urban areas. Because of topographic constraint and increasing occupancy of low income population in flood prone areas the existing urban drainage systems became not enough for handling the urban flood runoff of large magnitude. Beside this, some of the fast growing areas in the peripheries of the metropolitan region are not provided with the basic infrastructures required for management of urban storm.

In all eight regions, the most significant flood inundation damage occur in urban flood prone areas. In many cases the urban flood prone areas along rivers regime are occupied by low income families. In few cases, such as União da Vitoria-Porto União and Rio Negro-Mafra areas, the urban flood prone areas are occupied with relatively high cost infrastructures, important industries, commercial establishments, and high value houses.

(2) Assessment of Problems and Needs

Problems and Needs in flood control were assessed by region, taking as main criteria the magnitude of damages caused by the past flood inundation. The major flood inundation events in Paraná state were the floods of 1983 and 1992. During the last fourteen years the largest damage caused by flood inundation occurred within the Iguaçu river basin. The regional assessment of flood inundation damage and related issues are summarized as in Tables-8.2 in terms of flood region.

(3) Institution in Charge of Flood Control

The Brazilian constitution defines that flood control is a mater under the responsibility of the federal government. The National Department of Sanitation Works (DNOS), within the organizational structure of the Ministry of Agriculture, used to be the institution in charge of flood control at national level. DNOS was abolished in 1990, and since then in Paraná state there was not any specific institution responsible for planning, designing, promoting, constructing, operating and maintaining projects, structures and activities for flood control and mitigation of flood damage. Some institutions have projects or activities related to flood control for some specific areas, such as PROSAM in Curitiba metropolitan region. The National Department of Water and Electric Energy (DNAEE) has responsibility on flood warning, while the Civil Defense has responsibility for rescue activities.

In Paraná state there is a need for establishing an institution in charge at state level of coordinating all the aspects related to flood control and mitigation of flood inundation damage, including plan, design, promotion and implementation of projects, operation and maintenance of structures, flood warning, rescue of people affected by flood, and keeping systematic record of flood inundation damage. SUCEAM has taken over the position after the re-organization in February, 1995, but its administrative power and specific function is not clarified clearly yet.

Probable Peak Discharge [m3/s]

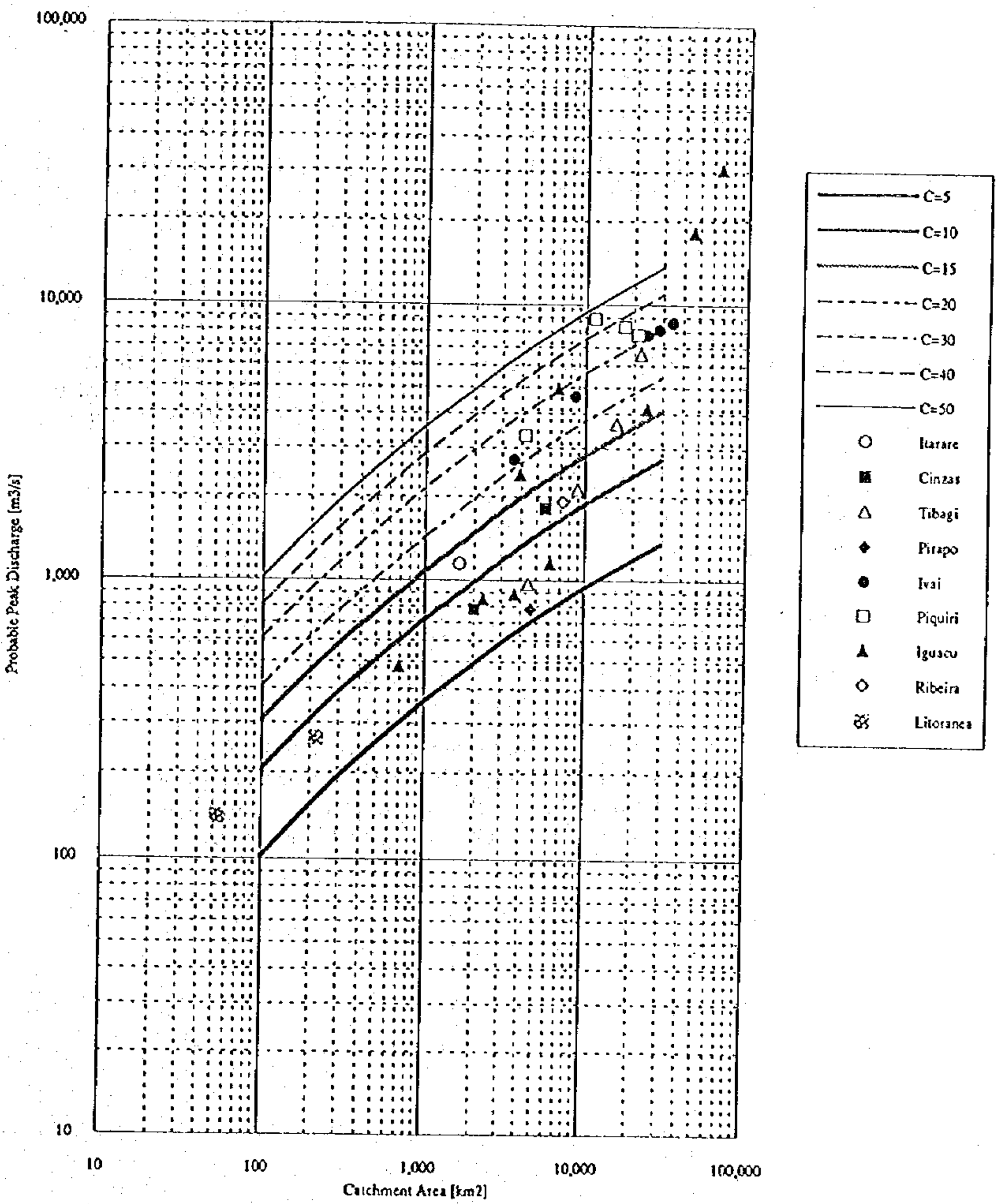

Figure-8.5 100 Year Probable Flood Peak Discharge in Paraná State

Table-8.2 Assessment of Flood Damage by Region in Paraná State

River Basin	Region	Degree of Flood Damage	Main Related Issues
Iguaçu river	From region 1 to region 5	4 for the entire basin	Resettlement, reservoirs operation
	Region 1 (Curitiba metropolitan area)	4	Resettlement
	Region 2 (São Mateus do Sul)	4	Resettlement
	Region 3 (Reboucas area)	2	Resettlement
	Region 4 (União da Vitoria)	5	Reservoir operation of Foz do Areia dam; Zoning and Resettlement
	Region 5 (Rio Negro area)	5	Resettlement
	Region 8 (Capanema)	2	Resettlement
Paraná river	Region 6 (Foz do Iguaçu area)	3 for the entire basin	Resettlement, reservoirs operation related to ITAIPU dam, and those dams on Iguaçu river
	Upstream of ITAIPU dam	2	Resettlement
Costal basin	Region 7 (Morretes area)	3	
Ivai river		1 for the entire basin	
Tibagi river		1 for the entire basin	
Others	Itarraré, Cinzas, Pirapó, Piquiri, Ribeira, Paranapanema	1 for all these basins	

Note : The degree of flood damage are classified as follows:
Degree 5 is serious damage; Degree 4 is high level of damage;
Degree 3 is medium level of damage; Degree 2 is low level;
Degree 1 is negligible level; and Degree 0 is no damage.

8.1.4 Strategy for Water Excess Management

(1) Alternative Flood Control Measures

The study of flood control considers both, structural and non-structural means as alternative to provide protection from flood inundation and to reduce the risk of flooding and the magnitude of damage caused by floods. The prospective structural flood control measures include flood control dams or gates, retarding basins, levees or dikes, flood walls, river channel improvement, and diversion or floodways. The prospective non-structural measures include flood proofing, flood forecasting, resettlement or relocation, flood warning and evacuation, and land use control.

(2) Management Policy

1) Goal and Principle of Water Excess Management

The goal of the flood control (broadly water excess management) is to protect the people in the flood prone areas from the risk of death, injuries and property damages including infrastructures.

Non-structural measures with appropriate combination of land use control and flood forecasting, warning and evacuation systems are to be principal flood control measures in Paraná State because present population density is generally not significantly high in the flood prone areas and alternative land resources are expected to be available in Paraná State.

Structural measures are also to be provided in addition to the non-structural measures for the areas where existing land use is highly enhanced and property value in the flood prone areas is significantly high.

2) Flood Control Level and Design Standard

The flood control (or protection) level must be determined appropriately taking into account social significance of damage level and efficiency of benefit and cost with the Principle of Risk and Benefit (refer to the Sectoral Report, Vol. L, Water Environment Management).

3) Model Area

It is recommended to designate the following regions as the Model Area for Water Excess Management to which specific monitoring and / or financial arrangement and support are to be provided in long term:

Region-1: Curitiba Metropolitan area
Region-2: Porto Amazonas, São Mateus do Sul
Region-4: União da Vitoria
Region-5: Rio Negro
Region-6: Foz do Iguaçu, Upstream of Itaipu Dam
Region-7: Morretes

The location map is shown in Figure-8.4.

(3) Long Term Plan for Water Excess Management

1) Flood Plain Management

Combination of structural and non-structural measures will be necessary for the municipalities of the Curitiba metropolitan area, São Mateus do Sul and União da Vitoria/Porto União. Non-structural measures are to be primarily employed for the flood prone areas of the other municipalities.

2) Urban Storm Water Management

Integrated view of urban sewage, flood protection, storm drainage and environmental protection will be required for Curitiba metropolitan area. Environmental protection includes waste disposal control, water quality control, protection of aqua ecosystem, and preservation of riverine landscape. View of urban storm water management might be evolved in other municipalities after the year 2005.

3) Non-structural Measures

Zoning for land use control is the most effective measure for all the flood prone areas in and around the urban areas in Paraná State (Region - 1 to 8). Zoning for land use control includes restricted area, river regime, natural preservation and recreational park, and retarding basin area. Zoning and resettlement are a tandem for implementation. Resettlement includes relocation of illegal residents occupying the river regime and legal residents in the flood prone areas. Zoning and resettlement have been widely applied in several municipalities in Paranã State such as the Curitiba metropolitan area, São Mateus do Sul, Porto Amazonas, Reboucas, Guarapuava, Irati, União da Vitoria, Rio Negro, etc.

Improvement of the existing flood forecasting and warning system will be necessary in the future together with enhancement of flood warning, evacuation and rescue activities which are mainly executed by the Civil Defense. Flood proofing such as elevating structures and re-arrangement of structural working space will be effective for some locally inundated areas. Review of the operation rule of the existing and planned dams and reservoirs will be necessary taking flood control function into consideration for integrated and effective operation.

4) Structural Measures

Continuation and extension of the flood control and drainage improvement projects of PROSAM is the first priority in the Curitiba metropolitan area. Supplemental provision of dams, dikes, floodways, retarding basins, and channel improvement may be necessary together with the integrated view of urban sewage and storm drainage after the year 2005 depending on the expansion of the urban area and the deterioration of the urban environment.

In São Mateus do Sul a dike system on the right bank of the Iguaçu river may be effective for the flood prone area where demand of development of low cost housing for low income people are very high in spite of the city's zoning requirement. A detailed engineering study will be necessary for technical evaluation.

Flood protection for the União da Vitoria and Porto União area will not be materialized by the provision of non-structural measures only.

It is recommended to conduct a feasibility study on provision of zoning and a set of structural measures which are composed of a dike system and sluice gates, because the property value and town function in the inundated areas affected during the 1983 and 1992 floods are significant.

Non-structural measures are most effective in particular by zoning in the Rio Negro and Mafra area. Structural measures for the mainstream of the Negro river will not be financially viable due to topographic constraints in this area. However channel improvement of the Passa Tress in Rio Negro municipality side and the da Lanca river in Mafra municipality side may be effective in the future.

Channel improvement including a short cut and channel excavation may be effective for the flooding along the Nhundiaquara river in Morretes. However, some detailed engineering study will be necessary for technical evaluation because there is a back water effect by the high tide of the Paranagua bay.

5) Flood Forecasting and Warning Systems

The Strategy for the flood forecasting and warning system (FFWS) in Paraná State aims to up-grade the existing system as a part of the integrated telemetric monitoring and operation system discussed in the Sectoral Report, Vol. L, Water Environment Management . It will also aims to reinforce a part of the nationwide flood forecasting and warning system under DNAEE.

6) Implementation Schedule

The implementation schedule for the water excess management is tentatively recommended in two stages as shown in Table-8.3 for non-structural measures and in Table-8.4 for structural measures.

Table-8.3 Proposed Non-structural Flood Control Measures and Implementation Schedule for Paraná State

Region	Municipalities	Non-Structural Measures	1st Stage Present - 2005	2nd Stage 2006-2015 onward
1.	Curitiba Metropolitan Region	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	Δ	Δ
		•Proofing	Δ	Δ
		•Operation Rule	Δ	O
2.	São Mateus do Sul	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
	Porto Amazonas	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
3.	Rebouças, Guarapuava Irati, Ipiranga	•Zoning	-	-
		•FFWS	Δ	Δ
		•Evacuation	-	Δ
4.	União da Vitória	•Zoning	Δ	Δ
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
		Operation Rule	Δ	O
5.	Rio Negro	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
6.	Foz do Iguaçu	•Zoning	Δ	Δ
		•FFWS	Δ	O
		•Evacuation	Δ	Δ
		•Proofing	Δ	Δ
		•Operation Rule	Δ	O
7.	Morretes	•Zoning	Δ	Δ
		•FFWS	-	-
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
8.	Capanema	•Zoning	-	-
		•FFWS	-	-
		•Evacuation	-	Δ

Notes

(1) Zoning = zoning for land use control with resettlement and parks;
FFWS = Flood Forecasting and Warning Systems ; Evacuation = evacuation and rescue activities;
Proofing = raising of ground level and buildings, etc.; Operation Rule = operation rule for reservoirs, flood control facilities, etc.

(2) - = Extention of present method; Δ = Improvement of present method; O = Employment of new concept

Table-8.4 Proposed Structural Measures and Implementation Schedule for Flood Control

Region	Municipality	Structural Measures	Project Cost (US$ 10^6)	Implementation Schedule	
				1st Stage Present - 2005	2nd Stage 2006 - 2015 onward
1.	Curitiba Metropolitan Area	Continuation of PROSAM - 15 km long channel excavation (about 1.3 million m^3); - landscape restoration and park development of river bank area; - Irai dam for flood control and to guarantee 1.8 m^3/s to Curitiba water supply; - relocation and resettlement of 1,400 houses located in risky areas including occupying river flood plains; - expropriation of 7,000 plots of land and rights needed for environment protection along rivers and environmentally sensitive areas;	Total 34.3 excluding Irai dam (1992 price)	O	-
		Extension of PROSAM - channel excavation by Curitiba municipality - Piraquara II, Pequeno, Alto Miringuava dams for water supply with flood control function	NA	O Δ	O
2.	Sao Mateus do Sul	Dike system with a sluice	11.1	-	O
4.	Uniao da Vitoria	Dike system with sluices	85.9	O	
7.	Morretes	channel improvement and dike	NA	Δ	O

Note : Δ : Partial Operation　　O : Full operation　　NA : Not available in this study phase

8.2 Water Quality and Sewerage

Studies on the strategy of water quality conservation and sewerage system improvement in Paraná state were conducted for the 11 river basins within the state. Existing data were collected and reviewed to understand the current condition of water quality and sewerage system. Then based on the population analysis conducted in the socio-economic sector, the water quality in the years of 2005 and 2015 was predicted. The characteristics and problems of water quality in each river basin was elicited from the analysis results. On this basis, plans for pollutant load reduction and water quality improvement were worked out toward the target year of 2015.

8.2.1 Present Conditions of Water Quality and Sewerage System

(1) Water Quality

In this study, "Result of the Study on the Water Quality in Paraná state " prepared by SUREHMA (the former IAP) and IAP was used as the major data source on water quality. These data were based on the water quality monitoring conducted from 1982 to 1993 for the 11 rivers in Paraná state. Figure-8.6 shows the locations of the 151 observation points.

The items of water quality monitoring include water temperature, DO, fecal coliform, pH, BOD, T-N, T-P, turbidity and T-S. Among them, BOD (biological oxygen demand) is thought to be the characteristic water quality parameter because organic pollutants from both domestic sewerage and industrial waste water are the main sources of water pollution. In Brazil, the quality of river water has been classified according to BOD concentration as follows:

A) Class 1 - BOD less than 3 mg/l

B) Class 2 - BOD 3-5 mg/l

C) Class 3 - BOD 5-10 mg/l

D) Class 4 - BOD more than 10 mg/l

The existing data show that in most of the rivers in Paraná state the water quality belong to Class 1 or Class 2, i.e. BOD < 5 mg/l, except for Iguaçu river where BOD has been measured as high as 10-109 mg/l at some monitoring points. The higher BOD mainly appears in the upper stream of the river near Curitiba M.A. due to the high pollutant load of domestic sewage and industrial discharge from this densely populated area.

(2) Sewer System

In Paraná state, only urban areas are served by sewer systems, and the percentage of the served population differs with river basin. According to the data of 1990 provided by SANEPAR, the lowest percentage is 1.2 % in Ribeira river basin while the highest percentage is 46.8% in Paranapanema river basin. The overall percentage of population served by sewer system in Paraná state is 23.5%.

(3) Sewage Treatment

As for sewage treatment, the percentage of the served population is only 15.4% in Paraná state.

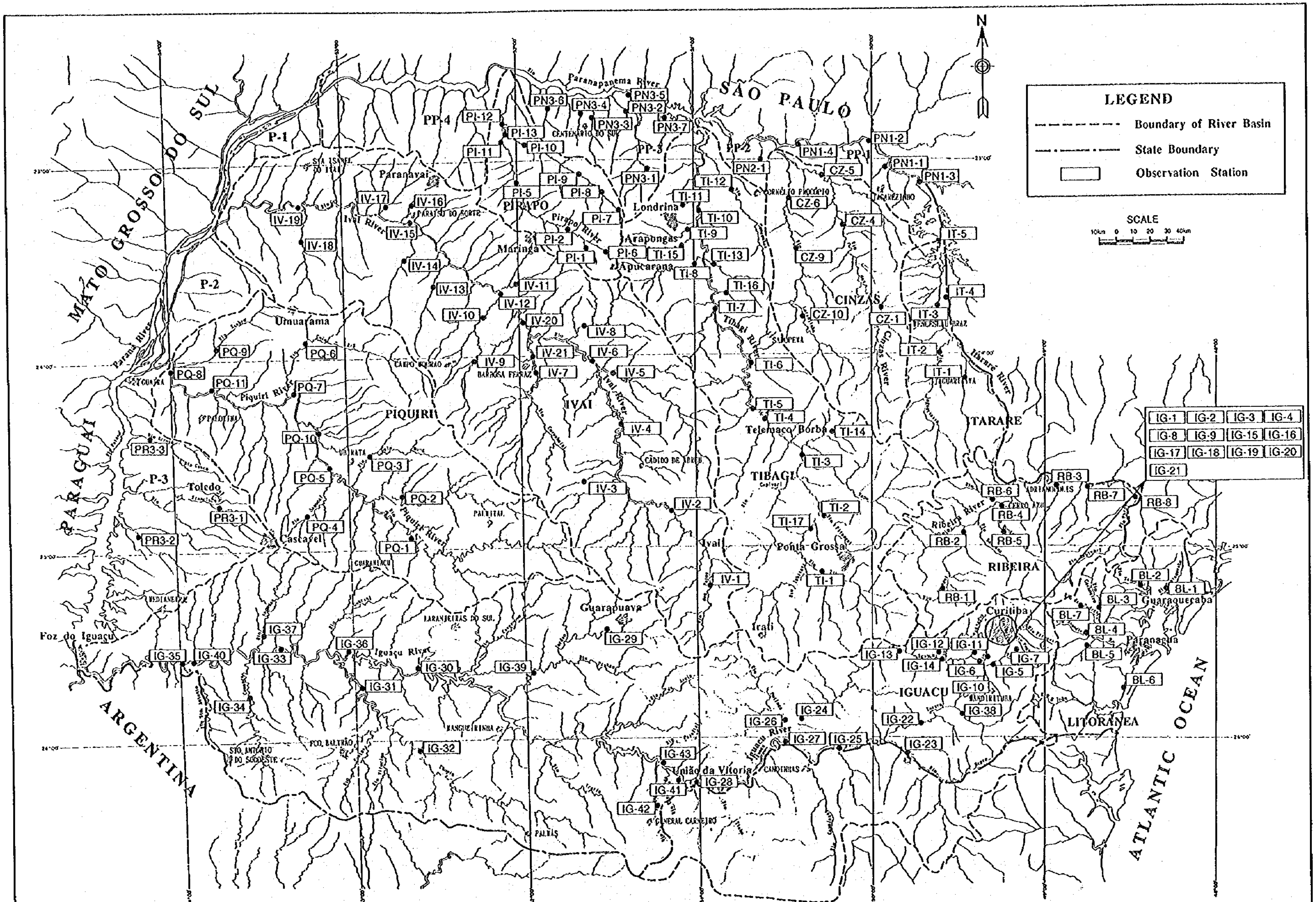

Figure-8.6 Locations of Observation Points for Water Quality

(4) Industrial Wastewater Treatment

Most of the industries in Paraná state are equipped with wastewater treatment facilities. On the average, BOD removal ranges between 83 to 100% in all the river basin areas except a lower removal of 65% in Iguaçu river basin. The average BOD removal in Paraná state is 97 %. Although the BOD removal is comparatively high as a whole, there are some industries which discharges industrial effluents of high BOD concentration to rivers. The effluents from some paper mills and tanners have a BOD concentration as high as 600-800 mg/l.

8.2.2 Pollution Analysis

In order to formulate a Strategy of water quality improvement toward the target year of 2015, pollution analysis was conducted on the 11 rivers in Paraná state. The condition of river water pollution by the years of 2005 and 2015 was predicted. Based on the analysis result, pollutant load reduction plan was formulated.

(1) Pollution Sources and Pollutant Load

Generally speaking, pollutants discharged into rivers are from artificial and natural sources. The artificial source includes domestic sewage, industrial wastewater and livestock wastes, and the natural source includes the pollutants induced by ecological phenomena and so on.

In this study, the above mentioned pollution sources are considered, and the corresponding pollutant load (as BOD) are calculated as follows:

- Domestic pollutant load: using a pollutant load factor of 54 g/person/day
- Industrial pollutant load: using existing data
- Livestock pollutant load: using pollutant load factors of 600 g/head/day for cattle, 200 g/head/day for pig and 9 g/head/day for chicken
- Natural pollutant load: using a pollutant load factor of 0.7 kg/Km^2/day

(2) Analysis of Present Condition

1) Method of Analysis

Analysis of the present condition was conducted in order to determine some of the fundamental parameters for the prediction of river water quality in future (the definition of the parameters used for the pollution analysis is shown in Table-8.5). The procedures of analysis are as follows:

a) Divide each river basin into several blocks and select water quality control points

b) Calculate the discharge BOD load from each pollution source

c) Calculate the run-off BOD load by taking into consideration the run-off ratio

d) Calculate the flow-out BOD load based on the current water quantity

e) Evaluate the purification-residual ratio

Table-8.5 Definition of the Parameters Used for Pollution Analysis

Parameter	Definition
Discharge BOD Load	Quantity of BOD from any of the pollution sources (Kg/day)
Run-off BOD Load	Quantity of BOD entering a river (Kg/day)
Flow-out BOD Load	Quantity of BOD flowing out of a cross section of the river course at a water quality control point (Kg/day)
Run-off Ratio	The ratio of the run-off BOD load to the discharge BOD load of the same origin
Purification-residual Ratio	The ratio of the flow-out BOD load to the run-off BOD load of the same origin

2) Analysis Result

The result of analysis is shown in Table-8.6.

(2) Analysis for Future Prediction

1) Method of Analysis

Method of analysis for the future prediction of river water quality is as follows:

a) Predict the discharge BOD load of each pollution source;
   - Domestic load: according to future population
   - Industrial load: according to a proportional increase of BOD load with the increase of GRDP
   - Livestock load: according to future livestock number

b) Calculate the run-off BOD load by multiplying discharge BOD load by BOD run-off ratio;

c) Calculate the flow-out BOD load by using the purification-residual ratio obtained by the above mentioned analysis of present condition, and evaluate water quality at each control point by using the draught river flow rate ($Q_{10,7}$);

d) Calculate the permissible flow-out BOD load at each control point in accordance with the target water quality of BOD $\leq$ 5 mg/l;

e) Calculate the difference between the predicted flow-out BOD load and the permissible flow-out BOD load, and estimate the quantity of BOD load to be reduced in future.

2) Result of Water Quality Prediction by the Year 2005

a) The result of the pollution analysis for each river in Paraná state is shown in Table-8.7.

b) The result of the water quality prediction for each river in Paraná state is shown in Table-8.8.

c) As is shown in Table-8.8, for the Rivers of Cinzas, Tibagi, Pirapo, Ivai, and Iguaçu, BOD concentration is of higher value than 5 mg/l at some of the control points and the calculated flow-out load exceeds the permissible flow-out load. In order to improve water quality, measures have to be taken for pollutant load reduction.

Table-8.6 Pollution Analysis of River Basin (1993)

River Basin	River Name	Control Point	River			Discharge BOD Load (kgBOD/day)					Run-off Ratio					Run-off BOD Load (kgBOD/day)						Purification Residual Ratio
			Ave.Water Quality (mg/l)	Average Flow (m3/sec)	Flow-out BOD Load (kgBOD/day)	Domestic Wastewater		Industrial Waste Water	Livestock Waste Water	Natural Load	Domestic Wastewater		Industrial Waste Water	Livestock Waste Water	Natural Load	Domestic Wastewater		Industrial Waste Water	Livestock Waste Water	Natural Load	Total	
						Urban	Rural				Urban	Rural				Urban	Rural					
ITARARE	JAGUARIAIVA	IT-02	1.33	18.13	2,083	1,247	659	814	39,967	1,137	0.8	0.10	1.0	0.05	0.1	998	66	814	1,998	114	3,990	0.52
CINZAS	CINZAS	CZ-01	1.55	18.09	2,423	1,955	1,161	204	81,952	1,411	0.8	0.10	1.0	0.05	0.1	1,564	116	204	4,098	141	6,123	0.40
		CZ-05	1.38	34.18	4,075	5,454	3,245	568	228,604	3,936	0.8	0.10	1.0	0.05	0.1	4,363	325	568	11,430	394	17,080	0.24
TIBAGI	TIBAGI	TI-01	1.26	40.56	4,416	9,179	2,090	2,802	88,171	3,114	0.8	0.10	1.0	0.05	0.1	7,343	209	2,802	4,409	311	15,074	0.29
		TI-03	1.93	40.72	6,790	18,455	4,201	5,636	177,322	6,262	0.8	0.10	1.0	0.05	0.1	14,764	420	5,636	8,866	626	30,312	0.22
		TI-06	2.09	153.34	27,690	32,173	7,317	9,823	309,090	10,916	0.8	0.10	1.0	0.05	0.1	25,738	732	9,823	15,455	1,092	52,840	0.52
		TI-10	1.45	211.73	26,526	30,662	10,298	13,824	434,979	15,362	0.8	0.10	1.0	0.05	0.1	24,530	1,030	13,824	21,749	1,536	62,669	0.42
PIRAPO	PIRAPO	PI-13	2.04	49.43	8,712	18,225	2,398	6,342	323,559	3,238	0.8	0.10	1.0	0.05	0.1	14,580	240	6,342	16,178	324	37,664	0.23
IVAI	IVAI	IV-02	2.36	21.57	4,398	4,018	2,106	659	177,337	2,512	0.8	0.10	1.0	0.05	0.1	3,214	211	659	8,867	251	13,202	0.33
		IV-04	1.14	67.89	6,687	9,639	5,054	1,580	425,248	6,024	0.8	0.10	1.0	0.05	0.1	7,711	505	1,580	21,262	602	31,660	0.21
		IV-12	1.19	199.13	20,474	27,108	14,218	4,444	1,196,123	16,945	0.8	0.10	1.0	0.05	0.1	21,686	1,422	4,444	59,806	1,695	89,053	0.23
		IV-15	1.17	262.71	26,557	31,822	16,697	5,217	1,404,223	19,893	0.8	0.10	1.0	0.05	0.1	25,458	1,670	5,217	70,211	1,989	104,545	0.25
		IV-19	1.25	355.97	38,445	38,545	20,223	6,320	1,700,992	24,097	0.8	0.10	1.0	0.05	0.1	30,836	2,022	6,320	85,050	2,410	126,638	0.30
PIQUIRI	PIQUIRI	PQ-01	1.00	33.58	2,901	3,791	2,819	497	180,440	2,955	0.8	0.10	1.0	0.05	0.1	3,033	282	497	9,022	296	13,130	0.22
		PQ-05	1.38	111.87	13,338	10,152	7,549	1,331	483,285	7,915	0.8	0.10	1.0	0.05	0.1	8,122	755	1,331	24,164	792	35,164	0.38
		PQ-07	1.29	219.41	24,455	15,714	11,691	2,061	748,142	12,252	0.8	0.10	1.0	0.05	0.1	12,571	1,169	2,061	37,407	1,225	54,433	0.45
		PQ-11	1.00	262.97	22,721	18,841	14,013	2,471	896,926	14,689	0.8	0.10	1.0	0.05	0.1	15,073	1,401	2,471	44,846	1,469	65,260	0.35
IGUACU	IGUACU	IG-18	1.03	1.29	115	65	76	36	2,773	94	0.8	0.10	1.0	0.05	0.1	52	8	36	139	9	244	0.47
		IG-14	6.48	22.03	12,334	79,466	1,242	612	47,133	1,602	0.8	0.10	1.0	0.05	0.1	63,573	124	612	2,357	160	66,826	0.18
		IG-13	4.88	30.73	12,957	80,087	1,976	972	74,859	2,545	0.8	0.10	1.0	0.05	0.1	64,070	198	972	3,743	255	69,238	0.19
		IG-24	2.01	50.85	8,831	81,185	3,294	1,620	124,765	4,241	0.8	0.10	1.0	0.05	0.1	64,948	329	1,620	6,238	424	73,559	0.12
		IG-28	1.59	232.03	31,875	89,461	13,171	6,480	499,060	16,964	0.8	0.10	1.0	0.05	0.1	71,569	1,317	6,480	24,953	1,696	106,015	0.30
		IG-36	1.65	532.17	75,866	99,322	24,916	12,258	944,055	32,090	0.8	0.10	1.0	0.05	0.1	79,458	2,492	12,258	47,203	3,209	144,620	0.52
		IG-40	1.04	662.11	59,495	101,358	30,737	15,120	1,164,473	39,582	0.8	0.10	1.0	0.05	0.1	81,086	3,074	15,120	58,224	3,958	161,462	0.37
	NEGRO	IG-25	1.64	76.21	10,799	4,811	4,320	2,124	163,581	5,560	0.8	0.10	1.0	0.05	0.1	3,849	432	2,124	8,179	556	15,140	0.71
	JORDAO	IG-39	1.31	49.67	5,622	2,360	2,122	1,044	80,404	2,733	0.8	0.10	1.0	0.05	0.1	1,888	212	1,044	4,020	273	7,437	0.76
	CHOPIN	IG-31	1.32	78.13	8,911	4,039	3,623	1,782	137,241	4,665	0.8	0.10	1.0	0.05	0.1	3,231	362	1,782	6,862	467	12,704	0.70
RIBEIRA	RIBEIRA	RB-03	1.33	86.87	9,982	2,592	3,553	1	48,490	5,074	0.8	0.10	1.0	0.05	0.1	2,074	355	1	2,425	507	5,362	1.00
LITORANEA	NHUNDIAQUARA	BL-04	1.70	4.86	714	302	86	2	598	153	0.8	0.10	1.0	0.05	0.1	242	9	2	30	15	298	1.00
	MARUMBI	BL-05	1.10	1.61	153	70	22	0	142	36	0.8	0.10	1.0	0.05	0.1	56	2	0	7	4	69	1.00

Table-8.7 Pollution analysis of River Basin (2005)

River Basin	River Name	Control Point	Discharge BOD Load (kgBOD/day)					Run-off Ratio					Run-off BOD Load (kgBOD/day)					
			Domestic Wastewater		Industrial Waste Water	Livestock Waste Water	Natural Load	Domestic Wastewater		Industrial Waste Water	Livestock Waste Water	Natural Load	Domestic Wastewater		Industrial Waste Water	Livestock Waste Water	Natural Load	Total
			Urban	Rural				Urban	Rural				Urban	Rural				
ITARARE	JAGUARIAIVA	IT-02	2,095	443	1,531	49,522	1,137	0.8	0.1	1.0	0.05	0.1	1,676	44	1,531	2,476	114	5,841
CINZAS	CINZAS	CZ-01	2,425	718	383	100,540	1,411	0.8	0.1	1.0	0.05	0.1	1,940	72	383	5,027	141	7,563
		CZ-05	6,766	2,009	1,069	280,453	3,936	0.8	0.1	1.0	0.05	0.1	5,413	201	1,069	14,023	394	21,100
TIBAGI	TIBAGI	TI-01	11,725	1,534	5,268	109,176	3,114	0.8	0.1	1.0	0.05	0.1	9,380	153	5,268	5,459	311	20,571
		TI-03	23,584	3,089	10,595	219,566	6,262	0.8	0.1	1.0	0.05	0.1	18,867	309	10,595	10,978	626	41,375
		TI-06	41,106	5,384	18,468	382,724	10,916	0.8	0.1	1.0	0.05	0.1	32,885	538	18,468	19,136	1,092	48,526
		TI-10	43,305	7,576	25,990	538,604	15,362	0.8	0.1	1.0	0.05	0.1	34,644	758	25,990	26,930	1,536	53,633
PIRAPO	PIRAPO	PI-13	23,744	1,188	11,923	393,719	3,238	0.8	0.1	1.0	0.05	0.1	18,995	119	11,923	19,686	324	51,047
IVAI	IVAI	IV-02	5,054	1,355	1,239	214,170	2,512	0.8	0.1	1.0	0.05	0.1	4,043	136	1,239	10,709	251	16,378
		IV-04	12,118	3,245	2,970	513,571	6,024	0.8	0.1	1.0	0.05	0.1	9,694	325	2,970	25,679	602	39,270
		IV-12	34,079	9,131	8,354	1,444,555	16,945	0.8	0.1	1.0	0.05	0.1	27,263	913	8,354	72,228	1,695	110,453
		IV-15	40,003	10,724	9,808	1,695,877	19,893	0.8	0.1	1.0	0.05	0.1	32,002	1,072	9,808	84,794	1,989	129,665
		IV-19	48,460	12,987	11,881	2,054,284	24,097	0.8	0.1	1.0	0.05	0.1	38,768	1,299	11,881	102,714	2,410	157,072
PIQUIRI	PIQUIRI	PQ-01	4,941	1,777	935	219,975	2,955	0.8	0.1	1.0	0.05	0.1	3,953	178	935	10,999	296	16,361
		PQ-05	13,235	4,763	2,503	589,173	7,915	0.8	0.1	1.0	0.05	0.1	10,588	476	2,503	29,459	792	43,818
		PQ-07	20,488	7,371	3,875	912,060	12,252	0.8	0.1	1.0	0.05	0.1	16,390	737	3,875	45,603	1,225	67,830
		PQ-11	24,559	8,834	4,645	1,093,443	14,689	0.8	0.1	1.0	0.05	0.1	19,647	883	4,645	54,672	1,469	81,316
IGUACU	IGUACU	IG-18	81	59	68	3,519	94	0.8	0.1	1.0	0.05	0.1	65	6	68	176	9	324
		IG-14	109,053	1,053	1,151	59,824	1,602	0.8	0.1	1.0	0.05	0.1	87,242	105	1,151	2,991	160	91,649
		IG-13	109,891	1,674	1,827	95,014	2,545	0.8	0.1	1.0	0.05	0.1	87,913	167	1,827	4,751	255	94,913
		IG-24	111,371	2,792	3,046	158,357	4,241	0.8	0.1	1.0	0.05	0.1	89,097	279	3,046	7,918	424	100,764
		IG-28	122,559	11,156	12,182	633,430	16,964	0.8	0.1	1.0	0.05	0.1	98,047	1,116	12,182	31,672	1,696	144,713
		IG-36	135,880	21,109	23,045	1,198,238	32,090	0.8	0.1	1.0	0.05	0.1	108,704	2,111	23,045	59,912	3,209	196,981
		IG-40	139,697	26,039	28,426	1,478,003	39,582	0.8	0.1	1.0	0.05	0.1	111,758	2,604	28,426	73,900	3,958	220,646
	NEGRO	IG-25	6,043	3,656	3,993	207,624	5,560	0.8	0.1	1.0	0.05	0.1	4,834	366	3,993	10,381	556	20,130
	JORDAO	IG-39	2,965	1,798	1,963	102,053	2,733	0.8	0.1	1.0	0.05	0.1	2,372	180	1,963	5,103	273	9,891
	CHOPIM	IG-31	5,076	3,067	3,350	174,193	4,665	0.8	0.1	1.0	0.05	0.1	4,061	307	3,350	8,710	467	16,895
RIBEIRA	RIBEIRA	RB-03	3,429	3,175	2	62,864	5,074	0.8	0.1	1.0	0.05	0.1	2,743	318	2	3,143	507	6,713
LITORANEA	NHUNDIAQUAR	BL-04	367	81	3	753	153	0.8	0.1	1.0	0.05	0.1	294	8	3	38	15	358
	MARUMBI	BL-05	86	22	1	178	36	0.8	0.1	1.0	0.05	0.1	69	2	1	9	4	85

Table-8.8 River Basin Water Quality Prediction (2005)

River Basin	River Name	Control Point	Run-off BOD Load (kgBOD/d)	Purification Risidual Ratio	Flow-out BOD Load (kgBOD/d)	River Flow (Q10.7) (m3/sec)	Average BOD (mgBOD/l)	Permissible Flow-out Load (kgBOD/d)	Difference between Calculated and Permissible Loads (kgBOD/d) as Flow-out	as Run-off
ITARARE	JAGUARIAIVA	IT-02	5,841	0.52	3,037	8.00	4.39	3,456	(419)	-806
CINZAS	CINZAS	CZ-01	7,563	0.40	3,025	3.20	10.94	1,382	1,643	4,108
		CZ-05	21,100	0.24	5,064	8.80	6.66	3,802	1,262	5,258
TIBAGI	TIBAGI	TI-01	20,571	0.29	5,966	8.60	8.03	3,715	2,251	7,762
		TI-03	41,375	0.22	9,103	17.00	6.2	7,344	1,759	7,995
		TI-06	47,710	0.52	24,809	25.60	11.22	11,059	13,750	26,443
		TI-10	56,949	0.42	23,919	32.20	8.6	13,910	10,009	23,830
PIRAPO	PIRAPO	PI-13	51,047	0.23	11,741	15.00	9.06	6,480	5,261	13,153
IVAI	IVAI	IV-02	16,378	0.33	5,405	4.20	14.89	1,814	3,591	10,882
		IV-04	39,270	0.21	8,247	7.60	12.56	3,283	4,964	23,638
		IV-12	110,453	0.23	25,404	14.00	21	6,048	19,356	38,712
		IV-15	129,665	0.25	32,416	146.00	2.57	63,072	(30,656)	-122,624
		IV-19	157,072	0.30	47,122	140.00	3.9	60,480	(13,358)	-44,527
PIQUIRI	PIQUIRI	PQ-01	16,361	0.22	3,599	30.00	1.39	12,960	(9,361)	-42,550
		PQ-05	43,818	0.38	16,651	69.00	2.79	29,808	(13,157)	-34,624
		PQ-07	67,830	0.45	30,524	108.00	3.27	46,656	(16,132)	-35,849
		PQ-11	81,316	0.35	28,461	98.00	3.36	42,336	(13,875)	-39,643
IGUACU	IGUACU	IG-18	324	0.47	152	0.85	2.07	367	(215)	-457
		IG-14	91,649	0.18	16,497	8.00	23.87	3,456	13,041	72,450
		IG-13	94,913	0.19	18,033	11.80	17.69	5,098	12,935	68,079
		IG-24	100,764	0.12	12,092	25.00	5.6	10,800	1,292	10,767
		IG-28	144,713	0.30	43,414	51.20	9.81	22,118	21,296	70,987
		IG-36	196,981	0.52	102,430	120.20	9.86	51,926	50,504	97,123
		IG-40	220,646	0.37	81,639	161.20	5.86	69,638	12,001	32,435
	NEGRO	IG-25	20,130	0.71	14,292	49.50	3.34	21,384	(7,092)	-9,989
	JORDAO	IG-39	9,891	0.76	7,517	28.20	3.09	12,182	(4,665)	-6,138
	CHOPIM	IG-31	16,895	0.70	11,827	40.10	3.41	17,323	(5,496)	-7,851
RIBEIRA	RIBEIRA	RB-03	6,713	1.00	6,713	72.80	1.07	31,450	(24,737)	-24,737
LITORANE	NHUNDIAQUA	BL-04	358	1.00	358	2.56	1.62	1,106	(748)	-748
	MARUMBI	BL-05	85	1.00	85	0.77	1.28	333	(248)	-248

3) Result of Water Quality Prediction by the Year 2015

a) The result of the pollution analysis for each river is shown in Table-8.9.

b) The result of the water quality prediction is shown in Table-8.10.

c) As is shown in Table-8.10, besides the 5 rivers mentioned above, the calculated flow-out BOD load in Ribeira river also exceeds the permissible flow-out BOD load. Therefore, pollutant load reduction plans have to be formulated for the 6 river basins.

8.2.3 Water Quality Improvement Plan

(1) Target Water Quality

The target water quality is BOD concentration of less than 5 mg/l, i.e. water quality Class 2 for rivers in Brazil. The values of the permissible flow-out BOD load shown in Table-8.8 and Table-8.10 are calculated in accordance with this target water quality.

(2) BOD Load Reduction Plan

The BOD load to be reduced for each of the 6 river basins can be obtained from the calculation results shown in Table-8.8 and Table-8.10 for the years of 2005 and 2015, respectively. At each of the water quality control points, the difference between the calculated flow-out BOD load and the permissible flow-out BOD load, if it is a positive value, is the minimum value of BOD load to be reduced in order to meet the target water quality. Therefore, the BOD load to be reduced for the whole river basin can be decided by choosing the largest value. The results are shown in Table-8.11.

Table-8.9 Pollution Analysis of River Basin (2015)

River Basin	River Name	Control Point	Discharge BOD Load (kgBOD/day)					Run-off Ratio					Run-off BOD Load (kgBOD/day)					
			Domestic Wastewater		Industrial Waste Water	Livestock Waste Water	Natural Load	Domestic Wastewater		Industrial Waste Water	Livestock Waste Water	Natural Load	Domestic Wastewater		Industrial Waste Water	Livestock Waste Water	Natural Load	Total
			Urban	Rural				Urban	Rural				Urban	Rural				
ITARARE	JAGUARIAIVA	IT-02	3,332	297	2,573	56,903	1,137	0.8	0.1	1.0	0.05	0.1	2,666	30	2,573	2,845	114	8,228
CINZAS	CINZAS	CZ-01	2,884	448	644	115,148	1,411	0.8	0.1	1.0	0.05	0.1	2,307	45	644	5,757	141	8,894
		CZ-05	8,046	1,247	1,796	321,203	3,936	0.8	0.1	1.0	0.05	0.1	6,437	125	1,796	16,060	394	24,812
TIBAGI	TIBAGI	TI-01	13,845	1,150	8,855	124,689	3,114	0.8	0.1	1.0	0.05	0.1	11,076	115	8,855	6,234	311	26,591
		TI-03	27,841	2,317	17,809	250,764	6,262	0.8	0.1	1.0	0.05	0.1	22,273	232	17,809	12,538	626	53,478
		TI-06	48,526	4,039	31,042	437,104	10,916	0.8	0.1	1.0	0.05	0.1	38,821	404	31,042	21,855	1,092	58,679
		TI-10	53,633	5,681	43,685	615,133	15,362	0.8	0.1	1.0	0.05	0.1	42,906	568	43,685	30,757	1,536	111,131
PIRAPO	PIRAPO	PI-13	28,172	605	20,041	451,822	3,238	0.8	0.1	1.0	0.05	0.1	22,538	61	20,041	22,591	324	65,555
IVAI	IVAI	IV-02	5,972	950	2,082	245,247	2,512	0.8	0.1	1.0	0.05	0.1	4,778	95	2,082	12,262	251	19,468
		IV-04	14,315	2,279	4,993	588,092	6,024	0.8	0.1	1.0	0.05	0.1	11,452	228	4,993	29,405	602	46,680
		IV-12	40,268	6,415	14,043	1,654,166	16,945	0.8	0.1	1.0	0.05	0.1	32,214	642	14,043	82,708	1,695	131,302
		IV-15	47,272	7,528	16,486	1,941,956	19,893	0.8	0.1	1.0	0.05	0.1	37,818	753	16,486	97,098	1,989	154,144
		IV-19	57,262	9,121	19,970	2,352,370	24,097	0.8	0.1	1.0	0.05	0.1	45,810	912	19,970	117,619	2,410	186,721
PIQUIRI	PIQUIRI	PQ-01	5,929	1,172	1,571	250,992	2,955	0.8	0.1	1.0	0.05	0.1	4,743	117	1,571	12,550	296	19,277
		PQ-05	15,876	3,137	4,207	672,249	7,915	0.8	0.1	1.0	0.05	0.1	12,701	314	4,207	33,612	792	51,626
		PQ-07	24,581	4,855	6,513	1,040,665	12,252	0.8	0.1	1.0	0.05	0.1	19,665	486	6,513	52,033	1,225	79,922
		PQ-11	29,468	5,821	7,808	1,247,623	14,689	0.8	0.1	1.0	0.05	0.1	23,574	582	7,808	62,381	1,469	95,814
IGUACU	IGUACU	IG-18	97	49	114	3,990	94	0.8	0.1	1.0	0.05	0.1	78	5	114	200	9	406
		IG-14	141,149	869	1,934	67,833	1,602	0.8	0.1	1.0	0.05	0.1	112,919	87	1,934	3,392	160	118,492
		IG-13	142,160	1,382	3,072	107,734	2,545	0.8	0.1	1.0	0.05	0.1	113,728	138	3,072	5,387	255	122,580
		IG-24	143,950	2,300	5,119	179,557	4,241	0.8	0.1	1.0	0.05	0.1	115,160	230	5,119	8,978	424	129,911
		IG-28	157,449	9,207	20,477	718,227	16,964	0.8	0.1	1.0	0.05	0.1	125,959	921	20,477	35,911	1,696	184,964
		IG-36	173,526	17,415	38,735	1,358,646	32,090	0.8	0.1	1.0	0.05	0.1	138,821	1,742	38,735	67,932	3,209	250,439
		IG-40	178,596	21,476	47,779	1,675,863	39,582	0.8	0.1	1.0	0.05	0.1	142,877	2,148	47,779	83,793	3,958	280,555
	NEGRO	IG-25	7,031	3,019	6,712	235,419	5,560	0.8	0.1	1.0	0.05	0.1	5,625	302	6,712	11,771	556	24,966
	JORDAO	IG-39	3,451	1,485	3,299	115,714	2,733	0.8	0.1	1.0	0.05	0.1	2,761	149	3,299	5,786	273	12,268
	CHOPIM	IG-31	5,908	2,533	5,631	197,512	4,665	0.8	0.1	1.0	0.05	0.1	4,726	253	5,631	9,876	467	20,953
RIBEIRA	RIBEIRA	RB-03	65,518	5,081	2	71,385	5,074	0.8	0.1	1.0	0.05	0.1	52,414	508	2	3,569	507	57,000
LITORANEA	NHUNDIAQUAR	BL-04	427	70	6	846	153	0.8	0.1	1.0	0.05	0.1	342	7	6	42	15	412
	MARUMBI	BL-05	103	16	1	200	36	0.8	0.1	1.0	0.05	0.1	82	2	1	10	4	99

Table-8.10 River Basin Water Quality Prediction (2015)

River Basin	River Name	Control Point	Run-off BOD Load (kgBOD/d)	Purification Risidual Ratio	Flow-out BOD Load (kgBOD/d)	River Flow (Q10.7) (m3/sec)	Average BOD (mgBOD/l)	Permissible Flow-out Load (kgBOD/d)	Difference between Calculated and Permissible Loads (kgBOD/d) as Flow-out	as Run-off
ITARARE	JAGUARIAIVA	IT-02	8,228	0.52	4,279	8.00	6.19	3,456	823	1,583
CINZAS	CINZAS	CZ-01	8,894	0.40	3,558	3.20	12.87	1,382	2,176	5,440
		CZ-05	24,812	0.24	5,955	8.80	7.83	3,802	2,153	8,971
TIBAGI	TIBAGI	TI-01	26,591	0.29	7,711	8.60	10.38	3,715	3,996	13,779
		TI-03	53,478	0.22	11,765	17.00	8.01	7,344	4,421	20,095
		TI-06	58,679	0.52	30,513	25.60	13.80	11,059	19,454	37,412
		TI-10	111,131	0.42	46,675	32.20	16.78	13,910	18,855	36,260
PIRAPO	PIRAPO	PI-13	65,555	0.23	15,078	15.00	11.63	6,480	8,598	21,495
IVAI	IVAI	IV-02	19,468	0.33	6,424	4.20	17.70	1,814	4,610	13,970
		IV-04	46,680	0.21	9,803	7.60	14.93	3,283	6,520	31,048
		IV-12	131,302	0.23	30,199	14.00	24.97	6,048	24,151	48,302
		IV-15	154,144	0.25	38,536	146.00	3.05	63,072	(24,536)	-98,144
		IV-19	186,721	0.30	56,016	140.00	4.63	60,480	(4,464)	-14,880
PIQUIRI	PIQUIRI	PQ-01	19,277	0.22	4,241	30.00	1.64	12,960	(8,719)	-39,632
		PQ-05	51,626	0.38	19,618	69.00	3.29	29,808	(10,190)	-26,816
		PQ-07	79,922	0.45	35,965	108.00	3.85	46,656	(10,691)	-23,758
		PQ-11	95,814	0.35	33,535	98.00	3.96	42,336	(8,801)	-25,146
IGUACU	IGUACU	IG-18	406	0.47	191	0.85	2.60	367	(176)	-374
		IG-14	118,492	0.18	21,329	8.00	30.86	3,456	17,873	99,294
		IG-13	122,580	0.19	23,290	11.80	22.84	5,098	18,192	95,747
		IG-24	129,911	0.12	15,589	25.00	7.22	10,800	4,789	39,908
		IG-28	184,964	0.30	55,489	51.20	12.54	22,118	33,371	111,237
		IG-36	250,439	0.52	130,228	120.20	12.54	51,926	78,302	150,581
		IG-40	280,555	0.37	103,805	161.20	7.45	69,638	34,167	92,343
	NEGRO	IG-25	24,966	0.71	17,726	49.50	4.14	21,384	(3,658)	-5,152
	JORDAO	IG-39	12,268	0.76	9,324	28.20	3.83	12,182	(2,858)	-3,761
	CHOPIM	IG-31	20,953	0.70	14,667	40.10	4.23	17,323	(2,656)	-3,794
RIBEIRA	RIBEIRA	RB-03	57,000	1.00	57,000	72.80	9.06	31,450	25,550	25,550
LITORANE	NHUNDIAQUA	BL-04	412	1.00	412	2.56	1.86	1,106	(694)	-694
	MARUMBI	BL-05	99	1.00	99	0.77	1.49	333	(234)	-234

Table-8.11 BOD Load Reduction Plan

Unit: Kg /day (as run-off BOD load)

River Basin	2005	2015
CINZAS	5,258	8,971
TIBAGI	26,443	37,412
PIRAPO	13,153	21,495
IVAI	38,712	48,302
IGUAÇU	97,123	150,581
RIBEIRA	-	25,550

(3) Sewage Treatment Plan

Of the pollutants from various pollution sources, reduction of the natural pollutant load is difficult, and industrial wastewater have already been treated at a relatively high BOD removal. Therefore domestic pollutant load should be the main objective of reduction. This needs implementation of sewage treatment facilities especially in the densely populated urban areas.

The sewage treatment plans to the years of 2005 and 2015 are shown in Table-8.12. The sewage quantities are calculated from the BOD load values in consideration of the BOD load factor (54 g/person/day), runoff ratio (0.8), BOD removal of treatment process (0.95 for standard activated sludge treatment, 0.80 for anaerobic + aerobic treatment) and unit discharge quantity (170 litter/person/day).

Table-8.12 Sewage Treatment Plan for 2005 and 2015

Period	~ 2005		2005 ~ 2015		Total		
River Basin	Treatment Quantity (m^3/day)	Population to be Served	Treatment Quantity (m^3/day)	Population to be Served	Treatment Quantity (m^3/day)	Population to be Served	Treatment Method
CINZAS	16,000	94,000	12,000	71,000	28,000	165,000	b
TIBAGI	83,000	488,000	35,000	206,000	118,000	694,000	b
PIRAPO	42,000	247,000	26,000	153,000	68,000	400,000	b
IVAI	122,000	718,000	30,000	176,000	152,000	894,000	b
IGUAÇU	300,000	1,765,000	174,000	1,024,000	474,000	2,789,000	a
RIBEIRA	-	-	80,000	471,000	80,000	471,000	b

a: Standard Activated Sludge Process
b: Anaerobic (RALF) + Aerobic Treatment

8.2.4 Cost Estimation

Table-8.13 shows the estimated costs for implementation of the sewage treatment facilities by the years of 2005 and 2015. The current unit construction cost in Paraná state, including that for sewage treatment plant and that for sewer pipelines, is referred in the calculation. By the year of 2005, a total amount of US$ 430.5 million will be needed for the construction of the sewage treatment facilities, and by 2015 US$ 273.1 million will be further needed. The total construction cost will amount to US $ 703.6 million.

Table-8.13 Cost of the Water Quality Improvement Project

Unit: 1,000 US$

River Basin	2005	2015
CINZAS	12,200	9,200
TIBAGI	63,500	26,800
PIRAPO	32,100	19,900
IVAI	93,300	22,900
IGUAÇU	229,400	133,100
RIBEIRA	---	61,200
Subtotal	430,500	273,100
Total	703,600	

8.3 Soil Erosion

8.3.1 Current Gross Soil Loss

Universal Soil Loss Equation, USLE, expresses in the following equation is a popular tool to estimate annual soil loss from the land surface. For the determination of each factor in USLE equation, it requires a long term experiment or observation. However, considering time allowed and objectives of the Strategy study, USLE was applied roughly to grasp soil erosion and examine the effectiveness of soil conservation practices. The determination of each factor in USLE equation and the result are described in the following section.

$$A = R \cdot K \cdot LS \cdot C \cdot P \quad \cdots\cdots (1)$$

where A: annual gross erosion (ton/ha), R: rainfall factor (MJ·mm/ha·hr), K: soil erodibility (ton·ha·hr/ha·MJ·mm), LS: slope length and steepness factor (dimensionless), C: cover and management factor (dimensionless), P: support practice factor (dimensionless)

USLE was applied to 8 river basins excluding Litoranea, Paranapanema and Paraná due to the data availability. Since forest is well conserved in Litoranea, the soil loss is negligibly small. Soil loss from Paraná and Paranapanema river basins are expected to be similar magnitude of nearby river basins.

(1) R

Rainfall factor depends on size and intensities of individual rainstorm and not annual rainfall. However, Rufino et al. (1993) correlated rainfall factor with the average monthly and annual rainfalls dividing the state in 9 regions. Their equation is as follows.

$$R = a + b \cdot Rc$$

$$Rc = p^2 / P$$

where R; rainfall factor, a and b: coefficient, Rc: rainfall coefficient, p: average monthly rainfall (mm), P: average annual rainfall (mm)

Since correlation coefficient of their equation in each river basin is high, it was adopted to compute the rainfall factor and the result ranges between 5,167 and 11,723 MJ·mm/ha·hr depending on the location.

(2) K

Available values of the soil erodibility in Paraná state are only for two soil classifications, Latossolo Roxo Distrofico and Latossolo Vermelho Escuro. These soils are characterized as resistant to erosion and the values obtained from the experiment ranges between 0.007 and 0.012 corresponding to the approximation of Foster et al. (1981).

Soils in Paraná state were classified in three categories in terms of the erodibility and K values approximated by Foster et al. (1981) were adopted. High erodible soils cover approximately 37 % of the state area, while soils resistant to soil erosion cover approximately 30 % of the state area.

Table-8.14 K Factor Adopted

Soil Group	K	Erodibility
Latossolo Vermelho Escuro, clay (LE clay)	0.01	resistant
Latossolo Roxo (LRa)	0.01	resistant
Latossolo Bruno (LBa)	0.01	resistant
Latossolo Vermelho Escuro, sand (LE sand)	0.03	moderate
Terra Roxa Estruturada (TRe)	0.03	moderate
Podzolico (PV)	0.06	high
Cambissolo (Ca)	0.06	high
Litolicos (Ra)	0.06	high

(3) LS

Since contour maps or slope steepness maps are not digitized in Paraná to enable GIS computation, the slope steepness was assessed using the soil map. Each class of soil is located in specific slope steepness. For example, 62 % of Latossolo Vermelho Escuro exists on the slope with 0 to 8 % gradient. The slope steepness where each soil class is located is available in Agricultural Land Aptitude of Paraná (1981).

Regarding the slope length of different land use, the assumptions made are, 1) Slope lengths of terracing for crop field and pasture depend on its steepness, 6 % slope: 30 m length, 8 % slope: 25 m length, 10 % slope: 20 m length, 20 % slope: 15 m length, 2) Slope lengths of forest and secondary vegetation are 100 m, regardless of their steepness., 3) Slope length of crop field where only contouring is practiced follows the slope length limits described in Agriculture Handbook Number 537 (Wischmeier and Smith, 1987).

After determining the slope steepness and length, LS was assessed entering the table or figure of LS in Agriculture Handbook Number 537 (Wischmeier and Smith, 1987).

(4) C

The cover and management factor is the ratio of soil loss from cropping land under certain conditions to the soil loss from clean-tilled continuous fallow. Since C is an integrated value of vegetation cover on soil surface and management practices to grow crops, it is dependent on many factors, such as combination of soil surface cover, crop sequence, tillage method and so on. Therefore, C value is a local dependent variable and obtainable through the field measurement.

Since representative values of C are not available in Paraná, they were approximated from the result of soil loss measurement in IAPAR experimental field (Biscaia and Osaki, 1994). Neglecting the spatial variation of C, C factors in Table-8.15 were adopted for USLE computation.

The soil loss in potato culture is the worst due to the heavy mechanization and no conservation practices, such as terracing. Since the soil conservation is well practiced in soybean and maize fields, their soil loss is considerably low.

Table-8.15 C Factor

Type of Crop	Soil Loss (ton/ha/year)	C facor
Bare Soil (no culture)	up to 80	—
Potato	60 - 70	0.750
Cotton	50	0.625
Cassava	—	0.625
Coffee	30	0.375
Maize	10 - 20	0.250
Soybeans	10 - 20	0.250
Wheat	5 - 10	0.250
Other Crops	—	0.250
Pasture	10	0.125
Forest	—	0.001
Secondary Vegetation	—	0.003

Source: Biscaia and Osaki (1994) for Soil Loss

(5) P

EMATER has classified the crop land either conserved or not conserved. The conserved area means; a) terracing, b) contour bunds and buffer strips, c) improvement of rural roads, d) soil improvement with green manure and lime, f) reforestation, g) guidance of adequate use of machinery.

As of 1992, the conserved area covered more than 40 % of the regional area in Toledo, Maringa, Londrina and Campo Moura EMATER regions (refer to section 6.3) according to EMATER. However, the sate average of conserved area in 1992 was 22.8 %. Thus, there are still lots of areas remained in Paraná without any soil conservation.

For the computation sake of USLE, it was assumed that terracing with contouring is implemented in the whole conserved area in EMATER classification and only contouring is a conservation measure practiced in non conserved crop land. Entering the tables in Agriculture Handbook Number 537 (Wischmeier and Smith, 1978) with the assumptions mentioned above, P values for different slope steepness were obtained. P values for pasture not conserved, forest and secondary vegetation are 1.0 due to their natures.

(6) Land Use

Based on the result of satellite imagery analysis by IAP and GIS computation by SANEPAR, the landuse of each river basin was identified. Although the satellite imagery analysis is based on the data in 1990, it was assumed that the current landuse does not vary from the one in 1994.

To categorize the crop land with specific crops, EMATER data for the year of 1993 associated with number of producers, crop area, area of specific crops, conserved area etc. was used. Since the data is EMATER division wise (refer to section 6.3), it was necessary to convert the data to the river basin wise by means of area weighted average.

(7) Result

The result of USLE approximation of the gross soil erosion is shown in Table-8.16. The average gross soil erosion from 8 river basins is 28 ton/ha. This is a rough approximation; however, the value is considered as adequate accuracy to compare the magnitude of soil erosion of 8 river basins. Cinzas, Ivai and Ribeira river basins are ranked as high gross soil erosion. The gross erosion of Itarare river basin is low compared to other basins due to the low rainfall erosivity.

Table-8.16 Gross Soil Erosion in 1994

River Basin	Soil Loss from Whole Basin (1000 ton/year)	Area (1,000 ha)	Gross Soil Loss (ton/ha-year)
Cinzas	33,066	929	36
Iguacu	154,804	5,532	28
Itarare	2,439	520	5
Ivai	115,309	3,588	32
Piquiri	66,328	2,471	27
Pirapo	9,387	501	19
Ribeira	27,471	913	30
Tibagi	58,568	2,464	24
Total	467,372	16,918	—
Average	—	—	28

Area: area only within Parana state

Problems associated with current soil erosion are summarized as follows. Although each problem interacts with one another, simple identification was tried to figure out main problems.

at field

- low crop productivity induced by soil degradation
- increase in fertilizer application resulting higher cost
- abandonment of land and stimulation of migration to urban area

in a river basin

- high sediment yield
- degradation of ecosystem
- water contamination

8.3.2 Suspended Sediment

(1) Suspended Sediment Load

The eroded soil is transported downward with runoff and some is deposited more flat place due to the reduction of flow velocity, while some reaches to a stream and moves further as suspended sediment and bed load. A correlation between suspended sediment and discharge was examined in order to assess the average annual suspended sediment yield of each river basin.

The data of suspended sediment measured is available in IAP, DNAEE and COPEL. The sediment in mass per time and discharge were plotted in logarithm. Logarithm of suspended sediment, S (g/s), somehow correlates linearly to logarithm of discharge, Q (m^3/s). The relation between S and Q of each river basin obtained is shown in Table-8.17.

Table-8.17 Q vs. S Relation

Log S = aLogQ+b

River Basin	a	b
Cinzas	1.728	0.569
Iguacu	1.269	0.487
Itarare	1.839	0.589
Ivai	2.191	-1.423
Litoranea	1.162	1.089
Pirapo	1.957	0.208
Piquiri	1.762	-0.229
Ribeira	2.360	-0.734
Tibagi	1.167	1.193

Flow regime of each river basin is available as a result of the hydrological analysis in the last 20 years (see section 4.3). From the flow regime, the mean discharge of a specific period in a year is obtainable. Annual unit suspended sediment (ton/km^2·year) of each river basin was computed applying the flow regime to S and Q relation. The result is shown in Table-8.18.

Each river basin was compared to others in terms of unit suspended sediment per year, ton/km^2·year. As a result, Ivai, Piquiri, Itarare and Cinzas yield suspended sediment higher than others. The annual suspended sediment in the Iguaçu river basin is low on the contrary to the expectation. The reason is that there are several dams in Iguaçu river basin and some of suspended sediment is deposited in dam reservoirs. Since no estimation of sediment deposit in the reservoirs is available, the effect of reservoirs on sediment transport is not predictable.

(2) Sediment Delivery Ratio

The sediment yield is defined as the total sediment, the sum of suspended sediment and bed load, delivered to a certain point of a river basin from its upstream area, and the sediment delivery ratio, SDR, is a fraction of the sediment yield to the gross erosion.

Since suspended sediment is a main problem in Paraná associated with water quality, bed load was assumed not significant compared to suspended sediment. Thus, SDR was computed by means of the fraction of suspended sediment to gross erosion. SDR was also computed with the following equation determined by the United States Soil Conservation Service (1971), USSCS. The equation shows the rough relationship between sediment and river basin area.

$$SDR = 0.3320x^{-0.2236}$$

where SDR: sediment delivery ratio, x: river basin area (km^2)

The result is shown in Table-8.18. Although SDR computed by gross erosion and suspended sediment excludes the bed load and SDR by USSCS is just area dependable, those figures are similar order magnitude, except Itarare. It implies that sediment yield in a large scale is more dependent on area due to sediment deposition.

Table-8.18 Estimation of Sediment Delivery Ratio

River Basin	Area (km²)	GSL (1,000 ton/year)	UAS (ton/km²year)	AS (1000 ton/year)	SDR	SDR US
Cinzas	9,290.7	33,066	84	780	0.024	0.043
Iguacu*	55,318.0	154,804	18	996	0.006	0.029
Itarare*	5,197.9	2,439	97	504	0.207	0.049
Ivai	35,878.9	115,309	137	4,915	0.043	0.032
Piquiri	24,707.9	66,328	106	2,619	0.039	0.035
Pirapo	5,005.9	9,387	69	345	0.037	0.049
Ribeira*	9,129.3	27,471	57	520	0.019	0.043
Tibagi	24,634.7	58,568	31	764	0.013	0.035

GSL: Gross Soil Loss, UAS: Unit Annual Suspended Sediment, AS: Total Suspended Sediment,
SDR: Sediment Delivery Ratio, SDR US: Sediment Delivery Ratio estimated by USSCS relation
Note: SDR in Iguacu is low due to reservoirs.
*: Area is only within Parana state.

(4) Erosion Susceptibility of River Basins

Erosion susceptibility of 8 river basins was evaluated based on estimations of gross erosion and suspended sediment as shown in Table-8.19. Most of river basins in Paraná, except Itarare, are suffered from exceeding permissible level of soil erosion and contamination of water. Among them, Ivai, Piquiri and Cinzas are ranked at high erosion susceptibility and high negative effect on the water environment. Therefore, proper land management and urgent implementation of countermeasures are required, especially in those basins.

Table-8.19 Evaluation of Erosion Susceptibility of River Basins

River Basin	GSL	SS
Cinzas	5	3
Iguacu	4	1
Itarare	1	4
Ivai	5	5
Piquiri	4	4
Pirapo	3	3
Ribeira	4	2
Tibagi	3	2
Rank		
1 tolerant	0 - 8	0 - 30
2 moderate	9 - 16	31 - 60
3 medium	17 - 24	61 - 90
4 severe	25 - 31	91 - 120
5 very severe	32≤	121≤
unit	ton/ha	ton/km²·year

GSL: Gross Soil Loss
SS: Suspended Sediment

8.3.3 Strategy for Soil Conservation

(1) Criteria

The soil conservation is to control the erosion below a threshold level depending on criteria. Threshold which only maintenance of soil fertility is considered as criteria will be different from one which both soil fertility and water environment are considered. Since one of objectives of this study is to improve the water environment, it is necessary to suppress the effect of soil erosion on the downstream. However, criteria to determine the threshold of erosion control are not available in Paraná so far.

Based on worldwide researches, Morgan (1980) approximated the appropriate values of the maximum permissible soil loss in terms of area. The permissible soil loss from the area more than 10 km^2 is 2 ton/ha·year and ones from medium scale and field size are 11 and 25 ton/ha·year, respectively. Since the areas of subjected river basins range from 5,000 to 55,000 km^2, 2 ton/ha·year is a threshold. However, this value is considered as too strict to be implemented in next twenty years. Therefore, 11 ton/ha·year was adopted as the threshold of soil loss to propose the Strategy by the year of 2015 and 2 ton/ha·year will be achieved in succession.

(2) Countermeasures

Soil conservation measures consist of agronomic measures, soil management and mechanical measures. Agronomic measures and soil management are effective on detachment and transport of soil particles, while mechanical measures are mostly effective on transport. The combination of agronomic measures and soil management usually results in successful soil conservation, and mechanical measures without agronomic measures are rarely effective to soil conservation.

1) Mechanical Measures

Terracing is a strong measure to reduce runoff velocity and induce sediment deposition in the drains. As a result, sediment yield from a field decreases. Besides, terracing has a multiplicative effect on erosion by means of reducing slope length.

The effect of terrace on the suppression of soil erosion was examined assuming that slope is 8 %, soil erodibility is 0.03 and no cover and management factor, C=1. Regardless of rainfall energy, the soil loss is reduced to 13 % of one with the application of contouring alone.

According to EMATER, several types of terracing has been currently applied to 3,000,000 ha of crop land, about 50 % of the total crop area. By the year of 2015, 100 % cover of terracing is essential for soil conservation.

Other mechanical measures should be considered for the soil conservation in Paraná are as follows.

a) contour bunds and buffer strips, especially where sandy soil is dominant and terracing does not work well

b) contouring

c) road improvement with proper surface cover and drainage system is essential.

d) gully erosion control

   Gully erosion is induced by the concentration of runoff. Therefore, runoff must be reduced by land use management and controlled by drainage system. Land use management is mulches, grasses, trees and their combination to decrease flow velocity with surface roughness and increase infiltration.

   In the Northwestern region of Paraná, the gully erosion in urban areas is a serious problem due to the improper drainage system. In these areas, drain water from a town must be conducted to several outlets if possible to avoid the concentration of drainage and measures to reduce flow velocity, such as energy dissipator at an outlet, must be applied.

e) sediment settlement pond

For the river basin management, sediment settlement ponds located at downstream end of a field are effective to reduce sediment yield. Concrete lining ponds are easy to clean sediment settled. This measure is costly and only recommended to where other measures do not satisfy the permissible sediment yield.

2) Agronomic Measures and Soil Management

The aim of agronomic measures is to increase surface cover and infiltration. As a result, surface runoff is minimized and permissible soil loss is achieved. Since mechanical measures must be combined with agronomic measures, agronomic measures are crucial factors for soil conservation.

Agronomic measures and soil management vary with crop, rainfall energy, land relief and so on. Therefore, the determination of countermeasures involves the careful evaluation of each factor associated with soil erosion. Common agronomic measures and soil management are summarized hereunder and the detailed is not discussed.

a) proper spacing of crop strips

b) proper crop calendar

c) maintenance of soil fertility with application of fertilizers and green manure

d) intercropping

e) mulching and residue cover

f) permanent vegetation cover

g) stabilization of aggregate

h) tillage practices

Inadequate application of tillage induces negative effects on soil properties, such as generating a hard pan due to excess operation of heavy machinery, soil erosion due to excess clearing and so on. Therefore, the proper management must be guided to farmers.

Non tillage was first introduced to Paraná state in 1972. At present, the area has expanded to approximately 760,000 ha which covers about 10 % of the crop land. Considering the advantages, non tillage is expected to expand 50 % of applicable crop land by the year of 2015. Main positive effect of non tillage on soil erosion is to maintain surface cover throughout the year.

(3) Assessment of future soil erosion with strategy

As a result of examination of countermeasures, the soil conservation strategy in Paraná state is summarized hereunder and the effect of the strategy was examined by USLE application. To achieve the final goal by the year of 2015, countermeasures of soil erosion stipulated must be implemented through the close cooperation among individuals and authorities concerned.

Soil Conservation Strategy by the year of 2015 are summarized below.

threshold 11 ton/ha·year

essential measures

1) 100 % application of terracing with contouring to crop land and pasture
2) improvement of farm roads with proper drainage
3) 50 % application of non tillage to crop land
4) application of agronomic measures and soil management depending on factors associated with erosion problem
5) proper land use
6) increase forest area

measures if required

1) sediment settlement pond
2) improvement of urban drainage system for gully erosion
3) drainage system with collecting channel, conduit and box at crop land

Among the countermeasures, terracing and non tillage are the most effective measures to suppress soil erosion. Therefore, only these two were applied to assess the gross erosion in 2015 quantitatively and examine the cost and benefit of measures.

The result is shown in Table-8.20 with suspended sediment expected. The gross erosion from each river basin is drastically reduced to 32 % - 19 % of the current gross erosion. Since other measures are not counted in estimation, the result is considered as an underestimation. It means that less gross erosion would be expected than estimated value if the strategy was implemented fully.

Assuming that the sediment delivery ratio does not vary with any soil conservation practices, the future suspended sediment yield was computed. The reduction of suspended sediment load would contribute to better ecosystem and water quality.

Table-8.20 Gross erosion and Suspended Sediment in 2015

River Basin	Area (1,000 ha)	2015 Erosion from Whole Basin (1000 ton/year)	Gross Soil Loss (ton/ha·year)	Sediment Delivery Ratio	AS (1000 ton/year)
Cinzas	929	6,521	7	0.024	157
Iguacu	5,532	45,823	8	0.006	275
Itarare	520	678	1	0.207	140
Ivai	3,588	29,466	8	0.043	1,267
Piquiri	2,471	17,955	7	0.039	700
Pirapo	501	2,845	6	0.037	105
Ribeira	913	7,229	8	0.019	137
Tibagi	2,464	17,195	7	0.013	224
Average			8		

AS: annual suspended sediment

AS for 2015 was computed applying the same SDR for 1994.

(5) Cost and Benefit

1) Cost

The costs for terracing in Paraná are available in EMATER. The costs vary with type of terracing and machinery applied. For example, the cost of impoundment terrace is approximately 120 US$/ha and one for large base terrace is 35 US$. Considering the popularity of type of terrace, 40 US$/ha was adopted to estimate the cost for terracing.

The costs for non tillage are mainly purchase of planters and herbicides. According to Derpsch et al. (1991), the costs for soybean and corn planters, 6 and 3 rows respectively, range from 4,700 to 7,900 US$, and farmers usually have two kinds of planters, one for narrow space planting and another for medium or wide space planting due to less efficiency of universal machinery. For the calculation sake, the following assumption was made.

a) Average machinery cost is US$ 6,500

b) Machinery lasts ten years. Therefore purchase within 20 years will be twice.

c) Universal machinery overcomes its less efficiency. Consequently, farmers have only one machinery.

d) Maintenance costs are negligible.

e) Farmers already adopting non tillage also purchase machinery twice by 2015.

f) The costs for herbicides is not considered.

g) Non tillage is applicable to crops considered, except coffee and pasture.

h) One machinery covers 200 ha planting in accordance with the average area of medium size farmers who are major to practice non tillage.

The total cost for soil conservation measures in next twenty years is US$ 443 million as shown in Table-8.21. If the measures were implemented evenly in next twenty years, the cost per year would be US$ 22.2 million .

2) Benefit

Paraná Rural Project has estimated nutrient loss compensated by fertilizers assuming the average soil loss of 20 ton/ha·year and enrichment ratio of 1.0. Consequently, the losses in whole Paraná state are US$ 60 million per year for nitrogen and US$ 5 million per year for potassium.

If soil conservation measures were implemented according to the strategy, 28 ton/ha·year in 1994 would be reduced to 8 ton/ha·year in 2015. Applying simply the ratio of nutrient loss to average soil erosion, nutrient loss in 1994 and 2015 were compared.

1994	US$ 84 million per year for N	US$ 7 million per year for K
2015	US$ 24 million per year for N	US$ 2 million per year for K

The cost to compensate the nutrient loss will be reduced to 30 % of the current one. This saved cost is considered as benefit. The benefit is effective one year later after the implementation of countermeasures.

SANEPAR has estimated the annual cost to purify water due to the suspended sediment at US$ 217 thousand. The cost for water purification in 2015 was estimated by a comparison between the total annual suspended sediment in 1994 and 2015 assuming that US$ 217 thousand was spent for water purification in 1994.

1994	US$ 217 thousand
2015	US$ 57 thousand

The benefit for water purification was approximated by the same way as the soil nutrient loss.

The effect, total cost and benefit by the year of 2015 with the implementation of Strategy are summarized in Table-8.21. The benefit is the saved capital with soil conservation measures. The total benefits by the year of 2015 are US$ 683 million for fertilizer and 2 million for water purification, while the total cost for conservation measures is US$ 443 million.

The increase in crop productivity is not analyzed; however, many researches show increase and stabilization of the productivity by means of soil conservation practices. The improvement of soil physical and chemical properties with soil conservation results in high productivity and less inputs, such as fertilizers.

3) Conclusion

According to the gross income of agricultural sector estimated (refer to Sectoral Report Vol. E, Agriculture), 3,955, 4,993 and 5,659 million US$ in the year of 1993, 2005 and 2015, respectively. Annual costs of conservation measures in 2005 and 2015 are 0.44 % and 0.39 % to the gross income, respectively. Therefore, the cost is considered as affordable level and lots of capital would be saved.

Although the benefit estimation is very rough, the result shows that soil conservation measures are worth to be implemented and cost can be compensated by capital saved and gained.

Table-S.21. Effect, Cost and Benefit of Conservation Measures

River Basin	1994		Countermeasures (1,000 ha)		2015		Cost by 2015 (million US$)		Benefit by 2015 (million US$)		
	ASL	AS	Terracing	Non Tillage	ASL	AS	Terracing	Non-tillage	N	K	Purification
Cinzas	33,066	780	384	233	6,521	157	15.4	15	49.50	4.10	0.131
Iguacu	154,804	996	1,935	1,063	45,823	275	77.4	69	201.70	16.80	0.540
Itarare	2,439	504	176	97	678	140	7.0	6	3.30	0.30	0.009
Ivai	115,309	4,915	1,334	565	29,466	1,267	53.4	36	159.50	13.30	0.424
Piquiri	66,328	2,619	964	514	17,955	700	38.6	33	89.70	7.50	0.239
Pirapo	9,387	345	184	80	2,845	105	7.4	5	12.10	1.00	0.032
Ribeira	27,471	520	293	116	7,229	137	11.7	7	37.60	3.10	0.100
Tibagi	58,568	764	751	479	17,195	224	30.0	31	76.60	6.40	0.205
Total	467,372	11,443	6,021	3,147	127,712	3,005	241.0	202.0	630.00	53.00	2.000

ASL: annual soil loss (1,000 ton/year)
AS: annual suspended sediment (1,000 ton/year)
Unit cost: terracing = US$ 40/ha, non tillage = US$ 6,500/machinery
N: Nitrogen, K: Potassium

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