Chapter 17

WATER QUALITY PREDICTION USING A MATHEMATICAL MODEL

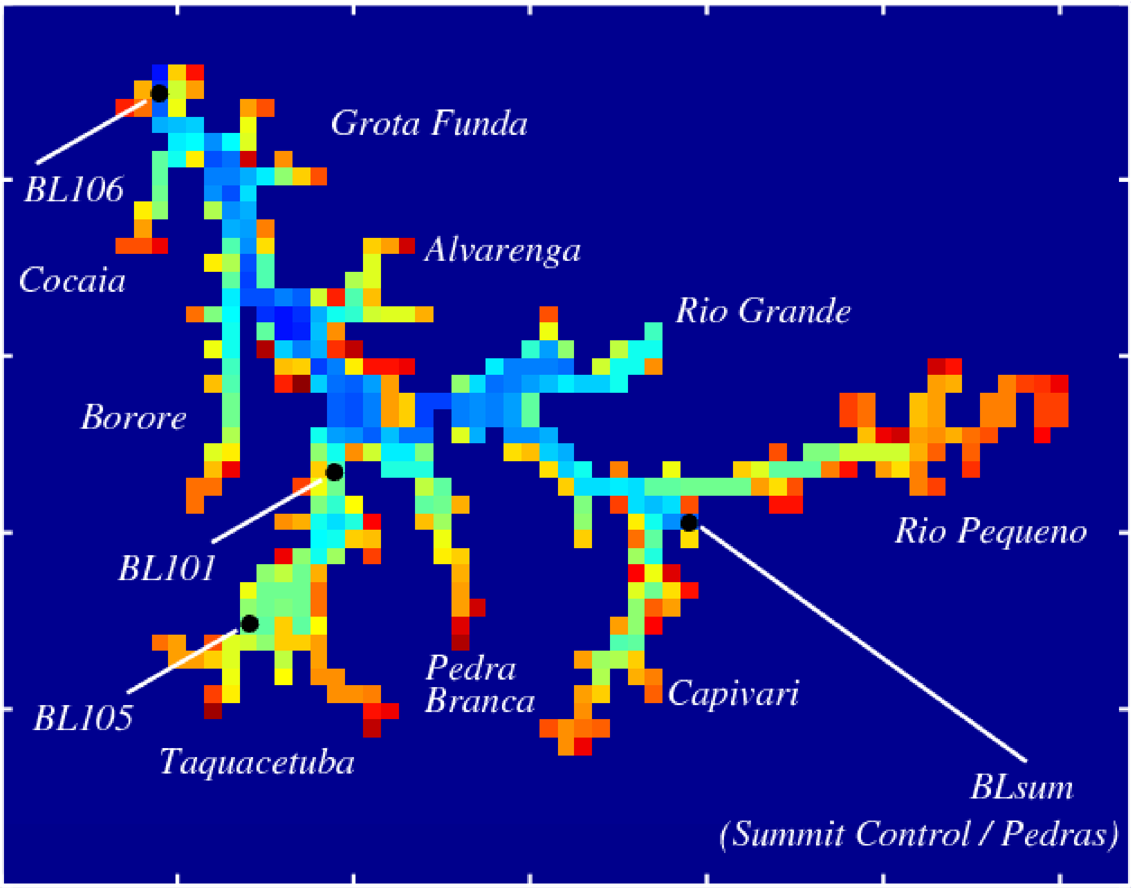
17. WATER QUALITY PREDICTION USING A MATHEMATICAL MODEL

17.1 Attainable Status of water quality conservation targets

17.1.1 Lake Billings

(1) Computational structure of the Lake billings for mathematical model analysis

The Lake Billings is expressed as the lake composed of approximately 16,000 cells with a dimension of 500 m long x 500 m wide x 1.0 m deep for each based on the bathmetic survey results conducted in 2004 by EMAE as shown in **Figure 17.1.1** for simulation. However, around the narrow portion of the Immigrantes Bridge, a cell has a dimension of 125 m long x 125 m wide x 1.0 m deep for each to communicate the situational change smoothly before and after the passage under the Immigrantes Bridge. The simulation for ten years take 36 hours.



Stations	Geographic Coordinates	
	Latitude	**Longitude**
BL-101	23°47'34"	46°37'16"
BL-105	23°50'36"	46°39'10"
BL-106	23°42'22"	46°40'14"

Figure 17.1.1 Monitoring points and computational structure of the Lake Billings

(2) Setting of initial conditions

a) Initial water quality of the Lake Billings and Rio Grande Arm

Initial water quality of the Lake Billings and Rio Grande Arm is set as shown in **Table 17.1.1**. The simulation period is one year with four month preliminary simulation period starting from September of the previous year with the following reasons:

- The lakes becomes relatively homogeneous at the end of winter (acclimation).
- During the starting period of September to January, the specific conditions of each scenario work effectively.
- The particular period is the same as that for the intensive limnological survey conducted by the CETESB and UFSCar.

Table17.1.1 Initial water quality of the Lake Billings and Rio Grande Arm

	Chla（μg/L）	DO （mg/L）	BOD （mg/L）	T-N （mg/L）	T-P （mg/L）
Lake Billings and	30	8.0	4.0	0.8	0.1
Rio Grande Arm	10	8.0	1.3	0.5	0.03

b) Elution rate

To calculate the elution load from bottom sediments, two type of elution rateos, or moderate and high, are assumed.

Table 17.1.2 Setting of elution rates

Elution rate				
moderate	Applied the experienced values collected by the Coastal Water Research (CWR), the University of Western Australia under the similar eutrophication condition（"Before change" below）.			
high			Before change	After change
	Higher elution rate	PO_4	0.0005 g/m^2・day	0.0010 g/m^2・day
		NH_4	0.0200 g/m^2・day	0.0600 g/m^2・day
		DOC	0.0080 g/m^2・day	0.0400 g/m^2・day
	Small increase of maximum growth rate of algae	cyanobacteria	1.2/ day	1.3/ day
		chlorophiceae	2.0/ day	2.1/ day
		diatoms	1.3/ day	1.5/ day
	Small reduction of cyanobacteria's fraction respiration to total metabolic loss		0.9	0.8

c) Water quality of pumping water from the Pinheiros River

The average water quality at PINH 04900 (downstream of the Pinheiros River) that is one of the monitoring points of the CETESB is given in **Table 17.1.3**. As the emergency pumping is done when the flow of the Tiete River exceeds 160 m^3/sec at the downstream of confluence with the Pinheiros River, or the time when Sao Paulo enters on the alert for flood, pumping water is assumed to be diluted by storm water and its water quality during wet weather is set as also shown in **Table 17.1.3**.

Table17.1.3 Water quality of pumping water from the Pinheiros River

Parameters		Untreated pumping water			Treated pumping water
		Rainy season	Dry season	During wet weather	
BOD_5	(mg/L)	44.0 (1)	68.0 (1)	25.0 (2)	10.0 (4)
DO	(mg/L)	0.1 (1)	0.1 (1)	0.1 (1)	4.8 (3)
TN	(mg/L)	10.5 (1)	16.5 (1)	6.0 (2)	6.0 (5)
TP	(mg/L)	1.5 (1)	2.5 (1)	0.8 (2)	0.1 (3)
SS	(mg/L)	100.0 (1)	100.0 (1)	100.0 (1)	2.0 (5)

(1) Average water quality during dry and wet seasons proposed by the CETESB
(2) Water quality considering the dilution effect during wet weather
(3) Water quality presented at the official website of the SMA, Sao Paulo State
(4) Based on the description in the above (3) that a BOD_5 concentration of 10 mg/L was obtained in the experiment.
(5) Adopted through the technical discussion in the CETESB meeting

Figure 17.1.2 shows the relationship between the water quality at PINH 0490 and the rainfall for three consecutive days including the sampling day and its previous two days during rainy season (October to March) in 2000 to 2005. 86% of pumping times and 91% of pumping amount occurred during rainy season in 2000 to 2004.

(3) Monitoring points

The checkpoints for simulation shall be the following four points that the CETESB has monitored water quality.

BL106: Pedreira Dam (inlet of pumping water)

BL101: Intermediate point of the Central Channel (confluence with the Taquacetuba Arm)

BL105: Taquacetuba Arm (SABESP’s intake point to pump lake water to Lake Guarapiranga

BLsum: Summit Dam (Intake for Henry Borden Power Plant)

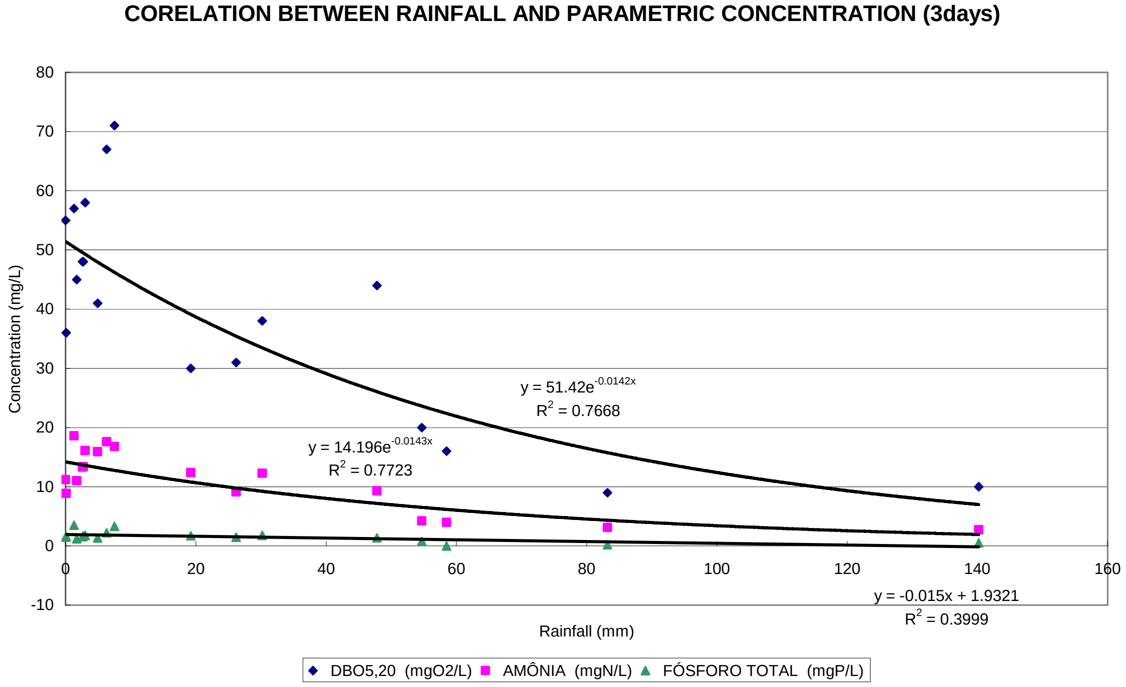


Figure 17.1.2 Relationship between the water quality at PINH 0490 and the rainfall for three consecutive days

(4) Simulation results

1) Attainment status of Water Quality Conservation Targets (WQCTs) (comparison between the present and future with project)

How to see the figures showing the simulation results is described in **Figure 17.1.3**.

The WQCT attainment status by project implementation is shown in **Figure 17.1.4** and **Table 17.1.4** by parameter. The WQCTs as shown in **Table 9.2.3** for the year of 2025 are same as those of the environmental standards.

According to the simulation results, the improvement effect of water quality is shown in all parameters of Chlorophyll-a, BOD_5, NH_4-N, PO_4-P and TP except for DO between the years of 2005 (before sewered) and 2015 (after sewered). However, the parameters of Chlorophyll-a and TP cannot attain the WQCTs. The extent of water quality improvement depends on parameter in which the improvement rate of water quality in 2015 to that in 2005 is biggest in PO_4-P by 35%, followed by TP (22%) and BOD_5 (20%).

Chlorophyll-a

- The concentration distribution on the water surface is improved moderately for 2005 to 2015, but slightly for 2015 to 2025.
- The concentration of Chlorophyll-a just clears the 2015 WQCT for Class 2 in 2025.
- Chlorophyll-a exceeds an environmental standard of 30 μg/L except for the remotest

area such as Rio Pequeno and Rio Capivari from Pedreira Dam, especially at the deepest portion of Alvarenga and Pedra Blanca with a concentration of around 80 μg/L.

BOD_5

- The concentration distribution on the water surface is improved moderately for 2005 to 2015, but slightly for 2015 to 2025.
- The concentration of BOD_5 clears the 2025 WQCT for Class 1 in 2015.
- Watching the profiles for the simulation period, the concentration in Summit Dam is stable at 2 to 4 mg/L throughout a year.

DO

- As for DO, higher concentration is better, but the concentration distribution on the water surface is gradually dropping in 2005, 2015 and 2025.
- The median of the DO concentrations meets the 2025 WQCT for Class 1 since 2005.

NH_4-N

- The concentration distribution on the water surface is stable at less than 30 μg/L all in 2005, 2015 and 2025.
- The 2005 new environmental standard of NH_4-N varies by pH, that is to say, the lower pH the higher the standard. For a pH of more than 8.5, an environmental standard of NH_4-N for Class 1 is less than 500 μg/L that is cleared since 2005
- At Summit Dam, the elution of NH_4-N from bottom sediments is observed during January to April and September to December.
- The median of NH_4-N drops to 23.2 μg/L in 2025 due to the remarkable progress of homogenization as a whole of the lake.

PO_4-P

- The concentration distribution on the water surface is improved moderately for 2005 to 2015, but slightly for 2015 to 2025.
- There is no environmental standard for PO_4-P, but its median is in a low level of 2.4 μg/L.
- At Summit Dam, the elution of NH_4-N from bottom sediments is observed during January to April and August to December.
- Watching the profiles for the simulation period, the concentration in the Taquacetuba Arm is stable at zero to 5 mg/L throughout a year.

TP

- The concentration distribution on the water surface is improved moderately for 2005 to 2015, but slightly for 2015 to 2025.
- The concentration of TP is in a level of 80 μg/L even in 2025, far from the 2015 WQCT of 30μg/L for Class 2.

It should be noted that the attainment status of water quality conservation targets for the Lake Billings in **Table 17.1.4** already reflects the influence of emergency pumping in the concentrations. For example, the improvement effect of BOD_5 by sewerage construction is from 3.40 mg/L to 2.77 mg/L, or 0.63 mg/L with emergency pumping, but from 2.38 mg/L to 1.34 mg/L, or 1.04 mg/L without emergency pumping. In other words, emergency pumping offsets the effect of sewerage construction.

By sewerage construction in the urban area and isolated communities, the middle-term and long-term targets are attainable for DO, BOD_5 and NH_4-N, but difficult for Chlorophyll-a and TP. According to the simulation results without emergency pumping which is shown as a reference, the environmental standard for Class 2 of 30 μg/L is attainable for Chlorophyll-a by sewerage construction, but not for TP even in 2025 that is slightly over the environmental standard for Class 2 of 30 μg/L. The environmental standard for Class 2 of 30 μg/L is also adopted in Japan and not so severe target. Domestic wastewater in the urban area that is the biggest pollution source is reduced to a level of almost zero by the conveyance to the outside of the basin for treatment, it is difficult to cut a load any more. Although a elution load is estimated by assuming a elution rate from bottom sediments in the present simulation (see **Annex A7.4.4**), it suggests that any measure is necessary for TP in addition to stopping the pumping from the Pinheiros River. However, emergency pumping is considered to be continued from now on, Chlorophyll-a and TP is presumably difficult to attain the environmental standard

2) Comparison the cases with Project and without Project

As shown in **Figure 17.1.4**, the case with Project improves water quality than the case without Project except for DO. According to the simulation results for 2015, the case without Project deteriorates water quality by 5 to 15%, while the case with Project improves it by 6 to 28%. This trend is little change in the case without Project for 2025, but there is more improvement by 15 to 35% in the case with Project.

Table 17.1.4 Attainment status of WQCTs for the Lake Billings

Parameter	Elution rate	2005	2015		2025		2025
			w/o Project	w/ Project	w/o Project	w/ Project	WQCT
With emergency pumping							
Chla (μg/L)	Moderate	70.96	75.18	62.76	74.89	59.74	≤30μg/L
	High	92.70	93.24	88.19	92.89	86.09	≤10μg/L
BOD_5 (mg/L)	Moderate	**3.40**	**3.68**	**2.91**	**3.68**	**2.77**	≤5mg/L
	High	6.17	6.28	5.59	6.27	5.43	≤3mg/L
DO (mg/L)	Moderate	**6.82**	**6.86**	**6.76**	**6.85**	**6.73**	≥5mg/L
	High	**7.04**	**7.02**	**7.05**	**7.02**	**7.04**	≥6mg/L
NH_4-N (μg/L)	Moderate	**27.52**	**29.23**	**24.63**	**28.86**	**23.26**	≤500μg/L
	High	**45.18**	**46.64**	**39.14**	**46.42**	**37.35**	≤500μg/L
PO_4-P (μg/L)	Moderate	3.67	4.32	2.69	4.32	2.43	—
	High	6.84	7.28	4.97	7.27	4.56	—
TP (μg/L)	Moderate	101.24	110.63	85.23	110.64	80.48	≤30μg/L
	High	143.01	148.90	118.67	149.19	113.39	≤20μg/L
Without emergency pumping (for reference)							
Chla (μg/L)	Moderate	48.52		31.02		**25.35**	≤30μg/L
	High	97.41		73.50		65.80	≤10μg/L
BOD_5 (mg/L)	Moderate	**2.38**		**1.60**		**1.34**	≤5mg/L
	High	5.79		**4.39**		**3.96**	≤3mg/L
DO (mg/L)	Moderate	**6.53**		**6.34**		**6.27**	≥5mg/L
	High	**7.09**		**6.84**		**6.74**	≥6mg/L
NH_4-N (μg/L)	Moderate	**26.84**		**20.60**		**17.36**	≤500μg/L
	High	**46.48**		**35.86**		**32.44**	≤500μg/L
PO_4-P (μg/L)	Moderate	1.38		0.93		0.82	—
	High	3.12		1.49		1.24	—
TP (μg/L)	Moderate	61.27		38.62		31.31	≤30μg/L
	High	97.48		66.96		59.73	≤20μg/L

Legend: **1.0** (double box) Attain WQCT for Class 1 **1.0** (single box) Attain WQCT for Class 2

Note: Values show the average of water quality at all water surface cells (every three hours for one year).

In a column for the WQCT, the upper shows Class 1 and the lower Class 2.

3) At the higher elution rate

The simulation results at higher elution rate are shown in **Figure 17.1.3** and **Table 17.1.4**. According to these, the distribution configuration of a histogram showing water surface cell concentrations is similar to that at the moderate elution rate, but the distribution width is extended with bigger medians and parameters excluding DO and NH_4-N do not meet the environmental standards. The concentration distribution on the water surface depends on parameters as follows:

Chla:	The deterioration of water quality is outstanding in the Arms of Taquacetuba, Capivari and Rio Pequeno.
BOD_5:	Water quality deteriorates significantly throughout the lake and the elution from bottom sediments is observed.
DO:	In comparison with other parameters, overall change is not so clear with relatively little rise in median.
NH_4-N:	The deterioration is marked near Pedreira Dam with bigger elution from bottom sediments as a whole.
PO_4-P:	The deterioration in the Central Channel is clear with bigger elution from bottom sediments as a whole.
TP:	The deterioration in the Central Channel is clear with bigger elution from bottom sediments as a whole.

4) Water quality as a water source

The CONAMA's environmental standards for Class Special are applied to the Taquacetuba Arm where the SABESP takes water for water supply. The relationship between the environmental standards for Class Special and water supply is described that disinfection is available for water supply. Due to almost no numerical standards for Class Special, when the water quality at the Taquacetuba Arm was checked with the environmental standards for Class 1 for convenience, as described in **5.2.2** and shown in **Table 17.1.5**, BOD_5, TP and Al have sometime don't meet the standards as well as cyanobacteria. The concentrations of BOD_5 and TP are rather higher than the standards and affect on the lake water quality, of which the results by the conveyance of wastewater outside the basin through sewerage construction is indicated in **Table 17.1.4**. Due to the continuation of emergency pumping in future, whether the TP concentration will meet the standard is fine even at a moderate elution rate. In the Lake Billings, frequent occurrence of water bloom is also expected in which the dominant species is *Microcystis* containing problematic *Microcystin* or hepatic toxic. The present process at the Alto da Vista Water Treatment Plant that receive water from the Lake Billings via the Lake Guarapiranga is composed of coagulation-sedimentation, sand filtration and chlorination which is expectedly not effective to odor and *Microcystin* removal. Therefore, it is considered that the advanced water treatment, for example granular activated carbon adsorption, biological oxidation, ozonation and so on may be required, depending on the occurrence situation of algae in future.

Table 17.1.5 Attainment status of Environmental Standards at the Taquacetuba Arm

Data / Parâmetro	Unidade	Padrão CONAMA Classe 1	Braço de Taquacetuba - BITQ02900						
			2005/1/5	2005/3/9	2005/5/4	2005/7/6	2005/9/20	2005/11/23	Média (A)
Absorbância no Ultravioleta	mg/L		0.078	0.086	0.09	0.065	0.097	0.094	0.085
Alumínio Total	mg/L		0.58	0.16	0.13	< 0.1	0.39	0.31	0.28
Arsênio Total	mg/L	0.01	< 0.02	< 0.002			< 0.002		0.008
Cádmio Total	mg/L	0.001	< 0.005	< 0.03	< 0.005	< 0.005	< 0.005	< 0.005	0.009
Carbono Orgânico Dissolvido	mg/L		6.59	6.89		5.59	5.99	7.52	6.52
Chumbo Total	mg/L	0.01	* 0.89	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	0.3
Chuvas nas últimas 24h	mg/L		1	2	2	1	2	2	1.7
Cloreto Total	mg/L	250	19.7	20.2	19.9	18.9	20.7	19.2	19.8
Clorofila-a	μg/L	10	63.36	32.35	67.27	28.32	52.13	71.46	52.48
Cobre Total	mg/L		< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	0.02
Coliformes Termotolerantes	UFC/100mL	200	2	< 1	< 1	< 1	3	< 1	1.5
Coloração	mg/L		5	5	5	5	5	5	5
Condutividade	μS/cm		190	184	187	193.5	184	192	188
Cor Verdadeira	mg Pt/L		10	< 5	< 5	< 5	5	30	10
Cromo Total	mg/L	0.05	< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	0.02
DBO (5, 20)	mg/L	3	* 5	* 4	* 5	3	* 4	* 5	* 4.3
DQO	mg/L		< 50	< 50	< 50	< 50	< 50	< 50	50
Fenóis Totais	mg/L	0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003		0.003
Feofitina-a	μg/L		13.37	12.39	8.51	13.74	11.68	15.27	12.49
Ferro Total	mg/L		0.17	0.22	0.18	0.28	0.21	0.23	0.22
Fosfato Orto Solúvel	mg/L		< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	0.007
Fósforo Total	mg/L	0.02	* 0.05	* 0.06	* 0.07	* 0.03	* 0.05	* 0.06	* 0.05
Manganês Total	mg/L	0.1	0.02	0.02	0.03	0.03	0.03	0.03	0.03
Mercúrio Total	mg/L	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001
Microcistinas	μg/L		0.31	0.37	0.3		0.26	0.28	0.30
Níquel Total	mg/L	0.025	< 0.02	< 0.1	< 0.02	< 0.02	< 0.02	< 0.02	0.03
Nitrato	mg/L	10	0.54	1.1	0.49	0.35	< 0.2	< 0.2	0.5
Nitrito	mg/L	1	0.03	0.06	0.03	0.03	< 0.004	0.01	0.03
Nitrogênio Amoniacal	mg/L		0.04	0.05	0.21	0.11	< 0.03	0.11	0.09
Nitrogênio Kjeldahl	mg/L		1.03	1.2	1.28	1.37	1.09	1.88	1.31
N° de Células de Cianobactérias	N. Células	20000	* 229200	* 306300	* 326400	* 168000	* 75700	* 788700	* 315717
Oxigênio Dissolvido	mg/L	6	8.9	10.3	9.5	8.38	10.11	12.13	9.89
pH	U. pH	entre 6 e 9	* 9.3	* 9.2	8.8	7.9	8.5	9.7	8.9
Potencial de Formação de THM	μg/L		483		375	288		269	354
Sólido Dissolvido Total	mg/L	500	112	136	102	122	114	134	120
Sólido Total	mg/L		114	144	102	122	132	160	129
Sólido Volátil Total	mg/L		50	44	< 100	< 100	< 100	< 100	82
Sulfato Total	mg/L	250	< 10	13.5	10.9		< 10	< 10	11
Teste de Ames 100 - S9	Rev./L			810	0	0	0	0	162
Teste de Ames 100 + S9	Rev./L			0	0	0	0	0	0
Teste de Ames 98 - S9	Rev./L			350	330	0	0	0	136
Teste de Ames 98 + S9	Rev./L			180	0	0	0	0	36
Temperatura da Água	ºC		24.7	27.2	21.6	19.4	19.6	24.8	22.9
Temperatura do Ar	ºC		23.6	30	22.5	19	19	29	24
Teste de Toxicidade Crônica	-	Não Crônica	* Crônica	* Crônica	* Crônica	* Crônica		* Crônica	
Transparência	m					0.8	0.6		0.7
Turbidez	UNT	40	12	8.23	5.85	8.7	20	13.4	11.36
Zinco Total	mg/L	0.18	< 0.02	< 0.1	< 0.02	< 0.02	0.03	< 0.02	0.04
SST	mg/L	500							
Colif. Fecal	NMP/100mL								
Colif. Total	NMP/100mL								
Sulfeto	mg/L	0.002							
Surfactantes	mg/L								
Óleos e Graxas	mg/L	*1							
Cromo +6	mg/L								
Ferro Solúvel	mg/L	0.3							
Prata	mg/L	0.01							
Selênio	mg/L	0.01							
Estnho	mg/L								
Molibdênio	mg/L								

*1 Virtualmente ausentes

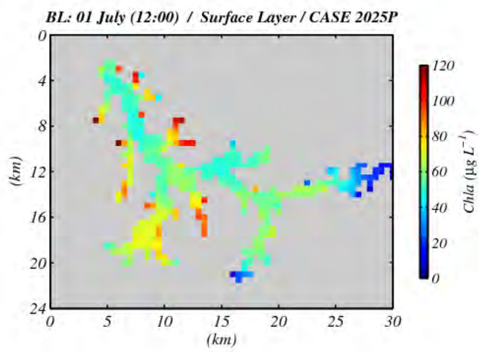
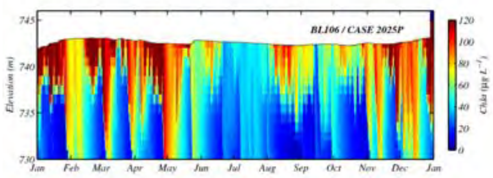
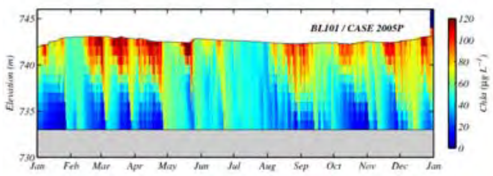
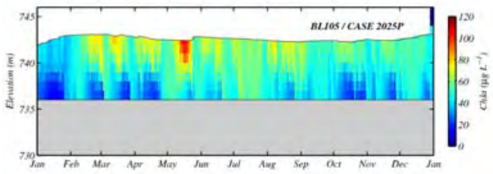
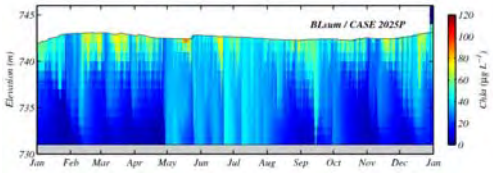
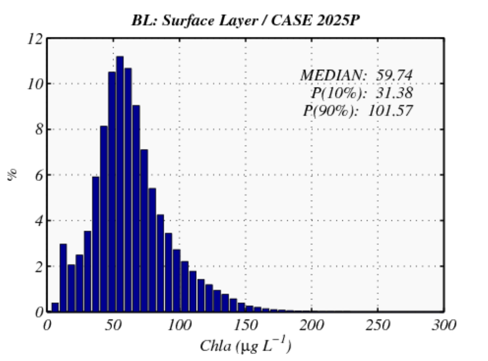
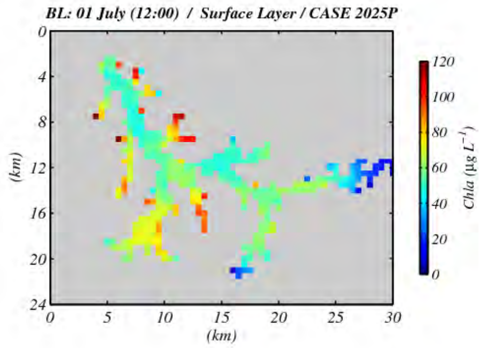
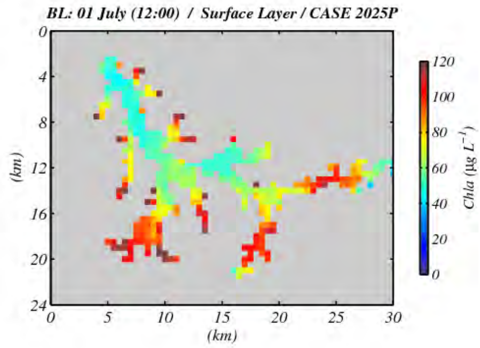
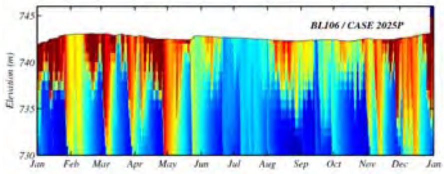
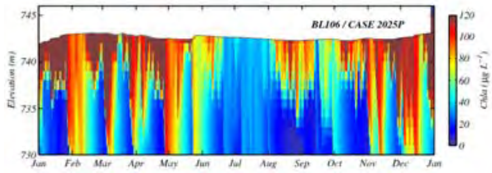
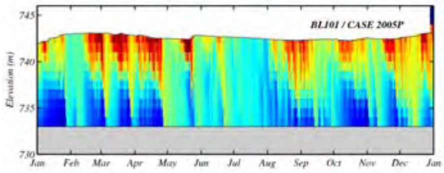
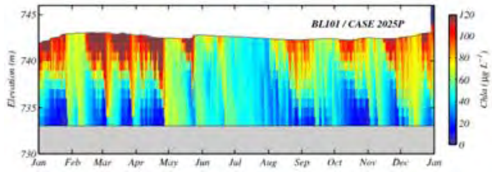
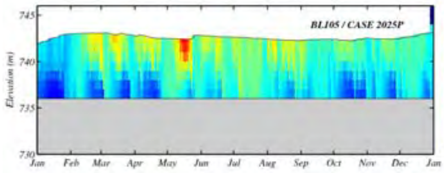
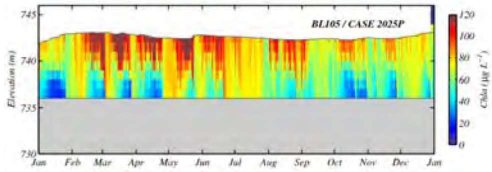
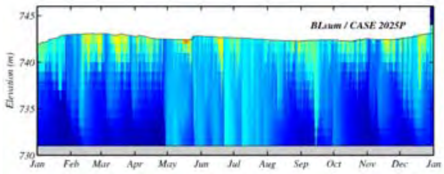
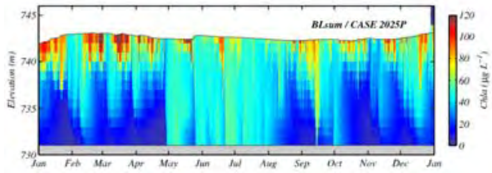
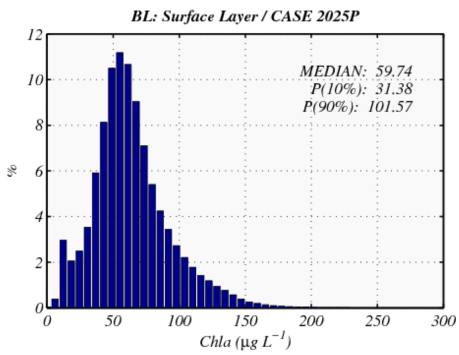
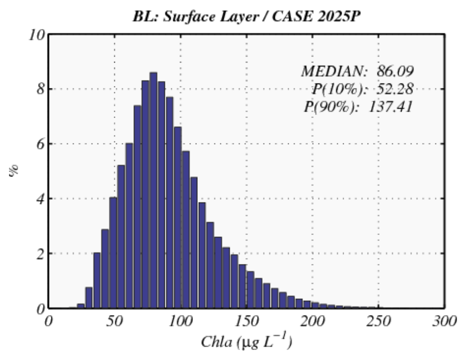
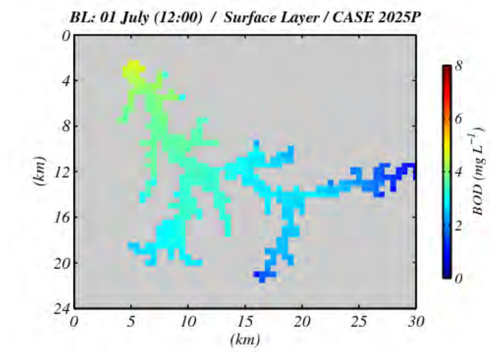
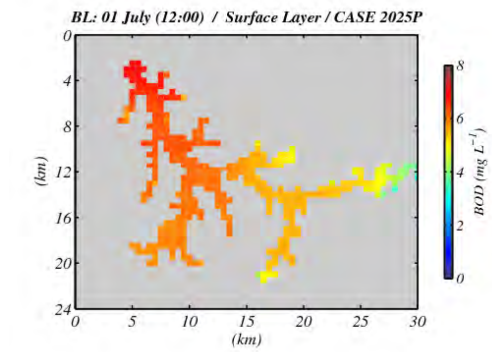
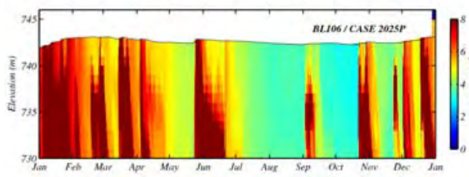
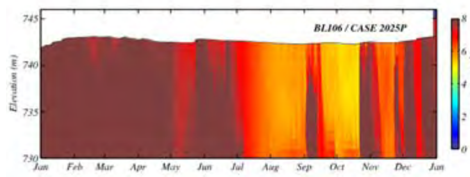
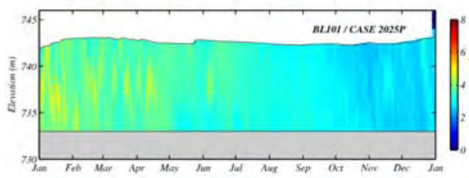
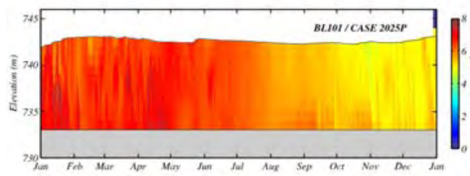
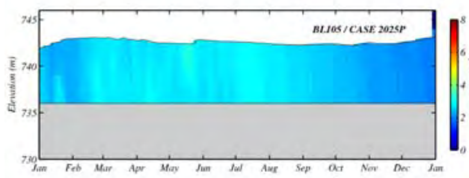
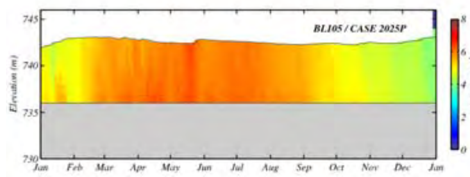
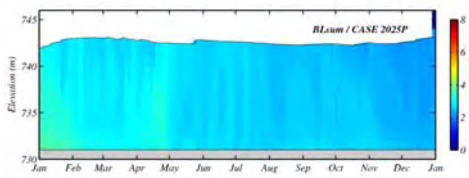
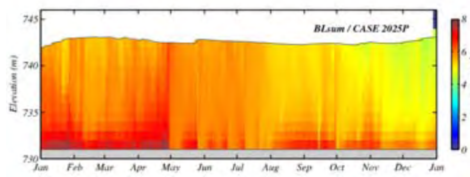
	Figures Showing the Simulation Results	Description
		• This figure shows the concentration distribution on the water surface at a certain time (in this case at 12:00 on July 1) and varies momentarily.
BL106 ***Pedreira***		• This figure shows the profile at each monitoring point during the simulation period of one year. • The monitoring points are shown in **Figure 17.1.1**. • The grey zone in the lower portion indicates that the bed is shallower the datum level.
BL101 ***Confluência***		
BL105 ***Taquacetuba***		
BLsum ***Summit***		
Class 1 ***≤10 μg/L*** ***Class 2*** ***≤30 μg/L***		• This histogram shows the occurrence frequency distribution in % every three hours during a simulation period of one year with a horizontal axis of concentration and a vertical axis of frequency. • "Class" in the left shows the 2025 WQCT for Class 1 for the particular parameter. • The figures on the right top show the median, 10% value and 90% value, respectively.

Figure 17.1.3 How to See the Figures Showing the Simulation Results

	Moderate Elution	***High Elution***
		
Pedreira		
Confluência		
Taquacetuba		
Summit		
Class 1 ***≤ 10 μg/L*** ***Class 2*** ***≤ 30 μg/L***		

Chlorophyll-a exceeds an environmental standard of 30 μg/L except for the remotest area such as Rio Pequeno and Rio Capivari from Pedreira Dam, especially at the deepest portion of Alvarenga and Pedra Blanca with a concentration of around 80 μg/L.

Figure 17.1.4(1) Attainment status of WQCTs for the Lake Billings (Chlorophyll-a in 2025 sewered)

<table>
<tr><th></th><th>Moderate Elution</th><th>High Elution</th></tr>
<tr><td></td><td>
</td><td>
</td></tr>
<tr><td>Pedreira</td><td>
</td><td>
</td></tr>
<tr><td>Confluência</td><td>
</td><td>
</td></tr>
<tr><td>Taquacetuba</td><td>
</td><td>
</td></tr>
<tr><td>Summit</td><td>
</td><td>
</td></tr>
<tr><td>Class 1
≤ 3 mg/L

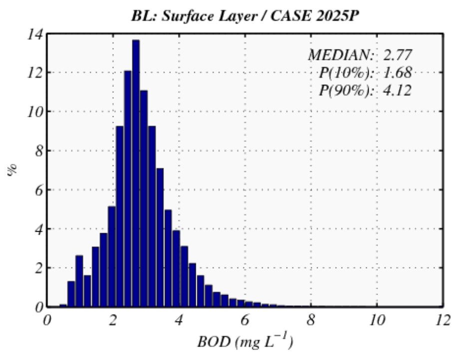
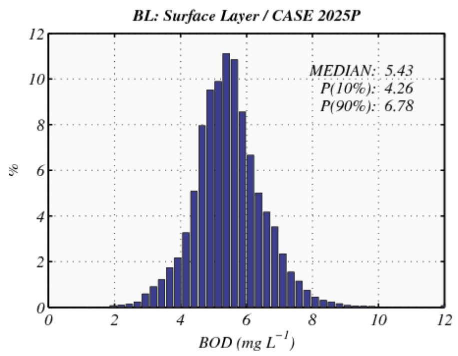
Class 2
≤ 5 mg/L</td><td>
</td><td>
</td></tr>
<tr><td colspan="3">Watching the profiles for the simulation period, the concentration in Summit Dam is stable at 2 to 4 mg/L throughout a year.</td></tr>
</table>

Figure 17.1.4(2) Attainment status of WQCTs for the Lake Billings (BOD_5 in 2025 sewered)

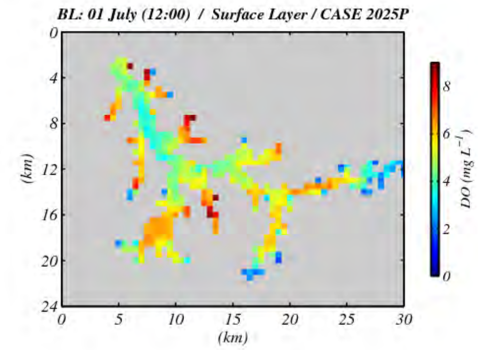
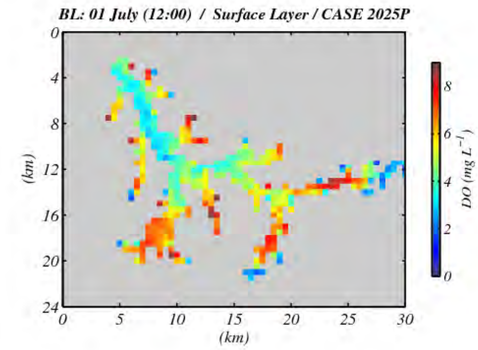
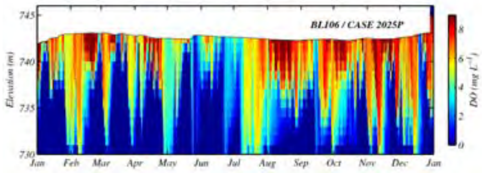
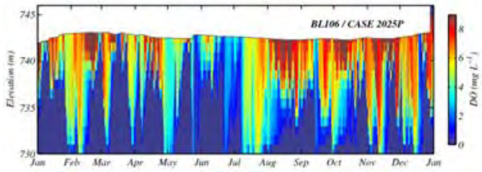
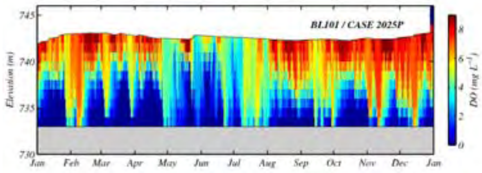
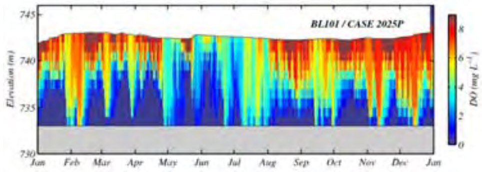
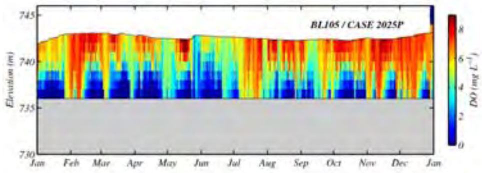
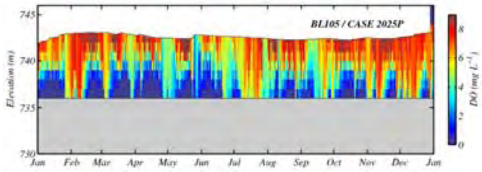
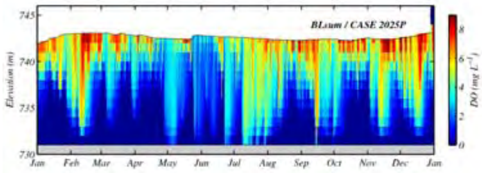
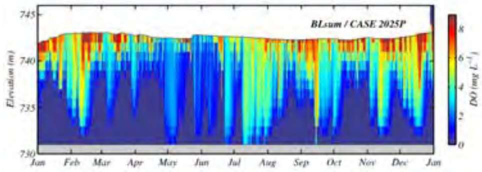
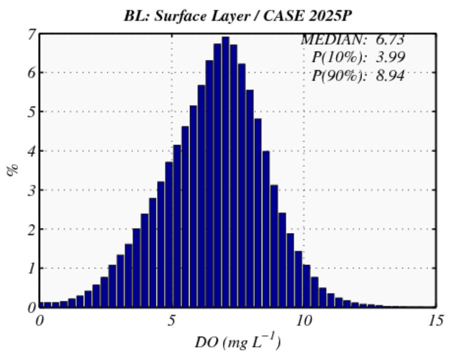
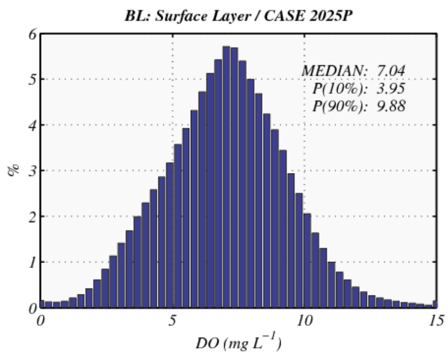
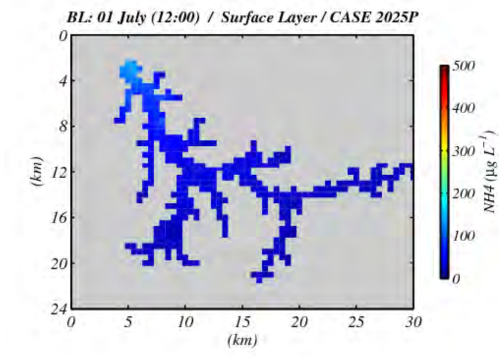
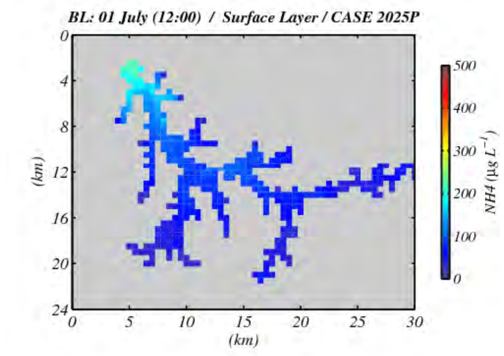
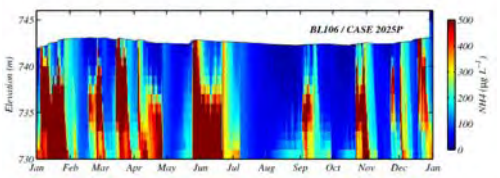
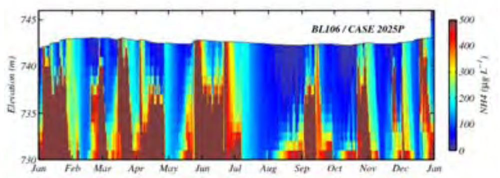
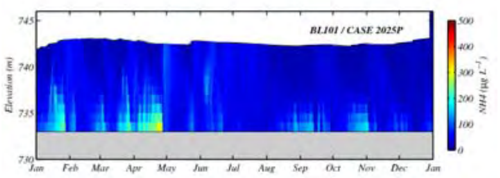
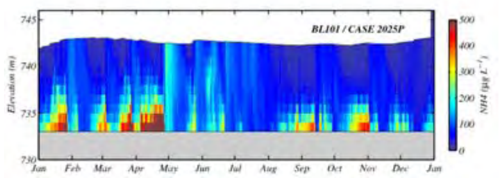
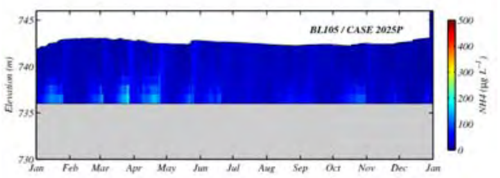
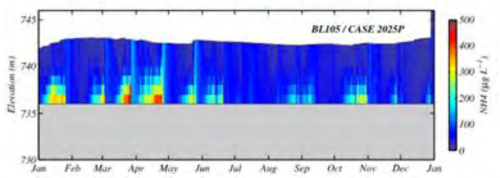
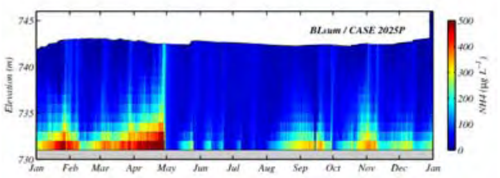
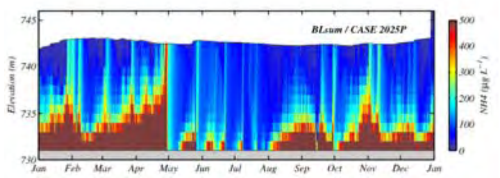
	Moderate Elution	*High Elution*
		
Pedreira		
Confluência		
Taquacetuba		
Summit		
Class 1 ***≥ 6 mg/L*** ***Class 2*** ***≥ 5 mg/L***		
The median of the DO concentrations meets the 2025 WQCT for Class 1 since 2005.		

Figure 17.1.4(3) Attainment status of WQCTs for the Lake Billings (DO in 2025 sewered)

<table>
<tr><th></th><th>Moderate Elution</th><th>High Elution</th></tr>
<tr><td></td><td>
</td><td>
</td></tr>
<tr><td>Pedreira</td><td>
</td><td>
</td></tr>
<tr><td>Confluência</td><td>
</td><td>
</td></tr>
<tr><td>Taquacetuba</td><td>
</td><td>
</td></tr>
<tr><td>Summit</td><td>
</td><td>
</td></tr>
<tr><td>Class 1
≥ 500 μg/L

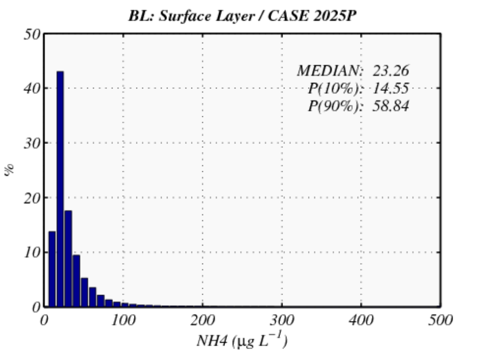
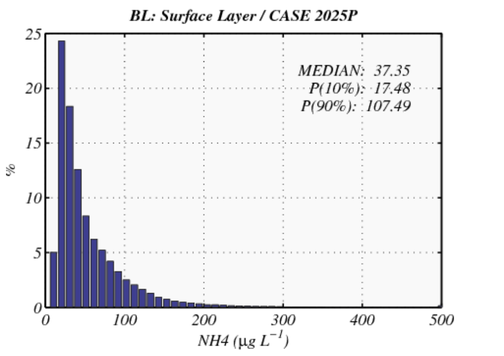
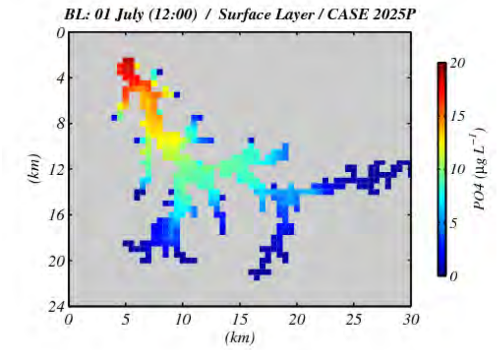
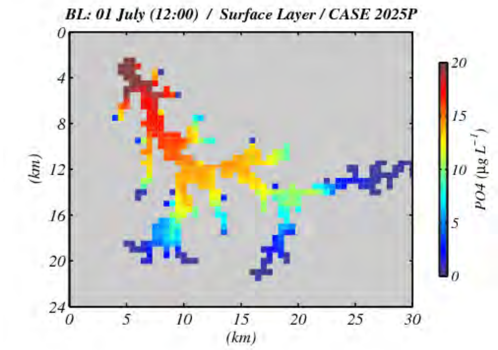
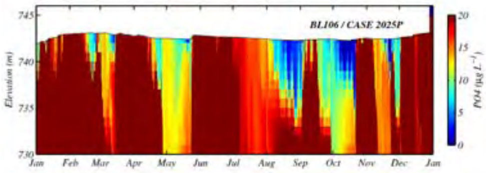
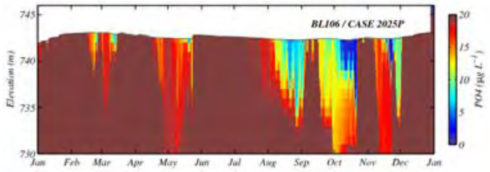
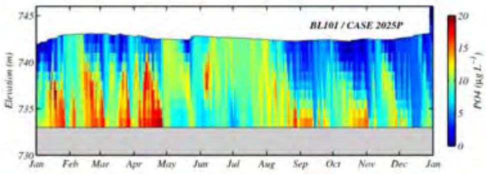
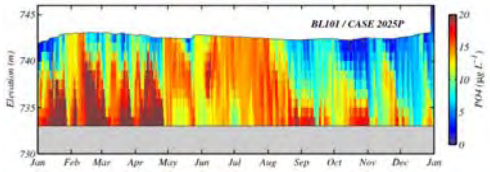
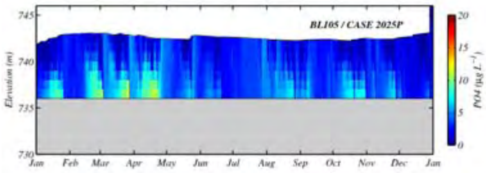
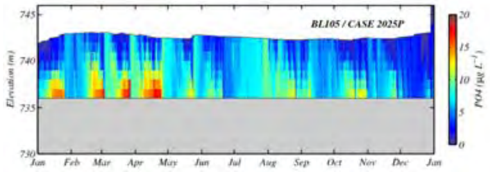
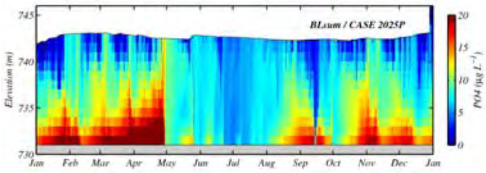
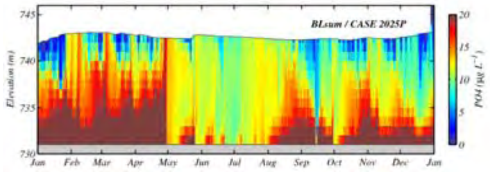
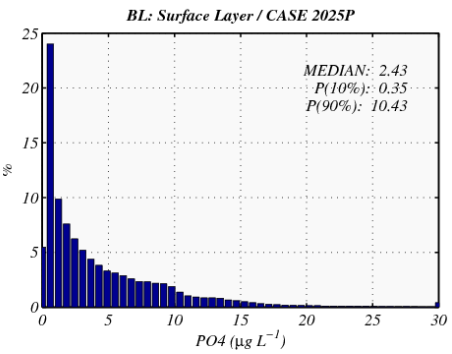
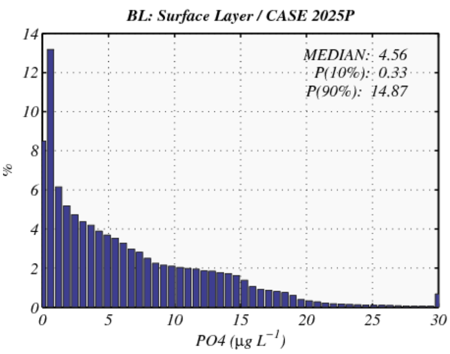
Class 2
≥ 500 μg/L</td><td>
</td><td>
</td></tr>
<tr><td colspan="3">At Summit Dam, the elution of NH_4-N from bottom sediments is observed during January to April and September to December.</td></tr>
</table>

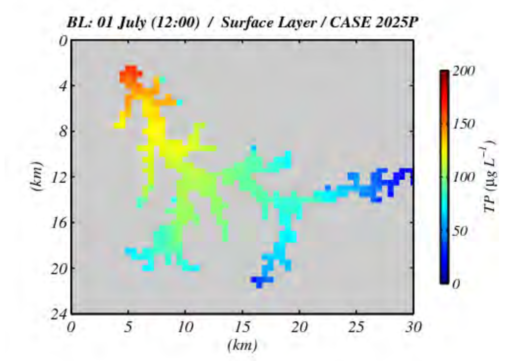
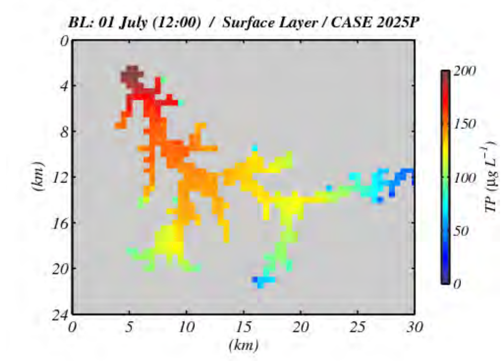
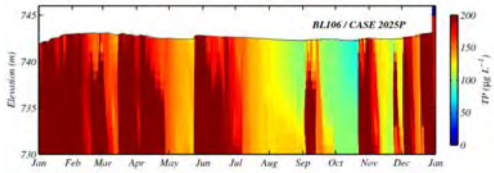
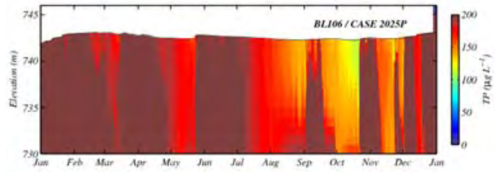
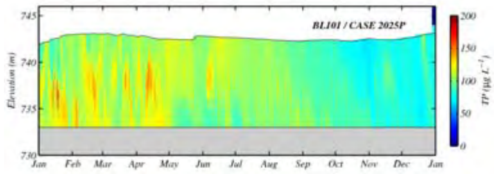
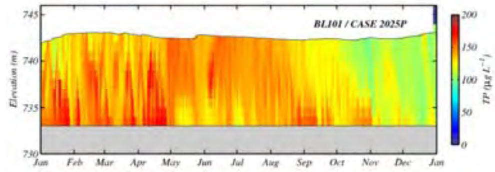
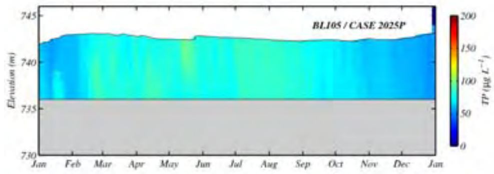
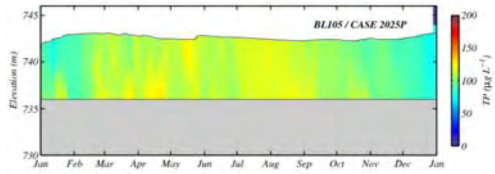
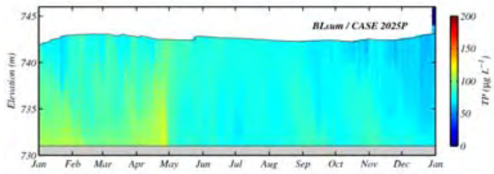
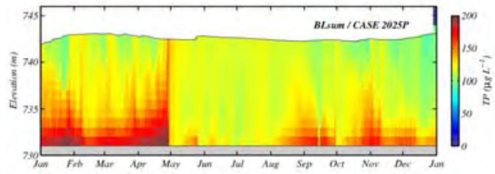
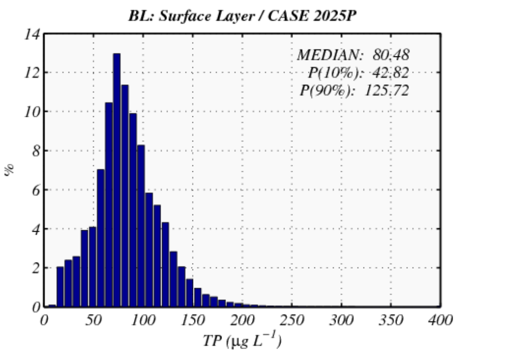
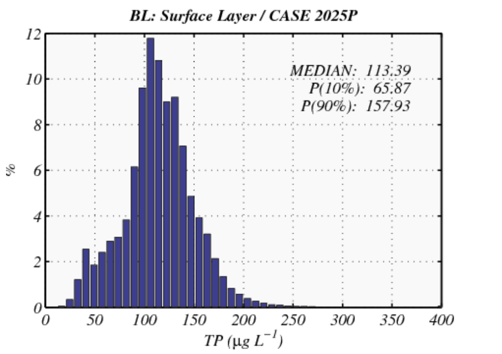
Figure 17.1.4(4) Attainment status of WQCTs for the Lake Billings (NH$_4$-N in 2025 sewered)

	Moderate Elution	High Elution
		
Pedreira		
Confluência		
Taquacetuba		
Summit		
Class 1 **-** **Class 2** **-**		

At Summit Dam, the elution of NH_4-N from bottom sediments is observed during Jan. to Apr. and Aug. to Dec..

Watching the profiles for the simulation period, the concentration in the Taquacetuba Arm is stable at zero to 5 mg/L throughout a year.

Figure 17.1.4(5) Attainment status of WQCTs for the Lake Billings (PO$_4$-P in 2025 sewered)

	Moderate Elution	*High Elution*
		
Pedreira		
Confluência		
Taquacetuba		
Summit		
Class 1 ***≥ 20 µg/L*** ***Class 2*** ***≥ 30 µg/L***		

The concentration of TP is in a level of 80 μg/L even in 2025, far from the 2015 WQCT of 30μg/L for Class 2.

Figure 17.1.4(6) Attainment status of WQCTs for the Lake Billings (TP in 2025 sewered)

17.1.2 Rio Grande Arm

(1) Computational structure of the Rio Grande Arm for mathematical model analysis

The Rio Grande Arm is expressed as the lake composed of approximately 6,000 cells with a dimension of 200 m long x 200 m wide x 1.0 m deep for each based on the bathomatric survey results conducted in 2006 by the JICA Study Team as shown in **Figure 17.1.5** for simulation. The simulation for ten years takes 36 hours.

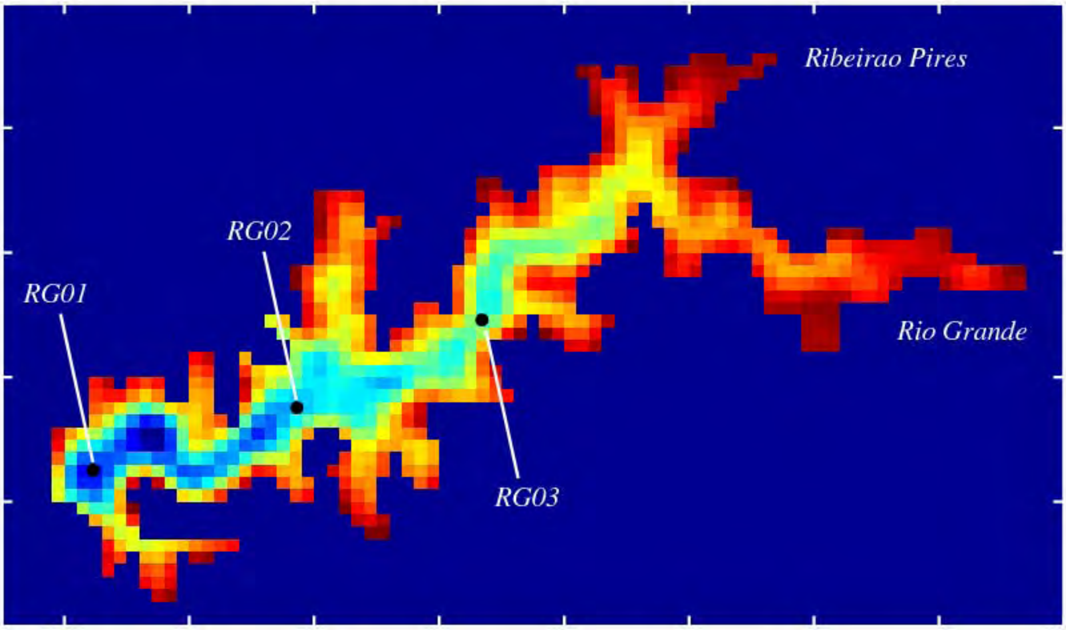


Figure 17.1.5 Monitoring points and computational structure of the Rio Grande Arm

(2) Setting of initial conditions

Same as the conditions in **17.1.1** established for the Lake Billings.

(3) Monitoring points (see **Figure 17.1.5**)

The checkpoints for simulation shall be the following three points that the CETESB has monitored water quality.

RG01: Intake point of the SABESP

RG02: Intermediate point of the Rio Grande Arm (downstream side)

RG03: Intermediate point of the Rio Grande Arm (upstream side)

(4) Simulation results

The simulation results is shown in **Annex A17.1.1** by parameter such as BOD_5, DO, chlorophyll-a, NH_4-N、PO_4-P and TP) and summarized below.

Table 17.1.6 Attainment status of WQCTs for the Rio Grande Arm

Parameter	Elution rate	2005	2015		2025		2025
			w/o Project	w/ Project	w/o Project	w/ Project	WQCT
Chla (μg/L)	Moderate	53.80	57.05	***24.34***	59.94	**15.43**	≤30μg/L
	High	52.05	52.01	***27.15***	54.09	**20.78**	≤10μg/L
BOD_5 (mg/L)	Moderate	**3.79**	**3.94**	**1.26**	**4.26**	**0.83**	≤5mg/L
	High	5.84	5.56	**2.39**	5.89	**1.79**	≤3mg/L
DO (mg/L)	Moderate	**7.46**	**7.49**	**7.42**	**7.50**	**7.40**	≥5mg/L
	High	**7.18**	**7.21**	**7.12**	**7.21**	**7.09**	≥6mg/L
NH_4-N (μg/L)	Moderate	**44.86**	**45.59**	**16.90**	**48.67**	**11.14**	≤500μg/L
	High	**52.05**	**53.55**	**27.15**	**56.91**	**20.78**	≤500μg/L
PO_4-P (μg/L)	Moderate	1.55	1.70	0.82	1.86	0.70	—
	High	1.42	1.44	0.77	1.54	0.68	—
TP (μg/L)	Moderate	52.07	55.57	**17.03**	60.57	**10.51**	≤30μg/L
	High	77.02	75.30	**28.88**	81.41	**21.23**	≤20μg/L

Legend: **1.0** (double box) Attain WQCT for Class 1 **1.0** (single box) Attain WQCT for Class 2

Note: Values show the average of water quality at all water surface cells (every three hours for one year).
In a column for the WQCT, the upper shows Class 1 and the lower Class 2.

The WQCT as shown in **Table 9.2.3** for the year of 2025 are same as those of the environmental standards.

1) At the moderate elution rate

Chlorophyll-a

- The concentration distribution on the water surface is considerably improved in the year of 2005, 2015 and 2025 stepwise.
- The concentration clears the 2015 WQCT for Class 2 and an environmental standard for Class 2 in 2015 and is very close to 10 μg/L for Class 1 in 2025
- The daily fluctuation shows high values of 80 to 100μg/L at RG03 for April to September but drops to 30μg/L for January to June at RG01.

BOD_5

- The pollution is outstanding near the estuary of the Ribeirao Pires.
- The concentration distribution on the water surface is considerably improved in the year of 2005, 2015 and 2025 stepwise.
- The distribution width on the histograms becomes narrower showing homogeneous improvement of the lake as a whole.
- The 2025 WQCT for Class 1 is cleared in 2015.

- The daily fluctuation shows high values of 8mg/L at RG03 except for May to June but drops to 2mg/L at RG01.

DO

- Although the higher concentration is better in terms of DO, the concentration distribution drops gradually in the year of 2005, 2015 and 2025 stepwise.
- The median of DO clears the 2025 WQCT for Class 1 since 2005.

NH_4-N

- The concentration distribution is always stable as below 100μg/L for the year of 2005,
- The elution from bottom sediments is observed for January to April and September to December at all monitoring points, which shows a high value of 500μg/L at the highest.
- The median of DO clears the environmental standard for Class 1since 2005.
- The median of DO drops to 11.14μg/L in 2025 by the progress of homogeneity as a whole.

PO_4-P

- The concentration distribution is improved in 2005, 2015 and 2025 stepwise, but the water quality of the downstream is worse.
- The elution from bottom sediments is observed for January to April and August to December at all monitoring points, which shows a high value of 20μg/L at the highest.
- The daily fluctuation shows high values of 80 to 100μg/L at RG03 for April to September but drops to 30μg/L at RG01 for January to June.

TP

- The concentration distribution is improved in 2005, 2015 and 2025 stepwise,
- The TP concentration clears the 2025 WQCT for Class 1 in 2015.

2) At the higher elution rate

The simulation results at higher elution rate are shown in **Figure 17.1.6** and **Annex A17.1.1**. According to these, the distribution configuration of a histogram showing water surface cell concentrations is similar to that at the moderate elution rate with bigger medians. The parameters of BOD_5, DO, NH_4-N and TP meet the environmental standards for Class 1 and Chlorophyll-a for Class 2. The concentration distribution on the water surface deteriorates as a whole with less characteristics by parameters different from those of the Lake Billings and the stronger elution from bottom sediments is observed in BOD_5, NH_4-N, PO_4-P and TP similar to the Lake Billings

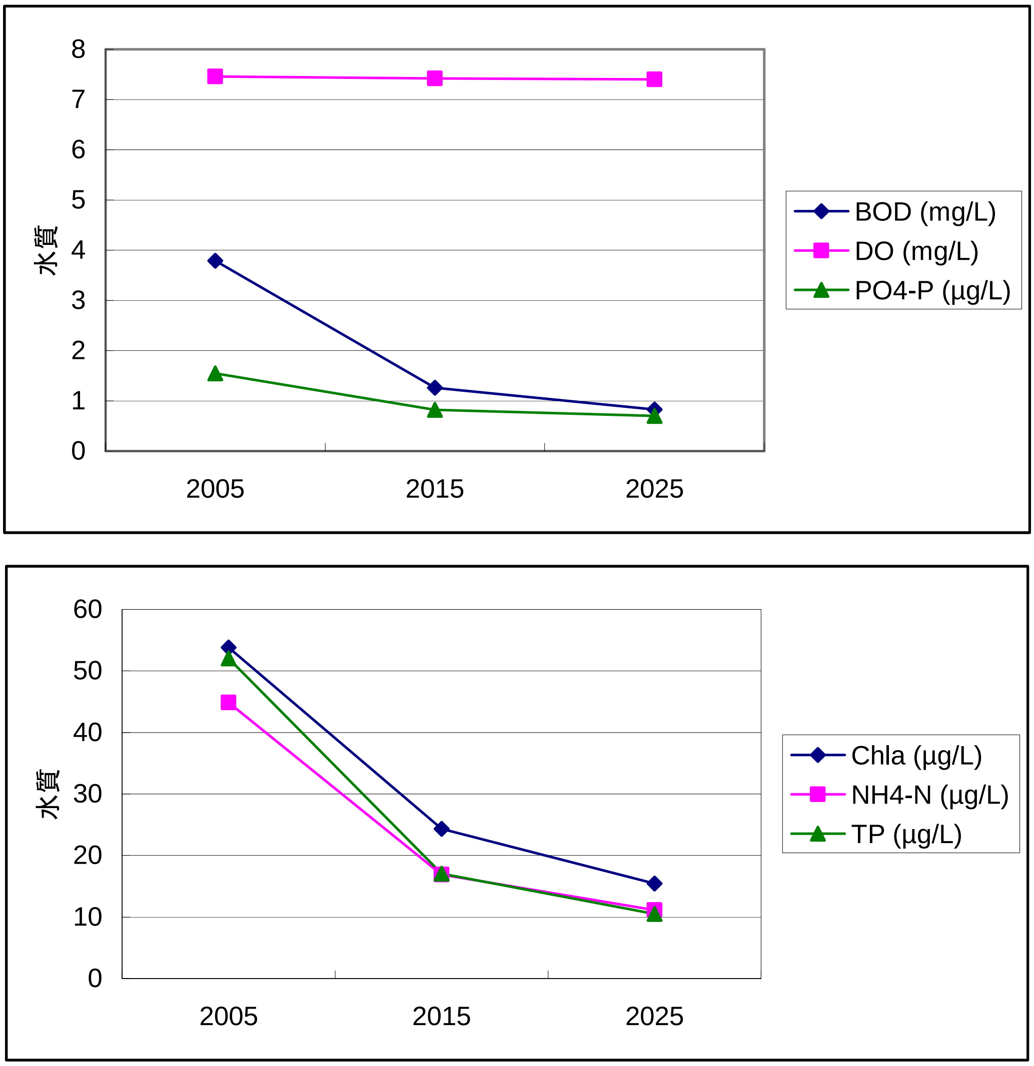


Figure 17.1.6 Change of water surface cell concentration in the Rio Grande Arm

As shown in **Table 17.1.6**, BOD_5, DO, NH_4-N and TP meet the environmental standards for Class 1 and Chlorophyll-a for Class 2 in 2015 by sewerage construction and Chlorophyll-a is close to the Class 2 standard in 2025. In case of no sewerage construction, BOD_5 meet only the Class 2 standard and Chlorophyll-a and TP cannot meet even the Class 2 standard in 2025.

3) Water quality as a water source

The CONAMA's environmental standards for Class 2 are applied to the Rio Grande Arm where the SABESP takes water for water supply. The relationship between the environmental standards for Class 2 and water supply is described that conventional treatment is available for water supply. As described in **5.1.2** and **5.2.2**, BOD_5, TP, Al, Fe and phenol have sometime don't meet the standards. Although the concentrations of Cu are also higher than the standard, it is presumably caused by the spreading of algaecide. For microorganisms, organisms and toxic parameters, there is no problem. The concentrations of BOD_5 and TP in wastewater are rather higher than the standards and affect on the lake water quality, of which the results by the conveyance of wastewater outside the basin through sewerage construction is indicated in **Table 17.1.6**. The concentrations of Al, Mn and phenol, although they are not simulated in the present study, are expectedly improved, judging from that they are conservative similar to TP and TP is largely improved.

17.2 Affect on water quality of the Lake Billings by continuous pumping of the Pinheiros River water

The purpose of the present Study is to control the water pollution in the Lake Billings and to maintain the use of lake water as a source for water supply. The plan for continuous pumping of the Pinheiros River water after treatment is expected to lead to the result against the purpose with the following fear:

- The simulation result for continuous pumping of the Pinheiros River water shows a big influence on the water quality at the intake point in the Taquacetuba Arm.
- The Pinheiros River water is categorized into treated wastewater. There is a fear of safety when it is used for a drinking water source with a mixing rate of about 78%.
- The BOD_5 load to be brought into the Lake Billings through continuous pumping of the Pinheiros River water is almost equal to the load by domestic wastewater currently discharged therein. Therefore, it is doubtful of its improvement effect, since there is almost no change in BOD_5 load reduction, even though the sewerage will be provided and almost wastewater will be conveyed to the outside of the lake basin.
- The floatation treatment is definitive in pollutant removal.

Hence, it should be fully discussed in Brazil regarding the issue on continuous pumping of the Pinheiros River water from the viewpoint of risk and safety as a drinking water source.

17.2.1 Setting of conditions and cases for simulation

At present, EMAE, the power company which owns the Henry Borden Power Plant, has a plan to install a treatment plant for Pinheiros River water with a capacity of 10 m^3/sec under the financial support of Petrobras, and to pump treated water to the Lake Billings for augmentation of a power generation capacity. If it will be successful, the pumping capacity will be increased to 50 m^3/sec by installing three treatment units in the main river and four units in its tributaries (see **Figure A17.2.1**). The study to check an influence of 50 m^3/s continuous pumping of the Pinheiros River water on the environmental standards was conducted as described below.

(1) Setting of initial conditions

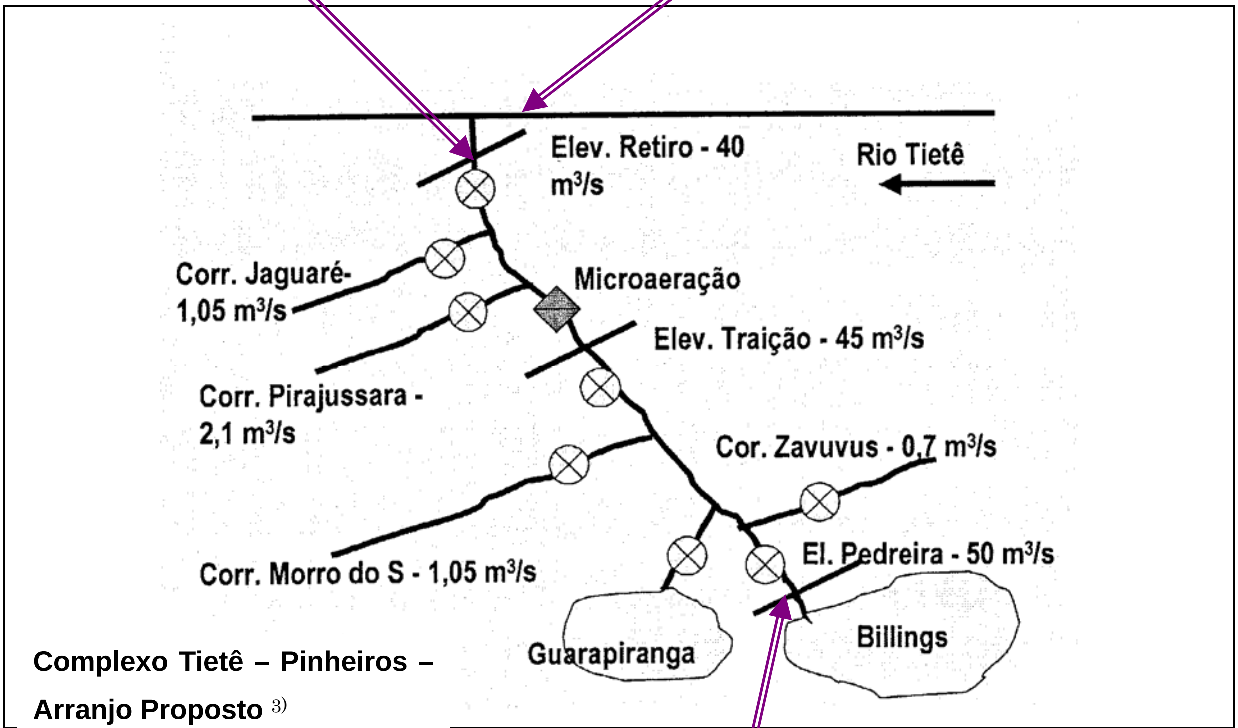
Same as established in **17.1.1**(2).

(2) Water quality of pumping

The water quality at the emergency pumping and continuous pumping shall be based on **Table 17.1.3**. Algae contained in the Pinheiros River water after treatment shall be zero.

PINH04900 [1)]	
BOD_5	60 mg/L
DO	0.1 mg/L
NH_4-N	13.15 mg/L
TP	2.097 mg/L

TIET04200 [1)]	
BOD_5	62 mg/L
DO	0.1 mg/L
NH_4-N	10.51 mg/L
TP	2.211 mg/L



Complexo Tietê – Pinheiros – Arranjo Proposto [3)]

Pinheiros River Water [2)]	
Fecal Coliform	4.6×10^6 NMP/100mL
BOD_5	87 mg/L
COD	179 mg/L
TP	1.8 mg/L
pH	7.13 mg/L
Turbidity	208 NTU
Color	882 mg/L
SS	124 mg/L
DO	ND
Oil & Grease	36 mg/L

PINH04100 [1)]	
BOD_5	15 mg/L
DO	1.4 mg/L
NH_4-N	4.7 mg/L
TP	0.682 mg/L

Figure 17.2.1
Plan of continuous pumping and quality of the Pinheiros River water

1) CETESB, "Relatório de Qualidagde das Águas Interiores Do Estado de São Paulo 2004", pp. 111-115, 2005
2) Departamento de Comunicação, Secretaria de Estado do Meio Ambiente, “Flotação: Nova vida para o Rio Punheiros”
3) “Seminario: Avaliação e Análise do Projeto de Implantação de Estações de Tratamento das Águas do Rio Pinheiros e

Venda de Energia Eletrica Adicional a ser Produzida pela UHE Henry Borden", Programa Interunidades de Pós Graduação em Energia, pp.74, 18 de Maio de 2001 (São Paulo)

(3) Pattern of continuous pumping

At present, emergency pumping is allowed at the time when the flow of the Tiete River exceeds 160 m^3/s downstream of the confluence with the Pinheiros River and Sao Paulo enters on the alert for flood. However, even though 50 m^3/sec continues pumping is realized, the flooding problem in Sao Paulo is not solved essentially. The standard pattern for continues pumping will be, therefore, a combination of patterns for emergency pumping and continuous pumping.

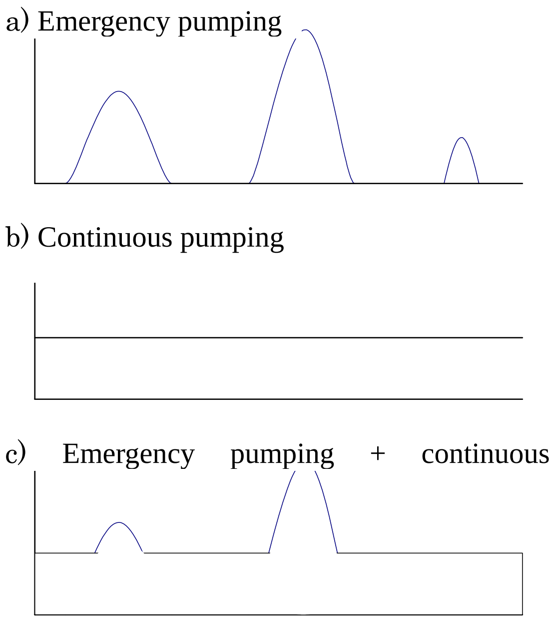


Figure 17.2.2 Possible pumping pattern

(4) Monitoring points

Same as established in **17.1.1**(3). (see **Figure17.1.1**)

(5) Cases for simulation

Simulation was conducted for the pollutant load conditions in 2005, 2015 and 2025 under emergency pumping and emergency pumping plus continuous pumping, respectively, as shown in **Table 17.2.1**. It is assumed that sewerage will be provided in 2015 and 2025.

Table 17.2.1 Cases for simulation

Case	Status of sewerage	Pumping pattern
BL2005P	Unsewered	emergency pumping
BL2015P	Sewered	emergency pumping
BL2025P	Sewered	emergency pumping
BL2005F	Unsewered	emergency pumping + continuous pumping、50 m^3/s discharge from Pedras
BL2015F	Sewered	emergency pumping + continuous pumping、50 m^3/s discharge from Pedras
BL2025F	Sewered	emergency pumping + continuous pumping、50 m^3/s discharge from Pedras

17.2.2 Simulation results

The simulation results are shown in **Figure 17.2.3** and **Table 17.2.2**, which are summarized below.

The WQCT as shown in **Table 9.2.3** for the year of 2025 are same as those of the environmental standards.

Watching the concentration of BOD_5 representing the magnitude of pollutant load into the Lake Billings and situation of water pollution therein, it is found that the case of emergency pumping plus continuous pumping worsens the water quality of the lake.

- The BOD_5 concentration in the case of emergency pumping plus continuous pumping is approximately 1.6 times that in the case of emergency pumping all in 2005, 2015 and 2025.
- In the case of emergency pumping, BOD_5 is over the 2025 WQCT for Class 2 in 2005, but clears that for Class 1 both in 2015 and 2025 by the effect of sewerage construction.
- In the case of emergency pumping plus continuous pumping, BOD_5 cannot attain the WQCT for Class 1 all in 2005, 2015 and 2025 in spite of sewerage construction.
- The BOD_5 concentration of 4.84 mg/L in 2015 and 4.71 mg/L in 2025 in the case of emergency pumping plus continuous pumping exceed that of 3.40 mg/L in 2005 not sewered. In other words, it means that the effect of sewerage construction is offset in the case of emergency pumping plus continuous pumping.

Other parameters are evaluated as follows:

(1) Chlorophyll-a

- The concentration distribution on the water surface, annual water quality fluctuation at the monitoring points and the distribution width on a histogram show that the case of emergency pumping plus continuous pumping brings the stabler and better results than that of emergency pumping.

- In the case of continuous pumping, the setting of Chlorophyll-a at zero works effectively.
- In the case of emergency pumping plus continuous pumping, the concentration is slightly over the 2025 WQCT for Class 1.

(2) DO

- In case of DO, the higher the better and the case of emergency pumping plus continuous pumping brings adverse effect on water quality.
- The Do concentration is 0.1mg/L in the case of emergency pumping and 4.8mg/L in the case of emergency pumping plus continuous pumping and the latter is rather better. However, the simulation result show that the case of emergency pumping brings the better results than the case of emergency pumping plus continuous pumping. This is presumably caused by the big DO supply by the waves in the Lake Billings, while, in the case of emergency pumping plus continuous pumping, the rise in Do is very slow due to its huge volume
- The both cases meet the 2025 WQCT for Class 1.

(3) NH_4-N

- The difference in water quality pattern of both cases well appears at Pedreira Dam.
- The distribution width on the histograms is remarkably narrower in the case of emergency pumping that the case of emergency pumping plus continuous pumping that suggests the progress of homogeneity as shown in the water surface.
- The case of emergency pumping plus continuous pumping worsens the water quality of the lake obviously.
- As long as the concentration distribution on the water surface is observed, both cases clear the the environmental standards for Class 1.
- The elution from bottom sediments is observed during September to April.

(4) PO_4-P

- The concentration distribution on the water surface, annual water quality fluctuation at the monitoring points and the distribution width on a histogram show that the case of emergency pumping plus continuous pumping brings the stabler and better results than that of emergency pumping.
- The elution from bottom sediments is observed during September to April.

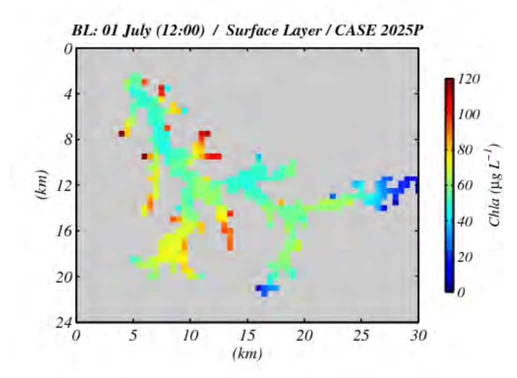
(5) TP

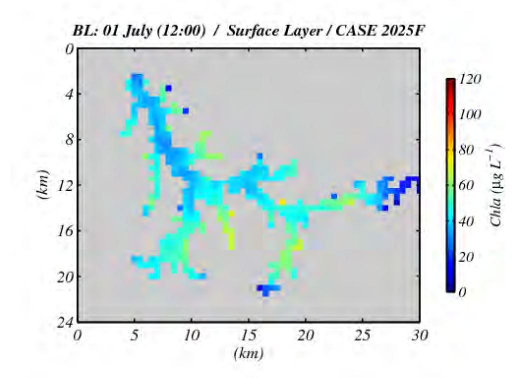
- Although the loading by emergency pumping is same in both cases, the TP concentration is lower in emergency pumping plus continuous pumping due to dilution effect by continuous pumping.
- The concentration distribution on the water surface, annual water quality fluctuation at the monitoring points and the distribution width on a histogram show that the case of emergency pumping plus continuous pumping brings the stabler and better results than that of emergency pumping.
- Even in the case of emergency pumping plus continuous pumping with better water quality, the TP concentration is high as 80 μg/L and far from the 2025 WQCT for Class 2.

The simulation result is different from the parameter as mentioned above. It should be noted that in case of emergency pumping plus continuous pimping, the quality for pumping water established gives a great effect on the simulation results due to its huge amount of continuous flow. The present quality is based on the performance in a small-scale pilot plant which tends to give the good results because of easiness in thorough operation control. While, the proposed seven treatment plants are too big as 50 m^3/sec in total capacity which is bigger than that of five big wastewater treatment plants under the SABESP for the Greater Sao Paulo. It is doubtful to maintain stably the water quality assumed for a simulation analysis in the course of the operation of such huge plants. For example, the BOD_5 concentration of 10 mg/L used for the simulation analysis was obtained at the Pomar pilot plant, but the official website of the Department of Environment, the State of Sao Paulo reported the average concentration of BOD_5 was 25 mg/L after floatation treatment at the Retiro pilot plant under the SABESP. The result varies largely by which one is adopted

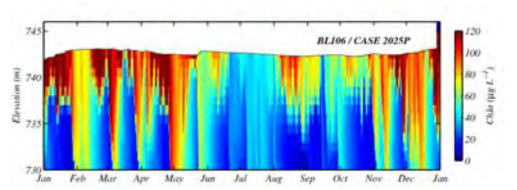
Billings - Chlorophyll-a - 2025

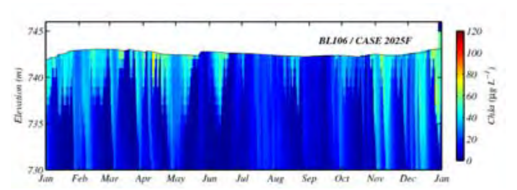
	Emergency pumping	Emergency pumping + Continuous pumping



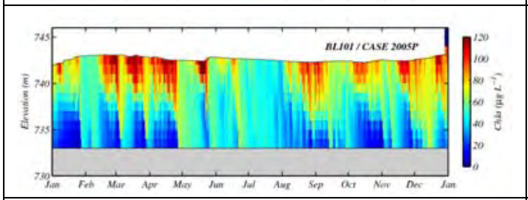


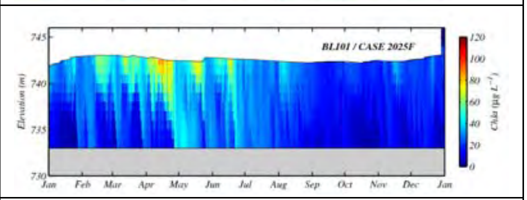
Pedreira



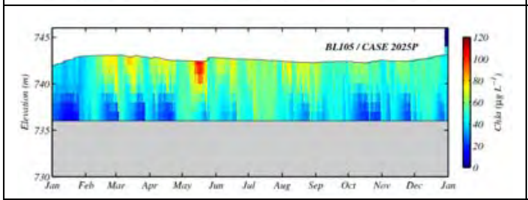


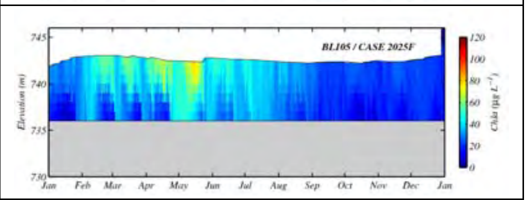
Confluência



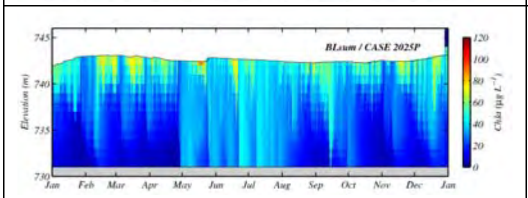


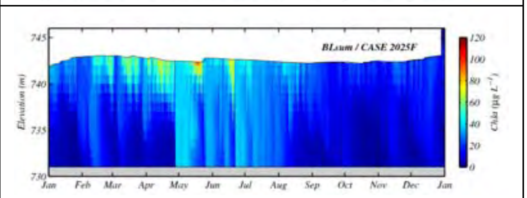
Taquacetuba





Summit



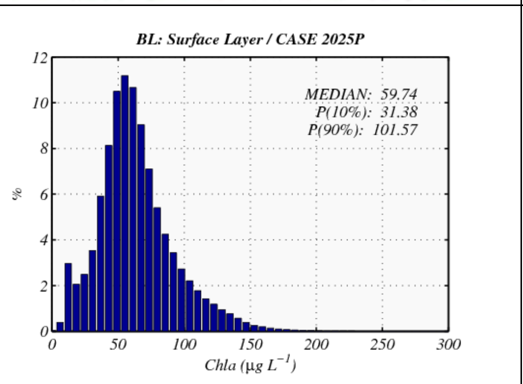


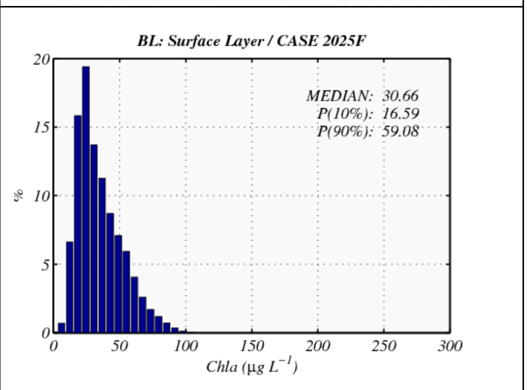
Class 1

≤ 10 μg/L

Class 2

≤ 30 μg/L

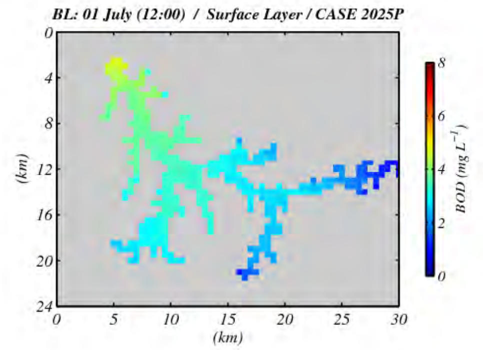
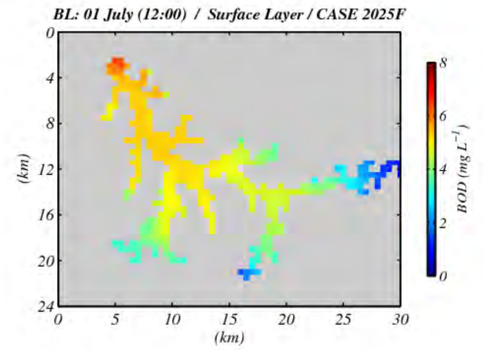
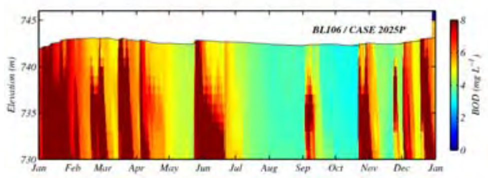
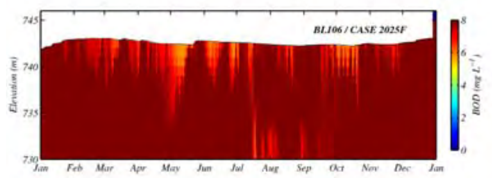
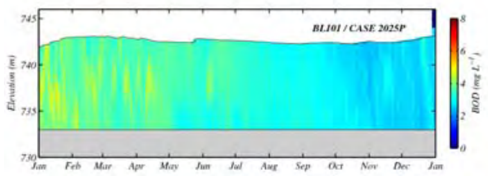
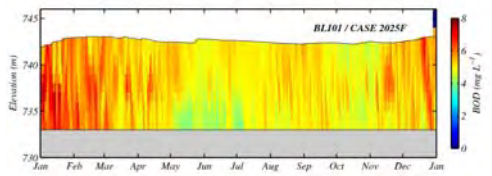
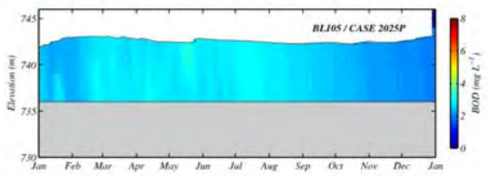
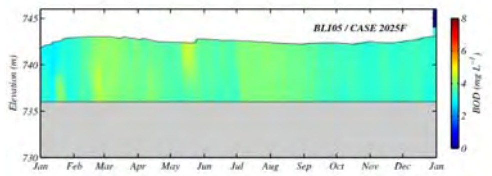
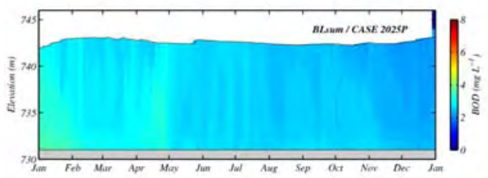
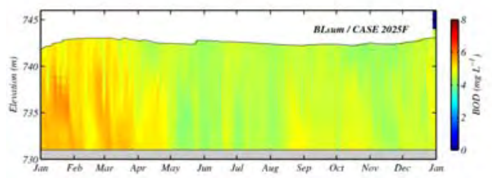




The concentration distribution on the water surface, annual water quality fluctuation at the monitoring points and the distribution width on a histogram show that the case of emergency pumping plus continuous pumping brings the stabler and better results than that of emergency pumping.

Figure 17.2.3(1) Attainment status of WQCTs for the Lake Billings (Chlorophyll-a)

Billings - BOD_5 - 2025

<table>
<tr><th></th><th>Emergency pumping</th><th>Emergency pumping + Continuous pumping</th></tr>
<tr><td></td><td>
</td><td>
</td></tr>
<tr><td>***Pedreira***</td><td>
</td><td>
</td></tr>
<tr><td>***Confluência***</td><td>
</td><td>
</td></tr>
<tr><td>***Taquacetuba***</td><td>
</td><td>
</td></tr>
<tr><td>***Summit***</td><td>
</td><td>
</td></tr>
<tr><td>***Class 1***
≤ 3 mg/L

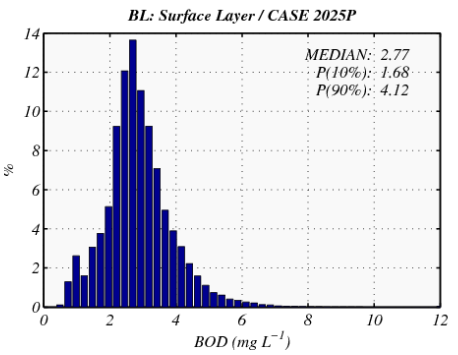
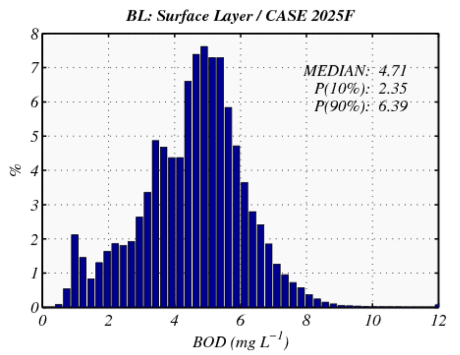
Class 2
≤ 5 mg/L</td><td>
</td><td>
</td></tr>
<tr><td colspan="3">The difference of water quality between both cases is clear especially at Pedreira Dam where the high concentration of BOD_5 appears intermittently in the case of emergency pumping and continuously in the case of emergency pumping plus continuous pumping</td></tr>
</table>

Figure 17.2.3(2) Attainment status of WQCTs for the Lake Billings (BOD_5)

Billings - DO - 2025

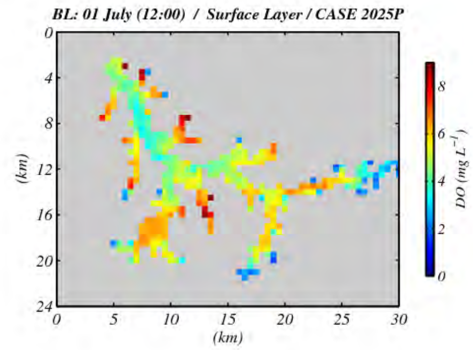
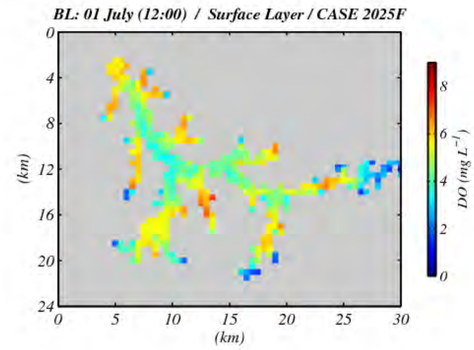
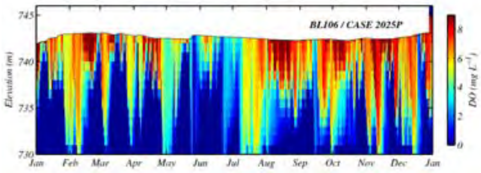
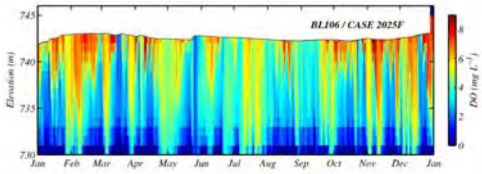
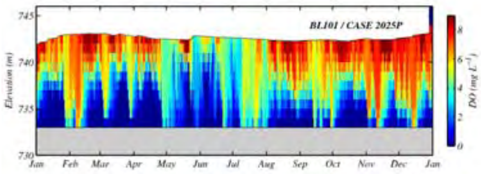
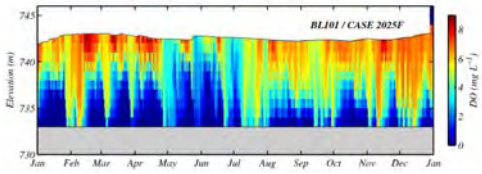
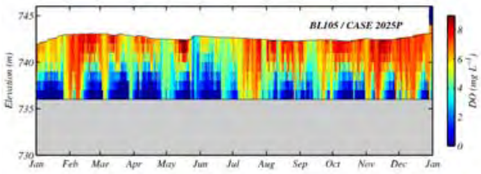
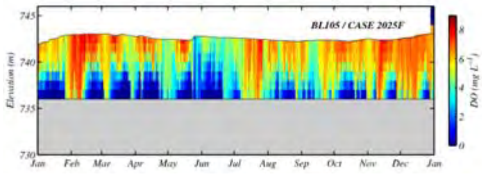
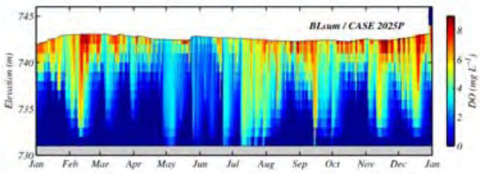
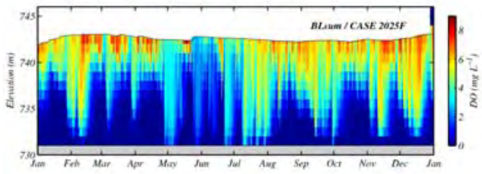
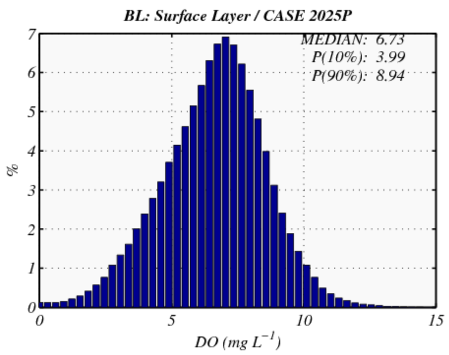
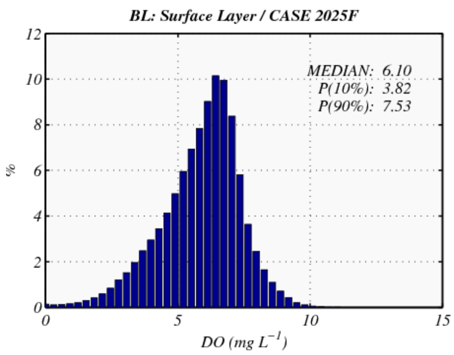
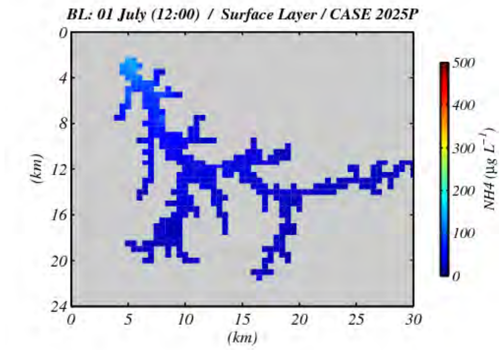
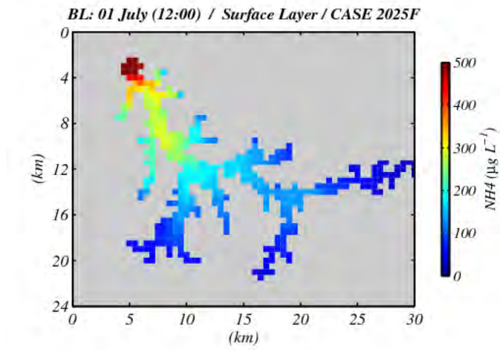
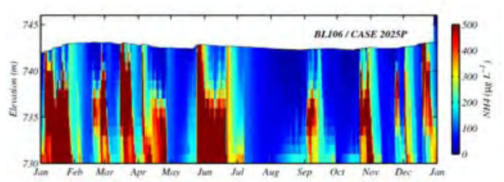
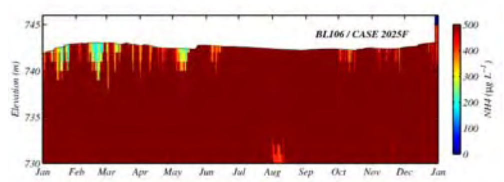
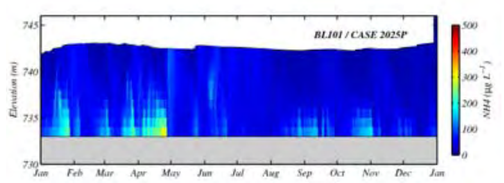
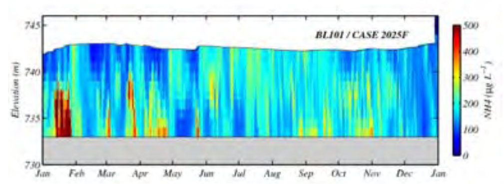
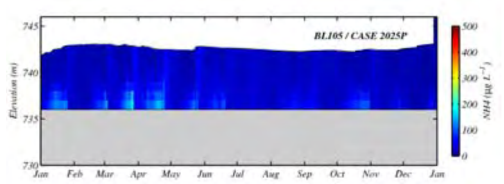
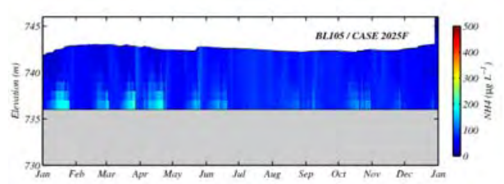
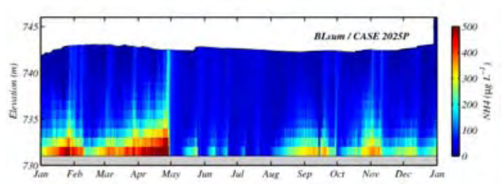
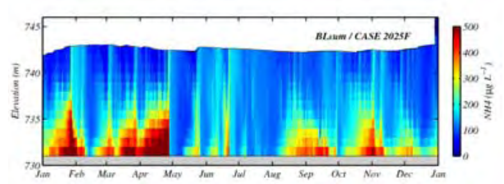
	Emergency pumping	Emergency pumping + Continuous pumping
		
Pedreira		
Confluência		
Taquacetuba		
Summit		
Class 1 ***≥ 6 mg/L*** ***Class 2*** ***≥ 5 mg/L***		
In case of DO, the higher the better and the case of emergency pumping plus continuous pumping brings adverse effect on water quality.		

Figure 17.2.3(3) Attainment status of WQCTs for the Lake Billings (DO)

Billings - NH_4-N - 2025

<table>
<tr><th></th><th>Emergency pumping</th><th>Emergency pumping + Continuous pumping</th></tr>
<tr><td></td><td>
</td><td>
</td></tr>
<tr><td>Pedreira</td><td>
</td><td>
</td></tr>
<tr><td>Confluência</td><td>
</td><td>
</td></tr>
<tr><td>Taquacetuba</td><td>
</td><td>
</td></tr>
<tr><td>Summit</td><td>
</td><td>
</td></tr>
<tr><td>Class 1
≥ 500 µg/L

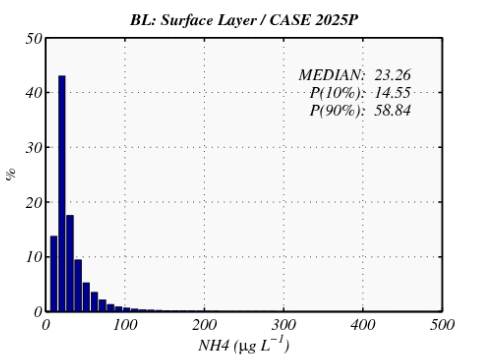
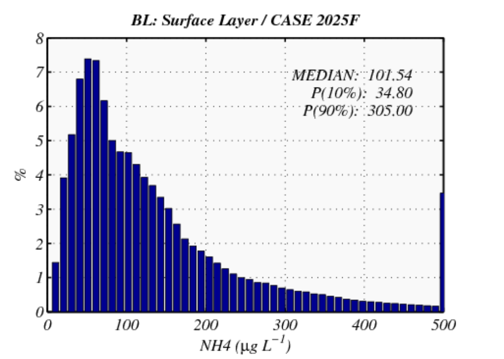
Class 2
≥ 500 µg/L</td><td>
</td><td>
</td></tr>
<tr><td colspan="3">The difference in water quality pattern of both cases well appears at Pedreira Dam.
The elution from bottom sediments is observed during September to April.</td></tr>
</table>

Figure 17.2.3(4) Attainment status of WQCTs for the Lake Billings (NH_4-N)

Billings - PO_4-P - 2025

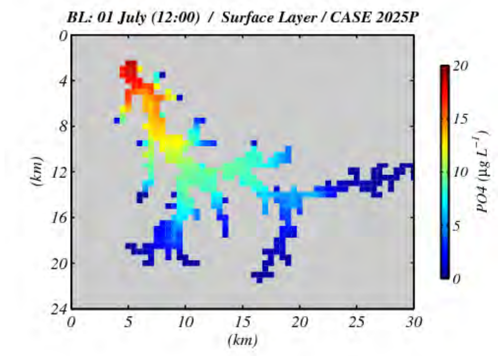
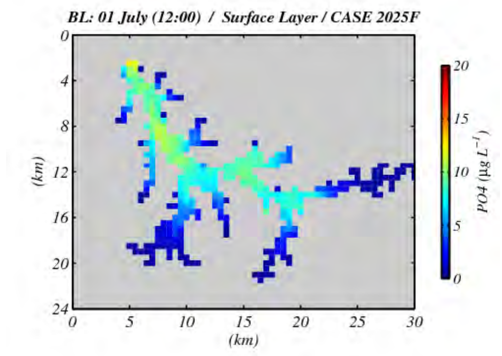
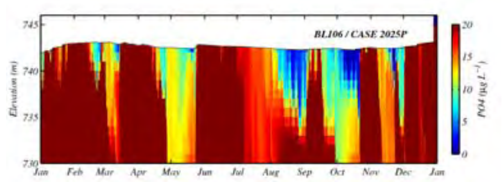
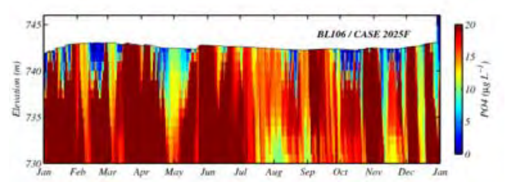
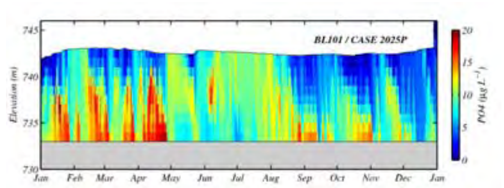
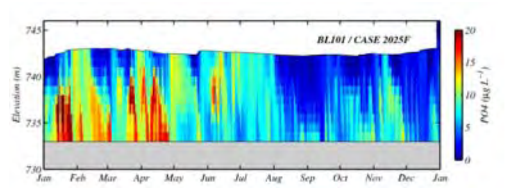
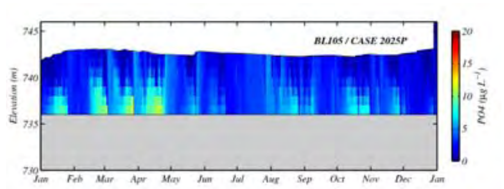
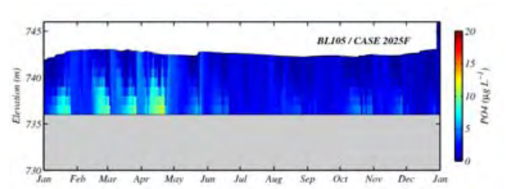
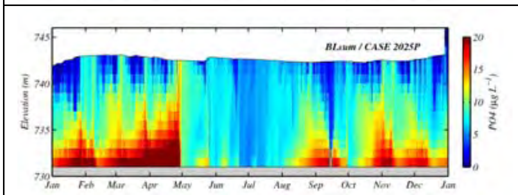
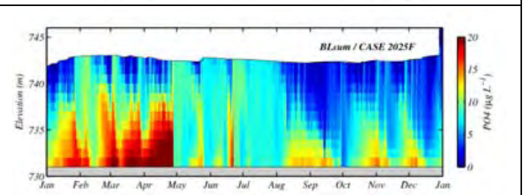
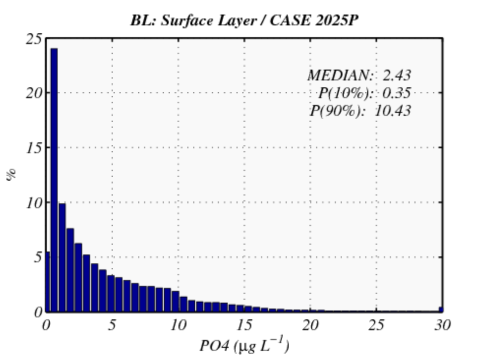
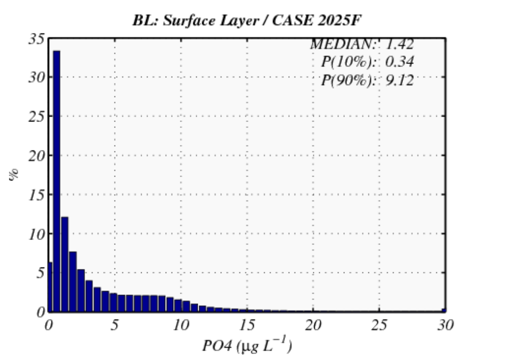
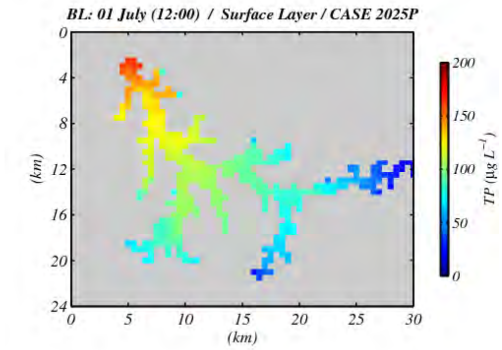
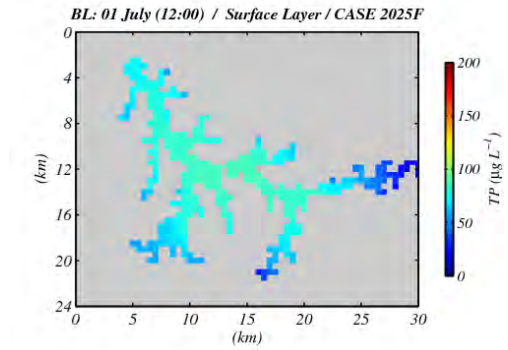
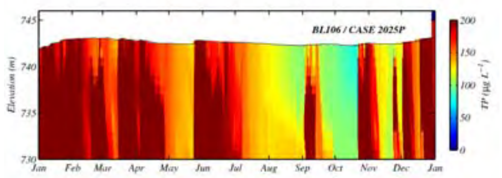
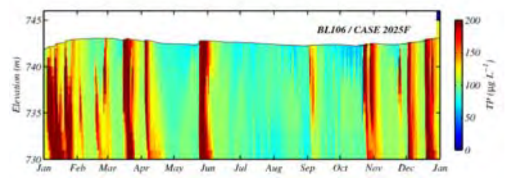
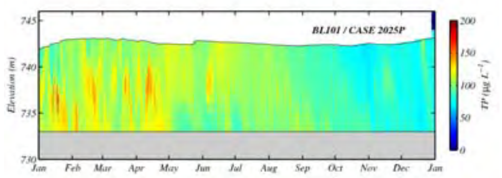
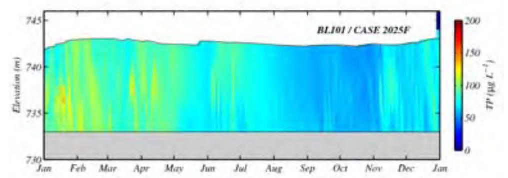
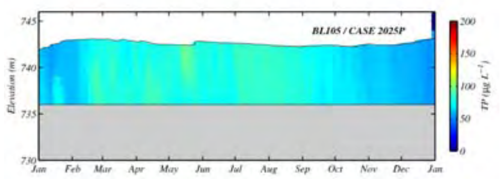
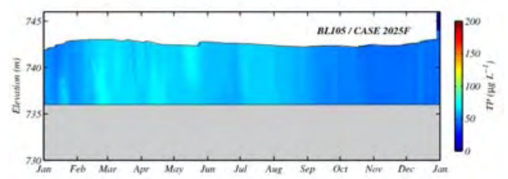
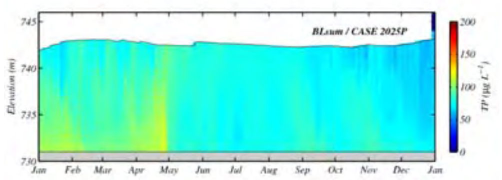
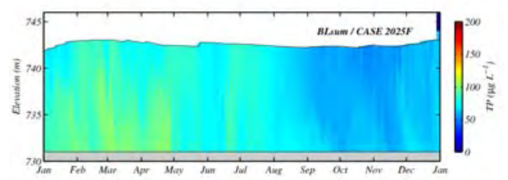
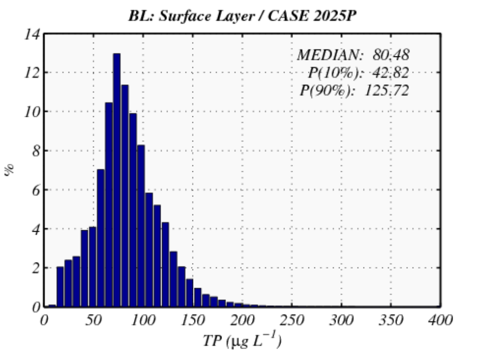
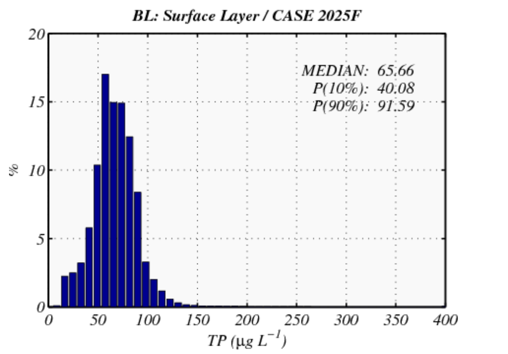
	Emergency pumping	Emergency pumping + Continuous pumping
		
Pedreira		
Confluência		
Taquacetuba		
Summit		
Class 1 - ***Class 2*** -		
The elution from bottom sediments is observed during September to April.		

Figure 17.2.3(5) Attainment status of WQCTs for the Lake Billings (PO_4-P)

Billings - TP - 2025

	Emergency pumping	Emergency pumping + Continuous pumping
		
Pedreira		
Confluência		
Taquacetuba		
Summit		
Class 1 ***≥ 20 µg/L*** ***Class 2*** ***≥ 30 µg/L***		

The concentration distribution on the water surface, annual water quality fluctuation at the monitoring points and the distribution width on a histogram show that the case of emergency pumping plus continuous pumping brings the stabler and better results than that of emergency pumping.

Figure 17.2.3(6) Attainment status of WQCTs for the Lake Billings (TP)

Figure 17.2.4 Attainment status of WQCTs

	Pumping pattern	Concentration			2025 WQCT
		2005 Unsewered	2015 Sewered	2025 Sewered	
Chla	Emergency pumping	70.96	62.76	59.74	≤30μg/L ≤10μg/L
	Emergency pumping + Continuous pumping	33.34	31.53	30.66	
BOD_5	Emergency pumping	**3.40**	**2.91**	**2.77**	≤5mg/L ≤3mg/L
	Emergency pumping + Continuous pumping	5.32	**4.84**	**4.71**	
OD	Emergency pumping	**6.82**	**6.76**	**6.73**	≥5mg/L ≥6mg/L
	Emergency pumping + Continuous pumping	**6.16**	**6.11**	**6.10**	
NH_4-N	Emergency pumping	**27.52**	**24.63**	**23.26**	≤500μg/L ≤500μg/L
	Emergency pumping + Continuous pumping	**106.06**	**103.01**	**101.54**	
PO_4-P	Emergency pumping	3.67	2.69	2.43	— —
	Emergency pumping + Continuous pumping	1.61	1.48	1.42	
TP	Emergency pumpin	101.24	85.23	80.48	≤30μg/L ≤20μg/L
	Emergency pumping + Continuous pumping	77.25	68.39	65.66	

Legend: **1.0** (double-lined box) Attain WQCT for Class 1 **1.0** (single-lined box) Attain WQCT for Class 2

Note: Values show the average of water quality at all water surface cells (every three hours for one year).

In a column for the WQCT, the upper shows Class 1 and the lower Class 2.

17.2.3 Application limit of mathematical model

The mathematical models improved for the Lake Billings and developed for the Rio Grande Arm in the present Study is able to predict the following parameters functionally:

- pH
- DO
- BOD
- SS
- T-P (PO_4-P, inorganic phosphorous)
- T-N (NO_3-N, NH_4-N, inorganic nitrogen)
- Metals (Fe, Mn, Al)

- Phytoplankton
- Zooplankton
- Fish
- Jellyfish
- Macro-algae

However, each parameter requires the substantial measured data and the predictable parameters in the present Study are limited to the following:

- DO
- BOD
- NH_4-N
- PO_4-P, T-P

Attention be paid for the fact that it does not mean that the lake is suitable with the drinking water source, even if the simulation results, foe example, of continuous pumping show the attainment of the environmental standards Class 2. That is to say, the predicted parameters as shown in **Table 17.2.3** is only a part of parameters established for the environmental standards Class 2 and for other parameters than predicted, it should be checked whether lake water itself meets the standards, otherwise it is evaluated as “unknown”.

In addition, the parameters established for the environmental standards Class 2 do not correspond to those for the drinking water standards. For such non-correspondent parameters, it goes without saying that they should be checked by the SABESP whether water treated at a water treatment plant clears the drinking water standards

17.2.4 Use of the Lake Billings as a drinking water source at continuous pumping

(1) Does treated river water clear the limits established for the drinking water standards?

In the mathematical model simulation in **17.2.2**, six parameters were predicted, but, as stated in **17.2.3**, the predictable parameters by the mathematical model are very limited. Treated river water be basically assessed based on whether each parameter meet the limit established for the environmental standards one by one.

(2) The Pinheiros River is no longer the natural river but the drain.

The State Government required on January 31, 2001 that pumping water from the Pinheiros River meets the environmental standards for Class 2 (CONAMA) as the condition to resume continuous pumping. The environmental standards is, in general, established for the natural rivers as objects. In case of the Pinheiros River, its water quality is 87 mg/L in BOD_5 and 179 mg/L in COD_{Cr} and it is regarded as no longer a natural river but a drain. Furthermore, there are many factories along the Pinheiros River which discharge wastewater therein. Therefore, such wastewater has a fear of pollutant inclusion not established in the CONAMA standards.

(3) Less dilution rate by fresh water at continuous pumping

For a continuous pumping flow of 50 m^3/s, the natural runoff into the Lake Billings excluding that for the Rio Grande Arm is 13.9 m^3/s in 2005. It means that a mixing rate of treated wastewater is 78% (=50 / (50+13.9) x 100), or very low dilution by fresh water.

(4) Pumping water may deteriorate the water quality of the Lake Billings.

The Department of Environment, the State Government gives an average BOD_5 concentration of 25 mg/L for the effluent from the floatation pilot plant in Pomar, saying that a BOD_5 of 10 mg/L is obtained in the test run. A good quality of treated water is easily obtained at the low flow due to easy operational control. When a flow is very big as 50 m^3/s, it is doubtful whether the treatment is steadily controlled so as to obtain a good quality of treated water over the average at the SABESP's wastewater treatment plant. Depending on the parameters, some may deteriorates the water quality of the Lake Billings, as described in **17.2.2.**

In the situation that sewerage is not provided within the basin of the Lake Billings, as the water quality of the treated Pinheiros River water is rather better that that of domestic wastewater currently discharged into the lake, the good results may be obtained apparently. However, under the situation that sewerage is fully provided and domestic wastewater is conveyed outside the lake basin, it is clear that continuous pumping worsens the water quality of the Lake billings, depending on parameters.

Figure 17.2.4 is prepared to compare the generation load, runoff load and pollutant load during the emergency pumping plus continuous pumping within the basin of the Lake Billings, which indicates that the pollutant load during the emergency pumping plus continuous pumping is almost equal to the generation load derived from domestic wastewater and stormwater in 2005 and offsets the load reduction effect by sewerage construction by 2015

(5) Is water quality improvement by flotation treatment actually possible?

The basic principle of floatation treatment is to dissolve the air in water under the pressure and reduce the pressure by the atmospheric pressure in a floatation tank, make the air dissolved in water fine bubbles which attach the coagulated flocs or suspended solids for floatation and removal. Therefore, flotation treatment is not effective for dissolved matter principally. Furthermore, the proper treatment and disposal of a huge amount of sludge to be generated through the flotation treatment of 50 m^3/sec river water should be clarified.

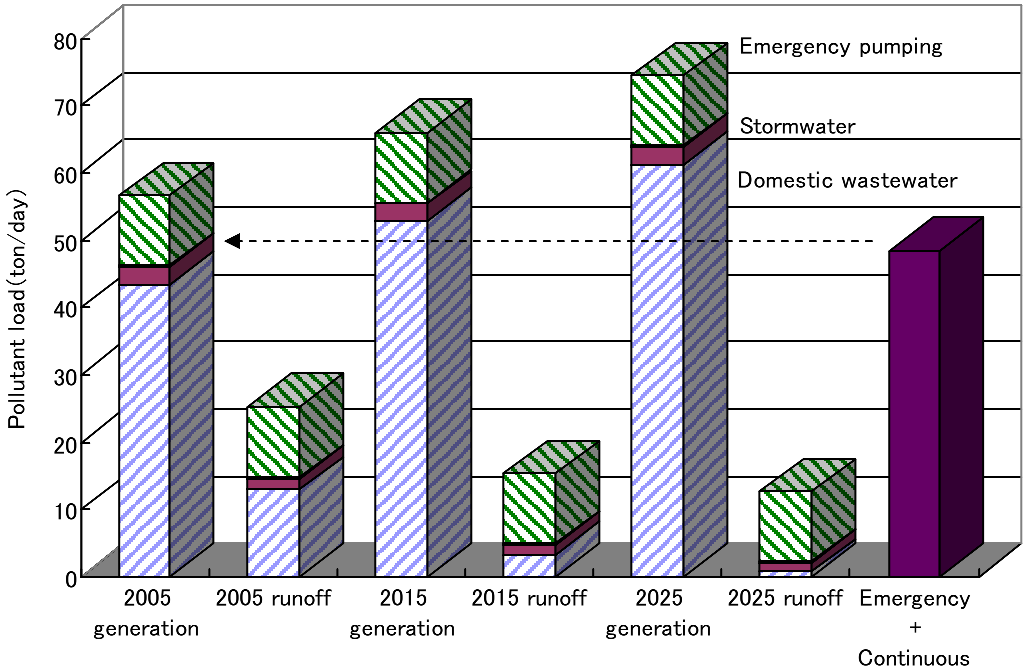


Figure 17.2.5 Comparison of Estimated Loads

(6) Present status of treated wastewater reuse for drinking purpose

Direct reuse of treated wastewater for drinking purpose is conducted in Windhoek, the capital of Namibia, which is only one place in the world. Wastewater after secondary treatment by the activated sludge process is treated in the combination process of floatation, sedimentation, filtration, ozonation and activated carbon adsorption and then diluted with 3.5 times fresh water after water treatment for water supply.

In Los Angeles County, California, U.S., the study on the indirect reuse of secondarily treated wastewater which is recharged into groundwater after filtration was started in 1978. Secondarily treated wastewater was diluted with the river water and stormwater by 16% in the beginning and recharge was done using infiltration ponds. In the comprehensive study conducted in 1985, no measurable adverse effect on human health of the people that lived in the groundwater area and take reclaimed wastewater was not found. These results called the concern of the State Government and the scale of indirect reuse was extended and a dilution rate was risen by 50%. After 30 years groundwater recharge, it was confirmed that there was no relationship between the cancer occurrence rate, morbidity, infectious occurrence rate and birth rate and reclaimed wastewater in both areas, reclaimed wastewater service area and non-service area.

Maximum endeavor and elaborate attention is always paid for indirect reuse of treated wastewater for drinking purpose like this.

Chapter 18

ECONOMIC -FINANCIAL ANALYSIS ON MASTER PLAN PROGRAM

18. ECONOMIC -FINANCIAL ANALYSIS ON MASTER PLAN PROGRAM

18.1 Rough Cost Estimation

18.1.1 Premise of Cost Estimation

(1) Sewerage construction Project in the Urban Areas

Sewerage construction project limited in SBC city was studied in the following chapter of F/S in detail. Using the cost estimation in FS, cost of the Master Plan was estimated.

Investment Cost	R$527,862,000 (Investment cost for SBC limited plan) / (Design population of SBC sewerage plan) × (Design population of Lake Billings basin) + Consulting Fee)	
SBC Investment Cost	Trunk & sub-trunk Sewers:	R$54,571,000
	Pumping Stations:	R$21,660,000
	Sewer network:	R$37,215,000
	Total	R$113,446,000
SBC design population	186,031 people as of 2025 years estimated	
Per capita cost	R$610	
Basin population	808,736 people as of 2025 years	
Consulting fee	7 % of construction cost (included in total of investment cost)	
Land acquisition costs	not count	
O&M cost:	R$4,687,000 per year 5% of the P/S construction cost (19% of construction cost of R$493,329,000)	

(2) Sewerage construction Project in the Isolated Communities

Master Plan for isolated communities is the same as FS Plan. The reasons are as follows:

- SABESP is installng sewers for Ribeirao Pires and Rio Grande da Serra, and SEMASA of Santo Andre is constructing a WWTP to be completed in 2010.
- District of the west end of Sao Paulo beside the crater is already included in SABESP Plan to be completed by 2015.
- Septic tank or Pit type restroom are proper for the other area than villages (Santa Cruz, Riacho Grande, Areian, Jussara, Caperinha) included in Sewer Project in Isolated Communities. by being an aspect of the population / population density, an a population of increase restraint

Investment Cost:	R$22,752,000	
	Riacho Grande System:	R$17,000,000
	Santa Cruz System:	R$4,000,000
	Total of construction cost	R$21,000,000
	Total of investment cost	R$23,000,000
Consulting fee:	7 % of construction cost (included in total of investment cost)	
Land acquisition cost:	In Santa Cruz; R$310,000 (included in total of investment cost)	
O&M cost:	R$837,000 in 2015	

(3) Permeable Pavement Project

Cost is calc ulated as estimated permeable road area (**Table 11.4.3**) multiplied unit cost.

Investment cost:	R$498,045,000 (Objective road area) × (Permeable pavement unit price) + (Consulting fee)
Permeable pavement area:	4,654,630 m^2objective for total road length 502.27 km
Permeable pavement unit cost:	100 R$/$m^2$
Consulting fee:	7 % of construction cost (included in total of investment cost)
Land acquisition costs:	Not account
O&M cost:	R$449,000

(4) Public Park – Green Space Development Project

Investment cost:	R$19,638,459 (Park area) × (Park construction unit cost) + (Consulting fee) + (Land acquisition cost)
Design area for park:	611,790 m^2 for none parks
Park construction unit cost:	30 R$/$m^2$
Consulting fee:	7 % of construction cost (included in total of investment cost)
Land acquisition cost:	Not account
O&M cost:	R$198,720 in 2015 for 7.2 persons

(5) Remediation Project For former Alvarenga Open Dumping Site

Investment cost:	Lowland ward works	R$2,116,000
	Low land part road, a drainage system	R$1,459,000

	Covering soil works	R$6,173,000
	Highland ward works	R$2,218,000
	Total construction cost	R$11,965,000
	Total of investment cost	R$12,803,000
Consulting fee:	7 % of construction cost (included in total of investment cost)	
Land acquisition cost:	Not account	
O&M cost:	R$129,000	

(6) Sludge Dredging of Lake Bottom

Investment cost:	Dredging	R$1,800,000
	Pier for unloading	R$120,00
	Transport on Lake	R$900,000
	Transportation to dumping	R$7,500,000
	Total of construction cost	R$10,320,000
	Total of investment cost	R$11,042,000
Consulting fee	7 % of construction cost (included in total of investment cost)	
Land acquisition cost:	Not count	

(7) Pilot Lake Purification Project by Using Water Plant

Investment cost:	Total of construction cost	R$665,000
	Total of investment cost	R$712,000
Consulting fee	7 % of construction cost (included in total of investment cost)	
Land acquisition cost:	Not count	
O&M cost:	R$98,000	

(8) Environmental Protection Center

Investment cost:	Building Construction cost	R$5,658,000
	Vehicles, Boats	R$2,083,000
	Laboratory Equipment	R$422,000
	Laboratory Glass	R$6,000
	Laboratory Reagent	R$23,000
	Total of construction cost	R$8,192,000
	Total of investment cost	R$8,766,000
Consulting fee	7 % of construction cost (included in total of investment cost)	
Land acquisition cost:	Not count	
O&M cost:	R$1,379,000	

18.1.2 Results of estimation

Estimated cost is as followed table. It is 1,101,620 R$ as investment cost for nine projects. Sewer projects for urban area and isolated communities have share of 50%.

Table1 18.1.1 Project Cost Rough Estimate

Project	Investment Cost (1000 R$)	Share (%)	O&M Cost (2015) (1000 R$)	Share (%)
Sewerage construction in the urban areas	527,862	48%	4,687	60%
Sewerage construction in the isolated communities	22,752	2%	837	11%
Permeable pavement	498,045	45%	449	6%
Public park construction	19,638	2%	199	3%
Remediation of the former Alvarenga solid waste dumping site	12,803	1%	129	2%
Dredging of sediments in the Lake Bottom	11,042	1%	0	0%
Installation of a pilot plant for lake purification using aquatic plants	712	0%	98	1%
Environmental Center for Experimental Study	4,383	0%	690	9%
Water Quality Management Center	4,383	0%	690	9%
Total	1,101,620	100%	7,778	100%

18.2 Financial Plan for Master Plan Program

(1) Policies for financial plan

- As for the Billings Lake water pollution preventive measures, an effect will be realized by continuous enforcement for a long term. On this account about expenses (investment cost and O&M cost) for municipalities to carry out projects, the federal government and the state government should secure municipalities and give guarantee for them according to laws.
- Polluter Pays Principle (PPP) should be applied for the anti-water pollution measures.
- Financial source fund should consist of the state budget, municipalities' budget, water service public corporation (SABESP) fund, borrowed money, and money from polluters.
- Program Management Unit (PMU) is essential for the Billings Program that has various stakeholders. PMU should contribute to PMU for the management and monitor the projects. In addition, a contributed fund should be managed adequately with well-designed system.
- Generally sewer project should cover investment cost, operation & maintenance costs with a sewer bill income. Because we cannot expect fee income besides a sewer project, the other projects are financed by the governments' budget principally.

- Sewer project is one of the most effective measures for preventing water pollution. However the necessary fund for sewage construction is so huge that we cannot expand the applied area to our satisfaction. Therefore, it is important from financial viewpoint that contamination load reduction measures in outbreak source with low cost are much preferable for reduction of financial burden to executors of projects in the future.
- Polluter Pays Principle should be applied to this sewage projects. However reasonable pricing is decided after examine ability to pay and willingness to pay of residents carefully. Consideration for low-income bracket is necessary, too.

(2) Funding Source

As for the enforcement subject of 9 projects to constitute a master plan program, SABESP, SBC beginning basin 6 Cities, Sao Paulo State, EMAE are assumed. Here study team reviewed the financing situation of each enforcement subject and assumed an assumed source of each project.

About a financial status of a basin-related city, it is mentioned in **Chapter 3 finance 3.2** Financial condition of basin-related cities. The latest data provided from federal Statistics Bureau are data in 2003. Where SBC is eligible to have direct loan based on Law of financial responsibility by data about in 2004, but we could not examine other 5 Cities because it was not received an offer of a suitable document.

Table 18.2.1 Funding Source by Project

No.	Project	Executing Agency	Financial Condition	Funding Source
1	Sewer Project in Urban Area	SABESP (Cities in Basin Area)	• As for the SABESP financial affairs situation, healthy (reference 4.3). • Diadem has borrowing qualification by Law of financial responsibility. (reference 3.2.3)	• SABESP budget • City budget • Borrowed money
2	Sewer Project in Isolated Communities	SABESP (Cities in Basin Area)	The same as above	• SABESP budget • City budget • Borrowed money
3	Permeable Pavement Project	SBC (Cities in Basin Area)	• A budget of indispensability expense is thought to be possibility from financial scale of a basin-related city. • SBC and Diadem have borrowing qualification by Law of financial responsibility. (reference 3.2.3)	• City budget • Borrowed money
4	Public Park - Green Space Development	SBC (Cities in Basin Area)	• A budget of indispensability expense is thought to be possibility from financial scale of a basin-related city. • SBC and Diadem have borrowing qualification by Law of financial responsibility.. (reference 3.2.3)	• City budget • Borrowed money
5	Remediation Project For former Alvarenga Open Dumping Site	SBC	• The financing situation is healthy. • SBC has borrowing qualification by Law of financial responsibility.. (reference 3.2.3)	• City budget • Borrowed money
6	Sludge Dredging of Lake Bottom	Sao Paulo State	• A budget of indispensability expense is thought to be possibility from financial scale of a state.	• State budget • Borrowed money
7	Pilot Lake Purification Project by Using Water Plant	SBC	• A budget of indispensability expense is thought to be possibility from financial scale of a city.	• City budget • Borrowed money
8	Environmental Center for Experimental Study	SBC; (Cities in Basin Area)	• A budget of indispensability expense is thought to be possibility from financial scale of each city.	• City budget • Borrowed money
9	Water Management Center	SBC, (Cities in Basin Area)	• A budget of indispensability expense is thought to be possibility from financial scale of each city.	• City budget • Borrowed money

18.3 Financial Analysis of Sewer Projects

Financial analysis is carried out about Sewerage Project 1 (Sewer construction in the urban areas) and Sewerage Project 2 (Sewerage construction in the isolated communities). As a master plan stage where many uncertain elements are existing on both expense and income sides, the calculation is based on a basic unit of the public of waterworks / a sewer business because.

The degree of precision is based on the phase of feasibility study.

Table 18.3.1 Financial / Operating indicators for the past five years of SABESP

	Indicators	Unit	2000	2001	2002	2003	2004
	Financial Indicators						
A	Net Revenue from Operation	(R$ million)	3,356	3,435	3,767	4,131	4,397
B	Cost of sales and services	(R$ million)	1,474	1,590	1,815	2,067	2,253
C=A−B	Gross Profit	(R$ million)	1,882	1,845	1,952	2,064	2,144
D	Selling Expenses	(R$ million)	333	333	385	298	503
E	Administrative Expenses	(R$ million)	137	203	226	254	314
F	Financial Expenses	(R$ million)	738	1,105	2,276	346	504
G=D+E+F	Operation Expense Total	(R$ million)	1,208	1,641	2,887	898	1,321
H=C−G	Income (Loss) from operation	(R$ million)	674	204	-935	1,166	823
I	Net Income	(R$ million)	521	216	-651	833	513
	Operating Indtcators						
J	Number of Water connection	(thous. Units)	5,535	5,717	5,898	6,044	6,358
K	Number of Sewage Connections	(thous. Units)	3,976	4,128	4,304	4,462	4,747
L	Population Served (Water)	(million inhab.)	20.6	20.9	21.2	21.3	22.3
M	Population Serrved (Sewage)	(million inhab.)	15.9	16.2	16.8	17.2	18.2
N	Volumes Invoiced (Bulk Sales)	(million m3)	318	322	339	346	251
O	Volumes Invoiced(Retail water)	(million m3)	1,413	1,376	1,431	1,419	1,441
P	Volumes Invoiced (Sewage)	(million m3)	1,070	1,054	1,105	1,110	1,141
Q=P/K	**Monthly Volumes (Sewage) per Unit**	(m3.month per unit)	22.43	21.28	21.39	20.73	20.03
S=L/J	**Average Population per Unit (Water)**	person	3.72	3.66	3.59	3.52	3.51
T=M/K	**Average Population per Unit (Sewage)**	person	4.00	3.92	3.90	3.85	3.83
U=G/(N+O+P)	**Unit Operation Cost (Water+Sewage)**	(R$ per m3)	0.43	0.60	1.00	0.31	0.47

Source: SABESP Annual Report 2004.

1) Water Produced and Water Invoiced

SABESP defines water losses as the difference between the amount of water produced and the amount of water invoiced. In the calculation, the following are excluded: (1) Water discharged for periodic maintenance of water mains and water storage tank; (2) water supplied for municipal uses such as firefighting; (3) water we consume in our facilities; and (4) estimated water losses associated with water we supply to favelas. SABESP currently marked 34.9% water losses in Sao Paulo Metropolitan Region and 31.4% in the Regional System. SABESP plan to reduce water losses associated with in both 26% by 2009. (SABESP Annual Report 2004 P.32)

At another page (P28) in the annual report, data about water produced and water invoiced. Based on this data losses are calculated as about 40% (1-collection rate 60%). Excluded items might cause the difference between above 31-35% and 40%.

Table 18.3.2 Amount of water produced and invoiced by the SABESP

The amount of water produced and invoiced by Sabesp for 2002-2004

	Year ended December 31,		
	2002	2003	2004
		(in millions of cubic meters)	
Produced			
Sao Paulo Metropolitan Region	2,046.10	2,085.90	2,046.40
Regional Systems	732.2	733.8	724
Total	2,778.30	2,819.60	2,770.50
Invoiced			
Sao Paulo Metropolitan Region(1)	1,275.90	1,278.20	1,205.90
Regional Systems	494.3	486.8	486.5
Total	1,770.20	1,765.00	1,692.40
Invoiced/Produced			
Sao Paulo Metropolitan Region	62%	61%	59%
Regional Systems	68%	66%	67%
Total	64%	63%	61%

(1) Includes water invoiced to wholesale customers of 339.6 in 2002, 346.2 in 2003 and 251.4 in 2004, each in millions of cubic meters.

Source: Study Team based on SABESP Annual Report 2004

2) Assumptions of calculation

<u>Income = (design population for sewerage) / (population per household) x (bill per household) x (collection rate)</u>

<u>Design population for sewerage</u>

It is mentioned in Chapter 10 Master Plan Framework.

<u>Population per household</u>

5.1 people per household

<u>Bill per household</u>

Adopting 21-50 cubic meter. Residential/Normal in the SABESP tariff table. Currently residents in SBC are adopted special Tariff as a shift step in the case of transfer to SABESP of a sewer business in 2004, but we assumed that rate same as the other area will be adopted at the time of this project operation)

<u>Collection rate</u>

Collection rate about sewage is not disclosed. Referring collection rate of water operation, the rate of collection (sewage invoiced/sewage treated) is assumed at 70%. While favelas are existing in this project area, the rate will increase because polluter pay principle will be recognized through environmental education.

Expense =(investment cost) + (operation and maintenance cost)

Investment cost

(object volume of sewage) x (unit cost of sewerage project) and divide it equally for a construction period.

Operation and maintenance cost

(object volume of sewage) x (unit cost of sewer operation and maintenance)

O&M unit cost is assumed at 0.25R$ per m^3 per year. That is half of average cost of SABESP as 0.50 R$. **(Table 13.12.4**) because this project is only transportation of sewage to existing sewage disposal plant and one part of the sewage system.

Table 18.3.3 Income calculation process for Sewer project in urban area

English Version
Sewer Project in Urban Area

		A	B	C	D	E	F	G	H	I	J	K	L
		Population in Basin Area	Population in Project Objective Area	Sewege per person	Sewege Volume	Population per household	Household	Monthly Sewege	Bill rank of Sewege	Monthly Bill	Objective Revenue	Collection Rate	Revenue
		Person	Person	m3/capita /day	Million m3/year	person /household	Household	m3/month	R$/month	R$/month	1000R$ /year	%	1000R$ /year
		A	B	C	D	E	F	G	H	I	J	K	L
0	**2005**	989,970	-	-									
1	2006	1,011,268	-	-									
2	2007	1,032,566	-	-									
3	2008	1,053,864	-	-									
4	2009	1,075,162	-	-									
5	**2010**	1,096,462	-	-									
6	2011	1,118,267	465,602	0.146	24.74	5.1	91,295	22.27	Rank 21to50	26.9	29,470	70%	20,629
7	2012	1,140,072	488,615	0.146	25.96	5.1	95,807	22.27	Rank 21to50	26.9	30,927	70%	21,649
8	2013	1,161,877	511,627	0.146	27.18	5.1	100,319	22.27	Rank 21to50	26.9	32,383	70%	22,668
9	2014	1,183,682	534,640	0.146	28.40	5.1	104,831	22.27	Rank 21to50	26.9	33,840	70%	23,688
10	**2015**	1,205,486	557,652	0.146	29.63	5.1	109,344	22.27	Rank 21to50	26.9	35,296	70%	24,707
11	2016	1,223,284	580,664	0.147	31.24	5.1	113,856	22.55	Rank 21to50	27.7	37,792	70%	26,454
12	2017	1,241,082	603,676	0.149	32.85	5.1	118,368	22.81	Rank 21to50	28.4	40,287	70%	28,201
13	2018	1,258,880	626,688	0.151	34.47	5.1	122,880	23.05	Rank 21to50	29.0	42,783	70%	29,948
14	2019	1,276,678	649,700	0.152	36.08	5.1	127,392	23.28	Rank 21to50	29.6	45,278	70%	31,695
15	**2020**	1,294,475	672,714	0.154	37.69	5.1	131,905	23.49	Rank 21to50	30.2	47,773	70%	33,441
16	2021	1,314,260	699,918	0.155	39.70	5.1	137,239	23.78	Rank 21to50	31.0	50,999	70%	35,700
17	2022	1,334,045	727,122	0.157	41.71	5.1	142,573	24.05	Rank 21to50	31.7	54,226	70%	37,958
18	2023	1,353,830	754,326	0.159	43.72	5.1	147,907	24.30	Rank 21to50	32.4	57,452	70%	40,216
19	2024	1,373,615	781,530	0.160	45.73	5.1	153,241	24.53	Rank 21to50	33.0	60,678	70%	42,475
20	**2025**	1,393,398	808,736	0.162	47.74	5.1	158,576	24.75	Rank 21to50	33.6	63,904	70%	44,733

Table 18.3.4 Income calculation process for Sewer Project in Isolated Communities

		A	B	C	D	E	F	G	H	I	J	K	L
		Population in Basin Area	Population in Project Objective Area	Sewege per person	Sewege Volume	Population per household	Household	Monthly Sewege	Bill rank of Sewege	Monthly Bill	Objective Revenue	Collection Rate	Revenue
		Person	Person	m3/capita /day	Million m3/year	person /household	household	m3/month	R$/month	R$ /month	1000R$ /year	%	1000R$ /year
		A	B	C	D	E	F	G	H	I	J	K	L
0	**2005**	989,970	23,072	0.144	1.21								
1	2006	1,011,268	24,383	0.144	1.28								
2	2007	1,032,566	25,694	0.144	1.35								
3	2008	1,053,864	27,005	0.144	1.42								
4	2009	1,075,162	28,316	0.144	1.49								
5	**2010**	1,096,462	29,627	0.144	1.56								
6	2011	1,118,267	30,938	0.144	1.63								
7	2012	1,140,072	32,249	0.144	1.69	5.1	6,323	22.03	Rank 21to50	26.3	1,992	70%	1,394
8	2013	1,161,877	33,560	0.144	1.76	5.1	6,580	22.03	Rank 21to50	26.3	2,073	70%	1,451
9	2014	1,183,682	34,871	0.144	1.83	5.1	6,837	22.03	Rank 21to50	26.3	2,154	70%	1,508
10	**2015**	1,205,486	36,177	0.144	1.90	5.1	7,094	22.03	Rank 21to50	26.3	2,235	70%	1,564
11	2016	1,223,284	36,754	0.149	2.00	5.1	7,207	22.78	Rank 21to50	28.3	2,446	70%	1,712
12	2017	1,241,082	37,331	0.154	2.09	5.1	7,320	23.51	Rank 21to50	30.3	2,658	70%	1,861
13	2018	1,258,880	37,908	0.158	2.19	5.1	7,433	24.22	Rank 21to50	32.2	2,870	70%	2,009
14	2019	1,276,678	38,485	0.163	2.29	5.1	7,546	24.91	Rank 21to50	34.0	3,081	70%	2,157
15	**2020**	1,294,475	39,061	0.167	2.38	5.1	7,659	25.58	Rank 21to50	35.8	3,293	70%	2,305
16	2021	1,314,260	39,504	0.170	2.45	5.1	7,746	25.95	Rank 21to50	36.8	3,423	70%	2,396
17	2022	1,334,045	39,947	0.172	2.51	5.1	7,833	26.31	Rank 21to50	37.8	3,553	70%	2,487
18	2023	1,353,830	40,390	0.174	2.57	5.1	7,920	26.66	Rank 21to50	38.8	3,684	70%	2,579
19	2024	1,373,615	40,833	0.177	2.63	5.1	8,006	27.01	Rank 21to50	39.7	3,814	70%	2,670
20	**2025**	1,393,398	41,274	0.179	2.69	5.1	8,093	27.35	Rank 21to50	40.6	3,944	70%	2,761

3) Results of Financial Analysis on Sewerage Projects

With the above-mentioned condition, financial indicators (FIRR, NPV, the C/B ratio) are calculated.

A value of FIRR appears with sewerage project 1 (Sewer Project in Urban Area) 2.0%, sewerage project 2(Sewer Project in Isolated Communities) 0.1%, and combined 2 projects 1.9%. From the financial viewpoint, the Project 2 is not feasible. The Project 1 is also not feasible with commercial funding rate but it could be feasible by the measure such as higher collection bills. The calculation process is summarized in **Table 18.5.5**.

Table 18.3.5 Financial analysis result

	No. 1+ project No. 2s	Project No. 1	Project No. 2
FIRR	1.9%	2.0%	0.1%
NPV (1000R$)	-162,827	-154,298	-8,529
B/C Ratio	0.41	0.40	0.42

Assumed collection rate with 70%, the plan expected consciousness improvement of a sewage user, and it is a key of business success to keep the collection rate of a sewer income highly. By the sensibility analysis about sewer bill, it is a key point for this projects to have appropriate tariff adoption.

18.3.6 Cash-Flow Analysis for Sewerage Construction

Project 1: Sewer Project in Urban Area (1000R$)

		Cost					
No.	Year	Construction Cost	Design & Management Cost	O&M cost	Cost Total	Revenue	Revenue - Cost
1	2006	0	0	0	0	0	0
2	2007	0	0	0	0	0	0
3	2008	0	4,933	0	4,933	0	-4,933
4	2009	0	4,933	0	4,933	0	-4,933
5	2010	98,666	4,933	0	103,599	0	-103,599
6	2011	98,666	4,933	0	103,599	0	-103,599
7	2012	98,666	4,933	1,172	104,771	5,412	-99,359
8	2013	98,666	4,933	2,343	105,942	11,334	-94,608
9	2014	98,666	4,933	3,515	107,114	17,766	-89,348
10	2015	0	0	4,687	4,687	24,707	20,021
11	2016	0	0	4,687	4,687	26,454	21,768
12	2017	0	0	4,687	4,687	28,201	23,514
13	2018	0	0	4,687	4,687	29,948	25,261
14	2019	0	0	4,687	4,687	31,695	27,008
15	2020	0	0	4,687	4,687	33,441	28,755
16	2021	0	0	4,687	4,687	35,700	31,013
17	2022	0	0	4,687	4,687	37,958	33,271
18	2023	0	0	4,687	4,687	40,216	35,530
19	2024	0	0	4,687	4,687	42,475	37,788
20	2025	0	0	4,687	4,687	44,733	40,046
21	2026	0	0	4,687	4,687	44,733	40,046
22	2027	0	0	4,687	4,687	44,733	40,046
23	2028	0	0	4,687	4,687	44,733	40,046
24	2029	0	0	4,687	4,687	44,733	40,046
25	2030	0	0	4,687	4,687	44,733	40,046
26	2031	0	0	4,687	4,687	44,733	40,046
27	2032	0	0	4,687	4,687	44,733	40,046
28	2033	0	0	4,687	4,687	44,733	40,046

FIRR	2.0%		
NPV	-154,298	259,174	104,876
B/C Ratio	0.40		

Project 2: Sewer Project in Isolated Communities

		Cost				
No.	Year	Construction Cost	Design & Management Cost	O&M cost	Cost Total	Revenue
1	2006	0	0	0	0	0
2	2007	0	0	0	0	0
3	2008	0	295	0	295	0
4	2009	0	295	0	295	0
5	2010	6,953	295	0	7,248	0
6	2011	7,587	295	0	7,882	0
7	2012	6,737	295	0	7,032	0
8	2013	0	0	822	822	1,347
9	2014	0	0	830	830	1,400
10	2015	0	0	837	837	1,557
11	2016	0	0	846	846	1,614
12	2017	0	0	854	854	1,671
13	2018	0	0	859	859	1,728
14	2019	0	0	867	867	1,785
15	2020	0	0	872	872	1,947
16	2021	0	0	880	880	2,010
17	2022	0	0	888	888	2,073
18	2023	0	0	896	896	2,138
19	2024	0	0	904	904	2,205
20	2025	0	0	908	908	2,236
21	2026	0	0	908	908	2,236
22	2027	0	0	908	908	2,236
23	2028	0	0	908	908	2,236
24	2029	0	0	908	908	2,236
25	2030	0	0	908	908	2,236
26	2031	0	0	908	908	2,236
27	2032	0	0	908	908	2,236
28	2033	0	0	908	908	2,236

FIRR	0.1%		
NPV	-8,529	14,637	6,108
B/C Ratio	0.42		

18.3.6 Cash-Flow Analysis for Sewerage Construction (Cont'd)

Project 1 + Project 2 (1000R$)

No.	Year	Cost				Revenue	Revenue - Cost
		Construction Cost	Design & Management Cost	O&M cost	Cost Total		
1	2006	0	0	0	0	0	0
2	2007	0	0	0	0	0	0
3	2008	0	5,228	0	5,228	0	-5,228
4	2009	0	5,228	0	5,228	0	-5,228
5	2010	105,619	5,228	0	110,847	0	-110,847
6	2011	106,253	5,228	0	111,481	0	-111,481
7	2012	105,403	5,228	1,172	111,803	5,412	-106,391
8	2013	98,666	4,933	3,165	106,764	12,682	-94,082
9	2014	98,666	4,933	4,345	107,944	19,166	-88,778
10	2015	0	0	5,524	5,524	26,264	20,740
11	2016	0	0	5,532	5,532	28,068	22,536
12	2017	0	0	5,540	5,540	29,872	24,332
13	2018	0	0	5,546	5,546	31,676	26,130
14	2019	0	0	5,554	5,554	33,480	27,926
15	2020	0	0	5,559	5,559	35,388	29,830
16	2021	0	0	5,566	5,566	37,709	32,143
17	2022	0	0	5,574	5,574	40,031	34,457
18	2023	0	0	5,582	5,582	42,355	36,772
19	2024	0	0	5,590	5,590	44,679	39,089
20	2025	0	0	5,594	5,594	46,969	41,375
21	2026	0	0	5,594	5,594	46,969	41,375
22	2027	0	0	5,594	5,594	46,969	41,375
23	2028	0	0	5,594	5,594	46,969	41,375
24	2029	0	0	5,594	5,594	46,969	41,375
25	2030	0	0	5,594	5,594	46,969	41,375
26	2031	0	0	5,594	5,594	46,969	41,375
27	2032	0	0	5,594	5,594	46,969	41,375
28	2033	0	0	5,594	5,594	46,969	41,375
					273,811	110,984	

FIRR	1.9%
NPV	-R$ 162,827
B/C Ratio	0.41

18.4 Economic Evaluation on the Master Plan

1) Methodology of Economic Evaluation

An economic evaluation of the master plan program is as follows.

- Setting Without Case and With Case.
- Measuring social Benefit.
- Measuring social Cost.
- Calculating economic evaluation indicators (EIRR, NPV,C/B ratio)

2) Setting of Case"Without" and Case"With"

Case"Without":

This is the case in which any measures will not be taken for the present issues. The water quality of Billings Lake continues turning worse, and the cost rises to take water from the Lake and to treat water for the water services. When the water extremely turned worse, it could become inappropriate to take water from the Billings Lake. In such case, the other source of water should be found. However in this study we assumed that the water quality of the Lake without case is still could be purified by chemical use.

Case"With":

In this case, suggested projects are supposed to be carried out. The water quality of Billings Lake shall be improved, and the cost for water purification shall be less than the case without. Conception diagram for relations of "Without" and "With" is shown as follows:

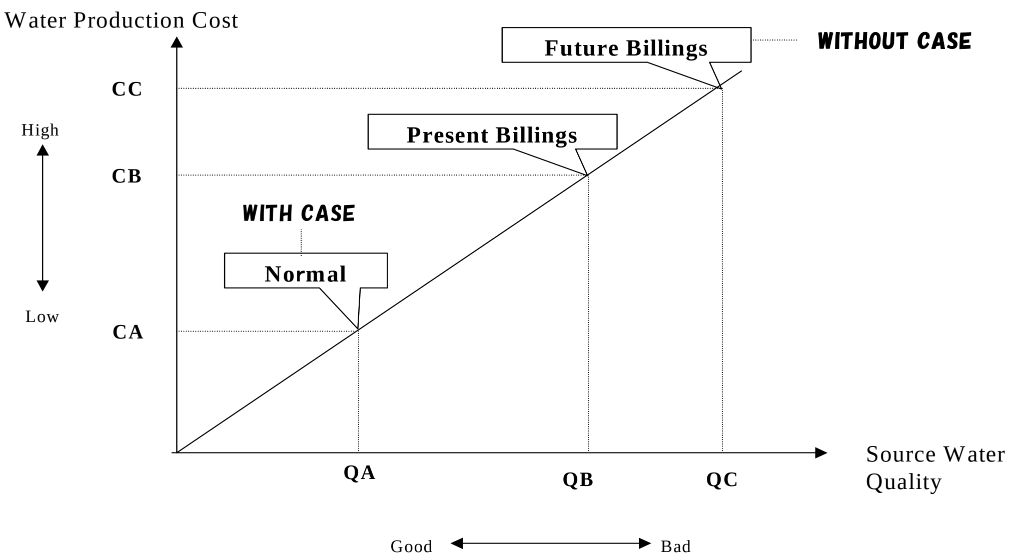


Figure 18.4.1. Water Production cost and Water Quality

3) Measurement method of Economic Benefits

Various types of effects will be expected with the program for Billings Lake to improve water quality: Effect of cost reduction, Effect of Industry promotion, Effect of sanitary improvement, Effect of environment protection, and Effect of living environment improvement. Because some of them are difficult to be measured, this study objects to Effect of cost reduction to take and purify water. Consideration about measurement of the effects is as follows:

Table 18.4.1 Measurement method economic benefits

Effect	Contents	A measurement method	Object of this Study
Cost Reduction Effect (raw sewage processing cost)	Expenses of waste water processing are reduced with the sewerage system	{(present raw sewage processing cost per household) - (sewage system processing cost / household)} ×(number of household in the area)	Checked off. Currently the cost of dumping waste water is sunk.
Cost Reduction Effect (water cost)	Purifying water cost of waterworks is reduced by water improvement of Billings Lake	{(Without clean water cost /cubic meter) - (With clean water cost /cubic meter)} ×(water volume purified)?	Object. Data come from SABESP.
Cost Reduction Effect (cleaning Lake water cost)	Current lake cleaning processing expense to be reduced.	Anti- Algae measure expense	Object. Data come from SABESP.
Sightseeing promotion Effect	A cost cut to be provided because visitors who went to a far-off beach come to the Lake with shorter distance.	(the number of the tourists increase) X (travel budget)	Checked off No available data.
Public sanitation improvement Effect	Healthy damage reduction of inhabitants by outbreak epidemic decrease.	added value from evaded absence time per time	Checked off. Specification of an epidemic is difficult.
Effect of environmental protection	Reduction effect of resources (recycling of processing water), reduction effect of environmental pollutant	Money conversion is difficult.	Checked off
Living environment improvement effect	Residents receive Satisfaction improvement of living environment	Rise of a land value.	Checked off Related to Favelas

4) Water Production Cost and Water Quality

A hypothesis is verified here: When water quality turns worse, water purifying costs increase.

SABESP provided study team data of use conditioner (chemicals, an oxidizer, a total of a sterilizer) and data of purified water volume of production in a water system of (1996 - 2004) two plants: the Rio Grande water purification plant which drew water from Lake billing now and Guarau water purification plant which took better water from other sources. Operation environment of two water purification plant is different, but the actual situation using about 2 times medicines from **Table 18.6.4** is clear.

Requested data about operation cost of Rio Grande water purification plant and intake water quality is not come from SABESP. On temporary basis, Study team estimated the data about cost from annual report of SABESP at present. Administrative expense on entire company average is 0.5R$/m^3/ year (**Table 18.5.1**). Based on this number, we assumed in Without Case 1.0R$/m^3/ year of 2 times for 2025 years from 0.5R$/m^3/ year. In With Case, we set it than the present conditions with 40% cost cut 0.3R$/m^3/ year. Therefore, unit price reduction of purifying water cost with the program becomes it according to the list shown below.

Table 18.4. 2 Water Treatment Cost Prediction

(R$/m3)

No.	Year	Without Case	With Case	Net (Withot – With)
0	2005	0.50		
1	2006	0.52		
2	2007	0.54		
3	2008	0.56		
4	2009	0.58		
5	2010	0.60	0.3	0.30
6	2011	0.62	0.3	0.32
7	2012	0.64	0.3	0.34
8	2013	0.66	0.3	0.36
9	2014	0.68	0.3	0.38
10	2015	0.70	0.3	0.40
11	2016	0.72	0.3	0.42
12	2017	0.74	0.3	0.44
13	2018	0.76	0.3	0.46
14	2019	0.78	0.3	0.48
15	2020	0.80	0.3	0.50
16	2021	0.84	0.3	0.54
17	2022	0.87	0.3	0.57
18	2023	0.91	0.3	0.61
19	2024	0.96	0.3	0.66
20	2025	1.00	0.3	0.70

5) Water intake

About quantity of intake water the Billings Lake supply to waterworks is performed with three places: Rio Grande system, Taquacetuba system, and Cubatao / Baixada Santista system (JICA progress report P1-26). We assumed Cubatao / Baixada Santista system taken off from object of this economic analysis calculation. Intake water of two water purification plant in future is shown in **Table 18.6.3**.

Table 18.4.3 Water supply plan by water purification plant

(m3/annual)

No.	Year	Rio Grande Arm	Taquacetuba Arm
0	2005	12,132,789	126,144,000
1	2006	12,254,106	126,144,000
2	2007	12,376,636	126,144,000
3	2008	12,500,391	126,144,000
4	2009	12,625,384	126,144,000
5	2010	12,751,626	126,144,000
6	2011	12,893,518	126,144,000
7	2012	13,036,989	126,144,000
8	2013	13,182,057	126,144,000
9	2014	13,328,738	126,144,000
10	2015	13,477,052	126,144,000
11	2016	13,609,741	126,144,000
12	2017	13,743,737	126,144,000
13	2018	13,879,052	126,144,000
14	2019	14,015,699	126,144,000
15	2020	14,153,692	126,144,000
16	2021	14,278,679	126,144,000
17	2022	14,404,769	126,144,000
18	2023	14,531,973	126,144,000
19	2024	14,660,300	126,144,000
20	2025	14,789,760	126,144,000

Table 18.4.4 Rio Grande and medicine use results change of Guarau water purification plant

Used Conditioner in Rio Grande System and Guarau System

	1996	1997	1998	1999	2000	2001	2002	2003
RIO GRANDE System								
Water Production (m3/year)	108,482,218	110,808,623	128,000,053	130,966,514	131,126,602	134,322,332	140,379,389	149,217,419
Used Conditioner (Kg/year)	10,453,709	9,987,992	11,538,945	11,676,306	11,826,478	15,363,523	19,271,854	12,904,496
Unit Conditioner (Kg/1000m3)	96.36	90.14	90.15	89.15	90.19	114.38	137.28	86.48
GUARAÚ System								
Water Production (m3/year)	1,051,488,425	1,044,354,296	1,035,519,461	1,044,295,067	1,018,596,541	957,282,495	1,004,567,858	988,148,999
Used Conditioner (Kg/year)	38,176,053	34,310,543	32,950,754	35,864,609	35,680,539	33,088,982	34,489,780	30,824,566
Unit Conditioner (Kg/1000m3)	36.31	32.85	31.82	34.34	35.03	34.57	34.33	31.19
Rio Grande / Guarau	2.65	2.74	2.83	2.60	2.57	3.31	4.00	2.77

Source：SABESP

6) Calculation of economic cost

From a nation economical point of view, economic price is calculated from market price in the economic analysis. Economic price excludes tax and subsidy. Standard Conversion Factor (SCF) converts market price to economic price usually. Because the breakdown of cost for the economic cost calculation was not set, the conversion was not adopted this time. We subtracted 31% as a tax / subsidy equivalency from market price and did it with an economic price. (Refer to World bank, Implementation completion report: Brazil for the water quality & pollution control project, June 2004, PP77)

A project cost uses the rough estimation of **Table 13.12.2** project expense.

7) Economic evaluation index (EIRR, NPV, B/C Ratio)

In the above-mentioned condition, economic evaluation index were calculated..

A value of EIRR got 6.3% and a calculation result. It is the program that it can carry out economically.

Table 18.4.5 Economic Assessment Result

	Lake Billing environment improvement program
EIRR	6.3%
NPV (1000R$)	-57,490
B/C Ratio	0.92

THE STUDY ON INTEGRATED PLAN OF E
IN THE CATCHMENT AREA OF LAKE BIL

Table 18.4.7 Economic Benefit (1000R$)

No.	Year	Economic Benefit		
		Reduced Water Treatment Cost (R$/m3)	Water Intake (thousand m3)	Benefit total
1	2006			
2	2007	0.04	138,521	5,240
3	2008	0.06	138,644	8,014
4	2009	0.08	138,769	10,896
5	2010	0.30	138,896	41,669
6	2011	0.32	139,038	44,323
7	2012	0.34	139,181	47,066
8	2013	0.36	139,326	49,898
9	2014	0.38	139,473	52,825
10	2015	0.40	139,621	55,848
11	2016	0.42	139,754	58,549
12	2017	0.44	139,888	61,328
13	2018	0.46	140,023	64,185
14	2019	0.48	140,160	67,125
15	2020	0.50	140,298	70,149
16	2021	0.54	140,423	75,338
17	2022	0.57	140,549	80,772
18	2023	0.61	140,676	86,461
19	2024	0.66	140,804	92,417

Table 19.4.8 Water Intake (m3/annual)

No.	Year	Rio Grande Arm	Taquacetuba Arm
0	2005	12,132,789	126,144,000
1	2006	12,254,106	126,144,000
2	2007	12,376,636	126,144,000
3	2008	12,500,391	126,144,000
4	2009	12,625,384	126,144,000
5	2010	12,751,626	126,144,000
6	2011	12,893,518	126,144,000
7	2012	13,036,989	126,144,000
8	2013	13,182,057	126,144,000
9	2014	13,328,738	126,144,000
10	2015	13,477,052	126,144,000
11	2016	13,609,741	126,144,000
12	2017	13,743,737	126,144,000
13	2018	13,879,052	126,144,000
14	2019	14,015,699	126,144,000
15	2020	14,153,692	126,144,000
16	2021	14,278,679	126,144,000
17	2022	14,404,769	126,144,000
18	2023	14,531,973	126,144,000
19	2024	14,660,300	126,144,000

Table 18.4.9 Economic Cost Calculation (1000R$)

		Cost (Economic)				Reduction				
No.	Year	Construction Cost	Consulting Cost	O&M Cost	Total Cost		Constructio n Cost	Consulting Cost	O&M Cost	Total Cost
1	2006	0	0	0	0	31%	0	0	0	0
2	2007	16,904	1,183	16	18,103	31%	24,498	1,715	24	26,237
3	2008	16,904	5,116	33	22,052	31%	24,498	7,414	47	31,959
4	2009	16,904	5,226	49	22,179	31%	24,498	7,574	71	32,143
5	2010	98,025	5,226	65	103,316	31%	142,065	7,574	95	149,734
6	2011	102,320	5,216	796	108,331	31%	148,289	7,559	1,153	157,002
7	2012	95,235	5,117	2,449	102,801	31%	138,022	7,416	3,549	148,986
8	2013	87,622	4,698	3,798	96,118	31%	126,989	6,809	5,504	139,301
9	2014	87,622	4,698	4,467	96,787	31%	126,989	6,809	6,473	140,271
10	2015	17,602	1,294	5,203	24,099	31%	25,510	1,875	7,540	34,926
11	2016	18,017	1,294	5,240	24,551	31%	26,112	1,875	7,595	35,582
12	2017	18,017	1,294	5,262	24,573	31%	26,112	1,875	7,627	35,614
13	2018	16,904	1,183	5,282	23,369	31%	24,498	1,715	7,656	33,869
14	2019	16,904	1,183	5,304	23,391	31%	24,498	1,715	7,687	33,900
15	2020	16,904	1,183	5,324	23,411	31%	24,498	1,715	7,716	33,929
16	2021	16,904	1,183	5,346	23,432	31%	24,498	1,715	7,747	33,960
17	2022	16,904	1,183	5,367	23,454	31%	24,498	1,715	7,779	33,992
18	2023	16,904	1,183	5,389	23,476	31%	24,498	1,715	7,810	34,023
19	2024	16,904	1,183	5,411	23,498	31%	24,498	1,715	7,842	34,055
20	2025	16,904	1,183	5,430	23,517	31%	24,498	1,715	7,869	34,082

Chapter 19

PROJECT EVALUATION

19 PROJECT EVALUATION

The projects proposed for basin improvement of the Lake Billings are evaluated from the viewpoints of financial, socioeconomic, technical, organizational and institutional, and environmental aspects.

19.1 Financial

The projects that can expect the income out of all the projects proposed in the M/P are only the sewerage construction in the urban areas and the isolated communities which share 50% of the total project cost. For this reason, financial analysis is conducted only for sewerage projects. The FIRRs calculated are 2.0% for the urban areas, 0.1% for the isolated communities and 1.9% for their integration. The sewerage construction in the isolated communities has less financial viability, but that in the urban areas has viability by taking measures such the raise in sewage charge. The key for business success is to maintain a high collection rate of sewage charge through the improvement of the people's awareness.

When the performance of the Rio Grande Water Treatment Plant with an intake from the Rio Grande Arm is compared with that of the Guarau Water Treatment Plant with an intake from the different river basin of which the water quality is relatively good, it is found that the chemical consumption at Rio Grande is approximately two times that at Guarau according to the data of chemicals including oxidizing reagent and algaecide and clear water production volume. From this fact, it is assumed that the worse the water quality the more the production cost, or the annual unit cost of production will increase from the present 0.5 R$/$m^3$ to double or 1.0 R$/$m^3$ in 2025 in case of "without Project", while will be 40% down to 0.3 R$/$m^3$ in case of "with Project". The EIRR calculated is 6.3% and the project can be said to be economically viable.

19.2 Socioeconomic

The implementation of the projects proposed in the present study bring the following obvious socioeconomic benefit in addition to the protection of rich nature, supply of safe water and the provision of rest place through the improvement of basin environment of the Lake Billings towards "Coexistence of Water, Human and Green":

- Increase in employment opportunity
- Reduction in water treatment cost for supply
- Reduction in removal cost of algae and aquatic plants
- Rise of land cost

It should be noted that the project intends to protect the living of 2.7 million people in the Greater Sao Paulo Region relying their water source on the Lake Billings by protecting its water quality from further deterioration.

19.3 Technical

In the present study, as for wastewater largely affecting the water quality of the Lake Billings through its discharge without any treatment except for the very limited area within the basin, the optimum sewerage plan was selected through the alternative comparison from the viewpoints of treatment inside the basin or conveyance outside the basin of wastewater, layout of facilities, construction method and so on, dividing the study area into the urban areas, isolated communities and others and taking into account the consistency with related programs and superior plans. The water quality requirement to the effluent discharged into the Lake Billings, construction and O&M costs, easiness in O&M are also reviewed. Therefore, the projects proposed in the M/P are technically feasible.

The projects other than sewerage construction are undertaken by the municipalities involved in the basin, but there is less constructional problem in permeable pavement, park provision, remediation of the former Alvarenga solid waste dumping site, building of the Environmental Centre for Experimental Study and construction of the Water Quality Management Centre. However, due to almost no technical experience in purification of the lake using aquatic plants and dredging of sediments piled in the lake bottom, it is better to advance the study steadily, starting from a pilot or small scale and accumulating the knowledge.

19.4 Organizational and Institutional

Out of projects proposed in the M/P, the sewerage construction is undertaken by the SABESP of which the State of Sao Paulo is the biggest stockholder. Notwithstanding of its giant scale, the SABESP has efficiently operated the facilities in the equivalent level of Japan and Korea internationally. No problem is found for SABESP.

Other projects than sewerage construction such as permeable pavement, park provision, remediation of the former Alvarenga solid waste dumping site, building of the environmental centre for experimental study and construction of the water quality management centre are undertaken by the municipalities involved in the basin such as Sao Bernardo do Campo. The municipality has already sufficient experience and organization to implement the projects for permeable pavement, park provision and remediation of the former Alvarenga solid waste dumping site.

The operation of the environmental center for experimental study and the water quality management center is the quite new projects and need the staff recruitment. As various people have concerns for the Lake Billings as represented in the "Seminário Billings 2002", conservation of human resources will be possible, if opening positions extensively, and to obtain the cooperation of volunteers. It is recommended to collect the public opinion widely in constructing and operating these facilities as the activity base for basin environment improvement of the Lake Billings.

Although the lake purification using aquatic plants is also a new experience, it is possible to manage it, starting from an experimental unit to study the know-how in cooperation with the university and institution step-by-step

It is expected that the dredging of sediments piled in the lake bottom requires a huge amount of cost and time, therefore the start from limited implementation is recommended in order to study the experience.

19.5 Environmental

In the present study, the screening was conducted in line with the JICA Guideline for Environment taking into account the requirements in the environmental impact assessment licensing system in the Brazilian side. As a result, each project is not classified into Category A (The project gives serious affect on the environment and society.), but into Category B (The project gives a little affect on the environment and society in comparison with Category A.).

Under the EIA system in Brazil, the preparation of EIA/RIMA, procedures after preliminary environment license, and acquisition of environmental license for treatment, conveyance and disposal of dredged sediments are required for the dredging of sediments piled in the lake bottom. For other projects than the above, there is no necessity to prepare the EIA/RIMA.

As this projects aim at improving the basin environment of the Lake Billings, the projects accompanied with works is mainly undertaken by the administrative sides and the activities for environmental improvement is done by stakeholders such as community and civic associations, schools, etc. in cooperation with the administrative sides. It goes without saying that such projects and activities will be done so as to minimize the environmental impact.

19.6 Overall Evaluation

Based on the reviews above-mentioned, the projects proposed are considered reasonable for implementation in light of financial, socioeconomic, technical, organizational and institutional and environmental aspects.

PART 3

FEASIBILITY STUDY (F/S)

Chapter 20

SELECTION OF PRIORITY PROJECT

20. SELECTION OF PRIORITY PROJECT

20.1 Proposed Projects

As the projects for basin environment improvement of the Lake Billings, the following projects are proposed by purpose.

1) Restoration of water quality

- Sewerage construction in the urban areas
- Sewerage construction in the isolated communities

2) Restoration of water quantity

- Permeable pavement
- Park provision
- Remediation of former Alvarenga solid waste dumping site

Note: The remediation of the former Alvarenga solid waste dumping site has initially a fear of inclusion of heavy metals in its leachate

3) Lake purification

- Dredging of sediments piled in the lake bottom
- Installation of a pilot plant using aquatic plants

4) Strengthening of combination among water, human and green

- Construction of the Environmental Centre

5) Study and research

- Construction of the Water Quality Management Centre

The selection of priority projects shall be done with the following three steps. That is to say, each project is evaluated from the viewpoint of emergency, effect and response to negative impact at the first step and possibility of realization at the second step. If a project passes both steps, it shall be acknowledged as a priority project, even though the evaluation score in each stage is low.

1) First step: Evaluation based on emergency, effect and response to negative impact

2) Second step: Evaluation based on possibility of realization, or acquisition of site and EIA/RIMA)

3) Third step: To pass both steps

The evaluation results to select the priority projects are shown in **Tables 20.1.1** based on the evaluation on emergency, effect, negative impact and possibility of realization in **Table 20.1.2** and correspondence to negative impact in **Table 15.5.1**.

Table 20.1.1 Selection of priority projects

	First stage					Second stage				Third stage
	Emer.	Effect	Neg. impact	Sub-total	Eval. (≥5)	Land acquis.	Environ. lisence	Sub-total	Eval. (≥4)	Overall judg.
Permeable pavement	1	2	2	5	○	2	3	5	○	◎
Prov. of the Alvarenga Park	2	1	2	5	○	3	3	6	○	◎
Imp. of the former Alvarenga solid waste dumping site	2	1	2	5	○	3	3	6	○	◎
Sewerage prov. in the urban areas	3	3	2	7	○	2	3	5	○	◎
Sewerage prov. in the isolated comm.	2	3	2	7	○	3	2	5	○	◎
Dredging of sediments	2	2	1	5	○	1	1	2		
Lake purification	2	1	2	5	○	2	2	4	○	◎
Environ. center for exp. study	3	3	3	9	○	3	3	6	○	◎
Water quality management centre	2	3	3	8	○	2	2	4	○	◎

Note: The meaning of scores is as follows: 3: high or easy, 2: moderate, 1: low or difficult
The evaluation for emergency and effect is based on the relative evaluation within the identical purpose.

From **Table 20.1.1**, the priority projects selected are as follows:

1) Sewerage construction in the urban areas
2) Sewerage construction in the isolated communities
3) Permeable pavement
4) Park provision
5) Remediation of former Alvarenga solid waste dumping site
6) Installation of a pilot plant using aquatic plants
7) Construction of the Environmental Centre
8) Construction of the Water Quality Management Centre

20.2 Measures for Pollutant Load Reduction

Table 20.2.1 and **Figure 20.2.1** show the pollutant loads by target year, source and loading mode such as generation, effluent and runoff. The runoff mode indicates the actual pollutant load entering into the Lake Billings. The contribution of pollutant load by elusion from sediments piled in the lake bottom is reflected in the mathematical model by giving elusion rates by parameter per square meter of bottom area. In **Table 20.2.1**, the elusion loads of TN and TP are calculated by assuming that it is equivalent to 26% of total runoff loads in 2005 (domestic sewage and storm water) and that the elusion load in 2005 is applied to those in 2015 and 2025.

From **Table 20.2.1** and **Figure 20.2.1**, the findings are as follows:

1) Difficulty to take measures against pollutant sources derived from pimping water and elusion

/ Since the pumping of the Pinheiros River water to the Lake Billings, when Sao Paulo enters into on the alert for flood, is considered to continue in the future and its volume is huge in a short time, it is difficult to take effective measures for pollutant load reduction.

/ For the internal pollutant source, the possible solution is the dredging of sediments piled in the lake bottom, but it is found that sediments is extensively distributed with a thickness of 30 to 50 cm throughout the whole lake. Therefore, even though conducting the dredging of sediments partially, it is very difficult to identify its effect. The above option is not adopted in the situation that the pumping of the Pinheiros River water to the Lake Billings will continue in the future.

2) For BOD_5, the measures for domestic sewage are the biggest issue at present.

The current biggest source of BOD_5 is domestic sewage (77.0%) followed by pumping water (18.4%) and storm water (4.5%) on the generation load basis. On the runoff load basis, the percentages of pollutant sources are 51.8%, 41.6% and 6.6% respectively, in which the share of pumping water is considerably up.

3) For TN and TP, the measures for domestic sewage is also the biggest issue

The pollutant load share of TN is 65.3% in domestic sewage, 20.3 % in pumping water and 13.2 % in internal source and 1.2% in storm water on the generation load basis, while 46.0%, 31.6 %, 20.6% and 1.8%, respectively, on the runoff load basis in which the percentages of pumping water and internal source are up. TP shows the similar trend to TN.

4) For BOD5, as the load derived from domestic sewage is almost cut in 2025 due to the progress of sewerage construction, the load by storm water relatively increases its share.

5) For TN and TP, the almost load in 2025 after the progress of sewerage construction is shared by those derived from pumping water and internal source.

Therefore, the measures for pollutant sources should be addressed to domestic sewage as a point source at the present time.

The sewerage construction in the urban areas is based on the idea to convey domestic sewage generated in the basin outside the basin, while the sewerage construction in the isolated communities has a plan to construct a phosphorous-removable treatment plants with a effluent BOD5 of 20mg/L. In other areas, the proper operation and maintenance of septic tanks is assumed, in which the effluent infiltrates into the ground and settled sludge is periodically withdrawn from the tank. Therefore, the load derived from domestic sewage is almost removed from the basin of the Lake Billings.

Table 20.1.2 Evaluation of emergency, effect and possibility of realization by project

Project	First step: emergency & effect		Second step: possibility of realization	
	emergency	effect	Land acquisition	Environmental license
Restoration of water quality				
Sewerage construction in the urban areas	Urban domestic sewage is the biggest pollution source.	Very effective due to conveyance of sewage outside the basin that makes a load zero in the basin. Load reduction: 15.95 ton/day[1)]	Condemnation and use of private land is required along the Couros Trunk Sewer.	Not necessary for EIA/RIMA, but requires procedures after application of construction license (LI)
Sewerage construction in the isolated communities	Domestic sewage in the isolated communities is the secondly biggest pollution source.	Effective due to phosphorous-removable secondary treatment. Load reduction: 2.07 ton/day[2)]	No problem in land acquisition for reconstruction of Riacho Grande WWTP and construction of Santa Cruz WWTP.	Not necessary for EIA/RIMA, but requirs submission of RAP to DAIA or CETESB that issues the licenses such as LP, LI and LO.
Restoration of water quantity				
Permeable pavement		Big effect for groundwater recharge Reduction of runoff Protection of unpaved roads from erosion	No condemnation for permeable pavement.	Not necessary for EIA/RIMA
Construction of Parks and Greens	If it is left as it is, there is a fear of formation of a favera.	Effective for groundwater recharge	No problem in land acquisition.	Not necessary for EIA/RIMA
Inprovement of the former Alvarenga solid waste dumping site	If it is left as it is, there is a fear of formation of a favera. The slope has a risk of collapse	Effective for groundwater recharge	The present favela is included in the existing relocation progarmme. No relocation of residents	Not necessary for EIA/RIMA The particular area is designated as a polluted area requiring a survey for pollution area management by the CETESB.
Lake purification				
Dredging of sediments piled in the lake bottom	Sediments have piled with a thickness of 30 to 50 cm over the whole area.	The effect is not clear by partial dredging. Emergency pumping is continued in the future.	Necessary for the EMAE' approval	Necessary for EIA/RIMA and procedures after application of construction license (LI) as well as a license for treatment, conveyance and disposal of dredged sediments.
Installation of a pilot plant for lake	Necessary for an experimental approach	Ideal due to use of natural purification function, if it works	Necessary for the EMAE' approval	Not necessary for EIA/RIMA but requires confirmation at the

purification using aquatic plants		well.		implementation stage.
Strengthening of combination among water, human and green				
Construction of the Environmental Center	The earlier public enlightenment and environmental calculation, the better	Effective as the place for public enlightenment and environmental calculation. Expected to be a symbol for the basin of the Lake Billings.	No problem due to construction at the municipality-owned park.	Not necessary for EIA/RIMA.
Study and Research				
Construction of the Water Quality Management Centre	No check of the pollution status in arms and streams at present.	Effective to check the conditions of arms and streams. Make studies for lake purification possible.	No problem due to construction at the municipality-owned park.	Not necessary for EIA/RIMA.

1) Design population of Sao Berando do Campo in 2025: 295,331, per capita pollutant load: 54 g/capita/day

295,331 x 54 = 15.948 ton/day

2) Design population of Riacho Grande (SBC) in 2025: 37,159 (7,135 m^3/day) and Santa Cruz (SBC): 4,041 (776 m^3/日), per capita pollutant load: 54 g/capita/day, target effluent BOD_5: 20 mg/L

(37,159 + 4,041) x 54 - (7,135 + 776) x 20 = 2.225 - 0.158 = 2.067 ton/day

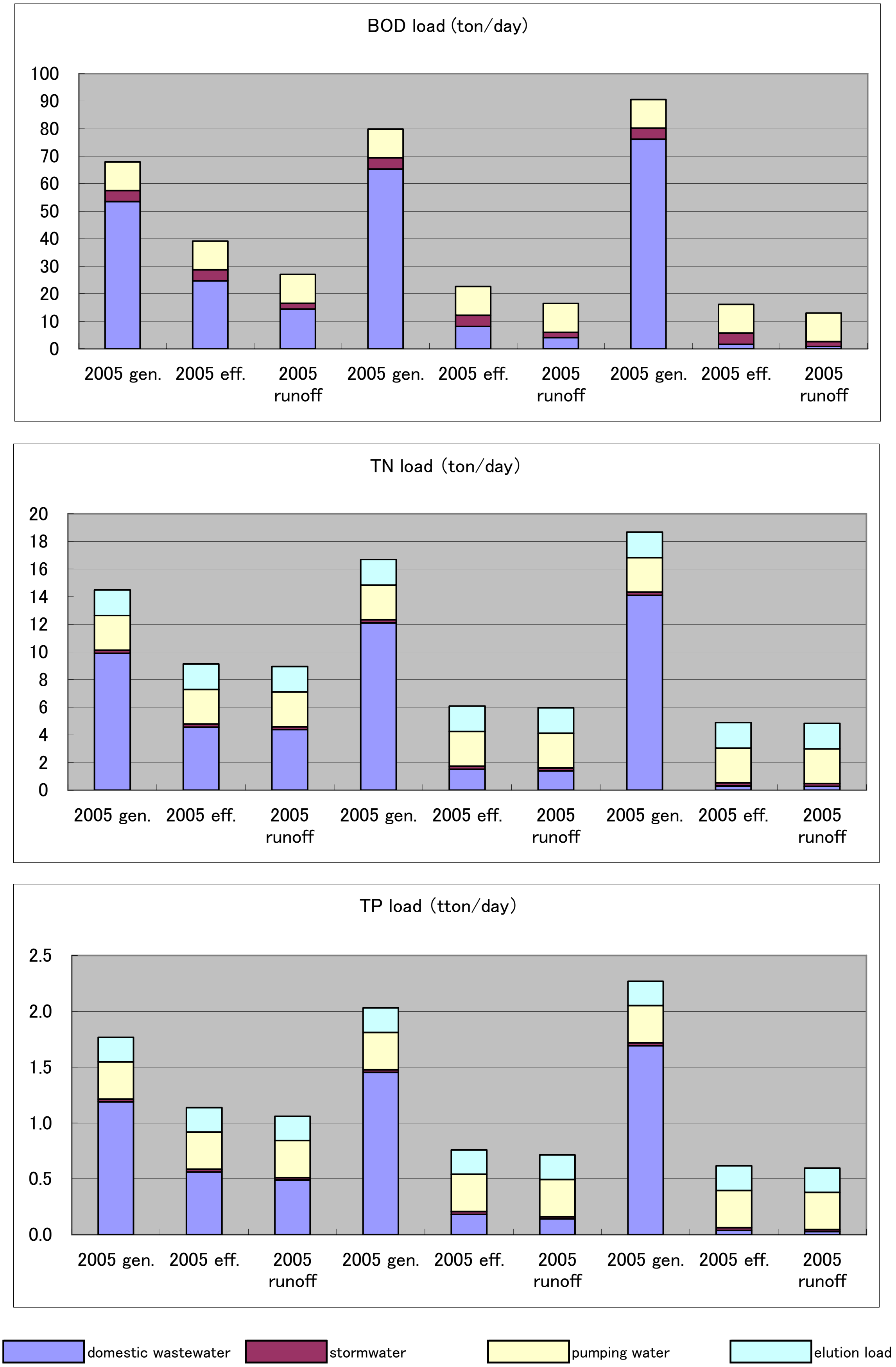


Figure 20.2.1 Composition of pollutant loads in the Lake Billings and The Rio Grande Arm

Table 20.2.1   Composition of pollutant loads on generation, effluent and runoff base

Pollutant loads (ton/day)

			BOD					TN					TP				
	Year	Category	Domestic (ton/day)	Stormwater (ton/day)	Pumping (ton/day)	Elution load (ton/day)	Total (ton/day)	Domestic (ton/day)	Stormwater (ton/day)	Pumping (ton/day)	Elution load (ton/day)	Total (ton/day)	Domestic (ton/day)	Stormwater (ton/day)	Pumping (ton/day)	Elution load (ton/day)	Total (ton/day)
Billings	2005	Generation	43.500	2.560	10.417		56.477	8.055	0.145	2.501	1.633	12.334	0.968	0.016	0.333	0.203	1.520
		Effluent	20.094	2.560	10.417		33.071	3.719	0.145	2.501	1.633	7.998	0.460	0.016	0.333	0.203	1.012
		Runoff	12.977	1.653	10.417		25.047	3.638	0.142	2.501	1.633	7.914	0.431	0.015	0.333	0.203	0.982
	2015	Generation	52.852	2.560	10.417		65.829	9.787	0.145	2.501	1.633	14.066	1.175	0.016	0.333	0.203	1.727
		Effluent	6.036	2.560	10.417		19.013	1.118	0.145	2.501	1.633	5.397	0.135	0.016	0.333	0.203	0.687
		Runoff	3.356	1.423	10.417		15.196	1.034	0.134	2.501	1.633	5.302	0.113	0.013	0.333	0.203	0.662
	2025	Generation	61.304	2.560	10.417		74.281	11.352	0.145	2.501	1.633	15.631	1.363	0.016	0.333	0.203	1.915
		Effluent	1.496	2.560	10.417		14.473	0.278	0.145	2.501	1.633	4.557	0.034	0.016	0.333	0.203	0.586
		Runoff	0.769	1.317	10.417		12.503	0.251	0.131	2.501	1.633	4.516	0.026	0.012	0.333	0.203	0.574
Rio Grande Arm	2005	Generation	10.003	1.492			11.495	1.852	0.086		0.213	2.151	0.222	0.009		0.016	0.247
		Effluent	4.581	1.492			6.073	0.842	0.086		0.213	1.141	0.101	0.009		0.016	0.126
		Runoff	1.479	0.481			1.960	0.744	0.076		0.213	1.033	0.058	0.005		0.016	0.079
	2015	Generation	12.505	1.492			13.997	2.316	0.086		0.213	2.615	0.278	0.009		0.016	0.303
		Effluent	2.112	1.492			3.604	0.391	0.086		0.213	0.690	0.047	0.009		0.016	0.072
		Runoff	0.738	0.522			1.260	0.365	0.080		0.213	0.658	0.029	0.006		0.016	0.051
	2025	Generation	14.844	1.492			16.336	2.749	0.086		0.213	3.048	0.330	0.009		0.016	0.355
		Effluent	0.162	1.492			1.654	0.030	0.086		0.213	0.329	0.004	0.009		0.016	0.029
		Runoff	0.052	0.479			0.531	0.026	0.074		0.213	0.313	0.002	0.005		0.016	0.023
合計	2005	Generation	53.503	4.052	10.417		67.972	9.907	0.231	2.501	1.846	14.485	1.190	0.025	0.333	0.219	1.767
		Effluent	24.675	4.051	10.417		39.143	4.561	0.231	2.501	1.846	9.139	0.561	0.025	0.333	0.219	1.138
		Runoff	14.456	2.134	10.417		27.007	4.382	0.218	2.501	1.846	8.947	0.489	0.020	0.333	0.219	1.061
	2015	Generation	65.357	4.052	10.417		79.826	12.103	0.231	2.501	1.846	16.681	1.453	0.025	0.333	0.219	2.030
		Effluent	8.148	4.052	10.417		22.617	1.509	0.231	2.501	1.846	6.087	0.182	0.025	0.333	0.219	0.759
		Runoff	4.094	1.945	10.417		16.456	1.399	0.214	2.501	1.846	5.960	0.142	0.019	0.333	0.219	0.713
	2025	Generation	76.148	4.052	10.417		90.617	14.101	0.231	2.501	1.846	18.679	1.693	0.025	0.333	0.219	2.270
		Effluent	1.658	4.052	10.417		16.127	0.308	0.231	2.501	1.846	4.886	0.038	0.025	0.333	0.219	0.615
		Runoff	0.821	1.796	10.417		13.034	0.277	0.205	2.501	1.846	4.829	0.028	0.017	0.333	0.219	0.597

Compostion rate of pollutant loads (%)

			BOD					TN					TP				
	Year	Category	Domestic (ton/day)	Stormwater (ton/day)	Pumping (ton/day)	Elution load (ton/day)	Total (ton/day)	Domestic (ton/day)	Stormwater (ton/day)	Pumping (ton/day)	Elution load (ton/day)	Total (ton/day)	Domestic (ton/day)	Stormwater (ton/day)	Pumping (ton/day)	Elution load (ton/day)	Total (ton/day)
Billings	2005	Generation	77.0	4.5	18.4		100.0	65.3	1.2	20.3	13.2	100.0	63.7	1.1	21.9	13.4	100.0
		Effluent	60.8	7.7	31.5		100.0	46.5	1.8	31.3	20.4	100.0	45.5	1.6	32.9	20.1	100.0
		Runoff	51.8	6.6	41.6		100.0	46.0	1.8	31.6	20.6	100.0	43.9	1.5	33.9	20.7	100.0
	2015	Generation	80.3	3.9	15.8		100.0	69.6	1.0	17.8	11.6	100.0	68.0	0.9	19.3	11.8	100.0
		Effluent	31.7	13.5	54.8		100.0	20.7	2.7	46.3	30.3	100.0	19.7	2.3	48.5	29.5	100.0
		Runoff	22.1	9.4	68.6		100.0	19.5	2.5	47.2	30.8	100.0	17.1	2.0	50.3	30.7	100.0
	2025	Generation	82.5	3.4	14.0		100.0	72.6	0.9	16.0	10.4	100.0	71.2	0.8	17.4	10.6	100.0
		Effluent	10.3	17.7	72.0		100.0	6.1	3.2	54.9	35.8	100.0	5.8	2.7	56.8	34.6	100.0
		Runoff	6.2	10.5	83.3		100.0	5.6	2.9	55.4	36.2	100.0	4.5	2.1	58.0	35.4	100.0
Rio Grande Arm	2005	Generation	87.0	13.0			100.0	86.1	4.0		9.9	100.0	89.9	3.6		6.5	100.0
		Effluent	75.4	24.6			100.0	73.8	7.5		18.7	100.0	80.2	7.1		12.7	100.0
		Runoff	75.5	24.5			100.0	72.0	7.4		20.6	100.0	73.4	6.3		20.3	100.0
	2015	Generation	89.3	10.7			100.0	88.6	3.3		8.1	100.0	91.7	3.0		5.3	100.0
		Effluent	58.6	41.4			100.0	56.7	12.5		30.9	100.0	65.3	12.5		22.2	100.0
		Runoff	58.6	41.4			100.0	55.5	12.2		32.4	100.0	56.9	11.8		31.4	100.0
	2025	Generation	90.9	9.1			100.0	90.2	2.8		7.0	100.0	93.0	2.5		4.5	100.0
		Effluent	9.8	90.2			100.0	9.1	26.1		64.7	100.0	13.8	31.0		55.2	100.0
		Runoff	9.8	90.2			100.0	8.3	23.6		68.1	100.0	8.7	21.7		69.6	100.0
合計	2005	Generation	78.7	6.0	15.3		100.0	68.4	1.6	17.3	12.7	100.0	67.3	1.4	18.8	12.4	100.0
		Effluent	63.0	10.4	26.6		100.0	49.9	2.5	27.4	20.2	100.0	49.3	2.2	29.3	19.2	100.0
		Runoff	53.5	7.9	38.6		100.0	49.0	2.4	28.0	20.6	100.0	46.1	1.9	31.4	20.6	100.0
	2015	Generation	81.9	5.1	13.0		100.0	72.6	1.4	15.0	11.1	100.0	71.6	1.2	16.4	10.8	100.0
		Effluent	36.0	17.9	46.1		100.0	24.8	3.8	41.1	30.3	100.0	24.0	3.3	43.9	28.9	100.0
		Runoff	24.9	11.8	63.3		100.0	23.5	3.6	42.0	31.0	100.0	19.9	2.7	46.7	30.7	100.0
	2025	Generation	84.0	4.5	11.5		100.0	75.5	1.2	13.4	9.9	100.0	74.6	1.1	14.7	9.6	100.0
		Effluent	10.3	25.1	64.6		100.0	6.3	4.7	51.2	37.8	100.0	6.2	4.1	54.1	35.6	100.0
		Runoff	6.3	13.8	79.9		100.0	5.7	4.2	51.8	38.2	100.0	4.7	2.8	55.8	36.7	100.0

20.3 Priority Order among Projects

(1) Sewerage construction in the urban areas

Only domestic sewage generated in the urban areas adjoining the expanding Greater Sao Paulo Region has a possibility to increase the pollutant loads in the basin of the Lake Billings. The sewerage construction in those areas, therefore, has a big effect on the reduction of pollutant loads. That is to say, the conveyance of sewage outside the basin makes a load generated in the basin zero. The effect on water quality improvement in the Lake billings is outstanding and therefore this project should be ranked first among the proposed projects.

(2) Sewerage construction in the isolated communities

For domestic sewage generated from the isolated communities, a variety of alternatives such as conveyance of sewage outside the basin similar to urban sewerage, independent sewage treatment at each community or integrated communities, treatment by septic tanks and their combination were reviewed. As a result, reconstruction of the Riacho Grande WWTP and construction of the Santa Cruz WWTP were recommended. This project has the effect on load reduction following urban sewerage construction, and should be naturally ranked second among the engineering measures

(3) Permeable pavement

The basin of the Lake Billings has high possibility for development in the future, resulting in an increase of impermeable area, storm water runoff and pollutant loads at the first flush during rainfall. The measures to mitigate such an increase of pollutant loads are the installation of storm water infiltration facilities and permeable pavement. It is advisable that the Municipality will implement these works by itself wherever possible, calling the stakeholders to adopt these facilities at their premises. The Municipality has already developed “Eco-town Movement” called “Bairro Ecologica”, in which the people cooperate to make their front sidewalk permeable. This project is reasonable to be included in priority projects.

Photo 20.2.1 Eco-town Movement（Bairro Ecologic）

(4) Construction of Parks and greens

The construction of parks and greens has effect on the protection of vacant spots from formation of wasteland or favela, or dumping site. The parks and greens are useful to contain storm water runoff, increase a water-holding capacity and to recharge groundwater.

(5) Measure for effluent from the old Alvarenga dumping site

This project is to augment the safety and stability of the former solid waste dumping site and to treat the leachate and storm water drainage. The site has a risk of collapse in a steep slope and the problem of squatters' invasion, which is a symbol of the negative heritage of Sao Bernardo do Campo in the basin of the Lake Billings. The Municipality is not in a position to neglect this problem and has strong intention for its improvement as one on basin environment improvement of the Lake Billings. It is considered as one of measures for green conservation, but not yet in such a stage to consider its reuse as a park. etc.

(6) Installation of a pilot plant for lake purification using aquatic plants

This project is to accumulate and master the technical now-how through the operation and maintenance of a pilot plant for lake purification using aquatic plants, utilizing the natural purification function in the lakes and lagoons, which is expectedly necessary in the future

(7) Construction of the Environmental Center for Experimental Study

At lakes and lagoons, it is very difficult to restore the previous conditions, once polluted, which require a long time and accumulation of little efforts. Even though the sewerage is constructed in the basin of the Lake Billing, it is useless, if there is little connection to a sewer system. For this purpose, it is necessary to always work on all stakeholders including the people so as to elevate their environmental awareness. The Environmental Center for Experimental Study aims at providing to the next generations the place for personal experience how important to conserve the nature is, and is positioned at the symbolic facility or the stronghold in the system to make the activities for basin environment improvement of the Lake Billings sustainable as well as the Association of "Clean the Lake Billings". Therefore, great emphasis be given to this project as well as the sewerage construction in the urban areas.

(8) Construction of the Water Quality Management Center

The CETESB is responsible for water quality monitoring to attainment of the environmental standards, however as it covers the whole State of Sao Paulo and all the environmental quality, it has no situation to display full ability only to the Billings Lake. Because the Lake' configuration is very complicated and composed of several arms which are different in water quality and locality, respectively. To grasp these conditions, it is necessary to construct the water quality sub-monitoring system in the form to complement the CETESB's monitoring system. The sub-monitoring system is linked to the CETESB's monitoring system so as to exchange the information. This project also makes the study and research close to the Lake Billings possible.

Including the coordination with the existing monitoring agencies such as the CETESB and SABESP, it is necessary for further detailed discussion regarding its scope of work and ranked lower at the present moment.

Based on the results of review, the priority order among the projects are as follows:

- Sewerage construction in the urban areas
- Construction of the Environmental Center for Experimental Study
- Sewerage construction in the isolated Communities
- Permeable pavement
- Construction of parks and greens
- Remediation of the former Alvarenga solid waste dumping site
- Construction of the Water Quality Management Center
- Installation of a pilot plant for lake purification using aquatic plants

Chapter 21

URBAN SEWAGE TRANSPORT SYSTEM

21. URBAN SEWAGE TRANSPORT SYSTEM

21.1.1 General Introduction of the northern part of the Billings Lake basin

In January 2004, water and sewerage system ownership in the municipality of São Bernardo do Campo was transferred from DAE to SABESP. DAE was deactivated and SABESP became the new concessionaire of water and sewerage services, and was assigned the power to define the policies related to the sewerage plan, respective implementation works, and maintenance of relevant facilities.

However, the Municipality (SBC) argues that it can reflect the municipality's opinions on sewerage system planning. This is based on CLAUSE FOURTH - MUNICIPALITY RIGHTS of the Basic Sanitation Utility Transfer Agreement entered into by and between the Municipality of São Bernardo do Campo and SABESP. This only occurs because SABESP needs the municipal government's support to carry out its sewerage system implementation works, as in the case of Ribeirão dos Couros trunk line.

The implementation of a trunk line along Ribeirão dos Couros (Couros River) which crosses no public ways will require the expropriation of parts of private properties and issuance of use license. That would not be possible without the cooperation of the local municipality. Municipal laws provide that the construction of facilities in a 15-m wide strip along rivers or channels is forbidden. When that strip is used for the construction of public works, as in the case of the sewerage trunk line implementation, the municipal government has the competence to assign the use of that strip to public Works. The local government's support is also indispensable at the negotiations with the respective owners of such landed estates.

Currently, basic sanitation works in Alvarenga and Lavras suburbs, in the municipality of SBC, are being constructed by SHAMA, which took over all DAE works. This does not mean, however, that SHAMA is currently controlling the sewerage work program; SHAMA applies funds from the Federal Government under the poverty alleviation policy to the environmental improvement of both suburbs. Sewerage plan is just another component of the life environment improvement program. On the other side, SABESP is quite concerned with the issue of destination of effluents from some 110,000 inhabitants of The Billings Lake basin: whether sewage will be treated on-site or will be taken outside the basin is a matter of high interest of SABESP. Anyway, it is incumbent to SABESP to carry out all sewerage works.

An agreement between the Municipality of São Bernardo do Campo and SABESP comprises the following objectives:

- To increase the piped water supply coverage rate from 87% to 100% by the year of 2008;
- To increase the sewerage service coverage rate from 74% to 95% by the year of 2009;
- To convey 90% of collected sewage to the treatment plant by the year of 2011;

- To reduce the piped water loss rate (leaks) from 57% to 30% by the year of 2008.

Currently, there are two SABESP trunk lines covering the municipality of SBC, whose western portion is covered by Meninos trunk line, and the eastern portion is covered by Couros trunk line. In such trunk lines, the major part of Meninos trunk line is completed, while only the section of Couros collector between its interconnection with Meninos collector and Curral Grande collector is completed. Regarding the section between Curral Grande and Jurubatuba channel, the Urban Transport Program (PTU) in the Municipality of São Bernardo do Campo provides for the execution of river improvement works and implementation of ways (streets/roads) financed by IDB. In turn, SABESP has already scheduled the start of planning and execution of works in that section financed by SABESP own funds.

Nevertheless, meeting its commitment to the municipality of São Bernardo do Campo, will require the further extension of Couros trunk line to receive sewage from the Billings Lake Basin. At the time of implementation of Meninos trunk line and Jurubatuba auxiliary trunk line, there was no specific plan to receive sewage from the Billings Lake basin. Thereby, it is now indispensable to complete Couros trunk line to allow the conveyance of sewage generated in the Billings Lake basin to ABC Sewage Treatment Plant located outside of the basin. As a result, this report also considers Ribeirão dos Couros trunk line.

SHAMA sewerage system plan provides for the conveyance of sewage to ETE ABC. As such, it provides for works of preparation and implementation of sewerage networks and construction of secondary trunk lines in Alvarenga and Lavras channel basins to convey all sewage through three pumping stations（EEE-1, EEE-2, EEE-3）to Ribeirão dos Couros trunk line. Regarding “A” & “B” areas adjacent to the Billings Lake, the discharge volume from such two areas will be considered as just a part of volume that will be conveyed to Couros trunk line, and will not be included in the sewerage services plan for the area. The municipality of São Bernardo do Campo will carry out the sewerage services in slums, and SABESP will carry out such services in all other areas.

In addition, in the northern part of the Billings Lake basin there are several populated areas that are not covered by SHAMA sewerage service plan (see **Figure 21.1.1**, Areas C - F). As sewage from such areas should not be disregarded, the areas shall be included in this project. With respect to funds for implementation of sewerage works by SHAMA, both Grant from the Ministry of Cities and loan from the World Bank - Mananciais Program are under consideration. For the former, an application has already been made, but it was not approved so far; for the latter, submission of documentation to COFIEX, responsible for the assessment of external loans, is delayed. Because of upcoming elections (including at Federal level scheduled for October 2006), there is no perspective of their definitive approval.

21.1.2 The Couros trunk sewer route

The Couros trunk sewer route, which is connected from sewers of the north part of the Billings Lake basin is shown in **Figure 21.1.1**. Its basis of the route selections is shown in **Annex A21.1.1**.

The Couros trunk sewer route is chosen on the basis of gravity flow and is through the Couros River aside from the lowest reaches of Est.Takagi trunk sewer. On the way, its route detours a flood-control reservoir and a part of route shall be constructed by pipe jacking method. The Couros trunk sewer connect the Jurubatuba trunk sewer which is the beginning of existing sewer of IDB Project.

21.1.3 The Project for transport of sewage in the northern part of the catchment area of Lake Billings

(1) Alternatives

Sewage generated in Alvarenga and Area A - F shall be transported to planned Couros trunk sewer in this project. In light of the situation described above, 4 alternatives are established for construction cost study. Alternatives suppose that sewage generated in each area of the northern part of the Billings Lake basin will be pumped up to the pumping station EEE-3.

Alternative 1: sewage transfer to Estrada Takagi channel;
Alternative 2: sewage transfer to Camargo channel;
Alternative 3: sewage transfer to Jurubatuba channel (Av. Robert Kennedy);
Alternative 4: sewage transfer to Camargo channel and Estrada Takagi channel

(2) Settlement of Alternatives

In the result of examination, alternative 2 is the most inexpensive in 4 cases. The basis of calculations is shown in **Annex A21.1.2** (design criterion, comparison of alternatives, construction and maintenance costs).

The trunk sewers located upper the Couros trunk sewer basin, J.Kubitschek, Sem Nome and Est.Takagi, are out of project. However, these basins are expected to be urbanized and industrialized in the future. Since construction work within 15 meters from a river is prohibited in Sao Bernard do Campo City, many Couros trunk sewer should be needed to preserve from this stage. (cf. Annex A21.1.1 C-B Section)

Therefore, alternative 1 which includes all trunk sewers in the Couros basin is adopted in this project.

Table 21.1.1 The comparison of construction and maintenance costs per capita by present value

	Construction Cost	Maintenance Cost	Total	Beneficiary	Per capita
	(R$million)	(R$million)	(R$million)	(Person)	(R$/capita)
Alternative 1	30.32	6.93	37.25	295,331	126
Alternative 2	26.37	5.76	32.13	259,731	123
Alternative 3	25.54	6.46	32.00	220,231	145
Alternative 4	35.22	6.24	41.46	295,331	140

21.1.4 General Project Description

This project covers sewage transport system for the Billings Lake basin area, which is designed to convey all collected sewage to ETE ABC through Couros Trunk Line. Currently, sewage is directly discharged (without treatment) in the lake.

Sewerage facilities under this Project are described below (see **Figure 21.1.1**):

- Couros Trunk Line in Couros River Basin (CT Couros)
- Secondary Trunk Line in Couros River Hydrographic Basin (Secondary CT Takagi, Nameless, Juscelino Kubistchek, Camargo, Jurubatuba)
- Coletor Tronco na Bacia Hidrográfica da Represa Billings (CT Imigrantes interligado com o CT Secundário Takagi)Trunk Line in the Billings Lake basin (CT Imigrantes and Secondary CT Takagi).
- Estação Elevatória EEE-01, EEE-02, EEE-03 (CT Imigrantes)Pumping Stations EEE-01, EEE-02 and EEE-03 (CT Imigrantes).
- Coletor Tronco Secundário do Ribeirão dos Alvarengas e Lavras (CT Alvarenga, CT Lavras projetado pelo Pat-ProSanear)Secondary Trunk Line in Alvarenga and Lavras stream basins (CT Alvarenga and CT Lavras designed by Pat-Prosanear).
- Redes Coletoras das Bacia do Ribeirão dos Alvarengas e LavrasTrunk Lines in Alvarenga and Lavras stream basins.
- Esgotamento Sanitário nas Áreas A a F (Coletores Tronco Secundários, Bombas Intermediárias e Redes Coletoras)Sewerage system in A-F areas (Secondary Trunk Lines, Intermediate Pumps and Sewerage Networks).

21.1.5 Project Area

Project area is shown in **Figure 21.1.1**.

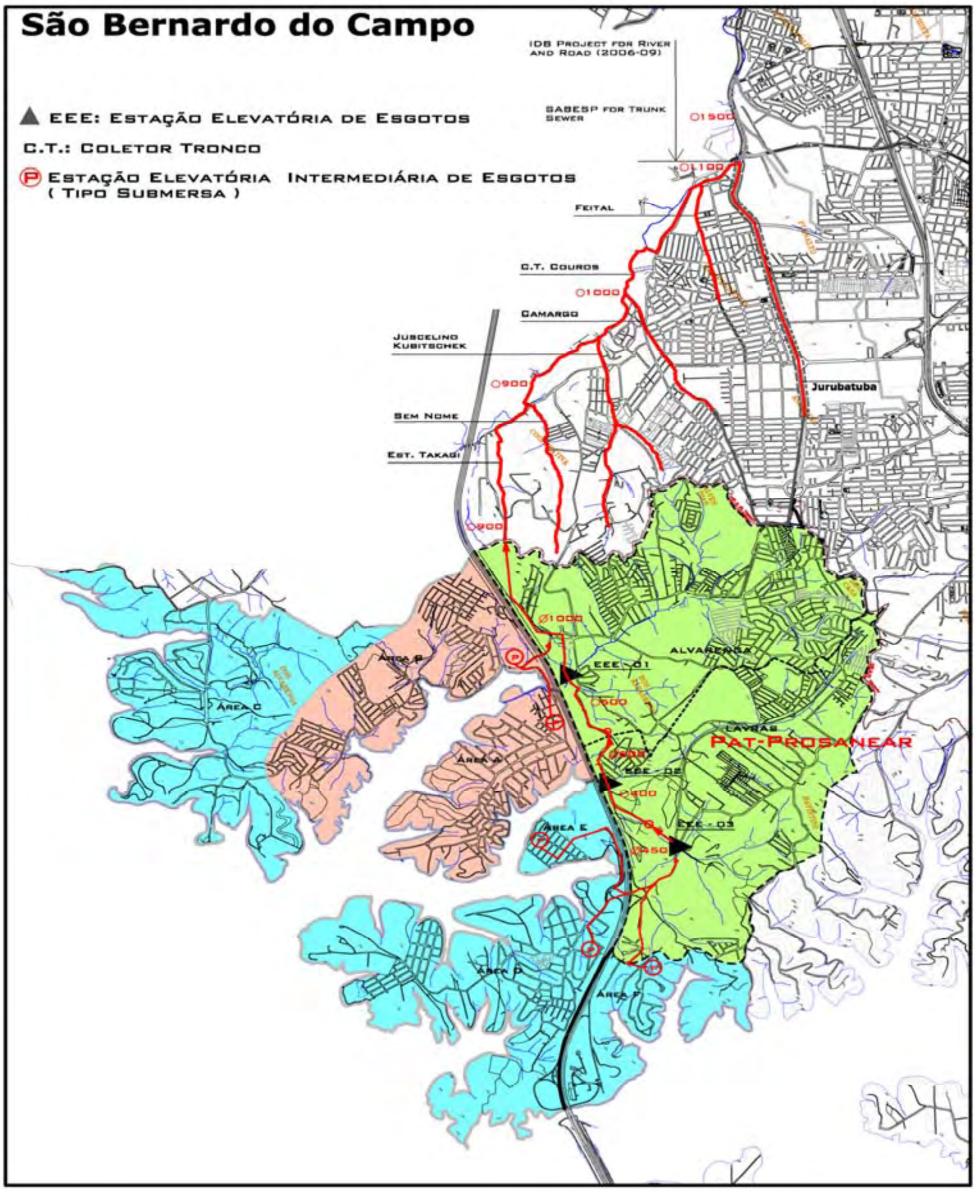


Figure 21.1.1 Location Map of Sewerage Project in Urban Area

21.1.6 Basic Requirements for Sewerage Projects

(1) Trunk Sewer

(a) Design criterion of trunk sewer follows “12.1.6 Design Criterion“.

(b) The minimum diameter of trunk sewer should be 250 mm. Pipes material is polyvinyl chloride till dia.300 mm and concrete more than 400 mm.

(c) The routes and ground levels of sewer pipes planning follow the projected roads which have Camargo and Juscelino Kubitschek trunk sewers.

(d) The ground levels of pipe planning of Est.Takagi and Sem Nome follow the present state levels because they do not have a projected road but thickets. However, their routes and ground levels will be possible to be changed by felling and leveling of ground since it is necessary to build maintenance roads for SABESP at the construction.

(e) The maintenance roads of trunk sewer are 4 meters wide.

(f) The covering from present river bed to pipe top is 1 meter in the river crossings (Est. Takagi, SemNome, Juscelino Kubitschek, Camargo and Feital)

(g) Open cut method is applied under the condition that a covering is less than 5 meters from ground level to invert level. On the one hand, pipe jacking method is available more than 5 meters of covering.

(h) Connecting point of the Couros trunk sewer is the beginning of trunk sewer of IDB Project.

(i) Pipes routes and locations of manhole type pumping station are set up by contour lines because topographic survey is not conducted in Alvarenga, Lavras and Area A-F.

(2) Sewage Pumping Stations

(a) Pumping Stations design includes horizontal-shaft pumps installed in dry well to make their maintenance easier. Alternative of submersible motor-pump assemblies was discarded, as it is preferably applicable to small pumping stations or spatially-limited densely populated locations;

(b) The general Pumping Station layout provides for the installation of an additional spare motor-pump assembly; under normal conditions, when almost all motor-pump assemblies are in operating conditions.

(c) Pumping Stations design does not include a sand sedimentation box, as the Brazilian system is of absolute separator type, that is, rainwaters are drained by a system separated from the sewerage system;

(d) All Pumping Stations have been designed for single-stage implementation, where motor-pump assemblies are alternated in the initial operation years;

(e) Circular format was selected for buried pumping station parts, because wall thicknesses are much more reduced as compared to rectangular format, as there is only compression strength and it makes the construction process easier.

(f) For each Pumping Station, the design provides for two tangent circles, the largest of which contains the suction well and the pump room, and the smallest contains the screen box and the spillway chamber;

(g) Protection against surges assumed in this report includes hydropneumatic tanks, although the possibility of other alternative tank protection systems are not discarded, especially the implementation of inertia wheels in motor-pump assemblies;

(h) Pumping Station EEE-01, the most import in the system, should be provided with an emergency electric power generator set for eventual power failures;

(i) Pumping Stations EEE-02 and EEE-03 are design to include locations, wiring and other facilities for the installation of portable emergency motogenerators;

21.2 Projects

21.2.1 Project Discharges

Project sewage discharges are shown in **Table 21.2.1** for each area.

Table 21.2.1 Project Sewage Discharges

		Design average daily wastewater flow (m^3/day)					Design maximum daily wastewater (m^3/day)					Design maximum hourly wastewater flow (m^3/day)					
	Area	2005	2010	2015	2020	2025	2005	2010	2015	2020	2025	2005	2010	2015	2020	2025	Ultimate※
Couros basin	Jurubatuba	10,900	11,300	11,800	12,300	12,800	11,700	12,200	12,800	13,400	14,000	17,900	18,700	19,500	20,400	21,400	-
	Feital	1,780	1,880	1,960	2,060	2,170	2,000	2,110	2,210	2,330	2,460	2,950	3,120	3,280	3,450	3,650	-
	Couros	1,760	1,820	1,890	1,960	2,020	1,900	1,970	2,060	2,140	2,220	3,050	3,150	3,290	3,400	3,520	-
	Camargo	5,380	5,630	5,870	6,140	6,400	6,110	6,400	6,700	6,990	7,320	8,390	8,840	9,300	9,730	10,300	-
	Juscelino Kubitschek	4,880	5,370	5,970	6,720	7,640	5,450	6,020	6,760	7,640	8,750	7,890	8,770	9,870	11,200	12,900	-
	Sem nome	1,040	1,100	1,160	1,220	1,310	1,070	1,140	1,210	1,280	1,390	1,320	1,420	1,520	1,640	1,800	-
	Est. Takagi	1,620	1,650	1,690	1,750	1,810	1,650	1,670	1,720	1,790	1,870	2,610	2,650	2,730	2,830	2,950	-
	Total	27,360	28,750	30,340	32,150	34,150	29,880	31,510	33,460	35,570	38,010	44,110	46,650	49,490	52,650	56,520	-
	≒	27,400	28,800	30,400	32,200	34,200	29,900	31,600	33,500	35,600	38,100	44,200	46,700	49,500	52,700	56,600	-
Billings Lake basin	Alvarenga※	10,469	11,524	12,504	13,429	14,309	12,043	13,309	14,484	15,596	16,651	16,762	18,662	20,425	22,092	23,674	39,353
	Lavras※	5,263	5,798	6,295	6,765	7,211	6,061	6,704	7,300	7,863	8,399	8,455	9,418	10,313	11,159	11,961	
	Area A※	3,412	3,731	4,028	4,309	4,575	3,896	4,268	4,632	4,956	5,284	5,329	5,897	6,444	6,920	7,412	7,887
	Area B※	4,056	4,445	4,806	5,148	5,472	4,645	5,098	5,542	5,936	6,336	6,391	7,082	7,748	8,327	8,926	9,093
	Area C	1,080	1,130	1,170	1,180	1,220	1,140	1,190	1,240	1,260	1,300	1,300	1,380	1,450	1,480	1,540	-
	Area D	3,380	3,650	3,930	4,160	4,400	3,810	4,120	4,460	4,730	5,020	5,080	5,550	6,070	6,460	6,900	-
	Area E	500	550	590	630	680	570	630	680	730	780	780	880	950	1,020	1,100	-
	Area F	560	620	680	720	770	640	710	780	840	900	900	1,000	1,110	1,190	1,280	-
	Total	28,720	31,448	34,003	36,341	38,637	32,805	36,029	39,118	41,911	44,670	44,998	49,869	54,510	58,647	62,794	67,153
	≒	28,800	31,500	34,000	36,400	38,700	32,800	36,100	39,200	42,000	44,700	45,000	49,900	54,600	58,700	62,800	67,200
	TOTAL	56,080	60,198	64,343	68,491	72,787	62,685	67,539	72,578	77,481	82,680	89,108	96,519	104,000	111,297	119,314	123,673
	≒	56,100	60,200	64,400	68,500	72,800	62,700	67,500	72,600	77,500	82,700	89,200	96,500	104,000	111,300	119,400	123,700

※PAT-PROSANEAR

21.2.2 The trunk and branch sewer design

(1) The catchment area of Lake Billings

(a) Project area in Lake The Billings Lake basin which includes Alvarenga, Lavras and Area A-F has planed three lift pumping stations (EEE01, EEE02 and EEE03). The relation between lift pumping stations and each area is shown below by the illustration (see **Figure 21.2.1**). The section between lift pumping station (EEE03) and the connected point of Couros trunk sewer is called as "Imigrantes trunk sewer"(as generic name).

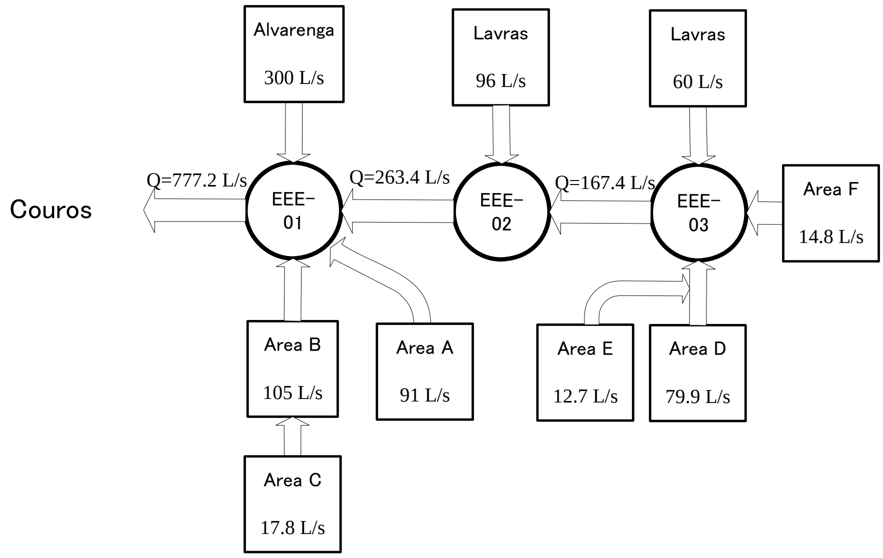


Figure 21.2.1 Imigrantes trunk sewer in the Lake Billings basin

(b) The branch sewers in all of areas (Area A-F) can not be installed legally at present. It is the reason that these areas are not still legalized to illegal residence places called "Requalificação". Comprehensive urbanized project is required for prevention of landslide and erosion measures by heavy rain, storm water drainage planning, formulation of roads, development water supply and electric service. JICA project includes sewerage system implementation and permeable pavement projects, but the urbanization projects except for sewerage system are belonged to the jurisdiction of Sao Bernard do Campo City. It is necessary for sufficient effect of sewerage system to resolve the illegal residence place issue by the urbanization in improvement water qualities of Lake Billings. This sewerage system implementation project of areas A-F was proposed on condition of the urbanization before undertaking the project.

(2) The Couros river basin

The Couros trunk sewer route detours flood-control reservoir and its route of pipe jacking method section is shown in **Figure 21.2.2**. The pipe jacking method is adopted in section A-B of 365 meters and section B-E of 648 meters with diameter 1000 mm. Point F is the crossing point of the Faital River, and point H is the connected point of trunk sewer for IDB project.

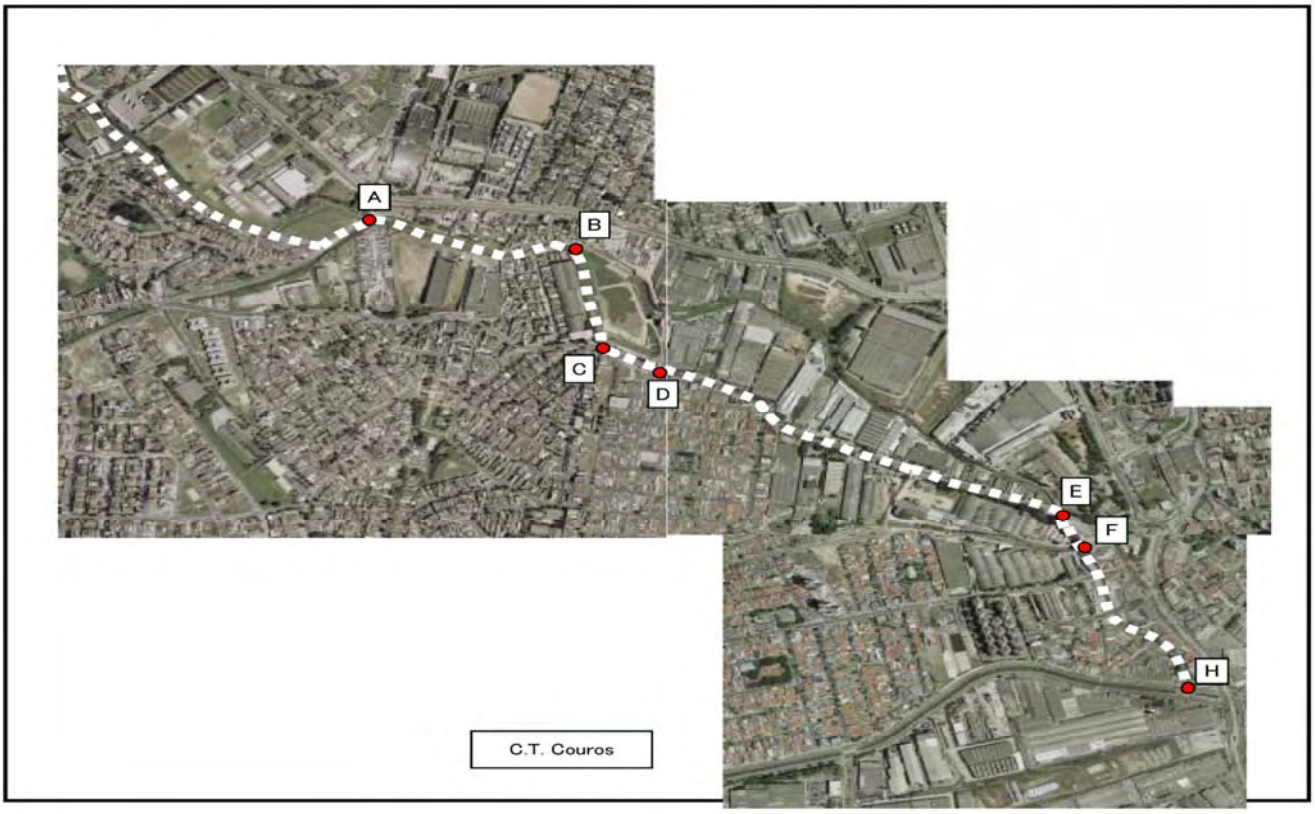


Figure 21.2.2 The route of Couros trunk sewer and sewer longitudinal section

(3) Total sewer length

The length of trunk and branch sewer by diameter is shown in **Table 21.2.2**.

Table 21.2.2 The length of trunk and branch sewer by diameter

	PVC			HP						DP							Total
	φ 200	φ 250	φ 300	φ 400	φ 500	φ 600	φ 900	φ 1000	φ 1200	φ 200	φ 250	φ 350	φ 400	φ 500	φ 600	φ 1000	
Imigrantes				688	891			5						480	614	1,768	4,446
Est.Takagi		1,057					1,263										2,320
Sem Nome		2,975															2,975
JK		1,672	925	1,550													4,147
Camargo		1,088	3,148	589	276												5,101
Feital		1,948	305														2,253
Jurubatuba		2,193	960	3,396	788												7,337
Couros		97					1,585	2,226	451								4,359
Total		11,030	5,338	6,223	1,955		2,848	2,231	451					480	614	1,768	32,938
Alvarenga/Lavras	24,783		900	2,400		1,800											29,883
Area A	4,149										6,078	1,310					11,537
Area B	14,956										6,094		530				21,580
Area C	4,395									3,994							8,389
Area D	10,317										8,412		1,360				20,089
Area E												2,550					2,550
Area F	5,565										4,641						10,206
Total	64,165		900	2,400		1,800				3,994	25,225	3,860	1,890				104,234
TOTAL	64,165	11,030	6,238	8,623	1,955	1,800	2,848	2,231	451	3,994	25,225	3,860	1,890	480	614	1,768	137,172

Unit: m

(4) Land use for space over Couros trunk sewer

The space over the Couros trunk sewer, a maintenance road was planned. Maintenance roads shall be used by maintenance vehicles in an emergency as well as promenade and jogging course for recreational use for the citizens.

Prerequisites and restrictions for the use of the space over the trunk sewer are listed below.

Prerequisites : A maintenance road will be secured for maintenance and repair pipes of SABESP. SABESP needs to purchase or borrow the land from owners for construction/utilization of the road.

Restrictions :

1. The subject section is newly constructed maintenance road space necessary for construction of pipeline except for the existing roads.

2. The maintenance roads of SABESP are 4 meters wide and available for vehicles.

3. When the sewers are installed aside the Couros river, river restoration work shall not be included, but bank protection work shall be accompanied.

The promenade of approximately 1,127 meters will be constructed above the Couros trunk sewer. General plan is shown in **Annex A21.2.1**.

21.2.3 Sewage Pumping Stations

(1) Projected flowrate

Projected flowrate (Qf) are shown in **Table 21.2.3** below:

Table 21.2.3 Discharges Adopted in this Study (L/sec)

YEAR	AVERAGE DISCHARGES (L/sec)			MAXIMUM DISCHARGES (L/sec)		
	EEE-01	EEE-02	EEE-03	EEE-01	EEE-02	EEE-03
2010	200.49	67.11	25.81	325.00	109.01	41.93
2013	210.74	70.56	27.14	343.46	115.22	44.32
2015	393.56	133.05	88.21	630.47	213.45	140.00
2020	420.61	142.07	93.88	679.12	229.50	150.02
2025	447.19	151.17	99.81	726.77	245.84	160.64
Final – Qf				780.0	264.0	168.0

(2) Hydraulic Characteristics and Pumping Station Facilities

Table 21.2.4 below shows a summary of hydraulic portion and motor-pump assemblies of the three Pumping Stations and force mains (also refer to the Calculation Sheet in **Annex A21.2.2)**

Table 21.2.4 Characteristics of Pumping Stations

PARAMETER OR CHARACTERISTIC	EEE-01	EEE-02	EEE-03
Maximum Project Discharge (L/sec)	780	264	168
Number of Pumps in Operation	3	3	3
Discharge per Pump (L/sec)	260	88	56
Level of Minimum N.A. of Suction Well (m)	743.30	745.15	741.33
Level of Discharge Point in Force Mains (m)	822.00	775.60	785.70
HG Geometric Difference of Level (m)	78.70	30.45	44.37
Diameter of Force Mains (mm)	1,000	600	450
Length of Force Mains (m)	1,850	683	355
Speed of Force Mains (m/sec)	0.993	0.934	1.056
Load Loss (mca)	2.65	1.71	1.65
Pressure Head (mca)	81.35	32.16	46.02
Power Consumed by Motor-Pump Assembly (HP)	352	51,7	49,1
Power of Motor of each Motor-Pump Assembly (HP)	450	75	60
Diameter of Pump Suction Pipe (mm)	500	300	250
Diameter of Pump Discharge Pipe (mm)	400	200	200
Diameter of well containing the pump room and the actual suction well (m)	16.00	13.00	11.5
Useful volume of suction well (m^3)	23.4	7.1	5.4
Model of preselected pumps (KSB brand)	LCC-H 200-610	Megaflow K–150-315	Megaflow K-100-400
Required NPSH (mca)	≈ 5.5	≈ 5.0	≈ 5.5
NPSH available (mca)	≈ 9.5	≈ 9.5	≈ 9.5

Table 21.2.5 below shows a general summary of the hydraulic portion and motor-pump assemblies of Pumping Stations in A-F areas of force mains:

Table 21.2.5 Characteristics of Pumping Stations

PARAMETER OR CHARACTERISTIC	AREAS					
	A	B	C	D	E	F
Maximum Hourly Discharge (L/sec)	91	105	17.8	79.9	12.7	14.8
Number of Pumps in Operation including one (1) spare pump	3	3	2	3	2	2
Pump Suction Diameter (mm)	200	200	150	200	100	100
Discharge per pump (m^3/min)	2.8	3.7	1.1	2.4	0.8	0.9
Pressure Head (mca)	14.0	15.0	28.0	15.0	15.0	14.0
Diameter of Force Mains (mm)	350	400	200	400	300	250
Length of Force Mains (m)	1,310	530	270	1,360	2,550	1,400

(a) General Aspects

Buried hydraulic portion of Pumping Stations, which contain the actual hydraulic units, shall be basically constituted of five chambers:

- The first upstream chamber contains the spillway;
- The second chamber contains the grate canals, floodgates and auxiliary equipment;
- The third chamber is the suction well;
- The fourth chamber is the pump room;
- The shallow fifth chamber contains the check valves and stop valves of each pump;

Because of its characteristics, the suction well and the pump room will be installed in a buried circular structure separated by a wall; the spillway chamber and grate channels will be installed in another circular structure also separated by a wall. Both structures are contiguous and appear in the design in the shape of an 8.

The pumping station will also be constituted of a building that will shelter the pump room, electric equipment, and loading and unloading areas. Out of the main building there will be a power substation, a hydro-pneumatic tank and, in the case of EEE-01, a shelter for the emergency generator.

(b) – Spillway Chamber

The spillway chamber will be provided with a floodgate to separate the grate canal. It will be operated manually from the top by a wheel, at the ground level, whenever it shall be necessary to interrupt the sewage flow through the Pumping Station or in the event of power failures.

– Screen Chamber

Screens in Pumping Stations are intended to protect pumps from large solids likely to pass through the pumps and damage them. Each station will be provided with two screens, being one automatic pump for mechanical cleaning, and one spare pump for manual cleaning, which will operate at eventual breakdowns of maintenance of mechanical screens.

Such screens will be installed in parallel channels where the flow may be diverted to any of them through the operation of light floodgates installed in those channels. Such floodgates will also be manually operated by wheel. Chamber and screen dimensions are shown below and in the calculation sheets of **Annex A21.2.2** do this report, as well as in blueprints and cross-section drawings.

- EEE-01 – Width: 1.20 m - Depth: 1.50 m
- EEE-02 – Width: 1.00 m - Depth: 0.65 m
- EEE-03 – Width: 0.80 m - Depth: 0.60 m

Buried reinforced-concrete circular structure that will house the spillway chamber and the screen chamber will have the following internal diameters:

- EEE-01 – Dg1 = 8.30 m
- EEE-02 – Dg2 = 6.60 m
- EEE-03 – Dg3 = 5.65 m

Access to screens will be made by a stairway mounted on the internal side of the well. Screened material should be removed by grab buckets operated by rotating arms provided with an electric hoist. The well will be protected by a guardrail and provided with a 20-cm high wall to prevent the egress of surface runoff water.

– Suction Well

Diameters of the circular concrete structure that will house the suction well and the pump room are shown below; however, the actual suction well will be separated by a vertical wall in the form of a bowstring with the following sweepbacks (see project drawings):

- EEE-01 – Db1 = 16.00 m - Sweepback1 = 5.45 m
- EEE-02 – Db2 = 13.00 m - Sweepback2 = 4.35 m
- EEE-03 – Db3 = 11.50 m - Sweepback3 = 3.85 m

The suction well will be provided with a surge mitigating basin to prevent turbulences likely to impair the flow inside the well. Suction well will also be provided with fillings to avoid dead volumes and minimize the time of permanence of sewage in the well.

The well will open to the atmosphere and be protected by a guardrail and a 20-m high wall to prevent the egress from surface runoff water.

– Pump Room

The chamber that will house the motor-pump assemblies (pump room) will occupy the remaining circle dimensions excluding the part corresponding to the suction well. Dimensions were considered to house slackly the motor-pump assemblies, suction mains, suction valves, disassembly joints, circulation between pieces of equipment, access stairway and drainage well operated by auxiliary pumps. Project drawings show the general equipment arrangement.

All pumps previous selected by manufacturer are provided with axial suction and upward radial discharge, both provided with flanged. Dimensions of motor-pump bases are:

- EEE-01 motor-pumps – 1,200 mm x 4,000 mm – 4 assemblies;
- EEE-02 motor-pumps – 970 mm x 2,030 mm – 4 assemblies;
- EEE-03 assemblies – 970 mm x 2,200 mm – 4 assemblies.

The pump was positioned to such a height to allow the suction mains to be submerged below the maximum suction well water level at startup and primed at all times. This condition determined the level of the pump room bottom.

Access to motor-pump assemblies shall be made through a concrete stairway mounted on the internal side of pump room well.

– Main Pumping Station Building

Main pumping station buildings were designed to cover the pump room and house the electric equipment and compressors and maintenance material. They will also be provided with a material loading and unloading area. Such buildings will be provided of rolling bridges for equipment assembly and maintenance.

Building are designed to be laterally closed by hollow tiles for ventilation, and provided with lateral windows for natural lighting. Internal dimensions of buildings are:

- EEE-01 - 11.5 m x 32.0 m = 368 m²
- EEE-02 - 13.0 m x 20.0 m = 260 m²
- EEE-03 - 8.5 m x 24.0 m = 204 m²

– Valve Box

Valve boxes should include the check valves of pump discharge pipes, an assembly joint, and a locking slide valve. Boxes will be made of concrete, buried and covered by a floor grate. In pumping stations EEE-01 and EEE-03, boxes will be placed outside the building, and in pumping station EEE-02, they will be placed inside the building, according to the possible disposition in the available land.

(c) Hydro-pneumatic Tank

For the purposes of this feasibility study, Force Mains will be provided with protection against surges, in the form of Hydropneumatic Tanks located at exits of Pumping Stations. Initially, a 1.45-m^3 tank with a diameter of 2.10 m and 4.20-m high cylindrical portion was designed for EEE-01, for a working pressure of 10.0 kgf/cm^2. For EEE-02 and EEE-03, 2.10-m^3 tanks with diameters of 1.10 m and 2.20-m high cylindrical portion were designed, for a working pressure of 5.0 kgf/cm^2. The system is complemented by air compressors to replace the air lost and dissolved in sewage.

(d) Electric Installation

– Substations

Because of the relatively high power of its motors, Pumping Station EEE-01 will be provided with a 2,000-kVA ground-level substation protected by a building exclusive for transformers, measurement and other equipment.

Because of their relatively low power, Pumping Stations EEE-02 and EEE-03 will be provided with a transformer mounted on a post, without any additional building.

– Emergency Generators

All Pumping Stations will be provided with emergency generators for eventual power failures. Such generators will be housed by a specific building, and their power will be consistent with the pump motors: 2,000 kVA for EEE-01 and 250 kVA for EEE-02 and EEE-03.

– Electromagnetic Outflow Meter

Pumping Stations will be provided with electromagnetic outflow meter. Preliminarily, this feasibility study provides for flanged reel-type meters with the same diameter as the force mains. Such meters are to be installed in specific buried boxes, which will also contain a general valve for the force mains discharge and an assembly joint.

(e) – Auxiliary Systems

Pumping Stations will also be provided with auxiliary systems comprising:

- Pressure water systems for equipment wash and sanitary uses, constituted of a reservoir, pumping system, piping, etc.;
- Deodorization system which may include the addition of lime to screened material, or mist formation by spraying special products mixed to water for encapsulation of screened material and, if necessary, the actual suction well surface;

- Rainwater drainage constituted of rainwater collectors (roof gutters, conductors, gully-holes, grates, etc.) and galleries to the nearest channel;
- Exhaustion and ventilation, especially in EEE-01 where motors have a relatively high power and eventually require forced ventilation, to be considered during the subsequent stages of project;
- Acoustic protection, the need of which should be considered in the subsequent stages of project, constituted of acoustic panels in the pump room, mounted on metallic structures;
- Drainage system in the dry well of main motor-pump assemblies, constituted of duct, collecting well, submerged motor-pump assemblies to be installed in the collecting well, and piping to convey the effluent back to the main suction well.

(f) - Urbanization

Area urbanization comprises the protective fence, gate, pavement of operation and building access areas, curbs, gardens in remaining areas, access ways to the station, etc.

The layout and cross-section of Pumping Station EEE-01 are shown in **Figure 21.2.5**. Drawings of Pumping Stations EEE-01, EEE-02 and EEE-03 are shown in **Annex A21.2.3** to this report.

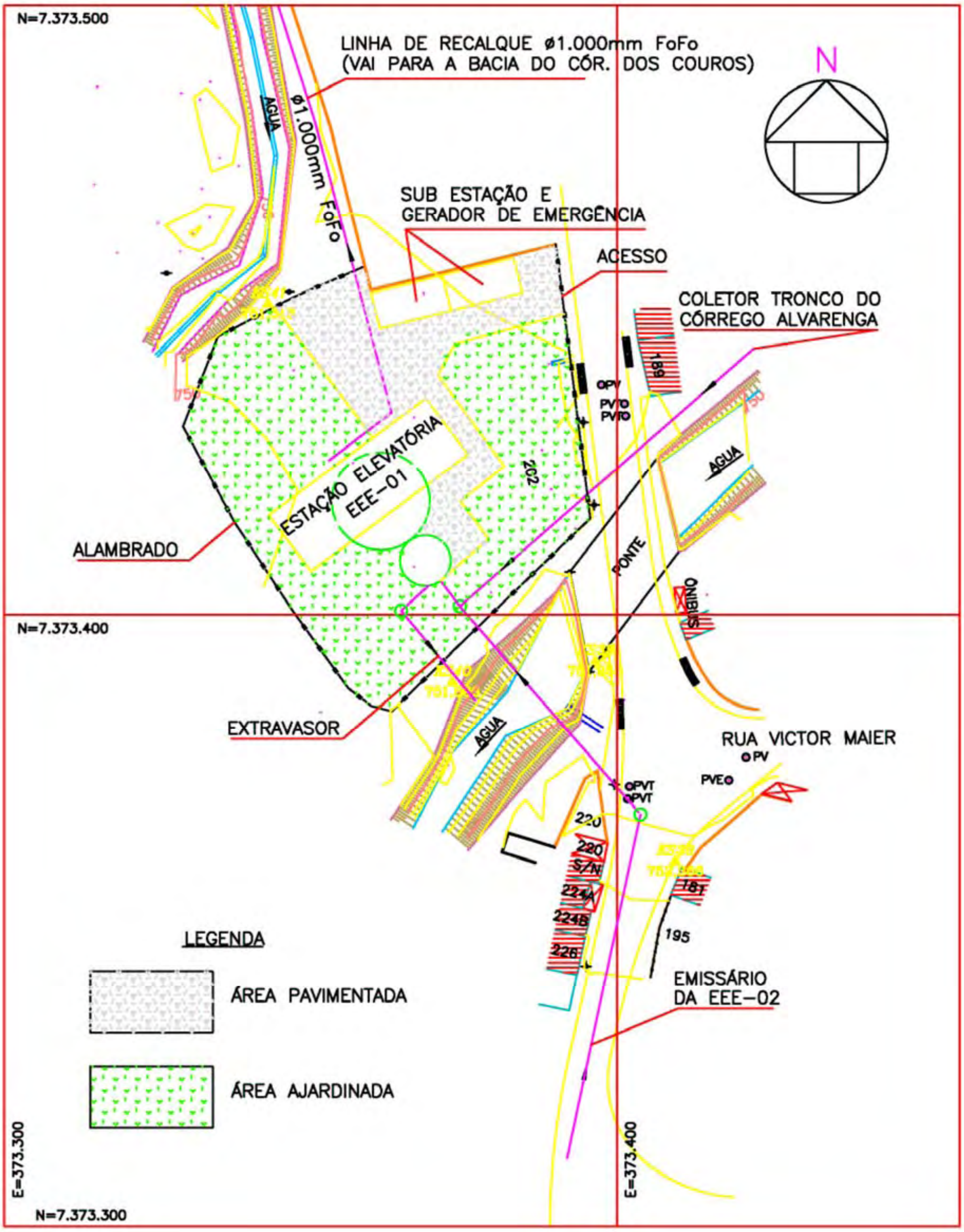


Figure 21.2.5 Drawings of Pumping Stations EEE-01

21.3 Implementation Plan

21.3.1 Soil Condition

Results from soil analysis are shown in **Table21.3.1**.

Table 21.3.1 Analysis of Soil Conditions

Area	Soil layer composition and structure	Ground condition	Ground water level and permeability
Couros main drainage line (Pump station portion)	Landfill, Quaternary deposit (clay, silt, sand), hard weathered portion of basement rocks are distributed. <Landfill> Main component; sandy silt, Layer thickness; 1.0 m to 4.8m <Quaternary> Layer thickness; 3.5～6.0m, clay and silt in upper and middle portion, sand and sand with gravel in lower portion <Base rock weathering portion> Schist lies under 9.0m of depth. Granite lies under 6.7 m of depth. Gneiss lies under 6.7m. Very soft clay and silt in upper portion, Sandy silt and silty sand in middle and lower portion	<Landfill> N-SPT3-4, partly 2 <Quaternary> N-SPT 0-2 in clay and silt, 1-9 in sand, partly 21 in sand with gravel, Max. 2m of layer thickness is very thin. <Base rock weathering portion> N-SPT 2-4, very soft, layer thickness 3-4m under upper boundary. N-SPT>10 under 5m from the boundary, N-SPT>15 under 5-10m from boundary, N-SPT>30 under 6-14 m from the boundary. <Very soft layer> Under 7m to 9m from the surface <Bearing layer> Under 15m to 19m from the surface as a pile foundation	<Ground water> Almost Correspondence to the adjacent river water level, 1.49 to 4.70m <Permeability> Hard weathered portion; k= 3.35 x 10^{-5} cm/sec。 Transmissivity k= 1x 10^{-3} cm/sec.
Couros main drainage line (Vertical shaft for shield tunneling portion)	Landfill, Quaternary deposit (clay, silt, sand), hard weathered portion of Tertiary deposit and basement rocks are distributed. <Landfill> Main component; sandy silt, Layer thickness; 1.0 to 2.0 m <Quaternary> Layer thickness; 5.0 to 6.8m, Sandy silt in upper portion, Sand, sand with gravel, sandy clay and sandy silt in lower portion <Tertiary weathering potion> Main component; silt and sandy silt, Distribution; under 6.0 m of depth, under 8.0 m of depth. <Base rock weathering potion> Main component; silt, sandy silt and silt sand, Kaolinite formed by hard weathering of felsic rock.	<Earth fill> N-SPT 3-4 <Quaternary> N-SPT 0-4 in clay and silt, 8-9 in sand and sand with gravel, especially very soft condition. < Tertiary weathering potion> N-SPT 3-10 <Base rock weathering potion> N-SPT 3-4, very soft layer, thickness; 3m under the upper boundary. N-SPT>15 lies under 4-6m of depth from the surface. N-SPT>20 leis under 8-9m of depth from the surface. N-SPT>30 leis under 8-13m of depth from the surface, but there is medium dense portion in deeper section. <Very soft layer> Distribution; up to 3m to 7m.	<Ground water> 2.90 to 9.65 m , Correspondence to the adjacent river water level. <Permeability> Transmissivity k= 2.21 x 10^{-3} cm/sec in sand with gravel, k= 4.96 x 10^{-5} cm/sec in Tertiary hard weathering portion, k= 2.90 x 10^{-4} cm/sec in base rock hard weathering portion.
Couros main drainage line (Gravity flow pipe line portion)	Earth fill and Quaternary deposit (clay, silt, sand) are distributed along the Couros river. Landfill, Quaternary deposit (clay, silt, sand), and hard weathered portion of Tertiary deposit and basement rocks are distributed in upper channel of Takagi area. <Earth fill> Main component; sandy silt, Layer thickness; 1.0m along Couros river, 7.5m in Takagi because of thick earth fill for road <Quaternary> Main component; clay, sandy silt and silt sand, Layer thickness; 4.0m and more along the Couros river, 1.0m in Takagi area <Base rock weathering potion> Main component; sandy silt, Distribution; under 9.0m of depth from surface in Takagi area.	<Earth fill> N-SPT 1-6 <Quaternary> N-SPT 0-2, partly 4 <Tertiary weathering potion> N-SPT 2, very soft <Base rock weathering potion> N-SPT 3, very soft	<Ground water> 2.70 to 3.17m <Permeability> Transmissivity k= 1.17 x 10^{-5} cm/sec in sandy silt

21.3.2 Construction Method

(1) Trunk and Brunch sewer

(a) The selection of pipe jacking methods must take the followings into account, a diameter of sewer, jacking length, soil condition and influence of circumference environment. As the result of the comparative study among thick slurry system, slurry system and soil pressure system, thick slurry system is adapted for this project. (see **Annex A21.3.1**)

Pipe jacking method : Thick slurry system
Jacking length : L1=365m, L2=648m
Diameter of sewer : 1000 mm, concrete

Starting and arrival shafts : The shape of shift is circle due to the construction and costs. The earth retaining process firstly excavates the circular shaft. Secondly, the reinforcing bars are installed inside wall. Finally, the earth retaining wall will be built by shotcrete. The pipe jacking could start after concrete work.

(b) The minimum diameter of trunk sewer shall be 250 mm because branch sewers have already been installed the Couros river basin. Pipes material is polyvinyl chloride. The minimum diameter of trunk sewer shall be 200 mm of polyvinyl chloride in the Billings Lake basin.

(2) Sewage Pumping Stations

(a) The pumping stations, composed of dry well and wet well with superstructure for housing of screen/grit chamber room and pump room were designed in the form of two geminated circles.

(b) The implementation requires ground water level lowering method which is considered more cost-effective than chemical feed method for cut-off of water. Even though it may cause subsidence of the land in the surrounding area, since the Pumping Stations are located in extensive self-owned land with no neighboring constructions, choice of lot locations may solve the problem.

(c) Walls of wells are coated with shotcrete for the outer layer, and cast-in place concrete for the inner main concrete structure. Reinforcement shall be designed as required.

(d) Construction sequence shall be designed according to the structure and site condition.

(e) Low-deep valve boxes will be constructed in the conventional manner, including excavation, construction of concrete box, and refill of external part.

(f) The housing structure shall be constructed in a conventional manner.

21.3.3 Implementation Schedule

(1) Trunk and Branch sewer

In implementation schedule, the first construction (Lot 1) will start in 2010 for the lift pumping stations (EEE01-03), trunk and branch sewer in Alvarenga/Lavras areas, the Couros trunk sewer, force main and Est.Takagi trunk sewer. The connecting point of the Couros in this project is the end of Jurbatuba trunk sewer. The pump capacities can correspond to the design maximum hourly sewage flow in target year 2025.

The second construction (Lot 2) will start in 2011 for trunk and sub-trunk sewers in Area A-F and main manhole type pumping stations.

The third construction (Lot 3) will start in 2012 for the branch sewer of Area A-F.

Although the second and third constructions are usually simultaneously, these Lots are divided due to the adjustment of legalized residence, the change of residence and urbanization (roads, electricity, storm water drainages and the slope stability).

(2) Sewage Pumping Stations

Execution of construction work is expected to take 24 months as shown below.

Table 21.3.2 Implementation Schedule of Pumping Station

Project for Sewage Reversion in Alvarenga, Lavras Basins and Areas "A", "B", "C", "D", "E" and "F"
Implementation Schedule of Works or Pumping Stations EEE-01, EEE-02 and EEE-03

ACTIVITY	MONTHS																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1 – Installation of Work Site	■																							
2 – Earthworks in Pumping Station Areas		■	■																					
3 - Installation of Water table Drawdown System				■																				
4 – Construction of Wells					■	■	■	■	■															
5 – Construction of Valve Boxes													■	■										
6 – Construction of Main Building										■	■	■	■	■										
7 – Construction of Auxiliary Buildings												■	■	■										
8 – Assembly of Equipment														■	■	■	■	■	■	■				
9 - Tests and Commissioning																			■	■	■	■	■	
10 - Preoperation																								■
11 – Building Finish																						■	■	■
12 – Area Urbanization																						■	■	■

21.4 Operation and Maintenance Plan

Operation and maintenance shall be conducted by SABESP. SABESP have established guidelines for maintenance and operation manuals for each station.

Suggestions for the operation and maintenance of pumping stations under this Project are listed below:

(1) Automatic control

The operation shall be controlled by measurement of the water level in the suction well, the head of pressure pipeline or flowrate. In most cases, control is made by water level in the suction well. Discharge may be controlled as follows;

- Number of operating pumps
- Variation of pump discharge by frequency inverters
- Throttling of pump discharge valves

(2) Automation

Each Station should be provided with:

- Water level, electro-magnetic flow meter;
- Electric pressure detector and electric butterfly valve
- Limit switch or safety device for discharge valve
- Solenoid valve for starter/trip air pipeline

(3) Protection

Pumping Stations should be protected against the following operating accidents through alarm sound and visual alarms on the panel and eventual equipment switching off:

- Electric power failure causing surges: Hydro-pneumatic tank ready for operation with open valve and insufficient air quantity
- Excess or deficient electric voltage;
- Low suction well level without the proper motor-pump switching off;
- Excessively high ambient temperature;
- Excessively high motor temperature;
- Failure at startup or trip of motor-pump assemblies;
- Pump operating with low or no discharge;
- Very high or very low rotation of motor;

21.5 Implementation Cost

21.5.1 Construction Cost

(1) Total Construction Cost

The estimated cost of implementation of works is shown in **Table 21.4.1**. Unit cost of force mains and trunk line is shown in **Annex A21.5.1**.

Table 21.4.1 Total Construction Cost

Units	Diameter (mm)	Material	Length (m)	Unit Cost (R$/m)	Total Cost (R$)
Transport System (Lot 1)					
CT and Secondary CT	400	HP	6,223	502	3,123,946
	500	HP	1,955	589	1,151,495
	900	HP	2,848	1,014	2,887,872
	1,000	HP	1,062	1,129	1,198,998
	1,200	HP	451	1,357	612,007
	250	PVC	11,030	355	3,915,650
	300	PVC	5,429	396	2,149,884
Connection with CT			131	3,000	393,000
Subtotal (1)					15,432,852
MIND	1,000	HP	1,169	5,000	5,845,000
C.T.Alvarenga	Pat-Prosanear				1,317,000
C.T.Lavras	Pat-Prosanear				1,470,000
Sewerage Networks Alvarenga/Lavras			24,483	300	7,344,900
Alvarenga Connection			55	3,000	165,000
Lavras Connection			34	3,000	102,000
Subtotal (2)					16,398,900
Pumping Station EEE01			1		9,039,989
Pumping Station EEE02			1		3,459,895
Pumping Station EEE03			1		3,138,312
Force Mains	500	DP	480	852	408,960
	600	DP	614	1,046	642,244
	1000	DP	1,768	2,061	3,643,848
Subtotal (3)					20,333,248
Use of upper of Couros			1,127	764.24	861,298
Withdrawal of above Couros			1		1,700,027
Grand Total Lot(1)					54,571,325

Secondary CT and Pumps in Areas A - F (Lot 2)					
Area A	EEE		1		3,328,669
	Force Mains	D=350	1,310	597	782,070
Area B	EEE		1		3,328,669
	Force Mains	D=400	530	680	360,400
Area C	EEE		1		2,511,491
	Force Mains	D=200	270	415	112,050
Area D	EEE		1		3,328,669
	Force Mains	D=400	1,360	680	924,800

Area E	EEE		1		2,473,322
	Force Mains	D=350	2,550	526	1,341,300
Area F	EEE		1		2,511,491
	Force Mains	D=250	1,400	469	656,600
Grand Total Lot (2)					21,659,531

Sewerage Networks and Connections in Areas A - F (Lot 3)					
Sewerage Networks					
Area A	Force Mains		6,078	469	2,850,582
	Gravities		4,149	300	1,244,700
Area B	Force Mains		6,094	469	2,858,086
	Gravities		14,956	300	4,486,800
Area C	Force Mains		3,724	469	1,746,556
	Gravities		4,395	300	1,318,500
Area D	Force Mains		8,412	469	3,945,228
	Gravities		10,317	300	3,095,100
Area E	Force Mains		0	469	0
	Gravities		0	300	0
Area F	Force Mains		3,241	469	1,520,029
	Gravities		5,565	300	1,669,500
Submerged Pumps			72	150,000	10,800,000
Connections			8,400	200	1,680,000
Grand Total Lot (3)					37,215,081
Grand Total (Lot(1) + (2) + (3))					113,445,937

(2) Construction Cost of Pumping Stations

Details of estimated costs are shown in **Annex A21.5.2**. Their summary is shown in **Tables 21.5.2** and **21.5.3** below:

Table 21.5.2 Construction Cost of Pumping Stations （Unit：R$）

ITEM	DESCRIPTION	EEE-01	EEE-02	EEE-03
1	CIVIL WORKS	1,635,551	1.026.941	897.594
2	MECHANICAL EQUIPMENT	2,663,148	813.450	696.605
3	ELECTRIC INSTALLATION	4,078,560	1.192.800	1.147.040
4	PLUMBING	381,722	145.696	116.065
5	MISCELLANEOUS	124,000	124.000	124.000
6	URBANIZATION	157,008	157.008	157.008
	TOTAL	9,039,989	3.459.895	3.138.312
	GRAND TOTAL	**15,638,196**		

Table 21.5.3 Total Cost of Sewage Pumping Stations – Areas A - F and Submerged Pumps

（Unit：R$）

ITEM	DESCRIPTION	ÁREA A	ÁREA B	ÁREA C	ÁREA D	ÁREA E	ÁREA F
1	CIVIL WORKS	947,715	947,715	476,519	947,715	476,519	476,519
2	MECHANICAL/EQUIPMENT	761,450	761,450	569,363	761,450	569,363	569,363
3	ELCTRIC/INSTALLATION	1,192,800	1,192,800	1,147,040	1,192,800	1,147,040	1,147,040
4	PLUMBING	145,696	145,696	116,065	145,696	77,896	116,065
5	MISCELLANEOUS	124,000	124,000	124,000	124,000	124,000	124,000
6	URBANIZATION	157,008	157,008	78,504	157,008	78,504	78,504
	Total	3,328,669	3,328,669	2,511,491	3,328,669	2,473,322	2,511,491
	GRAND TOTAL	17,482,311					

Value adopted for calculation of each of 72 intermediate pumps (submerged pumps) amounted to R$ 150,000.00 (Source: SABESP).

21.5.2 Maintenance Cost

Maintenance Cost comprises 2 parts: Power costs and Operation and Maintenance costs. Power cost was calculated by the formula shown in **Chapter 12**

Operation and Maintenance Cost was calculated at 5% of total cost of pumping station construction less civil works. According to SABESP, there is no estimated overhead for trunk lines and sewerage networks.

(1) Power Cost

Table 21.5.4 Power Cost

Ano	EEE-01, EEE-02 e EEE-03				Áreas A a F							Bomba Submersa	TOTAL GERAL
	EEE-01	EEE-02	EEE-03	TOTAL	Área A	Área B	Área C	Área D	Área E	Área F	TOTAL ÁREAS	Valor R$	Valor (R$x1.000)
2013	284.924	41.342	23.730	349.996	-	-	-	-	-	-	-	18.792	369
2014	289.613	42.025	24.123	355.761	-	-	-	-	-	-	-	19.102	375
2015	530.797	77.758	76.815	685.370	14.250	16.443	2.787	12.512	1.989	2.318	50.299	331.190	1.067
2016	538.220	78.829	77.818	694.867	14.447	16.671	2.826	12.685	2.017	2.017	50.662	335.779	1.081
2017	545.643	79.899	78.822	704.364	14.645	16.899	2.864	12.859	2.044	2.044	51.355	340.369	1.096
2018	553.066	80.970	79.825	713.861	14.842	17.127	2.903	13.032	2.072	2.072	52.047	344.958	1.111
2019	560.489	82.041	80.828	723.358	15.040	17.354	2.941	13.206	2.099	2.099	52.740	349.547	1.126
2020	567.912	83.111	81.831	732.854	15.237	17.582	2.980	13.379	2.127	2.127	53.432	354.136	1.140
2021	575.203	84.193	82.883	742.279	15.433	17.808	3.018	13.551	2.154	2.154	54.119	358.690	1.155
2022	582.493	85.275	83.934	751.702	15.629	18.034	3.057	13.723	2.182	2.182	54.806	363.244	1.170
2023	589.783	86.356	84.985	761.124	15.825	18.260	3.095	13.895	2.209	2.209	55.493	367.797	1.184
2024	597.074	87.438	86.037	770.549	16.021	18.487	3.133	14.067	2.236	2.236	56.180	372.351	1.199
2025	604.364	88.519	87.088	779.971	16.217	18.713	3.172	14.239	2.264	2.264	56.867	376.904	1.214

(2) Cost of Operation and Maintenance

Estimated Operation and Maintenance costs for Pumping Stations EEE-01, EEE02 and EEE-03, Areas A - F and Submerged Pumps are shown in **Table 21.5.5** below.

Table 21.5.5 Operation and Maintenance Costs

（Unit：R$）

Year	EEE-01, EEE-02 & EEE-03				Areas A-F							Submerged Pump	GRAND. TOTAL
	EEE- 01	EEE- 02	EEE- 03	TOTAL	Area A	Area B	Area c	Area D	Area E	Area F	TOTAL	R$	R$ x 1,000
2013	362,372	113,797	104,186	580,355	-	-	-	-	-	-	-	60,000	640
2014	362,372	113,797	104,186	580,355	-	-	-	-	-	-	-	60,000	640
2015	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2016	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2017	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2018	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2019	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2020	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2021	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2022	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2023	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2024	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746
2025	362,372	113,797	104,186	580,355	111,197	111,197	97,823	111,197	95,915	97,823	625,154	540,000	1,746

Detailed calculation sheet of Power and Operation and Maintenance costs for Pumping Stations EEE-01, EEE-02 and EEE-03 are shown in Annex t to this report.

(3) Expropriation Cost

Expropriation cost presented by the Municipal Government of São Bernardo do Campo – Strategic Planning Department in July 2006 amounted to R$ 1,480,000 (One million four hundred and eighty thousand reais). This amount just considers the expropriation of a 4-m wide strip along the Sewage Trunk Line to be constructed under this project.

More detailed data are shown in **Annex A21.5.3** to this report.

Chapter 22

SEWERAGE IN THE ISOLATED SMALL COMMUNITIES

22. SEWERAGE IN THE ISOLATED SMALL COMMUNITIES

22.1 Study on fundamentals

(1) General Situation

1) Existing condition

< Riacho Grande >

Area of Riacho Grande is equipped with sewerage facilities. Outline is as follows; Area about 25 hectares with about 6.3 km of pipeline extension, treatment by oxidation ditch method. (Lot of Sewage Treatment Plant A=7,350m^2, treatment capacity of OD V=450 m^3, current inflow Q=1,000 m^3/day, population served P=1000 / 0.130 = 7,700)

The population concentrates on the area and about 15 thousand people are living. About 51% of the residents are served with the sewerage, and the remaining are using septic tanks, pumping up and direct discharge. From the point of view of preserving water quality in the Lake and prevention of pollution of underground water, it is necessary to control the no-connected population.

2 areas have been showing sharp growth in the last years, that is Santa Cruz east of Riacho Grande, and the neighboring areas of Areiao and Jussara of the opposite shore to the north of Riacho Grande. Both have been spilling raw sewage directly to the lake.

< Caperinha >

The area of Caperinha has a population of about 5 thousand people. Approximately 650 m3/day of sewage has generated and discharged to the Lago Nacemandy. Depending on the level of the water, Lago Nacemandy's water flows to Rio Grande through pipe existing underground of the Rodovia Anchieta. Exact position and section of the pipe is not known. The quality of Lago Nacemandy's water is considered to be worse than that of Riacho Grande. By collecting sewage at the low part of the area and pumping up for 3,000 m, it is possible to send sewage to ETE*) Riacho Grande.

*) Remarks: ETE is Sewage Treatment Plant

< Areiao and Jussara >

In the areas of Areiao and Jussara, installation of sewers was made partly and all the sewage goes down Rio Simoes to the Billings Lake without treatment. Existing population of these areas is approximately 12 thousand, and about 1,600 m3/day of sewage with no-treatment is discharged to the Billings Lake. As for the arm Rio Simoes inflows, BOD shows 5mg/L which is the limit of allowable value, DO shows 3.3 mg/L which is lower than limit, the coliform shows 2.7x10^4 beyond the limit. It is possible to send sewage to ETE*) Riacho Grande by pumping for about 2,200 m in the route of Rodovia Anchieta.

Table 22.1.1 Fundamentals for Riacho Grande

Area	Population	Flowrate	Water Quality		
	number (2005)	m^3/day	BOD (mg/L)	OD (mg / L)	T-coli
Santa Cruz	4,887	625.5	No data for Lago Nacemandy		
Areiao / Jussara	12,232	1,565.7	5	3.3	2,7x104
Total	17,119	2,191.2			

Amount of sewage: Amount of daily sewage medium, population x 160 L/capita-day x 0,8

< ETE Riacho Grande >

ETE Riacho Grande uses oxidation ditch method and treatment capacity is, judging from capacity (450 m^3), 450 m^3 to 675 m^3, although inflow of 1,000 m^3/day (equivalent to population of about 7,700 people) is reported. Device of aeration is Kessener brushes. Inflow flowrate is beyond capacity of aerator. Discharge is made to the Billings Lake directly. Excess sludge is treated by sludge drying bed and disposed at the land fill.

2) Basic concept

< Integration of each area and method of sewage treatment >

As it was mentioned previously, the areas of the Riacho Grande, Caperinha and Areiao / Jussara are close to each other and it is possible to treat them in ETE Riacho Grande.

< Sewage pipelines >

As for the areas without sewers of the area of Riacho Grande, there is already a program of SABESP for construction. It is also necessary to install sewage pumping stations to pump sewage to ETE. These will be executed in the same program.

As the area of Areiao already has sewers and most of the area is dangerous zone with steep slope new sewers won't be installed. Pipelines of transmission from the existing network will be newly constructed with a sewage pumping station. As in a part of the area of Jussara, there exist sewers. The sewers shall be expanded to cover the whole area.

3) Plan of sewerage in Riacho Grande

The several elements of the sewer project for the area of Riacho Grande and its outskirt are shown below. The involved areas are presented in the **Figure 22.1.2**.

With this project, 1.8 tons of BOD / day, 657 tons of BOD / year shall be decreased.

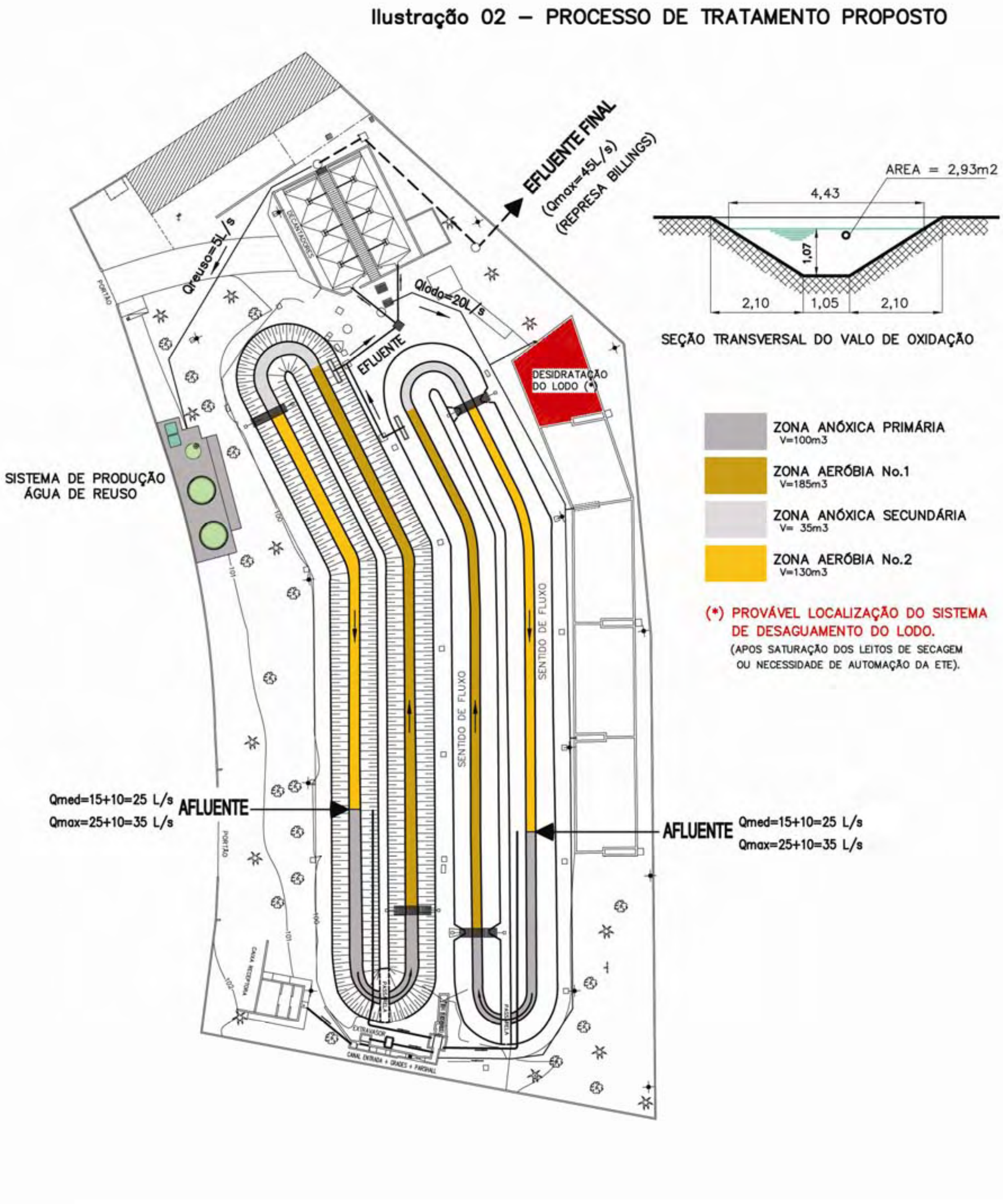


Figure 22.1.1   ETE Riacho Grande (present state)

Figure 22.1.2 The project area of Riacho Grande

Table 22.1.2 Plan of Sewerage in the Riacho Grande area

	2005	2015	2025	Remarks
1. Population with sewer (people)				
Riacho Grande	7700	.	.	
2. Population with projected (people) sewer				
Riacho Grande	7700	15641	16754	
Areiao / Jussara	0	13696	14671	
Caperinha	0	5353	5734	
Sub-total	7700	34690	37159	
3. Extension of the pipelines (m)				
Riacho Grande	6300	32100	32100	214 there are
Caperinha, Areiao / Jussara	0	5100	5100	
Sub-total	6300	37200	37200	
4. Unit Sewage flowrate per capita				
Daily average	128	144	160	L/capita/day
Daily maxim	153,6	172,8	192	
Hourly Maximum	230,4	259,2	288	
5. Projected sewage (m^3/day)				
Daily average	986	4995	5945	
Daily maxim	1183	5994	7135	
Maxim of the hour	1774	8992	10702	
Infiltration Water	272	1607	1607	43,2 m3/km
6. Pollutant load (g/capita-day)				
BOD	54	54	54	
SS	60	60	60	
NT	10	10	10	
PT	1,2	1,2	1,2	
7. Discharge of pollutant (kg / day)				
BOD	416	1873	2007	
SS	462	2081	2230	
NT	77	346,9	371,6	
PT	9,24	41,6	44,6	

(2) Santa Cruz

1) Existing condition

Santa Cruz's area (24ha) is located in inner part of Pedra branca, a sub-basin along the Imigrantes. In this sub-basin about 5,100 people are living and among these, about 70%, 3,400 people concentrate in Santa Cruz's area. According to the policy of Sao Bernardo do Campo, urbanization is planned in this area after Riacho Grande area.

Santa Cruz has existing sewer network with extension of the pipeline about 4.7 km. ETE is not installed and the sewage is flowing out to swamp upstream of Pedra branca. Sludge accumulates in the swamp causing anaerobic condition, effluent from the swamp is polluting the Billings Lake.

There is a distance about 8 km to ETE Riacho Grande and the route crosses the reservoir (500 m). As the cost of pumping stations and pipelines with the maintenance cost is larger than that of small sewage treatment plant, construction of new sewage treatment plant is more advantageous. For the future, it has additional merit of being possible to collect sewage of the neighboring village using spare capacity of treatment of the facilities.

< Condition of Santa Cruz's area >

Around of this area, 2 areas exist relatively close. (Tatetos and Garden IV Centennial) As sewers are not constructed, septic tanks are used in these areas. These areas are inside of environmental preservation area and the construction of house is especially restricted. It is necessary to pay attention that in the master plan of Sao Bernardo do Campo, the areas, except for Santa Cruz's area, are specified to be restricted growth area.

As the existing condition, Tatetos and Garden IV Centennial have about 3,000 people, but population density is very low, with 6 to 8 homes per hectare (about 5 people / home).

Table 22.1.3 Santa Cruz and villages around

	Area	Population		Population density	Distance to Santa Cruz
	hectares	2005	2025	person / there is	km
Santa Cruz	23.86	3,369	4,041	141 to 169	
Tatetos	65.64	2,206	2,558	34 to 39	3.5
Jardin IV Centennial	8.11	219	264	27 to 33	7.0
Total	97.61	5,794	6,863	59 to 70	

< Current water quality>

Water quality of the point in Pedra branca is presented in the **Table 22.1.4**. The type of area of this arm is of “special” class. Legally no any drainage/ effluent are allowed, and water quality should be possible to be drinking water without any treatment. But in the reality due to sewer discharge, water quality is far from drinking level. The area needs urgent improvements.

Table 22.1.4 Quality of the water in the sampling point of 24, 5

Local	Existing population	Amount of sewage	Quality of the water of the discharge destiny			
	(2005)	m^3/day	Position	BOD (mg/L)	OD (mg/L)	T-coli
Santa Cruz	3,369	431	24	6	3,96	1,3x105
Other	1,744	223	5	6	3,69	4,9x105
Total	5,113	654				

2) Basic concept

< Integration and Sewage Treatment >

As for the areas around Santa Cruz, because of low population density and distance of Santa Cruz, sewerage cannot solve the problem economically. It is necessary to strengthen the installation of septic tank properly and control of maintenance of septic tanks for the areas other than Santa Cruz.

<Sewer construction >

As a result of the study on existing pipeline in Santa Cruz, it was discovered that there are a lot of manholes and pipelines that cannot be confirmed. Still, manhole cover is worn out by abrasion, and they have projection with the surface of the roads. First priority should be placed on restoration of the existing pipeline with manholes. Detailed investigation must be made in basic design stage.

< Sewage treatment plant >

One lot for sewage treatment plant was confirmed to be available in Santa Cruz. The area and its location are most favorable for construction of sewage treatment plant.

Area of lot is 5,280 m^2 and location is terminal of existing pipeline, once it was a proposed lot for sewage treatment plant.

The treatment method shall be the same advanced treatment with the one for ETE Riacho Grande: Oxidation ditch method with phosphorus removal by feeding chemical.

Sludge will be transported 8km and treated in ETE Riacho Grande. Sludge shall be thickened by gravity to reduce the volume of sludge. Sludge will be dewatered in ETE Riacho Grande for transportation to dumping site.

3) Elements of the project

The several elements of the project of sewer of Santa Cruz are presented below, with information on the years of 2005, 2015 and 2025.

The treatment scale in 2025 is about 4,000 people with sewage about 980 m^3/day (including infiltration water, daily maximum rate) and about 0.24 t /day of SS discharge.

Through this project 0.2 tons of BOD/day and 73 tons of BOD/year of pollutant load will be decreased.

Table 22.1.5 Plan of sewerage in Santa Cruz

	2005	2015	2025	Remarks
1.Population for sewer				
Santa Cruz	3239			
2. Population projected				
Santa Cruz	3239	3773	4041	
3. Extension of pipeline (m)				
Existing pipeline	3364			
Unconfirmed Pipeline	1310			
Extension of the planned pipeline	4674	4674	4674	
4.Unit rate of sewage (L/capita-day)				
Daily average	128	144	160	
Daily maxim	153.6	172.8	192	
Maximum of the hour	230.4	259.2	288	
5. Planned (m^3/day) sewage				
Daily average	415	543	647	
Daily maxim	498	652	776	
Maxim of the hour	746	978	1164	
Water that penetrates	202	202	202	43.2 m^3/km
6. Discharge of pollutant original (g/capita-day)				
BOD	54	54	54	
SS	60	60	60	
NT	10	10	10	
PT	1.2	1.2	1.2	
7. Discharge of pollutant(kg / day)				
BOD	175	204	218	
SS	194	226	242	
NT	32	37	40	
PT	3,9	4,5	4,8	

22.2 Outline of the facilities

(1) Riacho Grande

The planned sewer pipeline is presented in the **Table 22.1.2**. As for the installation of new sewer pipeline, the minimum diameter of the pipe is 200 mm. The extension of the pipeline is about 5.1 km.

As for ETE, according to the requested treatment level and economy, treatment method was determined as oxidation ditch system with chemical feeding for the advanced treatment. Sludge treatment system shall be multi disk press filter type will be employed without using thickening system. Because of increase the economical efficiency, it was certain to treat the sludge together with sludge from ETE Santa Cruz (later mentioned). Dewatered sludge shall be transported to ETE ABC of about 26 km of distance.

Table 22.2.1 Design Water Quality for ETE Riacho Grande

Indices	2015			2025		
	Inflow (mg/L)	Removal rate	Effluent (mg/L)	Inflow (mg/L)	Removal rate	Effluent (mg/L)
BOD5	292	93.1%	20	265	92.5%	20
COD	583	93.1%	40	530	92.5%	40
SST	324	93.8%	20	295	93.2%	20
PT	6.5	84.6%	1.0	5.9	83.0%	1.0
NT	54	70.0%	16	49	70.0%	15

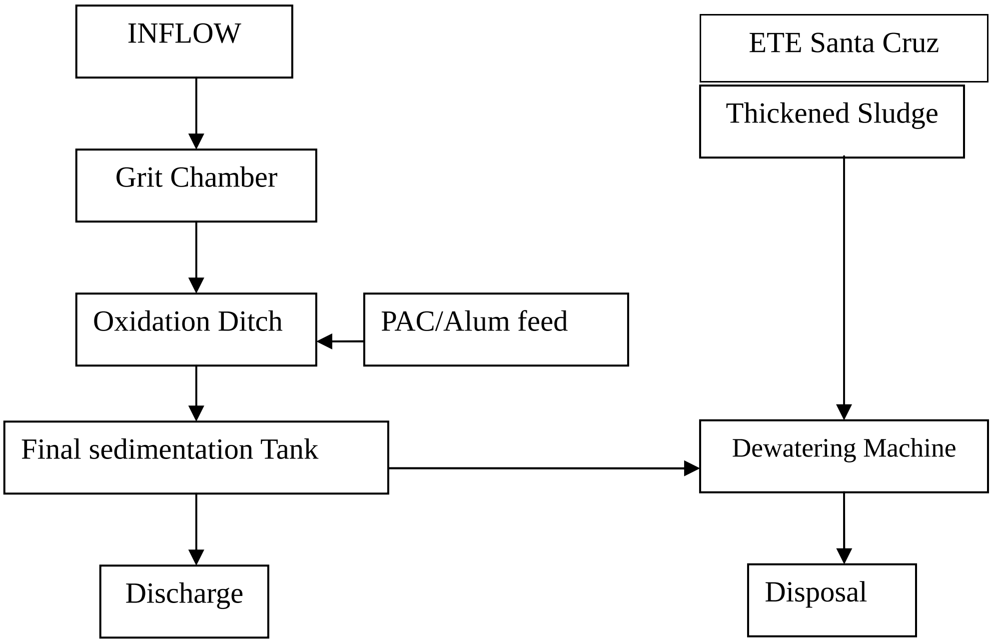


Figure 22.2.1 Flowchart of the treatment in ETE Riacho Grande

Table 22.2.2 Outline of ETE Riacho Grande

Name	Specifications	Qty	Capacity	
Inflow pipe	200 mm	1	Amount of load	0.1206 m^3/s
Receiving manhole	Manhole 1.8 m	1		
Screening/ Grit removal	Screen of stainless steel	.		
Oxidation Ditch	Reinforced concrete Width: 4.0 m Length: 212.6 m Depth: 3.5 m	2	Load of BOD / SS Detention time Capacity load of BOD	0.079 20.2 h 0.31
Aerator	Carousel type 18.5 kW	6	Capacity of provision of oxygen	31.4
Sedimentation tank	of armed concrete Circular Desarenador	2	Discharge area Stationary time	20.1 3.6 h
Chlorination tank	Width: 1.0 m Length: 24 m Depth: 1 m	1	Time of contact	14.6 min
Dewatering machine	Multi disk dewatering machine	2	Rate of sludge load	90 $kg/m^2/h$
Container of sludge cake	Steel plate Capacity 9 m^3	2		
Granular Filtration	450 m^3/day	1		

The facility arrangement in the lot is presented in **Figure 22.2.2** to **22.2.4**.

Figure 22.2.2 The facility arrangement of ETE Riacho Grande (1)

Figure 22.2.3 The facility arrangement of ETE Riacho Grande (2)

Figure 22.2.4 The facility arrangement of ETE Riacho Grande (3)

(2) Santa Cruz

Outline of the pipeline is shown in the **Table 22.1.5**. Minimum diameter of the pipe is 200 mm. The extension of the pipeline is about 4.67 km.

Oxidation ditch method shall be employed as ETE Riacho Grande. Sludge shall be thickened by gravity and transported (8 km) to ETE Riacho Grande.

Table 22.2.3 Design Water Quality of ETE Santa Cruz

Indices	2015			2025		
	Inflow (mg/L)	Removal rate	Effluent (mg/L)	Inflow (mg/L)	Removal rate	Effluent (mg/L)
BOD5	239	91.6%	20	223	91.0%	20
COD	477	91.6%	40	446	91.0%	40
TSS	265	92.5%	20	248	91.9%	20
PT	5.3	81.1%	1.0	5.0	79.8%	1.0
NT	44	70.0%	16	41	70.0%	15

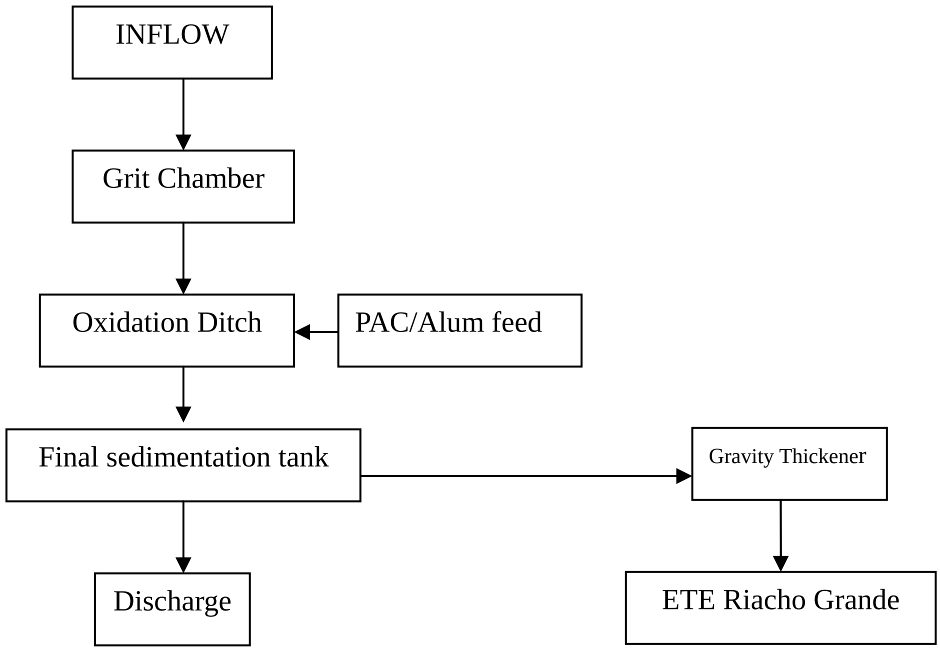


Figure 22.2.5 Flowchart of treatment in ETE Santa Cruz

Table 22.2.4 Outline of ETE Santa Cruz

Name	Specifications	Qty	Capacity	
Load pipe	200 mm	.	Flowrate	0.0158 m^3/s
Reception manhole	Pump of sewer 1.8m	.	Width 80 mm	
Grit chamber	Unit of screen	.		
Oxidation Ditch	Reinforced concrete Width: 5.7 m Length: 58.7 m Depth: 3.0 m	2	Load of BOD / SS Detention time Capacity of load of BOD	0.062 24.6 h 0.22
Aeration device	Screw type	3	Capacity of provisioning of oxygen	6.8
Sedimentation tank	Reinforced concrete Circular Width: 12.7 m Depth: 3.0m	1	Discharge area Detention time	7.7 3.6 h
Chlorination tank	Width: 1.0 m Length: 24 m Depth: 1m	1	Time of contact	14.6 min
Sludge Thickener	2.5 m x 2.5 m	1	Rate of sludge load	28 $kg/m^2/hr$
Sludge Storage Tank	Reinforced concrete Capacity 16 m^3	1		

In the **Figure 22.2.6** facility arrangement is presented.

Figure 22.2.6 ETE Santa Cruz

22.3 Construction Plan

22.3.1 Conditions of the soil

(1) Riacho Grande

It was not possible to confirm the former study of the soil condition at the first construction work. The result obtained in the area of Estoril can be used as example. In the area of Estoril, from 3 to 4 m of the surface layer is of silty soil with low bearing capacity. Lower layer is composed of sand and clay. It is believed that the deep part of the lower layer has enough bearing capacity.

Oxidation ditch is planned for ETE Riacho Grande and has about 5m depth to the base slab, as the load strength is of 60 to 80 kN/m^2, building the foundation directly is possible. Prior to the basic design, it is necessary to do supplemental study of the soil.

(2) Santa Cruz

The study of the soil was not accomplished in this point, but just as in the case of the area of Riacho Grande, result of the area Estoril can be used as example.

Oxidation ditch for ETE Santa Cruz has about 1 m of depth from GL to the base slab. As the load strength is from 40 to 50 kN/m^2, it may be difficult to use as direct foundation. Prior to basic design, it is necessary to conduct a study of the quality of the soil.

22.3.2 Construction Plan

(1) Riacho Grande

< Pipeline >

It was agreed that expansion of the pipeline and its rehabilitation of Riacho Grande area including outskirts shall be made the area with the work of SABESP.

As for the area of Areiao / Jussara and Caperinha, pipeline shall be constructed under this project, except for the secondary pipeline of Areiao area.

The work will start in 2010 and finish in 2011.

For sewage transmission from Areiao / Jussara for ETE Riacho Grande, a pumping station shall be installed. Pressure pipeline shall be constructed along Anchietta underground.

In the area of Caperinha, to collect the sewage in the low part, a sewage pumping station to pump for ETE Riacho Grande shall be constructed in this low part.

< ETE >

Besides removing one of the facilities out of two on the south side which is not being used in the moment, 1st oxidation ditch shall be constructed. After completion of 1st ditch, operation must be started to construct 2nd ditch. The building and equipment for the sludge treatment shall be constructed on the 1st ditch, to make use of the area on the ditch. In the construction of the second line, existing final sedimentation tank shall be removed.

The screw press with multi-disk type will be adopted, since it doesn't need thickening process, considering the efficient use of the limited lot of ETE.

(2) Santa Cruz

< Pipeline >

The maintenance and the repair of the pipeline and manholes shall be made mainly. The work will start in 2010 and finish in 2011. As for about 1,300 m of pipeline and manhole were not confirmed by site investigation, it is necessary to be verified prior to the basic design. Manhole covers are worn out by abrasion and aging and all of them must be changed. Still, height adjustment for the manhole cover and road pavement and removal of the deposited soil in the manhole shall be necessary.

< ETE >

Just as ETE Riacho Grande, it will employ oxidation ditch method with chemical feeding for phosphorus removal. As excavation depth is shallow, there will be few problems in terms of execution of the work.

22.3.3 Construction Schedule

Construction schedule is shown in the **Table 22.3.1**.

Table 22.3.1 Sewerage construction schedule for the isolated area

Classification	Item	2006	2007	2008	2009	2010	2011	2012	2013	Remarks
Design	Detailed Design									
Construction	Pipeline of ID									Santa Cruz Jussara
	ETE RG									OD
	Pipeline of SC									
	ETE SC									OD

ID: Riacho Grande, SC: Santa Cruz, SPT: ETE.

22.4 Operation and Maintenance

(1) Riacho Grande

Pipeline: Since part of the pipelines are old existing facilities, it is necessary to do repair works and change of materials as well as regular maintenance. The subject areas of these activities are Riacho Grande, Jussara and Areiao. Cleaning of the pipeline has little urgency in the moment, but it is recommended to conduct once every 5 years.

Manhole: It is necessary maintenance in the same manner with that of pipeline. Pumping station will be installed in two locations in Caperinha and Areiao / Jussara. Caution must be made to theft of equipments and cables. Also, installment of devices for emergency report that uses the phone line shall be made. The alert of mishaps should be sent to ETE Riacho Grande to be indicated on the CRT. As for the pumping equipment, generally it is possible to expect 15 years durability. But to increase the economy of the facilities, it is necessary to extend its durability through maintenance and change of regular pieces.

ETE Riacho Grande: Maintenance personnel shall be stationed

1) Operation control of ETE Riacho Grande.

Treatment method: Oxidation Ditch + Phosphorus removal by chemical feeding

Daily Maximum Sewage flowrate: 7,100 m^3/day (2025)

Daily Average Sludge Treatment: 9.6 m^3/day (Including sludge of Santa Cruz 2025)

Electrical Capacity of Equipment : about 170 kW

2) Maintenance of the pipeline and pumping stations of Riacho Grande, Santa Cruz and Areiao / Jussara.

3) Remote monitoring of equipment and operation control, examination of water quality of ETE Santa Cruz.

4) Maintenance of Santa Cruz's pipeline

(2) Santa Cruz

This ETE shall be operated from Riacho Grande by remote monitoring. Patrol and maintenance work shall be made routinely.

Capacity of the electric facilities of ETE Santa Cruz: about 45 kW

22.5 Project Cost

22.5.1 Construction cost

Table 22.5.1 Construction cost of ETEs

	Local (R$)	Foreign (Yen)	Remarks
< Riacho Grande >			
Sewer pipeline	3,890,000	0	
ETE	8,537,000	216,500,000	
Sub-total	12,427,000	216,500,000	
< Santa Cruz >			
Lot of STP	216,000	0	
Sewer pipeline	1,030,000	0	
ETE	2,147,000	65,300,000	
Sub-total	3,393,000	65,300,000	
Total	15,820,000	281,800,000	

22.5.2 Maintenance cost

The administration for the two ETEs shall be integrated and ETE Riacho Grande shall be the center of two. Water quality analysis for both ETE will be executed in ETE Riacho Grande.

Table 22.5.2 Maintenance cost of ETEs

	Yearly cost (R$)	Remarks
< Riacho Grande >	QA=5,548m^3/day	
Electricity	163,000	165kW
Chemical	98,000	Coagulant etc
Transportation	123,000	Dewatered sludge7.5m^3/day
Repair of equipment	121,000	3% of equipment price
Wages	166,000	2 personnel
Sub-total	671,000	
< Santa Cruz >	QA=622m^3/day	
Electricity	36,000	44kW
Chemical	5,000	Coagulant etc
Transportation	41,000	Thickened sludge7.2m^3/day
Repair of equipment	74,000	3% of equipment price
Wages	83,000	1 personnel
Sub-total	239,000	
Total	910,000	