Chapter 7

WATER POLLUTION ANALYSIS FOR LAKES AND RIVERS

7 WATER POLLUTION ANALYSIS FOR LAKES AND RIVERS

7.1 Pollution Load Analysis

This report is aimed at creating a water quality simulation model that allows us to explain the present situation of water pollution and make future forecasts, estimating the consequences of possible scenarios using this model and uncovering an effective reduction method for pollution loads.

7.1.1 Preface

The following lists the pollution load terms used in this report and their definitions (see **Figures 7.1.1** and **7.1.2**).

- Generation load: Load generated at point and non-point sources and not yet treated at treatment facilities
- Effluent load: Load discharged after passing through treatment facilities
- Runoff load: Load observed at a certain observation point when an effluent load from point sources and a load from non-point sources are discharged when it rains. Load observed when an attenuation load on the main stream arrives at a water quality check point in the lower reaches of the main stream.
- Attenuation load: Load observed when a pollution load discharged into a waterway or tributary reaches the main stream.
- Inflow Load: Load that flows into a lake
- Effluent Ratio: Ratio of an effluent load to a generation load. Effluent Ratio (1 - Treatment Efficiency)
- Attenuation Ratio: Ratio of an attenuation load to an effluent load
- Transference Ratio: Ratio of a runoff load to an attenuation load
- Runoff Ratio: Ratio of a runoff load to an effluent load.

$$\text{Runoff Ratio} = \text{Attenuation Ratio} \times \text{Transference Ratio}$$

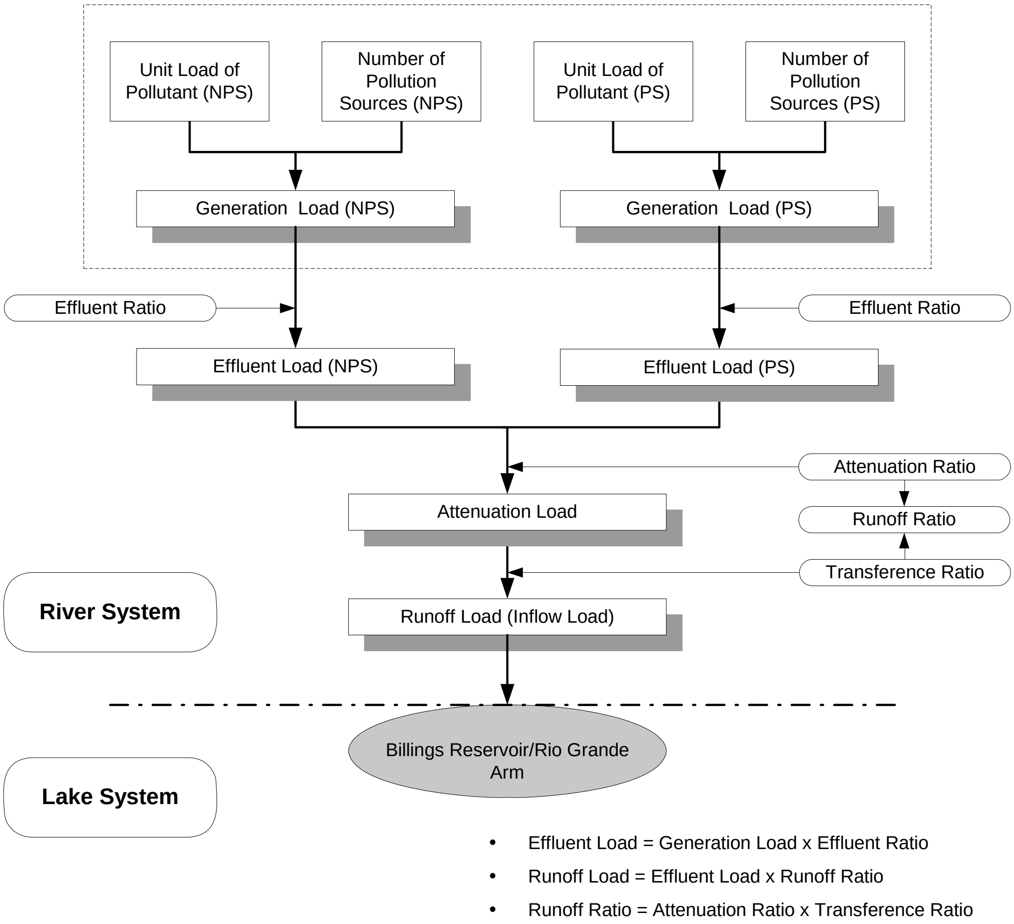


Figure 7.1.1 Definition of technical terms for pollution Load

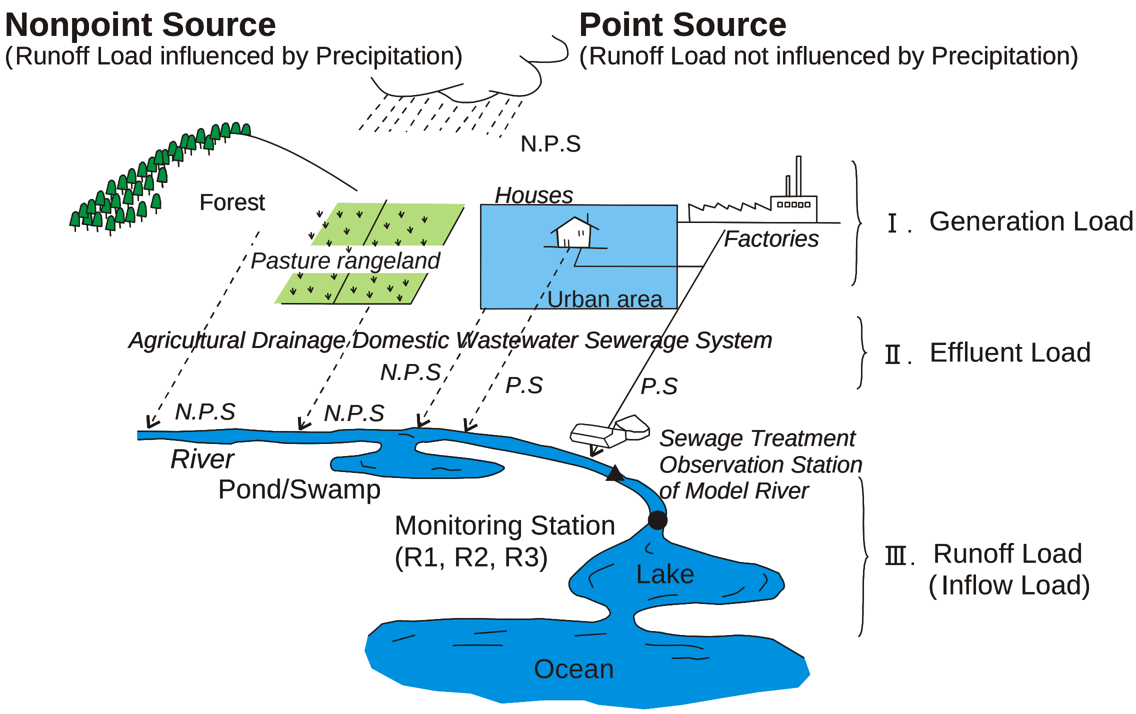


Figure7.1.1 Definition of Loads (Point Sources and Non-point Sources)

7.1.2 Generation Load and Treatment Efficiency

(1) Classification of Pollution Sources

Pollution sources can be classified into point sources and non-point sources. The former can be identified as points from which pollutants are discharged while the latter cannot.

In the current study, point sources correspond to houses, factories, livestock barns, sewage treatment plants, etc., while non-point sources correspond to forests, farmland, pastureland, etc. Although there are stock-farmers in the study area, most of them pasture their livestock and, therefore, they are regarded as non-point sources. Rainfall is also regarded as a non-point source (see **Figure 7.1.2**).

(2) Unit Load of Pollutant and Effluent Ratio

The amount of pollutants generated varies significantly with time at houses and factories, depending on the style of living and form of production, and at non-point sources depending on the rainfall condition. Therefore, long-term continuing study is required for each of the pollution sources, in order to accurately identify the amount of generated pollutants. Since the study period and budget were limited for the current study, a measurement survey on some of the pollution sources was conducted as well as a literature survey of unit pollution load. As a result, the unit generation load by category proposed by CETESB was used in the current study.

7.2 Work Flow of Water Pollution Analysis for Lakes

The work flow of water pollution analysis for lakes is shown in **Figure 7.2.1**.

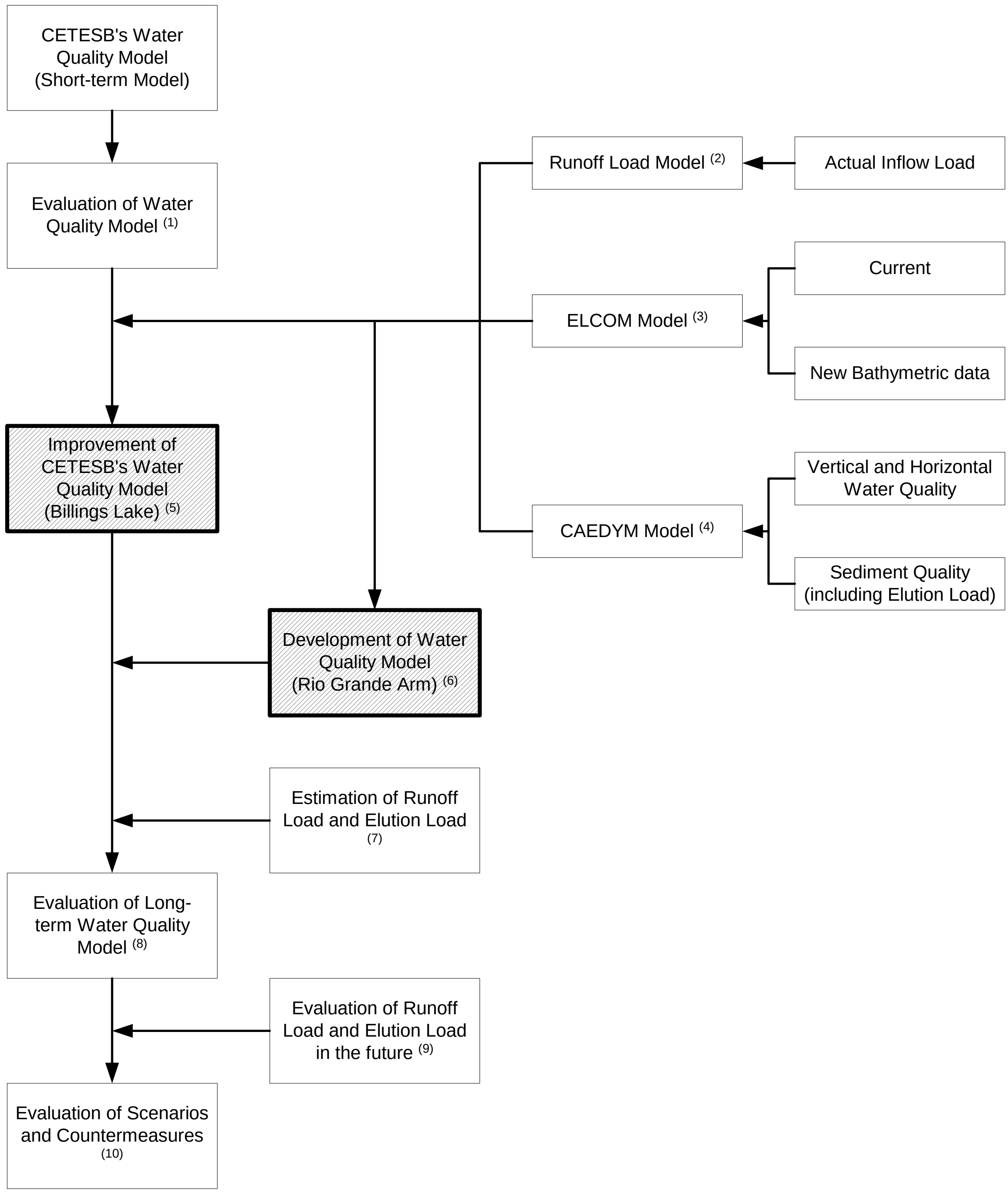


Figure 7.2.1 Work Flow of Water Pollution Analysis for Lakes

7.3 Runoff Load Model of CETESB

7.3.1 Overview of Runoff Load Model

1) Overview of Model

This is a runoff load model developed by Tajima in 1998 to calculate the runoff load from a basin in the Project for Developing a Mathematical Model for Water Quality Management on the Tiete River. This runoff load model is developed to enable separation of loads from point sources (not influenced by rainfall) and non-point sources (influenced by rainfall) and thus automate the forecast of daily runoff load and daily water quality.

This runoff load model is structured as shown in **Figure 7.3.1**. The runoff load model (Runoff Load by River Ver.2.2), when provided with data on rainfall, evaporation, discharge and water quality, enables forecast of the runoff load and identification of the ratio between loads from point sources and from non-point sources.

To use this model, first construct a tank model of each river in a period for which there are relatively more past data on hydrology and water quality, and provide past data on rainfall and evaporation to calculate the daily runoff. Next, use the existing runoff and water quality data and use the discharge(Q) and runoff load (L) for each river and water quality item to derive an L-Q equation ($L=aQ^b$).

To the L-Q equation, provide the daily runoff obtained earlier to calculate the daily runoff load.

Then, separate the runoff load from point sources and non-point sources, by assuming the minimum value (monthly average) of the runoff load generated in the dry season, when it rarely rains, as the runoff load from point sources in this basin (see **Figure 7.3.2**).

The concept of runoff load model is shown in **Figure 7.3.3** for reference.

Obtain the runoff ratio by comparing the obtained current runoff load from each river and the effluent load from each river basin, the latter of which is obtained through a different flow shown in **Figure 7.3.1** (Effluent Load Ver.2.0) by substituting an existing unit load. Then, estimate the runoff load of each river, using the effluent load and runoff ratio in the future and after pollution prevention.

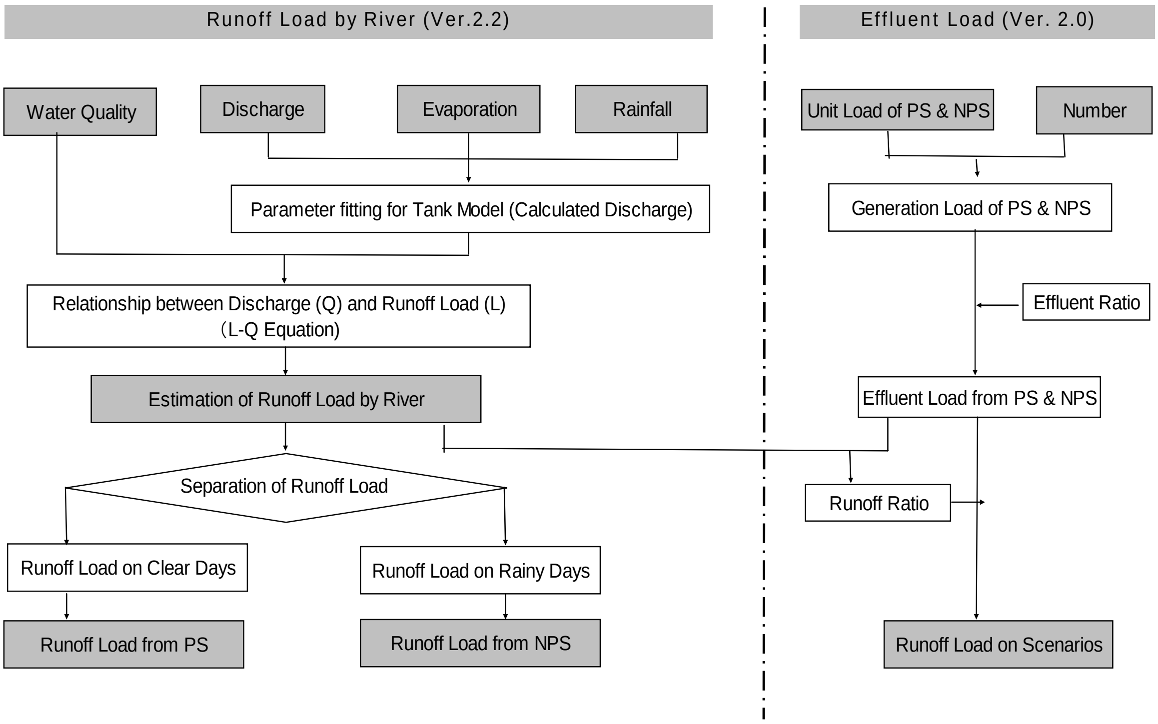


Figure 7.3.1 Runoff Load Model and Effluent Load Model
(Runoff Load Model and Effluent Load Model)

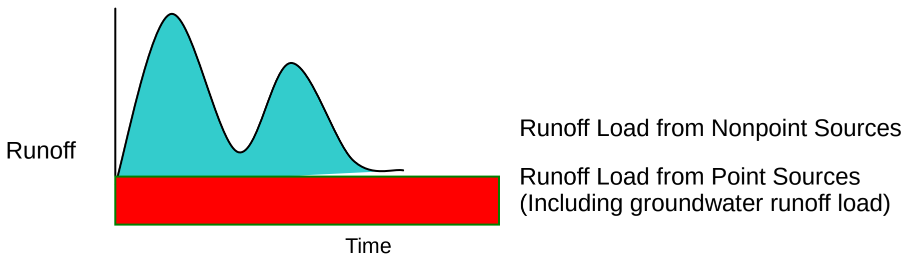


Figure 7.3.2 Separation of Runoff Load

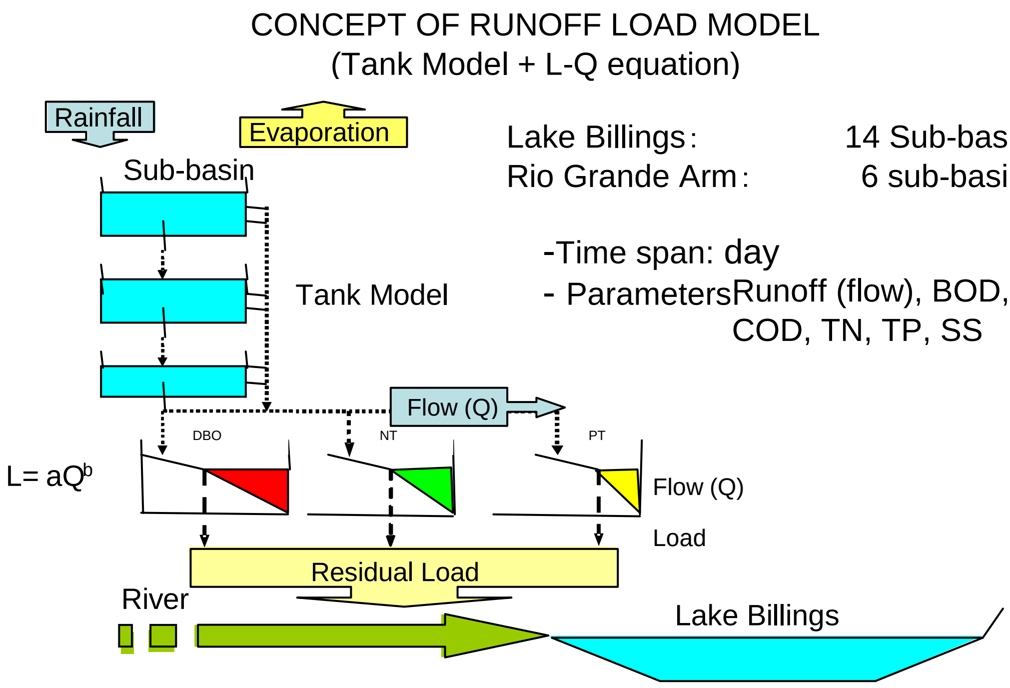


Figure 7.3.3 Detailed Diagram of Runoff Load Model

7.3.2 Calculation of Runoff Load from the Billings Lake and Rio Grande Arm.

The work flow for calculation of runoff load from the Lake Billings and Rio Grande Arm basin is shown in **Figure 7.3.4**. The work flow presupposes two cases.

(1) Calculating the runoff load from monitored model sub-basins

The runoff load from monitored model sub-basins shall be calculated by applying the runoff load model to the observation data.

(2) Calculating the runoff load from sub-basins other than model sub-basins

a) Calculate the runoff load from each of the model sub-basins by applying a runoff load model to the monitoring data (quality and discharge).

b) Calculate the effluent load from each of the model basins by using unit loads of pollutants and effluent ratio.

c) Compare the runoff load and effluent load from each of the model basins to obtain a runoff ratio. For each of the water quality elements, obtain a runoff ratio using a formula: Runoff ratio=Runoff load/Effluent load.

d) Form a correlation equation between Effluent load density/Basin area1/2 and Effluent load of model sub-basins and obtain the runoff ratio for each of the water quality elements.

Apply the above correlation equation for runoff ratios to the effluent loads of the sub-basins to calculate the runoff load of the sub-basins.

Procedure of Runoff Load Estimation

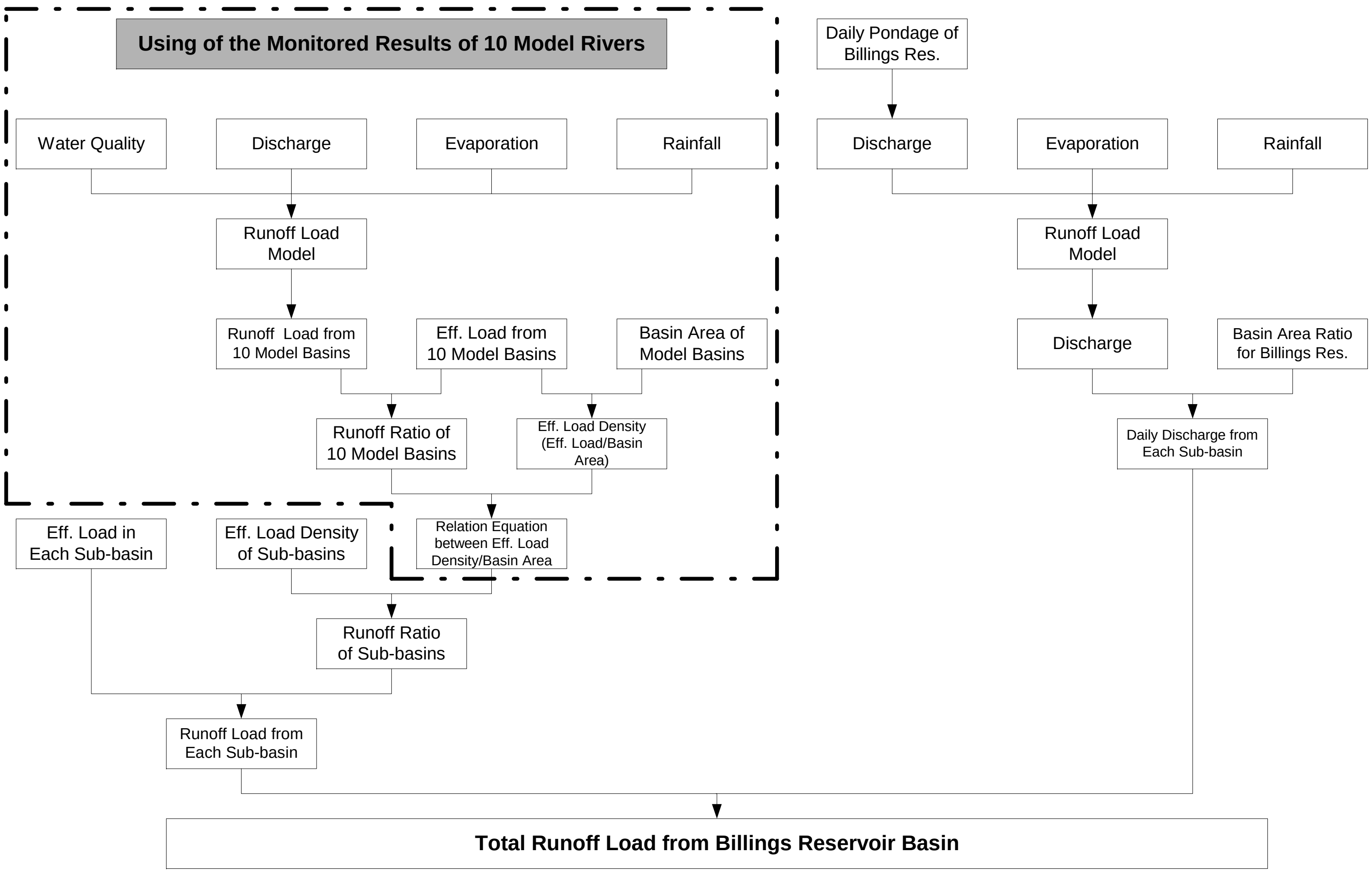


Figure 7.3.4 Work flow for calculation of runoff load from the Lake Billings and Rio Grande Arm basin Work flow of runoff load model applied to the Lake Billings and Rio Grande Armwork flow for calculation of runoff load from the Lake Billings and Rio Grande Arm basin

7.3.3 Improvement of Runoff Load Model

1) Creating an L=aQ^b equation with a high correlation

In the current study, we need to construct a highly reliable L-Q equation in the model basin by selecting twenty model sub-basins put to different land uses and observing the discharges and water quality required to create a highly accurate L-Q equation for each model basin. To improve the reliability of the measurement results in basins other than the models, we shall select 18 major rivers and 2 sewage treatment plants from which water flows into Lake Billings and Lake Rio Grande Arm and conduct discharge measurements and water quality surveys there three times each in the dry and rainy seasons. In particular, we shall attempt to improve the accuracy of the discharge measurements.

2) Calculating highly accurate unit loads of pollutants

The unit load is required to identify the present situation and estimate the future status of pollution loads in the basin and pollution loads from each of the generation sources. To improve the reliability of the unit loads of pollutants, therefore, we need to collect actual measurement data by the actual survey for the unit loads of pollutants for domestic load at Alvarenga district (SBC).

3) Grasping the accurate discharge data

We have to conduct highly accurate discharge for grasping of accurate runoff load at rivers. Therefore, the magnetic current meter was applicable at polluted rivers for river discharge measurement in order to get highly accurate discharge data.

7.3.4 Issues for application of Runoff Load Model

The issues for application of Runoff Load Model are as follows.

1) Calculating the Current Runoff Load

Use of the Runoff Load Model by River Ver.2.2 developed in the current study requires water quality survey data, including the daily and periodical flow rates observed at rainfall observation stations on the rivers in the sub-basin (the lowest stream area is the most appropriate), as shown in the flow in **Figure 7.3.4**. Additionally, data on daily rainfall and daily evaporation obtained at rainfall observation stations in the basin (observation stations in the vicinity) are required. The Runoff Load Model cannot be put to use without these types of data.

The necessary data is acquired from the following organizations as **Table 7.3.1**.The collected terms for the study data is two years from January 2004 to December 2006.

The two key issues in the current study are whether we will be able to collect sufficient basic data (discharge and water quality) on the Lake Billings basin to activate the model.

The one issue is to seek for good relationship between a daily rainfall/evaporation and a daily discharge. Another issue is to seek highly correlation between runoff load and discharge as Load(L) - Discharge(Q) ($L = a Q^b$) based on relationship between discharge and water quality.

Table 7.3.1 Acquisition organization of hydrological data

Observation items	Organization	Station Number
Daily rainfall	EMAE	5 (Billings basin)
	SABESP	1 (Rio Grande ETA)
	Bombeiro	2
Daily evaporation	IAG(USP)	1
Daily pontage /.water level (Billings Lake)	EMAE	1
Daily pondage /water level(Rio Grande Lake)	SABESP	1

The application examples of runoff tank model are shown in **Figure 7.3.5** for the Rio Grand and **Figure 7.3.6** for the Lake Billings and Rio Grande Arm, respectively.

2) Calculating the unit load and effluent load required to calculate the runoff load

The flow shown on the right (Estimation of Effluent Load) in **Figure 7.3.4** is intended to estimate the runoff load from the unit loads and effluent loads from point sources and non-point sources. Therefore, the reliability of the calculation result depends on the accuracy of the unit loads of pollutants and effluent loads. In Brazil, however, there seems to be few reliable unit loads, irrespective of whether they concern point sources or non-point sources.

We adapted CETESB’s data as a reliable data when we confirmed the data is highly reliability of unit load based on the unit load survey at Alvarenga district (SBC).

However, there is no data of non-point source’s unit load. Therefore, we adapted the unit load of non-point sources gotten by Guarapiranga basin survey on 1998.

Table 7.3.2 Unit Loads from Domestic Wastewater and Non-point Sources Derived in the SMA Study (Guarapiranga and Lake Billings Basin)

Unit Load of Pollutants (Point Source)

Domestic Unit Load	BOD (g/dia.hab)	TN (g/dia.hab)	TP (g/dia.hab)	COD (g/dia.hab)	TSS (g/dia.hab)
	54	10	1,2	108	60
Source	ABNT	SABESP Model	MQual2.0	COD=2*BOD (Von Sperling)	ABNT

Unit Load of Pollutants (Non-point Source)

Items of Non-point Source	BOD (kg/ha· yr)	TN (kg/ha· yr)	TP (kg/ha· yr)	COD (kg/ha· yr)	TSS (kg/ha· yr)	Coli (kg/ha· yr)
Urban Area – High Standard	58,4	3,472	0,496	-	2	3,65E+4
Urban Area – Low Standard	146	8,68	0,993	-	4	3,65E+2
Industrial and Commercial Use	116,8	6,076	0,695	-	2,8	3,65E+2
Agriculture	17,946	0,828	0,242	-	38,2	3,65E+2
Reforestation	4,277	0,219	0,007	-	9,1	3,65E+3
Forest	4,277	0,219	0,007	-	9,1	3,65E+2
Field	3,938	0,183	0,005	-	13,7	3,65E+3
Cottages	13,87	0,329	0,018	-	29,2	1,83E+3

(Source: SMA, “Calibracao de System Relacional de Correlacao do Manejo do Terriorio e da Qualidade Ambiental para o Preservatorio Billings”, Prme Engenharia, Outubro/2004)

3) How to Calculate Runoff ratio

The runoff ratio is intended to express from a macroscopic viewpoint the changes of load in the flow process from the pollution sources (point and non-point sources) dispersed in the basin. Therefore, the runoff ratio significantly varies depending on the geographic features, configurations, and geological conditions of the basin, magnitude of the basin area, magnitude of the effluent load, water quality elements, hydrological features, etc. Thus, the runoff ratio should be established based on the measurements in principle but, if it is difficult, should be calculated using the measurements taken in other basins.

In this study, the runoff ratio at each monitored sub-basins is searched based on comparison between a runoff load and an estimated effluent load (Runoff ratio=runoff load/Effluent load).

Each runoff ratio of the sub-basins is estimated by using of a correlation equation between Runoff ratio and Effluent load/Basin area/Basin area1/2 based on monitored river data.

a) Existing Study Results in Japan

According to the existing study results in Japan, the population density/basin area$^{1/2}$ and the runoff ratio of BOD load are known to have the following relationship:

Figure 7.3.7 shows the result of summarizing the measurements taken by the Public Works Research Institute, Ministry of Construction (1969) on the major rivers in Japan.

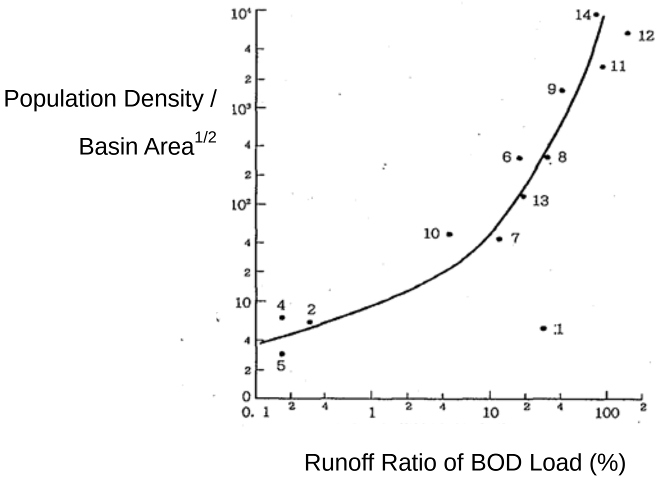


Figure 7.3.7 Relationship between Runoff Ratio and Population Density/Basin Area$^{1/2}$

Figure 7.3.8 shows the result of measurements summarized by the Edogawa Construction Office, Ministry of Construction in the same way as the Public Works Research Institute. The population density/basin area$^{1/2}$ (X) and the runoff ratio (Y) are known to have a relationship of Y = 2.0/1＋exp (-3.04 X＋6.34).

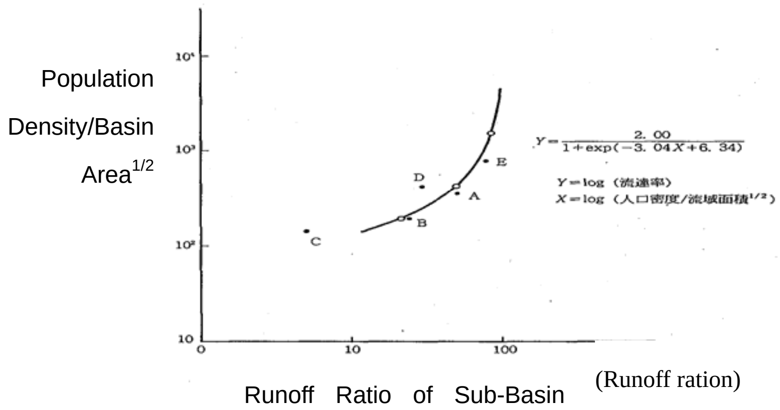


Figure 7.3.8 Relationship between Runoff Ratio and Population Density/Basin Area$^{1/2}$

The Guidelines and Explanation of Sewage System Construction Comprehensive Plan and Study by Basins published by Japan Sewage Works Association (1993) shows the standard values of runoff ratios as follows:

Table 7.13.3 Standard Values of Runoff Ratios

Classification		Runoff ratio
Rural area		0.0 to 0.20
Urban area	Surrounding area	0.1 to 0.6
	Central area	0.6 to 1.0
Public sewerage		1.0

Note: The runoff ratio is assumed to be determined by the development status of drainage canals and gutters.

b) How to Estimate Runoff Load from the sub-basins at the Billings and Rio Grande Arm

According to the study results in Japan, the population density/(basin area)$^{1/2}$ and the runoff ratio are known to have a relationship. However, it is inferred to be more rational to use, instead of the population density, the effluent load/basin area, i.e., the runoff load density including both the point and non-point sources.

If, in this study, the Runoff Load Model cannot be applied to the calculation of a runoff ratio, we first obtain a relational expression between the effluent load density and the runoff ratio and estimate the runoff ratio of each sub-basin to which the model cannot be applied (See **Figure 7.3.9**).

Therefore,

Runoff Load = Effluent Load × Runoff Ratio.

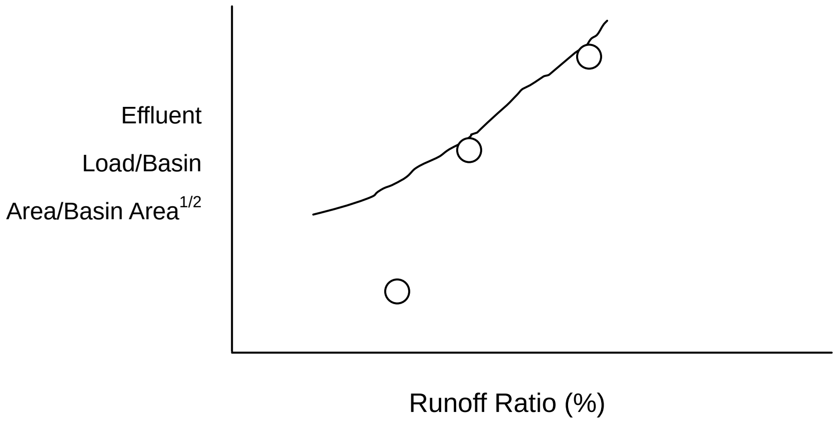


Figure 7.3.9 Relationship between Effluent Load/Basin Area/Basin Area$^{1/2}$ and Runoff Ratio

4) Pollutant Load Divided into Blocks

The runoff ratios of BOD, TN and TP was calculated using the data of flow and water quality conducted six times at 10 model streams and in accordance with the calculation method as mentioned above, of which results are shown **in Figure 7.3.10**. The runoff ratios for other streams than model streams are calculated from the relationship equation obtained in **Figure 7.3.10**.

Although the correlation coefficient of TN is low, it is possibly attributed to low unit pollutant loading generated of TN. COD is excluded from the calculations due to no COD data in the unit pollutant loadings generated for non-point sources.

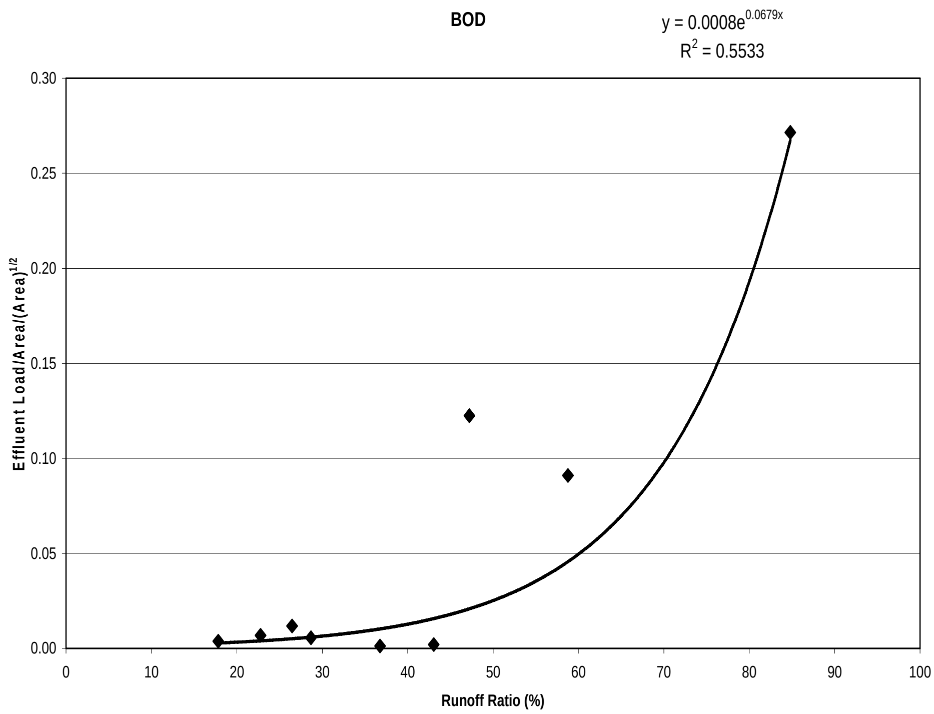


Figure 7.3.10(1) Relationship between effluent load (BOD) and runoff coefficient of model river

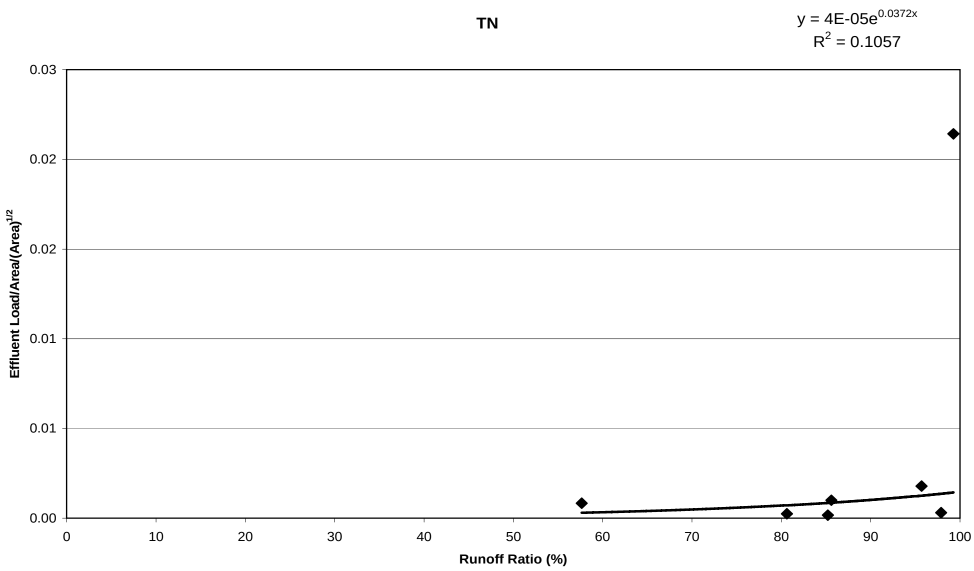


Figure 7.3.10(2) Relationship between effluent load (TN) and runoff coefficient of model river

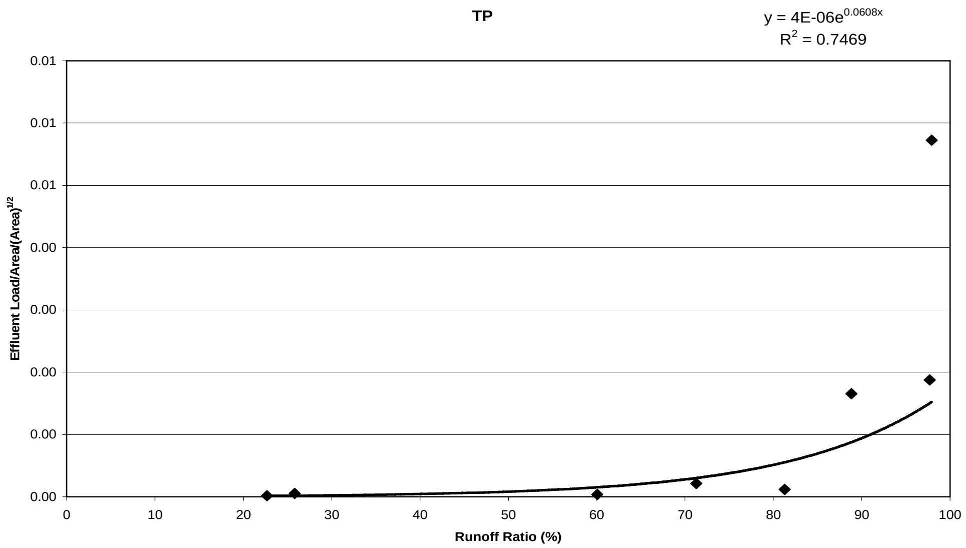


Figure 7.3.10(3) Relationship between effluent load (TP) and runoff coefficient of model river

4) Runoff Load Divided into Sub-basins

According to BILLINGS 2000, the Billings basin consists of 146 sub-basins. In order to analyze the generation, effluent and runoff status of pollutant loads, we integrated the sub-basins in the Lake Billings basin into 14 medium-sized basins and the sub-basins in the Lake Rio Grande Arm basin into 6 medium-sized basins, total number of medium sized basins is 20 (see **Figure 7.3.11**).

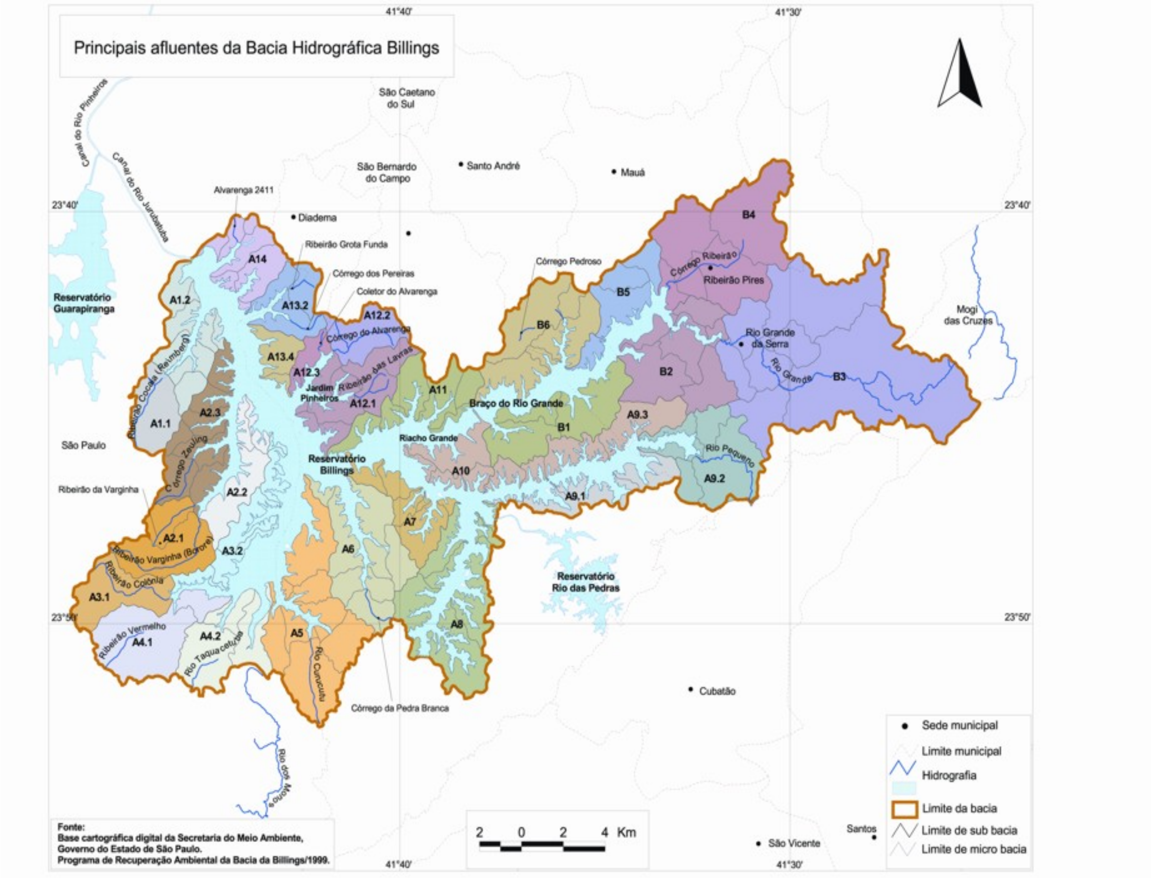


Figure 7.3.11 Map for sub-basins of the Lake Billings and Rio Grande Arm

7.3.5 Rainfall Analysis for the Year of 2005

It is necessary to analyze the hydrological feature of the base year for the Study in case of conducting middle-term and long-term simulations. The magnitude of rainfall in that year affects on the runoff loads into the lake which lead to a big change in water quality of the lake. The rainfall in 2005 that the present Study conducted, was 1461.1 mm/yr at IAG-USP E-035 almost equivalent to an average rainfall for 1984 to 2005 (see **Table 7.3.4** and **Figure 7.3.12**). The reason to select IAG-USP E3-035 from many rainfall gauging stations located in the basin is that reliable and long-term rainfall data is available therein.

According to the over probablity analysis of rainfall, the 2005 rainfall has a return period of 2.1 years under the Iwai's Method and 2.2 years under the Gumbel's Method and is an average rainfall occurred every two years.

It is reasonable to set the year of 2005 having an average rainfall as the base year for middle- and long-term simulations.

Table 7.3.4 Annual Rainfall for 1984～2005 (IAG-USP、E3-035)

Year	Rainfall (mm/yr)
1984	1075.7
1985	1175.8
1986	1558.3
1987	1655.6
1988	1714.0
1989	1705.9
1990	1515.3
1991	1923.5
1992	1442.7
1993	1304.5
1994	1285.8
1995	1650.7
1996	1924.1
1997	1428.1
1998	1386.9
1999	1207.7
2000	1252.4
2001	1324.3
2002	1453.1
2003	1063.2
2004	1745.7
2005	1461.6
Average	1466.1

Rainfall (2005)	1461.6	mm
Over probability		
Iwai Method	2.1	year
Thomas Method	2.1	year
Hazen Method	2.1	year
Ishihara & Takase Method	2.0	year
Gumbel Method	2.2	year

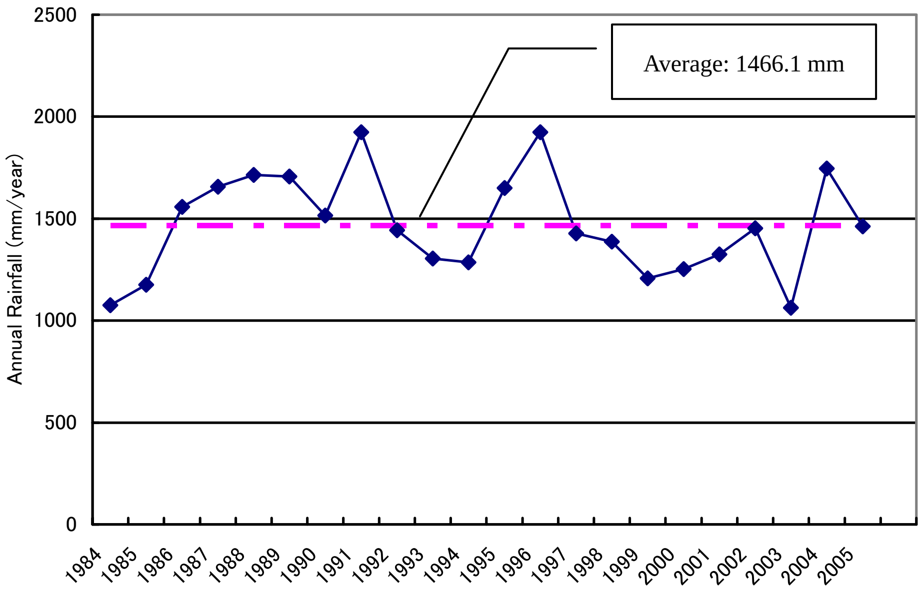


Figure 7.3.12 Annual rainfall variation for 1984～2005 (IAG-USP、E3-035)

7.3.6 Calculation of discharged load

(1) Discharge of pollution load from middle size basins

Discharge of pollution load from middle size basins was calculated in terms of point sauce and non-point sauce. Results are shown in **Table 7.3.5** and **Figure 7.3.13**.

The BOD discharge load to the Billings Lake is 22.7 ton/day. TN discharge load is 3.86 ton/day and TP discharge load is 0.48 ton/day.

The BOD discharge load to the Rio Grande arm is 6.07 ton/day. TN discharge load is 0.93 ton/day and TP discharge load is 0.11 ton/day.

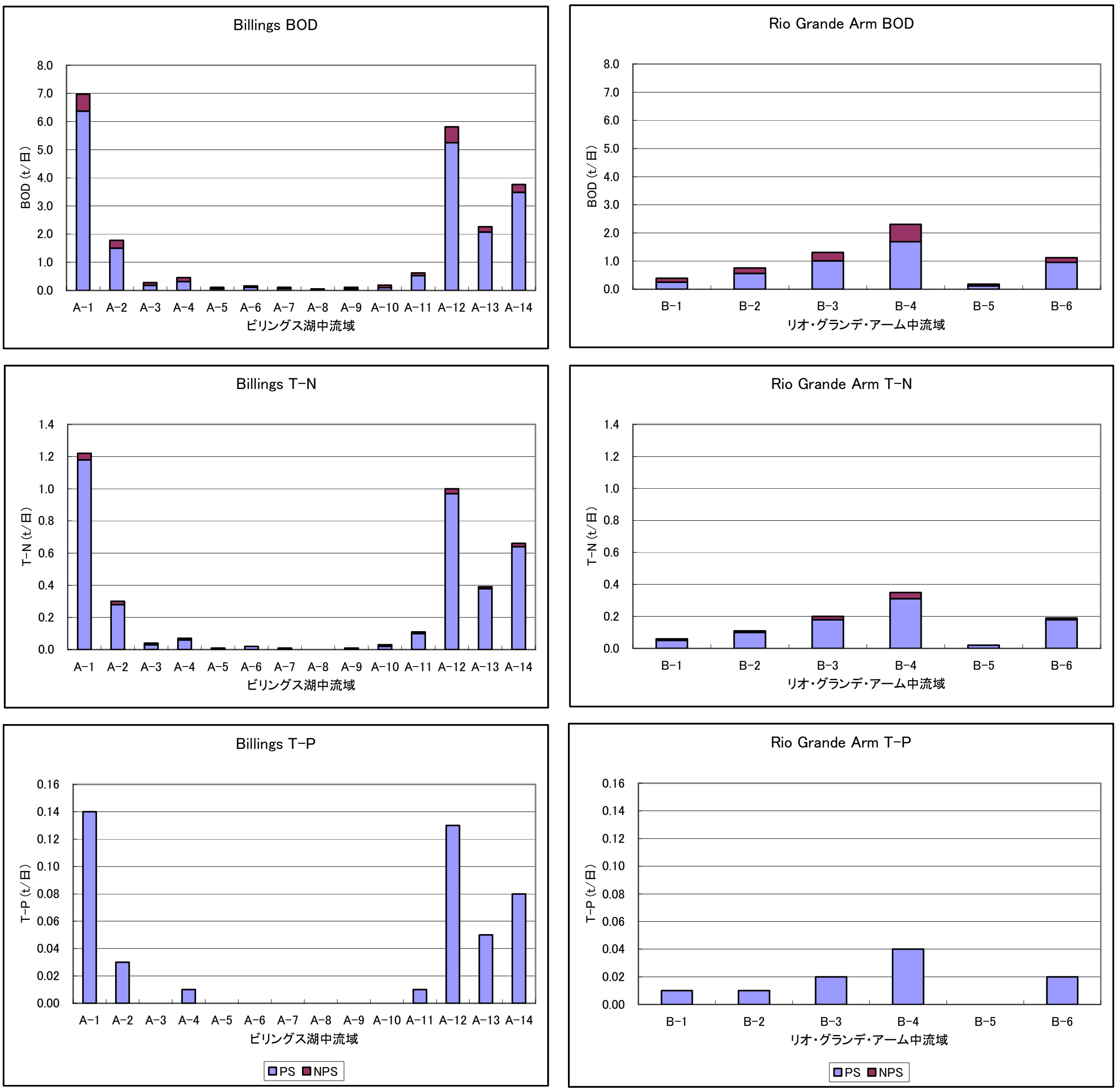


Figure 7.3.13 Estimated effluent loads by sub-basin

Table 7.3.5 Estimated effluent loads by sub-basin (2005)

Basin	Basin Area (km²)	BOD (t/day)				TN (t/day)				TP (t/day)				Discharge(m³/s)			
		PS	NPS	Total	%	PS	NPS	Total	%	PS	NPS	Total	%	PS	NPS	Total	%
A-1	20.98	6.37	0.60	6.97	30.79	1.18	0.04	1.22	31.45	0.14	0.00	0.15	30.63	0.1639	0.9524	1.1163	7.94
A-2	37.86	1.50	0.28	1.78	7.85	0.28	0.02	0.29	7.59	0.03	0.00	0.04	7.37	0.0386	1.7190	1.7576	12.50
A-3	20.52	0.18	0.10	0.28	1.21	0.03	0.01	0.04	0.99	0.00	0.00	0.00	0.95	0.0046	0.9316	0.9362	6.66
A-4	31.32	0.31	0.14	0.45	1.97	0.06	0.01	0.06	1.66	0.01	0.00	0.01	1.61	0.0079	1.4218	1.4297	10.17
A-5	29.48	0.06	0.05	0.10	0.45	0.01	0.00	0.01	0.32	0.00	0.00	0.00	0.29	0.0014	1.3382	1.3397	9.53
A-6	20.50	0.11	0.05	0.16	0.71	0.02	0.00	0.02	0.60	0.00	0.00	0.00	0.57	0.0029	0.9308	0.9337	6.64
A-7	9.49	0.07	0.04	0.11	0.49	0.01	0.00	0.02	0.39	0.00	0.00	0.00	0.37	0.0018	0.4308	0.4326	3.08
A-8	20.16	0.02	0.03	0.04	0.18	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.09	0.0004	0.9155	0.9159	6.52
A-9	38.76	0.05	0.06	0.11	0.49	0.01	0.00	0.01	0.33	0.00	0.00	0.00	0.28	0.0014	1.7599	1.7613	12.53
A-10	7.81	0.10	0.09	0.20	0.87	0.02	0.01	0.02	0.64	0.00	0.00	0.00	0.61	0.0132	0.3547	0.3679	2.62
A-11	12.74	0.52	0.10	0.62	2.73	0.10	0.01	0.10	2.64	0.01	0.00	0.01	2.55	0.0134	0.5782	0.5916	4.21
A-12	24.60	5.25	0.56	5.81	25.66	0.97	0.03	1.00	25.98	0.13	0.00	0.13	28.11	0.1396	1.1166	1.2562	8.94
A-13	13.30	2.07	0.19	2.26	9.98	0.38	0.01	0.39	10.21	0.05	0.00	0.05	9.93	0.0533	0.6040	0.6573	4.68
A-14	10.38	3.48	0.28	3.76	16.60	0.64	0.02	0.66	17.09	0.08	0.00	0.08	16.65	0.0895	0.4714	0.5609	3.99
Sub total	297.90	20.09	2.56	22.65	100.00	3.72	0.15	3.86	100.00	0.46	0.02	0.48	100.00	0.5319	13.5249	14.0567	100.00
B-1	15.84	0.25	0.14	0.39	6.40	0.05	0.01	0.05	5.83	0.01	0.00	0.01	5.80	0.0064	0.5782	0.5846	8.79
B-2	21.14	0.56	0.20	0.76	12.56	0.10	0.01	0.12	12.41	0.01	0.00	0.01	12.40	0.0145	0.7715	0.7860	11.81
B-3	74.86	1.01	0.30	1.31	21.58	0.18	0.02	0.20	21.34	0.02	0.00	0.02	21.18	0.0716	2.7326	2.8041	42.15
B-4	33.65	1.69	0.62	2.31	38.03	0.31	0.04	0.35	37.60	0.04	0.00	0.04	37.73	0.0821	1.2283	1.3104	19.70
B-5	10.81	0.12	0.06	0.18	2.98	0.02	0.00	0.03	2.82	0.00	0.00	0.00	2.80	0.0032	0.3944	0.3976	5.98
B-6	20.43	0.95	0.17	1.12	18.44	0.18	0.01	0.19	20.00	0.02	0.00	0.02	20.09	0.0244	0.7455	0.7700	11.57
Sub total	176.73	4.58	1.49	6.07	100.00	0.84	0.09	0.93	100.00	0.10	0.01	0.11	100.00	0.2021	6.4506	6.6527	100.00
T0tal	474.6	24.7	4.05	28.7		4.56	0.23	4.79		0.56	0.02	0.59		0.73	19.98	20.71	

(2) Breakdown of estimated effluent loads

The calculated effluent loads are as shown in **Table 7.3.5** and the breakdown of BOD, TN and TP is shown in **Table 7.3.6** to identify the pollutant sources in both lakes dividing into point and non-point sources. The point sources are categorized into two or domestic wastewater and industrial wastewater, while non-point sources are categorized into eight or agricultural land, reforestation, forest, field, cottage, urban area high standard, urban area low standard, and industrial and commercial land

1) Breakdown of BOD_5 loads (see **Figure 7.3.14**)

In the basin of the Lake Billings, the percentages of point and non-point sources to the total pollutant load are 89% and 11%, respectively, and 89% load is derived from domestic wastewater and less than 1% (0.04%) load from industrial wastewater in the total loads. The load from the low income residential area in the non-point sources shares 9% in the total.

In the basin of the Rio Grande Arm, the percentages of point and non-point sources to the total pollutant load are 75% and 25%, respectively, and 75% load is derived from domestic wastewater and less than 1% (0.5%) load from industrial wastewater in the total loads. The load from the low income residential area in the non-point sources shares 20.5% in the total.

2) Breakdown of TN loads

In the basin of the Lake Billings, the percentages of point and non-point sources to the total pollutant load are 96% and 4%, respectively, and 96% load is derived from domestic wastewater and less than 1% (0.0%) load from industrial wastewater in the total loads. The load from the low income residential area in the non-point sources shares 3% in the total.

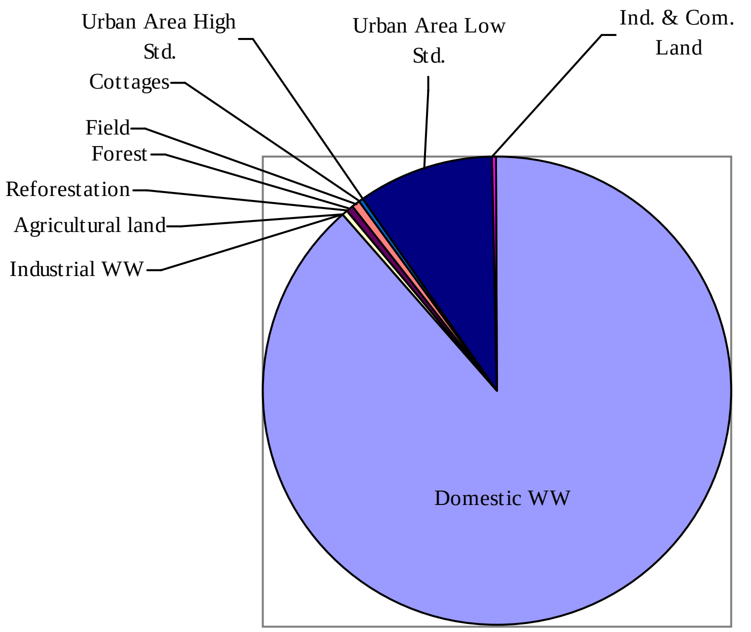
In the basin of the Rio Grande Arm, the percentages of point and non-point sources to the total pollutant load are 90% and 10%, respectively, and 90% load is derived from domestic wastewater and less than 1% (0.0%) load from industrial wastewater in the total loads. The load from the low income residential area in the non-point sources shares 8% in the total.

3) Breakdown of TP loads

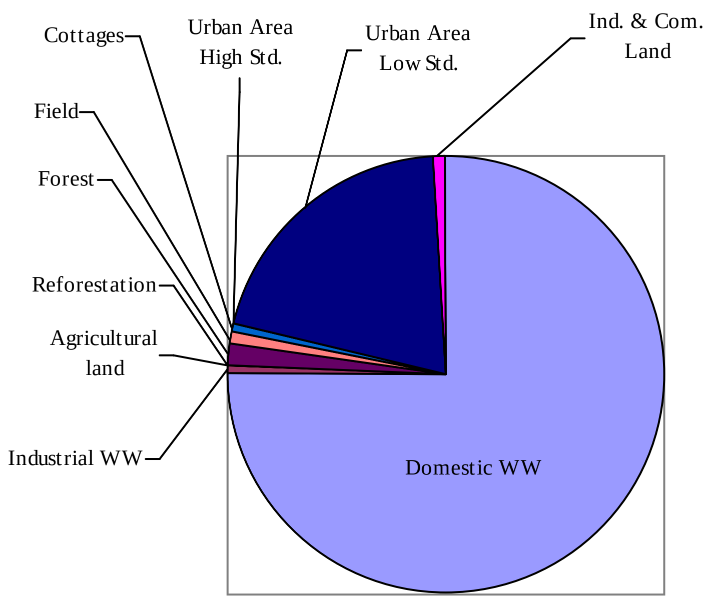
In the basin of the Lake Billings, the percentages of point and non-point sources to the total pollutant load are 96% and 4% same as TN loads, respectively, and 94% load is derived from domestic wastewater and 2% load from industrial wastewater in the total loads. The load from the low income residential area in the non-point sources shares 2% in the total.

The whole basin of the Rio Grande Aem: The percentages of point and non-point sources to the total pollutant load are 91% and 9%, respectively and 91% load is derived from domestic wastewater and less than 1% load from industrial wastewater in the total loads. The load from the low income residential area in the non-point sources shares 9% in the total.

As long as BOD_5 as an organic index and TN and TP as nutrient indices are concerned, as mentioned above, a majority of the loads (approximately 90%) is clearly caused by domestic wastewater and it can be said that the most important issue in both lakes is the measures for domestic wastewater.



Lake Billings



Rio Grande Arm

Figure 7.3.14 Composition of estimated runoff load from sub-basins

Table 7.3.6(1) Breakdown of estimated effluent loads from sub-basins in 2005（BOD_5）

Table 10.2.6-1 Breakdown concerning Estimated Effluent BOD Load(PS & NPS) from Sub-Basins

Basin	Basin Area	BOD (t/day)													
	(km²)	PS			NPS									Total	%
		Sub-total	Domestic Wastewater	Industrial Wastewater	Sub-total	Agricultural land	Reforestation	Forest	Field	Cottages	Urban Area High Standard	Urban Area Low Standard	Industrial & Commercial Land		
A-1	20.98	6.37	6.37	0.00	0.60	0.000	0.000	0.001	0.005	0.002	0.000	0.588	0.005	6.97	30.79
A-2	37.86	1.50	1.50	0.00	0.28	0.009	0.000	0.016	0.010	0.027	0.000	0.213	0.000	1.78	7.85
A-3	20.52	0.18	0.18	0.00	0.10	0.005	0.001	0.012	0.005	0.006	0.000	0.067	0.000	0.28	1.21
A-4	31.32	0.31	0.31	0.00	0.14	0.012	0.000	0.015	0.010	0.015	0.000	0.088	0.000	0.45	1.97
A-5	29.48	0.06	0.06	0.00	0.05	0.005	0.004	0.018	0.007	0.013	0.000	0.000	0.000	0.10	0.45
A-6	20.50	0.11	0.11	0.00	0.05	0.003	0.001	0.013	0.006	0.008	0.000	0.017	0.000	0.16	0.71
A-7	9.49	0.07	0.07	0.00	0.04	0.000	0.000	0.006	0.003	0.003	0.000	0.030	0.000	0.11	0.49
A-8	20.16	0.02	0.02	0.00	0.03	0.000	0.000	0.019	0.004	0.001	0.000	0.001	0.000	0.04	0.18
A-9	38.76	0.05	0.05	0.00	0.06	0.000	0.000	0.028	0.013	0.008	0.000	0.008	0.000	0.11	0.49
A-10	7.81	0.10	0.10	0.00	0.09	0.000	0.000	0.003	0.002	0.002	0.000	0.086	0.000	0.20	0.87
A-11	12.74	0.52	0.52	0.00	0.10	0.000	0.002	0.005	0.003	0.007	0.000	0.074	0.007	0.62	2.73
A-12	24.60	5.25	5.24	0.009	0.56	0.007	0.002	0.003	0.005	0.001	0.000	0.525	0.018	5.81	25.66
A-13	13.30	2.07	2.07	0.000	0.19	0.000	0.001	0.004	0.003	0.008	0.000	0.171	0.004	2.26	9.98
A-14	10.38	3.48	3.48	0.001	0.28	0.000	0.000	0.001	0.002	0.002	0.000	0.271	0.006	3.76	16.60
Sub total	**297.90**	**20.09**	**20.08**	**0.01**	**2.56**	**0.042**	**0.012**	**0.144**	**0.080**	**0.102**	**0.000**	**2.139**	**0.040**	**22.65**	**100.00**
B-1	15.84	0.25	0.25	0.00	0.14	0.001	0.000	0.011	0.003	0.002	0.000	0.123	0.000	0.39	6.40
B-2	21.14	0.56	0.56	0.0002	0.20	0.000	0.000	0.010	0.006	0.006	0.000	0.181	0.000	0.76	12.56
B-3	74.86	1.01	0.98	0.0285	0.30	0.000	0.002	0.054	0.020	0.012	0.000	0.166	0.047	1.31	21.58
B-4	33.65	1.69	1.69	0.0000	0.62	0.000	0.001	0.010	0.009	0.006	0.000	0.583	0.012	2.31	38.03
B-5	10.81	0.12	0.12	0.00	0.06	0.001	0.001	0.008	0.002	0.002	0.000	0.044	0.000	0.18	2.98
B-6	20.43	0.95	0.95	0.00	0.17	0.000	0.001	0.017	0.002	0.001	0.000	0.149	0.000	1.12	18.44
Sub total	**176.73**	**4.58**	**4.55**	**0.03**	**1.49**	**0.002**	**0.004**	**0.110**	**0.041**	**0.029**	**0.000**	**1.247**	**0.059**	**6.07**	**100.00**

Table 7.3.6(2) Breakdown of estimated effluent loads from sub-basins in 2005（TN）

Table 10.2.6-2 Breakdown concerning Estimated Effluent TN Load(PS & NPS) from Sub-Basins

Basin	Basin Area (km²)	TN (t/day)													
		PS			NPS									Total	%
		Sub-total	Domestic Wastewater	Industrial Wastewater	Sub-total	Agricultural land	Reforestation	Forest	Field	Cottages	Urban Area - High Standard	Urban Area - Low Standard	Industrial & Commercial Land		
A-1	20.98	1.18	1.18	0.00	0.04	0.000	0.000	0.000	0.000	0.000	0.000	0.035	0.000	1.22	31.45
A-2	37.86	0.28	0.28	0.00	0.02	0.000	0.000	0.001	0.000	0.001	0.000	0.013	0.000	0.29	7.59
A-3	20.52	0.03	0.03	0.00	0.01	0.000	0.000	0.001	0.000	0.000	0.000	0.004	0.000	0.04	0.99
A-4	31.32	0.06	0.06	0.00	0.01	0.001	0.000	0.001	0.000	0.000	0.000	0.005	0.000	0.06	1.66
A-5	29.48	0.01	0.01	0.00	0.00	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.01	0.32
A-6	20.50	0.02	0.02	0.00	0.00	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.02	0.60
A-7	9.49	0.01	0.01	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.02	0.39
A-8	20.16	0.00	0.00	0.00	0.00	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.00	0.11
A-9	38.76	0.01	0.01	0.00	0.00	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.01	0.33
A-10	7.81	0.02	0.02	0.00	0.01	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.02	0.64
A-11	12.74	0.10	0.10	0.00	0.01	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.10	2.64
A-12	24.60	0.97	0.97	0.00	0.03	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.001	1.00	25.98
A-13	13.30	0.38	0.38	0.00	0.01	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.39	10.21
A-14	10.38	0.64	0.64	0.00	0.02	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.66	17.09
Sub total	**297.90**	**3.72**	**3.72**	**0.00**	**0.145**	**0.002**	**0.001**	**0.007**	**0.004**	**0.002**	**0.000**	**0.127**	**0.002**	**3.86**	**100.00**
B-1	15.84	0.05	0.05	0.00	0.01	0.000	0.000	0.001	0.000	0.000	0.000	0.007	0.000	0.05	5.83
B-2	21.14	0.10	0.10	0.00	0.01	0.000	0.000	0.001	0.000	0.000	0.000	0.011	0.000	0.12	12.41
B-3	74.86	0.18	0.18	0.00	0.02	0.000	0.000	0.003	0.001	0.000	0.000	0.010	0.002	0.20	21.34
B-4	33.65	0.31	0.31	0.00	0.04	0.000	0.000	0.001	0.000	0.000	0.000	0.035	0.001	0.35	37.60
B-5	10.81	0.02	0.02	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.03	2.82
B-6	20.43	0.18	0.18	0.00	0.01	0.000	0.000	0.001	0.000	0.000	0.000	0.009	0.000	0.19	20.00
Sub total	**176.73**	**0.84**	**0.84**	**0.00**	**0.086**	**0.000**	**0.000**	**0.006**	**0.002**	**0.001**	**0.000**	**0.074**	**0.003**	**0.93**	**100.00**

Table 7.3.6(3) Breakdown of estimated effluent loads from sub-basins in 2005（TP）

Table 10.2.6-3 Breakdown concerning Estimated Effluent TP Load(PS & NPS) from Sub-Basins

Basin	Basin Area (km²)	TP (t/day)													
		PS			NPS									Total	%
		Sub-total	Domestic Wastewater	Industrial Wastewater	Sub-total	Agricultural land	Reforestation	Forest	Field	Cottages	Urban Area - High Standard	Urban Area - Low Standard	Industrial & Commercial Land		
A-1	20.98	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	30.63
A-2	37.86	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	7.37
A-3	20.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95
A-4	31.32	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.61
A-5	29.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
A-6	20.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
A-7	9.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37
A-8	20.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
A-9	38.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28
A-10	7.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61
A-11	12.74	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.55
A-12	24.60	0.13	0.12	0.013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	28.11
A-13	13.30	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	9.93
A-14	10.38	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	16.65
Sub total	**297.90**	**0.46**	**0.45**	**0.01**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.48**	**100.00**
B-1	15.84	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	5.80
B-2	21.14	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	12.40
B-3	74.86	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	21.18
B-4	33.65	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	37.73
B-5	10.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.80
B-6	20.43	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	20.09
Sub total	**176.73**	**0.10**	**0.10**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.11**	**100.00**

7.3.7 Calculation of Runoff Loads by Sub-basin

(1) Present (2005)

The runoff loads by sub-basin in the Lake Billings and the Rio Grande Arm are shown in **Table 7.3.7** and **Figure 7.3.15**, which are calculated the effluent loads by sub-basin multiplied by predicted runoff ratios.

The runoff loads from the Lake billings basin are 14.6 ton/day in BOD_5, 3.78 ton/day in TN and 0.45 ton/day in TP, while those in the Rio Grande Arm 2.0 ton/day in BOD_5, 0.82 ton/day in TN and 0.06 ton/day in TP, respectively. The loads from four urban stream basins share 90% in BOD_5, 89% in TN and 90% in TP against the total loads, as cleared through actual measurement

In the Rio Grande Arm basin, the runoff load from the Ribeirao Pires River has a big percentage in the total, or 47% in BOD5, 43% in TN and 43% in TP.

Table 7.3.7 Breakdown of estimated runoff loads from sub-basins in 2005

Sub-basin	Area	BOD Load		TN Load		TP Load		Discharge	
	(km^2)	(t/day)	%	(t/day)	%	(t/day)	%	(m^3/s)	%
A-1	21.0	4.9719	33.99	1.2156	32.12	0.1456	32.65	1.10	8.0
A-2	37.9	0.8591	5.87	0.2835	7.49	0.0273	6.12	1.73	12.5
A-3	20.5	0.0767	0.52	0.0308	0.81	0.0023	0.53	0.92	6.7
A-4	31.3	0.1024	0.70	0.0454	1.20	0.0035	0.79	1.41	10.2
A-5	29.5	0.0002	0.001	0.0022	0.06	0.0002	0.04	1.32	9.5
A-6	20.5	0.0180	0.12	0.0114	0.30	0.0009	0.20	0.92	6.6
A-7	9.5	0.0255	0.17	0.0104	0.28	0.0008	0.18	0.43	3.1
A-8	20.2	0.0001	0.00	0.0002	0.01	0.00001	0.002	0.90	6.5
A-9	38.8	0.0021	0.01	0.0029	0.08	0.0002	0.04	1.74	12.5
A-10	7.8	0.0705	0.48	0.0221	0.58	0.0017	0.37	0.36	2.6
A-11	12.7	0.2584	1.77	0.1018	2.69	0.0084	1.88	0.58	4.2
A-12	24.6	3.9811	27.22	1.0041	26.53	0.1293	28.98	1.24	8.9
A-13	13.3	1.5229	10.41	0.3935	10.40	0.0467	10.46	0.65	4.7
A-14	10.4	2.7393	18.73	0.6607	17.46	0.0792	17.75	0.55	4.0
Sub-total	**297.9**	**14.6**	**100.0**	**3.78**	**100.0**	**0.45**	**100.0**	**13.9**	**100.0**
B-1	15.8	0.1167	5.94	0.0446	5.44	0.0034	5.36	0.57	8.8
B-2	21.1	0.2563	13.05	0.1048	12.78	0.0080	12.61	0.76	11.8
B-3	74.9	0.1788	9.10	0.1082	13.20	0.0084	13.29	2.72	42.1
B-4	33.7	0.9152	46.60	0.3562	43.45	0.0272	42.81	1.27	19.7
B-5	10.8	0.0494	2.51	0.0205	2.50	0.0016	2.46	0.39	6.0
B-6	20.4	0.4477	22.79	0.1856	22.63	0.0149	23.48	0.75	11.6
Sub-total	**176.7**	**2.0**	**100.0**	**0.82**	**100.0**	**0.06**	**100.0**	**6.5**	**100.0**
Total	**474.6**	**16.6**		**4.60**		**0.51**		**20.3**	

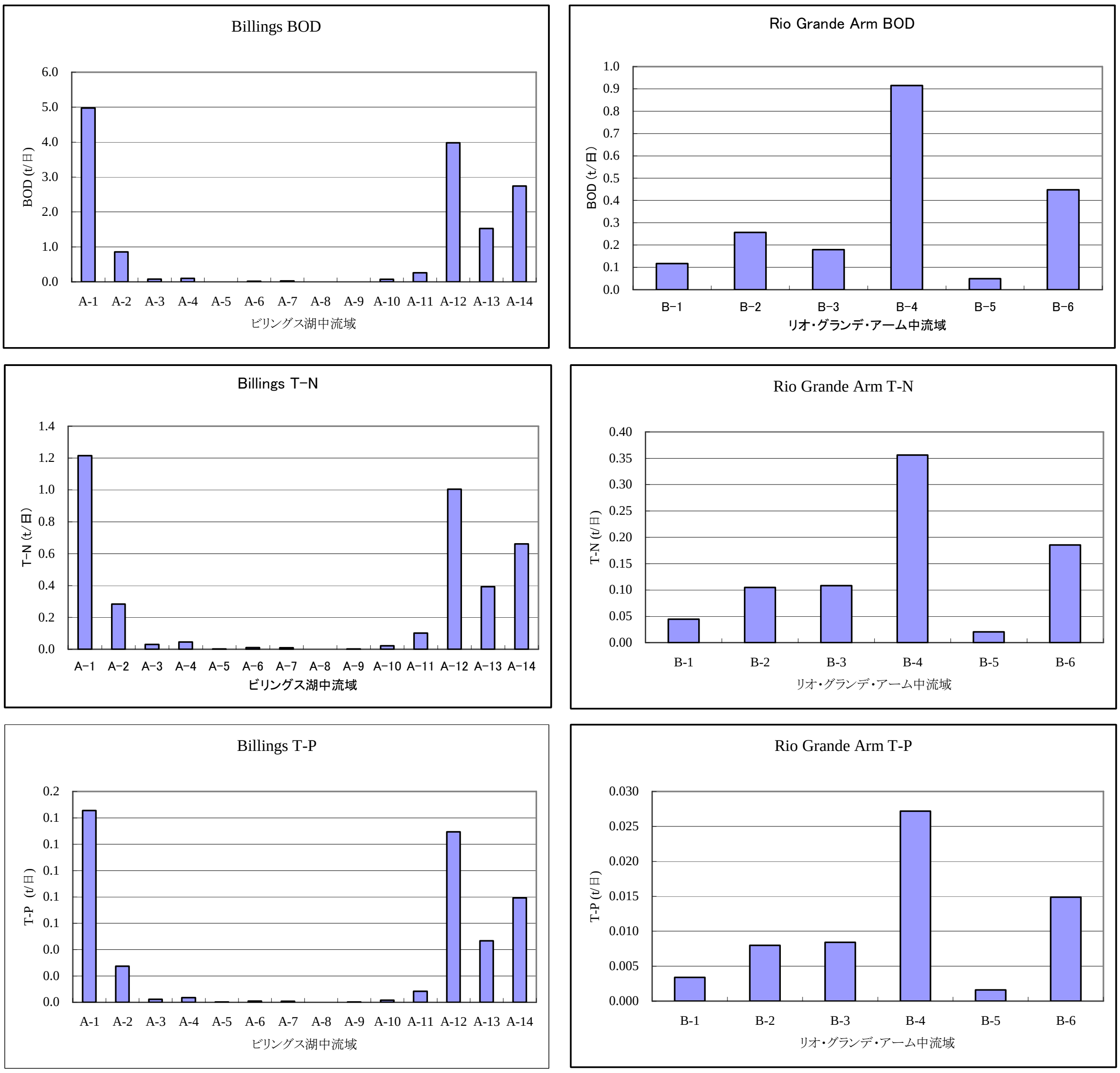


Figure 7.3.15 Estimated runoff loads from sub-basins in 2005 (BOD, TN, TP)

(2) Calculation of estimated runoff load by sub-basin for the middle- and long-term

The runoff load (BOD, TN, TP) by sub-basin run off from the basins of the Lake billings and the Rio Grande Arm was estimated as shown in **Table 7.3.7** and **Figure 7.3.16** for two cases, or with STP and without STP based on the middle- and long-term program. The Estimated runoff load by sub-basin is presented in **Figure 7.3.17**.

It is expected that the pollutant loads entering into both lakes are remarkably reduced through sewerage construction by 2015, although there is a increase in pollutant loads accompanied with population growth.

Comparing the present in 2005 with the future in 2015 when the sewerage will be constructed, the pollutant loads are reduced by 67% in BOD_5, 69% in TN and 71% in TP in the basin of the Lake Billings, while 36%, 45% and 44%, respectively, in the basin of the Rio Grande Arm

Table 7.3.7(1) Estimated runoff load from sub-basins by target year（BOD）

Basin	Basin Area	Without STP			With STP	
		2005(t/d)	2015(t/d)	2025(t/d)	2015(t/d)	2025(t/d)
A-1	20.98	4.97	6.76	6.52	1.69	0.58
A-2	37.86	0.86	1.22	1.18	0.35	0.14
A-3	20.52	0.08	0.11	0.03	0.11	0.03
A-4	31.32	0.10	0.14	0.04	0.14	0.04
A-5	29.48	0.00	0.00	0.00	0.00	0.00
A-6	20.50	0.02	0.02	0.02	0.01	0.01
A-7	9.49	0.03	0.03	0.03	0.03	0.03
A-8	20.16	0.00	0.00	0.00	0.00	0.00
A-9	38.76	0.00	0.00	0.00	0.00	0.00
A-10	7.81	0.07	0.11	0.10	0.08	0.06
A-11	12.74	0.26	0.35	0.37	0.27	0.29
A-12	24.60	3.98	5.42	5.79	0.77	0.46
A-13	13.30	1.52	2.15	2.24	0.45	0.17
A-14	10.38	2.74	3.52	3.45	0.87	0.29
Sub-total	**297.90**	**14.63**	**19.83**	**19.77**	**4.78**	**2.09**
B-1	15.84	0.12	0.12	0.12	0.06	0.04
B-2	21.14	0.26	0.29	0.32	0.08	0.07
B-3	74.86	0.18	0.20	0.23	0.06	0.05
B-4	33.65	0.92	0.34	0.88	0.34	0.27
B-5	10.81	0.05	0.07	0.04	0.05	0.02
B-6	20.43	0.45	0.78	0.23	0.66	0.08
Sub-total	**176.73**	**1.96**	**1.81**	**1.82**	**1.26**	**0.53**

Table 7.3.7(2) Estimated runoff load from sub-basins by target year (TN)

Basin	Basin Area	Without STP			With STP	
		2005(t/d)	2015(t/d)	2025(t/d)	2015(t/d)	2025(t/d)
A-1	20.98	1.22	1.68	1.62	0.36	0.07
A-2	37.86	0.28	0.41	0.40	0.10	0.02
A-3	20.52	0.03	0.05	0.01	0.05	0.01
A-4	31.32	0.05	0.07	0.01	0.07	0.01
A-5	29.48	0.00	0.00	0.00	0.00	0.00
A-6	20.50	0.01	0.02	0.01	0.01	0.01
A-7	9.49	0.01	0.01	0.01	0.01	0.01
A-8	20.16	0.00	0.00	0.00	0.00	0.00
A-9	38.76	0.00	0.00	0.00	0.00	0.00
A-10	7.81	0.02	0.04	0.03	0.03	0.02
A-11	12.74	0.10	0.14	0.15	0.11	0.11
A-12	24.60	1.00	1.39	1.50	0.14	0.06
A-13	13.30	0.39	0.57	0.59	0.10	0.02
A-14	10.38	0.66	0.86	0.84	0.19	0.04
Sub-total	**297.90**	**3.78**	**5.24**	**5.17**	**1.17**	**0.38**
B-1	15.84	0.04	0.04	0.05	0.02	0.01
B-2	21.14	0.10	0.12	0.14	0.02	0.01
B-3	74.86	0.11	0.13	0.15	0.02	0.01
B-4	33.65	0.36	0.08	0.33	0.08	0.05
B-5	10.81	0.02	0.03	0.02	0.02	0.00
B-6	20.43	0.19	0.34	0.08	0.28	0.02
Sub-total	**176.73**	**0.82**	**0.75**	**0.76**	**0.45**	**0.10**

Table 7.3.7(3) Estimated runoff load from sub-basins by target year (TP)

Basin	Basin Area	Without STP			With STP	
		2005(t/d)	2015(t/d)	2025(t/d)	2015(t/d)	2025(t/d)
A-1	20.98	0.146	0.201	0.194	0.044	0.009
A-2	37.86	0.027	0.040	0.038	0.010	0.002
A-3	20.52	0.002	0.004	0.000	0.004	0.000
A-4	31.32	0.004	0.005	0.001	0.005	0.001
A-5	29.48	0.000	0.000	0.000	0.000	0.000
A-6	20.50	0.001	0.001	0.001	0.001	0.000
A-7	9.49	0.001	0.001	0.001	0.001	0.001
A-8	20.16	0.000	0.000	0.000	0.000	0.000
A-9	38.76	0.000	0.000	0.000	0.000	0.000
A-10	7.81	0.002	0.003	0.003	0.002	0.001
A-11	12.74	0.008	0.012	0.012	0.009	0.009
A-12	24.60	0.129	0.162	0.174	0.016	0.006
A-13	13.30	0.047	0.067	0.070	0.012	0.003
A-14	10.38	0.079	0.104	0.102	0.023	0.005
Sub-total	**297.90**	**0.446**	**0.600**	**0.596**	**0.126**	**0.038**
B-1	15.84	0.003	0.003	0.004	0.001	0.001
B-2	21.14	0.008	0.009	0.011	0.001	0.001
B-3	74.86	0.008	0.010	0.012	0.002	0.001
B-4	33.65	0.027	0.006	0.026	0.006	0.003
B-5	10.81	0.002	0.002	0.001	0.002	0.000
B-6	20.43	0.015	0.027	0.007	0.023	0.001
Sub-total	**176.73**	**0.063**	**0.059**	**0.059**	**0.035**	**0.007**

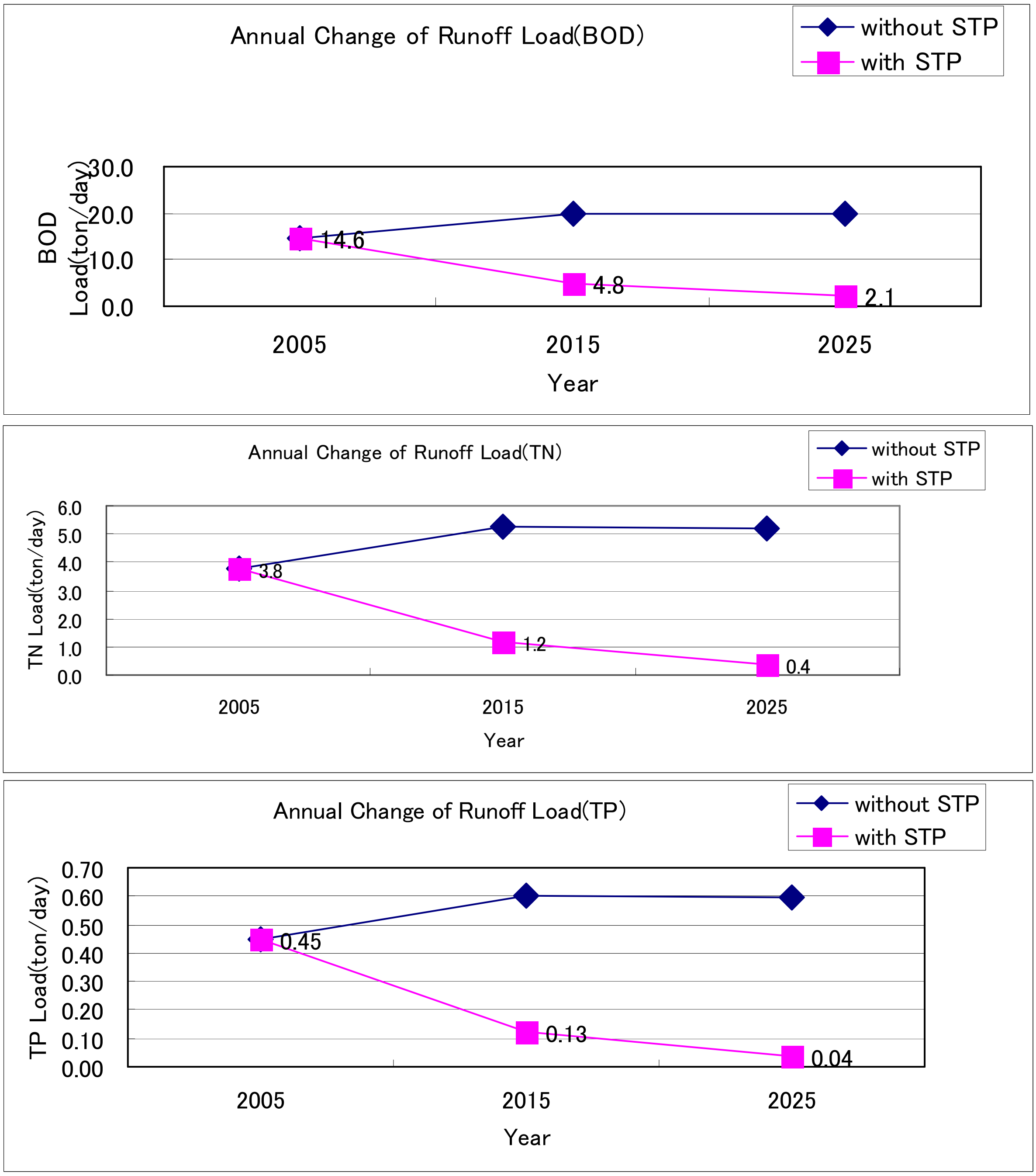


Figure 7.3.16 Estimated runoff load from sub-basins by target year

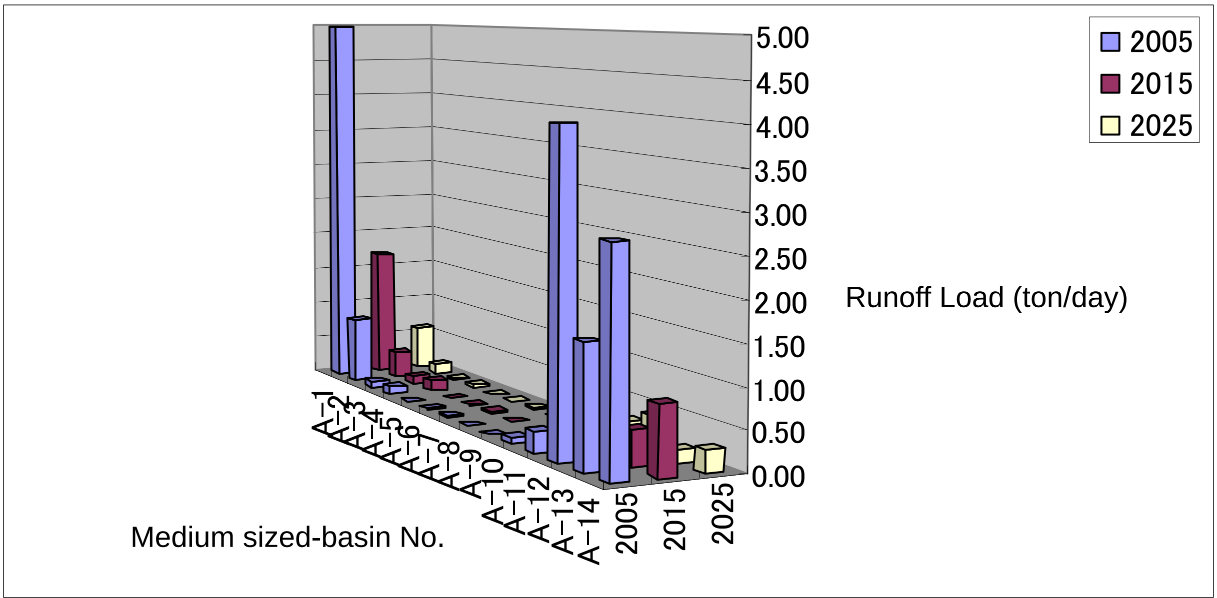


Figure 7.3.17 Yearly change of estimated runoff loads from sub-basins after sewerage construction （BOD）

7.4 Water Quality Model

(1) Introduction

The modeling component of the "Plano de Melhoramento Ambiental da Bacia da Represa Billings" aims to support the elaboration of a recovery plan for the Billings and Rio Grande Reservoirs. Particularly, the modeling should generate prognosis of water quality alterations as a result of sanitary actions promoted around Sao Bernardo do Campo area.

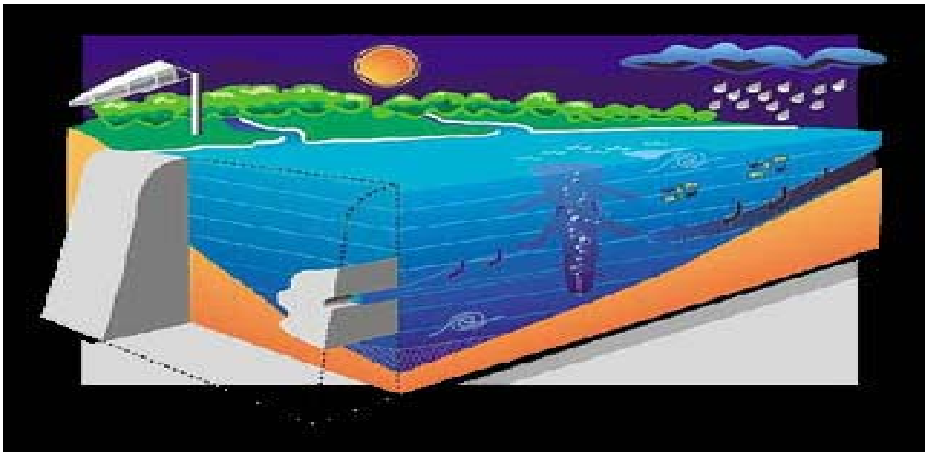
In order to reach such objectives the 3D hydrodynamical model ELCOM (CWR, 2004) and the ecological model CAEDYM (CWR, 2004a) were adopted. These models were selected among the main 3D models available worldwide on a recent comparison conducted in the project "Mathematical Model of the High and Middle Tiete over the Metropolitan Area of Sao Paulo, Brasil", supported by the International Development Bank – IDB.

Such model combination can consider the horizontal and vertical heterogeneities of the systems to be studied and, particularly for this application on São Bernardo do Campo Project, is proposed a new models configuration with the adoption of the large computational grid which should allow the representation of long term tendencies – necessary condition in the proposed simulations.

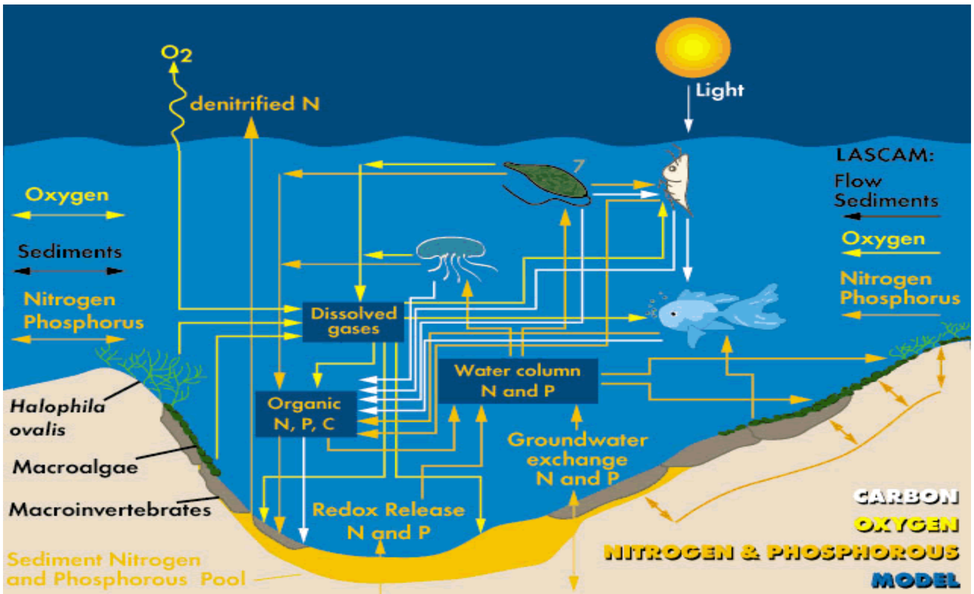
This continuity of the modeling work on Billings with the ELCOM/CAEDYM and the conduction of complimentary field studies in the area, as has been conducted in this project, are in accordance with IDB recommendations of adoption and improvement of the state-of-art modeling technology applied to Sao Paulo waterbodies.

(2) Hydrodynamical and Ecological Models

The 3D hydrodynamical model presented below was adopted on the IDB project “Mathematical Model of the High and Middle Tiete over the Metropolitan Area of Sao Paulo, Brasil” - mathematical modeling of the hydrodynamics and water quality of Billings and Barra Bonita reservoirs as the rivers Tiete and Pinheiros covering the metropolitan are of Sao Paulo as part of the state countryside. Such model was selected after a detailed comparison with the main world hydrodynamical models (e.g. DELFT3D, MIKE3, GLLVHT) and has all requirements for the accurate representation of Billings and Rio Grande Reservoir dynamics. Also, ELCOM perfectly couples with the ecological model CAEDYM – model selected in the IDB project as well (See **Figure 7.4.1**).



ELCOM (3D Hydrodynamics model)



CAEDYM (Water Quality Model)

Figure 7.4.1 ELCOM-CAEDYM MODEL

a). ELCOM

ELCOM (Estuary, Lake and Coastal Ocean Model) is a three-hydrodynamics model used for predicting the velocity, temperature and salinity distribution in natural water bodies subjected to external environmental forcing such as wind stress, surface heating or cooling. ELCOM is designed to facilitate studies of aquatic systems over time scales extending to a few weeks, though the limit of computational feasibility depends on the size and resolution requirements of an application and computational resources. ELCOM is suited for comparative studies of the summer and winter circulation patterns, spring versus neap tidal cycles, or dispersal conditions under different flow regimes. ELCOM can be run either in isolation for hydrodynamic studies, or coupled with CAEDYM for simulation of biological and chemical processes. The code is written in modular fashion to support future updates and improvements.

ELCOM has recently been modified to efficiently simulate narrow curved domains such as river, estuaries and reservoirs, systems in which the large ratio of length/width often hampers three-dimensional modeling. A new approach developed at CWR allows modeling these systems on a Cartesian grid while retaining the dynamics of the system due to horizontal curvature. The success of this approach is predicated on the natural characteristics of rivers and many reservoirs wherein the width (w) is significantly smaller than the horizontal radius of curvature (r). Under this condition, the curvilinear form of the shallow water equations can be reduced to the Cartesian form with additional perturbation terms whose leading order is w/r. These terms can be effectively added to a Cartesian-grid numerical model as explicit source terms. Thus, the morphology of a channel system can be straightened and discretized with rectangular Cartesian grids and modeled using any of a number of existing numerical models to which these source terms may be added.

In order to guarantee precision to the simulations of lakes and reservoirs, the model ELCOM include the following characteristics: conservative numerical scheme for the transport of scalars, sophisticated wind mixing layer turbulence closure scheme, continues boundary conditions, tributaries insertion and representation of inflows entrainment, as detailed surface thermodynamics (including atmospheric instability). The model also includes a method to reduce the adverse effects os numerical diffusion, thus allowing the simulation of short term events as extended periods.

ELCOM was developed by the Centre for Water Research, University of Western Australia, internationally recognized in the area of environmental fluid mechanics and solution of environmental problems. The model is also under constant evolution as results of recent scientific research are incorporated to its code.

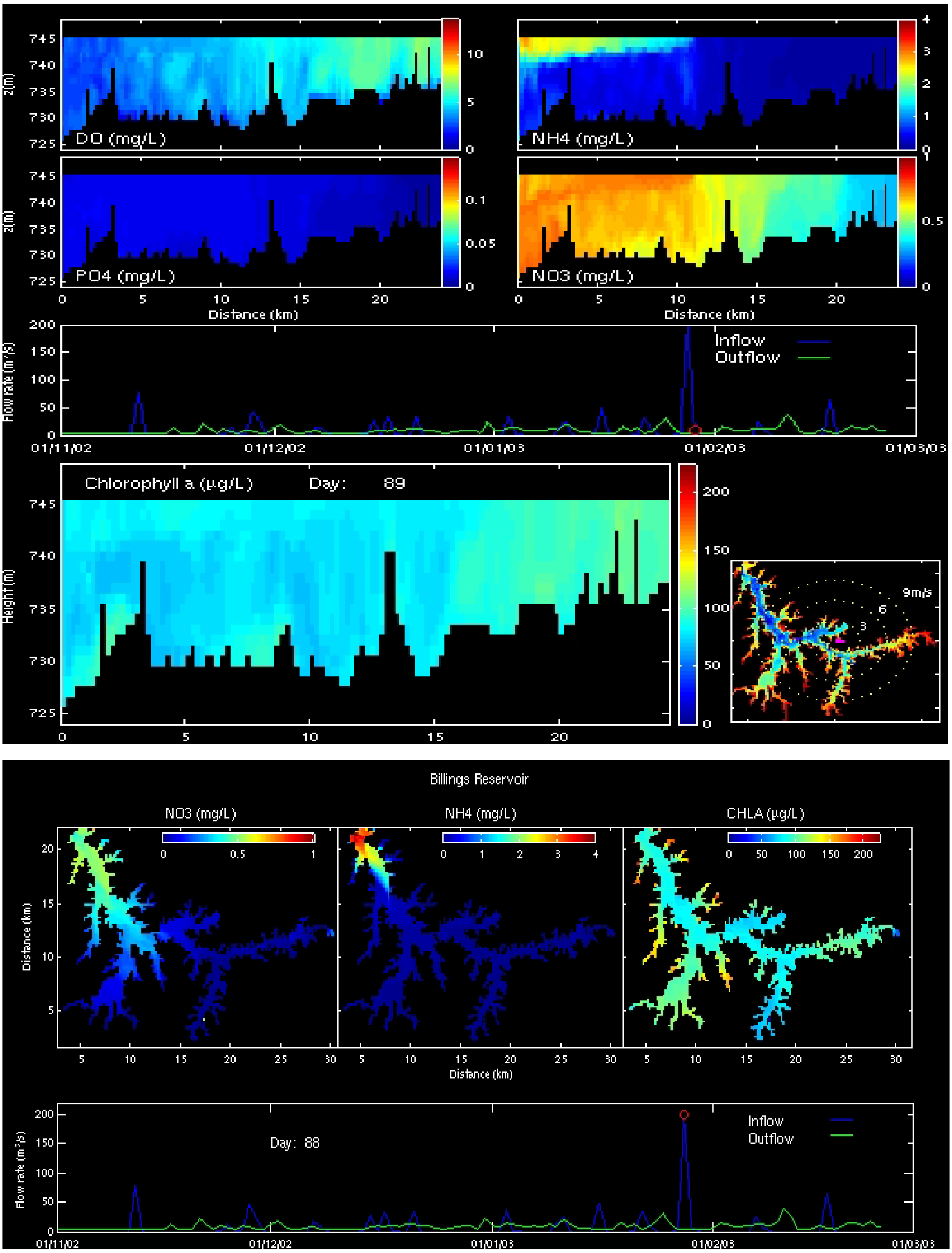


Figure 7.4.2 Example of ELCOM-CAEDYM Output for Billings Reservoir

(3) The Reservoirs

A description of Billings and Rio Grande Reservoir, as their multiple uses and importance to the Metropolitan Region of Sao Paulo, are presented in the Initial Report (June, 2005).

From the ecological point of view, both reservoirs are eutrophic as a result of elevated load inputs from the watershed as Rio Pinheiros pumping – constant in the past and only sporadic during the last decades (only allowed as flood control measure).

As a result of such loads, nowadays Billings and Rio Grande Reservoir show accentuated water quality problems (i.e. algal blooms, anoxia, toxicity) becoming even worse due to a crescent load pressure in the watershed and the accumulation of compounds in the sediments. The regular water quality monitoring conducted by CETESB – Sao Paulo environmental agency, shows these tendencies as suggests a strong horizontal heterogeneity due to dendritic conformation of both reservoirs (CETESB, 2005).

A recent intensive experiment conducted by *Universidade Federal de Sao Carlos* and CETESB confirms such horizontal heterogeneity on Billings Reservoir and demonstrates the occurrence of vertical gradients equally important. Figures 5.2.19-21 illustrate these gradients on several CTD surveys conducted between 29 and 30 September, 2004, during a passage of a cold front over the reservoir.

The complete series of these surveys will be presented on a scientific article (under preparation); however, the authors already confirmed that the main components determinant the horizontal gradients along Billings Reservoir are: (i) obstructions between reservoir arms (Imigrantes bridge – see conductivity gradients along transects T1), (ii) contribution of sub-catchments (see Rio Pequeno and Rio Grande arms – conductivity profiles and turbidity along transects T3), and (iii) the orientation of the reservoir´s arms regarding the main winds (see main water body and Taquacetuba – thermal stratification more accentuated along arms of shorter fetch on transects T2). As we follow the evolution of the profiles along the main water body becomes clear the dynamical character of the stratification by the thermocline tilting and “pilling” of water from the epilimnion downstream the wind direction – important results for the plankton distribution in the reservoir (Rio, 2003).

The short considerations above show that the numerical simulations of the system Billings/Rio Grand should be based on detailed estimative of the loads (external and internal), as the requirement of 3D capability of the models. During the last months, under the scope of the current project, several campaigns of water quality sampling in the reservoirs as more detailed estimative of the loads over a large number of tributaries has been producing a rich data set for model calibration and improvement of the load model.

Regarding the hydrodynamics and water quality, most of the conducted work was conducted in a new discretization which should imply on minimal loss of spatial representativeness as make feasible the use of these 3D models for the simulation of long periods.

7.4.1 Improvements over the water quality analysis model for the Lake Billings

(1) Work policy

As mentioned above, this project intends to improve the modeling procedures developed during the IDB project in Billings Reservoir. Below are listed several tasks that are under development:

1) A new model setup to allow the conduction of long term simulations and the evaluation of future water quality policies.

2) The setup prepared for the IDB project only focused on short term and events reproduction;

- Water quality analysis and flows measurements on 20 tributaries (twice during the dry season and twice on the wet season) aiming to improve the calibration of the load model;
- Water quality analysis on 9 sampling stations along Billings and Rio Grande Reservoir have been sampled aiming to provide better calibration data for reservoirs water quality model. These stations cover the main compartments of the reservoirs as also their sampling contemplates the vertical structure of the water bodies;
- ADCP current measurements under the Imigrantes bridge over Billings reservoir to provide a better understanding of the exchange flows between the main compartments of the reservoir and produce quality data for verification of the hydrodynamical model;
- Internal load experiments to provide better understanding of its impact on long term sanitation plans. A total of five cores (3 on Billings and 2 on Rio Grande Reservoir) should be extracted and provide material for nutrients and organic matter release experiments. On Lake Kasumigaura, the second largest lake of Japan, the internal load represents about 56% of total DQO load in the water body showing that an accurate representation of this interaction is essential for long term simulations and evaluation of remediation actions;
- In the tributaries, as in the reservoirs and sediments, detailed organic matter partition analysis have been conducted in a way to provide a more accurate interaction between the load model and the water quality reservoir model.

(2) Reservoir Model Setup

Basically, a model setup comprehend the decentralization and calibration of the system to be simulated.

Several activities support this work, mainly the conduction of bathymetric surveys, field experiments and gathering of secondary information (i.e. flows, water levels, wind direction and speed, air temperature and humidity, atmospheric radiation and several water quality and sediments variables). As exposed in the introduction, our modeling will give emphasis on the generation of long term scenarios; thus, an special attention is given to the surveys and analysis of the watershed loads and the determination of the system's internal loads.

Another special issue is making compatible the spatial resolution of the model to describe the main processes of the environment and computational effort.

Complementing the data set obtained by the regular water quality monitoring conducted by CETESB, several water quality field campaigns have been conducted covering the main tributaries as Billings and Rio Grande reservoirs

As the bathymetric data of Billings Reservoir and results of an intensive field experiment on this reservoir were already available (data provided by Dr. Angelo Saggio, Federal University of Sao Carlos - UFSCar, Brazil) we proceeded with ELCOM/CAEDYM setup for Billings reservoir, as described in the following section.

Billings Reservoir Setup

The bathymetry was mainly based on EMAE's 1985/86 survey complemented by shorelines extracted from several satellite images from the 90's and a recent survey on Pedreira's area (2003).

EMAE's 1985/86 survey was available on (i) digitalized contours of the side of Billings at West of Imigrantes bridge and 26 maps (scale 1:5000) of the East side of the Imigrantes bridge. These maps had contour levels 745 and 750 meters digitalized to complete elevation information necessary to grid the reservoir up its maximum level.

Five satellite images from the 90's with clear signal and covering elevation 739.77 to 745.79 meters were segmented and classified to extract shoreline's contours of the reservoir allowing us to verify and complement the information gathered from EMAE's 1985/86 survey.

Contour levels from a recent survey (EMAE, 2003) of a small area, ~ 200 meters wide and 2000 km long, close to Pedreira's dam updated the bathymetric information on a zone of the reservoir subject to both strong siltation and frequent dredging.

The elevation points and contours obtained from the above sources had their reference level changed from EPUSP to IBGE (IBGE=EPUSP+1.15m) and were incorporated in a GIS together with the hydrography and sub-catchments information provided by COBRAPE.

Several grids were computed using GRASS s.surf.rst routine – interpolation and topographic analysis using regularized spline surfaces with tension (Mitasova H. and Hofierka J., 1993)

The grids with the finest horizontal resolution were unsuitable for the simulation of long periods –

for example, 10 years long simulations with a grid 200×200 meters (adopted on IDB project) resulted in a computer time superior to 29 days on a Pentium 4 3GHz. Coarse grids, on their turn, resulted on accentuated loss of accuracy for the representation of the narrow section below Imigrantes bridge – which good representation is essential for the reproduction of the gradients along the Lake Billings (**Figure 5.2.19**).

Adopting the special capability of ELCOM/CAEDYM of operation with variable grids, it was obtained an optimal configuration through the adoption of a grid with vertical resolution of 1 meter and horizontal resolution of 500×500 meters with a enhanced grid resolution of 125 meters near the region of Imigrantes Bridge (**Figure 7.4.4**). This configuration allowed 10 years simulation on a computational time inferior to 2 days.

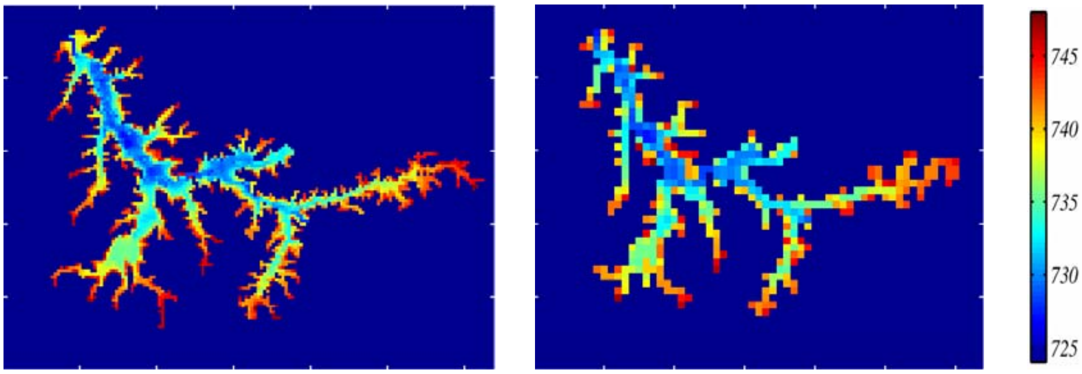


Figure7.4.4 Computational grids of Billings Reservoir

The left panel shows the 200×200 meters grid, adopted on the IDB project, while the 500×500 meters grid with enhanced resolution of 125 meters close to Imigrantes Bridge is shown on the right panel. The 200×200 meters grid is more suitable for short term and local effects simulations. The 500×500 meters grid with enhanced resolution near Imigrantes bridge is optimized for long term simulations as keep accurate representation of main gradients and determining processes in the reservoir.

In order to verify the capability of the new model configuration to reproduce the dynamics of Billings Reservoir, several simulations were conducted for September 2004. During this period Dr. Saggio had an automatic meteorological station in the reservoir, as also conducted intensives field experiments to register the variability of thermal structure on Billings while CETESB and SABESP were conducting successive water quality surveys. **Figure 7.4.5** shows model results for this period as also field registers obtained by SABESP automatic water quality station located on Taquacetuba arm – a site at the end of a long arm of Billings Reservoir and usually more difficult to reproduce due to large distance to the main body of the reservoir and different orientation of the arm regarding the main channel and preferential flows. The numerical results of the thermal structure show excellent agreement with the field data representing both diurnal and daily fluctuations on the signal. The simulations of dissolved oxygen also reproduced the local dynamics and there is a good margin of improvement as new sediment's oxygen demand rates become available – the sediments studies are planned and should be conducted during the next months.

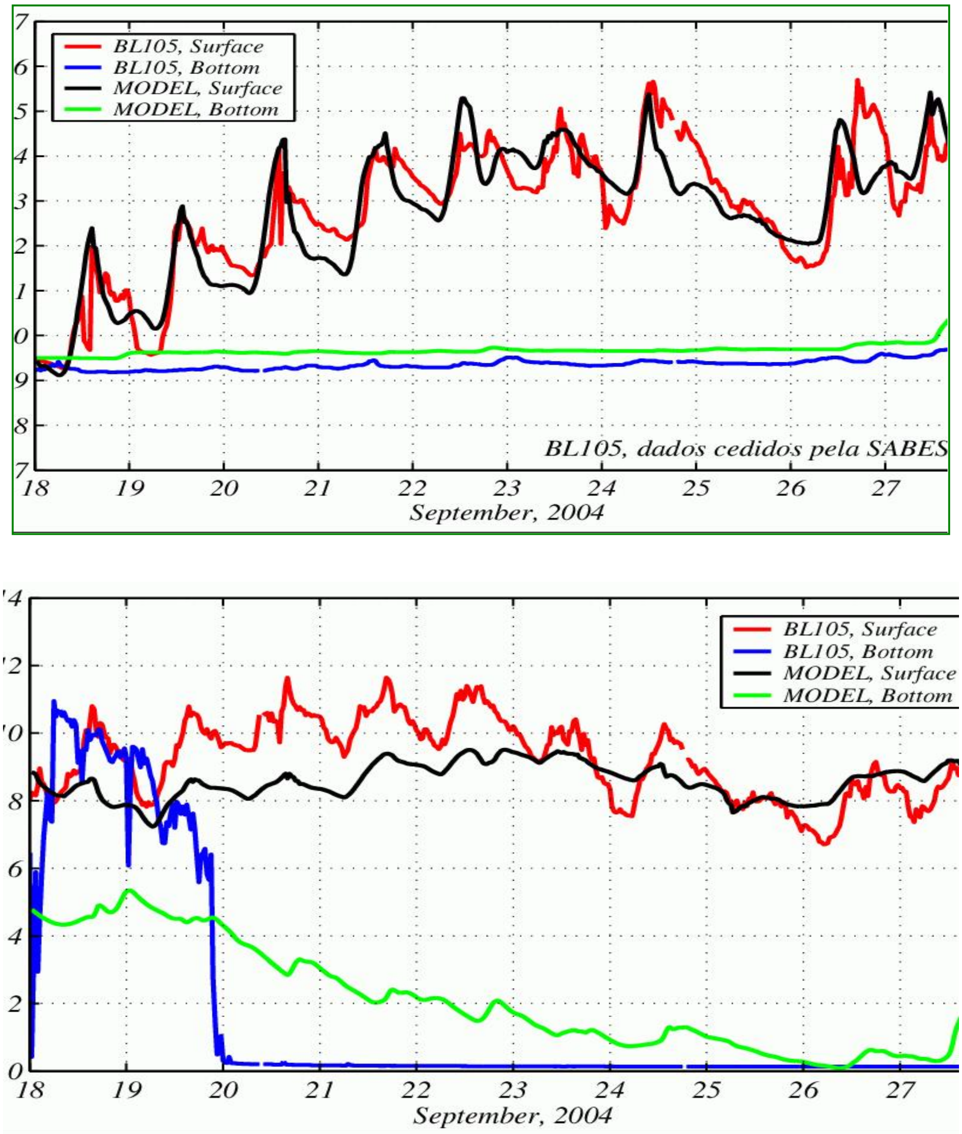


Figure 7.4.5 Comparison between numerical simulations with ELCOM/CAEDYM and field data obtained by SABESP automatic water quality station located at Taquacetuba arm of Billings resevoir. The top panel compares the water temperatura and the bottom one show the dissolved oxygen results. The simulations were conducted with the new grid (500×500 meters with enhanced resolution near Imigrantes)

As shown in **Figure 7.4.5**, the adopted discretization is able to provide a good representation of the notable compartmentalization of Billings Reservoir as also allow for long term simulation over reasonable computational times – as defined in our scope. With the new water quality results, improved watershed load model, better sediment-water interaction coefficients there is good room for calibration improvement of the water quality component of the model and, consequently, the production of more realistic scenarios.

References

- CETESB, 2005. **Qualidade das Águas Interiores do Estado de São Paulo – Série Relatórios, 2004.** Companhia de Saneamento Ambiental, Secretaria do Meio Ambiente.
- CWR, 2004. **Estuary and Lake Computer Model, ELCOM – v2.1 User Manual.** Centre for Water Research, The University of Western Australia. 82p.
- CWR, 2004a. **Computational Aquatic Ecosystem Dynamics Mode, CAEDYM – v2.1 User Manual.** Centre for Water Research, The University of Western Australia. 62p.
- Rio C. M., 2003. **Modelagem da Circulação de um Reservatório Tropical Polimítico.** Tese de Doutoramento, Universidade Federal de São Carlos, São Carlos, Brasil.
- Mitasova H. & Hofierka J., 1993. Interpolation by Regularized Spline with Tension: II. Application to Terrain Modeling and Surface Geometry Analysis. **Mathematical Geology 25**: 657-667.

(5) Setting for Hydrodynamics and Water Quality Models

From August 2005 to January 2006 several field campaigns were conducted on Billings and Rio Grande reservoirs. The compiled water quality data set was the basis for the update of the Load Model for Billings as the setup of the Load Model for Rio Grande reservoir. These new loads estimates, presented on section 12.2, are now supporting a refined calibration of the water quality reservoir model for both Billings and Rio Grande.

While the final calibration is still in progress as the field analysis only became available on February, this section describes the advances during this period including some preliminary long term simulations.

1) Billings Reservoir

A new bathymetric survey became available recently (conducted by EMAE during 2005) and an update of Billings discretization was performed. It resulted on minor changes in the computational grid as the current setup involves large cells to allow long simulation periods. The changes were incorporated anyway allowing that the current setup includes the most up-to-date information.

Significant advances in the water quality configuration where obtained though the analysis of both the fluxes between the model variables (e.g. nitrification, algae excretion, contribution of the several organic carbon species to the oxygen depletion) and the processes control variables (e.g. algae limiting factor). Despite the small changes in the resultant variables on short term runs, the coefficient's corrections produced more equilibrated results on tests of long term simulations.

Regarding phytoplankton, the setup produced during the CETESB/IDB project was mainly focused on the total chlorophyll as weren't much algae composition information available that time. In the current recalibration, more emphasis is given on the representation of the seasonal changes on the algal community as the model is now describing the oscillation of cyanobacteria, chlorophytes, diatoms and dinoflagellates. During the last meeting at CETESB (24^{th} of February, 2006) to discuss the advances on the calibration, this update on the model was very appreciated by the algae specialists as they consider this capability of the current setup essential to the discussion of long term tendencies in both lakes.

The new setup for Billings is very computationally efficient and the first long term 10 years runs have been conducted. A simulation example is illustrated below through time series at site BL101 – junction of Taquacetuba and the main branch of Billings. **Annex A7.4.3**, with these results, show the more equilibrated balances on carbon as also the algae dynamics discussed above. The hydraulic and meteorological environmental conditions of 2002 were repeated to generate synthetic boundary conditions for 10 years period for this example simulation. The general tendency of water quality deterioration in this example is partially attributed to the fact that 2002 was a dry year. On the following synthetic environment forcing time series generation for the scenarios runs different conditions can be easily generated by the Load Model - on which not only the probability of a dry or wet year can be exploited, but also the several loads conditions will be included (i.e. population grown, remediation strategies).

For the scenarios discussion, outputs like the time series at specific sites can be combined with layers snapshots as shown on **Figure 7.4.6**, that illustrates the evolution of a numerical tracer on Billings after a short pumping of the polluted waters of Pinheiros River into the reservoir.

The calibrated model coefficients are presented on **Annex A7.4.4** and the meaning of each coefficient is explained on "CAEDYM Science Manual" and CAEDYM User's Manual", both included in the appendix.

2) Rio Grande Reservoir

Rio Grande Reservoir, an isolated arm of Billings, also suffers similar water quality problems with high loads from the main tributaries and frequent algae blooms. Of course, due to the dam which segments this arm, the reservoir isn't exposed to the contribution of Pinheiros river during flood events in S. Paulo metropolitan area.

A bathymetric survey conducted last January, complemented by EMAE's data, constituted the basis for the generation of the computational grid. Rio Grande presented the same morphometric features of the main water body with a wide and flat bottom along the central body.

Using the same interpolation technique adopted for Billings, Rio Grande was discretized on 200×200 m cells in the horizontal and 1 meter height layers. The resultant computational grid (**Figure 7.4.7**) presents enough detail for the simulation of short events – like the IDB/CETESB setup for Billings, as also allow long simulation periods. With this new setup for Rio Grande, a 10 years simulation period can be performed on 48 hours with an integration step of 450 seconds on a Pentium 4HT 3GHz.

As Rio Grande can be considered an extension of Billings reservoir, inserted on a region with similar features, it was adopted the same water quality coefficients in the water quality models. However, a proper verification of these coefficients couldn't be conducted as information on quantities, dates and sites of application of algae control chemicals in the lake are not systematized by SABESP .

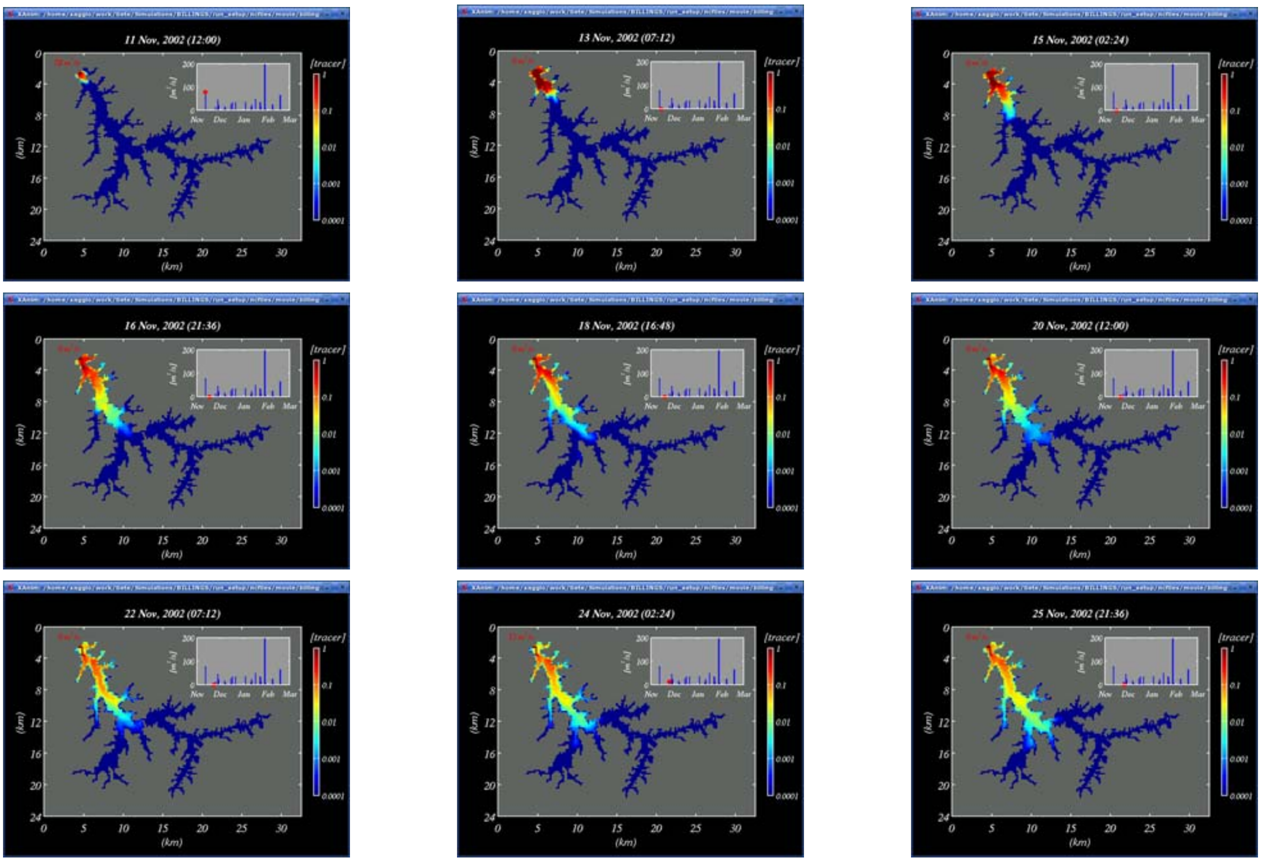


Figure 7.4.6 Frames of computer animation illustrating the evolution of a tracer inside Billings reservoir.

This same sort of output can be generated for other model variables and used to evaluate scenarios regarding local impacts of remediation strategies.

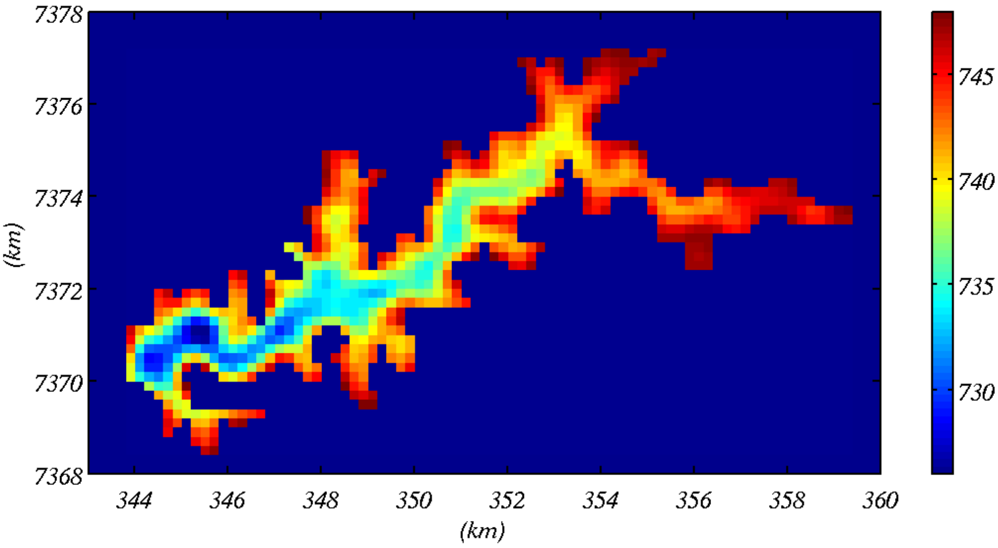


Figure 7.4.7 Discretization of Rio Grande Reservoir on 200x200 meters horizontal cells

Chapter 8

SOCIETY AND OPINION SURVEY OF THE BASIN REGION RESIDENTS

8 SOCIETY AND OPINION SURVEY OF THE BASIN REGION RESIDENTS

8.1 Purpose of the Survey

The public opinion survey is proposed with local residents in relation to the water and sewage services rendered to residences and different local establishments (industries, trade, agro-industry, etc.) as well as sanitary facilities, usage level, awareness level in respect to the environment, hygiene and preservation of the Billings Lake’s water quality. This survey is aimed at obtaining information on the following points:

- The living environment and the sanitary situation of the residents at the location and of the establishments (commercial, agricultural, agro-industrial, etc.), through the situation of coverage, usage and utilization of the basic sanitation and sanitary facility services.
- In respect to the level of income of local residents and businesses, their tariff payment possibilities (for rendered services). Use this data for future definition of water and sewage tariffs.
- In respect to the expectations of local residents and businesses, regarding the facilities of the water and sewage system, hygienic conditions, improvement of facilities, etc.
- In respect to the awareness of local residents and businesses in relation to the pollution of the Billings Lake and their experiences participating in some anti-pollution campaign and evaluate the level of awareness of the local population in respect to their participation intentions and expectancy of the improvement of the Billings Lake water quality.
- Use the information obtained through the survey as reference for the organization of stakeholder meetings and creation of environmental education material.

8.2 Methodology

With the purpose of ensuring the precision of the answers, and obtaining the desired answer rates, an individual interview methodology was adopted, with visits to homes and businesses made by surveyors to complete the questionnaires and listen to opinions.

8.2.1 Survey Procedure

This survey was conducted according to the procedure below:

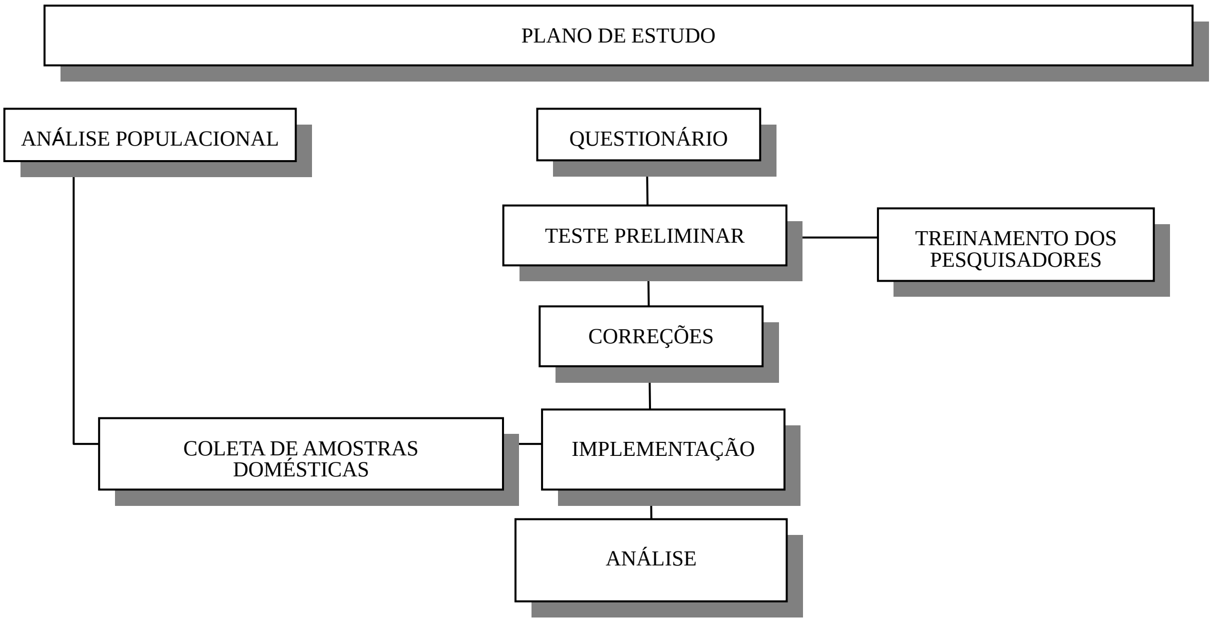


Figure 8.2.1 Procedure for the Society and Opinion Survey involving Residents of the Basin

8.2.2 Sampling Number and Distribution Method

The total number of families and/or establishments to be heard through the questionnaire was decided by the JICA Study Team, as being, 430 families and 120 establishments, totaling 550 samplings.

The distribution method of this number in the Billings Hydrographic Basin, partially covering 6 (six) cities such as São Bernardo do Campo, Diadema, Ribeirão Pires, Rio Grande da Serra, Santo André and São Paulo (Capital of the State of São Paulo), was preliminarily studied by the JICA Study Team and presented to the Study Counterpart, São Bernardo do Campo City Government.

After discussions in relation to the distribution methods, considerations related to specific aspects of the population, inclusion of domicile group of irregular occupations and other detailed procedures, these issues were bilaterally solved and concluded together with the above-mentioned responsible entity,, the Coordinator of the JICA Study Counterpart and the Department of Geopolitical and Economic Information, of the Secretary of Planning and Information Technology.

The distribution of the sampling number per city, divided into domiciles and establishments, together with the estimated population number in the year 1996 are presented on **Table 8.2.1**.

Table 8.2.1 Population (estimate of year 1996), Families (Domicile) and Companies

Nº	Nome de Município	População 1996 na Bacia	Número de Amostragem		Características da região da Bacia do Município
			Número de Domicílio	Número de Estabelecimento	
1	São Bernardo do Campo	188,181	200	0	Ele ocupa quase 22% de população da Bacia, e sua característica, na região norte da Represa, é de ambiente urbano, e na região sul da , é ambiente misto (urbano e rural).
2	São Paulo	468,041	130	30	Ele ocupa quase 54% de população da Bacia, e sua característica, na região norte, é de ambiente urbano, e na região sul da Represa, é de ambiente misto (urbano e rural).
3	Diadema	59,804	35	10	Ele ocupa quase 7% de população da Bacia, e sua Característica, na região, é de ambiente urbano.
4	Santo André	25,283	20	10	Ele ocupa quase 3% de população da Bacia, e sua característica na região, é quase ambiente rural.
5	Rio Grande da Serra	34,225	20	10	Ele ocupa quase 4% de população da Bacia, e sua característica na região é quase ambiente rural e uma parte muito pequena é de ambiente urbano.
6	Ribeirão Pires	86,470	25	10	Ele ocupa quase 10% de população da Bacia, e sua característica, na região, é quase ambiente rural e, na parte baixa da região, é de ambiente urbano.
	Total	863,004	430	120	

8.3 Execution of Survey by Interview and Survey's Approach Area

8.3.1 Survey Team, Training and Field Work.

This Social Survey's Team was composed of professionals, majority of which hold vast experience in studies of such nature, with academic background in human sciences – psychology, sociology, etc… also including two university students. The team was constituted by: 1 (one) Coordinator, 1 (one) Field/office supervisor and 14 (fourteen) teams of interviewers, put together by CONCREMAT.

Team that went through a training process in which the goals of the survey were discussed and specific training given on the questionnaires to be employed.

The field works were accompanied on site throughout the process by the field/office Supervisor as work support and gauging, solving occasional doubts generated by the peculiarities of the areas covered.

8.3.2 Execution of Survey by Interview

Based on the sampling number per City (presented on **Table 8.2.1**), and upon assessment of the population representation of each city in the Basin, the sampling process was designed based on:

The number of districts of the cities, components of the Basin

Selection of districts with the largest population concentration in the Basin, according to the city's urbanization rate according to geographical location, in the margins of the Billings Reservoir, ensuring the representation of each inhabited margin in geographical terms.

Selection of at least 50% of most populous city districts/villages, according to geographical location for the composition of the samples.

Identification of the areas of population concentration – streets and/or clusters (irregular and subnormal land parcels), large/medium scale companies situated in the sampled city districts/villages, and other representation conditions.

Draw, random selection, of streets and clusters of each city district, proportional establishing of residential and company sample-unit quotas, for each street or conglomerate;

Formatting of the sampling of companies, constituted by the random draw of large companies situated in the sampled city district/village and by the small and medium scale companies situated on the streets and population clusters, also selected by draw.

Table 8.3.1 Sampling number by City, Districts, Villages and Clusters

Nome de Município	Divisão de Grupo	Nome dos Bairros Vilas e Aglomerados	Número de Amostragem	
			Residência	Empresa
São Bernardo do Campo	Grupo 1	Botujurú / Dos Casa / Batistini / Alvarenga	166	48
	Grupo 2	Riacho Grande / Dos Finco / Varginha	27	2
	Grupo 3	Tatetos	7	0
Santo André	Grupo 1	Jd. Riviera / Chác. Recreio da Borda do Campo	10	6
	Grupo 2	Pq. Represa Billings / Jd. Clube de Campo	10	4
Diadema	Grupo 1	Vila Helas / Jd. Elen	8	5
	Grupo 2	Eldorado / Sapopema / Eldorado	13	5
	Grupo 3	Praia Vermelha / Jd. Elite	8	0
São Paulo / Cidade Dutra	Grupo 1	Jd. Graúna / Jd. Maria Rita / Jd Orion / Jd Rio Bonito	25	9
São Paulo / Grajaú	Grupo 2			
	Sub grupo 2.1	Jd. Castro Alves / Pq. Grajaú /	24	1
	Sub grupo 2.2	Conj. Habit. Faria Lima / Jd. Xangri-lá / Pq. Resid. Cocaia / Jd. Mariza	39	4
São Paulo / Pedreira	Grupo 3			
	Sub grupo 3.1	Balneário São Francisco / Pq. Primavera	25	5
	Sub grupo 3.2	Chácara Sete Praias / Praia Leblon	17	2
Ribeirão Pires	Grupo 1	Balneário Palmira / Caçula	5	2
	Grupo 2	Pq. Do Governador	15	6
	Grupo 3	Sítio do Francês / V. Suíça	15	2
Rio Grande da Sarra	Grupo 1	Centro	17	9
	Grupo 2	Oásis Paulista	3	1
Total			430	120

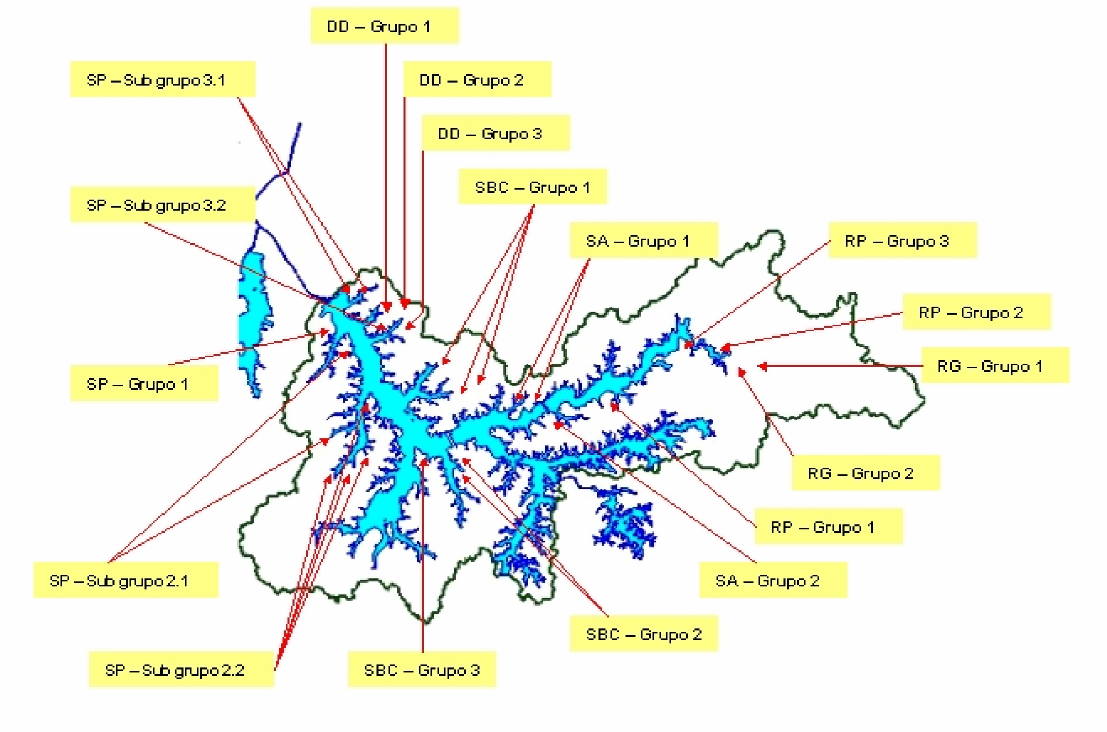


Figure 8.3.1 Billings Lake – Sampling Locations

8.3.3 Survey Area

(1) General

Relationship of Resident and/or Company with Billings Lake

- Environmental and Pollution Values
- Basic Sanitation Conditions in the area, residence or company: Water, Sewage and Garbage, including Garbage Recycling policies
- Knowledge levels on the Pollution of the Billings Lake
- Identification of Problems and Needs resulting from the Pollution of the Billings Lake on: public health, quality of life of residents and employees; company activities.
- Expectations, participation and engagement in a anti-pollution Program of the Billings Lake

(2) Specifics

(a) Residents – Socioeconomic Profile of the Resident through:

- Socio-economic level
- Family constitution
- Housing Conditions
- Identification of Local Leaderships

- Identification of real or potential participation in community actions

(b) Companies

- Classification of companies by activity, size, number of employees
- Identification of the types of liquid and solid wastes generated and the type of treatment
- Company's relationship with the Community: Actual or potential activities of social responsibility of the company towards the community.

8.3.4 Survey Instrument

With the objective of avoiding some conflicts with residents and/or business owners, and obtaining answers without confusion from those interviewed, the following instruments were prepared and have been presented in the AUXILIARY REPORT.

(1) Survey introduction letter per interview, by the Study Team of JICA.

(2) Two types of questionnaires

- RES: Questionnaire for residents
- EMP: Questionnaire for companies

8.4 Main Results – Residents and Companies of the Billings Basin

8.4.1 Main Results-Basin Residents

(1) Profile of the Resident Population of the Billings Basin – Surveyed Residents

Population residing in the Billings Basin, covering part of the geographic area of the cities of São Bernardo, Santo André, Diadema, Ribeirão Pires and Rio Grande da Serra, which integrate the so-called ABCD region in the Greater São Paulo region and of the city of São Paulo (capital), in the sub-districts of Pedreira, Cidade Dutra and Grajaú – south zone of the city.,

Through the interviewees, all the residents of the 430 domiciles sampled were classified, covering 1,734 residents, and a profile of the population residing in the Basin is;

- Population of Low Socio-Economic Level
- Low educational background (not superior to 4 years of studies)
- With specialized manual occupations or routine trade and services

1) Socioeconomic classification of the Families

For the socio-economic characterization, the Brazilian Socio-Economic Classification Criteria of ABEP – Brazilian Association of Research Companies was used, which defines the population into economic classes, assessing their purchasing power and educational background based on the head of the family (the one defined as such by the interviewee). The criteria allow dividing the population into 07 categories, with a given approximation of social classes (the detailed Classification Criteria is presented in the AUXILIARY REPORT).

Based on the Brazilian Socio-Economical Classification Criteria of ABEP, the socio-economic level of the population of the Basin is quite low:

- 71.2% belong to C - D economic classes
- 46.7% - class C
- 24.4% - class D

24% of the families belong to the economic class B, with a large concentration in its lowest segment (B2). 4.4% belong to economic class A, with its lowest segment predominating (A2).

There is also 0.5% of the economic class E, located in São Paulo.

The distribution of the economic classes found is quite close to the indicators existing in the Greater São Paulo region, presenting, however, a differential in the larger concentration of the economic class C (71.1%)   Among the 6 cities covered using the economic criteria as a possible indication of pauperization of the population (class C and D) of the Basin, we have the following classification, by the order, based on the lowest socio-economic level:

- 1º Rio Grande da Serra : 90.0%
- 2º Santo André: 85.0%
- 3º São Paulo: 74.7%
- 4º São Bernardo: 70.5%
- 5º Ribeirão Pires: 57.1%
- 6º Diadema: 52.0%

The detailed Socio-Economic classification of the Basin by 06 cities is presented in Figure 8.4.1.

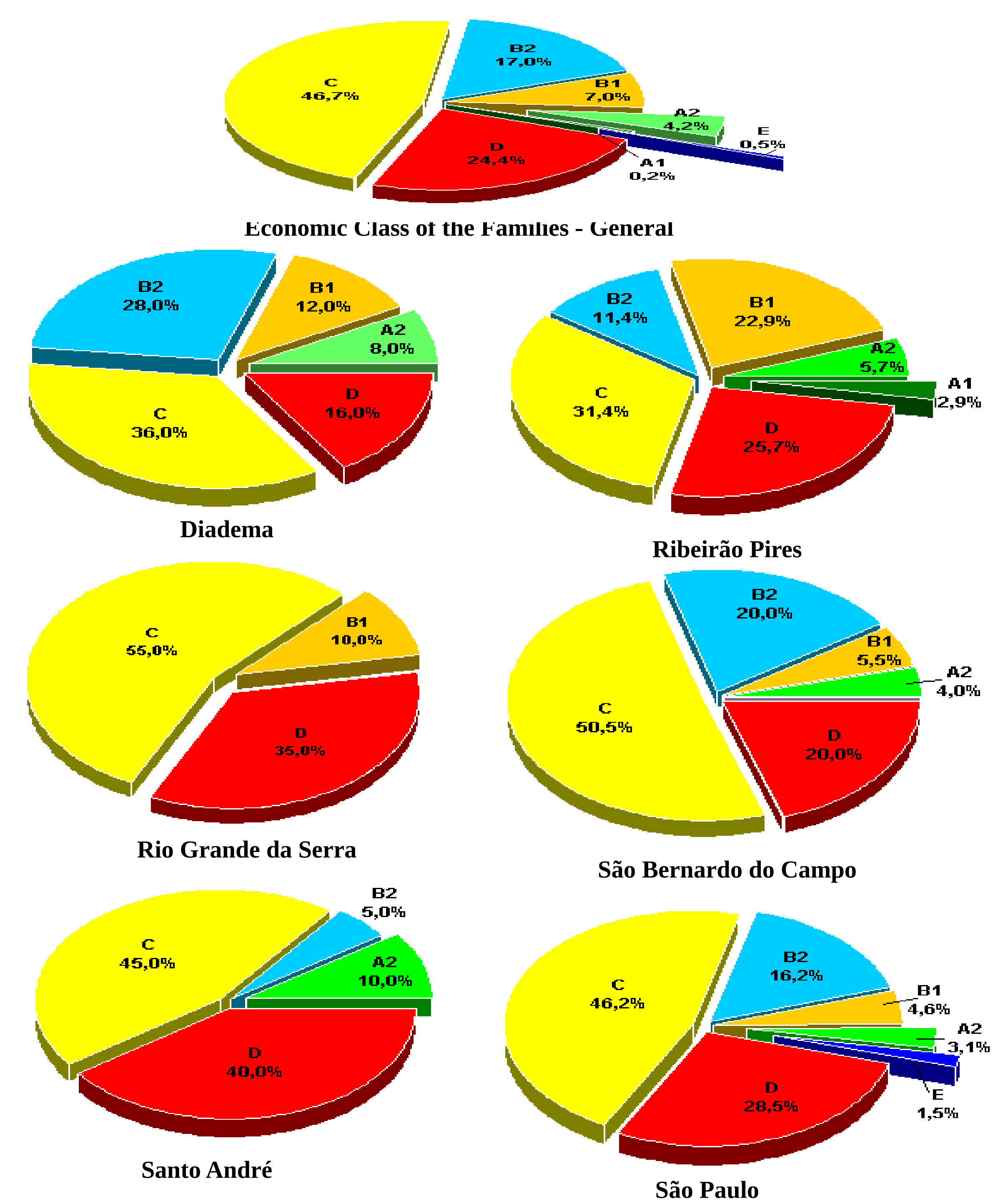


Figure 8.4.1 Socio-economic Classification of Families per City and in the Basin

2) Domicile

In the domiciles situated in the Basin, most (73.5%) of the Domiciles is of the individual home type – Homes owned by residents, built by them, with successive expansions of the original house with 5 to 6 rooms, 2 to 3 bedrooms and internal toilet – which houses 04 residents on average. However, there are 26.5% of new collective housing constituted of two and up to six geminated buildings, in the same land, and entry and or in the backyard of a main house (homes in the same yard) with single electricity, water and sewage facilities originating from a single service bill shared among the homes. Collective housing exists in a smaller proportion in the cities of Santo André and Ribeirão Pires.

In their majority, they are own homes, built by the residents themselves, on small plots, and out of these only 2.0% are actually financed, located in the cities of São Bernardo and São Paulo.

a) Possession of the Home

The conditions of ownership of the land / lot were not identified. In the Billings Basin, independent of the city analyzed, there is predominance of irregular lots in their origin and consolidated slum invasions, part of which were later urbanized, keeping the former physical distribution and access structure. It is considered that the state legislation in respect to the occupation of spring areas dates back to 1976. Possession of the Domicile per city and of the Basin is presented on **Table 8.4.1**.

Table 8.4.1 Possession of Domicile, per city and of the basin in (%)

Posse	Diadema	Ribeirão Pires	Rio Grande Da Serra	São Bernardo Do Campo	Santo André	São Paulo	Bacia (média)
Própria*	84.0	82.9	80.0	83.0	70.0	83.0	82.4
Alugada	8.0	5.7	10.0	13.5	10.0	9.2	10.9
Cedida	4.0	11.4	10.0	3.5	30.0	7.0	6.2
Outra**	4.0	-	-	-	-	0.8	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*** Includes 2.0% of owned homes being financed “paying”: 3% in São Bernardo and 1.5% in São Paulo.**

**** Invasion mentioned.**

b) Internal Distribution, Occupation and Residents per Domicile

The minimum standard placed by the HDI-Human Development Index is of 02 persons per room, and thus 44% of residents fall under this minimum standard. There are 23% of residents living in domiciles with high density, identifying slumming and precarious housing. Residents of Rio Grande da Serra and São Paulo, Santo André fall under these conditions. And the average standard for the Basin is of two rooms (2.21 rooms) for four persons (4.03 persons).

Predominance of internal toilets with w/c and shower in 99% of homes with an average of 1.52. The situation of inexistence of toilets was found in São Paulo in a single room home (the neighbor’s internal toilet is used) and also 03 situations of collective external toilet and 03 collective homes, 02 in São Paulo and 01 in Rio Grande da Serra.

Also found in the total of cities, 5% of external toilets in individual homes with internal toilets, which are more representative in São Paulo and Ribeirão Pires.

Table 8.4.2 Internal Distribution, Occupation and Residents per Domicile, per city and of the Basin

Número Média por Domicílio	Diadema	Ribeirão Pires	Rio Grande da Serra	São Bernardo do Campo	Santo André	São Paulo	Bacia (média)
Cômodo	6.32	6.54	5.60	5.66	5.20	5.60	5.73
Quarto	2.52	2.46	2.35	2.19	1.65	2.29	2.24
Banheiro	1.76	1.66	1.20	1.58	1.40	1.42	1.52
Residente	4.68	3.60	4.55	3.77	3.30	4.46	4.03

(3) Main Public Services

In the Billings Basin, the majority of domiciles is catered to by public water, electricity, garbage collection services, although in some areas, indirectly, with the use of illegal electricity wire tapping, or tapping of water from the water main, mentioned by some respondents.

The few residences not catered by the public water system (6%) use wells and springs usually located in their own land or receive water through tanker trucks of the respective city governments.

There is, however, in all cities, serious limitations in the sewage system, existing in about 65% of the homes, while in the remaining ones, different forms of drainage are used, which end up as exposed sewage from the kitchen and laundry water, or all residential water, including from the toilets and directed to the brooks and springs of the region, directly or indirectly reaching the Billings Lake.

The different forms of sewage drainage comprise :

- Septic or rudimentary cesspool combined with an internal kitchen and laundry water channeling system that goes directly to the street in 24.2%.
- Direct channeling of all sewage to the street in 10.0%
- There is also 1% of interviewees that live in rented homes and have no knowledge of the home sewage system.

In the case of garbage collection not conducted door-to-door, collection is made from public containers.

São Paulo presents, inclusively, a peculiar situation in the region of Pedreira where for some time now the public sewage system has been implemented but is not yet running or runs in a precarious form, in such manner that the population continues with the former drainage system and have serious criticisms in respect to the city government’s action.

When questioned about how their residential sewage is treated until its final disposal, almost all of the interviewees are ignorant of the forms of treatment or believe that the sewage is dumped *in natura* into lakes and the Lakes. Only 5.3% refer to the fact of there being a special treatment for domestic sewage before it is dumped.

Table 8.4.3 Basic Sanitation by the Public Service System per city and of the basin in (%)

Serviços Público	Diadema	Ribeirão Pires	Rio Grande da Serra	São Bernardo do Campo	Santo André	São Paulo	Bacia (média)
Rede de Água	96,0	97,1	100,0	96,0	25,0	99,2	93,9
Rede de Esgoto	84,0	48,6	60,0	86,0	25,0	42,3	65,5
Coleta de Lixo	100,0	100,0	100,0	99,5	100,0	99,2	99,5
Energia Elétrica	100,0	100,0	100,0	100,0	100,0	99,2	99,8

(4) Community

(a) Problem and Need

The main problems and needs of the community in relation to the environment, from the view of the residents are concentrated in the needs of the region and involve:

- BASIC SANITATION: inexistence of sewage network in several areas, exposed sewage, non-channeled and dirty brooks, untreated pipe water, outage, rationing of water, precarious garbage collection, accumulated garbage on the margins of the Lake and the proliferation of rats and insects, absence of inspection in spring areas and consequent invasion and proliferation of under-regulars **–**71.2%
- PUBLIC SERVICES – INFRASTRUCTURE, MAINTENANCE AND CONSERVATION: Roads full of pot holes, without sidewalks, poor street cleaning, conservation of sidewalks and public lighting, lack of leisure areas and squares, and the regularization of lots and deeds of ownerships – 50.0%

(b) Community and City Government

Residents of the Billings Basin are unsatisfied with the local action of the respective city governments. Thus, 65% of interviewees see this action as being between average and bad. The evaluation rate of local governments is presented on **Table 8.4.4**.

Table 8.4.4 Evaluation rate of City Governments per city and of the basin (%)

Avaliação	Diadema	Ribeirão Pires	Rio Grande da Serra	São Bernardo do Campo	Santo André	São Paulo	Bacia (média)
Muito Boa	4.0	0	5.0	4.5	0	0	2.6
Boa	40.0	22.9	25.0	40.5	5.0	23.8	31.6
Regular	24.0	42.9	50.0	37.5	35.0	39.2	38.1
Ruim	20.0	22.9	5.0	10.0	30.0	21.5	15.8
Muito Ruim	12.0	11.4	10.0	7.0	30.0	15.4	11.4
Não sabe	0	0	5.0	0.5	0	0	0.5
No de Pesquisa	25	35	20	200	20	130	430

(c) Community Leadership

Residents situate leaderships belonging to associations and Groups that gather residents, existing in all districts, politicians of the area and their advisors, members of churches – pastors, priests and assistants, school principals and teachers.

However, these leaderships are known by a small share of the population, not exceeding 35% the most popular ones, who are association members.

Politicians are recognized by 14%, religious leaders by 13% and educators by 8%.

Residents of São Bernardo are characterized for having a better knowledge of the residents' association leaders and politicians, while Santo André for the religious leaders.

Table 8.4.5 Knowledge of Community Leaderships per city and of the basin (%)

Lideranças Comunitárias	Diadema	Ribeirão Pires	Rio Grande da Serra	São Bernardo do Campo	Santo André	São Paulo	Bacia (média)
Associações de Moradores							
Conhecem	20.0	31.4	20.0	46.5	25.0	26.2	35.3
Não conhecem	80.0	68.6	80.0	53.5	75.0	73.8	64.7
Políticos moradores do Bairro							
Conhecem	12.0	2.9	15.0	21.0	5.0	9.3	14.5
Não conhecem	88.0	97.1	85.0	79.0	95.0	90.7	85.5

(5) Recognition of Billings Lake Pollution by Residents

92% of interviewees recognize the pollution of the Billings but not all related it to the population's life and health quality. The concept of pollution is directly linked to objectively perceptible aspects of environmental degradation such as garbage in the surroundings and within the the Lake and the bad odor released.

1) Reasons for the Billings Lake Pollution

Regardless of the concept of pollution, the reasons presented for this situation are directly linked to a basic sanitation situation in the region.

Among those who recognize the pollution of Billings, the main elements to blame are:

- The garbage and the debris discarded by the population directly into the the Lake – 80.3%
- The domestic sewage dumped without treatment into the the Lake – 65.3%.
- Also mentioned as polluting factors of lesser representation :
- Industrial sanitary waste – 31.6%
- Irregular buildings – 15.4%

2) Actions Required for the Environmental Preservation of the Billings Lake

Although they identify the pollution of the Billings Lake with the absence of a sewage system, the garbage in the area and air contamination, when mentioning possible environmental preservation actions, residents recognize the need of a broad range of actions in fighting the different types of pollution which involve its direct action and that of the public powers.

The actions required for Environmental Preservation are recognized, by order, as being:

Table 8.4.6 Main Actions Required for the Environmental Preservation of the Billings Lake

Nº.	Ações Necessárias	(%)
1	Fazer reciclagem de Lixo	84.4
2	Ampliar área verdes e evitar desmatamento	81.4
3	Ter rede de esgoto em toda cidade	75.8
4	Retirar população que mora em área de risco	75.3
5	Eliminar poluição do ar gerada pelas indústrias	72.6
6	Economizar no consumo da água	67.0
7	Ter água encanada em toda cidade	64.2
8	Evitar construções perto dos mananciais	64.0

8.4.2 Main Results – Businesses (Companies) situated in the Basin

According to the reference on **Table 8.2.1**, 120 establishments were interviewed (company) in the Basin, and in the sampling, mainly micro commercial and service companies of local operation predominate in the villages and districts. They cater to the basic needs of residents through small grocery shops, mini-marts, bars, stationary shops, mechanical workshops, electrical appliance repair shops, hairdressers, etc. Some are a complement of residences in slum areas or small properties in mixed commercial and residential areas, or also, bigger stores in the so-called commercial corridors of the districts. These corridors stay side by side in São Paulo with the large retail chain stores such as supermarkets Pão de Açucar, Casas Bahia, Drogaria São Paulo.

It is interesting to note that even in the poorer villages and clusters there are establishments such as gyms and video rental stores, reflecting the habits characteristic of the medium class. Also, due to the majority of homes being self-built, with continuous expansions, there is a substantial presence of building materials stores.

However, large branches of commercial food, furniture, electrical appliances, clothes and drug store groups, the latter situated in São Paulo, were not interviewed for reasons already surveyed.

(1) The distinguishing characteristics of the Establishments (companies), per City:

In the city of São Paulo, as an exception in the commercial activity of the Basin, there is a medium scale supermarket company, product of the expansion of the small local grocery shop of the sub-district of Grajaú, with 48 units and 3,000 employees, operating in the São Paulo inland districts of the Basin.

The city of São Bernardo is practically the only city to concentrate a significant number of large companies in the Basin with predominance for automotive paint industries. The city of Diadema tends to locate small and medium scale companies.

In the two cities, these companies are mainly the suppliers of the automobile industry.

The city of Santo André has its industries concentrated in the Industrial District, located out of the Basin’s area of influence.

The city of Ribeirão Pires stands out for its large weapons and munitions company with over 1000 employees.

The city of Rio Grande da Serra has few small and micro industrial establishments; it is a tourist region interested in developing its potential, which is quite incipient.

Among the large industries studied, four were identified and which are in the final phase of ISO 14.000 implementation.

Around the Lake, in all cities there are private clubs for water sports, with predominance for clubs of large workers’ associations such as Banco do Brasil, Public servants, GM, Volkswagen, among others.

(2) Profile of the establishments (Companies) surveyed:

The interviewees are the owners and/or partners and foremen of the small and micro companies, directors, managers and/or supervisors directly related to the environmental safety area of medium and large scale companies. In two situations, two environmental professionals answered the questionnaire conjunctly.

1) Trade and Activity

Throughout the Billings Basin the micro-scale commercial company predominates. And the segmentation of the economic activity is:

Commerce : 60.0%

Services : 25.0%

Industry : 13.3%

Livestock : 1.7%

2) Number of Employees

86% are micro companies administered solely by the owner or having 1 to 10 employees. In the opposite end are 8.3% of companies, which have between 101 and 4,000 employees, including the plants of multinational groups. They can be found in all cities with the exception of Rio Grande da Serra. This small town has only one commercial company which is also one of the largest in the Basin in number of employees – a regional supermarket chain, already mentioned, located in different points of the Basin, in the city of São Paulo and with its administrative headquarters in the sub-district of Grajaú. And in the intermediary range there are 5.8% of companies with 11 to 70 employees.

Companies with large numbers of employees are representative in the city of São Bernardo. Ribeirão Pires has a single large company with 1,200 employees. The largest companies of Diadema do not have more than 400 employees. In Santo André there is only one large company at the Basin. The rest are micro-companies of up to 03 employees.

Table 8.4.7 Number of Company Employees per city and of the Basin

Número de Funcionários	Diadema	Ribeirão Pires	Rio Grande Da Serra	São Bernardo Do Campo	Santo André	São Paulo	Bacia (média)
Nenhum	1	2	2	11	4	8	28
1 a 10	7	6	7	31	5	19	75
11 a 30	-	1	1	1	-	2	5
31 a 70	-	-	-	1	1	-	2
81 a 170	1	-	-	1	-	-	2
181 a 800	1	-	-	3	-	-	4
800 a 1.600	-	1	-		1	-	2
1.600 a 4000	-	-	-	1	-	1	2
Total	10	10	10	49	11	30	120

3) Main Public Services

(a) Water Supply

The companies situated in the Billings Basin, in their majority, are served by the public water system, although some of them also use artesian wells in the production process. The major exception in the supply of water is situated in the city of Santo André – the system caters to 27.3% of the companies, in a relationship similar to the one found in residential water supply.

The non-existence of a public water system leads to the use of wells, being about 11.7% of artesian wells and 3.3% of common wells, and 1% of tanker truck use. Santo André is the city with the highest use of wells for water supply, with 54.5% of artesian wells and 18.2% common wells.

Consumption in cubic meters of water from the public system was not possible of being identified as 60% of the interviewees did not have a bill for such verification. However, analysis of the values paid allows us to estimate a consumption volume. Therefore, by evaluating the value of monthly bills in Reals, we have:

Up to R$ 30.00

From R$ 31.00 to R$ 100.00

From R$ 101.00 to R$ 200.00

Over R$ 1,000.00

Did not answer.

Considering the value of the bills, it is possible to estimate the mean consumption to be at 30 m^3 to 40 m^3 for micro and small-scale companies, which are still the majority.

(b) Sewage System

60.8% of companies of the Billings Basin are provided with sewage system services. The public sewage system is practically inexistent for companies situated in Ribeirão Pires (10%) and cater to 27.3%, like for water, Santo André companies, and 53.3% of the São Paulo Companies.

In the inexistence of the public sewage system, 20% of companies use septic cesspools. They are rudimentary (11.7%) or septic cesspools (8.3%).

14% use different forms of refuse dumping to exposed areas, as in their great majority they employ some form of internal channeling, dumping refuse straight onto the street, into the storm water network, into rivers and into the Lake. The fact of there being an internal channeling that conveys the sewage out of the physical facilities of the company leads many entrepreneurs into believing that there is “sewage channeling” without identifying or recognizing the form by which it is dumped, which means non recognition of environmental pollution, even if by lack of knowledge;

3.3% send the refuse to treatment plants. It is the case of the large companies of the São Bernardo city and one company of Ribeirão Pires city.

Table 8.4.8 Number of Companies with Existing Public System per city and of the Basin

Rede Pública	Diadema	Ribeirão Pires	Rio Grande Da Serra	São Bernardo Do Campo	Santo André	São Paulo	Bacia (média)
Água	9	9	9	41	3	30	101
Esgoto	9	1	7	37	3	16	73
Total	10	10	10	49	11	30	120

4) The company and the Billings Lake Pollution

(a) Pollution Consequences

80% of companies consider that the Pollution of the Billings does not affect their activities nor the quality of life of its employees. Within the 20% that see some the damage caused by the Billings pollution, the following is mentioned:

- For the company activity – consequences of the foul odor, presence of rats and insects, and also the cost of the water. They establish thus a relation between water pollution and supply costs, and still, like the residents, they place pollution in their perceptible aspects of foul odor, rats and insects;
- In the quality of life of the staff – the pollution of Billings is seen as the source of illnesses and viral outbreaks, harming leisure possibilities. The foul odor is seen here also as harmful to the quality of life of the staff by 48% of the companies;
- For Tourist activities – 39% situate a burden of more general character, considering that the Billings pollution affects tourism throughout the Basin. This aspect is the main burden for Rio Grande da Serra and Santo André.

(b) Measures to Reduce the Pollution of Billings

To companies, the main form of reducing the pollution of Billings is in the treatment of sewage, based on the belief, or reality (in the absence of a system), that the sewage is dumped *in natura* into the Lake. They also see the need to create awareness and environmental education of the population living in the surroundings.

The treatment of sewage is the solution mentioned mainly by companies in the cities where sewage system are precarious, i.e. Santo André, Rio Grande da Serra and Ribeirão Pires.

The need for Environmental Education and creation of awareness in the population is seen as priority for companies in Diadema, São Bernardo and São Paulo.

PART 2

MASTER PLAN（M/P）

Chapter 9

FORMULATION OF WATER QUALITY CONSERVATION PLAN FOR THE BILLINGS LAKE

9. FORMULATION OF WATER QUALITY CONSERVATION PLAN FOR THE BILLINGS LAKE

9.1 Idea and Target

The Billings Lake was originally constructed as the artificial dam reservoir for hydro-power generation by pumping river water of the Tiete River system, which had also an intention to alleviate the flooding in Sao Paulo. The basin areas are 377 km^2 in the Billings Lake, 183 km^2 in the Rio Grande Arm, and 560 km^2 totally. The storage capacities are 110 billion m^3 in the Billings Lake, 13 billion m^3 in the Rio Grande Arm, and 123 billion m^3 totally for the control water level of 747 m (**Table 9.1.1**). The exchange times by the natural runoff are 3.80 years in the Billings Lake and 0.82 years in the Rio Grande Arm, showing that those lakes are typical closed waters.

Table 9.1.1 Fundamentals of the Billings Lake

	Lake Billings	Rio Grande Arm	Whole
Lake area			120 km^2
Storage capacity	1,102.5x10^6 m^3 *2	126.2x10^6 m^3 *2	1,228.7x10^6 m^3 *2
Control water level (max.)	747 m *2		
Storage capacity	950x10^6 m^3 *1	120x10^6 m^3 *1	1,070x10^6 m^3 *1
Control water level (max)	746 m		
Water depth			9 m
Exchange time	3.80 yr *3	0.82 yr *3	
Basin Area	377 km^2 *2	183 km^2 *2	560 km^2 *1
Longterm natural runoff	9.2 m^3/s *1	4.9 m^3/s *1	14.1 m^3/s *1
Basin specific flow			25.2 L/s/km^2 *1
Annual ave. runoff coef.			0.5 *1

*1 Fonte: "Diretrizes para a Proposta de Lei Específica e PDPA da APRM Billings-Tamanduateí - Relatório Final", Aril/2001, pp.32
*2 Fonte: "Billings Viva!", Toninho Macedo, 1992, pp.81
*3 Computed based on storage capacity in *2

Around 1937 when the Billing Lake was born, it was located calmly with the space of rich water and green in the mountains.

However, the time during the World War II required to cut the natural forests of the coastal ridge and its surroundings and to use them as fuel. The aspect surrounding the Billings Lake was completely changed as expressed that the natural forest were thoroughly lost.

After the War, while forestation was done unremittingly, the Billings Lake has been used as a water source since 1958. However, the water pumped from the Tiete River system to the Lake has been polluted with domestic and industrial wastewater, although anyone could not identify the time when it began, and the polluted conditions have been deteriorated year by year. One resident who knows the olden times of the Billings Lake says that the Lake was so clean and I could swim therein by 1970 and the municipal Memorial Stadium of Photos which collects the photos taken by the people keeps one photo showing the children enjoying a swimming in the Lake with a note of "decade de 70 (during the '70s)" as shown in **Photo 9.1.1**. There is the following description in "Billings Viva" published in 1992 by the SBC:

"Yearly 215.7 tons of fish was delivered to the market, or CEAGESP (old CEASA). However, the fishery service was practically extinct, as the fishes were not accepted commercially in the market in the beginning of the seventies."

The deterioration of water quality in the Billings Lake assumably started in the middle of '70s and progressed rapidly with offensive odor and foaming, which was supported by **Table 9.1.2**. For this reason, the dam was constructed beneath the Anchietta Highway in 1982 to isolate the Rio Grande Arm from the Billings Lake completely.

Photo 9.1.1 Children Enjoining a Swimming in the Billings Lake

The water pollution problem in the Billings Lake has developed the big environmental issue statewide and finally the state constitution in 1988 declared that the state and municipalities had to take effective measures so as not to pump wastewater, excreta and other pollutant matters to the Billing Lake within three years from the enforcement of this constitution. In 1992, the SMA/SES joint resolution 03/92 defined the conditions that pumping of river water to the Billings Lake was allowed when the flow of the Tiete River immediately downstream of the confluence of the Tiete and Pinheiros Rivers exceeded 160 m^3/s. By this joint resolution, the Billings Lake picked the improvement of water quality. As shown in **Figure 9.1.1** and **Table 9.1.3**, the pumping discharge to the Lake was reduced drastically and its water quality has been improved. But the new threat of water pollution has increased day by day which is caused by the population growth in the Billings Lake basin. The population of 110 thousand in 1970 has increased to 860 thousand in 2000 or about eight times for thirty years and still keeps a high annual average growth rate of 5.47% for these nine years (1991-2000). Such domestic wastewater is discharged into the Billings Lake without any treatment except for only the limited area and the achievement of environmental standards for class 2 is far away. In addition, this rapid population growth has eroded the forestry area where the feature of olden times has been restored, and reduced its share by 2.4% from 56.1% in 1989 to 53.7% in 1999 for these ten years.

Table 9.1.2 Deterioration of Water Quality in the Billings Lake (1975-1983)

		MBAS (mg/L)	Zn (mg/L)	Cu (mg/L)	Pb (mg/L)	Hg (mg/L)	Ni (mg/L)	Cr (mg/L)	Ca (mg/L)
SABESP Intake works	1975	0.28	0.0100	0.010	0.010	0.00020	<0.010	0.002	0.000
	1976	0.18	0.0100	0.020	0.000	0.00000	0.000	0.000	0.000
	1977	0.25	0.0150	0.020	0.020	0.00020	0.015	0.006	0.002
	1978	0.32	0.0100	0.020	0.005	0.00015	0.001	0.002	0.000
	1979	0.32	0.0100	0.018	0.002	0.00017	0.000	0.000	0.000
	1980	0.45	0.0100	0.004	0.001	0.00020	0.000	0.000	0.000
	1981	0.42	0.0100	0.035	0.001	0.00020	0.001	0.001	0.001
	1982	0.10	0.0100	0.040	0.001	0.00020	0.001	0.001	0.001
	1983	0.05	0.0100	0.020	0.001	0.00020	0.001	0.001	0.001
Riasho Grande ferry	1975	1.02	0.0100	0.010	0.000	0.00000	0.010	-	-
	1976	0.48	0.0100	0.010	0.000	0.00000	0.008	0.000	0.000
	1977	0.57	0.0100	0.010	0.020	0.00020	0.014	0.001	0.002
	1978	0.90	0.0150	0.002	0.002	0.00017	0.006	0.003	0.000
	1979	0.86	0.0080	0.001	0.001	0.00017	0.003	0.000	0.000
	1980	1.07	0.0100	0.001	0.001	0.00020	0.000	0.000	0.000
	1981	0.86	0.0100	0.001	0.001	0.00020	0.000	0.001	0.001
	1982	0.51	0.0100	0.001	0.001	0.00020	0.004	0.001	0.001
	1983	0.15	0.0070	0.001	0.001	0.00020	0.004	0.001	0.001

Fonte: "Billings Viva!", Toninho Macedo, 1992, pp.82

In consideration of the background of the Billings Lake abovementioned, the goals of the water quality conservation plan are set so as to reclaim the environment blessed with rich water and green that were existent at the Billings Lake and its surrounding area previously, or “clean water surrounded by green” and “habitats for diverse living tings” for long-term, and “achievement of environmental standards” and “coexistence of water, human and green” for middle-term (**Figure 9.1.2**).

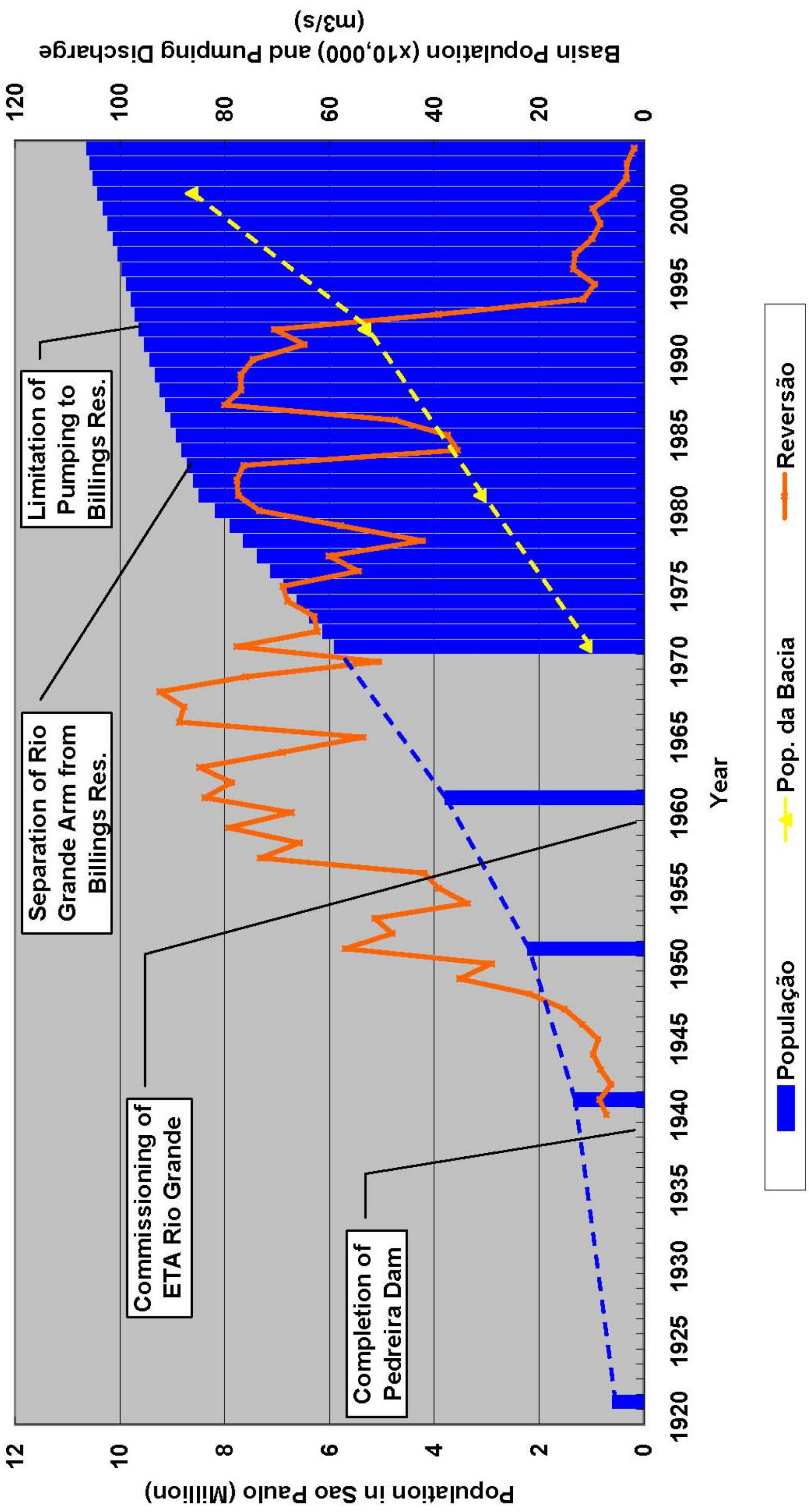


Figure 9.1.1 Population in Sao Paulo & Basin and Pumping Discharge to the Lake Billings Reservoir

Table 9.1.3 Change of the Billings Lake during This decade

Basin Pop

Year		1970		1980		1991		2000
(person)		111,000	1)	313,000	1)	534,000	1)	863,000 2)

注）Calculated population based on CENCUS

1) Fonte: "Termo de referencia para Programa de recuperacao Ambiental da Bacia Billings - Tomo 2/5", Julho/1999. pp. 403

2) Fonte: "Calibração de Sistema Relacional de Correlação do Manejo do Terristório e da Qualidade Ambiental para O Reservatorio Billings - Relatório Parcial RT-5", PRIME Engenhria, Março/2004, pp. 20

Pumping Discharge

Year		1970		1980		1990		2000
(m3/s)		77.7		77.4		64.8		5.6

Fonte: "Termo de referencia para Programa de recuperacao Ambiental da Bacia Billings - Tomo 2/5", Julho/1999. pp. 294-295

Land Use

Category					1989		1999	
					Area (ha)	(%)	Area (ha)	(%)
Densely unbanized area					1,485.85	2.55	1,653.66	2.84
Urvanized area					5,404.61	9.27	6,874.60	11.8
Despersed residential area					3,344.26	5.74	3,263.52	5.6
Bare area					61.59	0.11	57.56	0.1
Mining					192.9	0.33	156.89	0.27
Agricultural land					4,129.22	7.09	3,541.50	6.08
Factory					98.55	0.17	109.06	0.19
Sub-total（Artificial land）					14,722.11	25.27	15,661.92	26.89
Forestry（secondary）					699.15	1.2	647.32	1.11
Forestry（natural）					31,825.67	54.61	30,242.02	51.89
Forestation					188.26	0.32	398.35	0.68
Sub-total (Forestry)					32,713.08	56.13	31,287.17	53.68
Others					10,850.25	18.62	11,336.36	19.43

Fonte: "Billings 2000 - Ameças e Perspectivas para O Maior Reservatório de Água da Região Metropolitana de São Paulo", Instituto Socioambiental, Março/2002, pp.33

Water Level

		1970		1980		1990		2000
Minimum (Annual Ave.	(m)	742.82		744.23		744.11		
Maxmum (Annual Ave.	(m)	743.71		744.71		744.72		
Mean (Annual Ave.)	(m)	743.18		744.49		744.52		

Fonte: "Termo de referencia para Programa de recuperacao Ambiental da Bacia Billings - Tomo 2/5", Julho/1999. pp. 306-307

Water Quality

Monitoring Points	BOD_5		COD_{Cr}		T-P		TKN	
	1990	2000	1990	2000	1990	2000	1990	2000
PINE04100	48.0	17.0	10.7	23.7	1.1	0.5	21.9	6.1
BILL02100	-	7.2	15.2	26.2	-	0.1	-	2.0
BILL02500	15.2	5.7	-	-	0.7	0.1	10.5	1.7
BILL02900	12.2	5.3	-	-	0.4	0.1	3.4	1.4
RGDE02900	2.3	3.2	-	-	0.081	0.068	2.2	0.5

Note:Limitation of pumping discharge to the Billings Lakes since September 1992

COEXISTENCE OF WATER, HUMAN & GREEN

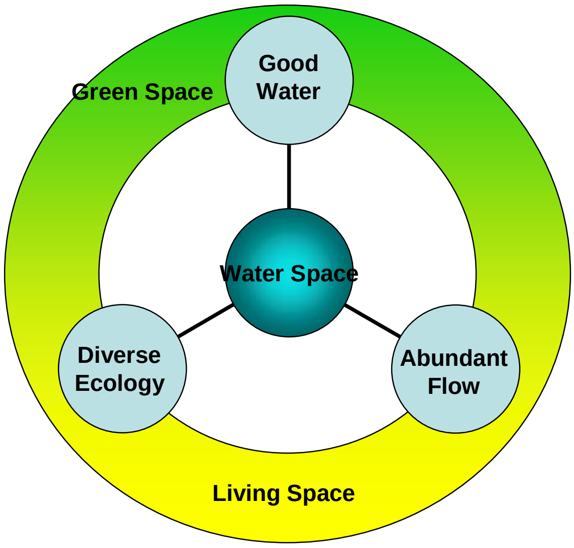


Figure 9.1.2 Image for Improvement of Basin Environment of the Billings Lake

9.2 Establishment of Water Quality Conservation

The purpose of water quality conservation program is to establish the desirable conservation targets so to attain and maintain water quality of public water bodies that are studied from the viewpoint of two targets, or one for water quality conservation on living environment (environmental quality targets) and the other for water quality conservation on drinking water source (drinking water source conservation targets)

9.2.1 Environmental Standards and Drinking Water Standards

Figure 9.2.1 shows the federal environmental standards for freshwater and drinking water standards. As fund in the former, the standards for Class 1 are completely same as those for Class 2 in both parameters and values in terms of inorganic and organic matters (Only values of total phosphorous are different in Classes 1 and 2).

The parameters and values defined in the environmental standards for freshwater and drinking water standards are not necessarily identical, but the environmental standards includes all the parameters other than surfactants out of inorganic matters for human health defined in the drinking water standards and their requirements are more stringent or equal to those in the drinking water standards. (Note: a value of NH4-N is different by a range of pH value in the environmental standards, but only one value in the drinking water standards.) For organic matters, the drinking water standards include other parameters than not included in the environmental standards, but their standards are generally stricter than in the environmental standards.

In reference with **Table 9.2.1** and the environmental standards in Japan, the water quality conservation targets shall be established for the Lake billings. As the drinking water standards show the requirements for effluent from a water treatment plant, for the parameters such as turbidity to be easily cleared at a water treatment plant, the loose values in the environmental standards shall be adopted and the parameters concerned with hazardous agricultural chemicals, disinfection by-products, radioactive materials not included in the environmental standards but included in the drinking water standards shall be excluded from the water quality conservation targets.

Table 9.2.1 also shows the parameters monitored by the CETESB and parameters predictable by the mathematical simulation model, which are owned by the CETESB and improved in the course of the JICA Study. As found from **Table 9.2.1**, the parameters monitored by the CETESB, excluding inorganic matters, does not cover the organic matters, hazardous agricultural chemicals, toxic cyanobacteria (Microcistis), disinfection by-products, and radioactive materials out of parameters for human health in the drinking water standards which are left to the checking by a water supply service provider itself. It should be noted that parameters predictable by the mathematical simulation model are very limited and even though there are theoretically predictable, they cannot be evaluated as a matter of fact, if there is no data actually measured.

Figure 9.2.1 **Federal** environmental standards for freshwater and drinking water standards

		Resolução CONAMA n° 357/05		Portaria n° 518		Monitoring parameters	Simulation parameters
		Artigo 14	Artigo 15	Artigo 14			
		Classe 1	Classe 2	Tabela 3	Category		
Condições/Padrões							
Toxicidade crônica aos organismos aquá ticos		Não detectado	Não detectado			X	
Materiais flutuantes		Virtualmente ausentes	Virtualmente ausentes				
Óleos e graxas		Virtualmente ausentes	Virtualmente ausentes				
Substâncias que comuniquem gosto ou odor		Virtualmente ausentes	Virtualmente ausentes	Não objetável	(drinking)		
Corantes (fontes antrópicas)		Virtualmente ausentes	Não será permitida a presença				
Resíduos sólidos objetáveis		Virtualmente ausentes	Virtualmente ausentes				
Coliformes termotolerantes		CONAMA n° 274/00 (recreação)	CONAMA n° 274/00 (recreação)			X	
		200/100 mL (demais usos)	1000/100 mL (demais usos)				
		E.coli – valor a critério do órgão ambiental	E.coli – valor a critério do órgão ambiental	E.coli – Ausência em 100mL			
$DBO_{5,20}$	(mg/L O_2)	≤ 3,0	≤ 5,0			X	X
DQO						X	
OD	(mg/L O_2)	≥ 6,0	≥ 5,0			X	X
Turbidez	(UNT)	≤ 40,0	≤ 100,0	5	(drinking)	X	
Cor verdadeira	(mg/L Pt)	Natural	Natural			X	
Cor aparente	(uH)			15	(drinking)		
pH		6,0 a 9,0	6,0 a 9,0	6,0 a 9,0		X	X
Temp. água	(ºC)					X	
Temp. ar	(ºC)					X	
Transparência	(m)					X	
Padrões / Parâmetros							
Clorofila a	(mg/L)	10,0	30,0				X
Densidade de cianobactéria	(cel/mL)	20.000,0	50.000,0				
	(mm^3/L)	2,0	5,0				
Sólidos dissolvidos total	(mg/L)	500,0	500,0	1,000	(drinking)	X	
Sólidos total	(mg/L)						
Sólidos Volátil total	(mg/L)						
Padrões / Parâmetros Inorgânicos							
Alumínio dissolvido	(mg/L Al)	0,1	0,1				
Alumínio	(mg/L Al)			0.2	(drinking)	X	X
Antimônio	(mg/L Sb)	0,005	0,005	0.005	(health)		
Arsênio total	(mg/L As)	0,01	0,01	0.01	(health)		
		0,14 (1)	0,14 (1)				
Bário total	(mg/L Ba)	0,7	0,7	0.7	(health)		
Berílio total	(mg/L Be)	0,04	0,04				
Boro total	(mg/L B)	0,5	0,5				
Cádmio total	(mg/L Cd)	0,001	0,001	0.005	(health)	X	
Chumbo total	(mg/L Pb)	0,01	0,01	0.01	(health)	X	
Cianeto livre	(mg/L CN)	0,005	0,005				
Cianeto	(mg/L CN)			0.07	(health)		
Cloreto total	(mg/L Cl)	250,0	250,0	250	(drinking)	X	
Cloro residual total (combinado + livre)	(mg/L Cl)	0,01	0,01				
Cloro residual livre	(mg/L Cl)			2			
Cobalto total	(mg/L Co)	0,05	0,05				
Cobre dissolvido	(mg/L Cu)	0,009	0,009				
Cobre	(mg/L Cu)			2	(health)	X	
Condutividade	(μS/cm)					X	
Crômio total	(mg/L Cr)	0,05	0,05	0.05	(health)	X	
Ferro dissolvido	(mg/L Fe)	0,3	0,3				
Ferro	(mg/L Fe)			0.3	(drinking)	X	X
Fluoreto total	(mg/L F)	1,4	1,4	1.5	(health)		
Fósforo orto sol.	(mg/L P)					X	X
Fósforo total (ambiente lêntico)	(mg/L P)	0,020	0,030			X	X
Lítio total	(mg/L Li)	2,5	2,5				
Manganês total	(mg/L Mn)	0,1	0,1	0.1	(drinking)	X	X
Mercúrio total	(mg/L Hg)	0,0002	0,0002	0.001	(health)	X	
Níquel total	(mg/L Ni)	0,025	0,025			X	
Nitrato	(mg/L N)	10,0	10,0	10	(health)	X	X
Nitrito	(mg/L N)	1,0	1,0	1	(health)	X	X
Nitrogênio amoniacal total	(mg/L N)	3,7 p/ pH ≤ 7,5	3,7 p/ pH ≤ 7,5			X	
		2,0 p/ 7,5 <pH≤ 8,0	2,0 p/ 7,5 <pH≤ 8,0			X	
		1,0 p/ 8,0< pH ≤ 8,5	1,0 p/ 8,0< pH ≤ 8,5			X	
		0,5 p/ pH ≥ 8,5	0,5 p/ pH ≥ 8,5			X	
Amônia (como NH_3)	(mg/L N)			1.5	(drinking)		
NKT	(mg/L N)					X	X
Prata total	(mg/L Ag)	0,01	0,01				
Selênio total	(mg/L Se)	0,01	0,01	0.01	(health)		
Sódio	(mg/L Na)			200	(drinking)		
Sulfato total (mg/L SO_4)	(mg/L SO_4)	250,0	250,0	250	(drinking)	X	
Sulfeto (H_2S não dissociado)	(mg/L S)	0,002	0,002	0.05	(drinking)		
Surfactantes	(mg/L)			0.5	(drinking)		
Urânio total	(mg/L U)	0,02	0,02				
Vanádio total	(mg/L V)	0,1	0,1				
Zinco total	(mg/L Zn)	0,18	0,18	5	(drinking)	X	
Padrões / Parâmetros Orgânicos							
Acrilamida	(mg/L)	0,0005	0,0005	0.0005	(health)		
Alacloro	(mg/L)	0.02	0.02				
Aldrin + Dieldrin	(mg/L)	0,000005	0,000005				
Atrazina	(mg/L)	0.002	0.002				

		Resolução CONAMA nº 357/05		**Portaria nº 518**		Monitoring parameters	Simulation parameters
		Artigo 14	**Artigo 15**	**Artigo 14**			
		Classe 1	Classe 2	Tabela 3	Category		
Benzeno	(mg/L)	0,005	0,005	0.005	(health)		
Benzidina	(mg/L)	0,000001	0,000001				
		0,0000002 (1)	0,0000002 (1)				
Benzo(a)antraceno	(mg/L)	0,00005	0,00005				
		0,000018 (1)	0,000018 (1)				
Benzo(a)pireno	(mg/L)	0,00005	0,00005	0.0007	(health)		
		0,000018 (1)	0,000018 (1)				
Benzo(b)fluoranteno	(mg/L)	0,00005	0,00005				
		0,000018 (1)	0,000018 (1)				
Benzo(k)fluoranteno	(mg/L)	0,00005	0,00005				
		0,000018 (1)	0,000018 (1)				
Carbaril	(mg/L)	0,00002	0,00002				
Clordano (cis + trans)	(mg/L)	0,00004	0,00004				
2-Clorofenol	(mg/L)	0,0001	0,0001				
Cloreto de vinila	(µg/L)			0.005	(health)		
Criseno	(mg/L)	0,00005	0,00005				
		0,000018 (1)	0,000018 (1)				
2,4-D	(mg/L)	0.004	0.004				
Demeton (demeton-O + demeton-S)	(mg/L)	0,0001	0,0001				
Dibenzo(a,h)antraceno	(mg/L)	0,00005	0,00005				
		0,000018 (1)	0,000018 (1)				
3,3 Diclorobenzidina	(mg/L)	0,000028 (1)	0,000028 (1)				
1,2-Dicloroetano	(mg/L)	0,01	0,01	0.01	(health)		
1,1-Dicloroeteno	(mg/L)	0,003	0,003	0.03	(health)		
2,4-Diclorofenol	(mg/L)	0,0003	0,0003				
Diclorometano	(mg/L)	0,02	0,02	0.02	(health)		
DDT (p,p'-DDT+p,p'-DDE+p,p'-DDD)	(mg/L)	0,000002	0,000002				
Dodecacloro pentaciclodecano	(mg/L)	0,000001	0,000001				
Dureza	(mg/L)			500	(drinking)		
Endossulfan (a+b+sulfato)	(mg/L)	0,000056	0,000056				
Endrin	(mg/L)	0,000004	0,000004				
Estireno	(mg/L)	0,02	0,02	0.02	(health)		
Etilbenzeno	(mg/L)	0.09	0.09	0.2	(drinking)		
Fenóis totais (substâncias que reagem com 4-aminoantipirina)	(mg/L C_6H_5OH)	0,003	0,003			X	
Glifosato	(mg/L)	0.065	0.065				
Gution	(mg/L)	0,000005	0,000005				
Heptacloro epóxido + heptacloro	(mg/L)	0,00001	0,00001				
		0,000000039 (1)	0,000000039 (1)				
Hexaclorobenzeno	(mg/L)	0,0000065	0,0000065				
Endeno (1,2,3-cd) pireno	(mg/L)	0,00005	0,00005				
		0,000018 (1)	0,000018 (1)				
Lindano	(mg/L)	0,00002	0,00002				
Malation	(g-HCH)	0,0001	0,0001				
Metolacloro	(mg/L)	0.01	0.01				
Metoxicloro	(mg/L)	0,00003	0,00003				
Monoclorobenzeno	(mg/L)			0.12	(drinking)		
Paration	(mg/L)	0,00004	0,00004				
PCBs-Bifenilas policloradas	(mg/L)	0,000001	0,000001				
		0,000000064 (1)	0,000000064 (1)				
Pentaclorofenol	(mg/L)	0,009	0,009				
		0.003 (1)	0.003 (1)				
Simazina	(mg/L)	0.002	0.002				
Substâncias tensoativas que reagem com o azul de metileno	(mg/L LAS)	0,5	0,5				
2,4,5-T	(mg/L)	0.002	0.002				
Tetracloreto de carbono	(mg/L)	0,002	0,002	0.002	(health)		
		0.0016 (1)	0.0016 (1)				
Tetracloreteno	(mg/L)	0,01	0,01	0.04	(health)		
		0.0033 (1)	0.0033 (1)				
Tolueno	(mg/L)	0.002	0.002	0.17	(drinking)		
Toxafeno	(mg/L)	0,00001	0,00001				
		0,00000028 (1)	0,00000028 (1)				
2,4,5-TP	(mg/L)	0.01	0.01				
Tributilestanho	(mg/L TBT)	0,000063	0,000063				
Triclorobenzeno (1,2,3-TCB+1,2,4-TCB)	(mg/L)	0,02	0,02	0.02	(health)		
Tricloroeteno	(mg/L)	0,03	0,03	0.07	(health)		
2,4,6-Triclofenol	(mg/L)	0,01	0,01				
		0.0024 (1)	0.0024 (1)				
Trifluralina	(mg/L)	0,0002	0,0002				
Xileno	(mg/L)	0.3	0.3	0.3	(drinking)		

(1) Padrões para corpos d'água onde haja pesca ou cultivo de organismos para fins de consumo intensivo.

1) Target year

Taking into the scale of the lake and basin, current situation of environmental administration in the basin, and the schedule of the Emergency Plan which the State Government of Sao Paulo has a plan to implement under the assistance from the World Bank, the target years are set in 2015 for the middle-term and in 2025 for the long-term.

2) Target level

The water quality conservation target is set so as to meet the environmental standards by 2025 with the interim target for the intermediate year or 2015 as shown in **Table 4**, considering the pollution status of the Lake Billings and the Rio Grande Arm, requests from the people, scale of measures required for solution and the time required for the effect appearance.

Therefore, the long-term targets are the environmental standards for Class 2 for the Central Channel in the Lake Billings and the Rio Grande Arm, and for Class 1 for the Taquacetuba Arm. Here, the environmental standards for the Taquacetuba Arm are essentially Class Special, but as the present condition is far from such requirements, Class 1 is applied to it due to no numerical target in Class special.

The interim targets with a target year of 2015 are set by applying one-class down environmental standards. For example, Class 3 is applied as an interim target to Class 2. However, since there is a big gap in BOD_5 between Class 2 and Class 3 or 5 mg/L and 10 mg/L, it is set at 8 mg/L as an interim target. It is a rough idea that TN is 10 times TP. But according to the monitoring results in the Lake Billings by the CETESB, TN is in the range of 23 to 54 times TP which is two to three times an environmental standard. The target TN is loosely set at 50 times TP for a middle-term and 40 times TP for along-term

Table 9.2.3 shows the middle- and long-term targets for water quality conservation.

Table 9.2.3 Water quality conservation target

Parameter		Middle-term target（2015）			Long-term target（2025）		
		Billings (Interim 1)	Billings (Interim 2)	Rio Grande (Interim 2)	Billings (Class 1)	Billings (Class 2)	Rio Grande (Class 2)
E. Coli	(MPN/100mL)						
BOD	(mg/L)	5	8	8	3	5	5
DO	(mg/L)	5	4	4	6	5	5
pH		6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0
Chl-a	(mg/L)	0.03	0.06	0.06	0.01	0.03	0.03
TN	(mg/L)	1.5	2.5	2.5	0.8	1.2	1.2
TP	(mg/L)	0.03	0.05	0.05	0.02	003	0.03

In Japan, COD_{Mn} is used for lakes and lagoons as an organic index, but BOD_5 in Brazil. When COD is used in Brazil, it is COD_{Cr} but not COD_{Mn} like in Japan.

9.3 Issues from the Environmental Viewpoint of the Lake Billings and the Rio Grande Arm

(1) Evaluation of water environment of both lakes

1) The water quality of the Lake Billings has been improved by the change from continuous pumping to conditioned pumping of the Tiete River water in 1992, but TP which governs eutrophication such as occurrence of water bloom has not yet met an environmental standard as well as other parameters and monitoring points that have not attained the environmental standards.

2) Industrial wastewater, which is one of possible pollutant sources in the basin of the Lake Billings is strictly monitored by the CETESB including operational stoppage and a factory with a fear of problems has an independent treatment plant or convey industrial wastewater outside the basin after tentative storage. The livestock industry that its existence was confirmed in 2000 has been forced to close a business or transfer outside the basin and has no threat in the future. There is no large-scale firm and crop requiring a large application of fertilizer.

3) From the situation mentioned above, the pollutant sources in the basin are limited to domestic wastewater, storm water, pumping water and sediments piled in the lake bottom. The BOD_5 loads on a generation basis are 87.0% in domestic wastewater and 13.0% in storm water in the Lake Billings, while 94.4% and 5.6%, respectively, in the Rio Grande Arm. This percentage of domestic wastewater is slightly higher in TN and TP. Therefore, the biggest issue in the basin of the Lake Billings is measures for domestic wastewater.

(2) Endeavor for pollutant load reduction

1) F or domestic pollutant load reduction which shares a majority of incoming loads, the SABESP has taken a leadership for sewerage construction and achieved a certain level of connection rate and treatment rate. From the viewpoint of further promotion of pollutant load reduction, the realization of wastewater conveyance from the Lake Billings basin to other basin is an important issue more and more, excluding the southern part of Sao Bernardo do Campo and Santo Andre

2) The loads from industrial and commercial wastewater is less and in addition, the specified factories have taken measures for pollutant load reduction in compliance with the new environmental regulations. Solvay Industry which was previously one of problematic factories is expected to discharge its effluent to a wastewater collection system under the SABESP and the biggest issue in this field will be solved.

3) Although the loads from non-point sources shares below 10 % in the total, taking into account insufficient information on loading conditions by first flush and effect on pollutant load reduction by measure, and the raise in accuracy for understanding the present situation through further augmentation of study and monitoring system and implementation of more effective

measures is indispensable.

4) It is necessary to position an approach utilizing natural purification function in the lake purification program.

(3) Contents and composition of water conservation program for both lakes

1) Although it is the most important issue to put an emphasis on pollutant load reduction to improve lake water quality as the contents of environmental conservation program for both lakes, full development of all measures for pollutant load reduction for the lake is indispensable, based on the experience in Japan.

2) New approach is necessary corresponding to diverse needs for water environment such as swimming, drinking water supply, recreation, etc. by stakeholders including the people

3) There are partly self-supportive approaches by NGOs up to now, but lack of reality like "Billings 2000" in contents and no presentation of practical visions from the middle- and long-term viewpoint.

4) The previous lake purification programs are standardized and does not reflect the diverse lake characteristics.

5) Although the approaches from the viewpoint of whole basin, restoration of hydrologic cycle including groundwater and ecological conservation are necessary, the contents of the lake purification program does not reflect such approaches.

6) In these year, there are some approaches by the communities and NGOs, based on public understanding and consent formation on the lake purification program and cooperation with the municipality, but the positioning of such approaches is not clear and no attention to consider participation form.

(4) Institution for policy evaluation and promotion

1) The institution for progress management of policy and quantitative evaluation is insufficient as shown in the present situation that many numerical targets such as a coverage ratio set for policy have not been attained or no setting of numerical target for measures for non-point sources construction level.

2) Lake evaluation is not well done in consideration of scale and characteristics of each sub-basin.

3) There is no system to share and utilize the information on water environment of lakes and lagoons.

4) The system to raise public awareness of water environment conservation is not established.

9.4 Basic policy of master plan

The basin environment improvement of the Lake Billings shall be promoted under the following policies:

1) The lake has a character that water is retained therein. From such hydraulic characteristics of a closed water body, the pollutant loads incoming to the lake is apt to settle for accumulation resulting in water pollution. It is not easy to restore its previous water quality, once the lake has been polluted. For this reason, such endeavor is not finished only by taking engineering measures, but requires a long-term approach.

2) As the basin environment improvement is attained not only by taking engineering measures such as infrastructure construction, but also adopting software measures so as to urge the innovation of public awareness towards the establishment of the environmental-friendly life style and business style, because it is important that a resident or entrepreneur has an environmental-friendly mind one by one and positively acts for water purification in his daily life.

3) For the conservation of water environment in a lake, it is important to have the comprehensive viewpoint such as restoration of hydrologic cycle and securement of growth and habitat environment for aquatic organisms including water quality improvement, water quantity restoration and conservation of water fronts and so on so as to control the whole lake. In the implementation of measures, the public involvement including NGOs and NPOs should be encouraged. In addition to the conventional role of the lake, the people want the formation of rich landscape, provision of water front with amenity and recreational place and strengthening of combination among water, being and green, resulted from the elevation in awareness and diversification of needs for water environment. It is also necessary to establish a system to measure the effect through the pollutant load survey and water quality monitoring in the basin, to provide the information on the actual status of the lake with plain description to the people, and to get the understanding of the people for the basin environment improvement, Therefore, the measures to be taken should be considered in the planning framework for the basin environment improvement, but not limited to only the pollutant load reduction.

4) All the stakeholders including the people are responsible for sharing the measures for water quality conservation of the lake and for evaluating their results. Therefore, the understanding of a whole lake image to correspond to such diverse viewpoints is dispensable.

   As the precondition in promotion of the measures for water quality conservation of the lake, it is necessary for all the stakeholders to get information on the details of a whole lake image in the plain form and to have the common concern and awareness. Sharing of problem recognition and reconstruction of cooperative framework is the basis to support the whole of policy. For example, it is important to make a stronghold of environmental information and education for production of common awareness and sharing of problem recognition.

9.5 Measures to be taken

(1) Establishment of the Association of "Clean the Lake Billings"

It is not easy to restore the lake, once polluted, but requires a long time and steady accumulation of little endeavor. There are six municipalities involved in the basin of the Lake Billings and state agencies, the people, community associations, schools, NGOs, agricultural association, housing estate developers, wastewater dischargers and universities are also concerned with the Lake Billings. The improvement of basin environment is not attained, if an individual stakeholder acts independently, but attained by sharing the roles among stakeholders and acting in combination with each other. For this purpose, it is recommended to establish the Association of "Clean the Lake Billings" gathering all stakeholders as early as possible.

(2) Public enlightenment and environmental education

According to the survey on public enlightenment and environmental education, the people living in the basin of the Lake Billings has less awareness on their contribution of water pollution of the lake, and low willingness-to pay for wastewater charge, which suggest the awareness of the people on the basin environment improvement. To make a plan surer, public enlightenment and environmental education are very important to elevate their awareness on the basin environment, and urge the people to connect to a sewer system immediately and make a payment for wastewater charge, when it will be completed, and to participate in the activities for the basin environment.

(3) Selection of projects from the comprehensive viewpoint

The projects for the basin environment improvement of the Lake Billings is studied in the planning framework catching from the viewpoints of water quality improvement, water quantity restoration, securing of growth and habitat environment for aquatic organisms, strengthening of combination among water, being and green, and the study and research as shown in **Figure 9.5.1**.

Figure 9.5.1 is composed of engineering measures to construct facilities and software measures to innovate the people's awareness and to urge the people to participate in the activities for the basin environment improvement. The software measures is essentially in nature to urge each stakeholder's awareness for action, which are the activities for public enlightenment and environmental education as a means of the administrative side to produce such awareness, or the issues to be tackled by the Association of "Clean the Lake Billings". In this meaning, software measures must be immediately tackled by the administrative side without waiting for the completion of engineering measures.

For engineering measures, they should be judged based on the local conditions and will be studied individually in **11**.

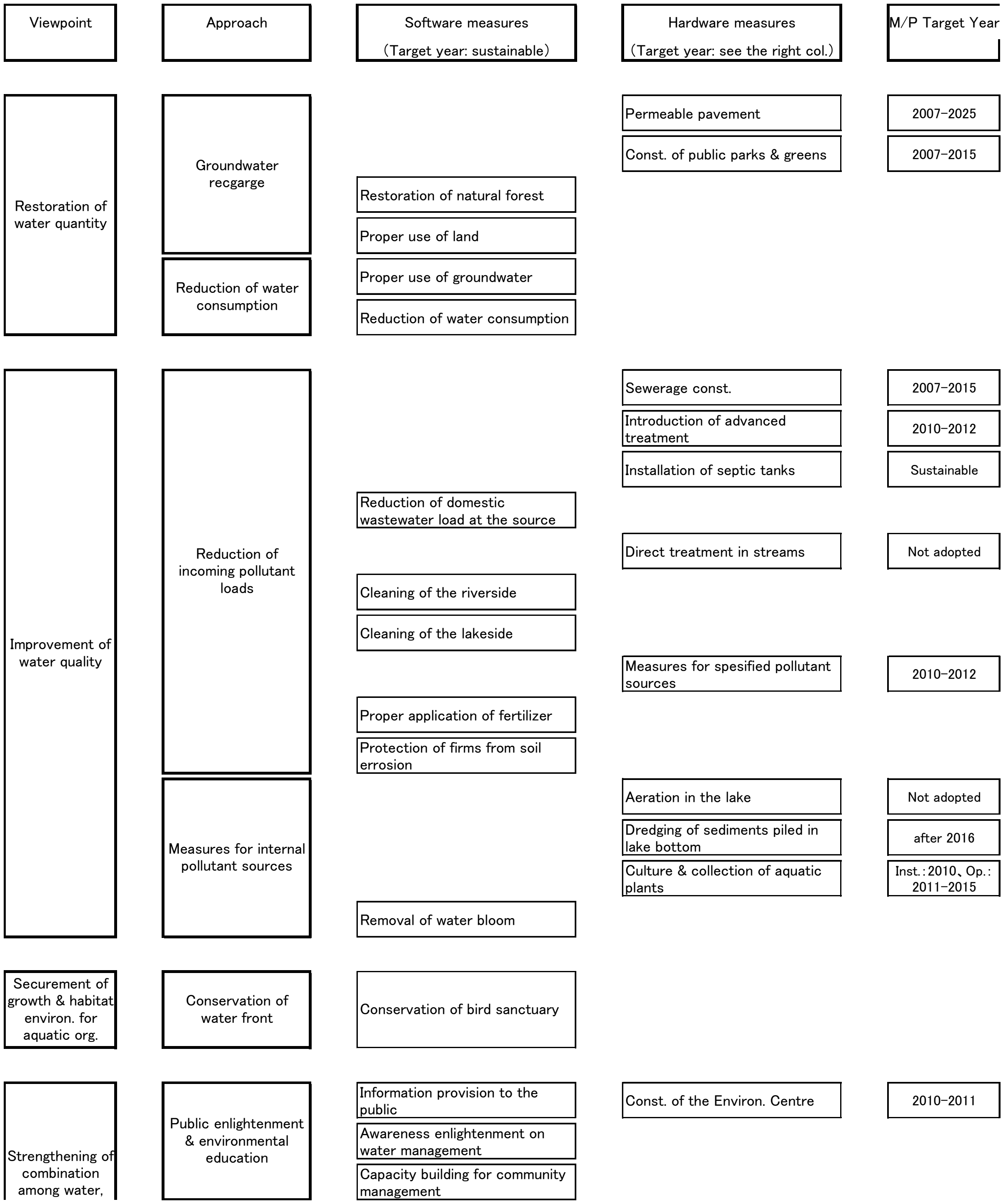


Figure 9.5.1 Planning framework for basin environment improvement of the Lake Billings

Chapter 10

ESTABLISHMENT OF SOCIO-ECONOMIC FRAME

10. ESTABLISHMENT OF SOCIO-ECONOMIC FRAME

10.1 Population

10.1.1 Target Year

Base year for population projection is set as 2005. Planned target year shall be 2025, 20years after of base year. 2015 is set as a middle year to evaluate the state of flux.

10.1.2 Projected area and population

(1) Projected area

Projected area is in the boundary of the Billings Lake and area of outside of the basin shall be included as the occasion demands such as the Couros sub-basin.

(2) Population

Table 10.1.1 and **Figure 10.1.1** shows the population projection by every 5years from the base year(2005) to the target year(2025) in 2 cases, that is, Prime and JICA.

The case Prime is a projection with population increase rates of past record in every small sub-basin. While case JICA basically follows the increase rates by Prime by the year 2015, after 2015 it employs the value obtained by examinations and Master Plan (MP) of San Bernald do Campo which was made by the city of San Bernaldo do Campo in 2006. MP is planning to apply various measures for population controls in the Billings Lake basin.

Population growth of Case JICA is far lower than the Case Prime. For example, population increase of Case Prime in 2025 against 2005 is 800,000 (3%-growth/yr), on the other hand that of JICA is 400, 000. (1.5%-growth/yr)

The case JICA is adopted for the future projection.

Table10.1.１ Population projection

		2000 [1)]	2005 Existing State	2010	2015	2020	2025
Prime	Population	865,870	989,970	1,136,101	1,308,684	1,513,107	1,755,949
	growth（%）		1.027	1.028	1.029	1.029	1.030
JICA Adopted	Population	865,870	989,970	1,096,462	1,205,486	1,294,475	1,393,398
	growth（%）		1.027	1.021	1.019	1.014	1.015

1) Census for the year 2000

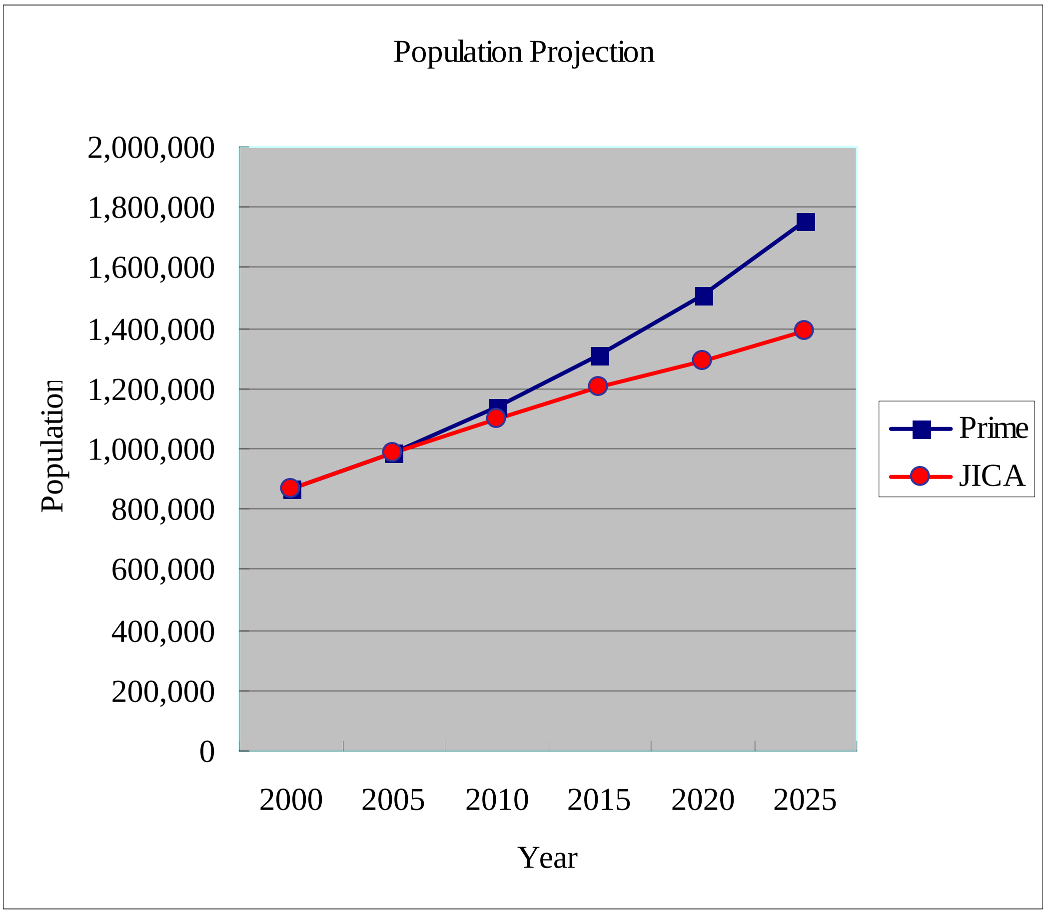


Figure10.1.1　Population projection(Adopted, CASE JICA)

10.2　Land Use

Current status of land use is shown in **Table 10.2.1**.　Land area is 475.5 km^2 (81.6%) in the area of 582.8km^2 of the Billings Lake, and that of water surface is 107.3 km^2.　Grassland and forest occupies 346km^2 (73%), residential area 87km^2, agricultural area 9km^2 and commercial/ industrial 3km^2.　The rest is Chacara which is cottage with cropland.

Largest share of the area is 32% of SBC and the second is San Paulo, 29%.　The feature of this area is that forest and grassland is preserved fairly well and shares of the agricultural/commercial/industrial area are comparatively small.　Agricultural area has been becoming smaller statistically, and it is nearly zero in Diadema, Santo Andre, Ribeirao Pires and Rio Grande da Serra.　70% of the agricultural area exists in Sao Paulo.

Development of lots for residential area has been made even now.

Table10.2.1 Land use in the basin of the Billings Lake in 2000

City	Unit	Agriculture	Reproduced Forest	Natural Forest	Grass Land	Chacara	Residential	Commercial Industrial	Total
SP	ha	635	214	4,484	3,576	1,640	3,329	44	13,922
	%	70.91 1)	15.34	20.66	31.8	47.47	39.34	14.4	29.33
DD	ha	33	34	87	310	31	662	17	1,174
	%	3.66	2.42	0.4	2.76	0.9	7.82	5.59	2.47
SBC	ha	215	840	7,861	3,274	1,046	1,664	63	14,963
	%	23.98	60.14	36.23	29.11	30.28	19.66	20.47	31.53
SA	ha	2	162	5,354	1,665	93	479	131	7,886
	%	0.18	11.59	24.68	14.8	2.7	5.66	42.53	16.61
RP	ha	11	134	2,129	1,470	306	1,819	38	5,907
	%	1.27	9.6	9.81	13.07	8.85	21.49	12.35	12.45
RGS	ha	-	13	1,783	952	338	511	14	3,611
	%	0	0.92	8.22	8.47	9.79	6.03	4.66	7.61
Total	ha	896	1,398	21,699	11,246	3,454	8,463	309	47,463
	%	1.89 2)	2.94	45.72	23.69	7.28	17.83	0.65	100

1) Share of each city is against total for each city (edge of the right hand side)

2) Share of total is percentage against the total area（47,463ha）

10.3 Economics

All the area of the Billings Lake is designated as special water source preservation area under the law. Land use of the special water source preservation area is classified into three categories as follows;

- Occupation-prohibited Area（ARO）
- Occupation- restricted Area（AOD）
- Environment Restoration Area（ARA）

Occupation-prohibited Area（ARO）among three exists only in the Coastal Mountain Range which is out of the Billings Lake basin. Occupation- restricted Area（AOD）is designated in the south of the Billings Lake, and land use with no influence to the water quality in the lake. Such land use includes restricted development for the residential area and recreational/leisure use. Environment Restoration Area（ARA）is area for the restoration of environment.

In the area of west, northern part and eastern of the basin, due to such regulation and severe restriction of appearance of favela, only legal residential area and accompanied small size commercial/industrial area shall be developed from now on. New construction of large size factory in the basin will be very difficult, though there are a lot of cabinetmakers, metalworking shops and machinery repairing shops in SBC.

At southern part of the Billings Lake the present condition as agricultural production area shall be maintained. Livestock industry will disappear from this basin.