JAPAN INTERNATIONAL COOPERATION AGENCY

THE STUDY ON INTEGRATED PLAN OF ENVIRONMENTAL IMPROVEMENT IN THE CATCHMENT AREA OF LAKE BILLINGS IN SAO BERNARDO DO CAMPO CITY IN THE FEDERATIVE REPUBLIC OF BRAZIL

Final Report

Main Report

February 2007

NJS CONSULTANTS CO., LTD.
&
YACHIYO ENGINEERING CO., LTD.

PREFACE

In response to a request from the Govemment of Federative Republic of Brazil, the Govemment of Japan decided to conduct 'The Study on Integrated Plan of Environmental Improvement in the Catchment Area of Lake Billings in Sao Bernardo do Campo City in the Federative Republic of Brazil" and entrusted to the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Ikuo Miwa of NJS CONSULTANTS CO., LTD. between July 2005 and October 2006. In addition, JICA set up an advisory committee headed by Mr. Haruo Iwahori, Senior Advisor, Institute for International Cooperation of JICA, which examined the study from specialist and technical points of view.

The team held discussions with the officials concemed of Sao Bernardo do Campo City and the Govemment of Federative Republic of Brazil, and conducted field surveys at the study area. Upon retuming to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between two countries.

Finally, I wish to express my sincere appreciation to the officials concemed of Sao Bernardo do Campo City and the Govemment of Federative Republic of Brazil for their close cooperation extended to the study.

February 2007

Ariyuki Matsumoto

Vice President

Japan International Cooperation Agency

February 2007

Mr. Ariyuki Matsumoto
Vice-President
Japan International Cooperation Agency

Letter of Transmittal

Dear Sir,

We are pleased to submit herewith the final report for *"The Study on Integrated Plan of Environmental Improvement in The Catchment Area of Lake Billings in Sao Bernardo do Campo"*.

The Study aims to achieve the environmental inprovement in the Lake Billings, and the Study Team formulated Master Plan in order to improve the water quality, Feasibility Study for priority projects and technology transfer through study activity and seminar/workshop.

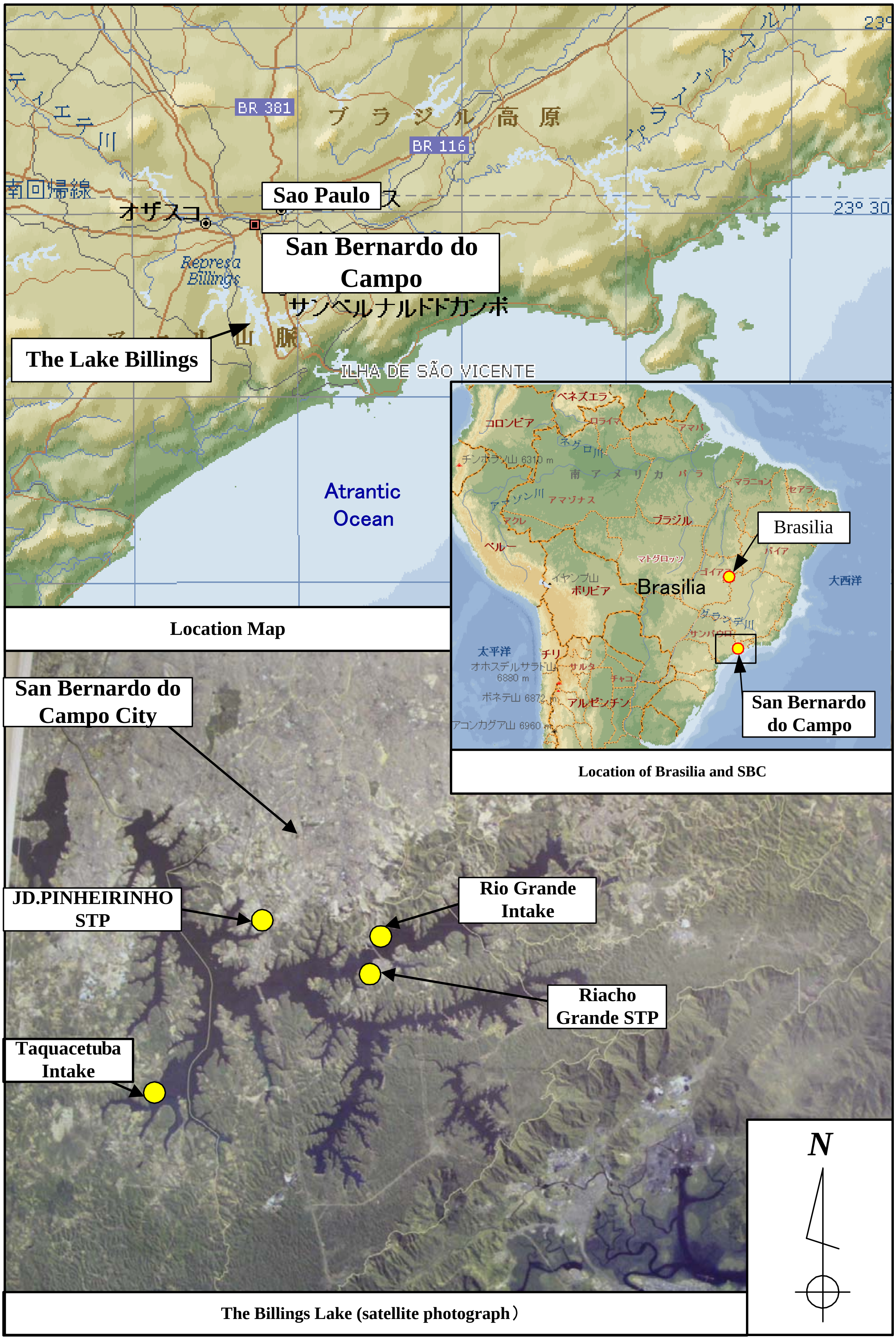
The Billings Lake one of the important water source in the grater San Paulo Region. However the situation is getting worse because of progress of water pollution in the Lake Billings arising from the increase of untreated sewage inflow by population growth and elution of nutrient from the sediment. To encounter these issues, soft measures such as residents education as well as engineering measures such as construction of sewerage and permeable pavement, etc. are planned. For the attainment of sustainablity of the project, the Environmental Protection Center is also planned. Some of the recommendations made by the Study Team have already been incorporated into the Master Plan of Sao Bernard do Campo city.

We wish to take this opportunity to express the sincere gratitude to the officials of your Agency, the Steering Committee, the Ministry of Foreign Affairs, the Ministry of Land, Infrastructure and Transport, and Japan Bank for International Cooperation for their kind support and advice. We also would like to show the appreciation to the officials of Sao Bernard do Campo City, SABESP(Public company of water supply and sewerage in Sao Paulo State), ABC Consorcium, JICA Brazil Office, and the Embassy of Japan in Brazil for their kind cooperation and assistance throughout the field survey. Finally, We hope that the recommendations of the Study Team will contribute to further environmental improvement in the Lake Billings.

Very truly yours,

三和育男

Ikuo Miwa
Team Leader
Study Team for The Study on
Integrated Plan of Environmental Improvement
in The Catchment Area of Lake Billings
in Sao Bernardo do Campo City



Location Map

Location of Brasilia and SBC

The Billings Lake (satellite photograph)

The Study on Integrated Plan of Environmental Improvement in the Catchment Area of Lake Billings in Sao Bernardo do Campo City, Brazil

THE STUDY ON INTEGRATED PLAN

OF

ENVIRONMENTAL IMPROVEMENT

IN

THE CATCHMENT AREA OF LAKE BILLINGS

IN

SAO BERNARDO DO CAMPO CITY

IN

THE FEDERATIVE REPUBLIC OF BRAZIL

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List of Abbreviations

ABC	Brazilian agency of Cooperation
ABNT	Brazilian association of Technical Norms
ANA	National agency of the Water
APA	Area of Environmental Protection
APRM	Area of Protection and Recovery of springs
ARA	Area of Environmental Recovery
ARO / APP	Area of Restriction to the occupation / Area of Permanent Protection
BB	Bank of Brasil S/A
BC	Central bank of Brazil
CADES	Municipal Council of Environment and Maintainable Development
CAEDYM	Computacional Model of Ecological Dynamics Aquatic
CEAM	Center of Environmental Education
CEF	Federal savings bank
CESP	Central Electric of Paulo Paulo S.A.
CETESB	Company of Technology of Environmental Sanitation
CONAMA	National Council of the Environment
CONSEMA	State Council of Environment
COT or TOC	Total Organic carbon
CPLEA	Coordination of Strategic Environmental Planning and Environmental Education
CT	Trunk Collector
DAEE	Department of Waters and Electric power
DAIA	Department of Evaluation of Environmental Impact
DBO or BOD	Biochemical Oxygen demand
DEPRN	State department of Protection of the Natural Resources
DNER	National department of Highway
DNPM	National department of the Mineral Production
DOC	Dissolved Organic carbon
DQO or COD	Chemical demand of Oxygen
EEA	Pumping Station of Water
EEE	Pumping Station of sewage
EIA/RIMA	Study of Environmental Impact / Report of Impact of the Environment

EIRR	Rate of Internal Economical Return
ELCOM	Model of Estuary, Lake and Oceanic Costa
EMAE	Metropolitan company of Water and Energia S.A.
EMPLASA	Metropolitan company of Planning of Great São Paulo
ETA	Station of Water Treatment
ETE	Station of Sewage Treatment
FIESP	Federation of the Industries of the State of São Paulo
FIRR	Rates of Financial Intern of Return
FUSP	Foundation of the University of São Paulo
Grande ABC	Santo André, São Bernardo do Campo and São Caetano do Sul
IBAMA	Brazilian institute of the Environment and of the Renewable Natural Resources
IBGE	Brazilian institute of Geography and Statistics
IPT	Institute of Technological Researches of the State of São Paulo
ISA	Environmental institute
JICA	Japan International Cooperation Agency.
M/M	Minutes of Meeting
MMA	Ministry of the Environment
MOD	Dissolved Organic matter
NPV	Net Present value
NT or TN	Total nitrogen
PAT–PROSANEAR	Technical support organization
PDPA	Plan of Development and Environmental Protection
PETROBRÁS	Brazilian petroleum
RMSP	Metropolitan area of São Paulo
SABESP	Company of water supply and sewerage of the State of São Paulo
SBC	São Bernardo do Campo city
SEMASA	Municipal of Environmental Sanitation of Santo André
SHAMA	General office of House and Environment
SIG/ISA	System of Geographical Information of the Partner-environmental Institute
SMA	General office of the Environment of the State of São Paulo
TAC	Term of Adjustment of Conduct
USP	University of São Paulo

PART 1
FUNDAMENTAL STUDY

Chapter 1

HISTORY AND ENVIRONMENT OF THE BILLINGS LAKE

1. HISTORY AND ENVIRONMENT OF THE BILLINGS LAKE

For understanding importance of this Study, it is necessary to know the present water use and its problems of the Lake Billings, and the importance as a water source for the Greater Sao Paulo Area, as well as the policy of the state government for water resource concerned with use in this waters and the legislation and institution for the conservation of water resource.

The previous headwater protection law severely regulated land use in the basin, as described in **2**, but could not control illegal land use in the protection area and population increase against the regulation.

From such past experience, the new law make possible with more flexible provisions to formulate the practical solutions for implementation so as to meet the characteristics of each basin. The law regards each basin as an object for planning and operation of the projects and provides to establish the laws and regulations which match the basin conditions in the environmental protection and improvement areas and to urge the participation of not only local governments but also civic groups.

Simultaneously, these laws provide the execution of an emergency countermeasure plan to cope with a state of emergency such as water pollution, and accept onsite wastewater treatment and refuse disposal in each basin, which are not admitted by the previous law

This Study aims at formulating a master plan for the environmental improvement in the catchment area of the Lake Billings. The plan meets the purpose of the PDPA (Plano de Desenvolvimento e Proteção Ambiental da Bacia) established by the state laws and will be submitted later to the Billings/Tamanuduatei River Sub-committee for discussion.

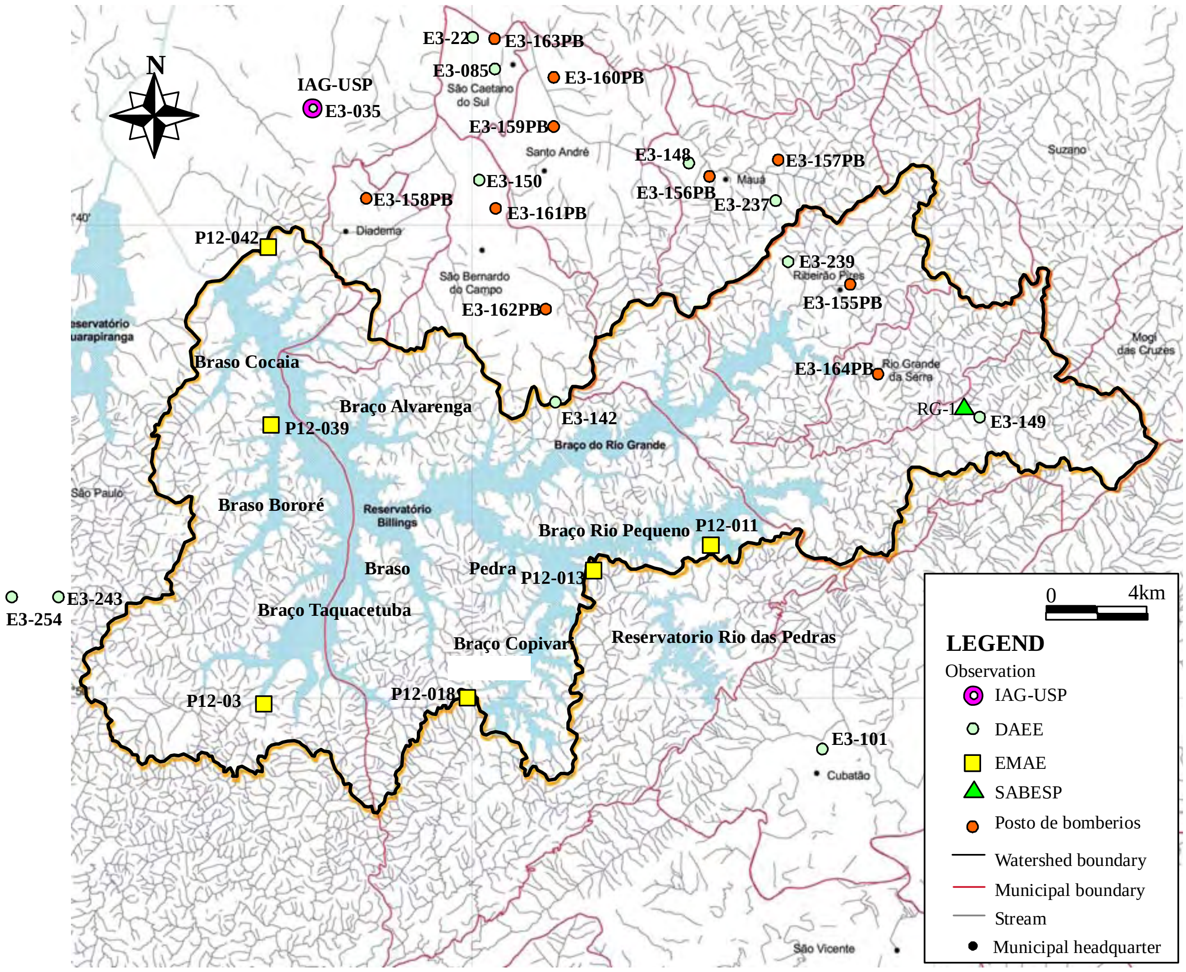
1.1 Natural condition of Lake Billings Basin

1.1.1 Weather

The Lake Billings basin is located at the edge in the plateau part where the relief is gentle and the altitude above sea level about 700m to 800m is steeply lifted from the costal low land with 0m to several 10m. The costal mountain stretches from west-southwest to east-northeast exists in southward of the Lake Billings basin. The costal low land also spreads with the same direction in southward the costal mountain.

The surrounding area of the basin is located near the southern circle and shows the highland climate of the subtropical climate zone. October - March is a rainy season with high temperature, and June - September is a dry season with comparatively low temperature. The southward region in the basin including the south slope in the coastal mountain and the edge of the plateau part is a rainy region because the air mass of the high temperature and humidity from the Atlantic Ocean in the south hits the coastal mountain wall, and it makes a large amount of rain fall in the rainy season.

The meteorological and hydrological observation stations around the Lake Billings basin are shown in **Table 1.1.1**, and the location map is shown in **Figure 1.1.1**. E3-035 (IAG-USP in Ipiranga park of the Sao Paulo Municipal) and P-12-042 (Pedreira dam of EMAE) are only the meteorological stations where the long-run observation are continued. A lot of rainfall station exists around the Basin, but quite a lot of station has missing values.



(Base map; Billings 2000 João Paulo Ribeiro Capobianco, Marussia Whately 2002 ISA)

Figure 1.1.1 Meteorological and Hydrological Observation Stations around the Lake Billings Basin

Table 1.1.1 Meteorological and Hydrological Observation stations around the Billings Reservoir Basin

Item	Frequency	Station No.	Station name	Latitude	Longitude	Elevation (m	Municipal	Sub Region	Organization
Meteorology-A									
Temperature	Daily	E3-035	Observatório IAG	23° 39'	46° 38'	780	São Paulo	Outside	IAG-USP
Humidity	Daily	E3-035	Observatório IAG	23° 39'	46° 38'	780	São Paulo	Outside	IAG-USP
Pressure	Daily	E3-035	Observatório IAG	23° 39'	46° 38'	780	São Paulo	Outside	IAG-USP
Wind	Daily	E3-035	Observatório IAG	23° 39'	46° 38'	780	São Paulo	Outside	IAG-USP
Duration of Sunshine	Daily	E3-035	Observatório IAG	23° 39'	46° 38'	780	São Paulo	Outside	IAG-USP
Evaporation	Daily	E3-035	Observatório IAG	23° 39'	46° 38'	780	São Paulo	Outside	IAG-USP
Meteorology-B									
Temperature	Nonthly	P-12-042	Pedreira	23° 41' 59"	46° 40' 11"		São Paulo	A-14	EMAE
Humidity	Nonthly	P-12-042	Pedreira	23° 41' 59"	46° 40' 11"		São Paulo	A-14	EMAE
Wind (Direction)	Nonthly	P-12-042	Pedreira	23° 41' 59"	46° 40' 11"		São Paulo	A-14	EMAE
Wind (Velosity)	Nonthly	P-12-042	Pedreira	23° 41' 59"	46° 40' 11"		São Paulo	A-14	EMAE
Evaporation	Nonthly	P-12-042	Pedreira	23° 41' 59"	46° 40' 11"		São Paulo	A-14	EMAE
Rainfall									
	Daily	E3-022	São Caetano do Sul	23° 38'	46° 35'	740	São Caetano do Sul	Outside	DAEE
	Daily	E3-035	Observatório IAG	23° 39'	46° 38'	780	São Paulo	Outside	DAEE
	Daily	E3-035	Observatório IAG	23° 39'	46° 38'	780	São Paulo	Outside	DAEE
	Daily	E3-085R	Vila Prosperidade(GM)	23° 37'	46° 33'	730	São Caetano do Sul	Outside	DAEE
	Daily	E3-101	Cubatão	23° 53'	46° 25'	6	Cubatão	Outside	DAEE
	Daily	E3-142R	Recalque do ABC	23° 45'	46° 32'	840	São Bernardo do Campo	A-11	DAEE
	Daily	E3-148R	Mauá	23° 40'	46° 29'	780	Mauá	Outside	DAEE
	Daily	E3-149R	Campo Grande	23° 48' 39"	46° 27' 45"		Santo André	B-3	DAEE
	Daily	E3-150R	Rudge Ramos	23° 40'	46° 34'	780	São Bernardo do Campo	Outside	DAEE
	Daily	E3-233	Poundura	23° 21'	46° 56'	740	Cajamar	Outside	DAEE
	Daily	E3-237	Sertãozinho	23° 42'	46° 29'	790	Mauá	Outside	DAEE
	Daily	E3-239	Guapituba	23° 42'	46° 27'	800	Ribeirão Pires	B-4	DAEE
	Daily	E3-243	Parelheiros	23° 50'	46° 44'	780	São Paulo	Outside	DAEE
	Daily	E3-245	Taiacupeba Mirim	23° 39'	46° 20'	800	Suzano	Outside	DAEE
	Daily	E3-254	Embura	23° 50'	46° 45'	780	São Paulo	Outside	DAEE
	Daily	P-12-011	Bar. Pequeno Perequê	23° 48' 39"	46° 27' 45"		São Bernardo do Campo	A-9-1	EMAE
	Daily	P-12-013	Summit Control	23° 49' 03"	46° 31' 24"		São Bernardo do Campo	A-8	EMAE
	Daily	P-12-018	Cubatão de Cima	23° 52' 05"	46° 34' 03"		São Bernardo do Campo	A-8	EMAE
	Daily	P-12-035	Bar. Córrego Preto	23° 52' 25"	46° 38' 51"		São Paulo	A-4-2	EMAE
	Daily	P-12-039	Bororé	23° 45' 58"	46° 39' 00"		São Paulo	A-2-3	EMAE
	Daily	P-12-042	Pedreira	23° 41' 59"	46° 40' 11"		São Paulo	A-14	EMAE
	Daily	E3-155PB	Ribeirão Pires	23° 42' 29"	46° 25' 05"		Ribeirão Pires	B-4	**Posto de Bombeiros**
	Daily	E3-156PB	Noêmia	23° 40' 03"	46° 28' 05"		Mauá	Outside	**Posto de Bombeiros**
	Daily	E3-157PB	Jardim Zaira	23° 39' 02"	46° 26' 26"		Mauá	Outside	**Posto de Bombeiros**
	Daily	E3-158PB	Diadema	23° 41' 04"	46° 36' 44"		Diadema	Outside	**Posto de Bombeiros**
	Daily	E3-159PB	Campestre	23° 38' 53"	46° 32' 47"		Santo André	Outside	**Posto de Bombeiros**
	Daily	E3-160PB	Lucinda	23° 37' 33"	46° 31' 06"		Santo André	Outside	**Posto de Bombeiros**
	Daily	E3-161PB	Jardim do Mar	23° 41' 15"	46° 33' 36"		São Bernardo do Campo	Outside	**Posto de Bombeiros**
	Daily	E3-162PB	Vila do Tanque	23° 43' 18"	46° 32' 11"		São Bernardo do Campo	Outside	**Posto de Bombeiros**
	Daily	E3-163PB	Barcelona	23° 36' 55"	46° 33' 20"		São Caetano do Sul	Outside	**Posto de Bombeiros**
	Daily	---	Rio Grande da Serra				Rio Grande da Serra	Outside	**Posto de Bombeiros**
Runoff									
	Daily	RG-1	Campo Grande	23° 48' 39"	46° 27' 45"		Santo André	B-3	SABESP
Discharge									
	Daily	P-12-013	Summit Control	23° 49' 03"	46° 31' 24"		São Bernardo do Campo	A-8	EMAE
Withdrawal									
	Daily		Taquacetuba				São Paulo	A-3-2	SABESP
	Daily		Rio Grande				São Bernardo do Campo	B-6	SABESP
	Daily		Ribarão Estiva				Rio Grande da Serra	B-3	SABESP
Inflow (Pumping-up)									
	Daily	P-12-042	Pedreira	23° 41' 59"	46° 40' 11"		São Paulo	A-14	EMAE
Water level (Billings Reservoir)									
	Daily	P-12-042	Pedreira	23° 41' 59"	46° 40' 11"		São Paulo	A-14	EMAE

(1) Temperature

The mean monthly temperature for 20 years of 1985 to 2004 at Pedreira dam is 16.6ºC to 23.4 ºC, and the lowest is in July, and the highest is in February. The mean annual temperature is 20.1 ºC, the minimum r temperature is 0.0 ºC, and the maximum temperature is 36.0 ºC. The upside of about 0.6 ºC is perceived by the mean annual temperature of 20 years (refer to **Figure 1.1.2(B)**).

In IAG(USP) observatory, it is 15.7 ºC - 22.4 ºC, and July is the lowest, and January and February are highest. The mean annual temperature is 19.3 ºC, the minimum air temperature is 3.4 ºC, and the maximum temperature is 35.4 ºC. The upside of about 0.5 ºC is perceived by the mean annual temperature of 20 years (refer to **Figure 1.1.2(B)**).

(A) Mean, Maximum and Minimum Monthly Temperature

(B) Mean, Maximum and Minimum Annual Temperature

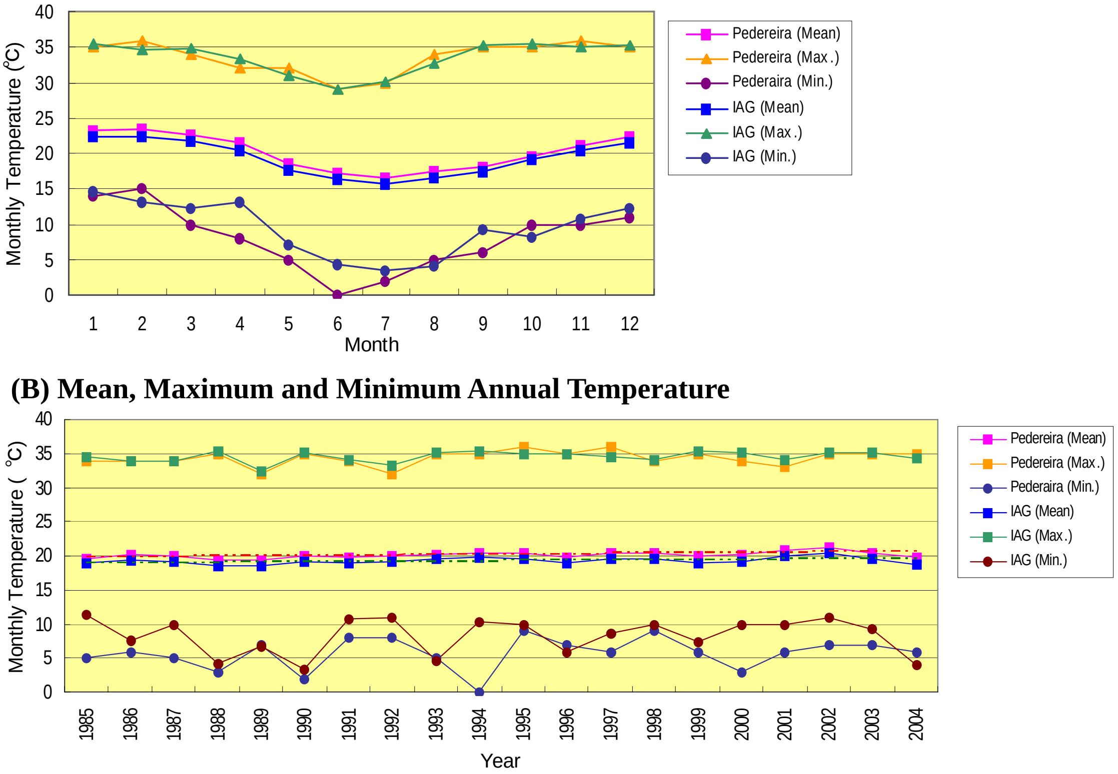


Figure 1.1.2 Mean Monthly and Mean Annual Temperature

(2) Relative humidity

The mean monthly relative humidity of the Pedreira dam for 20 years of 1985 to 2004 is 77.8 - 81.0%, and August is the lowest, and January is highest.

The mean annual relative humidity of 20 years is 79.1 - 83.1% (80.6% on the average), and a remarkable change is not perceived (**Figure 1.1.3**).

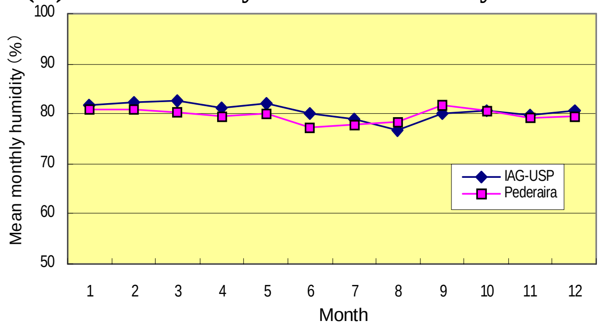
In IAG(USP) observatory, it is almost similar to the Pedreira dam station, the mean monthly relative humidity of 20 years is 76.8 - 82.2%, and July is lowest, and February is highest. The mean annual relative humidity of 20 years is 77.0-82.8% (79.7% on the average), and a remarkable change is not perceived (**Figure 1.1.3**).

(3) Atmospheric pressure

The atmospheric pressure is measured in the IAG(USP) observatory.

The mean monthly atmospheric pressure of 20 years of 1985 to 2004 is 922.8 - 929.6 hPa, December is the lowest, and July is the highest. The mean annual atmospheric pressure of and 20 years is 925.5 - 926.4 hPa (average 926.0 hPa), and a remarkable change is not perceived (**Figure 1.1.4**).

(A) Mean monthly Relative Humidity



(B) Mean annual Relative Humidity

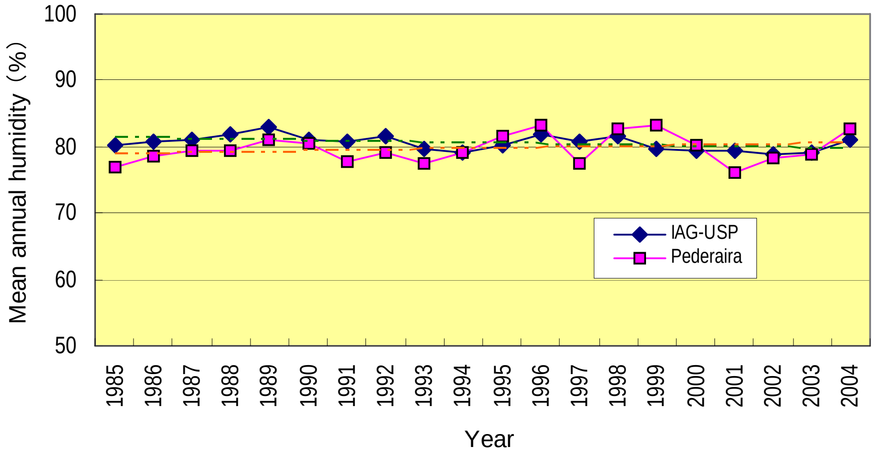
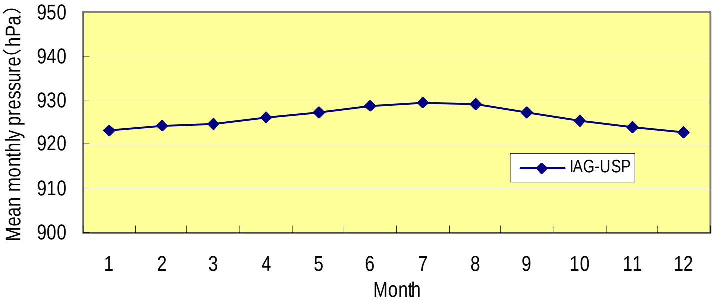


Figure 1.1.3 Mean monthly and Mean annual Relative Humidity

(A) Mean Monthly Atmospheric Pressure



(B) Mean Annual Atmospheric Pressure

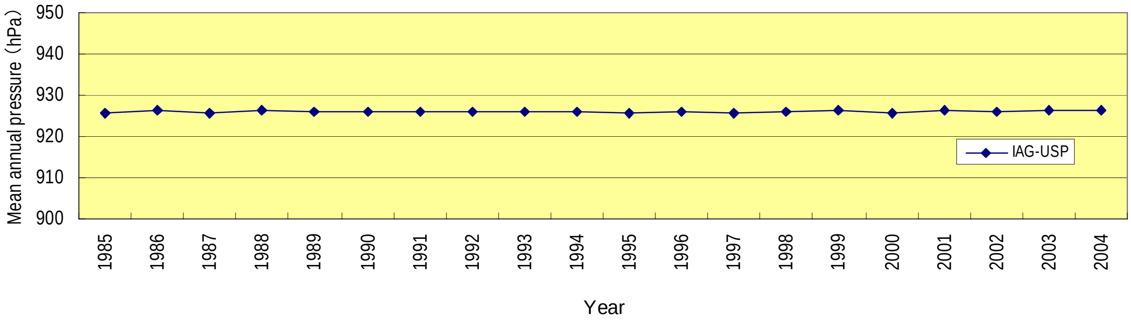


Figure 1.1.4 Mean Monthly and Mean Annual Atmospheric Pressure

(4) Wind direction and wind velocity

The monthly superior wind direction of the Pedreira dam station for 20 years of 1985 to 2004 is in southwest (SE), and the monthly secondary superior wind direction is in northwest (NW) in December to February. The mean monthly wind velocity is 1.9 to 3.0 km/h, but it has not records in order to non-observation since September 1988.

In the IAG(USP) observatory, the wind of northwest (NW) is superior in January, the wind of southeast (SE) is superior in February to April, the wind of south-southeast (SSE) to southeast (SE) is superior in September to November, and the wind of east- southeast (ESE) is superior in December.

The wind in the superior direction and the wind in the opposite direction mix in December to January, May, and August when the wind direction changes. The second superior wind in northwest (NW) direction mixes with the superior wind in the east-southeast (ESE) direction in December, and the wind in southeast (SE) or east-southeast (ESE) direction mixes with the superior wind in northeast (NW) direction or northwest (NE) direction in January, May and August.

The mean monthly wind velocity is 5.4 - 6.8 km/h. The wind is strong in October to December, and the wind is weak in March to July. The maximum daily wind velocity in month is 21.0 - 26.0 km/h except a temporary strong wind (Refer to **Table 1.1.2**).

Table 1.1.2 Monthly Wind Direction and Velocity

Month		1	2	3	4	5	6	7	8	9	10	11	12
Pederaira	Prevailing wind direction	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE
	Second prevailing wind direction	NW	NW	---	C	---	---	NW	---	---	---	---	NW
	Mean wind velocity (km/h)	2.7	2.3	2.3	2.5	1.9	1.9	2.3	2.4	3.0	3.0	3.0	2.6
IAG-USP	Prevailing wind direction	NW	SE	SE	SE	NE	NE	NE	NE	SSE	SE	SE	ESE
	Second prevailing wind direction	ESE	E/ESE	ESE	SSE	ESE	NNE	NNE	SE	SE	SSE	ESE	SE/NW
	Mean wind velocity (km/h)	6.2	5.9	5.6	5.8	5.6	5.4	5.7	5.9	6.6	6.7	6.8	6.7
	Maximum wind velocity (km/h)	22.0	21.0	21.0	22.0	25.0	25.0	26.0	78.0	22.0	26.0	23.0	22.0

(5) Evaporation

The evaporation for 20 years of 1985 to 2004 in the Pedreira dam station is observed at 2 methods of the pitch equipment and the tank on the ground.

The mean monthly evaporation is 82.2 - 108.7 mm at the pitch equipment, and May is the lowest, and February is highest. The annual evaporation of 20 years is 897 - 1421mm (1120.9 mm on the average).

Moreover, the mean monthly evaporation is 69.6-138.6 mm at the tank on the ground, and June is the lowest, and February is the highest. The annual evaporation of 20 years is 1159-1308 mm (1243 mm on the average).

In IAG(USP) observatory, the daily evaporation in January, 1992 to January, 2000 was observed. The mean monthly evaporation of eight years is 53.5 - 73.8 mm, and May is the lowest, and December is the highest.

The annual evaporation of eight years is 64 2 - 889 mm (763 mm on the average) (Refer to **Figure 1.1.5**).

(6) Duration of Sunshine

Duration of sunshine are observed in the IAG(USP) observatory.

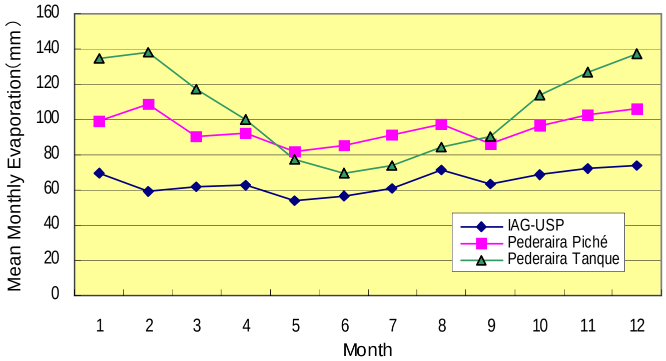
The mean monthly duration of sunshine of 20 years is 4.4 - 5.9 hours, and the mean monthly percentage of possible sunshine is 37.4 - 53.2%. It is short in September to October, and long in April and August. There is a little a lot of weathers of cloudy compared with the coastal area.

The mean annual duration of sunshine is 4.9 - 6.5 hours (average duration of 5.5 hours), the mean annual percentage of possible sunshine is 41.1 - 55.3% (average 46.6%). The increasing trend of about 0.7 hours during 20 years is perceived. (**Figure 1.1.6**)

(7) Rainfall

The mean monthly precipitation shows that a rainy season is in October to March, and a dry season is June to September in the surrounding area of the Lake Billings basin. It rains much in January - March, and August is the fewest (**Figure 1.1.7**).

(A) Mean Monthly Evaporation



(B) Mean Annual Evaporation

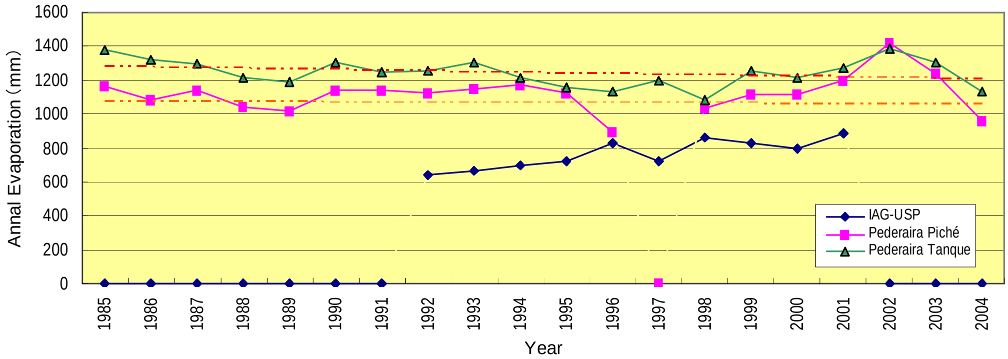
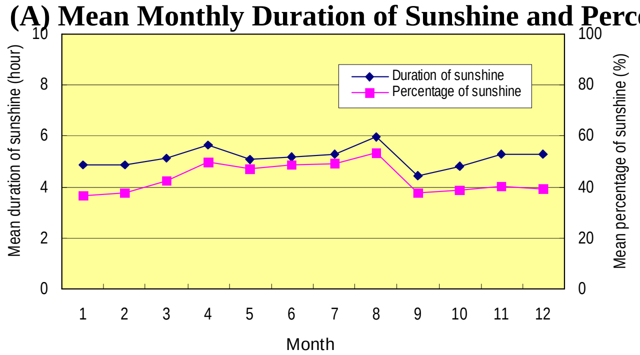


Figure 1.1.5 Mean Monthly Evaporation and Annual Evaporation

(A) Mean Monthly Duration of Sunshine and Percentage of Sunshine



(B) Mean Annual Duration of Sunshine and Percentage of Sunshine

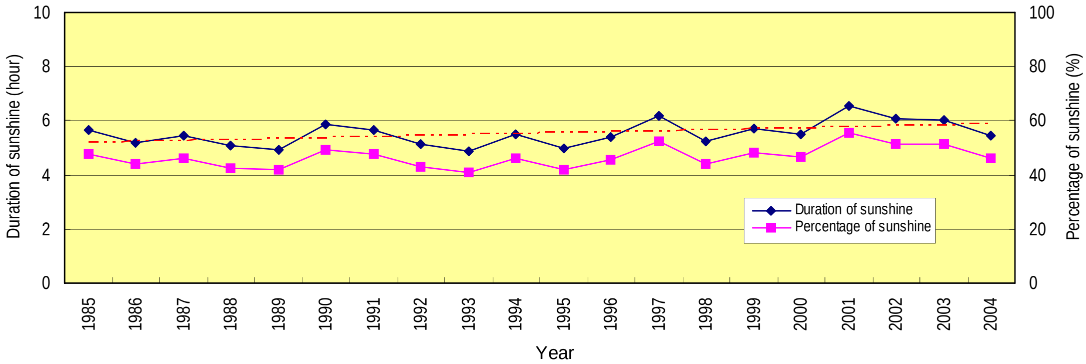


Figure 1.1.6 Mean Monthly and Annual Duration of Sunshine and Percentage of Sunshine

The annual precipitation of 20 years from 1985 to 2004 shows that little rainy year is in 1991 and 1996, and rainy year is in 1985, 1990, 1993 to 1994 and 2003. The downward trend of precipitation is perceived (**Figure 1.1.8**).

The mean annual precipitation of 20 years is 1486 mm in IAG-USP (E3-035), 1378mm at Pedreira dam (P12-042) on the north side of the Lake Billings, 1579 mm at E3-148 (São Bernardo do Campo), 1488 mm at E3-237 (Mauá), 1611 mm at E3-237 (on the south side of Mauá). It is 1544 mm in E3-243 (Parelheiros) on the west side of the Basin. In the south of the basin, it is 1725 mm (P12-035) to 2524 mm (P12-011) at the southwest of the basin where EMAE stations exist, 2830 mm at E3-149 (the south region of Santo André). In the south of the Lake Billings basin, precipitation is increased.

The features of the rainfalls of various areas in the basin are as follows.

1) West side area of the basin (Pedreira-Parelheiros-Embu)

The mean annual precipitation is 1377 - 1544 mm in Pedreira (P12-042), Bororé (P12-039), and Parelheiros (E3-243), and it increases in the south. In three stations, the trend of monthly and yearly variation indicates similar together. At Embu (E3-254) located in the outside west of the basin, the mean annual precipitation is slightly high with 1674 mm, and have a slightly different trend of monthly and yearly variation due to a lot of missing value.

2) Northwest area of the basin (São Bernardo do Campo, Diadema and IAG-USP)

There is a lot of missing value except IAG-USP (E3-035), The mean annual precipitation is 1486mm at IAG-USP(E3-035), 1162 mm at Diadema (E3-150) and 1579 mm at São Bernardo do Campo (E3-142). The three stations show a similar trend of monthly and yearly variation.

The four fire station observatories (PB) are little in mean annual precipitation with 1152 mm at São Bernardo do Campo (E3-162PB) – 1281 mm at Diadema (E3-158PB), and have a slightly different trend such as low precipitation in January to May compared with IAG-USP (E3-035) due to recent five years observation.

3) Northeast area of the basin (Mauá, the north region of Santo André and São Caetano do Sul)

The mean annual precipitation is 1471 mm at São Caetano do Sul (E3-085), 1474 – 1611 mm at Mauá,(E3-148 and E3-237), and increases a little in the south of the area.

The trends of the monthly and yearly annual variations are mutually resemble, and are similar to the stations in northwest side of surrounding the basin. The amount increases a little compared with the northwest side.

The mean annual precipitation of fire station observatory (PB) is 1170 mm at São Caetano do Sul (E3-163PB) – 1294 mm at the north region of Santo André (E3-159PB), and is few compared with DAEE stations due to recent five years observation. Variation trends between fire station observatories are similar.

4) East side area of the basin (Ribeirão Pires, Rio Grande da Serra, the south region of Santo André)

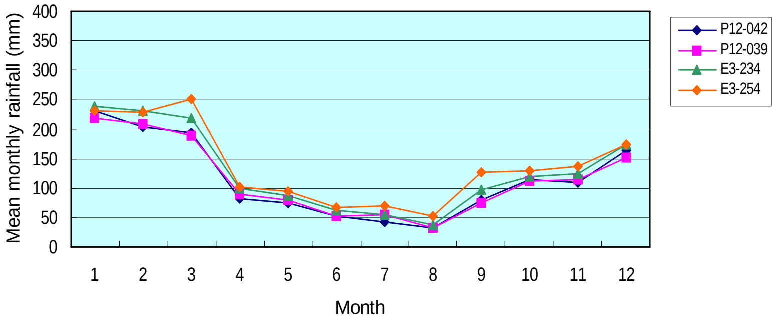
The mean annual precipitation is 1500 mm at Ribeirão Pires (E3-239), 2774 mm at the south region of Santo André (E3-149), and increases clearly in the south of the area. The variation trend of E3-149 is similar to the south side area of the basin.

The mean annual precipitation of fire station observatory (PB) is 1255 mm at Ribeirão Pires (E3-155PB), and is very few compared with DAEE stations.

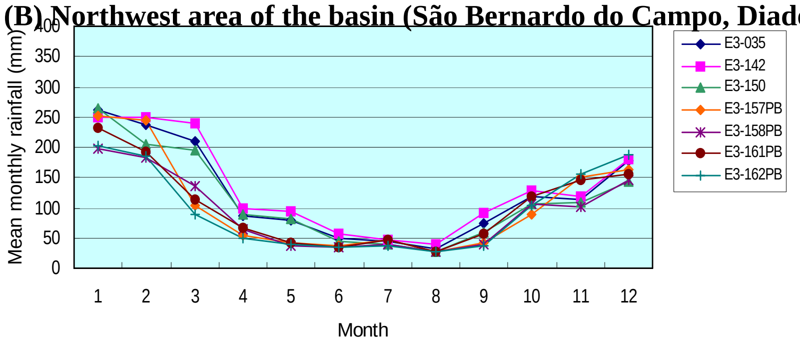
5) South side area of the basin (EMAE stations in the south side area of the basin and Cubatão)

The mean annual precipitation is 1725mm at Barragem Córrego Preto (P12-035) – 2525 mm at Barragem Pequeno Prequé (P12-011) and 2583 mm at Cubatão (E3-101), and is rather a lot of precipitations compared with the north side area of the basin. The variation trend of P12-011 and E3-101 are mutually similar, but E3-101 observation stopped since 1992. P12-013(Summit Control), P12-018(Cubatão do Crima), and P12-035 located in the southwest side of the basin show a mutually similar variation trend.

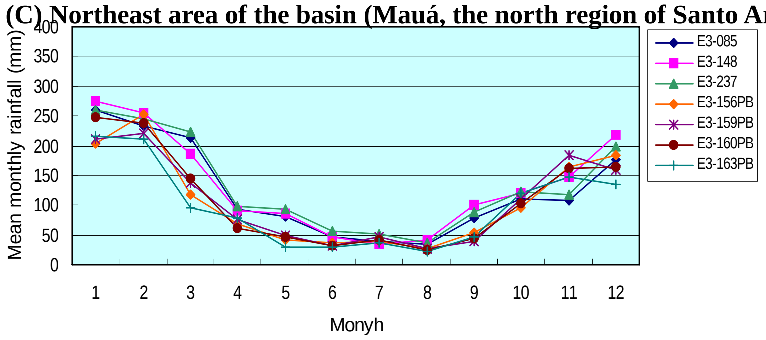
(A) West side area of the basin (Pedreira-Parelheiros-Embu)



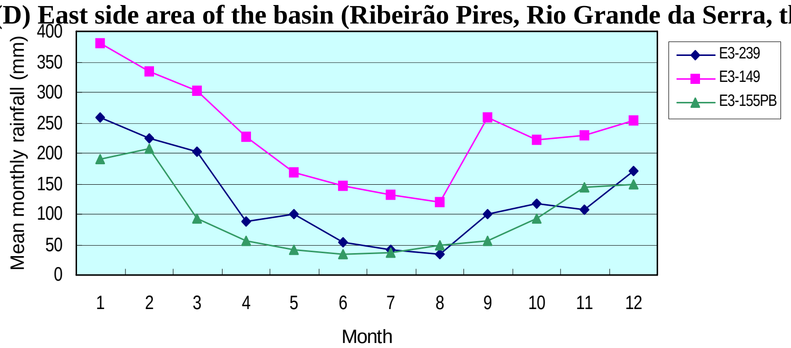
(B) Northwest area of the basin (São Bernardo do Campo, Diadema and IAG-USP)



(C) Northeast area of the basin (Mauá, the north region of Santo André and São Caetano do Sul)



(D) East side area of the basin (Ribeirão Pires, Rio Grande da Serra, the south region of Santo André)



(E) South side area of the basin (EMAE stations in the south side area of the basin and Cubatão)

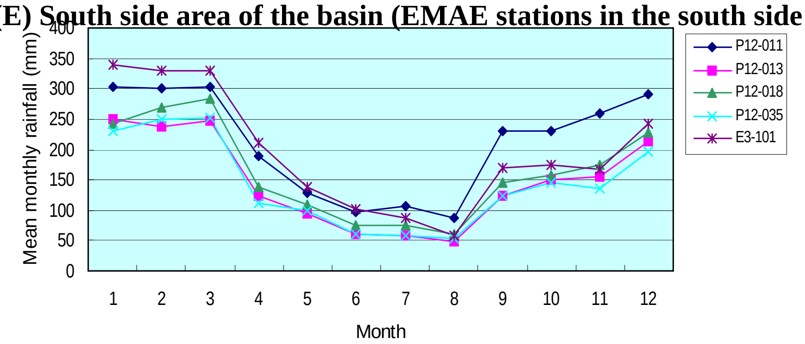
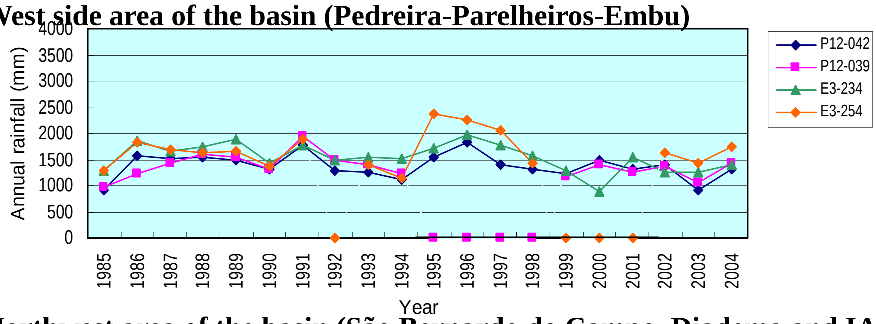
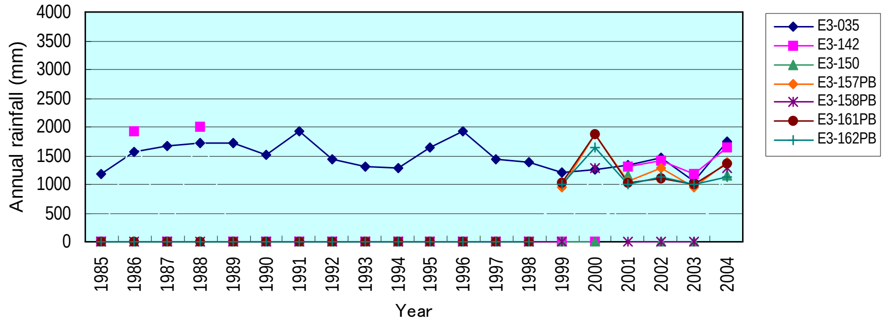


Figure 1.1.7 Mean Monthly Precipitation

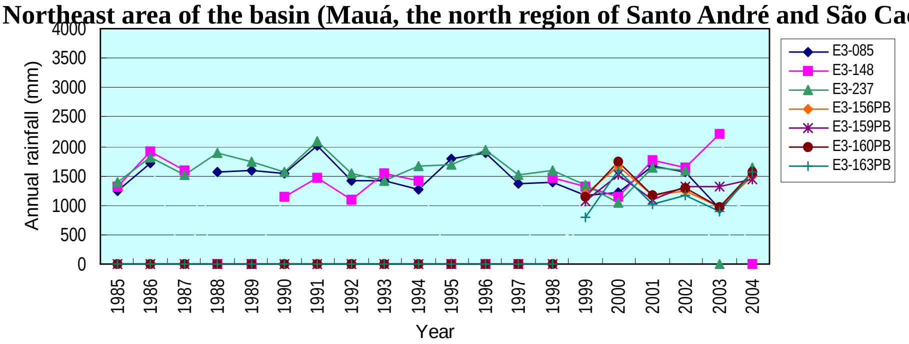
(A) West side area of the basin (Pedreira-Parelheiros-Embu)



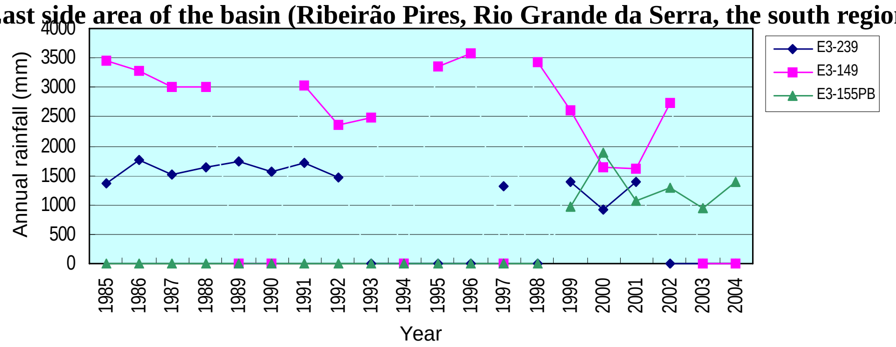
(B) Northwest area of the basin (São Bernardo do Campo, Diadema and IAG-USP)



(C) Northeast area of the basin (Mauá, the north region of Santo André and São Caetano do Sul)



(D) East side area of the basin (Ribeirão Pires, Rio Grande da Serra, the south region of Santo André)



(E) South side area of the basin (EMAE stations in the south side area of the basin and Cubatão)

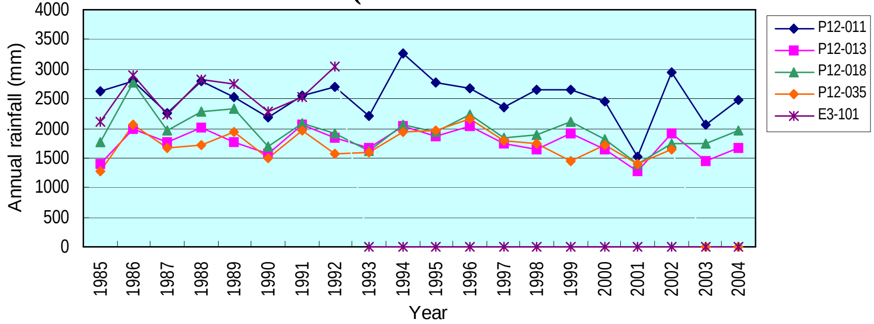


Figure 1.1.8 Annual Precipitation

1.1.2 Geography and Geology

(1) Geographical futures

In the southward of the Lake Billings basin, there is coastal mountain (Serra do Mar) that expands from west-southwest (WSW) to east-northeast (ENE) direction, and a vast plateau with rather gentle relief of elevation 700-1200 m in the north side of the mountain range and the low land of the coast of elevation 0-sebral 10 m in the south side of the mountain range is formed.

The south slope in the mountain range is a fault-line scarp according to the activity of Cubatão fault (Folha do Cubatão) in Paleocene of Tertiary since Cretaceous of Mesozoic, and the plateau is a lift zone.

The plateau stretches to the north side of the coastal mountain. It inclines rather gently to north-northwest (NNW), and the altitude is lowered gradually in the north.

The Lake Billings basin is located near the south edge of the plateau. The land area of the watershed is 582.8 km^2, and the surface area of the reservoir is 108,142 km^2 above sea level 747.65 m that EMAE manages (Source; Billings 2000 2002 ISA).

The watershed basin bounds to the coastal mountain cliff on the southeast side. The ridge of the south of Paranapiacaba (relay railway station of FEPSA between Santos and São Paulo of the southern part of the Santo André) is the highest peak (above sea level 1174 m) in the basin.

In the southwest of the basin, the altitude is lowered to from about 800 m to 750 m and the watershed ridge comes to leave the coastal mountain cliff gradually, and the plateau with gentle relief inclined the southward is formed between mountain cliffs and the watershed ridge of the basin.

The east side watershed ridge lowers gradually inclining to north side from above sea level about 900 m to 800 m, and the north side watershed and the east side watershed lower the altitude from above sea level about 800 m up to 750 m on the northwest side of the basin.

The map of Classification of declination in the surrounding area of the basin is shown in **Figure 1.1.9**.

There is a coastal mountain cliff on Cubatão side of the São Paulo state boundary (part of void), and few km of width along the cliff is steep slope land of more than 40% declination.

The slope land of 20-40% and partially the steep slope land of 40% or more are distributed on the east side watershed mountainous slope, the north side watershed mountainous slope in Ribeirão Pires to Santo André, and the east side slope of mountain between Rio Grade Arm and Rio Pequeno arm.

The plain of 0-5% stretches along the main river of the Rio Grande and others, and the shallow dip ground of 5-20% is distributed in the surrounding hill portion widely.

(2) Geological Future

The geological map in the surrounding area of Lake Billings basin is shown in **Figure 1.1.10** and **Figure 1.1.11**.

In geological features, the basement rocks of Precambrian is widely distributed in the whole area of the surrounding area of the basin, and clay, sand, and gravel in the São Paulo formation (Taupate group) of Tertiary to Quaternary are distributed at low hilly area in the vicinity of Lake Billings front. Moreover, clay, sand, and gravel of the alluvium of Quaternary are distributed on the low land area along the main river channel and the Colônia depression land (It is said that it was formed by the fall of the meteorite) in the southwest of the Basin.

The basement rock of Precambrian are distributed with zonal structures that stretch in direction from west-southwest (WSW) to east-northeast (ENE) or from southwest (SW) to northeast (NE).

migmatite/gneissource granite, maicashist/metaarenite, and granite/granodiolite are widly distributed, and dikes or small rock units that consist of amphiborite/metabasicrocks (Metadiabase, Metagabbro) or Diorite/Quartzdiorite are partly distributed in the southwest to west side of the basin. Small rock units of Phyllite/Meta-argillite with zonal structure are partly distributed in southeast side of the basin (**Figure 1.1.10**).

The geological age of the stratum and name of the formation and the group name are set in detail in **Figure 1.1.11**.

Costeiro complex (mainly consist of migamatite/gneiss) of Archean, Embu complex (Migmatite) of Proterozoic and various kind of granite and granitoid rocks of Proterozoic – Cambrian – Ordovician form basement rocks. São Paulo formation of Pliocene to Plicetocene forms low hilly portion and terrace. Alluvium of Holocene form low land along river, plain and costal low land.

The Lake Billings basin is the basically stability ground, but has the part where weathering progresses under the condition of uplift land exposed long-period since Paleozoic era.

In the Sao Paulo basin of northward of the basin, Tertiary to Quaternary formation makes thick layer in the central basin. In São Bernardo do Campo, deep wells are generally drilled up to 100-150m of total depth and reach the lower basement part to pump up the potable water or others. Usually clay or silt layer with about 40m thickness overlies basement rocks.

(3) Soils

The soil map in the surrounding area of the Lake Billings basin is shown in **Figure 1.1.12**.

Cambisol (Brown forest soil) is widely distributed in the basin. Acrisol (Reddish yellow Podzol) is distributed in the north side of Ribeirão Pires. Latosol is distributed in the east side mountainous area of Rio Grande da Serra .

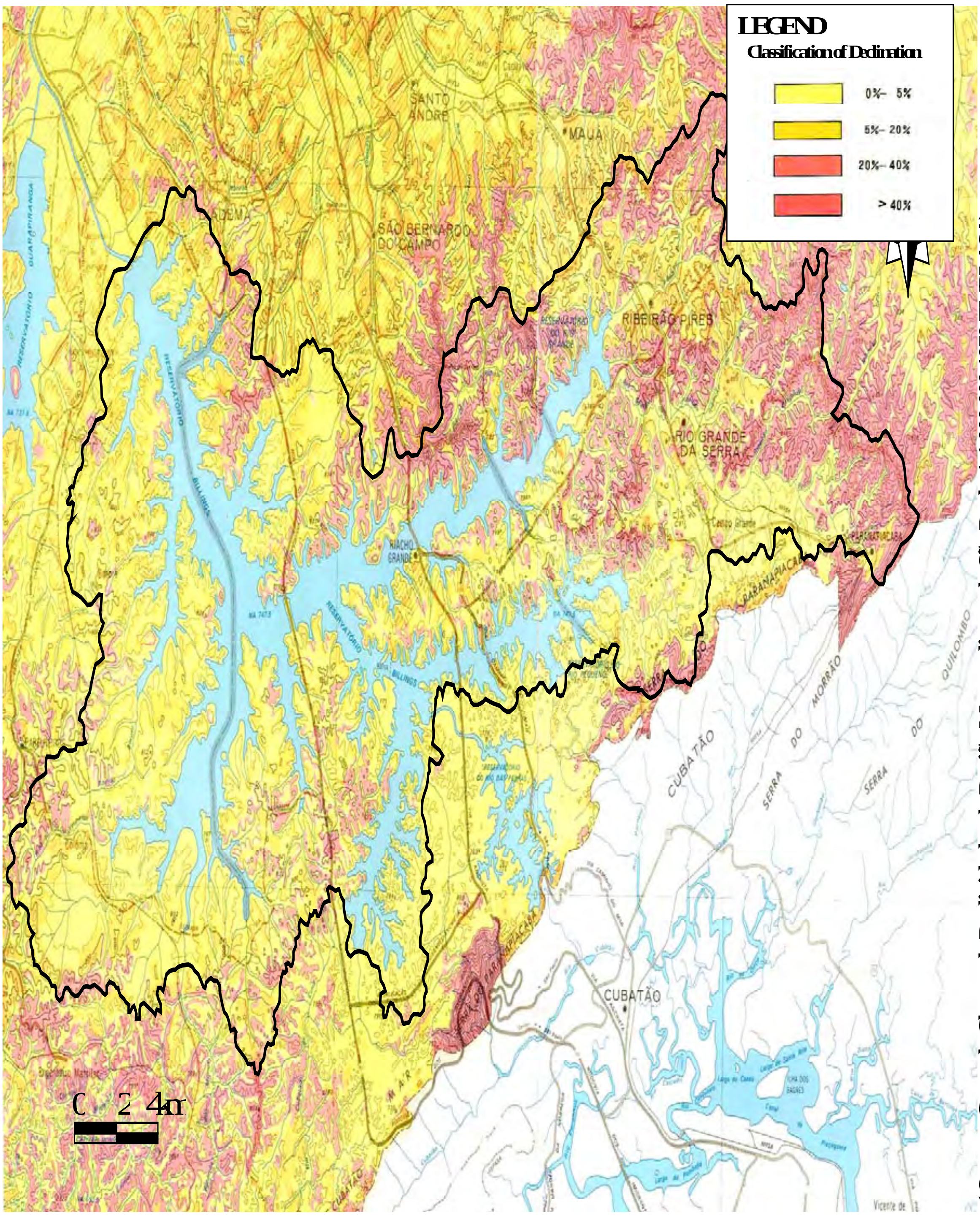
In tropical soil conservation, Cambisol is deteriorated when management is poor, and a biological maintenance procedure sustains production from soil and soil conservation. Because the Acrisol is deteriorated easily, and is difficult the reproduction, it is made to the soil that should be sustained in natural vegetation or the condition of the forest. The Latosol is acid soil (ruin soil) with the red color where abundant topsoil with the organic matter flow out by the rock weathering, and the oxide of iron and aluminum remained, and the productivity is low.

(4) Soil nature

The Map of classification of soil nature is shown in **Figure 1.1.13** and **Figure 1.1.14**.

In **Figure 1.1.13**, Susceptibility to erosion is high in the east side and northeast side of the basin evaluating combination of silty soils, cambisol and Maountainous relief on cristalline basement rock. Susceptibility to erosion is low in the wide area of the west, northwest, southwest and central area of the basin evaluating combination of argillaceous soils or latosol and wavy rerief on the cristalline rocks. Low land along the rivers is very low susceptibility to erosion.

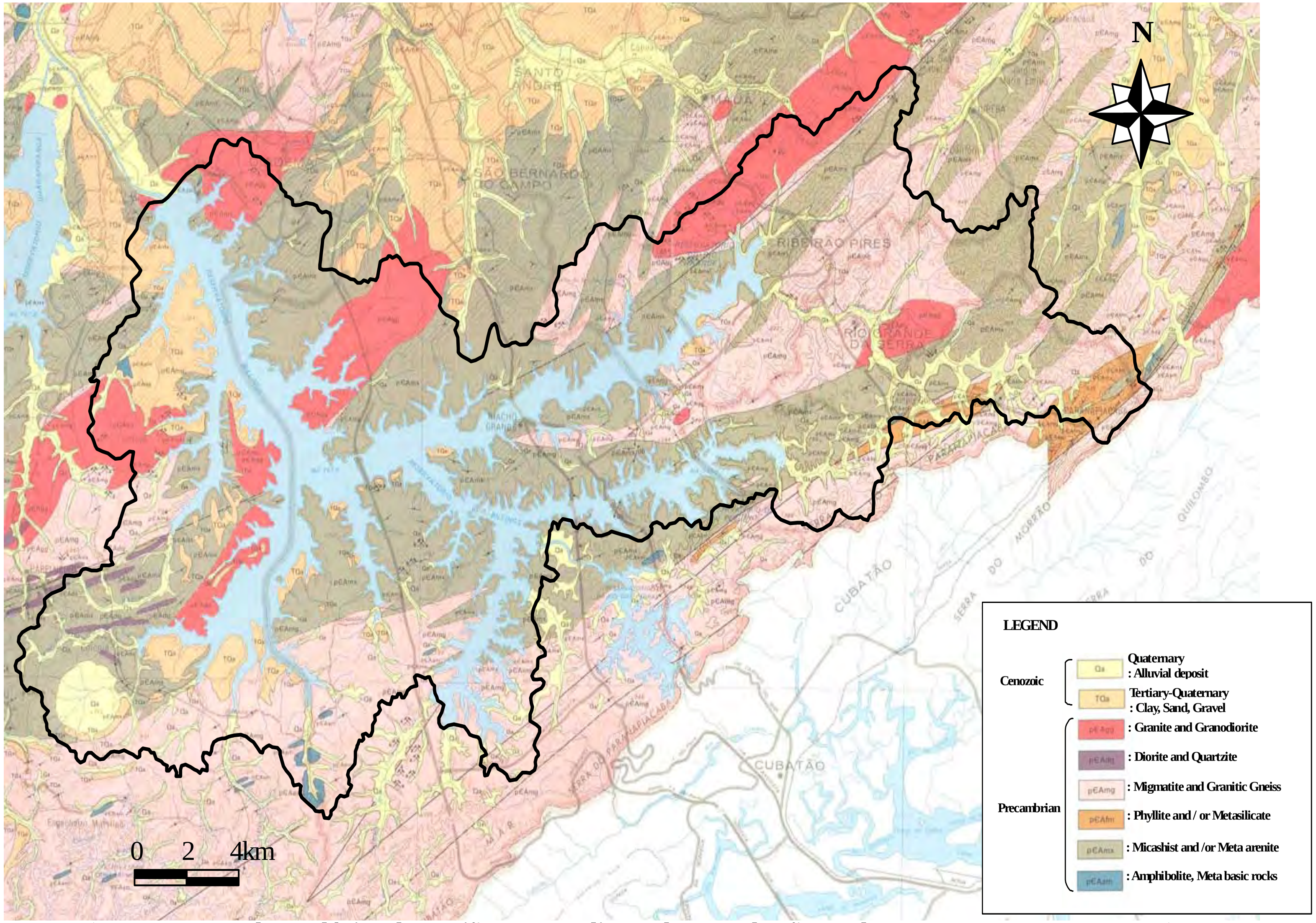
In **Figure 1.1.14**, Susceptibility to slope slide is high in mountainous area of the north side, northeast side and southeast side of the basin, and other area is middle. Susceptibility to erosion for surface and subsurface is high in the whole the basin except lowland along river or in plain. Low land is also high area of susceptibility of inundation or repression for foundation.



(Source; Carta de Classes de Declividades da Região Metropolitana da São Paulo 1:1,000,000 1979 EMPLASA)

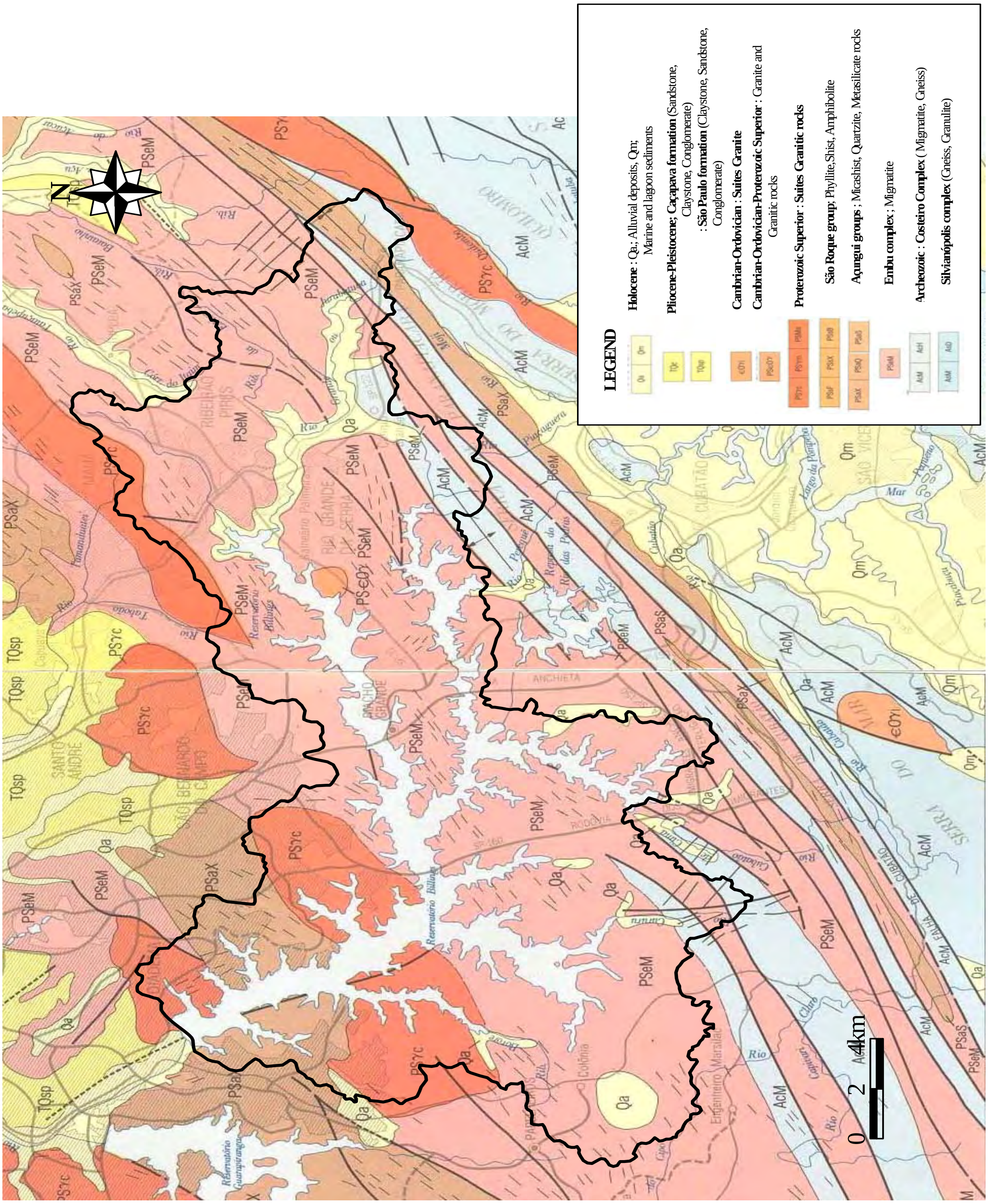
Figure 1.2.9 Map of Classification of Declination in Surrounding Area of Billings Reservoir Basin

Figure 1.1.9



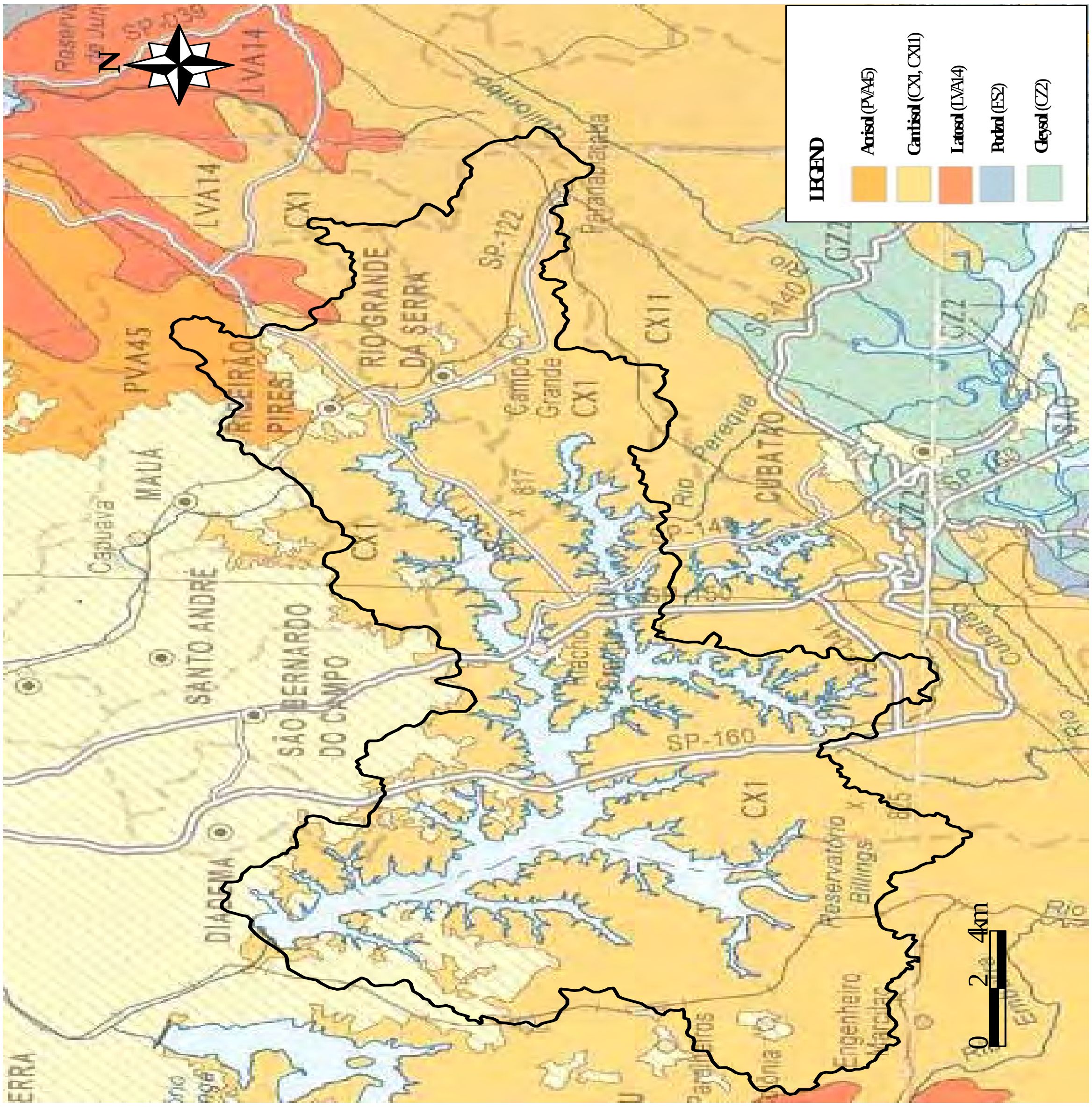
(Source; Carta de Geológica da Região Metropolitana da Grande São Paulo 1:100,000 1980 EMPLASA)

Figure 1.1.10 Geological Map in Surrounding Area of Billings Reservoir Basin (1)



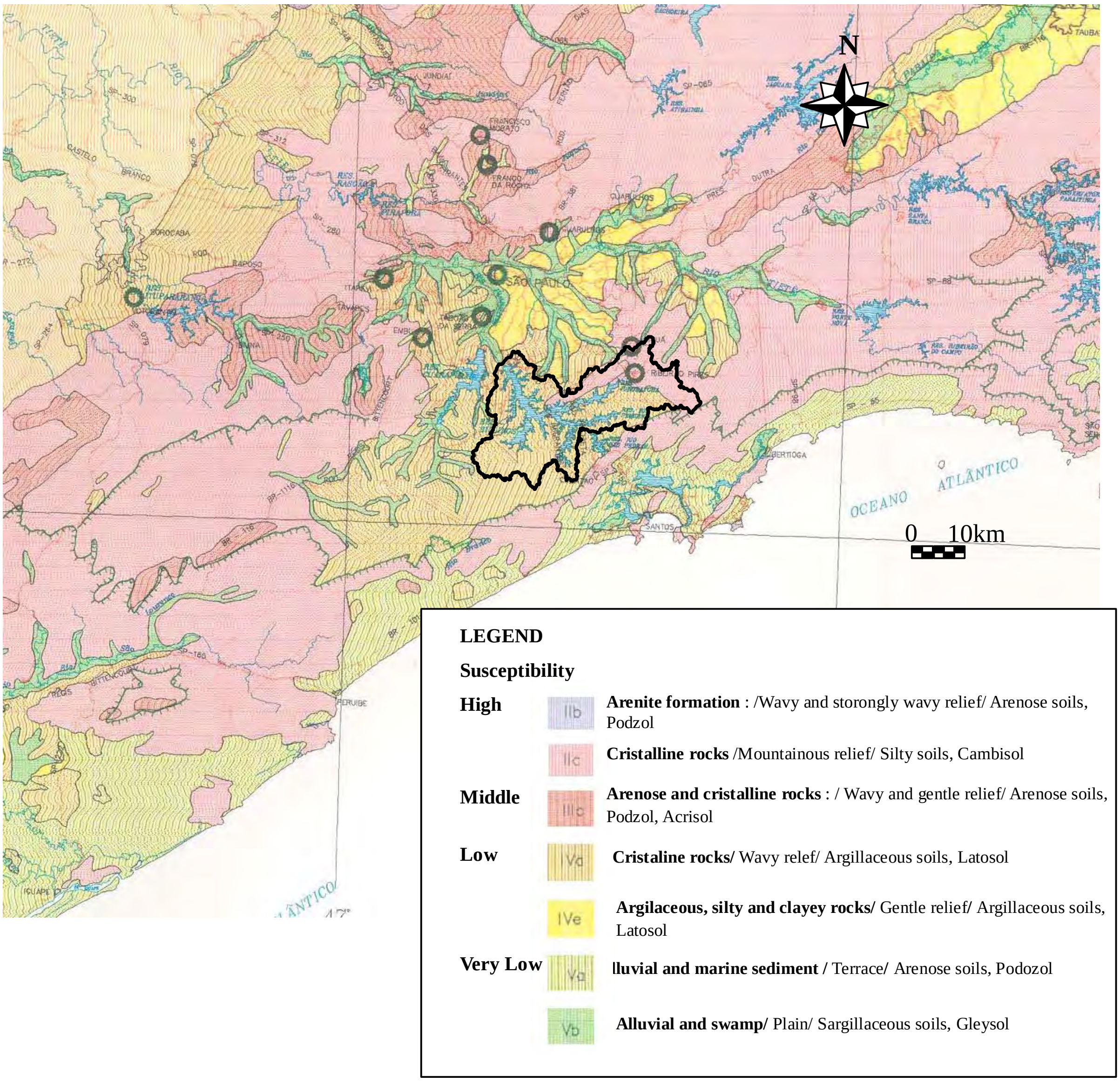
(Source; Mapa Geológico do Estado de São Paulo 1:250,000 1984 Universidase Estadial Paulista)

Figure 1.1.11 Geological Map in Surrounding Area of Billings Reservoir Basin (2)



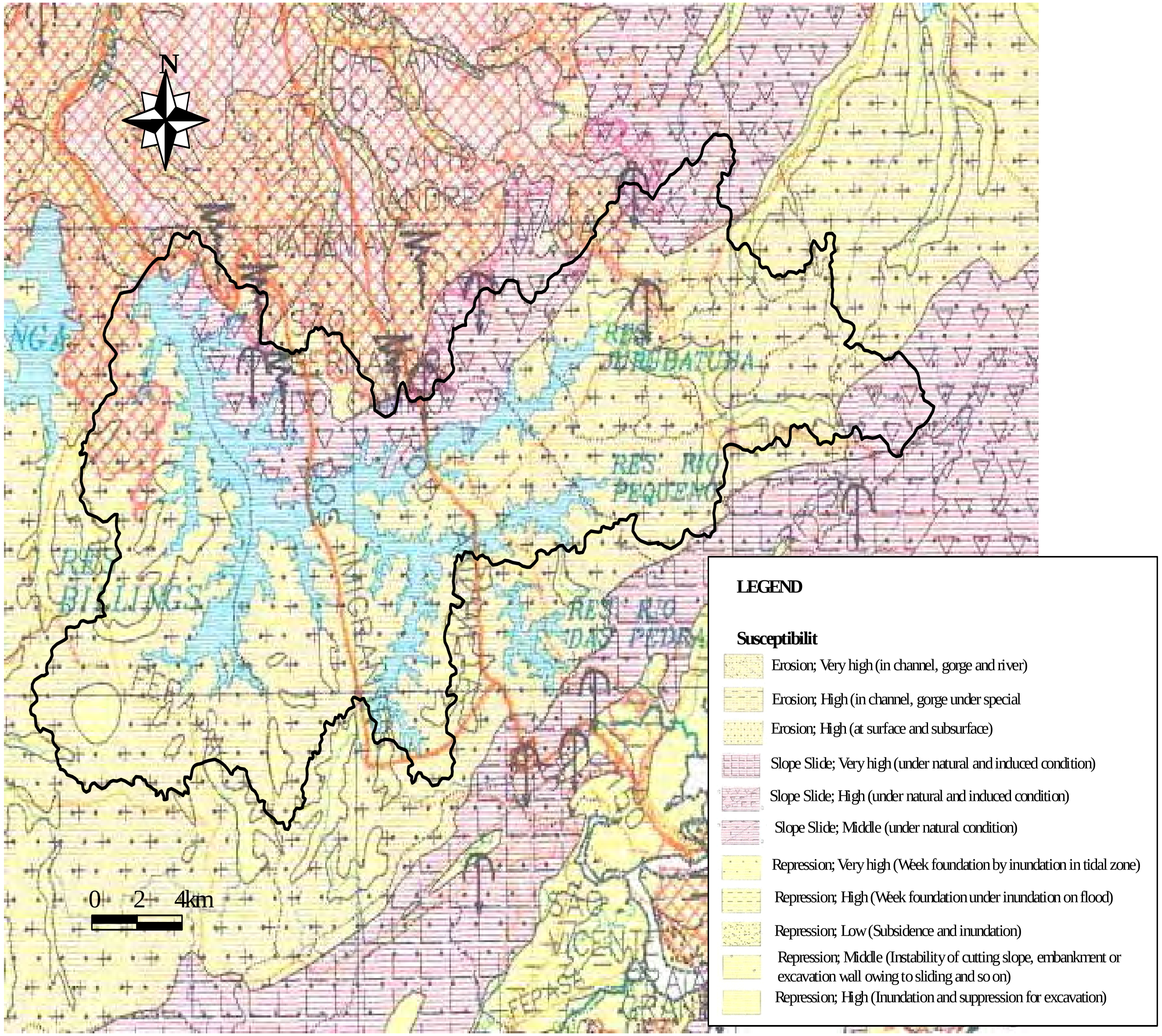
(Source; Mapa Pedológico do Estado de São Paulo 1:500,000 1999 EMPLASA)

Figure 1.1.12 Soil Map in Surrounding Area of Bllings Reservoir Basin



(Souce; Mapa de Eroão do Estado de São Paulo 1:1,000,000 1950 IPT)

Figure 1.1.13 Map of Susceptibility for erosion in Surrounding area of Lake Billings Basin



(Source; Carta Geotécnica do Estade São Paulo 1:500,000 1994 IPT)

Figure 1.1.14 Geotechnical Map in Surrounding Area of Billings Reservoir Basin