2.2. Demand and Supply Balance

2.2.1. Planning for Supply

The SABESP PLAN mentioned in the Chapter 3 of Part II, foresees the water supply to the Metropolitan Region of São Paulo up to 2000 with total capacity of 104 m^3/s. After the completion of Cantareira System, which will be enough to supply São Paulo up to 1987, several river basins are planned, but the SABESP PLAN has not essentially so much difference with HIBRACE PLAN developed 1968. In fact, the river basins and the reservoirs planned by SABESP are exactly same as HIBRACE PLAN and there is no perspective for the year after 2000, which means that the long term planning is judged to be necessary to consider.

On the other hand, HIBRACE PLAN was developed 14 years ago, and nowadays a lot of aspects are necessary to be considered for water supply plan, because Sao Paulo Metropolitan Region and the neighbourhood areas have developed too much, and the problem related to the water resources in Tiete River (upper basin), which is almost equivalent to the São Paulo Metropolitan Area, is quite different if compared with 1964 - 1968 of the development period of HIBRACE PLAN.

So, the following considerations are important to be included in the present study;

- The majority of planned water resources is consisted of small supply capacities and after 1990, for example, the annual growth rate of water demand is 3.8% which means that about 2.5 m^3/s of supply capacity has to be increased every year so that one reservoir per year in average will be necessary to be constructed.

- The Alto Tiete System planned to supply 19.8 m^3/s has limitations which are difficult to establish at present, because of mainly related to the water needs for other uses like irrigation and sewage dilution of Tiete River which is highly polluted.

- The Alto Juquia System, as planned by HIBRACE and SABESP in order to provide 19.3 m^3/s to Guarapiranga System, has a very troubleful interference with Companhia Brasileira de Aluminio - CBA (Alluminium Private Company), which has about

230 MW of total installed capacity with 6 hidroelectric power stations and generates a very cheap electrical energy.

- The Capivari-Monos System planned to provide 5.6 m^3/s is in a coastal basin and it is necessary to keep for the future of Coastal Region such as Santos, São Vicente, Praia Grande and Itanhaem Cities, which are the main tourist regions of about 70 km from São Paulo. Nowadays, there are water resources to supply these cities, but after 2010, the deficit is judged to be evident.

- The existing reservoir of Guarapiranga with about 9.0 m^3/s capacity is nowadays in gradual advance of pollution as a result of intensive urbanization, and actually, there are some days a year with the problems of eutrophization. It is assumed that Guarapiranga Reservoir will not be able to supply drinking water to São Paulo in 2000.

- The Cantareira System, which is actually in the final stage of completion, has troubles for its downstream region, mainly for Campinas Area and Piracicaba Area, because the remaining water resources of Jaguari, Atibaia and Piracicaba Rivers are not enough to supply the water requirements of these areas especially, during the dry season. In addition, it is necessary to consider that these areas are developing very fastly and the river pollutions are also increasing, so that it is supposed in near future, that a significant portion of water from Cantareira System has to be released to its downstream in order to supply Piracicaba Basin.

The present report of Juquia - São Lourenço Project presents an alternative plan to supply the Metropolitan Region of São Paulo to avoid the above mentioned aspects, and the demand forecast indicated in the item 2.1 of this Chapter is also taken into account.

2.2.2. Demand and Supply Balance

Figure III-2.6 indicates the water demand curve up to 2040 and the planned schedule of facilities to supply São Paulo from 1987 to 2007.

The existing water supply facilities and some others under construction have the total capacity of 53.7 m^3/s as follows:

TABLE III-2.3. EXISTING AND UNDER CONSTRUCTION WATER SUPPLY FACILITIES

Name	Supply Capacity (m^3/s)	Notes
Guarapiranga	10.5	(1)
Cantareira (1st Stage)	11.0	(2)
Rio Grande (Billings)	4.1	(3)
Rio Claro (Alto Tiete)	4.0	
Cantareira (Final Stage)	22.0	(2)
Others	2.1	
Total	53.7	

Notes:

(1) Partial diversion of upper Capivari River is included (1.5 m^3/s), with temporary facilities.

(2) Cantareira System, with total capacity of 33 m^3/s is considered in this table. It is judged that this capacity will be in near future reduced because it will be necessary to release much more water to the downstream basin (Piracicaba Basin).

(3) This is the existing supply capacity of Rio Grande System which is situated in the Billings Reservoir.

This 53.7 m^3/s capacity is enough to supply São Paulo up to 1987. After 1987, the development of Juquia - São Lourenço System is recommended according to the following water supply schedules.

TABLE III-2.4. PLANNED WATER SUPPLY UP TO 1995

Name	Supply Capacity (m^3/s)	Operation Year
EG - 3	1.8	1987
JR - 1	4.7	1988
Alto Tiete (*)	7.0	1990
Itatinga	5.1	1992
Itapanhau	3.5	1994
GD - 6 and LH - 3	2.1	1995
Total	24.2	

(*) Taiaçupeba, Biritiba, Jundiai and Ponte Nova Reservoirs.

According to this schedule, the total water supply capacity in 1995 is estimated as 77.9 m^3/s of which quantity is just balanced with water demand. Considering this schedule, São Lourenço Reversible Power Station has to start the operation from 1996 in order to pump up the water from the lower basin to the Sao Paulo, and the operation commencement years of lower basin are planned as follows:

TABLE III-2.5. PLANNED WATER SUPPLY FROM 1996 TO 2007 AT LOWER BASIN

Name	Supply Capacity (m^3/s)	Operation Year
LH-2A	4.2	1996
LH-1	8.3	1997
B-1	2.1	2000
B-2*	31.0	2001
Total	45.6	

*: B-2 shall be started operation in accordance with water demand. The second stage of Juquia - São Lourenço project is to be considered after 2007. (see Figure III-2.6)

By means of these schedules the total supply capacity is estimated as 123.5 m^3/s in 2007. However, for the purpose of present study, the limitations of Guarapiranga Reservoir and Cantareira Systems, as mentioned before, have to be considered in near future, though the limitations are difficult to establish exactly, and the below mentioned assumption are considered;

. Guarapiranga Reservoir will not be able to provide drinking water after 2000.

. Water supply capacity of Cantareira System will have to be reduced gradually during 2005 - 2010 by the rate of 3 m^3/s per year.

Considering these assumptions, the second stage of Juquia - Sao Lourenço Project has to commence the operation in 2007, because the supply capacity in this year sill be 108.5 m^3/s instead of 123.5 m^3/s mentioned before.

Figure III-2.6 indicates the demand and supply balance up to 2007, considering these assumptions.

It is important to mention that Cantareira System will have anticipation with the great probability to be limited after 2005. Available water resources evaluations and demand forecasts made by DAEE in the Piracicaba River and neighbour basins during the year of 1980 - 1981 are concluded that the scarceness of water in these river basins are very critic, as the industrialization and the population growth are fastly increasing.

Considering this reality, it is not impossible to suppose that the operation commencement schedule of some facilities have to be alternated. In this case, the São Lourenço Reversible Power Station planned for 1996, also have to be alternated.

Accordingly, when the following limitations are considered;

- Alto Tiete System with 7.0 m^3/s considered in this study has to be neglected in order to release water for irrigation and sewage dilution in highly polluted Tiete River.

- Cantareira System with 33 m^3/s has to be released 5 m^3/s to its downstream Piracicaba River Basin in 1990's.

As decreasing capacity is estimated as 12 m^3/s, São Lourenço Reversible Power Station has to be commenced the operation in 1992.

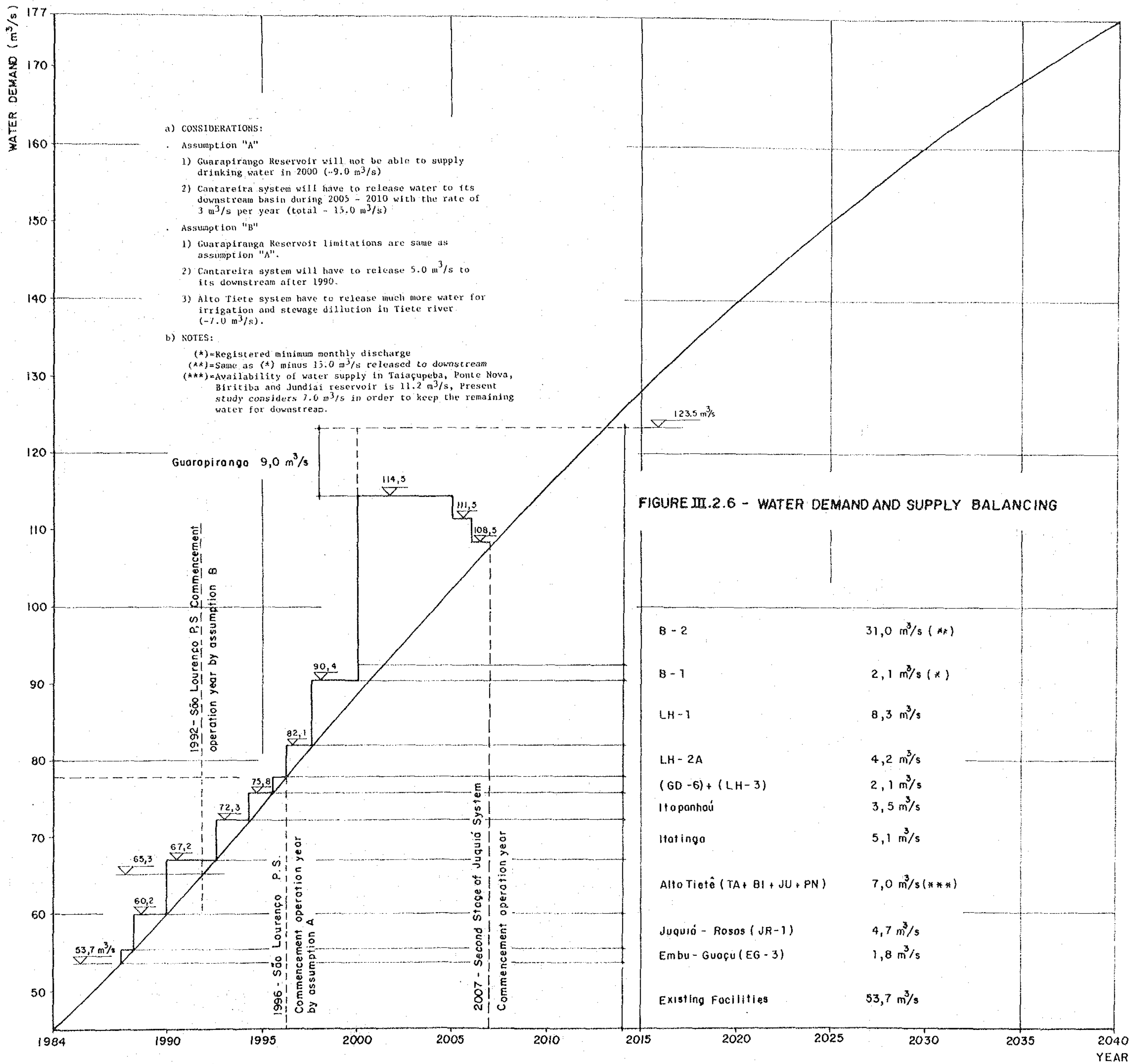

FIGURE III.2.6 - WATER DEMAND AND SUPPLY BALANCING

For the purpose of present report, the judgement about these limitations is very difficult to be included and it is considered that furthermore detailed analysis are necessary. Anyway, it can be concluded that São Lourenço Reversible Power Station in the Juquia - São Lourenço System is necessary to be operation commenced during 1992 - 1996 in order to provide the drinking water to the Metropolitan Resion of Sao Paulo, with an advantage that this system has very long development schedule, and it is possible to be gradually developed.

CHAPTER 3

PROJECT AREA

PART III

DEVELOPMENT PLAN

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Chapter 3. Project Area.

3.1. Outline of Project Area.

Juquia River Basin, which is the main tributary of Ribeira do Iguape River Basin, is located in the southeast region of the State of São Paulo and is confined between the latitudes 23° 50' and 24° 20' south and the longitudes 46° 50' and 48° 10' west respectively. This is surrounded by Tiete River Basin to north, High Paranapanema Basin to west, Ribeira do Iguape River Basin to south and lots of small coastal basins. The drainage area is 5,280 km^2 corresponding to 22% of Ribeira do Iguape River Basin.

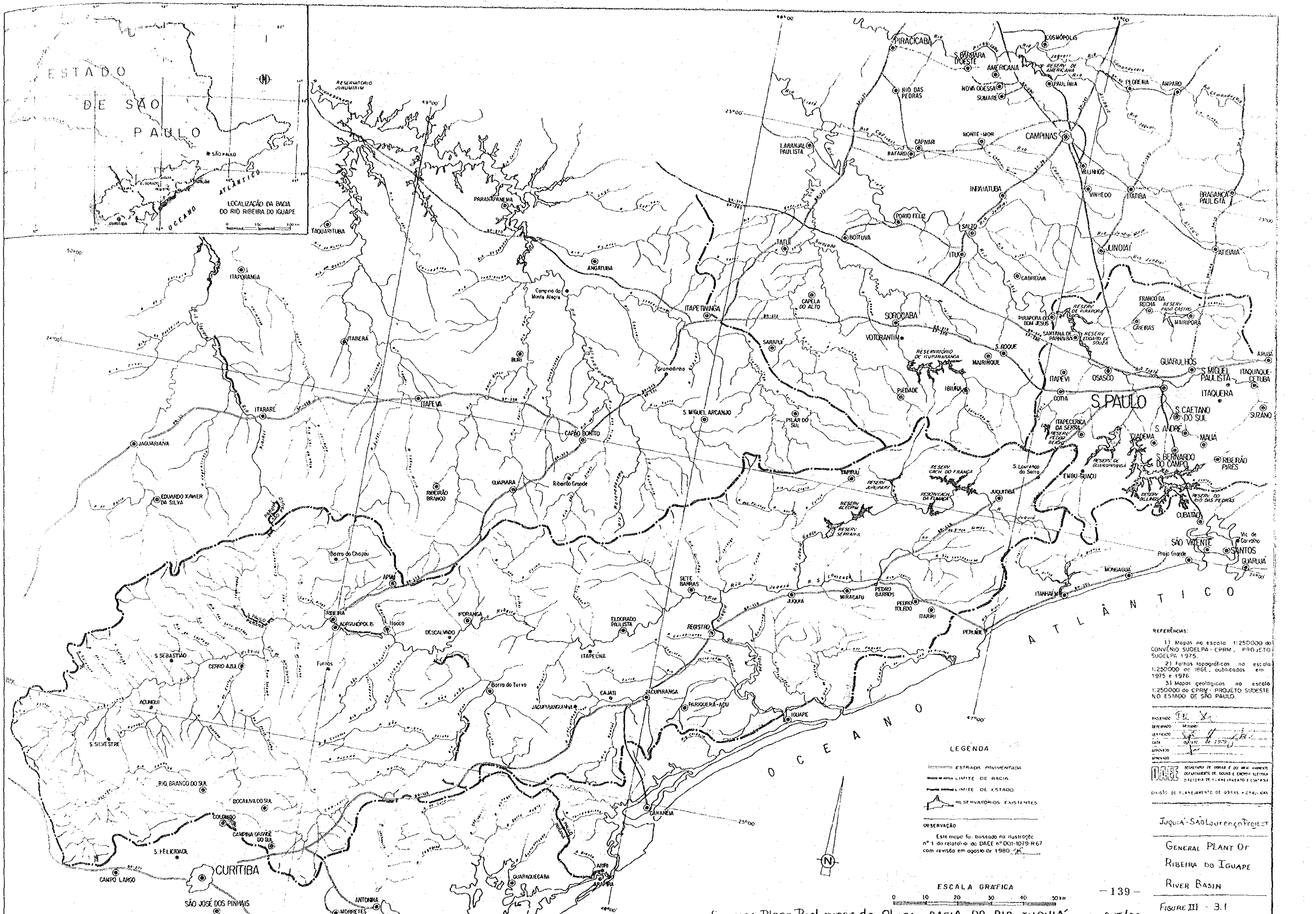
The main tributaries of Juquia River are São Lourenco River (1,746 km^2) at the left side and Ipiranga and Quilombo Rivers at the right side. The curse of Juquia River with 230 km runs more less in parallel with the coastal line and meets Ribeira do Iguape River at 10 km upstream of Registro Town. São Lourenco River with 130 km runs also more less in parallel with Juquia River and meets the aforesaid river near Juquia Town.

Figure III - 3.1. shows the general plan of Ribeira do Iguape River Basin and Figure III-3.2. is the general development plan of Juquia River Basin including the longitudinal profile of this project.

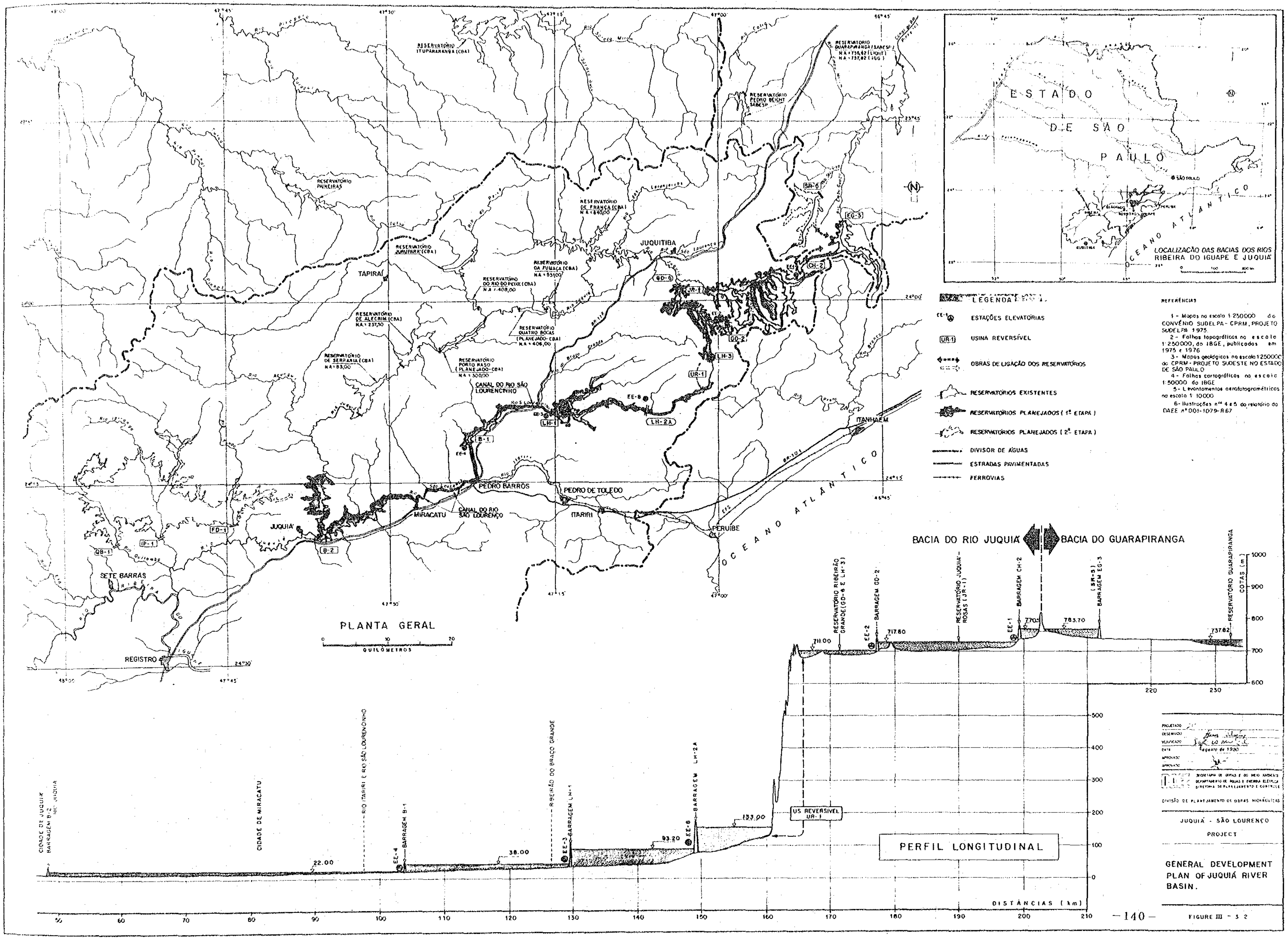
From the geographical viewpoint, almost all the basin is consisted of the coastal lowland and the remaining part lies in the coastal mountain chain (Serra of Paranapanema), whence originate all the tributaries of Juquia River. The relief of this part proves to be very steep such as change of altitude is from 700m on Paulista Plateau down to less than 40 m on the lowland plain.

By Koeppen International System, the climate of this region is classified as "Cfa" for the regions of Juquia and Sao Lourenco Rivers, and "Cfb" for the regions of watershed and plateau. Namely, Cfa; Humid hot climate without dry season, with rainfall of the driest month more than 30mm, and mean temperatures of the hottest and coldest months more than 22°C and less than 18°C respectively.

The rainfall increases by proximity to the ocean and the steep slope of mountainous chain. The mean anuual rainfall at Juquia Town is 1,700mm, with this value increasing at the same rate as approaching the watershead where is more than 2,000mm.



Source: Plano Preliminar de Obras - BACIA DO RIO JUQUIÁ



GENERAL DEVELOPMENT PLAN OF JUQUIÁ RIVER BASIN.

FIGURE III - 3.2

There are 5 main towns in Juquia River Basin and the population density does not exceed 20 inhabitants per km^2, in which the predominant part of rural population represents 65% of the total.

In terms of land utilization, the basin is poorly exploited, because almost all the area is covered with jungle and forest. The basic economy is farming and live-stock and the main agricultural products are banana, manioc, tea, vegetables, rice and maize.

The local road and railway systems are in general deficient, but Regis Bittencourt Railway (Br - 116 - SP-230) crosses the basin linking São Paulo and Curitiba, and access to Santos is connected with SP-165 and SP-55 Highway.

3.2. Present States of River Developments.

Companhia Brasileira de Aluminio (CBA) is granted to utilize the electric power potencial of Juquia River upstream of confluence with Acungui River.

The total installed capacity of CBA System is 225 MW, though at present operating 163 MW as shown in Table III-3.1, and the locations of the above mentioned power station is also shown in Figure III-3.2.

São Lourenco River and the downstream of Juquia River have not been developed at all.

Utilized water for Grande São Paulo is flowed to the both rivers of Tiete and Pinheiros as sewage, which is pumped up by the two pump stations to the existing Billings Reservoir through the canals of the above mentioned rivers. The gathered water into Billings Reservoir is transferred to Pedras Reservoir through Summit Control with gates and utilized for the hydroelectric power generation by means of namely Cubatão - I and II Power Station with 460 MW and 420 MW respectively and then flowed down to Cabatão River.

Many kinds of industries are using the water as industrial use along the above mentioned river.

3.3. Outlines of Development Plan.

This project has two main purpose, namely, water supply to Great São Paulo and hydroelectric power generation to supply the electric peak demand of the southeast districts.

Table III-3.1. Hydroelectric Power Station of Juquia River Basin.

Name	Drainage Area (Km^2)	Normal Water Level (m)	Max. Available Head (m)	Max. Available Discharge (m^3/s)	Number of Unit	Installed Capacity (MW)	Commencement Year of Operation
França	955	640	105	33	2	30	1958
Fumaça	1,096	531	125	34	2	37	1963
Quatro Bocas	1,439	406	106	37	2	34	under construction
Porto Raso	1,523	306	68.5	50.8	1	28	1982
Alecrim	1,656	237	154	53.4	3	72	1974
Serraria	1,754	83	51	54.1	1	24	1978

The former is to transfer the water from the lowland basin to Guarapiranga River Basin through the upper basin by means of the series of pumping-up system in order to supply the necessary water demand of Great São Paulo in the future of which water demand is forecast to be 177 m^3/s in 2040. This system comprises the combinations of dams, reservoirs, canals, pipe lines, pump stations and reversible hydroelectric power station. This system is shown in Figure III-3.2.

Though this system is at the pre-feasibility state now, the progress of this system will be able to be divided into two main stages; the first stage consists of utilization of Juquia River up to the confluence with São Lourenco River near Juquia Town, the second stage, in its return, involves the development of the water resources of almost whole of Juquia River Basin.

The latter is reversible hydroelectric power generation to supply the peak demand to the districts near-by which has two power stations; the first one is located at the most upstream of São Lourenco River, where is 560m water head difference between this river and Paulista Plateau called the upper basin so that the co-operative facility for water supply and electric generation sectors is planned at this location to make economize this project. Installed capacity is adopted as 2,835 MW (9 units) of which capacity has to be studied furthermore to find out the most economical solution from now on. The second reversible power station is located near the existing Cubatão Power Stations, of which power station is planned to pump-up the utilized water in Great São Paulo through the canals and pumping stations of Tiete River and Pinheiros River to the existing Billings and Pedras Reservoirs, from where the water is utilized for the compounded type resersible hydroelectric power generation with 695 m head difference by means of Cubatão Lower reservoir constructed in Cubatão River. Tough this power station is able to be planned as a general hydroelectric power station with Pelton type turbines, the compounded reversible type with capacity of 2,400 MW (8 unit) is adopted in consideration that the available discharge is increased year by year by the necessary water supply capacity for Great São Paulo so that economical development scale has to be studied from now on.

CHAPTER 4

HYDROLOGY AND METEOROLOGY

PART III

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Chapter 4. Hydrology and Meteorology.

4.1. Outline of Hydrological and Meteorological Conditions.

The project area is situated at the highland limited by Tiete river Basin to North and the lowland of Juquia River Basin. The drainage area is 4,352 km^2 with the main part of jungle and mountainous area of the lowland, with annual precipitation of 2,360 mm and 1,950 mm and mean temperature of 19°C and 21.2°C at the high and lowlands respectively. Annual specific run-off at the highland area is 4.0 m^3/sec. 100 km^2 and at the lowland area 3.0 m^3/sec. 100 km^2, and the number of days of precipitation is 130 annually and 160 days at the above mentioned areas respectively.

4.2. Run-off and Rainfall Gauging Stations.

There are numerous run-off and rainfall gauging stations in the project area and the surrounding area are 27 stations for the former and 75 stations for the latter as shown in Figure III-4.1.

4.3. Temperature and Evaporation.

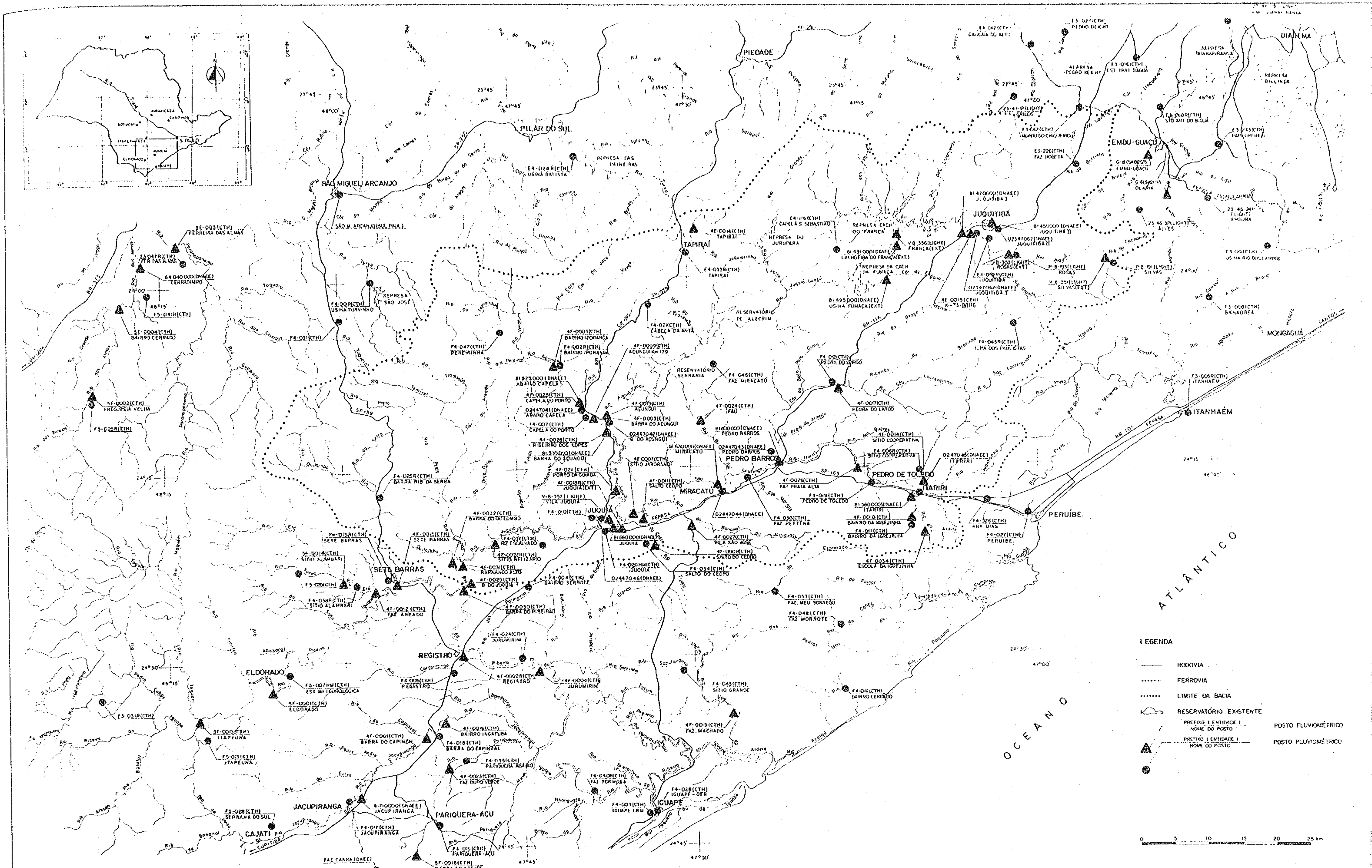
According to measured data at the meteorological gauging stations at São Paulo University and Juquia, of which data can be considered to be representative for the upper reach area and the lowland area of this project, annual average temperature and total evaporation are obtained as 19.0°C and 21.2°C, 1,360 mm and 900 mm respectively as shown in Table III-4.1. and Table III-4.2.

Table III-4.1. Temperature in °C.

	São Paul University			Juquiá		
	maximum	mean	minimum	maximum	mean	minimum
Jan	32.2	21.8	14.7	38.0	24.7	17.3
Feb	32.3	22.3	15.0	38.2	25.2	18.1
Mar	32.3	21.9	15.6	36.5	24.2	16.5
Apr	29.6	18.7	10.8	34.4	21.6	12.8
May	27.6	16.9	7.5	32.6	19.5	9.8
Jun	27.1	15.9	6.5	31.2	18.2	7.3
Jul	27.8	16.4	6.6	31.5	17.8	7.4
Aug	30.5	17.3	6.7	32.6	18.1	8.6
Sep	31.1	17.6	8.8	33.2	18.9	9.7
Oct	32.4	18.7	11.1	35.1	20.3	12.1
Nov	31.7	19.9	11.4	36.7	21.8	12.8
Dec	30.6	20.6	13.1	36.9	23.8	15.2
Average	30.4	19.0	10.6	34.7	21.2	12.3

Table III-4.2. Evaporation in mm.

	São Paulo University	Juquiá
Jan	136.3	106.8
Feb	132.3	104.4
Apr	93.0	59.6
May	80.0	50.0
Jun	72.3	41.3
Jul	89.9	46.5
Aug	113.1	54.7
Sep	110.7	60.7
Oct	133.2	82.0
Nov	144.8	97.5
Dec	133.9	105.8
Average	1,360.8	904.4



Source "Plano Diretor de Obras - JUQUIÁ - SÃO LOURENÇO DEZ/81"

DAEE
SECRETARIA DE OBRAS E DO MEIO AMBIENTE
DEPARTAMENTO DE ÁGUAS E ENERGIA ELÉTRICA
DIRETORIA DE PLANEJAMENTO E CONTROLE

JUQUIÁ - SÃO LOURENÇO PROJECT

HYDROMETRIC NETWORK

FIGURE III-4.1

4.4. Precipitation.

Consistency analysis of precipitation data for 75 stations are carried out and the result of analysis shows 51 stations as possible to be used with common period of 20 years from 1959 to 1979.

The seasonal variation of precipitation at the representative gauging stations for the project area is shown in Table III-4.3. The period from December to February is the rainy season and from June to August the dry season.

Table III-4.3 Representative Precipitation in mm.

	Highland Area		Lowland Area	
	Ibiuna	Alves	Itariri	Pedro Barros
Jan	202.3	295.3	248.2	222.4
Feb	177.2	246.2	241.1	206.3
Mar	135.8	217.5	223.0	169.8
Apr	66.1	145.4	149.8	89.2
May	62.4	86.9	82.8	87.4
Jun	51.7	74.1	52.9	57.8
Jul	41.6	72.9	51.4	56.0
Aug	42.2	76.0	49.5	50.1
Sep	89.2	121.3	79.6	85.0
Oct	138.7	173.1	138.6	134.3
Nov	136.8	174.0	127.8	108.2
Dec	216.0	250.6	180.5	183.7
Total	1,360.0	1,933.0	1,625.0	1,447.0
Average	113.3	161.1	135.4	120.6

Figure III-4.2 shows the geographic variation of precipitation by means of average annual isohyets from 1959 to 1979.

The annual variation of precipitation for the representative gauging stations as mentioned above is shown in Figure III-4.3. The hydrologic years from 1975 to 1976 at Alves Gauging Station is observed to be a very high annual value such as 3,220 mm. In general the four stations give rainy periods simultaneously as well as periods with less precipitation.

The number of days of precipitation less than 10 mm per day at the high and lowland areas is 300 days annually which mean that workable days a year show more than 80%.

4.5. Estimation of Run-off.

4.5.1. Available Run-off Data.

Data at the 27 run-off gauging stations are collected and analysed to determine the run-off potential in this project, and the 16 stations have been observed in terms of average daily discharge up to the present.

The following run-off gauging stations have long period data; Juquia and Barra do Acungui at Juquia River, and Pedro Barros at São Lourenco River since 1938, Franca at Juquia River from 1913 to 1952 and Guarapiranga at the same name river from 1906. These data are utilized as a main base for the correlation analysis and the extension of monthly run-off series.

These procedures provide series of data for the period from 1938 to 1979.

According to seasonal comparison studies of distribution between precipitation and run-off, the both have the same annual fluctuation, that is, December to February is the wet season and June to August the dry season.

Juquia River Basin can be seen to have high water potential in comparison with other similar river basins in São Paulo State, that is, this basin presents that specific average discharge at the downstream of confluence with São Lourenco River is 3.0 m^3/s. 100 km^2 and at the headstream 4.0 m^3/s. 100km^2.

Monthly correlation studies among the originally available periods at the selected stations are carried out to extend the unrecorded periods and to determine the monthly inflow at the given damsites.

Names and recorded periods of the run-off gauging stations to make correlation analysis are shown in Table III-4.4 and also correlated equations and coefficients of each correlation are shown in the same table, from which good correlation factors can be observed.

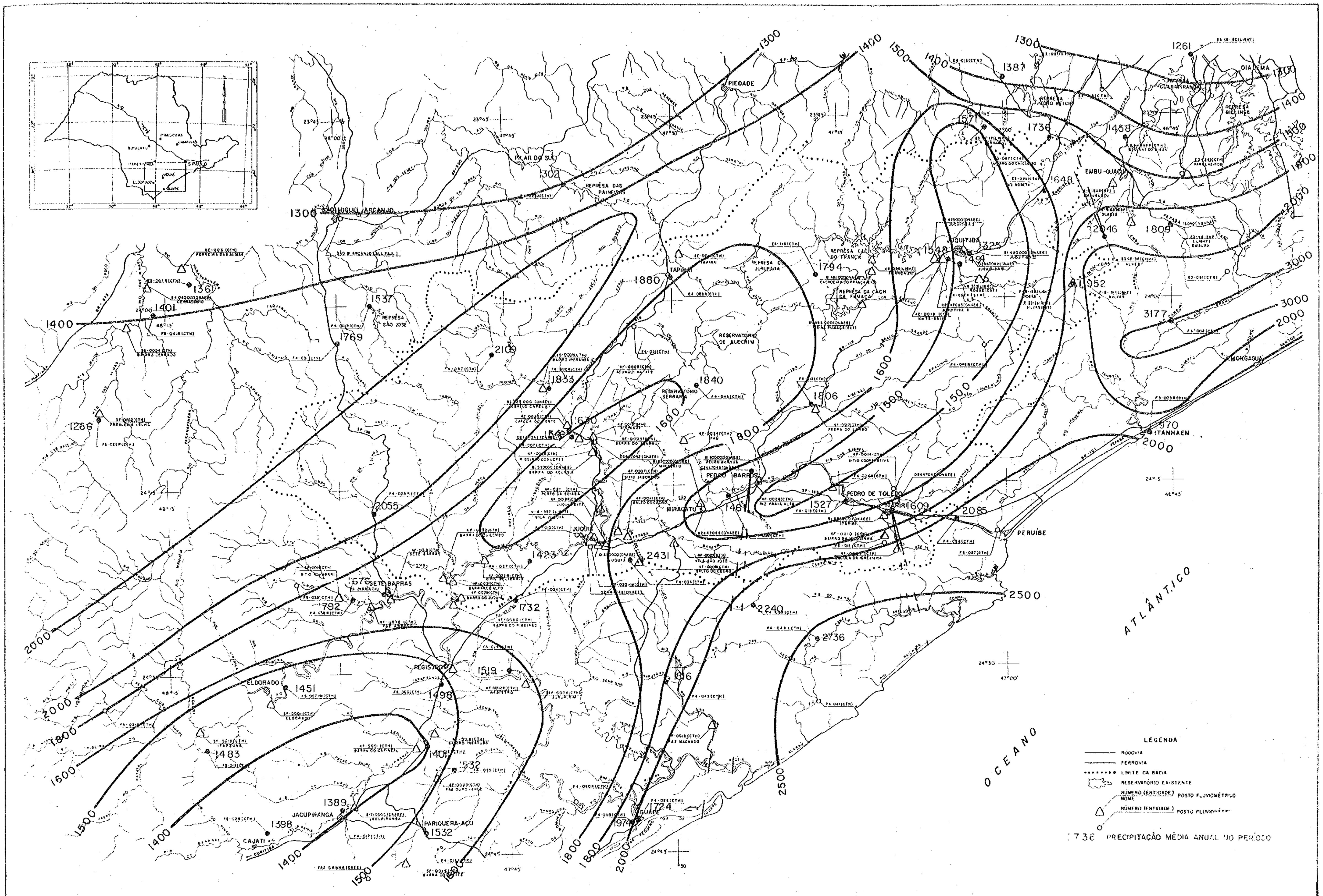
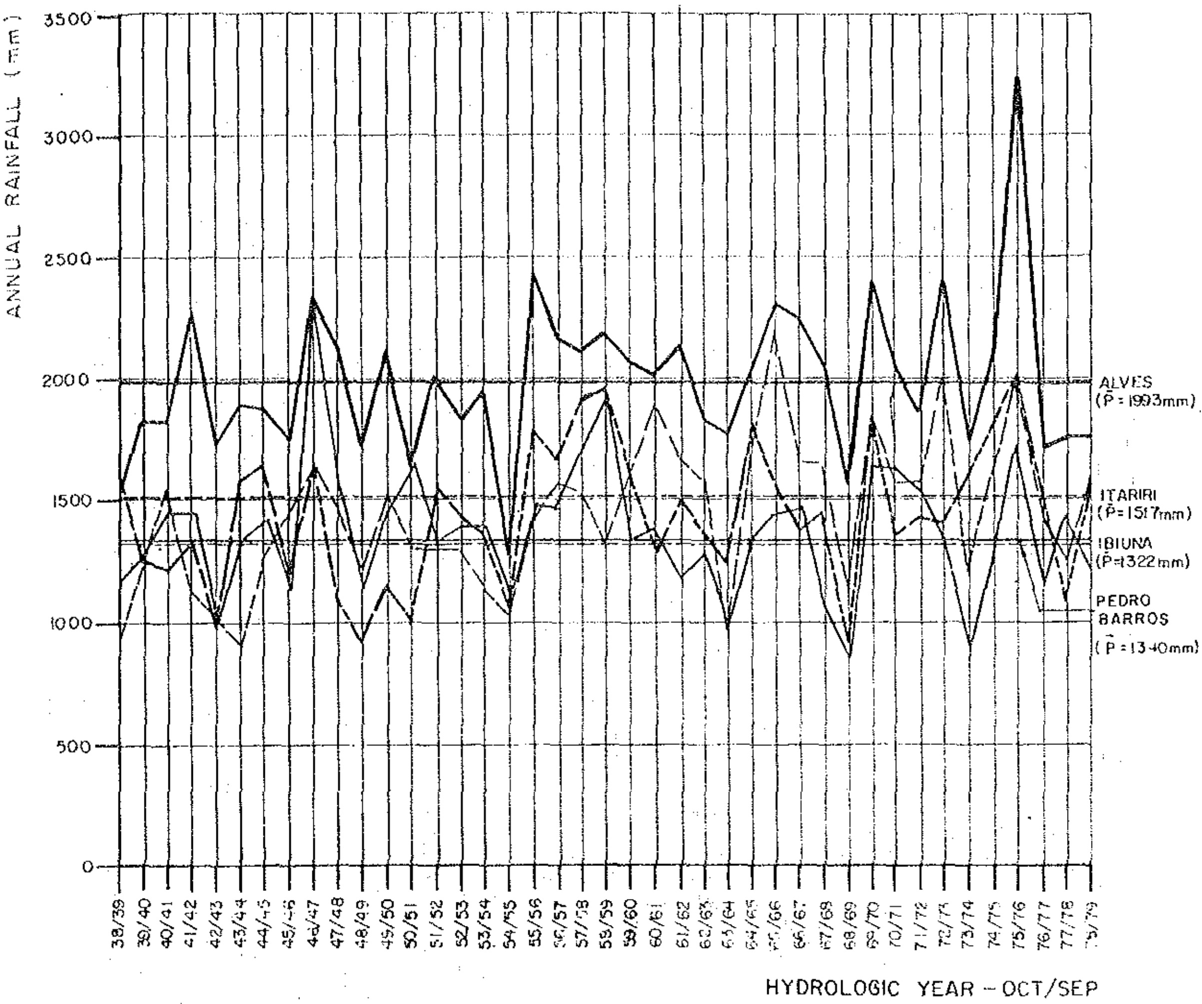


FIGURE III - 4.2 GEOGRAPHIC DISTRIBUTION OF RAINFALLS



LEGEND:

- ALVES STATION
- ITARIRI STATION
- IBIUNA STATION
- PEDRO BARROS STATION

PERIOD: 1938 to 1979

FIGURE III – 4.3 ANNUAL VARIATION OF PRECIPITATION

Appendix-A show the established monthly run-off date from 1938 to 1979 at Juquia, Pedro Barros, Pedra do Largo, Silvas, Rosas, Olaria and Embu Guacu Run-off Gauging Stations. These data are utilized at the given damsites which are also shown in Table III-4.4.

4.5.2. Run-off Estimation at Damsities.

The average monthly run-offs from 1938 to 1979 at each run-off gauging station are carried out by means of correlation and extension as mentioned in the preceding item.

The relation analysis of average run-off versus drainage area is performed and two main trends are observed; the one is related to São Lourenco River and Juquia River, downstream of Acungui River confluence, and the another to Juquia River Basin, upstream of CBA (Companhia Brasileira de Aluminio) Power Stations as shown in Figure III-4.4 and the following equations are established:

$$Q = 0.086A^{0.861} \quad \text{for the first trend}$$

$$Q = 0.094A^{0.810} \quad \text{for the second trend}$$

Where: Q is run-off in m^3/s

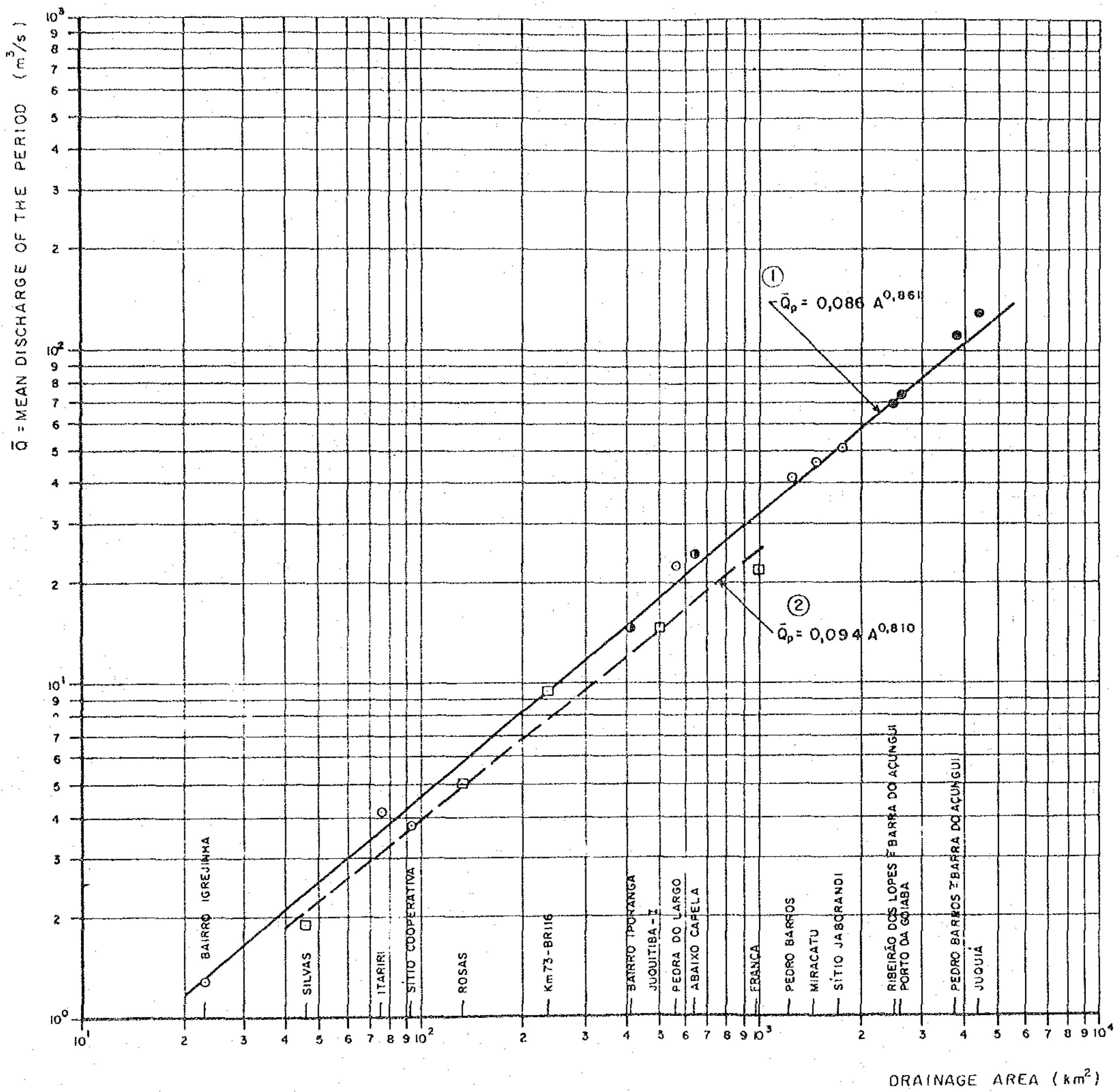
A is drainage area in km^2

The monthly inflow at a selected damsite can be estimated, using the above mentioned equations, based on monthly run-off series at a run-off gauging station as close as possible and on application of drainage area relation between local site and gauging station.

The monthly run-off series at Cubatão Damsite is taken from the report "DESENVOLVIMENTO GLOBAL DOS RECURSOS HIDRICOS DAS BACIAS DO ALTO TIETE E CUBATAO - Plano Diretor de Obras - Vol. VI", which are shown also in Appendix-B. This monthly run-off series for the period of 1912 to 1965 is estimated from the monthly run-off values at Capivari Gauging Station. For the estimation, it is utilized the drainage area relation and taking into account the annual precipitation data and evapotranspiration rates at Capivari and Cubatão River Basis.

TABLE III-4.4 Available RUN-OFF gauging stations

Damsite	(A) Gauge station used to calculate the run-off	(B) Record period originally available in (A)	(C) Gaugestation used to extend the record period available in (A) by correlation	(D) Correlation period	(E) Coefficient of correlation
B 2	Juquiá	08/1937 to 12/1979	Pedro Barros(Q_{JU}=2.637 Q_{PB}+19.998)	1938-1979	0.96
B 1	Pedro Barros	08/1937 to 12/1979	Juguia-Barra Acungui(Q_{BA+PB}=0.800 Q_{JU}+7.789)	1938-1979	0.99
LH 1	Pedra do Largo	08/1963 to 12/1979	Pedro Barros(Q_{PL}=0.479 Q_{PB}+2.240)	1963-1979	0.98
LH 2A	Pedra do Largo	08/1963 to 12/1979	Pedro Barros(Q_{PL}=0.479 Q_{PB}+2.240)	1963-1979	0.98
LH 3	Silvas	10/1926 to 10/1949	Rosas (Q_S=0.391 Q_R - 0.107)	1926-1949	0.91
GD 6	Silvas	10/1926 to 10/1949	Rosas (Q_S=0.391 Q_R - 0.107)	1926-1949	0.91
GD 2	Silvas	10/1926 to 10/1949	Rosas (Q_S=0.391 Q_R - 0.107)	1926-1949	0.91
JR 1	Rosas	07/1927 to 11/1956	Juquitiba I (Q_R=0.300 Q_{JI}+0.728)	1927-1932	0.88
CH 2	Silvas	10/1926 to 10/1949	Rosas (Q_S=0.391 Q_R - 0.107)	1926-1949	0.91
EG 3	Olaria	05/1970 to 12/1979	Guarapiranga (Q_{OL}=0.148 Q_G+0.180)	1970-1979	0.87
SR 5	Embu Guaçu	04/1970 to 12/1979	Guarapiranga-Olaria(Q_{EG+OL}=0.267 + 0.401)	1970-1979	0.89



STATION	D.A.(Km^2)	$\bar{Q}$ (m^3/s)	$\bar{q}$ ($l/s/Km^2$)
JUQUIÁ	4369	130,23	29,81
P. BARROS + B. AÇUNGUI	3712	111,87	30,14
PORTO DA GOIABA	2586	73,90	28,58
RIBEIRÃO DOS LOPES	2489	68,92	27,69
BARRA DO AÇUNGUI	2489	70,07	28,15
SÍTIO JABORANDI	1719	51,73	30,09
MIRACATU	1444	46,72	32,35
PEDRO BARROS	1223	41,79	34,17
FRANÇA	981	22,06	22,49
ABAIXO CAPELA	642	24,23	37,74
PEDRA DO LARGO	560	22,26	39,75
JUQUITIBA - I	500	14,54	29,08
BAIRRO IPORANGA	408	14,65	35,91
Km 73 - BR116	236	9,47	40,13
ROSAS	133	5,08	38,20
SÍTIO COOPERATIVA	92	3,76	40,87
ITARIRI	75	4,14	55,20
SILVAS	46	1,87	40,65
BAIRRO IGREJINHA	23	1,28	55,65

OBS.: $\bar{Q} = 0{,}086\ A^{0,861}$ (FOR SÃO LOURENÇO AND JUQUIÁ RIVER)

$\bar{Q} = 0{,}094\ A^{0,810}$ (FOR JUQUIÁ RIVER PSTREAM FROM FRANÇA STATION)

FIGURE III - 4.4 MEAN DISCHARGE OF THE PERIOD VERSUS DRAINAGE AREA

4.6. Estimation of Design Flood.

It is decided for the design flood of the several reservoirs on this system to adopt the procedures recommended by Bureau of Reclamation and U.S. Committee on Large Dams by reason of insufficiency of specific and necessary hydrological data for more study in detail.

4.6.1. Estimation of Design Rainstorm.

The main considerations to estimate the design rainstorm are summarized as follows:

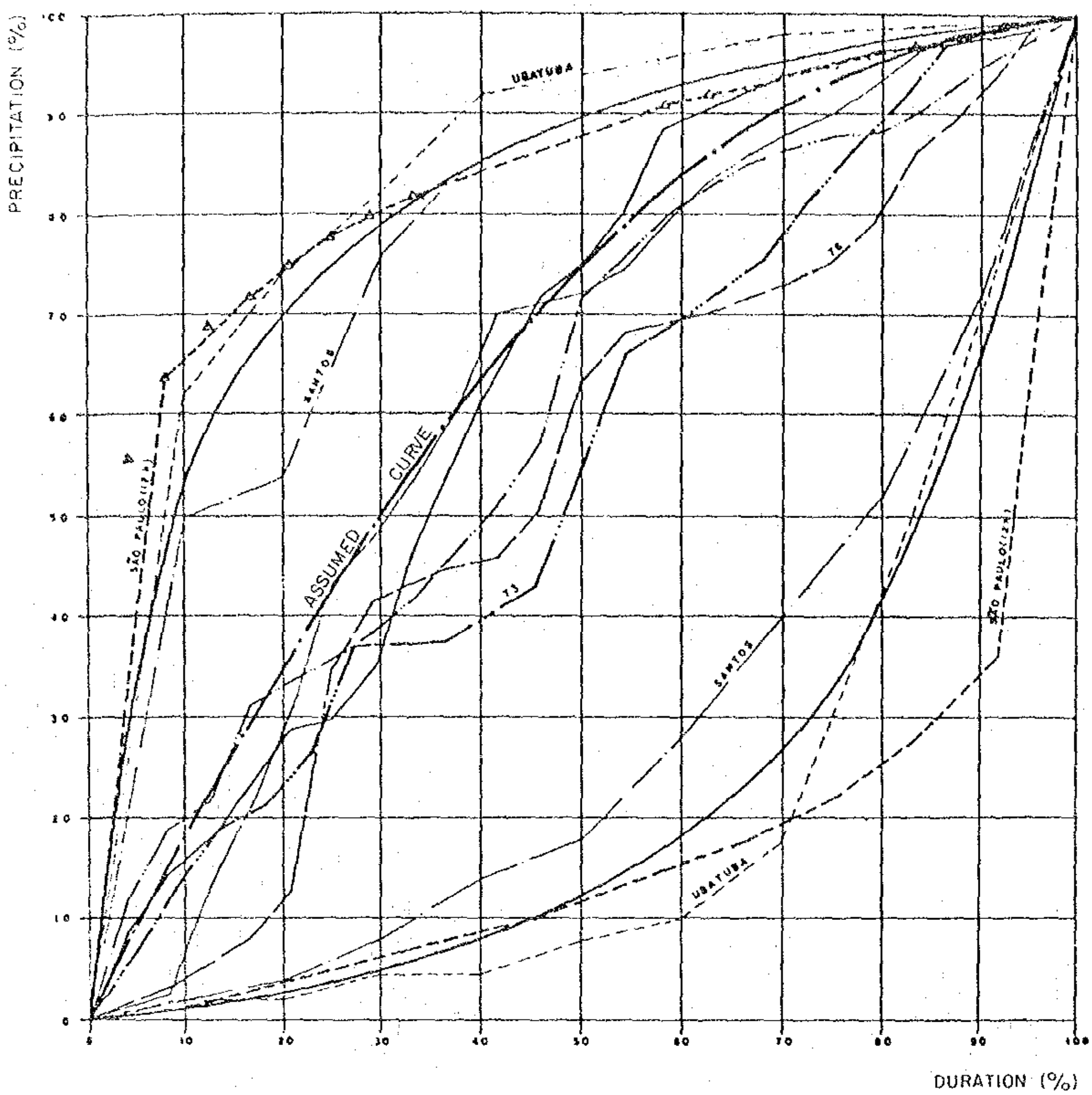
1) Alves and Itariri Rainfall Stations are assumed to be representative for design rainstorm determination of the plateau and the lowland areas respectively after analysis of several stations, because there is not other sufficient rainstorm data in this project area.

2) Though the times of rainstorm concentration in all river basins are verified to be generally less than 10 hours, the 24 hours rainstorm duration is adopted in accordance with recommendation by the Bureau of Reclamation.

3) The relation curve between total rainstorm value and the area made by U.S. Weather Bureau for the 24 hours rainstorm duration as shown in Figure III-4.5 is adopted to determine the total rainstorm intensity at the given drainage area.

4) Figure III-4.6 shows the dimensionless time and rainstorm distributions graph of the recorded main rainstorms at the plateau and the coastal regions, in and around the objective area, and the mean time distribution of the main storms at Ilha dos Paulistas is assumed to be representative over the project area. This curve is used to determine 24 hours rainstorm duration with 1 hour pitch, and Table - III.4.5 shows the standard desaggregation of the above-mentioned curve.

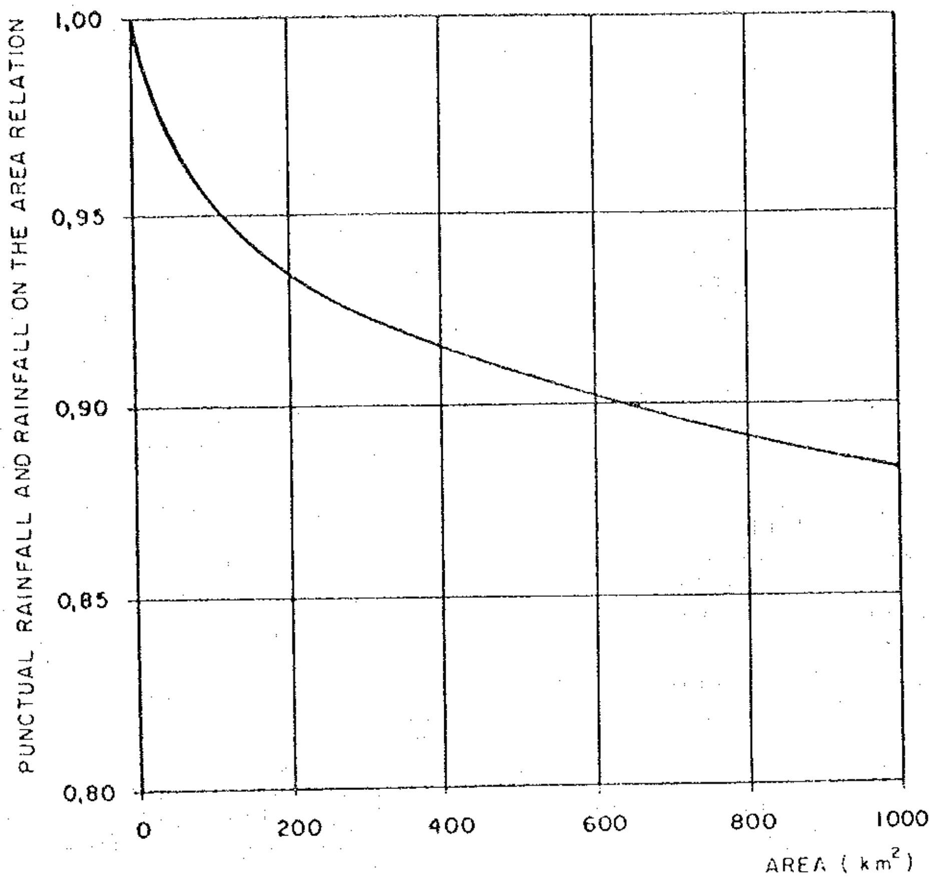
5) In 1966, the Astronomical and Geophisical Institute of Sao Paulo University realized a study to establish relations between maximum rainfall of 1 day and 24 hours durations based on annual series from 1928 to 1965 obtained from the simultaneous observation data in Sao Paulo City. The results show that, in terms of rainfall



OBS VALID FOR > 6 HOURS RAINFALL

FIGURE III - 4.5 DISAGREGATION OF RAINFALL TIMES SERIES

FIGURE III - 4.6 RELATION BETWEEN PUNCTUAL RAINFALL AND RAINFALL ON THE AREA FOR 24 hr DURATION



REF: U.S. WEATHER BUREAU

(HIDROLOGY - A.J. RAUDKIVI Pag. 94)

depth, the average of "1 day" and "2 days" rainfall can be considered as enough representative value for 24 hours rainfall duration which corresponds to the following equation;

$$P_{24hr} = \frac{P_{1\ day} + P_{2\ days}}{2}$$

6) Assuming the above mentioned relation, study of return period frequency analysis with the applicable data at Alves and Itariri Station mentioned before is carried out to determine "1 day and 2 days" maximum rainfall of several frequencies and further to estimate 24 hours rainstorm durations of correspondent frequency. The probable frequency distribution adopted is Pearson Type III at Alves and Log-Normal at Itariri Stations respectively, of which the former frequencies are applied for the plateau basin and the latter for the lowland basin. Table III-4.6 shows the results of return period frequency analysis for the above mentioned basins.

Table III-4.5 - STANDARD OF DESIGN RAINFALL

T (hours)	T (%)	ACCUMULATED RAINFALL (%)	ACCUMULATED RAINFALL (unit)
1	4.17	7.6	0.076
2	8.33	14.9	0.149
3	12.50	22.4	0.224
4	16.67	29.5	0.295
5	20.83	36.3	0.363
6	25.00	42.7	0.427
7	29.17	48.9	0.489
8	33.33	54.5	0.545
9	37.50	60.5	0.605
10	41.67	65.5	0.655
11	45.83	70.3	0.703
12	50.00	75.0	0.750
13	54.17	78.9	0.789
14	58.33	82.5	0.825
15	62.50	85.9	0.859
16	66.67	88.7	0.887
17	70.83	91.3	0.913
18	75.00	93.4	0.934
19	79.17	95.2	0.952
20	83.33	96.6	0.966
21	87.50	98.0	0.980
22	91.67	99.0	0.990
23	95.83	99.5	0.995
24	100.0	100.0	1.000

Table III-4.6 - Design Rainstorms.

Return Period (years)	Design Rainstorms (mm)					
	Plateau Basin (N=55)			Lowland Basin (N=42)		
	1 day	2 days	24 hours	1 day	2 days	24 hours
10	185	231	208	161	194	178
25	256	314	285	197	234	216
50	311	381	346	225	264	245
100	369	449	409	252	295	274
200	427	519	473	281	326	304
1,000	566	686	626	350	401	376
10,000	769	930	850	458	517	488

(Note) Observed period: 1938 - 1979.

4.6.2. Estimation of Design Flood.

The design flood is determined by synthetic unit hydrograph method because of lacking of specific unit hydrograph at each river basin.

It is assumed that the hydrograph produced directly by rainstorm over the reservoir is admitted as similar area to maximum normal water level, and that, as design criteria, floods produced by rainstorms of the return period T and the mean curve numbers of CN are as follows;

a) Spillway Designing

Curve number

CN = 70 for plateau basin.

CN = for lowland basin.

design return period; 1,000 years.

exceeding hazard ; r = 5%

b) Diversion Designing

Curve number CN = 40

Design return period; 25 years.

The CN value, mentioned above, represents a relation curve between rainfall and resultant run-off selected by hydrological classification of soil groups of the river basins which are assumed to be covered with same classification as well as to have the antecedent moisture conditions of the considered soils.

The results of spillway design flood studies for each damsite at this stage taking into considerations of the design rainstorms described before and the above mentioned are shown in Table III-4.7, and each design hydrograph and regulated flood curve at the given damsite is shown in the respective drawings.

4.6.3. Cubatao Design Flood.

The design rainstorn at Cubatao river basin was estimated by following depth-duration-frequency relationship derived for Rio das Pedras Rainfall Station:

$$P = 12.63\ T^{0.1616}\ t\ (t + 15)^{-0.6265}$$

where:

P = rainfall depth in mm

T = return period in years

t = duration in minutes.

It was adopted the mean curve number of CN=70 for spillway designing.

The Design Flood Hydrographs were obtained by the Bureau of Reclamation procedures except the unit hydrograph and the storm distribution curve which were taken from the report "OBRAS DE APROVEITAMENTO E CONTROLE DO RIO CUBATÃO - Estudos preliminares de viabilidade technica, economica e financeira" developed by HIDROSERVICE.

Table - III.4.7

Name of Dam	Drainage Area (km^2)	Design Rainstorm (mm)	Peak Flood (m^3/s)	Flood Volume ($10^6 m^3$)
SR-5	69.0	626	676	35.7
EG-3	57.0	626	581	31.3
CH-2	7.0	626	74.7	4.1
JR-1	135.0	626	1291	69.7
GD-6, LH3	55.3	626	530	31.6
LH-2A	141.2	531	1008	54.2
LH-1	208*	376	865	46.3
B-1	342*	376	1337	73.1
B-2	1898.5*	376	3142	377.0
Cubatão	128.0	580	1820	51.8

* Partial Drainage Area.

4.7. Sedimentation

The aspects of sedimentation quantity on this project are considered to be quite different by the geographical and vegetation conditions, namely, the suspended materials are dominant on the upper basin and the downstream area of lower basin, on the other hand, the bed loads are superior on the upstream area of lower basin and Cubatão River.

The available data on sedimentation are not obtained on this project so that sedimented quantities at each reservoir are assumed that those will be depended on the drainage area and the reservoir capacity, because the sedimentation by the landsliding especially around the reservoir after elimination of vegetation will be geographically the most predominant factor.

Accordingly, the following experienced formula is adopted to estimate the quantity:

$$q_s = 0.14 \left(\frac{V}{A}\right)^{0.58}$$

Where, q_s : sedimented quantity (m^3/km^2.year)

V : reservoir capacity (m^3)

A : drainage area (km^2)

Estimation of sedimentation is usually difficult matter so that the careful study, especially periodical measurement of suspended materials in relation to flow discharge, is judged to be important according to the field investigations.

CHAPTER 5

GEOLOGICAL FEATURES

PART III

DEVELOPMENT PLAN

LIST OF TABLES

LIST OF FIGURES

Chapter 5. Geological Features.

5.1. Geomorphology.

The project area is consisted of Juquia River Basin and the upstream reach of Guarapiranga River. From the geomorphological viewpoint, this area can be divided in the four distinct zones;

(I) The Dry Plateau Zone, with area of hills and muddy grounds and flooded plains between the tablelands, which is the basins of Santa Rita River and the rivers of Embu-Guaçu, Alto Juquia and Ribeirão Grande.

(II) Escarpment Zone of Cubatão Sierra, with steep area and enclosed by rivers, which is the basin of São Lourenço River.

(III) Cordillera Transition Zone, between the lowland and the plateau land, consisting of steep area and enclosed basin by São Lourenço Cordillera which are embraced by the basins of middle and lower São Lourenco River, Ribeirao Braço Grande and middle of Juquia River.

(IV) Lowland Zone, with basin of wide alluvial plains, river-saltbeds with terraces twisting around various lands, which are Juquia, Sete Barras, Registro, Ipiranga, Fundo and Quilombo River Basins.

5.2. Regional Geology.

The dominant geological features of the plateau area, cordillera and lowland are consisted of metamorphic rocks with medium and high degree of metamorphism of gneiss and schyst types, more or less migmatite interspersed with granite body of the precambrian age which is covered with layers of residual soil and or alluvial terraces. The metamorphic rock layers are complexed and intercalated with various minor lithologies, such as quartz, calcareous, schist, dikes and sills of diabase, various granulites, marble and so on.

Intersected great faults run accross the region, such as the fault zone of Cubatão, the Itariri Fault and the Caucaia Fault as well as other smaller ones. These faults divide the region into three great geological blocks; Juquitiba Block to the north of the Cubatão Fault, the Coastal Block to the south of the Cubatão Fault and the Itatins Block located to the south of the Cubatão Fault and the west of the Itariri Fault.

In the Juquitiba Block, in which the basins under study are located, schistic migmatitic gneisses are consisted containing minor bodies of quartzite and amphibolites, while the lithology of litoral block presents gneisses with and without visible migmatite structures and granulites as well as granites.

In the Cubatão Fault Zone, there occur vast areas of schist, biotite and chlorite with interlacings of phylite, quartzite and chalcosilicate, of which area extends from Quilombo River as far as the upper reach of São Lourenco River.

Superimposed on these formations, there appear sediments from the tertiary age up to the present, mainly alluvial. They are the formations of São Paulo and Pariquera-Acu, consisted of conglomerate, sand and clay disposing in strongly packed lenticular layers, but the quaternary formations being comparatively unconselidated.

The alluvials of plateau area are usually ample and coarse to fine. On the transition cordilleras towards the lowland, the alluvials are generally large and anastomosed, though no occuring in large widths. In the lowlands, the alluvials are complex and frequently mixed type, which mean that the materials show to be deposited in continental water such as strong marine actions. They are in general wide and thick with well defined terracing caused by past oscillation of the sea level.

In case of the folds, it is generally seen that the rocks present their main foliations as folded schistic bands, frequently transposed. Such feactures give evidence of various stage of folding. The most recently generated folds present N50° - 60°E in the Juquitiba Block, N20° - 30°E above the alignment of Clipo, EW to N80°W approximately inthe Itatins Block.

Figures III-5.1 and III-5.2 show the geological map of the project area. The compilation of these maps are based on the data of land marks of regional geological mappings on a scale of 1:250,000 as well as some observations mainly at the upper basin of Sao Lourenco. Also photo interpretation are done using aerial photographs on a scale of 1:40,000 to make these geological maps.

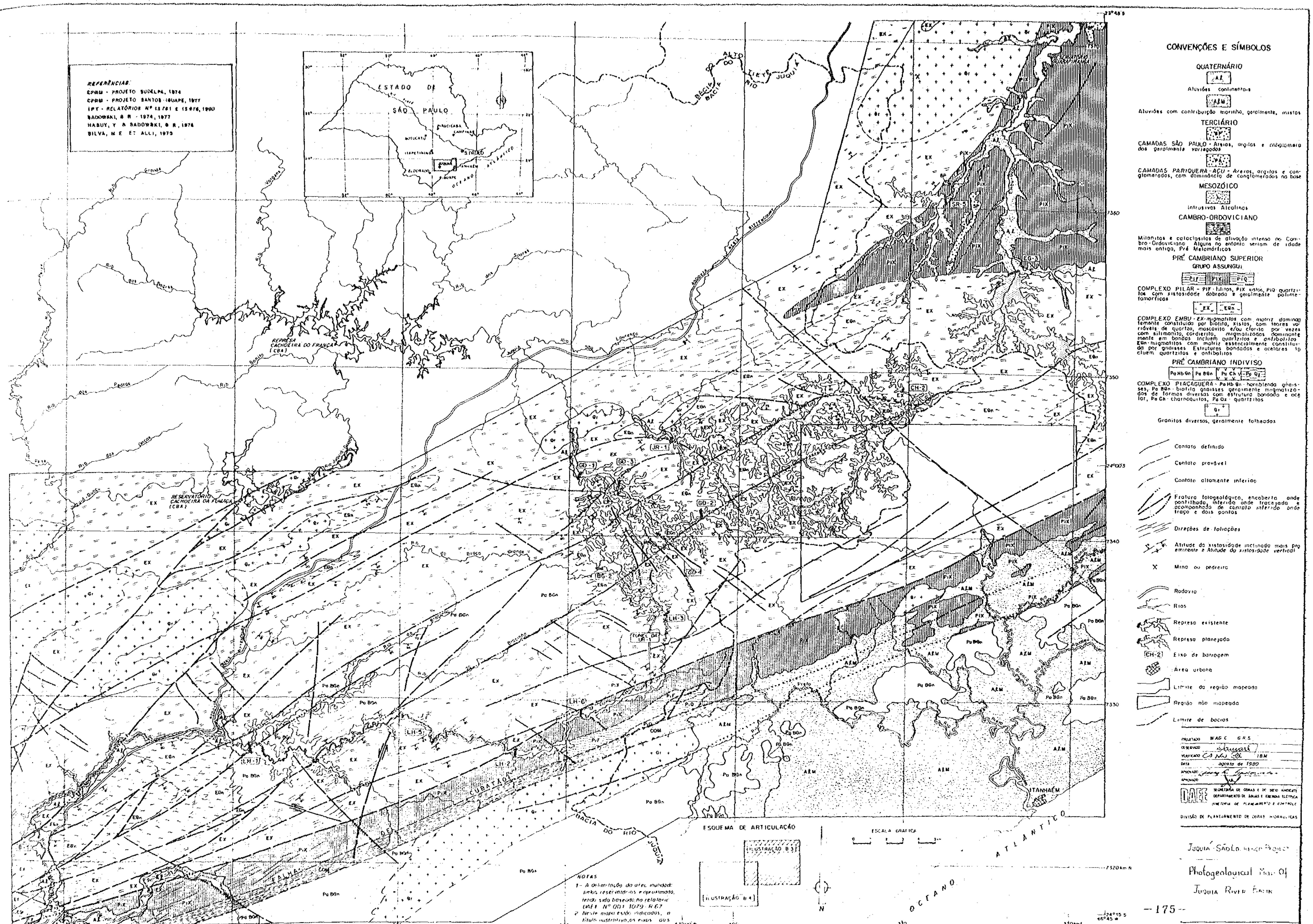
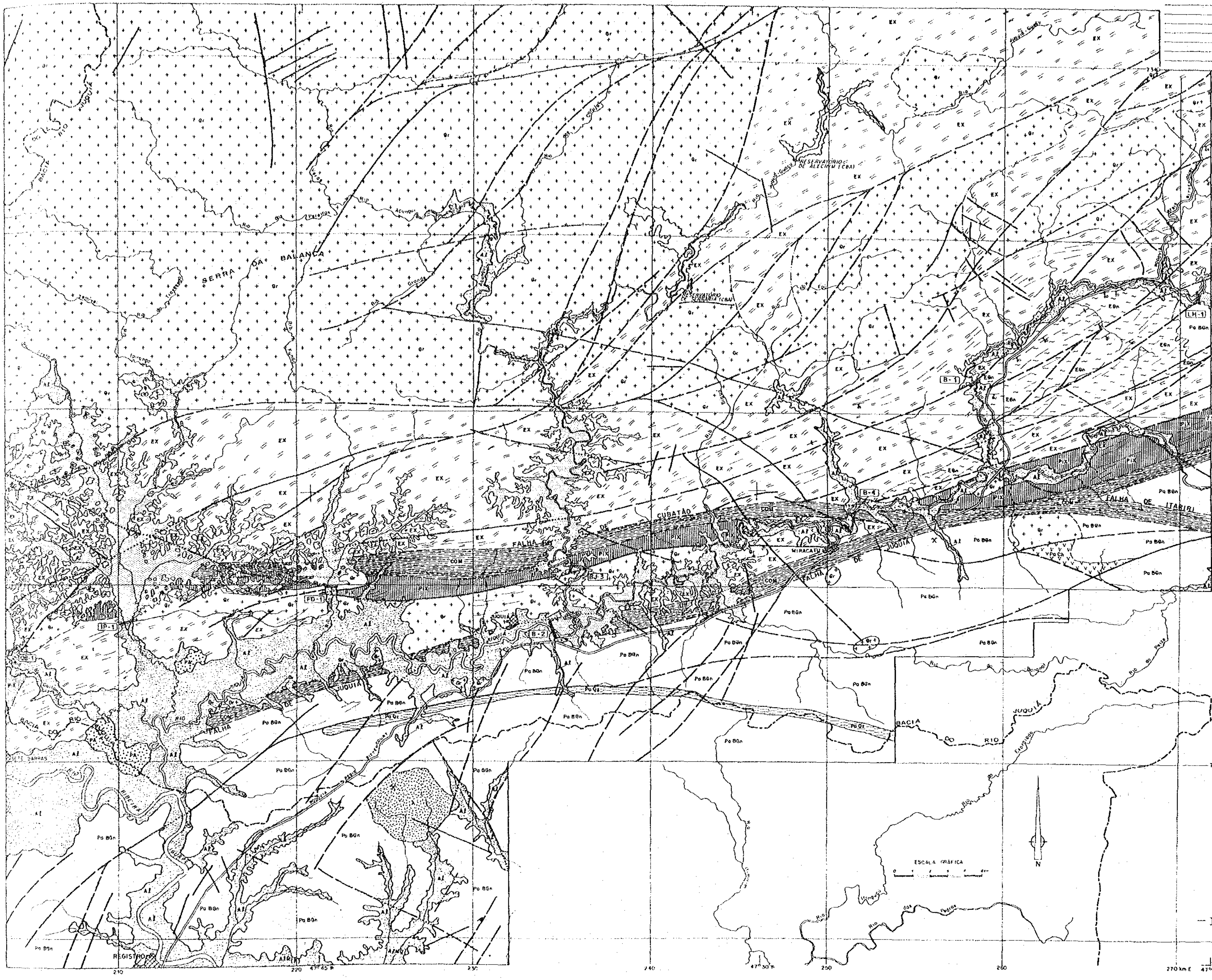


Figure III - 5.1

Source "Plano Preliminar de Obras BACIA DO RIO JUQUIÁ" Out/80



SOURCE "Plano Preliminar de Obras - BACIA DO RIO JUQUIÁ OUT/80"

NOTAS.

1- A DELIMITAÇÃO DA ÁREA INUNDADA PELOS RESERVATÓRIOS É APROXIMADA, TENDO SIDO BASEADO NO RELATÓRIO DAEE Nº 001-1079-R.67

2- OS BARRAMENTOS DE EIXOS BJ-3, FD-1, IP-1 E OB-1 ESTÃO COGITADOS PARA A SEGUNDA ETAPA DE APROVEITAMENTO

ESQUEMA DE ARTICULAÇÃO

ILUSTRAÇÃO B.3

ILUSTRAÇÃO B.4

PROJETADO W.AG.C. G.R.S.
DESENHADO [signature]
VERIFICADO [signature] /IBM
DATA agosto de 1980
APROVADO [signature]
APROVADO [signature]

DAEE
SECRETARIA DE OBRAS E DO MEIO AMBIENTE
DEPARTAMENTO DE ÁGUAS E ENERGIA ELÉTRICA
DIRETORIA DE PLANEJAMENTO E CONTROLE

DIVISÃO DE PLANEJAMENTO DE OBRAS HIDRÁULICAS

Juquiá - São Lourenço Project

Photogeological Map Of Juquia River Basin

Figure III - 5.2

5.3. Local Geological Features.

As already described before, the project area can be divided into four distinct regions. Some geological features for each region are described below.

5.3.1. Plateau Region.

The Ribeirao Grande, Rosas, Cachoeira, Embu-Guacu and Santa Rita Reservoirs are located in this region with dams such as GD-6, LH-3, RJ-1, GD-2, CH-2, EG-3 and SR-5 and great thick remaining soils are seen in association with low encircles hills and wide basins. These thick soils partially eliminate the influence of fractures and faults in the condition of relatively low water-tightness.

The main aspect preserved in these soils are mature with surface colluvial action effects.

The soils associated with the alteration of migmatite are, as a rule, sandy clay and clayey silt sand. The gneiss-migmatite soils are clayey silt sand and China clay tending to present boulders at certain levels.

The granite alteration soils are of varying thickness presenting both outcropping boulders and solid rock itself.

Fractures detected by radar scan and photographs are feared to affect to the dam axis JR-1 which is located in a transverse position to one of them.

5.3.2. Sierra Escarpment Region.

Dam site LH-2A located on the sierra escarpment, lie in an area of geological influence of Cubatao macro-fault zone. On the escarpment region, the depth to rock is relatively thin with rock outcropping mostly at the botton of valleys. Although there occur regionally talus and colluvials in zone, large bodies are not found. Since the slopes are steep and there are excessive coverings of soil in this area, some problems may be expected of Stability on the bank slope around the reservoir so that these matters have to be the subject of more detailed investigations from now on.

Along the waterway of Sao Lourenco Reversible Power Station, highly concentrated crack directions are found, more over some fault zones are surely observed so that geological investigations have to be performed before hand to determine this layout.

5.3.3. Cordillera Transition Region.

In the cordillera transition, dam sites of LH-1, B-1 and B-4 are located, where the remaining soil thickness is less and incidence of colluvial and talus is higher. The slopes are frequently concave and the younger undulations are found being compressed on the geological structures. The rivers are generally closed in either along the stretch of schistosity or along the fractures.

Although this region may be more favorable to find rock material, there are probabilities that geological structures are stressed by the influences of various faults and fractures especially at the relatively high slopes so that they have to be investigated closely and carefully from now on to assess their characteristics. The rivers are sometimes flowing through rock formation and present blocks of rock and boulders along their course.

Foundation of dams are generally migmatite with dam site of LH-1 being cut by a possible fracture, B-1 located sub-parallel and close to a line of eventual fracture and axis of B-4 situated in Cubatao Fault Zone.

5.3.4. Low Land Region.

In the low land region, three notable geological factors are found:

- Extensive alluvial plains consisting of very various soils with terraces
- Complex lithological foundation.
- Great density related to faults.

This region is situated at the confluence or tangent of the two great zones of ancient fault, namely, Cubatao and Juquia Faults. There still occur more recent faults of mesozoic action across this region.

Dam site of B-2, derivation of Juquia River, locates at the confluence of Juquia and Cubatao Fault Zones and its axis is transverse to the cataclastic foliation of Juquia Fault. This rock foliation shows a massive, faulty phylite formation.

5.4. Geology at Dam Sites.

5.4.1. Dam site of GD-6.

The planned dam axis is located on Ribeirao Grande, near the confluence with Juquia River. The river-bed elevation, at this dam axis, is 670 m with the both banks comprising rugged terrain.

The dam site is located on granitic zone of the pre-cambrian period.

Judging from the results of geophysical investigations, the weathered soil has a minimum thickness of 10 m at the both banks and 3 m at the river-bed. The elevation of the bed rock is 665 m at the central part of the valley and the bed rock has a tendency of the higher elevation, the deeper at the both banks.

The slope wash at the both banks is sandy clay with silt and its thickness is lower than 2 m.

As for the dam foundation, the weathered rock zone with 1.2 km/sec. of seismic speed is judged to be enough considering the dam height of 45 m by means of the field investigations. The bed rock of granite is supposed to be not so cracky, but some foundation treatment with grouting may be necessary.

5.4.2. Dam site of LH-3.

The planned dam axis is located on Sao Lourencinho River, about 2 km dowstream from the limit of the drainage area. The river-bed elevation is 670 m and the both banks are very steep.

Topographically, the neighbourhood of dam site is consisted of Very complicated features which are shown to be geomorphologically caracteristic of the pre-cambrian period and there is not any recommendable dam site near by there according to the field investigation, through the gradient of river bed is somewhat steep for the dam construction.

The lithology of this site consists of heterogeneous migmatite. At the north of the reservoir there are foliations with ENE direction. Regionaly, the principal structures have NE orientation.

There is not any expressive alluvial deposit or quarry but it is possible to expect enough clayey borrow areas.

According to the results of boring investigations, the colluvial layer which is composed of sandy clay with silt has a thickness lower than 2m. The weathered soil is a sandy silt with clay and it has a thickness lower than 10m. Two water pressure tests made in the soil indicate a coefficient of permeability about 2×10^{-3}cm/s in one case and 5×10^{-5}cm/s the other.

The dam foundation is judged to be enough at the upper zone of weathered rock line taking account of the dam height of 40 m, but the bed rock is supposed to be somehow cracry, to have concentrated crack direction judging from the field investigations so that the foundation treatment with grouting is necessary to keep the watertightness especially at the saddle portion. Furthermore, as the river gradient, especially near the saddle portion, is a little steep for the dam foundation, careful excavation to construct the dam has to be executed to make the dam stable including dam foundation.

5.4.3. Dam site of LH-2A.

The dam axis is located on São Lourencinho River, 16 km upstream of the dam site of LH-1. The river bed elevation is 60 m. The difference in level between the top and the down portion of the valley is higher than 200 m and the right bank is steep but the left is gentle which is supposed to be the trace of landslide.

The lithology of this site consists of heterogeneous migmatites and cataclased rocks. The migmatites presents foliation with E-W direction. Regionaly, the structures have N70°E and N80°W directions. The valley of São Lourencinho River is at the Cubatao Fault Zone.

Judging by the results of geophysical and boring investigations, there is a superficial colluvial soil consisted of sandy clay with silt with maximum thickness of 3 m. Bellow this layer there is a quartz-schist weathered soil with a thickness varying from 5 to 20 m. This layer is covered with a weathered quartz-schist that has a maximum thickness about 40 m. Under this, there is a sound quartz-schist that presents a surface justly parallel to the topography.

As for the dam foundation, a little deep excavation is necessary, specially at the left bank, to keep the dam stability and some foundation treatment with grounting may be necessary though the exposed rocks are shown to be massive according to the field investigations.

The geological and rock mechanical investigations are not executed yet as mentioned about so that these investigations have to be performed from now on considering topographical and geological conditions.

5.4.4. Site of São Lourenco Reversible Power Station.

According to the geological survey, the following types of rock occur at the site.

- Biotyte-gneiss: Occurs along the valley of São Lourencinho River and in several outcrops at NW direction. Its principal features are the gray colouration, medium graining and a characteristic feature of gneiss.

- Quartzites and chalcossilicates quartzites: Occurs intercalary in small portions as lens features with a maximum lenght of 100 m and are composed basicaly of quartz.

- Stromatites: Is the principal lithologic unit of the site. This is a metamorphic rock with granitic formation and it has good mechanical properties.

The intake is situated in a small basin fulfilled with a thin layer of saturated alluvial sediments. The adjacent small hills have differences in level of 30 m. According to the geological investigations, the transition of soil to rock has a thickness of 50 m at the site of the intake and 30 m at middle hillside. At the top of the hills, the thickness tends towards 40 m. Along the axis of the headrace tunnel and at the surge tank site, the transition of soil to rock maintains the mentioned thickness. At the site of the outlet, the rock is exposed or recovered with a thin layer of sediments. The end portion of the tailrace tunnel is at a steep slope with a dense weathered soil. After crossing the transition of soil to rock, the tailrace tunnel as well as the underground power house are situated inside the sound rock.

According to the field investigations along the existing forest road, some fault zones and concentracted crack directions are observed so that careful and detailed geological and rock mechanical investigations after taking into careful considerations of the field geological investigations are quite important to get the necessary informations for making the layout power structures, designing each structure and developing the construction procedures.

5.4.5. Lower dam and power structures of Cabatão Compounded Reversible Power Station.

The planned dam axis is located on Cubatão River, about 400 m downstream of the bridge of Imigrantes Highway and 5 km upstream Cubatão City.

The river-bed elevation, at the dam axis, is 5 m. The left side of the valley comprises the Cubatão Sierra and the difference in level between the top and the down portion of the valley is higher than 700 m. At the right side, this difference is about 100 m.

The valley of Cubatão River is at the Cubatão Fault Zone and the lithology consists of gneiss and schist of the pre-cambrian period.

The right bank is situated at a zone of schist and presents small areas with colluvium and talus. The left bank is at a zone of gneiss and has large areas with talus which are suffering creeping. After the filling and during the operation of the reservoir it will be possible to occur a disturbance with this soil affecting the foundations of the highways that cross this area.

According to the results of boring investigations, the alluvial layer that exists along the foundation of the dam, has a thickness of 13 m and a width of 250 m. Its coefficient of permeability is 3×10^{-1}cm/s. To solve the problem of percolation through the foundation it will be necessary to construct a blanket.

The underground structures of Cubatão Compounded Reversible Power Station are situated at left bank of Cubatão River.

The rocks of this site are of Archean and Proterozoic Age (Sao Roque Series). The upper portion of the waterway, including the headrace and the penstock are situated in grey biotitic feldspathic gneiss with minor zones of schist. At the surface there is a layer of overburden and weathered rock consisted of red and yellow sandy, very soft decomposed rock and residual boulders, with a thickness varyling from 10 to 50 m.

The tailrance tunnel crosses layers of quartzite, quartz-schist, dolomitic marble, white and grey marble. The thickness of the weathered rock reaches a maximum of 70 m.

The strike of the schistosity of the gneisses and schists varies between N30° - 75°E and it is essentially normal.

5.5. Geology in Reservoir Area.

The upper and lower reservoirs are situated in distinct environments. The upper reservoir is at the plateau region, which consists of quartz-micaschist, quartz-schist and migmatites. Near GD-6 axis there is a granitic body.

The direction of the rock foliation is NE and the dip is sub-vertical. Generaly, the relief presents mild slopes with asymetric valleys. The erosive process at the site is laminar type and it is increasing as a result of actual occupation. It is also observed that the steep slopes are submitted to slow creeping.

According to the geological investigations, there is a thick layer of weathered rock, including soil, covering the bed rock. The lowest thickness of this layer, at the valleys, is around 15 m and the maximum reaches 80 m.

The lower reservoir is at the Sierra Escarpment Region, in an area of geological influence of Cubatão Fault Zone. This site comprises migmatite, quartzschist and dikes of basic rocks. The foliations and structures maintain the same direction as mentioned for the plateau region.

The topography exhibits steep slopes with narrow valleys. As a result of the procedent facts it occurs creeps and slidings. This phenomenon affects to the restrict areas, but sometimes it can occur in large spaces, moving great volumes of material. This kind of degradation is a characteristic of Sierra Escarpment Region and has to be the subject of more detailed investigations to prevent problems around LH-2A reservoir.

Along the valleys, the rock emerges and, at the hillsides, there are thick layers of weathered rock. Frequently, at the base of steep slopes, there are deposits of talus. Sometimes, the slidings expose the sound rock.

The transition of soil to rock which is submitted to creeping m movements, presents some descontinuities which are suffering from a process of opening and therefore have high permeability. In such case, this weathered rock layers have to be the subject of detailed investigations, considering the construction of structures and the operation of reservoirs.

5.6. Construction Materials.

5.6.1. General Considerations.

According to construction materials, some fundamental soil mechanic tests at a few project sites are only performed so that the results of field investigation are described hereinunder also referring the above mentioned data. Therefore, the selection of borrow area for each project site, the field investigations and the laboratory tests of them are recomendable to be performed from now.

5.6.2. Dam Embankment Materials.

Excavated materials are, as a matter of course, to be utilized as much as possible to make the construction costs of the project economized considering qualities of material, construction procedures, schedules and so on.

(I) Dam of GD-6.

Excavated materials for the structures can be enoughly utilizable for the dam embankment excepting the organic material of which soils are classified as SC-SM classes according to the Standard Soil Classification. High mica content is observed by means of the field investigation so that the plastic index is assumed less than 20%. Therefore, the borrow area with low mica content and low weathered soil has to be selected to use the dam embankment materials because of excavated materials being anticipated not to be enough.

The fine rock at the borrow area must be planned to be used for the filter embankment material.

The coarse rock of it is to be used as much as possible for the outer zone, namely, semi rockfill zone.

(II) Dam of LH-3.

The weathered and or remain soils are consisted of especially migmatite. Excavated materials for the structures can also be usable as same as the case of GD-6. Soil characteristics are classified as SM - SC class and the plastic index is assumed to be more or less 20% of which value is advisable for the impervious core material. The borrow area for dam embankment has to be selected and the necessary soil mechanical tests are recommendable to be executed. But the borrow area has to be selected considering the ground water level, the available quantities and the easiness of transportation.

The filter and the outer zone materials are to be collected as the same way as the already mentioned.

(III) LH-2A.

Some soil mechanical tests are executed for the dam embankment materials and the average values are shown in Table III-5.1. The soil classifications are the mixed SM, ML, SL and SH and the grading is also desirable.

The filter and outer zone materials can be easily found out near the dam site because the exposed rock is observed, and these materials are also desirable because of schist.

Table III-5.1 Test Results of Impervious Core.

Item	Unit	Qualities
Specific Gravity	g/cm^3	2.82
Dry Density	g/cm^3	1.68
Natural Water Content	%	18.0
Optimum Water Content	%	18.6
LL	%	45
PI	%	22

(IV) Lower Dam of Cubatao Compounded Reversible Power Station.

The borrow area for impervious core and rockfill has to be selected at the righ bank hill where the weathered schist is distributed containing the rock block, but the embankment quantities balancing and deposited soil depth has to be considered for the selection of borrow area. The deposited soils are assumed as SM, CH classes according to the field investigations.

As for the filter material, the alluvial deposited material at the river bed is quite usable so that any problem is not existing at the damsite.

5.6.3. Concrete Aggregate.

(I) Damsite of GD-6.

As already described before, the bed rock is basically consisted of high mica contented granite. Concrete quantity is not big for this damsite and the damsite is isolated so that the ready mixed concrete, if there is a plant near by there, is most advisable in stead of utilization of crashed aggregate.

(II) Power Structures of Sao Lourenco Resersible Power Station and Dam Site of LH-3.

Crashed aggregate of excavated rock of the power structures is most recommendable for these concrete structures. Rock is basically consisted of schist and migmatite so that quality is judged to be desirable.

Aggregate plant and batcher plan are necessary to be installed at the both of upstream and downstream side of pwer structures. The programs of utilization of excavated rock are necessary to be carefully studied considering construction schedules.

(III) Damsite of LH-2A.

The most advisable and economical manufacturing procedure of concrete aggregate at this damsite is to produce it using the excavated rock of the structures and or transporting the rock from the borrow area of dam embankment materials, because the transportation length of aggregate and or ready mixed concrete is too long that means the cost being expensive.

(IV) Cubatao Compounded Reversible Power Station.

The three cases are considerable. The first is to use the ready mixed concrete, the second is to install the aggregate and batcher plants at the each location of intake and outlet sides of power structures to use the excavated rock or the deposited materials of river bed and the third is the combination of the above.

The economical study is the most essential subject about which case is beneficial considering all of the relevant items.

CHAPTER 6

DEVELOPMENT PLAN

PART III

DEVELOPMENT PLAN

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Chapter 6. Development Plan

6.1. Description of Development Plan.

As described in Chapter 3 on the Outline of Development Plan, the progress of works can be divided into Two Main Stages.

The first stage consists of the utilization of Juquia River up to the confluence with São Lourenco River near Juquia Town by means of the following main works, which have to be said that they are within the guidelines of the present stage.

- Dam EG-3 on Embu-Guacu River.
- Dam CH-2 on Cachoeira Stream.
- Linking up between Dam CH-2 and Dam EG-3.
- Pumping up by Pump Station EE-1 from Reservoir JR-1 to Reservoir CH-2
- Dams JR-1 on Juquia River and GD-2 on Grande Steam forming one single reservoir.
- Pumping up by Pump Station EE-2 (at Dam GD-2) from Reservoir GD-6 and LH-3 to Reservoir JR-1.
- Dams GD-6 on Juquia River and LH-3 on Sao Lourenco River forming one single reservoir.
- São Lourenco Reversible Power Station to connect Reservoirs GD-6 and LH-3 with LH-2A.
- Dam LH-2A forming the lower reservoir of São Lourenco Reversible Power Station and Pump Station EE-8A on São Lourenco River.
- Dam LH-1 and Pump Station EE-3 on Sao Lourenco River.
- Dam B-1 and Pump Station EE-4 on Sao Lourenco River.
- Dam B-2 on Juquia River which is located at the confluence with São Lourenco River.

As other alternative, a pondage type for the upper reservoir of São Lourenco Reversible Power Station is planned to avoid the vast reservoir area on the upper basin taking into consideration of decreasing reservoir cleaning cost to make water clean and of making no neoessiation to compensate hydroelectric energy loss for CBA which has river utilization right, and pumped up water is directly transferred to Reservoir EG-3 through pipe line with pump station.

The Second Stage, in its return, involves the development of the water resources of almost the whole of Juquia River Basin. The main works making up this stage are:

- Dam BJ-3 on Juquia River.
- Linking up between Reservoir BJ-3 and Fundo River.
- Dams FD-1 on Fundo River, IP-1 on Ipiranga River and QB-1 on Quilombo River forming one single reservoir.
- Others downstream developments.

Utilized water in Grand São Paulo is planned to be pumped up to the existing Billings and Pedras Reservoirs through two pump stations named Pedreira and Traicao, and the canal of Pinheiros River, from where the water is used for Cubatão Compounded Reversible Power Station by means of Cubatão Lower Reservoir constructed in Cabatão River.

6.2. Operation Plan of Reservoir.

Determination of each revervoir capacity for the water supply is executed as the below mentioned procedures:

After selecting the dam site, monthly inflow at the dam site of period from 1938 to 1979 is calculated using data of the given run-off gauging station as mentioned in Chapter 4 and the reservoir capacity curve is also estimated using 1: 5,000 scale topographical map, and a relation curve of the necessary reservoir capacity versus the firm discharge which is the minimum discharge during the given data periods is developed by means of mass curve, after that the most reasonable normal water level and firm discharge are selected taking into consideration of low water level for pumping up water depth and sedimentation surface, therefore adopted discharge can be called as the regulated design discharge, but cannot be correctly called as the most economical design discharge because the economical comparison of water cost versus construction cost is not performed.

As for São Lourenco Reversible Power Station with 6 hours peaking generation, the reservoir capacity is determined by means of so called weekly operation, that is, the maximum pumping up hours are 6 hrs and 24 hrs during week-days and week-ends respectively considering that pumping up capacity for the given hydroelectric generation and water supply is necessary to maintain until target year of 2040.

On the other hand, pumping up capacity at the pump station is determined considering that annual hydroelectric generation hours will be more less 900 hrs, during which pump station is assumed to be stopped because of the electric power system of this project excepting Cubatão Compounded Reversible Power Station being planned to be the same one and one unit of the installed units is assumed to be stopped for periodical repairment and or unexpected accident, but full day operation is considered to be possible during that time.

Accordingly, re-regulating reservoir capacity in addition to inflow regulation capacity is additionally accounted because pump station is better to be stopped during hydroelectric generation which are asumed to be 3.5 hrs/day in week-days. Also, inflow regulation procedure to Reservoir of LH-2A is adopted in accordance with operation pattern of Sao Lourenco Reversible Power Station.

Concerning Cubatao Compounded Reversible Power Station, generation hours of 6 hr for 8 Units are adopted because the existing Pedras Reservoir Capacity is limited as $9.2 \times 10^6 m^3$.

Main dimensions of each reservoir at the first stage are shown in Table III-6.1.

6.3. Development Scale.

During stay in Brazil, the reversible and compounded reversible power stations and 6 pump stations are preliminarily studied as shown in Table III-6.2.

As for São Lourenco Reversible Power Station, the 9 units with 315 MW each are selected as one alternative, of which development scale is determined taking into considerations that the hydroelectric peaking generation hours in 2040 will be reasonable to be more than 5 hrs even if so called weekly operation pattern is adopted because of the necessary pumping up capacity for water supply being increased year by year, and pumping up hours during week day will be equal or less than 6 hr excepting noom times and during week-end for 24 hours though the above mentioned pumping up hours and or pattern have to be determined more carefully considering actual energy resources, demand duration curves and so in future.

TABLE III-6.1 MAIN DIMENSIONS OF EACH RESERVOIR.

Name	Drainace Area (km^2)	Water Level			Reservoir Capacity		Available Discharge	
		H W L (m)	N W L (m)	L W L (m)	Gross (10^6m^3)	Effective (10^6m^3)	Average (m^3/s)	Firm (m^3/s)
EG-3	57.4	765.40	763.70	755.80	140.7	100.0	1.87	1.80
CH-2	7.2	770.80	770.50	-	22.8	-	0.40	-
JR-1 (d)	130.7	720.30	717.80	714.00	269.8	88.0	5.03	4.70
GD-2	4.1							
GD-6 (d)	58.0	709.70	708.00	702.00	240.0	89.2	2.60	2.10
LH-3	5.7							
LH-2A	142	153.00	153.00	130.00	173.0	99.2	6.45	4.20
LH-1	363	78.00	78.00	58.00	445.0	300.0	8.51	8.30
B-1	705	41.40	38.00	-	44.0	-	10.65	2.10(a)
B-2	4352	24.70	22.00	-	79.7	-	103.8	31.04(b)
Billings	560	747.00	746.50	728.00		1080(c)	11.7(c)	11.20(c)
Pedras	30	728.50	728.00	726.50		10.0	1.3	
Cubatão	128	35.00	33.00	29.00	33.2	9.2	7.4	

Observations:
(a) minimum observed discharge.
(b) ditto - 15 m/s.
(c) remaining reservoir.
(d) one single reservoir.

Two types of development system for Cubatão Power Station, namely, the compounded reversible and normal types, can be considered, but the generation hours, if the latter is adopted, are too much short for a while in the operation commencement years because of the two existing power stations being more less fully operated in accordance with electric demand using the same upper reservoir.

Though the development type is to be determined taking account of economy, balancing of electric demand and supply, economical operation lives and patterns of the existing power stations, site characteristics and so on, the compounded reversible type is selected as one alternative such as 8 units with 300 MW each because of the upper reservoir being restricted as mentioned already.

As for each pump station, the pumping up capacity is determined considering of the electric power system of this project being the same as São Lourenco Reversible Power Station as mentioned already.

The transmission line of generated power and energy for pumping-up at Sao Lourenco Reversible Power Station is planned to be connected with the existing Embu Guacu Substation with 2 circuits of 460 KV, and pumping-up energy at each pumped station connected with São Lourenco Reversible Power Station with 2 circuits of 138 KV. On the other hand, that of 2 circuits of 500 KV is planned to be constructed between Cubatão Compounded Reversible Power Station and Tijuco Preto Substation.

TABLE III-6.2 DEVELOPMENT SCALE

ITEM	UNIT	SÃO LOURENCO	CUBATÃO	EE-1	EE-2	EE-8A	EE-3	EE-4	PIPELINE
AVAILABLE DISCHARGE	m^3/s	630	424	170	165	160	150	150	160
EFFECTIVE HEAD	m	525	670	57	15	77	45	25	190
NUMBERS OF UNIT	N	9	8	4	4	4	4	4	6
GENERATION CAPACITY	MW	2,835	2,400	-	-	-	-	-	-
PUMPING UP CAPACITY	MW	3,060	2,560	114.0	30.0	146.0	84.0	44.0	360.0

CHAPTER 7

PRELIMINARY DESIGN

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CHAPTER 7 PRELIMINARY DESIGN

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