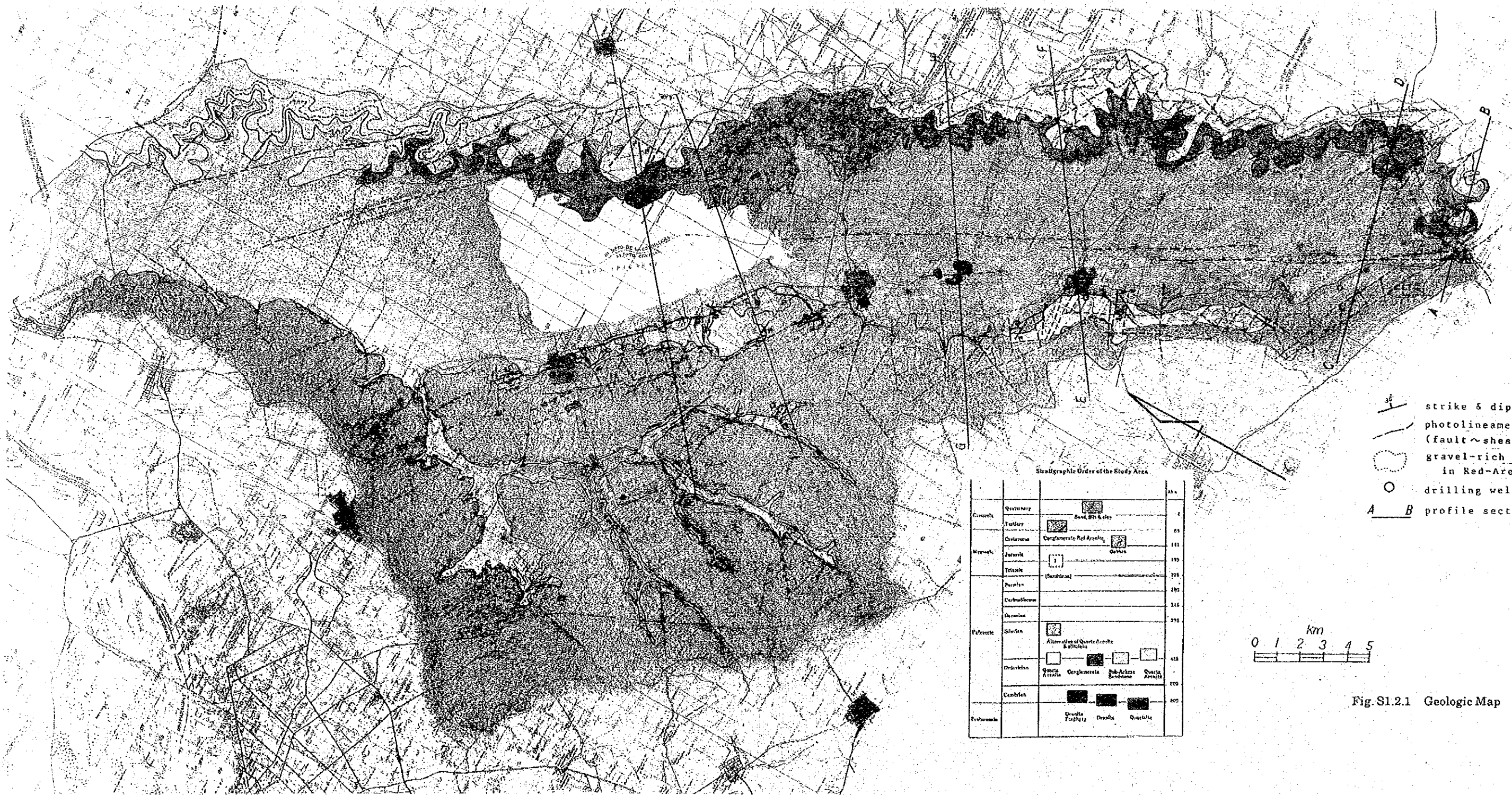


Fig. S1.1.1.11 Sites of River Traverse Survey



- strike & dip
- photolineament (fault ~ sheared zone)
- gravel-rich zone in Red-Arenite
- drilling well
- A B profile section line

Stratigraphic Order of the Study Area

Period	Sub-period	Unit	Approx. Elevation (m)
Cenozoic	Quaternary	Red, Silt & clay	100
	Tertiary		65
	Oligocene	Conglomerate, Red Arenite	111
	Quaternary	Quartzite	190
Mesozoic	Triassic	(Sandstone)	215
	Permian		280
	Carboniferous		315
	Devonian		390
Paleozoic	Silurian	Alteration of Quartzite & Siltstone	415
	Ordovician	Quartz Arenite, Conglomerate, Sub-Arenite, Quartz Arenite	500
	Cambrian		605
	Proterozoic	Dravite Porphyry, Dravite, Quartzite	

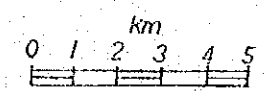


Fig. S1.2.1 Geologic Map

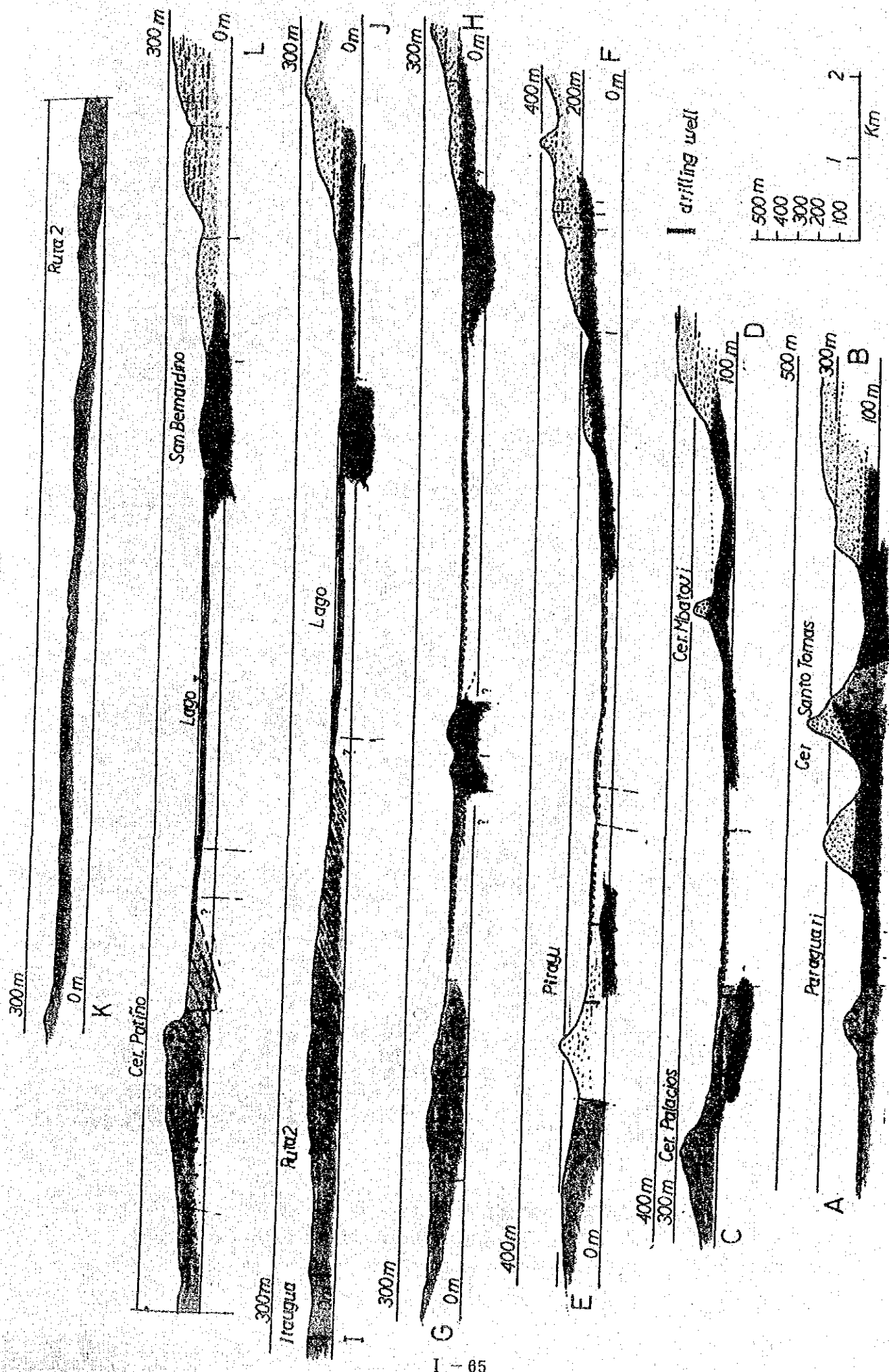


Fig. S1.2.2 Geologic Profiles

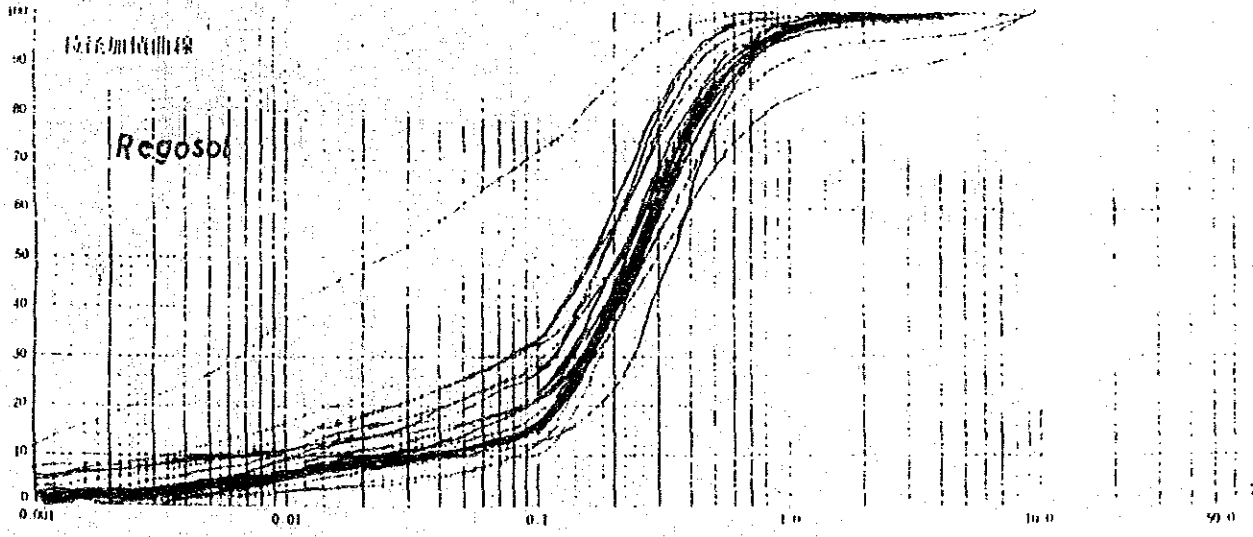
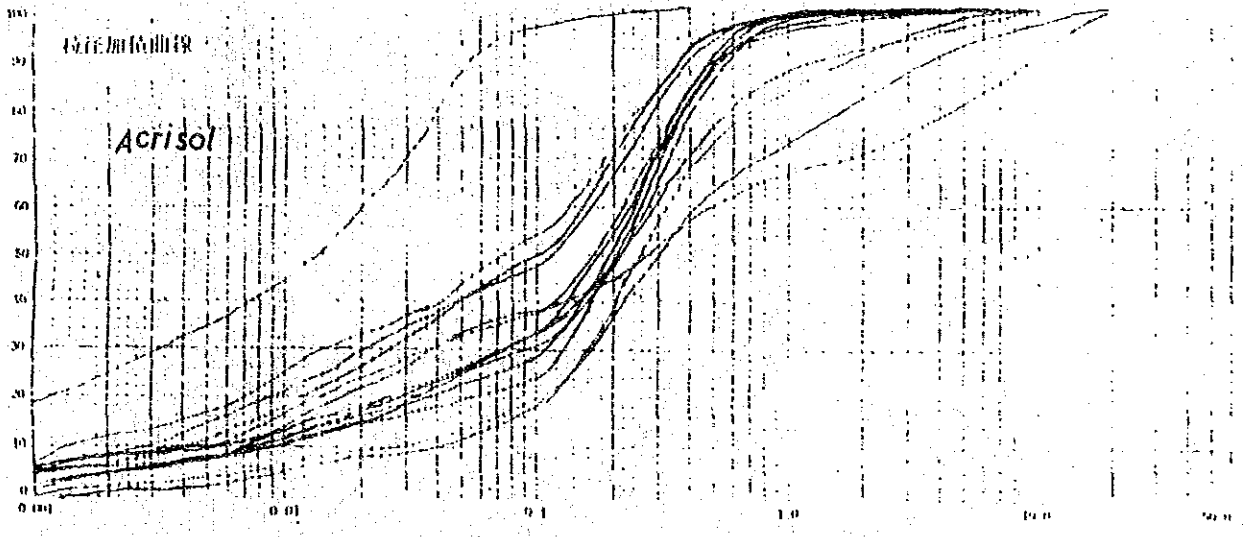
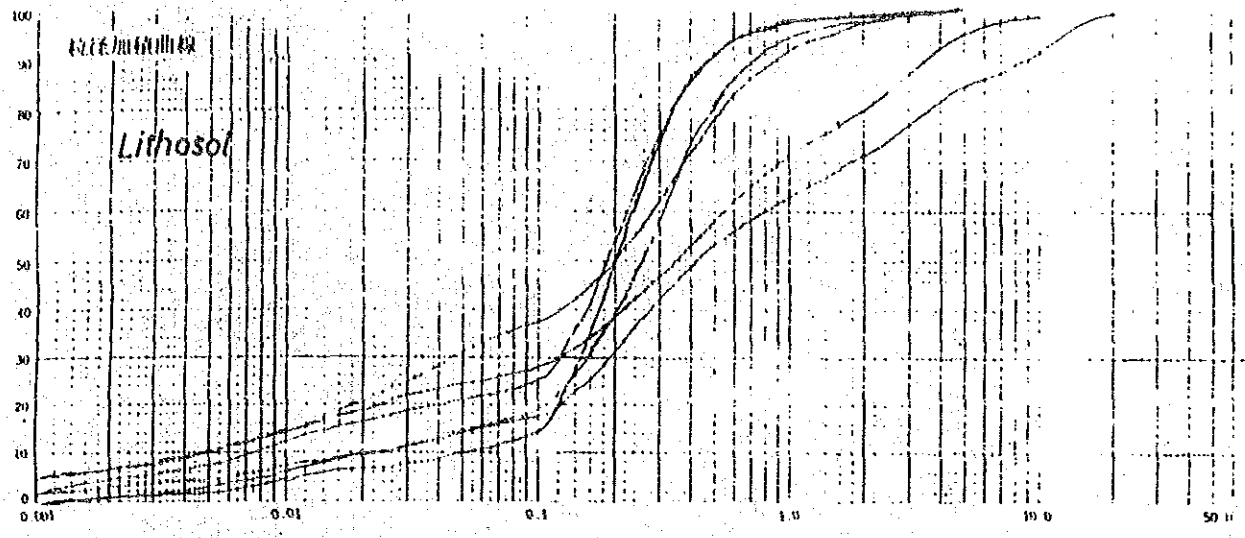
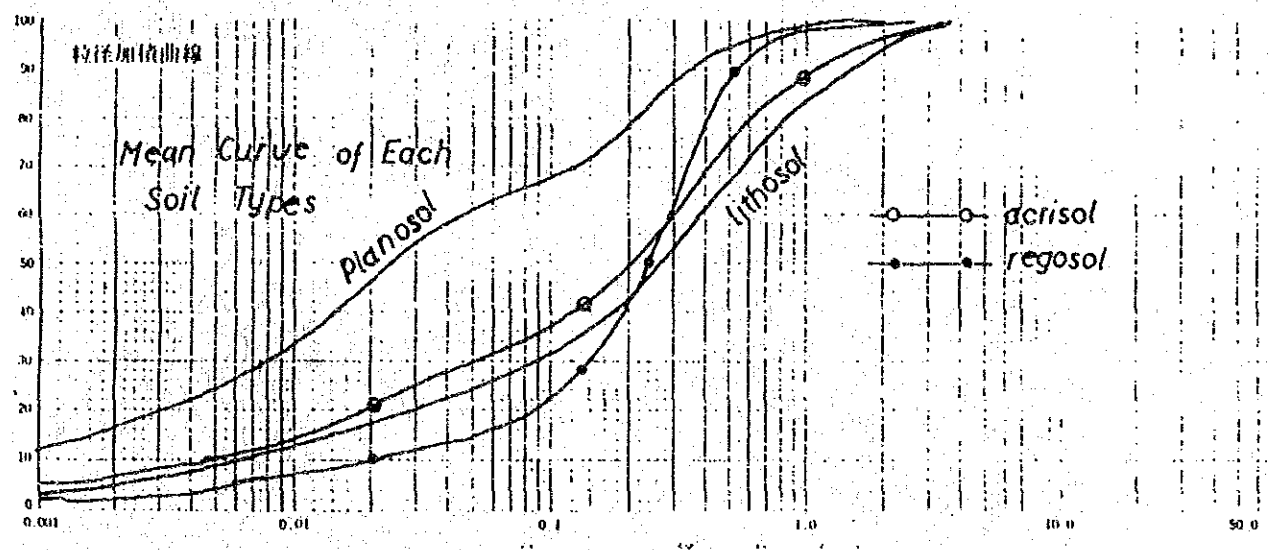
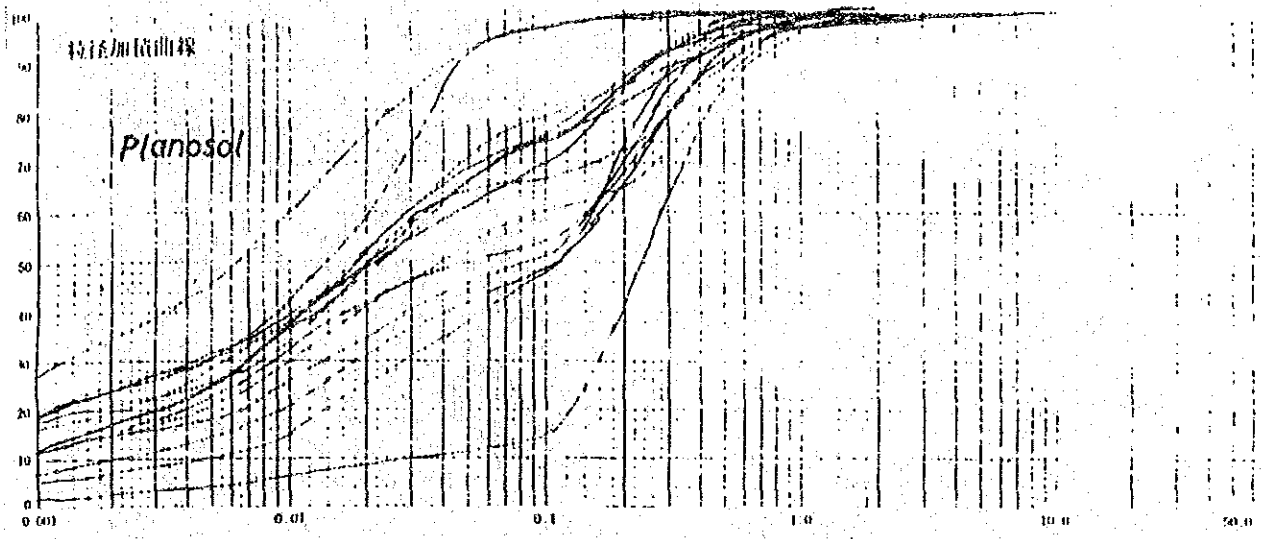


Fig. S1.3.1 Grain Size Accumulation Curve(1)



S1
Fig. 3.1 Grain Size Accumulation Curve (2)

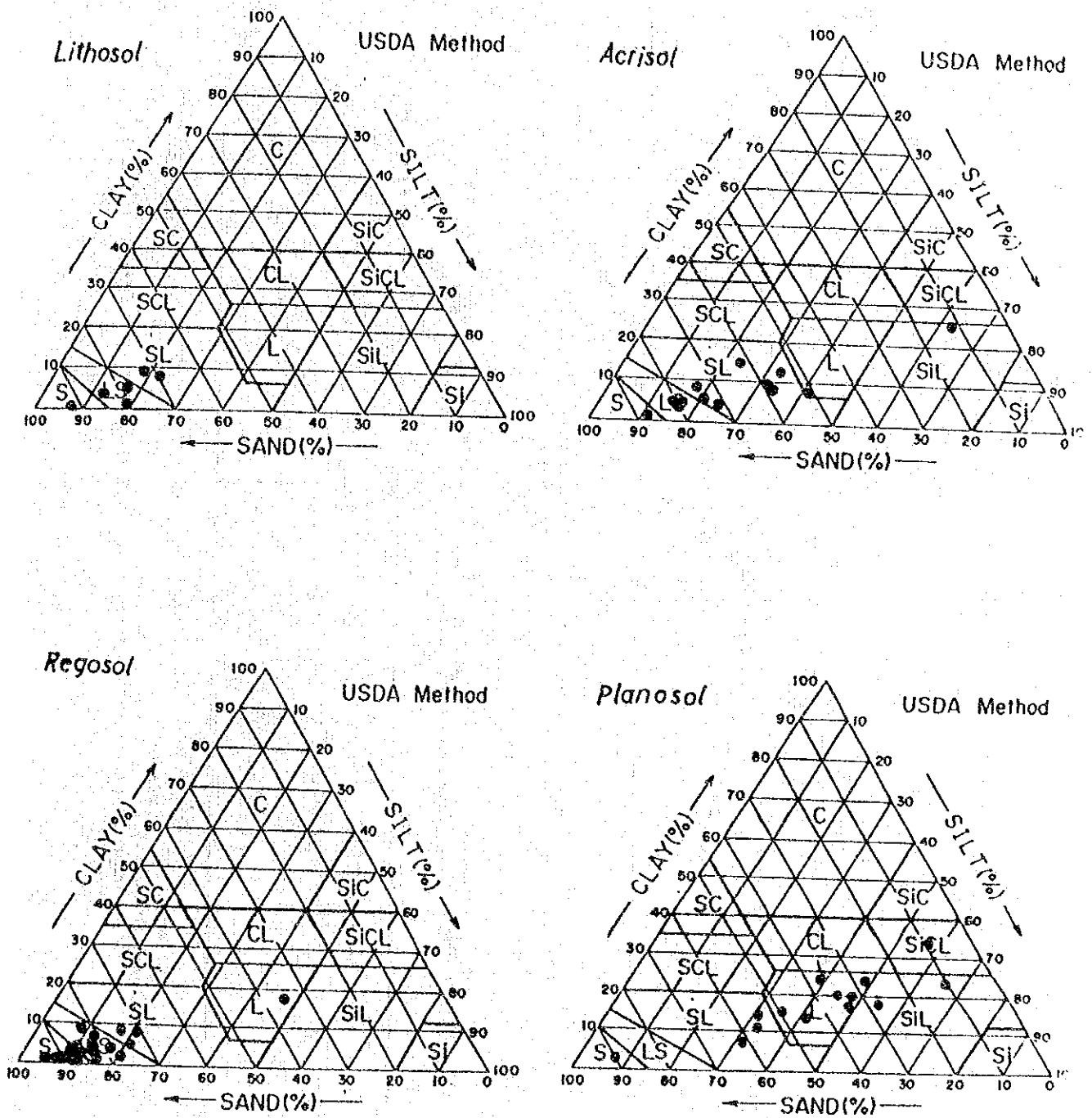


Fig. S1.3.2 Triangulation Diagram showing Texture of Soil Type

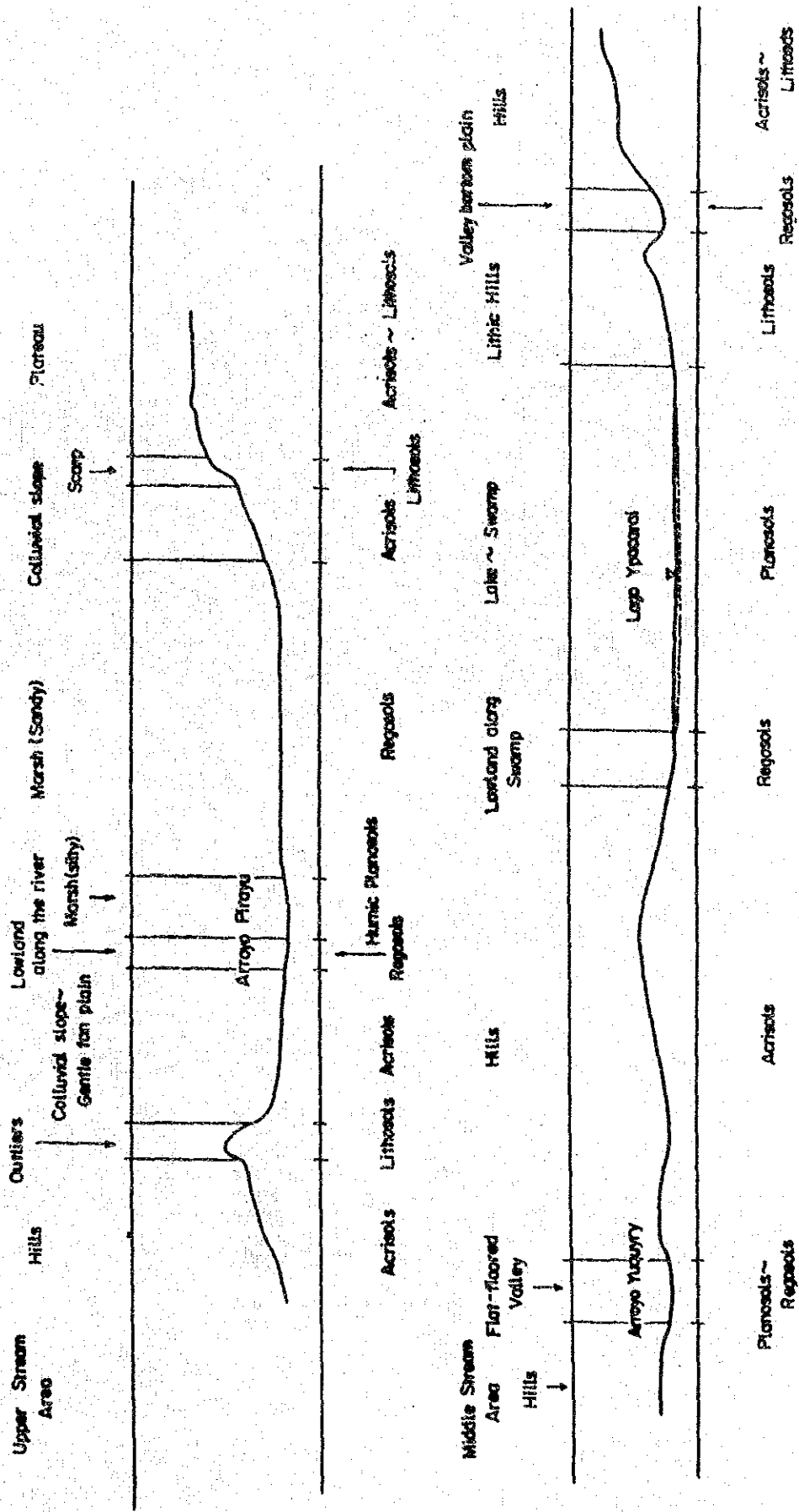
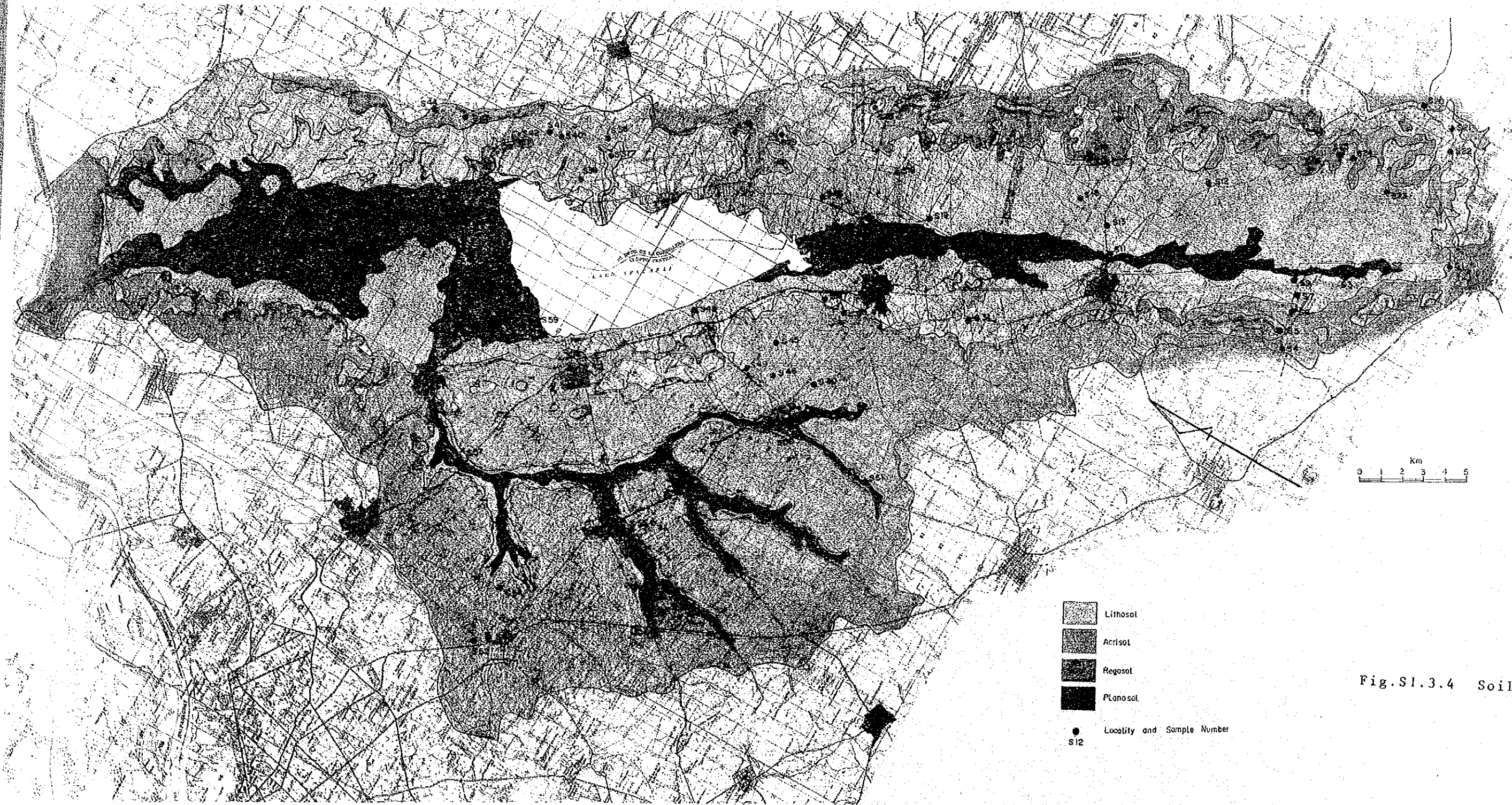


Fig. S1.3.3 Relationship between Topography and Soil Type



0 1 2 3 4 5
Km






-  Lithosol
-  Acrisol
-  Regosol
-  Planosol
-  Locality and Sample Number
S12

Fig.S1.3.4 Soil Map

SUPPORTING REPORT II

**METEOROLOGY, HYDROLOGY AND
HYDRAULICS**

SUPPORTING REPORT II

METEOROLOGY, HYDROLOGY AND HYDRAULICS

Chap. 1 GENERAL

1.1 Purpose of the Study II - 1

1.2 Study Procedure II - 1

Chap. 2 DATA COLLECTION AND OBSERVATION

2.1 Data Collection II - 3

2.2 Installation of Observation Stations II - 3

2.3 Observation II - 5

Chap. 3 METEOROLOGY IN THE BASIN

3.1 Atmospheric temperature II - 7

3.2 Humidity II - 8

3.3 Atmospheric Pressure II - 8

3.4 Rainfall II - 9

3.5 Sunshine Hours and Solar Radiation II - 9

3.6 Evaporation II - 10

3.7 Wind Direction and Velocity II - 11

Chap. 4 HYDROLOGY AND HYDRAULICS IN THE LAKE AND RIVERS

4.1 Water Level and Volume of the Lake II - 13

4.2 Water Level and Discharge of Rivers II - 14

4.3 Water Temperature II - 16

**Chap. 5 CHARACTERISTICS OF OBSERVATION DATA DURING THIS
INVESTIGATION**

**5.1 Meteorologic and Hydrologic Situation between March 1988 and February
1989 II - 17**

5.2 Study done on the Big Flood of Jan. 1988 II - 18

LIST OF TABLES

		<u>Page</u>
Table S2-1	Existing Meteorological and Hydrological Data ...	II - 21
Table S2-2	Meteorological and Hydrological Observation Stations Installed	II - 22
Table S2-3	Water Level of Lake Ypacarai	II - 23
Table S2-4	Precipitation in January, 1988	II - 24
Table S2-5	Water Level in the Lake in January, 1988	II - 24

LIST OF FIGURES

	<u>Page</u>
Fig. S2-1	Location of Existing Observatories II - 26
Fig. S2-2	Location of Installed Meteorological and Hydrological Observation Stations II - 27
Fig. S2-3	Atmospheric Temperature II - 28
Fig. S2-4	Humidity II - 29
Fig. S2-5	Atmospheric Pressure II - 30
Fig. S2-6	Rainfall / Asuncion, San Lorenzo, Caacupe and Carapegua II - 31
Fig. S2-7	Rainfall (Observed in this Project) II - 32
Fig. S2-8	Sunshine Hours and Solar Radiation II - 33
Fig. S2-9	Evaporation II - 34
Fig. S2-10 (1~2)	Wind Direction and Velocity / Asuncion II - 35
Fig. S2-11 (1~2)	Wind Direction and Velocity / (Observed in this Project) II - 37
Fig. S2-12-1	Water Level of Lake Ypacarai, Yagua-resa-u River and Yuquyry River (Observed in this Project) II - 39
Fig. S2-12-2	Water Level of Lake Ypacarai II - 40
Fig. S2-13	Relation between Water Level and Water Volume .. II - 41
Fig. S2-14	Rating Curves of Pirayu River and Yuquyry River .. II - 42
Fig. S2-15	Water Temperature II - 43

SUPPORTING REPORT II
METEOROLOGY, HYDROLOGY AND HYDRAULICS

CHAPTER 1

GENERAL

1.1 Purpose of the Study

The purpose of this study, entitled, Meteorology, Hydrology, and Hydraulics consists in the following two points :

(1) to collect data, recorded at existing observatories and at observatory stations newly set-up for this study, which relate in an overall sense to the meteorology of Lake Ypacarai Basin and to the hydrology and hydraulics within the Lake and its inflowing and outflowing rivers ; to arrange this data for pollution simulation.

(2) to analyze the data and distinguish characteristics of the studied items ; to offer this as information for other on-going related surveys.

1.2 Study Procedure

The procedure formulated for the Study is as follows :

(1) Data Collection

All the existing data (dating from 1950 and on) on atmospheric temperature, humidity, rainfall, sunshine hours, evaporation, wind direction and velocity and water level of Lake Ypacarai which was recorded at Lake Ypacarai vicinity observatories (Asuncion, San Lorenzo, Caacupe, Carapegua and San Bernardino) were collected.

(2) Installation of Observation Stations

Meteorological observation stations and water level gauging stations were installed (for atmospheric temperature and pressure, humidity, rainfall, solar radiation, wind direction and velocity, water level and temperature).

(3) Observation

Observations were carried out continuously (March 1988 - February 1989) at the observation stations. These observations included specific random discharge measurement in the inflowing Pirayu River and Yuquyry River, and the outflowing Salado River.

(4) Compilation and Analysis of Data

Compilation and analysis of existing data and the data recorded from these recent observations were performed.

The following chapters discuss the above procedure and other observation details ; Chapter II, items 1)-3) ; chapter III, item 4) and the overall meteorology of the Ypacarai Lake Basin ; and Chapter IV, the Ypacarai Lake and the hydrology and hydraulics of the inflowing and outflowing rivers.

CHAPTER 2

DATA COLLECTION AND OBSERVATION

2.1 Data Collection

In the vicinity of Lake Ypacarai Basin, there are 4 meteorological observatories, one each at Asuncion, San Lorenzo, Caacupe, Carapegua, and the San Bernardino water level gauge. As for the Asuncion observatory, the facilities had been moved from Armada to Sajonia and then to the Stroessner Airport. Therefore, that data dates as follows : Armada - before 1964, Sajonia - 1965-1968, international airport - from 1969 to present. The locations of the observatories and the water level gauge are shown in Figure-S2. 1.

From the existing data at the observatories and gauge, the selected data was that of the longest possible time period and that which relates to the following items, thought to be essential for this study : (see Table-S2-1)

- (1) Atmospheric Temperature
- (2) Humidity
- (3) Rainfall
- (4) Sunshine Hours
- (5) Evaporation
- (6) Wind Direction and Velocity
- (7) Water Level of Lake Ypacarai (elevation of Om on staff :62.29m)

2.2 Installation of Observation Stations

For this study, the 11 meteorological and hydrological observation stations shown in Table S2.2 were set-up in the Lake Ypacarai Basin (see Figure. S2.2 for the location of these stations).

The collected existing data was assembled along with the recent data relating to the following items :

- (1) Atmospheric Temperature : 3 locations
- (2) Humidity : 2 locations
- (3) Atmospheric Pressure : 2 locations
- (4) Rainfall : 6 locations
- (5) Solar Radiation : 1 location

- (6) Wind Direction : 1 location
- (7) Wind Velocity : 3 locations
- (8) Water Level of Lake Ypacarai and Rivers : 7 locations
- (9) Water Temperature : 1 location

Next are discussed the reasons for location selection of each station, the observation items, and the observation period.

San Bernardino Central Observation Station

The San Bernardino Station was chosen as central station due to its close proximity to the Lake, and, moreover, to the water pollution problem which has become exceedingly notable in San Bernardino. For each observation item - atmospheric temperature, rainfall, solar radiation, wind direction and velocity and water level and temperature of Lake Ypacarai - the daily maximum, minimum, mean and cumulative values were obtained as well as the instant value were listed sequentially on a chart. This water level observation by the Central Station was carried out in order to supplement the observation results of the aftermentioned Lake Ypacarai Water Level Gauging Station. The Om elevation at the observation facility is 62.84m.

Ypacarai and Aregua Meteorological Observation Stations

Two meteorological stations were set-up, one each in Ypacarai and in Aregua, close to the Lake, in order to assist the Central Station. The observed items were atmospheric temperature, humidity, atmospheric pressure, rainfall, and wind velocity. Each item along with its instant value is listed sequentially on a chart.

San Lorenzo, Pirayu and Paraguari Rainfall Gauging Stations

Along with the stations listed above, three rainfall gauging stations, one each at San Lorenzo, at Pirayu and at Paraguari, were set-up in order to grasp the complete rainfall situation in the Lake Ypacarai Basin.

Lake Ypacarai, Yagua-resa-u River, Yuquyry River, and Salado River Water Level Gauging Stations

For the water level observation of Ypacarai Lake, one more main water level gauging station has been set-up at the same location as the San

Bernardino Central Station (Om elevation : 62.39m). To determine the inflowing water quantity from the basin to the Lake, a station was set-up at Yagua-resa-u River (main branch river of Pirayu River) and at Yuquyry River.

To check the outflowing quantity, a station was set-up at Salado River. All of these were set-up near bridges on main roads for ease in maintenance management. However, due to the back water caused by high water in Paraguay River, no observations were performed at Salado Station and on June 7th it was dismantled. Thus, no data was obtained from the Salado Station.

Ypucu River and Salado River Water Level Gauging Staff

As reserve facilities for the water level gauging stations, water level gauging staffs were placed at Ypucu River (a branch of the Pirayu River) and at Salado River.

2.3 Observation

At the established observation stations mentioned in 2.2, meteorologic and hydrologic observations were conducted from March 1988 until February 1989.

From April 13 until June 23, 1988, discharge measurement was conducted at Yagua-resa-u which is Pirayu River's main branch river, at Ypucu which is Pirayu River's branch river, at Yuquyry River and at Salado River. A rating curve was prepared concerning the Pirayu and Yuquyry Rivers.

Date 1988	Pirayu River		Yuquyry River	Salado River
	Yagua-resa-u	Ypucu		
April 13	○	○	○	○
April 19	○	○	○	○
May 4	○	○	○	○
May 19	○	○	○	○
June 1	○	○	○	-
June 13	○	○	○	-
June 20	-	-	-	○
June 23	-	-	○	-

Note: ○ Signifies discharge measurement was conducted.

CHAPTER 3

METEOROLOGY IN THE BASIN

The study area in the Lake Ypacarai Basin is situated east of the Paraguayan capital, Asuncion, at 25°S 57°W, with a climate classified as subtropical, spring is September - November, summer is December - February, Fall is March - May and winter is June - August. The mean daily temperature in summer is approximately 27°C, in winter is 18°C, and yearly is 23°C. Though the rainfall (yearly : 1500mm) tends to be heavy in the summer and light in the winter, there is no rainy nor dry season distinguished.

Next, the meteorology of Lake Ypacarai basin, will be discussed following the data from recent and existing observations.

3.1 Atmospheric temperature

Data was collected on the mean, maximum and minimum daily temperatures in Asuncion, San Lorenzo, Caacupe and Carapegua. However, as there isn't much variance between these areas, Asuncion can be considered the region representative of the basin atmospheric temperature (the mean monthly and mean monthly values of maximum and minimum daily temperature in Asuncion from 1965 on, and the normal year mean are indicated in Figure S2.3).

As understood from Figure S2.3, the normal year value shows the mean monthly temperature at 27°C during the summer, at 18° - 19°C during the winter, at 20°-25°C during the spring and fall, and at 22.9°C for the year. According to the mean monthly value of maximum and minimum daily temperature, there is a $\pm 5^{\circ}\text{C}$ variance which changes parallel to the mean monthly temperature. This is a distinct characteristic that as daily change is large, seasonal change, by comparison, is relatively small.

As for yearly fluctuation, regarding the mean monthly temperature and mean monthly values of maximum and minimum daily temperatures for each month, the $\pm 5^{\circ}\text{C}$ difference is easily seen, and the fact that the temperature each month of the year doesn't necessarily follow the normal year value can be understood. Because of this, the mean yearly temperature is virtually fixed.

Only the monthly mean value of San Bernardino is illustrated in Figure S2.3. Although the data reveals a tendency for the temperature to increase in the order of Ypacarai, Aregua, San Bernardino, no essential disparities are recognized. The recent observations on mean monthly temperature of San Bernardino, compared with those of Asuncion from 1965 on, show a notable change of a high in March and a low in May and July.

3.2 Humidity

The data on the mean monthly humidity value in Asuncion, 1965 - 1969, was collected. The yearly value, as shown in Figure S2.4, indicates that the highs occur in March - June at 72%, the lows in September - December at 65%, and the yearly mean at 69%. Yearly variation is wide since for the same month, there can be a 20% higher or lower difference, which indicates a $\pm 6\%$ difference in the yearly mean. Thus, humidity expresses no clear seasonal tendency.

The recent results from the observations on maximum, minimum and mean daily humidity in Ypacarai and Aregua are shown in Figure S2.8. Although Ypacarai, compared with Aregua, shows a higher value, no substantial disparity is recognized.

The humidity observation in Asuncion shows the yearly mean with about the same tendency for fluctuation (see Figure S2.4).

3.3 Atmospheric Pressure

The existing data on atmospheric pressure has not been collected. The recent data on maximum, minimum and mean daily atmospheric pressure at Ypacarai and Aregua are similar. Since Ypacarai and Aregua values are almost the same, only the monthly mean of Ypacarai is illustrated in Figure S2.5.

3.4 Rainfall

The existing data on daily rainfall at Asuncion, San Lorenzo, Caacupe, Carapegua was collected. The monthly rainfall amount is shown in Figure S2.6.

There is a tendency noted upon regarding Figure S2.6, where at any location, the rainfall is large (150mm) from December - April and small (70 - 80mm) from June - September. However, although summer might be regarded as rainy season and winter as dry season, this difference is hardly notable. The yearly amount of rainfall at Asuncion is 1394mm, at San Lorenzo, 1525mm, at Caacupe, 1589mm, and at Carapegua, 1586mm. There are no greater differences than the slightly lower amount at Asuncion.

However, regarding the change during the yearly period the monthly amount and the yearly amount vary widely. The collected data shows the maximum monthly rainfall amount at Carapegua at 573.4 mm (April 1986) and the maximum yearly amount at San Lorenzo at 2456.3 mm (1965). Comparing the rainfall values of the same month in the same year for different locations, it can be seen that they vary widely indicating strong local rainfall characteristics.

The recent data on monthly rainfall in San Bernardino, Ypacarai, Aregua, San Lorenzo, Pirayu and Paraguari is shown in Figure S2.7. As can be understood from the figure, the approximate seasonal change tendency for rainfall observed at each location, doesn't differ from that recorded in the past. However, judging on a month to month basis, the rainfall amount in March and July, compared with that of the normal year, is extremely small, whereas the amount in April is nearly two times that of the normal year. And because of the nature of the locality, even within the same basin, a notable disparity is seen in the way it rains and in the amount in each area.

3.5 Sunshine Hours and Solar Radiation

Sunshine Hours

The existing data on the monthly sunshine hours in Asuncion, San Lorenzo, and Carapegua was collected. Since there is no

significant difference between the areas, the normal yearly value in Asuncion, the selected representative area, is shown in Figure S2.8.

As can be understood by looking at the normal year value, the summer period from December - February has 250 hours/month, the winter period from June - August has 170 hours/month and the yearly average stands at 2530 hours. Comparing yearly periods by months, there are some months which vary considerably, about two times and might cause a 20% difference for the yearly period. Considering this, the stipulated seasonal tendency cannot be considered as very distinct.

Solar Radiation

For the recent study, instead of sunshine hours, the daily solar radiation in San Bernardino was observed.

Figure S2.8 shows the monthly mean values. As can be understood by looking at Figure S2.8, the solar radiation data and the existing data on sunshine hours show proportionally the same seasonal changes.

3.6 Evaporation

The existing data on monthly evaporation in San Lorenzo and Caacupe were collected. However, the facilities needed for conducting present observations have not yet been established. The yearly evaporation value in San Lorenzo is approximately 880 mm, whereas that in Caacupe differs substantially at 1910 mm. The reason for this is based less on the regional differences than on the differences in observation methods. This is to say that the observation in San Lorenzo was carried out using a small pan, whereas for that in Caacupe, a piche - evaporimeter was used. According to the observer, there were problems with both methods, however the accuracy of the latter was higher. Accordingly, because of uncertainty in the values, the Caacupe values were chosen for use in this study. The normal yearly value for Caacupe is shown in Figure S2.9.

Regarding the normal year value in Figure S2.9, it is high from October - December at 200 mm/month and low from April - June at 120mm/month. However, there is wide yearly variation as in the sunshine hours. Therefore, the discussed seasonal tendencies cannot be considered as being so distinct.

3.7 Wind Direction and Velocity

The monthly data of wind direction and velocity recorded at Asuncion (international airport) during 1986 and 1987 was collected and is shown in Figure S2.10. The summary of the monthly results at San Bernardino is shown in Figure S2.11.

As for the wind direction at Asuncion, there is hardly any change on the monthly scale. Over a one-year period, the northeast and south winds are very prevalent, whereas, the west winds are hardly worth noting. The recent results at San Bernardino show practically the same tendency that throughout the observation period the east-northeast winds and the south-southwest winds were prevalent. As for wind velocity, it increases in the following order: Ypacarai, San Bernardino, Aregua and Asuncion. This is due not to regional differences, but rather to the conditions of location of each observation station.

CHAPTER 4

HYDROLOGY AND HYDRAULICS IN THE LAKE AND RIVERS

Lake Ypacarai, the area under observation, is sandwiched in between two mountain ranges, the Los Altos to the east and the Yaguaron to the west. Spread across a wide valley-bottom plain, the Lake has normally an area of 59.6 km², a maximum depth of 3 m, and a flat configuration. The two principal inflowing rivers are the Pirayu river coming from the south (branching out between the Yagua-resa-u River and the Ypucu River) and the Yuquyry River originating in the west and entering the Lake by an indirect round-about route. As for the outflowing rivers, there is only the Salado River (however, during flooding, the west of the Salado River widens into a swamp, out into which a fair amount of water flows) which carries the Lake water to the Paraguay River. The name and the area of each basin connected to the Lake is shown below (see Figure S2.2).

River Basin	Catchment Area (km ²)	Remarks
Inflow river basins	Pirayu River Basin 353.7	Yagua-resa-u and Ypucu Rivers
	Yuquyry River Basin 343.9	
	East Basin 75.2	
	West Basin 60.2	
Total 833.0		
Lake Ypacarai	59.6	at ordinary time
Salado River Residual Basin	191.4	no inflow to the Lake

In the following section, from the results of the recent observations of the water level, volume, and temperature of Lake Ypacarai, including the water level and discharge of the inflowing and outflowing rivers, data on the characteristics and fluctuation conditions have been collected and discussed.

4.1 Water Level and Volume of the Lake

Fluctuation characteristics of water level of Lake Ypacarai and relation between Lake water level and water volume are stated as follows.

Fluctuation Characteristics of Water Level

The data on monthly water level fluctuation, recorded by the Navy from 1965 on, in San Bernardino, are shown in Table S2.3. The mean yearly water level, at 1.20m, experiences little seasonal fluctuation, yet large yearly fluctuation occurs. Furthermore, as the correlation between monthly water level and rainfall is low, it is inferred that the Lake water level is influenced not only by the inflow amount but also by the state of the outlet to Salado River.

The daily water levels of the Lake at San Bernardino and the inflowing Yagua-resa-u and Yuquyry rivers, are indicated in

Figure S2. 12. Understood from Figure S2. 12 is that the lake water level rises simultaneously with the inflow rivers level. Once risen, the Lake water level does not lower readily even when the river level drops. The largeness of the area contributes to the reason, however more critical is the blockage of flood debris and islands of vegetation which obstructs the outlet to Salado River.

Incidentally, last year the water level of Paraguay River was the highest ever next to the 1983 record. For the peak shown in mid-July, the area affected by the back water of Paraguay River to 3Km down stream from the outlet of Salado River, the Lake water level compared to that of Paraguay River was still 2m higher. Furthermore, at that time, the Lake outlet to Salado River was in a state of virtually uniform flow. Therefore, the Paraguay River water level can't be thought to have any effect on that of the Lake.

Relation between Water Level and Water Volume

Based on recent data, Figure S2. 13 was drawn up, illustrating the relationship between the water level and water volume of Lake Ypacarai. The volume stands at $115.3 \times 10^6 \text{m}^3$ when water level is average (Naval staff reads 1.20m, EL 63.49m). At the time the surface area was 59.6Km^2 .

4.2 Water Level and Discharge of Rivers

This section discusses the characteristics of the water level and the discharge of the principal inflowing rivers (Pirayu River and Yuquyry River) and the outflowing river (Salado River).

Inflowing rivers (Pirayu and Yuquyry Rivers)

The recent data on daily water level recorded by the automatic water level gauges installed at Yagua-resa-u River and Yuquyry River (for location see Figure S2.2) are shown in Figure S2.12.

Understood from the figure is that although the type and amount of rain differ in each of the observed areas, the water level of the Yagua-resa-u and Yuquyry Rivers are similar. There exists a one or two-day lag between the rainfall peak and the peak of river water level.

Next is a chart illustrating the relationship between the water level and discharge of the Pirayu and Yuquyry Rivers.

This is based on data from discharge measurement conducted at Yagua-resa-u River and Ypucu River (6 times) and at Yuquyry River (7 times) at water level gauging stations or by water level staffs (see Figure S2.14).

(1) Pirayu River

$$Q = 6.76 (H - 0.04)^2$$

Q = Discharge of Yagua-resa-u and Ypucu Rivers (m^3/s)

H = Water level at Yagua-resa-u River (m)

Note : The area of the upstream basin is 311.2 km^2

(2) Yuquyry River

$$Q = 3.76 (H - 0.32)^2$$

Q = Discharge (m³/s)

H = Water Level (m)

Note : The area of the upstream basin is 275.3 km²

The daily discharge of the Pirayu and Yuquyry Rivers, calculated using the above formula, and the total daily discharge from all basins, calculated using the following formula :

$$Q_T = (Q_P + Q_Y) + \frac{AT}{AP + AY}$$

Q_T = Total discharge from all basins whose water is drained into the Lake (m³/day)

Q_P = Discharge of Pirayu River at the water level gauging station (m³/day)

Q_Y = Discharge of Yuquyry River at the water level gauging station (m³/day)

A_T = Total catchment area of the Lake (833 km²)

A_P = Catchment area of Pirayu River upstream of the water level gauging station (311.2 km²)

A_Y = Catchment area of Yuquyry River upstream of the water level gauging station (275.3 km²)

Outflowing River (Salado River)

The water level gauge recently installed in Salado River as described in 2.2, was dismantled on June 7.

This was due to the back water caused by Paraguay River's high water. Virtually none of the observations could be carried out. Thus, no water level data on Salado River was obtained.

However, at the same location as the water level gauging station discharge measurement was conducted a total of 5 times :

<u>Date 1988</u>	<u>Discharge m³/s</u>
April 13	17.2
April 19	11.8
May 4	14.7
May 19	17.2
June 20	15.6

Note : The water level was also observed, however due to the backwater influence, it is impossible to draft a rating curve.

4.3 Water Temperature

The recent data on mean monthly maximum, minimum and mean water temperatures in San Bernardino is shown in Figure S2.15.

Comparing Figure S2. 15 and Figure S2. 3 , there is a gradual seasonal change and a minimal daily change comparing the Lake Ypacarai water temperature to the air temperature. Because of the shallowness of the water (2.5 m), compared to that of any lake, the water temperature will tend to be more sensitive to the air temperature activity.

CHAPTER 5

CHARACTERISTICS OF OBSERVATION DATA DURING THIS INVESTIGATION

5.1 Meteorologic and Hydrologic Situation between March 1988 and February 1989

As meteorologic and hydrologic observation equipments were implemented from February 1988, the characteristics present over a one year period (Mar. 1988-Feb. 1989) of the meteorologic and hydrologic situation in the lake area are going to be explained.

(1) Rainfall

The average of annual rainfall around the lake resulted in 1,485mm after revising by the Thiessen method, data observed at six points.

The average over the past 38 years in Asuncion is 1394mm and that of the past 24 years in San Lorenzo is 1525mm.

The precipitation during the observation period could be considered as the average because the percentage varies greatly from year to year.

Throughout the year, the precipitation is highest in April at 192-388.5mm and is lowest in July at 1-5mm.

(2) Lake Water Level

The water level has been continuously 19-61cm higher than the average of the past 20 years.

(3) Temperature

Comparing the observation data from the past 38 years in Asuncion (please remember that it is not so easy to estimate due to different location), the average temperature in March 1988 was the highest ever. The May and July 1988 averages were the lowest. This is to say that the temperatures during observation were abnormal compared with the average year.

(4) Wind Velocity

The wind velocity was the highest in winter (July-September) when the south wind prevailed. This could be also reported as the tendency of the average year in Asuncion.

5.2 Study done on the Big Flood of Jan. 1988

From Jan. 13-16, 1988 there was heavy rainfall around the Lake, this could have helped purify the lake water. In this case, the overall situation in Jan. 1988 should be studied hydrologically.

(1) Rainfall

Rainfall observation data taken near the basin (not in the basin) is shown in Tab. S2.4. At Asuncion Airport it is 110mm from Jan. 13 - 16, and 151.5mm is close to the average in January (incidentally, in April at any of the observation points, the rainfall was measured at 200-400mm as a monthly average).

In Caacupe, the rainfall was 226mm from Jan. 13-16, which is fairly high. This shows that the rainfall can be highly concentrated in certain areas and hardly present in others simultaneously. Therefore, in the basin there could have been heavy rainfall possibly but as there exists no data on this it cannot be verified.

(2) Lake Water Level

The variation in the lake water level during flood is shown in Tab. S2.26. It varied from 1.68m, the level on the 13th preceding the flood, to 2.60m, which is an increase of 0.92m. Incidentally, let's estimate the precipitation as if the water didn't flow out of the lake.

$$\Delta H \cdot A_L = R \cdot f \cdot A_B + R \cdot A_L$$

H : variation of lake water level

A_L : area of lake = 59.6Km²

A_B : area of basin = 833Km²

R : total amount of precipitation

f : run-off coefficient

(ignoring evaporation amount on the surface of the lake)

If $\Delta H = 0.92\text{m}$ and $f = 0.3$, R would be 177mm.

In other words, if the water didn't outflow at all, about 180mm of rainfall in the basin would be necessary.

One reason considered for the water level increase is that the Salado which outflows from the lake was blocked by deposits of floating-leaved plants.

From the data we can learn that the water level did not decrease from the 16th to the 20th of Jan. It can be believed that the reason the water level decreased after the 20th was due to a human-built outflow canal.

(3) Study on the Cause of Purification

First of all, it is considered that there could be a proper amount of rainfall which does not appear in the observation data from around the area.

As a first reason for this, it is considered that the lake water was diluted because of the heavy rainfall.

As a second reason, it is considered that due to a heavy amount of washout, phytoplankton and its corpses settled at the bottom of the lake.

As a third reason, it is considered that the surface of the bottom deposit was flushed out when the water level decreased suddenly because of the excavation of the outflow canal.

In any case, the probability of the same natural phenomenon occurring could be once over several years. However, it is thought that this phenomenon suggests that not only the lake water level but the quality could be controlled possibly by installing a water gate at the outflow canal opening.

TABLES

TABLE S2-1

EXISTING METEOROLOGICAL AND HYDROLOGICAL DATA

Item	Sub-item	Location	Period	Remarks
Atmospheric temperature	Mean, maximum and minimum	- Asunción	Jan., 1965 - Feb., 1988	Shutdown
		- San Lorenzo	Jan., 1957 - Dec., 1979	
	daily temperature	- Caacupé	Jan., 1961 - Sep., 1986	- do -
		- Carapeguá	Jul., 1970 - Feb., 1988	- do -
Humidity	Mean monthly humidity	- Asunción	Jan., 1965 - Dec., 1979	
Rainfall	Daily rainfall	- Asunción	Jan., 1950 - Feb., 1988	Shutdown
		- San Lorenzo	Jan., 1957 - Dec., 1980	
		- Caacupé	Jan., 1961 - Feb., 1988	
		- Carapeguá	Jan., 1971 - Feb., 1988	
Sunshine hours	Monthly sunshine hours	- Asunción	Jan., 1970 - Feb., 1988	Shutdown
		- San Lorenzo	Jan., 1959 - Dec., 1980	
		- Carapeguá	Jan., 1971 - Nov., 1980	
Evaporation	Monthly evaporation	- San Lorenzo	Jan., 1957 - Mar., 1981	Shutdown
		- Caacupé	Jan., 1961 - Dec., 1978	
Wind direction and velocity	Monthly wind direction and mean monthly velocity	- Asunción	Jan., 1986 - Dec., 1987	Shutdown
Water level of Ypacarai Lake	Mean yearly and daily water level	- San Bernardino	1965 - Feb., 1988	

TABLE S2-2 METEOROLOGICAL AND HYDROLOGICAL OBSERVATION STATIONS INSTALLED

Station No.	Name of Station	Location	Latitude & Longitude	Observation Item
1	San Bernardino Central Observation Station	Centro Militar, Naval y Aeronautico "Club de Verano" in San Bernardino City	S25° 19' 00" W57° 17' 21"	- Atmospheric temperature - Rainfall - Solar radiation - Wind direction and velocity - Water level - Water temperature
2	Ypacarai Meteorological Observation Station	Colegio Dr. Ignacio A. Pane in Ypacarai City	S25° 24' 17" W57° 17' 07"	- Atmospheric temperature - Humidity - Atmospheric pressure - Rainfall - Wind velocity
3	Aregua Meteorological Observation Station	Colegio Nacional Cadete del Chato in Aregua City	S25° 18' 59" W57° 23' 14"	- do -
4	San Lorenzo Rainfall Gauging Station	Universidad Nacional de Asuncion, Facultad de Ingenieria Agronomica in San Lorenzo City	S25° 19' 28" W57° 31' 21"	- Rainfall
5	Pirayu Rainfall Gauging Station	Colegio Politecnico Juan Pablo Segundo in Pirayu City	S25° 29' 12" W57° 14' 18"	- do -
6	Paraguari Rainfall Gauging Station	Colegio Nacional de Paraguari in Paraguari City	S25° 37' 22" W57° 08' 39"	- do -
7	Ypacarai Lake Water Level Gauging Station	- Same as Station No. 1 -		- Water level; automatic
8	Yagua-resa-u River Water Level Gauging Station	Bridge of Route-2 crossing Yagua-resa-u River	S25° 23' 18" W57° 16' 11"	- do -
9	Yuquyry River Water Level Gauging Station	Bridge of Route Luque-Aregua crossing Yuquyry River	S25° 17' 32" W57° 26' 48"	- do -
10	Salado River Water Level Gauging Station	Bridge of Route Limpio-San Ber. crossing Salado River	S25° 07' 48" W57° 26' 50"	- do - (Shutdown on June 7)
11	Ypucu River Water Level Gauging Staff	Bridge of Route-2 crossing Ypucu River	S25° 23' 24" W57° 16' 29"	- Water level; manual (Discontinuous observation)
12	Salado River Water Level Gauging Staff	Bridge of Route Luque-San Ber. crossing Salado River	S25° 12' 24" W57° 22' 22"	- do -

Table S2-3 WATER LEVEL OF YPACARAI LAKE

Unit : m

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1965	-	-	-	-	-	-	-	-	-	-	-	-	1.18
1966	-	-	-	-	-	-	-	-	-	-	-	-	1.14
1967	-	-	-	-	-	-	-	-	-	-	-	-	1.00
1968	-	-	-	-	-	-	-	-	-	-	-	-	0.79
1969	-	-	-	-	-	-	-	-	-	-	-	-	1.24
1970	1.18	1.17	1.15	1.31	1.21	1.23	1.35	1.31	1.40	1.43	1.27	1.09	1.26
1971	1.49	1.46	1.59	1.22	1.18	1.14	1.14	1.31	1.15	1.07	0.96	0.91	1.22
1972	1.17	1.13	1.07	0.86	0.82	1.22	1.20	1.11	1.15	1.15	1.29	1.30	1.12
1973	1.28	1.13	1.21	1.20	1.33	1.35	1.32	1.33	1.26	1.37	1.43	1.45	1.31
1974	1.29	1.28	1.33	1.38	1.51	1.44	1.23	1.27	1.34	1.32	1.35	1.41	1.35
1975	1.35	1.31	1.16	1.55	1.58	1.45	1.50	1.40	1.57	1.54	1.48	1.61	1.46
1976	1.42	1.46	1.50	1.42	1.39	1.34	1.24	1.22	1.16	1.19	1.22	1.07	1.30
1977	1.08	1.18	1.09	1.03	1.20	1.30	1.38	1.24	1.15	0.91	0.92	1.25	1.14
1978	-	-	-	-	-	-	-	-	0.81	0.89	1.31	1.07	1.02
1979	0.72	0.47	0.43	0.98	1.35	1.17	0.99	0.93	1.24	1.11	1.25	1.86	1.00
1980	1.11	1.11	0.75	-	0.97	1.32	1.18	1.19	1.19	1.17	1.21	1.38	1.14
1981	1.29	1.34	1.33	1.21	1.23	1.17	1.07	0.86	0.86	0.84	0.72	1.10	1.09
1982	1.27	1.13	1.11	0.97	0.89	1.00	-	1.06	0.94	1.24	1.40	1.42	1.13
1983	1.19	1.44	1.24	1.21	1.73	1.68	1.36	1.34	1.28	1.26	1.38	1.28	1.37
1984	1.10	1.11	1.01	1.40	1.38	1.31	1.27	1.17	1.15	1.13	1.41	1.42	1.24
1985	1.29	1.17	1.05	1.16	-	1.38	1.31	1.47	1.48	1.40	1.40	1.21	1.30
1986	1.10	1.11	1.10	1.46	1.57	1.45	1.46	1.43	1.35	1.44	1.33	1.53	1.36
1987	-	-	1.50	1.59	1.67	1.56	-	-	1.42	-	-	-	1.54
1988	1.96	1.70	-	-	-	-	-	-	-	-	-	-	-
Average	1.25	1.22	1.15	1.25	1.31	1.32	1.27	1.23	1.22	1.22	1.25	1.29	1.20

Note: 1) The water level has been observed at San Bernardino by the Navy.
 2) The elevation of 0m of the staff is 62.29m.

Table S2-4 Precipitation in January, 1988

<u>ASUNCION</u>		<u>CAACUPE</u>		<u>CARAPEGUA</u>	
<u>DAY</u>	<u>mm.</u>	<u>DAY</u>	<u>mm.</u>	<u>DAY</u>	<u>mm.</u>
5	12.0	5	12.4	5	9.4
12	0.6	13	153.0	13	1.5
13	79.8	14	41.0	14	77.4
14	17.4	15	2.0	16	12.6
16	13.6	16	30.0	21	22.4
21	2.4	21	0.5	22	5.5
22	0.3	22	8.8	24	6.3
30	25.4	25	9.0	25	5.6
		26	0.3	31	71.5
		30	45.0		
<u>TOTAL</u>	151.5		302.0		212.5

Table S2-5 Water Level in the Lake in January, 1988

<u>DAY</u>	<u>WATER LEVEL (m)</u>	<u>VARIATION (cm)</u>	<u>DAY</u>	<u>WATER LEVEL (m)</u>	<u>VARIATION (cm)</u>
8	1.73	± 0	20	2.54	- 2
9	1.73	± 0	21	2.30	- 24
10	1.73	± 0	22	1.90	- 30
11	1.72	- 1	23	1.85	- 5
12	1.69	- 3	24	*	*
13	1.68	- 1	25	*	*
14	2.10	+ 42	26	1.84	- 1
15	2.50	+ 40	27	1.85	+ 1
16	2.60	+ 10	28	*	*
17	2.60	± 0	29	1.84	- 1
18	2.60	± 0	30	1.83	- 1
19	2.56	- 4	31	1.82	- 1