this gives rise to lateral erosion. Furthermore, during flooding, covering by surface run-off is quick to result.

The majority of the Regosol is sediment at the bottom of the Lake consisting of transported particles resulting from the erosion of surrounding plateaus and mountains during the period when the Lake was widely expanded. The transporting of these particles still occurs daily.

The main source of supply is Paleozoic sandstone bed and its surface soil.

The 23 samples of Regosol type show a pH of 4.19-7.03, with an average at 5.20. The soil texture percentages are sand at 75-95%, silt at 5-25%, clay at less than 10%, lying within the S-LS-SL range, closely resembling lithosol and a portion of acrisol (Fig. S1.3.1, Fig. S1.3.2)

The accumulation curves resemble each other, which indicates that the grain-sized particles must be quite similar in size, in spite of such a wide distribution range.

3.3.5 Planosol

This is distributed in the zone along the Pirayu's main course, in the riverbed of the Yuquyry's main tributary and in most of the Lake's downstream swamp. The soil is silty, with a color range of blackish gray-blackish brown-grayish brown, and is located in the relatively low areas of lowland zones.

The surface layer, being of low-permeability, is rich in humus and presents, at lower points, a progressed gleization. In the lowland, north of Ypacarai, and in the Yuquyry riverbed, this is either directly excavated or mixed with "Kaolin" to produce tile and brick-making materials for ceramic products. Land is often abandoned after excavation. The land is used for pasture. During times of flooding, the land easily becomes submerged, which leads to the belief that the amount of soil loosened and washed away is large.

The 14 samples of Planosol type has a pH of 3.65-7.48, with an average of 5.02. The soil texture percentage is sand at 35-70%, silt at 35-65%, clay at 5-35%, with a relatively widely scattered range of SL-L-SiL-SiCL (Fig. S1.3.1, Fig. S1.3.2)

3.4 Investigation of the Results of the Grain Size Analysis

The grain size accumulation curve is consolidated in the soil types and is shown and estimated by average soil type, in Fig. S1.3.1.

Lithosol and Acrisol show comparatively similar curves, with an accumulation level at 40-50%, at a diameter 0.25-0.5mm (medium sand).

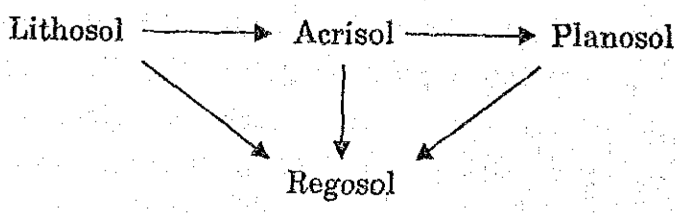
Regosol has an accumulation percentage of 60-70% at 0.1-0.5mm (fine sand-medium sand).

Planosol is accumulated at 30% at 0.01-0.05mm(silt) and at 20% at 0.1-0.4mm (fine sand-medium sand).

Based on the above, it is inferred that Lithosol and Acrisol are residual products of relatively high areas at the site, reflecting parent rock characteristics with an abundance of particles of a relatively large nucleus, however accumulated Regosol, in the process of being transported to lowlands by water, is sorted and even finer particles are washed out. Already along the water courses, transported Planosol shifts into fine silt.

As for the accumulation curve, that of Regosol is well consolidated, however those of other types are quite scattered.

Inferring from the triangulation diagram, the soil texture range for Regosol resembles the distribution range of Lithosol and a part of Acrisol, and the Planosol range, as compared to that of Acrisol, shows a decreasing sand amount and an increasing silt and clay amount. From this, the following movement process can be deduced.



The sampling points grain size distribution plotted on the soil map is extremely approximate, however the following tendencies can be seen.

(1) In Lithosol areas where there is vegetation cover, because weathered-immature soil is included, an average accumulation curve shows a tendency for a large diameter, however where the vegetation cover is poor, base rock composition is easily reflected.

(2) As for Acrisol, because the sampling point installation was biased, it is difficult to make out any tendencies. However, approximately speaking, at the top of the mountain range, more than indicated on the average curve, the fine particle distribution is large and, at the bottom, the particles are fairly coarse. That is to say, that there is a tendencey for the washing away of fine particles.

(3) Regosol, in the Pirayu basin lowland zone upstream area, more than as inferred on the average curve, is scattered and can be estimated as including various types of matters.

In the midstream area near Pirayu, it is close to the comparatively average curve and the downstream area near Ypacarai, as compared to the average curve, has a fairly coarser tendency.

That is to say, the particles sent from the surrounding sloping area, as they travel from the lowland upstream area, are sorted and, between the midstream area and the downstream area, still being sorted, there is a tendency for the finer particles to be sent into the Lake and the fairly coarse particles to be left behind.

(4) Planosol, among the four soil types, has an accumulation curve with the largest deviation. Because of this, the tendencies in the field were not definable.

To speak with extreme boldness, at the upstream area, as compared to the mean curve, is the finer side and the mid-to downstream area shows coarse particle side grain size distribution. Within the swamp, the tendencies are not very clear. As for the elements in the Yuquyry riverbed, they are nearly on the fine side.

3.5 Relationship between Landform and Soil Types

Soil types are controlled largely by the area's parent rock characteristics and topography. The relationslhip between the study area's topography and soil type is shown schematically in Fig. S1.3.3.

The Lithosol, found on the steep slopes within the plateaus and hills, and the Acrisol, found on gentle slopes, are residual soil.
In contrast to this, Regosol, found on lower slopes of hills, flood plains and valley bottom plains and Planosol, found in lowlands and marshes, are transported soil.

According to the soil particle moving accumulation process, as stated above, it is thought that soil particle movement goes in a Lithosol→Acrisol→Regosol→Planosol direction, however, this is thought to include both daily moving sediment (gradually going from upstream to downstream, in the order of coarse - fine particle sediment) and flooding period moving sediment (coarse particle moving sediment until downstream area). Even for the final coarse composition of the soil (Planosol) in the Lake lowland, combining the daily material and that during flooding, the tendencies are seen to vary largely.

CHAPTER 4

FUTURE OBJECTIVES

In this S/R-1, the various surveys carried out for the understanding of the natural environment in the basin were discussed. However, ample conclusions, due to time and human limitations as well as traffic accessibility, were not achieved, thus showing the necessity of future supplementary surveys. Apart from these, through this survey, there arose many more objectives proving clearly necessary for the future. In the following, these objectives have been consolidated and explained, strongly put forth for henceforth successive execution.

(1) LANDSAT False Color Image Analysis

According to the analog and the digital analysis of the LANDSAT false color image, the ability to obtain unified, accurate, specific data on the surface of wide areas is well known, and already even in Paraguay applied results are being obtained. *1

In this study, monochrome airphoto interpretation techniques were applied to geology, soil, vegetation and land use surveys and results on each were obtained. However, for the monochrome, as the present transport accessibility was insufficient, there are aspects where sufficient covering could not be accomplished. This weak point is supplemented by application of LANDSAT images which is extremely effective in attempting to grasp the relative differences in hard-to-understand land surface, subsurface strata moisture contents, the vitality degree of vegetation and the large geotectonic structure. As suitable ground truth has already been obtained in this study, extremely speaking, a more accurate soil map, relative hydration map, vegetation map, vegetation activity map and land use map could be obtained without carrying out a field survey but rather only by indoor work.

These maps would offer vital information when considering vegetation distribution, erosion control and proper location for the drawing up of a synthetic regional protection plan.

*1 LAND CONDITION STUDY

for the master plan on the irrigation and drainage project in the adjacent area to the YACYRETA DAM 1984

MINISTRY OF AGRICULTURE AND LIVESTOCK

JAPAN INTERNATIONAL COOPERATION AGENCY

(2) Topographic Map Modification Plotting

The 1/50,000 topographic map used in this study was based mainly on aerial photographs dating from 1965-1978 and plotting done in 1970.

From that point to the present, many basin changes-especially land use forms and city transformations- have come about, and needless to say, are not indicated on the topographic map. Especially, the roads, micro-topography, land classification and vegetation have not been sufficiently expressed.

For this study's use, roads have been supplemented by possible ranges, however not sufficiently enough.

From now on, in order to devise water quality preservation in the basin, drawing up basic land use plans and land preservation plans will be a prerequisite, however the foundation for that will be a topographic map which accurately illustrates the present conditions.

It is possible to accomplish the modification plotting by using the 1/40,000 monochrome photographs taken during this study (Feb. 1988). However, it is also possible to use color photographs taken more recently to obtain even more detailed information.

Especially, in this region with its low flatland and gentle slopes, at the time of devising new plans, minute topographic expression is necessary, thus leading to hopes of making even smaller spaces between the contour lines.

The completion of the topographic map is the nucleus of the national plan and if the present collective modification plotting for the Asuncion metropolitan area is done, effects will be extremely large.

(3) Soil Survey

In this study, from the point of view of the soil as supply source of the "Lake pollution", rough soil classification and a survey on physical properties were carried out, as opposed to say, a soil survey from the point of view of the farming and forestry industry.

As a part of the coming water quality preservation policy, it is necessary for basic and proper land use plans to be established.

Especially as soil erosion control, prevention of inflowing sand into the Lake, proper establishment and land vitality restoration and maintenance for forests and farmland will most likely be very important items, there will arise the problem of forest function restoration and proper crop selection according to proper vegetation species. As a base, it is necessary to profoundly grasp the land production characteristics.

In order to do this, it is necessary to accompany the survey conducted in this study, from the considered point of view regarding the forest and farming industries, and other development industries with a land classification survey including chemical aspects. Accompanied also by LANDSAT image analysis would be even more effective.

In this study, participation from the proper counterpart was not attained and, on top of this, it was forbidden to carry the essential soil in to Japan, thus it can't be said that sufficient results were obtained. In the next study, these points will be improved upon and, by the installment of a soil laboratory in Paraguay, along with a suitable amount of people from mainly Agriculture School of Asuncion National University, it is hoped that the execution will follow closely the set out plan.

(4) Groundwater Survey

The most immediate and important issue for the Lake and its basin, is the assurance of potable water. One of the largest objectives of the water quality preservation plan is the guarantee of the water for drinking purposes. In regarding the surface water amount and the water quality, henceforth the development of groundwater is the most important measure.

In this geologic survey, by surface survey and photo-interpretation, only a summary of the basin formation geology was grasped and important problems still remain unsolved concerning sub-geologic structure judgments prescribing Lake formation mechanisms and future change tendencies and basin groundwater existence possibilities.

Especially, as alluvial deposits and water plants cover the central plain upstream in the Lake and the swamp in the downstream, it was difficult to obtain much information from the surface survey.

Here as basic content of the groundwater survey, the execution of the following surveys is strongly recommended.

- Survey of the existing shallow wells
  (seasonal groundwater level, water quality analysis, electric conductivity, etc.)
- Electric prospecting (Resistivity method) about 1Km mesh.
- Drilling survey (150~300m/hole, about 3,000m in total)
- Pumping test

For the depth and location of drilling, the LANDSAT image, the SENASA drilling data , surface geological survey results were used for reference and the electrical prospecting will most likely be included as well.

Furthermore, this drilling will help to clarify scientific matters such as the sub-geologic stratigraphy, geostructure and subsurface resources (ceramic material, rock resource material), which is considered an important contribution to Paraguay national geological survey research.

(5) Lake-bottom Deposit Survey

There are many unclear aspects concerning the Lake's natural environment.

Questions are raised regarding the Lake's formation mechanism, changes following formation, sedimentation speed, chemical, physical and biological properties of sediment, clay mineralogy characteristics, pollutant properties and behavior and sand balance.

In particular, to know the sedimentation speed is of great importance in determining the lifespan of the Lake and, accordingly, the usage limitations concerning water supply and is also a problem extending to the root of water quality preservation measures.

Above-water drilling and columnar bottom sampling should be carried out in 2-3 places, and by the C^{14} method measurement to determine the age of the sediment would be performed. It would be good if this drilling were linked to groundwater survey.

(6) Soil Erosion Amount Survey

The surface soil erosion in the Lake and its basins advances normally by various types. Especially remarkable is that found on the left bank of the Pirayu, on the Lake's west bank and throughout the entire Yuquyry basin.

The cause for this is probably mainly forest clearing and farming and housing development in sloping areas. However, soil discharge, other than being a factor in decreasing farm production, it also aids in the shortening the lifespan of the Lake as it is a cause for sand inflowing and outflowing to and from the Lake.

Moreover, on a macroscopic worldwide scale, it is a factor in the problem of advancing desertification, which will pose a danger in the near future for South American countries such as Chile, Bolivia and the western part of Paraguay.

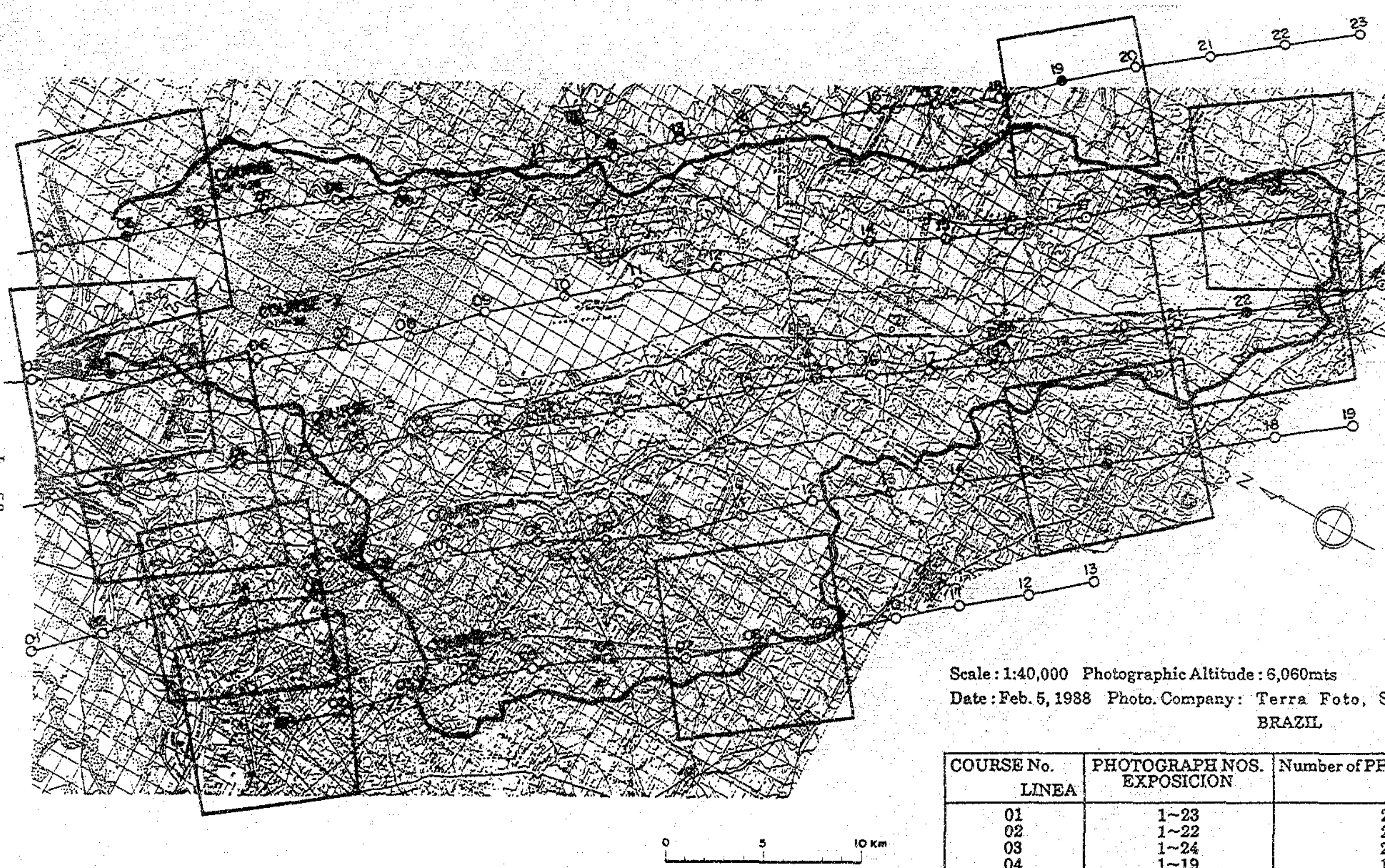
In this basin, to understand the yearly amount of erosion and that entering and exiting the Lake is, of course, a central aspect in water quality preservation and sand discharge measures.

In this basin, it is hoped that by thinking about soil, geology and erosion type, the yearly discharge amount can be learned and thus, proper discharge prevention measures can be applied.

However, as an physical problem, in order to succeed in the above, proper facilities, survey periods and organization are necessary for, as of yet, credible data has been difficult to obtain.

Accordingly, here in the final report for the project, as linked to proposed environmental protection education, the people of the country are requested to understand the gravity of the discharge problem, which could be taught through lectures, appeals and continuous PR.

FIGURES



Scale : 1:40,000 Photographic Altitude : 6,060mts

Date : Feb. 5, 1988 Photo. Company : Terra Foto, SAO PAULO, BRAZIL

COURSE No. LINEA	PHOTOGRAPH NOS. EXPOSICION	Number of PHOTOGRAPHS
01	1~23	23
02	1~22	22
03	1~24	24
04	1~19	19
05	1~13	13
		Total 101

Fig. S1.1.1 Index Map of Airphotographs

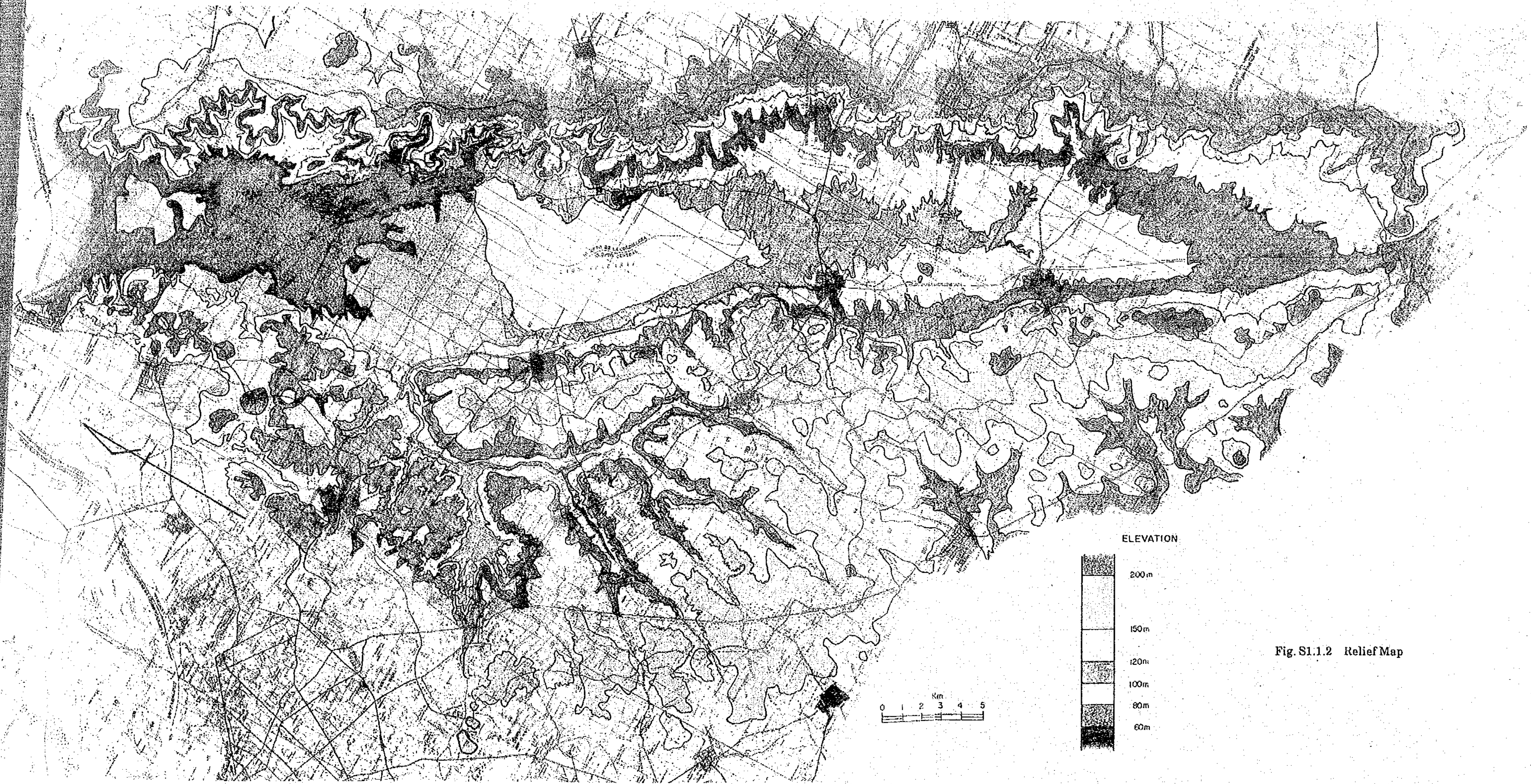


Fig. S1.1.2 Relief Map

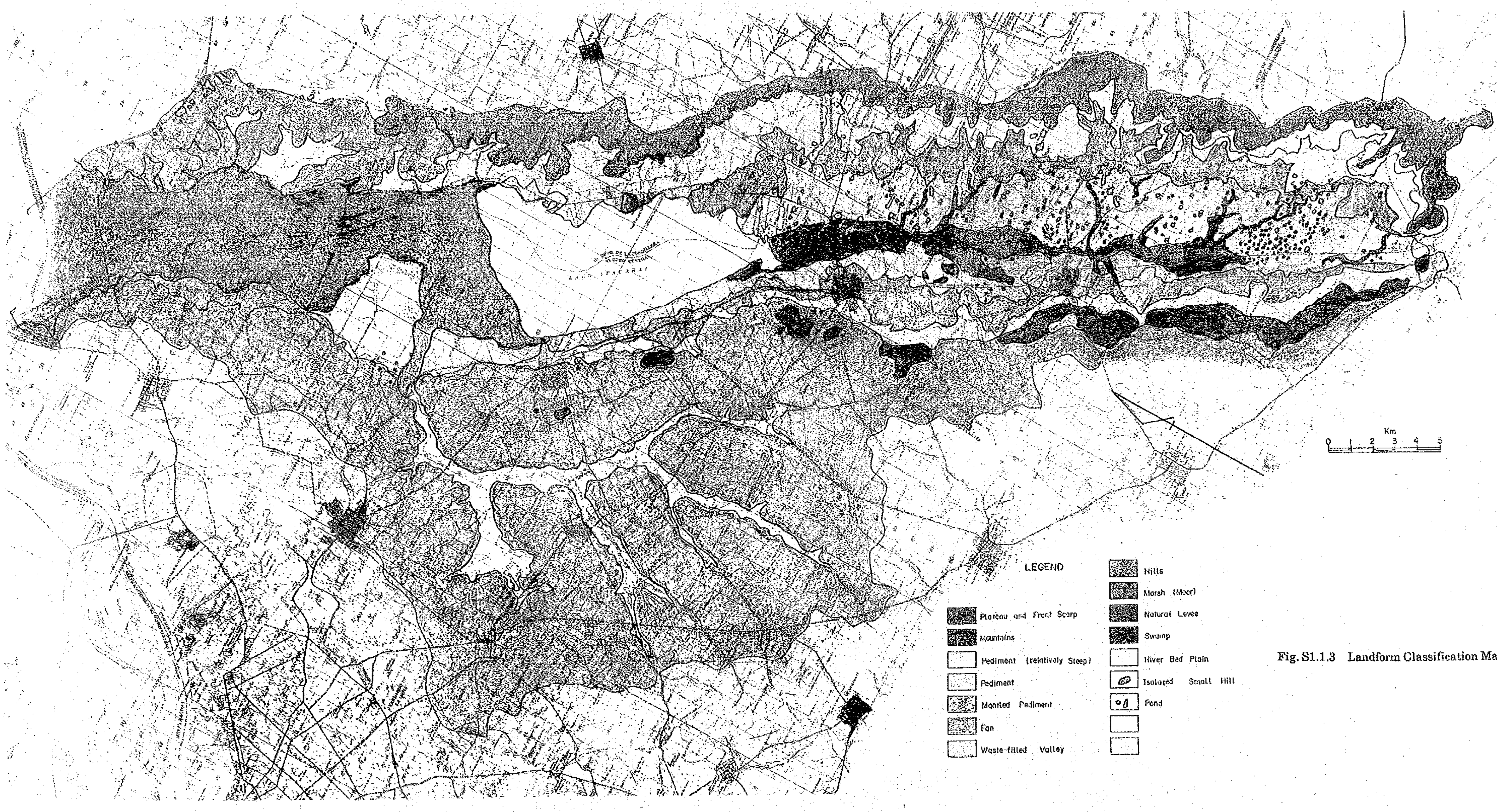


Fig. S1.1.3 Landform Classification Map

Fig. S1.1.4 Map showing Drainage System of the Lake Yp

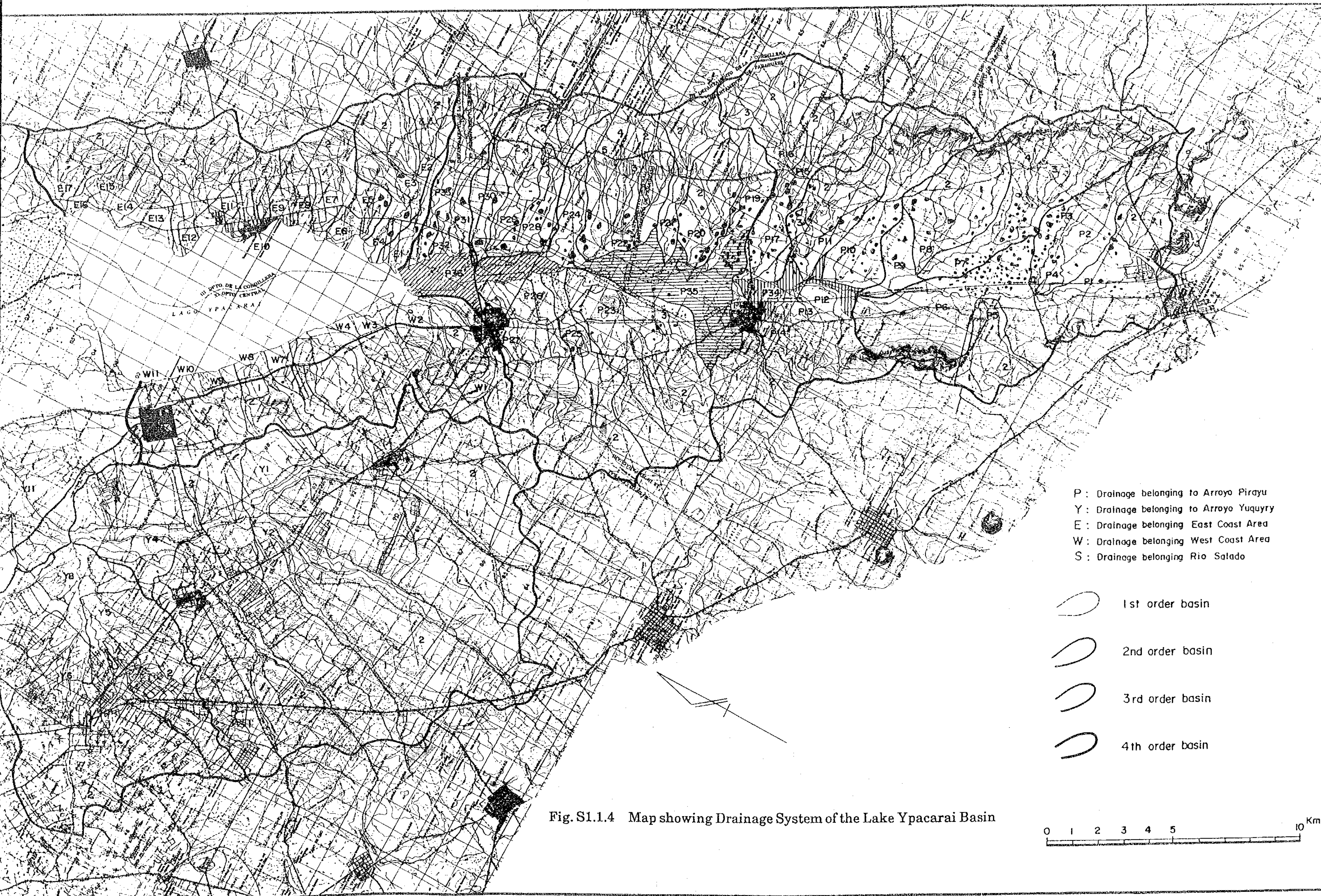


Fig. S1.1.4 Map showing Drainage System of the Lake Ypacarai Basin

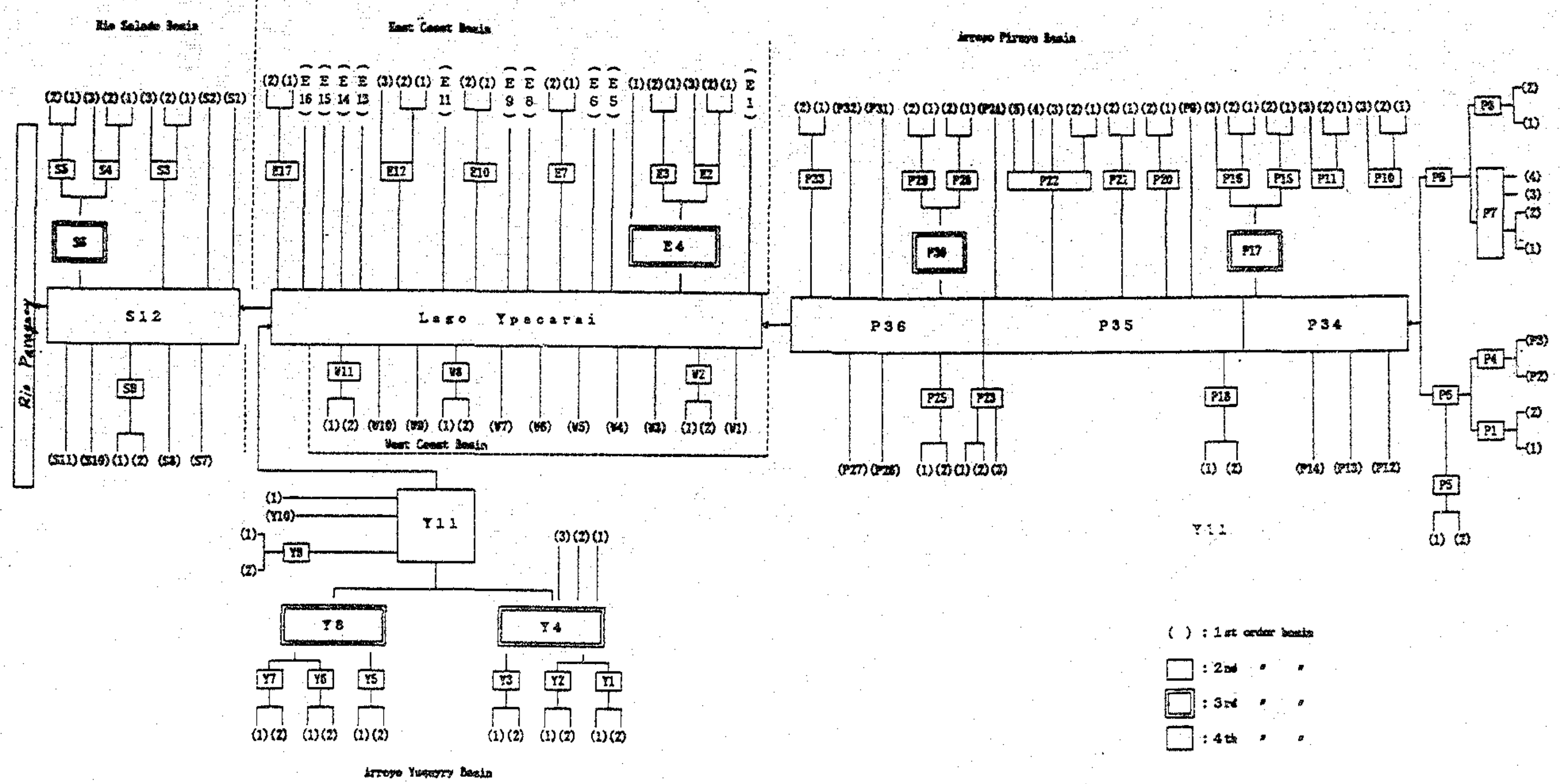


Fig. S1.1.5 Schematic Figure showing Drainage System of the Lake Ypacarai Basin

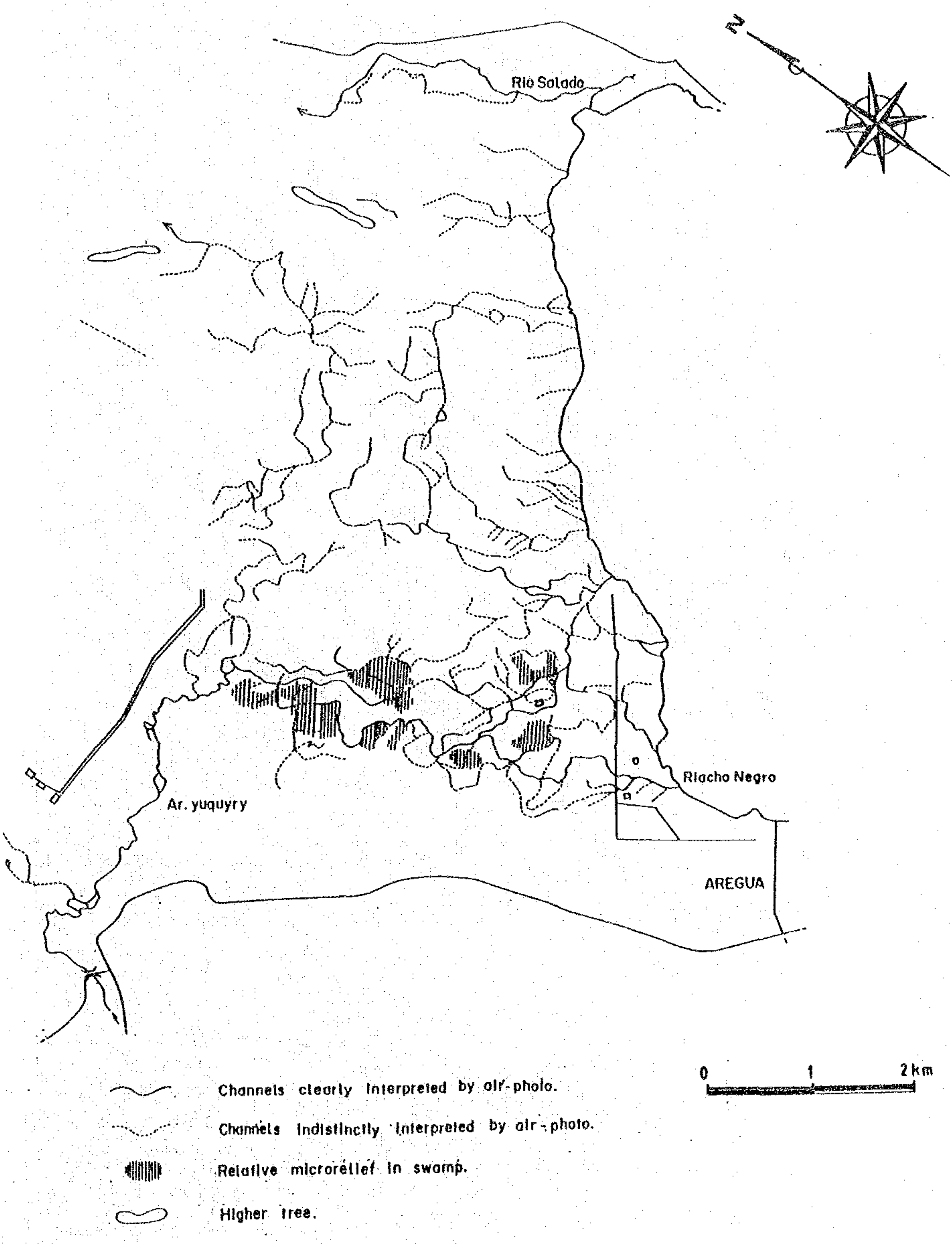


Fig. S1.1.6 Airphoto-interpretation Map of Lower Stream Area of the Yuquyry River

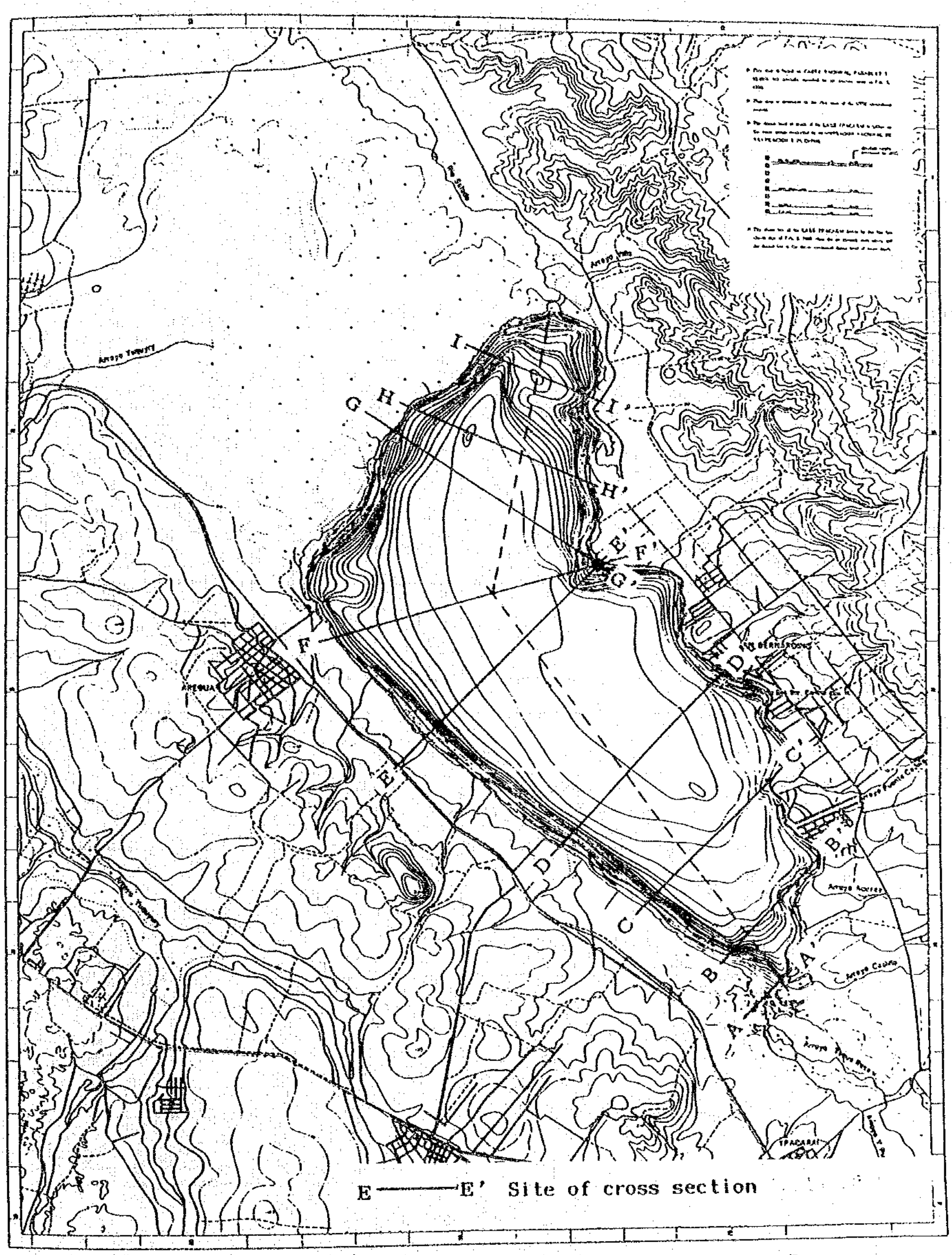


Fig. S1.1.7 Bathymetric Chart of Lake Ypacarai

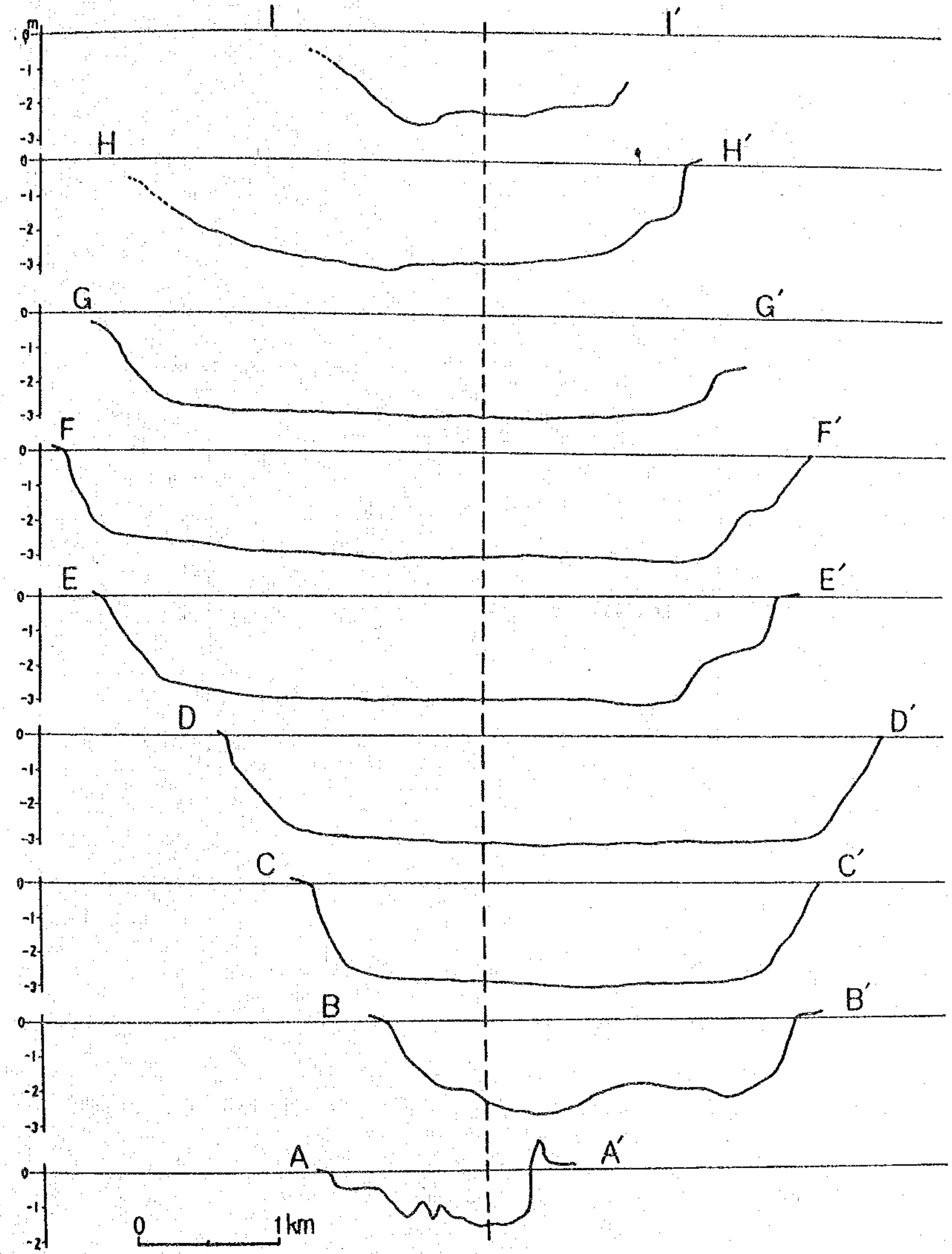


Fig. S1.1.8 Cross Section of Lake Ypacarai

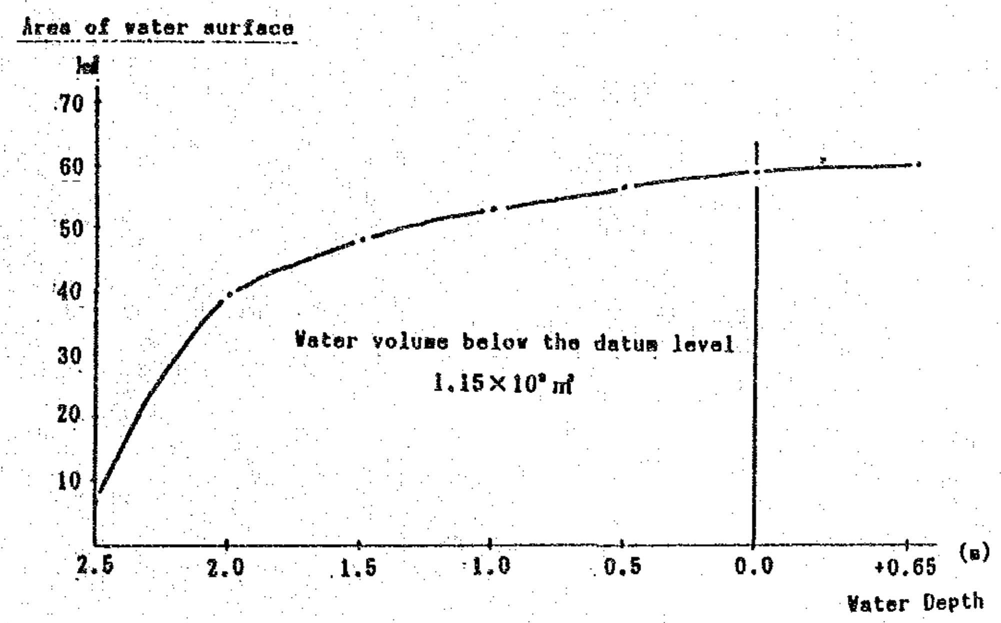


Fig. S1.1.9 Relation between Water-depth and Area of Lake Ypacarai

Fig. S1.1.10 Bottom Materials of Lake Ypacarai