Figures

LEGEND

- METEOROLOGICAL STATIONS (CLOSED)
- METEOROLOGICAL STATIONS (OPERATED)
- METEOROLOGICAL STATIONS (RECOMMENDED)
- HYDROLOGICAL STATIONS (CLOSED)
- HYDROLOGICAL STATIONS (OPERATED)
- HYDROLOGICAL STATIONS (RECOMMENDED)

77°10′ 77°00′ 76°50′ 76°40′ 76°30′ 76°20′ 76°10′

11°30′ 11°40′ 11°50′ 12°00′ 12°10′

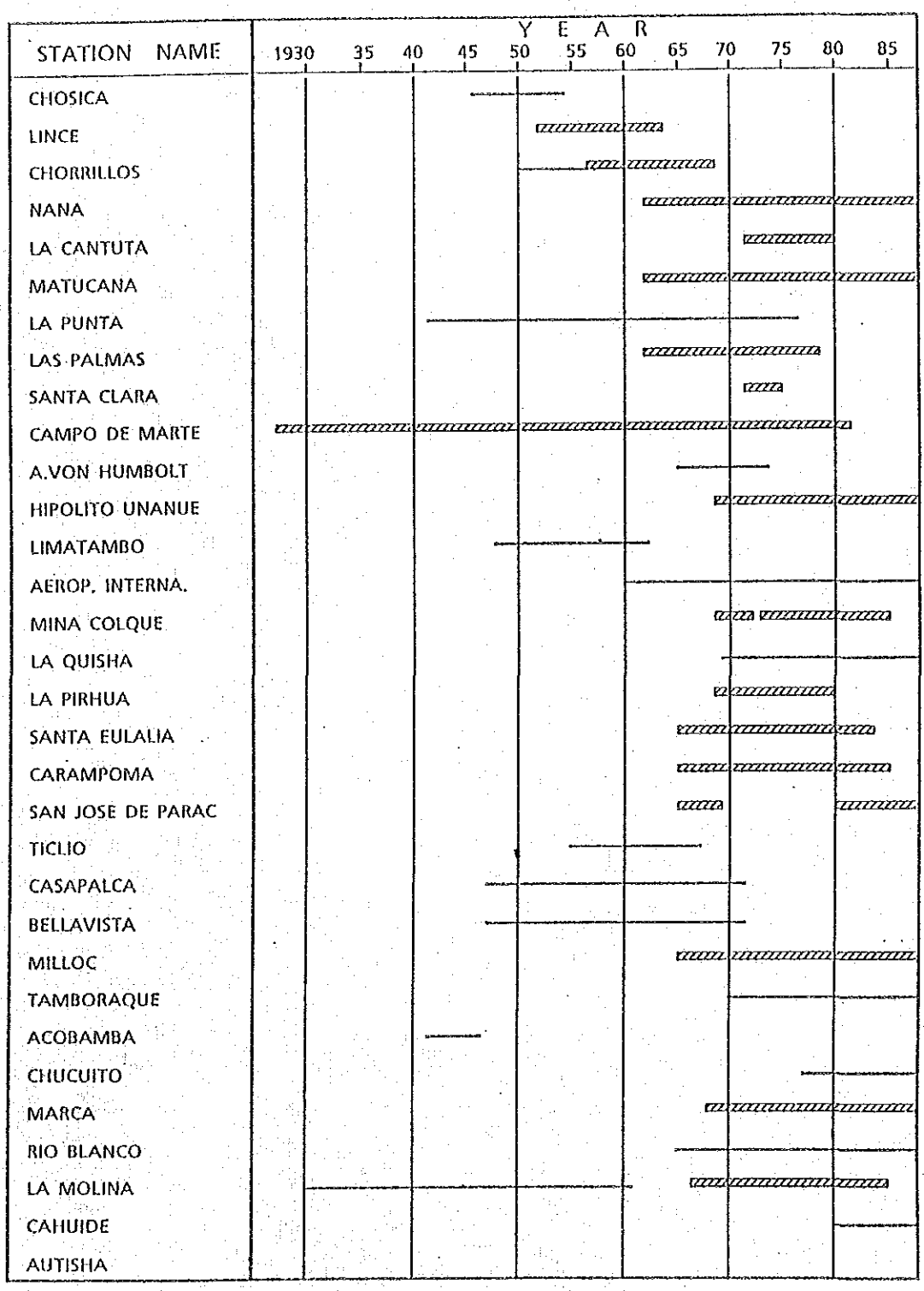
N

Acobamba
La Quisha
Carpa
Milloc
Mina Colque
Milloc
Ticlio
Casapalca
Carampoma
Shuncha
Sheque
Bellavista
La Pirhua
Chicla
Rio Blanco
Autisha
San Mateo
Rio Blanco
Tamboraque
San Jose de Parac
Tamboraque
Canchacalla
Yuracmayo
Matucana
Surco
RIO STA. EULALIA
Santa Eulalia
Cocachacla
Chosica
Chosica
Chacrasand
La Cantuta
Yanacoto
Chaute
Pte Los Angeles
Huampani
Nana
RIO RIMAC
Puente Piedra
Aerop International
Limatambo
Pte Huachipa
Cahuide
Santa Clara
Desmbocadura
Campo de Marte
La Punta
Lince
A.Von Humbolt
Hipolito Unanue
Chucuito
Lima
La Molina
Las Palmas
PACIFIC OCEAN
Chorrillos

0 4 8 12 16 20 Km

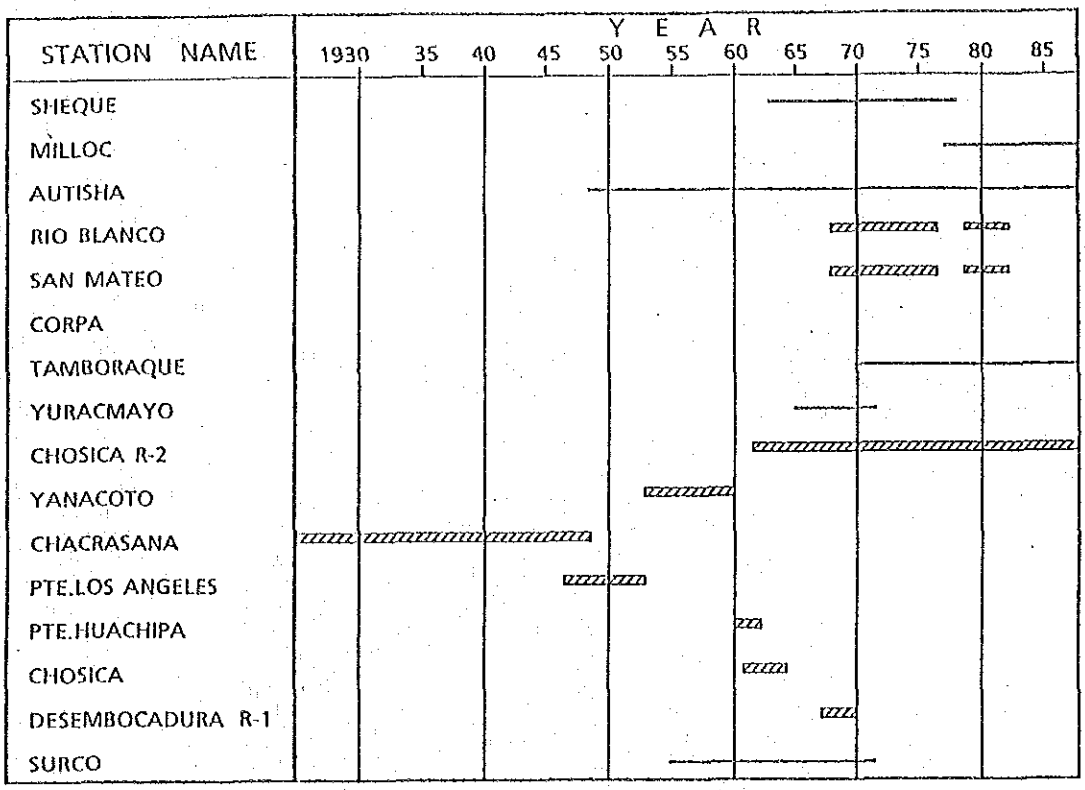
Fig. II - 1 - 1 Meteorological and Hydrological Stations in and around the Rimac River Basin

Fig.II-1-2 Period of Available Rainfall Record



Remarks: ▨:Daily rainfall data available

Fig.II-2-1 Period of Available Discharge Data



Remarks: ▨:Mean daily discharge data available

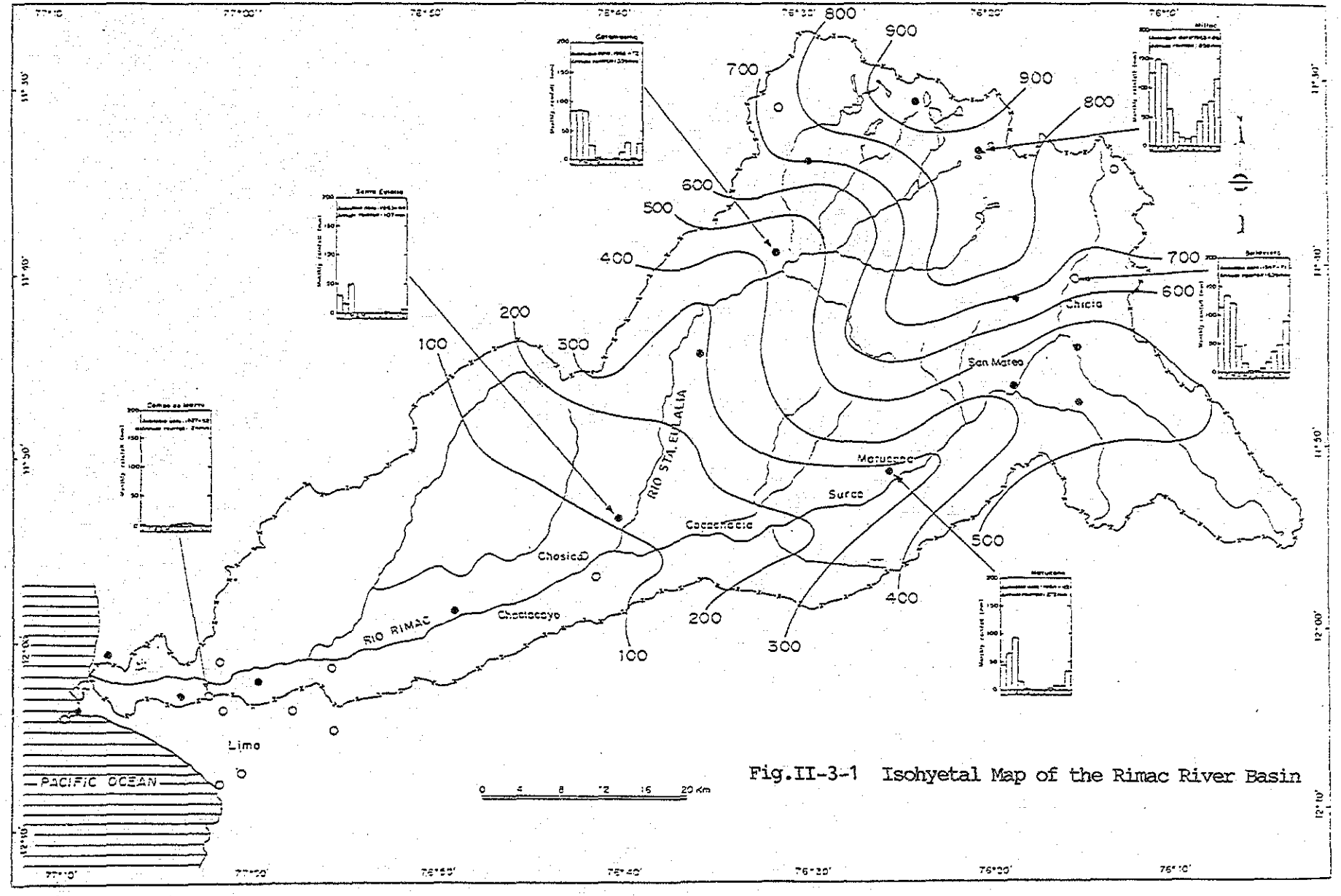


Fig.II-3-1 Isohyetal Map of the Rimac River Basin

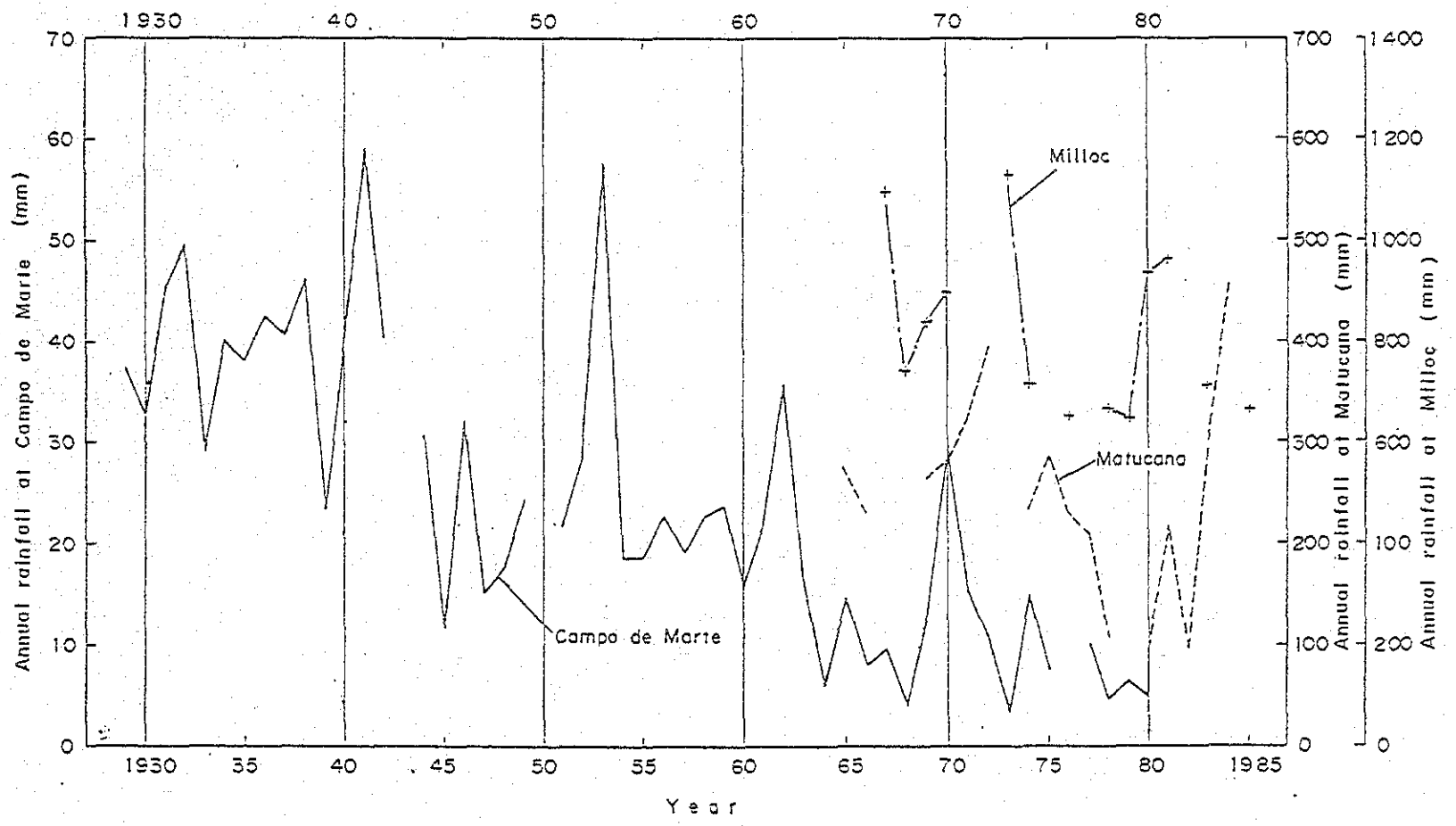


Fig.II-3-2 Annual Precipitation Record in the Rimac River Basin

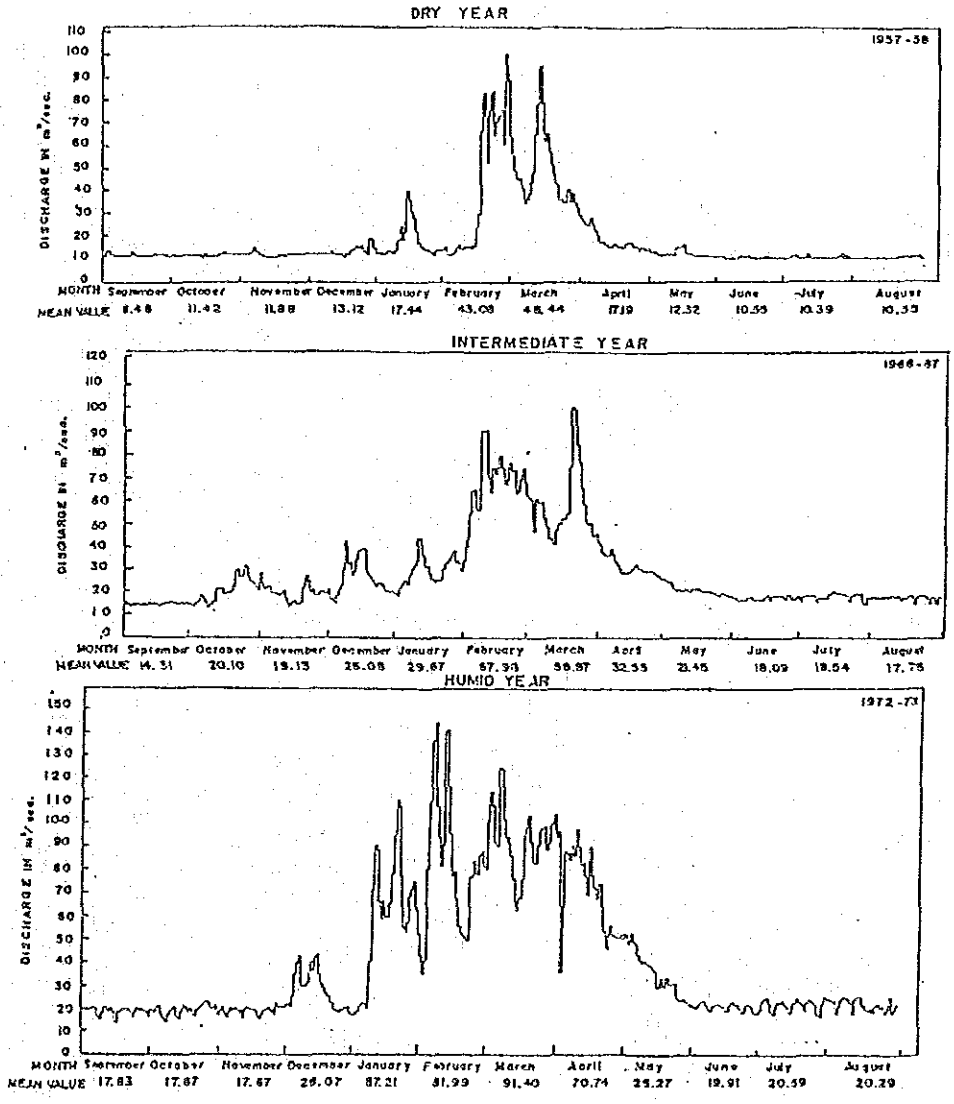


Fig.II-4-1 Hydrolographs in Characteristic Hydrological year at Chosica

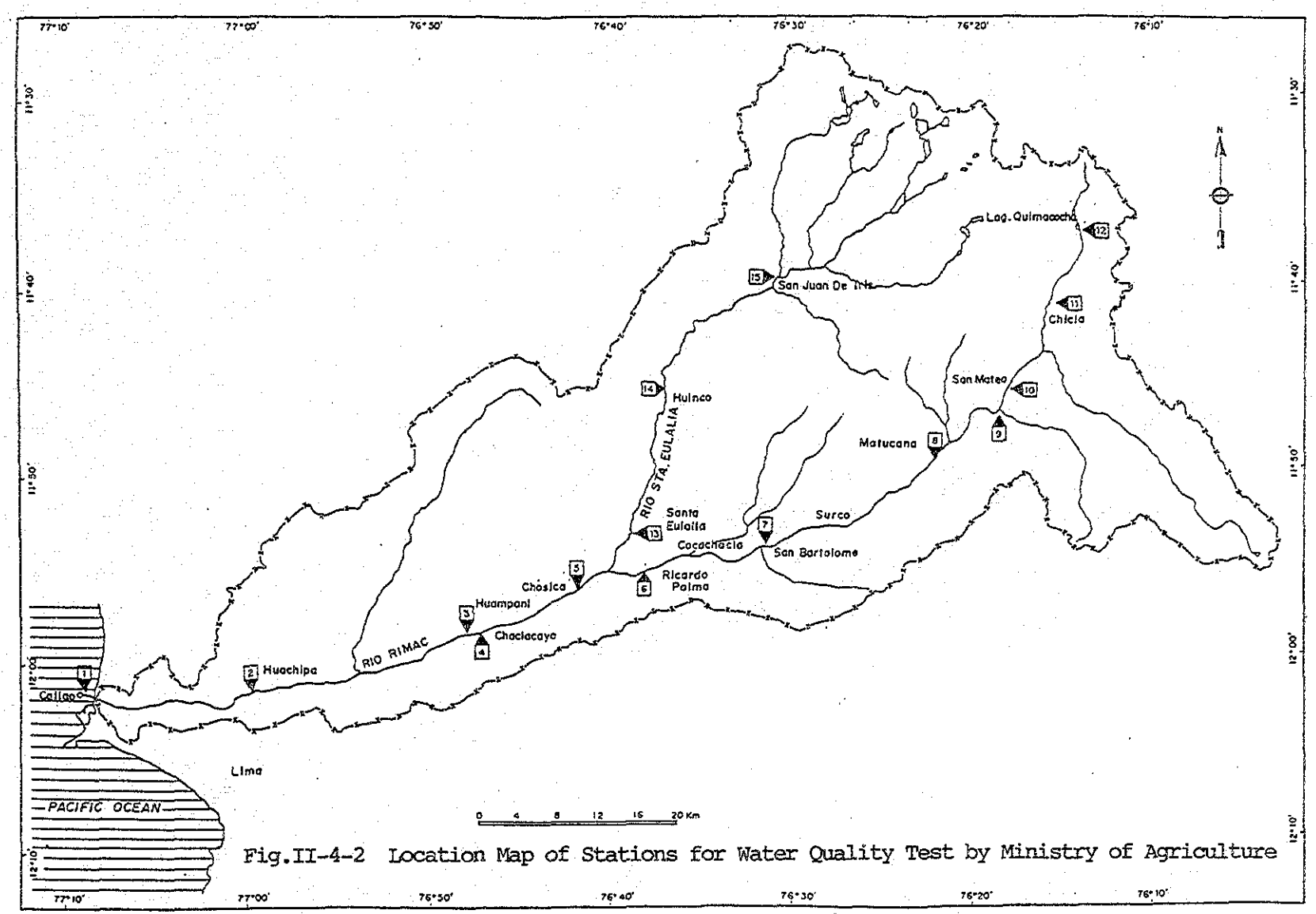
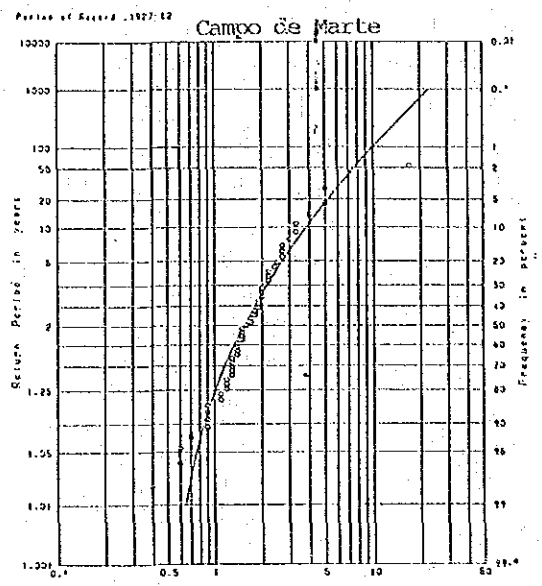
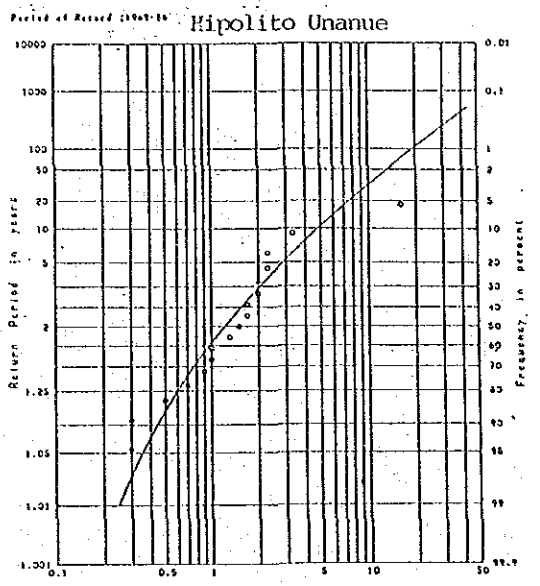
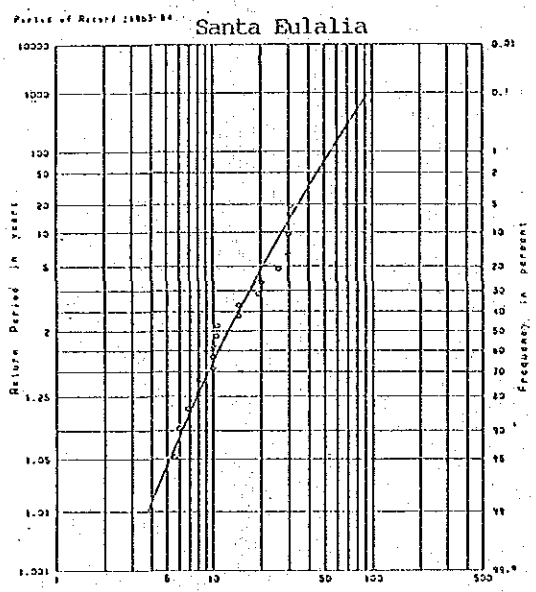


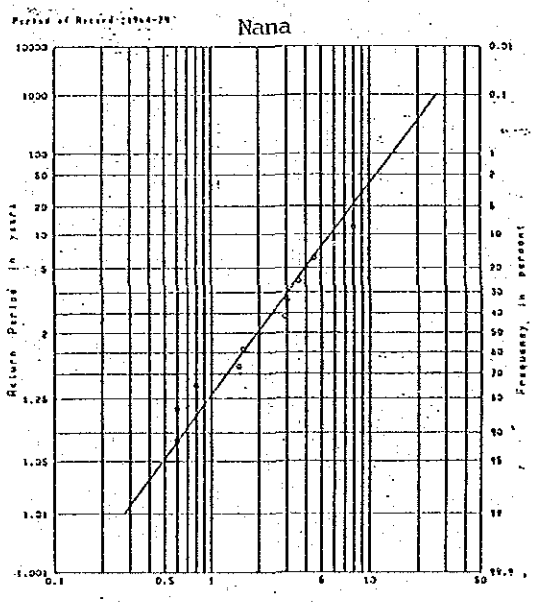
Fig.II-4-2 Location Map of Stations for Water Quality Test by Ministry of Agriculture

Fig.II-5-1 Frequency Curve of Annual Maximum 1-day Rainfall (1/2)









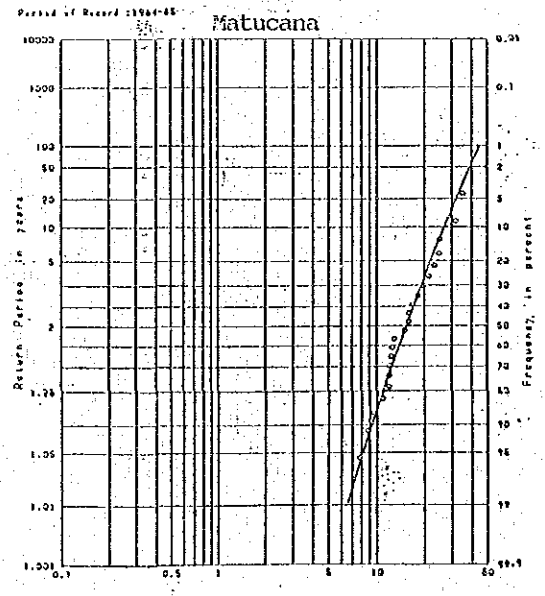
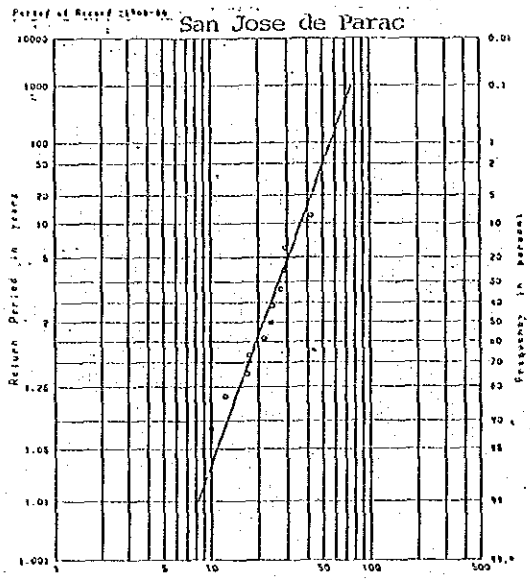
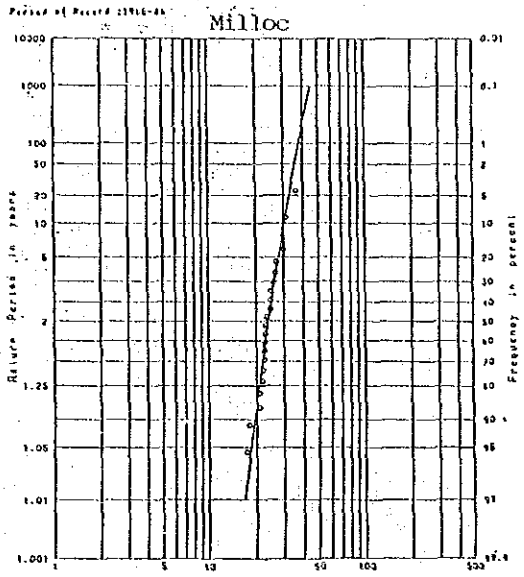
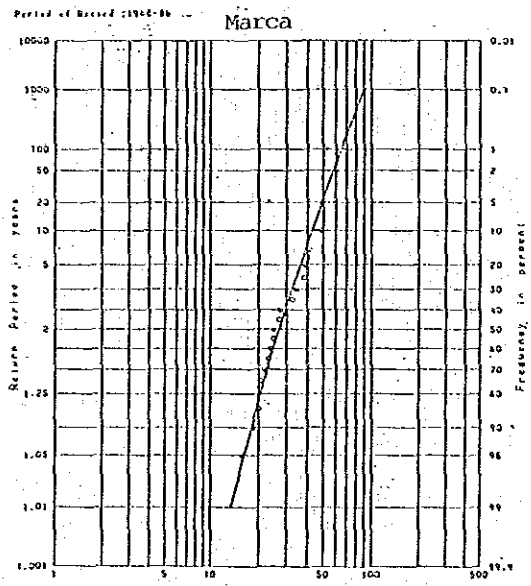
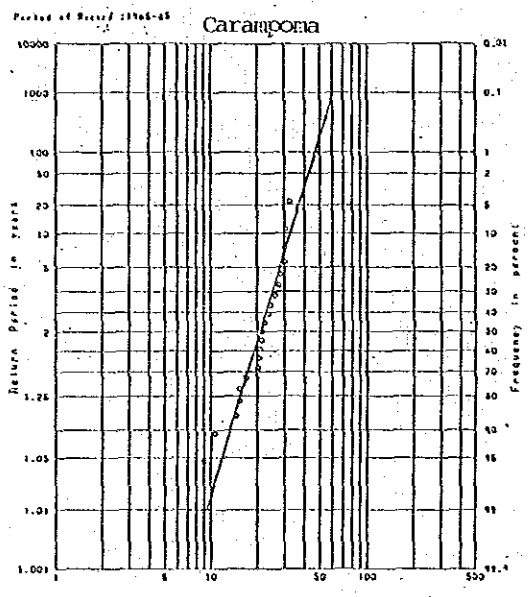


Fig.II-5-1 Frequency Curve of Annual Maximum 1-day Rainfall (2/2)









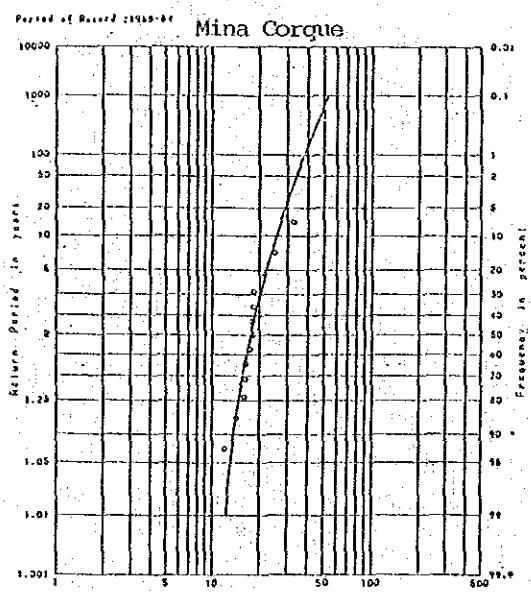


Fig.II-5-2 Probable Rainfall - Altitude Relationship (1/2)

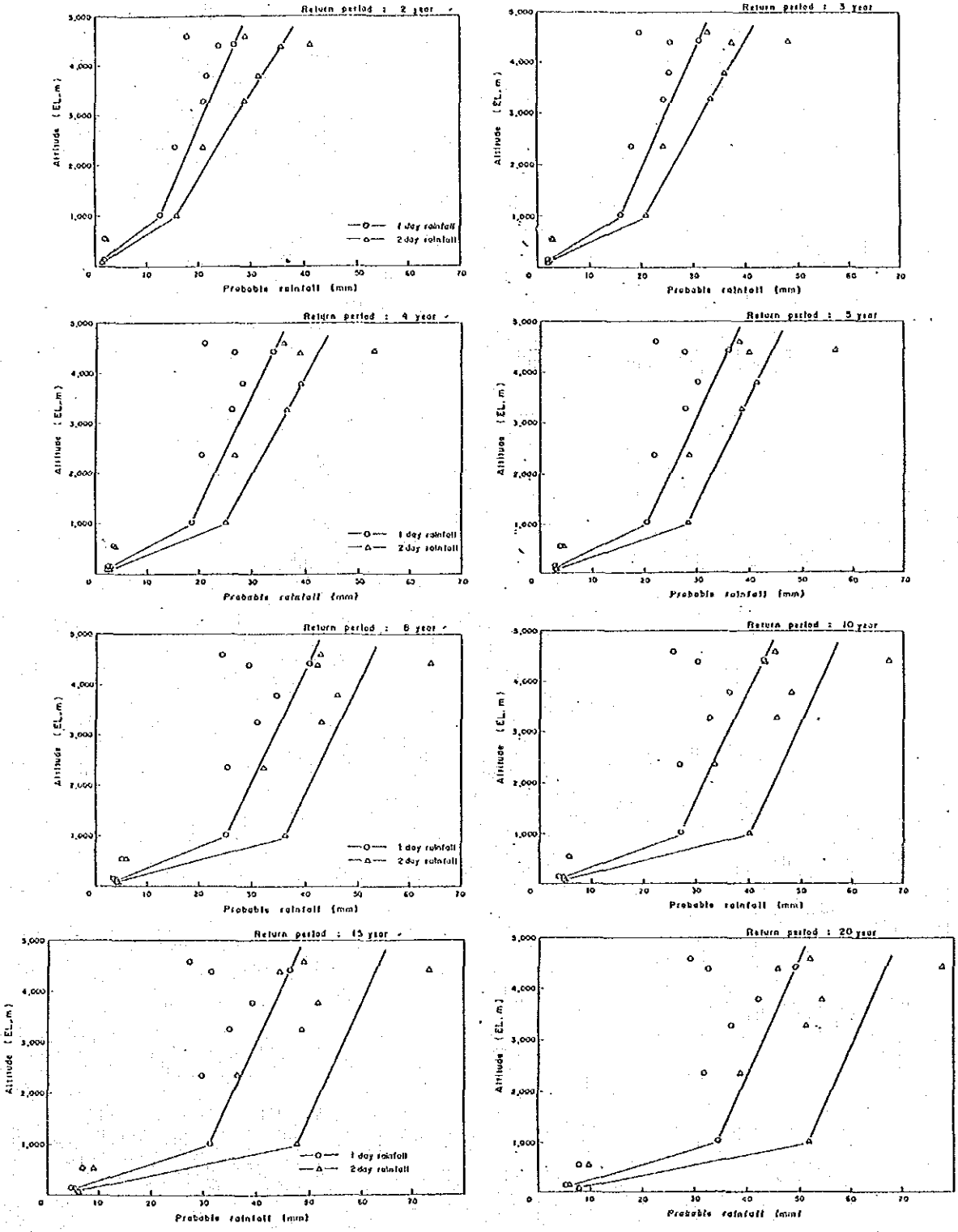
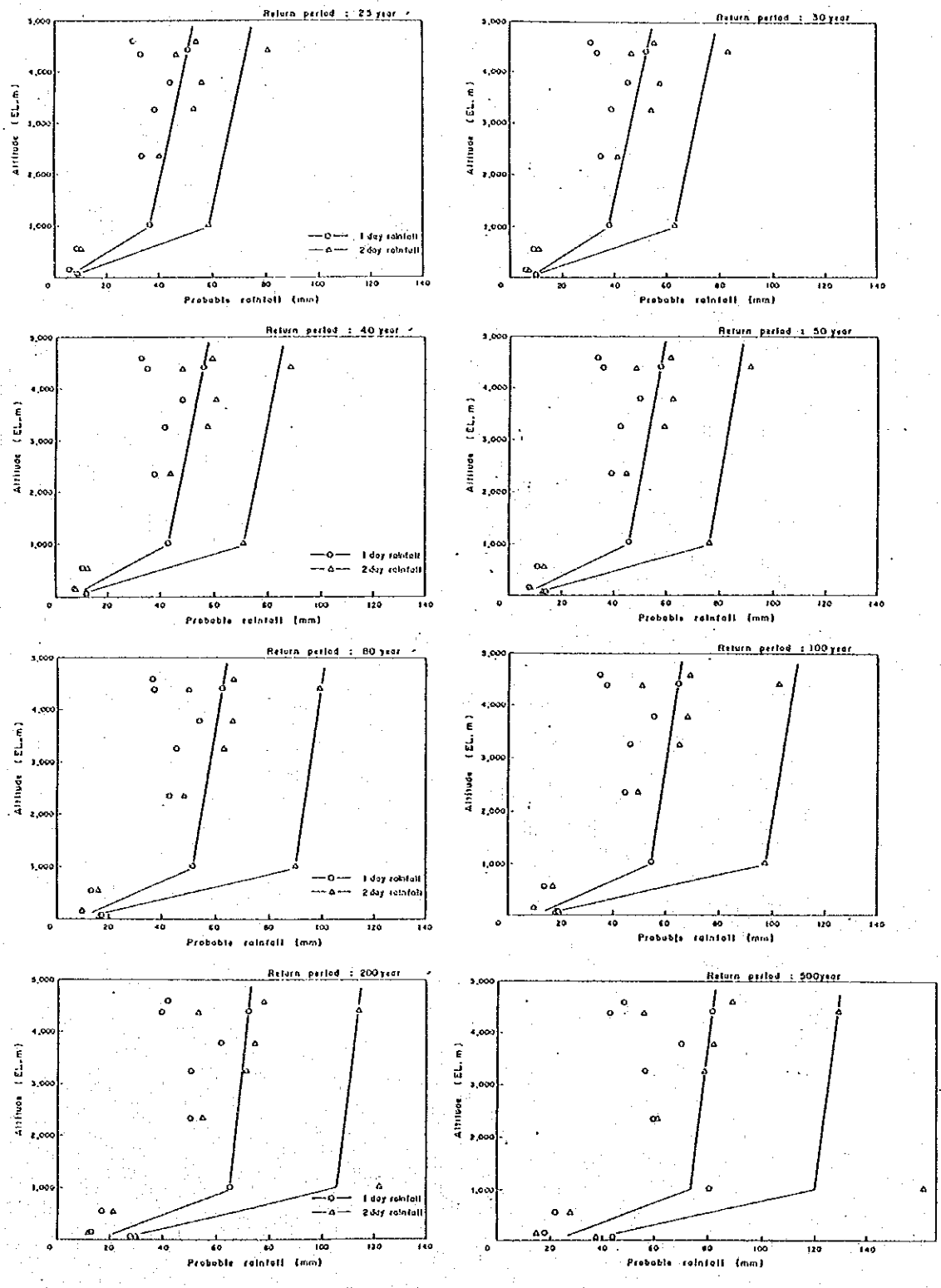


Fig.II-5-2 Probable Rainfall - Altitude Relationship (2/2)



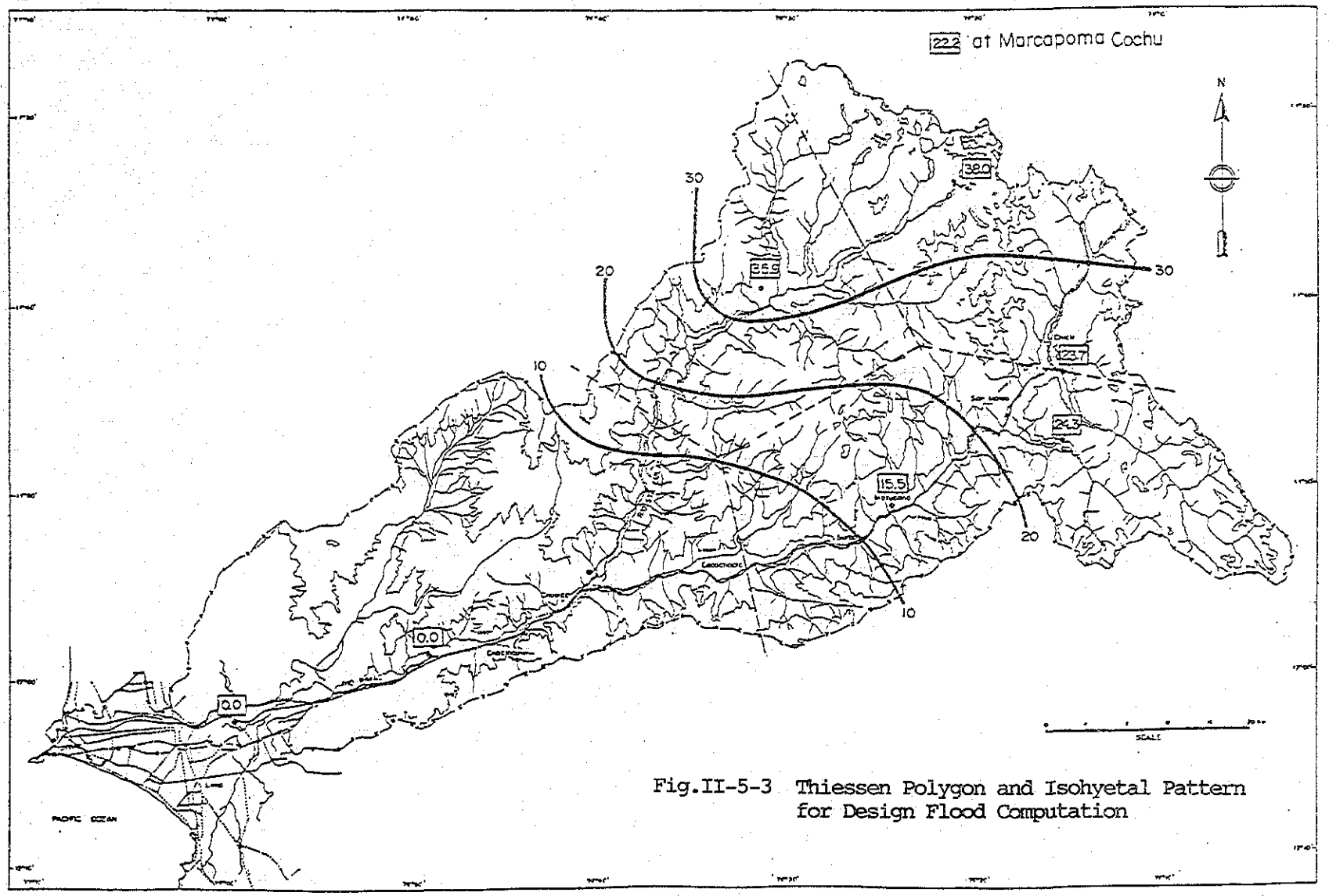


Fig.II-5-3 Thiessen Polygon and Isohyetal Pattern for Design Flood Computation

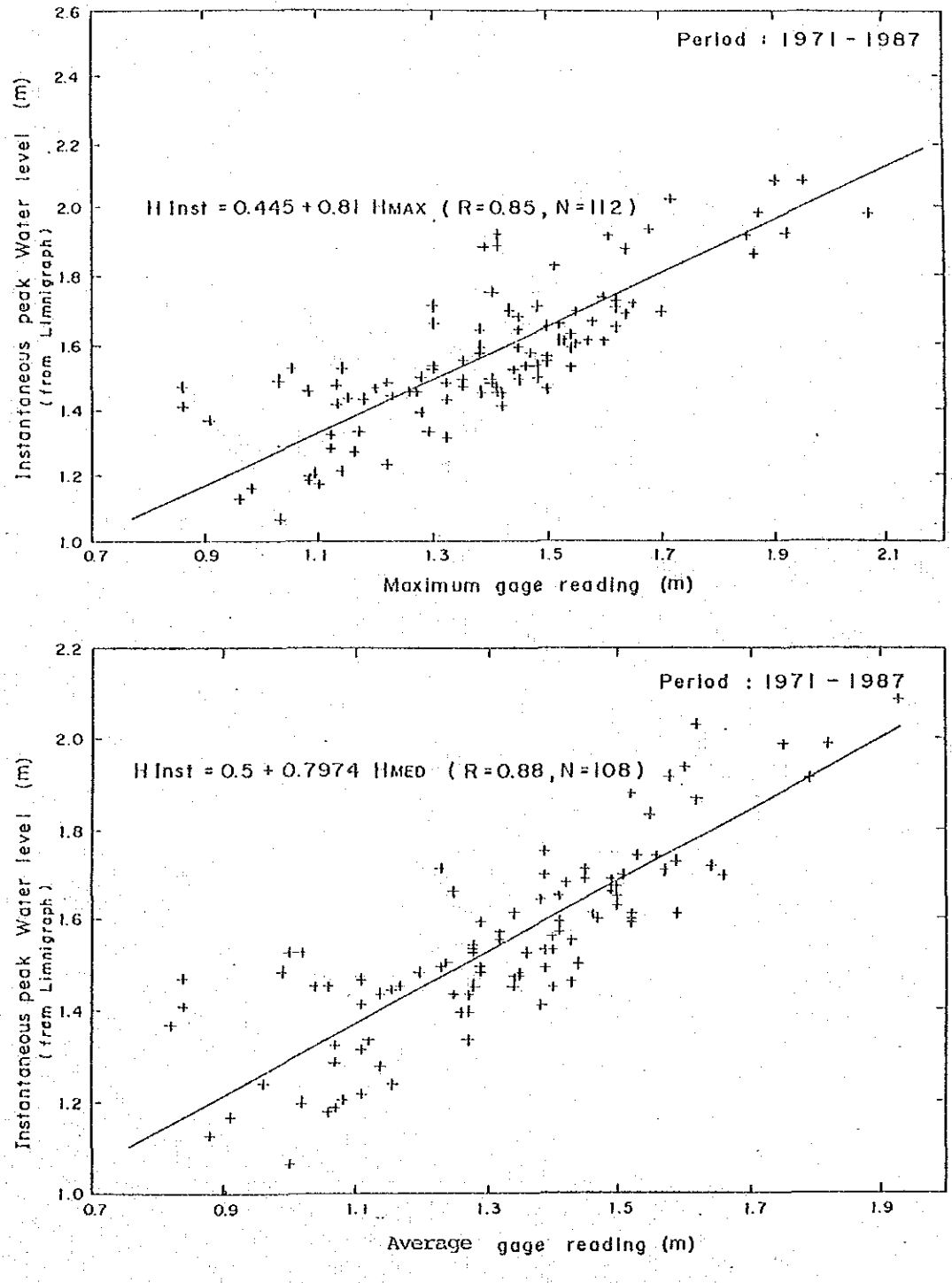


Fig.II-6-1 Relationship between Gage Reading Record and Instantaneous Peak Water Level

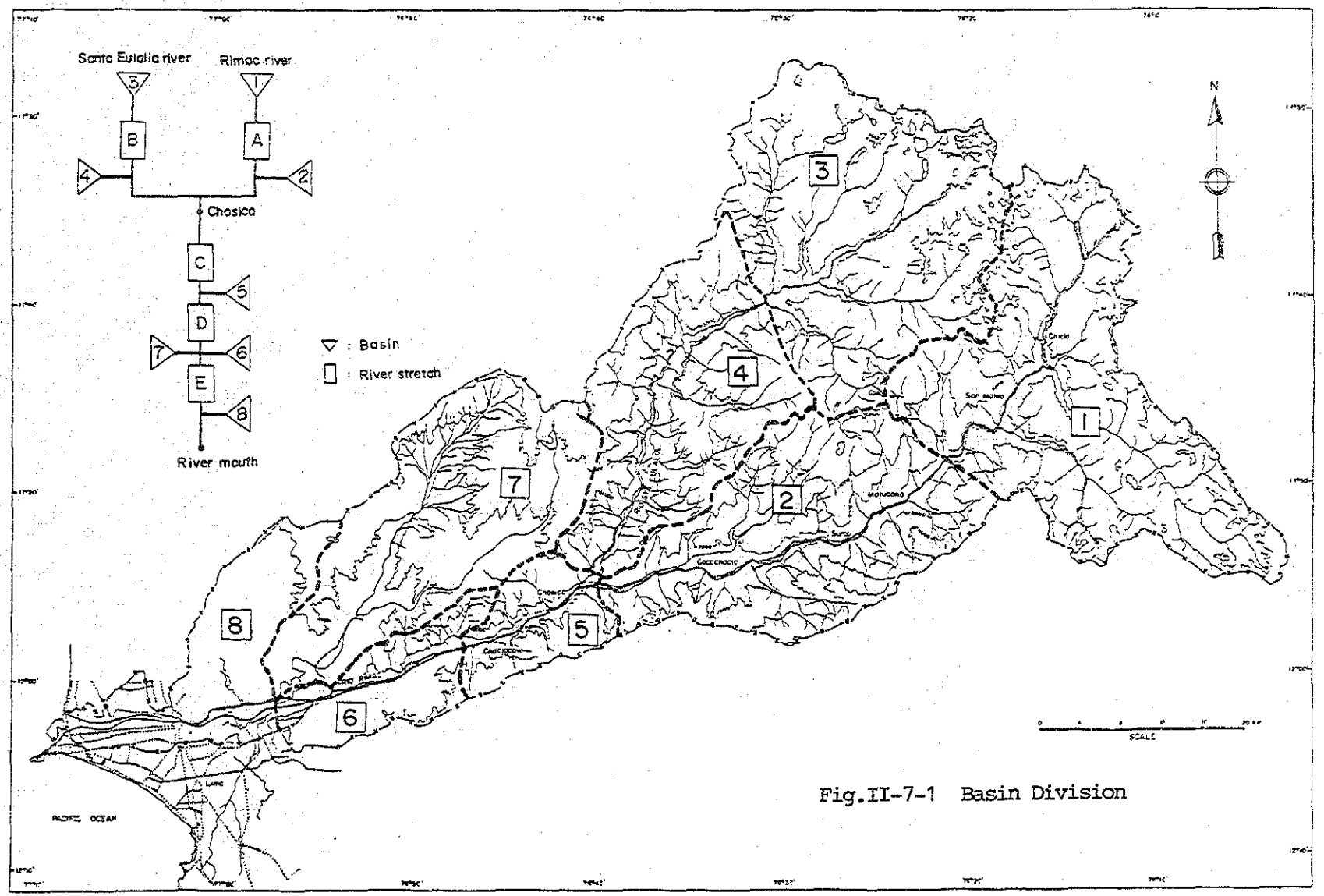


Fig.II-7-1 Basin Division

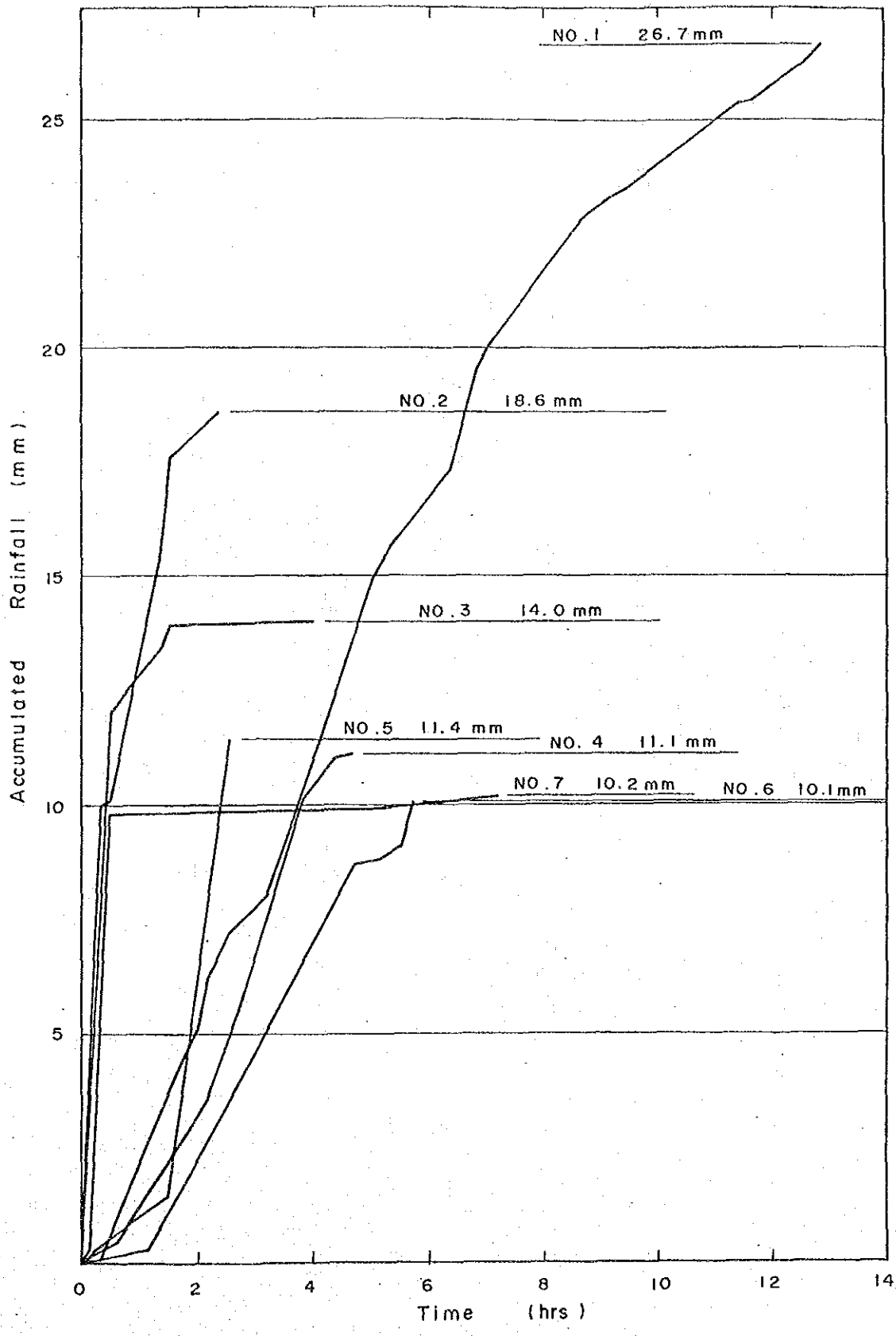


Fig.II-7-2 Accumulated Rainfall Curves at Matucana

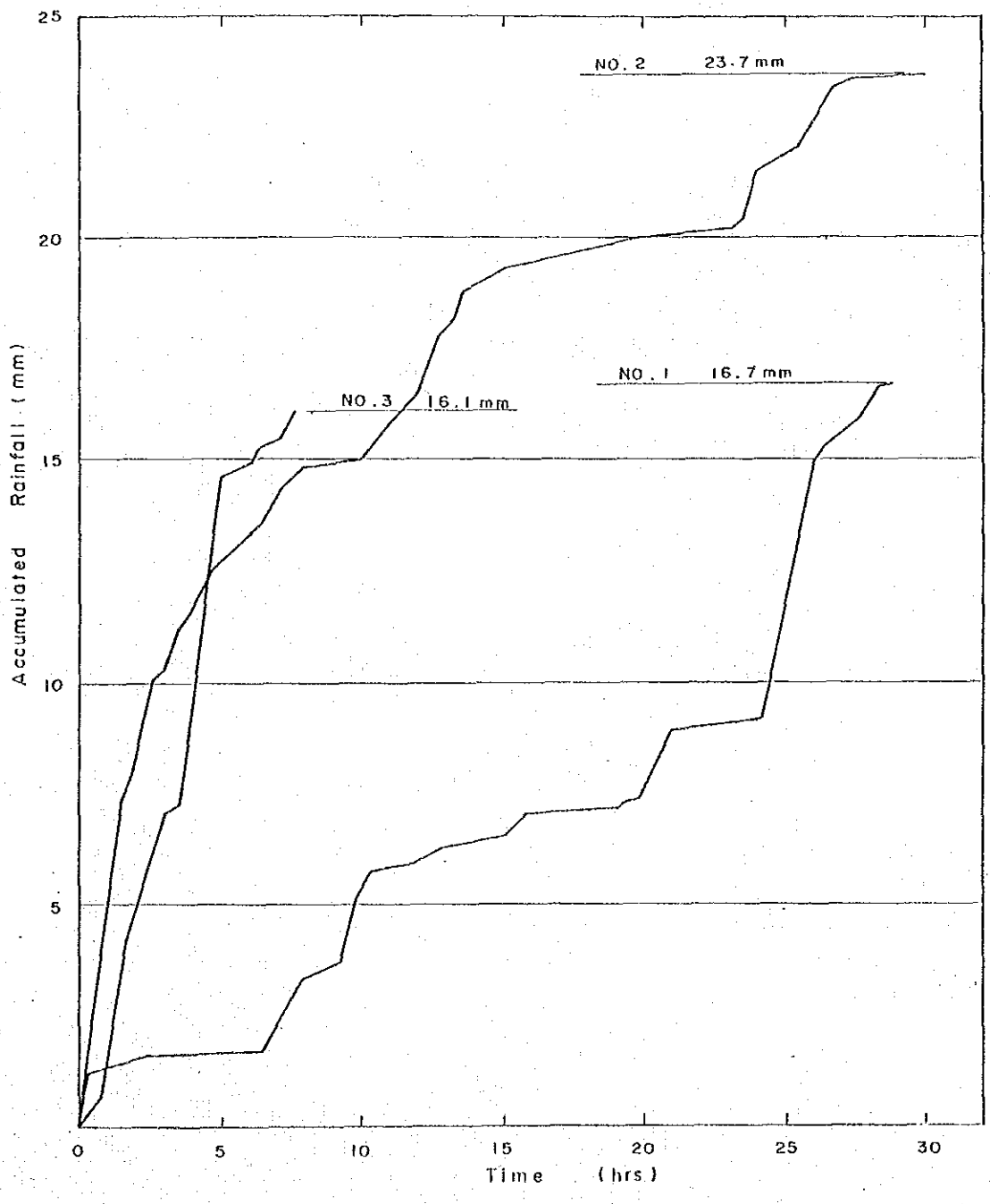


Fig.II-7-3 Accumulated Rainfall Curves at Rio Blanco

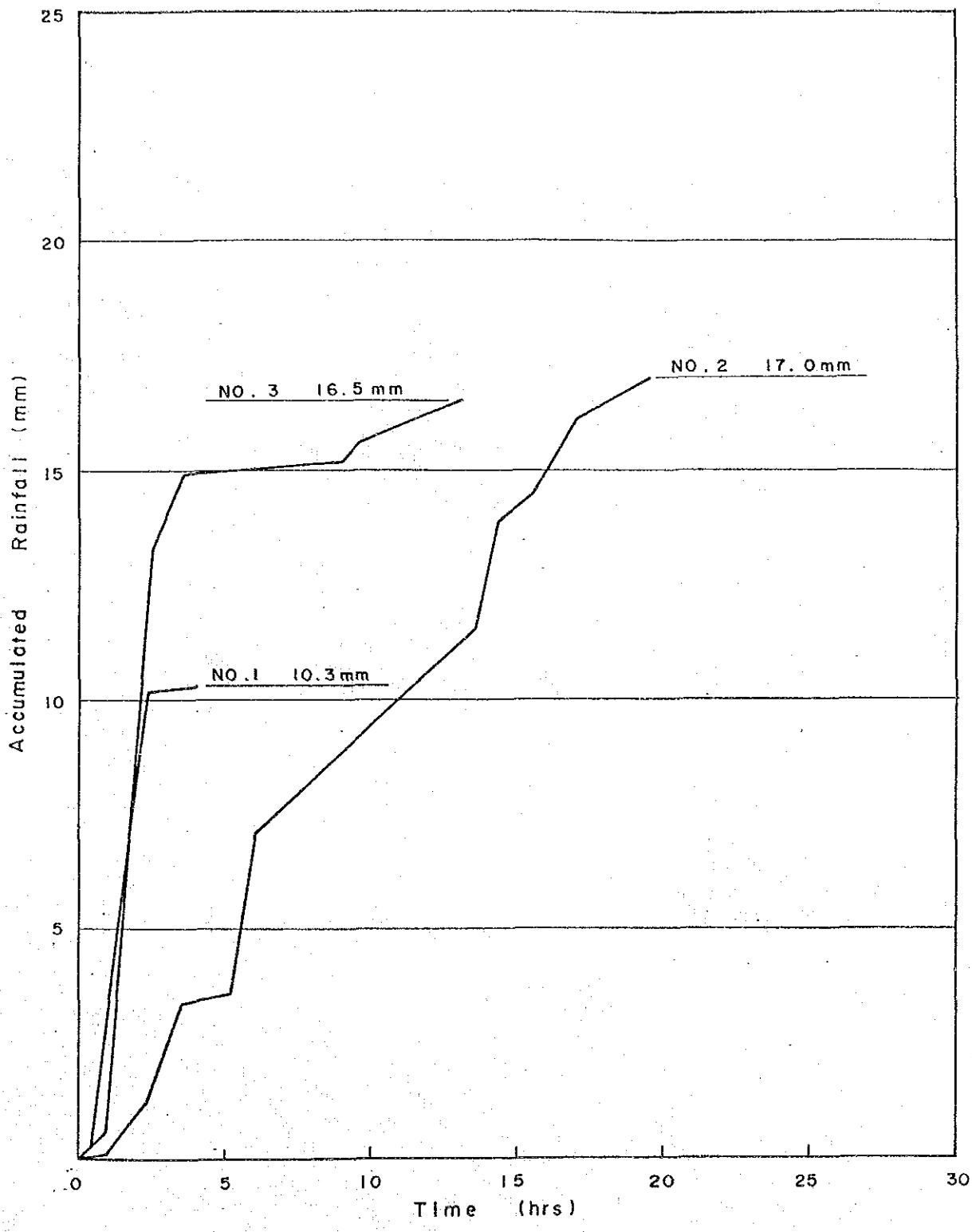


Fig.II-7-4 Accumulated Rainfall Curves at Milloc

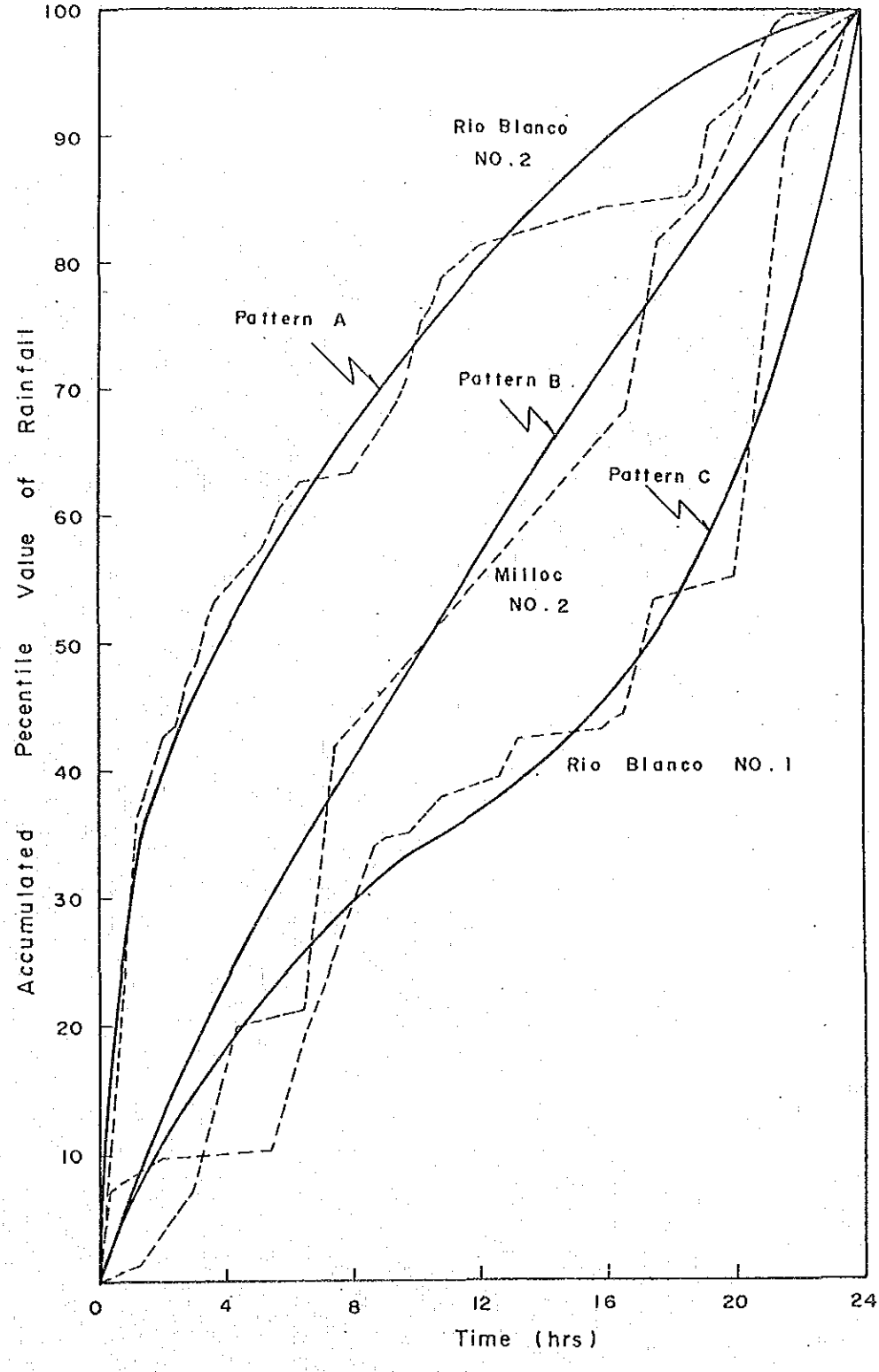


Fig.II-7-5 Non-Dimensional Accumulated Rainfall Curves

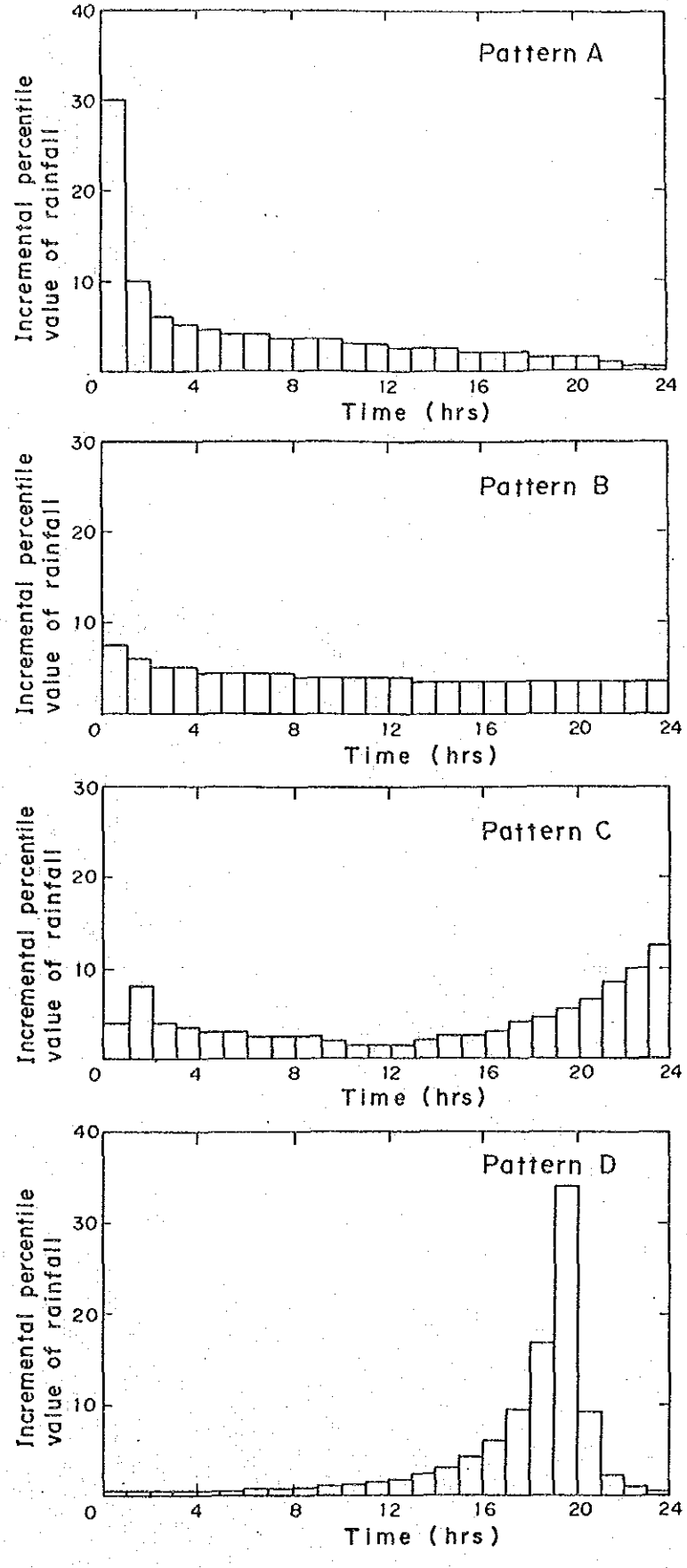


Fig.II-7-6 Rainfall Pattern for Computation of Design Flood Runoff

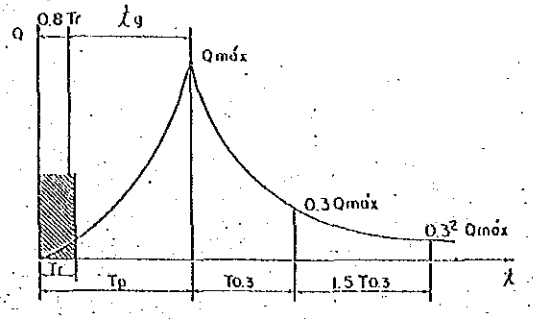
Equation of rising and recession curves are as follows :

$0 < t < Tp$: $Qa = Qmax \left(\frac{t}{Tr}\right)^{2.4}$

$0.3 < \frac{Qd}{Qmax} < 1.0$: $Qd = Qmax \left\{0.3^{\left(\frac{t-Tp}{Tk}\right)}\right\}$

$0.3^2 < \frac{Qd}{Qmax} < 0.3$: $Qd = Qmax \left\{0.3^{\frac{(t-Tp)+0.5Tk}{1.5Tk}}\right\}$

$\frac{Qd}{Qmax} < 0.3^2$: $Qd = Qmax \left\{0.3^{\frac{(t-Tp)+1.5Tk}{2.0Tk}}\right\}$



Notation

A : Drainage area (km2)
L : Maximum length of main stream (km)
tg : Lag time of instantaneous rainfall (hrs) $tg = 0.4 + 0.058L$
Tr : Duration of time of unit rainfall (mm)
Tp : Time from start to peak (hrs) $Tp = tg + 0.8Tr$
Tk : Time from peak to the point of 0.3Qmax $Tk = 0.47\,(AL)^{0.25}$
Qmax : Maximum ordinate of unit hydrograph (m3/sec) $Qmax = \left(\frac{1}{3.6}ARo\right) / (0.3Tp + Tk)$
Ro : Unit depth of rainfall

Description		Nos. of sub basins 1	2	3	4
A	(km2)	700	528	645	440
L	(km)	50.3 (38.1)	39.8	28.0	38.4
tg	(hrs)	3.3 (2.6)	2.7	2.0	2.6
Tr	(hrs)	1.0	1.0	1.0	1.0
Tp	(hrs)	3.4	3.5	2.8	3.4
Tk	(hrs)	6.4 (6.0)	5.7	5.4	5.4
Qmax	(m3/sec)	26.2 (27.7)	21.7	28.7	19.0

Coordinates of unit hydrograph

Time (hr)	1	2	3	4
0	0.0	0.0	0.0	0.0
1	1.4	1.1	2.4	1.0
2	7.3	5.7	12.8	5.3
3	19.4	15.0	27.4	14.1
4	23.4	19.5	22.0	16.6
5	19.4	15.8	17.6	13.3
6	16.1	12.8	14.1	10.6
7	13.3	10.4	11.3	8.5
8	11.0	8.4	8.9	6.8
9	9.1	6.7	7.6	5.5
10	7.7	5.8	6.6	4.8
11	6.8	5.1	5.7	4.1
12	6.0	4.4	4.9	3.5
13	5.3	3.8	4.2	3.1
14	4.6	3.3	3.6	2.6
15	4.1	2.9	3.1	2.3
16	3.6	2.5	2.7	2.0
17	3.2	2.2	2.4	1.7
18	2.7	1.9	2.1	1.5
19	2.4	1.7	1.9	1.4
20	2.2	1.5	1.7	1.2
21	2.0	1.4	1.5	1.1
22	1.8	1.2	1.4	1.0
23	1.7	1.1	1.2	0.9
24	1.5	1.0	1.1	0.8

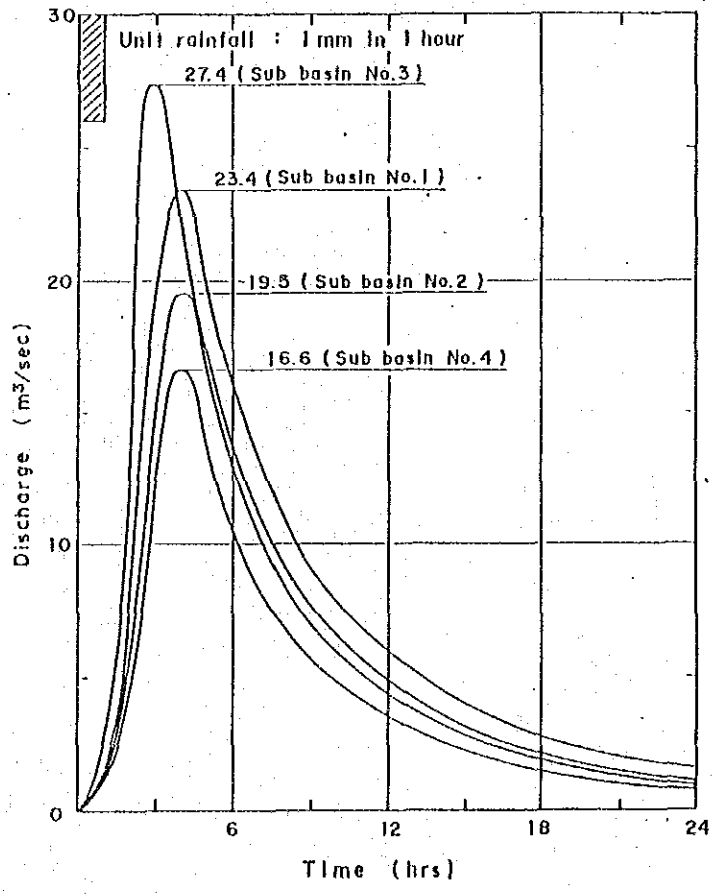


Fig.II-7-7 Unit Hydrographs of Sub Basins

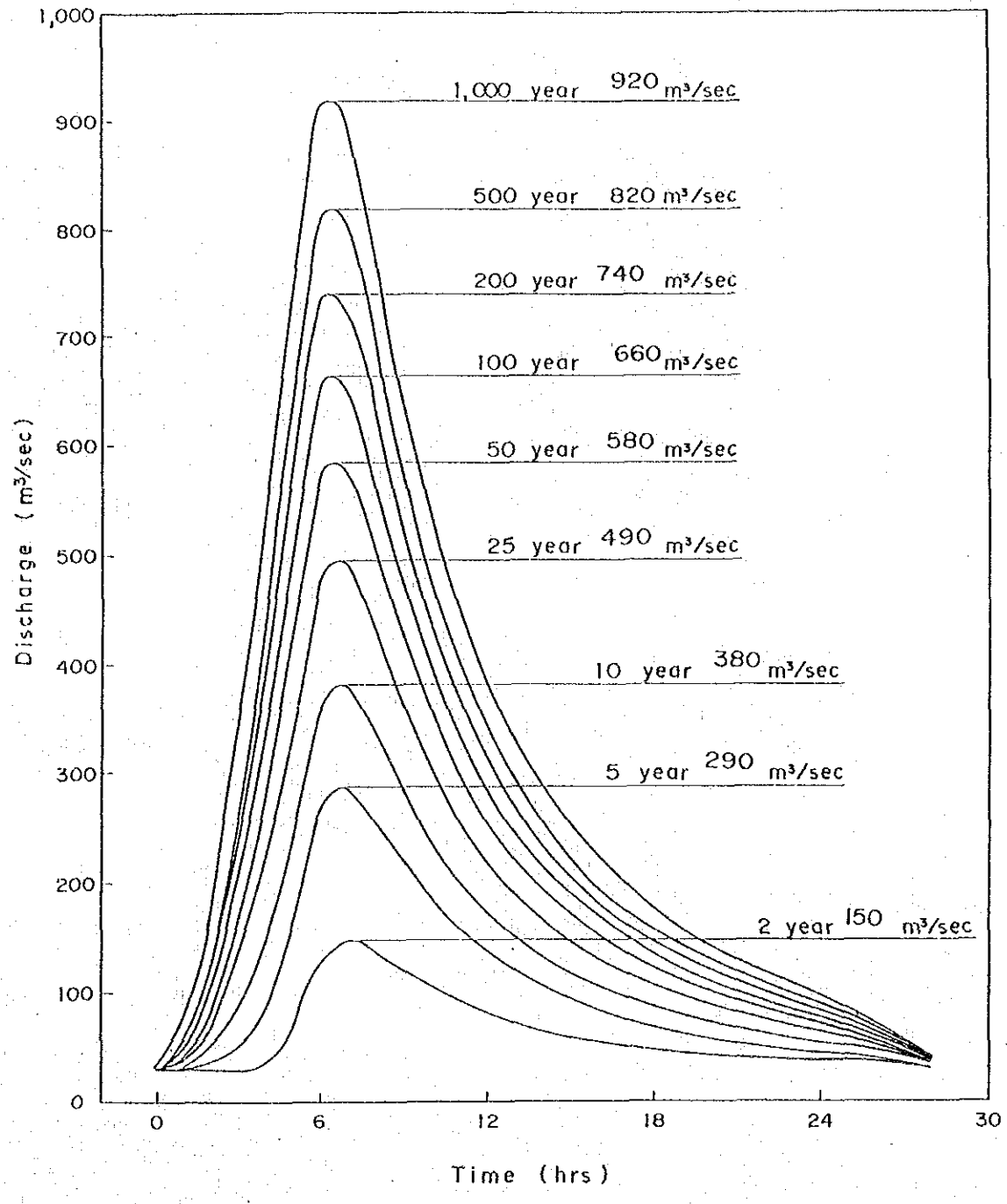


Fig.II-7-8 Flood Hydrograph at Chosica

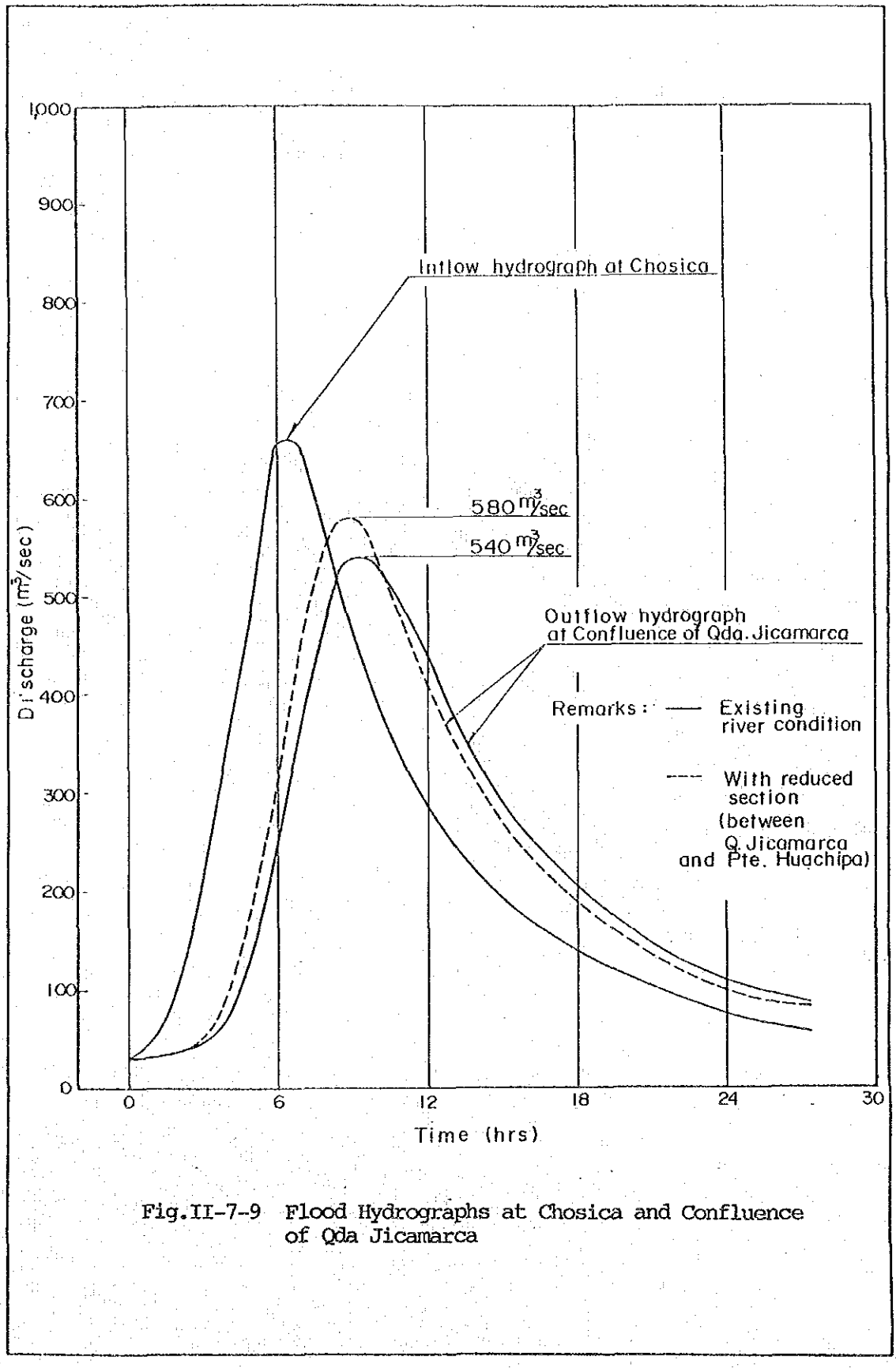


Fig.II-7-9 Flood Hydrographs at Chosica and Confluence of Qda Jicamarca

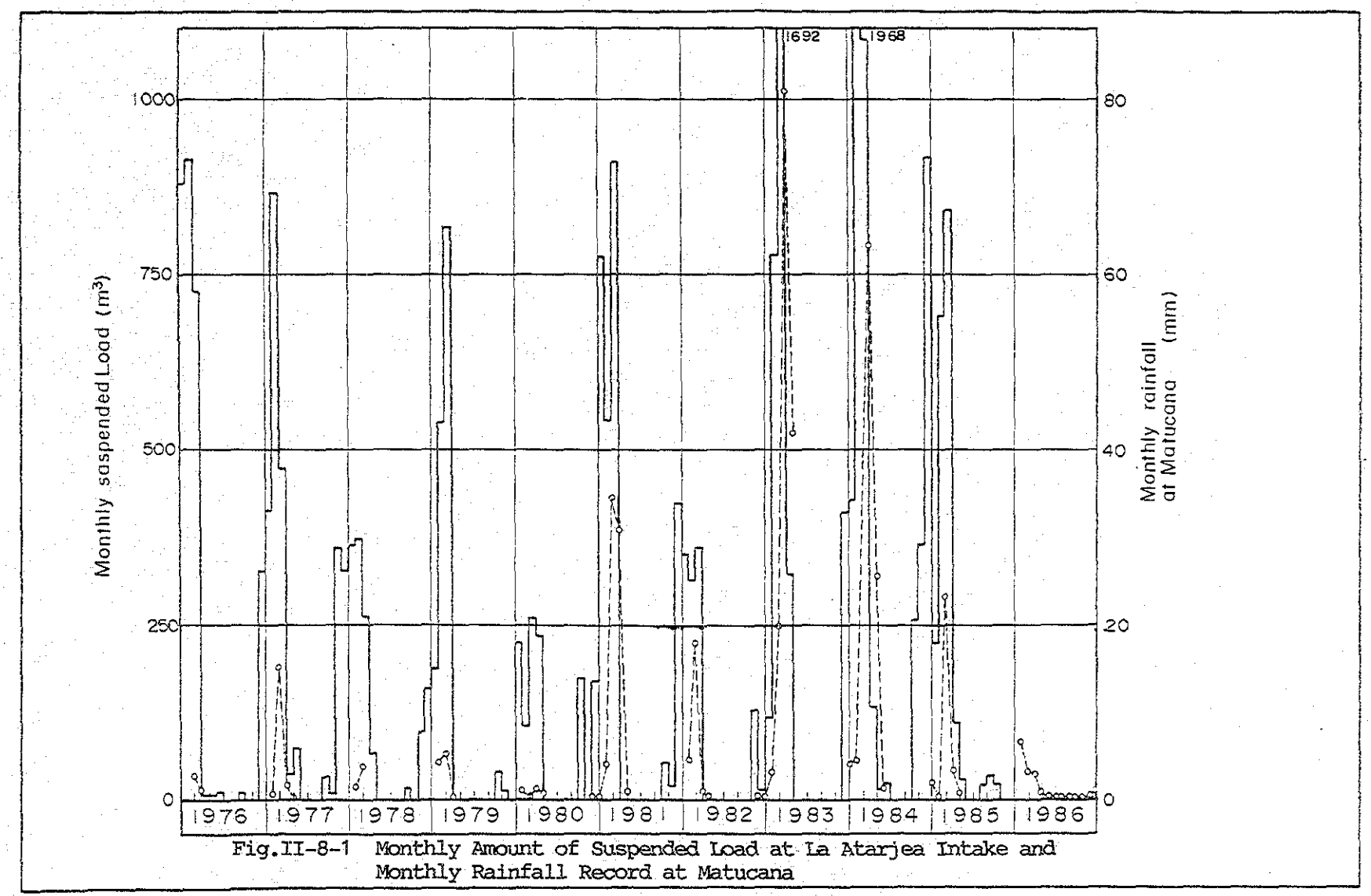


Fig.II-8-1 Monthly Amount of Suspended Load at La Atarjea Intake and Monthly Rainfall Record at Matucana

APPENDIX III

LAND USE AND VEGETATION CONDITIONS

Appendix III LAND USE AND VEGETATION CONDITIONS

Contents

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APPENDIX III
LAND USE AND VEGETATION CONDITIONS

1. METHOD OF LAND USE ANALYSIS

(1) Land Use

As described in Chapter II "AVAILABLE DATA", the land use map sufficiently available for the study of disaster prevention study was not found.

Therefore, the land use analysis was carried out on the basis of the following data.

(a) Aerial photographs
(b) Topographical maps

There are many aerial photographs of the Rimac river basin which were taken in the different locations/routes, in the different years from 1954 to 1987, and by the different scales as summarized in Section 3 of Chapter II. The aerial photographs taken after 1983 are desirable for studying the present land use conditions. Therefore, the photographs taken in 1983, 1986 and 1987 are used for checking the present land use conditions.

At the time of seeing aerial photographs, the topographical maps of 1/100,000, 1/25,000 and 1/5,000 in scale were used to confirm the location and topographic conditions.

However, it was hard to see all the land use conditions by only aerial photographs and topographical maps. It was required to confirm the actual land use condition by eyes at the site of some representative areas. The field reconnaissance was carried out for the land use classification during the investigation period from June 12 to July 7, 1987.

Three kinds of land use classification maps were made as explained below.

(A) Whole basin

using the map of 1/100,000 in scale to show the general land use conditions of the basin.

(B) Areas along the main stream

using the maps of 1/5,000 in scale to show the land use conditions along the main streams, the Rimac river and the Sta. Eulalia river. The classification is to be made in every area divided by 500 m meshes.

(C) Representative disaster area

using the maps of 1/25,000 in scale to show comparatively detailed land use conditions of some representative disaster areas.

The land use conditions were classified by the following items.

(A) For the whole basin

(a) Town/Village
(b) Farm (flat land)
(c) Farm (mountain slope)
(d) Mountain (without vegetation)
(e) Mountain (with vegetation)
(f) Swamp
(g) Glacier/Perpetual snow
(h) Lake
(i) River

(B) For the area along the mainstream

(a) Town/Village (house/building)
(b) Farm land
(c) Forest
(d) Pasture
(e) No use (swamp, mountain, river, grass land, etc.)

(C) For the disaster areas

(a) Town
(b) Village
(c) Farm land
(d) Forest (thin)
(e) No vegetation (no land use)
(f) River
(g) Road

(2) Vegetation

No detailed vegetation study was carried out as the general conditions of vegetation could be seen by the land use classification maps. Further, the detailed classification of vegetation conditions seemed to be not required at the Master plan level.

The vegetation map of the whole basin was to be prepared by aerial photographs, topographical maps and site reconnaissance.

The vegetation conditions were classified by the following items.

(a) Town/Village
(b) Farm land/Forest
(c) Grass land/Shrubs (high and low)
(d) Grass land/Shrub (low)
(e) Almost no vegetation (only cactus)
(f) No vegetation
(g) Lake/Swamp/Perpetual snow

2. LAND USE OF THE BASIN AND THE AREAS ALONG MAIN STREAM

(1) General Land Use of the Basin

The general land use conditions of the whole basin are shown in Fig. III-2-1 which was processed from the land use classification map prepared in 1/100,000 scale.

The ratio of land use is roughly measured as follows:

(a)	Town/Village	4.6%
(b)	Farm (flat land)	1.7%
(c)	Farm (mountain slope)	7.1%
(d)	Mountain (without vegetation)	30.0%
(e)	Mountain (with vegetation)	34.6%
(f)	Swamp	0.8%
(g)	Glacier/Perpetual snow	0.9%
(h)	Lake	0.3%

Note: The areas for river, road and railway are not counted.

In general, almost 90% of the basin is mountain area. The flat plain is developed only in the lower reach area which includes the Lima-Callao metropolitan district and in a part of middle reach area which is located along the main streams, the Rimac river and the Sta. Eulalia river.

In the mountain area, the most parts are bare land without vegetation or with very limited vegetation of some grasses, scattered cactuses, some low trees. The vegetation is seen in the mountain slopes and wide U-shape valleys of the upper reach area where the land is used for vegetable cultivation or pasturage. Many small mines with its villages are located in the mountain of middle and upper reach areas. In the area along the main streams, some towns such as Chosica, San Mateo, Surco, and Matucana are located and farm lands are developed. The main national roads and national railway are also running along this valley of main stream. That is, the main traffic trunk which contribute much to the Peruvian economy and society forms a part of the mountain area.

In the flat plain located in the lower reach, various kind of buildings, facilities, and structures are seen. The area is developed as the metropolitan district. That is, the level of land use is comparatively very high. Even in the suburb area of metropolitan district, the town areas are continuously adjacent and some main roads and a railway are located there. Farm lands and resort areas are also seen in the suburb zone.

(2) Land Use in the Areas along Main Stream

The Land Use Condition in the areas along the Rimac river and the Sta. Eulalia river is shown in Fig. III-2-2. The classification in this figure is made from the classification of every square with 500 m meshes on map of 1/5,000 in scale. Though the more specific classification is made in every mesh of 500 meters, the classification on the figure is shown by the most representative use in each square. That is, the detailed classification can not be seen in the figure. However, it seems to be available to see the distribution of main land use along the main river of which surrounding areas have high possibility to suffer disaster due to flood inundation, debris flow, slope failure, etc.

As the classification of land use along the main streams does not cover the upper reach due to the shortage of topographic map of 1/5,000 in scale, the descriptions of the upper reach is to be done mainly in accordance with the site inspection at the time of field reconnaissance.

In the lower reach ranging from Lima alluvial fan up to Chacracayo, land where water supply is possible, has been used as residential or farm land. Due to migration of P. Joven (poor people) into urban area of Metropolitan Lima, parts of river banks has been reclaimed illegally and their houses were constructed.

In the middle reach area of the basin from Chacracayo up to Matucana (Río Rímac) or up to Huinco (Río Sta. Eulalia), a flat plain of alluvium along the Rimac and Sta. Eulalia rivers is identified to be used as farm land. The lands along the valleys are generally used well. Some local towns such as Chacracayo, Chosica, Ricard Palma, Cocachacra, Surco, Matucana, Sta. Eulalia and Callahuanca are located and the remaining areas are used mainly as farm land, recreation land, road, railway, etc. However, some areas used as residential or farm land before large scale disaster occurred in 1983 still remain to be laid waste. These areas are identified on Tornamesa at most-upstream of confluence of the Seco river and Rimac river, a part of an alluvial fan of Oda. Chumayo in left bank of most-down-stream of Matucana, and a part of right bank at downstream of Sta. Eulalia river.

In the upper reach, from Matucana or Huinco up to the borders of Rimac river basin, some towns/villages such as Matucana, San Mateo, Chicla, Casapolca, San Pedro de Casta, San Lorenzo de Huachupanpa, Laraos, Sheque etc., are located.

Since flat land area is scarcely distributed in the upper reach of the basin, an mountainous slope is used as farm land, and residential area is identified in limited flat area. A traditional method called Andes is applied to farm land where stone hedges having the height of 1 or 2 m are constructed in the form of steps, and water is supplied to farm land through small irrigation canal.

In the upper-most area of the basin, most of land along the river are practically not used for farm land as the area is narrow and the climate is not suitable for cultivation. However, this narrow valley is available for main traffic route.

3. LAND USE OF SPECIFIC AREAS

The land use maps with more detailed area division and more specific classification for some representative disaster areas were prepared. The representative disaster areas are selected in consideration of past serious disaster as follows.

(a) Chosica area
(b) Rio Seco area
(c) Matucana area
(d) Huachipa area
(e) Campoy, Zarate area

The Land Use conditions of each area are shown in Fig. III-3-1 to III-3-5.

The Land Use conditions of each specific area are to be described below.

(1) Chosica Area

The town/resident area is developed along the main river (the Rimac river and the Sta. Eulalia river) and on the fan of quebradas. This area is the most densely populated zone except the metropolitan Lima district. Farm land and forest used for recreation club or villa district are also located in the surrounding zone of town area. However, the mountainous slope area is almost not used. The national road No. 20 and some town roads run densely in this area.

(2) Rio Seco Area

A village is located on the mountain slope along Qda. Rio Seco. The fan of Rio Seco is mainly used as farm land. There are railway and national road (No. 20), which cross the fan. Small town/villages (Cocachacra and Torna Mesa) are located in the upstream side and downstream side of the confluence of Rio Seco and the Rimac river.

(3) Matucana Area

Matucana town, the center of middle-upper reach, is located on the both banks of the Rimac river. On the fans of quebradas as well as on the mountainous slopes located nearby the town, farm lands are seen. A few small villages are located on the mountain slope along Qda. Paihua which enters to the Rimac river from the right side.

(4) Huachipa Area

Huachipa is located in the plain developing on the right bank of the Rimac river. Houses of village are located mainly along the roads which cover the most part of this area. Farm lands are well developed in the whole plain area. Qda. Jicamarca runs in this area and enter to the Rimac river.

(5) Campoy, Zarate Area

This area is located on the right bank of the Rimac river already a part of metropolitan Lima. Therefore, the resident houses, office buildings, public structures, etc. are densely situated. The area of farm land is scarce. The properties which suffer the disaster will be extremely high if this area is inundated. The main roads as well as town roads are densely situated in this area.

4. VEGETATION CONDITIONS

Vegetation is principally affected by climate. Any vegetation can not grow up without water in desert climate.

Although the Rimac river has brought about various natural disasters many times in the past period, on the other hand the river has also given important conveniences for human life.

The condition of vegetation in the basin is roughly shown in Fig. III-4-1. The ratio of each classification is obtained as follows:

(a)	Town/Village*	4.7%
(b)	Farm land/Forest	9.0%
(c)	Grass land/Shrub (high and low)	21.8%
(d)	Grass land/Shrub (low)	30.4%
(e)	Almost no vegetation (only cactus)	14.1%
(f)	No vegetation	19.1%
(g)	Lake/Swamp/Perpetual snow	0.9%

* There are many vegetation areas in parks, roads, house-yards, etc. in the town and village area.

As seen in the table above, almost the area of 35% of the basin has no vegetation and the area of 50% is covered with grasses and shrubs. However, the vegetation in this area is not so thick and the share of bare land is much wider than the actual vegetation land. Farm land and forest area located in and along the valleys of main streams.

More detailed ecological or vegetative map are not to be made for this study. Vegetation condition is generally classified based on difference of altitude. In accordance with this classification, the vegetation of each zone is described as follows:

(A) 0 - 1,000 m zone

As the rainfall is a type of desert climate, natural vegetation is very poor in this area except the area along the river. However, man-made vegetation is seen in almost every district of town and village. Farm land and forest in recreation zone are developed along the main rivers.

(B) 1,000 - 2,000 m zone

The area is also arid or semiarid in climate. Willow and special Molle trees grow in the riverside and various species of cactus on slopes.

(C) 2,000 - 4,000 m zone

A large part of slopes is covered with green colour in consequence of the change of vegetation conditions though they are not so dense in general.

(D) 4,000 - 5,000 m zone

There are grasses, so-called Ichu, varieties of cactus, and some native low trees.

(F) Over 5,000 m zone

No vegetation area.

From the viewpoint of agriculture, the vegetation is to be described that various vegetations have been cultivated in the riverside along the Rimac river and the Santa Eulalia river. Various types of verdure are cultivated in the lower reach. They are tomato, carrot, lettuce, alfalfa, etc. Many fruits area also cultivated in the middle reach. They are banana, avocado, apple, etc. A species of cactus is also cultivate as a material of toilet articles. Cultivation of maizes and potatoes is found on many slopes in the natural vegetation area. Forestation of pinetree and eucalyptus is seen on the river sides of the middle and the upper reaches.

Figures

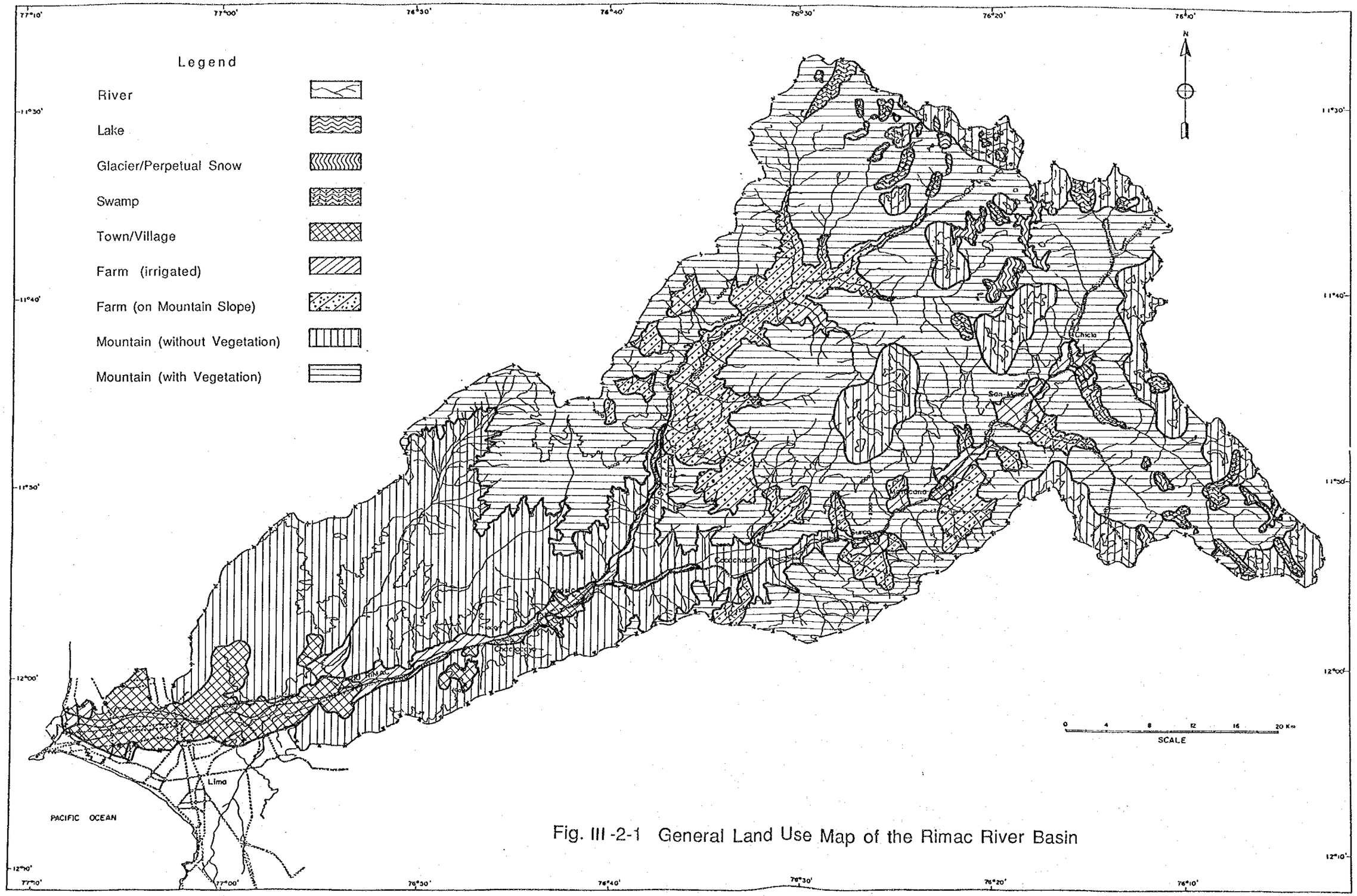
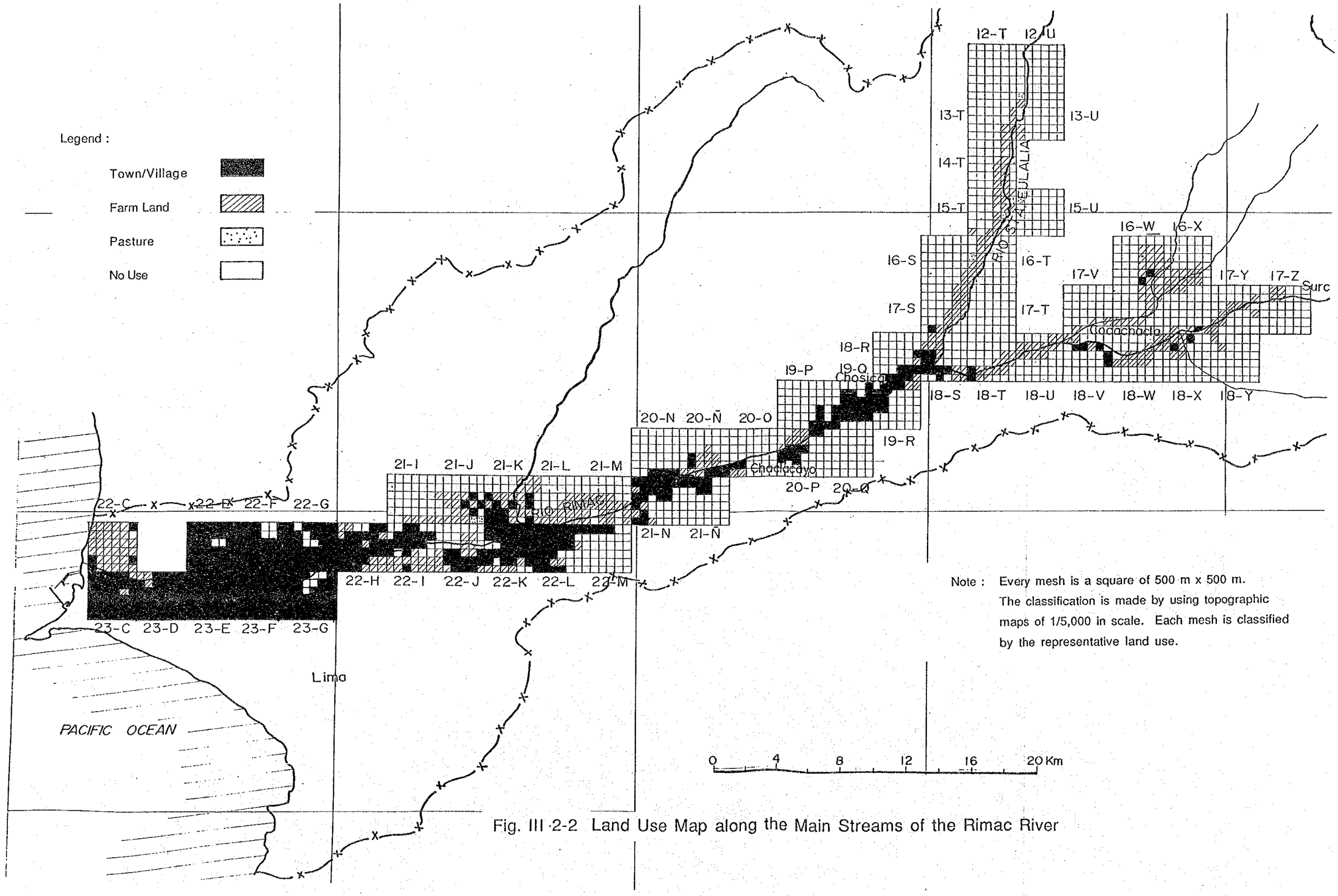


Fig. III-2-1 General Land Use Map of the Rimac River Basin



Note : Every mesh is a square of 500 m x 500 m. The classification is made by using topographic maps of 1/5,000 in scale. Each mesh is classified by the representative land use.

Fig. III 2-2 Land Use Map along the Main Streams of the Rimac River

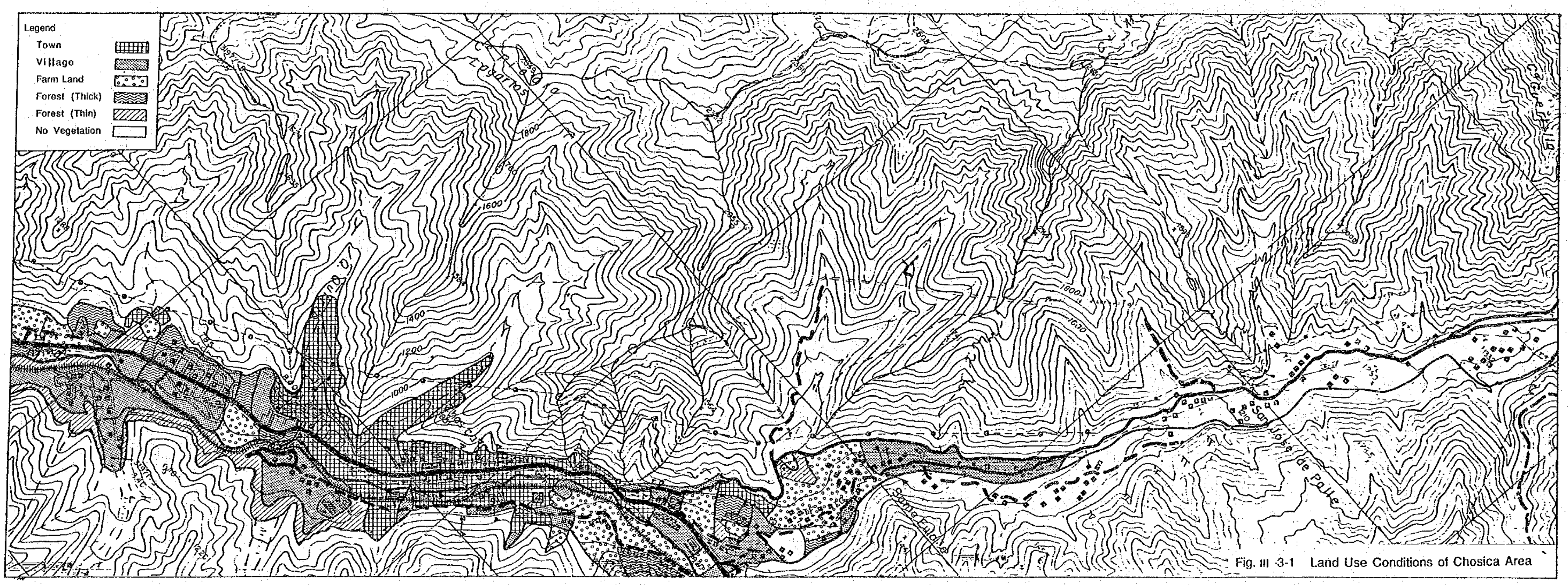


Fig. III-3-1 Land Use Conditions of Chosica Area

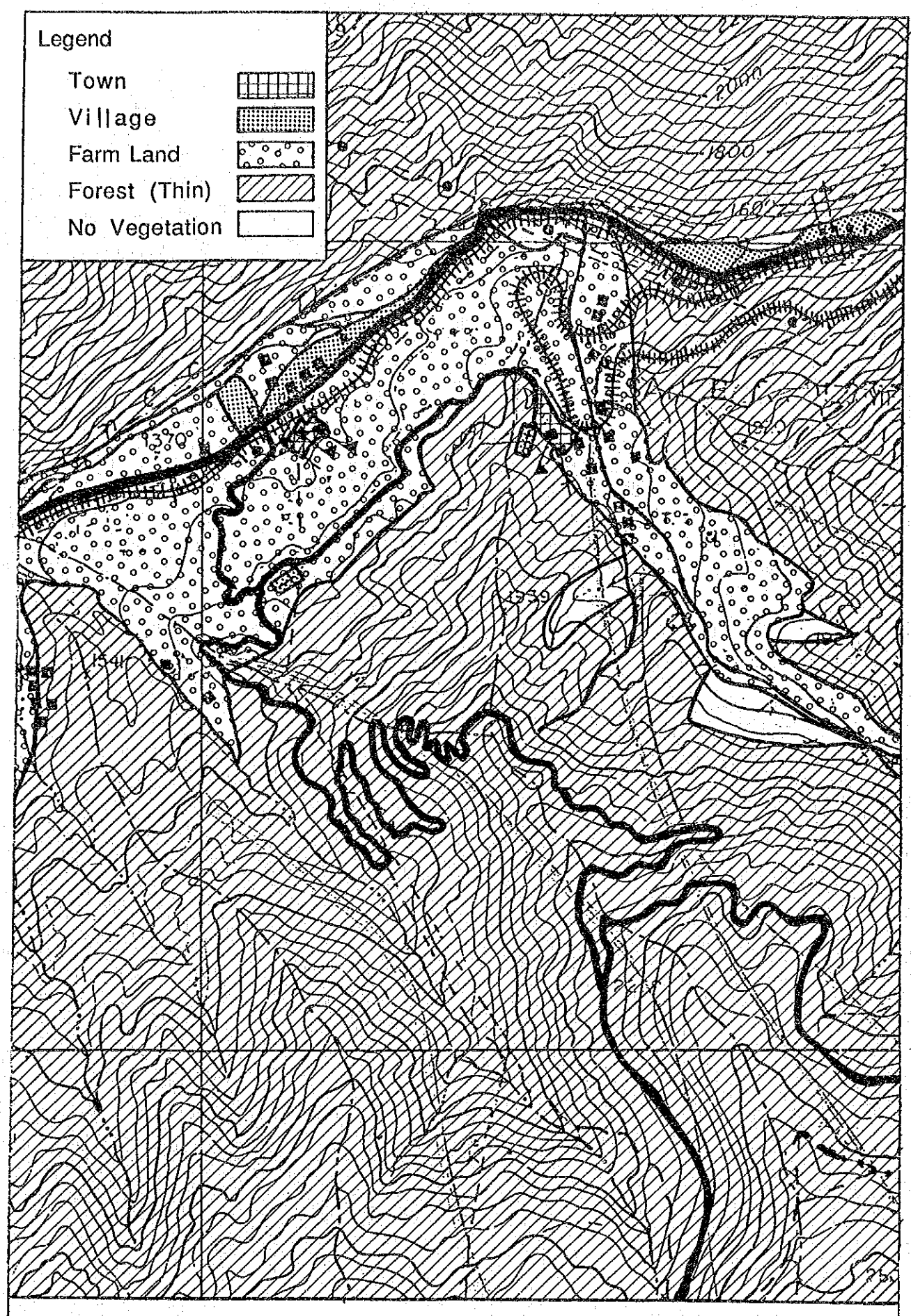


Fig. III -3-2 Land Use Conditions of Rio Seco Area

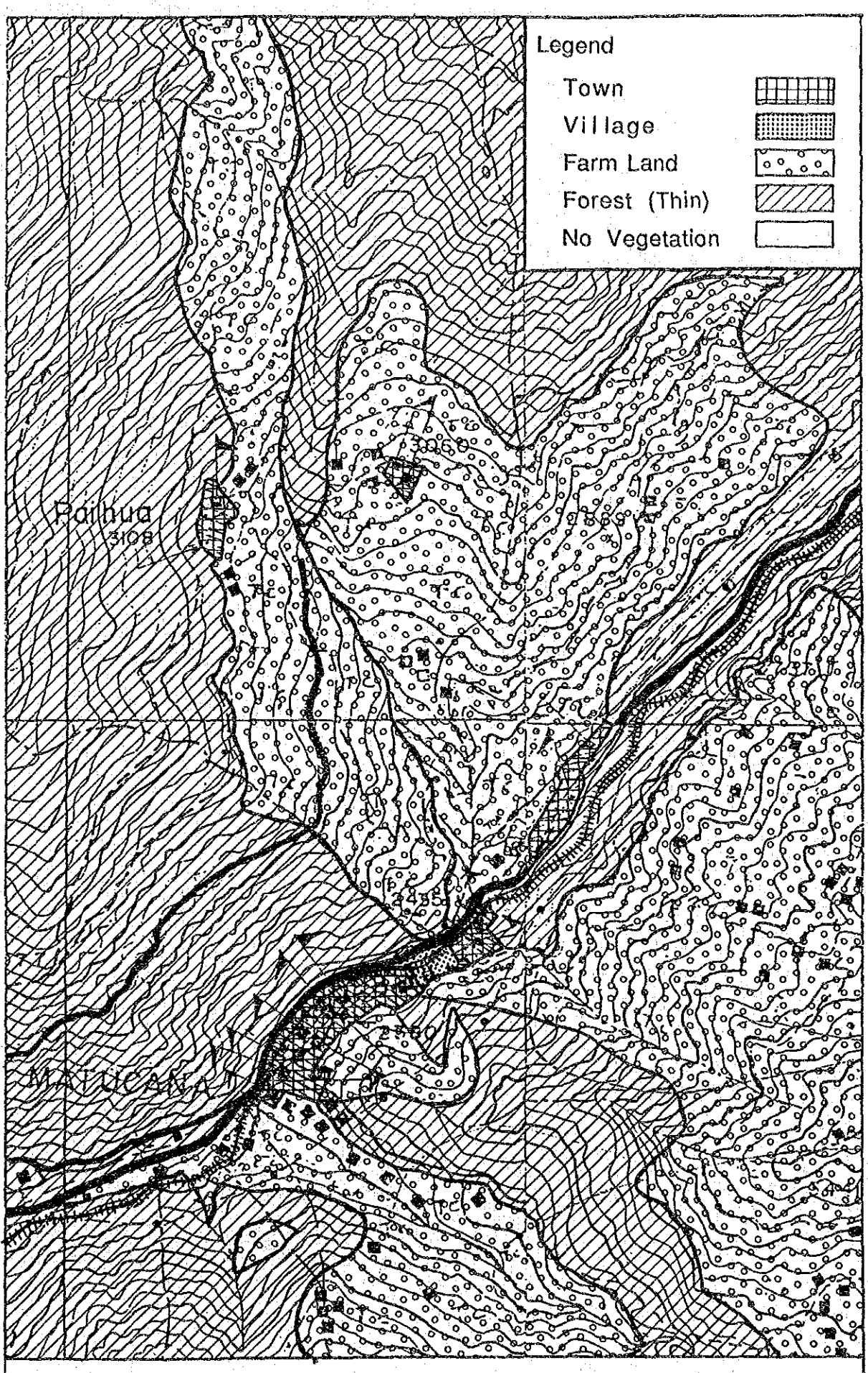


Fig. III -3-3 Land Use Conditions of Matucana Area

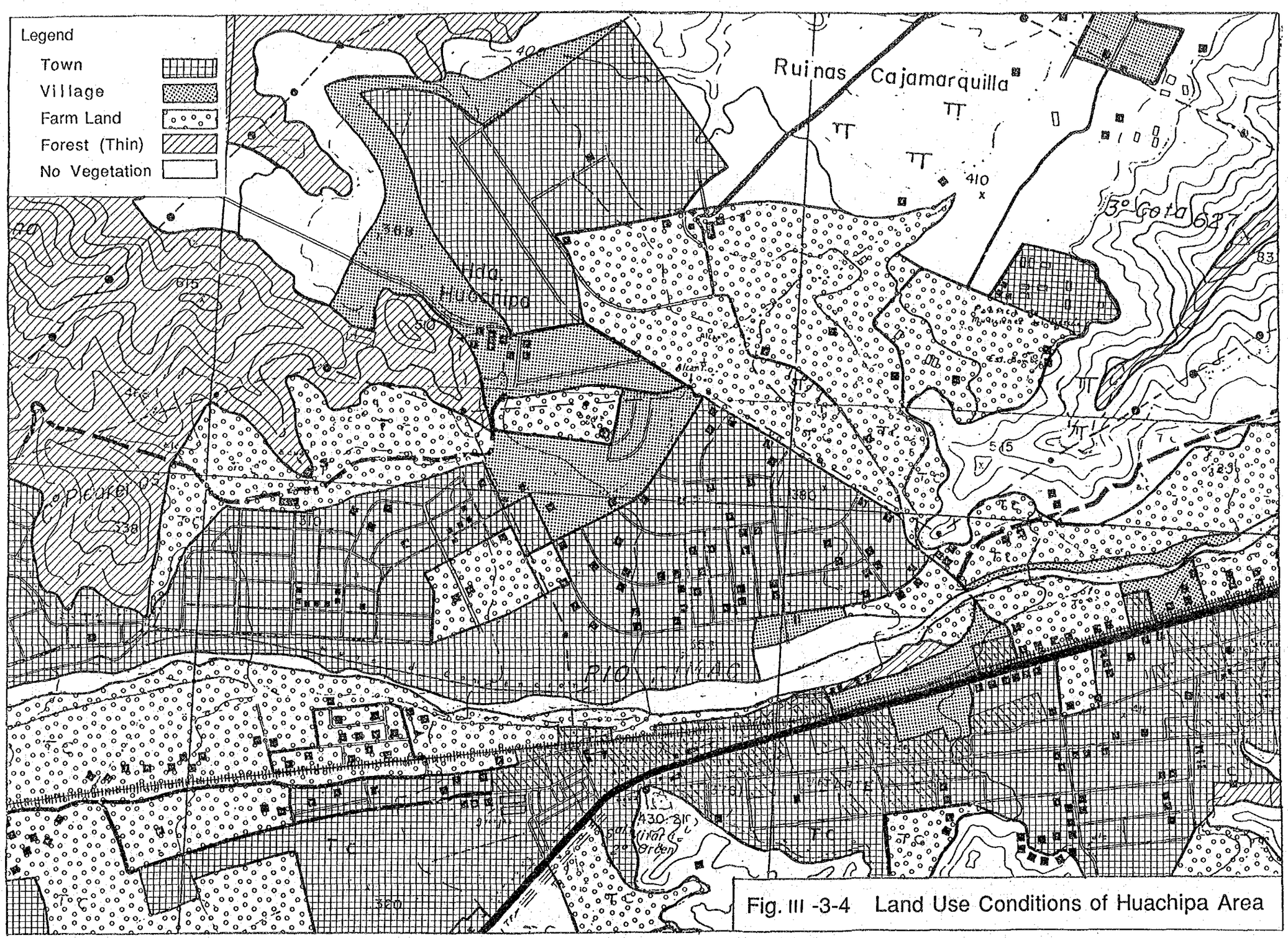


Fig. III -3-4 Land Use Conditions of Huachipa Area

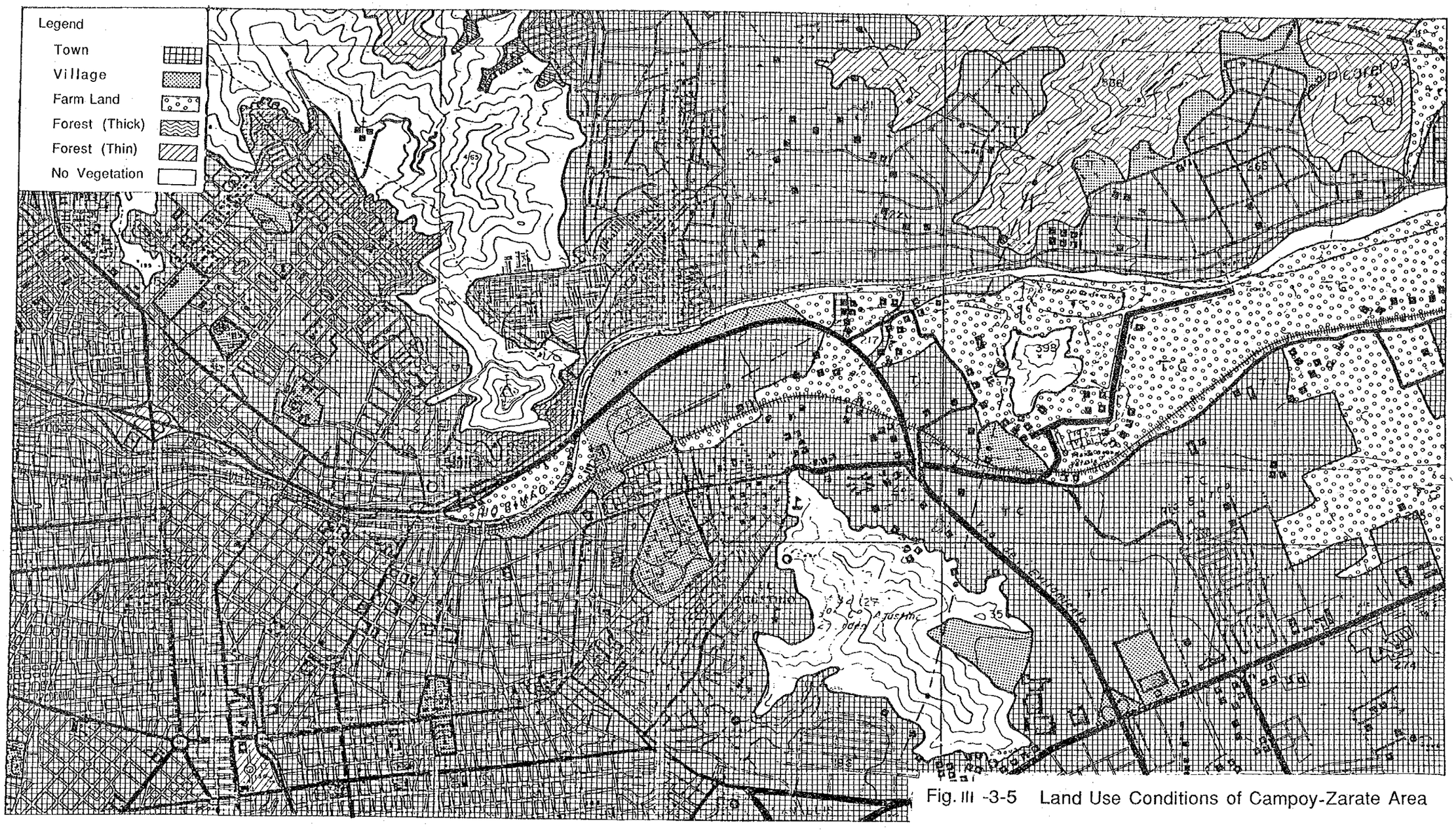


Fig. III -3-5 Land Use Conditions of Campoy-Zarate Area

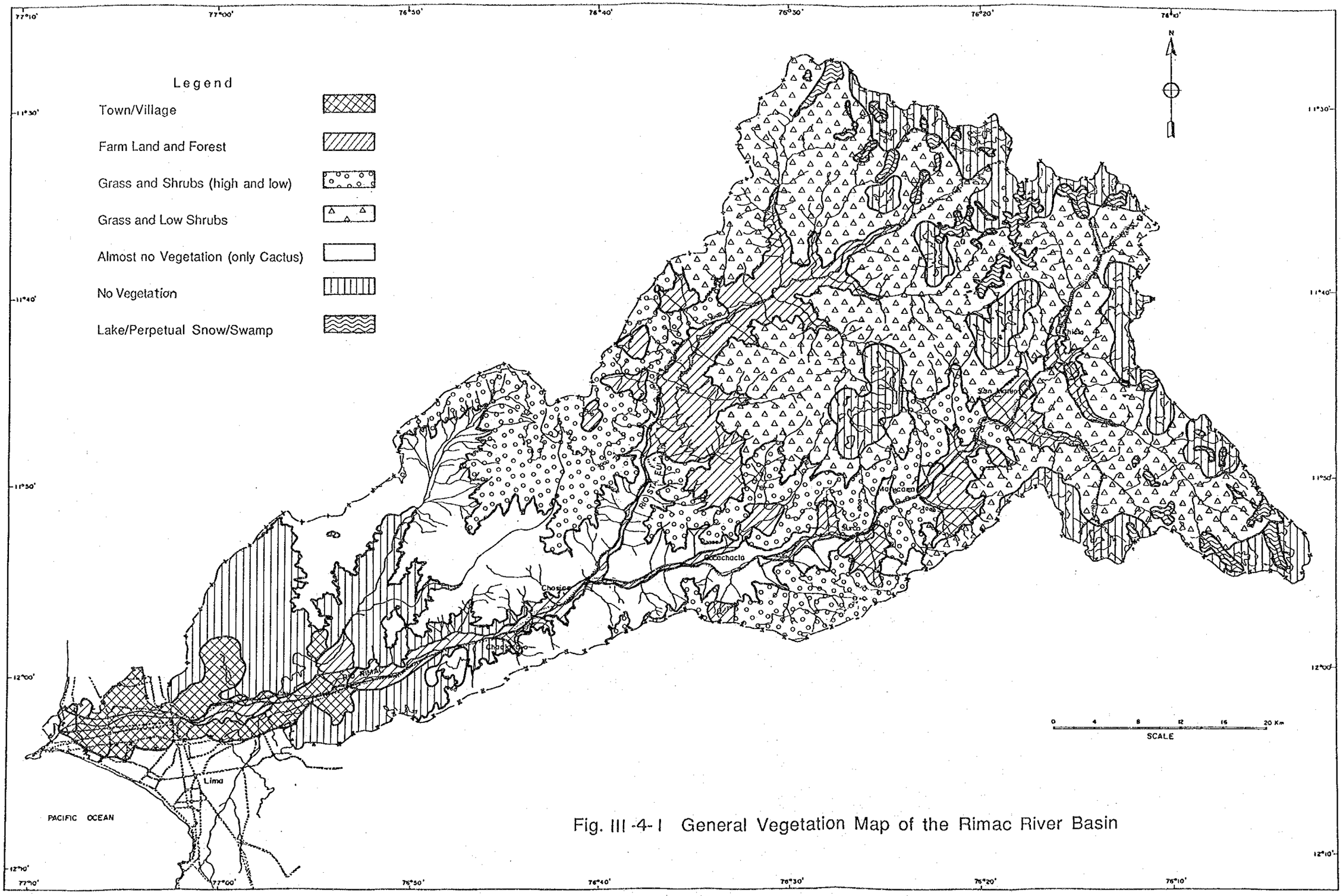


Fig. III-4-1 General Vegetation Map of the Rimac River Basin