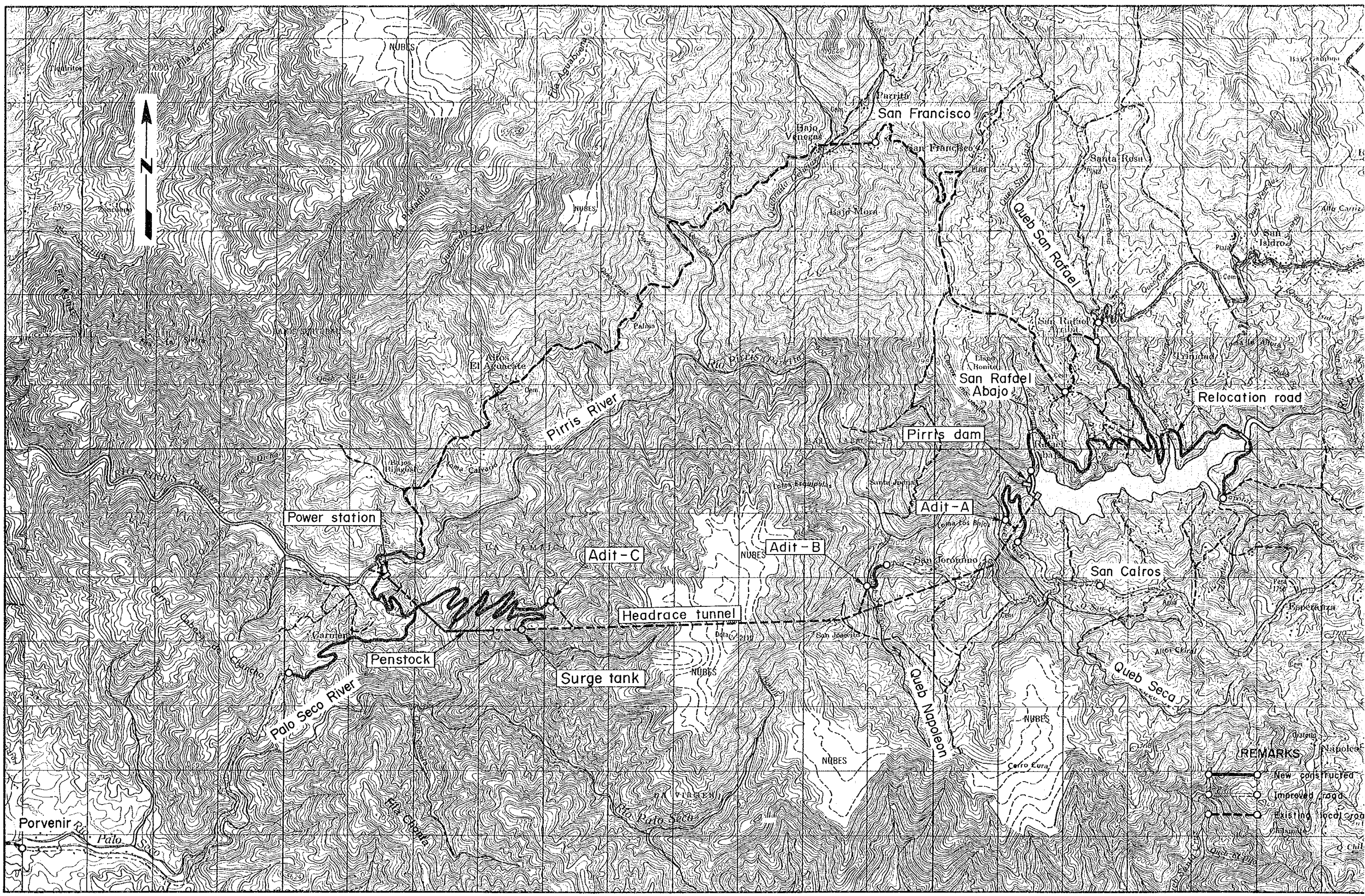
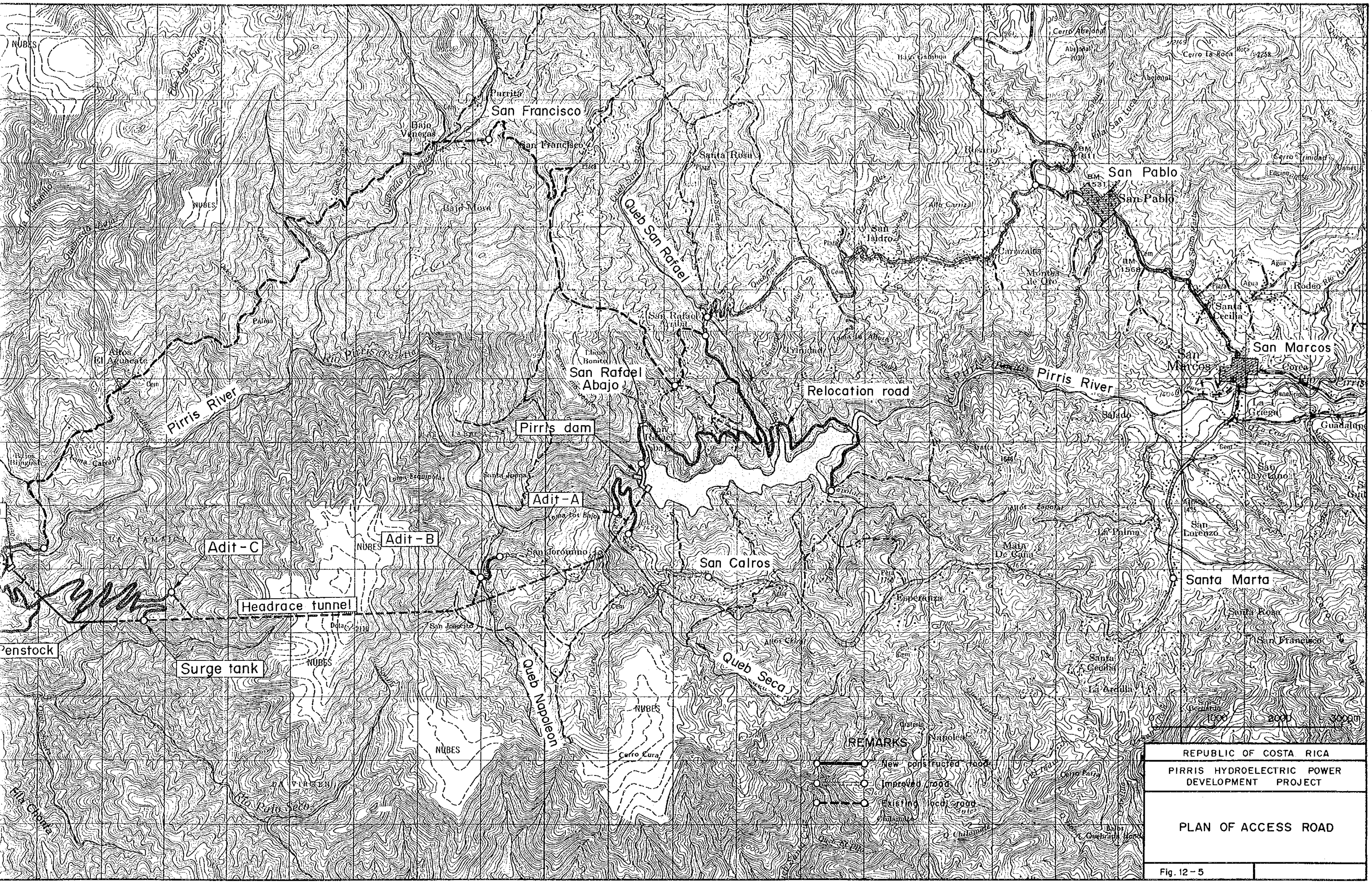


San Francisco
Qveb San Rafael
San Rafdel Abajo
Relocation road
Pirris dam
Pirris River
Adit-A
Adit-B
Adit-C
Power station
Headrace tunnel
Surge tank
Penstock
Palo Seco River
Queb Napoleon
San Calros
Queb Seca
Porvenir
REMARKS
New constructed
Improved road
Existing local road



REPUBLIC OF COSTA RICA

PIRRIS HYDROELECTRIC POWER DEVELOPMENT PROJECT

PLAN OF ACCESS ROAD

Fig. 12-5

CHAPTER 13 ENVIRONMENTAL IMPACT AND ITS COMPENSATION

CHAPTER 13 ENVIRONMENTAL IMPACT AND ITS COMPENSATION

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CHAPTER 13 ENVIRONMENTAL IMPACT AND ITS COMPENSATION

13.1 Executive Summary

The dam site is located at an altitude of about 1,090 m and about 30 km south of San Jose City, the capital of Costa Rica. There is San Marcos Town with a population of 5,000 at about 10 km east of the dam site. The power generation project site is located at an altitude of 325 m and about 10 km west of the dam site. Inside the project site, there are no designated areas such as natural parks and forest reserves . A reservoir with an area of about 1.10 km^2 is planned to appear on the Pirris River after the completion of the dam, but it is not necessary to remove anything except several houses since the area required to be submerged is now used as cultivated land and pasture ground. The percentage of the submerged land on the entire cultivated land and pasture ground in this region is so small that there will be almost no influence on regional industries. The section of the Pirris River from the dam to the power plant continuously has waterfalls, runs through a deep gorge and is not used at all. Therefore, the power generation project can coexist with industries in this region without any serious problems, and it is expected to greatly contribute to the development of Costa Rica as well as this region through the construction and operation of the power station.

In Costa Rica, river contamination caused by organic substances discharged from coffee-processing factories, which are this country's major industry, is regarded as a national environmental issue, and the Pirris River is also not an exceptional case. According to the results of water quality examination as well as preliminary investigation of the reservoir's influence on water quality, deterioration in water quality in the reservoir can not be prevented unless the discharge of organic substances is regulated. Therefore, it is necessary to study countermeasures to avoid discarding waste matters directly into the reservoir in addition to the regulation.

Since water downstream from the reservoir is not used and the reservoir is about 5 km away from the nearest village, deterioration in water quality does not seem to become a social problem directly. However, it is necessary to monitor water quality, etc., in the reservoir and to grasp environmental changes since deterioration in the function of power generation facilities by noxious gas, the outbreak of detrimental plants in the reservoir, etc., are considered possible.

Research on the effective utilization of organic substances discharged from coffee-processing factories is conducted in technological cooperation with the government of Japan. The technology of producing biodegradable plastic of high added value from waste matter is coming near the stage of practical use. The effect of legal regulations on the discard of waste matter can not be anticipated even from now on, but it may result in improving the effect of environmental measures by adding value to waste matter and providing its profit to the industry. While all coffee-producing countries in Central America, South America and Africa have similar water contamination problems, this new technology is expected to contribute to environmental improvement in the world.

13.2 Outline of the Survey Method and the Project

13.2.1 Introduction

The world has increasingly become aware of environmental conservation in recent years in hoping that all the energy development including hydraulic power stations will be planned as something suitable to coexist with natural and social environments in development areas by giving careful consideration to the environment. Feasibility studies (F/S) have been made up to now in view of technology and economy regarded as the main criteria of feasibility evaluation, but it is rapidly becoming common to regard three aspects as main evaluation criteria after adding another aspect, that is, environment to the above-mentioned two aspects. A sufficient survey of environmental impact should be made as much as possible in the early stage of the project, and the development project should reflect the results of the survey. Even if it is found necessary to reduce environmental impact, it will be very difficult to largely change a plan of power generation facilities after it is once approved. However, since it sometimes costs an unexpectedly-great deal to take environmental conservation measures, the project should be carefully designed in economical evaluation as well. With due regard to the above-mentioned matters, materials were collected, site investigation was conducted, environmental impact was assessed and useful information was given to persons in charge of technological and economical investigation in this survey to fully consider all the aspects of the feasibility study (F/S) of the development project in the early stage. In this survey, materials were collected and site investigation was conducted in cooperation with Instituto Costarricense de Electricidad (I.C.E.).

13.2.2 Survey Method

Firstly, "Target items required for environmental impact assessment", which met the requirements of the following documents, were specified with reference to manuals, guidelines, etc., prepared by the World Bank, Japan International Cooperation Agency, etc., in environmental impact assessment. Secondly, the method of environmental impact assessment was examined in detail by grasping the present environmental situation and characteristics of the project area and selecting environmentally-important items and items considered to have big environmental impact from the "Target items required for environmental impact assessment". Thirdly, a plan of environmental site investigation was designed in reply to the importance of aspects based on the method of environmental impact assessment in the "Target items required for environmental impact assessment" and the details of the plan were described in the preliminary analysis report. The site investigation was conducted based on the preliminary analysis report in coordination with I.C.E. The survey was conducted in cooperation with neutral organization such as a national university, etc., in Costa Rica to make the survey and its environmental impact assessment fair. In environmental impact assessment, the results of investigation in the items and contents of environmental impact assessment were considered to be effectively used in the future based on the environmental impact assessment system in Costa Rica.

13.2.3 Outline of the Project

The outline of the project is described below since it is necessary to specify activities which may affect the environment in the establishment of the power station.

(1) Location

The project site is located in the central highlands which is 30 km south of San Jose, the capital of Costa Rica, and this region belongs in Tarrazu District, San Jose Prefecture. The dam project site is located in a section with a relatively-gentle stream in the middle reaches of the Pirris River at an altitude of about 1,100 m, and the power generation project site is located at an altitude of about 300 m, about 16 km downstream or about 10 km rectilinearly distant from the dam (Fig.13-1).

(2) Outline of the Project

The power plant is the dam and conduit type with a (about) 120 m-high concrete arch gravity dam, and generates a maximum output of 128 MW using a total head of 895 m. A reservoir with an area of about 1.10 km^2 will appear on the Pirris River by construction of the dam. The outline of the Project is shown in Table 13-1.

(3) Transmission Line Plan

It is planned to construct a single-conductor, double- circuit transmission line (30 kV) which passes through the right bank of the Pirris River, goes up north and reaches Escausu (Fig. 13-1).

Fig. 13-1 Location of Planned Power Station Site and Transmission Line Route

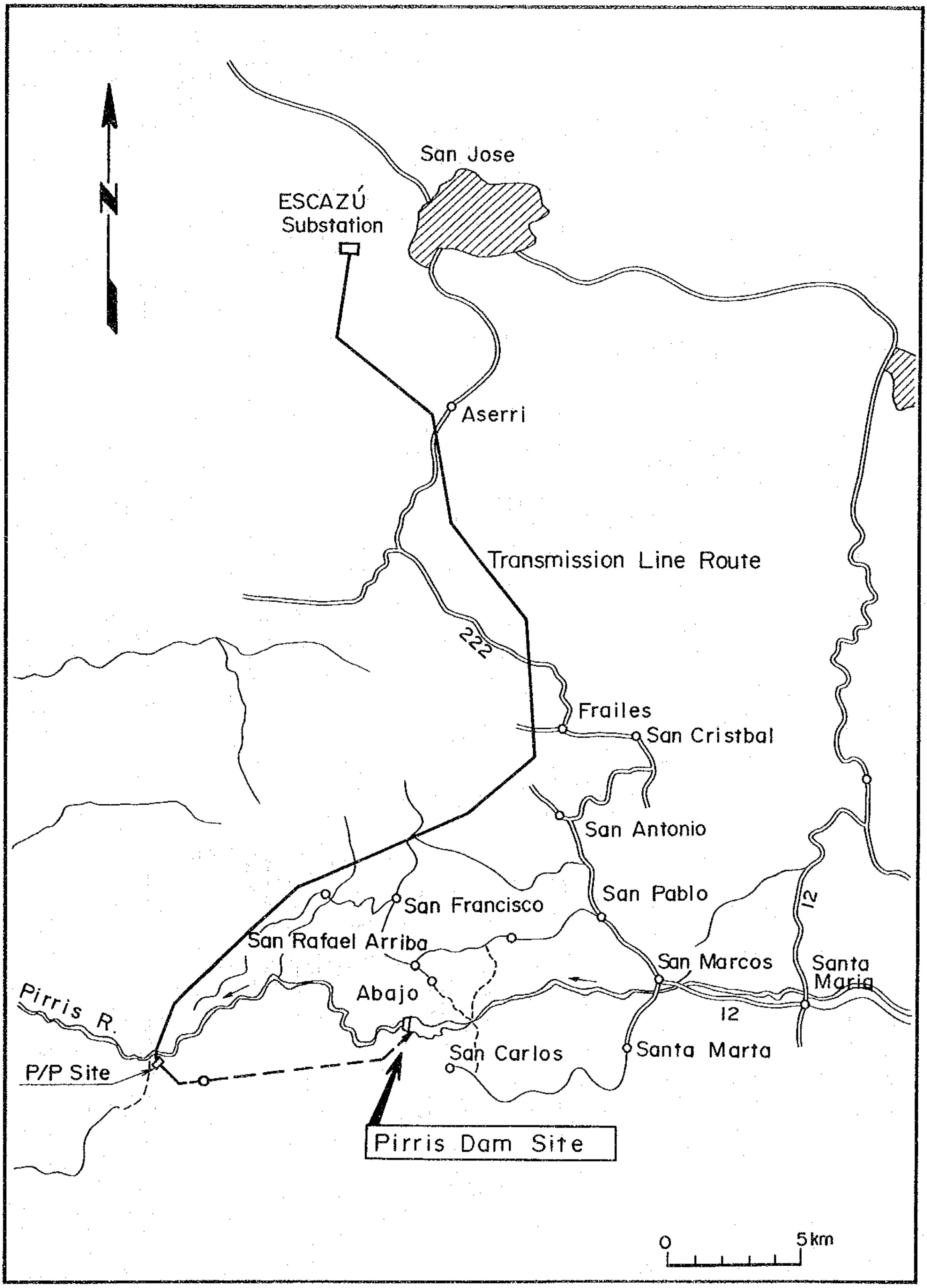


Table 13-1 Main Facilities of Power Plant

Item	Unit	Contents
Catchment Area	km²	250.8
Annual Inflow	10^6 m³	351.6
Design Flood Discharge	m³/s	1,670.0
Reservoir		
High Water Level	m	1,195.0
Low Water Level	m	1,149.0
Available Drawdown	m	46.0
Gross Storage Capacity	10^6 m³	37.5
Effective Storage Capacity	10^6 m³	30.6
Reservoir Surface Area	km²	1.1
Reservoir Length	km	4.5
Dam		
Dam Type	–	Concrete Arch Gravity
Height × Crest Length	m×m	120 × 225
Dam Volume	m³	390,000
Power Generation		
Power Generation Way	–	Dam and conduit Type
Installed Capacity	MW	128
Maximum Discharge	m³/s	18
Firm Discharge	m³/s	3.9
Rated Effective Head	m	830.7
Annual Energy	GWh	609.3

13.3 Present Environmental Situation

13.3.1 Natural Conservation

(1) Natural Conservation in Costa Rica

The forest today accounts for less than 30% of the land of Costa Rica because of rapid deforestation starting in and after 1950 although the forest used to cover over 90% of the national land. Deforestation has been done rather for obtaining cultivated land than for producing wood. It can be said that people's strong desire of possessing their land and the land possession system have given impetus to forest destruction. Remaining small forests (15,900 km^2) have been designated as national parks with an area of about 3,990 km^2, forest reserves with an area of about 3,860 km^2, reservations for Aborigines with an area of about 2,790 km^2 and sanctuaries for wild animals with an area of about 350 km^2 (Fig.13-2). The existence of non-designated forests with an area of about 5,000 km^2 is in danger due to a high annual deforestation rate of 7,000 ha. It is recognized that forest destruction causes soil erosion, decreases the productivity of agriculture regarded as the main industry in this country and largely damages the possibility of hydraulic power station and irrigation water projects, etc.

(2) Natural Conservation around the Power Plant

There are designated areas in the Pirris River basin, such as four water source reserves required for maintaining water quality and quantity, one forest reserve and two reservations for Aborigines, but they are away from the project site (Fig.13-3). A proposal for expanding the area of Caraigres Forest Reserve was made in the Pirris River Basin Management Plan designed in 1985 by the Forestry Bureau at the Ministry of Agriculture, Forestry and Pasturage, but the date and boundaries of the reserve have remained undecided. If the expansion proposal is realized, the reserve will include a part of the power station, conduit tunnel and transmission line. However, it will not interfere with the power station development project since the main purpose of establishing Caraigres Forest Reserve is to maintain water sources.

Fig. 13-2 Wildland Unit Legally Established by the Government of Costa Rica

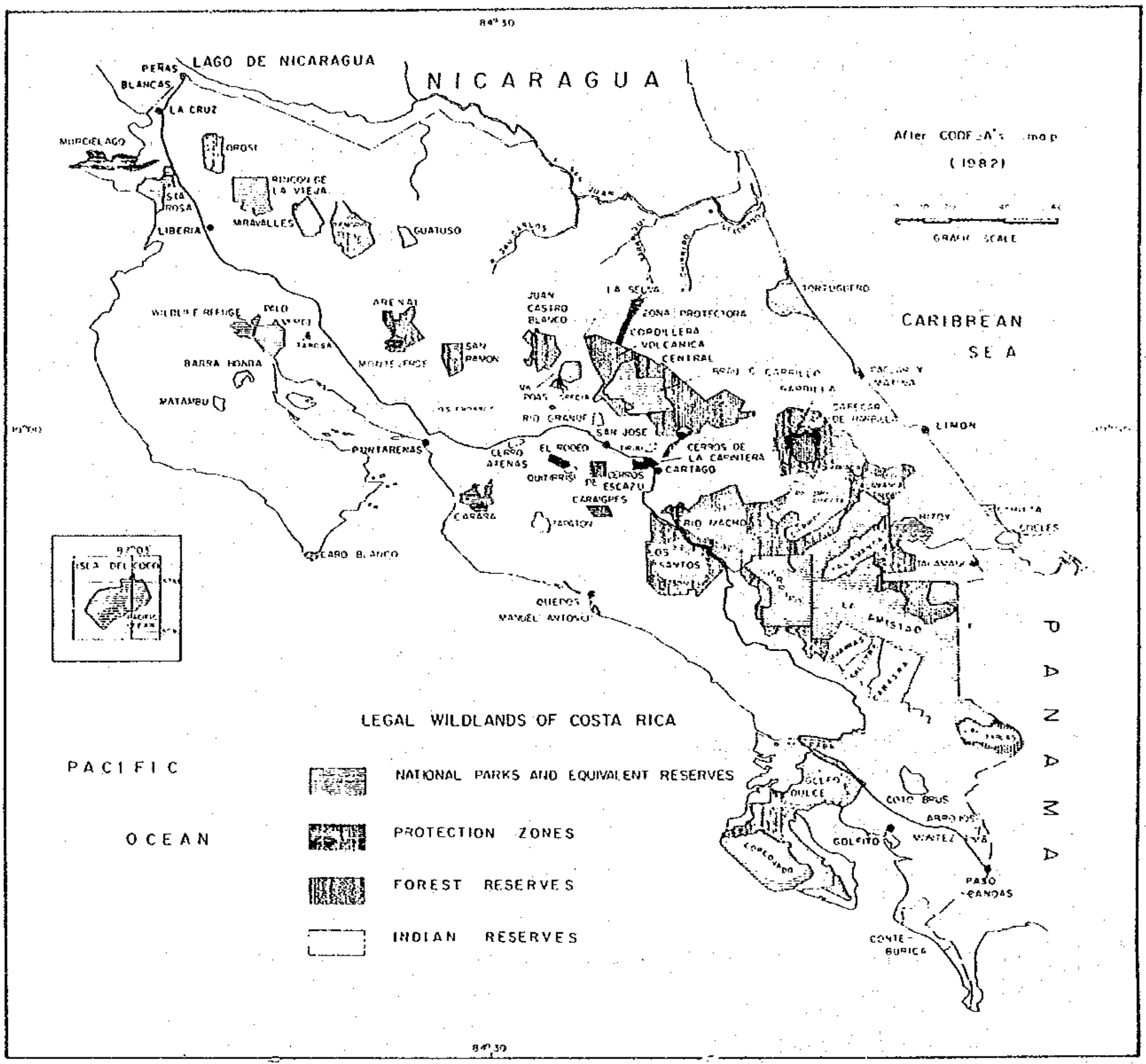
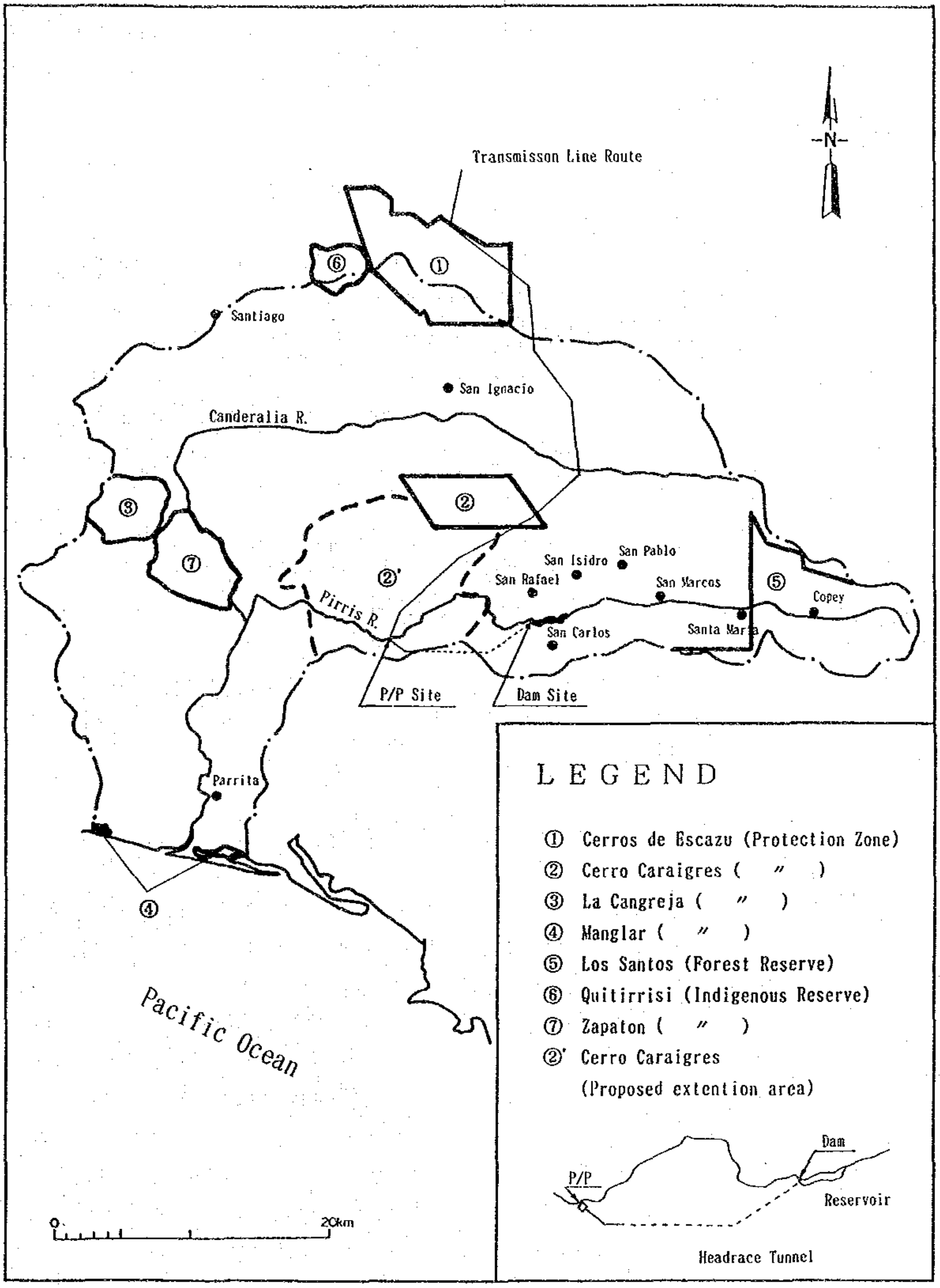


Fig. 13-3 Present State of Designated Areas for Protection of Nature



Sources: Plan de manejo de la cuenca del Rio Parrita, MAG, 1985

13.3.2 Natural Scenery

Natural scenery can be divided mainly based on its topography and the kinds of land utilization since the Pirris River basin has been developed (Fig.13-4).

(1) Upper Reaches of the River

The average gradient of the river from the dam site to its water source is about 1 in 50, continuously consisting of a relatively-gentle slope. There is only an untouched forest area 5 km in length on the upstream side in the entire section 30 km in length from the dam site to the water source. The area consisting mainly of secondary forest is designated as a forest reserve (Photo(1)). The section 25 km in length upstream from the dam site is used as orchards such as coffee, etc. In this section, there are San Marcos, Santa Maria and San Pablo Towns around a place with an altitude of 1,500 m, and about 10,000 residents engage in agriculture. The area along the river bed in the vicinity of the reservoir site is used as cultivated land, coffee, corn, etc., are grown there and mountain sides are used as pasture ground since topsoil is thin. Forests exist only on the banks of the river, along valleys and on and around mountaintops (Photos (2) and (3)).

(2) From the Dam Site to the Power Plant Site

The average gradient of the river from the dam site to the power station site is more than 1 in 15, consisting of a very steep slope. A part of the Pirris River runs down as continuous waterfalls, and several tributaries flow into the river. Both banks of the river near the dam site are very sharp slopes, base bets are exposed everywhere and the area is devastated land covered with bushes (Photo (4)). Forests remain relatively well on the right bank of the Pirris River compared with the left bank, and natural forests are seen at an altitude of 1,000 m or above in the vicinity of the power station site. The power station site consists of river terraces in topography, and it is used as pasture ground (Photo(5)).

(3) From the Power Plant Site to the River-Mouth

The average gradient of the river from the power station site to the river-mouth is less than 1 in 100, and the area is used as pasture ground and cultivated land. Irrigation cultivation is conducted around the river mouth (Photo (6)).

Fig. 13-4 Photographs of Natural Scenery (1)

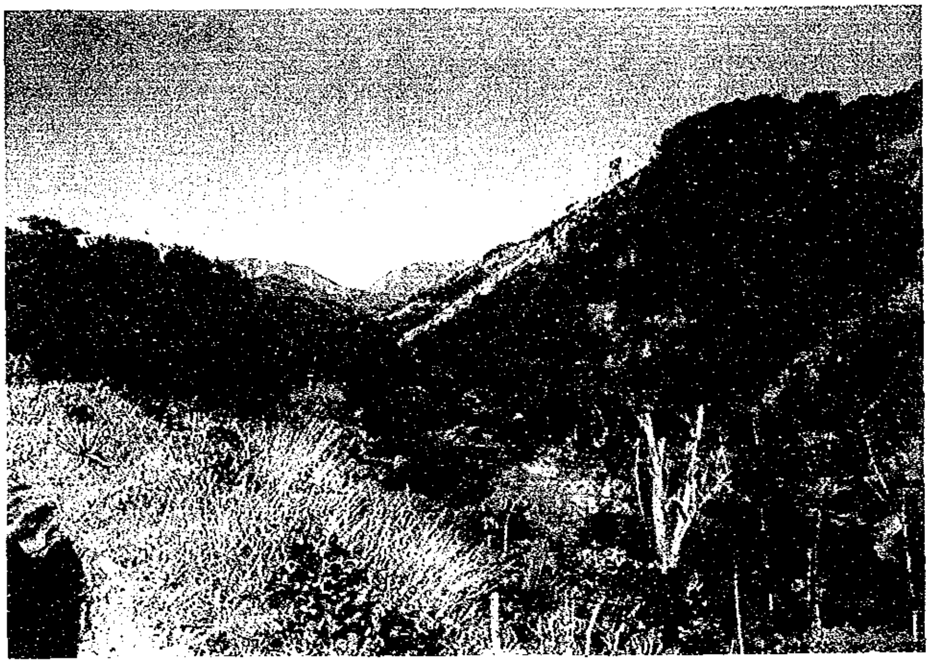


Photo (1) Scenery around Water Source

Photo (2) Scenery around the Reservoir

Fig. 13-5 Photographs of Natural Scenery (2)

Photo (3) Scenery around the Reservoir (on the Right Bank)

Photo (4) Scenery of the Dam Site

Fig. 13-6 Photographs of Natural Scenery (3)

Photo (5) Scenery of the Power Station Site

Photo (6) Scenery around the River-Mouth

13.3.3 Meteorology

Costa Rica belongs in the tropics, having the rainy season and the dry season. The amount of rainfall is big on the Atlantic Ocean side of the country next to the central high-lands and in the southern part of the country on the Pacific Ocean side, and it is small in the central highlands and in the northern part of the country on the Pacific Ocean side. According to the "Analysis of the Pirris River Basin (Analysis de la cuenca del Rio Pirris, 1981)", the Pirris River basin is divided into the following three climate zones.

(1) Temperate Wet Clime

It is dry in winter. The monthly maximum rainfall in summer is at least ten times larger than the monthly minimum rainfall in winter. The monthly average temperature is 18^0C or lower, but it dose not drop to 3^0C or lower. It becomes hot, standing at a monthly maximum temperature of about 22^0C. The project site belongs in this climate.

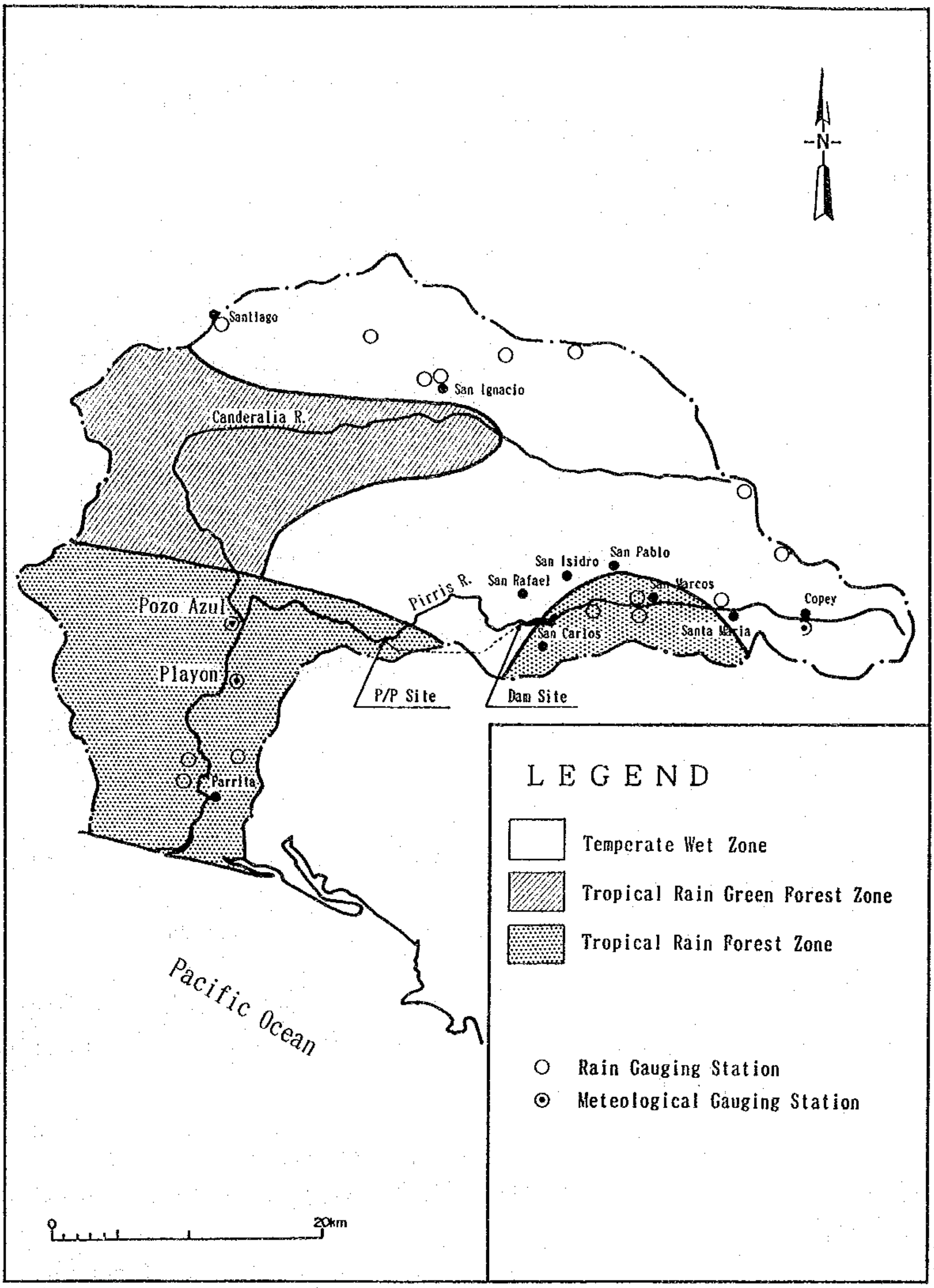
(2) Tropical Rain Green Forest Clime

It is very dry in winter (with a monthly rainfall of 60 mm or lower) and rains much in fall. The monthly minimum temperature is about 18^0C. The difference between the monthly minimum and maximum temperatures is 5^0C or less.

(3) Tropical Rain Forest Clime

The dry season is short and the total amount of rainfall is big enough to develop tropical forests. The monthly minimum rainfall is 60 mm or lower and the monthly minimum temperature is 18^0C or above. It rains most in fall, especially in the northern part of this area. The situation differs depending on the places, but there is generally the dry season (the driest in January and February) from January to March and the rainy season (with much rain especially in May, September and October) from May to October. The amount of rainfall is big in the watershed in the southern part of the river basin, and the annual average rainfall stands at about 5,000 mm or above in some rainy areas. According to variations in the annual rainfall at San Marcos Observatory, the difference between the dry season and rainy season is remarkably big and the monthly average rainfall stands at a maximum of 380 mm, especially in September and October. This phenomenon is called orographic rainfall caused by the trade winds coming from the Pacific Ocean in the rainy season and the mountain slopes structuring the river basin, but floods in the river basin are caused by hurricanes coming from the Atlantic Ocean, that is, non-orographic rainfall. At Poso Azul Observatory, the annual evaporation stands at an average of 1,500 mm and the monthly evaporation stands at a maximum of 180 mm in March and a minimum of 155 mm in November. Based on the equation of Turc, Rodrigues. L. E. (1983) evaluated the real annual evaporation at 1,642 mm in Poso Azul, 1,378 mm in San Igunacio de Acosta and 1,137 mm in Puriscal. In the vicinity of the power generation project site, the annual temperature stands at an average of about 20^{0}C forming a comfortable climate and there is a small difference in daily temperature.

Fig. 13-7 Climatic Zones



Sources: Análisis de la cuenca del Río Pirrís, Universidad Costa Rica, 1981

13.3.4 Topography and Geology

(1) Topography

It is characteristic of the Pirris River basin that it is mostly occupied by mountain areas. The areal distribution of altitude levels in the entire river basin including the Candelaria River is shown below, and the area with an altitude of 600 m or above accounts for about 70% of the entire river basin.

Alluvial plains (not higher than 100 m in altitude)	:	120 km^2, 8.9%
Areas of not higher than 600 m	:	316 km^2, 23.3%
600 m to 1,000 m	:	236 km^2, 17.4%
1,000 m to 1,600 m	:	310 km^2, 22.9%
1,600 m to 2,400 m	:	337 km^2, 24.9%
2,400 m or above	:	35 km^2, 2.6%

The classification of gradients in the Pirris River basin based on the width between contour lines on a map drawn on a scale of 1 to 50,000 is as shown in Fig. 13-8. The river basin is largely divided into three kinds based on typographical gradients. The first part is an area upstream from the reservoir, that is, an area consisting of Copey, San Marcos and Chonta. The land at a gradient of 60% or less accounts for 95% of the entire area, and the relatively flat land at a gradient of 15% or less is also included, accounting for 5 to 10% of this area. The second part is a section about 30 km in length reaching nearly the confluence of Pirris River and Candelaria by way of the reservoir and the dam. This area is very steep, having almost no place at a gradient of 15% or less. The land at a gradient of 80% or above also accounts for about 10% of the entire area. The third part is an area from the confluence of Pirris River and Candelaria River to the river-mouth, the land at a gradient of 45% or less accounts for 90% of the vicinity of the confluence and the land at a gradient of 15% or less accounts for 100% of the further downstream area. Fig. 13-9 shows the gradients of land in the Pirris River basin. The areas colored in red show slopes at a gradient of 60% or above. There are a lot of steep slopes at the project site. According to the results of interpreting the topography of land with a total area of 102 km^2, a north and south length of 6 km and a east and west length of 17 km in the vicinity of the project site based on aerial photographs on a scale of 1 to 25,000, the survey area can be largely divided into eastern and western sections from the central part as the border. In the eastern section, steep slopes are seen along Pirris River and its main tributaries, but slopes are generally gentle except these areas. Especially in the section on the left bank of the Pirris River, gentle slopes are distributed near a mountain ridge and ridge lines deriving from it and a lot of small-sized landslides including especially surface landslides are widely distributed. The western section is a steep mountain area with Dota (2,116 m) regarded as the main peak, and mountain slopes and valley bottoms are very steep. Mountain slopes are generally big, gullies and valley lines closely exist on the surface of the mountain slopes and a lot of valley tops are collapsed places and traces of collapsed ground. In the western section, landslides and wide pyramidal cliffs are concentrated on slopes along the Pirris River. Terraces are developed along the Pirris River downstream from Romacarbario. A lot of collapsed places and traces of collapsed ground are distributed on slopes along the Pirris River and on the eastern side of Dota Mountain, which are poor in vegetation. Most of them are collapsed ground by surface weathering and they are relatively shallow and small.

(2) Geology

The geological features distributed in the project area consist of Brito Layer originating in the Cenozoic, Tertiary and Eocene periods, turbidite layers in the Oligocene to Miocene periods and layers in the Quaternary period. Besides them, volcanic rocks, intrusive rocks, etc., are seen (Fig. 13-10). The foundation ground at the reservoir site mostly consists of Terraba Layer, and non-concreted sediment such as terrace sediment, pyramidal cliff sediment, landslide sediment and river-bed sediment are distributed on the foundation ground. There are some landslides and collapsed places on slopes higher than the reservoir, but all of them are small. The geology of the dam site consists of turbidite and dolerite. The action of classifying turbidite while being accumulated has remained well and the classification of particular sizes can be given clearly. This rock is freshly solid at the river-bed, but it is weathered and softer at higher positions of mountain slopes. Dolerite is also freshly solid at the river-bed, but it is weathered and soft on the surface of the mountain edge on the right side. The power station site is located on a wide flat terrace. The foundation ground consisting of dolerite at the site is covered with thick terrace sediment. A landslide exists at an altitude of about 700 m.

Fig. 13-8 Slope of Pirris River Basin (1)

Administrative Sectors		classes of slope (%)						
		0-15	15-30	30-45	45-60	60-80	80-	total
Copey	①	7.8	23.5	38.0	25.3	5.4	***	100.0
San Marcos	②	10.7	30.7	36.0	19.6	2.2	0.8	100.0
Chonta	③	4.5	16.5	43.2	33.6	1.3	1.2	100.0
San Carlos I	④	***	1.4	52.9	26.0	11.7	8.0	100.0
San Carlos II	⑤	***	13.1	40.7	22.0	24.2	***	100.0
Tiquires	⑥	0.3	6.3	34.1	25.1	18.2	16.0	100.0
Bijagual I	⑦	26.0	26.0	38.0	8.0	2.0	***	100.0
Parrita	⑧	99.8	0.2	***	***	***	***	100.0

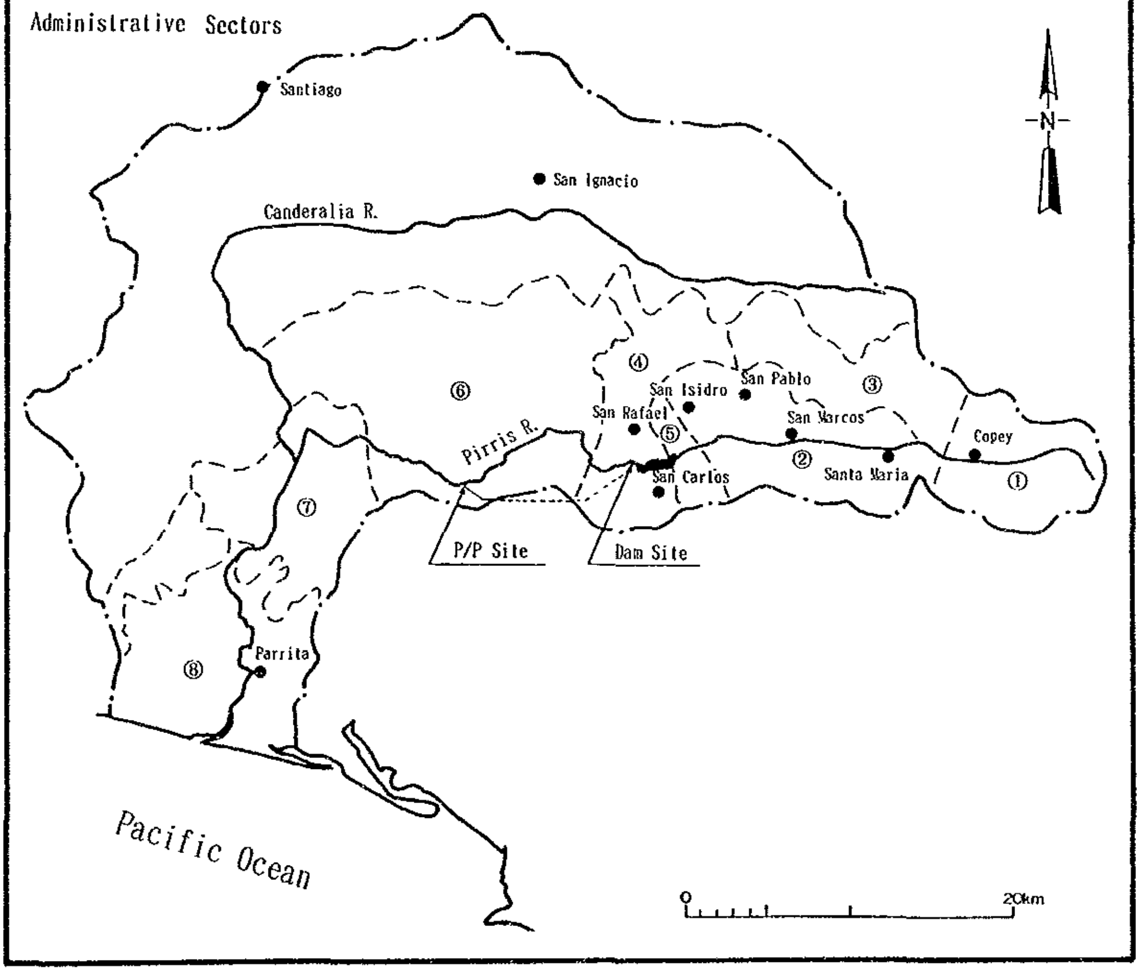
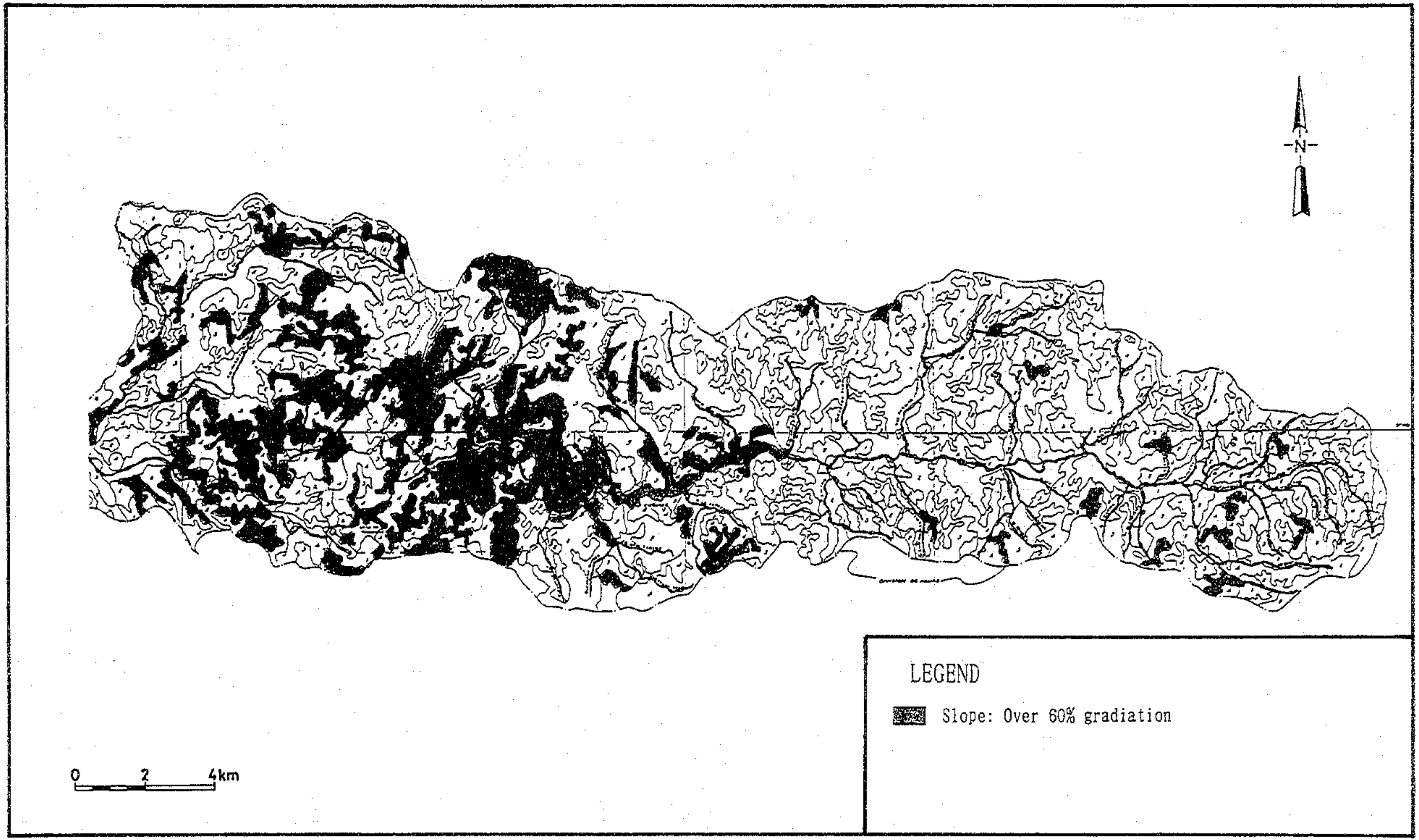
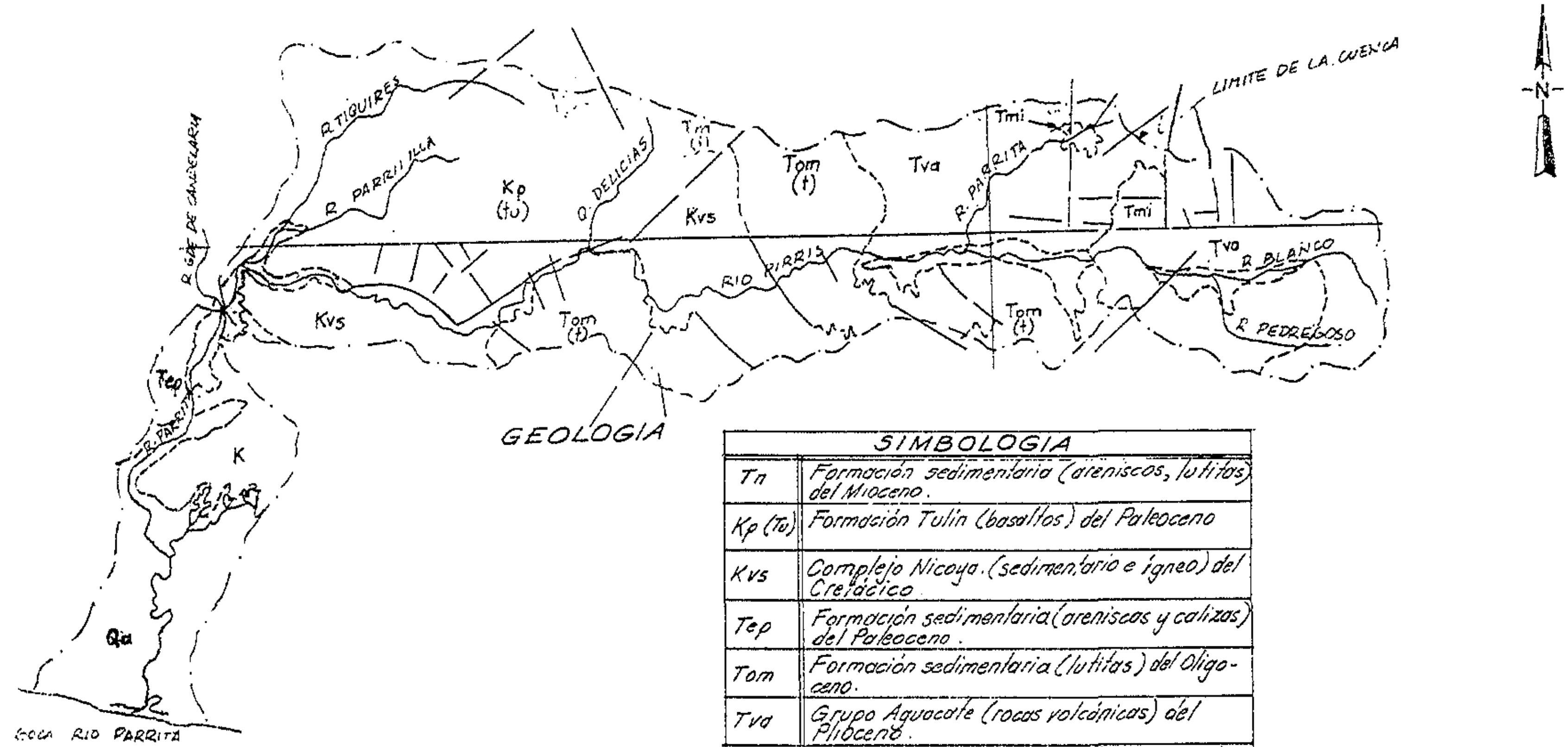


Fig. 13-9 Slope of Pirris River Basin (2)



Sources: Plan de manejo de la cuenca del Rio Parrita, MAG, 1985

Fig. 13-10 Geological Map



SIMBOLOGIA	
Tn	Formación sedimentaria (areniscas, lutitas) del Mioceno.
Kp (Tu)	Formación Tulín (basaltos) del Paleoceno
Kvs	Complejo Nicoya. (sedimentario e ígneo) del Cretácico
Tep	Formación sedimentaria (areniscas y calizas) del Paleoceno.
Tom	Formación sedimentaria (lutitas) del Oligoceno.
Tva	Grupo Aguacate (rocas volcánicas) del Plioceno.
K	Formación Rivas (sedimentario e ígneo) del Cretácico.
Tmi	Formación sedimentaria indiferenciada del Mioceno.
Qa	Manglares y pantanos del Holoceno

Fuente: Mapa Geológico de Costa Rica, escala 1:200000, hojas San José y Quepos MIRENEM - 1982.

Sources: Plan de manejo de la cuenca del Rio Parrita, MAG. 1985

13.3.5 Soil

<Soil>

Agriculture regarded as the economic foundation in Costa Rica is supported by soil. However, there are very few materials for soil. Fig.13-11 shows a part of soil distribution classified by Vasques (1979) based on Soil Taxonomy at the U.S. Department of Agricultural Affairs. Soil in the vicinity of the project site exactly fits "Sedimentary Soil on Very Steep Slopes", is the concreted debris soil type with accumulated horizons containing much $Fe2O3$ (hematite) on the metamorphic sediment foundation and consists of Humults, Ustults and Tropepts. This type of soil is seen most generally in mountainous regions in Costa Rica, accounts for about 26% of the soil in the entire national land and about 60% of that in the entire mountainous regions.

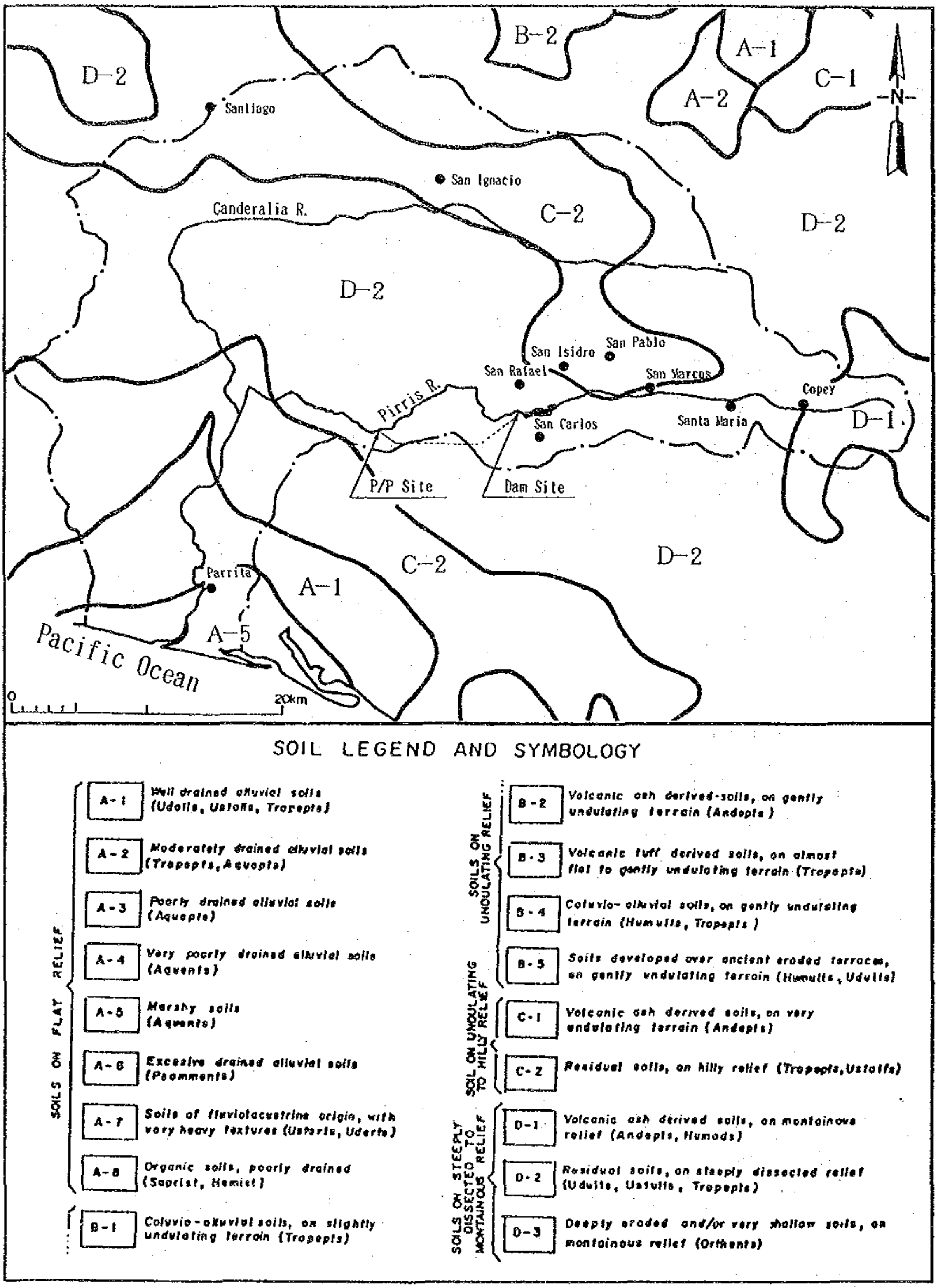
<Soil Erosion>

Table 13-2 shows the possibility of soil erosion in the river-basin on the Pacific Ocean side based on the classification in Fig. 13-11. According to researches conducted by Vasques (1979) and Tosi (1969, 1972), soil (C-2, D-2) in most parts of the Pirris River basin is in much danger of erosion. Most parts of the Pirris River basin are used as coffee plantations and pastures. As for the cultivation of coffee in this basin, coffee trees are often planted perpendicularly to the surface of slopes for easier weeding and weeding work is done considerably roughly by cutting off weeds together with surface soil. Pastures developed on steep slopes are a decisive factor in a series of erosion stages. Surface landslides occur and soil flows out from the exposed ground in the rainy season since steep pastures are trodden down as terraced fields by the weight of cattle and surface soil is originally thin. Roads are also the cause of soil erosion in the river-basin. Besides weathered soil with a lower hardness, unpaved roads constructed unreasonably on steep slopes are the cause of repeated collapse of slopes and rainfall causes soil to flow out in the rainy season. It is caught in a vicious cycle to increase the collapse of slopes since roads are repaired by bulldozing out earth and sand, a lot of earth and sand is discharged and the gradient of slopes becomes steeper.

< Distribution of Devastated Land >

Fig.13-12 shows LANDSAT (land satellite) photographs of the vicinity of the project site taken in February, 1987. A dot screen 30 meter square was optionally processed based on each frequency band by "LODIA" which is satellite picture processing software. Photo (1) was processed to show its topography clearly. The flow of the Pirris River is clearly shown in the center of the screen. Things seen in white are clouds. Photo (2) shows the distribution of devastated land and pastures, typical devastated land (an area enclosed with a white square, which was determined on site investigation) inside the screen is regarded as a reference point and areas with the same characteristics of reflection as this one are shown in red. The reference point is a slope on the right bank of the Pirris River shown in Photo (4) in Chapter 13.3.2 titled Photographs of Natural Scenery, and it is extremely-devastated land on this steep slope. Green shows forest, white shows clouds and black shows clouds and the shadow of mountains. Devastated land and pastures are widely distributed on the entire slope on the right bank of the Pirris River. The vicinity of the power generation project on the right and left banks consists of devastated land or pastures.

Fig. 13-11 Soil Map



Sources: Costa Rica, Environmental Profile, A Field Study, USAID. 1982

Table 13-2 Sensitivity against Soil Erosion *

Category / Area	①		②		③		④	
	km²	%	km²	%	km²	%	km²	%
A : 1-8	5,281	91.4	410	7.1	81	1.4	6	0.1
B : 1-5	667	24.4	1,798	65.7	231	8.4	41	1.5
C : 1-2	1,535	17.3	3,282	37.0	3,348	37.7	708	8.0
D : 1-3	3,697	38.0	2,549	26.2	2,660	27.4	813	8.4
Total	11,180	41.2	8,039	29.7	6,320	23.3	1,568	5.8

Category:

① No significant erosion from running water (wind erosion possible in some case)

② Light to moderate erosion: sympotoms of sheet and rill erosion visible, gullies absent or scarce

③ Severe erosion: abundant small gullies and deep tracks in pastured land, small landslips and occasional gullies, B-horizon exposed

④ Soil nearly destroyed or deeply truncated with exposure of subsoil in many places, abundant deep gullies, landslips, and occasional masssive landslides

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* Costa Rica, Country Environmental Profile, A Field Study
United States Agency for International Development,
Tropical Science Center, 1982.12

Fig. 13-12 Photograghs of Divested Land via Satellite

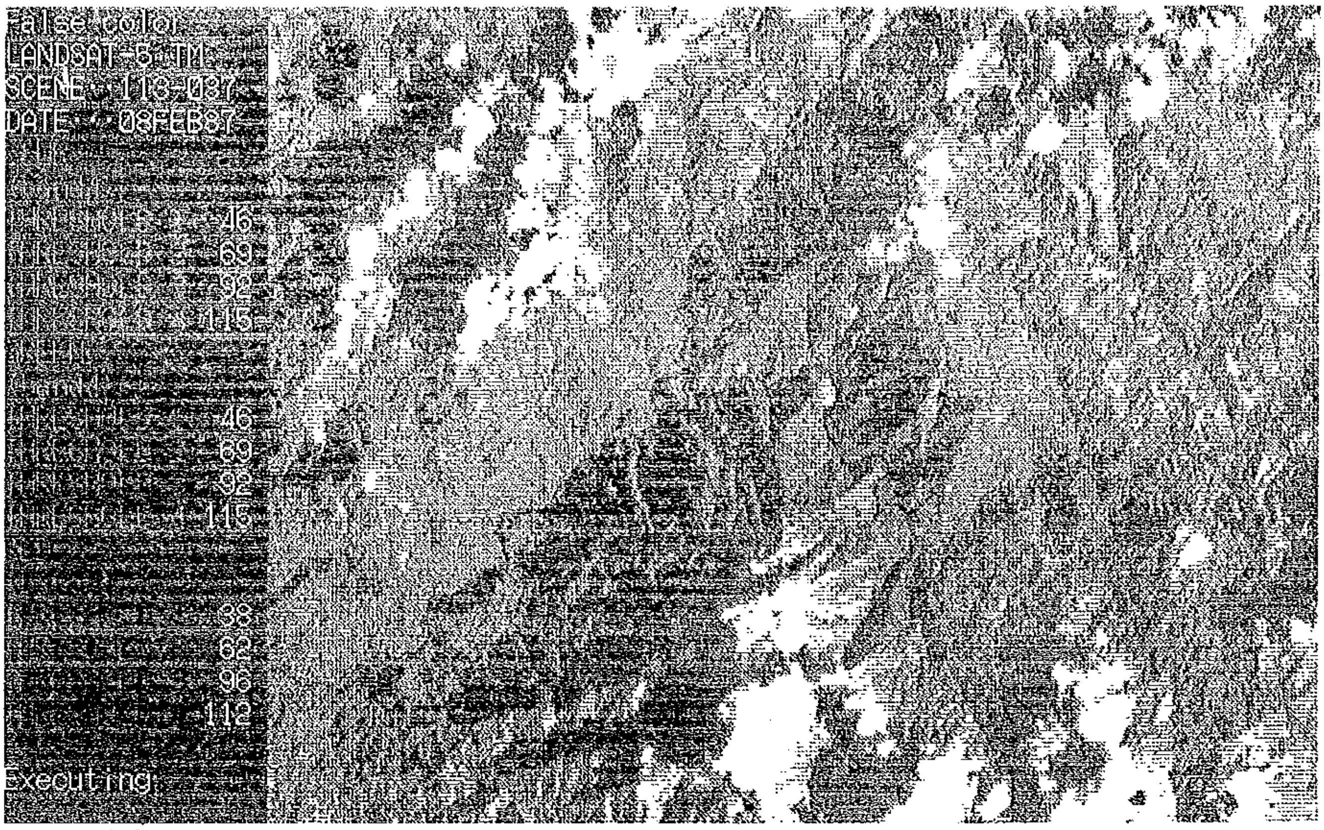


Photo (1) PIcture Processing to Show its Topography Clearly

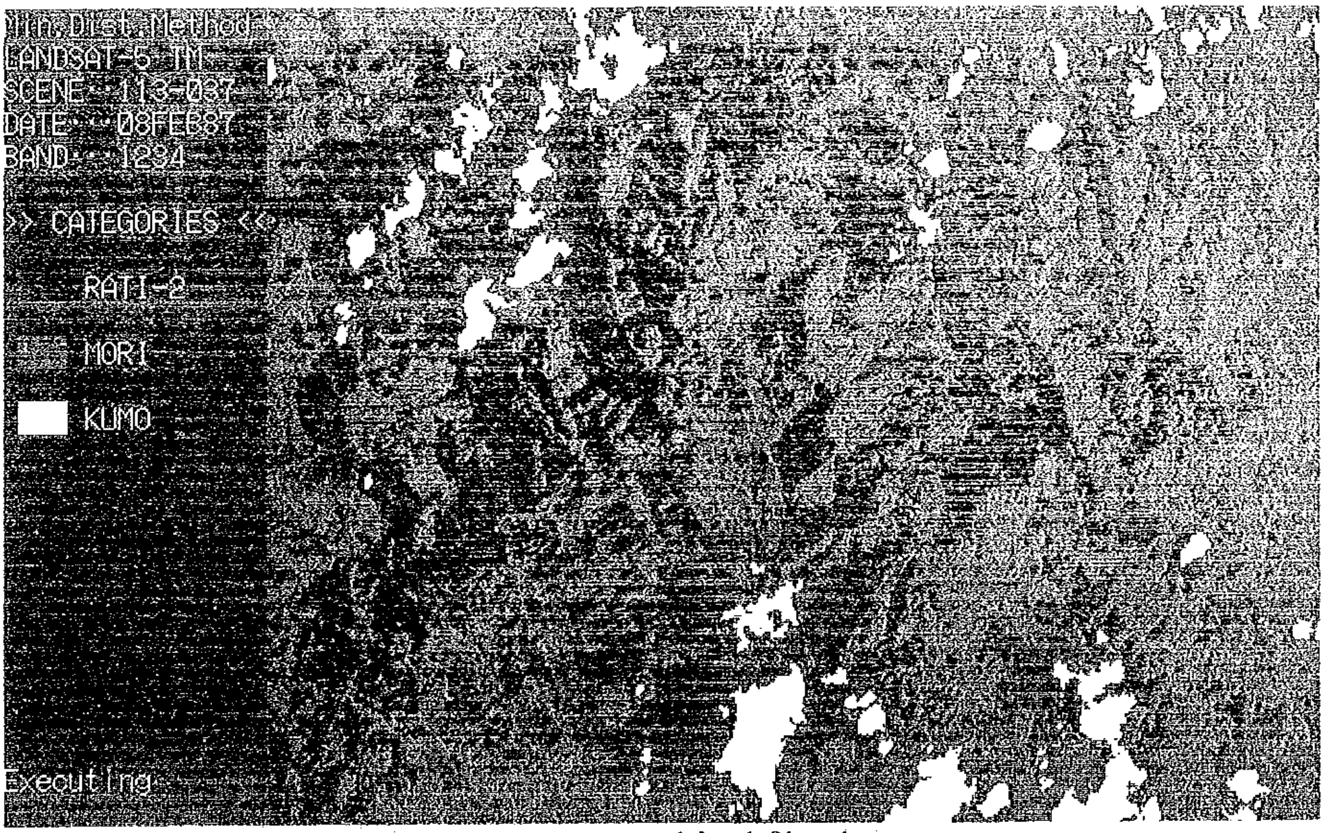


Photo (2) Picture Processing to Show Devastated Land Clearly

The figure was created by processing satellite picture data purchased from EOSAT company in the United States by satellite picture processing software (LODIA).

13.3.6 Vegetation

1) Outline of Vegetational Classification in the Pirris River Basin

According to the ecological map of Costa Rica (Tosi, 1968), the situation of vegetation in the Pirris River basin is classified into the following four areas based on the altitude levels (Fig. 13-13).

1. Tropical Area (Region tropical-piso basal)
2. Tropical Premountain Area (Region tropical-piso premontano)
3. Tropical Lower Mountain Area (Region tropical-piso montano bojo)
4. Tropical Mountain Area (Region tropical-piso montano)

However, most places have been developed up to now, and only few places with natural vegetation have remained.

(1) Tropical Area

This area represents tropical moist forests (bh-T) in the alluvial plain along Parrita River and its neighbor hill areas. As shown in Fig. 13-13, tropical wet forests (bmh-T) exist in the mountain district, which is upstream from the confluence of the Pirris River and Candelaria River, affected directly by the Pacific Ocean and located at a maximum altitude of about 500 m. According to Allen (1956), the types of trees indigenous to tropical wet forests are as follows:

Anacardium excelsum *Brosimun* spp. *Carapa quianensis* *Cedrela odorata* *Ceiba pentandra* *Chimnarrhis latifarla* *Chrysophyllum* spp. *Virola* spp.	*Cynometra hemitaphylla* *Dacryodes ephytica* *Dipterodendron costarricensis* *Huberodendron allenii* *Basyloxilon exelsum* *Terminalia* spp. *Caryocar costarricense*

Furthermore, Goodland (1969) mentions Pachira aquatica, Prioria copaifera and Anacardium excelsum as the main constitute trees in forests on slopes in the river basin. However, the power generation project site belongs in the above-mentioned vegetation zone.

(2) Tropical Premountain Area

The tropical premountain area in the river basin represents tropical premountain rain forests (bp-P) and tropical premountain wet forests (bmh-P).

i) Tropical Premountain Rain Forests

Tropical premountain rain forests are seen on both banks of the middle reaches of the Pirris River with an altitude of 800 m or above and an annual average rainfall of 4,000 mm or above, covering the watersheds of the Pirris River and Candelaria and areas which are directly affected by the Pacific Ocean. There is also a small forest inside the three imaginary straight lines which are extended between Platano, Agua and Buena in the western part of the river basin. The most common types of trees seen in this kind of forests are as follows. The dam project site belongs to in the above-mentioned vegetation zone.

Sideroxylon uniloculare	*Conostegia* spp.
Pachira aquatica	*Quercus quglielmitreleasi*
Cedrela adorata	*Ulmus mexicana*
*Ocotea*spp.	*Hieronyma* spp.
Miconia spp.	*Ficus tondizii*

ii) Tropical Premountain Wet Forests

Tropical premountain wet forests are seen especially around San Marcos in the highlands of the Pirris River Basin with an altitude of 800 m to 1,500 m. Tropical premountain wet forests are generally changed into tropical wet forests along the Pirris River up to the alluvial plain around Parrita River, covering the big alluvial fan at the confluence of Candelaria River and the Pirris River up to the bank of Parrita River. The types of trees indigenous to this vegetation zone consist of various kinds of big trees which are closely covered with epiphytic creatures. The main types are as follows:

Dicymopanax morototoni *Vochisia hondurensis* *Vochisia ferruginea* *Cornutia* spp. *Miconia* spp. *Virola* spp. *Oreamunnea pterocarpa* *Cordia alliadora* *Nectondra* spp.	*Ocotea* spp. *Hirtella americana* *Turpinia occidentalis* *Roupala montana* *Ficus* spp. *Rhus* spp. *Casearia* spp. *Cedrela adorata*

Lauraceas and Melastomaceas can be regarded as the representative families of trees.

(3) Tropical Lower Mountain Area

The lower mountain area in the river basin is covered with tropical lower mountain rain forests (bp-MB) and tropical lower mountain wet forests (bmh-MB).

i) Tropical Lower Mountain Rain Forests

Tropical lower mountain rain forests are seen around the village communities of Mata de Cana, Esperanza, San Carlos, etc., in the middle and lower parts of the river basin with an altitude of about 1,500 m. The land in this area consists of mountainsides which are exposed to wind and rain and is topographically severe except in villages between mountains, such as Copey (with an altitude of 1,850 m), etc. The types of trees commonly seen in this type of forests are as follows:

Quercus copeyensis *Quercus eugenifolia* *Quercus brenesii* *Cornus disciflora* *Alnus acuminata* *Mangnolia poasana* *Cleyera theoides*	*Freziera condicans* *Viburnum* spp. *Prunus* spp. *Rhamnus capraefolia* *Ulmus mexicana* *Weinmannia* spp.

ii) Tropical Lower Mountain Wet Forests

The types of plants in tropical lower mountain wet forests are similar to the above-mentioned ones, and there are more oaks and evergreen oaks (Quercus spp.).

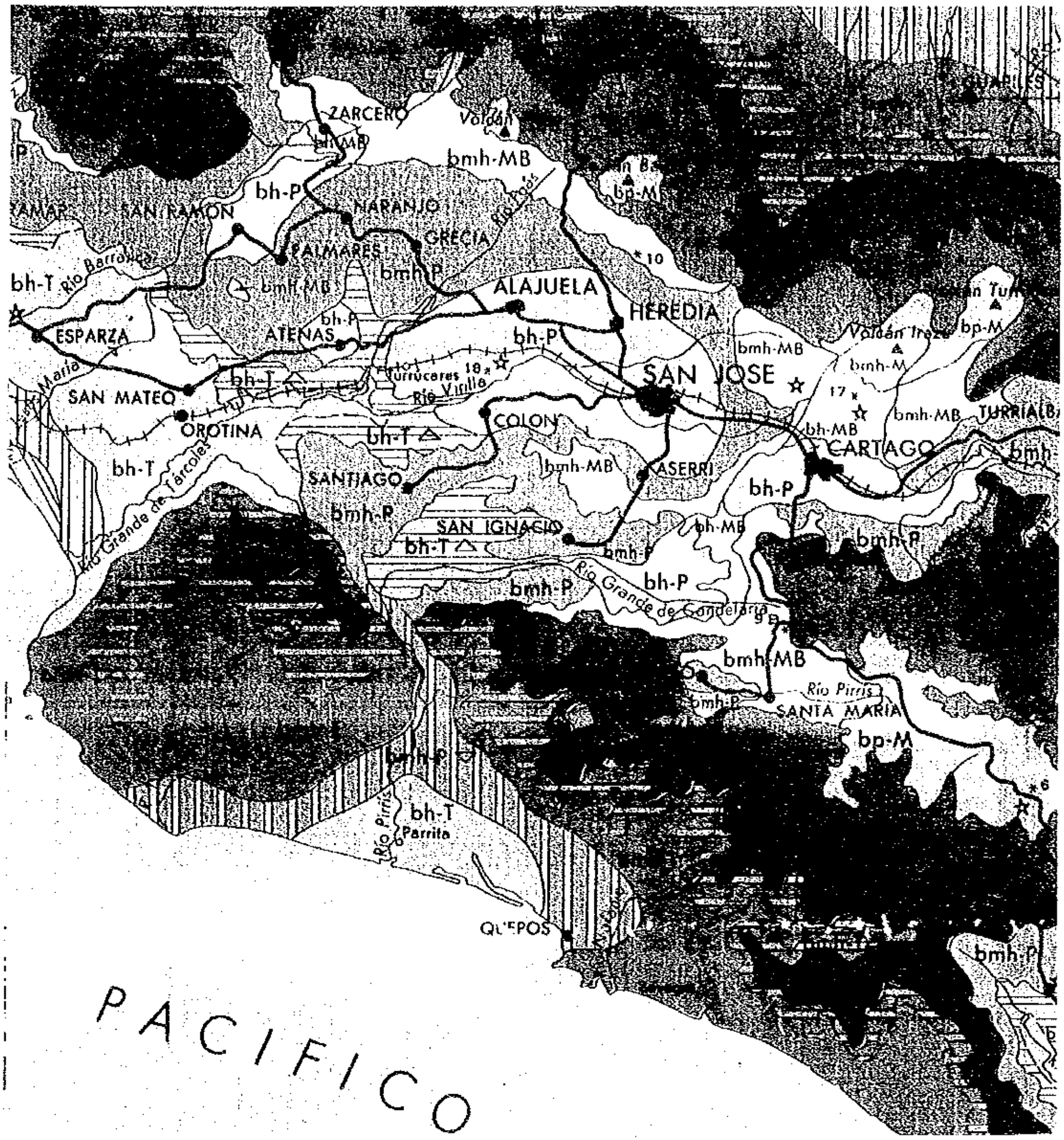
(4) Tropical Mountain Area

This area represents tropical mountain rain forests (bp-M), covering areas around the villages of Alto catarina, Paramo Veulutas, Sabana Vueltas, etc., and the source of the Pirris River with an altitude of 2,500 m. Forests indigenous to this area consist of various kinds of big trees covered with epiphytic creatures. The types of trees commonly seen in these kinds of forests are as follows:

Didymopanax morototoni	*Hirtella americana*
Vochisia hobdurensis	*Turpinia occidentallis*
Cornulia spp.	*Roupala montano*
Miconia spp.	*Ficus* spp.
Oreamnunnea pterocarpa	*Rhus* spp.
Cordia alliodora	*Casearia* spp.
Nectandra spp.	*Cedrela odorata*
Oco-tea spp.	

The most representative families of trees are Lauraceas and Melastomaceas.

Fig. 13-13 Vegetation Map



CLAVE PARA LAS ZONAS DE VIDA

REGION TROPICAL—PISO BASAL

- bs-T — Bosque seco tropical / *Tropical dry forest*
- bs-T — Bosque seco tropical, transición a húmedo / *Tropical dry forest, moist province transition*
- bh-T — Bosque húmedo tropical / *Tropical moist forest*
- bh-T — Bosque húmedo tropical, transición a perhúmedo / *Tropical moist forest, perhumid province transition*
- bh-T △ — Bosque húmedo tropical, transición a premontano / *Tropical moist forest, premontane belt transition*
- bmh-T — Bosque muy húmedo tropical / *Tropical wet forest*
- bmh-T △ — Bosque muy húmedo tropical, transición a premontano / *Tropical wet forest, premontane belt transition*

REGION TROPICAL—PISO PREMONTANO

- bh-P — Bosque húmedo premontano / *Premontane moist forest*
- bh-P ▽ — Bosque húmedo premontano, transición a basal / *Premontane moist forest, basal belt transition*
- bmh-P — Bosque muy húmedo premontano / *Premontane wet forest*
- bmh-P ▽ — Bosque muy húmedo premontano, transición a basal / *Premontane wet forest, basal belt transition*
- Bosque muy húmedo premontano, transición a pluvial / *Premontane wet forest, rain forest transition*
- Bosque pluvial premontano / *Premontane rain forest*

REGION TROPICAL—PISO MONTANO BAJO

- bh-MB — Bosque húmedo montano bajo / *Lower montane moist forest*
- bmh-MB — Bosque muy húmedo montano bajo / *Lower montane wet forest*
- bp-MB — Bosque pluvial montano bajo / *Lower montane rain forest*

REGION TROPICAL—PISO MONTANO

- bmh-M — Bosque muy húmedo montano / *Montane wet forest*
- bp-M — Bosque pluvial montano / *Montane rain forest*

REGION TROPICAL—PISO SUBALPINO

- pp-SA — Páramo pluvial subalpino / *Subalpine rain paramo*