CHAPTER 2

NATIONAL AND PROVINCIAL BACKGROUND

CHAPTER 2: NATIONAL AND PROVINCIAL BACKGROUND

2.1 BRIEF DESCRIPTION OF THE COUNTRY

2.1.1 Natural Feature

The territory of the Republic of Ecuador extends the latitude from approx. 1°N to 5°S and longitude from approx. 75°W to 81°W. The equator passes through the suburb of its capital city, Quito. The northern and northeastern edges border on Colombia, and southern and southeastern edges on Peru. Its territorial extension is approx. 270 thousands km2.

The Andes Mountain Range runs at the center of the country in north–south direction. Due to the topographic and climatic conditions, the territory can be divided into following four regions:

. Costa (costal region)	:	25.6% (by area)
. Sierra (mountainous region)	:	26.9%
. Oriente (eastern plain region)	:	44.5%
. Galapagos Islands	:	3.0%

"Costa" covers the area from Western Andes Mountains to the Pacific Ocean. It is comparatively flat and its altitude is almost lower than 300 m. The climate of the northern part of Costa is characterized with high temperature and heavy rain. The rainfall becomes fewer by shifting southward.

The width of "Sierra" is 100 – 200 km. The Andes Mountain Range running though Sierra in north–south direction can be divided into two sub–ranges. The agricultural fields expand in the area. The climate of Sierra is comparatively mild due to its high altitude, even though the area is located at the equatorial region.

"Oriente" is the area with tropical climate, which expands from eastern part of the Andes Mountain Range to Amazon.

The regional climates differ greatly due to the effect of complicated topography, Humboldt Current, etc. Thanks to its topographic and climatic conditions, Ecuador is endorsed with relatively rich water resources compared with the neighboring countries (Peru, Chile, etc.), even though the climate differs by region.

2.1.2 National Economy

The census in 1990 shows the following:

a. Ecuador had a population of 9,648 thousands, 55.4% of which were distributed in urban areas and the rest in rural areas.

b. The distribution of population by age group was as follows:

Age Group	Ratio (%)
0 – 14	38.0
15 – 24	20.3
25 – 64	36.6
Older than 65	4.3

c. An economically active population was 44% of the total and unemployment rate was 1.3%.

d. Population annual growth rate during the past ten years (1980–1990) was 1.6% and population density was 35.5 persons/km^2.

Agriculture was traditionally the basis of the national economy. Agricultural sector's share in the GDP has been decreasing since the oil production started in 1970. However, its sector still plays an important role in the national economy and an employment rate in the sector is still about 50% of the economically active population.

According to the data of the Ecuador Central Bank in 1990, the following economic figures can be clarified:

a. The GDP was 9.5 billion US dollars, in which agricultural sector represented 17.4%, oil sector 12.5%, industrial sector 16.3%, public (electricity, gas and water) sector 1.6%, construction sector 3.3%, commercial sector 14.8%, financial sector 10.8% and others 23.3%.

b. Total export earnings was 2.7 billion US dollars in FOB price, of which the agricultural sector contributed 680 million US dollars and main agricultural export products was banana, coffee and cacao, sharing 95% of the total agricultural export.

c. In recent years, the exportation of prawn has been increased and its contribution to the national economy is almost the same as that of banana.

d. The GDP per capita was 16,783 sucre which was equivalent to 996 US dollars.

According to the information of National Development Council (CONADE) and Ecuador Central Bank, national crisis on foreign currency balance and exchange rate occurred in 1988, and inflation rate in December 1988 reached 85.7%. Inflation during 1990 and 1992 (June) was averagely 50% per year. In parallel with this, the price of agricultural products in 1992 increased to 380 in the case of the price in 1988 was set at 100.

At present, based on the Cartaghena Agreement concluded in 1960 among the Andes countries (Venezuela, Colombia, Ecuador, Peru and Bolivia), the socio-economic development and economic cooperation in respective sectors have been discussed among these countries, and some of them have been realized. Free marketing system which will give the strong impact on the economy of these countries has been also progressively discussed. Among others the problems on customs are being discussed aiming at the entire free marketing system in the future.

Table 2.1.1 GDP by Sector (in 1975 Price)

(Unit: Million Sucre)

Item	1980	1985	1990
Agriculture, Forestry, Fishing	21,198	24,178	31,525
Oil, Mining	15,070	23,875	22,484
Industry, Manufacturing	26,807	28,710	29,474
Public (Electricity, Gas, Water)	1,115	1,833	2,984
Construction	6,906	6,742	5,914
Commerce	24,789	24,268	26,854
Traffic, Communication	10,038	11,506	15,438
Financial, Insurance	17,694	18,162	19,574
Social Service	7,612	9,529	10,618
Banking Service	-5,006	-4,519	-5,048
Sub-total	126,223	144,284	159,817
Government Services	13,709	14,842	15,609
Domestic Services	675	723	819
Total	140,607	159,849	176,245
Customs etc.	7,015	4,205	4,707
GDP	147,622	164,054	180,952

Source: Cuentas Nacionales 1985-1990, Banco Central de Ecuador

2.1.3 Agriculture

The Republic of Ecuador is the second oil-produce country next to Venezuela in South America and oil sector is the biggest one in the GDP. However, the agricultural sector still plays the important role as employment source in the national economy, although the sector's share in the GDP has been decreased down to 17%. The population in the rural area is still 48%. Therefore, Ecuador can be classified as an economically agriculture-based country.

The main agricultural products of the country are typical tropical ones such as banana, cacao, coffee and sugar, which contribute to foreign exchange earning. Cereals like wheat, however, depend mainly on importation.

In the mountainous areas which correspond to 27% of the national territory, traditional agriculture by small-scale farmers prevails. The agricultural activity is characterized by low productivity due to lack of irrigation water. Many farmers have migrated into urban areas because of severe living conditions.

Agriculture in Ecuador can be divided into two types in general. One is the agriculture in "Sierra", the climate of which is comparatively mild, even though it is situated in the tropical region, because of its high altitude of 2,000 – 3,000 m. The other is the one in "Costa", where the tropical farming is practiced because of its tropical climate.

"Costa" is the main agricultural area in the country, thanks to natural conditions such as climate, soil and water resources. Main products are banana, coffee, cacao, rice, maize, soybean, cotton, vegetables and fruits, which contribute to exportation of Ecuador.

In "Sierra", cereals, maize, beans, vegetables are progressively cultivated in spite of constraints of climate, soil and water resources. Livestock is also practiced extensively.

On the other hand, "Oriente" is the area of tropical rain-forest and livestock only is practiced. this area is not so important from the agricultural point of view compared with other areas.

Table 2.1.2 Agricultural Production in Ecuador

	Cropped Area (1,000 ha)	Harvested Area (1,000 ha)	Production (ton)	Yield (ton/ha)
Cereals				
Rice	294.74	283.90	848,181	2.99
Soybean	62.21	60.25	44,518	0.74
Maize (Dulo)	315.20	293.29	408,124	1.39
(Choclo)	21.58	20.83	41,436	1.99
(Seco)	187.31	180.96	110,608	0.61
Wheat	37.61	37.04	24,614	0.66
Tubers				
Potato	56.63	52.16	372,291	7.13
Cassava	21.56	19.12	90,279	4.68
Beans				
Kidney bean	66.47	59.69	37,112	0.62
Others	27.26	25.65	8,569	0.33
Oil crops				
Soybean	92.63	90.70	171,761	1.89
Coconut	83.87	68.63	872,741	12.72
Cotton	32.85	30.42	33,983	1.12
Export-oriented crops				
Banana	186.16	186.50	3,525,302	20.92
Cacao	343.32	331.98	100,454	0.30
Coffee	427.33	403.87	138,579	0.34
Sugarcane	100.69	88.53	3,661,246	74.91
Plantain	102.28	92.19	920,535	9.97
Others	169.58	127.13		

2.2 BRIEF DESCRIPTION OF IMBABURA PROVINCE

2.2.1 Location and Topography

The Imbabura Province involving the Study Area covers the northern part of Ecuador. Ibarra city, the capital city of the Province, is located approx. 140 km far from Quito city, the capital city of the country.

The territory of the Province is 4,463 km^2, which is the average size among 10 Sierra Provinces. The Province is located in the mountainous area and its average altitude is approx. 2,000 m. Many high mountains like the Mt. Cotacachi (4,944 m high) are

located in the Province. Most of the area of the Province are mountainous and, towns and farming fields are extended in the remaining plain area. Some of the farming field are developed in the sloped area.

2.2.2 Social Activities

The neighboring provinces of Imbabura are as follows:

- Northern and Eastern border: Carchi and Sucumbio, which border with Colombia
- Southern border: Pichincha
- Western border: Esmeralda which faces to the Pacific Ocean

The administrative division is as shown in Table 2.2.1.

Table 2.2.1 Administrative Division of Imbabura Province

Canton	Number of city, town and village
Ibarra	1 city, 7 villages
Antonio Ante	1 town, 4 villages
Cotacachi	1 town, 8 villages
Otavalo	1 town, 9 villages
Pimampiro	1 town, 3 villages
San Miguel de Urecuqui	1 town, 5 villages

The administrative system is as follows:

In Ibarra city:

- Provincial Government (Consejo Provincial de Imbabura) which deal with the local administration
- Provincial offices of the Central Government

In Cantons:

- Local offices of the Provincial Government, controlled by the Chief (Jefe Politica) appointed by the Government

In Villages (parroquia):

- Village committees operated by the members (Teniente Politica) selected by election

In Communities (Comuna):

. Community Committee (Cabildo)

According to the census in 1990, the population of the Imbabura Province was 265,499 which was equivalent to 2.8% of the national population. Population density was 58.2 persons/km2. 129,174 persons (48.7%) live in urban area and 136,325 (51.3%) in rural area. The economically active population was 90,831, 33.3% of which were engaged in agricultural sector (the first industry)

Table 2.2.2 Population by Canton

Canton	Population		
	Urban	Rural	Total
Ibarra	80,991	38,502	119,493
Antonio Ante	13,764	13,611	27,375
Cotacachi	6,051	27,199	33,250
Otavalo	21,548	34,738	56,286
Pimanpiro	4,950	10,409	15,359
San Miguel de Urcuqui	1,870	11,866	13,736
Total	129,174	136,325	265,499

2.2.3 Economy

The economy of the Imbabura Province is based on agriculture, and it is actually supported by the agricultural production and related agro-industries such as sugar manufacture, brewing and food-processing. In the rural areas around Otavalo, folk-art textile production is prosperous, and Cotacati is developed as the town of small-scaled leather industry. In addition to these agro-industries, a national cement factory named Selva Alegre is operated in Otavalo.

The yield ranking of the agricultural products is sugarcane, tomato, maize and kidney bean from the top.

Most of sugarcane is sold to the sugar-manufacturing factories. Increase of sugar production is expected because of shortage of its domestic supply (40 thousands ton/year).

Tomato is used for ketchup production, etc. Maize is produced for domestic consumption and mostly consumed in Imbabura Province. Kidney bean is outstanding as one of the export products to Colombia. However, its exported quantity and amount are not grasped due to the free market agreement between two countries that allows free border-passing and that the product is traded with Colombian Peso instead of US dollar. The exported amount of Kidney beans is assumed to be approx. 60% of the total its production in the Province (2,985 ton).

According to the census in 1990, the gross industrial production amount of the Province was 19,393,371,000 S/., equivalent to 0.5% of that of the country.

The commercial production amount was 4,452,633,000 S/., equivalent to only 0.3% of that of the country and 0.6% of that of Sierra area. The population who is engaged in the second industry was 23.6% (21,456 persons) of the total economically active population.

Table 2.2.3 Manufacturing in Imbabura Province

Item	No. of Factory	No. of Employee	Production Amount (1,000 S/.)
Food Processing	6	394	4,316,728
Textile, Leather	5	550	2,365,675
Paper, Printing	1	47	146,609
Chemical Product Processing	2	41	164,544
Cement	1	512	12,327,728
Canning	1	26	72,087

Source: Industrial Census, 1990

2.2.4 Agriculture

Agricultural land covers approx. 40% of total area of the Province, most of which is shared by pasture because of its topographic conditions. In resent years, crop cultivation area has been expanded in the agricultural land.

Table 2.2.4 Existing Landuse of Imbabura Province

(Unit : 1,000 ha)

Temporal Crop	Perennial Crop	Pasture	Fallow	Idle Land	Sub-total	Non-agricultural land	Total
25.2	12.5	100.3	30.2	5.3	173.5	272.7	446.2
5.6%	2.8%	22.5%	6.8%	1.2%	38.9%	61.1%	100.0%

Source: Sistema Estadístico Agropecuario Nacional 1991

Main crops in the Province are cereals such as maize (42%), barely (8%) and wheat (7%), covering approx. 60% of the total cultivated area. In addition to cereals, kidney bean (18%) and sugarcane (6%) are mainly cultivated. In recent years, the cultivation areas of sugarcane, potato and kidney bean are expanding. However, the total production volume of potato has been decreased in spite of the increase of cultivated area due to the yearly decrease of its unit yield. Furthermore, the cultivation area of cereals such as maize is decreasing and the production volumes of them are decreasing accordingly.

The livestock in the Province is mainly cow raising and the total heads of raised cow are 100 thousands. The milking cow is raised mostly on high lands, and the others are raised on comparatively low lands. The productivities of both meat and milk in the Province are higher than the average of the country. Besides cow raising, there are three large-scaled poultry farms and one cuy farm in the Province.

The raisings of pig, sheep, cuy, chicken are operated mostly with small scale or for domestic consumption. In recent years, the raisings of pig, sheep, etc are increasing and cow raising is decreasing in general. However, the head of milking cow has been increased and milk production has been progressed remarkably together with the improvement of productivity of cow raising.

Table 2.2.5 Agricultural Production of Imbabura Province

Crop	Cropped Area (1,000 ha)	Harvesting Area (1,000 ha)	Production (ton)	Yield (ton/ha)
Cereals				
Barely	4.95	4.47	2,482	0.55
Maize				
Duro	3.50	3.47	3,449	0.99
Choclo	1.32	1.32	3,658	2.77
Seco	21.50	20.17	9,343	0.46
Wheat	4.33	4.28	3,374	0.79
Tubers				
Potato	2.49	2.46	5,818	2.35
Beans				
Kidney bean	11.22	11.05	7,199	0.65
Export Crops				
Sugarcane	3.60	2.50	211,594	84.67
Plantain	1.44	1.35	7,300	5.39
Others	7.71	6.45		

Source: Sistema Estadístico Agropecuario Nacional 1991

Table 2.2.6 Number of Livestock and Milk Production of Imbabura Province

Cow (1,000 head)	Milking Cow (1,000 head)	Milk Production (1,000 lit.)	Pig (1,000 head)	Sheep (1,000 head)
100	17	92	52	65

Source: Sistema Estadístico Agropecuario Nacional 1991

CHAPTER 3

THE STUDY AREA

CHAPTER 3: THE STUDY AREA

In this report, "the Study Area" including its surrounding areas, indicates the area to be benefitted by the Project implementation and "the Water Resources Area" the watershed to become the water resources of new irrigation water for the beneficial area; mainly the watershed of the Piñán River.

3.1 GENERAL FEATURE

3.1.1 Location

The Study Area is situated in the Imbabura Province which covers the northern part of the country, and located approx. 20 km northwest of the Ibarra City, the capital of the Province. The Study Area is located approx. 140 km far from the Quito City, the capital of the country and also the biggest consumption area of the agricultural products, and approx. 110 km far from the border with Colombia, one of the important export countries of agricultural products from Ecuador.

3.1.2 Administration

The Study Area belongs to three Parroquias of San Miguel de Urcuqui, Tumbabiro and San Blas contained in Canton San Miguel de Urcuqui and Parroquias Imantag contained in Canton Cotacachi. These Cantons are two of six Cantons which belong to the Imbabura Province.

3.1.3 Population

The population in the Study Area is as shown in Table 3.1.1. The total number of household in the Area is 1,491 and the average number of persons of one family is 6.8.

Table 3.1.1 Population in the Study Area

Name of Parroquia	Population		
	Urban Area	Rural Area	Total
Canton San Miguel de Urcuqui			
Parroquia San Miguel de Urcuqui	1,870	2,181	4,051
Parroquia Tumbabiro	-	1,500	1,500
Parroquia San Blas	-	2,582	2,582
Canton Cotacachi			
Parroquia Imantag	-	3,922	3,922
Total	1,870	10,185	12,055

Source: Census 1992

3.1.4 Social Infrastructure

The Study Area can be reached in about 30 – 60 minutes by car from Ibarra City, the biggest city in and around the Study Area. The Pan-American Highway connects Ibarra City with Quito, the capital of the country, in two-hour drive. The main towns and villages in the Study Area can be reached by the frequent public bus service from Ibarra City and other main towns around the Study Area.

The principal roads are asphalt-paved. Other main roads in and around the Study Area are paved with concrete or stones with 4 – 6 m width. Almost all these roads can be accessible even during the rainy season. The maintenance of the principal roads is directed by MOP and the other main roads are maintained by the committees of respective Parroquias and/or farmers of the communities.

The electricity is supplied to the most part of the Study Area and its surrounding area by EMELNORTE through the transmission lines of the interconnection system.

Drinking water is supplied to the almost entire place in the Study Area. However, it is generally not purified and sterilized. In some places, it is sterilized only with chlorine. There is no sewage system in the Study Area.

There is no hospital and medical service is very poor. Only a health center is provided in respective Canton center or Parroquia center.

As for education, there are 19 elementary schools and 2 high schools in the Study Area. There is no university in the Area (there are 2 universities in Ibarra only). Education system of Ecuador is that 6 years for elementary school, 6 years for high school and 6 years (4 years) for university, scientific courses (cultural courses). The term of compulsory education is only 6 years of elementary school. The education ratio in Imbabura Province is 85.6%, that is a little lower than the national average of 90.2%.

3.2 NATURAL FEATURE

3.2.1 Topography

(1) Study Area

In general, the Study Area is classified as high land, the altitude of which is 1,700 – 2,540 m, and its extensions are approx. 20 km in northeast – southwest direction. As for its topography, deep valleys have been developed in northwest – southeast direction. Therefore, the Area is divided into some gentle ridges. The areas of the Study Area by altitude and slope are as shown in Tables 3.2.1 and 3.2.2, respectively.

Table 3.2.1 The Altitudewise Areas of the Study Area

Altitude (m)	Area (ha)	Ratio (%)
1,700 - 1,800	370	2.9
1,801 - 1,900	1,120	8.8
1,901 - 2,000	1,400	10.9
2,001 - 2,100	1,600	12.5
2,101 - 2,200	1,800	14.1
2,201 - 2,300	1,830	14.3
2,301 - 2,400	1,980	15.4
2,401 - 2,500	1,880	14.7
2,501 - 2,540	820	6.4
Total	12,800	100.0

Table 3.2.2 The Slopewise Areas of the Study Area

Land Slope (%)	Area (ha)	Ratio (%)
0 - 4.0	2,370	18.5
4.1 - 8.0	4,530	35.4
8.1 - 16.0	1,260	9.8
16.1 - 30.0	1,410	11.0
30.1 -	3,230	25.3
Total	12,800	100.0

(2) Water Resources Area

The proposed dam site is located on the Piñán River at altitude of 3,000 m. The straight distance between the dam site and the Study Area is approx. 22 km. The source of the Piñán River is located at 12 km north of the proposed dam site and at El 3,300 m. It flows southward and joins with the Pantaví River at 1 km downstream of the proposed dam site, forming the Pitura River. The stream of the Piñán River is gentle (1/150) and wide at the upstream section of the proposed dam site, but steep (1/12) and narrow at the downstream section.

The watershed of the river is gentle hill in general except for the boundary area being comparatively steep. Most of the watershed area are covered with "Paramo", special pasture in the highland, and the remaining small area is forest. The location of the proposed head race (23 km long) connecting the proposed dam and the Study Area is mostly the steep-sloped area between the limit of forest vegetation and pasture.

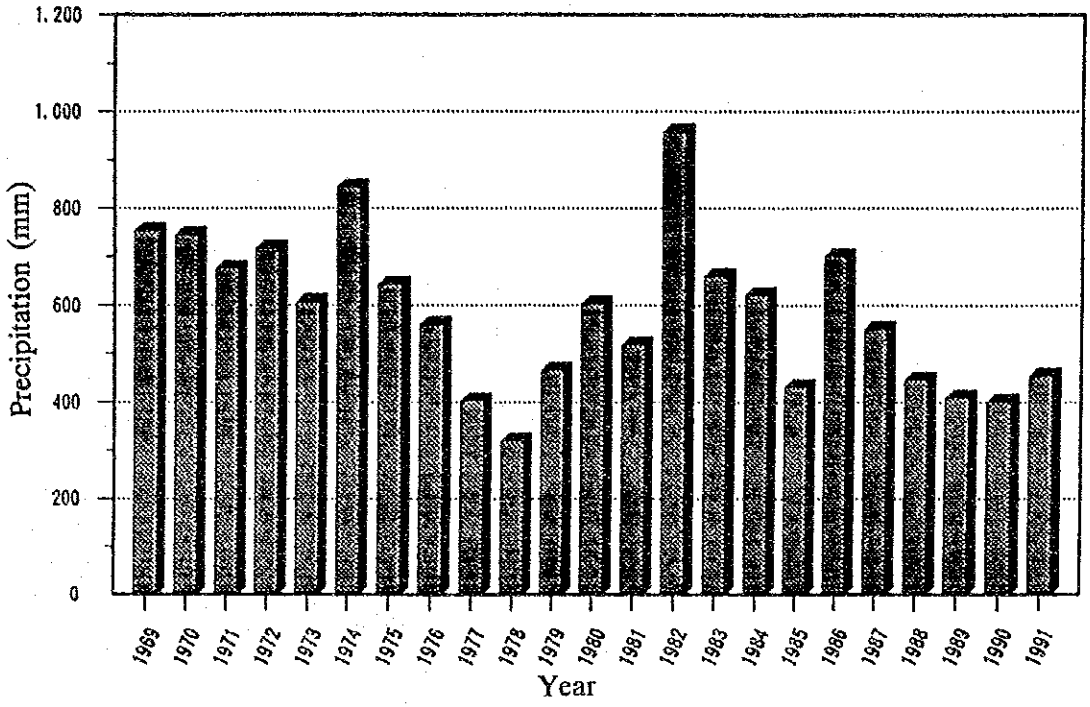
3.2.2 Meteorology

(1) Study Area

The records observed at the Tumbabiro Gauging Station are used as the data representing the meteorology of the Study Area, in consideration of the location, observation period, etc. of the Tumbabiro Station.

1) Rainfall

The observation of rainfall at the Tumbabiro Station was done for 16 years from October 1968 to July 1984. However, the rainfall has not been recorded for the recent 8 years. Therefore, the rainfall for this period is estimated based on the observation data at the Salinas Gauging Stations located 5 km east of the Tumbabiro Station. The average rainfall is estimated to be 590 mm based on the above completed rainfall data for 23 years from 1969 to 1991. (Fig. 3.2.1).



Note: Rainfall in 1985 – 91 is estimated based on the record of Salinas Station

Fig. 3.2.1 Annual Rainfall (Tumbabiro Station)

The probable rainfall is also estimated based on the rainfall data for 23 years above as shown in Table 3.2.3.

Table 3.2.3 Probable Annual Rainfall

Return Period (Year)	2	5	10	20	50	100
Probable Rainfall (mm)	564	448	398	361	324	301

There are two seasons; that is, the rainy season from October to April and dry season from May to September. Seventy seven (77)% of the annual rainfall are concentrated in the rainy season.

At the Tumbabiro Station, the daily rainfall only is being observed and no hourly rainfall has been observed. The maximum daily rainfalls have been recorded to be 79 mm at the Tumbabiro Station and 68 mm at the Salinas Station.

The hourly rainfall is being observed at Ibarra Airport Station located east of the Study Area. Based on the hourly rainfall data of this station, the probable rainfalls estimated for respective return periods are as shown in Table 3.2.4.

Table 3.2.4 Probable Hourly Rainfall

(mm/hr)

Return Period (Year)	Continuous Period (min.)					
	5	10	15	30	60	120
2	72.5	47.3	38.6	26.1	16.5	10.0
5	95.6	61.7	50.9	33.2	20.6	12.7
10	110.8	71.3	59.0	37.8	23.3	14.5
50	144.5	92.3	77.0	48.0	29.2	18.5
100	158.7	101.2	84.6	52.3	31.7	20.2

Source: Estudio de Intensidades, 1980, INAMHI

2) Temperature and Humidity

The monthly average temperature in the Study Area varies a little from 18.0 to 18.8°C through a year (Fig. 3.2.2). The average temperatures of the monthly maximum and minimum temperatures are 23.3 - 24.9°C and 11.9 - 13.7°C, respectively. The daily change of temperature is within 9.6 - 12.0°C. Relative humidity is between 69% and 81% through a year and it decreases by 10% during the dry season.

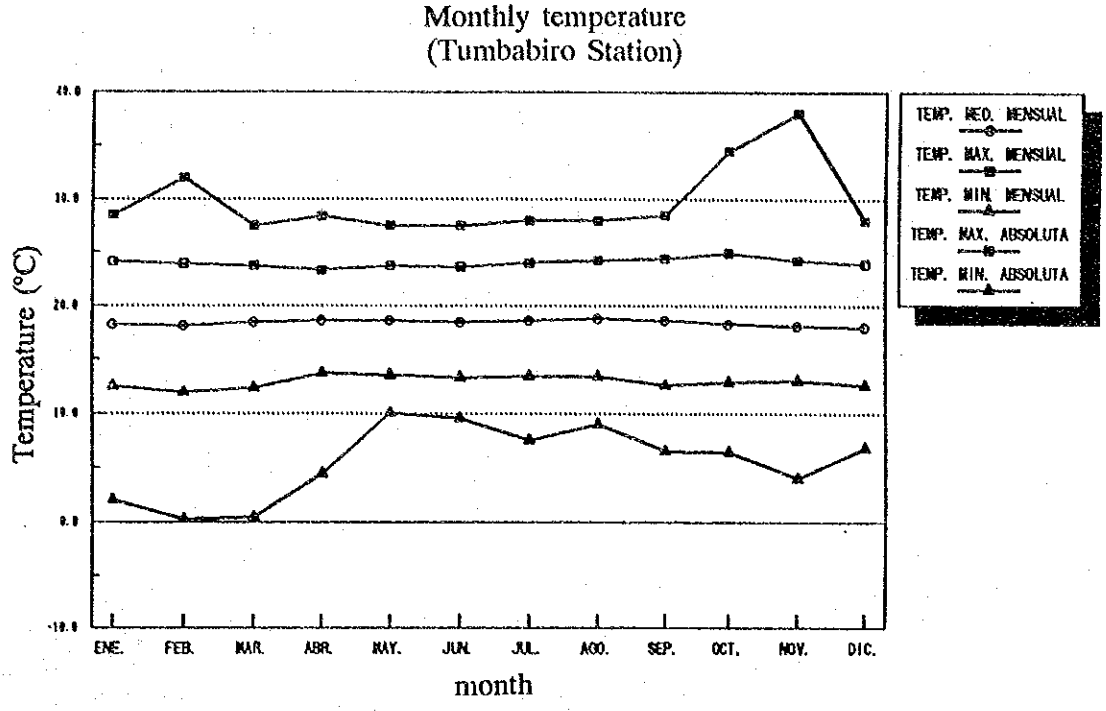


Fig. 3.2.2 Temperature of the Study Area

3) Sunshine Hour and Cloudiness

The monthly average sunshine hours in the Study Area are 174 hours (the annual average is 2,092 hr at the Salinas Station). This is enough for growing crops during both rainy season and dry season. The annual average cloudiness is 6th grade (based on 8 grade indication) and in the dry season the average decreases to 5th grade.

4) Wind Direction and Wind Speed

The annual average wind speed in the Study Area is 3 m/s and it increases to 5 – 6 m/s. The wind blows from west to east during July to March and from north to south during April to June.

5) Pan-evaporation and Probable Evapotranspiration

According to the data at the Tumbabiro Station, the annual pan-evaporation (A-

type) in the Study Area is 1,521 mm. The monthly one during July - August (dry season) exceeds 150 mm (Fig. 3.2.3).

The evapotranspiration in the Study Area has been estimated with the modified Penman and Blaney - Criddle methods using the data of the Tumbabiro Station. The annual probable evapotranspiration is 1,300 mm and its monthly change is shown on Fig. 3.2.3.

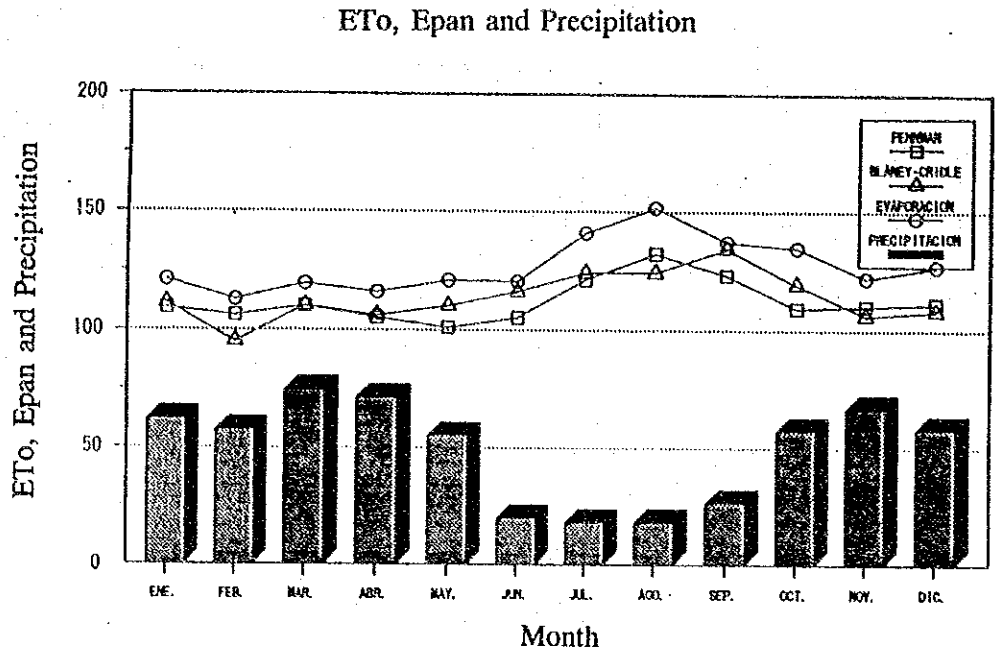


Fig. 3.2.3 Rainfall and Evaporation of the Study Area

(2) Water Resources Area

The outline of meteorology of the water resources area estimated based on the observed data at the Apuela gauging Station, etc is as follows:

Temperature:	Annual ave. of daily ave.:		12°C
	Annual ave. of daily max.:		18°C
	Annual ave. of daily min.:		7°C
Rainfall:	Annual ave.	:	1,800 - 2,000 mm
	Daily max.	:	120 mm
	Rainfall days	:	150 days/year
	Rainfall pattern	:	Tropical shower

The rain gauge provided by JICA is installed at the immediately upstream the proposed dam site and the data have been collected since Nov. 1992. The observed max values until May 1993 are 64.5 mm/day and 22.5 mm/hr.

Wind:	Occurrence of strong wind:	few (annual ave.; 3 – 8 m/s)
	Wind direction during rainfall:	W–SW

3.2.3 Hydrology

(1) Study Area

The main rivers flowing through the Study Area can be picked up from the north as follows:

Qda. Cachiyacu
Qda. Pigunchuela
Rio Huarmiyacu
Rio Cariyacu
Qda. Tushila
Rio Alambí

The former two rivers flow into Rio Chota directly and the remaining four flow into Rio Ambi, one of the branch streams of Rio Chota.

However, the continuous observation of the discharge of these rivers has not been made. The discharge records of the main rivers in the Study Area collected by the Study Team through INERHI are utilized as a part of the data for hydraulic analysis of the design discharge of the objective rivers.

The conditions of the discharge are as follows:

a. To select the observation point at the upstream section of which no induction of the river water is made as much as possible.

b. In case that the river water is induced at the upstream section of the observation point, the induced water quantity of the existing canals (acequia) is added to the observed river discharge for getting more accurate river discharge amount at the observation point.

(2) Water Resources Area

1) River Discharge Gauging Station

The river discharges concerning the Study are being observed at the following stations (Table 3.2.5 and Fig 3.2.4)

Table 3.2.5 Objective River Discharge Gauging Stations

Name of River	Name of Station	Watershed (km^2)	Equipment	Duration
Piñán	Piñán	63.2	Automatic Water Level Gauge	since Feb. 1981
Pantaví	Pantaví Grande	18.7	Automatic Water Level Gauge	since Aug. 1985
Salado	Salado	21.0	Automatic Water Level Gauge	since Jan. 1992

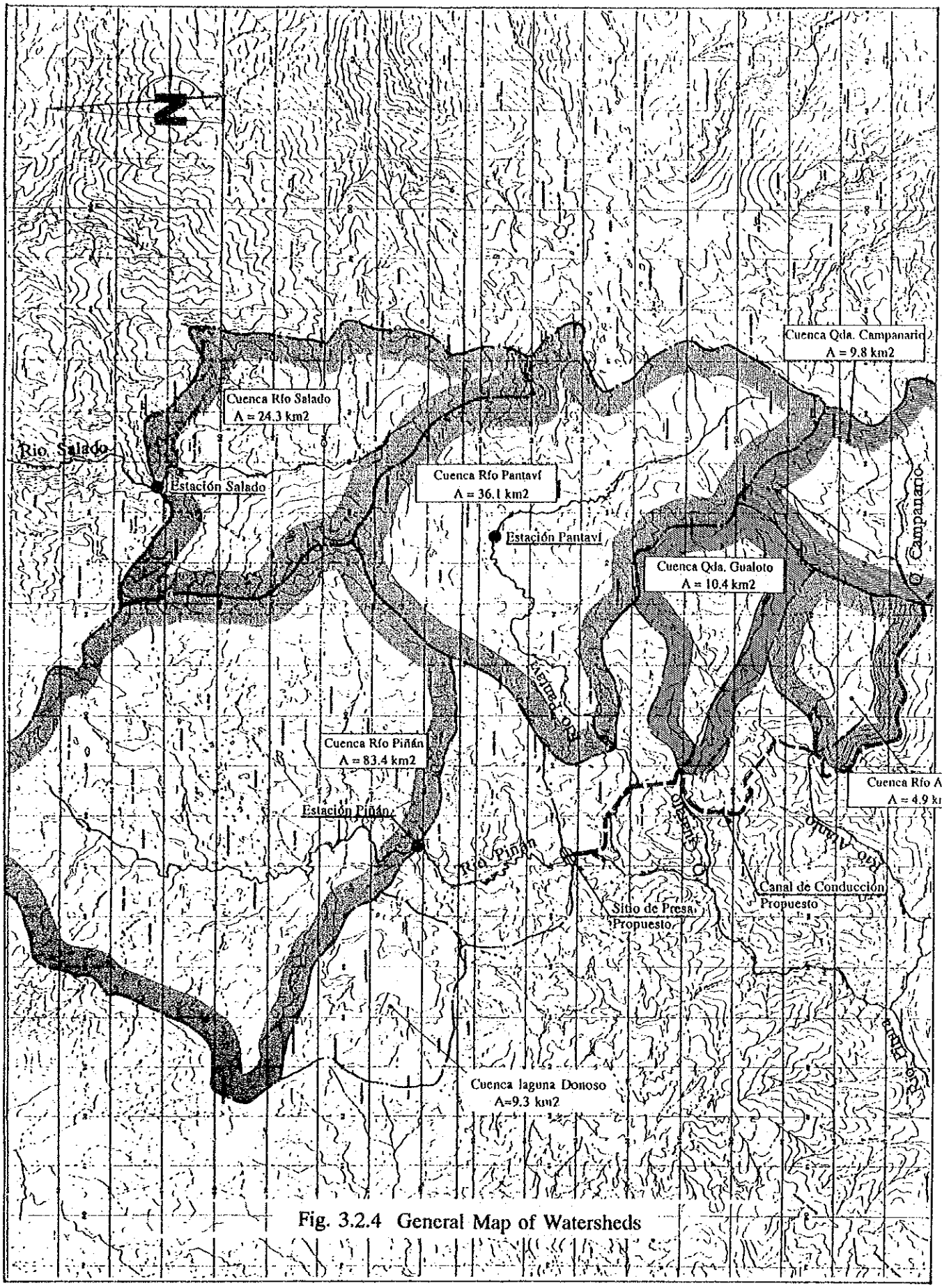


Fig. 3.2.4 General Map of Watersheds

2) Observed River Discharge

The river discharges observed at the Piñán and Pantaví Gauging Stations are as shown in Tables 3.2.6 and 3.2.7, respectively.

Table 3.2.6 Observed Discharge at Piñán Station (A = 63.2 km^2)

(m^3/s)

Year / Month	1986	1987	1988	1989	1990	1991	Ave. /63.2 km2	Ave. /100 km^2
Jan.	2.97	3.18	2.20	–	1.52	1.65	2.30	3.65
Feb.	3.36	2.16	2.47	5.64	1.85	1.47	2.82	4.47
Mar.	–	2.69	2.29	4.65	2.02	3.50	3.03	4.79
Apr.	–	3.06	4.14	3.02	3.43	2.22	3.17	5.02
May	–	4.24	3.17	4.42	–	–	3.94	6.24
Jun.	–	1.72	2.53	2.42	–	1.25	1.98	3.13
July	–	1.36	2.18	2.16	–	1.09	1.70	2.69
Aug.	–	1.32	1.63	1.92	1.61	1.11	1.52	2.40
Sep.	–	1.19	1.58	–	1.61	1.27	1.41	2.18
Oct.	2.10	1.73	–	–	2.22	1.57	1.91	3.02
Nov.	3.38	1.80	–	1.74	1.35	2.83	2.22	3.52
Dec.	2.34	1.33	–	1.28	1.18	3.20	1.87	2.95
Ave.	–	2.15	–	–	–	–	2.32	3.67

Table 3.2.7 Observed Discharge at Pantaví Station (A = 18.7 km^2)

(m^3/s)

Year / Month	1986	1987	1988	1989	1990	1991	Ave. /18.7 km2	Ave. /100 km^2
Jan.	–	0.112	0.080	0.589	0.178	–	0.240	1.28
Feb.	–	0.095	0.217	0.542	0.328	–	0.295	1.58
Mar.	–	0.165	0.130	0.628	0.211	–	0.284	1.52
Apr.	–	0.129	0.609	0.317	0.398	–	0.363	1.94
May	0.274	0.560	–	0.357	0.310	–	0.375	2.01
Jun.	0.106	0.095	–	0.263	0.114	–	0.145	0.77
July	0.054	0.042	–	0.136	0.089	–	0.080	0.43
Aug.	0.043	0.038	0.046	0.080	0.035	–	0.048	0.26
Sep.	0.029	0.099	0.094	0.096	0.022	–	0.068	0.36
Oct.	0.121	0.142	0.196	0.199	–	–	0.165	0.88
Nov.	0.232	0.068	0.603	0.093	0.027	–	0.205	1.09
Dec.	0.134	0.084	0.578	0.074	–	–	0.218	1.16
Ave.	–	0.137	–	0.280	–	–	0.207	1.11

Note: Water balance analysis is made using the observed data of 6 years from 1986 to 1991 which are almost sufficient (data of 1992 are insufficient)

As shown in Table 3.2.6, the minimum flow of the Piñán River is comparatively much even though the rainfall in dry season is almost none and the annual change of its discharges is small. Therefore, the discharge ratio (max. discharge/min. discharge) is small (Fig. 3.2.5). This phenomenon corresponds to the fact that the discharges are averaged because almost all the rainfall penetrates into the ground and is stored as groundwater in the volcanic ash and porous lava layers distributed widely in the watershed. The discharge of the Pantaví River also shows the similar tendency, but the discharge volume at the Gauging Station is very little in comparison with the watershed of the Gauging Station due to its underflow at the point. This phenomenon has been proved by the simultaneous flow observations at the Gauging Station and the downstream point.

The observed discharge data of the Pantaví Gauging Station have good correlation with those of the Piñán Gauging Station, even though the data of the Pantaví Station is not correct due to its underflow, as shown below:

$$Qt = 0.472 \times Qn - 0.74 \qquad (r = 0.827)$$

where : Qt = Discharge of Pantaví ($m^3/s/100\ km^2$)

Qn = Discharge of Piñán ($m^3/s/100\ km^2$)

The lacking discharge values of the Piñán Gauging Station can be estimated using this formula.

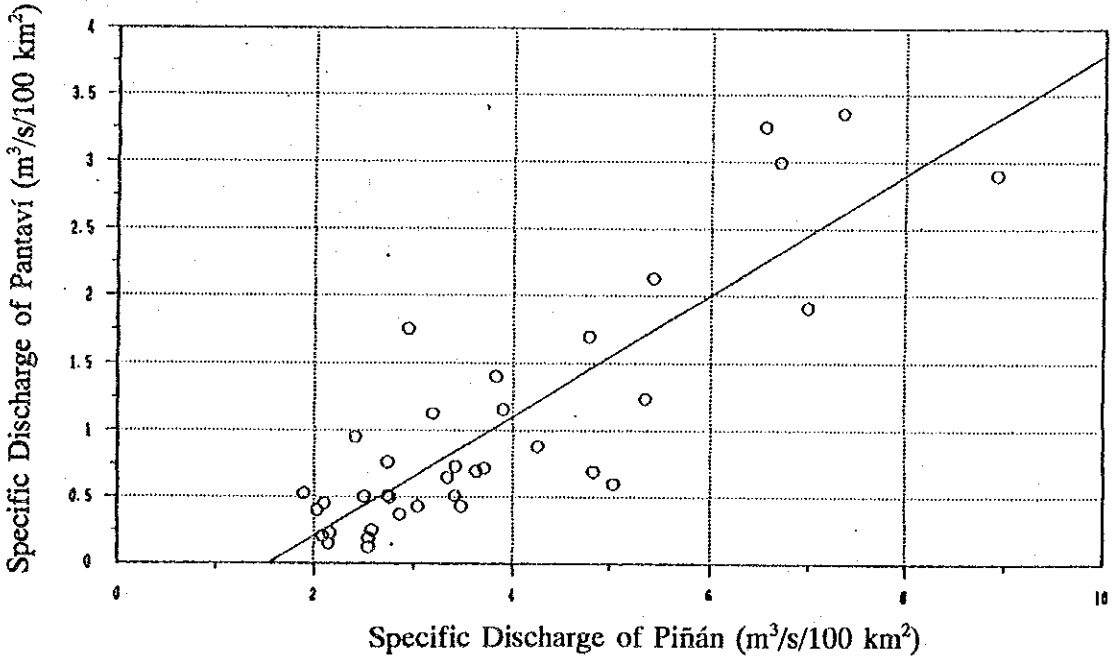


Fig. 3.2.5 Correlation between Discharges of Piñán and Pantaví

3) Estimated Specific Discharge

The design discharge should be preferably estimated using the observed discharge data of longer period that have high reliance. In this analysis, the following two methods have been considered :

a. To use the observed discharge data only
b. To use the discharge data estimated using the rainfall data of near by area in addition to the observed discharge data

The discharge data observed at the Piñán Gauging Station is most preferable if available. The period of the available data is only 6 years. Therefore, in order to get the discharge data of longer period, the estimation using the rainfall data is indispensable.

The rainfall gauging stations are not located in the same watershed as that of the Piñán River. The station nearest to the Piñán Gauging Station is the Apuela Gauging Station (observation has started since 1965) located at 18 km south of the proposed dam site. In the case of the Apuela Gauging Station, the data of a few years only can be used for the correlation analysis. The result of the analysis using such short period may not have high reliance. Therefore, in the water balance analysis of the Study, the observed discharge data of the Piñán Gauging Station for 6 years are used. The estimation of river discharge data using the rainfall data at the Apuela Gauging Station may be considered at the detailed design phase in the future.

Table 3.2.8 shows the design discharge of the Piñán River, in which some of the values are estimated with the correlation formula using the observed discharge data of the Pantaví River.

Table 3.2.8 Estimated Specific Discharge of the Piñán River

($m^3/s/100\ km^2$)

Month \ Year	1986	1987	1988	1989	1990	1991	Ave.
Jan.	4.70	5.03	3.48	8.04	2.41	2.60	4.379
Feb.	5.32	3.41	3.90	8.93	2.93	2.32	4.466
Mar.	6.39	4.26	3.62	7.35	3.19	5.54	5.059
Apr.	4.62	4.83	6.54	4.79	5.43	3.52	4.955
May	4.69	6.70	5.02	7.00	4.04	2.75	5.032
Jun.	2.76	2.73	4.00	3.83	2.86	1.98	3.026
Jul.	2.15	2.15	3.45	3.41	2.59	1.72	2.579
Aug.	2.03	2.08	2.58	3.03	2.55	1.76	2.338
Sept.	1.95	1.89	2.50	3.06	2.54	2.01	2.325
Oct.	3.32	2.73	3.15	3.83	3.52	2.49	3.173
Nov.	5.36	2.85	8.48	2.75	2.14	4.48	4.344
Dec.	3.71	2.10	6.63	2.04	1.86	5.06	3.566
Ave.	3.91	3.40	4.44	4.82	3.00	3.03	3.766

Note: Non-observed values are estimated with the correlation formula using the observed data of the Pantaví River

3.2.4 Geology

Geological investigation was conducted to grasp the geological condition of the proposed dam site and head race tunnels. It consisted of drilling including laboratory test and seismic exploration for the dam site and seismic exploration for the head race tunnels in addition to the field reconnaissance. The details of the investigation are complied in Annex.

(1) The Water Resources Area

1) Topography

The proposed sites for a dam and head race are characterized by the volcanic feature formed by Punguloma (El.4,254 m, known as Negro Puño), Cotacachi (El.4,944 m), Yanahurcu de Piñán (El.4,535 m) and Loma Pulumburo (El.4,211 m, known as Pumamaqui). The lava plateaus, lagoons and swamps saved in lava ditches/hollows, and lakes formed by damming up the rivers due to the volcanic eruptions and continuously followed lava flows are distributed at the sites.

The general configuration of the Water Resources Area presents the aspect of initial period characterized by gentle ridges and lava plateaus, and comparatively straight and deep rivers and streams with steep slopes. There are a few valleys

and a little formation of streams. On the other hand, the land configuration of the right bank at the dam site and reservoir presents the aspect close to the final period that are characterized by the formation of gentle ridges and open valleys with thick density, where the granodiorites belonging to the old basement rocks are distributed. Swamp zones present the flat and low lands that are originated by the lakes dammed up by the old volcanos such as Pitura, Pantaví Grande, Ciénaga del Hospital, etc. located at the upstream area of proposed dam site. Rivers flow with meandering in these flat and low lands.

The vegetation of the Water Resources Area is almost pasture, some of which have been transferred from the forest. The trees are distributed at the steep slopes that are not suitable for growing of pasture or along the steep streams which flow through the area where the volcanic rocks are distributed.

2) Geology

According to the existing geological data, the old basement rocks and volcanic rocks that are produced through volcanic activities and covering the old basement rocks are prevailing. The old basement rocks are composed of sandstone, limestone, Macuchi Formation and granodiorites which intrude into Macuchi Formation. The volcanic rocks are those of Pumamaqui, Yanahurcu, Cotacachi and Negro Puño. Alluvial layers covering these rocks are distributed in the area (Fig. 3.2.7).

Limestone is distributed in the Salado study area located north of the Water Resources Area and not in the Water Resources Area itself. Sandstone with shales is distributed in the immediately downstream section of the downstream dam site (site A). Pyrites and chlorites are formed through mineralization and chloritization, respectively. Geological age of these rocks is estimated to be before the granodiorites period (Cretaceous period), judging from the fact that a few amount of black mica is formed by granodiorites through contact metamorphism, even though there is no description about this matter in the existing documents.

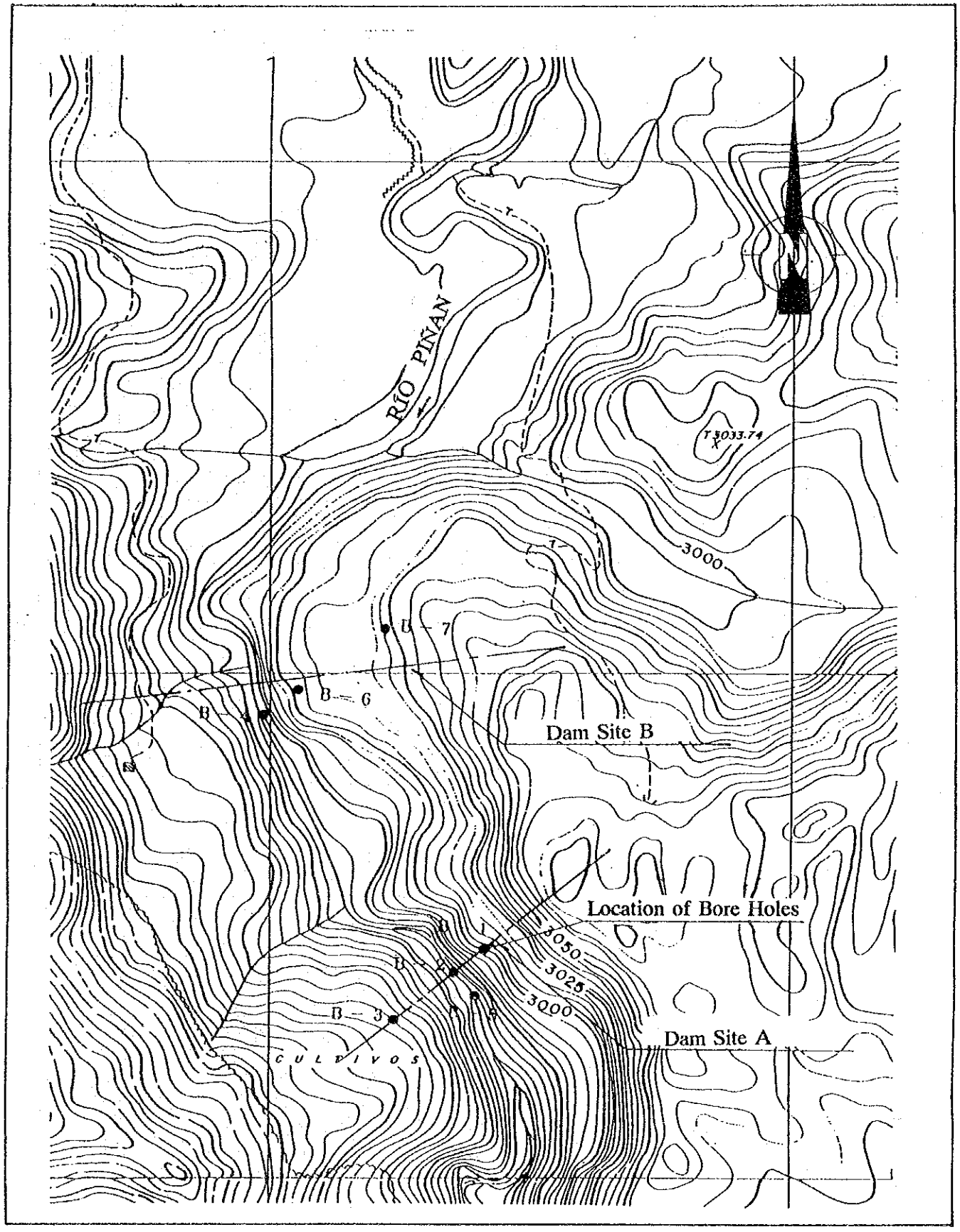


Fig. 3.2.6 Location of Bore Holes

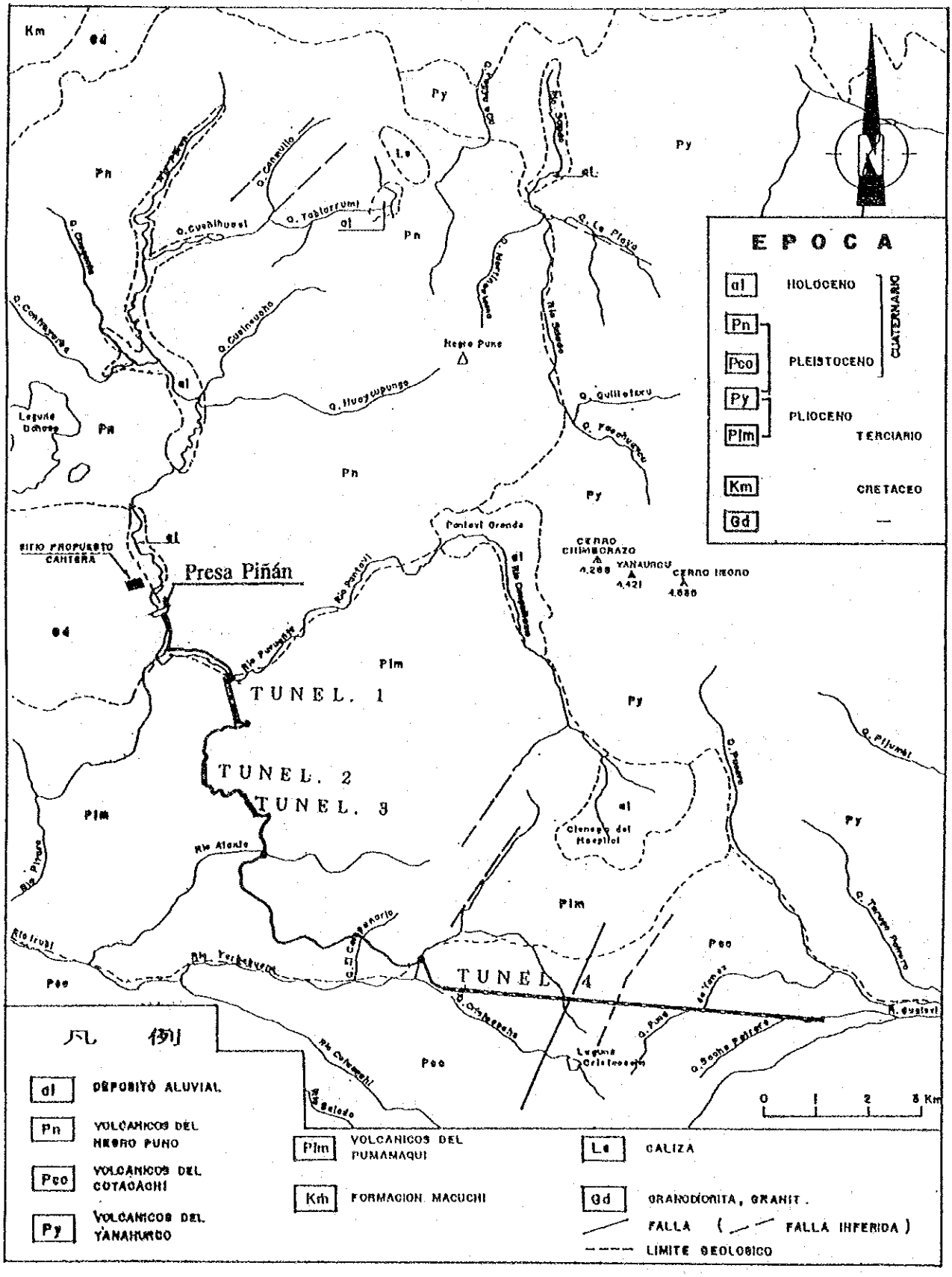


Fig. 3.2.7 Geological Map of the Water Resources Area

Macuchi Formation consists of pillow lava of metabasalt and is distributed in the north of the Water Resources Area. This formation has no direct relation with the proposed sites. Geological age of this formation is estimated to be cretaceous period in Mesozoic era based on the contained fossils.

Granodiorites are distributed from the right bank of the Pitura River in the Water Resources Area to the upstream section of the Piñán River. Granodiorites are composed of granodiorite, quartz diorite, diorite and partial acidic rocks, and intrude into Pumamaqui layer. These rocks are affected by mineralization and chloritization, and pyrites and chlorites are formed. They have turned to porphyritic structure by losing the uniform structure of the original rocks. Geological age is unknown. These rocks have relation with proposed dam site and reservoir area and are suitable for the fill materials.

Pumamaqui volcanic rocks are distributed up to the Pantaví River (northern limit) and Irubí River (southern limit), and the new investigation road is the eastern limit of the distribution of them. They are composed of andesite lava that corresponds to the old volcanic rocks of Pliocene epoch of Tertiary period in Cenozoic era, and more weathered and altered compared with other volcanic rocks.

At the outcrops along the investigation road, joints and minor faults of northeast direction are outstanding and fragment of these rocks can be seen. The above joints and minor faults correspond to the lineaments observed on the aerial photo. In the Project, proposed Tunnels No.1 – 3 pass through the area of these rocks.

Yanahurcu volcanic rocks are distributed long with north–south direction at the eastern area from the Pantaví Grande Plain. They are composed of pyroxine andesite lava and pyroclastite of the same materials, and some volcanic necks are formed.

Pyroclastite mostly forms the steep cliff. Geological age is estimated to be the Pliocene epoch of Tertiary period until Pleistocene epoch of Quaternary period. They have no relation with the proposed sites for the dam or tunnels.

Cotacachi volcanic rocks are distributed in the southern part of the Water Resources Area with the Cotacachi volcano being located in the center. They are composed of lava, pyroclastic rocks and lahars (volcanic mud flow), that consist of hornblende–pyroxine andesite and hornblende quarts andesite.

Geological age is estimated to be Pleistocene epoch of Quaternary period. The thickness of these strata is approx. 2,000 m. The proposed Tunnel No.4 passes through the area of these rocks.

Negro Puno volcanic rocks are distributed within the area limited by the Piñán, Pantaví and Salado Rivers. They are composed of pyroxine andesite lava and pyroclastite of the same materials. At the final stage of the volcanic activities, a lot of volcanic ash were spread and volcanic ash layer of 1 – 5 m thick was accumulated. Geological age is estimated to be the Pleistocene epoch of Quaternary period. They will become the foundation rock of the left bank of the proposed dam. Terrace deposits, lake deposits, fan deposits and talus deposits of Holocene epoch of Quaternary period cover these basement rocks.

Table 3.2.9 Geological Strata

Period	Strata	Symbol	Lithology	Remarks
Quaternary, Holocene	river deposit	rd	clay, sand, gravel	distributed along the rivers with a few gravel (5 cm dia. or less)
Quaternary, Holocene	talus deposit	ta	clay, sand, gravel, volcanic ash	including fan deposit that are similar to talus
Quaternary, Pleistocene	volcanic ash layer	pf	scoria ash (black), pumiceous ash (brown)	covers the area with thickness of 1 – 5 m
Quaternary, Pleistocene	lake deposit	ld	clay, sand, gravel, volcanic ash	formed by volcanic eruption of horizontal layer
Quaternary, Pleistocene	old talus deposit	ta'	clay, sand, gravel	including old river deposit
Quaternary, Pleistocene	terrace deposit	tr	sand, gravel	gravels of granodiorite and old lava
Quaternary, Pleistocene	negro puño volcanic rocks	PN	andesite lava, pyroclastite	hornblende–andesite, rhyolite
Post–cretaceous	sandstone	Ss	sandstone incl. shale	distributed locally
Post–cretaceous	grano–diorites	Gd	granodiorite, quartz–diorite, diorite	intrusive body

(2) Dam Site

1) Topography

The gentle ridges and steep valleys with deeply cut side slopes are distributed at the proposed dam site. The left bank of the river is characterized by the gentle ridges. However, these ridges have many lava's ditches/grooves and cliff on the steep side slope of the river. On the other hand, although the right bank is also characterized by the gentle ridges, many small valleys and talus are developed.

The topography of the left bank is older than that of the right bank. The gradients of the side slopes are 40° and 35° for the left bank and right bank, respectively.

The gradient of the river is gentle at the upstream section of the proposed dam site and it becomes steep from 30 m downstream of the compared downstream dam site. The gentle sloped wide areas are formed at El 3,005 m and higher altitude of the left bank and above El 2,994 m and higher of the right bank. These areas can be used as the construction yards.

2) Geology

The foundation rock of the proposed dam site mainly consists of granodiorites at the right bank and Negro Puno andesite lava of the Pleistocene epoch of Quaternary period distributed at the left bank which covers these basement rocks (granodiorites). These foundation rocks are covered by talus deposits, river gravel and volcanic ash layer. In addition, the old top soil, talus deposits and river deposits are estimated to exist between granodiorites and lava.

Sandstones are exposed like small windows at 35 m downstream section of the compared downstream dam site. They are composed of medium to fine tuffaceous sandstone and slate suffered from chloritization and pyritization, and very hard and minute.

Granodiorites are widely distributed at the right bank and they may be covered by Negro Puno lava. Granodiorites are the complex bodies composed of granodiorite as the main rock, quarts diorite and diorite suffered from chloritization and pyritization like sandstones. In some parts of them, thin layers of chlorites are formed and crystal structure of pyrites can been seen in the joints. A part of granodiorites are weakened by mineralization (typical at 25 m depth of Boring B-

3). The following three joint systems are formed and "a" is eminent.

a. strike/dip = N35E/80N
b. strike/dip = N70W/85N
c. strike/dip = N45W/40S

The result of the microscopic observation of the samples collected from the depth 29.66 m of Boring B-2 and the outcrop near the downstream dam site is as follows:

a. Principal minerals: plagioclase, hornblende, potashfeldspan, quartz
b. Secondary minerals: sericite, chlorite, epidote, kaoline
c. Accessory minerals: apatite

Negro Puño volcanic rocks are distributed at the left bank of the Piñán river and cover the granodiorites. They are mainly composed of andesite lava, and pyroclastic flow deposit can been seen at the place of high altitude. However, the detail of its distribution is not clear due to the existence of volcanic ash of a few meters thick covering the deposit.

According to the boring investigation, the basement rock at the proposed dam site is mainly composed of lava with a few layers of lava flow. Each layer can be divided into three parts by its lithology. The characteristics of the lithology are as follows:

a. Central lava part:
   grey to dark grey, hard joints being developed during cooling, high permeability due to development of such joints

b. Chilled margin part:
   reddish violet, a little polus due to foaming effect during cooling, hard, joints being less than those of central lava part.

c. Autobrecciated part:
   grey, composed of gravels in lava and matrix of them, fragile, openings being formed in some parts, rocks similar to tuff-breccia being observed in some parts of the top lager (at depths 20 m and 27.5 m of Boring B-1), troublesome as dam foundation in terms of hardness and permeability, composed of plagioclase (principal mineral), potashfeldspar and phenocryst of hornblende.

Furthermore, rhyolite composed of quartz and potashfeldspar, and quartz andesite formed by phenocryst of quartz are distributed locally. The result of the microscopic observation of the andesite sample collected at the riverbed is as follows:

a. Principal minerals: plagioclase
b. Phenocryst: potashfeldspar, hornblende

Volcanic ash layer covers all the slopes in the area of the proposed dam site and reservoir, and consists of black scoria ash and brown pumiceous ash. The thickness of this layer varies from 1 to 5 m due to the original ground condition and degree of erosion of ground. Its thicknesses are around 5 m on the gentle slope and 2 – 3 m on the slope of over 30° faced to the river and valley.

Talus deposits are distributed along the valleys in small scale and also under the volcanic ash layer. The thickness of them is a few meters in average. The talus deposits including fan deposits are loose deposits composed of volcanic ash clay, sand and gravels. Gravels are hard and the diameter of them becomes 1.5 m in maximum.

River deposits are distributed along the Piñán River. They are composed of clay sand and gravels and the thickness of them is 1 – 3 m. Gravels are hard and the thickness of them is mostly less than 5 cm.

3) Geological Structure

In general, the geological structure in the area presents the aspect that Negro Puño volcanic lava flown from the left bank covers the granodiorites of the right bank. The lava flows are divided into three layers and each layer covers the granodiorites ununiformly with the gradient of 10 – 15 degrees flowing from the left bank to the right bank. According to Boring B–6 and B–7, old top soil or old talus deposits do not exist at the boundary of respective layers.

From Boring B–7 and reconnaissance survey, the existence of old river deposits, old top soil, old talus deposits, etc. at the boundary between lava and granodiorites has not been confirmed. However, judging from the examples in other volcanic rock areas, there is a possibility of their existence.

Therefore, careful attention should be paid to confirm whether the old river flow

course exists or not during the detailed design phase of the proposed dam. Any faults could not been found in this study, but there is a possibility of the existence of faults, judging from the lineament of NNE direction which exists in the granodiorites body shown on the aerial photo.

4) Rock Soundness

The detail of andesite lavas at the left bank is as follows: D-class and CL-class rocks exist from the surface down to the depth of 13 m from the ground. D-class is partially weathered and changed into clay. It is hard but its joint is loose. CL-class rock holds the secondary clay in between. CH-class rock and CM-class rock of autobrecciated lava which is fresh but not consolidated well are distributed in between under D-class and CL-class rocks horizontally.

The detail of granodiorites at the right bank is as follows: According to Boring B-3, CL-class rock exists from the surface down to the depth of 12 m from the ground and 15 - 20 m at the high land higher than El 2,995 m. CL-class rock is hard but holds much secondary clay in its joints. CM-class rock which is hard but holds rust in its joint is distributed under CL-class rock. However, CM-class rock exists from the surface down to the depth of 5 m at the riverbed portion.

5) Permeability

Left Bank

The possibility of water leakage from the ridge of the left bank will be high due to the following reasons:

a. The width of ridge is min. 290 m at El 3,001.5 m (surcharge level) and the lugeon value of andesite lava which is distributed at the ridge is more than 20.

b. The groundwater level at the ridge is El 2,975 - 3,000 m which is 40 - 50 m below the ground surface.

Therefore, in the detailed design phase, the detailed investigations of groundwater level and permeability of the rocks not only at the dam site but also at the ridge of the left bank are required.

River Bed and Right Bank

These areas belong to the granodiorites distribution area and the groundwater level may become higher with the distance from the river, judging from the reconnaissance survey of the downstream dam site. Even though the lugeon value of Boring B-4 at the river bed is high (over 20), the permeability below the groundwater level may be comparatively low compared with that of the lava of the left bank.

(3) Reservoir Area

1) Topography

The left bank is characterized by the gentle sloped mountain top area, comparatively steep slope going down to the Piñán River and comparatively straight branch rivers/streams with a few small valleys. On the other hand, the right bank is characterized by the gentle ridges and gentle slope facing the river where the branch rivers/streams having a lot of small valleys are developed.

The recent lava is distributed at the left bank, but weathered and eroded granodiorites are developed at the right bank. Accordingly, the topography of the left bank is new and that of the right bank is old in general.

The flat land is expanding around the upstream section of the proposed dam site. This flat land was formed by the horizontal deposits of clay, sand and volcanic ash in the lake temporarily formed by the dam up of the Piñán River by the lava flow around the dam site. At this flat land, the terrace-shaped land formed before the formation of the lake is remained.

Near the outlets of the branch rivers/streams, the alluvial fans are developed in conic form and they form an integral body with the talus deposits at the mouths of the rivers/streams. The Piñán River shows an aspect that it was pressed by lava flow around the proposed dam site and also the upstream section of the reservoir to be formed by the dam.

From this topography, it is supposed that the old river might flow through a route more left than the present stream. The Piñán River presently is flowing slowly with meandering at the flat land section. However, its gradients are steep at the downstream section of the dam site and the upstream section of the reservoir.

2) Geology

Around the reservoir, Negro Puno andesite volcanic rocks are mainly distributed at the left bank and granodiorites at the right bank. Terrace deposits, lake deposits, volcanic ash, talus deposits, fan deposits and river deposits which cover these basement rocks are distributed. Any faults could not be confirmed through the investigation. However, based on the aerial photo three lineaments are distributed at the reservoir area. The lineament near the proposed quarry site may be the straight valley controlled by eminent joints with northeast direction. The detail of the remaining lineaments is not clear due to their bad outcrops.

3) Permeability

One of the subject matters in planning a dam in volcanic rock zone is the water leakage from the reservoir. The leakage has relation with the topography and groundwater table around the reservoir. The leakage from the reservoir will not occur due to the following reasons:

a. Lava is widely distributed.

b. Distance upto the adjacent rivers is more than a few kilometers.

c. The groundwater level around the reservoir will be higher than the estimated surcharge level of 3,001.5 m due to the high topography of the surrounding area.

4) Stability of Slope

At present, the slopes around the proposed reservoir is stable and land slide cannot be seen except for the small-scale rock falls. The large-scale land slide will not occur in accordance with the storage of water in the reservoir due to the fact that the talus deposits distributed in the reservoir area widely will be still stable because of the gentle slope of them even after the storage of reservoir water upto El 3,001.5 m which is in the zone of the talus deposits.

(4) Construction Materials

1) Rock Materials

According to the field investigation, the Sites A, B and C shown on Fig. 3.2.8 can be proposed as the quarry sites for rock materials. Rocks at Site A are granodiorites and those of Sites B and C are andesite lava. In the case of usage of andesite lava of Sites B and C as the concrete aggregate, possible alkaline reaction of the aggregates and the farther distance from the dam site compared with Site A have to be studied. Seeing from the above, Site A has the highest priority as the quarry site for rock materials, because the detailed site investigation and material tests have not been conducted.

Site A' will be useful in case of shortage of quantity of rocks at Site A. The weathered or heavily weathered granodiorites can be used as filter or core materials, but the quantity of these materials at Site A is not clear at present. The river deposits and terrace deposits which contain sand can also be used as filter material. However, quantity of them will not be much.

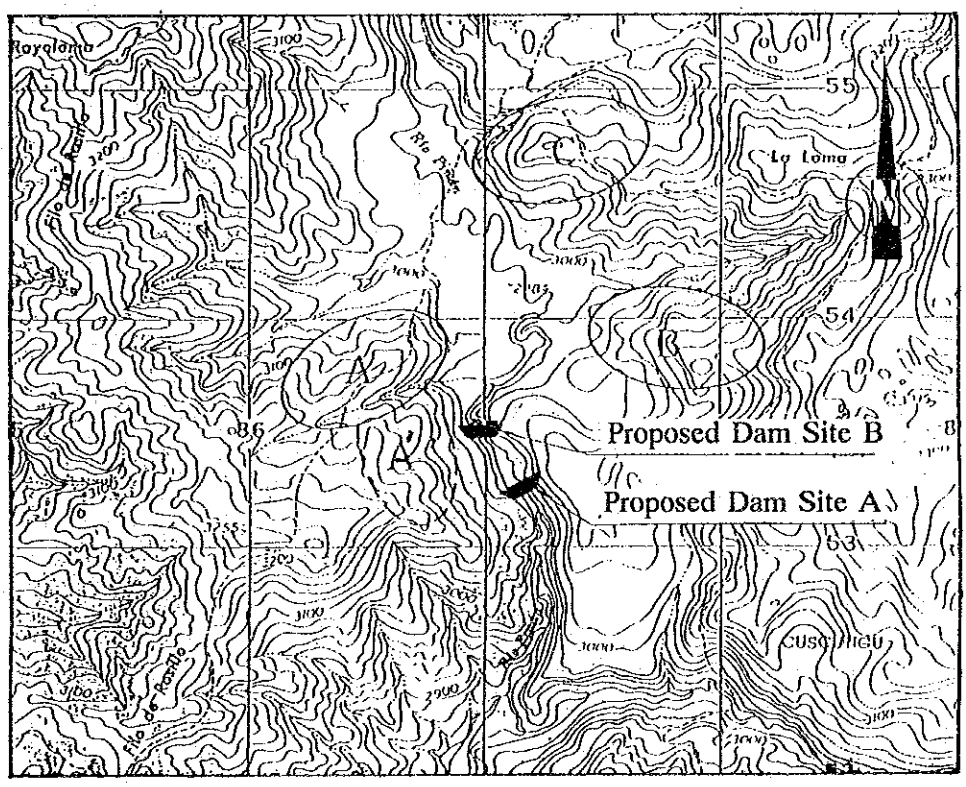


Fig. 3.2.8 Proposed Quarry Sites

2) Core Materials

As the core materials, talus deposits including fan deposits, lake deposits and volcanic ash layer can be considered. Quality of them will be enough for the core materials in case of adopting a zoned rockfill dam.

However, they have the following qualititative problems from the construction point of view:

a. Strength of lake deposits is low due to low sand contents because of lake deposits being mainly composed of volcanic ash clay. Their moisture ratio is high and specific gravity is low.

b. In the case of talus deposits, they are distributed irregularly and their quantity at one place is not so much. Furthermore, their moisture ratio is also high and specific gravity is low due to much content of volcanic ash in them.

c. The volcanic ash layer is composed of black scoria ash (10 cm – 2.5 m thick) and brown pumiceous ash (1 – 3 m thick), and distributed irregularly in the area. Both kinds of volcanic ash contain much volcanic glass. Their moisture ratio is high and specific gravity is low. Therefore, their workability and strength are low.

Consequently, a zoned rockfill dam with center core is judged to be unsuitable at present due to unavailability of good core materials near the dam site.

(5) Tunnel Sites

According to the results of seismic explorations and field reconnaissance of the proposed tunnel sites for the Head Race, the geological conditions of the respective tunnel sites are as follows:

1) Tunnel No.1

Tunnel No.1 will pass through the Pumamaqui volcanic rocks. Considering the nature of these rocks, there will be no serious troubles in excavating a tunnel of approx. 2 m diameter due to low possibility of meeting with any faults and earth cover of the tunnel being about 1,000 m.

Also there will be little problems in the excavation of the inlet mouth of the tunnel because of thin layer and steep slope of the talus deposits. On the other hand, there will be high possibility of the collapse of its outlet mouth due to the site being in the zone of vegetation, and thick layer (more than 5 m) and gentle slope of the talus deposits. Therefore, the open exaction at the outlet should be done until the earth cover becomes more than 10 m.

According to the seismic explorations, zones of low velocity exist at 115 m and 220 m points from the inlet mouth. However, there are no lineaments on the aerial photo and any faults could not be found out at the places that correspond to these zones of low velocity during the site reconnaissance. Therefore, these zones may possibly be those of concentrated joints. In this case, it should be noted that there is high possibility of water leakage from these zones.

2) Tunnel No.2

Tunnel No.2 will also pass though the Pumamaqui volcanic rocks. There will be no serious troubles in excavating a tunnel of approx. 2 m diameter due to the same reasons as for Tunnel No.1. However, the talus topographies are developed and the superficial layer is weathered at both inlet and outlet mouths. The sufficient reinforcement of the mouths will be required during the excavation of both mouths because of possible loose and low strength of the talus deposits.

According to the seismic explorations, the velocities of seismic waves upto 20 m points from both mouths are less than 1 km/s. It is judged from this fact that these zones are of talus deposits or creep zones of basement rock and that they may be loose. Even though the low velocity zones exist at 65 m, 125 m, 160 m and 225 m points from the inlet mouth, any faults could not be found out though the field reconnaissance or on the aerial photo. These low velocity zones may possibly be those of concentrated joints. In this case, it should be noted that there is high possibility of water leakage from these zones.

3) Tunnel No.3

Tunnel No.3 will also pass through the Pumamaqui volcanic rocks. Although the talus deposits are thin and their slope is steep at the inlet mouth, they are possibly loose. On the other hand, the topography near the outlet mouth is gently sloped and of rock-collapse.

The loose talus deposits of more than 5 m thick are distributed in the area. Therefore, careful exaction of the mouth is required. Judging from the aerial photo, no faults exist in the area.

4) Tunnel No.4

Tunnel No.4 will pass through the Cotacachi volcanic rocks. During the excavation of this tunnel, countermeasures against water leakage and for its drainage are required in consideration of thick earth cover (800 m) and possible high groundwater level.

A few lineaments of northeast direction exist around the area, according to the aerial photo. This fact corresponds to the rock conditions at the site that the rocks of the outcrops along the investigation road are cracked into small pieces and that a lot of small faults of the same direction (represented by direction N30E, dip 80NW) are developed. Judging from no clay being held in between the rocks, no sudden water leakage will occur during the excavation of this tunnel. However, the rocks may possibly fall down the groundwater pressure is changed because of the fragility of the basement rocks. The sections of the possible rock fall are estimated to be the zones of 1.6 km -- 2.0 km and around 4.1 km from the inlet mouth. Sufficient countermeasures against the possible rock fall are required.

The area of the inlet mouth is in the zone of vegetation and the talus deposits are thick. Therefore, the possibility of fall of the superficial layer is high. On the other hand, the area of the outlet mouth is covered with pasture, and its slope is gentle and earth cover is thin. The non-uniform earth pressure may act on the tunnel structure because the tunnel axis crosses the basement rock askew. The excavation of the mouth section with open cut method until the sufficient earth cover is obtained will be required as the countermeasures against the possible rock fall.

3.2.5 Soil

On the basis of USDA soil classification, the soil of the Study Area has been classified into 16 soil units. The distribution of respective units is shown on Fig. 3.2.9 and the characteristics of respective soil units are summarized in Table 3.2.11.

The general features of the soil in the Study Area are:

. All mother materials of soil are volcanic ash
. Soil texture is mostly composed of loam
. Drainability is good
. Soil pH is from neutral to weak alkaline because of high degree of base saturation
. Contents of organic matter, nitrogen and phosphorous are low.

3.2.6 Land Classification

The results of the land classification of the Study Area based on the soil survey are as shown on Fig. 3.2.10 and Table 3.2.10. The standard of land classification commonly used in Ecuador is adopted in classifying the land of the Study Area. The standard is shown in Table 3.2.12.

Table 3.2.10 Area by Land Class

Land class	1	2		3		4			5	6		TM	Total
Constraints	–	s	t	s	t	t	k	p		s	t		
Area (ha)	0	2,308	3,254	414	1,281	841	714	630	206	1,557	584	1,011	12,800
Ratio (%)	0	18	25	3	10	7	6	5	2	12	5	8	100
Total (ha)	0	5,562		1,695		2,185			206	2,141		1,011	12,800

Note) s : pH t : slope k : soil depth
p : gravel TM: river, village, etc.

S I M B O L O G I A			
A 1111	TYPIC HAPLUDOLLS	A 131	DURIC EUTROPEPTS
A 1112	VITRIC EUTRANDEPTS	A 132	ANDIC EUTROPEPTS
A 1121	TYPIC DURANDEPTS	A 2111	ENTIC HAPLUDOLLS
A 1122	USTOLLIC EUTRANDEPTS	A 2112	TYPIC DURIUDOLLS
A 113	ENTIC DURANDEPTS	A 212	ANDEPTIC USTORTHENTS,
A 1211	TYPIC EUTRANDEPTS		TYPIC DURIORTHENTS,
A 1212	TYPIC EUTROPEPTS		TYPIC EUTROPEPTS
A 122	TYPIC EUTROPEPT	A 31	TYPIC HAPLUSTOLLS
	ENTIC EUTRANDEPTS	A 32	UDOLLIC EUTROPEPTS
TM	MISCELANEAS		

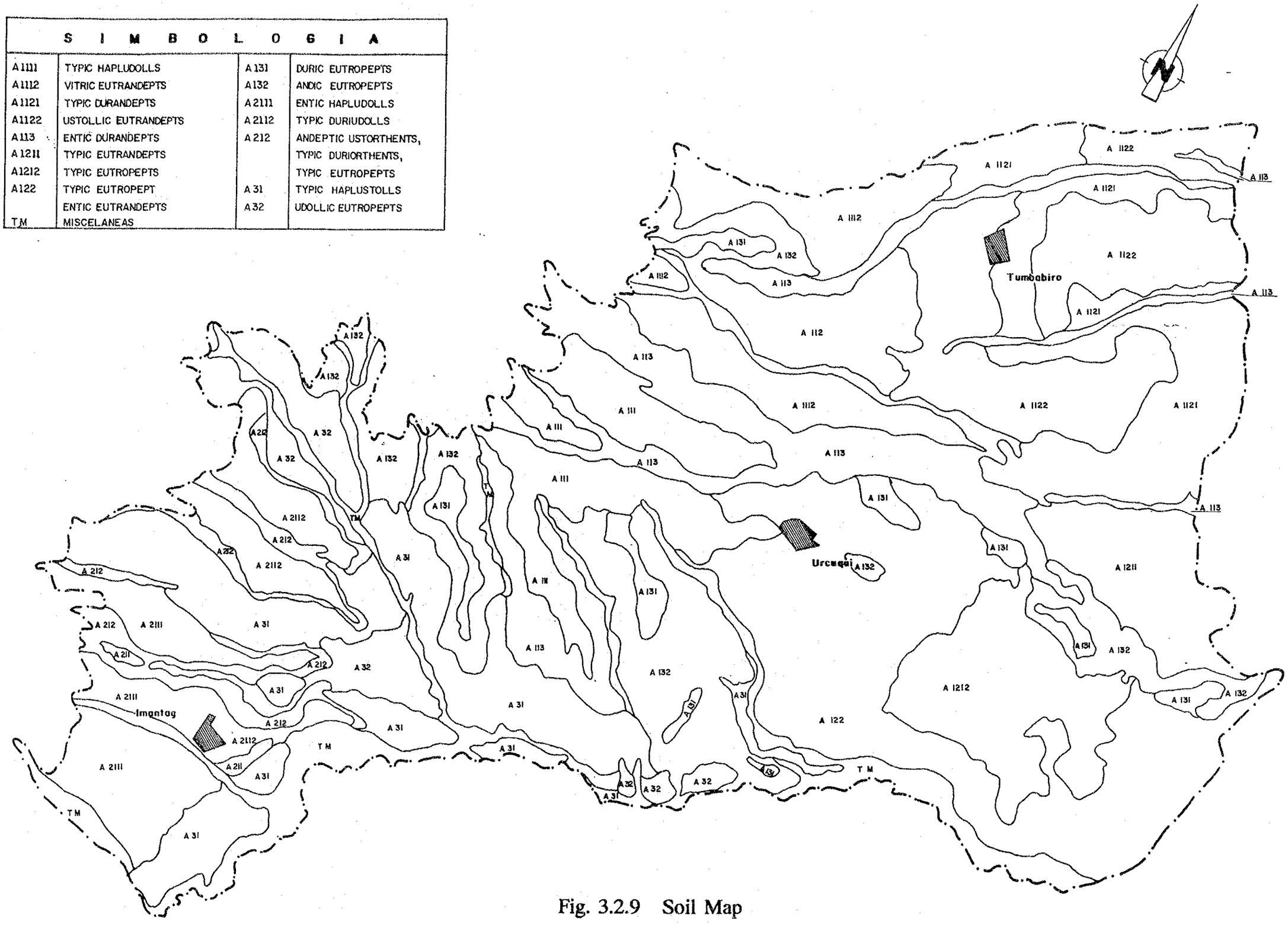


Fig. 3.2.9 Soil Map

LEYENDA

Symbolo	Clase	Sub Clase
	2	s
		t
	3	s
		t
	4	t
		p
		k
	5	
	6	s
		t
	Miscellaneous	

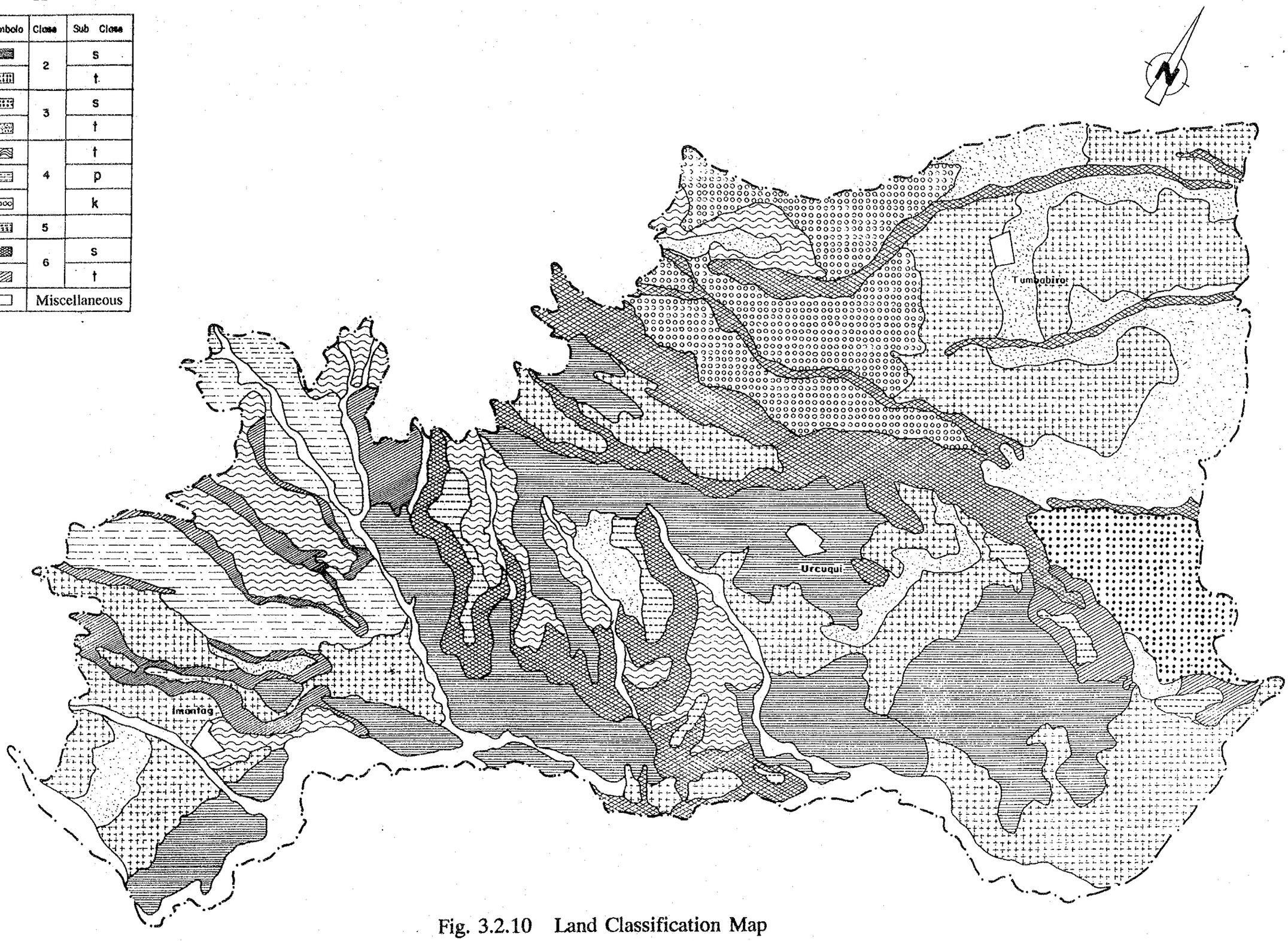


Fig. 3.2.10 Land Classification Map

Table 3.2.11 Characteristics of Soil in the Study Area

SYMBOL	SUB-GROUP	MOTHER MATERIAL	SOIL TEXTURE	DRAINAGE	SOIL DEPTH (m)	pH	EC	ION EXCHANGE	CATION-SATU-RATION DEGREE	ORGANIC MATTER	N	P	AREA (ha)	AREA (%)
A1111	Typic Hapludolls	Volcanic Ash	L, CL	Good	1.2 <	Al	N	M	MA	M	B	A	945	7.4
A1112	Vitric Eutrandepts	Volcanic Ash	L*	Good	0.4 - 0.6	N	N	M	A	B	B	M	714	5.6
A1121	Typic Durandepts	Volcanic Ash	L	Good	0.6 - 0.9	MFA1	N	A	MA	B	B	A	860	6.7
A1122	Ustollic Eutrandepts	Volcanic Ash	L*	Good	1.2 <	Al	N	M	MA	B	B	B	1,127	8.8
A 113	Entic Durandepts	Volcanic Ash	L*	Superior	-	Al	N	M	MA	M	M	B	1,235	9.6
A1211	Typic Eutrandepts	Volcanic Ash	L*	Good	1.2 <	FA1	N	M	MA	M	M	B	414	3.2
A1212	Typic Eutropepts	Volcanic Ash	L, CL	Good	1.2 <	FA1	N	M	MA	B	B	B	602	4.7
A 122	Typic Eutropepts EntricEutrandepts	Volcanic Ash	L*	Good	1.2 <	FA1	N	M	MA	B	B	M	1,530	`12.0
A 131	Duric Eutropepts	Volcanic Ash	L*	Superior	0.6 - 0.9	Ac	N	M	A	B	B	A	255	`2.0
A 132	Andic Eutropepts	Volcanic Ash	L, CL	Superior	1.2 <	Al	N	M	A	M	M	B	1,218	9.5
A2111	Entic Hapludolls	Volcanic Ash	L, SCL	Good	1.2 <	N	N	M	A	M	M	A	612	4.8
A2112	Typic Duriudolls	Volcanic Ash	CL	Good	0.6 - 0.8	N	N	M	A	B	B	B	384	3
A 212	Andeptic Ustorthents Typic Duriorthents Typic Eutropepts	Volcanic Ash Volcanic Ash Volcanic Ash	L, CL	Superior	0.4 <	FA1	N	M	A	M	M	B	285	2.2
A 31	Typic Haplustolls	Volcanic Ash	L, CL SiCL	Good	1.2 <	FA1	N	M	MA	B	B	B	1,150	`9.0
A 32	Udollic Eutropepts	Volcanic Ash	L, CL	Good	1.2 <	Al	N	M	MA	M	M	B	458	3.6
M	Miscelaneas	-	-	-	-	-	-	-	-	-	-	-	1,011	7.9
	Total												12,800	`100.0

pH: FAc = 5.1 - 5.5 Ac = 5.6 - 6.5 N = 6.6 - 7.3
Al = 7.4 - 8.4 FA1 = 8.5 - 9.0 MFA1 = 9.0 <
Ion Exchange (meq/100g): M = 10.01 - 20.00 A = 20.01 - 30.00
P (ppm): B = 1 - 10 M = 11- 20 A = 20 <
N (%):

	Sandy	SL	L, SiL	CL, L
B:	0.00 - 0.05	0.00 - 0.07	0.00 - 0.10	0.00 - 0.10
M:	0.06 - 0.01	0.08 - 0.10	0.11 - 0.15	0.11 - 0.20
A:	> 0.10	> 0.10	> 0.15	> 0.20

EC: N(No salino)=0-2
Cation Saturation Degree (%): M=11-3 A:31-60 MA:60<

Contents of Organic Matter (%):

	Sandy	SL	L, SiL	CL, L
B:	0.00 - 1.00	0.00 - 1.50	0.00 - 2.00	0.00 - 2.00
M:	1.01 - 2.00	1.51 - 2.00	2.01 - 3.00	2.01 - 4.00
A:	> 2.0	> 2.0	> 3.0	> 4.0

Table 3.2.12 Standard of Land Classification

Constraint	Class 1	Class 2	Class 3	Class 4	Class 6
Texture	L, SL	Sil, LS, CL, SCL, SiCL	SiC, SC, S, C	HC, S**	HC, S**
Depth (k)	120 cm or more	120 - 90 cm	90 - 50 cm	50 - 20 cm	20 cm or less
Gravel* (p)	5% or less	5 - 25%	25 - 50%	50% or more	50% or more
pH* (s)	6.6 - 7.3	7.4 - 8.4	8.5 - 9.0	9.0 or more, 5.0 or less	9.0 or more 5.0 or less
Slope (%) (t)	0 - 4%	4 - 8%	8 - 16%	16 - 30%	30% or more

Note 1. * depth 0 - 50 cm
** coarse sand
2. Class 5 is classified by other constraints than the above

3.3 AGRICULTURE

3.3.1 Land Use

The present land use map has been prepared based on the aerophoto of scale 1/60,000 (in 1989), topographical map of scale 1/25,000 and reconnaissance survey conducted by the Study Team. The result is shown on Fig. 3.3.1. The area by respective land use is shown in Table 3.3.1.

Table 3.3.1 Area by Present Land Use

	Cultivated land	Pasture	Forest	Abandoned land	Urban etc.	Total
Area (ha)	7,373	2,396	443	2,553	35	12,800
Ratio (%)	57.6	18.7	3.5	19.9	0.3	100.0

Note: Roads, canals etc. are included in respective land categories

The characteristics of present distribution of land by land use are summarized as follows:

a. Cultivated lands are distributed in the comparatively flat areas.

Legend	
	Cultivated land
	Pasture
	Abandoned land
	Forest
	Urban

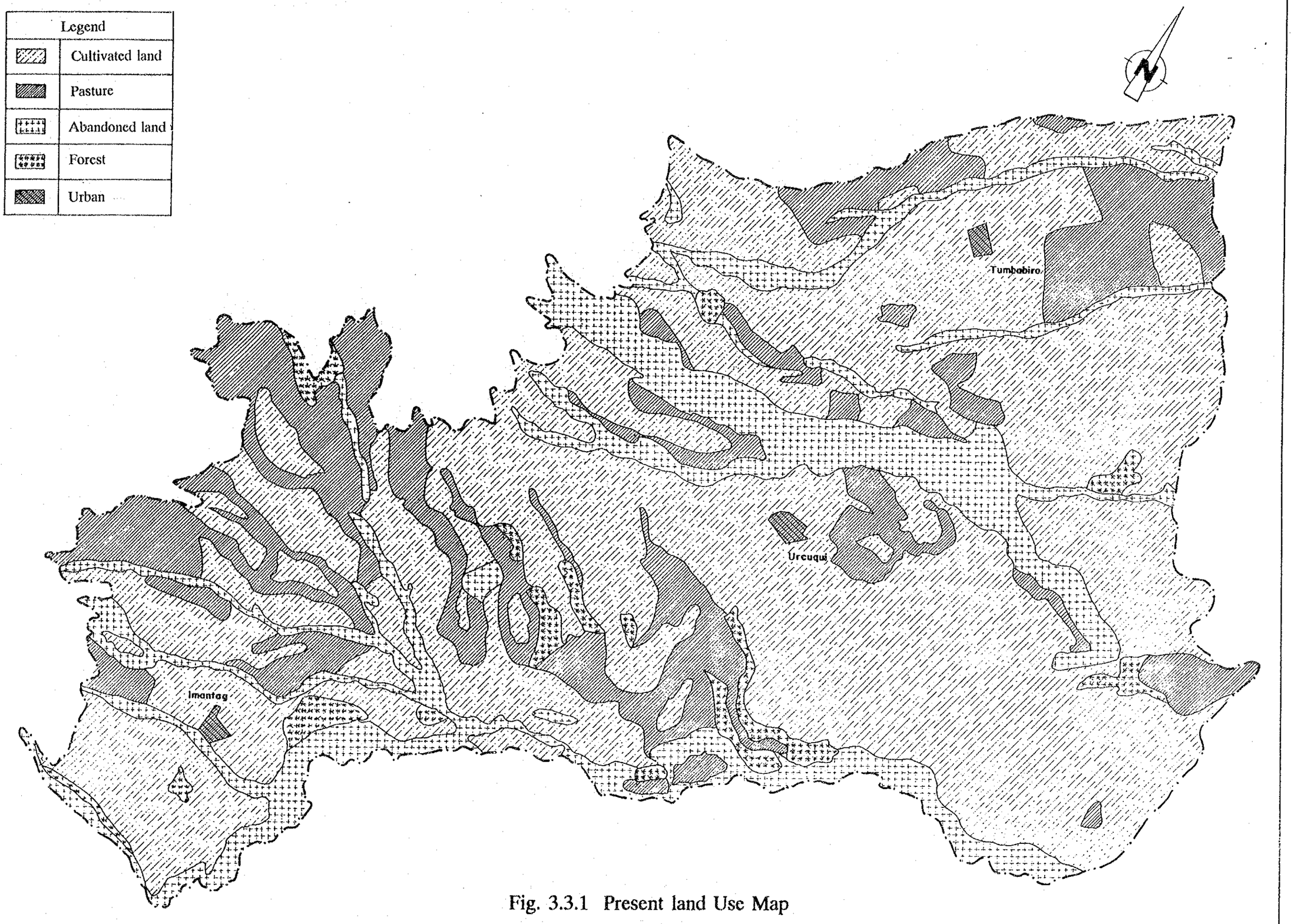


Fig. 3.3.1 Present land Use Map

b. Natural pasture is distributed in the steep-sloped area. On the other hand, improved pasture is distributed in the comparatively flat area.

c. Almost all the forest are the afforestation of Eucalyptus.

d. The abandoned lands that can not be used as agricultural land are distributed in the steep-sloped areas along the rivers.

3.3.2 Agricultural Production

The present cropped area and agricultural production are as shown in Table 3.3.2.

Table 3.3.2 Present Cropped Area and Production

Crop	Cropped Area (ha)	Unit Yield (ton/ha)	Total Production (ton)
Maize	1,602	0.91	1,457.6
Wheat	1,148	1.53	1,757.1
Barley	1,028	0.85	873.4
Kidney bean	761	0.89	676.9
Potato	186	11.61	2,163.7
Sugarcane	106	45.40	4,802.3
Green peas	55	0.54	29.6
Fruit trees	111	19.65	2,181.2
Vegetables	40	30.62	1,224.6
Total	5,037		

Note: Agacate and tomato are adopted as the represented fruit tree and vegetable, respectively.

In the estimation of the values in Table 3.3.2, the following are considered:

a. Cropped Area

Firstly ratio between cropped area and harvested area is estimated based on the statistical data on agricultural production for respective Parroquias prepared by MAG. Secondly the total cropped area is estimated based on the present land use area and irrigated area. Finally the cropped areas for respective crops are estimated based on the above and the ratio of cropped area for respective crops shown in the statistical data above with some modifications in accordance with the field survey by the Study Team.

b. Unit Yield:

The statistical data mentioned above are used.

c. Total Production:

The total productions for respective crops are estimated by multiplying the cropped area into unit yield.

Table 3.3.3 Cropping in the Study Area and Imbabura Province

	Imbabura* Province	Study Area	Ratio (%)
Total Area (ha)	446,200	12,800	2.9
Cultivated Area (ha)	25,200	7,373	29.3
Pasture Area (ha)	100,300	2,396	2.4
Maize (seco) Production (ton)	9,343	1,458	15.6
Wheat Production (ton)	3,374	1,757	52.1
Barley Production (ton)	2,482	873	35.2
Kidney Production (ton)	7,199	677	9.4

* Sistema Estadístico Agropecuario Nacional 1991

From the above figures and field survey, the following can be concluded:

a. From the fact that the cultivated area of the Study Area occupies almost 30% of that of the Province, even though the total area of the Study Area is only 2.9% of that of the Province, it can be said that the Study Area is the prominent cultivation area in the Province.

b. The main crops in the Study Area are maize, wheat, barley and kidney bean. The production ratios of these crops to those of the Province are 15.6%, 52.1%, 35.2% and 9.4%, respectively. Therefore, the Study Area plays the important role as the production area of the main staple foods.

c. Kidney bean produced in the Study Area is of high quality and mostly exported to Colombia for earning foreign currency. On the other hand, wheat in the Area plays the important role by providing the substitute of import item; resulting in the save of foreign currency.

d. Apple, avocado and tree-tomato are cultivated on a large scale in the Study Area. However, other fruit trees are cultivated mostly for self-consumption.

e. Asparagus only is cultivated on a large scale. Other vegetables such as carrot, cabbage, onion and lettuce are cultivated on a small scale.

3.3.3 Livestock

(1) Cattle Raising

The production amounts of beef cattle and dairy cattle in the Study Area have been estimated based on the present pasture area in the Study Area, the intensity of cattle raising of the Province, the average of a milking, etc. as shown in Table 3.3.4.

The total pasture area in the Study Area is 2,396 ha; 90% of which is the natural pasture and 10% is the improved pasture. Fifty (50)% of the improved pasture is used for cultivating alfalfa with irrigation and the remaining is for King grass, Ray grass, Kikkuyo, Mikai, etc.

The main raised cattle are Holstein (dairy cattle) and Criolla (local spices), which occupies approx. 90% of the raised cattle.

Brown Suiz and Brahaman spices are merely raised for beef production. A half of the produced milk are consumed at respective farms for making cheese, etc. and the remaining are sold to the milk processing factory in Cayambe.

Table 3.3.4 Livestock Production in the Study Area

Total Raised Cattle (head)	Raised Dairy Cattle (head)	Milk Production (ton)	Beef Production (ton)
2,389	406	615	149

(2) Other Livestock

Livestock other than cattle, like pig, chicken and cuy are raised by the small and medium-scale farmers for their own consumption or as assets. The chicken raising is performed by three companies shown in Table 3.3.5 on a large scale.

Table 3.3.5 Chicken Raising in the Study Area

Item \ Company	Avicola	Varguez – Velasquez	Avicola del Norte
Chicken (No./year)	200,000	125,000	64,000
Turkey (No./year)	70,000	–	–
Egg (piece/week)	–	84,000	12,000

3.3.4 Farming Practices

(1) Survey of Farmers

The survey of the farmers in the Study Area was conducted by the Study Team in addition to the analysis of the existing data in order to grasp the farming practices in the Study Area. The small and medium-scale farmers holding the farm of less than 14 ha was selected as the objective farmers. The average farm size of the surveyed farmers is 3.9 ha. The details of the surveyed farmers are as shown in Table 3.3.6.

Table 3.3.6 Surveyed Farmers by Category

		Less than 3.0 ha	3.1 – 14.0 ha	Total	Irrigated	Non-irrigated	Total
Farm	Household	18	13	31	20	11	31
	%	58	42	100	65	35	100

(2) Existing Cropping Pattern

The existing cropping pattern of the main crops in the Study Area differs in accordance with whether the farm land is irrigated or not. The typical cropping patterns of respective farm lands are shown on Fig. 3.3.2. In general, the cropping time of the non-irrigated farm land is almost the same. On the other hand, that of the irrigated farm land differs slitely by respective farms.

As the first season crop, the mixed cropping of maize and kidney bean is practiced in both irrigated and non-irrigated farm lands. As the second season crop, kidney bean and green peas the selling prices of which are comparatively high are cropped in irrigated farm land. However, wheat and barley are cropped in non-irrigated farm land. Vegetables are cultivated in the irrigated farm land only.

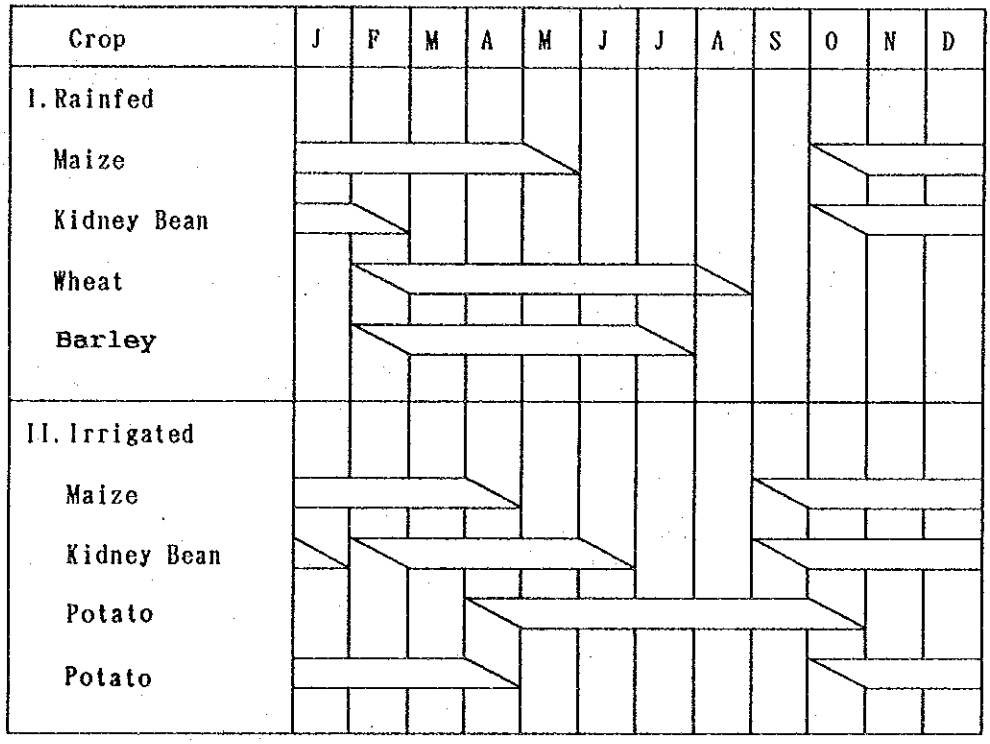


Fig. 3.3.2 Existing Cropping Pattern

(3) Distribution of Crops

Distribution by altitude of the main crops presently cultivated in the Study Area is as shown in Table 3.3.7.

Table 3.3.7 Altitudewise Crops Cultivated

Crop	Altitude	Crop	Altitude
Maize	all the area	Wheat	2,200 m or higher
Kidney bean	2,500 m or lower	Barley	2,400 m or higher
Tomato	2,200 m or lower	Potato	2,300 m or higher
Sugarcane	1,900 m or lower		

(4) Variety of Crop

The recommended varieties of respective crops in the Study Area are as shown in Table 3.3.8. Seeds are also produced in INIAP and sold to the farmers. However, the seed production in INIAP covers only 10% of the national demand. Therefore, more than 90% of the farmers in the Study Area are using the seed produced in their own farm. In general, the understanding about the importance of seed by the farmers is low. Yellows of potato the cause of which is the use of self-produced seed have been appeared in the Study Area. This is one of the causes of lowering its productivity.

Table 3.3.8 Recommended Varieties

Crop	Variety	Growing Period (day)
Maize	INIAP 101	190
	INIAP 130, 131	190
	INIAP 180	180 - 200
Kidney Bean	INIAP 400, 403	180
	INIAP 404, 411	120
Wheat	TUNGURAHUM	180
	COTOPAXI	180
Potato	LA ESPERANZA	150 - 180
	GABRIELA	150 - 180
	CHOLA, MARIA	150 - 180
Barley	DUCHICELA	150 - 180
	DORADA	150 - 180

(5) Farming Technique

Three service offices of MAG are installed in Cotacachi, Cauasuqui and Ibarra, and providing the extension services to the farmers. The demonstration farms of kidney bean and potato are installed in Perafan and Peribuera, respectively. According to the survey of the farmers, 71% of the farmers have not yet received the extension services and even in the case of the farmers who have received the services, the frequency of their reception of the services is only once a year. The contents of the services are soil management, framing method, etc.

The ratios of use of fertilizer and chemicals are 42% and 36%, respectively. The ratio of use of them by the medium-scale farmers is higher than that by the small-

scale farmers. The ratio of use of them in the irrigated farm land is much higher than that in the non-irrigated farm land. The yield in those irrigated farm lands is almost double that in the non-irrigated farm lands.

At present, the damages caused by harmful insects are widely occurred, but occurrence of nutrition lesion of the crops is almost none.

Table 3.3.9 Usage Ratio of Input

Farm Size	3.0 ha or less	3.1 ha or more	Irrigated Farm	Non-irrigated Farm	Average
Fertilizer (%)	39	46	50	27	42
Chemicals (%)	28	46	40	27	36

For plowing the farm land, 10% of the farmers are using a tractor, 48% are using cattle and 42% are using both tractor and cattle. In most case, tractors are rented to the farmers. Only two farmers holding the farm land of more than 10 ha own their tractors. The reasons why the farmers use cattle for plowing their farm lands are that the cost of plowing by cattle is cheaper (almost a half) than that by tractor and that most of the farm lands are of steep slope.

(6) Demand for Irrigation

According to the interview survey by the Study Team, all the farmers want to introduce the irrigation system. Even the farmers holding irrigation facilities want to increase the irrigation water because of its shortage. The crops that the farmers want to plant if the irrigation system is completed are fruit trees (24%), vegetables (23.5%), beans like kidney bean (22.4%), pasture (11.8%), maize (7.1%) and potato (7.1%) in order. From the above results, the farmers not holding irrigation facilities at present want to diversify their crops in the second cropping season, if the irrigation system is introduced to their farm lands.

(7) Livestock

Number of livestock by scale of farm is shown in Table 3.3.10. The small and medium-scale farmers are raising livestock for their own consumption or as assets. Number of livestock increases with the scale up of farm size. Almost 50% of cattle

raised by the medium-scale farmers are beef cattle, and dairy cattle and double purpose cattle share 25%, respectively. The small-scale farmers are mostly not raising any cattle.

Table 3.3.10 Farm Scalewise Number of Livestock

Farm Scale	Cattle (head/farm)	Pig (head/farm)	Chicken (no./farm)
3.0 ha or less	0.2	0.9	4.2
3.1 ha or more	1.9	2.8	6.4
Ave.	0.9	1.7	5.1

3.3.5 Farm Household Economy

Almost all the farmers in the Study Area are practicing the rain-fed cultivation and agricultural profit is very low because of low productivity of farming. According to the interview survey, the small-scale farmers are earning supplemental income by working at the plantation farms or towns due to impossibility of earning livelihood by the income from agriculture only. Some of the farmers holding irrigation facilities are not cultivating all their arable land because of the shortage of irrigation water.

These circumstances stress much more the severe household economy of the farmers and increase the degree of their povaty. It is practically impossible to receive the support from the public agricultural banking organizations.

Based on the interview survey, the present household economy of an average small-scale farmer is summarized as shown in Table 3.3.11.

Table 3.3.11 Household Economy of Average Small-scale Farmer

Item	Amount (Sucre)
Gross income from Agriculture	420,000
Income from Other Sources	500,000
Total Household Income	920,000
Production Cost (excluding family labor)	166,000
Living Cost	754,000
Surplus	0

Note: Size of Farm: 3 ha, Cropping: Single cropping
Crops: Maize (Choclo), No. of family: 5 persons

From the above table, the household economy is kept by both income from the sources other than agriculture and the family labor. At present, it is very hard to improve the agricultural production and living conditions of the farmers because of the instability of farming practices. The legal minimum wages established by the Government of Ecuador in 1992 is 60,000 sucre per month. The income of the sampled representative farmer whose income is comparatively high among the small-scale farmers slightly exceeds the legal minimum wages.

In the case of the farms whose farm size is smaller than this sampled farm, the ratio of the income from the sources other than agriculture becomes higher (almost 80%), the income from agriculture is almost nil and all the agricultural products are consumed by the family members. Therefore, at present, it is almost impossible for the small-scale farmers to bear the surplus in the household economy.

However, some of the farmers purchase the livestock like sheep, pig and chicken by using a part of income from the sources other than agriculture and this livestock becomes their valuable asserts or wealth.

3.3.6 Land Tenure

The present land tenure by farm size in the Study Area is as shown in Table 3.3.12. The average size of land holding is 8.6 ha. The area of land owned by the small-scale farmers (holding less than 3.0 ha of land) is only 6.8% of the total area, even though 72.3% of the farmers are categorized in the small-scale farmers. On the other hand, 75.7% of the total area are owned by the plantation farmers holding more than 20 ha of land, and they share only 5.4% of the farmers in the Area.

Table 3.3.12 Present land Tenure

Farm Size (ha)	Household		Owned Area		
	(No.)	(%)	(ha)	(%)	(ha/household)
Small-scale					
1.0 or less	781	52.4	315	2.5	0.4
1.1 - 3.0	297	19.9	553	4.3	1.9
Sub-total	1,078	72.3	868	6.8	0.8
Medium-scale					
3.1 - 5.0	141	9.5	573	4.4	4.1
5.1 - 10.0	139	9.3	956	7.5	6.9
Sub-total	280	18.8	1,529	11.9	5.5
Large-scale and Plantation					
10.1 - 20.0	52	3.5	717	5.6	13.8
20.1 - 50.0	32	2.1	1,032	8.1	32.3
50.1 - 100.0	18	1.2	1,324	10.3	73.6
100.1 or more	31	2.1	7,330	57.3	236.5
Sub-total	133	8.9	10,403	81.3	78.2
Total	1,491	100.0	12,800	100.0	8.6

Source: INERHI, 1990

3.3.7 Marketing System

(1) Distribution of Farm Products

In general, farm products produced in the Study Area are shipped to the market and/or the wholesalers in Ibarra through middlemen. The main market in Imbabura Province is Amazonas Market (Mercado Amazonas) in Ibarra City. On Saturdays and Sundays, fairs (ferias) are held in the towns of Parroquia and Canton. There are two large markets around the area for marketing farm products, one is in Quito City and the other in Ambato City.

There are 12 wholesalers who deal with farm products, especially cereals such as maize, green pea and lentil in Ibarra City. For the purpose of the distribution of kidney beans, ENAC (Commercial Corporation of Farm Products) in Ibarra City has established a collecting center equipped with selecting and drying facilities. The dealing amount of kidney beans of the center in 1989 was 27,608 quintals (1,242.4 ton). Almost all the kidney beans produced in the area are exported to Colombia.

According to the market price information (Jan. 1992 to Jul. 1993) of farm products related to the Study Area, in Ibarra, Ipiales (Colombia) and Quito, farm products produced in the Study Area are shipped to the market which has the most favorable market prices among the markets in Ipiales and Quito. Owing to the liberalization of trade between Colombia and Ecuador by the Agreement of Andean Countries, most of the products are shipped to Colombia. As an example, some 90% of the kidney beans in the market of Ibarra City are exported to Colombia.

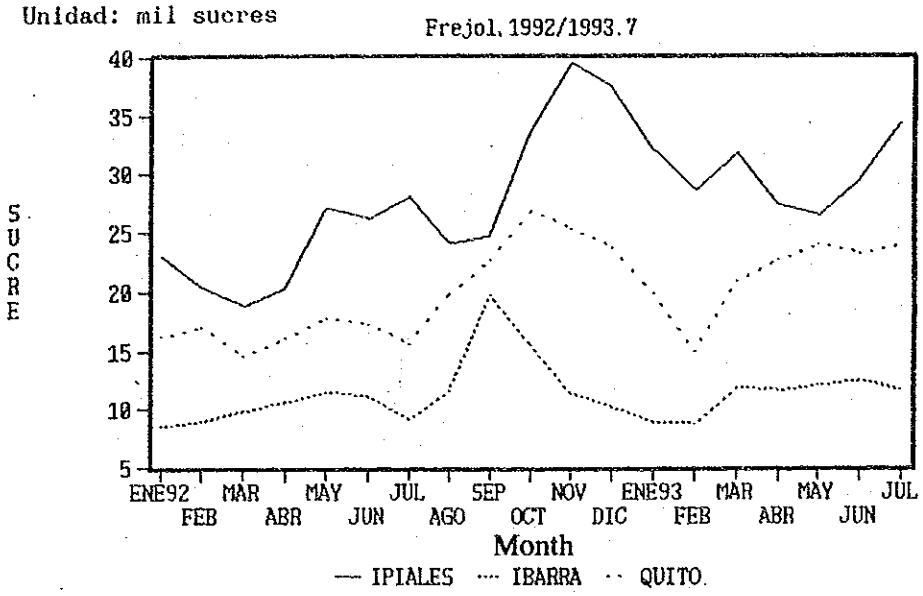


Fig. 3.3.3 Trends of Wholesaler's Market Price

The marketing channel of farm products in the Study Area is illustrated in Fig. 3.3.4.

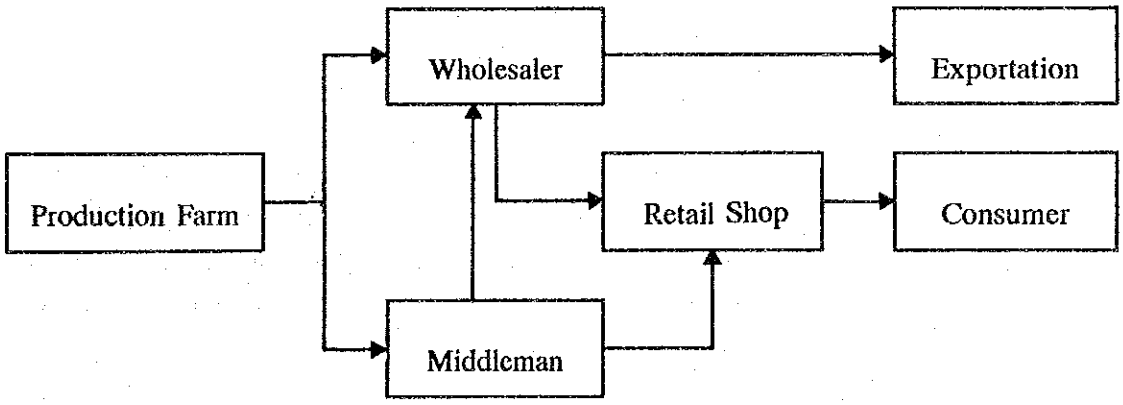


Fig. 3.3.4 Marketing Channel of Farm Products

The wholesaler's market prices (July, 1993) of main farm products in Ibarra City are as shown in Table 3.3.13.

Table 3.3.13 Wholesaler's Market Prices

Farm Product	Market Unit (kg)	Market Price (Sucre)
Maize (for feed)	45	15,000
Maize (for food)	45	37,000
Maize (Choclo)	55	13,000
Barley	45	17,000
Green pea (perishable)	50	55,000
Kidney bean (perishable)	50	17,000
Kidney bean (dry)	45	40,000
Broad bean (perishable)	32	12,000
Broad bean (dry)	45	75,000
Potato (La Esperanza)	45	14,000
Potato (Roja)	45	15,000

Note: Market prices show prices in market unit

(2) Distribution of Stock Farm Products

Main livestock in the Study Area is dairy farming, cattle raising and poultry farming. The market of these stock farm products is mainly in Quito City and the products are shipped to local markets through the market in Quito.

1) Dairy Products

In Ibarra City, there is a pasteurizing milk plant (FLORALP) which processes 11,000 litres per day. The pasteurized milk is sold and consumed in Ibarra City and its surroundings. The market price of raw milk in Ibarra is S/.750 per litre (July, 1993). Collection of raw milk is carried out directly by the above plant from dairy farmers in Carchi Province (mainly San Gabriel) and Imbabura Province. A major part of raw milk produced in the Study Area is shipped to the milk plant (Sociedad Industrial Hertob C.A.) in Cayambe.

2) Cattle Beef

A public slaughterhouse (Empresa Municipal de Rastro) exists in Ibarra City, and the number of head slaughtered per day is about 40 cattle (generally superannuated milk cow) and about 60 pigs and sheep. The meat produced in this slaughterhouse is provided to Imbabura Province. The market price of meat (beef) in Ibarra is S/.1,800 per pound (July, 1993).

3) Poultry

In the Study Area, there are three poultry farms; two farms (189,000 hens in total) in Tumbabiro and a farm (200,000 chickens and 70,000 turkeys) in Colimbuela, Cotacachi Canton. The eggs and chickens produced in these farms are shipped to the market and broiler factory in Quito City, respectively. The market prices are S/.130-140 per egg and S/.1,700 per pound of fowl (July, 1993).

3.3.8 Agro-industry

The agroindustrial factories in Imbabura Province are scattered throughout Ibarra City and its surroundings. Most of them are at the regional industry level. The factories of enterprise type are for sugar, alcoholic beverages, foodstuff and a dairy. The agroindustrial factories in the Study Area and its surroundings are tabulated in Table 3.3.14 (by field survey).

Table 3.3.14 Agroindustrial Factory around the Study Area

Industrial Field	Place	Production	Capacity
Sugar factory	Chota	Raw sugar	900 ton/day
Sugar factory	Urcuqui	Raw sugar	80 ton/day
Distillery	Ibarra	Alcoholic beverage	750 m^3/month
Food processing factory	Ibarra	Canning	Variable
Food processing factory	Atuntaqui	Processed meat	4 head/week
Food processing factory	Ibarra	Production of can	8,000 cans/month
Food processing factory	Pimanpiro	Tomato puree, Chili sauce	1 ton/day
Dairy plant	Caranqui	Pasteurized milk	11,000 lts/day

In addition to the above, some small factories such as a confectionery, a noodle factory and a feed factory, exist in Imbabura Province.

The Government of Republic of Ecuador emphasizes the promotion of export of farm products as a policy with an over-riding priority among the national policies. Aiming at the promotion of export of processed foods, the Ministry of Agriculture and Livestock (MAG) has been providing technical assistance to fruit-growing farmers through the technical cooperation program with Switzerland (COTESU), and also supporting the marketing and distribution between agroindustrial factories and farmers.

3.3.9 Agricultural Supporting System

The public supporting institutions related to agriculture and livestock in the Study Area are as follows:

(1) Agriculture and Livestock Provincial Directorate of Imbabura (DPA-Imbabura)

The DPA-Imbabura executes agricultural administration and agricultural support services in close collaboration with the Provincial Agriculture and Livestock Council. The summary of the services is as follows:

1) Agricultural Extension

In the Study Area, the agricultural extension offices (ASA) in collaboration with DPA-Imbabura carry out agricultural extension services for farmers. In Cotacachi, these services are carried out by the ASA-Cotacachi, comprised of a chief, a veterinarian, three extension workers, and in Ibarra through the Technical Department of DPA-Imbabura. The extension activities are carried out through visiting farmers, short training courses, observation patrols, demonstrative farms, working on farms, etc., in conformity with the Agriculture and Livestock Technical Development Program (PROTECA).

These extension services for agriculture and livestock are based on the following subject matters:

Agriculture Sector: Technical assistance for the crops such as barley, wheat, maize (suave), maize (duro), potatoes, kidney beans, green peas, lentils, broad beans, sugarcane, vegetables, tree tomatoes, avocados, peaches, apples, grapes and pasture,

and agricultural mechanization, soil conservation and plant sanitation.

Livestock Sector : Animal sanitation, artificial insemination, moving control of cattle and technical transfer.

Forestry Sector : Production, management and forest industry.

The National Institute of Agricultural Research (INIAP) also supports agricultural extension activities such as production and distribution of improved seeds of crops and fruit plants. Seeds of potatoes, maize, pulses and quinua are produced at the Santa Catalina Experimental Station, INIAP; and seeds of vegetables and fruit plants are produced at Tumbaco Experimental Station, INIAP.

INIAP situated in Chaltura, Imbabura Province, through the La Pradera Experimental Farm, is carrying out technical assistance programs, emphasizing the fruit-growing program among the programs. In Urcuqui, the formation of farmer's groups which have the intention of growing fruit, is encouraged through the distribution of fruit plants such as peaches and apples. The extension activities at the demonstration orchards of the experimental farm and of the progressive farmers in Urcuqui promote this program.

2) Rural Development

In order to improve the rural environment, the formation of farmer's organizations such as community, cooperatives and associations, is promoted by the Rural Development Section, DPA-Imbabura. These organizations perform social works to benefit the community such as construction of schools, community houses and bridges, improvement/maintenance of roads, and reforestation.

(2) National Development Bank (BNF)

The National Development Bank (BNF) is the public financing institution for agricultural credit. In the Study Area, Ibarra Branch Office and Otavalo Office play an important role in that sector of agriculture and livestock.

The loan conditions for the farmers are as follows:

Term

Short:	less than 2 years
Medium:	2 – 7 years (unredeemable for 2 years)
Long:	7 – 20 years (unredeemable for 2 years)

Interest 50% annually (Interest rate is adjusted to inflation rate)

Purpose

- Annual crops and perennial crops,
- Purchase and repairing of machinery, equipment and implements,
- Agricultural infrastructure construction works,
- Formation of cattle–ranches and purchase of draft animals,
- Investment for facilitating commercialization,
- Formation and maintenance of meadows,
- Purchase of agricultural inputs,
- Poultry farming,
- Formation and maintenance of forests, and
- Capital of operation.

Conditions

- Land owner,
- Farmer who has the farming technology,
- Farmer who is capable of repayment,
- Financing of 90% of the loan request for the old client and of 80% for the new client.

The total amount of loans to the sector of agriculture and livestock from January to September, 1992 in Ibarra Branch, BNF was S/.2,399,637,000.

3.3.10 Farmer's Organization

The Agriculture and Livestock Administration Bureau of Imbasbura (DPA–Imbabura) executes agricultural administration and support services to the farmers in the Study Area, and also promotes the organization of rural inhabitants in community, cooperatives and associations levels.

(1) Farmer's Organization

Farmer's organizations in the Study Area are formed in line with the guideline of the Parroquia committee (Junta Parroquia), which is organized by the Community Law (Ley de Comunas), in the indigenous community zone. This organization is operated by a committee (Cabildo) formed by a chief, a vice-chief, treasurer and two vocals, and carries out maintenance of social infrastructures such as schools, community houses and roads.

(2) Agricultural Association

In Imantag, there is an agricultural association named Peribuela which is comprised of 28 members, with an exploited area of 1,000 ha of community type.

(3) Agricultural Center

An agricultural center is established legally in each capital of Canton. The center provides agricultural input and equipment to the members in low price and also conducts projects to improve farming technology, giving short courses in farm management. The members can obtain a prior advantage for getting the agricultural credit in procurement of agricultural inputs and reducing the predial tax. The center is administrated by the directorate formed by a president, a vice-president and four vocals, who are elected in the general assembly. The agricultural centers in the Study Area are in Urcuqui with 800 members and in Cotacachi with 2,000 members. Presently the farming scale of the members is over 10 ha.

(4) Water Users' Association

In the Study Area, the farmers who have water right on irrigation water by canal (acequia) are organizing water users' associations (Junta de Usuarios de Agua) with the aim of dealing with operation and maintenance of irrigation facilities. The associations are administrated by a committee which is comprised of a president, a vice-president, a treasurer and two vocals with the collaboration of the Ecuadorian Institute of Water Resources (INERHI). The actual maintenance of irrigation canals is conducted by the beneficial farmers by themselves.

3.4 EXISTING IRRIGATION FACILITIES

3.4.1 Irrigation Facilities

In the Study Area, there are 24 existing irrigation canals "acequia" (mainly earth lined). The water resources of these canals are mostly the rivers/streams flowing around the Study Area, the intakes of which are located at the upstream sections of these rivers/streams and the altitude of intakes is much higher than the farm land. The water is induced to the farm land by long-distance. The distribution network of these canals are shown in Fig. 3.4.1.

Total length of the canals is approx. 240 km. Their gradiences are almost between 1/1,000 and 1/300. The registered intake water right is 1.17 l/s/ha in average (max. 871 l/s and min. 1 l/s per right). Seeing from the total discharge of the rivers/streams and the total area of the existing farm lands, serious shortage of irrigation water would not have occurred. However, the distribution of water has serious problem and the majority of the farm lands have the problem of irrigation water shortage.

The total area of the farm lands benefitted by these irrigation waters is 2,520 ha and number of persons who are paying the water charge is 1,730 (Table 3.4.1). The number of the persons who are paying the water charge exceeds the total number of the farm household in the Study Area due to the fact that some of the farmers have more than one water right per person, more than one person in one household are paying the water charge for one registration of water right, etc. Almost all the irrigation are performed by furrow irrigation method. Some of the large and medium-scale farmers are practicing sprinkler irrigation.

At present, the drained water is flown out through the streams and irrigation canals located in the Study Area with high density. Considering the amount of annual rainfall and intensity of the canals, there will be no serious drainage problem even after the Project implementation.

3.4.2 Operation and Maintenance of Existing Facilities

The operation and maintenance of the existing irrigation facilities are performed by the Water Use Union (Junta de Usuarios de Agua) organized by the beneficial farmers for respective canals. The irrigation at the field is conducted in turn according to the irrigation calendar, irrigation date and hour for each farm prepared by the Union. The

canals are eroded at many places because of their gradient being steep and their lining being earth. Therefore, the canals are not maintained well.

One of the other reasons for bad maintenance of the canals is that the canal water mostly cannot be used by the farmers living along the upstream section of the canal even though the canal passes through their lands, because of the farmer who has the water right having his farm at the downstream section of the canal.

The water charge is collected by INERHI and its annual amount has been 37.84 Sucre per l/s since 1975.

Fig. 3.4.1 List of Existing Irrigation Canals

Area No.	Name of Canal	Water Resources	Altitude (msnm)	Water Right (l./seg.)	Area (has.)	No. of payer of water drainage	Water Quantity (L/seg./has)
7A	Aceq. Pisangacho	Afl. Chuspihuaycu	2.820	14.91 (20)	82 (110)	20	0.18
7	Aceq. La Banda	Vte. La Banda	3.680	4	120	30	0.03
41	Aceq. Mindaburlo	R. Huanmiyacu	2.900	44	73	35	0.60
75	Aceq. Caciques	R. Huanmiyacu	2.670	203	180	60	1.13
5H	Aceq. Tapiapamba	R. Huanmiyacu	2.315	142	213	55	0.67
6J	Aceq. Madre de Conaqui	R. Huanmiyacu	2.270	529	490	93	1.08
1J	Aceq. Guzmana	Q. Cariaco	2.100	152	100	15	1.52
7I	Aceq. Nueva	Q. Conaqui	2.170	1	5	4	0.20
3I	Aceq. San Luis	R. Ambi	2.200	105.4 (112.5)	89 (95)	60	1.18
62	Aceq. la Chiquita	Q. Casa Quemada	2.715	116	120	55	0.97
40	Aceq. Peribuela	Q. Chimborazo	2.920	44.33 (133)	32 (96)	84	1.38
2D	Aceq. Yanayacu	Q. Artezon	2.500	118	65	350	1.82
1I	Aceq. Tushila	Q. Tushila	2.240	15.5	30	15	0.52
0	Aceq. Quitumba	Q. Caballito	2.835	45	60	12	0.75
43	Aceq. Los Molinos	R. Alambi	2.900	33	50	50	0.66
58	Aceq. La Carboneria	R. Alambi	2.730	136	85	350	1.60
7H	Aceq. La Molienda	Q. Quitubi	2.290	101	80	10	1.26
2F	Aceq. la Marqueza	R. Tuctara	2.450	70.91 (136.69)	83 (160)	200	0.86
3H	Aceq. Ambi o Jijona	R. Pichavi	2.325		200	45	4.35
3	Aceq. Del Pueblo	Q. Huada		40	90	80	0.44
1A	Aceq. La Calera	Q. Cruzacha	2.540	60	95	42	0.63
965	Aceq. Del Barrio	Q. Cachiyacu	2.680	25	65	15	0.38
1086	Aceq. La Raya	Q. Chuspihuaycu	1.870	50	63	15	0.79
5	Aceq. Edelmira	Q. Piguchuela	2.040 2.110	20	50	35	0.40
	Total			2,941.0	2.520	1.730	1.17

Note: ( ) including the area outside of the Study Area
Surved in Feb. 1992

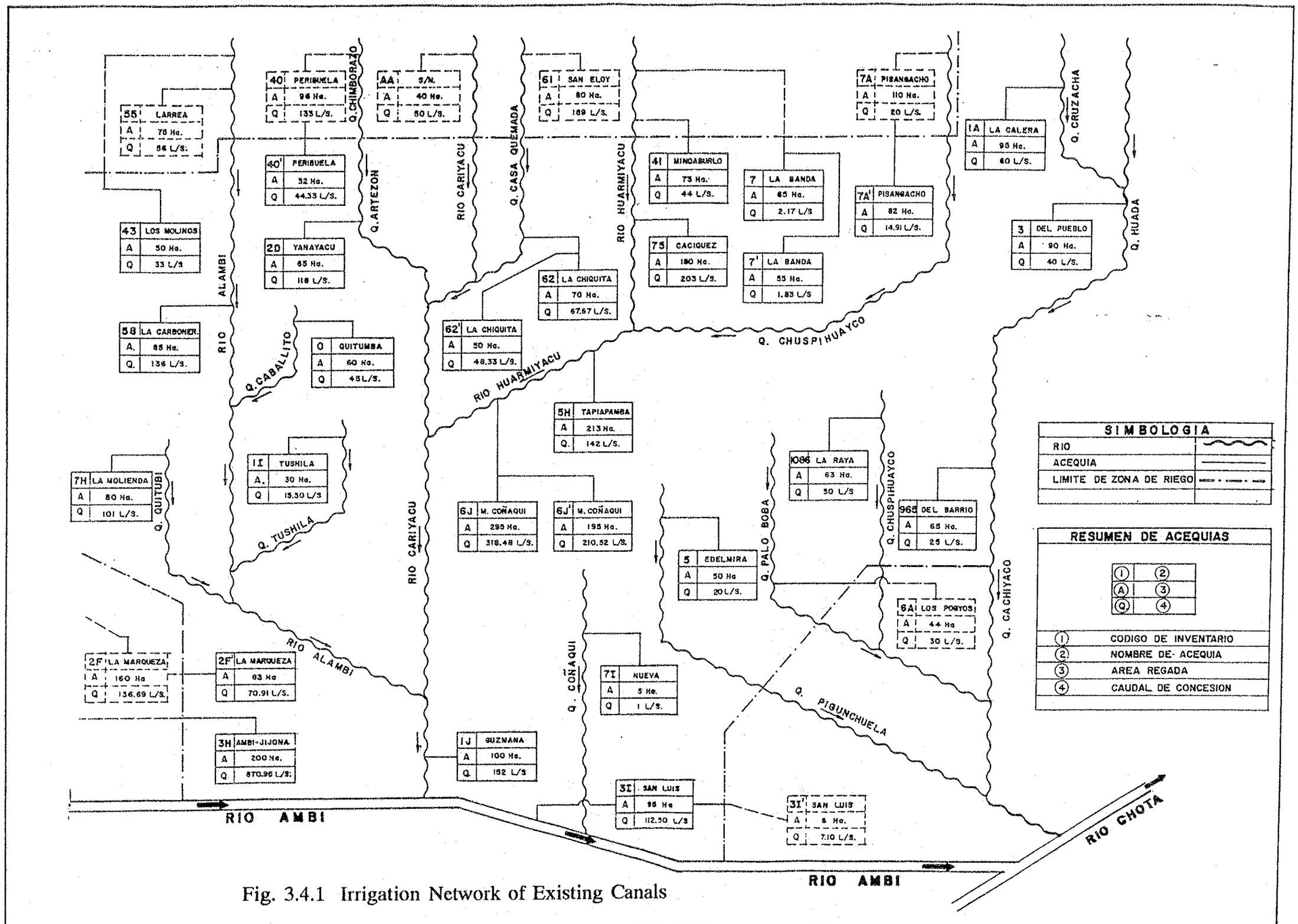


Fig. 3.4.1 Irrigation Network of Existing Canals

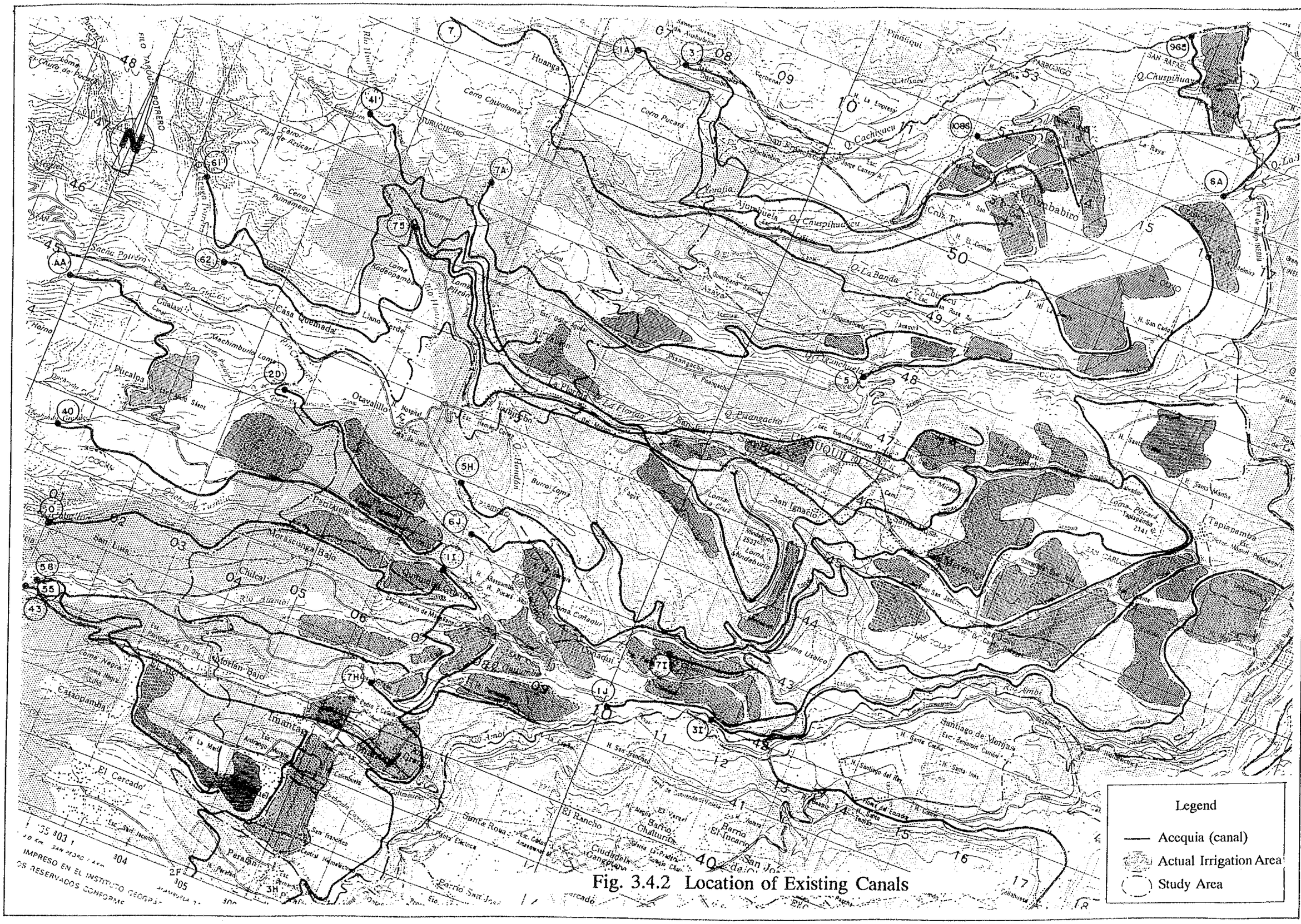


Fig. 3.4.2 Location of Existing Canals