

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MUNICIPALITY OF LA PAZ  
THE REPUBLIC OF BOLIVIA

THE STUDY ON  
CONTROL OF WATER CONTAMINATION OF THE RIVERS  
IN THE CITY OF LA PAZ

Supporting Report

MAY 1993

PACIFIC CONSULTANTS INTERNATIONAL

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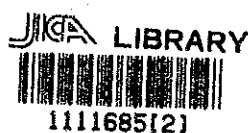


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In this report, project cost is estimated in June 1992 prices at an exchange rate of 1 US\$ = Bs. 3.87 (=¥127).

## Abbreviations

<b>ABIS</b>	<b>:</b>	<b>Asociación Boliviana de Ingeniería Sanitaria y Ambiental (Bolivian Association of Sanitary and Environmental Engineering)</b>
<b>ANESAPA</b>	<b>:</b>	<b>Asociación Nacional de Empresas e Instituciones de Servicio de Agua Potable y Alcantarillado (National Association of Enterprises and Institutions for Water Supply and Sewerage Service)</b>
<b>CORDEPAZ</b>	<b>:</b>	<b>Corporación Regional de Desarrollo de La Paz (Regional Development Corporation of La Paz)</b>
<b>DICOMAC</b>	<b>:</b>	<b>Dirección de Control y Manejo de Cuencas y Medio Ambiente, HAM-LP (Bureau of Control and Management of Watershed and Environment, HAM-LP)</b>
<b>DINASBA</b>	<b>:</b>	<b>Dirección Nacional de Saneamiento Básico, MAU (National Bureau of Basic Sanitation, MAU)</b>
<b>DSU</b>	<b>:</b>	<b>Dirección de Saneamiento Urbano, HAM-LP (Bureau of Urban Sanitation, HAM-LP)</b>
<b>GTZ</b>	<b>:</b>	<b>Deutsche Gesellschaft für Technische Zusammenarbeit (German Technical Cooperation Agency)</b>
<b>HAM</b>	<b>:</b>	<b>Honorable Alcaldía Municipal (Mayor's Office of the Municipality)</b>
<b>HAM-LP</b>	<b>:</b>	<b>Honorable Alcaldía Municipal de La Paz (Municipality of La Paz)</b>
<b>IGE-UMSA</b>	<b>:</b>	<b>Instituto de Geología Económica, UMSA (Institute of Economic Geology, UMSA)</b>
<b>IIS-UMSA</b>	<b>:</b>	<b>Instituto de Ingeniería Sanitaria, UMSA (Institute of Sanitary Engineering, UMSA)</b>
<b>INE</b>	<b>:</b>	<b>Instituto Nacional de Estadística (National Institute of Statistics)</b>
<b>MACA</b>	<b>:</b>	<b>Ministerio de Asuntos Campesinos y Agropecuarios (Ministry of Peasant and Stockbreeding Affairs)</b>
<b>MAU</b>	<b>:</b>	<b>Ministerio de Asuntos Urbanos (Ministry of Urban Affairs)</b>
<b>MPC</b>	<b>:</b>	<b>Ministerio de Planeamiento y Coordinación (Ministry of Planning and Coordination)</b>
<b>MPSSP</b>	<b>:</b>	<b>Ministerio de Previsión Social y Salud Pública (Ministry of Social Security and Public Health)</b>

- SAMAPA :** Servicio Autónomo Municipal de Agua Potable y  
Alcantarillado  
(Municipal Corporation of Potable Water and Sewerage in  
La Paz)
- SENAMHI :** Servicio Nacional de Meteorología e Hidrología  
(National Service for Meteorology and Hydrology)
- UMSA :** Universidad Mayor de San Andres  
(University of San Andres)

# The Study on Control of Water Contamination of the Rivers in the City of La Paz

## Supporting Report

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***PART (I)***

***INTRODUCTION***

# CHAPTER 1

## INTRODUCTION

### 1.1 BACKGROUND OF THE STUDY

The City of La Paz is the largest city in Bolivia and the de facto capital of the country with a population of about 720,000. It is the country's political and economic center. Geologically, it lies in a large valley in the eastern edge of a huge plateau called Altiplano that extends at a height of about 4,000 m above the sea level. The city has developed along the Choqueyapu River which constitutes the central axis of the urban area.

The Choqueyapu River and some of its tributaries have been suffering serious water pollution as the city has developed intensively during the recent decades. Major causes of the river water pollution are domestic and industrial wastewaters that are discharged into the rivers directly or via sewer outlets. Solid wastes also contribute to the water pollution, since some of the uncollected solid wastes ultimately finds its way into the rivers.

The degree of the pollution is such that the BOD value of the Choqueyapu River in the central zone of the city often exceeds 300 mg/l, a level surpassing that of normal domestic sewage.

This situation has brought about offensive odors and aesthetic deterioration along the rivers in the urban area, and serious damages to the use of the river water for irrigation of the farm lands scattered along the lower reaches of the Choqueyapu (La Paz) River.

Thus, river water pollution in the city has been one of the major problems to be solved by the authorities concerned and the citizens as well. In 1982, a comprehensive plan for developing sewerage and stormwater drainage systems in the metropolitan area was prepared, through the technical cooperation of then West Germany. But the plan has not yet been implemented except a few components, largely because of the limited financial capacity of the city and country.

In order to improve the degraded quality of the aquatic environment of the city and the adjoining areas, water pollution control plan is needed; one that can be implemented, if not easily, by means of a reasonable degree of resource input and cooperation between the authorities, industries, and citizens.

With this background, the Study on Control of Water Contamination of the Rivers in the City of La Paz (hereinafter referred to as "the Study") was undertaken by the Japan International Cooperation Agency (JICA) responding to a request made by the Government of Bolivia. The Scope of Work for the Study was signed between JICA and the Bolivian Government on February 27, 1991.

## **1.2 OBJECTIVES OF THE STUDY**

The objectives of the Study are to prepare a basic plan for control of the water pollution of the Choqueyapu River and its tributaries, and to conduct a feasibility study on the first priority project to be selected from the components of the basic plan.

## **1.3 STUDY AREA**

### **1.3.1 Administrative Division in Bolivia**

The land of the Republic of Bolivia is administratively divided into nine (9) Departments (Departamentos) as shown in Fig. 1.3.1, each having a departmental capital. The City of La Paz is the capital of the Department of La Paz as well as the de facto capital of the Republic.

Each Department is further divided into Provinces (Provincias) each having a provincial capital. The City of La Paz is located in the Province of Murillo as shown in Fig. 1.3.2, but the provincial capital is Palca.

The Province of Murillo consists of the two Cities (Ciudades), i.e., La Paz and El Alto, and ten (10) counties (Cantones). The metropolitan area of La Paz consists of the City of La Paz and the City of El Alto which was separated from La Paz in 1988. A southern part of the border between the two cities is not yet defined.

The urban area of the City of La Paz is divided into the Central Zone and the South Zone largely by the boundary between the catchments of the Orkojahuira River and the Irpavi River.

### **1.3.2 Study Area**

The study area is the catchment area of the La Paz River above the Lipari bridge as shown in Fig. 1.3.5 with a total area of 535 km<sup>2</sup>. The La Paz River belongs to the hydrological system of the Amazon River. It reaches to the Madera River, a major tributary of the Amazon, through the Boopi River and the Beni River as shown in Figs. 1.3.3 and 1.3.4.



# Bolivia

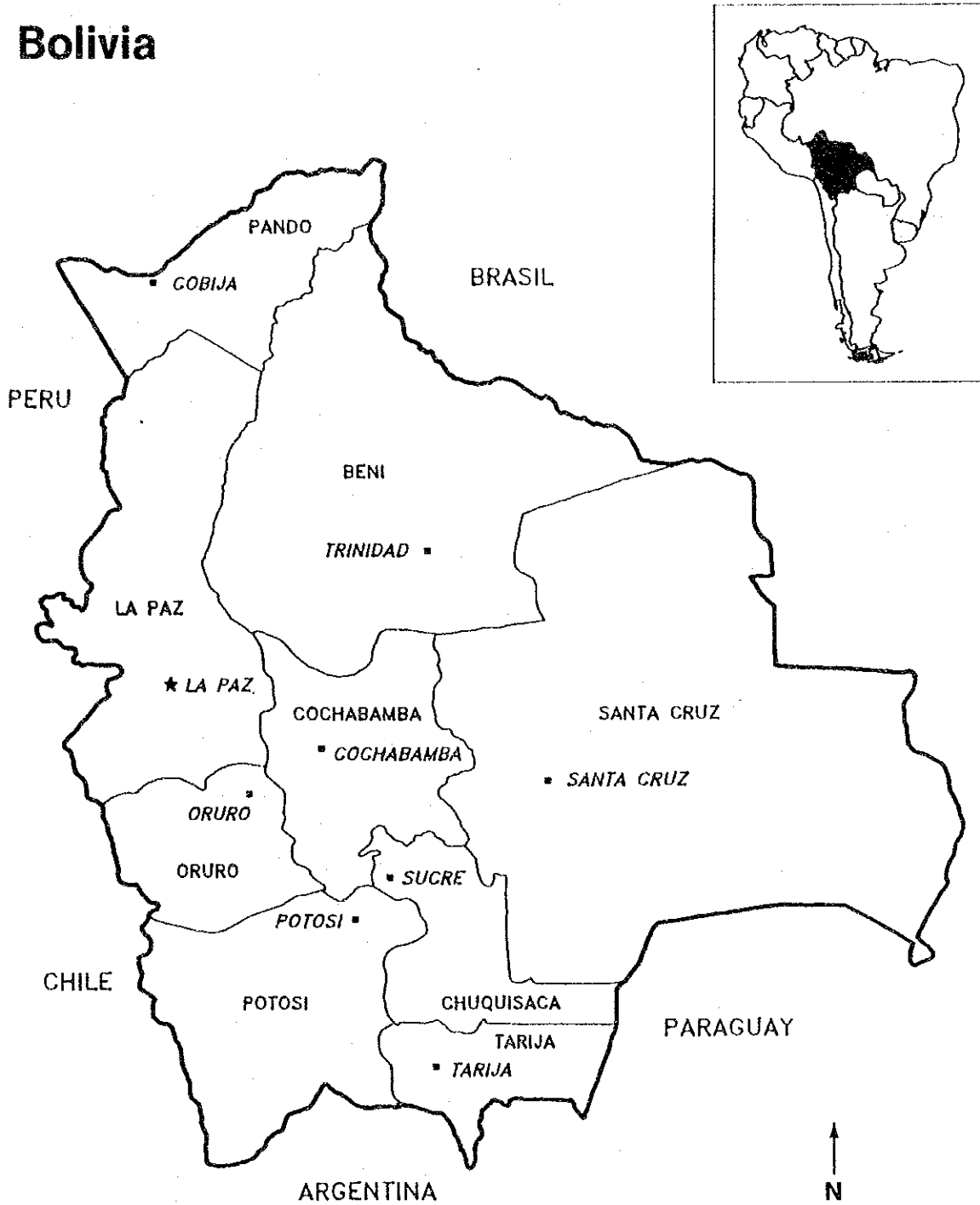
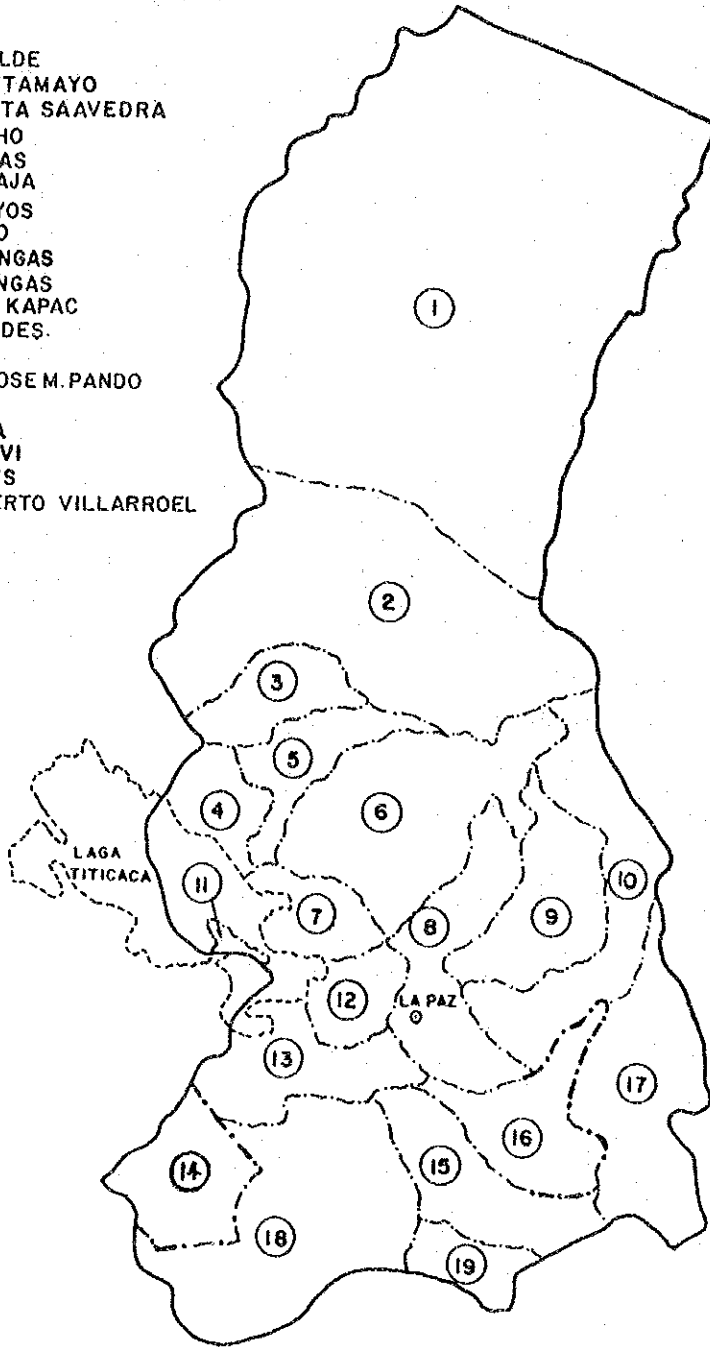


Fig. 1.3.1

Departmental Division in Bolivia

**PROVINCIAS**

- 1. ITURRALDE
- 2. FRANZ TAMAYO
- 3. BAUTISTA SAAVEDRA
- 4. CAMACHO
- 5. MUÑECAS
- 6. LARECAJA
- 7. OMASUYOS
- 8. MURILLO
- 9. NOR YUNGAS
- 10. SUD YUNGAS
- 11. MANCO KAPAC
- 12. LOS ANDES
- 13. INGAVI
- 14. GRAL. JOSE M. PANDO
- 15. AROMA
- 16. LOAYZA
- 17. INQUISIVI
- 18. PACAJES
- 19. GUALBERTO VILLARROEL



Source: Ref. B1

Fig. 1.3.2 Provinces in the Department of La Paz

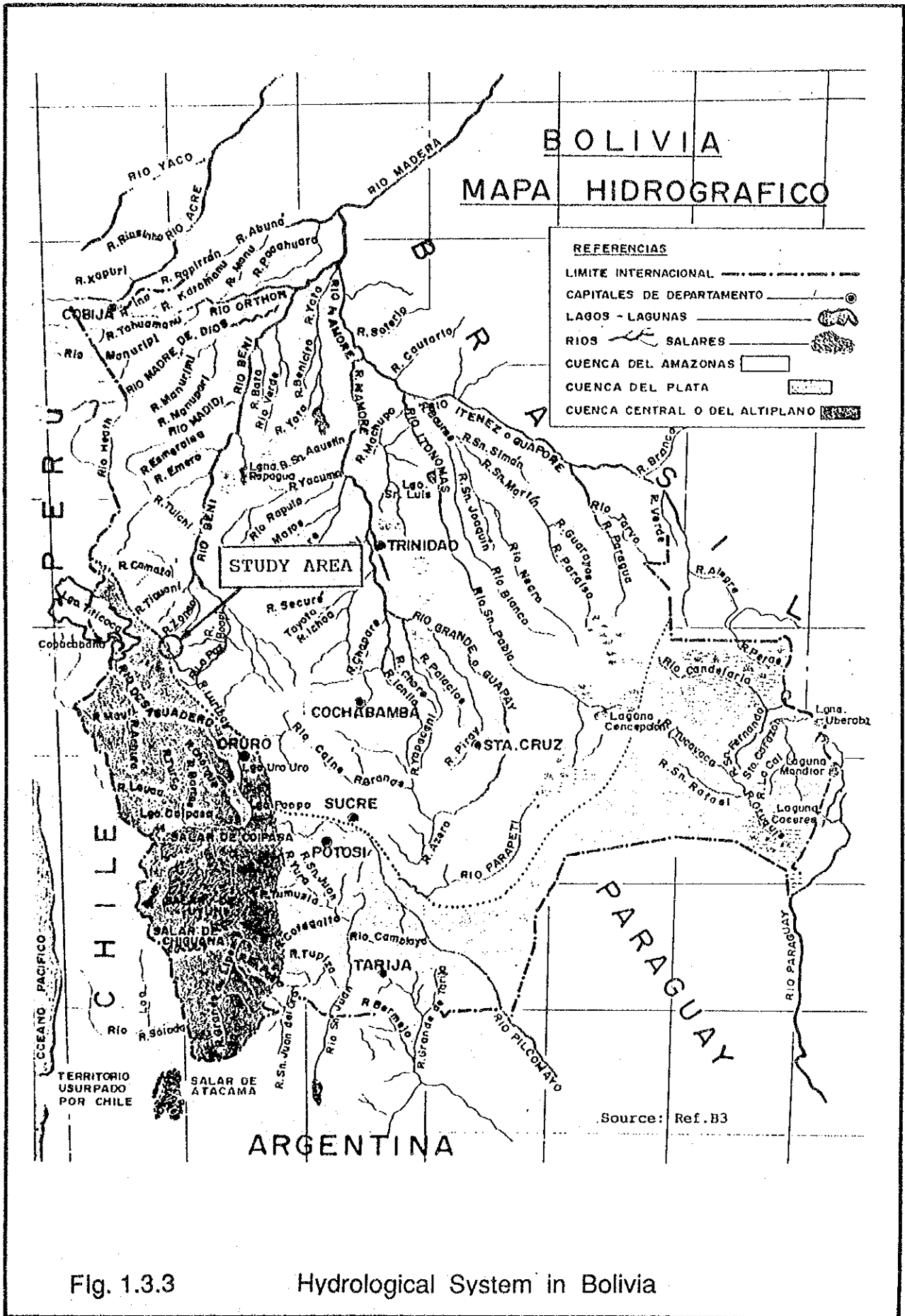


Fig. 1.3.3

Hydrological System in Bolivia

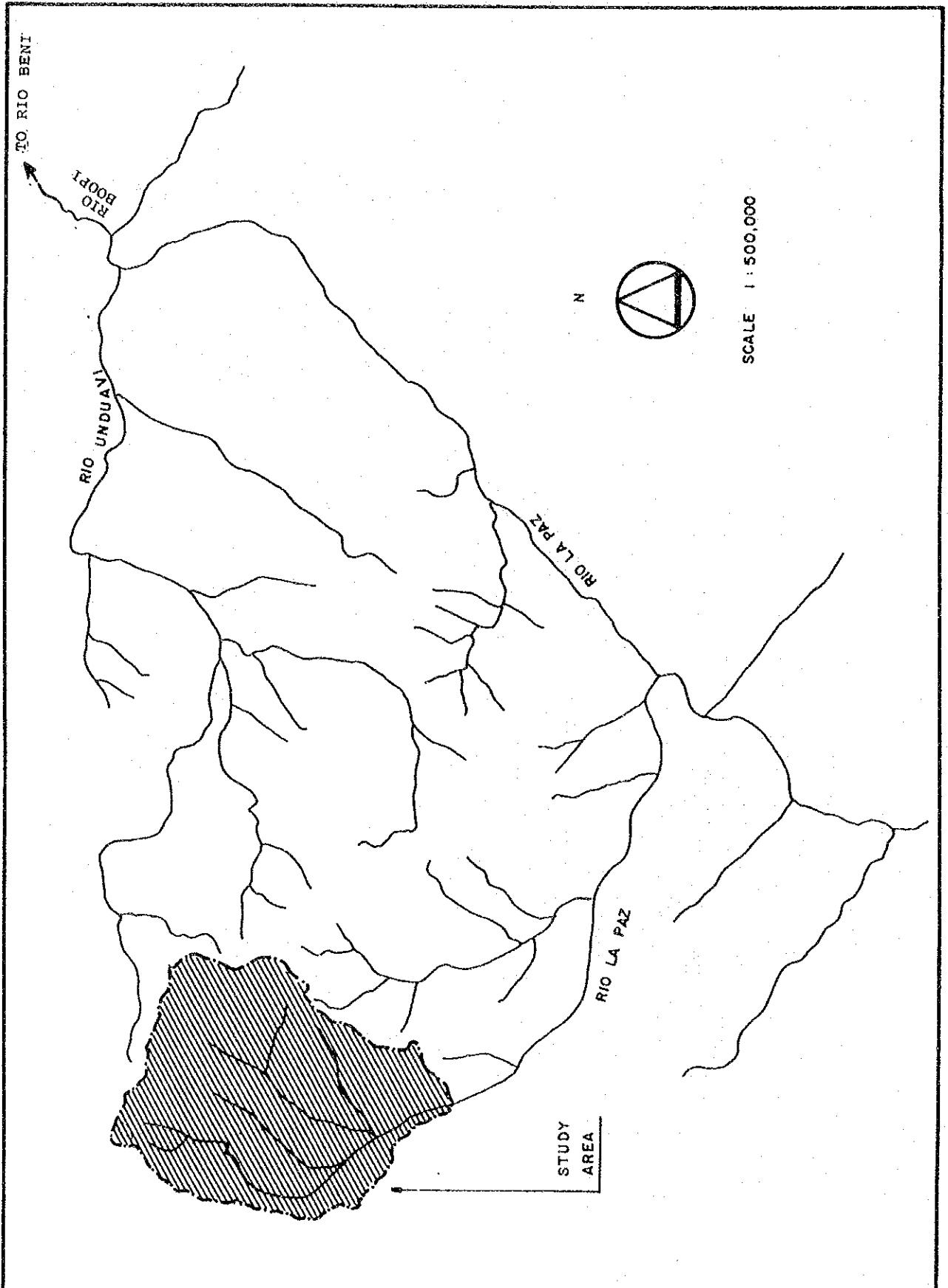


Fig. 1.3.4 River Courses Around the Study Area

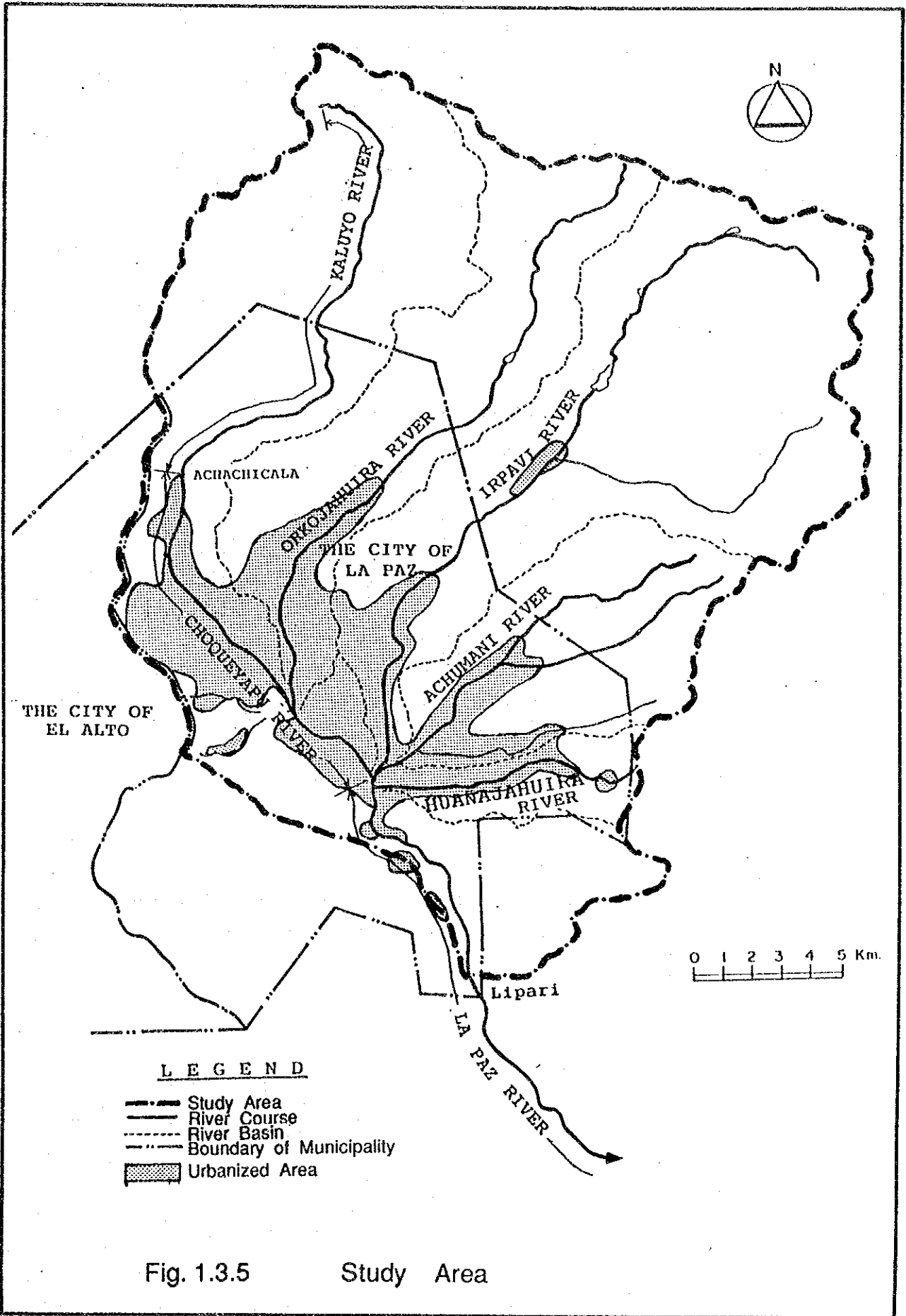


Fig. 1.3.5 Study Area

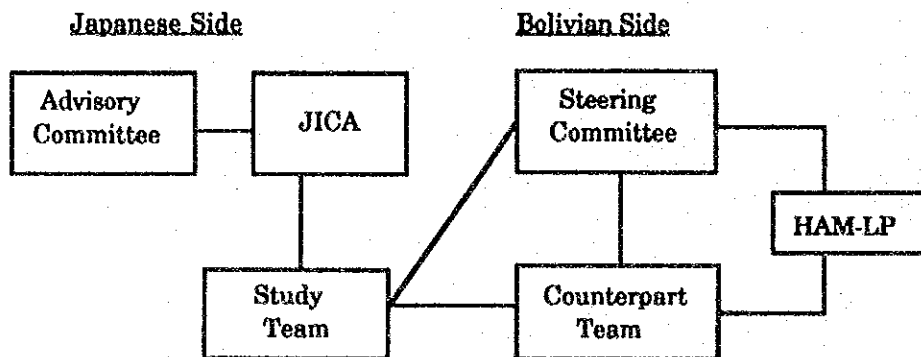
The study area covers most of the administrative area of the City of La Paz and a large area composing upstream catchments of the Choqueyapu, the Orkojahaira, and the Irpavi Rivers.

The Choqueyapu (or the La Paz) River, in fact, changes its name as shown in Fig. 1.3.5. In the present Study, however, the stretches of the Kaluyo, the Choqueyapu, and the La Paz Rivers within the study area will be called by the unified name "the Choqueyapu River".

## 1.4 STUDY ORGANIZATION

### 1.4.1 General Organization

The General organization for the Study is as shown below.



Note : JICA: Japan International Cooperation Agency.

HAM-LP: The Municipality of La Paz.

### 1.4.2 Japanese Organization

The Japanese Organization consists of the Study Team under the JICA headquarters and the Advisory Committee for the JICA headquarters.

The members of the Study Team are as follows:

<b>Name</b>	<b>Field in Charge</b>
Akira Uchida	Team Leader
Akira Takechi	Sewerage Planning
Akira Mihara	Sewage Treatment Planning
Tsutomu Kurihara	Water Pollution Analysis
Kenichi Takashima	Water Quality Analysis
Toshio Ago	Water Quality Analysis
Mitsugu Futaka	Environment/Sanitation
Dennis R. Harris	Facilities Design / Construction Planning / Cost Estimation
Tatsuo Tashino	Organization / Economic and Financial Analysis

The members of the Advisory Committee are as follows:

<b>Name</b>	<b>Field in Charge</b>	<b>Present Post</b>
Hitoshi Murakami	Leader	Executive Director, Japan Sewage Works Agency
Hironori Suzawa	Sewage Treatment	Assistant Manager, Planning Section, Construction Department, Sewage Bureau, Kitakyushu City
Eijirou Takashima	Water Pollution Control	Senior Researcher, Water Quality Division, Public Works Research Institute, Ministry of Construction

<b>Yasushi Irie</b>	<b>River Environment</b>	<b>Director of Investigation, Chikugo River Works Office, Kyushu Regional Construction Bureau, Ministry of Construction</b>
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#### **1.4.3 Bolivian Organization**

The Bolivian organization consists of the Counterpart Team, to the JICA Study Team, and the Steering Committee, with the general coordination of the Municipality of La Paz.

The principal members of the Counterpart Team are as follows:

<b><u>Name</u></b>	<b><u>Field in Charge</u></b>	<b><u>Position</u></b>
Joaquín Aguilar A.	Overall Coordination	Director of DICOMAC, HAM-LP
Alberto Yutronic C.	Technical Field	DICOMAC, HAM-LP
Jose Luis Márquez G.	Technical Field	DICOMAC, HAM-LP
Gaston Araoz T.	Development Planning	DICOMAC, HAM-LP
Camille Ponce F.	Economy and Management	DICOMAC, HAM-LP
Javier Marza T.	Main Sewer Interceptor / River Course Protection	DICOMAC, HAM-LP
Eddy Jaén F.	Sewerage Planning	Director of GIP, SAMAPA
Roger Saravia L.	Sewerage Operation and Maintenance	Director of GOM, SAMAPA
Andres Zegada L.	Sewerage Planning / Field Survey	GOM, SAMAPA
Diego Contreras V.	Sewage Planning / Field Survey	GOM, SAMAPA



Jose A. Diaz B.                      Sewage Treatment                      Director of IIS,  
UMSA

Grover Rivera B.                      Sewage Treatment / Water                      IIS, UMSA  
Quality Analysis

Note:    DICOMAC:    Bureau of Control and Management of  
Watershed and Environment

SAMAPA :    Municipal Corporation of Potable Water and  
Sewerage in La Paz

GIP :    Management of Engineering and Project

GOM :    Management of Operation and Maintenance

UMSA :    University of San Andres

IIS :    Institute of Sanitary Engineering

The members of the Steering Committee are as follows:

<u>Name</u>	<u>Position</u>
Oscar Paz R.	Technical Major Official, HAM-LP
Joaquín Aguilar A.	Director of DICOMAC, HAM-LP
Hernando Poppe A.	Director of DINASBA, MAU
Eddy Jaén F.	Director of GIP, SAMAPA

Note :    MAU :    Ministry of Urban Affairs

DINASBA :    National Bureau of Basic Sanitation

***PART (II)***

***BASIC PLAN***

## CHAPTER 2

### EXISTING CONDITIONS

#### 2.1 NATURAL CONDITIONS

##### 2.1.1 Topography and Geology

###### (1) Topography

Bolivian topography is characterized by four zones; mountains, plateau, valleys and plain. Among them, mountains play an important role in the climate, human activities and so on.

The Andes has been formed in the Tertiary geological epoch, and been separated into three parts in Bolivia. They are called, the Western Mountains (Cordillera Occidental), the Central Mountains (Cordillera Central) and the Eastern Mountains (Cordillera Oriental). The plateau called Altiplano has been formed by glacier-fluvial deposits between the Western Mountains and the Central Mountains, and stretches to Lake Titicaca in the north and to the contact point of the Western Mountains and the Lípez Mountains in the south.

The City of La Paz is located in deeply incised valleys near the eastern edge of the Altiplano. The Choqueyapu River originates in the Central Mountains and flows down through the city. The basin of the Choqueyapu River is in the natural depression formed by the past erosion and consists of relatively young valleys. The difference in height between the northern limit (Mt.Charquini) and the southern limit (Lipari district) of the study area is 2,372 meters, and the length of the stretch of the Choqueyapu River is about 44 kilometers. In the northern limit of the basin, there are high mountains belonging to the Central Mountains: Mt.Charquini (5,392 m), Mt.Chacaltaya (5,395 m), Mt.Colini (4,968 m). In the southern limit of the basin, there are mountains and settlements: Mt.Allpacoma (3,910 m), Lipari district (3,020 m). The urbanized area of the City of La Paz extends along the main channel of the Choqueyapu River and major tributaries, i.e., the Orkojahuirra River, the Irpavi River and the Achumani River, and is located between 3,200 m and 3,900 m above sea level. The western limit is the edge of the Altiplano which is roughly the same as the administrative limit of the La Paz municipality, and the eastern limit is the Murillo Mountains. The total catchment area of the basin as shown in Fig.2.1.1 is 535 km<sup>2</sup>.

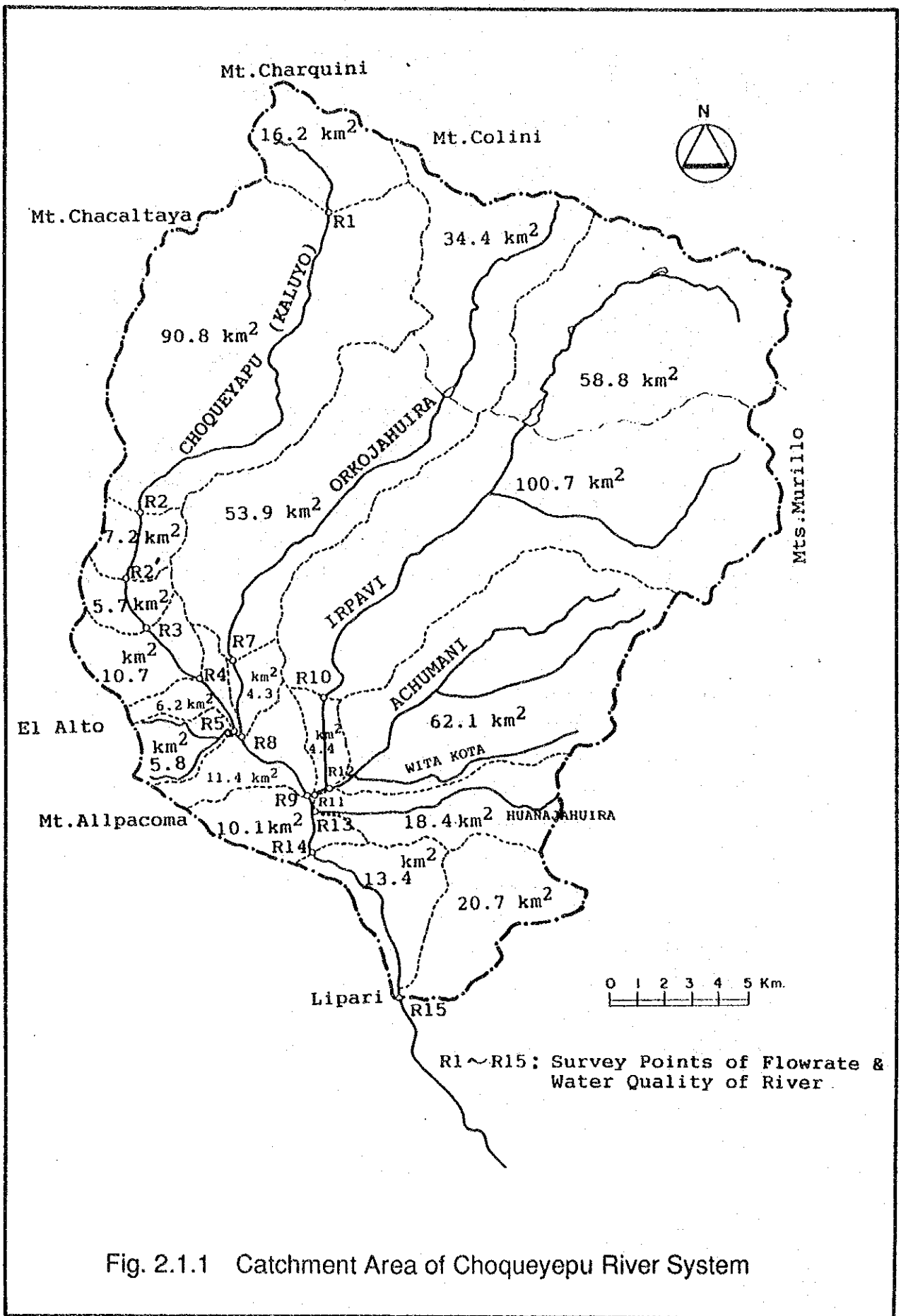


Fig. 2.1.1 Catchment Area of Choqueyapu River System

## **(2) Geology**

According to the existing geological map (Ref.B6) and reports (Refs.B9,B10), geological conditions in the basin of the Choqueyapu River and its vicinity are generally described as follows.

Generally, 30 % of the basin of the Choqueyapu River is composed of the sequence of the Paleozoic with a major area made up of the Silurian. The Paleozoic is composed of sandstone mixed with intercalated mica, quartzite and slate of the marine origin. The other 70 % of the basin is constituted of slightly consolidated clay, silt, sand and gravel of the La Paz Formation, and is also composed of a large quantity of fluvial-glacial deposits distributed in moraines that have formed the surface of the river basin and the terrace of Miraflores and central part of the city.

These groups of strata exposed in the basin of Choqueyapu River are classified in three categories as follows;

- Surface strata corresponding to the deposits originated in the epoch of recent erosion.
- Strata belonging to the sedimentary formation, which have formed the Altiplano and have suffered intensive erosion causing the topographical depression resulting in the La Paz valley.
- The stratum which is the oldest formation called "Zócalo" and is also distributed in the Central Mountains. The Zócalo comprehends the Paleozoic and the red strata of Cretaceous and "Huallaconi" formation attributed to the age of Eocene.

### **1) Zócalo Formation**

The rocks belonging to this formation are exposed in the upper and the northern part of the Choqueyapu River basin and extends widely. This type of rock is also exposed in the Aranjuez Mountains. They suffered tectonic movement with high intensity during the Paleozoic period.

### **2) Altiplano Formation**

The Altiplano is a result of filling the closed system valleys located at the foot of the Central Mountains. The filling process can be classified into two periods of deposition;

- During the Pliocene, the lake sediment of La Paz Formation was deposited.
- During the Pleistocene, there were two glaciation epochs separated by an interglacial epoch that had a lacustrine and fluvial environment.

### 3) Deposits and Landslides of River Basins

The period of excavation of Choqueyapu River basin can be classified into three epochs according to the level of erosion.

- **The First Stage of Erosion:** The erosion of Choqueyapu River reached to the level of 3,700 m in altitude, and landslides formed Pampahasi formation.
- **The Second Stage of Erosion:** In the upper part of the basin, the glacier advance carried lateral moraines that are exposed in the margins of the Kaluyo River, Chuquiaguillo(upper Orkojahaira) River and Irpavi River. After the glacier retreated, landslides occurred and formed the lake deposits in the tributaries of The Kaluyo River near Limampata. In the same manner, water flowing under the moraines deposited fluvial sediment in the valleys, and formed the Miraflores Formation. Debris of land collapse and landslides lie on the Miraflores Formation, one of which is called Laykacota landslide.
- **The Third Stage of Erosion:** The deposits of Altiplano and a little part of their substratum were excavated in this epoch. Land collapse of Achocalla River basin occurred in the form of mudflow spreading to Mallasa, Lipari and Mecapaca. The mudflow dammed up the water of Choqueyapu River at the ravine of Aranjuez and formed the lake deposits of Aranjuez-La Florida. The land collapse of Llojeta and Angani also occurred in the same epoch.

#### 2.1.2 Meteorology

The climate of Bolivia depends on three wind systems and the high mountains of the Andes. The first wind system is a northeasterly trade wind which blows from the Atlantic Ocean and carries a warm and humid atmosphere. The second system is a southeasterly trade wind which blows from Argentine pampas and carries a cold and dry atmosphere. The third system is a southwesterly wind which blows from the Pacific Ocean and carries a cold and dry atmosphere. The first wind system is

dominant in summer when the wind strikes the Andes and brings rainfall, especially much rain around the northeastern foot of the mountains. The second and the third systems are dominant in winter. There is a little rainfall and the atmosphere is dry and cold, especially in the Altiplano area.

The City of La Paz is located in the valleys near the eastern edge of Altiplano where the third wind system is rather dominant; therefore, its climate is rather cool and dry. There are two seasons according to the level of rainfall, because the monthly variation of the precipitation is significant but the variation in the temperature is not. The rainy season is generally defined as the period from December to March and dry season from April to November. The first wind system (northeasterly trade wind) may slightly influence the weather in the rainy season, and meso-scale system around the Titicaca Lake may also influence the weather.

There are some meteorological observation stations in the Choqueyapu River basin and its surroundings, but most of them only observe precipitation. The observation is conducted by various entities: SENAMHI (National Meteorology and Hydrology Agency), ASSANA (Administration of Airports and Aeronautic Navigation Service), HAM, SAMAPA and others. Most observed data are gathered and compiled at the headquarters of SENAMHI. Meteorological data have been obtained in this study for thirteen stations. Their location, observation entities, and items observed are shown in Fig.2.1.2 and Table 2.1.1. Table 2.1.2 shows the monthly variation of the meteorological factors observed at the Central La Paz station, and Table 2.1.3 shows the annual fluctuation of atmospheric pressure, temperature, precipitation and evaporation in the same station.

#### (1) Atmospheric Pressure

There is little annual or monthly fluctuation in the atmospheric pressure. The average annual mean at Central La Paz is 661.9mb.

#### (2) Temperature

Monthly averages of daily mean temperature vary only 3 °C annually, and there is no obvious fluctuation in the past forty years. The coldest month is July in the dry season with a mean daily temperature of 8.5°C and the warmest month is November or December in the rainy season with a mean daily temperature of about 12°C.

#### (3) Precipitation

Average annual precipitation of the City of La Paz is approximately 500mm, but the annual values varied widely in the 1980's.

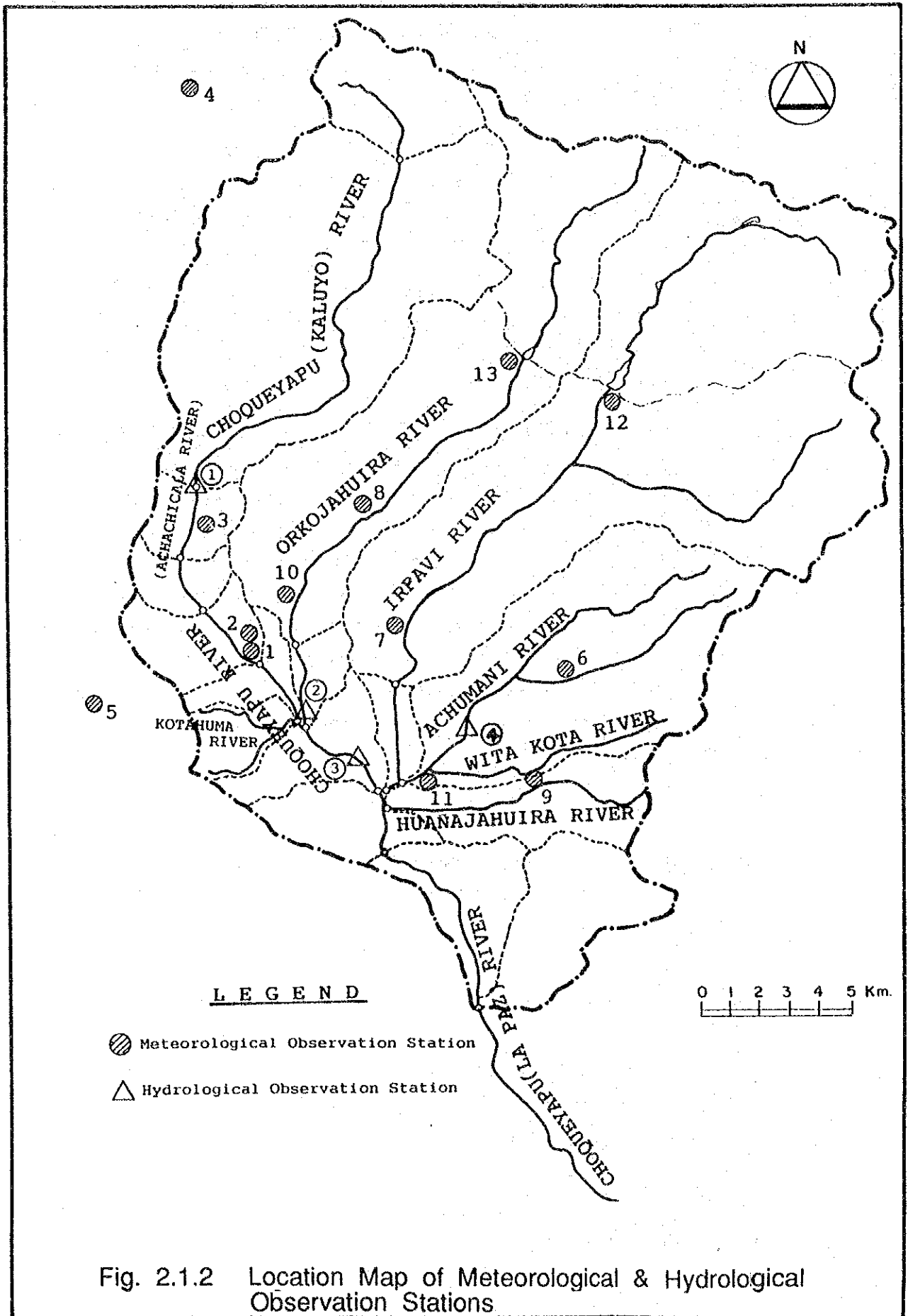


Fig. 2.1.2 Location Map of Meteorological & Hydrological Observation Stations



Table 2.1.1 Meteorological Observation Stations

No	NAME	LOCATION			OBSERVER	ITEMS OF OBTAINED DATA
		LATITUDE	LONGITUDE	ALTITUDE		
1	Central La Paz	16° 29' 45" S	68° 08' 11" W	3,632 m	SENAMHI	AP.T.P.E. W.H.S. etc.
2	San Calixto	16° 29' 43" S	68° 07' 57" W	3,658 m	School of San calixto	AP.T.P.E. W.H
3	Achachicata	16° 28' S	68° 09' W	3,700 m	SENAMHI	P
4	Milluni	16° 20' S	68° 10' W	4,550 m	SENAMHI	P
5	El Alto	16° 31' S	68° 13' W	4,071 m	AASANA	AP.T.P.E. W.H
6	Millipunku	16° 30' 12" S	68° 02' 22" W	3,775 m	HAM-GTZ	P.E
7	Chicani	16° 29' S	68° 05'	3,620 m	SENAMHI	P
8	Chuquiaguillo	16° 27' S	68° 06' W	4,080 m	SENAMHI	P
9	Ovejuyo	16° 32' S	68° 03' W	3,420 m	SENAMHI	P
10	Plaza Villarroel	16° 29' S	68° 07' W	3,660 m	SENAMHI	P
11	Calacoto	16° 34' S	68° 05' W	3,280 m	SENAMHI	P.T
12	Hampaturi	16° 24' 40" S	68° 01' 40" W	4,200 m	SAMAPA	P
13	Incachaca	16° 23' 01" S	68° 02' 30"	4,340 m	SAMAPA	P

Note : AP (Atmospheric Pressure), T(Temperature), P(Precipitation), E(Evaporation), W(Wind Direction, Wind Speed), H(Relative Humidity), S(Solar Radiation)

- The station of Central La Paz was moved to the location (16° 30' 26" S, 68° 07' 16", 3,510 m) on December 19, 1991.

Table 2.1.2 Meteorological Statistics in the City of La Paz

Parameters	Records	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Atmospheric pres. (mb)	'71-88	660.3	660.4	660.7	661.1	661.4	661.6	661.7	661.5	661.4	660.6	660.2	660.2	660.9 *
Mean Daily Temp. (°C)	'45-87	11.3	11.2	11.3	11.1	10.1	8.7	8.5	9.2	10.1	11.3	11.8	12.5	10.6 *
Mean Maximum Temp. (°C)	'45-87	17.6	17.4	17.9	18.2	17.6	16.6	16.4	17.0	17.5	18.7	18.9	18.5	17.7 *
Extreme Maximum Temp. (°C)	'45-87	25.0	24.2	26.1	24.2	23.2	23.0	22.2	24.0	25.2	25.8	26.0	26.0	26.1 **
Mean Minimum Temp. (°C)	'45-87	6.3	6.4	6.2	5.4	3.9	2.3	2.0	2.8	4.1	5.3	6.1	7.8	4.9 *
Extreme Minimum Temp. (°C)	'45-87	1.5	2.3	1.1	-0.6	-2.0	-6.0	-2.8	-5.0	-0.3	0.0	0.5	1.0	-6.0 **
Precipitation (mm)	'45-87	108.4	90.8	65.6	22.9	9.7	3.5	6.2	10.0	31.9	31.0	46.7	83.6	510.3 ***
Maximum Monthly Precipitation. (mm)	'45-87	219.6	169.9	174.2	64.3	37.9	20.0	30.0	61.6	86.6	109.7	113.5	141.8	219.4 **
Minimum Monthly Precipitation (mm)	'45-87	35.9	15.5	15.0	1.0	0.2	0.4	0.1	0.3	2.4	4.8	6.9	16.5	0.1 **
24 hour Maximum Preciptn. (mm/24hr)	'45-87	53.9	42.0	37.7	21.5	14.7	20.0	18.0	27.7	28.7	26.0	32.3	40.8	42.0 **
Relative Humidity (%)	'45-87	67	71	66	57	46	41	43	45	52	53	55	62	55 *
Evaporation (mm/month)	'45-87	124.0	111.8	125.8	119.3	130.2	120.7	124.2	138.0	140.5	164.5	155.7	155.0	1609.7 ***
Monthly Shining Hour (Hr/month)	'83-87	132.3	135.9	160.4	181.8	234.9	241.1	240.4	265.3	233.8	216.9	169.6	195.6	2407.9 ***
Prevalent Wind Direc.-Velocity(kt)	'52-87	SE-2	SE-2	SE-3	SE-2	SE-2	W-2	W-3	SE-3	SE-3	SE-3	SE-2	E-3	SE-2 *
Maximum Velocity and Direction (kt)	'65-87	W-25	WSW-22	NE-24	NW-28	SE-25	NW-30	NW-35	NW-40	NE-36	SE-40	NE-30	SE-30	NW-40 **
Days of Precipitation	'45-87	18	15	13	6	3	1	2	3	7	8	10	14	100 ***
Solar radiation (cal/cm/day)	'83-87	368	408	385	379	401	401	399	462	469	468	454	440	5034 *

Source: Ref. 87

Note:

\* Annual Average

\*\* Extreme Value

\*\*\* Total

Table 2.1.3 Long Term Fluctuation of the Weather

OBSERVING STATION : CENTRAL LA PAZ

Year	ITEMS			
	Ap (mb)	T (°C)	P (mm/year)	E (mm/day)
'52	-	-	402.5	-
'53	-	-	395.9	-
'54	-	10.7	466.6	-
'55	-	-	464.7	-
'56	-	-	329.2	-
'57	-	10.9	479.7	-
'58	-	11.8	372.5	-
'59	-	-	487.1	-
'60	-	11.5	660.7	-
'61	-	11.5	506.3	-
'62	-	10.1	431.0	-
'63	-	10.9	520.8	-
'64	-	11.5	522.4	-
'65	-	11.6	585.2	-
'66	-	11.9	388.0	-
'67	-	11.4	381.8	-
'68	-	10.8	524.9	-
'69	-	12.1	362.8	-
'70	-	11.5	613.8	-
'71	659.2	10.9	455.1	-
'72	659.8	11.6	493.8	-
'73	661.8	11.9	544.4	-
'74	661.9	10.8	627.8	-
'75	662.1	10.9	622.3	4.4
'76	660.8	11.0	533.7	4.9
'77	659.8	11.3	702.8	4.9
'78	659.8	11.3	551.6	4.7
'79	659.5	11.7	752.8	4.5
'80	660.1	12.0	470.1	4.5
'81	661.1	11.4	623.3	4.3
'82	661.5	11.8	467.5	4.5
'83	661.4	12.7	386.9	4.8
'84	661.0	10.8	798.1	4.0
'85	661.1	11.3	662.1	4.1
'86	661.4	11.0	673.5	4.3
'87	661.1	11.8	472.0	4.8
'88	660.6	11.3	628.4	4.6
'89	661.0	10.7	355.4	4.6
'90	661.7	11.0	631.7	-
'91	661.7	10.8	444.3	-
Average	660.9	11.3	566.6	4.5
Max.	662.1	12.7	798.1	4.9
Min.	659.2	10.1	329.2	4.0

AP : Atmospheric Pressure  
(Mean)

T : Temperature  
(Daily Mean)

P : Annual Precipitation

E : Evaporation  
(Daily Mean)

Table 2.1.3-2/2/93

Fig.2.1.3 shows the annual fluctuation of average monthly precipitation observed at the eight stations. From this information, Calacoto and Chicani, located in the southern part of the city, seem to have much more rain than the Altiplano (El Alto and Milluni) or Central La Paz. Chuquiaguillo and Achachicala, located in the upper part of the Choqueyapu river, also seem to have much more rain than Central La Paz. Though the quantity of rainfall varies with the location, the patterns of monthly precipitation curves in Fig.2.1.3 are similar. More than a half of the total volume of rainfall concentrates during the three months: December, January and February.

According to Ref. B2 and B7, the maximum values at the Central La Paz in the past forty years are as follows:

- Maximum annual precipitation : 798 mm (1984)
- Maximum monthly precipitation : 220 mm (1984.1)
- Maximum 24-hour precipitation : 54 mm (1988.1.31)

Rainfall tends to concentrate in a few hours in the City of La Paz and its surroundings, and the duration of heavy rain is estimated to be 2 to 3 hours. Ref. B2 has proposed the following equation for a probable extreme rainfall.

$$R(t,T) = 16.1 * t^{0.235} * ( 1 + 0.5093 * \log T )$$

where,

- R(t,T) : Probable extreme rainfall (mm)
- t : Duration (hour)
- T : Return period (year)

#### (4) Evaporation

Monthly and yearly fluctuations of evaporation are small. Annual total evaporation is about 1,600 mm/year, that is approximately three times as much as the annual precipitation.

#### (5) Wind

In La Paz, southeasterly winds, that may blow up along the La Paz valley, are prevalent. In June and July, westerly winds are dominant.

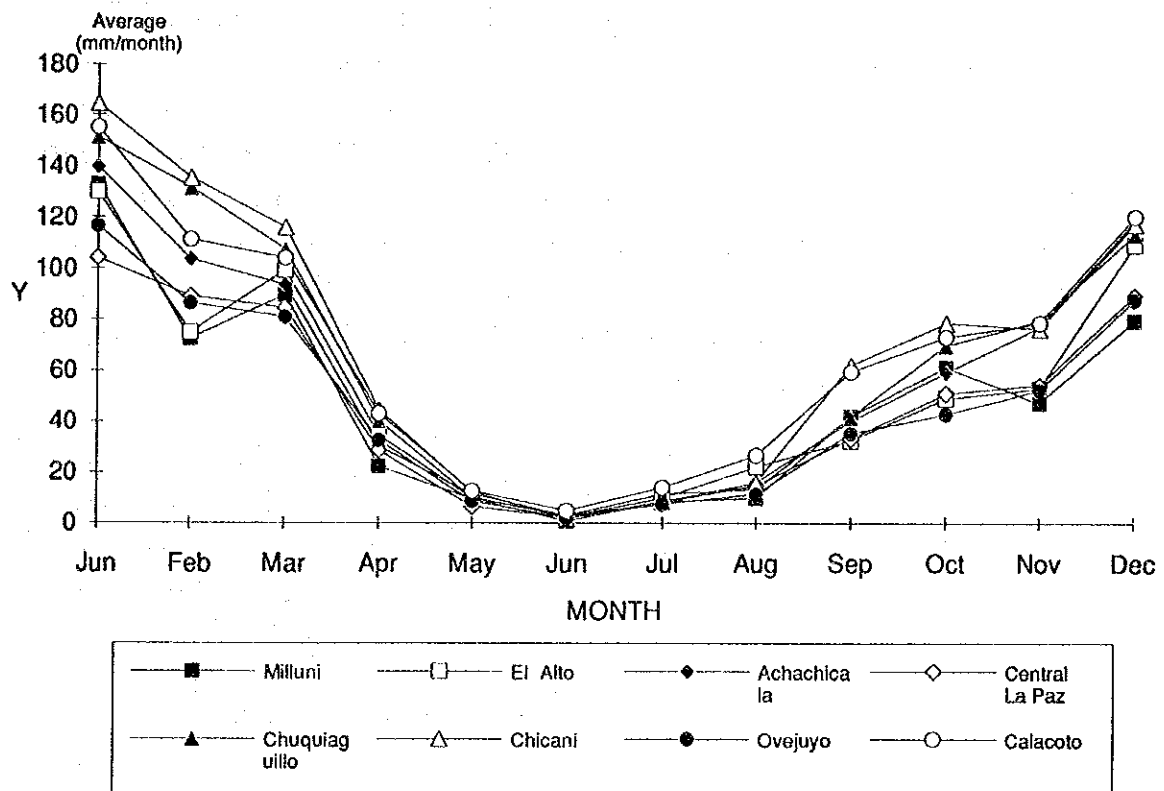


Fig. 2.1.3 Monthly Precipitation (Average)

### 2.1.3 Hydrology

Bolivia is generally classified into two hydrological zones, one the western zone and the other the eastern zone. In the western zone, hydrological systems of rivers and lakes are closed and there is no outflow to the sea. The water is born in the Andes and disappears into the Altiplano. River lengths are rather short and volumes of flow are relatively small. In the eastern zone, rivers are long and have large volumes of flow. The eastern zone is divided into two hydrological systems, one is the system of the Amazon and the other is the system of La Plata.

The City of La Paz is located on the boundary of the western and the eastern hydrological zones. The Kaluyo River is born in the Central Mountains and flows to the south, and changes its name to the Choqueyapu River when it enters into the center of the city. The Choqueyapu River flows down through the city joining with the tributaries (the Orkojahuirra River, the Irpavi River) and changes its name to the La Paz River when flows out the center of the city. The La Paz River flows across the Central Mountains in the province of Sud Yungas, and finally join the Amazon. On the other hand, the City of El Alto located in the Altiplano is in a hydrologically closed system where streams finally flow into Lake Titicaca.

There are some observation stations of river flow in the Choqueyapu River basin. The observations are conducted by SENAMHI, HAM and others, but most of observed data are kept separately without processing. Observed data of flow rate have been obtained in this study for four stations. The location of the stations are shown in Table 2.1.4 and Fig.2.1.2.

The flow data observed for a decade have been obtained for three stations, and monthly mean flow rates are shown in Table 2.1.5. They are also shown in Fig. 2.1.4 with that of the Achumani station where the data were available only for two years. The largest monthly average flow rate was observed in January: Achachicala(1.8 m<sup>3</sup>/sec), Holguin(2.0 m<sup>3</sup>/sec), Obrajes(13.8 m<sup>3</sup>/sec). The smallest monthly average flowrate was observed in July, August and September: Achachicala(0.4 m<sup>3</sup>/sec), Olguin(0.3 m<sup>3</sup>), Obrajes(2.3 m<sup>3</sup>). Extreme values are as follows;

Achachicala : 12.5 m<sup>3</sup>/sec (1982.3.5)  
Holguin : 13.2 m<sup>3</sup>/sec (1990.5.16)  
Obrajes : 63.5 m<sup>3</sup>/sec (1990.6.10)

Extreme values were not always observed simultaneously. They seem to occur during a short period by very local rainfall.

Table 2.1.4 Observation Stations of River Flow rate

No	NAME	LOCATION			RIVER BASIN	OBSERVER
		LATITUDE	LONGTUDE	ALTITUDE		
1	Achachicala	16° 27' 47" S	68° 10' 40" W	3,960 m	Choqueyapu (Achachicala)	SENAMHI
2	Holguin	16° 31' 02" S	68° 06' 46" W	3,380 m	orkojahulra	SENAMHI
3	Obrajes	16° 31' 40" S	68° 05' 50" W	3,260 m	Choqueyapu	SENAMHI
4	Achumani	16° 30' 30" S	68° 04' 21" W	3,380 m	Achumani	HAM

Table 2.1.5 River Flow Rate (Monthly Mean)

ITEM : FLOW RATE (Monthly Mean) (m3/sec)

Station	Value	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
ACHACHICALA (1980.2 --> 1992.3)	Ave.	1.81	1.67	1.92	1.14	0.57	0.42	0.41	0.41	0.47	0.67	0.90	1.14	0.98
	Max.	3.06	2.56	4.24	2.31	1.05	0.73	0.77	0.68	0.74	1.06	1.76	3.12	1.52
	Min.	0.82	0.80	0.73	0.48	0.21	0.09	0.12	0.15	0.22	0.31	0.43	0.52	0.47
HOLGUIN (1981.10 --> 1991.8)	Ave.	2.02	1.72	0.99	1.00	0.76	0.51	0.40	0.33	0.33	0.53	0.50	0.93	0.79
	Max.	3.09	3.84	2.26	3.07	1.77	1.52	0.61	0.51	0.49	0.88	0.68	1.93	1.05
	Min.	0.44	0.49	0.57	0.36	0.31	0.12	0.23	0.20	0.18	0.23	0.18	0.27	0.41
OBRAJES (1981.2 --> 1991.8)	Ave.	13.78	11.97	8.35	4.22	3.57	3.32	2.27	2.28	2.36	3.23	3.48	7.49	6.36
	Max.	22.70	32.20	17.70	5.85	9.39	9.52	3.36	4.06	3.53	4.46	7.36	16.50	8.31
	Min.	5.08	4.24	4.80	2.50	1.52	1.42	1.34	1.24	1.04	1.70	1.66	2.45	4.14

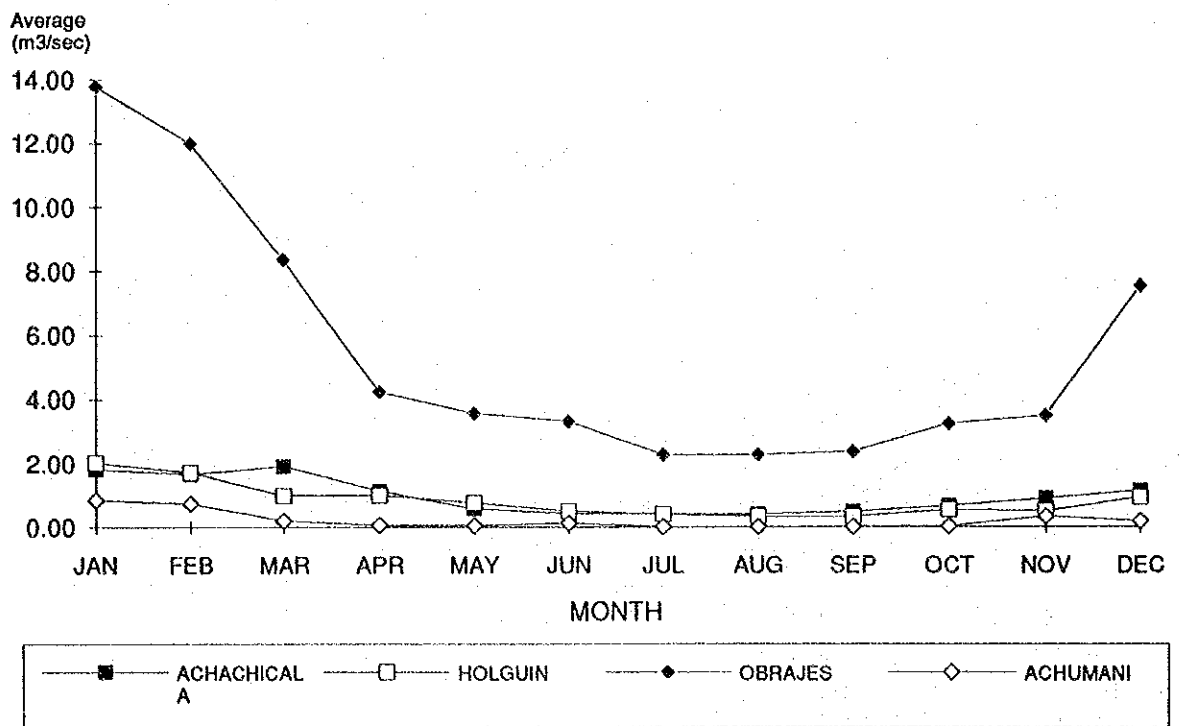


Fig. 2.1.4 River Flowrate (Monthly Mean)



Though the flow rates themselves vary, the patterns of monthly variation of flow rate for four stations are similar.

As for floods, Ref. B2 has proposed a rational equation for the Choqueyapu River at the Bueno bridge as follows:

$$Q(t,T) = 0.36 * R * S / 3.6$$

where,

- Q(t,T) : Extreme discharge (m<sup>3</sup>/sec)
- R : Probable extreme rainfall intensity (mm/hr.)
- S : Catchment Area (km<sup>2</sup>)

Sub-surface flows seem to contribute to the water balance of the river systems. However, according to Ref. B11, there is little groundwater outflow from the El Alto zone. The outflow from the whole of the El Alto zone in the dry season is about 0.5 lit/sec at most.

## 2.2 SOCIAL AND ECONOMIC CONDITIONS

### 2.2.1 Population

The national census in Bolivia was conducted in 1950, 1976 and 1992. Since the last one was just conducted in June 1992, the available results are partial and tentative. INE also made a check investigation of the population in 1988. Table 2.2.1 shows historical changes in the population of the entire country and the metropolitan area, as extracted from the results of these censuses and the 1988 investigation. Table 2.2.2 shows the population of the department capitals in Bolivia in 1976 and 1992 published in newspapers as tentative results of the 1992 census.

**Table 2.2.1 Historical Change in the Population of the Country and the Metropolitan Area**

	Population (persons)				Annual Average Growth Rate (%)	
	1950*	1976**	1988***	1992****	1976-1988	1976-1992
(1) National Total	3,023,031	4,613,486	6,405,100	-	2.89	-
(2) Metropolitan Area	321,073	635,283	976,793	1,103,714	3.65	3.51
(3) City of La Pza	-	538,598	669,399	710,940	1.83	1.75
(4) City of El Alto	-	96,685	307,394	392,774	10.12	9.16
(2)/(1) (%)	10.62	13.77	15.25	-		
(3)/(2) (%)	-	84.78	68.53	64.41		
(4)/(2) (%)	-	15.22	31.47	35.59		

Source : Ref. A2(\*), Ref. A16(\*\*), Ref. A1(\*\*\*), and Tentative result of the 1992 census published in newspapers in June, 1992 (\*\*\*\*)

**Table 2.2.2 Population of the Department Capitals**

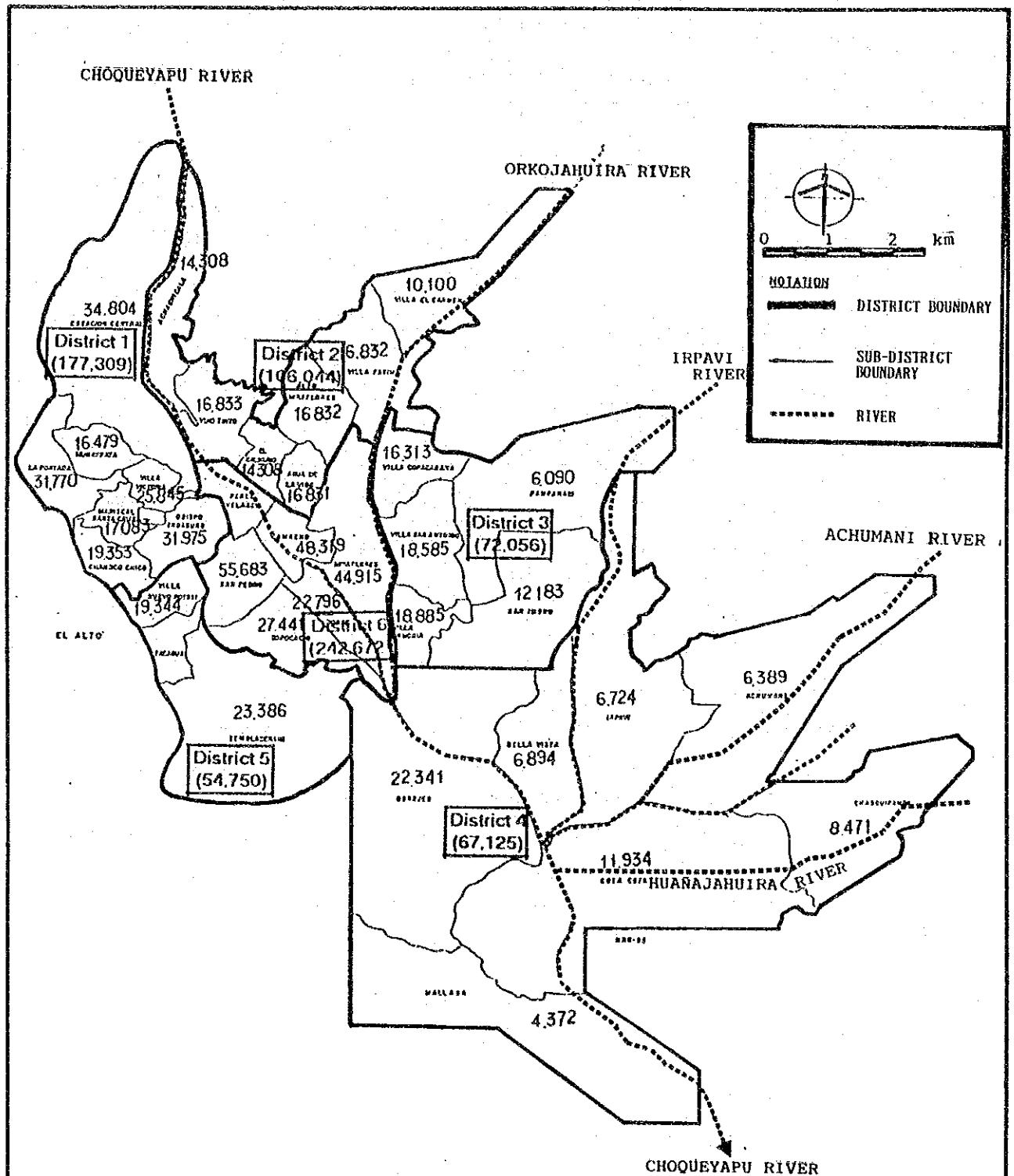
Department Capital	Population (persons)			Annual Average
	1992	1976	Difference	Growth Rate (%)
La Paz	710,940	539,828	171,112	1.76
Snta Cruz	692,039	254,682	437,357	6.38
Cochabamba	404,102	204,684	199,418	4.34
Oruro	182,916	124,213	58,703	2.47
Sucre	130,083	63,625	66,458	4.56
Potosi	112,004	77,397	34,607	2.36
Tarija	87,740	38,916	48,824	5.19
Trinidad	56,846	27,487	29,359	4.63
Cobija	9,676	3,650	6,026	6.22
<b>Total</b>	<b>2,386,346</b>	<b>1,334,482</b>	<b>1,051,864</b>	<b>3.70</b>

Source: Ref. A2(\*), Ref. A16(\*\*), Ref. A1(\*\*\*), and Tentative result of the 1992 census published in newspapers in June, 1992

The annual average population growth in the City of La Paz during the last 16 years shows a moderate rate at around 1.8%, while this rate in the metropolitan area including El Alto is about 3.5%. This indicates that the City of La Paz is approaching to the limit of its development potential because only a little land is available for new residential development, while El Alto enables large-scale development of residential areas at a relatively low cost. Table 2.2.2 shows the high population growth rates in the department capitals other than La Paz, especially, the City of Santa Cruz which has grown to the extent that its population is comparable to that of La Paz.

In general, the population growth of the metropolitan area, particularly the City of La Paz is ceasing and the growth is dispersing among other department capitals.

Information on the population distribution within the City of La Paz in 1992 was obtained from the Sanitation Unit, La Paz (Ref. I5). In this information, the City is divided into 6 districts and each district is divided into several sub-districts. Location of each district and the population of each sub-district are shown in Fig. 2.2.1. This gives a total population of the city as about 720,000 which is very close to the tentative result of the 1992 census.



(numbers in the figure indicate the population)

Fig. 2.2.1 Population by the Sanitation Districts in La Paz

The area covered by the above information is almost 100 % contained within the study area, except a small part of District 4 where the population is estimated at less than 200. The study area further covers upstream areas of the Districts along each river. Since no official information was available, the population in such upstream areas was estimated by conducting a field interview in each area. The present population thus obtained for the study area is shown in Table 2.2.3.

**Table 2.2.3 Estimated Present Population In the Study Area**

Zone /Area	District*/basin	Unit Population	Total Population
Central Zone	District 1	177,309	
	District 2	106,044	
	District 5****	50,000	
	District 6	242,672	
	District 3***	40,000	
	sub total		616,025
South Zone	District 3***	32,056	
	District 4	67,125	
	District 5****	4,750	
	Sub total		103,931
Total			719,956
Upstream areas**	Choqueyapu	800	
	Irpavi	500	
	Huañajahuira	250	
	Sub total		1,550
Grand Total			721,506

Note: \* Ref. 15

\*\* Based on the interview surveys in each area.

\*\*\*,\*\*\*\* The population in these districts are distributed between the Central and the South zones considering their catchment boundaries.

In the table, the estimated population by zones, i.e., the Central zone and the South zone, is also shown. The present population in the study area is as summarized follows:

La Paz city	Central zone	616,025
	South zone	103,931
	Total	719,956
Upstream areas		1,550
Grand Total for the Study Area		721,506

### **2.2.2 Land Use**

Summary of the existing land use in the study area is shown in Fig. 2.2.2.

A large part of the urbanized area in the City of La Paz is residential, particularly in the South zone.

A densely developed commercial area is located at the very center of the Central zone above the covered section of the Choqueyapu River. The commercial center is surrounded by commercial-residential-mixed areas which stretch up the slope towards the City of El Alto.

A factory-concentrated area lies a little upstream of the commercial center along the Choqueyapu River. There is another industrial area on the right bank of the Orkojahuirra river in the northern part of the Central zone.

Forests are scarce in the study area, but there are significant afforestations along the border between El Alto and the Central zone, and at the outskirts of the South zone on the both sides of the Choqueyapu River.

Relatively large farmlands within the study area are located upstream from the urbanized area along the Choqueyapu and the Irpavi Rivers. In addition, there are smaller farmlands in the South zone in the Achumani-Huañajahuira basin and near Lipari along the Choqueyapu River. From Lipari downwards, a number of farmlands are scattered along the lower reach of the Choqueyapu River.

In the upper basins of the Choqueyapu and the Irpavi Rivers, there are communities of stockbreeders each with a population of 100 to 500.

There are two abandoned mines and one lime extraction site in the upper basin of the Choqueyapu River, and one active mine for zinc, lead and silver in the upper basin of the Irpavi River.

### **2.2.3 Economic Profile of La Paz**

#### **(1) GDP and GRDP**

Gross domestic product (GDP) of Bolivia recorded continuously negative growth from 1981 to 1986, as shown in Table 2.2.4. During the period from 1982 to 1985, Bolivia experienced serious hyper inflation, and in August 1985 the government faced an economy that almost reached the point of chaos. The new government moved swiftly and decisively, and promulgated a new economic policy. The new policy succeeded

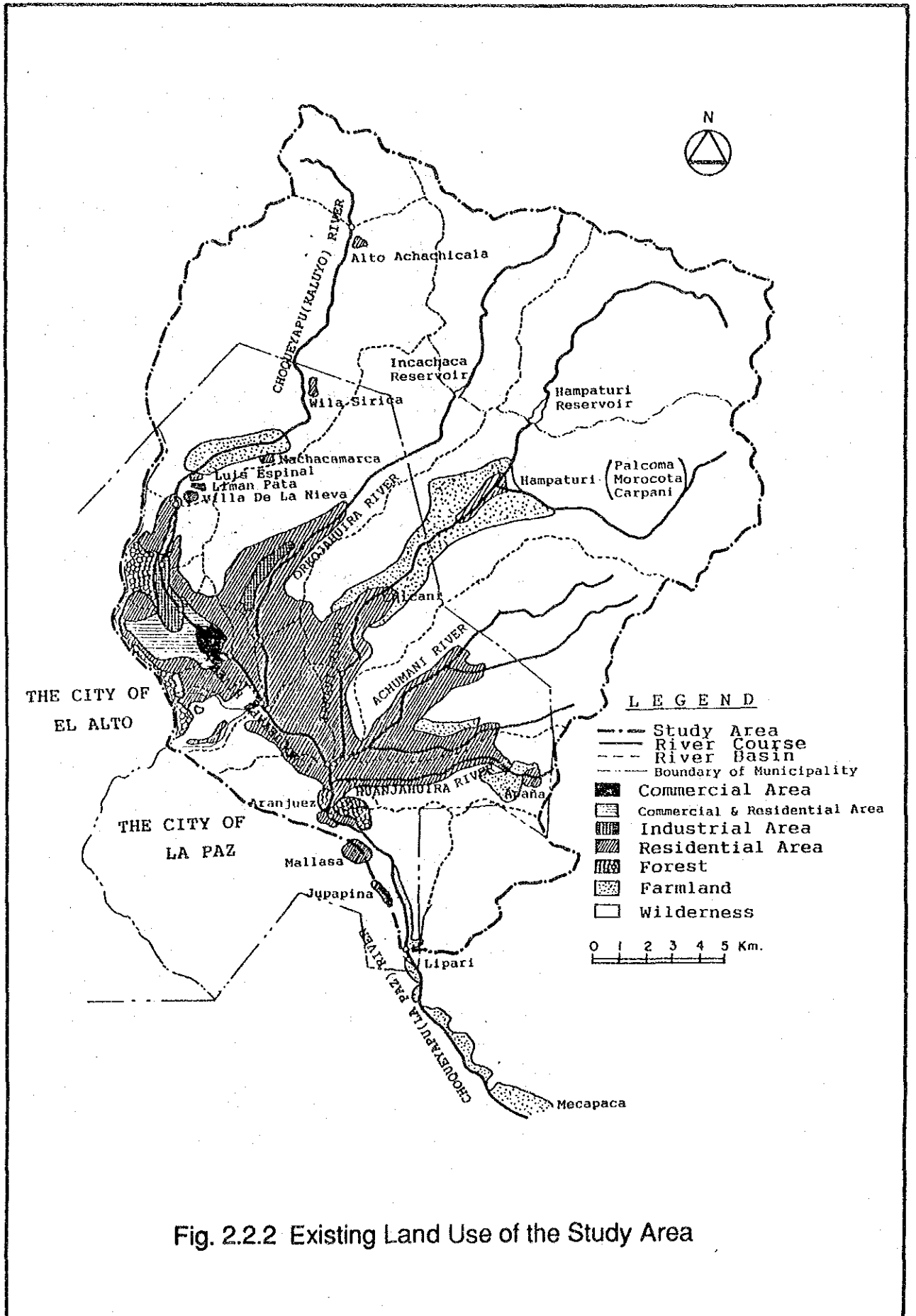


Fig. 2.2.2 Existing Land Use of the Study Area

Table 2.2.4 Gross Domestic Product at 1980 Constant Prices: 1980-1991

(Unit: Bolivianos at 1980 Constant Prices\*\*)

Economic Sector	1980	1981	1982	1983	1984	1985
1. Agruculture	22,563	22,354	23,900	19,788	23,553	25,372
- Crop	15,727	17,257	18,408	14,596	18,735	20,244
- Livestock	5,893	4,216	4,850	4,815	4,412	4,600
- Forestry, fishery, etc.	943	881	642	377	406	528
2. Extraction	19,407	20,139	19,526	18,112	15,902	14,211
- Crude oil & natural gas	6,728	7,072	7,476	7,176	7,015	6,973
- Mining & quarring	12,679	13,067	12,050	10,936	8,887	7,238
3. Manufacturing	17,974	16,581	14,531	14,558	14,707	13,483
4. Electricity Gas & Water Supply	806	907	930	951	1,025	986
5. Construction	4,521	4,058	3,698	3,714	3,518	3,389
6. Trading	13,261	14,418	13,464	15,983	13,243	13,316
7. Transportation & Communication	7,321	8,174	7,799	7,840	8,471	8,873
8. Other Services	20,865	20,506	19,987	18,548	18,452	18,631
9. Public Services	12,940	13,193	13,749	13,312	12,777	12,041
GDP at Factor Price	119,658	120,330	117,584	112,806	111,648	110,302
Indirect Taxes	3,288	3,753	1,090	572	1,048	1,306
GDP at Market Price	122,946	124,083	118,674	113,378	112,696	111,608
Economic Sector	1986	1987*	1988*	1989*	1990*	1991*
1. Agruculture	24,478	25,337	25,951	25,604	25,097	26,911
- Crop	19,305	20,064	20,424	19,862	19,099	20,773
- Livestock	4,603	4,694	4,978	5,178	5,411	5,546
- Forestry, fishery, etc.	570	579	549	564	587	592
2. Extraction	12,166	12,351	14,806	17,048	18,340	19,308
- Crude oil & natural gas	6,847	6,950	7,189	7,503	7,780	7,950
- Mining & quarring	5,319	5,401	7,617	9,545	10,560	11,358
3. Manufacturing	13,742	14,087	14,852	15,374	16,250	17,333
4. Electricity Gas & Water Supply	1,059	996	1,051	1,105	1,165	1,241
5. Construction	2,662	2,637	3,019	3,218	3,297	3,364
6. Trading	14,768	15,974	15,350	15,386	15,617	16,457
7. Transportation & Communication	9,346	9,825	9,868	10,074	10,361	10,771
8. Other Services	18,508	17,811	18,029	18,265	18,853	18,743
9. Public Services	10,118	10,365	10,210	10,336	10,809	11,026
GDP at Factor Price	106,847	109,383	113,136	116,410	119,789	125,154
Indirect Taxes	1,981	2,276	1,827	1,811	1,527	1,187
GDP at Market Price	108,828	111,659	114,963	118,221	121,316	126,341

Source: Ref.A11

Note: \* Preliminary estimates

\*\* Million Pesos Bolivianos before 1987's denomination



quickly in restoring macro economic stability. However, the recovery of the economy has been slow. In 1987, GDP grew for the first time in six years, although at only 2.6%, based on 1980 prices. Thereafter, it grew by 3.0% in 1988, 2.8% in 1989, 2.6% in 1990 and 4.1% in 1991.

In spite of the fact that GDP has grown slowly but steadily, GDP per capita did not grow as expected even after the recession. As shown in Table 2.2.5, GDP per capita recorded Bs.1,472 at current prices in 1986, which was equivalent to US\$765. In 1991, however, it was US\$832 or 8.8% more than that in 1986, although its nominal value was Bs.2,775 at current prices. This slow growth of GDP per capita was attributed to the high rate of population growth.

Gross regional domestic product (GRDP) is not available specifically for the study area. The GRDP in La Paz Department is used to understand the global economic situation in the study area. Table 2.2.6 shows GRDP by major economic sectors from 1980 to 1986 using 1980 constant prices. GRDP data after the recession period were not available. Since the Department was also under the recession, GRDP in the table constantly decreased in proportion to national GDP. GRDP during the period accounted for less than 30% of the total country GDP. Population in La Paz Department, however, accounted for more than 30% of the country continuously. Therefore, GRDP per capita was lower than the national average.

## (2) Agriculture and Livestock

The agricultural sector, absorbing more than half of the country's labour force, is one of the most important industries. However, the GDP share of the sector is only about 20%. This might be because the native people, who accounts for more than half of the total population and most of whom lives in high land area called "altiplano", carry on traditional and labour intensive subsistence farms and because their economic activities are not completely included in the national accounts.

La Paz Department is located in high land areas, so it is not suitable for certain types of crop cultivation. Nevertheless, some crops such as coffee, tea, cocoa, orange and banana(platano) are cultivated in the Department, as shown in Table 2.2.7. The Department is the main producer of cash crops such as coffee, tea and cocoa. On the other hand, the staple foods in the department, potatoes and wheat, are not produced sufficiently for covering self-consumption. Their production system is primitive and the productivity is very low. In the study area particularly, fertilizer might be used to cultivate potatoes only, and not be used for other crops. Within the river basin of the study area, there are no large-scale cultivated areas to account for substantial

Table 2.2.5 GDP Per Capita at Current Prices: 1986-1991

Item	1986	1987	1988	1989	1990	1991*
1. GDP at Market Price at Current Prices *2 (Bs. Million)	8,924	10,179	12,301	14,749	17,542	21,690
2. Projected Population (1000)	6,064	6,232	6,405	6,583	6,765	6,953
3. Official Exchange Rate *3 (Bs./US\$)	1.92	2.21	2.47	2.98	3.40	3.75
4. GDP per Capita						
- Bolivianos	1,472	1,633	1,920	2,241	2,593	3,120
- US\$ equivalent	765	739	778	752	763	832

Source: Ref.A17 and J5

Note: \* Preliminary estimates

\*2 Refer to Table 26 of Ref.A17.

\*3 Refer to Table 11.01 of Ref.J5

Table 2.2.6 GRDP of La Paz Department at 1980 Constant Prices: 1980-1986

Economic Sector	(Unit: Bolivianos*)						
	1980	1981	1982	1983	1984	1985	1986
1. Agruculture	3,906	4,032	4,192	3,874	4,618	4,987	4,922
- Crop	3,059	3,292	3,427	3,129	4,056	4,311	4,231
- Livestock	746	629	671	690	501	586	599
- Forestry, fishery, etc.	101	111	94	55	61	90	92
2. Extraction	2,891	3,242	2,572	2,139	1,623	1,410	1,071
- Crude oil & natural gas							
- Mining & quarring	2,891	3,242	2,572	2,139	1,623	1,410	1,071
3. Manufacturing	5,098	4,886	4,004	3,789	3,534	3,192	3,532
4. Electricity Gas & Water Supply	260	298	274	304	322	305	339
5. Construction	1,538	1,238	1,166	1,139	1,100	1,101	843
6. Trading	4,582	5,059	4,311	4,825	3,682	3,779	4,143
7. Transportation & Communication	2,420	2,562	2,859	2,330	2,634	2,661	2,997
8. Other Services	6,418	6,272	6,748	5,588	5,800	5,792	5,913
9. Public Services	7,229	7,290	8,148	7,599	8,268	7,336	6,975
GRDP at Factor Price	34,342	34,879	34,274	31,587	31,581	30,563	30,735
Indirect Tax, etc.	1,845	2,036	664	248	483	623	1,127
GRDP at Market Price	36,187	36,915	34,938	31,835	32,064	31,186	31,862

Source: Ref.A18 (Table 27)

Note: \* Million Pesos Bolivianos originally before 1987's denamination

Table 2.2.7 Crop Production in Bolivia and La Paz Department: 1989-1990 Crop Year

Crop	Bolivia			La Paz Department			Share of La Paz to Bolivia (%) (f)/(c)
	Cultivated Area (ha) (a)	Yield (ton/ha) (b)	Production (ton) (c)	Cultivated Area (ha) (d)	Yield (ton/ha) (e)	Production (ton) (f)	
1. Cereal	575,454			74,762			
Paddy	111,466	1.949	217,247	11,042	1.184	13,074	6.0
Barley	82,517	0.643	53,058	24,870	0.610	15,171	28.6
Maize	233,472	1.219	284,602	17,758	1.427	25,341	8.9
Wheat	86,193	0.692	59,646	2,604	0.581	1,513	2.5
2. Cash Crop	33,351			30,535			
Cocoa	4,268	0.590	2,518	2,726	0.585	1,595	63.3
Coffee	28,811	0.832	23,971	27,573	0.836	23,051	96.2
Tea	272	8.129	2,211	236	8.699	2,053	92.8
3. Fruit	72,739			22,376			
Banana	17,425	7.628	132,918	978	6.861	6,710	5.0
Orange	8,890	6.197	55,091	5,098	5.629	28,697	52.1
Banana (Platano)	31,118	9.710	302,156	10,484	10.234	107,293	35.5
4. Vegetable	76,023			13,635			
Pea	12,629	1.322	16,696	2,799	1.290	3,611	21.6
Broad bean	26,014	1.325	34,469	5,708	0.827	4,721	13.7
Tender maize	12,874	3.073	39,562	1,960	2.863	5,611	14.2

Source: Ref.A20

Table 2.2.8 Livestock Production in Bolivia and La Paz Department: 1989

Item	Bolivia		La Paz Department		Share of LP to Bolivia	
	Inventory (Nos) (a)	Production (ton) (b)	Inventory (Nos) (c)	Production (ton) (d)	Inventory (%) (a)/(c)	Production (%) (b)/(d)
Cattle	5,475,901	135,068	323,592	6,640	5.9	4.9
Alpaca	175,735	232	91,356	137	52.0	59.1
Llama	1,497,835	1,947	507,210	662	33.9	34.0
Sheep	7,701,137	15,838	2,238,623	3,850	29.1	24.3
Pig	2,126,537	43,045	241,206	3,473	11.3	8.1

Source: Ref.L14

production of agricultural crops, as far as the JICA study team was able to determine.

Instead of crop production, stock farming seems to be an important industry in La Paz Department. The production of Alpaca and Llama accounted for 59% and 34% of the country respectively, as shown in Table 2.2.8. In the study area, they are raised up in many places. However, there are no large-scale ranches in the area. All of them are managed in small-scale grazing.

### (3) Mining and Manufacturing

In Bolivian economy, the extraction industry, including crude oil, natural gas, mining and quarrying, is quite important for earning foreign exchange through exportation. It accounted for 15% of GDP in 1991, and is expected to grow as the most significant foreign money earner in the future. However, there are no crude oil and natural gas fields and significant major mines in La Paz Department. In fact, the extraction production in the department accounts for only 9% of that of the country, which is broken down to 0% in crude oil and natural gas sub-sector and 20% in mining sub-sector. There are some small-scale mines in the study area. From the environmental point of view, even these small-scale mining sources cause water pollution of rivers in the study area.

Although the manufacturing sector is important in Bolivian economy as well as the extraction industry, its types are biased to light industry such as food and beverage processing. Therefore, basic capital goods and intermediate materials are relied on import from foreign countries. Table 2.2.9 shows industrial production and VA by industrial types in Bolivia in 1986. In terms of production, a) flour and bread, b) meat products, c) petroleum refinery, d) basic metal products and e) beverages are the top five manufacturing types in order in the country. In the Department, a) flour and breads, b) beverages, b) meat products, d) sugar and confectionery and e) textile and garment are the top five manufacturing types.

### (4) Tourism

The foreign currency earning through tourism was US\$74.4 million in the country in 1989, as shown in Table 2.2.10. This amount accounted for approximately 10% of the merchandise exports (US\$724 million in FOB) in 1989, so its contribution was not small in the Bolivian economy.

Of the total arrivals in the country, 116,100 thousand or 55% arrived in La Paz City. Thus, La Paz City maintains the most important position in the tourism industry. Moreover, tourists into La Paz City stay somewhat longer and spend more money in

Table 2.2.9 Manufacturing Production in Bolivia and La Paz Department: 1986

(Unit: Bs. at 1980 Prices)

Industrial Type	Bolivia			La Paz Department		
	Output	Input	Value Added	Output	Input*2	Value Added*1
1 Meat products	5,233	3,950	1,283	1,345	1,015	330
2 Dairy products	421	265	156	102	64	38
3 Flour & breads	7,319	5,636	1,683	5,024	3,869	1,155
4 Sugar & confectionery	2,998	1,604	1,394	516	276	240
5 General foods	1,476	1,197	279	494	401	93
6 Beverages	3,778	1,204	2,574	1,037	330	707
7 Tobacco	530	117	413	377	83	294
8 Textile & garment	3,009	1,858	1,151	478	295	183
9 Wood products	1,033	532	501	86	44	42
10 Paper products	461	258	203	258	144	114
11 Chemical products	1,236	761	475	274	169	105
12 Petroleum refinery	4,607	3,014	1,593	0	0	0
13 Ceramics, non-metal proddusts	1,345	611	734	295	134	161
14 Basic metal products	3,532	2,609	923	0	0	0
15 Metal, machinery, electricity	484	240	244	73	36	37
16 Other manufacturing	205	69	136	53	18	35
Total	37,667	23,925	13,742	10,411	6,879	3,532

Source: Ref.A17 (Table 29 and 31)

Note: \*1 Rates of La Paz Department to Bolivia in 1986 were derived from the production data of INE, Industry Section.

\*2 Value added rates of respective products were assumed to be the same as the national ones.

Table 2.2.10 Foreign Tourists to Bolivia and La Paz City: 1989

Purpose	Number of Arrival Tourists by Staying				Estimated Consumption (US\$1000)			
	Total	Hotel	Resi- dential	Other Staying	Total	Lodging	Shopping	Others
<b>Bolivia</b>								
1. Vacation	87,878	51,291	16,560	20,027	32,325	8,833	7,066	16,427
2. Business	44,590	26,025	8,403	10,162	10,935	4,482	1,255	5,199
3. Studying	5,533	3,229	1,043	1,261	2,386	556	534	1,296
4. Research	6,512	3,800	1,227	1,485	2,336	654	968	713
5. Medical Treatment	978	570	184	224	1,421	96	923	401
6. Conference	6,510	3,800	1,227	1,483	2,100	654	550	896
7. Visiting	18,549	10,827	3,496	4,226	206	33	46	127
8. Sports Game	1,953	1,140	368	445	4,102	196	667	3,239
9. Employment	22,783	13,297	4,294	5,192	12,228	2,290	1,855	8,083
10. Others	17,575	10,259	3,312	4,004	6,395	1,767	1,413	3,215
Total	212,861	124,238	40,114	48,509	74,435	19,561	15,278	39,596
Total Man-days	734,520	420,718	159,305	154,497				
Average Staying per Tourist (Man-days/Tourist)	3	3	4	3				
Average Consumption per Tourist (US\$)					101	27	21	54
<b>La Paz City</b>								
1. Vacation	47,942	-	-	-	-	-	-	-
2. Business	24,326	-	-	-	-	-	-	-
3. Studying	3,019	-	-	-	-	-	-	-
4. Research	3,555	-	-	-	-	-	-	-
5. Medical Treatment	533	-	-	-	-	-	-	-
6. Conference	3,551	-	-	-	-	-	-	-
7. Visiting	10,119	-	-	-	-	-	-	-
8. Sports Game	1,065	-	-	-	-	-	-	-
9. Employment	12,429	-	-	-	-	-	-	-
10. Others	9,588	-	-	-	-	-	-	-
Total	116,127	75,226	22,436	18,465	-	-	-	-
Total Man-days	409,169	241,511	87,429	80,229	-	10,859	-	-
Average Staying per Tourist (Man-days/Tourist)	3.5	3.2	3.9	4.3				
Average Consumption per Tourist (US\$)					-	144	-	-
<b>Rate of La Paz City to Bolivia (%)</b>								
Total Arrival Tourists					54.6%			
Total Man-days					55.7%			
Average Staying per Tourist					102.1%			
Average Consumption per Tourist for Lodging					542.1%			

Source: Ref.A7

Note: "-" indicates that data were not available.

the city than the national average, as shown in the table. From the economic point of view, tourism in La Paz City should be promoted by means of improvement of infrastructure for tourism.

#### **2.2.4 People's Income and Expenditure**

Data on people's income is essential for appraising the viability of water supply and sanitation projects. At present, the people's income and its distribution data are not available. As regards expenditure, however, the household sample survey was conducted by INE in 1990.

Table 2.2.11 shows the household expenditure by household income groups in 1990. The average monthly household income of each quarter was Bs.225, Bs.407, Bs.609 and Bs.1,890 in order, respectively. The average monthly household expenditure was Bs.359, Bs.599, Bs.935 and Bs.1,816, respectively. Only the fourth quartile group's income can meet its expenditures.

The expenses for utilities such as water, gas and electricity were 3.1%, 2.6%, 1.9% and 2.2% of the total expenditure of respective quartile groups. In monetary terms, they were Bs.10.9, Bs.15.6, Bs.18.1 and Bs.39.8 per month, respectively. If the expenses for water is assumed to be one-third of the above amounts, they would be estimated at Bs.3.6, Bs.5.2, Bs.6.0 and Bs.13.3 per month. Incidentally, their Engel's coefficient, the ratio of food expenses to total household expenses, was 65%, 59%, 51% and 42%, respectively.

#### **2.2.5 Financial Status**

The public entities concerned with water are categorized into four groups as follows.

- 1) Central government
- 2) Government enterprise
- 3) Departmental government
- 4) Municipal government

The total amounts spent by these entities were: Bs.4.57 billion in 1986 at current prices; Bs.4.64 billion in 1987; and Bs.6.46 billion in 1988. On the other hand, GDP in the same period were: Bs.8.92 billion in 1986 at current prices; Bs.10.18 billion in 1987; and Bs.12.30 billion in 1988. Thus, the budgets by these public entities

Table 2.2.11 Household Income and Expenditure by Income Class in La Paz City: 1990

Item	Income Class				Entire Average (Total)
	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile	
A. Number of Sample Households	83	83	83	83	332
B. Average of Sample Households					
Number of Households Members	3.67	4.80	3.82	4.53	4.45
Number of Income Earners	1.45	1.71	2.07	2.14	1.84
Age of Households Head	42.34	41.78	41.40	45.28	42.70
Total Monthly Income (Bs.)	225.00	407.00	609.00	1890.00	783.00
Monthly Expenditure (Bs.)	359.00	599.00	935.00	1816.00	927.00
C. Housing Condition (%)	100.00	100.00	100.00	100.00	100.00
Own House	40.96	40.96	45.78	56.63	46.08
Rented	21.69	28.92	20.48	18.07	22.29
Others	33.73	25.30	27.71	19.27	26.51
Rented by Interest	3.62	4.82	6.03	6.03	5.12
C. Households Expenditure (%)	100.00	100.00	100.00	100.00	100.00
Foods and Beverages	64.55	59.31	51.23	42.40	49.50
Commodity and food stuff	52.13	49.90	39.26	30.44	37.90
Eating out	12.42	9.41	11.97	11.96	11.60
Clothes and Footwear	8.41	7.57	9.43	8.75	8.70
Housing Expenses	6.20	5.41	4.89	5.15	5.23
Housing	3.09	2.78	2.77	2.41	2.63
Water, gas & Electricity	3.05	2.61	1.94	2.19	2.28
Maintenance & fixing	0.06	0.02	0.18	0.55	0.32
Furniture	3.61	4.25	5.82	8.73	6.77
Medical Care	1.25	2.86	2.95	5.08	3.82
Transport & Communication	7.86	8.43	11.76	12.80	11.35
Education	2.57	6.21	5.41	6.11	5.61
Culture & Entertainment	2.08	2.68	4.90	6.80	5.20
Other Expenses	3.47	3.28	3.61	4.18	3.82

Source: INE - Family Budget Research, surveyed during February - April, 1990

Data are not official.



accounted for: 51% of GDP in 1986, 46% in 1987, and 52% in 1988.

Table 2.2.12 shows the actual financial accounts of the central government between 1986 and 1991. After the recession period, the new economic policy led the public accounts to succeed gradually in restoring stability. As seen in the table, the financial balance has recovered from a deficit to a balanced position. Moreover, since foreign assistance is increasing year by year as shown in Table 2.2.13, the public finance is expected to increase public investment in infrastructure development.

The municipal government is the responsible organization regarding water pollution control of the Choqueyapu river. As shown in Table 2.2.14, the government used public finance on basic infrastructure between 1986 and 1989 as follows: Bs.2.72 billion in 1986; Bs.11.87 million in 1987; Bs.54.10 million in 1988; and Bs.11.04 million in 1989. Bureau of control and management of watershed and environment (DICOMAC), in charge of the Choqueyapu river management, was allocated Bs.2.99 million in 1991 and Bs.42.08 million in 1992.

The Municipal Corporation of Potable Water and Sewerage in La Paz (SAMAPA) is operating and maintaining water supply and sewerage facilities in La Paz City and El Alto City. Table 2.2.15 shows the profit and loss (P/L) statement of SAMAPA for the latest five years. According to the table, it seems to be managed soundly from the financial viewpoint. In particular, income completely covered the expenditures for the latest three years. The major income consists of water supply and sewerage service charges, which accounts for as follows: Bs.25.41 million or 73% of the total income through water supply and Bs.6.99 million or 20% through sewerage service in 1990; and Bs.31.48 million (73%) and Bs.8.98 (21%), respectively, in 1991. In the same years, its fixed assets holdings are evaluated as Bs.324 million (US\$95.4 million equivalent) in 1990 and Bs.377 million (US\$100.7 million) in 1991.

### **2.2.6 Consciousness of the Public Toward River Water Pollution**

A survey questionnaire was carried out to throw light on people's consciousness of the river water pollution such as the water color/smell, the contraction of diseases, the expectation of water quality improvement and the conditions of water supply services in the Central and South zones. Pollsters visited every respondent with questionnaire forms and asked regarding the subject's consciousness of these matters. The survey was conducted from the beginning of April through the end of May, 1992. A summary of the results is discussed in this section.

Table 2.2.12 Financial Statement of Central Government: 1986-1991

(Unit: Bs. Million)

Item	1986	1987	1988	1989	1990	1991
<b>1. Revenue</b>						
Tax Revenue	603.0	932.9	1,204.0	1,342.6	1,733.2	2,335.2
Domestic revenue	174.2	274.7	367.2	446.6	560.5	819.3
Customs revenue	98.6	146.0	140.4	138.3	139.7	160.1
Communication	0.7	1.2	0.6	0.1	0.0	0.0
Consular	14.9	0.1	0.0	0.0	0.0	0.0
Royalty	314.7	510.9	695.7	757.6	1,033.0	1,355.7
Mineral	1.5	5.4	7.6	16.6	11.3	7.7
Petroleum	313.2	505.5	688.1	740.9	1,021.7	1,348.1
Other Revenue	238.1	94.0	43.4	210.6	124.2	440.4
Total	841.0	1,026.9	1,247.3	1,553.2	1,857.4	2,775.5
<b>2. Expenditure</b>						
Personnel Expenses	360.1	516.5	646.1	777.0	915.1	1,120.9
Purchase of Services	49.9	67.0	96.6	119.2	133.7	172.6
Purchase of Materials	114.8	122.7	114.1	149.2	160.6	188.2
Fixed Assets	52.1	43.4	45.4	46.8	64.7	82.6
Public Debt	145.6	142.4	185.2	234.2	389.6	690.2
Domestic Debt	36.4	7.0	16.2	22.3	138.5	320.0
Foreign Debt	109.2	135.5	169.0	211.9	251.1	370.2
Repayment	63.4	43.6	69.9	89.1	111.7	370.2
Interest	45.8	91.9	99.1	122.8	139.4	0.0
Transfer/Investment	244.3	164.3	200.0	225.3	322.7	350.8
Other Expenses	-	-	9.7	15.8	47.9	119.9
Total	966.9	1,056.4	1,297.1	1,567.7	2,034.3	2,725.1
<b>3. Balance</b>	(125.8)	(29.5)	(49.8)	(14.5)	(176.8)	50.5
<b>4. Rate of Expenditure to Revenue</b>	115.0%	102.9%	104.0%	100.9%	109.5%	98.2%

Source: Ref.J5 (Table 13.01 and 13.02)

Table 2.2.13 Foreign Assistance to Bolivia: 1988-1990

(Unit: US\$ Million)

Organization Country	1988			1989			1990		
	Loan	Grant	Total	Loan	Grant	Total	Loan	Grant	Total
<b>1. Multi-lateral Assistance</b>									
BID *1	199.7	-	199.7	107.9	-	107.9	317.0	-	317.0
IDA *2	114.3	-	114.3	94.7	-	94.7	124.5	-	124.5
FONPLATA	-	-	-	22.2	-	22.2	13.3	-	13.3
CAF	29.2	-	29.2	12.2	-	12.2	7.5	-	7.5
FIDA	5.6	-	5.6	-	-	-	-	-	-
OPEP/FNUOD	5.2	-	5.2	-	-	-	-	-	-
Total	353.9	0.0	353.9	237.0	0.0	237.0	462.3	0.0	462.3
<b>2. Bi-lateral Assistance</b>									
RFA-KIW	41.7	1.9	43.6	21.3	1.1	22.4	6.0	7.0	13.0
USAID	-	43.5	43.5	-	23.5	23.5	-	90.8	90.8
Belgium	-	-	-	-	-	-	-	8.0	8.0
Netherlands	-	23.4	23.4	-	19.8	19.8	-	20.2	20.2
Japan	57.5	36.9	94.4	70.0	18.8	88.8	-	14.8	14.8
Spain	13.4	6.6	20.0	3.4	-	3.4	100.0	7.4	107.4
Italy	-	9.3	9.3	-	0.9	0.9	51.2	-	51.2
China	-	-	-	-	-	-	6.4	0.4	6.8
Sweden	-	4.8	4.8	-	-	-	-	-	-
Switzerland	-	13.2	13.2	-	-	-	-	-	-
France	-	3.2	3.2	12.9	0.1	13.0	-	-	-
Total	112.6	142.9	255.5	107.6	64.2	171.8	163.6	148.6	312.2
<b>3. Grand Total</b>									
	466.5	142.9	609.4	344.5	64.2	408.8	625.9	148.6	774.5

Source: Ministry of Finance

Note: \*1 Banco Interamericano de Desarrollo ( Inter-american Development Bank)

\*2 International Development Agency

Table 2.2.14 Financial Statement of La Paz Municipal Government: 1986-1991

(Unit: Bs. Million)

Item	1986	1987	1988	1989
<b>1. Revenue</b>				
Municipal Revenue	24.87	19.83	12.21	15.02
Donation	0.00	0.00	0.09	0.00
Revenue Share	2.13	30.19	40.27	48.45
Special Revenue	0.04	0.00	2.67	4.71
Miscellaneous Revenue	5.63	2.77	0.02	0.00
Domestic Revenue	0.00	0.00	4.45	0.00
Total	32.68	52.79	59.70	68.19
<b>2. Expenditure</b>				
Recurrent	11.41	17.96	28.81	40.38
Technical service	5.73	9.41	14.51	18.65
Cultural service	0.53	0.86	1.03	1.93
Financial service	3.46	4.53	7.85	12.42
Extra-goven. organization	1.46	2.72	4.54	5.80
City council	0.24	0.43	0.88	1.57
Development	2.92	12.66	55.56	15.73
Fixed assets	0.20	0.78	1.17	1.26
Finacial activity	0.00	0.00	0.29	0.00
Urban equipment	0.00	0.00	0.00	3.43
Basic infrastructure	2.72	11.87	54.10	11.04
Repayment of Debt	9.08	5.50	5.02	5.33
Total	23.41	36.11	89.39	61.45
<b>3. Balance</b>	9.27	16.68	-29.68	6.74
<b>4. Rate of Expenditure to Revenue</b>	71.63	68.41	149.72	90.11

Item *1	1,991	1992*2
<b>Expenditure</b>		
Technical Vice-Mayor (P11,P12,P13 & P16)	53.40	140.26
Office of technical vice-mayor (P11/A01)	0.52	0.55
Bureau of research & projects (P11/A07)	1.54	5.82
Bureau of supervision (P11/A02)	0.62	0.63
Bureau of public works (P11/A04 & A08)	13.43	19.31
Bureau of watershed & environment management(P11/A05)	2.99	42.08
Bureau of urban development (P11/A03)	3.34	2.76
Bureau of forestation & tree planting (P11/A09)	4.04	7.44
Bureau of traffic & highway administration (P11/A06)	4.90	34.28
Bureau of urban improvement (P12)	0.22	10.50
Bureau of communal activity (P13)	1.41	10.12
Bureau of urban sanitation (P16)	20.41	6.78
Administrative Vice-Mayor (P03 & P04)	41.33	50.65
Cultural Vice-Mayor (P10)	6.66	5.90
Other Services	22.41	42.09
Total	123.80	238.90

Source: Ref.J7 and J8

Note: \*1 Code in parentheses means the program number of La Paz municipal government.

\*2 Budget for fiscal year 1992

Table 2.2.15 Financial Statement of SAMAPA: 1987-1991

(Unit: Bs. Million)

Item	1987	1988	1989	1990	1991
<b>1. Income</b>					
Operating Income	13.25	16.26	26.66	32.40	40.46
Water supply	-	-	-	25.41	31.48
Sewage treatment	-	-	-	6.99	8.98
Other Income	2.83	1.55	2.89	2.41	2.95
Total	16.08	17.81	29.55	34.81	43.41
<b>2. Expenditure</b>					
Personnel Expense	3.96	5.64	6.74	7.43	8.93
Welfare Expense	0.60	0.61	0.79	1.14	1.56
Material Purchase	2.12	1.71	2.23	2.59	3.28
Depreciation	4.61	5.33	5.56	8.79	12.72
Reserve for indemnification	1.07	0.90	0.90	1.02	1.33
Reserve for Bad Debt	0.92	4.83	3.77	8.58	1.90
Expenses of Loan	2.10	1.47	2.52	2.73	2.58
Appraisal Loss of Inventory	0.00	0.00	0.00	1.54	0.00
Total	15.38	20.47	22.50	33.82	32.29
<b>3. Operating Surplus/Loss</b>	0.71	-2.65	7.05	0.99	11.12
<b>4. Donation</b>	0.00	0.00	0.00	62.20	0.00
JICA	0.00	0.00	0.00	56.40	0.00
FSE	0.00	0.00	0.00	5.81	0.00
<b>5. Adjustment</b>	-1.37	11.51	-7.42	-13.07	0.89
Previous Operation	0.39	-0.43	-0.47	2.32	-0.05
Inflation	-1.76	11.94	-6.95	-15.39	0.94
<b>6. Balance</b>	-0.66	8.86	-0.37	50.12	12.01

Source: Ref.L2, L3, L4 and L13

### (1) Consciousness and Utilization of River Water

955 or 98% of the respondents, as residents, were aware that purification of river water around their houses is important, as shown in Table 2.2.16. This figure proves that the rivers in the city are contaminated and give an unfavourable impression to citizens. Also, the people are aware that the rivers function as sewers for the city, because 62% of the respondents answered that the rivers are used for sewerage. In addition, 15% of the respondents answered that the rivers are used for dumping garbage, as well.

Although a quarter of respondents think that there are no problems regarding river conditions, other people are conscious of the following problems: 1) 59%, aware of obnoxious odour from the rivers; 2) 42%, eye-sore in riparian conditions; and 3) 25%, breeding ground of mosquitoes and germs.

### (2) Contraction of Diseases

Table 2.2.17 shows the number of patients, among the total respondents to the questionnaire, who suffered from water-borne diseases during the last 5 years. The respondents were most susceptible to diarrheal diseases. After diarrheal diseases, the people in the area were most susceptible to the following water-borne diseases, in order of the number of patients: 2) skin sepsis and ulcers; 3) typhoid; 4) dysentery; and 5) infective hepatitis.

The people spent Bs.17,249 in total for medical care during the same period. Since the number of patient was 174 in total, this amounted at Bs.99 per patient on average.

The JICA study team tried to find out the relationship between the disease contraction rate and the people's consciousness on river conditions. The regression equation was as follows:

$$y = 2.204 + 1.403x_1 + 4.041x_2 + 0.196x_3$$

Multiple correlation coefficient: 0.167

where,  $y$  : Number of those who contracted water-borne diseases in the last five years (patients/1000 population: in this case, population was derived from five times of the total number of households members)

Table 2.2.16 Consciousness and Utilization of River in General Residents

1. Number of Respondents:	974	
2. Importance of River Condition		
Rate of people who think purification of a river near their home is important		
	Number	Rate
a) Yes:	955	98.0%
b) No :	19	2.0%
3. Existing Use of the River		
3.1 Use of the River (Plural answers)		
	Number	Rate
a) Washing	73	7.5%
b) Irrigation and agricultural use	9	0.9%
c) Recreation use	15	1.5%
d) Sewerage	605	62.0%
e) Garbage dumping	146	15.0%
f) No answer	25	2.6%
g) Others	136	14.0%
3.2 Conditions of the river around respondents (Plural answers)		
	Number	Rate
a) No problems	236	24.2%
b) Obnoxious odour	574	58.9%
c) Eye-sore	411	42.2%
d) Breeding ground of mosquitoes and germs	244	25.1%
e) No answer	16	1.6%
f) Others	29	3.0%

Table 2.2.17 Contraction of Diseases for Latest Five Years

Disease	Number of Patients	Medication Period (days)		Cost (Bs.)
		Outside Hospita	In Hospital	
1. Cholera	1	0	1	10
2. Typhoid	18	25	49	6,635
3. Paratyphoid	3	3	0	2,200
4. Infective Hepatitis	10	32	1	2,180
6. Shigelosis	1	1	0	0
7. Dysentery	14	9	1	1,000
8. Skin Sepsis and Ulcers	33	16	0	1,190
10. Nocardiosis	1	1	0	50
11. Diarrhoeal Diseases	84	58	6	3,094
12. Amebiasis	9	9	0	890
Total	174	154	58	17,249

Note: Including general residents and tenants of apartment houses



- $x_1$  : Average percentage of respondents who replied that water of rivers was giving off obnoxious odour (%)
- $x_2$  : Average percentage of respondents who replied that rivers were eye-sore (%)
- $x_3$  : Average percentage of respondents who replied that rivers were a breeding ground of mosquitoes and germs (%)

### (3) River Water Quality

More than 60% of the respondents desired that the quality of the river water be clear, as shown in Table 2.2.18. Also, 17% of them desired to eliminate odors from the contaminated river, 14% of them desired to get rid of the eye-sore in the river courses.

For improvement of river water quality, 58% of the respondents wanted people to stop throwing garbage into rivers. 24% agreed to establish a public sewage treatment plant, although the people would have to bear a fair share of the cost. 13% approved the regulation and control of industrial wastewater, although the prices of industrial products might increase a little as a result.

### (4) Household Income and Willingness to Pay for Purification of Rivers

The average family size of the respondents was 5.6 persons, of whom 1.7 persons were income earners in the family. The average monthly household income was Bs.763. Willingness to pay for purification of rivers was Bs.2.8/month, on average, or 0.37% of the total household income.

The relation between household income and willingness to pay was tabulated in Table 2.2.19. The regression equation derived from these data was:

$$y = 1.740 + 0.00137x \text{ (correlation coefficient: 0.414)}$$

where,

$x$  : monthly household income

$y$  : willingness to pay for purification of rivers

Table 2.2.18 Consciousness and Effects of River Water Quality

1. Desired River Water Quality		Number of Respondents*1:	1039
		Number	Rate
a) Clear Water		612	63.9%
b) Suitable for bathing		40	4.2%
c) Suitable for fish to live		9	0.9%
d) Suitable for agriculture		63	6.6%
e) No eye-sore		132	13.8%
f) No obnoxious odour		164	17.1%
g) Others		19	2.0%
2. Method of Water Quality Improvement		Number of Respondents*1:	1037
		Number	Rate
a) To establish public sewage treatment plant although people to bear a fair share of the cost.		225	23.5%
b) To regulate and control industrial wastewater although prices of industrial products may increase a little as a result.		120	12.5%
c) To stop throwing garbage into rivers.		554	57.9%
d) To introduce clean water into rivers from other water sources.		69	7.2%
e) No ideas		48	5.0%
f) Others		21	2.2%

Note: Including general residents and tenants of apartment houses

Table 2.2.19 Willingness to Pay by Households Income Level

Effective Number: 898 of Total Respondents\*1)

Monthly Households Income	Willingness to Pay									
	Nothing	Bs.1	Bs.2	Bs.3	Bs.4	Bs.5	Bs.7	Bs.10	Over Bs.10	Total
Less than Bs.100	26	16	8	3	1	3	1	0	1	59
Bs.101 to Bs.200	49	46	21	8	2	5	0	5	4	140
Bs.201 to Bs.300	47	49	38	10	2	5	3	0	5	159
Bs.301 to Bs.400	37	34	28	10	8	10	1	0	1	129
Bs.401 to Bs.500	17	21	10	3	2	6	0	1	3	63
Bs.501 to Bs.600	16	27	19	2	7	9	2	3	3	88
Bs.601 to Bs.700	11	12	13	6	3	17	2	4	3	71
Bs.701 to Bs.1000	21	17	10	13	0	14	7	9	3	94
Bs.1001 to Bs.2000	14	15	8	12	6	20	7	14	4	100
Bs.2001 to Bs.4000	6	2	7	3	2	12	5	13	1	51
Bs.4001 to Bs.6000	2	0	0	1	0	3	0	5	3	14
Over Bs.6000	0	0	0	0	0	0	1	4	3	8
Total	246	239	162	71	33	104	29	58	34	976

	Average	Standard Deviation
Monthly Households Income (X)	Bs.763/month	Bs.1,053/month
Willingness to Pay for Purification of Rivers (Y)	Bs.2.79/month	Bs.3.50/month
Correlation Coefficient (Simple Correlation):	0.414	
Regression Equation:	$Y = 1.740 + 0.00137 * X$	
Average Family Size of a Household:	5.6	
Average Number of Income Earners in a Household:	1.7	

: Including general residents and tenants of apartment houses

## **2.3 INSTITUTIONAL FRAMEWORK FOR WATER POLLUTION CONTROL**

### **2.3.1 Legal Framework**

#### **(1) Background**

The Constitution of the Republic of Bolivia (Ref. K9) assures the nation the rights of life, health and security (Art. 7). It further states that the State has the obligation of protecting the health of the population (Art. 158). The constitution requires the municipal governments, among other things, to attend and keep guard over the services related to a sound neighborhood, cleanliness, comfort, embellishment, town planning, and recreation (Art. 205, Item 4).

The Organic Law of Municipalities (Ref. K7) stipulates, in addition to the provisions in the Constitution, that the municipalities' competence includes preservation of the environment, control of pollution, and sustenance of the ecological balance in coordination with the national authorities concerned (Art. 9, Item 17).

With respect to water pollution control and environmental sanitation, some Governmental and Ministerial Decrees have been promulgated to regulate activities in this sector.

Until quite recently, however, there has been no legal provision that presents a comprehensive scope, concrete objectives and policies to deal with the environmental protection, conservation, and pollution abatement.

#### **(2) General Law of Environment**

After deliberation on the bill of the General Law of Environment (Ley General de Medio Ambiente; Ref. K1), the National Congress of Bolivia passed it with some revisions on April 20, 1992. It was enacted as Law No. 1333 (Ref. K12) on April 27. The law provides, for the first time in Bolivia, the objectives and the general policy concerning protection and conservation of the environment and natural resources in harmony with the sustainable development of the country. The law also provides the institutional arrangements including the creation of the National Environment Agency (Secretaría Nacional del Medio Ambiente; SENMA) in the National Government, and the departmental counsel of environment and the departmental agency of environment in each Departmental Government. A major function of SENMA is to formulate and direct the national policy on the environment in agreement with the general policy and the

plans of the nation for economic, social and cultural development. With respect to environmental control, its objectives are set forth as follows (Art. 19):

- To preserve, conserve, improve and restore the environment and the natural resources in order to enhance the quality of the life of the population.
- To standardize and regulate the utilization of the environment and the natural resources for the benefit of the society as a whole.
- To foresee, control, restrict and avoid activities that bring about harmful effects to the health and deteriorate the environment and the natural resources.
- To regulate and direct the actions of the State and the society relating to the protection of the environment and the sustainable utilization of the natural resources in order to guarantee the satisfaction of the necessities of the present and the future generations.

Concerning protection and conservation of water resources, the principles are provided as follows:

- Protection and conservation of water are fundamental tasks of the State and the society (Art. 36).
- Planning, protection and conservation of any form of water resources and the integral management and control of the basins constitute a national priority (Art. 37).
- The State regulates and controls disposal of any substance or residue of liquid, solid or gas that causes or may cause pollution of water resources or degradation of their neighborhood (Art. 39).

In the aspect of health and environment, the State is to promote actions for environmental sanitation as a national priority in order to guarantee the basic and other services for the urban and rural population (Art. 79). For this purpose, the Ministry of Social Security and Public Health (MPSSP), the Ministry of Urban Affairs (MAU), Ministry of Peasant and Stockbreeding Affairs (MACA) and the National Environment Agency (SENMA) are to establish respective standards, procedures and regulations in coordination with the responsible departmental and local sectors (Art. 80).

Thus, the promulgation of Law No. 1333 has provided a solid legal base for preservation and utilization of the environment and natural resources, as well as for

abatement of environmental pollution including water pollution. The responsibilities of national and local authorities have become much clearer than before.

It is expected that provision of specific laws, rules, regulations and standards to effect control and abatement of water pollution is to be made from now on by the relevant national and local authorities, based on the requirements of Law No. 1333.

### (3) Organization of the Basic Sanitation Sector

On November 1, 1991, the Government promulgated the Supreme Decree No. 22965 (Ref. K10) concerning reorganization of the basic sanitation sector in Bolivia. The "basic sanitation" is defined as those activities aimed to preserve and/or improve the health and the life quality of the people regarding services of potable water, sewerage, excretal elimination, solid wastes disposal, and environmental pollution control.

The decree designated the Ministry of Urban Affairs (MAU) as the national authority of the basic sanitation sector in charge of planning administrative reorganization of the sector. The functions of MAU and the national and the local organizations of the sector is described in Section 2.3.2.

### 2.3.2 Water Quality Standards

Under the provisions of the Article 80 of Law No. 1333 and the Supreme Decree No. 22965, MAU has been authorized to establish and enforce water quality standards for environmental waterbodies and wastewater effluents.

A draft of these standards was prepared during the period of 1983 to 1984 by the regulation commission composed of the members from the Ministries of Urban Affairs (then Urbanization and Housing, MAV), Industry and Commerce, Social Security and Public Health, Mining and Metallurgy, and Peasant and Stockbreeding Affairs, and San Andres University, SAMAPA, and the relevant industrial groups. The content was publicized as the Ministerial Resolution No. 010/85 by MAV. At that time, however, it was regarded that MAV did not have an authority to establish and enforce such regulation, therefore, the regulation has not been implemented until recently.

Given such authority to MAU by Law No. 1333 and the Supreme Decree as stated above, the regulation called "Regulation on Discharge of Industrial Wastes into Waterbodies" (Ref. K3) has just become effective.

The regulation gives specific water quality values as the upper limits for environmental waterbodies and industrial wastewater effluents. The former is shown in Table 2.3.1 and the latter in Table 2.3.2.

In Table 2.3.1, environmental waterbodies are divided into the five (5) classes according to the usage of the water as follows:

- Class Special:** Waters designated for public water supply without treatment or with simple disinfection.
- Class A:** Waters designated for public water supply after sedimentation, filtration and disinfection, for irrigation of vegetables edible raw, and for bathing.
- Class B:** Waters designated for public water supply after conventional treatment, i.e., coagulation, flocculation, sedimentation, filtration and disinfection, to preservation of flora and fauna, and for drinking water for animals.
- Class C:** Waters designated for public water supply after special treatment, for irrigation, scenic harmony, navigation, and for power generation.
- Class D:** Waters designated for transport and removal of wastes.

The maximum permissible values of water quality of wastewater effluents shown in Table 2.3.2 are applicable not only to industrial wastewaters but also to any wastewater when it causes water pollution.

The regulation also stipulates the details of wastewater discharge conditions, procedures for registering the discharge, reporting of the effluent quality, qualification of wastewater analysis, penalties, and others.

TABLE 2.3.1 Water Quality Standards for Environmental Waterbodies

PARAMETER	SPECIAL CLASS	CLASS A	CLASS B	CLASS C	CLASS D
<b>Physical-biological parameters</b>					
BOD5 (mg/l)	<2	<5	<10	<50	<300
DO	80% sat.	70% sat.	60% sat.	50% sat.	2 mg/l
Floating Solids	Absent	Absent	Absent	None that could be retained on a 2 mm sieve	None that could be retained on a 2 mm sieve
Suspended solids (mg/l)	500	1000	1500	2000	5000
Greases and oils (mg/l)	Absents	0.8	1	10	20
Coliform Bact. (MPN/100ml)	<500 < 50 in 80% of the samples	<5000 <1000 in 80% of the samples	<10000 <2000 in 80% of the samples	<20000 < 5000 in 80% of the samples	100000
PH	6.5 - 9.0	6.0 - 9.5	5.5 - 9.5	5.0 - 10.0	4.5 - 10.0
Color (Color unit)	<20	<50	<100	<200	<1000
<b>Chemical parameters (mg/l)</b>					
As	0.05	0.05	0.05	0.1	1
Ba	1	1	2	5	10
B	0.1	0.1	0.5	2	5
Cd	0.01	0.05	0.2	0.5	1
Cu	1	1.5	2	3	5
Cr 6+	0.05	0.05	0.1	1	5
Hg	0.001	0.005	0.01	0.02	0.05
Pb	0.05	0.1	0.1	0.2	2
Se	0.01	0.01	0.05	0.1	0.5
Cyanide	0.05	0.05	0.1	0.2	1
Phenols	0.001	0.002	0.005	0.01	0.1
Detergents (ABS and LAS)	0.15	0.5	1	2	5
Total Nitrogen NO3	45	50	60	80	100
Zn	5	10	15	20	50
Mn	0.5	1	2	5	10
Fe	0.5	1	2	5	10
Mg	100	200	300	400	500
Ca	200	300	400	500	700
F	0.6 - 1.7	0.6 - 1.7	2	3	5
Chlorides	500	500	700	1000	5000
Sulfates	400	400	600	1000	8000
<b>Herbicides (mg/l)</b>					
Aldrin	0.017	0.017			
Chlordane	0.003	0.003			
D.D.T.	0.042	0.042			
Dieldrin	0.017	0.017			
Endrin	0.001	0.001			
Heptachlorine	0.018	0.018			
Epoxyheptachlorine	0.018	0.018			
Lindane	0.056	0.056			
Metoxychlorine	0.035	0.035			
Organic Phosphate with Carbonates	0.1	0.1			
Foxatene	0.005	0.005			
Total Herbicides	0.1	0.1			

Source : Ref. K3

Note : ABS=Alkyl Benzene sulfonate  
 LAS=Linear alkylate Sulfonate  
 MPN=Most Probable Number



TABLE 2.3.2 Maximum Allowable Values for Industrial Wastewater Discharge to Waterbodies

PARAMETER	UNIT	MAXIMUM VALUE
Temperature	°C	40
PH	-	4.5 - 10.0
Sulfate (SO <sub>4</sub> )	mg/l	8000
Settleable solids	mg/l	1
BOD	mg/l	300
COD	mg/l	500
Floating solids	mg/l	None that could be retained on a 3 mm sieve
Greases and oils	mg/l	20
Coliform Bacteria	MPN/100 ml	100000
Color	color unit	1000
As	mg/l	1
Ba	mg/l	10
B	mg/l	5
Cd	mg/l	1
Cu	mg/l	5
Cr 6+	mg/l	5
Hg	mg/l	0.05
Pb	mg/l	2
Se	mg/l	0.5
Cyanide	mg/l	1
Phenols	mg/l	0.1
Detergents (ABS and LAS)	mg/l	5
Total Nitrogen NO <sub>3</sub>	mg/l	100
Zn	mg/l	50
Fe	mg/l	10
Mg	mg/l	500
Mn	mg/l	10
Ca	mg/l	700
Chlorides	mg/l	5000

Source : Ref. K3

Note : ABS = Alkyl Benzene Sulfonate

LAS = Linear Alkylate Sulfonate

MPN = Most Probable Number

### **2.3.3 Organization**

The Bolivian Government Decree 22965, proclaimed on November 1, 1991, classified the basic sanitation sectors as follows:

- 1) The Ministry of Urban Affairs (MAU)
- 2) The Regional Development Corporations
- 3) The Municipalities
- 4) The Administrative Entities
- 5) The Financial Entities
- 6) The Advisory Bodies

Besides these domestic entities, 7) Foreign Organizations contribute to the sanitation sectors as financing agencies.

#### **(1) Ministry of Urban Affairs (MAU)**

The MAU is the national government authority in charge of basic sanitation and water services. It attempts to improve and preserve the health and quality of life of the Bolivian people regarding potable water, sewerage, excretal elimination, solid waste disposal and environmental pollution control. Fig.2.3.1 illustrates the organizational structure of MAU.

Under MAU, National Bureau of Basic Sanitation (DINASBA) was created to prepare integral plans and projects of basic sanitation programs in the country. It also elaborates the other national development plans and programs, as well as with private, national and international financing organizations, in coordination with the Ministries concerned to these issues, such as the Ministry of Planning and Coordination (MPC) and the Ministry of Social Security and Public Health (MPSSP).

Under MAU, the National Tariff Council (CONATA), established on October 5, 1973, functions as a technical body in charge of research, evaluation and approval of tariffs and tariff structure for potable water and sewerage services. It is destined to regulate investments of the basic sanitation sector to ensure punctual debt servicing credits contracted by local entities and to guarantee efficient service maintenance.

#### **(2) Regional Development Corporations**

There are nine Regional Development corporations in the country. They were created to take over the administrative offices of the basic sanitation in their respective

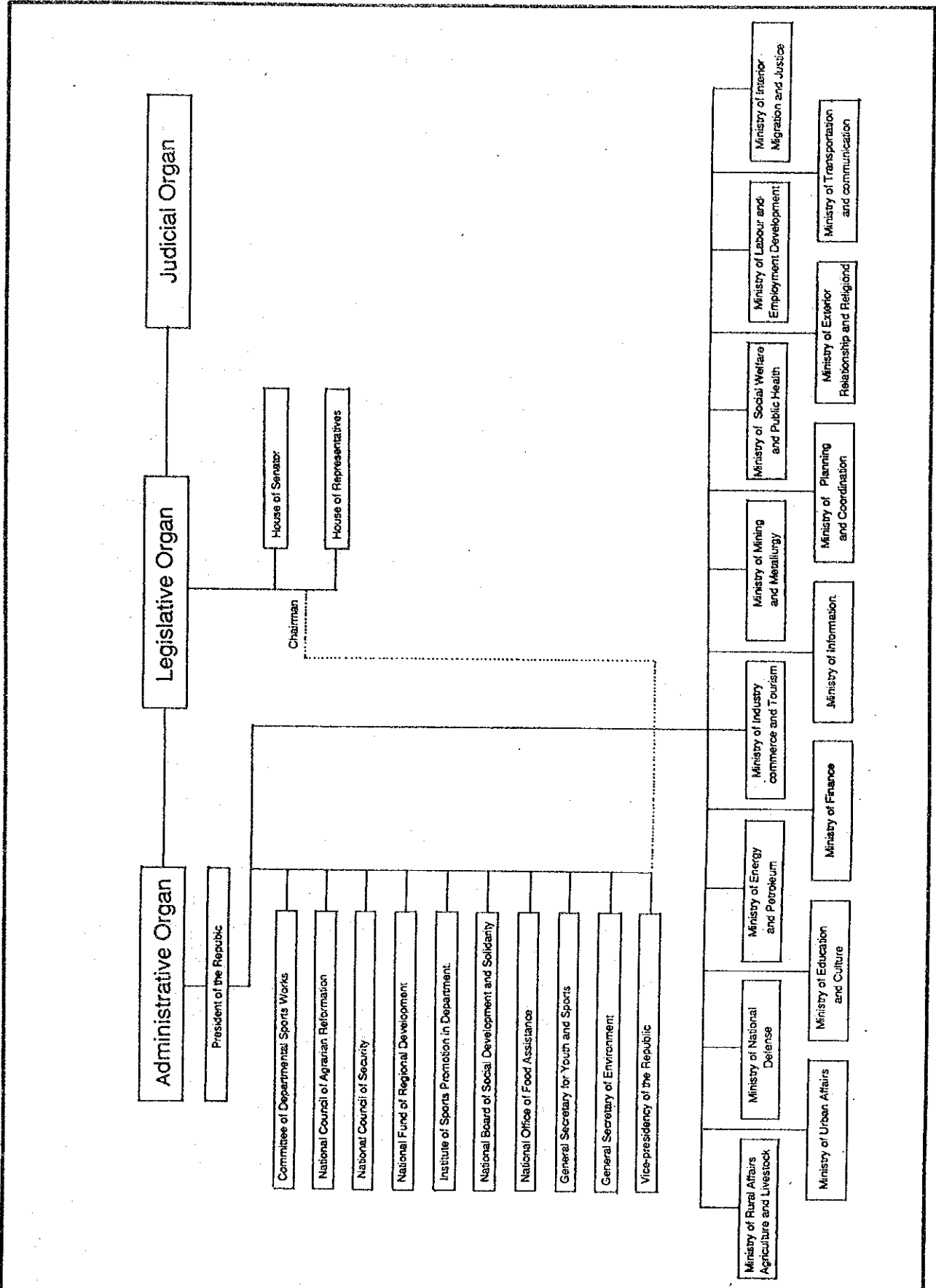


Fig. 2.3.1 Organizational Chart of Central Government

Departments. Regional Development Corporation of La Paz (CORDEPAZ) is the one in charge of regional development in La Paz Department. Its objective is to ensure an efficient execution of the projects regarding regional development, coordinating with the basic sanitation plans in urban and rural areas and with the provincial government concerned.

### (3) Municipalities

The Municipal Government of La Paz (HAM-LP) is a self-supported local government, which is in charge of water pollution control of the Choqueyapu river. It functions to coordinate urban development plans with local basic sanitation programs and to cooperate in procurement of financing for the local entities from the national authorities. HAM-LP is obliged to keep the Choqueyapu river clean and to prevent it from contamination. Bureau of Control and Management of Watershed and Environment (DICOMAC) is the responsible section in HAM-LP. Fig.2.3.2 illustrates the organizational chart of HAM-LP, which breaks down a part of DICOMAC in particular.

Besides the municipal government, the departmental and provincial governments are in charge of the same functions. However, they covers the entire areas in the Department or Provinces excluding the Municipal areas authorized by the central government.

### (4) Administrative Entities

Administrative entities are moreover categorized as follows: administrative bodies, cooperatives, private entities, associations and NGOs. These entities are self-supporting in administrative and financial matters. They are, of course, responsible for supplying basic sanitation services in their respective assigned areas.

The Municipal Corporation of Potable Water and Sewerage in La Paz (SAMAPA) is a monopolistic enterprise regarding water supply and sewerage systems, covering both the cities of La Paz and El Alto. Thus, the water supply and sewerage systems in the study area are mainly implemented, operated and maintained by SAMAPA. Fig.2.3.3 illustrates the present organizational chart of SAMAPA.

In addition to SAMAPA, cooperatives, religious groups and neighbouring groups implement water supply and sewerage systems on behalf of SAMAPA in the study area. Because SAMAPA is administratively so young and financially weak, these entities can implement these sanitation systems independently. However, they

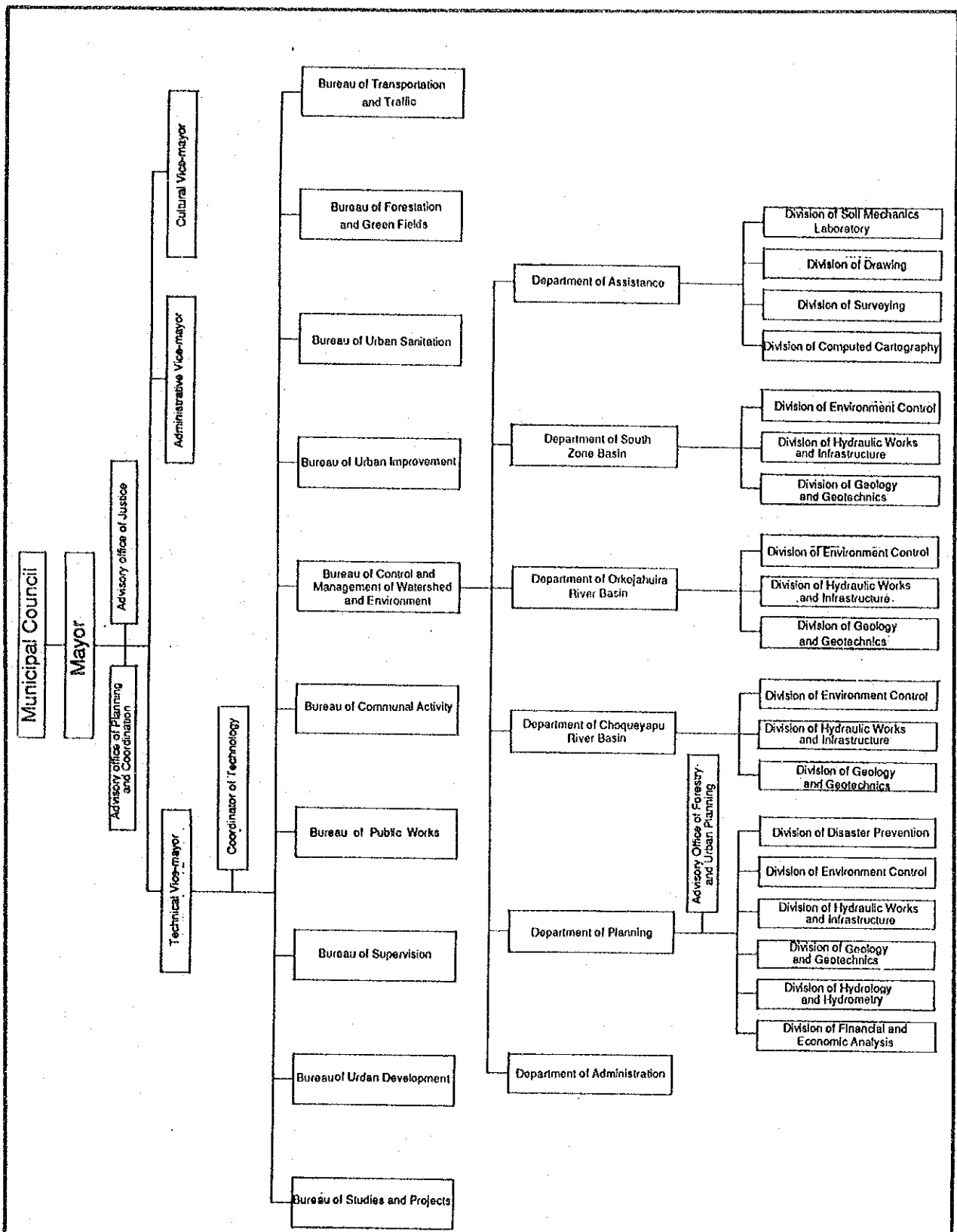


Fig. 2.3.2 Organizational Chart of Municipal Government

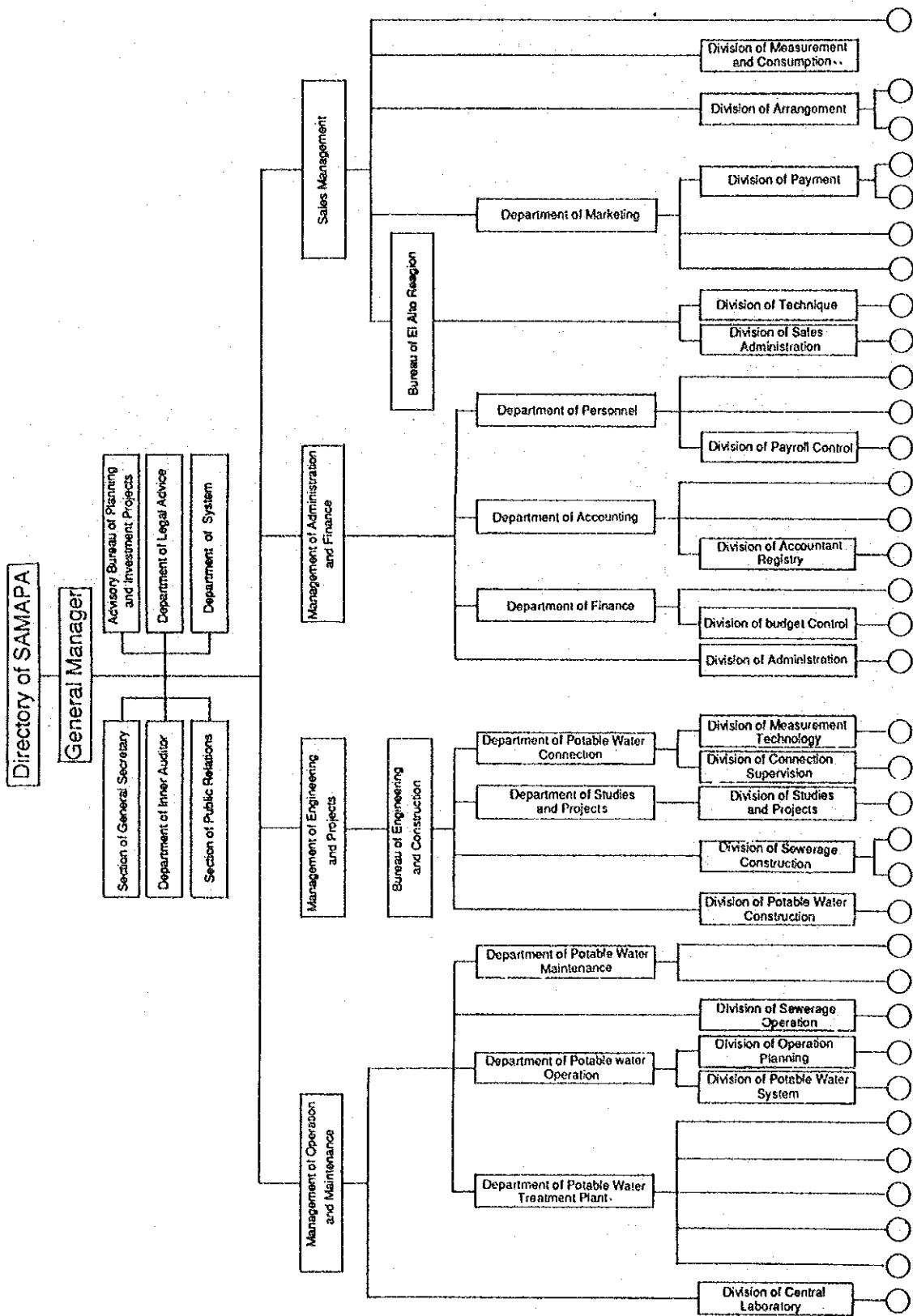


Fig. 2.3.3

Organizational Chart of SAMAPA

must conform to the technical standards of SAMAPA in order to be entrusted with the maintenance and operation of works after completion.

Table 2.3.3 shows investment in water supply and sewerage projects in La Paz Department by the above relating entities between 1987 and 1991. As seen in the table, SAMAPA is the largest entity in terms of investment in these sectors.

Investment amounts for water supply and sewerage projects during that period were as follows: US\$1,611 thousand, of which US\$55 thousand or 3.4% was for sewerage system, in 1987; US\$9,261 thousand, US\$1,675 thousand (18%) in 1988; US\$22,217 thousand, US\$3,234 thousand (15%) in 1989; US\$18,375 thousand, US\$1,838 thousand (10%) in 1990; and US\$5,552 thousand, US\$574 thousand (10%) in 1991.

#### (5) Financial Entities

The National Fund for Regional Development (FNDR) is an official agency to support all regional development projects by means of loans. It will cover public health sector projects in main urban areas having more than 2,000 people. Incidentally, the culvert project of a part of Choqueyapu river was financed by FNDR.

The Social Investment Fund (FIS) is a financial agent of the central government, functioning to finance sanitation projects through grants for the rural and urban poor. It does not finance sanitation projects in areas having more than 2,000 people and also individual domiciliary connections of sanitary systems.

#### (6) Advisory Bodies

The National Association of Enterprises and Institutions for Water Supply and Sewerage Services (ANESAPA) was created to exchange technical and managing information, and to cooperate in establishing unified tariff systems and standard specifications. Nine public corporations including SAMAPA are affiliated with ANESAPA in the country at present.

#### (7) Foreign Organizations

Regarding the water supply and sewerage sectors in La Paz, the following foreign organizations have contributed to the projects concerned: World Bank, Interamerican Development Bank (IDB), Germany (GTZ and KfW), Japan (JICA), United States (USAID) and CARE (NGO of the US). With regard to sewerage systems, World Bank, IDB and Germany contributed between 1987 and 1991. The amounts contributed by these organizations during the same period are shown in Table 2.3.4.

Table 2.3.3 Investment Records of Water Supply and Sewerage Systems in La Paz Department by Implementing Entity: 1987-1991

(Unit: US\$1000)

Entity	1987		1988		1989		1990		1991				
	Total	Local Foreign	Total	Local Foreign	Total	Local Foreign	Total	Local Foreign	Total	Local Foreign			
<b>1. Water Supply and Sewerage System in Urban and Rural Areas</b>													
Public Organization													
CORDEPAZ	407	0	407	284	226	58	473	421	324	0	312	312	0
CORPAGUAS	9	9	0	4	4	0	27	27	60	0	128	128	0
Municipal Government	221	111	111	383	117	266	617	146	471	245	109	55	55
Ministry of Urban Affairs (MAU)	-	-	-	16	0	16	4	0	4	-	-	-	-
Ministry of Social Security and Public Health (MSPSSP)	-	-	-	-	-	-	7	0	7	-	-	-	-
Ministry of Labour	-	-	-	-	-	-	-	-	46	0	46	-	-
Ministry of Transport	-	-	-	150	0	150	17	0	17	-	-	-	-
Provincial Government	-	-	-	-	-	-	-	-	30	0	30	8	8
SAMAPA	1,611	1,386	225	9,261	5,240	4,021	22,217	6,874	15,343	18,375	3,210	15,164	5,552
UNICEF	-	-	-	28	0	28	-	-	-	-	-	-	-
Non Governmental Organization													
ADRA (Religious group)	-	-	-	21	0	21	468	0	468	138	0	138	-
CARITAS (Religious group)	-	-	-	-	-	-	-	-	184	0	184	-	-
COOP	119	0	119	60	0	60	-	-	-	-	-	-	-
Neighboring Group	-	-	-	18	0	18	31	0	31	-	-	-	-
Save the Children	-	-	-	-	-	-	28	0	28	-	-	-	-
Total	2,367	1,506	861	10,225	5,587	4,638	23,889	7,468	16,421	19,580	3,773	15,807	6,109
<b>2. Sewerage System in Urban Area</b>													
Public Organization													
CORDEPAZ	56	0	56	-	-	-	-	-	-	-	-	-	-
Municipal Government	61	31	31	74	37	37	56	28	28	103	51	51	55
Ministry of Urban Affairs (MAU)	-	-	-	8	0	8	2	0	2	-	-	-	-
Ministry of Labour	-	-	-	-	-	-	-	-	46	0	46	-	-
Ministry of Transport	-	-	-	150	0	150	17	0	17	-	-	-	-
SAMAPA	55	0	55	1,675	992	683	3,234	2,794	440	1,838	1,093	744	574
Non Governmental Organization													
ADRA (Religious group)	-	-	-	21	0	21	468	0	468	138	0	138	-
CARITAS (Religious group)	-	-	-	-	-	-	-	-	69	0	69	-	-
Neighboring Group	-	-	-	18	0	18	31	0	31	-	-	-	-
Total	172	31	142	1,947	1,029	918	3,808	2,822	985	2,193	1,145	1,049	683
													55
													629

Source: Ref.12

Notes: \*1 Religious groups