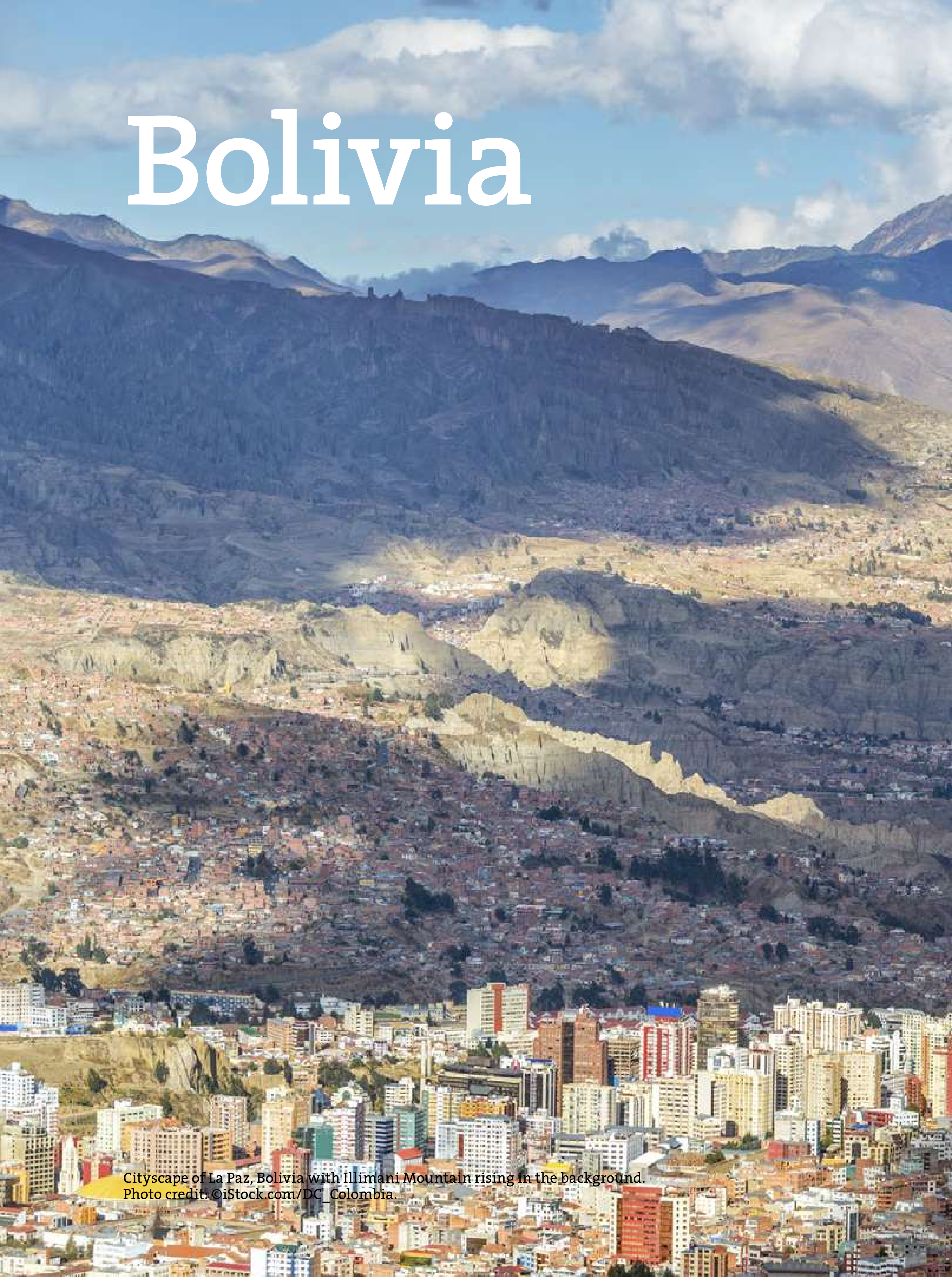
Bolivia



Cityscape of La Paz, Bolivia with Illimani Mountain rising in the background.
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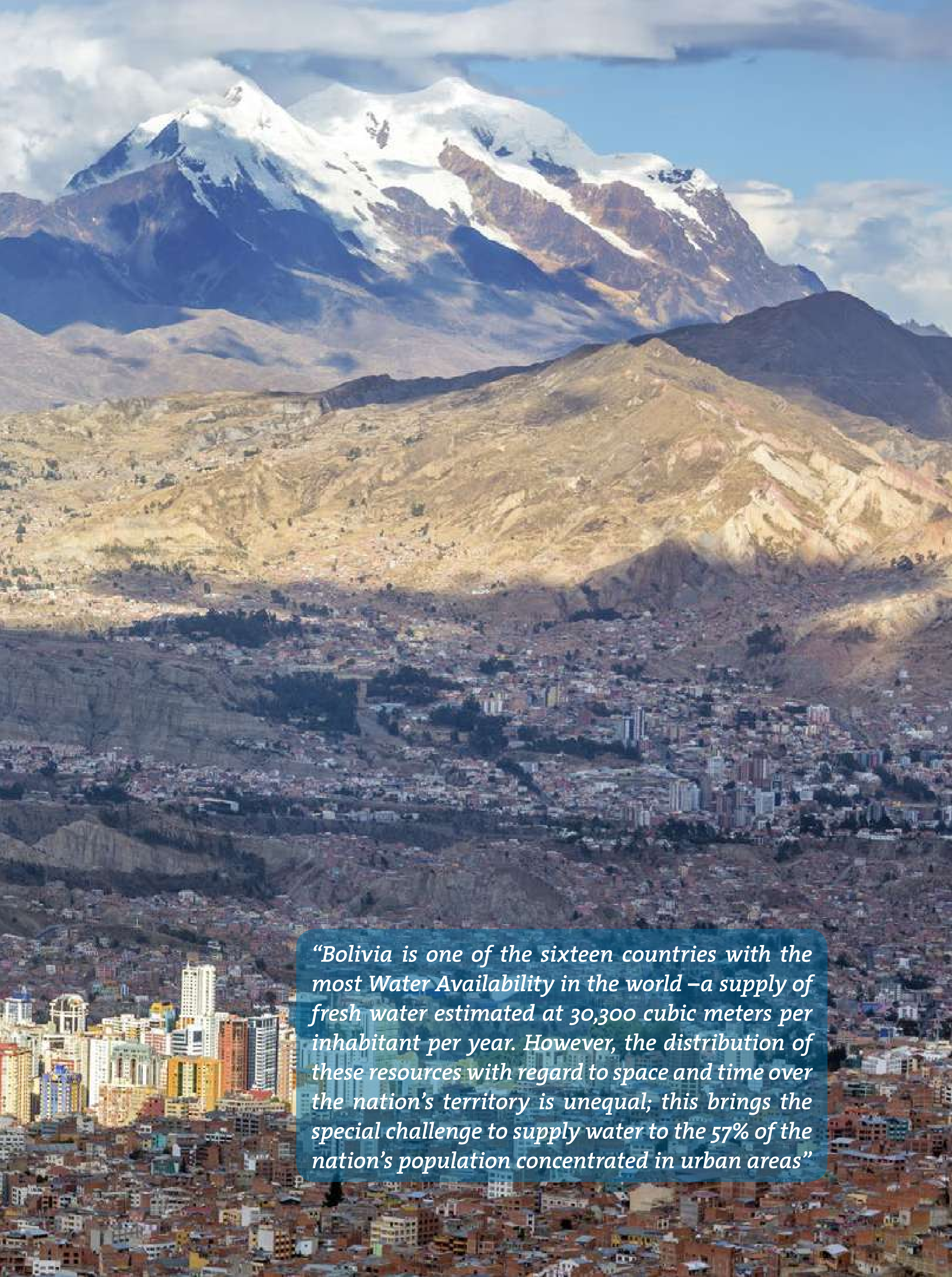

“Bolivia is one of the sixteen countries with the most Water Availability in the world –a supply of fresh water estimated at 30,300 cubic meters per inhabitant per year. However, the distribution of these resources with regard to space and time over the nation’s territory is unequal; this brings the special challenge to supply water to the 57% of the nation’s population concentrated in urban areas”

Compendium of the Water Resources in the Capital Cities of the Departments of Bolivia

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Summary

This study presents a compendium of the current use of water resources in Bolivia, with emphasis on the administration of the water cycle in the capital cities of the country's nine departments. It has been prepared for the Water Program of the Interamerican Network of the Academy of Science (IANAS) and contains some conclusions and recommendations for the Bolivian governmental authorities who regulate and administer water in the country. Since the National Population and Housing Census for 2012 (CNPV, 2012), carried out by the National Institute of Statistics (INE) has not yet been completely published, a combination has been used with the data from the prior CNPV, for 2001.

1. Introduction

Nine departments, with their respective capitals (See Figure 1.1), form the Plurinational State of Bolivia. They are the departments of La Paz, Oruro, Potosí, Cochabamba, Chuquisaca, Tarija, Pando, Beni and Santa Cruz. In these departments, there are 112 provinces, with 339 autonomous municipal governments.

The 2012 CNPV shows the total population of Bolivia, 10,027,254 inhabitants and a relative growth, between the 2001 CNPV and the 2012 CNPV, of 21.18, with an average annual growth of 1.71%. It also demonstrates that 71.1% of the population is concentrated in the La Paz, Santa Cruz and Cochabamba.

The 2012 CNVP also indicated that 57% of the nation's population live in urban areas and 42.5% live in the rural part of the country. inhabitants, departments of .

The Urban Metropolitan area of La Paz, comprising the cities of La Paz and El Alto, together with the cities of Santa Cruz de la Sierra Cochabamba, contains 60.2% of the urban population.

Table 1.1 shows the nine capitals and the city of El Alto (the Metropolitan Area of La Paz), and the volumes of water distributed in them. The city of Santa Cruz de la Sierra (14.5% of the national population), the City of La Paz (7.8%) and the city of El Alto (8.5%) presently have no major water supply problems. The supply of water to the capital cities of Cochabamba (6.3% of the nation's population), Oruro (2.64%), Sucre (2.59%), Tarija (2.0) and Potosí (1.89%) still show certain deficiencies. The supply of water to the capital cities of Trinidad (1.06%) and Cobija (0.4%) suffer severe shortages and severe weather impacts on their sources and distribution networks since their ductwork is obsolete, compromising the quality and quantity of water distributed to the population, even evidencing a limited water supply and daily rationing. It must be mentioned that all the Bolivian department capitals have problems of different degrees with their drainage and sanitary sewage system(for both domestic wastewater and rainwater).

Figure 1.1 Map of the Plurinational State of Bolivia and its Capital Cities

The 2001 CNPV found that 37.7% of the inhabited dwellings in the country do not have piped-in water. The 2012 CNPV shows that this percentage dropped slightly, to 33.9%, thus persisting as a common national problem requiring solution.

Table 1.1 Department Capital Cities

City	Number of Inhabitants[2]	Urban Radius Area (Km^2)	Number of Dwellings[3]	Volume of Water (liters/day)
La Paz /El Alto[1]	1,613,457	592	370,574	187,129,000
Santa Cruz	1,453,549	567	252,136	172,800,000
Cochabamba	630,587	108	123,477	73,785,000
Oruro	264,638	28.5	49,436	27,000,000
Sucre	259,388	33.9	49,979	25,435,000
Tarija	205,349	42	36,126	35,037,000
Potosí	189,652	31	35,182	18,064,000
Trinidad	106,422	23.5	15,588	10,500,000
Cobija	46,267	19.5	4,923	2,130,000
Total for all Cities	4,769,309	1,445.4	937,421	551,880,000
Total Bolivia	**10,027,254**	**1,098,581**	**1,977,665**	----

Notes: 1 La Paz Metropolitan Area; Cities of La Paz (population 764,617.) and El Alto (population 848,840.)
Source: In-house study based on the 2012 and 2001 CNPVs.

1.1 Bolivian Water Legislation and Standards

Water is often the cause of social and political strife. In addition, in Bolivia there is a close relationship between access to water and the conditions of poverty among the population. The lack of clean, safe water directly influences the health of the residents of Bolivia and their economic activity.

Bolivia still does not have a policy and a National Water Resources Administration Plan that contemplates the management of the water cycle. The water policy and the institutional situation are weak, incomplete and outdated. Its obsolete regulatory framework has prevented the creation of a modern, adequate administrative system contemplating the multiple sustainable uses for water, and has substantially weakened the national and local water authorities.

At present, Bolivia is still governed by the Water Ownership and Use Law, based on Supreme Decree (D.S.) dated September 8, 1879, which was promoted to the category of Law on November 28, 1906. It establishes the relationship between the State and its water resources. Sections of this law have been repealed by subsequent norms. Some of its provisions are still in force but are not enforced since they are unknown. There are also sectorial norms, passed before 2009 (e.g., the Irrigation Law), the forestry Law, the Environmental Law, the Drinking Water and Sanitary Sewage Law, et al) and institutional standard (e.g., the creation of a Ministry of Water, today known as the Ministry of Environment and Water; the Municipalities Law, the Administrative Decentralization Law, et al). These sectorial laws and regulations establish different, sometimes contradictory norms and deal in a limited way with sectorial water management.

There is still no government action reflecting a firm, decisive policy regarding the country's water resources management, despite recent strides in the norms, and the fact that the new Constitution, proclaimed on February 7, 2009 contains fourteen specific articles setting forth the state's present political vision regarding water. The most important of these are the following:

Article 373. I. *Water is a most basic right for life within the framework of sovereignty of the people. The State will promote the use of and access to water based on the principles of solidarity, complementarity, reciprocity, equity, diversity and sustainability.*

Article 373. II. *The surface and groundwater resources in every state constitute limited, vulnerable and strategic resources, and fulfill a social, cultural and environmental function. These resources may not be subject to private appropriation and neither these nor their services may be given up in concession.*

Article 374. I. *The State will protect and ensure the priority of the use of water to sustain life. It is the responsibility of the State to manage, regulate, protect and plan the adequate and sustainable use of water resources, with the participation of society, thus ensuring that all of its inhabitants have access to water. The Law will establish the conditions and limitations of all of its users.*

Article 375. I. *It is the responsibility of the State to formulate plans for the use, conservation, management and sustainable use of the watersheds.*

In addition, the current scenario of political "change" has fostered a predisposition on the part of the Federal Government to address the demands of the social organizations or movements –principally those of tenant farmers and the indigenous population (the native population), in many cases under the threat of conflicts, opening more or less formal scenarios of consensus or participation.

1.2 The Availability of Water

Bolivia is one of the sixteen countries with the most Water Availability in the world –a supply of fresh water estimated at 30,300 cubic meters per inhabitant per year. However, its distribution with regard to space and time over the nation's territory is unequal. There are regions with high rainfall (over 4,500 mm. per year) but in nearly half of the nation's territory this resource is scarce and there is a water deficit.

Bolivia is a country of both upstream (91%) and downstream (9%) waters. Its renewable internal water resources are estimated at 303 million cubic meters per year –the equivalent of 9,608 m^3/sec (Marka, 2009). The estimated 650 million cubic meters annually (FAO, 2000) of fresh water in Bolivia flow and fill four large internal basins.

a. The Amazon Macrobasin: Covers 65.9% of Bolivia's territory. About 572 million cubic meters per year flow down the Madera River to Brazil. The capital cities of La Paz/El Alto, Cochabamba, Santa Cruz de la Sierra, Trinidad and Cobija are located in this river basin.

b. The Plata Macrobasin: Covers 20.9 percent of the nation's territory. Its rivers, Pilcomayo, Paraguay and Bermejowhich have a a flow of 47,474 millions of cubic meters of water annually to Paraguay and Argentina. The capital cities of the Potosí, Sucre and Tarija departments are in this watershed.
c. The Central or Lake Macrobasin: : Covers 11.4% of the nation's territory. 14,700 cubic meters of water annually drain from Lake Titicaca and Lake Poopó, the Desaguadero River (with its Bolivian and Peruvian tributaries) and the major salt flats of Uyuni and Coipasa.
d. Pacific Ocean Macrobasin: : Covers only 1.8% of the territory, with almost no surface flow (rainfall of less than 100 mm. annually) and a significantan aquifer flow, consisting mainly in ancient waters (10,000 years old), flowing toward the Pacific Ocean in Northern Chile (the Loa River). This limited macro-basin has no major population settlement.

In the first three of the four above-mentioned macro-basins, the water with a quality fit for drinking and irrigation has, as its main drawback, the contamination caused by urban, mining, agriculture and industrial activities, which in many cases surpasses the maximum allowable limits for hazardous substances, and creates environmental problems.

There is no nationwide inventory or databank for aquifers and groundwaters, nor for the storage or recharge volumes. There are only records of studies, prospecting programs and the evaluation of a few specific zones. (GEOBOL, 1985).

In general, the temperature and rainfall increase from west to east across Bolivia. Depending on the zone, the average annual rainfall range varies from 100 mm. (in southeastern and southwestern Bolivia) to more than 4,500 mm.(in eastern and northeastern Bolivia). The rainy season is in the summer from November to March when sixty to eighty percent of precipitation falls in these five monthsThe runoff appears in great volumes on the plains of the Amazon macrobasin, but is negative when it causes flooding due to flows that exceed the watersheds carryingcapacity. This produces a negative impact on productive activities and infrastructure. The available weather data show that the Amazon macrobasin receives twice as much rain as the de la Plata River and four times more than the Central or Lakes macrobasin (Bolivian Water Balance, 1990). The difference is even greater in comparison with the Pacific Ocean macrobasin.

1.3 Use and Consumption of Water

Water consumption in Bolivia is estimated between 1,24 and 2 billion cubic meters annually –that is, only 0.3% of the estimated availability. The greatest water demand (94%) is for agriculture, for irrigation with canals and for open irrigation ditches (Van Damme, 2002). In second place is the demand for human consumption, from 110 to 125 million cubic meters annually. In urban areas water is used mainly for household purposes. Only seven of the nine

Table 1.2 irrigation systems and irrigated water by categories

Department	Micro		Small		Medium		Large		Total	
	Systems	Area (ha)	Systems	Area (ha)	Systems	Area (ha)	Systems	Area (ha)	Systems	Area (ha)
CHUQUISACA	275	1,653	373	11,370	26	4,261	4	3,884	678	21,168
COCHABAMBA	303	1,938	577	22,225	128	27,403	27	35,968	1,035	87,534
LA PAZ	263	1,703	665	21,047	28	6,052	5	7,192	961	35,994
ORURO	172	940	134	3,638	3	440	3	9,021	312	14,039
POTOSÍ	549	3,240	392	10,146	14	2,254	1	600	956	16,240
SANTA CRUZ	42	269	144	5,456	44	8,434	2	1,080	232	15,239
TARIJA	129	785	331	12,755	83	17,101	7	5,710	550	36,351
Total	1,733	10,528	2,616	86,638	326	65,944	49	63,454	4,724	226,564

Source: In-house document based on 2001 and 2012 CNPV.

departmental capitals have permanent, twenty-four-hour-a-day water service.

Despite the significant increase in drinking water service coverage, around 33.9% of all dwellings –over 2.81 million dwellings according to the 2012 CNPV– still lack piped-in water.

The transfer of responsibility for providing drinking water and sewage services to the autonomous municipal governments has created many conflicts because human consumption has priority over other uses. The greatest intrasectorial and intersectorial conflicts are in the irrigation sector –especially where water is scarce.

1.4 Administration of the Water Cycle in Urban Areas

At present, the federal Bolivian authority which administers water supply in the urban and rural areas is the Taxation and Social Control Authority for Drinking Water and Basic Sanitation (A.A.P.S.) of the Ministry of the Environment and Water Resources. This body was created in 2009 by Supreme Decree ("D.S.") No. 0071 to tax, control, supervise and regulate drinking water and basic sanitation under the Drinking Water and Sanitation Sewerage Law No. 2066.

The A.A.P.S. comprises a Board presided over by the Minister of the Environment and Water. Its members are the Vice-Minister for Drinking Water and Basic Sanitation, the Vice-Minister for Water Resources and Irrigation and two social representatives from the Technical Committees for Registration and Licensing (CTRL). The Board receives, studies and grants the right to provide drinking water and/or sanitary sewerage services and to regulate licenses and registrations for water use. Table 1.3 shows the administrative structures which provide local water supply services in the departmental capitals.

For the drinking water and sanitation sector, the urban region comprises four types of cities, identified according to their population: metropolis, large cities, intermediate cities and small cities. According to the 2012 CNPV and estimates for 2005, there are three metropoli: La Paz/El Alto, Cochabamba and Santa Cruz (56.6% of the urban population and 26.9% of the total population); nine large cities (12.3 percent of the urban population), 25 intermediate cities (5.5%) and 65 small cities (3.2%), with decreasing population growth. There is no official distinction of periurban as a function of the size of the population. It is simply assumed that it comprises the areas surrounding these four types of cities.

1.5 Sources of Water in Urban Zones and the Impacts of Urbanization

In the metropolis and the departmental cities of Bolivia (including the city of El Alto), the supply of basic services such as piped-in drinking water has not kept pace with either the population growth or the demand, but has been characterized by low investments, poor maintenance and the poor quality of basic services. This has caused health problems and discontinuityin the water supply.

Most of the services are in public hands (mainly municipal governments) and their rates have always been subsidized. They do not meet the costs of operation and maintenance. These conditions have prevailed despite efforts for privatization in the cities of La Paz/El Alto (the waters of Illimani) and Cochabamba (the waters of the Tunari – the "Water War" of 2000). There is limited and insufficient coordination among the A.A.P.S., the municipal authorities and the departmental governments.

Briefly, in the departmental capitals, 44% of the drinking water and sanitary sewerage system have some type of state (municipal) administration; another 44% have a co-operative administration while the remaining 12%, have joint, undefined administration. For lack of funds, the water does not reach the entire population. Accordingly, local initiatives have emergedspontaneouly for the construction of small systems, or to seek alternate sources of water supply such as tank trucks or the unauthorized drilling of shallow wells.

The intermediate cities develop their own administration and management of drinking water and sanitary sewerage. They had such programs as CORPAGUAS (Water Corporation) which offered technical assistance for their organization. The National Regional Development Fund (FNDR) and the Social Investment Fund (FIS) also provide pre-investment funds. The incumbent Federal Government has in place an investment program, known as "My Water", now in its third stage, to improve water services in cities and in the rural villages.

With regard to environmental protection, the A.A.P.S. does not exercise effective control over the water cycles. The capital cities and other intermediate and small urban areas do not have specific plans or effective environmental control systems for the protection of surface or groundwater. Its sanitation programs are limited to the canalization and piping of rivers and streams. The largest cities have limited tree-planting programs in the periurban areas. The municipal authorities take a permissive attitude regarding environmental control, and if it is carried out at all, it is limited to such points of industrial contamination as breweries, sugar mills, tanneries and others. There is strict follow-up of contamination from large-scale private mining companies, with little attention being paid to the many mining co-operatives and small mining companies.

2. Drinking Water Service Coverage

The partially published 2012 CNPV provides data regarding the department-by-department coverage

Table 1.3 type of administration and flow offered in the departmental capital cities

City	Administration	Water supply	Flow (liters/second) (lt/seg)
La Paz / El Alto	EPSAS S.A. (A quasi-governmental company))	8 sources of water from melting: Tuni, Condoriri, Huayna Potosí, Milluni, Choqueyapu, Incachaca, Ajan Khota, Hampaturi Bajo. Tilala System (30 water wells)	Rango: 2,011 – 3,000
Santa Cruz	SAGUAPAC (Cooperative)	Groundwater	Range: 347 – 2,067
	9 small private cooperatives	Surface water sources	722
Cochabamba	SEMAPA (Municipally operated company))	Surface water sources: Escalerani, Wara Wara, Hierbabuenani and Chungara	Range: 191 – 404
		Groundwater: Quillacollo	462
Sucre	ELAPAS (Municipally operated company))	Surface water sources: The Cajamarca system, which includes the Cajamarca, Safiri, and Punilla rivers	80
		Surface water sources: The Ravelo system, including the Ravelo Ravelo, Peras Mayum Jalaqueri, Murillo and Fisculco rivers.	390
Oruro	Local Aqueduct and Sewerage Service and - SeLA ((Municipally operated company)	Surface water sources: The Sepulturas and Huayña Porto Rivers	34
		Groundwater: (Challa Pampa, Challa Pampita and Airport)	528
Potosí	AAPOS (Community-owned Company))	Surface water sources: San Juan river and 21 lakes (Khari Khari, Tarapaya, Irupampa, Illimani, Challuna)	220
Trinidad	COATRI (Cooperative)	Groundwater	118
Tarija	COSAALT (Cooperative))	Surface waters: Rincón, La Victoria, Guadalquivir and San Jacinto Rivers	574
		Groundwater	279
Cobija	COSAPCO (Cooperative)	Surface waters: Bahía Creek	24

Source: In-house document based on data furnished by the operators.

Table 2.1 Piped-in water distribution to dwellings

Department	% Total Coverage	% Total Coverage	% Total Coverage	% Total Urban Area Coverage %	Total Urban Area Coverage
Source of Information	BM (1999)	INE (2001)	INE (2012)	OPS (2001)	INE (2001)
Chuquisaca	52	53.9	39.1	86.6	86.0
Cochabamba	66	53.9	54.4	70.5	68.6
La paz	80	65.5	70.6	99.9	85.6
Oruro	74	57.5	63.6	90.3	85.6
Potosí	52	44.0	55.6	81.3	86.5
Tarija	73	75.5	81.5	90.3	90.8
Santa cruz	83	77.7	82.3	94.2	90.4
Beni	57	35.1	40.8	---	47.6
Pando	31	38.6	32.0	---	73.5

Source: In-house document using data from 2001 and 2012 CNPVs.

of water services, sanitation sewerage and other services. (See Table 2.1). There are no city-by-city data; accordingly, a complete analysis cannot be performed.

The data analyzed and presented in Tables 2.2 to 2.4 are based on the 2001 CNPV. There are major discrepancies between the distribution of water between the urban and rural areas, and in the distribution by ductwork systems. In rural areas, over 43% of water used in homes comes from wells, waterwheels and surface sources such as rivers and streams.

2.1 Contamination of urban water

Practically all of the nation's urban centers lack modern domestic and rainwater drainage. Improvements in street pavement and the canalizing of rivers and streams are the cause of major problems in surface rainwater runoff. They represent one of the main problems affecting the environment and public health. The degree of contamination of the rivers and streams that run through the main departmental capitals and other intermediate and small urban centers is high and alarming.

A . Domestic urban contamination

Due to the increasing number of residents in the different cities, domestic contamination affects the rivers with which they are in contact. The load of organic contaminants in these rivers is extremely high –being estimated at more than 100 mg. per liter.

Only 40% to 60% of garbage, or solid waste, is collected by municipal services and treated in adequate landfills (see Table 2.5). The remainder of urban waste is clandestinely dumped in rivers, ravines, streets and storm drains, which causes these collectors to be plugged.

Due to the permanent demand for urbanized land and new urban thoroughfares, the banks of the river have been occupied. These occupations are irregular and not according to norms. However, the weak municipal governments allow the occupation of these high geological risk areas. The inadequate urban control prevents these areas, which are indispensable to the maintenance and safety of the water infrastructure, from receiving adequate ecological handling, thus affecting the course of the rivers.

In 1993, JICA and HAM estimated that 403,000 persons discharged wastewater into the River Choqueyapu from La Paz. This is the equivalent of a discharge of three million cubic meters annually. In the cities of Santa Cruz and Cochabamba, discharges were of the same magnitude. Today, with urban growth, the discharges are surely even greater. .

The overworking of dry lands in the high and low parts of the rivers endangers the safety of their slopes. In addition, unauthorized earthworks and

Table 2.2 Distribution of water in dwellings

System	Urban Area		Rural Area	
	Total dwellings	%	Total	%
Piped-in Water.	%	82.93	766,703	26.63
Public Water Pools		5.33		10.78
Well or Waterwheel with Pump		1.93		5.99
Well or Waterwheel without Pump		3.45		22.00
River, Slope or Channel or Canal		0.93		27.65
Lake, Pond or Pool		0.10		2.07
Tank Truck (Water Cart)		3.15		0.34
Other		2.18		1.54

Fuente: Elaboración propia con base en datos del CNPV 2001.

Table 2.3 Distribution of piped-in water

System	Urban area %	Rural area %
Inside the Dwelling	44.78	4.86
Outside the Dwelling but on the Lot	46.89	47.19
Outside Dwelling Lot	2.03	6.35
No Piped-in Water	6.30	41.57

Table 2.4 Sanitation service for dwellings

Availability	% Urban area	Rural area
Has	88.36	42.32
Does not have	11.64	57.68
Type of use	**Urban %**	**Rural %**
Private	63.82	36.12
Shared	24.54	6.20
No Bathroom	11.64	57.68
Bathroom or latrine drain	**Área urbana %**	**Área rural %**
Sewer	55.25	2.07
Septic Tank	12.51	4.08
Cesspool	19.66	34.27
Surface (street/river)	0.94	1.90
No bathroom	11.64	57.68

Source: In-house document based on 2001 CNPV data

Table 2.5 Garbage collection in the cities according to source (in metric tons)

Source	2008	2009	2010	2011
Total	**873,728**	**954,628**	**995,519**	**1,010,192**
Household	712,998	954,629	995,519	782,339
Public Spaces	63,008	62,070	70,469	57,273
Markets	52,848	59,064	73,263	68,428
Hospitals	7,254	7,309	9,642	11,267
Other	37,620	90,627	84,158	90,885

Source: Statistical Report on the Environment in Bolivia. 2012 .

clandestine settlements cause erosion of the slopes and greater flows of surface runoff, provoking mudslides and geo-hydrotectonic disasters.

B. Industrial contamination

In Bolivia there are approximately 15,000 industries. About ninety percent of them are small (one to ten employees), such as artisan workshops. Eighty percent are in the cities of La Paz, El Alto, Oruro, Cochabamba and Santa Cruz. The main industrial sectors are metallurgy, metal finishing, industrial minerals, chemicals, shoemaking and tanneries, and the textile, paper and food industries. They produce large quantities of liquid effluents, mixed with solids which add to the organic contamination coming from sewers in the urban areas. Generally, industrial wastewater and urban wastewater are discharged into the rivers. This makes it difficult to calculate the degree of contamination caused by industry alone.

The use of water in industrial activities is, in large measure, linked with the consumption of drinking water in the cities, since a high percentage is found in the urban or suburban area (for example, 67% in Cochabampa.) Very often, the factories or industries have their own source of water (generally a shallow well) and a contract with the basic sanitation company to discharge wastewater. The lack of adequate control means that these discharges give rise to major contamination processes which are often later used downstream for human consumption and nonindustrial agricultural irrigation.

C. Contamination from mining activities

Historically, the most important base of the national economy has been mining activity. This activity is presently concentrated in the Andean highlands and is carried out by the state-operated C*orporation Minera de Bolivia* (COMIBOL), small and medium-sized private companies and the growing co-operative mining sector.

For its settlements and mills, access to water resources is part of the mining concession or contract. Wastewater must be restored to the original waterways in equal quantity and quality, but this rarely happens. Both in the Andean zone –with traditional mining– and in the Amazon regions –with their processing of mercury– major contamination problems have arisen in the surface runoff and surface and deepacuifers.

The rivers most severely affected by mining contamination are in the Pilcomayo watershed (the Tupiza, Cotagaita, Tumusla and Pilcomayo rivers), of the Caine-Grande River (the Chayanta river) and the lake of Poopó (the Huanuni and Santa Fe rivers, among others).

Mining activities produce the following environmental problems:

- The generation of acid rock drainage (DAR).
- Contamination of rivers with heavy metals, and the degradation of the water ecosystems Contamination of groundwater reservoirs.
- Contamination of the soil, and of crops irrigated with contaminated water.
- Accumulation of metals in closed lakes.

3.Wastewater Treatment Systems in Bolivia's Capital Cities

In Bolivia, many of the intermediate and large cities and towns have sanitary sewage systems with no type of wastewater treatment. In most cases, they dischargewastewaters directly into such natural bodies of water as rivers or lakes. However, around three thousand liters of wastewater per second are treated in the different capital cities (See Table 3.1).

The overall outlook for wastewater treatment in Bolivia may be summarized in three situations:

- No treatment –discharged directly into a river, or else there are latrines.
- With primary treatment (septic and Imhoff tanks)
- With treatment in secondary or tertiary stabilization ponds

Table 3.3 offers a summary of the types of treatment existing in the country's departmental capitals. Most of these treatment systems have limited capacities or operate poorly for the following reasons:

- Weather conditions (low temperatures throughout the highland region)
- Water and organic overloading due to poor design or unforeseen population growth
- Lack of maintenance and operation due to insufficient economic resources
- Lack of projects for the reuse of treated water.

The reuse of wastewater in agriculture offers the following advantages: multiple uses of a scarce resource, recycling of nutrients, the prevention of river contamination and the supply of municipal water at a low cost (Van der Hoek, 2002). It involves, however, the following risks: (a) contamination of the soil with chemicals and heavy metals, and (b) the threat of the presence of water from zones where household wastewater and industrial wastewater are not separated. It is very important to seek solutions to urban and industrial contamination which optimize the economic benefits to farmers and, at the same time, minimize the health risks.

Table 3.1 Volume of wastewater treated by capital city (In liters per second)

Capital City	2008	2009	2010
La Paz/El Alto	s.d.	s.d.	s.d.
Santa Cruz	1,009	1,053	1,116
Cochabamba	795	655	522
Oruro	245	750	750
Sucre	140	152	145
Potosí	13	125	132
Tarija	162	167	174
Trinidad	74	76	76
Cobija	s.d.	s.d.	s.d.
TOTAL	**2,478**	**3,022**	**2,966**

Source: Statistical Report on the Environment in Bolivia, 2012.

Table 3.2 Shows in detail the quantities of wastewater generated in the capital cities.

Quantities of wastewater generated in capital cities in 2001			
Capital City	Urban Population	Wastewater discharge in liters per second	Volume
La Paz/El Alto	1,549,759	1,291.50	40.70
Santa Cruz	1,543,429	1,286.20	40.60
Cochabamba	855,277	712.70	22.50
Oruro	237,286	197.70	6.20
Sucre	217,019	180.80	5.70
Potosí	237,576	198.00	6.20
Tarija	247,690	206.40	6.50
Trinidad	244,207	203.50	6.40
Cobija	20,987	17.50	0.60
Total	**5,133,230**	**4,294.40**	**135.40**

Source: Durán et. al., 2002.

Table 3.3 Water treatment systems in Bolivia's Capital Cities

Treatment system	Type of treatment	Treatment capacity (design) q (liters per second) uantity	Present treatment of tributary q (liters per second) uantity	Effluent
Alba Rancho, Cochabamba (1986)	12 stabilization ponds (8 for secondary treatment; 4 for tertiary treatment)	400	568	290.0
Industrial Park Ponds, , Santa Cruz (1980)	6 stabilization ponds (5 in service) in series with tertiary treatment	27.2	27.1	26.7
Lagunas Norte Viejas, Santa Cruz (1970)	4 stabilization ponds operating in a facultative anaerobic system	102.8	102.9	102.7
New Ponds o North, Santa Cruz (1989)	4 stabilization ponds operating in series as a facultative finishing system	251.7	254.9	247.0
La Tabladita, Tarija (1992)	2 stabilization tanks (primary anaerobic treatment), 2 tanks (1 for secondary and 1 for tertiary treatment)	63.4	133	108.1
Puchuckollo, El Alto	12 stabilization tanks in 2 series, each with 6 ponds	446	267	248

Source: In-house document, using data gathered from the treatment plants

3.1 Multiple Uses of Water in Urban and Suburban Zones

Most capital cities do not perform any type of water purification treatment before distribution. Accordingly, the quality of the water distributed depends exclusively on the quality of the source. .

The main users of water in the capital cities are the urban population (for home use), industry, and irrigators. The latter are generally in the periurban areas. There is an interdependence among these sectors: the irrigators produce vegetables and fruit to supply urban markets, and irrigate their land with a resource which, thanks to the increasing demand from populated areas, is increasingly scarce. This intensifies the pressure on both surface and groundwater resources.

One of the strategies adopted to maximize the use of water is the use of urban wastewater for agricultural irrigation. This application is not universal throughout the country but is applied only in the Andean regions, highlands and valleys. The use of wastewater in these regions may be classified as follows:

A. **Direct Use.** That is, when they are carried from the outlet (either from the sewer or the treatment plant) directly to the plots of land, or as the result of intentional breakage of the sewage pipe to use it for irrigation purposes. Wastewater, whether treated or not, is not diluted before use. This is common in Andean zones where water is scarce. Its use is formal when supported by a formal settlement or other type of agreement.

B. **Indirect Use.** This means the use of water from rivers where wastewaters are discharged, a minority of which is first treated;therefore diluted. This happens in most of Bolivia and in almost all the rural and periurban areas of Bolivia downstream from the departmental capital cities.

3.2 Contamination of groundwater

The degree of contamination of surface and groundwater is not fully documented. However, groundwater is the most sensitive to all manner of contamination, since groundwater flows at lower, almost nonexistent speeds. For the contamination of groundwater there are isolated data for the Cochabamba Valley (Renner and Velasco, 2000); Oruro (PPO, 1996); (Huaranca, Olivera Neumann-Redlin, 2000), and el the Northern Highlands (ZONISIG, 2000). Other data are contained in several scattered and unpublished reports .

In Bolivia, , a large part of the groundwater is unfit for either human consumption or irrigation due to high salinity factors. Studies on the use of the country's water show that when the supply is limited, as happens in the cities of Santa Cruz, Cochabamba and El Alto, the industries resort to the immediate alternative of drilling unauthorized wells. This causes the over-exploitation of the aquifer, damaging it for other uses. Generally, these are waters with low to medium salinity and water with low sodium content which may be used for most crops in almost all types of soil. (Renner and Velasco, 2000).

The groundwater in the urbanized areas (Santa Cruz, Oruro, El Alto, Trinidad) are threatened with industrial, agricultural and, above all, domestic contamination. In the urban areas of most of the capital cities, the infiltration of liquids leached from sanitary landfills presents a serious problem.

4. Drinking Water, Sanitation and Health in the Departmental Capital Cities

There is no undisputable system for the supply of sufficient fresh water or drinking water in the country. This term takes in its bacteriological safety. The existence of contaminated water in Bolivian cities is very common. This represents a permanent threat to the health of her inhabitants and means high rates of water-related diseases including dengue, malaria, typhoid fever, salmonellosis, diarrhea and parasitosis.

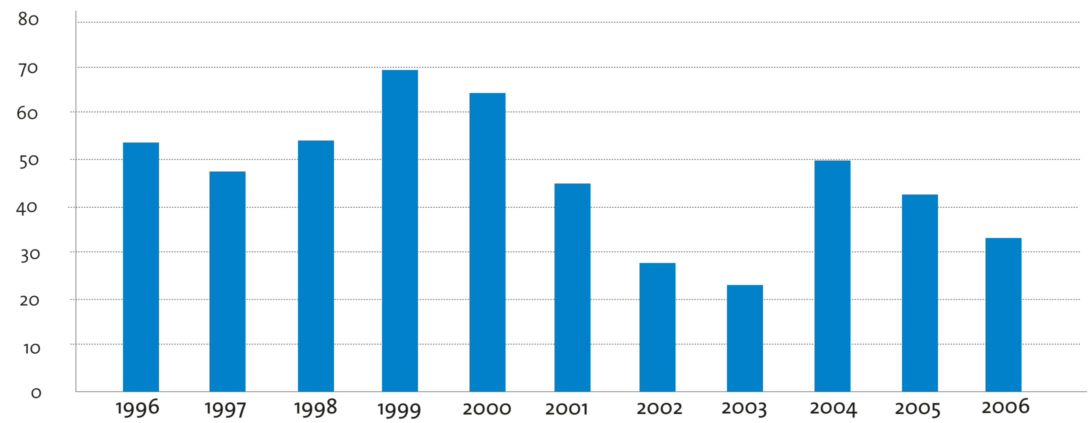
Drinking water and sanitation coverage in Bolivia has increased considerably since 1990, with heavy investments in this sector. However, the coverage is still the lowest in the continent and the quality of the service is mediocre. Political and

Table 3.4 Gives an idea of the general reuse characteristics of wastewater in the nation's different departmental capitals

Characteristics of the use of wastewater in the periurban areas of the departmental capitals and in the city of El Alto	
Capital City	Characteristics
Cochabamba	Direct use of the drainage from the treatment plant and indirect due to the use of the contaminated water from the Rocha River.
La Paz	Indirect use, through the drainage from the Río Choqueyapu river, where the sewage discharges, and from industry with no prior treatment.
El Alto (metropolitan area)	Indirect use from the Seco Seco River where wastewater from the Puchuckollo wastewater treatment is discharged.
Oruro	No reuse. The treatment plant discharges onto salt plains unfit for agriculture.
Trinidad, Cobija, Santa Cruz	No reuse. These are areas with heavy rainfall, where there is no irrigation.
Tarija, Sucre, Potosí	No data available

Source: Villarroel, 2001.

Chart 4.1 Shows the public investments made in the drinking water and sewer system sector between 1996 and 2006. They totaled 511 million dollars. However, this amount was insufficient to meet urgent needs.



institutional instability have served to weaken both federal institutions and many local institutions. The lowest degrees of coverage are found in the departmental capitals of Pando, Potosí and Oruro.

According to the WHO, in 2000 only 26% of urban systems offered disinfection, and 25% of the sewage was treated. According to the German Gtz study, in 2011 only 30% of the sewage collected was treated while 70% of the waters treated were inadequately treated because the sewage treatment plants did not operate properly.

The last three decades have revealed the fragility of the institutional framework of the sector, since it has undergone repeated restructuring as the result of the continuous turnover of the Federal Government. During the second administration of Hugo Banzer (1997-2001), the institutional framework of the sector was restored by Public Law 2029 issued in 1999, which established the legal framework for private sector participation and formalized the existence of a regulating body, the SISAB. The private sector received a concession for drinking water and sanitation services in La Paz/El Alto, granted to the company Aguas de Illimani, S.A. (AISA), a subsidiary of the French company SUEZ (which at that time was Lyonnaise de Eaux), in 1997, while in 1999 the system for Cochabamba was granted to Aguas de Tuman, a subsidiary of the multinational companies Biwater and Bechtel.

Due to two popular uprisings protesting the privatization of water –the first in Cochabamba in April 2000 (the Water War) and the second in El Alto in January 2005– these two concessions were cancelled.

The political platform of President Evo Morales for the 2006 elections proclaimed that "Water cannot be a privately run business because (if it turns into a commodity) it will be violating human rights. Water resources must be a public service." Accordingly, he created the Ministry of Water (now the Ministry of the Environment) in the institutional framework established in Public Law 2029 for Drinking Water and Sewerage Services, passed in 1999, revised and complemented in 2000 and with Public Law No. 2066. Morales' government is contemplating a new drinking water and sanitary sewerage service to be known as "Water for Life," which has not yet been approved.

The National Service in Support of Basic Sanitation Sustainability (SENASBA) is responsible for the planning and, in part, the implementation of community development, the promotion of hygiene and technical assistance to the service providers. In the cities, the municipal governments, either directly or through municipal service companies, are responsible for the administration and operation of these services. They are also responsible for formulating plans and programs for the expansion of the services in their area of jurisdiction in coordination with the Departmental Governments.

5. Description of the Sources of Water in the Departmental Capital Cities

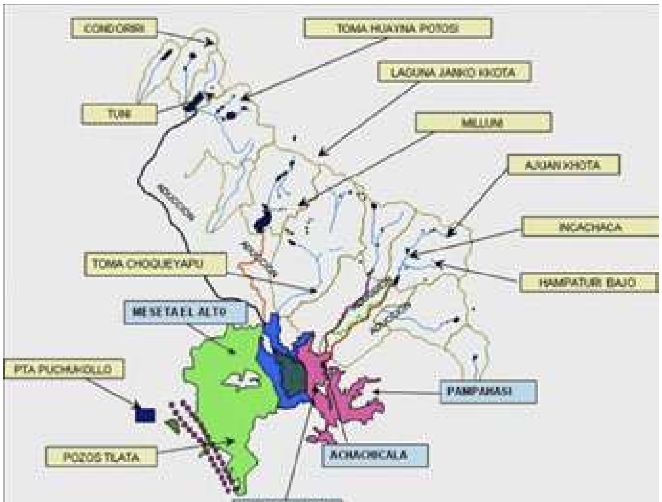
5.1 The LaPaz/El Alto Metropolitan Area

This treatise considers both cities La Paz/El Alto as the Metropolitan Area. The criteria used in defining the name “metropolitan area” are the following: continuing urban sprawl, and the relationship flow between both cities, including the public transportation system, the provision of basic drinking water, electric energy, public transportation and communications services. This creates a highly dynamic scenario, which consolidates the relationship between the two cities. However, they do not have the same quality and coverage of public services, especially with the supply and use of water.

5.1.1 Hydrology and Hydrogeology

The configuration and physical structure of the urban sprawl of the city of La Paz are influenced by the water network, comprising five water basins, which make up the La Paz River basin. It also has some 350 tributary ravines which open into rivers, streams and creeks which cause landslides and highly dangerous flash floods during the rainy reason. This water serves as a clandestine dump for approximately 100 metric tons of waste and rubble daily.

Figure 5.1 Layout of Water Sources and Systems for the Metropolitan Area



Source: EPSAS, La Paz.

A. The Rio de la Paz Basin . The formation of the Río de la Paz drainage network is parallel, due to the presence of uniformly spaced and relatively parallel rivers running from North to South. Its headwaters are in the snows of Chacaltaya, with the name Rio Kaluyo, which would later be changed to the Choqueyapu River, which runs all the way across the city of La Paz. It joins the secondary Orkojahuira River (known upstream as the Chuquiaguillo), the Irpavi and Hampaturi Rivers (known upstream as Khallapa and Mikhaya), and the Achumani and Huañajahuira Rivers to form the Río de la Paz, or La Paz River in the southern part of the Municipality, emptying its waters into the Amazon Basin. This basin has an area of 535 square kilometers and covers the entire urban area. (Núñez, 2004).
B. The City of El Alto , in the middle of the Bolivian highlands, at an elevation of 4,035 meters above sea level, has shallow ravines that cut through the fluvial-glacial quaternaries which, during the rainy season fill with water and tend to flood the lower parts of the city. The major ravines run North to South and are nearly parallel:
    a. The one known as Rio Seco (dry river) crosses the highway in route to Lake Titicaca and Peru.
    b. The Sake River ravine, which originates in the Milluni dam.

5.1.2 The Drinking Water Supply

The La Paz/El Alto Metropolitan area has a population of 1,613,457 inhabitants (CNPV, 2012) and a total of 370,574 dwellings. Of these, 86.35% receive piped-in water furnished by the Public Social Water and Sanitation Company (EPSAS), The population with drinking water service in the city of La Paz numbers 764,060 inhabitants, establishing a coverage of 91% according to EPSAS. This does not include around 30,000 inhabitants (4,763 water connections) served by 38 co-operatives from the slopes (the source of water from natural springs), who experience problems with the quality of their service. This increasesthe degree of coverage to 94.5%

For El Alto, the population with drinking water service numbers 981,812 inhabitants, with a coverage of 99%. (See Table 5.1 and Figure 5.2). In the city of La Paz there are three distribution systems which receive flows of water generated by the ice covering the mountain peaks of over 5,000 meters above sea level. The plateau system in the city of El Alto is also fed by glacial waters, while the Tilata system depends on 30 groundwater wells.

According to the EPSAS plans for 2011, the area covered by the drinking water piping network is 7,583 hectares (La Paz) and 13,455 hectares (El Alto), for a total of 21,028 hectares. This represents 80% of the potential service area. EDPSAS has records to show that the population with drinking water in both cities –La Paz and El Alto and their adjacent areas (Acholaca and Viacha)– reach 1,745,872 inhabitants. (See Table 5.1). This is an overall service coverage of 95%, and there are 312,117 active connections.

5.1.3 Sewerage Services

According to EPSAS (2011), a total of 1,376,562 inhabitants of the La Paz Metropolitan Area have sewerage service, out of a projected total of 1,836,737 inhabitants. (See Table 5.2). The overall coverage is 75%, with 216,866 active sanitary sewer connections. The present sewage service covers 6,372 hectares (La Paz) and 8,653 hectares (El Alto), for a total of 15,025 hectares. This means that the sanitary sewerage system covers only 57.2% of the potential service area.

Table 5.1 System-by-system drinking water service and connection area

System	Population in 2011	Area ((hectares)	Number of connections
Achacachi	215,028	1,256	
Pampahasi	256,048	3,937	
El Alto (La Paz Slope)	292,984	2,391	
La Paz – Population Served/Area with Piped-in Water	764,060	7,583	119,044
La Paz – Projection/ /Total Area	840,593	11,516	
La Paz Coverage	90.9%	65.8%	
El Alto (Plateau)	805,688	9,133	
El Alto (Tilata)	176,124	4,311	
El Alto – Population Served/Area with Piped-in Water	981,812	13,445	193,073
El Alto – Projection//Total Area	995,144	14,748	
El Alto Coverage	98.7%	91.0%	
Total – Population Served/Area with Piped-in Water	1,745,872	21,028	
Total – Projected Population/./Total Area	1,835,737	26,264	
La Paz/El Alto Coverage / TOTAL CONNECTIONS	**95.0%**	**80.0%**	**312,117**

Source: In-house document based on data from EPSAS in La Paz.

Table 5.2 Current sanitary sewer service and connections by systems

System	Population 2011	Area	Number of EPSA Connections
La Paz Serviced/Area with Piped-in Water	792,290	6,372	100,938
La Paz – Projection /Total Area	840,593	11,516	
La Paz Coverage	94.3%	55.3%	
El Alto – Serviced/Piped-in Water	584,272	8,653	115,928
El Alto – Projection /Total Area	995,144	14,748	
El Alto. Coverage	58.7%	58.7%	
Total – Serviced/Area with Piped-in Water	1,376,562	15,025	
Total – Projection /Total Area	1,836,737	26,264	
La Paz – El Alto Total Coverage	**75.0%**	**57.2%**	**216,866**

Source: EPSAS, 2011.

5.2 Santa Cruz de la Sierra - Capital city of the Department of Santa Cruz

Santa Cruz de la Sierra is the city which has undergone major transformations as the result of high growth and migration, thus requiring a continuous search for infrastructure and service solutions. It has a population of 1,114,095 (CNPV, 2011) and 252,136 dwellings. Of these, 91.74% have piped-in water. It is located on the right bank of the Pirai River. The city occupies an area of 567 square kilometers and has a perimeter of 110.2 km. The climate in Santa Cruz de la Sierra is warm and subtropical, with an average annual rainfall of 1,300 mm, and the heaviest rains in January and February.

5.2.1 Hydrology and Hydrogeology

The Pirai river, to the west of the city, with a flow of approximately 5,000 m^3/sec, crosses the city from north to south. It is also located between two major basins –that of the Grande (or Guapay) and Yapacani Rivers– all in the Amazon macrobasin. During 1990 and 1991, for the protection of the city, protection projects were carried out, covering a stretch of 15 kilometers running the length of the river. Practically one-hundred percent of the aggregates used to build the city of Santa Cruz de la Sierra and its environs come from the bed of the Pirai River.

At the end of the high Piraí River basin there is an enormous alluvial cone, which is confused with the alluvial cone of the Grande River and serves as the aquifer which is the source of drinking water for the city of Santa Cruz de la Sierra and the villages downstream from that city. The groundwater is of excellent quality for human and industrial consumption, and cooperatives of public and industrial services; it need only be chlorinated to be usable. The aquifer's recharge area are composed of the clastic deposits of the vast alluvial plain formed by layers of varying thickness of silty sand (SM), interspersed with low-compressble clay (CL). In addition, the aquifer receives rainwater and, to a lesser extent, infiltrations from the Piraí River and its tributaries.

In the city of Santa Cruz de la Sierra, where a substantial part of the demand for water is located, the absence for years of sanitary sewage has caused the contamination of the aquifers nearest the surface, due to the infiltration of untreated household wastewater. This has made it necessary to capture water from greater depths. At present, there are borings from depths of over three hundred meters.

5.2.2 The Drinking Water Supply

The drinking water supply system in the city of Santa Cruz de la Sierra depends exclusively on groundwater. Since 1979, this service has been furnished by the Drinking Water and Sanitary Sewerage Services Co-operative (SAGUAPAC). There are some other independent co-operatives which furnish only drinking water supply services.

SAGUAPAC is a co-operative and each owner of a water connection becomes a partner and co-owner, with the right to voice and vote. The co-operative seeks the well-being of its members, not monetary reward. SAGUAPAC has a rate structure with different social with different price levels according to characteristics of use: residential use, business use, industrial use and special use (hospitals, public schools, Government offices etc.)

SAGUAPAC operates the aquifers located in cretaceous and tertiary sediment more than five-hundred meters deep below the city of Santa Cruz de la Sierra, using for this purpose a group of sixty-one wells located in four fields (south, southwest, north and northeast), with four pumping stations, six storage tanks with a capacity of 29,000 cubic meters, a distribution net of 2907 km which hasan annual production (in 2003) of fifty-one million cubic meters. Taking into account the operation and recharge projections, some studies, , claim that by 2017 it will be necessary to incorporate an additional water source. SAGUAPAC has hydrogeological data about the aquifer's area of influence and has future, sustainable operation projects –that is, controlled extraction and supervision and follow-up on the aquifer's recharge.

The administrative structure of SAGUAPAC is complicated, but has been imitated in other South American cities. It has available a concession covering a specific area divided into nine districts. Each of these has a District Council, whose purpose is to gather the concerns of its members and seek to satisfy their requirements. The term served by the district council members is six years and there are three delegates who, together, comprise the Assembly of Delegates (twenty-seven members), whose main purpose is to approve all the important decisions of the co-operative. This Assembly of Delegates also elects the nine members of the Board of Directors and the six members of the Oversight Committee.

The following are some of SAGUAPAC's indicators for 2003:

- Drinking water coverage for 96% of the population
- Sanitary sewage coverage for 50% of the population
- A total of 123,597 drinking water connections
- A total of 64,096 sanitary sewage connections
- An average water tariff of 0.31 U.S. dollars per cubic meter
- An average sanitary sewage tariff of 0.29 U.S. dollars per cubic meter
- A water loss of 26%
- Annual invoicing of 19,500,000 U.S. dollars
- A 94% collection efficiency

5.3 Cochabamba, the Capital City of the Department of Cochabamba

The capital city of the department of Cochabamba (in Cercado province) is 2,535 meters above sea level and has a surface area of 10,605 hectares, a population of 778,442 inhabitants (CNPV for 2001) and 123,477 dwellings, of which 69.5% have piped-in water from the distribution network. It has an average annual temperature of 17.5°C. Rainfall varies between 400 and 500 mm. per year.

The Cochabamba Metropolitan Area is defined as the territorial, geographic and human area comprising the city of Cochabamba and the suburbs in its area of influence, including the districts of Sacaba, Cercado (Cochabamba), Tiquipaya, Colcapirhua, Quillacollo, Vinto and Sipe, all within the Rocha River subwatershed.

The urban expansion process of the Cochabamba Metropolitan Area has been horizontal, of low density, unordered and unplanned. The use of land suitable for agricultural production has created urban planning problems of different kinds, including conflicts arising from the occupation of public property, green areas and ecological and forest preserves. There are settlements ecologically classified as high risk, and as a natural catastrophe due to their location in gullies (the beds of tributary ravines of the Rocha River which carry torrents of mud). There has also been a proliferation of settlements on apparently vacant or abandoned lots, since their owners do not live on them.

An average of fifty percent of the population do not have access to piped-in water or public sanitation sewage.The contamination of shallow aquifers is alarming. The analyses carried out reveal vestiges of fecal matter and a wide range of bacteria, which represent a health hazard to the population.

Another environmental hazard is that only 64.7% of the total dwellings in the city have garbage collection and disposal service. The remainder of the population dumps its garbage in open fields, rivers or dumping grounds, forming focal points for contamination of the shallow groundwater.

The increase in the use of traditional organic fertilizers, industrial fertilizers and untreated wastewater in agriculture is also producing excessive nitrates, leading to a reduction of the soil's capacity for self-purification and nitrification.

5.3.1 Water Resources in the Cochabamba Urban Area

The city and valley are traversed, east to west, by the Rocha River, whose headwaters are in the Tuti sierra (in Chapare province) and the Tamborada river, its main tributary. Both rivers are highly contaminated and their flow is intermittent. They only carry continuously flowing water during the peak rainy season (December to February). Several intermittent rivers originating in the Northern Mountain Range of the valley (Tunari) empty their waters into the Rocha River during the rainy season. The Rocha River is 83 km. long from its headwaters to the point where it empties into the Caine River, southeast of the valley. Its flow of water spills into the Amazon macrobasin which flows across the watershed of the Mamorée River (Hydrography of Bolivia, 2007).

One of the main problems in the Cochabamba Metropolitan Area is the scarcity of water, caused by the low rainfall in their zone. The surface water reserve in some cases dries up completely. For this reason, it is necessary to prospect for and develop groundwater resources in the surrounding cities of Quillacollo, Sacaba and Tarata. The extraction of groundwater implies a substantial investment of funds which are difficult to raise. This leads to a deficient, inadequate development of the projects

Table 5.3 Average annual availability in potential surface and groundwater sources

District	Existing Sources		Potential Sources				
	Wells	Area Km²	Kewina Khocha Corani (lts.sec)	Palca Transfer	Misicuni Project Phases 1 & 2 (lts.sec)	San Miguel (lts.sec)	New wells
Cercado	600	254					50
Sacaba	149	31	1,046	160			20
Quillacollo	110					335	90
Tiquipaya	66	26			4,000		50
Colcapirhua	82						30
Vinto	52						40
Sipe Sipe	11	10					70
Totales	**1,070**	**321**	**1,046**	**160**	**4,000**	**335**	**350**

Source: SERGEOMIN, 2004.

which have been designed. However, the Municipal Drinking Water and Sanitary Sewer Service (SEMAPA) –the municipal company responsible for the administration of water in Cochabamba– owns a large number of wells, from which a significant flow is obtained.

The currents of water originating in the Cochabamba mountain range are calcium, magnesium and bicarbonate bearing (fresh water). These flows originate in sedimentary rocks such as volcanic rock. The concentration of the total dissolved salts generally does not exceed 300 mg. per liter. Important factors in their purity may be the steep topography of the terrain, which does not favor the retention of water in aquifers for long periods, and the acid composition of the rocks. The wells are not springs; therefore, the cost of pumping them must be added to make possible their exploitation.

The contamination of the groundwater in the mountain range is generally limited to the flows originating in the most shallow aquifers. The alluvial rivers are exposed to contamination through direct infiltration. These aquifers are in grave danger of being contaminated by such human activities as agriculture.

Thousands of dug or bored wells are found in the Central Valley. Their depth and flow vary, depending on their location. In general, their flows in the central region may be as high as 30 liters per second at depths of 125 meters. Toward the south, these values are lower. In the valley, SEMAPA drilled three wells in 1997, to depths greater than 200 meters. During Stage I, a well was dug down to 550 meters. The yields from these very deep wells do not exceed significantly the flow of the wells operating in more shallow aquifers. Permeability is reduced according to depth, due to the increased presence of clay between the productive layers, which prevents an adequate recharge of the aquifers. The age determined for the water from this deep well is eighteen thousand years BP.

5.3.2 Water Treatment Plants and Recycling in the City of Cochabamba

The main water treatment plants for reuse of water in Cochabamba are the following:

A. The Cala Cala plant, with a treatment capacity of 400 liters per second, treats waters coming from the Escalerani system and the Aranjuez plant, with a design capacity of 100 liters per second for treating the waters coming from the Wara Wara system.

B. Wastewaters are transported by the sanitary sewerage system, and are treated at the Alba Rancho treatment plant, which has a stabilization pond system to treat up to 400 liters per second. It has eight secondary ponds with an area of 21.9 hectares, and four primary ponds with an area of 13.7 hectares. It also has a complete distribution canal network as well as collecting canals, with their flow measurement systems. In addition, it also has a mechanism for controlling and recording the weather conditions and their impact on the behavior and efficiency of the plant. An uncontrolled increase in new input may cause a highly damaging overload.

5.3.3 The Sanitary Sewerage System

A part of the sanitary sewage system of the city of Cochabamba dates from 1928. Minor improvements were made in 1945 before the Sanitary Sewerage project was implemented. Its coverage reached 42%, taking in principally the central neighborhoods (Las Cuadras, Muyurina and Cala Cala), covering an area of 1300 hectares. The 1945 Sanitary Sewerage Project for the city of Cochabamba was planned to completely replace the network. However, the lack of financing made it necessary to realize only part of the project, retaining 131 km. from the old network. The sanitary sewage network attaining a length of 425.98 km., with 33,229 household connections and 320 industrial connections, for a total coverage of 53% at the end of the project. At present, there are 729.91 km. of sanitary sewerage network, for a total coverage of 75.7%.

5.4 Oruro, Capital City of the Department of Oruro

The city of Oruro is located 3,736 meters above sea level in the Central Highlands. It is the capital of Cercado Province in the Department of Oruro, with a territory of 285.08 square kilometers.

It has a population of 202,010 inhabitants (CNPV, 2001) and a total of 49,436 dwellings, of which 87.99% have a piped-in water supply. It is divided into five districts, comprising two areas:

- The urban area (district 1), or the intensive area, with an area of 103.58 square kilometers.
- The extensive area, covering Districts 2, 3, 4 and 5, with an area of 180.66 square kilometers.

In the ecoregion on the semiarid and arid Andean floor is uncultivated, surrounded by a small mountain range. Prominent in this are a series of porfidic domes associated with lava infiltration, as well as dikes and subvolcanic chimneys. These domes are part of the San Felipe, Pie de Gallo, San Cristóbal, San José, San Pedro, Colorada, Rubiales, Argentillo, La Tetilla, Santa Bárbara, Cerro Calvario and Cerro Alamasi hills. The mountain range is home to the E.M. San José mine and the drainage that flows from this range is radial and centrifugal, causing problems of rain runoff in the urban sprawl during the rainy season and brings in contamination of the acid water discharged by the mine.

Its climate ranges from 12.4°C to an average temperature of 2.6°C. During the winter the low temperatures are bearable thanks to the extreme dryness. An analysis of average temperature variations shows an upward trend, at the rate of 0.0045 degrees Celsius annually. The records of monthly rainfall show minimal variations, between 10 and 20 mm. during the months from July to August, and 190 to 220 mm. from November to February.

5.4.1 Surface Water Resources in the Municipality of Oruro

The city of Oruro is surrounded by bodies of surface water. The Tagarete River borders the eastern side of the city (Districts 3 and 4). To the southwest there is the Thajarita River and the Desaguadero River to the west (Districts 3 and 4). To the south there is Lake Uru Uru (District 4) formed by a natural reservoir of the Desaguadero River and Lake Poopó. The surface water sources supplywter to the Municipality of Oruro via a flow of 34 liters per second, and come from the Sepulturas and Huayña Porto rivers, and form part of the Endorreica macrobasin in the Bolivian highlands.

The Desaguadero River is the basin's main collector, draining the zone until it empties into the Lake Poopó to the south. The Desaguadero River carries an average of twenty m^3/sec of water from Lake Titicaca to Lake Poopó, forming several subbasins as it crosses the northern highlands, and a part of the inter-highland mountains. The flood plains of the Desaguadero are important in the framework of evaluating water resources both in the Department and in the city of Oruro.

Lake Uru Uru is triangular in shape, with a southward vertex. During the rainy season 10% of the surface of water is within the limits of the Municipality of Oruro. However, the water in this section tends to flow down due to the effect of sediment deposits carried by the Desaguadero River. Between Lake Uru Uru and Lake Poopó, the Desaguadero River runs for thirty kilometers, with an average slope of 0.03%. It spills over in this region, also forming the so-called Soledad Lake, adjacent to Lake Uru Uru, according to recent data.

5.4.2 Groundwater resources in the Oruro district

These resources are managed by the city-owned company known as "Local Aqueducts and Sewage

Service", or SeLA. The Challa Pampa aquifer, located to the northeast of the city of Oruro, is exploited in the zones of Challa Pampa, Challa Pampita, Challapampa Grande and Airport and furnishes 94% of the 564 liters per second of drinking water distributed by SeLA. The Challa Pampa aquifer is a tectonic depression filled with recent lake sediment (from Lake Minchin), glacial-fluvial sediment and with fluvial-colluvial sedimentation. The different sediments have caused changes of facies, according to the variations in the salinity of the water. SeLA operates a battery of 23 tubular wells, from 50 to 120 meters deep, and has systems to transport the water to the JKW tank plant in SeLA's building. From there it is distributed for urban supply.

5.4.3 Drinking Water Supply

The water resources used to supply water to the city of Oruro originate in surface and groundwater sources. Tables 5.43 and 5.5 show the use of drinking water and the number of connections according to the type of user.

5.4.4 The Oruro City Water Treatment Plant

The city of Oruro has a Special Wastewater Treatment Plant (PETAS) located 2.5 kilometers to the southeast of the city. It is operated by the Department's Government. The plant is in the process of being transferred to the Oruro Autonomous Municipal Government (G.A.M.O.) This plant has been shut down for some time; accordingly, the wastewater is discharged directly, and untreated, into Lakes Uru Uru and Poopó. Only 1.5 Km to the north of the plant there is an open canal which is used to redirect the wastewaters directly to Lago Poopó The wastewater flows at a rate of 400 liters per second, even though SeLA produces 300 liters per second of drinking water. This leads one to believe that this is the mixture of rainwater and sewage system water.

5.5 Sucre, capital city of the department of Chuquisca

Sucre is the constitutional and official capital of Bolivia and the capital of the Department of Chuquisca. Geographically, Sucre is located 2,750 meters above sea level. It is located in the medium high lands between the highlands of the Andean plateau and the Gran Chaco lowlands of the southeastern plains. It has a population of 194,888 in habitants (CNPV for 2001) and 49,979 dwellings. Of these, 78.73% have piped-in water.

The city of Sucre has the weather conditions typical to valley areas, with dry, moderate climate and temperatures which range from a high of 22°C in the summer and a low of 8°C in the winter. The average ambient temperature is 15.2°C, and the average rainfall is 650 mm. per year.

5.5.1 Water Resources for the City of Sucre

The geographical location of the city of Sucre coincides with the hydrographic divide of the Amazonas macrobasin (Chico and Grande rivers), and the Río de la Plata macrobasin the Cachimayu and Pilcomayo rivers). Hence, the city becomes an area with two drainage directions, since some of its waters run toward the Amazon (in Brazil) while others run toward the Río de la Plata (in Argentina).

5.5.2 The Drinking Water Supply

The Sucre Local Drinking Water and Sewage Company (ELAPAS) furnishes and manages drinking water and sewage services for the city of Sucre. ELAPAS comprises a decentralized Public Service

Table 5.4 Use of drinking water according to types of user january to november 2009 and 2010 (in cubic meters)

Type of user	January to November 2009		January to November 2010		Percentage Variation
	Consumption	Percentage Variation	Consumption	Percentage Variation	
Total	5,221,773	100.00	5,415,500	100.00	3.71
House-hold	3,565,204	68.28	3,736,765	69.00	4.81
Commercial	758,128	14.52	792,575	14.64	4.54
Industrial	255,293	4.89	262,362	4.84	2.77
State	643,148	12.32	623,798	11.52	(3.01)

Source: Local Aqueduct and Sewerage System Service (SeLA), Oruru and and and National Statistics Institute (INE), 2011

Company of the Sucre Municipal Government, with its own status as a legal entity, and administrative, financial, and management autonomy, an infinite corporate life, its own legal status and independence from the Municipal Government. It was created by Supreme Decree No. 07309 in 1965.

ELAPAS furnishes 25,435,587 liters of drinking water per day to 49,900 dwellings (CNPV for 2012). It has two systems, fed by surface water.

A. The Cajamarca System, which includes the Cajamarca, Safiri and Punilla rivers, with a flow of 80 liters per second.
B. The Ravelo System, which includes the Ravelo, Peras, Mayum, Jalaqueri, Murillo and Físculco Rivers and contributes with a total flow of 389 liters per second.

There are also transition and storage tanks made of stone masonry in Silvico and Guerraloma, respectively.

Among ELAPAS' medium-term projects intended to improve its service are the following:

1. The conclusion of the work for Phase I of the Lajastambo project. This is the main source of supply for the recently rehabilitated Cajamarca Transportation Water System.
2. The realization of Phase II of the Lajastambo project financed by the Federal Government.
3. A joint call for bids and for expressions of interest by the Ministry of the Environment and Water, the German company KfW and ELAPAS to study the final design of the project to increase the Sasanta-Yurubama flow/SUCRE III.

ELAPAS implemented its own rate structure, which contains a solidarity rate for consumption of less than 10 cubic meters, the purpose of this being to subsidize the families with the lowest income.

5.5.3 The City of Sucre Water Treatment Plant

Given the need for a water treatment plant, in 1970 the French company Francesca Degremont built the El Rollo Plant, with a capacity of 125 liters per second. In 1991, due to the accelerated population growth, the plant was expanded to a capacity of 250 liters per second. At present, due to the increase in the number of users, it covers only 85% of the flow required by the city. ELAPAS guarantees the purity of the water treated.

5.5.4 The Sewage System

The Sucre city sewerage system is used for wastewater and does not have a rainwater collection system. This system offers a coverage of 85.7%. However, its projection for 2015 is only 82.0%. Even so, ELAPAS ensures the collection of wastewater and their transportation from the system to the treatment plant. In 2009, the sewerage network was expanded by 6,350 linear meters of pipe in Lajastambo.

5.6 Potosí - the Capital of the Department of Potosí

The District of Potosi is in the southern geographical section of the Eastern Range of the Andes. It covers a territory of 1,255 square kilometers, while the city of Potosí occupies 19.8 square kilometers as urban area. This urban area includes twelve districts, while the rural area includes four districts. In terms of physical geography, the territory comprising the District of Potosí has scarce planes and plateaus and some intermediate planes between mountain ranges where the city of Potosí is located. Geologically, volcanic and sedimentary rock are predominant, conforming an interesting complex.

Table 5.5 Number of connections and percentage-wise participation according to type of user according to type of user january-november 2009 and 2010 (in number of connections)

Type of user	January to November 2009		January to November 2010		Percentage Variation
	Consumption	Percentage Variation	Consumption	Percentage Variation	
Total	**46,796**	**100.00**	**49,383**	**100.00**	**5.53**
Domestic	43,965	93.95	46,440	94.04	5.63
Commercial	1,969	4.21	2,061	4.17	4.67
Industrial	113	0.74	115	1.23	1.77
State	749	1.60	767	1.55	(2.40)

Source: Local Aqueduct and Sewerage System Service (SeLA), (SeLA), Oruro and National Statistics Institute (INE), 2011

Figure 5.2 Mining contamination in the city of Potosí.

It has a population of 133,268 inhabitants (CNPV for 2001) and 59,734 dwellings. Of these, 86.55% have piped-in water. It has an annual rainfall of 360 mm. and an average monthly temperature between 5.2° and 13.7°C.

5.6.1 Hydrography

In terms of hydrography, the rivers in the district of Potosí belong to the Pilcomayo subbasin, which is part of the Río de la Plata macrobasin. Along its trajectory the Pilcomayo River receives as tributaries the rivers known as the Mayus, which crosses the district, and the Tarapaya.

5.6.2 Drinking Water Resources

The administration of the facilities offering drinking water and sewage coverage to the city of Potosí is the responsibility of the Autonomous Administration for Sanitary Prospects (UAAPOS). During the five-year period from 1998 to 2002, the drinking water network has been expanded, taking in an overall total of 14,538 meters, corrective maintenance on the network (change of intake), preventive maintenance and changes in the main network running 3,250 meters, and changes in connections to 330 dwellings. Until 2002, the drinking water distribution network operated as a single circuit. In order to ensure that the water supply is continuous and at a pressure in accordance with national and international standards, it is now divided into two circuits: (a) the Chapini Circuit 1 and b) The Chapini Circuit 2.

The city of Potosí receives its supply of drinking water from surface water sources, collected and stored in 22 ponds, which allow for the impounding of 8,114,000 cubic meters, with a transportation network, or aqueducts, from six different subbasins, transported to the city, by six systems, to the Millner Treatment Plants built in 1974, where they enter a main tank with a capacity of 2,500 cubic meters and are gravity-fed to the distribution network.

a. The Kari Kari Ponds Source. The water from the Kari Kari Lagoons is used for human consumption. This system is vulnerable due to such natural phenomena as El Niño, characterized by an increase in temperature and a reduction of rainfall, causing a decrease in the water stored.

   The water stored in the Kari Kari ponds reaches a total of 8,114,000 cubic meters. However, during the dry season it drops to 2,143,489 cubic meters, presenting problems in its quality, since the sludge it carries aggravates the problems in the treatment plant due to the plugging of filters. This system has 32 artificial ponds which feed six treatment systems.

   There is also the possibility of incorporating the Laka Chaka water basin to complement the sources of supply that exist at Kari Kari. The waters from the Laka Chaka system are being transported by an intake system to mining plants. The water potential of this system is very high, and there is a junction of connections between the intake at mining plants and the Chalvir Millner intake.

b. The San Juan River Source This surface water source has been in use since the end of 1999, and has such modules as intake works, an intake line, a storage tank and chlorination station. The storage tank is in Cerro Chico. From here water is sent to the Chapini tank and to the network. This network supplies 97.21 liters per second –the equivalent of 3,065,709 cubic meters annually for a consumption of 64 liters per inhabitant per day. This is the equivalent of a deficiency in the system, which must operate at a total capacity of 150 liters per second.

c. The La Palca Pumping Source. This source of surface water is below the level where Potosí is located. Accordingly, it must use a pumping system. Due to its high operating cost, this system is not used and is held in reserve in case of severe drought.

5.6.2 The Treatment Plant

Until 2011, the district of Potosí had only a system of filters where the flow entered each storage tank. This did not guarantee a supply of water in accordance with the Bolivian quality standards.

The Government of Japan donated 14.6 million dollars for the construction of a water treatment plant and the rehabilitation of the intake ductwork. The plant furnishes drinking water to up to 95% of the population of Potosí, benefitting more than 73,586 persons. The drinking water treatment plant includes decanting, filtration and reagent treatment systems. It treats a flow of 510 cubic meters per hour.

5.7 Tarija, the Capital City of the Department of Tarija

The city of Tarija is the capital of the department and is administered by the Autonomous Municipal Government of the City of Tarija in Cercado Province. In 2007, the urban population in the district of Tarija was 79.8% and the rural population, 21.2% of the total population of 279,274 inhabitants, with an annual population growth of 3.1% and an annual migration rate of 3.9%. The City Government of Tarija administers twenty districts –thirteen urban and seven rural.

The urbanized area of the city covers 42 square kilometers and has developed in parallel to both banks of the Guadalquivir River –a river with a flow of 4.5 m^3/sec, which crosses the city of Tarija from northwest to southeast. It has 135,651 inhabitants (CNPV for 2001) and a total of 36,126 dwellings, of which 88.14% have piped-in drinking water.

5.7.1 Hydrography

The surface water sources in the Tarija district and Cercado Province are distributed in two subbasins_: (a) the Santa Ana River and (b) that of the Tolomosa and Sella Rivers, both of which are tributaries of the Guadalquivir River. Both subbasins belong to the Grande river of Tarija, the Bermejo River basin and, in turn, to the Río de la Plata macrobasin.

In 2007, the Prefecture of Tarija undertook the Huacata Project to relieve the water shortage in the Central Valley –especially during the dry season. The project built a reservoir to hold water in the Huataca River basin in the north and to transfer it to the Guadalquivir River basin. With the water from the Huacata, several communities in the highest part of the Guadalquivir River basin receive both drinking water and water for irrigation. With the water from the Huacata and the water from other sources, the Tarija Water and Sewerage Services Co-operative (COSAALT, Ltd.) can expand the volume of the drinking water networks.

The Prefecture of the Department and COSAALT worked on the Guadalquivir River Sanitation Project as an overall environmental recovery project for the river, with several complementary components. The sanitation of the Guadalquivir River benefits the entire Central Valley, which covers 3,060 square kilometers, taking in a large part of the districts of Cercado, Avilés and Méndez and covering a population estimated at 250,000 inhabitants (in 2007) –175,000 urban inhabitants and 75,000 rural inhabitants.

5.7.2 Drinking Water Resources

a. Surface Water Sources

In 1986, the Tarija Drinking Water and Sanitary Sewerage Services Co-operative (COSAALT, Ltd.) was established. It holds the concession for water use and sewerage services, with a life of forty years. It has shown an average increase of 92 new connections monthly. Accordingly, in 2007 there were 26,018 users while in 2012 there were 31,702 users. The incumbent Government of the Plurinational State of Bolivia granted a license to continue the operation of the co-operative service by issuing, in 2010, Regulatory Administrative Resolution AAPS No. 251/2010.

In the Municipal Government of the City of Tarja and Cercado Province there are several possible sources of surface water supply. None of them, however, can completely cover the present and future demand by itself (see Table 5.6). The La Victoria River efficiently covers the demand only during the rainy season. Neither could other surface water sources, regulated by reservoirs, meet the demand, since there is a limited flow for human supply, with the greatest part of the flow being used for agricultural irrigation. Among this group of sources, are the projects for the Huacata, Calderillas and Tolomosa River reservoirs. .

In order to adequately meet the hourly variations in consumption it is necessary to increase the storage both in the zones now in use and those contemplated for future urban extension growth areas. To do this, an increase of 12,600 additional cubic meters is being contemplated.

Table 5.6 Average annual flow from surface water sources

Province	Source	Type of Intake	Area (km²)	Average Annual Flow (liters/second))
Cercado	La Victoria Galería	Subsurface	34.36	924
	Victoria 1	Surface	32.05	
	Victoria 2	Surface	28.14	
	Erquis	Subsurface	104.95	907
	Las Tirpas	Surface	913.31	5,939

Source: COSSALT, 2011.

The production reported by COSAALT for 2011 was 15,792,026 cubic meters, or the equivalent of 501 liters per second –an amount insufficient to meet the maximum daily demand. Table 5.6 shows the average annual flow of the present surface water sources for 2011.

In Cercado province, the present water coverage is 97% (44,599 families). The projects currently planned will permit a coverage of 99% (45,750 families), leaving only 359 families with no water coverage.

In sum, the surface water sources for the supply of water to the city of Tarija are as follows:

- The el Rincón de La Victoria River
- The Erquis River, (which supplies the users in Tomatitas)
- The Guadalquivir River (Las Tipas)
- Lake San Jacinto

b. Groundwater Sources

COSSALT controls 15 groundwater wells, but only six of them operate during the dry season. In addition, a preliminary hydrogeological study was performed in the Guadalquivir River basin, taking in the Cercado, Méndez and Avliés provinces. It identified the presence of two types of aquifers located in the zones mentioned below:

A. A multi-layer aquifer in fluvio-lacustrine sediment where water circulates at a lesser depth, with the ability to be transported at rates between 10 and 300 square meters [sic] per day.

B. An aquifer of hard, fractured rock (with secondary permeability) where water flows at greater depths.

The potential zones identified are as follows:

1. The Northeastern strip of the city
2. The San Luis-San Blas zone
3. The alluvial plain at the foothills of the Tolomosa-San Andrés-Tablada subbasin

5.7.3 The Treatment Plant

Since the nineties, a part of the wastewater from the city of Tarija has been treated in the oxidation ponds located in the San Luis zone. In the urban parts of the city, with no sewage system, wastewater is treated in septic tanks, generally poorly managed or are thrown untreated into the numerous ravines. It is estimated that about thirty-five percent of all wastewaters is discarded untreated.

The oxidation ponds discharge effluents into the Guadalquivir River. However, the ponds are wholly inadequate and insufficient to treat the total volume of the city's wastewater. The overloading of the ponds causes foul odors which become worse during periods of brusque changes in barometric pressure and daily temperatures. In addition, due to spontaneous urban expansion, the ponds are now within the city's urban boundaries.

5.7.4 The Sewage System

COSAALT is in the process of expanding the urban drinking water and sewage networks, and intends to raise the current coverage from 65% to 90% by 2030. In 2007, as a first stage, COSAALT undertook a program to expand the sewage network to 46 outlying neighborhoods and the construction of 40 kilometers of wastewater collectors.

In 2011, COSSALT had 27,382 household sanitary sewerage connections, offering a coverage of 82% of the total dwellings registered in the district.

5.7.5 Environmental Contamination

COSAALT, as a concessionaire, controls the discharges of fifteen industries in Tarija. These industries have permits which regulate the allowable discharges. Only one industrial plant has wastewater pretreatment facilities, and a great part of the industrial wastewaters produced do not enter the sewage system, thus contaminating the subsoil. An evaluation of the available data indicates that about 35% of all urban wastewater is industrial. Howsoever, these waters contribute approximately 50% of the total wastewater load. The data from COSAALT indicates that only 14% of the total load is regulated.

Certain industries in Tarija do not discharge their wastewater at the San Luis plant. These include the municipal slaughterhouse and a number of tanners –major producers of wastewaters with high BOD and COD concentrations. The impression is that the industries regulated represent only a small part of all industrial wastewaters. The connection of these industries to the PTAR (wastewater treatment plant) not only produces a greater volume of wastewater but also possibly cause greater treatment problems.

Untreated wastewater in the city and the rural centers severely contaminates the Guadalquivir River. Downstream of the city are several communities of small producers, who use untreated, raw water to irrigate vegetables destined to the city's markets.

The following three components have been designed for the treatment of household and industrial wastewaters: (i) the construction of a new Wastewater Treatment Plant (PTAR); (ii) decentralized pre-treatment of Tarija's industrial waters, and (iii) the reuse of treated water as irrigation water for grapes and fruit agriculture in the driest regions of the Central Valley.

This plant will replace the oxidation ponds at San Luis, which are wholly inadequate to treat the household and industrial wastewaters and are sources of increasingly serious environmental deterioration. This plant, with anaerobic technology in combination with biological filters, will be located at La Pintada, and have the capacity to meet all requirements until 2030, and a population estimated at 480,000 inhabitants.

5.8 Trinidad, the Capital City of the Department of Beni

Trinidad, the section capitalof Cercado province is located in the southeastern section of the Department of Beni. It is the capital of the Department of Beni. The urban radius is bounded on the west by the Ibare River, on the north by the Mocoví River; on the east and south there is a radius of eleven kilometers from the center of the main plaza. Within the urban perimeter a radius of intensive use has been defined, reaching five miles in any direction, outside of which use is more extensive. There is neither planning nor regulation of the use of the soil outside the urban perimeter.

The climate is warm and humid, with an average annual temperature of 26° Celsius, fluctuating from 8°C to 38°C. The cold season, from May to June, is characterized by cold southern winds, known as *"surazos"*. The months with higher precipitation are from November to March. The average annual rainfall is 1,900 mm. The heaviest rainfall recorded on a single day was 319 mm.

In 2002, the "Case Study: Use of Land in the Trinidad District" was commissioned, introducing an environmental approach to urban planning. This study identified four environmentally sensitive zones, five buffer zones and several zones subject to flooding and hazards.

A basic environmental change occurred in 1997, with the shift of the Mamoré River bed five kilometers to the west. As a result, the area surrounding Trinidad no longer receives floodwaters from the overflow of the main river. Since that time, urban developments have proliferated in the southern and western part of the city, in a zone defined as a protection and forestry zone. Apart from lacking the basic necessary services, natural disaster situations have arisen, with hundreds of families left homeless by the heavy rains and flooding. There is a project profile of a far-reaching programm prepared to build an "Ecological Belt", with a pumping station which would make these lands habitable.-

In addition, the change of course of the Mamoré River has decreased the lateral recharge of the aquifer as a source of drinking water, to the extent that it cannot maintain the flow expected for a system of high quality water for the city. A definitive solution to the quantity and quality problem would be to bring the water from the Mamoré River twelve kilometers away.

The lack of employment opportunities in the Beni Department has increased the influx of population to the capital, causing a rapid spread of the unplanned urban sprawl. There has been an increase in the percentage of population without basic services (drinking water, electric energy, sewage etc.) This has produced a consequent increase in the contamination of the sources of water, the soil, with foul odors, the proliferation of disease carriers and public health problems.

The city of Trinidad has 75,285 inhabitants (CNPV for 2001) and a total of 16,145 dwellings. Of these, 47.15% have piped-in water.)

5.8.1 Hydrography

The city of Trinidad, founded on the right bank of the Mamorée River, is surrounded by several waterways and a series of drainage canals which tend to flood the city. The Mamorée River is one of the main bodies running through the Amazon River macrobasin in Bolivia. It has a flow of 1,690 cubic meters per second as it passes near Trinidad.

5.8.2 Drinking Water Resources

The supply of drinking water in the city of Trinidad is the responsibility of the Trinidad Drinking Water Service Co-operative (COATRI), founded in 1988 with the past assets and liabilities of the Beni Regional Sanitation Works Administration.

The source of the water supply is a system of groundwater, with a battery of eighteen wells drilled to depths from 44 to 144 meters. The diameter of the wells is six to ten inches. Overall, they offer a flow of 112 liters per second and a daily production of 10,500 cubic meters. Annually, a total of 1,295,208 cubic meters of water are distributed. Since 2003, water has been available twenty-four hours a day.

The basic household water tariff in Trinidad is one of the highest in the country after Camiri and Asunción de Guarayos. It is higher than the tariff recommended by the Pan-American Health Organization for developing countries, of between one and two working days' pay monthly.

Until 2005, the COATRI had a total of 7,875 household and industrial connections. Taking as an average 6.5 inhabitants per connection as its basis, the COATRI estimates that the population served was between 51,000 inhabitants, or 60% of the population.

In the city, the co-operative holds a concession contract covering an area of 1,780 hectares. The concession confers on COATRI the exclusive right to the use and the obligation to distribute water within the geographical limits defined. The geographical extension of the concession does not cover the entire urbanized area of the city.

Apart from COATRI's scant coverage of access to water services, not only in Trinidad but also throughout the municipality, the water from natural water wells is of poor quality, with excesses of magnesium and iron. This gives it a salty taste and, sometimes, a brown color and disagreeable smell. The presence of fine-grained soils, iron and other minerals means that the wells drilled require constant maintenance and cleaning to maintain their flow. If timely maintenance is not performed, the well could be unusable in barely more than a year.

A project has been designed to draw water from an old branch of the Mamoré River in the village of Puerto Varador. This water comes from filtration activities and, while untreated, is of high quality, with a flow sufficient to supply the city.

Another problem foreseen in implementing the new water system is the insufficient capacity of the piping system to withstand the increased water pressure. This could cause underground leaks, since many of the pipes are either obsolete or were designed for the old system, which did not generate much pressure.

The construction of the drinking water treatment plant was concluded and offers a treatment capacity of 600 cubic meters per hour. This made it possible to cancel nine active wells. The system operates with seven wells of greater diameter.

5.8.3 Sanitary Sewerage

As a component of the Drinking Water and Sanitary Sewage Project, a sanitary sewage system is being implemented in Trinidad, with financing from KfW in Germany. COATRI estimates that it will offer services to 60% of the population. The system has 38,217 meters of underground pipe and three pumping stations.

The sewage system was finished and put into operation in 2004. In all, 4,644 subscribers enrolled in the system with long-term financing. Approximately 400 members connect to the system every year.

In 2005, 401 new connections were formed, thanks to a joint venture between the Prefecture of Beni, the Office of the Mayor of Trinidad and COATRI, subsidizing the cost of household connections. During this same project clandestine connections were detected but they have not been quantified. At present there are a total of 1,476 official connections.

Due to the city's flat topography, the system operates with four pumping stations. Should a power failure coincide with heavy rains, the system could spill over, causing generalized contamination in a large part of the city. For this reason, installation of an emergency power supply is necessary, to include three electric generators. This was not contemplated in the project. It has also been found that in the central part of the city, rainwater enters the wastewater system. This causes the pumping system to overload, with wastewater spilling over into some dwellings.

With regard to industry, not all industries are in the sewer system's area of coverage. Accordingly, they continue emptying their effluents into nearby waterways (Caso Nudelpa, the Marbán slaughterhouse and some tanners). This situation has caused canals, drains and ditches of water are being used as a reservoir for wastewater. This causes foul odors, visual contamination and the proliferation of the carriers of diseases. Therefore, such waterways as the San Juan creek have been contaminated with wastewater. In addition, there exists the possibility of these wastes infiltrating directly from latrines and contaminating the groundwater sources that serve to supply drinking water to the city.

5.8.4 Rainwater Drainage

Rainwater drainage is one of the most basic problems of the city of Trinidad. The Trinidad district is in a zone with a slope of 0%, a high average rainfall, on preponderantly clay soil, which complicates natural water runoff. In addition, the natural system which used to exist in Trinidad, which allowed the water from the northern part of the city to drain into the Mocoví creek, has been slowly interrupted as thoroughfares are paved, informal neighborhoods are established on the river bed, and blocking it with bridges and sediment. In the case of District 8, the existence of rice paddies on the wetlands has interrupted the natural flow that drained into the Mocoví channel, This has caused the water to stagnate and streets to flood. In addition, Trinidad has no drainage system which could efficiently evacuate the large volume of rainwater. The provisional water evacuation system comprises a series of ditches or canals built without adequate planning, which are constantly plugged due to lack of timely maintenance.

Based on a topographical survey, the Master Plan defines a series of eight drainage basins for the urban area. It also identifies a series of reservoirs which would absorb the torrential rains until the pumping equipment could empty them within a prudent period. Of the existing reservoirs, the San Juan Creek is the most important –the only internal rainwater reservoir, clogged with sediment and residue, and with an uninterrupted flow for many years. This situation means that rain causes prolonged flooding in the low-lying parts of the city, with consequent overflowing of latrines and canals. There is a Master Rainwater Drainage Plan, drafted between 1999 and 2001 which set forth a definitive solution to the problem. However, it has not been implemented.

5.8.5 Environmental Contamination

The water treatment system has a capacity of 10,500 cubic meters per day. This system contemplates three treatment stages: sedimentation, oxidation and maturation. Properly treated water is expelled to the southwest of the city through a creek known as El Estribo.

The growth and development of the Municipality of Trinidad has given rise to activities which release contaminants and have negative impacts on the air, water and soil, as well as on natural resources and biological diversity. These impacts affect the environment, health and quality of human life. Worldwide, the main causes or situations identified as causing negative environmental impacts on the Municipality of Trinidad are the following:

- Deficient handling of garbage
- Deficient handling of liquid urban and industrial waste
- Deficient rainwater drainage
- The rapid growth of informal urban settlements
- Deficient drinking water service
- The disorganization and rapid growth of the vehicle fleet
- Improper use and occupation of the soil and space
- The unsustainable exploitation of natural resources

5.9 Cobija, the Capital City of the Department of Pando

Cobija is an Autonomous District and the capital city of the Department of Pando. It is the only urban agglomeration to the north of the Bolivian Amazon. It is located on the bank of the Acre River, the natural border with Brazil, at an altitude of 235 meters above sea level. However, it is the least populated departmental capital in the country. It has a population of 20,987 (CNPV for 2001), and a total of 4,923 dwellings, of which 69.31% have piped-in water.

Cobija, together with the Brazilian cities of Epitaciolandia and Brasileia, comprise a single metropolitan area. The three cities are located on the bank of the Acre River, with which they have established a number of relationships, among them being the use of water resources, which also have a negative impact on the environment.

5.9.2 Hydrography

The entire Cobija District is in the hydrographic basin of the Acre River. This basin occupies an area of approximately 30,000 square kilometers and covers territory in Bolivia, Brazil and Peru. The Acre River is the receptor body of all of Cobija's surface water and is a tributary on the left bank of the Purús River, whose headwaters are in Peru, and discharges on the right bank of the Amazon River in Brazilian territory.

The Acre River establishes the northern boundary of the Municipality. At the same time, it is the border between Bolivia and Brazil. It crosses Bolivia West to East, from Bolpebra to Cobija, along a course 125 kilometers long, receiving water from the subbasins of the Bahía, Virtudes, Noaya, Buenos Aires, Madre de Dios, San Miguel and Píapi creeks. It changes course from north to south in the city of Cobija, entering Brazilian territory and discharging into the Purús River.

5.9.3 Drinking Water Resources

The supply, distribution and treatment of water in the city of Cobija are carried out by the Cobija Drinking Water Supply Co-operative (COSAPCO). The supply of drinking water comes from the Bahía creek, on the border with Brazil. Bahía creek has a continuous flow with low flow periods of 0.7 cubic meters per second. However, for lack of dilution, its waters during this period are highly contaminated and murky. The level of the water depends to a great deal on the rainfall in the tributary basin, and on the calming effect produced by the Acre River. The variations in its level are around 10 meters, reaching very low levels, of a 1 to 1.5 metersduring dry periods.

The water capture works are installed in a floating structure, with one pumping unit and a deficiently installed suction pipe. Due to urban growth, this water capture work is located downstream of both Bolivian and Brazilian urban areas, which spill their wastewaters into the creek.

The lack of urban planning to regulate human settlements in harmony with the overall population growth, the limited economic capacity of the municipal government to provide a sanitary sewerage network to these new settlements, added to the lack of a garbage and liquid waste handling system to improve or expand the discharge collection and control systems, have created a complicated environmental and social problem in the middle and upper watershed of the Bahía Creek. .

The water supply service is deficient in the high parts of the city and the capacity of the system is limited by the treatment plant, which can operate at a flow of 33 liters per second. The system operates eighteen hours a day. Cobija has, as its main future source of public water supply, the Acre River, which is the river with the greatest flow, and the Bahía and Virtudes creeks, which are its tributaries.

In relation to the use of groundwater in the future, preliminary studies reveal the difficulty of finding water available and of physical and chemical qualities fit for human consumption.

With regard to the coverage of the sanitary sewerage system, it is minimal in Cobija. This service operates –and there with considerable difficulties– only in the neighborhoods which have implemented the "Neighborhood Improvement" program implemented by the City Government by a loan agreement from the National Regional Development Fund. This has been implemented in nine neighborhoods.

A rainwater sewage system exists only in the old part of the city, and has collapsed completely, engendering problems in the pavement in this area. In addition, there is no project to solve this problem.

6. Conclusions

In Bolivia, for many years, in both its urban and rural areas, most of the plans or projects for the supply and the proper and sustainable use of water have not been implemented, for multiple reasons both political and economic. These include the failure to pass a new Water Law (of which more than thirty-five drafts have been submitted to the legislature for consideration) to supersede the obsolete law passed in 1906. This has given rise to a lack of integration and coordination of plans and/or projects of the many organisms and organizations both national and local, which act almost autonomously. This integration and coordination is absolutely indispensable to the joint and concerted search for viable solutions to the water cycle.

6.1 The Main Actions Aimed at Containing the Harmful Trends

The following urgent measures are suggested, in order to control the processes which now affect or threaten the achievement of the objectives of water resource management:

- The passage of a new Water Law –concerted, flexible and easily enforced, based on the articles of the Federal Constitution of 2009.
- The passage of clear, precise regulations, easily implemented and enforced.
- The passage of laws which complement the Water Law. If necessary, revising, adapting, editing and promoting specific laws sector-by-sector, which foster the preservation of the water cycle through the use of technology which economizes all uses of water and facilitates its economical and efficient reuse.
- Water management must involve and define the role of the Federal Government with the decentralized areas of management and democratic, participatory decision-making.
- Updating of the National Basin Plan proposed by the Minister of Water in May 2007, which uses the water basin as a basic unit for water planning and management.
- To promote and implement the development of mechanisms contributing to the conservation and sustainable, overall use of water resources in transboundary watersheds, from surface waters and groundwater, and the conservation and rational use of wetlands.
- The performance of projects for the expansion and improvement of water and sanitation services, to ensure universal access. The management of water resources must harmonize the present requirements with the needs of future generations.
- Improve tariff systems and the their collection for water services, through mechanisms which enable the subsidizing of only the most vulnerable and needy elements of the population, and promote incentive forthe population to observe sustainable and responsible conduct.
- As far as economically possible, rescue the rivers, especially in parts of the flood valleys which were occupied for urban or industrial development, and eliminate sources of contamination.
- Eliminate the discharge of untreated effluents, supporting activities that confront the cost of treatment, including the original investment, and their operation, and public awareness campaigns.
- Make the users of groundwater more aware of the importance of participating in water management, to ensure its sustainable use. Install groundwater management systems in all Governments and Departments.
- Create a database with GIS data, centralized by the Ministry of the Environment and Water, to include permits for well drilling, environmental licenses, the storage of technical information and data gathered while drilling wells.
- Promote more aggressive actions by the organizations which oversee compliance with the standards prohibiting the contamination of rivers, lakes and aquifers.

6.2 Proposals for the Development of Water Resources in Priority Areas of Water and Sanitation

The main challenge to the country in the drinking water and sanitation sector is to make these services universally available. There is an imperative need to supply millions of inhabitants who lack drinking water and sanitary sewerage.

In addition it is indispensable that projects be implemented to increase wastewater treatment. In addition, the need for rational use of water and the protection of its quality must be disseminated, and the local governments, professionals, technicians and all sectors of the population must be made aware of this.

Therefore, we propose the following:

a. The design and implementation of economically sustainable social investment projects that contemplate, as a priority, making the services universally available, that ensure their financing through the allocation of resources in the budgets of the government agencies;
b. Improving the economic sustainability of the provision of water, achieving a greater rationale in the tariff structure.
c. Increasing the levels of efficiency in the management of operations and in the effectiveness of coordination among sectors and jurisdictions.
d. Refine the system of disseminating information about water management and its results
e. Promote the active participation of the civil society and local authorities, by taking the following actions:
    - Fostering and giving priority to investments in the sector, bearing in mind the resulting benefits and the impact they have on public health, the environment, social cohesion and the economy, including the reduction of indigence and poverty.
    - The integral management of urban wastewaters should be a national priority and should be included in the programs of integral management of water resources basedon the watershed.
    - Establish explicit mechanisms with incentives for the efficient management of the operating companies, and for the rational use of the services. The tariffplans should contain incentives for the rationalization of water use and the supply of water, which could be achieved by investments in maintenance in order to reduce losses in the water distribution systems.
    - Establish tariff levels that make it possible to cover the operating and maintenance costs, and at least in part, the amortization of capital, taking into account subsidies for those users who are unable to pay and, above all, to take into account the negative environmental externalities
    - Promote coherent urban recovery plans for every city.
    - Strengthen the functions of regulation and control in the performance of services, ensuring the technical capability and the independence of action by the responsible organizations.
    - Improve the legal and institutional mechanisms involved in the participation of the civil society and the local authorities, including improvement in the dissemination and communication of information regarding the performance of the operations and the overseeing authorities, and to intensify –basically in primary and secondary schools– the measures for educating students about the problems of drinking water and sanitation.

6.3 The Ordering and Assignment of Priority to Water Resource Management Measures

The National Hydrographic Basins Plan represents a strategic instrument for the productive and sustainable management of water resources. Analyze the potentialities and the problems, establishing the priority of actions and interventions at the hydrographic basin level. The agricultural and forestry potential has been considered the most relevant factor in determining potentialities, while soil erosion and the scope of poverty as the most limiting factors.

For each of the water ecology sectors, the potential has been identified for water-earth-vegetation resources, in addition to the limitations of the soil, erosion, climate, irrigation and flooding. Then the values of the potentialities, the limitations, the deterioration of renewable natural resources and the poverty index have been weighted to determine the level of priority for interventions for each of the water ecology sectors.

6.4 Limitations and Opportunities

Decentralization has established a new relationship between the Federal Government and decentralized units (departments, municipalities). The Federal Government is still responsible for establishing standards , while the local, municipal and regional governments act as required by solving problems within their jurisdictions. This new reality requires greater interaction among governments at different levels.

The hydrographic basins are not in agreement with the administrative jurisdiction that the State has forged by applying territorial and political criteria. This complicates the coordination and the overall management of water resources.

One opportunity to resolve this problem is as follows: the Commonwealth of Municipalities. This could overcome the demarcation of basins and municipal limits, thus creating instances thatwork on the planning and investment of the use and management of water resources.

Another future alternative is to make the demarcation of original communal lands and the protected areas compatible with the basins, offering an adequate space for management by the indigenous population or management by a water resources administration unit.

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