4.3 Potential for Groundwater Development

4.3.1 Past Groundwater Development

1) Distribution Conditions of Wells

According to the 1992 INE Census, 46.9% of all households in the Study Areas that are not receiving water supply service depend on well water. The population using well water is especially large in the southern part of La Paz, Oruro, and the northern part of Santa Cruz and it is presumed that the majority of the wells are shallow, hand-dug wells.

The number of wells determined from the well data in the Water Supply Database are tabulated in Table 4-3-1, and the locations of these wells are shown in Figure 4-3-1. Although the data are skewed towards regions of high population since relatively newly developed wells were targeted, the following trends can be seen.

① The regions in which groundwater development has been carried out actively include the vicinity of Santa Cruz City, the vicinity of Tarija City, the western region of Santa Cruz, which forms the boundary between Las Seranias Sub-Andinas and Llanura Chaco-Beniana and extends in a band-like manner in the north-south direction, the eastern Altiplano region, etc.

② The newer the well, the deeper the well depth.

③ In general, the well depths are approximately 50~100m in the Altiplano and approximately 100~300m in the western Santa Cruz region. There are wells that are 200 to 400m deep or even deeper in the Chaco region.

④ The yields vary widely from 1.5 to 10 liters per second in the Altiplano. The yields are approximately 4 to 10 liters per second in the western Santa Cruz region and approximately 1.5 to 3 liters per second in the Chaco region.

⑤ The static water levels are 20~25m in the Altiplano, 20~50m in the western Santa Cruz region, and may be 100 to 200m or even deeper in the Chaco region.

Table 4-3-1 Number of Wells according to Well Depth (based on the Water Supply Database)

Depth (m)	0~10	11~29	30~49	50~99	100~199	>=200	Total
Chuquisaca	0	7	4	22	7	11	59
S. of La Paz	17	3	6	3	0	0	29
Oruro	16	12	19	29	3	0	79
Tarija	22	7	2	24	37	0	92
Santa Cruz	2	33	81	277	153	11	557
Total	57	62	112	355	200	22	808

Figure 4-3-2 to 4-3-4 show the distributions of the well drilling depths, the well productivities (yields), and static water levels based on the well data in the Water Supply Database.

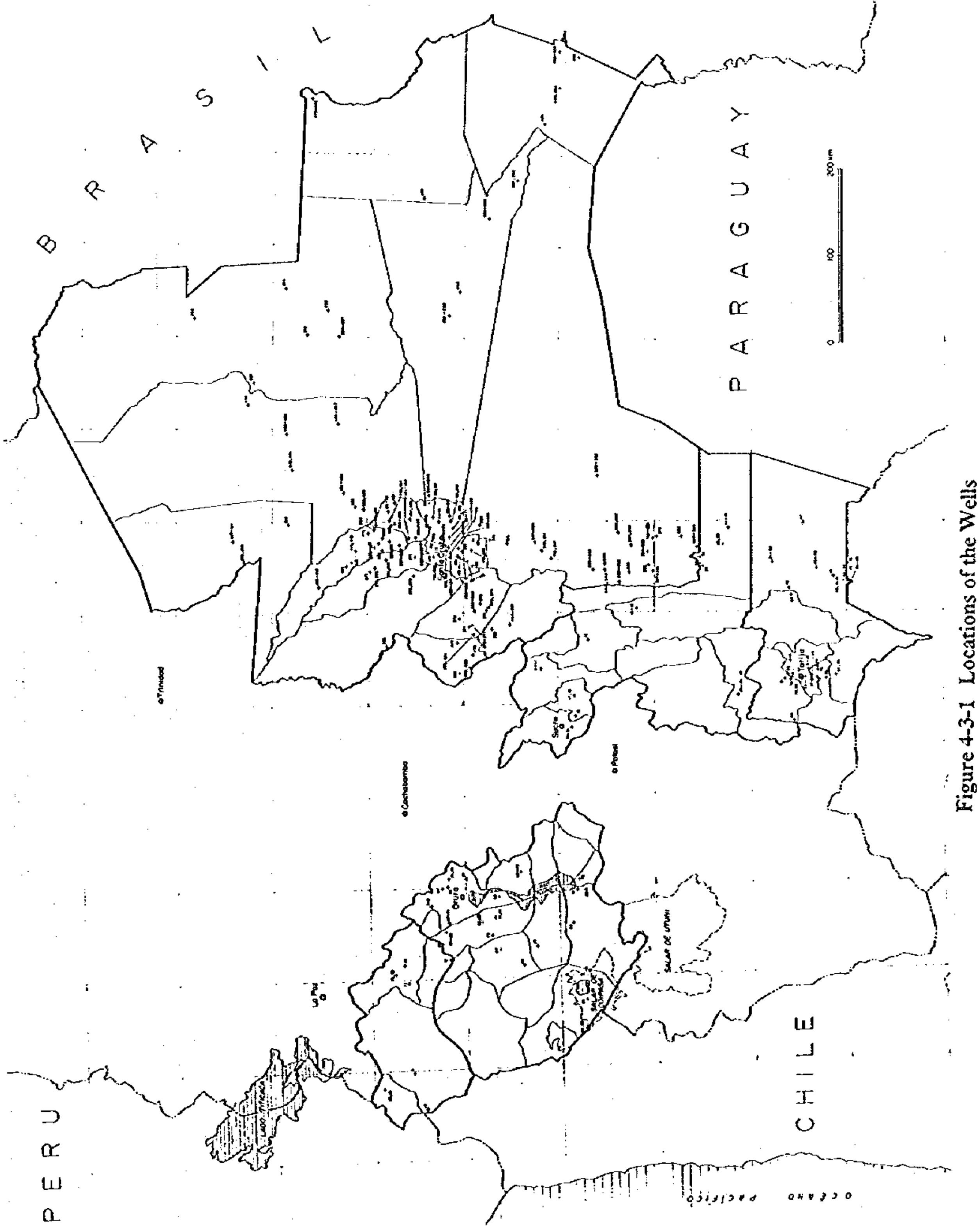

Figure 4-3-1 Locations of the Wells (from Water Supply Database)

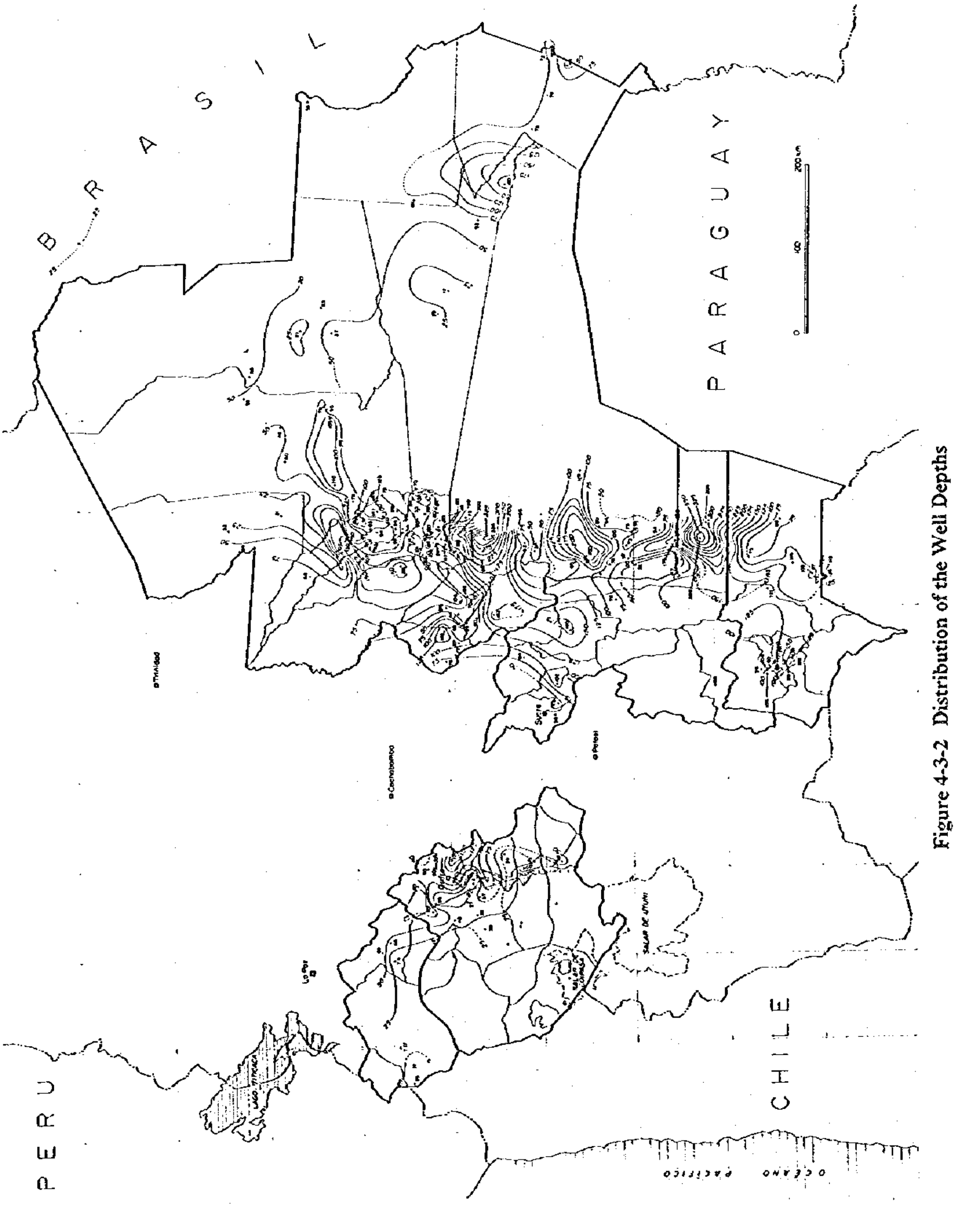

Figure 4-3-2 Distribution of the Well Depths (from Water Supply Database)

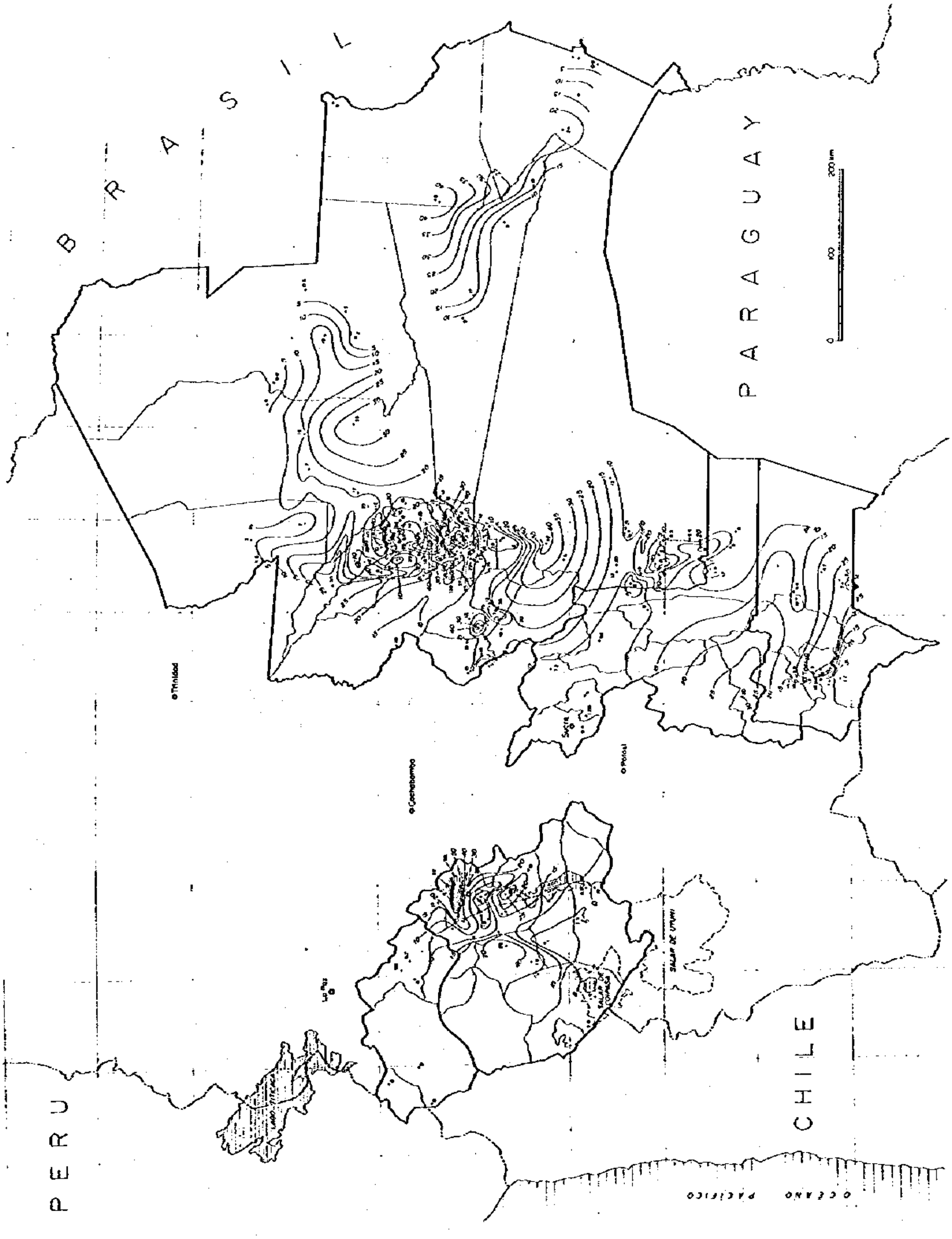

Figure 4-3-3 Distribution of the Well Yields

Figure 4-3-3 Distribution of the Well Yields (from Water Supply Database)

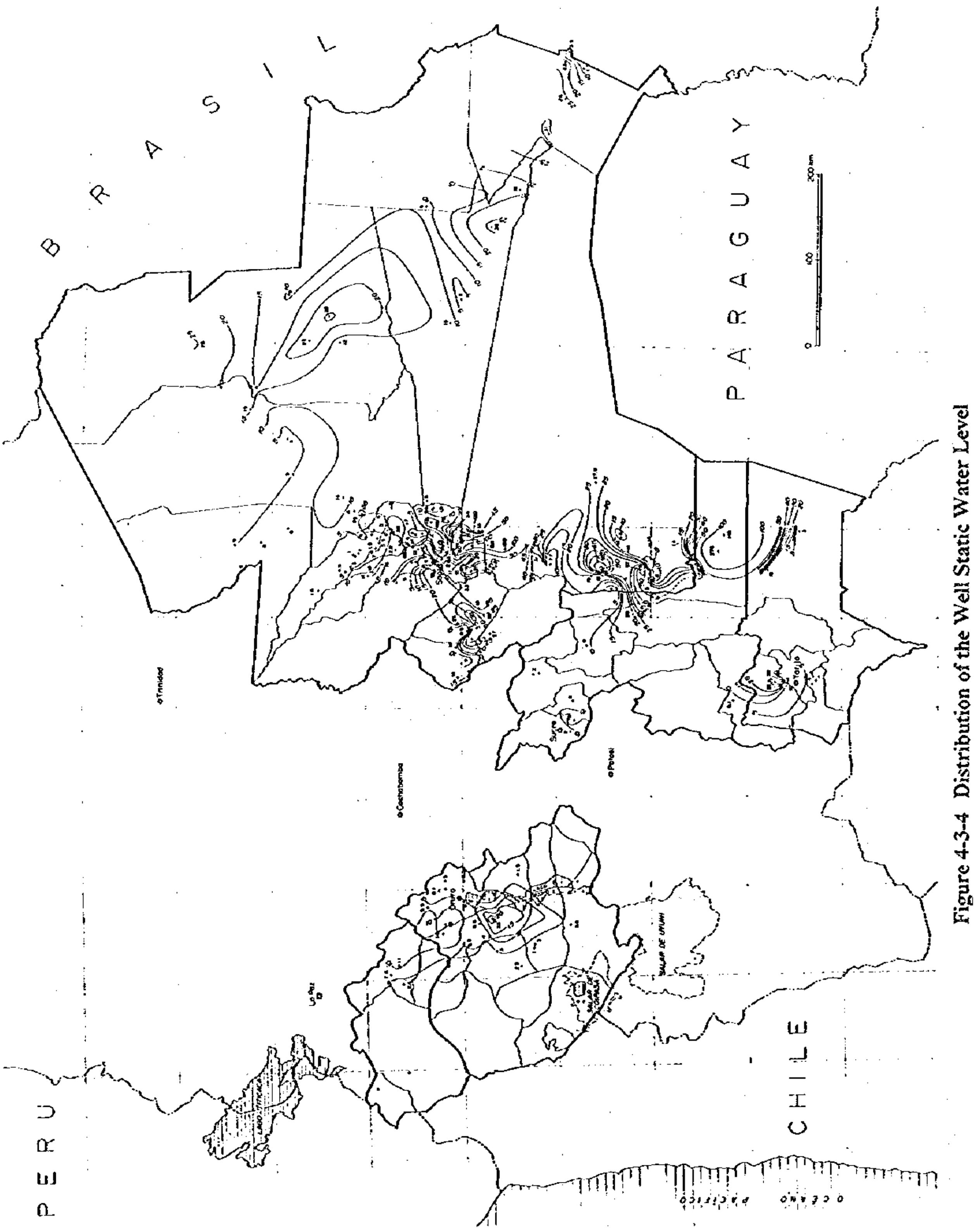

Figure 4-3-4 Distribution of the Well Static Water Level (from Water Supply Database)

2) Status of Drilling Equipment Ownership and Well Drillers

Among the Study Areas, the two Departments of Chuquisaca and Oruro respectively own well drilling equipment. However, the equipment are obsolete, 1974 or '75 model equipment with low capacity and drilling work is carried out only at one or two sites a year. The other three Departments do not own drilling equipment and have to commission groundwater development to private well drillers. Although several private well drillers exist in the Departments of La Paz and Santa Cruz, most are small to medium enterprises that own only obsolete well drilling equipment for shallow wells and are low in management ability. There are only 3 to 5 well drillers who have the capacity for drilling deep wells.

Besides the above, the Drinking Water and Sewer Corporation of Cochabamba owns relatively new Japanese drilling equipment and the YPFB owns large-scale petroleum prospecting equipment.

Although steel casings and general-purpose lift pumps, etc. can be obtained domestically, stainless steel screens, submerged motor pumps, special spare parts, etc. must be imported.

Although there are many persons who are experienced in drilling work and the well drilling technology of Bolivia has reached a considerable level, there is a shortage of information on groundwater prospecting methods and the newest drilling techniques and the number of engineers with hydrogeological know-how is low.

4.3.2 Assessment of Groundwater Development Potential

1) Hydrogeological Features

The hydrogeological map of Figure 4-3-5 and the hydrogeological cross section map of Figure 4-3-6 were prepared in order to assess the groundwater development potential of the Study Area. These maps are based on topographical and geological maps and reflect the well distribution and the results of geophysical prospecting, test boring surveys, etc. The geology, predicted aquifer depths, groundwater levels, yields, etc. are summarized according to Department and Provincia in Table 4-3-2.

With regard to the general groundwater development potential, the Study Area can be considered in terms of the following five hydrogeological zones.

(1) La Cuenca Endorreca del Altiplano Andino (Southern Part of La Paz, Oruro)

Groundwater basins, in which Quaternary deposits have accumulated, have formed in this zone and the permeability is relatively good. Although the rainfall is low, the existing groundwater quantity is high for the water zone as a whole. The Study Area which are located in the Altiplano are low in altitude and receive inflow of groundwater from the mountainous parts and northern regions. It is considered that in general, the deeper the depth, the greater the quantity of groundwater. Whereas good groundwater can be obtained from springs and from relatively shallow depths at the foot of mountains, it is difficult to obtain groundwater at locations other than deep locations at the central part of this zone.

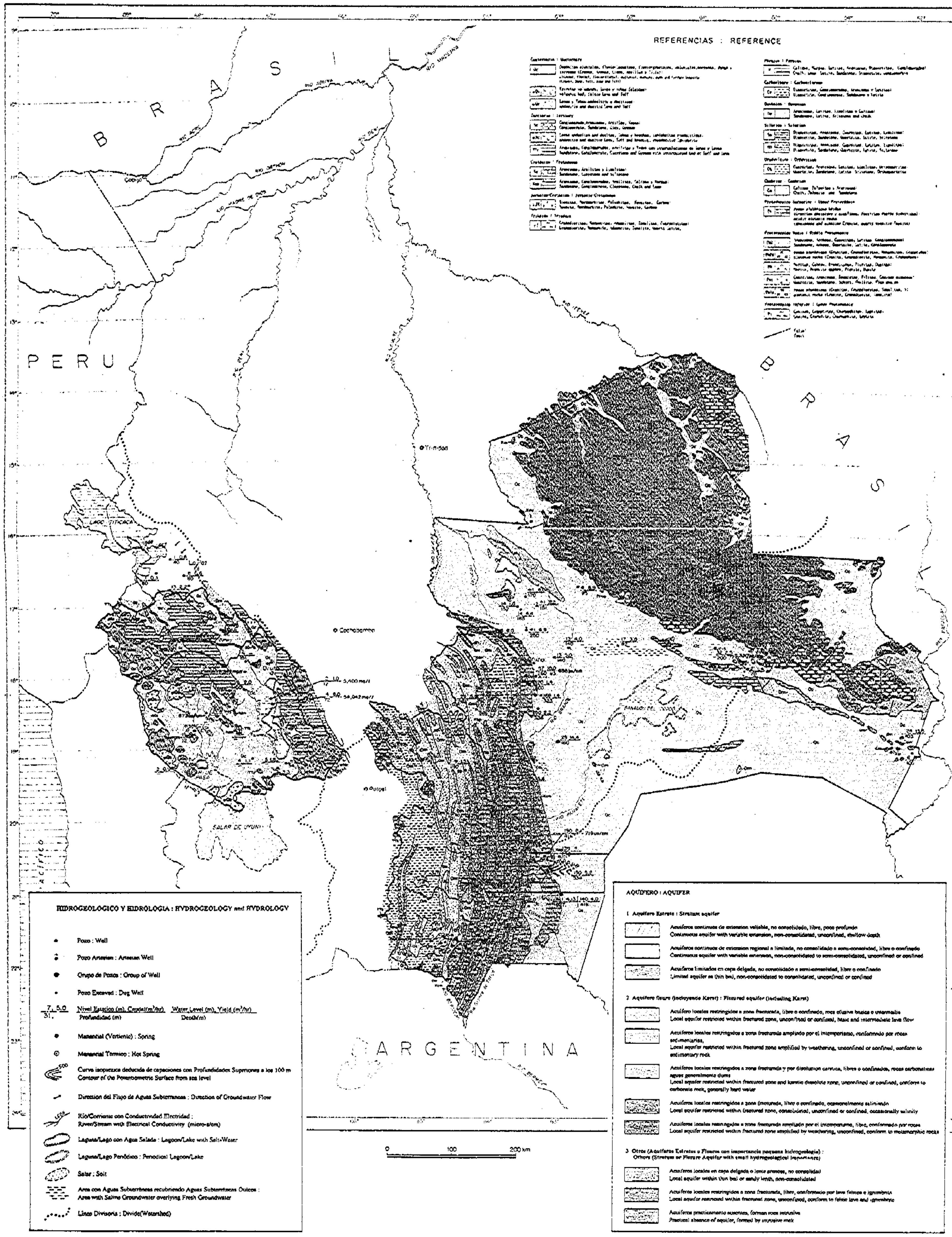

Figure 4-3-5 Hydrogeological Map of the Study Area

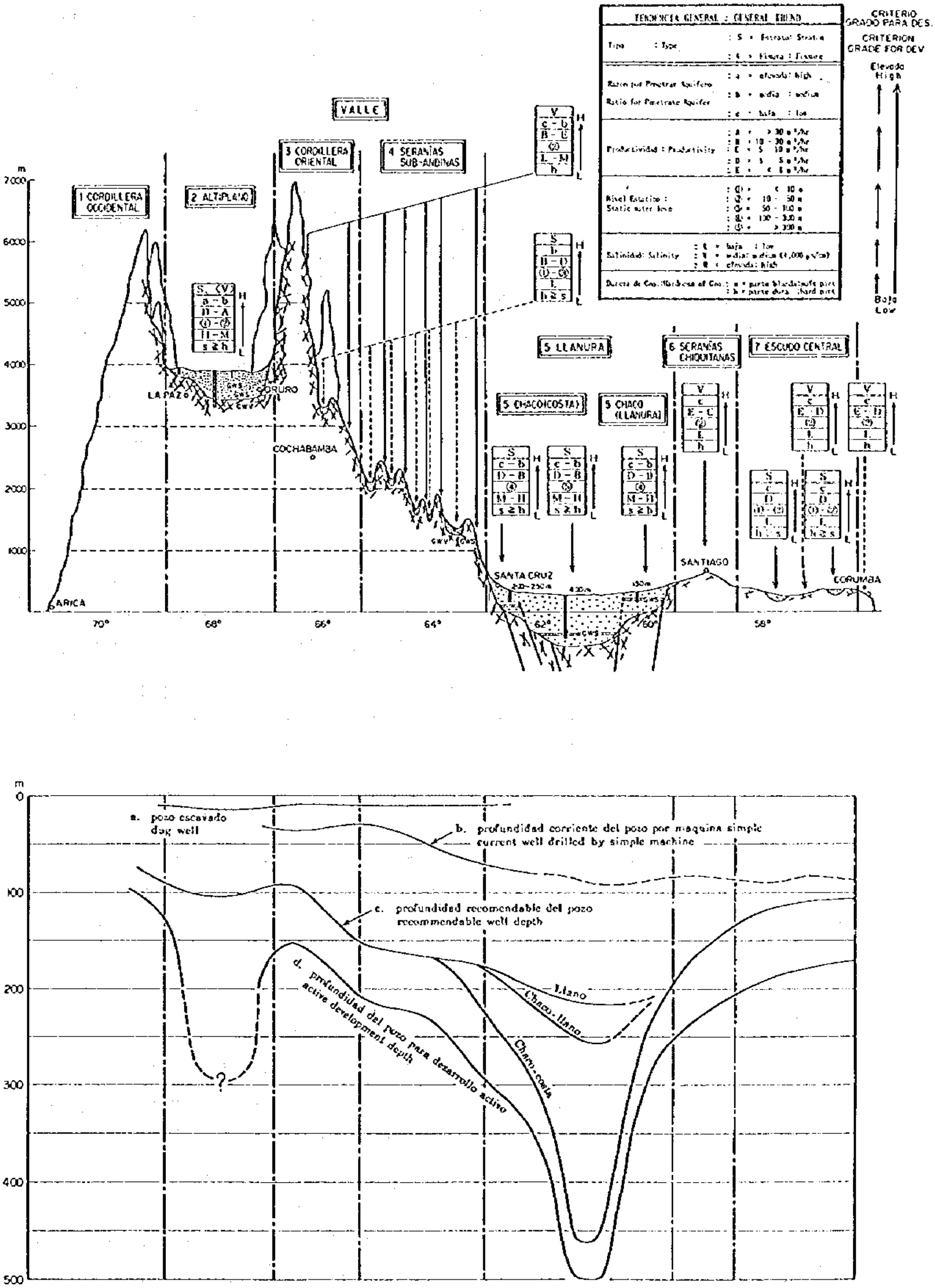

Figure 4-3-6 Hydrogeological Cross Section Map, and the Estimated Required Drilling Depth for Groundwater Development of the Study Area

The groundwater is salinized in part of the region and cavity water or fissure water in deep layers must be developed in such areas. Past groundwater development have been targeted at groundwater at relatively shallow locations and it is considered that the development potential for deep groundwater is high.

(2) Valley Zone (Chuquisaca, Western Tarija, Western Santa Cruz)

Although Paleozoic strata form the bedrock in the valley zone, erosion has progressed considerably and many small valley parts have been formed. The precipitation is 500~700 mm in parts of the "Cordillera Andina" zone at altitudes of 2,000m or more and 600 ~ 1,000 mm at the foot of the "Cordillera Andina" zone below altitudes of 2,000m. Although river water and spring water have been used frequently from the past and groundwater development has not been carried out often, a significant amount of groundwater flow can be anticipated at the valley parts and the potential for groundwater development is high. However, there are communities for which access by transportation is difficult and there are regions where well drilling is made difficult by the hard geology.

(3) Amazon River Basin (Central Santa Cruz)

The humid zone in the northern part has a high precipitation of 1,000~2,000 mm and groundwater can be obtained from relatively shallow locations. The dry zone in the southern part has a low precipitation of 500~1,000 mm and the aquifer depth is deep. Although the river basin area is vast and the groundwater development potential is high, there may be groundwater pollution due to floods in the northern region.

(4) El Escudo Central (Northeastern Santa Cruz)

This zone has an annual precipitation of 1,200~1,600 mm and belongs to the Itenez river system. Although the bedrock is formed from Pre-Cambrian strata, erosion is well progressed. The groundwater flow is considerably high and it is considered that the potential for groundwater development is high.

(5) Chaco Region (Chuquisaca, Eastern Tarija, Southern Santa Cruz)

Although the strata consist of Quaternary deposits and the permeability is good, because the precipitation is low, being only 500~700 mm, and because this zone is located at the watershed between the Amazon and La Plata river systems, the existing groundwater quantity is low. However, since surface water is hard to obtain and adequate water quantities cannot be obtained with shallow wells either, there is a need to carry out active development of deep groundwater. The aquifer depth is about 400m or more for the groundwater basin at the central part of Luis Carbo province of Chuquisaca. Well drilling is being performed with international cooperation from China in the Grand Chaco province of Tarija.

2) Groundwater Targeted for Development and Estimations of Depths and Yields

The groundwater of the Study Areas can be classified into the five types of ① unconfined groundwater that can be collected using shallow wells, ② confined groundwater existing as deep stratum water, ③ unconfined groundwater in the weathered parts of the bedrock, ④ fissure water in the bedrock, and ⑤ unconfined groundwater which exists as river infiltration water or as groundwater streams in the valley part.

Among the above, ① has been used most frequently for water conventionally in the Altiplano and the plains of Beni and Santa Cruz. However, the water is unsuitable as drinking water due to the salinity, turbidity, etc. and often dry up during the dry season. In the Chaco region, such groundwater can hardly be anticipated in terms of quantity as well.

Although groundwater of type ② has not been developed often in the past, it presents the highest development potential in terms of quantity and quality.

Groundwater of type ③ has been used in El Escudo Central from the past and is high in development potential. Depending on the region, such groundwater can be anticipated from the hill zone also.

Although groundwater of type ④ presents an adequate potential for development, it is difficult to locate. It should however be a development target since it may provide good water quality in cases where the stratum water is salinized and the water sources are lacking, such as in the Altiplano.

Water of type ⑤ are used widely as the water source for the existing water supply system in rural areas, and are collected by erecting water intake tanks and dams at the valley parts. Even in parts of the hill zone where there are no water supply system, there are many residents who collect water that remain at the bottom parts of dried rivers and valleys. There are many regions where the collection of water can be made possible by the construction of a shallow well or infiltration gallery at locations with groundwater flow. However, such sources may dry up during the dry season in the case of regions of small water collection area and water pollution and countermeasures against disaster must be taken into consideration in regions of large water collection area.

The present plan is targeted at the supplying of domestic water to regional residents. Deep groundwater, which are low in quantity variations in the rainy and dry seasons and have good water quality, are suited as water sources for such domestic water in the Study Area and are thus assessed to be high in development potential.

Figure 4-3-7 shows the aquifer depth distribution of the groundwater to be targeted in the plan as estimated based on the results of hydrogeological investigation, the Water Supply Database, etc. The estimated aquifer depths, potential yields, and groundwater levels are summarized for each Department and Provincia in Table 4-3-2.

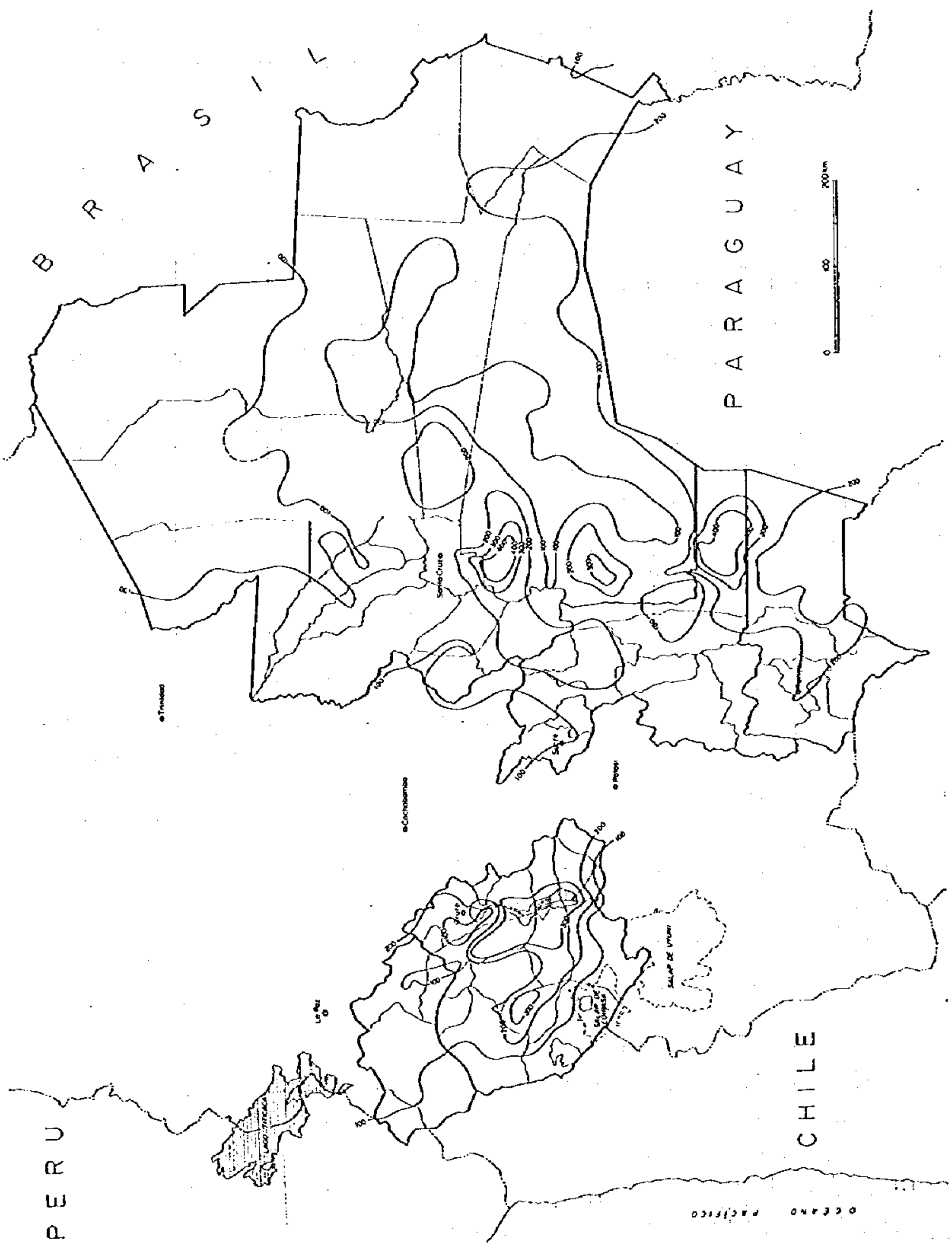

Figure 4-3-7 Estimated Depths of the Aquifer of Study Area

Figure 4-3-7 Estimated Depths of the Aquifer of the Study Area

Table 4-3-2 Groundwater Development Potential of the Study Area

Dept.	Province	Depth of Aquifer (m)	Static Water Level (m)	Potential Water yield (m3/hr)	Dynamic Water Level (m)	Specific Capacity (m3/day/m)
1. CHUQUI SACA	01. Oropeza	50~200	5~ 24	5~ 10	50	~ 0.3
	02. Azurduy	100~200	5~100	10~ 20	50	~ 0.8
	03. Zudanes	50~200	5~ 20	5~ 10	30	~ 0.3
	04. Tomina	200~300	5~ 30	5~ 10	50	~ 0.3
	05. H. Siles	100~200	15~ 90	5~ 20	50	~ 0.8
	06. Yamparaez	100~200	5~ 30	3~ 10	50	~ 0.3
	07. Nor Cinti	100~200	5~ 60	15~ 30	30	~ 1.0
	08. B. Boeto	200~300	5~ 30	10~ 20	50	~ 0.8
	09. Sud Cinti	100~200	5~ 30	20~ 30	30	~ 1.0
	10. Luis Calvo	100~450	5~270	3~ 15	92.9	0.08~ 0.5
2. SUR DE LA PAZ	03. Pacajes	50~200	5~150	3~ 15	50	~ 0.5
	13. Aroma	50~200	5~ 30	3~ 10	13.8	0.3 ~ 1.04
	18. G. Villarroel	50~200	5~ 20	5~ 15	30	~ 0.5
	19. G. J. M. Pando	50~200	5~100	5~ 10	50	~ 0.3
4. ORURO	01. Cercado	50~300	5~ 20	3~ 55	30	~ 0.8
	02. Challapata o Avaroa	200~350	5~100	10~ 20	30	~ 0.8
	03. Carangas	100~200	5~ 20	10~ 25	19.6	0.37~ 0.8
	04. Sajama	50~200	5~100	5~ 10	50	~ 0.3
	05. Litoral	200~350	5~100	10~ 15	50	~ 0.5
	06. Poopo	200~350	5~ 20	15~ 25	21.8	0.33~ 0.8
	07. P. Dalence	200~300	5~ 20	10~ 20	30	~ 0.8
	08. L. Cabera	50~300	5~100	3~ 10	50	~ 0.3
	09. Atahuallpa	50~200	5~160	5~ 10	50	~ 0.3
	10. Saucari	100~350	5~ 50	3~ 20	50	~ 0.8
	11. Tomas Barron	100~200	10~ 30	5~ 15	30	~ 0.5
	12. Sud carangas	200~350	5~ 30	3~ 10	50	~ 0.3
	13. San Pedro de Totora	100~200	5~ 40	3~ 10	30	~ 0.3
	14. S. Pagador	100~300	5~ 20	10~ 15	30	~ 0.5
	15. Mejillones	50~100	5~100	3~ 10	50	~ 0.3
	16. Nor Carangas	100~200	5~ 20	15~ 20	30	~ 0.8

Table 4-3-2 Groundwater Development Potential of the Study Area (continue)

Dept.	Province	Depth of Aquifer (m)	Static Water Level (m)	Potential Water yield (m3/hr)	Dynamic Water Level (m)	Specific Capacity (m3/day/m)
6. TARIJA	01. Cercado	100~300	5~ 20	15~ 30	20	~ 1.0
	02. Arce	100~200	5~150	3~ 30	20	~ 1.0
	03. Gran Chaco	100~400	3~100	5~ 30	90	~ 1.0
	04. Aviles	100~200	5~ 20	3~ 25	30	~ 0.8
	05. Mendez	100~200	5~ 60	15~ 20	30	~ 0.8
	06. Burnet O'connor	100~300	5~150	15~ 30	50	~ 1.0
7. SANTA CRUZ	01. Andes Ibanez	100~300	5~120	10~ 40	35.5	1.02~ 1.2
	02. Warnes	100~200	5~ 30	15~ 40	30	~ 1.2
	03. Velasco	50~100	10~ 50	3~ 20	50	~ 0.8
	04. Icbilo	100~200	5~ 50	10~ 25	30	~ 0.8
	05. Chuquitos	50~300	5~ 50	3~ 45	90	0.03~ 1.5
	06. Sarah	100~200	5~ 30	3~ 20	50	~ 0.8
	07. Cordillera	50~350	5~150	3~ 40	90	~ 1.2
	08. Valle Grande	100~300	5~ 70	15~ 30	50	~ 1.0
	09. Florida	100~300	5~ 70	10~ 40	50	~ 1.2
	10. O. Antiesteban	50~200	5~ 30	5~ 30	50	~ 1.0
	11. Nuflo de Chaves	50~200	5~ 30	5~ 30	90	~ 1.0
	12. Angel Sandoval	100~200	5~ 40	3~ 45	50	~ 1.5
	13. Manuel Ceballero	100~200	5~ 60	15~ 30	50	~ 1.0
	14. German Bushu	100~200	5~ 60	3~ 25	30	~ 0.8
	15. Guarayos	50~200	5~ 20	3~ 25	30	~ 0.8

4.3.3 Conditions for Groundwater Development

The technical conditions and themes for promoting groundwater development in Bolivia in the future can be summarized as follows.

1) Procurement of Well Drilling Equipment

Due to the low amount of equipment owned by public agencies, the well drilling in Bolivia have been carried out through hand digging and commissioned work using equipment owned by private enterprises. However, due to the well drilling by private enterprises being high in cost and because of the obsolescence and poor performance of publicly-owned equipment, groundwater development has been delayed.

Drilling equipment capable of deep drilling and with excellent performance are necessary in order to promote groundwater development in the future. The drilling equipment must be able to accommodate for the various geological features of the Study Areas and must be excellent in terms of mobility.

2) Improvement of Well Drilling Skills

Although well drilling has been mainly carried out by the private sector, much of it is dependent solely on experience and there are many enterprises which lack the fundamental know-how of drilling techniques and are low in management ability. Education of engineers is also inadequate and the spreading of the newest drilling technologies is delayed.

Experience in deep well drilling is lacking in particular and guidance and training of engineers on the operation methods of well drilling equipment, methods of formulating drilling work plans, equipment repairing skills, work management skills, logging, pumping test, and water quality test methods, etc. are needed. In order to acquire drilling skills, it is desirable to carry out cooperative work with engineers of advanced nations.

3) Spreading of Groundwater Prospecting Techniques

Data on the hydrogeological structures and groundwater flow conditions in Bolivia have not been accumulated adequately. In order to improve the rate of success of well drilling, preparatory studies by hydrogeological investigation, geophysical prospecting, etc. must be carried out in detail and it is important to spread groundwater prospecting techniques.

4) Spreading of Groundwater Conservation Measures

Groundwater is a valuable resource and in order to enable sustained groundwater utilization, residents must be encouraged and educated to prevent groundwater pollution and wasteful pumping, and measures, such as the furnishing of systems for monitoring the yields, water level, and water quality and the regulation of non-systematic groundwater development, must be taken.

4.4 Water Quality

4.4.1 Standards of Water Quality

1) Drinking water Quality Standard

Drinking water quality standards effective at present was published by the defunct Ministry of Urbanism and House (MUV) in 1976.

The standards are shown in Table 4-4-1 and Table 4-4-2. While some studies were conducted to amend the standards, new standards were not enforced by now. At present DINASBA makes effort to establish the drinking water quality standards forrural areas well as the design guidelines for system.

2) Water Quality Standards for water supply Receiving Waterbodies

The other water quality standards in Bolivia are for environmental waterbodies and wastewater effluent. The regulation was prepared in 1983 or 1984, but has not been implemented until recently because the Ministry of Urban Affairs (MUA) had no authority to establish and enforce such regulation.

The regulation on Discharge of Industrial Wastes into Waterbodies has just become effective in 1990. The regulation gives such specific water quality values as the upper limits for the environmental waterbodies and the industrial effluents. The former is shown in Table 4-4-3 and the later in Table 4-4-4.

In Table 4-4-3, environmental waterbodies are divided into the four(4) classes according to the usage of the water as follows.

Class Special:	Water designated to public water supply without treatment or with simple disinfection.
ClassA:	Waters designated to public water after sedimentation, filtration and disinfection, to irrigation of vegetable eatable in raw and to bathing.
ClassB:	Waters designated to public water supply after conventional treatment, i.e., coagulation, flocculation, sedimentation, filtration and desinfection, to preservation of flora and fauna, and to drinking water for animals.
Class C:	Water designated to public water supply after special treatment, to irrigation, to acenic harmony, to navigation and to power generation.
Class D:	Waters designated to transport and removal of wastes.

The maximum permissible values of water quality of wastewater effluents shown in Table 4-4-4 are applicable not only to industrial wastewater but also to any wastewater when it causes water pollution.

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

Table 4-4-1 Drinking Water Quality Standards

PARAMETER	UNIT	Bolivian Standards[1]		Standards for Rural Water		Japanese Standards
		Recommended Maximum Value	Acceptable Maximum Value	Recommended Maximum Value	Acceptable Maximum Value	
Turbidity	units	5	25	5.00	25.00	<2
Color	units	5	50	5.00	20.00	<5
Odor	-	0	No Rejectable	nil	nil	NA
Taste	-	0	No Rejectable	nil	nil	NA
Temperature	IC		<6.5			
pH	-	6.5-9.5	<9.2	7.0- 8.5	6.5- 9.2	5.8- 8.6
Saturation Index	-	10.5- -1.0	+1- -2		-0.5- +0.5	
Total Solids(TS)	mg/l			500.00	1,500.00	
Total Dissolved Solids(TDS)	mg/l	500	1,500			<500
Conductivity(EC)	lis/cm			500.00		<0.05
Alkalinity	mg/lCaCO3	In accordance with pH				
" (OH)	mg/l CaCO3			0.00	0.00	
" (CO3 2)	mg/lCaCO3			0.00	120.00	
" (HCO3)	mg/lCaCO3			0.00	250.00	
Total Hardness	mg/lCaCO3	250	500	100.00	500.00	
Sedimentary Suspended Solids	mg/l	0.0	0.2			
ABS			0.5			<0.5
As	mg/l	0.01	0.05	0.00	0.05	<0.05
Ba	mg/l		1.00	0.00	1.00	
Cd	mg/l		0.01	0.00	0.01	<0.01
Ca	mg/l	75	200	75.0	200.0	
CN	mg/l		0.05	0.00	0.05	ND
Chloroform	mg/l		0.2			
Free Chloride(Cl_2)	mg/l			0.00	1.00	
Chloride(Cl)	mg/l	200	600	200.00	500.00	
Cu	mg/l	0.05	1.50	0.50	1.50	<1.0
Cr^{+6}	mg/l	0.01	0.05	0.00	0.05	<0.05
F	mg/l	0.6	1.70	1.00	1.50	<0.8
Fe	mg/l	0.1	1.0	0.30	1.00	<0.3
Mg	mg/l	30	250	30.00	150.00	
Mn	mg/l	0.05	0.5	0.05	0.50	<0.3
Hg	mg/l		0.01	0.00	0.00	ND
Nitrate(NO3)	mg/l		45	0.00	45.00	<10
Nitrate(NO2)	mg/l			0.00	0.05	<10
Phenol	mg/l	0.001	0.002		0.05	
Pb	mg/l		0.10	0.00	0.10	<1.0
Se	mg/l		0.01	0.00	0.01	
Sulfate(SO_4)	mg/l	200	400		400.00	
Zn	mg/l	5.00	15.00	5.00	15.00	<1.0
Chloroform	IMNP/100ml			0.00	10	ND

Sources: 1) Normas de Discno para Sistemas de Agua Potable, MUV< 1976

2) Normas de Discno para Sistemas de Agua Potable en Poblacion menores a 5000 Habitantes, DINASBE, December 1994

Note: NA=NO Abnormal

ND=NO Detectable

Table 4-4-2 Water Quality Standards at Water Sources

Category		Good Water Sources Only Disinfection	Regular Water Source Usual Treatment like filtration and disinfection	Poor Water Source Specific Treatment and disinfection
BOD(5days)				
Monthly Average	(mg/l)	0.75-1.5	1.5-2.5	>2.5
Daily Maximum		1.0-3.0	3.0-4.0	>4.0
Coliform	(mnpllooml)			
Monthly Average		5.1-100	50-100,	>5,000
Daily Maximum		>100 in less 5% samples	>5,000 in less 20% samples	>20,000 in less 20% samples
DO	(mg/l)	4.0(min)	4.0(min)	>4.0(min)
Saturation Index		>75%	@60%	- - -
PH		6.0-8.5	5.0-9.0	3.8-10.5
Chloride(max)	(mg/l)	@50	50-250	>250
Phenol Compounds (max)	(mg/l)	nil	0.005	>0.005
Color	(unit)	0-20	20-150	>150
Turbidity	(unit)	0-10	10-250	>250
Chloride	(mg/l)	<1.5	1.5-3.0	>3.0

Source: Normas de Diseno para Sistemas de Agua Potable, MUV, 1976

Note : 1) *All superficial water source needs treatment, at least disinfection.*

2) *The limit value in this table indicates the relations and the planner must use it only as general guidelines for each cases.*

Table 4-4-3 Water Quality Standards for Environmental Waterbodies

PARAMETER	SPECIAL CLASS	CLASS A	CLASS B	CLASS C	CLASS D
Physical-biological parameters					
BOD(mg/l)	<2	<5	<10	<50	<300
DO	80% sat.	70% sat.	60% sat.	50% sat.	2mg/l
Floating Solids	Absent	Absent	Absent	None that could be retained on a 2mm sieve	None that could be retained on a 2mm sieve
Suspended solids(mg/l)	500	1,000	1,500	2,000	5,000
Greases and oils(mg/l)	Absents	0.8	1	10	20
Coliform Bacteria	<500	<5,000	<10,000	<20,000	
(MPN/100ml)	<50 in 80% of the samples	<1,000 in 80% of the samples	<2,000 in 80% of the samples	<5,000 in 80% of the samples	100,000
PH	6.5-9.0	6.0-9.5	5.5-9.5	5.0-10.0	4.5-10.0
Color(Color unit)	<20	<50	<100	<200	<1,000
Chemical parameters(mg/l)					
As	0.05	0.05	0.05	0.1	1
Ba	1	1	2	5	10
B	0.1	0.1	0.5	2	5
Cd	0.01	0.05	0.2	0.5	1
Cu	1	1.5	2		5
Cr"	0.05	0.05	0.1	1	5
Hg	0.001	0.005	0.001	0.02	0.05
Pb	0.05	0.1	0.1	0.2	2
Se	0.01	0.01	0.05	0.1	0.5
Cyanide	0.05	0.05	0.1	0.2	1
Phenois	0.001	0.002	0.005	0.01	0.1
Detergents(ABS and LAS)	0.15	0.5	1	2	5
Total Nitrogen N03	45	50	60	80	100
Zn	5	10	15	20	50
Mn	0.5	1	2	5	10
Fe	0.5	1	2	5	10
Mg	100	200	300	400	500
Ca	200	300	400	500	100
F	0.6-1.7	0.6-1.7	2	3	5
Chlorides	500	500	700	1,000	5,000
Sulfates	400	400	600	1,000	8,000
Herbicides(mg/l)					
Aldrin	0.017	0.017			
Chlordane	0.003	0.003			
D.D.T	0.042	0.042			
Dieldin	0.017	0.017			
Endrin	0.001	0.001			
Heptachlorine	0.018	0.018			
Epoxyheptachlorine	0.018	0.018			
Lindane	0.056	0.056			
Metoxychlorine	0.035	0.035			
Organic Phosphate with Carbonates	0.1	0.1			
Foxatene	0.005	0.005			
Total Herbicides	0.1	0.1			

Source: Reglamento soble Lanzamiento de Desechos Industriales en Cuerpos de Agua, MUV, Februaly 1990

Note : ABS=Alkyl benzene Sulufate

LAS-Linear Alkylate Sulfonate

MPN=Most Probable Number

Table 4-4-4 Maximum Allowable Values for Industrial Wastewater Discharge to Waterbodies

PARAMETER	UNIT	MAXIMUM VALUE
Temperature	℃	40
PH	-	4.5-10.0
Sulfate(SO_4)	mg/l	8000
Settleable solids,	mg/l	1
BOD	mg/l	300
COD	mg/l	500
Floating solids	mg/l	None that could be retained on a 3 mm sieve
Greases and oils	mg/l	20
Coliform Bacteria	MPNI100ml	100000
Color	color unit	1000
As	mg/l	1
Ba	mg/l	10
B	mg/l	5
Cd	mg/l	1
Cu	mg/l	5
Cr6'	mg/l	5
Hg	mg/l	0.05
Pb	mg/l	2
Se	mg/l	0.5
Cyanide	mg/l	1
Phenols	mg/l	0.1
Detergents(ABS and LAS)	mg/l	5
Total Nitrogen No3	mg/l	100
Zn	mg/l	50
Fe	mg/l	10
Mg	mg/l	500
Mn	mg/l	10
Ca	mg/l	700
Chlorides	mg/l	5000

Source: Reglamento soble Lanzamiento de Desechos Industriales en Cuerpos de Agua, MUV, Februaly 1990

Note : ABS=Alkyl benzene Sulufate

LAS-Linear Alkylate Sulfonate

MPN=Most Probable Number

4.4.2 Water Quality in the Study Area

1) Water Quality Conditions

As the Study Area is wide extended including from arid are in Altiplano to tropical lowlands, domestic water is removed from a variety of water sources; rivers, springs, ponds, groundwater and meteoric water, ordinary without any treatment. These natural water quality is affected by the geological conditions and the pollutant arrangement of each area.

(1) Natural Pollutants

Because no forest is found in Oruro, La Paz, and the western part of Chuquisaca and Tarija called as Sub-Andinas, most surface water and shallow groundwater have high turbidity easily.

The Altiplano is a enclosed area where is covered with many minerals such as heavy metal oxide, sulfate and chloride. The water, therefore, includes high contents of minerals and salts in many cases.

(2) Domestic and Livestock Effluent

Most domestic effluent is discharged without treatment all over the country and flows into rivers, ponds and shallow wells, resulting in the water pollution. Inhabitants drink the water after boiling to prevent water-borne diseases. Livestock is also a cause of pollution in rural area.

(3) Mining Effluents

Oruro and the southern part of La Paz have many mines where the wastewater is likely to contaminate the surrounding water quality Large-scale ore deposits exploiting tin, tungsten, silver and other metals are located in Dalence and Poopo Province in the eastern part of Oruro.

(4) Salinity

The Study Area contains wide arid or semi-arid areas having low precipitation rates like the Altiplano and the Chaco While the residents gather their water mostly from small sources such as spring, stream, puddle and shallow wells, the well water is frequently too salty to use. Based on the survey for Water Supply Database a considerable number of water supply blocks has the problems of high chloride content in drinking water 53% blocks in Oruro and 14% blocks in Tarija. Because the Altiplano plateau slopes gently from north to south, the density gets higher as going to south.

2) Drinking Water Quality

The Study Team had carried out water level measurement at existing wells and water quality test of drinking water including faucet water, well water, storage water in tank or bucket and water source water. The survey has conducted to identify the depth of groundwater and the quality of water which are used presently by residents in rural area, and to promote the technology transfer on the field survey to the counterparts.

The following equipment was used for the tests.

a. Potable Conductivity-TDS meter, HACK44600
b. Potable pH meter, HACK 43800-00
c. Digital Titrator, HACK 16900-01
d. Water Quality Analyzer, HACK DR-2000
e. Drinking Water Inspection Set. KYORITU WAS-D2

The results of water quality test are shown in Table 4-4-5 to Table 4-4-9 and the sampling points in Figure 4-4-1 to Figure 4-4-2.

Based on the results, present conditions of drinking water quality are summarized as follows.

(1) Chuquisaca

According to the Bolivian Census 1992, the conditions of pipes water supply services is low, accounting for 22% of the population in the Department except for the capital city. While arid Luis Calvo Province in Chaco claims drinking water removed from polluted wells, dirty ponds or rain water, mountain stream or spring water is mostly drawn, for domestic use in Sub-Andinas zone. With excluding a few cities with a treatment process, organic pollution is common for the low level of sanitation. Several water samples show a few high conductivity reaching 600-1, 300 micro-s/cm.

(2) Sur de La Paz

Water supply pervasion remains 28% in the rural area of La Paz. Most popular water source is shallow well, following the use of spring. Many samples show high conductivity over 500 micro-s/cm and the maximum value is 3,300 micro-s/cm. Signs of influence with mineral resources is found in Umala, showing high concentration of copper. Except for Berenguela, Santiago de Collana and Patacamaya, drinking water is polluted biologically by coliform or other bacteria.

(3) Oruro

Water supply pervasion is 37% and most communities rely on surface water ladling by human power and shallow wells to secure drinking water. The water quality is affected by the organic pollution and high content of dissolved solids. The groundwater in Toledo contains much salt content and the conductivity reaches 11,300 micro-s/cm. High concentration of copper may be the signs of mining pollution.

(4) Tarija

Water supply pervasion is comparatively high accounting for 48% except for the capital city. Drinking water is taken from various sources, but the most popular is spring and stream. However, the use of groundwater and pond water abounds in Gran Chaco Province where surface water is scarce. The water quality is comparatively good except for biological pollution and the high content of salts in Chaco zone.

(5) Santa Cruz

Santa Cruz has the highest coverage of rural water supply service in five Departments, accounting for 55%. While various kind of water sources is selected depending on the natural conditions, wells are used by around 70% of communities. Though most tap water is also polluted biologically and contains high turbidity, the water quality are not regarded as serious problems because the securing and providing the amount of water is more important for the region. However, some results of water quality tests shows the signs of heavy metal pollution and needs for quality control.

3) Groundwater Quality

Whereas few examinations had conducted to identify groundwater quality in rural areas, general conditions can be described as follows.

(1) Altiplano

Water quality in Altiplano is characterized as containing much dissolved solids and showing high value of hardness. In the southern area, shallow groundwater happens to be

too salty to drink like in Toledo. In order to exploit reliable and safe groundwater, special attention has to be paid to the concentration of salts. One option is cavern water sandwiched between bedrocks underground.

(2) Chaco

Water quality of existing well is generally polluted by human or livestock activities around the wells and contains relatively high density of dissolved solids, Conductivity says around 700 micro-s/cm on the average extending from 100 to 1,300.

(3) Other areas

While many existing wells is also polluted by organic solids or soil particles, the concentration of dissolved solids is not expected to be so high.

4.4.3 Present Conditions of the Water Quality of Domestic Water

1) Water Quality Examinations

In order to grasp the water qualities of water sources used for domestic water by residents of villages in the areas targeted for well boring, water quality examinations were conducted on samples collected from wells, springs, river water, stored water, etc. in the vicinity of such villages.

Table 4-4-5 Classification of Water Quality Examinations according to Water Source

Water Source / Targeted Village	Deep	Shallow well	Spring well	Rive water	Stored water	Total
Department Santa Cruz San Carlos	2 (1)	-	1	1	-	4 (1)
Department of Chuquisaca Campo Leon Simbolar	- (1)	1	-	-	2	3 (1)
Department of Tarija La Choza Bermejo	3 (1)	3	-	1	-	7 (1)
Department of Oruro Corque Penas	1	2 (1)	1	1		5 (1)
Department of La Paz Patacamaya	-	5 (1)				6 (2)
Total	6 (3)	11 (2)	3 (1)	3	2	25 (6)

Note: ( ) indicates faucet water number

2) Water Quality Characteristics of the Targeted Areas

The water quality characteristics of the water sources utilized shall be described below for each are targeted for well boring.

(1) San Carlos (Department of Santa Cruz)

[Color - Turbidity]

Although the faucet water drawn from deep wells and the spring water were colorless and clear, some of the river water and well water were brown or cloudy.

[pH]

Neutral to weakly basic water with pH of 7.5-8.5 were detected in the majority of cases.

[COD]

Although the COD was 3-5mg/l for water sources used for potable water, some of the river water had COD's exceeding 20mg/l.

[Nitrogen as Nitrate]

Values of 0.2-0.4mg/l were detected generally except with some of the well water.

[Total Hardness]

High levels of hardness of 300-500mg/l were detected in general and irrespective of the type of water source.

[Choride (Cl-)]

Relatively low concentrations of 5-75mg/l were detected irrespective of the type of water source.

[Free Cyanide(CN), Hexavalent Chromium (Cr+6)]

These were not detected from any of the water sources.

[Iron (Fe), Copper (Cu), Zinc (zn)]

Iron concentrations were 0.1-0.4mg/1,Copper was either undetected or detected only in minute concentrations. Zinc was undetected or detected only in minute concentrations in the majority of cases except for some of the deep wells which showed a concentration of 1.5mg/l.

[General Bacteria, Coliform Bacteria]

The examination results show the existence of significant amounts of general bacteria and coliform in all water sources except for spring water and faucet water drawn from deep wells.

On the other hand, these bacteria were either undetected or detected only in small amounts from faucet water and spring water.

From the above analysis results, it can be said that all water sources, except for spring water and faucet water drawn from deep wells, are highly contaminated with coliform bacteria and general bacteria and are not suitable for domestic water. The major reason for the water quality of spring water being relatively good is that the environment around the water sources are conserved by natural forests and orchards. On the other hand, it is contemplated that the contamination detected for some of the deep wells is due to the lack of facilities for domestic wastewater and to grazing livestock in the communities near the wells.

(2) Campo Leon, Simbolar (Department of Chuquisaca)

In many cases, the river, springs, and other water sources of the targeted villages dry up during the dry season. The water that is used consists of stored rainwater from roofs and water carried by tank trucks from distant wells and stored in containers.

In general, the stored water is highly contaminated with coliform bacteria and general bacteria due to inadequate storage methods and sanitation control of containers. Even growths of phytoplankton were seen in some of the cases. It can therefore be said that the water quality of stored water is unsuitable for domestic water.

Faucet water from shallow wells are also contaminated with Coliform bacteria and general bacteria and green water due to phytoplankton growth were seen in some of the cases.

(3) La Choza, Bermejo (Department of Tarija)

[Color - Turbidity]

At La Choza, the river water was brown and the well water was slightly cloudy. At Bermejo, brown-colored water was seen even in water from shallow wells.

[pH]
In general, neutral pH values of 7.5-7.9 were detected with the exception of some of the well water.
[COD]
Although, contamination by organic matters, amounting to COD s of 17mg/l or more, were seen with some of the shallow well water in Bermejo, the COD was in the range of 4-8mg/l in the majority of cases.
[Nitrogen as Nitrate]
Although nitrogen as nitrate was not detected from deep well water, values of 25mg/l were detected for river water and shallow well water.
[Total Hardness]
Although high levels of hardness of 300-500mg/l were detected for the shallow well water, relatively low levels of hardness of 95-130mg/l were detected for deep well water.
[Choride Ion(Cl-]
Besides some of the shallow well water which exhibited concentrations of 120-310mg/l, relatively low concentrations of 20-50mg/l were detected in the majority of cases.
[Free Cyanide (CN), Hexavalent Chromium (Cr+6)]
These were not detected from any of the water sources.
[Iron (Fe), Copper (Cu), Zinc (Zn)]
Although minute amounts of zinc were detected from deep well, iron, copper, and zinc were generally undetected or detected only in extremely minute concentrations.
[General Bacteria, Coliform Bacteria]
Examination results show the existence of significant amounts of general bacteria and coliform bacteria in all water sources except for deep well water. The amounts of general bacteria and coliform bacteria in deep well water were relatively low. The above analysis results show that river water and shallow well water are highly contaminated with coliform bacteria and general bacteria. Contamination by organic matter was also seen in some of the cases. It can thus be said that such water sources are unsuitable for domestic water. On the other hand, although microorganism contamination was also seen in deep well water, the two deep wells examined were private wells and it is thought growths of general bacteria were seen since these wells were not used constantly.

(4) Corque, Pefi as (Department of Oruro)

Although 80% of the population in Coruque is provided with water supply faucets, the supply of water from faucets is limited to about 30 minutes a day during the dry season. In terms of water quality, the water is slightly cloudy, exhibits a weakly acidic ph of 7.0, and is highly contaminated with coliform bacteria and general bacteria. It is thus considered that the water sources are unsuitable for domestic water. The cause of this is that the areas around the spring water sources are used as pastures and received with contamination from the grazing livestock.

Although water supply facilities using springs as water sources are furnished in Peñ as, these were not used during the dry season due to the drying up of the water sources. Although the water qualities of shallow well water and infiltrated river water are relatively good as indicated below, these are highly contaminated with coliform bacteria and general bacteria and it must be said that these are unsuitable as water sources for domestic water.

- In terms of color and turbidity, the water is colorless and clear.
-The pH is 8.0-8.4 and weakly basic.
-The concentration of nitrogen as nitrate is about 1mg/l/l.
-High hardness levels of 350-400 mg/l were detected.
-Chloride ion concentrations of 70-80 mg/l were detected.
-Cyanide and hexavalent chromium were undetected.
-Although minute concentrations of iron and zinc were detected, copper was undetected.
-Although the amounts were not significant, some contamination by general bacteria and coliform bacteria were detected.

For reference, the analysis results of the water qualities of groundwater and river water of the surrounding areas show that the levels of hardness and chloride ion concentration are extremely high in the plain are (Altiplano) of Oruro. This is due to the groundwater being found at shallower locations than the ground level. For this reason, spring water from the skirts of mountains or, as in the case of Toledo village, infiltration water of relatively low salt concentration are used as water sources for domestic water.

(5) Patacamaya (Department of La Paz)

[Color - Turbidity]
With the exception of some of the shallow well water, the water is generally colorless and clear.

[pH]
In general, neutral pH values of 7.0-8.5 were detected.

[COD]
The COD was about 3 mg/l for the majority of the cases except for some of the shallow wells.

[Nitrogen as Nitrate]
In general, concentrations of 1-2mg/l were detected.

[Total Hardness]
In general, hardness levels of 100-250mg/l were detected.

[Chloride Ion(Cl-)]
Relatively low concentrations of 30-55mg/l were detected with the exception of some of the shallow well water.

[Free Cyanide (CN), Hexavalent Chromium (Cr+6)]
These were not detected from any of the water sources.

[Iron (Fe), Copper (Cu), Zinc (Zn)]

Although minute concentrations of iron and zinc were detected in general, copper was undetected.

[General Bacteria, Coliform Bacteria]

Although the amounts were not significant, general bacteria and coliform bacteria were detected from all shallow wells with the exception of faucet water drawn from springs.

The above analysis results show that all shallow well water are contaminated with coliform bacteria and general bacteria. These water sources are thus considered to be unsuitable as water sources for domestic water. It is contemplated that shallow wells more or less receive the influence of domestic wastewater and contamination due to activities on the ground, such as grazing.

4.4.4 Evaluation of Groundwater Water Quality

1) Evaluations based on Studies on the Present Conditions of Water Quality in Rural Areas

The water quality characteristics of the utilized water sources were described for each rural area targeted for well boring in "4.4.3 Present Conditions of the Water Quality of Domestic Water" above. The water quality characteristics shall now be described in terms of the type of water source utilized.

(1) River water

Irrespective of the location, the majority of the river water are highly colored and turbid, are strongly contaminated by organic matter and microorganisms, and are thus unsuitable for direct use as domestic water.

(2) Springs

Good water quality is maintained in the case of springs where the environment surrounding the water source is well conserved. On the other hand, there are many springs for which the water source environment has been disturbed by deforestation or pasture or farmland development and such water sources are contaminated with organic matter and microorganisms.

(3) Shallow Well Water

A large part of the shallow well water in regions besides the Patacamaya region of the southern part of the Department of La Paz are highly contaminated with microorganisms and some of the shallow wells are also contaminated with organic matter. Although the amounts were not significant, some microorganism contamination were also seen in the shallow well water in the Patacamaya region.

In the plain areas of the Department of Oruro, the ground water are found at locations shallower than the ground level and the use of shallow wells is infrequent due to organic matter contamination and extremely high levels of hardness(dissolved solids) and salt concentration.

(4) Deep Well Water

Although only a few examination data were available on deep well water, the water quality of deep well water is generally good in comparison to that of other water sources. Since most of the deep well water at the sampling points are not well furnished water sources provided with sanitation control, the deep well water received the influence of contaminants from the ground and the intake parts in many cases.

The improvement of the surroundings of deep wells and sanitation control are considered to be the important factors for maintaining the good water quality of these water sources.

2) General Evaluation of Groundwater Water Quality

Well-furnished deep well water sources are scarce in the rural areas and water quality analysis data on water sources are even scarcer. A general evaluation of groundwater water quality shall thus be made based on data for urban areas where there are relatively many deep well water sources.

(1) Santa Cruz City

The percentage of population served with tap water is 85% in Santa Cruz City. 90% of this service has been provided by SAGUAPAC (Cooperation de Servicios Publucios Santa Cruz).

SAGUAPAC has conducted water quality studies on various types of well water distributed in Santa Cruz City and has reported the results in terms of shallow wells (depth: 45m or less) and deep wells (depth greater than 45m). The results of water quality studies of the water sources of Santa Cruz City are shown in Table 4-4-6. Some of the referenced materials are listed in the Appendix.

Table 4-4-6 Results of Water Quality Studies on the Water Sources of Santa Cruz City

	Shallow wells (depth: 45 or less)	Deep wells (depth: greater taken)
Type of well / Number of samples taken	Hand-dug wells 52 Bored wells 21 Total 73	Hand-dug wells 0 Bored wells 85 Total 85
Water temperature (t)	21.5-26.0	23.0-26.0
pH	6.5-8.0	7.0-8.0
Dissolved Oxygen (DO) mg/l	0.0-4.0	0.0-6.0
Conductivity μs/cm	500-1,500	250-750
Nitrogen as Nitrate *(NOs-N)* mg/l	10-50	5-35
Chloride (Cl-) mg/l	40-200	10-70
Sulfate (SO4-2) mg/l	30-90	10-30
Sodium (Na) mg/l	30-120	10-30
Potassium (k) mg/l	5-25	2-4
Calcium (Ca) mg/l	75-225	25-125
Magnesium (Mg) mg/l	15-45	10-30

Reference: Since the above study did not include microorganism tests, an adequate assessment of the degree of contamination from the ground in urban areas cannot be made. However, it can be seen that deep wells have generally low levels of nitrogen as nitrate in comparison to shallow wells and are less affected by contaminants from the ground.

Furthermore, the results of water source water source water quality studies on water sources conducted by SAGUPAC in 1995 show that while the concentration of nitrogen as nitrate was 0.2-6.7mg/l, the conductivity 311-493 li s/cm, the chloride concentration 11.8-16.O mg/l, and the total hardness 204-291 mg/l for 4 deep wells of depths of 161-182m. From this it can be understood that the water quality of deeper wells is less affected by contaminants from the ground and it can be assumed that the influence of contaminants on the ground reach deep into the ground in urban areas.

The results of water quality studies on water sources conducted by SAGUPAC in 1995 are organized in the Appendix.

(2) Tarija

a) Areas surrounding Tarija City (Province of Cerado, Province of Medez).

Water, quality analysis results for well water in Tarija City and its surroundings can be found in the study data compiled by COSAALT(Cooperative de Servicios de Agua y Alcantarillado)from February 1980 to March 1983 and from January to November of 1993. Table 4-4-7 shows an outline of the water quality of well water for the area surrounding Tarija City in terms of well depth.

Table 4-4-7 Outline of Water Quality of Well Water in the Area surrounding Tarija City

Classification of wells according to Depth Number of Samples Taken	Shallow fell, (depth:60m or less) 6	Deep Well (depth:60-loom) 12	Deep Well (depth:100-186m) 14
Color, Turbidity	colorless, clear in all cases	colorless, clear in all cases	colorless, clear in all cases
pH	7.5-7.9	7.7-8.8	7.5-8.1
Conductivity μs/cm	36-100	85-240	90-350
Nitrogen as Nitrite (NO 2: N) mg/l	0	0	0
Chloride (Cl-) mg/l	3-16.2	1.9-14.9	4.1-17.2
Calcium (Ca) mg/l	2.9-8.9	(7.4)	7.3-23.7
Magnesium (Mg) mg/l	13.5-33.8	(37.1)	16.5-77.0
Total Hardness (CaCOs) mg/l	16.4-42.0	(44.5)	26.9-88.6
Total Solids mg/l	(17.4)	(12.0)	9.6-49.9

Note) Figures in ( )are those for which the number of samples were few.
Especially abnormal values were excluded.

Since tests for organic matter and microorganisms are not included in the above water analysis data, the influence of contaminants on the various types of well water could not be confirmed, However, it can be seen in general that the hardness, dissolved solids, and chlorides tend to be greater for deep well water than for shallow well water.

b) Grand Chaco Province

A comparative study of the water quality analysis data for 38 wells in Grand Chaco Province shows that there are hardly any differences in water quality according to well depth, in Table 4-4-8, the water quality was generally found weakly basic with extremely high levels of conductivity dissolved solids, and hardness. Table 4-4-9 shown a classification of the wells in the data according to depth.

Since tests for organic matter and microorganisms were also not included in the above water analysis data, the influence of contaminants on the various types of well water could not be confirmed.

Table 4-4-8 Outline of the Water Quality of Well Water in Grand Chaco Province

Color, Turbidity		Clear but with floating solids
pH		8.2-8.6
Conductivity	us/cm	400-1,000
Ammonia (NH3)	mg/l	undetected
Chloride (Cl-)	mg/l	15-70
Calcium (Ca)	mg/l	20-50
Magnesium (Mg)	mg/l	200-300
Total hardness (CaCO5)	mg/l	250-350
Total Solids	mg/l	400-600
Total Dissolved Solids	mg/l	350-600

Table 4-4-9 Classification of Wells in Grand Chaco Province according to Depth

<Depth of Well>	<Number of Well>
63-99M	10wells
100- 199M	44wells
200-273M	3wells
700M	1well
Total	58well

(3) Oruro city

The supply of tap water in Oruro City is provided by SELA ORURO (Servicio de Acueductos y Alcantarillados).

Table 4-4-10 shows the major items of the most major-water sources of SELA and the recent water analysis results.

Table 4-4-10 Major Water Sources of SELA and Water Quality Analysis Results (Date of Examination; Mar.14, 1995)

Location of Well		Challapampita		Colo-Khaja			
Well No.		No.2	No.3	PP-7	PP-9	PP-10	PP-11
Depth of Well		65.0m	65.5m	96.0m	90.0m	92.0m	90.0m
Color		color-less	color-less	color-less	color-less	color-less	color-less
Turbidity	UNT	0.2	0.1	0.1	0.2	0.4	0.1
pH		7.7	7.7	7.7	7.7	7.7	7.7
Conductivity	μ S/cm	1,222	1,732	916	1,282	3,160	1,028
Nitrogen as Nitrite(NO2-N) mg/l		0.01C	0.00	0.004	0.005	0.320	0.003
Nitrogen as Nitrate(NO3-N) mg/i		1.10	0.08	1.04	0.70	1.20	1.30
Chloride	mg/l	182.0	341.8	73.5	180.6	728.0	101.5
Sulfate	mg/l	110.0	82.0	140.0	102.0	120.0	128.0
Silicate	mg/l	15.2	18.8	15.8	22.4	10.8	11.2
Phosphate	mg/l	0.34	0.28	0.09	0.14	0.38	0.15
Magnesium(Mg)	mg/l	12.8	24.8	12.4	16.4	17.8	18.4
Iron	mg/l	0.01	0.02	0.01	0.03	0.03	0.02
Copper	mg/l	0.03	0.02	0.03	0.02	0.02	0.01
Total Hardness	mg/l	171.4	288.1	154.5	130.5	199.4	171.4
Total Solids	mg/l	768.C	984.0	592.0	764.0	1,820.0	660.0

The above analysis results do not show significant differences in the water qualities of well water for different areas or according to well depth, In fact, wells with poor water quality are found among wells in the same area and of the same depth. Furthermore, water with a pH of 7.9-8.0, conductivity of 1,680-1,905μ s/cm, total solids of 1,624-81,504mg/l, a turbidity of 5-2,000 UNT or more, and having a brown to black color and emitting offensive odors was found from well No.4 of Challapampita in a study conducted in December 1992.

(4) Department of Chuquisaca, Department of La Paz (Southern Part)

Evaluations for the Eastern Chaco region of Chuquisaca shall be omitted due to the lack data for consideration of the water qualities Evaluations for the vicinity of Patacamaya in the Southern Part of the Department of La Paz shall also be omitted since there were hardly any deep wells and the water-qualities of deep and shallow wells could not be compared.

4.4.5 Water Quality Tests for the Study Wells

In order to examine that the water of study wells are suitable to use as the portable water, the water quality tests had been conducted by the local institutes of water quality analysis which are also the public corporations of water supply in the province capital cities.

The water quality test results have been evaluated according to the Bolivian Standards for Drinking Water Quality which was established on the basis of the WHO standard guidelines.

(1) San Carlos : Santa Cruz Province

3 water samples of San Carlos study well had been taken by the local well-drilling contractor "HIDROSUR S.A." during the water lifting test. Water quality tests had been conducted by the SAGUAPAC which is the public corporation of water supply in the capital city of Santa Cruz Province.

In the test results, water quality shows the less values than the limits of Bolivian Standards for Drinking Water Quality except that the alkalinity due to bicarbonate(HCO_3^-) is a little higher. Thus the water of study well is considered to be suitable for the portable water.

Since the contamination of the drilled holes, well casing pipes and filter gravel had not been sufficiently washed out by the continuous water pumping before water lifting test, The color and turbidity of water is observed to be rather less as test sample is taken latter in a day.

(2) Campo Leon : Chuquisaca Province

3 water samples of San Carlos study well had been taken by the local well-drilling contractor "HIDROSUR S.A." during the water lifting test. Water quality tests had been conducted by the SAGUAPAC which is the public corporation of Santa Crutz water supply, and is suitably located from Campo Leon.

Water quality shows the less values than the limits of Bolivian Standards for Drinking Water Quality except that the color and turbidity of water sample taken earlier during water lifting test exceeds the standard limits . Thus the water of study well is considered to be suitable for the portable water.

Since the contamination of the drilled holes, well casing pipes and filter gravel had not fully washed out due to the lack of drilling and washing water, it is considered that the high degree of color and turbidity were detected in the earlier water sample.

Subsequently it is observed that the well water gradually increases in purity and clean degree due to the long time water pumping. Water quality should not be evaluated only on a test result of water sample taken during water lifting test, but it is important to continue the evaluation on the periodic water quality tests from now.

(3) La Choza : Tarija Province

A water sample of La Choza study well had been taken by the local well-drilling contractor "HIDROSUR S.A." during the water lifting test. Water quality tests had been conducted by the COSALT which is the public corporation of water supply in the capital city of Tarija Province.

In the test result, water quality shows the weakly basic pH due to the high degree of bicarbonate(HCO3-) alkalinity. Generally, the water quality shows the less values than the limits of Bolivian Standards for Drinking Water Quality except of magnesium and the high degree of alkalinity.

(4) Quituquina : Santa Cruz Province

3 water samples of Quituquina study well had been taken by the local well-drilling contractor "HIDROSUR S.A." during the water lifting test. Water quality tests had been conducted by the SAGUAPAC which is the public corporation of water supply in the capital city of Santa Cruz Province. As shown follow, the water quality greatly exceed the limits of Bolivian Standards for Drinking Water Quality.

	<Test Results>		<Standard Limts>
· Color, Turbidity	: Brown and cloudy		
· Total Iron (Fe)	: 0.85 ~ 2.85	>	0.3 mg/l
· Bicarbonate(HCO_3^-)	: 684 ~ 719	>	250 mg/l
· Coride (Cl^-)	: 485 ~ 510	>	250 mg/l
· Sulfate (SO_4^{-2})	: 1,524 ~ 1,839	>	400 mg/l
· Fluorine (F^-)	: 2.03 ~ 2.11	>	1.5 mg/l
· Total Dissolved Solids	: 3,274 ~ 3,843	>	1,000 mg/l
· Conductivity	: 5,320 ~ 5,490 μ·mhos/cm		

The color and turbidity of well water could not be observed to be clear and pure by the continuous water pumping. From the test results, it is evaluated that the water of Quituquina study well is presently unsuitable for the portable water. Quituquina study well has been closed by the steel cap after water lifting test, because this well was not planned as the pilot well.

4.5 Environmental Condition

4.5.1 Natural Environment and Pollution

1) General

Bolivia is able to draw and abundant supply of natural resources. While the eastern half of the country is covered with extensive forest and pastures, and offers sizable sketches of land suitable for crop and livestock production, around half of population lives on a barren plateau in the Andes. Along with agriculture and livestock industry, mining is a large economic sector because the land provides with tin, zinc, silver, gold, autimony, copper and tangustin from the richest ore deposit in South America. Energy is derived principally from petroleum and natural gas.

The most pressing environmental issue in Bolivia concerns the responsible development of the abundant natural resources. Especially in the eastern lowlands where hold much potential for growth and rapid development has resulted in the wasteful exploitation of forest and other natural resources. Indiscriminate land clearing, poor land use and road construction may deplete the area of these valuable resources.

Water pollution is a problem especially in arid and semiarid regions where water is scarce. Water pollutants discharged by mimning industry are contaminating irrigation and drinking water. Urban pollution is also a concern.

2) Legal and Institutional Framework for Pollution Control

The General Law of Environment (Ley General del Medio Ambiente, Ley No. 1333) was established in April 1992. The law sets up the framework and the general policy for protectio and conservation of the environment and natural resources in harmony with the sustainable development.

The law consisting of 113 articles also provides the institutional arrangements including the creation of the National Environmental Agency (SENMA) in the National Government, the Departmental Counsel of Environment (CODEMA) and the Departmental Secretary of Environment in each Department. The present environmental administration was integrated to the Ministry of Sustainable Development and Environment (Ministerio de Desarrollo Sostenible y Medio Ambiente: MDSMA) by the reform of new administration layout on October 1993. The organization of the Ministry is shown below.

- MINISTERIO DE DESARROLLO SOSTENIBLE Y MEDIO AMBIENTE
  - SECRETARIA NACIONAL DE RECURSOS NATURALES Y GESTION AMBIENTAL
    - SUB-SECRETARIA DE CALIDAD AMBIENTAL
    - SUB-SECRETARIA DE RECURSOS NATURALES
    - SUB-SECRETARIA DE PROMOCION AMBIENTAL
  - SECRETARIA NACIONAL DE PLANIFICACION
    - SUB-SECRETARIA DE ESTRATEGIA Y DESARROLLO
    - SUB-SECRETARIA DE ORDENAMIENTO TERRITORIAL
    - SUB-SECRETARIA DE PROYECTOS Y PREINVERSION

As for water use, waterworks and sewerage system, the Law of Water (Ley del Agua) is studied in DINASBA at present to promote rational use of water and conservation of the environment.

3) Environmental Impact Assessment

The General Law of Environment prescribes that all of work and activity, whether public or private, should be identified in the following category of environmental impact assessment before the investment stage.(Art.35).

1. Necessary for the integral analysis of EIA.
2. Necessary for the specific analysis of EIA.
3. Unnecessary for the specific analysis of EIA but desirable to conduct conceptual examination.
4. Unnecessary for EIA

The process of presentation, categorization, evaluation, approval or rejection, control, follow up and monitoring on the environmental impact studies were to be stipulated in the corresponding regulation. However, its contents are under consideration and the regulation has not yet published.

4.5.2 Initial Environmental Examination

1) Description of the Project

(1) Purpose of the Project

As the Study Area lagged behind in the development of water for natural conditions and economical constraints, water supply service coverage is estimated to be an average of only 30% or below. The difficulty to secure water during dry season hinders the development and aggravates depopulation due to migration to urban areas.

Based on these circumstances, the development of safe drinking water will satisfy the residents essential demand and will contribute to stabilize and improve their living conditions. Groundwater development is accorded top priority among the basic water supply projects for the resolution of water shortage in the rural areas.

The main objectives of groundwater development project are to provide the Study Area with a stable supply of safe water for domestic use in sufficient quantity, to promote health and sanitation of residents and to improve their living conditions.

(2) Size and Scale of the Project

The Project area covers 532,361 km2 in all, but the objective sites of each project are dispersed in the rural areas. Each facility to be constructed is a small scale.

(3) Components of Activities

Major activities to be undertaken in each site from pre-construction to operation processes can be described as follows.

During construction
- a. Well drilling
- b. Construction of water supply facilities (Plant, tank, pipe and others)

After operation
- a. Space occupation by facilities
- b. Drafting of groundwater
- c. Facility operation (Well management, water distribution and others)

2) Initial Examination

Since groundwater development projects are conducted to improve the public health and sanitary conditions, they have strong positive impacts on the living conditions of inhabitants. In case of unsuitable construction or overdraft, however, they could cause several negative environmental shows in parts which are shown in the Matrix to identify the relations between the development activities and the impacts. Table 4-5-1 shows the causal relationship in connection with the environmental impacts.

Table 4-5-1 Matrix for Scoping

Environment Items \ Activities which may cause impacts			Before Operation		After Operation		
			Well Drilling	Construction of Facilities	Space Occupation	Groundwater Pumping	Facilities Operation
Social Environment	1	Resettlement					
	2	Economic Activity					
	3	Traffic and Public Facility					
	4	Split of Communities					
	5	Cultural Property					
	6	Water Rights/Rights of Common					
	7	Public Health Condition					
	8	Waste					
	9	Hazards (Risk)	○				
Natural Environmental	10	Topography and Geology					
	11	Soil Erosion					
	12		○				
	13	Hydrological Situation				●	
	14	Coastal Zone					
	15	Fauna and Flora					
	16	Meteorology					
	17	ndscape					
Polution	18	Air Pollution					
	19	Water Contamination	○			○	
	20	Soil Contamination					
	21	Noise and Vibration	○	○			
	22	Land Subsidence				●	
	23	Offensive Odor					

Note ● : *The environmental items which might cause serious impacts that may affect the project formulation, depending on the magnitude of the impacts and the possibility of the measures.*

○ : *The environmental items which may have a significant impact depending on the scale of the project and site conditions.*

No mark : The environmental items which the anticipated impacts are, in general, not significant

(1) Groundwater

Overdraft of well water causes the lowering of the groundwater table and the exhaustion of the groundwater sources which results when groundwater is used faster than nature replenishment. The impacts depends on the condition of groundwater resources and the available pumping capacity. Generally the impacts of this project might be small because the project aims for only domestic water in rural area and pumping volume is not so large. However, as the project area includes and or semi-arid area, special attention should be paid.

The changes of water level and water quality of existing well around the project site shall be examined before and after the pumping test to monitor the extent of the impacts.

(2) Land Subsidence

Land Subsidence is caused by consolidation and contraction of clay layers due to the lowing of groundwater table. Main cause of the impact is the overdrafting of groundwater as well as the geological conditions. However, the impacts are generally considered to be small because the pumping volume of this project is not so enormous like industrial use in big cities. If the project site is located in the area having thick-clay layer, the measures such as restriction of overdrafting should be examined to avoid the impacts.

(3) Water Pollution

During the construction periods, inadequate well drilling causes the disturbance of groundwater layer and the drilling mud and oil might cause the water pollution of rivers and groundwater. The impacts can be minimized when prudent construction method is employed for the implementation of the projects.

If water pumping is not brought into balance with recharge, eventually the underground might become too salty to use or depleted.

Water quality shall be examined and monitored for environmental consideration to avoid or alleviate the adverse impacts to existing wells.

(4) Water Rights

When many wells exist around the site, the lowering of groundwater table of existing wells might cause the problems such as obstruction of irrigation and water rights.

The present conditions of groundwater utilization and the inhabitants views on the projects shall be studied before the implementation of the projects.

(5) Hazards (Risk)

A few case of cavein accidents were allegedly occurred during well drilling in the area on thick sand layers. This kind of accidents however, can be avoided by planning the sequence of construction and selecting the adequate construction equipment.

(6) Others

For the wells and water supply facilities are small structure which can be placed in or out of the project, area, the resettlement problems of land occupation can be avoided.

As for noise and vibration, the impacts are not so large except in the densely populated areas nearby.

4.5.3 Terms of Reference on Environmental Impact Studies

The JICA study team carried out the initial environmental examination for the groundwater development in rural areas in cooperation with DINASBA and five (5) CORDES of Chuquisaca, Tarija, Oruro, Santa Cruz and La Paz. Based on the results, both sides discussed the necessity of the environmental impact assessment for pilot projects of the feasibility study in Phase 11 and 19, and agreed as showen in the Appendix.

4.5.4 Environmental Impact Assessment for Pilot Projects

On the basis of the Initial Environmental Examination result and the Terms of Reference agreed mutually, the environmental impact assessment for the pilot projects have been conducted according to the environmental standards in Bolivia and the JICA Environmental Guideline.

1) San Carlos, Santa Cruz Province

(1) Present Land Use and Land Occupation

The construction site for pilot plant in a part of stock farm privately owned by a person of San Carlos village. The land used by pilot plant is purchased as the public land of community with no objection to the land occupation.

(2) Surface Water Use and Water Lights

[Present Surface Water Use]

At 300m north from the pilot well, stream water risen from westside hills is used as portable water by about 50 households equivalent to 1/3 of San Carlos village.

At Losario village located in approx. 4km north from the pilot well, spring water led with piping from westside hills is used as portable water.

Two " ATAJADOS" provided for livestock near to the pilot site are mostly dried up during dry season. Small valley beside the pilot site is also dried up during dry season.

[Possible Environmental Impacts]

Since the stream water rises from the spring of 2km west hills, the stream water would not be influenced due to the water lifting of pilot well (depth @. 250m).

The water of small valley and the "ATAJADOS" water take those rises in the rain water and the spring water from hills, therefore these water also would not be influenced due to the water lifting of pilot well.

[Relevant Study and Evaluation]

As far as the environimental impacts possibly occured on the present utilization of surface water have been studied around the pilot site, it could not be found out that the water lifting of pilot well cause the harmful impacts on the water the pilot site, it could not be found out that lifting of pilot well cause the harmful lights of present surface water use.

(3) Groundwater Use

[Present Groundwater Use]

In Colonia San Juan village located at approx. 2km west from the pilot well, the handy pump well (approx. 1 1 Om depth) developed together with village and church is used as portable water by 120 households of Coinia San Juan

In the deep well (approx. 1,000m depth) drilled for petroleum development at approx. 5km south from the pilot well, the approx. 21an west from (approx. 1 1 Om depth) well water, is mixed with the oily materials, and then is not used as the portable water.

[Possible Environmental Impacts)

Since the well of Colonia San Juan locates in the another valley behind the hills, the groundwater stream in the valley of Colonia San 'Carlos is dif ferent with that in the, valley of in the another Colonia San Juan. Therefore, the well water of Colonia San Juan would not be influenced due to the water lifting of pilot well.

[Relevant Study and Evaluation]

After commencement of water lifting from pilot well harmful appearance such as the lowering of groundwater level is not presently observed in the well of Colonia San Juan.

(4) Risks/Hazards and Water Pollution during Construction.

As the countermeasure to prevent the risks and hazards during construction, the drilling rig had been installed stably and firmly and reinforced by streching wire ropes. The safety fencing had not been enoughly installed around the construction work area, however the construction work had been completed with no risks and no hazards by calling the inhabitant's safety attention. The water pollution due to construction waste water and the harmful effects due to construction vibration and noise had not occu'red.

It seems that the well drilling and construction work had been smoothly executed by the earnest cooperation and kind supports of San Carlos people.

(5) Land Subsidence

The pilot well had been drilled carefully to prevent the accidental cavein of the drilled well hole. And the filter gravel filling and backfilling around well casings had been been executed with firmly compaction. Therefore the ground surface changes such as land subsidence had not occured around the pilot well.

And also, the ground settlement and surface changes which is causable due to groundwater lifting have not been presently observed around the pilot well.

2) Campo Leon, Chuquisaca Province

(1) Present Land Use and Land Occupation.

The construction site for pilot plant located in a cornered part of elementary school ground. Since the land of school belongs to the community of Campo Leon, all village people agree to use a part of school ground as the pilot plant land with no objection to the land occupation.

(2) Surface Water Use and Water Lights.

[Present Surface Water Use]

Since the pilot site situates in the semi-arid climate area and locates on the ridge of hilly regions with 700-750m altitude, the surface water constantly used as portable water could not be found out around the site.

The water springs in valley line of hilly region are used by people as portable water and the "ATAJADOS" are provided for livestocks, however those water are dried up during dry season.

[Possible Environmental Impacts]

Since the hilly spring water and the "ATAJADOS" water take those rises in the shallow ground water and rain water, those water conditions would not be influenced due to the water lifting of pilot deep well(depth @-. 400m).

[Relevant Study and Evaluation]

As far as the environmental impacts possibly occured on the present utilization of surface water have been studied around the pilot site, it could not be found out that the water lifting of pilot well causes the harmful impacts on the water lights of present surface water use.

(3) Groundwater Use

Around this region including Campo Leon, any shallow and deep well water is not utilized.

(4) Risks/Hazards and Water Pollution during Construction.

As the countermeasure to prevent the risks and hazards during construction, the drilling rig had been installed stably and firmly with reinforcement of streching wire ropes. The construction work had been completed with no risks and no hazard by providing the safety fencing around construction work area, and by calling the inhabitants safety attention. The water pollution due to construction waste water and the harmful impacts due to machinery vibration observed.

It also seems that the construction work of pilot plant had been smoothly completed by obtaining the earnest cooperation and kind supports of Campo Leon people.

(5) Land Subsidence

The pilot well had been drilled slowly and carefully to prevent the accidental cavein of the drilled well hole. The gravel filter and backfill soil had been filled by firmly compacting all around well casings. Therefore the ground surface changes such as land subsidence had not occured around the pilot well.

And also, the ground settlement which is causable due to groundwater lifting, have not been presently observed near around pilot well.

3) La Choza, Tarija Province

(1) Present Land Use and Land Occupation

The construction site for pilot plant locates in a cornered part of the La Choza public land in which the church and elementary school are installed. The La Choza people have consented to install the pilot plant in the public land, with no objection to the land occupation.

(2) Surface Water Use and Water Lights

[Present Surface Water Use]

The pilot plant site situates on the hill behind of La Choza village distributed along the Rio Tarija. The river water of Rio Tarija has been led by the dug ditch land used for agricultural irrigation and domestic washings. The river infiltrated water has been lifted up from two shallow wells (depth - 1 0m), and used for portable water.

[Possible Environmental Impacts]

The size of pilot well is extremely small in comparison with the river water scale of Rio Tarija. And, since the pilot well water is lifted up from approx. 150m depth, the present surface water sourced with Rio Tari]'a river would not be influenced by water lifting of pilot well.

[Relevant Study and Evaluation]

As far as the environmental impacts possibly occured on the present utilization of surface water have been studied around the pilot site, it could not be found out that the water lifting of pilot well causes the han-nful impacts on the water lights of present surface water use.

(3) Groundwater Use

[Present Groundwater Use]

In the Suchuwaico district situated at approx. 1.5km east from the pilot well, two private deep wells (depth '-. 150m) have been used for agricultural irrigation water.

[Possible Environmental Impacts]

Two private deep wells in Suchuwaico district would not be influenced due to water lifting of pilot well, because lifting water volume of pilot well is very small and both wells are so far from the pilot well.

[Relevant Study and Evaluation]

After commencement of water lifting from pilot well, the harmftil appearance such as the lowering of ground water level has not been presently observed in two wells of Suchuwaico.

(4) Risks/Hazards and Water Pollution during Construction

The safety fencing had not been enoughly provided around the construction work area, however the construction work had been completed with no risks and no hazards by calling the safety attention to the students and inhabitants.

It also seems that the construction work of pilot plant had been smoothly completed by the earnest cooperation and kind supports of La Choza people.

(5) Land Subsidence

In this pilot well, the confined groundwater gushed out at the expected drilling depth, however the drilling hole had not collapsed because of the hard and rocky ground condition. The gravel filter and backfill soil had been filled by firmly compacting all around well casings. Therefore the ground surfaces changes such as land subsidence had not occured around the pilot well.

And also, the ground settlement which is causable due to groundwater lifting, have not been presently observed near around pilot well.

4) Corque, Oruro Province

(1) Present Land Use and Land Occupation

The construction site for pilot plant locates on a part of the public farm in the flat valley at distance of approx. 1km from Corque village. The village people have consented to install the pilot plant in the public farm, with no objection to the land occupation.

(2) Surface.Water Use and Water Lights

[Surface Water Use]

The sources of village portable water are two springs of hills. One spring locates at the behind hill of village and the other one locates at hill of lokm distance from village. Although 80% of population in Corque is provided with water supply faucents, the supply of water from faucents is limited, to about 30 minutes a day during dry season. On the other hand, the groundwater is found at shallower locations than the ground level in the plain area around Corque, and its quality shows the high concentration of chloride and minerals. Therefore, the utilization of surface water and shallow well water could not be found out near around Corque.

[Possible Environmental Impacts]

The pilot well locates at distance of approx. 2km from the nearest hill water spring used as portable water source. And, since the pilot well water is lifted up from approx. 100m depth, the present conditio . n of hill water spring would not be influenced by water lifting of pilot well.

In addition, the pilot well water will be substituted for the hill spring water as portable water source.

[Relevant Study and Evaluation]

As far as the environmental impacts possibly occured on the present utilization of surface water have been studied around the pilot site, it could not be found out that the water lifting of pilot well causes the harmful impacts on the water lights of present surface water use.

(3) Groundwater Use

Around this region, any shallow and deep well water is utilized.

(4) Risks/Hazards and Water Pollution during Construction

The plant construction site situates in the uninhabited farm far from village. The construction work of pilot plant had been completed with no risks and no hazards by providing the safety fencing around work area and by calling the safety attention to the inhabitants.

It also seems that the construction work of pilot plant had been smoothly completed by the earnest cooperation and kind supports of Corque people.

(5) Land Subsidence

The construction works of pilot plant had been executed carefully, therefore the ground surface changes such as land subsidence does not occur around the pilot well.

And also, the ground settlement which is causable due to groundwater drilling, have not been presently observed near around pilot well.

CHAPTER 5

REGIONAL GROUNDWATER DEVELOPMENT STRATEGIES

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5.1 Objectives and Basic Concepts

5.1.1 Objectives

The objectives of the groundwater development project are to develop new water resources for providing inhabitants of rural communities in five Departments of the Study Area with stable supplies of safe and sanitary drinking water at appropriate prices and to thereby improve and expand the current status of water supply services. The development strategies are aimed at arranging the conditions for early realization of the project and for formulating the basic policies.

These development strategies shall be formulated as plans of highest priority which are anticipated to be carried out as soon as possible in order to resolve the shortage of water in the rural areas of Bolivia.

5.1.2 Basic Concepts

The development strategies are formulated on the basis of the following basic concepts.

1) Stable Supply of Domestic Water to Rural Areas

A large difference in the supply of domestic water exists between urban areas and rural areas in the Bolivia. In the regional rural areas, the water supply coverage is extremely low and there is a serious shortage of water. An overwhelming number of communities completely lack water supply systems and the furnishing of water supply services is an urgent theme.

While the water demand in rural areas mainly consist of domestic water and agricultural water, at least drinking water and domestic water must be supplied in a stable manner to all inhabitants of the communities, and water supply system should be furnished with top priority.

2) Promotion of Groundwater Development

The greatest cause of the delay in water supply services in Bolivia is the difficulty of water source development. Although development of water sources based on surface water and shallow wells have been carried out from the past, adequate water quantities cannot be obtained and there are also many problems in terms of water quality. Furthermore, even in areas with an existing water supply system, the water source dries up in the dry season in many cases.

Water sources can largely be divided into surface water, such as river and lake water, and groundwater such as well water and spring water. As can be seen from the comparison of groundwater, river water, and lake water shown in Table 5-1-1, groundwater is generally stable in temperature and quality is good relatively. Furthermore, groundwater is suited as a water source for small-scale water supply systems since groundwater can be pumped up near the points of demand. Especially, deep groundwater is suited as a water source since it is stable in terms of quantity and presents a high development potential even in dry regions, such as the Study Area, where precipitation is low and water source is scarce.

Despite being high in development potential, the development of deep groundwater in the Study Area is delayed due to the lack of equipment, resources, and skills. The groundwater development should therefore be promoted actively as sources of domestic water.

3) Early Realization of the Project

There is an urgent need to furnish water supply services for rural communities and short-term, concentrated investments should be made to enable early execution of the groundwater development project, upon making adjustments among relevant domestic agencies, international cooperation, and NGO's. Effective and well-organized international cooperation should be promoted for the procurement of equipment, technology, and funds that are lacking in Bolivia to ensure the effectiveness of the project. Also, fortification of the project implementing organization and system, as well as technical improvement should be carried forth to promote the continuation of the project.

In executing the project, priority should be placed on impoverished regions with a high degree of necessity while taking into consideration the potential for groundwater development, investment efficiency, and sustainability of operation and maintenance.

4) Sustainability of Water Supply Systems

The operation and maintenance of water supply systems shall basically be carried out through self-management by beneficiary communities. In many cases in medium and small communities, the water supply systems are not provided with adequate maintenance and are abandoned even after a short time of operation. Therefore, operation and maintenance education and sanitation education, as well as guidance for the establishment of a self-management organization, should be provided to enhance the self-help abilities of the beneficiary communities. Efforts should also be made towards establishing a support system.

Also, in the construction of water supply systems, the adoption of appropriate technologies that match the operation and maintenance capabilities of communities and the participation of inhabitants should be promoted.

5) Conservation and Optimal Utilization of Groundwater Resources

In view of the conservation of groundwater resources, groundwater development shall be performed in a manner which will not destroy the water balance of groundwater basins and which will enable stable and long-term groundwater development.

Table 5-1-1 Comparison of Various Water Sources for Water Systems

	Groundwater	River Water	Lake Water
Water quantity	Nearly constant. Generally difficult to increase artificially in a short time.	Varies greatly with the seasons. Some level of artificial adjustment is possible through water source recharging forests, dam construction, etc.	Relatively stable. The amount of discharge (intake) can be adjusted in the case of dam lakes. Recharging of water sources in the collection area is essential.
Water temperature	Constant all year round.	Varies in accompaniment with the air temperature.	Varies in accompaniment with the air temperature at the surface layer. Differs at the lower layer.
Turbidity	Extremely low.	High. Exhibits large, temporary variations due to rainfall, etc.	High during flooding. Some turbidity is caused by living organisms.
Dissolved salts	Generally high in quantity. Tends to be hard water.	Relatively low.	Relatively low.
Influence of pollution	Usually tends to be unaffected with the exception of some substances. However, recovery is extremely difficult once the water is polluted.	Tends to be polluted easily. Both polluting substances and pollution levels may vary widely and an advanced ability to counteract is necessary.	Tends to receive pollution due to eutrophication. Recovery is extremely difficult once eutrophication occurs.
Others	Excessive drawing of water may lead to land subsidence and entry of salt water.	Drying up of spring water and loss of self-purification capacity due to river modification, etc. Intake of water discharged upstream at the downstream side through repeated use of river water.	Problems caused by living organisms tend to occur. Dilemma between the development of tourism and the conservation of water quality in the region.

5.2 Targets

5.2.1 Target Year

The target year for the development strategies shall be set to the year 2000. The term of the project has been set to five years, from 1996 to 2000.

Table 5-2-1 shows the projection of future population in 2000 by Department and area.

Table 5-2-1 Projection of Future Population in 2000

	Present Population			Future Population		
Dept.	Urban	Rural	Total	Urban	Rural	Total
Chuquisaca	12,944	276,185	289,129	16,802	295,271	312,073
S.of La Paz	8,512	117,765	126,277	8,491	111,259	119,750
Oruro	38,423	99,025	137,448	39,552	100,248	139,800
Tarija	69,325	130,833	200,158	93,610	151,652	245,262
Santa Cruz	284,924	367,211	652,135	354,313	440,479	794,792
Total	414,128	991,019	1,405,147	512,768	1,098,909	1,611,677

Source: Water Supply Database

5.2.2 Target Water Supply Coverage

The target water supply coverages for the year 2000 have been set for the urban area and rural area of each Department as shown in Table 5-2-2. These target coverages were established after examined the feasible scale of the project of well drilling and construction works for five years, as described in Section 5.3.2. It was supposed that in urban area and in cities whose present water supply coverage is over 60%, the present water supply coverages will maintain in the same level continuously to the target year.

Table 5-2-2 Target Water Supply Coverage (%)

	Present Water Supply Coverage			Target Water Supply Coverage		
Department	Urban Area	Rural Area	Total	Urban Area	Rural Area	Total
Chuquisaca	88.5	16.4	19.6	90	30	33
South of La Paz	26.0	16.4	17.0	80	30	34
Oruro	63.3	21.3	33.0	80	40	51
Tarija	88.8	36.8	54.8	90	50	65
Santa Cruz	83.8	26.4	51.5	90	40	62
Study Area	81.7	23.3	40.5	89	38	54

Planned population served in 2000 in accordance with the target coverage are estimated as shown in Table 5-2-3

Table 5-2-3 Planned Population Served in Target Year

Department	Target Coverage			Planned Population Served		
	Urban Area	Rural Area	Total	Urban Area	Rural Area	Total
Chuquisaca	90%	30%	33%	15,122	88,581	103,703
South of La Paz	80%	30%	34%	6,793	33,378	40,171
Oruro	80%	40%	51%	31,642	40,099	71,741
Tarija	90%	50%	65%	84,249	75,826	160,075
Santa Cruz	90%	40%	62%	318,882	176,192	495,074
Study Area	89%	38%	54%	456,688	414,076	870,764

5.2.3 Water Supply Service Targets

All households in the water supply districts shall receive water supply service over eight hours a day throughout the year, regardless of the rainy and dry seasons, or be accessible to such water supply points with a distance within 250 meters approximately.

The levels of water supply service are classified into three levels; namely Level 1 (point source), Level 2 (public faucet), and Level 3 (house-to-house connection). As a rule, house-to-house water supplies shall be furnished in concentrated-population type communities and public faucets shall be furnished in dispersed-population type communities. While this strategy focuses on the planning of water supply facilities up to the main distribution pipe, other facilities should be constructed in accordance with the actual conditions of the communities.

5.2.4 Water Quality Targets

The water quality for domestic use should be accorded with the following conditions.

① Not contain organisms or substances contaminated by pathogenic organisms.

② Not contain hazardous substances which may affect the protection of human health.

③ Not contain more than allowable amounts of hazardous substances that may cause problems for domestic water use.

④ Not exhibit unusual acidity or alkalinity.

⑤ Not have any unusual odors or taste.

⑥ Be substantially colorless and transparent in appearance.

The quality of the water to be targeted in the development should comply with the Drinking Water Quality Standards in Bolivia. Disinfecting and filtration equipment shall be provided in cases where the standards are not complied with and the water containing hazardous substances that may affect human health shall not be used as a water source for drinking water.

5.3 Approaches to the Strategies

5.3.1 Building up of the Water Supply Database

The groundwater development plan must be planned upon performing field studies on the current status of water demand and supply, groundwater development potential, existence of alternative water sources, topography, geology, meteorology, etc. to ascertain the actual conditions in each water supply block. However, since the Study Area is vast and contains 4,265 water supply blocks, a water supply database was built up to compile these data, and the groundwater development strategies was formulated on the basis of this water supply database.

5.3.2 Classification of Water Supply Blocks

1) Objectives and Concepts

In order to determine the targets, the development priorities, and to formulate the development strategies, it needs to estimate the quantity of facility and equipment, and calculate the project cost required to achieve the targets.

In the strategy formulation process, the water supply blocks were classified using the water supply database, and the project cost was estimated upon determining the standard specifications of water supply facilities and equipments for each classified package. Case studies on the planning targets and development priorities were then performed to examine the appropriate project scale, project strategy, project form, etc.

In the implementation stage for the groundwater development project, field studies must be carried out in advance to check the actual circumstances of each water supply block.

Since the database is utilized for classification, the items and classes of classification can be changed freely according to the purpose of use once the reliability of the data has been confirmed. The classification may be simplified using a small number of indices in order to grasp the overall trends in outline or items may be added and the classification be made finer in cases where more detailed examination is necessary.

2) Indices of Classification

The following indices, which are the basic data that indicate the characteristics of water supply blocks in terms of the urgency and potential of groundwater development and which are considered to be high in reliability among the data in the database, were set as the classification indices.

① Scale of the water supply block (present population)

② Circumstances of the water supply system (existence of water supply facility and present coverage)

③ Groundwater development potential (existence of aquifer and its estimated depth)

④ Site conditions of the water supply block (topography, geology)

The results of performing classification according to each Department using the above indices are shown in Tables 5-3-1 ~ 5-3-4.

Table 5-3-1 Number of Blocks by Population Scale

Population (persons)	>=2000	1000~ 1999	500~ 999	300~ 499	50~ 299	Total
Chuquisaca	4	11	54	190	964	1,223
South of La Paz	2	7	15	43	695	762
Oruro	8	10	15	50	461	544
Tarija	5	7	28	93	378	511
Santa Cruz	41	34	90	267	793	1,225
Total	60	69	202	643	3,291	4,265

Table 5-3-2 Number of Blocks by Existing System and Present Coverage

Present Coverage	No existing facilities	With existing facilities			Total
	-	1~29%	30~59%	60~100%	
Chuquisaca	959	64	71	129	1,223
South of La Paz	676	24	19	43	762
Oruro	396	57	47	44	544
Tarija	248	38	67	158	511
Santa Cruz	810	129	65	221	1,255
Total	3,089	312	269	595	4,265

Table 5-3-3 Number of Blocks by Aquifer Depths

Aquifer Depth (m)	0~ 49	50~ 99	100~ 149	150~ 199	200~ 299	>=300	Unknown	Total
Chuquisaca	349	268	351	155	79	21	-	1,223
South of La Paz	160	35	450	117	-	-	-	762
Oruro	23	224	228	52	17	-	-	544
Tarija	-	197	150	5	94	2	63	511
Santa Cruz	4	580	371	115	70	79	6	1,225
Total	536	1,304	1,550	444	260	102	69	4,265

Table 5-3-4 Distribution by Department of the Number of Blocks by Topographical Divisions

Topographical Divisions	Altiplano	Valley		Plain			Total
		Cordillera Zone	Seranias Zone	Eastern Plain	Escudo Central	Chaco Plain	
Chuquisaca	-	1,039	171	-	-	13	1,223
South of La Paz	689	73	-	-	-	-	762
Oruro	384	160	-	-	-	-	544
Tarija	-	315	130	-	-	66	511
Santa Cruz	-	-	295	732	167	31	1,225
Total	1073	1,587	596	732	167	110	4,265

5.3.3 Project Implementation Case Study

1) Objectives and Procedures

The conditions to realized the groundwater development project can be summarized as follows:

a. Urgent needs for groundwater development (water scarcity, no alternative water sources.)
b. Availability of groundwater development (aquifer with sustainable productivity.)
c. Financial feasibility of the project (procurement of investment funds.)
d. Willingness and technical ability of the organization concerned.
e. Sustainability for operation and maintenance of the system (community commitment, supporting system.)
f. Effectiveness of the project.

A case study was carried out in order to examine the plan targets and project implementation strategy of the groundwater development project in the Study Area. After determined the target coverages, project implementation strategies, and project forms for the groundwater development project in each Department, the applicable project was selected, and the necessary equipment, term of drilling, and investment amount were determined. The appropriate project scale, plan targets, and project implementation strategies were then examined upon assessing the feasibility of the project in financial, technological, and organizational aspects based on the results of the case study. Figure 5-3-1 shows the procedures for carrying out the case study.

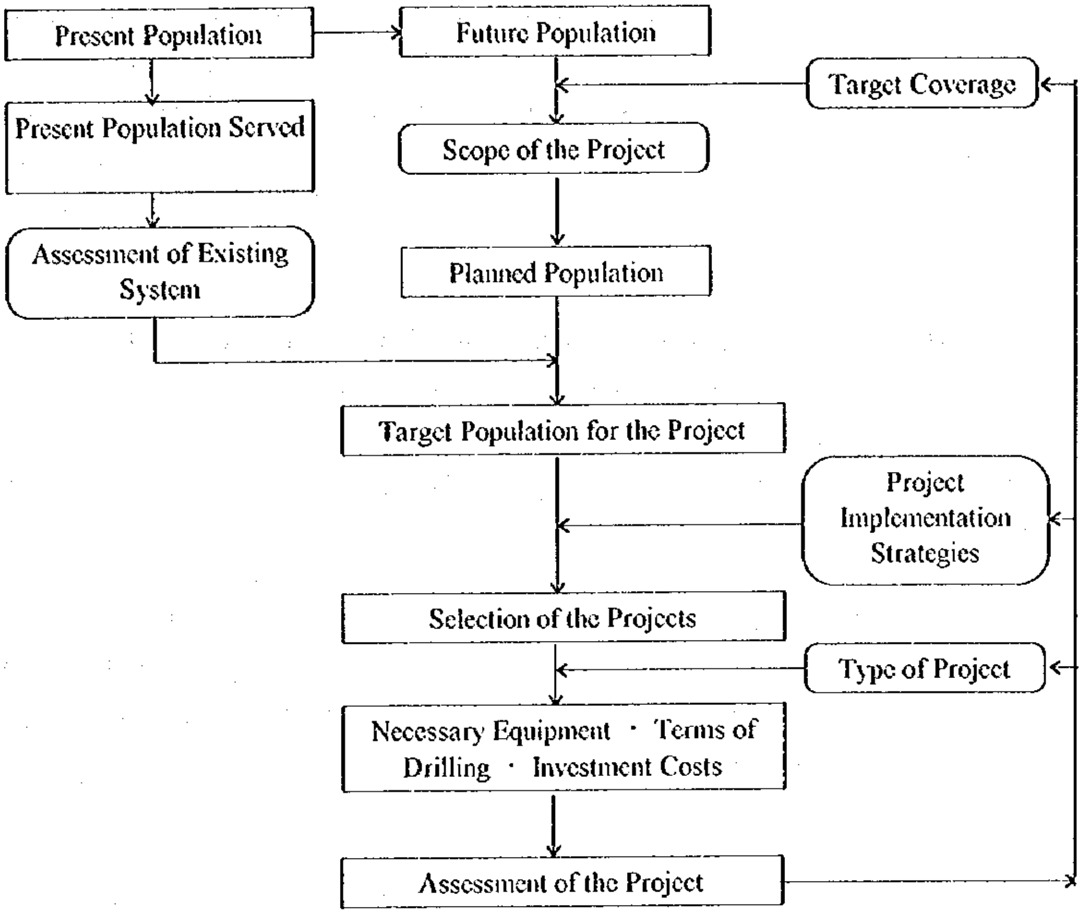

Figure 5-3-1 Procedures for the Case Study

2) Target Population

The target population was determined by subtracting the population served by existing facilities from the planned population served for the target year. The population served by existing facilities was determined for each water supply block by multiplying the present population served by the obsolescence factor of existing equipment. Next, the population to be targeted by the groundwater development project was determined by taking into consideration the factor of effectiveness after the start of provision of service to the applicable population.

Target population = [Planned population served] - [Population served by existing facilities]
Planned population served = [Population in the Study Area] × [Target coverage]
Population served by existing facilities = [Present population served] × [Obsolescence factor of existing water supply facility]
Target population of the project = [Applicable population] ÷ [Effectiveness factor]

Table 5-3-5 shows the results of calculating the target population of the groundwater development project for different target coverages set in 10% increments for the rural areas of each Department and subjecting only rural blocks with a coverage of less than 60%. Here, it was assumed that the present coverage level will be maintained as a whole in the target year in cities with a population of 2,000 or more and in rural blocks in which the present coverage has reached 60% or more.

Table 5-3-5 Target Population of the Groundwater Development Project (Targeting only the rural areas.)

Department	Present Coverage	Target Coverage (Year 2000)				
		20%	30%	40%	50%	60%
Chuquisaca	15.9%	20,019	56,928	93,836	130,746	167,655
South of La Paz	16.4%	5,955	19,863	33,770	47,677	61,585
Oruro	21.3%	-	16,095	28,626	41,158	53,689
Tarija	36.8%	-	-	11,845	30,801	49,758
Santa Cruz	25.1%	-	43,095	98,155	153,215	208,274

Note: The effectiveness of the project was presumed to be 80%.

Table 5-3-6 shows a procedure of calculating the target population for the project.

Table 5-3-6 Calculation of Target Population for the Project

		No. of Blocks	Present Cov.	Target COV.	Total Pop(2000)	target W.S. Pop.	Estimated W.S. Pop.	Planned Population	
Chuquisaca	Urban	5	87.6%	90%	16,802	15,122	13,066	2,056	
	Rural	1,218	15.9%	30%	295,271	88,581	34,823	53,758	
	≧60%	126	79.8%	80%	41,932	33,546	25,330	8,216	
	≦59%	1,092	5.1%	(21.7%)	234,627	55,035	9,493	45,542	→ 56,928
	計	1,223	19.6%	(33.2%)	312,073	103,703	47,889	55,814	
S. La Paz	Urban	2	26.0%	80%	8,491	6,793	2,209	4,584	
	Rural	760	16.4%	30%	111,259	33,378	13,871	19,507	
	≧60%	51	83.0%	84%	18,121	15,222	11,605	3,617	
	≦59%	709	3.3%	(18.4%)	93,138	18,156	2,266	15,890	→ 19,863
	計	762	17.0%	(33.5%)	119,750	40,171	16,080	24,091	
Oruro	Urban	8	63.3%	80%	39,552	31,642	24,323	7,319	
	Rural	536	21.3%	40%	100,248	40,099	12,006	28,093	
	≧60%	57	79.6%	80%	14,365	11,492	6,300	5,192	
	≦59%	479	11.8%	(32.9%)	85,883	28,607	5,706	22,901	→ 28,626
	計	544	33.0%	(51.3%)	139,800	71,741	36,329	35,412	
Tarija	Urban	5	88.7%	90%	93,610	84,249	61,449	22,800	
	Rural	506	36.8%	50%	151,652	75,826	33,455	42,371	
	≧60%	153	82.3%	83%	51,880	43,060	25,330	17,730	
	≦59%	353	13.5%	(32.8%)	99,772	32,766	8,125	24,641	→ 30,801
	計	511	54.8%	(65.3%)	245,262	160,075	94,904	65,171	
Santa Cruz	Urban	47	83.5%	90%	294,423	318,882	245,959	72,923	
	Rural	1,178	25.1%	40%	357,712	176,192	35,600	140,592	
	≧60%	181	87.9%	88%	87,563	94,171	32,103	62,068	
	≦59%	997	4.8%	(37.8%)	270,149	82,021	3,497	78,524	→ 98,155
	計	1,225	51.5%	(62.3%)	652,135	495,074	281,559	213,515	

Note :The estimated Water supply population in 2,000 is calculated by multiplying the present water service population and the superannuated rate of existing facility.

3) Selection of Water Supply Blocks of the Project

The development priority of the groundwater development project is considered to be high for districts with a large beneficiary population, districts with low present coverage, and districts where water source development is easy and has a high possibility of success. Besides these, the willingness of the inhabitants to participate, the accessibility, the efficiency of moving drilling equipment, work efficiency must also be considered.

In the case study, the water supply blocks of the project were selected upon setting up the following three project implementation strategies using the three indices of present population, present coverage, and estimated aquifer depth, which were used as indices for water supply block classification.

[1] Priority is placed on blocks with larger population unserved (economic efficiency).

[2] Priority is placed on blocks without existing water supply systems (basic human need).

[3] Priority is placed on blocks with shallower aquifer (drilling efficiency).

The numbers of selected blocks are shown according to target coverage and project implementation strategy for each Department in Tables 5-3-7 to 5-3-11. While the number of blocks will be the fewest with project implementation strategy [1], blocks will be included which, due to having a large population, are given high priority despite being high in coverage. With project implementation strategy [2], since only the blocks with a present coverage of 0% are selected, the number of blocks will be considerably high depending on the Department and blocks with an extremely low population will also be included. With project implementation strategy [3], areas in which it is difficult to obtain water from sources other than deep groundwater are excluded since blocks with a low drilling construction cost per inhabitant are selected.

4) Cost Estimation and Term of Drilling

The groundwater development project can be divided into the procurement of equipment, well drilling work, water supply facility construction, survey/design/control activities, etc. The following project forms can be considered with regard to the method of execution of the project in view of the division of domestic funds and foreign funds.

[A] Construction is carried out by Bolivia on its own. The project is executed by commissioning work to domestic private constructor.

[B] Well drilling is executed through grant aids, and the Bolivian side carries out the water supply facility work.

[C] Well drilling equipment are procured through grant aids and the Bolivian side carries out the works.

Tables 5-3-7 to 5-3-11 show the results of calculating the project cost and the term of drilling work according to project form upon setting the target coverage and project implementation strategy for each Department and selecting the blocks to be targeted by the project.

[Setting of Conditions]

The term of drilling work was calculated respectively for the case where the work is to be commissioned to and carried out by domestic private firms, the case where a foreign aid agency procures equipment from the corresponding nation and carries out the work, and the case where Bolivian engineers are to carry out the work using equipment procured from overseas. The project cost was estimated upon dividing it into the drilling equipment procurement cost, drilling work cost, water supply equipment procurement cost, water supply facility construction cost, and drilling work staff cost and setting unit costs for each water supply block classification package. The unit cost for the drilling work cost was set as a per meter unit cost, that for the procurement cost of water supplying equipment, such as well casings, screens, lift pump, generator, etc., was set as a per site unit cost, and that for the water supply construction cost including piping, tanks, etc. was set as a per person unit cost.

Table 5-3-7 Results of Project Implementation Case Study (Department of Chuquisaca)

Target Coverage	Project Implementation Strategy	Number of Blocks	Target Population	Form of Project	Number of Drilling Equipment	Project Cost (million US$) External Funds	Project Cost (million US$) Domestic Funds	Project Cost (million US$) Total	Project Cost per Person (US$) External Funds	Project Cost per Person (US$) Domestic Funds	Term of Drilling (Year)	Evaluation
20%	[1]	22	20,391	[A] Commission	1 set	–	3.2	3.2	–	156	1.6	×
				[B] Cooperate in DW	1 set	1.8	1.5	3.3	86	72	1.0	
				[C1] Cooperate in PE	1 set	5.1	2.0	7.1	252	97	1.3	
20%	[2]	27	20,094	[A] Commission	1 set	–	3.8	3.8	–	188	2.2	×
				[B] Cooperate in DW	1 set	2.5	1.5	4.0	124	77	1.4	
				[C1] Cooperate in PE	1 set	5.1	2.2	7.3	255	108	1.8	
20%	[3]	28	20,466	[A] Commission	1 set	–	3.3	3.3	–	161	1.4	×
				[B] Cooperate in DW	1 set	1.4	1.6	3.0	68	77	0.9	
				[C1] Cooperate in PE	1 set	5.1	2.1	7.2	251	103	1.1	
30%	[1]	94	56,995	[A] Commission	2 set	–	12.2	12.2	–	214	3.8	×
				[B] Cooperate in DW	5 set	8.6	4.7	13.3	151	83	1.0	
				[C1] Cooperate in PE	1 set	5.1	6.5	11.6	90	114	6.1	×
				[C2] Cooperate in PE	2 set	8.2	6.8	15.0	144	119	3.1	
30%	[2]	113	57,297	[A] Commission	2 set	–	14.5	14.5	–	253	4.9	×
				[B] Cooperate in DW	7 set	11.3	5.1	16.4	197	89	1.0	×
				[C1] Cooperate in PE	1 set	5.1	7.3	12.4	90	128	7.9	×
				[C2] Cooperate in PE	2 set	8.2	7.6	15.8	143	132	4.0	
30%	[3]	125	57,114	[A] Commission	2 set	–	12.8	12.8	–	224	3.2	×
				[B] Cooperate in DW	4 set	6.6	5.4	12.0	116	94	1.0	
				[C1] Cooperate in PE	1 set	5.1	7.2	12.3	90	126	4.9	
				[C2] Cooperate in PE	2 set	8.2	7.5	15.7	144	130	2.5	
40%	[1]	194	94,023	[A] Commission	4 set	–	24.3	24.3	–	259	4.1	×
				[B] Cooperate in DW	10set	18.4	8.6	27.0	196	91	1.0	×
				[C1] Cooperate in PE	1 set	5.1	12.1	17.2	55	129	12.9	×
				[C2] Cooperate in PE	3 set	10.0	12.7	22.7	106	135	4.3	×
40%	[2]	227	93,898	[A] Commission	4 set	–	27.7	27.7	–	295	4.8	×
				[B] Cooperate in DW	12set	21.9	9.2	31.1	233	98	1.0	×
				[C1] Cooperate in PE	1 set	5.1	13.4	18.5	55	143	15.3	×
				[C2] Cooperate in PE	4 set	11.8	14.2	26.0	126	151	3.9	×
40%	[3]	251	94,561	[A] Commission	3 set	–	25.5	25.5	–	270	4.7	×
				[B] Cooperate in DW	9 set	15.0	9.7	24.7	159	103	2.2	×
				[C1] Cooperate in PE	1 set	5.1	13.4	18.5	54	142	10.8	×
				[C2] Cooperate in PE	3 set	10.0	14.0	24.0	106	148	3.6	×

(Note)

[A] *Commission private constructor*

[B] *Cooperation in drilling work*

[C1] *Cooperation in procurement of equipment , in the case where one unit of equipment is to be procured.*

[C2] *Cooperation in procurement of equipment - the number of units required for the completion of drilling in 5 years is indicated.*

[shaded] *Indicates the unfavorable condition*

Table 5-3-8 Results of Project Implementation Case Study (Southern Part of La Paz)

Target Coverage	Project Implementation Strategy	Number of Blocks	Target Population	Form of Project	Number of Drilling Equipment	Project Cost (million US$) External Funds	Project Cost (million US$) Domestic Funds	Project Cost (million US$) Total	Project Cost per Person (US$) External Funds	Project Cost per Person (US$) Domestic Funds	Term of Drilling (Year)	Evaluation
20%	[1]	7	6,083	[A] Commission	1 set	–	1.1	1.1	–	188	0.6	×
				[B] Cooperate in DW	1 set	0.6	0.4	1.0	102	73	0.4	
				[C1] Cooperate in PE	1 set	4.3	0.9	5.2	707	140	0.5	×
20%	[2]	10	6,096	[A] Commission	1 set	–	1.1	1.1	–	235	0.8	×
				[B] Cooperate in DW	1 set	0.9	0.5	1.4	146	83	0.5	
				[C1] Cooperate in PE	1 set	4.4	0.9	5.3	715	153	0.7	×
20%	[3]	11	6,081	[A] Commission	1 set	–	1.4	1.4	–	225	0.7	×
				[B] Cooperate in DW	1 set	0.7	0.5	1.2	110	86	0.4	
				[C1] Cooperate in PE	1 set	4.4	0.9	5.3	717	154	0.5	×
30%	[1]	45	20,012	[A] Commission	1 set	–	5.5	5.5	–	275	3.7	×
				[B] Cooperate in DW	3 set	4.1	1.9	6.0	207	95	0.8	
				[C1] Cooperate in PE	1 set	4.6	2.8	7.4	228	142	2.9	
30%	[2]	57	20,013	[A] Commission	1 set	–	6.7	6.7	–	333	4.7	×
				[B] Cooperate in DW	3 set	5.3	2.1	7.4	264	107	1.5	
				[C1] Cooperate in PE	1 set	4.6	3.3	7.9	228	164	3.7	×
30%	[3]	77	20,102	[A] Commission	1 set	–	7.5	7.5	–	373	4.6	×
				[B] Cooperate in DW	3 set	4.9	2.5	7.4	245	127	1.5	
				[C1] Cooperate in PE	1 set	4.6	3.8	8.4	227	190	3.6	×
40%	[1]	105	33,783	[A] Commission	2 set	--	12.2	12.2	--	360	4.3	×
				[B] Cooperate in DW	6 set	9.8	3.8	13.6	289	112	1.8	
				[C1] Cooperate in PE	1 set	4.6	5.8	10.4	135	171	6.9	×
				[C2] Cooperate in PE	2 set	7.1	6.0	13.1	210	179	3.4	×
40%	[2]	128	33,934	[A] Commission	3 set	–	15.0	15.0	–	441	3.7	×
				[B] Cooperate in DW	7 set	12.6	4.3	16.9	372	125	1.7	×
				[C1] Cooperate in PE	1 set	4.6	6.7	11.3	134	198	8.8	×
				[C2] Cooperate in PE	2 set	7.1	7.0	14.1	209	206	4.4	×
40%	[3]	180	33,799	[A] Commission	3 set	–	17.9	17.9	–	530	4.2	×
				[B] Cooperate in DW	8 set	14.1	5.3	19.4	417	157	1.0	×
				[C1] Cooperate in PE	1 set	4.6	8.3	12.9	135	246	10.0	×
				[C2] Cooperate in PE	2 set	7.1	8.6	15.7	209	254	5.0	×

(Note)

[A] *Commission private constructor*

[B] *Cooperation in drilling work*

[C1] *Cooperation in procurement of equipment , in the case where one unit of equipment is to be procured.*

[C2] *Cooperation in procurement of equipment - the number of units required for the completion of drilling in 5 years is indicated.*

▒ *Indicates the unfavorable condition*

Table 5-3-9 Results of Project Implementation Case Study (Department of Oruro)

Target Coverage	Project Implementation Strategy	Number of Blocks	Target Population	Form of Project	Number of Drilling Equipment	Project Cost (million US$) External Funds	Project Cost (million US$) Domestic Funds	Project Cost (million US$) Total	Project Cost per Person (US$) External Funds	Project Cost per Person (US$) Domestic Funds	Term of Drilling (Year)	Evaluation
30%	[1]	20	16,427	[A] Commission	1 set	–	3.0	3.0	–	180	1.7	×
				[B] Cooperate in DW	2 set	1.9	1.2	3.1	116	74	0.6	
				[C1] Cooperate in PE	1 set	4.6	1.7	6.8	278	105	1.4	
30%	[2]	44	16,169	[A] Commission	1 set	–	5.5	5.5	–	338	4.0	×
				[B] Cooperate in DW	1 set	4.5	1.7	6.2	281	104	2.5	
				[C1] Cooperate in PE	1 set	4.6	2.7	7.3	282	164	3.2	×
30%	[3]	22	16,268	[A] Commission	1 set	–	3.0	3.0	–	185	1.7	
				[B] Cooperate in DW	1 set	1.8	1.3	3.1	112	77	1.1	
				[C1] Cooperate in PE	1 set	4.6	1.8	6.4	280	109	1.3	
40%	[1]	55	28,650	[A] Commission	1 set	–	7.1	7.1	–	248	4.8	×
				[B] Cooperate in DW	3 set	5.5	2.5	8.0	191	88	1.0	
				[C1] Cooperate in PE	1 set	4.6	3.7	8.3	159	128	3.9	
40%	[2]	113	28,650	[A] Commission	3 set	–	13.6	13.6	–	474	3.5	×
				[B] Cooperate in DW	7 set	11.9	3.7	15.6	416	129	0.9	×
				[C1] Cooperate in PE	1 set	4.6	5.9	11.0	159	208	8.3	×
				[C2] Cooperate in PE	2 set	8.2	6.2	14.4	286	217	4.2	×
40%	[3]	61	28,788	[A] Commission	1 set	–	7.3	7.3	–	252	4.6	×
				[B] Cooperate in DW	3 set	5.2	2.7	7.9	180	92	1.5	
				[C1] Cooperate in PE	1 set	4.6	3.8	8.9	158	133	3.7	
50%	[1]	108	41,314	[A] Commission	3 set	–	13.6	13.6	–	330	3.3	×
				[B] Cooperate in DW	6 set	11.2	4.2	15.4	272	102	1.0	×
				[C1] Cooperate in PE	1 set	4.6	6.4	11.0	110	154	7.8	×
				[C2] Cooperate in PE	2 set	7.1	6.6	13.7	171	161	3.9	×
50%	[2]	229	41,188	[A] Commission	5 set	–	26.1	26.1	–	633	4.1	×
				[B] Cooperate in DW	13 set	23.3	6.6	29.9	566	161	1.0	×
				[C1] Cooperate in PE	1 set	4.6	11.0	15.6	111	266	16.3	×
				[C2] Cooperate in PE	4 set	11.8	11.8	23.6	286	286	4.1	×
50%	[3]	118	41,261	[A] Commission	2 set	–	13.5	13.5	–	327	4.6	×
				[B] Cooperate in DW	7 set	10.4	4.4	14.8	251	107	1.5	×
				[C1] Cooperate in PE	1 set	4.6	6.6	11.2	111	159	7.3	×
				[C2] Cooperate in PE	2 set	7.1	6.8	13.9	172	166	3.7	×

(Note)

[A] *Commission private constructor*

[B] *Cooperation in drilling work*

[C1] *Cooperation in procurement of equipment , in the case where one unit of equipment is to be procured.*

[C2] *Cooperation in procurement of equipment - the number of units required for the completion of drilling in 5 years is indicated.*

(shaded box) *Indicates the unfavorable condition*

Table 5-3-10 Results of Project Implementation Case Study (Department of Tarija)

Target Coverage	Project Implementation Strategy	Number of Blocks	Target Population	Form of Project	Number of Drilling Equipment	Project Cost (million US$) External Funds	Project Cost (million US$) Domestic Funds	Project Cost (million US$) Total	Project Cost per Person (US$) External Funds	Project Cost per Person (US$) Domestic Funds	Term of Drilling (Year)	Evaluation
40%	[1]	16	12,245	[A] Commission	1 set	–	2.8	2.8	–	233	2.1	×
				[B] Cooperate in DW	2 set	2.5	0.9	3.4	205	76	0.7	
				[C1] Cooperate in PE	1 set	4.5	1.5	6.0	366	123	1.8	×
40%	[2]	22	11,912	[A] Commission	1 set	–	3.2	3.2	–	269	2.3	×
				[B] Cooperate in DW	2 set	2.7	1.0	3.7	223	87	0.7	
				[C1] Cooperate in PE	1 set	4.6	1.6	6.2	383	138	1.9	×
40%	[3]	21	12,105	[A] Commission	1 set	–	2.8	2.8	–	232	1.8	×
				[B] Cooperate in DW	2 set	2.0	1.0	3.0	161	85	0.6	
				[C1] Cooperate in PE	1 set	4.6	1.5	6.6	377	128	1.4	×
50%	[1]	59	30,983	[A] Commission	2 set	–	8.9	8.9	–	286	3.4	×
				[B] Cooperate in DW	5 set	8.0	2.7	10.7	259	88	0.9	
				[C1] Cooperate in PE	1 set	4.6	4.1	8.7	147	134	5.6	×
				[C2] Cooperate in PE	2 set	8.2	4.4	12.6	265	143	2.8	
50%	[2]	89	30,825	[A] Commission	2 set	–	11.2	11.2	–	362	4.2	×
				[B] Cooperate in DW	6 set	9.6	3.3	12.9	312	108	0.9	×
				[C1] Cooperate in PE	1 set	4.6	5.2	9.8	146	167	6.7	×
				[C2] Cooperate in PE	2 set	8.2	5.4	13.6	266	176	3.4	×
50%	[3]	72	30,905	[A] Commission	2 set	–	8.9	8.9	–	286	3.0	×
				[B] Cooperate in DW	4 set	6.7	3.0	9.7	216	97	1.0	
				[C1] Cooperate in PE	1 set	4.6	4.4	9.0	148	142	4.7	
				[C2] Cooperate in PE	2 set	8.2	4.7	12.9	265	151	2.4	×
60%	[1]	120	49,938	[A] Commission	3 set	–	16.4	16.4	–	328	4.2	×
				[B] Cooperate in DW	8 set	14.6	4.9	19.5	293	98	2.0	×
				[C1] Cooperate in PE	1 set	4.6	7.5	12.6	91	150	10.1	×
				[C2] Cooperate in PE	3 set	10.0	8.0	18.0	200	161	3.4	×
60%	[2]	185	45,184	[A] Commission	4 set	–	22.1	22.1	–	489	4.3	×
				[B] Cooperate in DW	11 set	19.7	6.0	25.7	436	132	1.0	×
				[C1] Cooperate in PE	1 set	4.6	9.6	14.7	101	212	13.7	×
				[C2] Cooperate in PE	3 set	10.0	10.1	20.1	221	224	4.6	×
60%	[3]	134	49,765	[A] Commission	3 set	–	16.3	16.3	–	328	3.9	×
				[B] Cooperate in DW	8 set	13.2	5.2	18.4	264	104	0.9	×
				[C1] Cooperate in PE	1 set	4.6	7.7	12.8	92	155	9.2	×
				[C2] Cooperate in PE	2 set	8.2	8.0	16.2	165	160	4.6	×

(Note)

[A] *Commission private constructor*

[B] *Cooperation in drilling work*

[C1] *Cooperation in procurement of equipment , in the case where one unit of equipment is to be procured.*

[C2] *Cooperation in procurement of equipment - the number of units required for the completion of drilling in 5 years is indicated.*

(shaded box) *Indicates the unfavorable condition*

Table 5-3-11 Results of Project Implementation Case Study (Department of Santa Cruz)

Target Coverage	Project Implementation Strategy	Number of Blocks	Target Population	Form of Project	Number of Drilling Equipment	Project Cost (million US$) External Funds	Project Cost (million US$) Domestic Funds	Project Cost (million US$) Total	Project cost per Person (US$) External Funds	Project cost per Person (US$) Domestic Funds	Term of Drilling (Year)	Evaluation
30%	[1]	45	43,322	[A] Commission	1 set	–	6.8	6.8	–	156	3.8	×
				[B] Cooperate in DW	3 set	4.4	3.1	7.5	100	71	1.0	
				[C1] Cooperate in PE	1 set	5.1	4.0	9.1	118	93	3.1	
30%	[2]	61	43,454	[A] Commission	1 set	–	8.8	8.8	–	202	2.7	×
				[B] Cooperate in DW	4 set	6.0	3.4	9.4	138	78	0.9	
				[C1] Cooperate in PE	1 set	5.1	4.6	9.7	118	107	4.2	
30%	[3]	49	43,520	[A] Commission	1 set	–	6.0	6.0	–	138	3.6	
				[B] Cooperate in DW	3 set	4.0	3.2	7.2	91	73	0.8	
				[C1] Cooperate in PE	1 set	5.1	4.1	9.2	118	94	2.8	
40%	[1]	145	98,554	[A] Commission	3 set	–	20.2	20.2	–	204	4.2	×
				[B] Cooperate in DW	8 set	14.5	7.8	22.3	147	79	1.0	×
				[C1] Cooperate in PE	1 set	5.1	10.6	15.7	52	107	10.1	×
				[C2] Cooperate in PE	3 set	10.0	11.1	21.1	101	113	3.4	
40%	[2]	179	98,341	[A] Commission	4 set	–	23.5	23.5	–	239	3.9	×
				[B] Cooperate in DW	10 set	17.8	8.5	26.3	181	86	1.0	×
				[C1] Cooperate in PE	1 set	5.1	11.9	17.0	52	121	12.4	×
				[C2] Cooperate in PE	3 set	10.0	12.4	22.4	102	126	4.2	
40%	[3]	154	98,417	[A] Commission	3 set	–	19.6	19.6	–	199	3.8	×
				[B] Cooperate in DW	8 set	12.9	8.0	20.9	131	81	0.9	×
				[C1] Cooperate in PE	1 set	5.1	10.7	15.8	52	109	9.1	×
				[C2] Cooperate in PE	2 set	8.2	10.9	19.1	83	111	4.6	
50%	[1]	275	153,248	[A] Commission	5 set	–	36.5	36.5	–	238	4.9	×
				[B] Cooperate in DW	16 set	28.3	13.2	41.5	185	86	1.0	×
				[C1] Cooperate in PE	1 set	5.1	18.4	23.5	33	120	19.7	×
				[C2] Cooperate in PE	4 set	11.8	19.2	31.0	77	125	5.0	×
50%	[2]	337	153,503	[A] Commission	7 set	–	43.4	43.4	–	283	4.4	×
				[B] Cooperate in DW	19 set	35.7	14.4	50.1	232	94	1.0	×
				[C1] Cooperate in PE	1 set	5.1	20.8	25.9	33	136	24.8	×
				[C2] Cooperate in PE	5 set	14.2	21.9	36.1	153	143	5.0	×
50%	[3]	297	153,497	[A] Commission	5 set	–	36.1	36.1	–	235	4.5	×
				[B] Cooperate in DW	14 set	25.3	13.6	38.9	165	89	1.0	×
				[C1] Cooperate in PE	1 set	5.1	18.7	23.8	33	122	17.8	×
				[C2] Cooperate in PE	4 set	11.8	19.8	31.6	77	129	4.5	×

(Note)

[A] Commission private constructor

[B] Cooperation in drilling work

[C1] Cooperation in procurement of equipment , in the case where one unit of equipment is to be procured.

[C2] Cooperation in procurement of equipment - the number of units required for the completion of drilling in 5 years is indicated.

(shaded box) Indicates the unfavorable condition

5) Evaluation of the Case Study

The supply-side restriction conditions for the realization of the groundwater development project include ① that the project can be expected to be completed within the planned term, ② that the project matches the funds provided and the financial ability of the bearing organization, ③ that the investment efficiency is not poor, and ④ that the project is feasible both in terms of organization and technology. The evaluation standards for the case study were thus set as follows:

[Evaluation Standards]

① In order to achieve the plan targets in 5 years, the term of drilling work is set to 5 years or less.

② The total investment amount of foreign funds is 10 million dollars or less per Department.

③ The total investment amount of domestic funds does not exceed the amount of funds estimated to be investable into the water supply department in the next 5 years. The amounts investable were estimated as shown in Table 5-3-12 based on the actual amounts invested to the basic sanitation department of each Department and the actual budget amounts of the former CORDES.

④ The investment amount per inhabitant is 500 dollars or less of foreign funds and 150 dollars of less of domestic funds.

Table 5-3-12 Estimation of the Annual Amounts Investable into the Water Supply Department

(Unit: 1000 dollars/year)

	Actual amount invested for basic sanitation (A)	Own funds of former CORDES (B)	Estimated amount investable (B×2)
Chuquisaca	3,352	882	1,760
South of La Paz	1,345	417	830
Oruro	3,472	476	950
Tarija	3,415	864	1,730
Santa Cruz	8,720	2,163	4,330
Total	20,304	4,802	9,600

Note: The actual amount invested for basic sanitation and the own funds of the former CORDES are averages for 1992-94.

The investment amount for the southern part of La Paz was calculated for 16% (proportion of population) of the entire Department of La Paz.