APPENDIX II

PRE-FEASIBILITY STUDY ON MICRO-HYDRO POWER PROJECT

CHAPTER 1 INTRODUCTION

1.1 Objectives of the Study

Objective of the whole study is to formulate a Rural Electrification Implementation Plan by Renewable Energy in La Paz and Oruro. The study on the micro-hydro power focused on the following objectives:

1) to review the inventory and identify potential of micro-hydro power;
2) to identify priority sites for micro-hydro power and evaluate cost competitiveness. The identified projects are to be included in the Rural Electrification Implementation Plan; and
3) to select high priority projects (2 projects) for pre-feasibility study and to conduct pre-feasibility study.

1.2 Survey and Study Conducted

The field survey commenced from August 7, 1999 and continued up to September 7, 2001 intermittently with the following survey stages:

1) first field survey : August 7, 1999 - September 20, 1999
2) second field survey : January 5, 2000 - February 12, 2000
3) third field survey : May 15, 2000 - July 14, 2000
4) fourth field survey : January 5, 2001 - February 15, 2001
5) fifth field survey : May 10, 2001 - June 8, 2001
6) sixth field survey : August 27, 2001 - September 7, 2001

Survey and study conducted during the above period are as follows:

- Study on inventory and identify sites for discharge observation
- Installation of staff gauges (2 in La Paz and 2 in Oruro)
- Daily water level observation on selected priority project sites

- Selection of high priority projects (1 in La Paz and 1 in Oruro) and their engineering survey
- Topographic survey and mapping on the selected priority sites (2)
- Pre-feasibility study on the selected priority projects (2) including Initial Environmental Evaluation (IEE)

Technology transfer to the counterpart staff was also conducted during the whole survey period and through three seminars carried out in January 2000, June 2000 and September 2001.

CHAPTER 2 FIELD SURVEY, DISCHARGE OBSERVATION AND TOPOGRAPHIC MAPPING

2.1 Data Collection

During the first field survey, collection of data such as topography, meteorology, hydrology, geology and other related information was made by the JICA expert in collaboration with counterpart persons from La Paz and Oruro prefectures. Inventory data of micro-hydro power were also collected mainly from the VMEH.

2.1.1 Topographical Map

Topographical maps were collected from the IGM (Institute Geographico Militar). Collected topographical maps are as follows:

- 1/500,000 map: 6 sheets are available (total 19 sheets), base map is 1/250,000 map.
- 1/250,000 map: 61 sheets are available (total 85 sheets), base map is 1/50,000 map.
- 1/50,000 map: 1,657 sheets are available (total 2,349 sheets). Base map is 1/50,000 map. 1/50,000 scale maps are not available for north part of La Paz department
- other scale maps: 1/100,000 map; only 9 sheets available for important areas. IGM has aerophoto (scale: 1/10,000 – 1/3,000,000) and digital map (CD-Rom).

Topographical conditions of La Paz and Oruro are summarized below:

1) La Paz department has 2 river basins (Amazon and internal) and Oruro department only has an internal river basin.
2) As shown in the river basin map of Bolivia (Figure 2.1), the north part of La Paz department belongs to the Amazon River basin. The rivers flow from south to north (the “Cordillera Real”), the elevation of which ranges from over EL.6,000 m to EL.180 m. The maximum altitude of La Paz department is 6,429m, which is located at south of the basin.

3) The area from south-west of La Paz department to the middle area of Oruro department is highland called "Altiplano".

High potential areas for hydropower in La Paz and Oruro are located in the following places (see Figure 2.2):

1) West ridge of La Paz and Oruro department along the "Cordillera Occidental de Los Andes"
2) East ridge of Oruro department along the "Cordillera de Azanaques"
3) West to southeast line at middle of La Paz department along the "Cordillera Real"

2.1.2 Meteorological Data

Meteorological data such as precipitation, temperature, humidity, evaporation, etc. are being collected by SENAMHI (Servicio Nacional de Meteorologia e Hidrologia), airports and laboratories of university (UMSA: Universidad Mayor de San Andres, Instituto de Hidraulica e Hidrologia). During the first field survey, following data were collected:

- SENAMHI Meteorological Observation Station List (Table 2.1 and 2.2)
- Isohyetal Map in Bolivia (Figure 2.3)
- Annual Temperature in Bolivia (Figure 2.4)

As shown in the Isohyetal Map, the areas with much rainfall are located northeast part of La Paz and Cochabanba. Annual rainfall is high at the Amazon River basin of La Paz.

Forest covers 51 percent of the Bolivian territory. Tropical and subtropical forest accounts for approximately 37 percent of the total land area. The Bolivian Amazon region has an area of 162,000 km^2 of pastureland. (Total area of Bolivia = 1,098,581 km^2, La Paz department = 133,985 km^2, Oruro department = 53,388 km^2)

Annual rainfall of these areas reaches the order of 2,000 mm/year, much rainfall compared to other adjacent areas of 200~400 mm/year in the south of La Paz or Oruro department. Rain concentrates during a short summer period and the runoff is particularly high.

From the meteorological data, high potential areas for hydropower in La Paz and Oruro are identified in the following places:

1) North part from the "Cordillera Real" at La Paz department (along the "Cordillera Occidental de Los Andes"),
2) High altitude mountain area, and
3) East ridge of Oruro department (near Cochabamba department side).

2.1.3 Hydrological Data

As shown in the river basin map of Bolivia (Figure 2.1), the river basin is divided into 3 basins, namely, 1) the Amazon River basin, 2) the Plata River basin, 3) internal (closed) basin.

Hydrological data such as water level or discharge in La Paz/Oruro are being collected by SENAMHI, Bolivia's navy, UMSA-IHH and electric companies. The Bolivian navy measures only water level for the purpose of boat sailing in the Lake Titicaca or big rivers. In addition to SIRESE (Sistema de Regulación Sectorial), the Water Superintendence has water supply data for urban areas.

The hydrological observation stations of SENAMHI are shown in Table 2.3, and the periods of available data are shown in Table 2.4 (La Paz) and Table 2.5 (Oruro). Collected hydrological data in La Paz and Oruro from SENAMHI are summarized below:

Collected Hydrological Data

No.	Station	Department	River	WL	Q	H-Q	CR	period
1	Abaroa	La Paz	Mauri	O	O	O	O	1965-99
2	Consata	La Paz	Llica	O	x	x	x	1979-81
3	Santa Rita Buenos Aires	La Paz	Coroico	O	O	O	O	1974-99
4	Sirupaya	La Paz	Unduavi	O	O	O	O	1979-99
5	Tora	La Paz	Tipuani	O	x	x	O	1969-76
6	Villa Barrientos	La Paz	Tamampaya	O	O	O	O	1975-99
7	Villa Barrientos	La Paz	Solacama	O	O	O	O	1975-99
8	Sacabaya	Oruro	Sajama	O	O	O	O	1973-98

Source: SENAMHI.
Note: WL: Water level, Q: Discharge, H-Q: Stage(WL:H) and flow(Q) relation curve, CR: Cross section survey data.

2.1.4 Geological Map

During the first field survey, the following geological maps were collected from SERGEOMIN (Servicio Nacional de Geologia y Mineria).

- "Mapa Geologico de Bolivia", scale of 1:1,000,000, YPFB & SERGEOMIN, 1996
- "Mapa Geologico de Carangas, Puerto Acosta, Apolo, Sorata, Ixiamas, Sacabaya,Sajama", at scale of 1:100,000, Servicio Geologico de Bolivia, 1965.

Geological condition of Bolivia is shown in Figure 2.5. For the micro-hydro power planning, geological condition is not a critical constraint because no large structural facilities are to be constructed.

2.1.5 Other Related Information

Other information related to micro-hydro power, Canton-wise household or population data, electrification data, etc. were collected from VMEH or INE (Instituto Nacional de Estadística-Bolivia). These data are included in “PRONER (Programa Nacional de Electrification Rural) Data Base”, VMEH (1998):

2.2 Field Survey

On the basis of the data and information collected, site selection for discharge observation was made in due consideration of the following items. The discharge observation on the selected sites was carried out by the JICA Study Team.

For measuring water level and discharge, staff gauges were installed on the three rivers under the cooperation with UMSA staff, and the actual measurement commenced from October 1999.

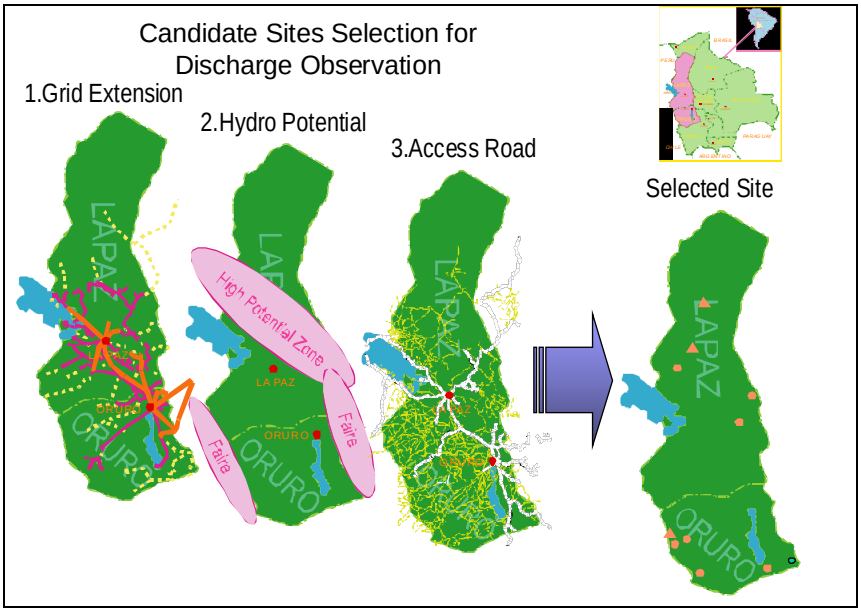
2.2.1 Selection of Discharge Observation Sites

For the site selection of the discharge observation, the following view points are applied:

- Sizable number of household

- Outside of the grid extension plan
- Good access to the site
- Hydro power potential (Discharge and Head)

Process of the selection briefly summarized in the following figure.



For the selection of the candidate sites, a meeting was held between the JICA Study Team and VMEH/ La Paz and Oruro prefectures and the requests from the Bolivian side were incorporated.

2.2.2 Discharge Observation

Field investigation was conducted on the selected rivers in collaboration with counterpart persons from La Paz and Oruro, and a staff from UMSA. Location of the discharge observation sites are shown below:

Discharge Observation Site
(La Paz Department)

No.	Province	Municipal	Canton	River
1	S. Yundas	La Asunta	Yanamayu	Rio Yanmayu
2	B. Saavedra	Curva	Calaya	Rio Opinuwaya
3	B. Saavedra	G. J. J. Pérez	Amarete	Rio Amarete
4	Munecas	Ayata	Camata	Rio Quillarwaya
5	Munecas	Ayata	Camata	Camata village canal
6	F. Tamayo	Apolo	Apolo	Rio Turiapu
				Rio Machariapu
				Rio Vilipiza
7	Iturralde	San Buenaventura	Ixiamas	Rio Tequeje
8	S. Yundas	Palos Blancos	Palos Blancos	Rio Covendo

Discharge Observation Site
(Oruro Department)

No.	Province	Municipal	Canton	River
1	Sajama	Curahuara de Carangas	Sajama / Caripe	Rio Tomarapi
2	Sajama	Curahuara de Carangas	Sajama	Rio Sajama
3	Sajama	Curahuara de Carangas	Sajama	Rio Milluni
4	Sajama	Turco	Chachacomani	Rio Jaruma
5	Sajama	Turco	Chachacomani	Rio Chohojho
6	Sajama	Turco	Ecia Centro Morgachi	Rio Sajama
7	Sajama	Turko	Chachacomani	Rio Tambo Quemado
8	Sajama	Sacabaya	Macaya	Rio Lauca
9	Atahuallpa	Co. Puquintia	Juro (Ecia Villyo)	Rio Pacokhaua
10	Avaroa	Santuario de Quillacas	Soraga	Rio Mallka

The rivers which have been investigated and results of the discharge observation are summarized in Table 2.6.

The photographs taken during the field investigation for micro-hydro are presented below:

Micro-Hydro Survey

(First Field Investigation, September 1999)

<table>
<tr><td>  </td><td>  </td></tr>
<tr><td>1. Río Yanamayu
[29Aug.1999](Yanamayu/S.Yungas/La Paz)
Altitude = 935 m, Q = 0.67 m^3/s</td><td>2. Río Opinuwaya
[3 Sep. 1999] (Culva/B.Saavedra/La Paz)
Altitude = 3,650 m, Q = 0.32 m^3/s</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>3. Discharge Obs. at Río Amarete
[3 Sep. 1999](Amarete/B.Saavedra/La Paz)
Altitude = 3,400 m, Q = 0.41 m^3/s
* MCH plan : D/D finished(1994), 220kW,
US$ 505,000- (EU), Household = 200 families</td><td>4. Discharge Obs. at Río Tomarapi
[7 Sep. 1999] (Tomarapi/Sajama/Oruro)
Altitude = 4,350 m, Q = 0.10 m^3/s</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>5. Discharge Obs. at Río Sajama
[8 Sep. 1999] (Sajama/Sajama/Oruro)
Altitude = 4,380 m, Q = 0.39 m^3/s</td><td>6. Discharge Obs. at Río Jaruma
[9 Sep. 1999] (E.Q.Jakke/Sajama/Oruro)
Altitude = 4,400 m, Q = 0.05 m^3/s</td></tr>
</table>

Micro-Hydro Survey

(Third Field Investigation, June 2000)

	
Photo-1. [03/Jun/2000] Discharge Obs. at Río Turiapu (Apolo/ Apolo/ F.Tamayo/ La Paz) Altitude = 1,585 m, Q = 2.50 m^3/s	Photo-2. [01/Jun/2000] Topographic Survey at Río Turiapu (Apolo) Proposed Intake Site (Alternative), El.= 1600m, Canal=362m, H=6.8m, P=85kW
	
Photo-3. [02/Jun/2000] Río Machariapu (Apolo,/F.Tamayo/La Paz) (Overview of Proposed Intake Site)	Photo-4. [02/Jun/2000] Río Machariapu (Apolo,/F.Tamayo/La Paz) (Overview of Proposed Penstock Site)
	
Photo-5. [16/Jun/2000] WL.Gauge Station at Río Tequeje (Ixiamas/ Iturralde/ S.Buenaventura/ La Paz)	Photo-6. [16/Jun/2000] Discharge measurement at Río Tequeje (Ixiamas/Iturralde/S.Buenaventura/ La Paz)

Micro-Hydro Survey

(Third Field Investigation, June 2000)

Photo-7. [18/Jun/2000]
Discharge measurement at Río Covendo
(Covendo/ Palos Blancos/ S.Yngas/ La Paz)
Altitude = 755 m, Q = 2.42 m^3/s

Intake(Río Covendo)

Power House

Canal

Headtank

Turbine and
Generator (2.7 kW)

Photo-8. [18/Jun/2000]
Existing Micro-Hydro Power at Covendo
(Covendo/ Palos Blancos/ S.Yngas/ La Paz)
MHP for the factory of Covendo church

Photo-9. [09/Jun/2000]
Río Tambo Quemado (Tambo Quemado/
Chachacomani/ Sajama / Oruro)
Altitude = 4,600 m, Q = 0.068 m^3/s

Photo-10. [09/Jun/2000]
Proposed Intake Site (Río TamboQuemado)
Head = 41.4m, Canal length = 960m, P=14 kW,
Demand = 40 Household + 11 office

Photo-11.
Río Sajama (Chachacomani, Oruro)

Photo-12.
Río Sajama (Chachacomani, Oruro)

2.2.3 Staff Gauge Installation and Water Level Observation

For continuous measurement of the discharge at selected four (4) rivers (two in La Paz and two in Oruro), installation of staff gauges and their measurement were carried out by UMSA staff in collaboration with counterpart persons.

The sites for installation of staff gauges and measurement are shown in the attached photos and summarized in the following table:

No	Name	Depart-ment	Province	Municipio	Canton	House hold	River (Cuenca)	Site	Install of Staff gauge	Daily W.L. observe	Obs. Discharge
1	Apolo	La Paz	F. Tamayo	Apolo	Apolo	580 (1977)	Rio Turiapu	10km from Aporo town	O (14-17 Oct. 99)	O	○ (14 Oct. 99-)
2	Ixsiamas	La Paz	Iturralde	S.Buenaventura	Ixiamas	650	Rio Tequeje	10m SW from Ixiamas town	O (23-25 Oct. 99)	O	○ (23 Oct. 99-)
3	Chachacomani Rio Jaruma	Oruro	Sajama	Turco	Chachacomani (Estancia Quimsa Jakke)	240	Rio Jaruma	4.5km SW from Quimsa Jakka town	○ (6-7 Nov. 99)	O	○ (6 Nov. 99-)
4	Tambo Quemado	Oruro	Sajama	Turco	Chachacomani (Comd. Tambo Quemado)	45 + 11 office	Rio Tambo Quemado	1.4 E from Tmbo Quemado	○ (1 July,2000)	O	○ (9 Jun,2000)

(1) Rio Turiapu (Apolo/ La Paz)

a) Installation of staff gauges

In the Turiapu River three (3) staff gauges were installed. Cross section survey of the river and the discharge measurement were conducted at the site where the staff gauges were installed. The location of staff gauges is around 10km south from the village and 100 meters upstream from the Inca bridge (Figure 2.6). The result of cross section survey is shown in Figure 2.7.

b) Water level observer

As an water level observer a man living 200 meters from the staff gauges was employed. The observer read the water level 2 times a day at 6:00 a.m. and 18:00 p.m. The daily water level was observed from October 14, 1999 to April 24, 2001 (19 months).

c) Discharge measurement

The discharge measurement was conducted as follows:

1) October 14, 1999 : Q = 1.99 m^3/sec, H = 0.39 m
2) January 21, 2000 : Q = 24.16 m^3/sec, H = 1.02 m
3) June 3, 2000 : Q = 4.97 m^3/sec, H = 0.66 m
4) July 24, 2000 : Q = 3.32 m^3/sec, H = 0.50 m
5) Sept. 15, 2000 : Q = 1.75 m^3/sec, H = 0.35 m
6) April 23, 2001 : Q = 11.20 m^3/sec, H = 0.89 m

Note: Q: discharge, H: staff gauge height

(2) Rio Tequeje (Ixiamas/ La Paz)

a) Installation of staff gauges

In the Tequeje River four (4) staff gauges were installed. The staff gauges were installed at 400m upstream from the cross point of Tumupasa-Ixiamas road with the Tequeje River (new bridge was completed in 2001). The location map is shown in Figure 2.8.

Cross section survey of river and the discharge measurement were made in the same place where the staff gauges were installed. The result of the cross section survey is shown in Figure 2.9.

b) Water level observer

A man living 400 meters from the staff gauges was employed as water level observer. The observer read the water level 2 times a day at 6:00 a.m. and 18:00 p.m.. The daily water level was observed from October 25, 1999 to April 30, 2001 (19 months).

c) Discharge measurement

The discharge measurement was conducted as follows:

1) October 23, 1999 : Q = 2.86 m^3/sec, H = 0.32 m (Oct. 25, 1999)
2) January 21, 2000 : Q = 16.70 m^3/sec, H = 0.96 m
3) June 16, 2000 : Q = 26.24 m^3/sec, H = 1.12 m

Note: Q: discharge, H: staff gauge height

(3) Rio Jaruma (Chachacomani/ Oruro)

a) Installation of staff gauges

In the Jaruma River one (1) staff gauge of metallic structure was installed. The location map is shown in Figure 2.10.

Cross section survey of the river and the discharge measurement were made in the same place where the staff gauge was installed. The result of cross section survey is shown in Figure 2.11.

b) Water level observer

The president of the civil committee was selected as the man for water level observation and who is responsible for organizing people of "Tambo Quemado" to read the water level gauge 2 times a day at around 7:00 a.m. and around 18:00 p.m. The daily water level was observed from November 7, 1999 to October 31, 2000 (12 months).

c) Discharge measurement

The discharge measurement was conducted as follows:

1) September 9, 1999 : Q = 0.040 m^3/sec, H was not available
2) November 7, 1999 : Q = 0.056 m^3/sec, H = 0.06 m
3) January 30, 2000 : Q = 0.072 m^3/sec, H = 0.11 m
4) June 10, 2000 : Q = 0.027 m^3/sec, H = 0.09 m
5) September 9, 2000 : Q = 0.008 m^3/sec, H = 0.05 m
6) January 20, 2001 : Q = 0.073 m^3/sec, H was not available

Note: Q: discharge, H: staff gauge height

(4) Rio Tambo Quemado (Tambo Quemado/ Oruro)

a) Installation of staff gauges

In the Tambo Quemado River one (1) staff gauge was installed by village people on July 1, 2000.

b) Water level observer

The president of the civil committee was selected as the man for water level observation and who is responsible for organizing people of "Tambo Quemado" to read the water level gauge 2 times a day at around 7:00 a.m. and around 18:00 p.m.

The daily water level was observed from July 1, 2000 to August 31, 2000 (2 months).

c) Discharge measurement

The discharge measurement was conducted as follows:

1) June 9, 2000 : Q = 0.072 m^3/sec, H was not available
2) September 9, 2000 : Q = 0.056 m^3/sec, H was not available
3) January 20, 2001 : Q = 0.092 m^3/sec, H was not available

Note: Q: discharge, H: staff gauge height

(1) Rio Turiapu (Apolo/ La Paz) [14 Oct.1999]

1. View of Río Turiapu

2. Installation of Staff Gauge at Río Turiapu

3. Discharge Obs. at Río Turiapu
Q = 1.99 m^3/s

4. Discharge Obs. at Río Turiapu
Q = 1.99 m^3/s

5. Discharge Obs. at Río Turiapu

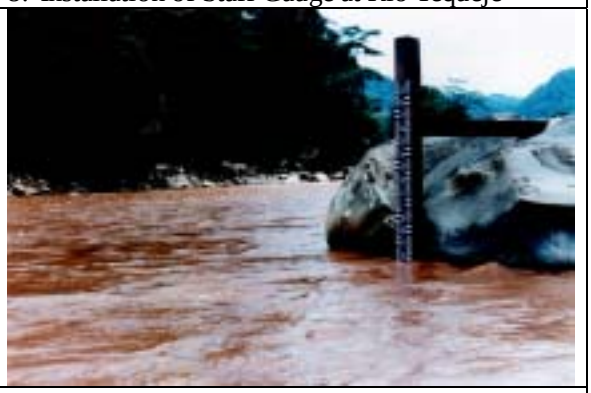
6. W.L. Observer Training at Río Turiapu

(2) Rio Tequeje (Ixiamas/ La Paz) [23 Oct.1999]

7. View of Río Tequeje

8. Installation of Staff Gauge at Río Tequeje

9. Installation of Staff Gauge at Río Tequeje



10. Installation of Staff Gauge at Río Tequeje

11. Cross Section survey at Río Tequeje
Q = 2.63 m^3/s

12. Discharge Obs. at Río Tequeje
Q = 2.63 m^3/s

13. W.L. Observer Training at Río Tequeje

14. View of Staff Gauge at Río Tequeje

(3) Rio Jaruma (Carangas/ Oruro) [6 Nov.1999]

15. Installation of Staff Gauge at Río Jaruma

16. Discharge Obs. at Río Jaruma
Q = 0.055 m^3/s

17. Discharge Obs. at Río Jaruma
Q = 0.055 m^3/s

18. Cross Secton Survey at Río Jaruma
Q = 0.055 m^3/s

19. W.L. Observer Training at Río Jaruma

20. W.L. Observer Training at Río Jaruma

2.2.4 Topographic Survey and Mapping

The topographic survey was conducted on the following two selected sites in La Paz and Oruro from September 2000 to January 2001.

No	Name	Depart-ment	Province	Municipio	Canton	River (Cuenca)	Site
1	Apolo	La Paz	F.Tamayo	Apolo	Apolo	Rio Machariapu	Around 12 km NE from Apolo town
2	Tambo Quemado	Oruro	Sajama	Turco	Chachacomani (Comunidad Tambo Quemado)	Rio Tambo Quemado	Around 3 km W from Tambo Quemado village

The survey work was subcontracted to SGE (Servicios Generales en Electricidad). For supervision of the survey work, JICA Study Team for micro-hydro power was dispatched in September 2000.

The survey works conducted are:

1) Benchmark survey
2) Longitudinal profile survey
3) Cross-section survey
4) Leveling / Traversing survey (for the topographic mapping)
5) Topographic mapping

Results of the survey were checked by the JICA Study Team and necessary revision on the topographic maps was made during the fourth field survey.

CHAPTER 3 INVENTORY OF MICRO-HYDRO POWER AND EXISTING TRANSMISSION LINE

3.1 Inventory of Micro-hydro Power Project

Information of the micro-hydro power inventory both for the existing and under planning in La Paz and Oruro was collected from VMEH, La Paz/ Oruro prefecture, UMSA and electric companies. General features of the plan were obtained in the list "Inventory of Micro-hydropower Project in Bolivia - 1998" prepared by CINER and VMEH. The Study Team also collected project reports related to the micro-hydro power.

The inventory of the micro-hydro power projects is summarized in Tables 3.1 and 3.2. Total number of the existing micro-hydro power are 23 and 2 in La Paz and Oruro respectively. In La Paz, the total installed capacity is 1,084 kW with 7,161 households of beneficiaries, while in Oruro, the total installed capacity is only 200kW with 170 households of beneficiaries.
Beside this, around 3,800 kW and 650 kW of micro-hydro power are planned in La Paz and Oruro.

The location of the existing projects and the projects under plan in La Paz and Oruro is presented in Figures 3.1 and 3.2.

3.2 Transmission Line

Information of the existing power grid line in La Paz and Oruro were collected referring national publications and through the hearing and discussion with VMEH, La Paz/ Oruro prefectures and distribution companies. The existing transmission/ distribution lines in La Paz and Oruro are presented in Figure 3.3 and Figure 3.4.

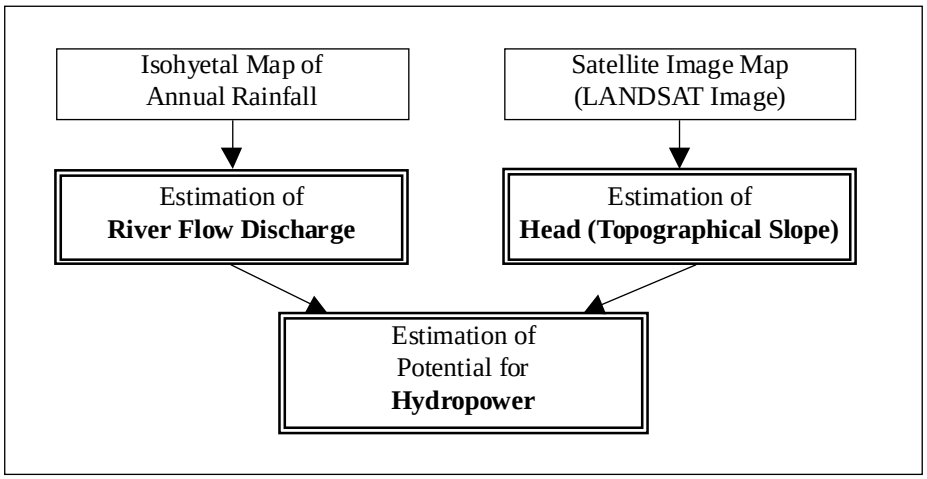
In La Paz department, the grid line extends from the capital city, La Paz to north east, north west, south east and south west directions. The areas located along the north west - south east corridor passing La Paz city are the most densely distributed area in the department. Even in La Paz, north part of the department has no grid line due to the sparse population density and limited economic activity.

Main grid line extends to west and south west, and south directions in Oruro. However, most of the areas located in the west side of Oruro have no grid line mainly due to the sparse population density.

CHAPTER 4 POTENTIAL FOR HYDROPOWER AND SELECTION OF PRIORITY MICRO-HYDRO POWER PROJECTS

4.1 Hydropower Potential

For identifying hydropower projects, potential for hydropower in La Paz and Oruro was reviewed and studied. The evaluation of the hydropower potential is made through the following procedure.



The potential of hydropower is to be measured by quantity of discharge/river flow and available head. For evaluating quantity of discharge, the isohyetal map of annual rainfall was used, while the satellite map was used for estimating available head.

The isohyetal map of annual rainfall was combined with topographic map in La Paz and Oruro as shown in Figures 4.1 and 4.2.

The estimated potential maps of hydropower in the department La Paz and Oruro are shown in Figures 4.3 and 4.4.

As indicated in the map, high potential area of hydropower is located at northwest - southeast corridor along "Cordillera Oriental de Los Andes" mountains in La Paz, while the potential of the hydropower is low and high potential area is quite limited in Oruro.

4.2 Selection of Priority Projects

4.2.1 Formulation of Candidate Projects

Identification of candidate micro-hydro power projects was made on the basis of hydropower potential map, available micro-hydro power inventory. The available inventory of micro-hydro power was firstly reviewed and was modified using collected information and results of the field investigation and discharge observation conducted during the field surveys.

Since micro-hydro powers to be formulated for the rural electrification are basically for isolated power source, the projects which plan to supply electricity to the areas with the existing grid in the near future were excluded from the candidate list.

Most of the main figures (installed capacity, number of beneficiaries, etc.) for the identified micro-hydro power are the same ones as originally estimated. But, some modification was made taking into account the results of the field survey.

Through this, priority projects of the micro-hydro power for the rural electrification were finally selected; 30 projects in La Paz and 3 project in Oruro as summarized in Tables 4.1 and 4.2. The installed capacities of the priority projects are 2,316 kW in La Paz and 102 kW in Oruro.

4.2.2 Criteria for Selection of Priority Projects

For the selection of the priority projects for micro-hydro power, evaluation was made whether the cost of the candidate micro-hydro is competitive to that of the grid line (if connected) or not. Only the hydropower projects which are more economical than that of grid extension are to be finally selected for the priority projects to be included in the rural electrification implementation plan up to year 2011. This is corresponding to the policy of the VMEH, that plans to explore indigenous renewable energies for the rural electrification, if they are economical.

The cost comparison between the candidate micro-hydro power and grid extension was made in the following procedure.

(1) Estimation of Energy Cost of MHP Projects

For the estimation of the energy cost (US$/kWh) of MHP Projects, the following parameters are used:

Effective Operation Hour per day	8 hour/day
Plant Factor for MHP	0.95
n : Economic Life of the System	20 years
R: Discount Rate	10 %
CRF (Capital Recovery Factor)	0.1175
OM Cost for MHP (% of total investment)	1.8 %

(2) Estimation of Energy Cost of Grid Extension Projects

For the estimation of the energy cost (US$/kWh) of Grid Extension Projects, the following parameters are used:

Effective Operation Hour per day	8 hour/day
n : Economic Life of the System	20 years
R: Discount Rate	10 %
CRF (Capital Recovery Factor)	0.1175
Maintenance Cost for Grid Line (% of investment)	2.5 %
Power Demand per Household	300 W/HH
Household Connecting Cost	100 US$/HH
Maximum Investment Cost per Household	1,200 US$/HH

For the estimation of investment cost of grid extension, the lengths of transmission line from the existing grid to the target village were measured. The unit costs of grid extension per kilometer were estimated using the following cost.

Capacity	Phase	Averaged cost at	Grid Extention Unit Cost
34.5kV	3	Yungas / Amazonia Area	US$ 18,000 / km
24.9kV	3	Altiplano Area	US$ 8,500 / km
19.2kV	1	Yungas and Amazonia Area	US$ 12,000 / km
14.4kV	1	Altiplano Area	US$ 6,000 / km
6.9kV	3	Altiplano Area	US$ 5,000 / km
380V	3	Yungas and Amazonia Area	US$ 5,000 / km
230V	1	Yungas and Amazonia, Alriplano	US$ 3,000 / km

Source: La Paz Prefecture

The above costs include materials, manpower, supervision cost, tax and other expenses. Referring to the above cost, adjustment factors were incorporated considering the topographic condition. The numbers of beneficiaries by grid extension were recalculated assuming that the proposed grid line extension is to provide electricity for the communities along the line in addition to the objective community.

(3) Comparison of Energy Cost of Micro-hydro Power and Grid Extension

Comparing the estimated energy costs, priority micro-hydro power projects were selected by the JICA study team only if the energy cost is competitive to that of grid extension. The selected priority projects for micro-hydro were summarized in Tables 4.1 and 4.2. The location map of the selected priority projects is shown in Figures 4.5 and 4.6.

4.2.3 Stage-wise Implementation of the Selected Priority Projects

For ranking the selected priority micro-hydro power projects, the following criteria are applied:

- Distance from the existing grid
- Comparative investment cost: cost of grid extension/ cost of micro-hydro power
- Beneficiary household size of micro-hydro power
- Project maturity

Applying the above criteria, scores were estimated for all the selected priority projects.

Based on the result of the ranking study, the micro-hydro power projects were divided into Phase-I to be implemented during 2002 - 2006 and Phase-II during 2007 - 2011 as summarized below and the details are presented in Table 4.3.

Proposed Micro-Hydro Power Projects (La Paz)

Phase	Year	Beneficiary Household (HH)	Installed Capacity (kW)	Investment Cost (MHP) (US$)
Phase - I	2002 - 2006	4,240	1,096	3,496,000
Phase - II	2007 - 2011	3,490	1,220	3,541,000
TOTAL	(2002 - 2011)	7,730	2,316	7,037,000

Proposed Micro-hydro Power Projects (Oruro)

Phase	Year	Beneficiary Household (HH)	Installed Capacity (kW)	Investment Cost (MHP) (US$)
Phase - I	2002 - 2006	45	62	240,000
Phase - II	2007 - 2011	140	40	128,000
TOTAL	(2002 - 2011)	185	102	368,000

As indicated above, 30 micro-hydro power projects, 13 during phase-I and 17 during phase-II are planned to be implemented in La Paz, while only 3 micro-hydro power projects in Oruro.

Total installed capacities are planned to be 2,316 kW with the beneficiaries of 7,730 households in La Paz. In Oruro, the capacity to be installed is rather small of 102 kW with 209 beneficiaries.

4.2.4 Selection of Projects for Pre-feasibility Study

Selection of the projects for pre-feasibility study was made based on the result of the ranking study and through discussion with VMEH and La Paz and Oruro prefectures.
The selected projects for pre-feasibility study are two projects, one in La Paz and one in Oruro.

1) La Paz : Apolo Machariapu River MHP (Apolo, F.Tamayo province)
2) Oruro : Tambo Qumeado MHP (Turco, Sajama province)