社会開発調査部報告書

Japan International Cooperation Agency (JICA)
Nepal Office, Kathmandu

Nepal Electricity Authority
Kathmandu, Nepal

The Basic Study for the Rural Electrification through Small Hydropower Development in Rural Hilly Areas in Nepal

FINAL REPORT

VOLUME: 1

Kathmandu, March 2003

Submitted by:

ITECO
ITECO Nepal (P) Ltd.
Panchakanya Marg - 96
P.O. Box 2147
Min Bhawan, New Baneshwor
Kathmandu, Nepal
Tel: 4 493 764 (Hunting Line),
Fax: +977-1-4 482 298
E-mail: iteco@mos.com.np
Web site: www.scaef.com/iteconepal

in association with

Butwal Power Company Ltd.
P.O. Box 11728
Kumaripati, Lalitpur
Kathmandu
Tel: 5 535 595 and 5 538 404
Fax: +977-1-5 527 901
E-mail: bpc@hydroconsult.com.np

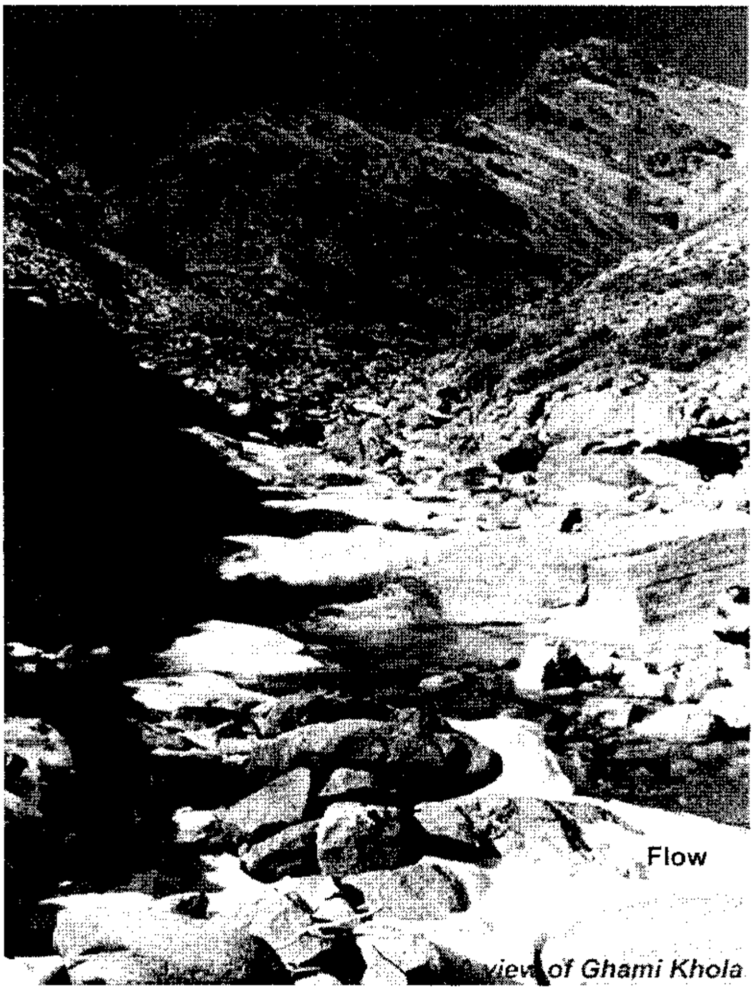
Japan International Cooperation Agency (JICA)
Nepal Office, Kathmandu

Nepal Electricity Authority
Kathmandu, Nepal

The Basic Study for the Rural Electrification through Small Hydropower Development in Rural Hilly Areas in Nepal

FINAL REPORT

VOLUME: 1



Kathmandu, March 2003

Submitted by:

ITECO Nepal (P) Ltd.
Panchakanya Marg - 96
P.O. Box 2147
Min Bhawan, New Baneshwor
Kathmandu, Nepal
Tel: 4 493 764 (Hunting Line),
Fax: +977-1-4 482 298
E-mail:iteco@mos.com.np
Web site: www.scaef.com/iteconepal

in association with

Butwal Power Company Ltd.
P.O. Box 11728
Kumaripati, Lalitpur
Kathmandu
Tel: 5 535 595 and 5 538 404
Fax: +977-1-5 527 901
E-mail: bpc@hydroconsult.com.np

The Basic study for the Rural Electrification through Small Hydropower Development in Rural Hilly Area in Nepal

FINAL REPORT

VOLUME 1
Main Report

VOLUME 2
APPENDIX – A: Review and Screening of SHP Projects
APPENDIX – B: Study of Ghami Khola SHP Project

ACKNOWLEDGEMENTS

It was a pleasure for us to get involved in "The Basic Study for the Rural Electrification through Small Hydropower Development in Rural Hilly Areas in Nepal". This was a very interesting assignment in the sense that in course of the involvement in this project the real problems of rural electrification in the hilly areas of Nepal became apparent.

We are thankful for JICA for awarding ITECO Nepal (P) Ltd. this interesting assignment and for the support given to us in course of the study.

We are also thankful to NEA for their full cooperation in providing us promptly all the reference materials and necessary software required for the study. Particularly, we would like to acknowledge the help of Dr. S. N. Mishra, Chief, SHP and RE Department, NEA and Mr. H. K. Ghimire, Assistant Director, SHP and RE Department, NEA in this respect.

Lastly we acknowledge with gratitude the untiring efforts of all the team members, computer operators, photocopy operators and other staff of ITECO Nepal (P) Ltd. without their cooperation, this study could not have been completed in such a short period.

Tuk Lal Adhikari
Project Manager
ITECO Nepal in Association with BPC

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABREVIATIONS

ACAP	Annapurna Conservation Area Project
ACSR	Aluminium Conductor Steel Reinforced
ADB	Asian Development Bank
AEPC	Alternative Energy Promotion Center
amsl	Above Mean Sea Level
BET	Break Even Tariff
BKPC	Bhote Koshi Power Company
BPC	Butwal Power Company Ltd
CBS	Central Bureau of Statistics
CEH	Center for Ecology and Hydrology, UK
CGI	Corrugated Galvanized Iron
DANIDA	Danish International Development Agency
DDC	District Development Committee
DHM	Department of Hydrology and Meteorology
DIZ	Direct Impact Zone
E/M	Electro-mechanical
EIRR	Economic Internal Rate of Return
EOCC	Economic Opportunity of Capital Cost
ESAP	Energy Sector Assistance Programme
FINNIDA	Finnish International Development Agency
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GTZ	Germany Technical Cooperation
HDC	Hydropower Development Company
HH	Households
HMG/N	His Majesty's Government of Nepal
HPL	Himal Power Ltd.
HYDEST	Hydrological Estimate
ICIMOD	International Center for Integrated Mountain Development
INDIZ	Indirect Impact Zone
INPS	Integrated Nepal Power System
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
kW	Kilo Watt
MBAF	Main Boundary Active Fault
MBT	Main Boundary Thrust
MCB	Miniature Circuit Breaker
MCT	Main Central Thrust
MFT	Main Frontal Thrust
MHP	Micro Hydropower
MHSP	Medium Hydropower Study Method
MIP	Medium Irrigation Project
MT	Mahabharat Thrust
MW	Megawatts
MWI	Monsoon Wetness Index
NEA	Nepal Electricity Authority
NPV	Net Present Value
NRB	Nepal Rastra Bank
NRs.	Nepalese Rupees
O&M	Operation and Maintenance
OPEC	Organization of Petroleum Exporting Countries
REDP	Rural Energy Development Program
SCF	Standard Conversion Factor
SHP	Small Hydropower
SHPD	Small Hydropower Department

T&D	Transmission and Distribution
UNCDF	United Nations Capital Development Fund
UNDP	United Nation Development Programme
VAT	Value Added Tax
VCB	Vacuum Circuit Breaker
VDC	Village Development Committee
WB	World Bank
WECS	Water and Energy Commission Secretariat

EXECUTIVE SUMMARY

Phase – I Study: Review and Screening Study of Load Centers and SHP

Background

The present basic study for the rural electrification through small hydropower development in rural hilly areas in Nepal is conducted for the Japan International Cooperation Agency (JICA). The objective of the study is to identify load centers and small hydropower potential sites for power generation in capacity range from 100 kW to 2000 kW in the rural hilly areas of Nepal, which will not be served by integrated Nepal power grid within the next decade.

Presently existing small hydropower projects mainly serve the district headquarters and major commercial centers in Nepal. The extension of small hydropower projects to rural areas away from district head quarters have not been realized mainly in the ground of poor economic and financial viability of small hydropower projects. Providing electricity to meet the energy needs of the rural poor through development of small hydropower has yet to be initiated. The efforts of the related promoting agencies such as Alternative Energy Promotion Center, ESAP/DANIDA and Rural Energy Development Programme (REDP) of UNDP have focused mainly in micro hydropower (up to 100 kW) development as one of the means to meet the energy needs of the rural population.

In the light of the above-mentioned facts, the development of small hydropower projects appears to be the appropriate solution for the rural electrification in the remote hilly areas of Nepal. The present basic study for rural electrification intends to identify small hydropower sites in the capacity range of 100 kW to 2000 kW in the hilly load centers areas of Nepal, which will not be served by the national grid within the next decade.

Identification of Priority Load Centers

The rural areas away from the national grid were identified on the basis of available secondary information. The power demand forecast was carried out in those area considering village development committees as load centers for period of 20 years. The forecast was based on autonomous demand in domestic, commercial, industrial and public sectors. Finally, priotization of the load centers in each district was carried out considering available information such as power demand (2022 AD), numbers of households operating industries, number of households involved in trade and business, number of households involved in services and number of school attending population in each load center. Selection of candidate projects for the study was based on priority load centers.

Project Identification

In process of identification of suitable sites previously studied projects by the NEA and other organizations were selected. 82 projects were selected out of which 32 projects serving priority load centers were found suitable for the study and investigations as they meet the requirements of the TOR and pass through exclusion criteria. The study team carried out detailed desk studies of those projects based on available secondary information.

Phase I Study Period

The identified potential sites in various development regions are as follows:

1.	Eastern region	:	8 projects
2.	Central region	:	5 projects
3.	Western region	:	6 projects
4.	Mid-western region	:	7 projects
5.	Far-western region	:	6 projects

The methodology used for the study and investigations of 32 projects consisted of compilation and review of secondary data and information. The secondary data consisted of published information by the Central Bureau of Statistics (CBS) of year 2001, project study reports prepared by GTZ/SHPD (NEA) and various consulting firms, hydro-meteorological data published by DHM/HMG/N in 1998, district energy profile prepared by REDP/UNDP and other relevant data published by WECS/HMG/N.

The technical study of the projects is based mainly on the reports of previous study and desk studies using the topographical and land use maps of Nepal (scale 1:50,000 and 1:25,000) prepared by Department of Survey.

Hydrological Review
Hydro-meteorological studies have been conducted using indirect methods, as the existing hydrological network is not adequate to cover all river basins of the country. The indirect methods used under the study are as follows:

- Medium irrigation project method (MIP)
- WECS / DHM method (HYDEST software, 1990)
- Medium hydropower study project method (MHSP 1997)
- HydrA software method (CEH 2001)

Socio-economics
Under socio-economic and power demand studies the approaches prevailing in the similar NEA small hydropower projects were adopted.

The present load demand forecast is based on 'bottom up' approach based on domestic, commercial, industrial and public sector demand. The demand forecast is done based on the present energy consumption pattern and its growth because of growth in population, increase in income, creation of new facilities etc.

The population of VDCs in the project area is obtained from latest national census (2001) records published by the Central Bureau of Statistics (CBS). The annual growth rate of population is considered as constant over the project period. The household size is calculated as the average household of VDCs and is considered as constant over the project period.

The income level is categorized into three groups: low, medium and high. The growth pattern of the income group is assumed to be gradual decrease in low-income group and increase in medium and high-income groups. The rate is based on the remoteness of the project area.

The number of households per commercial centre is based on the field survey. The growth rate is considered as 0.2% per annum and is assumed to be constant over the project period. Similarly, the number of households per public service unit is also based on field survey results. The growth rate is assumed as 0.2% per annum.

The demand for electricity based on above criteria is assumed to depend on the type of consumers. Essentially, the consumers are categorized into four groups for the consumption pattern existing in the hills and mountain regions. The groups are domestic, commercial, public and industrial.

Affordability
The method of analyzing the affordability of the rural household for electricity tariff is based on the sample household survey. The affordability of household for electricity tariff, therefore, is assessed on the basis of numerous parameters such as income level, land holding size, time required for fuel wood, household size, number of cooking stoves, type of

house etc. In general affordability for electricity bill by the consumer household is considered as 5% of the household income.

Willingness to Pay
The willingness to pay for electricity bill is based on the interest of the household to connect the electricity line. So, the information on willingness to pay must be based on the survey data. For the present study the value of the willingness estimated from the field survey is considered for demand analysis.

Sustainability
Sustainability of the projects is the most important factor for small hydropower project in rural hilly area. The economic and financial considerations must be worked out considering operation and maintenance cost for long-term sustainability. The project may be considered as sustainable when the project runs for long term maintaining the cost of operation, maintenance and rehabilitation. That is, at least the revenue generation per year from the project should cover the operation, maintenance and rehabilitation costs. Sustainability of the project also depends on the numerous other factors such as management of the project, availability of spare parts for maintenance and distance from project site to major market centers.

Project Cost Estimate
The cost of all studied small hydropower projects has been calculated using software named DIPEO module i3/4, which calculates the quantity of major structures and computes the cost using the supplied unit rates. The cost calculated using DIPEO module gives the detail cost break down of the SHP components.

Economic Analysis
The economic analysis is the basis of project evaluation. The economic analysis is conducted by converting market values to economically efficient values. For a project to be economically viable, it must be financially sustainable, as well as economically efficient.

Evaluation of the Project
The economic / financial analysis of the projects is carried out as per the results of the following economic and financial parameters:

- Economic internal rate of return (EIRR)
- Break even tariff
- Calculation of NPV of the capital costs, revenues and net benefit streams
- Benefit cost ratio

For the economic analysis, the costs and benefit streams are considered as follows: capital costs, and O&M cost in cost streams; and revenue from electricity supply and capacity benefit in benefit streams.

Environmental Assessment
The objective of the environmental assessment of the projects is to assess the physical, biological and social environmental impacts based on the previous studies. This report provides elements for decision-making on whether or not to implement the projects and on possible consideration for further environmental investigations. Generally EIA is not required for small scale hydropower projects (< 5 MW capacity) except for those projects situated in the national parks and protected areas. For this reason, the review criteria have been limited to important issues only.

The positive environmental impacts are significant in all the projects and therefore they are not repeatedly mentioned in the environmental examinations.

Screening and Ranking

The criteria of screening and ranking for selection of 10 most feasible small hydropower projects has been developed after consultation with the client and NEA. The screening criteria have been developed incorporating technical, economical, social and environmental and regional balancing parameters. Using the scoring and weightage system for all 32 projects, top 10 ranking projects (Table 1) are recommended for further studies and investigations.

Table 1: Recommended small hydropower projects for further studies

S. No.	Name of projects	District	Gross head (m)	Design discharge (m^3/s)	Capacity kW	Benefited population
1	Gandi Gad	Doti	135	1.36	1,280	14,800
2	Maiwa Khola	Taplejung	260	0.95	1,920	62,239
3	Molung Khola	Okhaldhunga	83	1.1	640	48,582
4	Leguwa Khola	Dhankuta	400	0.09	280	13,569
5	Sabha Khola	Sankhuwasabha	130	1.39	1,260	11,231
6	Ghami Khola	Mustang	147	1.05	1,080	15,740
7	Nilgarh Gad	Baitadi	400	0.088	240	18,345
8	Jamadi Gad	Baitadi	80	2.42	1,300	18,345
9	Mujkot Khola	Jajarkot	52	2.62	950	48,413
10	Galwa Gad	Humla	77	0.16	100	11,068
	Total:				9,050	262,332

Out of the 10 recommended projects, only one project Ghami Khola SHP was selected for preliminary study by JICA from security considerations.

Phase II Study: Preliminary Study of Ghami Khola SHP

Project location

The Ghami Khola small hydropower project is located in Ghami VDC of Mustang district in the western development region of Nepal. The project utilizes 1.1 m^3/s of discharge from Ghami Khola to generate 600 kW of hydropower. The intake structure is located at a distance of 1.5 km west from Ghami village and the powerhouse site is at a distance of 800 m north from Ghami village. The project components are entirely located at the right bank of the Ghami Khola. The geographical coordinates of the intake site are 29^0 04' 17" N, 83^0 50' 56" E. Similarly, the geographical coordinates of the powerhouse site are 29^0 04' 04" N, 83^0 52' 13" E. The project location map is presented in Figure 3.1.

Basin Characteristics

The Ghami Khola is one of the tributaries of Kali Gandaki river. The Khola flows eastwards from its source at Ghami Bhanjyang at 6000 m amsl in upper Mustang area. The Khola valley entirely lies in the Tethys Himalayas. Dhuya Khola and Naktan Khola are the two major tributaries of Ghami Khola upstream of the intake site. The length of the Khola up to intake site is 24 km and sweeps a total catchment area of about 232 km^2, out of which 16 km^2 lies between 3000 m to 5000 m elevation and the remaining 216 km^2 lies above 5000 m elevation. The river gradient is about 8.5%. The river width varies from 30 m to 42 m.

Hydrology
No river gauging station exists in Ghami Khola. The nearest river gauging station is at Seti Beni of Kali Gandaki river at 546 m elevation. Direct correlation of discharge to the river gauged station is not applicable because the catchment characteristics of the rivers are significantly different. Therefore, indirect methods such as WECS/DHM, HydrA Nepal, MHSP and MIP methods are applied for the hydrological computations. The methods yield substantially different results because none of the method is specifically applicable to such catchment which has larger proportion of snow melt and low annual rainfall (annual rainfall at Lomangthan is less than 300 mm). Based on subjective judgment on the applicability of methods and comparing to the discharge measured at site in middle of January (lowest flow month for snow fed streams), the following results are obtained:

Minimum discharge = 1.9 m^3/s (90% exceedance probability)
Peak flood discharge = 200 m^3/s (estimated from flood marks)
Irrigation discharge = 0.5 m^3/s (estimated from capacity of existing canal)
Riparian discharge = 0.2 m^3/s (10% of minimum discharge)

The discharge available for hydropower development thus becomes 1.4 m^3/s. After keeping flushing requirement of 0.3 m^3/s, the headrace canal and subsequent structures are designed for a design discharge of 1.1 m^3/s.

The flow duration curve obtained using MHSP method gives the following results:

Percentage exceedance	25	45	65	85	90	95
Flow (m^3/s)	10.14	4.17	3.43	2.24	1.90	1.56

Geology
Ghami SHP is situated within the Tethys Himalayas bounded by South Tibetan Detachment System to the south and Indus Tsangpo Suture zone to the north. The project area is included within Upper Chelegaon Formation and Ghami Khola Formation. Distinct outcrops of the formation are observed along the Kali Gandaki river banks. The unit is composed of an alternation of various facies – sandstones, conglomerate, lacustrine limestone and clay beds. The overlying layer above the Chelegaon Formation is covered by quarternary glacial and fluvio-glacial sedimentary deposit filled above the massive Tethys basin. No major geological instabilities are observed around the surface civil structures such as weir, desander, headrace canal, forebay, penstock and powerhouse sites. Local construction materials such as coarse aggregate and stone are available in the project sites. The sand must be transported from a distance of about 5 km distance from Kali Gandaki river bed.

Project Description
Ghami SHP was studied at feasibility level earlier by the SRCL/NEA. The earlier study is updated under the present study. The project is designed as run-of-the-river scheme without daily pondage as the discharge is sufficient to meet the peak demand.

The design discharge is safely diverted with a 1.5 m high diversion weir across the the stream. As per site and bed load condition, the weir is proposed with Tyrolean type of intake structure on right bank. The Tyrolean section is lowered by 0.30 m below general crest level.

A horizontal steel trash rack of 1.0 m width and 8.0 m length is provided with 10° inclination towards the downstream at Tyrolean section. The steel size of trash rack is of 20 mm thick trapezoidal bars with clear spacing 15 mm so that particles larger than 15 mm could be checked. Only silt and gravel particles smaller than 15 mm could enter into the intake.

Concrete intake gallery is inclined towards the right bank with 1:20 slope. This slope is sufficient to transport the discharge of 1.40 m^3/sec during normal flow of the river. At the end of the gallery a sluice gate of size 1.20 m x 1.0 m is provided to control the excess discharge during floods. The sluice gate is protected from flood damage by the concrete wall.

After the sluice gate, a concrete lined covered canal with 1:100 slope is provided to convey the flow from the intake to the desanding basin. A concrete lining of 15 cm thick is provided in the canal to prevent scouring as the velocity of flow could be 2.50 m/sec under flood condition. The canal is covered with RCC slab and is backfilled with gravel mixed soil.

A desanding basin with twin chambers is designed to remove sand particles of size greater than 0.2 mm. The length of basin is 30 m. The chambers are separated by a 50 cm thick stone masonry wall. The width of each chamber is 3.0 m. The basin comprises of an overflow spillway in order to spill out excess discharge during flood. The settled sediment at the bottom of the basin will be flushed away with the help of flushing gates. The size of flushing gate is 60 cm x 40 cm. Slots for stop logs are provided at inlet and outlet of each chamber in order to control the flow of water during maintenance.

A rectangular headrace canal has been proposed to suit the topography of the canal alignment with minimum cutting and filling. The headrace canal is designed to carry a flow of 1.10 m^3/sec with 1:250 slope. The thickness of stone masonry to the bottom and sides is 30 cm each and inner surface of the canal is plastered to reduce roughness. The flow velocity in canal is 1.70 m/sec which is well within minimum self cleaning velocity (0.30 m/sec) and maximum velocity in masonry lining (2.5 m/sec).

At the end of headrace canal, a rectangular forebay has been proposed. An overflow spillway 5 m long is provided to spill out excess of water. The spillway crest elevation is at 3722.30 and a spillway chute is provided to evacuate the excess discharge. The chute ends to the stable valley at right side of the forebay. Normal water level in the forebay is 3722.20 m and minimum level of water is 3721.40 m. The forebay has been designed for 198 m^3 as live storage to allow for sudden load acceptance the turbines for a retention period of about 3 minutes. A free board of 0.25 m is provided to prevent spilling of water from forebay during full load rejection.

At the end of forebay a penstock intake is provided to maintain sufficient submergence of the penstock. The bottom elevation of penstock is 3719.30 m. A steel trash rack is provided in front of penstock intake to check entry of floating debris. A clear gap at fine rack strips is 2.0 cm. A flushing outlet is 0.35 m below the penstock level, which will remove sediment deposited in the penstock intake.

A steel penstock of diameter 0.70 m is provided. The designed thickness of pipe wall is 7 mm considering the water hammer pressure and 2 mm additional thickness for corrosion. The pipes are buried below ground to protect from freezing. The total length of pipe is 400 m while two branches with diameter 0.50 m are with length of 20 m each. Considering the transportation constraint the pipes are proposed of 3 m segments each with flange coupling system. A total of 5 RCC anchor blocks are required at penstock bends. Expansion joints are provided in penstock after each anchor blocks. The velocity of flow in the pipe is 2.60 m/sec.

The dimension of powerhouse is 30 m long, 10 m wide and 10 m high so that E/M equipment can be accommodated and maneuvered easily. Two sets of E/M units are installed due to transport constraint. The spacing between the units is determined from the catalogue of equipment manufacturer. Sufficient spaces are provided providing repairing bay, auxiliary equipment, electrical panel board and operator room. An overhead gantry crane with lifting capacity of 8 tons is provided to facilitate erection and future refurbishment of equipment. The level of powerhouse floor is fixed at 3563.60 m where as the level of HFL in the river is 3559.0 m. The main building of powerhouse is consisted of RCC frame. The roof is designed with CGI sheets over pipe trusses.

A tailrace canal of total length 37 m long canal is provided to discharge the tail water flow from the powerhouse. The design discharge of 1.0 m^3/sec will be carried out by the rectangular canal of size 1.5 m width and 1.0 m height with 1:250 slope.

Project costing
The cost estimate is made on the basis of latest available district rates and HMGN norms for civil works. In case of electromechanical equipment, the cost is based on DIPEO results which represents average prices for SHPs in Nepal. For transmission and distribution lines, the costs are based on prevailing per km rates. A summary of project costing is depicted in the following table:

Table 2: Summary of cost for Ghami KholaSHP

Designation	Description of works	Amount (NRs.)	Remarks
A	General items	4,950,000.00	Based on HMGN norms and prevailing district rates
B	Intake structures	17,081,049.08	
C	Desilting basin	8,086,998.72	
D	Power canal	17,398,434.48	
E	Forebay	14,786,033.82	
F	Penstock pipe	16,014,746.38	
G	Powerhouse and tailrace	9,078,336.58	
Total		**87,395,599.05**	
H	Electromechanical equipment	48,268,350.00	Based on DIPEO results
I	Transmission and distribution lines	24,000,000.00	Based on prevailing per km rates
Grand total		**NRs. 159,663,949.05**	
Contingencies @ 10%		**NRs. 15,966,394.91**	
Total project cost		**NRs. 175,630,343.96**	**US $ 2,251,671.08**
Specific cost per kW		**NRs. 219,432 per kW**	**US$ 3,752.78 per kW**

Project Evaluation
Economic evaluation of the project is carried out by calculating benefit cost ratio (B/C) and economic internal rate of return (EIRR). Discounted cash flow method is applied considering the following parameters:

Base price : December, 2002
Exchange rate : 1 US$ = NRs. 78
Discount rate : 10%
Tariff rate : same as NEA tariff
Economic life of the project : 30 years
Construction period : 3 years

The results from the economic evaluation are as follows:

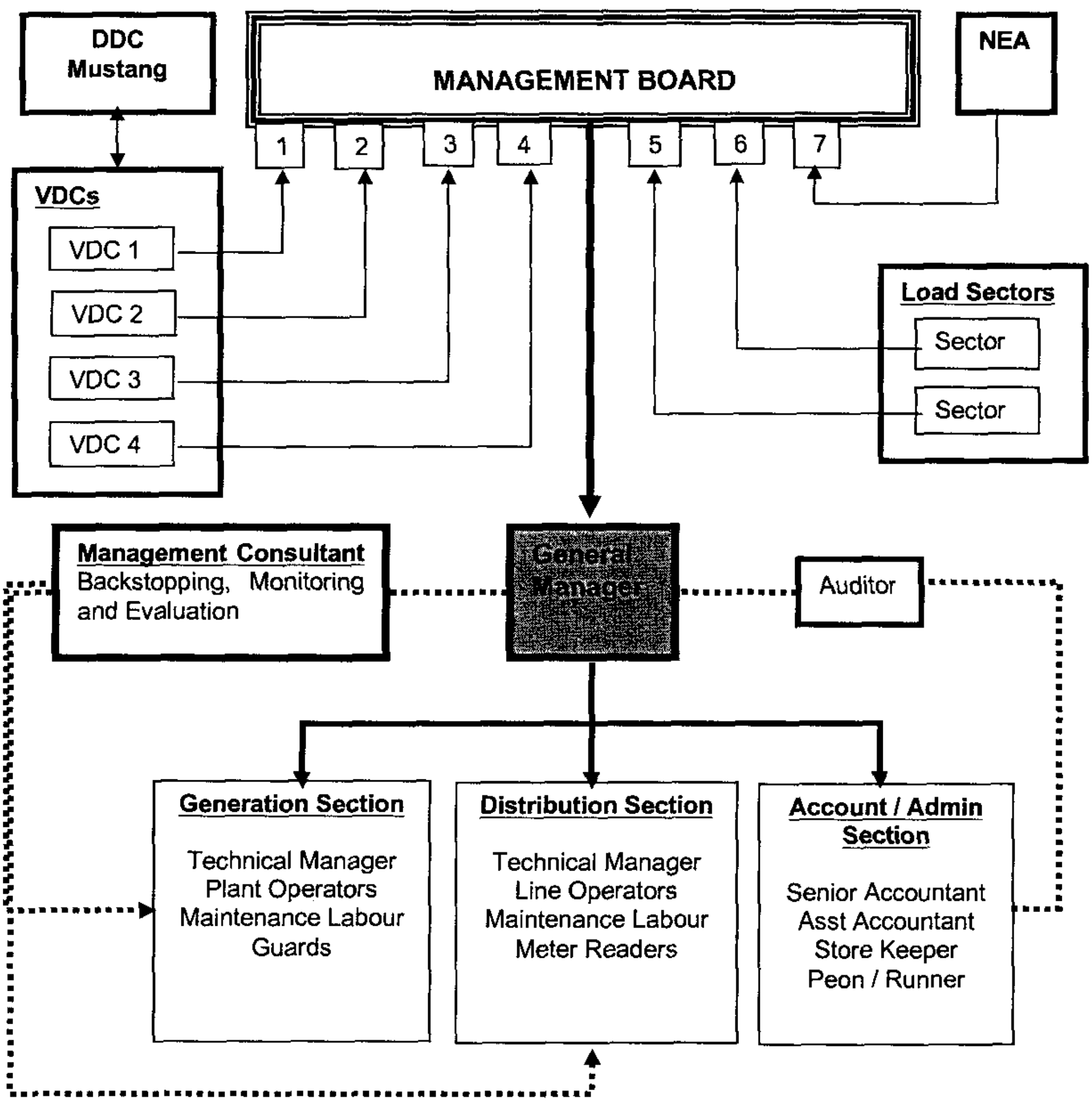
B/C ratio at 10% discount rate = 0.54
EIRR = 2.4
Unit energy cost = NRs. 3.73 / kWh = US$ 0.5 / kWh
Specific cost = US$ 2795 per kW

Based on the economic evaluation, the project is not attractive. The economic viability of the project may be significantly improved if other four VDCs of upper Mustang area and villages at Chinses side are included in the load centers. Further, the project is justified from social perspective, as the area is remote and the people have been sidelined from the mainstream of development.

Institutional Plan

The ongoing institutional management for the operation of the isolated SHPs including NEA management, lease management, private management and user management have been studied. In the context of the Ghami Khola SHP, an innovative institutional structure resembling to that of Salleri Chialsa SHP has been proposed. The basic feature of the proposed institution is empowerment of the local users and local bodies through ownership rights to operate and manage the plant after commissioning. The NEA being an apex body responsible for electrification in the country, it will also own the project jointly with the community and local bodies. The institution is in line with the gradual pull out of NEA responsibility from SHP management as well as with the spirit of the HMGN's decentralization process enacted by Local Self Governance Act, 2056 and corresponding regulation, 2057. It is anticipated that the proposed institutional structure will serve as sustainable institution in the long run. An indicative structure of the proposed institution is shown below.

Proposed Institutional Structure for Operation Management of GKSHP



SALIENT FEATURES OF GHAMI KHOLA SHP PROJECT

1.	**GENERAL**		
	Development Region	:	Western
	Zone	:	Dhaulagiri
	District	:	Mustang
	Location	:	Ghami VDC
	Name of the River	:	Ghami Khola
	Type of Scheme	:	Run-off River
2.	**HYDROLOGY**		
	Catchment Area	:	232 km^2
	Average Precipitation	:	250 mm
	Max. Design Flood	:	200 m^3/sec
	90% Dependable Flow	:	1.90 m^3/sec
	60% Dependable Flow	:	3.55 m^3/sec
	Design Discharge	:	1.40 m^3/sec
3.	**HEADWORKS**		
	Type	:	Concrete weir
	Weir Crest Length	:	41.5 m
	Opening under Sluice	:	1.20 m
	Weir Crest Elevation	:	3,733.55 m
	Max. Flood Level	:	3,735.25 m
4.	**INTAKE STRUCTURE**		
	Type	:	Tyrolean weir
	Crest Elevation	:	3,733.25 m
	Trashrack Length	:	8.0 m
	Intake Gate Size	:	1.20 m x 1.50 m
5.	**CLOSE DUCT**		
	Type	:	Rectangular RCC
	Size (Close Duct)	:	2 m x 0.77 m
	Design Discharge	:	1.40 m^3/sec
	Length (Close Duct)	:	20 m
6.	**DESILTING BASIN**		
	No. of Chamber	:	Two
	Particle Size to be Settled	:	Greater than 0.20 mm
	Length of Basin	:	30 m
	Length of Inlet Transition	:	8 m
	Length of Outlet Transition	:	8 m
	Size of Flushing Sluice Gate	:	0.6 m x 0.4 m
	Size of Flushing Duct	:	0.6 m x 0.4 m
	Length of Flushing Duct	:	15 m
7.	**HEADRACE CANAL**		
	Type	:	Rectangular stone masonry
	Total Length of Headrace Canal	:	800 m
	Size	:	1.25 m x 0.80 m
8.	**CROSS DRAINAGE WORKS**		
	No. of Cross Drainage Works	:	1 Nos.
	Type of Crossings	:	Concrete pipe dia 0.60 m

9.	**FOREBAY**		
	Dimensions	:	28 m x 4.0 m x 4.50 m
	Effective Storage Capacity	:	215 m^3
	Normal Operating Water Level	:	3,727.75 m
	Minimum Water Level	:	3,726.85 m
10.	**PENSTOCK**		
	Type	:	Steel flange pipe
	Length of Main Pipe	:	400 m
	Diameter of Main Pipe	:	700 mm
	Design Discharge	:	1.0 m^3/sec
	Velocity in the Pipe	:	2.60 m/sec
	Total Length of Branch Pipes	:	3 Nos., each 20 m, 500 mm dia
	Diameter of Branch Pipes	:	500 mm
	Thickness of Penstock	:	7 mm
	No. of Anchor Blocks	:	5 Nos.
11.	**POWERHOUSE**		
	Type	:	Surface
	Dimensions	:	20 m x 10 m x 10 m
	Installed Capacity	:	600 kW
12.	**TAILRACE CANAL**		
	Type	:	Stone masonry open channel
	Size	:	1.5 m x 1.0 m
	Length	:	37 m
	Tail Water Level	:	3640 m
13.	**TURBINES**		
	Type	:	Turgo
	Nos. of Unit	:	Two
	Rated Output	:	335 kW
	Design Discharge	:	1.00 m^3/sec
	Gross Head	:	85 m
	Net Head	:	80 m
14.	**GENERATORS**		
	Type	:	Horizontal shaft synchronous
	Nos. of Generators	:	Two
	Capacity	:	360 kVA
	Voltage	:	400 Volt
	Power Factor	:	0.8
	Cooling System	:	Air cooling
15.	**SUBSTATION**		
	Type	:	Indoor
	Area	:	10 m x 8 m
16.	**TRANSFORMERS**		
	Capacity	:	800 kVA (400 kVA x 2)
	Step up	:	400 v/11 kV
	Type	:	Oil immersed (indoor types)
17.	**TRANSMISSION / DISTRIBUTION NETWORK**		
	11 kV Distribution Line	:	33 km
	415 V Distribution Line	:	17 km

18. PROJECT COST IN NRs.

Civil Works	:	NRs. 87,395,599.05
Electro-Mechanical Equipment	:	NRs. 48,268,350.00
Transmission/Distribution Network	:	NRs. 24,000,000.00
Total Project Cost	:	NRs. 175,630,343.96 (including @ 10% contingencies)
Specific Project Cost	:	NRs. 292,717.24/kW or US $ 3,752.78/kW

19. ECONOMIC ANALYSIS

B/C Ratio at 10% Discount Rate	:	0.54
EIRR	:	2.4
Break Even Cost	:	NRs. 22.39 per kWh
Generation Cost	:	NRs. 3.73 per kWh

1 INTRODUCTION

1.1 GENERAL

The present report is prepared pursuant to the requirements of the terms of reference on "The Basic Study for the Rural Electrification through Small Hydropower Development in Rural Hilly Areas in Nepal". The study was conducted in two phases:

- **Phase I study**: review, screening and ranking of potential load centers and 10 out of 32 small hydropower projects studied earlier, and
- **Phase II study**: field investigation and preliminary design of one selected project out of 10 best ranking projects. Ghami Khola small hydropower project was selected for phase II study.

The outputs of the phase I study were included in the Interim Report submitted on 20th December 2002. The Interim Report was discussed and accepted by the 2nd meeting of the steering committee.

The present report summarise findings from phase I study and elaborates findings of the Phase II study conducted on Ghami Khola small hydropower project in Mustang district of western development region. The comments received on the draft final report submitted on 10th February 2003 are incorporated as appropriate in the present final report.

1.2 BACKGROUND

Nepal Electricity Authority (NEA) has maintained a generating capacity of 535 MW from hydropower projects, which is primarily distributed to meet the power need of major administrative, commercial and industrial centers in the kingdom through its national power grid. The national power grid serves about 17% of the population of Nepal. Limited effort has been made on the rural electrification through extension of the national grid to the rural areas. NEA is also providing electricity to remote district headquarters through development of isolated small hydropower projects. The access to electricity has been provided to about 6% of the rural population.

NEA had undertaken screening and ranking study for medium hydropower (10 MW to 300 MW) from among a large number of identified schemes. Similarly, Department of Electricity Development (DoED) had carried out screening and ranking study of small hydropower projects (5 MW to 10 MW). However, similar screening and ranking process was lacking for the smaller hydropower projects (100 kW to 5 MW). NEA had undertaken Small Hydropower Master Plan Project, to identify and catalogue a large number of small hydropower plants in the capacity range from 100 kW to 5 MW through assistance from the GTZ. Some other small hydropower projects are being studied under survey licensing by private developers for their own purpose.

The existing small hydropower projects have mainly served the district head quarters and rural commercial centers. The extension of small hydropower projects to rural areas away from district head quarters have not been realized mainly due to their poor economic and financial viability. Providing electricity to meet the energy needs of the rural poor through development of small hydropower has yet to be initiated. The efforts of the related promoting agencies such as Alternative Energy Promotion Center (AEPC) and Rural Energy Development Programme (REDP) have focused mainly in micro hydropower (up to 100 kW) development as one of the means to meet the energy needs of the rural population.

In the light of the above-mentioned facts, the development of small hydropower projects appears to be the appropriate solution for the rural electrification in the remote hilly areas of Nepal. The present basic study for rural electrification intends to identify small hydropower sites in the capacity range of 100 kW to 2 MW in the hilly areas of Nepal, which will not be served by the national grid within the next decade.

1.3 STUDY OBJECTIVES

The main objective of the present study is to formulate a basic plan for the development of rural electrification through small hydropower development in the rural hilly areas of Nepal. The study intends to formulate a sustainable plan for rural electrification according to the priority based on load factor, power demand, economic, technical, institutional and environmental considerations.

Under the present study, it is required to identify small hydropower potential sites for power generation in the capacity range between 100 kW to 2 MW in the rural hilly areas which will not be covered by the INPS within the next decade and to carry out field investigation and preliminary design of selected scheme.

1.4 SCOPE OF STUDY

The scope of study includes the following phases and milestones:

Activities	October	November	December	January	February
Phase I Study	∇ Inception Report		∇ Interim Report		
Phase II Study Option 1				Draft Final Report	∇ ∇ Final Report

The contents of study in each phase are as follows:

1.4.1 Phase I Study: Review and Screening Study of Load Centers and SHPs

- Collection of data, information and reports
- Identification and prioritization of load centers
- Identification of potential least cost SHP schemes
- Review of meteorological and hydrological studies
- Review of geological and geotechnical studies
- Review of power demand and supply studies
- Review of power potential in the project areas
- Review of electromechanical facilities
- Review of access road study
- Review of environmental examination
- Screening of ten top ranking SHP schemes

1.4.2 Phase II Study, Option 1: Preliminary Design of the Selected Scheme

- Socio-economic survey

- Infrastructure study
- Study of people's perception
- Hydrological survey
- Topographical survey
- Geological survey
- River situation survey
- Preliminary design of civil structures
- Preliminary design of turbines and generators
- Hydropower planning
- Construction planning
- Project cost estimate
- Environmental assessment
- Social assessment
- Formulation of project implementation plan

1.4.3 Phase II Study, Option 2: Study of Power Generation Plan of Existing Plant

- Selection of priority site
- Study of power station operation systems
- Study on types of generating system
- Study on canal route
- Prepare power generation plan
- Calculation of scale of power generation plan

1.5 REPORTS LAYOUT

The following reports are prepared under the scope of the present study:

- Phase I: Inception report
- Phase I: Interim report
  - Volume 1: Main report
  - Volume 2: Glossary of data and document, hydro-meteorological analysis
  - Volume 3: Summary of reviewed projects
  - Volume 4: Drawings
  - Volume 5: Power demand forecast, project cost estimate, economic and financial evaluation
- Phase II: Draft / final report
  - Volume 1: Main report
  - Volume 2: Appendices

2 PHASE I STUDY: REVIEW AND SCREENING OF LOAD CENTERS AND SHPS

2.1 IDENTIFICATION OF PRIORITY LOAD CENTERS AND SHPS

2.1.1 General

The outcomes from the Phase I study on "The Basic Study for the Rural Electrification through Small Hydropower Development in Rural Hilly Areas in Nepal" were elaborated in the Interim Report. This chapter summarizes the findings from the review, screening and ranking of the identified rural load centers and small hydropower projects with capacity between 100 kW and 2,000 kW.

2.1.2 Information Collection

The study team collected available data, reports, maps and information relevant to the present study from NEA, REDP/UNDP, AEPC, ESAP, DoED, Consultants and other agencies.

For the geological study of the project sites, geological map of Nepal (scale 1:2,000,000), geological map of development regions (scale 1:250,000) and available site geological maps were collected. Topographical maps of Nepal (scale 1:50,000 and 1:25,000) prepared by FINNMAP, JICA and other sources were collected covering the entire project areas and their catchments.

Meteorological and hydrological data were obtained from the Department of Hydrology and Meteorology (DHM). The data published in the form of "Climatological Records of Nepal" for a period up to 1998, "Hydrological Records of Nepal" published in April 1998 and "Surface Water Records of Nepal" were obtained.

The data on population, ethnicity, demography etc. were collected from the Central Bureau of Statistics. The data were mostly based on the most recent census (i.e., 2001). The data on energy consumption and demand in different regions and districts of Nepal were obtained from the Water and Energy Commission Secretariat, REDP, AEPC and the WB. The data on income status of people in different regions and districts were obtained on the basis of project reports, documents obtained from the National Planning Commission, Nepal Rastra Bank, Ministry of Agriculture, NGOs etc.

The data on the environment were obtained from the various reports, documents published by the Ministry of Population and Environment, Ministry of Forests, Ministry of Soil Conservation etc.

Other pertinent data such as product catalogues were obtained from the reputed manufacturers. The rates for electromechanical equipment were obtained from indicative quotations from the suppliers. The unit rates for civil engineering items were based on the established region wise rates on similar projects. Similarly software manuals for HydrA, HYDEST and DIPEO i ¾ were obtained from respective promoters / suppliers.

A complete glossary of data and documents is given in Appendix - A.

2.1.3 Identification of Priority Load Centers

2.1.3.1 Methodology

Demand forecasting is an important stage in project formulation. In the development of rural electrification the studies of the socio-economic and energy supply/demand scenario is an essential requirement in terms of the characteristics of demand for electricity both power and energy. These terms are co-related with the short and long term planning earmarked for the project area.

For the present study all population centers and their socio-economic activities in the project area were identified using the data obtained from the CBS. Since the study is based on the secondary data, which are obtained at VDC level such as VDC population, household size, district population growth etc.

The electricity demand forecast is considered as an autonomous growth of power consumption pattern of rural people and increase in demand due to electrification in future. The load forecast of all VDCs of selected districts is based on population, household size and population growth. The load forecast model is developed in a EXCEL worksheet format based on the population growth rates. The VDC population and household size data acquired from the CBS report for each of the VDCs, which is used to arrive at a load center demand in the project area over a period of 20 years. The load centers are identified in the proximity of the potential hydropower generation sites.

Ranking of VDCs in accordance with their socio-economic activities such as household size, household engaged in industry, services, trade and commerce, number of School going children etc was also undertaken during the desk study. The ranking values and the projected load forecasts for the VDCs provides a definitive basis for selection of VDCs on the parameters used. An in-depth understanding of the load centers was obtained from the results against the perspective of their socio-economic scenarios and the energy supply/demand situations. This assisted in defining to a more precise level the parameters for the estimation of the present and future load and energy demand.

The following methodology is applied to make a load and energy demand forecast for identified small hydropower projects in the selected districts of Nepal. The forecast will account for a changing economic situation for a time span of 20 years. The initial year of project realizations is assumed to be the year 2002. The forecast time span will thus cover the period 2002 to 2022.

The following working steps have been carried out in order to forecast the load demand of a project area (area proposed to be served by one SHPP):

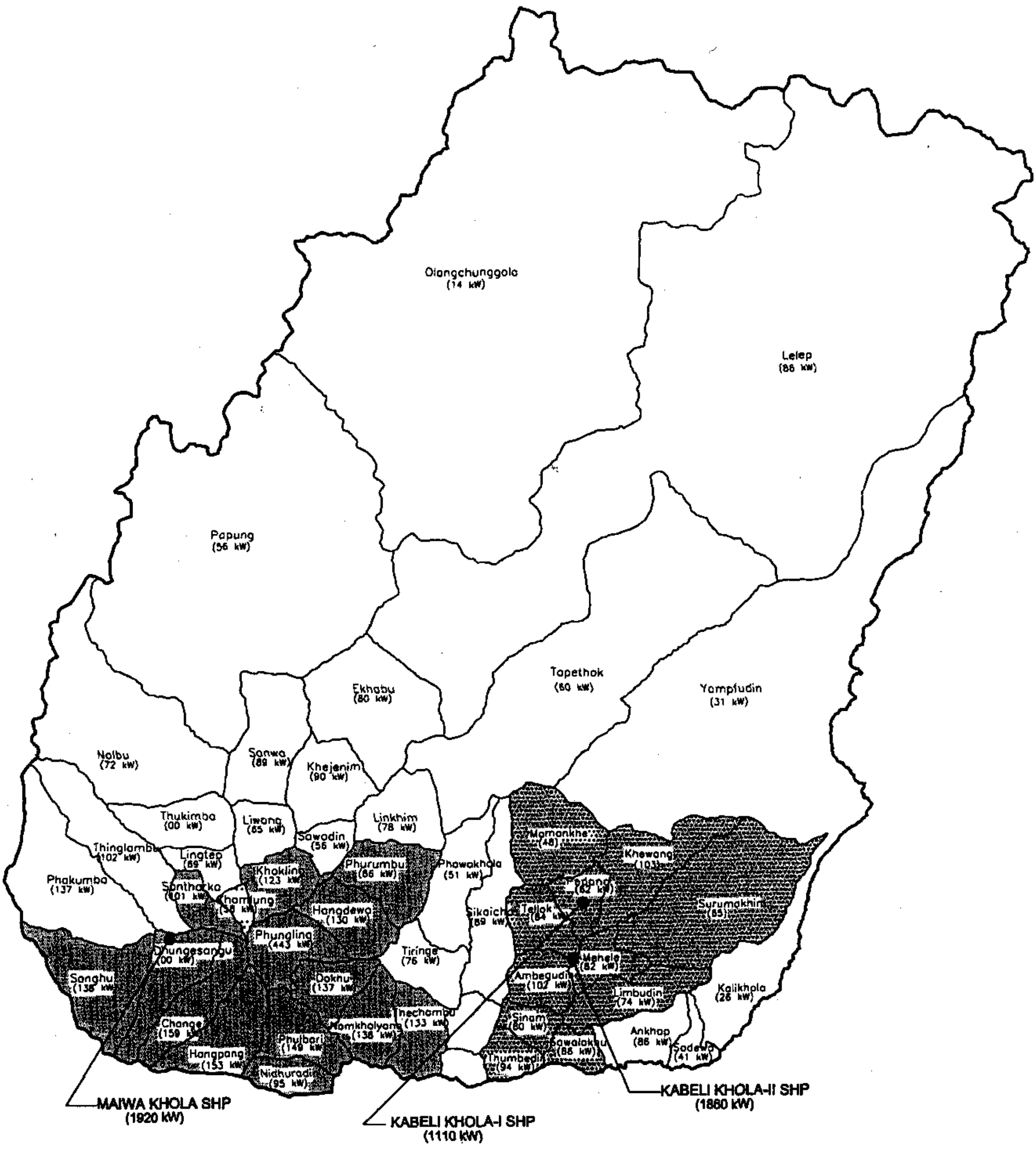
1. At first all the VDCs as potential load centers has been forecasted for demand electricity
2. Available socio-economic data information are identified for load forecast and ranking of load centers
3. Input data for the load forecast model are collected and calculated at VDC level.
4. The load forecast of each VDC load centers is calculated by using a typical model EXCEL spreadsheet.
5. As a result of the summary of the load forecast of all VDCs load centers is presented in Figure 2.1 to Figure 2.9.
6. Taking into account of socio-economic data the results of load forecast and ranking of these load centers for the identification is made (Appendix B).
7. After ranking only those load centers fulfilling the selection criteria were proposed for electrification (Appendix B).

2.1.3.2 Parameter of load forecast: autonomous growth

The following parameters are related to autonomous load growth and have been studied for each VDC load centers based on previous study reports and reliable source or by adjustment:

a) Initial population
b) Growth rate of district population
c) Household size

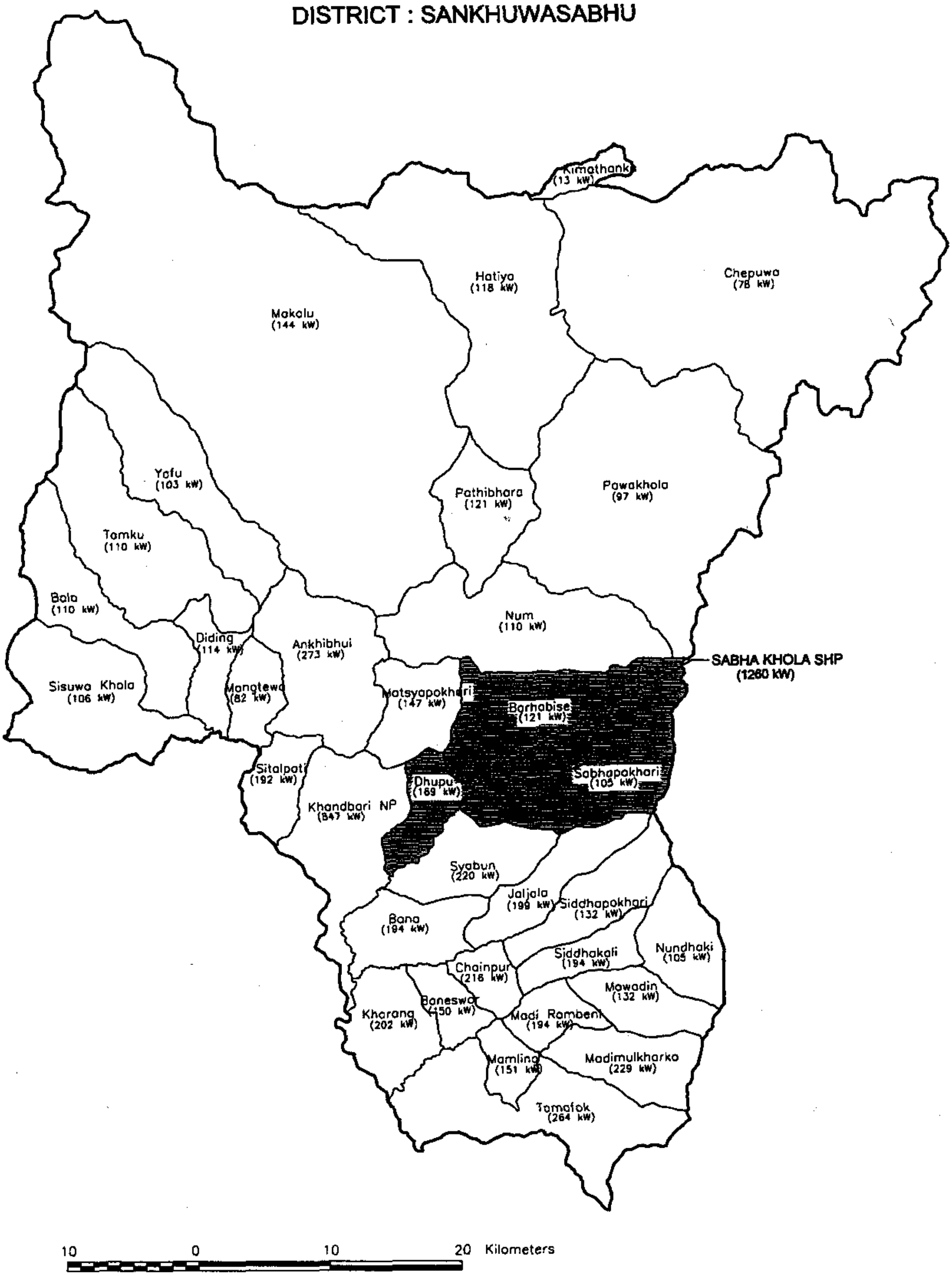
DISTRICT : TAPLEJUNG



Source : HMG Survey Department, National Geographic Information Infrastructure Project (NGIIP)

JICA SHP STUDY	
VDCwise Power Demand Forcast (2022)	
Taplejung	**Figure 2.1**

DISTRICT : SANKHUWASABHU



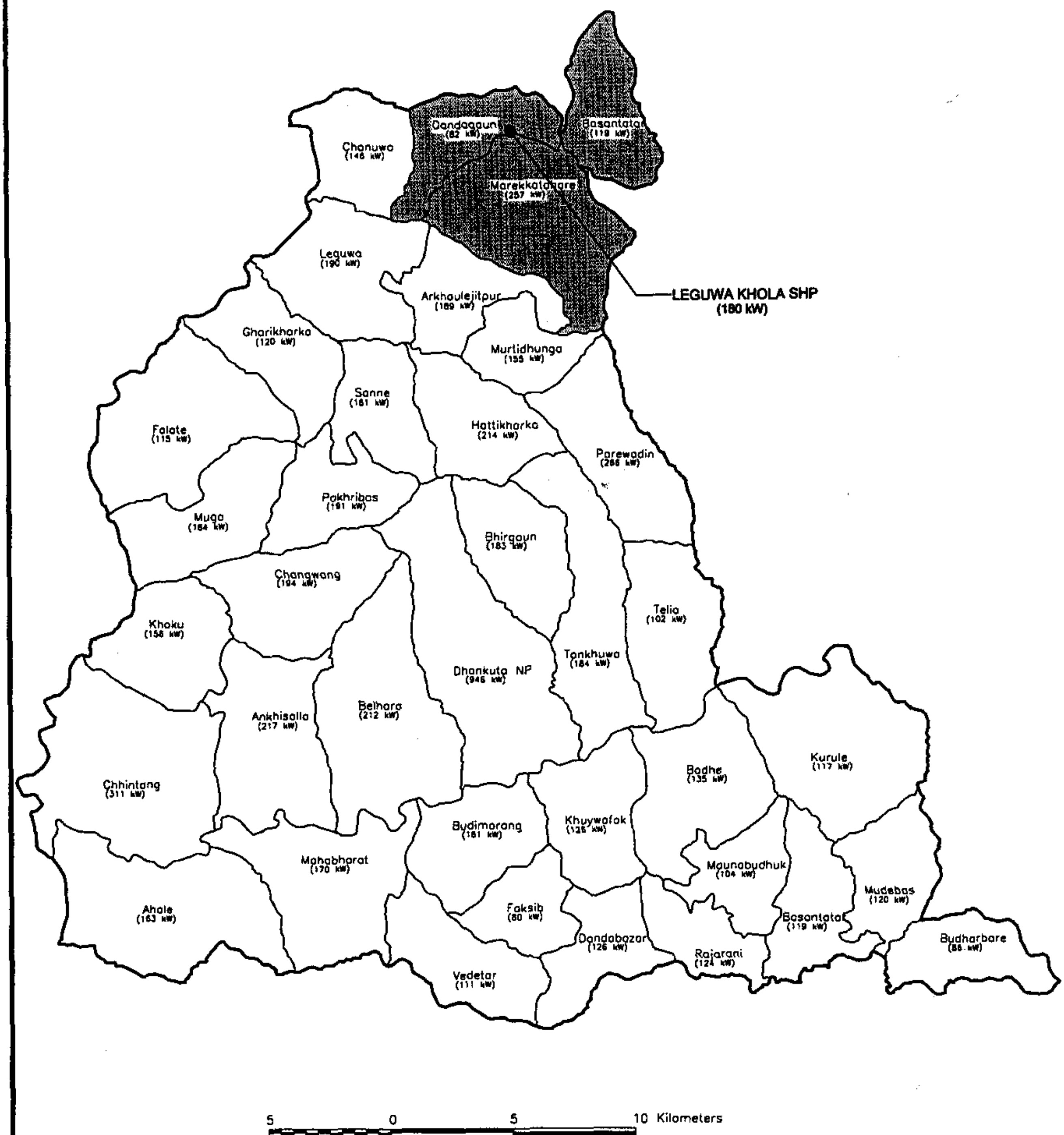
Source : HMG Survey Department, National Geographic Information Project (NGIIP)

JICA SHP STUDY

VDCwise Power Demand Forcast (2022)

Sankhuwasabha | **Figure 2.2**

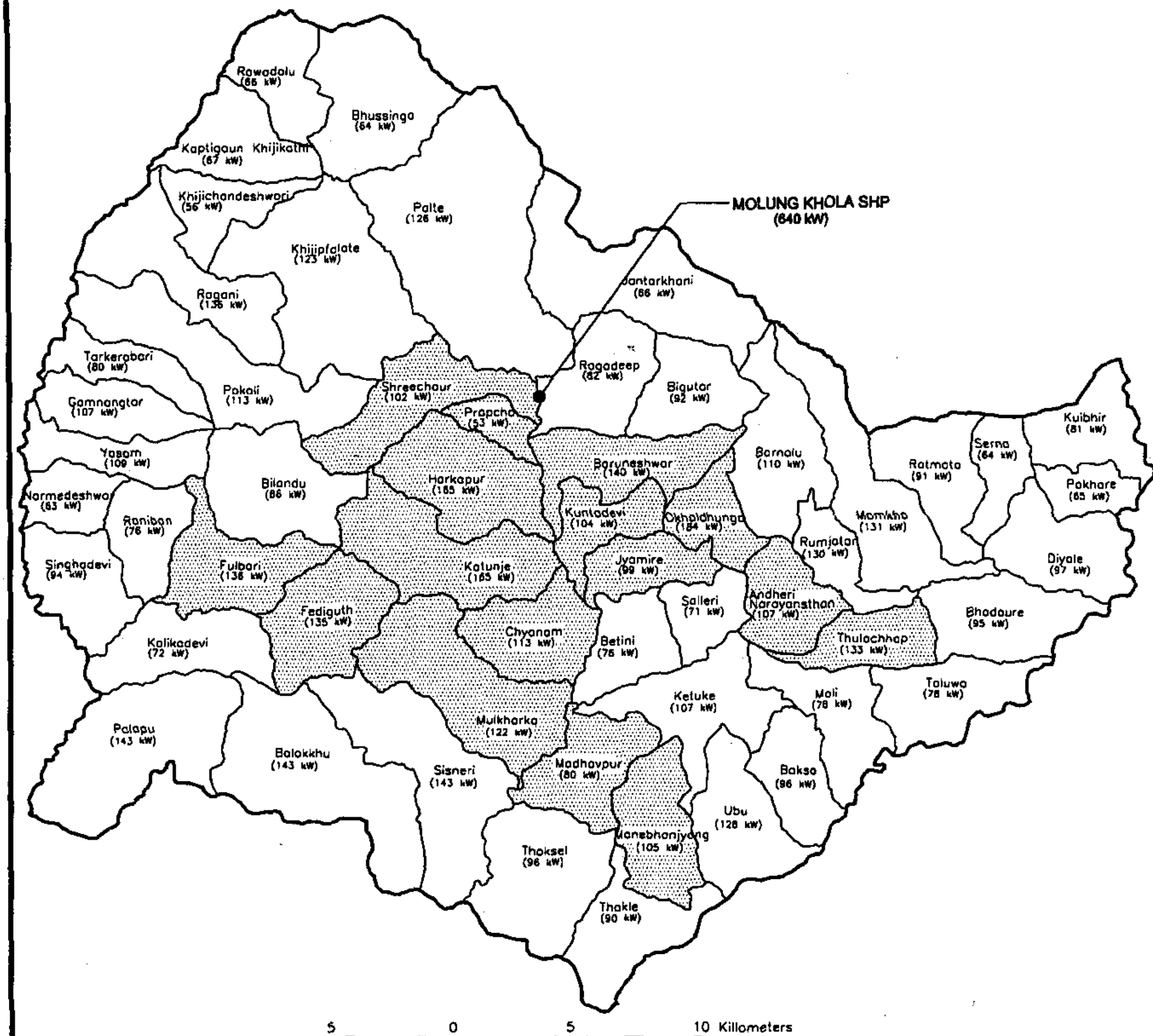
DISTRICT : DHANKUTA



Source : HMG Survey Department, National Geographic Information Infrastructure Project (NGIIP)

JICA SHP STUDY	
VDCwise Power Demand Forcast (2022)	
Dhankuta	**Figure 2.3**

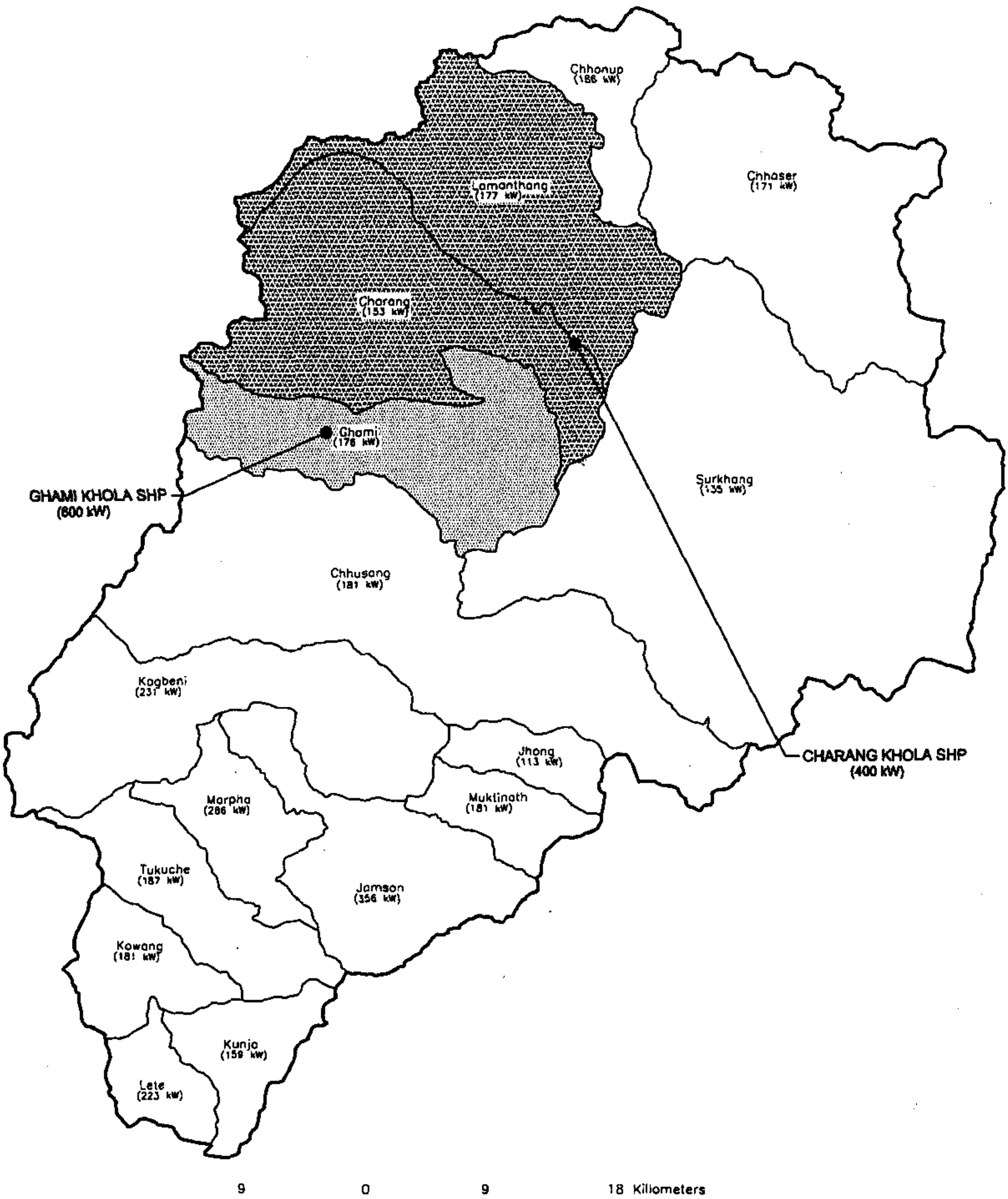
DISTRICT : OKHALDHUNGA



Source : HMG Survey Department, National Geographic Information Infrastructure Project (NGIIP)

JICA SHP STUDY	
VDCwise Power Demand Forcast (2022)	
Okhaldhunga	**Figure 2.4**

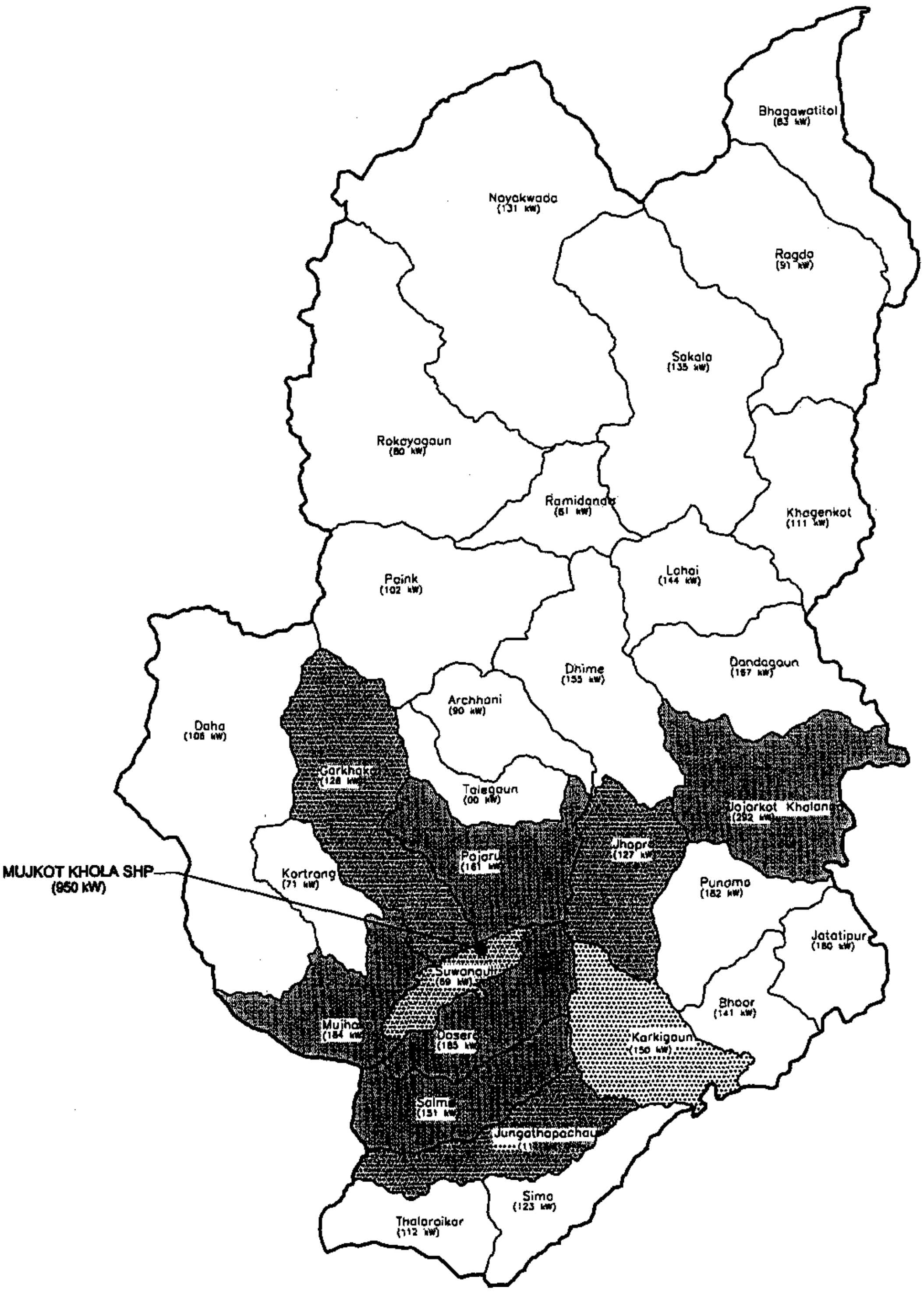
DISTRICT : MUSTANG



Source : HMG Survey Department, National Geographic Information Infrastructure Project (NGIIP)

JICA SHP STUDY	
VDCwise Power Demand Forcast (2022)	
Mustang	**Figure 2.5**

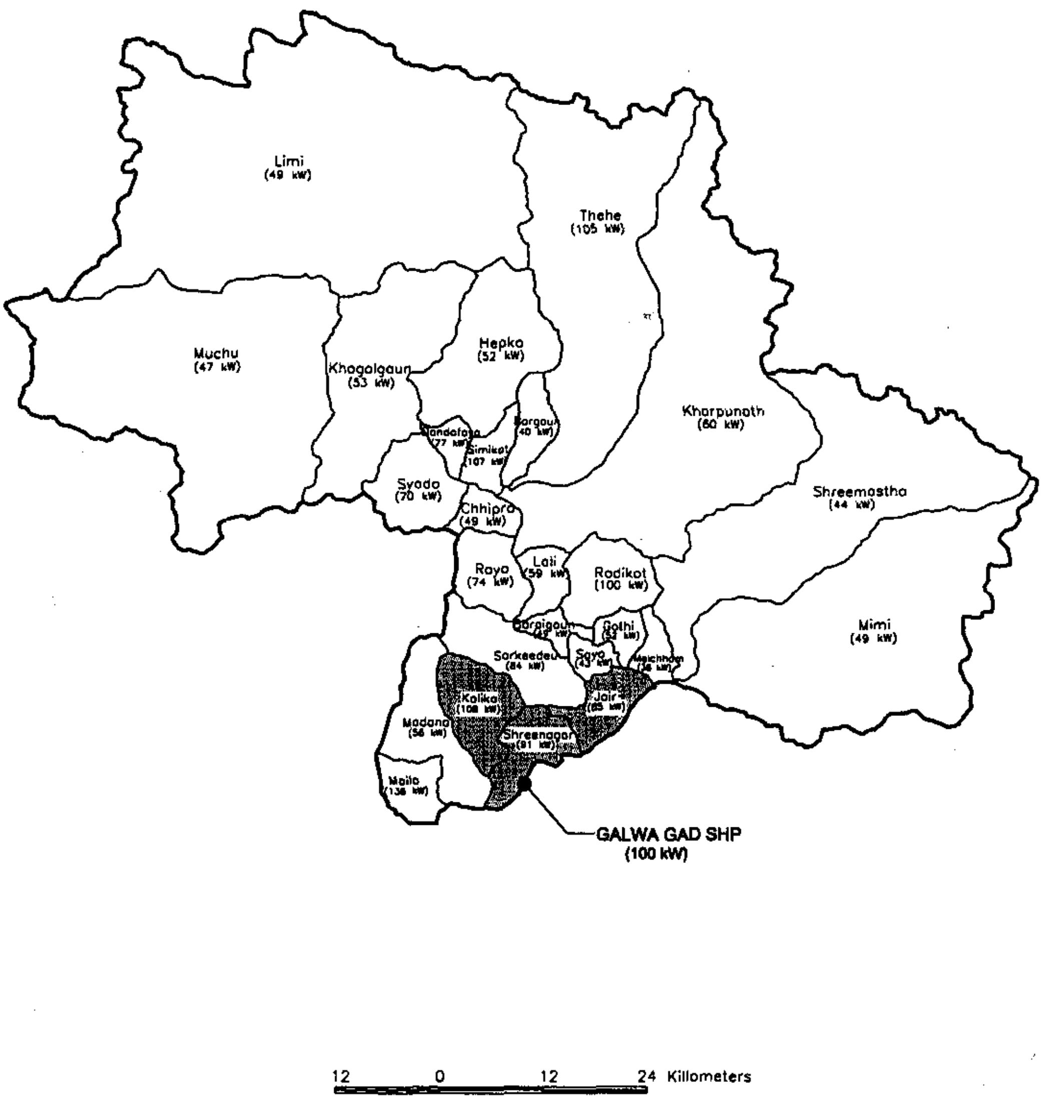
DISTRICT : JAJARKOT



Source : HMG Survey Department, National Geographic Information Infrastructure Project (NGIIP)

JICA SHP STUDY	
VDCwise Power Demand Forcast (2022)	
Jajarkot	**Figure 2.6**

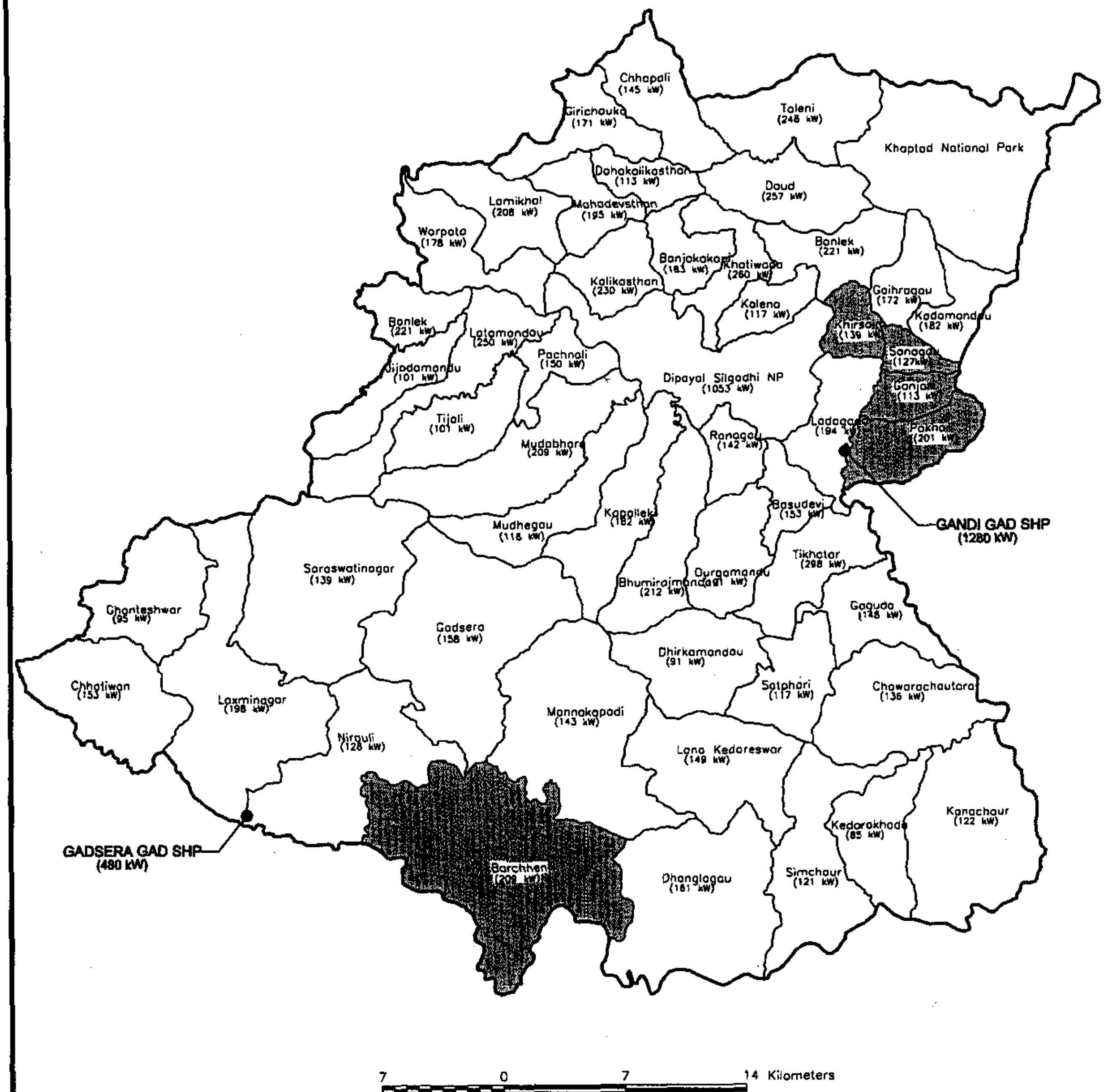
DISTRICT : HUMLA



Source : HMG Survey Department, National Geographic Information Infrastructure Project (NGIIP)

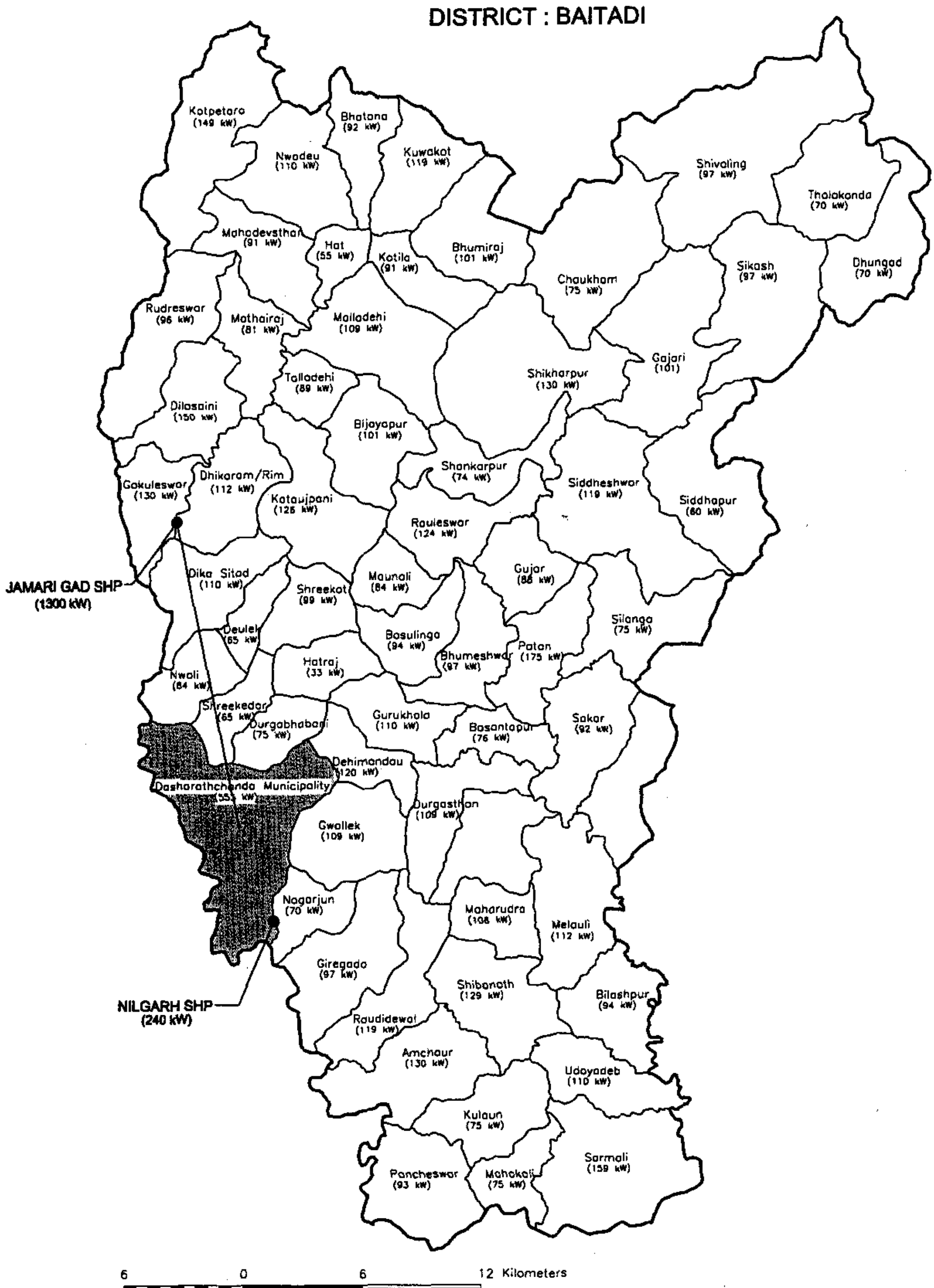
JICA SHP STUDY	
VDCwise Power Demand Forcast (2022)	
Humla	**Figure 2.7**

DISTRICT : DOTI



Source : HMG Survey Department, National Geographic Information Infrastructure Project (NGIIP)

JICA SHP STUDY	
VDCwise Power Demand Forcost (2022)	
Doti	**Figure 2.8**



Source : HMG Survey Department, National Geographic Information Infrastructure Project (NGIIP)

JICA SHP STUDY	
VDCwise Power Demand Forcast (2022)	
Baitadi	Figure 2.9

d) Income categorize of household groups
   - Low
   - Medium
   - High
e) Number of household per commercial center
f) Number of household per public service unit
g) Electrification coefficients
   - Low income household groups
   - Medium income household groups
   - High income household groups
h) Consumption (kWh) per
   - Low income household groups
   - Medium income household groups
   - High income household groups
   - Commercial centers
   - Public service units
   - Industrial growth
   - System losses
   - Load factors (hours of utilization)

2.1.3.3 Application of parameters

The parameters for the load centers may be explained as follows.

Population
A population figure for each VDC has been based on the 2001 census statistics obtained from the Central Bureau of Statistics. The initial population figure for the year 2001 has been adjusted with the district population growth rate for estimating population up to 2002.

Annual population growth rate
Since autonomous load results from the demand of the population and services directly related to population, the annual population growth rates for each VDC load centers is an essential determinant for future load development. The growth rates used in this study are obtained from the district figures.

Household size
The average household size has been considered from the CBS population census data 2001.

Household per income group
In absence of data o income group in the load centers, the previous study reports has been considered for the household income groups and adjusted with the inflation factor for the consistency of period year

It is assumed that the pattern of low, medium and high income groups changes on a basis of gradual decrease in percentage of low income group; a relatively lower rate increase in percentage of medium group and still slower rate increase in percentage of high income group during the project period. However the data are based on the secondary information.

2.1.3.4 Ranking of load centers

In the scenario described above the selection of load centers essentially evolved from the following criteria:

- Agro- based industries canters (Household engaged in industries)
- Administrative centers (Household engaged in service)
- Household engaged in trade and commerce
- Number of school going students
- VDC not yet electrified or improvement of electricity supply is necessary

- Population centers with appreciable population and socio-economic or industrial activity,
- Population centers in proximity to the site of the potential hydro power generation plant
- Length of transmission line from the SHPP to the load centers not exceeding 30 km

In accordance with the above criteria the VDC load centers are selected for each of the identified hydropower electrification site. The scoring criteria is based on the highest and lowest score point in each of the above socio-economic and load demand factors. The score is given 10 for highest load demand and 5 for other parameters such as households involved in industries, trade and commerce, service, and school going students. The lowest score is considered zero for all other cases. The score between zero and highest score is determined on the basis interpolation factors between the highest and lowest scoring point. The selected load centers together with load demand forecast are presented in (Appendix B).

2.1.4 List of Studied Projects

The study team collected all available project reports conforming to the study requirement and compiled a list of such projects. A complete list of the studied projects, which serve as least cost alternative to electrify priority load centers is shown in Table 2.1.

Table 2.1: List of identified projects

S. N.	Name of projects	Region	District
1	Kabeli I	EDR	Taplejung
2	Kabeli II	EDR	Taplejung
3	Maiwa Khola	EDR	Taplejung
4	Leguwa	EDR	Dhankuta
5	Sabha Khola	EDR	Sankhuwa
6	Rok Khola	EDR	Solukhumbu
7	Yari Khola	EDR	Udayapur
8	Molung Khola	EDR	Okhaldhunga
9	Chaunri Khola	MDR	Ramechap
10	Tadi Khola	MDR	Nuwakot
11	Khani Khola	MDR	Lalitpur
12	Phalankhu-II	MDR	Rasuwa
13	Phalankhu-I	MDR	Rasuwa
14	Daraundi	MDR	Gorkha
15	Chepe Khola	MDR	Lamjung
16	Charang	WDR	Mustang

S. N.	Name of projects	Region	District
17	Jyagdi	WDR	Shyanja
18	Ghami Khola	WDR	Mustang
19	Bhim Khola	WDR	Baglung
20	Chhal Gad	MWDR	Dolpa
21	Phoi Gad	MWDR	Dolpa
22	Chandabise Khola	MWDR	Jumla
23	Jaljala	MWDR	Jumla
24	Satya Khola	MWDR	Jajarkot
25	Mujkot	MWDR	Jajarkot
26	Galwa Gad	MWDR	Humla
27	Gandi Gad	FWDR	Doti
28	Gadsera Gad	FWDR	Doti
29	Kalagad	FWDR	Darchula
30	Jamadi Gad	FWDR	Baitadi
31	Bhartola Gad	FWDR	Darchula
32	Nilgarh Gad	FWDR	Baitadi

The locations of the identified projects along with existing SHPs are shown in Figure 2.10.

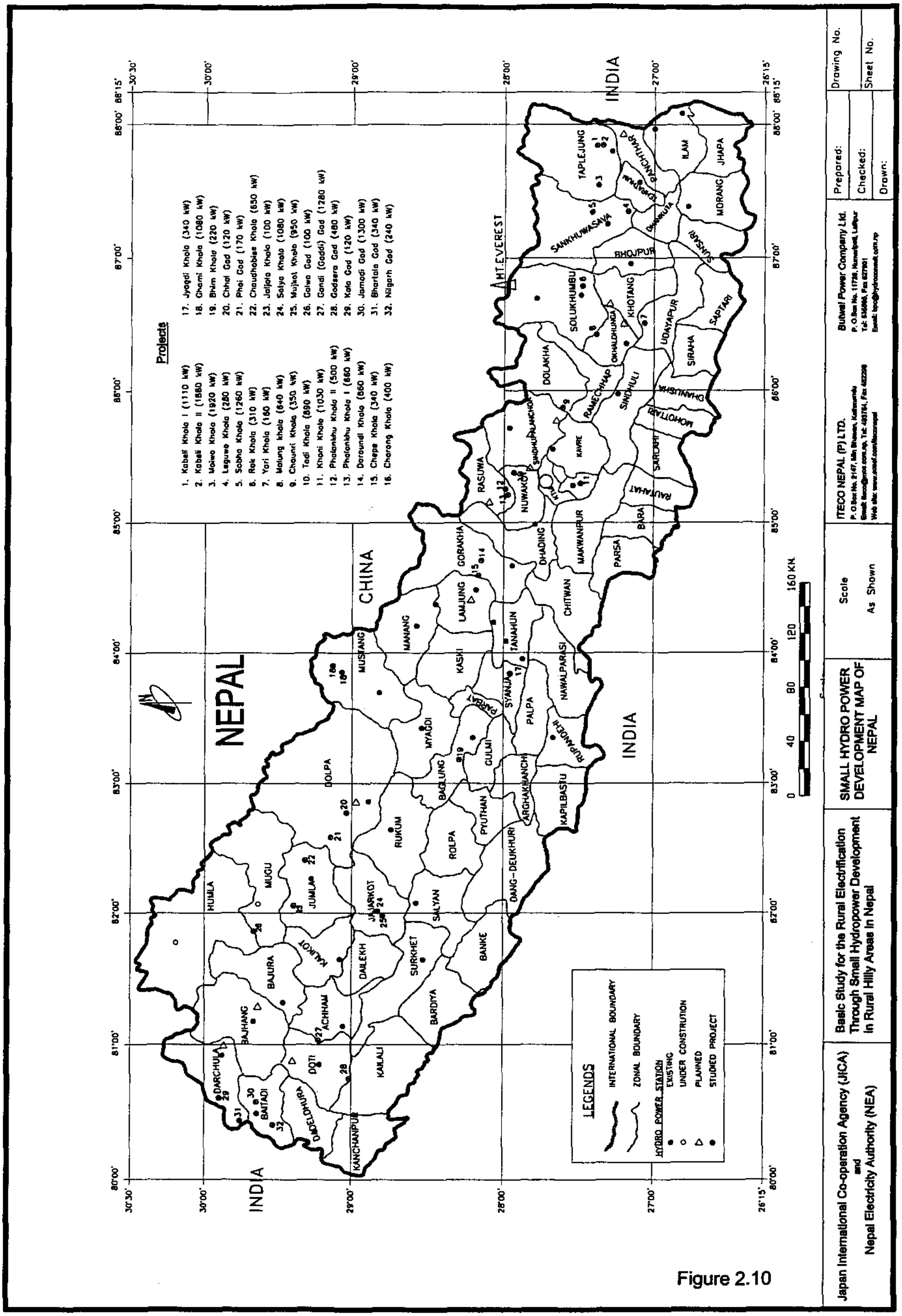

NEPAL
CHINA
INDIA
MT.EVEREST
Projects
1. Kabeli Khola I (1110 kW)
2. Kabeli Khola II (1880 kW)
3. Maiwa Khola (1920 kW)
4. Leguwa Khola (280 kW)
5. Sobha Khola (1260 kW)
6. Rok Khola (310 kW)
7. Yari Khola (160 kW)
8. Malung khola (640 kW)
9. Chaunri Khola (350 kW)
10. Tadi Khola (890 kW)
11. Khani Khola (1030 kW)
12. Phalankhu Khola II (500 kW)
13. Phalankhu Khola I (660 kW)
14. Daraundi Khola (660 kW)
15. Chepe Khola (340 kW)
16. Charang Khola (400 kW)
17. Jyagdi Khola (340 kW)
18. Ghami Khola (1080 kW)
19. Bhim Khola (220 kW)
20. Chhal Gad (120 kW)
21. Phoi Gad (170 kW)
22. Chaudhobise Khola (650 kW)
23. Jaljala Khola (100 kW)
24. Salya Khola (1080 kW)
25. Mujkot Khola (950 kW)
26. Golwa Gad (100 kW)
27. Gandi (Gaddi) Gad (1280 kW)
28. Gadsera Gad (480 kW)
29. Kala Gad (120 kW)
30. Jamodi Gad (1300 kW)
31. Bharlala Gad (340 kW)
32. Nilgarh Gad (240 kW)
LEGENDS
INTERNATIONAL BOUNDARY
ZONAL BOUNDARY
HYDRO POWER STATION
EXISTING
UNDER CONSTRUCTION
PLANNED
STUDIED PROJECT
0 40 80 120 160 KM.
Japan International Co-operation Agency (JICA) and Nepal Electricity Authority (NEA)
Basic Study for the Rural Electrification Through Small Hydropower Development in Rural Hilly Areas in Nepal
SMALL HYDRO POWER DEVELOPMENT MAP OF NEPAL
Scale
As Shown
ITECO NEPAL (P) LTD.
Butwal Power Company Ltd.
Prepared:
Checked:
Drawn:
Drawing No.
Sheet No.

Figure 2.10

2.2 REVIEW OF HYDRO-METEOROLOGICAL STUDY

2.2.1 Introduction

The main aim of hydrological studies has been to prepare the necessary flow and flood design data for hydropower planning of 100 kW to 2000 kW projects. The hydrological studies involved are:

- Collection and reviewing of documents related to the identified projects,
- Collection and analysis of hydro-meteorological data and information related to the projects,
- Determination of hydrological parameters for hydropower development projects.

2.2.2 Meteorological Information

There are 204 climatological recording stations most of which were established during the 1960s to the early 1970s. The stations provide precipitation, temperature and humidity data. Unfortunately, most of the stations are located beyond the project influential areas. The density of existing meteorological stations in Nepal is sparse; hence the available data are used for preliminary study only. A study was conducted for improvement of Hydro-meteorological data under "Nationwide Hydro-meteorological Data Management Project" by JICA in 1993 suggesting a minimum network of 470 rainfall stations within Nepal with the density of 250 km^2 / station in mountainous areas and 900 km^2 / station in the Terai plains.

The daily and mean monthly rainfall data published by the DHM up to 1998 in different volumes are available. Normal precipitation records from 1967 to 1998 are available in 84 stations with a few missing months in different stations. The mean monsoon index of recent year is available which is used in the present study. The Index Map and precipitation stations and their locations along with a summary of meteorological parameters are listed in Appendix A.

2.2.3 Hydrological Information

There are more than 6000 rivers and rivulets in the country but only a few of them have discharge gauging stations. For surface runoff information of major rivers "Hydrological Records of Nepal 1998", published by DHM is available which includes maximum, minimum and mean monthly discharges and the annual series of instantaneous peak and low discharges. The records are available up to year 1995.

The first systematic hydrological records "Surface Water Records of Nepal" was published in 1967. The DHM has also published a data record book of 77 hydrological stations. It contains the records of major rivers since 1963. Amongst the 77 stations, 38 stations have existing DHM gauging stations where stream flow data exist on a daily basis. A table of the name and location of the recorded gauging stations are presented in Appendix A.

2.2.4 Methodology

The following indirect methods have been used to determine the hydrological parameters such as the design flow, low flow and flood flow of un-gauged rivers.

- Medium irrigation project method (MIP)
- WECS / DHM method (HYDEST Software, 1990)
- Medium hydropower study project method (MHSP 1997)
- HydrA Nepal software method (CEH 2001)

2.2.4.1 Medium irrigation project method (MIP)

This method was developed in 1982 by Sir M. MacDonald and Partners and uses the regionalized hydrograph technique. In the method, Nepal is divided into seven hydrological regions. The hydrographs of mean monthly flow per unit area of each region were prepared. The hydrographs are based on a series of wading measurements taken on an intermittent basis by the DHM. For each region a non-dimensional hydrograph was prepared by dividing the ordinates of the mean monthly flows by the mean April flow. For application to an ungauged site, it is necessary to obtain at least one low flow discharge measurement at that site. The flow measurement can then be used in conjunction with the non-dimensional hydrograph to determine a representative hydrograph of mean monthly flows for the site. In this method non-dimensional regional hydrographs coefficients for the mean monthly flows and flow coefficients for 80% reliable flows are used.

2.2.4.2 WECS/DHM method (HYDEST software, 1990)

The WECS/DHM method was developed to estimate hydrologic variables of ungauged catchments. The results are particularly applicable to the mountainous and hilly regions.

The WECS/DHM method is based upon the long-term flow records of the DHM. The flow records up to 1985 of selected DHM gauging stations were used in a multiple regression analysis. For flood frequency analysis, 33 stations were selected while for low flow and long term flow analyses 44 stations were selected. In this method, the hydrological parameters were expressed in the form of prediction equations. There are three sets of equations for the mean flow, low flow and flood flow.

Mean flow

For the estimation of the mean flow, this method requires the user to input the catchment area below 5000 m and the monsoon wetness index (rainfall from June - September) estimated form the DHM isohytal map.

$$Q_{mean} = C \text{ X } (A_{total})^{A1} \text{ X } (A_{below\ 5000m} + 1)^{A2} \text{ X } (\text{monsoon wetness index})^{A3}$$

Where,
Q_{mean} is the mean monthly flow in m^3/s
C, A_1, A_2 and A_3 are constants derived from the regression analysis
A is the catchment area of a basin in km^2
The constants are presented in Table 2.2

Table 2.2: WECS prediction equation constants for mean flow

Month	C	A_1	A_2	A_3
January	0.014230	0	0.9777	0
February	0.012190	0	0.9766	0
March	0.009988	0	0.9948	0
April	0.007974	0	1.0435	0
May	0.008434	0	1.0898	0
June	0.006943	0.9968	0	0.2610
July	0.021230	0	1.0093	0.2523
August	0.025480	0	0.9963	0.2620
September	0.016770	0	0.9894	0.2878
October	0.009724	0	0.9980	0.2508
November	0.001760	0.9605	0	0.3910
December	0.001485	0.9536	0	0.3607

Low flow

For the estimation of the low flow only the area below 5000 m is required.
The monthly low flows are computed as:

$$(Q_{monthly2y})^{0.5} = 0.0929 + 0.09269\ (A_{below\ 5000m} + 1)^{0.5}$$
$$(Q_{monthly10y})^{0.5} = -0.00749 + 0.08480\ (A_{below\ 5000\ m} + 1)^{0.5}$$

Where,

$Q_{monthly2y}$ 2-year, monthly low flow in m^3/s
$Q_{monthly10y}$ 10-year, monthly low flow in m^3/s
A Catchment area in km^2

Flood flow

The catchment area below 3000m is used for the estimation of floods of various return periods. This method has to be used with caution for catchments that have significant areas above the snowline.

$Q_{inst2} = 1.8767 \times (A_{below\ 3000m}+1)^{0.8783}$
$Q_{inst100} = 14.630 \times (A_{below\ 3000m}+1)^{0.7343}$

Where,
Q_{inst2y} 2-year, instantaneous flood in m^3/s
$Q_{inst100y}$ 100-year, instantaneous flood in m^3/s

2.2.4.3 Medium hydropower study method (NEA 1997)

The Medium Hydropower Study Project (MHSP) under NEA developed a method to predict long term flows, flood flows and flow duration curves at ungauged sites through regional regression technique.

Daily flows and maximum and minimum instantaneous flows of 66 hydrometric stations obtained from the DHM were used in the regression. The input variables were similar to those used in WECS/DHM method.

Mean flow

The variables used in the WECS/DHM method were used in the multiple regression analyses. It was found that the total drainage area was more statistically significant than the area below 5000 m. Hence, the total area is used in the prediction equations.

$Q_{mean} = C \times (A)^{A1} \times (\text{mean monsoon precipitation})^{A2}$

Where,
Q_{mean} mean monthly flow in m^3/s
C,A1, and A2 constants derived from the regression analysis
A total catchment area of a basin in km^2

The constants are presented in Table 2.3

Table 2.3: MHSP prediction equation constants for mean flow

Month	C	A1	A2
January	0.03117	0.8644	0.0000
February	0.02417	0.8752	0.0000
March	0.02053	0.8902	0.0000
April	0.01783	0.9558	0.0000
May	0.01193	0.9657	0.0000
June	0.01135	0.9466	0.2402
July	0.01641	0.9216	0.3534
August	0.02592	0.9095	0.3242
September	0.02206	0.8963	0.3217
October	0.01504	0.8772	0.2848
November	0.00792	0.8804	0.2707
December	0.00538	0.8890	0.2580

Flood flow

To derive the prediction equations for the flood flow the country is divided into three regions, Eastern, Central and Western. Annual maximum instantaneous flows are used in the frequency analysis and the results related flood magnitude to the drainage area. Similar to the WECS study areas below 3000 m are found to give the best statistical results.

$Q = k \times A^{b}$

The coefficients derived from the multiple regression equation for each of the regions are presented in Table 2.4.

Table 2.4: Regression coefficients for regional analysis of flood peaks

Return Period	Region					
	Western		Central		Eastern	
	k	b	k	b	k	b
5	2.0409	0.8632	1.6762	0.9660	7.4008	0.7862
20	3.2895	0.8510	3.2303	0.9281	13.0848	0.7535
50	4.2570	0.8444	4.6090	0.9071	17.6058	0.7380
100	5.2225	0.8352	5.9865	0.8888	21.5181	0.7281
1000	9.2270	0.8148	12.6603	0.8429	39.9035	0.6969
10000	14.4580	0.8063	24.6431	0.8019	69.7807	0.6695

Flow duration curves characteristics

The country as a whole has been taken as a single unit to derive the flow duration curves. Daily flows of 61 gauging stations are used. The predicted coefficients from the multiple regression analyses are presented in Table 2.5. The equation is in the form:

$Q = C \times (A)^{b} \times (MWI)^{a}$

Where, C, a, b are constants
A is the total drainage Area in km^2
MWI is the Monsoon Wetness Index

Table 2.5: Daily flow duration curve's coefficients developed by NEA

Dependent Variable	b	a	c
Maximum flow (Q_0)	0.8120	0.5337	0.0614105
25% exceedance	0.9279	0.2986	0.0124336
45% exceedance	0.9239	0.2018	0.0089146
65% exceedance	0.9044	0.0000	0.0248313
85% exceedance	0.9256	0.0000	0.0144905
95% exceedance	0.9531	0.0000	0.0086449
Minimum flow	1.1689	0.0000	0.0007382

2.2.4.4 HydrA Nepal software method

HydrA Nepal software is introduced for estimating discharge and hydropower potential at ungauged or gauged sites in Nepal. The software was developed jointly by the DHM of Nepal, Centre for Ecology & Hydrology, U.K. and ICIMOD and is applicable for small-scale hydropower schemes up to 10 MW capacities in Nepal. It derives a synthetic flow duration curve describing the hydrological regime to estimate key catchment characteristics including area, mean flow, hydrological response, average rainfall and evaporation. The design flows of 90% exceedance obtained by HydrA Nepal have been mostly used in the present study.

2.2.5 Findings

Each project is treated independently and hydrological parameters are determined separately because the projects are located at different river basins having diverse hydrological characteristics. For projects where recorded data are available, the flood frequency analysis method is used to determine the flood discharge. Then the discharge is transferred to the project site by specific discharge method. The details of results obtained by various methods are presented in Appendix A. The summary of findings of 90% dependable low flow and 100 years return period flood, have been presented in Table 2.6.

Table 2.6: Summary of findings of discharges by various methods

S. No.	Name of Projects	District	Capacity	Head	90 % exceedance flow					100 Yrs Return Period Flood			
					Ungauged river			Previous	Gauged river	Ungauged river		Previous	Gauged river
					HYDEST	HydrA	MHSP			HYDEST	MHSP		
1	Kabeli I	Taplejung	1110	74	2.59	3.00	2.50	3.70	N/A	651	1422		N/A
2	Kabeli II	Taplejung	1860	80	3.57	4.50	3.58	5.10	N/A	894	1860		N/A
3	Maiwa Khola	Taplejung	1920	260	1.23	1.73	0.46	1.25	N/A	542	892		N/A
4	Leguwa	Dhankuta	280	400	0.77	0.10	0.23	0.16	N/A	153	215		N/A
5	Sabha Khola SHP	Sankhuwa	1260	130	0.79	1.54	0.94	0.77	N/A	378	657		N/A
6	Rok Khola	Solukhumbu	310	340	0.12	0.13	0.16	0.15	N/A	101	173		N/A
7	Yari Khola	Udayapur	160	100	0.30	0.23	0.40	0.29	N/A	240	339		N/A
8	Molung Khola SHP	Okhal	640	83	1.22	0.65	1.39	1.54	N/A	588	890	500	N/A
9	Chaunri Khola	Ramechap	350	50	1.02	0.96	1.18		N/A	554	484		N/A
10	Tadi Khola	Nuwakot	890	121	1.03	0.35	1.16	1.24		369	774	375	N/A
11	Khani Khola	Lalitpur	1030	135	0.62	1.09	0.66		N/A	440	278		N/A
12	Phalankhu-II	Rasuwa	500	60	N/A	N/A	N/A		1.17	N/A	N/A		423
13	Phalankhu-I	Rasuwa	660	105	N/A	N/A	N/A		0.91	N/A	N/A		423
14	Daraundi	Gorkha	860	52.3	1.50	2.66	1.69	2.70		579	680	538	N/A
15	Chepe Khola	Lamjung	340	20	1.40	2.55	1.56	2.27		566	415		N/A
16	Charang	Mustang	400	60	0.21	0.96	1.70			15*	685		N/A
17	Jyagdi	Shyanja	340	80	1.22	0.61	1.36		N/A	624	371		N/A
18	Ghami Khola	Mustang	1080	147	0.11	1.33	1.90			15*	494	90	N/A
19	Bhim Khola	Baglung	220	75	0.69	0.50	0.83	1.00		393	235		N/A
20	Chhal Gad	Dolpa	120	155	0.30	0.13	0.46	0.35	N/A	75	139		N/A
21	Phoi Gad	Dolpa	170	135	0.18	0.18	0.24		N/A	19	78		N/A
22	Chandabise Khola	Jumla	650	64	1.49	1.64	1.93		N/A	18**	500		N/A
23	Jaljala	Jumla	100	140	0.31	0.10	0.41		N/A	49	125		N/A
24	Satya Khola	Jajarkot	1080	152	0.71	1.13	0.85		N/A	375	242		N/A
25	Mujkot	Jajarkot	950	52	1.97	2.91	2.11		N/A	710	543		N/A
26	Galwa Gad	Humla	100	77	0.73	0.18	0.88		N/A	319	247		N/A
27	Gandi Gad	Doti	1280	135	1.10	1.36	1.16		N/A	545	318		N/A
28	Gadsera Gad	Doti	480	50	1.20	1.48	1.28		N/A	590	348		N/A
29	Kalagad	Darchula	120	95	0.21	0.18	0.27		N/A	151	84		N/A
30	Jamadi Gad	Baitadi	1300	80	1.68	2.42	1.73		N/A	743	453		N/A
31	Bhartola Gad	Darchula	340	180	0.27	0.27	0.34		N/A	212	107		N/A
32	Nilgarh Gad	Baitadi	240	400	0.27	0.09	0.34		N/A	213	107		N/A

Note: N/A means not applicable

* means area of basin below 3000 m is 0%

** means area of basin below 3000 m is 0.2% only

2.3 REVIEW OF POWER POTENTIAL

2.3.1 Review of Rated Design Discharge

In the previous studies, the rated design flow for grid connected projects varied from 60% to 85% dependable flow with the objective to utilizing the excess of discharge during wet months.

The projects under present study are isolated projects, designed to serve rural areas with reliable supply of electricity throughout the year. The entire supply will be utilized over respective load centers. The projects are run-of the river types. Hence rated design discharge is based on 90% dependable flow. The 90% dependable flow is calculated using applicable methods. During selection of design discharge 10% of minimum flow is released to the river as riparian flow. Where irrigation projects exist necessary discharge is left in the river to serve downstream water usage.

2.3.2 Review of Plant Capacity

The plant capacities from previous studies have been reviewed thoroughly. The load centers are also updated based on further available data.

The future power demands were computed considering parameters of rural household, rural economic development and expected future development activities.

The plant capacity depends on site of the project. For run-of the river isolated projects the discharge is adopted as 90% probability of exceedance. The forebay and powerhouse are selected at suitable places to utilize available head. The plant capacity of each project is determined using the HydrA Nepal software. The types and number of turbines suitable for the project have also been ascertained. A summary of power potentials in the reviewed hydropower projects is as shown in Table 2.7.

Table 2.7: Summary of power potential

S. N.	Name of projects	District	Capacity kW	Head m	Design flow m^3/s	Net annual production MWh	Type of turbine
1	Kabeli I	Taplejung	1110	74.0	2.18	8790	Turgo
2	Kabeli II	Taplejung	1860	80.0	3.03	14675	Turgo
3	Maiwa Khola	Taplejung	1920	260.0	0.95	14859	Pelton
4	Leguwa	Dhankuta	280	400.0	0.09	4434	Pelton
5	Sabha Khola	Sankhuwa	1260	130.0	1.39	10007	Pelton
6	Rok Khola	Solukhumbu	310	340.0	0.12	2445	Francis
7	Yari Khola	Udayapur	160	100.0	0.21	1274	Pelton
8	Molung Khola	Okhaldhunga	640	83.0	1.10	5063	Pelton
9	Chaunri Khola	Ramechap	350	50.0	0.86	2766	Francis spiral
10	Tadi Khola	Nuwakot	890	121.0	1.05	7035	Pelton
11	Khani Khola	Lalitpur	1030	135.0	0.98	8146	Pelton
12	Phalankhu-II	Rasuwa	500	60.0	1.04	3997	Pelton
13	Phalankhu-I	Rasuwa	660	105.0	0.81	5227	Pelton
14	Daraundi	Gorkha	860	52.3	2.39	6637	Francis
15	Chepe Khola	Lamjung	340	20.0	2.35	2715	Francis
16	Charang	Mustang	400	60.0	0.86	3193	Pelton
17	Jyagdi	Shyanja	340	80.0	0.55	2694	Pelton
18	Ghami Khola	Mustang	1080	147.0	1.05	8553	Pelton
19	Bhim Khola	Baglung	220	75.0	0.42	1739	Pelton
20	Chhal Gad	Dolpa	120	155.0	0.12	1002	Pelton
21	Phoi Gad	Dolpa	170	135.0	0.18	1343	Pelton
22	Chandabise Khola	Jumla	650	64.0	1.48	5154	Francis
23	Jaljala	Jumla	100	140.0	0.09	775	Pelton
24	Satya Khola	Jajarkot	1080	152.0	1.02	8592	Pelton
25	Mujkot	Jajarkot	950	52.0	2.62	7288	Francis
26	Galwa Gad	Humla	100	77.0	0.16	689	Pelton
27	Gandi Gad	Doti	1280	135.0	1.36	10142	Pelton
28	Gadsera Gad	Doti	480	50.0	1.48	3839	Francis
29	Kalagad	Darchula	120	95.0	0.18	946	Pelton
30	Jamadi Gad	Baitadi	1300	80.0	2.42	10546	Turgo
31	Bhartola Gad	Darchula	340	180.0	0.27	2688	Pelton
32	Nilgarh Gad	Baitadi	240	400.0	0.09	1938	Pelton