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Delineation of Run of River Hydropower Potential of Karnali Basin-Nepal Using GIS and HEC-HMS

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ABSTRACT

Water resources are the most important natural resources because they are not only renewable natural resources but also abundantly available in Nepal. A favorable topographic condition because of high variation of elevation makes Nepal one of the richest countries in terms of hydro power potential. Despite the vast amount of sources, not all have been used in Nepal. Many small to large scale private-run and Government owned companies operate their hydropower projects throughout Nepal. This study is to assess the run of river hydropower potential of the Karnali Basin by using GIS (Geographical Information System) and Continuous Semi-distributed Hydrological Model (Hydrological Modeling System – HMS). The digital Elevation model (DEM) is used to calculate the elevation data of upstream and downstream ends of the reaches and daily discharges of the reaches are derived from precipitation data using HEC-HMS model with Nash efficiency ranging from 61.7% to 82.02 % and the volume deviation -1.52 % to 17.3 % for calibration and validation period. Using design discharge corresponding to 40th percentile flow with the hydraulic head, total power potential of 14150.80 MW is determined.

Key words: Hydropower, GIS (Geographical information system), DEM (Digital elevation model), percentile

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INTRODUCTION

Water resources are the most important natural resources because they are not only renewable natural resources but also abundantly available in Nepal. A favorable topographic condition because of high variation of elevation (from less than 100m to 8848 m) makes Nepal one of the richest countries in terms of hydro power potential. Hydropower is the major source of electricity in this country. World's 20% of the electricity is produced by Hydropower. In contrary, 96 % of electricity in Nepal is generated by Hydropower [1]. That says a lot of Nature Power of Nepal. Hydropower electricity is environment friendly as it does not cause in pollution of the air or the land and is also the most efficient method of all.
Even though Nepal is rich in water resources, we are only able to utilize about one and half percentage of our hydropower potential until now. In Nepal, electricity is available to limited percentage of people in urban and semi-urban areas. Hence, most Nepalese living in villages uses firewood for their energy requirements. On the other hand, the growing industrial sector needs reliable energy supply, which can only be fulfilled by hydropower in the country like Nepal.

Purpose of Research

Despite the vast amount of sources, not all have been used in Nepal. Many small to large scale private-run and Government owned companies operate their hydropower projects throughout Nepal. Due to insufficient amount of electricity available, many parts of Nepal share the amount of electricity that is available to them.

Medium Hydropower Study Project (MHSP), Nepal Electricity Authority (NEA) conducted a Screening and Ranking study of various identified hydropower projects ranging from 10 to 300MW capacity for major basins of Nepal. The project reported the total installed capacity of 138 projects as 9,613MW before fine screening and ranking study [2]. Under the power system master plan project, NEA conducted the feasibility study of hydroelectric projects ranging from the 14 MW to over 10,000MW. The project reported the aggregated installed capacity and annual energy availability as 18,500MW and 59,800 GW/hr respectively [3]. And, there are 38 hydropower potentials schedules in Karnali basin and Mahakali basin [4].

WECS (Water Energy Commission Secretariat) studied the economically feasible hydropower projects and estimated the power potential of 42,915MW. DOED (Department of Electricity Development) conducted the study of small hydropower projects of 5-10MW capacity and reported the installed capacity 305.8 MW of 45 identified projects on three major basins Koshi, Gandaki and Karnali [5].

The study made by Shrestha (1966) is long back when fewer hydrological and metrological data was available. The Power potential estimate made by the NEA, WECS and DOED was under the policy of the government with priority of small, medium and large hydroelectric and multipurpose project at different facet of time. It is realized that the past effort for identifying undeveloped hydropower capacity made by the different government agency is more project-oriented and the methodology for undeveloped hydropower resources assessment was not well defined.

Recent advances in computer technology have offered many benefits to the field of water resources especially due to emerging of Geographic Information Systems (GIS). GIS in conjunction with rainfall runoff hydropower model can be used in a variety of hydrologic applications like delineating the drainage pattern in a watershed. Especially in the hydropower sector the fewer example of GIS application has been used. The main basis of this study is to couple the GIS with the modeling tool to assess the hydropower potential of the river reach.

Study Area

Karnali Basin lies in Western Development Region of the Nepal. The Karnali River, one of the major three rivers in Nepal originates from the south of Mansarovar and Rokas lakes located in China (Tibet) and enter in Nepal near Khojarnath flowing in southern direction. The drainage area in China is approximately 2500 km^2 and that of Nepal territory is approximate 41500km^2. Therefore the total drainage area is approximately 44000 km^2 [6]. In Nepal it becomes Humla Karnali. It makes a sharp bend at Naralagna Himal. From there, it flows towards east and to south west at Nima-pipalang. There it is joined by Mugu Karnakli and Kharte Khola meets at Sukhadik. In between these two tributaries the Rara daha (lake) is situated.

The tentative length of Mugu Karnali is 160 km and Humla Karnali has 100 km. In Terai it flows a distance of 30 km inside Nepal before entering the Indian border. Comparing to other rivers, the Karnali valley is steep and confined in narrow gorges except at the Jaksi Ghat to Sundargaon reach where it swells to approximately 800 m width, and rest of the valley is good for cultivation.

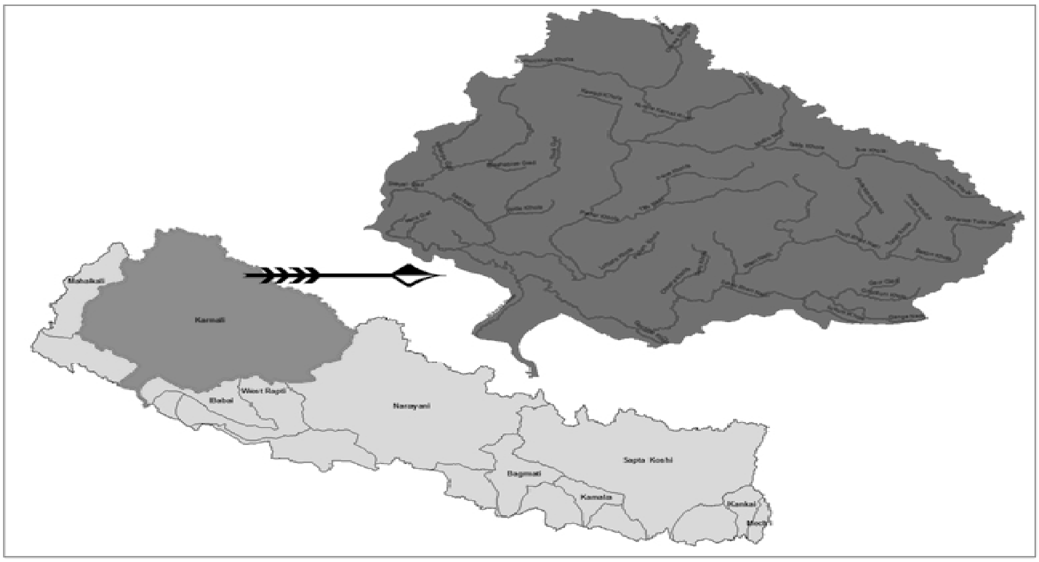

Fig.1 Watershed for Karnali River

Bheri, Seti, Thuligad and Burhiganga are the main tributaries of the Karnali River. Karnali in the upper part is in granite and gneiss whereas, in mid land mostly in chlorite schist and dolomite[6]. The Mugu Karnali coming out of Laddakh Himal joins the Humla Karnali originating from China (Tibet) at Galwa, giving rise to the Karnali river also known as Ghagra in India, which meet the Ganges. The Karnali, 507 km in length, with its shifts currents, forms several gorges.

Data Discussion

There are 32 meteorological station used in this study and daily rainfall data of 1st Jan 2001 to 31st December 2006 are used for the model but air temperature, wind speed and relative humidity are not used in this study. The average basin rainfall was estimated by construction of thiesson polygon. The gauge weight for each sub-basin was calculated as:

$$W_i = \frac{A_i}{A} \tag{1}$$

Where, i = index for gauge stations W_i = gauge weight, A_i = intersected thiessen polygon area A = Total area of sub-basin under consideration

Fig. 2 Thiessen polygon developed using areal –rain in GIS

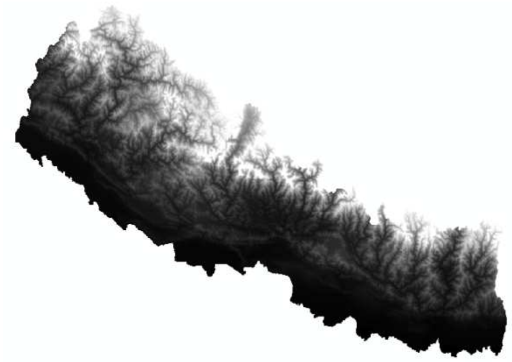

Fig. 3 100 meters resolution DEM of Nepal Basin

Fig. 4 Effective rainfall station of Karnali River

Fig. 5 Hydrological station distribution of Karnali River Basin (Source: DHM)

The four different stations as shown in fig. 5 i.e. Bheri River at Samaijighat, Seti River at Gopaghat, Sinju Khola at Diware and Karnali River at Chisapani are used for calibration and validation of the rainfall-runoff simulation model (HEC-HMS).

A DEM is an ordered array of numbers that represent the spatial distribution of elevation above some arbitrary datum. DEM describes the elevation of any point in the study are in digital format and contains the information on drainage, crest and breaks of slopes. The DEM is the primary spatial data source based on which GeoHMS extract the catchment boundary, stream network files indicating stream properties are generated from the DEM using GIS.

METHODOLOGY

The study focuses on the assessment of theoretical hydropower potential of Karnali basin, a sparsely gauged basin, using the geographic information system tool in conjunction with the semi distributed continuous rainfall runoff modeling tools. The overall process is as below:

- Digital Elevation Model (DEM) processing to calculate physical characteristics of the watershed.
- Use of HEC-HMS tools to simulate the rainfall-runoff process.
- Power Estimate

DEM Processing

HEC Geo-HMS is an extension of GIS. The input of HEC GeoHMS is DEM to derivate dataset which describe the drainage patterns of the watershed and allows stream and sub-basin delineation. These data sets are flow direction, flow accumulation, stream definition, stream segmentation and watershed delineation.

The resulting datasets from terrain processing are used as a spatial database for the study. With centralizing information in the spatial database, pertinent data sets were extracted for subsequent work on building the hydrological model. Further channel geometry needed for hydrological modeling is extracted from HEC-GeoRAS, an Arc View GIS extension tools.

Rainfall Runoff Modelling

Instead of empirical or formula or regression equation or lumped model, a semi distributed deterministic model will give a more realistic picture of the flow parameters within the watershed. As an improvement to statistical methods and lumped models, Geo HMS coupled with HEC-HMS seems to be the best suited model that satisfies the requirement to meet the objectives of this study.

For hydropower design and other water related projects, the determination of hydrological extremes and flows during in normal conditions are very necessary. Such quantities are determined by statistical analysis of long term hydrological data collected at a project site on a regular basis. Rainfall runoff model is used for generating long term daily discharges for catchment of the sparsely gauged river basin.

Power Estimate

Many factors such as detail knowledge of the geomorphology and geology, geotechnical, seismic conditions and other too many aspects are considered to calculate the power assessment at any site. In this, the hydropower potential is calculated by considering the flow and the head only. After obtaining the discharge, the power is calculated at every junction with 40% dependable flow which is according to the design guideline of Department of Electricity Development (DoED).

The theoretical power potential is calculated as:

$$P = 9.81 \, \eta \, Q \qquad (2)$$

Where, η = overall efficiency   Q = design discharge

For determining the power potential, the following are the design consideration:

a. The net head is considered as 90 % of the gross head which is common practice for power potential assessment for desk study level.
b. The efficiency considered for turbines, generators and transmission are 90 %, 95% and 98% which yields to the overall efficiency of 84%.
c. The downstream release of 10 % is considered for environmental consideration.

The 10% seasonal outage is considered for both dry and wet period.

Fig. 6 River Network Extracted from HEC Geo HMS with 85 Numbers of Sub-Basins

RESULT AND DISCUSSION

The results are presented in two sections. First section presents the calibration and the validation of the model. The second section shows the power potential assessment.

Model Calibration and Validation

The model is calibrated and validated at basin outlet at Chisapani and other three different place stations i.e. Bheri River at Samaijighat, Seti River at Gopaghat, and Sinju Khola at Diware for rainfall-runoff simulation model (HEC-HMS). A manual calibration as well as automated calibration technique is applied to estimate values of model parameters with care to limit the parameter values within acceptable range. The model simulated the discharge at Chisapani and others station for year 2001-2003 for calibration and 2004 – 2006 for validation with Nash efficiency ranging from 61.7% to 82.02 % and the volume deviation ranging from -1.52 % to 17.3 % .

Power Potential Assessment

The study reveals that at 40 percentile design flow the theoretical power potential of Karnali basin is **14150.80 MW.** The hydropower potential of Karnali Basin assessed by Adhikari (2009) resulted 15661.16 MW as installed capacity on his energy mapping. There is little different in between his assessment and on this study. This may be due to the difference in the methodology adopted in computing the potential power. Adhikari (2009) linearly interpolated the discharged based on the area to determine the design discharge for an ungauged site. Unitary method was used to account the discharge in the river. The rainfall pattern and distribution were not considered. Since there is no significant difference between two methods has been found and the calibration and validation in this method was done using the lesser number of gauging stations, the result well justifies the objective of present study.

CONCLUSION

This study delineate the hydropower potential of Karnali basin for run of river scheme using a semi distributed rainfall runoff model for a gauged basin that could interpolate the flow hydrograph at any ungauged site within catchment. GIS tool is used for the processing and HEC-HMS for routing the basin. Model was calibrated for the three years period starting from 2001 and also validated for the later three years period starting from 2004. Hydropower potential of the basin was calculated after calibration and validation of the model.

The study draws a conclusion that for runoff river scheme at 40% flow, the total hydropower potential of 14150.80 MW.

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