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Integration of Climate Change Impact Parameters in Hydropower Planning in Nepal: A Case Study of Kaligandaki Gorge HP

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Abstract

Nepal has a considerable hydropower base to build on. However, given the urgent need to mitigate climate change, hydropower infrastructure will have to be planned within the ranges of uncertainty that climate trends impose, moving away from static planning and design. Plans will likely need to accommodate forecasts for targeted operations based on climate and demands, with flexible infrastructure. Kaligandaki gorge hydropower is an upcoming peaking run-off-river type station like most of the others installed around Nepal. Fed by river runoff throughout the year, it is more susceptible to impacts of climate change than a reservoir based hydro installation. Based on meteorological data obtained from Lete station near the project site, the precipitation patterns seem to be changing. There is a slight increase of 0.28 mm rainfall around the area measured at Lete station. However the discharge for Kaligandaki river seen from hydrological data obtained from nearest station at Jomsom shows a steep decreasing trend. The temperature projections didn't show any radical departure from current trend. Besides these hydrological and meteorological data, the integrated approach of water resource management presented by analytical tools like WEAP and LEAP can help address many pressing concerns. WEAP can be used to analyze available data on precipitation trends, flow and water availability to allocate available water resources, addressing supply and demand challenges with ecological considerations whereas LEAP can then be used to analyze the production and consumption patterns with emission analysis. Such analytical usage of tools can help show development of hydropower infrastructure like that of Kaligandaki gorge in a sustainable manner.

Keywords

Climate change – ROR – Hydropower – WEAP

1. Introduction

Nepal's electricity generation is dominated by hydropower and most of the hydropower systems installed are based on run-off-river (RoR) type. There are two climatic factors that contribute to increased variability of river runoff: glacier retreat and change in timing and/or intensity of precipitation [1]. Since there is only one seasonal storage project in the Nepal's hydropower system i.e. the Kulekhani HP in Makwanpur district, most of the others are in critical danger from impacts of changing climatic parameters. Already, there is a general shortage of electricity during winter and dangers of spill in wet season. The large seasonal variation in electricity generation in Nepal results in acute power crisis during dry months. Before melting of snow and when there is less rainfall during winter, the discharge level in the river decreases resulting in very less production of electricity. In recent years the installed capacity (689.5 MW) has always failed to fulfill the peak demand that has forced to power shortage of up to 18 hours a day during winter. The year 2009/10 witnessed new records of power and energy demand, generation and import. Annual peak demand recorded during this period was 885.28 MW registering an 8.96% growth from the 812.5 MW of previous year [2].

2. Background

Kaligandaki Gorge Hydropower represents a typical run-off-river type system like most other projects in Nepal. Of the three major river systems in Nepal, kaligandaki forms a large portion of the Gandaki river system. The Kali Gandaki river source is at the Nhubine Himal Glacier in the Mustang region of Nepal at an elevation of 6,268 metres (20,564 ft) [3]. The headwaters stream on some maps is named the Chhuama Khola. It then flows southward through a steep gorge known as the Kali Gandaki Gorge, or Andha Galchi, between the mountains Dhaulagiri, elevation to the west and Annapurna I. Development works of a 252 MW hydropower at this location is currently supported by Hydro solution (P) Ltd.

Table 1: Technical Details of Kaligandaki Gorge HP

Location	Myagdi
Project type	PRoR
Installed capacity	252 MW
Turbine	Pelton, Vertical axis-8
Net head	498.3 m
Catchment area	3570 m3/s
Design discharge	61.66 m3/s
Annual energy	1010 GWh
Overall efficiency	83.4%
Project cost	US$363.99 million
Transmission line	132 kV; 1.5 km long

3. Objectives

The goal of this research project is to assess and recommend measures to negate the impacts of climate change on an upcoming hydropower like Kaligandaki gorge project in Nepal. The specific objectives include::

- Analysis of climatic data to assess effects of climate on water availability.
- Application of WEAP to address water management challenges, allocation of resources with integration of supply-demand and ecological considerations.
- Recommend options to make possible design changes to better accommodate climatic variation on the target hydropower.

4. Methodology

The research design is quantitative and deductive in nature. It will incorporate study of the Kaligandaki gorge hydropower with available data to provide case study for climatic considerations in developing a hydropower.

Literature Review and scope setting: This thesis has taken the river system approach instead of basin approach based on suitable bulk of research and time frame of the thesis period.

Identify the controlling factors: Daily rainfall data of three nearby stations (Jomsom, Lete and Ranipauwa) from 1985 to 2014 was analysed during the study. Secondary data of the rainfall were taken from Department of Hydrology and Metrology (DHM). Optimum number of stations required for the study was based on statistical principal that a certain number of rain gauge stations are necessary to give average rainfall with a certain percentage of error. The optimum number of rainguages (N) was obtained by the following equation:

$$N = \left(\frac{C_v}{E}\right)^2 \tag{1}$$

where, E = allowable percentage error in the estimate of basic mean rainfall
Cv= coefficient of variation of rainfall based on existing raingauge station and it is determined as,

$$C_v = \frac{\sigma}{P_m} \times 100\% \tag{2}$$

The standard deviation is given by:

$$\sigma = \sqrt{\frac{\sum (P_m - P_i)^2}{n-1}} \tag{3}$$

where, P_m = mean average annual rainfall values

$$P_m = \frac{\sum P_i}{n} \tag{4}$$

n = existing number of raingauges

Pi = normal annual rainfalls at existing raingauges

For accuracy in various practical purposes, three stations were taken minimizing the error to 5%.

For temperature analysis the maximum, mean and minimum monthly temperature data recorded at Jomsom for the last 30 years were analysed. Also 17 years' worth of

Table 2: % Error vs Optimum no. of Raingauges

% error (E)	Optimum no. of raingauges (N)
10%	1
5%	3
4%	4

climatological data recorded at Lete stations from 1998 to 2014 was also analyzed during this study.

Discharge data for the past 20 years (1995 to 2014) were analyzed for Kaligandaki river. This was obtained from Jomsom hydrological station. Monthly discharge of the river at intake of the hydropower were provided by Hydrosolutions Pvt. Ltd.

Develop experimental plan: To explore, compare, explain and demonstrate the identified factors WEAP was used to analyse water demands and supply to evaluate water management options taking into account competing uses of water systems.

Result interpretation and recommendation: Results from data analysis and modeling are interpreted in the form of graphs and tables as listed below followed by recommendations.

5. Scope and limitations

The study is carried out at the Kaligandaki gorge HP that lies at northeastern part of Myagdi district in the Western Development Region of Nepal. Scope of work of the proposed study includes following major activities:

- Case study of Kaligandaki River to analyze changes in river flow with respect to physical and socio economic changes affecting design capacity of hydropower plant.
- Collection of secondary data; desk study and analysis of the data.
- Interpretation and analysis of available rainfall and temperature data for interpretation of climate change along with the analysis of water and energy demand using LEAP and WEAP.

Taking into consideration the limitation of resource, time and extent within this thesis work, the limitation for thesis work are:

- Detailed impact assessment wasn't be carried out. The major focus is on temporal variation of rainfall, temperature and discharge, water and energy demand.
- The study is based on the secondary data from the concerned agency, the validation of the data depends on the organizational competence
- Budgetary and time constrains to conduct an in-depth study.

6. Results

6.1 Data analysis

6.1.1 Precipitation

Nepal receives nearly 80% of annual precipitation during the months of June-September in most locations [4]. Distribution of rainfall around the Kaligandaki gorge hydropower project area is not uniform either. Elevation as well as exposition of mountains within the area plays major roles for uneven rainfall distribution. The 30 years of daily data available (1985-2014) for the area near the project site shows that 62% of rainfall occurs in monsoon with 25% in pre-monsoon followed by 8% and 5% in post-monsoon and winter respectively.

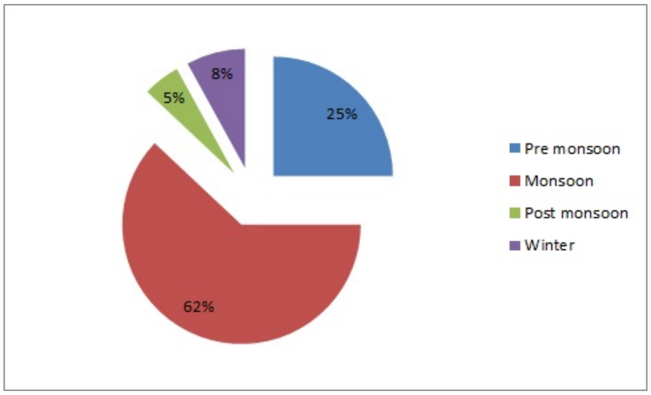

Figure 1: Seasonal rainfall distribution at Lete (1985-2014)

In a PRoR project like Kaligandaki gorge project, electricity generation will vary as per precipitation patterns, which means dry seasons may require a substitute source for the demands to be met.In a reservoir based hydropower station like Kulekhani however, usage of water accumulated during monsoon can accomodate for electricity generation throughout the year. As illustrated by the graph belo, precipitation around the project area peaks up from June to August and is highest during July. Winter months beginning from November and ending in January receives the lowest amount of precipitaion.

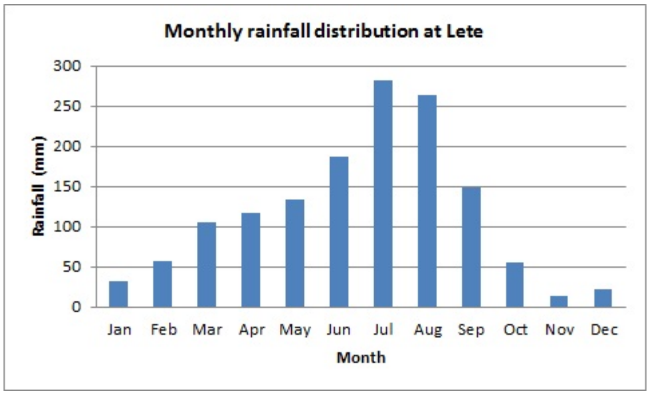

Figure 2: Monthly rainfall distribution at Lete (1985-2014)

The monsoon normally starts in the second week of June and continues until the fourth week of September. Monsoon is the main source of rainfall in the project site similar to other regions of Nepal. The large amount of rainfall within a short period causes flash floods, landslides, soil erosion and sedimentation in hilly and mountainous regions, and inundation of the plains areas [5]

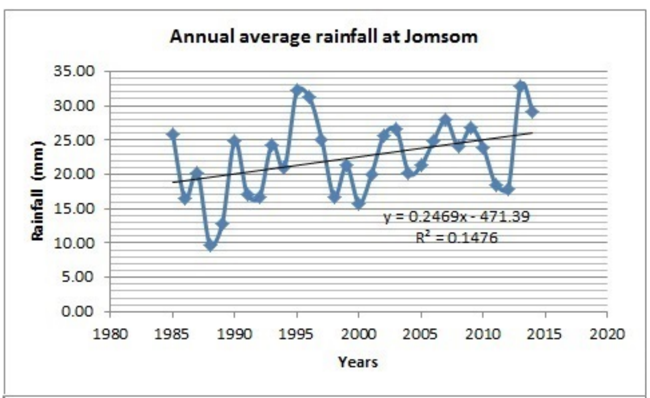

Figure 3: Annual average rainfall trend at Jomsom (1985-2014)

There is no significant change in annual precipitation in Nepal [6]. This study shows that the annual average rainfall around the Kaligandaki project site is increasing at a slight rate of about 0.246 mm and 0.284 mm measured at Jomsom and Lete stations respectively as shown in the plot below. This concurs with slight increase in precipitation rate as seen in study based on data from Andhi Ghat Station, Mustang [5].

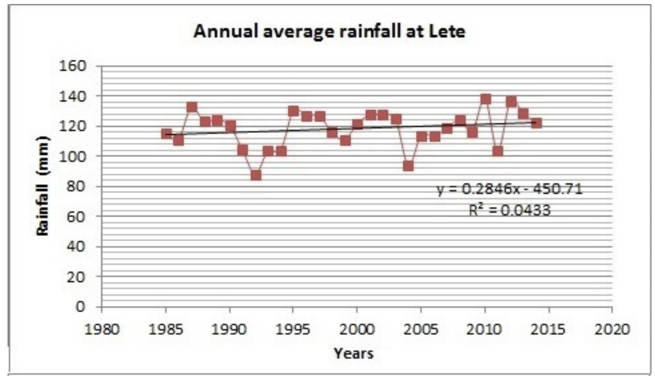

Figure 4: Annual average rainfall trend at Lete (1985-2014)

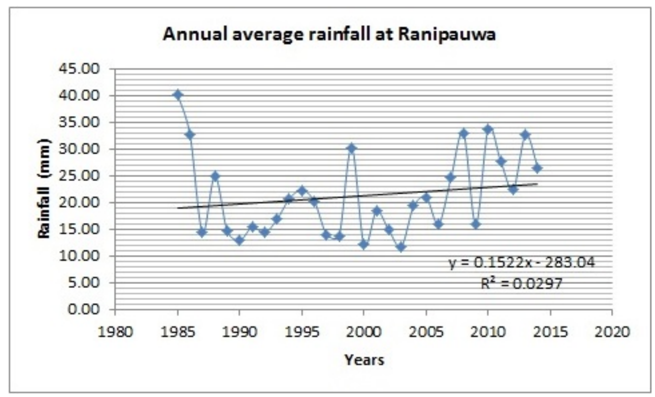

Figure 5: Annual average rainfall trend at Ranipauwa (1985-2014)

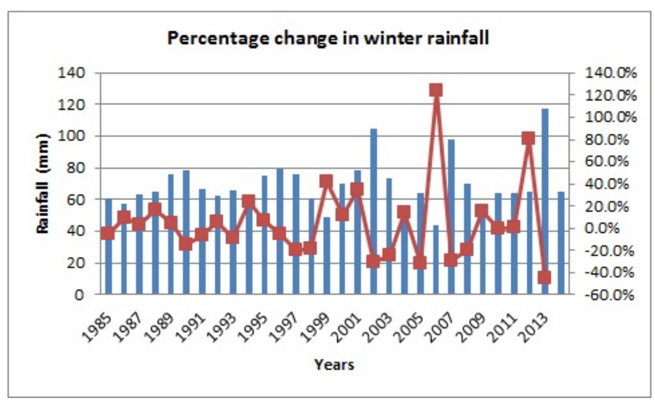

Figure 6: Percentage change in winter rainfall at Lete (1985-2014)

Winter average annual rainfall distribution shows a slight increasing trend in recent years. This trend has continued in pre-monsoon and monsoon which provides for the annual increase in rainfall as mentioned earlier. There is an slight decrease in post monsoon rainfall.

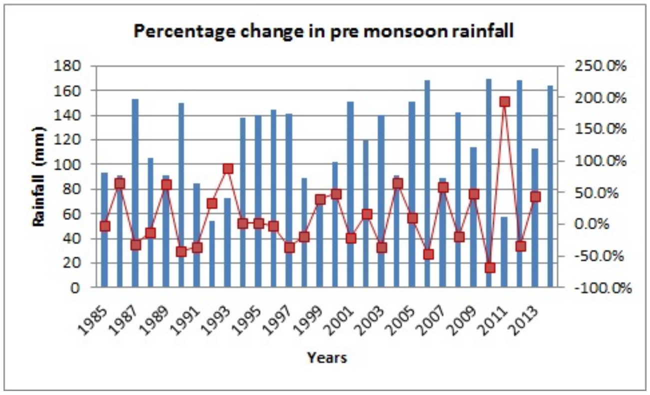

Figure 7: Percentage change in pre monsoon rainfall at Lete (1985-2014)

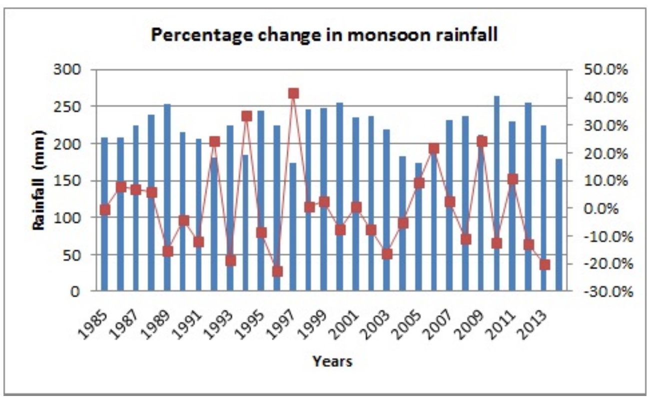

Figure 8: Percentage change in monsoon rainfall at Lete (1985-2014)

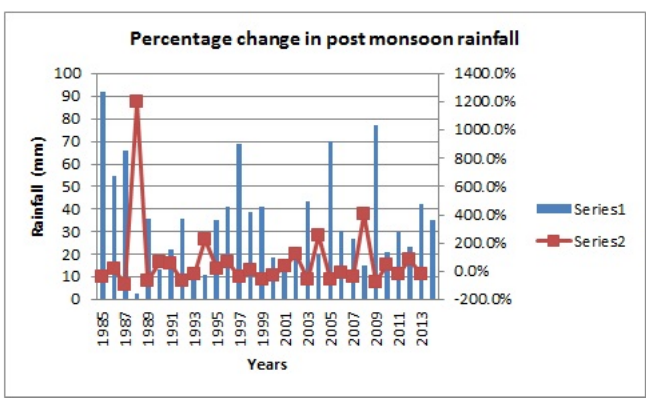

Figure 9: Percentage change in post monsoon rainfall at Lete (1985-2014)

6.1.2 Temperature

Annual temperature in Nepal is reported to be increasing and the impacts of warming have already been observed in the Himalayan glaciers [7]. Annual mean temperature in Nepal has increased steadily at a linear rate of 0.4C per decade from 1975 to 2005 [6]. Data collected from Jomsom meteorological station for 1985 to 2014 shows an increment in annual maximum, minimum and mean temperatures.

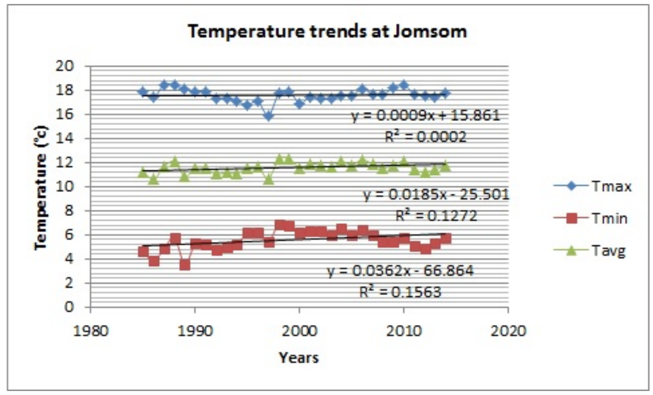

Figure 10: Annual temperature trend at Jomsom (1985-2014)

6.1.3 Discharge

Analysis of the available data from 1995 to 2013 shows that the average flow of 86 m3/s in 1995 has gradually decreased to 18.4 m3/s coming into 2014.

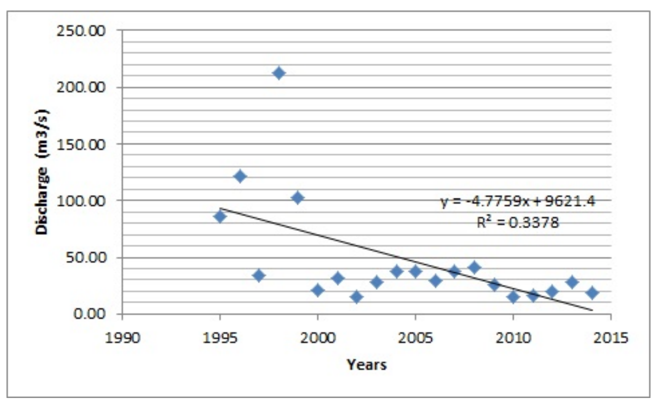

Figure 11: Annual average discharge of Kaligandaki river at Jomsom (1985-2014)

Analyzing the yearly mean flow, 1998 was the maximum with a mean average flow of 213 m3/s and 2002 was the minimum with 15.1 m3/s. Though precipitation data shows slight increase in rainfall, the decrease in discharge may be credited to decrement of melt from glacier.

Monthly discharge measured at the intake of the planned hydropower shows increase in discharge during the monsoon i.e. July and August [8]. Annual average flow seen at intake is around 40 m3/s which concurs relatively with the data obtained from DHM.

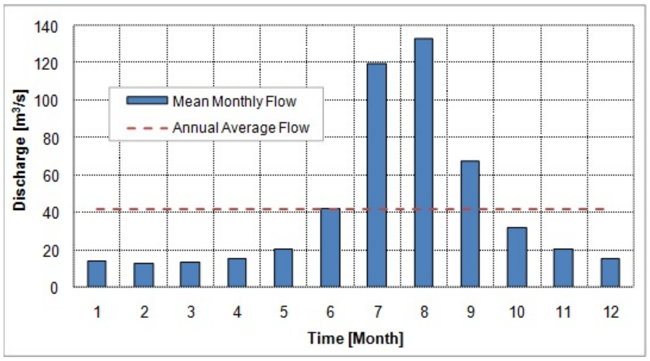

Figure 12: Monthly discharge measured at intake (2001-2007)

6.2 Modelling - WEAP

Table 3: Key Parameters

Per capita annual water use	890 m3 [9]
Unit domestic water use	30.527 m3 (3.43%) [9]
Unit irrigation water use	854.4 m3 (96.16%) [9]
Domestic variation	0.9 for Jan, Feb and Dec 1.0 for Mar, Apr, May, Sep, Oct 1.1 for Jun 1.15 for Jul and Aug
Monthly irrigation variation	0 for Jan, Feb, Mar, Oct, Nov and Dec 5 for Apr 10 for May and Jun 20 for Jul 30 for Aug
Irrigated land in Mustang	0.233ha/household [10]
No. of households	Lete - 189 [8] Kunjo - 147 [8] Narchyang - 421 [8] Dana - 398 [8]
Irrigated land area	Lete - 44 ha [8] Kunjo - 34.2 ha [8] Narchyang - 98.1 ha [8] Dana - 92.7 ha [8]

The zone of impact of the Kaligandaki Gorge hydropower includes 4 VDCs of Mustang: Lete, Kunjo, Dana and Narchyang. Water usage in the area is mainly dominated by agricultural and domestic purposes. There is also consumption in commercial sector but due to unavailability of exact figures, we have only taken the first two sectors as competing for water usage.

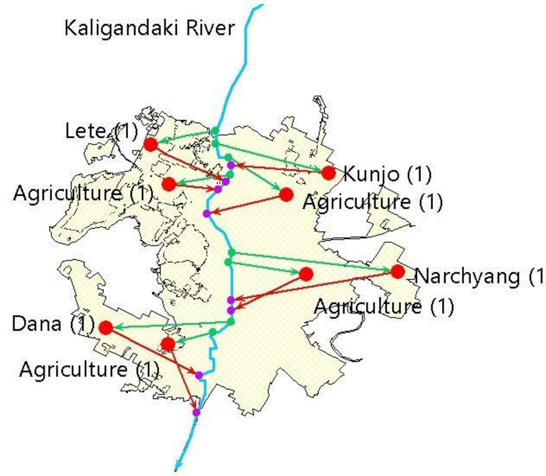

Figure 13: Schematic of demands at various VDCs within the zone of impact

Modeling results

Table 4: Water Demand (not including loss, reuse and DSM) (Cubic Meter)

Competing sectors	2034 demands
Irrigation total	229934.42 m3
Lete - Domestic	27901.68 m3
Kunjo - Domestic	20392.04 m3
Dana - Domestic	54551.75 m3
Narchyang - Domestic	53788.57 m3

All Branches, Scenario: Reference, Annual Total, Branch: Demand Sites

7. Conclusion

Change in hydrology of rivers is seen as a major impact of climate change resulting in anomalies in hydro resources which could be critical to important infrastructures like hydropower. Climate change affects the dependability of hydro resources and hence the changing climatic parameters is an unavoidable factor in the forecasting system of hydropower projects. Some generalizations drawn for the study area are as follows:

- An increasing trend of temperature is seen around the study area.
- Though there is a general increasing trend in precipitation, shift of the rain fall seasons can increase the hydrological impacts and challenges.

- Kaligandaki gorge HP being run of river type system is highly susceptible to dry seasons water scarcity. The flow curve of the analyzed period and rivers shows the flow is decreasing, not in a pattern. This will result in the decrease in the full capacity power generation of the plant.

8. Recommendation

Integration of climate change impact assessment in hydropower planning is imperative for the effective planning and management of the power systems in our country. The following are the some recommendations for hydropower planners, policy makers, and other concerned agencies for coping with climate change and planning accordingly for the management of the ongoing power crisis:

- The rainfall distribution around the region is very uneven and basin has insufficient rain-gauge network, discharge and rainfall recording network should be increased for intensity data that are most essential for hydrologic models and other detail hydrological study.
- Since the data analysis shows that hydrology is changing, the design capacity of the hydro system should be revised. In the long run, sufficient water may not be available; water storage in damp should be a good method to control the flow of the river.
- Only a basic modeling has been done during this project. Creation of scenarios is a potential analytical tool to predict and assess the optimization needs of subsequent demand increment as seen from demand forecasts.

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