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Optimization of Sediment Management Measures for Andhikhola Storage Project Using RESCON-2 Model

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Abstract
Reservoir has multiple advantages and it's sustainability is important to meet the future water demand. Sedimentation in reservoir has challenged reservoir sustainability. Sediment inflow and the type of sediment management measure plays important role in the life of reservoir. RESCON 2 model is widely used tool for optimizing sediment management strategies in any Reservoir. Sediment measurement in a river is challenging task and it require both cost, time and qualified manpower. Very often sediment measurement data are not available at the planning stage of the project. So, sediment inflow is estimated using different empirical or semi-empirical formulas. This article focusses on the evaluation of sediment yield using BQART model and Optimization of sediment management strategy for Andhikhola Storage Project (AKSP). The model output shows No action will be economic method, as there is no any cost of implementation of this method but the aggregate Net Present Value of Benefit is higher with this method among other alternatives.

Keywords
Reservoir Sedimentation, Sediment Yield, Sustainability

1. Introduction

In Nepal, Water Resources are important. Nepal has a lot of potential for hydropower. The main source of energy in the nation is hydroelectricity. Nepal has a century long history of hydropower development; however, it has nor progressed at the required rate or level of availability. As of now, there is only 2190 MW of installed capacity [1], which is filled by a variety of ROR, PROR and Storage project as well as some imports from India from during the dry season. The Nepali Government has identified hydropower as a key industry for the ensuing decades and has proposes to carry out a number of storage projects there. Major projects being studied by the government of Nepal include Dudhkoshi (635MW), Upper Arun (1060 MW), UtterGanga (828MW), AndhiKhola Storage Hydroelectric Project (180MW), Kimathanka Arun Hydroelectric project (450 MW), Nalgad Hydroelectric Project (410 MW).

The Nepal Electricity Authority has looked at the Andhikhola Storage Project (180 MW) (AKSP) Project. The AKSP is a seasonal storage facility that stores water during the monsoon and produce electricity in the dry season. The reservoir will becomes completely entrained with sediment causing storage loss. Problems caused by reservoir sedimentation include loss of storage, damage to turbines, reduction in reservoir and hydropower life span, loss of generation, loss of flood control and changes in river morphology both upstream and downstream of the dam. Therefore, a study on sediment control must be done for the storage project. In order to manage sediment sustainably in the AKSP, this research aims to evaluate sediment management options and optimize sediment management practices.

2. Problem Statement

Aside form hydropower generating, reservoirs have benefits including irrigation, flood control, navigation and water supply. Water production and water variability have changed as a result of climate change. Unplanned construction projects, Nepal's fragile geology, sedimentation issues in its rivers all contribute to the production of a lot of sediment. Experience form the Kulekhani Hydropower project indicates that sediment control and the viability of

storage projects are the key challenges facing both existing and green reservoirs. Any reservoirs economic life will be significantly impacted by reservoir sedimentation. The majority of sediment is carried during monsoon season in Nepal because to its lithological make-up and undulating terrain [2, 3, 4]. Nepal has a significant sediment load because of its young mountatins, active geology and strong seasonal rainfall. The breath and impact of the sediment problem present, hence it is essential to optimize sediment management strategies while constructing projects in Nepalese rivers. Specialized instruments and strategies for controlling silt are required to extend the life of the reservoir and maximize its advantages. To find the best method for treating reservoir sedimentation, RESCON 2 will be a crucial tool. Watershed management can be a valuable strategy to prevent erosion and sediment from anthropogenic factors, according to [5] Kaligandaki Basin will suffer sediment problems to a greater extent. The financials of the Andhikhola Storage project in the Kaligandaki Basin will be impacted by the decrease in active storage, the shortening of the reservoir's life, generation loss, and an increase in operating and maintenance costs. In order to lessen these effects, the Andhikhola Reservoir must identify and implement the appropriate adoption measures. Using the RESCON 2 model, this study aims to pinpoint the best sediment management strategies for the AKSP.

3. Objective of the Study

Optimizing technically and economically feasible sediment handling and management technique in Andhikhola Storage hydropower Project using RESCON 2 Beta is objective of study. Other specific objective of study is listed below:

- To understand RESCON 2 Model and its Working Principle and Governing Equations.
- To evaluate optimal sediment management technique and sediment handling measure for Andhikhola Storage Project.

4. Methodology

Reservoirs have significant issues managing sediment. Depending on the kind of sediment and characteristics of the river system, several approached are now used. Sediment handling is cost related in addition to being dependent on the technical factors. In order to get better results it is necessary to identify or apply the best sediment handling procedures. This study uses various hydrological, sedimentary, and economic data to simulate the Andhikhola Storage Project Reservoir in RESCON 2. For the Andhikhola Storage Hydroelectric project, Nepal Electricity Authority (NEA) collected the reservoirs hydrology and geometry data. The world Bank (WB) and the RESCON 2 user manual will be utilized to provide the environment safe guard data.

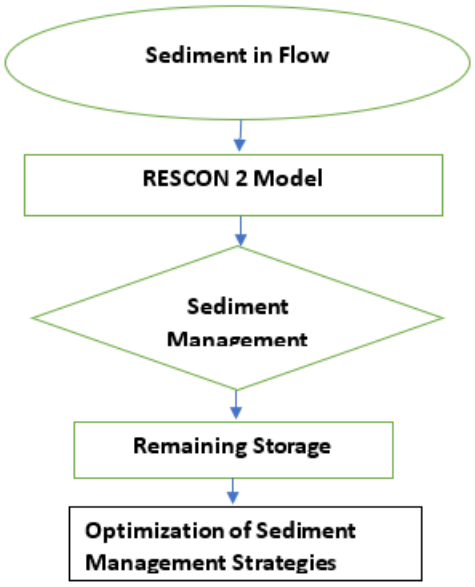

Figure 1: Methodological Framework

5. RESCON 2 Model

Sediment management is challenge for the sustainable use of reservoir for long run, eyeing this issue and considering sustainability of reservoir World Bank Initiated RESCON (Reservoir Conservation) for assessment and promotion of reservoir in December 1999, [6]. It is excel based useful for Prefeasibility study of reservoir. Latest version in RESCON 2 Beta, with improved calculation capacity, User interface and additional methods of sediment handling. Since 2001, RESCON project has been widely used in Kenya, Sri lanka Morocco, presently the focus has started Reservoir of counties like India, Pakistan, Switzerland, Japan [7]. RESCON identifies best solution considering their Net Present Value (NPV), Long term reservoir capacity and reservoir life.

RESCON 2 Model evaluate optimal solution among following different methods suggested by RESCON 2 Model. These methods are listed in Table 1.

Table 1: Sediment Management Strategies in RESCON 2 Model

Sediment Management Alternative	Description	Remarks
No Action	No any sediment management practice implemented.	
Catchment Management	Sediment inflow into reservoir is controlled	
Sluicing	Increases flow Velocity, Volume of reservoir reduced during Flood.	Sediment Routing
Sediment By Pass	Diverted sediment laden flow, before it comes to reservoir	Sediment Routing
Density Current Venting	Turbidity transported in reservoir by means of density currents	Sediment Routing
Flushing	Removal of Sediment form reservoir by increasing the flow velocity in the reservoir.	Removal of Sediment
HSRS	Hydrostatic Head at the dam will supply Energy for dragging	Removal of Sediment
Dredging	Pumping water entrained sediment from Reservoir	Removal of Sediment
Trucking	Heavy equipment deployed for sediment removal from drained reservoir.	Removal of Sediment

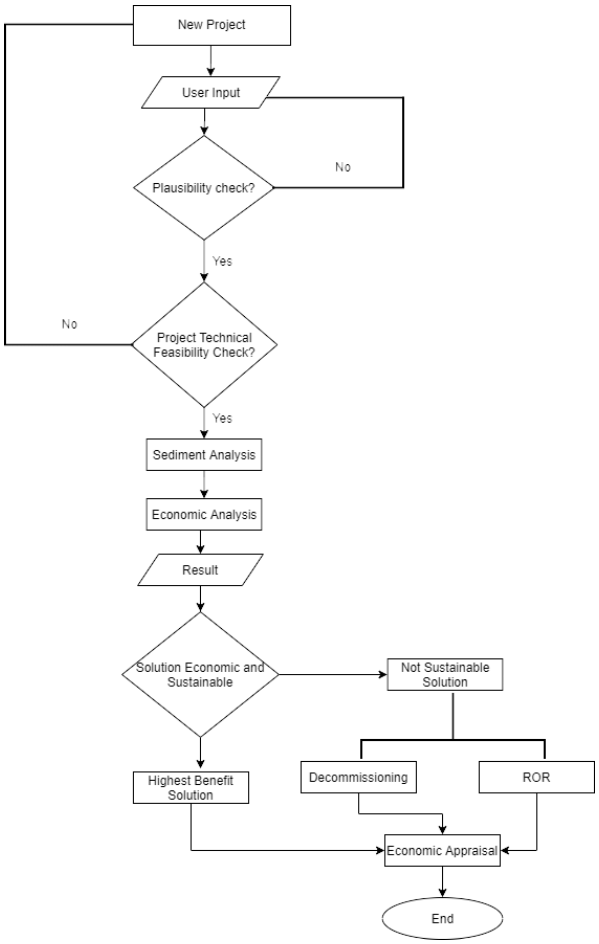

Figure 2: RESCON 2 Model Flowchart

6. Study Area

Andhikhola Storage Hydroelectric Project is located about 300 km west of Kathmandu in Syangja district of Gandaki Province of Nepal. The project area lies in the Midlands of the Lesser Himalaya in the western Nepal. The dam site is located at downhill of Motichaur village, on Andhikhola gorge at about 2.7 km upstream of its confluence with Kali Gandaki River. The Installed Capacity was fixed at 180 MW. The gross head for this project is 328.6m. the Reservoir is about 21.7 Km in length with a total storage volume of 401 MCM of which 341MCM is live storage volume. The total catchment area of AKSP is 472 Sq.Km. which ranges form 543m to 2473m.

Figure 3: Study Area

Estimation of Sediment Yield: Estimation of sediment transported by river are important for evaluating the impacts of Reservoir Sedimentation and to adopt different sediment management measures [8]. Sediment Yield refers to amount of sediment exported by a basin over a period which will enter into reservoir located downstream [9]. For Estimation of sediment yield RESCON 2 model has inbuilt tool as BQART model to calculate sediment load. It a quick assessment tool in case of limited data. This model consider Basin Properties, Basin Lithology, Basin area, Basin relief and Basin temperature, Runoff and Ice Cover.

$$Qs = wBQ^0.31A^0.5RT\ for T >= 2oC \quad (1)$$

$$Qs = 2wBQ^0.31A^0.5R for T < 2oC \quad (2)$$

Where,

Qs =Sediment Load [M/T]

w : constant for sediment load unit (0.02 for units of kg/s, or 0.0006 MT/yr)

Q = Mean annual water Flow (km3 /yr.)

A= Basin Area km2

R = Maximum Relief of drainage Basin (km)

T= Basin average Temperature (oC)

B = Term for Geological condition in basin

BQART Model estimates annual Sediment inflow to AKSP Catchment equal to 0.62 Million ton / Year. There are many parameters for RESCON 2 Model. The Basic input parameters are Reservoir Data and Hydrologic Data. In this section the key data are Storage capacity (live and Dead Storage), Bed elevation and Pool Elevation. Similarly, Sediment input are key input parameter for RESCON 2 Model. These sediment data include sediment type, Character and Quantity of sediment data. Economic data are also major input parameter. These data include unit cost of construction, Discount rate, unit value of Reservoir Yield, Financial analysis period. Sediment management techniques and their parameters include allowable loss, Year of Implementation, frequency of events. Environment and Social Safeguard data are other important parameters in RESCON 2 Model. For Hydrological, Sediment data, Economic data sources of these data were Feasibility Study Report of Andhikhola Storage Hydroelectric project. For sediment management techniques and their parameter user manual of RESCON 2 model are major sources. Climate change data were considered as default values. For RECON 2 model for AKSP. The mean annual reservoir water inflow for AKSP is 1019 million m3 /a. the Coefficient of variation of annual run of volume for AKSP is 0.16 and the representative temperature in AKSP Reservoir is 20 °C. Bed load responsible for reservoir sedimentation is taken as 15 percent of total sediment load incoming in the reservoir. It is assumed only during 5 percent of time this percentage of bed load will be transported in the reservoir. Different sediment management measure was evaluated during this study. The total cost of Reservoir impounding in US dollar 281,000,000. The model was evaluated at 6 Percent discount rate and market interest rate was taken as 8Percent. The annual operation and maintenance costs is US dollar 4,215,000 per Year.

7. Result

Output from Model run shows all the method No action, Catchment management, Sluicing, By pass, Density Current Venting, Dredging, Sluicing, Trucking and Flushing will provide sustainable solution. Further No action will yielding highest aggregate Net Benefit of US dollar 1,684,810,081.00 The lifetime of the reservoir will be more than 300 Year. The Long term reservoir gross storage capacity will be 239.921 MCM. Summary of Different method is shown in Table 2 below:

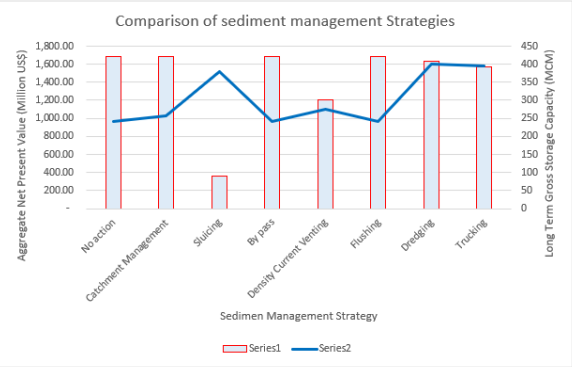

Figure 4: Comparison of Sediment Management Strategies

HSRS method of sediment management is not technically feasible because the fundamental criteria of HSRS to be sustainable, for this the length of reservoir has to be with in 5Km, but in case of AKSP length of Reservoir is 21.7Km.

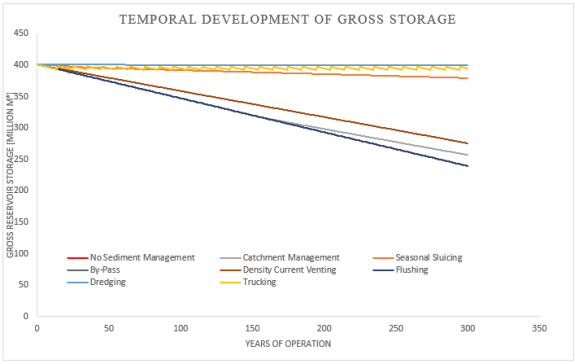

Figure 5: Temporal Development of Gross Storage

The gross storage decreases with time for Flushing, Catchment management, and Density Current till 300 year of operation. While applying methods like Dredging, Seasonal Sluicing, Sediment By pass and Trucking the gross storage capacity can be maintained about 379 MCM from initial 401 MCM even after three hundred years of operation.

Table 2: Summary of Model Output

Sediment Management Strategy	Aggregate Net Present Value (USD)	Long term Reservoir Gross Storage Capacity (MCM)
No action	1,684,810,080.55	239.921
Catchment Management	1,684,806,273.19	257.273
Sluicing	356,811,772.95	379.204
By pass	1,684,810,079.03	240.15
Density Current Venting	1,201,742,573.61	276.018
Flushing	1,684,810,080.55	239.921
Dredging	1,635,265,336.71	399.71
Trucking	1,565,610,844.17	394.88

8. Conclusion and Recommendation

Conclusion

The Gross storage of reservoir decline with time as the sediment inflow in the reservoir goes up. So sustainability is a major challenge. For the optimization of sediment management strategies in AKSP with sediment inflow of 0.62 Million ton per year. No action was found to have higher net aggregate Present Benefit, among different method employed. All the strategies are technically and financially viable for sustainable sediment management in AKSP, although HSRS and Sediment By pass have technical limitation, which indicates the reservoir length limited to 5Km.

Recommendation

Sediment inflow in any reservoir plays important role in the reservoir sedimentation and hence sediment management strategies need to be evaluated on the basis of sediment inflow, so sediment inflow estimation in the reservoir need to be taken special care. RESCON 2 is in development phase with large number of input parameter, some of these parameters are taken as default parameter but in actual case these parameters significantly vary with geological setting and Hydrological and sediment inflow. Climate change scenarios are not taken into consideration during this study, while these are considered there will be drastic change in the results obtained.

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