



# **Numerical modelling tools for sediment management in PROR reservoir of Kabeli A Hydroelectric Project (Nepal)**

**Diwash Lal Maskey and Dr. Nils Ruther**

## **Abstract**

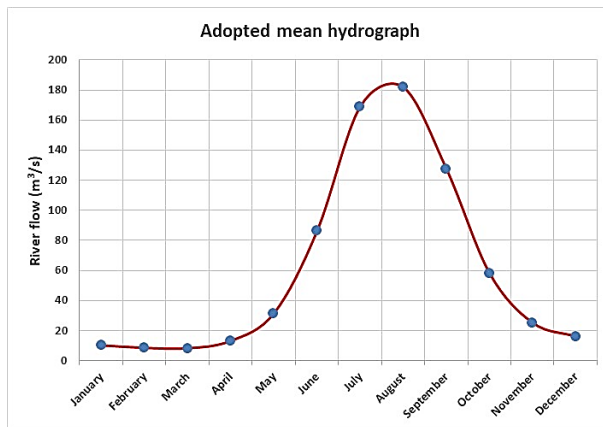
Physical hydraulic modelling tests were conducted to optimize the hydraulic design of headworks structures of Kabeli A Hydroelectric Project in Nepal. The model tests included the determination of capacity of the barrage gates, study of sediment deposition pattern in the reservoir, flushing efficiency study of the reservoir, use of diversion tunnel for bypassing bed load, bed load deposition in front of the intake and efficiency of the stilling basin for energy dissipation. The test finalized the design of the headworks for the optimum operation of the peaking reservoir, sediment management strategies and sizes of the structure from hydraulic point of view. A 1D (HEC-RAS) modelling was performed for the sediment flushing studies of the project and a 3D (SSIIM) modelling study was conducted to estimate the sediment fluxes passing through the intake. The results of the numerical model study are compared with the physical model test in determining the use of these models as a tool for decision making in similar projects for sediment management and optimization.

Keywords: sediment management, reservoir flushing, bypass tunnel, HEC-RAS, SSIIM

## **1 The project**

Kabeli A Hydroelectric Project (KAHEP) is a Peaking Run-of-River hydropower project being constructed in the Eastern part of Nepal. The project utilizes the river discharge of Kabeli River, one of the tributaries of the Tamor River. The capacity of the project is 37.6MW with 6 hours of peaking during the dry season obtained utilizing a head of 111.6m and discharge of 37.7 m<sup>3</sup>/s. The total storage volume of the reservoir is estimated to be 0.66 million cubic metres out of which 0.334 million cubic metres will be utilized as live storage for peaking purposes.

The catchment area at the intake is about 862 km<sup>2</sup> with the elevation ranging from 550 masl to 5500 masl. The average annual precipitation is 2135mm and average annual flow at the intake site is 61.4 m<sup>3</sup>/s. The adopted mean monthly hydrograph is presented in Figure 1 and the estimated flood values are presented in Table 1.



**Figure 1: Monthly hydrograph (KAHEP)**

**Table 1: Estimated flood values**

Return period (yr.)	Flow (m³/s)
1	133
2	710
5	1004
10	1210
20	1417
100	1920

The river at the location is fairly straight with an average width of about 60m within the reservoir stretch. The river is moderately steep with a slope of 1% with the bed composed of gravels and sand. The banks of river contain large boulder measuring more than 1m in dimension.

Measurement of the suspended sediments have been performed in the river revealing high sediment concentrations during the monsoon flow. The results of concentration measurements are around 4000ppm with a record of 8500ppm at one instance. The mineralogical investigation shows high percentage of Quartz and Feldspar totaling around 60% of the volume.

## 2 Physical hydraulic modelling

Physical hydraulic modelling tests of the headworks were conducted at Hydro Lab Private Limited in Kathmandu, Nepal. The objectives of the tests were to determine the capacity of the flood gates, study the flow pattern around the intake, conduct deposition and flushing tests of the reservoir, optimize the component size and assist in preparation of reservoir operation rules.

The tests were performed in the river model with the geometric scale ratio of 1:50. The model study helped in finalizing the layout of the headworks component. The tests resulted in modification of the stilling basin for efficient energy dissipation. The alignment and sizes of the intake openings were finalized for smooth flow. The transition for the settling basin was finalized. The tests also verified the capacity of the gates to safely pass the floods and sediment d/s of the barrage.

Similarly, the study of the reservoir sedimentation and flushing verified the operation of the reservoir at two levels for preserving the live storage volume. The study recommended drawdown flushing through the barrage gates as the best solution for passing sediments down of the barrage. In the study, the use of diversion tunnel as a sediment bypass tunnel was also investigated. The intention of the study was to use the diversion tunnel to pass the deposited sediment d/s of the barrage. In doing so, the reservoir will be operated at higher elevation only and will eliminate the need of additional settling basin. The inlet of

the diversion tunnel was very close to the barrage which led for lowering of the water level in the barrage to pass deposited sediment into the bypass tunnel. Shifting of tunnel inlet further upstream of the reservoir was not investigated for the reasons of increased cost for long tunnel. Similarly, the question of tunnel erosion, maintenance cost and efficiency of the river as settling basin did not have clear answer. For a low design discharge of  $37.7\text{m}^3/\text{s}$ , a more conventional headworks with settling basin was preferred. This system is more practiced in Nepal with the project owners having good experience of operation.

### 3 HEC-RAS modelling

1D modelling in HEC-RAS was performed to investigate its application on sediment deposition and erosion in a reservoir of KAHEP by comparing with the results of physical hydraulic modelling. HEC-RAS is chosen for being free and easy to run.

The river geometry was built in the model with the cross section of the river at 20m interval. The discharge.

The simulation is performed for sedimentation and flushing with the average monsoon flow and minor flood flows data as mentioned in Figure 1 and Table 1. The details regarding the time for deposition and flushing are presented in Table 2. The major flood events are not simulated, since during large floods, the recommendations from the physical hydraulic modelling tests is to stop the power plant and operate the reservoir in flushing mode.

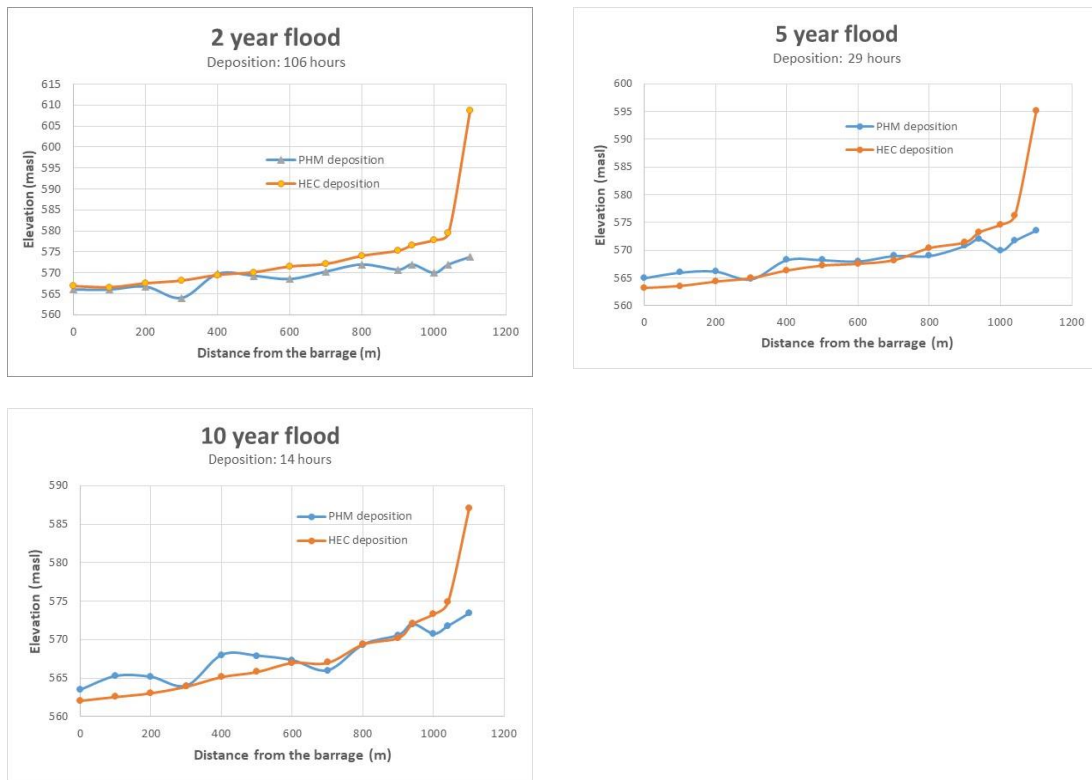
**Table 2: Discharge and sediment data for HEC-RAS simulation**

S. No.	Discharge ( $\text{m}^3/\text{s}$ )	Time for deposition (hr)	Time for flushing (hr)	Total Sediment load (tonnes/day)
1	133 (average monsoon)	1128	10	18,690
2	710 (2 yr flood)	106	10	612,370
3	1004 (5 yr flood)	29	10	1,261,353
4	1210 (10 yr flood)	15	10	1,861,254

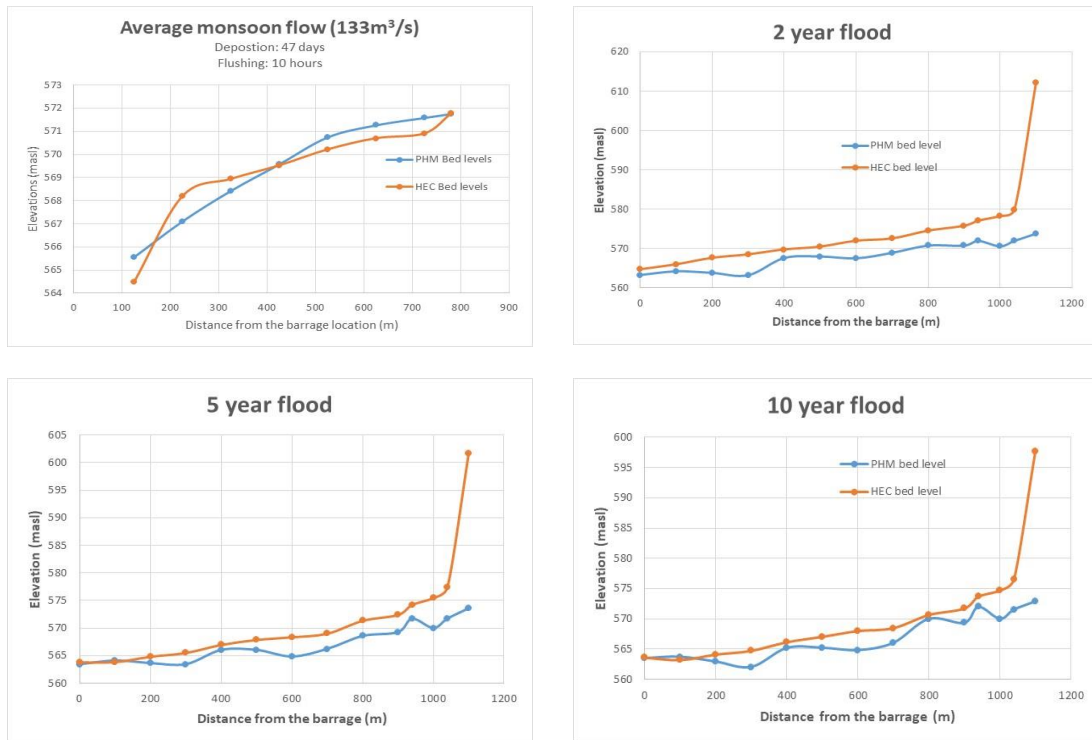
In the total sediment load, the suspended sediment constitutes 70% by volume.

#### 3.1 Results

The results of the simulation are presented in the Figure 2 and Figure 3.



**Figure 2: Comparison of deposition between physical hydraulic modelling tests and HEC-RAS simulations**



**Figure 3: Comparison of bed levels after 10 hours of flushing**

The bed levels after deposition and flushing from HEC-RAS are reasonably comparable with the results of physical hydraulic modelling. However, very high depositions are obtained at the beginning of the river for HEC-RAS. The reason could be the high bed load immediately entering the system.

It has to be noted that the results from the 1D modelling are compared with a physical hydraulic modelling study, and hence the spatial movement of the water in the later study cannot be neglected.

The results can be checked with different bed load transport formula, time step for calculations, including additional geometrical data upstream. The sensitivity analyses could verify the high deposition obtained at the initial sections.

#### **4 Conclusion**

1D HEC-RAS modelling for sediment transport study have been performed by different investigators or researchers all around the world with a mixed conclusion of its reliability. The numerical simulations for the reservoir of KAHEP performed here gives reasonable results compared to the physical hydraulic model studies. It can be concluded that 1D HEC-RAS modeling for sediment transport can be performed to get acquainted with the sedimentation and erosion processes in a narrow reservoir and also the model can be adopted during the physical hydraulic modelling studies to expedite the simulation works.

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#### **Authors (Text style: Authors Address)**

Diwash Lal Maskey (corresponding Author)

Dr. Nils Ruther

Department of Civil and Environmental Engineering, Norwegian University of Science  
and Technology (NTNU), Norway  
Email: [diwash.lal.maskey@ntnu.no](mailto:diwash.lal.maskey@ntnu.no)