Flood Mitigation and Land Reclamation in Hilly Rivers: A Case Study of Toorsa River, Bhutan

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Abstract

The rivers flowing in hilly terrain are generally flashy in nature and most often achieve supercritical flow. These rivers after emerging from the foot hills behave completely differently. The flow velocity gets reduced, the meandering sets in and spreading occurs. This reduction in speed reduces the carrying capacity of the flow. Accordingly, the river bed in the immediate proximity of the hilly terrain becomes a 'fill' area, where all the 'debris' carried by the high velocities gets deposited. These deposits alter the flow regime and make the river to meander. Meandering flow makes the river change its course and cause erosion of the banks.

Erosion control in such rivers becomes a challenging task for the engineers. With the advanced Numerical modelling tools, although, river flow could be accurately replicated, defining a suitable engineering solution still remains a challenge. However, a combination of numerical simulations and sound engineering judgment can be worked out in order to make the solution feasible and applicable to real life conditions.

In this regard, a case study of the feasibility of flood mitigation and land reclamation of River Toorsa in Bhutan offers an excellent example. The Toorsa River is the main river of the Amo Chhu River system, which forms the westernmost river basin of Bhutan. . The Amo Chhu system has its origin in China and flows through the western districts of Ha and Samstse before finally draining into the plains of India. Typical of the majority of the rivers of Bhutan, the Toorsa River profile changes rapidly from a steep slope with a well defined course in the valley, to a flat alluvial plain along the western periphery of the city of Phuentsholing. The city of Phuentsholing is located at a geographically and commercially important point along the Indo-Bhutan border and is the "gateway" to Bhutan. Due to increasing population and limited area, the city is facing serious shortage of land for development. The uncontrolled river has already eroded vast land in the western part of the city. Over the years, the river has also changed its course several times causing serious problems of erosion. It has been roughly assessed that about 4 square kilometers of very high value land has been lost on the left bank of the river, placing severe constraints on the development of Phuentsholing.

The study area was found to be much more complicated than anticipated due to the fact that, in addition to the sedimentation caused by the main river, the adjoining watershed brought in lots of sediments through steep tributaries and deposited in the river bed. Such deposits, elevated the river bed locally, thereby changing the river flow pattern.

The key to finding the solution was hinged on proper understanding of the problem. It was recognized that the reduction of the flow momentum is the main cause of reduction of the carrying capacity of the flow and therefore, it was necessary to design a self flushing flow channel, which would prevent sedimentation in the area. In other words, the spreading of the flow was required to be canalized in to a well defined flow path, maintaining the flow momentum good for carrying the bed load down stream. Accordingly, the flow velocities under the maximum flow (when the carrying capacity is maximum) was maintained at a value, which would not only allow flushing of the sediment carried from upstream, but also stop eroding the bed, beyond permissible limits. In this regard, the minimum cross section area in the study was identified and the new section was designed to conform to this cross section. One dimensional and two dimensional flow modeling tools were deployed to

calculate and illustrate the flow patterns and velocity profiles for a series of alternative design scenarios. Long term simulations were carried out in order to evaluate the flow regime and the phenomenon of meandering. It was concluded that, such solutions of creating an artificial self maintaining flow channel is possible and with suitable engineering design it is feasible to arrest deposition of the sediments to an appreciable degree. The flows from the other catchments were treated separately.

It was noted that, design of such a controlled flow channel would result in reclaiming 4.1 square kilometers of land in addition to protecting the threatened Phuentsholing City. The land could be utilized by the city for expansion and development of the city. The engineering and construction of such a scheme involves considerable finances which are beyond the scope and capacity of the City authorities. Accordingly, it is necessary to find out a self financing scheme, which, not only would take care of the construction cost but also would evolve a mechanism for operation and maintenance. Accordingly, the financial aspects of the project were also analyzed, which indicated that it is financially feasible and sustainable if the proposed river training works are implemented.

Preliminary cost estimates and financial evaluation indicated a healthy return on the investments, which was attractive even for the private entrepreneurs to consider investing.

This paper presents an application of a numerical modelling system to find a solution to a complex real life river control problem. Detailed hydraulic analysis supported by the numerical models carried out in conjunction with economic analysis enabled in an informed decision making in full consultation with the stakeholders.