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HYDRAULIC MODEL STUDIES FOR CHANNELIZATION OF RIVER KOSI FOR A REACH FROM CHATRA TO KOSI BARRAGE USING HOCKEY STICK SHAPE SPUR

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Abstract:- *Channelization of a stream may be undertaken for making it more suitable for navigation and to restrict water to a certain width to reclaim lands for other important purposes. Another reason is to avoid inundation and spread of flood water over large stretches of flood plains, which is also associated with sedimentation and related complications. The river Kosi has been provided with levees along the banks at a width ranging from 6 km to 16 km to avoid notorious shifting of the river. The average bed level in many places has risen by 0.1 to 2 m due to insufficient velocities in the river required to carry the sediment. It is estimated that out of about 187 million tonnes of sediment brought from Himalaya every year by the river Kosi, only about 30% is transported to river Ganga and the rest is settled in the Kosi river belt. Due to heavy inflow of sediment, major reaches of the River Kosi are braided and at several places it is perched also. River engineers are apprehensive of increased attack of the river on the embankments (levees) requiring higher maintenance cost. In view of this, channelization of river Kosi is thought to be one of the methods by which the velocities in the river could be increased, thereby increasing the sediment carrying capacity of the river. This would avoid settlement of sediment in the river course and maintain the regime channel. Physical model studies conducted to investigate the various options for channelizing the stretch of river Kosi from Chatra to Kosi barrage are presented in this paper. For the maximum observed discharge of 15,586 m^3/s, it was seen that the hockey-stick shape spurs guide the flow of water with an average velocity of 3 m/s and helps to form bed regime.*

1. Introduction

Kosi River originates from Tibet and flows in the gorge area of the Himalayas. The river carries huge quantity of sediment, due to high velocity in the gorge area. The sediment carrying capacity of sediment is high; however, when the river flows in plain areas, velocity of flow is reduced drastically and the river gets braided. A braided river consists of a number of small channels separated by small and mostly temporary islands called braid bars. A river becomes braided, if its slope suddenly changes from very high to low and if it carries huge sediment load (Schumm and Khan, 1972).

Several studies related to braided rivers and channelization's of rivers have been reported in the literature. Channelization is done either for making a stream suitable for navigation or for further development of navigation to make possible movement of larger vessels with heavy draughts. Another reason can be to control water to a defined area of a stream's natural lower land so that the mass of such lands can be made available for agriculture. One more reason can be for flood control. Channelization can give a river an adequately large and deep channel to carry ample flow so that flooding beyond these limits can be minimized. One major reason is to decrease natural erosion. The common purposes of river channelization are flood control, creation of new spaces for urbanization or agriculture, maintenance or improvement of navigation, land drainage improvement and reduction of bank erosion. In a meandering river, sand and gravel are generally deposited towards the convex bank of the meander, where the velocity are low, and erosion takes place on the concave side, when the velocity are high due to change in direction. Channelization of a waterway by straightening prevents the water from changing directions randomly, which reduces net erosion (Gray and Harding, 2007).

In this paper, based on model experiments, channelization of river Kosi from Chatra to Kosi barrage about 41 km reach is suggested, using hockey stick shape spur. For channelization of river, initially it is required to fixed the waterway, therefore for various waterway were analyzed by using mathematical model results are as follows

2. Fixation of waterway by using Mathematical model studies

This study was based on 1D mathematical model HEC-RAS 4.1 version to get an idea about hydraulic aspects of channelizing the river and the reach consider is from Chatra to 47 km downstream of barrage (Figure 1).The river Kosi has been provided with levees along the banks, at a width ranging from 6 km to 16 km to minimize further shifting of river. Various channelization widths ranging from 800 m to 2000 m were examined adopting the same bed profile, which showed that the width of 1100 m would minimize the aggradations and degradation of the river for a dominant discharge of 15586 m^3/s.

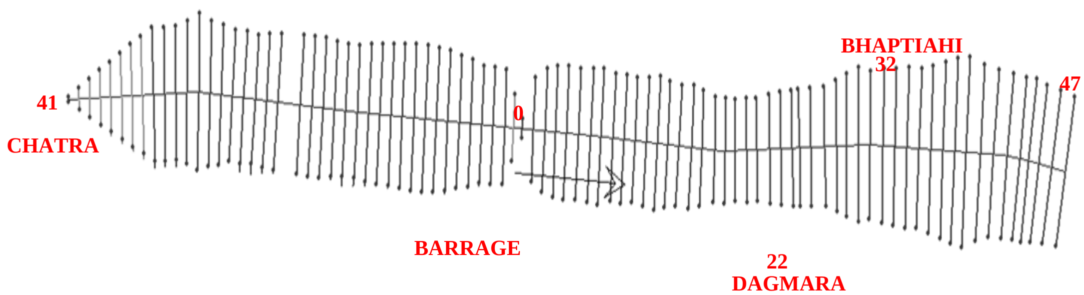


Figure1 Plan showing cross-section

The water way computed using Lacey's formulae $W = 4.83\sqrt{Q}$ (for Q = 26900 m3/s maximum flood) is 800 m. The waterway provided at the Kosi barrage is 1100 m. These two waterway were adopted for computation along with a waterway of 2000 m and without any constriction i.e. river flowing between the existing levees. The aggradation / degradation in the bed profile for various waterway widths are presented in Fig.2.It was observed from Fig. 2 that the river bed is aggraded when the waterway is 2,000 m, and it is degrading when the waterway provided is 800 m, equivalent to Lacey's waterway. However, the river bed degradation is high in the initial year mathematical model run, afterward degradation is minimum when the waterway provided is 1,100 m and a regime channel is formed. The average velocities in the river without any constriction is about 1.5 m/s. However the average velocity were 2.2, 2,7 and 3.3 m/s for 2,000 m, 1,100 m and 800 m water way respectively, as shown in Fig. 3. In the proto site, it is also observed that in the vicinity of Kosi barrage, the sedimentation near the spillway portion has not affected the operation of the barrage over nearly 50 years. The barrage has a waterway of 1,100 m. The river Kosi reach constricted to 1,100 m width would result in a regime channel, which will not be in either degradation or aggradation stage. (Burele el al., 2014)

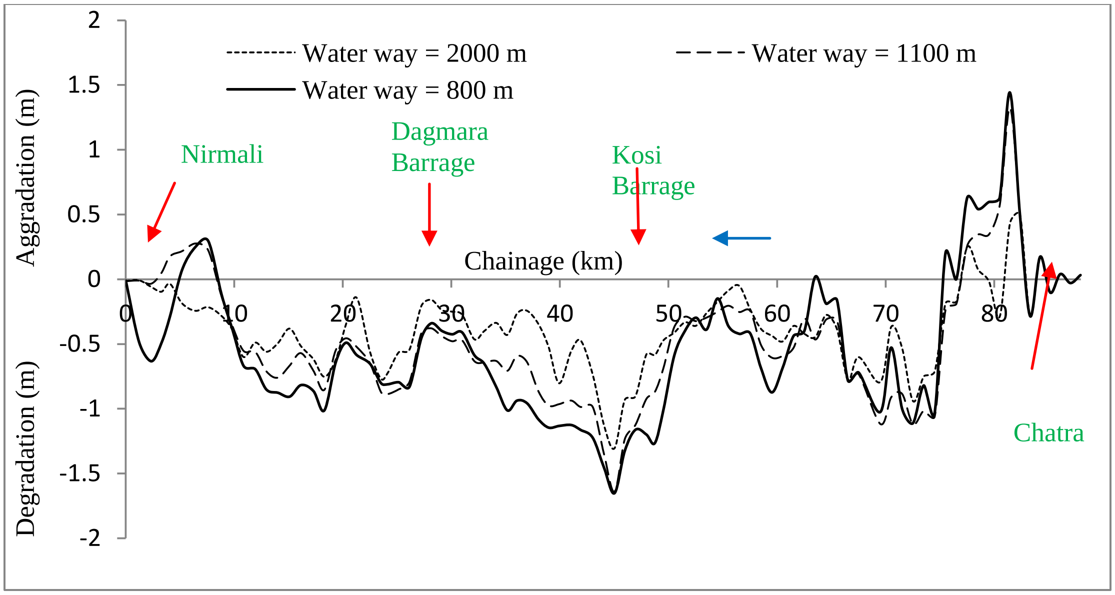


Figure 2 Morphological changes of bed level with respect to river bed level of year 2002 (Burele el al., 2014)

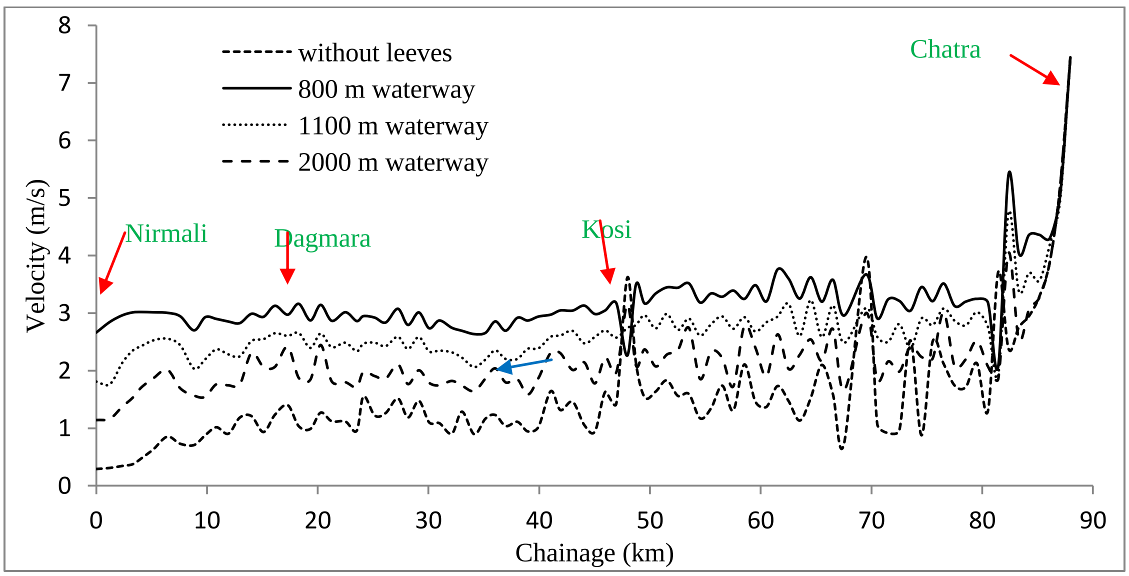


Figure 3 Velocity distributions longitudinally for various channelization width(Burele el al., 2014)

3. Physical model studies for fixation of waterway

a) Survey data

Reach considered for model study was from Chatra to Kosi barrage which is about 40 km. In this reach there was no gauging station available, which was required for calibrating the model. So, further model was extended upto rail and road bridge, Nirmali, Bihar, where there were two gauges available one at Dagmara and another at Bhaptiahi.

In order to reproduce the prototype of the river in the model, the bed configuration of river Kosi and the formation of deep channels, the survey data from 40 km upstream to about 47 km downstream of Kosi Barrage (i.e. upto Nirmali) collected during April and May 2002 has been used. The cross sections of the river within the embankments, available at a regular interval of 1.0 km were also used.

b) Design discharge

The highest known discharge at Kosi barrage is 22,375 m^3/s during the year 1968. But, the analysis of annual peak flood discharges, recorded at the Kosi barrage during the years 1969 to 2009which is shown in Fig. 4indicates the maximum discharge has been fluctuating around 14,330 m^3/s (5, 00,000 cusecs) only. Thus the enveloping discharge of 15,586 m^3/s (5, 50,000 cusecs) is considered in the present study.

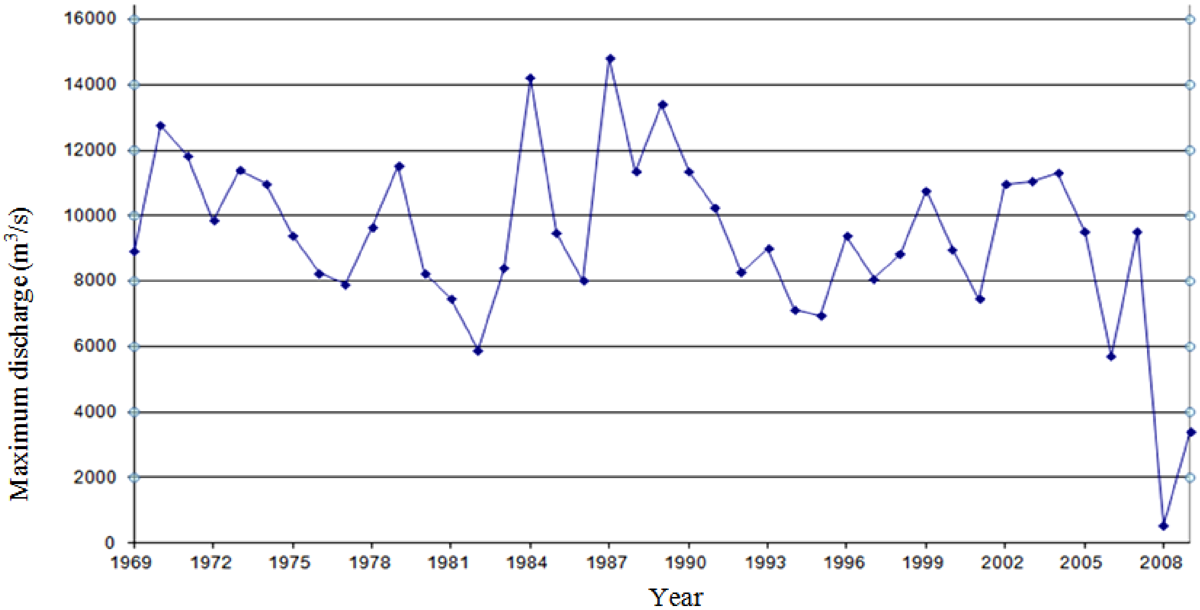


Figure 4 Annual peak flood discharges

c) Model construction activity

In the Kosi river model, the width of the river varies from 6 to 16 km and depth of flow is about 9 to 12 m. Therefore, keeping this in mind, scale of the model is decided. Length scale of 1/500 and a depth scale of 1/70 is adopted. Figure 5 a) shows the construction of datum at the bank of river in the model. Figure 5 b) shows laying of reduced cross-section using depth rod. Figure 5 c) shows fixing the peg given for cross section using cement mortar. Figure 6 show side and top view of sediment injector used in the model. At the bottom of the Hopper an adjustable slit is provided for injecting the required sediment in the model.

The sediment feeding setup was set to supply a constant sediment quantity of0.25 m^3/hr. This was mainly introduced at Chatra, where the river width is 330 m. Downstream of Chatra, river width increases. Sediment was supplied to simulate the sediment motion and its distribution from the gorge area the downstream plains between Chatra and Nirmali. Figure 7 shows the standing wave flume from where the required discharge is taken into the model.

Figure 5 a

Figure 5 b

Figure 5 c

Figure 6 Silt injector(Front view)

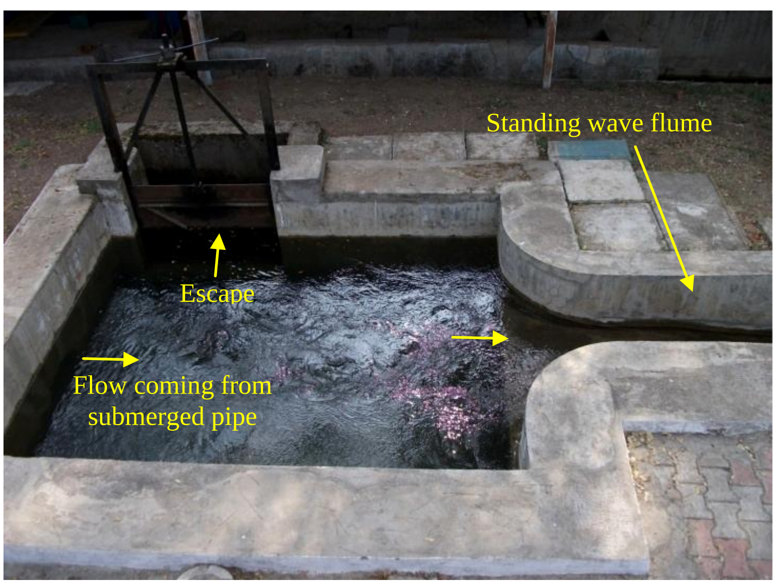


Figure 7 Shows standing wave flume from where the measured discharge is taken in to model

d) Model

Three-dimensional physical model of river Kosi, covering the reach from 40 km upstream to about 47 km downstream (Nirmali) of Kosi Barrage, was constructed to a horizontal scale of 1/500 and the vertical is a scale of 1/70. Figure 8 shows full view of model from Chatra to Nirmali with channel configuration, while Fig. 9 shows a view of the model from Kosi barrage to Nirmali with channel configuration. The bed configuration of the river, including deep channels, shoals and spill portion etc. are reproduced in the model as per the survey data (post flood 2002). Figure 10 shows view of the model from downstream. The grain size distribution of the material used in the bed of the model is presented in Fig. 11 with d_{50} = 0.26 mm. The derived scales for velocity and discharge are 1/8.36 and 1/292831, respectively.

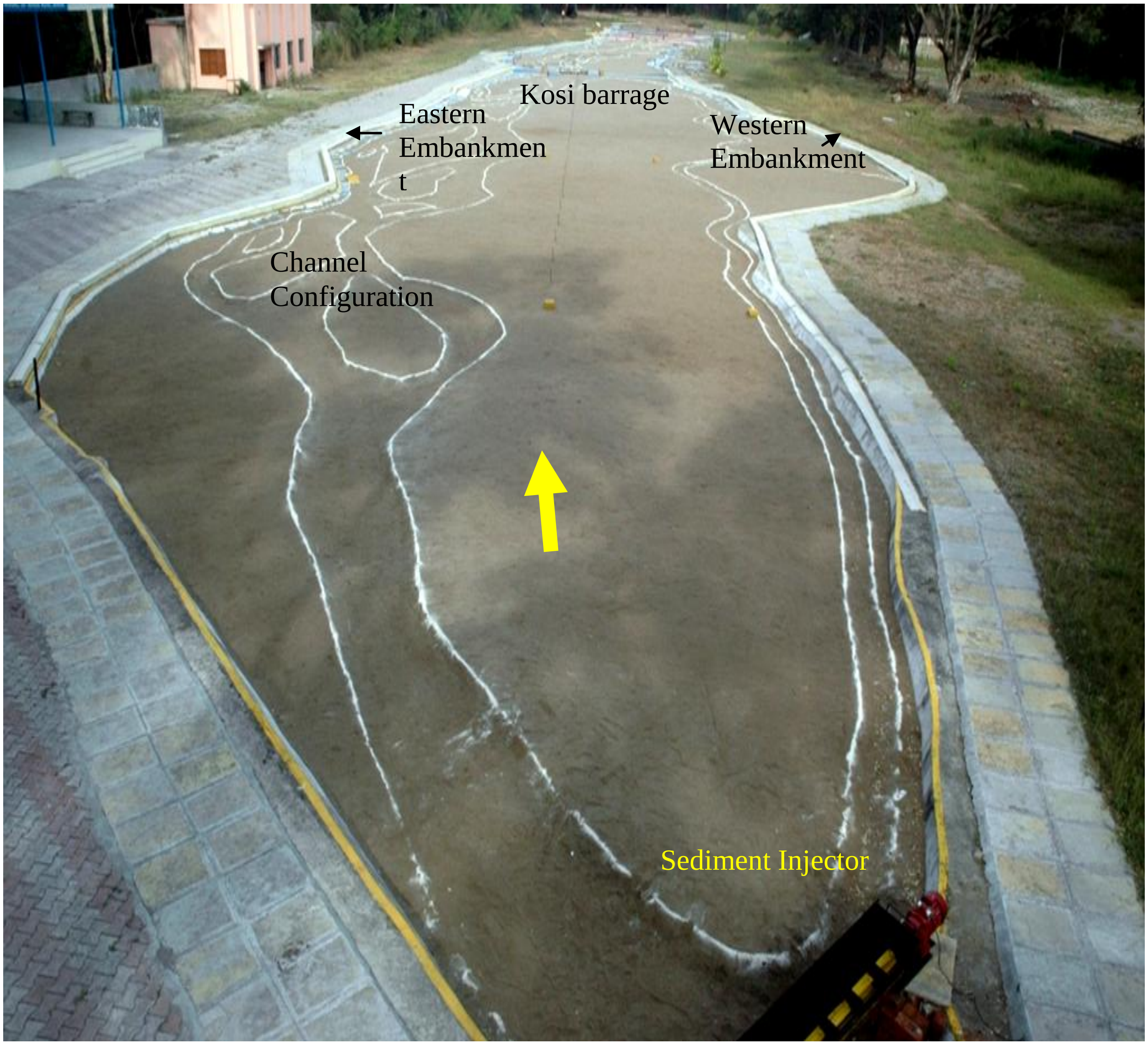
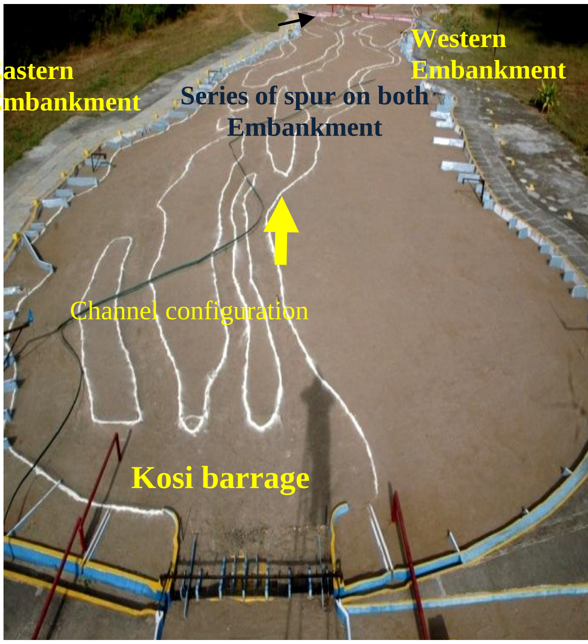


Figure 8 Full view of the model



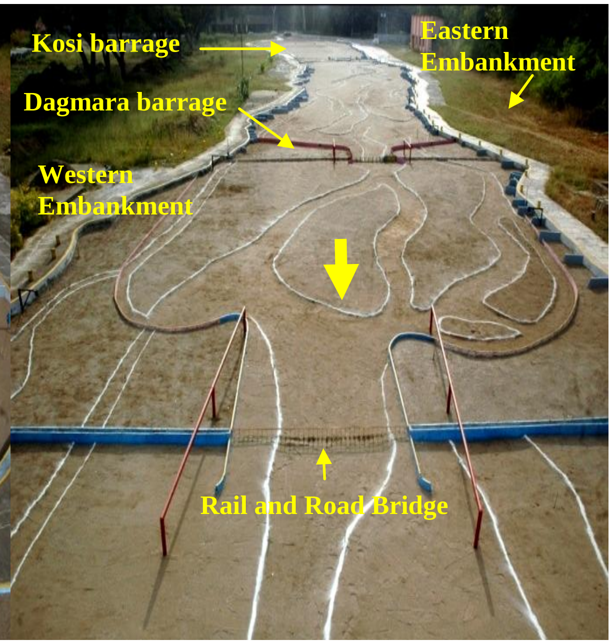


Figure9 View from upstream end and from Kosi barrage to Nirmali of the model

Figure10 View from downstream end

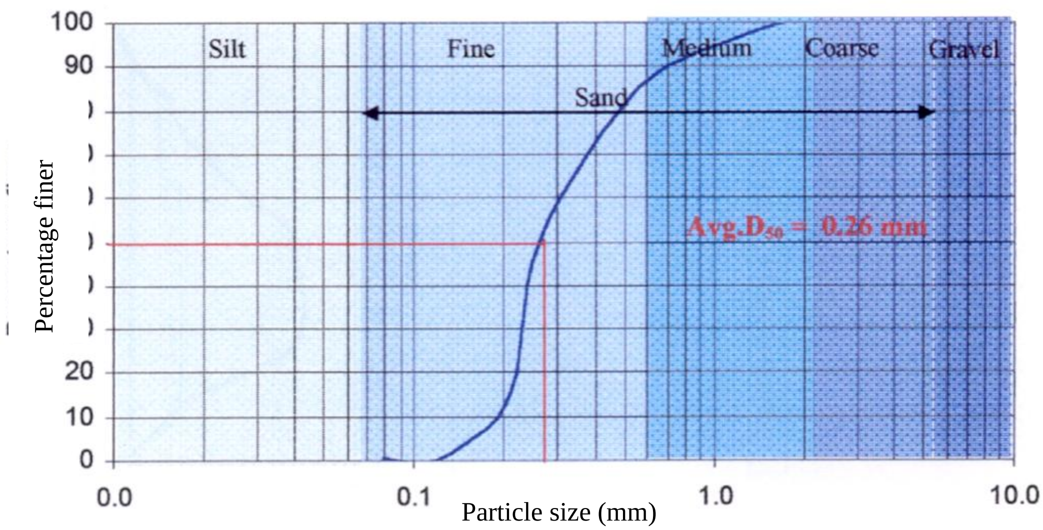


Figure 11 Grain size distribution curve of bed material used in the model

e) Model proving studies

Proving studies were carried out for verifying the conformity between model and prototype data in respect of water levels, and water surface profile in Kosi river. The discharge and water level data of the Kosi river, available for the monsoon of the year 2002, were utilized for this purpose. The maximum discharge recorded at the Kosi barrage during this period was 10,960 m^3/s (3, 87,000 cusecs), equivalent of which was run on the model. The corresponding water levels recorded at Dagmara and Bhaptiahi were of the order of 64.30 m and 60.20 m respectively. The gauge at Bhaptiahi in the model was controlled accordingly and corresponding water level at Dagmara was measured. It may be seen from Fig. 12 that the water level observed in the model compares fairly well with the prototype data recorded during the flood of year 2002. In view of this close agreement between the physical model and the prototype data, the model was considered as proved.

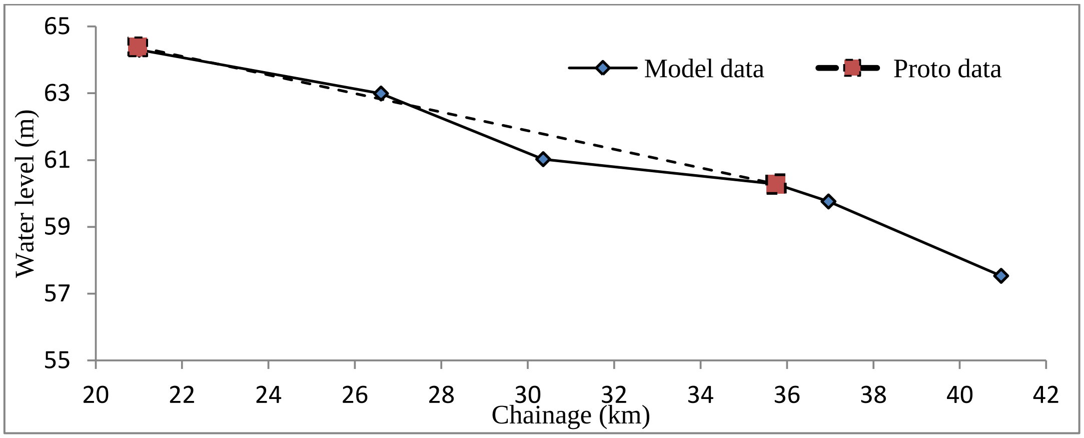


Figure 12 Comparison between observed and recorded water level for Q = 10,960 m^3/s

f) Model studies under Pre-structure condition (no constriction)

Flow pattern

The study was initially conducted under existing site condition, i.e. with spurs, structures and embankments. A discharge of 0.053 m^3/s, which corresponds to a discharge of 15,586 m^3/s on the prototype was taken as upstream boundary condition and water level = RL 57.79 m was taken as downstream boundary condition near rail-cum-road bridge at Nirmali. The model was run and the velocity at different locations and the flow pattern in the river were observed. In the upper reach(i.e., upstream of barrage), the flow was hugging the left bank, whereas in the downstream reach (i.e., downstream of barrage), the river was seen to spread widely over the reach from Chatra to Kosi Barrage (Fig. 13 a), b).

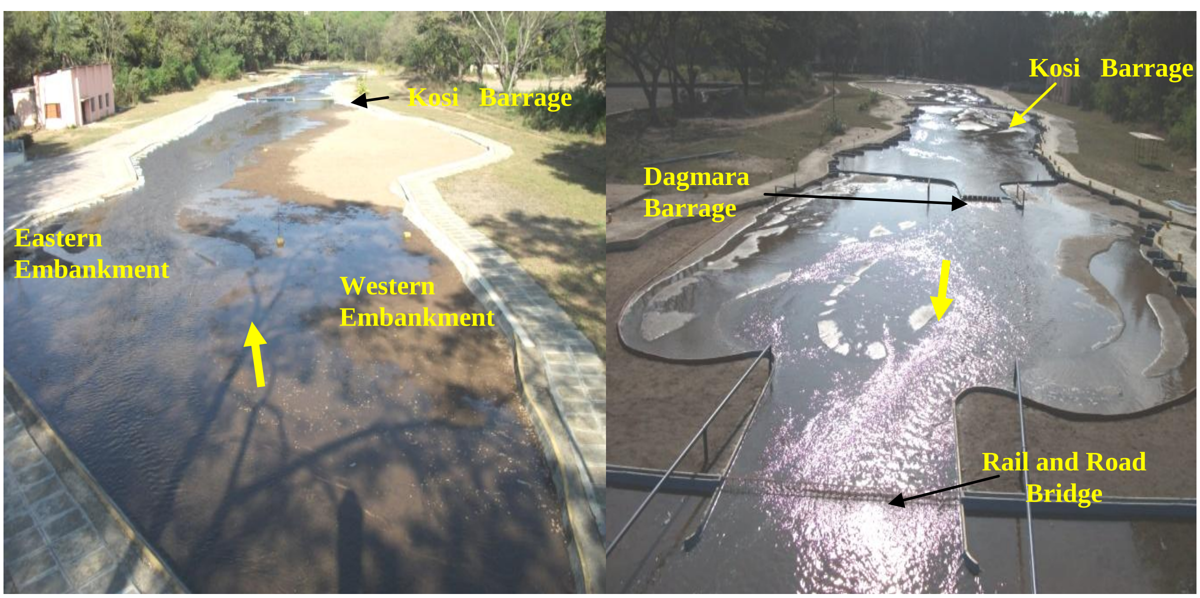


Figure13 a) upstream View**b)** A downstream view of the model(Q = 15,586 m^3/s)

It was further observed that the shoals present along the river deflect the flow and make the flow oblique, which starts hitting the flood embankments (Fig. 14). From the past studies conducted at CWPRS, Pune, it was found that at low discharge, the river flows through the braided channels, and the braided channel gets merged and the river start flowing haphazardly as the discharge increases. When the flood recedes, the sediment present in the flow gets deposited, which results in the formation of shoals? The flow thus starts attacking the existing flood embankments. To avoid this hitting, a series of sedimenting type of spurs were provided on both the embankments, the safety and maintenance of which is also difficult task. Further, extension of old spurs and constructions of new spurs were required from year to year due to changing morphology of the river. In view of this situation, it is required that the flow of the river should be straight as far as possible by providing hockey stick shape spurs along both the banks.

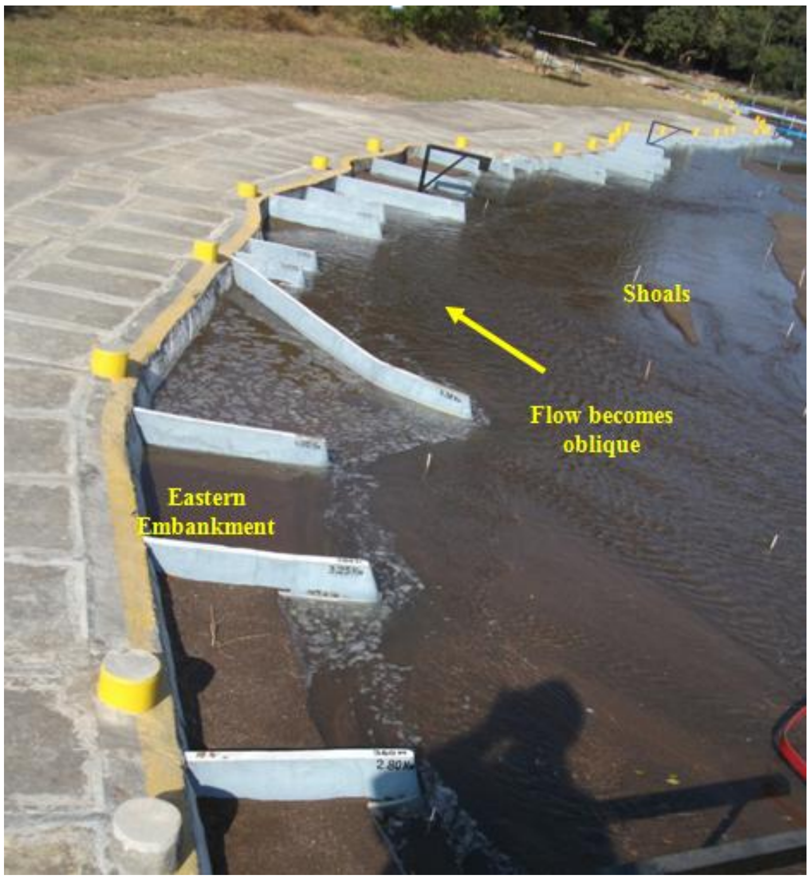


Figure14 Close view of flood embankment (Q = 15,586 m^3/s)

g) Channelization studies (with constriction)

Hockey-stick shape spurs were provided with a spacing of 1,500 m on both the banks to achieve a waterway of 1,100 m, for a reach from Chatra to Kosi barrage as shown in Figs. 15, and 16. Figures 17 and 18 show that how the channel are formed. It was observed that the sediment introduced and shoal present in the channel are flushed downstream of Kosi barrage. For the maximum observed discharge of 15,5865m^3/s, it was seen that the hockey-stick shape spurs guide the flow of water with an average velocity of 3 m/s and form the bed regime as shown in Fig. 19.

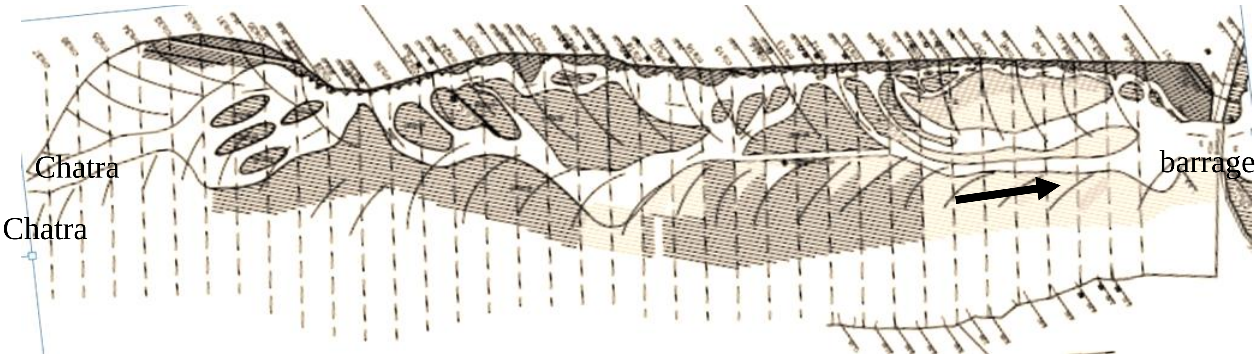


Figure 15 Plan showing layout of embankment and showing position of hockey stick shape groynes for a reach from Chatra to Kosi barrage(Waterway = 1,100 m,)

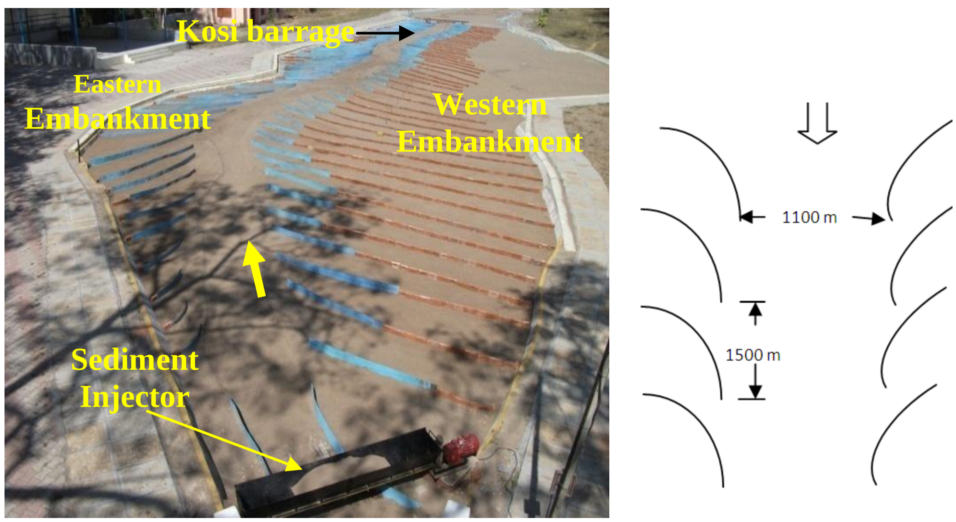


Figure 16 a) Channel configuration showing position of hockey stick shape groynes from Chatra to Barrage **b)**Detail of hockey stick shape groynes provided in the model

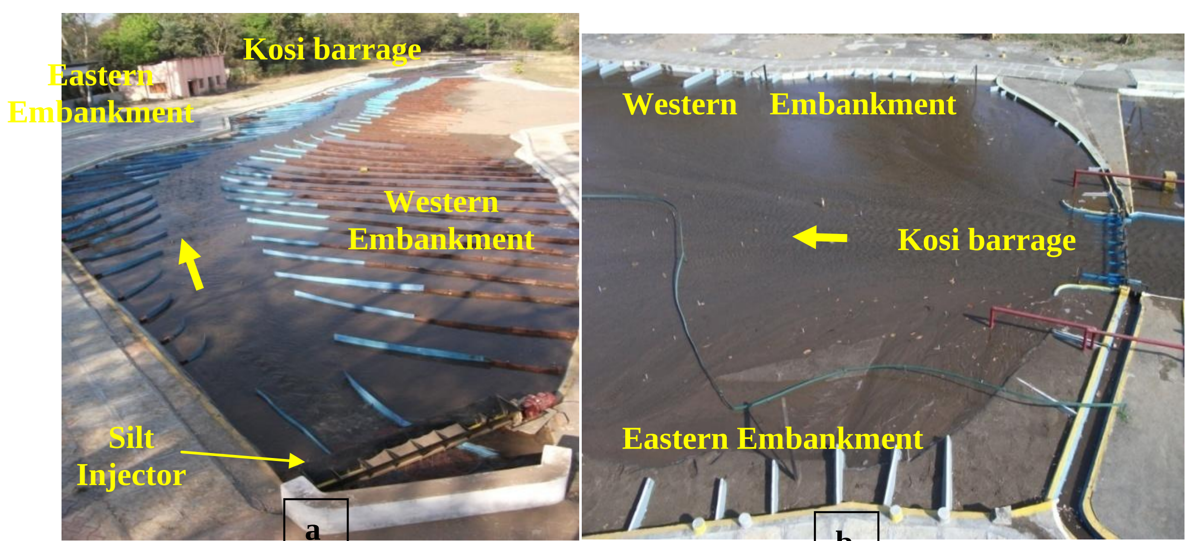


Figure 17a)Upstream view of model with a discharge of 15586 m^3/s for a reach from Chatra to Barrage b) Side view of model near barrage showing flow pattern for discharge of 15586 m^3/s

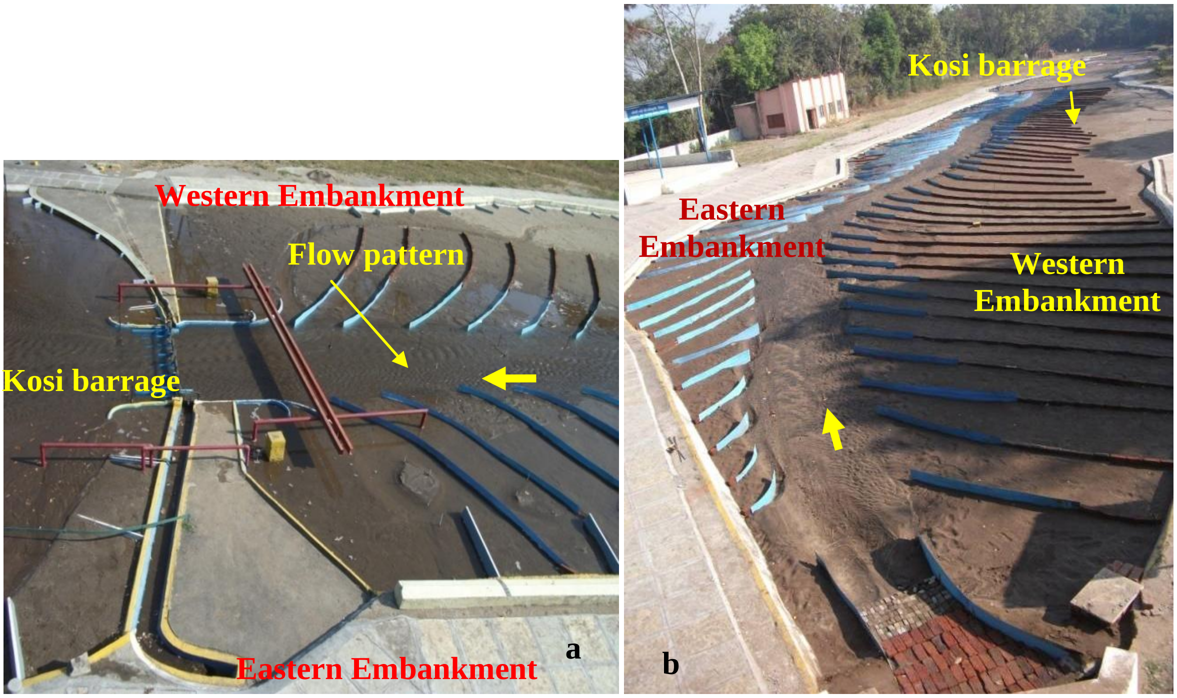


Figure 18a)Side view of model with a discharge of 15586 m^3/s at Barrage b) Upstream view of model showing bed formation after a discharge of 15586 m^3/s

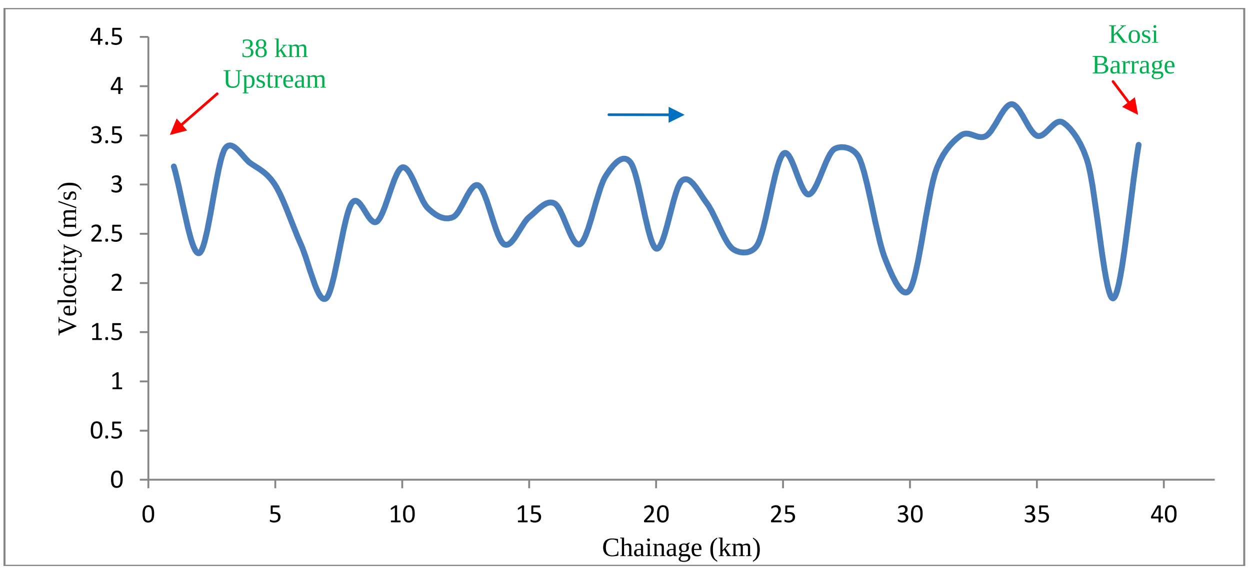


Figure 19 Velocity along the river for Q = 15,586 m^3/s

4. Conclusions

The satisfactory results obtained from the mathematical modeling for a waterway of 1,100 m with the Hockey-stick shape spurs were also observed in the case of the physical modeling. Utmost care has been taken such that alignment of levees should be through the channels. Studies were conducted for a reach considered was from Chatra to Kosi barrage.

Hockey-stick shape spurs were provided from Chatra to Kosi barrage with a spacing of 1,500 m on both the banks to achieve a waterway of 1,100 m. In this, the sediment introduced and the shoals present in the channel were seen to be flushed downstream of Kosi barrage. For the maximum observed discharge of 15,586 m^3/s, it was seen that the hockey-stick shape spurs guide the flow of water with an average velocity of 3 m/s and helps to form bed regime. Thus this method was also found to be an effective way for channelization of river Kosi on technical grounds.

5. Acknowledgements

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