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ARTIFICIAL CUT-OFF AT ISLAM HEAD WORKS

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The paper deals with the development of a Horse-shoe bend in the Sutlej river at Islam Headworks which was straightened by an artificial cut-off in apprehension of unfavourable consequences of an unpredictable natural cutoff. The knowledge of meandering behaviour of alluvial channels is essential for effectively dealing with problems like the one under discussion. In this regard, series of experiments conducted at the Vicksburg Station U.S. Army Corps of Engineer had revealed that :

(a) Bank erosion was responsible for meandering when other factors of changing flow conditions were absent.

(b) An irregularity in a straight alluvial channel imparts curvature to the streamlines, setting up a circulatory current which would eventually develop a meander. The question, whether varying erodibility and other irregularities cause meandering or a straight channel develops circulatory current which creates irregularity, is debatable.

(c) The meandering once initiated progressed indefinitely with the bends consistently migrating downwards. A stage was reached for bends with large lengths where resistance to the flow became greater in the bend than

that along the bar opposite to it, and the channel, therefore, started cutting through the bar to form a chute. The channel maintains a constant length by chute development for a constant discharge.

(d) The meandering pattern depended upon the hydrograph of flow. Low, high and medium flows mainly attacked respectively the upstream end, the downstream end, and the middle part of the concave bend.

(e) If material at the downstream end was less erodible than that at the upstream end, a horse-shoe bend would form (with flow directed up-valley), a phenomenon often witnessed in natural rivers.

Artificial cut-offs have been used for river training. The first regular scheme for cut-offs for the river channel improvement for flood control was executed on Mississippi River in U.S.A. The river length of 680 miles was reduced by about 25% with the help of 2 natural and 14 artificial cut-offs, a guage reduction of 12 to 13 ft for comparable flood discharge had also resulted. Other instances include cut-offs executed to eliminate horse-shoe bends upstream of the river structures which threatened the retired embankments. Cutt-offs have also been used to rectify the aggrading river channel downstream of the headworks.

It has been noticed that any artificial or natural cut-off results in availability of excessive energy which brings about violent changes in the river by eroding river banks upstream and aggrading the river channel downstream. Straight cut-offs create a river path in conflict with the meandering behaviour of the river. The meandering tendency ultimately endangers the agricultural lands etc. at unpredictable places, and these problems were still exsperienced when some artificial cut-offs in Europe were excavated to full river size. The consequences were as detrimental as those resulting from natural cut-offs.

Study of river survey plans for the years 1929 to 1961 indicate a tortuous course of the river Sutlej Upstream of Islam Headworks. Five cut-offs took place from 1929 to 1959, out of whcih only one was artificial (1959), the other 4 were natural. Increased tortuousity is an

effect of construction of the Islam diversion weir on an alluvial river. The two possible reasons are;

(i) obstruction offered by the weir to the downward journey of the meanders and

(ii) deposition of coarser material on upstream which increases tortuousity.

It is believed that tortousity (river length divided by straight line distance from a given point to the weir) varies directly with the sediment load. The existing problems on the upstream of the headworks are a sand shoal at the nose of the Right Guide Bund, Southern creeks downstream of the G.H. Spur, and the horse-shoe bend. The development of the horse-shoe bend may be attributed to presence of erosion resisting patch on downstream of the bend which obstructed further migration of its lower arm. The thalweg-neck distance ratio of the loop had increased to 4.2 which was an obvious indication of a likely development of a natural cut-off in flood season with serious possible consequences due to the close proximity of the Headworks. It was, therefore, decided to create a natural cut-off during the low flow season of winter 1958.

Capacity of the cunnete should be limited to 8 to 10% of the river discharge. The cut should be made tangential to the river course at entrance and exit, and the entrance should be bell mouthed with double the width in first 300 to 600 ft. in order to avoid shock losses. A mild curvature should be provided in the alignment to increase the tractive force for enhancing transport sediment capacity. The best cunnete section is the one, which provides a good scouring velocity, and is made as deep as possible with the available means. The cunnete should be such that $Rc/Lc^2 > Rr/Lr^2$ (R&L stand for hydraulic mean depth and length while the subscripts c&r represent cunnete and river respectively). Elimination of a full 'S' curve should not be aimed at by a single cut, and the upper bend must be eliminated first. In case multiple cut offs are required, it is a good practice to start from the lower end.

The length of the cunnete was 5700 ft with a constant bend width of 30 ft. A side slope of 1.5:1 was provided in 3500 ft length of the head reach

and 1:1 elsewhere. The bed levels at the head and tail were fixed as 447 and 446 respectively. For a river discharge of 60,000 Cs the discharge in cunnete was estimated to be 2500 Cs with velocities of 4.5 & 6.0 ft/sec. at head and tail respectively. The mean value of the tractive force at head and tail worked out to be 0.18 & 0.34 lb/ft^2 which was sufficient to erode fairly compact and compact sandy clay (sand content less than 50%) at head and tail respectively.

The cut was opend at 9.30 AM on 8.7.59. Discharge upstream of the headworks was 55040 (minimum required for generating scouring velocity in the cunnete) at the time with an expected rise in the river upto 8000 cs over next couple of days. At the time of breaking the check bund, the head across the bund was 3.1 ft. The cut passed 2500 Cs with an estimated velocity of 7 ft/sec. within an hour of its inception. A rapid development of the cut followed. The percentage of the river discharge passing through the cut increased from 25.4% on 22.7.59 to 72% on 26.7.59 whereafter a moderate increase was observed till 100% flow through the cut on 12.8.59. The main river course was closed during sharply falling flood. The rapid development of the cut can be attributed to proximity of the headworks, erodibility of the strata, and a rather higher loop-neck ratio of 4.4 against a recommended value of around 2.0 for the artificial cut-off. The pond level initially kept at 453.95 to accelerate the development of cut was raised by 0.9 ft to control the silt entry into the canals. The rapid development of the cut resulted in deterioration of the river downstream. However, two creeks intersecting at RDs 2200 & 3500 absorbed part of the silt load. It may be, however, emphasized that for full utility of the cut off, it also requires essential bank protection.

Longitudinal section of the Mailsi canal, off-taing from right flank of Islam Headworks, observed in the following months indicated a gradual rise of the bed level as a direct consequence of the increased sediment load due to the artificial cut, and the channel during the period upto October 1959 showed a marked tendency of meandering. Meandering in turn effected the structures starting with damage to the first bridge at RD 20180, where oblique flow and excessive scour was observed. Similar conditions were experienced on other structures and stone dumping was resorted to. Excessive sediment entry in Mailsi Canal accompanied with scour at the structures has continued till the time of writing of the paper in 1962, in addition to the other observations made already.