TRAINING OF RIVER GANGA NEAR FARAKKA BARRAGE

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ABSTRACT

...tructed in 1971, Farakka barrage across the river Ganga is diverting 1135 cumec flow to Hoogly river ... Kolkata port. Over the years, the river has eroded its left bank upstream and right bank downstream ... resulting in colossal loss of life and properties. If the erosion continues, the river may either ... barrage or it may join Hoogly river - both causing disaster. Existing, conventional river ... and their ineffectiveness have been discussed. After analysing the basic cause of erosion ... meandering of the river, author has suggested some alternative measures for training of the river ... ar Farakka barrage.

...UCTION

Farakka Barrage was constructed at a cost of Rs. 2000 million in the year 1971 across river Ganga. Its principal function is to divert a maximum of 1135 cumec flow to the river Hoogly (Bhagirathi) for saving Kolkata port (Mookerjea 74). It helps maintaining the navigability of Hoogly river (Institution of Engineers '73) apart from providing vital rail and road link with North East India to the rest of the country. Before the construction of the barrage, course of the river in between Rajmahal (in Bihar) and Farakka (in West Bengal) was more or less straight (Fig.1). Over ...ars 1971-2001, the river has been gradually ... towards the left bank (Malda side) upstream ... Downstream of the barrage, the river ... ards the right bank (Murshidabad ... both the districts of Malda and ... subjected to devastating erosion ... 99). Properties worth several ... of crores have already been destroyed ... er Pathey). The river breached marginal and ... embankments upstream of Farakka Barrage causing disastrous floods in Malda district on several occasions. Total estimated cost of damage in 1998 flood (Mazumder 2000) alone is Rs. 10,000 million approximately. It is of utmost importance, therefore, to train the river Ganga both upstream and downstream

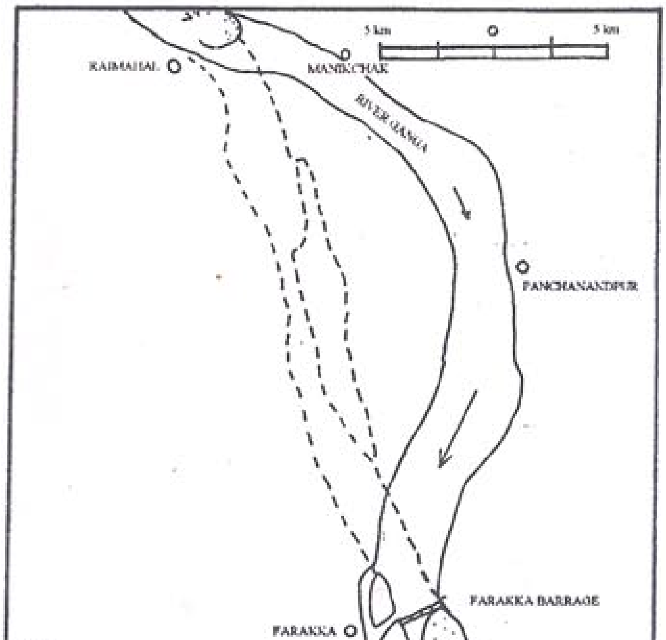

Fig. 1 Change in Ganga River Course upstream of Farakka Barrage during 1923 -99

of the barrage to arrest bank erosion. If the upstream erosion continues, the river may outflank the barrage and try to merge with the adjoining 'Mahananda' river thereby wiping out Malda with a population of about 5 lakh. Uncontrolled erosion on the downstream side, on the other hand, will result in destruction of Feeder canal and merger of Ganga main flow with Hoogly river, thereby causing unprecedented flood problems in all the major towns in West Bengal lying on the Hoogly river bank. Gap between Ganga and the feeder canal is narrowing as the river is eroding right bank downstream of Farakka barrage and at some places the gap is as small as 250 m or so. Any change of river course either upstream or downstream of the barrage is going to completely damage the railway and road (NH-34) links between north east India with rest of the country.

RIVER GANGA AND ITS BEHAVIOUR NEAR FARAKKA BARRAGE

Originating at Gangotri (Uttarkashi District in Uttaranchal) at an elevation of 7010 m, River Ganga flows through the States of Himachal Pradesh,. Uttar Pradesh, Bihar and West Bengal traversing a distance of 2200 km upto Farakka barrage near Malda in West Bengal. Thereafter, the river enters Bangladesh and joins Brahmaputra river. The combined flow of Ganga and Brahmaputra (Meghna river) discharges into Bay of Bengal. The river has a catchment area of 861 thousand sq. km

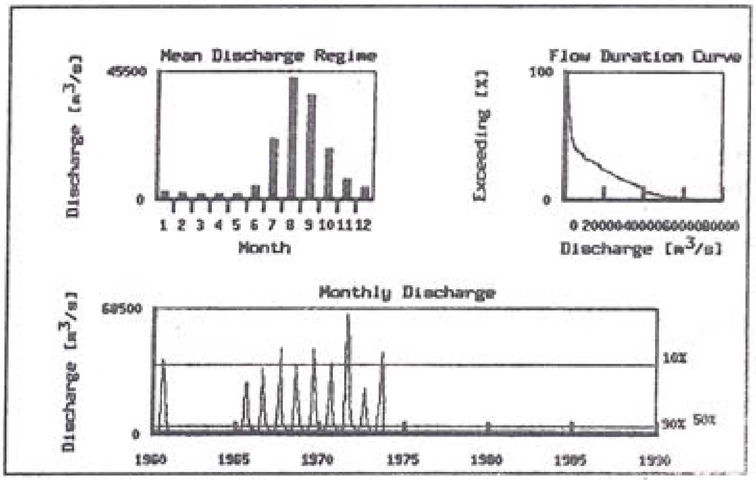

Fig. 2 Distribution of Ganga Flow at Farakka

in India and 190-thousand sq. km in Nepal totalling 1051 thousand km² upto Farakka Barrage. Principal tributaries of Ganga are Yamuna, Chambal, Ramganga, Gomti, Ghagra, Gandak, Kosi, Sone and Mahananda. Average monthly distribution of flow in Ganga at Farakka over a period of 252 months is shown in Fig. 2. The maximum daily flow recorded at Farakka was 75,900 cumec (27 lakh cusec) on 6.9.98, when the river attained the highest stage of 26.545m. Farakka barrage has a design discharge of 70,930 cumec and the corresponding design high flood levels are 26.1 m upstream and 25.6 m. downstream with an afflux of 0.5 m. Both the marginal embankment and the afflux embankment upstream were breached in Sept 1998 when the upstream high flood level exceeded the design HFL. Mazumder (2000) analysed the role of Farakka barrage for the disastrous 1998 flood in Malda. Similar flood damages had occurred in other years too after the barrage construction. One of the principal causes of these breaches and bank erosion is the gradual shifting of the river towards

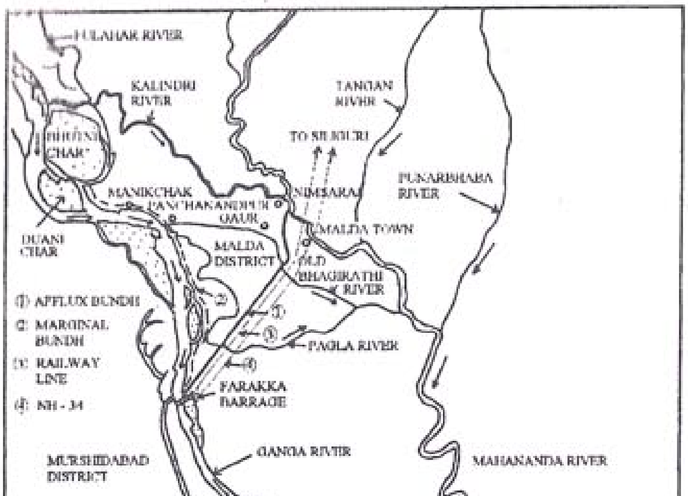

Fig. 3 River Ganga and its tributaries near Malda Town showing meandering near Farakka Barrage.

bank upstream and deposition of sediments and formation of a big char on the right bank as seen in Fig. 3. This has resulted in the formation of a typical meander with Farakka Barrage (Fixed Point) at the centre (Mazumder 91). It is mainly due to the growth of the char that the river meandering is increasing every year and the river is shifting towards left bank upstream and right bank downstream of Farakka barrage. River Ganga carries an average of 38.4 million ha-m of water and 60,000 ha-m sediments in a year upto Farakka barrage. Before the barrage construction, the river used to carry the sediments downstream of the barrage with a normal bed slope of about 1 in 21,000. After the construction of the barrage, sediment carrying capacity of the river has reduced considerably due to afflux and consequent flattening of hydraulic gradient upstream. It is estimated that about 80,000 ha.m of sediments has already deposited upstream of Farakka barrage during the last thirty years. It is this deposition of sediments which is responsible for the creation of chars (islands) on the right bank and the river is meandering near the barrage. More acute is the meander upstream, more severe will be the river erosion on the right bank downstream. In fact, erosion on the right bank in Murshidabad district can be substantially reduced by reducing the meandering curvature upstream towards Malda side.

NECESSITY OF RIVER TRAINING

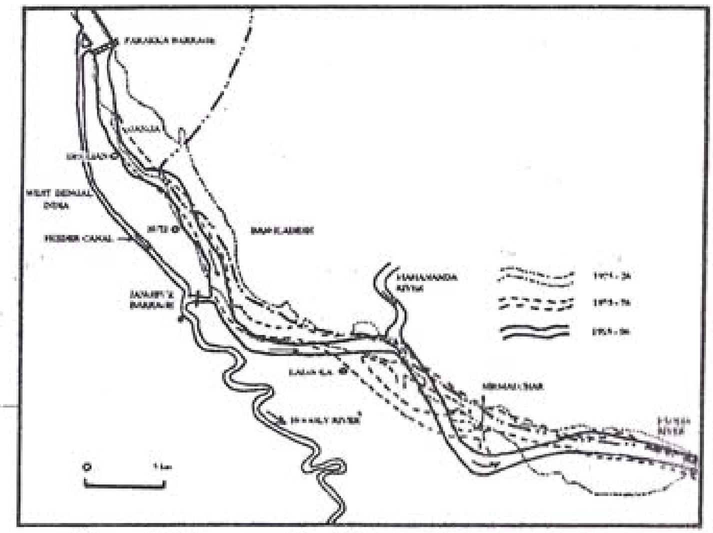

Fig. 4 Change in River Ganga course downstream of Farakka Barrage during 1925 - 96

As already discussed, river Ganga is eroding its left (East side) bank upstream of Farakka barrage and right (West side) bank downstream of the barrage. The left bank is being protected to avoid possible outflanking of the barrage and to arrest tendency of the river to join Mahananda or other tributaries like Kalindri, Pagla and old Bhagirathi in Malda

Basin (Fig. 3). Any outflanking will render the Farakka Barrage/Feeder Canal ineffective. Malda which is located in between Ganga and Mahananda rivers will be wiped out. . NH-34 and the broad gauge railway connecting North East India with rest of the country will also be breached. Minimum distance between the Pagla and Ganga was 8.53 km in 1923. Now it is reduced to only 300 m. Very fertile land lying in Malda district is flooded almost every year damaging crops and properties. River training measures are needed also to arrest erosion of right bank downstream of Farakka Barrage. Unprecedented erosion has already narrowed the gap between river Ganga and the Feeder canal (Fig. 4). NH-34 and the broad gauge railway lines are also under attack. If the river Ganga merges with Feeder canal, the combined flow may pass through Hoogly river or it may merge back with Ganga river damaging the Jangipur Barrage. Both the situations are dangerous. Hoogly river will be either flooded or dried, thereby paralysing the economy of West Bengal.

EFFECTIVENESS OF RIVER TRAINING MEASURES ADOPTED SO FAR

As shown in Fig. 3, marginal embankment of about 30 km length was constructed upstream to protect the left bank and stop erosion by arresting the meander. Made of fine alluvial soil, marginal embankment breached on several occasions. 27 spurs were constructed to protect the marginal embankment. Afflux embankment (Fig. 3) of about 25 km length was also constructed to protect NH-34, Railway and Malda town. Most of the marginal embankment and the spurs have been washed out regularly in several stretches. Afflux embankment also breached in 1998 flood. Retired embankments were constructed one after the other. After destroying 6 retired embankments built near Manikchak, it is now on the verge of destroying 7th retired embankment. 20 out of 27 spurs are washed out. To protect the right bank of the river downstream of barrage, 96 spurs were built and 28 km length of bank was protected with stone pitching. 30 spurs and most of the stone pitchings are washed out. Ganga is continuing its erosion of right bank. All the towns, the feeder canal, NH-34 and the railway on right bank downstream of Farakka barrage are in grave danger.

FUTURE TRAINING WORKS PLANNED

Based on the model study at CW & PRS, Pune, Pritam Singh Committee recommended building of two long spurs at a distance 28 and 29 km upstream of barrage with a view to deflect the main river flow from left to right bank and protect the left marginal bund. At all those places where the marginal bunds have been weakened (due to breaching and destruction of spurs), it is proposed to build retired embankments behind the existing marginal embankment. It is proposed to rebuild these and further strengthen them by proper pitching. A pilot channel through the centre of Bhutni char is proposed to reduce the curvature of river Ganga between Bhutni char and Rajmahal. Just upstream of Farakka barrage, main flow of the river is moving from left to right bank primarily due to the upstream meander and growing char on the right (Farakka) side (Fig. 3). As à result of the oblique flow, the main stream is eroding the right bank downstream of the barrage. Ganga has already eroded about 102 km of the right bank from Farakka to Jalangi (Fig. 4). In 1996, Planning Commission appointed Keshkar committee to look into the problems of erosion upstream and downstream of Farakka barrage. The six-member committee has drawn a comprehensive plan of Rs. 752 crores for anti erosion measures as follows:

Measure	Priority I (Rs. Crore)			Priority II (Rs. Crore)			Total (Rs. crore)
	Malda	Mushidabad	Total	Malda	Mushidabad	Total	
Short term	17	128	145	-	40	40	185
Long Term	-	567	567	-	-	-	567
						Grand Total	**752**

ANALYSIS OF GANGA RIVER EROSION

As already pointed out, bank erosion near Farakka barrage is basically due to gradual shifting of Ganga river course towards left bank (Malda side) upstream and right bank (Murshdabad side) downstream of the barrage. It has already formed a typical meander between Malda and Murshidabad with Farakka barrage at the centre (Fig. 3). Being located on the outer side of the upstream meander, the river is eroding Malda side bank (left) upstream. Similarly, Murshidabad is subjected to erosion, as it is located on the outer side of the downstream meander.

Fig.5 shows the schematic view of cross sections (not to scale) of meandering Ganga river upstream (a) and downstream (b) of Farakka barrage. Secondary current (shown by arrows), generated in the cross sectional plane of the river, (due to centrifugal effect) is responsible for erosion of the outer bank and deposition of sediments on the inner bank. As the outer bank erodes, curvature of the stream (in plan) increases and the centrifugal effect increases further resulting in greater depth, higher shear stresses and greater erosion of the outer bank. Eroded materials are deposited on the inner bank. It is due to this process of continuing erosion of the outer side and sedimentation of the inner bank that the stream goes on moving outward and depositing sediments in the inner bank. Bed of the stream gets inclined with deep channel (Thalweg) on the outer side and very shallow channel on inner side. Considerable research studies exist on the subject "flow through bends and river meandering". Some of the eminent persons working on flow through bends and river meandering are Engelund (1973), Zimmerman and Kennedy (1978), Rozovsky (1979), Chitale (1981), Chang (1983), Odgaard (1986), Wang (1994), Garde and Raju (2000). Wang (1992) developed a mathematical model of the flow phenomenon and proved that the typical cross sectional shape (Fig. 5) of a meander arises for stability of the bed of the river subjected to the effect of secondary current.

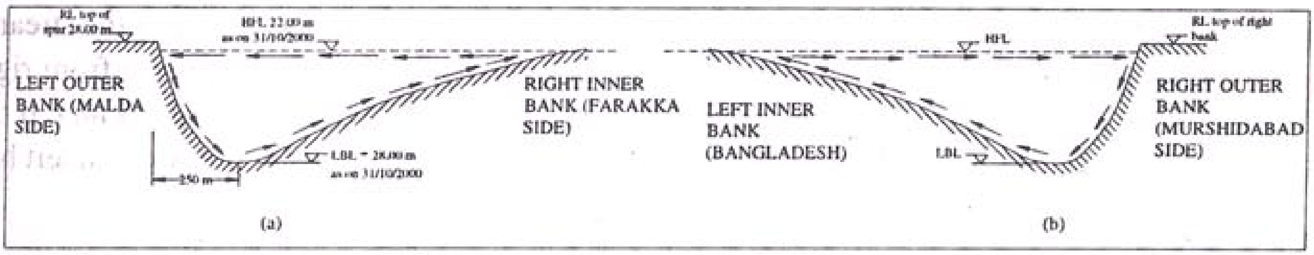

Fig. 5 - Schematic view of cross section of meandering Ganga River (a) upstream of Farakka Barrage and (b) downstream of Farakka Barrage showing the secondary current and deep scour near outer bank.

Being in the alluvial flood plane with a mean flow of 34,000 cumec and a bed slope of 1 in 21,000, river Ganga flows in a meandering stage (Valentine '92) near Farakka barrage. Cross section of the river upstream near outer bend (near spur No. 20) is similar to the one shown in Fig.5. The depth of flow at a distance 250 m from the outer left bank is found to be 50 m. No bank can be protected with embankment, pitching and spurs when there is a scour depth as much as 50 m near the bank. Fine silty soils by which the embankment and spurs are built have extremely poor shear strength. The bank of the river and the spurs, subjected to huge shear stress (governed by flow depth), simply collapse into the scoured area. Even the long spurs (28^{th} and 29^{th}) envisaged for deflecting flow from left to right bank are likely to fail. Spurs cause head loss and long spurs may create flow instability (Mazumder, 92 and 93). It is presumed that the long spurs will deflect the stream from left to right bank thereby encouraging siltation on the left bank. But the spurs themselves are likely to be washed out and their performance may not be as expected (Kulkarni, 1999). With similar expectations, Kosi Project Authority had constructed 364 spurs to save the marginal embankments. But the river Kosi is still breaching its banks (Mazumder, 1988, Chitale, 2000) either left or right almost every year.

RECOMMENDED RIVER TRAINING MEASURES

Since the conventional method of training Ganga river near Farakka barrage has been found to be mostly ineffective over the last thirty years and the river is continuing to erode the banks and increasing its meander every year, author would like to recommend some alternative measures as follows:

Inter Basin Flow Diversion

It has been observed that upto a flow of about 28,000 cumec (10 lakh cusec), the river banks remain stable. It is, therefore, prudent to divert excess flow (above 28000 cumec) through diversion channels upstream of Farakka barrage. Existing streams e.g. Kalindri, Bhagirathi, Pagla and Mahananada may be utilised for carrying the excess flow with suitable link canals and improving their conveyance. It requires, however, a comprehensive physical and mathematical model study of the entire river system and the response of flow diversion to Ganga river behaviour near Farakka Barrage.

Intra Basin Flow Diversion

One of the reasons of meandering of Ganga towards left bank is the presence and continued growth of Bhutni Char (Fig. 3). Earlier, (before barrage construction) the main channel of Ganga used to flow through the Fulahar branch (east of Bhutni) and the river course upstream of Farakka was more or less straight (Fig. 1). But now most of the flow of Ganga is along the right channel (West of Bhutni). Being located on the inner bank of Ganga, Bhutni Char is growing with years, resulting in higher curvature of the stream on the right bank and skew flow downstream. It is due to this skewed approach flow coming from right bank (Rajmahal Hill side) that the Ganga river is meandering more on the left bank towards Malda. If the main Ganga flow can be diverted either through Bhutni or through its Fulahar branch, pressure on left bank will be reduced and Ganga may shift towards the right bank.

Dredging of Sediments Deposited Upstream of Farakka Barrage

Fig. 3 shows a big char growing upstream of Farakka Barrage. Main channel near the left bank carries most of the flow coming from Rajmahal. Original right bank (now a thin course) being located on the inner side of the river receive more sediment compared to the left main channel since sediments move inward due to secondary current. It is likely that in the coming few years the original branch adjoining right bank will be totally choked and total flow of Ganga river will be coming through the left branch causing greater scour of left bank. As the char will grow in size, the curvature of flow will also increase resulting in still greater erosion of the left bank. Dredging of the sediment, particularly near the head of the char with a view to admit more flow through the right branch of Ganga will be highly effective in controlling growth of the char, reducing curvature of the stream and admitting more and more flow through the right branch. This will certainly reduce erosion of left bank. If the char is allowed to grow, flow intensity will further increase towards left bank and the river may ultimately outflank Farakka barrage. The excess sediment must be removed to avoid char formation on the right bank. Attempt should be made to build up the left bank upstream and right bank downstream of the barrage by using sediments deposited upstream of the barrage.

Use of curved submerged vanes

Submerged vanes as shown in Fig 6 have been successfully used (Odgaard - 1983, 1991) in controlling erosion of outer bank in meandering rivers. Placed at an angle varying from 15° to 25° with the mean flow, these inclined vanes with their pressure (or stagnating) side towards the outer bank of meander and their suction side towards the inner bank neutralises the secondary current responsible for erosion of bed and bank on the outer side of the channel. With these vanes in position, the water and sediments tend to move as they do in a straight channel since the secondary current is opposed by the vanes. Steel sheet piles, RCC

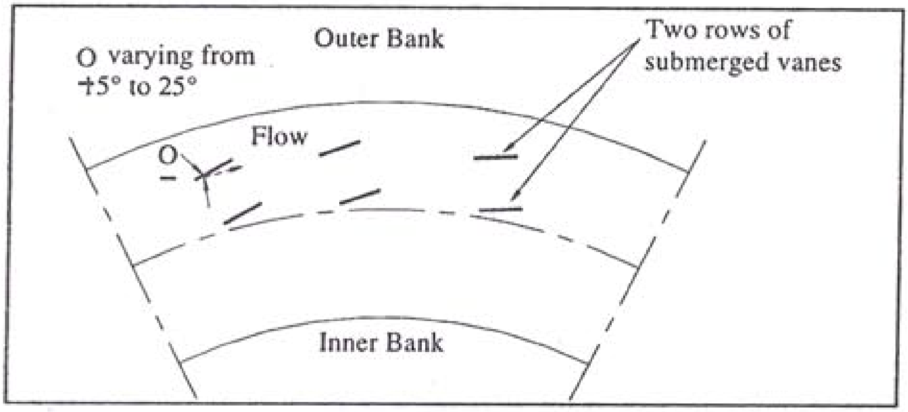

Fig.6 Submerged vanes for erosion control

panels and wooden planks have been successfully used in some rivers in USA for controlling erosion and encouraging siltation of outer bank and a gradual shift of the river from outer to inner bank in a typical meander.

Strengthening the River Bank

One of the primary reasons for erosion of the Ganga banks is the existing bank soil condition. Ganga river bank near Farakka barrage is made of very fine alluvial silt and clayey soil which has very little shear strength. The shear strength can be improved artificially through ground improvement using admixtures, geotextiles, geojute, etc. Suitable revetments placed on properly sloped bed can also be used in addition to strengthening of embankment soil. Impermeable spurs may be replaced with either permeable bamboo spurs or dagger type stone spurs.

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REFERENCES

BANDYOPADHYAY, D (1999),"To Prevent a National Disaster- The Voice of West Bengal", published in the book Flood Situation on West Bengal- Agenda for Action, Directed Initiative, Calcutta

CBI & P (1989) "River Behaviour, Management and Training" Volume-I

CHANG H.H. (1983) "Energy Expenditure in Curved Open Channels" JHE, ASCE, Vol. 109, No. 7, pp. 1012-1022

CHITALE, S.V. (1981) "Shape and Mobility of River Meanders" Proc.XIX IAHR Congress, Vol. 2, New Delhi, pp 281-286

CHITALE, S.V. (2000) "Future of the Kosi River and the Kosi Project" J. of The Institution of Engineers (India), Vol. 81, December, pp. 109-114

The Institution of Engineers (India) (1973), "Farakka Barrage Project for Preservation of the Port of Calcutta" Bulletin of the Institution of Engineers (India), Volume 22, No. 12, August