

1. INTRODUCTION

Every year, considerable areas on the banks of the rivers are lost by failure of the banks due to erosion, scour and sliding of slopes due to saturation during floods of long duration or by seepage of water flowing back to the river after the flood recedes. Such loss of land is generally compensated by accretion elsewhere along the river. However, it is the loss of land that is already developed or under use which attracts attention or causes concern while the accretion of land is not noticed.

Erosion or scour of the banks occurs due to the instability of the river or disturbances in its regime conditions. These are attributed to the variations in discharge, amount of sediment, slope of the river and composition of bed and bank material. The conditions in a river are constantly changing, and, therefore, equilibrium conditions are seldom attained. Depending upon the river characteristics, bank failure takes place, to a lesser or a greater degree, on almost all the rivers at one place or the other. But, the situation attracts attention only when considerable erosion or loss of land occurs, especially when this endangers important areas, lines of communications and affects large population.

2. EROSION PROBLEM IN INDIA

2.1 The problem of bank erosion exists almost on all

rivers, but is serious at many points along the Brahmaputra in Assam and a few points along the Ganga in Uttar Pradesh, Bihar and West Bengal. It is also prominent at some places on the tributaries of the Ganga, such as the Great Gandak in U.P. and Bihar, and Burhi Gandak and Kosi in Bihar.

2.2 Erosion on the Brahmaputra

The main cause of erosion on the Brahmaputra is the instability of the river as a result of excessive sediment brought into it. The sediment charge is due to the denudation of forests in the friable hills, disturbances caused by earthquakes and erosion by faulty land use. This has created a serious imbalance which, aided by the large variation in the discharge of the main river and its tributaries, changes the pattern of the cross channels and leads to formation of shoals. Consequently, the banks come under the attack of the river to varying degrees. Some places are continuously under attack while at others it lasts only for a short time. Statistics of the areas affected by erosion in the last few years indicate that, on an average, 230 villages, 10,000 ha of land and 505 families are affected by erosion every year. The damage due to erosion is about Rs. 50 lakhs annually. The extent of damage varies from year to year depending upon the pattern and severity of floods. This annual loss affects agricultural production and leads to considerable dislocation of rural life. Even though the loss of land by erosion at one place is made good by accretion at another, it will be sometime before the newly formed land can be put to effective use. Therefore, in Assam, where the valley portion of the Brahmaputra is 80 to 100 km in width and where most the agricultural operations are done, the loss by erosion has serious repercussion on the agricultural production. Erosion also endangers the protective embankments, vital communications and important towns.

A few years ago, erosion was pronounced *and* serious at Majuli, Biswanath, Singri, Sanlakuchi, Mukumua, Pahari and Alipram on the north bank of the Brahmaputra, and Mathola, Oakland, Mohanghat, Desangmukh, Neamatighat, Dhansirimukh, Hathimura and Goalpara on the south bank. While erosion continues at these places to some extent, it has become very acute in the last two to three years at Kokilmukh on the south bank and Dhubri on the north bank threatening the safety of Jorhat and Dhubri towns. (Protective measures at Dhubri have been dealt with in Section 5).

2.3 Erosion on the Ganga and its Tributaries

2.3.1 The Ganga is normally well poised, but erosion has been taking place near some of the important towns such as Varanasi, Balia, Patna, etc., against which town protection works have been implemented in the past. In the last few years, the erosion has been severe at some points along the river in U.P., Bihar, and West Bengal.

In U.P., erosion is pronounced in a length of about 600 m near Gaighat village which is protected by the Ballia Baria Bund constructed in 1955-56. The erosion is threatening the Ballia Baria Bund and an area of 25,000 ha protected by it. (Measures being taken are discussed in Section 5).

Erosion near village Simra, Khulla, etc. in Mirzapur district of U.P. has also been noticed. The average rate of erosion in the last two years is about 200 m in a length of 7 km.

In Bihar, the Ganga has been eroding its left bank near Mansi in a length of 12 km extending from Rahimpur village to downstream of Mansi during the last 8 years. It has become very serious during the last two years and is threatening the North Eastern Trunk Railway line to Assam.

and the National Highway No. 31, running parallel to the railway line near Mansi. The minimum distance now left between the river margin and the National Highway is about 300 m. (Please see Section 5 for the anti-erosion measures taken or being taken).

Severe erosion has also been noticed on the right bank of the Ganga immediately downstream of the Mokameh Bridge. This erosion is in a length of about 10 km. The area eroded in 1968 was about 400 ha and in 1969 about 450 ha.

2.3.2 Erosion on the Tributaries of the Ganga

Erosion has been continuing on some of the tributaries of the Ganga since a long time, even though it is not confined to any particular point and has been shifting from place to place. Some of the tributaries on which the problem is chronic are the Ghagra, the Great Gandak, the Burhi Gandak and the Kosi.

2.3.2.1 A few years back, erosion was very severe on the Burhi Gandak near Muzaffarpur which threatened the town, but the situation was controlled by taking prompt measures. At present the erosion is serious near Bariarpur. The erosion is over a length of 0.9 km and in the course of last six years, nearly 85 ha have been eroded, requiring the retirement of the protective embankment on the right side five times.

2.3.2.2 The Great Gandak has shown a tendency to move westwards during the last 50 years. In this process, erosion has been taking place on the right bank from the site of the Gandak barrage downwards. The tendency of erosion has been checked in the reach up to a few kilometres above Chhitaunighat by construction of spurs and river training works. At present, erosion is prominent along the

Khadda-Chhitauni Railway Section near Chhitauni Railway Station, and to a lesser extent, along the right bank from Chhitauni Ghat to Madhubani in Bihar. Nearly 1.2 km width of river margin has been eroded in a length of 8 km in the last 10 years along the railway embankment near Chhitauni Railway Station. (Please see Section 5 for protection measures taken or proposed).

2.3.2.3 On the Ghagra, erosion has been taking place on the right side near the Srinagar-Turtipur embankment. Severe erosion at this site led to the retirement of embankment in a length of 7 km. Upstream on the right bank, erosion was noticed in 1967 which continued and resulted in the abandonment of Bahramghat Railway section and posed a threat to the Ganeshpur village. However, latest reports indicate that shoaling has taken place in front of the village, and it is no longer in danger.

2.3.2.4 The tendency of the Kosi to move westwards has been arrested after the construction of the Kosi barrage and flood embankments. The river is yet to attain stability disturbed after construction of the new structures, viz. the barrage and flood embankments. In the process, there has been attack and erosion at a number of points, on both the banks threatening the safety of the embankments. Remedial measures are being continuously taken to keep the situation under control. These measures have been discussed in Section 5. At present, erosion is active at Dalwa and Kanauli on the right side and at Bhatania, Bhalkahi and Neema on the left side.

3. CAUSES OF BANK EROSION

3.1 River bank erosion is caused either on account of the bank material not being sufficiently strong or when the river currents are too fast. Strength of some type of soils is very weak and with saturation they are known to cause

sloughing of the river bank. Bank erosion on the Barak and some other rivers in Assam is of this type. Banks of some of the rivers are composed of relatively stiffer material when dry. The strata, if it is porous, permits easy percolation of the drainage water from the adjoining lands. On the contrary, if the material is somewhat impermeable, the drainage water could make the river banks composed of such soils unstable on account of back pressure. Failure of the river bank in this fashion is common, a typical example of which is the Pohru, a tributary of the Jhelum in Kashmir.

3.2 The river bank erosion also depends on the severity of the river attack. At the foot hills in Sub-mountain regions, rivers have braided pattern, i.e. having several inter-twining channels. Bank erosion in such channels is caused on account of oblique attack during floods. Bank erosion on the Kosi river in North Bihar and in Brahmaputra river in Assam are of this type. In the plains, the rivers normally form a meandering course. These meanders are generally not stationary but have a tendency to move progressively in the downstream direction. In such meandering rivers, erosion occurs on the outside of bends on account of secondary helicoidal flow which removes the material from the eroding bank on to the shoal on the opposite side. The bank erosion on Ganga river in Manshi bend is an example of this type of erosion.

3.3 Significant changes in river regime could be brought about by natural phenomena like earth-quakes. Assam valley traversed by Brahmaputra river is an illustration to the point where incidence of earth-quakes is high. Considerable material is brought down in the river after earthquakes which takes long period spread over years before it could be carried down to the sea. The river bed changes during this process are rapid which could cause severe bank erosion at vulnerable places. Deforestation on account

of fires, cutting of jungle wood for fuel, grazing by the cattle, etc. also result in rapid removal of the forest cover and feeding the river with sediment which ultimately cause bank erosion, the effect being similar to that of earthquakes on river regime.

3.4 Bank erosion could also be caused on account of natural and artificial changes taking place in the river regime when structures like dams, barrages, etc. are constructed which arrest free sediment movement on the river bed, and consequently the river reaches downstream get affected.

4. PROTECTION MEASURES AGAINST EROSION

Measures to prevent erosion of the river margin can be broadly classified in two groups:

- i) Direct protection; and
- ii) Indirect protection

Direct protection consists of the works done directly on the bank itself such as slope protection of embankments and upper river bank and toe protection of lower river bank against erosion and grading the sloping surface and provision of drainage arrangements to ensure stability against seepage and saturation.

Indirect protection works are constructed in front of the bank with the object of reducing the erosive force of the current either by deflecting it away from the bank or by inducing silt deposition in front of it. These works include groynes or spurs at adequate spacing.

Under both direct and indirect protection, the type of work can be further divided according to the durability

of the works. These categories are:

- i) Temporary works to check erosion at the time of emergency;
- ii) Semi-permanent works that will last and will be effective for comparatively short time; and
- iii) Permanent works.

The protection works undertaken in India so far under the above categories are as follows:

4.1 Direct Protection Works

4.1.1 Temporary and Semi-permanent Works

These include the construction of flexible screens made up of matured bamboos interwoven by wires, bamboo pallsading constructed with whole matured bamboos and bamboo floating raft. Permanent works constructed include bank revetment and vegetable cover either by turfing or sodding or by quick-growing plants. The temporary and semi-permanent works mentioned above have been carried out on the Brahmaputra and its tributaries. Construction of revetment as a permanent measure has been adopted at a number of places such as Gauhati, Dhubri, Jorhat, etc. along the Brahmaputra in Assam and for the protection of Muzaffarpur on the Burhi Gandak in Bihar. Bank protection by plantation has been done on the Krishna river downstream of the Vijayawada barrage.

4.2 Indirect Methods

4.2.1 Temporary and Semi-permanent Measures

These include the construction of bamboo spurs and tree spurs.

4.2.2 Permanent Measures

These include construction of permeable spurs made with wooden piles, semi-permeable boulder spurs which are essentially permeable spurs, but strengthened by dumping boulders on both upstream and downstream and impermeable spurs which consist of rockfill or earth core armoured with resistant material like stones, fascine mattress or sausages filled with stones.

4.2.3 Indirect protection measures, both temporary and permanent, have been used on the Brahmaputra and its tributaries. Semi-permeable and impermeable spurs have also been used in the protection of the river margin on the right bank of the Great Gandak river, downstream of the Gandak barrage.

4.3 Bottom panelling which has been developed in the Chateau Laboratories in France has also been tried as an anti-erosion measure at Dhubri on the Brahmaputra where the bank has been subjected to severe erosion, with the idea of inducing siltation near the bank. This work consists of panels of corrugated sheets or any other material resting on the river bed and held in position by vertical piles driven below the bed level. The method has been found to be very successful in low water training for navigation purposes. Its use at Dhubri has, however, not been very encouraging as an anti-erosion measure, but it is felt that if the work is planned properly after a study of the changes in the river course for a number of years from aerial photos and surveys and the work is carried out in addition to other training measures, it can be effective and the maintenance of conventional anti-erosion works can be substantially reduced.

4.4 Dredging has not so far been adopted as an anti-erosion measure. However, it has been considered that dredging could be carried out to provide a suitable leading

channel to divert the main stream from the vulnerable bank. With this intention, arrangements have been made to procure two dredgers to work at selected places along the Brahmaputra where erosion of the banks is a serious problem.

4.5 Concrete and timber mattresses have been extensively used on the Mississippi river in the United States for bank protection and have been found to be very effective. However, these measures have not so far been tried in India due to their high cost and also the costly plant and machinery that are required in their execution.

5. EXAMPLES OF SOME ANTI-EROSION MEASURES

5.1 During the last 15 years, a number of anti-erosion measures have been taken up on different rivers for the protection of important towns and areas. Some of the more important are discussed briefly to indicate the size of the problem, nature of measures taken and their cost.

5.2 Dibrugarh Town Protection Works (Assam)

The problem of erosion by the Brahmaputra in the vicinity of Dibrugarh had existed for a long time. But it had assumed serious proportions after the earthquake of 1950. By 1954, the erosion had become so severe that it posed a threat to the safety of the town. The erosion was in a length of about 3,600 m. The measures to check erosion were evolved after conducting model studies. These measures comprising of stone spurs, semi-permeable spurs, permeable spurs and revetment were completed in 1957 at a cost of Rs. 2.3 crores. By 1962, the erosion moved downwards affecting a length of about 3,600 m. The protection work had therefore to be extended and existing works strengthened. These have been completed at a cost of Rs. 2 crores. The capital cost of the works so far

implemented for the protection of the town and adjacent areas is about Rs. 4.5 crores.

The protection works have stood well, even though they have been under continuous attack of the river through successive monsoons. These have required continuous and often heavy maintenance. The average annual maintenance cost is about Rs. 8 lakhs.

5.3 Dhubri Town Protection Works (Assam):

Erosion has been taking place on the right bank of the Brahmaputra near Dhubri since 1955. This erosion is over a length of about 4,300 m. Anti-erosion measures by providing revetment over a length of 1220 m were taken in 1955-56. Subsequently, erosion continued downstream of the protected reach to some extent but it became serious after the floods of 1968 threatening some of the vulnerable assets on the river bank. The area eroded since then is about 130 ha. Anti-erosion measures have been taken up for implementation early in 1970 on the advice of C.W.P.R.S. These consist of 2,400 m of revetment and one stone spur to divert the flow away from the bank. The estimated cost of the work is Rs. 97 lakhs.

5.4 Mansi Protection Works (Bihar)

In 1961, the main course of the Ganga was at a safe distance from the North-Eastern Trunk Railway line to Assam and the National Highway No. 31 near Mansi. During the floods of 1961 and 1962, severe erosion took place, and as a result, the left bank of the river came within 750 m of the railway line. It was considered necessary to check further erosion in the interest of the safety of the railway line and the national highway. Accordingly, nine short spurs were constructed in 1964, at a cost of Rs. 36 lakhs. Subsequently, the erosion moved downwards

and 300 metres of river margin was eroded during 1964 in a length of 4 km. Three more spurs were constructed in the affected reach at a cost of Rs. 31 lakhs. In the following years, these spurs have been under constant attack necessitating repair and additional works at a cost of Rs. 28 lakhs during the period 1965 to 1968. -

During the floods of 1969, the upstream spurs came under severe attack and suffered considerable damage. The margin left between the railway line and the river bank was only about 300 m. It was considered that without anti-erosion measures there is considerable danger of the river moving further northwards endangering not only the railway line and the highway but also leading to the possibility of an avulsion into the Bagmati. Therefore, proposals have been made for strengthening of the existing spurs to the required standards. These are estimated to cost Rs. 1.6 crores. Some portion of the proposed works have been executed at a cost of Rs. 45 lakhs before the floods of 1970. Further works will be carried out after the floods taking into account the river behaviour.

5.5 Kosi River Training Works (Bihar)

In the past the river Kosi had shown a tendency to move westwards. It was also spilling over the banks almost annually causing considerable havoc. The tendency to move westwards and the spilling have been controlled after the construction of the Kosi barrage and the flood embankments lower down. The river at present swings between the two marginal embankments and in the process attacks the river margin and embankments at different places. In order to control the attack to ensure the safety of the embankments, protective measures have been taken almost every year. These consist of closing of spill channels and construction of permeable and semi-permeable and impermeable spurs. Dredging has also been tried to develop a central channel. The average annual cost

of such measures is about Rs. 75 lakhs. These measures will have to be continued for some more years till the river attains stability conditions.

5.6 Protection Work on the Left Bank of the Ganga near Gaighat (U.P.)

An embankment known as the Ballia Baria Bund 32 km in length was constructed in 1959 at a cost of Rs. 14 lakhs to protect an area of 25,000 ha on the right bank of the river Ganga near Gaighat. When the bund was constructed, the minimum distance between the river margin and the embankment was over 0.8 km. During the last few years, the river has been eroding its left bank in a length of about 2.6 km.

Protection measures were carried out between 1965 and 1968 to check further erosion. These measures mostly being of the nature of temporary works such as short permeable spurs, and dumping of wire crates filled with burnt bricks were not successful and erosion continued. The average rate of erosion in each year was about 50 m. In 1968, the main course of the river came within 12 m of the toe of the bund in a length of about 300 m. During the 1969 floods, a part of the embankment in this reach was eroded. A possible breach was averted by taking emergent measures consisting mainly of dumping wire-crates filled with burnt bricks.

While there is a proposal to retire the embankment to protect as much area as possible, in case the bund should fail, there is a persistent demand to hold the river at the present position. Accordingly a scheme has been drawn up after carrying out model experiments. This is likely to cost about Rs. 3 crores and consists of six solid spurs and five submersible bars with pitching between the spurs. As this scheme is still to be finalised and can be implemented

only after the floods of 1970, temporary measures to hold the river have been carried out by dumping wire crates in the affected areas at a cost of Rs. 10 lakhs before the floods of 1970.

5.7 Protection works on the Right Bank of the River Gandak (U.P.)

Like the Kosi in Bihar, the Gandak has a tendency to move westwards and spill in some parts of U.P. and Bihar. An embankment known as the Chhitauni Bund was constructed in a length of 22 km in U.P. territory at a cost of Rs. 22 lakhs to protect an area of 50,000 ha in 1954. Lower down in Bihar territory also, embankments have been constructed on the right bank for protection against floods.

Since its construction, the Chhitauni Bund was subjected to periodic attacks by the river and consequently, anti-erosion and river training schemes had to be taken up for saving the embankment. Up to 1965-66, the investment on the works of the Chhitauni Bund amounted to Rs. 114 lakhs. In spite of these measures, the lower portion of the embankment in a length of about 6 km was washed away.

The western movement of the river was also affecting the river margin upstream in Nepal territory. With the taking up of the Gandak project, it became necessary to take measures for ensuring the safety of the Western Gandak Canal. With this object, works consisting of spurs were carried out in the Nepal territory at a cost of Rs. 1.6 crores between 1963 and 1965. Subsequently, these works were strengthened by additional spurs at a cost of about Rs. 70 lakhs based on the recommendations of the Chhitauni Bund Committee appointed by the Government of India, in 1965.

Between 1935 and 1967, the river started eroding the right bank in the upper reaches of the Chhitauni Bund. This posed a serious threat to the Western Gandak Canal. Anti-erosion and river training works mainly by construction of long spurs were carried out between 1936 and 1968 at a cost of Rs. 5 crores based on the recommendations of the Chhitauni Bund Committee.

The above works have helped in diverting the river away from the bank and to prevent further western movement. However, during the last two years, erosion has shifted downstream along the Khadda Chhitauni Railway embankment near Chhitauni Railway Station. It has been considered necessary to hold the river at this railway embankment to save valuable cultivable areas and also some sugar mills. Accordingly, river training works have been taken up which will cost about Rs. 120 lakhs when completed. Bulk of this work has been completed before the floods of 1970.

There is a proposal to provide a retired embankment with adequate protection in the portion where the original Chhitauni Bund has been washed away in a length of about 6 km to protect the area from river spills. This work is expected to be taken up after the floods of 1970 and will cost about Rs. 70 lakhs.

3. LIMITATIONS IN THE IMPLEMENTATION OF THE ANTI-EROSION MEASURES

3.1 The experience of the anti-erosion measures undertaken at specific locations, as discussed in Section 4, indicates that such measures can be effective only if they are properly planned and constructed to the necessary standards. Temporary measures can only help in checking the rate of erosion and in gaining time for planning of permanent measures. Effective control is possible only by construction

of permanent measures such as stone spurs and revetment.

6.2 Anti-erosion measures which have been implemented so far have been very costly as is evident from the works carried out at Dibrugarh and on the right bank of the river Great Gandak for the protection of the Western Gandak Canal. Anti-erosion works also require careful maintenance often at very high costs. The initial cost and the cost of maintenance of anti-erosion works is much more than the flood protection works such as embankments. The benefit cost ratio of such work is also often very small. Therefore, at present, when the outlays that are available for protection measures are small and attempts are to be made to derive maximum benefits from the meagre available outlays, anti-erosion measures can be justified only when protection of large assets is involved. It is on this account that anti-erosion measures taken up so far have been mostly for protection of important towns such as Dibrugarh, Muzzaffarpur etc. and for ensuring the safety of vital structures such as the Western Gandak Canal and vital communications as in the case of protection works at Mansi.

6.3 It is desirable to take necessary steps against erosion as early as possible after it is first noticed. The cost of anti-erosion measures, when erosion is allowed to continue, leading to the development of deep scour and sharp and irregular bends in the river course will be many times more than if the problem is tackled in the initial stages. However, there are several difficulties in tackling of the problem with the desired speed. In the first instance, proper planning of the scheme has to be done after a detailed study of the river course and its behaviour over a number of years. The nature of the work and the effect of carrying out anti-erosion measures on other areas along the river will have to be studied on a hydraulic model. The collection of data and carrying out the tests necessarily take some time. Further, even when the works are planned it is often found that requisite funds are not available for the

speedy implementation of the work. It may, therefore, be necessary to extend or modify the erosion measures already planned after taking into account the changes in the erosion pattern during the various flood seasons over which the work is implemented.

In order to obviate delays in taking up of anti-erosion works, annual river surveys should be carried out on rivers which have problems of erosion, in addition to observation of continuous hydrological data.

6.4 As stated earlier in Section 1, erosion is caused by the instability of the river due to various reasons which include the effect of the works constructed across or along the river. Therefore, when anti-erosion measures are constructed for the protection of some areas, it is likely to cause disturbances in the regime leading to erosion and attack by the river at some other points. This may, in turn, require the extension of the works already constructed or new works at another point at a very high cost. This aspect has to be kept in view while planning anti-erosion measures.

Further, in alluvial rivers which build their own planes, bank erosion is more or less a continuous process, especially in their formative stages. This would necessitate a continuous maintenance programme even if erosion is stopped at some points.

6.5 In view of the high initial cost and maintenance cost and other limitations as stated earlier, anti-erosion measures will have to be restricted for the protection of important towns, strategic areas and vital communications. Anti-erosion measures for saving predominantly agricultural areas will not be justified especially at the present juncture when available resources will have to be utilised for getting maximum benefits.

**LIST OF IMPORTANT ANTI-EROSION WORKS
COMPLETED OR IN PROGRESS**

(in Rs. lakhs)

S.No.	Name of work	River	Estimated cost	Remarks
1	2	3	4	5

ASSAM

1.	Protection of Dibrugarh town	Brahmaputra	444	
2.	Protection of Gauhati town	Brahmaputra	35	
3.	Protection of Silchar town	Barak	30	
4.	Protection of Goalpara town	Brahmaputra	60	
5.	Protection measures at Kokilamukh	Brahmaputra	281	Work in progress
6.	Protection of Dhubri town	Brahmaputra	97	Work in progress

BIHAR

7.	Mansi Protection works	Ganga	95	Cost of works completed up to March 1969
8.	Strengthening of Mansi protection works	Ganga	156	Work in progress

1	2	3	4	5
9.	Protection and river training works along the Kosi embankments	Kosi	863	This is the cost of works implemented up to end of 1969.
10.	Muzaffarpur town protection works	Burhi Gandak	33	
<u>ORISSA</u>				
11.	Construction of spurs at Dalaighai	Mahanadi	32	
<u>UTTAR PRADESH</u>				
12.	Repairs and Reconstruction of Varanasi Ghats	Ganga	201	
13.	Chhitauni Bund Protection works	Great Gandak	500	
14.	River Training works along the Khadda-Chhitauni Railway line	Great Gandak	150	Work in progress

WEST BENGAL

15. Jalpaiguri town protection works	Tista	66
16. Cooch-Bihar town protection works	Torsa	61
17. Protection of eroded Right Bank of the Bhagirathi at Kalna in the district of Burdwan	Bhagirathi	27

DELHI

18. Construction of spurs and revetment on the right bank of river Yamuna from Power House to Nallah No. 12	Yamuna	13
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TRIPURA

19. Belonia town protection scheme	Muhuri	11
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