Flood Prevention in the Rivers of Bihar, North Bengal and Assam

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To keep the river channel deep and free from siIt, and the course of the river straight—this is the only acceptable aim of river graining which dams and revetments do not secure.

Dead and dying rivers are a curse; silking and rising river beds aggravate instead of preventing floods. Bengal engineers, therefore, have very good reasons for fighting shy of embankments. 'This docs not mean that they are prepared to resign themselves to the ravages of Hoods,

Modern engineering can improve upon indigenous methods for dcepening river beds and keeping them silt free. Flood damages from rivers in Bihar, North Bengal and Assam can be prevented by parallel works of permeable screens constructed with materials that are available locally and the work can be done by local labour, under local supervision, as bandalling is well known on North Indian rivers. It will not be necessary to have foreign experts, nor much foreign exchange.

The author who had been intiamately connected with rivers in Assam and Bihar, as Special Officer, Rivers, in the Assam PWD and Member, Development Hoard, Bihar, argues persuasively for the adoption of permeable screens. A summary of the principal findings and conclusions precedes the. article.

Summary

THE floods have affected 30,000 square miles in Bihar, North Bengal and Assam, where 10 million people live, the damage being Rs 100 crores. Only flood-stricken people can realise what a calamity it is.

Excessive precipitation is beyond the control of man. Attempts have been made by man to reduce the ill effects of excessive precipitation, the methods adopted being:

(1) Embankments to confine the waters within the river.
(2) Afforestation to reduce the run-off from a river catchment.
(3) Dams and reservoirs to reduce river flow.
(4) Channel improvement to increase the discharging capacity.

The evils of embankments are well known. In China, embankments have caused a gradual rise in river bed and flood heights, necessitating rise in embankment heights, so that the Yellow River now flows high on a ridge of the alluvial plain. A breach in its banks causes sudden submergence, and in 1897 led to the death of a million people.

EMBANKMENTS CONDEMNED

In the USA, between 1777 and 1927, embankments along the Missis sippi had to be raised 17 feet higher. Yet the 1927 floods caused breaches and 350 people died. Embankments arc destroyed by river erosion. 'Thus in the Yazoo Embankment District, 305 miles of new embankments have been constructed on successive retired alignments, to maintain the 178 miles originally constructed.

In India, embankments have generally been condemned. A Chief Engineer, Bihar, considers that embankments are " in no small measure responsible for the present troubles ". Embankments cost large sums of money, are unremunerative and do not provide protection against major floods.

Afforestation, terracing, or con torn bunding, has little effect on the volume of water that runs off a river catchment, during periods of prolonged heavy precipitation, when rivers break into flood.

Dams and reservoirs can effect a reduction in the volume of flow, thus lowering flood heights in the lower river. But as an alluvial river automatically adjusts its channel to correspond to its flow requirement, reduction in flow leads to deterioration, and in a few years the lowering effect of flood heights in the lower river is vitiated,

That a reduction in the volume of flow deteriorates a river channel is evident from the example of the Bhagirathi after the diversion of Ganga water through the Padma, and that of the Ganga after diversion of its water through the irrigation canals.

Floods have occasionally readied great heights, causing immense damage, even when a river is carrying a comparatively low discharge. 'Ibis happened in July 3943 in the Damodar, when it was carrying a discharge of only 300.000 cusees or less than half that of 640,000 cusecs, which it drained away without flood damages in 1041. Similarly flood occurred in the Kosi in 1953, when it carried a discharge of only 2.30,000 cusecs, less than half that of 470,442 cusecs, which it drained away *in* 1048.

The fundamental truth is that a river is created in the process of drainage of water, the flow of water being due to the action of gravity down the inclined plane of the land, its channel being formed by the power of erosion and of transportation of silt load, of running water The fact that flood can be high and flood damages can occur, when a river is carrying a low discharge, shows that flood heights do not depend on the volume of discharge, but on the discharging capacity of the river. A river with a narrow, deep and straight channel has a high velocity and a high discharging capacity. A river has a natural tendency to concentrate into a narrow, dqcp and straight channel. Many rivers with credible banks have been observed to maintain a straight and stable alignment.

The Seine and the Weser in Europe have been guided to a narrow, deep and straight alignment, joined by flat curves, by a series of parallel works of guide dams, the cost of winch is very high, on account of the large quantity of stone laid in the flowing water on the river bed.

PERMEABLE SCREENS AS GUIDE DAMS

In India, Steamer Companies use bamboo band ailing, to narrow and deepen a wide and shallow river, for providing a navigation channel in the dry season. The bamboos of the bandalling, however, get undermined and topple over as the channel deepens;. To prevent this, the author has developed a type of bandalling—permeable screens—which has a wide base, resting on the river bed, so that toppling over is prevent erh when the channel deepens. Permeable screens act in the same way as guide dams, guiding a wide and shallow river with a' tortuous alignment, to a narrow and deep channel with a straight alignment, joined by flat .curves." The cost of the screens varies from Rs 20 to

Rs 40 Per running foot.

The high velocitv in the narrowed river maintains a stable alignment, as the current flows parallel to the parallel new banks of the river. The high velocity also transports the whole of the silt load to- the river's outfall into the sea, so that its channel is maintained in good order. The river is thus able to drain away its maximum discharge, flood heights remain low, and there are no flood damages.

Where there is an important city, the new parallel river banks, formed by the permeable screens, are protected by pairs of guide banks, in which bricks or stones are laid on the slopes of the bank to a thickness of 3 or 4 feet. The length of each guide bank is 2½ times the width of the narrowed river. The cost of guide banks varies from Rs 300 to Rs 600 per running foot, depending on. the depth of maximum scour.

Flood damages from the Kosi, Tista, Torsa, Brahmaputra, etc, can be prevented by a series of parallel works of permeable screens, in which local materials are used, by local labour, and under local supervision, as such bandalling works are well known in rivers in North India,

Thousands of square miles of fertile lands will thus be reclaimed from the wide, sandy waste of existing river beds, in the process of narrowing and deepening of the rivers, to form parallel river banks. Food crop production will thus be increased, while the deepened channel will provide perennial navigation, so that crops could be easily carried and sold at the most profitable markets, which will be an inducement to grow more food. Land for rehabilitation will also become available.

How to Control Rivers

UPPERMOST in the minds of every Indian today is how best we can relieve the distress of our flood-stricken countrymen. It is, however, a colossal task, as 30,000 square miles of Bihar, North Bengal and Assam have been affected, 10 million people have been hit by the floods, the damage being estimated at Rs 100 crores. A flood goes on for days and sometimes for weeks. Thousands of families with women and children, the aged and the sick, have to leave their homes in a hurry, sometimes wading for miles through water, with a few belongings that they can carry, exposed to rain, storm, or the sun. They consider themselves lucky, if they can find even temporary shelter. Food is scarce, and there is sickness. When flood water subsidies, it leaves a whole area plastered in mud and stench. One has to imagine the heartache of these countrymen of ours, as they return to their wrecked homes and devastated lands. Floods bring in their wake hunger and disease, while the flood-Stricken have to eke out a miserable existence after lit flood is over.

RE FLOODS BENEFICIAL?

There is a belief that floods are beneficial the flood waters depositing rich vium that vitalises the soil Flood waters, from rivers in their upper reaches immediately below the fool Wills, do not deposit alluvium on river side lands, but sand. Thousands of square miles of fertile lands in the upper Kosi valley have thus become barren. Half a century ago, our British Rulers considered floods beneficial. F J E Spring, a Chief Engineer in the PWD, wrote (Government of India Technical Paper No 153 of 1903—River Training and Control, Chapter IV, para 12, page 14):

> " It is pretty certain that at least once in each generation and possibly half a dozen times, the inhabitants . . . are liable to find themselves . . . dug out of house and home. . . . 'These vicissitudes are by no means looked on as calamities of the first magnitude, as would be the case with a *white* race *living* under while men's *conditions.* They merely necessitate a more or less hurried shifting of a few bamboos and mats and of not more household goods than can easily be carried in a few trips of the family boat, . . . The excellence of the newly *deposited* soil . . . quite compensates *them for the temporary* inconvenience incurred, in. a warm climate where the river people may *almost he* described as semi-aquatic."

In modern times, should we consider the horrors of a flood as " temporary inconvenience", which is " quite compensated by the excellence of the newly deposited soil "? Should our countrymen be considered as " semi-aquatic " beings? Should not they ever aspire to live as members of " a white race " under white men's conditions?

METHODS OF FLOOD PREVENTION

A river has flood when its channel is not able to drain may to waters quickly, so mat there is rise in the level of the water, overflow of water from its channel and submergence of land. For prevention of overflow from a river, the methods adopted are:

(1) Embankments to confine the flood waters within the river channel.

(2) Afforestation, etc, in the catchment area for absorption of rain water by the soil, thus reducing the volume of water that runs off into a river channel, thereby lowering flood heights.

(3) Dams and reservoirs, releasing a regulated discharge, thus reducing the volume of water flowing through the lower river, thereby lowering flood heights.

(4) Channel improvement works, increasing the discharging capacity of the river to drain away quickly the maximum discharge.

EVILS OF EMBANKMENTS

Embankments have existed in China from 603 BC, along the Yellow River. From old Chinese records, it appears that embankments have proved uneconomical and positively harmful. River bed levels and flood heights have risen, so that height of embankments had to be raised, and now the Yellow River flows high on a ridge of the great alluvial plain. Under such conditions, a breach in the river banks causes sudden submergence of lands. Thus in 1897, breaches in the Yellow River banks caused the death of a million people.

In the USA, embankments were first raised in 1777, along the Mississippi River. As in the Yellow River, due to a gradual rise in river bed levels and consequently in flood heights, the height of embankments had to be raised by as much as 17 feet by 1927. Yet in 1927, floods breached the embankments, caused the death of 350 people and extensive damages estimated at billions of dollars. Maintenance of the embankments costs a lot of money from year to year. Thus in the Yazoo Embankment District in the Lower Mississippi there are 178 miles of embankments. Most of these have been destroyed by erosion, necessitating the construction of 305 miles of new embankments on successive retired alignments.

In Bengal, C Addams-Williams, a Chief Engineer, wrote in 1920, With regard to embankments, our experience has been that wherever they exist, they raised problems as great, if not greater than they were intended to deal."

In Modern India Series 6, issued in 1949 by the Publications Division, Ministry of Information and Broadcasting, Government of India, it is stated in Chapter 7, page 40:

"The present policy of keeping floods in check by marginal embankments is not successful. It costs large sums of money, is unremunerative, and does not provide protection against major floods."

In the Damodar River in West Bengal, embankments were originally constructed along both banks of the river by local zamindars. Their maintenance was taken over by the Government in 1846. As many breaches occurred from year to year, the right bank embankment was removed in i860. Even then the left bank embankment has continued to be breached.

In a Foreword to the "North Bihar Flood Problem", published by the Bihar Government in 1048, Capt G F Hall, Chief Engineer, writes:

"In the old days whenever flood problems arose, the answer was let us build a bandh (embankment). . . . Famine relief works, which frequently comprised the erection of bandhs, were in no small measure responsible for the present troubles."

At the annual meeting of the Central Board of Irrigation and Power in 3953, our Prime Minister remarked:

"When floods appear, we run with a shovel in our hands to collect earth for preventing floods."

But on September 14, 1954, Shri Gulzarilal Nanda, Union Minister for Planning, said:

' If we can muster 230,000 able-bodied persons for a period of four months each year, the work of the construction of embankments on both sides of the Kosi can be completed within a period of two years, instead of the scheduled period of six."

Early in September 1954, the Chief Minister of Assam said:

"We hope to take up immediately a- scheme for running embankments along the Brahmaputra, from a point near the foothills to the point where it reaches the border of the State."

Thus in spite of the fact that the evils of embankments are so well known, how pitiful the attempt is, "to run with a shovel in our hands to collect earth for preventing floods", 'by building embankments!

LOWERING FLOOD HEIGHTS BY AFFORESTATION

Afforestation, terracing, or contour bunding of hill slopes, no doubt, increases the absorption of water by the soil in a river catchment, so that there is reduction in the volume of water that runs off into a river channel. In fact, in the earlier part of the rainy season, the porous, crumbly, forest soil, or the terraced or bandhed hill slope, absorbs practically the whole of the rain water that falls on it. But after the first month or two of rainfall in the four months of the rainy season, the soil becomes thoroughly saturated with water. If there is then continuous heavy rain for 2 or 3 days or more, giving no chance for the soil to dry, it can absorb no more water. On such forest covered, terraced, or contour bunded river catchment, rain water flows with practically no absorption, as over bare consolidated soil.

That there is no noticeable effect on the volume of water that runs off a river catchment, by either deforestation or afforestation, appears to he the experience in the USA, and France. G W Pickels has mentioned in his Flood Control Engineering, page 63:

"The bed of humus and debris that develops under a forest cover, retains precipitation during the summer season, or moderately dry periods at any time of the year, more effectively than do the soils and crops of deforested areas similarly situated. It acts as a reservoir moderating the rim-off from showers and mitigating the severity of freshets, and promotes uniformity of flow at such periods.

"The above action fails altogether in periods of prolonged and heavy precipitation (italics mine), which alone produce great general floods. At such times the forest bed becomes thoroughly saturated, and water falling upon it flows off as readily as from the bare soil. Moreover, the forest storage, not being under control, flows out in swollen streams, and may, and often does, bring the accumulated waters of a series of storms in one part of the watershed upon those of another which may occur several days later: so that, not only does the forest at such times exert no restraining effect upon the. floods, but, by virtue of its uncontrolled reservoir Action, may actually intensify them.

"The effect of forests upon the run-off resulting from snow-melting is to concentrate it into brief periods and thereby increase the severity of freshets. This results (a) from the prevention of formation of drifts, and (b) from the prevention of snow-melting by sun action in the spring, and the retention of the snow blanket until the arrival of the hot weather.

"After the great 1910 flood on the Seine River in France, the French engineers investigated the effect which reforestation of some 595,000 acres of land in the Seine Valley would have on a flood of similar magnitude. The conclusion was the total volume of flood discharge would be decreased about 5 per cent at a cost *of* $35,600 per million cubic feet of water stored and transpired by the forest cover. The engineers recommended that:

"The government should not take up the reforestation of the Seine Basin directly; especially as they considered that the action of heavy forest cover in retarding run-off disappears *almost entirely in the* great *rainfalls* (italics mine) that cause the Seine floods; and also considering the rich agricultural lands that would be taken up for forests.

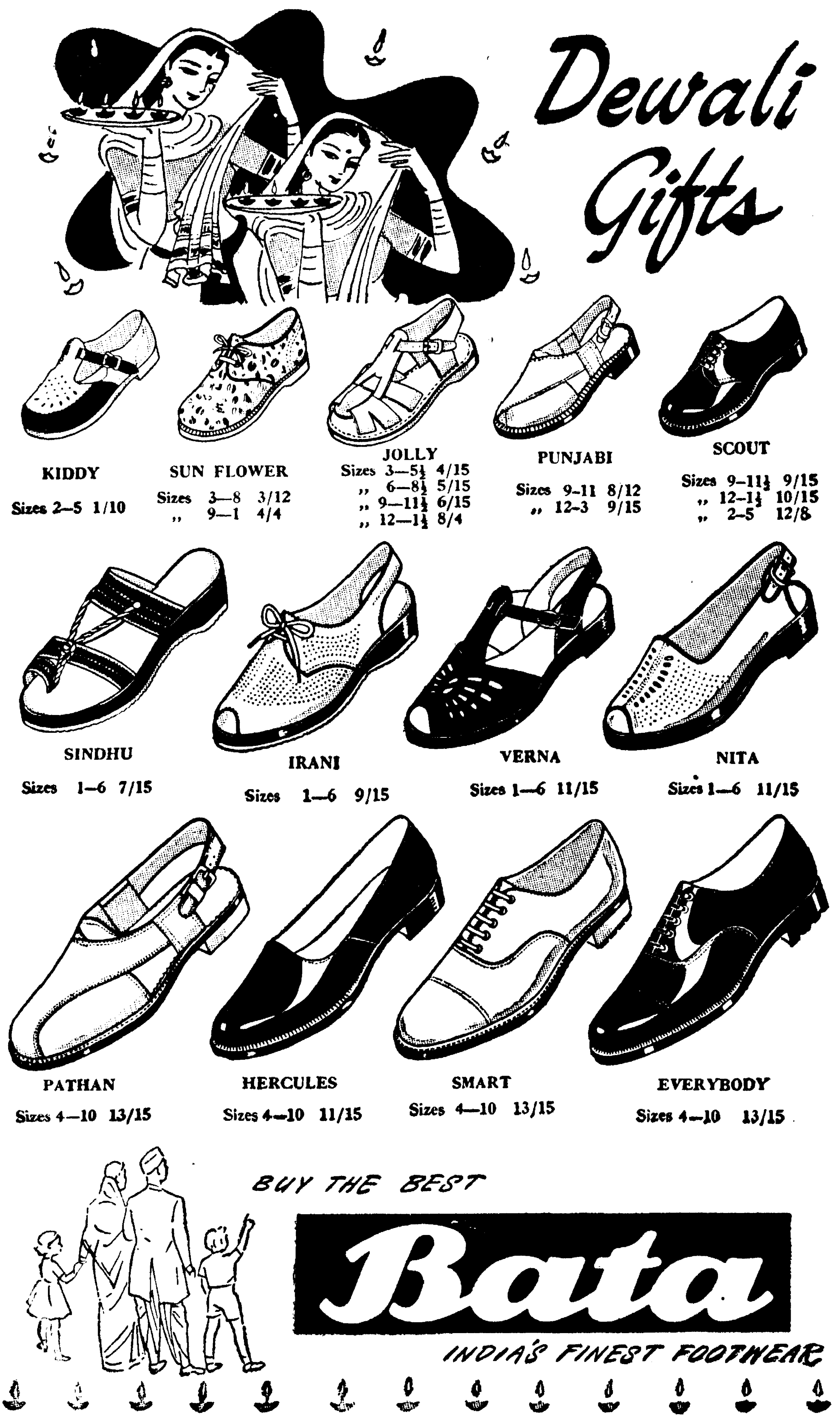
The Director of the French Forestry Service in his Report *on* the 1910 flood stated:

"In the exceptional circumstances which always produce the floods of the Seine, the action of forests, whether evergreen or deciduous, becomes for the moment negligible in its effect on the volume of water carried by the river",

Tims in the latter part of the rainy season, in August and September, when floods occur, reduction in the volume of water that runs off a river catchment into a river channel, is not possible by afforestation, or terracing, or contour bunding of the hill slopes. There can thus be little or no lowering of flood heights in the river channel.

BY DAMS AND RESERVOIRS

By constructing a dam across a river, the water running off a river catchment can be collected m the reservoir. A regulated release at the dam can effect a considerable reduction in the volume of flow in the lower river, resulting in lowering of



Dewali Gifts
KIDDY
Sizes 2—5 1/10
SUN FLOWER
Sizes 3—8 3/12
" 9—1 4/4
JOLLY
Sizes 3—5½ 4/15
" 6—8½ 5/15
" 9—11½ 6/15
" 12—1½ 8/4
PUNJABI
Sizes 9-11 8/12
" 12-3 9/15
SCOUT
Sizes 9-11½ 9/15
" 12-1½ 10/15
" 2-5 12/8
SINDHU
Sizes 1—6 7/15
IRANI
Sizes 1—6 9/15
VERNA
Sizes 1—6 11/15
NITA
Sizes 1—6 11/15
PATHAN
Sizes 4—10 13/15
HERCULES
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SMART
Sizes 4—10 13/15
EVERYBODY
Sizes 4—10 13/15
BUY THE BEST
Bata
INDIA'S FINEST FOOTWEAR

flood heights. The fundamental faw of hydraulics, proposed by Doincmco Guglielmini, in the 17th century, is:

> An alluvial river automatically adjusts its 'channel to correspond to its flow requirements.

The reduction in the volume of flow, by the regulated release at the dam, will cause the lower river to adjust its channel to correspond to its flow requirement, so that its channel will deteriorate.

That tins happens, is also the opinion of Shri Kanwar Sain, Chairman, CW & PC, which will appear from his speech, published in the January 1954 issue of the Journal of the Cenral *Board* of *Irrigation* and Power:

> " With the construction of a dam in the upper reach of a river, a problem sometimes arises whether the lower reach can be kept alive with the diminished supplies from the storage dam."

Such deterioration in the lower river channel, as a result of the reduction in the volume of flow effected by a regulated release at the dam, would, in a few years, follow the lowering of flood heights.

REDUCTION IN FLOW AND SILTING OF RIVERS

That there is deterioration of the lower river channel, with a reduction in the volume of maximum flow, will be evident from the example of the Bhagirathi, which in ancient tunes was the main outfall channel of the Gauga waters. After the diversion of Ganga waters through the Padma, the Bhagirathi is now a branch of the Padma. In the 4 months of the flood season, only a part of the Ganga waters flows through the Bhagirathi, the flow being cut off in the 8 months of the dry season. As a result of the reduction in flow, the Bhagirathi channel has deteriorated considerably, so that its bed, and consequently flood heights, have been raised. At present, even with the reduction in the volume of flow, there is overflow and flood damages from the Bhagirathi. Another example is that of the Ganga. From time immemorial, and at least for the last 2000 years, the Ganga has acted as the highway for commerce, so that flourishing cities have sprung up on its banks. In the days of the East India Company, steamers used to ply between Calcutta and Garhmuktesar, which is about 55 miles cast of Delhi, carrying passengers and goods. With the construction, of the Ganga Canals, a considerable volume of uanga waters was diverted through them for irrigation. With a reduction in flow, there has been deterioration of Che Ganga channel, as a result of which steamers of even 5 feet draft cannot go up the Ganga beyond Monghyr.

LOW FLOOD DISCHARGE AND FLOOD HEIGHTS

Another phenomenon that has been observed is that even when a river is carrying a comparatively low flood discharge, flood levels have been high, there have been overflow horn the river and flood damage-,. Thus in the Damodar 111 West Bengal, a discharge as high as 640,000 cusees in the year 1941 could be drained away without overflow and flood damages. Yet in July 1043, when the Damodar was carrying much less than half this discharge, or 290,000 cusees, flood levels were high, there was overflow and submergence *of* the country near Burdwan " to a depth of 6 or 7 feet at several places and many villages were devastated ", the El Railway lines were breached and railway communications stopped from July 18 to October 8. Similarly in the Kosi, the maximum discharge observed in 1948 was 470,442 cusees. Yet in 1053, when the Kosi was carrying less than hall this discharge, or 230,000 cusecs, flood levels were high, there was overflow and sub mergence of 1,085 square miles of North Bihar, with flood damages estimated at Rs 21 crores.

THE TRUTH ABOUT A RIVER

The fact that extensive flood damages have occurred from a river, when it was carrying less than half the flood discharge, as recorded in certain years, shows that a reduction in the volume of flow, by afforestation, terracing, or contour bunding, may not always lead to a lowering of flood heights. Similarly dams and reservoirs, by causing a reduction in the volume of flow through the lower river, may not always lead to a lowering of flood heights. On the contrary, such heavy reduction m the volume of flow by dams and reservoirs leads to deterioration of its channel, " while a problem sometimes arises whether the lower reach can be kept alive with the diminished supplies from the storage dam" Such deterioration of a channel is explained by the fundamental law of hydraulics that an alluvial river automatically adjusts its channel to correspond to its flow requirements. The idea of constructing embankments to confine the flood waters within the river channel, appears to have arisen from the belief, that man is living in a hostile world, where he has to wrest all the wants from an unwilling and alien arrangement of things, that he has to discipline himself to fight nature, that he has to tame nature and force her to serve his purpose. I his belief is not, however , correct. The great truth should be realised that man can use the forces of nature for his own purpose, in so far as these purposes are 111 harmony with nature and do not knock against nature's laws. The life object of man should be to realise the fundamental truth of the unity of creation, this great harmony in feeling and action. Man has to live m a state of fear, so long as he is not able to find this truth, Facts are many; but truth is one. The apple falls from the tree, rain descends upon the earth—these are facts; but once the law of gravitation is realised, the necessity of collecting facts *ad infinitum,* can be dispensed with.

The fundamental truth about a river is: A river is created in the process of drainage of water from precipitation on the land back to the seas, the flow of water being due to the action of gravity down the inclined plane of the land, the river channel being formed by the power of erosion and of transportation of sediment load. Tin's motive force of gravity should be utilised by the river for the drainage of water and for the transportation of sediment load, to its outfall into the sea, and not dissipated in the erosion of river banks and in disturbed flow through an irregular shaped channel of varying width and depth. The laws governing the flow in rivers are the same for all rivers in all countries. Once the fundamental truth about river flow is realised, the methods to help nature in channel improvement may be evolved. Harrington Emerson has stated : " As to methods there may be a million . , but principles are few. The man who grasps principles can successfully *select* his own methods. The man who tries methods, ignoring principles, is sure to have trouble".

QUICKER DRAINAGE TO FLOOD HEIGHTS

The fact that the flood level may rise even when a river is carrying a comparatively low flood discharge, shows that flood docs not always depend on the volume of discharge. Flood height also depends on the condition of the river channel. It should be realised that a river channel does not always maintain the same shape, size, or depth, For example, if there is erosion of river banks with widening of river channel, there is decrease in velocity, deposit of silt, rise in river bed level, together with corresponding rise in flood heights; where a channel becomes narrow, there is increase in velocity, downscouring and deepening of river bed and lowering of flood heights. Thus in the 1954 floods in the Brahmaputra, although the flood height at Dibrugarh was the same as that of 1946, the flood height near Cauhati was 5 feet lower. This may be explained by the fact that since 1046, the Brahmaputra has widened and shallowed its channel at Dibrugarh, while with hills on both banks near Ganhati, there has' been no erosion of river banks. The width remaining the same, the river has deepened its channel, so that the velocity of flow and the discharging capacity have increased. With a quicker drainage of water, flood heights have been lowered by 5 feet.

A NARROW, DEEP AND STRAIGHT CHANNEL

It is observed that in a wide river, water has a tendency to flow through a narrow, deep and straight channel. C Addams-Wilhams, a Chief Engineer, Bengal, wrote in ipso:

> " In a wide channel, the current is liable to concentrate into a local gutter; so why not provide what the river requires at the outset? "

A narrow, deep and straight channel develops a high velocity and consequently a high discharging capacity. A river with a high velo ' city is found to maintain a straighter and stabler channel. F J E Spring says (River Training and Control, page 15):

> " A comparatively rapid current may flow alongside and parallel to an erodiblc bank, without causing it to cave appreciably ".

Similarly G W Pickels writes (Flood *Control* Engineering, page 333):

> " As an example, there is a straight stretch of the Missouri River above the mouth of the i file Sioux River, where the banfs on both Sides are *of* sand, unprotected by revetment, yet the stretch has not changed its position more than 50 years. Also the channel of the Mississippi River between St Louis and Cape Girardeau ant below New Orleans is unusually stright and stable."

In a narrow, deep and straight channel, the velocity of flow and the discharging capacity is high, maximum flood discharge is drained away quickly, so that flood heights remain low, there is no overflow and no flood damages from the river. In extra-ordinary floods, which occur at intervals of many years, flood height may rise above the natural river banks and river side lands' may be submerged. But owing to the quicker drainage, the period of submergence is for a few hours or may be a little longer, so that the inconvenience caused to the inhabitants is not great.

CHANNEL IMPROVEMENTS BY PAIRS OF GUIDE DAMS

The natural tendency of a river to concentrate into a narrow, deep and straight channel, has been helped by parallel works of guide dams, in the Seine in France and in the Weser in Germany. The guide dams are generally constructed of stones, laid on the river bed in a triangular section, along two short lengths of parallel straight lines, opposite each other, and along the alignment of the new parallel river banks. A series of pairs of parallel guide dams are constructed at suitable distance apart along the river course. The decrease in the velocity, between the guide dam and the original river bank, causes silt deposit on the river bed, so that new parallel river banks are formed. The increase in velocity, between the parallel guide darns, dowmcours and deepens the river channel. A series of pairs of parallel guide dams thus guides a wide and shallow river into a narrow and deep channel, with a straight alignment, joined by flat curves. Each pair of guide dams draws in the river channel from upstream, narrows and deepens it, and straightens its alignment downstream. The straightening action on a river channel downstream by a pair of guide dams, together with the drawing in action of the next downstream pair of guide dams, prevent erosion of the the revetted concave bank, between the adjacent pairs of guide dams, and neutralises the natural tendency of the river bend to migrate downstream. A series of pairs of parallel guide dams thus guides a river into a narrow, deep and straight channel, joined by flat curves, and ensures a stable alignment for the river. The cost of such guide dams, owing to the enormous quantity of stones laid on the river bed in flowing water, is very high.

BAMBOO BANDALLING BY STEAMER COMPANIES

In India, parallel works of bandalling, consisting of bamboos driven in the river bed, have been in extensive use by the steamer companies to provide a narrow and deep channel in the wide and shallow rivers in the dry season. In such bandalling, the bamboos are driven in the river bed to a depth of 3 or 4 feet. Due to decrease in velocity between the bandalling and the original river bank, there is deposit of silt on the river bed, while between the lines of bandalling, there is increase in velocity and downscouring' of the river bed. Thus the necessary depth is provided for navigation. With the deepening of the river bed, the bamboos of the bandalling are under minef and they topple over. As such bandalling works arc only temporary, the greater river depth in the next flood season makes their use unnecessary. The cost is also very low, being not more than about Rs 8 per running foot. Such bandalling can be constructed by local labour with bamboos, strings, etc, all available locally.

PARALLEL WORKS OF PERMEABLE SCREENS

To prevent the bamboos from being undermined, a type of bandalling was developed by the author, which is known as permeable screens. It consists of units of trapezoidal structure, each about 10 feet long, having a triangular section, the bottom width varying from 6 to 12 feet and the height varying from 12 to 24 feet, according to the depth of water in the river. These are constructed of stout bamboos, fixed to each other at the joints by mild steel wires. Each unit of permeable screen is laid on the river bed along the alignment of the new parallel river banks, being kept in position by 4 concrete anchors, fixed to the 4 bottom corners of each screen. Adjacent units of screens, after they are laid on the river bed, arc firmly tied to each other by mild steel wires. A wire cable is also fixed to the top of the line of permeable screens, to provide additional stability. Owing to the width of the base of the screens, they do not topple over when the river channel is deepened, as happens with bamboos in ordinary bandalling. In a deeper river, with a lesser velocity of flow, where uprooted trees do not float down the river in the flood season, another type of permeable screens known as Barua Cages, also constructed with bamboos, are floated on the river channel. They act in the same way as bamboo bandalling, in narrowing and deepending a river. The cost of permeable screens varies from Rs 20, to Rs 40 per

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