# RIVER PROBLEMS IN BENGAL.

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## FORMATION OF THE DELTA.

**No marine deposit within 1300' depth.**

1. In a joint note (published with the 'Report on the Hooghly river and its Head Waters', 1919) Messrs. Hayden and Pascoe of the Geological Survey of India state that "the absence of tertiary marine deposits, and the presence of tertiary fresh water deposits, throughout the outer Himalaya from Dehra Dun to Sikkim shew that, since the elevation of the Himalaya, marine conditions have not existed in that area, nor is there any evidence of the existence of such conditions at any point in the Gangetic plain between the Himalaya and the Peninsula". They admit that the evidence in support of this theory is rather meagre, being derived from a few borings at Ambala, Agra, Lucknow, Chandarnagore, Fort William and Port Canning, the deepest of which was only a little over 1,300 feet deep. But they argue that, in the absence of any evidence in favour of a contrary view, it would not be safe to reject the generally accepted conclusion, "that the conditions prevailing over the Indo-Gangetic plain from comparatively early tertiary times have not been dissimilar to those that exist at the present day, and that there has been a slow but gradual subsidence permitting of the accumulation of an enormous mass of alluvial deposits". In the 'History of the Rivers in the Gangetic delta' Mr. C. Addams Williams, C.I.E., late Chief Engineer, Irrigation Department, has also given prominence to the view, 'that before the present upper strata of the delta were laid down, it appears that there was an older delta composed of materials totally different to those deposited by the Ganges. A stratum of yellow clay and sand appears to underlie that upper and newer strata of blue clay and sand. At Cowkhally on the lower Hooghly the yellow clay is about 60 feet from the surface as shown by borings taken in 1914. At Kushtia there are outcrops of the same stratum, and the general outcrop appears to be roughly round the extreme edges of the present delta'. Mr. Addams Williams concludes, 'It appears that this delta was laid down by the rivers issuing from the north or north-east, and that presumably the Ganges had not then become a factor in the case. The old delta was depressed and the Ganges appears to have then entered on the scene and began forming the new delta on the top of the old, from the neighbourhood of Rajmahal'.

**Enormous mass of alluvial deposits by the rivers.**

**The present delta built on another older delta.**

2. In dealing with the river problems as we find them to-day we are really only concerned with the concluding portions of both the extracts quoted above which establish the point that the land we live in, up to a depth that we need think of, was built up gradually by the silt carried by the rivers mainly from the Himalayas and partly from the hills of Chhota-Nagpur and the Sonthal Parganas.

**How the delta was formed.**

3. To appreciate the river problems in Bengal it is necessary to envisage how the rivers, especially the Ganges, functioned in that early age and are still functioning in building the land and in extending it towards the sea. The process of raising and extension of the delta towards the sea has been going on for thousands of years, and it will probably continue for an indefinite length of time as the stock of building material, *viz.* detritus carried by the rainwater over thousands of square miles of catchment area, including a considerable portion of the mighty Himalayas, is almost unlimited.

**Stock of building material almost unlimited.**

4. Millions of tons of this silt is thus being transported every year by the strong current of the Ganges flood and brought down to its mouth, where the current is checked by coming in contact with the sea and the silt in suspension drops into the bed. Land was thus formed at the head of the delta and as it began to extend, the Ganges, like the other delta builders, began to approach the sea in several diverging branches, enclosing and intersecting the delta already built, so as to raise it in the quickest possible time and to extend it towards the sea in ever-increasing width. Each branch carried its due share of the silt-laden flood and as the bank on either side was low to start with, it was inundated during floods with the result that silt carried in suspension was dropped on the bank which was thus gradually raised, the raising being more rapid nearer the river.

**Thicker deposit close to the river.**

5. Along with this process of raising the delta already built, so as to make it fit for human habitation, the other important function of extending the delta towards the sea was being carried on by the main volume of the floods carried down the several diverging branches dropping the silt near to their mouths.

A mere extension of the delta towards the sea-face would not be of much use, as what is required is that it should be sufficiently raised so as to be fit for human habitation and cultivation. If the task of raising the delta was left entirely to the carriers of upland floods, the process would have been exceedingly slow as we can expect these floods only during the monsoon months, *i.e.* only in 4 out of 12 months every year. It is therefore in the economy of nature that the tides should come to our assistance in this respect. Tides flow up these rivers with strong velocity, twice daily throughout the year, and as there is a vast reservoir of unconsolidated silt at their mouths, deposited there by the

upland floods during the monsoon months, they pick up this silt almost to the saturation point on their way inland. So long as the banks of these rivers within tidal limits are below the high-tide level and the rivers are free to spill, the silt laden tides perform exactly the same function as the upland flood, *viz.* raising of the delta already built, with this difference that while the latter function only during the actual floods in the monsoon the beneficent activity of the tides continues throughout the year.

**Tides help in raising the delta.**

6. The second function of the tides is to fill up the interior of the delta lying between the upland flood carriers. As mentioned above, the depth of silt deposit by upland floods, or by the tides carried up these rivers, is greatest close to the river banks, where the velocity, which determines the proportion of silt that can be carried, is first checked, and as the spilling proceeds away from the river banks the silt content of the spilled water and consequently the depth of silt deposit is less and less. If nature had to depend entirely on this agency, the area lying midway between the contiguous upland flood carriers would have remained low—probably in the shape of creeks extending from the sea, till these rivers, after performing the function of raising the banks close to their channels would burst through the banks and follow the low valleys. This would have been a slow process and to facilitate the work of delta building, here also nature requisitions the services of the tides which, picking up the silt on their way up these creeks or tidal rivers, gradually raise their beds and banks until they are raised up to high-tide level and rendered fit for cultivation. There is no doubt that the source of this silt supply is the detritus carried to the sea by the upland floods for ages, but the tides by their constant movement keep it in an unconsolidated state and distribute it all along the delta-face between the two main estuaries, *viz.* those of the Hooghly and the Meghna.

7. It will be clear from the above that nature has been employing both the agents, *viz.* the upland flood carriers and the tides in her work of delta building. She has been assisted in her task by two favourable factors, *viz.* the high ranges of the Himalayan system of mountains, which have been furnishing the building material in abundance during the monsoon months, and the abnormally high tidal range, due to the funnel-shaped form of the Bay of Bengal, which has been helping in distributing these materials twice daily throughout the year. But though the abnormal tidal range at the delta-face has been so helpful in raising the delta—in fact raising it higher than what would have been possible if the range was lower—this very fact, however, has stood in the way of rapid extension of the delta towards the sea; for, owing to the high tidal range, more and more of the alluvium brought down into the sea by the upland flood carriers is being dispersed along the delta-face to be picked up by the tides

**Two agents employed by nature in building the delta—upland flood carriers and the tides.**

travelling inland through innumerable tidal channels, and less and less of it has been deposited in a consolidated state to extend the delta.

**High tidal range helpful to navigation.**

8. The high tidal range has also been helpful to navigation and it is not surprising that the people of Bengal look upon the rivers, both tidal and non-tidal, with veneration, for they created the land, are draining and fertilizing it and are helping in carrying the produce. Fertilization by tidal silt may not be apparent, but as the source of this silt is really what is carried by the upland floods, the manurial properties of which are so highly valued, it is only a question of time, *i.e.* after the salt carried with the tidal silt has been washed away by rains, before its fertilizing properties are manifested as is so amply demonstrated in the case of the reclaimed land in the Sunderbans.

**Function of rivers in Bengal.**

9. Bengal being mainly an agricultural country, the rivers are the principal source of the economic wellbeing of the people. Where they are still active and are performing their original functions, as in East Bengal, the people are healthy and prosperous; where they are deteriorating and their beneficial activities have been interrupted, either due to natural causes or through human interference, as in Central and Western Bengal, the area is progressively deteriorating both as regards the health of the people and the productivity of the soil. River problems in Bengal are thus virtually the problems for Rural Development in Bengal and have to be solved if she has to be saved, especially her western and central parts which even as late as a century ago used to be very healthy and prosperous, from reversion to swamps and jungles from which she was reclaimed by the rivers.

**Rivers are an essential factor in Rural Development.**

**Riversclassified into three groups.**

For a proper appreciation of the 'River problems in Bengal' and their solution it would be convenient to classify the rivers, having regard to their special characteristics, into three groups as indicated below.

10. Group I:—Primary delta builders originating from the snow-capped Himalayas, maintaining a more or less perennial flow and navigable especially in their lower reaches.

The principal rivers in this group are (*a*) the Ganges series including the tributaries and the spill channels, (*b*) the Brahmaputra series including the Teesta and (*c*) the Meghna. By far the most important delta builder is of course the Ganges which, traversing a length of 1,540 miles and draining an average annual rainfall of 42 inches over a catchment area of 397,500 sq. miles and with the recorded maximum flood discharge of about 2,000,000 cusecs (at Sara) has been mainly responsible in building, raising and fertilizing the delta. The Brahmaputra was originally a comparatively small river, but since her connection with the Tsan Po of Tibet through her tributory the Dihong (in Upper Assam), and subsequent additions of the floods of the

Teesta (since 1787), she has been a formidable rival of the Ganges and promises to play a more and more important part in the future. She now traverses a length of 1,800 miles and drains an average annual rainfall of 88 inches (in the Assam valley) over a catchment area of about 361,000 sq. miles.

11. Group II:—Primary delta builders originating from the low hills of Chhota-Nagpur and the Sonthal Parganas such as the Damodar, the Ajay, the More, the Cossye, etc. They are torrential rivers, the flow being mainly confined to the monsoon months from June to September. Though they bring in enormous volumes of floods at times (the maximum flood discharge of the Damodar, the largest of the group, with a catchment area of 7,200 sq. miles, amounts to as much as 650,000 cusecs), they dwindle down to a mere trickle sometimes even during the rainy season, and during the dry season there is practically no flow. Though their contribution towards the building of the delta could not be much compared with that of the Ganges, it is believed that the eastern portion of the Burdwan district and the western portion of the Hooghly and Howrah districts owe their origin to the delta building activity of the Damodar, and the eastern portion of Midnapore district to that of the Cossye and the Rupnarain. Their value, however, lies in the fact that they constitute the only source available for supplying the water needed for artificial irrigation and for flood flushing. I shall deal with flood flushing later but I propose to discuss the necessity of artificial irrigation and how this aspect of the problem can be solved at this stage, as irrigation is required in Western Bengal.

**Irrigation required in Western Bengal.**

12. Though the total rainfall in Western Bengal is sufficient in normal years its distribution during the crop period is erratic, especially after the middle of September, when the rainfall is hardly sufficient to meet the requirements of the paddy crop. Even in normal years artificial irrigation is thus a necessity in Western Bengal to ensure a normal harvest. To provide an insurance against famine it is a vital necessity in years of abnormally low rainfall, which occur say once in 5 to 7 years. Again, since practically the whole of the rural population lives on agriculture and the allied industries and the *raiyats* are too poor to afford artificial manure, canal irrigation, by providing natural manure in the shape of highly fertilizing silt carried by the canal water, seems to be the only means available for increasing the yield from the land and improving the economic condition of the people.

**Erratic distribution of rainfall in Western Bengal.**

**Irrigation the only means of improving the economic condition of the people.**

I do not propose to lengthen this paper by dealing in detail with this important factor in rural development in Western Bengal, as this aspect of the problem and its solution is more or less similar to what is being experienced in the rest of India. I shall merely emphasize some of the points that have

come to my knowledge in the course of my official duties and then pass on to other aspects of river problems which are peculiar to Bengal.

13. Bengal has an important advantage over the rest of India in the fact that during the transplantation season, when a very large quantity of water is required by the crops, the rainfall is usually adequate. In fact in normal years artificial irrigation is usually required to meet the deficiencies of the north-eastern monsoon from the middle of September to the end of October. Unfortunately this is the very time when the rivers in Western Bengal also bring in a rather scanty flow, though earlier in the season, *i.e.* during the south-western monsoon, they usually bring in enormous volumes of floods which run to waste. It is, therefore, apparent that to meet the irrigation needs of Western Bengal storage is a necessity, *i.e.* the water should be stored in natural storage works constructed in the upper valleys of these torrential rivers in Western Bengal during floods and utilised in times of scarcity. Storage works are no doubt costly, but as stored water has to be supplied mainly in October, when the requirement of crops is minimum, they are likely to be profitable undertakings in Bengal. The area that could be irrigated by a stream by its daily flow can be increased many times over if only a portion of its flood could be stored and utilised in times of scarcity to supplement the daily flow. In Madras, where storage works are also needed for the transplantation of paddy owing to the failure of the south-western monsoon, 1 m. Cft. of stored water can irrigate only about 5 acres. In Bengal, on the other hand, for the reasons mentioned before, it can irrigate over 30 acres. Again, for growing sugarcane and *rabi* crops storage works seem to be an absolute necessity, as from November till April no rain is usually expected in Western Bengal.

**Necessity for storage to supplement the river flow.**

14. But though storage schemes seem to be an absolute necessity for the development of irrigation and the economic uplift of the people in Western Bengal, owing to the flatness of the country it is difficult to obtain suitable sites for storage dams within the boundaries of the Province. For good sites we have really to search in the upper valleys of these rivers lying within the hilly regions of Chhota-Nagpur and the Sonthal Parganas in the Province of Bihar. Two good sites have been discovered so far in connection with the investigation of the Dwarkeswar and More projects, and it is estimated that by constructing suitable storage works, etc., about 200,000 acres can be irrigated by the former and 432,000 acres by the latter.

**Scarcity of sites in Bengal for storage schemes.**

**More and Dwarkeswar Reservoir Projects.**

15. Group III:—Subsidiary delta builders or tidal rivers. These are mainly the lower reaches of the rivers of groups I and II within tidal limits which, as has been explained above, continue their beneficent activities of raising, fertilizing and draining the lower portion of the delta twice daily throughout the year and help in transporting the produce of the whole country.

## River Problems with reference to health and productivity of the soil.

16. In all the accounts that have been preserved from ancient sources Bengal is reported to have been healthy and prosperous. Bernier wrote about the middle of the 17th century : "The knowledge that I have acquired of Bengal in two visits inclines me to believe that it is richer than Egypt". Even as late as 1815 Hamilton wrote of Hooghly, Howrah and Burdwan, which area is now one of the worst as regards health and impoverishment of the soil, as follows : "In productive agricultural value in proportion to its size, in the whole of Hindusthan Burdwan claims the first rank and Tanjore second". In her eastern parts where she is being nourished by her rivers, Bengal still continues to be prosperous and healthy. Even in the rest of Bengal there is no dearth of water resources but the growing deterioration in the health and in the productivity of the soil has to be traced to their faulty distribution. Through some streams more water flows than is necessary, frequently causing disastrous floods, while at other places the scanty flow through natural waterways has caused serious deterioration, in many cases rendering them even incapable of draining the countryside. Indeed, many of these streams which were originally intended by nature —this is a phenomenon peculiar to deltaic areas—to spill over the land which they traverse and keep it in plenty by supplying the rich silt of the Ganges, the Damodar, etc., have now been converted into stagnant pools of water providing an excellent breeding ground for mosquitoes, and many a district of Bengal especially in the centre and in the West has been rendered extremely unhealthy with steadily decreasing population and with land gradually going out of cultivation.

**Bengal highly prosperous even about a century ago.**

**Progressive deterioration due to faulty distribution of water resources.**

17. This faulty distribution of the available water resources which has brought about the present deplorable condition is attributable partly to human interference with the natural process of building up the delta and partly to natural causes. The most prominent instance of human interference which has mainly affected the rivers of groups II and III referred to above is to be found in the flood embankments, mainly in Western Bengal, but partly also in Central Bengal which, by cutting off the flood spill and depriving the land of natural manure, have killed the net-work of natural spill and drainage channels within the area and have brought about the present deplorable condition.

**Faulty distribution due to human interference and natural causes.**

18. There is no dearth of natural hydraulic resources. In fact Bengal has been highly favoured by nature in this respect. The rainfall, though somewhat erratic in distribution in the western parts, is normally quite adequate to meet the requirement of at least the *Kariff* crop in other

parts, and Bengal can count on abundant monsoon floods to nourish her soil with fertilizing silt and to kill the mosquito larvæ if only these floods could be properly distributed. A more equitable distribution of the water resources is thus vitally needed for the rural development of Bengal. I shall now go into the question somewhat closely dealing with each group of rivers separately and examine a representative type of each group in detail.

**Solution lies in more equitable distribution of the abundant water resources available in Bengal.**

## Rivers of group I.

### Primary delta builders originating from the Himalayas.

19. The areas which have been adversely affected mainly by natural causes, *i.e.* by major changes in the courses of the rivers of this group, are (1) in Central Bengal by the diversion of the Ganges through its present channel of the Padma sometime towards the beginning of the 16th century; (2) in North Bengal by the diversion of the Teesta sometime towards the end of the 18th century (1787); and (3) in portions of Mymensingh district by the diversion of the main Brahmaputra through the present Jamuna channel soon after. There is no doubt as regards changes (2) and (3) as they occurred comparatively recently and can definitely be proved by reference to Rennel's maps which were prepared earlier. Before the diversion, the Teesta used to discharge its waters through the Panarbhaba (a tributary of the Mahananda), the Atreyi and the Karatoa which used to fall directly into the Ganges. The large number of spill and drainage channels which intersect Northern Bengal were, in consequence, allowed to continue their beneficent activities as explained above and the area was healthy and prosperous. After the diversion of the Teesta, completely cutting off the head-water supply laden with fertilizing silt from the Himalayas, these channels are gradually deteriorating, bringing in their train water-logging due to inadequate drainage and progressive deterioration of the country as regards health and productivity of the soil.

**Major changes in the river courses have caused deterioration in Central and Northern Bengal and in Mymensingh district.**

20. Even as regards the Ganges it seems to have been an admitted fact hitherto that the Bhagirathi originally constituted the main course of the Ganges till the end of the 15th century when the main channel was diverted along the present Padma channel. In recent years, however, this view has been challenged by the late Sir William Willcocks who, in a lecture delivered before the Calcutta University in 1930, has propounded the rather extraordinary theory that the Bhagirathi and other rivers in Central Bengal were originally really canals excavated by the old Hindu rulers of Bengal for the purposes of overflow irrigation.

**Canal theory regarding the origin of the Bhagirathi untenable.**

As the challenge has come from a delta Engineer of the reputation of Sir William, it seems necessary to examine this point in some detail.

**Evidence in support of the established theory that the Bhagirathi was the original course of the main Ganges.**

21. A glance at the map of Bengal will show that the extension of the delta towards the sea is greatest towards its western end, *i.e.* along the Hooghly estuary, and least at its eastern end, *i.e.* along the Meghna estuary, the present outfall of the Ganges. This is in spite of the fact that the Meghna estuary is also receiving the flood of the Brahmaputra which, since her connection with the Tsan Po of Tibet, is probably much larger in volume than that of the Ganges. This ought to serve as conclusive evidence in support of the established theory that the main volume of the Ganges flood, which constitutes the main delta builder, has been passing down the Hooghly estuary for a much longer period than along the Meghna as at present, unless it can be proved that there were other delta builders discharging into the Hooghly and contiguous estuaries to the east, floods even larger in volume than that of the Ganges, Brahmaputra and Meghna combined. Such a river does not exist and could not possibly have existed in the present geological epoch. Taking the present geological disposition of watersheds and considering the present meteorological conditions, such a river or rivers could have drained only an average rainfall of about 50 inches from the catchment area of about 25,000 sq. miles, which is roughly the combined catchment areas of the rivers of Western Bengal originating from the hills of Chhota-Nagpur and the Sonthal Parganas. As compared with this, the Ganges alone drains an average rainfall of 42 inches over a catchment area of 397,500 sq. miles, and the Brahmaputra, even before her connection with the Tsan Po of Tibet, had a very large catchment area in the submontane region of Assam with an average rainfall of about 88 inches. According to Sir William Willcocks the south western portion of Central Bengal was also built up by the Damodar. That this theory is not at all tenable will be apparent from the fact that the Damodar has a catchment area of only 7,200 sq. miles with an average rainfall of about 50 inches. Its maximum flood discharge is only 650,000 cusecs as compared with 2,000,000 cusecs of the Ganges. Floods of this order again occur only at long intervals (1913 and 1935) and are short-lived, of not more than 2 or 3 days at a time. The average flood discharge of the Damodar and all the Western streams combined will be a mere fraction of that of the Ganges.

22. Among other evidences in support of the established theory the following may be mentioned:—

*Religious and traditional evidence.*

From the mythological period the Hindus have considered the Ganges as sacred and people by thousands have been going on pilgrimage to places on the banks of the Ganges such as Navadwip, Katwa, Tribeni (a few miles above

Hooghly town and also called Mukta Beni where the Ganga, Jamuna and Saraswati, which were united at Allahabad, were separated), Kalighat and Ganga Saugor, all situated on the Bhagirathi or the Hooghly below the present offtake from the Ganges. No such sanctity attaches to the Padma below the Bhagirathi offtake nor is there any place of pilgrimage on her banks. (*N.B.* Major Hirst has dealt with this matter more fully in his report 'Nadia Rivers, 1915'.)

*Historical evidence.*

Pliny (116 A.D.) and Ptolemy (140 A.D.) mention Tribeni referred to above. Arrian (161 A.D.) refers to Katadupa or Katwa. (Notes by Mr. Reaks published with the report on the Hooghly river and its head waters.) No such places of antiquity are found on the banks of the Padma.

I am also informed by my brother Dr. R. C. Majumdar of the Dacca University that there is indisputable historical evidence, for instance, in the Khalimpur Copper Plate of King Dharmapala (780–820 A.D.) to show that the Ganges, even above Rajmahal, was also called the Bhagirathi in the olden days. The Padma has never been called by this name; but the western branch is still called the Bhagirathi, thus establishing the point that the latter was really the main course of the Ganges, and that the Padma (if it was really in existence then) was either unconnected with that river in the olden days, or it was a branch not large enough to claim the honour of bearing the same name with the main river.

23. It is also a matter of history that Gaur on the Bhagirathi was the capital of Bengal up to the beginning of the 16th century, and I quote the following from Major Hirst's report on "Nadia Rivers" (1915) to shew that the Padma could not have existed in those days as a branch of the Ganges and, even if it did exist, it must have been a comparatively minor channel, as otherwise both the upper and lower reaches separated by the Padma could not have been named the Bhagirathi as we find it up to the present day:—

"The upper Bhagirathi (Gaur arm) meets the Ganges and the Padma at the place where the Ganges loses its name. The lower Bhagirathi (Upper Hooghly) emanates from the present Ganges on the south bank practically opposite the mouth of the upper Bhagirathi. The alignment of the upper and lower Bhagirathi streams is essentially one which a river would follow and the only portion of the alignment that is missing is occupied by the main bed of the Ganges. From this fact it is clear that if the upper Bhagirathi was the main Ganges originally, and the history of Gaur proves that point, then the Padma as a main river is a more recent channel than the Bhagirathi upper and lower."

**Major Hirst's explanation for major changes in the river courses.**

24. Major Hirst further remarks that: "There was a severe earthquake in 1505 A.D. and shortly after it, the Ganges left its old course past Gaur and retreated southwards. The cause of this great change is not known, but it may have been due to earth movements between the old alluvium of Malda and Chhotanagpur outliers." In fact Major Hirst attributes the major changes of the river courses in Bengal to tectonic activity which theory has not, however, been accepted by geological experts (Messrs Hayden and Pascoe of the Geological Survey of India, *vide* Report on the Hooghly river and its Head waters, 1919).

25. But it does not seem to be necessary to rely on tectonic activity to find an explanation for the changes in the courses of rivers in deltaic Bengal which seem to be not only inherent in their very nature but necessary for the purpose of building and raising the delta.

**Simpler explanation offered which seems to be more probable.**

In the process of building up the delta, the river has a tendency to oscillate within wide limits; first, flowing on one side and after the riparian tracts have been raised to a certain extent, it bursts through its banks and opens up new channels through the comparatively lower areas of the contiguous tract and so on. After these latter areas have been raised sufficiently the process is reversed to raise still higher the tract which has been raised already. This is perfectly consistent with the natural conditions governing the flow of a river which, following the immutable laws of nature, always tends to take the line of least resistance. The lower land not only gives it a better hydraulic slope but by providing better facilities for spill, and consequently abstracting large portion of its silt burden, helps to maintain the river in a more efficient condition than if it has to pass through higher land.

26. Before the diversion of the Ganges, the Mahananda and North Bengal rivers probably had an independent outfall more or less along the present Padma channel. The shifting of the Bhagirathi or the Ganges southwards of Gaur, mentioned by Major Hirst, made the condition favourable for a cut-off between the left bank of the Bhagirathi or the Bhairab which probably constituted the easternmost branch and the right bank of the Mahananda. Owing to the existence of lower land to the east, which had not received so much attention hitherto as the western area as regards delta building activity, this Mahananda outfall after the above cut-off, rapidly developed and constituted the main course of the Ganges and the lower Bhagirathi began to deteriorate.

*Central Bengal.*

27. There is no doubt that Central Bengal has been built up by the silt carried by the Ganges which, in the olden days, used to distribute her waters mainly through the Bhairab, which probably constituted the easternmost branch, and the Bhagirathi in the lower reaches, trifurcated into three

main branches at Tribeni a few miles above Hooghly, *viz.* the Jamuna, the Bhagirathi (or Hooghly) and the Saraswati. Since the diversion of the Ganges flood, however, through the Padma channel, these rivers began to deteriorate.

**Central Bengal—built up and fertilized by the Ganges before her diversion.**

The Bhagirathi, which once constituted the main channel of the Ganges, now remains practically cut-off from this river, except during floods, and moreover the share of the Ganges flood it now receives is almost insignificant as compared with what used to pass before the diversion. In consequence, its western and eastern branches, *viz.* the Saraswati and the Jamuna, are now dead and the Bhagirathi also would probably have shared the same fate but for the rivers in Western Bengal, which have their outfalls into this river, and the tidal flushing in the lower reaches which, thanks to the conservancy measures of the Calcutta Port Trust, is being allowed as freely as is possible. In the upper reaches, however, the river is fast deteriorating and even in the lower reaches its condition is not free from anxiety as further deterioration will threaten the very existence of Calcutta as a Port. The Bhairab also is now dead having been cut through first by the Jalangi and then by the Mathabhanga. These latter rivers opened up comparatively recently after the diversion of the Ganges but they are also fast deteriorating (partly due to artificial interference) and, though not completely dead yet, can no longer draw sufficient water from the Ganges to be able to spill over the land nor to keep their distributaries alive. The large number of distributary channels such as the Nabaganga, the Chitra, Kobadak, Betna, Kodla, etc., which used to distribute this spill equitably over the entire area, have also died or are dying, resulting not only in the progressive impoverishment of the soil but acute difficulty in drainage and water-logging. Practically the whole area traversed by these channels is highly malarious and unless the old conditions of flushing by the Ganges flood can be restored, this area will gradually revert to swamps and jungles from which it was reclaimed by the rivers.

**After the diversion, the spill channels deteriorated.**

28. The principal spill channels which are not yet completely dead and on which we have to depend for the purpose of drawing from the Ganges and carrying a portion of her flood for flushing this area are the Bhagirathi, the Jalangi and the Mathabhanga. In view of the apparent tendency of nature to enrich the Padma at the expense of these rivers, the question of primary importance to be considered in connection with their improvement is whether an appreciable portion of the Ganges flood can at all be induced to pass through them in preference to the Padma of which the hydraulic conditions are of course much more efficient. The late Sir William Willcocks advocated the construction of a barrage across the Ganges with a view to induce a portion of the Ganges flood to pass through these channels. But the cost of the barrage together

**Technical feasibility regarding the restoration of the Ganges spill considered.**

with that of the river protective works that would be necessary to prevent outflanking and their maintenance would be so heavy that those who have to finance the scheme may not be disposed to seriously discuss it in the present economic condition of Bengal. We have, therefore, to consider the question of improvement of these rivers without the barrage.

**Ganges Barrage.**

29. It may first be considered whether the Ganges has permanently or only temporarily forsaken this tract. In view of the characteristics of deltaic rivers as explained above, especially in para 25, it seems reasonable to expect that after the Ganges has raised the tract through which she is now flowing, she will again turn her attention to Central Bengal and the present decadent rivers of these parts may improve. It may be mentioned here that an authoritative Committee recently examined the question of the head waters of the Hooghly and, after examining all the evidences on the subject, stressed the importance of the Ganges freshets carried by the Nadia rivers (Bhagirathi, the Jalangi and the Mathabhanga), and came to the conclusion that these rivers pass through successive phases of deterioration and improvement and that there is no definite proof that they have permanently deteriorated to any great extent (*Report on the Hooghly River and its Head Waters*).

30. In this connection it may be mentioned that diversion of the Brahmaputra through the present Jamuna channel, which meets the Ganges just above Goalundo, might have given some of these Nadia rivers (at least the Mathabhanga which is nearest to the junction) a chance of revival. The Brahmaputra flood usually reaches the junction earlier and acts more or less as a barrage trying to hold up the Ganges flood to seek some other outlet higher up. But, unfortunately for the Nadia rivers, such an outlet was found in the Gorai which, in Rennel's time, was only a minor channel but which has since considerably developed. As there is an extensive area of low land yet to raise, the Gorai will probably continue to develop. In fact, even apart from raising and fertilizing extensive areas of low land along her left bank in the District of Faridpur, thanks to the Halifax Cut made by the District Board of Jessore in 1901-02 connecting the Madhumati (lower reach of the Gorai) and the Nabaganga, the Madhumati is now discharging the delta building functions, left unfinished by the Bhairab and the minor spill channels Nabaganga, Chitra, etc., in the eastern portions of Jessore and Khulna districts. It is, however, possible that after these lower areas have been raised the barrage effect caused by the Brahmaputra flood may even reach the neighbourhood of the Mathabhanga offtake and a larger portion of the Ganges flood might be induced to flow down that channel.

**Barrage effect of the Brahmaputra flood.**

**Development of the Gorai.**

31. The popular view is that the Hardinge Bridge, which was completed in 1915, might also help in improving the Mathabhanga. But the offtake of the Mathabhanga being located about 25 miles higher up the Ganges, it does not appear that the bridge has caused a sufficient afflux yet to effect any material improvement of the Mathabhanga.

**Afflux created by the Hardinge bridge not material so far.**

About half the width of the Ganges underneath the bridge has however silted up well above the low water level along the left bank. As widening of the channel along the right or southern bank is being prevented by extensive bank protective works and as deepening by scour is being restricted by extensive stone dumping round the piers, it seems possible that this bridge may in future act more and more as a barrage, with larger and larger afflux, holding up the Ganges flood to seek an outlet higher up. If, however, the afflux increases materially, it seems more likely that the river will find this outlet in the Lalpur bight, a few miles above Sara on the left bank, and there will be an avulsion through the extensive low areas near about Chalan Bil, outflanking the Hardinge bridge on the north. But till this catastrophe occurs, the effect of the increase in the afflux, if any, will probably be to improve the Mathabhanga.

**But it may increase to the advantage of the Mathabhanga and may even induce far-reaching changes in the regime of the Ganges.**

32. We may have to wait for decades or perhaps centuries before nature turns her attention to Central Bengal and the point for consideration is whether it is not possible to effect any lasting improvement of these rivers by artificial means. Railway authorities should also be interested in this matter; for diversion of an appreciable portion of the Ganges flood through the Nadia rivers ought to relieve the pressure on the Hardinge bridge thus reducing the cost of its maintenance and averting a possible danger of avulsion on the left bank as discussed above. The recent changes in the Ganges which might be attributable to the causes referred to above seem to be hopeful. The huge *char* which hitherto masked the offtake of the Mathabhanga has practically disappeared and its position in relation to the Ganges is definitely improving. The offtakes of the other two principal spill channels in Central Bengal, *viz.* the Jalangi and the Bhagirathi are also showing signs of improvement though not to the same extent as the Mathabhanga.

**Mathabhanga offtake appears to be improving.**

33. But mere improvement of the offtakes is not enough; it merely shows the tendency of nature. To be able to utilise fully these tendencies to our advantage, it is necessary to improve the carrying capacities of these channels and provide suitable outlets of distributory channels of adequate capacity, and other facilities for spill over the country side. For, unless the increased discharge that could be drawn in view of the favourable position of the offtakes, could be carried by these channels and disposed of, no material improvement over the present condition can be expected. The function allotted by nature

to these spill channels in deltaic Bengal is that they should spill over the land during floods and deposit the highly fertilizing silt carried by the flood water. Being relieved of the silt burden, the comparatively clear water should then flow down these channels and maintain them in an efficient condition. If it is not allowed to spill a good portion of its silt content, the flood water entering these channels, owing to the reduced velocity due to flatter gradient available in the lower portion of Bengal will not be able to transport the large quantity of silt and will deposit it in their beds, thus again deteriorating the channels. Improvement by dredging or by hand cut, where feasible, will no doubt be necessary initially to give these works of improvement a good start. But it is impossible to maintain a river by dredging alone, for, apart from the question of cost, the dredged soil has necessarily to be deposited on the banks close to the river channels, which will go on rising as the dredging continues and soon reach a height beyond the lift of the dredger. An essential condition of success, therefore, is that, after their initial improvement, forces, which were in operation before, when these channels were in a live condition, should be restored so that they may again be self-maintaining or, in other words, they should be allowed to spill extensively over their banks without hindrance as far as possible. To what extent this may be feasible, it is not possible to say without a contour survey with lines of levels taken at fairly close intervals, and detailed investigation made as regards the vested interests that are likely to be adversely affected, and the remedial measures to be adopted to safeguard those interests. The problem is undoubtedly a very complicated one and what I wish to emphasise is that no piecemeal solution is really possible; and the problem has to be thought out and dealt with comprehensively.

**Dredging alone cannot maintain a channel permanently.**

**Land flushing essential for the preservation of spill channels.**

34. About one point, however, there seems to be no doubt, *viz.* the necessity for a substitute crop in the lower areas which will not be affected adversely by uncontrolled flushing when the Ganges is in flood in August and September. In the case also of these lower areas, mostly '*bils*' and '*baors*', the problem to be solved is one of premature reclamation. But since the vested interests have already been created and now constitute the source of livelihood of a large number of people, we have to face the problem as it stands and find a solution. The only practicable solution appears to be that *raiyats* should be encouraged to grow in these *bills* and other lower areas a crop which can be harvested before the Ganges rises sufficiently high early in August, or a crop like the long-stem paddy of East Bengal which grows with the rise in water level and will not be damaged by uncontrolled flushing. In any case, unless a practicable solution can be found for this problem, the prospect of flood flushing schemes for Central Bengal, which appears

**Introduction of a substitute crop for the lower areas of Central Bengal seems to be an essential preliminary to flood flushing scheme.**

to be urgently necessary to arrest the growing deterioration in health and productivity of the soil, as also to revive the dying spill channels, seems to be rather gloomy. It does not appear to be feasible to have controlled flushing without a barrage across the Ganges, the cost of which will of course be prohibitive. But even if the flushing could be controlled, the lower land, the *bils* and other low areas are likely to be inundated, in the process of flushing to a depth which will probably make it impossible to continue the present method of cultivation. We had practical experience of this difficulty during the recent high floods when, owing to the abnormally high flood level of the Ganges and of its spill channels, the crops over a large area of Central Bengal were damaged. Necessity for growing in these low areas a suitable substitute crop, as an essential preliminary step before launching a flood flushing scheme, cannot therefore be exaggerated.

### Group II:—Primary delta builders originating from the hills of Chhota-Nagpur and the Sonthal Parganas.

35. The rivers of this group serve Western Bengal (the whole of the Burdwan division) and in the western portion of this tract they pass through a non-deltaic region. The problems presented for solution in this region, *viz.* those in connection with irrigation, are common to the rest of India and have already been dealt with. The eastern portion of the tract is deltaic, and due to human interference with the beneficent activities of the rivers traversing this portion, has given rise to problems which are unique and it is doubtful if a satisfactory solution can be found at all.

**Unique problem presented by the embanked rivers in Western Bengal.**

36. The area is flat and has been built up by the silt carried by these rivers of Western Bengal, particularly the Cossye in Midnapur district and the Damodar and the Ajay in Burdwan district. But before the land could be sufficiently raised by such natural deposits it began to be reclaimed by flood embankments long before the British occupation. In those days, these embankments do not appear to have been efficiently maintained by the Zemindars and breaches were frequent. Though this caused temporary inconvenience and damage, the land used to be flushed occasionally by silt-laden floods and the health and the productivity of the soil did not deteriorate to the same extent as at present. The evil effects of these embankments were not of course realised in those days and for efficient maintenance they were gradually taken over by Government and improved with the object of preventing breaches as far as possible. In consequence, though the breaches are now less frequent and the protection enjoyed by the people is now more thorough, this very fact

has brought into prominence the evil effects of these embankments. The land has been deprived of even the occasional flushing with silt-laden flood-water, which it was enjoying when these embankments were inefficiently maintained by the Zemindars. This is not only causing progressive deterioration in public health and productivity of the soil but, being deprived of their source of sustenance, *viz.* the river spills, the natural channels within the embanked area, have all badly deteriorated and the difficulty of draining these areas is becoming more and more acute.

**Premature reclamation by embankments responsible for present deterioration.**

37. The embankments have thus prevented the gradual rise of the land by silt deposits during flood flushing. Indeed, it is actually becoming gradually lower, though at a very slow rate, due to the loss of the surface soil washed away by the rains. To make the case worse the floods, confined within embankments and unable to spill and deposit on the land as was intended by nature, are depositing a portion of the silt-contents within the river beds which are gradually rising. The Irrigation Engineers in Bengal are thus faced with the most unenviable situation created by the low level of the land to be drained and the rise of the river beds into which the drainage has ultimately to be disposed of, and it has already become impossible to drain some areas by gravity. As a direct consequence of embanking these rivers and preventing free spill over the countryside there was a considerable rise in the flood level soon after these embankments were constructed and this level is tending to rise higher and higher owing to the gradual rise of the river beds, necessitating higher and higher embankments to prevent overflow by the floods. Indeed, during the Damodar floods of 1935 it was observed that, though the embankment was over 20 feet higher than the country level, at some places it was about to be overflowed, and this could be prevented only by raising the embankment during the progress of the flood. It is needless to say that breaches at such places would have been attended with disastrous consequences to the countryside owing to the terrific velocity which a wall of water over 20 feet high rushing out of the breach would have generated, sweeping away everything in its way—houses, cattle and even human beings.

**Drainage difficulty gradually increasing.**

**Tendency of flood level to rise necessitating higher and higher embankments.**

**Sudden and concentrated discharge through breaches much more harmful than gradual inundation.**

38. The potential danger to life and property that is likely to be caused by concentrated discharge through breaches at low places needs special mention and it is in such areas where high embankments have necessarily to be maintained, that breaches are more likely to occur. In fact, there is a limit as regards depth of water which can safely be withheld by unprotected earthen bunds. At some places in the Damodar Embankment this limit has almost

been reached and, if the flood level rises higher, it will probably be necessary to go in for expensive surface protection of these embankments. But even then these earthen bunds can hardly be made breach-proof, for a little rat-hole may easily lead to a disaster; and where there are hundreds of miles of such embankments to look after, it is almost impossible to ensure that all such tiny holes have been detected and attended to in proper time. In fact, such holes are usually covered by vegetation and can only be detected when the flood level has reached their river side ends, and if these ends are located high up the slope they may not be detected till the flood has risen very high, when it may be too late to do anything. In view of these difficulties occasional breaches in the unprotected earthen embankments and the consequent loss of life and property caused by concentrated discharge can hardly be avoided and it is surprising that they do not occur oftener than is the case at present.

**Occasional breaches in earthen embankments can hardly be avoided.**

39. On the other hand what would happen if these rivers were left in their natural condition? The conditions now prevailing in Eastern Bengal furnish the answer. No doubt there would have been flooding of the area now inefficiently protected by the embankment, but the flood being allowed to spill over the countryside, the depth of flooding would have been much less and it would be lower and lower as the land rose higher and higher by the silt deposit. What I wish to emphasise is that there would have been no loss of life or property that is now caused by the high velocity of concentrated discharge through breaches. Moreover, there would be no distress among the people for, being accustomed to annual flooding, they would have erected their houses on mounds above the flood level, as is the practice in Eastern Bengal.

40. The position is undoubtedly very serious and unless a bold policy of improvement is followed, this tract will, in course of time, revert to swamps and jungles from which it was prematurely reclaimed in the olden days. The ideal solution would be to remove the cause of deterioration, *i.e.* the embankments, and raise the land and increase its productivity by allowing the flood water to spill and deposit the silt which is very rich in manure. Where possible this solution should certainly be adopted. Millions of tons of this valuable silt is now being carried away by the floods and lost to the country and the land, for which this silt was intended by nature, is starving. Above the tidal limits, where the water is sweet, such natural flood flushing need not necessarily destroy crops nor cause such acute distress amongst the people as is now being caused occasionally by the concentrated discharge through breaches in the embankments. For, when the embankments are removed, the flood level will also fall considerably lower, as compared with its present level, and as the floods in

**Bold policy is needed.**

**The ideal solution.**

**Land is starving while its source of sustenance is being carried by the river floods into the sea.**

these parts are short lived, lasting not more than 2 or 3 days at a time, such flooding may even be beneficial to the crops except in years of very high floods when, no doubt, the crops will be destroyed till these lands have been sufficiently raised by the silt deposit. The loss, however, will be more than compensated for by the increased yield in normal years due to the manurial value of the silt and improvement in health. As regards distress caused to the people by the collapse of houses it can certainly be avoided or at least minimised by erecting houses on earthen mounds and by avoiding mud walls, as is the practice in Eastern Bengal.

**Important vested interests come in the way of a bold policy being followed and controlled flood flushing seems to be the only practicable solution.**

41. In most of the areas, however, owing to important vested interests such as the existence of railways, towns, etc., such uncontrolled flood flushing is hardly practicable and here we must be satisfied with limited flushing as may be found possible by drawing the flood water through regulated escapes to be built on these embankments. It is quite possible to introduce such limited flushing in the area lying between the Cossye, the Selye and the Roopnarain rivers in Midnapore district and that lying between the Damodar, the Banka and the Hooghly rivers in Burdwan, Hooghly and Howrah districts. For this latter area considerable progress has already been made towards the proposal of a flood flushing scheme. A contour survey of the area was made a few years ago and the Government, on being advised that such a scheme is technically feasible, appointed a special officer to prepare an approximate estimate of cost. This estimate has since been prepared and it was found during scrutiny that a mere flood flushing scheme, without provision to ensure irrigation in October, when rain and river supply both fail in these parts, though highly beneficial as regards improvement in sanitation and productivity of the soil, cannot ensure good harvest except in years of well distributed rainfall, and as such is neither likely to be popular nor financially sound. Necessary orders were accordingly issued to make such provisions, *i.e.* a storage reservoir in the upper valleys of the Damodar river and a Barrage across the Damodar near Burdwan. The rough cost of the combined flushing and irrigation scheme, including the above provisions for October irrigation, comes to Rs. 2,72,77,000 and it is intended not only to irrigate an area of 3,50,000 acres, where crops periodically fail for want of timely rainfall, thereby ensuring a good harvest in every year, but also to improve materially the sanitation and productivity of the soil by adequate flushing with the highly fertilizing silt-laden water of the Damodar floods. The next step is to prepare the detailed project estimate for which purpose one temporary Circle has recently been formed. The area proposed to be served by the project used to be one of the healthiest and most prosperous in Bengal, and though it has deteriorated to its present deplorable condition mainly by the acts of man, it is hoped that

**Damodar flushing and Irrigation scheme.**

human agency will again make it possible to retrieve the situation and to restore the area to its original condition of health and plenty.

42. It may be mentioned here that as soon as the evil effects of the embankments were realised the Bengal Embankment Act was passed. In this Act there is an important provision making it a criminal offence to construct embankments, without previous permission, within certain areas which are being declared as prohibited from time to time. The area is, however, vast and enforcement of this provision, which involves frequent detailed inspection of the countryside and prosecution of the offenders, is proving rather a heavy burden with the very inadequate staff.

43. Even apart from the question of flood flushing, so necessary in the interest of health and productivity of the soil, the question of maintenance of these rivers is presenting problems of a more and more serious nature as the years pass. Considering the Damodar as a representative of this group of torrential rivers it may be mentioned that this channel near about Burdwan is barely sufficient to carry more than say 2,50,000 cusecs which represent its normal flood discharge. This capacity is again being progressively reduced due to the gradual rise of the bed in consequence of the marginal embankments and, in the lower reaches, owing to large quantities of silt brought in by the tides twice daily throughout the year, which the occasional floods during the rains cannot clear, it can hardly carry more than say 50,000 cusecs. The potential danger of a flood of the order of 6,50,000 cusecs as occurred in 1913 and 1935 rushing down this channel can easily be imagined.

**Increasing difficulty in the maintenance of the Damodar in her present channel.**

44. Originally the river was embanked on both sides but, appreciating this potential danger, the right embankment was abandoned towards the middle of the last century. This no doubt relieved the pressure on the left embankment for a time. But the right bank is also gradually being raised by the silt deposit with more and more pressure thrown on the left embankment and the time is not far distant when it will be impossible to maintain the left embankment, unless nature finds a remedy by cutting through the exposed right bank an escape into the Roopnarain, or it is provided by an artificial cut at a heavy cost. In fact nature appears to have already cut an escape in the Begua khal which is now carrying a considerable volume of the Damodar flood into the Roopnarain, but it takes off too far down the river and about 35 miles of the left embankment protecting a thickly populated area, including the town of Burdwan and the E.I. Railway line which runs very close to this portion of the embankment, is still being exposed to the full pressure of the Damodar flood; this is bound to increase more and more as the right bank and the river bed continue to rise by silt deposit.

**Abandonment of the right embankment has not solved the problem.**

45. If there were no flood embankments on either side as was intended by nature, the gain in elevation of the bank by silt deposit would at least have kept pace with the rise in the river bed as has been experienced in the case of the Nile. It appears that the Nile was embanked only recently and that before then "during the Christian era while the matter deposited by the overflow of the Nile has raised the surface of Egypt by 4½ inches per century, the bed of the river has also been raised at the same rate" (Samuelson in his "Note on the Irrawadi river" quoted in Mr. Reak's Report on Nadia Rivers). If both the embankments were retained, the country level on both the banks would have remained the same and though an avulsion would have been inevitable ultimately, owing to the gradual rise of the river bed and consequently of the flood level, it would have been left to nature to cut it either through the left bank towards the Hooghly or through the right bank towards the Roopnarain, probably the latter (as is evidenced by the natural formation of the Begua escape), owing to open country available on that side as compared with the left, where the country is full of obstructions such as E.I. Railway and G.T. Road embankments, etc. The policy of abandonment of the right embankment and retention of the left, on the other hand, has resulted in the rapid rise of the country level on the right side; that on the left side has even probably been lowered by surface washing caused by the local rainfall. The inevitable consequence, therefore, it seems to me, will be that nature will try to force an avulsion through the left bank towards the Hooghly unless we can take adequate remedial measures in the meantime.

**Avulsion through left bank towards the Hooghly probable.**

46. Such an avulsion will of course mean a serious disaster for, apart from the very large vested interests on the left bank which will be adversely affected, the important city of Calcutta and the large business interests on either bank of the Hooghly will be in great danger. It is no doubt true that till the middle of the 18th Century one of the Damodar outfalls was at Noaserai, a few miles above Hooghly town, but owing to desertion by the Damodar floods since then and by subsequent encroachments, the Hooghly channel has considerably shrunk and near about Calcutta it can hardly carry more than 3,66,000 (Mr. Reak's estimate in 1918 of maximum flood discharge) or say 3,50,000 cusecs in its present condition. The seriousness of the situation that will arise by the avulsion referred to above can, therefore, easily be imagined if it is remembered that in 1913 and in 1935 the flood discharge of the Damodar was of the order of 6½ lacs cusecs. Furthermore when the Damodar is in high flood it is very likely that the other western tributaries of the Bhagirathi also will be in high flood simultaneously owing to the proximity of their catchment areas.

**Potential danger to Calcutta and the large business interests on the Hooghly.**

47. The above consideration should rule out any proposal for remedial measures by means of uncontrolled escapes on the left bank, while as regards controlled escapes, it may be mentioned that the rough estimate which was recently prepared for flushing the decadent area on the left bank referred to before amounts to Rs. 2,72,77,000. The proposal provides for the extraction from the Damodar and distribution over the area of only about 13,000 cusecs out of the total maximum flood discharge of about 6,50,000 cusecs, a mere drop, which will not cause any material lowering of the flood level nor its pressure against the left embankment. To afford such relief we should extract something of the order of say about 2,00,000 cusecs. Apart from the prohibitive cost this extra discharge cannot possibly be carried by the Hooghly in the vicinity of Calcutta and above. Increasing the capacity of the Damodar channel by dredging does not also appear to be a feasible alternative. As I have mentioned already, apart from the question of cost, no river can permanently be maintained by dredging. This is all the more true in the case of the Damodar with such a wide range of flood discharge,—maximum flood occurring at long intervals—, and with the lower reaches liable to be chocked up by silt carried by the tides functioning twice daily.

**Escapes through left bank not practicable.**

**Maintenance by dredging impossible.**

48. As regards remedial measures the only feasible alternatives, therefore, seem to be either to construct flood moderating reservoirs in the upper valleys, probably the most satisfactory, though costly, solution, or to provide an escape into the Roopnarain through the right bank which should take off from a point as far above Burdwan as is possible. It seems to me that once upon a time, the Roopnarain probably constituted the outfall of the Damodar. The tendency of nature to restore the old condition through the Begua escape is not sufficiently helpful. We should help nature by taking off this escape from a point higher up the river. Along with the escape it is also necessary to improve the carrying capacity of the Roopnarain in her upper reaches by removal of some of the circuit embankments on her banks (Chetua and Mohankhally circuits, etc.) which, for reasons explained before, seems to be necessary even in the interests of the areas prematurely reclaimed by these embankments.

**The only feasible alternatives.**

**Capacity of the Roopnarain.**

## Group III :—Tidal rivers.

49. In their lower reaches these channels of groups I and II discussed above are tidal and, except where free tidal flushing of their spill areas has been interfered with by premature reclamation, their condition is not so bad. They are still continuing their beneficent activities mentioned above including the provision of cheap means of transport by water, a natural asset, which should be preserved at all costs. Mere

**Tidal channels are valuable assets for purpose of communication and drainage.**

tidal flow, unless reinforced by supply of upland water, cannot, however, maintain any channel for an indefinite period. Tides in these parts carry a large proportion of silt with which nature is trying to raise the lower portion of the delta now deserted by the Ganges floods. But it is only a question of time when the spill areas having been raised up to tide level, this silt, unable to spread over the land, will deposit in the channel bed in larger and larger quantities and will finally choke it. A gutter channel will probably remain for draining the local rainfall but the channel will no longer be fit for navigation.

**Salt water limit is advancing up the delta.**

Besides, with the reduction of pressure of sweet water from above, the salt water limit is also being pushed up these channels, and a serious situation is likely to arise if the upper reaches of these channels continue to deteriorate and the supply of sweet water is further reduced. In fact, it appears that the salinity of the Hooghly water near Calcutta, on which this big city is dependent for its water-supply, is showing a tendency to increase during the dry season. The case is probably similar or perhaps worse with regard to the tidal portion of the other spill channels in Central Bengal, as the only source of sweet water for these channels is the Ganges and from December till June they remain entirely cut off from this source, except the very small supply that is drawn by percolation through the sandy beds at their offtakes.

50. But where free tidal flushing has been interfered with by premature reclamation of spill areas by means of marginal embankments, the situation has already become serious, and at several places owing to the deterioration of the tidal channels the difficulties of drainage are becoming more and more acute. As mentioned already, apart from serving as carriers of country drainage with which we are all familiar, these rivers of Bengal, which are both upland flood carriers as also the tidal channels, perform the most important function of raising the delta we live in. Owing to the diversion of the Ganges the upland flood carriers are no longer functioning in Central Bengal, and so tidal channels are the only agencies now left by which the lower portion of Bengal could be raised and made fit for human habitation. Another point to be noted is that when the upland flood carrier dies in a particular area, as for instance in Central Bengal, though that area suffers, its beneficent activities are not lost to the country; only these are transferred elsewhere. If, however, a tidal channel is obstructed it usually gets choked in its own bed without any chance of diversion by avulsion as the energy required for the purpose is lacking, it not being possible for a tidal channel to rise above the tide level. Thus the consequence of premature reclamation by marginal embankments or other obstructions in tidal channels is that their beneficent activities of raising this portion of the delta will be lost to the country for ever and the land will continue to remain

**Tidal channels not only serve the purpose of communication and drainage but are the only agency now left by which the lower portion of Bengal could be raised.**

**Death of a tidal channel is a permanent loss to the country.**

low with increasing difficulties of drainage until it becomes unfit for human habitation and reverts to swamps and jungles. We have instances of this almost next door to Calcutta, *viz.* the low areas served by the Bidyadhari which, owing to earlier reclamation of the spill areas, is now completely dead and can no longer serve as a carrier of drainage, with serious consequences to the city of Calcutta and suburban areas. The Peali is also fast dying and will probably share the same fate as that of the Bidyadhari unless steps are immediately taken to throw open sufficient spill areas for this river.

**Supply of upland water essential for preservation of tidal channels permanently.**

51. In fact the provision of spill areas by the removal of marginal embankments seems to be an urgent necessity for prolonging the life of these tidal channels. But this is not enough. If these channels have to be given a permanent lease of life the supply of upland water seems to be an essential requirement. As this point is not usually understood it seems necessary to explain the physical characteristics of tidal rivers.

52. The energy which creates the tidal flow, *viz.* the attraction of the sun and the moon in the sea is very limited and is manifested partly as potential energy, *viz.* rise in tide level, and partly as kinetic energy, *viz.* velocity of flow. The former causes the tidal flow up the rivers and the latter determines its power of transporting silt. As the velocity of the tide when it enters the mouths of these tidal rivers is high and as there is a vast reservoir of unconsolidated silt in suspension along the delta face, the tide as it flows up these rivers is highly charged with silt. It is generally observed that the duration of ebb tide in a tidal river is much longer than that of the flow tide. As the same quantity of water must ebb out as flowed in, it, therefore, follows that the average velocity of 'ebb' is less than that of 'flow'. Now the capacity of water to transport silt depends on its velocity. Consequently the ebb tide is generally unable to carry back all the silt that has been carried up these tidal rivers by the 'flow tide'. Even a slight deposition of silt will add to the accumulation as the tides function twice daily throughout the year and the channel will begin to deteriorate. The deterioration would impede the propagation of the tidal wave which would cause further deterioration and the vicious circle would continue till the channel is completely dead.

53. It will appear from the above that to maintain the life of a tidal river what is necessary is an additional supply of water not saturated with silt, *i.e.* which has the reserve capacity to pick up more silt, to supplement the tidal flow during ebb so as to scour out fully the silt that has been admitted into the river by the flood tide. This could be effected either by the supply of upland water, local drainage, or by throwing the existing spill area open to the daily ebb and flow or by adding new spill areas, if possible. The spill area is of course an important flushing agent but it would function only for a limited period at a gradually diminishing rate, till the whole area is raised to high water level and its storage capacity is reduced to nil. The local drainage would

also be specially helpful, while crops are standing in the fields, as the water at such time would be practically silt-free. But this agency can function only during the rains, and for 7 months (November to May) no material contribution can be expected from local drainage, however large the drainage area may be, to help in flushing the river during ebb. The third agent, *viz.* upland water, is certainly the most important and if it were possible to arrange for its supply perennially, so as to flush the river even during the dry season, there is no reason why a tidal river should not live and continue her beneficent activities for a great length of time.

54. Improvement of the spill channels of Central Bengal and diversion through them of a portion of the Ganges flood thus appear to be necessary even in the interest of the tidal portion of Central Bengal as this water, after spilling over the land and depositing the silt content, will have to pass through these tidal channels for disposal into the sea. With the help of a copious supply of sweet water, it will be possible not only to maintain these tidal channels permanently but also to push down the salt water limit and extend cultivation more and more towards the sea-face even without embankments, as is the practice in Eastern Bengal.

**Bidyadhari river.**

55. In recent years the Bidyadhari river has been very much in the public eye owing to the increasing difficulty that is being experienced in disposing of the drainage from Calcutta through this outfall. I, therefore, propose to take up this river as a typical representative of this group and briefly review its life-history to illustrate the points discussed above.

56. As discussed in dealing with the Primary delta builders of Group I, the Jamuna, before the diversion of the Ganges flood through the Padma, constituted one of the main branches of the Ganges. Separated off at Tribeni the flood used to flow down this stream to the sea. In fact, between the Bhairab and its branches to the east and the Hooghly river to the west, the Jamuna was perhaps the most important delta builder in those days, and largely contributed to the raising of this portion of the Sunderbans. The Bidyadhari was an important spill channel of the Jamuna and to her was allotted the task of raising the delta just to the east of the areas near about Calcutta. Channels connecting the Bidyadhari with the Jamuna in the olden days (Nowi, Sunti and Nanagong) can still be traced reaching within a few miles of the present abandoned course of the Jamuna.

**Bidyadhari was a spill channel of the Jamuna and carried her share of the upland flood when the Jamuna was active.**

57. But the most indisputable evidence that the Bidyadhari used to receive a considerable supply of upland floods is afforded by the width[1]

[1] The width varies from 350 ft. to 900 ft., the average being 660 ft. and the level of the bank from 10·21 to 16·66, the average being 12·57 ft. within a length of about 10 miles above Bhangore canal. As compared with this the highest tide level recorded at

between the high banks of what is now called the Bidhyadhari khal just above Bhangore canal. In fact I was surprised to find such high natural banks in the midst of what was known to be a purely tidal area when I inspected the khal in 1933. I had several cross sections taken to ascertain whether they were really above the high tide level as that would prove conclusively that the Bidyadhari used to receive upland floods. As the cross sections show, these banks are much above the high tide level even of the present day (which must be considerably higher than when the river was allowed to spill freely over the banks), and they could not have been built up by the tidal silt but must have been raised by the silt carried by the upland water. Having regard to the characteristics of delta builders of which the banks slope away from the river edge, the width between the crests of these high banks, therefore, gives a rough measure of the extent of upland flood supply in the olden days and, judged by this standard, it must have been considerable.

**Indisputable evidence left by nature in her bank levels which are much higher than the tide levels.**

**Width between crests of banks gives a rough measure of her old prosperity.**

58. I would particularly emphasise the importance of this method of reconstruction of the life-history of deltaic rivers by means of cross sections. After completion of the contour survey of Central Bengal, portions of which have already been surveyed, we should have a lot of data to help us in this direction. For instance from cross sections of the country round about the Saraswati I found that this river, which now looks like a gutter, was originally a big river, thus corroborating the view that the Saraswati was a branch of the main Ganges as there is no other delta builder on this side of the country which could throw a branch of this size.

**Field for research in reconstructing the life-history of rivers in Deltaic Bengal.**

59. By similar evidence left by nature it was also found that the Kultigong, which now constitutes the outfall of the Nowi, Sunti and Nanagong (formerly feeders of the Bidyadhari), probably opened up much later than the Bidyadhari. In any case it was originally a channel of minor importance as compared with the Bidyadhari. Measured from the present outfall of the Nanagong into the Haroagong (the connecting channel between the Kulti and the Bidyadhari) high banks much above the high tide level extend to only a little over 6 miles along the Kulti route, while along the Bidyadhari they extend to at least 14 miles. I have discussed these points at length in my official report on the 'Bidyadhari Restoration scheme' and it will unduly

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Bamanghata on the Bidyadhari, which is progressively rising, was 10·33 and the average High water 8·8 in 1932. At Haroa (a short distance above the length considered) the H.H.W. and the average H.W. level in 1932 were 11·0 ft. and 8·75 ft. respectively.

All levels referred to are taken on O.M.S.L. or P.W.D. datum.

lengthen the size of this paper if these evidence and arguments are reproduced here. I shall merely summarise the conclusion that I arrived at after a critical analysis of all the available evidence.

**Life-history of the Bidyadhari river reconstructed.**

60. So long as the Jamuna remained active the Bidyadhari used to get a considerable supply of upland water (including a portion of the dry weather flow of the Ganges), not only the flood carried by the Nowi and Sunti, but also the major portion of the flood carried by the Nanagong. Deterioration of the Jamuna probably set in soon after the diversion of the main volume of the Ganges flood towards the end of the 15th Century or early in the 16th Century. It seems probable, however, that it still continued to receive, at least during the rains, a share of the Damodar flood, which had one of its outfalls into the Hooghly near Kalna until about 1660 and near Noaserai until about the middle of the 18th Century, both the places being above the offtake of the Jamuna at Tribeni. Diversion of the Damodar down its present channel with its outfall below Uluberia at the latter date finally sealed the fate of the Jamuna which, together with the spill channels, began to deteriorate rapidly.

**Stoppage of upland water supply and meeting of tides—natural causes of deterioration.**

61. Deprived of the upland water supply, the Bidyadhari was then thrown entirely on her own resources, *viz.* local drainage and spill area to prolong her life as long as she could. At this stage another characteristic, peculiar to tidal rivers carrying a large proportion of silt, hastened her decay. The Kultigong, the next parallel tidal channel to the east, had already opened up and by means of the connecting channel, now known as the Haroagong, provided a meeting ground for tides coming up both this river and the Bidyadhari. Owing to check in velocity there is always a heavy deposition of silt at the tidal meeting ground, but so long as these rivers received a plentiful supply of upland floods, this silt could be cleared by flushing during floods. After the stoppage of this supply, the silt deposited as a result of the meeting of the tides became a grave menace to the preservation of both the channels. Nature had thus to sacrifice one for the preservation of the other. It seems to me that by this time the Kultigong, which was originally discharging into the Matla through Kumerjolgong, had her present outfall into the Roymangal Estuary definitely established. Now the Roymangal is one of the deepest estuaries in the delta and the conditions for the propagation of the tidal wave being more favourable, the stronger tide up the Kultigong could travel higher and higher up the connecting channel (Haroagong), thus shifting the tidal meeting ground more and more down the Bidyadhari. The Nanagong, the Sunti and the Nowi, which originally used to feed the Bidyadhari, were thus gradually absorbed by the Kultigong for her own sustenance. By robbing the Bidyadhari of the drainage and spill areas of these feeders, the Kultigong thus began to develop at the expense of the Bidyadhari and the latter river deteriorated rapidly.

62. But though the fate of the Bidyadhari as a permanent channel was thus sealed, the existence of a large spill area in the salt lakes should have made it possible for her to function as an outfall for the drainage from Calcutta and the neighbouring areas for a much longer period but for the acts of man. The salt lakes, even after reclamation along the borders now measure about 55 sq. miles and, it seems to me, define the boundary between the area built up from the north by the upland floods and that from the south by the tides carried up the Bidyadhari and the Peali. Even after the stoppage of upland floods it should have been possible for nature but for human interference, to raise this area by tidal deposit instead of leaving it as a nuisance so close to the city.

**Death of the Bidyadhari hastened by the acts of man.**

63. The first interference was the premature reclamation of the land on either bank of the Matla and of the Bidyadhari by means of marginal embankments, towards the middle of the last century. This was one of the earliest areas to be reclaimed, and consequently both the channels began to deteriorate with progressive rise in tide level or what may be called 'heaping up of tides'. At Port Canning (Bidyadhari outfall into the Matla) the highest high water level has risen from 6·28 in 1865 to 12·83 in 1930 (O.M.S.L. data). At Dhappa the ordinary high water level in 1830, as gathered from old records, was 1·5 in the dry season and 3·5 in the rains. The H.W. level was 9·41 in 1926. At Bamanghata on the Bidyadhari the H.H.W. level has risen from 9·1 in 1894 to 11·00 in 1926. It will be of no use referring to the level at Dhappa and Bamanghata in recent years as tidal flow is practically non-existent and the level is really ruled by the discharge of Calcutta drainage, but it may be noted that the present level is considerably higher. The Bidyadhari, which hitherto used to drain Calcutta, is now trying to drown the city with the sewage and we are trying to prevent the catastrophe by means of flood embankments proposed to be constructed along the eastern boundary.

**Rise in tidal level—an inevitable sign of deterioration.**

64. Now this 'heaping up of tides', which occurs when a tidal wave is unable to dissipate itself over the spill area, is another characteristic of tidal rivers, and where tides carry a large proportion of silt, as in Bengal, it causes deterioration of the channel by the dropping of silt. The explanation is probably as follows: 'Heaping up' of tidal flow really means gain in potential energy. But as the sum total of the energy which generates this flow, *viz.* tidal impulse created in the deep sea by the attraction of the sun and the moon, etc. is constant during each tide, this gain in potential energy must be attended with a corresponding loss in its kinetic energy, or in other words the flood tide can only rise in level at the expense of its velocity. Now the silt-carrying capacity of the flow being proportional to the velocity, it follows that

**Significance of 'heaping up of tides' explained.**

as soon as 'heaping up' occurs a portion of the silt brought up by the tides, in excess of what the reduced velocity can carry, drops on the bed, thereby further impeding the tidal wave and accelerating the deterioration of the channel in a vicious circle. This phenomenon of 'heaping up of tides' is going on more or less in almost all the tidal rivers, where the spill area has been unduly curtailed and really constitutes the preliminary warning of deterioration. In the Bidyadhari, and at the head of the Matla Estuary, the 'heaping up of the tides' is probably the worst as their spill areas have been the earliest to be reclaimed. It becomes less and less as we move towards the eastern parts of the delta.

65. The second stage of human interference was the discharge of the Calcutta sewage into the Bidyadhari. While the liquid content has probably been helpful, especially during the dry season, the solid matter has certainly been harmful specially by forming a gelatinous coating over the channel bed and slope which the ebb flow finds it difficult to scour. The large number of fisheries in the salt lakes and other low areas also contributed to the deterioration of the Bidyadhari by preventing free tidal spill. Finally, the Kristopur canal (excavated in 1910), by cutting off a good portion of the salt lake spill area (Ghuni Jatragatchi—about 18 sq. miles) and interfering with the natural drainage from the north, accelerated the death of the Bidyadhari.

**All attempts for revival of the Bidyadhari have failed.**

66. Attempts were made to revive the Bidyadhari both by acquiring a spill area (about 2½ sq. miles which was found to be much too small) and also by dredging at a heavy cost. But the opposing forces were found to be much too strong and the Bidyadhari continued to deteriorate. She is now absolutely dead without any chance of revival and it would be interesting to note the rapid rate of deterioration from the following figures:—

| | 1883. | 1904. | 1936. |
|---|---|---|---|
| Lowest Bed level near Bamanghata referred to O.M.S.L. or P.W.D. datum .. | −58·69 | −29·71 | +5·75 |

The present bed is even higher than the country level on either side.

| | 1894. | 1915. | 1917. | 1926. | 1932. | 1936. |
|---|---|---|---|---|---|---|
| L.L. water level at Bamanghata .. | −4·9 | 0·0 | +0·17 | +2·5 | +5·92 | +11·05 |

| | 1926. | 1936. |
|---|---|---|
| Cross sectional area at Bamanghata below R.L. 9·75 .. .. | 2,440 sq. ft. | 363 sq. ft. |

67. All attempts at the restoration of the Bidyadhari have now been rightly abandoned and the Calcutta Corporation are dredging an independent outfall into the Kultigong. As the proposal has received the approval of Government and the work is in progress I refrain from making any comments.

Nor would such comments be really appropriate in the present paper, which only deals with river problems in general and does not aim at finding a solution to any specific local problem like the drainage problem near about Calcutta. This problem is sufficiently important and complex to form the subject of a special paper. I wish only to add in this connection that the Peali, a branch of the Bidyadhari, is also fast deteriorating and will soon share the same fate as the Bidyadhari. Immediate steps are, therefore, necessary to prolong the life of this river. After the death of the Bidyadhari, the Peali is now the only source of drainage for a large portion of 24-Parganas district and constitutes the outfall of several drainage schemes constructed by Government at a heavy cost. The death of the Peali will not only mean the loss of this capital but, due to consequent water logging, the area affected will gradually revert to swamps and jungles from which it was prematurely reclaimed by the acts of man.

**Life of the Peali must be prolonged in the interest of drainage of a large area.**

## River problems with reference to Navigation.

68. I have dealt with the river problems in Bengal so far as they have arisen in respect of the beneficent activities of the rivers in draining and fertilising the land which they have created. I now refer to another aspect of river problems in respect of the valuable services which the rivers are rendering to the country in the matter of carrying the produce by cheap water routes. Together with the tidal portion of Central Bengal, Eastern Bengal possesses very important natural resources in her navigable channels, the value of which in promoting trade and providing facilities for cheap communication can hardly be exaggerated. We have first the principal highways, *viz.* the Ganges, the Brahmaputra and the Meghna, providing water communication with the neighbouring provinces of Bihar and Assam. Then we have the network of feeder channels connecting these main waterways with the trade centres including Calcutta, one of the important ports in the world. Again, in Eastern Bengal, which is inundated by the floods of these rivers, it is possible during the monsoon to carry goods by water practically from every village to the nearest feeder channel, and from there to one of the principal highways for transport to the several trade centres. This is perhaps unique in the history of the world, for, though there are other countries possessing natural waterways, I do not know of any where the system of internal boat communication has been so thoroughly planned by nature as in these parts. Apart from its value to trade it is also providing employment to hundreds or thousands of people, the importance of which in a province like Bengal, where the pressure of population is already being felt, can hardly be exaggerated.

**Waterways constitute a valuable natural asset.**

69. The importance of conserving and improving, where possible, this valued gift of nature is, therefore, obvious. As regards the principal highways no attention is really needed except during the dry months, when it may be necessary, near bad shoals, to train and divert the available flow through particular channels so as to increase the depth of water to suit the requirements of navigation. A large quantity of the discharge of the Ganges and her tributaries is, however, being utilised for irrigation in the upper provinces and so long as it is extracted during the monsoon months, it does not seriously matter as there is plenty to spare. But further extraction of low water discharge of these rivers should be a matter of serious concern to Bengal and Bihar as not only is this likely to endanger navigation in the Ganges during the low water season, but, after the improvement of her spill channels in Central Bengal, we shall require more and more of this discharge to pass through them to keep them efficient. It, therefore, seems necessary to keep an eye on the future development of irrigation schemes in the Ganges basin in the upper provinces and, as the interests of these provinces are likely to conflict with those of Bengal, the necessity for the establishment of a representative body to adjudicate those interests has to be considered.

**Conservancy of waterways—the pressing need for Eastern Bengal.**

**Further reduction of low water discharge of the Ganges—a matter of serious concern to Bengal.**

**Necessity for an interprovincial River Commission.**

70. But the main problem which we have to face at present in the matter of improving facilities for communication by water is with regard to the feeder channels connecting these principal highways, especially with Calcutta. In the olden days, when the Bhagirathi was in better condition, Calcutta was of course directly connected by water with the Ganges. Later, as navigation through the Bhagirathi became more and more difficult, the Jalangi and the Mathabhanga were being utilised for the purpose. In those days steamers were of course unknown and, as can be gathered from the old records, navigation even by boats was difficult during the dry months. It appears that even up to about the middle of the last century there was considerable activity in connection with attempts made to maintain the Mathabhanga as a feeder route to Calcutta from the Ganges. (*N.B.*:—The Churni connecting the Mathabhanga with the Hooghly appears to have been an artificial cut made in the interest of navigation.)

**Maintenance of feeder channels constitutes the main navigation problem.**

Most of the supply drawn from the Ganges by the Mathabhanga offtake was in those days escaping into the Kumar and steps were taken to prevent this by artificial action. It also appears that in 1860 and 1861 five chord cuts were made across some of the bad loops of the Mathabhanga thereby shortening the river by 21 miles and making its fall equal to that of the Kumar.

71. These attempts, however, did not prove very successful and more and more attention was paid in improving the boat route through the

Sunderbans. The construction of Calcutta Canals including the Chitpur lock was taken up early in the 19th Century and the canal route was gradually improved by the construction of New cut canal in 1859; Dhappa, Bamanghata and Kulti locks in 1895; and lastly the Kristopur canal in 1910, which was intended for boats. When steamers were introduced later, they used to enter the Bidyadhari through Tolly's nalla (excavated in 1770) and take the Sunderban route *via* Port Canning and Matla. Owing to the deterioration of the Bidyadhari and the Matla the steamer route is being gradually shifted more and more towards the sea face. Here again nature has helped us by providing cross connections between outfalls of primary delta builders (estuaries), usually flowing north to south. But for these cross connections navigation from Calcutta to the Ganges would have been difficult by steamers and probably impossible by boats, as they would have to pass out into the sea to get into the next north-to-south channel and so on. In fact our main problem at present in respect of navigable waterways is with regard to the maintenance of these cross connections. The maintenance of the north-to-south channels is also proving more and more difficult and will be impossible ultimately, as these channels, in the absence of upland water supply and with spill areas prematurely reclaimed, continue to deteriorate as in the case of the Bidyadhari and the Matla.

**Cross channels —valuable natural gift.**

**Their maintenance constitutes the main navigation problem.**

72. The existence of these cross channels is probably attributable to the funnel-shape of the Bay of Bengal, the deepest sea being in the middle ending in the 'Swatch of no ground', more or less in a line with the centre of the delta and the shallower and shallower sea running along the coast lines to the east and west. Owing to the more favourable conditions available for the propagation of the tidal wave along the deeper or central portion of the Bay, the tide makes first at the head of the 'Swatch of no ground' and travels along the delta face, one branch running to the west and another to the east. For this reason and also due to the irregular extension of the delta as pointed out above, the tides do not make absolutely at the same time at different points in the same latitude along the delta face, thus giving rise to cross currents between the deeper channels just below the outfalls of contiguous north-to-south delta builders. As pointed out by Major Hirst (*Report on Nadia Rivers*, 1915) the delta, in consequence, has not probably extended continuously but in the shape of islands between two contiguous outfalls, leaving a cross channel between the island and the main land. So long as the difference in the time of arrival of the tide at either end was such as to prevent the formation of a tidal meeting ground within the cross channel, it remained. But where, owing

**Origin of cross channels explained.**

to irregular extension of the island at its outer face, due probably to one delta builder being more active than the other, this difference was altered so as to provide a tidal meeting ground within the cross channel, it closed up, joining the island with the main land. In this way many of the cross channels have now disappeared throwing the steamer route more and more to the sea face. The gradual rise of the tide level with a tendency to drop a larger and larger proportion of the silt content has also helped in this process.

**Meeting of tides—a grave menace to the maintenance of cross channels.**

73. It has been stated above that, along with the improvement of the rivers in Central Bengal in their upper reaches and diversion through them of a portion of the Ganges flood, their tidal reaches will also automatically improve and with the copious supply of upland water thus available a solution may be found to maintain these tidal channels on a permanent basis which is so vitally necessary in the interest of inland navigation in Bengal.

74. In this connection it may be mentioned that to shorten the distance by water between Calcutta and the Ganges, the *Madaripur Bil Route* was opened early in the present century. As the name indicates, it was a passage about 20 miles long cut through a series of *bils* connecting the Madhumati at Manickdah with the Kumar river at Fatehpur and through that river and the Ariel Khan with the Ganges. The scheme was highly successful as the spill of the Ganges and the Madhumati, after depositing the silt on the *bils* and the country-side lying to the north and west of these channels, was sufficient to give them a thorough flushing and they were more or less self-maintaining. This route practically monopolized the whole volume of waterborne traffic between Calcutta and Bihar and Upper Assam and, apart from immense benefit to trade, it was also yielding a decent revenue to Government. But to meet the demand of the growing heavy traffic it was considered necessary to widen the bil route which, in consequence, began to draw more and more of the available spill supply at the expense of the Kumar which, for want of sufficient nourishment, is now being starved to death and in which navigation is no longer possible during the dry months. It is a highly complicated subject and cannot be dealt with properly in a short note. But I mention it to show that in this case also we have the requisite natural resources in the large volume of flood water now running to waste in the Ganges and the Madhumati and the problem is one of diverting a portion to feed the Kumar which is starving to death for want of an adequate supply.

**Difficulties in the maintenance of the Lower Kumar river—cross connection between the Madhumati and the Ganges.**

75. While dealing with this subject of communication, I should like to sound a note of warning especially to those who live in areas which are still being favoured by nature in the shape of annual flood flushing. We hear talk of the extension of railways in those parts, for instance the rail road from Barisal to Madaripur and between Dacca and Aricha, etc. The improvement

of facilities for communication is certainly necessary as these are vital factors in the cultural and economic uplift of a nation. But rail roads in these parts have to be carried on high embankments, materially interfering with the flushing arrangement devised by nature. We should not, therefore, repeat the mistakes made in the case of Western Bengal and, instead of embanked roads or railways, our policy in future should rather be to meet the demand for communication in these parts by improving the existing waterways and making new waterways where none exist at present.

## River problems with reference to erosion.

**Erosion problem—inherent in the conditions of flow of deltaic rivers.**

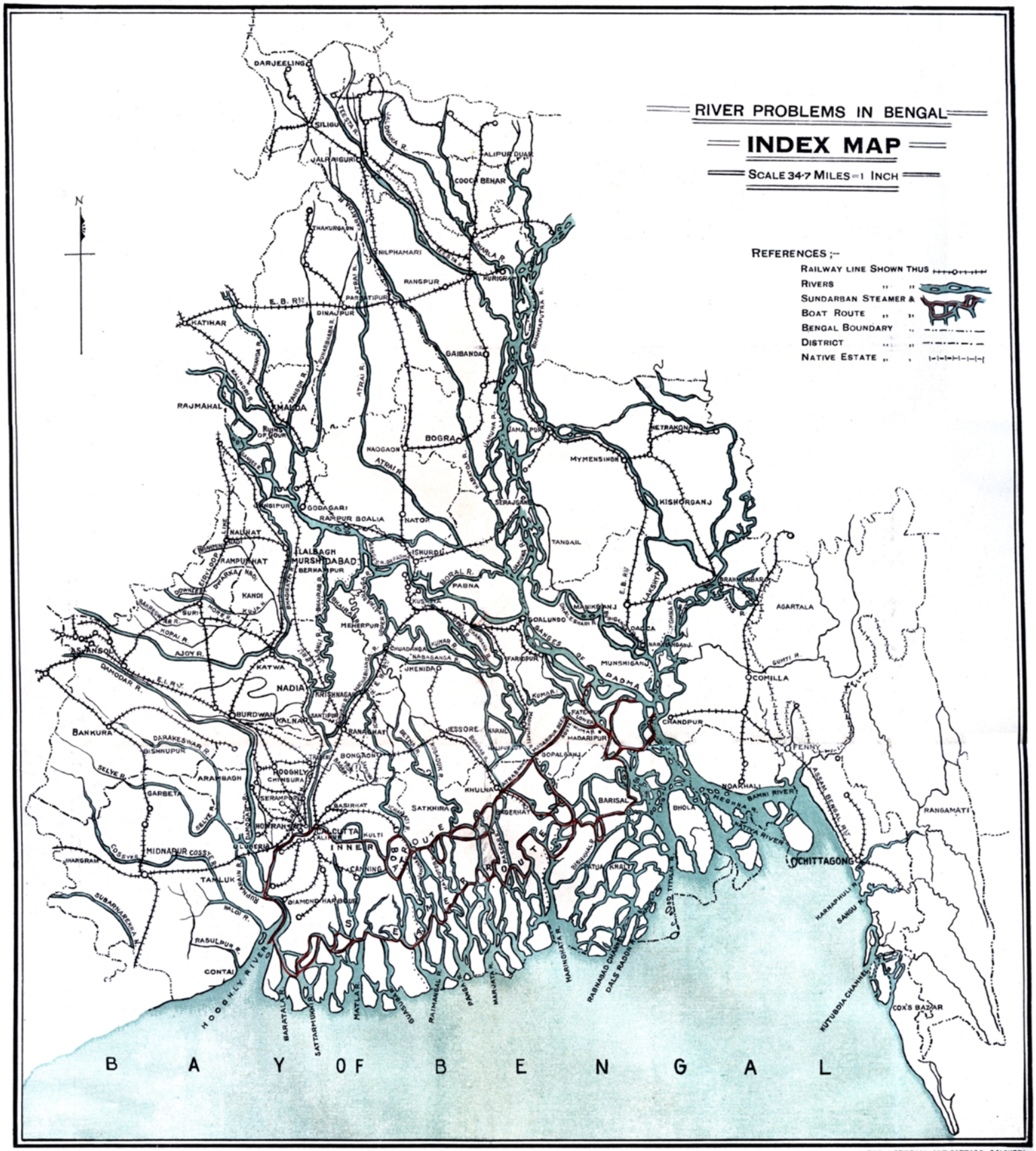
76. Another problem that I should like to mention before I conclude is what is being created especially by the primary delta builders of group I, in Eastern and Northern Bengal, by the rapid erosion of the banks. The problem is to a certain extent inherent in the conditions of flow of deltaic rivers, but it has been aggravated by the natural tendency to concentrate all available flow into the two principal rivers—the Ganges and the Jamuna. Resuscitation of the rivers in Central and Northern Bengal, so as to enable them to carry their due share of flood water, will no doubt make the position somewhat easier, but the erosion will still continue to remain a problem as the soil through which these rivers flow is extremely soft. Special study in a laboratory may perhaps reveal some cheap method of river conservancy by which this problem can be satisfactorily solved. But the method of direct action, *viz.* the protection of the eroding bank by brick mattress, etc. that is now followed, is so very costly that it can hardly be adopted except for the protection of important towns.

**Silt factor dominates the river problems in Bengal.**

77. It will be seen from the above that the all-important factor which dominates the river problems in Bengal is the large proportion of silt carried by the floods. It is the silt which has created the land and made it habitable by raising it through centuries. It is the silt again which is fertilizing the land, and where the process is still operating the country is healthy and prosperous, while where it has ceased to function the country is progressively deteriorating in health and productivity of the soil. But though the silt has proved to be such a beneficial gift of nature this very factor has given rise to most of our river problems that we find to-day. It is the silt which, by deteriorating the old river channels, has forced their diversion through lower areas which, though beneficial to the latter, has been so harmful to the area served by the former as we have seen in the case of Central and Northern Bengal. It is the silt which, by raising the beds and consequently the flood level of embanked rivers, has created problems highly complex and unique in character, as we have seen in the case of the rivers of Western Bengal, especially the Damodar. It is the silt which has killed

many of the tidal rivers in Central Bengal and threatens to kill the rest with disastrous consequences to the interests of navigation and drainage, unless we can reinforce the ebb flow in her struggle against the silt brought in by the flood tides. It is the silt again which is killing the cross channels so valuable in the interests of navigation, which, like a thoughtful mother, nature left between the north to south channels for the benefit of Bengal in the process of extending the delta. Silt, in short, is one of our greatest benefactors and, in some respects, also a malefactor and we ought to make the closest study of this all-important factor. Unfortunately we possess very little information on the subject beyond the general knowledge as indicated above. What is required is a fully equipped laboratory to study this and other questions amenable to laboratory treatment, thoroughly and scientifically, and to guide us in our effort to solve the rather complicated river problems in Bengal. Many of these problems are rather unique and without parallel. The results achieved elsewhere will not help us much; we have to find the solution ourselves by long and concentrated study of local conditions.

**Necessity for research.**


RIVER PROBLEMS IN BENGAL
INDEX MAP
SCALE 34·7 MILES = 1 INCH
N
REFERENCES ;–
RAILWAY LINE SHOWN THUS
RIVERS
SUNDARBAN STEAMER & BOAT ROUTE
BENGAL BOUNDARY
DISTRICT
NATIVE ESTATE
DARJEELING
SILIGURI
JALPAIGURI
COOCH BEHAR
ALIPUR DUAR
THAKURGAON
NILPHAMARI
RANGPUR
KURIGRAM
PARBATIPUR
DINAJPUR
KATIHAR
GAIBANDA
RAJMAHAL
MALDA
BOGRA
JAMALPUR
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NAOGAON
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KISHORGANJ
GODAGARI
RAMPUR BOALIA
NATOR
TANGAIL
NALHATI
LALBAGH
MURSHIDABAD
BERHAMPUR
ISHURDI
PABNA
BRAHMANBARIA
AGARTALA
KANDI
SURI
MEHERPUR
GOALUNDO
MUNSHIGANJ
DHARAMPUR
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KATWA
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KUTUBDIA CHANNEL
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B A Y OF B E N G A L
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THE IMPERIAL ART COTTAGE, CALCUTTA.