Evolution of the Mayurakshi river system -

The evolution and the broad framework of the erosional history of the Mayurakshi basin can be correlated fairly well with the geomorphology and the denudational chronology of the Chotanagpur plateau. In this part of eastern India fluvial erosion and weathering processes are the dominant determinants of landform evolution besides the endogenetic ones.

The Mayurakshi basin, an integral part of the peninsular shield, is intimately connected with the ancient primeval landmass of Gondwana land. The geological framework of the basin is the result of the developments of latter formations like the Gondwanas, Rajmahal traps and inter-trappenAs over the denuded precambrian granite and gneissic floor.

The initial drainage lines must have developed over the Archaean landmass. Unhindered erosion exposed the roots of the granitic and gneissic hills and the batholithic intrusions were bevelled down. Denuded Ramgarh ranges are the relicts of the ancient mountains.¹

Late Carboniferous glaciation "must have temporarily arrested some of the drainage lines of the country. ... The melting of the glacier lead to a confused drainage lines".² The drainage pattern developed during this period, was deranged, the drainage lines being lost and merged into the marshy land without any relationship with the underlying structure.

² Ibid.
The history of the hayurakshi river system begins with the pre-Tertiary peneplain. The monsoonal precipitation initiated heavy surface run off over the peneplained surface and the network of tributaries developed.

During the Jurassic period lava flows obliterated the pre-existing drainage lines. Ash and lava flow covered most of them, but some must have truncated and extended themselves headwards. New stream evolved over the lava surface and adjusted themselves by river capture and stream piracy. These streams have divided the lava surface into flat broad water divides and narrow valleys.

It seems that the first drainage lines were west flowing. To the west of the basin the basement complex of the Archeans is exposed, while to the east and south-east later formations cover the parent rocks. It should be logical to think that as the erosion starts from the base level of erosion, the lower course of the rivers exposed the granito-gneissic floor while the upper surface escaped erosion.

In the beginning of the Tertiary age, the area was uplifted to the southwest and titled to the northeast. Streams of the west were rejuvenated and new drainage lines were in the process of evolution over the uplifted land. The direction of the hayurakshi river system changed, having firstly a south-easterly and easterly and then a north-easterly course. Dwarka and Kopai - tributaries of hayurakshi - are firstly south-east flowing streams, then formed a boathook bend and changed their courses north-eastwards.

It seems that the locations of their diversions are a zone of hypersubsidence.\(^4\) "Imposing western scarps of Rajmahal stand in great contrast to the gently dipping lands of the north and east.\(^2\) Tilting in a downstream direction accelerated the stream energy, imparting them a renewed erosive power. These rejuvenated streams degraded their courses along the entire length of the tilted land, while the rivers rejuvenated by upliftment adjusted themselves by headward erosion and thus formed knickpoints or distinct breaks in the long profile.

There is difference of opinion about the formation of the zone of older alluvium. Some attributed this to be the alluvial fan,\(^3\) but others are in the opinion that this is the first deltaic landform of Bengal.\(^4\) Fossiliferous strata of late Cretaceous to Tertiary states that the present Bengal delta was under the grip of alternative marine regression and transgression and it was very late in the Pleistocene that the sea finally receded from the Bengal basin and the Bay of Bengal got its present shape (see ch.II). The Mayurakshi and her tributaries have brought the sediments from the gneissic plateau and deposited them at the confluence of the rivers with the sea. The deltaic condition of the river began near Suri, where its first distributary Manikarnika has taken off. The height at the apex of the delta is 150\(^1\) (45.72 m\(^1\)) and the slope is east and north-eastwards. Due to the declination of the slope

\(^{3}\) Bagchi, K (1944) - op.cit., pp.8-19
\(^{4}\) Chakraborti, S. (1970) - op. cit. p.20
at the confluence of the pleistocene sea the rivers deposited their loads and were divided in a number of distributaries. The zone of older alluvium and laterites of Birbhum are evidences of the deltaic deposition of the Mayurakshi. The laterites of Birbhum lack the charaterics of the primary laterite formed in situ but rather formed because of the transportational agencies. "... The presence of a subsurface layer of Kaolinitic clay bed tinged from above by ferrous collids, an admixture of rounded pebbles of heterogenous rocks with the laterites and a general absence of normal lateritic horizon indicate that more probably these detritues carried by rivers in shallow coastal areas." 1

The Bhagirath delta formation commenced only at the later part of the Tertiary age. Geoophysical surveys by the oil and natural Gas commission have indicated the presence of a burried ridge below the Tertiary sediments2 which kept the rivers of the Ganga plain completely separated from the Bay of Bengal through most of the Tertiary. 3 Only very late in the Tertiary the Ganga has taken a south easterly course due to the post-Siwalik movements in the north-west Punjab causing a dismemberment of the "Siwalik rivers", 4

The Mayurakshi and her tributaries extended their channels over the deltaic plain of the Bhagirathi. The north-south trending delta of the Bhagirathi and the east-west trending delta

1. Ibid.
4. Wadia, D.N. (1966) - 'Geology of India', p.56, ELBS.
of the Bhagirathi and the east-west trending delta of the Mayurakshi meet at Murshidabad district. The delta formation of the Mayurakshi ceased after the recession of the sea and the Bhagirathi left a moribund delta in this region while active delta formation continued to the south.

Over this zone of moribund delta deposition commenced in a continental environment. The rivers have built their flood plains forming ex-bow lakes, cut-offs and natural levees.

The deterioration of the Bhagirathi river and the change of its course have a long term effect on the Mayurakshi river system. The shifting of the main flow of the Ganga through Padma due to the blocking up of the Hooghly estuary by tidal sand caused the deterioration of the Hooghly river. The raising of the beds and high flood level have created a large number of back swamps at the mouth of the Mayurakshi. Due to the high water level of the Bhagirathi, the rivers of the Mayurakshi system can not discharge their water into the main river during their high discharge condition thereby creating an inundated area in the lower catchment.

The oldest map of the Mayurakshi system is of Rennel (1779). He shows that the Dwarka and Mayurakshi, instead of making the united channel of Babla, separately joined the Bhagirathi.

3. Rennel (1779) - op. cit.
The present landform owes its origin to the original constructional surface, tectonic activities and erosion mainly by fluvial processes. Repeated marine regressions and transgressions changing the local base level of erosion are evidenced from the breaks in the long profile of the rivers (fig. 77).

Along with geology and structure, climate plays a distinct role to a great extent influencing the geomorphological processes over the area. The increase of the population of the tributary streams and ramification of the basin took place in the classical processes of drainage elaboration and finally their integration under the tropical monsoon conditions.

The attainment of maturity was disturbed by uplifts in the Tertiary period accompanied by warping, a faulting and tilting of the erosion surface. The Dhobhi river (tributary of the Mayurakshi in its upper catchment) shows a youthful character of the valley. The Mayurakshi, Tepra, Brahmani and Sidhisari are characterised by graded profiles in the upper courses whereas in the lower reach they are still in the processes of being graded (fig. 77).

All the valleys of the streams of the Mayurakshi system have steep and high banks. Signs of incision are present on the Mayurakshi near Hassanjor, on the Dwarka near Deocha and Brahmani near Masania (fig. 10/12/3).

The average height of the residual hills of the eastern part (Rampurhat and Nalhati P.S. of Birbhum district) are lower
DRAINAGE SYSTEM OF THE EIGHTEENTH CENTURY - THE MAYURAKSHI BASIN

SOURCE: RENNELL J (1779) - THE JUNGLETERY DT. WITH THE ADJACENT PROVINCES OF BIRBHOMO RAJMEL BOGHFOUR & COMPREHENDING THE COUNTRES SITUATED BETWEEN MOORSIDABAD & BIHAR

FIG. 40
DRAINAGE SYSTEM OF THE MAYURAKSHI BASIN

(Based on LANDSAT IMAGERY 1975)

SOURCE: ERTS LANDSAT imagery on 30.3.75
than that of the western upland (Santthal Pgs). This is due to the initial tilting of the north-eastern part in response to the earth movements.

The residual hillocks and the dissected uplands present in the basin are the products of sculpture and erosion by the Mayurakshi and her tributaries. A number of accordant summit levels are the evidences of different cycles of erosion.

Different periods of erosion, uplift and tilting have complicated the character of the drainage here. The drainage lines in the upper catchment follows the lines of joints with the continual process of headward extension.

A comparison of the drainage maps of Rennell (1779), Survey of India topographical sheets (1922-23) and landsat imageries (1975) show that the rivers have changed their courses within a very short period (fig.1,40).

From the above analysis we can summarise the major episodes of drainage development.

1. The first drainage lines of this part of the Chotanagpur plateau developed in accordance with the basement of the Archaean complex.
2. During the Gondwana period, carboniferous glaciation caused the development of deranged and inequent streams.
3. Lava flows arrested most of the drainage lines during the cretaceous, but some of them truncated themselves and new drainage lines established.
4. In the Teritary, the earthmovement resulted into the tilting of the landform causing the change of direction of the streams north-eastwards.

5. Delta formation of the Hayurakshi continued up to the pleistocene period.

6. Bhagirathi started delta building after the Ganges changed its direction due to the "post-Siwalik" movements.¹

7. Both the deltas have attained the moribund stage and recent floodplain formation continued.

Drainage Pattern -

Drainage pattern refers to the spatial relationships and alignment of the network of streams or rivers. The pattern of individual streams differ in their spatial relationships to one another as they are governed by initial slopes, rock resistance, structural control, climatic parameters mainly the precipitation and temperature characteristics and the geomorphic history of the region. Some geomorphologists draw distinction of "drainage patterns" based primarily on their network pattern and the factors controlling their developments. They are referred more to the spatial relationships of individual streams than to the overall pattern made by the individual drainage lines.²

The drainage pattern of the Hayurakshi basin reflects the effects of geological formations and geomorphic history. The

¹ Wadia, D.N. (1966) - op.cit., p.56.
² Thornbury (1954) - op.cit., p.123.
different resistance of rocks, the erosional character of the Archean terrain, the erosional lava plateau, the depositional plain and occasional tectonic disturbances are responsible for the 'complexity' in the drainage pattern of the area under study.

Above 100 meter (above mean sea level) the flow of the drainage network of the Kayurakshi basin shows an overall north-west - southeast alignment. Below this surface the rivers have a north-easterly and easterly slope. The Kayurakshi itself is guided by joints and lines of foliation of the granitic and gneissic rocks. The main rivers of the Mayurakshi system - Mayurkshi, Dwarks, Brahmani, Siddheswari, Bakreswar and Kopai flow nearly parallel to each other.

Radial pattern is well developed in the terrain of the residual hilly ranges and isolated hillocks.

Though not the main tributaries, most of the first and second order rivers meet the next higher order at acute angles forming dendritic patterns in the sub-basins.

The drainage pattern of the upper catchments of the Dhobhi, Tepra, Matihara and Siddheswari are rectangular which reflect the control exerted by the joints. The steep slopes of the scraps of the Ramgarh hills have developed parallel drainage pattern.

The important drainage patterns bearing the imprints of the variation of structure, geology, relief and erosional history are:-(1) Dendritic, (2) Rectangular, (3) Parallel, (4) Radial, (5) Barbed, (6) Pinnate and (7) Annular.
(1) **Dendritic drainage pattern**

To the western part of the Kayurakshi basin, over the granite-gneissic peneplain gently dipping south-eastwards, the Siddheswari, Matihara, Brahmani and Dwarka have joined their master streams at acute angles. "The pattern of drainage -- is dendritic, having steam, branches, limbs and twigs, it is like an oak tree in the organisation of its parts".¹

The Kopai and Bakreswar rising from the igneous and metamorphic terrain of Chotanagpur have large sections of their middle and lower courses over the older and newer alluvium. These two river basins display the dendritic drainage pattern over the rocks of uniform resistance (fig. 1).

The closeness of the dendritic pattern depends upon the permeability of the underlying rock and the amount of precipitation.² But there is very little variation in the amount and nature of precipitation over the catchment under study and if we have a look at the basin, the influence of the permeability of the rocks appears to be clear. The impermeability of the granite rocks causes heavy surface run off and thereby results into the denser network of streams, while through the permeable older alluvium in the lower catchment, a high percentage of rainfall penetrates under-ground, leaving a small amount as surface run off which causes the growth of a sparser network of drainage lines.


Fig. 42a
DRAINAGE PATTERN

DENDRITIC & RADIAL

SATGARH HILLS

MARSANJOB

N24°05' E87°15'
N24°10' E87°20'
24°10'N 87°20'E

N24°05' E87°15'

N24°10' E87°20'
24°10'N 87°20'E
Though the main streams of the Hayurakshi system display rectangular pattern, the second and third order tributary basins have dendritic pattern. Headward erosion of these streams on rocks of uniform resistance lacking structural control, leads to the formation of this pattern here (fig. 412).

A modified dendritic pattern is the "anastomosing pattern." Anastomosing of the rivers initiated below the 36 meter contour line. Average slope of the zone is below 1°. The channel gradients of the rivers of the Hayurakshi system over this region is very low (table 38). Due to the declination of the slope, the rivers are not able to carry their load and deposition begins in the form of channel bars, shoals etc. A big riverine island has been formed near Suri. The first distributaries of the Hayurakshi the manikarnika has taken off from this area. Below 18 m contour line, the country is a region of anastomosing rivers, swamps and bills (fig. 436).

2. Rectangular pattern -

The subsequent tributaries of the Hayurakshi - Dhobhi, Siddheswari, Tepra, Nunbil join their master stream at right angle. They have also formed right angle bends and their tributaries join them forming a rectangular pattern (fig. 4). "This pattern is invariably result of geological controls, ... well-defined lines of weakness such as joints or faults." \(^2\)

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In the upper catchment of Dhobhi, Siddheswar, Tepra and Rumbil, the drainage pattern is rectangular (fig. 42c). The drainage of a small area near Dumka displays rectangular pattern. This pattern attained in some parts of the Mayurakshi owe it to the predominant jointing system and fracture zones over the Archaean granite and gneiss.

The sinuosity Index of the Mayurakshi is 1.03. Such linearity is due to the control on the river channel exerted by joints and structural lineaments. Therefore instead of well-developed meanders it has many right angled bends (fig. 1).

It is recognised that some tributaries of the Katihara near its source, some upper catchment tributaries of Tepra and a number of tributaries of the Siddheswari do not meet their master streams exactly at right angles, but angular form is prominent and the control of structure is conspicuous. This is because faults or joints do not always join each other at right angles, but at acute or obtuse angles. Therefore it is better to designate them as "angulate pattern".1 (fig. 1).

3. Parallel pattern -

"The parallel pattern as the name implies, consists of parallel master and tributary streams. Pronounced regional slope, parallel faults and parallel topographic features are conducive to the formation of this drainage type."1

1. Thornbrough (1958): op. cit., p. 120.
Fig. 42a

DRAINAGE PATTERN

PARALLEL STREAMS FROM THE RAJMAHAL HILLS FORMED DENDRITIC PATTERN AT THE FOOThILL ZONE

1 MILE

1/6 KMS.
The course of the tributaries and sub-tributaries of the Mayurakshi - Siddheswari and Chandna, Brahmani, Iro, Gumra and Tripita, Tepra and Matihara - all are more or less parallel to each other. Mayurakshi, Brahmani, Dwarka, Kopai and Bakreswar run almost parallel to each other and instead of joining each other at right angled bends, they converge at the same place to form the river Babla. These rivers obviously are structurally controlled. The jointing system of the igneous terrain and the parallel faults are responsible for such alignments of the streams (fig. 17).

On the erosional slope of the Rajmohal pahar also the pattern is almost parallel. From the elevated tracts of the erosional hills short tributaries run parallel to each other towards their master streams (fig.42a).

The same drainage pattern has developed on the fault scarp of the Ramgarh hills. Emerging from the steep slopes of this fault scarp, a number of small tributary streams running parallel down the slopes join the tributaries of the Dwarka river (fig. 42c).

In some places of the granite-gneissic terrain, owing to steep gradient, the pattern is parallel. This is the case of the tributaries of the Siddheswari river (fig. 1).

4. Radial Pattern -

Over the rolling topography of the Archean complex, harder varieties of rocks have developed radial drainage pattern (fig. 42a). From the elevated landform, drainage lines radiate in all directions down the erosional slopes in all sides (fig. 42b).
To the north-east of the Chotanagpur plateau stand the eroded Rajmahal hills composed of basaltic lava and to the south-west of it stand the Ramgarh hills formed of Gondwana sedimentaries. From these residual hillocks streams spread out to all directions forming radial drainage pattern (fig. 42b).

5. Barbed pattern -

The characteristic 'boat hook bends' typical of barbed drainage pattern is not common in this area. In the source region of the Dwarka, there are some examples of barbed drainage pattern (fig. 41f). This is the result of stream pracy which has affected a reversal of the separate drainage system.

Thornbury (1969) believes that another cause of drainage reversal is warping or tilting. The Dhobhi, Bhurbhuri and Gambhira rivers in their upper courses formed boathook bends pointing upstream (fig. 1). This is due to the Tertiary tilting.

6. Pinnate pattern -

To the west of the Mayurakshi basin over the graniteland gneissic country (above 150 m. contour line) short subparallel streams meet the Siddheswari river at acute angle forming pinnate pattern (fig. 1). The term "Pinnate" means leaflets on each side of an axis, i.e. short sub-parallel streams joining the master streams at acute angle.

Above the confluence of the Tepra river, the tributaries of Matihara evolved the above pattern upto about 20 miles of its course (fig. 1).

Another pinnate pattern is developed by Tepra and the tributaries from 870E to the confluence point with the Matihara (fig. 1).

1. Thornbury (1954) - op. cit. p. 120.
This subparallel dendritic pattern owes to the steep slopes of the erosional surface. Another hypothesis for their development is that, jointing system of the Archean terrain controlled the alignment of these tributaries (fig. 7).
ANNUAL DISCHARGE OF THE MAYURAKSHI

TOTAL DISCHARGE

DISCHARGE THROUGH THE RIVER CHANNEL

DISCHARGE IN 00 CUSECS

MONTHS

FIG. NO. 43
Flow Pattern -

The chief characteristics of all the streams in the Mayurakshi system is that they flow with tremendous velocity in the monsoon months, carrying substantial volume of sand and silt, but becomes almost dry in winter. During the monsoon they often overflow their banks.

The channel morphometry is controlled by the hydraulic characteristics of the stream channels which include width, depth, slope, velocity, discharge, bed material and load. But here sufficient data are not available for the successful analysis of the hydraulic characteristics of the streams. Therefore only some of the features are discussed here. In the case of the rivers of the Mayurakshi valley the present pattern of discharge (restricted flow due to the construction of dam and barage) can affect very little of the shape of the channel. Here, only the discharge below dam through the canals and the flow through the channel have been given (fig. 43, Table 32). The sediments of the river bed has an inverse relationship with the quantity of discharge. From the shape of the river bed, we can assume that the discharge through the channels were higher in the pre-dam than the present time. During the pre-dam period the siltation index of the catchment of Mayurakshi dam was 0.75 Ac. feet/sq.mile while it was 4.21 ac. ft/sq.mile of the catchment area as per survey of 1972-73.¹

¹ Source: Irrigation & Waterways Deptt., West Bengal.
FLOOD MAP OF THE AREA STUDIED

AREA UNDER FLOOD
RAIL ROAD

FIG. No. 46

SCALE
16 0 16 MILES
25.6 25.6 KMS
FIG 45
FLOOD LEVEL CURVE OF RIVER BABLA AT ITS OUTFALL AT BHAGIRATHI (1971-1978)
If we can take it as the common case for the whole of the Mayurakshi basin, we can account for the gradual elevation of the river beds. With the surface wash mainly during the rain, sediments come to the river channel from its catchment area. But in the scarcity of the regular and also high discharge through the channels, these sediments can not be washed away, instead of that they are deposited on the river beds (fig.57a).

Thus in the Mayurakshi river valley, the broad cross sectional area and the shape of the river channel owe their origin to the discharge of the pre-dam period and the present condition of the river is a misfit channel with a very low discharge.

**Flood**

As the discharge is restricted through the main channels of the Mayurakshi and her tributaries, flood is now the more important phenomenon in determining the shape of the river beds. "The term annual flood is employed in the usual sense of peak discharge in a given water year", ¹ Both the velocity and shear stress on the bed increase with the rise in stage accompanying flood passage through a river reach.²

The term 'flood stage' is related with inundation stage. In the Mayurakshi valley inundation occurred during 1956, '59, '71 and '78 within the period from 1956-1978.² The term flood stage is in most instances used interchangeably with flood damage stage.³ During the period from 1971 to 1978, Bhagirathi has

crossed the flood danger level in 1971, 1978 and in 1973 and 1977 it was at a close proximity of the above mentioned stage (fig. 45).

The principal cause of the flood in the lower catchment of the hayurakshi is the higher stage of the Bhagirathi. At the outfall of Babla, its danger level is at 54' (16.46 mt) which is actually the bankful stage. In the immediate vicinity of Katwa, the river Bhagirathi has got a maximum carrying capacity of 1,27,000 cusecs. In 1956, the Ajay brought 300,000 cusecs of water which aggravated the flood condition of the Bhagirathi. The Bhagirathi is the ultimate outfall of the rivers of the Hayurakshi system. With the rise of stage of the Bhagirathi during the flood, the water brought down by these rivers cannot find their way out and caused inundation.

1978 Flood - Widespread floods are uncommon in the hayurakshi valley, but in 1978, a catastrophic flood occurred which caused radical geomorphological changes of the basin. The origin of this inundation lies in both the physigraphic conditions and the pedological conditions of the area. The geomorphic process especially the rill and gully erosion have largely contributed to the inundation by these rivers.

As we have already discussed, due to the construction of the irrigation project, the main river channels got very little run off (fig. 49). But due to rapid destruction of forest, soil erosion has increased (see ch. III). We have noticed that siltation of the catchment area is higher in the post-dam than the

4. Majumdar, D (1975) - op. cit., p.17
FLOOD LEVEL CURVE
OF
THE MAYURAKSHI
(26.9.78 - 5.10.78)

FIG. NO. 47
pre-dam period. These sediments which come in the river channels as surface-wash are deposited and the river beds are gradually elevated.

With this background was added the cyclonic rainfall of the September of 1978 (fig. 46). During the last week of August, a Cyclonic storm with a large tract caused flood in the lower Gangetic rivers, which caused the Bhagirathi to attain a nearly bankful stage.\(^1\). Then on 21st September, a depression formed near Baleshwar and crossing the Coromandal Coast reached the Daltonganj on 25th September.\(^2\) This 'low' turned south-east and east and on 27th hovered near Asansol and developed into a deep depression (fig. 46). On the 27th September the rainfall recorded in the hayrakshi catchment is:

<table>
<thead>
<tr>
<th>Table No. 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm)</td>
</tr>
</tbody>
</table>

|  | Hassanjor | Naya Dunke | Jama | Jaramundi | Suri | Sainthia |
|  | 287.50    | 300.80    | 311.80 | 157.20    | 400.00 | 190.00   |
|  | Ahmedpur | Labpur    | Tilpara Barrage |
|  | 360.30    | 268.50    | 354.30   |

Another low pressure started from Andaman and moving northwest reached the Bayhead on 3rd October.\(^3\) Continued torrential rainfall (over 450 mm in about two days) forced the authorities to open the gate and a huge quantity of water (16,77,829 cu sec on 27th October) rushed below the dam

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2. Ibid.
3. Ibid.
through the canals and the main river and a section of the afflux bundh was bleached. The main rivers and canals were overflown. The feeble banikarnika was flanked with the overflowing hayurakshi (fig. 4A). The sandbank below Tilpara was washed away. The embankments of the Dwarka were shattered. When the floodwater met the Quey river (combined water of the Bakreswar and the Kopai) it could not hold the flow and its banks were widely breached along with the railway bridge and lines at Goalparaghata near Labpur town. At the lower catchment Khargram, Barwan and Kandi police stations were damaged extensively.

**Magnitude-frequency analysis of discharge**

Very high discharges are rare and low discharges are common in the hayurakshi system of drainage. Here an attempt of magnitude-frequency analysis has been made to analyse the occurrence of peak discharge in the rivers of the hayurashi valley. Although high discharges are not common, one cannot predict that a recorded high flood cannot be followed by another higher one. In order to show their time relationship, Gumbel method has been followed.

Following this method, the highest peak discharge recorded in each year for a station has been taken. The series is formed by one peak discharge or flood per year in the annual

---

series. In Gumbel method the recurrence interval of these peak discharges are determined. By arranging the floods in descending order of magnitude and ranking them, recurrence intervals (R.I.) are determined by the equation, \( R.I. = \frac{n + 1}{r} \), where R.I. is the recurrence interval of flood discharge, n is the total number of items in the series, and r is the ranking order of the particular peak discharge (table 34).

Peak discharges with a recurrence interval of 25, 50, 100 and 1000 years have been calculated by the Irrigation and Waterways Department of West Bengal which are as follows:

**TABLE - 15**

<table>
<thead>
<tr>
<th>Rivers</th>
<th>Peak discharge in 10^4 cusecs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 yrs.</td>
</tr>
<tr>
<td>1. Mayurakshi Down Tilpara</td>
<td>17.8512</td>
</tr>
<tr>
<td>2. Brahmani down Brahmani barrage</td>
<td>5.5185</td>
</tr>
<tr>
<td>3. Dwarka down Dwarka barrage</td>
<td>3.9727</td>
</tr>
<tr>
<td>4. Bakreswar down Bakreswar weir</td>
<td>1.6951</td>
</tr>
<tr>
<td>5. Kopai down Kopai barrage</td>
<td>2.6878</td>
</tr>
</tbody>
</table>

Besides, these, the R.I., mean and median values of peak discharge have been calculated by the author. The median of peak discharge of the rivers occur at 2.00 to 2.11 recurrence interval of years where mean comes at 2.11 to 4.15 yrs. (table 34).
"By strict definition, channel morphometry is the measurement of channels while channel morphology is the study of the channel shape." But both the terms are used for the purpose of channel pattern analysis.

Channel pattern is the alignment of the channel in plan as it appears from an airplane. Although there are a large number of well represented types, the natural channels are generally straight, braided and meandering.

Among these patterns, straight patterns rarely exist in reality. Straight channel seldom exceeds the length more than that equal to 10 channel width. Experiments show that where the channels are apparently straight, the thalweg wanders back and forth near one bank to other forming pools and riffles.

As the development of pools and riffles indicate that the uniform bed slope necessary for the straight reaches are uncommon, the straight reaches in some parts of the Mayurakshi and her tributaries owe their existence to geological control.

Meandering pattern is a common occurrence in most of the natural channels. Its properties very with bankful discharge. The channel width, w, varies with bankful discharge Qbf thus, \( w \propto 3Qbf^{0.5} \). Again, meander wavelength (L) is the linear function of \( w \), i.e. \( L = 10w \).

Therefore \( L \propto Qbf^{0.5} \) or \( L \propto 30Qbf^{0.5} \).

2. Leopold et. all (1964) - op. cit., p.281.
**GEOMETRY OF MEANDERS**

- **L**: MEANDER LENGTH (WAVE LENGTH)
- **A**: AMPLITUDE
- **R**: MEAN RADIUS OF CURVATURE
- **W**: WIDTH

**FIG. 48**
In the Mayurakshi river basin, meander length of the rivers range from 9-11 times the channel width (fig. 49).

For the case of the amplitude of meanders Leopold et. al (1964) states that as it properly correlates with meander length, the amplitude of the meander loops is determined by valley side material rather than some hydrological factors.¹

The braided pattern is characterised by bars and bifurcation and reunion of multiple channels. In the Mayurakshi valley the braided condition of the rivers started from the area where the underlying material is older alluvium. Over the zone of older alluvium coarser bed material causes the collapsing of the banks rapidly and the channel becomes wider and shallower. When the bars grow the slope of the divided streams are steeper than the simple one and the enhancement of downward erosion causes stream deepening and the bars dry out at most stages and plant-growth gives the bar stabilization.²

In equal discharge, braided streams have steeper slope than meandering one.

Over the older and newer alluvium zone, the dominant pattern of the Mayurakshi and her tributaries are analranching and anastomosing. Where the offshoots rejoin the trunk stream or another neighbouring stream the pattern is anastomosing and anabranching developed where the distributaries after a long journey have their outfall at sea or a separate right which is the base level of erosion of their mother stream.

Channel pattern of the Mayurakshi.

We find the development of the above mentioned patterns in the case of the Mayurakshi river. Although, it is generally agreed that straight channels rarely exist in reality, Mayurakshi and her tributaries do not have well developed meanders in large parts of their reaches. But they are not truly straight reaches and better be termed as sinuous (fig. 1).

From Sibnagar (86°54'00"E: 24°30'30"N: 87°02'30"E: 24°37'30"N) for a distance of 12 miles (19.31 km), the channel of Mayurakshi is almost straight. After Beldaha the river has developed three bends but could not develop a true meandering pattern. In this part the river valley is narrow and almost v-shaped.

After the confluence of the Tepra with the Mayurakshi, the later is sinuous up to Hijla Pahar near Dumka (87°15'00"E: 24°15'00"N) for a distance of 5.3 miles (8.53 km). From the outfall of Siddeswari and Phatik Nullah at 244' (74.37 mt) the bed of the Mayurakshi widens rapidly but the channel is almost straight and the banks are steep and high.

The anastomosis of the river starts from Khairakund (87°31'30"E: 23°57'N). This is section of the off-taking of the Manikarnika river and a large riverine island has been formed in the main channel. Another riverine island has been formed near Saora. From 87°45'E and 23°55', the river bed becomes narrower than the former part. But the channel is meandering in this section. Sand bars and riverine islands also formed in this section. Two riverine islands have been formed near Dudhka, one near Narayanpur and four near Panchthupi of Birbhum district. In this area of lower catchment,
the river has been divided into a number of distributaries - Atkhora, nala, Beli, Kana Mor etc. These rivers meet the river Babla near Kandi P.S. of Murshidabad district.

**The Brahmani**

The Brahmani river shows predominant meandering pattern. Up to the Ramgarh hills over the Archaean tract, the river is sinuous with narrow v-shaped beds and steep banks. Over the Barakar sandstone and shale the river has formed well developed meanders (S.I. = 2.0). The river has a south-easterly course up to $87^\circ 25'\text{E}$ and $24^\circ 17'\text{N}$ and then it has turned to the east.

The river bed widens (411 rut.) where Tripita meets. From this area cut-offs and ox-bow lakes have been formed giving an indication of intensive development of meandering.

Over the older alluvium zone from Nalhati the river bed is meandering and has thrown a number of distributaries. In the Brahmani floodplain a characteristic feature is the formation of back swamps.

**River Dwarka**

The channel pattern of the river Dwarka is meandering as it has developed symmetrical bends throughout its whole reach and the sinuosity index is greater than 1.5 (Table 238). The sinuosity index of the river is 1.6 up to the crossing of the East Indian Railway Loop Line and in this zone the river width varies from 80.50 mt. to 238 mt. From this point to $87^\circ 45'\text{E}$ the course is almost straight and from $87^\circ 45'\text{E}$ and $24^\circ 12'30''\text{N}$ the river forming a boat hook bend turns to north-east. At Ranpur it throws off its first distributary
and near Kabichandrapur the river left its first cut off. A
large number of cut offs and ox-bow lakes developed in due
course with the intensive development of meandering.

The Kopai -

Like the other rivers of the basin, Kopai has a sandy
bed with a narrow channel. The well developed meandering pattern
and the dominance of topographic sinuosity index (Tsi) over hydra-
ulic sinuosity index (HSi) indicate that the river is free from
geological control and has obtained maturity. The Kopai, at its
upper part, is southeasterly and from Monoharpur (87°37'30"E:
23°42'00"N) it turns north-east, just as the case of the Dwarka.

The Bakreswar meets the sinuous channels of Kopai near
Patharghata (87°47'30"E: 23°47'30"N). The united flow is called
the Koiya Nala. Numerous cut-offs and ox-bow lakes formed in
this section, shows the migration of the meanders. The river
throws off its first distributary near Labhpur. The Kopai and
her tributaries pour some water in the Nangalthata bil which is
nothing but a back swamp zone.

After 88°00'E, the river is anastomosing. The area between
Atkhora nala (distributary channel of the Mayurakshi) and the
Kiu river is usually flooded from July to September. Maldah
beel is situated here. Between the Babla and the Kiu there is
a vast back water zone where a number of distributaries lost
their courses.
**Sinuosity Index**

All streams possess some amount of sinuosity which is associated with bending and curving of the stream channels. Sinuosity varies with stage, age, topographic and geologic background of the streams.

The most common process of deriving sinuosity index is by dividing the length of the channel by the length of the valley.¹ According to Leopold and Langbein (1966), Sinuosity Index may be derived by "dividing the length of the channel in a given curve by the wavelength of the curve."² Leopold, Bagnold, Wolman and Brush (1960) introduced another index of sinuosity which is the ratio of the thalweg line and the length of the valley of a stream.³

But as all these indices do not consider the role of topographic characteristics as one of the controlling factors of the channel pattern, the sinuosity index of Mueller (1968)⁴ has been adopted here. Mueller considered both the role of topographic and hydraulic factors for the determination of the tortuosity of the course.

For the quantitative study of the sinuosity of the rivers,

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the measures are as follows:

\[ \text{CL} = \text{the length of the channel of the stream under study.} \]
\[ \text{VL} = \text{The length of the valley of the stream.} \]
\[ \text{AL} = \text{The shortest air distance between the source and the mouth of the stream.} \]

Channel Index or an index of total sinuosity = \( \text{C.I.} = \frac{\text{CL}}{\text{AL}} \).

Valley Index or an index of topographic sinuosity = \( \text{V.I.} = \frac{\text{VL}}{\text{AL}} \).

Hydraulic sinuosity Index, which means the amount of departure of the straight line course due to the hydraulic sinuosity.

\[ \text{H.S.I.} = \% \text{ of } \frac{\text{C.I.} - \text{V.I.}}{\text{C.I.}} \]

Topographic sinuosity Index which is the amount of stream's departure from a straight line course due to the topographic interference.

\[ \text{T.S.I.} = \% \text{ of } \frac{\text{V.I.} - 1}{\text{C.I.} - 1} \]

Analysis:

Following Muellear's model, all the above measures of the Mayurakshi and her tributaries are shown in table. The study reveals the following facts:

(i) All the streams of the Mayurakshi basin are sinuous in nature. The highest S.I. is 2.45 for Dhobhi river and the lowest is 1.48 for the Mayurakshi river.

(ii) Though the sinuosity indices are high for the small streams of the upper part of the basin, in the majority of the cases the channel deviation is controlled topographically.

(iii) The S.I. of the Part-II and Part-III of the Mayurakshi are 1.19 and 1.18 respectively. In these parts, the channels are almost straight in nature. This straightness owes to the line of foliation and numerous joints of the igneous' terrain.
From bend no. III of the Mayurakshi, S.I. is high with a high percentage of H.S.I. Here the floodplain of the river is well-developed. On the fifth part of the river, the channel pattern is anastomosing. Here the TSI is high because of the rapid downward erosion of the divided channels.

(IV) The TSI values of all the rivers are higher than the HSI values. This may be attributed firstly to the fact that the Dhobhi, Tepra etc. and a large part of the Mayurakshi flows over the Archaean terrain with numerous joints. The other cause of this high TSI is the occurrence of three successive earthmovements of the Chotanagpur during Oligocene, mid-Miocene and Pleistocene with the upliftment of the Himalayas.¹

Long and Cross sections:

The river bed is wide containing a narrow channel throughout the year. This suggests that the bank caving of the river is a rainy season effect rather than the excavation throughout the year.

After the construction of the Canada dam at Massanjore the river does not carry the total discharge, only a very insignificant percentage (41/°) passes through the river Mayurakshi. Only during the flood the main channel gets a bankful discharge. Though normal bank erosion goes throughout a bankful the year maximum excavation occurs during the flood.

FIG. 49

LONG SECTION OF MAYURAKSHI FROM MAHAMMAD BAZAR TO TRIMOHINI

MAHAMMAD BAZAR

DISTANCE IN FEET

HEIGHT IN FEET

RIGHT BANK
LEFT BANK
BED LEVEL
HIGH FLOOD LEVEL

SOURCE: I & W.D.
The shape of the river valley is a concurrent product of discharge, underlying formations, slope and the stage of the rivers attained. The cross sections of the rivers concurrently vary with varying channel patterns.

In the Mayurakshi Valley, the channel pattern may be called the wandering type in many sections and there the cross section is symmetrical. Downward corrosion of the rivers dominating over lateral erosion is responsible for such type of valley formation. But as we have already stated that these wandering channels which are almost straight, are also sinuous to some extent and most of them have a tendency to be assymetric in nature (fig.38).

The cross profiles of the meandering streams are clearly assymetrical in nature. This owes to the lateral erosion of the river. The fastest current impinges on the outer bend of the river and the back flow come to the convex bend carrying the eroded particles. This causes the steepness of the concave bank and the formation of a slip-of-slope near the convex bank. But the cross sections of the river Mayurakshi near Dumka show steepness of both the banks. It emphasises on the formation of entrenched meanders there (fig.37).

A characteristic feature of the sinuous channels is the pool-and-riffle sequence which is found even in the straight channels. The flashing flood during the rainy season causes the scour and fill of the channel developing a pool-and-riffle sequence. The long section of the Mayurakshi from Mahammad Bazar to Trimohini shows alternate pools and riffles.
CROSS SECTION OF THE MEADERING CHANNEL OF THE MAYURAKSHI

C. S. AT 48768.00 MT DISTANCE BELOW THE TILPARA BARRAGE

SOURCE I.W.D.

FIG 50
CROSS SECTION OF THE BRAIDED CHANNEL OF THE MAYURAKSHI

(C.S. AT 518.6 MT DISTANCE BELOW TILPARA BARRAGE)

SOURCE: I.R.W.O.

FIG. 57
The asymmetric cross sections are characterised with point bars and occasional shoals near the convex bands (fig. 50). But the development of shoals and bars near the convex bank — which has been observed by the author in the Dwarka river near Rampurhat (plate 24) and another one in Kopai near Shantiniketan by Basu (1972) do not owe to normal erosional and depositional effects. The mechanism has been discussed earlier (ch. III).

In the meandering channels, the width/depth ratio of the cross sections is high (Table 29). The change from meandering and straight channel to a braided one has resulted the widening of the cross sections. A typical diamond shaped bar is located at a distance of 32.2 miles (51.32 km) downstream from Tilpara barrage (10). The individual channels are narrow and deep. The w/d ratio is much lower than the meandering one.

In the toposheet surveyed during 1922-23, it is found that a large riverine island was formed in the channel of the Mayurakshi near Suri town of Birbhum district. The colonization of the plants turned it to a stabilized state. The undivided channel was meandering in fashion. The divided channels were also sinuous. They reunited at Bengra. From the landsat imagery (1975), it is found that the riverine island has become stabilized with the growth of plants and development of settlements. The slope of this section is 0.858 ft/1000 ft, while the slope of the reunited meandering section is 0.569 ft/1000 ft.

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CROSS SECTION OF THE KANA MOR (Anbranching channel)

C.S. AT 3352.80 MT EAST OF THE OFF-TAKING POINT FROM THE MAYURAKSHI
CROSS SECTION OF THE ANABRANCHING CHANNEL OF THE DWARKA

C.S. AT 85344 MT DISTANCE BELOW THE DWARKA BARRAGE AT DEOCHA

ELEVATION (MT)

DISTANCE (MT)

SOURCE I & W D

FIG. 1
The anastomosis and anabranching of the Mayurakshi and her tributaries begin with a decrease of slope. The slope of the meandering reach of the Mayurakshi is 0.516 ft/1000 ft., while the slope of the anastomosing one is 0.272 ft/1000 ft. The anastomosing channels and anabranches sometimes form straight and sometimes meandering reaches. But the cross sections are always symmetrical with steep and high banks with narrow beds (fig. 53, 54). The cross section of the Babla at its outfall is almost v-shaped. The width/depth ratio of this section is very low (table-37).

River Valley erosion -

The predominant agent of erosion and deposition in the study region is the Mayurakshi and her tributaries. Leopold et al. (1964)\(^1\) used the term "scour-and-fill" for the process operated during a short period while "aggradation and degradation" should involve mean change brought about during a long period. The rapid rate of scour and fill is the characteristics of the rivers like those of the Mayurakshi system with high-flood discharge conditions (fig. 36, 37).

The change of the channel pattern is a product of river erosion and deposition which are controlled by slope, lithology and stream flow condition. The change of cross sections of straight to meandering and braided channels is the resultant effect of stream competence and capacity.

\(^1\) Leopold et. al (1964) - op. cit. p.227.
FIG. No 55

CROSS SECTION AT 500' (152.4 M) UPSTREAM OF DWARKA BARRAGE

DATUM 150' ABOVE M.S.L. 150

SCALE

15' 24" 15' 24 M.

- - 1954
- - 1955
- - 1956
- - - 1957
CROSS SECTION OF THE MAYURAKSHI AT 9280' UPSTREAM OF THE TILPARA BARRAGE FOR THE YEARS 1954 & 1955

SOURCE: I.W.D.
The Mayurakshi has a straight reach in its upper course (over the plateau), meandering and braided in the middle course (over the plateau fringe) and anastomosing and anabranching pattern near its confluence with the Bhagirathi. In the straight reaches, v-shaped river valleys owe to the prominence of downward erosion over lateral erosion. Where the river is sinuous, lateral erosion of the rivers in the concave side and deposition in the convex one cause the growth of asymmetric cross section. In the lower section of the rivers the process of erosion and deposition of the meandering channels have given rise to a number of ox-bow lakes and cutoffs (fig. 36,48). In the braided section of the rivers, with a greater slope than the meandering channels, the energy of the streams enhanced, which is used in valley cutting. As a result, the cross sections of the braided reaches are narrow and deep.

Though channel scour and fill is a normal effect of discharge the process is much enhanced during the flood time. With the rise of the stage, the velocity increases and the valley is scoured. With the fall of the stage, the sediment contributed by scouring of the valley upstream is deposited downstream.1

1. Ibid.
NET CHANGE OF BED ELEVATION

(CROSS SECTION OF THE DWARKA AT 500' UPSTREAM OF DWARKA BARRAGE)
NET CHANGE OF BED ELEVATION

(CROSS SECTION OF THE MAYURAKSHI AT 9280' UPSTREAM OF TILPARA BARRAGE)
A comparison of the cross sections of the rivers of the Mayurakshi system of different years gives us a clear picture of the net change of the level of the river beds. Fig. no. 75 gives an idea of the bed elevation change of the Dwarka river at 500' (152.4 mt.) upstream of the Dwarka barrage for a period of 1954-57. During the period of 1954 to 55 agradation dominated over degradation and in most part of the bed there was very little even no change of bed elevation. The picture is the same during 1955-56, and the little change which occurred was mostly in the aggradational side. Maximum bed elevation was one feet, while lowering 0.5 ft. The maximum net change of bed elevation occurred in the period of 1956-57, when both the maximum elevation and lowering was 2.0 ft. This pattern of aggradation and degradation occurred in other rivers also.

This type of bed elevation can be related with the peak discharge of the rivers. At 1954 the peak discharge is 15,500 cm. secs, at 1955 is 3700 cusecs. The peak discharge of 1955 cause the least change in 1955-56.

The broad sandy beds of the rivers and the occurrence of bars and shoals, natural levees etc. are evident of a high degree of deposition by rivers.

These deposition features have been dischassed in ch. III in the context of the geomorphological forms.