STUDY OF THE SEDIMENT CHARACTERISTICS OF THE GANGES, GORAI AND MATHABHANGA AND ITS EFFECTS ON RIVER HYDRAULIC GEOMETRY

RESEARCH REPORT
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RIVER RESEARCH INSTITUTE, FARIDPUR

MINISTRY OF WATER RESOURCES

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

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PREFACE

Bangladesh is a flat deltaic country formed by the sediment carried by the three main rivers namely the Brahmaputra-Jamuna, the Ganges-Padma and the Meghna. These main rivers and their distibutaries and tributaries play an important role in the development of overall economy of the country. But these rivers are being silted up every year. The deposition of sediment in the river and channel beds creating problems for navigation, flood inundation, irrigation and maintenance of river ports and harbors. Due to deposition of sediment in the river bed BIWTA is spending a large sum of money for dredging riverbed to maintain navigable water depths. Chittagong and Mongla port authorities are facing problem to maintain accessibility to the port and harbor. BWDB is also facing problem in keeping the irrigation channel free from siltation. On the other hand rivers of Bangladesh are characterized by severe bank erosion that eats up many installations, homesteads etc, causing economic loss of the country. The river courses are very unstable due to large variation in water discharge and sediment load. The water environment and socio-economic condition of the people of Bangladesh are significantly influenced by the characteristics of the rivers. The characteristics of the sediment load coming from the up stream country and the characteristics of the local riverbed are most important for determining the river channel hydraulic geometry. The bar deposits, flood plain and planform of the river are influenced by the sediment characteristics. Hence a good knowledge of sediment characteristics of the rivers are essential for better understanding of sedimentological and morphological processes of the rivers. Keeping this idea in mind RRI had taken up a research project to study the sediment characteristics of the Ganges, Gorai and Mathabhanga and its effects on river hydraulic geometry.

The findings of the study may help the planners and designers to understand the characteristics of the sediment of the rivers under study and its effects on the river hydraulic geometry due to variation of sediment load. The study also provides some information about post dredging developments in the river Gorai at the down stream of the off-take.

The researchers are very much grateful to the officials of the different organizations particularly of BWDB for providing necessary data. If the outcomes of the study help to develop understanding of the morphological processes of the rivers to some extent the efforts of the research team would be considered fruitful.

27/6/02

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1. Introduction

1.1 Background

Bangladesh is a flat deltaic country. The sediment deposit of the three great rivers namely the Brahmaputra-Jamuna, Ganges-Padma and the Meghna and numerous other rivers formed the main land of this country since time immemorial. It has a unique system of rivers that plays an important role in the development of overall economy of the country. The rivers are getting silted up every year. The deposition of sediment in the river and drainage channel bed is creating serious problem for navigation, flood inundation, irrigation and maintenance of river ports and harbors. The flood has become almost a regular phenomenon in this country causing serious damage to standing crops, lives and properties. Due to deposition of sediment in the river bed BIWTA is spending a large sum of money for dredging riverbeds to maintain navigable water depths.

Chittagong and Mongla port Authorities are facing problem to maintain accessibility to the port and harbor. BWDB is also facing many problems in keeping the irrigation channel free from siltation. The rivers of Bangladesh are characterized by severe bank erosion that eats up many important government and private installations, homesteads and valuable agricultural land causing colossal economic loss of the country. The river courses are extremely unstable due to large variation in discharge and sediment load. The water environment and the socio-economic condition of the people of Bangladesh are significantly influenced by the characteristics of the rivers. The characteristics of the sediment load coming from the upstream country and the characteristics of the local riverbed and bank material are the most important for determining the river channel hydraulic geometry of the rivers. The sediment transport rate is related to the size of the material. The coarser the bed material the smaller the transport rate. Even the sediment deposition depends on its size. The smaller the particle sizes the smaller the settling velocities and slower the particles settle. The bar deposits, the composition of bank material and flood plains, the channel geometry and planform of the rivers are influenced by the sediment characteristics. Hence a good knowledge of the sediment characteristics of the rivers is very essential for better understanding of sedimentological and morphological processes of the river. So it is imperative to study the sediment characteristics of the rivers and its effects on river hydraulic geometry. Keeping this end in view RRI has taken up the research project, "Study of the sediment characteristics of the Ganges, Gorai & Mathabhanga and its effects on river hydraulic geometry."

1.2 Objectives of the study:

The objectives of the study are:

- To investigate the sediment characteristics of the rivers selected for the study
- To study the temporal variation of different dependent hydraulic variables with flow discharge
- To study the influence of variation in the suspended sediment discharge on river hydraulic geometry,
- To study the effects of dredging at Gorai offtake on downstream river condition.

2. Description of the rivers

2.1 The Ganges

The Ganges is one of the largest rivers of Bangladesh. It is noted for its massive water discharge and huge amount of sediment load during monsoon and low flow during dry season. The Ganges River originates from the west of Nanda Devi range in Himachal Pradesh and northernmost Uttar Pradesh, west of Nepal. The Ganges basin includes the entire territory of Nepal and Uttar Pradesh of India. The total length of the river from its source to Daulatdia is about 2200 km and its drainage area is about 1.1 million sq. km. Among the three major rivers the Ganges has the highest drainage area yet its water yield is the least of the three rivers (Barua 1994). This is primarily due to the distribution of rainfall in the drainage basins that is higher in the eastern drainage basins and lower in the western drainage basins. The other notable characteristics of the Ganges are its wide meandering planform and average water surface slope of about $5x10^{-5}$ (Khan and Barua 1994). The bank line migration is very erratic in nature and varies widely from bend to bend as well as year to year. The bed material size is about 0.14 mm (D_{50}) (RSP Report 1996). The mean annual discharge is about 11000 m^3/s and the bankfull discharge is about 43000 m^3/s.

2.2 The Mathabhanga

The river Mathabhanga is one of the distributaries of the Ganges. It takes off from the Ganges at Jalangir in the district of Murshidabad of West Bengal. It enters Bangladesh at Insafnagar in the district of Kushtia. Then it flows towards the south through Daulatpur, Bheramara, Alamdanga, Chuadanga and Meherpur. It again enters Indian territory near Chuadanga and finally discharges into the Bhagirathy after joining the river Churna in West Bengal. Within Bangladesh territory its length is about 130 km and average width is about 190m (Wazed 1991). Kumar, Chitra, Naboganga and Kabodak are its main distributeries. The offtake position of the river is very unstable. The minimum and maximum water discharges recorded at Hatboalia from the year 1998 to 2000 are 4.5 m^3/s and 268 m^3/s respectively.

2.3 The Gorai

The river Gorai is an important distributary of the Ganges. It takes off from the right bank of the Ganges at Talbaria, 19 km dounstreem of Hardinge in the name Gorai. It flows through the district of Kustia and enters the district of Jhenaidah at Goneshpur. Therefrom it travels along the border of Kushtia-Jhenaidah and enters Rajbari district at Chadat. From Rajbari it flows along the border of Faridpur-Magura in the name Gorai-Modhumati to enter the district of Bagerhat. Then it flows through the district of Barishal and falls into the Bay of Bengal at Haringhata. Gorai is a long and wide river. The total length of the river from its source to Haringhata is about 372 km of which 89 km upto Mohammadpur in the district of Magura is named as Gorai; therefrom upto 137 km downstream it is named as Madhumati and in the remaining 146 km upto Haringhata it is known as Baleshwar. Kumar. Kaligonga, Dakua, Burigorai etc. are its main distributeries and Chandana is the tributery of Gorai. The river Gorai is a very old river and its former name was Gouri. The water level gauging stations of the river Gorai are situated at GORAI RLY Bridge, Kamarkhali, Nazirpur and Pirozpur. As the river Gorai flows through the districts of Kushtia, Jessore, Faridpur, Khulna and Barishal the agricultural development and water environmental condition of these region are largely dependent on use of water of this river. Due to large-scale siltation at the Gorai mouth the offtake of the Gorai was completely disconnected from the Ganges particularly in the dry season. Due to reduced dry season flow of the Gorai the environmental quality of southwest region of Bangladesh is at stake. In 1999 Government of Bangladesh took up a project named Gorai River Restoration Project (GRRP) with financial assistance of donor agencies to augment the dry season flow through the Gorai. The maximum and minimum water discharges recorded at Gorai Railway Bridge during the year from 1998 to 2000 are 6145 m^3/s and 103 m^3/s respectively. On the other hand those values measured at Kamarkhali for the same time period are 4550 m^3/s and 57 m^3/s respectively.

3. Literature Review

3.1 Sediment transport mechanism and classification of sediment

When the flow condition reach the critical stage that is when the value of bed shear velocity just exceeds the critical value for initiation of motion, the bed material particles start moving by rolling or sliding in continuous contact with the bed. With the increase of bed shear velocity the particle moves along bed by more or less regular jumps that are called saltation. When the value of bed shear velocity begins to exceed the fall velocity of particles, the sediment particles can be lifted to a level at which the upward turbulent force will be of higher order than the submerged weight of the particles, as a result the particles may go into suspension. At any time a good number of particles may jump but eventually some of them return to bed again., by that time other particles go into suspension and the process goes continuously. As a result depending on the magnitude of the turbulence, the shape and size of the bed particles some of them remains in suspension and move along with the flowing water. The main sources of sediment are materials of streambed, bank material due to erosion and the fine materials that come from the catchment of the river. According to sources sediment can be divided into two groups viz, bed material load and wash load. but according to transport mechanism sediment can be classified into two categories viz, bed load and suspended load (Jansen , 1979). Suspended load consists of sediment particles held in suspension by balancing their gravitational force with upward forces due to turbulence of the fluid. The wash load is defined as material (finer than some 50 micron) than the bed material, which originates from upstream catchment area or from bank erosion. It is independent on capacity of the river and almost uniformly distributed throughout the river. Bed load is characterized by the movement of the bed material by rolling, sliding and small jumps. Bagnold defined (ASCE, 1977) the bed load transport as the sediment transport in which the successive contacts of particles with bed are strictly limited by the effect of gravity.

3.2 Causes of Sediment deposition

The main rivers and its tributaries and distributaries play an important role in the development of overall economy of the country. From ancient time to present days the rivers of Bangladesh have been playing a dominant role for waterways transportation, irrigation, fish culture etc. From the few decades back the rivers of the country have been undergoing morphological imbalances causing a large siltation in the riverbeds due to different man made interference. The drainage areas of the Brahmaputra and the Ganges are about 550,000 km^2 and 1111,000 km^2 respectively. During monsoon huge amounts of sediment enters these rivers from their vast drainage basins together with water. The combined flow of water and sediment makes the river behavior very much complex. Since the country is a deltaic flat plain the rivers can not carry so much sediment and sediment deposition occurs on riverbed as well on the flood plain eventually. In fact delta building process is still continuing through deposition of sediment every year.

3.3 Factors influencing the river channel geometry

The hydraulic geometry of a river can vary largely due to properties of the rainfall, the characteristics of catchment area and the influence of men in the river system. The discharge and sediment transports of a river vary with time and it has large influence on morphological parameters. The bed material transport is determined by the composition of the bed and by the hydraulic characteristics of the river. On the other hand the amount of wash load in a reach is only determined by the upstream supply. Hence it is not determined by the hydraulic parameters of the stream. The grain size, valley slope and human interference by major river training can influence the shape of the river. Moreover, the river may change its shape that is hydraulic geometry as a function of time.

4. Data collection

4.1 Sediment data

The sediment samples that have been received from BWDB are of routine nature. A large number of suspended sediment, bed material samples of the Ganges, Gorai and Mathabhanga are tested in the sediment laboratory of RRI during the period from 1998 to 2000. The results obtained from the sediment testing have been analyzed to have an overall understanding about the sediment characteristics of the concerned rivers.

4.2 Hydrological and hydraulic data

The cross sectional data of the Ganges are collected from SWMC, Dhaka. The hydrographic chart of the Ganges and Gorai are collected from BIWTA. The cross-sectional data and hydrographic chart that are collected from SWMC and BIWTA are not sufficient, consistent and regular. The discharge and water level data of the Gorai, Ganges and Mathabhanga are collected from Bangladesh Water Development Board (BWDB). For collection of discharge and water level data the time range and stations are selected keeping in view the objectives of the study. The data is collected for 2 (two) to 4 (four) years between the period from 1997 to 2001. Detail discharge measurement data is collected for the purpose of the study.

5. Methodology

5.1 Analysis of sediment data of the rivers

In order to study the sediment characteristics of the Ganges a large number of suspended and bed material samples collected by BWDB from the Ganges at Hardinge Bridge have been analyzed. Tests were carried out on the bed material samples for determining grain size characteristics. Ranges for percentages of sand and silt content, D_{16}, D_{50}, D_{84} and geometric standard deviation are calculated from the study of the grain size characteristics (RRI Report Sed-75). The results of bed material size distribution have been presented in Table 1.

Table 1: The results of bed material size distribution

No. of Sample	Location	Percent by WT.		D_{16}	D_{50}	D_{84}	Geometrical standard deviation
		Sand	Silt				
10	4 km D/S of H. Bridge	90-100	0-10	0.15-0.10	0.20-0.15	0.25-0.18	1.29-1.35
90	U/S of H. Bridge	80-100	0-20	0.18-0.08	0.20-0.08	0.32-0.13	1.36-1.24

The suspended sediment samples have been tested for determining sediment concentration and grain size distribution. The results of grain size distribution for the river Ganges have been shown in the following table (Table 2).

Table 2: The results of suspended sediment size distribution

No. of Sample	Location	Percent by WT.		D_{16}	D_{50}	D_{84}	Geometrical standard deviation
		Sand	Silt				
110	H. Bridge	75-35	25-65	0.058-0.012	0.11-0.08	0.20-0.095	1.85-3.92

The suspended sediment transport rates have been calculated from concentration values and corresponding water discharges (Sed-7, 1999, Sed-4, 2001).

To study the sediment characteristics of the Gorai a large number of suspended sediment samples collected by BWDB from the river Gorai at Gorai Rly. Bridge and Kamarkhali during the year 1998 to 2000 are tested in the sediment technology laboratory of RRI. From the suspended sediment samples sediment concentration has been determined (Sed-2, 2001, Sed-4, 2000,Sed-8, 1999). From these concentration values and corresponding flow discharges suspended sediment transport rates have been calculated.

A large number of suspended sediment samples collected by BWDB from the river Mathabhanga at Hatboalia during the period from 1998 to 2000 have also been tested in the sediment laboratory of RRI. From the tests suspended sediment concentrations have been determined (Annual Report, 1998, 1999 &2000). The suspended sediment transport rates are calculated from the suspended sediment concentrations and corresponding water discharges.

5.2 Analysis of hydrological and hydraulic data

The collected data is processed first. The processed data is then used to analyze the trend in temporal variation of suspended sediment transport with flow discharge. It is done for all rivers selected for the study. Then trend analysis is made to see the temporal variation of dependent hydraulic variables with flow discharge. In some cases temporal interrelationships among different dependent variables have also been established. River channel hydraulic geometry varies with flow and sediment transport. Some other factors may also play role in shaping its hydraulic geometry. Here the analysis is made to see the temporal variation of dependent hydraulic variables with flow discharge. This analysis will enable the reader to visualize the temporal variation of the hydraulic parameters with flow discharge due to variation in the suspended sediment transport. It is to be noted here that some other factors may also influence such variations.

6. Effects of variation of suspended sediment transport on river hydraulic geometry

6.1 The Ganges

Variation in the Suspended sediment transport

The water discharges and the corresponding suspended sediment transports recorded at Hardinge bridge have been plotted in Figure-1 for the years from 1998 to 2000. It can be seen from the figure that transport rates have decreased a bit in 1999 for discharges upto about 35000 m^3/s and substantially increased for discharges higher than that compared to the situation in 1998. In fact large sediment transport occurred in 1999. On the other hand sediment transport rates are seen to have decreased further in 2000 compared to the both 1998 and 1999 situation.

Variation in the water level (WL)

The water levels and corresponding discharges recorded at Hardinge Bridge have been plotted for the years 1998 to 2000 and shown in Figure-2. From the figure it is noticeable that water levels have dropped slightly in 1999 in comparison with situation in 1998 particularly for higher discharges. However, in 2000 situation the water levels have again attained the almost 1998 condition.

Variation of the hydraulic parameters at the downstream of Hardinge Bridge

In order to investigate the effects of variation in the suspended sediment transport on downstream hydraulic geometry two cross-sections are selected. One is at Talbaria (G11), just upstream of Gorai offtake and another (G10) is at about 9 km downstream of the first one. The cross-sectional data is collected for two years namely 1998-99 and 1999-2000. The cross-sectional survey was conducted in the wintertime (December-January). From these cross-sectional data it is possible to investigate the influence of large increase in the suspended sediment transport on hydraulic geometry of the river. For this purpose trend analysis is made to see the variation of one dependent variable with the other. The variation of average depth (D) with water width (W) for both the cross-sections is shown in Figure-3 & 4. As to the situation at c/s G10 it can be seen that for widths upto about 2800m average depth is increased and for the widths larger than that it is decreased in 1999-00 compared to the 1998-99 situation. On the other hand at c/s G11 the average depth is reduced in 1999-00 for about all widths in comparison with that of 1998-99. In Figure-5 & 6 the temporal relationships between area (a) and elevation (E) have been shown for c/s G10 and c/s G11 respectively. It can be seen that at c/s G10 in 1999-00 situation a relatively smaller elevation is required to have the same area of 1998-99 situation for cross-sectional areas upto about 13000 m^2. However, for higher cross-sectional areas a reverse trend is noticeable. As to the situation at c/s G11 it is to be seen that for cross-sectional areas upto about 19000 m^2 a higher elevation is required in 1999-00 in order to have the same cross-sectional areas of 1998-99 situation and a reverse trend is noticeable for cross-sectional areas higher than 19000 m^2.

6.2 The Gorai

Variation in the Suspended sediment transport

The variation in the suspended sediment transport with discharge at Gorai Railway Bridge and Kamarkhali appears in Figure-7 & 8 respectively. It can be seen from the Figure-7 that suspended sediment transport is reduced in 2001 compared to that in 1999 at Gorai Railway Bridge. As to the situation at Kamarkhali it is noticeable that a decrease in the suspended sediment transport for flow discharges upto about 2500 m^3/s and an increase for discharges higher than that have been occurred in 2000 compared to the situation in 1998. However, in 2001 suspended sediment transport is increased for discharges upto 3000 m^3/s and decreased for higher discharges compared to the situation in 1998.

Variation in the water level (WL)

The temporal variation of the water levels with discharges at Gorai Railway Bridge and Kamarkhali is shown in Figure-9 & 10 respectively. It is revealed from Figure-9 that water levels have dropped in 2000 compared to the situation in 1998 whereas in 2001 water levels are again seen to have gone up for discharges upto about 2500 m^3/s and dropped a bit for higher discharges in comparison with 2000 situation. As to the situation at Kamarkhali it can be seen that a drop in the water levels occurred in 2000 and 2001 compared to the situation in 1998.

Variation in the mean bed level (MBL)

The temporal variation of mean bed levels for different discharges at Gorai Railway Bridge and Kamarkhali is shown in Figure-11 & 12 respectively. The mean bed levels are seen to have gone up at Gorai Railway Bridge in 2001 compared to the 1999 mean bed level situation. At Kamarkhali a fall in the mean bed levels also observed in 2000 compared to that of 1998. However, in 2001 situation the mean bed levels are seen to have increased again and for discharges higher than about 700 m^3/s it even exceeds the 1998 levels.

Variation in the average depth (D)

The plots of discharge (Q) vs. average depth (D) for both at Gorai Railway Bridge and Kamarkhali appear in Figure-13 & 14 respectively. At Gorai Railway Bridge the average depth is decreased in 2001 compared to that in 1999 for discharges upto about 2000 m3/s. However, at discharges more than that the average depth is increased. At Kamarkhali it can be seen that at discharges less than 1000 m^3/s the average depth (D) is increased whereas a reverse trend is noticeable for discharges higher than 1000 m^3/s.

Variation in the water width (W)

The plots of discharge (Q) vs. water width (W) for both at Gorai Railway Bridge and Kamarkhali appear in Figure-15 & 16 respectively. It can be seen from Figure-15 that at Gorai Railway Bridge the water widths have been increased in 2001 in comparison with those in 1999 for all discharges. At Kamarkhali water widths are increased in 2000 for discharges upto about 2100 m^3/s and decreased for higher discharges compared to the 1998 situation. However, in 2001 situation water widths are reduced from the 2000 situation for all discharges. For discharges upto about 400 m^3/s it has reached the 1998 situation.

Variation in the average velocity (V)

The plots of discharge (Q) vs. average velocity (V) for both at Gorai Railway Bridge and Kamarkhali appear in Figure-17 & 18 respectively. It can be seen from Figure-17 that at Gorai Railway Bridge the average velocities have been decreased in 2001 in comparison with those in 1999 for all discharges. As to the situation at Kamarkhali (Figure-18) it is interesting to notice that for discharges upto about 1500 m^3/s average velocity is decreased and it is increased for higher discharges in 2000 compared to 1998 situation. In 2001 the average velocity is increased for all discharges compared to the 2000 situation.

Variation in the cross-sectional area (A)

The plots of discharge (Q) vs. cross-sectional area (A) for both at Gorai Railway Bridge and Kamarkhali appear in Figure-19 & 20 respectively. It can be seen from Figure-19 that at Gorai Railway Bridge the cross-sectional areas have been increased in 2001 in comparison with those in 1999 for all discharges. As to the situation at Kamarkhali (Figure-20) it is interesting to notice that for discharges upto about 1500 m^3/s cross-sectional area is increased and it is decreased for higher discharges in 2000 compared to 1998 situation. In 2001 the cross-sectional area is decreased for all discharges compared to the 2000 situation.

6.3 The Mathabhanga

Variation in the Suspended sediment transport

The variation in the suspended sediment transport with discharge at Hatboalia is shown in Figure-21. It can be seen from the figure that suspended sediment transport is increased in 2000 compared to the situation in 1998 in 1999.

Variation in the water level (WL)

The temporal variation of the water levels with discharges at Hatboalia is shown in Figure-22. It is revealed from figure that water levels have dropped in 2000 compared to the situation both in 1998 and 1999.

Variation in the mean bed level (MBL)

The temporal variation of mean bed levels for different discharges at appears in Figure-23. The mean bed levels are seen to have dropped from 1998 to 2001.

Variation in the average depth (D)

The plot of discharge (Q) vs. average depth (D) for Hatboalia appears in Figure-24. It can be seen from the figure that average depth is reduced in 2001 for all discharges compared to the situation both in 1998 and 2000.

Variation in the water width (W)

The plot of discharge (Q) vs. water width (W) for Hatboalia appears in Figure-25. It can be seen from Figure-25 that the water widths have been decreased in 2000 in comparison with those in 1998 for all discharges. However, in 2001 situation water widths are seen to have increased for very smaller discharges (<30 m3/s) and further reduced for higher discharges.

Variation in the average velocity (V)

The plots of discharge (Q) vs. average velocity (V) for Hatboalia appears in Figure-26. It can be seen from figure that the average velocities have been increased in 2001 in comparison with those both in 1998 and 2000 for almost all discharges.

7. Discussions on the results

The grain size analysis of the bed material of the rivers shows the bed of the river Ganges upstream and downstream of the Hardinge Bridge mainly consists of sand particles with small amount of silt. In case of suspended sediment load it is noticed that size distribution varies with time within a single year. During lean period the percentage of sand particle decreases and the percentage of silt particle increases. The reverse trend is noticeable during flood season. It perhaps happens due to the fact that at high discharges a part of the bed material discharge goes into suspension resulting in an increase in the percentage of coarser material.

In the study temporal variation in the suspended sediment transport with discharge is shown for the river Ganges, Gorai and Mathabhanga. The temporal variation of the dependent hydraulic variables with discharge has also been shown. If other independent variables remain more or less constant during the time period considered the temporal variation in the morphological parameters might have caused due to the variation in the suspended sediment transport. As to the situation of the river Gorai the temporal variation in the dependent variables as revealed from the study has much to do with the dredging at the Gorai mouth. The boundary conditions at the offtake may also vary during the time period taken into account. Therefore, it is not fair to state the temporal variation in the dependent hydraulic variables occurred only due to variation in the suspended sediment transport. However, as to the situation at a rather downstream location (Kamarkhali) the influence of variation in the suspended sediment transport on the river channel hydraulic variables can not be undervalued.

The results obtained for the river Ganges is indicative of the fact that a large variation in the suspended sediment transport can force the river channel to undergo substantial changes in its shape. A large increase in the suspended sediment load will cause large siltation in the river channel resulting in a decrease in the average depth and a rise in the mean bed level. It would cause widening of the river and consequent bank erosion.

The results obtained from the analysis of the data of the river Mathabhanga clearly indicate what may be the immediate response of the river to an increase in suspended sediment transport. It is seen from the analysis of the data that with the increase in the suspended sediment transport the river makes attempt to transport the increased load by increasing the flow velocity. An increase in the flow velocity means an increase in the water surface slope. Therefore, a drop in the water level is inevitable.

It is to be mentioned here that a river undergoes complicated morphological processes due to variation in its independent variables and also due to human interference and tries to reach a Quasi-equilibrium state.

8. Conclusions and recommendations

Based on the outcomes of the study the following conclusions have been drawn:

- Variation in the suspended sediment transport has much to do with the morphological changes in the rivers

- A sudden increase in the suspended sediment transport may cause major changes in the hydraulic geometry of the river downstream

- If the suspended sediment transport exceeds the transport capacity of the river the reduction in the water depth would be caused by deposition of sediment

- For the river Mathabhanga the immediate response of the river to an increase in the suspended sediment transport is recognized by a decrease in the width and depth, drop in the water level and an increase in the flow velocity

- The river undergoes complicated morphological changes due to variation in the discharge and sediment transport

- The Gorai could not be restored favorably if no measure is taken to control the suspended sediment entering the Gorai

The following recommendations are put forward based on the study:

- In order to develop the vast water resources of Bangladesh the morphological processes that the rivers are undergoing should be recognized regularly

- The present hydraulic and hydrological data collection should be improved and extended

- Detailed study of morphological processes of the important rivers with wide range of data series is recommended

References

1. **Barua, D.K.(1994),** ' The Environmental Controls of Bangladesh River System', Asia Pacific Journal on Environment and Development, Bangladesh Unnayan Parishad, pp-81-98.

2. **ASCE Report No 54 (1997)**, 'Sedimentation Engineering'.

3. **Khan, Z.H. and Barua, D.K. (1991)**, ' Seasonal Variation of Certain Hydraulic Parameters of the Ganges River', Proceeding of Technical Session 39th Annual Convention of IEB, Chittagong, Bangladesh.

4. **Jansen, P.Ph (1979)**, 'Principal of River Engineering'.

5. **RSP Report No.8 (1996)**, 'Bed Material Sampling in the Ganges, Padma, Old Bhrahmaputra and Jamuna'.

6. **RSP Report No. Annex 4 (1996)**, 'Sedimentology'.

7. **RRI Report No. Sed-4 (2002)**, ' Grain Size Analysis of Suspended Sediment Material of the Ganges'.

8. **RRI Report No. Sed-7 (1999), Sed-8 (1999), Sed-2 (2000), Sed-4 (2001), Sed-7 (2001)and Annual Report, 1998, 1999 and 2000**, 'Study of the Sediment Concentration of Suspended Sediment Samples of the Ganges, Gorai and Mathabhanga'.

9. **Wazed,A. (1991)**, ' Rivers of Bangladesh'.

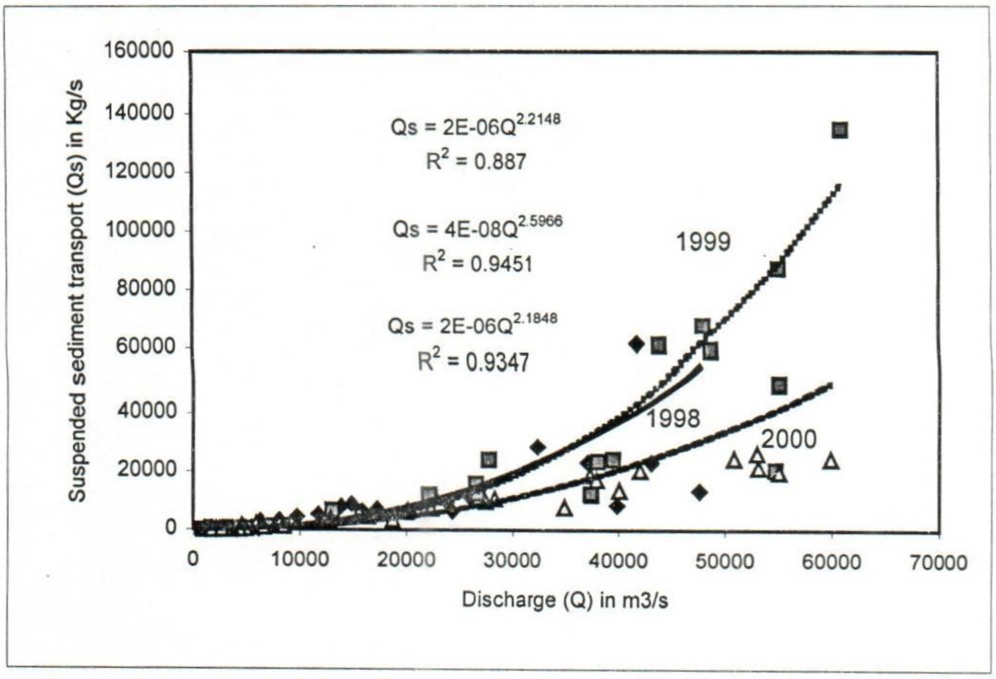

Figure 1 : Temporal variation of suspended sediment transport with dicharge of the river Ganges at Hardinge Bridge

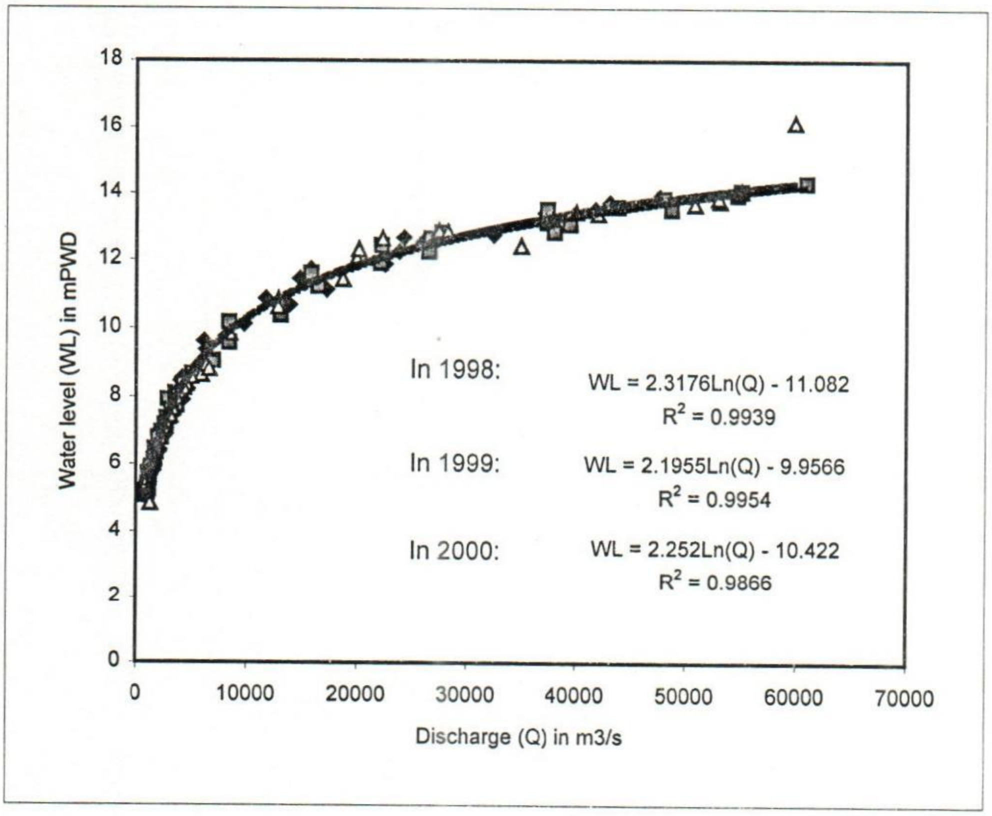

Figure 2 : Temporal variation of water level (WL) with dicharge (Q) of the river Ganges at Hardinge Bridge

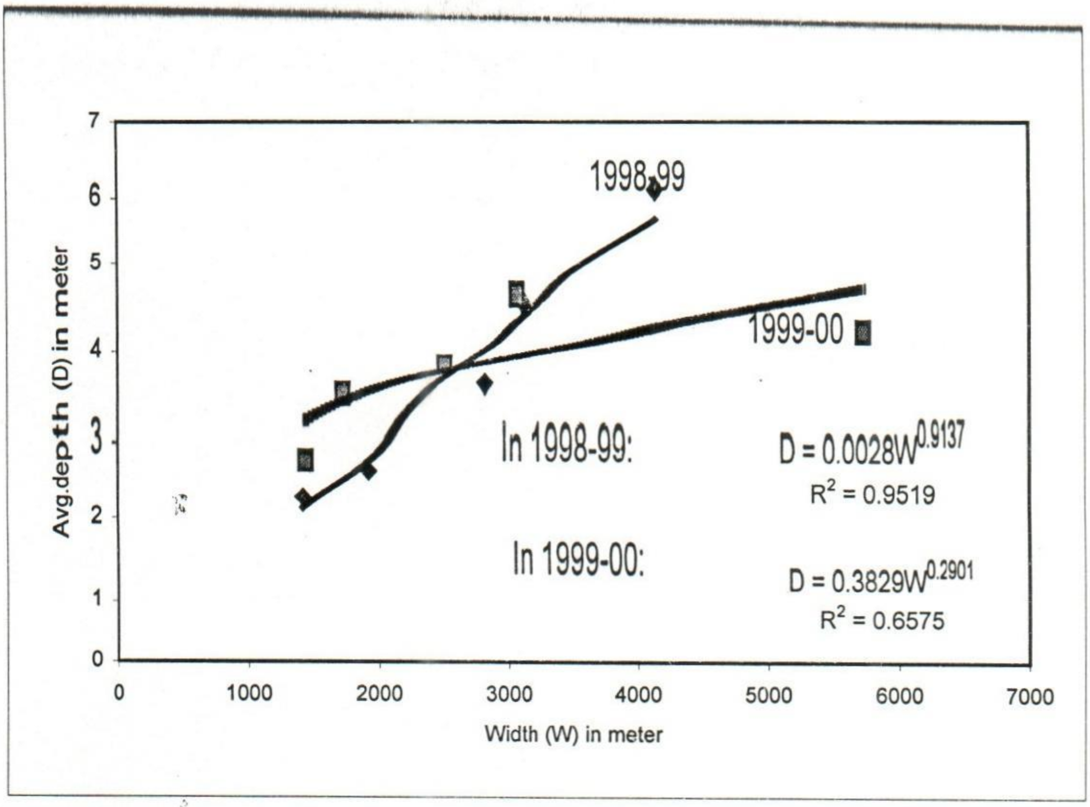

Figure 3 : The variation of average deoth (D) with water width (W) of the river Ganges at c/s G10

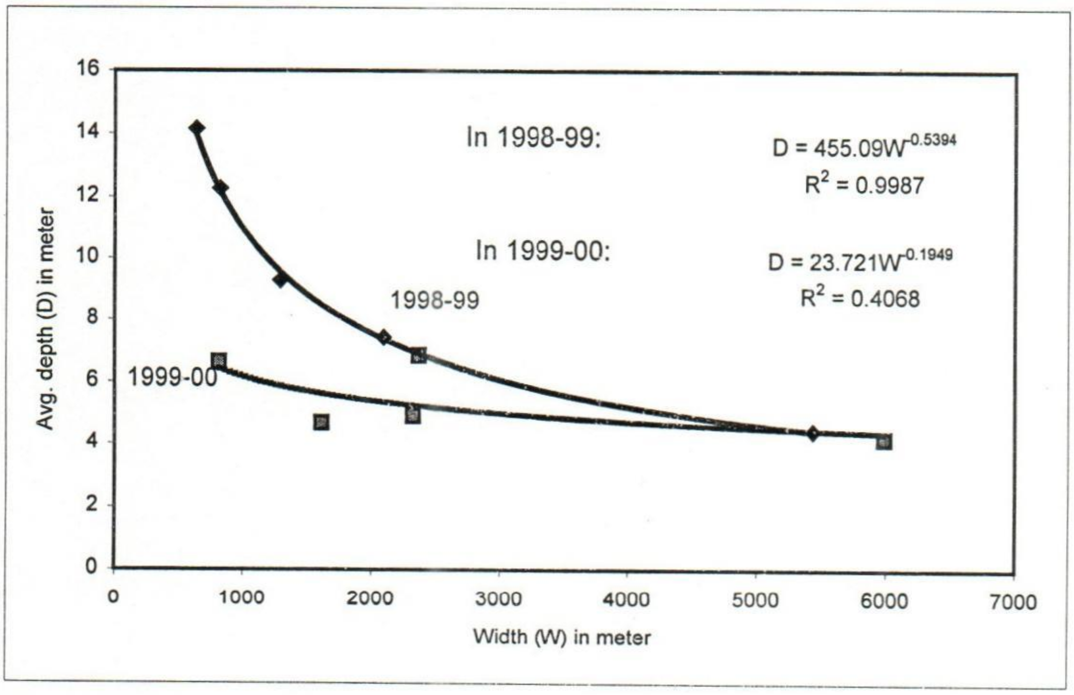

Figure 4 : The variation of average deoth (D) with water width (W) of the river Ganges at c/s G11

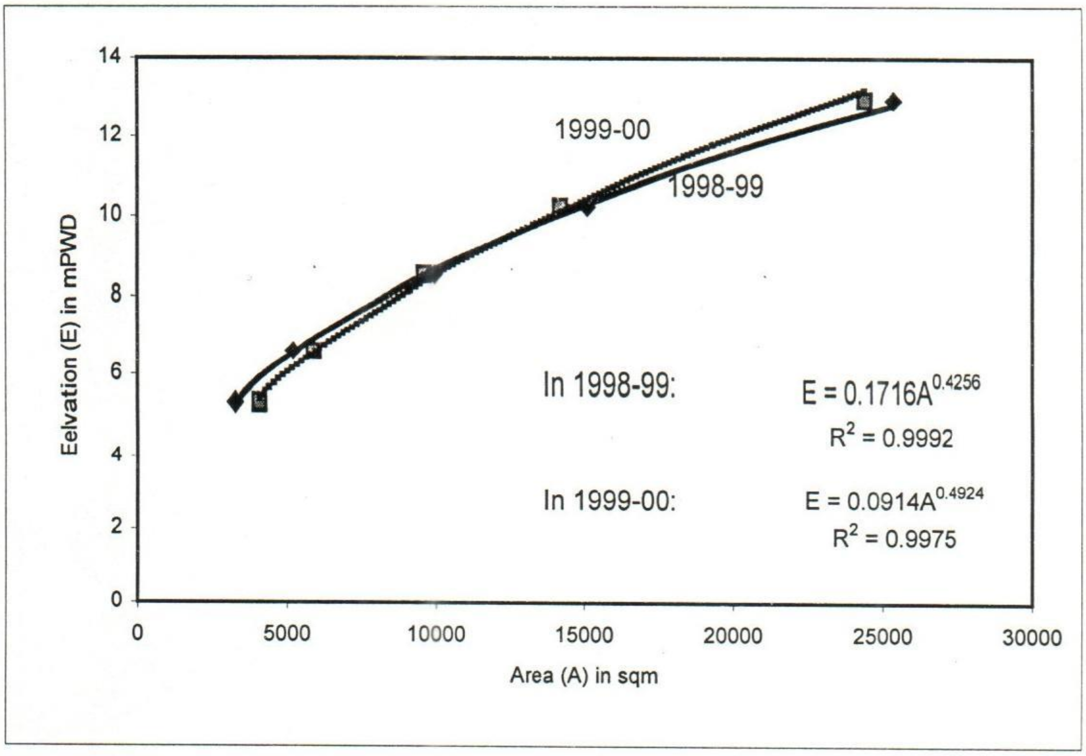

Figure 5 : The variation of cross-sectional area (A) with elevation (E) of the river Ganges at c/s G10

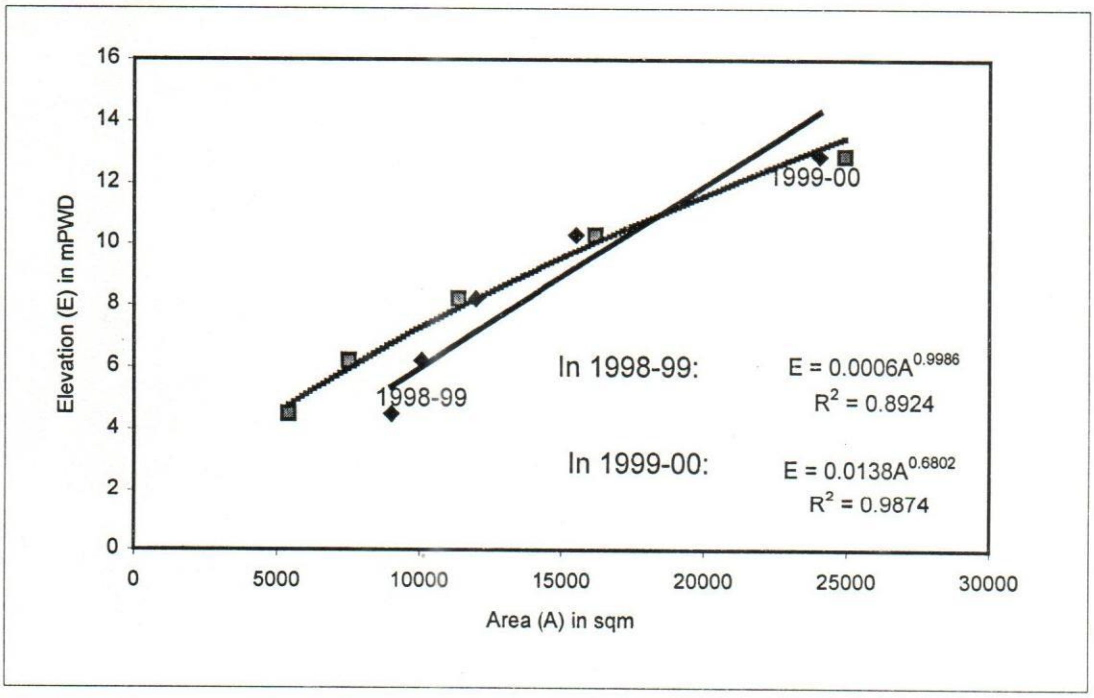

Figure 6 : The variation of cross-sectional area (A) with elevation (E) of the river Ganges at c/s G11

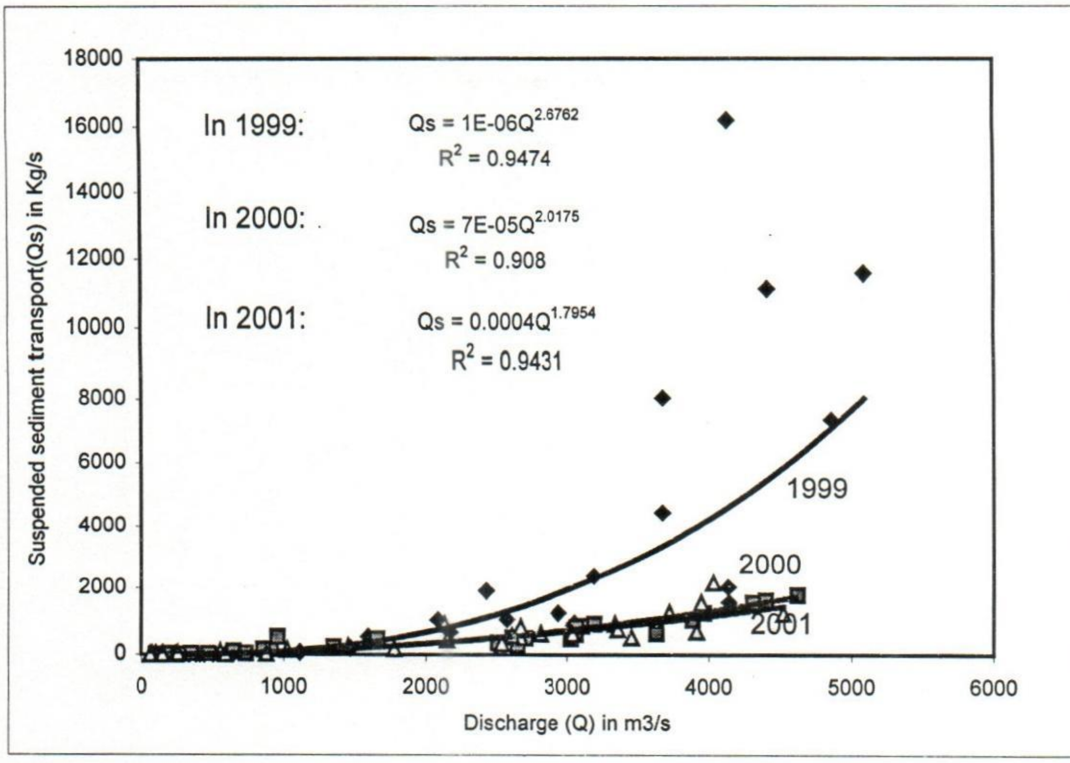

Figure 7 : Temporal variation of suspended sediment transport with discharge of the river Gorai at Gorai Railway Bridge

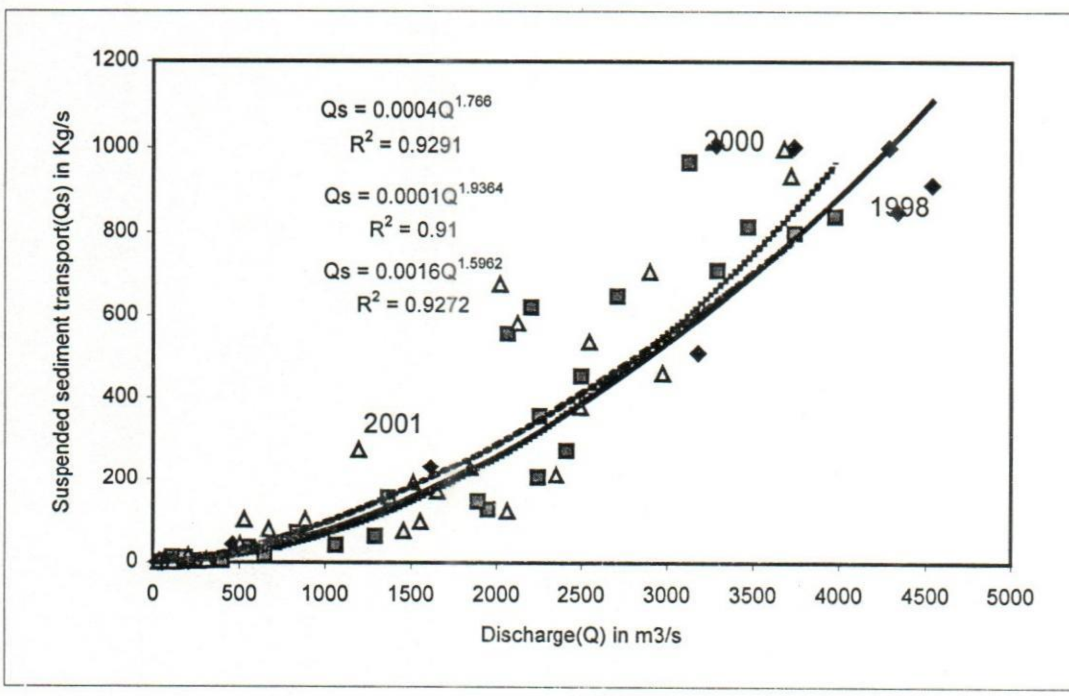

Figure 8 : Temporal variation of suspended sediment transport with discharge of the river Gorai at Kamarkhali

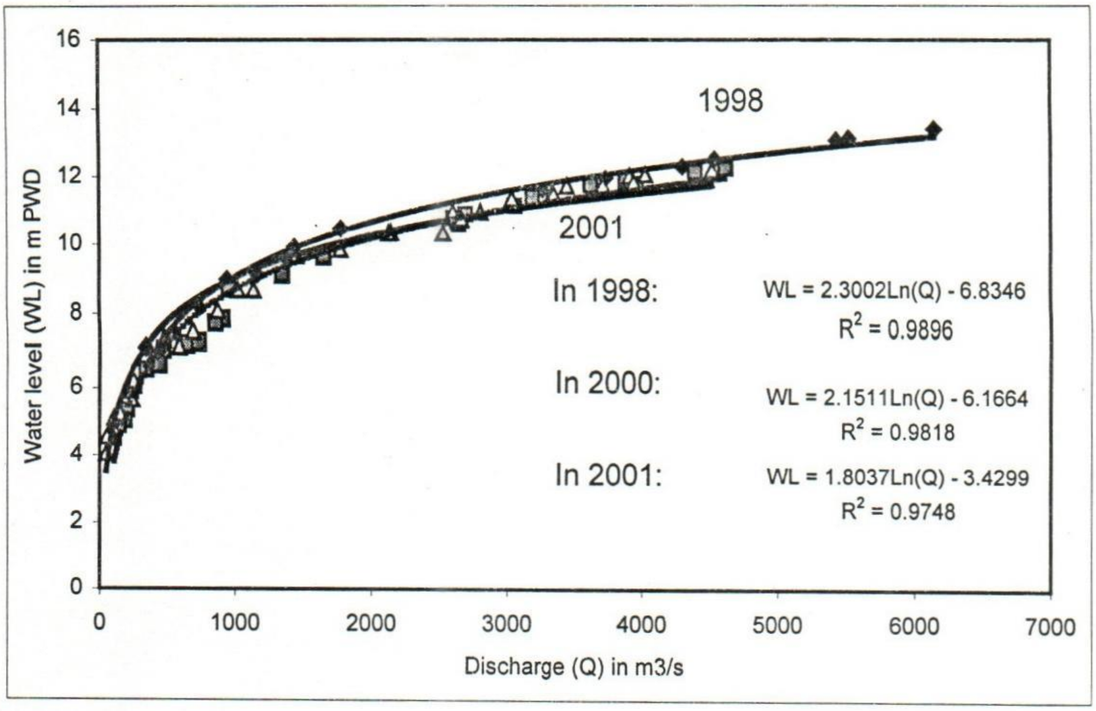

Figure 9 : Temporal variation of water level (WL) with discharge of the river Gorai at Gorai Railway Bridge

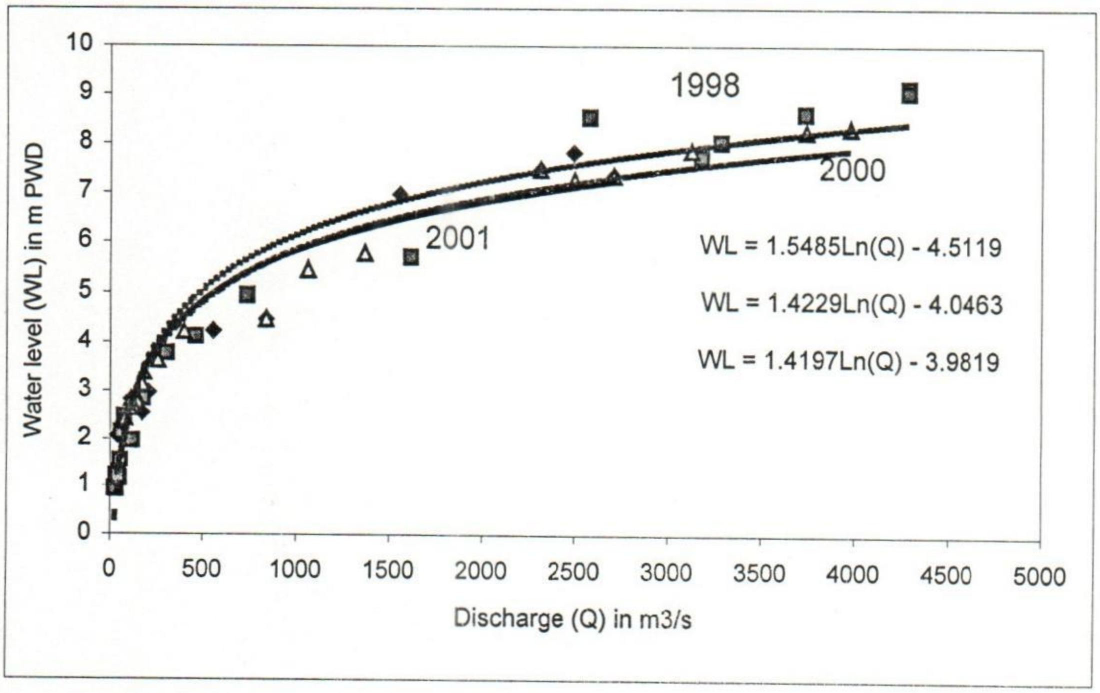

Figure 10 : Temporal variation of water level (WL) with discharge of the river Gorai at Kamarkhali

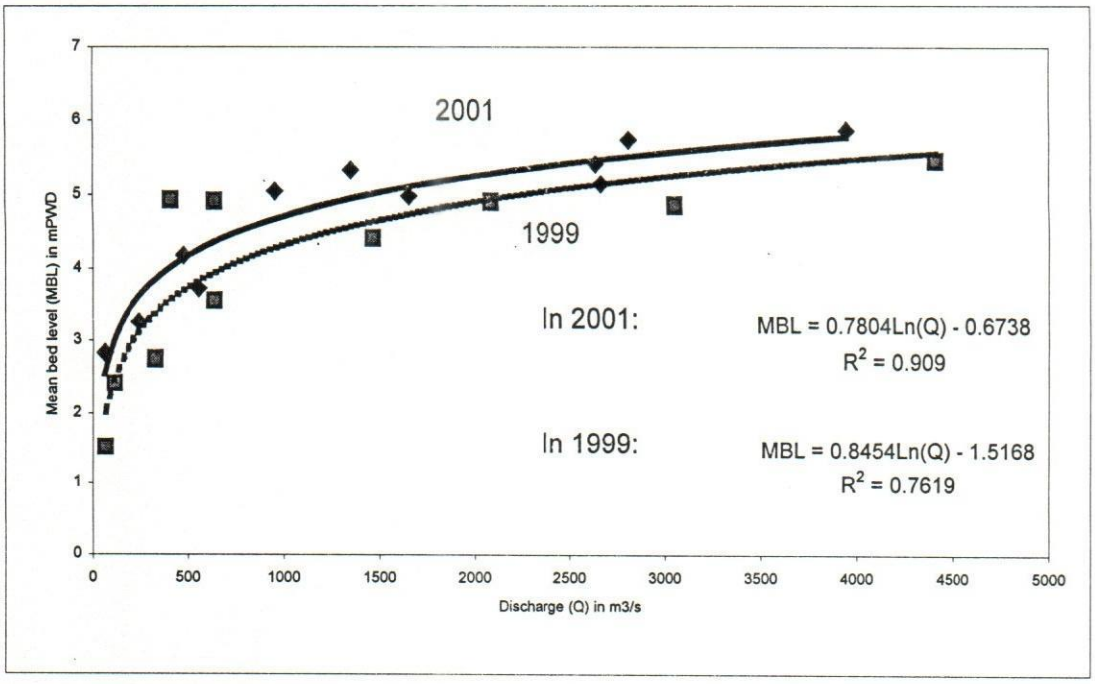

Figure 11 : Temporal variation in the mean bed level (MBL) with discharge of the river Gorai at Gorai Railway Bridge

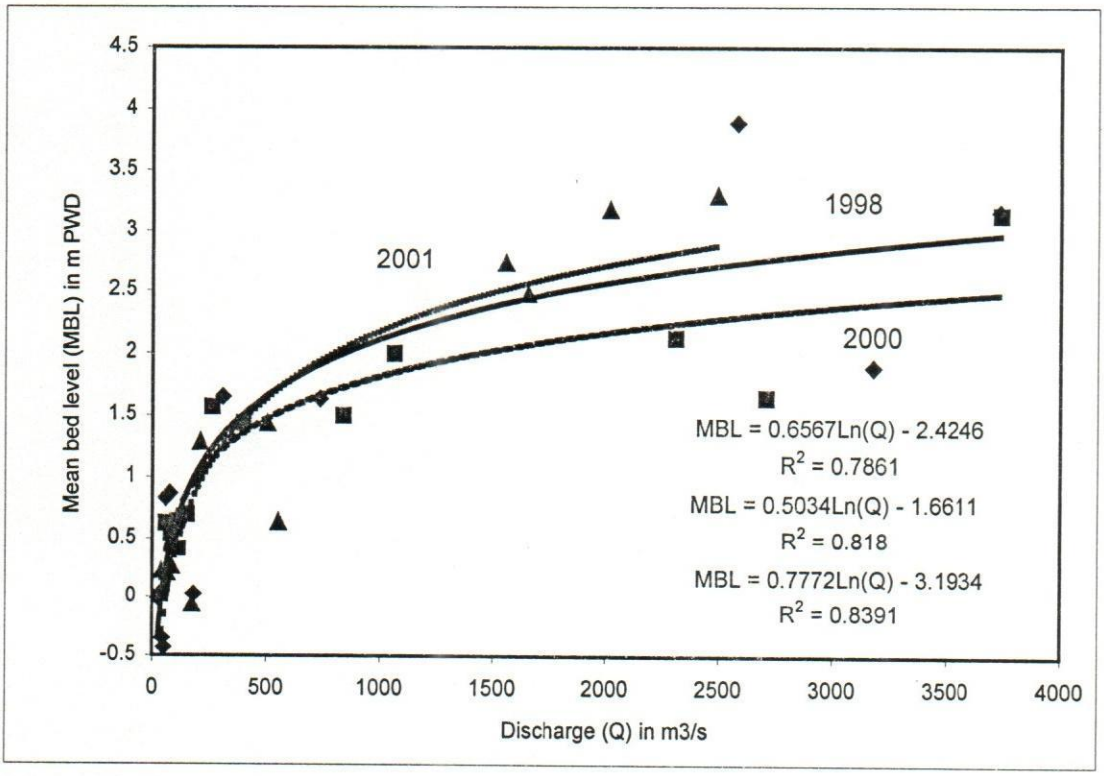

Figure 12 : Temporal variation in the mean bed level (MBL) with discharge of the river Gorai at Kamarkhali

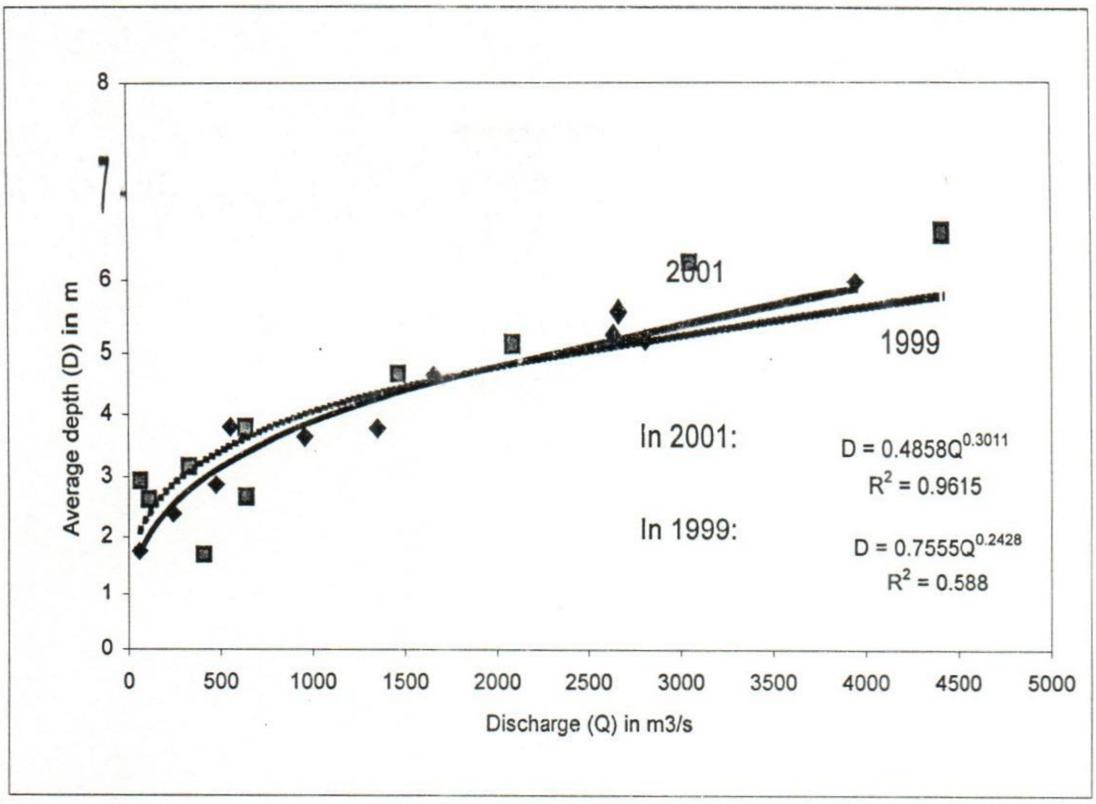

Figure 13 : Temporal variation in the average depth (D) with discharge (Q) of the river Gorai at Gorai Railway Bridge

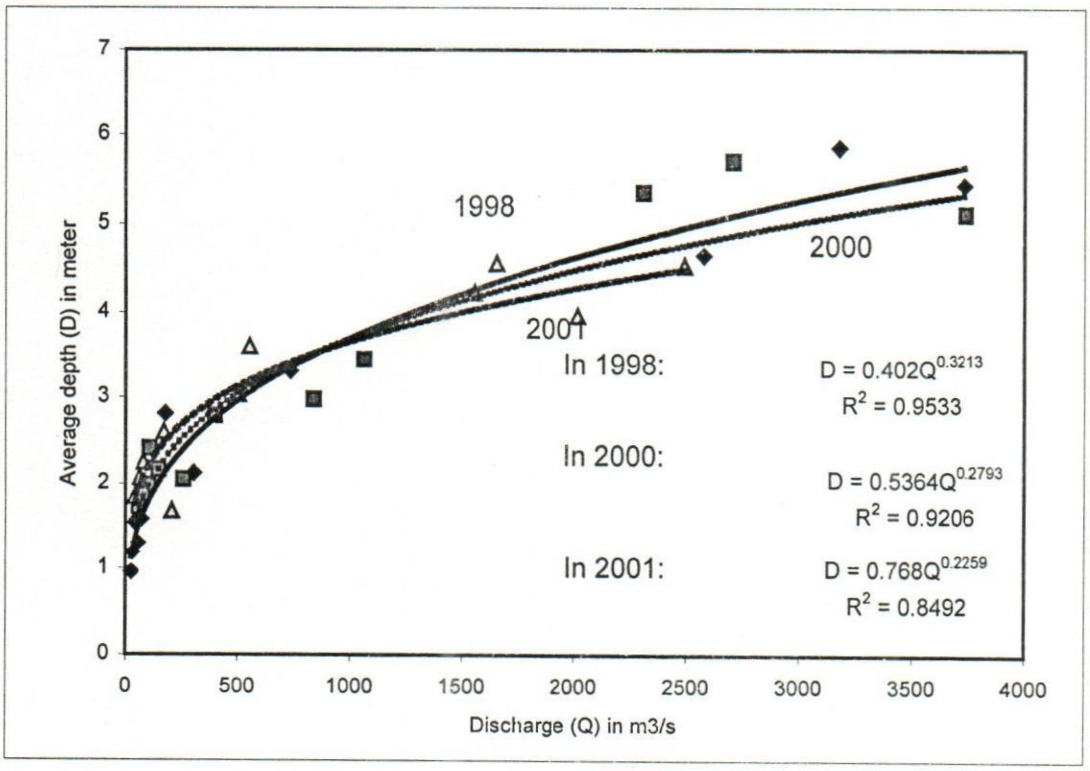

Figure 14 : Temporal variation in the average depth (D) with discharge (Q) of the river Gorai at Kamarkhali

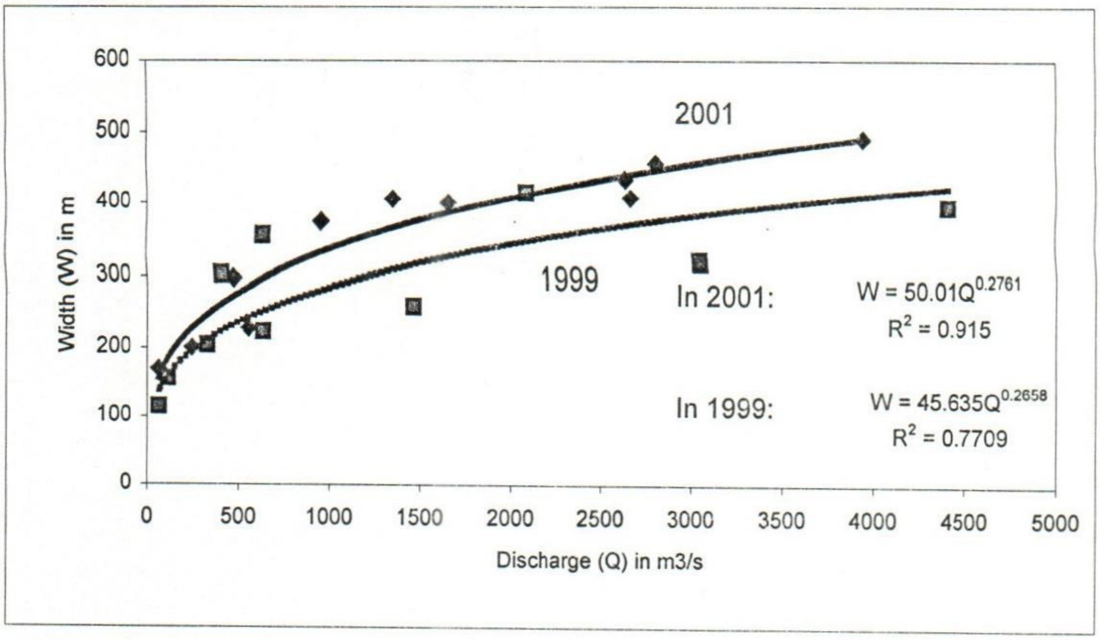

Figure 15 : Temporal variation in the water width (W) with discharge (Q) of the river Gorai at Gorai Railway Bridge

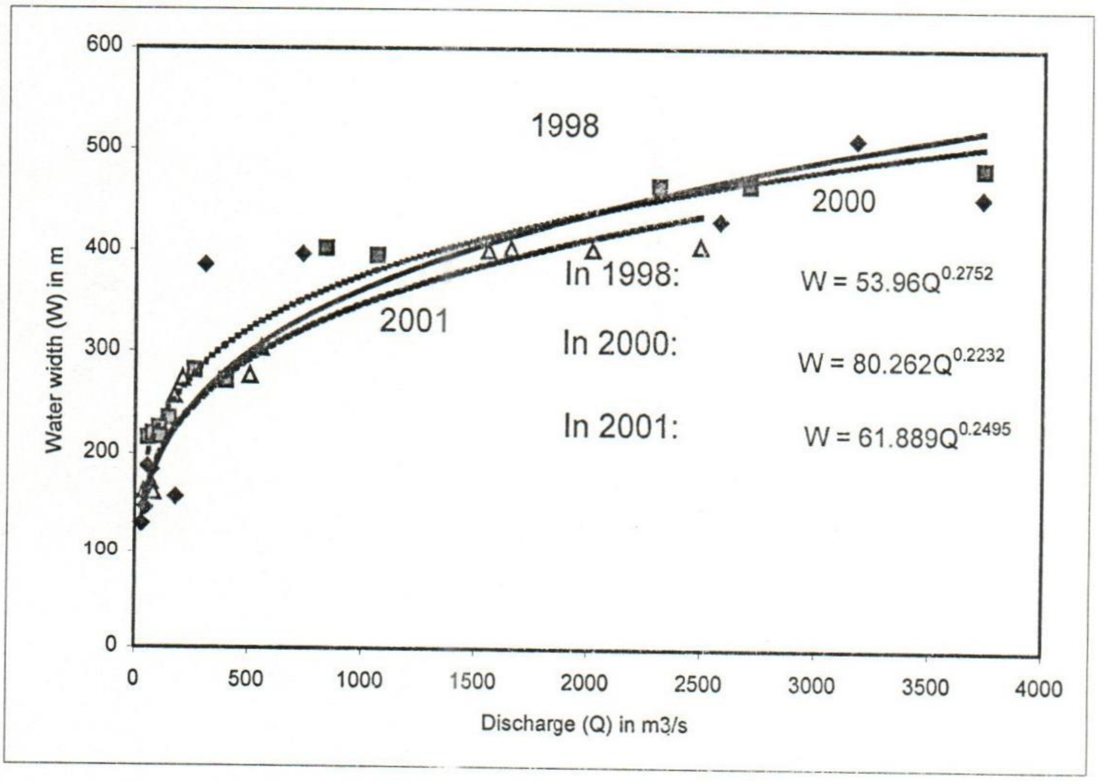

Figure 16 : Temporal variation in the water width (W) with discharge (Q) of the river Gorai at Kamarkhali

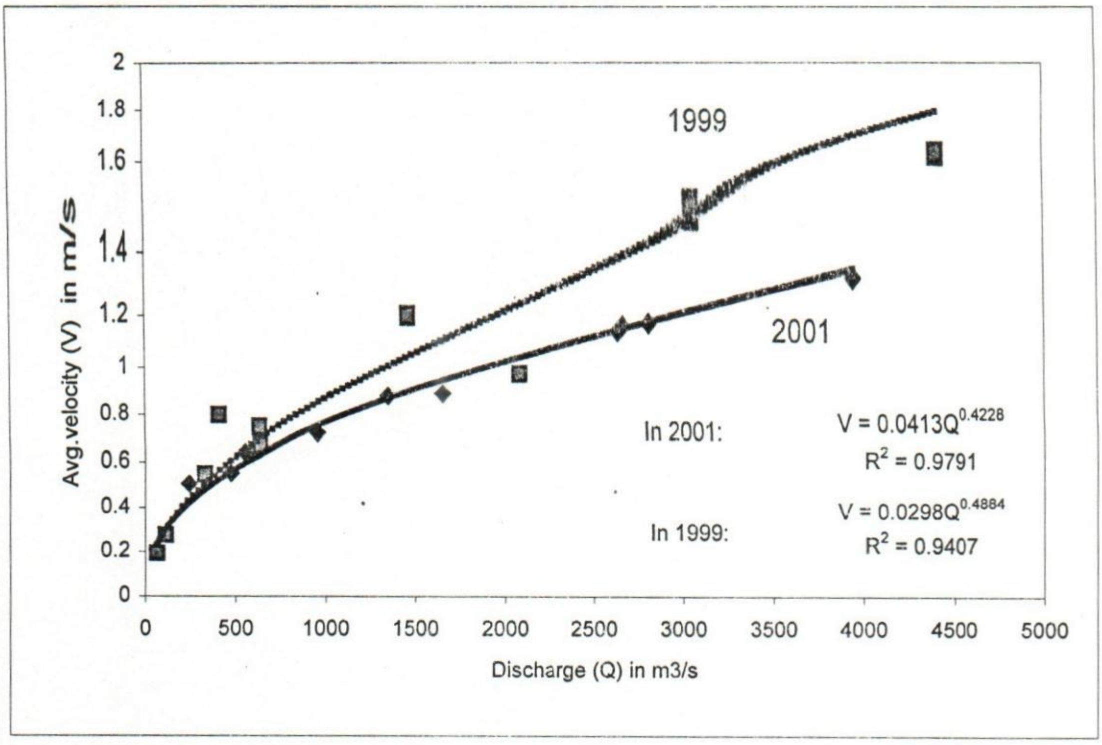

Figure 17 : Temporal variation in the average velocity (V) with discharge (Q) of the river Gorai at Gorai Railway Bridge

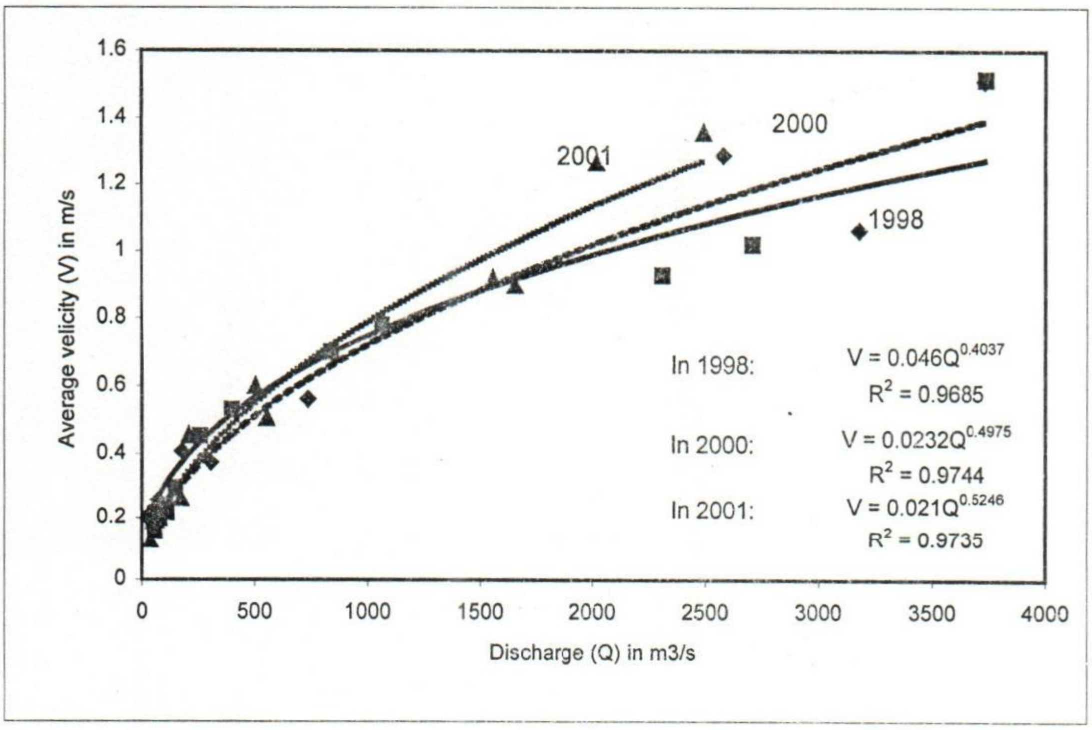

Figure 18 : Temporal variation in the average velocity (V) with discharge (Q) of the river Gorai at Kamarkhali

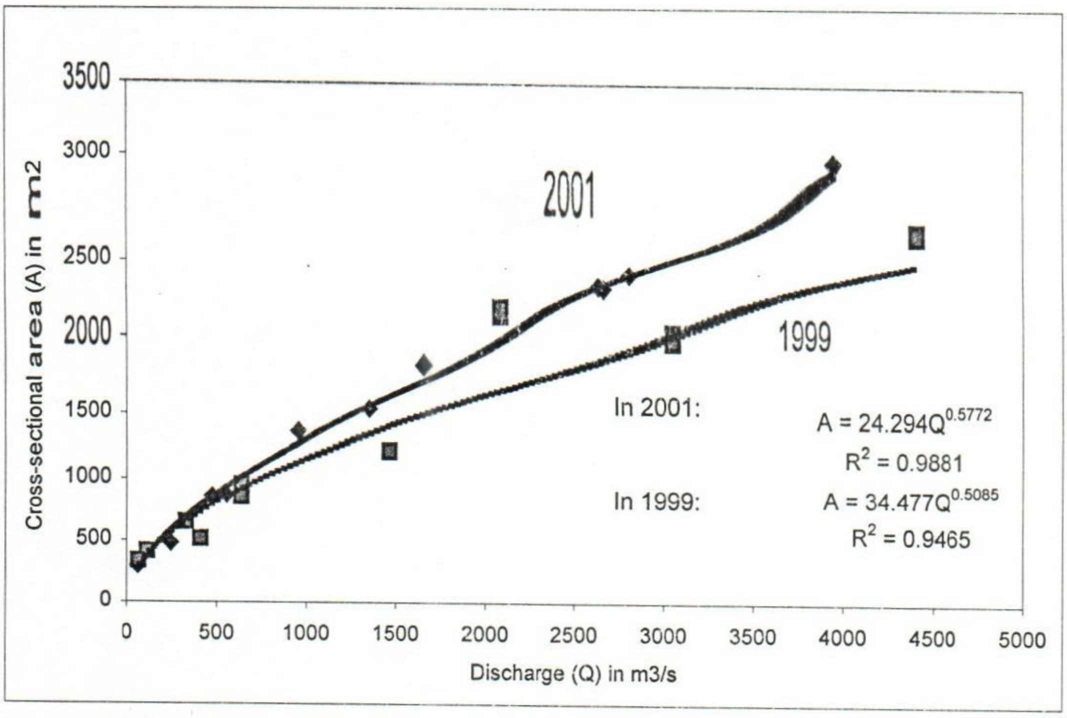

Figure 19 : Temporal variation in the cross-sectional area (A) with discharge (Q) of the river Gorai at Gorai Railway Bridge

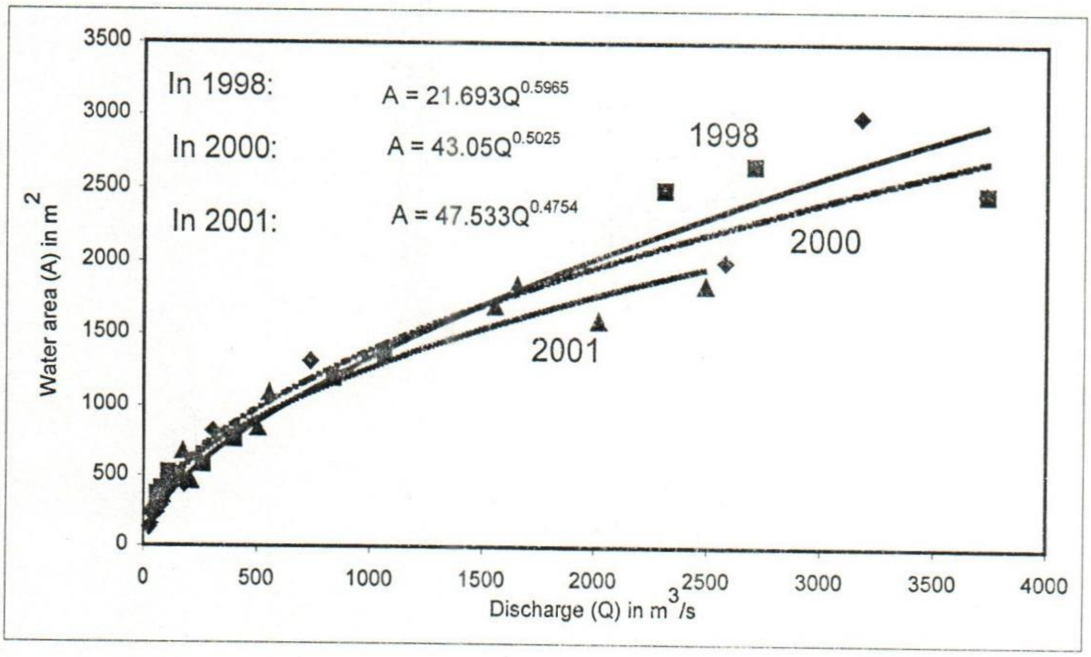

Figure 20 : Temporal variation in the cross-sectional area (A) with discharge (Q) of the river Gorai at Kamarkhali

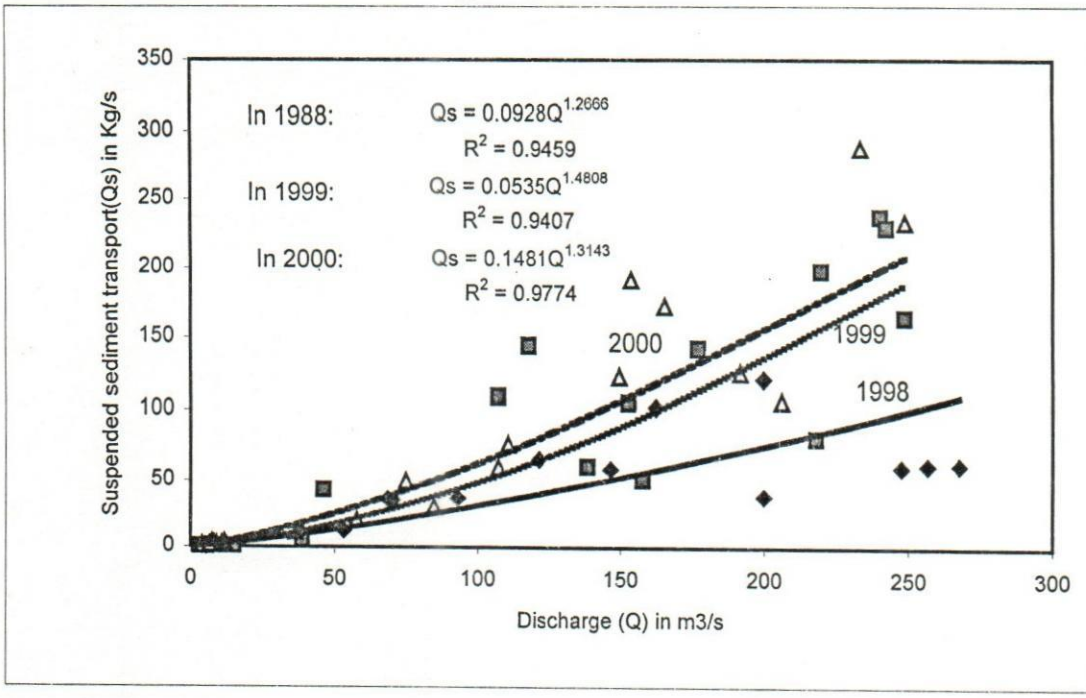

Figure 21: Temporal variation in the suspended sediment transport with discharge (Q) of th river Mathabhanga at Hatboalia

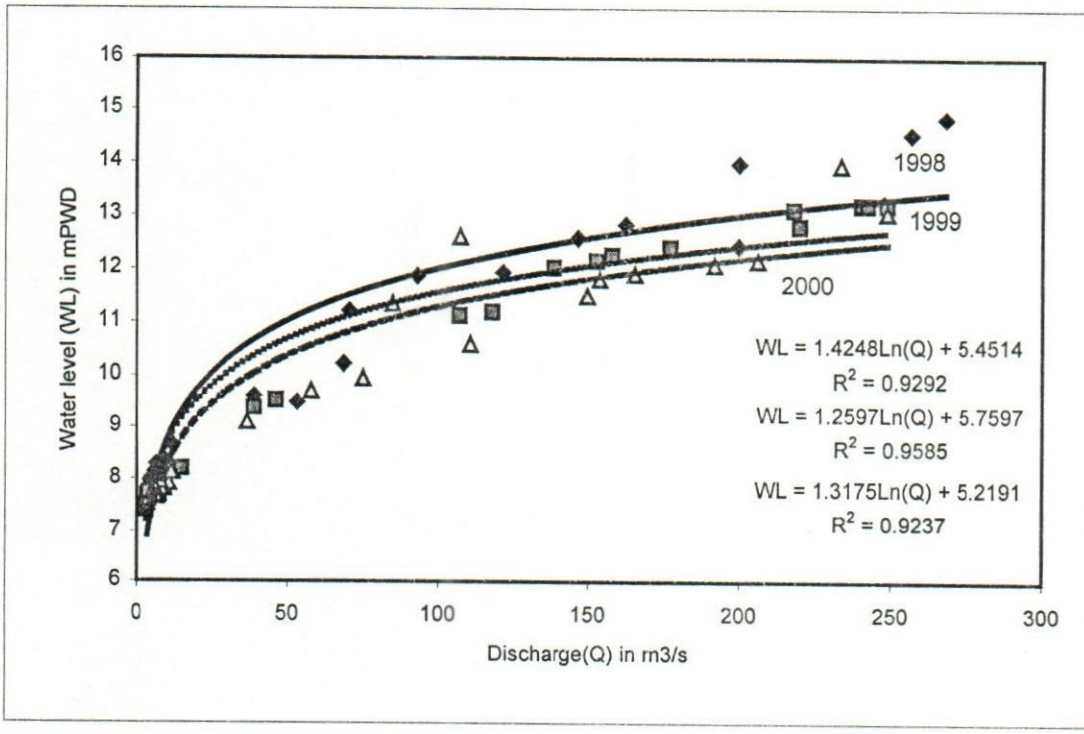

Figure 22: Temporal variation in the water level (WL) with discharge (Q) of the river Mathabhanga at Hatboalia

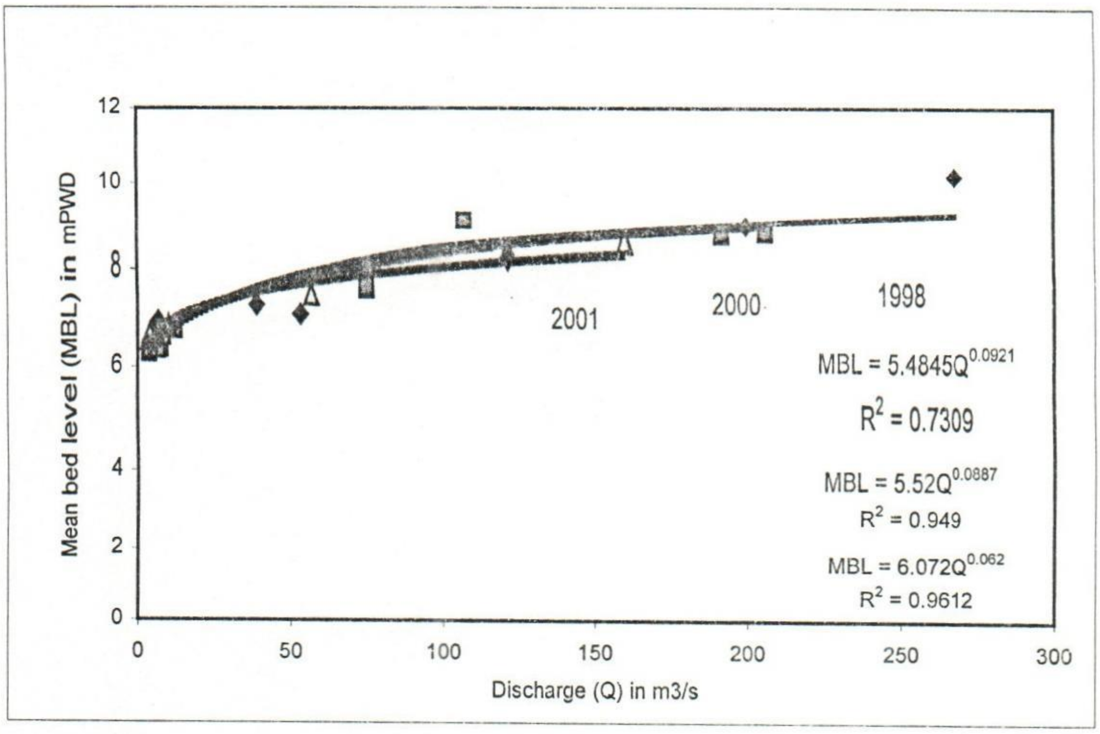

Figure 23: Temporal variation in the mean bed level (MBL) with discharge (Q) of the river Mathabhanga at Hatboalia

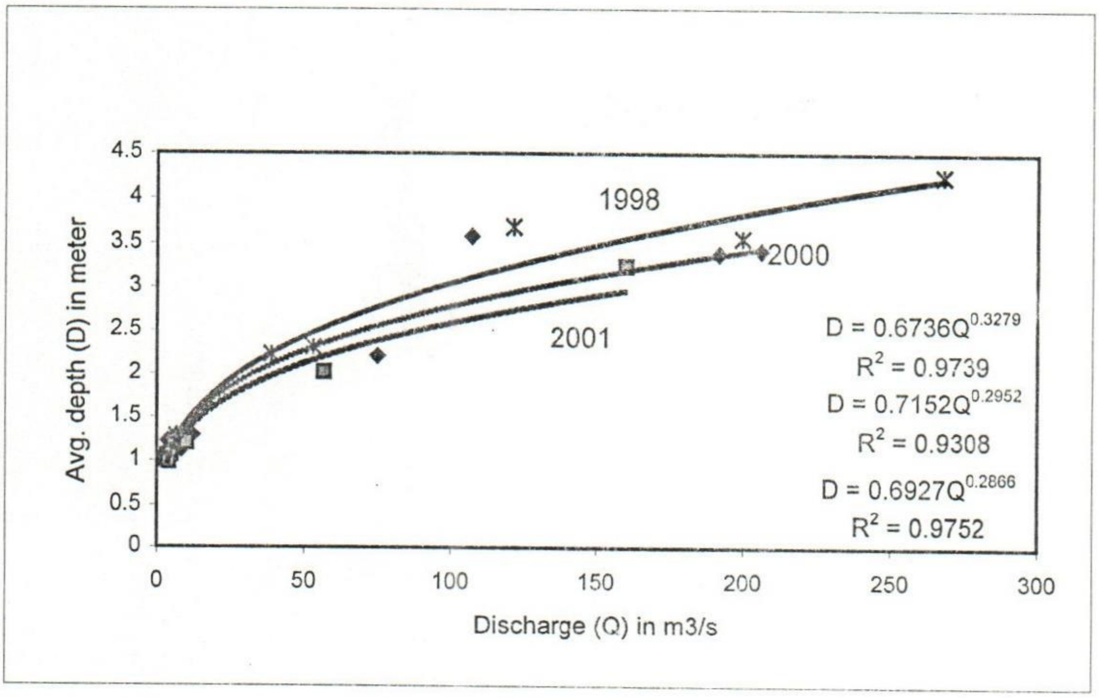

Figure 24: Temporal variation in the average depth (D) with discharge (Q) of the river Mathabhanga at Hatboalia

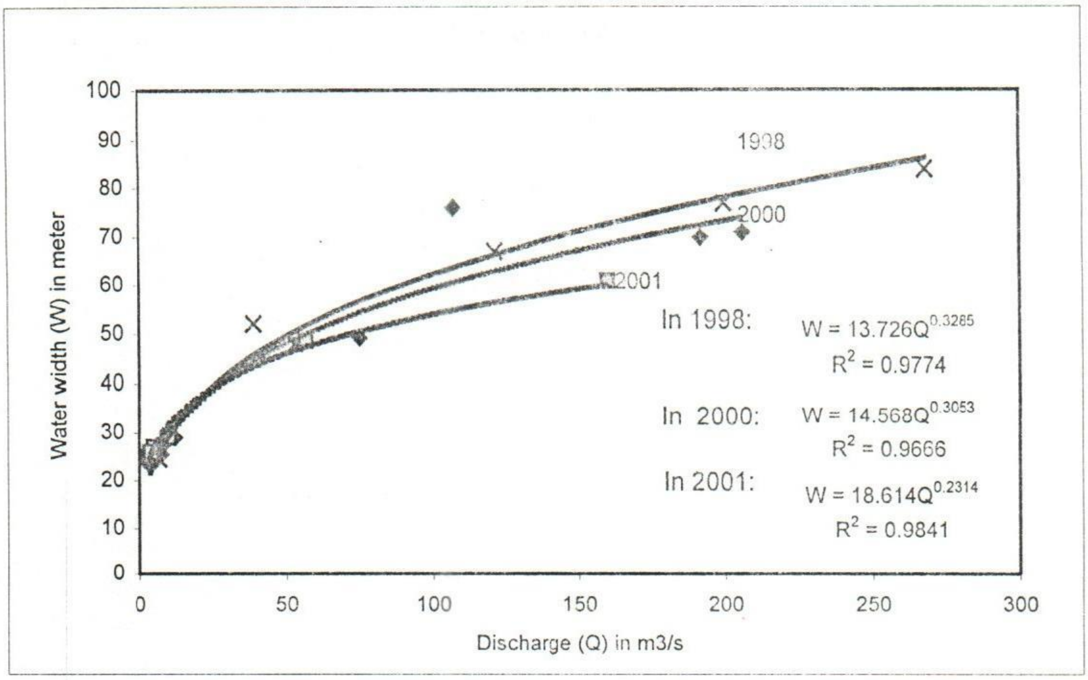

Figure 25: Temporal variation in the water width (W) with discharge (Q) of the river Mathabhanga at Hatboalia

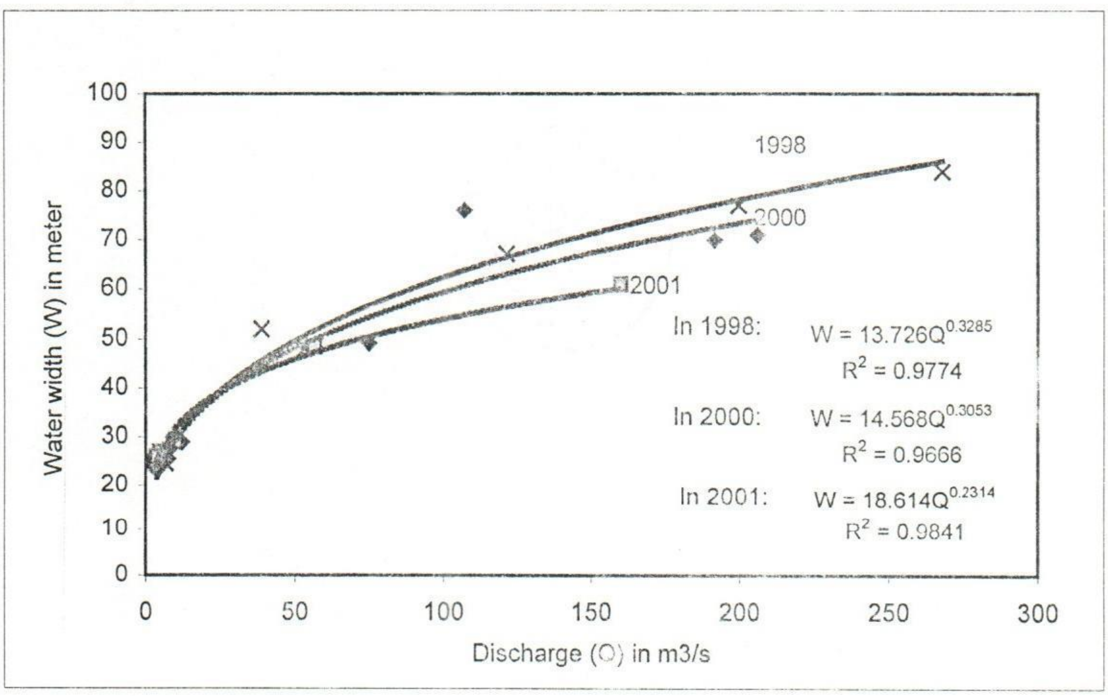

Figure 26: Temporal variation in the average velocity (W) with discharge (Q) of the river Mathabhanga at Hatboalia