ENVIRONMENTAL IMPACT DUE TO CHANGES IN GEOMETRIC CHARACTERISTICS OF THE KAPATAKSHA RIVER

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CERTIFICATION

The thesis titled "**Environmental Impact due to Changes in Geometric Characteristics of the Kapataksha River**" submitted by Mahzabeen Rahman, Roll No: MF0328025, Session April'03 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT on July 03, 2005.

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TO

MY BELOVED MOTHER

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Abbreviations

BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BWDB	Bangladesh Water Development Board
CDP	Coastal Development Partnership
CEGIS	Center for Environmental and Geographical Information Services
CIP	Chandpur Irrigation Project
DOE	Department of Environment
DoF	Department of Fisheries
EIA	Environmental Impact Assessment
ESCAP	Economic and Social Commission for Asia and the Pacific
FCD/I	Flood Control, Drainage and Irrigation
FPCO	Flood Plan Coordination Organization
GBS	Gabcokovo Barrage System
IEC	Important Environmental Component
IUCN	International Union for Conservation of Nature and Natural Resources
IWM	Institute of Water Modeling
LGED	Local Government and Engineering Department
MRBC	Mahi Right Bank Canal System
PWD	Public Works Department
RKRP	Re-excavation of Kapataksha River Project
SRDI	Soil Resources Development Institute
SWMC	Surface Water Modeling Center
T.Aman	Transplanted Aman

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ABSTRACT

The Kapataksha river is one of the main arteries of the water resource system located in the southwest region of Bangladesh. In the past, continued flow of fresh water from the Ganges through Mathabhanga river kept the saline water away from the upstream of the river and pushed it to the downstream and flushed the incoming sediments into the Bay of Bengal. But, after being disconnected from the Ganges, the Kapataksha river has been subjected to tidal domination, associated with increasing sedimentation by tidal pumping process. Gradual sedimentation causes the reduction of the cross-section of the river and loss of the conveyance capacity of the river. Change of these geometric characteristics of the river results in water logging at the adjacent area of the river and thereby other adverse impact on environmental components. Various types of direct and indirect environmental impacts are shown through network. The main activities that were performed in this study are simplification, building up a conceptual model to show how the impacts are taking place, impact analysis and impact classification.

During the period of 1994 and 2001, the cross-sectional area of the river decreased about 86% to 95% and the conveyance decreased 96% to 99% over the study area. The width and average depth decreased about 15% to 58% and 84% to 88%, respectively over the study area from 1994 to 2001. Deterioration of drainage capacity of the river has resulted in wide spread drainage congestion, which further causes water logging to its adjoining area. About 55% to 77% of the total areas of the villages over the study area were waterlogged in 2000. Due to prolonged water logging, various types of environmental degradation are taking place over the study area. Due to water logging problem, diversity of fish species over the study area has been reduced. In addition with the reduction of fish species, after water logging, availability of some fish species (mostly floodplain & beel fisheries) are increasing whereas, availability of some fish species (reverine fish species) are decreasing over the study area. Due to stagnancy of water, a good portion of the river stretch over the study area is covered by water hyacinth, about 60% to 80% ponds of the study area were affected by various means after waterlogging condition has set in and they could not be used this water for household purposes. The wetlands and water bodies of the study area are also becoming degraded due to the drainage congestion and waterlogging problem. In addition with these environmental impacts, changes of the geometry of the river have also impacted the tidal condition and navigation of that area.

Chapter 1
INTRODUCTION

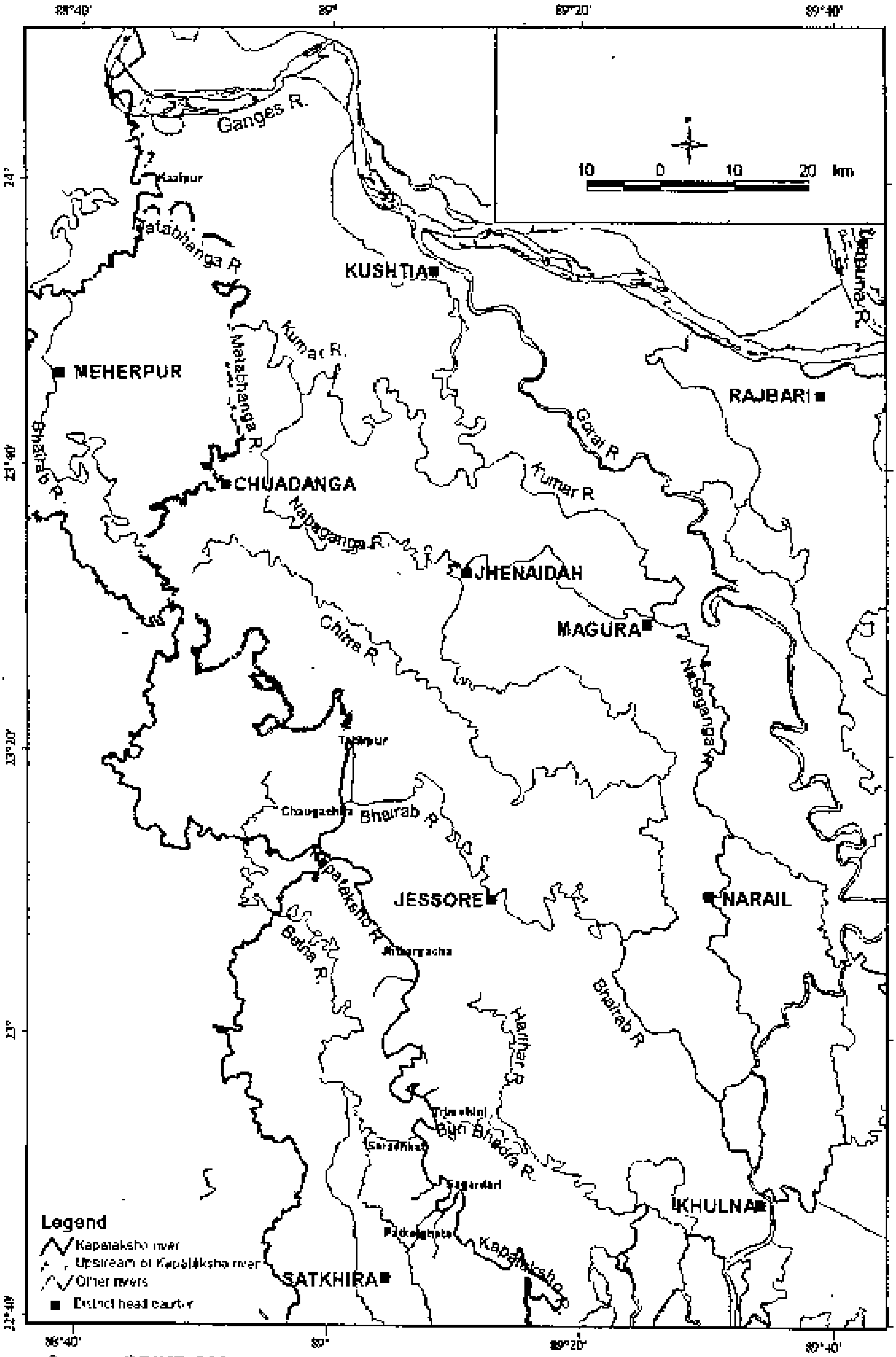
1.1 Location

River Kapataksha is one of the main arteries of the water resource system located in the South -West region of Bangladesh. It is an alluvial river flowing north to south direction over the most developed part of the Gangetic delta (Fig –1.1). The Kapataksha river is an important output channel for the flood spills and rainfall- run-off of a vast area covering the district of Jhenaidah, Jessore and Satkhira. This river drains an area of about 1.07,600 hectares spread over nine upazila of the three aforementioned districts (CEGIS, 2004).

1.2 Background information of the Kapataksha river

The Kapataksha river originates from the Mathabhanga river at Tahirpur in Jessore district (CEGIS. 2004). About two hundred years ago, the Mathabhanga river was the dominant fresh water source of the Kapataksha river and supplied fresh water throughout the year to this river. But, over time, the Mathabhanga river started to deteriorate due to interventions at upstream (CEGIS, 2004). As a result, the Kapataksha river virtually could not be fed from the Mathabhanga river any more. After-being cut-off from the Mathabhanga river. the river Kapataksha now has merely become a local "river" draining the rainfall from its catchment's and no connection with the main river system. It now only drains flood spill from the Ganges through Mathabhanga and surface runoff generated from monsoon rainfall.

Due to geographical location, lower reach of this river is tidal, where saline water enters during flood tide and leaves during ebb tide. Generally, high salinity brings huge sediments and gets deposited It is the normal morphological balance that upstream high fresh water flows push the salinity towards the sea and wash away the deposited sediments at the time of ebb tide In this river, this natural morphological balance has been destroyed due to loss of connectivity and reduction of upland fresh water from the Ganges. After being disconnected from the Ganges, sediments started to enter the Kapataksha river system from the downstream through tidal pumping processes. The high salinity level in the river facilitates deposition of sediment at the location of tidal limit especially during the dry season. These phenomena caused



Source: CEGIS, 2004

Figure 1.1: Kapotaksha and its surroundings rivers

reduction of the cross-sectional area and thereby loss of conveyance capacity of the Kapataksha river. Gradual sedimentation created a hump on the riverbed. As a result, the downstream tidal flow could not move upstream beyond this hump and resulted in drainage congestion over that area (CEGIS, 2004).

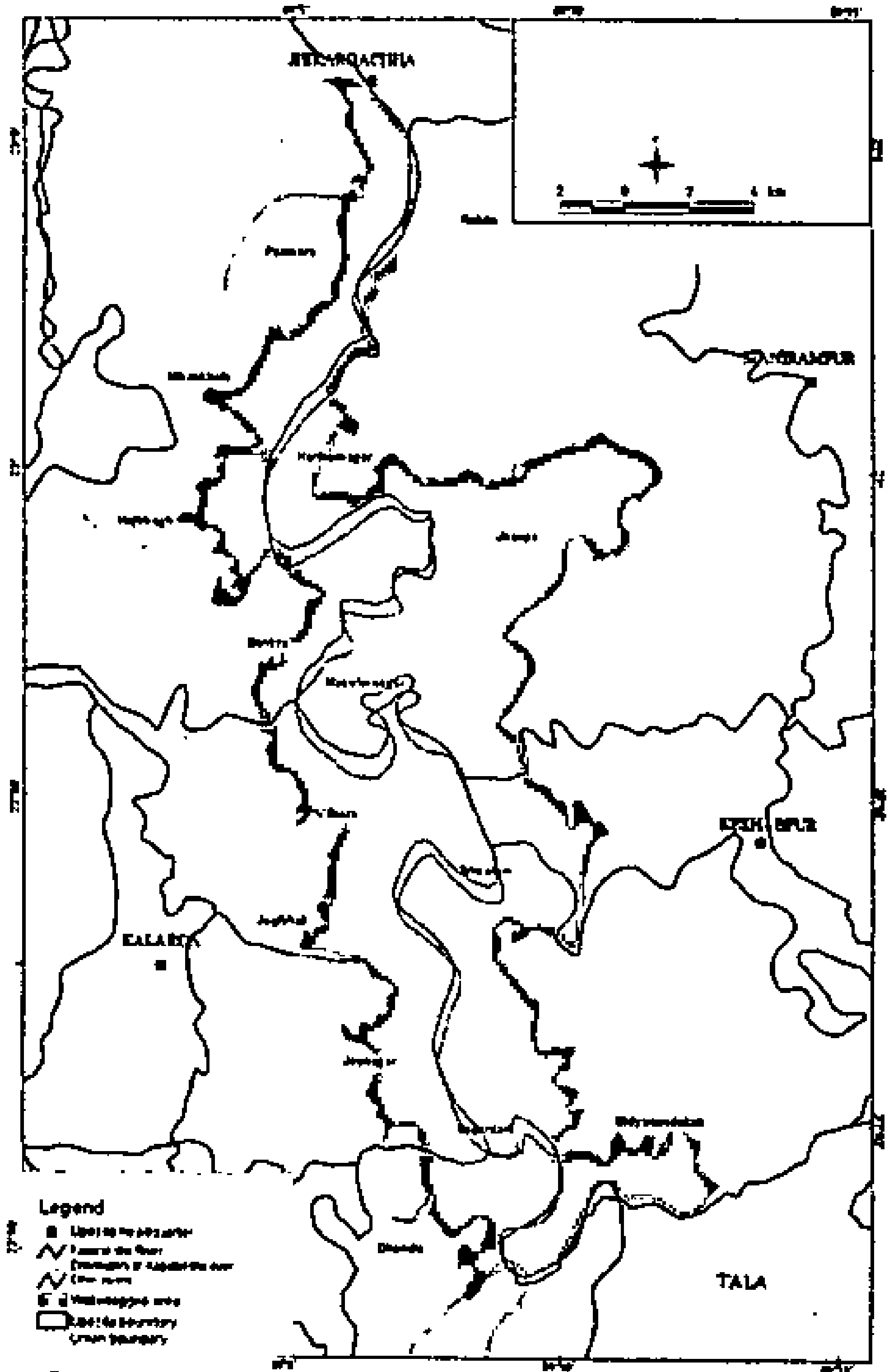
1.3 Adjacent environment of the Kapataksha river

The ecosystem of the area adjoining the Kapataksha river reached climax in prehistoric time. But the aforementioned changes of the Kapataksha river are imbalancing the ecological harmony and thereby causing degradation to its surrounding environment.

Malfunctioning of the river system resulted in the reduction of cross sectional area and conveyance capacity of the river. It also caused dying of the connecting drainage cannels, which drained out water into the Kapataksha river. As a result, during the last few years drainage systems of the Kapataksha river declined rapidly which further caused water logging in the adjacent area of the Kapataksha river. About 1,15,000 populations of 22,000 households are suffering from water logging problem (CEGIS, 2004).

According to the local people. the drainage congestion and waterlogging problem has deteriorated sharply after the flood of 2000. In 2000. the flood occurred due to huge amount of overland flow coming from India, which exceeded the conveyance capacity of the Kapataksha river. In 1999 total water logging area was 400 hectare. It increased to an area of 7320 hectare in 2003 (CEGIS, 2004). The extent of water logging area in 2003 is shown in Figurer 1.2.

The Kapataksha river was an important riverine habitat for fish and plays an important role in fish migration and movement. In the past. river was deeper and wider with higher flow velocity. At that time. fishes were abundant in both quantity and species composition. It has been reported from local people that before dying of the river, Hilsa, Pangus, Tapsi and brackish water fishes were available at more upstream than present At present, due to less flow of the river, reduced depth and tide, brackish water fish species shifted to downstream. Reduction of depth, width and flow of river resulted in drainage congestion and water logging problem. This water logging further causes some other impacts. Due to stagnancy of water a



Source: CEGIS, 2004

Figure 1.2: Extent of water logged area in 2003

considerable portion of river surface has been covered with water hyacinth. This water hyacinth has not only restricted fish movement but also reduced the level of dissolved Oxygen to support diversified fish species. Moreover, due to water logging a number of fish pond and ghers were submerged and as a result cultured fish came out to the flood plain. Abut 925 no. of ponds of an area of 115.44 hectare have been affected by fish loss (CEGIS,2004).

The agriculture of the area is severely affected by drainage congestion and water logging. Before the area was affected by water logging problem, two to three agricultural crops were grown on the same pieces of land. The cropping intensity was 209% during the period of 1999-2000 (Kranti, 2000). But as this problem was advancing, the cropping intensity fall down. Now cropping intensity is about 197% (CEGIS, 2004). The waterlogging problem of the area has reduced the cropped area for Rabi crops. This has also damaged transplanted amon crop and hampered timely transplantation of Boro crops.

Wetlands are the important environmental components interconnecting aquatic and terrestrial environment of the area. Oxbow lakes (baor) and beels are the important wetlands of the area. Local inhabitants used the wetlands as source of fish and other aquatic products in a sustainable way. But water logging caused a lot of damage to the overall wetland ecosystem. Now, the diversity of wetland plants, wildlife and fishes is declining rapidly. Many trees including jackfruit trees and also mango trees have died out in many waterlogged villages during last three years of flooding due to drainage congestions in the area.

Another remarkable feature is that, due to stagnancy of water most of the Kapataksha river surface is covered with dense water hyacinth. The situation is degrading the riverine biological system. Navigation and fishes are obstructed, and irrigation and drainage systems also become blocked due to this problem. The consequences are devastating for those communities reliant on water bodies for water, food, sanitation and transport. These are creating health hazards.

1.4 Dredging activities of the Kapataksha river

People of the area adjoining the river Kapataksha raised persisting demands to the Government for re-excavation of the river to get rid of drainage congestion and to restore the flow of the Kapataksha. Bangladesh Water Development Board (BWDB) conducted a feasibility study regarding that concern. That feasibility study came up with recommendation for dredging as a short-term solution. After technical and engineering examination, in September 2003, BWDB launched a program of dredging.

It is expected that this man-made intervention, that is dredging would change the geometry of the river and thereby improve the conveyance of the river and its flow condition. Some improvements have already been observed. Unlike last few years, waterlogging condition over that area was comparatively less severe after the monsoon of 2004. The local people have also welcomed the present dredging activities of the BWDB.

1.5 Aim and objectives of the study

The aim of this study is to analyze the change of geometric characteristics of the Kapataksha river and its impact on environment. The geometric characteristics that were analyzed in this study are river's cross-section, width, depth, conveyance and thalweg profile. And the environmental impacts are analyzed on some selected components like drainage condition, water logging, fisheries, wetlands, water body, tidal condition and navigation. Two major objectives of this study are:

i) To study the change of geometric characteristics of the Kapataksha river.

ii) To analyze environmental impact due to geometric changes in a selected reach of the river.

1.6 Arrangement of contents

This section provides the outline of this thesis. Chapter two describes the literature that were reviewed for this study. Literature regarding the Kapataksha river and its adjoining area, regarding Environmental Impact Analysis and regarding Tools and Techniques, are provided here. In Chapter three, the methodology followed in this study is discussed. The steps that were carried on to perform the study are also described in this Chapter. Chapter four provides description of the study area Location. Population characteristics, Livelihood, physical environment, Agriculture, Fisheries etc. of the study area are described here. In Chapter five, results and discussion are given. In this Chapter, the change of geometry of the Kapataksha river and its impacts on environment are analyzed. To perform this task, a conceptual network was formulated describing how various types of impacts are taking place due to the change of geometry of the river. Conclusion and Recommendations are given in Chapter six. In this chapter, major findings of the study and recommendations for further study are given.

Chapter 2
LITERATURE REVIEW

2.1 Introduction

This chapter provides description of the literature that were reviewed for this study. The literature reviewed for this study are categorized into three groups, such as literature regarding the Kapataksha river and its adjoining area, literature regarding Environmental Impact Analysis and literature regarding Tools and Techniques. used for this study.

2.2 Literature regarding the Kapataksha river and its adjoining area

Widespread drainage congestion in the Kapataksha river and its adjoining areas has turned into regular phenomenon for the local people of that area. People of this area raised persisting demands for restoring the flow of Kapataksha river. Responding to the demand of the local people of that area, BWDB launched a program of dredging of river and connecting khal between the Kapataksha river and low laying areas. For this purpose, CEGIS was engaged to conduct Environmental and Social baseline studies of Kapataksha River Project (CEGIS. 2004)

CEGIS (2004) recorded all important environmental and social baseline conditions of the study area. The year 2003 was considered as the base year when the dredging was initiated by BWDB. The report contains information about water resources, land resources, biological resources, ecological and socio-economic conditions. The study has established reliable database on hydrological, environmental, ecological, fisheries, agriculture and socio-economic aspect (both in quantitative and qualitative terms) showing the extent and magnitude of drainage congestion. The study will help to monitor the impacts of dredging as well as to develop the management strategy for future.

The feasibility study report for re-excavation of Kapataksha river conducted by Kranti Associates Ltd in association with Desh Upadesh limited provides important information about the area (Kranti, 2000). The physical settings, agriculture, fisheries, physical and biological environment and socio-economic features of that area are described there.

Bangladesh experienced a very abnormal late monsoon flood in the year 2000 in the western part of the South West region. The late monsoon flood of September and October of 2000 was an unusual extreme event. The flood was of very unusual in nature because the area in the last 50 years or so did not experience a flood of such a magnitude (SWMC, 2000). SWMC identified that the flood occurred in three stages. In the beginning flood spill from the Ganges occurred during the period September 17-20. Floodwater spilled into Kumar-Nabaganga, Begabati-Bhadra and Kapataksha system. The second spill came from the overflowing Kodla and Ichamati rivers, which began on September 22. Flood spill this time entered Kapataksha and Betna rivers in Meherpur, Mahespur and Sarsa areas. The third flood infiltration from Sonai river occurred by breaching the Polder 1 embankment in Satkhira near Baikeri. Another source of spill was at Keragachi just north of Polder 1 (Figure A-1, given in Appendix A). The natural and manmade causes that were responsible for the flood of 2000 are climatic factors, reservoir release, tidal influences, Ganges flood spills, natural topography, siltation of the river, unplanned development, uncoordinated infrastructure development etc. According to SWMC, polders on coastal region also play negative roles to drain out the flood water. The construction of large number of polders resulted the closure of many tidal channels. As a result, these channels are creating problem for drainage of water from polders. It also creates problem for communications, because traditional navigation channels have become blocked from siltation.

Coastal Development Partnership (CDP) is an information center located in southwest region of Bangladesh. They published several reports and bulletins providing information of Kapataksha river and its adjoining area. CDP (2002) described the water logging condition of that area. This report also explained the causes and consequences of water logging problem. The damages of water logging on different social groups also were encountered in this report.

CDP (2003) described the bank erosion of the Kapataksha river and the socio economic impacts of this bank erosion over that area. The downstream part of the Kapataksha river was subjected to bank erosion. The villages Dargamahal, Senatonkathi, Rahimpur , Uldanga of Paikgacha and other villages like Golbati, Boalia Bazar, Hetampur of Kupilmuni were affected by bank erosion of the Kapataksha river (CDP, 2003).

CDP (2003) described about the unusual tidal flood of the Kapataksha river and the rivers of south western region of Bangladesh. Mainly down stream part of the Kapataksha river was subjected to the tidal flooding. The water logging problem and other damages caused by this unusual flooding to the adjoining area of the Kapataksha river was discussed in this report.

2.3 Literature regarding Environmental Impact Analysis

A set of comprehensive guidelines for the EIA assessments were published in 1992 for use in ongoing FCDI and water management project of Bangladesh (FPCO, 1992). The EIA guidelines provide a consistent and common basis for the application of EIA to FAP developments to protect environment by ensuring that only environmentally sound projects are designed and implemented. The guidelines also assist EIA practitioners in identifying, quantifying and evaluating potential environmental consequences of flood control, drainage and irrigation (FCD/I) and other FAP interventions so that the impacts of a project are highlighted and the project design can be altered or management measures can be developed to enhance positive impacts and lessen or alleviate negative impacts.

Manual for Environmental Impact Assessment (EIA) (FPCO, 1995), published in 1995, is a companion documents to the Guidelines for EIA in the Water Sector. While the EIA Guidelines outline the steps in the EIA process and describe what is required of EIA, the EIA Manual details how the steps and procedures are to be achieved.

2.3.1 Methodology for EIA

Several activities are required in an environmental impact study, including impact identification, preparation of a description of an affected environment, impact prediction and assessment and so on To carry out these tasks, there are several methods of EIA, the common methods are Checklist, Environmental Evaluation System, Matrices. Networks, Overlays. Environmental Impact Indices, Cost-Benefit Analysis, Simulation Modeling Workshops (LGED, 1992).

2.3.2 Selection of Methodology

There is no universal decision-focused methodology for meeting the EIA needs for all projects type in all environmental settings Accordingly, selection of an existing methodology (or portion thereof) or the development of a new methodology may be required to study an impact. The techniques and procedures to be adopted for environmental impact assessment may vary from one project to another (IUCN 1993).

Nichols and Hyman (1982) identified seven criteria for evaluating environmental assessment methods. These criteria are summarized in Table A-1 (given in Appendix A). The first three reflect the complex attributes of real environmental responses to natural or man-induced changes. The remaining four represents the preferable attributes of a planning and decision-making process.

Some desirable characteristics of an EIA method selected for usage include the following: (1) it should be appropriate to the necessary task, such as impact identification or comparison of alternatives (not all methods are equally useful for all tasks), (2) it should be sufficiently free from assessor bias (the results should be essentially reproducible from one assessor group to another), and (3) it should be economical in terms of cost and its requirements of data, investigation time, personnel, and equipment and facilities (Lee, 1983).

Hobbs (1985) suggested four issues to be considered in choosing an EIA method; these are (1) the purpose to be served, (2) the ease of use (time, money, necessary computer facilities, etc), (3) the validity of the method, and (4) the anticipated results when compared to other methods.

Canter (1996) identifies five activities and relevant useful methodologies. For example, matrices and network are particularly useful for impact identification. Checklists are important for selection of proposed action (based on evaluation of alternatives). For describing affected environment, network and checklists are useful.

In this study, network has been used for analyzing the impacts on environmental components. "Network" are those methodologies which integrate impact causes and consequences through identifying interrelationship between causal actions and the impacted environmental factors, including those representing secondary and tertiary effects (Canter, 1996). Networks are extensions of matrices which involves the development of a "stepped matrix" of "cause-condition-effect network" to indicate the nature of environmental interrelationships (ESCAP 1985). Networks are capable of identifying direct and indirect impacts, higher-order effects and interactions between impacts and hence, are capable of identifying and incorporating mitigation and management measures into the planning stages of a project. Network analyses are particularly useful for identifying anticipated impacts associated with potential projects. Network can also aid in organizing the discussion of anticipated project impacts. Network displays are useful in communicating information about an environmental impact study to the interested publics. The primary limitation of the network approach is the minimal information provided on the technical aspect of impact prediction and the means of comparatively evaluating the impacts of alternatives. In addition, network can become visually very complicated (Canter, 1996).

2.3.3 Related studies

Bisset (1987) developed structured aids or approaches for assessment of environmental impacts, which is commonly known as EIA methodologies. He accounted the following main activities that should be considered in environmental impacts assessment. The activities are impacts identification, impact prediction and measurement, impact interpretation or evaluation, identification of monitoring requirements and mitigation measures and communication of impact information to users such as decision-makers and members of the related public.

Sorensen (1971) developed a network diagram of dredging project showing potential environmental impacts. Network diagram is shown in Figure A-2 (given in Appendix A). The reasons for dredging are shown in the diagram. The causal actions and impacted factors are delineated in the network. The network shows that the impacts of dredging projects are influenced by the type of dredging.

Mirza (1991) carried out a study on environmental impacts of Chandpur Irrigation Projects (CIP). The "networking" methodology was used for impact assessment in this study. Major components that were considered for impacts assessment of Chandpur Irrigation Projects (CIP) by Mirza are: fisheries, agriculture, livestock, vector borne diseases, diarrhoeal diseases, irrigation and flood protection, navigation, use of agricultural input etc. Both adverse and beneficial impacts were indicated in this study For example, agricultural impact and culture fish production increased due to this project But captured fisheries, livestock, various types of water borne diseases and navigations were subjected to adverse impacts. In this study, it is also mentioned that water hyacinth of the project area created more problems to the navigation.

Irrigation projects may create water logging and consequent salinity problem, if proper drainage capacity is not provided It has been experienced in the Mahi Right Bank Canal System (Michael, 1987). The MRBC(Mahi Right Bank Canal System) command area is characterized by a gentle flat topography and restricted to natural drainage. As a result, water logging and salt accumulation problem developed there. Water logging problem further causes other problems like rising of water level, increase of water borne diseases and degradation of water quality.

Smith, et. al (2000) studied the environmental impacts of a river diversion using satellite imagery. A hydroelectric power system known as the Gabcokovo Barrage System (GBS) was completed on a section of Danube River between Hungry and Slovakia in 1996. Environmental impacts of the GBS that were detected and measured by satellite remote sensing fall into three categories: (i) Change in the hydrological regime (ii) Change to forest land within the wetland downstream from the diversion and (iii) reduction of land used for agricultural production. Approach was to correlate field observations with the satellite imagery.

Khosru (1998) carried out a study on assessment of environmental impacts of water development projects using overlay technique. Some important environmental components that were considered for impacts assessment are: flood control, drainage, irrigation, crop damage and capture fisheries.

In this study, water hyacinth was used as an indicator to describe the status of water body. National Committee on Environmental Planning and Coordination, Department of Science and Technology, Government of India conducted an aquatic weed survey in order to assess the nature and magnitude of aquatic weed infestation (Gopal and Sharma, 1981). Among the identified weeds, the infestation due to water hyacinth was reported to be the most troublesome in India (Gopal and Sharma, 1981). Major problems that were identified due to this aquatic weeds are: hindrance to fisheries, choking of flowing water, interferences with growth of cultivated plants, impediment to water transport, pollution of water, increased loss of water through evapotranspiration, others problems like breeding of insects etc.

2.4 Literature regarding Tools and Techniques

In 1889, the Irish engineer Robert Manning presented a formula for computation of uniform flow velocity, which was later modified to the following form (Chow, 1969):

$$V = \frac{1}{n} R^{2/3} S^{1/2} \qquad (2.1)$$

Where, V is the mean velocity, R is the hydraulic radius of the channel, S is the slope of the energy line, and n is the coefficient of roughness, specially known as Manning's n. This formula Eq. (2.1) is further used for computation of the conveyance of a channel.

The discharge of uniform flow in a channel may be expressed as the product of the velocity, represented by Eq. (2.1), and the water area, or

$$Q = VA = \frac{1}{n} R^{2/3} S^{1/2} A = K S^{1/2} \qquad (2.2)$$

Here, $K = \frac{1}{n} A R^{2/3}$ $\qquad (2.3)$

The term K is known as conveyance capacity of a channel. Conveyance is a major indicator of carrying capacity of the channel section. In this study, Eq. (2.3) has been used for computing of conveyance capacity of the Kapataksha river.

Hann (1977) has described how a dependent variable is related with several independent variables. He provided the basic principles that are used for developing a multiple regression model. He discussed about the following general linear regression model, Eq (2.4) for predicting a dependent variable, which are dependent on several independent variables.

$$Y = \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_p X_p \qquad (2.4)$$

where Y is a dependent variable, $X_1, X_2, \ldots, X_p$ are independent variables and $\beta_1, \beta_2, \ldots\ldots, \beta_p$ are unknown parameters.

Chapter 3
METHODOLOGY

3.1 Introduction

The major objective of this study is to analyze the environmental impacts caused by the change of geometry of the Kapataksha river. The methodology in this study is discussed in this chapter. The steps that were carried on to perform the study are also described.

3.2 Methodology of the study

The term "methodology" used herein refers to structured approaches for accomplishing basic activities. The methodology for analysis of environmental impacts was developed following the EIA methodology prepared by EIA Manual (FPCO, 1995). The methodology that was followed in this study signifies the following basic activities:

- Simplification
- Models
- Impact Analysis
- Impact Classification

3.2.1 Simplification

Ecosystem and environmental resource systems are complex with many components and many types of interactions between and among these components. To make comprehensible and useful analysis of impacts, some form of simplification is required. The definition of simplification that was provided by EIA Manual (FPCO, 1995) is as follows:

"Simplification is a process of breaking down a large complex system with associated complex questions into smaller, more manageable pieces with simpler questions, which are more easily dealt with, and restricting the activity to a few selected questions relating to the most important components and impacts".

For simplification, at first, the impact causing factors were identified. In this study, the environmental impact causing factors are changes of geometric characteristics of the Kapataksha river. After identifying impact-causing factors.

important environmental components (IECs) were selected upon which impacts were analyzed. Here, those environmental components have been selected as IECs that are ecologically important and impacted by the change of geometry of Kapataksha river In this study, the environmental components upon which impacts were analyzed are water logging, drainage congestion, fisheries, water body (local ponds and river water), wetlands (beels and baors), tidal condition and navigation. The process of simplification is shown by following diagram (Figure 3.1).

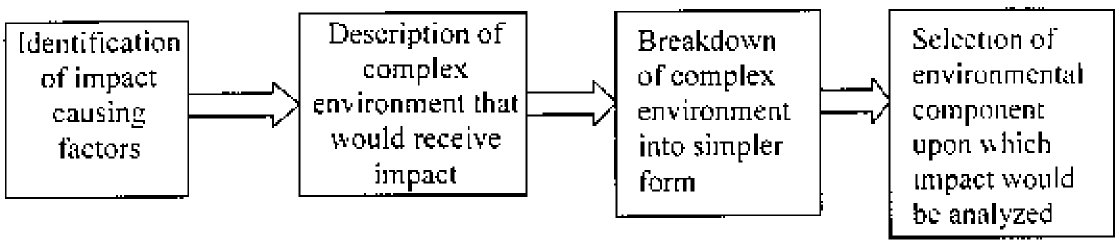


Figure 3.1: Flow chart showing simplification process

3.2.2 Model

After simplification the next task was to display the interrelationship among the environmental components as well as the way by which these environmental components are impacted, in a representable manner. Models are simplified representations of complex environmental systems. A conceptual model provides a description of environmental components of an area, their interrelationship as well as the way by which the components are affected by impact causing factors. In this study, a conceptual model was developed to describe and analyze the environmental impacts. The model describes how the aforementioned seven (water logging, drainage congestion, fisheries, water body, wetlands, tidal condition and navigation) environmental components are interconnected among themselves. The model also displays a linkage showing how environmental components are being affected and influenced by change of geometry of the Kapataksha river. Diagrams, flowcharts, verbal descriptions are the important useful part of this model. The tool that was used for building the conceptual model is network. The network is constructed by using field observational data, primary data, secondary data, expert opinion and local indigenous knowledge. The following figure (Figure 3.2) represents the steps for developing the conceptual model.

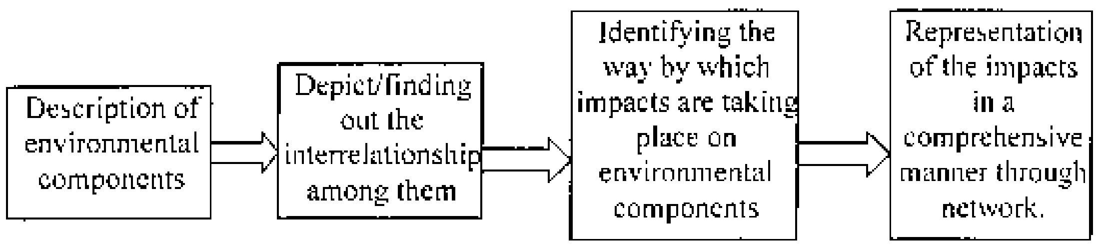


Figure 3.2: Steps for developing of a conceptual model

3.2.3 Impact analysis

In this stage, the impacts on the aforementioned environmental components were analyzed and evaluated. The impacts were measured in quantitative term in most cases and in qualitative term in some cases. In some cases, it was not possible to measure the impacts directly. In those cases indicators were used to measure the impacts. The analysis of the impacts was performed through mainly comparison of the data between pre-waterlogged and post-waterlogged condition and some computation. Process of analysis of impacts is shown in Figure 3.3.

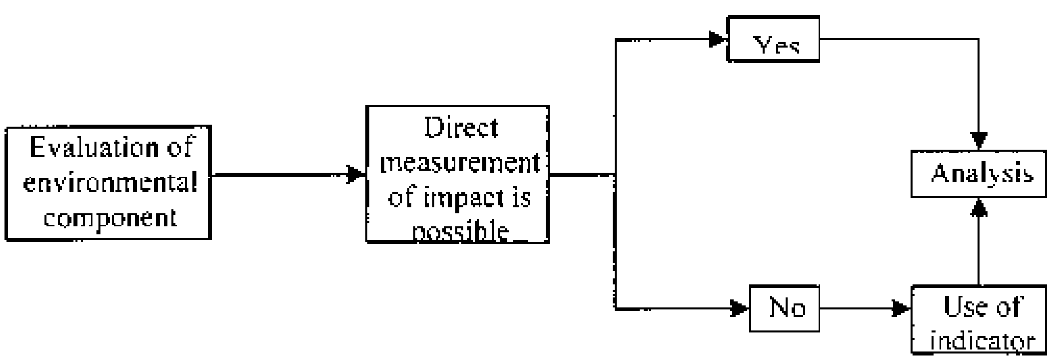


Figure 3.3: Process of analysis of impacts

3.2.4 Impacts classification

Impacts were characterized according to a number of criteria like cumulative or non-cumulative, direct or indirect, direction of the impacts etc. It was studied whether the impacts are cumulative by nature or it is a single impact. It was also studied that if the impacts were direct or indirect (secondary, tertiary). The direction of impacts (increase or decrease) was also observed. The classification of impacts is shown in Figure 3.4.

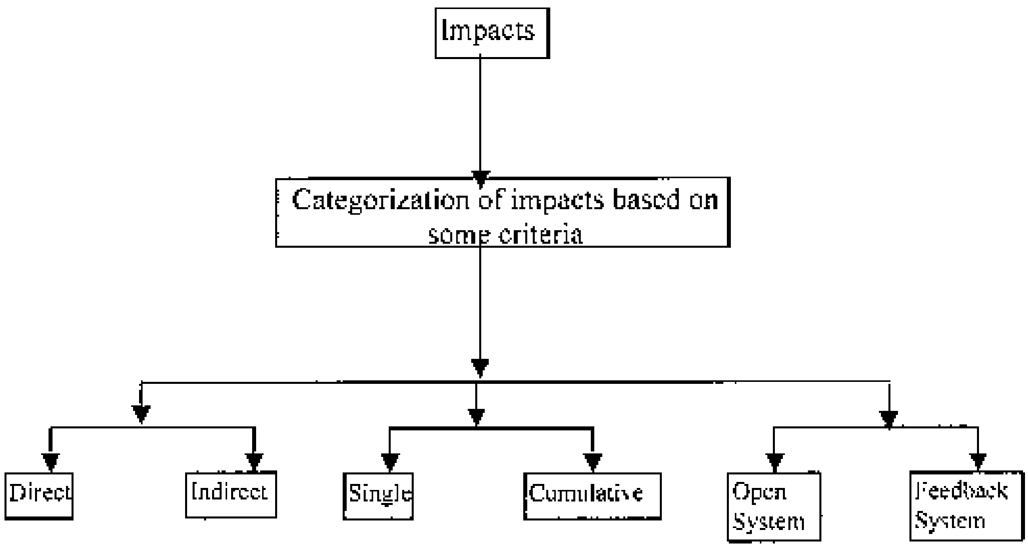


Figure 3.4: Classification of impacts

3.3 Steps of the study

The tasks, to carry on the study, were performed in several steps. The steps that were followed in this study are given in Figure 3.5.

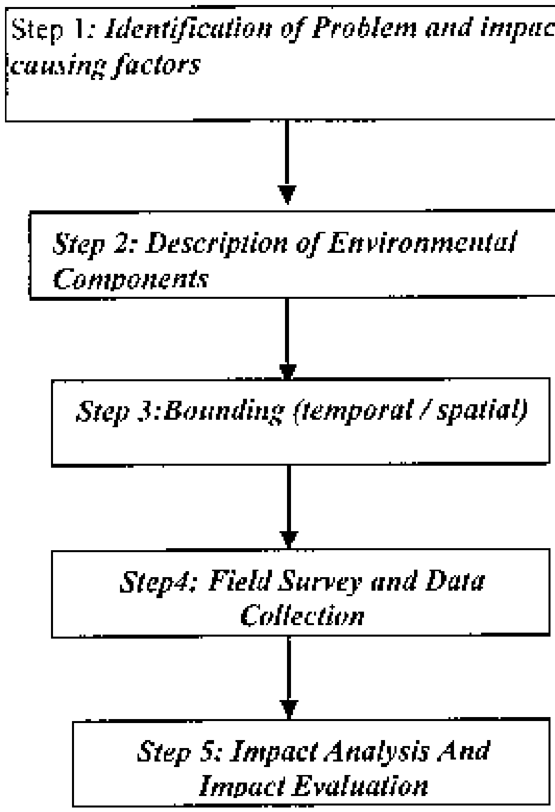


Figure 3.5: Steps of this study

3.3.4 Identification of Problem and impact causing factors

This is the first step of this study, identifying the causes, which are responsible for creating impacts on environmental components. In this study, the impact causing factors are the change of geometric characteristics of the Kapataksha river and the effects are the impacts on environmental components. The geometric characteristics that were analyzed are width, average depth, cross sectional area, conveyance capacity and thalweg profile of the Kapataksha river For analyzing geometric characteristics of the Kapataksha river, cross sectional data was collected from BWDB. From these data width, average depth, cross sectional area and conveyance were calculated. The cross-sectional area of the river was calculated by using trapezoidal formula. For calculating conveyance Manning Formula (Chow, 1969) was used. The formula for computing conveyance is represented in Eq. (2.3).

3.3.5 Description of Environmental Components

Generally, descriptions of the environmental components are comprehensive studies that provide information to characterize the environment that would receive impacts. Figure 3.6 depicts a conceptual framework, which can be used for preparing a description of the environmental setting. The methodology involves (1) the identification of one to several lists of environmental factors, (2) the application of a screening process leading to selected list of environmental factors, (3) the procurement of relevant data for the selected factors and/or the conduction of pertinent baseline studies, and (4) the preparation of the description of the setting (Canter, 1996).

Selecting environmental factors from an initial list could involve site visits, interdisciplinary team discussions, scooping, the application of criteria questions, and/or professional judgment.

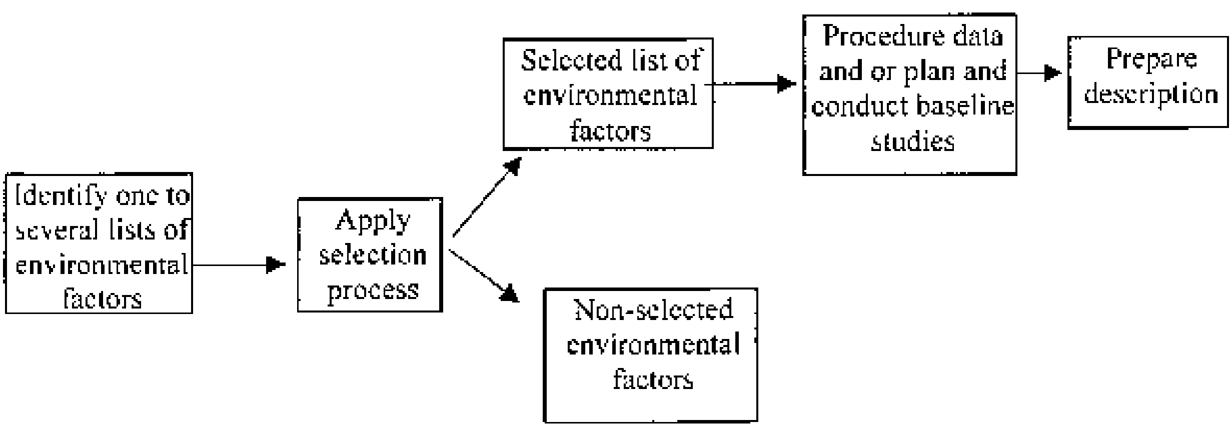


Figure 3.6: Conceptual framework for preparing a description of environmental settings (*Source* Canter, 1996).

In this study, the environmental components upon which impacts have been analyzed are drainage system, water logging, fisheries, water body, wetlands, tidal condition and navigation. The state of aforementioned seven environmental components at pre-waterlogged condition has been considered as reference for measuring the impacts. Necessary information regarding these environmental components was collected from review of literatures and local people's opinion

3.3.6 Bounding

The process by which spatial and temporal limits for the impact analysis are determined is termed as bounding. In this step, duration of time and spatial boundary over which impacts were assessed was selected. In this study, the change of geometric characteristics of the Kapataksha river have been analyzed from 1994 to 2001 and the impacts on environmental components were analyzed from 1994 to 2004.

The change of geometric characteristics of the Kapataksha river have been analyzed over a stretch ranging from 0 km to 170 km (station ID. kbd 1 to kbd 14) along the river. Environmental impacts were analyzed over Trimohini union of Keshabpur upazila in Jessore district.

3.3.7 Field Survey and Data Collection

Both primary and secondary data were used in this study. To collect primary data five field visits were made to the study area. One visit was made at pre-monsoon, two visits were made during the monsoon and the last two visits were made after the monsoon. Primary data was collected through questionnaire survey, opinion from local people and visual observation The sample size for questionnaire survey was fifty. These were categorized into three groups (agriculture, agricultural labor and fisheries) based on the main occupation of the household head. A sample of questionnaire is given in Appendix D. Secondary data were collected from BWDB (Bangladesh Water Development Board), SRDI (Soil Resources Development Institute) and BBS (Bangladesh Bureau of Statistics) etc. Besides these, some secondary information were collected from CEGIS (Center for Environmental and Geographical Information Services) and CDP (Coastal Development Partnership).

3.3.8 Impact Analysis and Impact Evaluation

The most important step in this study is "Impact Analysis And Impact Evaluation" where identification of impacts, analysis of identified impacts and evaluation of impacts in numeric or descriptive terms were made. The analysis and evaluation of impacts have been performed using the methodology described in section 3.2 of this chapter.

Chapter 4
DESCRIPTION OF THE STUDY AREA

4.1 Introduction

In this study, the change of geometric characteristics of the Kapataksha river were analyzed over a stretch ranging from 0 km to 170 km (station ID, kbd 1 to kbd 14). Location map along the river is shown in Figure 4.1. For analysis of environmental impacts, a small representative area, which was severely affected by drainage congestion problem, was selected as a study area. In this chapter, description is given of that study area, which was selected for analysis of environmental impacts.

4.2 Location and area

In this study, Trimohini union of Keshabpur upazila in Jessore district was selected as a study area for analysis of environmental impacts (Figure 4.2). Keshabpur upazila lies between the latitude about 22^0 48' and 22^0 57' N and longitude lies between 89^0 7' and 89^0 22' E (SRDI, 1999). The area of the Trimohini union is 3462 hectare. The villages in which field investigation and survey were made are Mirzanagar, Barandali, Saraskati and Shahpur. The areas of the four villages are given in Table 4.1

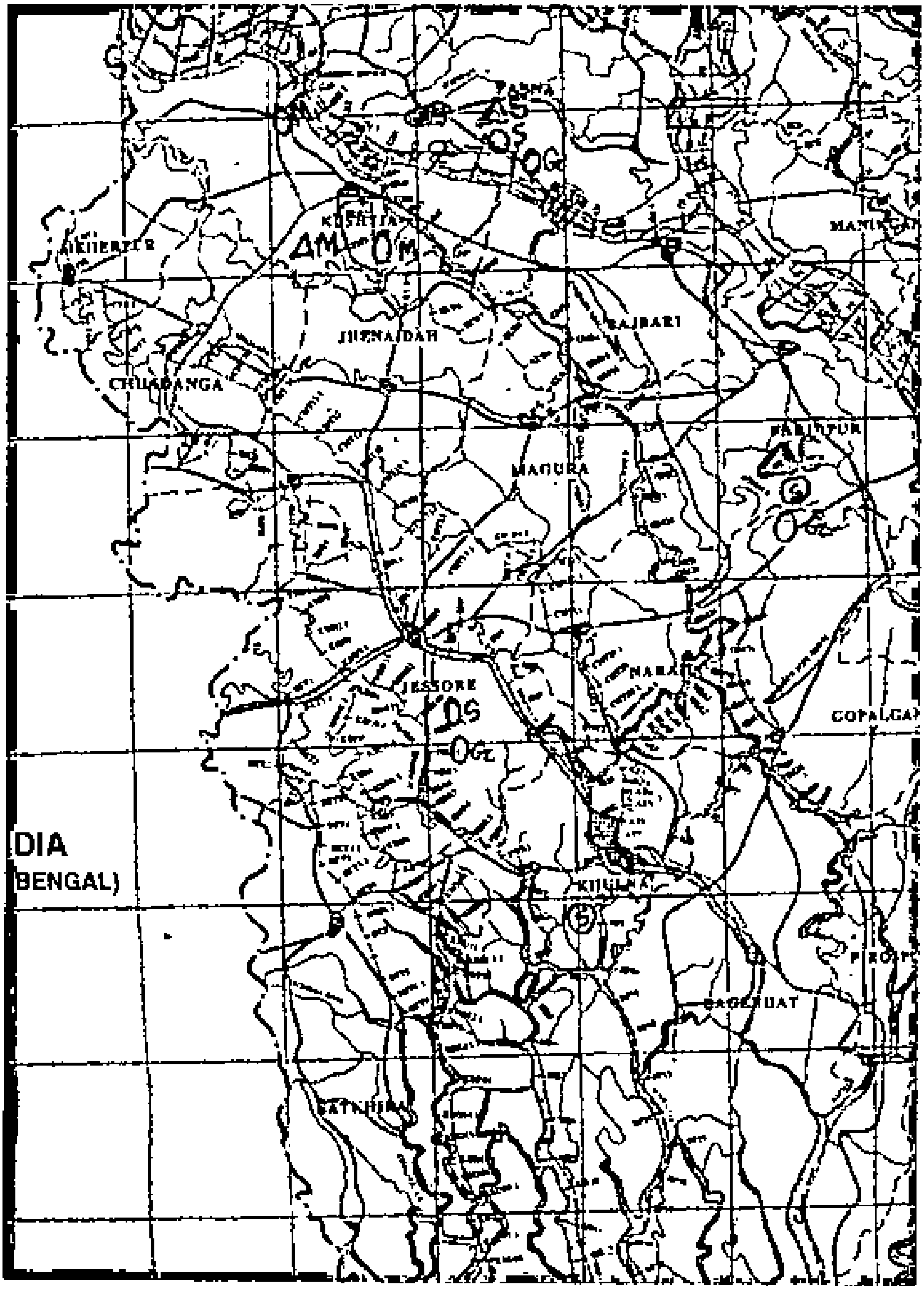
Table 4.1: Area of the villages of the study area

Village	Area (ha)
Barandali	476
Mirzanagar	456
Shahpur	84
Saraskati	49

Source: BBS, 1989

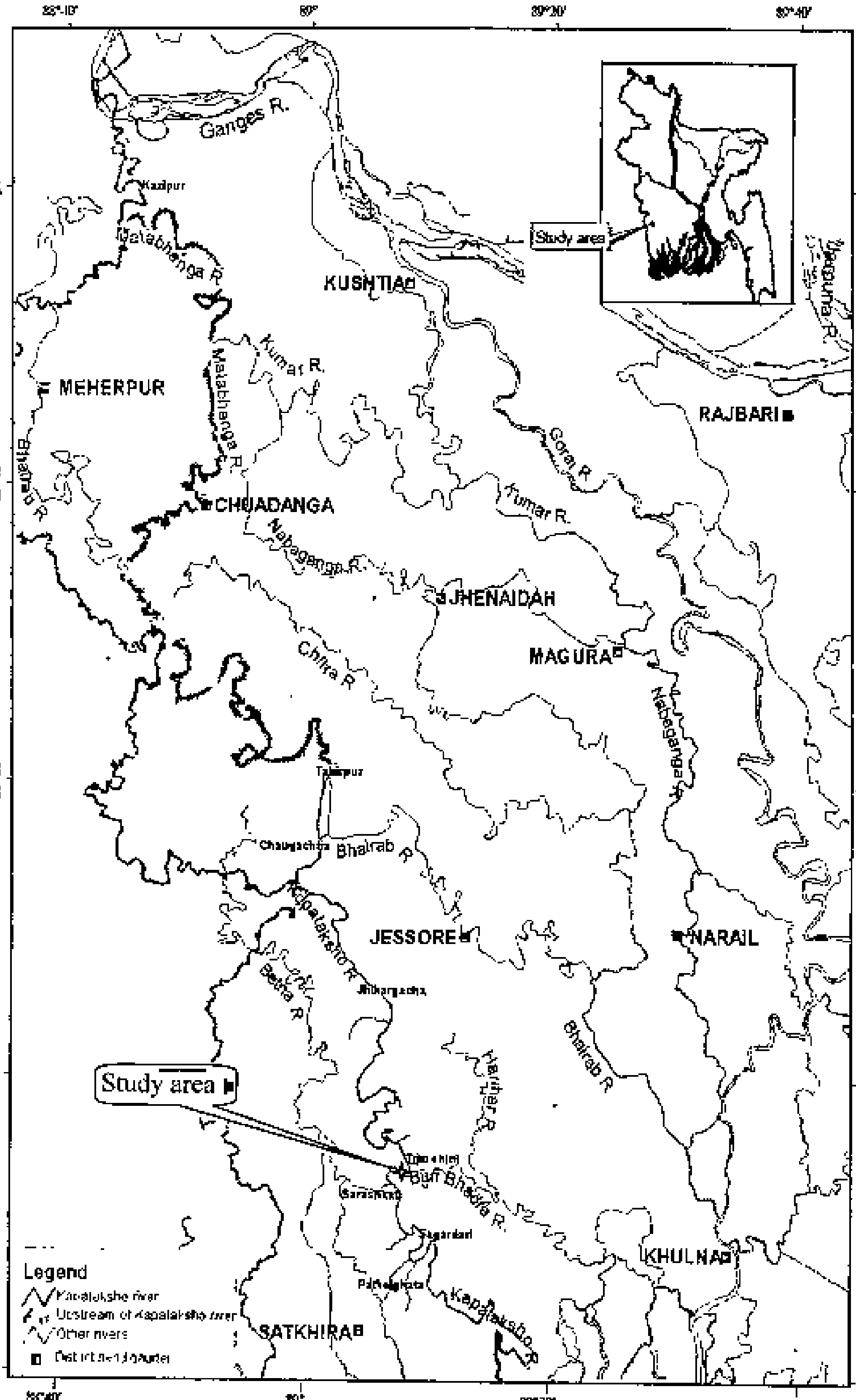
4.3 Population characteristics

The total population of Trimohini union is 25700 (BBS, 1991). The sex ratio of Trimohini union is 95 female per 100 male. Table 4.2 represents the total population, sex ratio and literacy rate of the four villages of the study area. In every village, literacy rate is lower than the national average literacy rate (32.4%). In the



Source: BWDB

Figure 4.1: Location of the cross sectional ID of Kapataksha river



Source: CEGIS, 2004

Figure 4.2: Location map of the study area

study area the highest literacy rate is in Mirzanagar village and the lowest literacy rate is in Shahpur (Table 4.2).

Table 4.2: Population characteristics of the study area

Village	Population			Literacy rate (%)
	Total	Male	Female	
Barandali	3545	1787	1758	21.4
Mirzanagar	3167	1648	1519	30.2
Shahpur	722	377	345	18.9
Saraskati	334	177	157	24 3

Source- BBS, 1991

4.4 Livelihood

Most of the households in Trimohini union earn their livelihood by cultivating or sharecropping. In Trimohini union 40.79% of the total population is involved in household works. Agriculture labour is also important activities in the study area. In Trimohini 32.91% of total population is involved in agricultural activities. The occupational structures of the four villages of Trimohini union are represented in Table 4.3.

Table 4.3: Livelihood pattern of the study area

Village	Total households	Cultivator/ Share cropper	Livestock, Forestry, Fisheries	Agriculture labour	Non Agriculture labour	Hand loom	Construction	Transportation	Business	Employee	Others
Barandali	561	252	1	190	6	-	5	3	54	16	34
Mirzanagar	582	307	-	180	11	-	2	3	64	9	6
Shahpur	142	70	2	39	9	-	3	1	14	1	3
Saraskati	69	15	-	29	1	-	-	4	16	-	4

Source: BBS, 1991

4.5 Climate

Like other areas of Bangladesh, Tropical Monsoon climate is observed in the study area. Among six seasons, three seasons are observed distinctively. Rainy season usually starts in May and continues up to October. About 92 percent of annual rainfall occurs during this time. Winter starts in November and ends in February. March and April are considered as summer and pre- rainy seasons (SRDI, 1999). The temperature and long-term rainfall condition over the study area are given in Table 4.4 and Table 4.5, respectively.

Table 4.4: Maximum, Minimum and Average temperature of the study area

Temperature	January	February	March	April	May	June	July	August	September	October	November	December
Maximum	25.9	28.9	33	35.2	34.2	32.8	33.8	31.9	32.3	31.8	29.4	26.5
Average	18.7	21.5	26.2	29.2	29.8	29	28.8	28.9	28.9	27.5	23.4	19.4
Minimum	11.3	14.1	19.2	23.4	24.8	25.8	25.8	25.9	25.5	23.3	17.7	12.5

Source: BARC, 1996

Table 4.5: Rainfall of the study area

	January	February	March	April	May	June	July	August	September	October	November	December
Rainfall(mm)	11	23	45	76	152	301	308	290	215	133	22	9

Source: BARC, 1996

4.6 Rivers and Khals

The Kapataksha is the main river of the study area. The Kapataksha river originates from the Mathabhanga river at the Tahirpur in Jessore district (Figure 1.1). It is flowing north to south over the most mature part of the Gangetic delta. From Tahirpur to its confluence with the Sibsa river, the length of the Kapataksha river is around 200 kilometers. This river drains an area of about 1067 square kilometers spread over the nine upazilas in Jhinaidah, Jessore and Satkhira district (CEGIS,2004). Due to geographical location, lower part of this river is tidal while the upper part is non tidal.

In addition to the Kapataksha river, there is another small river named Buri Bhadra. It originates from Kapataksha river and ultimately falls into upper Bhadra river

Along the Kapataksha river area, Jhikarghacha station (station id162) is situated at the upstream of the study area and Tala Magura station (station id163) is situated at the downstream of the study area .The water level of these two stations are given in Table 4.6.

Table 4.6: Surface water level of the Kapataksha river in different year

Station name	Station ID	Maximum water level (m+PWD)				Minimum water level (m+PWD)				Average water level (m+PWD)			
		1999	2000	2001	2002	1999	2000	2001	2002	1999	2000	2001	2002
Jhikarghacha	162	4.03	5.45	3.88	4.39	1.27	1.47	1.63	1.78	2.52	3 07	2.88	3.22
Tala Magura	163	2.92	3.02	-	-	-1 02	-1.10	-	-	0.75	0.77		

Source: CEGIS, 2004

Khals are important elements of natural drainage system over the study area. There are five khals in the study area. Among them, three khals are in Barandali village and two khals are in Mirzanagar. Barandali khal, Natun khal and Puratan khal are situated in Barandali village. Mirzanagar khal and Buri Bhadra khal are situated in Mirzanagar.

4.7 Beels and Baors

Beels and Baors are the lacustrine freshwater wetlands of the study area (BCAS, 1994). Baors are normally depressed area and abandoned river course which are developed by loop cutting of river bend and acts as perennial water bodies. In the study area, there are one baor named Mirzanagar baor. It is situated in Mirzanagar village of Trimohini union. The baor is important to the local people mainly for its natural fish sources.

Beels are small saucer like depression and are mostly over grown with marsh vegetation. The beels over the study area are good habitat for the aquatic flora and fauna. Beels are also used for agricultural production. There are many beels scattered all over the study area.

4.8 Agriculture

The study area is a potential area for producing wide ranges of agricultural crop. The soils of the study area support more than one agricultural crop Usually, two to three agricultural crops are grown on the same piece of land On the higher part of the study area, B.Aus or Jute is followed by T.Aman and then by Rabi crop Rabi crops include pulses, oil seeds, wheat, potatoes and vegetables. T.Aman followed by Boro crop is grown on the lower part of the study area. Table 4.7 describes the cropping pattern of the study area.

Table 4 7: Cropping pattern of the study area

Land type	Cropping pattern
High land	B.Aus-Rabi crops
	Teel-Rabi crops
	Jute –T.Aman-Rabi crops
	B.Aus-T.Aman-Fallow
	Teel-T.Aman-Fallow
	T.Aman-Boro
	T.Aus-A.Aman-Fallow
Medium highland	T.Aman-Rabi crops
	T.Aman-Boro
	T.Aman-Fallow
Medium lowland	Boro-Fallow

Source:CEGIS, 2004

4.9 Fisheries

Fisheries resources of the study area are comprised of inland capture fisheries of the Kapataksha river, canals, beels/floodplains and baors, and culture fisheries of the ponds and ghers. This river stretch is a corridor between the Sundarbans or the coast in the south and Ganges in the north through Mathabhanga river. The area plays an important role as a migratory route between upstream fresh water fisheries and downstream brackish water fisheries.

Fish production of the study area comprises fish from river, canal/floodplain, baor, ponds, ghers etc. Table 4.8 shows the estimated fish production of the area Here, it should be mentioned that Table 4.8 does not represent fish production of only Trimohini union. It represents the fish production of the RKRP (Re-excavation of Kapataksha River Project) area.

Table 4 8: Fish production of RKRP area

Source	Production (mt/anum)
From rivers	40
From canals	10
From floodplain/beels	30
Baors	250
Ponds	240
Ghers	30
Total	600

Source CEGIS, 2004

Chapter 5
RESULTS AND DISCUSSION

5.1 Introduction

In this chapter, the change of geometry of the Kapataksha river and its impacts on environment were analyzed. To perform this task, at first a conceptual network was formulated describing how the impacts are taking place due to the change of geometry of the river. Then, the geometric characteristics of the Kapataksha were analyzed. After that environmental impacts were analyzed following the aforementioned network over the study area.

5.2 Network

Upstream flows as well as surface runoff flow over land surface through a network of drainage channels towards sea. Where there is no distinct drainage system, water is held in natural depression. If the drainage system is declined significantly, then water cannot drain out properly and remains at the adjacent area of the channels creating waterlogging condition. And this water logging condition creates further impacts on its surrounding environment.

The phenomenon that took place to the Kapataksha river and its adjoining area is described through a conceptual network diagram (Figure 5.1). The Kapataksha river is one of the main arteries of the water resource system located in the southwest region of Bangladesh. In the past, the Kapataksha river used to get fresh water perennially from Ganges through river Mathabhanga and flowed down to the Sundarbans. Continued flow of fresh water from the Ganges through river Mathabhanga kept saline water away from the upper habitable land and pushed it to the downstream. In the Figure 5.1, this state of the river is labeled as the original state of the Kapataksha river. But in course of time, Mathabhanga started to deteriorate naturally and/or due to human intervention (Kranti 2000; CEGIS 2004). As a result, the Kapataksha river could not get supply from Mathabhanga river through out the year. After losing its connection with the Ganges, Kapataksha has started to decline to adjust its size with the new regime of flow and sediment. After being cut-off from the Mathabhanga river, the Kapataksha river has been subjected to tidal domination,

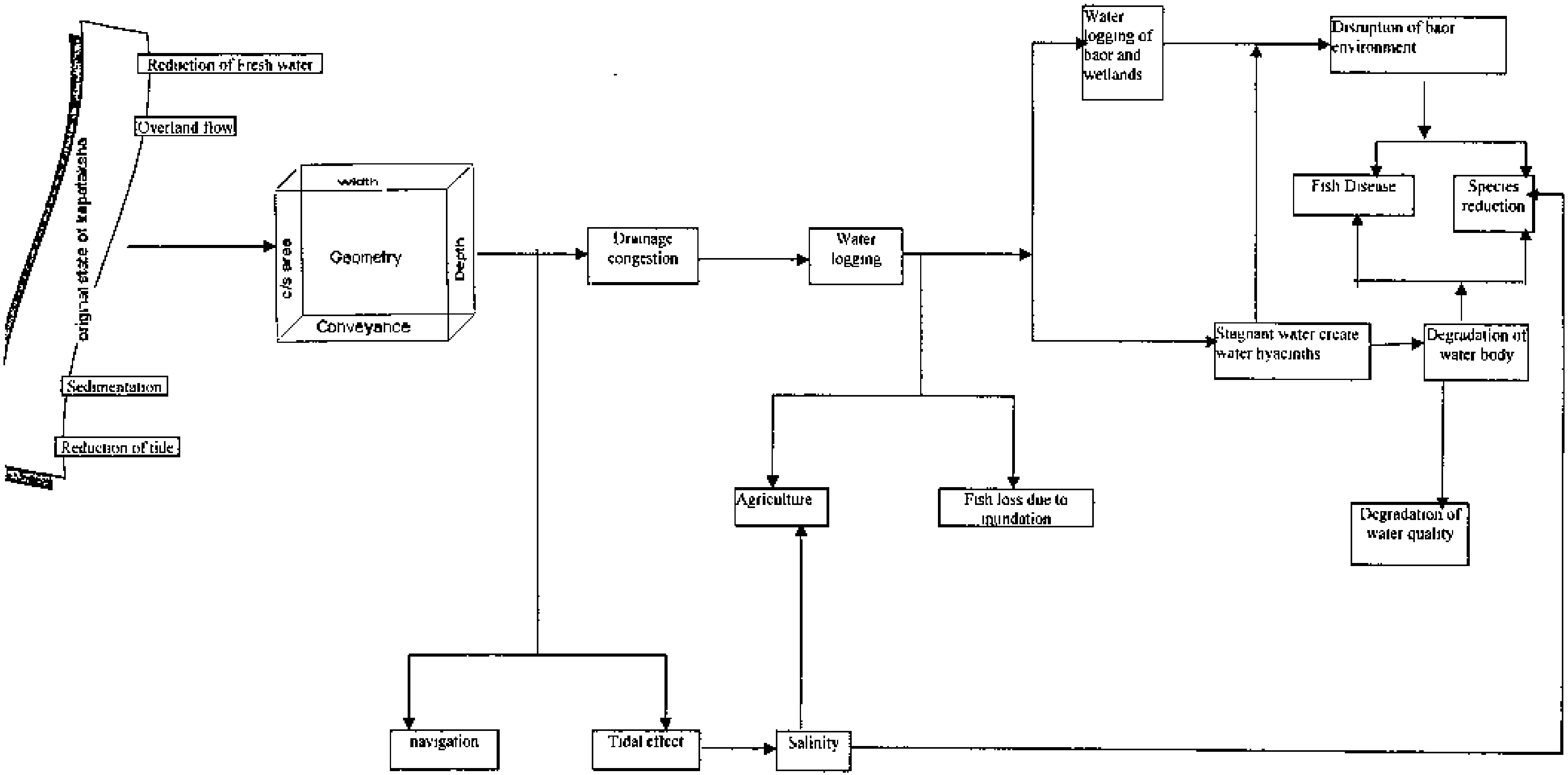


Figure 5.1: Network showing the Environmental Impacts due to geometric change

associated with increasing sedimentation by tidal pumping process. The high salinity level in the river facilitated the deposition of sediment at the location of tidal limit, specially in the dry season. Gradual sedimentation, due to above-mentioned physical process, raised the riverbed along with the reduction of the cross-section of the river and loss of the conveyance capacity of the river.

In Figure 5.1, it is shown that the change of geometry of the river is causing drainage congestion, which further leads to waterlogging. The drainage system of the Kapataksha river consist of a number of drainage channels and khals. The drainage channels and khals originate from beels, baors low lying depressions, and drain to Kapataksha river Thus, they maintain the hydraulic connectivity between beels, baors low lying depression and the Kapataksha river itself. With the reduction of cross-sectional area and loss of the conveyance capacity of the river, khals and other drainage cannels are also dying. As a result, the drainage capacity of that area has declined rapidly. Especially during last few years, huge sedimentation created a hump in the lower middle reach of the river (on the river bed). As a result, the downstream tidal flow could not move upstream beyond this hump and thereby caused drainage congestion over the area. The malfunctioning of drainage system has been created due to not only natural sedimentation process but also due to direct human intervention. The man made causes are river constriction through construction of fish patta, construction of fish ponds and construction of big intervention at the upstream.

In this declining condition of drainage system, the storm/rain water cannot drain out properly and creates water logging (Figure 5.1). In addition to storm/rain water, over landflow that exceeds the conveyance capacity of the river, creates severe water logging over that area (e.g. flood of 2000).

The ecosystem of that area could not cope with this water logging condition and for this reason various kinds of environmental changes took place over the study area. The various environmental parameters that are impacted are shown in Figure 5.1 Fishery is one of the environmental components that is affected by water logging condition in various ways. Once upon a time, the river was wide, deep and turbulent and then fish was abundant in not only quantity but also in species composition. Reduction of river depth, reduced river flow, and increased sedimentation has led to drainage congestion, which further resulted in water logging. This water logging has influenced fisheries resources of the study area. Fish species composition is being changed. Instead of riverine species, floodplain, beel resident fish species are dominating over that area. Due to stagnancy of water a good portion of the Kapataksha river within the study area is completely blocked by water hyacinth. Water hyacinth has reduced the level of Dissolved Oxygen and as a result, survival of diversified fish species is hampered. Many ghers and pond have been damaged due to excessive accumulation of water hyacinth and completely unsuitable for fish culture. Water hyacinth also restricted fish movement and flow of water. Not only depth of the river but also tide and salinity has a great influence on fish resources. In the past, when tide used to go more upward, the brackish water fishes were available up to more upstream of the river. But at present, due to less flow and depth and reduced tide/salinity brackish water fish species shifted to downstream Besides these, due to water logging, number of fish ponds and ghers were submerged and culture fish came out to the floodplain. So fish loss occurred over the study area.

Figure 5.1 shows that agriculture is being influenced by water logging over the study area. In the past, agricultural lands became drained by Kapataksha river through the connecting khals between river and agricultural lands. But at present, the khals act in a reverse way transferring the congested water to agricultural lands. As a result, due to water logging, agricultural crops especially Aman crops have been severely damaged. Due to this problem, timely transplantation of Boro crops are also hampered over the study area. The drainage congestion of the area has also reduced the cropped area of Jute, Sugarcane, Pulse, Oilseed, and Vegetable. Other dry land crops (Jute, Sugarcane, Pulses) are not being sown timely because of wetness of the soils. Previously these areas were excellent for early rabi crops. Because of aforementioned problems, farmers are severely restricted for growing wide ranges of crops in these areas.

Due to discontinuity of flow water remains stagnant. And this stagnant water is favorable for excessive growth of water hyacinth (Figure 5.1). Excessive accumulation of water hyacinth (Eichhorina spp.) makes the riverine ecosystem anaerobic. A dense water hyacinth mat affects the aquatic environment by reducing dissolved oxygen concentrations (DO), pH and temperature, and increasing dissolved

CO_2 levels. Moreover, under favorable conditions it can double its mass between few days, forming new plants on the ends of stolons. It also grows from seed, which can remain viable for longer time. This enormous reproductive capacity causes annual reimburse from seed and rapid coverage over bare water. At present, most of the Kapataksha River surface is covered with water hyacinth like a carpet. The situation is degrading the riverine biological system and lowering water quality for domestic uses. Navigation and fishing are obstructed, and irrigation and drainage systems also become blocked.

Wetland eco-system is one of the most important eco-system of the study area as well of the country. Water logging condition is affecting the wetlands of the study area. Under a natural cycle, wetlands are connected with the parent river during monsoon and get disconnected during the dry season. Now, due to drainage congestion, the wetlands remain connected with the river throughout the year. As a result, fisheries, agricultural crops and other vegetation of the wetland area are being damaged.

River geometry has a great impact on navigation. Once upon a time, Kapataksha river played an important role for navigation from downstream river port to far inland areas. At that time, the river was navigable enough to facilitate the navigation. But with change of the geometry of the river, the flow has become so reduced that navigation is severely affected, specially where the depth of the river has reduced significantly. Except some small scale local navigation in wet season, there are almost no navigation facilities over the area. Moreover, good portion of river surface is covered by carpets of water hyacinth, which also hamper navigation.

In this section, it is discussed how the environmental impacts are taking place due to the change of geometric characteristics of the Kapataksha river through a network diagram (Figure 5.1). Following the network, environmental impacts have been analyzed in this study The changes of geometric characteristics of the river as well as its impacts on environmental components are described in the consecutive sections of this chapter.

5.3 Changes in geometric characteristics of the Kapataksha river

In this section, the geometric characteristics of the Kapataksha river were discussed from 1994 to 2001. The geometric characteristics that were analyzed here are thalweg line, area, depth, width, and conveyance of the river. The geometric characteristics of the river were analyzed based on the cross-sectional data collected from BWDB. Tahirpur of Chowgacha upazila was considered as 0 km for measuring the length of the Kapataksha river. In the previous section (section 5.2), it is discussed that water logging is one of the major environmental impacts caused by the change of geometry of the river. To realize the extent of waterlogging area along the river reach, the water logging area is indicated in the figures describing the geometric characteristics of the river.

5.3.1 Changes in Thalweg

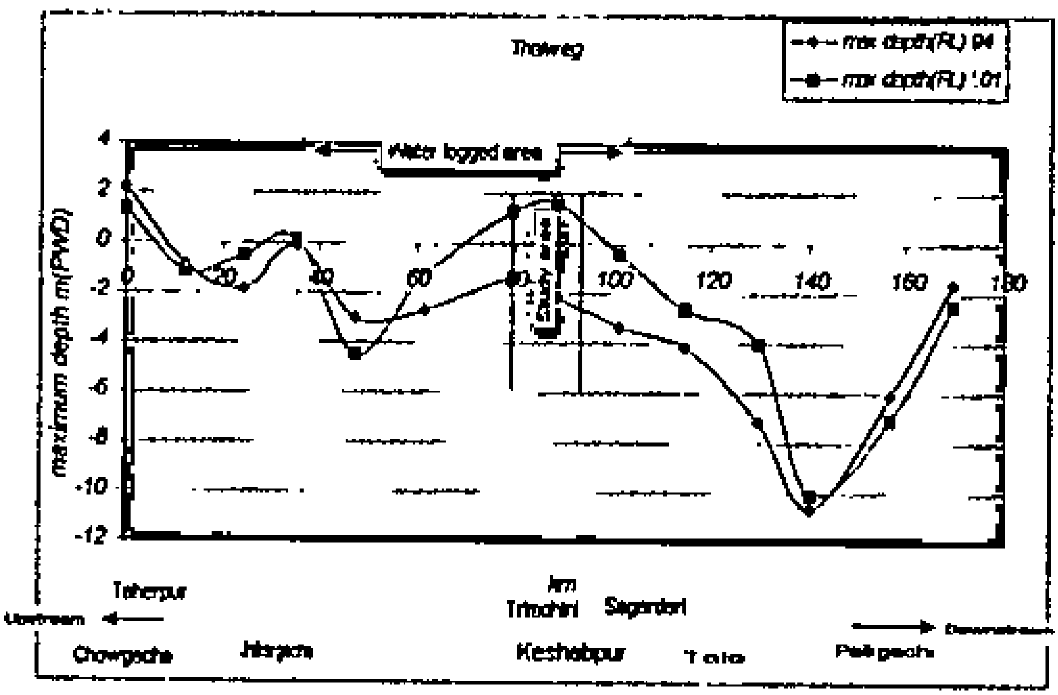


Figure 5.2: Thalweg profile along the Kapataksha river

In the past, the Kapataksha used to get fresh water perennially from Ganges through Mathabhanga river and flowed down to the Sundarbans. Continued flow of fresh water from the Ganges through Mathabhanga river, kept the saline water away from the upstream of the river and pushed it to the downstream and flushed the incoming sediments into the Bay of Bengal. After being disconnected from the Ganges, the pressure of upstream flow of the Kapataksha river was so feeble to push back the saline water come from the downstream and as a result, sediments started to enter this river system from the downstream through tidal pumping processes. The high salinity level in the river facilitates deposition of sediment at the location of tidal limit especially during the dry season and thus, Gradual sedimentation created a hump on the riverbed. Graphical presentation of the thalweg profile (Figure 5.2) reveals that there is a hump from about 70 km to 105 km along the river reach (Trimohini to Sagardari). From Figure 5.2, it is observed that the extent of water logging area has started from behind the hump. Figure 5.2 also represent that the bed level of the river is maximum in the study area (about 1.57 m PWD).

Figure 5.3 signifies that in 1994, the trend of thalweg line was downward to the downstream of the study area. But in 2001 there was a surprising uplift of thalweg line at the downstream of the study area. This reverse slope of thalweg line in 2001 compared to 1994 indicates that more sediment was deposited over the study area during 1994 to 2001 than that of before 1994. Here it should be mentioned that due to the shortage of data analysis were made upon only two locations over the study area.

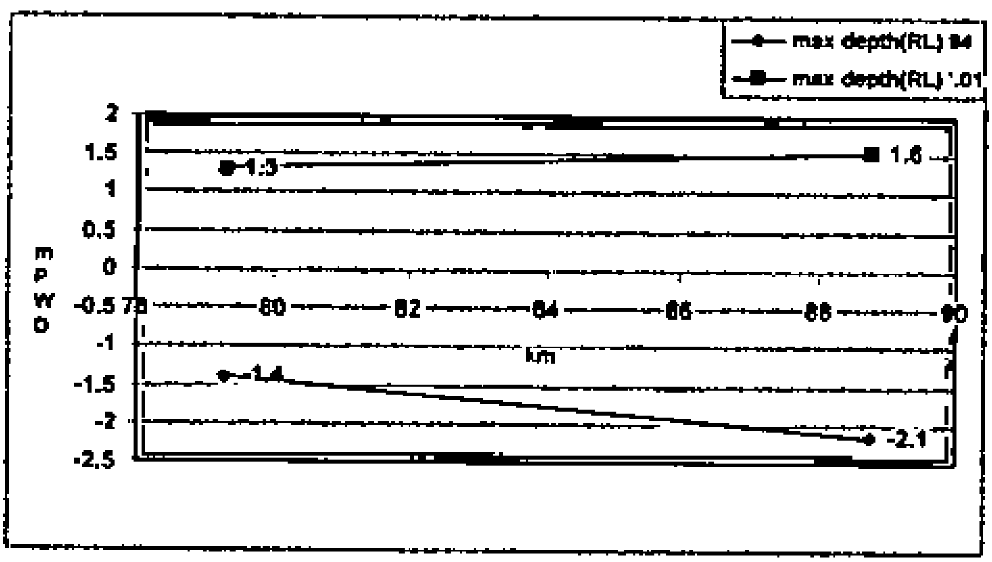


Figure 5.3: Thalweg profile over the study area

5.3.2 Changes in Cross-sectional Area

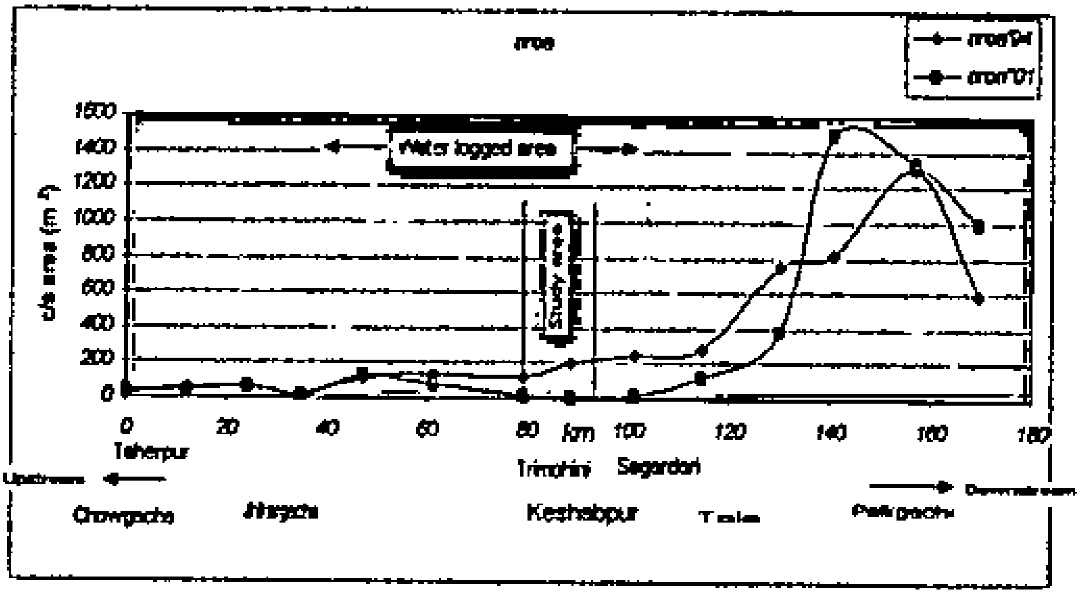


Figure 5.4: Cross sectional area along the Kapataksha river

From Figure 5.4 it is observed that the cross sectional area of the Kapataksha has been decreased in between 1994 and 2001. Figure 5.4 signifies that the cross sectional area has been decreasing significantly from about 60 km to 130 km.

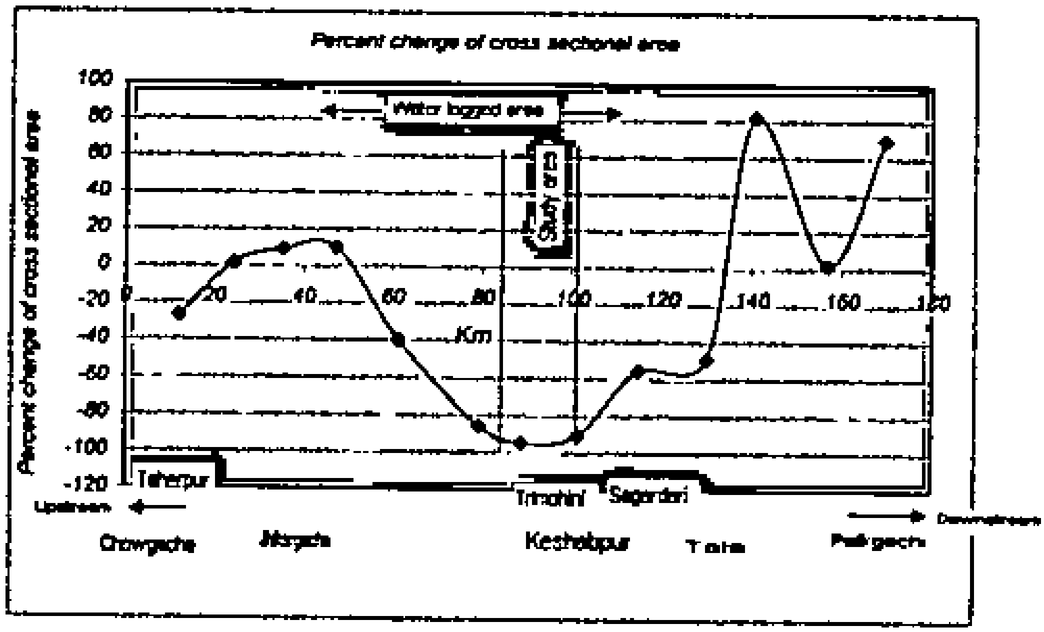


Figure 5.5: Change of percentage in area along the river

From Figure 5.5 it is observed that from 0 km to 60 km along the river reach the cross sectional area has not been changed very significantly but from 60 km to 130 km along the river reach the cross sectional area has been changed very significantly between 1994 and 2001. From 60 km to about 89 km it is observed that the cross sectional area has been decreased from 40% to 95%. From 89 km to 130 km along the river reach the cross sectional area has decreased 95% to 49% (Figure 5.5). However, downward from 130 km, cross sectional area of 2001 is increasing than that of 1994. River erosion may be the cause of this change (Figure 5.4 & Figure 5.5). From Figure 5.5 it is also observed that water logging condition prevails over that area where the cross sectional area has decreased significantly.

From the thalweg profile of the Kapataksha river (Figure 5.2), it is observed that there is a hump between 70 km and 105 km. In this reach, the cross sectional area has been decreased from 40% to 95%. So, it can be seen that the cross sectional area of the Kapataksha river has decreased significantly where the hump is present.

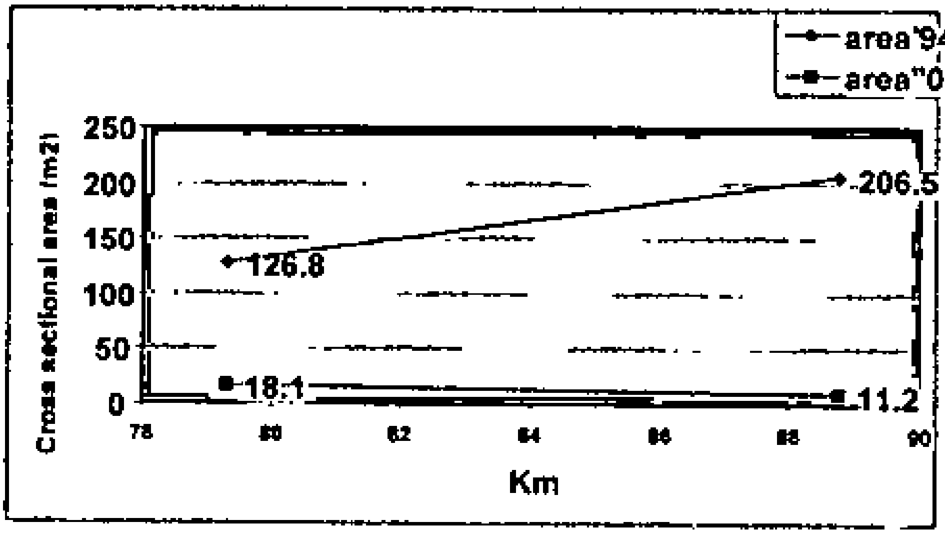


Figure 5.6: Cross sectional area over the study area

From Figure 5.6, it is observed that the cross sectional area was dramatically decreased from 1994 to 2001 over the study area. The cross sectional area over the study area was decreased 86% in upstream (about 79 km) to 95 % downstream (about 93 km). From Figure 5.6 it is observed that in 1994, the trend was upwards towards downstream. It means that the cross sectional area of the river was increasing towards downstream in 1994. Whereas the trend is reverse in 2001, which means, the cross sectional area of the river was decreasing more towards downstream in 2001.

5.3.3 Changes in average depth

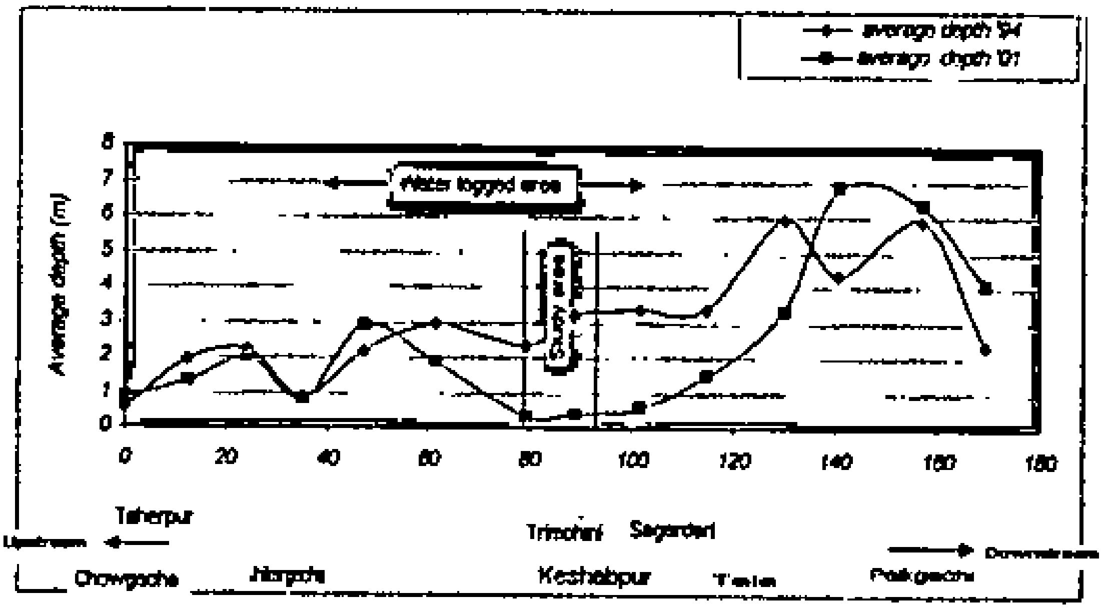


Figure 5.7: Average depth along the Kapataksha river

Like cross sectional area, the average depth of the Kapataksha river has also decreased between 1994 and 2001 (Figure 5.7). Figure 5.7 signifies that the average depth is decreasing significantly from about 55 km to 135 km. From Figure 5.7 it is observed that the depth is lowest in the study area.

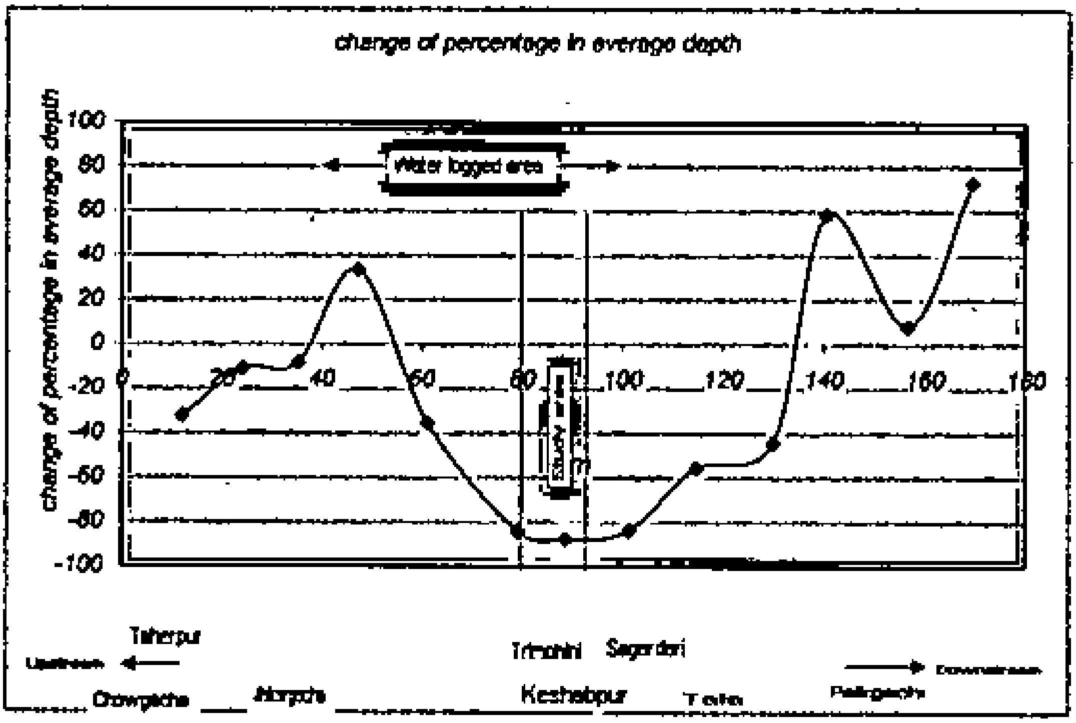


Figure 5.8: Change of percentage in average depth along the river

Figure 5.8 represents that the average depth of the river has decreased significantly from 55 km to above 130 km along the river reach. From 60 km to 89 km along the river reach, the average depth of the river has decreased from 36% to 88%. Whereas, the average depth of the river has decreased 88% to 44% from 89 km to 130 km along the river reach. It reveals that maximum percent change of depth has occurred in the study area.

Figure 5.2 shows that the hump is present from about 70 km to 105 km along the river reach. So, it is observed that the decreasing rate of the average depth of the Kapataksha river is highest, where the hump is present.

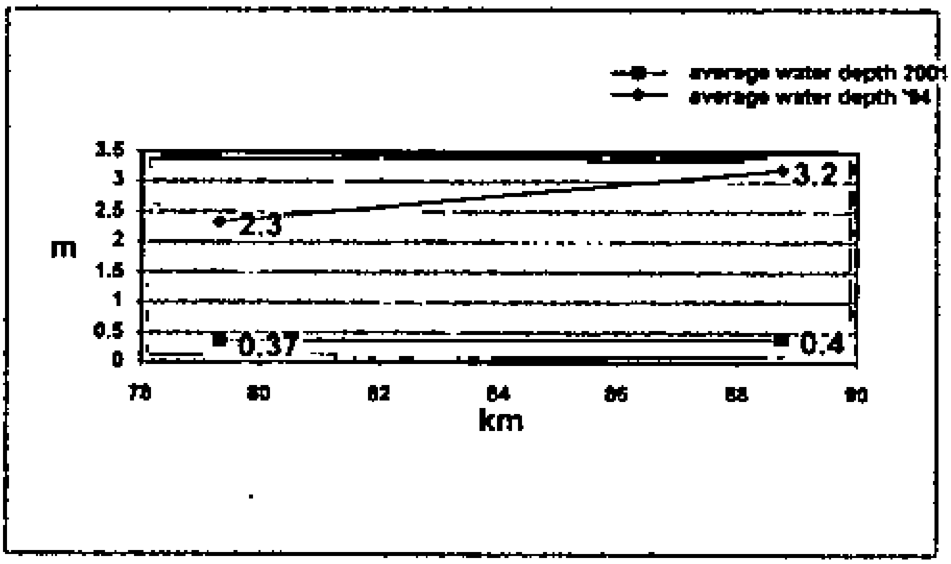


Figure 5.9: Average depth over the study area

In 1994 at upstream of the study area (79 km), the average depth was 2.33 m whereas, in 2001, the average depth was 0.37 m (Figure 5.9). At the downstream (93 km) of the study area, the average depth was 3.2 m and 0.4 m in 1994 and 2001 respectively. So, the average depth has decreased 84% in upstream (about 79 km) to 88 % downstream (about 93 km) over the study area. It indicates that the average depth was decreasing more towards downstream over the study area.

5.3.4 Changes in width

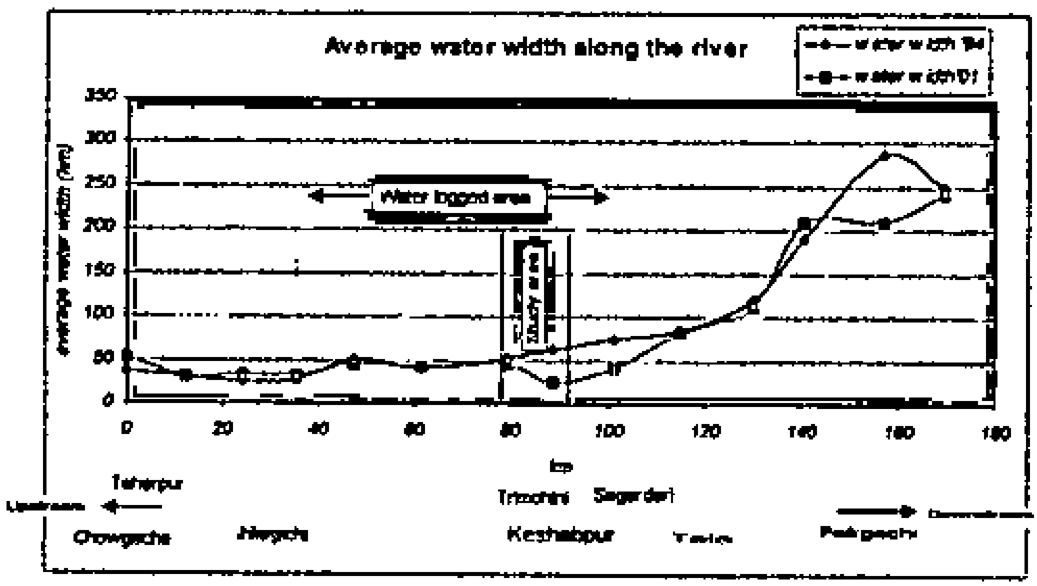


Figure 5.10: Water width along the river

From Figure 5.10 it is observed that the water width along the Kapataksha river is decreasing especially from 70 km to 105 km (near Trimohini to Tala). The river width from 115 km to 142 km along the river (Tala to Paikgacha) is almost same between 1994 and 2001. But, the river width again decreased from142 km to 170 km along the river between 1994 and 2001.

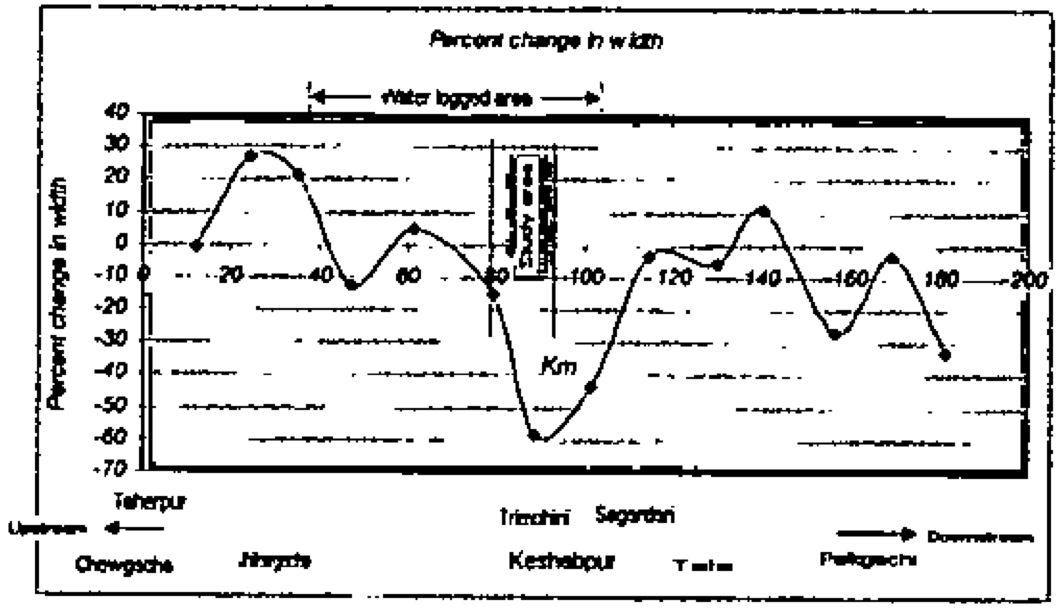


Figure 5.11: Change of percentage in width along the river

From Figure 5.11, it is observed that the width of the Kapataksha river has changed about 26% to –58% along the river reach. From 0km to 40 km has increased up to about 30%. From about 79 km along the river reach, the width started to decrease significantly. From 79 km to 89 km the width of the river has decreased 15% to 58% (Figure 5.11). But from 89 km to 114 km along the river, the width of the river has decreased 58% to 3% (Figure 5.11). It is observed that the decreasing rate of the river width is highest over the study area.

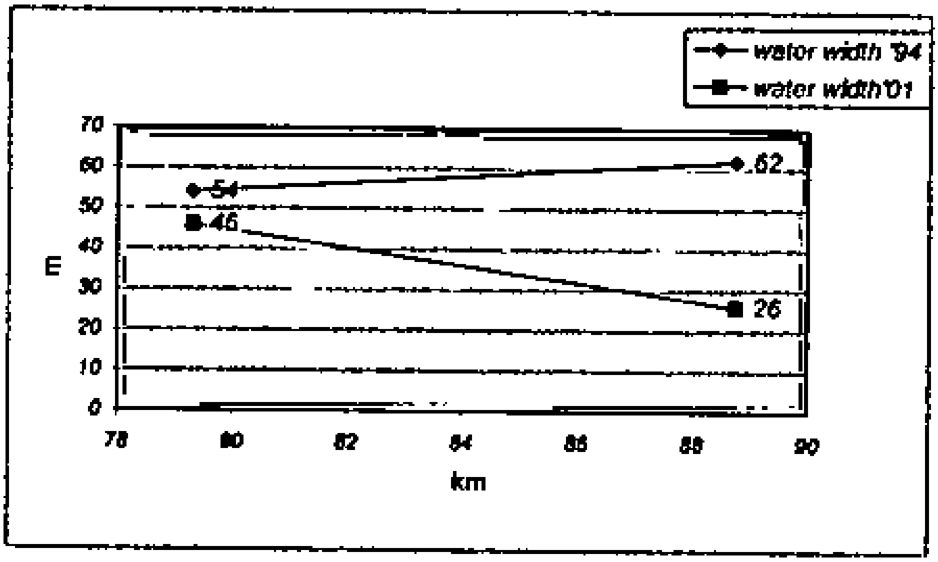


Figure 5.12: Water width over the study area

The width of the river was 54m and 46m in 1994 and 2001 respectively at the upstream of the study area. And at the downstream of the study area, the width of the river is 62m and 26m in 1994 and 2001 respectively (Figure 5.12). It signifies that the width was decreased 15 % in upstream and 58 % in downstream over the study area between 1994 and 2001.The trend of the width in Figure 5.12 signifies that the width of the river was reduced comparatively more towards downstream than that of upstream over the study area between 1994 and 2001. Naturally, channel becomes wider at downstream compared to upstream. But, it is observed that in 2001, width of the Kapataksha river over the study area was decreased at downstream than that of upstream.

5.3.5 Changes in conveyance

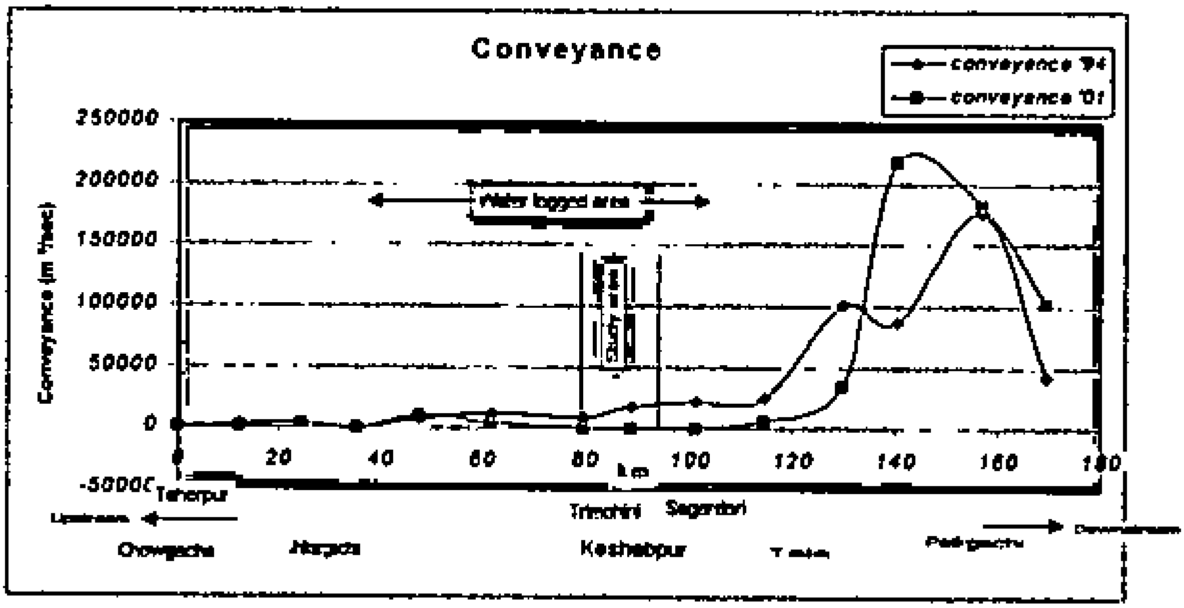


Figure 5.13: Conveyance along the river

It is very likely that the conveyance of any river will decrease with the decreasing of area, depth and width of that river. It is observed from Figure 5.13 that like area and depth, the conveyance of the Kapataksha river has reduced between 1994 and 2001. The conveyance represents the carrying capacity of a channel. So, the reduction of the conveyance of a channel indicates the deterioration of drainage capacity of that channel.

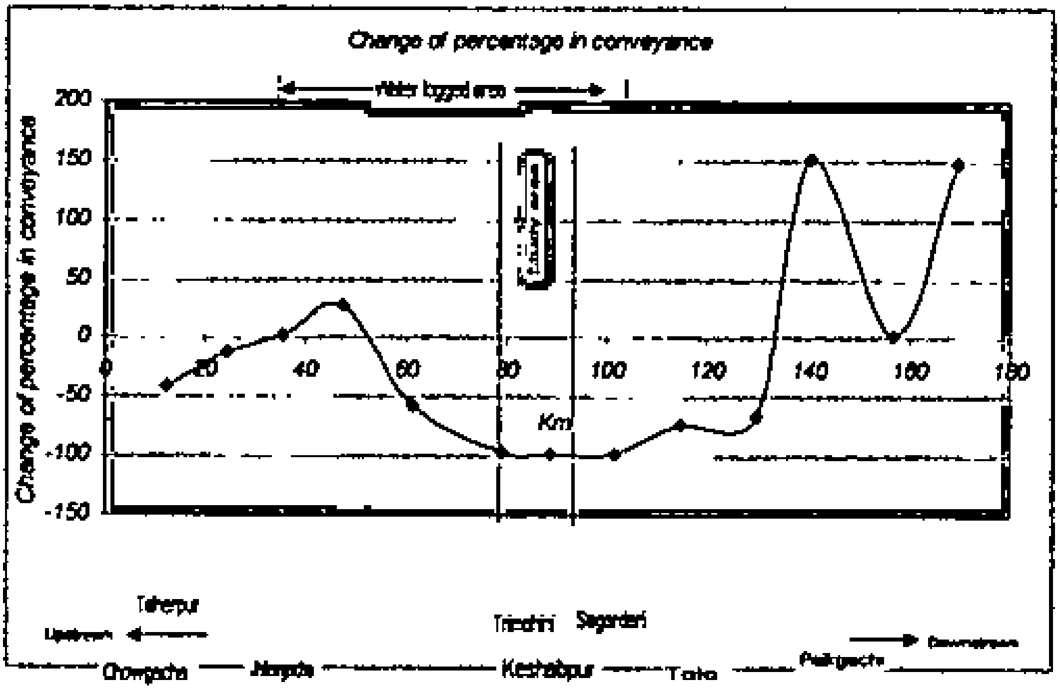


Figure 5.14: Change of percentage in Conveyance along the river

From Figure 5.14, it is observed that the conveyance of the Kapataksha river has been started to decrease from 60km. From 60km to 89km, conveyance of the river was decreased 57% to 99%. From 89 km to 130km, conveyance of the river was decreased 99% to 66%. It is observed that the conveyance of the river was lowest at the study area.

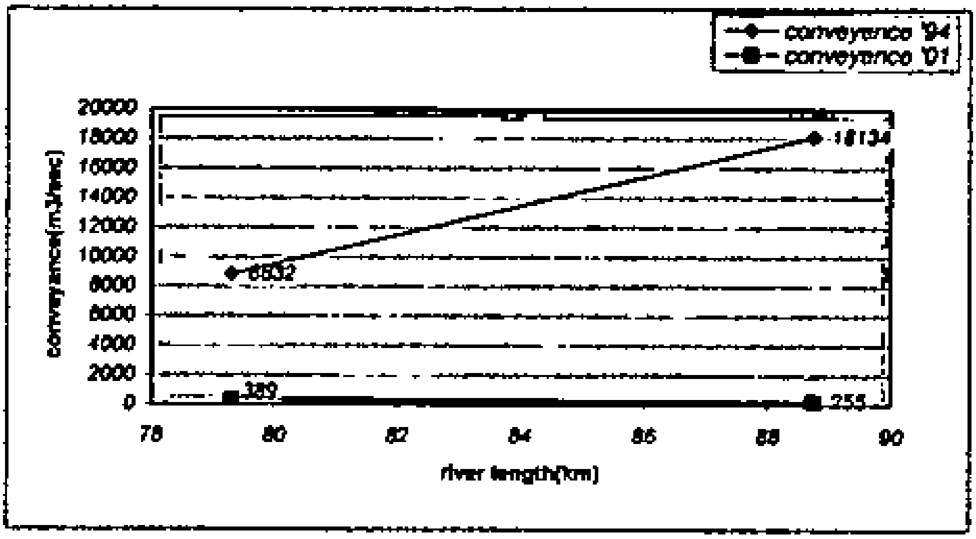


Figure 5.15: Conveyance over the study area

In 1994, conveyance of the river was 8832 m^3 /sec and in 2001, it was 389 m^3 /sec at upstream over the study area (Figure 5.15). So the conveyance has been decreased about 96 % at the upstream of the study area between 1994 and 2001. At downstream of the study area the conveyance of the river was 18434 m^3 /sec and 255 m^3 /sec in 1994 and 2001 respectively (Figure 5.15). So the conveyance has been decreased 99 % at the downstream of the study area between 1994 and 2001.

The geometric parameters along the Kapataksha river over the study area that have been discussed in previous sections are summarized in Table 5.1

Table 5.1: Change of geometric parameters from 1994 to 2001 over study area

Geometric parameter	Change from 1994 to 2001
Cross-sectional area	Decreased 86% to95%
Average depth	Decreased 84% to88%
Width	Decreased 15% to58%
Conveyance	Decreased 96% to99%

5.3.6 Changes in planform

An attempt was made to observe the planform changes of the Kapataksha river over the years from 1772 to 1997. In order to perform this task, the planform map of the Kapataksha river of years 1772, 1918, 1963 and 1997 was overlaid. In this case, the map showing planform of the Kapataksha river of the years of 1772, 1918, 1963 was collected from Kranti (2000) And the map of the Kapataksha river of 1997 was collected from CEGIS (2004).

The map of the Kapataksha river of 1997 has coordinate information (Latitude and Longitude). But, the problem was that there was no coordinate information (Latitude and Longitude) of the map showing planform of the years of 1772, 1918, and 1963. But, various locations along the Kapataksha river were identified in this map Tahirpur is one of the locations, which was identified in all the maps. In this case, the location of Tahirpur was considered as a reference point for overlay of the maps.

After completing the task of overlay, it was observed that the pattern of the planform of the river of 1963 and 1997 is almost same. But the shifting rate of the river between 1963 and 1997 is much greater than that of 1918 and 1963. The maximum shifting rate of the river between 1918 and 1963 was 0.08 km/year whereas the maximum shifting rate of the river between 1963 and 1997 is 21.7 km/year. But other information like dying of the river, reduction of river flow and depth, narrowing down of the river width reveals that the Kapataksha river did not shift at all especially over the last few years. One thing is very clear that the Kapataksha river has lost its perennial connection with Ganges through Mathabhanga river long before. The name of river itself is evidence of it. 'Kapataksha' means 'pigeon-eyed'. The water of this river was clear and transparent like the eyes of a bird. 'Kapat' means pigeon and 'Aksha' means eye It indicates that from long ago sediment supplies were stopped to enter this river from upstream. After losing connection with Ganges, Kapataksha had started to decline to adjust its size with new regime of flow and sediment. Due to reduction of the width of the river, the area along the bank side of the river, was incised into terraces (Figure 5.16)

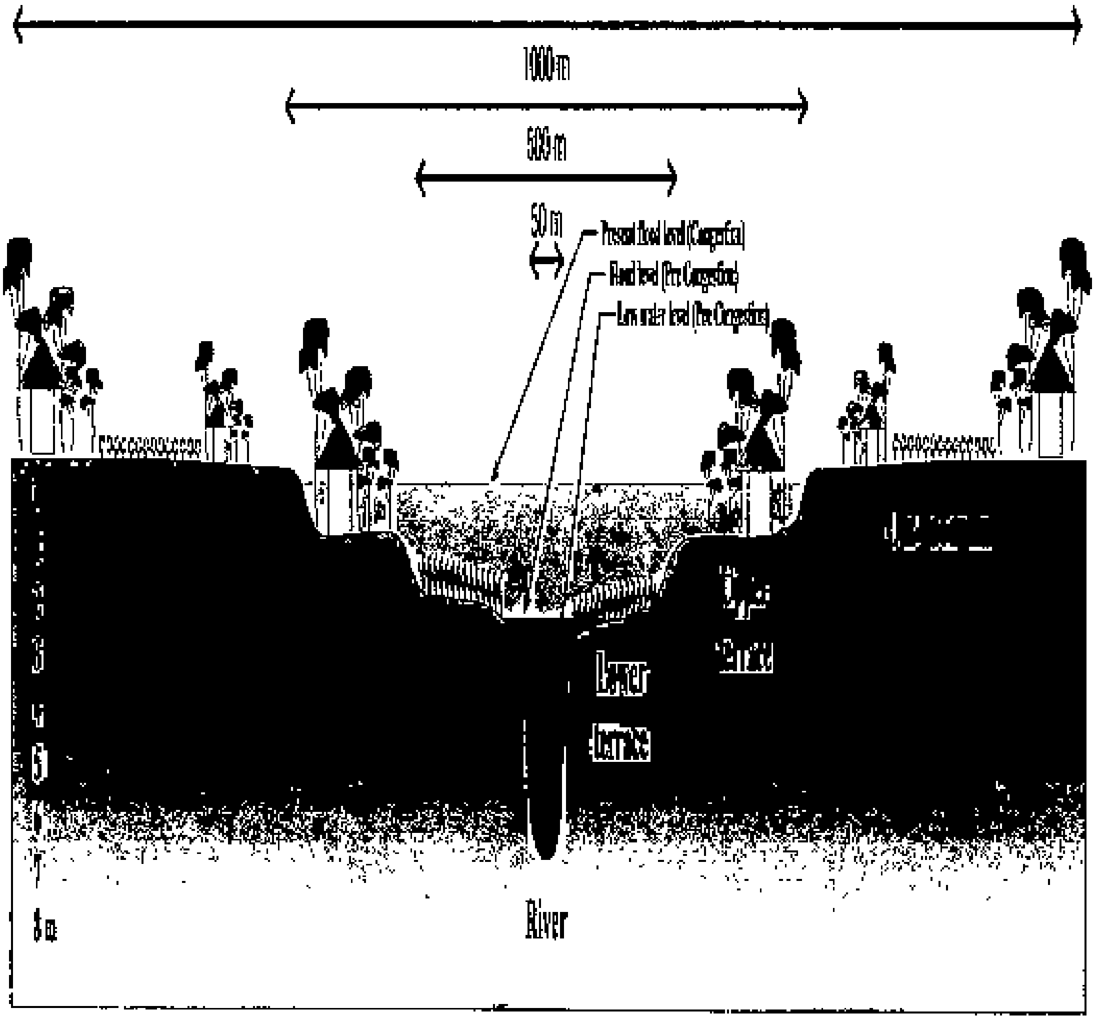


Figure 5.16: Reduction of the width of the Kapataksha river

Two level terraces (upper terrace and lower terrace), shown in Figure 5.16 indicate that day-by-day the width of the river is narrowing down. So it is very abnormal that the shifting rate of that river is so high, which is narrowing down so significantly. So it can be assumed that the maps were not overlaid exactly. If so, the cause behind this is that the map, showing plan form of the river of the years of 1772, 1918, and 1963 had no latitude and longitude information. Moreover, there is doubt about the accuracy of the maps because these were prepared long ago. But, in this case, the map of 1997 of the Kapataksha river has actual latitudinal and longitudinal information So, the map of 1997 of the Kapataksha was considered as the reference for defining the coordinates (latitude and longitude) of other maps. Then the overlay was made and Figure 5.17 was obtained.

Though, Figure 5.17 does not provide information about the actual shifting rate of the river over different years, it gives an indication about the planform change of the river. It is observed that in 1772 the river was straight but in 1918 it became meandered (Figure 5.17). A good number of ox-bow lakes at that region gives evidence about the meandering of the river.

From Figure 5.17, it is observed that in 1772 the river Kapataksha was almost straight. There is a doubt about the accuracy of the Planform of the Kapataksha of 1772 because in 1772 the available tools by which the map was generated were not so sophisticated. Besides, depending on other information and image of the Kapataksha it seems that the Planform of the Kapataksha of 1772 was unusual straight.

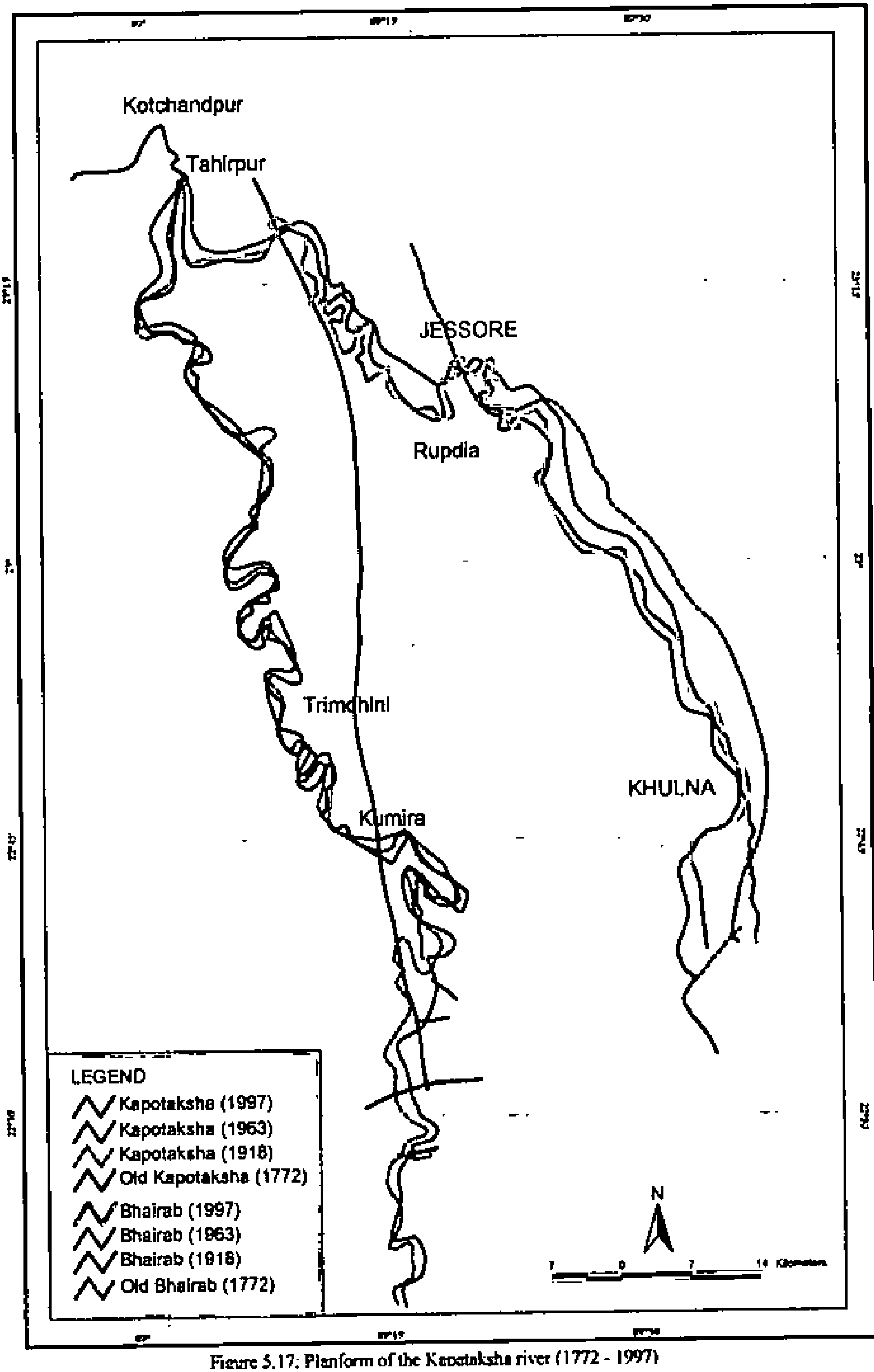


Figure 5.17: Planform of the Kapotaksha river (1772 - 1997)

5.4 Environmental impacts over the study area

In this section, the environmental impacts were analyzed over the study area. The environmental components upon which impacts were analyzed are drainage system, water logging, fisheries, water body, wetlands, tidal condition and navigation

5.4.1 Impacts on drainage system and water logging

Uprising of the bed level over a particular reach is a prominent feature in the Kapataksha river (Figure 5.2). A huge sedimentation created a bump on the riverbed from Trimohini to Sagardari. Not only that the depth, area and conveyance of river also have drastically decreased from 1994 to 2001 over the study area, which has caused the deterioration of drainage capacity over the study area.

In this study, the drainage system indicates the way by which water drains out from the study area. Khals are the important elements of any natural drainage system. Most of the khals over the study area have originated from low lands and beels and they finally drain into the river. Based on local people opinion it is perceived that all the khals are drying with the decreasing of depth and width of the river (Table 5.2). As a result, at present they cannot drain water properly. Again in some cases, the situation is that the khals are deeper than the river (the bottom level of the khals are lower than that of the river). As a result water cannot be drained out in this case.

Table 5.2: Status of drainage khals of the study area

Name of village	No. of khal(s) (previous/1994)	No. of khal(s) (present/2004)	Name of khal(s)	Status of Khals(2004)
Barandali	3	3	Barandali khal, Purano khal. Natun khal	All khals are drying
Mirzanagar	2	2	Mirzanagar khal, Buri bhadra khal	All khals are drying

According to local people, besides natural drying of the khals, some man-made interventions are also responsible for the drainage congestion. A good number of fish barricades and komar (accumulation of branches of tree in water to trap fish) causes deposition of silt on riverbed. It causes decrease of width and depth of the river. The number of fish barricades and komar are shown in Table 5.3. This number of fish barricades and komar are enough to add difficulties to the existing drainage congestion.

Table 5.3: Number of fish barricades and komors in study area

Activities	Trimohini to Saraskati(Chainage 83to 93 km)
Number of fish barricade(s)	100
Number komor(s)	250

Source- CEGIS, 2004

Water logging is a common phenomenon in that area where drainage systems become deteriorated. Data from local people over the study area gives evidence of it. In this study, waterlogging condition is expressed through indicating the percent of waterlogged area with respect to the total area of the villages. Figure 5.18 describes the percent of waterlogged area of different years over the study area.

According to the local people there was no waterlogged area in 1994 over the study area. In every village, water logging has started from 1999 (Figure 5.18). But, it was in a small scale. From Figure 5.18, it is observed that the percent of waterlogged area increased sharply in 2000.The cause of this sudden increase of waterlogged area in 2000 is that there was an abnormal flood over the study area in that year. As the drainage capacity has declined over that area, the floodwater could not drain out properly. As a result, a huge area became waterlogged.

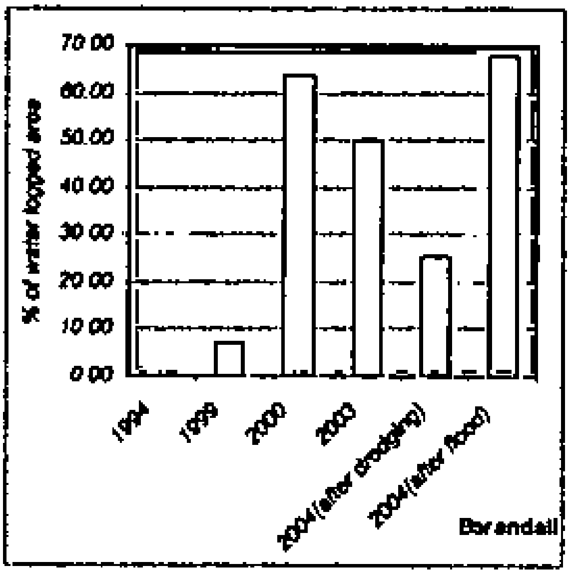


Figure 5.18 (a): Percent of water logged area at Barandali of different years

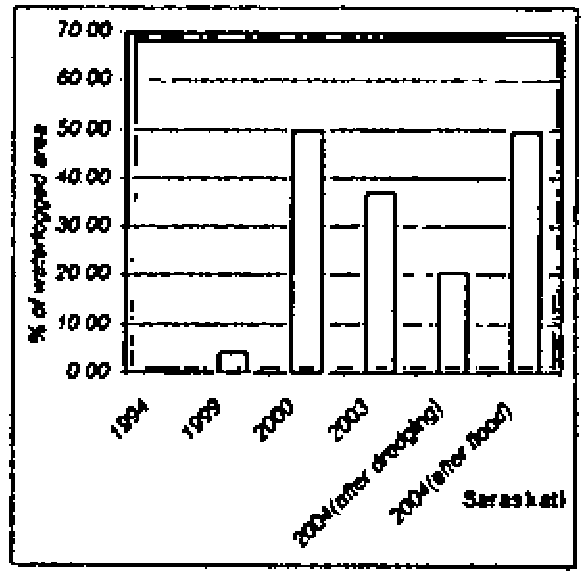


Figure 5.18 (b): Percent of water logged area at Saraskati of different years

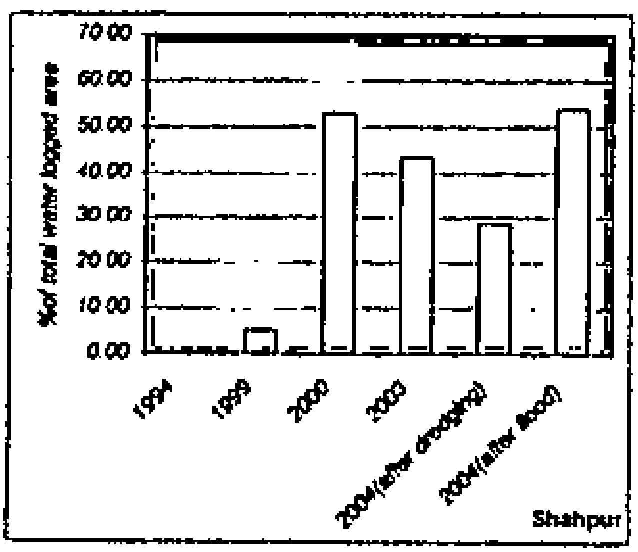


Figure 5.18 (c): Percent of water logged area at Mirzanagar of different years

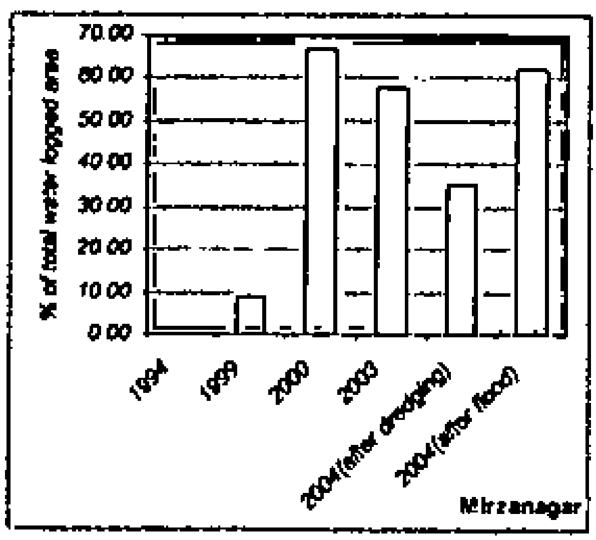


Figure 5.18 (d): Percent of water logged area at Shahpur of different years

Figure 5.18 indicates that after dredging, water logged area over the study area started to decrease. It means that after dredging, the drainage capacity of the river was improving and as a result, the logged water started to drain out from the area

Another remarkable feature of Figure 5.18 is that after flood of 2004 the percentage of water logged area again increased significantly. Here, it should be mentioned that when the survey was made, floodwater was not recessed completely. It has been reported from the local people that due to dredging the drainage capacity was improving and as a result, flood water of 2004 was draining out quickly than before.

5.4.2 Impacts on fisheries

River geometry affects fisheries in various ways by affecting fish migration route, fish habitats and by changing fish species composition etc. Besides these, change of river geometry causes drainage congestion and water logging. Water logging further causes fish loss due to inundation and fish diseases by degrading water quality. Here impacts are shown mainly through representing the changes in fish species composition and fish loss due to inundation.

The fish species available over the study area in 2004 and before 1994 are described Table 5.4. From Table 5.5. it is observed that some species are extinct or not available at 2004, which were available before 1994. Again, Table 5.5 shows that some species are less available at present compared to past, while some species are more available at present compared to past. Chital, Folio.Koi, Gule, Fesha, Tenra, Sing, Magur are less available at present compared to past. The species that are more available at present compared to past are Taki, Shoal,Gazar, Puti, Kholisha, Chela, Chingree, Bele,Boal (Table 5.5).

Table 5.4: Available fish species in study area

Fish available before 1994	Fish available at 2004
Kalbaus, Hilsha,Tapsi, Rui, Katla, Mrigel, Silver carp, Grass carp Taki, Khalisha, Kai, Magur, Sing, Shoal, Gazar, Boal, Puti, Bele, Telapia, Chela, Golda chingree	Rui, Katla, Mrigel, Silver carp, Grass carp Taki, Khalisha, Koi, Magur, Sing, Shoal, Gazar, Boal, Puti, Bele, Telapia, Chela, Golda chingree

Table 5.5: Status of availability of fish species

Fish going to be extinct at present	Kalbaus, Hilsha,Tapsi
Rare fish or less available fish at present* compared to past**	Chital, Folio,Koi, Gule, Fesha, Tenra, Sing, Magur
Increased culture fish species at present* compared to past**	Rui, Katla, Mrigel, Silver carp, Golda, Grass carp, Telapia,
More available fish species at present* compared to past**	Taki, Shoal,Gazar, Puti, Kholisha, Chela, Chingree, Bele,Boal

Present*= at 2004

Past**= before 1994

From Table 5.5, it is observed that Kalbaus, Hilsha,Tapsi are going to be extinct from the study area. By using local knowledge, CEGIS developed a matrix (Table 5.6) to show various factors affecting the availability of fishes. From Table 5.5 & Table 5.6, it seems that due to reduction of depth and salinity, some species (e.g Hilsha and Tapsi) are becoming rare or going to be extinct over the study area. Table 5.5 also shows that practice of culture fisheries has increased at present compared to past.

Table 5.6: Factors affecting the availability of fish

Fish	Dependency	Conditions
Hilsha	Dependent mainly on depth and salinity	More if depth and salinity is available
Tapsi	Dependent mainly on depth	More if river depth is more
Pairsa	Dependent mainly on salinity	More if river salinity is more

Source: CEGIS, 2004

Besides the changes of fish species composition, fish loss also took place due to inundation over the study area. According to CEGIS report, many ponds have been damaged and fishes escaped due to water logging. Table 5.7 shows number of affected ponds of the study area where fish loss took place.

Table 5.7. Area and number of ponds affected by fish loss

Village/Mouza	Nos. of affected ponds	Area (hectare)
Mirzanagar	75	15.49
Barandali	100	9.32
Saraskati	9	1.01
Shahpur	25	2.17

Source: *Upazila Fisheries Office, Keshabpur,* CEGIS, 2004

5.4.3 Impacts on water body

Change of river geometry results in water logging and long-term water logging condition creates adverse impact on water body Because water remains stagnant and due to this stagnancy water hyacinths grow there. Excessive water hyacinth affects the water body by reducing dissolved oxygen concentration. pH level and increasing dissolved CO_2 level.

Survey over the study area indicates that the water of river and beel area are covered by water hyacinth. Above 80% of the river stretch are covered by water hyacinth (CEGIS, 2004). During field investigation it was observed that a good portion of beel area over the study area is covered with water hyacinths like a carpet.

According to local people, the ponds of the study area are affected by various means after waterlogging condition has been started and they cannot use this water for household purposes. The color of water of some ponds is becoming black; some ponds result in fish diseases while some cause skin diseases to the people. Local people informed that due to stirring in household ponds water hyacinth could not grow there. A small number of ponds beside the riverbank are affected by water hyacinth. Percent of total numbers of affected ponds (black color of water, ponds that result in fish diseases and skin diseases, affected by water hyacinth) are shown in Table 5.8

Table 5.8: Status of affected ponds

Name of village	Percentage (%) of affected pond(s) after water logging condition
Barandali	75
Mirzanagar	60
Saraskati	80
Shahpur	80

As sediments come from downstream; the particle size is small (silt and clay) having more cohesiveness. This may lead to absorption of contaminants and thereby pollution of water. However no attempt was made for further analysis about this. Chemical tests of water quality parameter were not performed. In this study, impacts on water body are described by indicating the number of affected ponds over the study area.

5.4.4 Impacts on wetland

Baors and beels are the lacustrine wetlands over the study area. Baors are the ox-bow lakes formed from a cut-off channel in an abandoned section of a river. There are a good number of Baors in adjacent area of the Kapataksha river. In the study area of this study, there is one baor named Mirzanagar baor, situated in Mirzanagar village. Under a natural condition the baors are connected to the parent river during monsoon and get disconnected during dry season. During pre-water logged condition, the Mirzanagar baor got connected with the Kapataksha river through a Khal in monsoon and became disconnected from the river in dry season. But, at present due to water logging, this baor remains connected to the river throughout the year.

Mirzanagar baor was important to the local people for it's fish resources. According to local people, a huge amount of natural/capture fish was available in this baor during pre-waterlogged condition. But, after waterlogging condition started, the amount of natural/capture fish has declined. According to local people, at present culture fisheries are increasing compared to pre-water logged condition in this baor. Beside these, during pre-waterlogged condition the area at the bank side of the baor was used for agricultural production. But due to water logging those area now cannot be used for agricultural production.

Beels are saucer like depression and mostly overgrown with marsh vegetation. The energy and nutrients stored in wetlands autotrophs (such as plants), directly or indirectly supply the needs of heterotrophs (such as animals) in wetland related food chains; these animals often supplement the diets of humans (Sather and Smith, 1984). During pre-water logging condition, a large number of aquatic plants (eg. Shaola, Kalmi, Padda, Shapla, Hydrilla, Patajhajhi and many other grasses) used to grow over the beel areas. Those aquatic plants were the sources of food and shelter of many aquatic birds, fish and other animals including humans (CEGIS 2004). But due to water logging, the aquatic plants of the land have been damaged. Moreover, during the field survey it was observed that a good portion of the beel area is covered by dense water hyacinths, which have turned the land of no use.

Earlier, when tidal function was active, local people were able to cultivate crop in the beel area. But, at present due to the drainage congestion, agricultural land of the beel remains inundated even during dry season. Local people reported that about 1.25 to 1.5 feet of water stands on the beel area. As a result, they cannot use the land for crop production or any other purposes. They reported that waterlogging problem starts at post monsoon and continue up to January.

5.4.5 Impacts on tidal condition

According to local people, at past tide used to arrive up to Jhikarghacha (upstream of study area). But, at present, tidal influence is not observed at the study area.

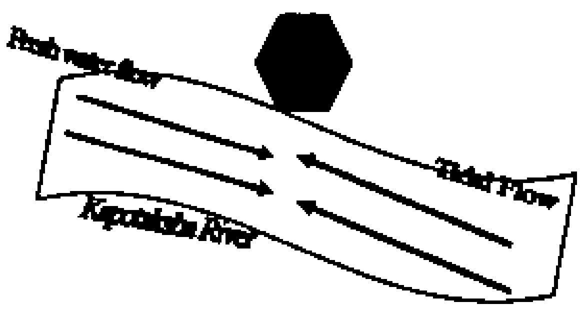


Figure 5.19a: Normal morphological balance of the river

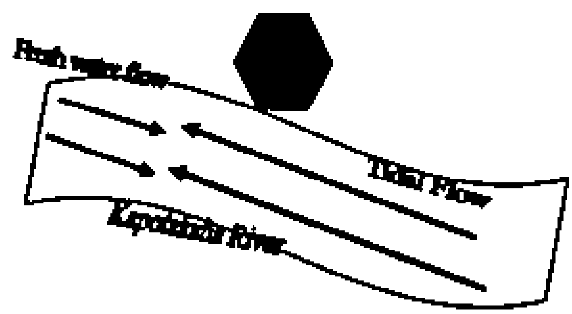


Figure 5.19b: Reduction of upland fresh water flow

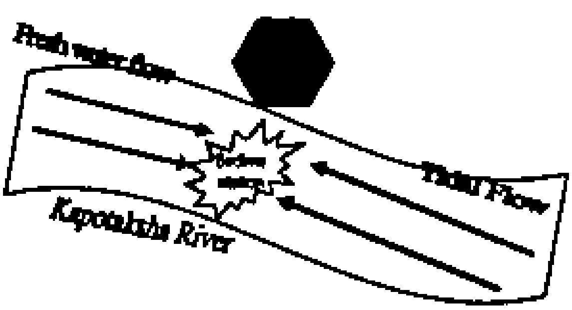


Figure 5.19c: Deposition of sediment

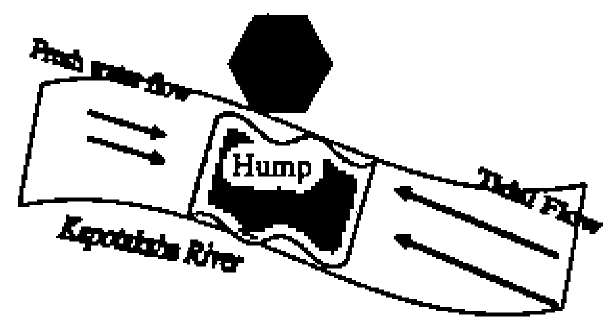


Figure 5.19b: Gradual sedimentation created a hump

Figure 5.19: A schematic diagram showing the change of tide at study area

It was observed in Figure 5.2 that there is a hump on the riverbed and tide cannot move upstream beyond this hump. The influence of the hump on tidal condition over the study area is expressed in following diagram (Figure 5.19) Figure 5.19a describes the normal morphological balance of the Kapataksha river. It indicates that upstream fresh water flow pushes the tidal flow towards Sea. In the second stage (Figure 5.19b) tidal flow (sediment laden saline water) from downstream started to penetrate more upstream due to reduction of upland fresh water flow. At this stage, sediment started to enter the river system from downstream through tidal pumping system. In the third stage (Figure 5.19c) the high salinity level facilitated the deposition of sediment at the location of tidal limit. Thus, gradual sedimentation created a hump on the riverbed and as a result, the downstream tidal flow could not move upstream area beyond this hump (Figure 5.19d). From Figure 5.19d, it is observed that the study area is located behind the hump. Due to this location, tide cannot arrive at the study area at present.

Due to the aforementioned process of hump formation, the tidal range was deccasing with time over the study area. Table 5.9 represents the tidal range of various years over the study area. According to local people, during 1994 to 1999 the tidal range was higher than that of 2000 over the study area. Table 5.9 indicates that there was no tide in 2003 over the study area. Tidal action was observed at Saraskati and Shahpur after dredging (Table 5.9), though the tidal range was very low.

Table 5.9: Tidal range of different years at study area

Year	Tidal range (m) at Mirzanagar	Tidal range (m) at Barandali	Tidal range (m) at Saraskati	Tidal range (m) at Shahpur
1994	2.13-2.44	2.44-2.74	2.44-3.05	2.44-3.05
1999	0.91-1.22	1.22-1.83	1.22-1.82	1.22-1.82
2000	No tide	0.30-0.91	0.30-0.91	0.30-0.91
2003	No tide	No tide	No tide	No tide
2004 (after dredging)	No tide	No tide	0.30-0.61	0.30-0.61

Water level data at Pazakhola (upstream of the study area) and Sagordari (downstream of the study area) from November 2003 to June 2004 is plotted in Figure 5.20. It is observed that water level at Sagordari has been influenced by tide (though the tidal range is very low) from the month February 2004 due to dredging of the Kapataksha river ((IWM, 2004).

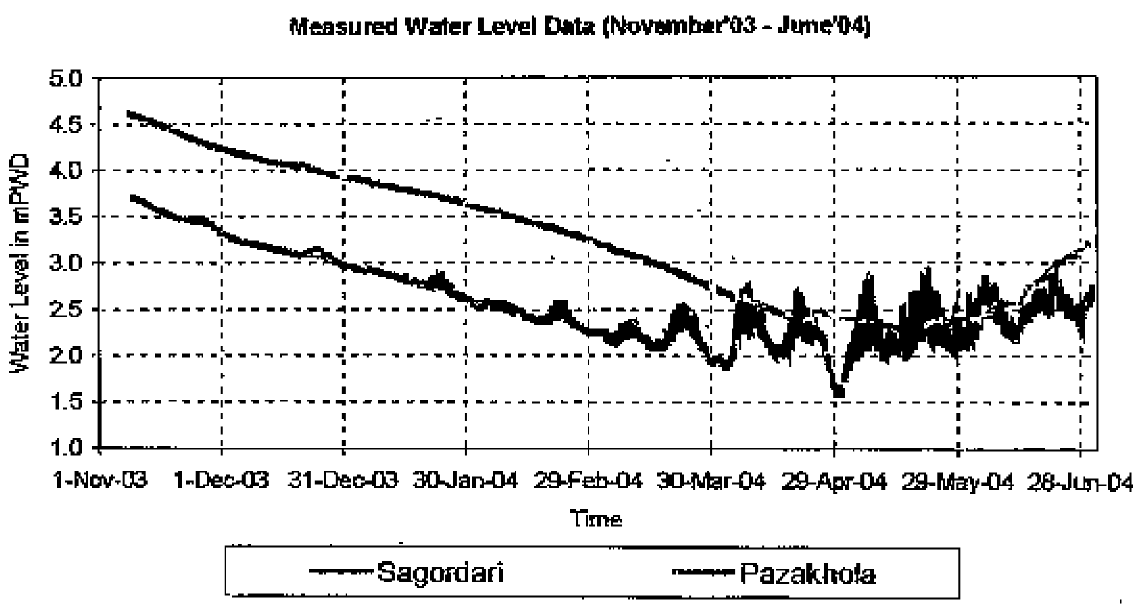


Figure 5.20: Measured water level data at Pazakhola and Sagordari
Source: IWM, 2004

5.4.6 Impacts on navigation

Once upon a time, the Kapataksha river used to be navigable up to Jhikarghacha (upstream of the study area) and played an important role in inland navigation of that area. Peoples were used to bring their saleable goods from downstream river port to far inland area up to Jhikarghacha. There was a regular launch round trip from Jhikarghacha to Kupilmuni (downstream of the study area).

Tahirpur is at upstream and Sagardari is at downstream of the study area. So, the study area is situated in between Tahirpur and Sagardari. Presently, there is no navigation facility between Tahirpur to Sagardari (CEGIS, 2004). This indicates that there prevails no navigation facility along the river reach over the study area. The cause behind this is that water flow in this reach of the river remains very low during most of the year. In addition to that the river is covered by water hyacinth densely, which obstacles navigation.

Over the study area, specially during rainy season, some cross navigation, in a very limited scale, are available in the khals and beels that are connected to the Kapataksha river. Mainly country boats are used for this purpose.

5.5 Relation Between Geometric Parameters and Environmental Components

The previous sections of this chapter have presented the network showing how the environmental components are being impacted due to the changes of geometric characteristics of the Kapataksha river. Then following the network, the impacts were evaluated, analyzed and quantified. Based on these observed and analyzed data an attempt was made to analyze the pattern of relationship between these geometric parameters and environmental components.

The network (Figure 5.1) shows that drainage congestion and waterlogging are direct consequences of the change of geometry of the river. Due to this water logging, most of the environmental components, like fisheries, agriculture, water body and wetlands are impacted.

According to Rahman (2002), Figure 5.21 shows different orders of impacts of any impact causing activity.

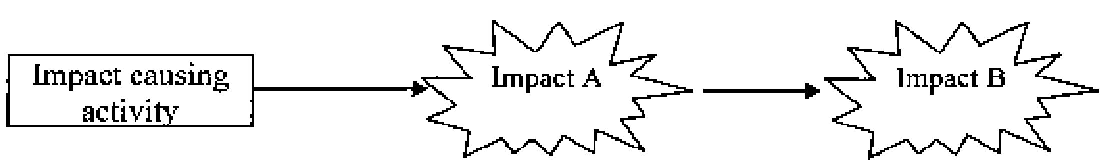


Figure 5.21: Direct and indirect impacts of any impact causing activity
Source: Rahman, 2002

Following Figure 5.21, the impacts of the change of geometry of the Kapataksha river that was shown in the network (Figure 5.1) can be represented in following simple way (Figure 5.22):

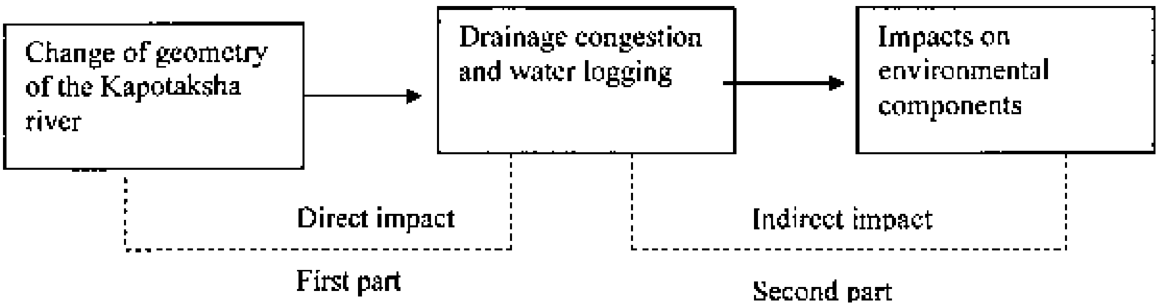


Figure 5.22: Direct and indirect impacts due to change of river geometry

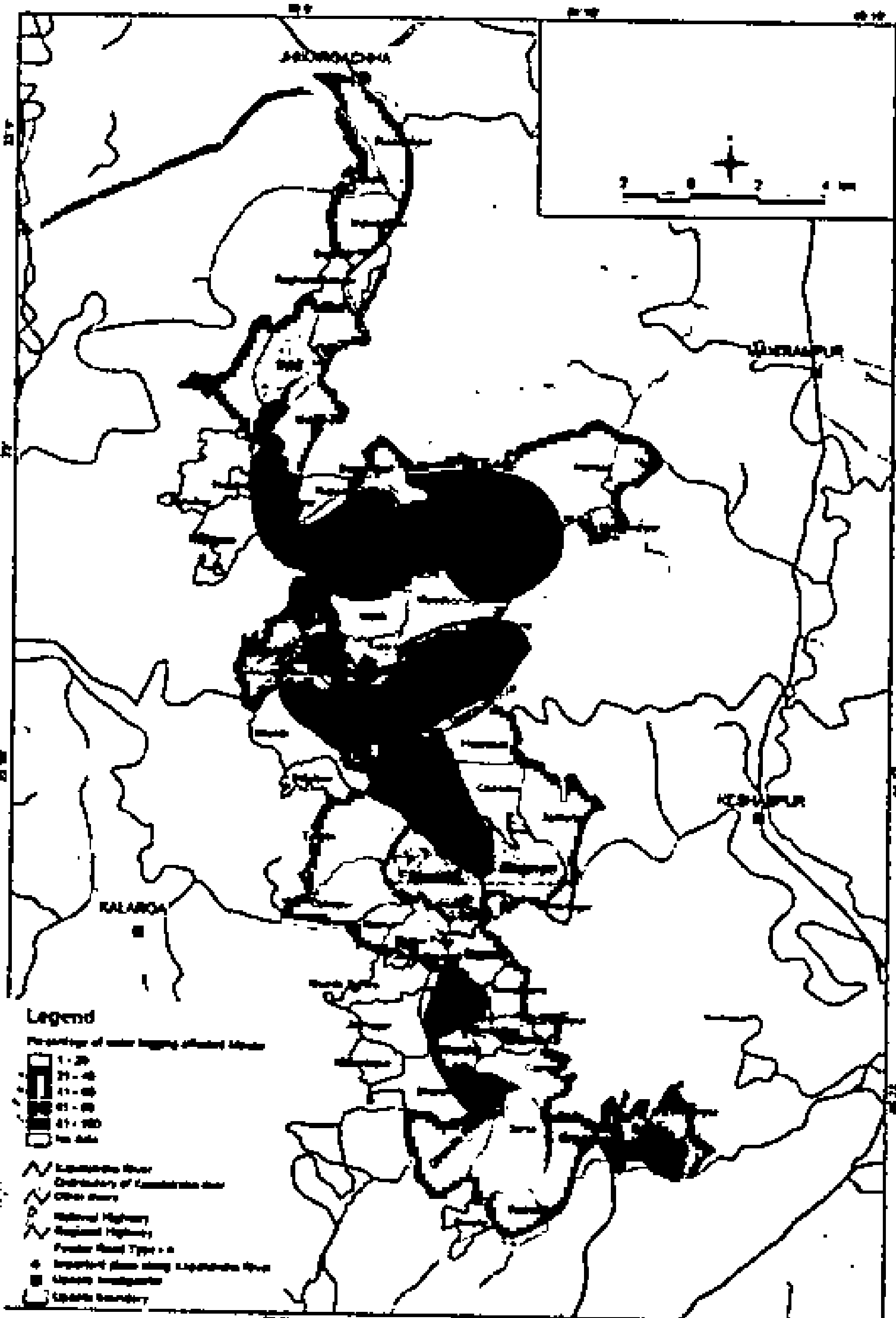
5.5.1 Geometric Parameters and Water logging

The first part of the Figure 5.22 indicates that the direct impacts of the change of river geometry are drainage congestion and water logging. Here the "causes" are "change of river geometry" and the ultimate consequence is "water logging condition". So, in this first part of the Figure 5.22, the dependent variable is waterlogging condition and the independent variable is the change of the geometric characteristics of the river. Here the geometric parameters that are considered are width, depth and conveyance. So, more clearly it can be said that waterlogging condition is a function of width, depth and conveyance capacity of the river. For building up the mathematical relation between the above mentioned parameters a statistical tool, multivariable regression model is used here. To perform this task, several steps were followed. At first, the adjacent water logging area of the river was identified (Figure 5.23). This stretch of the river, which is affected by water logging, was again divided into several reaches. This division was made based on available data of BWDB cross sectional station. Then for each reach, the average percent change of width, depth and conveyance from 1994 to 2001 was calculated. After that the average water logged area for every reach was measured from Figure 5.23. Thus the data obtained by this process was used to develop Eq. (5.1), which is:

$$WA = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \qquad (5.1)$$

Where, WA = water logged area in km^2 for per km length of the river.

X_1 = percentage change of width



Source: CEGIS, 2004

Figure 5.23: Status of affected water logged area in the year 2003

X_2 = percentage change of depth

X_3 = percentage change of conveyance

Here, β_0, β_1, β_2, β_3 are the coefficients. The values are:

$\beta_0 = 4.85$

$\beta_1 = -0.01$

$\beta_2 = -0.94$

$\beta_3 = 0.97$

Here the r-squared value is 0.98, which indicates a strong relationship between water logged area and the change of geometric characteristics of the river and the pattern of the relationship is like Eq. (5.1). Other statistical estimates regarding this regression is given in Appendix B.

Here, it should be mentioned that the aim of presenting this regression Eq. (5.1) is only that water logging condition and change of river geometry follows a definite relationship between them for a particular reach. But Eq. (5.1) does not represent the real value of actual water logging area. Because, all the independent variables that play a significant role in creating waterlogging conditions are not considered here. For example, meandering of the river has a significant impact on creating water logging condition, which has not been considered here. Again, it was observed that severe water logging condition started after flood of 2000, which was caused by overland flow. So, this flood has also an important role behind the magnitude of water logging condition. This parameter is also absent in this Eq. (5.1). On the other hand the size of data is too small. To get more accurate result and to have a predictive model, data regarding both geometry of the river and water logging condition should be large enough and accurate. Moreover this model is not capable to show the individual influences of the geometric parameters on waterlogging.

5.5.2 Water logging and Other Environmental Components

In the second part of the Figure 5.22, it is shown that environmental components are being affected by water logging condition. Here, it should be mentioned that environment is a highly complex and interconnected system. Here, each environmental component is affecting and is being affected by other environmental components. Components of the environment are intricately related through dynamic interdependences (IUCN, 1991). When one component of this relationship is changed or disturbed, the influence is manifested or felt in other parts of the environmental system (IUCN, 1993). It is not an easy task to represent the web of their interaction in a complete manner. Figure 5.22 is a simple expression showing that the environmental components over the study area are being impacted by waterlogging. But, actually the environmental components are being affected not only by waterlogging, they are also being affected by themselves through their own interaction as well as the river geometry itself.

However, in the second part of the Figure 5.22, it is shown that water logging is causing impacts on environmental components. There "water logging" is cause and "environmental impacts" are the effects.

It was discussed before that water bodies over the study area are being affected by excessive accumulation of water hyacinth. Excessive accumulation of water hyacinth represents degradation of water body (section 5.4.3). Over the study area, the way by which water logging condition causing excess growth of water hyacinth is shown by following diagram (Figure 5.24).

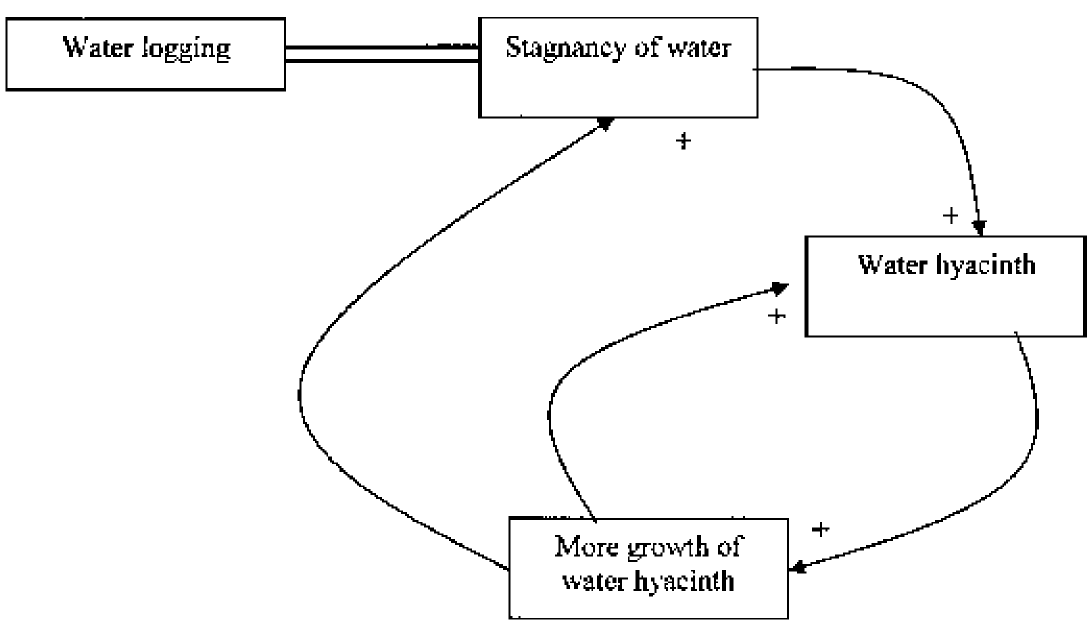


Figure 5.24: Feedback system of water hyacinth growth

In Figure 5.24, it is observed that the way by which water logging is creating water hyacinth is not an open system, but rather a closed one. In open systems, the output has no influence on the input. A closed loop system is a feedback system where the inputs are changed based on the output (Bala, 1999). Here, in a closed system water hyacinth, grown due to stagnancy of water, further increase their mass by themselves. Because, it is capable of spreading at an explosive rate due to its enormous reproductive capacity. Again when excessive water hyacinth accumulates like a carpet, it blocks river flow. This leads to more stagnancy of water, which in turn causes more growth of water hyacinth. So, here outputs are dependent on inputs and these outputs have again an influence on inputs. Thus, this system is a feedback system forming closed loop diagram.

Feed back system may be classified as positive feedback system and negative feedback system (Bala, 1999). Positive feedback system implies the increase of impacts. Here, Figure 5.24 is a positive feedback system since the growth of water hyacinth is increasing at every step/phase of the system. So, if any intervention is not taken to reduce waterlogging, then the rate of water hyacinth growth would remain increasing which would cause more degradation of water body of the study area.

Impacts on fisheries over the study area are analyzed in section 5.4.2. Here, it is observed that fish species diversity was more at pre-waterlogged condition compared to that of after water logging condition. So, diversity of fish species over the study area is reducing after waterlogging condition has set in.

From Table 5.5, it is observed that availability of some fish species were increasing whereas availability of some fish species are decreasing over the study area after waterlogging. The fish species that are more available after water logging are Taki, Bele, Kholisa, Puti, Chela etc., which are mostly floodplain and beel fisheries. Again the fish species that are less available or becoming rare are Kalbaus, Hilsha, Tapsi etc. which are mostly reverine fish species. The graphical expression of this phenomenon is represented in Figure 5.25. The fish species, which are less available after waterlogging, are categorized as type 1, and species, which are more available after water logging, are categorized as type 2 in Figure 5.25.

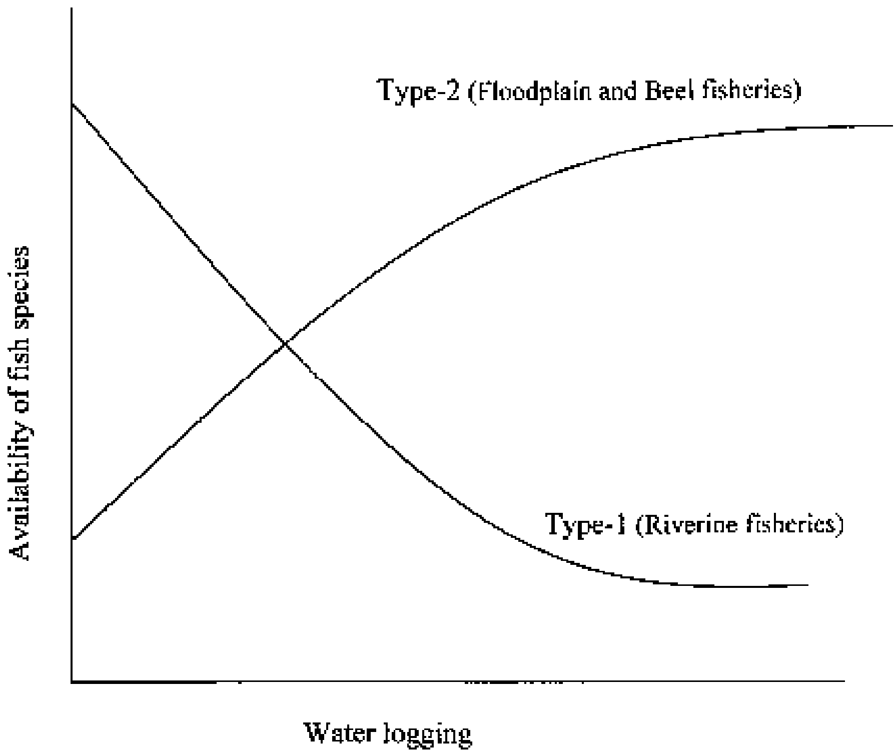


Figure 5.25: A schematic diagram of changes of fish species composition

From Figure 5.25, it is observed that at pre-waterlogged condition, type 1 was dominating species over the study area. But due to water logging condition type 1 has started to decrease, but type 2 has started to increase. This indicates that if waterlogging condition remain increasing then, instead of type 1, type 2 species would be the dominating species over that area. This means that the dominating fish species over study area are changing from riverine fish species to flood plain & beel fish species with increase of water logging.

5.6 Necessary Measures to overcome the problem

After analyzing the environmental impacts due to change of geometry of the Kapataksha river, it is perceived that drainage congestion is one of the major impacts which is responsible for creating other impacts. Overall study suggests that to get rid of these problems, it is essential to improve the drainage capacity of the area. For this dredging of the Kapataksha river as well as connecting khals (the khals which maintain the hydraulic connectivity between low lands and the Kapataksha river itself) is a must. People of this area also raised demands to the Government for re-excavation of the river to get rid of drainage congestion. BWDB responded to the people's demand for dredging of the river and proposed to dredge a length of 47 km of the river and the connecting khals (CEGIS, 2004). The dredging has started from November 2003 and was continuing as the time of this study. Meanwhile, Some improvements due to this dredging activity were observed during the period of survey of this study. For example, the flood of 2004 was more severe than the flood of 2000. But due to dredging, drainage capacity of the river was improved and as a result the flood water drained out quickly than before. Besides, traditional boat navigation has also increased. Another important positive impact of dredging is that tidal action has also started at some places. But it should be mentioned that dredging is a short time solution for quick removal of logged water. Dredging as the only means is not a proper and sustainable solution for this problem. There is possibility of further sedimentation. Because tidal action has been started and sediment would further enter by tidal pumping process as happened before. So, long time solution would be to ensure upstream fresh water inflow from Ganges river through re-excavation of Mathabhanga off-take and other dead river reach connected to Kapataksha river. But it is comparatively difficult to implement. However, for sustainable solution of the drainage congestion problem of the Kapataksha river, the following tasks should be carried out:

- Re-excavation of all the khals, which maintain the hydraulic connectivity between lowlands and the Kapataksha river itself.
- Continuous monitoring is required and further dredging is to be done if needed to eliminate siltation that can occur again by tidal pumping process.
- As the downstream part of the river is tidal, tidal action should be restored by tidal river management (TRM) intervention.
- There are several causes of unwanted drainage congestion, some are due to natural processes and some are man made. It is necessary to

build up people's united attitude for the removal of man made obstacles like fish patta, Komor and illegal barriers/ intervention from the river width, which obstruct river flow.

- Water hyacinth causes blockage of river flow and adverse condition on aquatic environment. Moreover, it can grow very quickly due to its enormous reproductive capacity. Local people should be motivated to clear off it voluntarily, where possible.

Chapter 6
CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Uprising of the bed level over a particular reach is a prominent feature in the Kapataksha river. A huge sedimentation created a hump on the riverbed from Trimohini to Sagardari. The depth, area and conveyance of the river also has been drastically decreased from 1994 to 2001, which has caused the deterioration of drainage capacity of the river, particularly over the study area. Deterioration of drainage capacity of the river has resulted in wide spread drainage congestion to its adjoining area, specially, during last few years. This drainage congestion further creates waterlogging. Due to prolonged waterlogging, various types of environmental degradation are taking place over the study area. The major observations of this study are as follows:

- The high salinity level in the river facilitates deposition of sediment at the location of tidal limit and this, gradual sedimentation created a hump on the riverbed from about 70 km to 105 km along the river reach (Trimohini to Sagardari).
- During the period of 1994 and 2001, the cross-sectional area of the river decreased about 86% to 95% and the conveyance decreased 96% to 99% over the study area. The width and average depth decreased about 15% to 58% and 84% to 88%, respectively along the river from 1994 to 2001.
- Change of river geometry resulted in the deterioration of the drainage capacity of the study area. With the decreasing of depth and width of the river all the khals over the study area are drying which further creates severe waterlogging. About 55% to 77% of the total areas of the villages over the study area were waterlogged in 2000.
- Prolonged waterlogging condition created adverse impact on other environmental components over the study area. After waterlogging condition has set in, diversity of fish species over the study area is reducing. In addition with reduction of fish species, the dominating fish species over study area are changing from riverine fish species to

floodplain & beel fish species with the increase of water logging. In addition to these some cultured ponds and ghers were subjected to fish loss due to inundation.

- Due to waterlogging the amount of capture fish of baor were declined and aquatic plants of beel area were damaged. Moreover due to stagnancy of water a good portion of the river stretch and beel area were covered by dense water hyacinth.
- According to the local people, about 60% to 80% ponds of the study area were affected by various means after waterlogging condition has set in and they could not be used this water for household purposes.
- Tide used to arrive up to Jhikarghacha (up stream of study area) in the past. But at present tidal influence is not observed in the study area
- At past the Kapataksha river played an important role in inland navigation of that area. But at present there prevails almost no navigation facility along the river reach over the study area due to mainly very low flow of the river and presence of dense water hyacinth.

6.2 Recommendations for further studies

The recommendations for further studies are as follows:

- To build up a predictive mathematical model to compute the water logged area by using the geometric data of the river.
- To analyze the impacts of water logging on agriculture and salinity.
- To analyze the impacts of re-excavation of the Kapataksha river on environment.

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Appendix A

Table A-1

Criteria for evaluating EIA methodologies

1. Assessment method should recognize the probabilistic nature of effects. Environmental cause-effect chains are rarely deterministic because of many random factors and uncertain links between conditional human activities and states of nature.
2. Cumulative and indirect effects are important, although there are obviously limits on the extent to which they can be considered. Natural systems are highly interrelated, and a series of minor actions may have significant cumulative impact. Indirect effects may be cyclic due to positive or negative feedback.
3. A good methodology should reflect dynamic environmental effects through a capacity to distinguish between short-term and long-term effects. Impacts may vary over time in direction, magnitude, or rates of change. The larger system itself may be in ecological or social flux, and decision makers have time horizons of varying lengths.
4. Decision making necessaries encompasses multiple objectives ((or multiple values). Assessment method should include the diverse elements of environmental quality: maintenance of ecosystems and resource productivity; human health and safety; amenities and aesthetics; and historical and cultural resources. Environmental values can be divided into three types: social norms, functional values (environmental services, e.g., fisheries), and individual preferences. In addition, a good assessment method should recognize other societal objectives, such as economic efficiency, equity to individuals and regions, and social well-being.
5. Environmental assessment necessarily involves both facts and values. Values enter the process when deciding which effects to examine, whether an effect is good or bad, and how important it is relative to other effects. Methods should separate facts and values to the extents possible, and identify explicitly the source of values. Where the influence of values is obscure, the analysis itself may become a source of conflict. Under optimal conditions, results should be amenable to a sensibility analysis where alternative value judgments are applied to a set of factors.
6. It is also important to consider whose values enter the analysis. Assessment techniques should encourage a participatory approach to incorporate the multiplicity of values provided by the public as well as by expert from varying disciplines and interest groups. Lack of participatory by key factors can mitigate the usefulness of assessment results.
7. With all other things held constant, the best decision process is efficient in its requirements for time, money, and skilled labor. Increased complexity is justified only when there is a sufficient increase in the validity and decision-making utility of the analytical results.

Source Nichols and Hyman , 1982

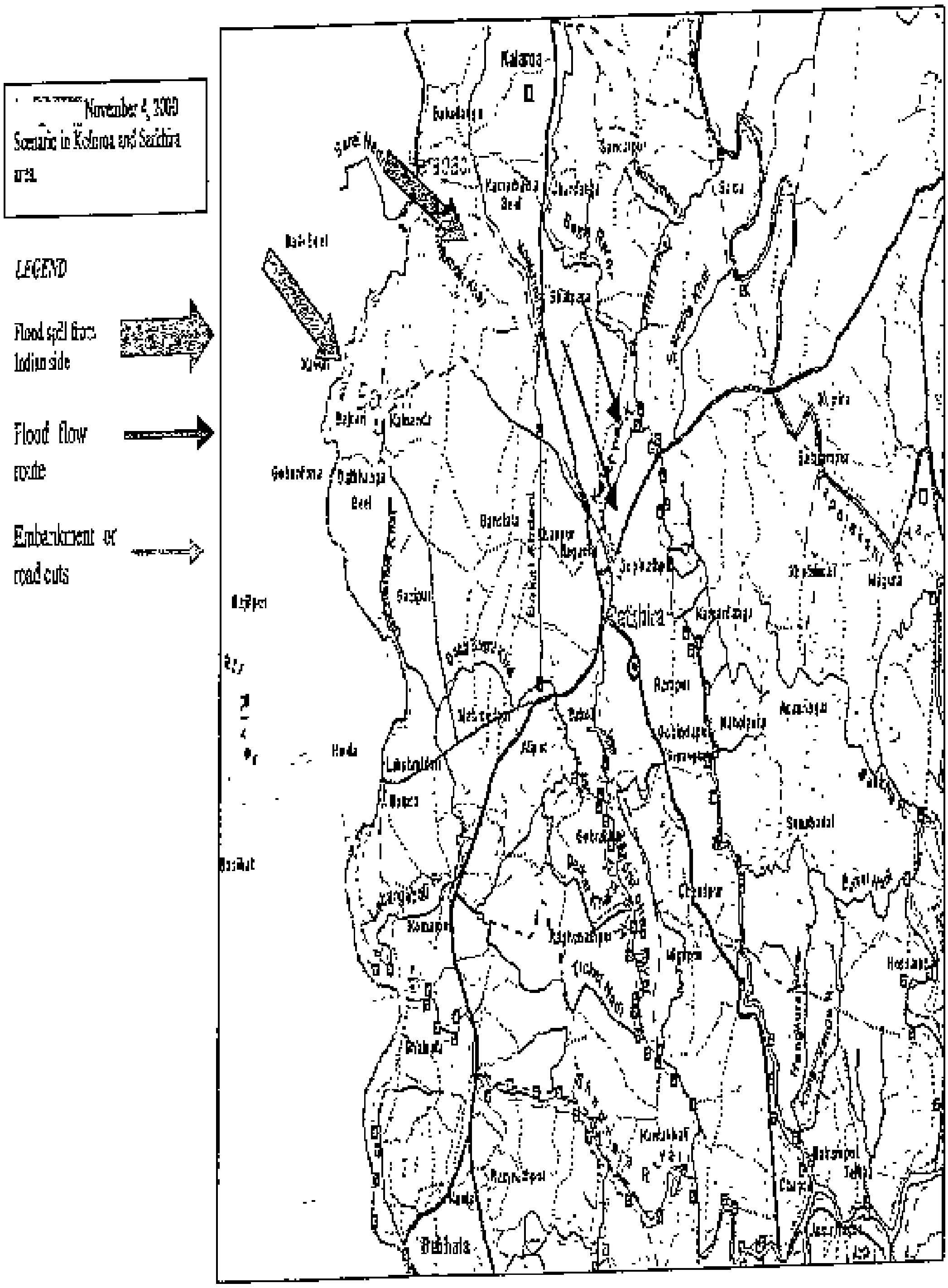


Figure A-1: Scenario of flood of 2000*(source: SWMC, 2000)*

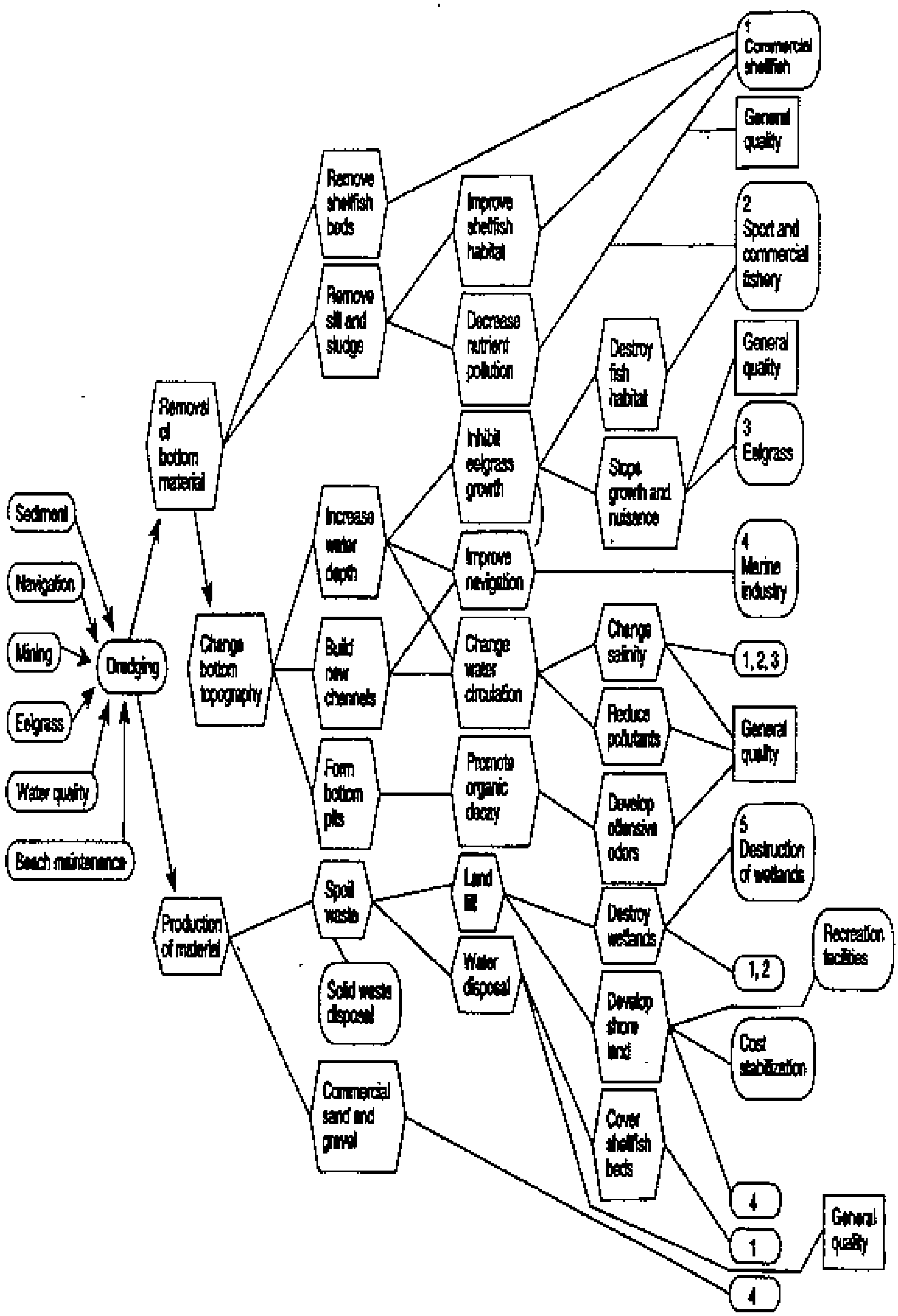
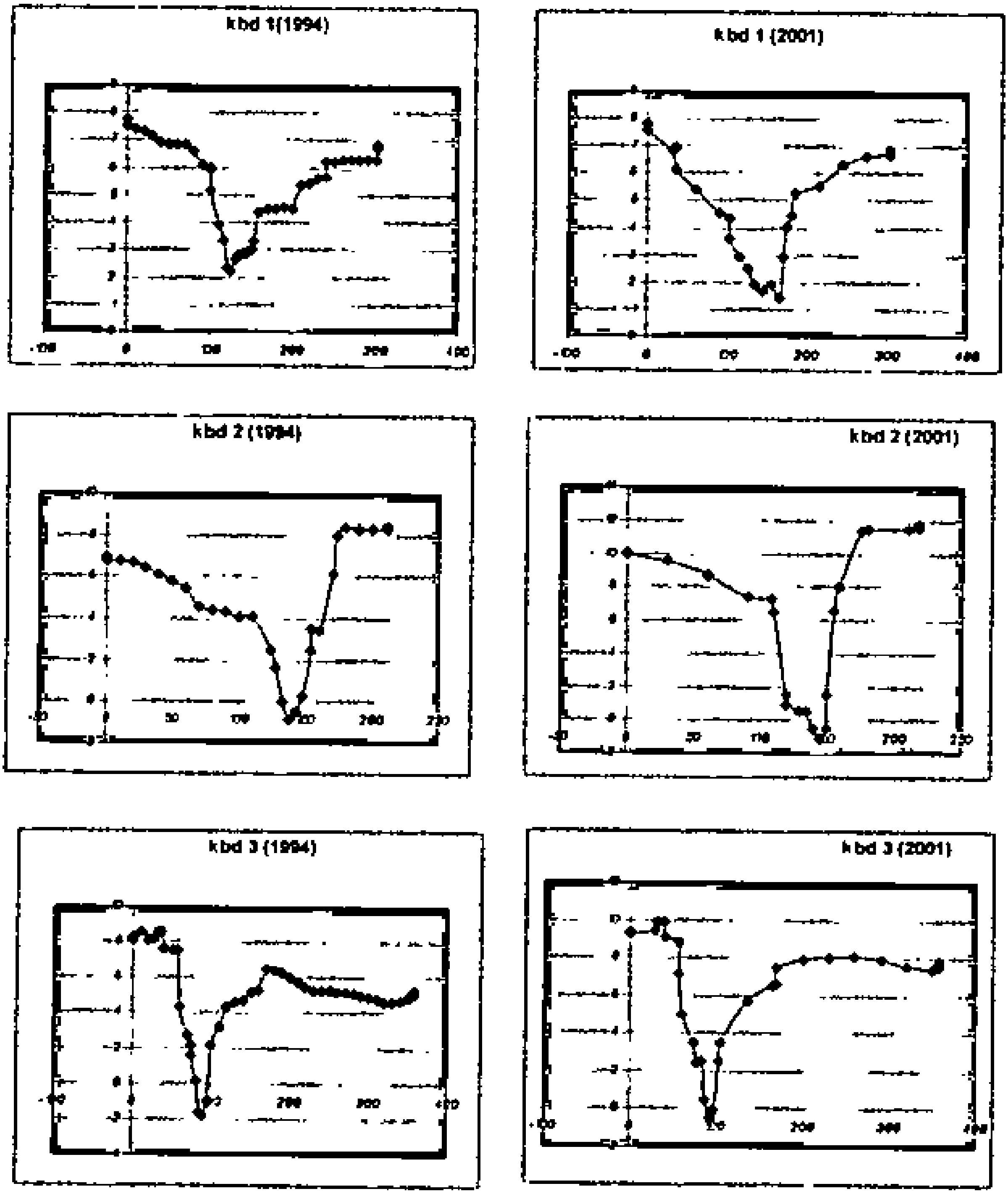
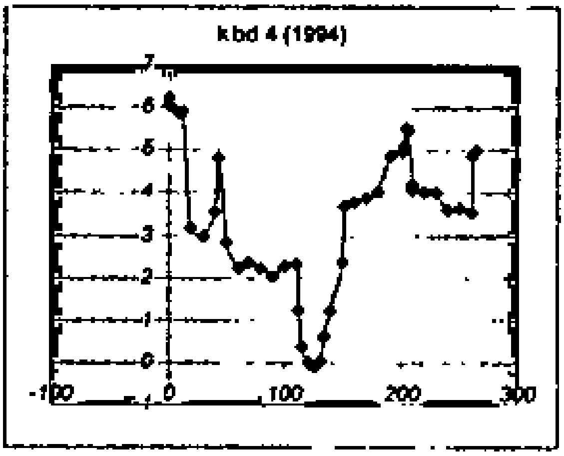


Figure A-2: Network diagram for dredging project (*Sorensen, 1971*)

Appendix B

Cross sectional area of the Kapotaksha river

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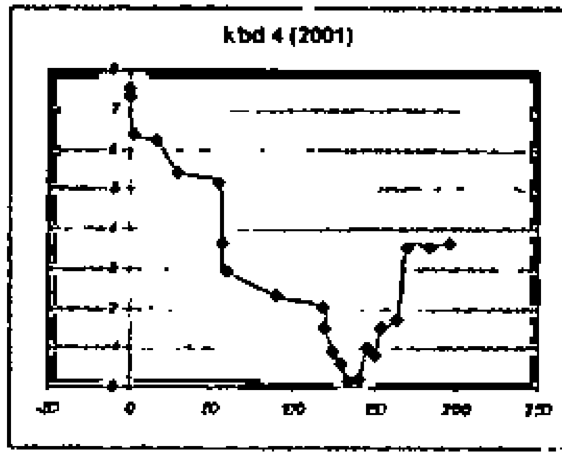
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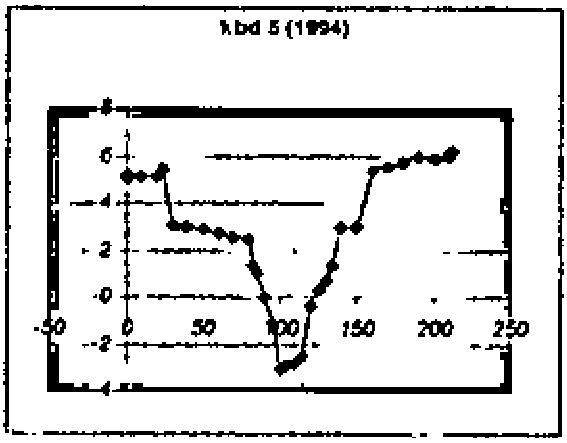
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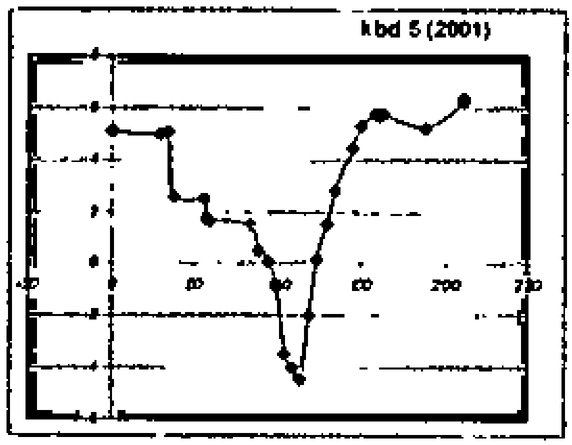
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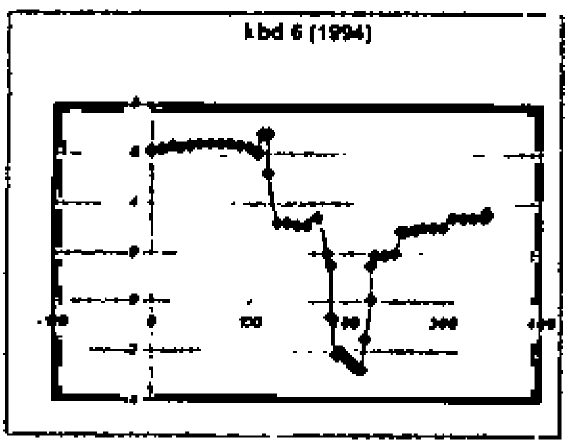
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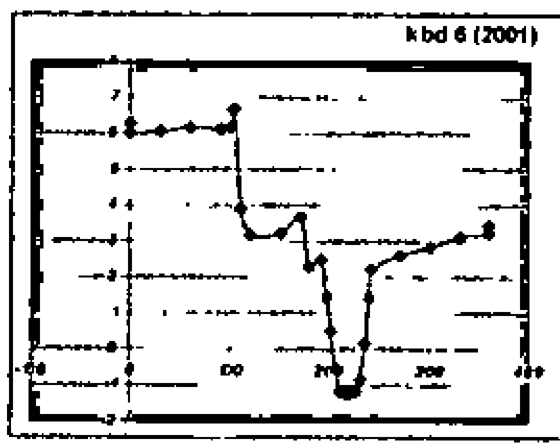
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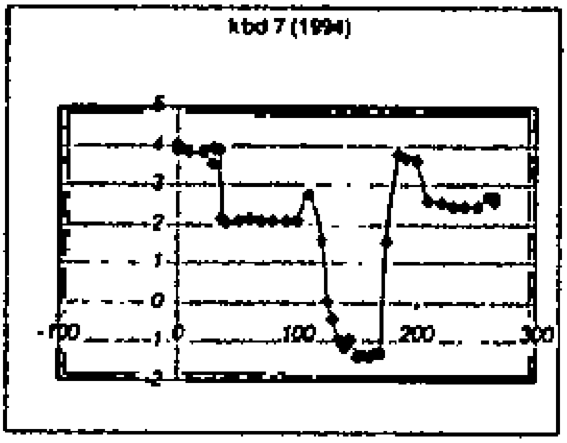
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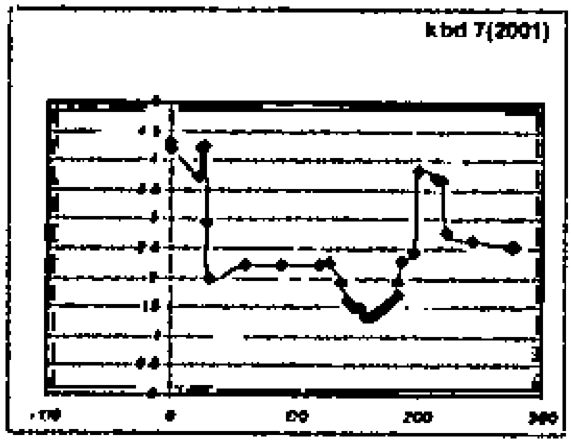
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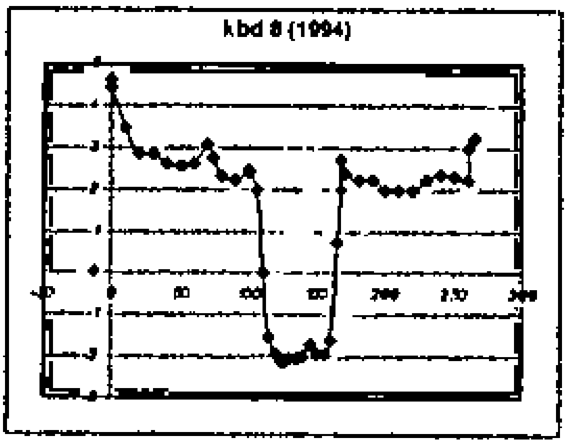
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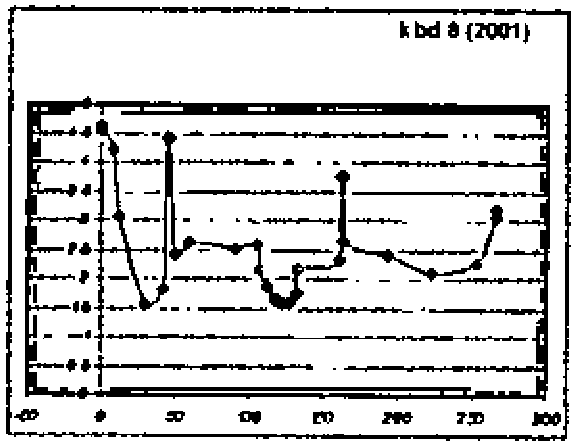
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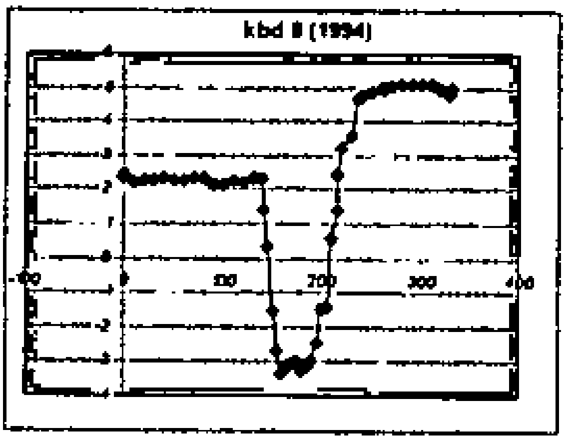
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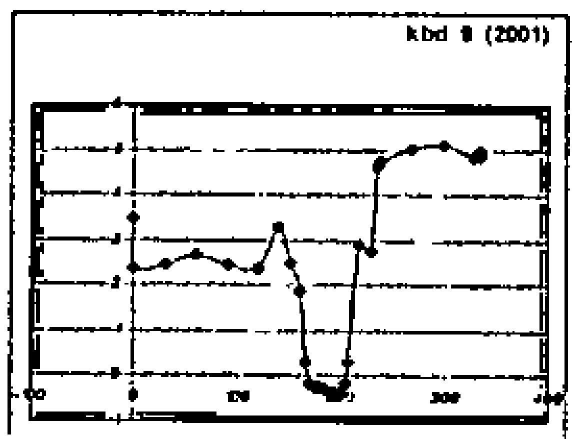
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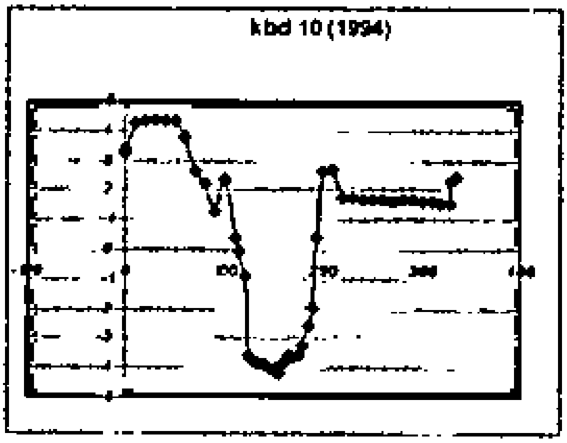
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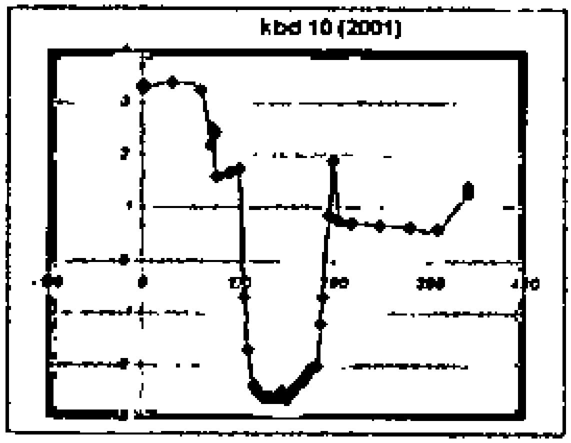
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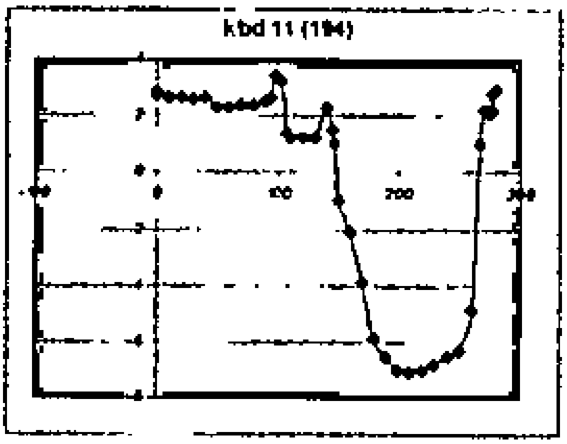
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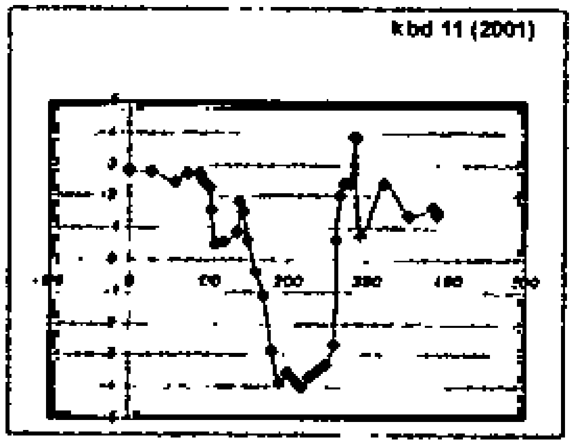
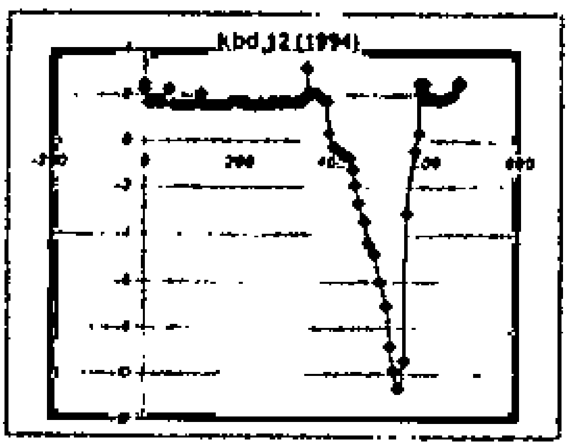

kbd 11 (2001)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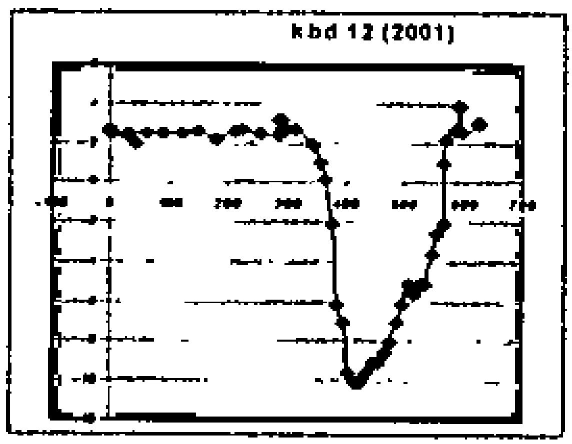
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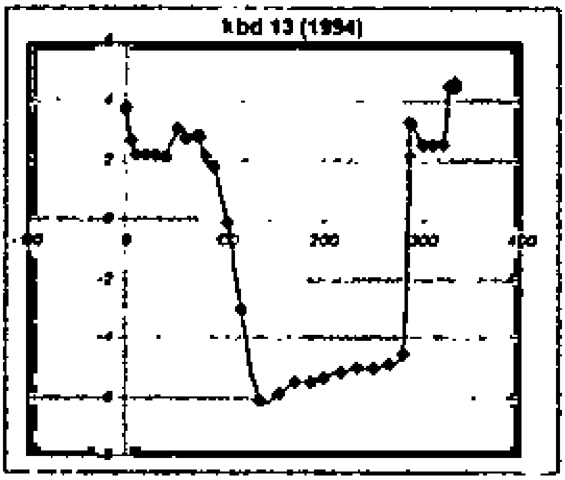
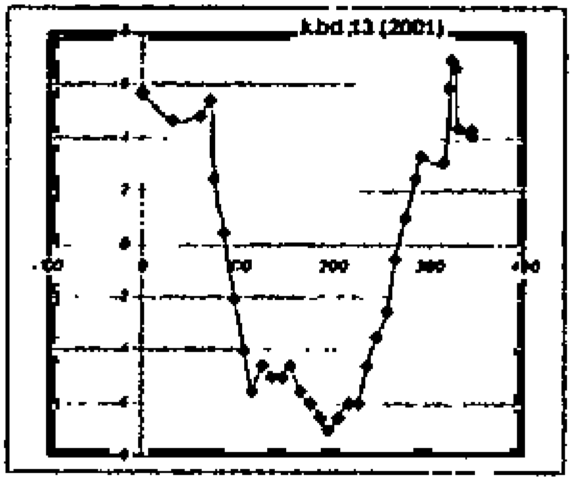
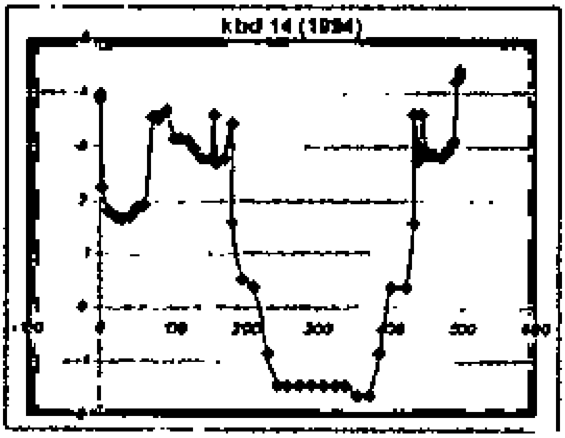

kbd 13 (1994)


kbd 13 (2001)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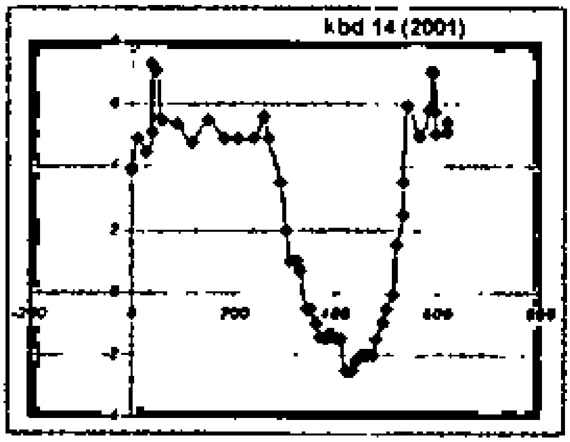
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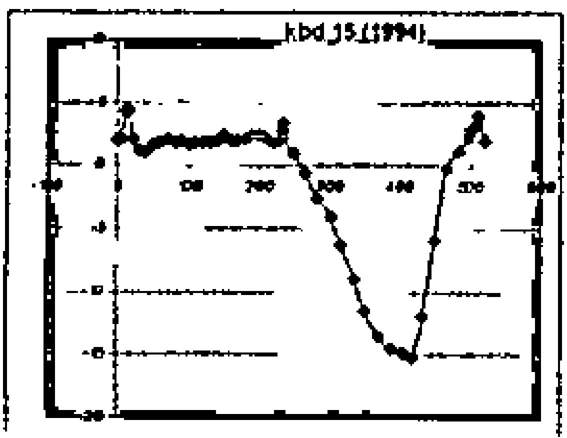
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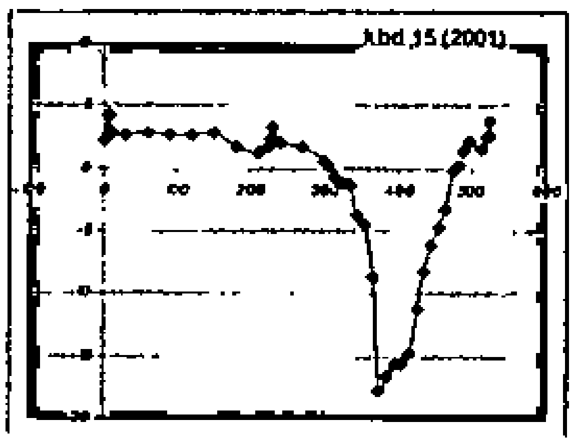
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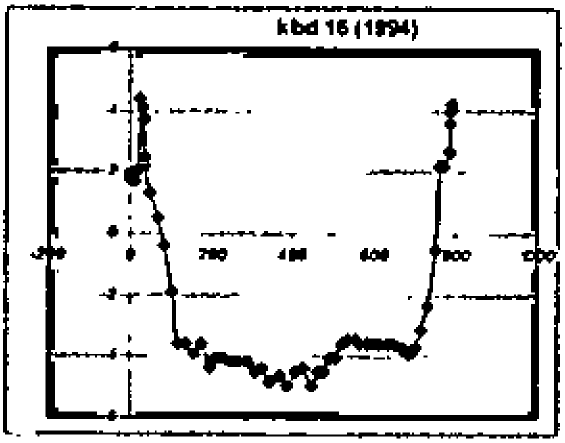
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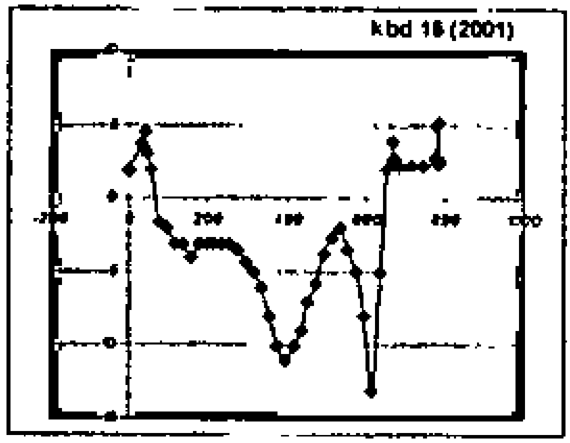
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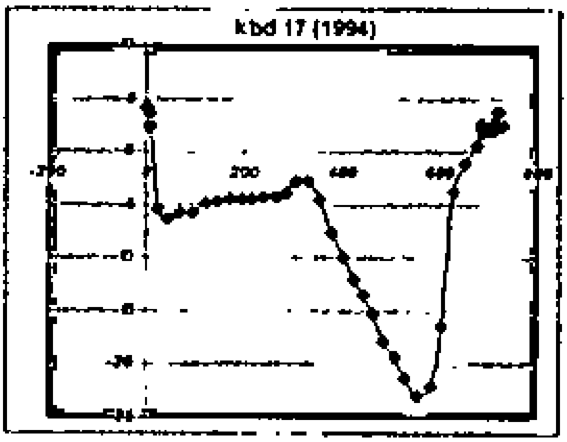
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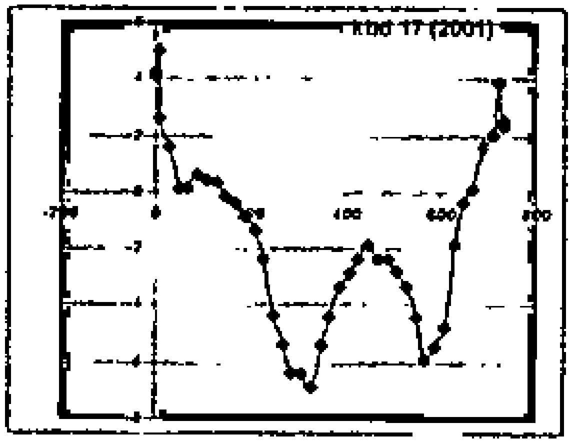
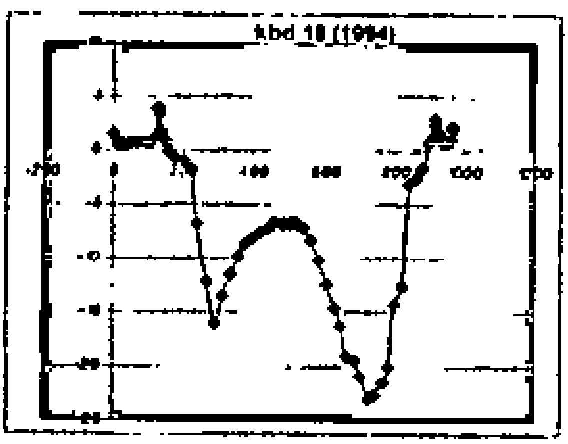
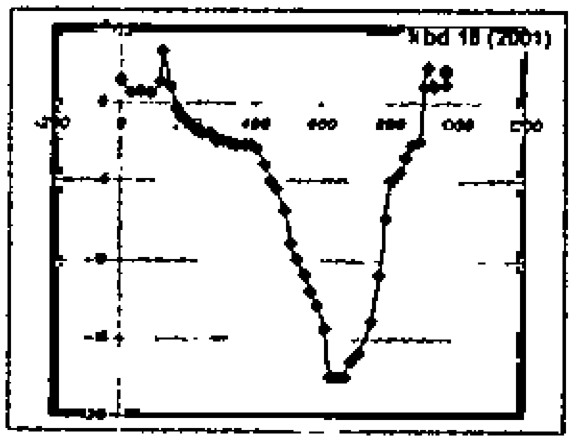

kbd 17 (2001)


kbd 18 (1994)


kbd 18 (2001)

Geometric characteristics of the Kapotaksha river of 1994

ID	Yr.	area	Water width	Perimeter	Water level	Average Water depth	Max depth	Max depth RL	Conveyance '94	R
RMKBD1	1994	21.35	38	38.1573124	3.322	0.55	1.1	2.222	579.8797436	0.559526
RMKBD2	1994	60.05	31.2	31.8150785	2.46	1.941666667	3.3	-0.84	3868.637911	1.88747
RMKBD3	1994	66	26	27.6498312	2.12	2.233333333	3.95	-1.83	4715.251851	2.386995
RMKBD4	1994	24.65	28	28.1996072	1.202	0.85	1.3	-0.098	901.4178598	0.874126
RMKBD5	1994	118.705	51.6	53.1745456	1.33	2.169181818	4.39	-3.06	8110.341726	2.232365
RMKBD6	1994	141	42	44.6886348	1.5	2.96	4.2	-2.7	12132.78367	3.165165
RMKBD7	1994	126.825	54	55.2116935	1.559	2.331818182	2.95	-1.391	8831.762821	2.297068
RMKBD8	1994	208.525	62	63.4999161	1.977	3.211638462	4.1	-2.123	18134.22257	3.262367
RMKBD9	1994	252.98	73.9	75.2949542	1.444	3.382	4.8	-3.356	22701.52335	3.359986
RMKBD10	1994	286.826	84.5	85.5484962	0.439	3.388058824	4.599	-4.16	25871.09397	3.35045
RMKBD11	1994	753.15	119.6	122.539772	1.016	5.923076923	8.1	-7.085	101082.9125	6.146168
RMKBD12	1994	822.0595	190.21	193.291369	0.37	4.323421063	10.973	-10.603	88316.82739	4.252858
RMKBD13	1994	1307.909	287.5	211.130238	2.152	6.872357143	8.23	-6.078	176463.6685	6.194795
RMKBD14	1994	590.822	250.1	251.223088	1.588	2.3335	3.2	-1.612	41794.07545	2.351782
RMKBD15	1994	2351.118	262.82	266.517671	2.276	8.8880625	17.526	-15.25	401513.2436	8.82162
RMKBD16	1994	4103.144	726.88	727.781873	2.205	6.573380952	7.163	-4.958	519900.7372	5.637876
RMKBD17	1994	7303.963	673.83	681.489822	2.307	10.69693333	25.298	-22.991	1420206.137	10.71764
RMKBD18	1994	8389.47	749.46	755.194118	0.729	11.05105405	23.774	-23.045	1670761.276	11.10902

Geometric characteristics of the Kapotaksha river of 2001

ID	Yr	area	water width	Perimeter	water level	Average water depth	max depth	max depth RL	KM	R	Conveyance '01'
RMKBD1	2001	46.5	54	54.3144743	2.9	0.85	1.5	1.4	0	0.856125	1677.016522
RMKBD2	2001	44	31	32.581906	1.52	1.314285714	2.6	-1.08	12.25	1.350443	2150.288851
RMKBD3	2001	67	33	34.3821399	3.49	1.985714286	4	-0.51	24.25	1.948686	4181.153003
RMKBD4	2001	26.9	34	34.2065729	1.53	0.778571429	1.4	0.13	35.25	0.786399	916.7285301
RMKBD5	2001	130.5	45	47.1164968	1.52	2.9	6	-4.48	47.25	2.769613	10294.76769
RMKBD6	2001	85.1	44	44.5503412	1.46	1.905555556	2.7	-1.24	61.25	1.910199	5240.530287
RMKBD7	2001	18.1	46	46.0377937	1.92	0.37	0.6	1.32	79.31	0.393165	388.5509254
RMKBD8	2001	11.2	26	26.0950216	2.17	0.4	0.6	1.57	88.75	0.429201	254.908855
RMKBD9	2001	24	42	42.0919889	0.34	0.55	0.7	-0.36	101.38	0.67018	660.1040986
RMKBD10	2001	128	82	82.2854283	-0.7	1.508823529	1.95	-2.65	114.75	1.555561	6873.764541
RMKBD11	2001	384.45	113	114.769973	0.64	3.3	4.6	-3.96	130	3.349744	34427.66602
RMKBD12	2001	1494.5	211	214.972651	0.91	6.854545455	11	-10.09	140.56	6.952047	217753.1181
RMKBD13	2001	1335	210	211.636326	2.45	6.357142857	9.5	-7.05	156.75	6.307991	182306.4183
RMKBD14	2001	1004	242	242.777963	3.49	4.032	6	-2.51	169.5	4.135466	103468.9411
RMKBD15	2001	1394.25	177	183.721901	0.31	7.75	18	-17.69	181.28	7.588916	215370.9509
RMKBD16	2001	4174.5	599	603.738243	1.93	6.963333333	15	-13.07	192.53	6.91442	606040.493
RMKBD17	2001	2773.05	659	659.83611	1.64	4.202727273	8.5	-6.86	204.03	4.202635	288867.6597
RMKBD18	2001	6126.63	765	756.888128	1.1	7.858378378	18.51	-17.41	216.65	8.094492	987963.7891

Percent change of geometric characteristics of the Kapotaksha river between 1994 and 2001

ID	KM	area'94	Area '01	Change of percentage in area	water width '94	Water Width '01	change of percentage in width	Average Depth '94	average depth '01	change of percentage in average depth	conveyance '94	Conveyance '01	change of percentage in conveyance
RMKBD1	0	21.35	46.5	117.799	38	54	42.105	0.55	0.85	54.545	579.880	1677.019	189.201
RMKBD2	12.25	60.05	44	-26.728	31.2	31	-0.641	1.942	1.3142	-32.311	3668.538	2150.289	-41.386
RMKBD3	24.25	66	67	1.515	26	33	26.923	2.234	1.986	-11.088	4715.252	4181.153	-11.327
RMKBD4	35.25	24.65	26.9	9.128	28	34	21.429	0.85	0.779	-8.403	901.418	916.729	1.699
RMKBD5	47.25	118.705	130.5	9.937	51.6	45	-12.790	2.169	2.9	33.690	8110.342	10294.77	26.934
RMKBD6	61.25	141	85.1	-39.645	42	44	4.762	2.96	1.906	-35.623	12132.784	5240.530	-56.807
RMKBD7	79.31	126.825	18.1	-85.728	54	46	-14.815	2.332	0.37	-84.133	8831.763	388.551	-95.601

ID	KM	area'94	Area '01	Change of percentage in area	water width '94	Water Width '01	change of percentage in width	Average Depth '94	average depth '01	change of percentage in average depth	conveyance '94	Conveyance '01	change of percentage in conveyance
RMKBD8	88.750	206.525	11.200	-94.577	62.000	26.000	-58.065	3.212	0.400	-87.545	18134.223	254.909	-98.594
RMKBD9	101.380	252.990	24.000	-90.513	73.900	42.000	-43.166	3.382	0.550	-83.737	22701.523	660.104	-97.092
RMKBD10	114.750	286.626	128.000	-55.343	84.500	82.000	-2.959	3.386	1.509	-55.440	25671.094	6873.765	-73.224
RMKBD11	130.000	753.150	384.450	-48.954	119.600	113.000	-5.518	5.823	3.300	-44.286	101082.912	34427.686	-65.941
RMKBD12	140.560	822.060	1494.500	81.799	190.210	211.000	10.930	4.323	6.855	58.544	86316.827	217763.118	152.275
RMKBD13	156.750	1307.909	1335.000	2.071	287.500	210.000	-26.957	5.872	6.357	8.255	176463.669	182308.418	3.311
RMKBD14	169.500	590.822	1004.000	69.933	250.100	242.000	-3.239	2.334	4.032	72.788	41794.075	103468.941	147.568
RMKBD15	181.280	2351.118	1394.250	-40.698	262.820	177.000	-32.654	8.888	7.750	-12.804	401513.244	215370.951	-46.360
RMKBD16	192.530	4103.144	4174.500	1.739	726.880	599.000	-17.593	5.573	6.963	24.939	519900.737	606040.493	16.569
RMKBD17	204.030	7303.963	2773.050	-62.034	673.830	659.000	-2.201	10.697	4.203	-60.340	1420206.137	288867.680	-79.660
RMKBD18	215.650	8389.470	6126.625	-26.972	749.460	755.000	0.739	11.051	7.858	-28.890	1670751.275	987963.769	-40.867

Water logged Area of various villages of study area

Name of Village: Barandali
Total area of Barandali=1176 acre

Year	Water Logged Area	% Of water logged area with respect to total area
1994	0	0.00
1999	0	0.00
2000	750	63.78
2003	590	50.17
2004(after dredging)	300	25.51
2004(after flood)	800	68.03

Name of Village: Saraskati
Total area of Saraskati =121 acre

Year	Water Logged Area	% Of water logged area with respect to total area
1994	0	0.00
1999	0	0.00
2000	60	49.59
2003	45	37.19
2004(after dredging)	25	20.66
2004(after flood)	60	49.59

Name of Village: Mirzanagar
Total area of Mirzanagar=1127 acre

Year	Water Logged Area	% Of water logged area with respect to total area
1994	0	0.00
1999	0	0.00
2000	750	66.55
2003	650	57.68
2004(after dredging)	400	35.49
2004(after flood)	700	62.11

Name of Village: Shahpur
Total area of Shahpur=208 acre

Year	Water Logged Area	% Of water logged area with respect to total area
1994	0	0.00
1999	0	0.00
2000	110	52.88
2003	90	43.27
2004(after dredging)	60	28.85
2004(after flood)	112	53.85

Mouza wise Average Waterlogged Area in 2003

Mouza name	Average waterlogged area (Km^2)
Purandar pur	2.01
Rajapur	0.507
Purandar pur	2.01
Rajapur	0.507
Mohinikati	0.921
Mohatabnagar	0.127
Naoali	0.612
Kanarali	0.933
Balla	2.155
Kanarali	0.933
Bolla	2.155
sadipur	0.448
Moktarpur	0.867
Goalbari	1.309
Mohadebpur	0.513
Rupashpur	0.178
Uzzalpur	2.954
Pachputa	0.924
Mollikpur	0.204
Khalla	0.543
Hanuar	1.905
Jhapa	11.115
Monoharpur	0.27
Dural Khali	0.711
Monoharpur	0.27
Uzzalpur	2.954
Jhapa	11.115
Ghoshalpur	3.069
Digdana	2.058
Matsia	2.035
Noali	0.768
mashim Nagar	1.062
Baor Kahjura	1.449
Kathal tala	0.351
Shamser bagh	0.387
Perkhajura	4.872
Kismat Chakla	0.72
Kismat Chakla	0.72
Perkhajura	4.872
Hazara kati Sora	0.159
pakuria	0.345
Chandra	0.873

(Source: CEGIS, 2004)

Mouza name	Average waterlogged area (Km^2)
Diara	7.07
Diara	7.07
Chandra	0.873
Satbari	1.35
Tarulia	1.653
Mirzanagar	2.28
Tarulia	1.653
Ophapur	1.158
Barandali	2.38
Mirzanagar	2.28
Datta Nagar	0.065
Shahpur	0.42
Ophapur	1.158
gazna	0.465
Khetrapara	0.669
saraskati	0.147
Ramkrishnapur	0.09
Shahpur	0.42
Gopsena	1.155
Meherpur	1.988
Bashbaria	0.531
Meherpur	1.988
Bashbaria	0.531
Fatepur	0.201
Gobindapur	0.47
Dharmapur	0.69
Mirzapur	0.69
Chingra	0.84
Sarsa	1.35
Dhandia krishnanagar	2.155
Sagardari	1.525
Nehalpur	0.31
Mominpur	0.558
Rajahati	0.53
Bishnapur	1.323
Dhandia krishnanagar	2.155
Sarsa	1.35
Kumarpara	0.895
Sagardari	1.525
Mohadebpur	0.567
Baga	0.91
Mominpur	0.558

Waterlogged area geometric characteristics which was used for developing Eq (5.1)

Waterlogged area	% change of width	% change of convey	% change of depth
0.489026063	4.31893688	17.69473495	12.6437994
4.885862451	-4.014396454	-0.966081489	-0.96608149
2.791383495	-5.026455024	-59.87783836	-59.87783837
2.564966368	-36.43966547	-85.83873189	-85.8387319
1.999976665	-50.61547864	-85.64117183	-85.64117183

Statistical estimates regarding the Regression Eq. (5.1)

R Square	0.98

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	9.844743285	3.281581095	14.91161755	0.187583952
Residual	1	0.220068754	0.220068754		
Total	4	10.06481204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4.86	0.46	10.55	0.06	-0.99	10.71
% change of width	0.00	0.02	-0.13	0.91	-0.24	0.24
% change of convey	-0.94	0.14	-6.67	0.09	-2.74	0.85
% change of depth	0.97	0.15	6.62	0.10	-0.89	2.84

Appendix C

Inundated house during waterlogged condition

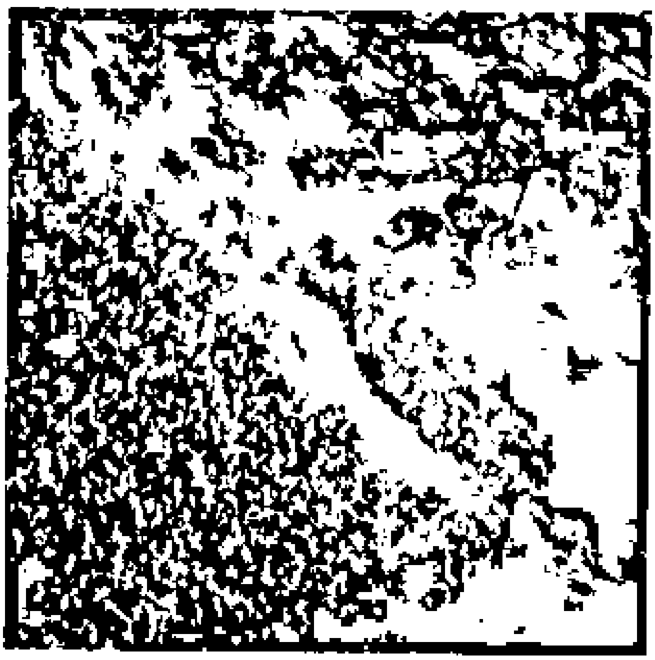
Inundated homestead during waterlogged condition

Khals affected by dense water hyacinth

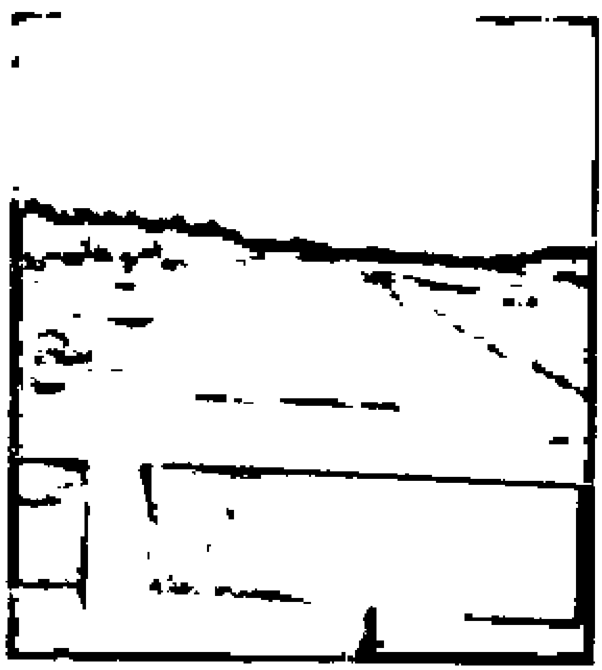
Khals affected by dense water hyacinth

Beels area affected by water logging and water hyacinth

People are fishing in inundated beel area



The Kapotaksha river affected by water hyacinth



The Kapotaksha river

Appendix D

A sample of questionnaire is as follows:

নামঃ　　　　　　　　বয়স ঃ　　　　　　　　গ্রামঃ

পেশাঃ　　　　　　　　শিক্ষাগত যোগ্যতাঃ

১। এখন থেকে কত বছর আগে নদী বেগবান ছিল এবং কবে থেকে নদী বেশী পরিমান (rapidly) শুকিয়ে যাচ্ছে ? কোন স্থান থেকে ?

২। জলাবদ্ধতা কবে থেকে শুরু হয়েছে এবং বিভিন্ন স্থানে জলাবদ্ধ জায়গার পরিমান কত ? জলাবদ্ধতার স্থায়িত্ব কেমন ?

সাল	F0	স্থায়িত্ব	F1	স্থায়িত্ব	F2	স্থায়িত্ব	F3	স্থায়িত্ব	F4	স্থায়িত্ব
১৯৯৮										
১৯৯৯										
২০০০										
২০০১										
২০০৩										
২০০৪										

৩। (Geometry change- এর ধরন এবং তার সাথে Water logging এর evolution – সময় এবং স্থান)
জলাবদ্ধতা কখন শুরু হয়েছে, যখন নদীর গভীরতা / প্রস্থ কমে গেছে ? কোনটার সাথে সম্পর্কিত বেশী ?

৪। পূর্বে কতটুকু (water level) জোয়ার ভাটা ছিল এবং বর্তমানে জোয়ার ভাটার পরিমান কত (water level).

সাল						
water level (ফুট)						
Area						

৫। জোয়ার ভাটার বেগ কি পরিবর্তন হয়েছে ? কিভাবে ? (কমেছে না বেড়েছে)

৬। নদী শুকিয়ে যাবার পূর্বে এবং পরে বিভিন্ন বছরে কতটুকু Area তে কত সময় লোনা পানি থাকত ?

সাল	Area	Time (মাস)

৭। নদী শুকিয়ে যাবার পূর্বে এবং পরে পানিতে লবনাক্ততার পরিমান কেমন ? পানিতে লবনাক্ততার মান বেড়ে যাচ্ছে / কমে যাচ্ছে কি ?

৮। কি কারনে নদী শুকিয়ে যাচ্ছে এবং এই শুকিয়ে যাওয়া রোধ করতে কি করা উচিত ?

৯। (বন্যা ২০০৪- এর আগে ও পরে) Drabdging করার ফলে জলাবদ্ধতার কি কোন পরিবর্তন হচ্ছে ?

১০। Dradging করার ফলে জোয়ার ভাটার কোন পরিবর্তন আছে কি ?

১। জলাবদ্ধতার প্রধান করন কি ?

ক) পানি নামছে না, না নামার করন ?

খ) পানি নামছে, কিন্তু যে পরিমান নামছে তার থেকে বেশী পানি আসছে ?

২। (পনি না নামার জন্য infrastructure – এর ভূমিকা) রাস্তা ঘাট অথবা এ ধরনের কোন কিছু (বাঁধ / অন্যকিছু) পানি না নামার জন্য দায়ী কিনা ?

৩। পূর্বে (নদী যখন বেগবান ছিল) তখন পানি নামার কি কি রাস্তা (Way) ছিল এবং এগুলোর সংখ্যা কত ছিল (খাল বা এ জাতীয় অন্য কিছু)

সাল	খাল	নাম (খালের)		

৪। নদী শুকিয়ে যাবার ফলে খাল গুলোও কি শুকিয়ে যাচ্ছে বা অন্য কোন পরিবর্তন আসছে ? এদের(শুকিয়ে যাওয়া খাল)সংখ্যা কত ?

৫। Baor (বাওড়) গুলো কি কখনো (Connected) নদীর সাথে সংযুক্ত ছিল ? বাওড় গুলো কি নিজেদের মধ্যে সংযুক্ত ছিল ? বর্তমান ও পূর্বের অবস্থা কি ?

৬। (বন্যা ২০০৪) Dredging-এর ফলে পানি নামছে কেমন করে :

ক) সরাসরি নদীতে
খ) খালের মাধ্যমে খাল পুনরায় খনন করা লাগছে কি ? (সংখ্যা)

৭। পানি নামার গতি কেমন ?

১। নদী শুকিয়ে যাবার পূর্বে এবং পরে বিভিন্ন সালের মোট পুকুর এবং কচুরিপানা দ্বারা আক্রান্ত পুকুরের সংখ্যা কত ?

সাল	মোট পুকুরের সংখ্যা	কচুরিপানা দ্বারা আক্রান্ত পুকুরের সংখ্যা

২। বর্তমানে পুকুর ব্যাতীত অন্যান্য জলাশয়ের পরিমান (No / area) এবং কচুরিপানা দ্বারা আক্রান্ত জলাশয়ের পরিমান কত ?

মোট জলাশয়ের পরিমান	
কচুরিপানা দ্বারা আক্রান্ত জলাশয়ের পরিমান	

৩। বর্তমানে কচুরিপানা দ্বারা আক্রান্ত পুকুর এবং অন্যান্য জলাশয়ের status (বেশী আক্রান্ত / কম আক্রান্ত) কি ?

	নষ্ট হয়ে গেছে (কচুরিপানা দ্বারা বেশী আক্রান্ত)	অপেক্ষাকৃত কম আক্রান্ত (কচুরিপানা পরিস্কার করা যেতে পারে)
পুকুর		
জলাশয়		

৪। কচুরিপানা দ্বারা আক্রান্ত পুকুর বা জলাশয়ের জলজ প্রানীর (মাছ বা অন্যকিছু) কি পরিমান ক্ষতি হচ্ছে ? (Kg)

	মাছ	অন্যকিছু
পুকুর		
জলাশয়		

৫।Dradging করার ফলে কোন আক্রান্ত পুকুরের বা জলাশয়ের কচুরিপানার পরিমান কমছে কি ? যদি কমে থাকে এর পরিমান কত ? (No. / area)

৬। কচুরিপানা ছাড়া বিভিন্ন পুকুর / জলাশয় (wetland) এর পানির গুনগত মান (water qualty) (গন্ধ / স্বাদ) তে কি ধরনের পরিবর্তন হয়েছে ?

৭। সবগুলো জলাশয়-ই কি কচুরিপানা সমস্যার (দ্বারা) আক্রান্ত ? অন্য কোন ধরনের (water quality) পনির মান সক্রান্ত সমস্যা ?

১। নদী শুকিয়ে যাবার পূর্বে এবং পরে বিভিন্ন সালের বিভিন্ন প্রজাতি মাছের উৎপাদনের পরিমান কত ?

সাল	প্রজাতি	উৎপাদন (kg)

২। মাছের উৎস কি ছিল ? নদী, খাল, অন্যকিছু ?

৩। স্থায়ী জলাবদ্ধতার জন্য কিকি প্রজাতির মাছ বিলুপ্ত হয়ে যাচ্ছে, এবং কোন প্রজাতির মাছ বেশী পাওয়া যাচ্ছে ?

৪। Inundation-এর ফলে কি পরিমান মাছ মুক্ত জলাশয়ে চলে যাচ্ছে ?

Normal Condition	
বন্যা' ২০০৪	

৫। মাছ প্রাপ্তির স্থান কি পরিবর্তন হয়েছে ? বর্তমানে Floodplain - এ মাছ পাওয়া যাচ্ছে ? আগে পাওয়া যেত ;

৬। wet land - এর মাছের অবস্থা কেমন (পূর্বে এবং পরে)

৭। চাষ কৃত (culture) মাছের এবং অ-চাষকৃত (capture) মাছের পরিমান কত ?

সাল				
চাষকৃত				
অচাষকৃত				

৮। Dradging-এর ফলে মাছ চাষে কি কোন ধরনের পরিবর্তন আসছে ? মাছের প্রাপ্তি এবং প্রজাতির উপরে কি ধরনের প্রভাব পড়ছে ;