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Bangladesh Water Development Board

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River Training Studies of the Brahmaputra River

Master Plan Report

1994

Technical Annexes
Annex 3
Initial Environmental Evaluation

A-26

Sir William Halcrow & Partners Ltd.
in association with

Danish Hydraulic Institute
Engineering & Planning Consultants Ltd.
Design Innovations Group

HALCROW

Government of the People's Republic of Bangladesh
Bangladesh Water Development Board

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FOREWORD

The BRTS Master Plan Report was issued on 28 June 1993. Comments from BWDB and FPCO were received from July 1993 onwards, and responses to those comments were issued in a single volume on 7 March 1994. The report was approved at the 20th FAP Technical Committee Meeting on 9 August 1994 subject to certain amendments. The amendments have duly been incorporated and the report was reissued in its present form in December 1994.

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RIVER TRAINING STUDIES OF THE BRAHMAPUTRA RIVER

MASTER PLAN REPORT

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GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
BANGLADESH WATER DEVELOPMENT BOARD

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ABBREVIATIONS

BIWTA	-	Bangladesh Inland Water Transport Authority
BRE	-	Brahmaputra Right Embankment
BRTS	-	Brahmaputra River Training Study
BWDB	-	Bangladesh Water Development Board
BRDB	-	Bangladesh Rural Development Board
DHI	-	Danish Hydraulic Institute
DoE	-	Department of the Environment
EIA	-	Environmental Impact Assessment
EIRR	-	Economic Internal Rate of Return
EMP	-	Environmental Management Plan
FAP	-	Flood Action Plan
FIDIC	-	Federation International des Ingenieurs-Conseils
FPCO	-	Flood Plan Coordination Organisation
GOB	-	Government of Bangladesh
HFL	-	High Flood Level
ICB	-	International Competitive Bidding
IDA	-	International Development Association (World Bank)
IEE	-	Initial Environmental Evaluation
JMB	-	Jamuna Multipurpose Bridge
JMBA	-	Jamuna Multipurpose Bridge Authority
LAD	-	Least Available Depth
LCB	-	Local Competitive Bidding
LWL	-	Low Water Level
MARS	-	Monitoring and Resettlement Section
NGO	-	Non-Government Organisation
NPV	-	Net Present Value
PIANC	-	Permanent International Association of Navigation Congresses
RE	-	Resident Engineer
TOR	-	Terms of Reference

ANNEX 3 - INITIAL ENVIRONMENTAL EVALUATION

1. INTRODUCTION

1.1 Introduction

This report presents the Initial Environmental Evaluation (IEE) of the Master Plan developed from the River Training Studies of the Brahmaputra River (BRTS), a project designated under the Flood Action Plan (FAP). These studies have sought to determine the most effective solution for flood protection on the right bank of the Brahmaputra river in Bangladesh.

Traditionally this protection has been provided by an almost continuous embankment: the Brahmaputra Right Embankment (BRE). There is ample and readily visible evidence that during the 25 years of its existence the BRE has provided effective relief from the uncontrolled and sustained inundation originating from the high flood flows in the Brahmaputra River and that this has assisted in the very substantial increase in agricultural production and general development in the protected areas.

This level of security against damaging floods is now under threat from the continuing erosion of the right bank of the river (see Table 1.1), which increasingly causes breaches of the BRE. In addition to this problem there is the more direct hardship that arises from the massive erosion of fertile farmland along the bankline and the displacement of the farmers, who are forced to take refuge on the remaining flood embankment as the only safe haven available. Contrary to the belief held by some, there is no discernible link between the construction of the BRE flood embankment and this rapid bank erosion, which has been a feature of the river since its avulsion some 200 years ago.

These breaches and the ensuing sudden floods have become more frequent over recent years as progressively greater lengths of the BRE come within range of the more aggressive river bends. The consequent displacement of families from their homes and land has added to the already daunting problems of homelessness, resettlement and unemployment. As an example of the order of magnitude of the problems, the potential damage in the short term is given in Table 1.2, for six locations along the BRE that have been experiencing severe bank erosion during the past four or five years. Because of the cyclical nature of erosion, as the threat to these sites reduces, so attack will intensify at others, resulting in similar levels of damage.

The instability of the river has in general discouraged the growth of sizeable urban concentrations close to the river but one notable exception to this is the large and active town of Sirajganj, with a population of around 100,000, which is located at a point on the river that, for reasons that are obscure, experienced less severe bank erosion during the first decades of this century. This together with marginally higher ground elevations in the vicinity was sufficient for it to become established as a railway ferry terminal of some importance. The stability of the bankline proved to be only a temporary phenomenon and by the 1960's bank stabilization measures were necessary. The situation has become progressively worse since then.

The objective of the Master Plan is to develop a strategy for the long term amelioration of the problems arising directly and indirectly from the instability of the river. Additionally, Priority Works have been identified and designed under the BRTS to provide immediate improvement to the stability of the right bank at locations where there is particular need for early action to stabilize the river bank, either to ensure the proper and sustained functioning of the BRE or to protect major centres of infrastructural investment.

The Master Plan is fundamentally a detailed strategy for the management of the Brahmaputra River and the improved performance of flood control measures on the right bank flood plain, with a timeframe flexible enough to accommodate financing constraints. It covers both structural and non-structural measures and is geared to meeting both short and long term objectives, supported by an indicative draft plan showing the scope of structural works involved (as perceived at this stage) with guidelines that will allow planners to respond to the situation as it develops. In this form the plan can be continuously upgraded in response to the changes in the river pattern and as more data becomes available.

1.2 Background to the Project

1.2.1 The Brahmaputra Right Embankment (BRE)

The Brahmaputra-Jamuna river system is one of the largest in the world, and is also the largest and most important river system in Bangladesh, accounting for more than 50 percent of the total inflow into Bangladesh from all cross border rivers.

The Brahmaputra moved to its present course about 200 years ago. It is a braided river without fixed banks and with frequently shifting channels. Short term channel migration can be quite drastic with annual rates of movement as high as 800 m. The bank erosion process is a complex mechanism and is influenced by a number of factors. Within the study reach the overall river width varies between 6 km and 14 km. During the past 30 years the river has been becoming steadily wider. It has been possible to plot this trend over the last 20 years more precisely and this has shown that not only is the trend very consistent when the study area is considered as a whole but also that the rate of widening has been appreciably faster south of Sirajganj than to the north. This together with the evidence provided by the braiding index measurements points strongly to the conclusion that the river is continuing to become wider and more braided.

Following the favourable outcome of a feasibility study, the 220 km long earth embankment, known as the Brahmaputra Right Embankment (BRE), was constructed in the late 1960s - early 1970s on the western bank of the Jamuna River to protect the flood plain lands against the sustained deep flooding caused by the passage of the annual flood wave down the Brahmaputra river. The BRE performed very satisfactorily during the first 15 years or so, and the parts that remain intact are generally in fair to good condition.

The major cause of failure of the BRE is undercutting due to rapid bank erosion or, less frequently, direct erosion by high flow velocities as the main river channel coming within a few tens of metres of the embankment. Every year the BRE has to be retired landward in order to maintain its continuity. A total length of about 140 km of retired embankment has been re-constructed over the past 20 years, in some cases several times.

No cases of failure due to overtopping have been substantiated and the few reports of public cuts are confined to the northern stretch of about 20 km where the fall of the land is towards the Jamuna river and breaches in the Teesta embankment can result in localized flooding. There is one substantiated report of piping failure attributed to rat holes in the environs of Sirajganj. The rare examples of minor local slumping and wave wash damage are all confined to hastily constructed retired embankments built to a substandard specification.

1.2.2 The Flood Action Plan

In November 1989, a five year Flood Action Plan (FAP), coordinated by the World Bank, was initiated by the Government of Bangladesh. The initial phase of studies is directed towards the development of a comprehensive system of long-term flood management and drainage works. Priority has been given to the alleviation of flooding from major rivers, of which the Brahmaputra is possibly the most significant. The BRTS forms component No 1 of a total of 26 components comprising the FAP during the plan-period 1990-1995. The other FAP studies that have specific links with the BRTS are:

FAP-2:	North West Regional Study
FAP-3:	North Central Regional Study
FAP-3.1:	Jamalpur Priority Project
FAP-12:	Flood Control, Drainage and Irrigation Projects Agricultural Review
FAP-13:	Operation and Maintenance Study
FAP-14:	Flood Response Study
FAP-15:	Land Acquisition and Resettlement
FAP-16:	Environmental Study
FAP-17:	Fisheries Study and Pilot Project
FAP-18:	Topographic Mapping
FAP-19:	Geographic Information System
FAP-20:	Compartmentalization Pilot Project
FAP-21/22	Bank Protection and River Training/AFPM Pilot Project
FAP-24:	River Survey Project
FAP-25:	Flood Modelling/Management Project

1.3 Rationale for the Project

1.3.1 Potential Consequences of Present River Erosion Regime

It seems likely that the pattern of bank erosion will continue for at least the next 30 years. Under the present nominal strategy (i.e retire by the distance equivalent to 5 years erosion) this will result in 130 km of the existing BRE being eroded away and reconstructed at least six times; 50,000 ha of land will be lost and about 600,000 people will become not only homeless but also landless with no means of support.

Lost land may be replaced partly by accretion on the left bank and partly by char growth, but the quality of such land for agricultural purposes will be substantially inferior and will have no protection from inundation, and consequently its productivity will be much lower. The newly emerged land is in any case not available for use by those who have been displaced since it is legally the property of whoever held title to that area before the river earlier occupied it;

in practice the situation is less well defined with the larger landowners wielding much influence.

Breaching of the BRE will continue to occur even if the nominal 'five year set back' rule is correctly applied and planned retirement of the embankment is implemented. It would be socially unacceptable, and economically unjustifiable, to set the embankment far enough back to reduce to a minimal value the risk of the occasional very aggressive bend (that can erode the bank at more than 800 m per year) from causing a breach.

Analysis of significantly scouring bends which have occurred over the last 20 years suggests that on average six right bank concave significant bends can be expected to be discernible each year; of which about half will be in their active period. In the absence of an effective system for identifying potentially aggressive bends and instituting pre-emptive retirement of the embankment, an average of one or two breaches a year would thus not be exceptional.

The damage resulting from a breach of the BRE will vary with location and the water levels in the Brahmaputra at the time. Estimates for immediate agricultural damage from a single breach range from about Tk 10 million in the vicinity of the breach, though the average is nearer Tk 30 - 60 million over the affected area. In addition the direct damage to roads and other infrastructure and the interruption to land communication is substantial.

1.3.2 Breakthrough to the Bangali River

The Bangali river is now within the range of one of the more aggressive bends on the Brahmaputra river that have occurred during the past 15 years. If no preventative action is taken it would appear highly probable that the Brahmaputra river will break through into the Bangali river within a matter of a few years, with the added risk that in the medium to longer term the Brahmaputra might favour this channel and eventually occupy it as a major anabranch.

Once the breakthrough had occurred it would be necessary to realign the Bangali channel itself westwards in order to maintain the continuity of the BRE while ensuring that drainage of the area to the north was not severely impeded. It has been estimated that such a realignment could cost of the order of Tk 2,000 million in construction costs alone, and require the acquisition of 850 ha of prime agricultural land, together with the displacement of a large number of farming households. During the construction period the BRE would be substantially ineffective over this reach and downstream areas would suffer accordingly. The negative social and consequential economic impacts of such a breakthrough would be massive.

1.3.3 Security of Sirajganj and Fulcharighat

The important district centre of Sirajganj with its population of about 100,000 is under constant threat of erosion from the river. It is the only significant river port on the Brahmaputra and it is the railhead for the southern ferry crossing. During the past four years the erosive attack has switched from a deep embayment north of the town to a point immediately south of the downstream limit of the existing revetment, leaving the hardened length of the bank projecting into the river.

Velocities along the revetment face are high and deep scour holes occur where the main flow of the river is deflected. Because most of the revetment has insufficient provision for scour, rapid localized collapse occurs. To date emergency action, including the dumping of railway wagons, has prevented progressive collapse but the situation is becoming increasingly unstable and a major failure appears to be imminent.

Fulcharighat is the northern railhead with freight and passenger services to Bahadurabad. It has a long history of bank erosion and in recent years has experienced a particularly aggressive bend that has demolished the upazila headquarters and is now forcing the railway spur to fall back towards the BRE. Although the Bangladesh Railways are well organized and set up to cope with the mobility of the situation, services are affected each time the terminal has to be relocated. In the medium term the continuing erosion is expected to erode the main marshalling area behind the present BRE and in due course will threaten the main railway line itself.

1.4 Assessment Methodology

1.4.1 FAP Environmental Guidelines

The Environmental Study (FAP-16) has produced a series of updated Environmental Guidelines and an EIA Manual to be followed by the FAP regional studies. These guidelines (the May 1992 edition being current when this Evaluation was prepared) are designed for schemes involving active intervention measures aimed at flood control and drainage, such as the construction of new flood embankments and polders, and as such are not directly applicable to the Brahmaputra situation. There is some further ambiguity as to the use of these guidelines for broad assessment of the environmental implications of area strategies (referred to as Initial Environmental Evaluations (IEE) in the guidelines).

The environmental assessment has identified the important environmental factors within the project area, and used these to determine the probable impacts of the options in the Master Plan. The system used is similar to that used in the earlier EIA on the Priority Works, but now modified to meet the wider +/-5 multi-criteria analysis scale, in accordance with the May 1992 edition of the FPCO EIA Guidelines. It is further explained in Chapter 5 and Appendix A.

1.4.2 Data Collection and Analysis

The project area for the Master Plan covers the right bank of the Brahmaputra (Jamuna) River from its confluence with the Teesta River to the Hurasagar confluence.

Extensive field work has been undertaken by the BRTS team over a period of two years and sophisticated numerical modelling techniques have been used in support of satellite image interpretation and physical modelling for evaluating the effectiveness and physical impact of alternative intervention measures. This large amount of primary data generated by the project provides a solid basis for assessing the environmental impact of the proposed works in physical terms.

Primary data collection covering the socio-economic factors has also been undertaken but much of the ecological and social data has been drawn from secondary sources, the majority from the FAP supporting studies and the regional studies.

The environmental assessment is thus an analysis of the data available at present, and a projection of the main areas and processes that may impact the existing situation. Data has been collected for the many different components of the project, from which environmental data has been isolated, collated and analyzed for this report.

To provide confirmation that information taken from secondary sources is both relevant and up-to-date, field observations were made by the environmental specialists and anecdotal data gained from discussions with local groups in the affected project areas, as well as Government officials, other FAP and project workers, and interested parties, during the earlier Environmental Impact Assessment (EIA) on the Priority Works.

1.5 Format of the Report

The IEE has followed, within the project constraints, the form of assessment developed for the Flood Action Plan, and contained in the May 1992 Draft Guidelines for EIA approved by the Flood Plan Coordinating Organization (FPCO).

An earlier Environmental Impact Assessment was made on the Priority Works (July 1992) - Sariakandi, Mathurapara and Sirajganj in which it was stated that:

> "...All data is not yet available to provide a complete environmental assessment covering the full scope of the master plan, and so the report has been divided into two parts:
>
> Part 1 : The Priority Works
> Part 2 : The Master Plan"

This annex represents the second part of the environmental assessment, and covers the additional impact assessments relating to the Master Plan and which will form part of the BRTS Final Report.

To provide ease of understanding, this IEE is presented as a separate report, and some introductory parts of the earlier EIA on the Priority Works have been repeated in this report. The analysis and conclusions are however distinct from the specifically directed assessments of the priority projects.

For a detailed review of the sociological considerations, the reader is referred to Annex 1 of the Master Plan Report. Detailed plans regarding resettlement of persons displaced by the Priority Works have been drawn up and are of relevance to this IEE. The draft Resettlement Plans were issued in December 1992.

1.6 Nomenclature

A list of abbreviations and acronyms used is given at the beginning of this report.

The name frequently used for the Brahmaputra River in Bangladesh is the Jamuna. Although the name Brahmaputra is more generally used in this report, the name Jamuna, when it appears, is not intended to imply any differentiation.

2. PROJECT DESCRIPTION

2.1 Project Concept

Despite the possible implications of the title of the Study, the current intention, at least in the short term ~~and medium~~ term, is not to attempt to channelize the river but rather to stabilize the right bank so that its westward migration is arrested. This may be accompanied by selective hardening of the left bank also and in due course by measures aimed at consolidating the more permanent chars.

The available evidence indicates that such an approach would not result in any sustained adverse impacts for either the human population or the ecosystem in general. However despite the substantial progress that has been made during the past three years, the present state of knowledge of the behaviour of the river still does not permit predictions to be made with a level of confidence that is commensurate with the scale of the intervention that is envisaged and the possible consequences. It is therefore proposed that initially physical intervention should be limited to those locations where the call for some bank protection is now urgent and to monitor the performance of the works themselves and the morphological and other consequences before embarking on the next phase.

2.2 Project Scale and Location

2.2.1 Project Scale

The Master Plan is concerned with the stabilization of the entire length of the river between the Teesta and the Hurasagar confluences. This is a long term goal that is likely to take many decades to realize. During this period remotely sensed data collection will continue and if the proposals incorporated in the study recommendations are implemented, analysis of this data in conjunction with direct field measurements will be continuously carried out to provide a progressively better understanding of the relationship between intervention and the morphological and ecological consequences.

The BRTS Study has two distinct components. The Master Plan sets out a strategy whose long term objective is the stabilizing the full length of the right bank of the river within the study limits. The timescale for such a massive undertaking is measured in decades.

The second component is the preparation of a scheme for implementation, consisting of bank stabilization works at priority locations where the consequences of bank erosion are particularly severe and early action is called for in advance of completion of the Master Plan. It is intended that the timescale for the implementation of these priority works should be less than five years from identification.

In accordance with the study TOR, six priority locations were selected using a ranking system designed for this purpose. From this short-list of six, three sites stood out clearly from the others in terms of both economic and sociological considerations and it is these three, two of which are closely related, that have been identified by the IDA (World Bank) as being suitable subjects for financing under the River Bank Protection Project. The Priority Works placed the greater emphasis on Sirajganj, Mathurapara and Sariakandi the other three locations being Fulcharighat, Kazipur and Betil.

2.2.2 The Project Area

The recurrent breaching of the Brahmaputra Right Embankment (BRE) as a direct consequence of progressive erosion of the right bank of the river, and the Government's desire urgently to address this serious problem, were the principal reasons for the formulation of the project. It is for this reason that the boundaries of the BRTS are narrowly focused on the that strip of the right bank of the Brahmaputra River lying between the Teesta and Hurasagar confluences (see Figure 2.1).

This rather narrow focus is unsatisfactory when analyzing the river's behaviour and considering the possible impacts of intervention options. In practice for much of the study work it has been necessary to consider the river as a whole. For quantifying the benefits due to the flood embankment and evaluating any negative impacts it has been necessary to extend certain aspects of the study to cover parts of the right bank flood plain. In general however, the identification and quantification of problems to the west of the BRE and the preparation of means of addressing these problems, fall within the scope of the North-West Regional Study (FAP-2), with which close liaison has been maintained throughout.

The boundaries for this IEE are therefore considered as general limits rather than spatial areas. The northern and southern limits are defined by other by the Teesta and Hurasagar confluences with the Brahmaputra. The westward limit of the study area is strictly the present alignment of the BRE. The eastern limit extends to the east bank of the Brahmaputra, in respect to the river environment only. Any specific intervention measures on the left bank or relating directly relation to the stabilization of the numerous chars are however outside the scope of this study.

Although the Priority Works have identified three out of six important sites, and these have been the subject of a separate EIA, the six sites are important areas within the overall Master Plan, and their importance is summarized here:

The town of Sirajganj is situated 70 km upstream of the Ganges confluence and 7 km upstream of the site for the proposed Jamuna Multipurpose Bridge (JMB), and is the largest urban centre within the project area. It is essential to consolidate the existing town protection works, which in their present state are insufficiently robust to withstand severe or sustained attack by the river (Figure 2.2).

Structural measures in the reach between Mathurapara and Sariakandi are proposed in order to prevent the Brahmaputra from breaking through into the Bangali river. The minimum works necessary to achieve this purpose comprise the strengthening of the existing Kalitola Groyne and the construction of two new hard points, each linked to the realigned BRE by low earthen embankments known as cross-bars (Figure 2.3).

The fourth most important location is the rail ferry terminal of Fulcharighat. The works needed to stabilize the bank line in the immediate vicinity of the railway ghat and to provide a secure alignment for the BRE are indicated on Figure 2.4.

The works associated with stabilization of the bankline and realignment of the BRE at the remaining two sites, Betil and Kazipur, are shown in Figures 2.5 and 2.6 respectively, and should be taken as indicative of the type of works that would be appropriate.

2.3 Project Preparation

2.3.1 Background

The first systematic morphological study of the Jamuna River was undertaken by J M Coleman between June 1967 and March 1968 culminating in his paper "Brahmaputra River: Channel Processes and Sedimentation" published in 1969. He was the first to identify, from interpretation of aerial photography, that the course of the river had progressively moved westward during the recent geological period until the major avulsion that took place around the end of the 19th century. He tentatively concluded that westward migration was continuing. In addition to this important piece of deductive work he observed and documented many of the sediment transport processes that are distinctive features of the river's braided form. Although Coleman's interpretation of his observations provides much valuable material on the behaviour of the river, he was not concerned with structural intervention in any form and therefore did not focus on many of those aspects that are of primary relevance when considering bank stabilization.

The next set of studies were related to the feasibility of constructing a bridge across the Jamuna. The first field work consisted of a programme of sub-soil investigations and soil testing completed by Soiltech, with financing from JICA, in 1975. These were followed by further studies carried out during the period 1986 to 1989 by Rendell Palmer & Tritton (RPT) in association with NEDECO and Bangladesh Consultants Ltd. and included a substantial morphological study based on the analysis of river surveys data, the interpretation of maps and satellite imagery, and physical and mathematical modelling. The studies added considerably to the information available on the behaviour of the river but naturally focussed on the particular issues that were relevant to the construction of a bridge at the preferred site 7 km south of Sirajganj.

The form of the bank stabilization works for the bridge abutments have much in common with the hard-point revetments that are now being proposed as the principal structural elements for the Priority Works at Sariakandi/Mathurapara and Sirajganj. The feasibility study and associated environmental impact assessment consequently contain much of relevance in this respect.

The BRTS was set up by the Government of Bangladesh (GOB) with support from IDA in 1990 with the Bangladesh Water Development Board (BWDB) as the executing agency. The BWDB appointed Sir William Halcrow & Partners Ltd (Halcrow) in association with the Danish Hydraulic Institute (DHI), Engineering and Planning Consultants (EPC) and Design Innovations Group (DIG) to undertake the three-year study leading to the development of a master plan for stabilizing the right bank of the river and the design of specific structural measures for urgent implementation at selected priority locations. An advisory group from the Bangladesh University of Engineering and Technology (BUET) worked with the Consultants Team. The River Research Institute, with its facilities at Faridpur, undertook the physical modelling studies under the direction of the BRTS.

The need for a study of this scope and focus was recognised by the GOB because of the seriousness of the sociological and economic problems caused by the progressive erosion of the right bank, particularly the increasing frequency of destruction of lengths of the BRE, and the marginal effectiveness of the considerable investment in stabilization measures over the past decade. The principal objective was therefore to identify structural designs that will perform satisfactorily under the arduous conditions experienced on the Jamuna and that will not create any significant adverse impact. The role of the Master Plan is to ensure that works carried out at individual locations are consistent with a larger scale strategy aimed at achieving a sustainable solution to the problems of the river as a whole.

2.3.2 Problem Identification

Breaching of the BRE

The TOR place a strong emphasis on the need to find means by which the frequent breaching of the BRE can be prevented. At the start of the study, it was not clear to what extent this breaching was directly due to attack by the river and how much could be attributed to geotechnical failure and human action (public cuts). There was also very little reliable information on the magnitude of the damage and distress caused by the breaches in the embankment.

One of the first tasks that was initiated was therefore a detailed survey of the BRE, which was made with the objectives:

(a) to establish the bank height over the full length, from which the risk of overtopping could be determined at any section on the embankment.

(b) To determine how well the existing embankment has performed in terms of:

- location, length, frequency of breaches;
- causes of breaches
- relationship, if any, between original embankment geometry, soils, construction techniques, vegetative cover, use, maintenance regime, and the probability/frequency of failure.

(c) To provide the basis for drawing up guidelines for construction of embankments that will have the desired life. In particular to identify possible measures and their technical feasibility, for improved performance of the BRE in terms of flood protection, including the practicability of retirement of the embankment in different reaches.

(d) To obtain opinions from the communities living on the BRE as to the efficacy and value of the BRE and the causes of failures.

It has proved difficult to build up a reliable history of breaches. Most people's recollection becomes hazy prior to the 1988 breaches, and official records, other than the bankline sketch maps maintained by the BWDB since about 1980, are not readily available.

From the latter it is possible to estimate that the first retirements took place, possibly in the vicinity of Kazipur, around 1975, only a little over 10 years after the original construction, but that the problem started to become significant in the early 1980's. It is clear however that the problem has been becoming more serious over the past 5 years as progressively more of the BRE becomes within range of aggressive bend erosion. The number of times that different lengths of the BRE have been reconstructed is illustrated in Figure 2.7.

The survey showed that the embankment was generally in fair to good condition except for short stretches that had been constructed to a low standard as emergency measures to repair a breach. Direct undermining as a consequence of bank erosion was reported as by far the major cause of breaches and only one substantiated case of piping failure was recorded (caused by rat holes and attributed to insufficient maintenance). Public cuts occur from time to time but are confined to the most northern reach, upstream of Fulcharighat, and are associated with breaches in the Teesta section of the BRE causing flood water to build up on the landward side of the Jamuna section of the BRE. With this exception, the general perception of the farmers receiving the protection of the BRE was found to be positive and favourable. This is consistent with the common experience that public pressure is always for reconstructing a breached section of the BRE as close to the river as feasible, so that the largest number of people benefit. Unfortunately this pressure results in a higher risk of future breaches occurring.

The only options open to reduce the frequency of breaching are therefore either to construct the embankment sufficiently far back from the river, which leaves a large number of farmers unprotected, or to stabilize the bankline.

Towns and Ferryghats

Erosion of the river bank poses not only a threat to the integrity of the BRE but also results in the destruction of property and infrastructure and the disruption of ferry services. Discussions have been held with the ferry operators and samples of the users of the services, from which it is apparent that to a large extent the operators have adjusted to this situation and are well organized for the relocation of the terminal point at short notice. It has been found that the interruption of regular ferry services is less due to the dislocation caused by bank erosion than to the difficulty of maintaining a navigable route through the tortuous and constantly shifting braided channels during periods of low flow.

Bank erosion is however a very real and serious threat to towns that are now situated close to the river, although when founded they may have been several kilometres away from the bankline. Sirajganj is clearly the most important in this category but the upazila headquarters such as Sariakandi and Belkuchi are also significant.

Socio-economic

Bank erosion has a devastating impact on the lives of those whose farmland has been washed away by the river. The BRE survey results give some indication of the scale of this problem: it is estimated that around 100,000 people are squatting on the embankment as the only available place for them to find sanctuary; in addition it is estimated that at least 30,000 more are squatters in the Sirajganj municipal area. All of these people have been displaced by bank erosion. Some study of this problem was carried out jointly be the Universities of Manitoba and Jahangirnagar between 1984 and 1988 and further field work has been undertaken by the BRTS and is recorded in Annex 1 to the Master Plan Report.

The resettlement of displaced persons is a major problem in Bangladesh as a whole because of the high utilization of land. The most direct way of tackling the issue in the case of the Jamuna is to address the root cause; that is to stabilize the river bank. An ameliorating measure is to provide improved conditions for settlement on the BRE but this can never help all those in already in need, let alone those who will join the ranks of the displaced in the coming years.

River Morphology

The problem of river bank erosion has to be seen in the context of the character of the river. One of the distinctive features of a braided river is the constantly shifting pattern of channels (anabranches) and the ever-changing shape and position of sand-bars and islands. If the river banks are relatively firm then this shifting takes place in a well-defined braid belt whose limits may only alter over a period of decades. However if the properties of the bank material are broadly similar to the bed material in the river, and both are highly erodible, as is the case for the Jamuna, then the boundaries of the braid belt are liable to be also very unstable. The alarming scale of bank erosion experienced on the Jamuna is thus not attributable to any particular external influences that could be addressed but is rather an inherent characteristic of the river. Without human intervention the river course will continue to shift in a seemingly chaotic manner, the only natural constraints being the harder materials encountered when it impinges on the Meghalaya Hills or the Barind and Madhapur Tracts, which delineate the edges of the river valley.

The construction of artificial "hard points" is a means of emulating these naturally occurring constraints and in effect of stabilizing the planform of the braid belt. This principle, which is being followed for the Priority Works, is a relatively mild form of intervention in morphological terms and is unlikely to result in any significant adverse consequences. The next and far more actively interventionist step of stabilizing the planforms of the anabranches themselves is considerably more ambitious and calls for a higher order of understanding of the river processes, gleaned from monitoring the behaviour of the river and the performance of short and medium term structures, if it is to be successful and sustainable.

2.3.3 Problem Quantification

The BRTS Programme

The first 18 months of the three year programme was occupied largely with the identification of the problems followed by the execution of an extensive programme of river surveys and other primary data collection and analysis. Physical models were constructed at the RRI facilities at Faridpur and 1-D and 2-D mathematical models were set up and calibrated using the data that had been collected for this purpose. Old maps were obtained and compared with more recent maps and satellite imagery in order to elicit as much information as possible about the morphological dynamics of the river, such as bank erosion rates and the life cycle of anabranch bends. During the subsequent six months various analytical techniques were coordinated in order to quantify the magnitude of the problems and to assess alternative options for their amelioration.

Simultaneously the data necessary for the design of structural measures for bank stabilization were being collected and criteria were drawn up and material specifications prepared.

The following sections outline the scope of these varied activities.

River Surveys

A very extensive programme of river and topographical surveys were carried out, mainly directly by BRTS team members. This was the first time that river survey work had been carried out on the Jamuna River during the monsoon period and a series of logistical and technical problems had to be solved. The outcome was a comprehensive set of data covering two consecutive monsoon and dry seasons. The scope of the surveys is indicated in Table 2.1.

The data collected, covering bathymetry, directional velocity measurements and sediment concentrations and gradings, was used for the setting up and calibration of both physical and mathematical models and, after analysis, provided the basis for determining design criteria for the Priority Works.

Geotechnical Investigations

Data from previous investigations for the Jamuna Bridge were collated and some further analysis carried out to supplement the information presented in the JMB feasibility report. Based on this, a limited programme of site investigations was drawn up by the BRTS and carried out by the BWDB Groundwater Circle. This achieved the objective, which was to confirm that the bank material was broadly homogeneous, in terms of relevant properties, over the whole study reach.

Physical Modelling

In the context of the BRTS, the principal value of physical modelling as a design tool lies in the ability to simulate complex three dimensional flow conditions. The principal limitation lies in the distortions that arise from scaling effects. In general therefore, with the highly mobile bed conditions encountered in the Brahmaputra, physical modelling is seen as more useful as a detailed design aid than for applications at the planning level.

A series of physical models were set up using the RRI facilities at Faridpur over a period of 18 months. The first of these models were site specific and designed to investigate the performance of alternative arrangements of groynes and bank revetment at Sirajganj, Fulcharighat and Kazipur, in terms of scour and velocity distribution.

Subsequently it was concluded that the very rapid variation of planform and bathymetry with time made such site specific modelling only relevant where some existing structural measures were involved, such as at Sariakandi and Sirajganj. It also became apparent that although the morphological characteristics do vary along the length of the river the scale of this diversity is small in relation to the overall magnitude of uncertainties involved. It is thus legitimate to develop design criteria that are applicable to conditions that may occur at a given level of probability for any location on the right bank of the river within the study area. As knowledge of the river processes improves over time, these criteria may be refined and made more reach specific.

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Mathematical Modelling

The various forms of mathematical modelling are indispensable working tools for analyzing time dependent dynamic processes that cannot readily be addressed by less sophisticated techniques. The four main forms in which mathematical modelling has contributed to the BRTS are:

(a) 1-D hydrodynamic modelling of the Jamuna River using a refined version of the SWMC General Model, which has been used to provide design water levels for the short-term works, boundary conditions for the 2-D and physical models, water level and discharge data for the morphological studies and as a tool for assessing the hydrodynamic impact of alternative containment strategies. It has also been used to quantify the probability distribution of flow velocities below certain values as a means of determining reliable construction windows for river works.

(b) 1-D hydrodynamic modelling of the Karatoya-Bangali-Ichamati river system has been used to quantify the change in flooding regimes consequent upon breaches in the BRE.

(c) 2-D morphological modelling (which includes 2-D hydrodynamic modelling), to gain insight into and to quantify the morphological processes that are associated with scour development and bank erosion and to investigate the viability of alternative means of influencing channel development.

(d) 1-D sediment transport modelling, as a part of the assessment of the magnitude of long term channel geometry changes that are associated with the alternative levels of river containment.

The physical and mathematical modelling studies are now complete and the results have been used in developing the designs for the Priority Works. The model investigations are recorded in the Report on Model Studies (BRTS, March 1993).

Geomorphological Analysis

The objectives of the geomorphological studies are firstly to learn as much as possible about the morphological characteristics of the river from its historic behaviourial patterns and then to extrapolate this understanding to provide a basis for predicting future behaviour.

Sources of information that have been used for this study are:

(a) old maps dating back to 1765 (Rennell) and 1830 (Wilcox) which provide a broad qualitative picture of the changes in the macro planform of the river;

(b) more recent maps from 1914 onwards which can be used to quantify bankline movements and island development on a coarse time scale;

(c) satellite imagery since 1973 which when rectified and digitised provides an accurate basis for the quantification of planform changes at a timescale of between 1 and 5 years;

(d) analysis of historic river cross-sections surveyed annually since 1967, which when digitised provide information on channel geometry characteristics and trends; data quality however limit the value of these results.

(e) systematic field observations of river bank form and material characteristics.

(f) a large number of bathymetric surveys carried out by the BRTS and by BIWTA.

The most reliable information that has been obtained from this multi-faceted study concerns the average bank erosion rates, braid width variation and maximum channel depths since 1967. Less reliable but nonetheless valuable has been the data derived from analysis of bend histories.

2.3.4 Morphological Prediction

Morphological data has been analyzed with the object of deriving relationships and quantifying trends that can be used as the means of predicting the response of the river to changing conditions, either imposed through intervention or resulting from natural environmental changes.

As this work proceeded the complexity of the processes involved became yet more apparent and the likelihood of simple relationships emerging that would, for example, make it possible to predict where bank erosion was most likely to occur at a particular time remained low. The most promising way forward appears to be through the detailed analysis of bank line movements using digitised satellite image data for the period since 1973. This is however a very short time series in relation to the timescale of the variables involved and in view of the stochastic nature of the problem.

Significant progress has nonetheless been made in defining the range of values applicable to parameters that are of immediate concern for the design of sustainable and cost effective bank stabilization measures. The two most important of these being the flow velocity and the maximum depth of scour. Structural works can thus now be designed with adequate confidence that they will perform satisfactorily in this respect.

Less certain is how the planform of the river, in particular the bankline, will respond in the reaches between and upstream and downstream of structural works; however the example of Sirajganj, where bank hardening has been undertaken for at least two decades, indicates that the consequences are likely to be largely masked by the naturally shifting pattern of the river and it will be several years before any discernible trends can be identified. The most likely response, again corroborated by the Sirajganj experience, is that embayments will develop between the stabilized sections of the river in a manner that is familiar from coastline morphology. General river morphology experience and theory predicts that, provided the hardened sections are not outflanked, these embayments will in due course reach an equilibrium limit, after which they may experience cyclical accretion and erosion without further development.

Thus although there remain a large number of unknowns regarding the river processes and trends, the level of understanding is now sufficient to allow limited intervention, in the form of bank stabilization, to be undertaken without undue concern as to the consequences. Clearly in these circumstances the more passive the intervention the less the risk that unexpected undesirable knock-on effects will arise.

2.3.5 Intervention Options

A range of options from the very active approach of full confinement of the river into one or more well-defined channels to the "do-nothing" scenario have been assessed under the Master Plan study. It is apparent that while full confinement is probably technically feasible, this would involve not only a very high investment cost but also a permanent commitment to recurrent maintenance costs that would be represent a major drain on the country's resources. It is also clear that a considerably better understanding of the river dynamics is required before such a programme could be embarked upon with sufficient confidence in the outcome.

Lying between the two extremes are a number of feasible strategies based on a sensitive approach to the real problems facing the population living on the right bank of the river. It has been shown that the high cost of bank stabilization can be justified, in conventional economic terms, in certain situations where the consequences of inaction will be particularly pronounced. These locations are fortuitously located at morphologically important sections of the river and it is anticipated that stabilization of the bankline in these vicinities will represent an important contribution to stabilization of the river at the regional scale.

At the local level however, the proposed priority stabilization works will have only a limited zone of influence and outside this the pattern of cyclical bank erosion will continue unchanged until such time as further investment funds become available for an extension of the bank stabilization measures. Although the stabilization of much of the river bank is therefore not financially feasible in the short term, there is a need to reduce the frequency of breaches in the BRE that are a direct consequence of the bank erosion. This could be addressed through a combined programme, aimed at both the social and engineering issues involved, of strategic embankment retirement that is both socially acceptably and economically optimal.

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3. DESCRIPTION OF THE ENVIRONMENT

3.1 Introduction

This chapter describes the present environment of the project area and the main components that would be affected by environment change brought about by project works.

There is a need to stress the confined boundaries of the project area, which have been set by historical events, as well as the scope of the project works. The Master Plan studies have to consider the entire river, and the environmental consequences that would flow from any training strategy. The immediate concern of the project, however, must be the right bank of the Brahmaputra and the consequences of strategies on this area. Detailed assessments of the floodplain of both left and right banks are being undertaken by other FAP studies, and the BRTS provides alternative strategies that can be integrated into those considerations.

In respect of the individual works components of any strategy, the impacts will be defined by the nature and locality of these works: their scale, and the environs/sectors affected by specific project proposals. The environment under consideration will be that of the right bank in the works' localities, as well as the sectors/environs that may be affected.

In all cases of works it is essential that the effect of scale be seen in its proper perspective. The Brahmaputra is a major river, whose anabranches are large enough to be considered as individual, large rivers. The works are likely to have an impact only in a small area, although as a strategy in the long-term the cumulative effect of these works will be to provide a greater degree of security from river movement and erosion than is enjoyed by the occupants of the right bank at present.

3.2 The Physical Environment

The project area consists of the Brahmaputra-Jamuna river system, from the Brahmaputra/Teesta confluence to the Brahmaputra/Hurasagar confluence and on the right bank: the 220 km long earth embankment BRE and, as a consequence, the lands protected by the BRE (Figure 2.1).

The region slopes from the north towards the south-east, with an altitude range of 90 m to less than 10 m above sea level. There is considerable physical diversity and micro-relief which has a major impact on agriculture and the incidence of flooding. The basic morphological division is between the geology of the flood plains and the old Himalayan Piedmont Plain. The Teesta flood plain dominates the northern part of the area, whilst the southern bank of the Brahmaputra-Jamuna is developed from the flood plain of this river and the Karatoya-Bangali flood plain (Figure 3.1).

The soils can be divided into Floodplain and Terrace soils, which are described as follows (Bogra, Gaibandha and Sirajganj are used as reference districts):

FLOODPLAIN SOILS

Non-calcareous alluvium

Neutral to alkaline, raw sandy and silty alluvial deposits, usually stratified either from the surface or below the cultivated topsoil in the massive floodplain areas (young charlands), or massive in the older floodplain areas. Teesta and Brahmaputra alluvia are rich in mica and biotite (all districts)

Non-calcareous grey floodplain soils

Slightly acid to neutral, prismatic and/or blocky structured grey sandy loams to silty clay loams on young floodplain ridges, and silty clay loams to clays in basins (all districts).

Acid basin clays

Very strongly acid, grey to dark grey, heavy plastic clays (Bogra and Sirajganj).

Non-calcareous dark grey floodplain soils

Slight acid to alkaline, structured dark grey loamy soils on old floodplain ridges, and heavy clays in basins (all districts).

Non-calcareous brown floodplain soils

Slightly to strongly acid, non-calcareous brown sandy loams to clay loams, occurring in the Teesta and Brahmaputra floodplains (Bogra and Gaibandha).

TERRACE SOILS

Deep red-brown terrace soils

Slightly to strongly acid, brown to red, friable clay loams to clays, gradually integrating into a pale-brown, friable, weathered Madhupur clay substratum at a deeper depth (Bogra and Gaibandha).

Brown mottled terrace soils

Slightly acid, structured, friable clay loams to clays integrating into brown, rather friable and weathered Madhupur clay substratum (Bogra and Gaibandha).

Shallow grey terrace soils

Slightly to strongly acid, whitish-grey, porous silt loams to silty clays integrating into a mottle dark-grey, compact Madhupur clay substratum at shallow depth (Bogra and Sirajganj).

Deep grey terrace soils

Slightly to strongly acid, whitish-grey, mottled, friable and highly porous silt loams to silty clay loams, usually grading into a mottled, red/grey friable and permeable Madhupur clay substratum at deeper depth (Bogra).

Slopes in the in the Barind Tract, which has non-alluvial soils, are generally steeper and flooding is much less widespread than in most parts of the alluvial zone. Rainfall varies substantially, being highest in the north-east (eg: Rangpur) and lowest in the south-west (eg: Rajshahi). The range of rainfall is shown in Tables 3.1 and 3.2 (with Bogra representing the central point of the area).

The landscape is agricultural, dominated by rice. This extensive monoculture is broken up in places where other crops provide a local dominance. Around Sariakandi large quantities of pepper (Capsicum frutesens) are grown, and moving northward small plantations of banana (Musa sapientum) are found. However, even where other crops are grown extensively, rice fields are still the dominant feature of the landscape. The landscape is flat and featureless, broken only by clusters of rural villages. The villages are dominated by copses of trees (mainly mango (Magifera indica) and jack-fruit (Artocarpus heterophyllus)) and bamboo stands. These copses are the village forests of the area,and represent an important timber resource for the local community.

In the area of the Barind Tract there are extensive brickfields that take advantage of the large clay deposits. The major conurbations are at Betil and Shazapur in the south, Sirajganj on the Brahmaputra river, Bogra in the centre, and Gaibandha towards the north-east.

3.3 The Brahmaputra River

3.3.1 Brief History of the River

The first reliable information on the planform of the river is probably the map published by Rennell in 1765, showing a braided river hugging the Shillong hills and then taking a south-easterly alignment to follow the eastern edge of the Madhupur Forest tract, which is a slightly elevated area of more resistant Pliocene deposits. Somewhere in the vicinity of Mymensingh the river changed to a much more meandering pattern of low sinuosity.

The Brahmaputra had previously followed courses further to the north-east and had trended south-west to its 1765 course. Given this trend and its contact with the harder Madhupur material, the river was clearly poised for a major channel shift, or avulsion.

The factors initiating the shift, or the precise timescale, may never be fully known and are probably of only secondary importance in view of the long term trend. Unless the tectonic pattern changes substantially it would seem unlikely that the river would be inclined to return to its old course in the foreseeable future.

The map published by Wilcox in 1830 is considered to provide a reliable picture of the planform of the river a few years after it had effectively completed its avulsion. The river south of the avulsion point has an almost pure meandering single thread planform. whereas further north the braid pattern remains strongly pronounced. The underlying straight alignment, corresponding not only to the shortest course but also perhaps linked to the pilot channels mentioned earlier, is also noteworthy in terms of the river's macro planform evolution.

By 1914 the major meander loops had broken down through a process of multiple chute channel development to create a largely braided appearance, but with a distinctive long straight reach north of Sirajganj; it would appear that some creep westwards had already been initiated (Figure 3.2).

More modern maps based on aerial photography are available for the period 1951-57 and by this time the river had taken on a planform that is generally recognizable today.

The evolution of the river in its new course is consistent with the theory proposed by Bettes and White (1969) which, much simplified, is based on the thesis that a river has a preferred slope which it achieves by meandering if the valley slope is sufficiently flat, but if the valley slope is steeper it can only achieve stability by splitting into one or more anabranches and taking up a braided pattern. The fact that the river passed through the meandering stage and entered the braiding mode, where it has remained since is a strong indication, though not conclusive, that it is now in its preferred state.

The present day planform would appear to be approaching the fully developed pattern with major islands and their satellites. It is probable that the evolution over a timescale of the order of 30 years will consist of further widening of the braid belt as secondary islands grow, superimposed on a general tendency for the river to migrate slowly westwards.

Over a period of ten years the pattern of channels has changed beyond recognition. Short-term channel migration can be quite drastic with annual rates of bankline movement sometimes exceeding 800 m/year over a length of several kilometres. The bank erosion process is complex and extremely sensitive to small changes in planform and channel cross-section that occur as the highly mobile smaller chars (islands) migrate down the river. The development of these bends is therefore very hard to predict and the current state of knowledge permits only approximate forecasts of the location and severity of erosion.

The only place on the right bank that nett accretion has occurred during the last 30 years is south of Sirajganj although that reach has seen erosion on both banks in recent years. It is possible that the notable relative stability of the river planform south of Sirajganj since the early 1960s could be linked to the sustained efforts that have been made to harden the bank in the vicinity of the town during this period. If this incipient hard point were to fail the there could be very rapid and large scale adjustment of the planform between Sirajganj and Belkuchi.

3.3.2 River Sediment Transport

The flow in the Brahmaputra is due to Himalayan snow melt and rainfall in Assam and in northern Bangladesh, and flows are consequently highly variable and seasonal. In the dry season flows may range from 3,500 m^3/s to 6,500 m^3/s. In April the melting snows in the Himalayas and Tibetan plateau cause the flow to increase rapidly and this is then reinforced by the monsoon rainfall in Assam, resulting in peak flows that may exceed 100,000 m^3/s (100 year return period). Average recorded daily flows, between 1956 to 1988, at Bahadurabad

Transit (left bank Brahmaputra), with an catchment area of about 500,000 sq.km, varied between 20,000 m^3/s and 100,000 m^3/s.

This variation in the flow rate results in a corresponding variation in the sediment transport. Sediment transport in the river can be very high. Survey measurements between July and November 1990 gave concentrations of silt and clay between 0.05 g/l and 0.4 g/l.

Cumulative sediment transport curves for the three different sediment rating curves were derived by progressively accumulating the sediment loads for each discharge class (reported in BRTS Second Interim Report, Annex 4). The resulting curves are very similar all showing the distinctive "S" shape with a very steep, almost linear increase in cumulative sediment load for discharges between 32,500 and 50,000 m^3/s. Thus flows in a range of only 17,500 m^3/s, are responsible for transporting about 40 percent of all the sediment moved by the Brahmaputra River and the cumulative contribution of all floods greater than 50,000 m^3/s is less than about 20 percent of the total load, while that of flows greater than 70,000 m^3/s is less than 2 percent. These results highlight that high, in bank flows between 25,000 and 50,000 m^3/s have a disproportionate impact on channel form since they transport about half of the total load.

The long profile of the Brahmaputra River in the study reach has been investigated using the records for the surveyed, monumented cross-sections established by the BWDB. Preliminary examination of the data indicated that within reaches there may be nett erosion or deposition occurring over the period 1965 to 1989, while in terms of overall change for the full length of the river there is no discernible trend.

The sediment that is produced through the process of bank erosion is treated by the river in one of three ways:

(a) transported out to the Bay of Bengal;

(b) carried some distance before being deposited in a mobile bed form;

(c) transported some distance before being deposited as long- term storage in an upper level meta-stable char.

If the river is in dynamic equilibrium as suggested by the specific gauge analysis and the interpretation of the long section data, then it would be expected that the bed and suspended sand load entering at the head of the river reach should be equal to that leaving at the bottom of the reach, when measured over a reasonable period of time.

A pilot exercise was carried out using data from the 1986 and 1987 imagery derived maps contained in the JMBA Report for the reach between sections J-11-7 and J-5-6 (a distance of 76 km) and the measurements of sediment load at Bahadurabad made during the interval (BRTS Final Report, Annex 2).

These results would indicate that bank erosion in the study reach may add of the order of 15 to 30 percent to the wash load coming in from upstream, depending on the assumptions made in the analysis, but that the sand fraction is probably in balance with as much material being deposited in the form of char building/bank accretion as is yielded from bank erosion.

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The inference is that a large proportion of bank silt yield follows is transported directly to the Bay of Bengal but the sand yield follows relatively short travel distances from bank source to either the mobile bed forms or the meta-stable chars.

These results are based on only part of the river over one year and must therefore be interpreted with extreme caution they demonstrate the potential value of this form of calculation. Recognition of the intimate link between bank erosion and char growth, and of the pivotal role of the sand size fraction in both processes have important implications for predicting the river's response to bank stabilization and river training.

3.3.3 Chars

Perhaps the most prominent features of a braided river are the braid bars (chars) which are responsible for the river's characteristic multi-channel cross-section, very high width/depth ratio, braided planform and shifting nature.

A visual examination was made of the water surface elevation corresponding to dominant discharge in relation to char top elevations at all river cross-sections surveyed in 1988/89. Water surface elevations were taken from a preliminary run of the BRTS version of the Mike 11 1-D General Model, for a flow of 38,000 m^3/s. The results are shown in Figure 3.3.

Two distinct char top levels may be discerned along much of the course of the river. A typical cross-section shows a higher char at close to bankfull elevation and lower chars at a little less than dominant flow level. Practically in all cases, the dominant flow inundates the lower chars but does not overtop the upper chars. On this basis, dominant flow may be seen to corresponds to char topping discharge of the lower chars. For the upper chars to be inundated requires "bankfull" flow of perhaps 60,000 m^3/s, compared to the JMB study estimate of 45,000 m^3/s.

In this respect, the lower chars are "adjusted" to the present dominant flow and are contemporary morphological features. The upper chars, or islands, divide the flow even at dominant discharge and their tops are inactive except during high magnitude, out-of-bank flow events.

Comparing the cross-sections with the March 1989 SPOT imagery showed a very good correlation between the upper chars and the mature vegetated areas; providing confidence in the general reliability of the cross-sectional data.

3.3.4 Water Quality

The dominant features of the project area are the morphological and hydraulic characteristics of the Brahmaputra. There is less information over the chemical quality of the river's water. reflecting the relatively few sources of toxic or organic wastes generated from industry and urban centres. Agrochemical pollution though possible from improved agriculture is undefined: though continuous dilution both seasonally and from tributaries must reduce this toxic loading.

The environmental control of polluting discharges needs to addressed by other investigations in the agricultural areas behind the BRE. Earlier studies on Sirajganj, which is the largest urban centre, do not indicate significant pollution from this source.

The cloth industry in the Betil area may provide some small amount of pollution from dyes and washing water, but this is insignificant outside of a small localized area. The other main centre of potential pollution would be at Fulcharighat from fuel oil and engineering waste. This is the major rail-ferry terminal in the project area. Nevertheless, the loading of such pollutants is small in relation to the receiving waters. Some localized bankside surface pollution is evident, but no data is available to suggest more widespread chemical contamination of the river water.

These urban and commercial centres would provide a degree of pollution from runoff, and be associated with water-related disease where sanitation is either lacking or is flooded out. This problem should not be seen as affecting long term river water quality, but be addressed by sanitation improvements in affected areas.

There is little data on the effect of pollution on water quality. Table 3.3 gives data for selected right bank locations collected during the study. This indicates a generally acceptable quality for river water, although there are indications of increased iron concentrations in some samples. The need for continuous water quality data is highlighted by the results of this `spot' analysis. The later set of samples (Table 3.4) do not exhibit these higher iron concentrations.

3.3.5 Impact of the River on the Environment

The influence of the Brahmaputra river on the environment is the extensive bank erosion (a year-round process) and the extensive flooding during the monsoon (in the absence of flood protection). In the river itself the large sand bars can become relatively stable for periods, but invariably represent mobile structures.

River-bank erosion provides the main threat to embankments and provides a major hazard for towns located along the Brahmaputra river such as Sirajganj. Within the study reach, the focus historically has been on the stabilization of the river bank in areas where erosion results in the loss of agricultural land or in threatening property and infrastructure. Where the stabilization results in some accretion then this is an added benefit.

Although the maintenance of navigation channels requires a regular programme of dredging, the stabilization of such channels has not to date been addressed by structural measures, the preferred option being to relocate the ferry terminal when the dredging requirements become excessive. These relocation costs are relatively low and through experience the task can be undertaken with little disruption to the flow of traffic.

3.4 The Brahmaputra Right Embankment (BRE)

The construction of the BRE started in 1957 between Belka and Fulchari, the remainder, between Kaunia and Bara, being constructed during the period 1963 - 1968. The purpose of the BRE - to ensure flood protection on the right bank floodplain of the Brahmaputra river - has not been fully realised due to the constant erosion of the banks of the river and breaching of the BRE. By 1977, some 40 km of the 220 km long BRE had been retired.

The progressive retirement of the BRE demonstrates of the seriousness of the natural bank erosion of the Brahmaputra River. Some retired sections are now located about 2 km inland from the alignment of the original embankment, which was built at a distance of 1.6 to 2.4 km from the 1968 river bank.

The Brahmaputra Right Embankment (BRE) has breached several times, allowing serious flooding to occur periodically on adjoining protected land. Public cuts in the embankments have also been made, either where people living on the river side of an embankment seek to relieve high flood levels threatening their homesteads or land (by releasing water into adjoining protected land) and where run-off from heavy rainfall accumulates on the inside of an embankment and submerges farmers' crops (demanding immediate action).

In the years following the construction of the BRE, additional measures have been taken at various points, in the attempt to maintain the security of the flood defence. These measures have included:

- cross-bars and groynes, with the aim of creating zones of low velocity flow immediately adjacent to the bank

- bank revetment, with the aim of hardening the bank sufficiently that it could withstand the near bank velocities.

A considerable amount of investment has been made in bank stabilization measures over the past 20 years but the only example of relative success is the Sirajganj town protection, consisting primarily of multiple layers of randomly dumped concrete cubes. The protection of Sariakandi by means of the Kalitola groyne may be considered a partial success in that the erosion was controlled for long enough to see the main point of attack move further downstream. The survival of Kalitola is probably attributable to the fact that the most severe conditions did not develop at this location before the eroding bend died naturally due to a transfer of anabranch flow. If conditions such as experienced at Fulcharighat or Kazipur had developed it is unlikely that the groyne would have survived.

3.5 The Human Environment

3.5.1 General

The population density in the region approaches 1000 per sq.km in some areas, with a rural population of about 85 percent in the study area. The average farm size has been declining over the last 20 years and the number of landless households is increasing. Many of the people have been displaced by the continuing erosion of the river, and they remain homeless through the lack of available resettlement land under control of the Government and local authorities.

Agriculture remains the main source of new employment in rural areas, both directly and indirectly through linkages to input supply and processing industries. FCD/FCDI schemes have provided increased yields to those rural families that own land, and there is employment as farm workers for some displaced persons. However, the trend is for increasing unemployment, with a consequent drift to the towns and an increase in poverty levels in a section of the community.

3.5.2 Social Impact of River Erosion and Flood

The social consequences of river bank erosion and flooding from a breach in the BRE can be reflected in terms of the number of people likely to be displaced over the next five years (Table 1.2). While population data are useful for comparative purposes, there is the danger of understating the dire consequences of river bank erosion and severe flooding for a very substantial number of poor families. The loss of land and livelihood, as well as physical, emotional and financial costs of displacement, which renders the vast majority of the displaced population destitute, cannot be adequately assessed in a quantitative manner.

There are, at present, no government programmes to resettle, rehabilitate or even assist these displaced families in finding alternative sources of income, consequently they remain destitute and depend almost entirely on hiring out their labour (mainly to local farmers). It is evident that both a firm political policy and a programme are urgently required for the rehabilitation of these displaced families in order to address this chronic problem.

3.5.3 Reaction to the BRE

The views of the local communities with respect to the improvements in quality of life offered by FCD/FCDI schemes is very important, if the full value of the schemes is to be realised. Under the BRTS the views of leaders, groups and individuals as to the value of the BRE to their communities and themselves have been sought directly.

The primary purpose of the BRE Inventory Survey, covering the full length of the embankment, was to assess the condition of the structure; however the opportunity was taken to elicit the views of local groups at each of 129 reference sections. The persons interviewed were mainly those living along the embankment crest, and most would fall into the category of landless squatters who had migrated to the BRE for reason of safety.

The responses were consolidated for each section and provide some insight into the opinion of this group of people. Not only was a positive/ negative response to the BRE sought, but also any comment on its possible improvement. Only at three sections was there a general consensus that the BRE was not desirable. These sections were centred around Mathurapara/ Chandanbaisa, where the BRE is under active erosion and multiple breaching had recently occurred.

The other sections provided views that the BRE was "a good thing/doing its job/reliable". Some 80 percent of the people offered advice on improvements of the BRE covering aspects including increase in height, better compaction, local retirement, width improvements, maintenance and overall improved construction standards.

Specific consultation visits were made in the course of the study (July 1991) to important districts along the BRE. In these visits the views of the local authorities, influential persons and villagers were determined through open discussion. These views were not confined to the BRE, but to the quality of life that existed within the protected areas, and the consequences experienced as a result of breaches in some areas.

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The main issues raised in these visits are summarised below:

Kazipur

At the time of the visit the town was suffering from severe river bank erosion. Also visited were some chars, most of which were about to be inundated, with the people living there looking for shelters for themselves and livestock. Discussions were held with the local union Parishad chairman, teachers, farmers, shopkeeper and other local people.

The general opinion was that the BRE retirements do not last long (according to their observations) due to weak construction, and that the embankments should be raised so that flood water could not flow over during high flood period (although there is no evidence of failures due to overtopping).

Though fish production declined, crop production increased by almost double due to flood protection, which allowed production of three crops in a year. The embankments serve as a temporary shelter for flood affected people, besides providing a good road communication system in the rural areas when most of the land remains under water.

Though fish capture would have been higher had there been no flood protection devices, the people acknowledged that flood protection brought immense benefits to them. Prior to the 1964 embankment, extensive damage in all sectors used to occur; the embankment of 1964 (and retirement of 1984) were certainly perceived to be of much benefit to them.

Their desire was for a fairly stable flood protection structure which would last for a considerable period (say about 15 - 20 years). Frequent breaches, especially at uncertain moments in time were a disaster to the people living in the areas affected. They are convinced that fairly large areas of Kazipur, Sirajganj and Bogra have benefitted substantially from the flood protection at Kazipur.

Betil

Betil is an important locality downstream of Sirajganj, famous for its weaving industry. No permanent construction has been seen, however, which may be ascribed to the threat from river bank erosion. Betil has experienced serious bank erosion for many years and the flood embankment has been shifted in stages quite a distance westward. Discussions were held with the local chairman of the union parishad, teachers, a doctor, weavers, farmers and others.

The local chairman and some aged people (who were born and brought up there) reported that in the past the river bank was about 10-15 km eastward from the present position, the maximum river width was only 4-6 km during the monsoon period and river was quite deep enough for navigation all the year round, needing no dredging at all.

The people expressed a lack of awareness of government plans for protection against erosion. Erosion is gradually increasing, reducing their land holding. They are confident that the land they have lost (and are losing) to river bank erosion will never be recovered in their lifetime, or in the next generation.

When a part of the original embankment of 1964 eroded, a retirement was built behind the breaches, and then another retirement had to be built against new breaching. This successive process of retirement resulted in a substantial loss of protected land every year. The view was that had the embankments or retirement been stable this loss of land, homesteads, etc. would have been avoided.

Construction of successive BRE retirements is deplored by the local people, as they are gradually losing their land; accordingly they desire permanent flood protection which would last for at least 10-15 years.

Crop production has increased to almost double. Irrigation and introduction of HYV (encouraged by flood protection) has contributed greatly to this increase.

When "water logging" takes place, due to heavy rainfall inside the embankment, causing damage to crops, the people have been known to cut the embankment. They indicated that had there been any pumping out process or appropriately located sluice gate to drain out water, crops could be saved. Another reason given for cutting the embankment is to express their grievances, because they are not being compensated properly or in due time for the land acquired for embankments or retirements.

Fulcharighat

During discussion with the chairman of the gazari union parishad, and local people of different trades, it was reported that about 70 percent of this union is inundated by river flood every year, resulting in a heavy resettlement problem during the monsoon period. Refugees take temporary shelter on the high land near the retired embankment and also in the char areas which are not flooded. Frequent shifting of Fulchari railway terminal due to erosion has caused dislocation of railway communications between the eastern and western part of the country.

Crops could not be raised effectively when flood water receded, and the number of flood affected people is increasing every year. They considered that immediate flood protection as at Sirajganj (by building a hard-point or groyne) was necessary. The public also reported loss of life due to water borne disease when the flood water receded. Sanitation is poor, and drinking water is abstracted from a shallow aquifer about 12-15 m deep. This water is suspected of being contaminated with pathogenic bacteria due seepage of polluted surface water.

Conclusion

While these reports contain a certain degree of hyperbole and some clear inconsistencies with established facts these are common features of such open consultation meetings. The general picture that emerges is that at all levels in the rural society the BRE is perceived by the large majority as providing clear net benefits to the community as a whole. The desire is that ways be found to improve the performance of the BRE so that confidence in its function may be enhanced. This improved performance is commonly linked in people's minds with stabilization of the river bank and the consequent reduction in loss of arable land and homesteads. There is, however, generally very little comprehension of the magnitude of the task and the scale of the costs involved.

3.6 **Agriculture**

3.6.1 The Rice Crops

Rice in the region generally falls into three categories: local varieties, local improved varieties (pajam), and high-yielding varieties (HYV). The first crop is planted between mid-February and early September and is transplanted Boro rice. The spring rice, Aus, is usually broadcast (B Aus) in March/April, though occasionally is transplanted (T Aus). The summer crop is Aman rice. Fixed height Aman (local and HYV) is transplanted in July/August (T Aman). Floating Aman can be broadcast (alone or mixed with Aus) in March/April, or transplanted (after Boro) in June. Floating Aman is capable of growing to survive flood waters.

3.6.2 Effect of Breaches in the BRE on Rice Crops

The direct consequence of flooding due to a breach of the BRE is the loss of at least one crop. Much depends on the severity of the breach, the duration of flood and the height of inundation. Crops are particularly vulnerable to flood damage at the times shown in Table 3.5. The cumulative effect of an open breach is most damaging, as it is very difficult successfully to cultivate a monsoon crop in subsequent years when the area is exposed to high velocity flood water and deep inundation.

Locally, heavy deposition of sand occurs at the time of the breach which initially renders the land unsuitable for crop production in the following Rabi season. In subsequent years farmers attempt to grow Boro rice or other Rabi crops but productivity is low. Increasingly, these areas are being planted with sugar cane, which can withstand high levels of inundation, but with lower yields.

The scale of the areas severely affected by a breach in the BRE varies between locations and is related to the length of the breach, local topography and the proximity of a river channel. Information based on the interpretation of aerial photographs, coupled with field visits to breach locations, indicates that a breach typically devastates an area extending to approximately 3.5 to 4 sq.km (400 ha).

In addition to the specific crop losses resulting from a breach in the BRE, the other main area of concern is the effect on future cropping systems and agricultural development within the BRE protected area. If a breach remains open farmers will not tolerate annual crop losses from repeated flooding but adjust their cropping patterns in response to the changes in flood regimes; this reduces the risk of total crop failure but depresses average yields.

Most of the agricultural benefits from flood control have primarily resulted from an expansion of HYV T Aman during the kharif season replacing either B Aman or a mixture of B Aus and B Aman. With continued exposure to flooding from a breach, this development will be reversed. The Rapid Rural Appraisal (RRA) of Kazipur (FAP-12) found evidence for this change in cropping systems resulting from a frequent breaching of the BRE. The Kazipur RRA concluded that:

> "The BRE did successfully change the B Aus/Jute-B Aman-minor Rabi cropping pattern into a B Aus/Jute-T Aman pattern and then into irrigated HYV Boro-HYV T Aman over

a large area. There has been a 50 percent increase in T Aman production and about a 10 percent increase is total monsoon rice production due to the project.

The embankment breaches since 1984 have again caused uncertain and serious flooding in 3 out of every 5 years, making T Aman production vulnerable to flood damage. Consequently both acreage and output of T Aman has declined due to flooding caused by breaches of the BRE".

3.6.3 Livestock

In general, flood control projects have had an adverse impact on livestock feed resources through reducing fallow and grazing land, and by switching to short-strawed HYV of rice. (HYV straw also has much lower levels of digestibility and palatability than local varieties).

This is said to have led to a deterioration in livestock health and productivity, as well as a marked decline in livestock numbers; particularly cattle which are reported to have decreased by 25 percent to 40 percent over the past ten years in certain parts of the BRE protected areas. Coupled with the increase in cropping intensity, this decline has created a noticeable shortage of draft power, especially for small and marginal farmers.

The North-West Regional Study (FAP-2) indicated that draft animals are reducing both in numbers and strength; and that increased fodder production could only take place at the expense of human food production, thus making the availability of good quality cattle feed unlikely.

No accurate statistics are available on livestock losses. Discussion with farmers during the field surveys, reveal that significant livestock losses were experienced in the areas severely affected by a breach in the BRE. However, flooding from a breach in the BRE is not likely to make a significant contribution to livestock feed resources, and so will have neither a negative nor positive impact on future livestock populations and productivity. With regard to the impact on future livestock development within the BRE protected area, it has been assumed that breaches in the BRE would not have a significant overall effect.

3.7 Fisheries

The fishery of the Brahmaputra river is the main biological focus in the project area. The fishery contains both migratory fish and resident species. The floodplain is essential for stock recruitment.

Spawning occurs slightly in advance of the monsoon, and the non-mobile spawn are carried deep into the floodplain by the early monsoon floods. Here the spawn and fingerlings grow within the beel depressions, surviving through the dry seasons in the deeper, perennial ponds, tanks and baors.

On reaching maturity the fish return to the river, usually at the end of the monsoon, by active swimming with the receding floods towards the rivers. Migratory species will move downstream, but in all cases the cycle can now start again with the sexually mature adults.

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The development of flood embankments restricts the dispersal of spawn in the early flood. Deep, mobile rivers in flood are unsuitable for the growth of fingerlings and the mortalities, resultant from the denial of shallow, protective and nutrient rich waters, are high. These mortalities represent a loss of future breeding stock, and, with every year of floodplain denial, a cumulative reduction in sustainable fish stocks occurs. The logical end of such a reduction in stocks will be the eradication of species from a particular river system.

Capture fisheries has been identified as one of the sectors worst affected by flood control projects. The main negative effects of FCD/FCDI schemes on fish production can be summarized as follows:

construction of flood control embankments reduces the area of perennial beels and floodplain available for fish nursery and feeding grounds, thereby reducing the overall fish production potential

construction of regulators and cross dams prevents migration of fish to and from breeding grounds, resulting in reduced stock of migratory species (principally higher value carp)

increased use of chemical fertilizers and pesticides, associated with the adoption of HYV leads to the pollution of natural water bodies and to higher fish mortality rates

the reduced areas of open water within flood protected areas has severely restricted subsistence fishing, with detrimental consequences on the income and nutrition of the poorest section of the community

reduced fish stocks and lower catch rates have endangered the livelihood of fisherman, many of when have been forced to migrate from the protected areas in search of alternative employment.

Certainly anecdotal evidence from older fishermen along the Brahmaputra river would circumstantially support the view that the BRE has produced effects as summarized above. This is not surprising, and demonstrates a conflict that exists in the country: the protection of flood plain for crop production, or the 'living with floods' concept that favours fisheries at the expense of improved crop yields.

Within the Brahmaputra floodplain, the BRE has contributed significantly to such a reduction in fish stocks. The capture fisheries in the Brahmaputra river have suffered seriously over the past decade. Annual fish catches since 1983 have dropped by over 50% in practically all stations (Figure 3.4). The data for Bogra and Tangail (left bank) districts show very similar declines, and the fishery can be considered to be operating at barely subsistence level at present.

There is no simple solution to the problems posed by this conflict. The solution will depend on the political policy of the country, as well as harmonization of the social and economic aspirations of the rural communities that benefit from FCD/FCDI and the fishing communities that do not.

Some improvements could be made in floodplain fisheries using stock fish; but whilst stocks are reliant on wild catches of spawn and juveniles, without natural recruitment these will continue to diminish. In this area however, two actions to encourage pond fisheries are worth considering:

a reduction in the risk of losses of fish pond stocks due to flooding, which could encourage a more rapid development of fish farming;

an improvement in the prospective returns from fish production in other water bodies, such as borrow pits.

Some FAP projects have considered the use of fish passes in embankments, and controlled flooding, to improve floodplain fisheries, and hence river fisheries. There may be value in considering pilot schemes for such concepts in future bank stabilization works. Preliminary observations during the pre-/post-monsoon in 1992, showed that sluice management (south of Sirajganj) appeared to allow fish passage freely. It is too early to draw much hope from these observations, particularly as 1992 had a relatively 'dry' monsoon, and the sluice operation may have been atypical.

One specialized area of river fishing, the fish-spawn fishery, does continue on a commercial scale, though here again at diminished levels, due to lower stocks. The reduction in total catch for the collection districts on the Right Bank Brahmaputra (Tangail on the left bank has a very small collection centre) is given below:

Right Bank Districts Annual Fish-spawn Catch (kg)

1984	1985	1986	1987	1988	1989
15,437	11,128	5,321	12,762	6,957	9,075

The fish-spawn fishery represents the most important sector of the commercial fishery remaining on the river. Catches are usually made in the months May-July, at the start of the monsoon when the fish spawn mass drifts downstream on the flood waters. Sirajganj has the largest collection centre for this fishery on the river (Figure 3.5), and the fish-spawn catch makes a small, seasonal, but substantial input into the overall fishery income of this district.

The present situation with regard to the river fishery in general is one of a declining sector, with reliance on artisanal fisheries, and a reducing fish-spawn catch.

3.8 Water Resources

Much of the water supply in the areas protected by the BRE are from groundwater sources, both from shallow aquifers and deep tube wells (DTW). However most rural families still use surface waters for bathing and washing, and even for drinking water in many cases. The relatively poor sanitation facilities (pit latrines), and cases of open defecation and animal faeces, can cause contamination of the shallow aquifer and surface waters as floods recede.

For communities along the bank of the Brahmaputra river, the river provides bathing and washing areas. In many of the villages, and along the BRE where squatter communities have developed, both local authorities and agencies such as UNICEF have provide village hand pumps for supply.

Most of the area of the Brahmaputra floodplain, and the northern area of the Teesta floodplain, appear to receive adequate recharge under present conditions. There is some concern about aquifer recharge in the southern areas of the region, especially in a belt north of the Ganges (Figure 3.6).

4. THE MASTER PLAN STRATEGIES

4.1 Introduction

The Master Plan fundamentally is a detailed strategy for the containment of the Brahmaputra River and the improved performance of flood control measures on the right bank flood plain, with a time frame that is flexible enough to accommodate financing constraints. It covers both structural and non-structural aspects, supported by an indicative draft plan showing the scope of structural works involved as perceived at this stage, and guidelines that will allow planners to respond to the situation as it develops. In this form the plan can be continuously upgraded in response to the changes in the river pattern and as more data becomes available.

It is important to realize that the Master Plan has two primary components which are dependent on the time frame of implementation. The components are:

- the stabilization of the river channel

- the improvement of flood embankment performance.

Both components need to be put in place, but as stabilization measures proceed the requirements for planned retirement of flood embankments will be reduced. Thus, although each component serves to address a different issue, the components are intrinsically linked, and the final form of the strategy will depend on the actual time frame allocated for the implementation of any component.

4.2 Description of the River Behaviour

Going back in time from 1973, the quality of data becomes progressively sparser and of lower quality, but it is sufficient to provide a clear general picture of the progression of the river from a meandering channel soon after the late 18th century avulsion to the highly braided pattern today. There is strong circumstantial and deterministic evidence that this progression is not yet complete and that in the absence of intervention the degree of braiding is likely to become more intense, particularly south of Sirajganj.

The planform history of the river since 1973 when satellite coverage began is now known in considerable detail. The comprehensive processing of satellite imagery by ISPAN under the FAP-19 programme has produced a database which has provided a highly reliable source on which to base quantitative analyses in support of earlier hypotheses. The results from the analysis of these recently available data have not radically changed the overall picture but they have provided a greater level of detail and thereby much improved confidence in the tentative inferences that had been drawn.

With a greater understanding of the processes controlling sediment transport and the conditions that lead to deep scour, it is now possible to estimate the probability of occurrence and severity of such scour, with and without structural intervention. The relationship between bank erosion and char building has been investigated both as a further aid to predicting future behaviour and in order to assess the possible consequences of bank stabilization.

The combination of morphological studies and mathematical and physical modelling has led to a good overall understanding of the river behavior and this has provided a sound basis for the planning of bank stabilization measures. What appeared at the outset to be a system with little if any discernible pattern can now be seen as a complex interaction of stochastic processes that in combination produce a high degree of variability but underlying which there is a considerable degree of consistency.

It is not possible to predict with certainty exactly where and at what rate bank erosion will take place, even next year, but it is possible to assign probability values to these parameters that will be specific to particular reaches of the river. Moreover the characteristics of aggressive bends, those that are responsible for the relative uncommon but very destructive high rates of bank erosion, are now known and some degree of early warning is possible.

It is expected that the river will tend to become more braided, particularly south of Sirajganj. This tendency is closely linked to the overall widening of the river braid belt (outer bank to outer bank) and the steady growth of charlands. However the wetted channel width at bankfull does not appear to have changed significantly except in situations where multiple channels have developed from a single channel. Widening is thus seen as primarily a function of char growth but linked also to an increase in braiding.

Superimposed on this widening tendency there has over the past 35 years been a measurable net westward movement of the river as a whole demonstrated by the greater net erosion of the right bank compared with the left bank. Morphologically this is reflected in the very much more clearly defined right bankline and the numerous attached chars on the left bank, a feature that is virtually absent on the right bank below Fulcharighat. Although this trend has been weaker during the past 20 years than during the previous 15 years, it remains distinct and in the absence of contradictory evidence it is prudent to assume that and it will continue for the foreseeable future.

4.3 A Set of Guidelines that can be used to Anticipate the Behaviour of the River

Analysis of bankline movement since 1973 and extrapolation back to 1956 has provided a good basis for predicting future bankline retreat in terms of mean annual rate and duration. Plots of actual movement at 2 km intervals down the river show repetitive, though not clearly cyclical, patterns of quiescent periods followed often by above average rates of erosion. From analysis of this data it has been possible to estimate the probability of a certain erosion rate lasting for more than a certain period. Thus it is found that it is very rare for rates of more than 400 m/y to be sustained for more than two years. Conversely quiescent periods rarely last for more than 10 years. By looking at the past history of a particular reach it is thus possible, within broad confidence limits, to make some forecast of the probable bankline movement during the coming five years. For longer periods of time the average rates provide a better basis for prediction. The Master Plan envisages the use of this type of predictive procedure can be followed and applied by anyone with a reasonable understanding of river morphology.

4.4 The Strategy Options

This section summarizes the river training and BRE retirement strategies that have been considered for the Master Plan. Different aspects of similar strategies have been considered in other volumes of this report, principally the sociological aspects in Annex 1 and the economic aspects in Annex 2.

The possible timescale of implementation and the consequences of this scheduling are considered later.

Option 1: the 'no change' strategy

The simplest strategy available is to maintain the status quo. Under this arrangement the form of intervention would be largely reactive, either by hasty retirement over short sections immediately prior to a threatened breach, or even after the occurrence of a breach. Either way, the planning horizon for this strategy is extremely short term, and there is no long term consideration of confinement of the river channel or bank stabilization.

Option 2: planned retirement of the BRE

The second option would be to plan the retirement of the BRE in advance of any possible breach. This strategy is still effective only in localized areas, but nevertheless provides a pro-active solution to the flood protection problem (though it does not address bank stabilization). This second option uses the predictive procedures (section 4.3) as a 'triggering mechanism' to define what lengths of the BRE need to be retired. The set back distance would be selected so as to provide an optimal level of security against breaching. Determination of the set back distance might vary, using a general formula of E_d + 200m, where E_d is the expected bank retreat over a 4 year period or a percentage thereof depending on the extent of the anticipated erosion and the confidence with which it can be predicted. The planning horizon of 4 years is taken as this is the minimum time necessary to observe and confirm an erosion hazard and to complete the necessary retirement of the BRE.

A more permanent variant of the second option would be strategically to retire the BRE to a distance such that a breach would not be expected within 30 years. Such a strategic retirement would need set back distances of between 2-5 km from the present alignment.

Option 3: beneficial 'hard points'

The third option considers both components of the Master Plan, and introduces the concept of bank stabilization. In this option, bank stabilization by means of 'hard-points' and revetments would be undertaken where benefits were clear. Additionally planned retirements of the BRE (as under option 2) would be undertaken, and the BRE rehabilitated where necessary. This strategy has an advantage in that the works can be phased progressively as both the physical condition of the river and finances dictate.

This option has effectively been put in place, as an initial step, by the Priority Works. The works that are proposed at Sirajganj and Sariakandi/Mathurapara are essential (at this time) to safeguard the populations in these areas from further bank erosion and flooding. The 'hard point' that is proposed ar Sariakandi will be the first step in a sequence to stabilize the right bank of the river.

The sequence put in place by the Priority Works will continue through the execution of follow-on works at the two sites, and then by completion of hard points as shown in figures 2.2 - 2.6.

At the same time, the BRE will be retired as determined by events at the time of construction, and in accordance with the predictive system, to provide flood protection.

Option 4: strategic bank stabilization

This option considers that the 'hard point' concept be implemented, regardless of the immediate benefits at any area (but still prioritizing construction) and that the right bank be completely stabilized. In addition there will be a need for retirement of the BRE to ensure flood protection until bank stabilization is completed for the entire length of the study reach.

This option would require a committed programme of development, and would be executed over the longest time frame. However, it offers the most secure longterm solution to the flood protection problem. For the strategy to be fully effective as a river training as opposed to a bank protection strategy, it needs to be integrated with the strategies defined for the left bank of the Brahmaputra River.

4.5 The Strategy Timetable

Whatever strategy is finally chosen, the optimal concept is to ensure that the Brahmaputra River is fully stabilized. This requires consideration of both banks and of the stable island chars. Sequentially, the programme could be expected to follow the following timetable (although exact time limits cannot be placed on the programme at present):

- stabilization of the right bank of the river
- stabilization of the right and left banks of the river at present bankfull levels
- stabilization of the islands to produce a braided channel, but with the overall bankfull width unchanged
- establish a single meandering channel within which some multiple thalweg formation could be accommodated

The possible planform of the last components of this timetable are shown in Figures 4.1 and 4.2.

This programme of river training will require a considerable number of years to implement. At each stage in the possible development of the continuing strategy it is important that a detailed environmental impact assessment be executed. It is likely that the cumulative changes produced by each stage in the programme will show up strongly as major impacts (both positive and negative) in the later stages of the programme.

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5. INITIAL ENVIRONMENTAL EVALUATION

5.1 Introduction

This environmental evaluation is not a substitute for a full environmental impact assessment, which will be needed at every stage of strategy development.

The environmental assessment has identified the important environment factors within the project area and, with respect to these, assessed the possible impacts of each Master Plan strategic option. A discussion and outline of the system applied, and the criteria chosen, together with the scoring system are given in Appendix A.

Evaluation of the impacts was set against a baseline situation, taken as the present regime of flood protection as provided by the BRE.

For each of the environmental components a score was determined, which provided a measure of the benefit/dis-benefit. To ensure that the evaluation complied with the FPCO multi-criteria analysis scale of $\pm$ 5 (in accordance with the May 1992 FPCO Environmental Guidelines), a conversion was derived by which the project assessment score could be confidently translated to the $\pm$ 5 scale.

5.2 Environmental Assessment Components

5.2.1 Primary Environmental Elements

The four primary environmental elements are defined as follows:

PHYSICAL/CHEMICAL

Covering all physical and chemical aspects of the environment, including finite (non-biological) natural resources, and degradation of the physical environment by pollution.

Within this assessment two important, common aspects of this element have been identified, both relating land loss. The strategies are too long term, and passive, to have major impacts on water quality.

BIOLOGICAL/ECOLOGICAL

Covering all biological aspects of the environment, including renewable natural resources, conservation of bio-diversity, species interactions, and pollution of the biosphere.

Two resources, fisheries and timber, are important within the strategies, and these have been identified in four components.

SOCIOLOGICAL/CULTURAL

Covering all human aspects of the environment, including social issues affecting individuals and communities, together with cultural aspects, including conservation of heritage, and human development.

Security of homesteads, changes in livelihood, nutrition, and artisanal transport are components in this element that are assessed. These provide in a broad measure of the social impacts of each strategy. Additionally, impacts on important local social centres are considered.

ECONOMIC/OPERATIONAL

To identify qualitatively the economic consequences of environmental change, both temporary and permanent, as well as the complexities of project management, within the context of the project activities.

The strategies all involve passive constructions, but there are components of operation and maintenance, as well as inter-institutional linkages, that will affect the success of any option.

5.2.2 Important Environmental Components

Within these four primary elements the following issues have been identified as the important environmental components (IEC) for this environmental assessment.

PHYSICAL/CHEMICAL

PC1 River flood protection

This component forms the main requirement of the project, and an on-going condition of considerable importance.

PC2 Land loss to embankments and borrow pits

This component takes account of the impact on productive land of strategies that rely on embankments as a major form of intervention.

BIOLOGICAL/ECOLOGICAL

BE1 Floodplain fish migration

This component assess the impact of interventions in preventing the effective use of the floodplain for natural growth within the life-cycle of the river fishes.

BE2 Spawn-fish capture

Although localized, this form of fishery is very important to the economy of these localities, and hence is a major fishery component.

BE3 River fishery

Though linked to the production of the floodplain fishery, this fishery forms the main remaining artisanal exploitation of the fish resources of the river, and is directly affected by some forms of intervention.

BE4 Village forest groves

These resources are indirectly linked to forms of intervention by the continuing use of timber for fueling brick kilns. Mitigation is possible in some cases, but the fragility of the resource requires its inclusion in any impact assessment.

SOCIOLOGICAL/CULTURAL

SC1 Security of homesteads

This component is linked to the impacts brought about by erosion along the river, and flooding in and adjacent to breaches in the river defenses, as well as the displacement of families (even temporary) brought about by construction.

SC2 Change in agricultural livelihood

This component seeks to assess the overall impact on agricultural development brought about by individual strategies. It is not a measure of the negative impacts due to any breach or flood event.

SC3 Change in fishery livelihood

This component considers fisheries in a similar manner to the preceding component.

SC4 Artisanal transport

This component considers the value of strategies in providing access routes between villages and communities, which is a valuable by-product of some forms of intervention.

SC5 Nutrition

This component seeks to combine the overall potential for long-term change in nutrition brought about by changes in agriculture and fisheries as a result of any strategy.

SC6 Sites of social/cultural value

Few cultural sites are at risk within the project boundaries, but some areas of important social need (services centres, ferryghats, markets) do lie within the area, and are so considered.

ECONOMIC/OPERATIONAL

EO1 Operational simplicity

This is a measure of the simplicity, in economic and construction terms of implementation, as well as on the operation and maintenance of the system.

5.3 Assessment Baseline

The present system of flood protection by reliance on the BRE is taken as the baseline condition. For assessment purposes this condition would normally score zero, as a 'no change' condition. However, there have been positive and negative impacts brought about by the BRE, and it is important to understand the true environmental status of the present situation.

Table 5.1 shows the matrix evaluation for the present situation compared to the original floodplain. Comparison of the present situation with the earlier floodplain that existed before construction of the BRE demonstrates the effect both on fishing and agricultural livelihood. Whilst the floodplain fishery has suffered from restrictions to stock recruitment, the improvement in agricultural production, and hence incomes, has been equally significant.

It is against this understanding of the historic reduction in fish production, and the establishment of thriving agriculture by the provision of flood protection, that any new environmental evaluation must be made.

5.4 Impacts of Common Issues

5.4.1 Brick Making

There is a need for bricks in the construction and rehabilitation of revetments. It is also common in Bangladesh to break down bricks for aggregate in concrete. This practice makes use of exploitable natural resources, whilst also providing labour both in expanded brick making and the reduction of bricks into aggregate.

Brickfields are developed on rented land close to a source of clay, and are temporary works, operating only in the dry season. The kilns are single or multiple burners, using sectional chimneys, and are constructed of bricks and earth. A single chimney kiln can produce (on average) about 130,000 bricks per firing, and about 5 firings are averaged in a year. Additional burners increase the production by a simple multiplier based on the chimneys (kilns).

The brickfields are extensively spread throughout the country and provide local employment for labour, as well as a market for landowners to sell clay and timber.

Traditionally the brick works have used timber or coal, with a preference for timber which is a locally produced resource. To preserve the rapidly dwindling stocks of timber, a prohibition on timber firing in brickfields was introduced in 1983/84. Nevertheless, timber is still extensively used in present brick making operations. Discussions with brickfield operators indicate that 100,000 bricks require about 23 tonnes of coal for firing, whilst 57 tonnes of timber would be required.

On a field visit in March 1992, 32 brickfields were observed from the roads between Nagarbari-Sirajganj-Kazipur-Bogra-Shariakandi-Fulchari. Of these all were seen to have piles of bamboo roots, as well as large stacks of timber. In a few cases the kilns were actually seen being loaded with timber. Only in six cases were coal piles or bunkers observed. No attempt was made to hide the use of timber at any site. The minimum present annual requirement for fuel for these observed works would be 5,980 tonnes of coal, and 14,820 tonnes of timber, producing about 30,500,000 bricks.

Whilst in operation, the brick works deny land for cultivation, and often the site is abandoned without complete clearance of debris. Old brickfields are readily identified by both stored bricks and mounds of discarded bricks which are rapidly grassed over, but represent a permanent loss of land.

Where clay is close to the surface farmers will often sell the top few feet for brick making, in order to lower their field levels. Where clay has to be abstracted from depths, deep localized borrow pits are created which have no future use either for crops or artisanal fisheries.

However, the main concern in environmental terms is the use of timber as fuel in the brick works.

There will be a minimum requirement of bricks for revetment works, and the requirement for aggregate could be met either from bricks or stone (although the latter is expected to be more expensive). Alternatively dumped rock could be used instead of concrete blocks.

Within the project area the timber would normally come from the village forests (the copses of fruit, shade trees and bamboo planted around the villages). The recent use of bamboo roots to fire the kilns may, in the longer term, reduce the stock of bamboo, which is the main housing material for kutcha homes (more than 90 percent of rural housing).

Whilst this increase in brick production locally would certainly provide a positive benefit, in the form of increased local labour and services during the life of the project, the continuing use of timber for brick works in the area must lead to considerable concern over the further impact of timber resources that the project would impose on the present apparently un-controlled situation.

Bricks are required for the project and the full impact of production cannot be offset by mitigation. There will be a degree of land degradation, and localized increase in dust/soot levels during the project/production period. The use of fuel cannot be avoided, but an imposition can be placed in contractor's contracts, for the contractor to guarantee to obtain bricks from specified, coal-only fired kilns; as well as ensuring independent, regular monitoring of the designated brick works by the Engineer.

The question of use of bricks for aggregate is more difficult. The brickfields will bring considerable local employment for the production period, which must be seen as positive benefit, and the use of stone is expected to add to the cost of armouring.

There are two possible ways by which this problem could be reduced:

(i) place a contractual obligation on the contractor to guarantee to obtain bricks from specified, coal-only fired kilns, with inspection of the designated brick works by the Engineer, as part of project monitoring.

(ii) use stone for aggregate or use rock armouring, accepting a lower local employment benefit, and potentially a higher cost of materials. This option will reduce the project related impacts and land degradation.

Action (i) will be an express requirement of the Priority Works contracts, and tenderers are required to price all three armouring options.

If the brick works are local, there will be an added benefit of employment, although there will be negative impacts relating to increased dust/soot levels during the project, and some land degradation that will be a permanent impact.

If the contractor chooses to use larger brick works outside the local area, there will be an increase in the impact of vehicles and boats in the transport of materials to the project site, a reduction of local employment benefit as well as in project related impacts and land degradation.

To keep the demands of the river training works on the nation's brick production in perspective (assuming that brick aggregate concrete blocks form the selected armouring) it is worth recording that the Priority Works in total, over two years construction, will require approximately one thirtieth of the total annual brick production in Bangladesh.

5.4.2 Navigation

The Bangladesh Inland Water Transport Authority (BIWTA) classifies river routes and maintains channel depths by dredging where necessary. Specific channels are maintained at a published Least Available Depth (LAD). Within the project area the LAD south of Sirajganj is 2.0 m and north of Sirajganj an LAD of 1.75 m is maintained.

The BIWTA maintains pontoon stations for river cargo vessels (which could be used by the contractor for material supply to site). Additional to this major traffic by ferries and motor vessels is the traffic by country boats. These are small vessels, of extremely shallow draft, capable of loads of up to 35 tons. Country boats moor at any convenient spot.

The possible impacts on navigation relate to the reduction of LAD by deposition of sediments released by any dredging works, for instance there is some temporary disruption likely to the BIWTA pontoon station at Sirajganj and possibly to the railway ferry.

It may also be necessary for the contractor to undertake some channel development, particularly if he intends to use motor vessels to bring in materials, and where there is no suitable landing for such boats.

These impacts on navigation are likely to be small, and experienced only in dry season conditions, for short periods during the project. Sedimentation of the main shipping channels is unlikely to be a problem if the works are executed to the accepted standards required of International Competitive Bidding (ICB) and properly supervised by the Engineer.

The railway and pontoon berths are capable of some movement, and the Bangladesh Railways (BR) has considerable experience of re- location of ferry ghats due to the natural

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erosion of river banks. Good liaison is essential between the contractor and the BIWTA, BR and the Engineer.

5.4.3 Dredging and Hydraulic Fill

There will be requirements for both dredging and hydraulic fill operations to be carried out at project sites. The concerns about these operations are their possible impacts on navigation and fisheries, particularly in the dry season, as during the monsoon such operations are reduced, and the natural sediment transport and flows in the Brahmaputra river are considerably increased.

Dredging operations are likely to be localized, either for contractor's access, or for clearance around structures and for grading of underwater slopes. Hydraulic fill operations are required, particularly for hard points and for the new embankment at Sirajganj.

In all cases the main material likely to be displaced is sand. This sediment fraction is will not travel far. A simulation by the Mike 21 2-D model, has demonstrated that fine sand will cause a narrow ellipsoidal plume with a maximum spread of about 1500m at a 1 mg/l suspension (Figure 5.1). This would keep the sediments within the localities of the project sites, and impact would be confined to these local areas.

The impacts on fisheries are unquantifiable. The baseline for fisheries has already been considerably damaged, and operations are not going to change the existing fisheries significantly from their present status. There will be some disruption of local artisanal fishing. This disruption may be as much due to migration of fish away from an area of considerable activity as by sediment plumes that may be released during dredging. The scale of this disruption will depend on the season, and the degree of control over the shore and channel dredging, and the hydraulic fill operations.

The problems of sediments being released will be largely controlled in two ways:

(i) the relatively small are affected by the sediment plume

(ii) the control of hydraulic filling by the use of temporary bunds, etc., and other measures that would be applied to an ICB contract and monitored through the course of the project.

There should be little disruption to the fish-spawn fishery, especially if dredging works are programmed to run-down rapidly with the onset of the monsoon (between May-June). Where local fishermen identify suitable fish-spawn catch areas (which may vary from year to year), care should be taken to avoid these areas for the short catching season, and to carry out necessary dredging from areas downstream wherever possible. The main areas of concern for this fishery may be in the Sirajganj area (though this is reported to be a collection centre rather than a fishery).

In all cases close liaison with the local fishermen, the Department of Fisheries (particularly the local district office in Sirajganj), and some flexibility in the works timetable to meet short-term local concerns, will considerably reduce major local impacts.

5.4.4 Water, Sanitation and Public Health

The project components of any strategy are unlikely to alter the present situation with regard to water supply or sanitation to the main dwellings in the project areas. There will be a need to consider some new provision for these services in the case of the relocation of squatter families.

Public health is generally a matter of hygiene and disease transmission is mainly by water or vectors. Works may temporarily extend water bodies, though the Engineer can insist on adequate spraying or drainage to reduce the vector problem.

In this regard two main aspects must be covered in the ICB contract:

(i) provision of adequate drainage of inundation water in any areas for temporary re-location of squatter families. Such drainage will also ensure that sanitation wastes are not brought up through flooding, and so reduce the risk of water borne infection in this area.

(ii) spraying of the borrow pits created during embankment/hard point/cross bar construction (particularly where these are near to temporary work camps, housing). At the end of the project these borrow pits are expected to be used for crop/fish production.

5.4.5 Resettlement of Squatter Families

The families that presently reside on the river embankments may need to be moved for the period of any works.

These people are representative of the largest resettlement group identified by the Land Acquisition and Resettlement Study (FAP 15). This study has recommended that amendments are needed both in the legal framework and in the procedures for dealing with this group of people. The problem is found throughout the country, and no adequate solution, or political policy has yet been formulated.

It is therefore intended that these families be relocated for the duration of the project works and be allowed to resettle in their previous position on completion of the works. The form of the new embankment will allow a better quality of life, and provide these families with a secure home base. In certain areas, e.g. the Priority Works sites, permanent relocation may be more appropriate. These considerations are the subject of detailed study in the draft Resettlement Plans for the Priority Works, issued in December 1992.

The exact location of the resettlement site will depend on the land acquired, and on the installation of water and sanitation services. The squatter families to be moved, and the other local residents along the embankment, will need to consulted; as will the local authorities and the NGOs who may be best placed to assist in this temporary relocation.

Adequate provision should be made in the contract for the contractor to provide water supplies and sanitation (pit latrines) in the resettlement area, and to ensure that the families and the contractor's site/works do not interfere with each other. This will ensure provision of these services as well as a measure of control.

5.4.6 Transport of Construction Materials and Concrete Block Making

The only access to the project area is by road or boat, and transport of materials to the site will need careful planning. The BRE is unsuitable for site access and its use for this purpose is proscribed in the Priority Works contracts. Much of the materials transport will need to be brought to the site by boat.

Access during construction could be a major problem, and cause significant temporary impacts in the various areas of the project. The contractor will have to create new access roads and boat terminals to execute the works on these sites. This will impact on local settlements, and on the artisanal fishery.

To help mitigate these impacts due to access, it is essential that the contractor be instructed in the ICB contract to execute such transport works in a sensitive manner to the natural and human environment, and that his responsibilities in clearing these access works (or providing them to the local communities for future use) be fully delineated. The Engineer will provide the necessary supervision and control over these works.

Blockmaking on site will lead to a period of increased localized dust and noise levels. This situation is temporary, during the block production period, and seasonal in that conditions will be worst in the dry season.

There is little in the way of mitigation for these localized impacts, except to ensure that the contractor executes these works in a manner sensitive to the local environment. Such conditions should form conditions of the ICB contract, and be supervised by the Engineer.

There will be positive, though temporary, impacts from this component relating to the increase in project-generated employment on the contractor's site, and indirectly from the income obtained by local services to the contractor's work force.

Once the works have been completed, the conditions in the contractor's contract will ensure that the sites are cleaned, and cleared of all debris. The clearance of access routes, if required, must also be done effectively. The Engineer bears considerable responsibility to ensure that this activity is completely carried out. The land will be potentially productive, and should not be taken out of production by uncleared materials or machinery.

5.4.7 Use of Borrow Pits

Construction of realigned lengths of the BRE, and of cross-bars to hard-points where there is not an excess of dredged fill, will necessitate the excavation of fill material from borrow pits.

These can be locally destructive and, finally, unproductive areas if not excavated with an ultimate object in mind. The design envisaged considers a depth of pit of not more than 2m, with a level base. This design will require a larger surface area, but will allow the use of the borrow pit for either crops or fish ponds in the future. This will provide some return of useful land to the local inhabitants, and for the communities along the new embankments, and is seen as a positive long-term benefit.

5.4.8 Floodplain Fishery Improvements

The BRE has provided considerable benefit over its history to the agricultural production of the hinterland, but in turn has caused considerable depletion in the recruitment stock of the floodplain fishery. This historic stock depletion has been cumulative over the years, and the present fishery is probably only in existence through recruitment within the left bank floodplain.

The problem is due to the inability of surface borne spawn to enter the floodplain at the beginning of the flood season, and for adult fish to migrate out into the river towards the end of the season. Structures used for drainage could be adequately designed to allow for these two passages to occur, thus improving the floodplain fishery on the right bank.

Design and construction of suitable structures will not, in themselves, be sufficient to ensure a recovery in the fisheries. The structures will need to be operated at appropriate times, and this will require some institutional cooperation between responsible agencies, and incorporation into the operational schedule for these structures. Such institutional changes are relatively slight, and could easily be effected, providing the responsible bodies have the will to ensure the revival of the fishery.

5.4.9 Wildlife

The area of the works contains bank communities, both above and below water. Available land is invariably cultivated in the dry season, or flooded in the monsoon. Thus the wildlife of the area are naturally at risk from damage that human activities and the erosive nature of the Brahmaputra river will cause in any case. Whilst there will be some habitat loss through the creating of new areas, and construction works, this damage is unlikely to be significant when set against the natural condition.

No significant or lasting damage to wildlife is expected to result. The locations where works are to be constructed are localized areas of urban development or cultivated land. The wildlife baseline is correspondingly localized and poor. More mobile species (e.g. birds) that are disturbed by the construction activity are likely to migrate away from of the project site. On completion of the works, with the creation of new habitats, an inward migration of all classes of fauna can be expected, which will rapidly fill available ecological niches and establish new communities.

5.5 Off-project Impacts

Consideration has been given to determine whether there are any significant impacts from areas or events external to the construction of river training works.

Bearing in mind the comments made earlier on the scale of the works, and of their generally passive nature, no short-term, on-project impacts have been isolated.

In the longer term, the extension of the hard-point concept along the right bank, works on the left bank and the possible Jamuna Bridge (south of Sirajganj) may have some impact on the environment. These projects are in their pre-feasibility stages (with the exception of the Jamuna Bridge), and any actions consequential on their concepts will require a detailed EIA at some future date.

The means by which the left bank of the Brahmaputra river may be stabilized will also affect the situation on the right bank. This is especially the case when considering how a stabilized bankfull river channel can be created and maintained. The full stabilization of both banks, with associated flood protection embankments would severely affect the floodplain fishery of the Brahmaputra River. At this point in the strategy it would be essential for changes in embankment structures to be made, and institutional arrangements set in place to ensure an adequate passage of spawn into, and fish out of, the floodplain to maintain recruitment of fish stocks.

5.6 Sociological Impacts

Since even an intensive bank stabilization programme would involve large scale investment spread over several decades, the problems associated with bank erosion and maintenance of an effective flood protection structure have to be addressed in the short and medium term. The principal issues then become firstly the setting of priorities for bank stabilization and secondly ensuring that the interim measure of flood embankment realignment is carried out in the most efficient and least socially disruptive manner and thirdly, and perhaps most critically, how to accommodate the large number of people who will become displaced through bank erosion.

It is estimated that at present about 100,000 people are squatting, illegally, on the BRE and a further 30,000 have found temporary refuge in and around Sirajganj. It is further estimated that during the coming five years alone more than 7,000 ha will be lost to erosion and at least 70,000 more people will become homeless. Since the BRE is rapidly becoming fully utilized as a refuge this will mean that a large number of people will find themselves with no immediate solution to their dilemma. The social and political ramifications are self evident.

Compared with this major problem, the issues relating to the optimal management of planned flood embankment realignment may appear parochial but they are of importance not only to those immediately affected but also to the large number of farmers in the floodplain who suffer whenever there is a breach in the embankment. At present the process of realignment is carried out with only a low level of consultation and opportunities for local participation are not exploited.

Certain key issues need to be addressed. At the local level: setting up an effective procedure for reaching agreement on the optimal tradeoff between the two conflicting requirements of providing the maximum number of people with flood protection (minimizing set-back) and the social upheaval and disruption that is associated with frequent realignments.

At the national level: upgrading the institutional structure to enable the sensitive subject of land acquisition to be implemented in a manner that is equitable and efficient. Also at the national and regional level, institutional arrangements have to be strengthened in order to provide the framework for the setting of priorities for bank stabilization, providing the necessary financial and logistical support for planned BRE alignment, addressing the plight of the massive displaced population, and mitigating the harsh conditions faced by those left exposed on the riverside of the embankment.

Much can be done to improve conditions for this latter group in the way of relatively low cost measures that fall under the general heading of Flood Proofing: improved raised earthfill platforms for houses and commercial and public premises; road and footpath embankments; livestock and human refuge highpoints; secure dry storage facilities; reliable all season water supply; effective relief and rehabilitation services; flood warning.

The impact of flood embankment realignment can be alleviated by local consultation and greater involvement of those affected. Many of the reported problems relating to holding fragmentation and exacerbated social division are potentially capable of mitigation given the appropriate approach to the issue. Loss of productive land to borrow areas can be mitigated by a greater emphasis on sourcing of material.

For those displaced by erosion the problems are more difficult to resolve but priority should be given to formalizing the occupation of the flood embankments and designing the realigned sections in order to provide the maximum refuge potential. Participation in maintenance, and possibly also realignment, by those resident on the embankment is a possibility that deserves serious consideration. In the long term, bank stabilization appears to offer the only sustainable solution.

5.7 Impact of Different Levels of Intervention Strategy

5.7.1 General

The philosophy underlying the river management programme being proposed in the Master Plan is the minimum divergence from the natural characteristics of the river. The concept is one of encouraging the river, by means of selected structural intervention, initially to become stabilized within its present boundaries. Only after this first stage has been achieved and the response of the river quantified would consideration of possible further confinement into a single channel be appropriate.

5.7.2 Change in Channel Geometry

Analysis of river cross-sections surveyed regularly since 1964 show a considerable short-term temporal and spatial scatter in the values of the principle channel parameters, mean and maximum depth, width and conveyance, but a notable overall long-term consistency with no discernible trends and little longitudinal variation. It is reasonable to infer from this evidence that the channel characteristics are prone to a stochastic variability, this being a reflection of the dynamic nature of the braided channel, but that provided the dominant discharge is not significantly changed there should be no induced change in the mean channel geometry. Stabilization of the bankline could however be expected to result in some greater regularization of the thalweg pattern and therefore rather less variability in the channel geometry about the mean values.

5.7.3 Bed Aggradation/Degradation

Well known cases of bed aggradation following on from river canalization have drawn attention to this potential hazard. This effect may result from either increased transport in the confined reach of the river, causing deposition in a lower unconfined reach, or from the planform stabilization of a river that is in a naturally aggrading state.

Although the timescale of the available data is short in relation to that of this type of process, the specific gauge analyses and the cross-section data analysis both indicate that the river is in a state of dynamic equilibrium. This was further endorsed by the 1-D morphological modelling carried out jointly with the SWMC. On these grounds, stabilization of the river alone should have no impact on mean bed level.

The effect of confinement of out-of-bank flows between continuous flood embankments has been investigated both through determining the impact on the dominant discharge and by means of the 1-D morphological modelling. The former showed that the impact of confinement only became significant if all left bank distributaries were closed off. The latter predicted that a confinement of the river to a maximum width of 6,000 m over its full length would have only minor impact on the average depth and bed level but that further confinement would result in increased sediment transport, resulting in a lowering of the bed level and consequent deposition in the Padma downstream until a new equilibrium was established. It is thus important that the full confinement of the river be set at limits that would not encourage bed scour.

5.7.4 Change in Macro Planform

It has been suggested that confining the river could encourage it to change from a predominantly braided planform to a more meandering form and that this in turn might mean that larger more aggressive and inherently less stable bends could become more common. The concern seems to arise from the perception that the river is in an unstable transition between meandering and braided and that any intervention may push it over the line into a meandering phase.

A further presumption is that this would be hazardous because the meandering river would be less stable. The arguments applying to potential change in channel geometry would seem to apply equally in this case. Stabilization of the right bank alone will have no impact on the shape of the dominant discharge curve and therefore should have no direct impact on channel morphology overall. If it were to result in a lower braiding intensity locally due to channel planform stabilization then this could only be advantageous from a human perspective provided that the stabilization works are designed to prevent bends of dangerously short radius from developing.

5.7.5 Induced Bank Erosion and Scour

The problem of intervention at one point resulting in adverse impact elsewhere in the system is widely recognised. If accretion is encouraged in one location then this will normally be at the expense of net material loss at another location; this may take the form of bed scour or erosion of the opposite bank.

In the case of the Brahmaputra river, in which the products of bank erosion represents a high proportion of the net sediment throughput, there is the particular concern as to the consequences of arresting or reducing this erosion. It has been established that there is a close relationship between net bank erosion and net char growth and that the time interval linking the two processes is relatively short.

If it is accepted that the river is in dynamic equilibrium then by simple conservation of matter, any new material introduced from the bank that is not removed by the river in the form of wash load must be deposited in a char or temporarily stored in a sandbar. Although it is difficult to measure these two exchanges accurately, the computations that have been carried out support this thesis. In which case stabilizing the bank may be expected to have the effect of stopping further char growth but should not on average cause any loss of char land.

It is also expected that as a consequence of reduced bank sediment contribution the scour adjacent to a stabilized length of bank will tend to increase and this will provide a preferential path for the flow. However it is known from examples such as Sailabari Groyne that this in itself is not sufficient to hold the thalweg in a position that is inconsistent with the current dominant main waveform of the river.

Looking for precedents, the only example of long-term stabilization on the Brahmaputra is that associated with the town of Sirajganj, which dates back at least 20 years; the reach of the river immediately downstream is noted for its remarkable stability over the same timescale.

Thus, the impact of right bank stabilization works is expected to be a general stabilization of the planform but that this may take several years to become discernible against the normal background of local planform variability.

5.7.6 Effect on Populated Chars

The more stable chars, whose tops are at much the same level as the river floodplain, are distinguished by their strong vegetative growth and semi-permanent population. Although the cores of many of these islands have a long life the peripheries undergo constant, and sometimes dramatic, change in shape. Stabilization of the main river banks alone will have no affect on the dominant discharge nor the frequency and duration of inundation of the chars; the influence on the stability of the islands arising from other processes such as the shifting of thalwegs, is hard to predict but there is no known reason to suppose that the situation will become any worse than at present.

The construction of a continuous left bank flood embankment would result in some short-term increase in the frequency and duration of inundation of the chars, as would the construction of the Jamuna Bridge. The strip of floodplain between river bank and flood embankment would be similarly affected. The evidence provided by the development of new chars, with tops at floodplain level, over a period of only a few years suggests that this adjustment process could be over a similar timescale.

5.8 Evaluation of Strategy Options

The evaluation of the strategy options has been done by comparison of the options against the present conditions. The present situation is not without environmental consequences. The reactive nature of this strategy places a considerable degree of insecurity on the population in areas where breaches may occur. Little can be done in terms of forward planning to mitigate against the negative consequences of a breach. The historic depletion of the floodplain fishery continues, with reliance on recruitment of river stocks from the left bank floodplain. No retarding of the westward drift of the Brahmaputra channel can be made with this strategy.

It is against this background that the other three options have been evaluated, and the results of the evaluation are given in the matrices presented in Tables 5.2 and 5.3. Options 3 and 4 score in a similar manner, as they represent the alternative approaches to the combination of bank stabilization and flood protection. The variation between these options is more marked in the detail of the economic and social cost/benefits they provide.

Option 2 shows a largely neutral strategy that provides some benefit in respect of flood protection and land loss, as well as in security of households, agricultural livelihoods and nutrition.

Options 3 and 4 improve on the positive benefits of Option 2. However, there are large negative impacts in relation to land lost to construction, and depletion of village timber reserves as a measure of timber fired brick manufacture if the proposed measures concerning use of coal are not strictly enforced. These negative impacts can be mitigated against by careful planning and the use of the systems defined above.

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6. OUTLINE ENVIRONMENTAL MONITORING AND ACTION PLAN

6.1 Introduction

It is important that construction not only proceeds in an environmentally and socially sensitive manner, but that the benefits of the works are maximized as well as any negative impacts reduced. This requires a number of continuous actions that should begin in the pre-construction phase, and be maintained well after completion of the project.

Institutional responsibilities may change as the project proceeds, particularly in relation to decision making, although the fundamental data collection and analysis tasks remain the same. It is important, therefore, to provide a simple, yet effective, system of monitoring which can be readily transferred between agencies when the situation demands.

This approach demands, at the earliest moment, an effective, open and harmonious system of liaison between a number of different bodies and groups. Without this effective interaction the benefits of the project become neutralized by ignorance or indifference, and a negative perception of the gains made by the investment can develop in the public mind.

Such a programme must operate within the legal, cultural and institutional frameworks that exist in Bangladesh. The plan must be flexible, and capable of initiating and executing changes by local institutions and groups, if necessary, in the future.

6.2 Liaison

For the full project benefits to be realized, a system of liaison between institutions and groups should be set up and maintained. Such liaison will allow all interested parties to become aware of the progress of the project, allow project decisions to respond to local interests and concerns as they may occur, provide greater public confidence in the purpose of the project, and ensure the efficient and economic execution of the works.

The BWDB will bear the responsibility for developing the system of liaison, particularly within the localities of the project sites. The Engineer for the future construction contracts will be play a major role in this respect, and the actual system will reflect his judgments on frequency, type and inputs into the liaison process.

Liaison will be required between the local administration, other public institutions and utilities, and local public interest groups, all of which will require different degrees of interaction with the project.

At the national level the FPCO and BWDB will continue to maintain an on-going exchange of information with the national bodies regulating sectors affected by the project, together with the donor agencies and international agencies.

An initial step in the development of a system of liaison is ensuring a close inter-department system of monitoring and reporting which includes the environmental and social aspects of the project.

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6.3 **Role of NGOs**

There are a number of active NGOs in Bangladesh, as well as international agencies that have programmes of assistance to rural areas. These bodies can play an important role in the liaison process, as well as in public awareness and assistance to specific communities.

The need to ensure that local people and officials are made aware of the works that will be undertaken, of the local importance of these works, of the benefits that will accrue to the communities and of how best the people themselves might benefit from these works, can be undertaken by the pourashava or upazilas, although it may be possible to involve local bodies and NGO's in the programme.

The NGOs have been identified as group in the liaison process but certain organizations have specialized roles that would be of importance at specific times during the project cycle. Among these organizations are:

ASHA(Hope)
promoting population control, sanitation, social awareness, and rural employment

BRAC (Bangladesh Rural Advancement Committee)
promoting rural sanitation and public health

GANASASTHYA
promoting public health and sanitation awareness

GANA SAHAZYA SANGSTHA
to promote rural self-employment

NIJERA KARI (Work Ourselves)
undertaking social work in rural communities, including self-help, kitchen gardens

PROSHIKHA
undertaking rural programmes for irrigation, water supply, rural sanitation and training on human development

Amongst international agencies that have active programmes in the country in rural situations are:

UNICEF
rural water supplies, sanitation, and public awareness

CARE INTERNATIONAL
rehabilitation and resettlement.

6.4 **Consultation**

The system of liaison will need to take account of the interests of the people who will be affected by the project, as well as the regulatory and planning concerns of the authorities. To this end, the liaison system will need to coordinate a series of consultation activities to obtain public opinion.

There are a number of actions that can be taken in this consultation process, and the use of any, or any combination, will depend on the situation at any period in time.

Direct consultation with affected individuals, householders and land owners is needed when land acquisition or displacement activities are planned. This consultation should include group and public meetings, as well as consultations with affected individuals. It is important to include in the consultation process all persons that might be affected in the localities, not merely the persons whose land or homes are to be acquired.

As a part of the consultation process, surveys of interest groups should be undertaken, particularly when a project activity has indicated a possible impact (positive or negative). These may be household or sector groups. To provide data for future decision making, follow-up surveys of these same groups should be undertaken to determine public opinion on the success of the operation.

6.5 Monitoring

The project will not significantly impact on natural resources or sensitive ecological zones, but may provide local changes that need to be taken account of in river and floodplain management programmes, which fall within the remit other projects under the Flood Action Plan (FAP).

There are no authorities that, at present, have the institutional capabilities or resources, at a local level, to monitor environmental change, or adequately provide a record of environmental and social change at this time. Accordingly a method must be found whereby some records can be presented at regular intervals to allow independent scrutiny and evaluation of any on-going negative impacts.

It is proposed that the BWDB take on the responsibility for assessing these impacts during the course of the project and of reporting on these aspects of the work. After completion of the project the BWDB may continue the process of monitoring or may mutually agree to pass this task over to a national or local body which may, by then, be able to take on this role. Consideration has been given to the setting up of a Monitoring and Resettlement Section within the Bangladesh Rural Development Board (BRDB), but at present it is thought more likely that this role will be filled by BWDB.

The BWDB Executive Engineer for each area would be given the responsibility of ensuring the recording of the observed social and environmental changes, and reporting at six-monthly intervals (November and May) on these changes. In this regard the information supplied by the system of liaison that would be set up in the local communities will be very important.

Specifically a record should be maintained of monthly observations on the following:

(i) any squatter or other persons moved from the area to allow works to proceed. This information should record number of families affected; number of persons moved; places where they were relocated (if any); date of movement/re-location; any compensation paid or compensation works undertaken

(ii) any reported loss of income or disruption of normal work practices (including artisanal fishing), houses or shops temporarily closed or vacated as a result of works. This information should record number of families affected; number and types of businesses affected; number of persons affected in each family/business; places to where they were relocated (if any); date of movement/re-location; any compensation paid or compensating works undertaken

(iii) any specific aspect of works that caused prolonged disruption to local services (eg: street closures; traffic delays; loss of power/communication services; closure of ferry ghats)

(iv) any change in the nature of the river at any point during construction. Specifically this should be done by observation by the BWDB, and discussion with appropriate authorities (eg: BIWTA, DoE) and local communities, and should report on new channels, chars, sand banks or erosion that is occurring, with either sketch maps or subjective quantification of the changes noted.

(v) any concerns, events or actions that have been identified by the liaison and consultation process, and the results of any meetings, surveys, or agreements made through these processes

These half-yearly records and report should be evaluated by the BWDB and the other regulatory authorities, and should include the earlier comments of the local pourashava and upazilas. It is recommended that the BWDB coordinate with the Department of the Environment (DoE), Ministry of Environment and Forests (as the identified authority responsible for national environmental monitoring and regulation) to assist in this evaluation process.

Recommendations made as a result of these evaluations should be communicated to the appropriate authority, and some follow-up action be take to assess the results of action taken on these recommendations.

6.6 Mitigation Control

Certain mitigation measures will be applied as a result of the consultation and liaison processes. Many will be effected by the standard construction impact and nuisance mitigation measures available under ICB conditions of contract and the contract specification. The Engineer will be responsible for monitoring and enforcing these measures. Within the project cycle the following summarizes the main areas for mitigation that are part of the monitoring and action plan for the project:

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Land acquisition:

The consultation processes will be used to determine the alignment of future embankments, disruptions and compensation necessary.

Contractor's land acquisition and site development

ICB procedures will be used to ensure minimal disruption and nuisance in contractor's site development, including a requirement for adequate consultation on site selection.

Production and stockpiling of materials

The controls applying to brick manufacture will be enforced. The contractor will be required to ensure adequate safety and security measures, and to minimise nuisance under the ICB contract.

Transport of materials

Consultation with the local authorities, police and the contractor will be undertaken to ensure routes for site access that provide the minimum of congestion and nuisance. Public consultation with residents/businesses along alternative routes will also be undertaken. The contractor will abide by conditions then laid down for the transport of materials.

Block making

The ICB contract will ensure that this activity is undertaken in a safe manner, and that all nuisance and pollution is kept to a minimum. The contractor will need to provide all necessary water supply and drainage, in accordance with accepted standards.

Movement and re-settlement of families

Full consultation with the local authorities, the affected communities, and families will be undertaken. NGO's will be invited to participate in this process and to assist in reducing the impact of resettlement. The contractor may be required to provide the necessary water and sanitation services to resettlement sites, together with any other works that may be reasonably required as a result of the consultation process.

Dredging and hydraulic fill

The contractor will be required to work to required ICB standards in all dredging and hydraulic fill operations. It may be necessary, in local areas, to limit the area of operations in the light of fishery and/or transport problems that may arise during the project cycle.

Construction of new revetments and embankments

The contractor will be bound by the standards required in the ICB or LCB contract, and will ensure that disruption and nuisance from the works is kept to a minimum. It may be necessary, in local areas, to limit the area of operations in the light of fishery and/or transport problems that may arise during the project cycle.

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Borrow pits

The contractor will be obliged to maintain the form and size of the borrow pits as laid down in the ICB or LCB contract, and to ensure that these pits are left in a condition such that they can become useful land/ponds for production in the future.

Site clearance

The contractor will clear all debris from the site, to ensure that productive land is not lost through uncleared materials, machinery or works. Useful improvements to the site (water supply, drainage, access points, roads) where required to be left in place, should be handed over in good condition.

The contractor will be obliged to indicate the materials, machinery and other debris that will need to be cleared, and where and how these will be disposed of (to ensure that the problem of disposal is not merely exported to another area). The contractor will also be required to indicate how he will restore such works as sediments ponds, spoil tips, etc. Site clearance will be carefully controlled under the ICB or LCB contract to ensure proper restoration and improvement of the site environment.

Action Plan

By way of example the Action Plan for Monitoring and Mitigating Impacts as drawn up for the River Bank Protection Project, Brahmaputra Right Bank Priority Works EIA, is included as Appendix B. This lists the potential impacts which may be encountered in the course of the works, and the measures available under the ICB contract to offset them.

6.7 Environmental Impact Assessment

The actual implementation of any strategy will require careful evaluation as to its environmental, sociological and economic impacts. These may change within the timeframe considered for any strategy, and such changes are likely to be pronounced at the local level.

To ensure that the strategy can be implemented optimally, each stage of implementation should be undertaken only after a full environmental impact assessment has been executed. In undertaking such an assessment, the views of local people should be carefully and widely canvassed, so as to ensure that the component of the strategy is in line with the expectations and wishes of the people most likely to be affected.

These assessments should also identify permanent and non-permanent impacts; as well as highlighting both positive and negative impacts arising from strategy implementation, the EIA should show how mitigation may be used to minimise the negative impacts of the works.

As the strategy proceeds, it is likely that impacts, both positive and negative, may become cumulative. It is thus important that the earlier EIA's are undertaken in a transparent manner to ensure that their reasoning can be applied, or modified, as appropriate to the on-going situation.

7. INFORMATION SOURCES

The main information sources included a large number of published reports, survey work undertaken during the project, discussions with local people and with specialists in related FAP projects, as well as other experts. The following are the main reports and the organizations and individuals who have provided data to the project.

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7.2 Organizations and Individuals

Bangladesh Water Development Board
Bangladesh Inland Water Transport Authority
Bangladesh Standards & Testing Institute, Dhaka
Dept. of the Environment, Ministry of Environment & Forestry
Dept. of Fisheries, Ministry of Fisheries & Livestock
Dept. of Forestry, Ministry of Environment & Forestry
Depts. of Chemistry & Soil Science, Univ. of Dhaka
Flood Action Plan Project Specialists
Local government officials, professionals and townspeople in:

- Betil
- Fulchari
- Kazipur
- Mathurapara
- Sariakandi
- Sirajganj

TABLES

Table 1.1 Mean Erosion Rate for Each 10km Reach

Reach (Y coordinates)	1953 - 1992 (m/yr)	1953 - 1973 (m/yr)	1973 - 1984 (m/yr)	1984 - 1992 (m/yr)
845000 - 835000	-14.48	42.29	-43.37	-116.69
835000 - 825000	-80.01	-113.34	-29.69	-65.85
825000 - 815000	-70.86	-48.90	-39.21	-169.25
815000 - 805000	-19.28	-18.42	72.67	-147.87
805000 - 795000	-25.86	85.07	-84.56	-222.45
795000 - 785000	-27.16	90.37	-154.90	-145.35
785000 - 775000	-54.72	-46.95	-94.73	-19.12
775000 - 765000	-14.43	81.24	-168.23	-42.14
765000 - 755000	-60.93	-50.45	-115.12	-12.63
755000 - 745000	-122.89	-147.55	-87.84	-109.41
745000 - 735000	-96.20	-46.69	-166.25	-123.66
735000 - 725000	-110.86	-130.06	-56.19	-138.04
725000 - 715000	-64.81	-8.93	-77.33	-187.28
715000 - 705000	-19.79	-47.24	-24.08	54.72
705000 - 695000	0.22	34.15	81.31	-196.08
695000 - 685000	-16.23	19.10	5.40	-134.29
685000 - 675000	-83.25	-108.28	-112.62	19.73
675000 - 665000	-73.75	-62.32	-90.56	-79.21
665000 - 655000	-18.58	-31.76	11.30	-26.71
655000 - 645000	-34.29	-19.30	-67.29	-26.41
645000 - 640000	-80.99	-136.81	-11.43	-37.09

Note: Accretion positive, erosion negative

Table 1.2 Expected Land Loss and Population Displacement over the Next Five Years

Priority Location	Total Area of Eroded Land over the next 5 years (hectares)	Total Economic Value ('000 Tk.)	Number of People Displaced by	
			Bank Erosion	Flooding in Severely Affected Area
Fulchari	250	38,200	12,250	3,600
Sariakandi	300	63,000	17,700	8,700
Mathurapara	500	63,125	7,950	5,000
Kazipur	250	40,175	11,320	7,600
Sirajganj	375	168,750	126,000	31,000
Betil	250	52,500	10,000	8,800

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Table 2.1 Summary of Data Collection During River Surveys

Item	Quantity	Unit
Level Traverses For Bench Marks	190	km
Level Traverses For Topographic Surveys	80	km
Plane Table Surveys	330	ha
Bankline Surveys	15	km
Bankline Movement Surveys	25	km
Bathymetry Traverses (Test Area 1)	270	km
Bathymetry Traverses (Test Area 2)	150	km
Bathymetry Traverses (Priority Sites)	165	km
Velocity Readings	231	No
Float Tracking Traverses	40	km
Suspended Sediment Readings	378	No
Dune Tracking	120	km
Bed Samples	102	No

TABLE 3.1

Annual rainfall at selected stations of Bangladesh (mm)

Name of Station	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Bogra	2228	1630	1756	1229	1778	1629	1708	2146	1941	2185	1734
Dinajpur	-	-	1960	1197	1934	2068	2094	1983	2925	2144	1927
Ishwardi	1276	1456	2252	1282	1635	1545	1179	1484	1607	1116	1430
Rajshahi	1767	1576	2136	1090	1633	1742	1249	1516	1515	1963	1318
Rangpur	2038	2120	-	1993	2273	3523	2872	2310	3242	2497	1878
Saidpur	-	-	-	-	-	-	1874	1927	1981	2137	1618

Source: Bangladesh Meteorological Department

TABLE 3.2

Monthly Rainfall in mm during 1989

Locations	J	F	M	A	M	J	J	A	S	O	N	D	Total Rainfall
Bogra	00	16	02	04	462	229	605	102	282	28	00	04	1734
Rangpur	07	18	02	00	335	219	719	110	414	48	04	02	1878
Rajshahi	04	08	05	02	224	190	350	117	332	78	00	08	1318

TABLE 3.3

RESULTS OF DIFFERENT PARAMETERS OF 6 WATER SAMPLES
(Results have been expressed in PPM except pH & EC - Value)

Lab. Sl. No.	Station/ Hole No.	Location (U.Z. & Dist.)	Sample Collec-tion Dept	Date of Collection	pH	EC-Value µmhos/cm	Free CO_2	CO_3	HCO_3	SO_4	Cl	Ca	M_g	Total Hardness as $CaCO_3$	Fe	TDS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	SG/1	B L High School Sirajganj	59 ft. 50 ft.	13.3.91	7.81	445	4.99	NT	233.63	8.33	27.33	30.00	15.56	143.19	3.1	238
2	BTL/1	Betil Sirajganj	"	22.3.91	7.98	624	28.26	"	564.86	12.25	175.93	61.00	34.80	295.61	-	378
3	KP/1	Kazipur Sirajganj	"	28.3.91	7.63	203	11.28	"	122.00	36.75	16.89	23.60	5.40	81.15	3.3	152
4	SK/1	Sariakandi Sirajganj	"	4.4.91	7.48	475	14.98	"	192.76	12.25	46.11	42.60	12.60	158.25	0.24	370
5	KJ/1	Kamarjani Sirajganj	"	23.4.91	7.20	292	13.40	"	199.10	7.35	26.33	27.60	20.88	154.39	0.54	330
6	FC/1	Fulchari FC/1	"	29.4.91	7.30	414	14.62	"	242.65	4.90	24.35	31.80	29.15	199.45	0.60	281

NOTE: 1. N.T. = Not traceable
2. The test results for pH, EC-Value & TDS of sample bearing hole No.SG/1 have already been sent vide this office Memo No.W-19/91/RRI/Soil/993 dated 6.4.91 (Report No. CHEM-3(91), but for information which again shown in this Table alongwith other parameters.
3. Fe test of the sample BTL/1 could not done as acidified sample was not supplied.

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TABLE 3.4

RESULTS OF DIFFERENT PARAMETERS OF 5 RIVER WATER SAMPLES TAKEN SOUTH OF SIRAJGANJ ON 24 APRIL 1992

TESTING BY RRI, FARIDPUR

Sl.No	Bottle No	Carbonate	Bi-Carbonate	Sulphate	Chloride	Total Hardness	Calcium	Magnesium	Iron
1	2	3	4	5	6	7	8	9	10
1	A1 BRTS	N.T	18.69	9.80	13.91	72.19	21.00	4.80	0.40
2	B2 BRTS	N.T	17.30	9.82	15.90	69.78	23.00	3.00	0.28
3	C3 BRTS	N.T	17.30	7.35	21.17	64.81	22.00	2.40	0.32
4	D4 BRTS	N.T	18.00	4.90	19.18	89.64	27.00	5.40	0.36
5	E5 BRTS	N.T	18.04	7.38	19.11	64.86	24.00	1.20	0.41

Note: N.T = Not traceable.

Table 3.5 **Critical Stages of Growth by Crop**

Crop	Month	Stage of Growth
B Aman	October	Flowering/Maturing
B Aus	June	Flowering/Maturing
T Aman	July-November	All stages
T Aus	April-July	All stages
Boro	April-May	Flowering/Maturing

TABLE 5.1 PRESENT SITUATION

PC1			PC2																				
A1	3	ES	A1	2	ES	A1		ES	A1		ES	A1		ES	A1		ES	A1		ES	A1		ES
A2	2	42	A2	-2	-28	A2		0	A2		0	A2		0	A2		0	A2		0	A2		0
B1	3	----	B1	3	----	B1		----	B1		----	B1		----	B1		----	B1		----	B1		----
B2	2	+4	B2	3	-3	B2			B2			B2			B2			B2			B2		
B3	2		B3	1		B3			B3			B3			B3			B3			B3		

BE1			BE2			BE3			BE4														
A1	3	ES	A1	1	ES	A1	2	ES	A1	0	ES	A1		ES	A1		ES	A1		ES	A1		ES
A2	-2	-54	A2	-2	-18	A2	-2	-36	A2	0	0	A2		0	A2		0	A2		0	A2		0
B1	3	----	B1	3	----	B1	3	----	B1	1	----	B1		----	B1		----	B1		----	B1		----
B2	3	-4	B2	3	-2	B2	3	-4	B2	1	0	B2			B2			B2			B2		
B3	3		B3	3		B3	3		B3	1		B3			B3			B3			B3		

SC1			SC2			SC3			SC4			SC5			SC6								
A1	3	ES	A1	3	ES	A1	3	ES	A1	2	ES	A1	3	ES	A1	1	ES	A1		ES	A1		ES
A2	3	54	A2	3	72	A2	-2	-54	A2	1	12	A2	2	48	A2	0	0	A2		0	A2		0
B1	3	----	B1	3	----	B1	3	----	B1	3	----	B1	3	----	B1	2	----	B1		----	B1		----
B2	2	+4	B2	2	+5	B2	3	-4	B2	2	+2	B2	2	+4	B2	2		B2			B2		
B3	1		B3	3		B3	3		B3	1		B3	3		B3	1		B3			B3		

EO1																							
A1	2	ES	A1		ES	A3		ES	A1		ES	A1		ES	A1		ES	A1		ES	A1		ES
A4	3	30	A2		0	A2		0	A4		0	A2		0	A2		0	A2		0	A2		0
B1	2	----	B1		----	B1		----	B1		----	B1		----	B1		----	B1		----	B1		----
B2	2	+3	B2			B2			B2			B2			B2			B2			B2		
B3	1		B3			B3			B3			B3			B3			B3			B3		

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TABLE 5.2 OPTION 2

PC1			PC2																				
A1	2	ES	A1	2	ES	A1		ES	A1		ES	A1		ES	A1		ES	A1		ES	A1		ES
A2	1	10	A2	2	28	A2		0	A2		0	A2		0	A2		0	A2		0	A2		0
B1	2	----	B1	2	----	B1		----	B1		----	B1		----	B1		----	B1		----	B1		----
B2	2	+2	B2	2	+3	B2			B2			B2			B2			B2			B2		
B3	1		B3	3		B3			B3			B3			B3			B3			B3		

BE1			BE2			BE3			BE4														
A1	2	ES	A1	2	ES	A1	1	ES	A1	1	ES	A1		ES	A1		ES	A1		ES	A1		ES
A2	0	0	A2	0	0	A2	0	0	A2	0	0	A2		0	A2		0	A2		0	A2		0
B1	2	----	B1	2	----	B1	2	----	B1	1	----	B1		----	B1		----	B1		----	B1		----
B2	2	0	B2	2	0	B2	2	0	B2	1	0	B2			B2			B2			B2		
B3	3		B3	1		B3	3		B3	1		B3			B3			B3			B3		

SC1			SC2			SC3			SC4			SC5			SC6								
A1	1	ES	A1	1	ES	A1	1	ES	A1	1	ES	A1	2	ES	A1	1	ES	A1		ES	A1		ES
A2	2	10	A2	2	14	A2	0	0	A2	0	0	A2	1	14	A2	0	0	A2		0	A2		0
B1	2	----	B1	2	----	B1	2	----	B1	1	----	B1	2	----	B1	1	----	B1		----	B1		----
B2	2	+2	B2	2	+2	B2	2	0	B2	1	0	B2	2	+2	B2	1	0	B2			B2		
B3	1		B3	3		B3	3		B3	1		B3	3		B3	1		B3			B3		

EO1																							
A1	1	ES	A1		ES	A3		ES	A1		ES	A1		ES	A1		ES	A1		ES	A1		ES
A4	3	9	A2		0	A2		0	A4		0	A2		0	A2		0	A2		0	A2		0
B1	1	----	B1		----	B1		----	B1		----	B1		----	B1		----	B1		----	B1		----
B2	1	+1	B2			B2			B2			B2			B2			B2			B2		
B3	1		B3			B3			B3			B3			B3			B3			B3		

TABLE 5.3 OPTIONS 3 & 4

PC1			PC2																				
A1	3	ES	A1	2	ES	A1		ES	A1		ES	A1		ES	A1		ES	A1		ES	A1		ES
A2	2	30	A2	-1	-12	A2		0	A2		0	A2		0	A2		0	A2		0	A2		0
B1	2	----	B1	2	----	B1		----	B1		----	B1		----	B1		----	B1		----	B1		----
B2	2	+3	B2	2	-2	B2			B2			B2			B2			B2			B2		
B3	1		B3	2		B3			B3			B3			B3			B3			B3		

BE1			BE2			BE3			BE4														
A1	2	ES	A1	2	ES	A1	1	ES	A1	2	ES	A1		ES	A1		ES	A1		ES	A1		ES
A2	0	0	A2	0	0	A2	0	0	A2	-2	-28	A2		0	A2		0	A2		0	A2		0
B1	2	----	B1	2	----	B1	2	----	B1	2	----	B1		----	B1		----	B1		----	B1		----
B2	2	0	B2	2	0	B2	2	0	B2	2	-3	B2			B2			B2			B2		
B3	3		B3	1		B3	3		B3	3		B3			B3			B3			B3		

SC1			SC2			SC3			SC4			SC5			SC6								
A1	2	ES	A1	1	ES	A1	1	ES	A1	1	ES	A1	2	ES	A1	1	ES	A1		ES	A1		ES
A2	3	30	A2	2	14	A2	0	0	A2	0	0	A2	1	14	A2	0	0	A2		0	A2		0
B1	2	----	B1	2	----	B1	2	----	B1	1	----	B1	2	----	B1	1	----	B1		----	B1		----
B2	2	+3	B2	2	+2	B2	2	0	B2	1	0	B2	2	+2	B2	1	0	B2			B2		
B3	1		B3	3		B3	3		B3	1		B3	3		B3	1		B3			B3		

BO1																							
A1	1	ES	A1		ES	A3		ES	A1		ES	A1		ES	A1		ES	A1		ES	A1		ES
A4	1	3	A2		0	A2		0	A4		0	A2		0	A2		0	A2		0	A2		0
B1	1	----	B1		----	B1		----	B1		----	B1		----	B1		----	B1		----	B1		----
B2	1	+1	B2			B2			B2			B2			B2			B2			B2		
B3	1		B3			B3			B3			B3			B3			B3			B3		

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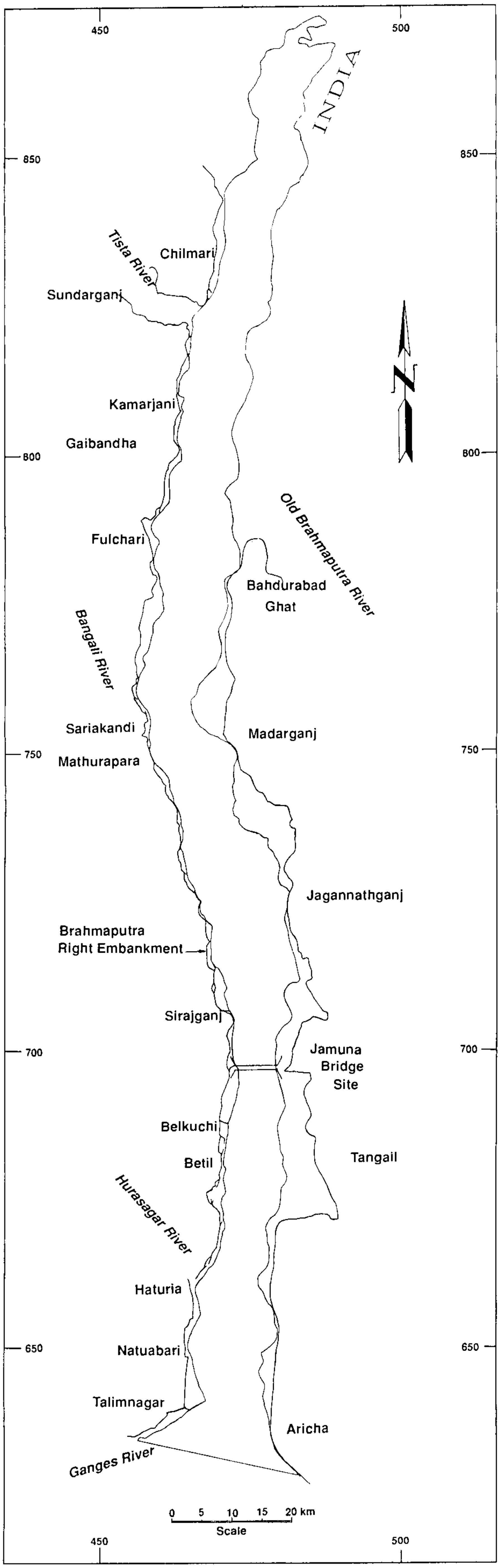
FIGURES



Jamuna Bankline 1992

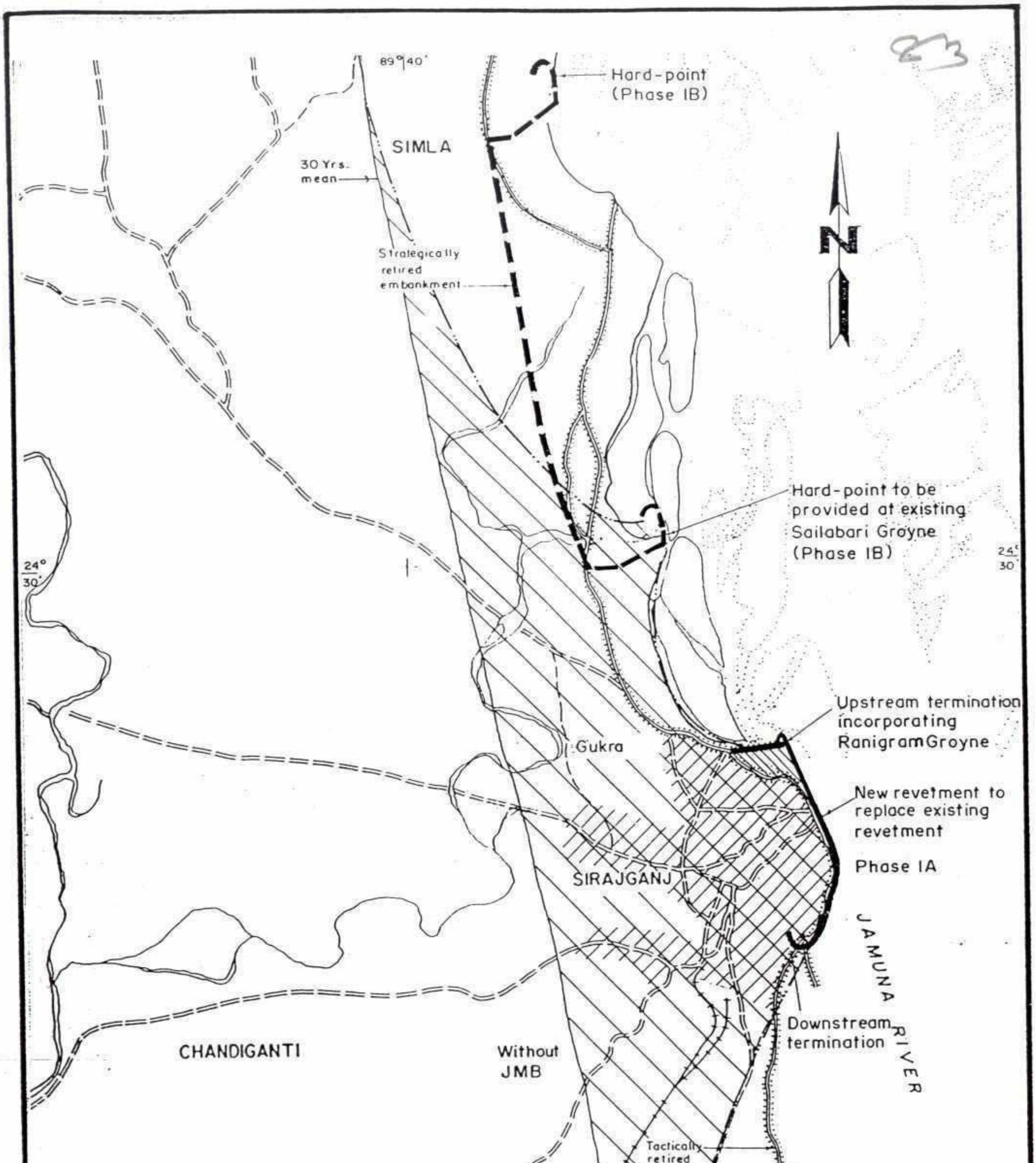
Halcrow/DHI/EPC/DIG

May 1993

Annex 3

Figure 2.1

Source: USAID/ISPAN FAP-19



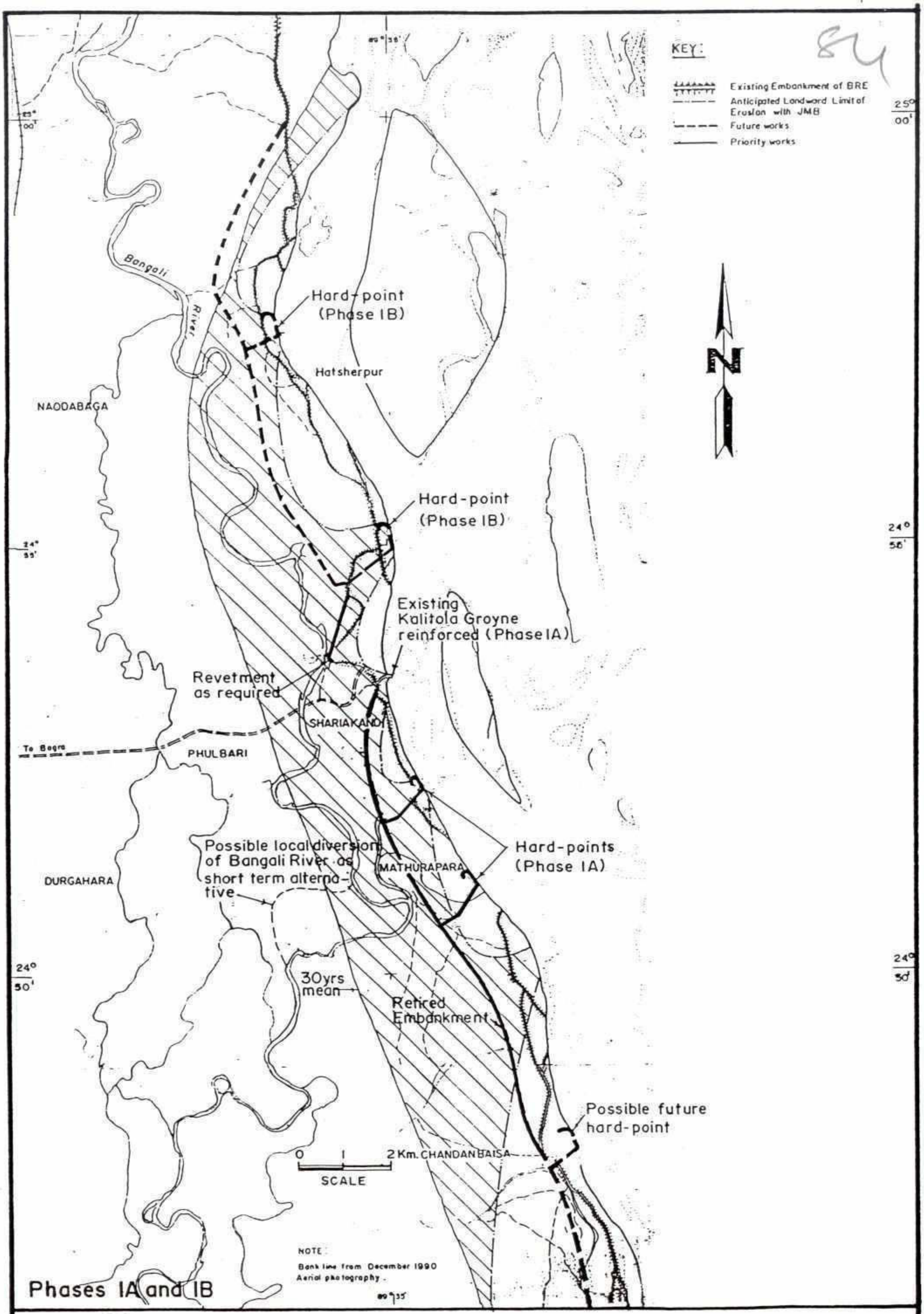
Priority and Future Works at Sirajganj

Annex 3

Figure 2.2

Halcrow/DHI/EPC/DIG

May 1993

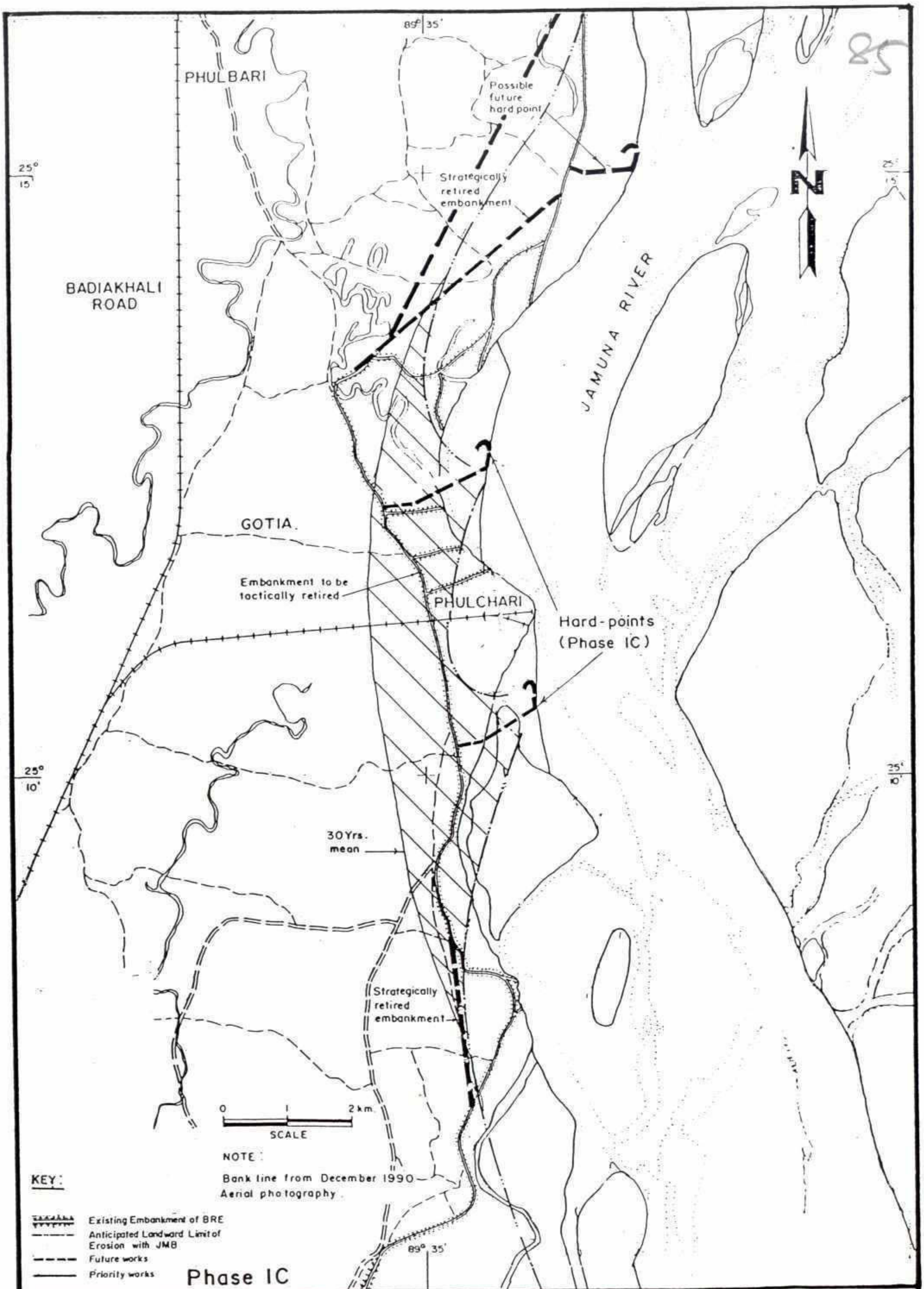


Priority and Future Works at Sariakandi and Mathurapara

Annex 3

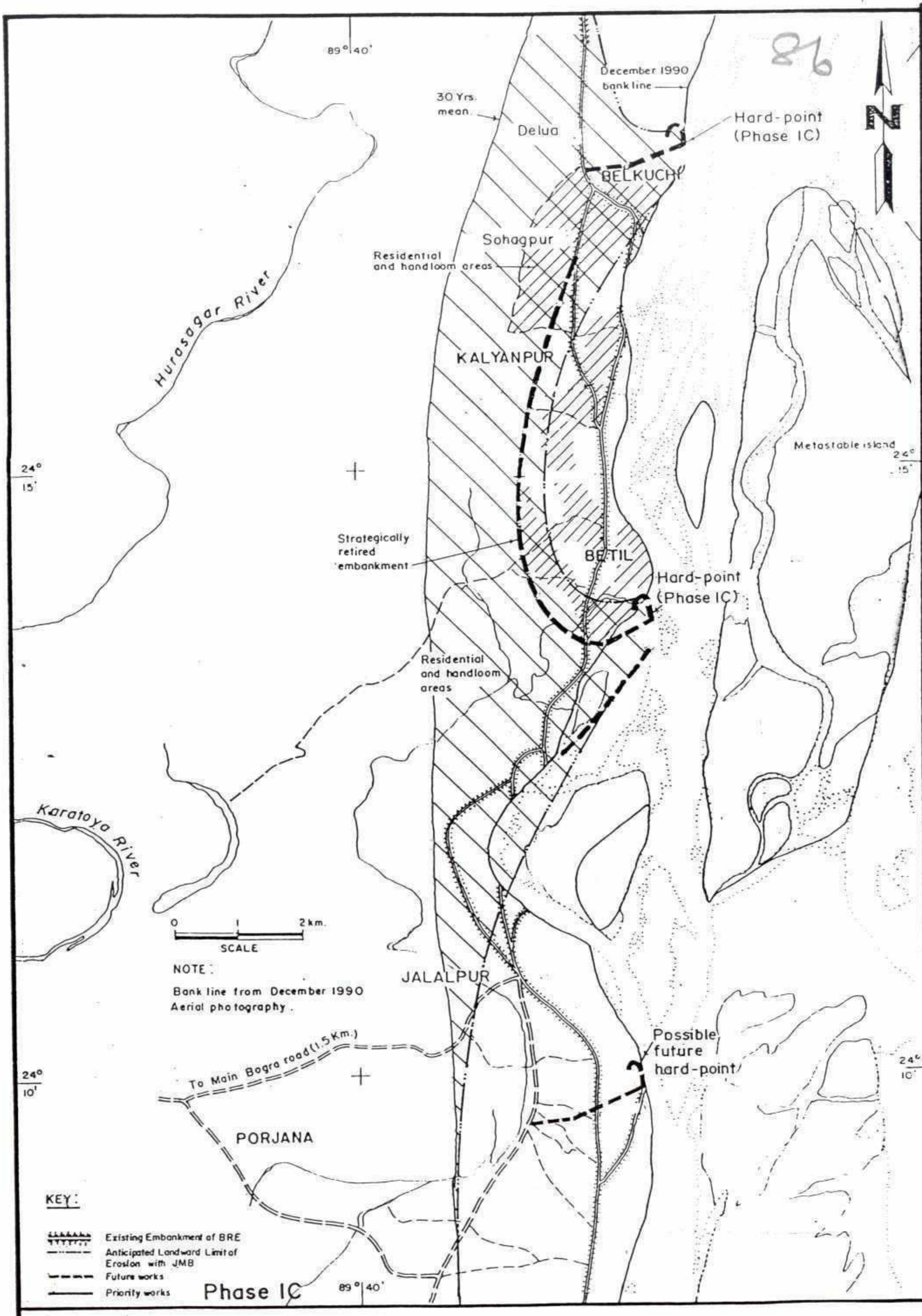
Figure 2.3

Halcrow/DHI/EPC/DIG *May 1993*



Priority and Future Works at Fulchari

	Annex 3
Halcrow/DHI/EPC/DIG May 1993	Figure 2.4



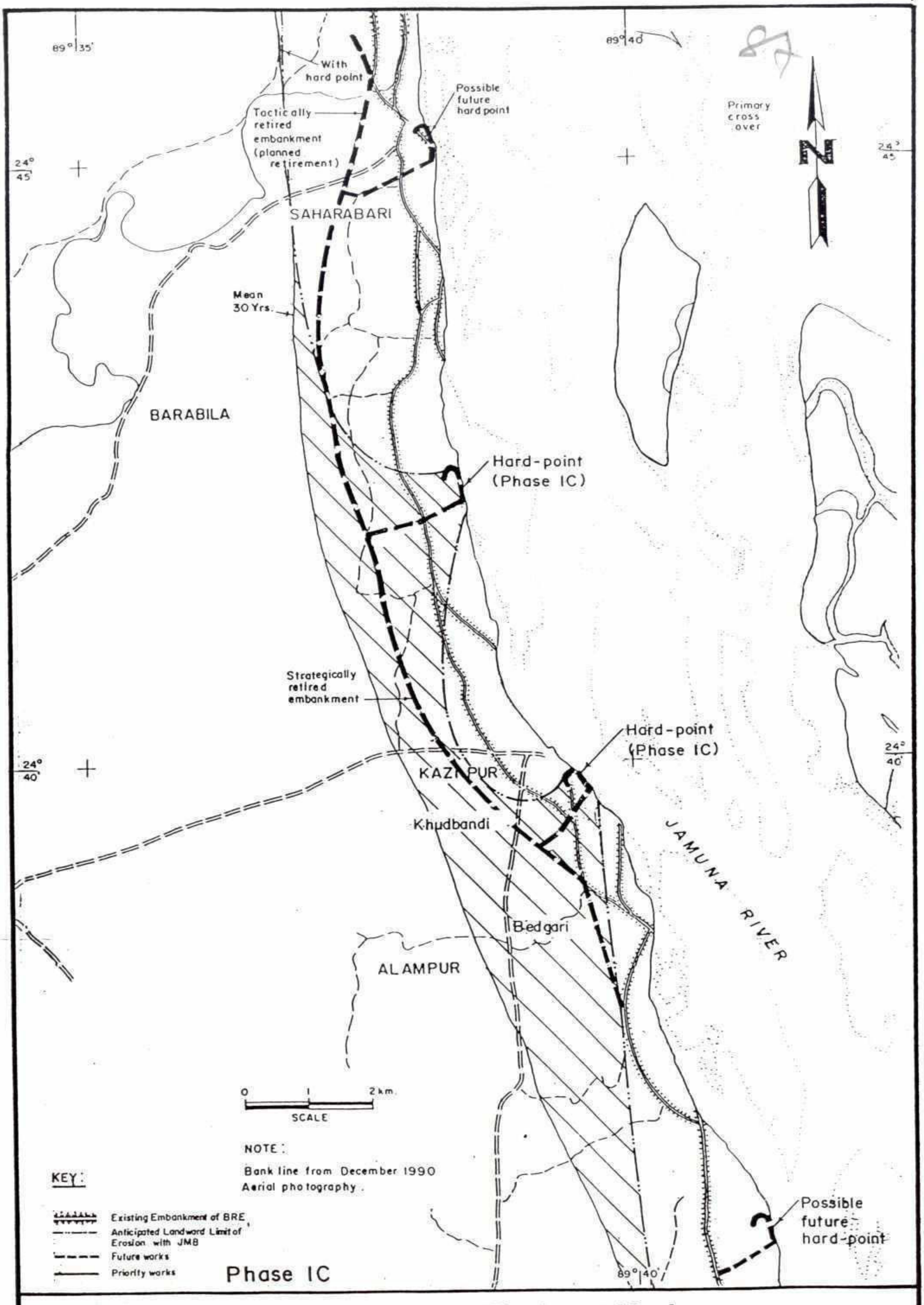
Priority and Future Works at Betil

Annex 3

Halcrow/DHI/EPC/DIG

May 1993

Figure 2.5



Priority and Future Works at Kazipur

Annex 3

Figure 2.6

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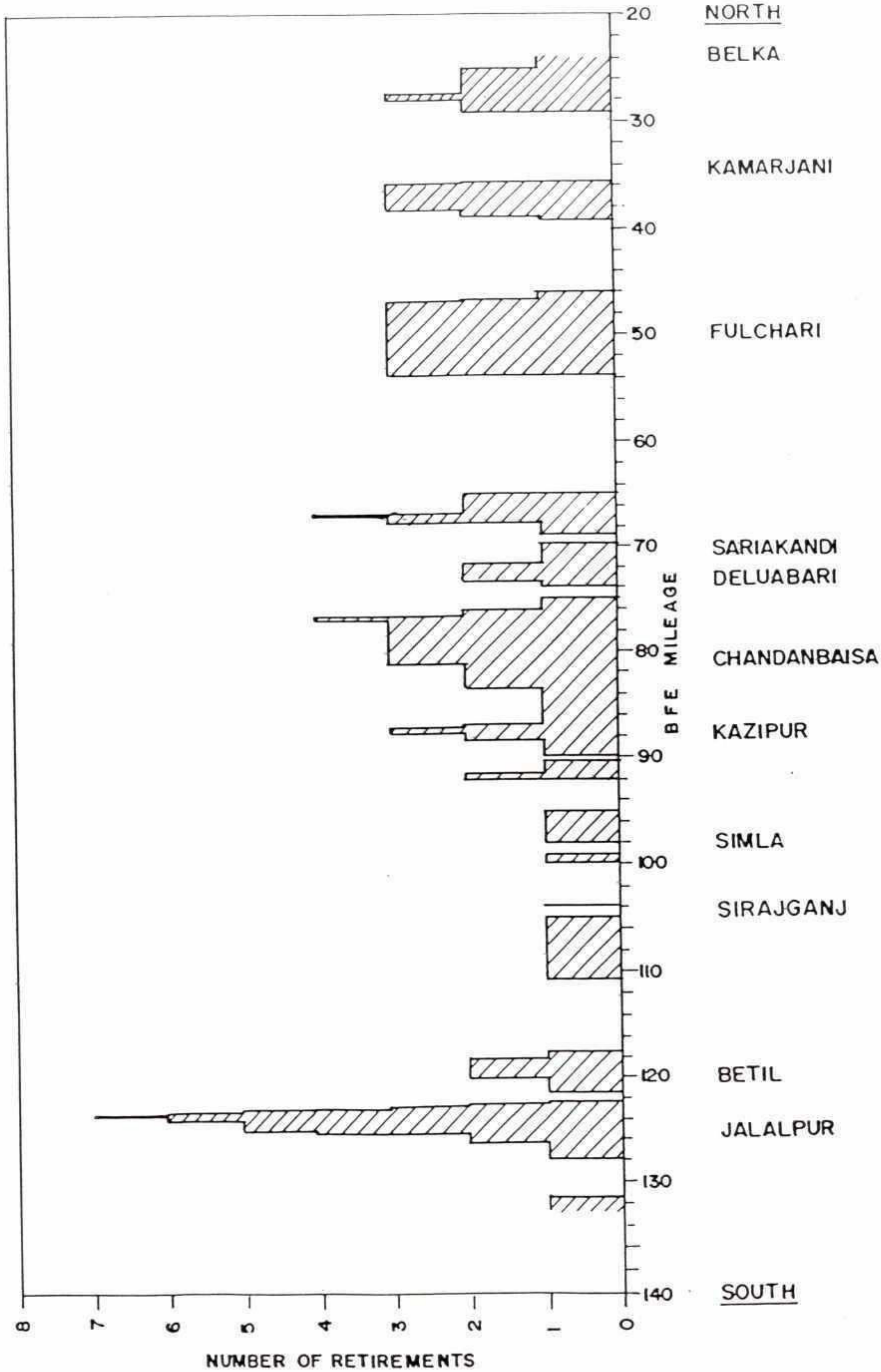
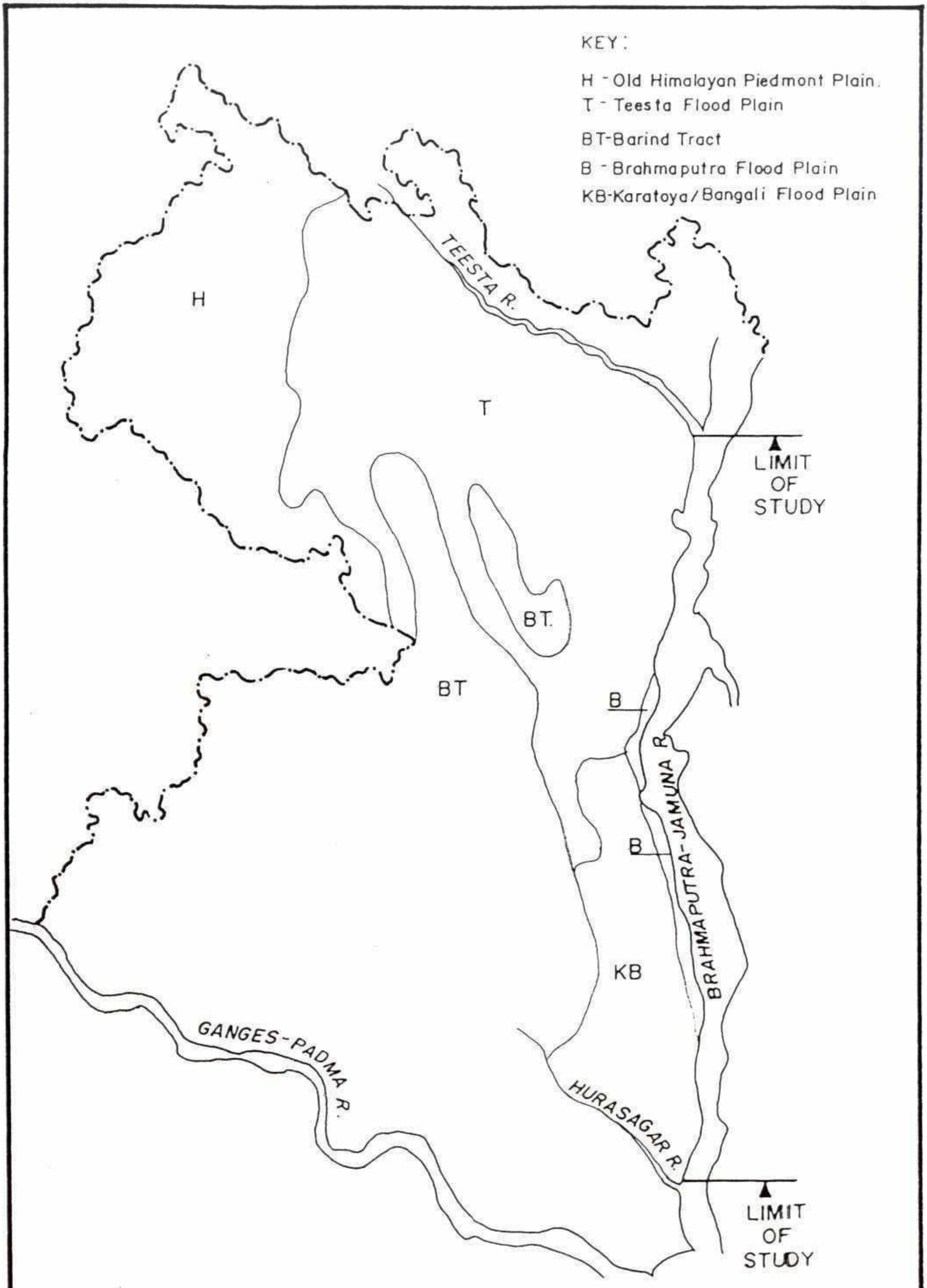
May 1993



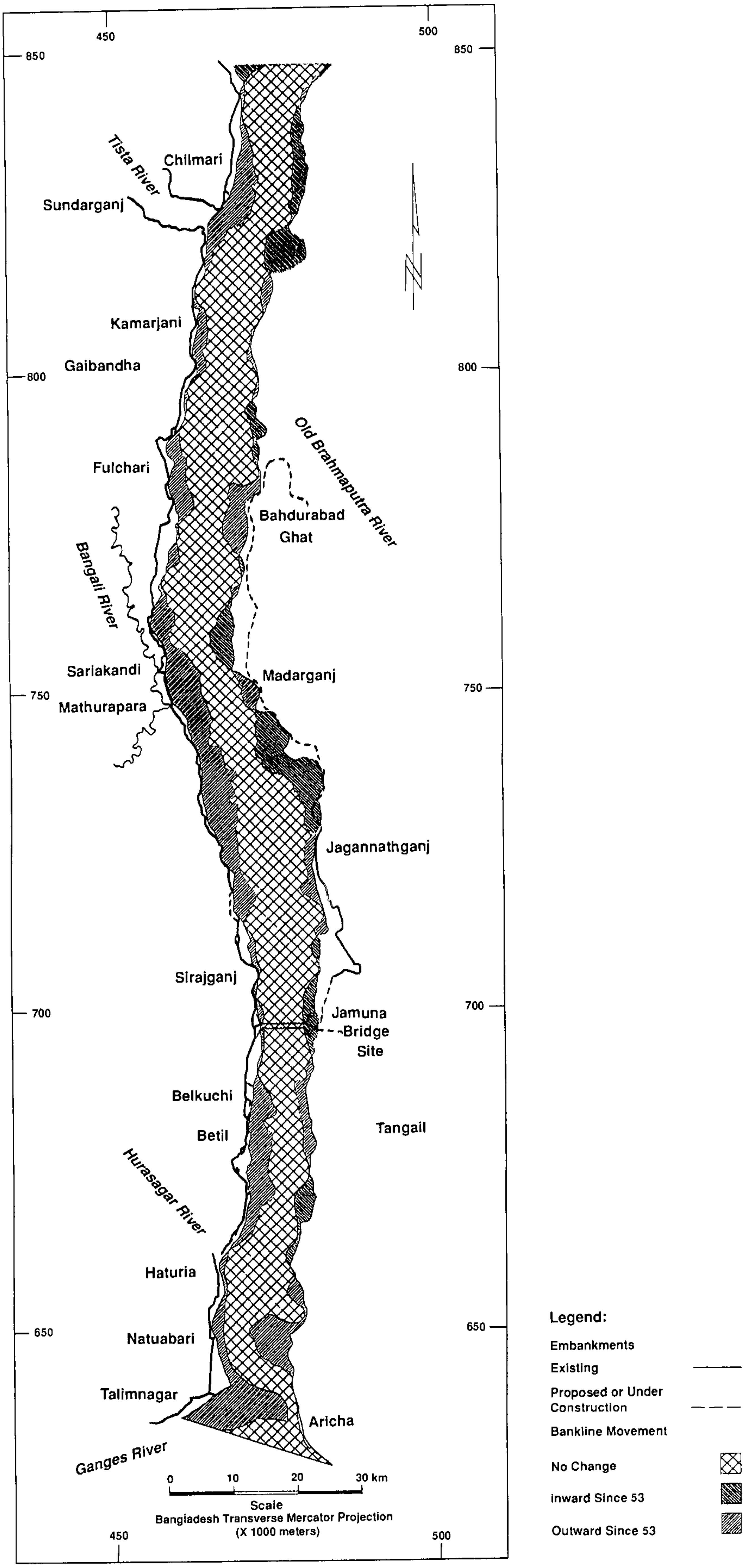
Number of BRE Retirements

Halcrow/DHI/EPC/DIG | May 1993 | Annex 3 | Figure 2.7



Teesta, Jamuna and Karatoya-Bangali Flood Plains

		Annex 3
Halcrow/DHI/EPC/DIG	May 1993	Figure 3.1



Jamuna River Bankline Movement 1953-1992

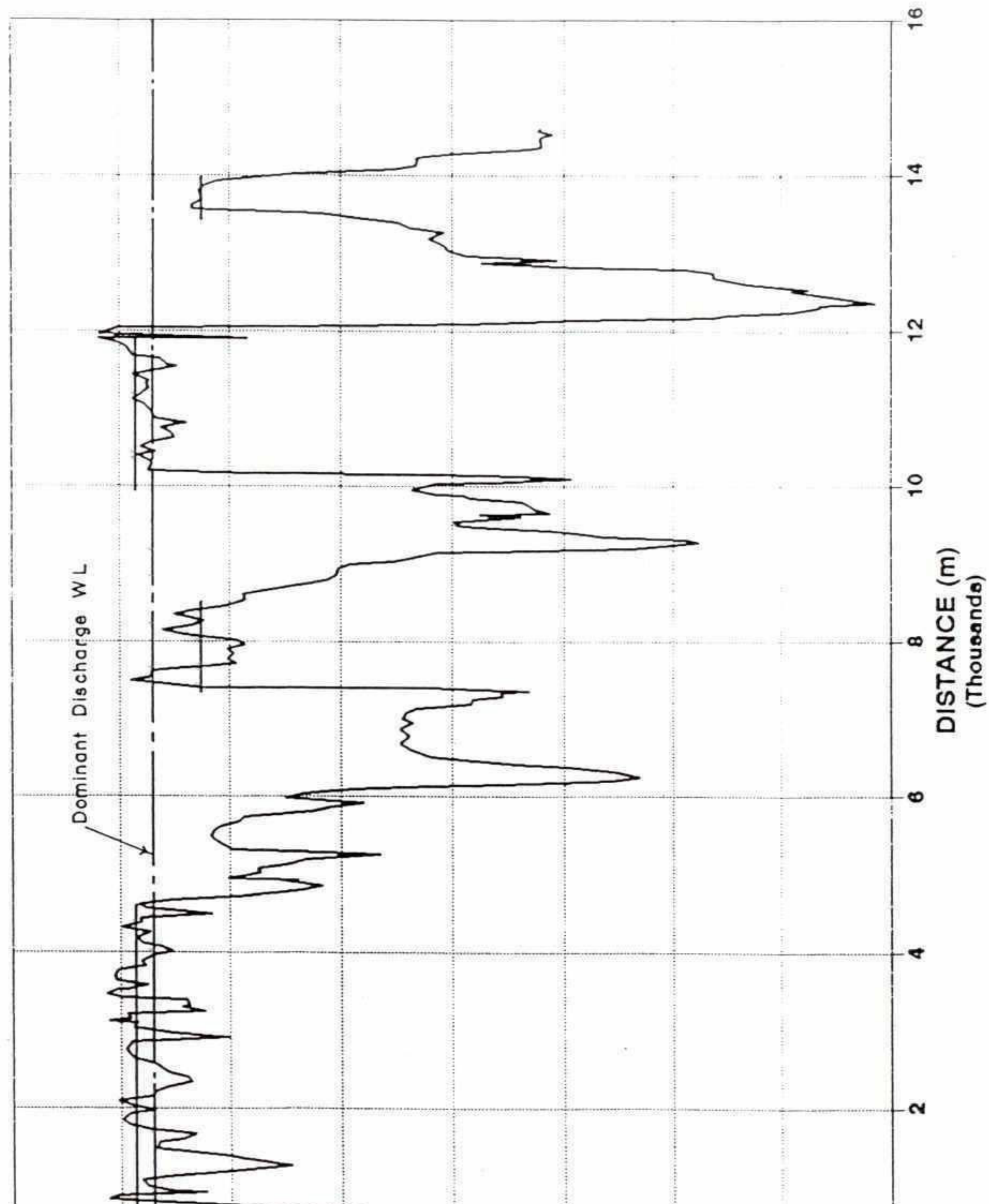
Halcrow/DHI/EPC/DIG

May 1993

Annex 3

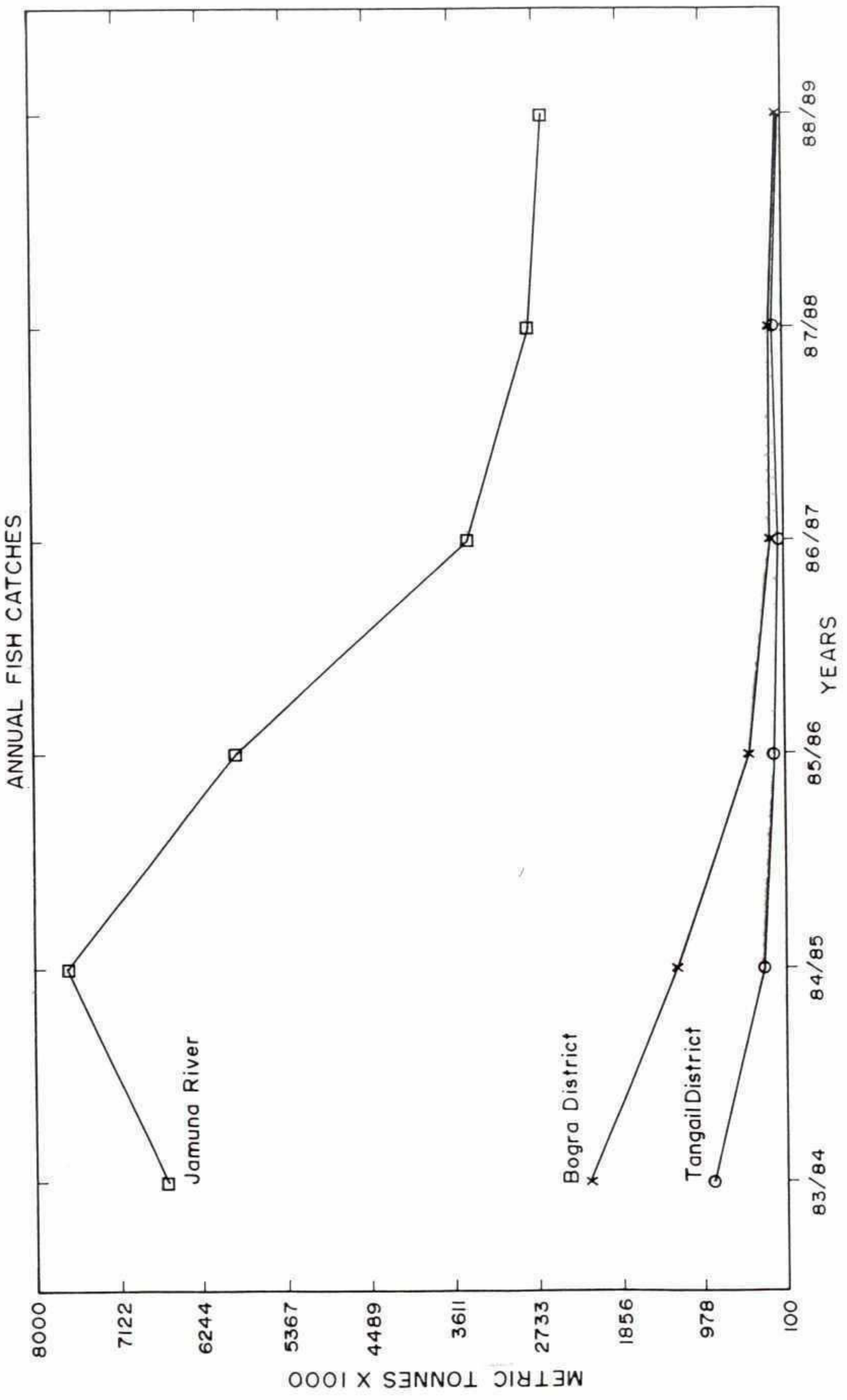
Figure 3.2

Source: USAID/ISPAN FAP-19



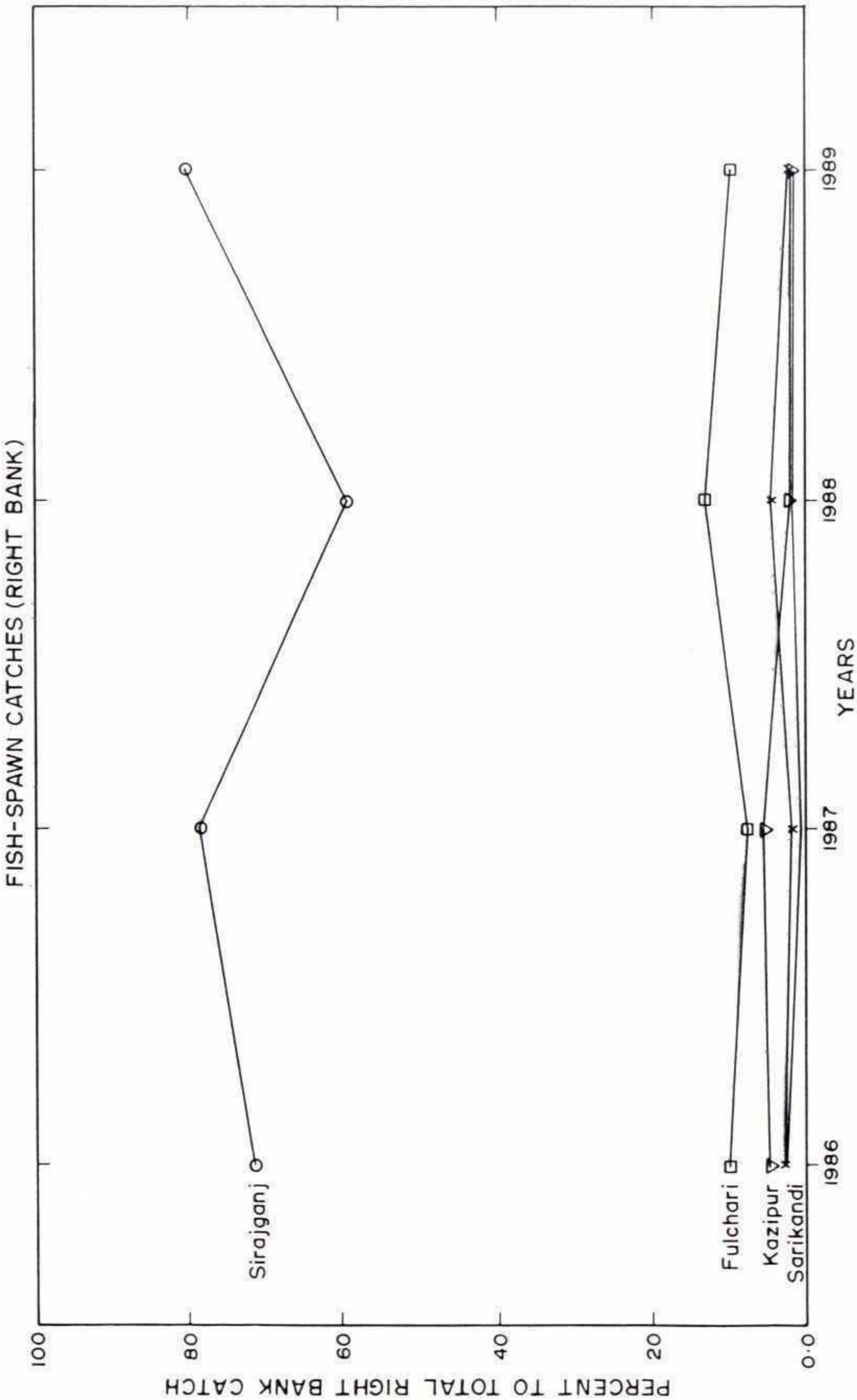
Typical River Cross-Section Showing Upper and Lower Char Top Levels

	Annex 3
Halcrow/DHI/EPC/DIG *May 1993*	Figure 3.3



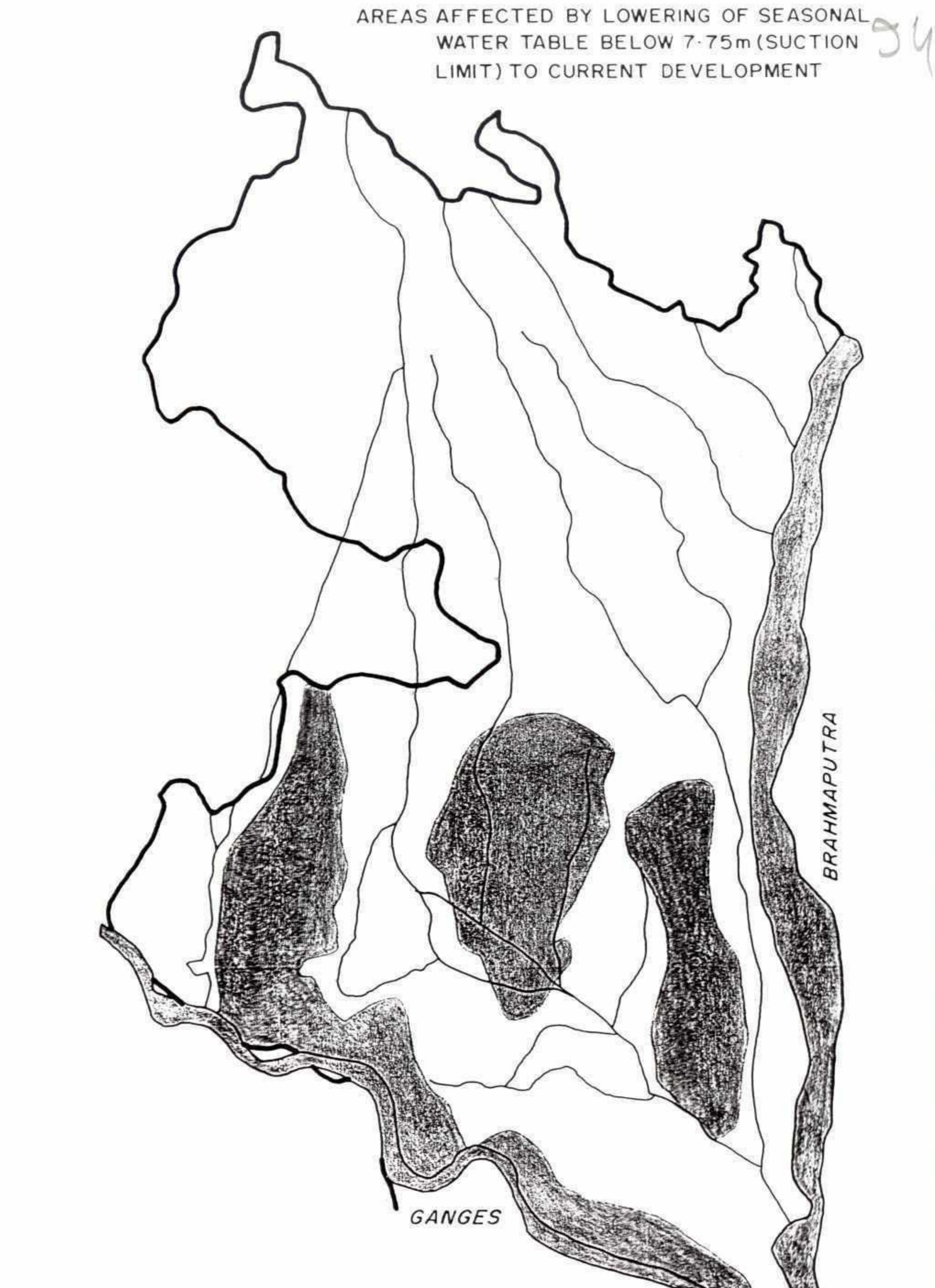
Annual Fish Catches in the Jamuna 1983 to 1989

	Annex 3
Halcrow/DHI/EPC/DIG *May 1993*	Figure 3.4



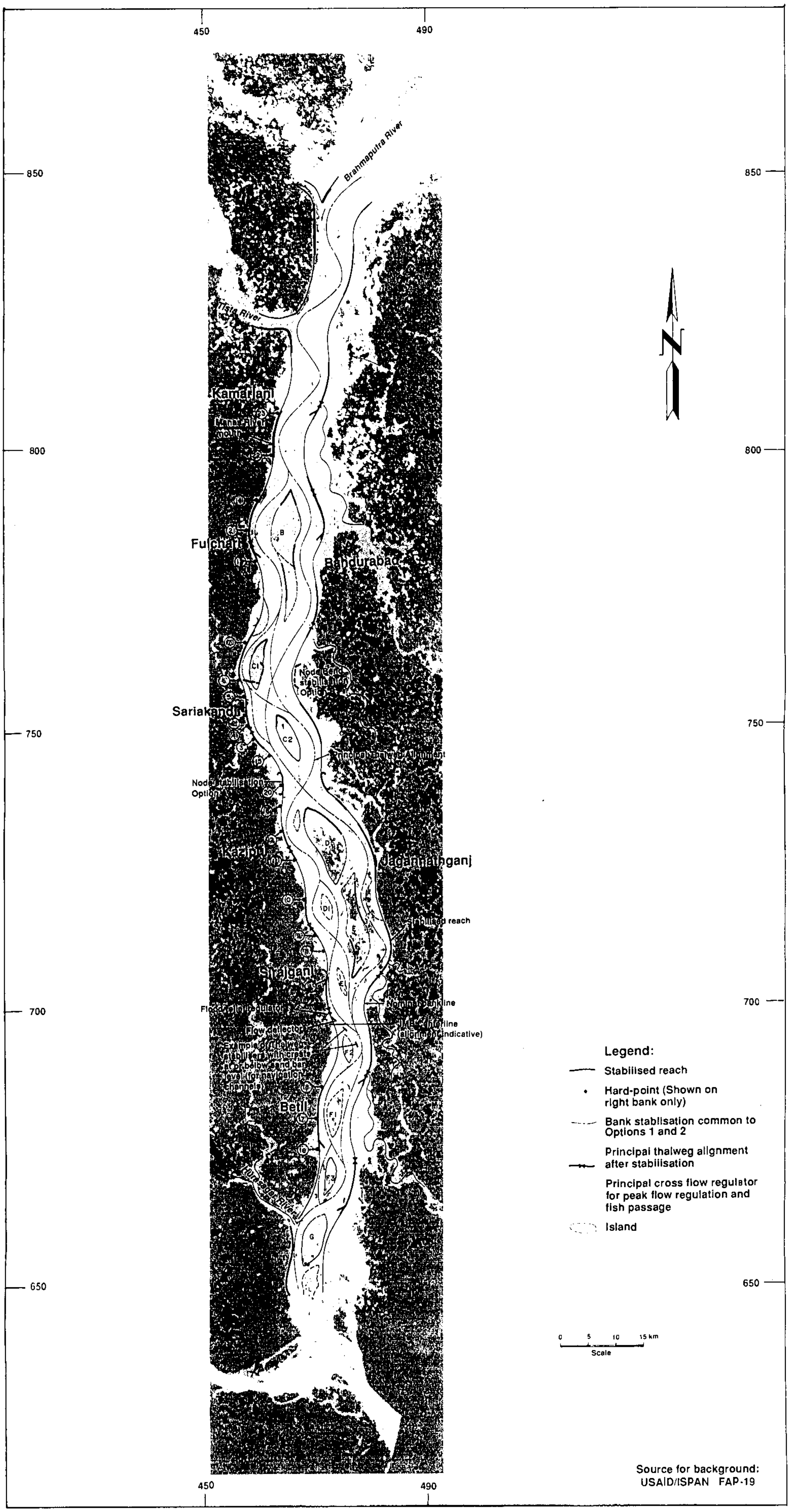
Fish Spawn Catches, Jamuna Right Bank, 1986 to 1989

	Annex 3
Halcrow/DHI/EPC/DIG *May 1993*	Figure 3.5



Areas Affected by Lowering of Seasonal Water Table

		Annex 3
Halcrow/DHI/EPC/DIG	*May 1993*	Figure 3.6



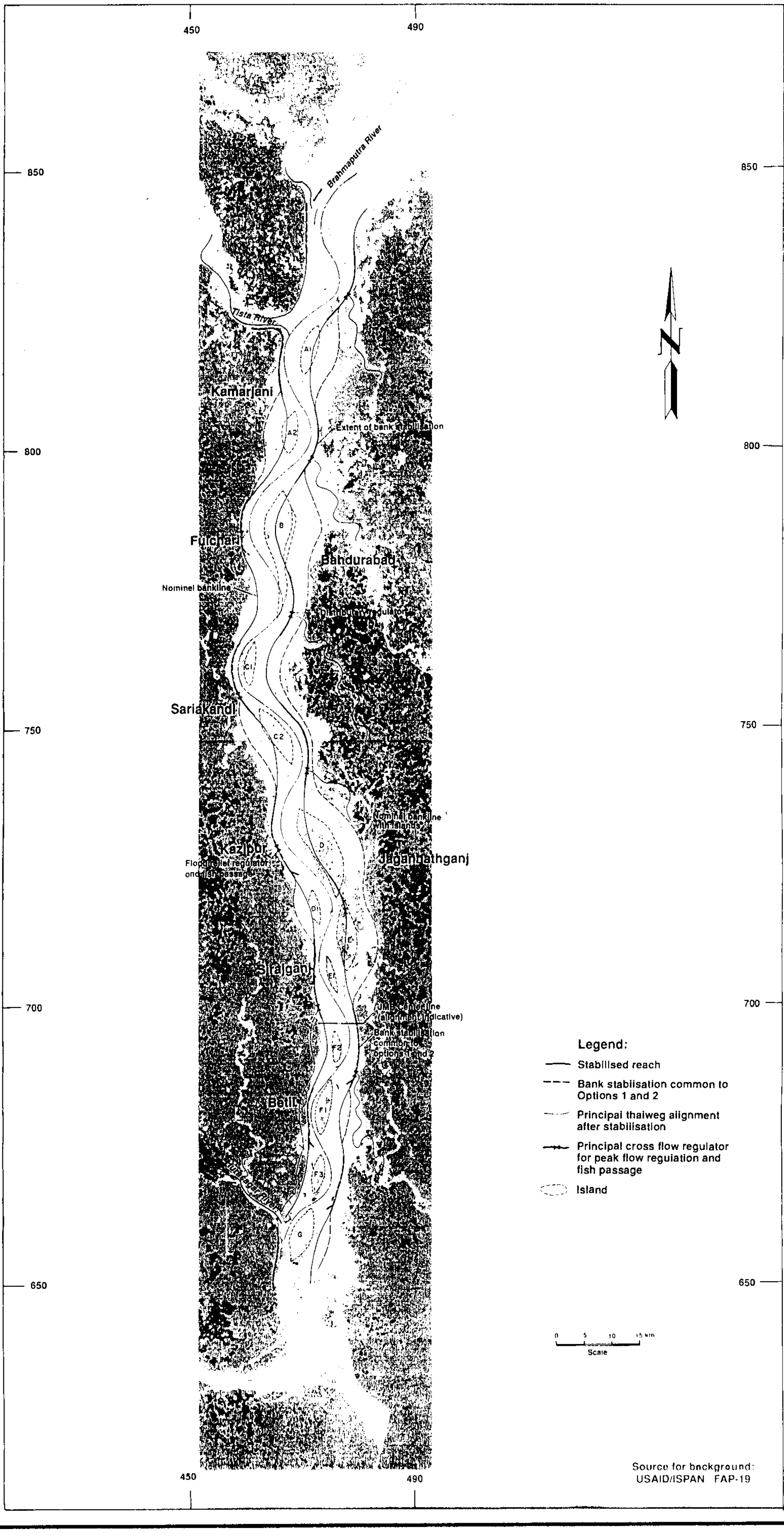
Tentative Planform for Long Term River Training Option 1

Halcrow/DHI/EPC/DIG

May 1993

Annex 3

Figure 4.1



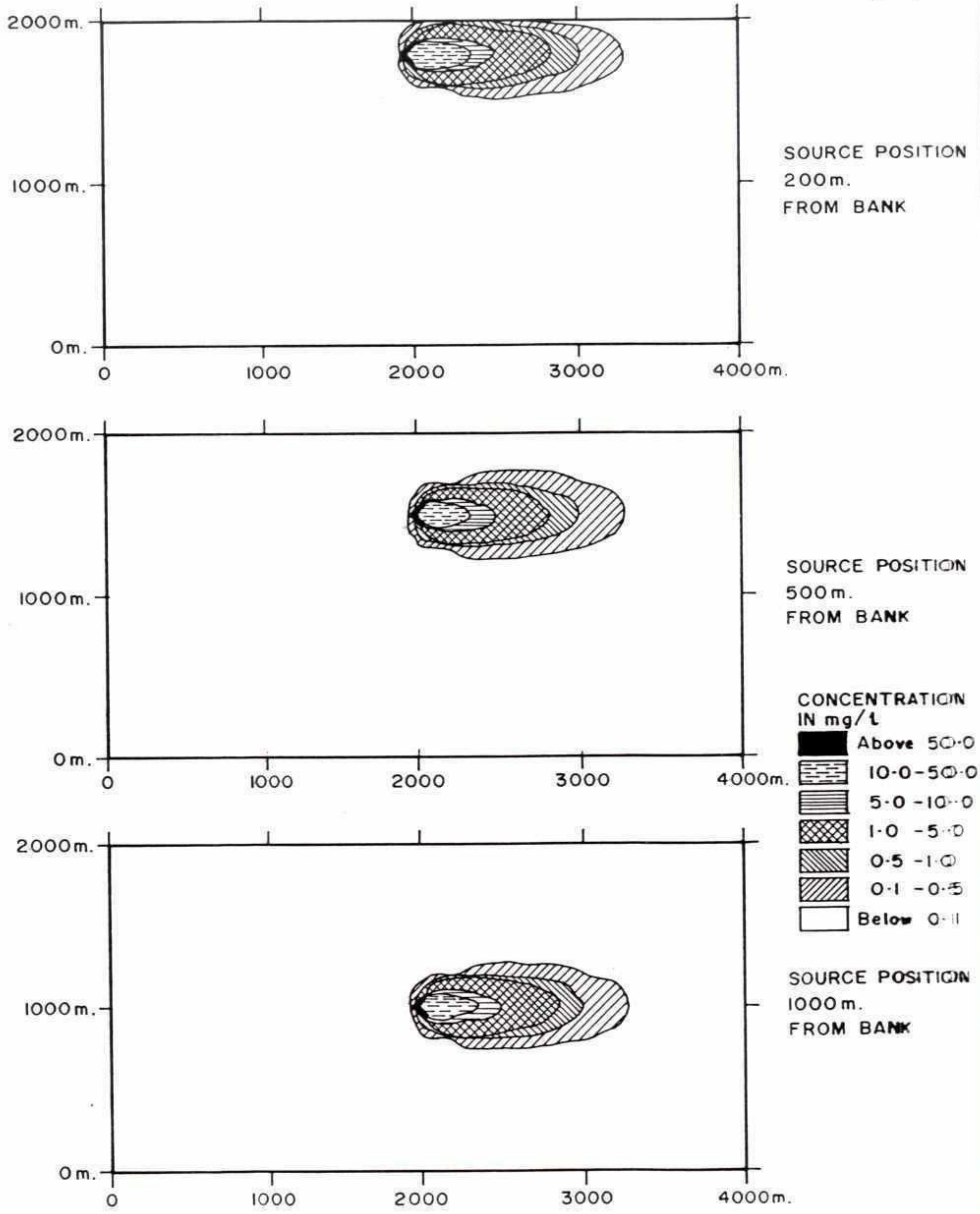
Tentative Planform for Long Term River Training Option 2

Halcrow/DHI/EPC/DIG

Annex 3

May 1993

Figure 4.2



ASSUMPTIONS:

Discharge: Continuous single point discharge, rate 60/m³/hour (44·2 kg/s at density 2·65 t/m³).

Flow velocity: 1 m/s across the entire section.

Channel cross-section
Rectanguar, Width 2000m, Depth 6m.

Settling velocity:
0·025 m/s (Fine sand, d50 = 0·18 mm)

SOURCE: DANISH HYDRAULIC INSTITUTE MARCH 1992

Silt Plume Estimate

Annex 3

Halcrow/DHI/EPC/DIG *May 1993* **Figure 5.1**

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APPENDICES

HALCROW

APPENDIX A

EVALUATION AND ASSESSMENT METHOD

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MASTER PLAN REPORT - ANNEX 3

APPENDIX A

EVALUATION AND ASSESSMENT METHOD

1. INTRODUCTION

This appendix describes the system used to quantify the subjective, qualitative judgements made in the environmental assessment. The system accepts the need to provide a transparent and effective tool by which a record of the judgements made can be scrutinised and reviewed.

The system has been tested on a series of arbitary conditions and in a number of actual project situations on a number of projects, and has been found to provide rapid and reproducible assessments.

2. DISCUSSION: PROJECT IMPACT ASSESSMENT

In conducting any impact assessment where reliance has to be placed on incomplete secondary data, and where no possibility exists for independent confirmation, or for primary data collection, assessment will tend to be subjective. This subjectivity can provide a competent analysis of the probable changes and effects, but suffers in that it is neither reproducible nor transparent.

Where qualitative evaluation of impacts has to be made, it is important that these evaluations should conform to a defined system of analysis. EIA/IEE evaluations need to be re-assessed with the passage of time, and the data contained therein should be open to scrutiny and revision as new data becomes available.

Wholly subjective and descriptive systems are not capable of such revision, dependent as they are on the expertise and experience of the original assessors and on the quality of the descriptive record left behind.

To provide some degree of transparency and objectivity in the qualitative assessment and evaluation of the impacts on this project, a system of scoring has been used for both the EIA on the Priority Works and for the IEE on the Master Plan. This system allows subjective judgments to be quantitatively recorded. This allows for an impact evaluation to be made whilst at the same time providing a record that can re-assessed in the future.

The system was tested on a series of arbitrary conditions, and actual examples, and was found to provide a rapid and reproducible basis for assessment of the conditions and to highlight changes, within a matrix, between a without- and with-project situation.

3. ASSESSMENT/EVALUATION SYSTEM

3.1 **Basis of System**

The system is based on the definition of important assessment criteria and a means by which values for each of these criteria can be collated to provide an accurate and independent score for each condition.

The criteria fall into two groups:

(a) criteria that are of importance to the condition and which can, individually, change the score obtained

(b) that are of value to the situation but, individually, should not be capable of changing the score obtained

The scoring system relies on a simple multiplication of the scores given to each of the criteria in Group (A). The use of multiplication for Group (A) scores is important for it implicitly ensures that the weight of each score is expressed, whereas simple summation of scores could provide identical results for different conditions.

The value scores are added together to provide a single sum. This ensures that the individual value scores cannot influence the overall score but that the collective importance of all values (Group (B)) are fully taken into account.

The sum of the Group (B) scores are then multiplied by the result of the Group (A) scores to provide a final assessment score for the condition. The process can be expressed:

(1) (a1)x(a2)x(a3)x...(aN) = aT
(2) (b1)+(b2)+(b3)+...(bN) = bT
(3) (aT)x(bT) = ES

Where:

(a1)..(aN) are individual criteria scores for Group (A)
(b1)..(bN) are individual criteria scores for Group (B)
aT is the result of multiplication of all (A) scores
bT is the result of addition of all (B) scores
ES is the assessment score for the condition

3.2 **Scales**

The scale of ES scores will vary with the number of Group (A) and (B) criteria applied and also if the scales for each criterion vary. The advantages of using different criteria scales are that the sensitivity can be varied for each criterion, and that weighting can be applied directly in the assessment process. As the criteria and the scales are defined, this process is wholly transparent. The system also allows a "what if..." condition to be applied by varying the weighting given, particularly with respect to value criteria (Group (B)).

Benefit and dis-benefit can be obtained by using scales that pass from negative to positive values through zero. Zero thus becomes the 'no-change' or 'no-importance' value. The use of zero in this way in Group (A) criteria, allows a single criteria to isolate conditions which show no change or are unimportant to the analysis.

Zero is a value to be avoided in the Group (B) criteria. If all Group (B) criteria score zero, the final result of the ES score will also be zero. This condition may occur even where the Group (A) criteria show that the condition of importance and should be recognised. To avoid this, scales for Group (B) criteria should use (1) as the 'no-change/no-importance' score.

3.3 Criteria Used

Although four criteria are defined for Group (A), the number of criteria used in making an assessment will comprise two under Group (A) and three under Group (B), to allow for a standardization of scales and ranges.

<u>GROUP (A)</u>

IMPORTANCE OF CONDITION (A1)

A measure of the importance of the condition, and is assessed against the spatial boundaries or human interests it will affect. The scales are defined:

4 = important to national/international interests
3 = important to regional/national interests
2 = important to areas immediately outside the local condition
1 = important only to the local condition
0 = no importance

MAGNITUDE OF CHANGE/EFFECT (A2)

Magnitude is defined as a measure of the scale of benefit/dis-benefit of an impact or a condition:

+3 = major positive benefit
+2 = significant improvement in status quo
+1 = improvement in status quo
0 = no change/status quo
-1 = negative change to status quo
-2 = significant negative dis-benefit or change
-3 = major dis-benefit or change

SECURITY OF CONDITION (A3)

This provides a measure of the risk of failure of the flood defence system by comparison with the present system of reaction to the event or potential event of a breach.

4 = no likelihood of failure
3 = likelihood of failure much less than present
2 = likelihood of failure less than present
1 = likelihood of failure slightly less than present
0 = no change/status quo

COMPLEXITY (A4)

This is a measure of the degree of complexity or difficulty that is required by a condition to be enacted or maintained.

+3 = very simple/easy
+2 = simple/easy
+1 = simple/easy but requiring some skill/assistance
0 = not relevant/status quo
-1 = not simple/easy and requiring skill/assistance
-2 = complex/difficult
-3 = very complex/difficult

GROUP (B)

PERMANENCE (B1)

This defines whether a condition is temporary or permanent, and should be seen only as a measure of the temporal status of the condition (e.g. an embankment is a permanent condition even if it may one day be breached or abandoned, whilst a coffer dam is a temporary condition, as it will be removed).

1 = no change/not applicable
2 = temporary
3 = permanent

REVERSIBILITY (B2)

This defines whether the condition can be changed and is a measure of the control over the effect of the condition. It should not be confused or equated with permanence. (eg: (i) an accidental toxic spillage into a river is a temporary condition (B1) but its effect (death of fish) is irreversible (B2); a town's sewage treatment works is a permanent condition (B1), the effect of its effluent can be changed (reversible condition)(B2)).

1 = no change/not applicable
2 = reversible
3 = irreversible

CUMULATIVE (B3)

This is a measure of whether the effect will have a single direct impact or whether there will be a cumulative effect over time, or a synergistic effect with other conditions. The cumulative criterion is a means of judging the sustainability of a condition, and is not to be confused with

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a permanent/irreversible situation. For instance, the death of an old animal is both permanent and irreversible, but non-cumulative as the animal can be considered to have already passed its breeding capabilities. The loss of post-larval shrimp in the wild, is also permanent and irreversible, but in this case cumulative, as all subsequent generations that the larvae (as adults) may have initiated will also have been lost.

1 = no change/not applicable
2 = non-cumulative/single
3 = cumulative/synergistic

3.4 Ranges

The formulae given above, and the defined scales for scoring the criteria, provide a final ES score. Individual scores need to be banded together into ranges where they can be compared. In the FPCO Environmental Guidelines (May 1992) 11 bands are recognised: 0, ±(1 to 5).

Ranges need to be defined, not by simple numerical limits, but by conditions that act as markers for the change in bands. These conditions would normally reflect the changes in Group (A) scores, combined with the upper or lower scores possible with the Group (B) criteria.

The conditions have been considered to produce six ranges (each can be positive or negative except the zero range). The limits of these ranges can be defined as follows:

Conditions that have neither importance nor magnitude will score zero, and can be banded together. Any condition in this band is either of no importance, or represents the status quo, or a no change situation.

A condition that is of slight importance (A2=1), and a slight change from the status quo (A2=1), yet is permanent (b1=3), irreversible (B2=3) and cumulative (B3=3), represents the upper limit of the 'slight change' condition.

A condition of 'change' will occur up to a slight condition (A1=1) with significant magnitude (A2=2), that is permanent (B1=3), irreversible (B2=3) and cumulative (B3=3).

A condition of moderate change will then lie between the limits of 'change' and 'significant change'. The lower limits of 'significant change' can be taken as the point when a condition is 'better' (A1=2) but is of major importance (A2=3), yet is temporary (B1=2), reversible (B2=2) and non-cumulative (B3=2).

A 'major change' will occur at a point when the condition involves most security of defence (A1=3) and is of major importance (A2=3). Such a change would also be permanent (B1=3), irreversible (B2=3), though it could be non-cumulative (B3=2).

These ranges can be translated into the 11-point FPCO environmental guideines scale as shown in Table A.1

3.5 **Environmental Components**

To use the evaluation system described, a matrix has been produced for each project option, for determination of impact against specified environmental components. This process of scoping is described here, where the environmental components selected are defined.

The environmental components are generally considered as four primary components, and these were used for the EIA on the Priority Works. However, in the Master Plan, conceptual strategies are considered, and the detailed construction schedules available for the Priority Works are not relevant here. Therefore, for the IEE on the Master Plan, each primary element has been further reduced to identify specific environmental components that better demonstrate the possible impacts of each strategy.

TABLE A.1

CONVERSION OF RANGES TO FPCO ENVIRONMENTAL VALUES (MAY 1992)

Evaluation Score (ES) range	FPCO Environmental Guideline value	FPCO Environmental Guideline value description
+72 to +108	+5	Highly positive
+36 to +71	+4	Very positive
+19 to +35	+3	Moderately positive
+10 to +18	+2	Positive
+1 to +9	+1	Slightly positive
0	0	No impact/status quo
-1 to -9	-1	Slightly negative
-10 to -18	-2	Negative
-19 to -35	-3	Moderately negative
-36 to -71	-4	Very negative
-72 to -108	-5	Highly negative & irreversible

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APPENDIX B

RIVER BANK PROTECTION PROJECT

BRAHMAPUTRA RIGHT BANK PRIORITY WORKS

ENVIRONMENTAL IMPACT ASSESSMENT

ACTION PLAN FOR MONITORING AND MITIGATING IMPACTS

APPENDIX B

RIVER BANK PROTECTION PROJECT
BRAHMAPUTRA RIGHT BANK PRIORITY WORKS

ENVIRONMENTAL IMPACT ASSESSMENT

ACTION PLAN FOR MONITORING AND MITIGATING IMPACTS

1. Land Acquisition for Permanent Works

(a) Bank Protection

- o Consultation with affected persons and thana chairmen at least one year prior to commencement of construction (BWDB/DC)
- o Fixing of cross-bar alignments to minimise fragmentation of holdings, and avoid interference with homesteads etc (BWDB/BRTS/RBPP)
- o Timely completion of land acquisition procedures (BWDB)
- o Establish formal liaison and regular meetings between thana chairmen, BWDB Executive Engineer and Contractor, chaired by the Resident Engineer (RBPP)
- o Construction Programme to be sensitive to cropping programme.

(b) BRE Realignment

- o Consultation with affected persons and thana chairmen at least one year prior to commencement of construction (BWDB/DC/RBPP)
- o Fixing of alignments to minimise fragmentation of holdings, and avoid interference with homesteads etc (BWDB/RBPP)
- o Timely completion of land acquisition procedures (BWDB)
- o Establish formal liaison and regular meetings between thana chairmen, RBPP BRE Planning Unit and local contractors, chaired by Executive Engineer (BWDB/RBPP)
- o Construction Programme to be sensitive to cropping programme.
- o Occupation of refuge berm on landward side of BRE to be restricted to those displaced by bank erosion (BWDB/DC).
- o One-off compensation to be paid to tenants and landowners on river-side of new BRE (WB/BWDB/DC).

2. Temporary Resettlement of Squatters (Sirajganj)

- o Preliminary identification of persons affected (BRTS/RBPP)
- o Make provision in civil works contract BOQ and Specification for temporary resettlement (BRTS/BWDB)
- o Consultation with affected persons and town authorities at least one year prior to commencement of construction (BWDB/DC/RBPP)

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- o Establish detailed procedures in accordance with World Bank Directive on Involuntary Resettlement (WB/RBPP)
- o Final identification of persons affected prior to Award of civil works contract (BWDB/DC)
- o Establish formal liaison and regular meetings between town authorities, squatters' representative, BWDB Executive Engineer and Contractor, chaired by the Resident Engineer (RBPP)
- o Maintain formal liaison with the DC (RBPP)

3. Establishment of ICB Contractor's Facilities

- o Contractor to be made solely responsible for legal and financial arrangements for temporary acquisition of land (BRTS/BWDB).
- o Establish formal liaison and regular meetings between town/thana authorities, BWDB Executive Engineer and Contractor, chaired by the Resident Engineer (RBPP-RE)
- o Provisions written into the ICB Contract Conditions and Specification (see list of clauses) to cover the proper establishment of facilities, including adequate attention to sanitation, disease vectors, noise and dust nuisance (BRTS/BWDB).
- o Contractor to furnish detailed proposals and drawings for approval of the Engineer prior to commencement of any work (RBPP-RE)
- o Enforcement of all contract provisions by the Resident Engineer (RBPP-RE)

4. Procurement of Clay Bricks

- o Provisions written into the ICB Contract Conditions and Specification (see list of clauses) to limit the procurement of bricks for the works to kilns using coal for fuel (BRTS/BWDB).
- o Contractor to furnish list of kilns (owner and location) for prior approval of the Resident Engineer (RBPP-RE)
- o Spot checks to be made to ensure compliance (RBPP-RE/BWDB)
- o Strict rejection of non-complying material (RBPP-RE)

5. Precasting Cement Concrete Blocks

- o Provisions written into the ICB Contract Conditions and Specification (see list of clauses) to cover the proper establishment of facilities and abatement of noise and dust nuisance (BRTS/BWDB).
- o Contractor to furnish detailed method statement for approval of the Engineer prior to commencement of any work (RBPP-RE)
- o Compliance with provisions and method statement to be monitored and enforced by the Resident Engineer (RBPP-RE)
- o Contractor's Land and Water Transport
- o Provisions written into the ICB Contract Conditions and Specification (see list of clauses) making the Contractor responsible for ensuring that his activities do not unreasonably interfere with navigation, fisheries and road users (BRTS/BWDB).

- o Provisions written into the ICB Contract Conditions and Specification (see list of clauses) debarring the Contractor from using roads in congested urban areas and making him responsible for making good any damage to roads resulting from his use (BRTS/BWDB).
- o Liaison to be maintained with relevant authorities (RBPP-RE)

6. Dredging and Hydraulic Fill

- o Confirmation that river bed and bank material contains no significant amount of toxic materials (BRTS)
- o Provisions written into the ICB Contract Conditions and Specification (see list of clauses) making the Contractor responsible for ensuring that his activities do not unreasonably interfere with navigation and fisheries (BRTS/BWDB).
- o Locations of all sources of dredged material either shown on Drawings or subject to approval of the Engineer (BRTS/RBPP-RE)
- o Establish formal liaison and regular meetings between BIWTA/BR/DOF and representatives of country boat operators and fishermen, BWDB Executive Engineer and Contractor, chaired by the Resident Engineer (RBPP)
- o Contractor to furnish detailed method statement for approval of the Engineer prior to commencement of any work (RBPP-RE)
- o Compliance with provisions and method statement to be monitored and enforced by the Resident Engineer (RBPP-RE)
- o Samples to be taken during hydraulic fill operations and analysed for toxic content (RBPP-RE)
- o Sediment concentrations to be monitored downstream of dredging operations (Contractor/RBPP-RE)
- o Procedure to be established for recording and evaluating complaints and feedback to the Resident Engineer (BWDB)
- o Contractor required to take all practicable measures to minimise turbidity arising from dredging (see list of Clauses) (BRTS/BWDB).
- o Contractor required to observe:

  Environmental Pollution Act
  Marine Pollution Ordinance
  Inland Shipping Ordinance

  and, when enacted, the Inland Waterways III project requirement for river bed sample testing prior to dredging (see list of Clauses) (BRTS/BWDB)

7. Utilization of Borrow Pits

- o Provisions written into the ICB Contract Conditions and Specification (see list of clauses) making the Contractor responsible for ensuring that borrow pits do not constitute a health hazard during the construction period and are left on completion in a suitable condition for subsequent use by farmers (BRTS/BWDB).
- o Design of works to include suitable vegetation to be planted to stabilize the borrow pits (BRTS/BWDB)
- o Consultation with landowners and tenants concerning the location of borrow areas (BWDB/RBPP)

- o Contractor to furnish detailed method statement for approval of the Engineer prior to commencement of any work (RBPP-RE)
- o Compliance with provisions and method statement to be monitored and enforced by the Resident Engineer (RBPP-RE)

8. Reinstating the Construction Site

- o Provisions written into the ICB Contract Conditions, BOQ and Specification (see list of clauses) requiring the Contractor to properly reinstate the Site (BRTS/BWDB).
- o Contractor to furnish detailed method statement for approval of the Engineer prior to commencement of any work (RBPP-RE)
- o Compliance with provisions and method statement to be monitored and enforced by the Resident Engineer (RBPP-RE)

9. Changes in River Morphology

(a) Prior to and during construction

- o Satellite imagery CCT (two scenes) to be procured from Bangkok as soon after the start of each low flow season as cloud cover permits and once during the high flow season (BWDB/WB)
- o CCT initially to be analyzed by FAP-19 and subsequently alternative arrangements to be made (FPCO/BWDB/WB/RBPP)
- o Interpretation of imagery and monitoring of morphological changes (BRTS/RBPP-TA)
- o Regular bankline and bathymetric surveys in the vicinity of Priority Works and their interpretation (Contractor/RBPP-RE/RBPP-TA)
- o Training of selected BWDB personnel in interpretation (RBPP-TA)

(b) post-construction

- o Regular bankline and bathymetric surveys in the vicinity of Priority Works and their interpretation (BWDB-MMU)

10. Resettlement of Persons Displaced by Bank Erosion

- o Refuge berm on landward side of BRE and downstream side of cross-bars to be reserved for occupation by displaced person only (including landless farm labourers) (BWDB/DC).
- o Pilot project for income generation for displaced persons and their involvement in maintenance (BWDB/WB/RBPP)
- o Possibilities to be investigated for use of embankment borrow pits BWDB/WB/RBPP)
- o Alternative forms of resettlement to be investigated (BWDB/WB/RBPP)
- o Regular monitoring of status of erosion and displaced persons (BWDB/RBPP/Dhaka Univ)

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LIST OF ABBREVIATIONS USED IN ACTION PLAN

BIWTA	Bangladesh Inland Water Transport Authority
BOQ	Bill of Quantities
BR	Bangladesh Railway
BRE	Brahmaputra Right Embankment
BRTS	Brahmaputra River Training Studies (FAP-1)
BWDB	Bangladesh Water Development Board
CCT	Computer Compatible Tapes
DC	Deputy Commissioner
DOF	Department of Fisheries
FAP	Flood Action Plan
FPCO	Flood Plan Co-ordination Organisation
ICB	International Competitive Bidding
MMU	Monitoring and Maintenance Unit
RBPP	River Bank Protection Project
RE	Resident Engineer
TA	Technical Assistance
WB	World Bank

LIST OF CLAUSES PERTAINING TO MITIGATION OF IMPACTS

1. **General Conditions of Contract**

Clause No.	Description
8.2	Site Operations and Methods of Construction
13.1	Work to be in Accordance with Contract
19.1	Safety, Security and Protection of the Environment
26.1	Compliance with Statutes, Regulations
29.1	Interference with Traffic and Adjoining Properties
30.1	Avoidance of Damage to Roads
30.2	Transport of Contractor's Equipment or Temporary Works
30.3	Transport of Materials or Plant
30.4	Waterborne Traffic
32.1	Contractor to Keep Site Clear
33.1	Clearance of Site on Completion
45.1	Restriction on Working Hours

2. **Conditions of Particular Application**

Clause No.	Description
34	Labour
34.11	Health and Safety
34.12	Measures against Insect and Pest Nuisance
34.13	Epidemics
45.1	Restriction on Working Hours

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3. Specification

Clause No.	Description
Part 1	**Description of Works**
102	Scope of Contract (includes provision for squatter resettlement in Contract No. 2, Sirajganj)
104	Working Areas (Contractor responsible for temporary acquisition of additional land)
Part 2	**Preliminary and General**
214	Sanitary Conveniences
216	Drains, Streams, Watercourses, etc.
220	Access (restriction on construction traffic, etc)
223	Safety of Adjacent Structures or Works
224	Interference with Existing Works
225	Abatement of Nuisance
231	Contractor's Accommodation (Contractor to furnish details for Engineer's approval)
241	Temporary Works (Contractor to furnish details for Engineer's approval)
244	Notice to Mariners
245	Navigation
248	Liaison with Public Authorities
Part 3	**Earthworks**
318	Borrow Pits
Part 4	**Dredging and Reclamation**
403	Borrow Area (Contract no.2 - other dredging areas shown on the Drawings)
408	Discharge into the River

409	Dredging Method Statement
412	Compliance with Regulations
417	Filling in Reclamation Area (including submission of method statement)
Part 5	**Concrete**
504	Aggregates - General
504(5)	- source to be approved by the Engineer
505	Coarse Aggregate
505(5)	- requirement to use only coal-fired kilns for bricks
Part 6	**Revetment Works**
617	Rock Armour (alternative armouring to c.c. blocks)
617(2)&(5)	- quarry rock to be supplied only from sources approved by the Engineer
617(8)	- Contractor to submit proposals for rock handling and stockpiling
618	Brick Filter Layer (bricks to conform to Sub-Clause 505(5)).
619	Revetment Construction Method Statement
Part 7	**Roads (Contract No. 2** only)
703	Aggregate Sources for Bitumen Macadam (subject to the Engineer's approval)
Part 8	**Piling (Contract no.** 2 only)
801	Piling Plant and Methods
801 (1)	- Contractor to submit details for the Engineer's approval
806	Disturbance and Noise