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Flood Action Plan

North West Regional Study (FAP-2)

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THE REGIONAL PLAN - ENGINEERING

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REGIONAL PLANNING - ENGINEERING

CONTENTS

1. BACKGROUND 1-1

2. PRESENT SITUATION 2-1
   2.1 General 2-1
   2.2 Existing and On-going CFD/CFDI schemes 2-1
   2.3 Present River Conditions and Carrying Capacity 2-5
   2.4 Present Drainage Condition 2-9

3. PLANNING AND DESIGN CRITERIA 3-1
   3.1 Introduction 3-1
   3.2 Planning criteria 3-1
   3.3 Design criteria 3-4

4. THE MAJOR DRAINS 4-1
   4.1 General 4-1
   4.2 Alternative Alignments 4-1
   4.3 Capacities 4-3
   4.4 Conclusions 4-4

5. PLANNING OPTIONS AND SCENARIO 5-1
   5.1 Planning Units 5-1
   5.2 Planning Condition 5-3
   5.3 Planning Units No. 1 and 2: Thankurgaon and Upper Atrai 5-4
   5.4 Planning Unit No.3 : Teesta Right Bank 5-9
   5.5 Planning Unit No.4 : Teesta Left Bank 5-10
   5.6 Planning Unit No. 5 - Kurigram 5-12
   5.7 Planning Unit No.6 : Upper Karatoya 5-15
   5.8 Planning Unit No.7 : Gaibandha 5-18
   5.9 Planning Unit No.8 : Middle Bangali Basin 5-19
   5.10 Planning Unit No.9 : Joypurhat 5-22
   5.11 Planning Unit No.10 : Barind Tract 5-24
   5.12 Planning Unit No.11 : Mohananda Basin 5-25
   5.13 Planning Unit No.12 : Atrai Left Bank 5-27
   5.14 Planning Unit No.13 : Atrai Right Bank 5-35
   5.15 Planning Unit No.14 : Lower Bangali 5-39
   5.16 Planning Unit No.15 : Pabna 5-43
   5.17 Bangali Floodway 5-45
   5.18 Discharge Distribution under the Development Scenario 5-49

6. COST ESTIMATE 6-1
   6.1 Major Construction Items and Quantification 6-1
   6.2 Basic Conditions and Assumptions Adopted for Costing 6-2
   6.3 Estimated Implementation Cost of Each Option 6-4

List of Tables

2.1 Existing/On-going FCD and FCD/I Projects in the Region
2.2 List of Existing Drainage Regulators

4.1 Cost Comparison of Alternative Routes of Major Drains

5.1 Spillage of Upper Karatoya
5.2 Channel Cross Sections of the Bangali Floodway
5.3 Cost Comparison of Options of the Bangali Floodway

6.1 Implementation Cost of Planning Unit No.3
6.2 Implementation Cost of Planning Unit No.4 (Option-1)
6.3 Implementation Cost of Planning Unit No.4 (Option-2)
6.4 Implementation Cost of Bangali Floodway (Option-1)
6.5 Implementation Cost of Bangali Floodway (Option-2)
6.6 Implementation Cost of Bangali Floodway (Option-3)
6.7 Implementation Cost of Bangali Floodway (Option-4)
6.8 Implementation Cost of Bangali Floodway (Option-5)
6.9 Implementation Cost of Bangali Floodway (Option-6)
6.10 Implementation Cost of Planning Unit No.9
6.11 Implementation Cost of Planning Unit No.11
6.12 Implementation Cost of Planning Unit No.12 (Whole Unit of CFD Area)
6.13 Implementation Cost of Planning Unit No.12 (Polder 2 Area,CFD Area)
6.14 Implementation Cost of Planning Unit No.12 (Polder 3 Area,CFD Area)
6.15 Implementation Cost of Planning Unit No.12 (Whole Unit of Flow Area)
6.16 Implementation Cost of Planning Unit No.12 (Polder 2 Area,Flow Area)
6.17 Implementation Cost of Planning Unit No.12 (Polder 3 Area,Flow Area)
6.18 Implementation Cost of Planning Unit No.13 (Whole Unit of CFD Area)
6.19 Implementation Cost of Planning Unit No.13 (Polder A Area,CFD Area)
6.20 Implementation Cost of Planning Unit No.13 (Polder B Area,CFD Area)
6.21 Implementation Cost of Planning Unit No.13 (Polder C Area,CFD Area)
6.22 Implementation Cost of Planning Unit No.13 (Polder D Area,CFD Area)
6.23 Implementation Cost of Planning Unit No.13 (Whole Unit of Flow Area)
6.24 Implementation Cost of Planning Unit No.13 (Polder A Area,Flow Area)
6.25 Implementation Cost of Planning Unit No.13 (Polder B Area,Flow Area)
6.26 Implementation Cost of Planning Unit No.13 (Polder C Area,Flow Area)
6.27 Implementation Cost of Planning Unit No.13 (Polder D Area,Flow Area)
6.28 Implementation Cost of Planning Unit No.14 (Whole Unit of CFD Area)
6.29 Implementation Cost of Planning Unit No.14 (Hurasagar North,CFD Area)
6.30 Implementation Cost of Planning Unit No.14 (Hurasagar South,CFD Area)
6.31 Implementation Cost of Planning Unit No.14 (SIRDP Area,CFD Area)
6.32 Implementation Cost of Planning Unit No.14 (Whole Unit of Flow Area)
6.33 Implementation Cost of Planning Unit No.14 (Hurasagar South,Flow Area)
6.34 Implementation Cost of Planning Unit No.14 (SIRDP Area,Flow Area)

List of Figures

2.1 Present River System and Location of Existing/On-going CFD And CFD/I Projects in the Region
2.2 River Features of the Atrai River
2.3 River Features of the Kakra River
2.4 River Features of the Shib-Barnai River
2.5 River Features of the Little Jamuna River
2.6 River Features of the Kharkharia River
2.7 River Features of the Tulsi Ganga River
2.8 River Features of the Nagor River
2.9 River Features of the Bangali-Karatoya River
2.10 River Features of the B-Chikly River
2.11 River Features of the Ghagot River
2.12 River Features of the Alai-Ghagot River
2.13 River Features of the Manash River
2.14 River Features of the Teesta River
2.15 River Features of the Dharla River
2.16 River Features of the Dudhkumar River
2.17 River Features of the Mohananda-Tangon River
2.18 River Features of the Mohananda-Punarbhaba-Dhepa River

4.1 Major Drain Alignments
4.2 Major Drain Sections

5.1 Planning Units in the Region
5.2 General Layout of Thakurgaon and Upper Atrai (Planning Unit No.1 & 2)
5.3 Conveyance Capacity and Probable Discharge in Thakurgaon and Upper Atrai (Planning Unit No.1 & 2)
5.4 General Layout of Teesta Right Bank (Planning Unit No.3)
5.5 Longitudinal Profile of Teesta Right Bank
5.6 General Layout of Teesta Left Bank (Planning Unit No.4)
5.7 Longitudinal Profile of Teesta Left Bank
5.8 General Layout of Kurigram (Planning Unit No.5)
5.9 General Layout of Upper Karatoya (Planning Unit No.6)
5.10 Conveyance Capacity and Probable Discharge in Upper Karatoya (Planning Unit No.6)
5.11 Longitudinal Profile of Upper Karatoya
5.12 General Layout of Gaibandha (Planning Unit No.7)
5.13 General Layout of Middle Bangali (Planning Unit No.8)
5.14 General Layout of Joypurhat (Planning Unit No.9)
5.15 Conveyance Capacity and Probable Discharge in Joypurhat (Planning Unit No.9)
5.16 General Layout of Barind Tract (Planning Unit No.10)
5.17 General Layout of Mahananda (Planning Unit No.11)
5.18 Relation of Daily Water Level between Rohanpur and Capai Nawabganj
5.19 Probability Analysis of Peak Water Level at Rohanpur by Gumbel Method
5.20 Longitudinal Profile of Mahananda
5.21 General Layout of Atrai Left Bank (Planning Unit No.12)
5.22 General Layout of Naogoan Polder
5.23 General Layout of Bogra Polder 2

5.24 Atrai Longitudinal Profile
5.25 Shib-Barnai Longitudinal Profile
5.26 L. Jamuna Longitudinal Profile
5.27 Nagor River Longitudinal Profile
5.28 General Layout of Atrai Right Bank (Planning Unit No.13)
5.29 General Layout of Lower Bangali (Planning Unit No.14)
5.30 Bangali River Long Section
5.31 General Layout of Pabna (Planning Unit No.15)
5.32 Alternative Routes of the Bangali Floodway
5.33 General Layout Plan of the Bangali Floodway
5.34 River Features of The Bangali Floodway
5.35 General Layout of Green River
5.36 Design Discharge Disribution

CHAPTER 1

BACKGROUND

The North West Region with a total area of 34,600 km2, which is delineated by two major rivers, the Brahmaputra on the east and Ganges on the south , is drained by the perennial rivers such as the Atrai, Teesta, Dharla, Dudhkumar and Mohananda which originate in India, and other non-perennial rivers. The Region suffered disastrous floods in 1987 and 1988, which were caused by localized rainstorms over the catchment and synchronization of high stages of these two major rivers. To mitigate such flood damages in the region, the Interceptor and Diversion Drains have been conceived as the effective means in the "National Flood Protection Program" prepared by Ministry of Irrigation, Water Development and Flood Control in November 1988. This was followed by the preliminary study in framing the FAP studies.

The engineering study in the Interim Regional Study of FAP 2 was proceeded with in March 1991 with input of the River and Drainage Engineers in order to establish the interim flood control and drainage plans in collaboration with other disciplines taking into account the comprehensive measure to reduce the flooding problems in the lower Atrai, including the aforesaid major drains. Main objectives of the engineering study were;

- To identify and assess the flood control and drainage problems in the region from engineering aspect on the basis of the available data and information to be collected from the governmental organization concerned and through the site reconnaissance,

- Based on the hydraulic modelling analysis, to work out the comprehensive flood control and drainage plans in the Atrai-Hurasagar river system including the major drains and make a preliminary quantification and costing concerning each of them,

- Based on the hydraulic modelling analysis, to set up the flood control and drainage options necessary to mitigate the flooding problems within the region,

- To make the preliminary quantification and costing for each of the FCD options for making their ranking studies by combining with the benefits, in order to select the priority project for which a feasibility study is to be carried out in the next stage,

- To prepare TOR for the feasibility study for the priority project to be carried out in next year with respect to engineering discipline.

The Interim Regional Study continued up to November 1991. It worked out the Interim Regional Plan for the planning units suffering severe flooding problems including the Lower Atrai and assessed the viability of the major drains with respect to the alternative routes identified. As a result of the Interim Regional Study, it is concluded that the major drains would not be the economically viable measure to mitigate the flooding in the Lower Atrai from a viewpoint of the cost-effectiveness and that the further study thereof is not to be carried out in the successive regional study of next year (1992). Besides, the Gaibandha Improvement Project has been selected as the priority project for which a feasibility study is to be carried out in next year.

In succession to the Interim Regional Study, the engineering study for the regional planning has been continued between February and October 1992, aiming mainly at;

- To further refine the flood control and drainage options from engineering aspect, established through the Interim Regional Study based on the hydraulic modelling analysis to be improved,

- For other planning units than those covered by the Interim Regional Study, to identify and assess the flood control and drainage problems and set up the FCD options if the promising ones are identified,

- To assess the viability of the shortened Interceptor Drain (called the Bangali floodway in this Report) in view of mitigation of flooding in the lower and upper reaches,

- To make the quantification for each option to be set up finally through the regional study and make costing therefor applying the new unit rates worked out through the study on cost estimate.

As stated in the Inception Report, the North West region has already been covered by a number of existing and planned FCD or FCDI schemes with different protection levels, especially in the low-lying areas susceptible to habitual flooding such as the Lower Atrai. It appeared that these polders had been provided without any concept of the region-wide flood control plan, which is essential for areas like this region where rising of river stages by implementing one project has a significant affect on those in other areas. In addition, it has been recognized through the site reconnaissance that most of flood embankments in those existing schemes have deteriorated due to insufficient compaction of embankment layers as well as use of unsuitable embankment materials at the construction stages. Moreover, due to insufficient number and capacities of drainage facilities, these flood embankments have been cut by local people residing inside the polder. Cuts were also made by those living outside polders to reduce levels by allowing internal flooding. Accordingly, the engineering study has focused on establishment of a comprehensive flood control and drainage plan with a definite protection level on the region-wide basis as well as rehabilitation of existing schemes and improvement of the present drainage condition against the outer river stages worked out through the hydraulic modelling analysis.

CHAPTER 2

PRESENT SITUATION

2.1 General

Flooding and drainage problems in the region have been identified through review of reports of different existing and on-going projects, data analyses, field investigations and consultation with FPCO to identify sub-regional CFD options to be taken up as appropriate framework for the comprehensive flood control planning. The following sections discuss the present river and drainage situation and existing and on-going CFD and CFDI projects in the region.

2.2 Existing and On-going CFD/CFDI schemes

In north west region a number of CFD/CFDI projects were completed and several projects are under construction, which are summarized in Table 2.1 and their locations are shown in Figure 2.1. These are explained in the following sub-sections.

2.2.1 Flood embankment along major rivers

Flood embankments are built on the major rivers, the Brahmaputra, Ganges and Teesta to protect the region from the flooding. The embankments along the Brahmaputra frequently breached at Kazipur and Sariakandi due to severe erosion which causes substantial damage to the lower Bangali basin. Teesta river also erodes the river bank and embankment, especially at Nohali, Mohipur, and Sundarganj areas, causing serious flooding problem to the Ghagot and Karatoya basin. Whilst the Ganges left embankment mostly remains intact and flooding through the Ganges is not common.

The area affected by flooding from Brahmaputra is under study by other FAPs as follows:

- FAP1 Strengthening of BRE
- FAP12 Evaluation of the impact of previous CFD measures, including the two area in the region Kazipur and Kamarjani.
- FAP20 The compartmental pilot project in the north of Sirajganj.
- FAP21/22 Active flood plain management and river training pilot project in the Gaibandha area near Manos.

FAP-1 proposed in the Second Interim Report to give high priority to Sariakandi and Sirajganj areas for strengthening of BRE with river training works and to repeat retirement of BRE in other areas taking into account the extent of flood damage. The investigation and findings have been taken into consideration for planning of the affected reaches.

FAP-20 proposed compartmental pilot project at north of Sirajganj town with a gross area of 11000 hectare bounded by BRE in the west, Ichamati river in the north and west. So far engineering survey has been carried out and 6-gauge station were installed. Compartmentalisation Pilot Project is being undertaken to examine controlling flooding and drainage including scale of a compartment, water control method, institutional arrangement, and operation and maintenance.

In the area along the Brahmaputra significant drainage problem exists in Gaibandha area due to a number of complex hydraulic reasons. The Ghagot river was closed by BRE and normal flows to Brahmaputra was replaced by the Manos regulator which is inadequate. The impeded drainage problem has increased manifold after construction of Sonail embankment scheme by the side of BRE and south of Gaibandha. This led to public cut to BRE at Manos in every year, during the study period cuts are made in 1990 and 1991. In the north of the confluence of the Teesta and Brahmaputra river erosion and bank movement was observed for the last few years near Chilmari, which is not covered under FAP1 study.

The flooding from the Ganges has stopped significantly after completion of the left embankment and Charghat off take regulator. However the river is actively threatening the Rajshahi township for long time and river training works have been made with spurs and groynes.

The Teesta is a braided one with 2 to 3 active channels and an average width of about 4 to 5 km. The Teesta is well known for its unstable river course and continuous bank shifting. River erosion was observed in both the banks and a number of river training works exists in the Teesta but those works have been damaged by high flow velocity of flood flow and due to poor construction method and material. It is confirmed that sealing of TRE with sufficient river training works are urgently requires since the flooding from the Teesta affects wide areas south of TRE.

2.2.2 Lower Atrai

This is a complex area of deep flooding mainly due to outfall constraints at the Hurasagar which restricts the drainage from Atrai basin and Karatoya - Bangali basin. CFD development in the lower Atrai basin has started in the 1970's with construction of embankment in the Chalan beel polder A, B, C and D on the right bank. There are various projects are going on like Barnai project and Baral project, most of the projects in this area are with different protection standard and design criteria. On the left bank CFD development was initiated in the 1980's with construction of Bogra polders and Naogaon polder. Bogra polder 4 which commands the larger area in the lower Atrai remains undeveloped for flows and storage purpose.

a) Lower Atrai Left Bank

In this area there are four major schemes, Tulshiganga project, Raktodoha - Lohachora (R-L), Nagor Valley scheme and Upper Nagor Valley scheme. Concerning the Tulshiganga scheme, the beel area is subjected to flooding due to the upland flows. New provision of regulators are proposed by Early Implementation Project for removing drainage congestion. R-L scheme is a completed one but embankment along Atrai river is being regularly breached at several location, the area receives large drainage flows from the upland and the regulators are not effectively functioning due to outfall condition. In the Upper Nagor Valley scheme located on the right bank of Nagor, flooding was reported at upstream reaches from Talora to Dhupchachia. The embankment of Nagor valley project has been breached regularly due to overland flows from north.

The Nagor river project situated on the left bank of the Nagor is also breached at lower reaches due to rushing of overland flows from R-L schemes and Nagor Valley project.

In the north of lower Atrai left bank area, a number of small scale CFD schemes have been developed through EIP and FFW, which includes Potnitola, Chilimpur and Badalgachi schemes. Spilling from the north of Badalgachi scheme causes flooding and drainage problems in the Naogaon areas. Other schemes are well functioning at present.

b) **Lower Atrai Right Bank**

The area suffers serious flooding and therefore protection works was started in Chalan beel since 1970's. Chalan beel polders A and B are not complete. The Chalan beel polder C and D are completed but inoperative due to public-cuts and breaches. In Polder B, a CFD scheme was developed at north west end known as Barnai River sub-project which aims effective controlling flood. Along Sib river, the Barnai project is under construction through the IDA funded FCD-IV program. Concerning Pabna project, Phase-1 area consisting of CFD/I development will be completed in the 1992/93 funded by ADB and Phase - 2 development is now under active consideration of the government based on the recent updating of feasibility study in 1991.

2.2.3 Lower Bangali and Karatoya

The lower Bangali area suffers flooding severely due to breaches in the BRE, public-cuts in SIRDP embankment and back water influence of the Brahmaputra through Hurasagar river. At the lower end of the basin there are two completed CFD projects, namely Sirajganj Integrated Rural Development Project (SIRDP) and Hurasagar scheme. The SIRDP polder embankment is cut regularly by people outside the polder for drainage and reduction of flood water level outside the polder. After 1988 flood prior to FAP-2 study, modification in the original plan was done by introduction of one escape-structure at Baghabari to allow flooding in the lower end of the SIRDP. The Escape structure,however, was washed away in 1991 flood and the polder requires further modification . The Hurasagar project situated on the confluence of the Hurasagar and Brahmaputra river is being regularly breached due to poor quality of the embankment body.

2.2.4 Lower Mohananda basin

This basin receives flows from the catchments of the Mohananda, Punarbhaba and Pagla river. At present the existing Nawabgonj - Rohanpur road built along the left bank of the Mohananda river forms functions as the left flood embankment of Mohananda river but there is no flood embankment on the right bank of the Mohananda river. However the Morcher Darna scheme on the right bank is protecting some area in the right bank. The flooding situation in the area is mostly due to rainfall run-off from the high lands and high stage in the Ganges. There is a number of small CFD scheme in the area along Mohananda mainstream, Pagla and tributaries as listed below:

a) Left bank	:	Shingri beel Drainage Scheme, Bhitabari Damos Mohananda Scheme, Somespur Drainage Scheme
b) Right bank	:	Morcher Darna scheme, Bhatia Beel Drainage Mohanada Scheme
c) Pagla basin	:	Toker Danra Scheme, Kumirdah scheme

Out of the basic schemes listed above, the schemes located on the both bank of the Mohananda are under study by System Rehabilitation Project (SRP). SRP recommends improved operation and maintenance of the existing scheme for water management and operational purpose. A pre-feasibility study by SRP is going on for Jhanjhania scheme in the north west of the basin.

2.2.5 Kurigram district

A feasibility study for flood control, drainage and irrigation of Kurigram area was commissioned in 1969. In feasibility study two units were suggested for planning consideration, which are namely north and south units.

Flood embankments are almost completed in north unit with drainage regulators . A feasibility study was conducted in 1989 for the north unit and is going on for the south unit by JICA. Since the flood embankments surrounding both areas are completed together with the regulators but there are several breached portions, the feasibility studies recommends rehabilitation and strengthening of the existing embankments together with improvement of drainage.

Kurigram town area, located along the Dharla, has been threatened with river bank erosion and therefore FAP - 9A proposed Kurigram town protection work as one of the priority projects.

2.2.6 Teesta basin

The Teesta right bank mainly suffers flooding through breaches along the embankment due to river bank erosion. The area near Sundarganj and Nohali are affected by the breaches in Teesta right embankment. Due to breaches large amount of flood water flows into the Ghagot and Jamuneswari river which heighten flood water levels in the downstream reaches and causes drainage congestion in particularly Gaibandha, Sadullapur and Ghoraghat areas.

The Teesta left bank suffers relatively less flooding due to breaches but Sati Nadi scheme located on left bank is subject to frequent breaches due to river bank erosion along about 10 km long river reach.

2.2.7 Upper Reaches

a) Upper Karatoya basin

In this area flooding frequently occurs in the reaches downstream of Siraj water level gauging station. The Karatoya river is presently affected by spilling through the breaches of TRE both in India and Bangladesh. BWDB completed Nuruller Beel scheme located near the crossing point of Bogra highway and Karatoya river and starts Karatoya CFD project funded by EIP to mitigate flooding to some extent in the Ghoraghat area.

b) Ghagot and Alai basins

There are two schemes, Satdamua Katler Beel project on the left bank of Ghagot and Sonail Embankment scheme on the left bank of the Alai. Satdamua Katler Beel Project provides flood embankment between Gaibandha and Bamondanga towns with drainage regulators as well as irrigation facilities and is scheduled to be completed in 1992/1993 fiscal year. Sonail Embankment scheme is completed but severe drainage congestion is induced by high water levels along the Alai and Brahmaputra and public-cuts for drainage has been repeated since the completion.

c) Northwestern area

The northwestern area of the region is located in comparatively high land, and therefore flooding is limited into the localized areas near Dinajpur town, Shamjiaghat and Panchagar areas through spillage

from Punarbhaba , Atrai - Kakra and Karatoya rivers. There are two CFD project in the area, Punarbhaba Embankment project and on going Atrai - Kakra project. The existing Punarbhaba left and right embankments are constructed to protect the Dinajpur town and adjoining areas. However since the Dinajpur and Panchagar towns are still suffering from flooding and river bank erosion due to remarkable meandering, FAP-9A selected a priority scheme for protection of Dinajpur and Panchagar town.

2.2.8 Other Irrigation projects

Beside the Kurigram irrigation project and Pabna project there are three other irrigation projects that were being considered in the regional planning and selection of routes of major drains.

The Teesta project is a major irrigation project with a barrage which was completed in 1990 and the main irrigation canals in phase-1 are almost complete, while distribution system is under construction.

Boral basin project is a irrigation /drainage project currently under study with funding by CIDA. The area is situated in the high land and after construction of Baral off take structure in Charghat the flooding problem of the area has reduced.

The Rajshahi North Irrigation is the subject to recent feasibility study completed by JICA. The proposed development in the region will not affect the plan of Rajshahi North Irrigation project.

2.3 Present River Conditions and Carrying Capacity

2.3.1 Introduction

The overall river systems in the region are illustrated in Figure 2.1. The North West Region is bounded by the Indian border on the north and west, the Brahmaputra on the east and the Ganges on the south. All rivers draining the region outfall to these major two rivers. The region has been divided into three major basins as follows:

- Atrai basin
- Teesta district
- Mohananda basin

2.3.2 Atrai Basin

The Atrai basin is further divided into three subbasins which are the Atrai river, Karatoya-Bangali and Ghagot rivers. The great part of the region is drained by two main river systems of the Atrai and Karatoya-Bangali, which cover a catchment area of 11,820 and 6,700 km^2, respectively. The sum of these areas corresponds to around 55 % of the total land area of the region. In the north, these two catchments are bounded by the line of the railway running north from Hilli through Saidpur. Topographic and hydraulic features of these rivers are shown in Figures to 2.13 and summarized in the following paragraphs.

a) The Atrai river

The Atrai river originates at the alluvial fan in India where the annual rainfall is about 3,000 mm. In Bangladesh, the Atrai river flows down southward through the alluvial fan and distributes the Dhepa river at about 30 km upstream of Dinajpur city. After passing Dinajpur, the Atrai river runs about 50 km long river stretch in India and reaches the lower Atrai river stretch in Bangladesh. Afterwards, it separates into two rivers, the Punarbhaba and the Kakra, and it joins many tributaries, the Shib-Barnai and Baral rivers from the right bank side, and the Kakra, Little Jamuna and Nagor rivers from the left bank side. About 15 km upstream of the outfall at Hurasagar, it also joins Karatoya-Bangali river. The total river length of the Atrai in Bangladesh is about 400 km.

The Atrai river has the average river-bed slopes of 1/3,150 by river section in the upstream reach and of 1/10,700 to 1/17,000 in the lower reach. A depth of the river channel from river-bed to bank ground elevation is about 5 to 10 m on average but it deepens to more than 10 m when nearing its outfall. The river width between river banks is about 100 m to 500 m in the upstream reach and 50 m to 200 m in the lower reach.

To assess the present carrying capacity of the river under the present bank protection, uniform flow calculation is made by means of the Manning's formula, being independent of the outfall stage, using the average river-bed slopes and river cross sections. The roughness coefficient is assumed at 0.03 taking into account the present river conditions. Consequently, the carrying capacity is estimated at 500 m^3/s to 2,000 m^3/s in the upstream reach and 100 m^3/s to 3,000 m^3/s in the lower reach. The uniform flow calculation results indicate that the river stretch near the outfall has a large carrying capacity of more than 1,000 m^3/s but the water level in this stretch is dominated by the back-water of the Brahmaputra so that, as shown by hydraulic modelling analysis, the carrying capacity comes to be very small during flood when the outfall stage rises.

The small tributaries joining the Atrai, along which the flood embankments has been constructed through the CFD/CFDI projects, have the following river features and carrying capacity:

Name of river	Average river-bed slope	River Width (m)	Carrying Capacity (m^3/s)
Karka	1/3,000	100 to 200	200 to 1,400
Shib-Barnai	1/30,000 to 1/17,000	40 to 140 (150 to 200)	100 to 1,000
Little Jamuna	1/12,200	100 (400 to 600)	300 to 700
Kharkharia	1/3,000	30 to 130	50 to 100
Tulusi Ganga	1/8,000	30 to 80	100 to 200
Nagor	1/12,200	50 to 150 (150 to 300)	200 to 700

Note 1: For river widths above, figures in left side show those between both river banks, while figures in right side parentheses are those between flood embankments on both banks, which are set back.

Note 2: The Kharkharia and the Tulusi Ganga are tributaries of the Little Jamuna.

(b) The Karatoya-Bangali river

The Karatoya-Bangali river originates in the alluvial fan near the border with India with altitude of about 55 m and an annual rainfall of about 2,500 mm. The Karatoya-Bangali river is called the Jamuneshwari river in Rangpur District, and changes its name to the Karatoya river near Dinajpur, the Katakhali river in Gaibandha District and the Bangali river in Bogra District. About 10 km

upstream of the outfall to the Ganges, the Karatoya river joins the Hurasagar river which constitutes the most downstream stretch of the Atrai river. The Karatoya-Bangali river has two old river channels which are called the old Karatoya and old Bangali river, respectively. The total length of the river is about 390 km.

The Karatoya-Bangali river has the average riverbed slope of about 1/3,500 in the upstream reach, about 1/10,000 in the middle reach and 1/19,300 in the lower reach. The depth of the river channel from riverbed to bank ground elevation is about 10 m in the lower reach and is 5 m in the middle and upstream reaches. The riverbed between 100 km and 200 km upstream of the confluence with the Atrai is rising due to the sediment deposition in the reach with the gentle riverbed slope. The river width between both river banks is about 100 m in the upstream reach and 400 m to 500 m in the lower and middle reaches. The present carrying capacity of the river is estimated to be about 200 m^3/s in the upstream reach and 500 m^3/s to 1,000 m^3/s in the lower reach. In the middle reach where the riverbed is rising notably by the sedimentation, the carrying capacity is as low as 400 m^3/s.

c) Ghagot River

The Ghagot river was originally one of the distributaries of the Teesta river but the confluence was closed by the construction of the Teesta right embankment. The river originates in the northern part of Barind Terrace with altitude of about 40 m and an annual rainfall of about 2,000 mm. The Ghagot river flows southeast and after passing Rangpur it takes the course along the railway till Gaibandha. At Gaibandha, the Ghagot river branches off into two river channels. One is led to the Brahmaputra through the Manash Regulator provided on BRE. The other river channel, called the Alai river, is connected with the Karatoya river. The total river length of the Ghagot river is about 190 km from its origin to the confluence with the Karatoya river.

The Ghagot river has the average riverbed slope of about 1/12,000 and a depth of river channel from riverbed to bank ground elevation is about 2 to 5 m. The river width between both river banks is about 40 to 120 m. The present carrying capacity of the river is estimated at about 50 m^3/s to 300 m^3/s through the aforesaid uniform flow calculation.

2.3.2 Teesta district

The Teesta district comprises the Teesta, Dharla and Dudhkumar rivers which originate in the Himalayan piedmont in India or Bhutan. The main river features of these rivers are illustrated in Figures 2.14 to 2.16 and summarized as follows.

a) Teesta river

The Teesta river originates near Gangtok city in India where the annual rainfall is about 3,000 to 4,000 mm. After flowing down to Jalpaiguri city in India, it reaches the border with Bangladesh. In Bangladesh, the Teesta river reaches the Teesta Barrage about 115 km upstream from the outfall which is an intake weir for the Teesta Irrigation Project with an irrigable area of about 315,000 ha. Passing through the Teesta Barrage, the Teesta joins the Buri Teesta river, and it flows down north of Rangpur through a railway bridge at Kaunia, and finally outfalls to the Brahmaputra. A flood embankment was provided on both right and left banks of the Teesta by BWDB. The total river length of the Teesta in Bangladesh is about 135 km.

The Teesta has an average riverbed slope of about 1/1,050 to 1/5,000 by river sections. The river width between both river banks is about 500 m on average downstream of the Kaunia railway bridge and 3 km in the upstream reach. The setback distance of the existing flood embankment is in general more than 1 km from the river bank but it is abruptly narrowed at the Kaunia railway bridge site to about 500 m. The depth of the river channel from riverbed to bank ground elevation is about 5 m and becomes deeper near the confluence with the Brahmaputra. The average height is about 2 to 3 m downstream and about 4 m upstream from the Kaunia bridge. The present carrying capacity is estimated to be about 1,000 m^3/s in the upstream reach and 5,000 m^3/s to 15,000 m^3/s in the lower reach.

The Teesta is characterized by meandering and formation of sand bars due to huge amount of sediment inflow from the Himalayan piedmont. The meandering width is about 2 to 3 km and the river course is always shifting as flood flows cause the river bank erosion and collapse of the existing flood embankment at several places on both sides of the river.

b) Dharla river

The Dharla river originates near the southwestern border of Bhutan and India where the annual rainfall is about 3,000 to 4,000 mm. After flowing down southeastward in India, it reaches the border with Bangladesh upstream of Talukshimulbari in the Fulbari Upazila. Finally, the river outfalls to the Brahmaputra near Kadamati through Kurigram city. The embankment was built on the right and left banks by BWDB. The catchment area is 5,130 km2 and the total length of the Dharla river in Bangladesh is 55 km.

The Dharla river has an average riverbed slope of about 1/4,680 to 1/6,390. The width of low water channel formed by natural river banks is about 300 m to 500 m and the existing flood embankment is 500 m to 1,000 m set back from the river bank. The depth of the river channel from riverbed to bank ground elevation is about 5 m and the average height of the existing embankment is about 2 to 3 m from the bank ground level. The present carrying capacity of the river is estimated at about 2,000 to 6,000 m^3/s.

c) Dudhkumar River

The Dudhkumar river originates in the southwestern part of Bhutan where the annual rainfall is 3,000 to 4,000 mm. After passing through Cooch Beahar in India it reaches the border with Bangladesh upstream of Pateswari railway bridge. Finally, the river outfalls to the Brahmaputra through about 50 km long river stretch downstream of the bridge. Along this stretch an embankment on the right bank was provided for flood protection in the Kurigram North area. The catchment area and total river length in Bangladesh are 5,880 km2 and 50 km, respectively.

The Dudhkumar river in Bangladesh has an average riverbed slope of about 1:16,500. The width of low water channel is about 1,000 m and the existing right embankment is set back by 1,500 m from the river bank. The depth from riverbed to bank ground elevation is about 5 to 7 m and the average height of the existing embankment is about 3 m from the bank ground level. The present carrying capacity of the river is estimated at about 1,000 m^3/s.

2.3.3 Mohananda basin

The Mohananda river system in Bangladesh consists of Mohananda-Tangon and Dhepa-Punarbhaba rivers which originate in an alluvial fan with an elevation of about 60 m and an annual rainfall of

2,000 mm in the northwestern part of the region. The main features of these rivers are illustrated in Figures 2.17 and 2.18.

The Tangon river flows for 100 km through the western part of Thakurgaon and afterwards passes for about 110 km through India. Then, the Tangon changes its name to the Mohananda river. The Mohananda river joins to the Ganges 70 km downstream of the border with India. The total river length of the river in Bangladesh is 180 km. The Punarbhaba river flows down towards Dinajpur and joins the Dhepa river, one of the distributaries of the Atrai river. Then, the Punarbhaba flows along the border with India, and joins the Mohananda river 20 km downstream of the border with India.

River	Average riverbed slope	River width	Carrying Capacity (m3/s)
Mohananda	1/18,800	300 to 500	2,200 to 4,000
Tangon	1/3,400	100 to 300	100 to 800
Dhepa-Punarbhaba	1/5,000	150 to 400 (400 to 800)	400 to 3,000

Note : For river widths above, figures on left side show those between both river banks, while figures in right side parentheses are those between flood embankments on both banks, which are set back.

The Mohananda river has a large carrying capacity according to the results of the uniform flow calculation by the Manning's formula. In fact it is much influenced, during the monsoon season, by high stage at outfall to the Ganges. Consequently, the beel area extends widely in the low-lying areas along the right bank due to drainage congestion.

2.4 Present Drainage Condition

2.4.1 Situation

The existing drainage pattern of the NWR can be catagorized into two different systems, namely; independent drainage system and inter-related drainage system. The Teesta, Dharla and Dudhkumar constitutes the independent draingage systems. While, the Atrai, Nagor, Little Jamuna and Karatoya-Bangali rivers are of inter-related systems and influenced by the backwater effct of the Brahmaputra in the lower reaches.

The present flooding and drainage problems in the NW region are presented in detail in Chapter 5. The present drainage situation in the NW region is summarised hereinafter.

- Thakurgaon and Upper Atrai

The catchment of the Atrai has a rather wide area extending to India so that it is directly influenced by the flooding situation in India and presently suffers from flash flood from India. The area is drained by the Tagon, Punarbhaba, Atrai and Little Jamuna. Except for the Little Jamuna, all other rivers generally flow down southward to the international border with India. Accordingly, the large scale flood control works as well as the significant drainage improvement in the area may have direct impact on the water level of the downstream reach in India. This area has rather steep ground slope of about 1/4,500 as compared with that of about 1/20,000 in the southern area of the NW region.

- Teesta Right Bank

The Teesta Right Bank area, which is located in the upstream part of the area drained by the internal rivers originating in the NW region, spreads on the right bank of the Teesta. The drainage basin does not extend to the Indian territory accross the international border. Accordingly, the FCD measures in the area can be set up without any inter-relation with those in India. Due to frequent breaches of the Teesta Right Embankment (TRE), on the other hand, the area has been suffering the flooding damage. The flood water spilled from the Teesta flows down southeastwards. This area is mainly drained by the Ghagot. The drainage improvement in the area will not have any adverse effect on the downstream areas as long as the TRE is sealed.

- Teesta Left Bank

The drainage area covered by the Teesta Left Bank extends to the Indian teretory from the hydrological point of view. The rainfall runoff taking place in the area is drained to the Teesta. The area suffers the flooding caused by intrusion of flood water in the Teesta due to breaches of the flood embankemnt as well as insufficient provision of the FCD facilities. The area also suffers the river bank erosion along the Teesta. The improvement of the area will not have any adverse effect on the downstream areas.

- Kurigram

The Kurigram area has the similar characteristics to the Teesta Left Bank concerning the flooding problems. The area is bounded by major rivers such as the Teesta, Darlah, Dudkumar and Brahmaputra that all come from India. Hence, the area suffers from prolonged drainage congestion due to high and long duration of flood in these major rivers and severe bank erosion. Due to the geographical condition flood control and drainage in this area would not any adverse effect on the downstream areas.

- Upper Karatoya

The drainage area of the Upper Karatoya is located mostly in Bangladesh and has a quite small drainage basin in India. The flooding along the Upper Karatoya is accordingly due to heavy rainfall in the basin and insufficient provision of the FCD facilities. The flood water spilled from the Upper Karatoya accross the left bank flows down far downstream to the Joypurhat area or the Middle Bangali area. The area is not affected by backwater of the Brahmaputra. Full confinement of the Upper Karatoya would increase the flood discharge of the Middle Bangali and accordingly have adverse effect on the downstream reaches in the Bangali.

- Gaibandha

The Gaibandha area is bounded by the Teesta, Brahmaputra and Ghagot. The drainage basin of the area is almost located inside of the area. Due to breaches of the flood embankment on the right bank of the Brahmaputra and Teesta that are mainly caused by bank erosion, the area has been suffering flooding from these rivers. The spillage from the Ghagot also comes into the area. The internal rainfall runoff in the area is drained to the Brahmaputra through Manas regulator and also to the Middle Bangali area through the Alai.

- Middle Bangali

The Upper Karatoya and the Ghagot through the Alai flows into the Middle Bangali. The spillage from the Brahmaputra also intrudes into the area. Those flood water including the internal rainfall runoff to the downstream reaches through the Middle Bangali. The Old Karatoya also functions as main drainage chennel of the area. The Middle Bangali area is located just upstream of the area affected by backwater of the Brahmaputra and Hurasagar.

- Joypurhat

Joypurhat is located in the drainage basin of the Little Jamuna and Tulsi Ganga. The internal rainfall runoff is drained to the area of the Lower Atrai Left Bank through these rivers. This area basically does not experience any serious flooding problem. It is not affected by backwater of the Brahmaputra.

- Barind Tract

The Barind Tract area is of a rather high land and not affected by other areas. Therefore, it has suffered no serious flooding problem.

- Mahananda

The Mahananda river basin has a large drainage basin in India and is much affected by the flooding situation in India through the Mahananda, the Pagla and the Ganges. This area has also drainage basin in Barind Tract with high ground elevation. This area is drained through the Mahananda to the Ganges but due to high backwater of the Ganges with long duration the area suffers inundation on the right bank of the Mahananda.

- Lower Bangali

The Lower Bangali area has been suffering flooding due to breaches of the BRE and spillage from the Lower Bangali. This area is much affected by backwater of the Brahmaputra through the Hurasagar.

- Lower Atrai Left and Right Bank

The Atrai Left and Right Bank areas comprise a very wide low-lying area and has been functioning as a wide flood retention area before outfalling to the Brahmaputra. Flood flow of the Atrai, Little Jamuna, Nagor, Badhai, Shib-Barnai, Lower Bangali and other many small streams all flow into this area. This area is also a wide area affected by backwater of the Brahmaputra. Since the flood of the Brahmaputra continues for a long duration in the monsoon season, this area is inundated for a long duration.

- Pabna

The Pabna area is located in the Ganges flood plain. This area is bounded by the Brahmaputra and the Ganges. The riverine area suffers from serious bank erosion.

2.4.2 Drainage Constraints

The present drainage problems aid constraints in NWR are generally identified as follows;

(1) Road and railway network: It is said that during extreme floods in 1987 and 1988, serious drainage congestion due to the trunk road connecting Nagarbari and Rangpur was caused so that public-cut of the road was incurred. Accordingly many culverts have been being constructed along the road since then even at locations where no channel nor stream are found. The Road & Highway Department seems to avoid to utilize the road as the flood embankment even though certain flood control project needs to close the road without culverts. On the other hand, present trunk roads in NWR and many road networks of sub-districts, unions and villages have been constructed without sufficient drainage culverts or enough consideration on drainage. These caused overtopping of roads by overland flow which occurred even along the trunk roads, and breaches of culverts or public-cut of roads.

(2) Drainage channel network: In many cases, drainage channel is not found in the field even at the site of drainage sluices. In these cases, drainage sluices just function for very limited local drainage except the very deeply inundated cases.

(3) Carrying capacity of drainage channel: In NWR, it is often seen that existing drainage channels have insufficient carrying capacities mainly due to siltation. Siltation is seemingly partly caused by provision of closure on channels to take water in dry season and then to grow rice in the channel. Because many channels in NWR are non-perennial ones, water shortage in dry season is a major problem in the region. The other reasons are gentle slope of channels in NWR and main catchment areas of channels are arable lands mainly consisting of bear ground or paddy field different from forest covered with sufficient vegetation.

(4) Channel constriction due to bridge: This is also often seen in the NWR.

(5) High flow of outer river: The high river stages of the Brahmaputra(Jamuna), Ganges(Padma), Hurasagar, Atrai, Teesta, and other rivers continues for a long duration usually from June to October. During such duration, gravity drainage from countryside to rivers becomes impossible in the low-lying areas. But in many cases, once certain area is empoldered, inundation due to inland rainfall runoff is less severe than that due to flooding from outer rivers.

(6) Network of side drain: When flood embankments along rivers are to be constructed, generally side drains along the embankment on the country side should be provided to collect inland runoff and then the flow is led through the side drains to drainage sluices constructed along the embankment to drain to outer rivers. But in NWR, as long as surveyed during the field reconnaissance, only a few of those drainage system were found.

(7) Network of drainage sluice: For the macro scale drainage facilities, the network of drainage sluice is rather well planned and constructed in NWR. But due to lack of side drain network and undulations of objective area, localized drainage congestion is still seen at locations. Instead of construction of side drain network, construction of drainage culverts with flap gate is implemented in the case of the Naogoan Polder Project. This is also one way for drainage improvement. But as mentioned in the above, construction of side drain will reduce the number of drainage culverts with flap gate. Selection of drainage culverts with flap gate or drainage sluice with manually operated sluice gate depends on the drainage capacity needed at the location.

(8) Capacity of drainage sluice: Capacities of drainage sluices of the existing CFD projects have been rather well designed and implemented in NWR. But these seem to have been designed based on the assumption that no overland flow from the outside of the project area would occur even though the embankments are planned to be open to the upstream basins. Other than this, natural breaches of embankment or public-cut of embankment in upstream portion of the objective area result in more load to those drainage sluices causing drainage congestion at the downstream end and again public-cut of embankments there. The drainage capacity of sluice, assuming no other additional inflow to the objective area, is determined in such a way that water-level inside of countryside should soon draw down within 2 weeks after the outer river water-level becomes lower than that in countryside.

(9) Deterioration of drainage sluice: Damage or deterioration of existing drainage sluices are often seen in the field. In some case, it is reported that because the gates were impossible to open, inland runoff accumulated at the drainage sluice site and that the river flood water overtopped the embankment from the country side thereto damaging the embankment. In other cases, gate leaf is already lost showing that during high flow of outer rivers, it is impossible to stop intrusion of the river water into the country side. In this sense, O & M of facilities is an important factor for CFD. Even well designed and constructed facilities need proper O & M.

Table 2.1 EXISTING/ON-GOING FCD AND FCD/I PROJECTS IN THE REGION

Name of Projects	Related River	Type of Develop.	Stage	Existing Facilities: Project Area (sq.km)	Length of Flood Embankment (km)	Nos. of Regulators/ Sluices	Length of Drainage Canal (km)	Other Structures
(1) Lower Atrai								
1. Pabna Phase I	Hurasagar	FCD/I	U/C	1,967	160	48	93	1 pumping station
2. Baral Basin Phase 1	Baral	FCD	C	-	-	1 (Chargat R.)	-	
Baral Basin Phase 2	- do above -	FCD	C	630	16	4	19	
3. Barnai	Barnai	FCD	U/C	566	50	44	448	
4. C.B.P. A	Atrai/Baral	FCD	U/S	306	2	1	64	
5. C.B.P. B	Atrai/Barnai	FCD	C	321	103	7	69	
6. C.B.P. C	Atrai/Barnai	FCD	C	436	138	11	81	
7. C.B.P. D	Atrai/Sib-Barnai	FCD	C	531	134	17	115	
8. Hurasagar	Atrai/Bangali	FCD	C	365	12.5 (Excl. BRE)	2	77	
9. SIRDP	Atrai/Bangali	FCD/I	C	974	55	14	44	1 overflow spillway
10. Bogra Polder 3	Atrai/Nagor/Bhadal	FCD	C	358	54	17	-	
11. Bogra Polder 4	Atrai/Nagor/Bhadal	FCD	F/S	570	-	-	-	
12. Nagor Valley	Atrai/Nagor/L.Jamuna	FCD	C	358	59	12	7	
13. R.L.	Atrai/L.Jamuna	FCD	C	747	13	15	30	
14. Tulsiganga	L.Jamuna/Tulsiganga	FCD	C	251	150	19	-	
15. Tulsiganga Left	Tulsiganga	FCD	U/C	120	28	10	-	
16. North Rajshai	Sib/Ganges	I/D	F/S in 1988	723	-	2 *	-	Drainage pump (51 cu.m/s) *
17. Naogaon	Atrai/L.Jamuna	FCD	U/C	461	64	5	74	
18. Potnitola *	Atrai	FCD						
19. Chilmpur *	Atrai	FCD						
(2) Upper Atrai								
20. Atrai-Kakura	Atrai	FCD	U/C	42	42	6	-	
(3) Bangali/Ghagot								
21. Nurullar Beel	Karatoya	FCD	C	166	31	4	5	30 irrigation inlets
22. Sonail	Alai/Brahmaputra	FCD	C	57	19	3	-	20 irrigation inlets
23. Satdamua-Kafler Beel	Ghagot	FCD	C	21	19	9	0	3 culverts and 50 irrigation inlets
(4) Teesta								
24. Kurigram North	Dudhkumar/Dharla	FCD/I	F/S in 1990	410	61	9	-	
25. Kurigram South	Dharla/Teesta	FCD/I	On-going	650	108	16	119	2 groins for Kuriguram Town Protection
26. Sati Nadi	Teesta	I/FCD	C	-	-	-	-	
27. Teesta South Embankment	Teesta	FCD	C	768	119	1	503	
28. Teesta Irrigation	Teesta	I	U/C (Phase I)	2,223	-	unknown	80 *	Teesta Barrage (completed: Crest length 610 m, Weir height 12 .2 m, 44 gates)
(5) Mohananda								
29. Projects along Mohananda	Mohananda	FCD	C	-	1	12	-	
30. Projects along Pagla	Pagla	FCD	C	-	-	2	-	
Total					1,544	328	1,829	

Source :
1. Updating of the Inventory of Water Development Systems, June 1991, BWDB/UNDP
2. Data from the Executing offices of BWDB in the Northwest Region

Remarks:
1. Numbers with * indicate facilities proposed by the project.
2. Stage: U/C : Under construction, C : Completion, F/S : Feasibility Study completed, U/S : Under study
3. Projects with * show that data on project facilities is not collected yet.
4. Ganges left embankment (92 km) and BRE (219 km) are excluded in the above table.

Table 2.2 LIST OF EXISTING DRAINAGE REGULATORS IN THE REGION (1/4)

(1) Bogra Polder 2

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Chakalam	2	1.52x1.83	10.66	Little Jamuna
2	Kujail	2	-do-	10.81	-do-
3	Ratandhara	1	-do-	9.73	-do-
4	Ahsanganj	2	-do-	11.40	Atrai
5	Kashiabari	10	1.82x2.13	10.71	-do-
6	Islamganti	1	1.52x1.83	10.90	-do-
7	Sameshpara	2	1.22x1.83	10.75	-do-
8	Khorsuti	2	1.52x1.98	8.62	Nagor
9	Lalpara	1	1.52x1.83	8.31	-do-
10	Soria	2	-do-	9.14	-do-
11	Chatardighi	1	0.92x1.22	9.60	-do-
12	Chapapur	1	-do-	11.89	-do-
13	Saila	2	1.52x1.83	10.36	-do-
14	Bagichapara	2	-do-	10.67	-do-
15	Gobardhan	2	-do-	10.36	-do-

(2) Bogra Polder 3

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Damdama Khari	3	1.52x1.83	7.50	Gur
2	Rakhal Gachi	4	-do-	7.47	-do-
3	Sahbazpur	1	-do-	9.75	-do-
4	Sonamukhi	1	-do-	9.75	Nagor
5	Bhulbaria	1	-do-	9.45	-do-
6	Rossainpur	1	-do-	7.50	-do-
7	Kaligonj	1	-do-	9.45	-do-
8	Chardighi	3	-do-	9.30	-do-
9	Damdama	1	-do-	9.30	-do-
10	Nagorkandi	1	-do-	9.10	-do-
11	Krishnapur	6	-do-	10.10	-do-
12	Jamalpur	1	-do-	10.10	-do-
13	Parshan	2	-do-	10.32	-do-
14	Palankuri	3	-do-	10.52	-do-
15	Bagichapara	1	-do-	10.51	-do-
16	Rajonpur	1	-do-	10.51	-do-
17	Nisindarna	1	-do-	10.51	-do-

(3) Bogra Polder 4 : none

Table 2.2 LIST OF EXISTING DRAINAGE REGULATORS IN THE REGION (2/4)

(4) SIRDP

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Taras	2	1.52x1.83	8.50	Atrai
2	Dobila	3	-do-	8.50	-do-
3	Handial	3	-do-	8.50	-do-
4	Rupsi	2	-do-	8.50	-do-
5	Lokhmikole	2	-do-	8.50	-do-
6	Baghabari	11	3.00x3.00	8.00	Baral
7	Milkvital	1	1.52x1.83	8.00	-do-
8	Escape Structure		90.0x42.0	8.00	Baral
9	Deobhog	1	1.52x1.83	-	flushing
10	Bhuyagati	2	-do-	-	-do-
11	Billsuria	2	-do-	-	-do-
12	Talgachi	1	0.91x1.22	9.00	-do-

(5) Hurasagar Scheme

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	R-1	4	1.52x1.83	4.88	Hurasagar
2	R-2	4	-do-	4.88	-do-
3	Bonbaria	1	-do-	9.14	Jamuna
4	Baoitara	1	-do-	9.44	-do-
5	R-7	1	-do-	8.50	-do-

(6) Chalan Beel Polder D

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Goalmara	2	1.52x1.83	11.30	Atrai
2	Daulatpur	8	-do-	9.76	Fakirni
3	JokerKhal	1	-do-	10.40	-do-
4	Birkaya	6	-do-	10.98	-do-
5	Gopalpur	1	-do-	9.76	-do-
6	Bagmara	3	-do-	9.50	Barnai
7	Monglar Dhara	2	-do-	9.15	-do-
8	Gobindapur	5	-do-	9.15	-do-
9	Dhopaghata	1	-do-	10.98	-do-
10	Chandpur	2	-do-	11.28	-do-
11	Kashimala	2	-do-	10.98	Shib
12	Dangapara	3	-do-	11.59	-do-
13	Ratandanga	1	-do-	10.98	-do-
14	Singa	4	-do-	11.28	-do-
15	Saldah	1	-do-	11.28	-do-
16	Pabni	5	-do-	11.50	-do-
17	Kalamara	1	-do-	11.90	-do-

Table 2.2 LIST OF EXISTING DRAINAGE REGULATORS IN THE REGION (3/4)

(7) Chalan Beel Polder C

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Sutkigacha	8	1.52x1.83	9.76	Atrai
2	Jatmarul	4	-do-	9.45	-do-
3	Sahebgonj	1	-do-	7.32	-do-
4	Dobai	1	-do-	9.15	-do-
5	Udaypur	12	-do-	10.67	-do-
6	Kalamnagar	1	-do-	7.62	-do-
7	Beel Halti	9	-do-	7.32	Barnai
8	Beel Josy	1	-do-	8.23	-do-
9	Bhabanigonj	4	-do-	9.67	Fakirni
10	Kalikapur	1	-do-	8.23	-do-
11	Halikhali	4	-do-	9.45	-do-

(8) Chalan Beel Polder B

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Machgram	2	1.52x1.83	9.10	Barnai
2	Muchipara	4	-do-	9.10	-do-
3	Mudhupur	1	-do-	9.20	-do-
4	Bashbhog	2	-do-	9.10	-do-
5	Godai	12	-do-	9.00	Nandakuza
6	Pangasia	1	-do-	9.20	Atrai
7	Mohishmari	1	-do-	9.00	-do-
8	Haribhanga	7	-do-	9.00	-do-

(9) Chalan Beel Polder A : none

(10) Mohananda Basin

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Kansat	5	2.40x3.20	15.24	Pagla
2	Bhitabari	8	1.52x1.83	16.82	Mohananda
3	Singri	6	-do-	17.23	-do-
4	Chachania	2	-do-	17.00	-do-
5	Dhukumari	1	-do-	17.00	-do-
6	Marichar Danra	7	-do-	13.87	-do-
7	Bahadurpur	2	-do-	17.07	-do-
8	Charai Someshpur	3	-do-	15.24	-do-

Table 2.2 LIST OF EXISTING DRAINAGE REGULATORS IN THE REGION (4/4)

(11) Kurigram South

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Ratnai	8	1.52 x 1.83	25.38	Dhara
2	Siramali	3	-do-	23.75	-do-
3	Palashbari	2	-do-	22.85	-do-
4	Malbhanga	16	-do-	21.80	Brahmaputra
5	Bamni	12	-do-	21.45	-do-
6	Bamni Ad	3	-do-	21.36	-do-
7	Magura Beel	3	-do-	21.03	-do-
8	Chilmari	10	-do-	21.03	-do-
9	Harichari	12	-do-	20.12	Teesta
10	Kisharpur	12	-do-	22.77	-do-
11	Gharial Dhanga	2	-do-	24.38	-do-

(12) Gaibanda

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Kalirhat	1	1.52x1.83	18.50	Teesta
2	Rajib	1	-do-	18.50	-do-
3	Bhairhat	1	-do-	18.50	-do-
4	Narayanpur	1	-do-	18.50	-do-
5	Kasiabari	1	-do-	18.50	-do-
6	Chandipur	2	-do-	17.00	Jamuna
7	Lalcharman	1	-do-	17.00	-do-
8	Sreepur	1	-do-	17.00	-do-
9	Sarai	6	-do-	16.40	-do-
10	Manos	12	-do-	16.48	-do-
11	Bhangayiore	1	-do-	17.25	Ghagot
12	Bhangamore north	1	-do-	17.25	-do-
13	Bhangamore south	1	-do-	16.50	-do-
14	Mchishadi	1	-do-	16.50	-do-
15	Kantanagar	1	-do-	16.50	-do-
16	Beramara	1	-do-	16.50	-do-

(13) Teesta Right Embankment

No.	Name	Vent		Sill Level	Remarks
		No.	Size m	(m)	
1	Manos no.1	4	1.52x1.83	28.00	Teesta
2	Manos no.2	2	-do-	28.00	-do-
3	Hariswar	1	-do-	27.00	-do-

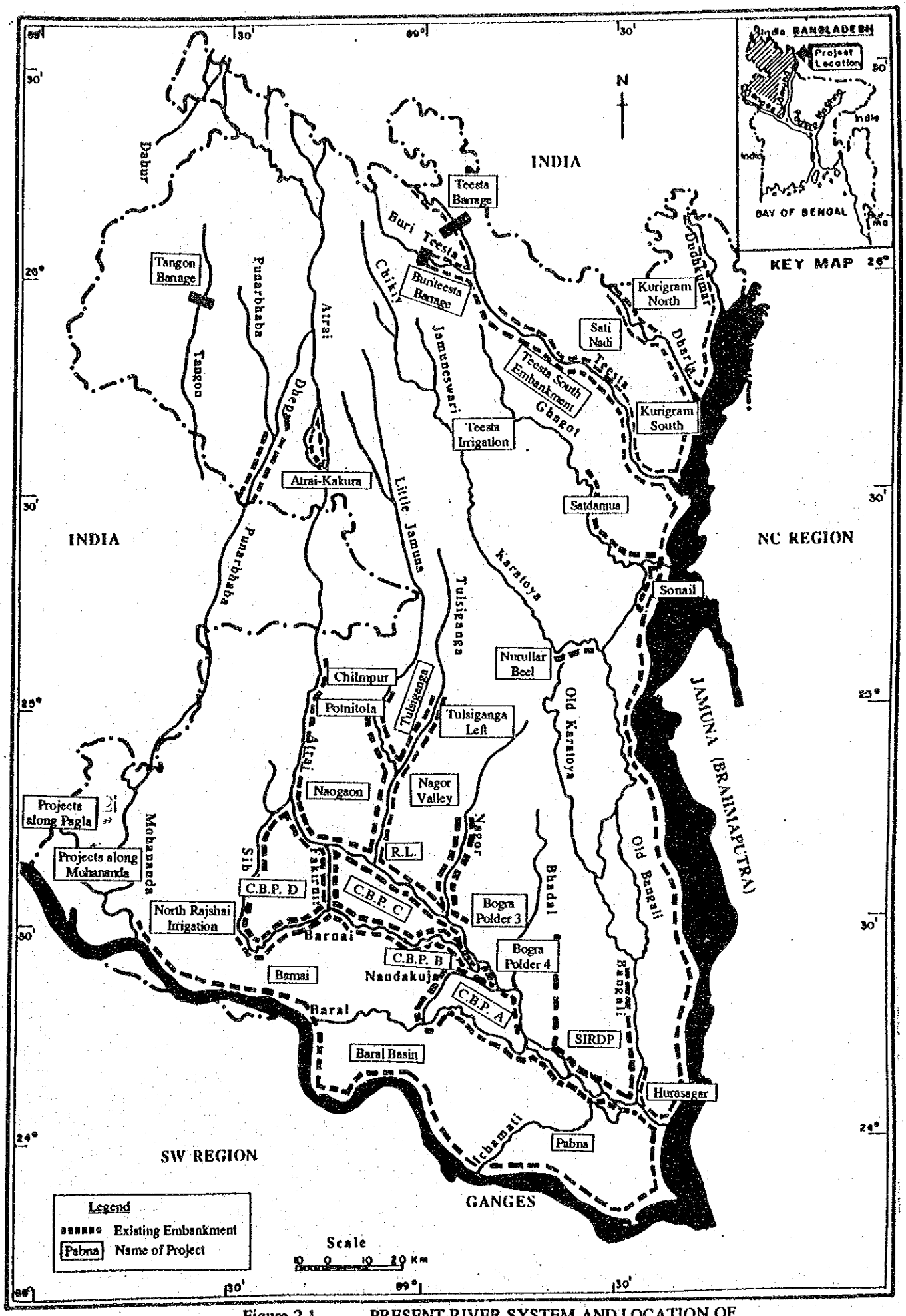


Figure 2.1 PRESENT RIVER SYSTEM AND LOCATION OF EXISTING/ON-GOING FCD AND FCD/I PROJECTS IN THE REGION

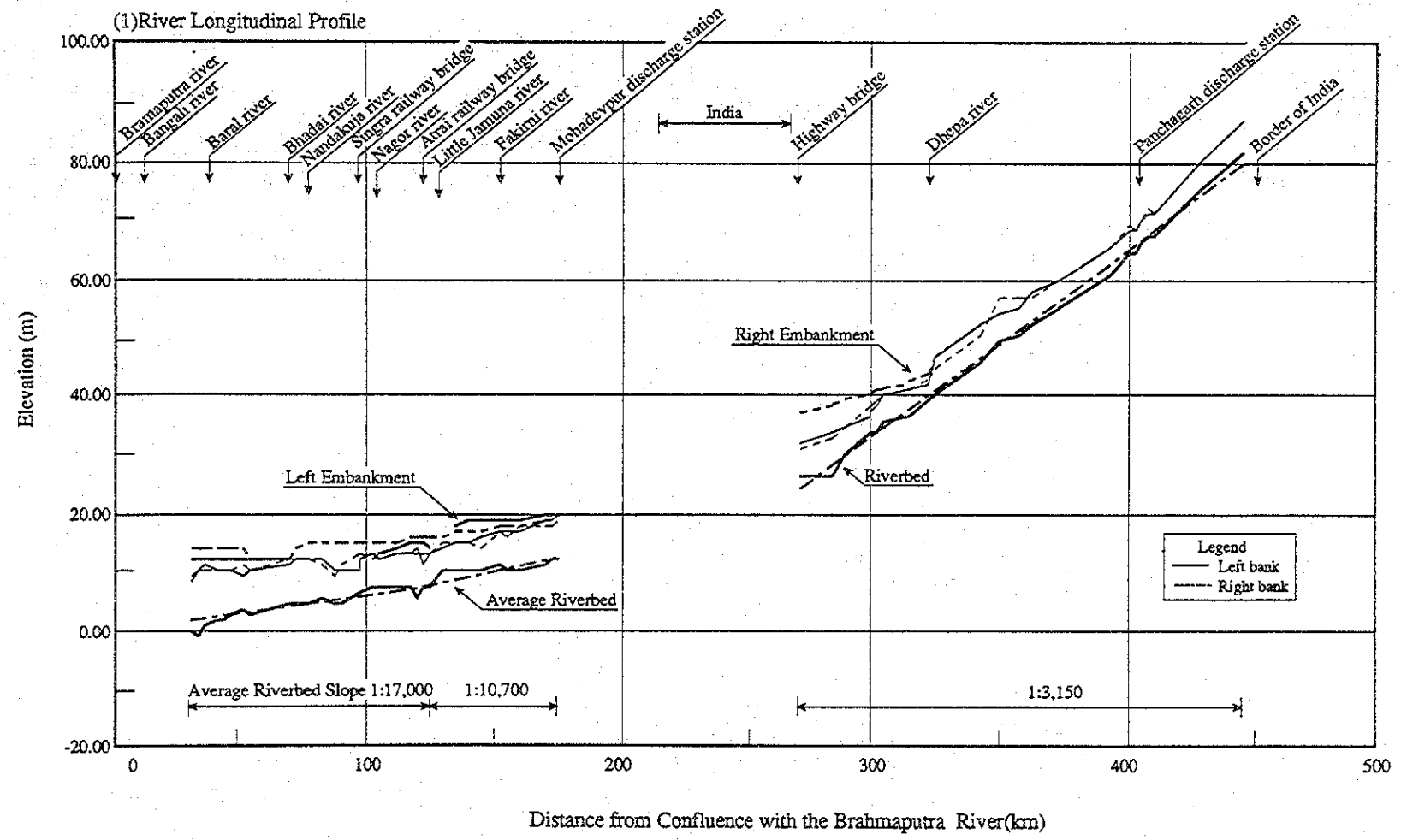
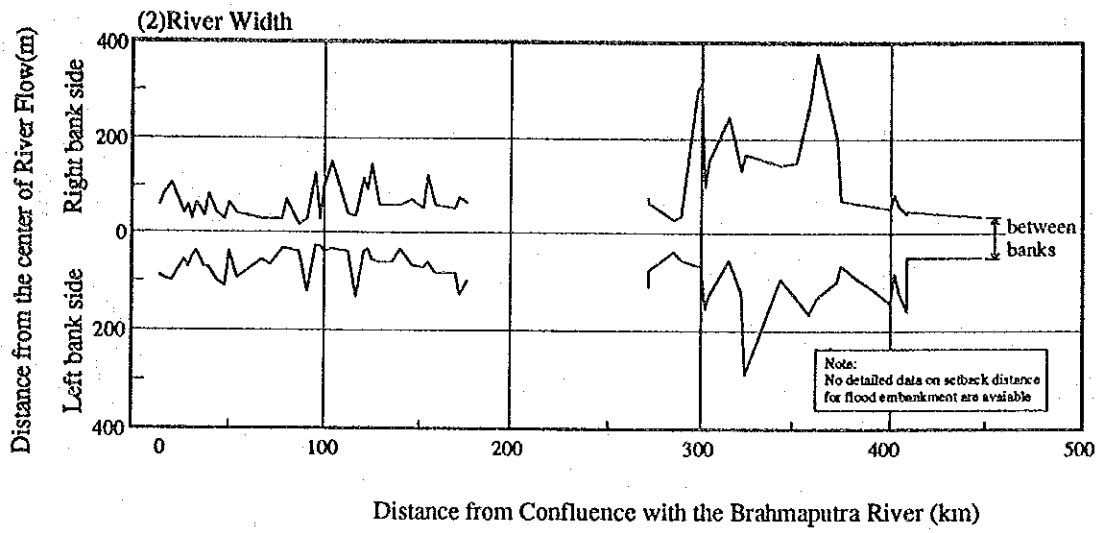


Figure 2.2 RIVER FEATURES OF THE ATRAI RIVER (1/2)



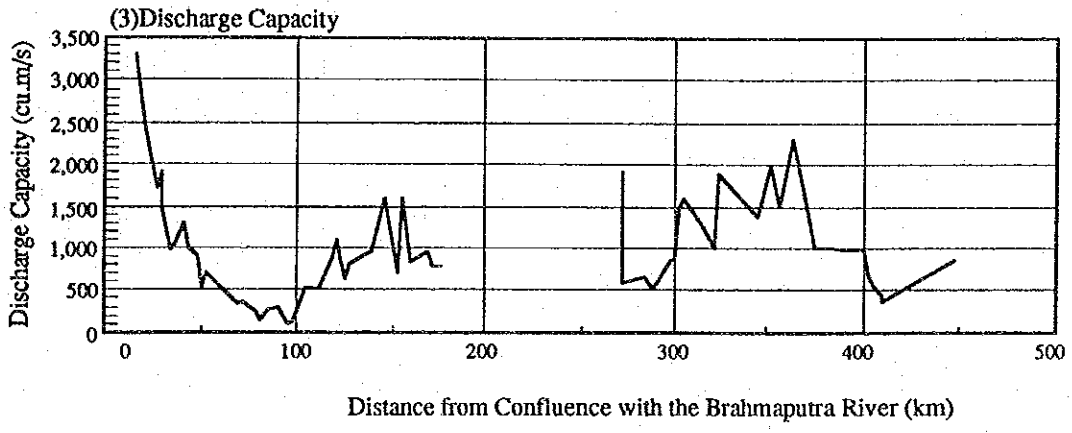
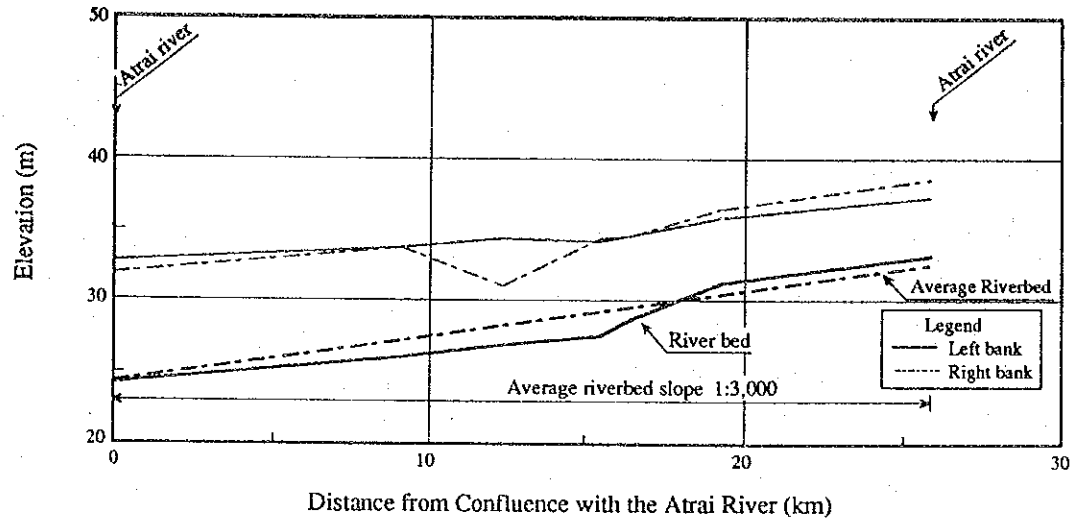
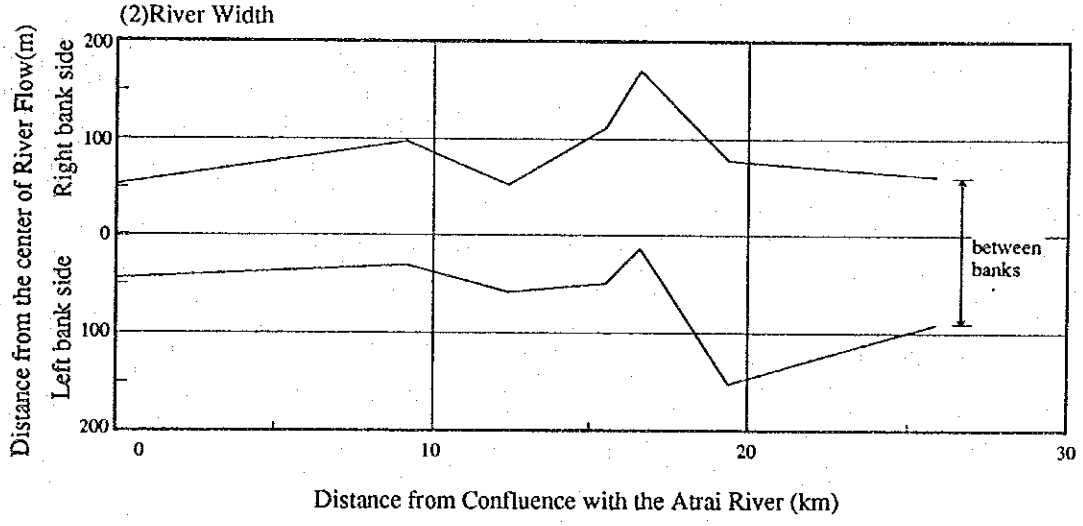


Figure 2.2 RIVER FEATURES OF THE ATRAI RIVER (2/2)

(1)River Longitudinal Profile



(2)River Width



(3)Discharge Capacity

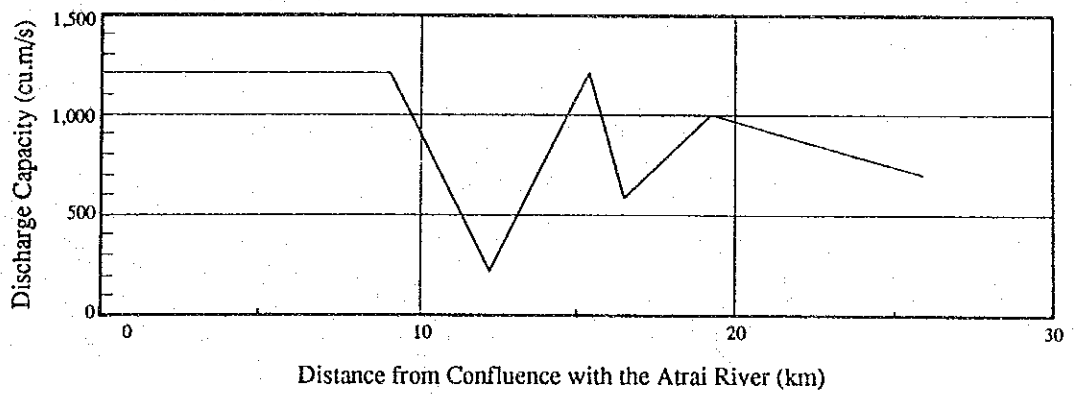


Figure 2.3 RIVER FEATURES OF THE KAKRA RIVER

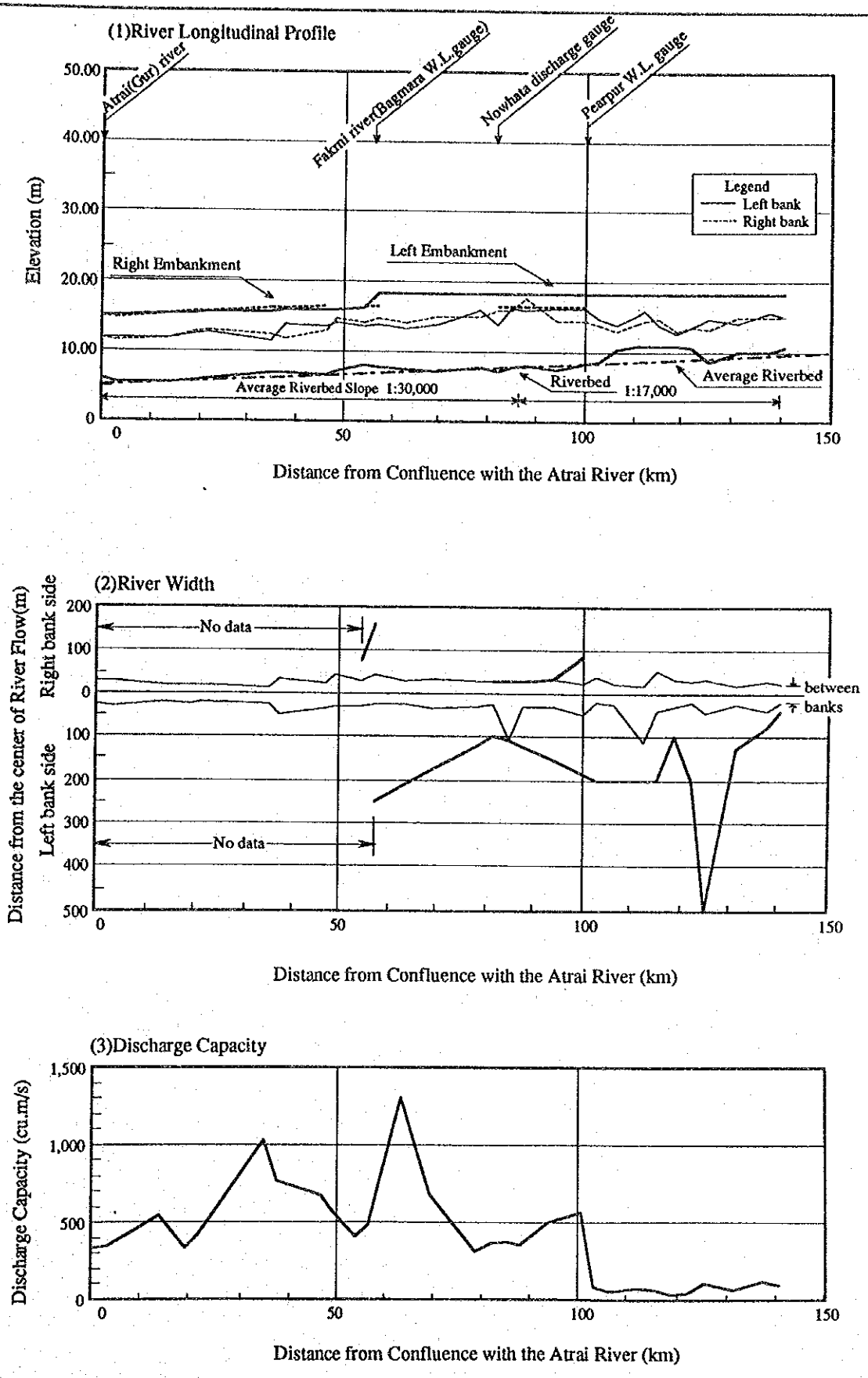
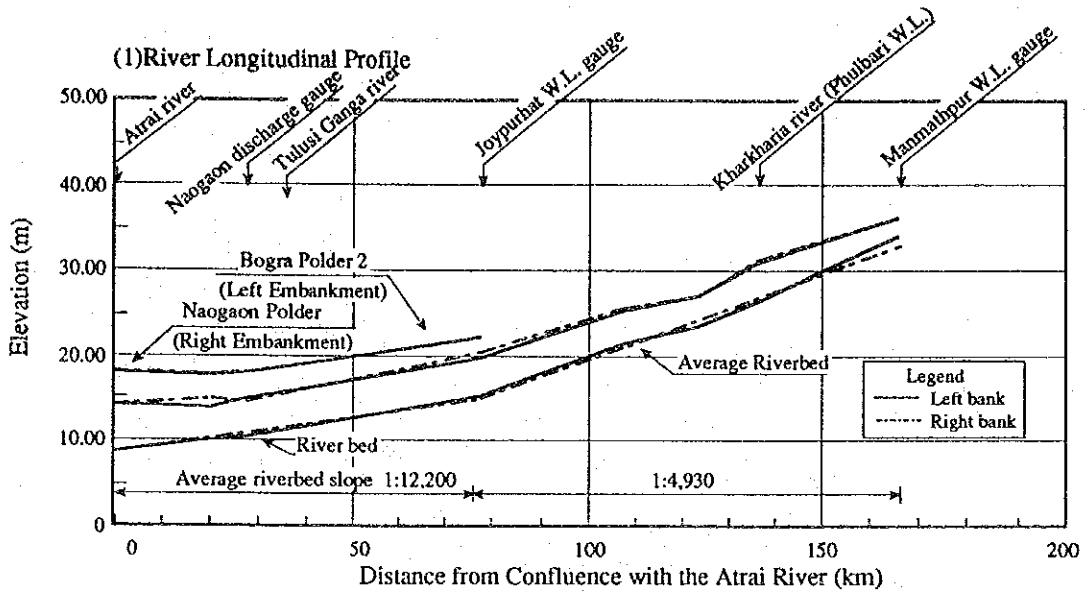
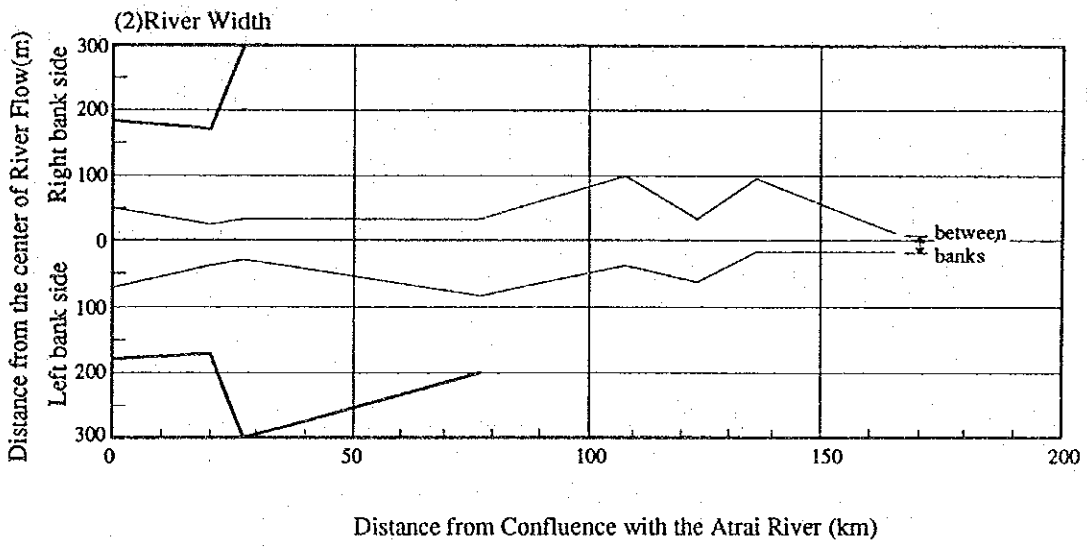


Figure 2.4 RIVER FEATURES OF THE SHIB-BARNAI RIVER





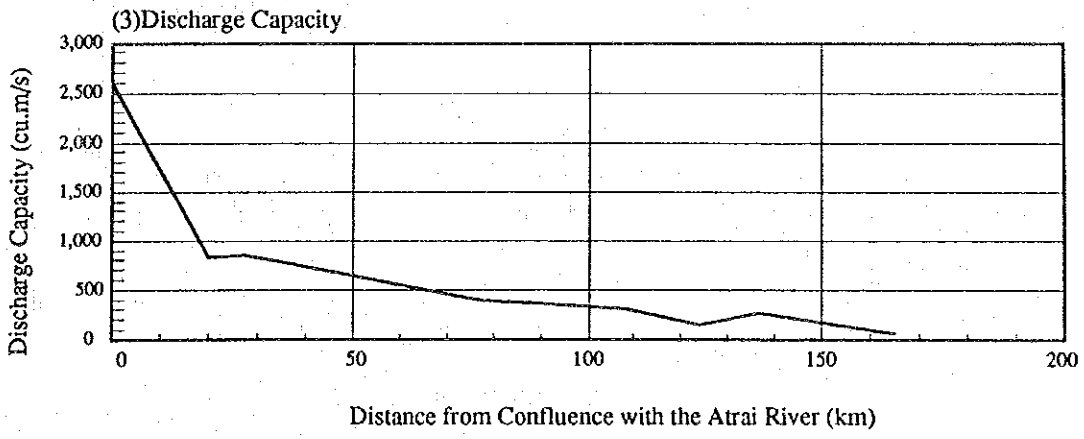
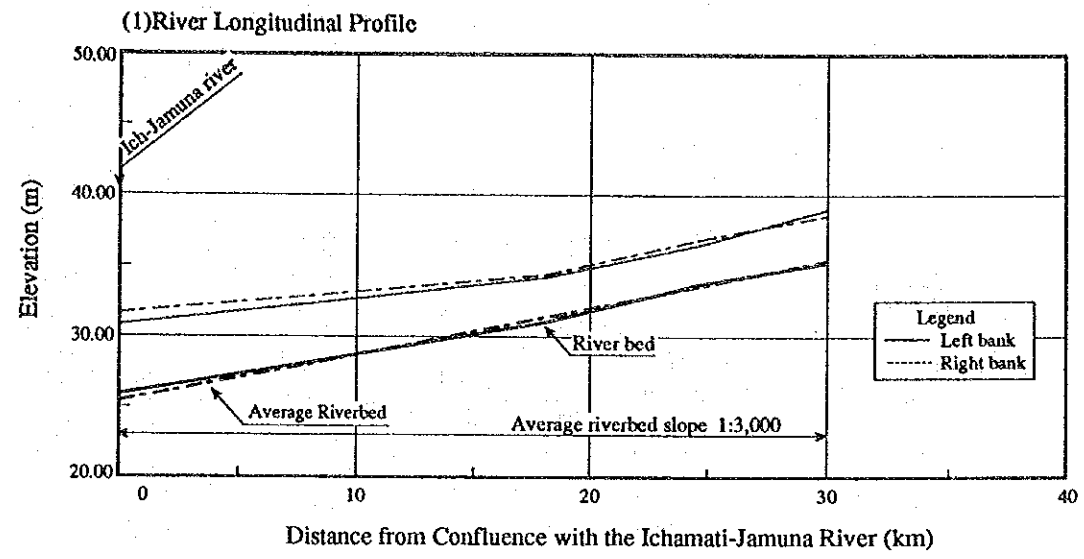
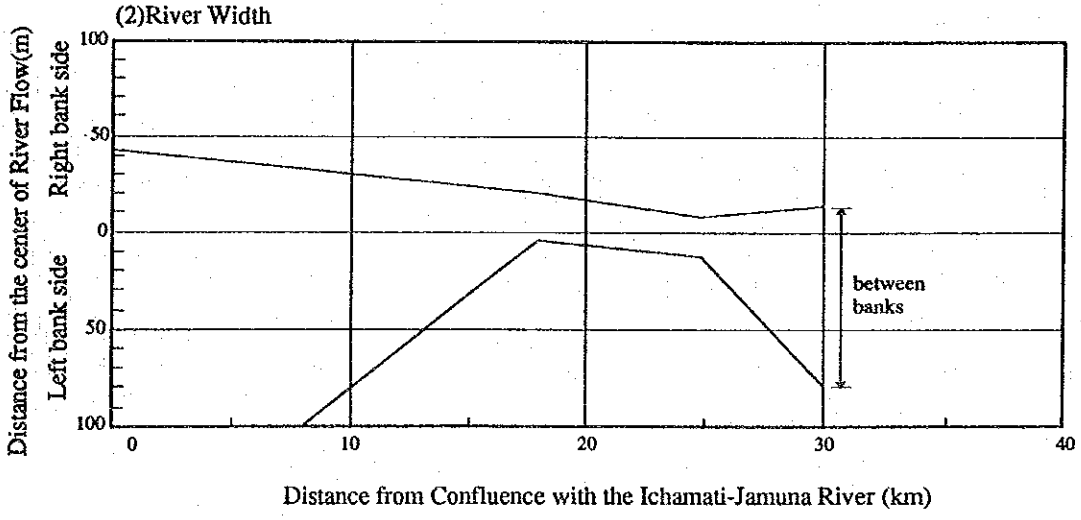


Figure 2.5 RIVER FEATURES OF THE LITTLE JAMUNA RIVER





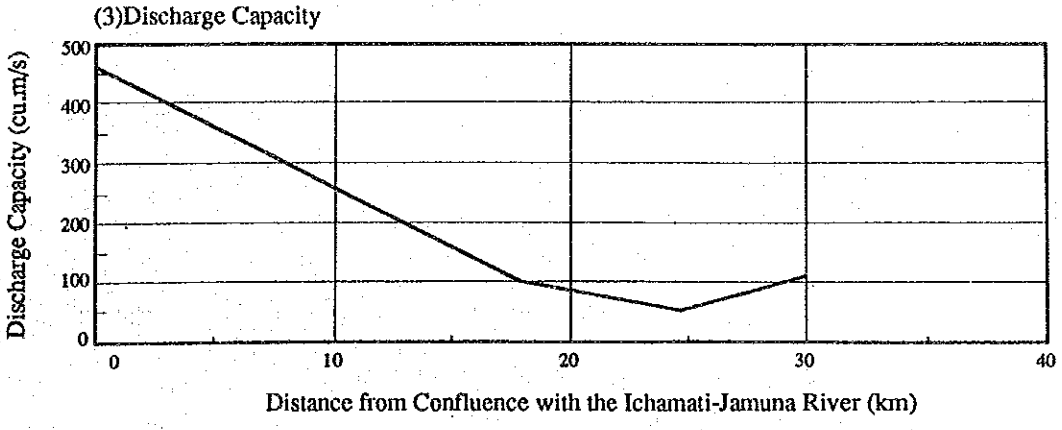
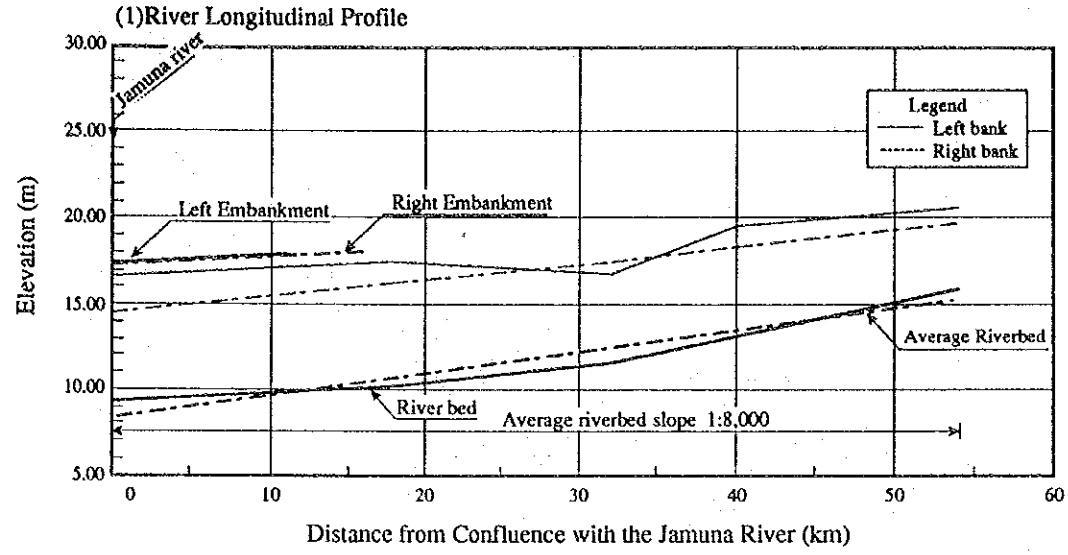
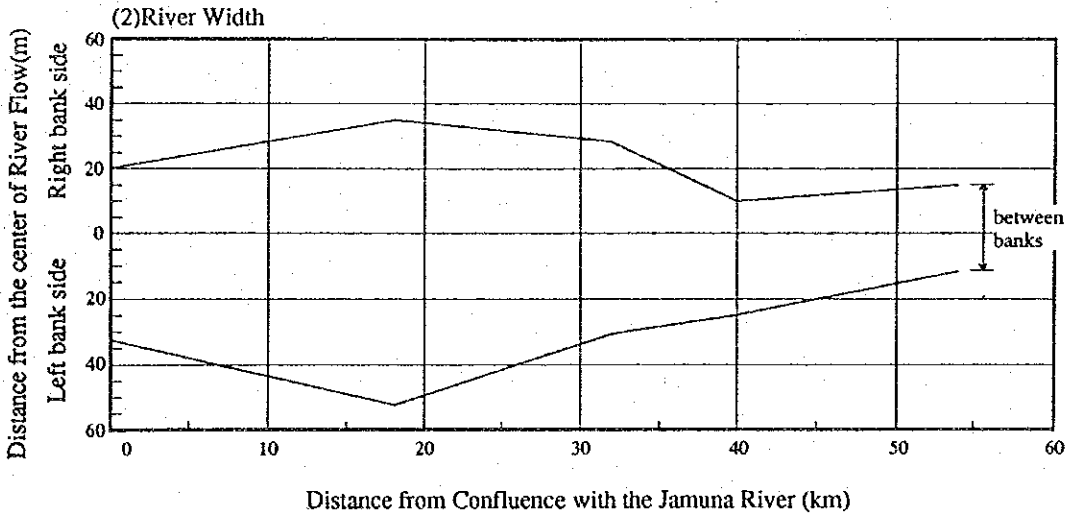


Figure 2.6 RIVER FEATURES OF THE KHARKHARIA RIVER





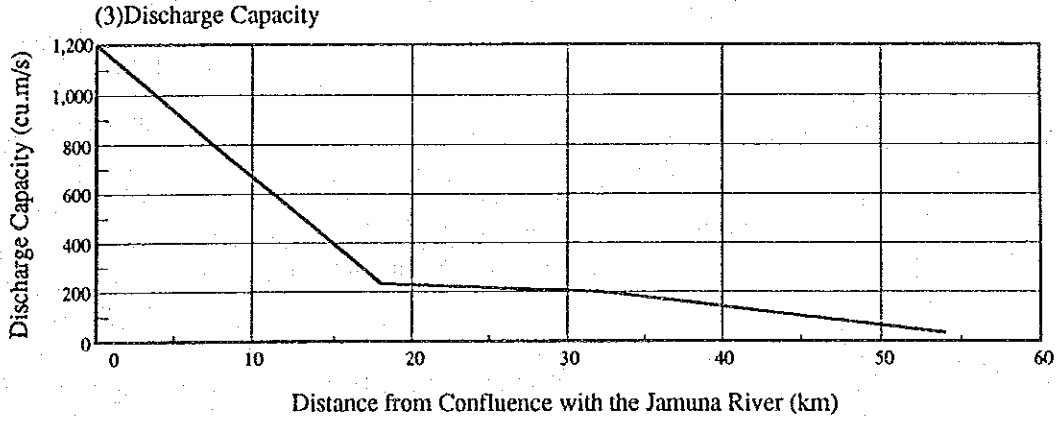


Figure 2.7 RIVER FEATURES OF THE TULUSI GANGA RIVER

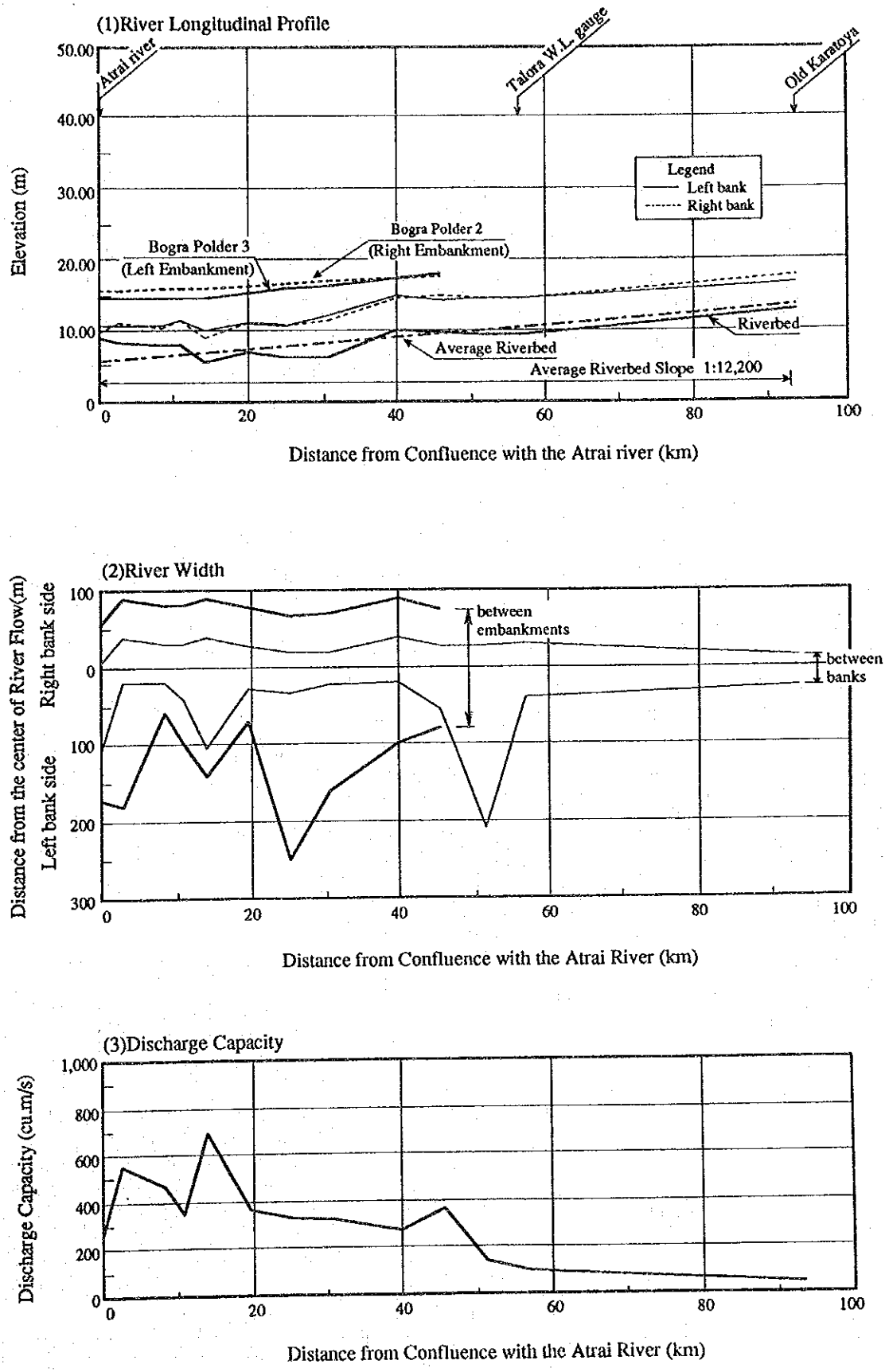


Figure 2.8 RIVER FEATURES OF THE NAGOR RIVER

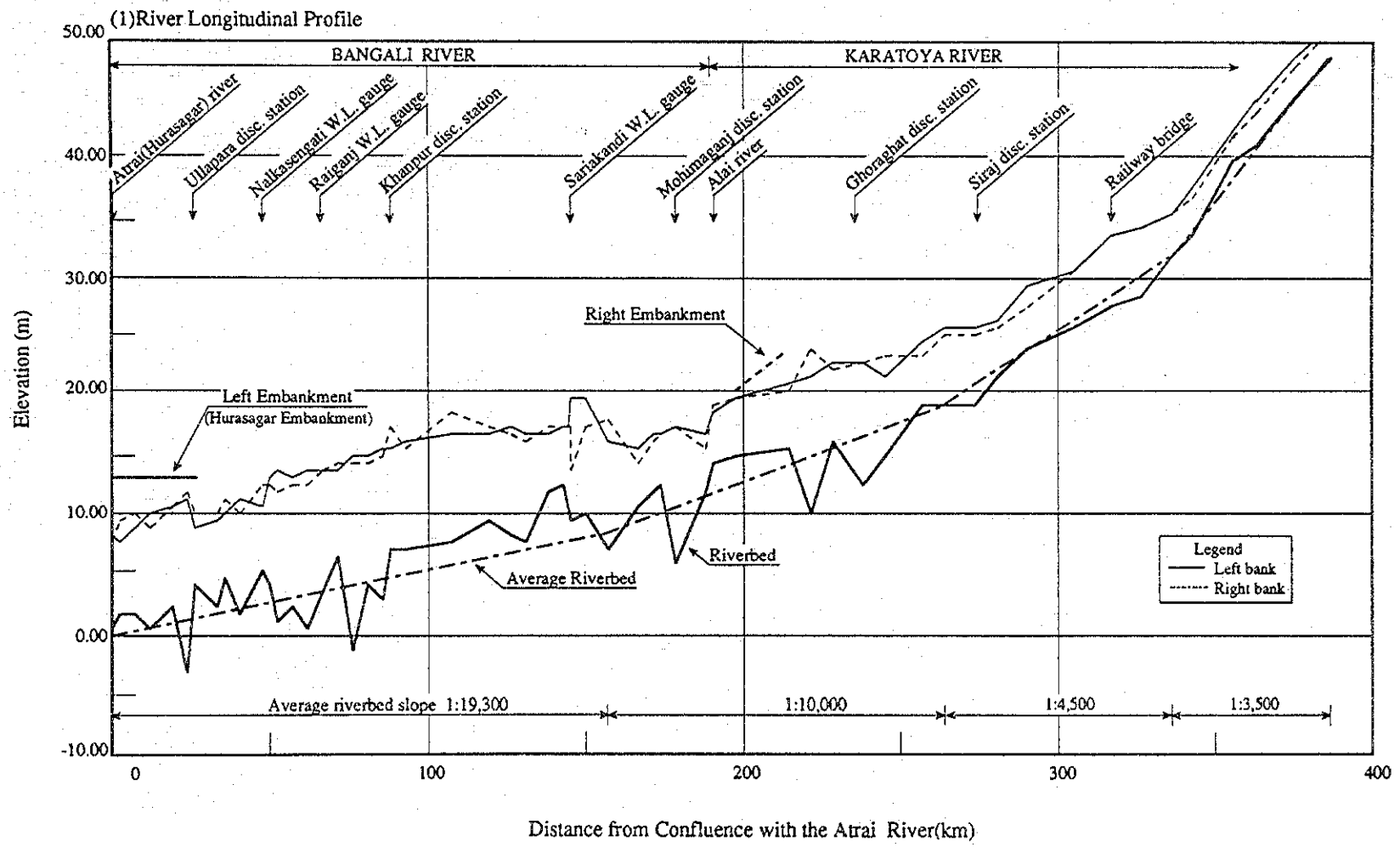
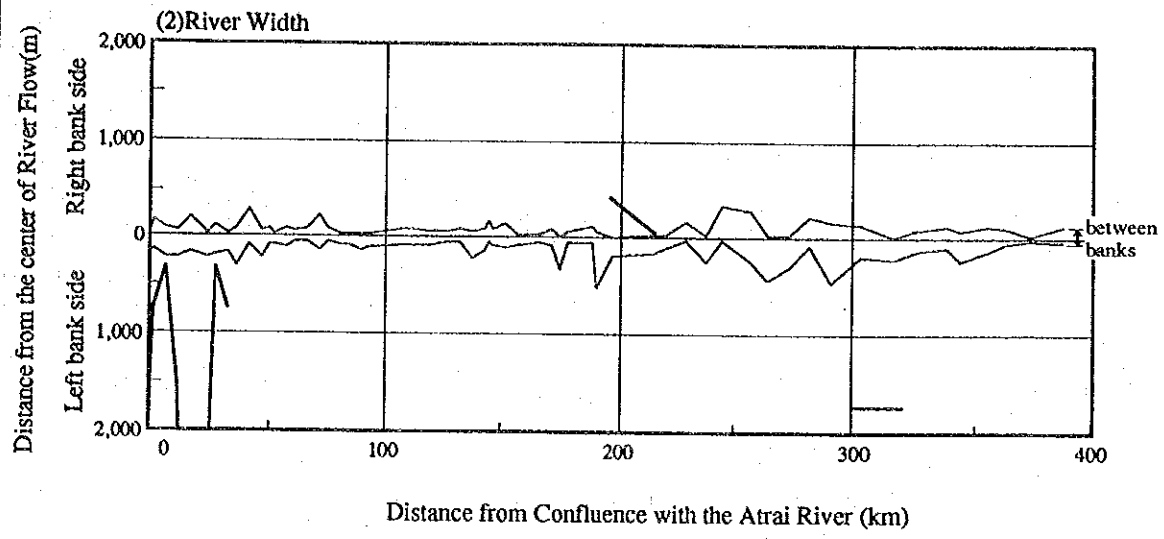


Figure 2.9 RIVER FEATURES OF THE BANGALI-KARATOYA RIVER (1/2)



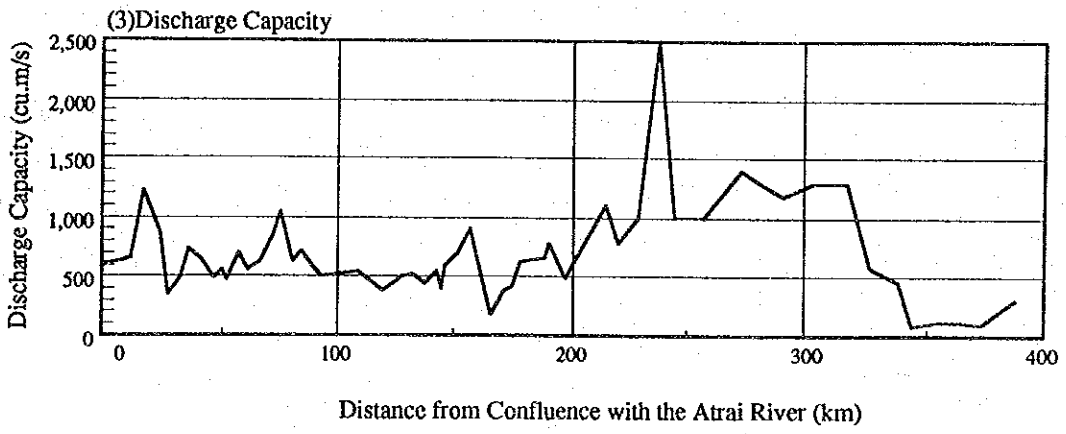
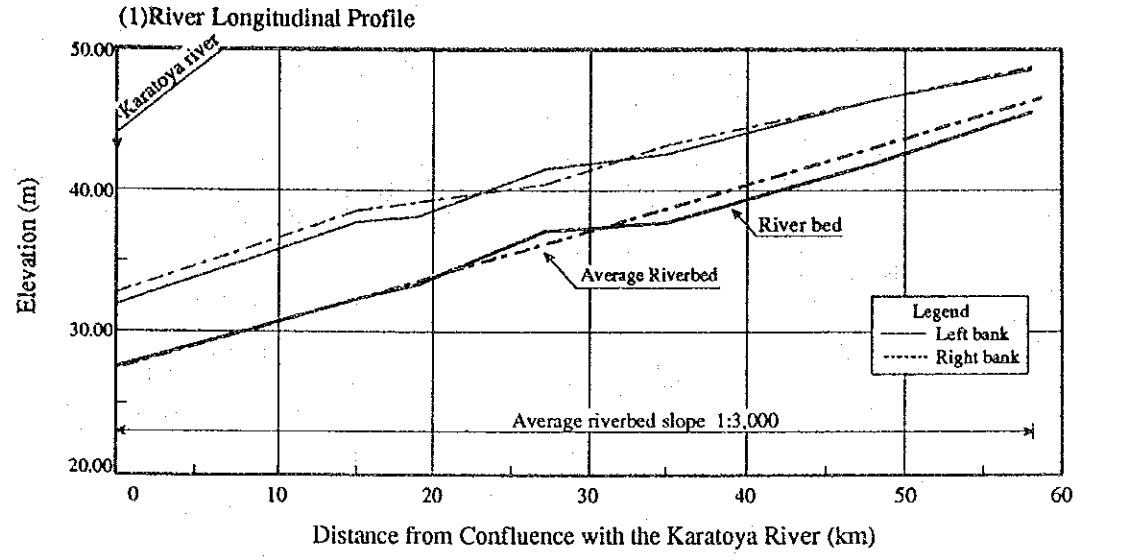
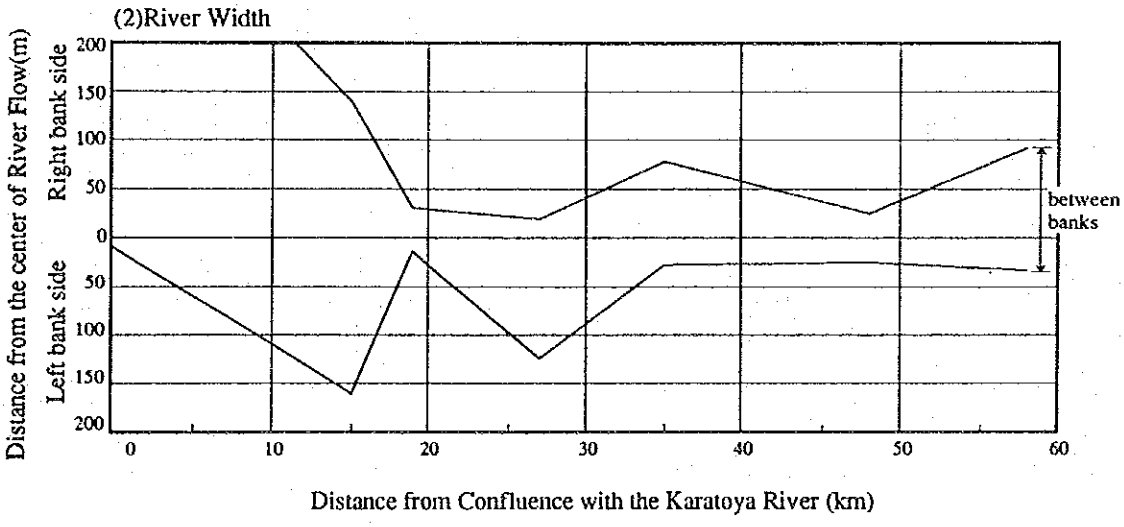


Figure 2.9 RIVER FEATURES OF THE BANGALI-KARATOYA RIVER (2/2)





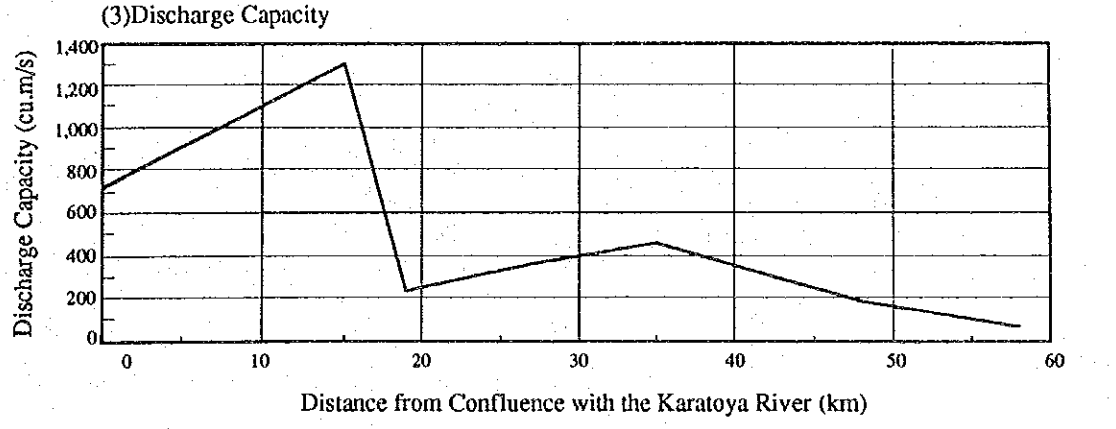


Figure 2.10 RIVER FEATURES OF THE B-CHIKLY RIVER

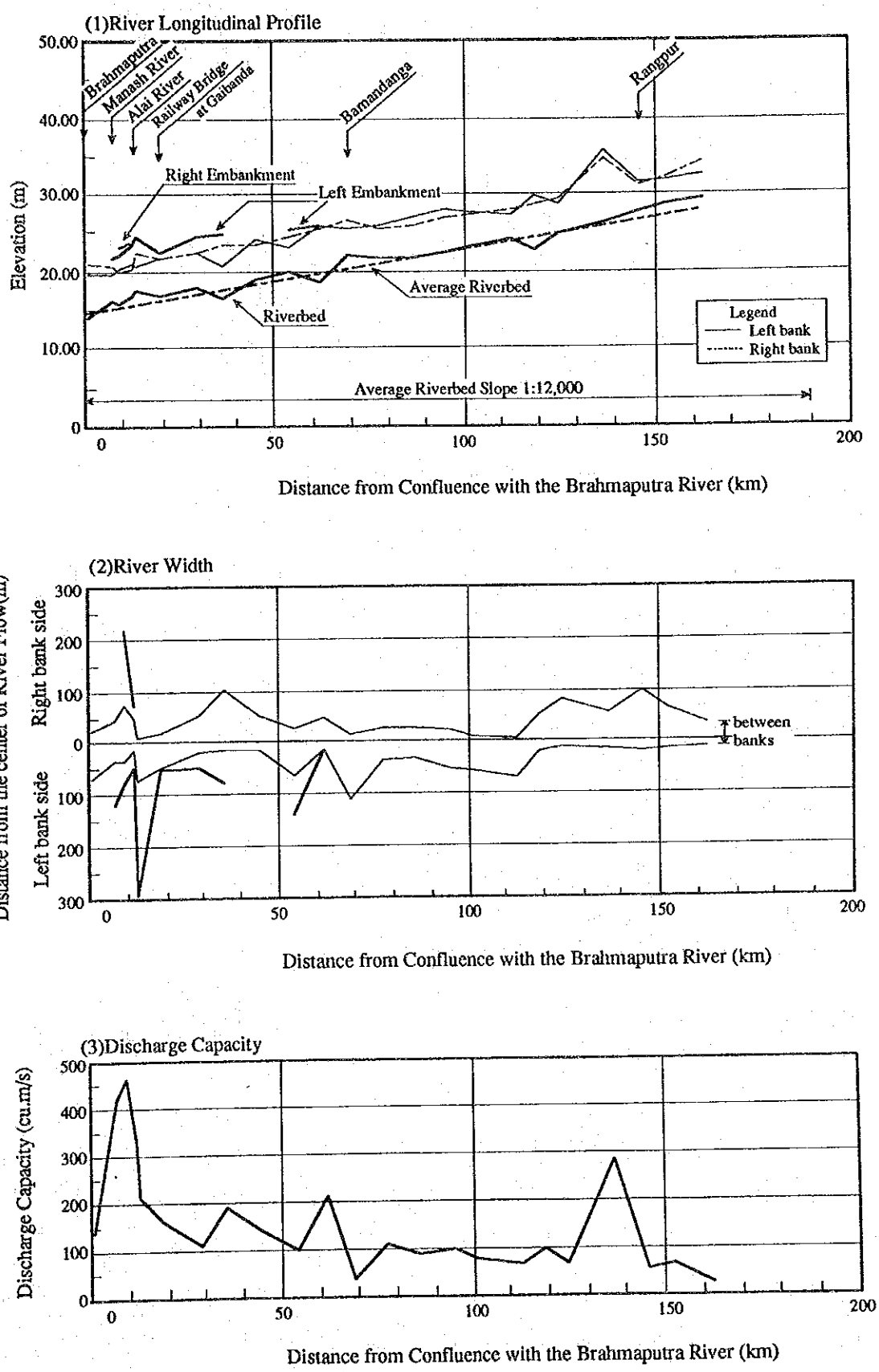


Figure 2.11 RIVER FEATURES OF THE GAHGOT RIVER

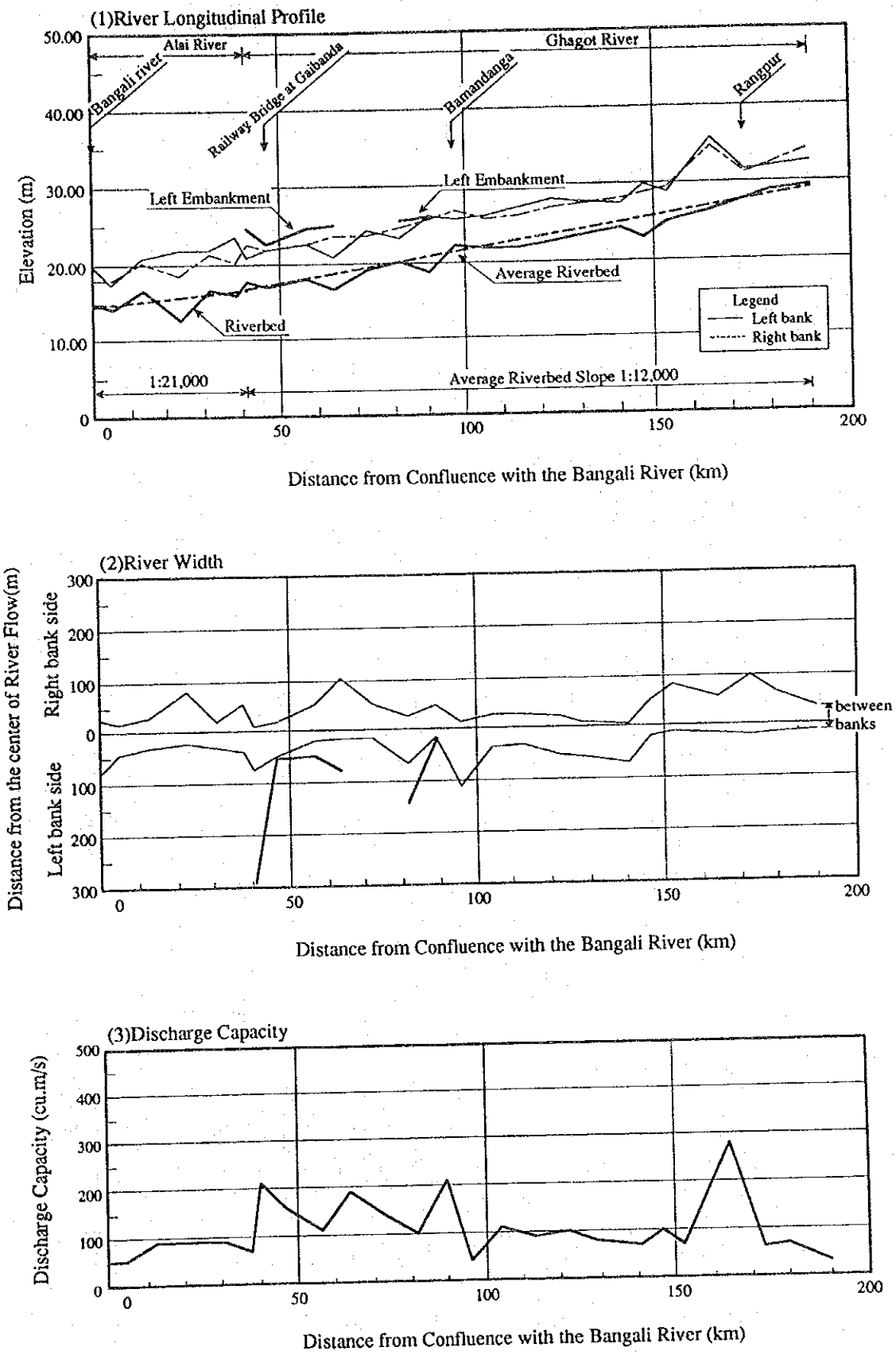


Figure 2.12 RIVER FEATURES OF THE ALAI-GAHGOT RIVER

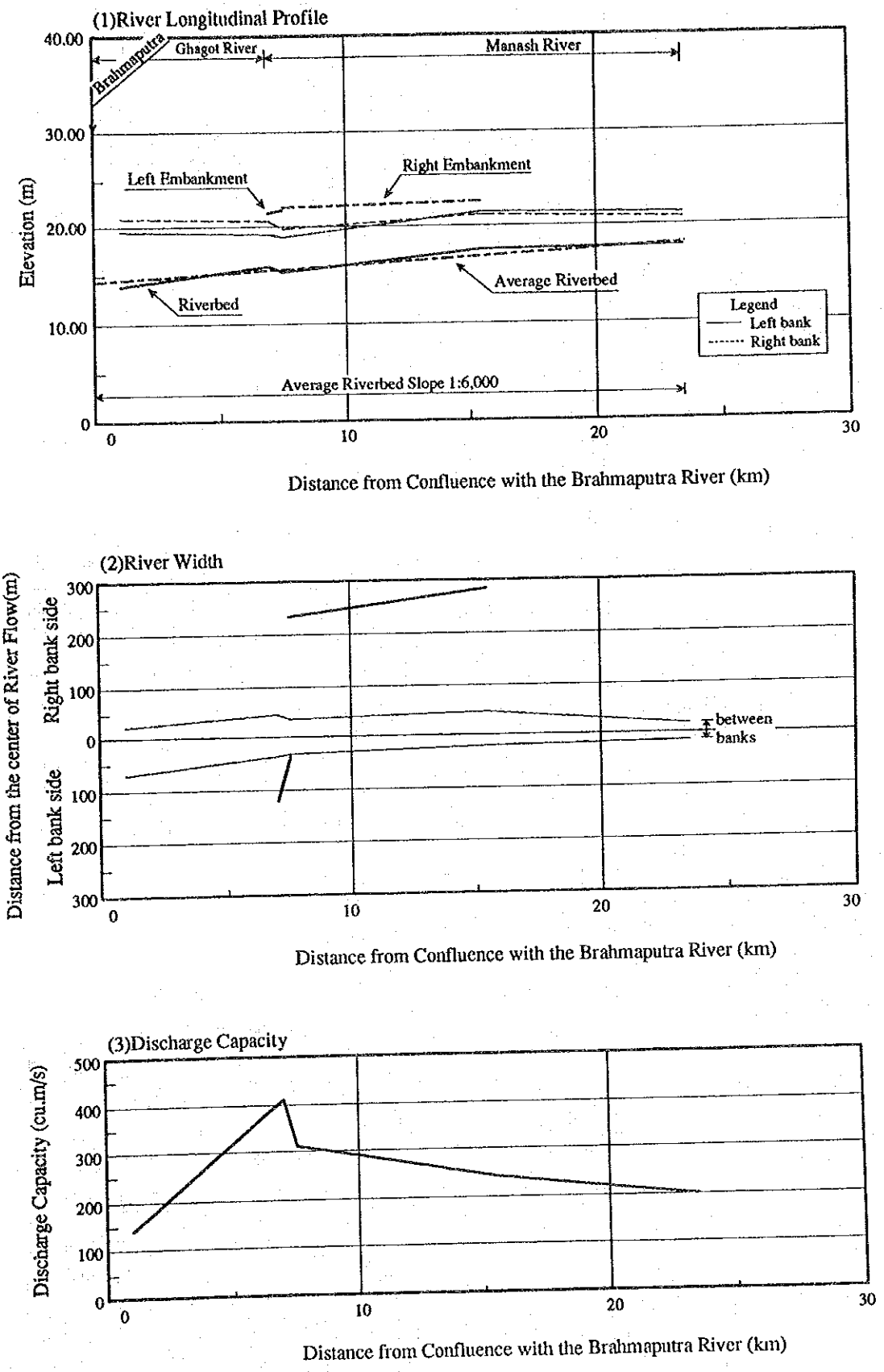


Figure 2.13 RIVER FEATURES OF THE MANASH RIVER

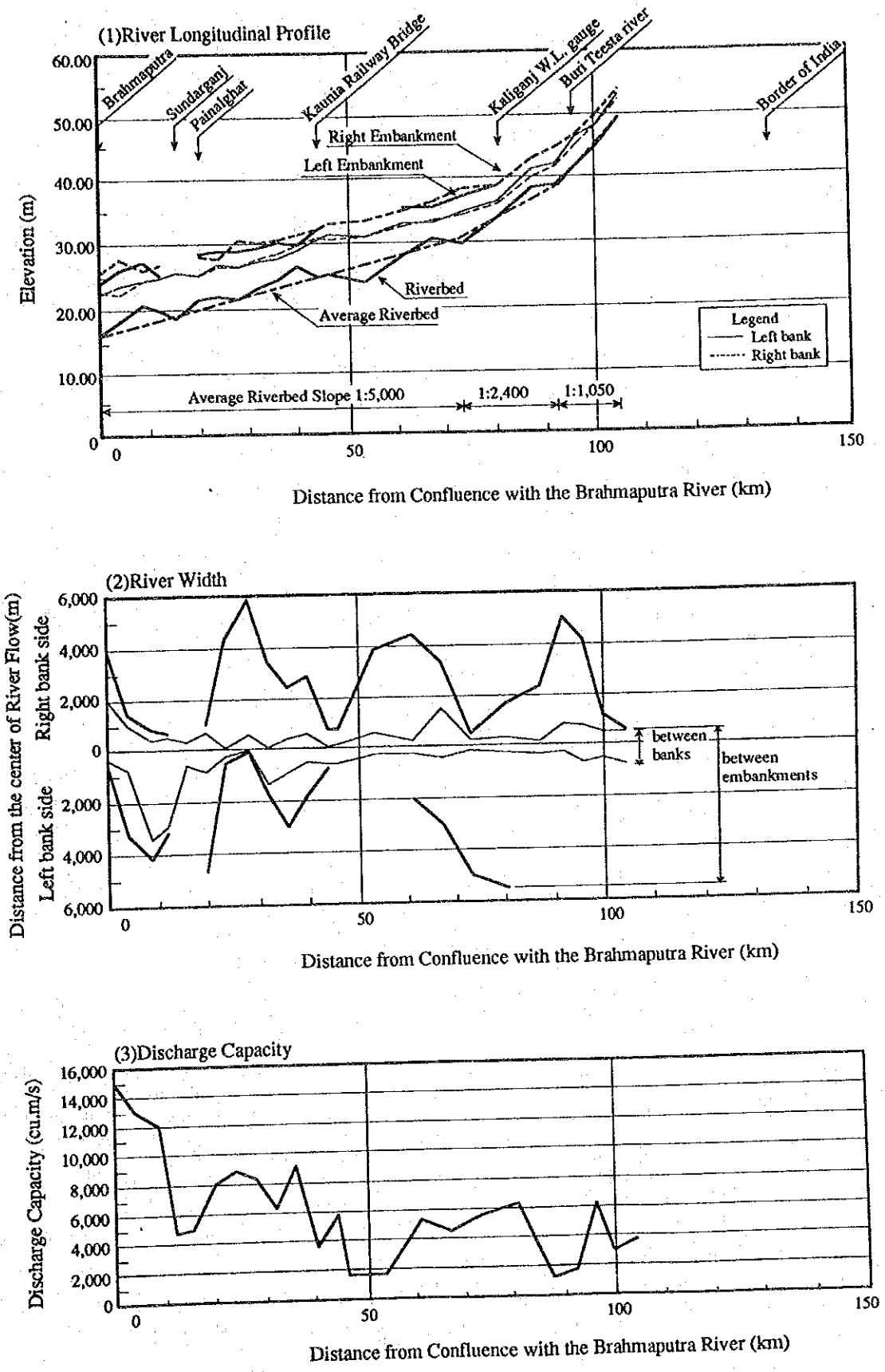


Figure 2.14 RIVER FEATURES OF THE TEESTA RIVER

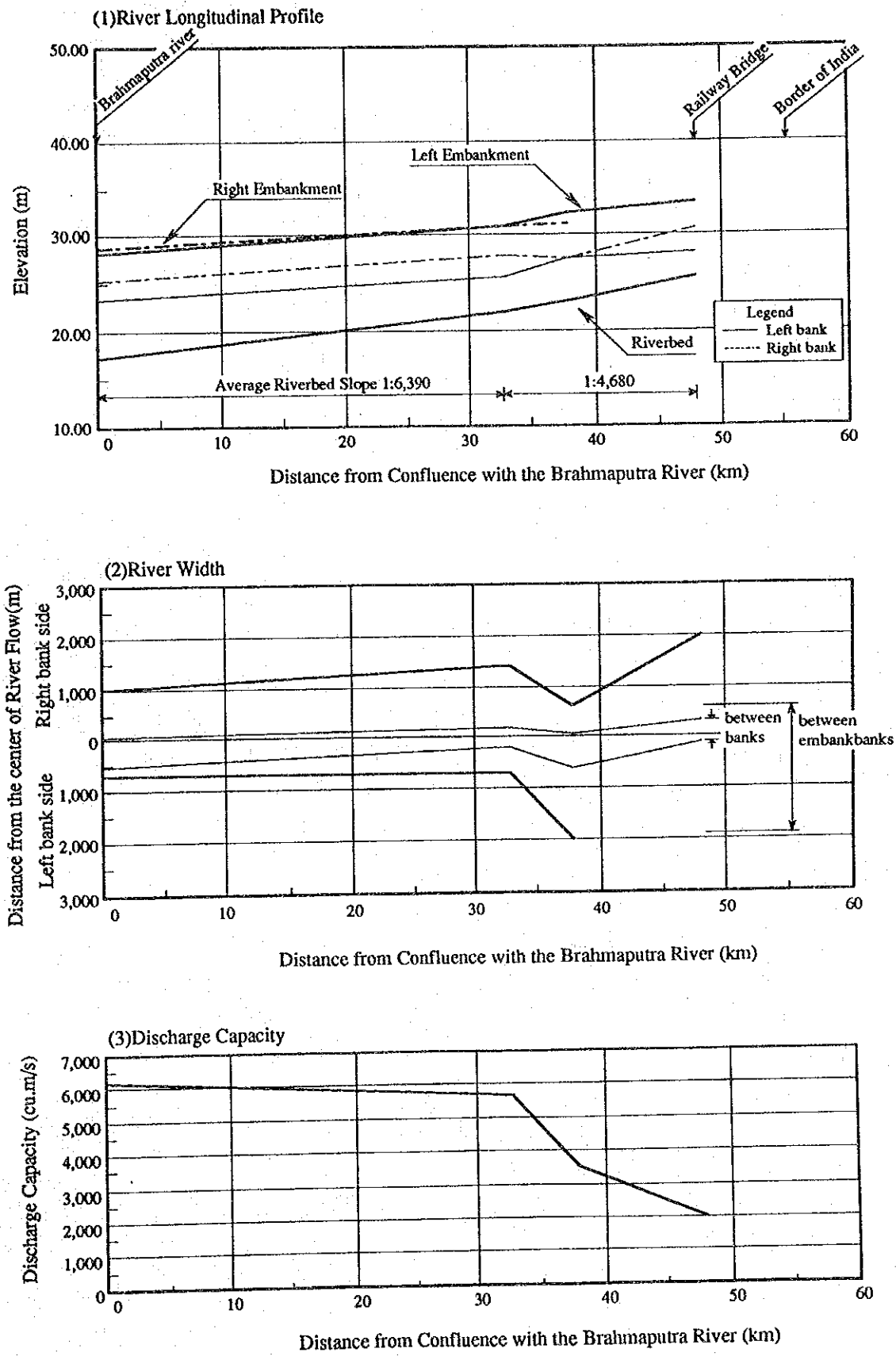
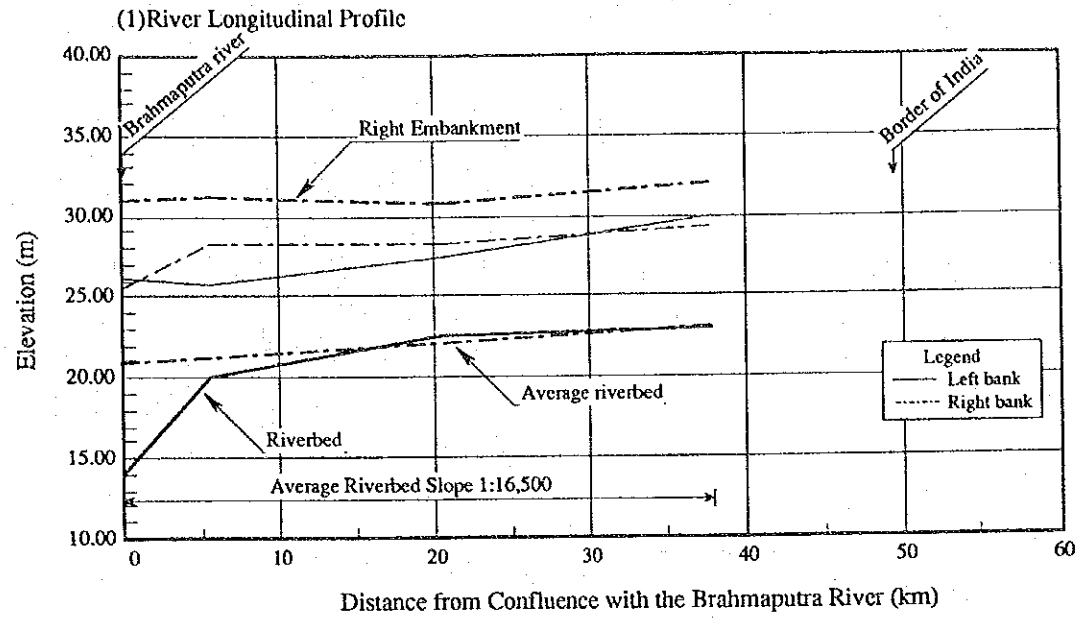
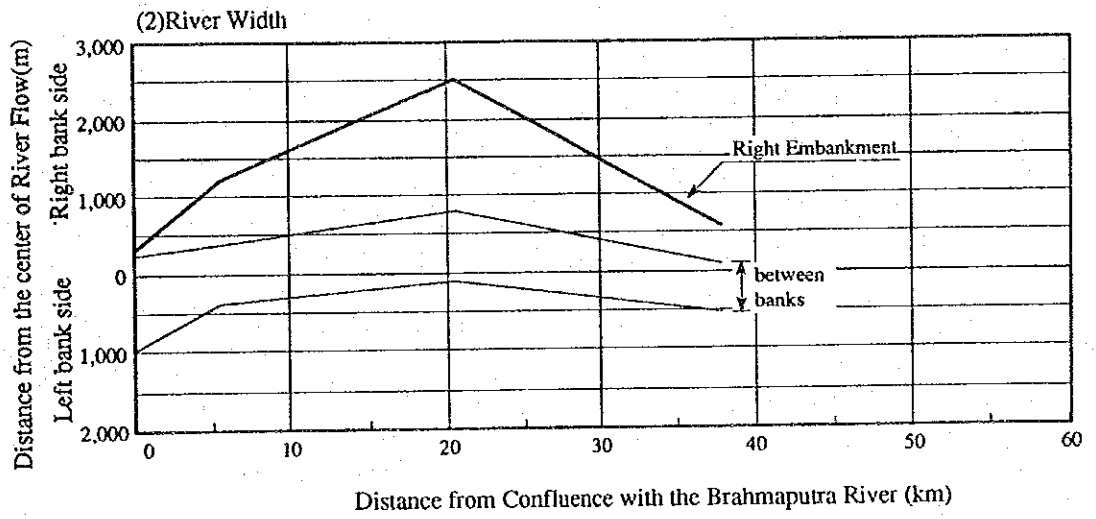


Figure 2.15 RIVER FEATURES OF THE DHARLA RIVER





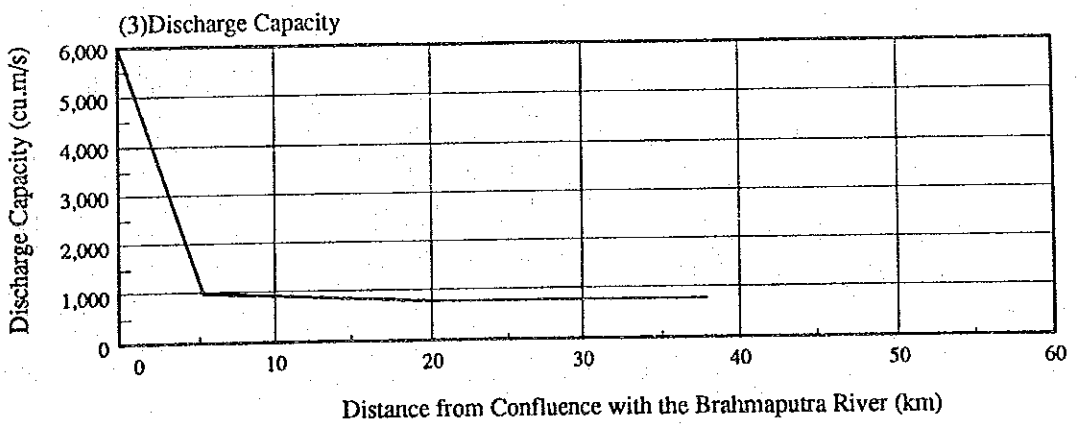


Figure 2.16 RIVER FEATURES OF THE DUDHKUMAR RIVER

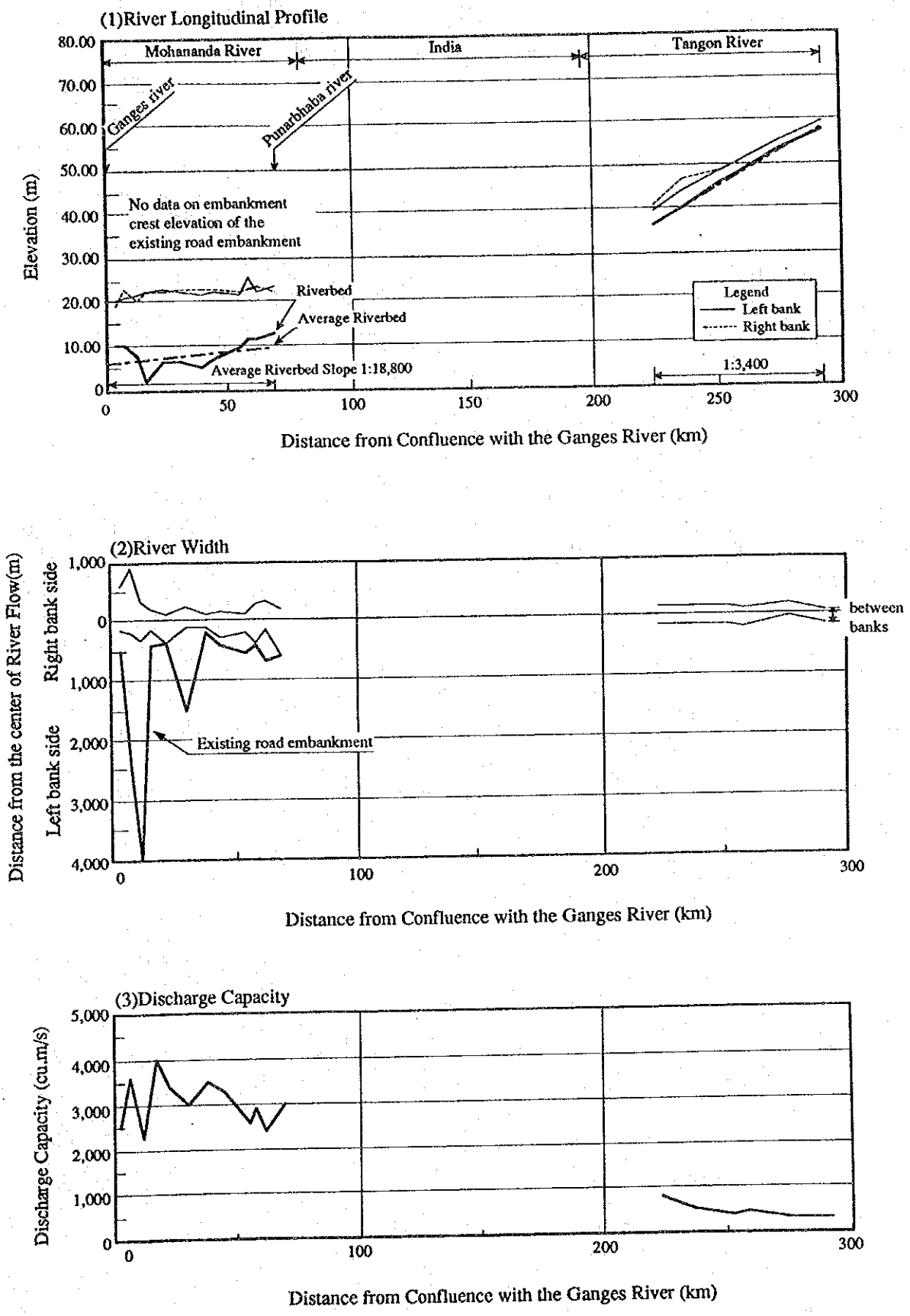


Figure 2.17 RIVER FEATURES OF THE MOHANANDA-TANGON RIVER

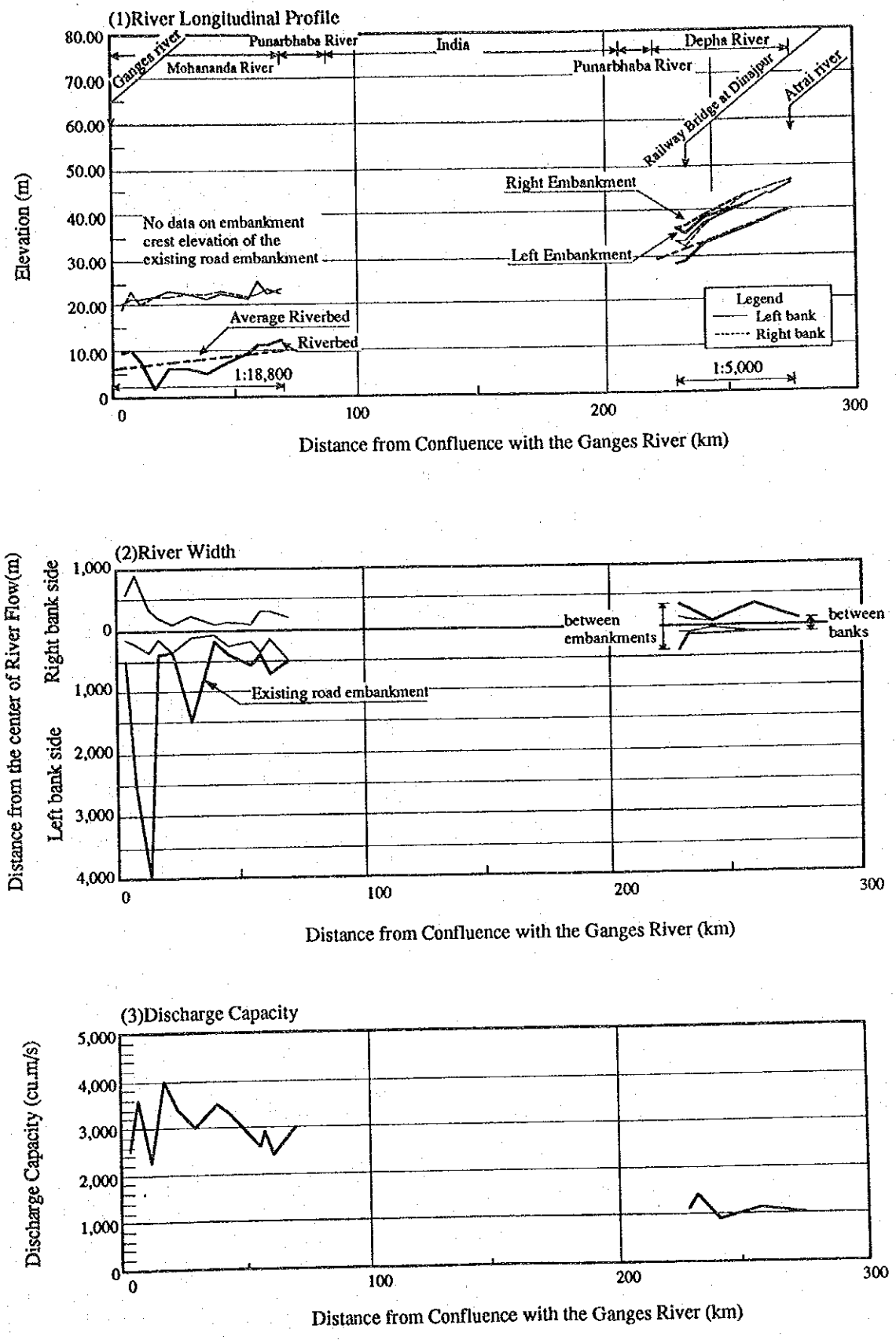


Figure 2.18 RIVER FEATURES OF THE MOHANANDA-PUNARBHABA-DHEPA RIVER

CHAPTER 3

PLANNING AND DESIGN CRITERIA

3.1 Introduction

The planning and design criteria applied in the Regional Planning are determined by reference to those adopted in existing and on-going CFD/CFDI projects in Bangladesh but take into account the concepts and approaches of the flood Action Plan.

3.2 Planning criteria

a) Flood embankments

Flood protection levels for the existing schemes in the region are as follows:

CFD or CFD/I Project		Protection Level in Return Period(year)	Water Stage in the Brahmaputra or Ganges
- Brahmaputra Right Embankment		100	-
- Ganges Left Embankment		100	-
- Kurigram CFD/I Project		50*	2-year probable flood water level for drainage and 100-year for flood control in the Brahmaputra.
- Teesta Project		100*	
- Chalan Beel Project	Polder-A	5	
	Polder-B	Not studied	-
	Polder-C	-do above-	
	Polder-D	5	
- Tulshi Ganga Project		20	
- Tulshi Ganga Left		20	
- Naogaon Polder		20	
- R-L Scheme		20	
- Upper Nagor Valley		20	
- Nagor Valley Scheme		20	
- Serajganj I.R.D.P. (SIRDP)		20	
- Hurasagar Scheme		unknown	
- Pabna Scheme		100	100-year probable flood water level in the Brahmaputra with full confinement along the lower Atrai.
- Barnai Project		5	

Note ; * : Flood embankments are originally planned at the protection level but not completed yet.

As seen above, the major rivers such as the most downstream reach of Atrai, Teesta, Dharla and Dudhkumar rivers have or are planned to have protection levels of 50-year to 100-year probability and flood embankments have been constructed or are under study or designed to secure these levels. In the tributaries of the lower Atrai, flood protection works have been carried out or under implementation for protection levels of 5-year to 20-year probabilities. In the upper catchments, no flood protection work except local embankment or river channel improvement is made along the river course.

In this study, 20-year probable flood is basically used for flood control planning taking into account that agricultural damage due to flood is dominant in the region. For the Regional study, data from years 1965 to 1991 are available for modelling analysis and 20-year probable flood is obtained using this data by each basin.

On the other hand, the rivers in the NWR join the Brahmaputra or Ganges and therefore the water levels in the lower reaches of these rivers are affected by the back-water effect of these major rivers along which the flood embankments are provided to cope with 100-year probable flood.

According to the present conditions mentioned above, the flood protection levels in the major river basins are set as follows.

River Basin		Flood Protection Level in Return Period(year)
i)	Dudhkumar	20
ii)	Dharla	20
iii)	Teesta	20
iv)	Ghagat	20
v)	Karatoya-Bangali	20
vi)	Upper Atrai	20
vii)	Lower Atrai	20
viii)	Mohananda	20
ix)	Interceptor Drain	20
x)	Diversion Drain	20
xi)	Tributaries	20

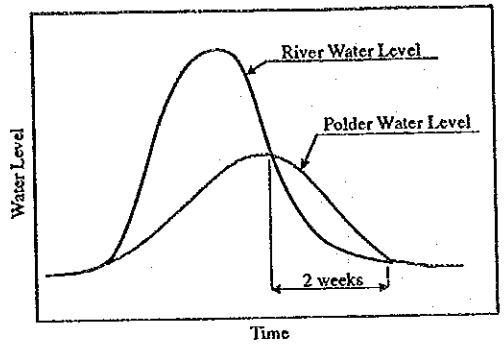
b) Drainage provisions

A large part of areas have been or are to be enclosed with embankments through existing and on-going CFD/CFDI projects. Even though the areas are protected from floods in the rivers through provision of flood control works mentioned above, these empoldered areas are subject to the drainage congestion, especially in low-lying areas extending along embankments, due to high river stage which usually lasts between July and October.

An analysis has been carried out of the feasibility of pumped drainage. This was done by assessing the incremental benefits in one of the FAP2 planning units (the Mohananda basin) of installed pump capacities of 10,20 and 30 m^3/s. The analysis, which is given in Annex-7 Economics, clearly shows that drainage pumping is not feasible. It has not therefore been considered further in this study.

In the Regional study, the drainage plan aims to enable the internal water to be drained out to the outer river by gravity flow through new provision of drainage facilities such as regulator within certain period immediately after the outer river stage becomes lower than the water level inside the polder. Besides, to avoid concentration of internal rainstorm waters to the low-lying areas inside polder, existing polders covering large area are planned to be compartmentalised with new provision of subpolders therein. In connection with compartmentalization, the drainage networks inside the polder are contemplated through provision of new drainage channels and/or improvement of existing ones.

The planning criteria to determine capacity of the drainage facilities is that the water level inside the polder has to be lowered to the outer river stage by gravity flow in two weeks from the date that both water levels inside and outside the polder coincide during the recession of flood in post monsoon season. This criteria is schematically shown below.



The following table gives example of the return periods for which internal drainage in CFD schemes in the region are designed.

Scheme	Return Period(years)
Kurigram CFD/I Project	5
Teesta Project	5
Chalan Beel Polders A,B,C,D	10
Pabna Scheme	10
Barnai Project	5

Drainage measures for FAP-2 are designed to have a 5-year protection level. These criteria are consistent with those specified by the terms of reference for the South East Regional Study (FAP-5) and, as shown in the above table, are similar to those commonly used in Bangladesh.

Concerning the drainage plan, on the other hand, the magnitude of the flood event is required to be assessed in consideration of synchronized probability of the outer river stage and rainstorm inside the polder. In addition, the analysis should not be made for an isolated meteo-hydrological event of short duration, but for the yearly one lasting during the monsoon season. 5-year probable flood is also estimated using the data from years 1965 to 1991 by each basin for drainage analysis.

Applying river stage and rainfall of 5-year return period obtained above, the dimensions of regulators required to satisfy the aforesaid criteria are derived for each subpolder through the trial and error calculations using the following differential equation for all polders contemplated for CFD development in the Regional study.

$$dV/dt = I - O(H,h)$$

Where,
- V : Volume of inundated water inside sub-Polder (m3)
- t : Time (hour or 3,600 sec)
- I : Inland runoff resulting from internal rainstorm (m3/sec)
- O(H,h) : Outflow to the adjacent river through regulator (m3/sec)
- H,h : water level inside subpolder and the adjacent river stage,respectively (m)

Inland runoff above is estimated based on the rainfall dividing the empoldered area into inundated and non-inundated zones, of which the latter takes into account evapotranspiration and percolation losses. As a result, long-term daily inundation levels in the polder for the entire monsoon season are derived from an area-elevation curve prepared from MPO's irrigation maps with spot heights on 1 km square grids. Also for the year of 20-year probable flood, the effect of reduction in water levels inside the polders under the drainage provision, whose capacities are determined based on 5-year probable flood, are estimated by the above equation so as to assess the agricultural benefit from reduction in crop damage.

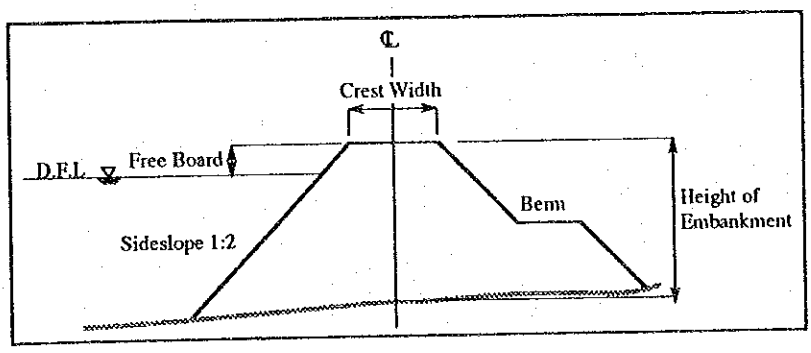
3.3 Design criteria

The major CFD structures and works proposed in the Interim Regional study comprise the following.

- CFD embankment
- Overflow weir
- Dwarf embankment
- River bank protection works
- Improvement or new provision of river and drainage channels
- Bridge, gated weir and syphon structures for major drains

These structures and works are designed based on the standards in Bangladesh, and those in Japan where applicable.

a) CFD embankments



Design Flood Water Level along the river stretch is determined by the hydraulic modelling study using probable flood discharge distribution of the river established in hydrological study, available river cross sections and water level condition of rivers at outfall with the Brahmaputra and Ganges. Setback distance for new embankment construction is determined based on the hydraulically required setback distance for the design flood discharge and taking into account the land areas to be acquired. Crest Elevation of flood embankment is determined by adding the free board to design flood water level. In Bangladesh, the following criteria on free board is established based on wind velocity. These criteria are applied to the Regional study.

Fetch (km)	Free Board(m)	
	Normal	Minimum
Less than 1.6	1.22	0.91
1.6 to 4.0	1.52	1.22
4.0 to 8.0	1.83	1.52
8.0 to 16.0	2.44	1.83
more than 16.0	3.05	2.13

Notes; Normal : Wind velocity $\geq$ 160 km/h
Minimum: 80 km/h $\leq$ Wind velocity < 160 km/h

Crest Width is taken at 4.25 m considering the uses of inspection/rural road.

Side slope of 1:2 in both the river and land sides is generally applied to the flood embankments in areas where soil materials suitable for the embankment are obtainable from its neighbourhood. On the other hand, in the areas where available soil materials are composed of sandy texture like the Teesta right embankment, side slopes are designed at 1:3 to secure the stability against seepage and slope failure.

Berm is also provided to secure the stability against seepage and slope failure. A 2 m wide berm is provided at an interval of 3 m in height downward from crest.

Embankment Surfacing Works with brick/steel wire, widely used for slope protection in Bangladesh, is provided, if necessary, at existing damaged portions or at portions where the surface erosion is likely to take place due to insufficient strength of embankment materials and/or insufficient setback distance and meandering.

b) Dwarf Embankment

In principle, dwarf embankment is designed in accordance with the following criteria.

Existing flood embankments are reformed for use as dwarf embankment, as far as possible, by means of providing the aforesaid embankment surfacing works.

Dimensions of dwarf embankment are similar to those of the main flood embankment, but no berm is provided in consideration of the hydraulic performance of overtopping flow during monsoon season.

Overflow section whose crest level is lower than surrounding embankment portions is provided, if necessary, to pass river flood flow into the polder during monsoon season and its dimensions are determined based on the hydraulic modelling analysis.

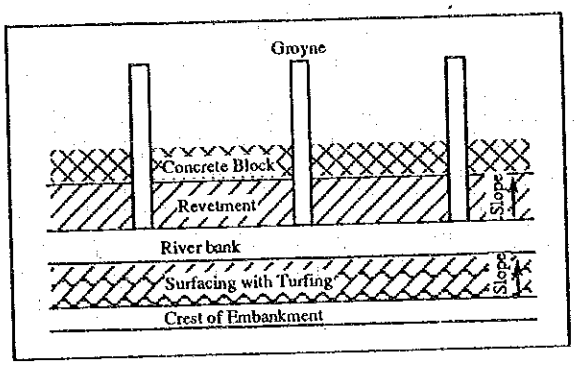
c) Overflow Weir

The basic hydraulic function of an overflow weir is same as that of a dwarf embankment and the design is made following the criteria of dwarf embankment mentioned in above section b). An overflow weir is planned to cope with overtopping flow with high water head compared with dwarf

embankment, and the overflow section is, therefore, lined with concrete to avoid damage due to accelerated overtopping flow.

d) River Bank Protection Works

To protect river banks from erosion due to attack of flood flow of river, a combination of impermeable spur dikes, groynes, revetment works and surfacing works is considered to be the most effective countermeasure. These are used for the town protection works along the Teesta and Dharla rivers as well as the Brahmaputra.

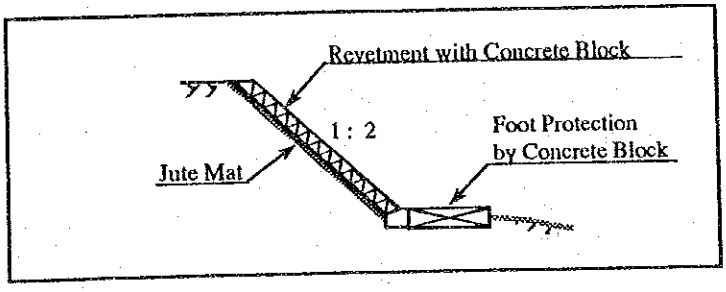


Groynes with the following features are provided at the severe erosion points mainly located in the Teesta and Dharla rivers in the study area. The performance of existing groynes is also to be assessed in deciding dimensions.

a) Length	:	10% of river width during drought season taking into account its effectiveness as well as economical advantage
b) Crest elevation	:	River bank elevation
c) Spacing	:	10 times height or 1.5 to 2.0 times length

Impermeable spur dikes, which are constructed mainly with earth materials, are designed to have smaller dimensions with reference to existing ones along the Teesta right bank.

Revetment works are provided with foot protection works by concrete block.



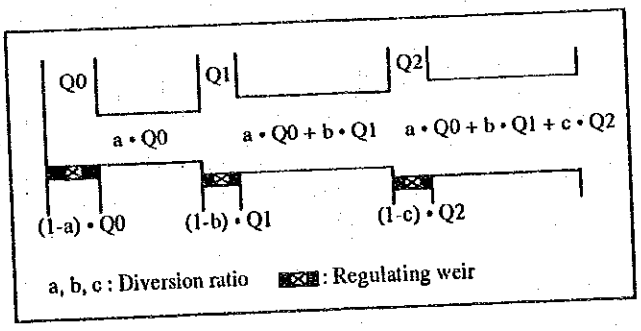
e) River Channel Improvement

River channel improvement works are made by bank excavation and river-bed dredging to form river channel with flow capacity of 20-year probable flood discharge. In planning, a single cross section is basically applied as typical one and is based on the present river width between banks, river-bed width and average river-bed slope. Banks in areas where ground elevation is locally low are heightened by filling with excavated material. On the other hand road and channel improvement works for drainage are made to have a flow capacity of 5-year probable flood discharge.

f) Major Drains

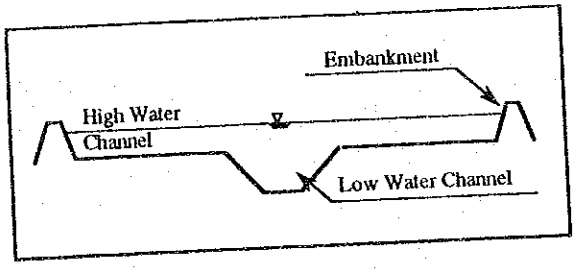
Design of major drains is based on the following design criteria.

Design Flood Discharge Capacity of the major drains is based on the 20-year probable flood and assessed by applying several different diversion ratios in the study.



Design River-bed Slope is determined taking into account (i) design elevations at joining and branching points with the existing rivers of the Atrai, Karatoya-Bangali, Teesta and Ghagat rivers; and ii) ground surface elevation along the route.

With regard to the typical cross section, two different types, single and compound sections are conceivable. In case of the compound section, it is designed to have low and high water channels (refer to the following figure). Low water channel will have a flow capacity corresponding to 2-year flood discharge and high water channel will carry the flood discharge in excess of the flow capacity of low water channel.

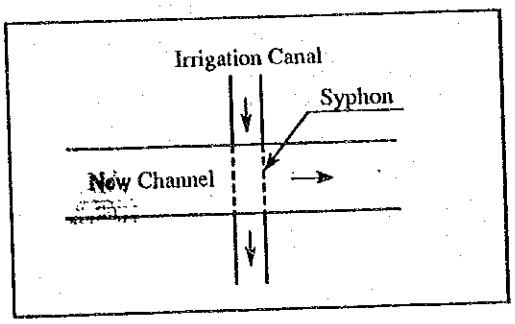


Other Related Structures

Regulating weir with a number of gates in the Atrai, Jamuna, Karatoya-Bangali and Ghagat rivers is required to control flood flow into the downstream of these rivers. In addition, construction of gated weir in new channel is also required to ensure utilization of river water in the downstream reaches during the drought period. Therefore, complicated and integrated gate operation at each weir site is required to control flood discharges during monsoon season and to pass river flow during drought season.

Regulating gates of weir are designed to be slide gate type with flow capacity corresponding to 100-year flood peak discharge at the weir site.

Syphon Structure will be required at the crossing of the Interceptor Drain and the irrigation canals of the Teesta Irrigation Project.



Bridge across the major drain is designed to be of prestressed concrete type taking into account the required span length in order not to diminish the flow area of the channel.

CHAPTER 4

THE MAJOR DRAINS

4.1 General

As stated in Chapter 1 "Background", the engineering study for the major drains was carried out at the pre-feasibility level in the Interim Regional Study Stage. This Chapter summarizes the engineering study results as well as the downstream impacts on reduction water levels in the lower Atrai, which were analyzed through the hydraulic modelling in the Interim Regional Study.

The assessment of the downstream impact was made for the 1987 flood. While, the cost estimate was made assuming that the mechanical construction method be adopted taking into account the huge volumes of work quantities, especially the earth works such as excavation and embankment for construction of major drains which occupy a large part. Since the unit rates for the earth works estimated in the present study have raised from those in the Interim Regional Study Stage, the CFD options contemplated in the present study have resulted in higher capital and O&M costs as compared those in the Interim Regional Study. Therefore, it is judged that the low economic viability of the major drains stated in the FAP2 Interim Report still remains unchanged, needless to make again the assessment on it.

An important element in the analysis of the possible development scenarios for the Lower Atrai was the investigation into the major drains. These drains were first identified at the time of the Flood Policy Study, and subsequently clarified in concept during the Preliminary Study for NWRS. Two drains were originally conceived:

- the Interceptor which is intended to divert water from the northern reaches of the Atrai and pass it eastward to the Brahmaputra, intersecting the Jamuneswari and Upper Karatoya rivers on route and

- the Diversion Drain, off taking from the lower Atrai, flowing down the Shib before out-falling to the Ganges west of Rajshahi. Both of these drains were expected to make a major change in the hydrological regime of the lower Atrai by diverting a significant portion of the flows which cause flooding due to the outfall constraints at Hurasagar.

A large number of alternatives were investigated for each of the drains. This was done to ensure that the best possible plan was analyzed for its feasibility. The alternatives covered alignment, section and capacity, as discussed briefly in the following sections. The best design for each of the Diversion and Interceptor drains was selected on the basis of cost effectiveness - maximum reduction in water levels in the Lower Atrai per unit of cost. This analysis and its subsequent economic and impact assessment, were fully described in the Interim Main Report and summarised here.

4.2 Alternative Alignments

Five different alignments of the Interceptor and two for the Diversion were considered as shown in Figure 4.1. In the case of the Interceptor, alignment IC0 takes the most northern route among the alternatives to connect the off take at the confluence of the Atrai and Ghoramara rivers and its outfall located just downstream of Teesta Barrage. The length of IC0 is 50 km, being the shortest among the

five alternative routes. Since the whole length of IC0 consists of new channel and is aligned on relatively high land with an altitude of 60 m PWD to 47 m PWD, a large quantity of excavation volume would be required per unit length of drain.

IC1, aligned south of IC0, intercepts the head water of the Atrai and diverts the flow to its outfall into the Teesta, about 20 km upstream of the outfall. On the way, it interconnects with the Jamuneswari and Ghagot. Its total length is about 129 km.

IC2 takes the same route as IC1 to the confluence of the Ghagot and Alaikumaria rivers over a length of about 96 km from its off take and then changes its course southwards along the Ghagot to harness larger hydraulic head. It finally outfalls to the Brahmaputra passing the northern side of the town of Gaibandha. Its total length is about 180 km.

IC3 originates just upstream of Bhusirbandar on the Atrai river and connects with the Little Jamuna river via a length of new channel. A short section of new channel then connects to the Karatoya-Katakhali and flows from these to the Brahmaputra through a new channel branching off from the Katakhali river at the confluence with the Bangali river. The total length of IC3 is 159 km, which consists of 45 km of new channel and 116 km of river improvement works along the Little Jamuna-Karatoya-Bangali river systems.

The alignment of IC4 follows that of IC3 except the lowermost part of about 20 km flows along the Bangali river before outfalling to the Brahmaputra river near Sariakandi . Its total length is about 176 km, being almost same as that of IC2.

The most important link between the Teesta Irrigation Project and the Regional Water Plan would be through the Interceptor Drain, if it were to be constructed. The proposed Interceptor alignments cut the Teesta main canals and distribution system. This not only requires that crossing structures be provided, but also raises the possibility that the drain could be used as a source of additional supplementary water during the dry season. However, this could only be done by abstracting water from rivers such as the Atrai which are already short of water at this time, and thus depriving downstream users of customary rights to the water. It is thus unlikely that this could be seen as a major benefit for the Interceptor.

For the Diversion drain, alignment DD1 off takes 7 km south of Mohadevpur, on the Atrai, and joins with the Shib river through to Nowhata before ultimately outfalling into the Ganges river west of Rajshahi. The total length of DD1 is about 107 km with provision of 14 km new channel and 93 km of river improvement works along the Atrai and Shib rivers. A possible northern extension of the Diversion Drain connects the Little Jamuna and Atrai rivers, which would require an additional 19 km of new channel.

The alignment of diversion drain DD1 follows the alignment of the proposed irrigation canal for the Paba flood plain area within the North Rajshahi Irrigation Project. The irrigation benefits for this area could therefore be added to the benefits of DD1, with inclusion of necessary low lift pumps. Provision of irrigation supply to the Barind area from Diversion Drain would probably not be economic due to the high pumping lifts required (approximately 20 m). In other respects the project would not have a high priority from the regional planning perspective, since it is primarily an irrigation project, to serve an area which does not appear to suffer particularly from flooding and drainage problems.

DD2 passes down the Fakirni and outfalls to the Ganges through the Baral Basin project area. The total length of DD2 is about 119 km, which consists of 65 km new channel and 54 km of river improvement works.

A third alignment for the Diversion drain, passing down the Fakirni and then across to the Baral and down the Mara Baral, was considered at the time of the Inception Report. It was concluded, however, that this would not show sufficient benefit for its cost. This alignment was therefore not investigated further.

Cross Section

A number of different cross-sections were considered as shown in Figure 4.2. The alternatives were:

- a single trapezoidal cross-section or a compound cross-section, with a low water channel and high flows carried between flood berms;
- the channel section designed so that flood flows were carried at or near ground level, compared to a channel section designed to carry low flows at ground level, with peak flows at up to 2 m above ground level.

In a comparison carried out for drain IC4, the compound cross-sections gave the highest cost, because of their large widths (up to 2.5 km between flood berms in the case of the largest drain considered), although they are to be preferred on morphological grounds. With regard to water levels, it was thought preferable to carry these, as far as possible, at ground level, in order to avoid drainage congestion being caused upstream of the drain alignments. (In view of the high water levels at the outfalls to the Brahmaputra and Ganges, embankments are generally required at the downstream ends in any case).

The case of the single cross-section with design water level at ground level was therefore considered, for the purposes of comparing different alignments.

4.3 Capacities

Two different capacities were considered for each of the main alignments, "large capacity" and "small capacity". The large capacity drain is designed to divert all of the discharge in the rivers with which it intersects, apart from a small residual flow which is allowed downstream for fisheries, navigation, irrigation and domestic purposes. The small capacity drain is sized approximately according to the mean monthly maximum flow of the rivers with which it intersects.

The large capacity drain has of course a much greater effect on water levels in the Lower Atrai, particularly in the case of the large Diversion Drain, which abstracts all but 200 m^3/s of the flows in the Atrai river at that point. This necessitates, however, a very large channel. In the case of the Interceptor IC4, its design capacity is 3000 m^3/s at the downstream end, while for the Diversion Drain the outfall capacity is 1400 m^3/s.

The small drains investigated have capacities of the order of 450 m^3/s for the Interceptor and 400 m^3/s for the Diversion. As they are sized by reference to the mean monthly maximum flow in the rivers, they would be expected to flow approximately full for about one month, and would moreover necessitate much less construction cost because they are approximately the same size as the rivers they

join. On the other hand, they have correspondingly less effect on flows in the Lower Atrai. Indeed, in the case of IC4, they actually have negligible effect in some situations, when flows in the other rivers, the Jamuneswari and the Karatoya, are greater than the drain capacity.

4.4 Conclusions

Capital and O&M costs for each of the main alternatives considered are given in Table 5.1. Costs of the drains were of the order of Tk 15 billion ($ 500 million) or more, based on outline costing principles determined during the Interim Report stage. Economic returns were low, 2% for DDI and negative % for IC4. Whilst the more accurate analysis methods available during the second stage of the study would have changed both costs and benefits somewhat, the overall returns would not change significantly. In addition these would be very large projects with uncertain environmental impacts. It was therefore concluded that the major drains should not form part of the regional plan.

Table 4.1 COST COMPARISON OF ALTERNATIVE ROUTES OF MAJOR DRAINS

(Unit : Tk Million)

Description	Intercepter Drain										Diversion Drain		
	IC0	IC1	IC2	IC3	IC4					IC4 Shortened	DD1		DD2
					Case 1	Case 2	Case 3	Case 4	Case 5		Case 1	Case 2	
I. Length of Major Drain (km)	49.5	129.2	179.6	159.2	176.4	176.4	176.4	176.4	176.4	48.5	102.7	102.7	119.4
II. Project cost													
1. Construction Cost	7,000	15,747	25,804	15,549	64,146	27,729	17,628	11,729	4,393	2,576	7,661	4,410	8,953
a) New channel construction and river improvement work including flood embankment	5,660	11,973	21,794	12,414	55,432	19,725	14,296	8,879	2,421	2,148	5,988	2,837	7,141
b) Regulating weirs													
• Nos. of weirs	2	6	6	8	8	8	8	8	8	2	6	6	8
• Cost	700	2,569	2,728	2,318	3,357	3,213	2,389	2,075	1,637	360	1,274	1,271	1,461
c) New bridge construction													
• Nos. of bridges	5	10	11	12	14	14	14	14	10	2	8	8	9
• Cost	244	863	929	646	4,310	3,785	772	616	273	68	399	302	351
d) Syphon for Teesta Irrigation Project													
• Nos. of syphons	1	2	2	1	1	1	1	1	1	0	0	0	0
• Cost	396	342	353	171	1,047	1,006	171	159	62	0	0	0	0
2. Land acquisition cost													
a) Area (sq.km)	56.0	113.0	222.0	112.0	761.0	475.0	133.0	72.0	36.0	17.0	53.0	29.0	61.0
b) Cost	1,680	3,390	6,660	3,360	22,830	14,250	3,990	2,160	1,080	510	1,590	870	1,830
3. Physical contingency (25 % of Total of Items 1 and 2.)	2,170	4,784	8,116	4,727	21,744	10,495	5,405	3,472	1,368	772	2,313	1,320	2,696
4. Engineering service (15 % of Total of Items 1. to 3.)	1,628	3,588	6,087	3,545	16,308	7,871	4,053	2,604	1,026	579	1,735	990	2,022
Grand Total	12,478	27,509	46,667	27,181	125,028	60,345	31,076	19,965	7,867	4,437	13,299	7,590	15,501
(Equivalent million US$)	(347)	(764)	(1,296)	(755)	(3,473)	(1,676)	(863)	(555)	(219)	(123)	(369)	(211)	(431)
III. Operation and maintenance cost per annum	350	749	1,348	770	3,751	1,810	932	599	236	131	366	176	435
IV. Cost per km	252	213	260	171	709	342	176	113	45	91	130	74	130

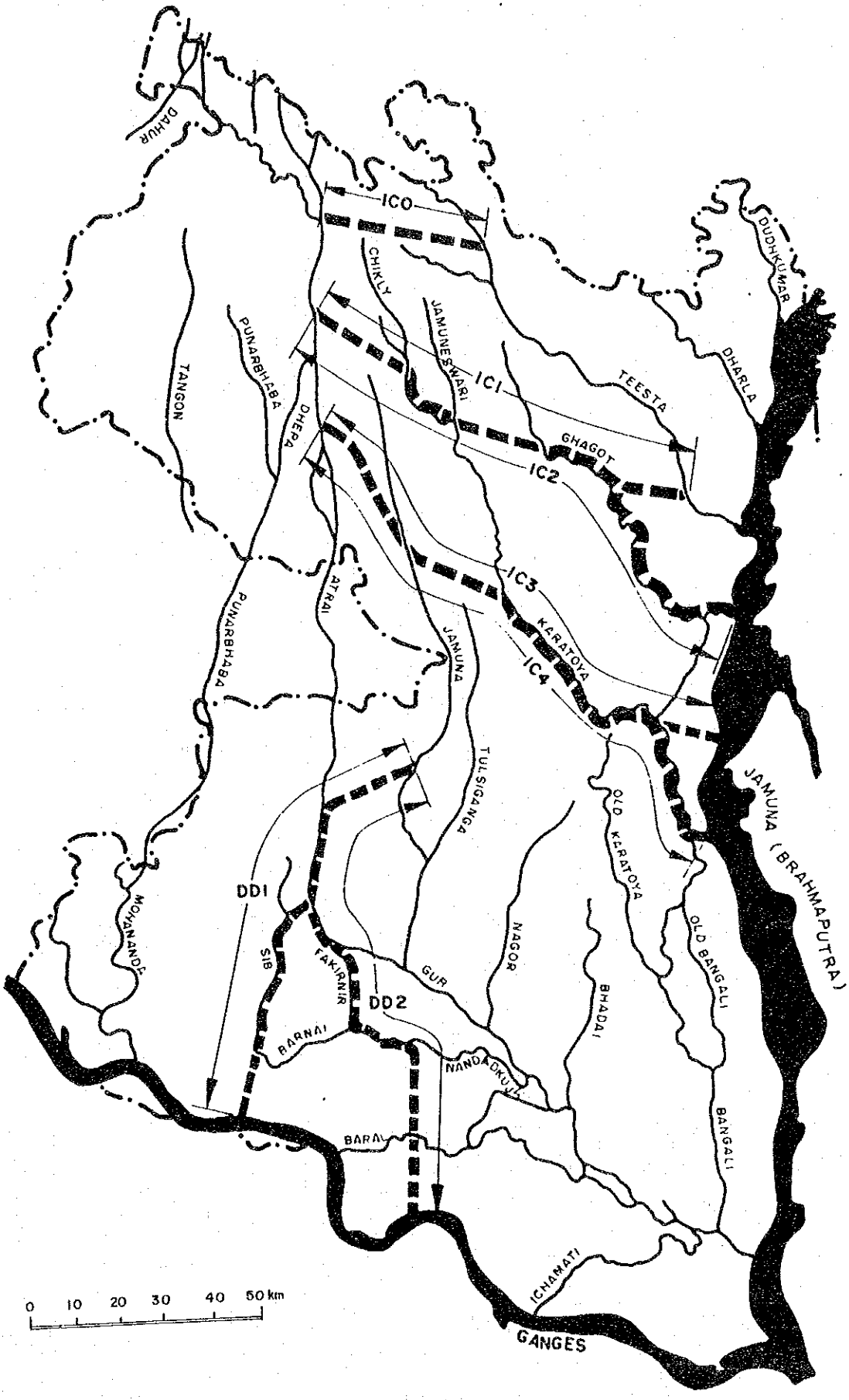


Figure 4.1 MAJOR DRAIN ALIGNMENTS

Cases	Dimensions of the Section	Design Discharge
Case 1: Compound river cross section with maximum capacity (D.F.W.L. at average ground level)	Location Distance from river mouth (km) / B0 (m) / h0 (m) / B1 (m) 0.0 to 97.25 / 70 / 5.0 / 1,300 97.25 to 120.76 / 70 / 3.5 / 825 120.76 to165.76 / 60 / 3.5 / 700 165.76 to 176.43 / 45 / 3.5 / 600	Design Discharge (m^3/s) 3,000 1,900 1,900 1,600
Case 2: Compound river cross section with maximum capacity	B0 (m) / h0 (m) / B1 (m) / h1 (m) 30 / 7.0 / 1260 / 2.0 30 / 5.5 / 800 / 2.0 25 / 5.5 / 680 / 2.0 20 / 5.5 / 570 / 2.0	
Case 3: Single river cross section with maximum capacity	B0 (m) / h0 (m) 235 / 7.0 220 / 5.5 200 / 5.5 160 / 5.5	
Case 4: Single river cross section with maximum capacity	B0 (m) / h0 (m) / h1 (m) 150 / 7.0 / 2.0 130 / 5.5 / 2.0 110 / 5.5 / 2.0 95 / 5.5 / 2.0	
Case 5: Single river cross section with lower capacity corresponding to monthly maximum mean flow	B0 (m) / h0 (m) 30 / 7.0 30 / 5.5 25 / 5.5 20 / 5.5	Design Discharge (m^3/s) 450 375 275 200

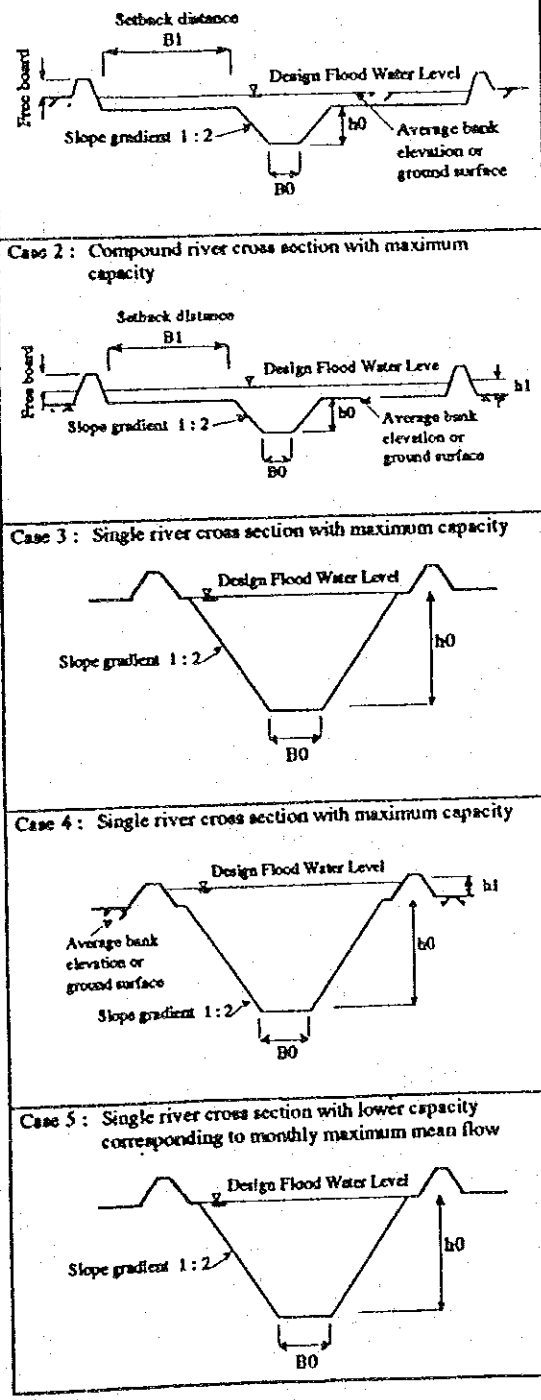


Figure 4.2 MAJOR DRAIN SECTIONS