Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Water Resource Planning Organisation

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

JURI RIVER PILOT FLOOD WARNING PROJECT EVALUATION REPORT

Final Report
April 1997

SNC ♦ LAVALIN International
Northwest Hydraulic Consultants

in association with

Engineering and Planning Consultants Ltd.
Bangladesh Engineering and Technological Services

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ACRONYMS AND ABBREVIATIONS

BDR	Bangladesh Rifles
BM	Bench Mark
BMD	Bangladesh Meteorological Department
BSF	Border Security Force (of India)
BWDB	Bangladesh Water Development Board
CO	Community Organizer
CIDA	Canadian International Development Agency
FAP	Flood Action Plan
FCD	Flood Control and Drainage
FPCO	Flood Plan Co-ordination Organization
IBB	Indo-Bangladesh Border
NERP	Northeast Regional Water Management Project
PCC	Project Coordinating Committee
PWD	Public Works Department or Public Works Datum
SSC	Secondary School Certificate
TE	Tea Estate

GLOSSARY OF TERMS

Beel	Floodplain lake which may hold water permanently or dry up during the winter season.
Bhela	Raft made from Banana stems
Boor	Bamboo raft
Haor	Depression on floodplain, located between two or more rivers, which functions as a small drainage basin
Khicuri	Hotchpotch meal
Machan	Household platform
Madrassa	Religious school
Maund	Local unit of weight measurement (one *maund* = 37.5 kg)
Parishad	Council
Samaj	Local social structure
Samiti	Cooperative society
Sari	Traditional women's dress
Thana	Smallest administrative unit; below district (formerly *upazila*)

EXECUTIVE SUMMARY

This report presents an evaluation of a pilot flash flood warning project proposed for the Juri River under the Northeast Regional Water Management Plan.

The Juri River originates in hill country in the Indian State of Tripura and flows due north into the Moulvibazar District of northeast Bangladesh. Heavy rainfall over the Indian headwaters of the catchment may result in flash floods which cause serious damage to river-side communities in Bangladesh. A pilot flash flood warning system was proposed as a means of alleviating such damage.

Work performed for the evaluation consisted of a program of field work and data analysis with two basic components:

i) a program of community surveys and interviews to characterize the population affected by flash flood in the Juri River valley, including the size and distribution of the affected population, and the population's response to floods; and,

ii) a program of hydrometric data collection and analysis which was undertaken to characterize the hydrologic response of the Juri catchment during floods, and to evaluate the technical feasibility of producing flood forecasts with sufficient accuracy and lead time to meet the needs of the affected population.

The two programs of field work were executed concurrently during the 1995 monsoon season.

The community survey program found that although the Juri valley experiences frequent severe floods, relatively few lives are lost. There is however considerable damage to property, including livestock, food stocks, household goods, homes, and infrastructure.

While flood warnings could, in principle, be useful in reducing or avoiding flood damage, the people of the Juri valley face a number of severe constraints which may prevent them from taking advantage of flood warnings. These include: fear of theft (people are extremely reluctant to leave their homes because of thievery), lack of suitable shelters or places of refuge from flood, lack of adequate transport to move the household and their goods to safe ground, and lack of suitable escape routes. In the face of these difficulties, flood warnings by themselves may be of relatively little practical value. Of much greater benefit would be a flood disaster management program, of which flood warning could form one component.

The hydrometric data program was successful in obtaining comprehensive rainfall, water level and river discharge data from the Juri River catchment in Bangladesh. Water level data were collected at four locations along the river from the Indian border to the point at which the Juri River discharges into Hakaluki *Haor*. Rainfall data were collected at a 3-hour interval, while water level data were collected at intervals varying from 1 to 12 hours depending on the gauge location. More detailed water level data were collected at a 5 minute interval during flood conditions at several of the gauge sites. As far as we are aware, these are the most detailed and comprehensive hydrologic data obtained to date on a flashy river in Bangladesh.

Analysis of the hydrometric data showed that the Juri River has a slower flood response than had been previously thought and that there is a good potential for producing flood warnings. However, data collected over the 1995 monsoon season are insufficient to establish forecast methodologies which are reliable enough for general application throughout the Juri valley. With the data available to date, the most practical means of producing flood forecasts would be a simple rate-of-rise technique applied at individual communities.

It is evident from the hydrologic analysis and the catchment physiography that the Juri River is not typical of the flashy rivers of the Northeast Region. In particular, the findings of this study cannot be applied to the much steeper and much flashier rivers which originate in the Indian State of Meghalaya to the north of the Northeast Region.

Recommendations are provided for follow-up work in three areas:

i) Development of a flood disaster management program on a trial basis at three flood prone villages along the Juri River in Bangladesh, just downstream from the Indian border.

ii) Continuation of hydrometric monitoring on the Juri River to improve the reliability of flood forecast techniques.

iii) The presence of embankments along the banks of all the rivers of the Kangsha basin will render a flood warning system ineffective on those rivers, should embankments breach. However, should the development of a flood disaster management program proceed on the Juri river and prove effective, consideration should be given to extend this program to other rivers of the basin.

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1. INTRODUCTION

1.1 Background

Development of improved flood warnings for the flash-flood prone rivers of the Northeast Region was proposed as an initiative by the Northeast Regional Project (NERP) in the Northeast Regional Water Management Plan. The stated purpose of the Improved Flood Warning Project was to "provide timely, readily understood, warnings to villagers in flash flood-prone areas of the Northeast Region of flash floods imminent in their locality and posing danger to them, and to promote their appropriate response to the warnings".

A pre-feasibility study of improved flood warning was subsequently funded by CIDA. That work, described in the September 1994 "Improved Flood Warning Concept Paper"[1] (hereinafter referred to as the "Concept Paper"), assessed the regional impacts of flash floods at a reconnaissance level, identified the Juri River as a suitable site for a pilot flood warning project, and provided conceptual level design of a possible flood warning scheme on the Juri.

The work described in this report provides a further, more detailed evaluation of a pilot flood warning project on the Juri River, emphasizing both the sociological and hydrologic aspects of the proposed scheme. More detailed background information on the evolution of the project is provided in the Concept Paper, to which the interested reader is referred.

1.2 Study Objectives and Terms of Reference

The stated objectives of the current study were:

1. to develop and evaluate a technique or techniques for providing timely, readily understood flood warnings to villagers in flash flood prone areas, and

2. to promote their appropriate response to such warnings.

Development and evaluation of the warning technique was to be based on a pilot project on the Juri River.

The study terms of reference, as modified in March 1995, incorporated the following work activities:

1. Prepare a detailed methodology for evaluation of the (warning) system and develop criteria for assessing its success.

2. Select suitably pre-qualified candidate observer/technologists for training in rainfall observation.

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[1]Northeast Regional Water Management Project (FAP 6), September 1994, "Improved Flood Warning Concept Paper"

3. Establish an observation post on suitably elevated ground and carry out visual observation of storms producing rainfall on the Juri River catchment.

4. Establish a staff gauge on the Juri River close to the international border and monitor water levels in the Juri River through the pre-monsoon and early monsoon season to July 1995.

5. Inform the local community about the rainfall observations through project community organizers. The need for the initiative should be reviewed, and the basic operation of the proposed warning system explained to the local community.

6. Assess the reliability and effectiveness of the rainfall observers.

7. Prepare the Evaluation Report including the criteria for success and the conditions constraining success. Reference to the Flood Management Model shall be made.

In the course of the study, it became apparent that there were significant social constraints which would prevent the potential benefits of a flood warning system from being fully realized in practice. The direction of the project was thus modified to a certain extent to place more emphasis on the sociological aspects of the study, including developing a better understanding of the community's response to flooding and the particular problems faced by women.

1.3 Methodology

The objectives of the study described in this report were met through a program of original field data collection and analysis. The field data collection involved two basic components which were executed concurrently during the monsoon season of 1995. These were:

i) a program of community surveys and interviews to characterize the population affected by flood in the Juri River valley, including the size and distribution of the affected population, and the population's response to floods; and

ii) a program of hydrometric data collection which was undertaken to characterize the hydrologic response of the Juri catchment during floods, and to evaluate the technical feasibility of producing flood forecasts with sufficient accuracy and lead time to meet the needs of the affected population.

The detailed methodology is described in the main body of the report.

1.4 Organization of the Report

The report is organized into 7 chapters as follows:

Chapter 1 provides a brief description of the background of the study, its relationship to previous studies and the study objectives and terms of reference.

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Chapter 2 describes the physical setting of the pilot project, i.e. the Juri River catchment, including brief reviews of the location, physiography, climate, and flood characteristics of the study area.

Chapter 3 describes the methodology and findings of the community survey program performed to characterize the population affected by floods in the Juri River valley. The chapter describes the size and distribution of the affected population and analyses the population's response to flood.

Chapter 4 describes the program of hydrometric data collection which was implemented to obtain the information necessary to characterize the hydrologic response of the Juri catchment and to evaluate the technical feasibility of forecasting floods.

Chapter 5 discusses flood warning and flood forecasting concepts, summarizes the community need for flood warnings, and evaluates the potential for producing flood forecasts and warnings on the Juri River.

Chapter 6 outlines the requirements for a broader flood disaster management program in the Juri valley, and,

Chapter 7 presents conclusion and recommendations arising from the evaluation.

1.5 Terminology

Several organizations are involved in the study or production of flood forecasts and flood warnings in Bangladesh. Where possible, this report attempts to use commonly accepted terminology.

As is recommended elsewhere[2] this report attempts to make a clear distinction between **flood forecasts** and **flood warnings**.

A **flood forecast** is a prediction, usually made by technical staff, of the future occurrence of a flood. The forecast may or may not include a quantitative estimate of the time of occurrence or magnitude of the flood.

A **flood warning** is a message, based on flood forecast information, which is broadcast or otherwise disseminated to the public to advise them of the possibility of flooding.

The **danger level** of a river is defined as the level above which a flood will likely cause damage to crops or homesteads. The danger level is defined at a specific location for a specific damage centre which lies in the immediate vicinity.

A **damage centre** is the geographic area at risk from flooding when the danger level is exceeded at a specific point. Damage centres would usually be defined for specific concentrations of population, such as a township.

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[2]Expansion of Flood Forecasting and Warning Services (FAP-10), March 1995, "Development and Improvement of Forecast Outputs, Public and User Awareness and Dissemination".

Warning lead time is defined for a specific damage centre and is the estimated time between the broadcast of a warning to the public and the time at which the danger level will be exceeded at the damage centre.

Forecast lead time is defined for a specific damage centre and is the estimated time between the production of a flood forecast and the time at which the danger level will be exceeded at the damage centre.

2. PHYSICAL CHARACTERISTICS OF THE JURI RIVER AND ITS CATCHMENT

2.1 Location

The Juri River originates in hill country in the northern part of the Indian State of Tripura, flows due north, crossing the Indo-Bangladesh border (IBB) into Kulaura *Thana*, Moulvibazar District in northeastern Bangladesh, and ultimately discharges into Hakaluki *haor* about 45 km east of the town of Moulvibazar. The Juri River catchment is approximately 54 km in length and about 22 km wide at its widest point. It is bounded on the west and southwest by the Manu River catchment and on the east and northeast by the Sonai-Bardal River catchment. The total catchment area is approximately 790 sq km, of which about 560 sq km falls in India. A location map of the catchment is provided in Figure 2.1, and a more detailed catchment map in Figure 2.2.

2.2 Physiography

Bangladesh is almost entirely an alluvial deltaic plain with the exception of some hilly areas in the north, northeast and southeast. Within the alluvial plain, there are slightly elevated areas of older alluvium referred to as terrace areas, as in the Madhupur tract immediately west of the Northeast region.

The hilly areas of the southeast consist of a series of parallel north-south trending synclinal valleys and anticlinal ridges. These ridges sweep northward from the Chittagong area through the Indian State of Tripura and dip to the Sylhet plains. The Juri River flows through one of these synclinal valleys, with the catchment bounded by anticlinal ridges on the east and west. The ridges are composed mostly of heavily eroded sandstones, but with isolated outcrops of dense conglomerate, and generally range in height from about 60 m to 300 m. For the most part, they are covered with thick bamboo forests and tea gardens. Overall elevations range from a maximum of about 500 m in the extreme south eastern corner of the catchment to about 10 m above sea level near the outlet of the catchment at the township of Juri.

For much of its length, the Juri River valley forms a broad, flat flood plain from 2 to 3 km wide. In several locations, however, spurs of low hills extend from the east or west ridge-lines into the flood plain, constraining the path of the river and greatly constricting the flood plain width. The upper Juri valley in India is shown on available topographic maps as being especially flat with many depressions and extensive areas of flat, marshy ground or wetlands through which the Juri River and its tributaries flow.

2.3 The River System

The Juri River (Figure 2.2) rises in the extreme southeast corner of the Juri catchment at an elevation of about 300 m. The river flows northwest and then north for a distance of about 45 kilometres through the Indian State of Tripura to reach the Indo-Bangladesh border just upstream from the Bangladeshi village of Purba Botali. The principal tributaries to the river in India are the Ragna Chara, Kakian Chara, Hakai Nadi, Kakri Chara, Pratyekray Chara and Ichai Chara. As will be noted in Figure 2.2, the international border actually follows the Ragna Chara to the west of Purba Botali. The catchment area at Purba Botali is about 420 sq km lying almost entirely within India.

From Purba Botali, the river continues to flow due north and for the next 15 km forms the boundary between India and Bangladesh. The river enters Bangladesh completely just upstream from the Bangladeshi village of Selua where it is joined by its single largest tributary, the Thal Gang. From Purba Botali to Selua, the right bank (the Indian bank) of the river is bounded by hills and a high flood embankment.

At Selua, the Juri River fully enters Bangladesh and follows a more meandering course north and west through a broad, flat floodplain to the township of Juri. At Shilghat about 15 km downstream of Selua and 2 km upstream from Juri railway bridge, the Juri River splits. The main stem Juri River flows almost due north into Hakaluki *Haor*, while its distributary and major branch, the Continala, continues in a generally northwesterly direction also discharging into Hakaluki *Haor*. Running through the *haor* the two branches rejoin and ultimately meet the Kushiyara River at Fenchuganj.

During the monsoon season, the lower reaches of the Juri River, below the township of Juri, are completely inundated as water levels in Hakaluki *Haor* rise. High water levels in the *haor* impose backwater effects on the Juri which are felt to a point several kilometres upstream from Shilghat.

From Purba Botali to the township of Juri, the river drops approximately 9 m over a distance of about 30 km. An approximate longitudinal profile for the Juri River from Hakaluki *Haor* upstream to Purba Botali is shown in Figure 2.3.

2.4 Climate and Weather

Like all parts of the Northeast Region, the Juri River catchment has a typical tropical monsoon climate. From December to March, air flows from the northeast over the catchment. This flow (the Northeast Monsoon) brings cold dry air from China. Rainfall during the period is low and generally makes up only about 5 percent of the annual total.

From June to September air flows from the southwest. This flow (the Southwest Monsoon) brings moist air from the Bay of Bengal and results in heavy rainfall over the Juri catchment and the Northeast Region in general. About 65 percent of the annual rainfall occurs during the Southwest Monsoon.

Airflow reversals occur twice annually. The first reversal happens in spring (April/May) when the airflow changes direction from northeast to southwest via the northwest. Severe weather conditions ("nor-westers") with squally winds, thunder storms, hail storms, and heavy localised rainfall, may occur over the catchment. In the second reversal, in autumn (October/November), the airflow changes direction from the southwest to the northeast via the southeast.

Very severe weather conditions, in the form of cyclones originating in the Bay of Bengal, may occur during either the spring or autumn reversals. Severe cyclone damage is generally restricted to the coastal areas of the Bay of Bengal. However, as cyclones move inland, degenerating into tropical depressions, they can bring significant rainfall and serious flooding to the Northeast

Region, as happened in April 1991 when the Tripura border area of the Northeast Region experienced its worst flooding in recent memory.

The Northeast Region has the highest annual rainfall in Bangladesh. Available isohyetal maps show that the mean annual rainfall over the Juri catchment ranges from about 3200 mm in the northern-most part of the catchment in Bangladesh, to about 2600 mm in the catchment headwaters in the Indian State of Tripura. The mean annual rainfall for the catchment as a whole is about 2900 mm.

No information is available on short-term rainfall extremes in the Juri catchment. However analysis of rainfall data from the nearest BWDB rainfall gage, at Dakshinbagh about 15 km north of Juri, gives the 2-year annual maximum 1-day rainfall as about 150 mm, and the 10-year annual maximum 1-day rainfall as about 220 mm.

During the Northeast Monsoon, most days are sunny and dry with temperatures ranging from the average annual minimum in December/January of about 6°C to the average annual maximum in April/May of about 36°C. During the Southwest Monsoon the days are mostly cloudy and rainy with intermediate and stable temperature.

2.5 Flood Characteristics

The Juri River is classified in Bangladesh as a "flashy river". The headwaters of the flashy rivers of the Northeast Region all lie in hill country in India where channel slopes are comparatively steep. Heavy rainfall over the Indian headwaters (conditions which probably also extend into Bangladesh) may result in severe floods with a rapid rise in water levels as the flood wave moves downstream and crosses the Indo-Bangladesh border into Bangladesh. The flashy rivers of the region can be conveniently put into one of two categories: those originating in Meghalaya to the north of the Northeast Region, and those originating in Tripura to the south of the Northeast Region.

The flashy rivers originating in Meghalaya generally have extremely steep channel slopes (typically about 40 m/km in India) and are believed to have an extremely rapid (flashy) hydrologic response, with flood hydrographs rising from base flow to peak in as little as 2 to 4 hours. It is likely that hydraulic bores occur on many of the flashy rivers originating in Meghalaya. Anecdotal reports of bores on these rivers are mentioned in the Concept Paper and NERP project staff observed a bore at Durgapur on the Someswari River in June 1995.

The flashy rivers originating in Tripura have much lower channel slopes than the Meghalaya rivers. The Juri River between the township of Juri and Purba Botali, for example, has an average slope of about 0.3 m/km (Figure 2.03) and continues into India for a distance of about ten kilometres upstream from the border at a comparable slope. As a result, the Juri, and other flashy rivers originating in Tripura, have a correspondingly slower hydrologic response to heavy rainfall. As will be discussed later in this report, a typical flood hydrograph on the Juri River at Purba Botali appears to rise from base flow to peak over a period of from about 24 to 36 hours. Although much slower in response than the Meghalaya Rivers, the Juri is still "flashy" when compared to the slow rise and fall of the major rivers of Bangladesh.

Flooding is almost an annual phenomenon on the Juri River. Floods may occur in both the monsoon and pre-monsoon seasons. Flooding may also occur several times in one flood season, as in 1993 when the catchment experienced 3 flash floods. Local inhabitants report that in recent years the most serious flooding occurred in 1984, 1991, and 1993.

The only readily available historic hydrologic data from the Juri catchment are water level data collected by the BWDB on the Continala distributary in the township of Juri. Review of historic information from this site for floods in 1993 shows that water levels at Juri rose in response to flood over a period of several days. It is apparent however that water levels in Juri and rates of rise of water level are both heavily influenced by downstream water levels in Hakaluki *Haor*. At the outset of this study, no information at all was available on the catchment's response to floods upstream of the area affected by backwater from Hakaluki *Haor*.

The program of data collection instituted to more adequately characterize floods in the Juri catchment together with the evaluation of these data is described in Chapter 4.

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3. SOCIAL ASPECTS

3.1 Introduction

For many of the people who live in the Juri River valley, 1984 was, in a sense, the "first" flood year. Some reports cite 1977 as important and a few older residents mention a highly significant flood that occurred about 1930. Local folklore holds that many lives were lost in this event. But for most people in the Juri River valley, whatever awareness they have about local flood hazards was acquired in the 1984 and 1993 floods. It seems that the two decades or so before the mid-eighties were a period of unusually low rainfall and little or no flooding was experienced in the valley.

It may also be the case that some flood control and drainage structures were built on the Indian side of the border in the early 1980s. There is a perception that the severity of the flood in 1984 was exaggerated by the operation of an FCD project. Some field reports suggest that warnings of the imminent flood originated from a watch-tower associated with the drainage structure of an Indian FCD project. Whatever the truth of these reports, 1984 seems to have been the year that changed local people's perceptions about flood hazard in the valley.

Because their experience of flooding started with a severe event and because people were more or less unprepared for it; it had a significant effect on people's awareness of how much of a hazard an unexpected flood can constitute.

The present chapter describes the population in the Juri River valley that is impacted by the flood and their response to it. It includes material on how people evaluate floods, how they prepare for them, what men and women do when floods come, problems they experience in responding to the floods and their suggestions about how the problems they associate with floods could be reduced. The methods that were employed to develop the social science perspective are described in Annex C.

3.2 Infrastructure and Economy of the Juri River Valley

Historically Juri was known as a place rich in forests, tea plantations, bamboo and fruit. Migrants were attracted to the area by the presence of tea plantations which held the promise of employment. During the British Raj, people came from as far away as Orissa to seek employment here. In more recent times people from the crowded districts of Comilla, Dhaka and Mymensingh have moved into the area and occupied the low-lying farmland along the river, especially north of the road and railway that serves Juri. There is some hostility between people who consider themselves as original to the area and more recent arrivals; even so during flood times there is a signal amount of cooperation and mutual help which even extends at times of severe floods to India.

Probably because of the tea plantations, Juri is served by a railroad spur with daily trains to Moulvibazar. It also has a metalled road with comprehensive bus services to other parts of Bangladesh. Road access is available right down the valley almost to the confluence of the Juri and the Ragna Chara, both of which form the border with India at this point.

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Table 3.1 Distribution of Villages by Zones of Flood Hazard

Zone	Flood Hazard		
	High	Moderate	Low or None
A	Purba Botali, Paschim Botali, Biraintail, Konagaon, South Sagarnal, North Sagarnal, Purba Baradhar, Babusinghgaon, Baroitali, Mointrigaon Jogi Mora.		
B	Paschim Selua, Kapnapahar T.E., Kashinagar, Suhagirpar, Horirumpur, Mointoil, Gouripur, Bhugtera, Bishnath, Bhabaniur (West, South, North and East), Bhabaniganj Bazar, Kaminiganj Bazar.	Purba Selua, Ratna T.E., Madarpur, Batnigat, Pathila Sangan, Magura, Goal Bari, Daha Para, Eraligul, Selua T.E., Tati Para.	Jalalpur, Puti Sara, Durbin Tila, Babu Tila, Dhamai T.E., Amuli Bosthi, Kali Tila, Shil Ghat, Dakstin Tila, Muroli Tila, Chatera [Others]
C	Fultala Basthi, South Baradhar, North Baradhar, Jangalia Baruakandi.	Fultala Bazar, Fultala T.E., Sagarnal T. E., Chungabari, Rahimpur Tholai *Haor*.	Albin Tila T.E., Rajki T.E., Nurpur, Matinpur, Alipur etc.
D	Kalinagar, Hamidpur Jaifar Nagar.	Hasnabad, Bahadurpur, Bhuai and Nurpur	Champak Lata, Chatera
E	Jahangirai, Belagaon, Sonapur, Basirpur, Gobindrapur Gorergaon.	Noyagram, Simul Tala, Yousuf Nagar, Taltala, Khagteka, Nizkalnigor, Kalnigor, Amtoil, Shahapur, Rajapur, Dhigol Bar, Kankorchok, Nischintrapur, Monohorpur, Proladpur, Hekimpur.	Part of Amtail and Basirpur villages.
F		Chota Dhamai, Bara Dhamai, Paschim Bara Dhamai, Kuchai T.E., Bel Bari, Lati Tila, Doma Bari, Kachur Gul, Elapur.	Tagia Ura, Purba Goal Bari, Mali Para, Suna Rupa T.E., Durgapur, Gobindrapur, Binothpur, Jamkanthi, Uttar Faga Sara, Dakhin Faga Sara and Atiakandi, Sukna Sara, Haya Sara, Lati Sara, Rupa Sara, Lal Sara, Zari Sara, Uttar Kuchai Thol, Kuchai Thaol, Dhakkin Kuchai Thol, Nala Pungi, Thil khucha T.E.

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Tea still plays a significant role in local employment practices and tea plantation workers constitute one of the more vulnerable of the flood-prone populations. Nowadays the principal occupation of the valley is farming. Some people also work in forestry and fishing. Richer people have moved into trade. The proximity of the Indian border also provides an opportunity for smuggling. In the time available we did not make any attempt to work out a sophisticated typology of occupations and living space. In a crude way, it can be said that poorer people live nearer the river and on the lower and more vulnerable land. Richer people have either built up their households or occupy the higher land. Tea plantation workers who are almost always women are conspicuous among the poorest settlements in the most flood prone areas.

Table 3.2 Literacy Rates in Juri River Valley Unions

Union	Literacy (%)	
	Male	Female
Fultala	23	9
Sagarnal	24	9
Goalbari	20	7
Jaifarnagar	21	8
Paschim Juri	31	15
Purba Juri	21	5
Total	23	9

3.3 Affected Population and Flood Zoning.

Approximately 100,000 people can be affected by flooding in the valley. The way in which flood hazard has been classified is described below. As in most areas of Bangladesh, there are marginally more men than women. A little more than half—58 percent—of the population is Moslem and about 40 percent Hindu. There is a small minority of tribals and others. Settlements are listed in Table 3.1. The population is largely uneducated with literacy rates below the national average. Literacy figures are presented in Table 3.2.

Flood Classifications

Flood hazard is classified as "high" or "moderate." Areas of high hazard are marked by more or less rapid onset combined with high sustained flood levels and the absence of easily accessible shelter. There is credible risk of danger to life in high hazard areas although loss of life has not been a substantial feature of Juri River valley flooding. Moderate hazard areas are higher in elevation and have more access to higher ground. In general, no loss of life occurs in moderate hazard areas although there is loss of property.

Flood Hazard Areas

Table 3.3 shows how the population is distributed with respect to the flood zones and flood hazards. Among the flood zones that have been identified for the valley three areas account for about 60 percent of the total and almost all of the high flood hazard. These are Zone A on the low-lying left bank of the river where it forms the border with India, Zone B on both sides of the river after it turns into Bangladesh, and Zone E which is an area downstream of Juri mostly on the north side of the road and railway that connect Juri to Moulvibazar. The reason that only one side is affected in the upper reach is that, besides being in India, the right bank of the river is strongly embanked. This makes flooding on the Bangladesh side more serious than it would otherwise be.

An attempt has been made to classify flood hazard on two dimensions: location and level or seriousness of the hazard. The resulting zones are shown on Figure 3.1. They are based on a common-sense topographic classification as follows.

Table 3.3: Flood-affected population by zones.

Zone	Affected Population*		
	High Flood Hazard	Moderate Flood Hazard	Total
A	9,900 (100%)		9,900
B	12,200 (83%)	2,400 (17%)	14,600
C	2,200 (55%)	1800 (45%)	4,000
D	3000 (50%)	3,000 (50%)	6,000
E	10,500 (55%)	8,500 (45%)	19,000
F		1,000 (100%)	1,000
Total	37,800 (70%)	16,700 (30%)	54,500

* Population figures are taken from 1991 *Union Parishad* data. Figures in parentheses are the percentage of the population affected by level of flooding in the zone. Percentages were estimated in consultation with affected villagers. Numbers have been rounded.

Zone A is a very high risk low-lying area on the left bank of the river, more or less between the river and the road. It contains the eleven villages shown in the table that lie between Purba Botali and Jogi Mora where the river turns left into Bangladesh. The villages are listed in Table 3.1.

Along this reach, the river forms the border with India. Where it enters Bangladesh it is joined by a minor stream called the "Ragna Chara" which also forms a border with India. Floodwater coming across the border from India affects the villages of Zone A first. There are almost no high lands or hilly areas in Zone A. Almost ten thousand people live in the eleven villages.

Zone B is an equally low-lying area further downstream. It is situated on both sides of the river and between the river and the higher ground between Purba Selua and Juri township. Because it is further downstream, it receives more notice of the onset of flood hazards although a local stream called "Thal" flows across Lati Tila and joins the Juri near Selua. This small river augments the flow of the Juri and contributes to flooding in this zone.

The highest risk part of Zone B contains thirteen villages and is about equally vulnerable to high levels of sustained flooding as is Zone A. Another ten villages are considered to be at moderate risk. Most Zone B people go to the nearby hilly areas which are reasonably accessible for shelter. Some people in Juri township use the railway and road embankments.

Zone C is more or less the area to the west of the access road that runs down the valley. It is marked by rising ground with many more hillocks and other shelter potentials. It constitutes the refuge for persons living in Zone A. Nevertheless there are five villages containing about 2,200 people in this zone which are identified as having high hazard. Another six housing about 1,800 people are seen as having moderate hazard.

Zone D is a flat area on the south side of the road and railway embankments. It contains three villages or about three thousand people that are considered to have a high hazard rating. Ten more villages are classified moderate hazard. The total population of Zone D is about nine thousand. Zone D is flood-prone because the road and railway embankments constitute a constraint on floodwater flow to the north. This area is also affected by the Pabijuri River.

Zone E is an area downstream of the road and railway embankments. It contains 22 villages with a population of about nineteen thousand people. Most of the people of this zone are said to be migrants from Comilla, Dhaka, Mymensingh and other points south. Six of the villages are classified as high hazard. Flooding here is controlled by water levels in Hakaluki *Haor*. Flooding occurs at much lower flow rates when the *haor* is high than when it is low. There are no high lands or hill areas in Zone-E except Amtoil and Basirpur. During floods, people from Zone-E take shelter on the railway and highway embankments.

Zone F contains eight villages of moderate flood hazard with about twelve hundred people. It is generally outside the area that is vulnerable to flash floods. It can be affected by sustained high water levels. It is marked by hills and hillocks where people can take shelter during very high river stages. Much of the area is, in fact, quite impervious to floods because of the hills.

3.4 People's Reports of Floods: Historical & Contemporary Accounts from the Juri River Valley

The social inquiry into floods in the Juri River valley had two separate goals. First of all, we were interested in how people view and respond to the flood problems: we wanted to map our knowledge of the hydrology onto people's experience of the floods. Secondly our knowledge of the hydrology was partial. We were interested in learning how the flood we had observed in the 1995 monsoon season compared with past floods.

People reported that flooding had occurred on the Juri River in recent years in 1977, 1984, 1985, 1986, 1987, 1989, 1990, 1991, 1993, and 1995 although many people were a bit confused about the actual dates. In some years, several serious floods were reported to have occurred. For example in 1993 there were three. Overall, opinions varied about the relative severity of various years. People tended to remember the years in which they were personally affected as more serious. There seemed, however, to be wide agreement that the 1984 and 1993 floods were the most severe of all of those that had occurred in the past 13 years. The flood of 1993 is clearly remembered for the widespread damage and suffering that occurred.

As was mentioned in the introduction, at least one very serious flood appears to have occurred in the valley earlier in the century. Older people speak of an event that occurred about the Bengali year 1336 (1930). Knowledge of this is sketchy. It is mythologized in songs and dialogues that remember the pain of losses. People are said to have had to resort to climbing trees to save themselves. Many women and children could not save themselves. Many lives and much livestock and other property were reported to have been lost. There were suggestions that it was caused by the collapse of an embankment in Monipur in India.

In the period since then, especially during the sixties and seventies, the floods in the Juri River valley were relatively mild. Although it may not have been the first of the more recent floods, the flood of May 1984 took people unaware. One account reports that it "rushed suddenly after about 10 years." As a result people, unused to severe floods, were, as our anthropologist reports "caught by wrong foot." Many villagers remember this as the worst flood. Since about 1984 there seems to have been some degree of flooding in the valley almost every year, sometimes two or three times in the year.

In the section that follows we have assembled a number of observations and personal stories from the two previous floods that people report as notable. These are the 1984 flood and the 1993 flood. Following this we have presented material from what amounts to an "eye-witness" account of the 1995 flood. Wherever possible, comparisons are made among the floods.

3.4.1 The 1984 Flood

In May 1984, before the flood started, it rained continuously for two days. More than 44 inches of rainfall was recorded at the Kapnapahar Tea Estate for the month. On May 15, the Indian authorities started making announcements by megaphone advising people that a flood was coming. The people in Zone A on the Bangladesh side also heard the announcement. They had, however, little or no experience of floods and did not take any special precautions.

Reports about the rate of rise of the water at Purba Botali vary substantially. Some reports make it sound as though it took quite a long time–about nine hours: 4 pm to 1 am the next morning–to rise to the level of the homesteads. Other people remember it as comparatively rapid. These people say that two hours after the waters overtopped the bank of the river it had risen an additional two or three feet to the courtyards of the houses. People, they say, started to make banana rafts which usually take about two hours to make; in the time that it took to make the rafts the water rose another three feet. It is not possible to completely resolve the conflicting perspectives. They might be accounted for by the fact that the people who reported longer times were situated at higher elevations; it may be that the numbers are no more than symbolic. There is the possibility that some short time reports are related to embankment failures. Certainly the situation was made worse (and perhaps the evaluation of time more confused) by the fact that not only was the flood a new experience but it occurred at night.

Everybody in the village tried to move to higher ground. Some people even took shelter in India. The situation seems to have been the same throughout Zone A. For example, people in Konagaon and Sagarnal talk of water rising to the level of the household platforms within three hours. Here too after another three hours, houses were said to be under four feet of water.

In Zone B the process was slower and, of course, people had slightly more warning. Water rose, however, to high levels in the houses. In places it reached five feet above the floor. The embankments that contain the river through Zone B were breached and water flowed into the fields damaging the standing crops. By good fortune not very many lives were lost but a lot of livestock, food and dwellings were damaged and the road system was heavily damaged. Some personal accounts follow.

Md. Habibur Rahman is a teacher in Purba Botali. He is 48 years old. There are nine people in his household. He says that, during his life, he has experienced several flash floods. He thinks that the severest occurred in 1984. Water in the Juri River, he said, swelled at 4 pm after almost 36 hours of rain. Nine hours later his house was under water. It was eventually covered to a depth of six feet.

His wife and children were rescued by a boat that came from Sagarnal. Boats were scarce and he remarked that he had no idea who the owner was suggesting the chaos of the evacuation and the mobilization of even anonymous community resources. The boat took them to safety and they took shelter in a relative's house on a hill in Paschim Botali.

Despite the seriousness of the situation, Habib seems to have been able to save his livestock. He said that he moved the cows and goats to a kinsman's homestead. Habib himself stayed at his house to protect it from theft. He said that the Indian Boarder Security Force provided boats and helped people from Purba Botali.

Jahur Ali, who is 71, repeats the story about the lengthy rise of the water from 4 pm to sometime in the middle of the night. The exact coincidence of the figures, however, weakens the account. Jahur said that their homestead was flooded "at 1 am" and they took shelter on a cot. They left their house the next day by a boat from Biraintail further downstream. They lived in his sister's house for three days. Jahur's sister was only able to give them one meal and he had to borrow money from a money-lender to maintain the family.

Part of their property was damaged by the flood. The children of the household suffered from fever. They were able to save their cows by moving them to high ground but they lost eight goats. The household chickens sheltered on the roof but Jahur said they lost 60 *maunds* (a little over 2,200 kg[3]) of sweet potatoes and some pumpkins.

3.4.2 The 1993 Flood

Although not everyone records it as such, in gross terms the 1993 flood appears to have been easily the most serious event that has occurred in the valley. It caused more damage and more loss of life than any of the other floods people discuss.

Although the descriptions of events are cast in slightly different terms, reports of the rise of the 1993 flood are consistent with the reports of the 1984 flood; they suggest a rapid rise of the water. Reports from Purba Botali, for example, describe the water as rising roughly four feet in four hours. At Konagaon and Sagarnal the reports suggest a similar condition. Here the water took four or five hours to rise the two feet above the house plinth the point that most people consider critical.

Since 1984, some of the wealthier people had raised their houses and some shelter was available that had not been available before. People said that property damage was less than it had been in 1984 and attributed this to the fact that people had the experience of the previous flood. Nevertheless loss of life was much greater. Houses near the river bank that had not been improved were sometimes inundated very fast. Maitun Nesa who is 60 years old and lives in Selua at the upstream end of Zone B said that the water entered his house within fifteen minutes of it overtopping the bank although this was probably caused by the collapse of an embankment.

Further downstream the water rise seems to have been just as dramatic. Pakhi Miah, who was born in 1945 and has experienced all the floods discussed in this report was at the bazaar in Juri getting his paddy husked when the flood arrived. He was taken completely unaware. As he put it, "the water sped into in a sunny day." He was astonished to find so much water without rain.

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[3] One maund is equivalent to 37.4 Kg.

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Pakhi Miah lives in Bhabanipur, a village in Zone B not far from Juri township, with his daughter and five sons. He piled 100 *maunds* of paddy in a boat; got help from twelve labourers and headed home. Although the bazaar is only 1 kilometre away from his homestead, he could not make it because of the velocity of the water. And even with the help of twelve labourers he could not save his paddy. The boat seems to have capsized and he lost the entire 100 *maunds*. Pakhi himself had to find a banana tree and make his way to his home which he reached six hours later.

When he got home he sent the women and children of his household to his maternal uncle's house in Bajir Tila. He and his younger brother returned to the house later in the evening and stayed there to guard against theft. They had no food except a few raw eggs and they were very hungry. He purchased a boat and went again to Juri Bazaar next day to replenish his paddy supply.

Hasna Begum is 25. She lives in her father's house in Purba Botali along with her family of nine. The worst flood she remembers occurred in 1993. Her house was flooded and because of the high velocity of the floodwater flow they were unable to save their livestock and other goods. They had a bamboo raft but three people could not move it against the current. The house was destroyed and they had to rebuild it after the water had receded.

Ariza Begum, who is 28, lives in Sagarnal in Zone A with her husband Modhalib. They have three daughters. A fourth child was born during the 1993 flood but died of exposure. She said that the floor of their house was flooded to a depth of three feet in one hour (presumably of the water arriving at the house). Once again this can only be explained by an embankment being breached. She and her family left the house on foot at 9 pm. They reached the shelter at Fultala Bazar "with much trouble."

3.4.3 The 1995 Flood

Almost 30,000 people were affected by flood water in 1995. However, relative to the flood of July 1993, losses were comparatively low. Only one death, of a six year old boy from Sagarnal in Zone C, could be directly related to the flooding. He fell from the raised bamboo platform in his home and drowned. One infant died within hours of birth.

Losses of livestock were relatively small. This was attributed by local villagers to the fact that most livestock had been moved to high ground before escape routes became submerged. About 20 percent of food stocks and household belongings were damaged by flooding. There were also fairly substantial losses to standing crops, homestead gardens, vegetable gardens, and tank fish.

In addition to personal losses, there were losses to local infrastructure. Embankments were breached at several places, roads were eroded, and culverts and bamboo bridges were washed out. Two buildings in Juri township, just upstream of the road bridge at the bifurcation of the Juri River and the Continala branch, collapsed due to erosion. The Juri River also eroded its left bank and cut the road from Juri to Fultala. By May 19 parts of the Juri to Moulvibazar road were under water. Several bamboo rafts were washed away by flood water from Juri township into Hakaluki *Haor*. Road communication from Juri to Fultala and Juri to Selua was cut for a week, causing disruption in the transport of tea and timber.

According to the villagers at Purba Botali on the Bangladesh border, the June 1995 flood was on a smaller scale than the flood of 1993. Reports say that it took between eight and ten hours for the rise that had taken only four hours in 1993.

The story in Konagaon and Sagarnal was the same. It took eight to 10 hours for water to rise above the house floors. Some damage to property occurred and some household platforms were damaged. People were prepared and not much property was lost although the standing crops were damaged. People had made more improvements to their homesteads and by now are more attentive to what needs to be done in a flood.

The NERP anthropologist monitored two flood events, one in May and the second in June. The June event was the more serious of the two although it was smaller than the 1993 flood.

Flooding in May
During the period Wednesday May 17 through Friday May 19 there was a minor flood event. At the observation post at Chungabari 163 mm of rainfall was recorded between 6 pm on Tuesday May 16 and 6 pm on Wednesday May 17. The river started rising at Purba Botali at midnight on Tuesday night. It continued to rise for a little more than a day. At Selua it rose for nearly two days and at Shilghat adjacent to Juri town for more than two days.

The river was close to bank full but in most areas the flow was contained within the river channel. Hakaluki *Haor* was almost empty and there was little or no backwater effect. No homesteads were submerged and even though the *beels* upstream of Juri township were flooded, people said that livestock, food-stocks and homestead-garden produce are not vulnerable to this type of minor flooding; no evacuation was undertaken. People did, however, watch the weather and the river flow carefully.

Flooding in June
Abdur Rob, the Secretary of Sagarnal, *Union Parishad* said that it rained continuously for 36 hours before the June flooding started. Water from India came slowly and inundation was correspondingly slow. Villagers say it usually takes between 15 and 30 hours to affect the Juri area. People speculated that the flooding was less severe because the rain stopped early in the flood process and India did not have to release water from storage although the existence of this storage is itself speculative. People do think, however, that whenever water becomes surplus and harmful for India the excess is dumped into Bangladesh.

The flood of June 16 through 21 occurred following about 30 hours of heavy rainfall on June 16 and 17. During that 30-hour period, Purba Botali recorded 212 mm of rainfall. At about noon on the 16th the river started to rise at Purba Botali. It did not reach flood level (19.3 PWD) until a whole day later: noon on June 17. After that it continued to rise for another ten hours reaching a peak of 20.2 PWD at 10 pm on the seventeenth.

The Juri River at Purba Botali does not have any kind of containment dykes on the Bangladesh side and once it overtopped its banks water flowed out towards the west to fill the broad flat floodplain on the left bank between Purba Botali and Fultala. The water was very muddy and flowed between the houses in Purba Botali with velocities estimated at up to one metre per second. By the night of June 17, the area between the Indian border and Fultala was completely inundated.

The area between Fultala and Selua, fifteen kilometres downstream from Purba Botali, was also

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badly affected by the flood. The river has a high, well-built embankment on the right (Indian) bank which provided good protection from flooding. The left (Bangladesh) embankments are, however, both low and discontinuous and they were either overtopped or bypassed as flood flows moved downstream through the left bank floodplain.

At Selua, the river started to rise at 1 pm on June 16. It reached flood level (roughly 14.6 PWD) two days later at 1 pm on the eighteenth when it peaked at 15.1 m PWD. The total time to the peak was about 46 hours. The peak at Selua occurred some 15 hours after the peak at Purba Botali.

The flood water breached the right embankment in Selua on June 17. Considerable flow passed through the breach, flooding houses in Selua and destroying standing crops. Two other breaches of the right embankment occurred with similar effects at Kashinagar about four kilometres downstream of Selua.

Hashem, the NERP anthropologist, went to Fultala by Jeep on June 17. The road between Juri and Fultala was already inundated in three places and the section from Fultala to Purba Botali was in very bad shape with a lot of mud. Eventually he got to Purba Botali on foot and worked his way around the households with the help of a *bhela* [banana raft].

Hashem talked to about 20 villagers in Purba Botali about the flood situation. People were alert to the dangers and were monitoring the water level. Household heads were talking with other family members about where they would go and how they would get there. He was told they would leave for higher ground when their houses became inundated. Many households had already transferred their livestock, food stocks and other goods to higher ground. Men, women and children were making *bhela* for moving and preparing emergency food stocks. Some people were trying to catch fish.

On June 18, the situation worsened. The anthropologist went out again to visit the affected areas. The first place he reached was the village of Ranimura in the high flood hazard part of Zone B. Ranimura is about a mile and a half south of Juri town. It was raining heavily and he stayed to talk with a man he knew called Safique. Safique told him that in the morning he had transferred his wife, children and livestock to a relative's household at Champaklata (a nearby hillock area). Safique loaded a raft with food and dispatched it and the NERP anthropologist went on to visit another 10 homesteads.

By this time he could see that Zone A was under water and Zones B and C were partly flooded. The area on the Bangladesh side of the river between Fultala and Selua, some 15 kilometre downstream from Purba Botali, was also badly affected by the flood. Almost 20 percent of Zone E was also flooded. Water was very close to the houses of the other zones. Many people from Zone A had already taken shelter in the hilly areas. Others were still perched on *machans* [household platforms].

On June 19, the flood situation in the Juri area deteriorated. Runoff from the hills across the border was entering the Juri through its tributaries. Much of the vulnerable six unions that constitute the Juri River valley were by now under some water. The road from Juri to Fultala was under water. A bridge on the road between Magura and Jilua, five or six miles south-west of Juri on the road to Moulvibazar, had been washed away.

There were already 27 breaches in the embankments that line the river as it flows through Zone B. As the anthropologist remarked, "these embankments are not high, not compacted and not properly graded." A small river which joins the Juri at Juri township was flooding and caused the Juri-to-Selua Tea Garden road to be closed for ten days.

3.5 Flood Impacts and Issues

3.5.1 Predicting and Preparing for Floods

After the experiences of 1984 and 1993 the population of the Juri valley is well aware of the dangers that floods present and have developed a number of ways of alerting themselves to the fact that one may be imminent. While it was initially thought that local prediction might constitute a substantial part of the study's findings, in fact the approaches of local people are pragmatic and not very surprising. The symptoms of flood danger that were reported to our field worker are set out below.

Continuous heavy rain. People know that if you get continuous heavy rain in the Juri valley in the monsoon season this can be a precursor of floods. Local people have neither folk nor scientific ways of evaluating the quantity of the rainfall. While they understand that continuous heavy rain represents a warning, they have no means of evaluating how long it needs to rain for or how heavy the rain needs to be for flooding to occur.

Muddy and foamy water. People say that water in the Juri River is very turbid when there is a flood. They tell us they see a considerable quantity of foam floating on the water surface when a flood comes. Similar conditions were observed by the NERP project field crews during the flood of June 1995.

Cool water. The river water at the onset of and during a flood is reported to be cooler than in non-flood periods. People think that this is because it is released from storage in India.

Rate of rise. The population appears to be in touch with the common-sense notion that rapid rates of rise in the river level may be a precursor to flooding. They have, however, no way to make the quantitative evaluations that could help them correlate specific rates of rise with particular levels of risk.

The symptoms listed above are all indicative. Because people do not have any technology that allows them to map their experiences onto flood probabilities, they cannot treat the symptoms as more than a generalized alert. Neither, apparently, do heavy rain nor the arrival of muddy water appear by themselves to initiate preparations for a possible flood. Rather these symptoms heighten people's attention to the river conditions.

3.5.2 Balancing Acts

When floods occur in the Juri River valley the population has to achieve a number of balancing acts. They have to weigh the danger of staying at their houses against the danger of having no means of reaching safety later in the flood. They have to weigh the risk of leaving their houses against the risk of having their goods stolen. They have to balance the risks and discomforts of a flooded homestead against the risks and discomforts of a crowded shelter. The sections which follow sketch out some of the dimensions of these balancing acts.

3.5.3 When to Leave: Theft and Hesitation in Departure

One of the balancing acts that has to be achieved is that of deciding when to leave. Now that people are experienced in floods they know that it may be dangerous to stay on their property too long. There are no longer, it seems, reports of women having to be forcibly removed from their houses although they still leave with some reluctance. Everybody knows it is potentially necessary to evacuate.

Especially if the flood occurs at night, people are reluctant to set out before morning. During that time, people have more difficulty with the water because they cannot see where they are. They are particularly worried about being swept away in the dark. A typical interview with two housewives of Jugimara (reported elsewhere in this document) produced the comment that flood water reached their riverside dwelling at three o'clock in the morning and this "was not a proper time to leave the house." They waited on their *machan*, their household safety platform, until the next morning when they were evacuated by boat.

Several other considerations seem to go into the calculation. The first is that if you leave too soon there is real danger that thieves will steal your goods. Many of the stories about deciding to leave or not to leave households mentioned the risk of theft as a major consideration.

But if they leave too late people know that it may be difficult or impossible to actually get to the shelter they anticipate going to. There may not be any boats around or the water may be flowing exceptionally fast or there may not be any materials left to build rafts.

As in everything else, there are differences between men and women and between richer families and poorer families. Richer families are likely to have several advantages over poorer families. First of all they are likely to have spent money to raise their household platform or to have occupied a higher piece of ground in the first place. Secondly they can hire people to guard their houses so that they don't have to be so worried about theft. They are also more likely to have well-off extended family members who can provide them with refuge.

Poorer families have an exactly inverse opportunity-set. They live in worse areas; their household platforms are lower; they cannot hire people to guard their goods; and they are less likely to have well-off extended families. Poor people therefore tend to stay longer in their household. And when the evacuation is finished, it is quite likely they leave one or two persons behind to guard their property.

Leaving too late or Not leaving at all

People without extended families which can offer sanctuary on high land also tend to linger in their households. As one report said, ".. they stayed in their houses either on cot or *machan* at first, ... They said that they were not interested to evacuate earlier." "Where will we go?" "How will we get there?" "Who will save the food-stocks and other items in the house ?"

Staying, of course, has its risks. People who stay in the house basically depend on the *machan*, a platform made of bamboo and wood. It is often located at the height of the top of the windows or even at the level of a kind of false ceiling in the house, that means about six or seven feet above the floor. This is where the food is stored to prevent it being damaged in the flood. But staying on a *machan* has dangers as two stories illustrate.

A one year old drowned during that flood, when he slipped from the raised platform of the house.

Mr. Ali (70 of Konagaon) said that flood played a painful role. He stayed in his house on a *machan* for fear of thieves. It is very risky and sometimes the *machan* is washed away by the strong current. Four *maunds* of paddy, one of rice and other materials were lost during the flood of 1993. Thus, they suffered from shortage of food.

3.5.4 High Velocity Water

The velocity of the water during flood times is recognized as an exceptional phenomenon. One villager with lots of experience of floods said that during flash floods, "the velocity of the flood water is tremendous." "The situation," he said, "cannot be expressed without experience." It seems to be so prevalent a feature of floods that the presence of high velocity water is identified as a symptom that there will be a flood. As one resident, asked how he predicts floods said, "when the water in Juri River increases and the velocity of water-flow seems speedy."

The difficulties of getting around during the flood is recorded in many stories:

"The velocity of the flood water were so high that nobody could move from one house to another without the help of any river transport."

"During flood the workers cannot work in the tea estate because while only half of the garden goes under flood water they cannot move due to the high velocity of the flood water."

The difficulty becomes especially extreme at night when people report that they "cannot move due to the high velocity of the flood water and darkness, ..."

The risks are well known too. High velocity is recognized as a real danger to both people and property although as one report notes "buffaloes are excellent in withstanding pressure of the velocity of the water and so there was no loss.." However other animals are not so secure and many reports record that people ".. could not save livestock and other goods due to high velocity of the flood water."

As is noted in the section on how deaths occur (Section 3.5.7), the high velocity is especially frightening for people. The largest cause of death is identified as high velocity water. The difficulties are captured in a story of a man who was swept away rescuing his 8-months old son. "After saving Zaman, [they] moved to save Mr. Motaleb but they ... were quickly swept apart by the heavy velocity of the flash flood."

3.5.5 Community Cooperation and Assistance

Community surveys found a considerable degree of both formal and informal community cooperation and assistance during floods. This included everything from the fact that timber merchants near Juri town lend households bamboo so that people can construct *boor* rafts, to anonymous boat owners coming to rescue people stranded on rooftops and *machans*.

Most striking among these efforts are those of the Indian Border Security Force (BSF) in providing boats and shelter for people trapped near the river on the Bangladesh side. The people of Purba Botali, in particular, expressed their appreciation for this cooperation and assistance. An old man from Pashim Selua on the right side of the river near Selua gauge said that the in the 1993 flood the BSF informed the BDR (Bangladesh Rifles—the Bangladesh equivalent of the BSF) by wireless that flood water was entering Bangladesh from India. The BSF, he said, rescued the affected people of Bangladesh and provided food to them.

Richer local people, elected officials and others in positions of patronage also have obligations to provide help in flood times. In the June 1995 flood, the *Union Parishad* of Sagarnal established 12 committees with the express purpose of providing flood relief.

There are a number of community organizations (*Samiti*) in the Juri area, such as Nabarun and Binodhan, which have been very active in past floods. Much of their work has been in rescuing those stranded by high water and moving them and their livestock to places of shelter, and in distributing food.

All in all, there is a considerable amount of mutual assistance among peoples of the valley. This gives grounds for hope that a process of social organization for flood disaster management has a reasonably good chance of succeeding in the Juri River valley.

3.5.6 Shelters

Usually by the time water crosses the threshold of their houses people know that they must immediately or imminently leave their homes and move to high ground. As was sketched out above, the decision of when to leave is not easy. Many villagers were found to use *machan* or other people's houses where those are elevated. But apart from the considerations already discussed, the business of selecting a suitable place to move to adds an extra difficulty. The people who need shelter first are the people who live along the river bank and most of the shelter centres are quite a long way away.

Availability

Given the large population potentially affected by flooding, the number and size of safe shelters is alarmingly small. A list of shelters that were used in 1995 along with their approximate capacity is provided in Table 3.4. These shelters consist of a variety of community buildings, schools, market buildings, community halls, etc. As is noted in the section on women's issues (Section 3.5.9), women are frequently reluctant to take advantage of the available shelters because of the lack of accommodation separate from the men.

The lack of formal shelters means that road embankments, small hillocks, and any other high ground are widely used as refuges. The choice may be dictated by the distance to the refuge or the means of reaching it. Many of the small hillocks in the Juri valley are owned by timber merchants who may or may not grant permission for people to take refuge on their property.

For those living close to the river upstream of Selua, the closest high ground suitable for refuge may actually be across the river in India. Amir and Hamid Ali along with 35 households from Purba Botali went to the Bakbaki Tila in India and stayed there for three days. The Indian authorities appear to have made no objection to this because it was obvious that the flood victims could not reach a Bangladesh shelter.

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Table 3.4: Juri River Valley Flood Shelters

Location	Resources (Quality*)	Capacity**	Villages Served
Paschim Botali	House of the Raw Tila (Bamboo, tin, wood etc.)	100+(♂&♀)	Purba, Paschim Botali and the bank of the Ragna Chara
Fultala Basthi	Fultala Sasthi Madrassa (Bamboo and Straw)	100 max (♀)	Biraintail, Paschim Botali and Gultala Basthi
Fultala Bazar	Shed of the fish market. (Semi Pucca)	100 max (♂&♀)	Konagaon
Konagaon	The homesteads of Karimullah and Aftab Ali (Bamboo, tin, wood etc.)	50 max (♂&♀)	South Sagarnal and Konagaon
Kapnarahar T.E.	Thup Ghar (Pucca)	36 max (♂&♀)	Kapna & Pahar T.E.
Pathila Sangan	Pathila Sangan Primary School (Semi Pucca)	200 max (♂&♀)	Kashi Nagar
Batnigat	Batnigat Primary School (Semi Pucca)	100 (♂&♀)	Batnigat
Zangalia	Batnigat School (Semi Pucca)	130 max (♂&♀)	Boraitoli, Moitrigaon, Zangalia etc.
Babusing Gaon	Mokam Bari Primary School (Semi Pucca)	150 max (♂&♀)	Babusing Gaon, Baraitali
Babusing Gaon	Houses of Mokam Tila (Bamboo, Tin, Wood etc.)	100 max (♂&♀)	Babusing Gaon, Baraitali
Sagarnal	Union Community Hall (Pucca)	50 max (♂&♀)	Sagarnal
Sagarnal	Sagrnal Senior Madrassa (Pucca)	100 max (♂&♀)	Sagarnal
Sagarnal	Sagarnal Puja Mandop (Pucca)	80 max (♂&♀)	Sagarnal
Mointri Gaon	Homestead of cherag Ali (Bamboo, Tin, Wood etc.)	50 max (♂&♀)	Mointri Gaon
Purba Selua	Temple in Bhayrab Bari (Pucca)	125 max (♂&♀)	Paschim and Purba Selua
Pachim Selua	Bardar Bari (Bamboo, Tin, Wood etc.)	85 max (♂&♀)	Paschim Selua, Sohagir Par, Baradar
Magura	Homestead of Bimar Ali (Bamboo, Tin, Wood etc.)	100 max (♂&♀)	Magura
Magura	Temple in Bhaktar tila (Pucca)	80 max (♂&♀)	Magura
Champak Lata	Champak Lata Primary School (Semi-pucca)	50 max (♂&♀)	Mointail, Gauri Pur, Bhabanipur
Pachim Bara Damai	Primary School of Pachim Bara Damai (Semi-pucca)	90 max (♂&♀)	Paschim Bara Damai

* Pucca means brick construction; semi-pucca usually means galvanized corrugated steel sheet

* Based on 1993 population. "Max" means the facility was full; "+" means that it was not full; "♂" means male; "♀" means female temporary shelter in community buildings or take refuge on any available high ground such as a road or railway embankment.

Choice of Shelter and Access
The first choice for people who are affected by flooding is to go to the houses of their extended families. Where possible people affected by floodwater seek shelter with relatives who have property on high ground. However, a large number of people must either rely on temporary shelter in community buildings or take refuge on any available high ground such as a road or railway.

As is apparent in the case of the people who took shelter in India, local shelters are not always nearby or easily accessible. Absence of accessible shelter has been enough to persuade some families to move to more accessible accommodation. Here, for example, is a report from two housewives, Howarun Nesa (40) and Khursed Ali (50), of Jugimara near Selua. Here the Juri turns towards the northwest and where there is reasonably good access to local high ground. They said they used to live [presumably somewhere else further upstream] "on the left bank of the river" but there was no high land nearby to take shelter in during flood.

Some choices of shelter are difficult to understand. In the 1993 flood the family described above took shelter in the homestead of Akub Member who lives in Magura or Magra. This is a full mile and a half north of the river on the opposite side of the river from their village. The risks are increased by this decision and the only explanation for their choosing it can be that he was kinsman. Their 23-year old son, Baten, tried to transport two cows across the river to reach the same place but he seems to have lost both of them in the attempt.

This story emphasizes that the most hazardous period of a flood is the period when people are trying to move to the shelter of higher ground. The commonest feature of stories about trying to reach shelter is the danger from high velocity water. The great danger is that people who leave too late have trouble negotiating the, by now, rapidly-flowing water. Overbank velocities greater than 1 m/s were observed in some locations during the flood of June 1995.

People travel to the high ground by a variety of means. They wade, swim, use rafts made of bamboo or banana stem or they use country boats. Wading or swimming is made more difficult, or impossible, in areas with high overbank velocities. Added to this is the often repeated remark that the *saris* worn by women greatly hamper their ability to wade or swim through flood water.

Temporary floats made from banana stems or bamboo are probably the commonest life-raft although there is sometimes a serious shortage of both materials. Bamboo for *boor* rafts may be purchased or borrowed from timber merchants in the lower part of the valley. *Bhela* rafts are made from banana stems cut from the homesteads. Rafts do not appear to be made in advance of flood season; they are made as required and as material is available when the need for evacuation becomes apparent. People also draw attention to the fact that this means of transportation limits the amount of property that can be saved during flood.

The best method of getting away is to use a country boat but country boats are often not available on the Juri River above Shilghat. The scarcity of country boats is due in part to restrictions imposed by the BDR to control cross-border smuggling.

Amenities
Amenities at these locations are minimal. There are almost always shortages of food. Safe water is sometimes available at some of the more formal shelters but those who are forced to take refuge on road and railroad embankments invariably do not have access to safe supplies. At many places the evacuated people have to build temporary shelters from bamboo and banana leaves. As

elsewhere throughout Bangladesh, drinking of contaminated water during floods frequently results in diarrhoeal disease and an associated increase in deaths.

3.5.7 Deaths: How People Lose Their Lives.

No matter how you count them, the number of deaths in the Juri catchment as a result of floods is surprisingly small and much less than the number implied in the Concept Paper. The rather intensive enquiry carried for this study identified eighteen directly flood-related deaths for the period 1984-95. Even then only half of these were from drowning. The nine drowning cases are summarized in Table 3.5.

Figures from different sources differ. For example the records of the six *Union Parishad* offices record about 40 flood related deaths for the period from 1984 to the present. The larger number includes, however, both direct and indirect causes of death including diarrhoeal and other diseases.

Of the eighteen deaths mentioned above the distribution is indicative of the relative risks in the several zones. The largest number occurred in Zone A, about ten or eleven. Four occurred in Zone B, two in Zone C and one in Zone E. The last was in a village not listed in the zones. Eleven of the total of 18 occurred in the 1993 flood. In 1983 there were two deaths, in 1991, four and in 1995 only one directly related to drowning.

The Zone A deaths included the two infant deaths described below. One of these children died of exposure and the second died in what could be called an accident. He fell from the roof of the house and was swept away. All of the remaining Zone A deaths were caused by people being swept away while they were trying to escape in fast-flowing water.

In Zone B two of the four deaths were caused by the collapse of the walls of a house on two women. The other two were also of women who were swept away trying to reach safety through rapidly-flowing water.

In Zone C one of the deaths was caused by a six-year old boy falling off the platform on which his family was sheltering. He appears to have been swept away in fast-flowing water. The second death was caused by a person being swept away while trying to get to safety.

The deaths in Zone E and in the unlisted village were also caused by persons being swept away in rapidly-flowing water.

Eight deaths (half of all those reported) were caused by people being swept away while trying to reach safety.

Two typical risks for young children are taken from the 1995 eye-witness account:

"In Babusingaon Harun's newly-born child died [of exposure]. Suratar Nesa, a village doctor said she went to the house of Harun to treat Harun's pregnant wife. Harun's homestead was flooded at that time and the pregnant mother had to stay in the house which was very cold. She suspected the child to have died out of excessive cold."

Another boy named Salim (6), son of Abdul Jalil, in Sagarnal died, when he dropped down the raised platform of the house and drowned.

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Table 3.5: Flash-flood Related Drownings

Year	Name	Age	Village	Where died	Apparent Cause
1984	Salim	Male, 1 year	Purba Botali	Purba Botali	Drowned when he fell from the roof of his house.
1984	Haria	Male, 39 years		Kapnapahar C & B Road	Drowned on the way to Juri township
1984	Pran Gopal	Male, 42 years	Sagarnal T.E.	Konagaon	Drowned in fast-flowing water
1991	Mothaleb	Male, 60 years	Biraintail	Biraintail	Drowned in fast-flowing water while waiting in Bhela trying to get to Fultala Basthi.
1991	Bashir	Male, 21 years	Jangalia	Road in Jangalia	Drowned in fast-flowing water while attempting to save his cows.
1991	Momina	Female 30 years		Gouripur	Drowned in fast-flowing water en route to high ground.
1991	Nikhil	Male, 19 years	Sohagirpar	Sohagirpar	Drowned in fast-flowing water trying to save his cows.
1993	Zaifar Ali	Male	Konagaon	Konagaon	Drowned in fast-flowing water en route to another house.
1993	Rashid	Male, 5 years	Mointrigaon	Road in Mointrigaon	Drowned in fast-flowing water trying to get to Zangalia

Many other deaths occur after the flood. The main cause is disease connected with the poor conditions experienced during the flood event. A characteristically tragic account was reported by Abdur Gafur of Biraintail just to the north of Purba Botali. Abdur Gafur is 65 years old. In 1993 he was living with his two brothers in a joint family. Four members of his family died of diarrhoea: his 50-year old wife, Rakhitun Nesa, his 60-year old brother, Chamru Miah, his brother's wife Samerun Nesa who was 45 and another brother's wife Kamala Bibi who was 43.

3.5.8 Property Losses

As it is widely agreed that the 1993 flood was the one which caused the largest losses in the Juri River valley we have attempted to estimate the extent of damage associated with this event. Table 3.6 presents a summary of the information that was collected. It constitutes an attempt to estimate, for the areas that were actually flooded, the property losses that people incurred. Figures are indicative. They were obtained from the *Thana* offices and from interviews with villagers.

Relative to the flood of July 1993, losses due to the June 1995 flood were comparatively low. Two deaths were reported. One new born infant died apparently because of excessive cold. The second death, of a six year old boy, occurred when he fell from the raised bamboo platform in his home and drowned.

Losses of livestock were relatively small. This was attributed by local villagers to the fact that most livestock had been moved to high ground before escape routes became submerged. About 20 percent of food stocks and household belongings were damaged by flooding. However, there were very substantial losses to standing crops, homestead gardens, vegetable gardens, and tank fish.

In addition to personal losses, there were losses to local infrastructure. Embankments were breached at several places, roads were eroded, and culverts and bamboo bridges were washed out. Two buildings in Juri township, just upstream of the road bridge at the bifurcation of the Juri River and the Continala branch, collapsed due to erosion. The Juri River eroded its left bank and cut the road from Juri to Fultala. Several bamboo rafts were washed away by flood water from Juri township into Hakaluki *Haor*. Road communication from Juri to Fultala and Juri to Selua was cut for a week, causing disruption in the transport of tea and timber.

3.5.9 Women's Problems

Status

As in other parts of Bangladesh, women's role in the family is highly structured by tradition. Women are the family specialists. The social structures of, for example, village *samaj* and like organizations are patriarchal and women are excluded from public participation in these processes. Women take care of all the domestic matters including child-care, gathering fuel, cooking, animal husbandry and so forth. Women are also supposed to be responsible for managing the household budget. This becomes especially stressful at times when there is a flood and financial resources are scarce.

Women are expected to help prepare the household for the flood. They may be required to move the livestock to the highlands and gather the household goods together for the flood onslaught.

Deciding to leave home

Now that people have experience of a number of serious floods in the valley it seems to be generally agreed that when water covers the floor of the household it is time to leave. Often livestock and moveable property have already been moved by this time and now it is time to move women and children.

Table 3.6: 1993 Flood Estimated Property Losses

Item	Loss (%)
Buffalos	15
Cows	20
Goats	50
Chickens	90
Food Stocks	35
Consumer goods	20
Personal effects	50
Home gardens	90
Standing crops	100
Tea plants	30
Tea Nurseries	75
Infrastructure	40

Women who have no set place to go are often quite reluctant to leave. In fact, in earlier floods there were stories of women being physically dragged out of their homesteads. But even now there is a certain reluctance. Women who do not have extended family who can shelter them are especially reluctant to leave. They know that there are no suitable facilities at the public shelters and they are not keen to go there. Because they delay it often becomes more difficult and dangerous to get to the shelter.

Travelling to the shelter.
Although there are many hills and hillocks and potential shelter places in the valley the means to access these places is not always readily available. The system of access roads is inundated quite early in the process and the high velocity of the water makes it difficult to wade through it. Women are reported to find this especially difficult.

When no access road is available it may be necessary for people to be able to swim for short distances or to swim to a raft. Few people seem to actually resort to this and in fact if more did one would expect more reports of drowning. Women are said to be able to swim although their saris make this cumbersome.

In fact most people escape by boat or raft. *Boor* or *bhela* are the main means of transport during flood. An additional dependency derives from the fact that these means of transportation are the exclusive monopoly of men. Women are not expected to be involved in the operation of boats and other water transportation and must await the patronage of the men who do this work.

Shelter issues: food and water
Most places where people find shelter are severely short of food and water. Within the flooded areas themselves, tubewells are usually inundated by the flood. Women who have remained in the village have either to go to high land using rafts to get water or resort to the floodwater itself.

Collecting fuel for the household is part of women's responsibility and during the flood this becomes especially difficult. Fuel is in short supply and it is almost impossible to even think of boiling drinking water even if that were a tradition. This is true whether women stay in their villages or move to shelters. At the shelters, because so many families are gathered the difficulty is acute.

Food in the shelters is usually in short supply. Families are often not able to carry any food with them and have little money to buy it. Once again it is women who bear the brunt of this scarcity. Traditionally women only eat after their menfolk and the children, especially male children, have finished. While actual starvation seems to be rare deprivation is real. Many women suffer from malnutrition and illness.

Typical stories of hardship were collected from many sources. Anamika (30), Chancala (18), Praba (48), Kalpana (39) and Zosna (23) of Purba Botali said that in the 1993 flood, they had to fast most of the time they were in the shelter. There was very little food, not much fire wood and a lot of people got sick.

Minera (20), Chini (33), Hazera (30), Sabarun Bibi (30) and Arabjan (45) of Konagaon reported that although the UP Chairmen distributed the *Khicuri* (hotch-potch meal) during flood in 1993, they had to face other problems, like housing, sanitation, drinking water, medicine etc.

Shelter Issues: health
Diarrhoeal diseases are very prevalent during and immediately after the flood and women are especially vulnerable. Pregnant women are especially hard hit although only isolated comments were collected during the fieldwork. All the difficulties are made worse by the absence of medical facilities and shortages of money.

Shelter Issues: personal hygiene
Public shelters that have to be resorted to at flood times offer a minimum of facilities. Especially difficult is the fact that there are no resources that provide even privacy for defecation. Women who are menstruating have the additional difficulty that they cannot find privacy for washing at a time when they are considered especially "unclean." They have special difficulty finding a place to bathe or wash their clothes.

Shelter issues: other privacy and modesty issues
The sheer number of people who are clustered together in shelters makes for special difficulties for women. Whatever schools, community centres, bazaars, religious institutions and other shelters are available to flood refugees are extremely crowded. Traditional culture recommends that women are ideally confined to the homestead. At the shelters there is usually almost no partitioning of family space and often no separation of space for men and women although this is sometimes solved by simply banning men from the shelter for at least part of the time: "above 100 women took shelter in this *madrassa*. No male person was permitted to stay in the shelter at night. Male persons stayed in another house." This absence of the security of segregation is one of the strongest reasons why many young girls and women are reluctant to go to these shelters.

Shelter Issues: sexual harassment
Part of the reason that women are reluctant to move to the shelters is that apart from the lack of privacy (or because of it) women are also subject to sexual harassment. Shelters are occupied by all sorts of people including what people refer to as "bad elements of the locality." Ordinarily women are protected from these threats by a whole village structure and the men of their families. But in the shelters, separated and segregated as they are for modesty reasons, they become more vulnerable. Women themselves report that they become especially vigilant under these conditions.

After the flood
After the flood it is women who are expected to undertake the cleanup and repair of the house and its amenities. At this time additional stress derives from the fact that damaged households have lost substantial assets and cleanup and repair is that much more difficult. Special materials to repair the floor and the walls and roof have to be found at a time when there is competition for these resources.

Women's Economic Issues
Apart from other economic considerations, floods cause some special economic problems for women. Their contribution to the household economy may be threatened or come up for critical review. For example, because these are times of severe economic stress in the household issues connected with dowries can be brought to the forefront. Women say that after the flood when money is scarce the fact that their family may not have paid sufficient dowry may be revived as an issue.

Women working as wage-earners too may lose wages during the flood period. House-maids with

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other households usually go unemployed and have to return to their families increasing the stress on limited resources.

One of the important contributions that women make to the family income often includes a loan from an NGO. Women report that even during flood times they are still expected to pay their weekly instalment against their loan. This additional cost at a time of extreme shortage often forces them to go to money lenders to get the required amount. Obviously this acts as a kind of lever to exacerbate their losses.

3.6 Aftermath

There is not much to write about the aftermath of the floods. People go home and assess the damage. Women work to clean out the house and refinish the floors which get damaged by the floodwater. Kitchen gardens are revived. Men go into the fields and often resow their crops. One of the most valuable commodities they try to retain when they evacuate their households is seed in anticipation of this activity. Richer people make plans to raise and strengthen their household platform.

At present, apart from raising the household platform and restoring the *machan* there is no systematic approach to flood-proofing houses.

3.7 Remedies: The potential for Flood Warning and Disaster Management

Although many people interviewed in the survey program expressed an interest in having a flood warning system on the Juri River, it appears that a flood warning, in isolation, may be of limited value and bring relatively little benefit to the population in terms of either reduced deaths, or reduced property losses.

While the Juri River valley experiences extremely severe and damaging flooding conditions, comparatively few lives have been lost as a direct result of floods. The project's interview program identified a total of 18 deaths as a direct result of flooding in the period 1984 through 1995. According to the *Union Parishad* of the flood affected areas, a total of 40 people died during and after flash floods from 1984 through present.

Whether the number of deaths attributable to flooding is 18 or 40, this number is much less than previously thought and appears small in relation to other everyday hazards. Furthermore, the number of lives lost may not have been much reduced even if a perfect flood warning system were in place. In 1993, for example, three children were drowned during a flood when they fell into the river from the railroad embankment in Juri. A warning system cannot prevent "accidental" deaths of this kind that occur at flood times.

The great majority of flood-related deaths are caused by people being swept away by high velocity flood water while attempting to reach safe ground. The interview program suggests that many people stay in their homes during a flood until they are compelled to leave. This is because of real need to protect their property from theft. There is no reason to suppose that a flood warning would change this behaviour. These deaths are the result of people staying in their homes too long and misjudging the depth and velocity of flood-waters.

Floods in the Juri Valley result in considerable damage to property including food stocks, livestock, crops, and homesteads. Reliable flood warnings with a lead time of two to four hours could in principle allow the affected population to save some of their food stocks and much of their livestock. Longer lead times might allow people to save a portion of their crops. Again, however, it is probably easy to overstate the potential value of flood warnings. A warning by itself may not be of much value. Many people have no established refuge on safe ground, no safe place to move their property to, and no adequate means of transportation. A safe, readily accessible refuge is probably a prerequisite if inherently uncertain flood warnings are to be of value to and heeded by the population.

While it appears that flood warnings by themselves may be of little immediate value to the population of the Juri valley, it is possible that flood warnings could, in the long term, be a useful component of a broader flood disaster management program as discussed in Chapter 6.

4. HYDROMETRIC DATA COLLECTION AND EVALUATION

4.1 Introduction

A hydrometric data collection network was designed, installed, and operated during the 1995 monsoon season to obtain the information necessary to evaluate the feasibility of forecasting floods on the Juri River. In common with all the flashy rivers of the Northeast Region, the headwaters of the Juri lie in India and in the past it has been generally assumed that hydrometric data from India would be necessary to forecast floods with any useful degree of reliability. Given the extreme difficulty (if not impossibility) of obtaining data from India in a timely fashion, one of the goals of the project was to determine whether hydrometric data collected in Bangladesh could, in fact, provide a basis for forecasting floods and producing flood warnings on the Juri River. The hydrometric data network operated in the Juri catchment was designed to provide information for three related objectives:

i) to characterize the hydrologic response of the Juri catchment;
ii) to determine whether measurements of water level, stream discharge, and rainfall depth in Bangladesh could be used to forecast the occurrence of floods on the Juri River from the Indian border downstream to the township of Juri; and,
iii) to determine whether visual observation of conditions over the headwaters of the Juri catchment in India could contribute to the ability to forecast floods.

Data for the first two objectives were obtained through installation and operation of a small network of conventional water level and rainfall gauges. For the third objective, a meteorological observation post was constructed on a hilltop near the village of Chungabari, close to the Indian border and with unobstructed views of the headwaters of the Juri catchment in India. The locations of gauge sites and the meteorological observation post are shown on Figure 4.1.

Hydrometric data were collected for a little less than 5 months during the 1995 monsoon season, from 14 April 1995 to 30 August 1995. The data collection network and data collected are discussed in more detail below.

4.2 Water Level Data

Staff gauges for monitoring water levels were installed at four locations along the Juri River as follows:

- Immediately downstream from the India/Bangladesh border at the village of Purba Botali, 30 km upstream from Juri township.
- Immediately below the confluence of the Juri River with Thal Gang at the village of Selua, 15 km upstream from Juri township.
- Just upstream of the Continala distributary of the Juri River at Shilghat, 2 km upstream from Juri township.

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- On the Continala distributary of the Juri River at Belagaon, about 2 km downstream from Juri township.

Each installation consisted of two or more staff gauges installed at different levels to permit water level observations over an approximate range of up to 6 m. Gauge locations are shown on Figure 4.1.

It had been initially intended to monitor water levels at Purba Botali and Juri only, Purba Botali being the closest point to the Indian border at which water levels could be measured, and Juri being the largest township on the Juri River. The additional site at Selua was added principally to facilitate development of a reliable discharge record on the lower Juri below the confluence with the Thal Gang (the largest tributary to the Juri below Purba Botali) but upstream from the point at which water levels (and hence discharge ratings) are affected by backwater from Hakaluki *Haor*. The gauge at Belagaon, on the lower reach of the Continala (essentially in Hakaluki Haor), was added to allow investigation of the effects of water levels in Hakaluki *Haor* on critical (i.e. flood producing) discharges at Juri.

Water level gauge readers were recruited from amongst the local population. The gauge readers each had educational qualifications close to SSC (Secondary School Certificate) standard and were given practical training in reading the gauges and recording the observations. Two gauge readers were retained for each of the monitoring sites at Purba Botali, Selua, and Shilghat, to allow round the clock observations, while a single gauge reader was retained for the Belagaon site.

Water levels at the Purba Botali, Selua, and Shilghat gauges were read hourly round the clock except during high flow events when water levels were read at a 5 minute interval. The shorter interval (5 minute) observations were taken in an attempt to produce more reliable estimates of flood wave travel time from Purba Botali to Selua and Shilghat, and to allow detection of hydraulic bores that might be associated with high flow events. The possibility of hydraulic bores was suggested in the project Concept Paper. However, it was recognized that bores are more likely to occur on the very steep rivers originating in Meghalaya than on a relatively low gradient river such as the Juri.

Water levels at the Belagaon gauge site were generally read at 06:00, 12:00, and 18:00. This coarser time step was used because water levels in Hakaluki *Haor* were known to change slowly during flood events.

The water level data collected during the monitoring period are plotted in Figure 4.02. Water level data for the Purba Botali, Selua, and Shilghat gauges are plotted at an hourly time step. The 5-minute water level data collected at those sites during high flow events showed very little variation with absolutely no indication of hydraulic bores or other rapid short term water level fluctuations.

The water level records from each site are complete for the common period from 00:00 14 April through 23:00 30 August with one exception; no data were obtained from Belagaon for the period from 29 May through 12 June. The water level in this period dropped below the zero level of the lowest staff gauge. It will be noted (Figure 4.02) that the period of missing data followed a relatively high flow event in mid-May, and that the water levels at Belagaon following the May event are actually lower than water levels at the end of the dry season in April, when observations first began. Water levels at Belagaon and Shilghat during the dry season are maintained at artificially high levels by temporary cross dams on the Continala distributary of the Juri, below Belagaon. These cross dams were apparently breached during the May high flow event, resulting in a subsequent drop in low flow water levels in the lower Juri.

Comparisons of water level data between sites show no obvious inconsistencies and the data are considered to be reasonably reliable. The slow change of water level at Belagaon represents water level change in Hakaluki *Haor*. Figure 4.02 clearly shows the effects of high water levels in Hakaluki *Haor* on water levels at Shilghat. The data also suggest that sustained high monsoon water levels in the *haor* may affect low flow water levels as far upstream as Selua.

The water level data are examined in more detail for individual high flow events in Section 4.6.

4.3 River Discharge Data

Direct discharge measurements were made at the Purba Botali, Selua, and Shilghat water level gauge sites. During the approximately 5 month monitoring period, a total of 32 discharge measurements were made at Purba Botali for discharges ranging from 5.6 to 188.3 cumecs. Similarly, a total of 30 discharge measurements were made at Selua for discharges ranging from 15.9 to 201.1 cumecs, and 10 discharge measurements were made at Shilghat for discharges ranging from 40.0 to 140.4 cumecs. The discharge measurements at Selua and Shilghat were based on velocities measured using a Valeport current meter. Measurements of velocity at Purba Botali were taken by float because of difficulty in obtaining India's permission to make current meter measurements by boat. (The Juri river at Purba Botali forms the India/Bangladesh border).

No discharge measurements were made at Belagaon. Water levels and discharge ratings at both Belagaon and Shilghat are affected by the presence of downstream cross dams in the dry season and by water levels in Hakaluki *Haor* during the monsoon season. The Belagaon water level gauge effectively measures water levels in Hakaluki *Haor* during the monsoon season.

Discharge measurements at Purba Botali and at Selua are plotted against water level in Figures 4.3 and 4.4 along with fitted rating curves.

The rating curve for the Purba Botali gauge site (Figure 4.3) shows a good fit over the range of observations from about 10 to 200 cumecs. The critical water level at Purba Botali (i.e. the level at which water flows out of bank and flooding starts) is approximately 19.3 m PWD (corresponding flow about 200 cumecs). Significant out of bank flows occur above this level, as observed in the flood of 17 June, 1995. Extrapolation of the rating above about 19.3 m PWD is thus subject to considerable uncertainty.

The rating curve for Selua (Figure 4.4) is somewhat less well defined than that at Purba Botali with greater scatter in the discharge data about the curve. Nevertheless the rating is believed to be reasonably reliable over the range from about 20 to 180 cumecs. The Juri is embanked through Selua. At high water levels (above about elevation 14.5 m PWD) considerable flows bypass the gauge site. Furthermore, the embankments are apparently prone to breaching. In the flood of June 1995, the left embankment was submerged and the right embankment breached at a water level somewhat less than 15 m PWD. The rating is uncertain above about elevation 14 m PWD.

No attempt was made to establish a stage/discharge rating at Shilghat. As pointed out previously, water levels at Shilghat are influenced by temporary downstream cross dams in the dry season and by water levels in Hakaluki *Haor* in the monsoon season. As a result, a single valued stage-discharge relationship does not exist.

The rating curves for Purba Botali and Selua were used to transform water level data from those two sites to discharge, to produce an hourly discharge record from about 14 April through 30 August. The time series of hourly discharge at the two sites are shown in Figure 4.05.

Further discussion of flows during selected high flow events is provided in Section 4.6.

4.4 Rainfall Data

Three rainfall gauges were installed in the Juri River catchment close to the Indian border. The rain gauge locations are shown on Figure 4.1.

Two of the rainfall gauges were standard BWDB storage (non-recording) gages. One was installed at Purba Botali close to the Purba Botali water level gauge. The second was installed at the observation post near the village of Chungabari. The elevation at Purba Botali is approximately 20 m and at the Chungabari observation post approximately 150 m. Chungabari is approximately 8 km southwest of Purba Botali.

The third gauge was an automatic recording (tipping bucket) rain gauge with an electronic data logger. This gauge was also installed at the observation post near Chungabari to measure short interval rainfall intensities. However the data logger malfunctioned very early in the project and no useful data were obtained.

Rain gauges were read by locally recruited, trained observers. The rainfall gauge at Purba Botali was read by the same two observers retained to read the Purba Botali water level gauge. The Chungabari meteorological observation post was staffed by a team of three observers. Two of the observers were from the nearby village of Chungabari with education close to SSC level. The third observer was a junior engineer, with a Bachelor's degree in Civil Engineering, who supervised the day to day operation of the observation post.

The non-recording rainfall gauge at Purba Botali was read 8 times a day at a 3-hour interval for the duration of the monitoring period (i.e. from mid-April through August). The gauge at Chungabari was read every 3 hours during daylight hours only (from 06:00 to 18:00) in April and May, switching to round the clock observations at a 3-hour interval when the observation post was fully staffed at the beginning of June. The 06:00 gauge readings at Chungabari for April and May therefore actually represents the 12-hour cumulative rainfall depth from 18:00 the previous evening.

Time series of daily rainfall amounts at Purba Botali and Chungabari for an observation day ending at 06:00 are shown in Figures 4.06.

The consistency of the rainfall data was checked by plotting cumulative rainfall at Purba Botali against that at Chungabari (Figure 4.07). The plot shows a distinct break in slope at about 15 July (corresponding to a cumulative rainfall total at Purba Botali of about 1100 mm) implying that rainfall amounts at Purba Botali increased relative to amounts recorded at Chungabari after that date. A slope change similar to that shown on Figure 4.07 is often indicative of data error. However, no specific source of error has been identified in this case and it is possible, though somewhat unlikely, that the slope change could be the result of spatial variations in rainfall amounts within the catchment and the small sample of data available for analysis.

Daily rainfall amounts at Purba Botali and Chungabari for an observation day ending at 06:00 are further compared in the scatter plot of Figure 4.08. With one exception, daily rainfall totals at the two stations are reasonably well correlated for daily rainfall amounts in excess of about 60 mm. The one exception (daily total at Chungabari of 48 mm as against 148 mm at Purba Botali) occurred on 19 July, just after the break in slope in the plot of cumulative rainfall totals discussed in the previous paragraph.

The above analysis is inconclusive but suggests some form of inconsistency or error in the rainfall data at either Purba Botali or Chungabari.

Further discussion of rainfall data for selected high flow events is provided in Section 4.6.

4.5 Other Meteorological Data and Observations

As mentioned in the introduction to this Chapter, a meteorological observation post was constructed on a small hill (elevation about 150 m) just south of the village of Chungabari and with an unobstructed view of the headwaters of the Juri River in India (Figure 4.1). The post was staffed with locally recruited observers trained to make simple visual observations of meteorological conditions over India and to measure basic meteorological parameters such as rainfall depths and air temperature. In addition to monitoring rainfall depths, as already discussed under Section 4.4, the observers at the Chungabari observation post collected the following meteorological information:

Air Temperature - Maximum, minimum and current air temperature were measured using a standard maximum/minimum thermometer.

Wind Direction and Strength - Wind direction and strength were monitored by means of a wind sock. The angle of the wind sock from the vertical was used as an index of wind strength. Wind speed measurements were not taken.

Visibility - Visibility in the direction of the catchment headwaters in India was recorded on a qualitative scale (nil, poor, fair, good, and excellent) based on the ability to see landmarks such as villages and roads from the observation post.

Cloud Characteristics - Percentage cloud cover, cloud type and direction of cloud movement over the Indian portion of the catchment were recorded. The speed of cloud movement was also recorded on a qualitative scale.

Lightning - The direction and frequency of lightning was recorded.

Thunder - The direction and frequency of thunder was recorded.

Rainfall - In addition to measuring rainfall depths at the observation post, the percentage of the Indian catchment over which rain could be seen falling was recorded.

The above meteorological observations were made every 3 hours during daylight hours only (from 06:00 to 18:00) in April and May, switching to round the clock observations at a 3-hour interval at the beginning of June.

As discussed further in Section 4.6, observation of conditions over the Indian headwaters of the Juri proved to be impossible during storm events because of poor visibility. With the exception of rainfall data, other at-site meteorological observations also proved to be of no value in predicting or forecasting floods. Consequently, except for the rainfall data already presented in Section 4.4, no attempt has been made to summarize the body of meteorological data collected at Chungabari. Meteorological conditions observed during selected high flow events on the Juri are, however, discussed in Section 4.6.

4.6 Flood Characteristics

4.6.1 Analysis of 1995 High Flow Data

The Juri catchment experienced 6 distinct and essentially independent high flow events in the monitoring period from early April to late August 1995. These events were over the periods:

- 16-20 May
- 12-15 June
- 16-24 June
- 18-22 July
- 26-29 July
- 12-20 August

Reasonably comprehensive and reliable hydrometric data were collected for each of these events as discussed below.

Period 16-20 May 1995
This was a moderately large event which produced close to bank full flows at Purba Botali. As far as can be determined no significant out-of-bank flows occurred anywhere along the main stem of the Juri within Bangladesh although low-lying *beels* upstream from Juri township were flooded. Data collected are complete except as noted below:

- The Chungabari observation post was only staffed from 06:00 through 18:00 each day until the end of May when round-the-clock observations began. Rainfall data reported at 06:00 each day therefore represent the rainfall total over a 12-hour period from 18:00 the previous day.

- The water level observer at Selua failed to consistently note the hour of each observation. Although an attempt was made to reconstruct the chronology of observations, the exact timing of high flows at Selua for this event may be in error by +/- 1 hour.

Hydrometric data collected during this event are shown in Figure 4.09. Hourly discharges at

Purba Botali and Selua are plotted against the 3-hour rainfall amounts from Purba Botali in one plot. The second plot on the figure shows a comparison of hourly water level data from Purba Botali, Selua, Shilghat, and Belagaon.

The discharge and water level hydrographs and rainfall data recorded at Purba Botali were analyzed in some detail. Runoff volume, peak discharge rate, maximum rate of rise, concurrent rainfall depths and other parameters are summarized in Table 4.1.

Finally, meteorological data collected during this event at the Chungabari observation post are summarized in Table 4.2 for the period leading up to the peak flow at Purba Botali. Note that visibility throughout this period was reported as poor (less than about 2 km). Note also that the 06:00 rainfall amounts at Chungabari for this event represent the cumulative rainfall depth from 18:00 the previous day.

Period 12-15 June 1995

The event of 12-15 June was a relatively small event with peak water levels well below top of bank at all observation points. Data collected from each gauge site are complete. Plots of discharge data, rainfall data and water level data are provided in Figure 4.10. Runoff volume, peak discharge rate, and other relevant characteristics of the flood hydrograph response at Purba Botali are summarized in Table 4.1. Meteorological data collected at Chungabari for the period leading up to the peak flow at Purba Botali are summarized in Table 4.3.

Period 16-24 June 1995

The event of 16-24 June was the largest flood event in the monitoring period and the only event which resulted in significant out-of-bank flooding. Extensive flooding of the Juri valley occurred from Purba Botali downstream to a point just above Juri township. Peak water levels at Purba Botali were almost 1 m above the top of bank resulting in significant out of bank flows. The river at Selua is embanked. However, at the height of the event, the left embankment was submerged and the right embankment breached resulting in flooding of the village of Selua. Water levels at the township of Juri were below top of bank and no flooding occurred there.

Almost complete data were obtained for this event at all monitoring sites. The water level gauge at Purba Botali was swept away close to the peak flow. However a replacement gauge was immediately installed and less than one hour of data were lost. Out of bank flows also inundated the rain gauge site at Purba Botali. However because of the lag between rainfall and peak flows, rainfall had actually stopped before the gauge site was inundated and no data of any consequence were lost.

As with other events, plots of discharge, rainfall and water level data are provided in Figure 4.11. Similarly, runoff volume, peak discharge rate, and other relevant characteristics of the flood hydrograph response at Purba Botali are summarized in Table 4.1. Meteorological data collected at Chungabari for the period leading up to the peak flow at Purba Botali are summarized in Table 4.4.

Period 18-22 July 1995

The event of 18-22 July was a relatively small event with 3 distinct peaks at Purba Botali. Peak water levels were well below top of bank at all observation points. Plots of discharge data, rainfall data and water level data are provided in Figure 4.12. Runoff volume, peak discharge rate, and other relevant characteristics of the flood hydrograph response at Purba Botali are summarized in Table 4.1. Meteorological data collected at Chungabari for about a 24-hour period prior to the last and largest of the three peaks at Purba Botali are summarized in Table 4.5.

Period 26-29 July 1995
The event of 26-29 July was another relatively small event with peak water levels well below top of bank at all observation points. Plots of discharge data, rainfall data and water level data are provided in Figure 4.13. Runoff volume, peak discharge rate, and other relevant characteristics of the flood hydrograph response at Purba Botali are summarized in Table 4.1. Meteorological data collected at Chungabari for the period leading up to the peak flow at Purba Botali are summarized in Table 4.6.

Period 12-20 August 1995
The event of 12-20 August was a long duration high flow event with multiple peaks. Peak water levels were close to top of bank at all water level monitoring sites. Low lying agricultural land was flooded at several locations but no homesteads were flooded. Plots of discharge data, rainfall data and water level data are provided in Figure 4.14. Runoff volume, peak discharge rate, and other relevant characteristics of the flood hydrograph response at Purba Botali are summarized in Table 4.1. Meteorological data collected at Chungabari for the period leading up to the peak flow at Purba Botali are summarized in Table 4.7.

4.6.2 Assessment of Hydrologic Response and Meteorological Conditions

It appears from the data collected in 1995 that the Juri catchment has a slower hydrologic response to rainfall than had been previously thought. The speed of response was reasonably consistent for the six high flow events experienced in 1995 and described in the preceding section.

The time to peak at Purba Botali (Table 4.1) ranged from 12 to 53 hours, with the shorter response times corresponding to the smaller of the observed events. The corresponding lag to peak (time from centre of mass of rainfall to peak discharge) similarly ranged from 9 hours to 28 hours with the shorter lags corresponding to small multiple peak events.

As one moves down the system, the response becomes progressively slower, with times to peak ranging from 23 hours to 62 hours at Selua, and from 31 hours to 89 hours at Shilghat (ignoring the two small multiple peak events in July). The corresponding lag to peak ranged from 20 hours to 37 hours at Selua, and from 28 hours to 65 hours at Shilghat. A comparison of time to peak data is provided in Table 4.8.

Visual examination of the rainfall hyetographs and flood discharge hydrographs at Purba Botali and Selua in Figures 4.09 through 4.13 shows a strong correspondence between heavy rainfall at Purba Botali and a high flow response on the Juri. Evidently, in flood producing events, the weather systems that are responsible for rainfall are of a large enough scale that they cover not only the Indian headwaters of the Juri catchment but they also extend well into Bangladesh.

Detailed analyses of runoff volumes and storm rainfall depths at Purba Botali, shown in Table 4.1, indicates, as might be expected, that the magnitude of the hydrologic response to rainfall is heavily dependant on antecedent moisture conditions. Direct runoff as a percentage of total event rainfall, as measured at Purba Botali, varied from about 19 percent at the end of the dry season in May to about 63 percent in the middle of the monsoon season in mid August.

Although rainfall depths as measured at Purba Botali show a strong correspondence to high flow events on the Juri, other meteorological observations appear to have no flood forecast value. In particular, the meteorological observations at Chungabari (summarized in Tables 4.2 through 4.7) show unequivocally that it is not feasible to use visual observations of conditions over the Indian headwaters for flood forecasting.

4.7 Comparison of 1995 High Flow Data with Historic Information

The hydrologic response of the Juri catchment, as determined through the program of monitoring conducted in 1995, was found to be slower than anticipated. The time to peak for the flood event of 16-24 June, for example, varied from about 34 hours at Purba Botali to in excess of 60 hours at Shilghat. Rates of rise during the event were also relatively slow with maximum rates of 0.43 m/hr at Purba Botali and 0.25 m/hr at Shilghat. The relatively slow response, particularly in the lower part of the catchment, is consistent with the low gradient of the Juri and the large amounts of flood plain storage available. However, the slow response appeared to be inconsistent with some of the anecdotal information on historic floods collected during the community surveys described under Chapter 3.

Interviews conducted during the community surveys indicated that historic floods may have had faster rates of rise than the high flow events of 1995, implying that the 1995 hydrometric data may not be representative of "flash" floods in the Juri catchment. Unfortunately, none of the community surveys were able to provide specific information from which historic rates of rise or response time could be reliably estimated. The 1995 data were therefore compared with a limited amount of hydrometric data from the severe flood of July 1993.

A limited amount of historic hydrometric data are available from the Juri catchment. The BWDB monitors water levels by means of a staff gauge on the Continala distributary in Juri and by means of an automatic strip chart recorder at Shilghat. Unfortunately, reliable interpretation of the strip chart record for historic events has proved to be impossible and no water level or discharge data are available upstream of Shilghat. Daily rainfall data are apparently collected at several of the tea estates in the catchment, including the Rajke Tea Estate, located approximately 4 km northeast of the Chungabari observation post.

Daily rainfall data were obtained from the Rajke Estate for the flood of July 1993 along with concurrent water level data from the BWDB staff gage at Juri. The data for the period leading up to the peak water level at Juri are summarized in Table 4.9. The daily rainfall amounts at Rajke for 1993 are believed to have been read at the standard time of 09:00. The daily rainfall record therefore suggests that rainfall stopped prior to 09:00 on 22 July and that peak rainfall amounts fell sometime between 09:00 20 July and 09:00 21 July. The peak water level at Juri of about 11.54 m was reached some time between 18:00 22 July and 06:00 23 July. The lag between the approximate centre of mass of the rainfall hyetograph and the peak water level was therefore of the order of 50 hours. The comparable figure for the lag to Shilghat for the June 1995 event was somewhat longer: about 65 hours. The maximum rate of rise observed at Juri in the July 1993 event was about 0.10 m in 3 hours. The maximum rate of rise at Shilghat in the June 1995 event was 0.56 m in 3 hours and at Belagaon 0.27 m. The rate of rise in the vicinity of Juri is, however, affected by the water level in Hakaluki *Haor*, which was almost 2 m higher at the start of the July 1993 flood than in the June 1995 event.

In summary, the available data from Juri for the 1993 flood show response characteristics which are similar to those observed in June 1995 at Shilghat. All available quantitative data suggest that the hydrologic response of the Juri River is quite slow. No reliable quantitative historic information is, however, available on flood response upstream of Juri. Because of the very short period of data available from 1995, the information developed to date on hydrologic response upstream of Juri should be treated with caution.

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5. EVALUATION OF FLOOD WARNING POTENTIAL IN THE JURI RIVER VALLEY

5.1 Introduction

Most flood warning systems have three basic components:

- a means of forecasting the occurrence (and often also the magnitude) of a flood,
- a means of converting a forecast into a meaningful warning, and
- a means of disseminating the warning to the appropriate recipients.

The ideal flood warning system for the Juri River valley would be one in which each affected party could be reliably informed of the depth and duration of flooding at any point of interest with sufficient lead time that potential flood damages could be avoided to the greatest extent possible. To achieve this technically ideal goal would require accurately forecasting the future flood hydrograph, producing an area/inundation map for the Juri valley, and disseminating that information in an understandable manner.

At a minimum, production of such flood inundation maps for the Juri valley would require acquisition of representative real time rainfall data from the catchment (either by radar or telemetry), application of a hydrologic model to transform rainfall data to one or more runoff hydrographs representing inflows to the Juri River, and application of a hydraulic model to route the forecast runoff hydrographs through the valley and to determine flood depths and inundated area. Forecasts with long lead times would further require accurate quantitative rainfall forecasts over the catchment.

As discussed in the Concept Paper, such sophisticated forms of forecasting are, in our opinion, infeasible for the flashy rivers of the Northeast Region for several reasons which include:

- the difficulty of obtaining real time hydrometric data (especially from the catchment headwaters in India)
- the time required to actually produce such forecasts and then issue a warning (by the time a forecast is produced the flash flood to be forecast may already be receding)
- the cost and skilled resources needed to implement, operate, and maintain such a system

One of the principal objectives of the present study was to evaluate the use of much simpler forecast techniques for the flashy rivers of the Northeast Region which could be implemented, operated, and maintained on a local community or local government basis.

5.2 Lead Times and Forecast Reliability

The flood warning lead times desired by the people of the Juri valley were determined through interviews conducted in the course of the community survey program described in Chapter 3. Desired **minimum** lead times were approximately as follows:

- 2 hours to save human lives;
- 4 hours to secure food stocks and livestock; and,
- 15 hours to harvest some of the matured standing crops

In general, the shorter the lead time required of a flood warning, the greater the reliability of that warning. Ideally the warning lead time should be closely matched to societal needs. However, in practice, given that flood forecasts become increasingly unreliable as forecast lead times are extended, a compromise is often required between the warning lead time actually provided and societal expectations of lead time and forecast reliability. With any type of flood warning, the target population must be educated to the meaning and limitations of the warning and the uncertainties inherent in the warning.

The warning lead time provided by a flood warning system is the forecast lead time less the time required to translate the forecast into a warning and then disseminate that warning. For the purposes of this discussion we will assume that the time to translate a forecast into a warning, and the time to disseminate the warning are both minimal. The warning lead time is then synonymous with the forecast lead time. We will concentrate on the evaluation of the forecast lead time.

Flood forecasts with very short lead times can sometimes be based on direct measurements of water levels either at the damage centre of interest or at some nearby location where the water level provides an accurate index to the water level at the damage centre. A warning is simply issued when the water level exceeds some "critical level."

As the desired forecast lead times become longer, the warning system has to rely on less direct predictors of future water levels, and forecasts become progressively less reliable. There are a number of simple options for providing flood forecasts with extended lead times. The options for extending lead times evaluated in this study are based either on:

- the flood wave travel time from a point remote from the damage centre, or,
- the water level rate of rise at the damage centre of interest.

The possible use of meteorological observations to augment river water level observations is also discussed. More sophisticated options for extending warning lead times, such as use of weather radar and hydrometric data telemetry, were explored in the Concept Paper and found to be infeasible for reasons mentioned earlier.

5.3 Critical Water Level Warnings

A warning that a critical water level has been exceeded at or very close to a potential damage centre is the simplest form of flood warning and the one with the shortest lead time.

This type of warning system is attractive from a number of points of view:

- It is probably the most accurate type of system in terms of its ability to warn of a potentially damaging event; it simply advises the population that flooding is occurring now or is very close to occurring at the monitoring point.

- The equipment required to produce a warning is the simplest and most robust possible.

- Implementation is simpler and operation and maintenance costs are lower than those of a system providing extended warning lead times.

This type of system is probably most useful for providing warning of potentially catastrophic situations such as the overtopping of an embankment, with lead time of the order of minutes rather than hours. Note that the Juri is embanked at several places along the river including at Selua and Juri. However these embankments are relatively low and embankment overtopping or failure does not appear to pose a threat of catastrophic flooding. The approach has several drawbacks for general application in the Juri valley:

- It provides no indication of the maximum water level likely to be reached in the event and hence no indication of the area of inundation. It can be viewed more appropriately as a "wake-up" call or advisory of a potentially dangerous condition. Whether this results in serious flooding at a particular location would be left to the judgement of the affected population.

- The hydrometric data collected in the 1995 monsoon season indicates that the Juri River rises relatively slowly during flood, especially in its lower reaches. By and large, the population appears to be well attuned to conditions in the river. Since the river rises slowly, it is likely, at least during daylight hours, that the majority of people would know that the river is high without needing a warning system of this type. However, the interview program described in Chapter 3 did identify people who were taken unawares by flood at night. A critical water level warning could help in such circumstances, assuming that people could take appropriate measures to prepare for flood at night.

Critical water levels, defined as water levels above which damaging overbank flooding could start, were determined by survey at three of the key damage centres, Purba Botali, Selua, and Shilghat, as follows:

- Purba Botali 19.3 m PWD (corresponding discharge 200 cumecs)
- Selua 14.6 m PWD (corresponding discharge 260 cumecs)
- Shilghat 11.2 m PWD

The critical water level was exceeded only once in 1995 at Purba Botali, Selua, and Shilghat, during the flood of 16-24 June. Note, however, that because of an embankment failure, flooding at Selua started at a water level below the "critical" level. The maximum water level at Shilghat, of 11.42 m, was only slightly above the critical level and no flood damage was experienced.

During the June flood, once the critical water level of 19.3 m was exceeded at Purba Botali, the water level continued to rise for the next 10 hours to a peak water level of 20.2 m. The maximum rate of rise during that period was 0.15 m/hour. Maximum overbank rates of rise at other water level monitoring sites for the June flood were 0.10 m/hr at Selua and 0.04 m/hr at Shilghat.

Data available to date are insufficient to provide reliable estimates of maximum overbank rates of rise. However, if we assume the above rates are representative of overbank rates of rise during major floods there are things that could be done. For example, if people in non-embanked areas took precautionary measures as soon as the critical water level was reached, they would have several hours in which to secure their homes. They could also move livestock and food stocks before water levels rose sufficiently to seriously impede movement.

5.4 Warnings Based on Flood Travel Time

One of the simplest way of extending warning lead times is by taking advantage of the flood wave travel time from some upstream monitoring point to the damage centre of interest. So, for example, a warning that critical water levels will be exceeded at Selua could be based on water levels at Purba Botali and the flood wave travel time between Purba Botali and Selua.

The warning lead time that can be achieved through this approach depends on the length and hydraulic characteristics of the river reach between the monitoring point and the damage centre. However, on the Juri, there are two factors which greatly complicate simple application of this approach:

- the amount and timing of additional inflows to the river between Purba Botali and downstream damage centres such as Selua and Shilghat.

- the effect of variable water levels in Hakaluki *Haor* on the discharge rate at which flooding would start in the lower reaches of the river, such as at Shilghat.

In the absence of comprehensive hydrometric data, a simple hydraulic model of the Juri River was constructed from Purba Botali to Hakaluki *Haor*, using the MIKE 11 river modelling system. This model was used in conjunction with the short record of available hydrometric data to estimate the flood wave travel time between Purba Botali and Selua and to investigate the relationship between water levels in Hakaluki *Haor* and those at Shilghat for various flow rates at Shilghat.

Input to the model were observed discharge hydrographs at Purba Botali and concurrent hydrographs at three additional downstream points representing local inflow between Purba Botali and Shilghat. In the absence of more detailed information, the local inflow hydrographs were taken as the Purba Botali discharge hydrograph scaled on the basis of drainage area. The model's downstream boundary condition consisted of the observed stage hydrograph in Hakaluki *Haor*. The hydraulic geometry of the model was based on a total of 14 channel and flood plain cross-sections developed from field surveys and available topographic maps. The model was calibrated approximately to the available 1995 water level and discharge data.

The drainage area of the Juri River is about 420 sq km at Purba Botali (river km 30)[4], about 650 sq km at Selua (river km 15), and approximately 790 sq km at the most downstream damage centre at Juri (river km 0.0). As can be seen in the 1995 flood hydrographs shown in Figures 4.09 through 4.14, there is a considerable increase in runoff volume between Purba Botali and Selua. For the 1995 monitoring period from 14 April through 30 August, the runoff depth at Purba Botali was about 850 mm and at Selua about 1000 mm. (The total rainfall depth at Purba Botali over that period was 2160 mm.) On average then, runoff volumes at Selua are about 80 percent larger than volumes at Purba Botali for a drainage area that is 55 percent larger. Similar differences in runoff volume are apparent during the 1995 high flow events, so it is clear that local runoff downstream from Purba Botali could have a significant influence on flooding in the lower reaches of the river.

Comparison of flood discharge hydrographs and water level hydrographs (Figures 4.09 through

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[4] River km measured upstream from the Juri railway bridge

4.14) show that flood hydrographs start to rise almost simultaneously at Purba Botali, Selua, and Shilghat. Translation of flood hydrographs from Purba Botali to Selua is apparently masked by local inflows although there is a reasonably consistent difference in the timing of peak flows at those two points of about 10 hours. Similarly, there is a reasonably consistent difference in the timing of peak water levels between Purba Botali and Shilghat of about 25 hours.

For the high flow event of 18 June (the only event in which critical water levels were exceeded), the lag time between the exceedance of critical water levels at Purba Botali and Selua was 17 hours, and between Purba Botali and Shilghat 35 hours.

To gain more confidence in estimates of travel time, the MIKE 11 model was used to simulate the movement of the 16-21 June hydrograph from Purba Botali to Selua in the absence of local inflows. This simulation produced a minimum travel time from Purba Botali to Selua of about 15 hours but with significant attenuation of the peak.

The critical water level at Purba Botali of 19.3 m PWD corresponds to a discharge of 200 cumecs, while the critical water level at Selua of 14.6 m PWD corresponds to 260 cumecs. Note from Figures 4.09 through 4.14 that even though the runoff volume at Selua may be as much as 80 percent greater than at Purba Botali, the difference in peak flows is much less, averaging about 25 percent for the six high-flow events analyzed in detail. The MIKE 11 simulations and analyses of available data suggest that when the critical water level at Purba Botali is exceeded, the critical water level water level at Selua may not be exceeded. Whether it is or not depends on the amount of attenuation of the flood hydrograph and the amount of additional local runoff. The data available to date are insufficient to reliably determine under what conditions the critical water level at Selua will be exceeded given that the critical water level has been exceeded at Purba Botali. However, the lag time between exceedance of critical water levels at Purba Botali and Selua of about 17 hours as determined from the June flood data is probably reasonably reliable. Channel and flood plain characteristics between Purba Botali and Selua are fairly homogeneous and so the lag times to intermediate points can be determined by interpolation.

Predictions that critical water levels will be exceeded at Shilghat or Juri are further complicated by the fact that water levels at those points are a function of both the discharge **and** the downstream water level. In the dry season, the downstream water level is maintained at an artificially high level by temporary crossdams on the Continala distributary. These dams are generally washed out in pre-monsoon floods. Water levels at Shilghat then become controlled by the hydraulic characteristics of the downstream channel for as long as water levels in the *haor* remain low. However, water levels in the *haor* rise quite rapidly (over a period of several days) at the start of the wet season, with backwater effects then again extending from the *haor* up the Juri River some distance beyond Shilghat.

The relationship between water levels at Belagaon and Shilghat is illustrated by the 1995 water level data shown in Figure 4.02. Belagaon is located on the Continala distributary some 2 km below Juri and above the crossdams. After mid-June, the measurements at Belagaon are effectively measurements of water levels in Hakaluki *Haor*.

The MIKE 11 model was used to investigate the effects of various tailwater levels in Hakaluki *Haor* on water levels at Shilghat for a range of discharges. The results of this investigation are summarized in Figure 5.01. This shows the relationship between discharge at Shilghat and water level at Shilghat for various fixed water levels in Hakaluki *Haor*. Figure 5.02 shows the critical discharge at Shilghat as a function of Hakaluki *Haor* water level for a critical water level at Shilghat of 11.2 m PWD. On the basis of 1995 water levels recorded at Belagaon, the critical (i.e. flood producing) discharge at Shilghat is estimated to vary from about 400 cumecs at the end of the dry season to about 200 cumecs at the height of the monsoon season when water levels in Hakaluki *Haor* are at their highest.

It is clear that a forecast of the exceedance of critical water levels at Shilghat requires a forecast that a critical discharge (a function of Hakaluki *Haor* water levels) is exceeded. Unfortunately, estimates of the discharge at Shilghat, on the basis, for example, of discharge at Selua, are complicated not only by local inflows, but also by flood wave attenuation between Selua and Shilghat. The degree of attenuation is a function of the peak flow and flood volume at Selua, and, again, the water level in Hakaluki *Haor*. High water levels in Hakaluki *Haor* cause water to move into overbank storage upstream of Shilghat earlier than they would do otherwise.

Our evaluation of the hydrometric data from 1995 together with limited hydraulic simulations using MIKE 11 shows that available data are insufficient to establish the conditions under which the exceedance of critical water levels at Purba Botali will result in critical water levels being reached at downstream points. Additional information on the characteristics of local inflows downstream of Purba Botali may allow the development of reasonably reliable simple techniques to predict critical water level exceedance as far downstream as Selua on the basis of water levels at Purba Botali. However, reliable prediction that critical water levels will be reached in areas affected by backwater from Hakaluki *Haor* is sufficiently complex that hydrologic and hydraulic modelling would be required. The need for hydrologic or hydraulic modelling would immediately eliminate the possibility of a simple community based forecast and warning system for the lower reaches of the Juri.

Although we cannot, with available data, reliably predict the exceedance of critical water levels on the basis of water levels at Purba Botali, it appears that if critical water levels are exceeded throughout the catchment, then the lag time between the start of flooding at Purba Botali and at various points down the system would be of the order of hours. The lag time to Selua and Shilghat would probably be more than the 15 hours stated as being required to harvest some of the standing crops.

5.5 Warnings Based on Water Level Rate of Rise

The warning lead time at a monitoring point can be extended by using the rate of rise of discharge or water level. The rate of rise can be used to forecast the time at which the water level at the monitoring point would exceed a critical level. A rate of rise warning could be used in conjunction with estimates of flood wave travel time (see Section 5.4) to provide extended warning of flooding at a downstream damage centre at a later time.

Use of rate of rise introduces, however, opportunities for further inaccuracies in the warning lead time. As always, forecast accuracy decreases with increasing lead time. The principal difficulty in using rate of rise lies in predicting how the current rate of rise will change over the warning lead time. For example, will the current rate of rise be maintained until the critical water level is reached at the monitoring point, or will the rate of rise drop and the flood hydrograph achieve its peak before the critical water level is reached.

The maximum observed water level rises in 1 hour, 3 hours, 6 hours, and 12 hours for the six high flow events observed on the Juri in 1995 are shown in Table 5.1. The maximum observed rates of rise are similar for each of the six high flow events at Purba Botali and Selua. Rates of rise are lower at Shilghat and substantially lower after the flood event of 16-21 June than before. The dramatic reduction in maximum rates of rise at Shilghat in the July and August events is due to increased water levels in Hakaluki *Haor* and the resultant backwater effects at Shilghat.

Water level data at Purba Botali were analyzed as follows to demonstrate how a simple rate of rise approach could be used to produce a 4-hour warning at Purba Botali that the critical water level of 19.3 m PWD would be exceeded:

i) Assuming (interpolating from Table 5.1) a maximum likely water level rise over 5 hours of about 2 m (maximum average rate of 0.4 m/hour), active monitoring of water level rise would be instituted at a level of (19.3 - 2.0) or 17.3 m PWD.

ii) The time required for water levels to rise 0.4 m to elevation 17.7 m PWD would be observed and the rate of rise computed. This might, for example, be 0.3 m/hour.

iii) The "initial warning level" is computed at which a warning must be issued to provide 4 hours notice of the possible exceedance of the critical water level, assuming that the rate of rise computed in step ii) is maintained. Thus, if the rate of rise in step ii) is 0.3 m/hour, 4 hours notice would be provided when the water level reaches (19.3 -1.2) or 18.3 m PWD.

iv) If the initial warning level from step iii) is less than the current water level then a warning would be issued immediately, indicating that the critical water level will probably be exceeded in less than 4 hours.

v) If the initial warning level from step iii) is greater than the current level, then the time of rise to the initial warning level is monitored. When the initial warning level is reached, the rate of rise is updated and the warning level re-computed assuming that the updated rate of rise will be maintained for the next 4 hours.

vi) Water levels are monitored until either:

- the updated warning level is reached, at which time a warning is issued, or,
- the water level peaks below the warning level and starts to recede.

If the approach outlined above had been implemented at Purba Botali for the 1995 monsoon season, the system would have been "activated" a total of 10 times, i.e. whenever the water level exceeded 17.3 m PWD (corresponding discharge about 73 cumecs).

The steps that would be taken in issuing a warning for each of these 10 events are outlined in Table 5.2. It can be seen that this procedure would have resulted in the release of a flood warning with a minimum four hours lead time for the events of 16-21 June and 12-19 August. Flooding actually occurred during the June event. However, the actual warning lead time provided would have been of the order of 12 hours instead of the required 4 because of a substantial decrease in the rate of rise of water level after the warning had been issued. The hydrograph in the August event similarly showed a substantial decrease in the rate of rise after the warning had been issued, and the water level actually peaked at 19.2 m, 0.1 m below the critical water level.

Similar analyses for 4-hour warnings were investigated using data at Selua and Shilghat. At Selua, it was assumed that the maximum likely average rate of rise over 5 hours was about 0.30 m/hour. Thus the warning system would be activated at elevation (14.6 - 1.5) or 13.1 m PWD. At Shilghat, the maximum rate of rise appears to depend on water levels in Hakaluki *Haor*. A maximum likely average rate of rise over 5 hours was assumed to be 0.17 m/hr prior to July 1, with the warning system activated at (11.2 - 0.85) or 10.35 m PWD, and 0.05 m/hr after July 1, with the warning system then activated at (11.2 - 0.25) or 10.95 m PWD. The steps taken in determining whether to issue a warning for the 1995 hydrometric data are summarized in Tables 5.3 and 5.4 for Selua and Shilghat respectively.

The results in Tables 5.3 and 5.4 show that a warning would have been successfully provided for the June flood at both Selua and Shilghat. The warning at Selua was quite accurate. The warning at Shilghat only provided 3 hours lead time instead of the target 4 hours because of an increase in the very low rates of rise after the warning had been issued.

For the short period of hydrometric data available, the rate of rise approach appears to be moderately successfully in predicting with a minimum 4-hour lead time that critical water levels will be exceeded. The results would presumably have been more accurate for a 2-hour lead time.

The above approach assumes that the maximum rates of rise observed in 1995 are reasonably typical of maximum rates of rise found in severe floods. The figures from 1995 only include one event with significant overbank flows, that of 16-21 June. If an approach such as that outlined above is adopted, then the methodology should obviously be refined as experience is gained in producing flood warnings in the Juri valley. Additional data are necessary to establish more reliably the level at which such a system should be activated. This is particularly true for Shilghat where water level fluctuations depend on the water level in Hakaluki *Haor* and are much smaller than at either Selua and Purba Botali.

5.6 Use of Meteorological Observations

The original Concept Paper raised the possibility of using visual observations of meteorological conditions over the Indian portion of the Juri catchment to forecast the occurrence of floods on the Juri River. Observations from the Chungabari observation post during the 1995 monsoon season (see Section 4.6 and Tables 4.2 through 4.7) demonstrate unequivocally that such an approach is infeasible; visibility during each flood event in the 1995 monitoring season was less than about 2 km and occasionally nil. Although lightning could be seen during low visibility conditions there is no apparent relationship between the occurrence of lightning and severe flood-producing storms.

The idea of investigating the use of visual observations of conditions over India as a means of forecasting floods appears to have arisen because of: i) the difficulty of obtaining real time rainfall data from the Indian headwaters of the flashy rivers, and ii) the perception that data from India were absolutely necessary to forecast the occurrence of flash floods with any degree of reliability.

It appears from this study, however, that, at least in the Juri catchment, there is a reasonably strong relationship between large rainfall amounts in Bangladesh close to the Indian border and the occurrence of floods (see Figures 4.05 and 4.06). Daily rainfall amounts in excess of about 60 mm consistently produced a high flow event on the Juri. In large flood-producing events it appears that the weather systems responsible for rainfall are of a large enough scale that they cover not only the Indian headwaters of the Juri but they also extend well into Bangladesh. We therefore assume, from the relatively consistent response, that rainfall depths at Purba Botali are somewhat representative of catchment-wide rainfall amounts during storm events.

Rainfall and discharge data for the six largest flow events of 1995 were analyzed in detail in Chapter 4 and the results were presented in Table 4.1. It can be seen from Table 4.1, that, as might be expected, the detailed hydrologic response of the Juri at Purba Botali is heavily dependant on antecedent moisture levels over the catchment. The high flow in May 1995, with a peak flow of about 160 cumecs, resulted from 235 mm of rainfall over 2 days at the start of the monsoon season when the ground was dry and rainfall losses large. The second largest event in the monitoring period occurred in mid August. This event had a peak flow of 194 cumecs and resulted from a total of only about 155 mm of rainfall in 2 days when the ground was wet and rainfall losses relatively low.

Although the occurrence of heavy rainfall at Purba Botali is certainly indicative of future high flows (as is already known by the local population - see Section 3.5.1) available data are again insufficient to form the basis for a quantitative flood forecast (i.e. one which either states that a critical water level will be exceeded or in which flood magnitude and timing are predicted). However, with additional data, the **potential** clearly exists for using rainfall data observed at Purba Botali to forecast floods. The relatively large and consistent lag between the centre of mass of the rainfall hyetograph and the resultant discharge hydrograph is of particular interest.

The greatest difficulty in using rainfall data to forecast flooding would appear to be the strong dependence of the hydrologic response on antecedent moisture conditions. It appears that reliable forecasting would require some form of hydrologic modelling that accounts for antecedent moisture levels. This level of sophistication would likely preclude a community-based approach to forecasting using quantitative rainfall data.

5.7 Potential for Community Based Flood Warning

The previous sections of this Chapter presented an evaluation of a number of simple techniques for forecasting floods on the Juri River. The potential clearly exists for using simple techniques such as rate of rise or flood wave travel time to forecast the occurrence of floods with lead times from about 4 hours at Purba Botali to 12 hours or more at Shilghat. However, the body of hydrometric data available to date is insufficient to establish a reliable forecast methodology.

Of the techniques evaluated, the rate of rise approach implemented at individual damage centres in the Juri valley appears to be the most practical. The approach has a number of advantages for a local community or local government warning system:

- It can be implemented at individual villages and damage centres and is not reliant on communication from upstream sites.
- The technique is sufficiently simple that it could be operated by suitably trained village observers.

- The system should be quite robust since only one basic piece of electro-mechanical equipment would be required. This would be a sensor which activates the system (summons the operator) when a base warning elevation has been reached. Beyond that point the system would be operated manually until such time as a warning is issued. The warning for a village system could be broadcast by megaphone.

- The evaluation presented in Section 5.5 shows that the rate of rise approach has the potential to provide up to 4 hours warning that a critical water level will be reached or exceeded. This was the minimum lead time stated in community surveys as being required to save livestock and food stocks from flooding.

- For a warning with a four hour lead time, the rate of rise approach is probably the most reliable of the techniques evaluated given the body of hydrometric data available to date.

The principal disadvantage of the rate of rise approach, is that it only gives warning that a critical water level will be exceeded. It gives no information on the maximum water level expected. However, it could be used to give warning that the water levels at a specific village or over a specific escape route would rise to such a level that people would **have** to move to high ground. In this case the definition of "critical level" would be the level at which evacuation would be needed rather than the level at which overbank flooding starts. Other alternative definitions of "critical level" are of course possible. More sophisticated methods would be required to provide information on maximum levels expected. In our opinion, as stated previously, those techniques are infeasible for the flashy rivers of the Northeast Region.
The important question then is: "Would people make use of a warning that tells them that a critical water level will be exceeded in 4 hours"? The results of the community survey program described in Chapter 3 suggest that the answer to that question may be "No." As discussed in Chapter 3, although the population has expressed a definite interest in a flood warning system, they also face a number of severe disincentives to evacuating their homes during flood and the existence of a warning system by itself may be of limited practical value. The fact that the Juri River responds quite slowly to flood means that the valley is not subject to sudden catastrophic inundation; to a certain extent the population can afford to watch a flood develop and judge for themselves when they have to leave.

In short, although the potential exists for producing warnings of the occurrence of floods, such warnings may not be widely used. In our opinion the only way in which to judge the value of a warning system would to implement a system on a trial basis on two or three villages in the upper Juri Valley. Of more immediate value to the population would be a flood disaster management program. We recommend that a flood warning system be developed on a trial basis as one component of a broader disaster management program. This is discussed in the following chapter.

6. FLOOD DISASTER MANAGEMENT NEEDS

6.1 Introduction

From the surveys of the affected population described in Chapter 3, it appears that a flood warning system, as originally envisaged in the Concept Paper, may be of only limited value to the people of the Juri valley. The hydrologic data collected indicate that reasonably reliable forecasts of impending flooding could be provided with lead times of at least four hours. The social inquiry, however, indicates that a flood warning should probably constitute only one part of a comprehensive disaster management approach to flood planning.

To reiterate some of the key findings from Chapter 3:

- There are comparatively few deaths as a direct result of flooding. People are well attuned to river conditions and are apparently aware that they are unlikely to be overrun by a sudden catastrophic increase in flood levels. The deaths that do occur are primarily accidents (e.g. falling into fast flowing water from a raft or place of refuge) or a result of people staying in their homes to protect belongings until it is too late to leave safely.

- People are very reluctant to leave their homes during flood because of fear of theft, and lack of suitable flood refuges for themselves, their livestock, and their moveable property.

- Once a decision is made to evacuate, people face severe difficulties reaching flood refuges because of lack of safe escape routes and shortage of water transport (boats, rafts, etc).

- Food and seed stocks are often stored in containers which are difficult to move in the event of flood.

The existence of a flood warning system by itself is unlikely to alter the population's immediate response to floods. For example, as pointed out earlier, even if a flood warning were provided, the problem of theft will not be diminished and people will continue to stay as long as possible in their homes to protect their belongings. Considerably greater benefits could be derived from a more general flood disaster management program within the Juri valley. A flood warning might provide one component of such a plan. A disaster management program might include elements which would:

- Provide for a more comprehensive and predictable community response to flood events; and by this reduce the population's exposure to flood related hazards;
- reduce flood impact on foodstocks and livestock;
- provide more accessible and better equipped flood shelters;
- alleviate suffering to the extent possible during and in the aftermath of floods.

While some possible components of such a program are discussed in the following sections the essential feature of a comprehensive participatory flood disaster management project is that it should be based on community organizations constituted for that purpose. The sections of this chapter are intended therefore to be indicative rather than prescriptive. It is assumed that any flood disaster management program would involve mobilizing local people to participate in the y8

shaping and implement a comprehensive program of their own design. This would need to be supported by a funding mechanism which could also provide funds for improved infrastructure. It would also usefully be integrated with the Bangladesh NGOs involved in disaster management: the Disaster Forum.

The sections which follow sketch out some of the considerations that would be fed into such a process. They speak to the disaster management plan elements listed above.

6.2 Community Organization

A participatory flood management plan needs to start with a comprehensive approach to mobilizing and organizing the whole flood-vulnerable community of the Juri River valley to focus on their flood related needs.

It is important to emphasize again here that the flood management organization itself would be the creation of local communities rather than that of outsider experts. The following steps are suggested which could constitute such a program. The process would involve a number of iterations and would have separate facilitators for men and women.

The steps in developing a community response program would include the following:

1. Field a number of teams of Community Organizers (COs) plus a supervisor with experience in community-based flood management. The number of COs will be determined by how rapidly it is desired to accomplish the objectives of the program. It is assumed below that the number would be about eight.

2 Establish a field office for disaster management.

3. Hold about four to six public meetings to advise people of the purposes of the program.

4. Visit flood-prone villages and set up flood disaster planning organizations within each village.

It might be assumed that the initial village polling and organization should be scheduled over a period of about six months. NERP's records list 86 villages that are rated as having either "high" or "moderate" flood hazard. If a two-person team must work for a full week with each village within the six month period then about four teams would be needed.

The process of setting up flood management planning committees in flood-prone villages can act as a focal point for discussion on what remedies need to be undertaken. These discussions can be guided by a specialist in flood management. They would include discussions focussed on the problems of theft, flood-proof storage for food and seed stock, village-based flood shelters and all the other issues that constitute villagers' flood problems.

When villagers have become involved in working out what needs to be done to improve flood preparedness, they can be encouraged to propose members for a number of flood preparedness committees. These committees need to be integrated into an organization structure that can be integrated with a higher level organization. It is suggested that, consistent with current FPCO perspectives, the higher-level organization can be a Project Coordinating Committee (PCC).

Flood preparedness committees can then prepare a set of flood preparedness plans, perhaps on a union by union basis. The result of this would have the potential to become a donor-fundable project as well as a model for how participatory flood management can be undertaken in Bangladesh.

6.3 Reduce the Population's Exposure to Flood-related Hazards.

The majority of deaths directly attributable to flooding occur when people are attempting to reach safe refuge. They have usually stayed in their homes to protect their belongings from theft and have stayed too long to safely leave. From the fieldwork described in Chapter 3, it appears that most of those who are drowned in this manner have no access to boats or rafts and are attempting to reach safe ground by wading or swimming.

The flood management program should investigate methods of conveying to villagers information with which they can better judge the seriousness of their situation and the risks they face in reaching safe ground. One possible approach would be to install flood markers in the villages, graduated to indicate the depth of water likely to be encountered along escape routes to safe ground. Such markers could also be used to determine the rate of rise of water level.

The majority of deaths directly attributable to floods occur when people are trying to reach safe ground or shelters. Refuge is reached by wading or swimming, or by using rafts, or, more rarely, by country boat.

Those who wade or swim are hampered by the high velocity of floodwaters. Women face the additional impediment of having to wade or swim in saris. People forced to wade are further hampered by difficulty in following submerged roads or escape routes. Flood water are generally so turbid that submerged roads or tracks cannot be seen.

In many locations, refuge can only be reached by boat or raft. This is particularly true along the Juri River between Selua and Purba Botali, where the closest safe high ground is immediately across the river in India. Very few people in the Juri valley actually own boats, in part because of restrictions imposed by BDR. During floods, people frequently build rafts from banana stems or bamboo. There is however a shortage of suitable building material.

For communities where escape by wading is possible, a flood disaster management program should:

- Identify escape routes for each affected community and educate the community as to the use of those routes.
- Mark escape routes by means of trees or other markers so the escape route can be safely followed during flood.
- If necessary, raise local low points in submerged escape routes to eliminate particularly dangerous points.
- Raise heavily-used escape routes above typical high water levels, providing culverts and/or bridges as necessary to maintain the flow of flood waters

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For communities where the only feasible means of escape is by boat or raft, a flood disaster management program could:

- Promote the growth of banana, bamboo or other material suitable for building rafts in sufficient quantity to meet needs during flood.
- On a community organization level establish a program for bringing boats up the Juri valley for transporting people to high ground during flood.
- Also on a community organization level, establish procedures with timber merchants for wider distribution of bamboo rafts on loan to transport people and belongings to high ground.

Identification of escape routes should be coordinated with the identification of flood shelters and refuges as discussed in Section 6.4.

6.4 Reduce Flood Impact on Foodstocks and Livestock

The disaster management program should investigate and promote flood proofing methods for reducing flood damage to homesteads and property, particularly food stocks.

The community survey program in Chapter 3 found that there are very significant losses of food and seed stocks during flood. Rice for example is often stored as paddy in large woven bamboo baskets in people's houses. Up to 10 or 12 *maunds* of paddy rice may be stored in each basket. Since a full basket may weigh more than 300 kg it cannot realistically be moved during flood. Furthermore, under present conditions, people have no means of transporting large quantities of food or seed stocks and no safe place to move them to. Various alternative methods should be explored for floodproofing food stocks.

Homestead buildings suffer serious damage during floods. Damage may be due to either the high velocities of overbank flow or waterlogging of mud walls. High velocity flows can simply knock out the walls of buildings or push them off their footings. After prolonged inundation, mud walls disintegrate and collapse.

Simple modifications to building practices should be explored with a view to reducing flood damage. This may take the form, for example, of introducing an admixture to mud walls which extends their life during flood.

6.5 Provide More Accessible and Better Equipped Flood Shelters

As pointed out in Chapter 3, there is a serious shortage of suitable shelters in which people, with their belongings, could take refuge from flood. The shelters that are available are too small for the number of people requiring temporary accommodation and are often too far from those in need. Suitable refuges for livestock are also too few in number and too far from the place of need. There is a similar and perhaps even more serious shortage of food and safe drinking water during flood. Although there are no exact figures on disease-related deaths during and immediately after floods in the Juri valley, the general experience in Bangladesh is that more people die from diarrhoeal disease as a result of having to drink contaminated water than drown in flood waters.

The disaster management program should:

- Identify shelter and refuge requirements for the affected population, their belongings and their livestock.
- Complete an inventory of existing buildings that are or could be used for shelter and arrange for their use in the event of flood or other disaster.
- Improve existing shelters to provide.
- access to adequate safe water supply.
- access to adequate community food stocks.
- sufficient sanitary latrines.
- separate accommodation for women.
- Where insufficient shelters exist within reasonable proximity of the affected population, pursue the construction of local elevated earthen platforms which could provide refuge during floods.

6.6 Flood Forecasting/Warning

As has been indicated in several places a flood warning, or flood forecasting system may be able to make a contribution to a flood disaster management plan. Several simple approaches to flood forecasting were evaluated in Chapter 5 and it was concluded that a rate of rise technique implemented at individual villages was the best approach given the current body of hydrometric data. This technique could provide four hours warning that a critical water level will be reached. A lead time of four hours was estimated by villagers as being the minimum necessary to save livestock and other moveable property from floods. The technique is described below.

To implement a flood warning system would require the following steps at each target village:

- explain to the local villagers the function of warning system, and the meaning of the warnings to be issued.
- in consultation with the local villagers, identify the appropriate critical water level for the warning system.
- also in consultation with the villagers outline a recommended course of action once a warning has been issued.
- install a water level sensor and staff gauge, and establish the warning system activation or "wake-up" level.
- determine the rate of rise procedure appropriate to the specific village.
- identify and train one or more village observers to perform the necessary rate of rise computations and issue flood warnings.

The system would operate as follows:

- once the activation or wake up level was reached, the water level sensor (installed in a stand pipe on the river bank) would ring a bell arousing the observer.
- the observer would then proceed to measure water level rates of rise and compute warning levels as outlined in Section 5.3.
- once the warning level was reached, warnings would be issued by megaphone.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The study described in this report involved two basic components which were executed concurrently during the monsoon season of 1995. These were:

- a program of community surveys and interviews to characterize the population affected by flood in the Juri River valley, including the size and distribution of the affected population, and the population's response to floods; and

- a program of hydrometric data collection and analysis which was undertaken to characterize the hydrologic response of the Juri catchment during floods, and to evaluate the technical feasibility of producing flood forecasts with sufficient accuracy and lead time to meet the needs of the affected population.

7.2 Conclusions from the Community Survey Program

The principal finding of the community survey program is that although the people of the Juri River valley often endorsed the potential usefulness of flood warnings, their behaviour during floods is so severely constrained by other factors that they may not take advantage of such warnings in practice. The reasons for this are related to the hydrology of the Juri catchment, a lack of suitable infrastructure and institutions for limiting or managing flood disasters, and societal behaviour in general. More specifically the study found that:

- Although the Juri River valley suffers from frequent severe floods, the river, especially in downstream portions of the catchment, usually rises sufficiently slowly that it does not constitute a deadly threat. The nature of flooding is such that the population, which is generally well attuned to river conditions, is not at risk of being inundated or overrun by a sudden, unexpected rise in water level. Flash floods as defined by a sudden catastrophic rise in water levels do not occur on the Juri.

- People are extremely reluctant to leave their homes during flood because of a well-founded fear of theft. They stay in their homes until water levels are such that they are compelled to leave to reach high ground safely. The availability of a flood warning may not induce people to leave their homes any earlier.

- While fear of theft is probably the greatest single deterrent to people evacuating their homes, the lack of suitable shelters or refuges from flood is also a significant problem. Many people have no safe place to go to take refuge from flood and no access to safe drinking water or food. The result is again a reluctance to leave their homes; a reluctance that again may not be affected by the availability of a flood warning.

- There are comparatively few deaths directly attributable to floods in the Juri catchment. Deaths that do occur are often attributable to accidents, the lack of a safe refuge from flood, or the failure of people to leave their homes in advance of rising water, primarily because of a fear of theft. Consequently, the availability of a flood warning system would probably not reduce the already small number of flood-related deaths in the Juri valley.

- The population suffers from significant losses of livestock, food stocks, and seed stocks during floods. The ability to save this property is limited by shortage of suitable refuges and a shortage of suitable transportation. It is noted that food stocks such as paddy rice are often kept containers weighing 300 kg or more which cannot realistically be moved.

In summary, a flood warning system in isolation may be of limited value to the people of the Juri Valley. Greater benefits would be derived by improving flood disaster management in the catchment. A flood disaster management program, of which flood warning could form one component, should be a community based program which focusses on: improving the means by which people reach safe ground, improving flood refuges and shelters, and developing and promoting flood damage reduction techniques such as flood warning and flood proofing. An outline of the components of a flood disaster management program is provided in Chapter 6.

7.3 Conclusions from the Hydrometric Data Collection Program

Detailed rainfall, water level, and river discharge data were collected from the Juri catchment during the 1995 monsoon season. Meteorological data were also collected from an observation post on a hilltop close to the Indian border to determine whether visual observations of conditions over the Indian headwaters of the catchment could be used to forecast the occurrence of floods. The river experienced one significant overbank flood in the 1995 monsoon season, two moderately high bank-full flow events, and three smaller events. The principal conclusions are:

- Because of poor visibility, visual observations of conditions over India are not possible during flood events and hence are of no value for forecasting floods in the Juri catchment.

- The hydrologic response of the Juri catchment during the 1995 monsoon season was slower than had been expected. The time to peak of floods varied from an average of about 24 hours at Purba Botali, where the river first enters Bangladesh, to about 60 hours at the township of Juri just above the point at which the river discharges into Hakaluki *Haor*.

- The observed rates of rise on the Juri River are sufficiently low that reasonably reliable forecasts of the exceedence of critical water levels can be made using a simple rate of rise forecast for lead times of up to about 4 hours.

- Evaluation of the 1995 hydrometric data suggests a reasonably strong relationship between rainfall observed in Bangladesh and flood events on the Juri. It had previously been thought that rainfall/runoff forecasts of floods on the flashy rivers of the Northeast Region could only be done using data from India. It now appears that flood-producing weather systems on the Juri are large enough that they extend from the Indian headwaters into Bangladesh. Data collected in 1995 are insufficient to develop reliable rainfall/runoff relationships, but the data collected to date do show potential for rainfall/runoff forecasts.

7.4 Applicability of Findings to Other Rivers of the Northeast Region

It is not clear to what extent the findings of the work on the Juri River can be generalized to other flashy rivers of the Northeast Region.

The findings of the hydrometric data collection program is probably transferable in a general sense to other low gradient "flashy" rivers originating in Tripura State, such as the Khowai, Dhalai (S), and Manu. These low gradient rivers can be expected to have a slow hydrologic response similar to that of the Juri. However, the hydrologic response will, of course, differ in detail, depending on factors such as catchment area and shape, soil type, slope etc..

One of the greatest differences between the Juri and the other Tripura rivers is that the Juri has no or very low embankments, while the Khowai, Dhalai(S) and Manu all have high embankments. While these high embankments may protect the population from smaller frequent floods, the risk of catastrophic flood damage due to embankment failure is much higher on the these rivers than on the Juri. As a result, the population's response to flooding (due to embankment failure) may be quite different to the response on the Juri.

The findings of the hydrometric data collection program are almost certainly not generally applicable to the flashy rivers originating in Meghalaya. The Meghalaya rivers are at least an order of magnitude steeper than the Juri River and can be expected to have a very different and much more rapid hydrologic response. In fact, NERP community organisers witnessed a hydraulic bore and very rapid water level rise on the Someswari River at Durgapur just downstream from the Meghalaya border in June 1995.

The somewhat unexpected finding in the Juri catchment that rainfall data collected in Bangladesh may be of value in forecasting floods originating in the headwater catchments in India, may hold for the Meghalaya rivers. However, the nature of the catchments (aspect, slope, size, shape, etc) is sufficiently different that a hydrometric data collection program would be required on one or more of the Meghalaya rivers to determine whether this, in fact, is the case.

The community response to floods on the Juri is almost certainly conditioned to some extent by the slow hydrologic response of the river. Rates of rise are slow enough that the population can afford to watch the flood develop and evacuate their homes in a relatively orderly manner. On the Meghalaya rivers, however, the hydrologic response is very rapid and people would probably have very little warning of impending, possibly catastrophic, floods. Consequently, flash flood warnings on the Meghalaya rivers, if reliable, may be of more immediate practical value than those on the Juri.

7.5 Recommendations

Recommendations for follow-up work are provided in 2 areas:

- development and implementation of a flood disaster management program in the Juri River valley;
- continued hydrometric data collection on the Juri River (contingent on the implementation of a flood disaster management program);

Flood Disaster Management in the Juri Valley
It is apparent from this evaluation study that there is potential for producing reasonably reliable flood warnings on the Juri River. However, in isolation, these warnings may be of little practical value to the population of the valley because of a variety of constraints that may prevent people from taking action to reduce or avoid flood damages once a warning has been issued. Greater benefit could be realised from a broader flood disaster management program, of which flood warning could form one component.

We therefore cannot recommend implementation of the pilot flood warning project on the Juri River, as originally proposed in the September 1994 Concept Paper. We recommend instead the development and implementation of a pilot flood disaster management program for the Juri valley as outlined in Chapter 6 of this report. The flood disaster management program should be implemented on a trial basis at three small flood prone villages adjacent to the Juri River just downstream from the Indian border; Purba Botali, Biraintail, and Konagaon.

Provision should be made for monitoring the community response to the proposed disaster management program and to the flood warnings issued as part of that program. Of particular value would be information on the actual (rather than theorized) response of the community to flood warnings. Such monitoring should extend for a minimum period of 3 years to assess the sustainability of the program and warning system.

Continued Hydrometric Data Collection on the Juri River
If the recommendation for developing a flood disaster management program is accepted, then additional hydrometric data should be collected concurrently from the Juri catchment. This will not only provide data with which to assess the value of the pilot disaster management program, but will also allow the refinement of flood forecast techniques.

Although the rate of rise forecast technique described in Chapter 5 can be implemented on the basis of available hydrometric data, the reliability of warnings could be improved if additional flood data were available. The development of reliable warnings with longer lead times, for example based on flood wave travel time, would also require additional hydrometric data.

Data to be collected should consist of:

- hourly water level data at Purba Botali, Selua, Shilghat and Belagaon
- 3-hour rainfall depths at Purba Botali
- river discharge measurements near Purba Botali and Selua to refine existing stage-discharge relationships

APPENDIX A

Table 4.1

Analysis of Hydrologic Response for High Flow Events at Purba Botali (April - August 1995)

Event Period of Analysis	Peak Discharge (cumecs)	Time of Peak	Total Runoff (mm)	Direct Runoff (mm)	Time to Peak (hours)	Maximum Rate of Rise (m/hr)	Maximum 3-hr Rainfall in 36 hours Prior to Peak flow (mm)	Rainfall Depth (mm) in Period Prior to Peak Flow of:			Approximate Lag to Peak (hours)	Direct Runoff as Percentage of Total Rainfall
								24-hrs	36-hrs	Total		
00:00 17 May - 23:00 19 May	158	06:00 18 May	54	45	30	0.50	53	136	219	235	21	19
06:00 13 June - 12:00 15 June	105	22:00 13 June	26	20	16	0.47	48	97	98	105	13	19
12:00 16 June - 00:00 21 June	284	22:00 17 June	113	92	34	0.43	62	138	212	212	22	43
00:00 19 July - 00:00 23 July	101	04:00 21 July	47	32	12	0.37	65	42	84	232	9	14
21:00 26 July - 00:00 29 July	110	22:00 27 July	42	30	12	0.50	19	71	83	83	11	36
14:00 12 August - 00:00 17 August	194	19:00 14 August	112	93	53	0.39	40	21	95	148	28	63

Notes:
1. Runoff depths corrected to eliminate estimated runoff due to rainfall subsequent to peak flow.
2. Direct runoff is total depth less estimated base flow contribution.
3. Runoff depth based on estimated drainage area at Purba Botali of 420 sq km.
4. Time to peak is total time of rise (to first peak in multiple peak hydrographs)
5. Lag to peak is approximate time from centre of mass of rainfall to peak flow (to first peak in multiple peak hydrographs)
6. Rainfall measured at Purba Botali.

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Table 4.2

Meteorological Observations at Chungabari for the Period 16-18 May 1995

Date	Time	Rainfall (mm)	Air Temperature (°C)	Wind		Visibility	Lightning	Thunder
				Direction	Strength			
16 May	06:00	8	24	E	Moderate	Poor	None	None
	09:00	8	26		Calm	Poor	None	None
	12:00	3	26		Calm	Poor	None	None
	15:00	5	26	E	Slight	Poor	None	None
	18:00	6	24	W	Moderate	Poor	None	None
	21:00	No observations						
17 May	00:00	No observations						
	03:00	No observations						
	06:00	78	24	SE	Strong	Poor	None	None
	09:00	15	22	E	Strong	Poor	None	None
	12:00	27	23	E	Very Strong	Nil	None	None
	15:00	31	24	W	Strong	Poor	None	None
	18:00	12	22	Variable	Gusty	n/r	Occasional	None
	21:00	No observations						
18 May	00:00	No observations						
	03:00	No observations						
	06:00	36	23	SE	Strong	Poor	None	None
Juri River at Purba Botali peaked at 07:00 18 May at 158 cumecs								

Notes: The Chungabari observation post was only staffed during daylight hours for this period

n/r = not recorded

Table 4.3

Meteorological Observations at Chungabari for 13 June 1995

Date	Time	Rainfall (mm)	Air Temperature (°C)	Wind		Visibility	Lightning	Thunder
				Direction	Strength			
13 June	03:00	8	22	Variable	Gusty	Poor	None	None
	06:00	32	22	S	Very Strong	Poor	None	None
	09:00	65	22	Variable	Gusty	Poor	None	None
	12:00	7	23	Variable	Gusty	Poor	None	None
	15:00	10	23	Variable	Gusty	Poor	None	None
	18:00	0	25	S	Strong	Poor	None	None
	21:00	0	25	Variable	Gusty	Poor	None	None
Juri River at Purba Botali peaked at 22:00 13 June at 105 cumecs								

Table 4.4

Meteorological Observations at Chungabari for the Period 16-17 June 1995

Date	Time	Rainfall (mm)	Air Temperature (°C)	Wind		Visibility	Lightning	Thunder
				Direction	Strength			
16 June	06:00	0	27	S	Very Strong	Poor	None	None
	09:00	0	27	S	Very Strong	Poor	None	None
	12:00	30	24	Variable	Gusty	Poor	Occasional	Frequent
	15:00	24	23	SE	Strong	Poor	n/r	Occasional
	18:00	3	23	SW	Strong	Poor	None	None
	21:00	23	23	S	Strong	Poor	Frequent	n/r
17 June	00:00	112	23	S	Moderate	Poor	Continual	None
	03:00	15	23		Calm	Poor	Frequent	None
	06:00	75	22	S	Strong	Poor	Occasional	None
	09:00	8	22	S	Moderate	Poor	None	None
	12:00	13	23	n/r	n/r	Poor	None	None
	15:00	4	24		Calm	Poor	None	None
	18:00	0	23	S	Moderate	Poor	None	None
Juri River at Purba Botali peaked at 22:00 17 June at 284 cumecs								

Note: n/r = not recorded

Table 4.5

Meteorological Observations at Chungabari for the Period 20-21 July 1995

Date	Time	Rainfall (mm)	Air Temperature (°C)	Wind		Visibility	Lightning	Thunder
				Direction	Strength			
20 July	03:00	0	28	S	Moderate	Poor	None	None
	06:00	0	26	SW	Slight	Poor	None	None
	09:00	0	26	S	Moderate	Poor	None	None
	12:00	0	25	S	Moderate	Poor	None	None
	15:00	0	26	SW	Strong	Poor	None	None
	18:00	33	26	SW	Strong	Poor	Occasional	None
	21:00	0	26	SW	Strong	Poor	Frequent	None
21 July	00:00	0	26	SW	Very Strong	Poor	None	None
	03:00	0	26		Calm	Poor	None	None
Juri River at Purba Botali peaked at 04:00 21 July at 102 cumecs								

Table 4.6

Meteorological Observations at Chungabari for the Period 26 - 27 July 1995

Date	Time	Rainfall (mm)	Air Temperature (°C)	Wind		Visibility	Lightning	Thunder
				Direction	Strength			
26 July	21:00	20	26	S	Moderate	Poor	None	None
27 July	00:00	15	27	S	Moderate	Poor	None	None
	03:00	0	28	S	Strong	Poor	None	None
	06:00	0	28		Calm	Poor	None	None
	09:00	0	27		Calm	Poor	None	None
	12:00	16	25	S	Strong	Poor	Occasional	None
	15:00	3	25		Calm	Poor	None	None
	18:00	0	25		Calm	Poor	None	None
	21:00	0	25		Calm	Poor	None	None
Juri River at Purba Botali Peaked at 23:00 27 July at 110 cumecs								

Table 4.7

Meteorological Observations of Chungabari for the Period 13-14 August 1995

Date	Time	Rainfall (mm)	Air Temperature (°C)	Wind		Visibility	Lightning	Thunder
				Direction	Strength			
13 Aug	03:00	11	26	S	Very Strong	Poor	None	None
	06:00	5	24	S	Very Strong	Poor	None	None
	09:00	16	24	S	Moderate	Nil	None	None
	12:00	14	25	S	Strong	Nil	None	None
	15:00	26	24	S	Strong	Nil	None	None
	18:00	9	24	S	Moderate	Poor	None	None
	21:00	0	23	S	Moderate	Poor	None	None
14 Aug	00:00	0	24	S	Moderate	Poor	None	None
	03:00	16	23	Variable	Gusty	Nil	None	None
	06:00	7	23	Variable	Gusty	Poor	None	None
	09:00	0	25	Variable	Gusty	Poor	None	None
	12:00	0	26		Calm	Poor	None	None
	15:00	0	29	S	Moderate	Poor	None	None
	18:00	0	26	SW	Strong	Poor	None	None
Juri River at Purba Botali peaked at 19:00 14 August at 194 cumecs								

Table 4.8

Comparison of Stage Hydrograph Response Characteristics

Event	Time to Peak (hours)			Lag to Peak (hours)		
	Purba Botali	Selua	Shilgat	Purba Botali	Selua	Shilgat
16-20 May	30	43	54	21	34	45
12-15 June	16	23	31	13	20	28
16-24 June	34	49	77	22	37	65
18-22 July	Multiple peaks - not suitable for comparison					
26-29 July	Multiple peaks - not suitable for comparison					
12-20 August	53	62	89	28	37	64

Note: Lag to peak is time from centre to mass of rainfall to peak discharge or peak water level

Table 4.9

Hydrometric Data from the Flood of July 1993

Date	Daily Rainfall at Rajke Tea Estate (mm)	Water Level at Juri (m PWD)	
		06:00	18:00
July 20	134	10.88	11.03
July 21	237	11.16	11.38
July 22	171	11.49	11.53
July 23	0	11.54	11.54

Notes:

1. Daily rainfall was believed to have been recorded at 09:00

2. Water level is measured on the Continala distributary immediately downstream from the Moulvibazar to Bara Lekha road and about 0.2 km below the Juri railway bridge

Table 5.1

Maximum Observed Water Level Rise (m) for Durations from 1 to 12 Hours (April - August 1995)

Event	Shilghat				Selua				Purba Botali			
	1-hr	3-hrs	6-hrs	12-hrs	1-hr	3-hrs	6-hrs	12-hrs	1-hr	3-hrs	6-hrs	12-hrs
16-18 May	0.21	0.57	0.85	1.16	0.38	0.83	1.50	2.70	0.50	1.35	1.88	2.69
12-14 June	0.20	0.56	0.98	1.69	0.31	0.90	1.67	2.73	0.47	1.20	2.01	2.74
16-21 June	0.25	0.56	0.93	1.33	0.43	1.14	1.85	2.62	0.43	1.09	2.11	3.01
18-22 July	0.01	0.03	0.05	0.08	0.22	0.61	1.05	1.62	0.37	0.90	1.65	2.09
26-29 July	0.03	0.09	0.17	0.27	0.32	0.72	1.24	2.10	0.50	1.21	2.04	2.50
12-19 August	0.05	0.13	0.25	0.47	0.22	0.59	0.97	1.68	0.39	0.89	1.46	2.21
Average	—	—	—	—	0.31	0.80	1.38	2.24	0.44	1.11	1.86	2.54
Maximum	0.25	0.57	0.98	1.69	0.43	1.14	1.85	2.73	0.50	1.35	2.11	3.01

Note: Average not computed at Shilghat because of dependence on Hakaluki Haor water levels.

Table 5.2

Development of Rate of Rise Warning at Purba Botali

Event	Starting Date	Time of Rise from 17.3 to 17.7 m (hours)	Rate of Rise (m/hr)	Initial Warning Level (IWL) (m)	Time of Rise from 17.7m to IWL (hours)	First Updated Rate of Rise (m/hr)	First Updated Warning Level (m)	Outcome
1	17 May	1.67	0.24	18.34	6.08	0.11	18.86	First updated warning level not reached
2	13 June	2.17	0.18	18.58				Initial warning level not reached
3	17 June	1.17	0.34	17.94	0.42	0.57	17.00	Warning issued-critical level reached 12 hours after warning
4	19 July							Elevation 17.7 m not reached
5	20 July							Elevation 17.7 m not reached
6	21 July	3.00	0.13	18.78				Initial warning level not reached
7	27 July	1.50	0.26	18.26				Initial warning level not reached
8	13 August	1.50	0.26	18.26	5.25	0.11	18.86	Warning issued but river peaked at 19.2m
9	20 August							Elevation 17.7 m not reached.
10	21 August							Elevation 17.7 m not reached.

Notes:
Critical water level at Purba Botali is 19.3 m

Table 5.3

Development of Rate of Rise Warning at Selua

Event	Starting Date	Time of Rise from 13.1 to 13.4 m (hours)	Rate of Rise (m/hr)	Initial Warning Level (IWL) (m)	Time of Rise from 13.4 m to IWL (hours)	First Updated Rate of Rise (m/hr)	First Updated Warning Level (m)	Outcome
1	17 May	6.50	0.05	14.40				Initial warning level not reached
2	17 June	2.50	0.12	14.12	13.00	0.055	14.38	Warning issued - critical level reached 4.5 hours after warning
3	28 July							Elevation 13.4 m not reached
4	13 August	5.17	0.06	14.36				Initial warning level not reached

Notes:
Critical water level at Selua is 14.6 m

Table 5.4

Development of Rate of Rise Warning at Shilghat

Event	Starting Date	Time of Rise from 10.35 to 10.52m or 10.95 to 11.00 (hours)	Rate of Rise (m/hr)	Initial Warning Level (IWL) (m)	Time of Rise from 10.52 or 10.95m to IWL (hours)	First Updated Rate of Rise (m/hr)	First Updated Warning Level (m)	Outcome
1	17 May							Elevation 10.52m not reached
2	17 June	5.33	0.03	11.08	30	0.02	11.12	Warning issued-critical level reached 3 hours after warning
3	15 August	14.00	0.004	11.16				Initial warning level not reached

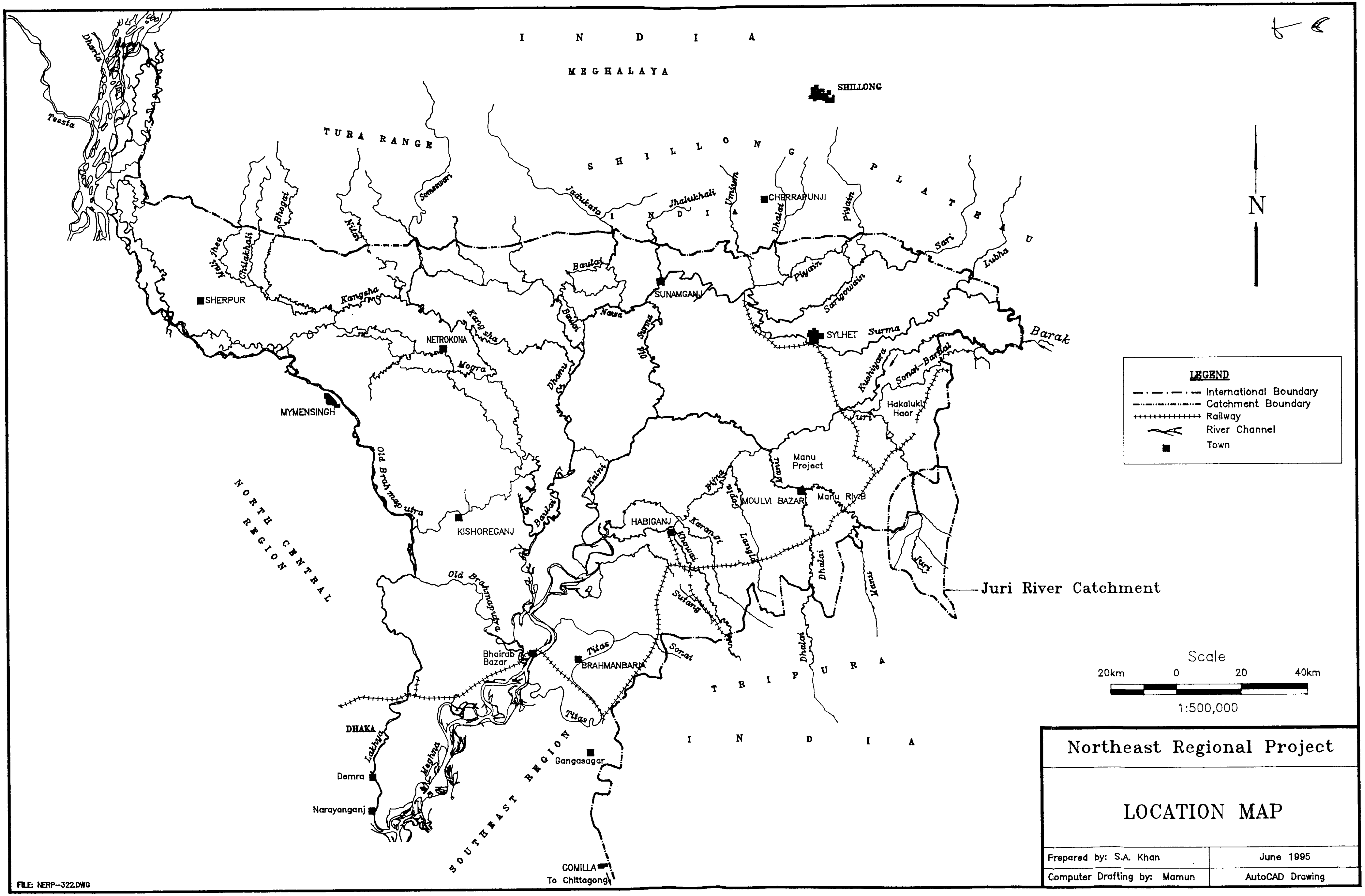
Notes:
Critical water level at Shilghat is 11.2 m

Initial rate of rise determined from 10.35 to 10.52 m prior to July 1
and from 10.95 to 11.00 m after July 1

Minimum rate of rise of 0.01 m/hr assumed

APPENDIX B

Figure 2.1

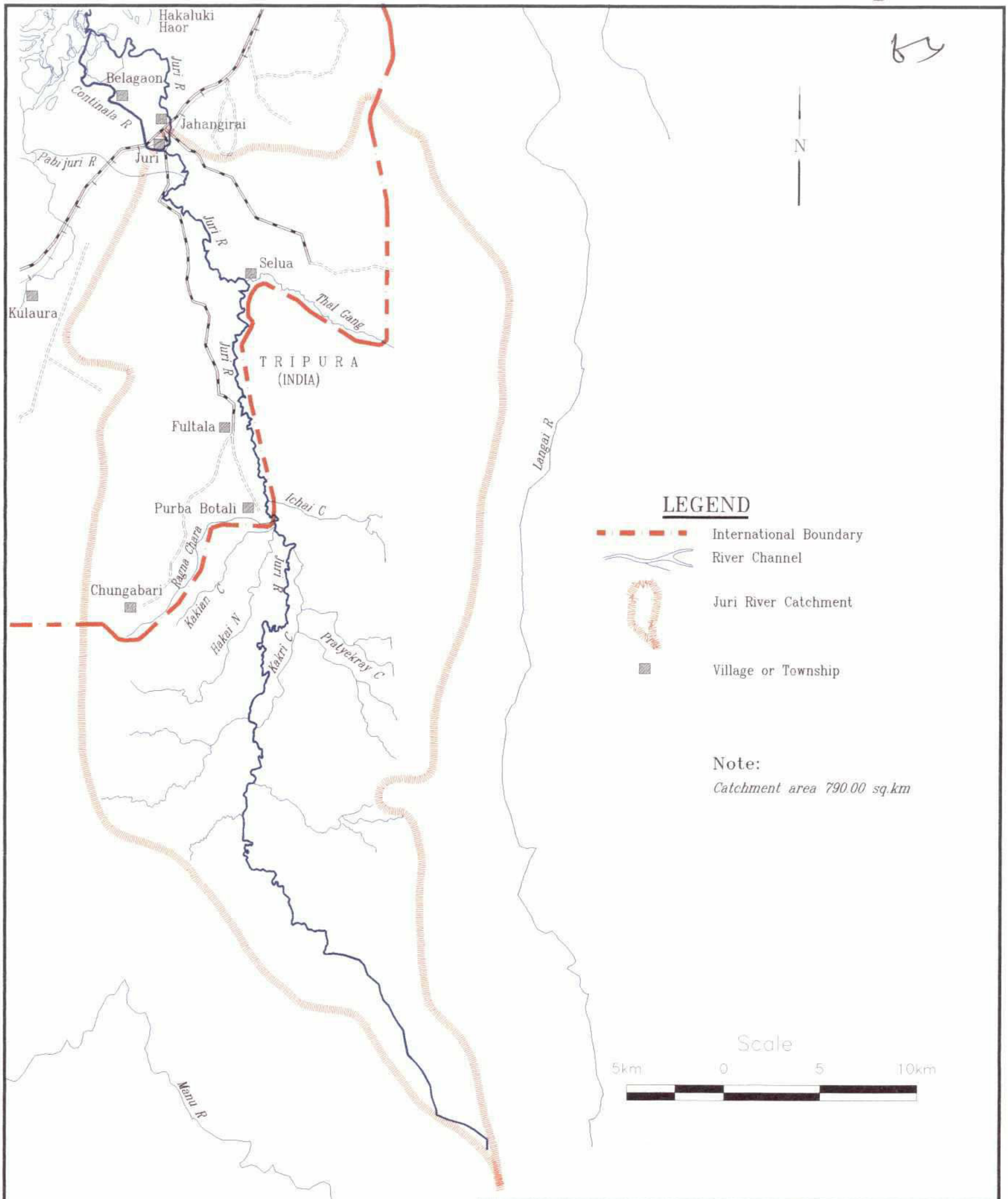


Northeast Regional Project

LOCATION MAP

Prepared by: S.A. Khan	June 1995
Computer Drafting by: Mamun	AutoCAD Drawing

Figure 2.2



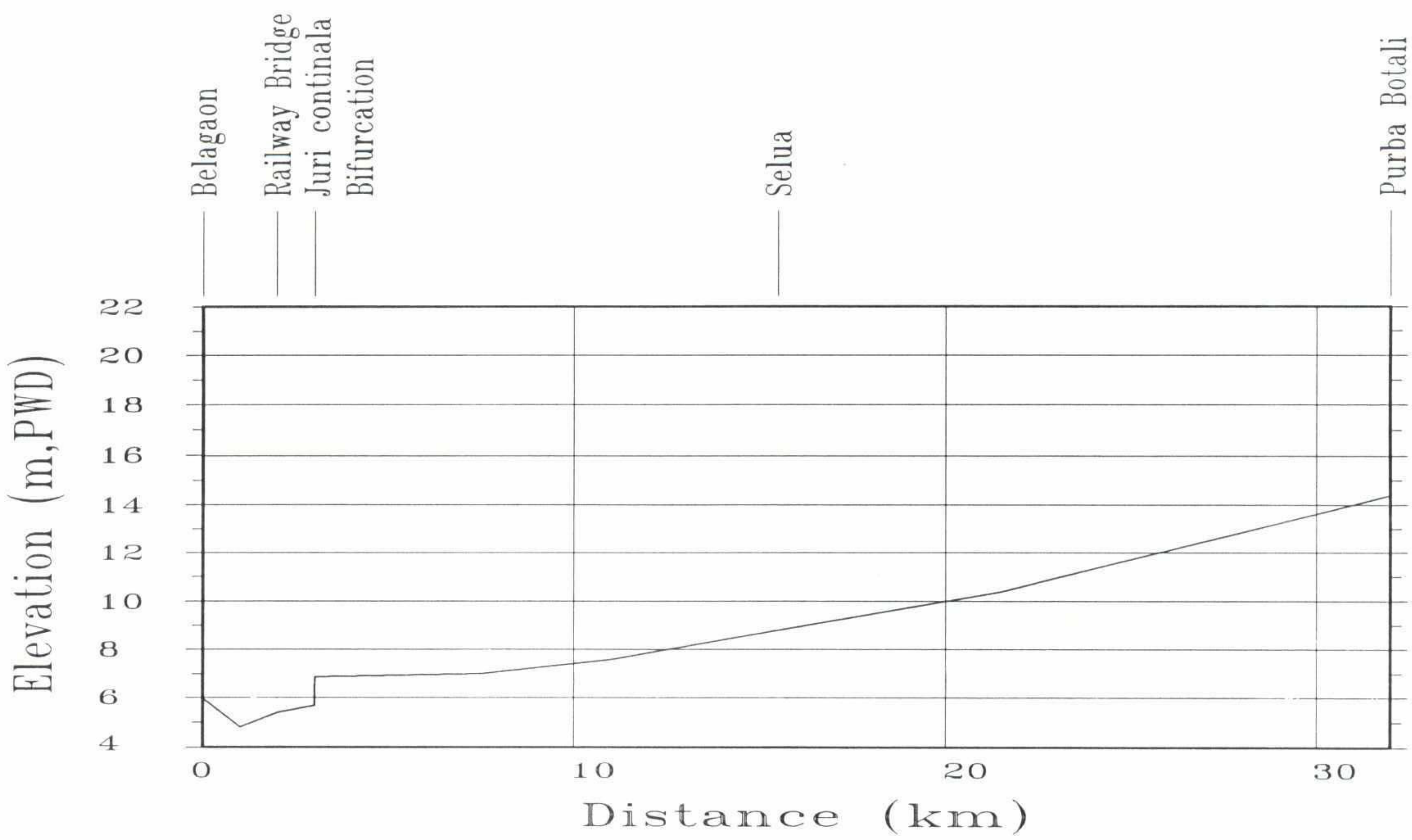
Northeast Regional Project

The Juri River Catchment

Prepared by: S.A.Khan	October 1995
Drawn by: Jalal	AutoCAD Drawing

FILE: NERP-396.DWG

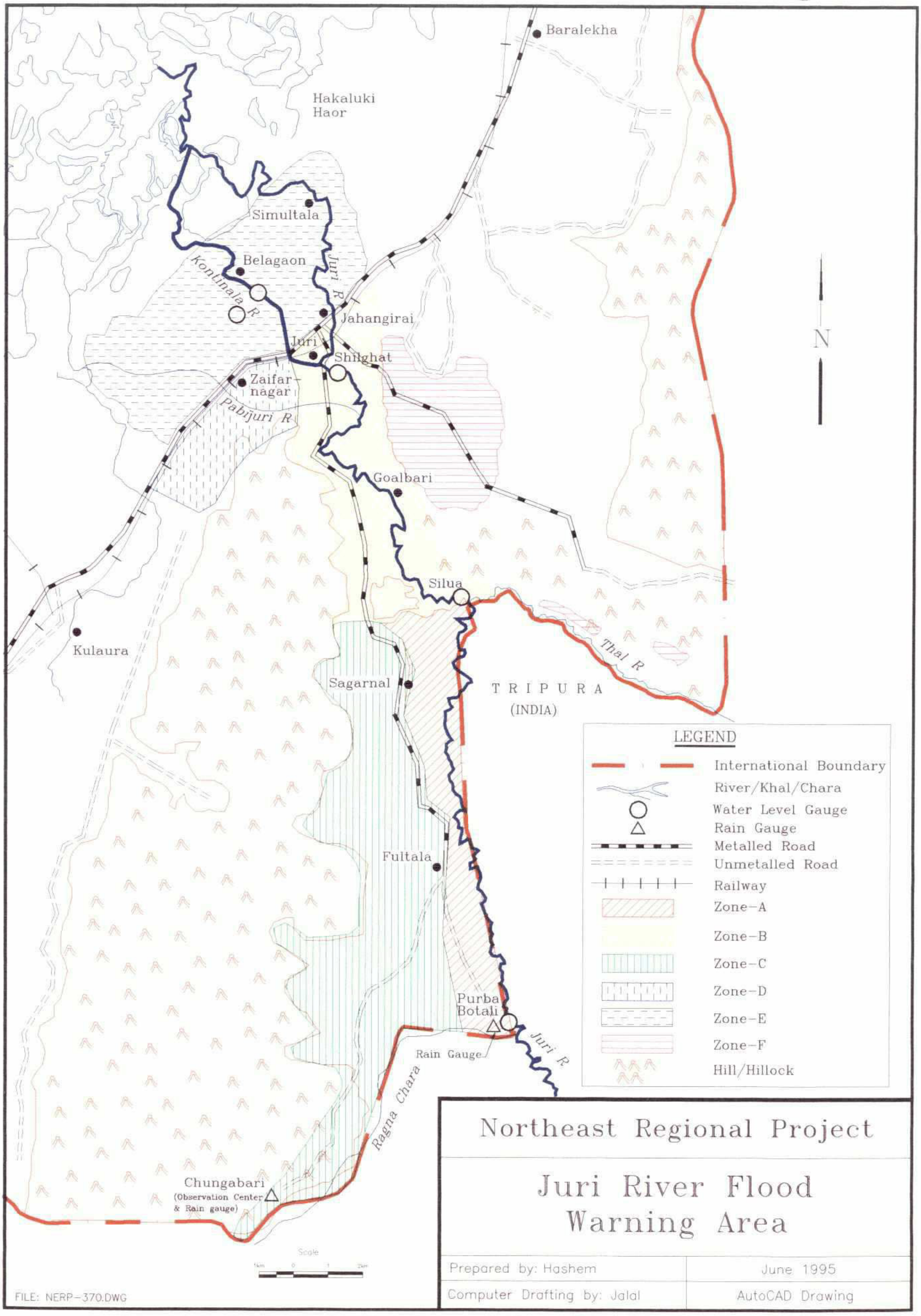
Figure 2.03



Northeast Regional Project	
Longitudinal Profile of the Juri River from Belagaon to Purba Botali	
Prepared by: Saifuddin/MKL	DATE October 1995
Drawn by: Nahid	AutCAD Drawing

FILE: BORD11X8.DWG

Figure 3.1

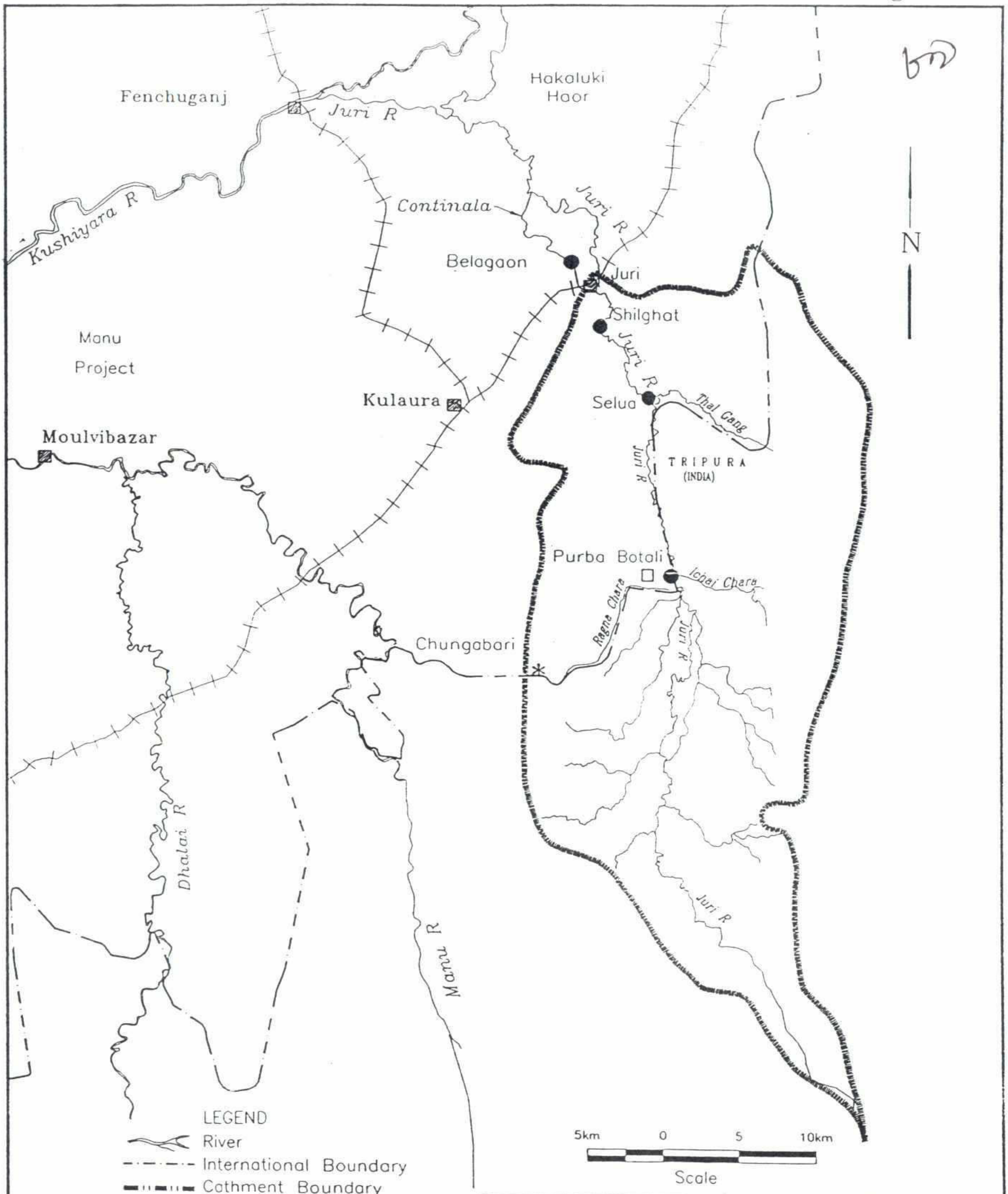


Northeast Regional Project

Juri River Flood Warning Area

Prepared by: Hashem	June 1995
Computer Drafting by: Jalal	AutoCAD Drawing

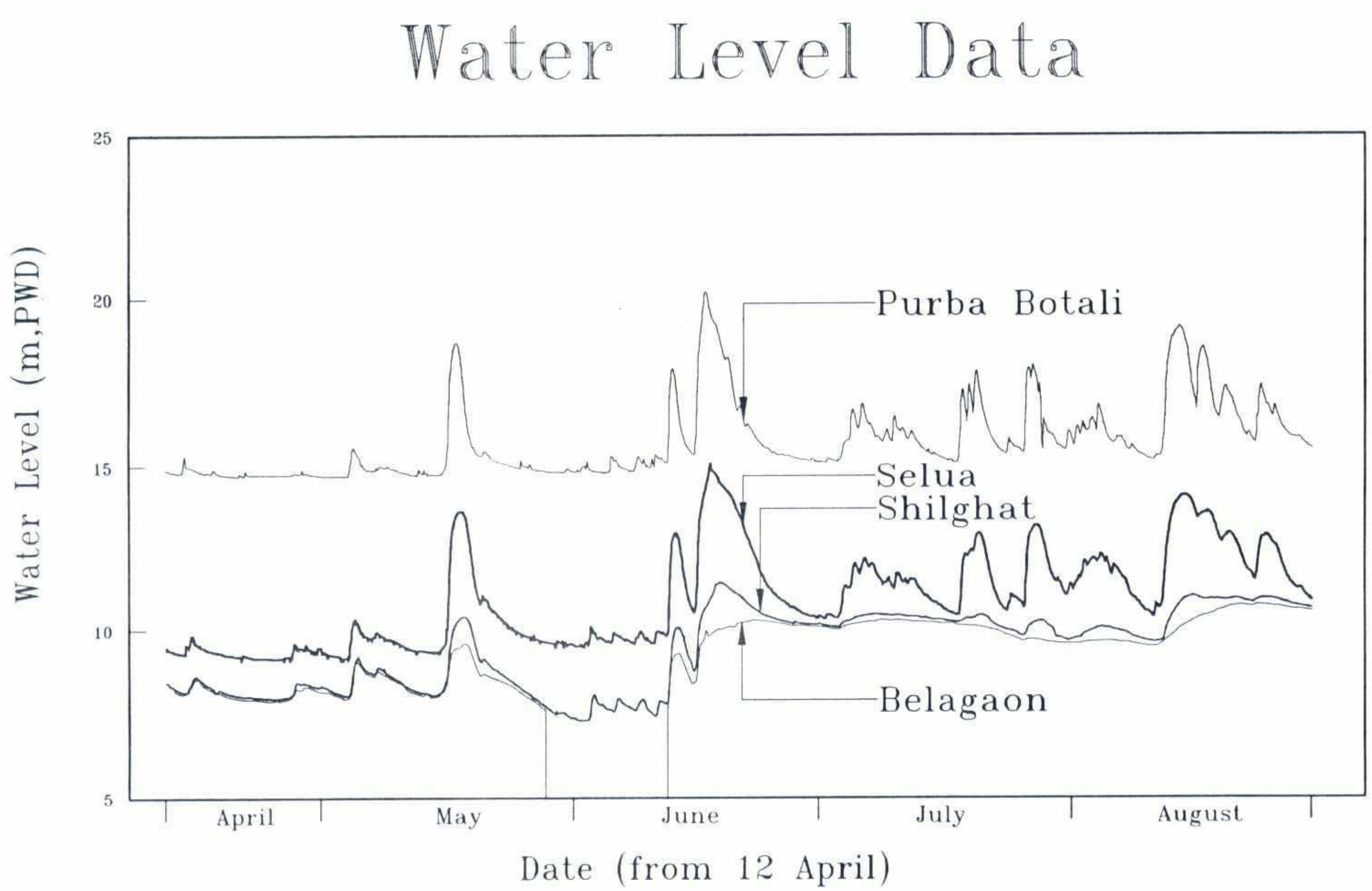
Figure 4.1



Northeast Regional Project

Hydrometric Data Collection Network

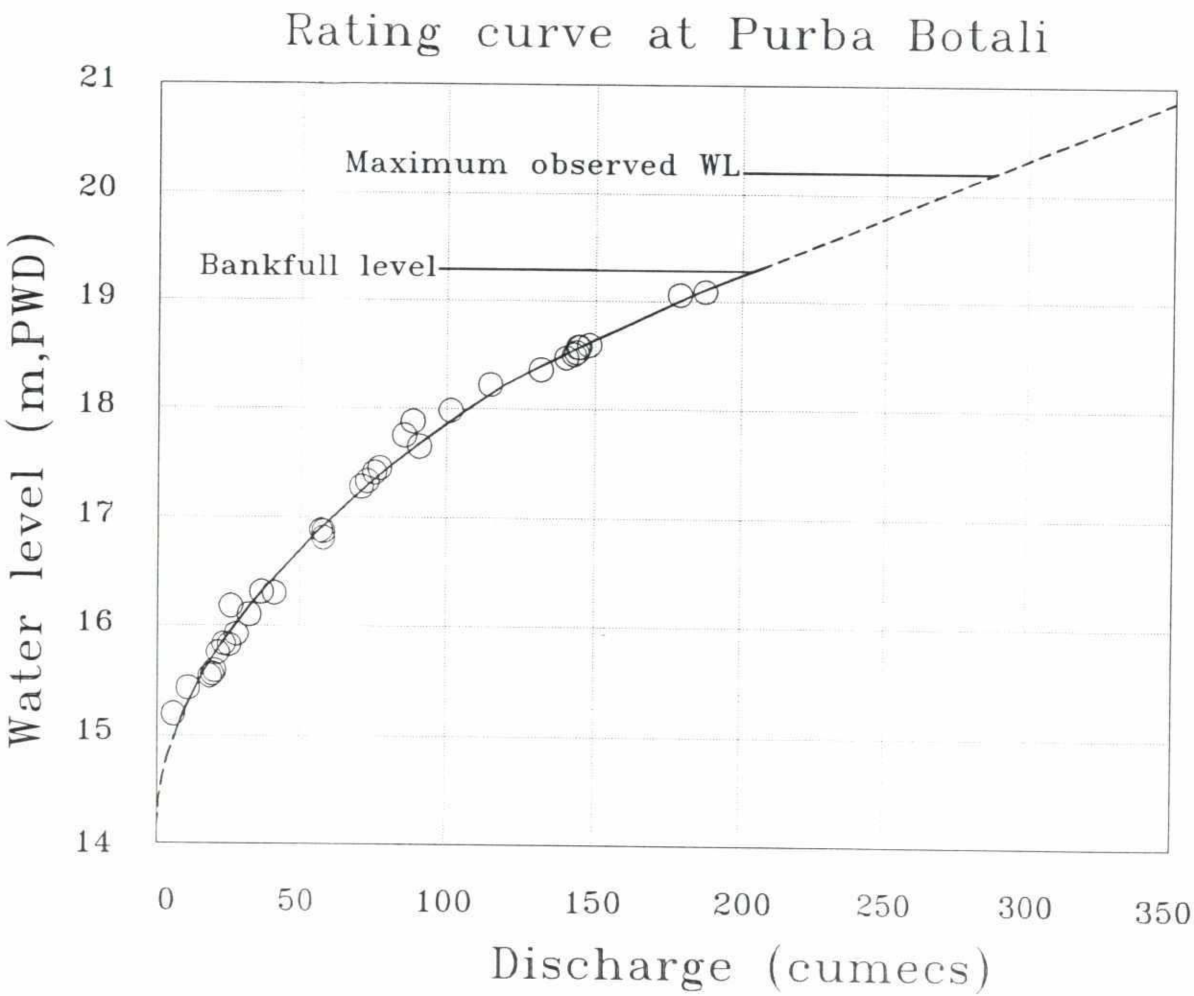
Prepared by: S.A.KHAN	July 1995
Computer Drafting by: Mamun	AutoCAD Drawing



Northeast Regional Project	
Juri River Water Level Data	
Prepared by: Ashek	October 1995

FIGURE-4.02

FILE: FIG-402.DWG

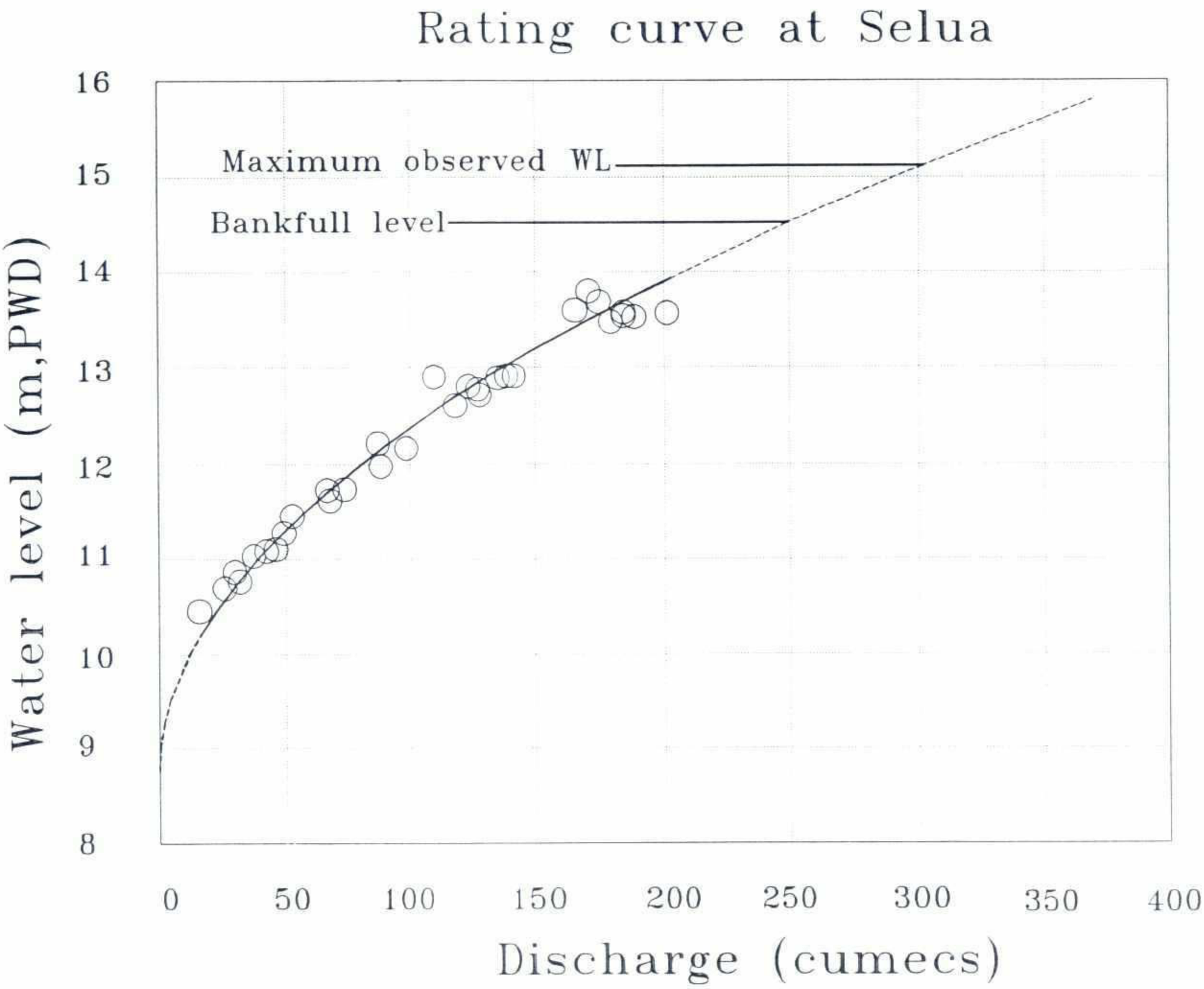


$Q=8.887(H-14.2)^{1.864}$ $[14.2 \leqslant H < 18.2]$

$Q=27.15(H-15.606)^{1.54}$ $[H \geqslant 18.2]$

Northeast Regional Project
Stage - Discharge Rating Juri River at Purba Botali
Prepared by: SA/MKL/Nahid — October 1995

FILE: PURB.DWG.DWG

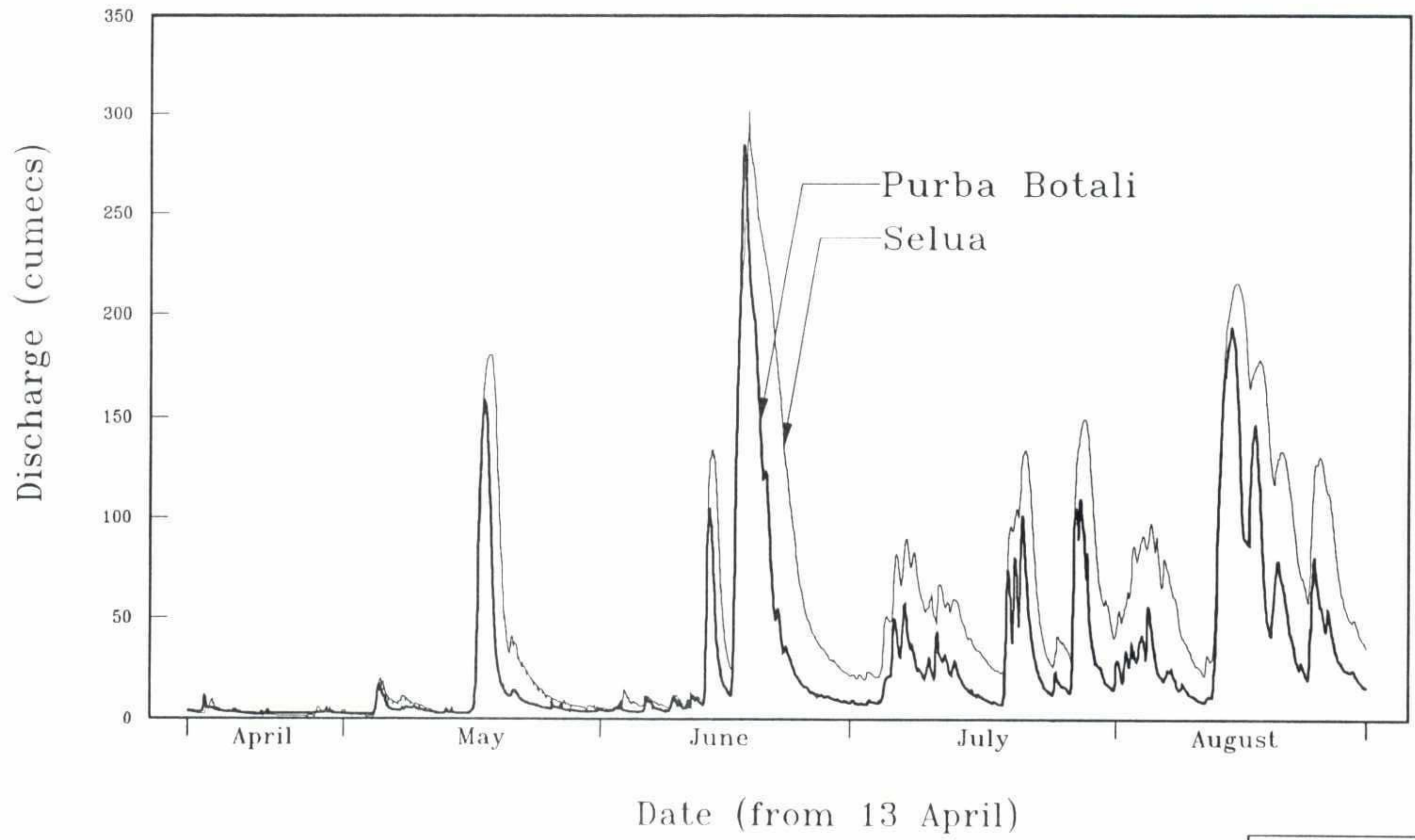


$Q=8.366(H-8.77)^{1.942}$ $[8.77 \leqslant H<16]$

Northeast Regional Project	
Stage - Discharge Rating Juri River at Selua	
Prepared by: SA/MKL/Nahid	October 1995

FILRC-SIL.DWG.DWG

Discharge Data



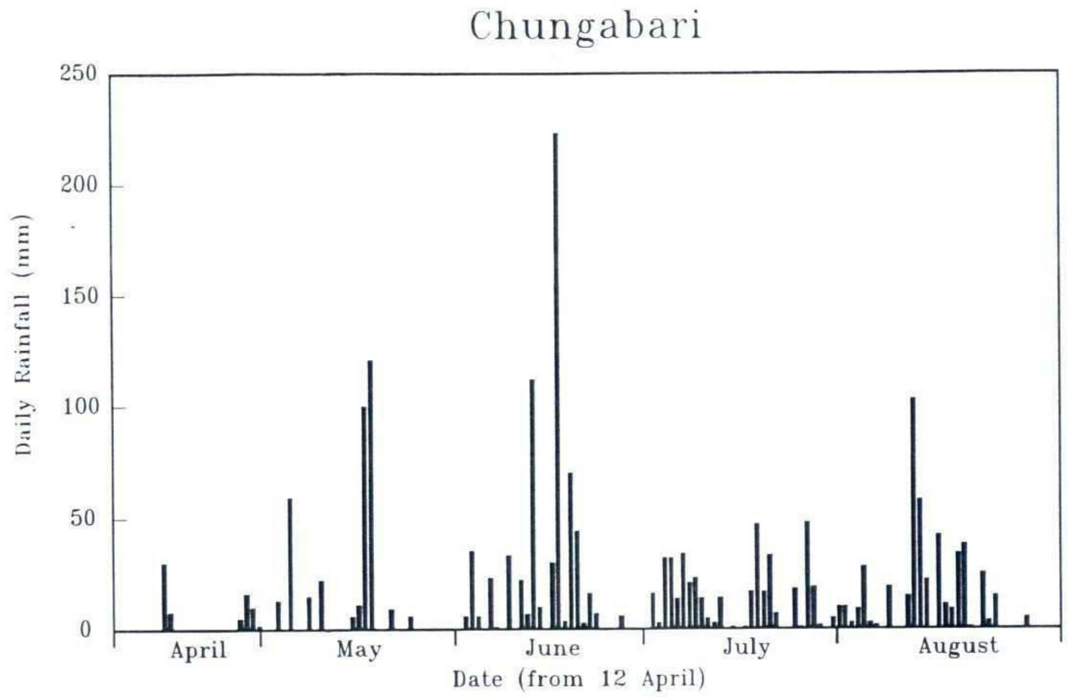
Northeast Regional Project	
Juri River Discharge Data	
Prepared by: Ashek	October 1995

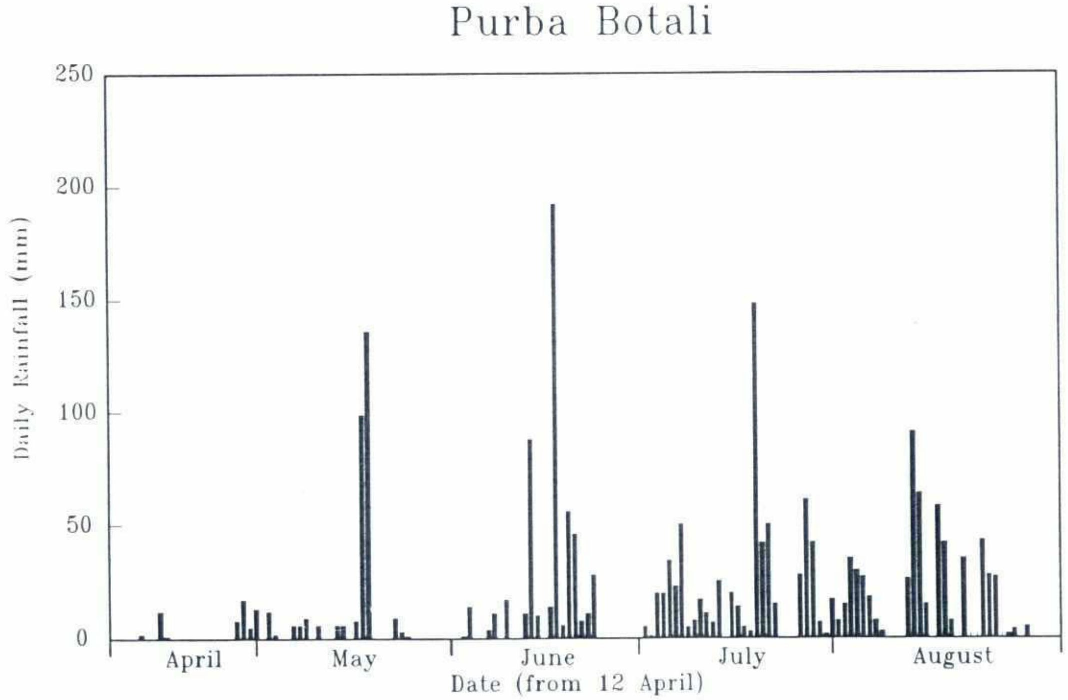
FIGURE-4.05

26

FILE:FIG-405.DWG

Figure-4.06



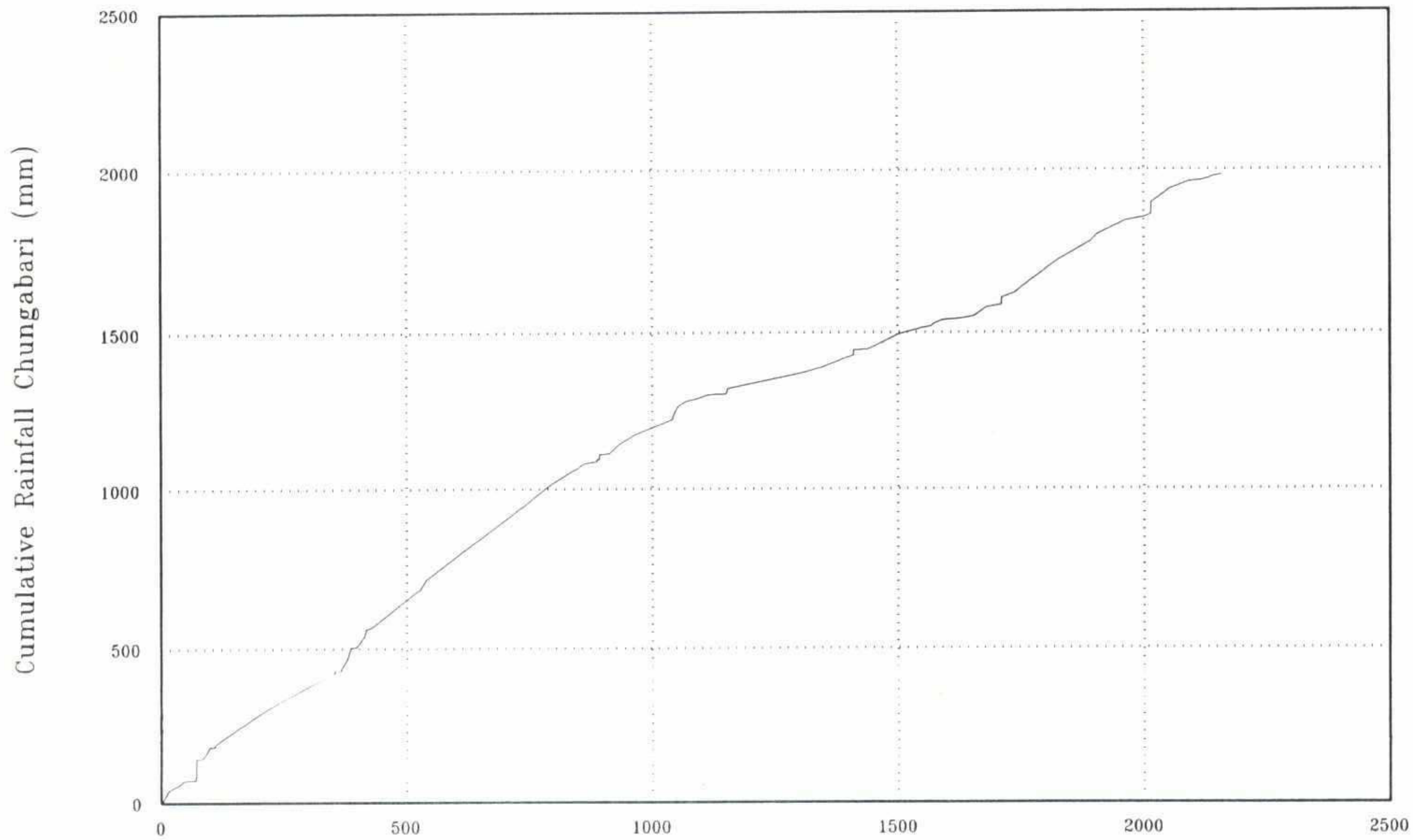


Northeast Regional Project	
Juri River Rainfall Data	
Prepared by: Ashek	October 1995

FILE: FIG-406.DWG

Cumulative Daily Rainfall

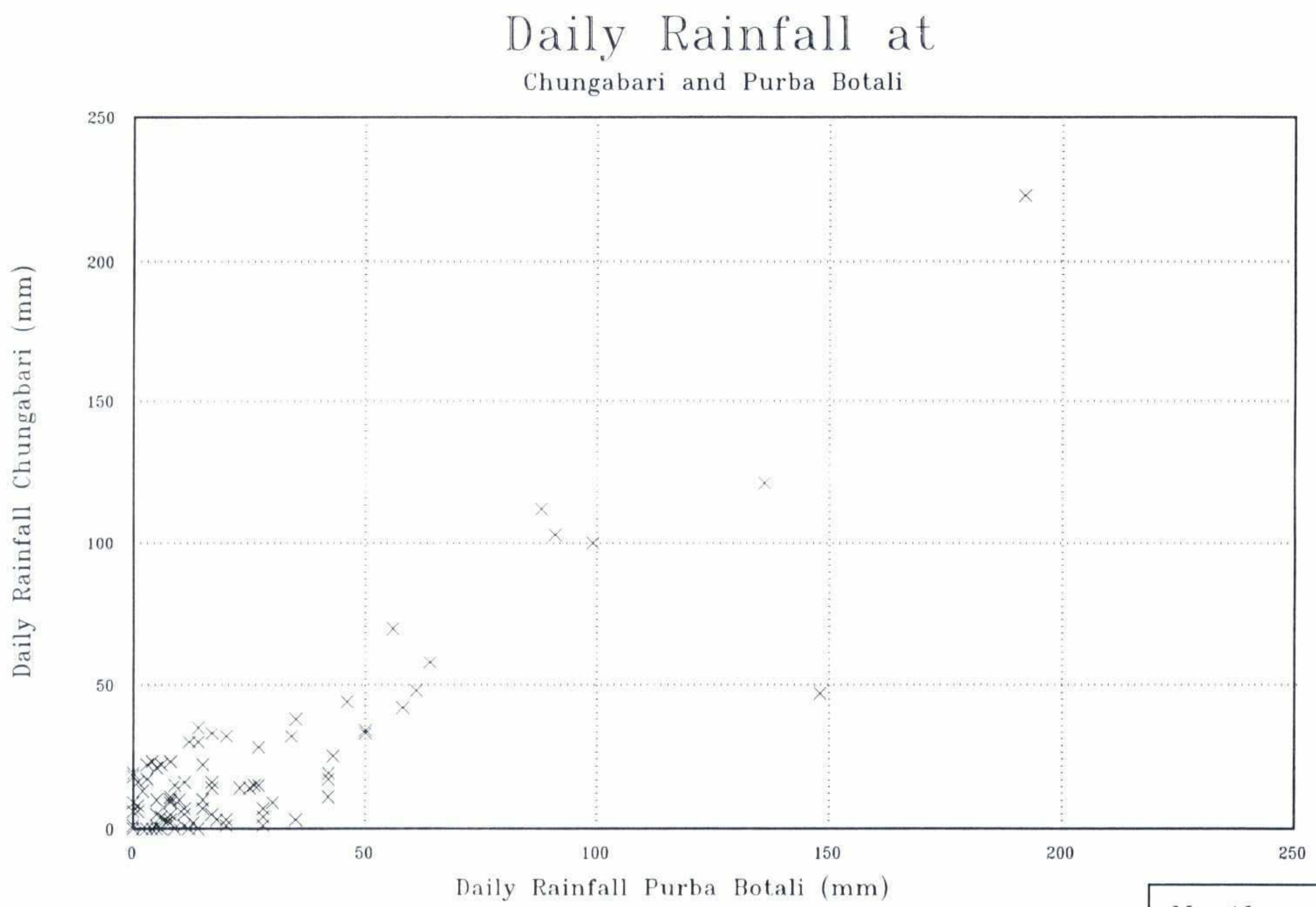
12 April 1995 through 31 August 1995



Northeast Regional Project	
Comparison of Cumulative Rainfall Amounts at Purba Botali & Chungabari	
Prepared by: Ashek	October 1995

FIGURE-4.07

FILE:FIG-407.DWG



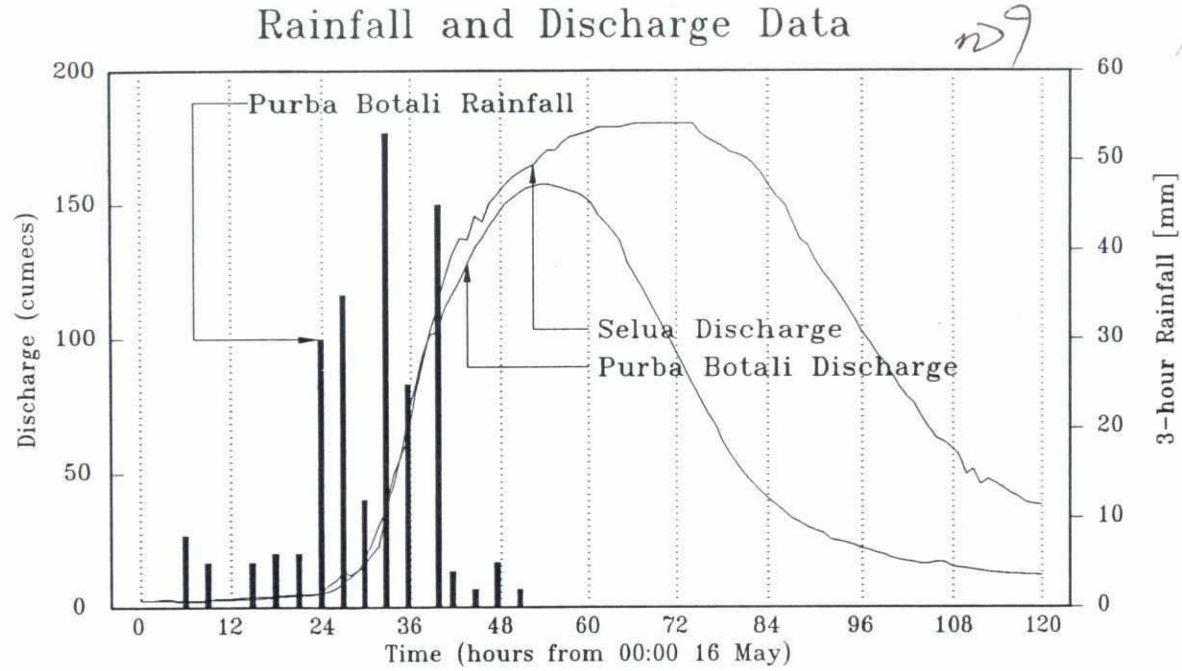
Northeast Regional Project

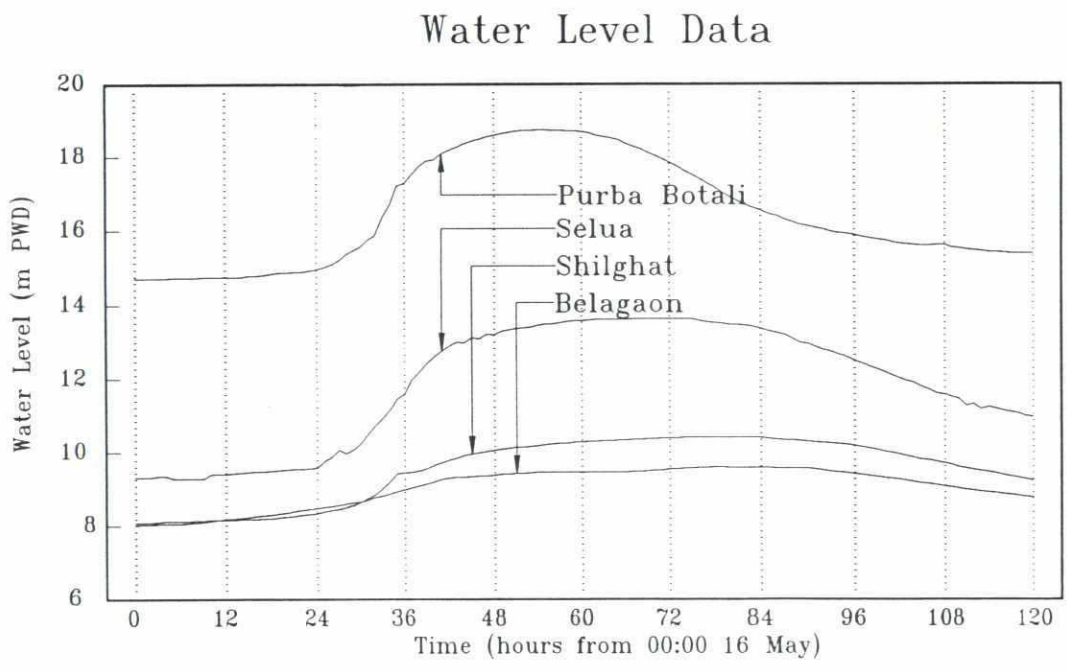
Comparison of
Daily Rainfall Depths at
Purba Botali & Chungabari

Prepared by: Ashek | October 1995

FIGURE-4.08

FILE: FIG-408.DWG





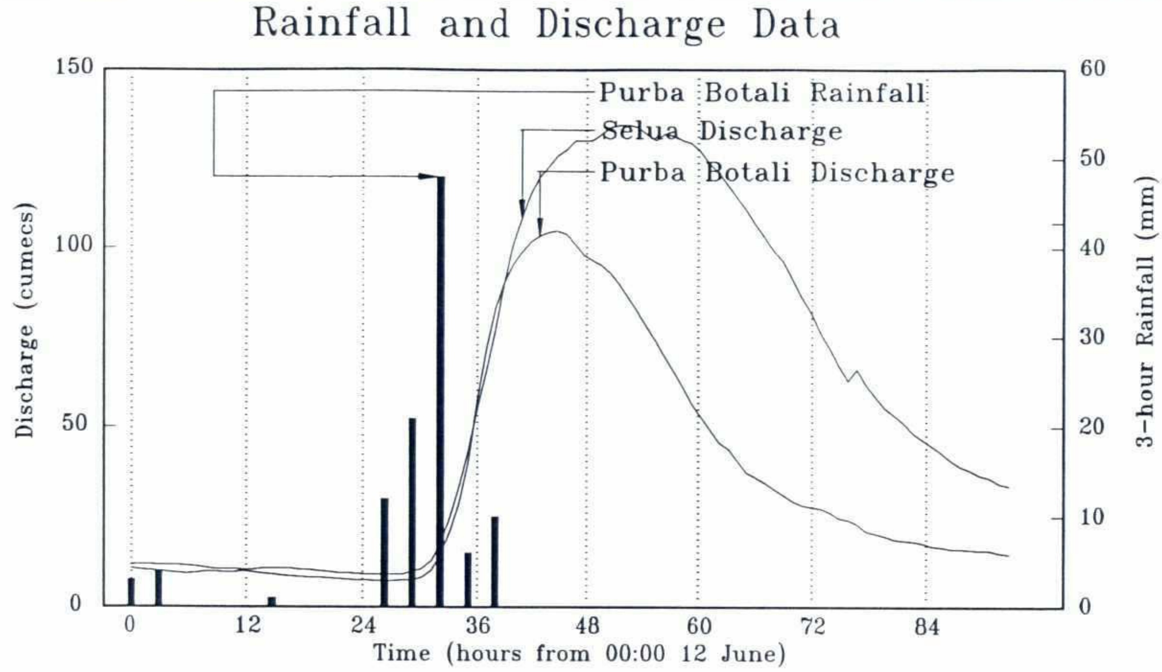
Northeast Regional Project

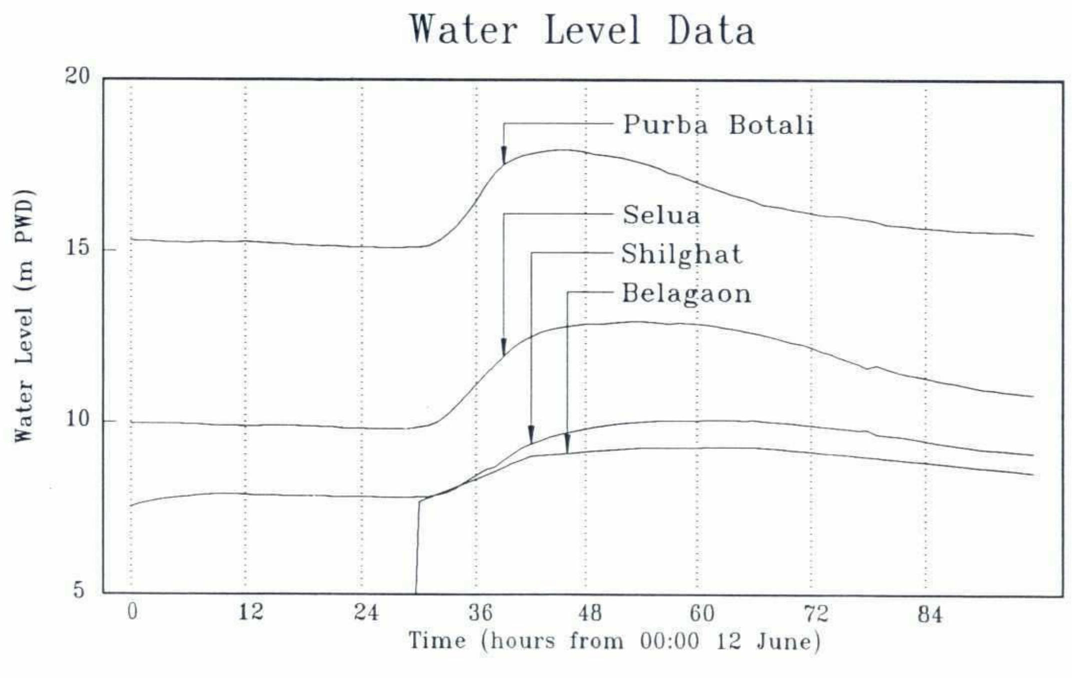
Hydrometric Data
for High Flow Event of
16-20 May 1995

Prepared by: Ashek | October 1995

FILE: Fig-409.DWG

Figure-4.10





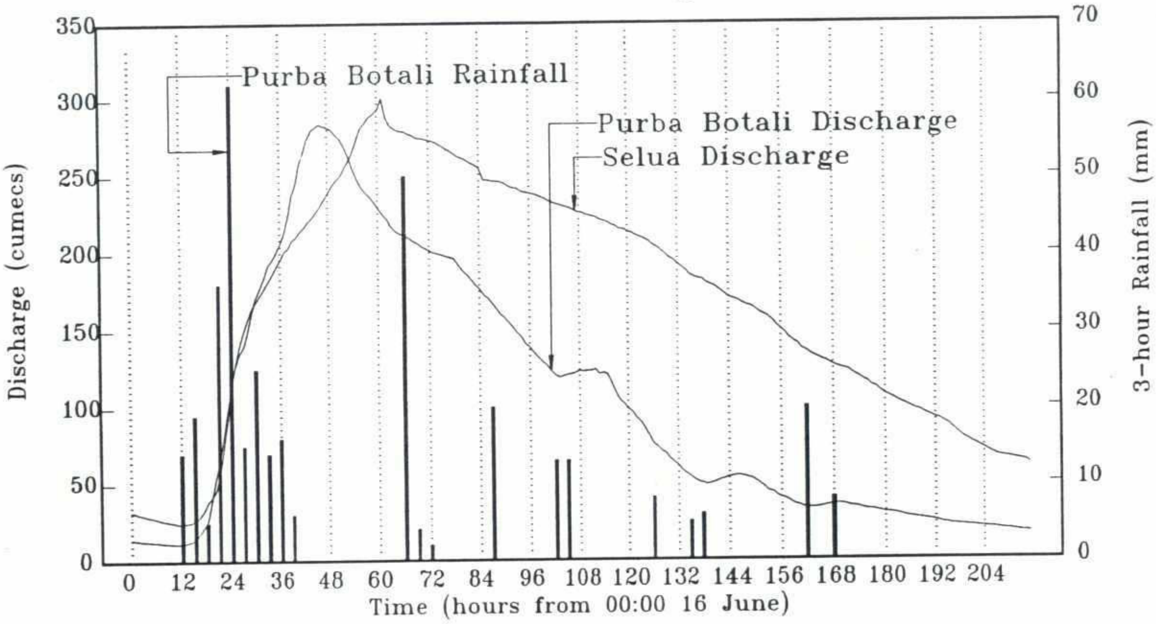
Northeast Regional Project

Hydrometric Data for High Flow Event of 12-15 June 1995

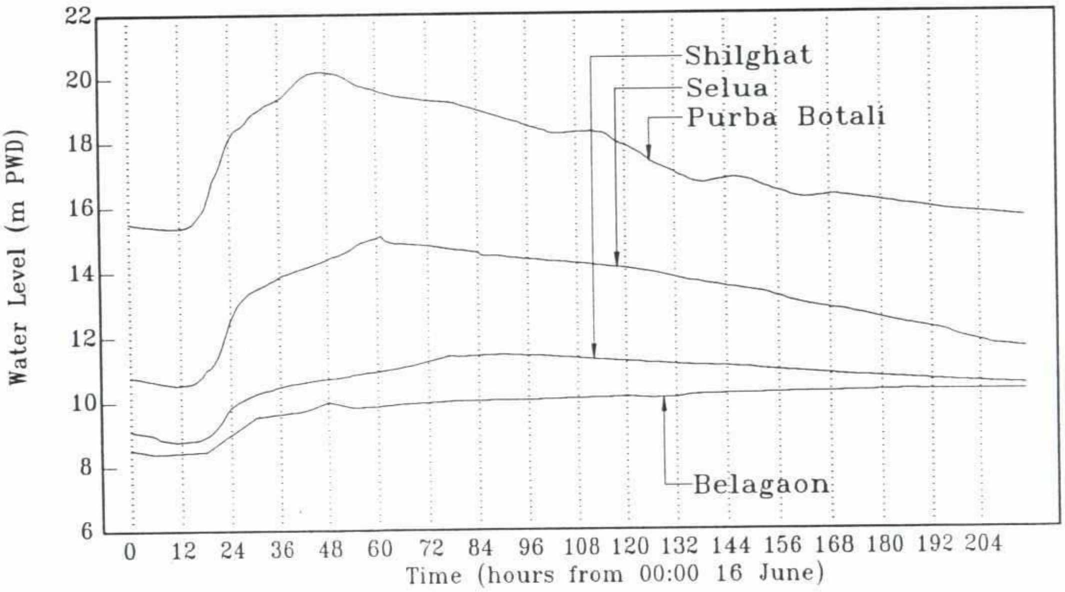
Prepared by: Ashek | October 1995

FILE: Fig-410.DWG

Rainfall and Discharge Data



Water Level Data



Northeast Regional Project

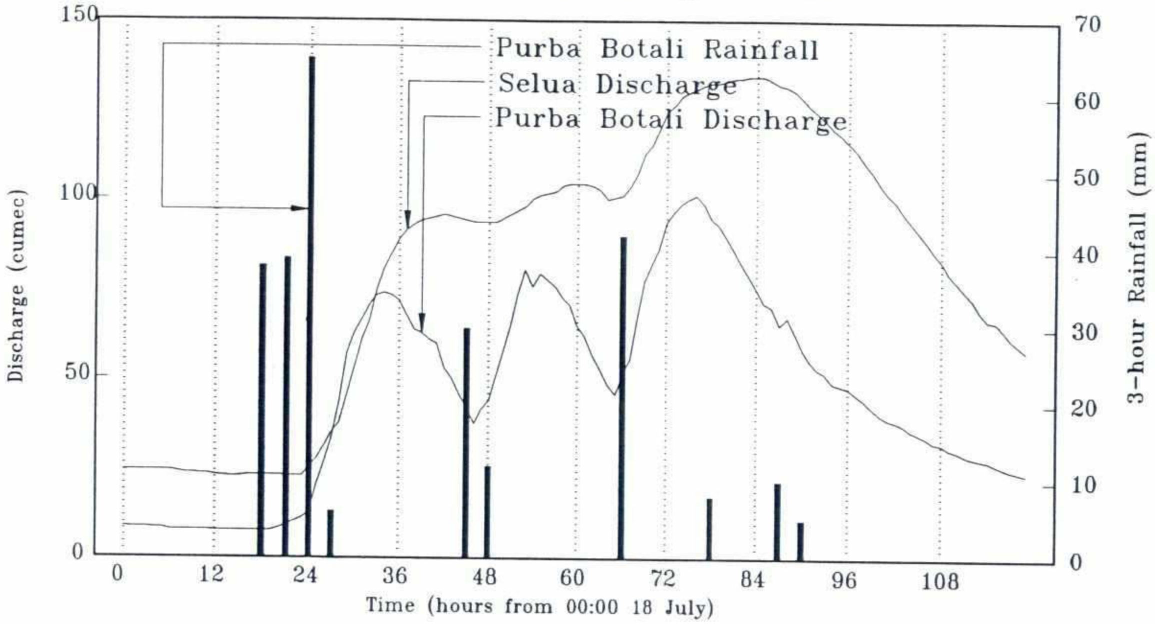
Hydrometric Data
for High Flow Event of
16-24 June 1995

Prepared by: Ashek | October 1995

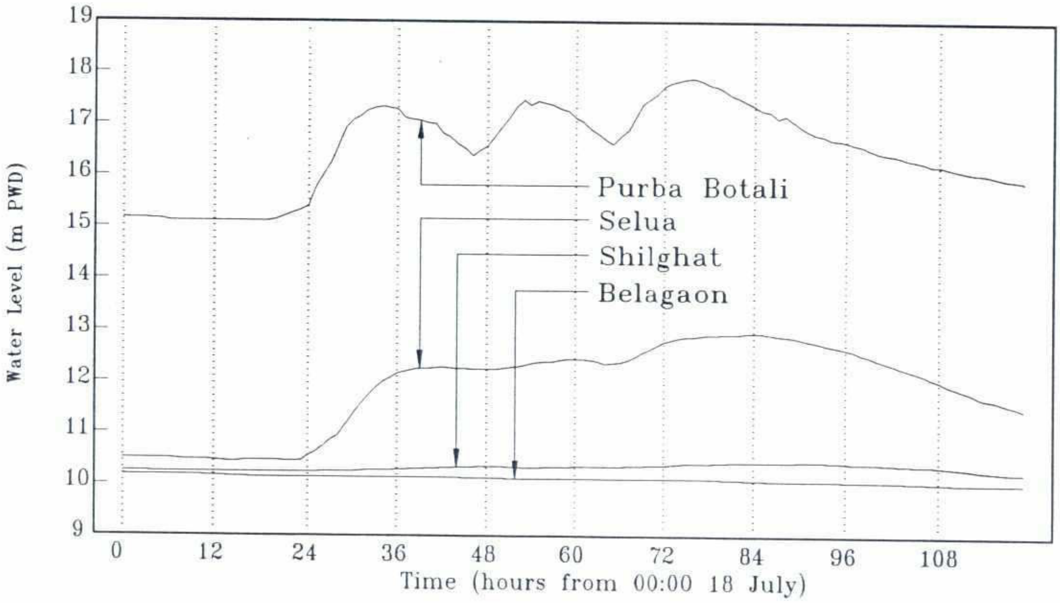
FILE:Fig-411.DWG

Figure-4.12

Rainfall and Discharge Data



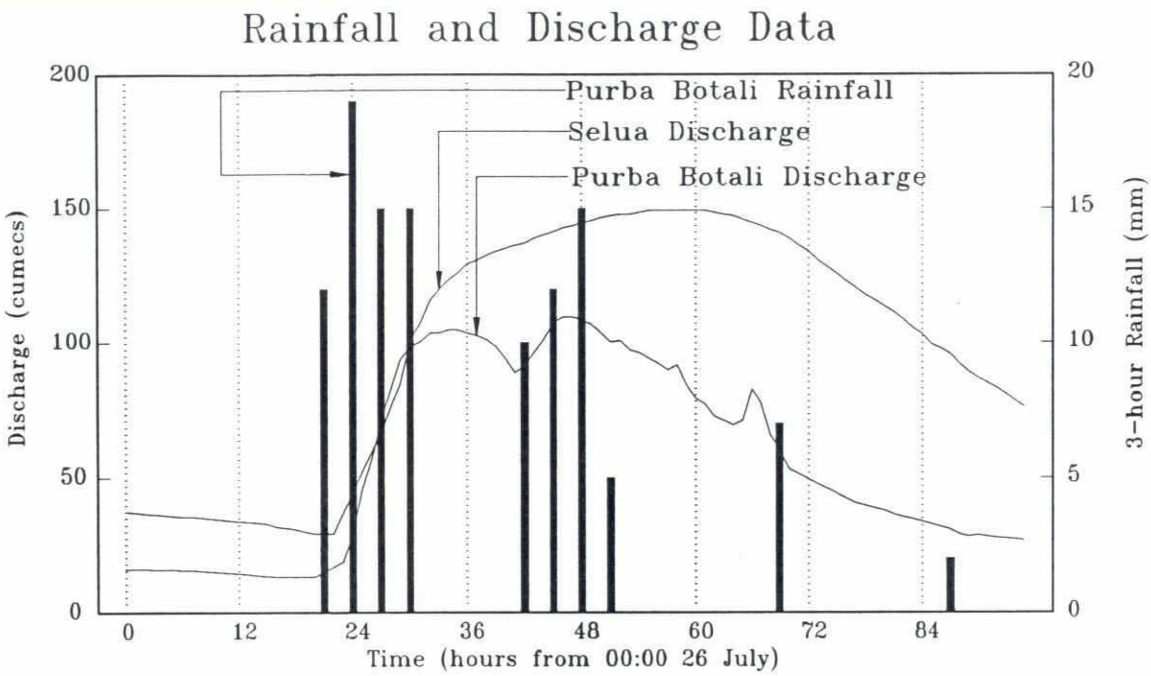
Water Level Data

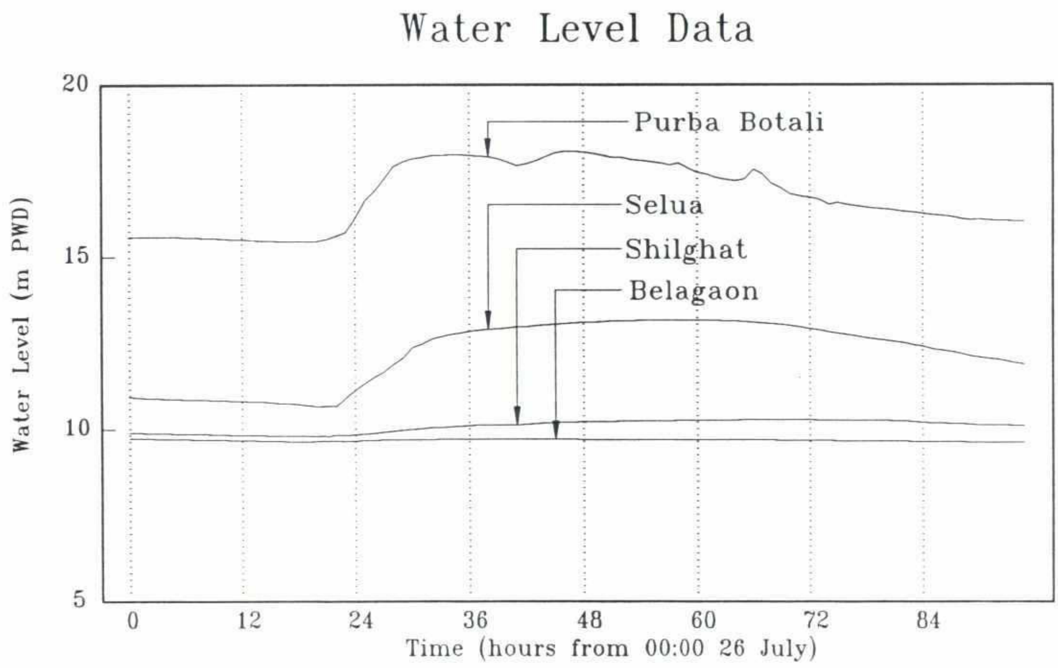


Northeast Regional Project	
Hydrometric Data for High Flow Event of 18–22 July 1995	
Prepared by: Ashek	October 1995

FILE: Fig-412.DWG

Figure -4.13





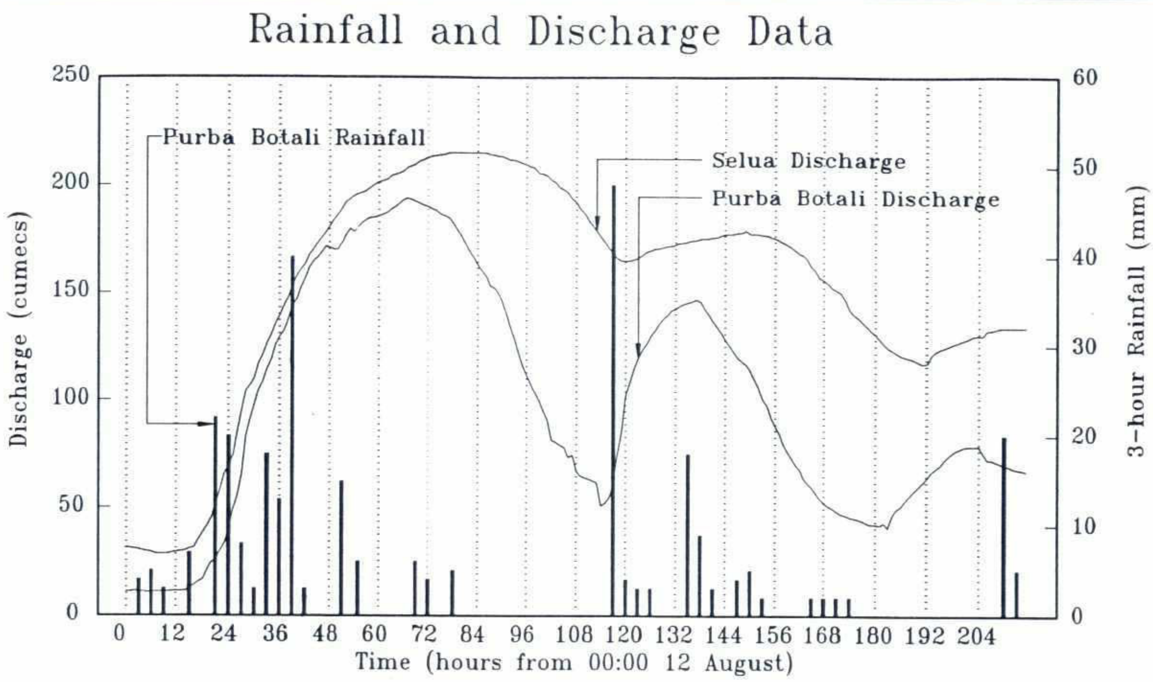
Northeast Regional Project

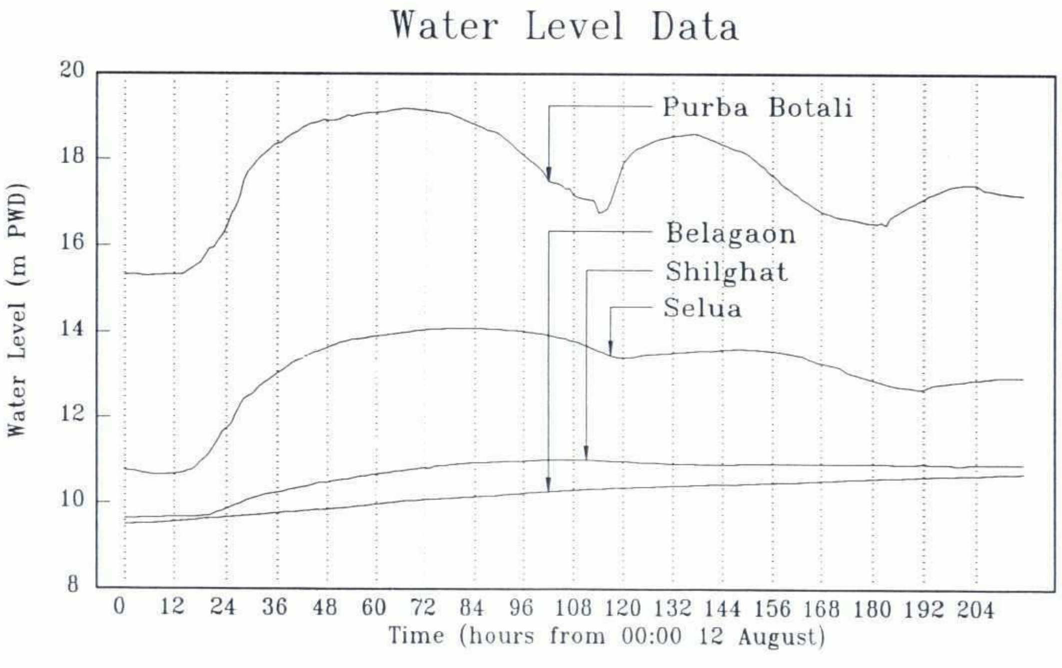
Hydrometric Data for High Flow Event of 26-29 July 1995

Prepared by: Ashek | October 1995

FILE:Fig-413.DWG

Figure-4.14

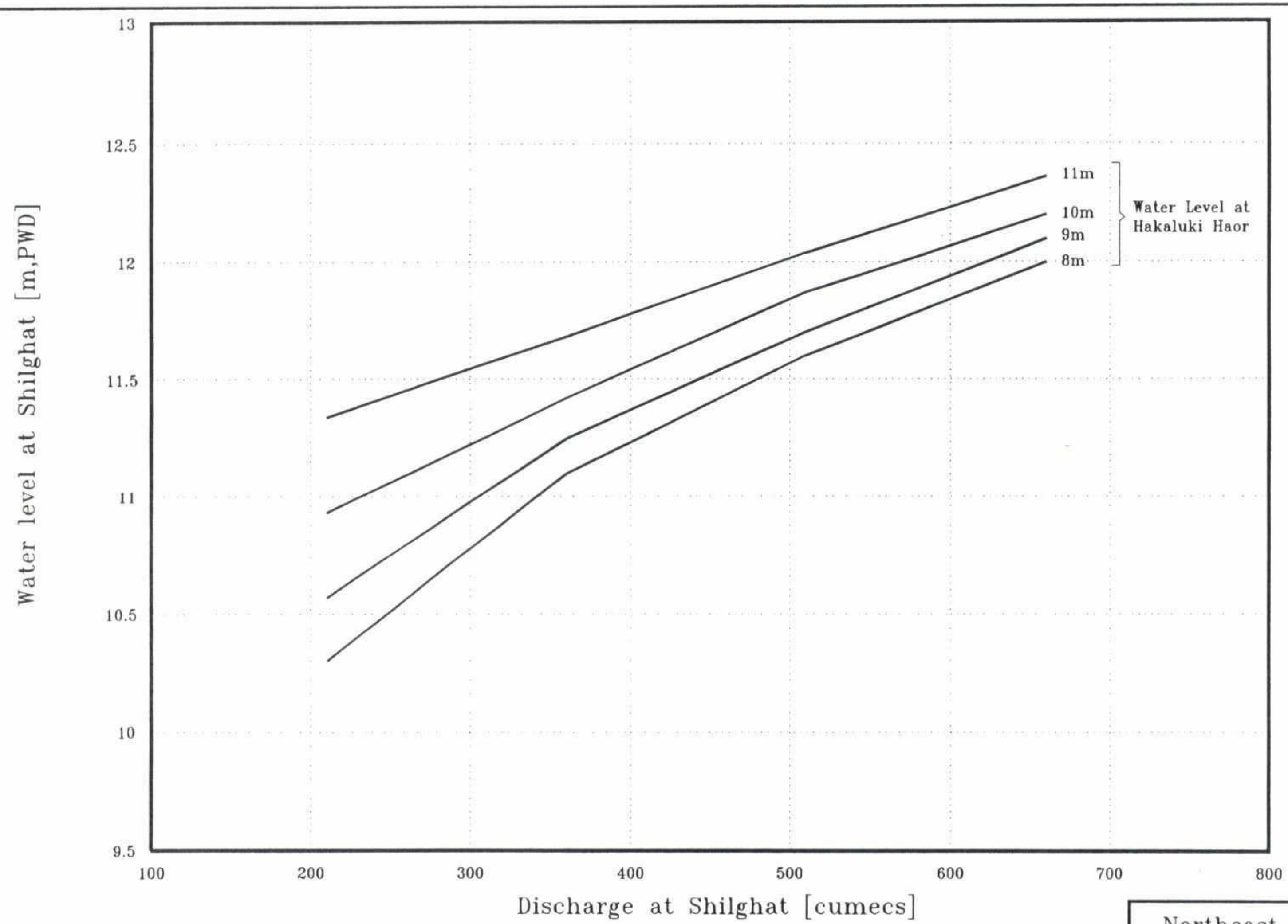




Northeast Regional Project	
Hydrometric Data for High Flow Event of 12-20 August 1995	
Prepared by: Ashek	October 1995

FILE:Fig-414.DWG

Figure 5.01



Northeast Regional Project

Relationship between Water Level and Discharge at Shilghat for various Water Levels at Hakaluki Haor

Prepared by: Saifuddin/MKL	Date : October 1995
Computer Drafting byNahid	AutoCAD Drawing

FILE: FIGDWG

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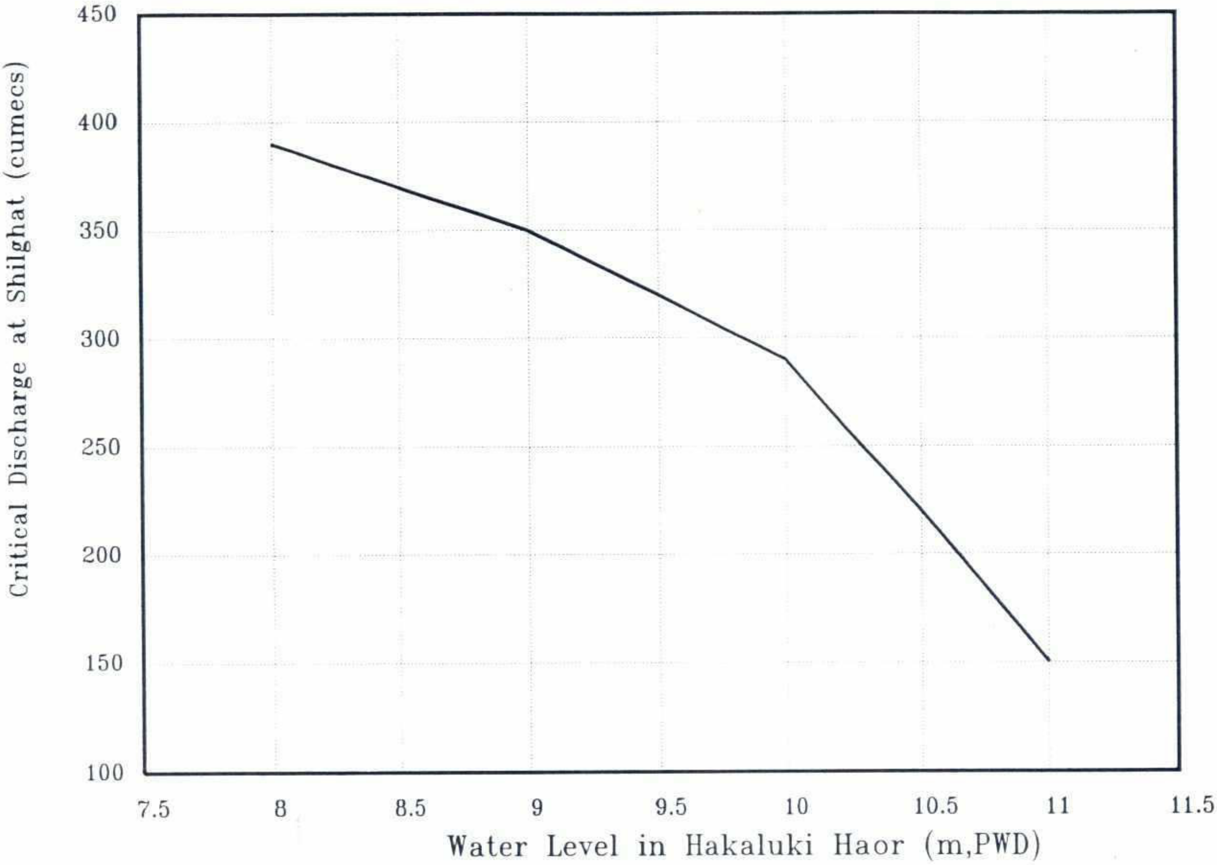

Note: Critical discharge at Shilghat corresponds to critical Water Level of 11.2 m,PWD at Shilghat

Northeast Regional Project	
Relationship between Critical Discharge at Shilghat and Water Level at Hakaluki Haor	
Prepared by: SA/MKL/Nahid	October 1995

FILE: fig5-02.DWG

APPENDIX C

APPENDIX C: METHODOLOGY OF THE SOCIAL INQUIRY

The methodology for the inquiry into the social aspects of the flood problems in the Juri River valley contained a number of different strands. Method in the social sciences is often an iterative dialogue in which the researcher negotiates a perspective with several interest groups and continuously checks out assumptions with others until his or her own perceptions about events more or less correspond with others' perceptions. In the case of the Juri River valley project the first thing we tried to negotiate was a social science perception on what the "problem" was.

Initially the approach to the project was based on mainly hydrological considerations. It was assumed that the problem was known; it was "flash" flooding. It was assumed that what was needed was a system for providing local people with a flood warning. And it was assumed that, to be effective, a warning would require information about the upper catchment. It was further assumed that information relevant to this perspective could actually be collected and that such a collection system would be replicable in a prototype flood warning system. It was these assumptions that recommended the project design that was proposed. It included the construction of towers and the installation of a system of lights and sirens to provide the warning. The first task of the social scientist was to renegotiate many of these assumptions and the conclusions that flowed from them.

The initial social science scrutiny raised several critical questions grounded in considerations developed from an interpretive sociology perspective. The most basic question reduced to whether it was possible, using the methods proposed, to predict a flood i.e. to correlate the observations proposed with a recognizable event in the Bangladesh part of the catchment. The point was raised that, from a social perspective, this predictability had to be extremely reliable if any flood warning was to be effective. If people received warnings about events that turned out to be, from their perspective, trivial, the whole system would be discredited.

In response to this interaction, the project was revised so that the questions could be approached in two stages. The first stage was designed to test whether a flood could be predicted. The hydrological work reported in this document deals with that question. The social science work deal with basic questions about the people who live in the Juri River valley and their experience and perception of floods

Field data for the social perspective were collected by a form of Participatory Rural Appraisal (PRA). PRA constitutes a systematic approach to data collection based on the assumption that local people are "experts" on their own problems. It provides for various ways to structure questions and cross-check answers so that reliable information can be obtained.

A social anthropologist and two women field workers visited the valley at regular intervals starting in April 1995. They continued to collect information through August 1995. The anthropologist was present during the June flood and was able to collect a great deal of first-hand information about flood impacts; at that time it was difficult for the women field workers to get around and, in fact, the anthropologist spent part of his time going from village to village on a *bhela*—the traditional raft made from banana stalks that local people so often use to reach safety in floods. At other times though, the women field workers were able to meet with focus groups to explore women's understandings of flood problems.

The work involved visiting villages and interviewing, individually and in groups, villagers who had experience of floods. Interviews were conducted within the framework of a check-list of issues that the project was interested in. The check-list is presented in Table C-1 below. However, consistent with the spirit of PRA inquiry, the issue of what the most important flood issues were was, as far as practical, kept open during the enquiry. Information from interviews was checked by "triangulation." Information collected from individuals was cross-checked against others' perceptions and also against community opinions aired in group interviews.

We entered the area with the assumption that the river valley was subject to "flash-floods." Our first interest was in how many people had been killed in flash-flood related incidents in the Juri River valley. We assumed that in an area subject to sudden and unpredictable floods, flood-related deaths would be the most important problem. Our preliminary inquiry, however, suggested that the number of people actually killed in floods was quite small. This changed the character of the inquiry and we pursued other issues related to the flood events that make life difficult for local people.

The process followed was more or less the following:
We started out with a general survey of the area. We determined where the villages with the highest risk were located and developed the flood hazard classification system discussed in Chapter 3 and shown on Figure 3.1. This allowed us to develop an interview schedule to address the questions that were emerging.

Our anthropologist visited all the villages that were located immediately adjacent to the Juri River and started to develop a perspective on how people viewed the flood issue. We then proceeded to quiz people about historic floods. This led us to select two floods (apart from the 1995 events which the field workers were present for) for detailed reconstruction.

Next our anthropologist started to collect oral histories of the two flood events that were of particular interest to us. Our women field workers focussed more on collecting general information about women's problems during floods.

We carried out a large number of group discussions focussed on the questions from the check list. We also followed up on the issues like where flood shelters are located and how people decide which shelter to use. Information was collected using note books and a cassette recorder. Focus groups usually had at least five people. Each session lasted about two hours.

About once every couple of weeks the field workers came to the Dhaka office and discussed the progress of the work with a senior NERP social scientist and the HOD (Human and Organization Development) Advisor. The HOD advisor visited the Juri River and spent some time reviewing the data that was being collected when the office visits were scheduled.

Eventually the senior field worker wrote up an account of the findings of his fieldwork. An edited version of this was produced after considerable discussion with the fieldworker. Some additional checking was done before the final version was produced. The final version formed the basis of the accounts which are presented in this document.

Table C-1 Checklist for field workers

1. Identify the parts of the valley which are actually affected by flood where people live and how much of the valley is actually affected by flood.
2. Total population of the Intervention area.
3. Identification of the flood zoning areas according to the level of risk. (classification into flood prone zones and proof zones).
4. Traditional norms, values and beliefs relating to flood occurring in the area;
5. Local men and women's experiences and special problems;
6. Patterns of river transportation.
7. Deaths caused by floods and how they occurred.
8. Morbidity due to the flood.
9. Men and women's oral histories of historic flood events.
10. Men and women's responses to flood events including:
    - where they go for shelter?
    - how do men and women get to the flood shelters?
    - Are there differences?
    - what were the channels of flood water movement?
    - under what circumstances did the men and women decide to leave their houses; who left first and who took the decision to make for flood-shelters?
    - what was the velocity of flood water? (fast- medium fast- slow)
    - how many families were forced to leave their houses during flood?
    - who are the members in the families left the houses and why?
11. Identify those that extended help during flood for ensuring shelter.
12. Recording the years flood visited the project area, with mention of and the degree of flood level.
13. Warning lead time, appropriate for each risk area.
14. Collect data on the flood shelters covering the following areas of information:
    - What are they?
    - Where are they?
    - What is their accommodation capacity?
    - How many people were accommodated?
    - Who uses them (Male- Female) ?
    - Where do they come from ?
    - Were the shelters full ?
    - Was there an overflow?
15. Record men and women's reports of details of damage / loss (Human lives, poultry birds and domestic animals) during the flood of 1993.
16. What symptoms do people use to alert themselves to the danger that a serious flood is occurring?
17. How long was it from the time they were aware that there was a flood before the *bhitis* (the floor of the house) went under water.
18. How long did it take and how did villagers reached the flood shelters.
19. Who went to the shelters? Why did they go and why did others not go?
20. Identify problems that the people who used the flood shelters encountered.