Government of the Peoples Republic of Bangladesh
Flood Action Plan

North West Regional Study (FAP-2)

DRAFT FINAL REPORT

VOLUME 8

GHAIBANDHA IMPROVEMENT PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

October 1992

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CHAPTER 1

ENVIRONMENTAL IMPACT ANALYSIS

1.1 Setting

This report provides the Environmental Impact Assessment (EIA) for the Gaibandha Improvement Project (GIP) as required under the Guidelines for Project Assessment (FPCO, May 1992). The GIP has been studied as part of the overall Flood Action Plan (FAP) North West Regional Study (NWRS) - FAP 2. The GIP was selected for more detailed study as a result of the preliminary regional analysis of potential projects (FAP 2 - Interim Report, October 1991). The study is carried out as a Project Preparation Study. In most respects this is a Feasibility Study. However, various uncertainties exist relating to the delays in some of the FAP supporting studies. There is also the need for further research and monitoring work to help integrated the planning with the needs of other sectors. This necessitates that the opportunity be left open for further analysis in the detailed design phase, should this project be found desirable to take forward for financing.

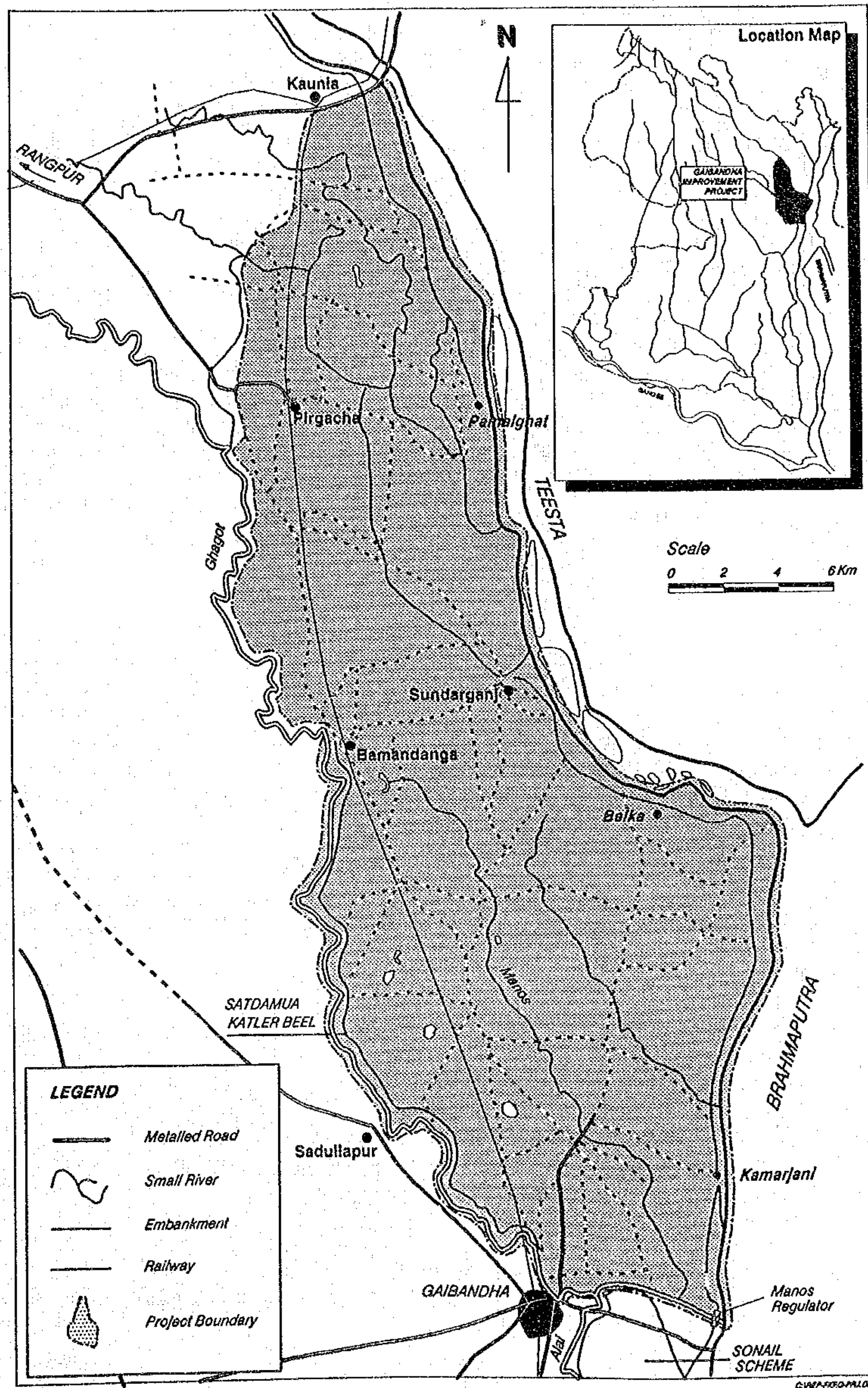
1.2 Background

The GIP study area is located at the confluence of the Teesta and Brahmaputra rivers and between the Ghagot and Manos rivers as indicated in Figure 1.1. It is an area where historical flood damage has been significant from spillage and erosion of the Teesta and Brahmaputra rivers. The construction of the Brahmaputra Right Embankment (BRE) between 1964-70 and the Teesta Right Embankment (TRE) from 1977-82 reduced this risk. Erosion and breaches particularly on the TRE have created recurrent flood damage problems in the GIP area. The Manos regulator at the confluence of the Ghagot and Brahmaputra rivers was constructed in 1968. This has proved to be undersized and led to impeded drainage which created additional flood hazards in the southern part of the GIP area. The Manos regulator is believed to be in imminent and irretrievable danger of being eroded and washed away by the shifting course of the Brahmaputra. It has been assumed throughout the planning that this event cannot be mitigated on its present site. Continued building of village roads has led to an arrangement of internal embankments whose design has not been based on flood alleviation criteria, These do nevertheless established an existing network of compartment throughout the GIP area.

To address the full scope of the evolving FAP objectives has required that the important potential social and hydrological impacts of the FAP on the thousands inhabiting the islands ("chars") located within the braided, active floodplain of the Jamuna, and those living on the BRE means the *de facto* planning and impact assessment area of the study has been extended to include these zones. All the planning, engineering and impact assessments for the BRE are the responsibility of FAP 1 and have not been dealt with under the GIP. Studies under FAP 21 and 22 also affect the BRE.

The study established the range of feasible options and has selected a preferred option to rationalise flooding and minimise flood damage. This has been achieved through a internally developed process of public participation, economic and agricultural analysis, impact assessment, engineering survey and design, and hydraulic modelling using the MIKE 11 computer model which is being developed throughout the regional FAP studies.

Figure 1.1
PROJECT AREA



Source : NWRS

1.3 Rationale for Current Planning

The rationale for current planning is based primarily on the Terms of Reference (TOR) as given in the April 1992 Progress Report. This follows closely on the original underlying premise of the FAP and its guiding principles (UNDP, 1989). However, the premises of FAP are evolving as understanding develops on a wide range of flood-related policy and analytical issues. Changes in this thinking that have occurred during this period of this study have not always been possible to accommodate given the already agreed staffing, phasing and contractual arrangements.

The methodology follows the Guidelines for Project Assessment (GPA) as closely has been practical and feasible, given the constraints on data quality, time and resources. These Guidelines themselves have been subject to numerous revisions since this study became operational. The latest version was issued in May 1992 and this version has been referred to.

The TOR for the GIP study were solely related to flood alleviation. The mainstream engineering for GIP, therefore, did not intend to plan for integrated water management for a multitude of potential users. Neither is it a study focused specifically at poverty alleviation or the development of sustainable rural development strategies. These, by definition, would have to be truly inter-sectorial in their approach and outlook. The proposed scheme for flood alleviation is thus only one tactic for a single problem and must be assessed independently as to whether this complements a wider strategy to achieve sustainable development in the GIP area.

1.4 Environmental Assessment Process for FAP

Desire for proper assessment of the environmental implications of projects being considered under FAP began with agreements at the G-7 summit meeting in July 1989. This was reflected in the assignment of FAP 16 to undertake the preparation of guidelines for EIA and other environmental special studies to support the planning of the regional studies. The concern for proper environmental assessments was also high on the agenda of the 2nd Donors Conference held in Dhaka in early 1992. The national requirements have been laid out in draft Ordinances from 1989 and the Environmental Policy adopted by the Government of Bangladesh in mid-1992.

All the FAP regional studies and various of the priority pilot projects are undertaking various levels of ecological and social impact assessments and preparing EIA according to the Guidelines for Project Assessment. Impact assessments are carried out at either a Feasibility study level where an EIA is produced. For the pre-feasibility level of the regional planning an Initial Environmental Evaluation (IEE) is produced.

1.5 Scope and Format of Report

The scope and format of the report follows that as developed in the drafting of the FAP EIA Guidelines. Limited time, resources and data often mean that the full requirements of the guideline cannot be met. The most critical feature to be noted is that the phasing of the study and its staffing did not allow a full year of data collection to proceed to scope the seasonal cycle of natural resource and ecological processes. Given that no previous baseline surveys have ever been undertaken our knowledge is, at the best, incomplete and, in practice, our understanding is far from adequate to allow proper planning and judgements to be taken on the best means of sustaining the natural resource base and of having a reasonable level of confidence in predicting potential effects of the proposed project options. In the absence of good data considerable reliance has been placed on professional judgement.

This has been generated from the ex-post evaluations of existing FCD(I) scheme, the opinions of the specialists on the team, the opinions of local people though the rounds of public participation and from the first principles of theory in the fields of science involved. Considerable emphasis was placed on holding inter-disciplinary discussions, using the results of the public participation and using the output of the MIKE 11 model as a sensible planning tool.

Chapter 2 considers the planning approach and assessment of options for flood alleviation. Chapter 3 lays out the description of the proposed plan. Chapter 4 gives a profile of the existing environment and important trends in resource processes that affect planning. Chapter 5 details the impact assessment identifying the effects of the project in the various stages of its potential evolution. Chapter 6 looks at how risks and hazards planning. Chapter 7 details the potential response in terms of an mitigation, management and monitoring programme and details the forms of disaster preparedness that may have to be considered.

This EIA report only summarises the key data, descriptions and conclusions from the detailed studies carried out by the specialist on the planning team. The wider range of information on the existing environment is to be found in the IEE of the Regional Plan. The annexes for the EIA have amalgamated the bibliography and summary data sheets which would be of general interest and guidance. For full details in the respective disciplines reference will have to be made to the appropriate annexes. Many of these studies are contained as part of the overall regional planning study volumes and are as follows:

Volume 1	The Regional Plan
Volume 2	The Regional Plan - Planning Units and Options
Volume 3	The Regional Plan - Engineering
Volume 4	The Regional Plan - Initial Environmental Evaluation
Volume 5	GIP - Main Report
Volume 6	GIP - Engineering
Volume 7	GIP - Topographic Survey and Geotechnical Investigations
Volume 8	GIP - Environmental Impact Analysis
Volume 9	Hydraulic Studies
Volume 10	Hydrology and Groundwater
Volume 11	Social Impacts
Volume 12	Agriculture and Fisheries
Volume 13	Economics
Volume 14	Ecology
Volume 15	Health, Navigation and Cultural Heritage

1.6 Research Sources

The study working papers and reference materials have been logged with the main Mott Macdonald office in Dhaka. A comprehensive bibliography of direct source and research background sources has been compiled for the Regional Study. To avoid lengthy repetition this is not reproduced here and interested researchers should refer to the Initial Environmental Evaluation report (Volume 4) where it is presented in full. Similarly a glossary of common terms used in the various fields covered in the regional studies is presented in Volume 4 and is not repeated here.

CHAPTER 2

PLANNING APPROACH AND ALTERNATIVES

2.1 General Planning and Component Options

The GIP area has been bounded in different ways depending on the planning issue involved. For general planning purposes the area was broken down into hydrological cells that reflect the division of the landscape into catchment and drainage basins. These divisions are not based on natural features as most boundaries overlay onto key infrastructural features, such as existing roads of various sizes and the main river embankments. These divisions should also not suggest separate basins as inter-connections of water and flows from one cell to another vary according to flood depth, timing, and drainage conditions. The planning and assessment of biological features has made reference to basic differences in habitats, wetland type and biological processes, such as migration and energy pathways in as much as it has been possible to identify these. The mapping of habitats cannot be easily represented at an A4 scale. The location of the main beel areas are indicated in Figure 2.1.

The major components of the project involve engineering structures to divert and control the flow of water. These will include the construction of new embankments, the raising of existing embankments, the construction and rehabilitation of river training works, the redesign of existing regulators, the construction of new regulators and the closure of various drainage paths and removal of existing structures, such as bridges. Each of these involves the use of varying amounts of renewable and non-renewable natural resources, as well as labour, capital and institutional capabilities.

2.2 Selection of Options

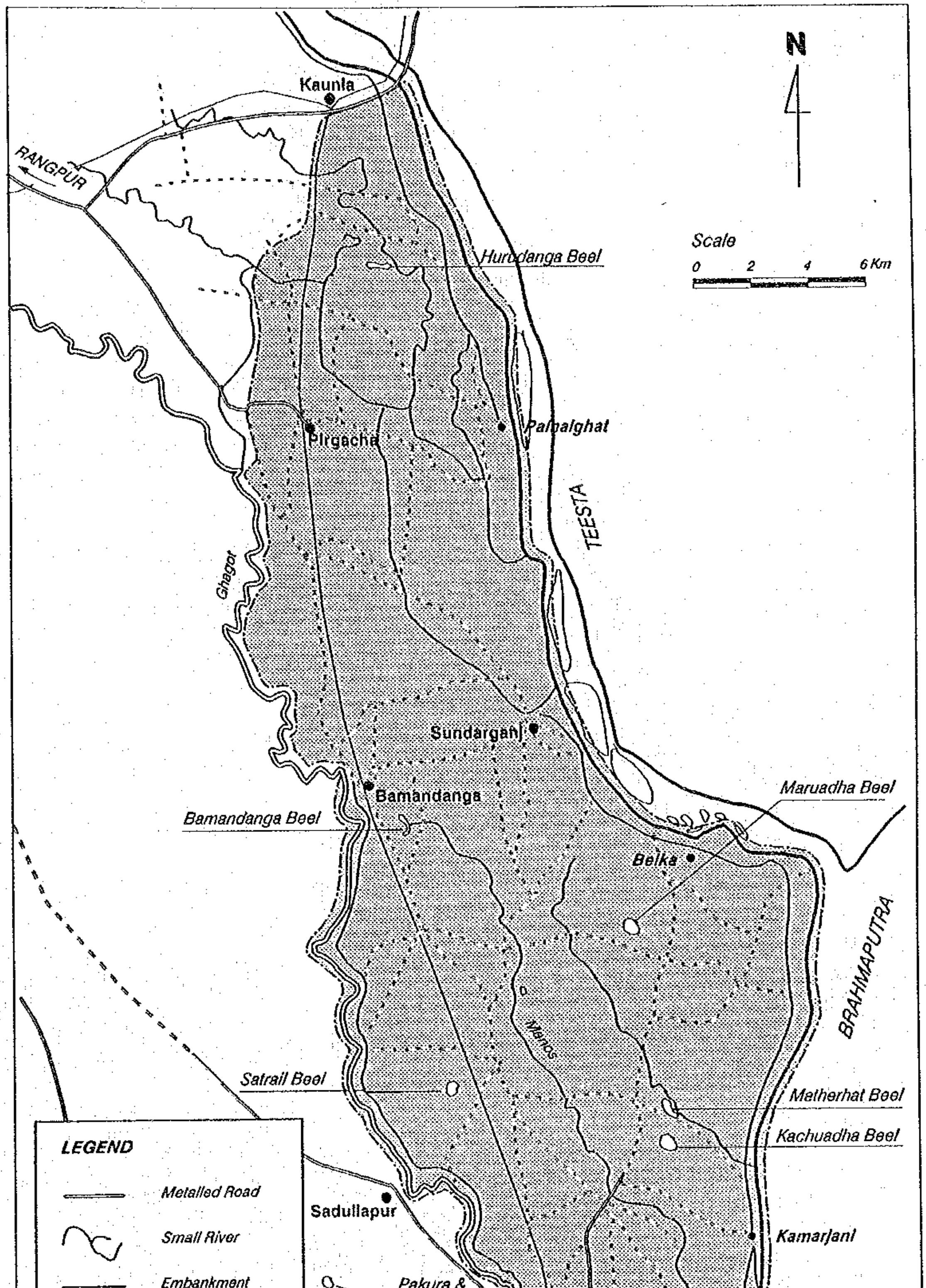
2.2.1 Scale of Selection

The area bounded by the GIP project boundary totals 57 600 ha. The size of cell for hydraulic modelling averages 2 500 ha. and has been able to use water level recordings from 5 stations on the Ghagot and two on the Teesta. A new topographic survey was carried out based on road transect spaced at 100 m spot heights with further spot heights taken from cross transect into the countryside. This has produced information showing 0.5 m. contours based on a grid spaced at an average of about 200 m. intervals. This is the first scale limit to the level of planning possible. Variations of topography below this scale level have not been possible to accommodate. Previous experience of FCD projects have established that variations in micro-topography within the grid do cause problems of impeded drainage that may not be easily represented in the economic analysis. These detailed aspects will have to be taken up at the detailed design phase. There has also been a heavy reliance on the use of existing infrastructure whether these are located in preferable positions or not. This approach is thus pragmatic.

2.2.2 Structural and Non-structural Options

By definition the TOR and staffing of the study have been concerned with the design and analysis of structural solutions to flood alleviation. The option of undertaking non-structural options alone has not been considered, nor would this seem to have been desirable given the results of the rounds of public participation and the existence of such large amounts of infrastructure in the GIP area which include the BRE, the TRE, the main regional road network and the local village road networks. The

Figure 2.1
LOCATION OF MAIN BEELS



Source : NWRS

option of enhancing non-structural response to floods can still continue whatever structural investments are made in the areas. These options will in any case have direct significance to all the char dwellers who will remain in unprotected areas, the embankment dwellers who will suffer from erosion damage and all people throughout the GIP area when the rainfall and river flow events occur that exceed the design criteria and the system fails.

2.2.3 Technology Options

It is becoming increasingly understood as a result of FAP and other studies that the selection of technology within FCD projects are not benign. Traditional selection of technology for straight control of water control structures have been clearly shown to have dis-advantaged both the fisheries and navigation sectors with the attendant dis-benefits to other ecological processes and habitats. For the issue of navigation a redesign of structures to allow for passage of boats of different sizes is technical easy to include in the selection of technology. Establishing biological criteria is fundamentally limited by the lack of basic research and specific knowledge on both the requirements for individual species and an engineers understanding of the role and management of water to sustain key ecological processes.

2.2.4 Capital and Labour Options

A detailed analysis of options for mechanical or labour intensive methods of construction and maintenance was prepared in a Working Paper No.9. (Implementation Planning, FAP -2 Progress Report No.6., July 1992). Both options were recommended to be followed through for analysis as there would be both substantial changes in costs, employment generated, technical work quality, institutional complexity and time periods for construction depending on the methods selected. The two options form a part of the main analysis of options in the economic analysis.

2.2.6 Analytical Options

a. The "Do Nothing and Future Without" Scenario

In order to arrive at as reasonable a comparison of the "with" and "without" project scenarios for economic analysis various changes have been accepted in the "future without" project scenario which will make this comparative base different from the "present" situation. The only difference assumed is that future breaches in the BRE will not occur in either the "with" or "without" project scenarios, or that they will contained by the appropriate combination of river training works or bank retirement.

b. The "Do Something Else" Scenarios

The GOB and donors have choice in the investment allocation between sectors and thus in the strategy for how to response to the advantages and disadvantages of floods. This study has been the option of the role of investments in selected structural tactics with or without non-structural responses. It does not look at the costs or benefits of other responses to improving the capacity to gain benefit from floods or improvements in flood response measures. Thus, improvements in farming systems, health sector improvements or measures to improve flood preparedness from early warning and disaster response are not appraised independent of major structural measures whether these would produce a better rate of return, quality of life, or more rational strategy for sustainable rural development.

c. The "With Project" Alternatives

In total 17 different configurations of flood alleviation have been considered in the derivation of the final selected project options. It was possible to reject many of these options based on grounds other than economic. The main criteria used included rejection through the rounds of public participation, unacceptable levels of downstream impacts, MIKE 11 model run indicated a "no benefit" or "worsening" situation with regard to flood conditions, or illogical planning with reference to the GIP analysis required. The full details on model runs and comparisons are described in detail in Volume 9.

The main component options which have been included in the final combination of configurations include some items which are clearly justifiable in their own right and some that policy makers may wish to consider on other grounds. These are as follows:

- The sealing of the TRE: This not only provides detectable major benefits for the GIP area in flood alleviation, but also confers benefits to other areas and would therefore be better seen as part of the regional strategy. It would be the main technically sound tactic to achieve the benefits in the GIP.

- Flood protection and river straightening for Gaibandha town: Localised erosion on a meander bend within the confines of the town led to plans to straightening this section of the Ghagot.

- Internal Compartmentalisation: The natural drainage pattern means that water accumulates in the outfall of the Manas river into the Ghagot and from the Ghagot into the Brahmaputra. This tactic will cut off small inter-basin flows and divert these with the main drainage route for sub-compartments within the GIP area. These compartments are mostly defined by existing roads and regulators. This forms the main tactical alternative within the GIP area itself.

- Removal of the existing Manas regulator and new regulators at the head of the Alai and the outfall of the Manas: These components are selected to rationalise the high design criteria flood protection associated with the BRE. Without these some flooding would enter into the Manas basin within GIP area. Risks of Brahmaputra flows down the Alai justify this regulator which in itself will divert Ghagot and Teesta water from flooding into the Alai floodplain.

- Extension of the Ghagot left embankment: This component is only justifiable as a source of flood protection to an area on the Ghagot left bank within the GIP. It is not an item that would be incrementally economic but will act as a secondary line of defence should there be future breaches in the TRE.

- Extension of the BRE to join with the Ghagot left embankment: This component is necessary to seal the BRE once the Manas regulator is eroded away.

- Extension of the Ghagot right embankment around and upstream of Gaibandha town: This is necessary to provide the backwater embankment to the BRE with a similar level of flood protection and to protect Gaibandha town.

CHAPTER 3

DESCRIPTION OF PLANS AND PROJECTS

3.1 Overview

The final details of exactly which components will be included in the final GIP plan await the review of the results of this study. The overall layout of the project components is given in Figure 3.1.

3.2 Structural Components

The main structural components can be simply reviewed as follows:

Component	Purpose	Key Design Features
Sealing the TRE	Major Flood Protection	1:20 Year Flood Protection Embankment, River Training Works
Internal Compartmentalisation	Internal Flood Dispersion and Improved Controlled Drainage to Brahmaputra	Raising existing roads, 5 new regulators and closures of existing inter-basin drainage lines
Ghagot Left Embankment	Minor Flood Protection	1:20 Year Flood Protection Embankment
New Manas and Alai Regulators and Embankments	Protection Against Brahmaputra Flood	1:100 Year Flood Protection

3.3 Flood Proofing and Non-Structural Components

The study surveys, rounds of public participation and the coordination with FAP 23 (Flood Proofing) study led to the following potential response in the GIP area as part of FAP planning:

- provision of tubewells on TRE and BRE and associated chars
- provision of sanitary latrines on TRE, BRE and associated chars
- provision of employment programmes for LCS direct to embankment dwellers
- provision of food storage provisions for communities on embankment and chars and for all communities as a disaster preparedness programmes
- provision of extended berms for vegetable and medicinal herb production
- organisation of women as flood warning committees

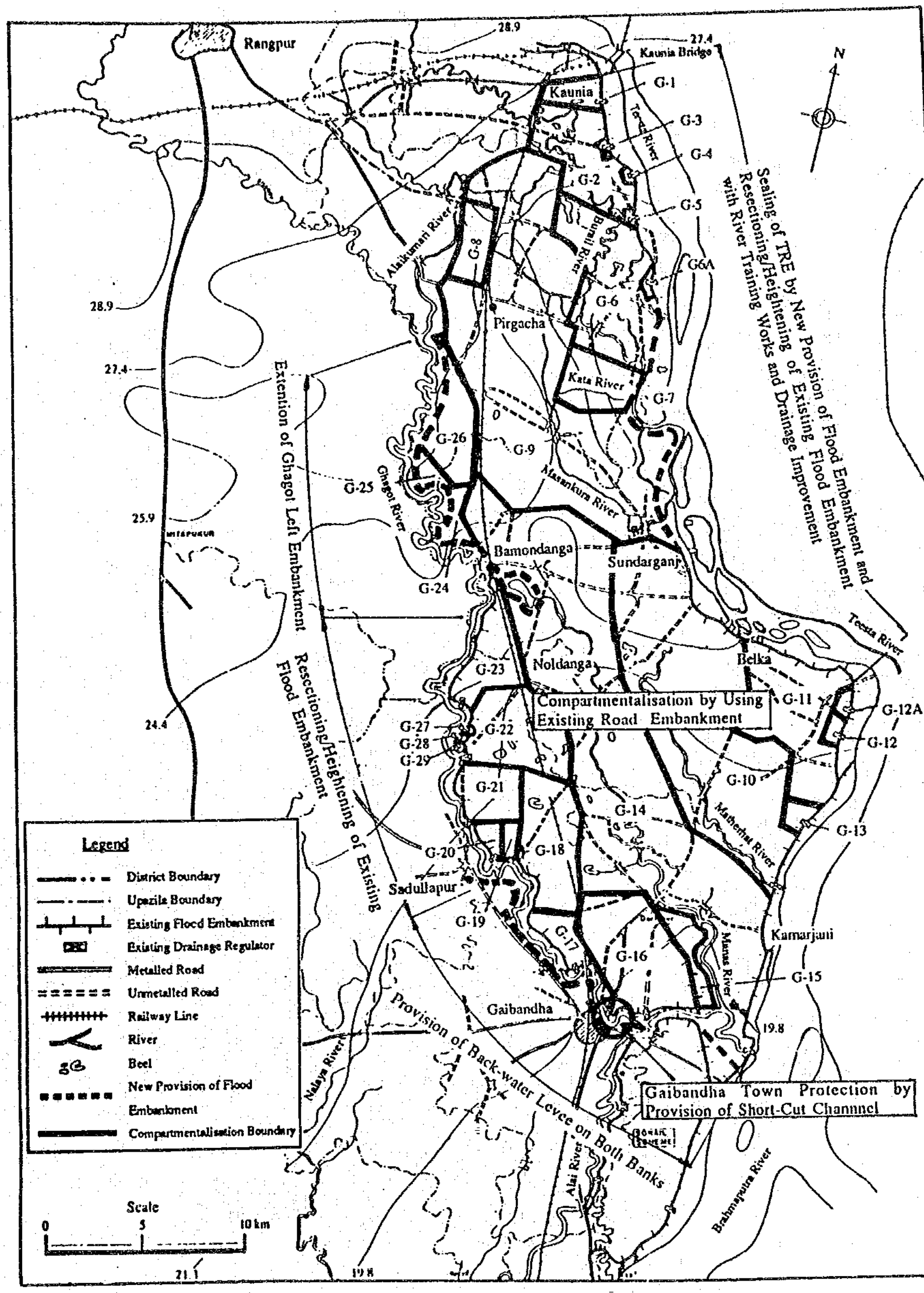
- provision of river ambulances and emergency boats for char dwellers

- provision of, or adaptation of, raised buildings as multipurpose community flood shelters (i.e. schools)

- establishing formal committees to interface between BWDB and embankment settler communities.

- raise design standards and flood protection around key public service infrastructure (i.e. roads, railways, ferry ghats,electricity supply, water supplies, sanitation facilities, health centres, government offices and communication networks).

PROJECT LAYOUT - GIP



3.4 Pre-Construction Phase Activities

Following an assessment of the results of this study a decision on how to proceed will be taken. If the proposals are taken as they stand this would involve the immediate liaison and coordination with other sectors of government, local government and the public that are detailed elsewhere. Additional studies that are required before the detailed design phase can begin include the establishment of proper environmental monitoring programmes. The detailed design phase is planned to start in 1994 and would last for a period of 8 years for the works overall. The final TOR for this study would have to be amended to take account of any results of further institutional coordination, the next rounds of public participation and the identification of a suitable source of funding.

3.5 Construction Phase Activities

The construction phase is currently envisaged to begin in 1996 and would last for 10 years. The phasing of the key components is shown in Figure 3.2. The phasing has assumed that mechanical and labour intensive methods would be involved. The phasing takes into account the seasonal limitations on construction imposed by high river levels and rainfall and the need for more surveys in the GIP area.

3.6 Operational Phase Activities

This study has focused on key aspects of project viability, design and construction method. As yet there is still considerable work that would be needed to assess and decide on potential options for new opportunities for future institutional arrangements for operation and maintenance, water management strategy and the integration of rural development strategies and environmental management into the framework set by the project as designed. All these aspects would need to be given careful consideration as part of the detailed design studies.

3.7 Abandonment

Embarking on a project and strategy of this nature would envisage no stage of abandonment in the foreseeable future. All elements of the project are assumed to be regularly maintained and would be rehabilitated or replaced when the end of the economic and physical life was reached. It is not envisaged that this would present any particular technical difficulties. Only if there were any major morphological changes related to changing river courses, a major change in policy with regard to FCD tactics, or some event that is currently unforeseen would there be any scenario of abandonment. Should circumstances arise that required abandonment this would not overall be a difficult task as the natural drainage channels and floodplain system would soon stabilise and would regenerate in physical terms. Biologically the system would show a rapid recolonisation of the changing habitats subject to the human interventions. The greatest impact would be for a major shift in land use and social arrangements to re-adapt to a floodplain, delta agro-ecosystem that was characteristic of the area prior to the construction of the BRE and TRE.

Figure 3.2

IMPLEMENTATION SCHEDULE

Phase	Construction Works	Year 1	2	3	4	5	6	7	8	9	10	11
I.	Sealing of TRE with river training works											
	a) Upstream of Kaunia	Detailed Design	Detailed Design	Construction	Construction	Construction	Construction					
	b) Downstream of Kaunia	Detailed Design	Detailed Design	Construction	Construction	Construction	Construction					
II.	Construction of backwater levee along Ghagot and Gaibandha town protection (Left bank: 25.0 km, Right bank : 32.7 km)											
	a) Observation of erosion situation at Manas regulator site	Observation works	Observation works									
	b) D/D and Construction			Detailed Design	Detailed Design	Construction	Construction	Construction	Construction			
III.	a) Resectioning/heightening of existing Ghagot left embankment (25.0 km to 43.0 km)							Detailed Design	Detailed Design	Construction	Construction	Construction
	b) Extension of Ghagot left embankment (43.0 km to 75.9 km)							Detailed Design	Detailed Design	Construction	Construction	Construction
	c) Compartmentalisation (576 sq.km)											
	• Hydraulic and hydrological observation for Model updating	Observation works	Observation works	Observation works	Observation works	Observation works	Observation works					
	• D/D and Construction							Detailed Design	Detailed Design	Construction	Construction	Construction

Legend
- Detailed Design
- Construction
- Observation works

CHAPTER 4

DESCRIPTION OF THE EXISTING ENVIRONMENT AND TRENDS

4.1 Introduction

The basic profile of the GIP has been prepared using secondary and survey sources. The need for additional studies during the detailed design phase must be weighed against the level priority of problems envisaged and the need for further research to allow proper management planning to take place. To avoid duplication certain subjects have been discussed in more detail in the IEE for the regional plan.

The basic biological surveys undertaken could only cover a four month period from February-May 1992. This does not conform to the basic minimum of one years research required for either the FAP Guidelines or the criteria set down by the World Bank or other international donors. The profile is thus only an introduction to the human and biological system of the areas and will likely be revised as a result of future studies and monitoring. The location of the ecological survey sites is shown in Figure 4.1. The basic surveys undertaken included:

- collection of a set of dry season and early wet season water quality samples from rivers, beels and tubewells in an attempt to provide some sort of baseline data. These were analyzed in a laboratory for both chemical and organic components.

- a review of the existing soil survey data to establish likely trends as a result of FCD interventions.

- a baseline inventory of fauna and flora in selected wetland sites with the aim of establishing any likely change as a result of project interventions. The survey covered two main beels and their surrounding homesteads and agricultural land and three transects across major river and char habitats. The latter cover one site on the Teesta, one site at the confluence of the Teesta and the Jamuna and one at the confluence of the Ghagot and Jamuna.

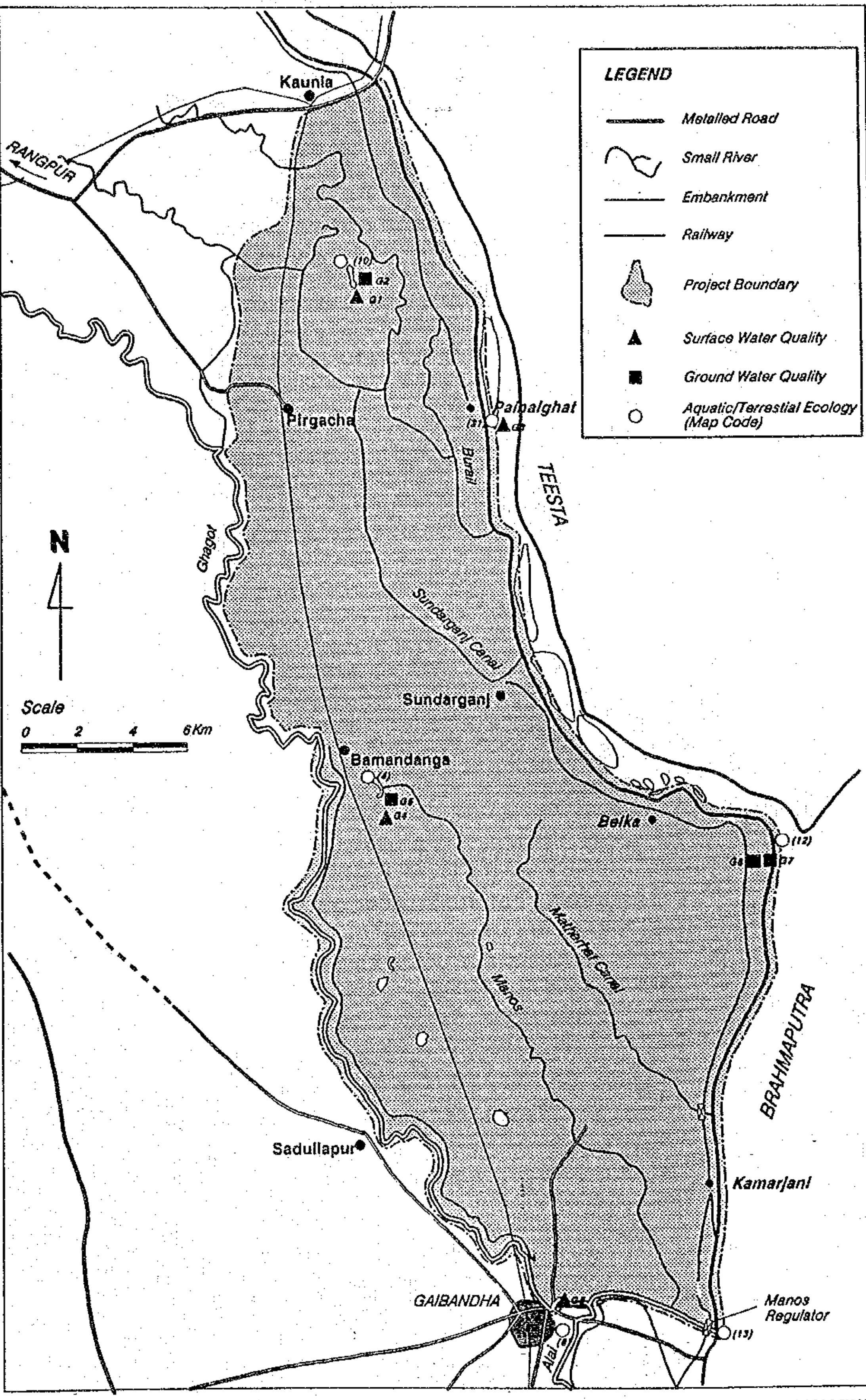
- collection of data on the present state of human health and nutrition in the area. This confirmed the serious problems with waterborne disease and nutritional related dis-orders in the study area. The greatest problem facing the use of this data is predicting likely future trends as a result of CFD.

- survey of archaeological and other sites of historical and cultural interest.

In addition, the study accessed to other databases which proved useful in resources assessment and analysis. This includes a series of dry and wet season Landsat and SPOT satellite images over the last 19 years. This proved invaluable for river morphology studies, specifically erosion and accretion and also for studies on the dynamics of char lands. This was done in collaboration with FAP 3.1 (Jamulpur Priority Project), the FAP 16 Charlands Study and FAP 19 (GIS).

A serious constraint to impact assessment still remains which is the lack of detailed topographic data combined and calibrated with the hydraulic modelling. Only when the awaited Digital Terrain Model (DTM) data is available and can be combined with the hydraulic simulation model will a better indication both of the present and predicted extent, depth and timing of flooding within the study area be gained.

Figure 4.1
GIP ECOLOGY SAMPLING SITES



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4.2 Area and Location

The GIP being considered for benefits from the project investments comprises an area of approximately 57 600 hectares, lying between latitudes N. 30° 25' and N. 25° 45', and longitudes E. 89° 25' and 89° 35'. The investment area will include the proposed works on the TRE through to the Teesta barrage. The GIP area supports a present population of about 550 000 people. Its boundaries are delineated on the west and the south by the left bank of the River Ghagot, and on the north and the east by the right banks of Rivers Teesta and Brahmaputra respectively.

Gaibandha town lies immediately to the south of the project area of the region's surface area but it not being seriously affected from existing flood regimes. It was not part of the TOR but has nonetheless become part of the study engineering components for flood protection works. By its nature the town has a disproportionate effect on the local use of, and demand for, resources as a result of its of urban landscape and high density of human population. It cannot be ignored in the impact analysis, particularly with regard to effects on local drainage hydraulics, impact of growing urban demands for land and in-filling, and downstream water quality from urban and industrial discharges of sewage and effluent.

4.3 Physical Features and Resources

4.3.1 Atmosphere and Climate

The seasonal pattern of climate shows two main seasons, separated by transition seasons. The monsoon (May/June until September) has heavy rain and very high humidity. The dry season (November to February) is sunny and relatively cool, with only occasional scattered showers. The transition in October-November is relatively smooth, with declining temperature, humidity and storm frequency. The start of the dry season transition period is also smooth, but the pre-monsoon period in April and May has somewhat unstable atmospheric conditions. This period is very hot and is characterized by thunderstorms and squalls and coincides with the peak cyclone season in the Bay of Bengal. The tracks of cyclone damage do not reach inland to the North West Region, but the area may be affected by associated storms.

The region has an average annual rainfall of a little over 1900 mm which is significantly below the national average of 2320 mm. The highest rainfall is in the far north with averages around 3000 mm. Annual rainfall shows considerable variability. From 1962 to 1990 the average annual rainfall ranged from 1350 - 2600 mm. The extreme annual rainfall have been measured at 554 mm at Bagdogra and 5633 mm at Bhitargarh. There is a small trend of increasing rainfall since 1962, but this is not believed significant when compared to similar to variations earlier this century. Storm rainfalls can be very heavy in all parts of the region. Daily falls of 200 mm have been recorded, with the absolute maximum being 485 mm at Rajshahi in 1965. 10-day totals of 700 mm or more are not uncommon, with the most extreme recorded value being over 1100 mm at Kaunia in 1987. Rainfall in the GIP areas lies between the ranges of 1,750 and 2,000 mm. Correlation between wet years in the region and over the upper catchments qualitatively assessed based on flows in the main rivers suggests some correlation. Consequently severe rainfall conditions are quite likely to coincide with, and be exacerbated by, severe floods on the main rivers.

The sub-tropical location produces temperature variations that are pronounced. Diurnal variation is a low 5°C during the monsoon but around 15°C in February. Maximum temperatures range from around 35°C in April/May to about 25°C in January, while minima peak at about 26°C in August and drop to 10-11°C in January. Seasonal patterns and absolute values show relatively little variation with

location. Peak temperatures are closely connected with the passage of the monsoon. Daily maxima occur just before the arrival of the monsoon, while the highest night-time minimum occurs at the peak of the monsoon season.

Humidity levels are consistently very high during monsoon, and only drop significantly for a relatively short period at the end of the dry season. Sunshine levels are of course low during the monsoon, but from November to May are consistently high. Wind speeds are at a maximum in the early part of the monsoon, but drop substantially by the beginning of the dry season.

Evapotranspiration reaches a maximum in April when temperature, sunshine and wind are all at or close to their maxima for the year, while humidity is a little below its peak. Evapotranspiration drops substantially thereafter as the humidity reaches very high levels and the other significant parameters all also become less favourable for evapotranspiration. Evapotranspiration is exceeded by average rainfall from May to October, while for the remaining months it is substantially higher than rainfall.

4.3.2 Physiography

Out of the three major geomorphological zones and the twenty physiographic units of Bangladesh the GIP area falls within the physiographic unit no. 2, the Teesta Floodplain. This is composed of the younger part of the Teesta alluvial fan and floodplain, comprising a variety of landscapes which were created as the Teesta river formed and abandoned successive channels across the area. At various times in the past, the Teesta has occupied the channels now followed by the Mohananda, Punarbhaba, Atrai, Little Jamuna, Karatoya and Ghagot since two hundred years ago.

The unit mainly comprises young alluvial land within and adjoining the Teesta river (and other smaller rivers crossing the unit). The surface deposits are predominantly grey, stratified silts with some sands. They occupy a low, generally smooth, but locally irregular, relief of ridges, depressions and partly infilled channels. Seasonal flooding is generally shallow, but all the rivers are subject to flash floods during which inundation is deeper for a few days and when crops may be drowned, buried by new alluvium or damaged by rapidly flowing currants. Teesta alluvium is rich in weatherable minerals, especially mica. An important feature is the instability of the alluvial formations, both in outline and in relief. Shifting river channels erode large areas of river banks and islands (chars) during the monsoon season and deposit large areas of alluvium as new land within the channels or on top of older deposits.

4.3.3 Geology

Bangladesh forms the major part of the Bengal basin. This is considered part of the Himalayan Foredeep which is a subsiding region stretching across the Indian subcontinent. The rivers that originate from the Himalayas, entering the subsiding foredeep, are diverted along it either to the southwest into the Indus system, or to the east to the Ganges-Brahmaputra river system. However, plate tectonics theory suggests that the Bengal Basin forms a rifted, passive, marginal basin of the Indian plate that is gradually closing due to plate destruction in the subduction zone beneath the Indo-Burma ranges in western Myanmar. The Bengal basin cover West Bengal, Tripura and Assam. It comprises a flat surface created by the geologically recently formed delta and alluvial plains of the Ganges, the Brahmaputra and Meghna rivers, with a total area of 60,000 km^2. The basin is essentially a Cretaceous-Eocene depositional centre within major delta building episodes during the recent Oligocene age. About 85% of Bangladesh is a plain covered with unconsolidated Holocene sediments;

the remainder being underlain by the early to late Tertiary rocks in the north east region and Neogene sedimentary rocks in the eastern folded belts.

The unconsolidated sediments comprise coastal, deltaic, paludal, alluvial, and alluvial fan deposits of Holocene age. The older alluvium consist of Madhupur, Barind and Lalmai residual deposits of Holocene-Pleistocene age. In general, the deposits range from coarse sand and gravel in the alluvial fan areas to silty clay and clay in the mangrove swamps in Sundarban. Different rivers carry different kinds of sediments depending upon their source materials. The Brahmaputra river sand is coarse to fine grained and contains mostly quartz, feldspar, mica and a little amount of heavy minerals.

The GIP area geologically falls within the alluvial fan deposits. The eastern part of the fan is active, flooded annually by the Teesta river and its distributaries. On the other hand, sand depositing in the GIP area is generally finer and contains more silt.

4.3.4 River systems

The GIP are is bounded by the River Ghagot to the South and West, the Brahmaputra/Jamuna to the East and the River Teesta to the North. The GIP model incorporates these are the rivers which influence flooding in the GIP. The areas and rivers covered by the models are indicated in Figure 4.1.

The flood network can be characterised as a highly complex riverine floodplain system, rather than a river catchment. The flood regime falls into three categories: fluvial, interaction and backwater. In the fluvial zone, the water levels respond to the local flow rate and are not influenced by tail water conditions at the outfall of the river system. In the backwater zone the water level is nearly independent of the discharge in the river and is governed by the tail water level at the outfall. The interaction zone lies between the fluvial and backwater zones and the relative importance of the river flow and tail water level changes progressively along this zone. Peak flood levels are dominated by the backwater effect from the Brahmaputra. Generally the effects of engineering works will be small in the backwater zone.

In addition there is the local rainfall run-off system, some parts of which drain into isolated pools, although the number and extent of these varies depending upon the degree and timing of river flooding and the intensity, timing and location of rainfall.

The flooding and drainage pattern is significantly affected by the existence of man made structures, particularly the railway and road networks which are on embankments of varying heights incorporating hydraulic structures of differing types (bridges, culverts etc). In addition there is a relatively long history of construction of flood embankments in the area and these are kept in varying degrees of repair and are at times deliberately breached to solve drainage problems. These existing structures form the basis for a water and land management system for the area.

4.3.5 River Morphology

Historic data indicates a trend of movement of the Teesta river to the South-West. The cause of this movement is not clear. A study of the topography of the area, particularly along the right bank of the river, indicates that there are no effective natural constraints to prevent further movement to the South-West. If this movement continues into the future then the frequency of breaching of the present

Teesta embankment will increase and any further embankments or structures constructed along the right bank will be threatened by erosion.

The channel pattern and its evolution is similar to that of the Brahmaputra where a sequence of locations along the river have anabranches coming together and more or less a single channel is formed. These locations are more or less fixed and the river appears relatively stable. Between these the river divides into a number of anabranches, each of which has a sinuous form. These areas have a large belt width and a highly variable plan form. The fixed locations or nodes are approximately located at Belka, Kaunia, upstream of Kaunia and Purba Chihandi. Any dramatic change of course due to a major earthquake would likely take place at one of the nodes.

The time for morphological re-adjustment in the river Teesta is likely to be 20 to 50 years.

The available data on the bed level of the Ghagot shows a pattern of sediment movement is consistent with spills from the Teesta introducing large quantities of sediment which is deposited in the Jafarganj reach and immediately downstream. The difference in calculated transport at Jafarganj and Islampur is consistent with the inferred bed level rise at Jafarganj of approximately 0.05 m per year. Recordings from Islampur and Gaibandha do not exhibit any discernible trend up or down. Calculations immediately upstream and downstream of the confluence with the Alai Kumari suggest that this brings significant quantities of sediment into the Ghagot which is deposited in the reach to Gaibandha.

The time for morphological re-adjustment in the Ghagot and Alai Kumari rivers is likely to be less than 20 years.

4.3.6 Groundwater

In terms of groundwater resource availability, no serious constraints exist within the Gaibandha Project. Potential recharge is high, and both high specific yield values and high aquifer transmissivity will allow for full development with suction mode technology. Groundwater salinity forms no constraint to its use for irrigation and water supply although problems of iron toxicity can occurred. A constraint to tubewell development may, however, be the occurrence of highly permeable soils, which make traditional surface irrigation inefficient. There are around 450 DTWs, 6200 STWs, 140 LLP and 760 other types of irrigation units in the GIP areas.

Shallow tubewells powered by small diesel pumps are in widespread use for irrigation. These are normally installed by individual farmers with access to sufficient capital to irrigate their own land and surplus water is sold to neighbouring farmers. Temporary earth channels are constructed to distribute the water. The numbers of deep tubewells have been increasing steadily of the last decade. They provide greater discharges of water to larger areas and require more formalised canal systems to distribute the water. They are usually co-operatively managed, sometimes under the control of larger and/or more influential farmers.

Very shallow treadle pumps are used for small scale irrigation at the farm level and shallow hand pumps for domestic supply at household or village level.

4.3.7 Soils

Figure 4.2 shows the agro-ecological zones and soil associations for the area. The soils derive from the Teesta and are of medium to medium-heavy texture. Unlike many of these soils they dry out reasonably quickly after the rains making it possible to prepare the land in time for the major rabi crop which is wheat.

There is a cyclic alternation in biochemical oxidation in the soil, as water saturation during the flood season reduces oxygen availability. During the dry season, organic residues are recycled by the energy-efficient process of aerobic oxidation, whereas when soils are flooded the process is carried out by the very much less efficient anaerobic glycolysis.

The activities of nitrogen fixation by the Rhizobium - legume symbiosis are suspended during the floods, although the poor representation of the Leguminous on the floodlands means that this loss is probably not very significant.

The fixation of atmospheric nitrogen by terrestrial plants is replaced by the same process carried out by submerged Cyanophyceae in the plankton and by floating commensal (usually Pteridophyte - ferns) during the floods. The contribution from such sources is probably of the order of 35-50 kg/ha of nitrogen, which is incorporated into the soil as the flood waters recede. This source is particularly valuable, since it is a 'slow release' fertiliser, and therefore equivalent to several times its nominal weight of artificial chemical fertilisers which are subject to rapid leaching. However, the full potential for using these biological nitrogen sources is substantially higher than the current agricultural practices allow.

Flood protection interventions have the potential to affect soil biology because they alter the balance between the two groups of processes which alternate through the annual inundation cycle. The present semi-natural system relies to a considerable degree on the aquatic components, and CFD interventions which cause an increase in the length of time that the soils remain unsaturated each year will certainly cause a reduction in nitrogen fixation. This represents a major cost to the agricultural sector, since this nitrogen is another of the 'free goods' of the floodplain which will need to be replaced by traded goods if the natural cycle is disturbed.

Only the adoption of active policies of nitrogen harvesting by the Leguminous as an integral part of the agricultural system, in contrast to the present low level of dry season nitrogen fixation, will redress this loss with minimal cost. Indeed, the adoption of such nitrogen harvesting technology as is already available elsewhere would be capable of producing a substantial improvement in the yields of a number of existing crops-Subba Row and others have quoted increases in rice yields of up to 50% from the adoption of Azolla-rice culture techniques. If these techniques are adopted in conjunction with FCD interventions, then a positive benefit to soil productivity may be available.

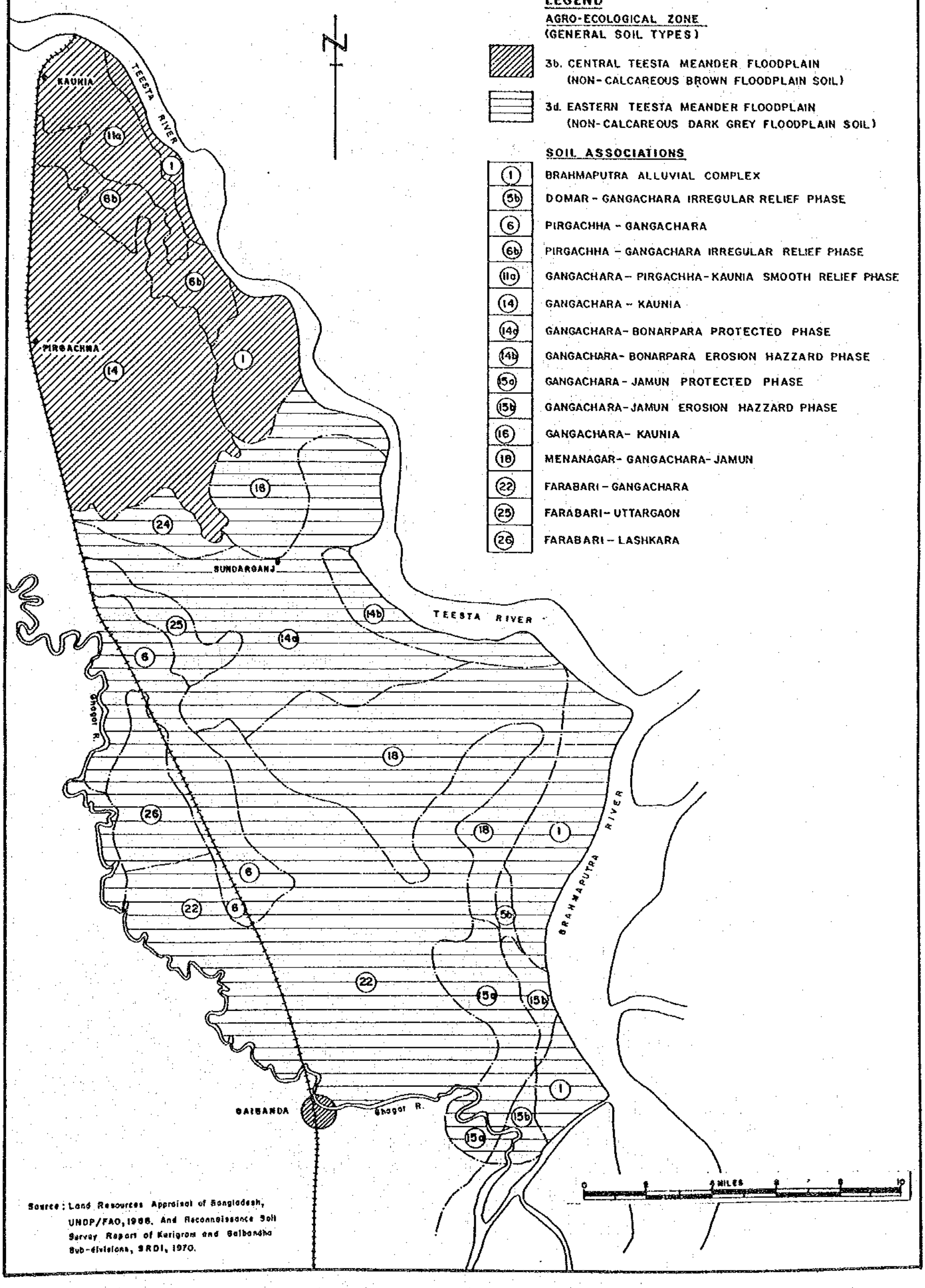
4.4 Biological Features and Terrestrial Resources

4.4.1 Land Use and Cropping

The overall breakdown of land use in the GIP area is shown in Table 4.1. and its present cropping is as shown in Table 4.2.

Figure 4.2

AGRO-ECOLOGICAL ZONES AND SOILS - GIP



Source: Land Resources Appraisal of Bangladesh, UNDP/FAO, 1988. And Reconnaissance Soil Survey Report of Kurigram and Gaibandha Sub-divisions, SRDI, 1970.

Table 4.1 Land Use in the GIP

ITEM	Area (Ha.)
Gross Area	57 600
Comprising	
Floodplain Agricultural Land excluding	48 510
Fishable Floodplain Agricultural Land	620
Rivers and Canals	1 800
Ponds	470
Seasonal Beels	180
Perennial Beels	200
Homesteads and Roads	5 900

Table 4.2 Present Cropping in the GIP

Crop	%	Crop	%
HYV boro	29	HYV t. aman	41
Local t. aman	43	B. aman	
B. aus	20	Jute	19
Wheat	9	Oilseeds/pulses	5
Potatoes	1	Vegetables/spices	1
Tobacco	1	Others*	tr
Total cropping intensity: 170%			
* sugar cane 244 ha; orchards 22 ha.			

Rice, predominantly HYV boro, taking up some 133% of the cropped area. Jute is locally important with its area well above the regional average of 7%. The wheat area is also above average due to the cool winters and the moisture retention of the soil which enables a reasonable crop to be grown on residual moisture. Conversely, the area of oilseeds and pulses is low due to these being less profitable than wheat, when it is grown under suitable soil and climatic conditions. The others are principally grown on the lighter soils and in climates where wheat is not a reliable crop. The small area of tobacco, most of which is concentrated in the north-west is taken to the large tobacco market in Rangpur.

In the future the only likely change will be in the irrigated area and therefore the potential area for boro. This is expected to increase from the present 29% to 48% and the total cropping intensity moving to around 180%. In the with project situation little change in cropping intensity is expected

The additional security from flooding risks will induce farmers to make the effort to plant more HYV t. aman than they would without a project. Some of this will replace local t. aman, some will follow the expected smaller area of jute, wheat, oilseeds and pulses.

4.4.2 Flora and Fauna

Natural vegetation has all but disappeared although there is widespread use of vegetative matter for building construction and stall fed fodder. There is extensive use made of various naturally occurring plant species for medicinal use. The area is very poorly endowed with mammals, anything of any size has been hunted, either for food, sport or as a nuisance or has been displaced by habitat change due to the intensity of human settlement and cultivation. There are no gazetted Wildlife, National Parks or Forest Reserves in the study area.

The detailed results of the surveys into the terrestrial flora and fauna are given in Volume 14. Annex A summarises the main macro flora and fauna identified in the field survey and identifies their main uses. Nine common mammals, 40 bird and fowl species, 11 reptiles and two amphibians were surveyed in the GIP in the four months from February - May 1992. Floral collection recorded 36 different varieties of trees common grown the village groves and waysides. 52 species of herb, grass or scrub were identified many of these being of direct economic or medicinal value. These are also predominantly managed or cultivated species in and around the village and homesteads.

4.4.3 Major Terrestrial Habitats

Crop Lands

The croplands are generally regarded as the most important areas, and it is correct to attribute the highest economic values to them. From an ecological viewpoint, however, they are almost barren, with extremely low species diversity and abundance values. The field margins provide facilities for a surprisingly wide range of plants and animals, and the small field sizes undoubtedly plays an important part in the maintenance of some diversity across the agricultural lands as a whole. The adoption of a more enlightened approach to intercropping, especially with nitrogen fixing species, would greatly improve diversity, with a number of benefits.

Intercropping with these species does not necessarily reduce crop yields, because over a number of years both the soil nitrogen reserve and the soil structure improve. In addition, the intercrop species can be used as high food value fodders for livestock, a factor of considerable importance in maintaining draft power capacity on the farms.

The increase in diversity also promotes pest management, since a more diverse field system will support more species which are able to predate crop pests.

The Highlands as Centres of Diversity

The vast majority of the natural resources of the region are centred on the highlands. Floral species diversity is far higher in these habitats, and it is notable that the most common forms of dominant species have a large number of uses. The importance of these resources almost certainly exceeds in value even the fish resources of the floodlands for poor people, since they provide shelter, food, materials for earning money from craft work, and free medicines as well.

The floral diversity promotes a comparatively high animal diversity, and it is noticeable that a very large number of the birds which are common in the highland homestead areas feed principally on insects. The highland homesteads therefore represent a major refuge for crop pest control species. The lack of investigation of insect species precludes speculation of the role of these habitats in providing refuges for those insects which also help to control insect crop pest species.

CFD interventions may potentially encourage the preservation of the floral and animal diversity in the highlands by reducing high water tables in the flood season. This will enhance the growth of the trees which form the dominant group in the highland habitats, and so improve the resource availability of those species which rely on them.

The embankments are floodland habitats which have some of the characteristics of highland. It is therefore not surprising that they have a diverse biological community. They act as refuges for people and animals alike during floods, and this may result in some conflict for space and resources which frequently is to the detriment to some human individuals who may fall victim to venomous snakes.

However, the role of the snakes in controlling the mammalian commensals of man, such as the mice and bandicoots, should not be overlooked. Since some small mammals can act as vectors for serious human diseases, snakes should be seen as playing a positive role in the regulation of public health hazards, despite the manifest hazard associated with a few species. (It is worth emphasising that the majority of snakes recorded in this study were not venomous).

The embankments serve as important linear habitats and are major dispersal corridors for many species, some of which may be reservoirs of infection of diseases which affect humans. They are also important as dispersal routes for the agents of some contagious human and animal diseases. They provide shelter - often the only shelter - amongst the open and generally treeless fields of the floodland for the wild birds which feed on insects which may at times become crop pests.

The Char Lands

The charlands are the most ecologically diverse of the floodland and lowland habitats, but show the lowest resource potential for human occupancy and colonisation. There is a distinct pioneer plant assembly, the dominant members of which are generally either noxious to grazing animals or extremely small and compact to reduce drag during the floods. Despite the general attraction of the lowland river channels and charlands for water-living birds, the Bangladesh charlands are very sparsely inhabited by wild birds of all kinds, and cannot be regarded as major wild bird or wildfowl habitats. There are therefore no significant conservation issues which are of specific relevance to FCD interventions.

4.5 The Aquatic Environment

4.5.1 Water Quality

The water is generally of good chemical quality, although its low hardness provides only weak buffering capacity. The calcium in hard water is a good general antagonist of many toxic pollutants when they are dissolved in water. Its low concentration in Jamuna water means that any toxic materials will exert detectable effects at fairly low concentrations. Many fish larvae and fry are particularly sensitive to toxins, and water quality standards aimed at protecting fish and other aquatic life should reflect the low hardness of the water supplies.

The bacterial quality of many surface water supplies is unsatisfactory, and is a major cause of diarrhoeal disease outbreaks. Without adequate sanitation development, this situation cannot be expected to improve. The lack of appreciation of the risks of contaminated water to human health requires attention.

The chemical standards set for drinking water are in some cases irrelevant - for example the minimum value set for dissolved oxygen (6mg/l) would preclude every tubewell source tested in this study, despite their being generally the best quality water available. Groundwater, particularly that from deep tubewells, represents the safest source of supply for human consumption. Shallow tubewells, especially hand-operated units, are often constructed with inadequate sealing around the wellhead, and this permits contamination of the adjacent zone of the aquifer by downward seepage of contaminated water from the surface.

The low level of iodine in all water sources is responsible for the widespread incidence of iodine deficiency syndrome and the high incidence of cretinism in some areas. However, the uneven intensity of the problem suggests that there may be some plant resource which is capable of accumulating iodine, and some effort should be made to investigate this in view of the administrative problems of distributing iodised salt to the more isolated parts.

There is presently little any of chemical herbicides as the majority of these have to be imported into the country and are prohibitively expensive for local farmers. Weeds are harvested as a valuable fodder resource. There is some limited but increasing use of chemical pesticides for control of insects particularly in areas of HYV rice cultivation. Fertilisers use is far more extensive but there are no indication of water quality problem at the current time.

There is an insufficient data base to fully assess the problems of water quality for potable and other uses. From groundwater there are some cases of iron, boron and bromide problems which affect both crop production and human health. These have been recorded from the field surveys and other sources in the Kurigram, Lower Karatoya and Mohananda basins. The problems related to surface water sources are from industrial pollution, agro-chemical pollution, eutrophication in stagnant pools, low available oxygen due to enrichment and pollution with sewage and waste effluent, and the health risks from poor sanitation and drainage conditions, both inside and outside FCD schemes. Considerably more survey and monitoring work is required to make proper regional or project planning responses to these problems.

4.5.2 Aquatic Productivity

The most significant factor controlling primary aquatic productivity is light penetration into the water. The heavy silt loads of the principal rivers throughout the year, and of the more mobile flood waters during the flood season, severely limit energy capture in the aquatic habitats, and most of the energy available to aquatic organisms is derived from energy captured by terrestrial plant photosynthesis during the dry season.

In the surface waters, oxygen concentrations are rarely low enough to present any threat to fish and other aquatic organisms. In standing waters phytoplankton provide a biological source of oxygen during the dry season, but this process fails in all except the most sheltered waters during the wet season. However, the high levels of dissolved oxygen in the rivers, even when they are carrying most silt and therefore incapable of supporting phytoplankton, indicate that turbulent flow and surface absorption are sufficient to ensure full oxygen saturation at all times.

Plant nutrient levels in the surface waters are adequate for phytoplankton growth, and silica levels are high enough to permit strong growths of the Bacillariophyceae (Diatoms) which compete with the Cyanophyceae ('Blue-green algae') more effectively under these conditions.

However, in standing waters phytoplankton nutrients are rapidly absorbed, and Cyanophyceae frequently become dominant. It is possible that some fish mortalities reported during the dry season may in fact be due to phytotoxin produced occasionally by the Cyanophyceae, rather than to unspecified pollution by industrial and agrochemicals as is widely alleged.

FCD interventions are unlikely to have any significant effect on surface water oxygenation, since reducing current flows permits the development of phytoplankton, which form an alternative source of supply for aquatic organisms.

4.5.3 Flora, Fauna and Habitats

Rivers and Wetlands

The lowland habitats are fluvial in nature. Within the river channels, both past and present, the deposition of relatively coarse-grained particles of sand has resulted in a mobile system of sandbanks (chars) which represent the only source of new land for colonisation, for both humans and for plants and wildlife. The fluvial habitat is extremely erratic, with extreme changes in the depth and configuration of the river bed, even during the dry season. This is reflected by the constant erosion of the banks of the permanent river channels, and the downstream migration of chars over a period of years:

- Permanent river channels. The permanent river channels are characteristically almost barren. They carry a high silt load throughout the year, preventing the establishment of aquatic flora.

- Temporary river channels. The rivers of the GIP only flow for the wet season and a short period after. During the dry season the channel changes from a rapidly-flowing environment carrying a very high silt load to a series of shallow, stagnant pools in which the silt settles out, allowing light penetration and the growth of phytoplankton. During the dry season, environmental conditions in these pools approach those which develop in the flushed beels of the floodplain.

The importance of the beels does not lie in their conventional role as wetland reserves for wildfowl, but as dry-season refuges for the floodland fish. The preservation of the fish stocks, which should be a matter of international concern, demands that the present network of beels and river channels should be maintained and the fish sheltering in them protected by sound and effective management policies, to ensure that their access to their essential energy source, the floodland, is continued. In FCD terms, this means that compartmentalisation centred on the major beel complexes but allowing some access to the river channels as well, is the correct approach to the management of the fish stocks of the Region.

In the Jamuna and Teesta Rivers, young fish in their first year after hatching (year-class 0+) play an important role in the transfer of chemical energy contained in organic residues on the floodplain at the end of one dry season to the aquatic environments at the start of the next. The anomalously high fish species diversity is a result of niche specialisation for exploiting terrestrial energy sources, rather than very small niche hypervolumes in the dry-season river ecosystem.

The importance of the timing of access by spawning fish and planktonic fry to the floodplain has already been described in relation to the longitudinal fish migrants - mainly the major carps (Cross, 1992), and FCD planning for providing such access is already beginning to appear. However, it is important to realise that the peaks of abundance of fry in the river waters may only extend for two or at most three days at a time. Access to a large area of the floodland by fry in such a short period can only be achieved by allowing large volumes of water to move across the floodlands in this short period. Structures which attempt to concentrate fry in small volumes of water will almost certainly result in increased predation by larger fish, as well as intensification of the already excessive fry harvesting by man.

In addition to these problems, the post-larval fry need to gain access to the feeding grounds within a very short time of using up their yolk supply, since there is no food supply available to them in the rivers. The only source of the essential high-protein foods (zooplankton) is the more sheltered beels. Any delay in their gaining access to these waters will cause substantial mortalities, an eventuality to be particularly avoided since fry numbers are already in very serious decline in the Region, and indeed over almost all the country. FCD structures designed for fry access facilities therefore must not delay access to the floodland, since the fish are at a very critical time in their life cycle, and even apparently short delays will be fatal to many.

86 species of zooplankton were identified during this survey. They comprised 38 species of Crustacea and 48 species of Rotiferal. 137 species of phytoplankton were identified during this survey. They comprised of 64 species of Chlorophyceae, 38 Cyanophyceae, 26 species of Bacillariophyceae and nine other species.

A number of these aquatic micro-flora and micro-fauna are commonly used as indicator species for assessing particular problems related to pollution and other environmental processes. The limitations of time and resources prevented this approach to the analysis. It is hoped that the first database of this kind can now be used for continued monitoring, research and analysis for precisely these purposes.

There is considerable monthly fluctuation in species abundance in both the phytoplankton and the zooplankton. In the principal rivers, the positions of the Jamuna sites will fall back towards the position of the Teesta by April, and the values for both rivers will reach the origin by May. This is indicative of the loss of the plankton, and reflects the increase in silt transportation at the start of the flood season.

The temporary river indexes will also fall in a similarly abrupt fashion as soon as they begin to be affected by either floodwater or heavy surface runoff, whilst those of the flushed beels will fall slightly later. However, the index of those beels which are less strongly flushed or which only receive rainwater or surface run-off, may well not fall so markedly, since silt transportability will fall as the current velocity reduces, and phytoplankton growth will be maintained.

In the beels, the values reflect the very marked short-term blooms of individual phytoplankton species populations, and the corresponding slightly delayed blooms of the zooplankton in response to them. Species richness, however, will be comparatively stable during the dry season.

However, with the onset of the floods, this situation will change rapidly. In the flushing beels, the species abundance values will move towards the origin at rates which will depend on the current velocity and origin of the water which flushes them. Where there is a sudden onrush of river water because of a breach in an embankment, the species abundance value will fall rapidly towards zero, and the plankton will disappear almost instantly. However in gently flushed beels, the effect will be less marked, as the slower-flowing water will deposit its silt load and become more transparent.

The Flushed Beels

These waters are flushed (but not scoured) annually by floodwater from the rivers, augmented by run-off from the adjacent land. Species diversity is high, with Cyanophyceae approaching the significance which they attain in the unflushed beels. In general, however, there is no clear dominance between groups, with different families taking then loosing dominance from month to month in different beels. The zooplankton in these beels is dominated by Crustacea, even as late as May. Populations are still high when flood waters reach them in early June, a point of vital importance to floodplain fisheries.

Surveys in Bamandanga beel identified 25 species of fish currently to found there as follows: Rui, Catla, Mrigal, Calibaus, Chala, Tengra, Puti, Chanda, Chingri, Boal, Tengra, Chapila, Gozer, Khoira, Moa, Batasi, Baim, Poa, Bela, Chital, Pholi.

The beel since 1988 has suffered from the ulcerated fish disease which occurs in the post monsoon period when the flood water are just receding. Local fishermen associate this disease with the following changes in the area:

- use of gypsum chemical fertilizer since 1988,
- use of pesticides near the main water area of the beel (HYV boro season),
- siltation from the flood water of Ghagot ,
- minimum depth of water in the dry season (due to irrigation by 4 shallow tubewells.

The Permanent (Unflushed) Beels

The permanent beel phytoplankton was dominated by the Cyanophyceae throughout the period of study. These permanent beels appear to contain a higher proportion of Cyanophyceae than any other water type examined in this study. The zooplankton is much more diverse. Although the numerical dominance tends to favour Crustacea, the diversity indexes for the four months are higher than those for other waters, and it is clear that the community structure of the zooplankton of the permanent beels reflects a relatively stable environment.

Ponds

The ponds in the highland zone are in a different category from the floodland beels, as they receive only run-off from rainwater, and are never flushed. The phytoplankton of the old permanent ponds shows some variability in dominance, whilst the zooplankton is an even mix of Rotiferal and Crustacea.

The temporary pond phytoplankton in March was very species-poor and dominated by Euglenophyceae. The phytoplankton of these ponds therefore appears to be similar to that of those beels which are pumped dry at this time of the year. The zooplankton is heavily dominated by Rotiferal in which Crustacea dominate at this time.

4.6 Socio-Economic Environment

4.6.1 Demographic and Social Features

The population of the NWR has increased by over four millions between 1981 and 1991 forcing population density up over the same period from 630 to 751 per square kilometre (BBS, July 1991). While population growth has contributed to pressure on land the disappearance of land into the Brahmaputra and Teesta is also a severe impediment. In the next five years some 1500 ha. of land are expected to be eroded by the Brahmaputra and this would displace around 170 000 people who have to find alternative means of livelihood.

In Gaibandha District the pressure on land has been greater than that of the national and regional areas. Between 1981 and 1991 the population grew from 1.57 to 1.85 million increasing the population density for the same period from 723 to 851 persons per square kilometre (ibid 1991). There is, therefore, greater pressure on land by an order of one hundred persons more than the regional figure. If this is coupled to the fact that the northern and eastern boundaries of the district are the Teesta and Brahmaputra rivers with the erosion they have caused over the last twenty years, the pressure is even more significant.

In the area which specifically comprises the special improvement project the increases in population density are even greater. Table 4.3 compares the three major upazilas in the improvement project area with national and regional figures over the same decade.

Table 4.3 Population by Thana - Gaibandha Improvement Project (Density of people per square kilometre)

Area/UPZ	Pop. Density 1981	Pop. Density 1991	Increase
Bangladesh	651	781	131
NW Region	630	751	121
Pirgacha	788	973	165
Sundarganj	758	892	134
Saidullahpur	856	1008	152

Source: (BBS : 1991)

Increases in population density can also create problems when planning for flooding contingencies. Resettlement costs if calculated on a reasonable basis for house and homestead garden will increase if humanitarian considerations are fully taken into account. One of the problems of impoverished communities generally is a lack of space.

The Thana Development Monitoring Project (1989) produced a number of key socio-economic and development indicators for upazilas nationally. Included in this study were eleven in the northwest region which were comparatively analysed with the national indicators including Gaibandha town and Palashbari thana. Table 4.4 shows these indicators.

Table 4.4 Key Socio-Economic Indicators (Selected Areas)

Indicator %	Bangladesh	Gaibandha	Palashbari
Drinking Water			
Pond Water	9.03	Nil	0.20
River Water	3.10	0.20	2.40
Tubewell	76.82	74.20	80.60
Literacy			
Males	36.29	30.85	31.05
Females	22.29	16.89	17.69
Combined	29.55	24.05	24.66
Housing			
Pucca	1.41	1.00	0.20
Semi-Pucca	3.98	1.60	7.80
Katcha	94.61	97.40	91.40
RAR*			
Male	77.71	80.87	78.35
Female	7.66	7.60	8.09
Combined	44.15	45.64	44.75

* The Refined Activity Rate is the proportion of those over 10 years old who are economically active. The figures for females should be treated with caution as many young women working eg as domestic servants are not recorded.

Source: UDMP, 1989.

In the same study for Gaibandha and Palashbari it showed that around seven percent of the population was totally landless while almost 45 percent in both upazilas were functionally landless, i.e. having less than half an acre. In Gaibandha District as a whole over forty percent of all households are now non-farming.

The population of the area of the GIP area is approximately 670,000 people with an average population density of between 900 and 1,000 persons per square kilometre. This is nearly two hundred more than the average for the country as a whole. This high density coupled with other demographic and socio-economic features make the project area one of the poorest in Bangladesh characterised by:

- low rates of literacy
- poor housing

- few good quality roads
- poor drainage in the project area
- high levels of male migrant labour
- high rates of landlessness
- large number of embankment dwellers

All of these demographic and socio-economic features highlight enormous problems for the Gaibandha area, in particular. Any plan to relieve flooding and improve the quality of life in the region is to be welcomed and any special initiative to bring a better standard of living to Gaibandha District is appropriate in terms of its impoverished socio-economic status.

Chars Dwellers in the Brahmaputra

In surveys and rural appraisals carried out in chars off Gaibandha, Chilmari and Bhuapur the findings conclude that living on the these islands and sandbanks in the major rivers is one of the harshest types of existence imaginable. They are physically isolated from centres of government and therefore services and from markets and social institutions like credit facilities and medical practices. It is believed that in the order of 100,000 people live in the charland adjacent to the GIP area.

They are also agriculturally difficult and producing crops is an arduous and hazardous occupation. The only cash crop in evidence was groundnuts and only a little aus and an aman variety which does not require much fertiliser; some sweet potato and wheat are also grown. There is also the problem of accreted land which legally becomes government khas but in effect is frequently settled by rich landowners (jotedars and talukdars) who "permit" the char settlers to sharecrop or to rent the land from them. Only in Bhuapur and Chilmari, where a strong NGO presence was evident, was there any attempt to get land titles for the people who had settled the chars.

They are also regarded with disdain by mainland communities. This is almost caste-like in character and they become a sub-culture which is referred to as "chaura" which has a negative connotation. They are extremely aware of this and reported to the field workers that when they have to go to the mainland for help during very severe floods they feel like outcasts.

Yet, there is a degree of collective endeavour on the chars that is not much in evidence in villages elsewhere. They told the field workers that they do help each other and even involve the women and children to a high degree in this. For example, prior to the flood season women and older children help in the construction of the macha which is a type of bamboo loft inside the house above the flood levels. Making the bhelas (rafts made of banana tree) on which the women and children squat during very high floods is a community effort. Data show that men of the chars tend not to migrate for work during the floods, unlike the landless men on the embankments, preferring to stay and protect family and community.

The availability of clean drinking water is a perennial problem for char dwellers and in the household survey for over ninety percent of the respondents the supply of clean drinking water and the provision of sanitary latrines came high on the list of priorities for improving the quality of life. They told the field workers that they had constant problems from water-borne diseases like diarrhoea and dysentery.

Unlike many of the mainland communities their social conscience is strong. They have a salish (community arbiter) who settles disputes and is consulted on access to reclaimed land which has not been grabbed by powerful mainland interests. Neighbours help each other when the men migrate for work and support is given during sickness and when the community has to move during severe flooding.

When asked what sort of flood control they would like to see on the char they found it difficult to respond since no one had ever asked their opinion before. It took fully fifteen minutes to get the dialogue re-established after the question was asked. Yet they have opinions which if sought more regularly and acted upon would lead to an improvement in their way of life. They also have individual and collective strength to survive in situations which many would find impossible.

4.6.2 Settlement Patterns and Migration

The past settlement history is hard to assess. The 1794 map prepared by Rennell indicates a large number of evenly distributed settlements, including the area now occupied by the Brahmaputra river. The distribution of population is characterised by a few larger nucleated urban settlements associated with old river trading posts along the Brahmaputra and the Teesta and a dispersion of smaller nucleated villages and hamlets raised on higher ground for flood protection.

The administration division of the area is based upon the 1908 1":1 mile map. These boundaries are rigidly adhered to and there is a strong territorial attachment of local people to their traditional lands which include those land that are now in the braided channel of the Brahmaputra. The situation on the charlands is complex and is under study by both FAP 16 and FAP 3.1.

Land tenure and value systems mean that land is a very highly valued as an asset and the major means of economic survival and freedom in rural areas. A system of statutory cadastre or revenue mapping which is theoretically updated to reflect with sub-divisions due to inheritance, adjudication and transfers. The land allocation in emergent attached char land at present under law shows that land tax continues to be paid on land lost to the river for up to a 20 year period. After this time no tax is paid but owners forfeits their rights to the land which revert to the state. If these reappear they can be reallocated as Khas land. In practise, land owners appear to prefer continued tax payment in the hope that as and when land reappears the can again take up their land rights, rather than forfeiting them.

There is a significant land displacement problem along the whole of the eastern and northern boundaries of the GIP where rates of erosion from the Teesta and the Brahmaputra are considerable and getting worse with the trends of movements of both rivers that are into, and not away from, the project area. This results in a dispossessed refugee and squatter problem along the embankments. Wherever possible the people do in the dry season move back onto newly emergent charland to eke out a precarious existence.

4.6.3 Flood Survival Strategies

Surveys identified general strategies which occur in nearly all communities. These are:

- Borrowing money usually at high rates of interest
- Selling labour and sometimes migrating to do so
- Selling livelihood or domestic assets
- Mortgaging or selling land

These strategies may vary from community to community but they are fairly widespread in attempting to deal with severe floods.

Char dwellers survival strategies surveyed included:

During Floods

1. Act collectively;
2. Perch on roof of house with family on **bhela**;
3. Sleep on **macha;**
4. Cook on **agla chula** if food is available;
5. Collect drinking water using bhela;
6. During severe floods move to embankments by hiring boat.

After Floods

1. Men migrate for work;
2. Take informal loans at high rates of interest;
3. Reduce food intake.

Flood survival strategies of agricultural communities included:

1. Shift from T to B amon;
2. Raise ground for cash crops;
3. Patrol embankments;
4. In severe floods sometimes cut embankments;

After Floods:

1. Plant a winter boro crop;
2. Take informal loans at high rates of interest;
3. Reduce food intake;
4. Work on rich farmer's land;
5. Mortgage land for cash from moneylender;
6. Sell agricultural assets.

Fishermen adopt the following strategies:

During floods

1. Migrate to find work (in the case of Hindu communities some go to India and do not return leaving their families behind);
2. Rent fishponds at high rates of interest;
3. Reduce food intake in some cases starve;
4. Mortgage themselves to rich men who control fishing rights.

After floods:

1. Borrow money at high rates of interest from **mohajons** (moneylenders);
2. Sell fishing equipment;
3. Sell domestic assets;
4. Leave fishing permanently and migrate to urban areas.

Womens's strategies included:

Prior to floods:

1. Storing dried food and fuel for cooking;
2. Making or maintaining the **agla chula**;
3. Storing food for livestock and chickens;
4. Helping to make or repair the **macha**.

During floods:

1. Moving livestock to high ground and looking after them;
2. Looking after children sometimes on the **bhela**;
3. Feeding the family using the **agla chula**;
4. Reduce food intake especially for themselves;
5. Fetching clean water for drinking.

Women do not play a major role in post-flood situations since loans and relief and rehabilitation are usually the province of their menfolk. Recently, however, women have been working in rehabilitation programmes usually run by NGOs and earning cash or food. In essence this takes them out of **purdah** at least for the duration of the rehabilitation programme.

Embankment dwellers strategies included:

During flood:

1. Move to the crest of the embankment;
2. Go back to the house at night to sleep on the **macha**;
3. Go inside the embankments to fetch clean water from tubewells;
4. Try to catch fish in the river;
5. Cook on the **agla chula** on the top of the embankment;
6. Reduce food intake or starve which frequently is the case.

After floods:

1. Men migrate to find work;
2. Women occasionally get credit at local **dokan** (shop);
3. Take informal loans at high interest rates;
4. Sell domestic assets.

4.6.4 Public Participation Findings

There were a number of findings in the GIP which were supported by all the communities in the public participation sessions (for details see Volume 11). There were also a number which were determined by much more local needs. The process involved taking both sets of findings back to the FAP2 office and analysing them in relation to the hydraulic model and to concepts being derived from engineering principles. The next stage which coincided with the next round of public participation meetings was to offer options to the same communities derived from both the communities views and those derived by hydrologists and engineers. The findings which produced a consensus in all areas were as follows:

- Effective sealing of the Teesta Right Embankment;
- Effective sealing of the Brahmaputra Right Embankment;
- Stop the overspilling of the Ghagot;
- Make the drainage at the Manas Regulator effective.

Findings determined by local considerations were as follows:

- Re-excavate the Ghagot;
- Dismantle the EIP embankment on the left bank of the Ghagot;
- Construct an embankment on the right bank of the Ghagot;
- Re-excavate the Alai Kumari;
- Improve drainage through the Sonail Embankment;
- Re-excavate the Alai;
- Rehabilitate khals in the Masankura and Mirganj area;
- Improve access of water and fish from Ghagot to GIP beels.

4.7 Culture and Heritage

There were no resources to attempt a detailed reconstruction of local history. A brief review of the history of the region is given in the IEE for the Regional Study. The impact review shows that there are potentially important sites that may be affected: the survey of these will require senior staff from the National Museum to supervise this work.

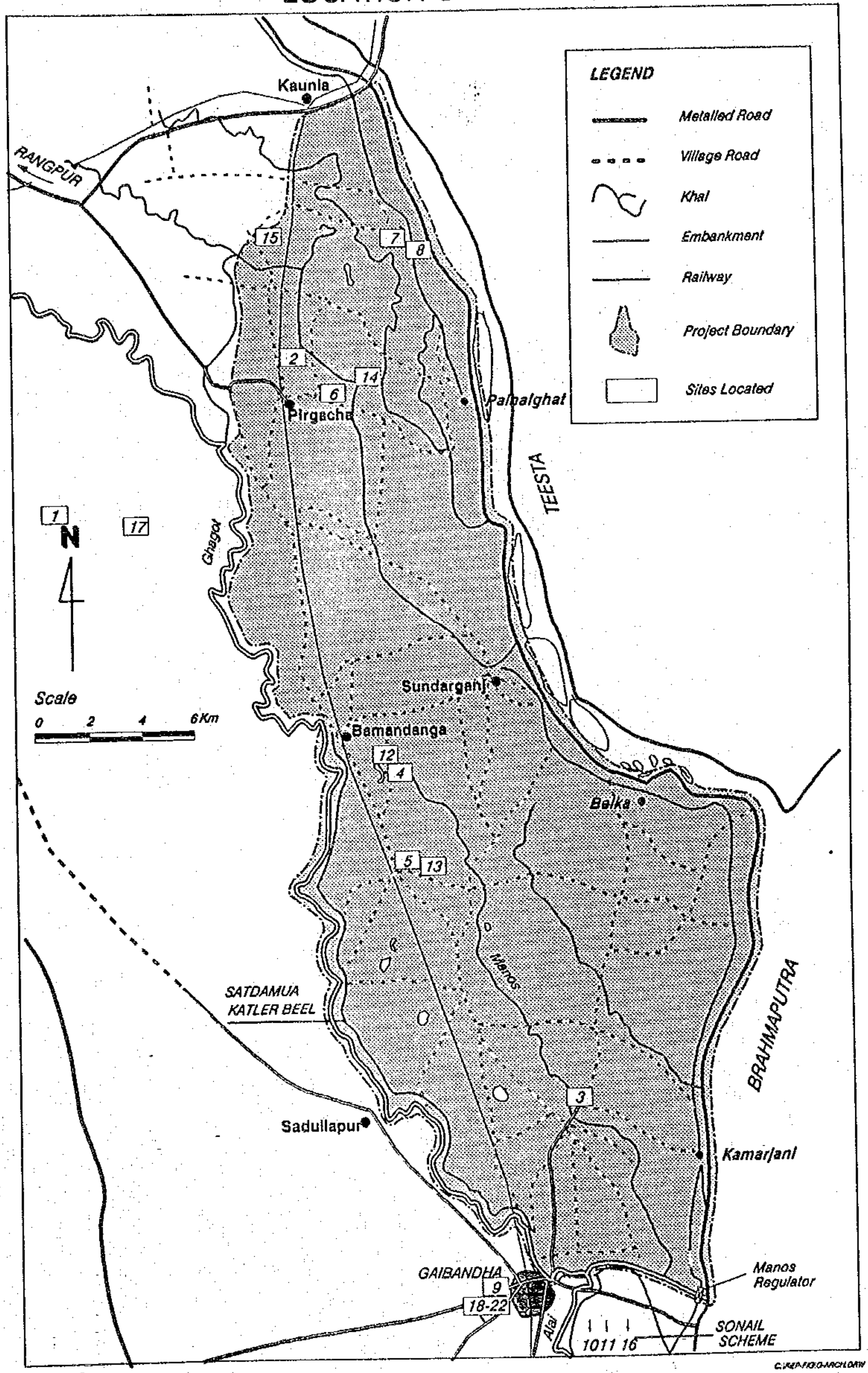
The literature review identified no previous surveys within the GIP area. There are a number of known sites close to the project area but outside of its boundaries. The archaeological sites that have been surveyed are all new and have logged with the Department of Archaeology.

Four types of sites have been identified - mosques, temples, Zaminadar palaces, crematoria and graveyards. No buried archaeological sites were identified which does not mean that these do not exist given the reconnaissance level of survey. The location of these sites is given in Figure 4.3 and are listed in Table 4.5. The sites were also transfer to the 1:50 000 and 1:20 000 planning maps to allow engineers direct access to knowledge on the proximity of their works to any identified site. Table 4.5 has also indicated a level of significance of these sites.

Most of the mosques derive from the late Mughal period. The palaces and temples are typically 200-300 years old with some being up to 450 years old. The sites often have important architectural design, inscription, paintings and floral motifs features. Some have special cultural significance for religious purposes and for the holding of fairs. Some are used by both Hindu and Muslim

Figure 4.3

LOCATION OF ARCHAEOLOGICAL SITES



communities. The Dariapur mosque has a rare characteristic in its beautiful Minaret with staircase and also living quarter underneath the minar.

As with most archaeological sites in Bangladesh those surveyed are in a state of disrepair. The reasons are numerous. The annual flooding and poor drainage which damages foundations, walls and floors and sometimes results in subsidence. Excessive monsoon rain and high humidity encourages growth of wild vegetation. The root system of the Banyan tree especially can literally tear buildings apart. Water gets inside cracks in the structure and over the years the cracks get bigger ultimately making the structure fall apart.

Intense river erosion has washed many sites into the major rivers. The GIP sites have been equally vulnerable to the historical movement of the Teesta and Jamuna. Many archaeological sites and their land have been taken over for cultivation and their materials used for building houses. Bricks, terracotta designs and figures are also stolen because of their antique value. Most sites in the GIP area have suffered in the hands of these treasure hunters.

Table 4.5 Location and Significance of the Archaeological Monuments in the Region of the GIP

Name	Thana	Union	Village	Age (Years)	Significance
Mithapukur Mosque	Mithapukur	Mithapukur	Mithapukur	2-300	1
Chandipur Mosque	Pirgacha	Pirgacha	Chandipur	2-300	1
Dariapur Mosque	Gaibandha	Ghagon	Dariapur	2-300	1
Bamondanga Temple	Sundarganj	Sarbananda	Ramvadra	2-300	2
Naldanga Temple	Sadullahpur	Naldanga	Dashalia	2-300	2
Pirgacha Temple	Pirgacha	Pirgacha	Bara Pancha	200	1
Sadra Temple	Kaunia	Tepamadupur	Sadrataluk	400	1
Temple	Kaunia	Tepamadupur	Rajib	?	3
Temple	Gaibandha	Shapara	Tulshighat	?	3
Temple	Fulchari	Kanchipara	Rasulpur	150	2
Temple	Shaghata	Saguna	Bharat Khali	400	1
Bamondanga Z Palace	Sundarganj	Sarbananda	Ramvadra	450	2
Naldanga Z. Palace	Sadullahpur	Naldanga	Dashialia	?	3
Pirgacha Z. Palace	Pirgacha	Pirgacha	Bara Pancha	200	2
Itakumari Z. Palace	Pirgacha	Itakumari	Itakumari	300	2
Rasulpur Z Palace	Fulchari	Kanchipara	Rasulpur	150	2
Begum Rokeya's Palace	Mithapukur	Pairabad	Khardamuradpur		2
Hindu creamatory	Gaibandha	Ballamjhar	Islampur		3
Hindu crematory	Gaibandha	Ballamjhar	Kumarpur		3
Hindu crematory	Gaibandha	Ramchandrapur	Vagabanpur		3
Hindu crematory	Gaibandha	Ramchandrapur	Gopalpur		3
Hindu crematory	Gaibandha	Bowali	Radha Krishnapur		3

Significance rating:
1 = Highly Significant
2 = Significant
3 = Not So Significant