World Bank
Government of the People's Republic of Bangladesh

Gumti Phase II
Sub-Project Feasibility Study

FINAL REPORT

EXECUTIVE SUMMARY

September, 1993

Mott MacDonald Limited
in association with
Nippon Koei Company Limited
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Desh Upodesh Limited

2

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3

PREFACE

The Gumti Phase II Feasibility Study describes proposals for an area of approximately 140 000 ha, to the north-west of Comilla. This area was previously studied in a report submitted in 1990. This present report reviews the 1990 report and also considers less costly alternatives.

The Final Report was submitted in draft form in June 1993 and consisted of the following volumes:

Main Report (including Annex A, the Terms of Reference)

Annex B	Hydrology and Hydraulic Modelling
Annex C	Groundwater Investigations
Annex D	Ecology
Annex E	Agriculture
Annex F	Fisheries
Annex G	Sociology and People's Participation
Annex H	Environmental Impact Assessment
Annex I	Engineering
Annex J	Financial and Economic Analysis

Following comments received and according to practice, minor amendments have been made and the above volumes were submitted as the Final Report in September 1993. In addition to these 10 volumes, a further two have also been submitted. They are:

- The Executive Summary (this volume)
- Annex K - Comments received on the Draft Final Report.

GUMTI PHASE II SUB-PROJECT FEASIBILITY STUDY

EXECUTIVE SUMMARY

List of Contents

List of Tables:

List of Figures:

1 Introduction

The Government of Bangladesh, in implementing the third Flood Control and Drainage Project financed under IDA Credit 591-BD, undertook the preparation of a feasibility study of Phase II of the Gumti Project. The purpose of this study was to formulate a project that would mitigate the effects of periodic flooding and poor drainage in the project area, develop its irrigation potential and alleviate any adverse effects of the Gumti Phase I Project on the adjoining Gumti Phase II area. The study report, referred to hereafter as the "1990 Report" was accepted by the Bangladesh Water Development Board (BWDB) but not IDA, who believed that less capital-intensive options should also have been investigated and evaluated. In addition, IDA considered that the study should be compatible with the framework and guidelines of the Flood Action Plan (FAP) and current IDA project preparation policy. This implied the need for an environmental impact assessment of the project and consideration of any dis-economies and their mitigation measures in the economic analysis. In order to continue its support of project preparation, IDA requested that the feasibility study be revised and extended.

New Terms of Reference for the Study were drawn up and funds were provided from a Japanese Grant Facility executed by the World Bank.

2 The Project Area

Location

The Gumti Phase II project area lies to the north-west of Comilla. It is bounded to the south by the Gumti River, to the west by the Meghna River, to the north by the Titas (or Pagla) River and to the east by the border with India. The area, shown in Figure 1, is 140,854 hectares in size and generally varies between 2.5 and 6 metres above sea level. An exception to this is a small area of relatively high land, rising to 9 m above sea level, just north of Comilla.

Population

As shown in Table 1, the present population of the Gumti Phase II project area is estimated to be approximately 1.9 million, with an average density of 1330 persons per square kilometre. The population density is thus nearly twice the national average and substantially higher than that for the south-east region as a whole (1078 persons per square kilometre). The average annual growth rate between 1981 and 1991 was 1.9% for Comilla and Brahmanbaria districts which is slightly below the national average of 2.2%, but the same as the south-east region as a whole.

Climate

The project area experiences a typical monsoon climate, with hot wet summers from May to September and cooler dry winters. The mean annual rainfalls at Comilla and Nabinagar are 2365 and 1874 mm respectively. Average evapotranspiration exceeds average rainfall for the months of November to March, and boro rice generally requires irrigation. Several major cyclones have crossed the project area, but damage is normally caused by high winds rather than tidal surges.

Figure 1

Location of the Gumti Phase II Project Area

TABLE 1

Estimated and Projected Population Figures for the Gumti Phase II Project Area (Density in Persons per Square Kilometre)

Zones		Zone A	Zone B	Zone C	Zone D	Total Area
Area (ha)		31,976	26,782	41,400	40,696	140,854
1981	Households	55,988	42,371	72,432	83,277	254,069
	Population	335,298	249,388	420,928	480,081	1,485,694
	Density	1,049	931	1,017	1,180	1,055
1993	Households	70,602	53,431	91,339	105,014	320,385
	Population	422,817	314,482	530,797	605,390	1,873,486
	Density	1,322	1,174	1,282	1,488	1,330
2023	Households	120,574	91,248	155,987	179,341	547,149
	Population	722,081	537,068	906,487	1,033,876	3,199,513
	Density	2,258	2,005	2,190	2,540	2,272

Source : Consultant Estimates based on 1981 BBS census data

Flooding

The project area is drained by the Upper Meghna River, which forms its western boundary. Other significant rivers are the Gumti River (forming the southern boundary) and the Titas and its tributaries - Buri, Salda, Gunghur and Bijni. In the western half of the area the rivers generally have flat slopes and come under a small tidal influence. In the eastern half of the area, the channels draining the Tripura hills (eg Gumti, Gunghur and Salda) are steeper and more liable to flash flooding. The Gumti River is fully embanked over about three quarters of its length from the Indian border, under the recently completed Gumti Phase I Flood Control and Drainage Project.

Geology

The whole of the project area is underlain by alluvial aquifers of Quaternary age. Most of the area has a surface cover of 5 to 15 metres of silts, overlying a thick fine sand aquifer from which hand tubewells and some shallow tubewells pump. This in turn overlies the main medium sand aquifer from which deep tubewells draw water. In the south-central part of the project area, the two aquifer layers are separated by a sandy silt aquitard, which is as much as 40 metres thick in Muradnagar.

Irrigation

Approximately 53% of cultivable land is under irrigation in the project area, however, this is unevenly distributed. Within different thanas, deep tubewells, shallow tubewells, manual tubewells and low lift pumps all play major roles in existing irrigation. Estimated irrigated areas from the 1990 Report are compared with Agriculture Sector Team (AST) data for 1991 in Table 2.

TABLE 2
Comparison of Minor Irrigation Estimates

Irrigation Mode	1987 (1990 Rpt)	1989 (1990 Rpt)	1991 (AST)
LLP	15,725	24,519	30,384
STW & DSSTW	5,888	12,517	16,219
DTW	5,414	7,625	10,899
Total	**27,027**	**44,661**	**57,502**

Note : (1) All numbers in the table are total irrigated areas in hectares.
(2) The 1987 and 1989 surveys did not count the areas irrigated by manual tubewells and traditional methods

A recent survey of new and operating wells by the IDA/ODA Deep Tubewell II Project has shown a broad band of slightly saline groundwater in the west of Comilla and Brahmanbaria districts. Although a small number of wells have been abandoned because of crop damage, the feasibility of groundwater is demonstrated by the fact that there are more than 50 DTWs operating successfully in Muradnagar. It has been shown that high salinity (EC >2 000 μS/cm) is mainly restricted to the lower aquifer in areas where there is a thick lower aquitard.

Groundwater development is also constrained by discharges of gas, which interfere with the operation of pumps. The gas is probably derived from the decomposition of organic matter in the shallow aquifer. Discharge of gas mainly affects the operation of shallow tubewells breaking the suction and necessitating frequent 'restarts', which is not popular with farmers, but is generally only of nuisance value at deep tubewells.

Agriculture

The net cultivable area (NCA) within the Gumti Phase II area is estimated at 118 034 ha out of a gross area of 140,854 ha. Following surveys and updated secondary data, the total cropping intensity was taken as 171% as an average over the four zones. Almost all the boro is irrigated, and about two or three hundred hectares each of the wheat and potatoes. The irrigated area quoted in the 1990 Report was 28,747 ha. Estimation from February/March 1989 SPOT satellite imagery suggests that this area may have increased to about 50,000 ha and further surveys show an additional increase of mechanised irrigation to approximately 59,000 ha. In addition, the use of hand tubewells will bring the expected total to 63,000 ha, which is 53% of the NCA.

Fisheries

The Gumti Phase II area is very rich in capture fisheries, particularly in the Meghna floodplain in the west and in the central area near Nabinagar and Muradnagar. Survey work and data collection carried out by the project have suggested that the actual fish production in the Gumti Phase II area is approximately 31,500 tonnes per year. This value, which is consistent with the findings of FAP 17, is over three times the amount assumed in the 1990 Report. In the riverine thanas of Nabinagar, Bancharampur and Homna it is estimated that 8% of the population are full-time fishermen, whilst a further 65% are part-time or occasional fishermen.

Ecology

The Gumti Phase II area includes some of the major wetland habitats within the country. The direct economic impact of flood control and drainage works upon capture fisheries and poor fishermen, with its socio-economic and nutritional consequences, is now well recognised, although methodologies for quantification are so far very crude. There are, however, less obvious impacts which affect the well-being of certain sectors of the community, and in particular the free resources which are an essential part of the survival strategies of the disadvantaged. Even more imponderable is the loss of floral and faunal species diversity and changes in soil chemistry, the role of which within the natural environment biological process is not well understood.

Communications

Although the project area is crossed by two major roads from south to north, and the south-west is linked to the south-east by the Daudkandi to Comilla road, internal road communications are very poor. During the wet season the thana headquarters of Bancharampur is barely accessible by road, as the embankment tends to become submerged. Unfortunately in some cases the road embankments themselves may have an adverse effect upon drainage, through a lack of cross-drainage structures. The main Chittagong to Sylhet railway passes through the east of the area but contributes little to internal communications.

Waterways are of major importance in the project area. The Chitibhanga River from near Homna to beyond Bancharampur and the Buri/Salda River upstream of Nabinagar are classified as permitting boats of up to 2.0 m draft, whilst the remainder of the Salda River almost to the Indian border permits a draft of 1.5 m. Unclassified routes serve Daudkandi, Debidwar, Gouripur and Ramchandrapur, whilst during the flood season country boats ply over the whole western part of the area.

3 People's Participation

The Gumti Phase II project area is very diverse. There is high ground in the south-east, towards the border with India. There is also relatively high ground in the central eastern area near Kasba. In the west of the area, the land is low and there is extensive annual flooding each monsoon. Because the area is so varied, it was considered very likely that each region would have different water-related problems calling for different solutions. The project area was therefore split into four zones, based on topographic and agro-ecological considerations. These four zones are shown in Figure 2, along with the location of the villages selected for consultation. Four villages were randomly selected in each zone, to represent grass root opinion throughout the project area.

In order to establish the needs of the villagers in the project area, two meetings were held in each of the 16 selected villages. The proposed project interventions were formulated out of the conclusions drawn from these meetings.

During the first round of meetings the project team listened to the villagers' water related problems. Possible interventions were then considered, and discussed at the same villages during the second round of meetings. A third round of meetings was held in each of the Thana Headquarters, where the reviewed proposals were discussed with thana officials, union chairmen and NGOs.

The main concerns of the people in the east of the project area were related to flash flooding. Another concern voiced everywhere, but mainly in the west, was related to supply of irrigation water. It was interesting to note that the normal, Meghna-related, annual flooding was not cited as a problem anywhere in the area. In the western zone, villagers were hostile to provision of a flood protection embankment along the Meghna.

4 Development Options

There are three main reasons why it is difficult to find economically feasible projects which develop agriculture in the Gumti Phase II area.

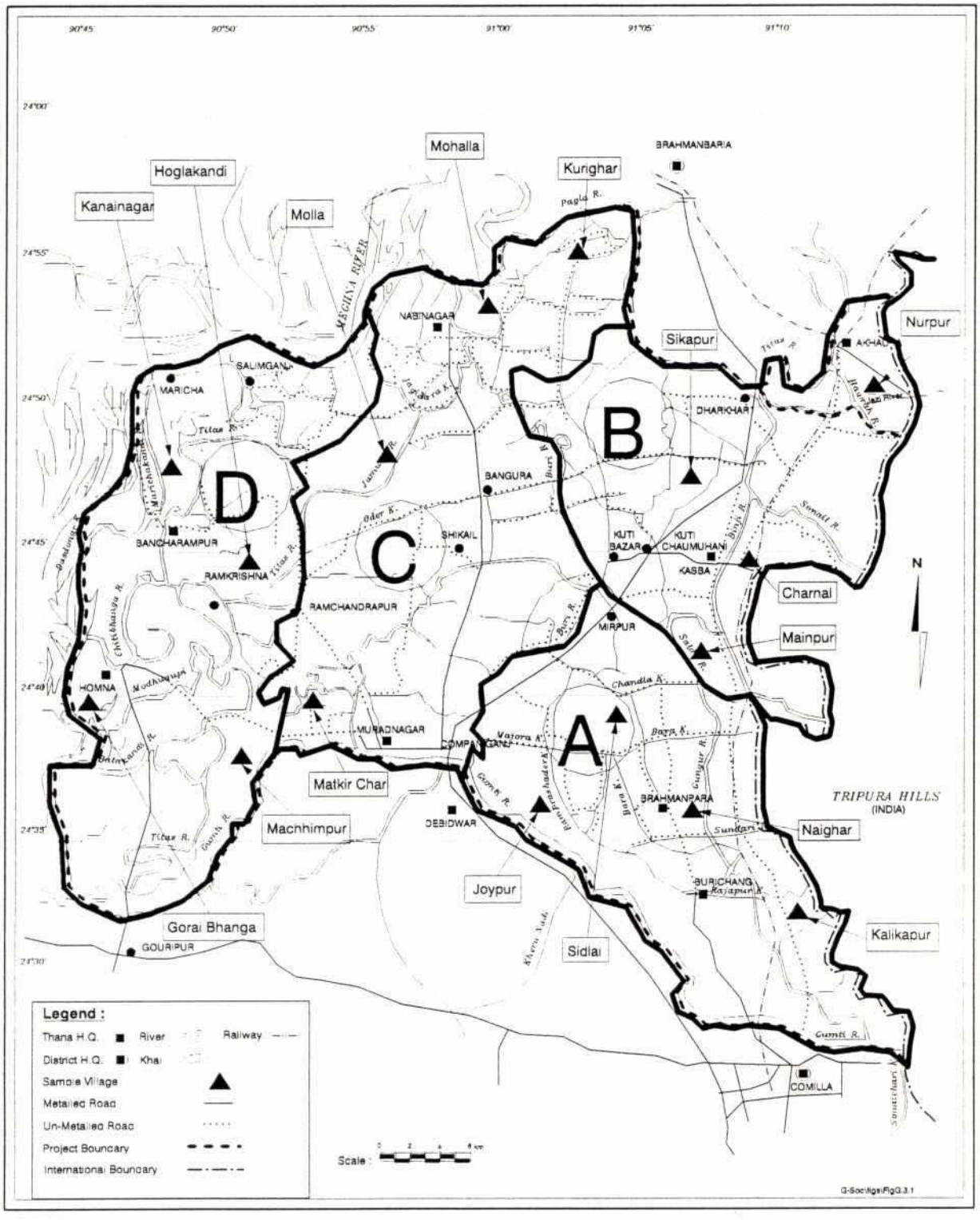
The first is that the project area is one of the most productive floodplain fishery areas in Bangladesh. This means that attempts to polder off any portion of the existing floodplain will involve heavy fishery losses. The second is that there is a heavy sediment load coming annually into the east of the area, from the Tripura hills in India. This makes annual maintenance of khals expensive. The third reason is that despite gas and salinity constraints, it is technically feasible to irrigate the entire net cultivable area to ensure winter crops, including boro, using groundwater. Therefore schemes which require two stage pumped irrigation are unlikely to be economic.

However, it should also be noted that the population density has increased significantly in the area and additional food and employment is greatly required. People's participation meetings highlighted many specific problems in each part of the project area and also gave possible solutions to these problems.

It was therefore concluded that despite the above constraints, agricultural development was still important in

Figure 2

Location of People's Participation Villages



the area. However, viable schemes would have to be sympathetic to environmental considerations and should specifically address local water related problems.

Based on what was learned during the meetings, various development options were considered. Good liaison between the project environmentalists and engineers during the planning stage ensured a set of options which were as sympathetic as possible to the environment. These development options were then run with the hydraulic model in order to determine their effect, as well as to optimise them.

Nomenclature of Developments

The original set of developments which required investigation were given in the Terms of Reference. These alternatives have been termed "Strategies" and are as follows:

- **Strategy (a)** Without Project Scenario
- **Strategy (b)** Basic Flood Response and Development
- **Strategy (c)** Intermediate Flood Response and Development
- **Strategy (d)** Flood Control and Drainage (FCD) Polder
- **Strategy (e)** Flood Control, Drainage and Irrigation (FCDI) Polder
- **Strategy (f)** Phased Development

Development Strategies (d) and (e) were put forward in the 1990 Report and are reviewed in this report. However, this report recommends a set of proposals pertaining to Strategies (b), (c) and (f).

In order to properly investigate development Strategies (b), (c) and (f), a set of "Interventions" was considered. These interventions were determined as a result of the people's participation meetings and then checked and optimised using the hydraulic model.

The layout of considered interventions is shown in Figure 3. They are as follows:

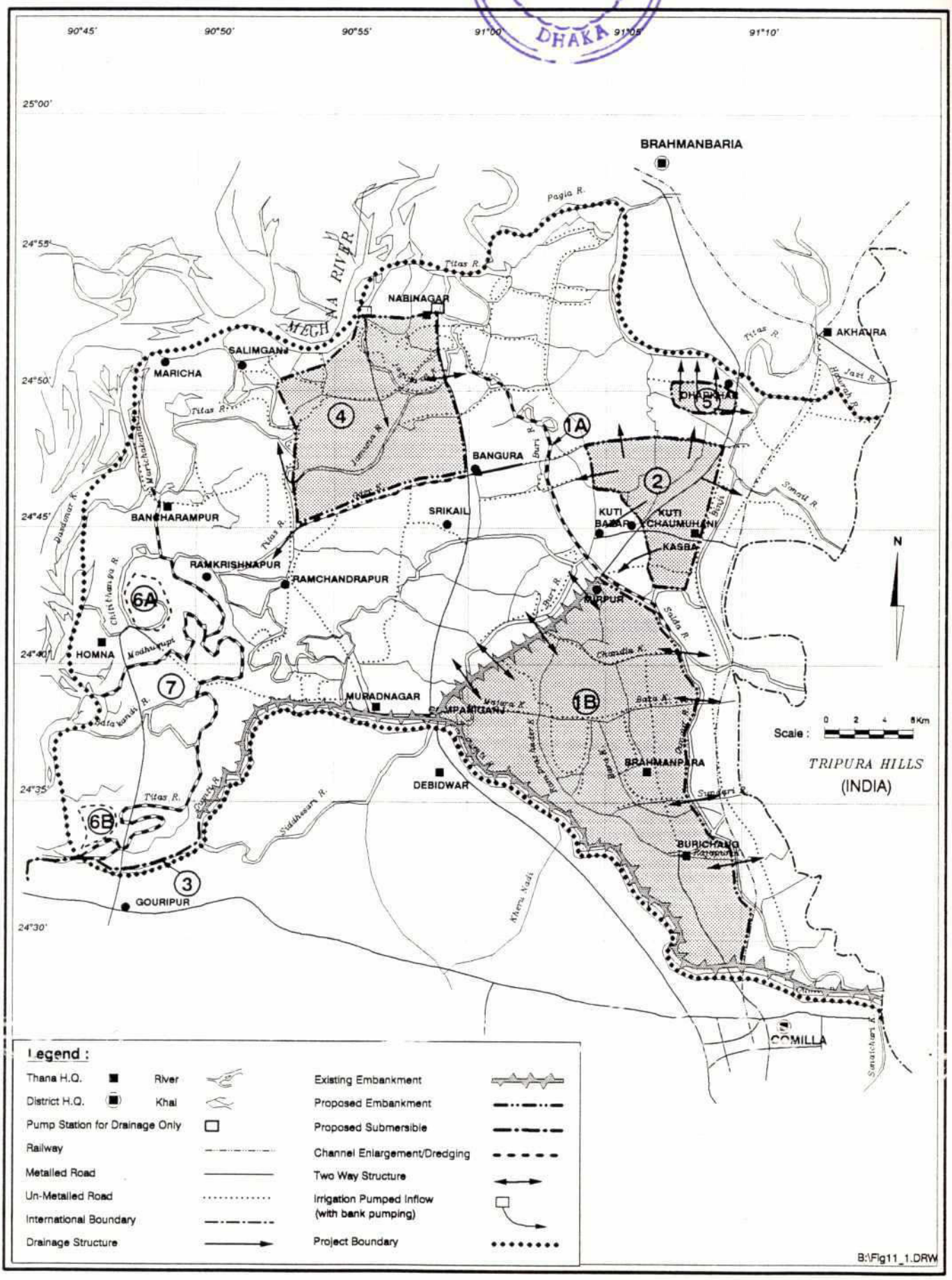
- **Intervention 1A** (River excavation)
- **Intervention 1B** (Polderization in Zone A)
- **Intervention 2** (Polder in Zone B)
- **Intervention 3** (Extension of Gumti River right embankment with a submersible embankment)
- **Intervention 4** (Polderization and pumped surface water supply)
- **Intervention 5** (Small polder to the north of Zone B)
- **Intervention 6** (Two separate submersible embankments for boro crop protection)
- **Intervention 7** (Khal excavation for irrigation water supply in Zone D)

The above listed Interventions have been considered individually for environmental assessment, however, they were not always well grouped from an engineering or economic point of view.

The term "Scheme" has therefore been used to group the prospective interventions into discrete engineering packages, which have undergone economic analysis. The Schemes are listed (A to E) in order of priority.

Figure 3

Layout of Interventions



The Schemes are as follows:

Scheme A

Scheme A includes Interventions 1A, 1B and 2, shown in Figure 3. Intervention 1B includes a flood protection embankment along the left bank of the Gunghur River as well as sealing the Comilla to Sylhet road and providing fish friendly drainage regulators. Intervention 1A involves excavation of the Salda and Buri Rivers, which will help drain the area inside and outside the 1B protected area. Intervention 2 raises the level of existing roads to form a protected area around Kasba. It is included in Scheme A as it also benefits from the river excavation works under Intervention 1B.

Scheme B

Scheme B includes extending the Gumti north embankment to Gouripur to prevent flash flooding in the area (Intervention 3). Because protection is only required for boro crops, a submersible embankment is being proposed. The scheme is therefore inexpensive (approximately 16 million Taka) and is not expected to incur fishery losses.

Scheme C

Scheme C includes excavation to the existing network of khals in Zone D (Intervention 7). This will provide LLP irrigation to approximately 10,000 ha. This type of intervention is very beneficial to the area as it helps fisheries by extending the area of perennial khal as well as providing the cheapest source of irrigation.

Scheme D

Scheme D includes an embanked area north of Oder khal, 2 pump stations in the north and channel excavation for the provision of surface water supply and pumped drainage (Intervention 4). Pumped surface water is to be supplied to an area of approximately 9,800 ha, within a gross area of 20,000 ha, both north and south of the Oder khal. During the monsoon season, both pump stations will reverse and drain rainwater from the embanked area north of the Oder khal. It should be noted that this drainage pumping will more or less eradicate the floodplain fisheries from within the embanked area of approximately 9,000 ha.

As already observed, despite present gas and salinity constraints, the whole project area can be effectively irrigated using groundwater. In some areas, new shallow force mode tubewells may be needed in place of the common shallow suction mode tubewells, to overcome the constraints. While shallow force mode tubewells can be more expensive than shallow suction mode tubewells, they are economically cheaper than double lift surface water irrigation.

If farmers take up force mode tubewell technology in the next ten years, the "without project" situation will include full irrigation, and the scheme will therefore have a low Economic Internal Rate of Return (EIRR). However, after Schemes A, B and C have been completed, if farmers have not taken up the new tubewell technology, then this scheme should be seriously considered.

Scheme E

Two submersible embankment schemes were identified in Zone D, one north-east of Homna (Intervention 6A) and the other north of Gouripur (Intervention 6B). Under present circumstances, these schemes do not produce benefits, as farmers plant their boro early and therefore do not suffer losses. However, if FAP 6 alters the timing of the floods with its developments, then it is quite possible farmers in these areas will have difficulty in harvesting in time. In this case, the schemes could be recommended as mitigation measures.

The 1990 Report

The recommendation of the 1990 Report was for full polderization of the project area along with provision of reversible pumping stations of approximately 100 cumecs total capacity (Strategy (e)). An alternative of flood control and drainage without surface water irrigation was also presented (Strategy (d)).

These options were reviewed during the present project but were not found to be feasible. The main reasons for this were :

a) the latest information available showed that the existing area presently under irrigation was much larger than adopted in the 1990 report.

b) the proposed interventions produced a much smaller area of land converted to F0 (< 0.3 m peak flood depth) than was assumed in the 1990 Report.

c) fisheries losses were higher than those used in the 1990 Report.

5 Fisheries

Freshwater fish are an important source of income and cheap protein for a large proportion of the human population of Bangladesh, and capture and culture fisheries are the two main forms of fishing that are practised in the country.

The Gumti Phase II project area is a significant and productive wetland, having an extensive network of seasonal and perennial rivers and khals, making it particularly important for capture fisheries. Most of the project area lies within an annually flooded part of the country, as such it is believed to play an important role as a fish habitat. This extensive flooding enhances the fisheries every year by carrying those species which migrate from the main rivers into the floodplain aquatic habitats for breeding, feeding or dispersal purposes. Out of a gross project area of 140,854 ha, an area of 127,173 ha, consisting of rivers, khals, beels, ponds and floodplain is assumed to support fisheries.

Using national production estimates, it can be seen that the annual capture fisheries production in the Gumti Phase II area amounts to 10,179 tonnes, with an increasing production from Zone A towards Zone D. Pond production shows a different pattern, with highest yields in Zone A (1,878 tonnes) and C (1,379 tonnes), followed by Zone B (779 tonnes) and lastly, Zone D (398 tonnes). Overall estimated production, including

ponds, amounts to 14,615 tonnes, which results in a production level of 115 kg/ha, over the area of 127,173 ha.

Using the production levels estimated during this study for internal rivers/khals and beels, FAP 17's estimated production levels for floodplains of 152 kg/ha (FAP 17, 1993), which include the commercial catch, and the average pond production levels reported by the Thana Fisheries Office (TFO) of 1,760 kg/ha, the results are quite different. The estimated total catch for the Gumti Phase II project area, including ponds, was 31,499 tonnes, this resulted in a production level of 248 kg/ha. This is shown in Table 3. However, if only the capture fisheries are considered, the resulting estimated total production in open waters is just over 24,100 tonnes, with a production level of 196 kg/ha, over an area of 122,971 ha. Both these production levels are comparable with fish production reported for other tropical countries (Lowe-McConnell, 1987).

To obtain an estimate of the market value of the catch in the project area, the information collected during the eight week market survey was linked by species to the catch data. Following this procedure, it was possible to separate the results of the catch assessment survey into three categories: high, medium and low value fish. From the market price survey, an average price for fish was obtained for each of these categories as follows: high value - 58 Tk/kg, medium value - 39 Tk/kg and low value - 27 Tk/kg.

TABLE 3

Gumti Phase II Fish Production Levels

Fishery System	Zones				Total (tonnes)	Production Level (kg/ha)
	A (tonnes)	B (tonnes)	C (tonnes)	D (tonnes)		
Meghna River	0	0	627	4,091	4,717	557 *
Int Rivers & Khals	378	314	477	477	1,646	557 *
Beels	0	85	758	296	1,139	489 *
Floodplains	2,750	3,021	5,458	5,372	16,601	152 **
Subtotal	3,128	3,420	7,319	10,236	24,103	196
Ponds @	3,133	1,299	2,300	664	7,396	1760 @
Grand Total	6,261	4,719	9,619	10,900	31,499	248

Notes:

* Average production levels estimated from this study's catch assessment survey

** FAP 17's new estimate for floodplain production from DOF data including commercial catch

@ Average pond production for 'cultured' ponds from Thana Fisheries Office Survey

The current market value of the annual capture fisheries production (24,103 tonnes) in the project area was estimated to be Tk 855 million, of which Tk 263 million was contributed by the high value species, Tk 206 million by the medium value species and Tk 386 million by the low value species.

It should be remembered that these estimates refer only to the commercial catch, as far as it is known. The subsistence catch (i.e. that consumed directly which does not pass through the market) has not been taken into account in this analysis.

Estimation of Impact on Fisheries of the Proposed Interventions

The estimated impacts for the proposed interventions are given in Table 4. These impacts have been costed and included in the economic analysis. The combined annual fish production loss for all interventions in the project area was 3,119 tonnes, representing a mean loss of 30.8% within direct intervention areas.

Under Strategy (d) (FCD proposed in the 1990 Report), overall losses were estimated to be around 34%, that is approximately 9,223 tonnes, having a market cash value of Tk 328 million. Because there was to be no khal re-excavation that could result in increased water availability, the heavy losses estimated as a direct result of the prevention of species' access to the areas within the polders could not be compensated for. In addition, all other fishing systems are seriously impacted, especially the floodplain catch in Zone A which suffers significant losses (nearly 71%) and Zone B (56%). The decline in beel production is approximately the same for Zones B, C and D.

Under Strategy (e) (FCDI in the 1990 Report), overall estimated losses were slightly lower than for the FCD proposals due to some benefits being accrued from khal re-excavation for gravity irrigation in the dry season. However, losses in floodplain production were increased in Zone A as a result of further division of the poldered area. The rest of the fishing systems were assumed to be impacted to the same extent as Strategy (d).

6 Environmental Impact Assessment

Environmental Impact Assessment for proposed development programmes attempts to place the considered interventions within a context of environmentally sound and sustainable development. A comparative assessment (including looking at a predicted without project situation) was carried out for a wide range of water and land development strategies and interventions being considered for the area. As a result of this, assessment recommendations were made as to the detailed interventions that were favoured, on broad environmental grounds, for further study.

The Natural Environment

From the point of view of trying to draw up an integrated water and land management programme for the area, the key issues are all underpinned by the surface water hydrology, specifically the nature of flood patterns. These have been studied by mapping the output of the MIKE 11 hydraulic model for each 10 day period, using a water level at that time for each of the thirty modelling cells which cover the study area. This was carried out, firstly, for the present without intervention situation and latterly for each of the post construction situations

TABLE 4

Estimated Fisheries Impacts Due to Interventions Without Mitigation

	Intervention	1	2	3	4	5	6A	6B	7	
	Gross Area (ha)	23,400	5,000		10,459	823	1,560	1,060		
Systems										
Int Rivers and khals	NOW	276	59		156	10	18	12	1,111	
	WO Yr 6	252	54		142	9	17	11	1,015	
	WI Yr 6	244	39		150	6	24	11	1,374	
	Change %	-3	-27	0	6	-27	41	-6	35	
Beels	NOW	0	9	0	67	3	33	12	0	
	WO Yr 6	0	8	0	61	3	30	11	0	
	WI Yr 6	0	3	0	26	1	12	5	0	
	Change %	0	-58	0	-57	-58	-58	-58	0	
Floodplain	NOW	2,013	760	0	1,590	125	237	161	0	
	WO Yr 6	1,838	694	0	1,452	114	217	147	0	
	WI Yr 6	525	203	0	145	33	91	62	0	
	Change %	-71	-71	0	-90	-71	-58	-58	0	
Ponds	NOW	2,293	243	0	528	0	25	17	0	
	WO Yr 6	2,986	316	0	688	0	33	23	0	
	WI Yr 6	2,986	316	0	688	0	33	23	0	
	Change %	0	0	0	0	0	0	0	0	
										TOTAL
TOTAL	NOW	4,582	1,070	0	2,340	138	313	203	1,111	9,758
	WO Yr 6	5,077	1,072	0	2,343	126	296	192	1,015	10,120
	WI Yr 6	3,755	562	0	1,009	41	160	99	1,374	7,001
	Change (tonnes)	-1,321	-510	0	-1,334	-85	-136	-92	359	-3119
	Change %	-26	-48	0	-57	-67	-46	-48	35	-31

for the developments under consideration. There was an interactive process, by which each configuration of small scale multiple interventions was analysed and subsequently modified, with the aim of minimizing any serious induced impacts, particularly increased upstream flooding and downstream backing up of water and/or drainage congestion. The modified interventions were then re-modelled to see if the modifications were successful in addressing the previously identified problematic impacts. The modelled output for the 1 in 2 year flood of the present situation is shown in Figure 4 for a rising flood. The mapped outputs from the model were supported by field observation and reporting.

The mapped outputs show that the area first floods from the east, due to flash flooding from the Indian hills. The consequences of this show on the 1 in 2 year model output as flooding at the western end of the River Gumti right bank flood plain where the embankment stops before it reaches the Meghna River. This flooding is thus effectively the downstream impact of confining the Gumti River, a process that was started sometime before the year 1660. The Gumti flash flooding would appear to be an annual occurrence whilst the flash flooding from the hills north of this seems to be less common, probably as it is not concentrated in a confined channel. During the pre-monsoon, there is flow to the north-west along the Gunghur and Salda Rivers. However, in the monsoon, when the River Titas levels rise, the River Gunghur flow meets the southbound Buri Nadi flow and both flows are conveyed to the Meghna River in the west. If the flash floods are severe (as was the case in April/May 1993) then this causes flow to go westwards from the Indian hills into Zone A. The main Meghna River is the last to rise, by which time much of the eastern part of the area has already been flooded and rainfall has filled all the depressions. Flooding extent and timing appear to be determined by the water level in the main Meghna River channel, and the scope for changing the situation by engineering interventions would seem to be very restricted due to this and the high amounts of rainfall that occur.

Development Options and Strategies

A preliminary range of intervention strategies was drawn up, as discussed in Section 4. Environmental considerations were then borne in mind when finalizing an agreed intervention strategy for the area, which was studied in greater detail, leading to recommendations being made as to which components of this were thought to be beneficial in overall terms.

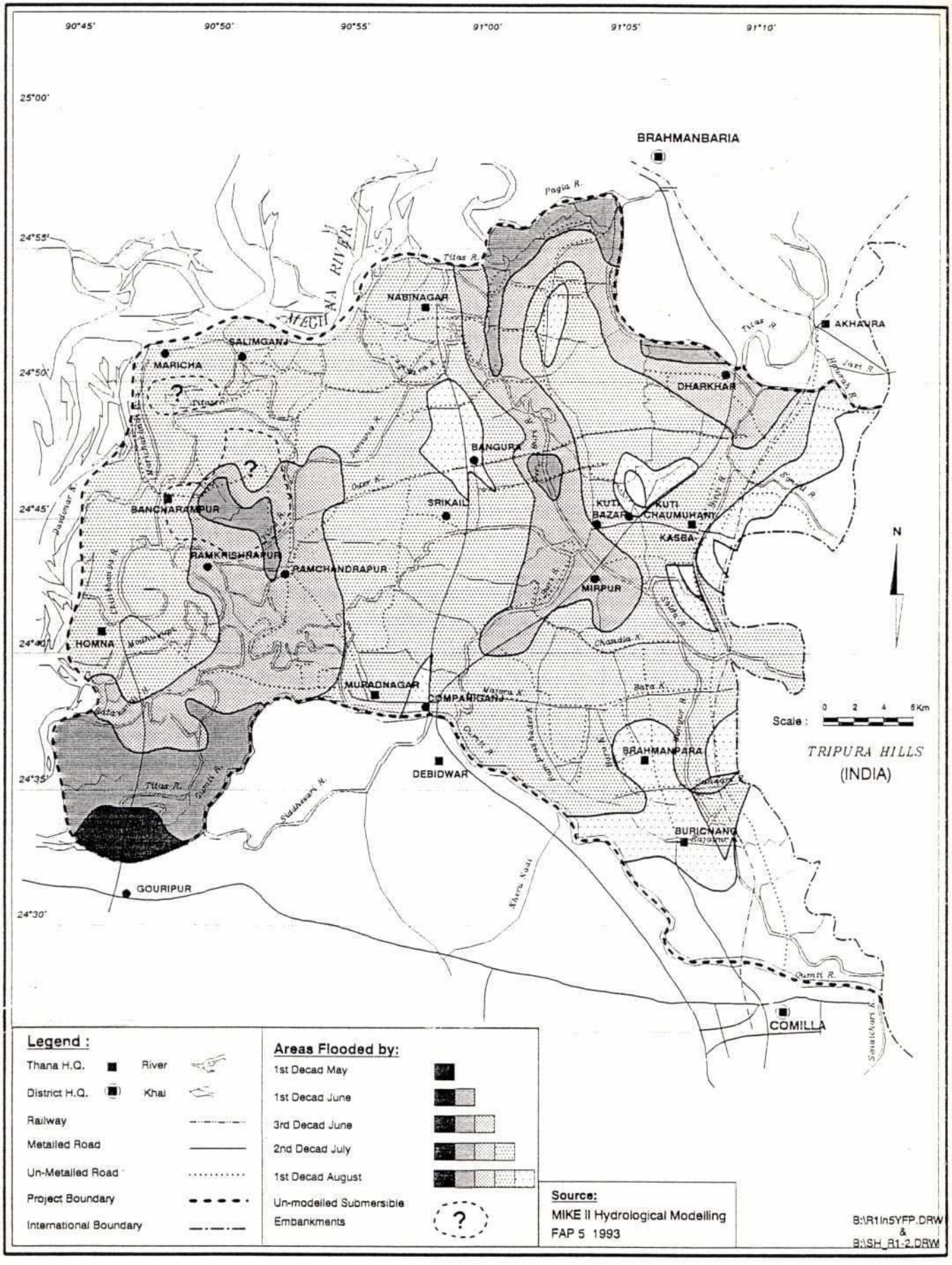
Five possible broad policy strategies, labelled (a)-(e) with (a) being a without intervention option, were drawn up for comparative consideration. Strategies (b), (c) and (f) were grouped to form a mixed strategy which took into consideration the study areas great diversity, looking at different interventions in the various planning zones based upon proposed interventions suggested in the people's participation exercise. Strategies (d) and (e) were those suggested in the 1990 Report, the impacts of which are briefly discussed at the end of this section.

As a result of the preliminary assessment, the following detailed interventions were proposed for further study. It should be noted that some of these cross planning zone boundaries and are considered to depend or be conditional upon others, both for mitigation of induced negative impacts and also for economic feasibility. They are summarised by Intervention number, as discussed in Section 4:

1A Khal depending of the Buri/Salda River system justified in its own right but considered a conditional requirement of Intervention 1B.

Figure 4

Rising 1 in 2 Year Flood Pattern



1B Controlled flooding of the western part of Zone A. This allows limited managed in-flow into the area via 4 gated structures in the north-west which uses an existing road embankment as one side of the protected are and four in the east placed within a new embankment on the west bank of the Salda River.

2 A medium sized polder in Zone B using existing road embankments which prevents all surface water in-flow to the area.

3 Extension of the Gumti right bank embankment westwards to Gouripur.

4 An enclosed medium sized polder in the north of Zone C and part of Zone D. This includes complete exclusion of all surface water in-flow and also has monsoon pumped drainage and pumped dry season surface irrigation using deepened khals. In addition the construction of the southern embankment will allow the Oder khal to be enlarged. The provision of pumping also allows the unprotected area south of this to be irrigated, using gravity surface means along deepened khals and drains.

5 A small polder in Zone B using remodelled existing road embankments and excluding all external surface flow into the area.

6A6B Submersible embankments in Zone A similar to those recently completed in the north-west part of the study area.

7 A major khal deepening programme throughout the study area. In Zone A this is intended to allow the khals to remain full of water in the dry season for surface irrigation to take place. In the unprotected part of Zone C this would be for dry season pumped irrigation conveyance. Throughout the rest of the study area this is intended to improve drainage.

The proposed detailed interventions that have been incorporated into the hydraulic model are shown in Figure 3. The broad conclusion of this analysis is that Intervention 3 is partially effective in preventing the early flooding due to downstream impacts of previous upstream Gumti River embanking. Intervention 1B is effective in delaying flash flooding into the protected part of Zone A and throughout a normal year reduces the mean extent of flooding on the protected area by some 30%. The induced flooding effects of this on surrounding land are nearly all mitigated for by Intervention 1A. Intervention 2, the medium sized polder, results in an internal mean annual floodplain loss, whereas Intervention 4 (pumped polder) is very effective indeed and the most of the floodplain remains flooded to a depth of less than 0.30 m all the year. According to the model, Intervention 5 has little effect on the extent of flooding. The interventions have been optimised to ensure that there is very little increased extent of flooding elsewhere in the area as a result of the developments. Overall, the changes in floodplain extent as a result of the interventions are surprisingly small.

A summary of the environmental rating matrix for each of the seven interventions is shown in Table 5. This is on a scale of +5 to -5 and uses a six year period for impact assessment. It aims to give an indication of what are the important issues for each intervention so that more detailed and targeted data collection can be carried out. It is not weighted by priority, instead an indication is given of those issues which are felt to be important.

TABLE 5

Environmental Rating Matrix of Proposed Detailed Interventions

ISSUES	P	Intervention							MP	MC
		1	2	3	4	5	6	7		
THE NATURAL ENVIRONMENT										
Flooding Damage to Land	*	+5	+3	+4	+4	+2	+1	0		
Drainage Problems	*	+3	-1	0	+5	-1	-1	+2		
Surface-Water Availability		-3	-2	-1	+4	-1	0	+3		
Groundwater Irrigation		+4	+4	0	+2	+2	0	0		
Sedimentation Side Drainage	*	+2	+1	+3	+2	+1	0	+4		
Sedimentation		+2	+1	+3	+2	+1	0	+4		
Clogging/Smothering		+3	+2	+2	+2	+2	+1	+3		
Soil Fertility		-1	-1	0	-2	-1	-1	-1		
Navigation	*	-2	-2	-2	-3	-2	-2	+3		
Soil Quality /Chemistry		-1	-1	0	-2	-1	-1	0		
Soil Waterlogging		0	+1	+1	+2	+1	+2	+1		
Flora Ecology		-1	-1	0	-2	-1	-1	-2		
Fauna Ecology		-1	-1	-1	-2	-1	-1	-2		
Fish Ecology	*	-2	-4	0	-5	-4	-4	+3	N	
THE HUMAN ENVIRONMENT	P	1	2	3	4	5	6	7	MP	MC
Economic Livelihoods										
Risk		+3	+2	+3	+3	+1	-2	+3		
Settlement		+2	+2	+3	+2	+1	+1	0		
Land Scarcity		-1	-2	-2	-3	-2	-2	-2		
Land Values		+2	+2	+3	+3	+1	+1	+2		
Common Resource Rights										
Fish	*	-2	-4	0	-5	-4	-4	+2	VD	
Fuelwood		-2	-2	0	-3	-2	-1	-1		
Grazing		-2	-2	0	-3	-2	-1	-1		
Fodder		-2	-2	0	-3	-2	-1	-1		
Agricultural Output		+2	+4	+1	+5	+2	+2	+4		

Table 5 (Continued)

ISSUES	P	Intervention							MP	MC
		1	2	3	4	5	6	7		
Fishing ("Professional")	*	-2	-3	0	-5	-3	-4	+3	PO	CO
Forestry and Fuelwood		-2	-2	0	-3	-2	-1	-1		
Livestock		-2	-2	0	-3	-2	-1	-1		
Wage Paid Employment	*	+3	+3	0	+4	+3	+1	+5		
Industry		+2	+2	0	+3	+2	0	+2		
Drinking Water Availability	*	-1	-1	0	+2	-1	0	+2		
HUMAN HEALTH										
Diarrhoea	*	-3	-2	-1	-2	-2	-1	-1		
Cholera	*	-3	-2	-1	-2	-2	-1	-1		
Nutrition	*	-2	-4	0	-5	-4	-4	+2	VD	
Mental Health		+1	+1	+2	+1	+1	0	0		
ACCESS AND TRANSPORT										
Waterborne		-3	-3	-3	-3	-3	-3	+3	PO	
Road		+2	+2	+1	+2	+1	+1	0		

LEGEND

RATING OF IMPACT

-5 Severe Irreversible Negative Impact
-4 Significant Negative Impact
-3 Moderate Negative Impact
-2 Slight Negative Impact
-1 Very Slight Negative Impact
0 Present Baseline Situation and No Change
+1 Very Slight Positive Impact
+2 Slight Positive Impact
+3 Moderate Positive Impact
+4 Significant Positive Impact
+5 Very Significant Positive Impact
MI = Mitigation is Addressed Intrinsically
VD = Mitigation Very Difficult
PO = Mitigation Possible
CO = Mitigation Costly
PC = Mitigation Prohibitively Costly
N = Mitigation Not Possible

ABBREVIATIONS/HEADINGS

P = Expert Priority Issues
1 = Intervention 1
2 = Intervention 2
3 = Intervention 3
4 = Intervention 4
5 = Intervention 5
6 = Intervention 6
7 = Intervention 7
MC = Mitigation Possible?
MC = Mitigation Costly?
(+1) = A Constraint not an Impact
* = Major Issues
F = In Times of Flood
LF = In Low Flows
PF = In Peak Floods
? = Insufficient Data to Assess

Note: The predicted impacts are assumed to be those some six years after completion of construction of the proposed interventions.

Strategy (d) - Polderization, Drainage and Tubewell Irrigation

Strategy (d) is likely to result in some increase in agricultural benefit but the potential for this is very limited as the hydraulic modelling shows that even with the total exclusion of all external in-flow of surface water the extent of peak flooding still remains similar to the without project situation. However although the extent of flood plain is not greatly diminished, the fisheries system is likely to suffer heavy losses due to the effects of creating closed embankments around the whole study area which affect fish migration. The nutritional implications of this loss in fisheries could be severe, especially to occasional fishing households who are unlikely to be in a financial position to purchase replacement aquaculture fish even if it were available. The disruption to monsoon season navigation, even if some locks were provided is likely to be severe and replacement access provision would need an integrated embankment top road provision programme. There are also likely to be requirements for significant land acquisition leading to issues of compensation and resettlement.

Strategy (e) - Polderization, Drainage and Pumped Surface Irrigation

Strategy (e) has similar problems to Strategy (d) and would appear to be as equally unsound in environmental terms. It also has the further complication of depending upon pumps in an attempt to address the drainage problem that the scheme itself makes worse, as well as for providing irrigation benefits in the dry season. All these dis-benefits would seem to negate against its consideration irrespective of its economics which also reflect its likely poor performance.

7 Project Evaluation

The methodology used to evaluate project interventions is based on FPCO Guidelines for Project Appraisal. The economic analysis is based on 1991 constant prices, whereas the financial analysis uses 1992 prices. Economic prices have been calculated by applying FPCO conversion factors to 1991 financial prices.

Benefits resulting from project interventions include:

- increased agricultural production resulting from either improved flooding regimes or from the provision of flood protection to crops

- avoidance of flood damage by the provision of protection to housing, livestock, fish ponds, and Government property.

Dis-benefits (or costs) to capture fisheries arise as a result of changed flooding regimes, where there is a direct conflict of interest between agriculture (which benefits from reduced flooding depths) and fisheries which suffer.

The Gumti Phase II project area is richly endowed with groundwater resources. The economic analysis has therefore assumed that the only benefit which can be claimed from the provision of irrigation is the difference in cost between the exploitation of groundwater and the provision of surface water for low lift pumping out of khals.

The major source of agricultural benefits is expected to arise from decreased flooding depths in the wet season, which enables farmers to switch from either low yielding deepwater rice varieties to local varieties of transplanted aman; alternatively, they can switch from locally transplanted varieties of aman to high yielding short strawed varieties. Reductions in flood depths, which would in theory permit increased areas of deep water aman to be grown, are not expected to materialise as there are conflicts between the cultivation of boro, which is virtually certain to increase, and broadcast deepwater aman.

The methodology used to determine the areas of T aman in the "future with" situation is based on the hydro-dynamic model, which predicts flooding depths at various probabilities. These results are then combined with the land level database to give areas flooded to certain depths in each 10 day period. The depths are checked against histograms of submergence tolerance for the crop (i.e. maximum depths which the crop can tolerate throughout its life cycle) to obtain the maximum area of crop which can be safely grown at a specified

probability level. Any submergence of the crop for more than four consecutive days was deemed to result in failure and the area associated with such an event was excluded from the "safely grown" total.

A summary of the economic findings for the recommended schemes are presented in Table 6. The EIRRs for the FCD and FCDI full scheme protection, as recommended in the 1990 Report, were negative and were therefore not included.

TABLE 6

Summary of Economic Findings

SCHEME	COST (Million Taka)	NCA (ha)	EIRR	PRINCIPAL IMPACTS	
				Positive	Negative
A	385	22,115	15 %	Flash flood protection and conversion of B aman to T aman	Fisheries losses of 30%
B	16	300*	24 %	Flash flood protection	
C	69	10,000*	28 %	Low lift pump irrigation and drainage	
D with SFMTW	496	22,346	9 %	Irrigation supply and pumped drainage, enabling a large percentage of the area to have boro and T aman crops.	Fisheries losses of 57%
D without SFMTW	496	22,346	18%		Flora and Fauna species diversity losses

Note : * approximate

8 Recommendations

Schemes A, B and C are being recommended for immediate design and implementation, while Scheme D should be delayed until it is known if tubewell technology has been taken up by farmers. Scheme E should be delayed until the FAP 6 intervention downstream effects are known. If required, Scheme E should be taken up as a FAP 6 mitigation measure.