Government of the People's Republic of Bangladesh

Ministry of Irrigation, Water Development and Flood Control
Flood Plan Coordination Organization

BANGLADESH ACTION PLAN FOR FLOOD CONTROL

COMPARTMENTALIZATION PILOT PROJECT (FAP 20)

SIRAJGANJ CPP INTERIM REPORT

ANNEX 3: ENGINEERING

(FINAL DRAFT)

June 1993

Euroconsult/Lahmeyer International/Bangladesh Engineering & Technological Services/House of Consultants

under assignment to

DIRECTORAAT GENERAAL INTERNATIONALE SAMENWERKING
Government of the Netherlands

and
KREDITANSTALT FÜR WIEDERAUFBAU
Federal Republic of Germany

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ANNEX 3 : ENGINEERING

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i GLOSSARY

Aquaculture	-	The cultivation of aquatic products
Aman	-	A group of photoperiod-sensitive rice planted in July-August and harvested in November-December.
Aus	-	A group of photoperiod-insensitive rice varieties sown during March-April and harvested during June-August.
Beel	-	Small lake, low-lying depression, a permanent body of water in a floodplain or a body of water created by rains or floods.
Boro	-	A group of photoperiod-insensitive but fairly cold tolerant rice varieties transplanted in December-February and harvested in April-May.
Borrowpit	-	Excavated small and seasonal waterbodies present mainly along the public roads.
Chawk	-	A chawk is readily recognigeable manageable field unit bounded by village road and settlement areas. These are physical entities and are easily recognised by village people. Each chawk has water inlet or outlet through bridges, culverts, road breaches etc.
Compartment	-	A (semi) protected area or part thereof in which effective water management particularly through controlled flooding and controlled drainage, is made possible through structural and institutional arrangements. A compartment will be sub-divided into Sub-Compartments and operational Water Management Unit.
Compartmentalization	-	The spreading of the flood water over the flood plains by establishing interlinked compartments, with the objective to provide a more secure environment for agriculture, fisheries and integrated rural and urban development through water management (controlled flooding and drainage).
Controlled drainage	-	The control of the water flow out of a (sub)compartment according to the local or regional requirements.
Controlled flooding	-	The spreading of the flood over the land in a (semi)controlled way with the help of provisions incorporated in compartments, embankments, roads etc.
Embankment breaching	-	A breach is an occurrence in the embankment in which physical

damage, directly or indirectly by the external river water has caused an opening such that river water freely flows into the compartment in an uncontrolled way.

Embankment failure by Erosion - If the embankment is eroded due to the bank erosion of the main river, it is termed as embankment failure by erosion.

Embankment Sealing - An embankment is assumed to be sealed if the quality and locality of the embankment is such that embankment breaching - eroding may occur once in a 5-year period.

Fully-controlled structure - A structure through which the water flow can be fully regulated.

Khal - A natural channel.

Mike11 - A commercially available software package which contains a number of process module developed by the Danish Hydraulic Institute (DHI) and is taken for unsteady flow simulation in Bangladesh.

Multi-criteria analysis - An analysis and display of the impacts of proposed structural and non-structural works in which a wide range of criteria are used, such as social, environmental and economic. Impacts can be quantified in financial terms or may be evaluated using a scale from -5 to +5. Those items that cannot even be rated on such a scale are dealt with in a descriptive way.

Rapid Rural Appraisal - A systematic, but semi-structured activity carried out in the field by a multi-disciplinary team and designed to quickly acquire information.

Salish - Traditional informal village court which mitigate the disputes of the villagers. The traditional village Matabbars (Chieftains) are the judges.

Sub-Compartment - A sub-unit of a compartment, in which to a certain extent the water management can be controlled by the people living in the area represented in a Water Committee. The sub-compartment is mostly separated from the adjoining ones by embankments or roads provided with (semi)controlled structures.

Union	-	Smallest electoral unit of areas outside municipalities comprising several mouzas (or villages), and generally divided into three wards. It has an Union Parishad (Council).
Water Management	-	It is the controlled quantitative and qualitative usage of water, including early late and deep flooding, rainfall and groundwater for agriculture, fisheries, transport, sanitation, domestic and industrial purposes.

ii REFERENCES

North West Regional Study (FAP-2), Draft Final Report,
vol-2: Regional Data & Planning Units, 1992

North West Regional Study (FAP-2), Draft Final Report,
vol-10: Hydrology and Groundwater
October 1992

A Database report on lift irrigation census in March 1991, Final Report,
Census of Irrigation in BanglaDesh:
Bangladesh-Canada Agriculture Sector Team
December 1991

Draft Final Report, River Training Studies of the Brahmaputra River
January 1993, Main Report, FAP 1

Preliminary O&M PLAN, BWDB Systems Rehabilitation Project
ALA/89/06-BWDB, January 1993
Sir William Halcrow & Partners Ltd.
BCEOM and DHV Consultants

Draft Report, The interaction of flood regulating structures and migrating fish fry
HR Wallingford/FAP 17, Dec. 1992

Rapid Rural Appraisal of Brahmaputra Right Embankment Kazipur Reach,
FAP 12, FCD/I Agricultural Study, December 1991

National Water Plan Policy Study, Technical Report no. 5, MPO, 1987

1 INTRODUCTION

This Engineering Annex gives an overview of the main engineering aspects involved in CPP Sirajganj.

First, the Concept of Compartmentalization (Chapter 2) is being explained from an engineering point of view. From this concept a set of design criteria is being developed which encompasses the considerations emerged from this concept (Chapter 3: Development of Design Criteria) especially from the hydrologic and hydraulic point of view; furthermore agriculture and fisheries are being considered. A set of standard designs is attached.

The current Sirajganj setting is described in Chapter 4. Based on the actual setting and a number of baseline surveys together with the consultation meetings a set of possible development options have been described (Chapter 5). More detailed data are being provided in Chapter 6 (Subcompartmental Development).

The respective options are evaluated in terms of total cost estimates and its implementation schedule (Chapter 7). The Operation and Maintenance aspects are discussed (Chapter 8) for compartmental development and the relationship between the compartment with the adjacent areas are highlighted (Chapter 9).

2 CONCEPT OF COMPARTMENTALIZATION AND ITS APPLICATIONS

2.1 Controlled flooding and drainage

The concept of compartmentalization emerges from the idea that flood water will flow into the compartment and spread over the area in a (semi)-controlled way by means of regulating structures in the primary embankments along the main river and the gated or ungated openings in the secondary embankments between the compartments.

The way the flood, as well as the drainage of excess rainfall, has to be controlled will be determined by the demands from inside the compartment. The concept of compartmentalization is instrumental for the implementation of water management interventions.

The following definition will be used:

> *A compartment is a (semi-)protected area or part thereof in which effective water management, particularly through (semi-)controlled flooding and controlled drainage, is made possible through structural and institutional arrangements. Compartmentalization is linked to area development with sound water management as the main agent. A compartment will be sub-divided into sub-compartments and operational water management units.*

It is obvious that a compartment can be a large area and that hydrology, topography, existing infrastructure, landuse and administrative boundaries are important factors to consider. To make participation of the affected people in project planning, design, construction, operation, maintenance, monitoring and evaluation successful, it would be preferable to subdivide the compartment into rather small units which are more manegeable than larger sized units.

The criteria to design a compartment and its subdivision into operational units are subject of the CPP study. It goes without saying that it will be advantageous to design units that are homogeneous in many ways, as well as manageable as a distinct unit. The following factors have been considered for the *Sirajganj* Pilot Project:

- **Physical parameters**; the topography and hydrology of the area will have a significant effect on the size of the units; an operational unit should preferably have its own facilities for controlled flooding and drainage; assuming that it will be convenient from a management point of view that each unit has its own water level regulation and associated management mode within the unit.

- **Landuse patterns**; different landuse patterns require different water management modes; in order to simplify the management of the units, predominant landuse should be the prevalent criterium in selecting water management units.

Other factors which may have to be taken into account:

- **Administrative boundaries**; in the design and management of irrigation systems, it can often not be prevented that administrative boundaries and the boundaries of the water management (tertiary) unit do not coincide. This complicates the functioning of the Water User Groups. A compartment is not the same as an irrigation system but, certainly, there are some lessons to be learned from experience with the management of irrigation systems in the design of water management systems for compartments;

- **Social homogeneity**; operational units should also, from a social point of view be as homogeneous as possible. Using landuse as a criterium for the design of the operational unit may in itself result in some homogeneity of the group within the unit. By aiming at rather small units, social homogeneity will also be enhanced;

- **Manageability**; O&M of the smaller operational units should as far as possible be the responsibility of the affected groups themselves (Water User Groups). In the design of irrigation systems, it is generally accepted that service units should not be much larger than 50 hectares and/or have not more than 30 to 40 farmers.

Moreover, sub-compartments may be sub-divided for economic or operational reasons at a later stage. Finally, operational linkages should be established between sub-compartments. This controlled flooding can only be achieved if there is a natural or man-made barrier to separate the floodplain from the floodplain land.

The rural population perceive normal flooding as a very positive factor in the seasonal cycle. The mechanisms behind the positive influence of the normal flooding are in many cases well acknowledged. However, it is difficult to judge flooding in the framework of the positive vs. the negative. Reality is much more complicated than a simple mathemathical formula, besides from the fact that many items involved or affected cannot even be quantified. Only qualitative terms are often used for a number of indicators. Plan development for the region should definitely be implemented in close collaboration and cooperation with the local people to ensure viability and sustainability of the proposed programme.

It will be necessary to make a distinction between flooding which originates from rivers and flooding from local rainfall. Control of flooding from rivers can be achieved through the construction or rehabilitation of river embankments with control structures. One of the main issues here is to consider the effect of flood control on the neighbouring areas. Control of flooding inside the embankment (compartment) from local rainfall is basically a matter of (temporarily) flood retention within the operational units to avoid that flood water will accumulate in the low lying areas. The realization of this objective is more a matter of improving the internal drainage system, but is bound by downstream water level conditions.

Compartments can be identified by the following main characteristics:
*) a physical, identifiable and homogenous unit;
*) the compartment is physically a separate component in the floodplain area and is located adjacent to a main river;

*) the compartment is divided into more subcompartments which are sized such that these are the smallest watermanagement units within the compartment;
*) the compartment allows water to enter from a river system through a system of inlets, regulators constructed in the main embankment next to the main river system and outlets in the (sub)compartment embankments to influence the waterlevel within the (sub) compartment;
*) the required waterlevels are determined by agricultural and piscicultural needs in a dynamic fashion; also infrastructural constraints are to be taken into account;
*) a drainage system within the (sub)compartment connected to the already existing drainage system outside the compartment should be designed such that the sufficient flexibility can be maintained for water inflow, water storage and water outflow in a time and place dynamic fashion.

The main advantages of compartmentalization:
*) the concept allows planners to think in regionalized and localized planning efforts bound to physical features;
*) the smaller sized physical units allow for more direct contact and more involvement of local people and therefore allows for more involvement of the affected people;
*) the compartment principle cannot be applied in a rigid way in a wide variety of settings but needs considerable fine-tuning at local level in order to coope with local conditions;in other words a succesful concept does not necessarily mean a successfull local impact because the interaction and collaboration at local level is a *conditio sine qua non* for a proper implementation of the programme;
*) to certain extent flood zoning can be implemented within the compartment by containment of floodwater to certain subcompartments if embankment fails; and
*) the overall development and future prospects of the compartment is very much a function of watermanagement.

2.2 Water management

FAP 20 has defined water management within the context of compartmentalization as:

> *Water management is the controlled quantitative and qualitative usage of water, including early, late and deep flooding, rainfall and ground water for agriculture, fisheries, transport, sanitation and domestic and industrial purposes.*

Watermanagement is a main cornerstone in the compartmentalization approach. It allows controlled flooding within the compartment taking into account agriculture, fisheries, infrastructure and urban land. The development of a watermanagement picture over the year is difficult due to localized conditions and the highly variable base assumptions for each setting regarding the hydrological features.

In general, intake regulators and drainage sluices will be managed to control the timing, depth and duration of flooding on the land during the rainy season within certain limits that ensure the most favourable conditions for agricultural, fisheries/aquaculture and infrastructural interests.

The controlled flooding aims to provide farmers with greater crop security during the wet season. On appropriate land and soil types, expansion and intensification of HYV is envisaged. Furthermore prevention of damaging floods to agricultural land and crops will be substantial. Different crops, cropstages and varieties need different waterlevels at different times. If these waterlevel requirements are not met, adjustements in watermanagement and/or cropping patterns are relevant.

The overall objective of FAP 20 is:

> "*....to establish appropriate watermanagement systems for the development of protected areas so that criteria and principles for design, implementation and operation can be made available for the Action Plan.*" [ToR, page 4].

Specifically this will entail the

> "*...testing of the compartmentalization concept in the field under real operating conditions, addressing all relevant socio-economic, institutional and environmental issues and trying out water control works and water management systems.*"[ToR, page 4].

FAP 20 has to produce not only the structural works and an institutional set-up for CPP-*Sirajganj*, but also criteria, guidelines, manuals and a training and demonstration programme for the establishment of other compartments.

It is therefore suggested to use the subcompartmentalization principle to guide the options to be considered. The advantage of subcompartments is that certain watermanagement emergencies like a BRE breach can be localized and not, or to a lesser extent being allowed to affect adjacent compartments. The subcompartment boundaries (which are almost always paved roads or local roads) would then act as localized cells.

Water management ideally is a continuous process in which the people concerned participate in a decisive way. It starts with the identification of the existing water related problems and possibilities, followed by planning, design, construction, operation and maintenance, but also monitoring and evaluation of the results. Water management includes reconciling competing interests and it should lead to sustainable development.

It is, therefore, necessary to institutionalize the people's participation in water management. Of course, this will not be easy. However, farmers do cooperate informally for irrigation, ploughing etc. and in the *Salish* to reconcile disputes.

This water-management-related institutionalization will have to be initiated at the local level, but will ultimately have to extend up to the national and even the international level. It will also have to include legislation, including the formulation of by-laws, defining rules and regulations about the privilages and duties of the people and organizations concerned. Here again, it is necessary that these are sustainable, and accepted as legitimate by the people.

2.3 People's Participation in the Planning Process

The FAP 20 ToR puts much emphasis on people's participation and its institutionalization;

> "*The compartment is basically a management unit in which the involvement of beneficiaries is considered essential for its success.*" [ToR, p. 3]

> "*The non-structural output which constitute the basic objectives of the Pilot Project will cover the following:*
>
> .....
>
> 2. *Social Aspects*
>
> *Policies and Guidelines of involving the scheme beneficiaries and disadvantaged groups in the planning and implementation of physical works and their management*
>
> ...
>
> 4. *Institutional Arrangements*
>
> *Policies and Guidelines for strengthening existing institutions and/or establishing new ones for the management of compartments or sub-compartmental development with the emphasis on local government and beneficiary participation* .... [ToR page 6, 7)

The need for this emphasis on the non-structural aspects of compartmentalization has strongly been indicated by evaluations of existing FCD/I projects (see particularly FAP 12/13). These have highlighted that success and sustainability require people's participation in all phases of the FCD/I projects and close collaboration between and within the various government organizations. This was reconfirmed during the Third FAP conference (May, 1993).

People's participation requires an open approach whereby interaction among the interest groups and coordinating agencies is guarenteed and whereby this interaction leads to an active process in which all parties concerned have an active voice. This process is a continous effort covering the entire range of decision making at different levels from its very inceptive ideas to the implementation of the Operation and Maintenance.

Through the performance of Needs Assessment Surveys with the various target groups in the envisaged compartment area and its adjacent areas, multiple consultation rounds with these groups are organized in which emerged proposals for interventions are discussed. Through this process public opinion is guarenteed to be involved in this entire gradual process of decisionmaking.

3 DEVELOPMENT OF DESIGN CRITERIA

3.1 Hydraulic and hydrologic aspects

3.1.1 Selection of design criteria

The actual development of the design criteria for hydraulic/hydrologic purposes is a combination of the requirements imposed by;

- Agriculture; five hydrologic features are equally important for assessing the potential agricultural damage. The yearly maximum flood level is not the only indicator for the potential damage to agriculture.
  These five features are:
  - Flood level;
  - Timing of the flood;
  - Speed of rise of a flood;
  - Flood duration;
  - Sediment load of a flood.

- Fisheries; certain waterlevels need to be maintained during certain time of the year in order to propagate the use of the floodplain area confined within the compartment for fisheries purposes. Preferably the rising waterlevels of the main river should be allowed to enter through the BRE inlet structures into the confined floodplain area where the fish fry can develop.

- Infrastructure; it is predominately determined by the level of the flood and only slightly by the duration, the timing, the speed of rise and the sediment load of the flood. The yearly maximum event is a typical indicator for the potential damage.

Two indicators are therefore used:

1) the maximum allowable floodlevel with a certain return period (annual maximum); or
2) the maximum 3-day mean waterlevel per decade.

1) The maximum allowable flood level for distinct return periods indicates the probable flood level associated with a distinct return period, irrespective of the period within the flood season. For infrastructural concerns, the maximum allowable flood level is a good indicator for specific design features. Roads, embankments, water control structures ought to include this feature in their specific designs.

2) The maximum 3-day mean water level per decade identifies the maximum water level which is reached on the average for a 3-day period. The time period for which this is calculated for is limited to 10-day intervals. For agricultural purposes this analysis provides the necessary fine-tuning with respect to certain water levels associated with return period.

3.1.2 Embankments

In general embankments serve as a protection measure for identified areas against certain waterlevels with a specific return period. This design level for an embankment is based on statistical interpretation of waterlevels at or near the location of the embankment or derived through mathemathical calculation from a location upstream or downstream from the considered area.

3.1.2.1 Main embankments

These embankments have as purpose to act as the main protection from major rivers to safeguard areas from flooding hazard. The main embankment for CPP Sirajganj is the Brahmaputra Right Embankment.

Key indicators for the main embankment design:

Embankment height	**1:100-year annual peak level (Jamuna river)**
Crest width	**24 ft**
Side slope(river side)	**3:1**
Side slope(country side)	**3:1**
Normal embankment height	**10-15 ft**
Free board	**5 ft**

For retired embankments, the design for the crest width is reduced to approx. 14 ft. The original BRE design (beginning 1960's) was based on the assumption that the embankment would be used as a road. However, during and after the implementation of the BRE, it was realized that this objective could not be met. Consequently the design crest width for retired embankments is limited to 14 ft.

Other details are according to standard BWDB (O&M) manual.

3.1.2.2 Secondary embankments

These embankments have as purpose to act as a protection on the periphery of the compartment or serve as a hydrological boundary between subcompartments. These embankments protect the areas from rivers which are of less importance than the rivers which are protected by the main embankment; they may also serve as a hydrologic boundary between subcompartments.

Key indicators for the design of secondary embankments:

Embankment height	**1:20 years annual peak level (Ichamuti river)**
Crest width	**10-14 ft (according to need for transportation)**
Side slope(river side)	**3:1**
Side slope(country side)	**2:1**
Freeboard	**3 ft**

Other details are according to standard BWDB (O&M) manual.

3.1.2.3 Breach mitigation embankments

Some of the subcompartmental embankments act as breach mitigation embankments by providing protection to areas affected by a BRE breach. These embankments have as purpose to act as an internal protection from impact of a BRE breach which either takes place in the CPP Sirajganj area directly or originates from an area upstream of CPP Sirajganj.

Key indicators for the design of breach mitigation embankments:

Embankment height	**1:20 years annual peak level Jamuna river**
Crest width	**10-14 ft (according to need for transportation)**
Side slope(river side)	**3:1-2:1 (according to local situation)**
Side slope(country side)	**2:1**
Freeboard	**2-3 ft**

3.1.2.4 Temporary embankments

In some cases urgent construction of temporary embankments are necessary which protect certain areas (villages, etc) for a limited time from the influence of the Brahmaputra river. This situation occurs if suddenly an existing embankment is damaged, partly or entirely and the villages and/or agricultural land are exposed to the main river. The limited time during which these temporary embankments are planned to be used, does in principle not exceed a few years or even a few months only.

The affected villages and agricultural land are located on the river banks. The original embankment which is located between the village and the river is not functioning any more. In order to protect the people from being washed away by a minor storm or moderately increased waterlevel, it is recommended to construct an embankment which temporarily protects people and their assets. This temporary embankment would give the people from the concerned villages time to find new shelter. Any major waterlevels (beyond 1:5 years) from the Brahmaputra cannot be withhold from these areas. Land acquisition for these temporary embankments should be provided by the local people.

Key indicators for the design of temporary embankments:

Embankment height	**design height (1:3-5 years Jamuna river level)**
Crest width	**8-10 ft**
Freeboard	**2 ft**
Side slope(country side)	**1:2**
Side slope(river side)	**1:1.5**

Other details are according to BWDB (O&M) manual.

3.1.3 Channels

3.1.3.1 Main channels

Channels will be designed on the basis of rainfalldepth duration-frequency analysis. The external water entering from outside the catchmnet area belonging to the channel, will be accounted for separately. Depending on the accumulated maximum periodical rainfall for pre-monsoon, monsoon and post-monsoon the drainage channel will mainly be designed considering the need for agriculture and fisheries. The developed drainage system will, in general, not drain out local beels. The corresponding multi-day maximum rainfall (1-10 day) for pre-monsoon, monsoon and post-monsoon is presented in table 3.1 (Gumbel-distribution and 26 years of data, 1965-1991).

The pre-monsoon drainage is linked to an agricultural system whereby crops are sown under dryland conditions and thus prefer a soil moisture regime around field capacity. Consequently all water in excess of field capacity or the moisture level which the crops can tolerate (whichever is more constraining) needs to be drained out. The premonsoon rainfall pattern is characterized by short duration, heavy intensity and localized rainfall. The drainage cacpacity should be sufficient enough to absorb the sudden rise of short period waterlevel.

The post-monsoon drainage is applicable to a system whereby crops need a dryland condition and prefer a moisture regime again around field capacity. Consequently early in the post-monsoon, excess moisture accumulated during monsoon should be removed. This allows for timely harvesting of crops and seeding of the rabi crop.

In general, the monsoon drainage rate is taken as a guideline for the internal (within compartment level) drainage which can be manipulated through the operation of regulators. However, the internal drainage system connected with the external drainage system is related to an expected head difference between these two systems during the monsoon season. In the monsoon season, this required head difference is often not available.

The premonsoon rate will be compared with the post monsoon rate and the maximum value of either two will be used.

The design channel slope will be non-silting and non-scouring for sandy loam soils and thus the allowable velocity will be in the range of 0.3-0.7 m/s. Freeboard of the channels will be 2 ft. Soil deposition will be on both sides of the channel at a distance of 50 ft. from the channel bank. Side slopes will be 2:1 (river side, country side). The assumed Manning's coefficient is 0.03 for reexcavated channels. The connection to other channels and should be as gradual as possible in order to avoid severe erosion in these soils.

Table 3.1: N-day Maximum Rainfall Data Sirajganj
For Pre-Monsoon, Monsoon and Post-Monsoon

Pre-Monsoon (March - June)										
	n-day maximum									
Return Period (Years)	1	2	3	4	5	6	7	8	9	10
5	151	188	219	239	256	275	290	304	318	325
10	184	228	227	291	308	330	348	363	379	387
20	215	266	312	340	357	382	403	420	438	446
50	256	316	371	404	422	450	474	494	514	522
100	286	353	415	452	470	501	528	550	571	580

Monsoon (July - September)										
	n-day maximum									
Return Period (Years)	1	2	3	4	5	6	7	8	9	10
5	151	210	253	281	299	306	319	335	348	361
10	177	246	300	332	352	360	373	392	408	422
20	202	281	345	382	403	411	425	447	465	480
50	235	325	403	446	469	477	492	517	540	556
100	260	359	446	494	519	526	542	570	596	613

Post-Monsoon (October)										
	n-day maximum									
Return Period (Years)	1	2	3	4	5	6	7	8	9	10
5	88	115	128	135	141	146	152	157	159	165
10	110	145	161	170	179	184	192	198	200	208
20	131	174	193	204	214	220	231	237	240	250
50	159	212	234	247	261	267	280	289	291	303
100	179	240	265	280	295	303	318	327	330	344

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3.1.3.2 Minor Channels

Also these channels will be designed on the basis of rainfall duration- frequency analysis. The external water level will be accounted for separately. Depending on the drainage rate for premonsoon, monsoon and post monsoon the drainage channel will be designed as for the need for agriculture. The critical period as identified in agriculture is for pre-monsoon drainage and priority wil be given for pre-monsoon drainage. Also the premonsoon rate will be compared with the post monsoon rate and the maximum value will be used.

The design channel slope will be non-silting and non-scouring for sandy loam soils and thus the allowable velocity will be in the range of 0.3-0.7 m/s. Freeboard of the channels will be 1-2 ft (according to local conditions). Soil deposition as a result of excavation will be on both sides of the channel at a distance of at least 20 ft from the actual bank of the channel and in depression along the bank openings will be left for drainage water from the surrounding area to enter the drainage channel. Side slopes will be 1:2 (river side, country side). The assumed Manning's coefficient is 0.03 for reexcavated channels. The connection to other channels should be as gradual as possible in order to avoid severe erosion in these soils.

3.1.4 Roads

3.1.4.1 Regional Roads

Regional roads function as a major mode for transportation between regional centers and serve as a boundary between hydrological units within the compartment. Coincidentally some of these roads will also be used as a BRE breach mitigation embankment and therefore comply with the design criteria set for breach mitigation embankments (Section 3.1.2.3).

Existing structures located at these roads will be converted, adjusted or newly designed for serving the special function which these embankments assign to these structures.

The following criteria are therefore used:

Embankment/road height	**1:20 years annual peak level (Jamuna river)**
Side slope	**3:1-4:1 (upstream)**
Side slope	**2:1 (downstream)**
Crest width	**14-? ft (according to transportation need and BRE)**
Freeboard	**5 ft**

Other details will be according to BWDB (O&M) and LGED manual.

3.1.4.2 Subcompartmental boundary roads

Subcompartmental boundary roads can also function as a mode for transportation between local centers and/or act as the boundary of a hydrological unit within the compartment. This road will be used as subcompartment boundary and BRE breach mitigation embankment. The design criteria for the BRE breach mitigation embankment will prevail in this case due to the assigned dimensions of the road in case breaches occur. In case the road is within the zone of influence of the Ichamuti and out of the direct influence of the Jamuna river, an annual peak waterlevel of the Ichamuti river may be taken as the design height.

In case these roads are located in the vicinity of the BRE, these roads become classified as regional roads/breach mitigation embankments (Section 3.1.4.1).

Existing water conveyance structures at these roads will be converted,adjusted or newly designed for serving this special breach mitigation function.

The following criteria are used for subcompartmental boundary roads:

Road height	**1:10 years annual peak level (Jamuna or Ichamati)**
Side slope	**3:1-4:1 (facing upstream)**
Side slope	**2:2 (facing downstream)**
Crest width	**14-? ft (according to need for transportation)**
Freeboard	**3 ft**

Other details according to BWDB (O&M) and LGED manual.

3.1.4.3 Local roads

Local roads bear much less importance than regional roads or subcompartmental boundaries. Their importance in the overall infrastructure is localized and most commonly do not go beyond the level of transportation from one village to the next village.

The following criteria for the design of local raods are suggested:

road height	**1:2-5 years annual peak level (Ichamuti river)**
side slope	**2:1 (both sides)**
crest width	**8-10 ft (according to need for transportation)**
freeboard	**1-2 ft**

Other details according to BWDB (O&M) and LGED manual.

3.1.5 Structures

3.1.5.1. General

The proposed structures can be classified as:

i)	peripheral control structures (except BRE inlet structures)	(Section 3.1.5.2)
ii)	BRE inlet structures	(Section 3.1.5.3)
iii)	internal structures	(Section 3.1.5.4)
iv)	bridges/culverts	(Section 3.1.5.5)
v)	irrigation structures	(Section 3.1.5.6)

Furthermore some sample designs are presented (Section 3.1.5.7).

3.1.5.2. Peripheral Control Structures

The main function of peripheral control structures will be to control inflow from external areas (either river inflow or overland flow) into the compartment area; specifically controlled flooding and controlled drainage. The BRE inlet structures will be discussed in Section 3.1.5.3. The allowed inflow wil primarily be designed on the basis of the water requirement of the specified area and also the water conveyance capacity of the peripheral drainage system.

The drainage will follow the same criteria as mentioned under channel design. The water requirement for the compartment will be calculated as follows:

* the agricultural water requirements
* the fisheries requirements

The crop water requirements are based on calculations for evapotranspiration, water used for land preparation and water lost through percolation by maintaining ponded condition in case of puddled fields. Evapotranspiration can be calculated by theorethically derived formulas which depend on croptype, cropstage and climatic factors. Water loss due to land preparation can be estimated from field experience. Percolation losses are determined mainly by soil properties, the most important of which is soil texture. The total area under agricultural demand is also to be included in the agricultural water requirement.

Rainfall amounts indicate the total amount accumulated over a certain period of time. Rainfall also can meet partially or fully crop water needs. Dependable rainfall is a level of rainfall which is met with a 5-year return period (80%) and as such included in the agriucltural water requirements calculation.

The fisheries requirements are limited. Substantial fish fry influx into the compartment area will only take place in case a BRE breach occurs north of the CPP Sirajganj. However, this is assumed to be an exceptional case and thus will, in principle not be considered as the main factor in determining the design criteria for peripheral control structures. However, it is possible that in a later stage new BRE inlet structures will be built in the area north of CPP Sirajganj which allow fish fry to enter CPP Sirajganj through these structures and then be conveyed to the Ichamuti khal and Ichamuti branch. However, in this stage these considerations are not taken into the analysis.

Dimensions of the peripheral control structures will be based upon the above mentioned criteria and the actual dimensions will be calculated through a mathemathical model.

The sill level, height and width should be in accordance with the agricultural and fisheries requirement. The hydrological model Mike 11 can provide valuable information in providing a consistent design compartment-wise.

3.1.5.3. BRE inlet structures

The main function of the structures will be to control water inflow from the Jamuna with a twofold objective:

1) fish migration;
2) supplemental irrigation.

1) The critical period for fish migration from the Jamuna to the floodplain area is May-June and may even extend to July. As the fish fry comes with the raising waterlevel in the Jamuna river, it is of utmost importance to allow these raising waterlevels into the compartment area uninterruptedly. If the waterlevel difference between riverside and countryside is too much then preferably the BRE inlets should be gated.

2) The critical period for agriculture is June-August. It is also possible that if the Jamuna water level is relatively high in the pre or post monsoon period in comparison with the average ground level within the compartment supplemental irrigation can take place. Therefore the sill level will be based on the above mentioned months.

The inflow wil be designed on the basis of the water requirement of the specified area and the drainage will follow the same criteria as mentioned under channel design (Section 3.1.3.1).

Dimensions of these structures will be based upon the above mentioned criteria and the actual dimensions will be calculated through a mathemathical model.

These structures can be also be used as irrigation inlet if they are placed on the high contours (countryside) in order to be able to distribute the incoming water into the subcompartment.

The following fish-related constraints are common in the design of water conveyance structures (HR Wallingford/FAP 17):

1. Total obstruction to fish passage;
2. Physical damage to the fish by contact with the structure;
3. Damage to the swim bladder through rapid changes in pressure;
4. Damage arising from turbulence downstream of the structure.

1. It is not considered that a normal design of regulator using vertical lift gates will completely exclude fish fry but may delay them if the gates are undershot and the gate opening is small.

2. Damage to fish by contact with the surface would most commonly occur at small culvert type regulators where the velocities are high and the fish are in close proximity to an extensive surface.

   Culverts using impact energy disipators are unsuitable for fish passage but this type of dissipator is used where tailwater depth is low and fish movement is not likely to be high. Culvert regulators could be improved to some extent for the passage of fish by increasing the size to minimize velocities and streamlining the entry.

3. Damage to the swim bladder could be a serious problem and is most likely to occur with undershot gates operating at small openings. Free surface flow as occurrs with overshot gates or fully open gates will minimize the problem.

4. Turbulence downstream is not yet a proven cause of damage to fish fry in passage but clearly it is preferable if the exposure of fish fry to the often violent fluctuations downstream of a regulator can be minimized.

Undershot gates are providing the most convenient method of controlling the downstream level within a small range but free surface flow is most beneficial for fish passage.
It is therefore suggested that a combination of both undershot and overshot gates are provided within the same structure for that same reason.

Main considerations for the design criteria for BRE inlet structures:

Top level	**1:100 years (coinciding with BRE standards)**
Opening height	**1:20 years**
Freeboard	**coinciding with top level BRE**
Gate size	**as wide as possible, not less than 2 meters wide**
Heigth	**no particular constraints**
Sill level	**1:2 annual peak level**
Mode of operation	**Allow as much water as possible untill approx. 15 July (or certain specified level or level difference between river side and country side). Preferably no throttling alllowed before this date. A combination of undershot and overshot gates should be used.**

3.1.5.4. Internal structures

The main function of the internal structures will be to regulate flow between subcompartments (regulators) and to retain water within a subcompartment (water retention structures) in order to sustain certain waterlevels necessary for agricultural and fisheries purposes.

The regulators serve as a means to control the flow between subcompartments either as a result of a BRE breach and/or controlled flooding. The critical period for agriculture is June-July and for fisheries untill the first main flood enters the area (approx. 15 July). It is also possible that if the Jamuna water level is relatively high in the pre or post monsoon period in comparison with the average ground level within the compartment supplemental irrigation can take place. Therefore the sill level fixation will be based on the above mentioned months (June-July).

The inflow wil be designed on the basis of the water requirement of the specified area and the drainage will follow the same criteria as mentioned under channel design (Section 3.1.3.1.)

Dimensions of these structures will be based upon the above mentioned criteria and the actual dimensions will be calculated through a mathemathical model.

The group of internal structures also include water retention structures.
The water retention structures provide:

*) additional surface waterstorage in those areas which are drought-prone at the end of the monsoon season or dry season and/or
*) a sill level which is beneficial for fish propagation purposes.

The design criteria for those water retention structures are very location and area specific.

3.1.5.5. Bridges/culverts

The main objective of these structures is to facilitate the internal transport system of the area and can also be used as a water management tool.

The dimensions will be determined on the basis of the local situation.

The maximum (standard) size of box culverts should not be more than 6-8 m. while the regular culverts do not exceed 1-1.5 m.

If the structure is based as a conveyor of overland flow, the dimensions are determined by the catchment area and the restriction that the outflow from this structure should be similar to the inflow. The actual restriction on the existing upstream flow pattern should be minimal. If the structure is based in an existing or to-be-excavated khal, then the dimensions are determined by the upstream catchment area, size of the khal and downstream condition.

Other details will be according to BWDB (O&M) and LGED manuals.

3.1.5.6. Irrigation structures

The objective of this type of structure is to provide irrigation facilities during the moisture stress period in the month of May-June and September/October. On the intake side, the structure should be placed on relatively low contourlevels such that it can accumulate water on the upstream side and that on the outlet side it would preferably be placed on the highest contour possible in order to enable to irrigate an area. Sufficient drop should exist between inlet and oulet.

Sometimes these irrigation structures can be used as a drainage outlet in other periods of the year in case excess water acccumulates on the upstream side while the outside water levels are lower.

The precondition for this structure is the availability of water on the upstream side of the structure and the groundlevel on the downstream end. Sometimes these structures are provided with gates in order to control inflow/outflow.

Its impact area varies from a few ha to maximum of 10 ha. The dimensions are 1-2 ft and the material used are RCC pipe culverts.

3.1.5.7 Examples of proposed designs

The actual available topographical and hydrologic data for CPP Sirajganj do not allow for a detailed design of the proposed structures and other measures associated with the development options.

However, the following sample designs are presented for a number of types of structures:

*) Typical flushing sluice (Figure 3.1)
*) Typical flushing cum drainage sluice (Figure 3.2)
*) Typical road pipe culvert and mutiple barrel box culvert (Figure 3.3)
*) Typical water control structure (Figure 3.4); and
*) Typical bridge with a semi controlled structure (Figure 3.5)

3.1.6 Without and With-Project Situation

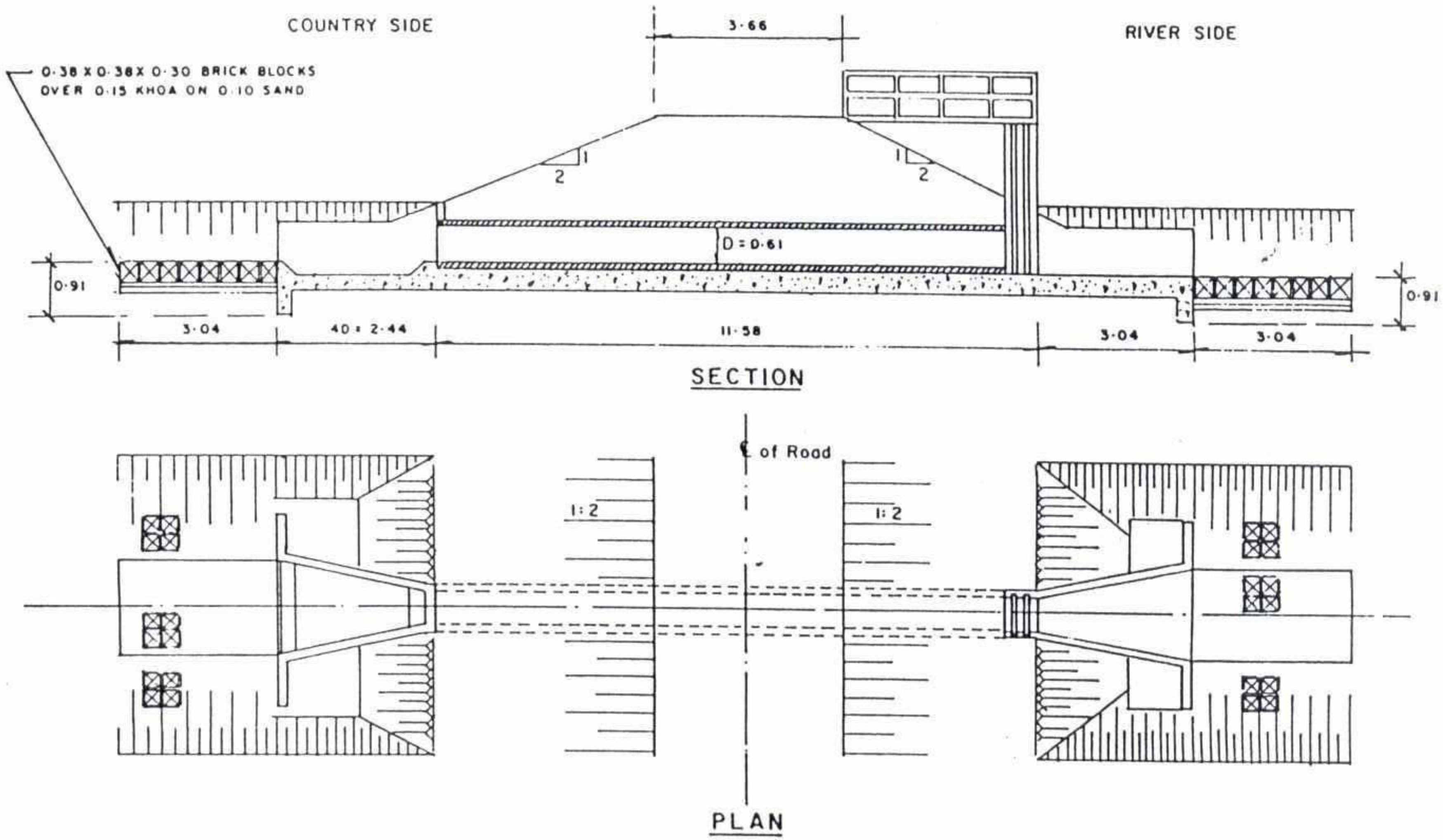
The Without-Project situation resembles the actual situation in CPP Sirajganj area. It is assumed that at present the BRE is sealed. However, the question is if this sealing provides a guarantee that no breach will occur in the (near) future. Consequently the existing drainage situation is mainly influenced by the BRE behaviour and excessive runoff which may occur from the upper Bangali river system.

The With-Project situation resembles the features specified with the items developed for the possible options for intervention within the concept of CPP (Section 5.2). Regarding the BRE and its related problems it is assumed that according to ToR a sealed BRE is a precondition for further development of CPP Sirajganj. On the other hand there is no absolute guarantee that no breach will occur in the BRE either within or upstream of the CPP Sirajganj area. Consequently all options for possible interventions should incorporate measures which can coope with a possible BRE breach within the CPP Sirajganj area or north of it.

3.1.7 O&M guidelines

O&M guidelines should be developed based on the compartmentalization concept whereby sufficient flexibility is expected for an integrated watermanagement approach. This integrated water management approach takes place within the compartment itself. However, one should incorporate the specifc features of the adjacent areas and the impact from CPP Sirajganj on those areas.

The special features of the compartmentalization concept urges for an approach whereby a time and location dynamic system is developed which allows for the required flexibility. In general, the operation of the system requires a set of external (peripheral) internal and outlet regulators which are linked through channels. These regulators are often located on subcompartmental boundaries which allow for subcompartmental watermanagement taking into account requirements for the various interest groups in the subsequent subcompartments.



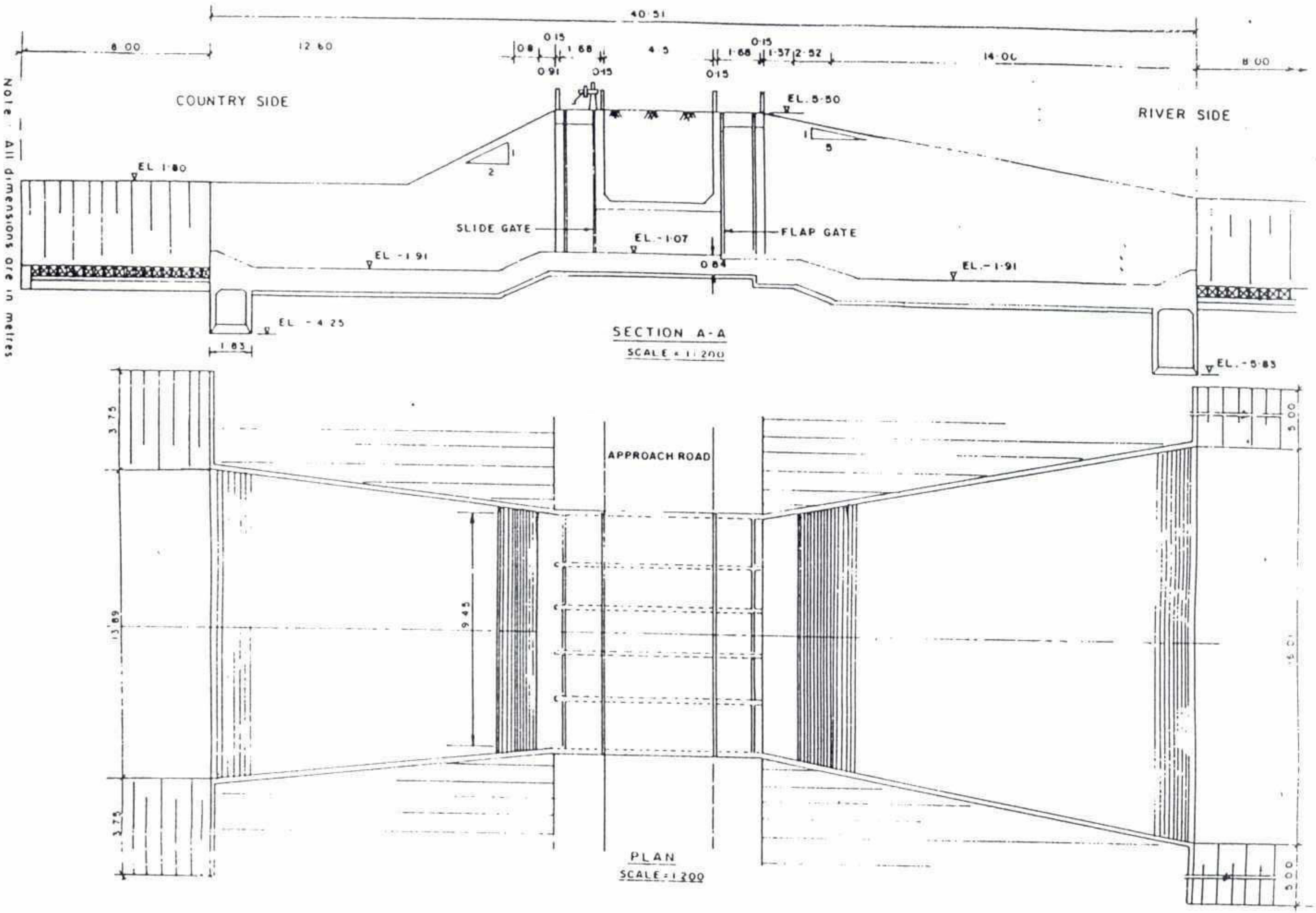
Note :
ALL DIMENSIONS IN METERS
INVERT LEVEL TO BE DECIDED TO SUIT SPECIFIC LOCATION

COMPARTMENTALIZATION PILOT PROJECT
SIRAJGANJ (FAP 20)

TYPICAL FLUSHING SLUICE

Figure no. 3.1

20



Note : All dimensions are in metres

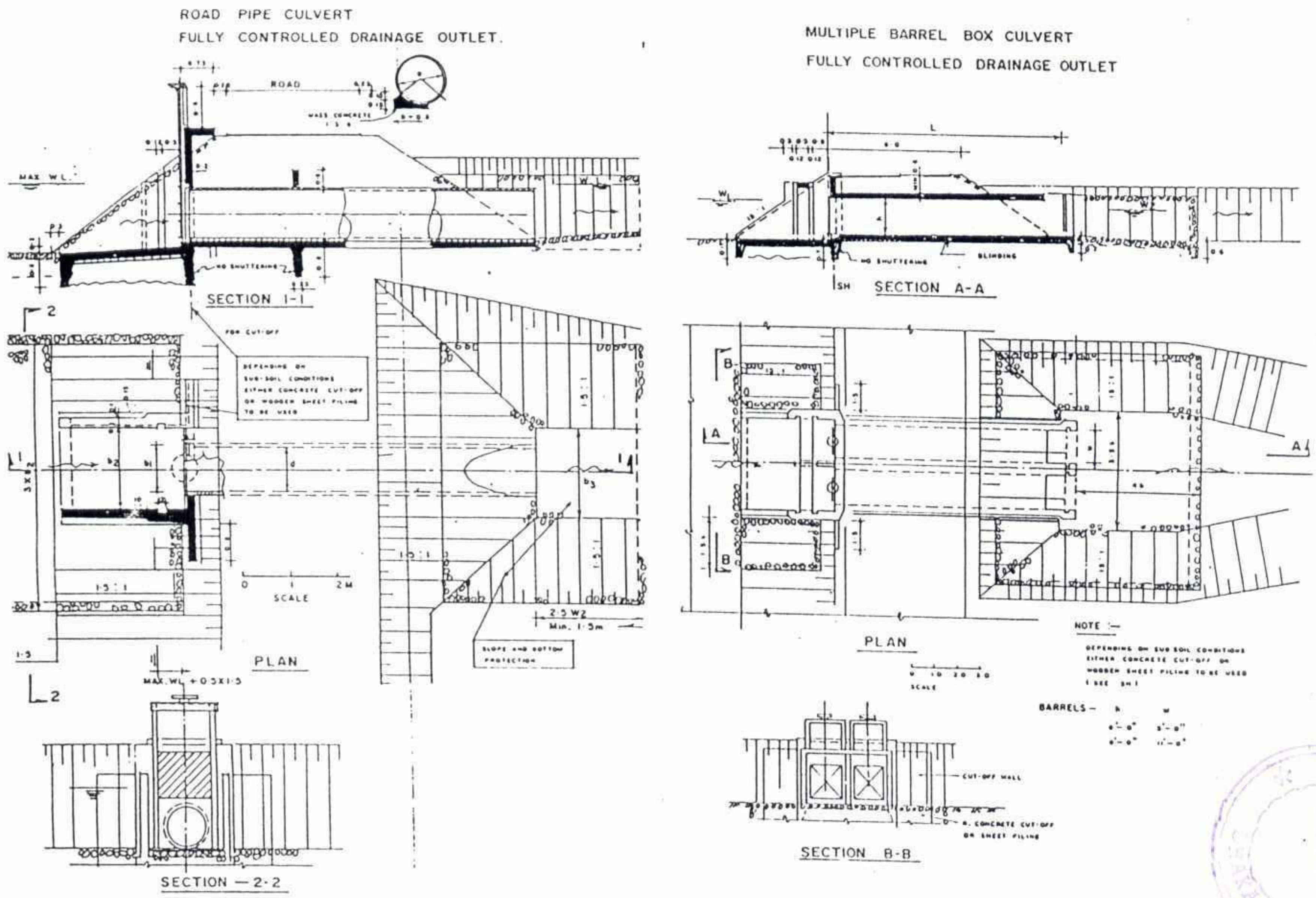
Pilling to be provided if required

COMPARTMENTALIZATION PILOT PROJECT

SIRAJGANJ (FAP 20)

TYPICAL FLUSHING CUM DRAINAGE SLUICE

Figure no. 3.2



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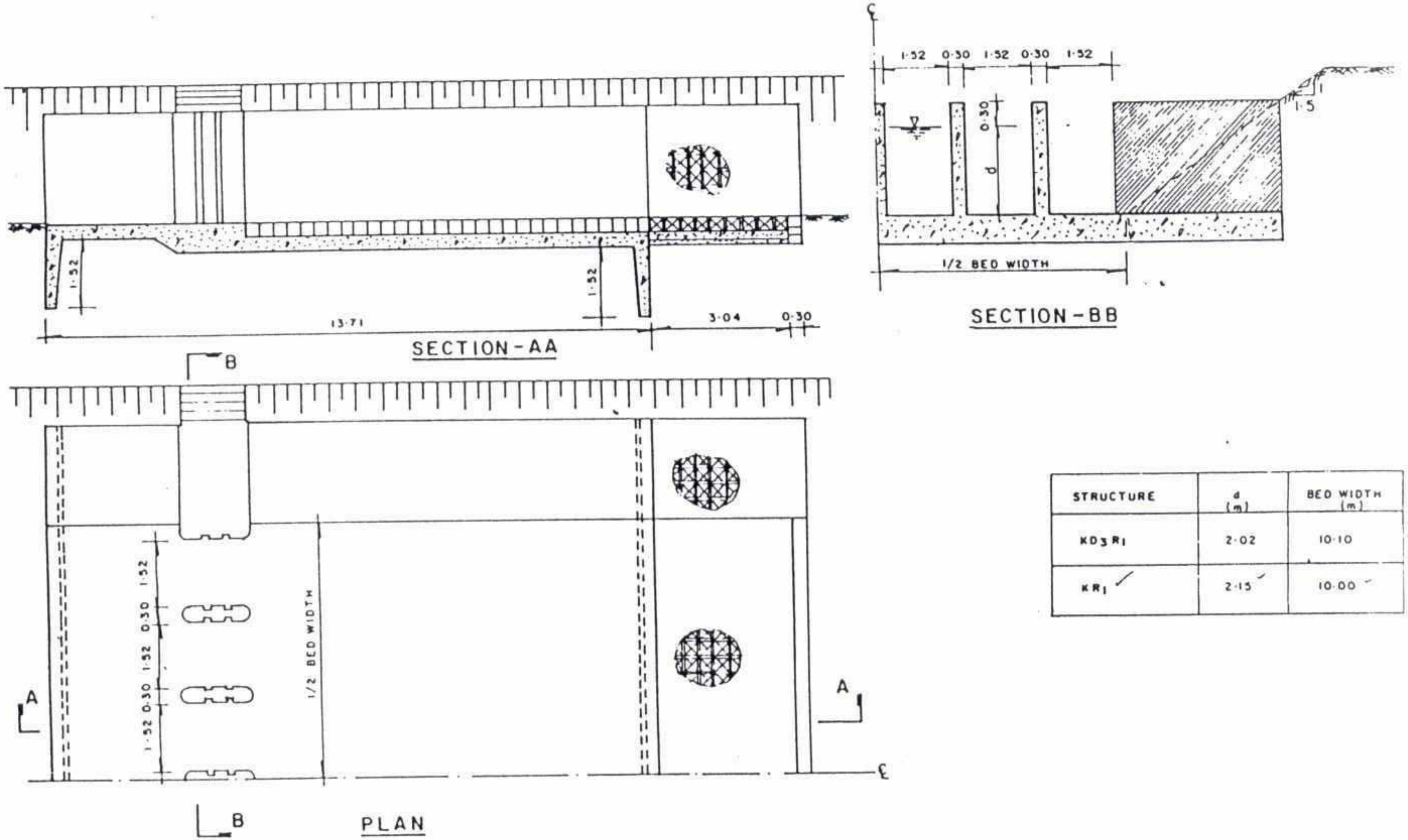
FLOOD PLAN COORDINATION ORGANIZATION

COMPARTMENTALIZATION PILOT PROJECT

SIRAJGANJ (FAP 20)

TYPICAL ROAD PIPE CULVERT AND MULTIPLE BARREL BOX CULVERT

Figure no. 3.3



STRUCTURE	d (m)	BED WIDTH (m)
KD3R1	2·02	10·10
KR1	2·15	10·00

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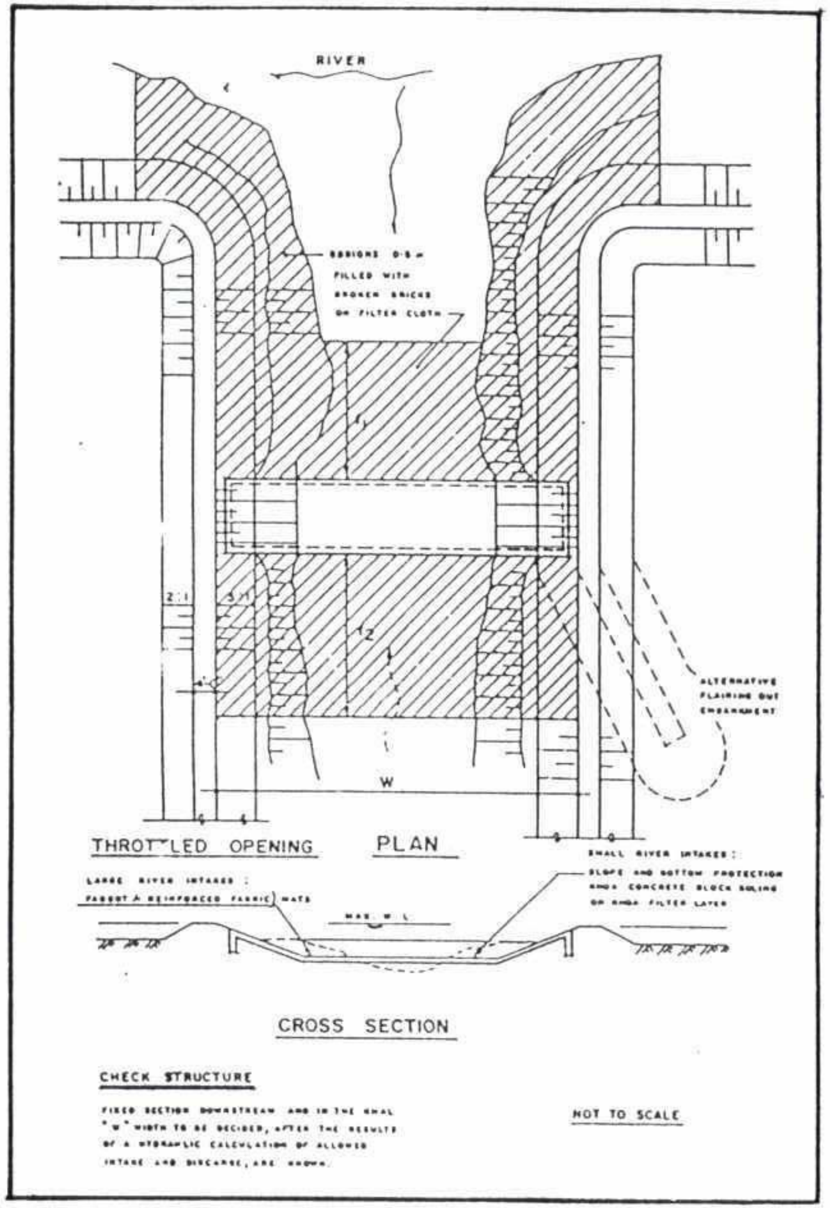
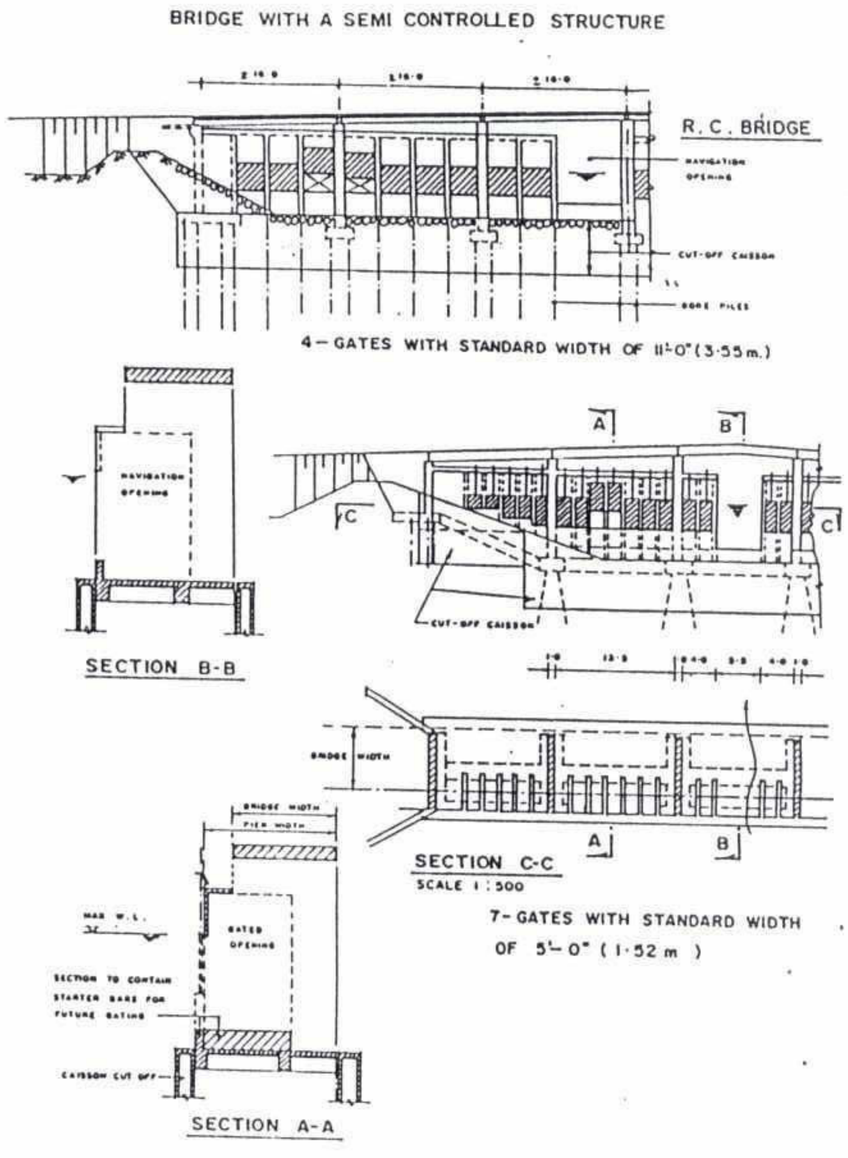
SIRAJGANJ (FAP 20)

TYPICAL WATER CONTROL STRUCTURE

Figure no. 3.4





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SIRAJGANJ (FAP 20)

TYPICAL BRIDGE WITH A SEMI CONTROLLED STRUCTURE

Figure no. 3.5

The maintenance component is developed such that the operational part can be performed adequately. Special care should be taken for maintenance of special embankments and the large amount of peripheral, internal and outlet regulators.

3.2 Agriculture

Agriculture in all its diversity is an important factor in the overall setting and operation of the compartment. A number of key indicators can be identified in thsi respect.

The main type of information necessary for agricultural assessment of the situation is the combination of land types and corresponding flooding depths to be expected for various proposed development scenarios.

3.2.1 Selection of Base and With-Project Situation

CPP Sirajganj compartment is confined between the river Jamuna, the Ichamuti river and Ichamuti khal assumed to be protected by the Brahamputra Right Embankment.

Agriculture in CPP Sirajganj depends on the reliability of the BRE to provide protection. The BRE has in some cases failed to provide that protection due largely to embankment breaching, river erosion or structural failure.

The folllowing situations affect the agricultural utilization of this area:
1) a BRE breach occurring at the CPP-BRE boundary;
2) a BRE breach located upstream of CPP Sirajganj and thus affecting CPP Sirajganj by excess floodwater;
3) runoff water from upstream areas not caused by a BRE breach;
4) runoff water caused by heavy rainfall within the compartment; and
5) any combination of the above.

In characterizing the Base-situation, four basic assumptions have been made:

1) The BRE within the CPP Sirajganj boundary is assumed to be sealed and provide protection 4 out of 5 years.

2) The maximum 3-day mean waterlevel occurring with a 5-year return period is used. The evaluation of these levels is based on 25 years of daily water level data at Dhunot (approx. 30 km north of the northern boundary of the CPP-Sirajganj) and the station Nalkasengati which is located at the southwestern boundary of CPP Sirajganj. Conversion of Dhunot water levels to waterlevels associated with those for the northern boundary of CPP Sirajganj has been determined by a calculated gradient between the two stations (FAP 2). The associated probability levels are calculated through an assumed Gumbel distribution. Compartmental and subcompartmental extrapolation were generated through extrapolation of contour gradients.

3) Digitized contourlevels of the 1964 BWDB four inch to a mile topographic map are used. It is assumed that contour levels have not changed substantially. Field verification and aereal photographs have confirmed this assumption.

4) Existing BRE inlet structures are inoperative.

The With-Project situation:

The first three features are also valid for the With-Project situation. However, the existing BRE inlet structures are being replaced in the With-Project situation by three new structures at various locations at the BRE. Furthermore an extensive set of regulators breach mitigation measures and drainage channel improvement is included in the With-Project situation. This set of measures should provide the necessary means for implementation of the compartmentalization concept.

3.2.2 Interaction with modelling

The hydrological model results can be used to calculate the flooded area according to the waterlevels calculated. The conversion takes place through digitized topographical maps (1964 BWDB maps) which are transfered to area-elevation curves for each SC.
An exact allocation of landtypes within the (sub) compartment can be performed in 2 ways: either GIS is used to allocate the land within a sub(compartment) which belong to a certain landtype or the area elevation curves can be used whereby the total acreage under a certain landtype is determined. The area elevation curve can be deternmined by GIS or manually from topographical maps.

Now a days mathematical models are increasingly used as planning tool. The 'with project' is assessed with the help of a hydrological model.

Sirajganj compartment is modelled incorporating the features of all the existing channels and floodplain area. The rainfall-runoff is also included in the model. The model generates time series of water level and discharges along the channel alternatively.

The whole compartment is divided into 9 Sub-compartments. Each of the Sub-compartments is hydraulically linked to the others either by natural channel or by floodplain flow. The model included all these linkages. For each Sub-compartment, area-elevation curves are prepared based 1964 BWDB topographical maps.

For analysis, a water level are selected in such a way that it represents the Sub-compartment correctly. A program has been written to transform this water level into inundation depth (such as F0, F1, F2, F3 and F4) classification by taking the area-elevation of each sub-compartment. The final output is the inundation depth-area decadewise. This table is used in the agricultural analysis.

TABLE 3.2: MAXIMUM 3-DAY MEAN WATER LEVEL (+ M.PWD) PER DECADE FOR VARIOUS RETURN PERIODS, DHUNOT (1964-91)

Year	April			May			June			July			August			September			October			November			December			January			February			March		
1964	10.98	11.00	10.98	12.11	11.98	11.28	12.58	13.87	14.81	15.04	15.27	15.70	16.04	15.58	14.84	14.80	14.96	14.87	14.45	13.52	12.90	12.25	11.52	10.91	10.60	10.43	11.02	10.98	10.96	10.20	10.90	10.92	10.91	10.91	10.88	10.90
1965	10.89	10.89	10.86	10.90	12.00	12.01	13.76	13.80	14.04	14.31	14.43	14.59	14.78	15.67	15.37	14.93	14.80	14.79	13.95	12.52	11.49	11.25	11.18	11.06	11.03	10.99	10.95	10.95	10.91	10.60	10.96	10.96	10.96	10.95	10.94	(1.00)
1967	11.32	11.38	11.39	11.82	11.73	11.48	11.53	11.95	12.22	12.40	13.38	13.35	12.63	12.41	12.26	11.96	12.15	12.67	12.66	12.78	12.25	11.82	11.65	11.54	11.44	11.39	11.35	11.30	11.25	11.21	11.17	11.16	11.14	11.12	11.12	11.10
1968	11.13	11.11	11.09	11.03	11.28	11.34	11.32	12.00	12.66	13.44	13.75	13.74	13.83	13.53	12.90	12.98	12.50	13.08	13.31	13.44	13.35	12.30	12.08	11.99	11.91	11.83	11.69	11.50	11.44	11.41	11.37	11.30	11.25	11.23	11.23	11.26
1969	11.24	11.36	11.36	11.30	11.46	11.85	12.18	12.48	12.72	12.98	13.67	13.89	13.74	13.64	13.88	13.89	13.62	13.62	13.99	13.95	12.73	12.02	11.88	11.79	11.68	11.58	11.51	11.44	11.39	11.37	11.34	11.27	11.23	11.17	11.14	11.10
1970	11.07	11.09	11.09	11.08	11.22	11.25	11.60	11.90	12.98	13.09	13.40	14.38	14.72	14.69	14.27	13.08	12.41	12.71	13.08	12.96	12.32	12.04	11.82	11.75	11.59	11.53	11.45	11.37	11.37	11.34	11.32	11.30	11.22	11.18	11.17	(1.00)
1972	11.30	11.29	11.27	11.28	11.28	11.32	11.42	12.06	12.55	12.43	12.04	13.46	13.89	13.89	12.69	12.83	12.85	12.31	12.26	12.18	11.95	11.79	11.70	11.59	11.52	11.48	11.44	11.42	11.41	11.40	11.15	11.06	11.12	11.13	11.11	10.88
1973	10.88	10.71	11.01	11.20	12.13	12.37	11.94	13.01	14.56	14.76	14.75	13.63	14.25	14.59	14.36	12.82	14.80	15.24	14.97	13.75	13.39	12.23	12.02	11.76	11.65	11.50	11.41	11.35	11.30	11.34	11.31	11.28	11.19	11.12	11.04	11.14
1974	11.19	11.21	11.14	11.33	12.15	12.56	12.21	12.35	13.43	13.84	14.52	14.83	14.80	14.65	14.19	14.13	13.81	13.64	13.67	13.66	13.26	12.59	12.13	11.87	11.78	11.61	11.55	11.50	11.45	11.40	11.37	11.36	11.30	11.25	11.12	10.82
1975	10.64	10.73	10.85	10.70	10.90	11.66	11.71	11.50	11.78	12.27	12.83	13.37	13.37	12.78	12.65	12.51	13.30	13.29	13.18	12.66	12.31	11.87	11.63	11.45	11.33	11.25	11.19	11.15	11.13	11.12	11.11	11.09	11.04	10.98	10.95	10.90
1976	10.79	10.42	10.78	10.91	10.98	11.15	12.00	12.71	12.45	13.27	14.00	14.21	13.95	14.04	14.01	13.83	12.88	12.67	12.66	12.23	11.79	11.52	11.39	11.32	11.23	11.18	11.13	11.12	11.09	11.09	11.08	11.07	11.04	10.99	10.95	10.94
1977	10.93	10.96	10.96	11.23	11.24	11.93	12.83	13.47	14.20	14.03	13.46	14.02	14.09	13.56	13.51	14.30	13.82	13.13	13.41	13.52	12.60	12.04	11.94	11.81	11.57	11.49	11.41	11.29	11.25	11.18	11.13	11.05	10.98	10.96	10.91	10.89
1978	10.87	10.95	11.00	11.23	11.32	11.92	13.06	13.29	13.49	13.37	12.96	13.44	13.59	13.40	12.57	12.19	13.09	13.11	12.68	12.12	11.76	11.52	11.47	11.43	11.35	11.30	11.28	11.22	11.23	11.21	11.15	11.07	11.03	10.99	10.92	10.89
1979	10.78	10.93	10.91	10.85	10.81	10.85	10.92	11.08	11.11	11.08	12.08	13.46	13.49	12.88	13.55	3.81	13.95	13.91	13.36	13.37	12.65	12.01	11.75	11.57	11.62	11.56	11.50	11.47	11.44	11.36	11.13	11.09	11.05	10.94	10.88	10.86
1980	10.78	10.69	10.71	11.36	12.33	12.25	12.78	12.38	12.47	12.01	13.18	13.53	13.17	13.41	13.90	13.76	13.06	13.32	13.30	13.15	13.48	12.47	11.93	11.75	11.63	11.51	11.45	11.39	11.43	11.40	11.34	11.29	11.05	10.99	10.90	10.88
1981	10.94	11.45	11.40	11.41	12.24	12.81	13.17	12.50	11.86	13.18	13.42	13.99	14.03	13.91	13.78	14.02	14.00	13.92	13.21	12.48	12.07	11.85	11.70	11.58	11.50	11.50	11.45	11.39	11.32	11.25	11.20	11.15	11.08	11.00	11.01	10.98
1982	10.88	10.81	10.79	10.76	10.85	10.88	11.28	12.54	12.69	12.84	13.31	13.48	13.53	13.52	12.79	12.69	13.14	13.29	13.10	12.25	11.94	11.89	11.64	11.56	11.43	11.33	11.27	11.28	11.27	11.23	11.17	11.12	11.03	10.91	10.83	10.76
1983	10.65	10.56	10.82	10.92	11.20	11.90	11.71	11.61	12.01	12.58	12.74	12.98	13.55	13.34	13.11	13.12	13.56	13.79	14.19	14.40	14.18	13.11	12.21	11.90	11.73	11.64	11.74	11.53	11.47	11.42	11.33	11.27	11.21	11.15	11.03	10.98
1984	10.93	10.91	10.77	11.06	11.92	12.66	13.58	14.25	14.47	14.56	15.60	15.84	15.82	15.06	13.73	14.68	16.28	16.26	14.96	13.90	12.85	12.18	11.90	11.63	11.51	11.44	11.38	11.33	11.30	11.27	11.22	11.16	11.12	11.09	11.02	10.95
1985	10.93	10.76	10.79	10.79	11.29	12.06	12.26	12.20	12.03	12.76	13.27	14.07	14.31	14.23	13.17	13.30	13.58	13.46	13.23	12.72	12.99	12.52	11.77	11.56	11.44	11.38	11.31	11.26	11.23	11.20	11.09	11.03	10.91	10.86	10.81	10.74
1986	10.77	10.70	10.79	10.85	11.29	11.55	11.31	11.23	12.34	13.47	13.49	13.01	13.35	13.34	12.72	13.03	13.49	14.45	14.73	14.59	14.26	12.89	12.23	11.94	11.81	11.73	11.65	11.51	11.46	11.42	11.38	11.28	11.19	11.12	11.13	11.13
1987	11.05	10.97	11.34	11.42	11.37	11.33	11.29	11.53	12.53	13.82	14.10	15.50	15.94	15.80	15.59	14.78	14.86	14.25	14.61	13.73	13.10	12.56	12.00	11.85	11.65	11.56	11.48	11.43	11.42	11.37	11.25	11.17	11.14	11.10	11.02	11.02
1988	10.91	10.85	10.93	10.99	11.03	12.03	12.31	13.38	14.10	14.27	14.50	14.34	13.69	13.87	16.87	16.85	15.85	14.71	13.82	13.69	11.88	11.70	11.55	11.60	11.64	11.45	11.41	11.37	11.35	11.33	11.28	11.22	11.16	11.15	11.13	11.11
1989	11.09	11.06	11.01	10.96	10.91	12.71	12.81	12.87	12.97	13.79	14.18	14.18	13.99	12.84	12.41	13.08	13.43	13.38	13.50	13.35	12.20	11.79	11.64	11.54	11.44	11.37	11.31	11.29	11.26	11.21	11.12	11.13	11.12	11.07	11.03	11.02
1990	11.03	11.02	11.02	11.03	11.36	12.14	12.92	13.66	14.36	14.06	14.86	15.24	15.19	14.72	14.70	14.70	14.39	15.04	15.31	15.32	14.61	12.97	12.22	12.00	11.84	11.72	11.64	11.58	11.55	11.51	11.43	11.31	11.26	11.21	11.13	11.09
1991	11.00	10.94	10.97	10.98	11.69	13.05	13.03	14.00	14.64	14.92	15.83	15.42	15.10	15.26	15.20	15.19	15.32	15.27	14.86	13.52	12.87	12.15	11.92	11.77	11.66	11.57	11.64	11.72	11.70	11.52	11.29	11.30	11.28	11.25	11.20	11.13
Num	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	24
Return Period																																				
2	10.93	10.92	10.97	11.08	11.38	11.76	12.08	12.46	12.89	13.28	13.66	13.99	14.04	13.87	13.61	13.56	13.67	13.69	13.57	13.17	12.60	12.06	11.77	11.61	11.50	11.42	11.38	11.33	11.30	11.27	11.20	11.15	11.10	11.05	11.01	10.96
5	11.11	11.18	11.14	11.34	11.80	12.36	12.83	13.34	13.90	14.39	14.65	14.71	14.84	14.77	14.60	14.57	14.63	14.57	14.37	13.93	13.33	12.51	12.07	11.96	11.91	11.86	11.62	11.54	11.51	11.46	11.36	11.28	11.22	11.17	11.13	11.09
10	11.23	11.36	11.26	11.51	12.07	12.75	13.33	13.93	14.58	15.13	15.30	15.19	15.37	15.36	15.25	15.24	15.27	15.16	14.90	14.44	13.81	12.81	12.27	12.19	12.18	12.15	11.77	11.68	11.65	11.58	11.47	11.37	11.30	11.25	11.21	11.18
20	11.34	11.53	11.38	11.68	12.34	13.13	13.80	14.49	15.22	15.84	15.92	15.64	15.88	15.93	15.87	15.88	15.88	15.72	15.40	14.92	14.28	13.09	12.47	12.41	12.44	12.42	11.92	11.81	11.78	11.70	11.57	11.45	11.38	11.32	11.28	11.26
25	11.38	11.58	11.41	11.73	12.42	13.25	13.95	14.67	15.42	16.06	16.12	15.79	16.04	16.11	16.07	16.08	16.08	15.89	15.56	15.07	14.42	13.18	12.53	12.48	12.52	12.51	11.97	11.85	11.82	11.74	11.60	11.48	11.40	11.34	11.31	11.29

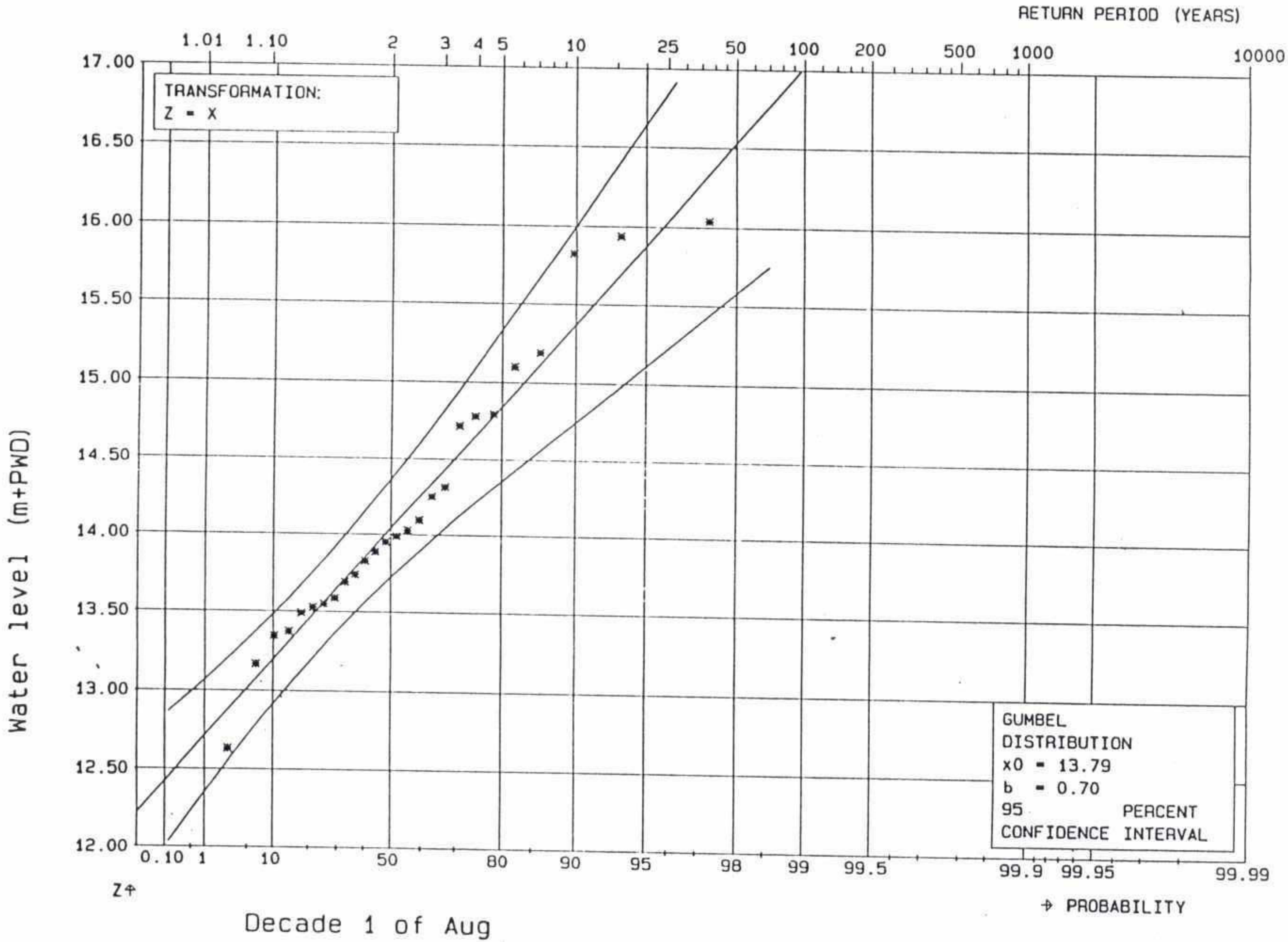


Figure 3.6 : Probability - Water Level (+M PWD) relationship for the first decade of August, based on Dhunot (1964-1991)

3.2.3 Interpretation of land type classification

According to MPO the following classification of land types is used;

Table 3.3: Land type classification

LAND TYPE	FLOODING DEPTH (METER)
F_0	0-0.3
F_1	0.3-0.9
F_2	0.9-1.8
F_3	> 1.8

In order to generate the F_o-F_3 land types calculated for CPP Sirajganj, the area-elevation curves calculated per subcompartment and the 5 year-return period waterlevel for the maximum 3-day mean waterlevel per decade are used.

3.2.4 Watermanagement Guideline

Agriculture poses a number of constraints to the watermanagement system. Its particular demands are highly flexible in time and space.

Structural and non-structural interventions within the project concept should lead to a flexible water management for agriculture. Flood protection and breach mitigation measures will ultimately lead to considerable prevention of crop damage. This security of the crop environment can be utilized to develop an effective water management system utilizing the compartment and sub-compartments.

The aim is to develop field block (or chawk) level water management. Individual sub-compartments are composed of several field blocks or chawks bounded by village roads or settlement areas. These chawks are physical entities and easily recognised by village people. Each field block has water inlets or outlets through bridges, culverts, roads breaches etc. By sealing road breaches, placing minor structures, pipe culverts, water retention devices, an effective water management at the field level will be established. Three important components of water management for agriculture are:

- **Drainage Improvement**: The actual impedance of drainage water in pre-monsoon and post-monsoon within the context of the existing infrastructure is a main constraint in further developing the area with an improved water resources control which should lead to increased agricultural production. Re-excavation of existing khals is proposed.

- **Water Retention:** Water retention to the physical withholding of water on the field or in a depression (or beel) in order to evenly distribute water specially rain water on different levels of land contours. This can be realized either by the construction of bunds or by the construction of water retention structures located in a depression, khal or existing beel.

- **Irrigation**: Dry season irrigation is an important component in water management. In *Sirajganj* area, irrigation is developed using the underground water. Use of surface water in dry season irrigation is very limited in areas near mainly to Ichamati khal. With re-excavation of khals and water retention measures, water can be stored and managed for dry season irrigation. Possibilities of irrigation inlet construction is phased later when surface water is available through the construction works of initial phases.

Four distinct agro-hydrological periods; pre-monsoon, monsoon, post-monsoon and the dry season with different management needs are considered.

Pre-monsoon (March to June)

During this period the Boro is harvested. It is cultivated from lowland upto high land areas. This crop may be damaged by water logging caused by execessive early rainfall or an early high stage of the river.

Damage can be reduced by providing an effective drainage system. Furthermore, water retention can be established by construction of bunds on higher lands. An early high stage of the river can possibly be semi-controlled by installing and operating the peripheral/ internal structures.

Monsoon (July to September)

One of the aims of the project is to increase the area planted to monsoon rice including T.Aman (HYV). Due to the risk of high waterlevels from mid-July onwards, the present situation restricts the cultivation of extensive HYV Aman. In order to improve this situation, the waterlevels within the compartment should be lowered. The highest water level occurs during July. August will determine the potential area planted to T. Aman.

In order to get lower waterlevels during monsoon within the compartment, the following elements will be considered:

- peripheral control
- control intake of water in the compartment through the Ichamati branch
- control between the Ichamati river and the sub-compartments (controlled flooding and drainage)
- control between the sub-compartments (controlled flooding and drainage)
- water retention on the higher grounds especially highland and medium high land.

"Control" may assume various levels, including "semi-control" by ungated structures.

Post-monsoon (October)

During this period the lower land should be drained as early as possible in order to permit the cultivation of oil-seeds or other rabi from November onwards. The required water management element is the drainage of the low lying areas (not the permanent beels). This can be established by improving the existing drainage system.

Dry-season (November to February)

The dominant activity during this period is the irrigation of the Boro crop by means of shallow and deep tube wells. Early drainage will enable timely sowing of Boro and a slight increase in the potential area. The actual recharge of the groundwater, in the *Sirajganj* compartment area, does not affect the availability of groundwater during the dry season in the future (Annex 6).

3.3 Fisheries

3.3.1 General

The basic principle of the Mike 11 model results also applies to the fisheries component of CPP Sirajganj.

With the mathematical model, developed especially for the CPP-area, the hydrological environment for the different scenario's is simulated, resulting in the total area of beels and inundated floodplain for each decade during the period of 1st May up to 31st of November. Outside this period the floodplain/beel area is gradually reduced to an assumed minimum dry season area.

A fisheries spreadsheet model was developed. This model was calibrated with the hydrological data of the present situation (with breaches of the BRE) and the floodplain/khal fisheries production, beel fisheries production and beel fishing intensity obtained through the fisheries household survey. Within this model it is assumed that the total production from the floodplain and the khals is caught during the period of June 20 to November 10, the period when floodplain/beels are connected with the river system and the total beel production is caught in the remaining period and area. The effect of reduced inundated floodplain area is calculated by multiplying the simulated inundated area with the estimated floodplain production of 1.535 kg/ha/decade. It is assumed that there is a linear relation ship between "beel" fish production and the available reproduction area (which is a minimum concept). The effect of the reduced reproduction area for "Beel" fish is brought into the spreadsheet by taking the Beel area of the 10st of june, in the 1991 situation as a standard. A reduction of this area under the different scenario's leads to a proportional reduction in fish.

In order to facilitate an economic analyses of the different scenario's, the total fish production is sub-divided species wide. The species distribution for the different habitats is obtained from the Sirajganj district fisheries statistics of the year 1988/1989.

3.3.2 Watermanagement guideline

The eternal controversy between agricultural and fisheries requirements will also here be very much present. The dynamic waterrequirements both in place and time in the CPP Sirajganj do urge for a compromise between these two "opponents".

In general, it can be stated that the overall guideline should be such that floodwater which enters the compartment through the BRE inlet sluices should be allowed free surface flow. It is important to allow the fish fry to enter the compartment area uninterruptedly as much as possible. However, one should also be aware that if the riverside waterlevel and landside waterlevel differ too much, regardless of the date that occurs, one should regulate the inflow in order to avoid damage to agricultural and infrastructural resources. In case regulating is necessary, non-submergence conditons should prevail. Overshot flow conditions would be the best way in order to protect the fish fry from being damaged. After sufficient fish fry has entered the area, the regulators may be closed.

However, requirements and constraints from agriculture and infrastructure should also be taken into account. In case the waterlevels never reach the expected levels, the inlet structures may be left open all the time.

4 SIRAJGANJ COMPARTMENT

4.1 Description

The Sirajganj compartment forms part of the Middle Bengali Planning Unit as defined by FAP2 (Figure 4.1).

Topography:

The general slope from CPP Sirajganj is from north-east towards south-west. The average land elevation varies from 11.5 to 13.1 m. PWD and is classified as medium to highland (FAP 2). It is observed that almost no land belongs to F2-F4, so the problem of deep and prolonged flooding is not existing in the area.

Hydrology:

In this region, Karatoya-Bangali is the principal river. The Ichamati river drains rainfall-runoff of eastern Bogra and acts as an overspill of the Lower Karatoya into the Bangali river. The Ichamati khal and branch (See base map in back of this report) originate from BRE flowing south-west and merges with the Ichamati river. Another important river in the CPP-project area is the Baniajan river which originates from the BRE and ultimately meets with the Ichamati river near Bhadraghat.

The Sirajganj compartment falls under moderate rainfall zone (annual rainfall approx. 1700mm). Table 4.1 shows the mean monthly figures for the area while table 4.2 the maximum 10-day rainfall figures.

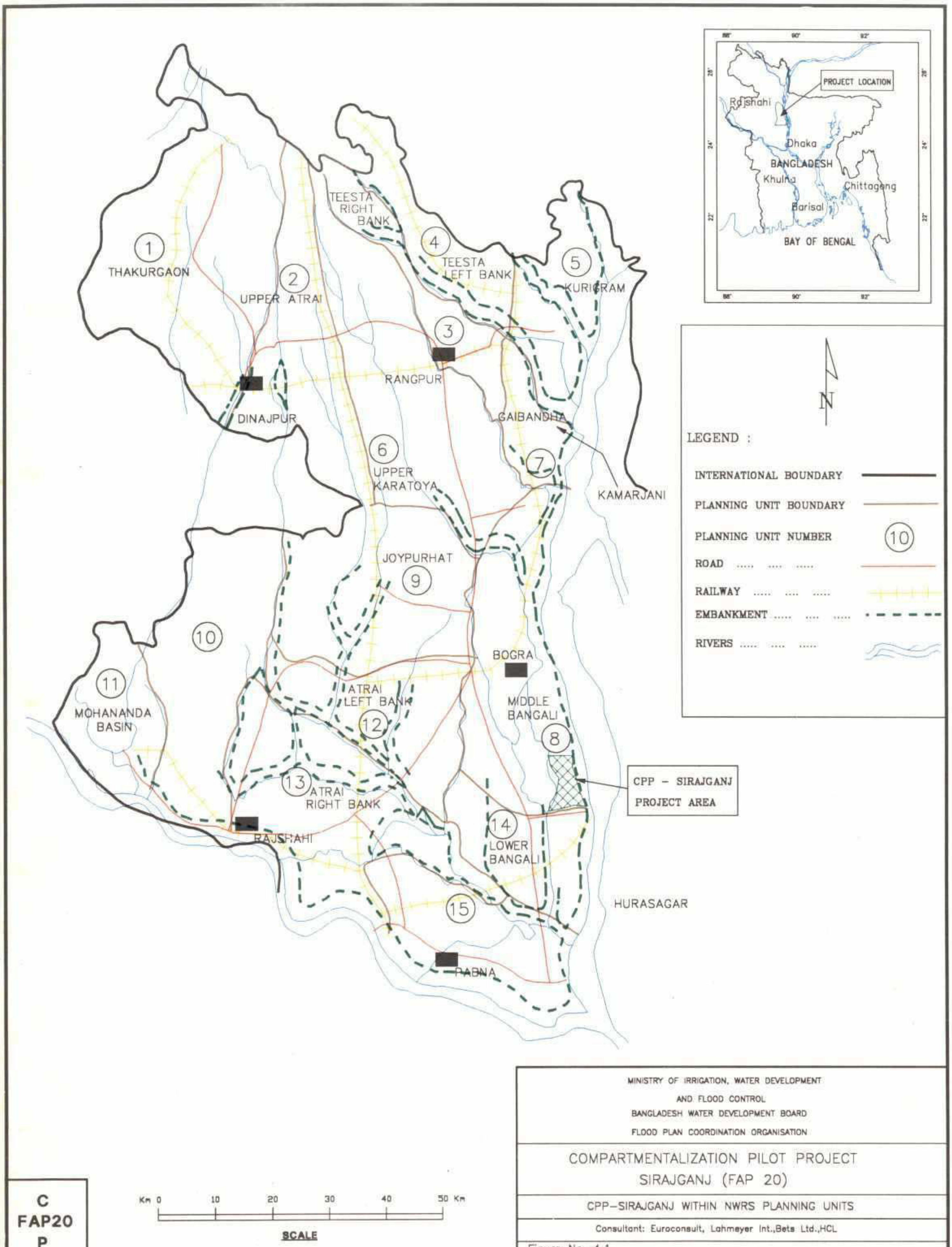
Table 4.1: Mean Monthly and Annual Rainfall (mm)*

Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
86	208	318	319	318	246	142	16	2	12	17	35	1719

Table 4.2: 10-Day rainfall (mm) totals for distinct return periods*

STATION	RETURN PERIOD (YEARS)				
	5	10	20	50	100
Sirajganj	325	386	445	522	579

* based on Sirajganj rainfall station (1965-1992) interpretation



MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
FLOOD PLAN COORDINATION ORGANISATION

COMPARTMENTALIZATION PILOT PROJECT SIRAJGANJ (FAP 20)

CPP-SIRAJGANJ WITHIN NWRS PLANNING UNITS

Consultant: Euroconsult, Lahmeyer Int.,Bets Ltd.,HCL

Figure No. 4.1

C FAP20 P

Agriculture

In general, the agricultural system in CPP Sirajganj is geared towards the incorporation of minimizing risk regarding BRE breaches. Areas closer to the BRE, which are likely to suffer directly from breaches are often planted with sugarcane. Sugarcane does not need irrigation, tolerates flooding and is suitable to be planted in sandy soils. Further away from the direct-impact area, rice and wheat are the dominant crops while vegetables are also planted on the higher elevations where there is sufficient moisture.

Irrigated agriculture forms a major activity in CPP Sirajganj. The use of groundwater sources for irrigation purposes is very likely to increase in the future [ref 3].
The use of STW will increase in quantity considerably as long as the groundwater recharge in the area will be sufficient. However, it is indicated that a lowering of the seasonal water table beyond the suction lift of domestic pumps has been associated with both FCD and groundwater irrigation. It has been mentioned that in the Sirajganj district, the growth in STW has been increased 138% over the years [ref 1].

Fisheries

From the fisheries point of view, the current situation can be regarded as a partial reversal of the situation back to the pre-BRE construction times. These times were for the floodplain fisheries a prosperous time due to the influx from Jamuna water during the (pre-) monsoon season in which the fish fry is abundantly present. After the construction of the BRE, the floodplain area was sufficiently protected from the Jamuna river and consequently the influx of Jamuna river water and fish fry was limited.

In the beginning of 1980's, the access of Jamuna water to the floodplain area was improved from an almost inaccessible floodplain area to a partially accessible area.
The direct access of Jamuna river water to the floodplain is limited to the BRE inlets and occasional BRE breaches (either directly within CPP Sirajganj or in area north of CPP Sirajganj). The BRE inlets are at present not functioning properly (Section 4.6.4) due to a combination of sedimentation, faulty design of the structures, placement of retired embankments and sometimes operational problems.

4.2 Infrastructure

CPP Sirajganj is bounded on the east by the BRE; its length is about 13km from Sirajganj town to Kazipur. It is an earthen embankment, the width of which is about 20 ft. and side slope are 1:3 (both sides). This BRE is provided with five small regulators to allow river water to pass through the embankment for irrigation of monsoon season crops when required. In practice, these regulators seem to be little used as the existing BRE inlet structures are not functioning properly and tubewell irrigation are now widely spread over the area. The main purpose of BRE is to prevent river water from spilling over the area during high river stage. But in recent years due to bank erosion several sections of the BRE have needed to be retired and several breaches have also occured causing serious flood accompanied by sand deposition on neighbouring land.

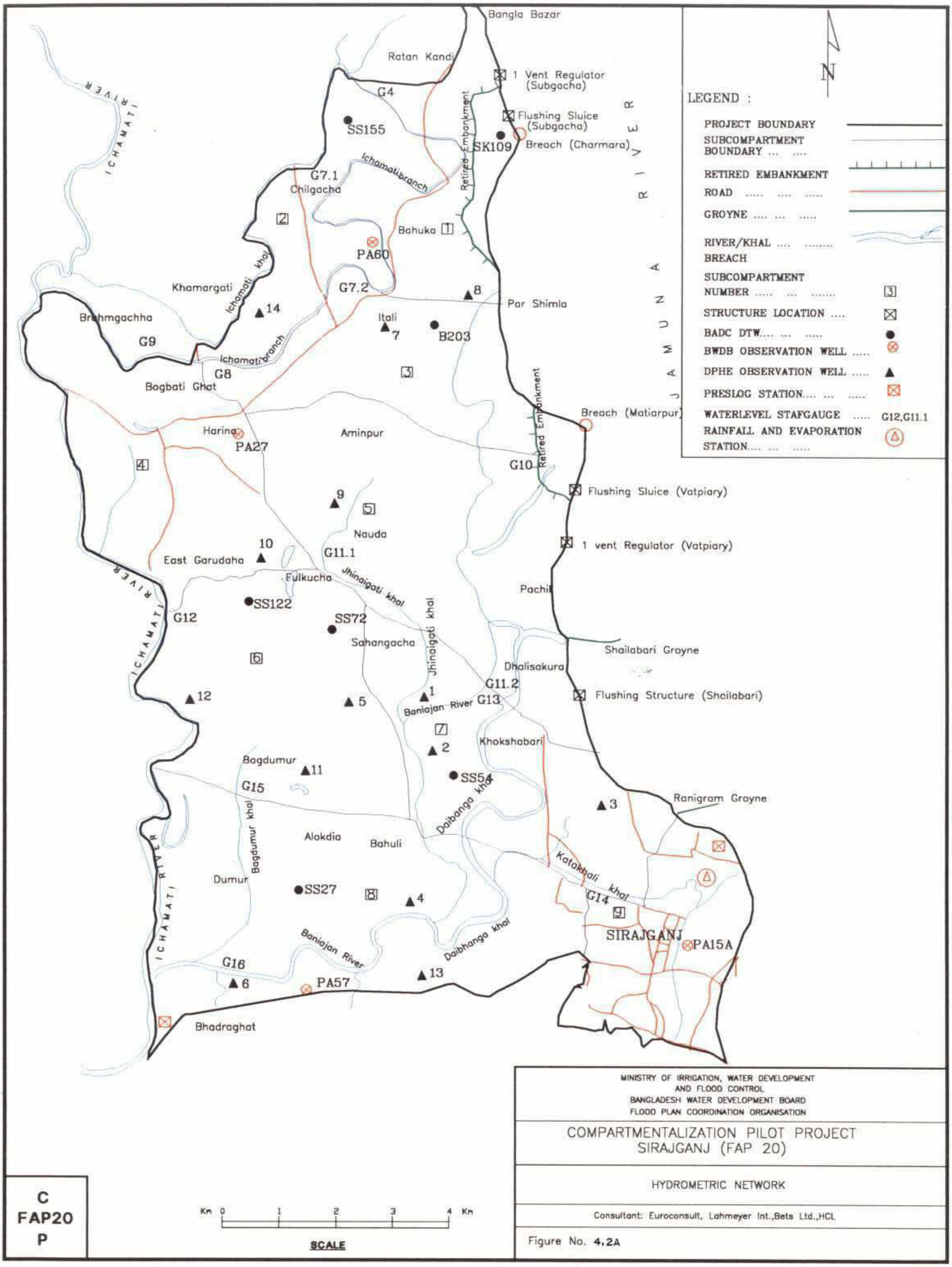


Figure No. 4.2A

84

On the southern side, CPP Sirajganj (Figure) is bounded by metal road from Sirajganj to Bogra; the Sirajganj-Kazipur road splits the project area into two halves. In addition to the above, there are number of both dry season motorable and non-motorable earthen village roads and paths inside the project area. Normal flooding does not interfere with road transport and adequate number of bridges/culverts of different span are provided in it to prevent drainage congestion.

There are number of khals/rivers within the project area which are used for internal drainage of which the Baniajan river, Daibhanga khal, Katakhali khal, Ichamati branch are important. The Banijan river Daibhanga khal and Katakhali khal originate from the Jamuna river presently BRE close the intake of there khals flow in zig-zag way inside the project area and ultimately fall into the Ichamati river which runs along the western boundary of the project. The Ichamati branch originates from the Karatoya river flows in zig-zag way within the project area and ultimately falls into the Ichamati river. In addition to this there are other minor khals such Bagdumur khal, Khangati khal, Sundar beel khal which carry the drainage water of the project into the river. All the above khals/river are now silted up which are needed to be re-excavated for drainage improvement.

4.3 Groundwater

The presence of FCD project has definitely an impact on the groundwater availability. The implications of existing FCD and development on minor irrigation has been studied by FAP 2. The study concluded that the aquifer system has the capability to support large scale groundwater extraction. The current recharge takes place from deep percolation of rain, floodwater and irrigation return flow. Current recharge seems to be sufficient to cover current and future demands in the Sirajganj district.

However, the results of the Needs Assessment Survey has indicated that in some parts of the CPP-Sirajganj area groundwater availability seems to be decreasing, expecially for the dry season crops. However, significant trends or decrease of availbility cannot be proven due to the short-term availability of groundwater monitoring programs, performed by the agencies involved.

The groundwater assessment is essential to assess the impact of controlled flooding and drainage and also to evaluate the historical development and to forecast future developemnt with and without compartmentalization.

The project area aquifer system has the three main division (MPO):

- an upper layer, composed of silts and clays, which acts as a semiu-confining layer. The thickness of this layer is variable but doesnot commonly exceed 10m in the area.

- a composite aquifer which is composed of very fine sands, and which overlies the main aquifer.

- a main aquifer which is composed of medium to coarse sands and which has excellant water transmitting properties.

Recharge to the aquifer is predominantly derived from deep percolation of rain and flood water. Lateral contribution from rivers comprise only a small percentage (0.04%, MPO) of total potential recharge.

Over the years, the development of minor irrigation is quite rapid. The data clearly indicate that the increase in minor irrigation development relates mainly to the rapid increase in the number of STW since 1986 (79% increase).

Data availability

There are four BWDB and seven BADC groundwater stations are located within the boundaries of CPP Sirajganj collected for analysis (Figure 4.2A). The period collected for analysis is 1982-1991.

Figure 4.2B and Figure 4.2C show the groundwater monitoring from wells which are located near the southern boundary (PA-57), approx. 6 km from Sirajganj town and the second one near the breach-prone area at 3 km from BRE (PA-60). Trend analysis does not give conclusive and significant results regarding a stablizing increasing or decreasing waterlevel.

The average variation for all wells in the area is found between 4 to 6 m. In 1992, some of the wells the groundwater level dropped upto 8 m below the ground surface. A study is proposed to assess the 'with project' situation.

4.5 The River System and its flooding regime

The Middle Bangali Planning Unit is comprised by the Brahmaputra on the east side and the Ganges on the south side (Figure 4.1). These two rivers play a dominant role in constraining the drainage from the area bounded by these two rivers. The rivers n this part of Bangladesh have very flat gradients of 1: 5000 or less. The rivers are in general therefore meandering and thus have very limited capacity for passing flood discharges. It should also be mentioned that flood levels in the Jamuna are often equal to or higher than internal river levels for long periods during the monsoon (FAP 2, vol 1).

The Jamuna forms part of a regional network which is a highly complex floodplain system. The hydrological regime of the floodplain is highly variable, dynamic and unstable.
Floods can be classified (FAP2, vol.1) as:

"areas normally flooded by major river spills"; and

"areas normally flooded by minor rivers".

the former naturally lie along the main river embankments and the latter cover most of the rest of the region.

Figure 4.2B : Water depth below groundlevel (PA 57)

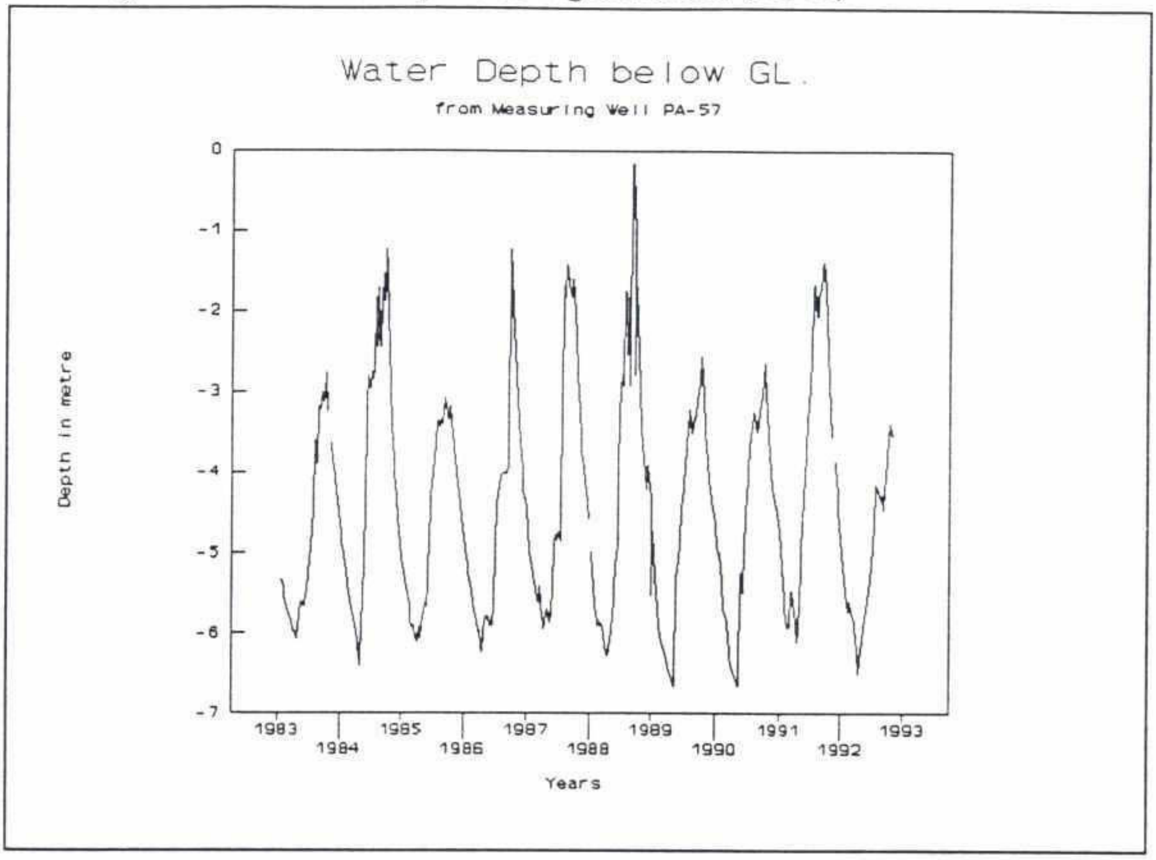
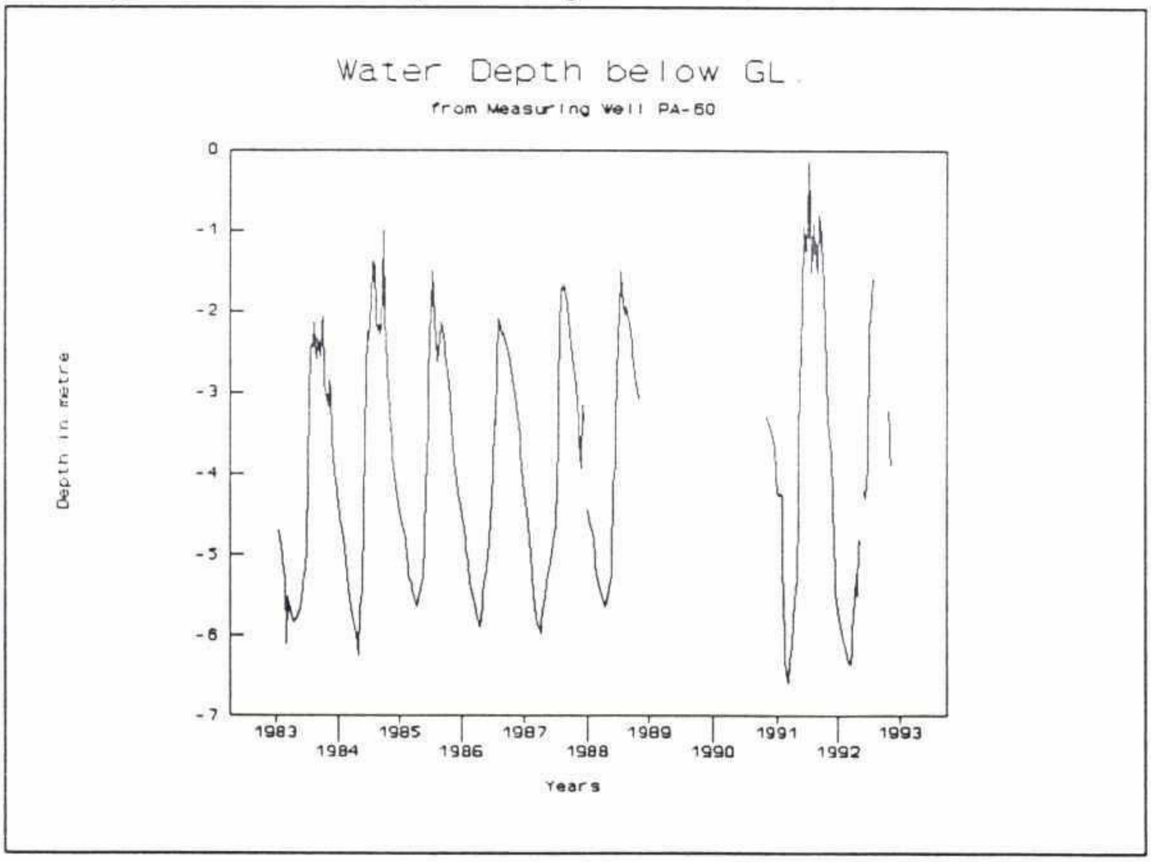


Figure 4.2C : Water depth below groundlevel (PA 60)



The first type of flooding is due to breaches in the embankments of the major rivers. Flood damage is only partially related to the severity of the flood event because accidental or intentional breaches can occur with "normal" as well as extreme floods.

The second type of flooding is due to outfall constraints, primarily in the lower stretches of the Jamuna river near Hurasagar. This then results in flooding in the Middle Bangali Planning Unit which causes backing up of water levels in the river system. The severity of flooding is apparently also related to local rainfall conditions within the region because the total flow volume from the internal rivers must be stored until the levels in the Jamuna permit natural drainage. The severity of the flooding is therefore directly linked to the severity (i.e. return period) of the conditions both in the main rivers and in the region itself.

4.6 The Brahmaputra Right Embankment

4.6.1 General Situation

The BRE is one of the first FCD projects in Bangladesh. The *Brahmaputra* originates from the northern slopes of the Himalayas in Tibet; its actual catchment area in Bangladesh is limited to only 5% of the total catchment area of 520,000 sq.km.

The BRE has been originally built at a length of approx. 200km from *Hurasagar* to *Kamarjani* (Figure 4.1) between 1957 and 1968. Its main purpose is to limit the extensive flooding by the *Brahmaputra* on its right bank and protect an area of approx. 240,000 ha. The design return period of the BRE was determined at 1:100 years at the time of the design process in the beginning of 1960's. Initially this approach was succesful, but more recently constant erosion of the banks of the river resulted in frequent breaches/retirements.

The annual hydrograph is characterized by low flows during the dry season associated with the winter months and high flows during the summer due to snowmelt in the Himalayas and heavy rainfall in the Assam valley and Bangladesh itself. In most years, the *Brahmaputra* peaks in late July or early August and some overbank flooding occurs at that time.

The progressive retirement of the BRE demonstrates the severity of the natural bank erosion of the *Brahmaputra* river [FAP2, vol2]. From 1975 onwards, major rehabilitation was carried out. The River Training Studies of the *Brahmaputra* River indicates that:

> *" .. It appears that the present westward movement of the right bank (of the Brahmaputra) will continue for several decades, probably at a similar rate to that experienced over the last 35 years; at the same time, the river is becoming steadily wider."*

It is clearly shown [FAP2,vol 2] that the most serious flooding problems occur along the *Brahmaputra* due to breaches in the BRE. That same source mentions that most flooding problems in the BRE affected area can be efficiently eliminated if the BRE can be properly sealed.

Along the entire BRE, the *Kazipur* reach is one of the most unstable sections (FAP 12). The *Kazipur* reach is a section of the BRE from which the southern boundary overlaps with the CPP *Sirajganj* project area. It is reported that there are frequent breaches and embankment retirements in this section and because the land slopes away from the embankment, the breaches cause severe damage. Most frequently, the number of retirements to date ranges from one to three. The *Kazipur* reach and the boundary with the *CPP-Sirajganj* project area is located on the map.

The present situation is depicted in Figure 4.3 which is an image taken in the dry season of 1993. Superimposed on this map are the CPP Sirajganj boundaries which on the eastern side coincide with the BRE alignment. On the south-eastern side of CPP Sirajganj, clear accretion has taken place over the years since the construction of the BRE beginning 1960's.

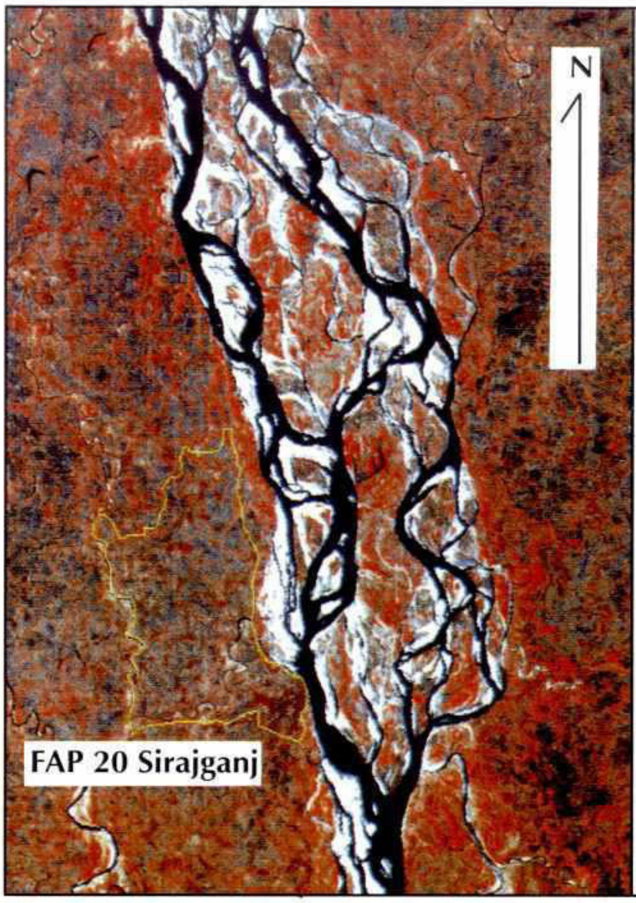
In case a major breach occurs, the CPP project area will be impacted by either floodwater from the area around *Kazipur* or directly from a breach in the CPP BRE boundary area. It is mentioned [FAP 12] that:

> *"...the embankment section in the Kazipur reach is very poorly maintained and supervised. Due to lack of proper maintenance severe damage occurs to the embankment which jeopardises the stability of the embankment and security of crops, lives and property in the project area (Kazipur reach)".*

One of the most severe floods in Bangladesh occurred in August 1987. A comparison between the dry season image of Februry 7, 1987 (Figure 4.4 A) and the image taken during the flood on August 18, 1987 (Figure 4.4 B) clearly depicts the severity of flooding and the impact of this few kilometer long BRE breach on the CPP Sirajganj area.

This behaviour of the Jamuna river is part of a systematic gradual morphological change which is taking place. An indication of longterm predictions on the Jamuna river and its flow pattern can be demonstrated by images. The incidence of low flows from the Jamuna river for the dry season (Figure 4.4 C) shows that most preference (within the stipulated period) is given to that course which is actually located next to CPP Sirajganj area and approaching in particular Sirajganj town in the far south-eastern corner. The images taken in 1973 and 1992 (Figure 4.4 D) clearly show those areas which have suffered from land erosion and land accretion over this 20 year time period. The land erosion takes place especially in the north-eastern side of CPP Sirajganj which required a number of retired embankments since the 1980's. Land accretion has also taken place but in the south-eastern side of CPP Sirajganj.

Figure 4.3 : Present Situation of Jamuna River and Sirajganj CPP area.

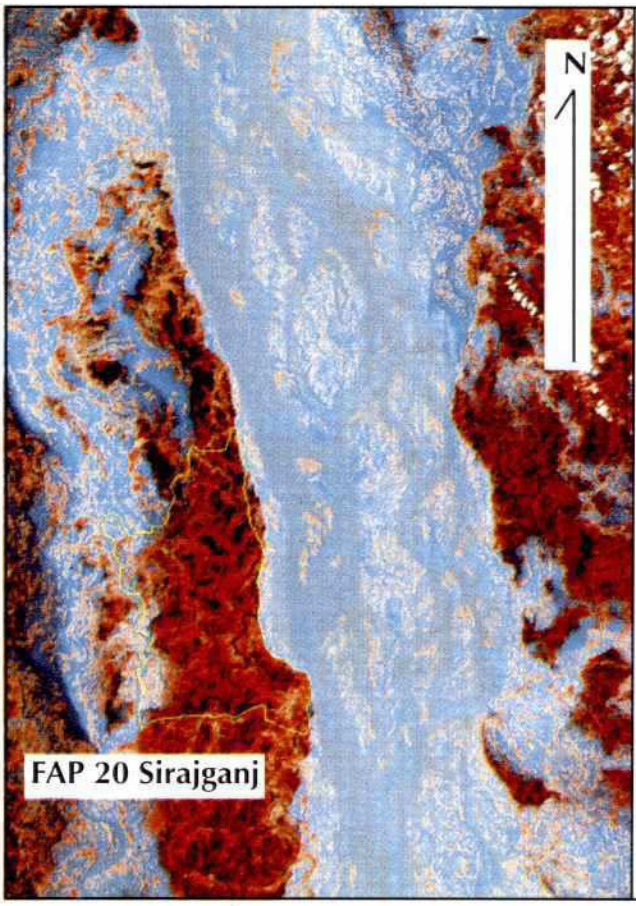


Jamuna River, Sirajganj CPP Area
Febr. 1987 dry season.

0 5 10 15 km
SCALE

Figure 4.4A

Source : Landsat MSS processing by ISPAN/FAP 19

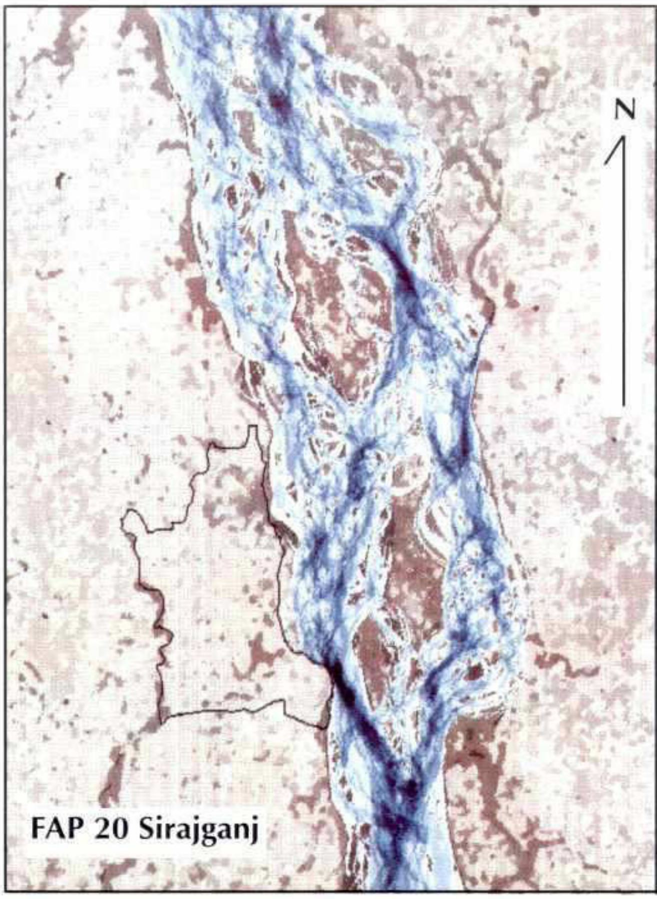


Jamuna River, Sirajganj CPP Area
Aug. 1987 Flood Extent.

0 5 10 15 km
SCALE

Figure 4.4B

Source : Landsat MSS processing by ISPAN/FAP 19



Jamuna River, Sirajganj CPP Area
Incidence of Low Flow Channel over Selected Periods, 1973-1992.

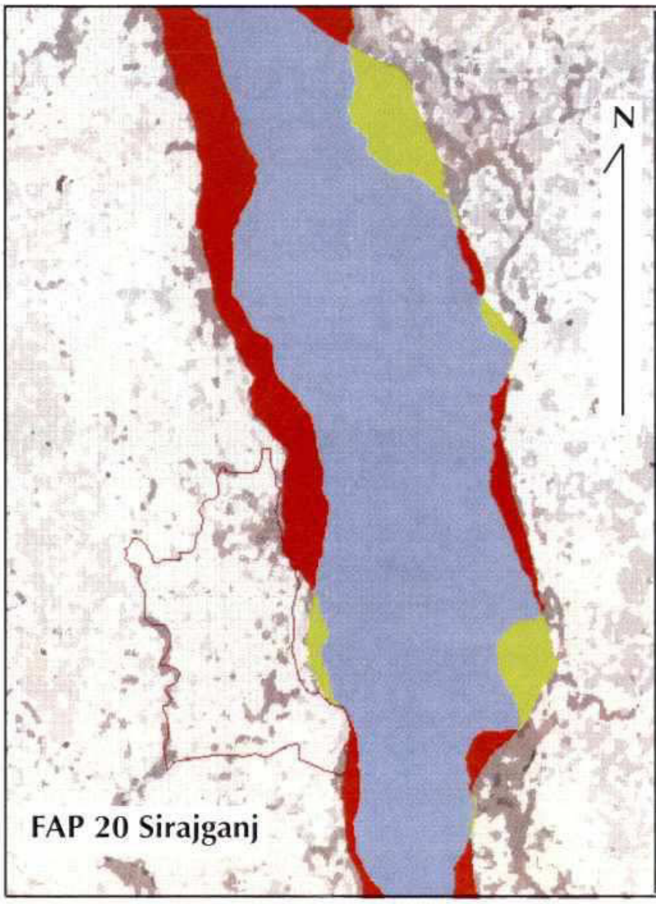
LEGEND
NUMBER OF DATES CLASSIFIED AS CHANNEL

- 1 Date
- 2 Dates
- 3 Dates
- 4 Dates
- 5 Dates
- 6 Dates
- 7 Dates
- 8 Dates

0 5 10 15 km
SCALE

Figure 4.4C

Source : Landsat MSS processing by ISPAN/FAP 19



Jamuna River, Sirajganj CPP Area
River Bankline Net Change Over Period 1973-1992

LEGEND

NUMBER OF DATES CLASSIFIED AS CHANNEL

- 1 No Change
- 2 Accretion
- 3 Erosion

0 5 10 15 km
SCALE

Figure 4.4D

Source : Landsat MSS processing by ISPAN/FAP 19

Furthermore, actual implementation of planned retired embankment often faces problems which are delaying timely implementation of these embankments. This partially causes also unauthorized settlement of the affected people on the newly constructed embankment which in turn results in poor quality.

It has proved difficult [FAP 12] to build up a reliable history of breaches. Relevant information regarding breaches and its impact on the affected area is not readily available from the BWDB. It is assumed that the first retirements took place in the vicinity of *Kazipur* around 1975, only approx 10 years after the original construction. The problem became more significant in the early 1980's. It is clear that the problem is becoming more serious over the past 5 years as progressively more of the BRE becomes within range of aggressive bend erosion.

For the *Kazipur* reach, embankment breaches since 1984 have caused serious flooding in 3 out of 5 years. It is reported that breaches occurred in the project area in 1990 and in 1991.

For the *Sirajganj* CPP area, several breaches have occurred at several locations along the BRE (Figure 4.5). The damage assesssed for the floods from 1987-1991 is in Table 4.3.

Table 4.3: Flood damage assessment for CPP Sirajganj, 1987-1991

ITEMS	Value of Damage (in ml.Tk)			
	1987	1988	1990	1991
Crops	63.07	68.44	15.82	13.24
Livestock and Poultry	0.17	0.44	.02	.00
Private rural houses	2.74	18.13	2.46	3.55
Infrastructures	49.09	195.62	24.53	9.40
Total Damage	115.07	282.63	42.83	26.19

Source : Computation based on Sirajganj Thana Project Implementation Office

Number of retired embankments, especially since beginning 1990's have been indicated. This area in the north east of CPP Sirajganj seems to be especially vulnerable to Jamuna river erosion.

4.6.2 Analysis of BRE breach occurrence

The stochastic nature of major flooding and BRE breach occurrence challenges the viability of the CPP-project approach. The analysis will very much depend on the interpretation of the stochastic behaviour of this flood occurrence and its impact on the area.

Flooding may be caused by :

1) a local BRE breach on the boundaries of CPP Sirajganj;
2) a BRE breach in the upstream part of CPP Sirajganj;
3) major runoff from the area which drains into CPP Sirajganj;
4) hewavy local rainfall; and
5) any combination of the above four.

The dilemma at the moment is if and how far the BRE and its required maintenance is to be incorporated in the analysis. The BWDB (O&M) is responsible for the proper functioning.

Main considerations in this analysis are:

1) Frequency analysis of the annual maximum waterlevel is NOT the only yardstick to indicate flood probabilities and its impact on the area. The difference between a 1:20 years and 1:50 years flood is less than 30 cm (FAP 25).

2) A second factor involved here is that in the analysis of annual peak water levels there is no indication of in which direction the Jamuna streams near the area under consideration. The presence of charlands can dramatically adjust the direction of riverflow. In other words, it is possible that with a low waterlevel the water pressure will be built up together with the prevailing wind direction during storm and resulting wave action may all contribute to a "locally" increased waterlevel.

3) The third factor which is a considerable factor of importance but difficult to quantify is the quality of the BRE embankment. A 1:100 year embankment (plus freeboard) can even be breached by a 1:5 year flood due to the poor quality of the embankment.

4) The fourth factor is the endurance of the flood. A short timed peak waterlevel will have less longlasting effects than a waterlevel which is sustained at that level for a considerable long time.

The annnual peak waterlevels with the corresponding return periods for Kazipur (located approx 30 km north of CPP Sirajganj) and Sirajganj are depicted in Table 4.4 and Figure 4.6. Furthermore, the occurrence of a breach/retired embankment has been indicated for the period 1987-1992. The annual peak waterlevel at Kazipur in 1987 corresponded to a return period of approx. 11 years which corresponds to the Sirajganj waterlevel with a return period of approx. 12 years. In Table 4.4, it can be seen that at Kazipur for 1987, there was a breach/retired embankment, while for the CPP Sirajganj there was none. In 1988, the return period of the floodlevel rose to approx. 95 years in Kazipur and 52 years in Sirajganj. Kazipur did suffer from this while CPP Sirajganj did not. This situation continued in the same way untill 1990. In 1991, there was no breach/retirement reported in Kazipur but it was in CPP Sirajganj and similarly in 1992.

In case a major part of the embankment is being eroded and breached as it was in 1987 (Figure 4.4 B), it requires considerable effort from the responsable agency (BWDB) to organize and actually implement an new retired embankment. According to the available information, the locations where the breach occurred were not fully prepared and consequently the floodlevel of 1988 had a more severe impact on the (retired) embankment than it would have had if the embankment had been properly repaired or a properly built retired embankment. For Kazipur this situation actually continued untill 1991 while the return periods were just average.

In 1991, the damage to the BRE did not cause Jamuna water to enter CPP Sirajganj. This same situation occurred in 1992 whereby the actual damage to the embankment occurred in December 1992 while there was a low water level. The receding groundwaterlevel caused the seepage line in the embankment to drop and caused this damage which urged for a retired embankment.

Concluding, one can state that the analysis of BRE breach occurrence is a complkicated issue whereby no specific factors can be singled out. Merging of the above mentioned factors which together resemble the actual setting of the Jamuna river, act as a black or grey box approach whereby the resources and results are visible and many times quantifiable but where the mechanism which produces a breach or erosion is not clear. The morphology of a braided river of this magnitude is apparently very difficult to grasp in clearcut analysis or in morphological modelling as confirmed by Brahmaputra Right River Bank Study (ISPAN/FAP 19).

4.6.3 Breach Measures

The flooding due to breaches and overtopping has seriously reduced the scope for monsoon crop intensification, which require a controlled water regime. Two types of measures are feasible in order to control the flooding situation:

- Retired embankments
- Protective works

Retired Embankments:

It is the task for the BWDB to construct, operate and maintain the BRE, in order to keep the area from unwanted flooding. Any damage should be assessed and realignment should be put forward by the BWDB and implemented. The present practice in case of breaches is that new alignments will be identified by the BWDB (O&M SECTION) and subsequent retired embankments implemented after land acquisition has taken place. This process in some cases leads to untimely construction of the embankments.

Protective Works:

The construction of protective works is one of the measures to protect or stabilize a reach of a river. Both groynes and revetments have been widely used (FAP 19). If groynes are the preferred solution then they are normally provided in a series and are often laid out with opposing sets on both banks in order to encourage the formation of a single channel. Only two groynes (Figure 4.5) have survived: at Sariakandi north of CPP Sirajganj, the groyne was constructed in 1986/1987 and upstream of *Sirajganj* town the Ranigram groyne was completed in 1985 to provide additional upstream protection to the existing revetment stabilizing the bank in the immediate vicinity of *Sirajganj* town.

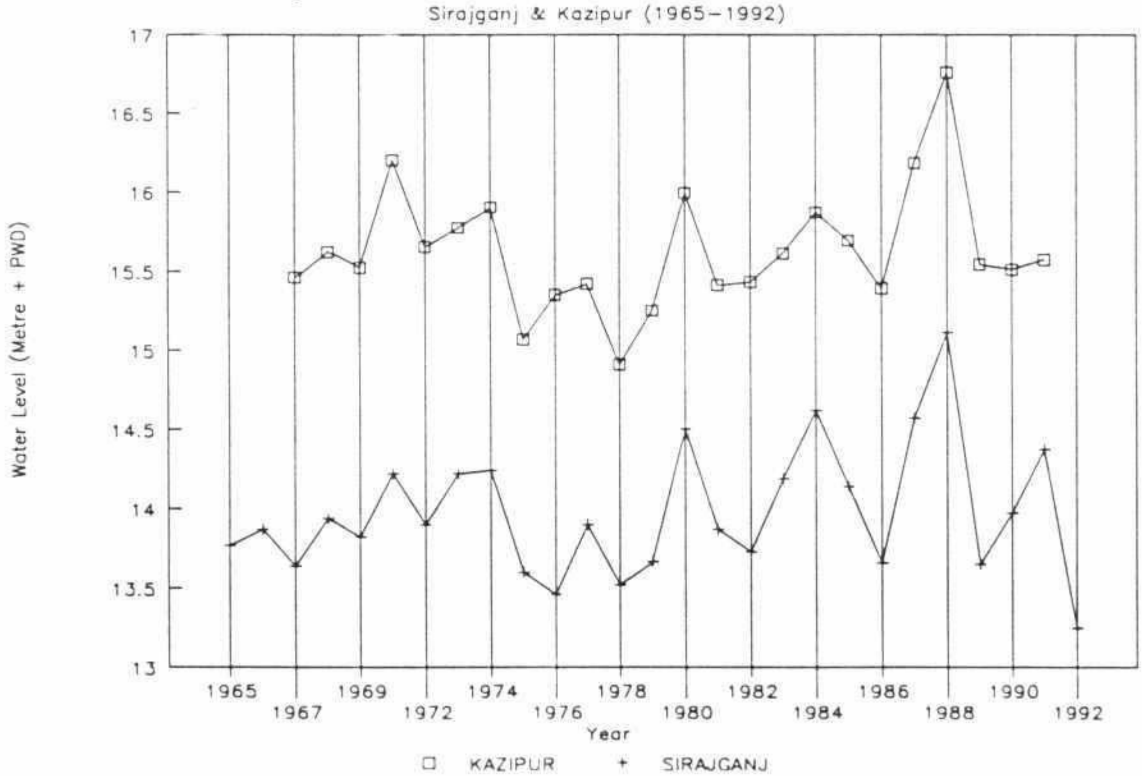
TABLE 4.4 OBSERVED ANNUAL PEAK WATER LEVELS, RELATED RETURN PERIODS AND BREACH/RETIREMENT FOR SIRAJGANJ AND KAZIPUR, JAMUNA RIVER

	KAZIPUR			SIRAJGANJ		
YEAR	PEAK	RETURN PERIOD	BREACH	PEAK	RETURN PERIOD	BREACH
1965	NA	-		13.77	1.49	
1966	NA	-		13.87	1.84	
1967	15.46	1.56		13.64	1.20	
1968	15.62	2.14		13.94	2.16	
1969	15.52	1.74		13.82	1.65	
1970	16.20	11.49		14.22	4.45	
1972	15.65	2.28		13.90	1.97	
1973	15.77	3.06		14.22	4.45	
1974	15.90	4.39		14.24	4.69	
1975	15.07	1.05		13.60	1.14	
1976	15.35	1.33		13.46	1.02	
1977	15.42	1.47		13.90	1.97	
1978	14.91	1.01		13.52	1.06	
1979	15.25	1.19		13.67	1.26	
1980	15.99	5.76		14.50	9.64	
1981	15.41	1.44		13.87	1.84	
1982	15.43	1.49		13.73	1.39	
1983	15.61	2.09		14.19	4.10	
1984	15.87	4.03		14.62	13.47	
1985	15.69	2.51		14.14	3.59	
1986	15.39	1.40		13.66	1.24	
1987	16.18	10.73	YES	14.57	11.72	NO
1988	16.76	94.84	YES	15.11	51.65	NO
1989	15.54	1.81	YES	13.65	1.22	NO
1990	15.51	1.70	YES	13.97	2.07	NO
1991	15.57	1.93	NO	14.37	7.43	YES
1992	NA	-	NO	13.25	1.01	YES

* Breach/Retirement data from 1987-1992

Fig 4.5: Annual Peak Water Level

Sirajganj & Kazipur (1965-1992)



However, based on the existing situation (breaching occurs) and perceived development in the coming years, the assurance is given by the BWDB that the sealing of the BRE at the CPP *Sirajganj* project area reach will come into effect shortly. Improvements at the *Kazipur* reach have not yet been confirmed. Especially at the CPP project area, problems occur at a number of sites. The maintenance and repair of these currently deficient sections of the BRE by the O&M section of the BWDB, however, is not sufficient to guarantee that breaching of the BRE by erosion will not occur any more in the future.

The present deficient status of the BRE in a number of crucial places, urges for an integrated and consistent approach whereby at national/regional level decisions are taken for a betterment, stabilization of the BRE.

Therefore, for the assessment of possible developments for CPP Sirajganj, it is assumed that the BRE is sealed at the location of the project site. However, there is no guarantee that there will be absolutely no breach in the future.

4.6.4 Existing BRE Inlet Structures

There are five watercontrol structures on the BRE in the eastern border of Sirajganj compartment (see Base map in back of this volume). Out of five, two are regulators and rest three are flushing inlets.

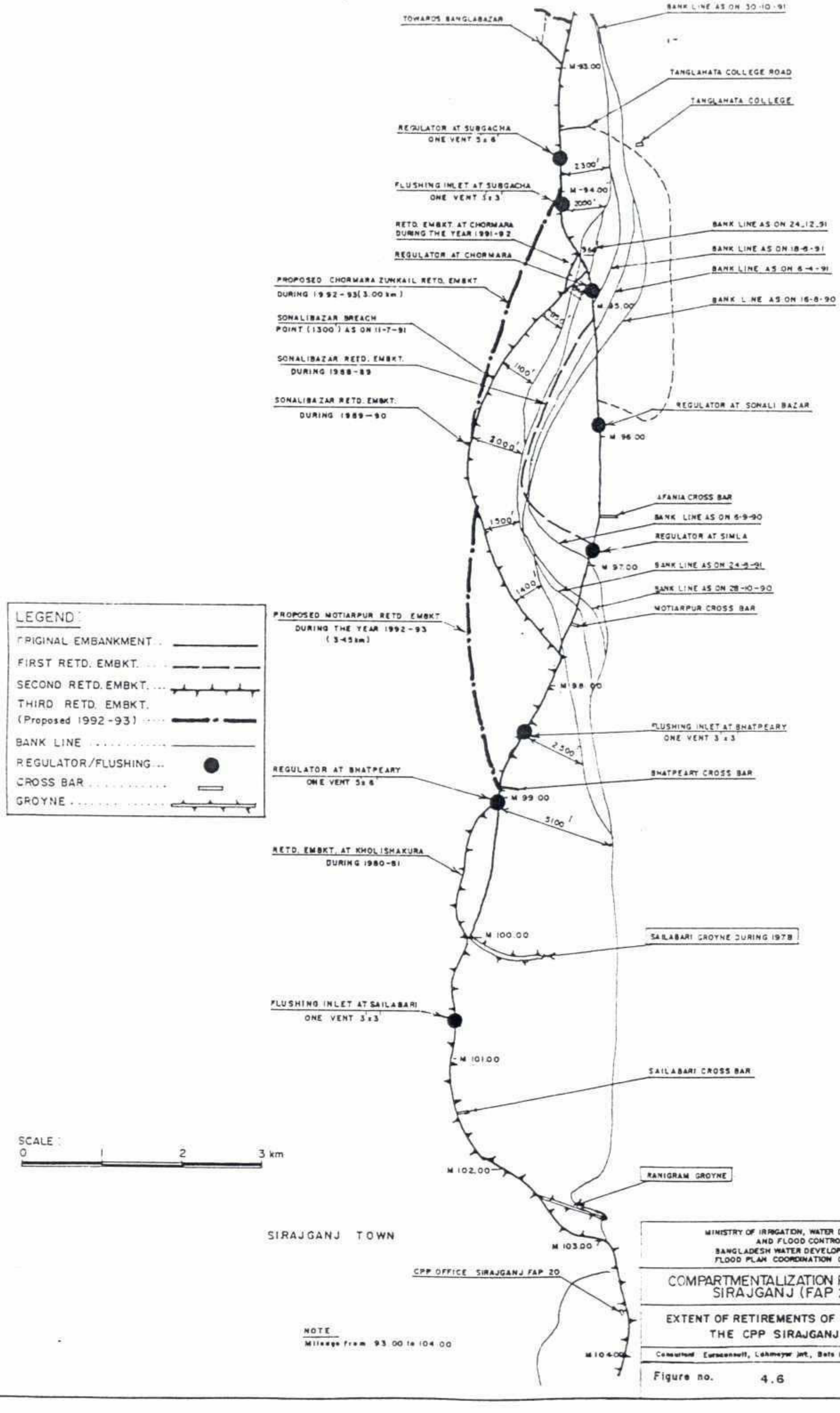
The (two) regulators are situated; one at Bhatpiari and the other at Subgacha. And the three flushing inlets sites are: a) Bhatpiari, b) Char Subgacha and c) Sailabari.

History and Existing conditions of the Regulator and Flushing inlets

Regulator at Subgacha .

This one vent regulator was constructed about 10 years after the BRE (in the area) was completed. The gate served as for flushing purposes upto 1988. An operation committee was installed during the period of its function and a agte operator assigned. The regulator was found beneficial for a command area of approx 40 ha.

At present, the newly constructed retired embankment (1993) has excluded this structure from access to the floodplain area (land side). Therefore, now, they see no use of the existing regulator at Subgacha. But some people opined that the regulator may help remove drainage congestion of about 10-12 acres of land. They also suggested to put the regulator under a committee if it is ever brought under operation.



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EXTENT OF RETIREMENTS OF THE BRE WITHIN THE CPP SIRAJGANJ AREA

Consultant: Euroconsult, Lahmeyer Int., Bots Ltd, HCL

Figure no. 4.6

Regulator at Vatpiari.

This one vent regulator (5 ft by 6ft) which was constructed 1-2 year after the BRE (in the area) was completed. This structure has been used both for drainage and flushing (mostly) purposes according to the local people. Initially there was no committee for operating the regulator, but a committee was formed in a later stage which was discussed.

The gateman faced difficulties in operating the gate because of the conflicting interest between low and high land farmers and between nearer (to the structure) and distant farmers. The gateman strongly recommends for a sluice committee for its future operation.

The command area of this structure is about 200 ha of land and the farmers still consider the gate as beneficial for them.

Vatpiari flushing inlet.

This inlet was constructed during 1982-83 for flushing purposes and was in function upto 1988. After 1988 the structure remained unused because of absence of required water-level and the closure of the intake mouth by garbage and sand/earth. A sluice committee never came into operation.

The structure had a command area of 50-60 ha of land.

The construction of a new retired embankment in 1993, left the structure out of the protected area (See Base map in back of this report).

The total area that now falls within the embanked area (between the old embankment and the retired one) is about 400 hectares and about 800 families live there. People of this area think that the flushing inlet now may be used as a drainage outlet and to improve its functioning the gate size is to be increased.

Char Subgacha flushing inlet. This flushing inlet was constructed during 1982-83. It had a small command area of about 10-15 Ha of land but it served well until 1991. It was operated through a committee.

The present condition of the structure is satisfactory but both its intake and outfall is blocked by earth and garbage. After thorough cleaning the gate could be operated again.

After the 1993 retired embankment was completed, this structure had been left outside the protected area (See Base map in back of this report).

Flushing outlet at Shailabari. This structure was built during 1982-83 for flushing purposes only. The gate was in operation and served well till 1988. During the 1988 flood the gate remained closed it was thought it may be washed away by the severe flood. But after 1988, the gate has not been operational anymore.

On one or two occasions, the gate was operated by the local people for fishing purposes. Because of insufficient water (at the river side) the gate could not be operable from 1989 untill May/June 1993. Meanwhile, the handlebar of the gate has been stolen (in 1991). The local people informed the matter to the BWDB (O&M) authority but no action has yet been taken by the WDB to repair the handle of the gate. According to the local people, the gate (when was in operation) provided them with substantial benefit.

The gate was never run by a committee nor a permanent gate keeper was appointed for its operation and maintenance. Local people operated the gate by the decision of elderly and influential persons. Beside the rehabilitation of the gate, people also demanded the gate be operated by a committee and a gate keeper should be appointed.

Conflicts between upstream and downstream farmers have been reported. The total command area of this structure is about 20-30 ha.

4.7 Sirajganj Town

Sirajganj town forms a separate subcompartment. Due to its environmental impact and its special status in the compartment, a special study needs to be performed.

A special feature of Sirajganj town is its severe erosion on the Bramaputra banks.After the construction of the groynes and other protective works, the erosion stopped. For the town the following points have been considered:-

- town protection
- drainage problem
- sanitation
- environmental problem
- groundwater

The only channel, Katakhali khal is flowing through the Sirajganj town. For sanitation, the katakhali khal can be linked with the Jamuna and structure is proposed to flush the town from time to time. For further details see Annex 6.

4.8 Data Availability

4.8.1 Hydrometric Data and Surveys

The following hydrometeorological data were available at the time of making this report. (Table 4.5). Furthermore, waterlevel gauge readings (daily) from CPP Sirajganj are taken from 17 locations within the area from early 1992 onwards. Furthermore discharge measurements are taken from particular locations within the compartment during the (pre-) monsoon season (see ANNEX 2).

4.8.2 Topographical Information

In order to process and generate maps in a more eficient way, a first step has been taken in digitizing the 1964 BWDB contour maps. Through the use of GIS systems, these maps ultimately have produced per compartment and subcompartment area-elevation curves which are very helpful in visualizing the effect of certain waterlevels calculated through the hydrological model. Area-elevation curves are available for all subcompartments and all catchment areas as defined by the hydrological modelling exercise.

The following topographical surveys have been executed following an inventory of all topographical data available. An overview of the sections surveyed in the field is identified (Figure 4.8).

Table 4.5: Waterlevel, rainfall and discharge data available for Sirajganj area

Data of	*Name of Station*	*Code of Station*	*Years available*	*No. of Years*
Water level:				
	Sariakandi	LDY11A	82-91	10
	Dhunot	LDY324	65-91	27
	Kazipur	LDY49A	67-70,72-91	24
	Sirajganj	LDY49	62-91 except 63,71	28
	Ullapara	LDY66	65-92 except 81,82	26
	Nalkasengati		91-92	2
	Subtotal			117
Rainfall:				
	Sirajganj	RDY34	65-91	27
	Rayganj	RDY29	65-91	27
	Dhunot	RDY11	65-92	28
	Subtotal			82
Discharge:				
	Khanpur	QDY11	73-91 except 81-83	16
	Shimulbari	QDY10	73-91	19
	Bogra	QDY65	65-91 except 71,82,85,87	23
	Subtotal			58
Total				256

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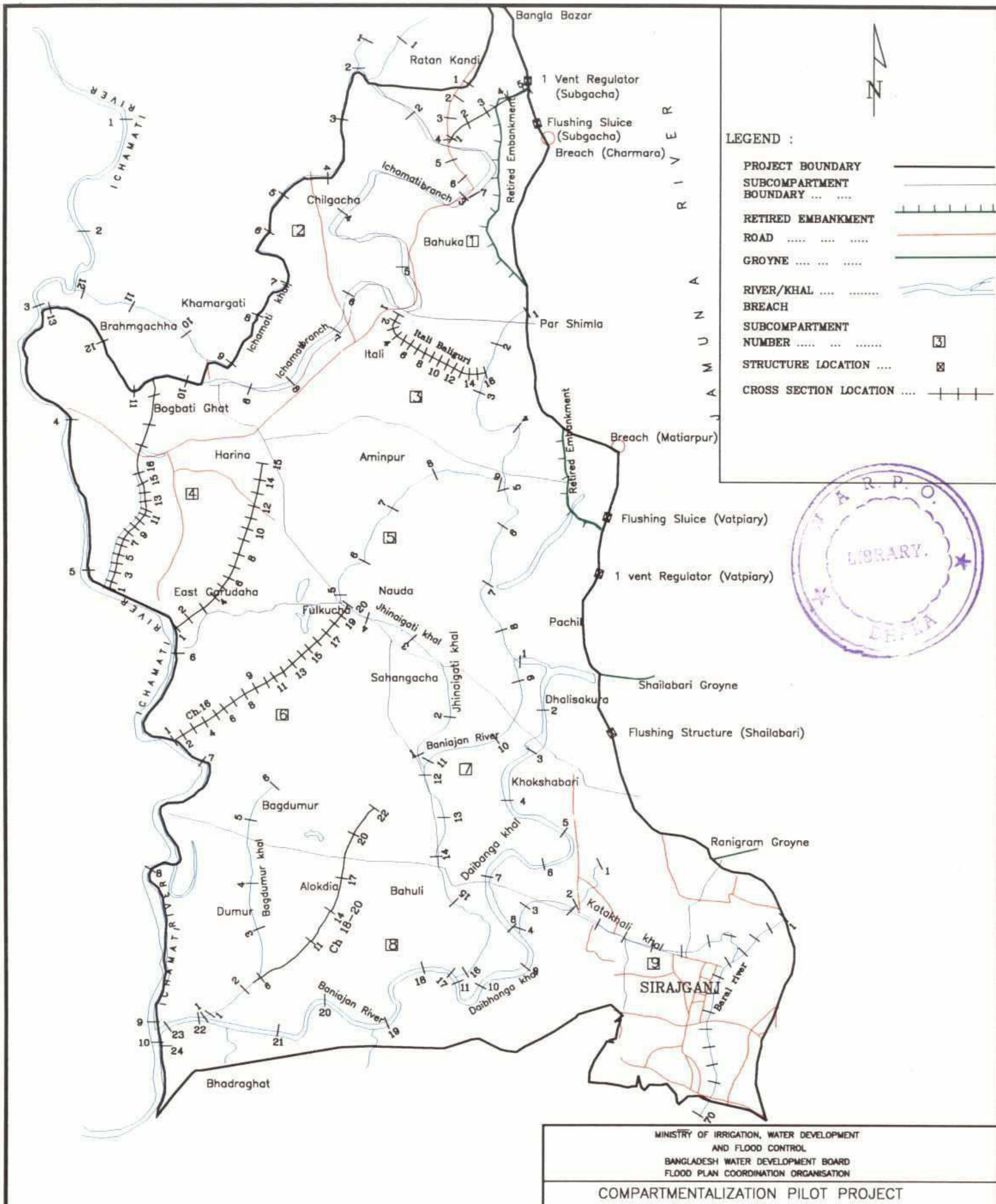

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SIRAJGANJ (FAP 20)

CROSS SECTION LOCATION MAP

Consultant: Euroconsult, Lahmeyer Int., Bets Ltd., HCL

Figure No. 4.7

4.8.3 Contour Maps and Satellite images

The most recent available contour maps for the Sirajganj area is based on the 1964 topographical survey (1:50,000) performed by the Survey of Bangladesh. This map has been compiled from aerial photographs 1:30000 and revised on the ground in 1978-1979, and also during 1984-1985 and 1988-1989.

In order to expedite any required amount of maps and reproducable maps, it was decided that the topographical data from these maps would be entered (digitized) and the Autocad program be used in order to reproduce these maps. Also areal photographs have been acquired and G(lobal) P(ositioning) S(ystem) groundsurveys have been executed in order to verify the map information with reality. Based on these digitized and adjusted maps it became clear that high quality and sufficiently reliable maps could be produced.

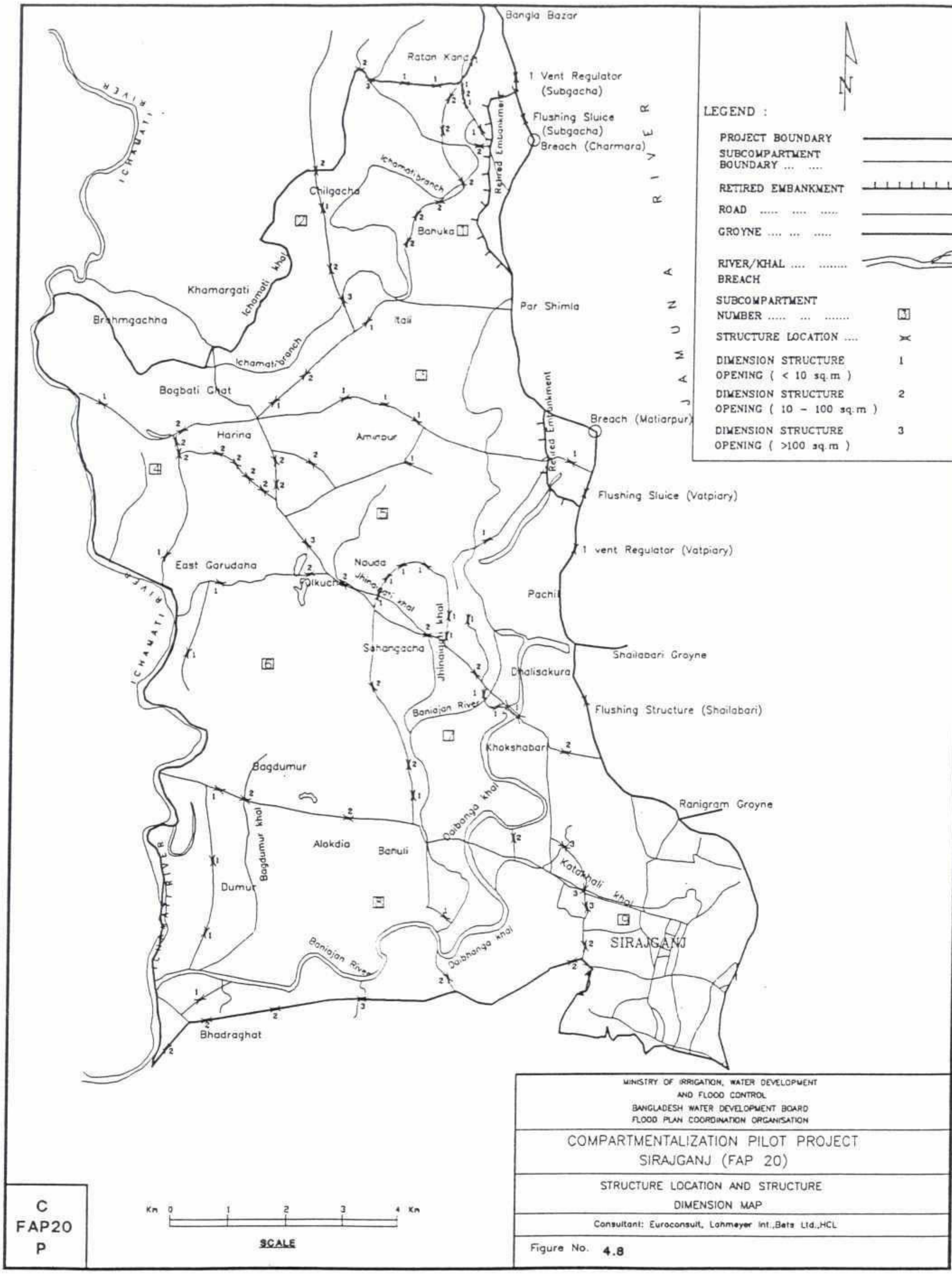
The following areal images were available:

- Multispectral SPOT Images, scale 1: 50,000, 1990
- Satellite Image Mosaic Bangladesh, scale 1: 50,000, 1990 (LGED)
- Areal Photographs (FINNMAP), scale 1:20,000, December 1990
- Photomap of Flood Action Plan Area (FINNMAP), scale 1:10,000, 1990

4.8.4 Waterconveyance structures

The following structures have been identified and the basic measurements notified for the structures within the CPP Sirajganj area. The total amount of water conveyance and control structures has been performed within CPP Sirajganj and a classification is made on the opening of the structures for waterconveyance. Three classes of structure-groups were determined (Figure 4.8):
1) water conveyance opening less than 10 sq.m.;
2) waterconveyance opening between 10 and 100 sq.m.; and
3) waterconveyance opening larger than 100 sq.m.

For class 1 a total of 34 structures, group 2 contains 37 and group 3 just 8 structures were identified.



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STRUCTURE LOCATION AND STRUCTURE DIMENSION MAP

Consultant: Euroconsult, Lahmeyer Int.,Bets Ltd.,HCL

Figure No. 4.8

5 DEVELOPMENT OF OPTIONS

5.1 General

The planning for Sirajganj compartment should be developed in line with the objective of the project as defined in the Inception Report *"... to establish appropriate water management systems for the development of protected areas so that criteria and principles of design, implementation and operation can be made available for the Action Plan"*.

This chapter mainly focuses on the planning for the Sirajganj compartment and stipulates a number of possible scenarios/options which can be developed in a more detailed framework in due course.

The Sirajganj compartment is situated behind the Brahmaputra Right Embankment (BRE) and therefore largely depends on the quality of the BRE. So the protection from the Brahmaputra flood is assumed to be provided by the BRE. As part of this planning exercise which forms the basis for future elaboration, design and implementation it is necessary to identify a number of options (scenarios) which are amongst the most feasible to implement within the project framework. Taking into account the overall likely development of projects in the region, agricultural, hydrological, economical and social aspects are to be identified and weighted in these scenarios. Although at this time it is not possible to weigh these factors in a consistent framework, one should estimate the importance of these factors in general terms.

The western boundary of the CPP-compartment is formed by the Ichamati river and the eastern boundary is the BRE (see Base map in back of this report). The southern boundary follows the Sirajganj-Bogra road (New Bogra Road). The northern boundary follows the Ichamati khal. The major flooding problems in the CPP-project area are the result of breaches in the BRE which are taking places either at CPP-project area, in upstream areas north of the project area. Also localised rainfall north of CPP Sirajganj can produce floodlevels approaching CPP Sirajganj. In case these floodquantities are approaching the project area, it is suggested to divert part of the drainage water outside the CPP Sirajganj area in order to keep the Ichamuti branch waterlevel as low as possible.

An additional complication is formed by the runoff quantities conveyed by the Ichamati river which originates from the upper catchment. Inside the compartment, the Baniajan river and Ichamuti branch are the only rivers that flow through the compartment.

Needs assesments surveys performed in the CPP-area and its adjacent surroundings indicate that people living near the BRE have severe criticism on:
1) the principle of constructing a retired embankments and its timing: and
2) the quality of the actual implementation of the retired embankments.

As a result of these surveys, it is also noted that both quantity and quality of peripheral regulators in the BRE is not sufficient to fulfill the needs for agricultural and fisheries purposes. Furthermore, it was suggested by the people that proper and timely construction of the retired embankment should be performed and also construction of groynes or revetments ought to be taken into account.

The general free drainage situation is depicted by preferential flows based on field information (Figure 5.1). The free drainage situation indicates that the area in general is draining from the north-eastern side to the south western side. Major runoff quantities based on local rainfall can be conveyed to the existing drainage syytem. A number of infrastructural devices convey this water from SC to another SC. Intake structures at the BRE will allow water from the Jamuna to enter CPP Sirajganj in a controlled mode.

In a congested drainage situation, the drainage water will accumulate in the Ichamuti river. The congested drainage in the lower Bangali river system will not allow drainage water to be drained properly to the existing drainage system. During flood, flow pattern of the Ichamati river which generally flows from north to south changes in reverse direction which ultimately effects the flow pattern of sub-compartment-8, 6, 9 and partly 7. Flow of the above mentioned sub-compartment turns in reverse direction but due to high elevation and existance of Sirajganj-Kazipur road back water of the Ichamati river cannot change the flow pattern of the other sub-compartments appreciably. Flow pattern of sub-compartment 1,2,3,4,5 & 7 sometimes also change due to breach of BRE and it depends on the location, size and discharge of flood water through the breach.

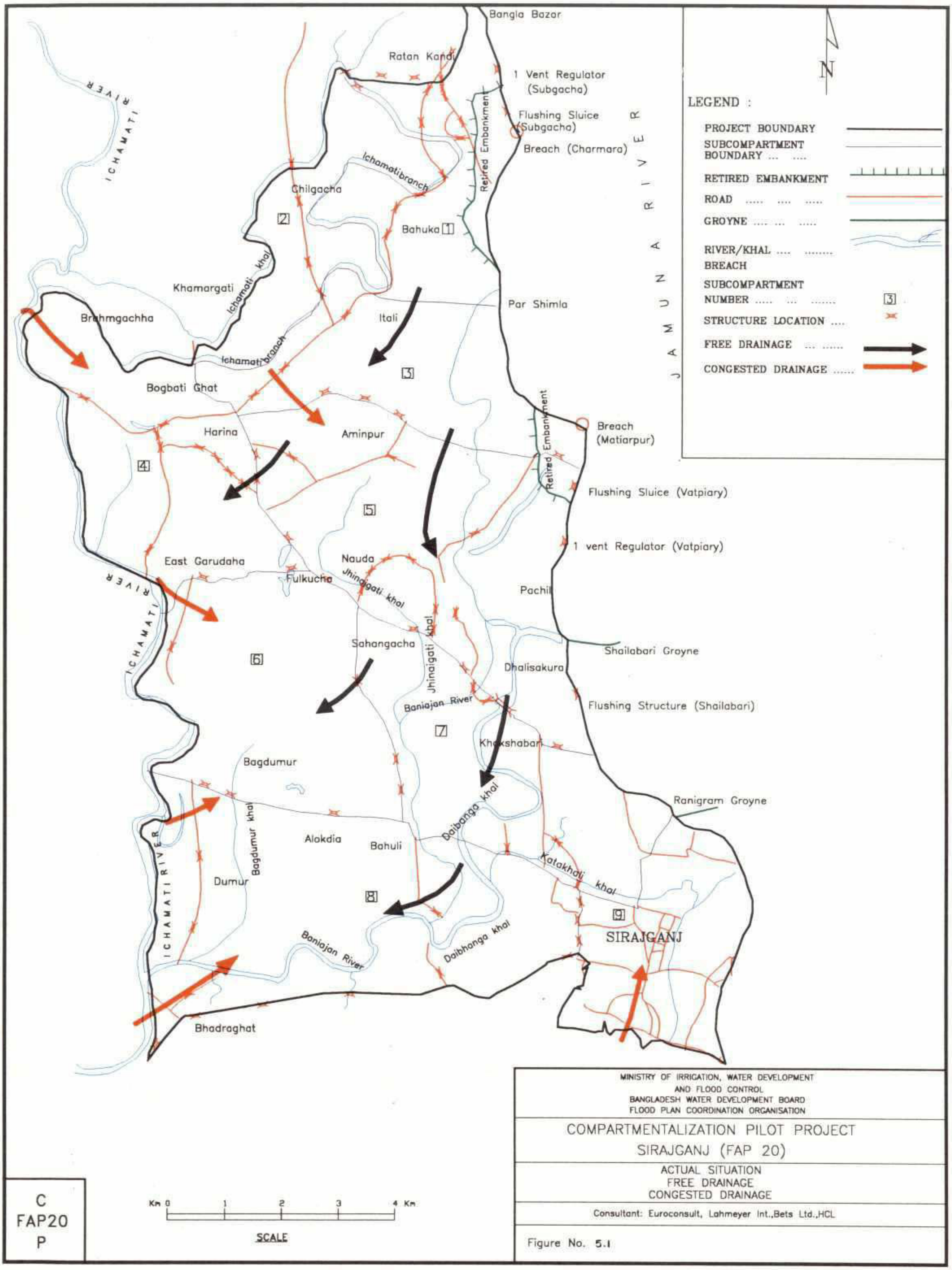
Sirajganj town will be dealt with separately. It has been assigned as a separate subcompartment. Due to its environmental impact and its special status in the compartment, a special study needs to be performed. In order to improve the Sirajganj town sanitation problem, the Baral river needs to be re-excavated from its intake at BRE upto the Hurasagar river with provision of one flushing sluice at its intake for flushing purposes. Existing culverts need to be modified to increase their flowing capacity and a few culverts are needed to be constructed at suitable locations. The existing internal drainage system within town also needs to be improved to remove waterlogging. Existing drains are inadequate in size, length and number.

All proposed development options incorporate the effects of the possible occurrence of BRE breaches. In the first presented option, the emphasis of a BRE breach is incorporated in the design, while for the remaining options "other than BRE breach features" are the common denominator in the options presented.

5.2 Development Options

The planning for Sirajganj compartment is developed to test the compartmentalization concept. More specifically the compartmentalization was developed in line with the following objectives:

- * controlled flooding into and within the compartment;
- * controlled drainage within compartments and between neighbouring compartments;
- * improve agriculture and irrigation;
- * improving fisheries;
- (* improve infrastructure)



MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
FLOOD PLAN COORDINATION ORGANISATION

COMPARTMENTALIZATION PILOT PROJECT
SIRAJGANJ (FAP 20)

ACTUAL SITUATION
FREE DRAINAGE
CONGESTED DRAINAGE

Consultant: Euroconsult, Lahmeyer Int.,Bets Ltd.,HCL

Figure No. 5.1

Common features of the presented options

Breach Mitigation

Breach mitigation measures mainly aims at mitigating the breach impact from the BRE occurring as a result from the erosive force of the Jamuna river, due to high waterlevels, preferential incidence of streamflow along certain course or others. Breaches are being observed in the eastern boundary of and north of the CPP Sirajganj project area. The direct impact of a BRE breach are damages to infrastructure and crops.

In physical terms this means that the actual impact of a breach occurrence can be mitigated through upgrading the existing roads (or other structural elements) which can serve as embankments and development of the existing structures. This should be performed such that breach water can gradually be released from the directly affected subcompartment(s) without damaging the crop and infra-structure.

Drainage Improvement

The current impedance of drainage water in pre-monsoon and post-monsoon within the context of the existing drainage system is very constraining in further development of this area. An improved water resources control is needed which ultimately should lead to increased agricultural production. Many parts of the drainage system are silted up and do not function any more according to the original setting.

Flood Protection

In order to protect the area from river flooding, embankment are necessary. The flood protection measures are taken regarding floods which originate from waterlevel raising from the secondary river system beyond a certain probability level. At the moment no embankment exist on the northern and western periphery of CPP Sirajganj.

Flooding can be caused by:

1) a local BRE breach on the boundaries of CPP Sirajganj compartment;
2) major runoff as a result of local rainfall upstream of the CPP Sirajganj project area;
3) backwater (or backflow) effect from the Karatoya river system back into the Ichamati river and other areas;
4) any combination of the above three.

Water Retention

Water retention is one of the important element of compartmentalization. The objective of the retention is to retain rainfall or flood water in a specific area and gradully release it into the next sub-compartment.

Watermanagement

The flood water will flow into the compartment and spread over the area in a controlled way by means of regulating structures in the embankments along this river and the gated or ungated openings in the secondary embankments between the compartments. The structural and non-structural measures needed to achieve this can be called the macro (main) system.

The way the flood, as well as the drainage of excess rainfall, has to be controlled will be determined by the demands from inside the compartment. The required structural and non-structural measures for water management within the compartments can be called the micro system.

It is obvious that a compartment can be a large area and that hydrology, topography, existing infrastructure, landuse and administrative boundaries are important factors to consider. In analogy with an irrigation system, it is possible to make a distinction between the macro (main) system and the micro (minor) system. Clearly, to make the participation of the beneficiaries in project planning, design, construction, operation, maintenance, monitoring and evaluation successful, it will be necessary to subdivide the compartment into rather small units.

All presented options carry out a watermanagement approach whereby the waterrequirements for each SC will be the basis for water management. As indicated earlier, the boundaries as defined are preliminary boundaries. In due course these subcompartmental boundaries may need to be changed as a result of agronomic, hydrologic, economic or other reasons. For that reason, homogeneous unit have to be developed.

The following three options are presented:

OPTION 1:	**COMPARTMENT DEVELOPMENT SITUATION WITHOUT THE ICHAMATI EMBANKMENT**
OPTION 2A:	**COMPARTMENT DEVELOPMENT WITH THE ICHAMATI EMBANKMENT FOLLOWING EXISTING ROAD**
OPTION 2B:	**COMPARTMENT DEVELOPMENT WITH THE ICHAMATI EMBANKMENT FOLLOWING RIVER BANK**

5.2.1 Description OPTION 1

Option 1 is titled:

"COMPARTMENT DEVELOPMENT SITUATION WITHOUT THE ICHAMATI EMBANKMENT".

This option aims to improve the drainage situation in the entire compartment in view of the BRE breaching possibility and the impact of excess runoff from the upstream catchment area originating from beyond the CPP northern boundary (see Option 1 map in the back of this volume).

Major existing drains will be adjusted and improved. Drains will be excavated if necessary. As explained earlier, the sealing of the BRE is not definite, so the probabality of breaching is present. In case there is a breach, the excess water in the various subcompartments will be confined as much as possible to the respective subcompartments and the flow will be channeled as much and quickly as possible to an adjacent river or major khal. Subcompartment boundaries need to be upgraded in order to enable them to act as flood retention structures. A number of flood conveyance structures are needed in the subcompartment boundaries in order to function as such.

Although SC-boundaries coincide many times with existing roads, a number of these SC-boundaries do not follow this pattern. One should also realize that certain SC boundaries are preliminary fixed and may need to be altered according to more detailed analyses. In some cases these changes may be considerable and may consequently result in stiff construction expenses as well as considerable land acquisition problems.

The general trend is that one should reckon with major BRE breach which will consequently cause major drainage congestion. It is also possible that major overland flow from the upstream area will ultimately fill up the Ichamuti khal and cause additional problems. Diversion of major floods from entering into the compartment area are proposed in this option. Consequently the Ichamuti branch will be available as much as possible for "breach" water which enters directly or indirectly from the BRE into the CPP Sirajganj.

The following assumptions are identified:

1. Sealed BRE;
2. Improved Drainage;
3. BRE Inlet structures;
4. Peripheral control structures;
5. Sub-compartment BRE breach mechanism;
6. Internal water management;
7. Sirajganj town development.

In case there is a breach in the CPP-Sirajganj area, the following approach is suggested:

1) confine incoming BRE breach floodwater to a restricted number of subcompartments;
2) convey these floodwaters adequately and quickly through water regulators in the subcompartment boundaries to improved drainage channels.

It is assumed that BRE breaches might occur. The principle of subcompartmental development will be used to guide the water entered into the project area and eventually the SC will drain into the neighbouring SC and/or will drain into a major khal without causing excessive damage. For this purpose the existing structures (bridges or culvert) will be adjusted/developed to handle the breach water. The maximum duration in which the floodwater is allowed to remain in the affected subcompartment is not more than 48 hours and should preferably not exceed 72 hours.

The main drainage system within the compartment is proposed to be improved. A drainage diversion regulator is proposed at Bir Subgacha which keeps the Ichamati branch capacity available for drainage water from inside the compartment. Any major waterflow which originates from the area north of the compartment will only partially enter into the compartment area and will partially be diverted through the Ichamuti khal to the Ichamuti river.

Three inlet structures at the BRE are being proposed and access canals are being maintained for proper acess from Jamuna water to the project area. The purpose of these inlet structures is to regulate water during the pre-monsoon season to facilitate the fish migration. A fourth BRE inlet structure is proposed for Sirajganj town in order to flush the town sewage system.

Advantages OPTION 1:

In general this option has to be seen in the light of national and regional planning whereby disbenefit at local level is sufficiently compensated by benefit at regional level. In case of major flooding caused directly by a BRE breach at the boundary of the CPP-project, this flood will be confined to one or two subcompartments. The confinement of floodwaters results in a mitigation of flood occurrence at regional level.

The accumulated floodwater will be conveyed from the affected subcompartment(s) through regulators to major khals/rivers in adjacent areas. In SC-3 and SC-5 a combination of regulators and improved drainage will regulate and convey the quantity to khals/rivers.

Disadvantages OPTION 1:

Depending on the assumed magnitude, duration and frequency of flooding from the BRE, it is estimated that the affected areas (SC's which are directly affected by the floodwater) will considerably suffer from the breach. Most probably, the areas which are inundated extensively by the floodwater will not produce in agricultural terms except for the relative higher areas and for the submergence tolerant crops.

Besides from the BRE breach which directly affects the CPP-area, it is also possible that either a major breach occurs in the area upstream of CPP-compartment or heavy runoff occurrs which result in flood levels in the Ichamuti and Karatoya. This combined effect will cause excessive flood levels in the Ichamuti river and branch and will result in major flooding in the adjacent areas next to these drainage systems.

5.2.2 Description OPTION 2A

Option 2A is titled:
"COMPARTMENT DEVELOPMENT SITUATION WITH THE ICHAMATI EMBANKMENT FOLLOWING THE EXISTING ROAD".

The assumptions of this options are as follows (see Option 2 A map in the back of this volume):

1. Ichamati river left embankment which follows the existing road;
2. Sealed BRE;
3. Improved Drainage;
4. BRE Inlet structures;
5. Peripheral control structures;
6. Sub-compartment BRE breach mechanism;
7. Internal water management;
8. Sirajganj town development.

The difference with **OPTION 1**, that there is substantial improvement of the OPTION 1 situation by including an embankment along the Ichamati river/khal which also provides protection from flooding. This embankment is proposed to protect CPP Sirajganj from floods which cause congested drainage. This congested drainage is caused by an impeded drainage process at the confluence of the Ganges and Brahmaputra. This backwater effect (or backflow) clearly affects the drainage capacity of the area in the (pre-)monsoon and therefore hampers the drainage situation in the CPP Sirajganj area.

Furthermore an extensive system of internal and outlet regulators is added to the ones which are included in Option 1. This comprehensive set of measures should provide the necessary means to enhance the compartmentalization concept.

The proposed Sirajganj town development remains the same as oulined in the OPTION I. The objective of the upstream structure of Ichamati branch (near Bir Subgacha) is to divert partial flow through the Ichamati khal. The major objective is to avoid BRE breach water originating from areas north of CPP Sirajganj to enter into the project area. In order to increase the carrying capacity of the Ichamati khal, re-excavation is proposed. The Ichamati side structures are provided with the objective to regulate the flow from the Ichamati into the project and when needed to retain water inside also. The BRE structures will be used to bring water into the project area. The primary objective is the fish migration. The structures are wide and sill level follows the inside river bed level.

Advantages OPTION 2A:

Also this option has to be seen in the light of regional planning whereby regional benefit prevails over local disbenefit. Although the BRE is assumed to be repaired (sealed), the compartmentalization concept provides a set of mitigation measures for cooping with a BRE breach. The risk of any major flood will be confined to one or two subcompartments whereby major flooding will take place in very localized spots. Gradually, the accumulated floodwater will be conveyed through regulators to major khals/rivers. In SC-3, and 5 new regulators will be constructed water, the quantity to khals/rivers. The embankment on the left bank of the Ichamuti river will prevent major backflow from the Ichamuti river back into the CPP-project area.

Disadvantages OPTION 2A:

Depending on the magnitude and duration of flooding from the BRE, it is estimated that the affected areas within the CPP project area will considerably suffer from the breach and that most probably the areas will not produce much except for the higher areas and for the flood tolerant. It is also expected that certain localized area on the Ichamuti right bank will suffer from extended flood levels.

Furthermore, an embankment on the left bank of the Ichamuti may cause local drainage congestion on the Ichamuti river right bank. However, one should also realize that the location of the Ichamuti river left embankment allows for sufficient drainage water to be stored along the river in its immediate floodplain.

It is also anticipated that the area confined between the embankment and the Ichamati river bank will suffer due to the location of the embankment. Mitigation measures are necessary for this area.

5.2.3 Description OPTION 2B

Option 2B is titled:

"COMPARTMENT DEVELOPMENT SITUATION WITH THE ICHAMATI EMBANKMENT FOLLOWING THE RIVER BANK".

Basic assumptions (see Option 2B map in the back of this volume)::

1. Ichamati embankment follows the Ichamati left river bank and Ichamuti khal bank;
2. Stable BRE;
3. Improve Drainage;
4. BRE Inlet structure
5. Peripheral control structure;
6. Sub-compartment BRE breach mechanism;
7. Internal water management;
8. Sirajganj town development.

The only difference with option 2a is the location of the Ichamati river embankment. This embankment follows the river bank. The other features remain basically the same.

The proposed Sirajganj town development remains the same as oulined in the OPTION I.

The objective of the upstream structure of Ichamati branch (near Bir Subgacha) is to divert partial flow through the Ichamti khal. The major objective is to avoid influx from BRE breach water into the project area. In order to increase the carrying capacity of the Ichamati khal, re-excavation is proposed. From modelling point of view, the difference with the OPTION 2A is the river width and the embankment height. The Ichamati side structures are provided with the objective to regulate the flow from the Ichamati in to the project and when needed to retain water inside also. The BRE side structures will be used to bring water into the project area. The primary objective is the fish migration. The structures are wide and the sill level follow the inside river bed level. The proposed Sirajganj town development remains the same as oulined in the OPTION I.

The operation rule for the mentioned structures is as follows:-

* The Ichamati branch upstream structure will divert water into the Ichamti khal. The structure is a weir and so consequently operation rule are needed.

* The second structure on the same river will drain water when the Ichamati permits to drain.

* The Ichamati river structure will be operated when the Ichamati river stage will be low. Basically the up- and downstream water level will guide the structure operation.

* The BRE structures will remain open, in general, till the first week of the July. But mainly operation of these structures will depend on the arrival of first flood in the Jamuna river and its duration. The Sirajganj town structure will allow the water to enter into the town till it reaches level 13.5 M. PWD. So the structure will remain open untill the inside water level reach the mentioned level and during receding period of Jamuna, it will start draining back into the Jamuna.

* The other internal structure will be guided by the local demands. The detailed water management will be the guiding factor for these structures. Apart from these, the structure will serve to mitigate the effects of the breach.

It is assumed that breaches might occur and to coope up with the BRE breach, the sub-compartment will be used to manipulate the water entered into the project area and eventually the SC will drain into the neighbouring SC and/or will drain into a major khal/river without causing excess damage. For this purpose the existing structures will be developed to handle the possible breaches.

Advantages OPTION 2B:

The risk of any major flood will be confined to one or two subcompartments whereby major flooding will take place. The accumulated floodwater will be conveyed through regulators to major khals/rivers. In SC-3 and SC-5 new regulators will be constructed water to convey the quantity to khals/rivers. The embankment on the left bank of the Ichamuti river will prevent major backflow from the Ichamuti river back into the CPP project area.

The problems related to a newly proposed embankment are mitigated considerably due to the adjustement of the embankment to already existing roads.

A considerable improved watermanagemnent system in contrast to the existing situation will regulate the internal (intercompartmental water regulation) as much as possible. The expected benefits are in terms of more sustainable agricultural (and fisheries) production.

The functioning of improved BRE regulators will largely depend on the change of cthe Jamuna course and its pattern of erosion. That in turn will influence the potential for floodplain fish development. However, the relatively minor quantities of fish fry will not impact the existing situation considerably, unless culture fish is being introduced systematically. However, under the given conditions, this development is not very likely due to the sandy soils in many parts of the CPP Sirajganj.

Disadvantages OPTION 2B

Depending on the magnitude and duration of flooding from the BRE, it is estimated that the affected areas within the CPP project area will considerably suffer from the breach and that most probably the areas will not produce much except for the highlands and for the planted sugarcane. It is also expected that certain localized area on the Ichamuti right bank will suffer from extended flood levels.

The location and implementation of embankement cum road may cause considerable difficulty, both from a land acquisition point of view and from the allocation point of view.

5.3 Mathematical Modelling of Options

5.3.1 General

The discussed options are to be translated and schematized into the mathemathical modelling program (MIKE 11) in which the most relevant hydrological and topographical features are included (see Annex 2).

The options as described earlier are tested with the help of mathematical model. The Sirajganj Model includes all the internal and external channels and also the BRE. This model is calibrated with 1992-situation. The calibrated model is used as planning to find out the optimum dimension of the structures. The operation rules were developed considering both agriculture and fisheries requirement. The model was run to simulate the design year. The design year for CPP Sirajganj is 1970 based on an assessment of the North West Region (FAP 2) as an entity which shows similar pattern of 1 in 5 year return period. The output of the model are interpreted in to flood depth (F0,F1..F4 classification) for agricultural and fisheries analysis (area flooded).

5.3.2 Output Processing

The output of the MIKE11 model is composed of water levels and discharges in alternate points along a channel. For sub-compartment analysis, a water level point is selected in such a way that it represents the flooding pattern of the sub-compartment.

A computer program for processing the results of the various simulation has been developed in order to determine the distribution of flooded areas for each sub-compartment.

Cropping Pattern Analysis

For each sub-compartment, the selected water level point is used to calculate the respective areas of various categories of level:

* F0 flood free land or land inundated to a depth less then 30 cm.
* F1 land inundated to a depth of 30 to 90 cm.
* F2 land inundated to a depth of 90 to 180 cm.
* F3 land inundated to a depth of 180 to 300 cm.
* F4 land inundated to a depth of more than 300 cm.

Fisheries Analysis

The decade-wise analysis for flooded area is also used in the fisheries analysis. The impact of the proposed structure along the BRE on fisheries are analysed. The most important factors regarding the structure size are sill level, width and height of the opening. The structures proposed along the BRE are fish frindly in character. The operation rules are developed in such a way that the first flood can easily enter through the structure i.e the gate will remain open till the first flood passes approx during the second week of July or any other week in which th first major flood has passed..

5.4 Analysis of results for the Without- and With-Project situation

The model is used to make available water level and discharge throughout the project area. The **without project** situation is the existing situation. There are four ways the area can be flooded namely i) local excessive rainfall within the compartment,
ii) BRE breach inside the project area and iii) floodwater coming from the Ichamati river (may be due to the BRE breach in the north) or a combination of the above aspects.

Table 5.1: Sub-compartmentwise 1:5 year water level for Desired, Base and with Project situation for the CPP area, Sirajganj.

Subcompartment	Desired Water level (ha)	1:5 year Water Level (m)		
			With Project	
		Base	Option 1	Options 2A & 2B
1	13.00	12.31	12.44	12.44
2	13.00	13.43	13.43	12.44
3	12.50	12.96	12.43	12.43
4	12.50	13.38	13.38	13.02
5	12.20	12.98	12.43	12.43
6	12.10	12.98	12.98	12.43
7	12.00	12.44	12.30	12.30
8	12.00	12.43	12.43	12.33
9	11.80	12.40	12.30	12.30

Source: Base and with project water levels are Mike 11 model results. Desired water level is compution of the Agronomist.

There are three options that are tested with the help of Sirajganj model. Table 5.1 shows the flood depth analysis of the three options with proposed structural interventions.

Table 5.3 shows the expected waterlevel and With-project option1,2A , 2B waterlevels. The desired or expected waterlevels are computed on the basis of agricultural requirements. On this basis the structural operational rule are adjusted to achieve the desired waterlevels. In some cases, the desired waterlevel cannot be achieved due to the absence of detailed watermanagement.

The Base-situation waterlevel replicates the assumed waterlevel situation (1970). The With-Project for Option 2 A indicates the change in waterlevel only in SC 3, 5, and 7. The other SC's remain in the Without-project situation. For option 2 B the With-project waterlevel situation shows decreasing in most of the SC's. In SC 8 due to the backwater effect from the Ichamuti river, the Baniajan river could not drain proporly.

Table 5.2: Sub-compartmentwise land types of the NCA in three different options of With Project situation

SC	NCA	Option 1				Option 2A				Option 2B			
		F0	F1	F2	F3	F0	F1	F2	F3	F0	F1	F2	F3
1	750	727	23	0	0	727	23	0	0	727	23	0	0
2	709	160	224	265	60	524	131	39	15	524	131	39	15
3	893	651	206	36	0	651	206	36	0	651	206	36	0
4	1132	98	411	526	97	92	409	533	98	314	470	294	54
5	1656	1132	413	111	0	1132	413	111	0	1132	413	111	0
6	1196	119	462	541	74	526	257	343	70	537	464	195	0
7	1071	666	343	62	0	666	343	62	0	666	343	62	0
8	1981	722	774	458	27	698	780	472	31	868	716	381	16
9	191	105	80	6	0	105	80	6	0	105	80	6	0
Total	9579	4380	2936	2005	258	5121	2642	1602	214	5524	2846	1124	85
%		46	30	21	3	53	28	17	2	57	30	12	1

Source: CTP computation based on 1:5 year WL at different options

The impact of the With-Project measures are shown in the Table 5.2. The net increase on F0 type of land from Option 1 to Option 2B is 1144 ha. The F1 area is decreased from Option 1 to Option 2B.

5.5 Impact Assessment of Adjacent Areas

As described in the Options, the external areas will be affected due to the structural interventations. The water level for both **without** and **with** projects are the maximum water levels taken from the model. The years selected for the analysis are 1970 and 1990. The maximum water levels are assessed when all the gates of the structures are closed to assess the maximum rise in water level upstream of the structural site.

Table 5.3 gives a summary of the rise of the peak water level in the impact area of the compartment.

Table 5.3: Maximum waterlevel rise as calculated by Mike 11 for Option 2B

LOCATION/CONDITION	RIVER LOCATION	LEVEL 1990 (M+PWD)	MAX RISE IN 1990 (M)	LEVEL IN 1970 (M+PWD)	MAX RISE IN 1970 (M)
U/S Ichamati Branch	Ichamati Branch	15.79	0.40	13.85	0.27
Confluence Ichamati Branch and Ichamati river	Ichamati River	14.64	0.27	13.52	0.18
Garudaha Ichamati River	Ichamati River	14.23	0.18	13.06	0.12
Confluence of Ichamati River and Baniajan river	Ichamati River	13.54	0.15	12.46	0.10

The following can be concluded:

- The highest rise of waterlevel is in the area just upstream of the compartment (0.25 to 0.40 m). .

- The impact on the downstream Ichamati floodplain is not significant. The main reason is that the eastern side existing road is acting like an embankment in the Without-project situation. Also the western bank of the Ichamati River has slopy bank. The influence is felt in the upper part of Ichamati.

- The impact on the Jamuna is not found. But in case of a BRE breach inside the project area, the influenced area will be the adjacent Char land area.

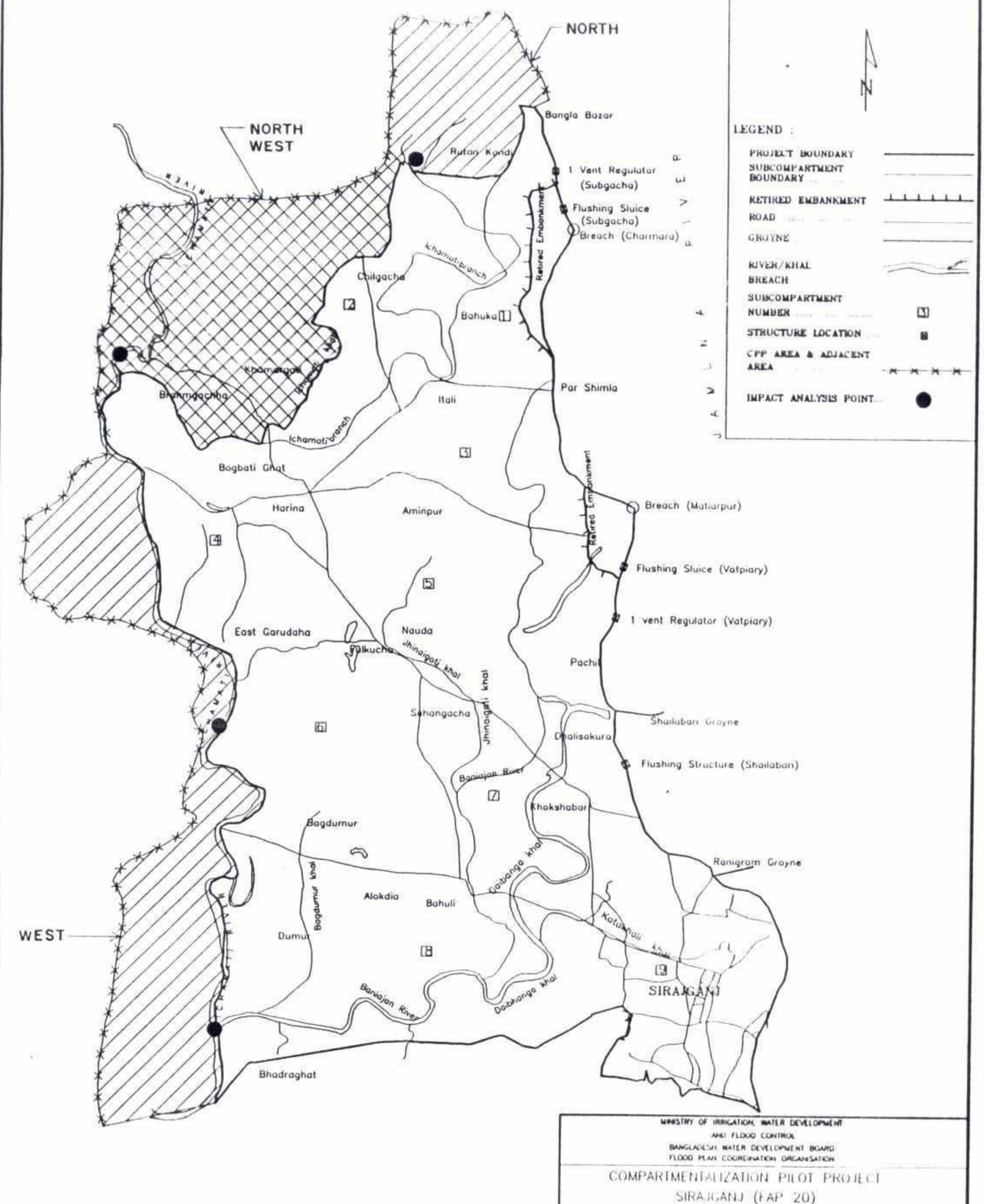
- There is no effect on the waterlevels on the southern boundary.

5.6 Mitigation of the adjacent areas

Mitigation measures depend on the implementation of the development option. The adjacent areas are defined on those areas which are on the outer boundary of the project area and which are likely to be impacted by project activities. The adjacent areas have been identified (Figure 5.2) and their boundaries do opten coincide with rivers, roads or other main infrastructure.

In case development Option 1 is chosen, mitigation measures will be implemented which are a result of the overall congested drainage situation especially along the Ichamuti river. The congested drainage situation here is caused by a regional feature in which the Karatoya river ultimately drains into the confluence of the Ganges and Brahmaputra. As a result of the poor drainage situation at the confluence area, the Karatoya river cannot drain properly, expecially in the monsoon season. It is therefore suggested that general flood alleviating measures can be taken and eventually resettlement can be considered for certain flood prone areas. Especially the W and NW adjacent area will be affected.

If development option 2A will be implemented, then four areas will be affected.



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COMPARTMENTALIZATION PILOT PROJECT
SIRAJGANJ (FAP 20)

ADJACENT AREAS

Consultant: Euroconsult, Lahmeyer Int., Beta Ltd., HCL

Figure No. 5.2

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The first area will be the area confined between the proposed embankment along the Ichamuti left river bank following the existing road system and the Ichamuti river. Due to the constructed embankment this confined area is likely to be affected by increased floodlevels.

The second area is characterized as the west adjacent area and will suffer from two effects. The first one is the one which is already mentioned under Option 1, whereby the hydrological situation can be classified as congested drainage in the monsoon season. The second effect is caused by the construction of the embankment on the Ichamuti left bank. For both aspects, construction of an emabnkment, reexcavation of the Ichamuti river and resettlement are possible interventions in this respect.

The third area affected will be the NW area where the impact is expected to be less than in the NW area due to the distance between the congested drainage area near the Karatoya-Ichamuti confluence. Also here the suggested mitigation measures can be implemented.

The fourth area is located north of CPP Sirajganj which will probably show a more severe effect as the NW adjacent area. It is possible that flood levels, as calculated and presented in Section 5.6, will increase most in this area in comparison with the present situation.

6 SUB-COMPARTMENTAL DEVELOPMENT

6.1 General

Under non-BRE breach circumstances, there is no major river flowing through the compartment. Consequently controlled flooding has less effect here. On the other hand controlled drainage is the most important issues in Sirajganj compartment and hence needs careful attention. As explained previously it would be unwise at the short term NOT to incorporate the effects of major breaches in the BRE into this planning execrise. If breaches occur, the keyword "controlled flooding" changes into "flood control". The actual time span that this event occurs during a major BRE breach may vary from a single day to weeks depending on the magnitude and duration of the breach.

It is therefore suggested to use the subcompartmentalization principle to guide the options to be considered. The advantage of subcompartments is that certain watermanagement emergencies like a BRE breach can be localized and not, or to a lesser extent being allowed to affect adjacent compartments. The subcompartment boundaries (which are almost always paved roads or field roads) would then act as localized cells.

6.2 Watermanagement for Agriculture

One of the main targets of the structural interventions is the water management for agriculture. Flood protection and breach mitigation measures will ultimately lead to considerable prevention of crop damage. This security of the crop environment can be utilized to develop an effective water management system utilizing the compartment and sub-compartments.

The aim is to develop field block (or chawk) level water management. Individual sub-compartments are composed of several field blocks or chawks bounded by village roads or settlement areas. These chawks are physical entities and easily recognised by village people. Each field block has water inlets or outlets through bridges, culverts, roads breaches etc. By sealing road breaches, placing minor structures, pipe culverts, water retention devices, an effective water management at the field level will be established. Three important components of water management for agriculture are:

- **Drainage Improvement**: The actual impedance of drainage water in pre-monsoon and post-monsoon within the context of the existing infrastructure is a main constraint in further developing the area with an improved water resources control which should lead to increased agricultural production. Re-excavation of existing khals is proposed.

- **Water Retention**: Water retention to the physical withholding of water on the field or in a depression (or beel) in order to evenly distribute water specially rain water on different levels of land contours. This can be realized either by the construction of bunds or by the construction of water retention structures located in a depression, khal or existing beel.

- **Irrigation**: Dry season irrigation is an important component in water management. In *Sirajganj* area, irrigation is developed using the underground water. Use of surface water in dry season irrigation is very limited in areas near mainly to Ichamati khal. With re-excavation of khals and water retention measures, water can be stored and managed for dry season irrigation. Possibilities of irrigation inlet construction is phased later when surface water is available through the construction works of initial phases.

Four distinct agro-hydrological periods; pre-monsoon, monsoon, post-monsoon and the dry season with different management needs are considered.

Pre-monsoon (March to June)

During this period the Boro is harvested. It is cultivated from lowland upto high land areas. This crop may be damaged by water logging caused by execcessive early rainfall or an early high stage of the river.

Damage can be reduced by providing an effective drainage system. Furthermore, water retention can be established by construction of bunds on higher lands. An early high stage of the river can possibly be semi-controlled by installing and operating the peripheral/ internal structures.

Monsoon (July to September)

One of the aims of the project is to increase the area planted to monsoon rice including T.Aman (HYV). Due to the risk of high waterlevels from mid-July onwards, the present situation restricts the cultivation of extensive HYV Aman. In order to improve this situation, the waterlevels within the compartment should be lowered. The highest water level occurs during July. August will determine the potential area planted to T. Aman.

In order to get lower waterlevels during monsoon within the compartment, the following elements will be considered:

- peripheral control
- control intake of water in the compartment through the Ichamati branch
- control between the Ichamati river and the sub-compartments (controlled flooding and drainage)
- control between the sub-compartments (controlled flooding and drainage)
- water retention on the higher grounds especially highland and medium high land.

"Control" may assume various levels, including "semi-control" by ungated structures.

Post-monsoon (October)

During this period the lower land should be drained as early as possible in order to permit the cultivation of oil-seeds or other rabi from November onwards. The required water management element is the drainage of the low lying areas (not the permanent beels).

This can be established by improving the existing drainage system.

Dry-season (November to February)

The dominant activity during this period is the irrigation of the Boro crop by means of shallow and deep tube wells. Early drainage will enable timely sowing of Boro and a slight increase in the potential area. The actual recharge of the groundwater, in the *Sirajganj* compartment area, does not affect the availability of groundwater during the dry season in the future (Annex 6).

6.3 Watermanagement for Fisheries

Improved water management for agriculture will always have an adverse impact on fisheries due to the fact that the "water needs" of both production systems are in - principle conflicting. Within this context it is stressed upon that the objectives of the FAP 20 ToR can only be reached if all parties (ie; Agriculture and Fisheries) have a genuine willingness to compromise in this matter.

Optimal water management for agriculture as flood protection and drainage affects the piscicultural development as follows;

- Flood protection especially influences the river fish negatively as spawning grounds, nursing area for the hatchlings and ongrowing fish is reduced.
- Drainage of the rainwater congestion during the pre-monsoon hampers the reproduction of "Beel" fish due to an decreased rise in waterlevel in the beels, needed to stimulate spawning and limits recruitment even further due to a reduction in nursing area, needed for the just born larvae.

In order to increase the fisheries production within the project area, the following elements will be considered:

- Controlled water intake from the Jamuna river through "fish friendly" regulators (low sill level under free flow conditions whereby low/medium water velocities are maintained).
- Structural interventions for improvement of drainage will be executed in such a way that natural spawning of "beel" fish will be guaranteed as much as possible. A certain amount of rainwater congestion will be permitted in the beel area's during the pre monsoon. This can be done by the installation of fixed sill levels at the entrance of the drainage canal, below this level drainage will be impossible or by the construction of submergible embankements.

Flood protection will have a positive effect on aquaculture as ponds get not flooded anymore and the potential area where this kind of activity can be executed will be expanded.

6.4 Water management for Urban areas

In the existing situation, *Sirajganj* town areas may get flooded occasionally from high river stages, intensive rainfall or a combination of the two. The water management elements as required for the safety of the compartment and for agriculture will improve this situation, especially with respect to the river flooding.

Flushing of sewage system and industrial waste is of concern for *Sirajganj* town water management. The Baral river is to be re-excavated from its intake at BRE upto the Hurasagar river with provision of one flushing sluice as its intake for flushing purposes. An numbers of existing culverts shall be modified to increase their flowing capacity. A few new culverts are needed to be constructed. The existing internal drainage system within town are also needed to be improved to remove waterlogging. Existing drains are inadequate in size, length and number.

7 IMPLEMENTATION SCHEDULE AND COST ESTIMATES

7.1 General

The philosophy of the compartmentalization project can be realized through the implementation of a set of development targets. These development targets consist of both structural and non-structural aspects.

The implementation schedule of the structural targets is a function of;
*) the actual quantity and complexity of structures to be built;
*) the preparatory arrangements;
*) the finite planning horizon;
*) priority setting for the structures;
*) the implementation capacity of the executing agencies; and
*) the controlling/supervising capacity of the BWDB.

The actual quantity of the construction work will be primarily determined by the development optión as decided in a Consultation process to be held with the various interest groups in the CPP-Sirajganj area (including adjacent areas) . Also the complexity of the proposed structures will be largely determined by the people's opinions. The people's opinions are to be translated to feasible physical targets which can be implemented in a realistic time frame.

The preparatory arrangements of the structures-to-build mainly refers to all the detailed investigative work (topographical and hydrological surveys) in order to be able to submit a design to the responsable design office (DESIGN CIRCLE, Dhaka) which will be submitted in August 1993.

Nine steps are involved:

1) physical verification of proposed structure site;
2) plane table survey;
3) subsoil boring;
4) preparation of design documents;
5) preparation of land plan;
6) preparation of cost estimate;
7) preparation of tender document;
8) finalization of tender; and
9) issue of work order.

The total process of the first eight steps takes 3-4 months.

The finite planning horizon is determined by the project duration in which ultimately an identifiable target is to be achieved according to the ToR. The achievement of the set target is then used to evaluate the project on its merits and demerits and reach to a stage whereby a proper evaluation can be performed. In this case this phase has not yet been decided in a direct and clear mode.

The expected construction phase would approx take three years, starting from the 1993/1994 dry season. The duration would include the 1994/1995. Spillover would include the 1995/1996 year.

The actual sequence of structures to be built is largely determined by function of the structures within the overall context of the concept of compartmentalization. Certain categories of structures are proposed and the actual implementation sequence is performed according to the type of structures and its role in the overall setting.

The implementation capacity of the implementing agencies is to be taken into account due to its inherent constraints for implementation. Not only physical mobilization of contractors is constraining also factors such as the timely preparation of a construction program, available field personnel, transport for field personnel etc..

Construction supervision is an important component in the construction phase. It forms the backbone of a high quality construction program in which major flaws can be avoided and timely corrected.

7.2 Implementation schedule of structural elements

The following groups of structural elements have been identified.

I) EMBANKMENT/ROAD (EXCEPT BRE)

All the embankments on the periphery of CPP SIRAJGANJ can be included in this set of measures. Its main function is to protect the area from major floods originating from outside CPP Sirajganj. In OPTION 2A and OPTION 2B the proposed embankment actually encompasses a continuous embankment which includes the entire northern and western side of the compartment.

II) REGULATORS/BRIDGES

These structures have as main function to regulate water
*) from outside the compartment (as peripheral); or
*) from a neighbouring SC
to

*) a neighbouring SC; or
*) the external drainage system.

III) IMPROVING EXISTING REGULATORS

Some of the existing regulators need an improvement or adjustment based on changed circumstances for its perceived use, faulty design or lack of maintenance.

IV) DRAINAGE CHANNEL EXCAVATION

Drainage channel excavation forms an important part of the improvement on the drainage system. The most important channels in the existing drainage system need to be re-excavated.

V) EROSION PROTECTION

The breach mitigation measures (embankments/roads) are to be accompanied by erosion protection measures. These are especially necessary adjacent to the major structures in the breach mitigation embankments due to the high risk of excessive erosion as a result of anticipated high waterlevels and/or high flow velocities.

VI) FIELDLEVEL WATERMANAGEMENT

Fieldlevel watermanagement forms the backbone of an integrated water manangement system which can considerably improve the water use efficiency. Microlevel changes in fieldlevel can make watermanagement less effective. It is proposed that in all SC's this microlevel improvement is to be performed.

VII) MITIGATION MEASURES

The impact of the CPP Sirajganj project activities on the surrounding area and within the area can affect the people concerned negatively. The most obvious places for mitigation measures are those areas where the impact of the Ichamuti emabnkmnet is felt. Therefore, a special set of mitigation measures are proposed to counterbalance these negative effects.

VIII) BRAHMAPUTRA RETIRED EMBANKMENT

Based on historical data it is estimated that on the average, every year a certain length of the BRE needs to be retired. In a number of consecutive years, this can be even the same location which suffers from a breach.

IX) SIRAJGANJ TOWN DEVELOPMENT

Sirajganj town is part of the compartment and due to its urban population and needs, it is proposed to treat Sirajganj town as a separate unit. This set of measures are aimed at improving the existing sewage system in town by the construction of a flushing inlet together with the excavation of the major khal in town.

7.3 Cost estimates of structural elements

The estimate on total construction cost is based on Schedule of Rates for Compartmentalization Pilot Project, BWDB, Tangail effective from 1-9-1992. For a number of items a unit cost price approach is maintained while for a number of items a lump sum approach is used.

The total set of possible structural elelments have been divided into Groups. Each Group is a functional unit whereby all structures with similar purposes are put together. The only exception is Group IX which encompasses Sirajganj Town Development.

Group I is formed by items including Embankments/Roads.
The total volume for this group is estimated on a M3 basis. For the Ichamuti embankment scenarios a detailed survey has been performed while for other SC boundaries and roads an estimate has been made based on topographical maps.

The Group II (Regulators/Bridges) and Group III (Improving Existing Regulators) cost estimate is based ón a lumpsum approach only.

Group IV (Drainage Channel Excavation) cost estimate is based on detailed topographical survey.

Group V (Erosion Protection), Group VI (Fieldlevel Watermanagement), Group VII (Mitigation Measures Adjacent Areas) Group VIII (Brahmaputra Retired Embankment) and Group IX (Sirajganj Town Development) are in principle all based on lumpsum approaches.

TABLE 7.1: COST ESTIMATE FOR OPTION 1

COMPARTMENTALIZATION PROJECT WITHOUT THE ICHAMUTI EMBANKMENT

ITEM	Unit	Qty.	Unit Price	Cost 93/94	Cost 94/95	Cost 95/96	Total Lakh
I EMBANKMENT/ROAD							
EMBKMT SC1/3	M3	83270	0.0003	25.0	-	-	25.0
EMBKMT SC3/5	M3	135850	0.0003	40.8	-	-	40.8
EMBKMT SC5/7	M3	50000	0.0003	-	-	15.0	15.0
EMBKMT SC4/6	M3	30000	0.0003	-	-	9.0	9.0
IMPROVING ROADS	M3	200000	0.0003	-	-	60.0	60.0
II REGULATOR/BRIDGE							
REG. BIR SUBGACHA 5-VENT	PCS	1	80	40.0	40.0	-	80.0
REG. ITALI 5-VENT	PCS	1	80	40.0	40.0	-	80.0
REG. PEOPLE BARIA 5-VENT	PCS	1	80	40.0	40.0	-	80.0
BRIDGE BAHUKA	PCS	1	20	-	-	20.0	20.0
REG. SHAMPUR 5-VENT	PCS	1	80	-	80.0	-	80.0
REG. DEGREE PAKA 5-VENT	PCS	1	80	-	80.0	-	80.0
REG. BAHULI 3-VENT	PCS	1	60	-	60.0	-	60.0
REG. CHALKFULKOCHA 3-VENT	PCS	1	60	-	60.0	-	60.0
REG. JHINGATI 3-VENT	PCS	1	60	-	60.0	-	60.0
INLET BRE	PCS	3	30	30.0	30.0	30.0	90.0
III IMPROVING EXISTING REGULATOR							
REG. 3-VENT SALUA BHITA	PCS	1	10	-	10.0	-	10.0
IV DRAINAGE CHANNEL							
BANIAJAN RIVER	M3	54500	0.00026	-	14.2	-	14.2
RAGHURGAH KHAL	M3	59397	0.00026	-	15.4	-	15.4
BAGDUMUR KHAL	M3	35000	0.00026	-	9.1	-	9.1
JHENIGATI KHAL	M3	20000	0.00026	-	5.2	-	5.2
KHANGATI KHAL	M3	8000	0.00026	-	2.1	-	2.1
SUNDIBEEL KHAL	M3	28800	0.00026	-	7.5	-	7.5
PINEALGATI KHAL	M3	46750	0.00026	-	12.2	-	12.2
ICHAMATI KHAL	M3	599000	0.00026	155.7	-	-	155.7
ICHAMOTI BRANCH	M3	134500	0.00026	35.0	-	-	35.0
V EROSION PROTECTION							
BREACH PROTECTION BIR SUBGACHA	LS	1	25	-	12.5	12.5	25.0
BREACH PROTECTION ITALI	LS	1	15	-	7.5	7.5	15.0
BREACH PROTECTION PEOPLE BARIA	LS	1	15	-	7.5	7.5	15.0
BREACH PROTECTION DEGREE PAKA	LS	1	15	-	7.5	7.5	15.0
BREACH PROTECTION CHALKFULKOCH	LS	1	15	-	7.5	7.5	15.0
BREACH PROTECTION JHINGATI	LS	1	15	-	7.5	7.5	15.0
BREACH PROTECTION SALUABHITA	LS	1	15	-	7.5	7.5	15.0
VI FIELDLEVEL WATERMANAGEMENT							
MICROLEVEL/CHAWK IMPROVEMENT	LS	1	50	-	50.0	-	50.0
WATERRETENTION STRUCTURES	LS	10	15	-	150.0	-	150.0
FLUSHING SLUICES	LS	10	10	-	100.0	-	100.0
CULVERTS	PCS	20	5	-	100.0	-	100.0
VII MITIGATION MEASURES	LS	1	71	-	61.0	10.0	71.0
VIII BRAHMAPUTRA RETIRED EMBANKMENT							
RETIRED EMBANKMENT PER YEAR	KM	2	20	13.3	13.3	13.3	40.0
IX SIRAJGANJ TOWN DEVELOPMENT							
CONSTRUCTION FLUSHING SLUICE	PCS	2	30	-	30.0	30.0	60.0
CONSTRUCTION BRIDGES	PCS	3	20	-	30.0	30.0	60.0
EXCAVATION KATAKHALI KHAL	M3	100000	0.00026	-	13.0	13.0	26.0
EROSION PROTECTION SLUICE	PCS	2	20	-	20.0	20.0	40.0
Annual Construction Cost				419.8	1190.5	307.8	
Total Construction Cost : Option 1							1918.1

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TABLE 7.2: COST ESTIMATE FOR OPTION 2A

COMPARTMENTALIZATION PROJECT WITH THE ICHAMUTI EMBANKMENT (ALIGNMENT I)

	ITEM	Unit	Qty.	Unit Price	Cost			Total
					93/94	94/95	95/96	Lakh
I	EMBANKMENT/ROAD							
	ICHAMUTI EMBKMT ALIGNMENT I	M3	876400	0.00028	81.8	81.8	81.8	245.4
	EMBKMT SC1/3	M3	83270	0.0003	25.0	-	-	25.0
	EMBKMT SC3/5	M3	135850	0.0003	40.8	-	-	40.8
	EMBKMT SC5/7	M3	50000	0.0003	-	-	15.0	15.0
	EMBKMT SC4/6	M3	30000	0.0003	-	-	9.0	9.0
	IMPROVING ROADS	M3	200000	0.0003	-	-	60.0	60.0
II	REGULATORS/BRIDGE							
	REG. GARUDAHA 3-VENT	PCS	1	60	-	-	60.0	60.0
	REG. ISAMOTI 3-VENT	PCS	1	60	-	-	60.0	60.0
	REG. BEEL GAJARIA 5-VENT	PCS	1	80	-	40.0	40.0	80.0
	REG. BIR SUBGACHA 5-VENT	PCS	1	80	40.0	40.0	-	80.0
	REG. ITALI 5-VENT	PCS	1	80	40.0	40.0	-	80.0
	REG. PEOPLE BARIA 5-VENT	PCS	1	80	40.0	40.0	-	80.0
	BRIDGE BAHUKA	PCS	1	20	-	-	20.0	20.0
	REG. SHAMPUR 5-VENT	PCS	1	80	-	80.0	-	80.0
	REG. DEGREE PAKA 5-VENT	PCS	1	80	-	80.0	-	80.0
	REG. BAHULI 3-VENT	PCS	1	60	-	60.0	-	60.0
	REG. CHALKFULKOCHA 3-VENT	PCS	1	60	-	60.0	-	60.0
	REG. JHINGATI 3-VENT	PCS	1	60	-	60.0	-	60.0
	INLET BRE	PCS	3	30	30.0	30.0	30.0	90.0
III	IMPROVING EXISTING REGULATOR							
	REG. 3-VENT SALUA BHITA	PCS	1	10	-	10.0	-	10.0
IV	DRAINAGE CHANNEL							
	BANIAJAN RIVER	M3	54500	0.00026	-	14.2	-	14.2
	RAGHURGAH KHAL	M3	59397	0.00026	-	15.4	-	15.4
	BAGDUMUR KHAL	M3	35000	0.00026	-	9.1	-	9.1
	JHENIGATI KHAL	M3	20000	0.00026	-	5.2	-	5.2
	KHANGATI KHAL	M3	8000	0.00026	-	2.1	-	2.1
	SUNDIBEEL KHAL	M3	28800	0.00026	-	7.5	-	7.5
	PINEALGATI KHAL	M3	46750	0.00026	-	12.2	-	12.2
	ICHAMATI KHAL	M3	599000	0.00026	-	155.7	-	155.7
	ICHAMUTI BRANCH	M3	134500	0.00026	-	35.0	-	35.0
V	EROSION PROTECTION							
	BREACH PROTECTION BIR SUBGACHA	LS	1	25	-	12.5	12.5	25.0
	BREACH PROTECTION ITALI	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION PEOPLE BARIA	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION DEGREE PAKA	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION CHALKFULKOCHA	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION JHINGATI	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION SALUABHITA	LS	1	15	-	7.5	7.5	15.0
VI	FIELDLEVEL WATERMANAGEMENT							
	MICROLEVEL/CHAWK IMPROVEMENT	LS	1	50	-	50.0	-	50.0
	WATERRETENTION STRUCTURES	LS	10	15	-	150.0	-	150.0
	FLUSHING SLUICES	LS	10	10	-	100.0	-	100.0
	CULVERTS	PCS	20	5	-	100.0	-	100.0
VII	MITIGATION MEASURES	LS	1	71	-	61.0	10.0	71.0
VIII	BRAHMAPUTRA RETIRED EMBANKMENT							
	RETIRED EMBANKMENT PER YEAR	KM	2	20	13.3	13.3	13.3	40.0
IX	SIRAJGANJ TOWN DEVELOPMENT							
	CONSTRUCTION FLUSHING SLUICE	PCS	2	30	-	30.0	30.0	60.0
	CONSTRUCTION BRIDGES	PCS	3	20	-	30.0	30.0	60.0
	EXCAVATION KATAKHALI KHAL	M3	100000	0.00026	-	13.0	13.0	26.0
	EROSION PROTECTION SLUICE	PCS	2	20	-	20.0	20.0	40.0
	Annual Construction Cost				310.9	1503.0	549.6	
	Total Construction Cost : Option 2A							2363.5

TABLE 7.3: COST ESTIMATE FOR OPTION 2B

COMPARTMENTALIZATION PROJECT WITH ICHAMUTI EMBANKMENT (ALIGNMENT II)

	ITEM	Unit	Qty.	Unit Price	Cost 93/94	94/95	95/96	Total Lakh
I	EMBANKMENT/ROAD							
	ICHAMUTI EMBKMT ALIGNMENT II	M3	1379500	0.00028	128.8	128.8	128.8	386.3
	EMBKMT SC1/3	M3	83270	0.0003	25.0	-	-	25.0
	EMBKMT SC3/5	M3	135850	0.0003	40.8	-	-	40.8
	EMBKMT SC5/7	M3	50000	0.0003	-	-	15.0	15.0
	EMBKMT SC4/6	M3	30000	0.0003	-	-	9.0	9.0
	IMPROVING ROADS	M3	200000	0.0003	-	-	60.0	60.0
II	REGULATORS/BRIDGE							
	REG. GARUDAHA 3-VENT	PCS	1	60	-	-	60.0	60.0
	REG. ISAMOTI 3-VENT	PCS	1	60	-	-	60.0	60.0
	REG. BEEL GAJARIA 5-VENT	PCS	1	80	-	40.0	40.0	80.0
	REG. BIR SUBGACHA 5-VENT	PCS	1	80	40.0	40.0	-	80.0
	REG. ITALI 5-VENT	PCS	1	80	40.0	40.0	-	80.0
	REG. PEOPLE BARIA 5-VENT	PCS	1	80	40.0	40.0	-	80.0
	BRIDGE BAHUKA	PCS	1	20	-	-	20.0	20.0
	REG. SHAMPUR 5-VENT	PCS	1	80	-	80.0	-	80.0
	REG. DEGREE PAKA 5-VENT	PCS	1	80	40.0	40.0	-	80.0
	REG. BAHULI 3-VENT	PCS	1	60	-	60.0	-	60.0
	REG. CHALKFULKOCHA 3-VENT	PCS	1	60	-	60.0	-	60.0
	REG. JHINGATI 3-VENT	PCS	1	60	-	60.0	-	60.0
	INLET BRE	PCS	3	30	30.0	30.0	30.0	90.0
III	IMPROVING EXISTING REGULATOR							
	REG. 3-VENT SALUA BHITA	PCS	1	10	-	10.0	-	10.0
IV	DRAINAGE CHANNEL							
	BANIAJAN RIVER	M3	54500	0.00026	-	14.2	-	14.2
	RAGHURGAH KHAL	M3	59397	0.00026	-	15.4	-	15.4
	BAGDUMUR KHAL	M3	35000	0.00026	-	9.1	-	9.1
	JHENIGATI KHAL	M3	20000	0.00026	-	5.2	-	5.2
	KHANGATI KHAL	M3	8000	0.00026	-	2.1	-	2.1
	SUNDIBEEL KHAL	M3	28800	0.00026	-	7.5	-	7.5
	PINEALGATI KHAL	M3	46750	0.00026	-	12.2	-	12.2
	ICHAMATI KHAL	M3	599000	0.00026	-	155.7	-	155.7
	ICHAMUTI BRANCH	M3	134500	0.00026	-	35.0	-	35.0
V	EROSION PROTECTION							
	BREACH PROTECTION BIR SUBGACHA	LS	1	25	-	12.5	12.5	25.0
	BREACH PROTECTION ITALI	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION PEOPLE BARIA	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION DEGREE PAKA	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION CHALKFULKOCH	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION JHINGATI	LS	1	15	-	7.5	7.5	15.0
	BREACH PROTECTION SALUABHITA	LS	1	15	-	7.5	7.5	15.0
VI	FIELDLEVEL WATERMANAGEMENT							
	MICROLEVEL/CHAWK IMPROVEMENT	LS	1	50	-	50.0	-	50.0
	WATERRETENTION STRUCTURES	LS	10	15	-	150.0	-	150.0
	FLUSHING SLUICES	LS	10	10	-	100.0	-	100.0
	CULVERTS	PCS	20	5	-	100.0	-	100.0
VII	MITIGATION MEASURES	LS	1	71	-	61.0	10.0	71.0
VIII	BRAHMAPUTRA RETIRED EMBANKMENT							
	RETIRED EMBANKMENT PER YEAR	KM	2	20	13.3	13.3	13.3	40.0
IX	SIRAJGANJ TOWN DEVELOPMENT							
	CONSTRUCTION FLUSHING SLUICE	PCS	2	30	-	30.0	30.0	60.0
	CONSTRUCTION BRIDGES	PCS	3	20	-	30.0	30.0	60.0
	EXCAVATION KATAKHALI KHAL	M3	100000	0.00026	-	13.0	13.0	26.0
	EROSION PROTECTION SLUICE	PCS	2	20	-	20.0	20.0	40.0
	Annual Construction Cost				397.9	1510.0	596.6	
	Total Construction Cost : Option 2B							2504.3

7.4 Implementation Schedule of Non-Structural Measures

The main non-structural interventions are:

- establishing the Compartmentalization Pilot Project Steering Committee
- facilitating GOB interdepartmental cooperation
- training programme
- consultation process
- establishing and facilitating Water Users Groups
- establishing and facilitating Landless Contracting societies
- establishing and facilitating Sub-Compartmental Water Management Committees
- establishing and facilitating Embankment, Channel and Structures Maintenance Groups

The CPPSC is to be established by November 1993. From mid 1994 onwards the CPPSC is to be expanded with representatives from the SCWMC. This process will continue until mid 1995. By that time the CPPSC should be transformed into the Sirajganj Compartment Water Management Committee. For more details see Annex 7.

The training programme is to start by September 1993. It will peak during the first year after that and then continue at a lower level for another 2 years. For more details see Annex 7.

The activities related to water management inside the compartment (from the consultation process to establishing Embankment Maintenance Groups) are phased in such a way that they precede the planned structural interventions (see previous section). The following overall implementation schedule is planned;

- Oct 1993-May 1994; Sub-compartments 1, 2, 3 and NE and NW adjacent areas
- Oct 1994-Feb 1995; Sub-compartments 4, 5, 6, 7, 8, 9 and the Western adjacent area

The following detailed plan is proposed to complete the consultation process. It may be noted that, before writting the SIR, one first phase consultation meeting was held in each sub-compartment for each interest group. As this does not provide sufficient coverage to facilitate futhure institutionalization, one more meeting per sub-compartment and per interest group is now planned to complete the first phase of consultation meetings.

<u>**Sub-Compartments 1-3, N and NW adjacent area**</u>

1st Oct - 25 Nov. 1993	:	Second half of first phase (with Sub-Compartmental Development Plan) consultation meetings with separate Interest Groups
25th Nov. - 15 Dec. 1993	:	Combined meetings with contact persons including elected Representatives, local Elites and village Matabbars.

20th Dec. - 15 Feb. 1994	:	Second phase of separate Interest Group meetings
10th Feb. - 15th Mar. 1994	:	Combined meetings with contact persons including elected Representatives, local Elites and village Matabbars.

Sub-Compartments 4 - 9, & Western adjacent area

21st Mar. - 31 May 1994	:	Second half of the first phase consultation meetings with separate Interest Groups.
June 1994	:	Combined meetings with contact persons including elected Representatives, local Elites and village Matbars.
September- December 1994	:	Second phase of separate Interest Group meetings
January 1995	:	Combined meeting with contact persons and elected Representatives

The above schedule has been made to fit in with the proposed construction schedule. As such it does not delay the construction, but runs parallel. This schedule leaves time for the necessary feedback to the planners so that plans can be adjusted in the light of the findings during the consultation process. If few conflicts of interest exist in an area, then the second phase of separate meetings may be shortened.

Within this overall framework the consultation process will be the starting point for the non-structural interventions in the Sub-Compartments. It will be followed by the establishment of WUGs and SCWMCs.

In October 1993 a start will be made with establishing LCSs. EMG will be formed as and when embankments are completed and maintenance can be taken up.

7.5 Cost Estimates of Non-Structural Measures

The cost estimate of the non-structural interventions has been calculated based on the experience gained from CPP-Tangail to date.

	1993/94	1994/95	Total Lakh Tk
1 Consultation process	3	2	5
2 Establishing CPP/SC and SCWMC	2	1	3
3 Establishing WUGs	15	8	23
4 Establishing SCWMCs	1	3	4
5 Facilitating LCSs and EMGs	2	2	4
6 Publicity and information	2	1	3
7 Seminars, courses, workshops	3	4	7
8 Training in Bangladesh	4	5	9
9 Training outside Bangladesh (Except Netherlands)	15	16	31
10 Training in The Netherlands	6		6
Total	*53*	*42*	*95*

7.6 Implementation Schedule

The work planning of structural and non-structural interventions have been merged in such a way that a fine-tuned match is found between these components.

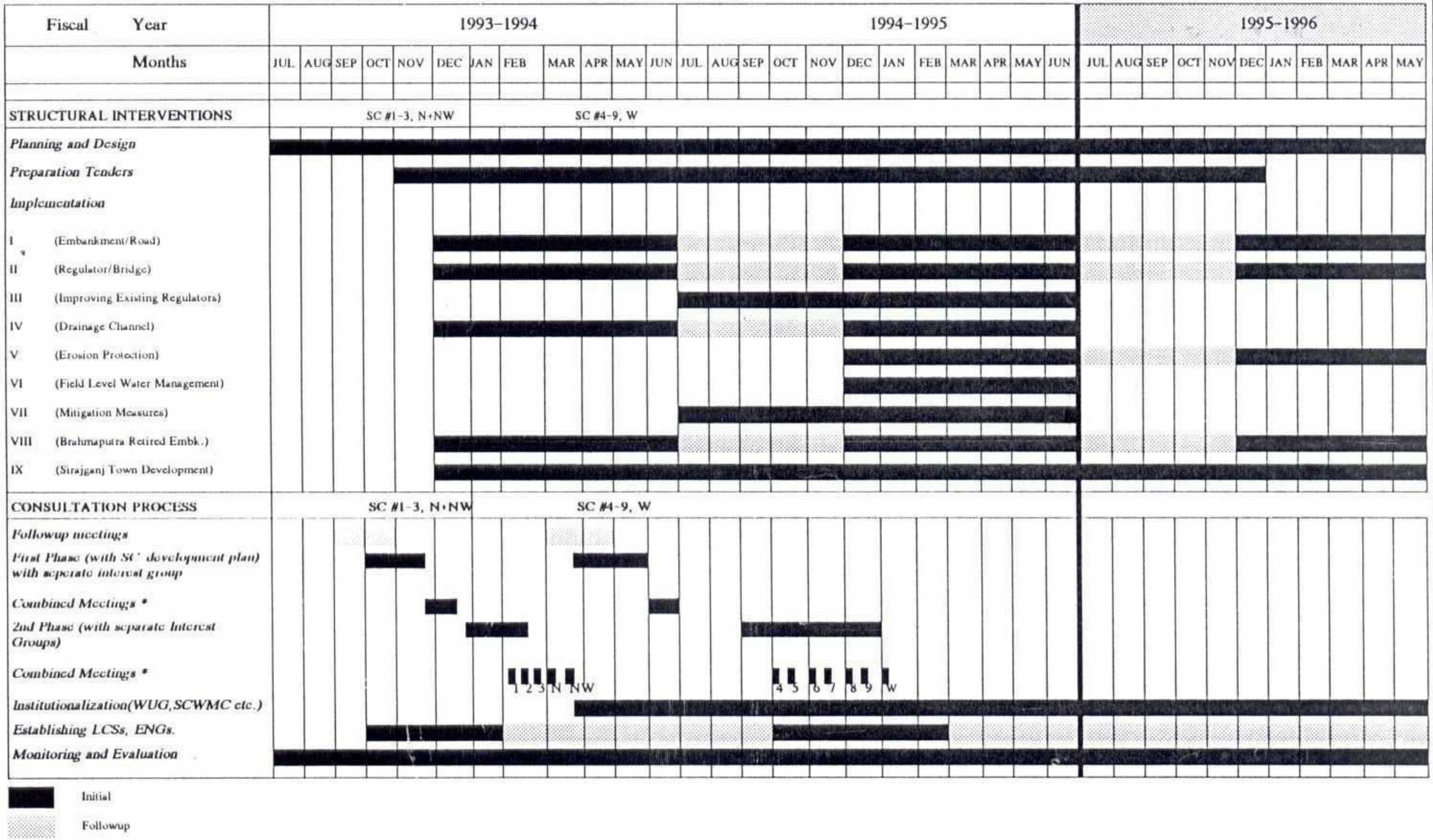
The main points from the proposed work planning Figure 7.1.

*) The consultation process in all its phases preceeds any structural intervention.

*) The priority is given to consultation and a direct follow up by implementation of structural elements in the SC 1,2 and 3 for the first year. This allows sufficient time for the consulation proces to be performed in all the other SC's in the second (1994/1995) year.

*) The priority is based on the assumption that although the BRE is sealed, there is still a chance that a breach may occur under exceptional circumstances. Therefore, the protection of the compartment should receive first priority in case a breach occurs.

FIGURE 7.1 : GENERAL IMPLEMENTATION SCHEDULE OF CPP SIRAJGANJ : 1993-1995 (1996)



* Including contact persons, elected representatives, local elites, village matabbars etc.

8 OPERATION AND MAINTENANCE

8.1 General

The O&M of the entire CPP-compartment is incorporated in the O&M responsability of the BWDB, LGED, DRH and local government. Due to the fact that this CPP project has a temporary character, the actual O&M responsability should be, in principle entirely be covered by already existing institutions which are bound to remain functioning in the area. However, it is possible that certain specific tasks for the O&M of this area is being executed by a temporary agency and in a later stage provisions are made to hand over (turnover) this responsability to existing and permanent agencies.

A special case is the presence of the main embankment along an erosive and braided river. Since its construction in the 1960's, reality has proven to be worse than the expectations during construction. The number of breaches, which started to emerge in thge 1980's poses severe restrictions on the usefullness of the BRE as a device for flood protection at aregional scale. The impact of breaches in any section of the BRE can be substantial according to the frequency, duration and location of the breach.

One should realize that the BRE post-breach management definitely includes the resource allocation to repair the major damages done by a BRE breach. This resource allocation should come from the present organization in charge of the BRE construction and maintenance (BWDB). Regarding longterm planning, a regionally or nationally operating FAP project should make the necessary funds available for a more consistent and general solution of the BRE breach control. The necessary financial and other resources will be accordingly adjusted and allocated.

Operation and Maintenance (O&M) is an easy subject to discuss about in general terms, however, the specifics are commonly very complicated. For the operation and maintenance of structures (including roads and embankments) there are a number of departments involved. At this stage of the interim report on Sirajganj, a fine distinction of responsabilities between the different Departments is not being proposed. The Operation and Maintenance responsabilities of the two main organizations involved are pointed out in general terms.

These departments are: BWDB and LGED.

Their responsabilities are: BWDB:

1) (O&M report):

a) prepare for approval of the GOB a scheme for the control of floods in the development and utilization of water resources of Bangladesh;

b) frame a scheme or schemes for the whole of Bangaldesh or any part thereof providing all or any of the following matters, namely:

i) construction of dams, barrages, reservoirs and other original works, irrigation, embankments and drainage;

ii) flood control including watershed management;

iii) prevention of salinity, water congestion and reclamation of land;

iv) maintenance, improvement and extension of channels, including dredging of channels but excluding all such operations asa may be assigned by the Government to any other agency; and

v) regulation of channels to concentrate river flows for more efficient movement of water.

In 1983 a separate member O&M was appointed to head O&M organization with responsibilities for:

* preparation of detailed operations and maintenance manuals

* operation and maintenance of completed schemes

* annual report with full data for all operating schemes

* rehabilitation of completed schemes

* identification, design and implementation of small schemes

The Zonal Chief Engineers through their Superintending Engineers, are responsable for the O&M field divisions. O&M field divisions, headed by an Executive Engineers are responsable for:

- operation and maintenance of completed schemes
- rehabilitation of deteriorated schemes

- surveys and investigations for new small schemes initiated by the O&M organization
- implementation of small schemes

The Local Government Engineering Bureau (LGED):

The LGED was established under the Local Government Division, Ministry of Local Government Rural Development and Cooperatives.

Its main functions are to provide technical support to Zila Parishads, Upazila parishads, Pourshavas and agencis like BRDB in the construction , operation and maintenance of local civil infrastructure. In addition to their responsabilities to local water control facilities such as embankments and their appurtenant structures, the responsabilities of the LGEB also extends to small FCD schemes transfered from the jurisdiction of BWDB.

Operation and Maintenance forms the backbone of water related projects. Many times, this O&M falls short of expectations due to a long list of possible shortcomings. The most prominent are:

*) poor planning
*) design deficiencies
*) organizational constraints
*) institutional difficulties.

In the ToR a compartment is described as a "management unit". Of such a compartment it is said that "... the involvement of the beneficiaries is considered essential for its success." [ToR, p.3].

8.2 Special status of the Brahmaputra Right Embankment (BRE)

The BRE is of paramount importance in the overall appraisal of CPP Sirajganj. It is the single most important feature of the project area. The Operation and Maintenance of the BRE is officially under supervision of the BWDB (O&M) division , Bogra Circle. The actual tasks performed by the BWDB (O&M) division has ONLY been the construction of retired embankments in the areas under supervision of BWDB (O&M)-Bogra. Other tasks have apparently not been performed although one would assume that actually all the O&M of water related isues in the CPP Sirajganj is under BWDB (O&M) responsability.

The BRE performs a peculair task within the CPP project setting and therefore should be as such be treated in the overall concept.

It has also been concluded from previous studies (FAP 1) that single groynes have demonstrated limited value, especially in a braided river such as the Brahmaputra where the approach conditions can vary so rapidly and widely. Under the most favourable conditions, the influence of the groyne may extend up to 2.5 times its length downstream. Any change in the angle of approach or alignment of the river will reduce the zone of influence.

The BRE is a structure built in 1960-1980 period and its condition very much influences the present and future on the development of the CPP-area. The BRE has been acting as a barrier to flood occurrences originating from the Jamuna since its initiation in 1963. Its entire length of more than 200 km and its deteriorating status at the moment does have a major impact on the mid and short term. In fact the impact area of the BRE can be estimated at an area of at least 30 KM parallell from the actual BRE with at some locations even more due to the indirect effect of floods originating from the Jamuna which then cause major areas to experience moderate to severe drainage congestion for shorter or longer periods of time. These 20 miles are related to surface water behaviour and refers to the parallell distance between the Jamuna and river.

8.3 Operations of the structures

The wide range of structures as presented previously permits a flexible water management of the compartment. It should be such that different requirements can be met and that a wide range of circumstances can be controlled.

In principle drainage water (either from runoff within the compartment and/or local rainfall) is to be kept out of the compartment during the monsoon season. The preferred situation of the pre- and post-monsoon is that water can be kept in the compartment but at a minimum level so that agricultural damage is minimized.

The situation for agricultural/piscicultural purposes is that it is necessary to "fill up" the compartment sufficiently in the pre-monsoon to let the fish-fry enter through the BRE inlets and through the major rivers
(e.g. Bangali river-system).

However, the rate of waterlevel raise in certain compartments should be carefully monitored during pre-monsoon season together with the rate of waterlevel raise from the Jamuna and other rivers. If both river systems show a fast waterlevel raise, one should drain the SC as much as possible through the internal drainage system in order to be able to coop with local rainfall and rainfall-runoff within the compartment area.

The responsability for the operations of the structures is originally covered by the organizatuon who has implemented it and subsequently this agency or organization is to turnover the operation to the beneficiaries. However, it is possible that the time lapse between the time of construction could be finished and the actual turnover to the beneficiaries will take a long time. Furthermore, for compartment level decisions an active role is needed by the BWDB.

The structures as presented in Chapter 3, should permit a flexible water management of the compartment. It should be such that different requirements can be met.

This may go from the simulation of the existing situation where only during high flood the peripheral control structures will be closed (when it is decided to install gates in the northern inlets). It may also go up to a fully controlled situation where, depending on the hydrological conditions, only limited amounts of water will be allowed to enter the compartment and excess rainwater will be drained whenever possible.

As the operation procedures for the first situation are rather simple, all gates are open until an extreme flood event occurs whereupon all peripheral gates will be closed, this will not be dealt with here. However, it should be understood that a strong institutional set-up is a pre-requisite for such gated structures.

The operation procedures for the second situation is more complex and are fully dependant on the prevailing hydrological conditions. In the following sections the structures will be grouped as follows:

- Peripheral control structures with regional requirements. This is the main inlet structure at the entrance of the *Bir Subgacha*.

- Peripheral control structures without regional requirements. This implies the medium inlet structures at *the new inlet structures locations at the BRE.*

- Compartmental outlet structures. This implies the structures at the Ichamuti river at Garudaha, Isamoti, and Beel Gajaria.

- Subcompartmental regulating structures at Itali, People Baria, Chalk Fulkocha, Degree Paka, Jhinaigati, Salua Bita and Bahuli.

- Minor drainage outlets to the *Ichamati River,* to major drains and to the southern adjacent area.

- Irrigation inlets along the Ichamoti river/khal/branch

- Irrigation passes along the adjacent rivers for dry season and wet season supplemental irrigation.

- Water retention structure at Shampur

In the ToR a compartment is described as a "management unit". Of such a compartment it is said that "... the involvement of the beneficiaries is considered essential for its success." [ToR, p.3]. In the long term this means that all concerned must be involved in operation. To provide the necessary sustainability their involvement in maintenance is also essential.

In this chapter the technical side of operating the different types of structures is dealt with first. Next the institutional side of operation is looked at and in the final section maintenance.

8.4 Technical guidelines

The following indication for the operation of the structures will be based on a typical year that starts with a dry compartment and low rivers; with abundant rainfall during the pre-monsoon; rising water levels in the rivers and the compartment during the monsoon and declining rainfall and river levels during the post-monsoon.

Peripheral control structure with regional requirements (main regulator)

At the start of the monsoon season the gates of the main inlet will be fully open. Flooding from the river is highly unlikely before mid June so that there will be no harm to the *Boro* crop.

In general, upto mid-July there is no requirement for flow-regulation for agricultural purposes. However, it may be necessary to throttle the regulator openings before that date in case early flooding occurrs which may damage the Boro harvest. During this first period fish migration should be facilitated as much as possible.

From mid-July onwards there is a need for reduced water levels within the compartment for the planting of HYV Aman.

Peripheral control structures without regional requirements

These structures will also remain open till mid-July in a typical year. There after it is possible to regulate the flow, depending on the needs of the beneficiaries flow will be regulated. It is proposed that for these structures again 2 blade vents will be used. This will imply that a first stage of regulation will be done by lowering the first blade, still permitting overspill flow, which is considered less harmful to fish migration.

In order to obtain sufficient control over the water levels within the compartment, these gates shall be completely closed for several days during several flood/rainfall events during the monsoon season. Depending on the downstream water level condition these structures may be fully open again during low flood periods in the monsoon.

At the end of the monsoon these structures are to be fully opened again as they will provide some drainage of a limited command area. These gates should also be opened when the emergency spillways start functioning (expected with the 1:20 years flood).

Compartmental outlet structures

These structures may serve both as inlet and outlet structures depending on the compartment/river water level.

Before mid-July they shall be open. They may serve as an outlet for the compartment during high local rainfall or as in inlet, permitting fish migration, during an early flood situation.

After mid-July the emphasis of these structures shall be on drainage promoted by the head difference over the main inlet. At a river stage higher than the compartment level they shall be closed and be opened again when the situation reverses.

Sub-compartmental regulating structures

These structures do consist of two parts; a low section with a regulator based on the pre-monsoon discharge requirement and a weir section where the fixed weir level is based on the required water level in the upstream part during the monsoon.

The regulator part will be open during pre-and post-monsoon periods and closed from mid July onwards.

During an extreme flood when the emergency spill sections are functioning, the weir section will permit a full discharge.

Minor drainage outlets

The operation procedures for these structures may be similar to the compartmental outlet structures. Since the operation procedures for the compartmental outlet structures are quite complicated it is suggested that the minor drainage outlets be open during pre and post monsoon and be closed continuously from mid July onwards. Their capacity is limited and it may be expected that the necessary discharge during the monsoon passes via overland flow to the compartmental outlet structures.

Irrigation inlets

The irrigation inlets will normally be closed. Only during dry spells in the monsoon period they may be opened for flooding of the compartment.

Irrigation passes

Irrigation passes mainly serve a purpose during the dry season to permit flow from low-lift pumps through the embankment. They are normally closed during the wet season except for supplemental irrigation during dry spells with low water levels in the adjacent rivers.

When the river flooding is late start of the regulation should be at a later date to permit sufficient migration of fish. When river flooding starts exceptionally early it may be suggested to invoke peripheral control in May/June in order to prevent damage for the Boro harvest.

It may be suggested furthermore that different parts of the compartment will be exposed to different levels of control thus favouring fisheries or another group of beneficiaries, instead of agriculture.

8.5 Institutional guidelines for operation

The complexity of the structure and the scope of its impact will determine which institutional arrangements for its operation are desirable. The actual competence of a particular institution will determine whether responsibilities for operation will indeed be delegated to that institution, possibly after training and with provisions for technical advice.

In practical terms this means that operation of structures that affect areas larger than the compartment will, for the time being, be done by the BWDB. Lacking any representative institutions beyond the compartmental level and taking into account the sophistication of operation requirement, the BWDB provides the only practical option.

Going below this level the envisaged Compartment Water Management Committee can, when built up to a sufficient degree of capability and representation, be charged with decisions regarding operation that affect the compartment as a whole. FAP 20 intends to install the Provisional Compartment Water Management Committee after mid 1995, when all sub-compartments will be established physically and institutionally, and when relevant training is expected to be completed. The precursor to this provisional committee is the

CPP/Executive Committee which might gradually become involved in advice and guidance regarding operation of main structures. Whatever the precise arrangements will be, three conditions will need to be met in the case of compartmental institutions assuming some degree of responsibility for operation:

- the establishment of operational guidelines by CPP and BWDB
- the establishment of consultative arrangements with Sub Compartment Water Committees.
- effective understanding with other relevant agencies, such as LGED, Union Councils.

For structures that substantially affect more than one sub-compartments either the concerned SCWC will establish a mechanism for joint operation, or the CWMC will assume responsibility for these structures. The latter will be the case if the number of involved sub-compartments and/or the competence or compatibility of the concerned sub-compartments do not allow the decentralization of these decisions and their monitoring.

For structures that essentially affect only a particular sub-compartment, the SCWC will be in charge. In a number of cases the "boundary conditions" for the operation of such structures will be determined by the CWM. This will be determined on a case by case basis, depending on technical criteria. The SCWC will oversee operation, consulting with CWM and BWDB on the one hand and with Water Users Groups on the other.

Structures that affect only an area within a sub-compartment will be the responsibility of a Water Users Group, provided such a group exists and reflects a balanced representation of the various socio-economic categories of those concerned. In many cases this will be obvious, e.g. an irrigation inlet supplying an identifiable group of farmers. In other cases the situation could be more complicated, as down-stream or upstream interest groups (fishermen!) can be affected. In such situations the SCWC will either set boundary conditions for the Water Users Group operating the structure, or will establish a mechanism for the various affected groups to work out common solutions or, in case all else fails, will assume operational responsibility for the structure.

Summarizing the rule will be that the responsibility for operation of structures will be put at the lowest possible level (which will normally be the level exclusively affected by the structure) with consultation towards the next lower level and supervision by the next higher level. In the following diagram these various aspects are displayed.

Structure type	deciding agency	consulta-tion	operat. criteria	executing agency	controling
peripheral control with regional req.	BWDB	MIWDFC	regional WL	BWDB operator	MIWDFC
peripheral control w/out reg	CWMC	SCWC	US/DS WL	CWMC operator	BWDB
compartment outlet structure	CWMC	SCWC	US/DS WL	CWMC operator	BWDB
sub-compartmental regulator	SCWC	WUG	US/DS WL	SCWC operator	CWMC
minor drainage outlet	SCWC	WUG	US/DS WL	SCWC operator	CWMC
irrigation inlet	SCWC	WUG	rain/ flood	SCWC operator	CWMC
irrigation pass	WUG	farmers	rain/ flood	WUG operator	SCWC

Following abreviations have been used:

- MIWDFC: Ministry of Irrigation Water Development and Flood Control.
- BWDB: Bangladesh Water Development Board.
- CWMC: Compartmental Water Development Committee.
- SCWC: Sub-Compartmental Water Committee.
- WUG: Water User's Group.
- US/DS WL: Upstream and Downstream Water Level.

8.6 Maintenance

8.6.1 General

Maintenance in the compartment is required for structures, embankments and channels.

In line with the procedures elaborated by SRP maintenance can be divided in:

- preventive maintenance
- periodic maintenance
- emergency maintenance and
- rehabilitation.

Preventive maintenance entails replacement of minor spare-parts, greasing, painting, filling of earthwork patches, turfing etc. at fixed time intervals.

Periodic maintenance is the verification of the structural works on their functioning and general performance, repairing elements as required.

Emergency maintenance is required when the proper functioning of the structure can not be guaranteed any more because of the degradation or mal-functioning of some parts of the structure.

Rehabilitation is done when the design standard is not met after emergency maintenance or when the design standard need be adjusted.

8.6.2 Responsibilities

Maintenance of structures has traditionally been done by the BWDB and, for minor structures, by the Local Government Engineering Department (LGED). Under compartmentalisation other participants will also be involved in maintenance, to the degree such participants are organized in a structured and accountable institution:

- CWMB (Compartmental Water Management Board), with the CPP/EC as its predecessor,
- SCWC (Sub-Compartmental Water Committee),
- WUG (Water Users Groups)

It needs to be worked out to what extent local contributions will be sought through these various institutions. The long-term objective is that the maintenance costs of sub-compartmental specific structures will become the responsibility of the SCWC, with subsidy from the GOB (via BWDB). Subsidy arrangements will need to be elaborated. Local contributions can be collected via levies and labour input collected at the sub-compartmental level.

For more sophisticated structures at the sub-compartmental level, that require more specialized maintenance the BWDB and LGED will be the executive agency. However the SCWC will be responsible. Subsidy arrangement will have to be established, whereby labour will be an accepted form of local contribution.

For structures at the compartmental level the BWDB will do maintenance, unless other arrangements are made, while responsibility will eventually be with the CWMB, which will in due course supersede CPP/EC. No local contribution is envisaged for O&M at this level.

8.6.3 Execution

For the actual realization of maintenance three types of maintenance groups may be involved:

- SMG: Structures Maintenance Group.
- EMG: Embankment Maintenance Group.
- CMG: Channel Maintenance Group.

The distribution of roles for these groups or agencies for specific tasks is proposed as follows:

For **structures** different aspects are important for the implementation mode of maintenance:

- a controlled or semi-controlled structure.
- the size and impact of the structure.

This will determine the degree of specialisation of the work. Most tasks will be so much specialised that the BWDB has to be involved, while in a number of situations LGED will do the work (e.g. culverts, bridges). Only for related earthwork of controlled and semi-controlled, medium and main structures may other agencies or groups be involved. Provided that they receive a proper training, preventive maintenance may be done by a SMG.

Only the very minor structures (e.g. irrigation passes) may possibly be fully maintained by a SMG or even a WUG under responsibility of a SCWC.

Maintenance of **embankments** requires a considerable amount of non specialised work for filling of erosion trenches and replanting of the turf layer. This may be done by EMG's and eventually WUG's.In case of an embankment failure, overtopping during a high flood or up-grading of the design standard, emergency maintenance and rehabilitation will be required. In order to maintain the design standard, specialised supervision is required (BWDB).

For the maintenance of **channels** a distinction can be made between local channels for the drainage of a *beel* area and (sub)-compartmental channels for the drainage of a larger area. The former can be excavated by a group of interested users. The (sub-) compartmental channel will not be excavated in this way because it has more regional implications. Payment for the work by CMG's is required.

The principal maintenance activity is excavation of earthwork. Channels that are completely silted up may be rehabilitated under supervision of the CWMC or the LGED.

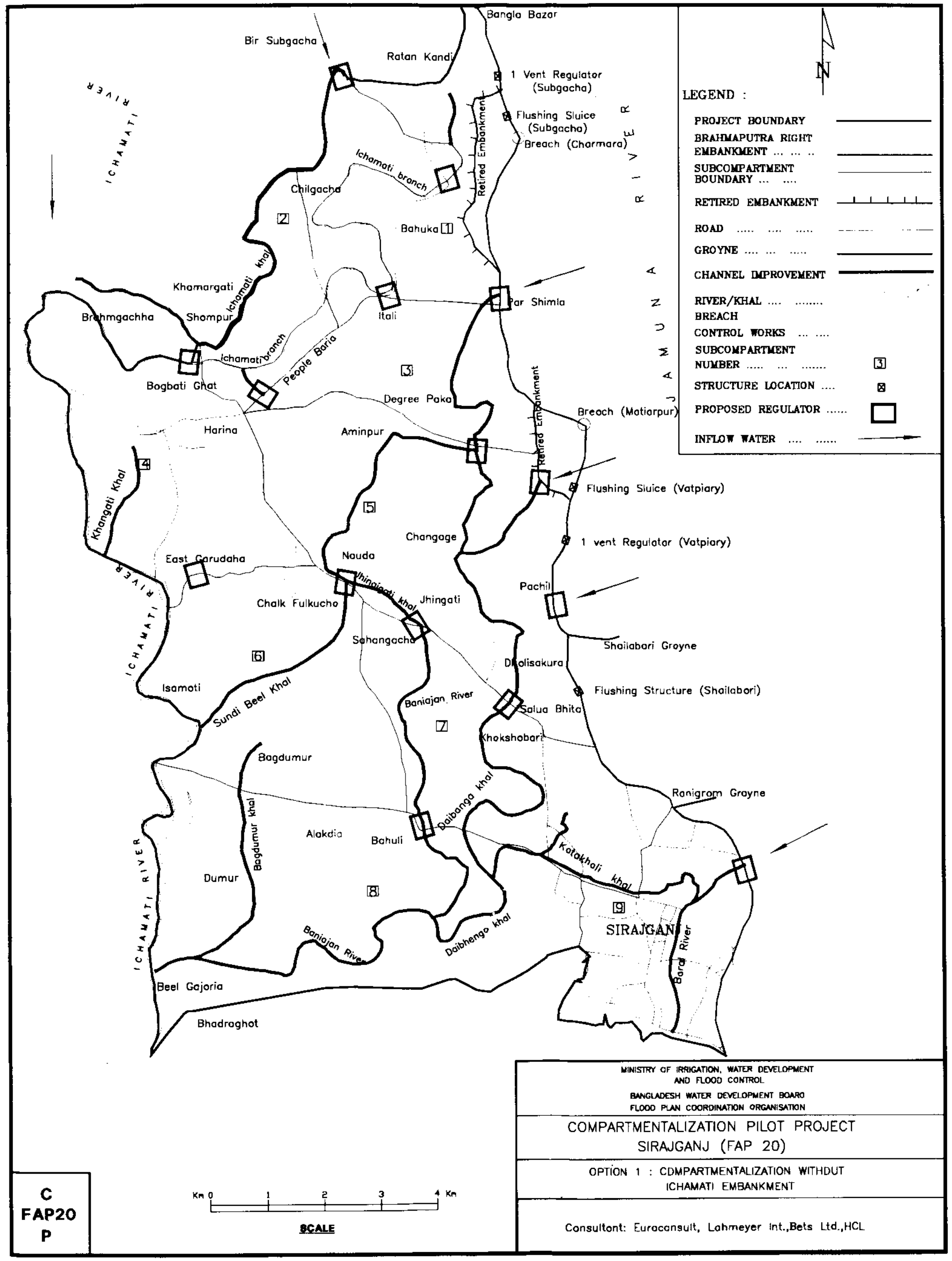
The following table summarizes maintenance tasks and the institutions involved. The most appropriate institution for maintenance monitoring has also been indicated:

Distribution of responsibilities for Maintenance:

Maintenance for:	Maintenance	Rehabilitation	Monitoring
Major structures	SMG/BWDB	BWDB	BWDB/CWM
Medium structures	SMG/BWDB/ LGED	BWDB/LGED	BWDB/LGED/ CWMC
Roads	DRHW	DRHW	DRHW/CWMC
Minor structures	SMG/LGED	LGED/BWDB	SCWC/BWDB
Embankments	EMG	BWDB/CWMC	BWDB/CWMC/ SCWC
Earthwork major/ medium structures	SMG	SMG/BWDB	BWDB/CWMC/ SCWC
Sub-compartment channel	CMG	SCWC/LGED/ CWM	SCWC/CWMC
Beel channel	WUG	SCWC/LGED/ WUG	SCWC
Retention bunds	WUG/farmer	WUG/SCWC	SCWC/DAE

The following abbreviations have been used:

BWDB: Bangladesh Water Development Board
CWMC: Compartment Water Management Committee
SCWC: Sub-Compartment Water Committee
LGED: Local Government Engineering Department
DRHW: Department of Roads and Highways
WUG : Water Users Group
EMG : Embankment Maintenance Group
CMG : Channel Maintenance Group
SMG : Structures Maintenance Group
DAE : Department of Agricultural Extension


LEGEND :
PROJECT BOUNDARY
BRAHMAPUTRA RIGHT EMBANKMENT
SUBCOMPARTMENT BOUNDARY
RETIRED EMBANKMENT
ROAD
GROYNE
CHANNEL IMPROVEMENT
RIVER/KHAL
BREACH
CONTROL WORKS
SUBCOMPARTMENT NUMBER
STRUCTURE LOCATION
PROPOSED REGULATOR
INFLOW WATER
N
ICHAMATI RIVER
JAMUNA RIVER
Bangla Bazar
Bir Subgacha
Ratan Kandi
1 Vent Regulator (Subgacha)
Flushing Sluice (Subgacha)
Breach (Charmara)
Retired Embankment
Ichamati branch
Chilgacha
Bahuka
Khamargati
Ichamati khal
Brahmgachha
Shompur
Itali
Par Shimla
Bogbati Ghat
People Baria
Degree Poka
Breach (Matiarpur)
Harina
Aminpur
Flushing Sluice (Vatpiary)
1 vent Regulator (Vatpiary)
Khangati Khal
Changage
East Garudaha
Nauda
Jhingati khal
Jhingati
Pachil
Chalk Fulkucho
Sahangacha
Shailabari Groyne
Dholisakura
Flushing Structure (Shailabari)
Isamoti
Sundi Beel Khal
Baniajan River
Salua Bhita
Khokshobari
Bagdumur
Ranigram Groyne
Daibanga khal
Bagdumur khal
Alakdia
Bahuli
Katakhali khal
Dumur
SIRAJGANJ
Baniajan River
Daibhenga khal
Baral River
Beel Gajaria
Bhadraghat
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SCALE
MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
FLOOD PLAN COORDINATION ORGANISATION
COMPARTMENTALIZATION PILOT PROJECT
SIRAJGANJ (FAP 20)
OPTION 1 : COMPARTMENTALIZATION WITHOUT ICHAMATI EMBANKMENT
Consultant: Euroconsult, Lahmeyer Int.,Bets Ltd.,HCL
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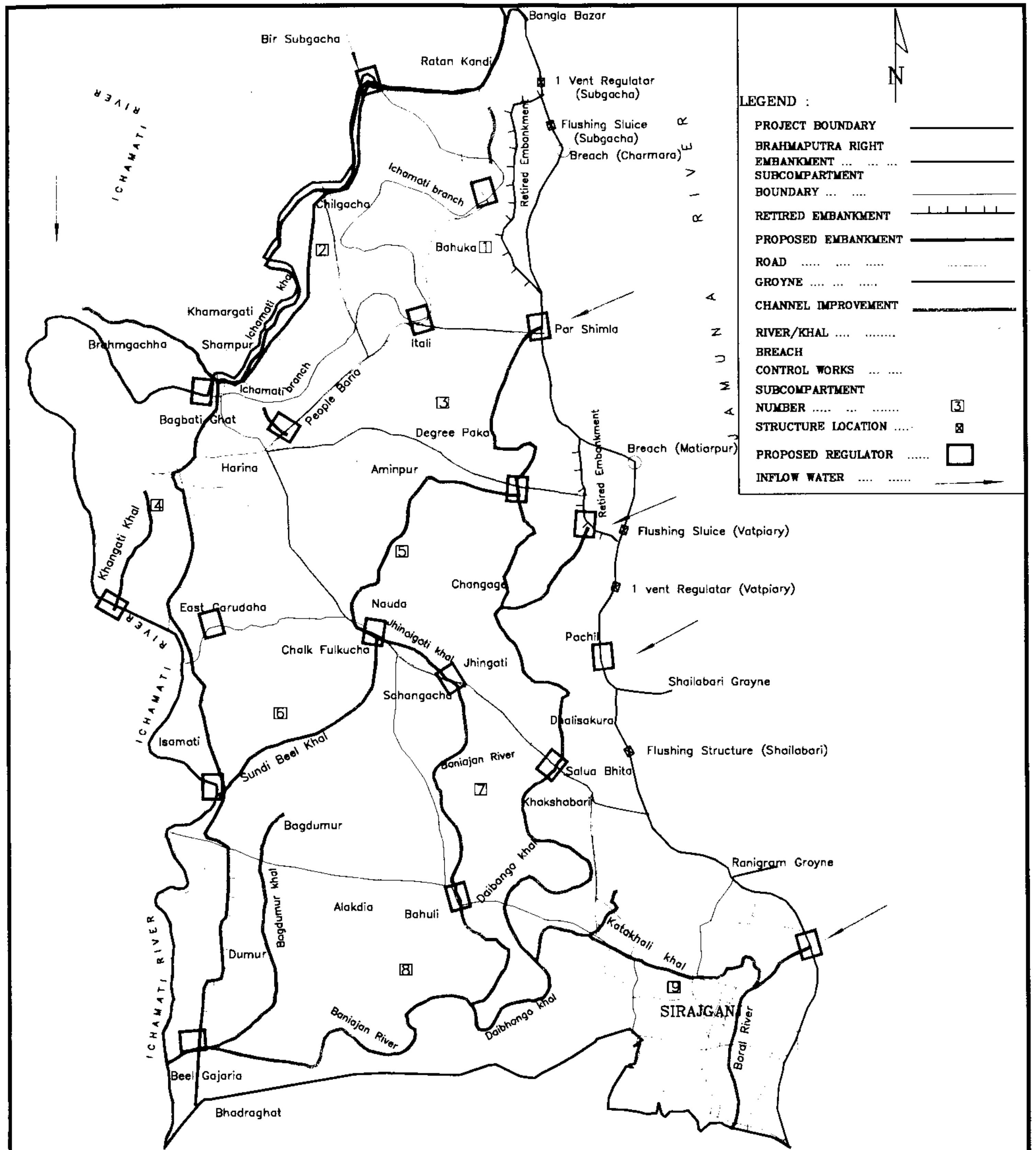

MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
FLOOD PLAN COORDINATION ORGANISATION

COMPARTMENTALIZATION PILOT PROJECT
SIRAJGANJ (FAP 20)

OPTION 2A : COMPARTMENTALIZATION WITH ICHAMATI EMBANKMENT (ALIGNMENT I)

Consultant: Euroconsult, Lahmeyer Int.,Bets Ltd.,HCL

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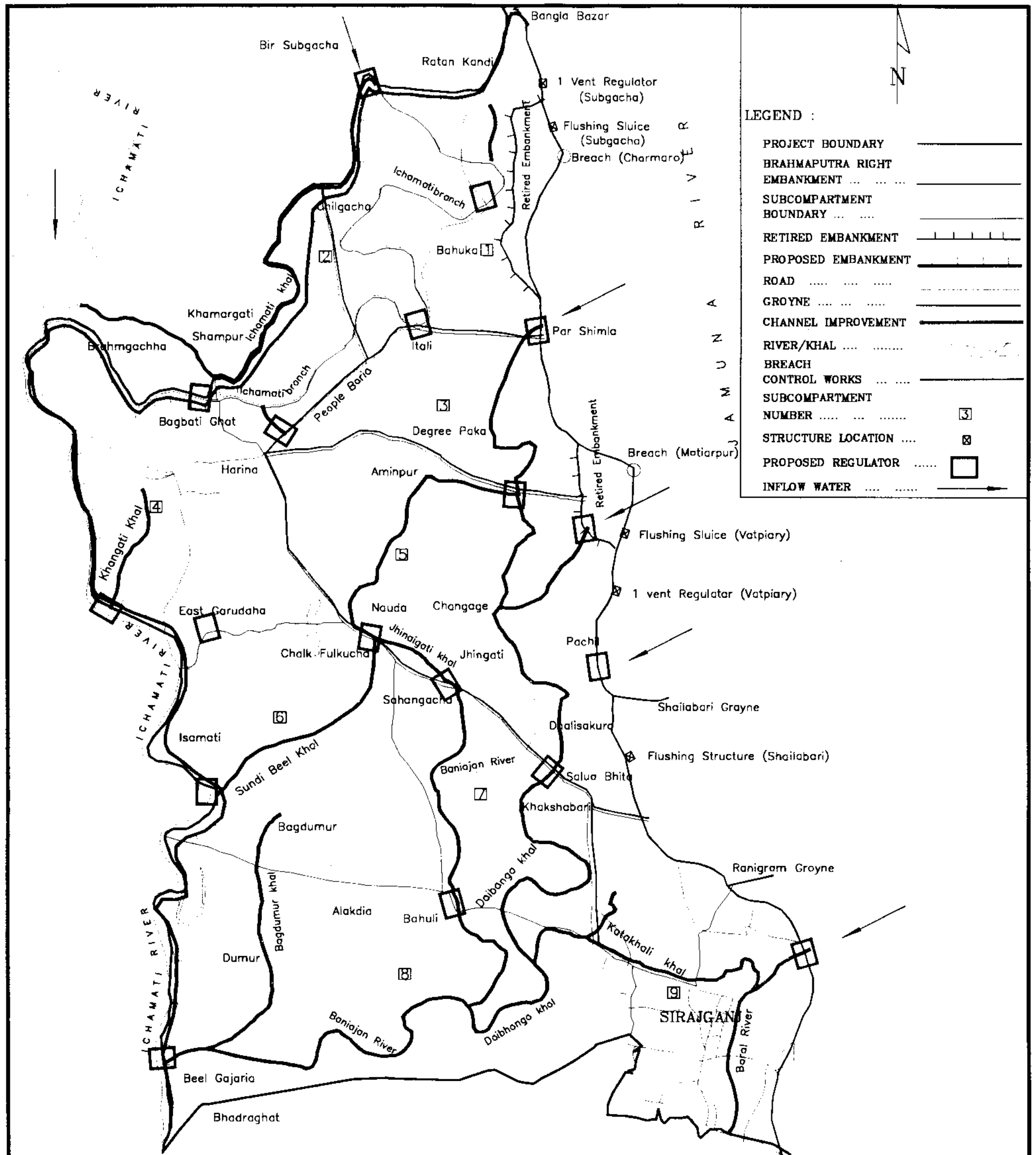

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SCALE

MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
FLOOD PLAN COORDINATION ORGANISATION

COMPARTMENTALIZATION PILOT PROJECT
SIRAJGANJ (FAP 20)

OPTION 2B : COMPARTMENTALIZATION WITH ICHAMATI EMBANKMENT (ALIGNMENT II)

Consultant: Euroconsult, Lahmeyer Int.,Bets Ltd.,HCL

C
FAP20
P