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Government of the People's Republic of Bangladesh
Ministry of Water Resources
Bangladesh Water Development Board
Water Resources Planning Organization

COMPARTMENTALIZATION PILOT PROJECT TANGAIL



FINAL REPORT Main Report

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COMPARTMENTALIZATION PILOT PROJECT TANGAIL



FINAL REPORT
Main Report

Acronyms and Abbreviations

AA	-	Adjacent Area
AARC	-	Adjacent Area Represent Committee
ADAB	-	Association of Development Agencies in Bangladesh
ADB	-	Asian Development Bank
ADP	-	Annual Development Plan
AEP	-	Agriculture Extension Program
AEZ	-	Agro- Ecological Zone
AIT	-	Asian Institute of Technology
ARC/INFO	-	GIS Software program
ASSP	-	Agricultural Support Services Project
ATAP	-	Annual Technical Assistance Program
BADC	-	Bangladesh Agricultural Development Corporation
BAE	-	Bilateral Associate Expert (GoN)
BAFRU	-	Bangladesh Aquaculture and Fisheries Resources Unit
BARI	-	Bangladesh Agricultural Research Institute
BARD	-	Bangladesh Academy for Rural Development
BBS	-	Bangladesh Bureau of Statistics
BCAS	-	Bangladesh Center for Advanced Studies
B/C ratio	-	Benefit/Cost ratio
BELA	-	Bangladesh Environmental Lawyers Association
BFRSS	-	Bangladesh Fisheries Resources Survey System
BKB	-	Bangladesh Krishi Bank
BLE	-	Bangladesh Left Embankment
BM	-	Bench Mark
BMD	-	Bangladesh Meteorological Department
BMDC	-	Bangladesh Management Development Centre
BPIS	-	Buried Pipe Irrigation System
BR	-	Bangladesh Rice
BRAC	-	Bangladesh Rural Advancement Committee
BRDB	-	Bangladesh Rural Development Board
BRE	-	Bangladesh Right Embankment
BS	-	Block Supervisor
BSS	-	Bittahin Samabay Samity (Landless Cooperative Society)
BURO	-	Bangladesh Unemployment Rehabilitation Organization
BUET	-	Bangladesh University of Engineering & Technology
BWDB	-	Bangladesh Water Development Board
BWFMS	-	Bangladesh Water and Flood Management Strategy
CA	-	Command Area
CARE	-	Co-operative for American Relief Everywhere
CC	-	Chawk Committee
CDS	-	Controlled Drainage Structure
CE	-	Chief Engineer
CFD	-	Controlled Flooding & Drainage
ChWMC	-	Chawk Water Management Committee
CMG	-	Canal Maintenance Group

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CPP	-	Compartmentalization Pilot Project
CPPSC	-	Compartmentalization Pilot Project Steering Committee
CPT	-	Core Planning Team
CT	-	Consultants Team
CWMC	-	Compartment Water Management Committee
CWM forum	-	Compartment Forum
DAE	-	Department of Agricultural Extension
DC	-	Deputy Commissioner
DEM	-	Digital Elevation Model
DFO	-	District Fishery Officer
DGIS	-	Directoraat Generaal Internationale Samenwerking
DFL	-	Dutch Guilders
DHI	-	Danish Hydraulic Institute
DLAC	-	District Land Acquisition Committee
DoF	-	Department of Fisheries
DPHE	-	Department of Public Health Engineering
DS (WL)	-	Downstream Water Level
DSS	-	Departmental Social Services
DTC	-	District Technical Committee (Agriculture)
DTW	-	Deep Tube Well
DWA	-	Deep Water Aman
DWTA	-	Deep Water Transplanted Aman
EAD	-	Expected Annual Damage
EC	-	Executive Committee
EIA	-	Environmental Impact Assessment
EIRR	-	Economic Internal Rate of Return
EMG	-	Embankment Maintenance Group
EMP	-	Environmental Management Planning
EPT	-	Extended Project Team (CPP)
FA	-	Financial Assistance
FAP	-	Flood Action Plan
FAP 19	-	Geographic Information System FAP
FAP 20	-	Compartmentalization Pilot Project FAP
FAP 25	-	Flood Modeling and Management FAP
FAO	-	Food and Agricultural Organization
FCD	-	Flood Control and Drainage
FCD/I	-	Flood Control, Drainage and Irrigation
FDAM	-	Flood Damage Assessment Modeling
FFW	-	Food for Works
FMM	-	Flood Management Model
FPCO	-	Flood Plan Co-ordination Organization (merged with WARPO)
FRG	-	Federal Republic of Germany
FRI	-	Fisheries Research Institute
FTG	-	Farmers Testing Group
FWMM	-	Flood and Water Management Model

FY	-	Financial year
GB	-	Grameen Bank
GDI	-	Gender related Development Index
GIS	-	Geographical Information System
GHK	-	Consultants Group
GoB	-	Government of Bangladesh
GoN	-	Government of Netherlands
GPA	-	Guidelines for Project Assessment (FPCO 1992)
GPC	-	Gated Pipe Culvert
GPI	-	Gated Pipe Inlet
GPS	-	Global Positioning System
GPV	-	Gross Product Value
GO	-	Government Organization
ha	-	Hectares
HD model	-	Hydrodynamic Model
HDI	-	Human Development Index
hh	-	Household
HTW	-	Hand Tube well
HYV	-	High Yielding Variety
ICDDR'B	-	International Center for Diarrhoeal Disease Research, Bangladesh
ICID	-	International Commission on Irrigation and Drainage
ICWMC	-	Initial Compartmental Water Management Committee
ID	-	Institutional Development
IDC	-	Information Dissemination Center
IDP	-	Institutional Development. Promoter
IOV	-	Inspectie Onderzoek Ter Velde (DGIS- M&E unit)/ Operations Review Unit (Ministry of Foreign Affairs GoN)
IPM	-	Integrated Pest Management
ISPAN	-	Irrigation Support Project for Asia and the Near East
IWRM	-	Integrated Water Resources Management
JrE	-	Junior Engineer
JMBA	-	Jamuna Multipurpose Bridge Authority
JWME	-	Junior Water Management Engineer
KfW	-	Kreditanstalt für Wiederaufbau
KJDRP	-	Khulna Jessore Drainage Rehabilitation Project
KSS	-	Krishak Samabaya Samity
LCS	-	Landless Contracting Society
LGED	-	Local Government Engineering Department
LFP	-	Lohajang Flood Plain
LLP	-	Low Lift Pump
Lps	-	Liters per second
LUS	-	Land Use Survey
LV	-	Local Variety
MAEP	-	Mymensingh Aquaculture Agriculture Extension Programme (GoB)
MARC	-	Multi - Action Research Center
MBSS	-	Mohila Bittahin Samabay Samity (Women's Landless Cooperative Society)

ME	-	Mechanical Engineering Department, BWDB
M&E	-	Monitoring & Evaluation
MDF	-	Management Development Foundation, Netherlands
MDSCS	-	Multi- disciplinary Sub- compartmental Survey (CPP)
meq	-	Milliequivalent
MIKE II	-	Name of Modeling Program
MIWDFC	-	Ministry of Irrigation, Water Development and Flood Control
MoU	-	Memorandum of Understanding
MOT	-	Manually Operated Tubewell
MP	-	Muriate of Potash
MPO	-	Master Plan Organization (now WARPO)
m+ PWD	-	Meter plus Public Works Department
MT	-	Metric Tons
MV	-	Modern Variety
MoWR	-	Ministry of Water Resources (formerly MIWDFGC)
NAA	-	Northern Adjacent Area
NACOM	-	NGO
NAM	-	Rainfall -runoff module of MIKE II
NAS	-	Needs Assessment Survey
NAI	-	Needs Assessment Intervention
NCA	-	Net Cultivable Area
NCRS	-	North Central Regional Study
NGO	-	Non-Government Organization
NPV	-	Net Present Value
NWMP	-	National Water Management Plan
NWP	-	National Water Policy
NWRS	-	North West Regional Study
ODA	-	Overseas Development Agency
O&M	-	Operation and Maintenance
OFR	-	On- Farm Research
OFRD	-	On-Farm Research and Demonstration
OFTD	-	On-Farm, Testing and Demonstration
OFTR	-	On- Farm Testing and Research
OM	-	Organic Matter
P	-	Phosphorus
PAP	-	Project Affected Person
PC	-	Project Council
PD	-	Project Director
pH	-	Hydrogen-ion concentration
PoE	-	Panel of Experts (FPCO)
PPG	-	Peoples Participation Guidelines
PPM	-	Parts per Million
pm	-	Person month
PRA	-	Participatory Rural Appraisal
PSA	-	Production System Analysis

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PT	-	Project Team
PWD	-	Public Works Department
RASDO	-	Rural Agricultural Social Development Organization
R&H	-	Roads and Highways
RF	-	Resident Facilitator
RNE	-	Royal Netherlands Embassy
RRA	-	Rapid Rural Appraisal
SATU	-	Social Advancement through Unity
SC	-	Sub-Compartment
SCF	-	Standard Conversion Factor
SCWMC	-	Sub-Compartment Water Management Committee
SDE	-	Sub-Divisional Engineer
SFS	-	Social Forestry System
SIDO	-	Sr. Institutional Development Officer
SIR	-	Sirajganj Interim Report
SIRDP	-	Sirajganj Integrated Rural Development Project
SMG	-	Structure Maintenance Group (CPP/PAP)
SO	-	Section Officer
SRDI	-	Soil Resources Development Institute
SSS	-	Senior Scientific Officer/ Society for Social Services
SRP	-	Systems Rehabilitation Project
SUS	-	Samaj Unnayan Sangstha
STW	-	Shallow Tube Well
SWMC	-	Surface Water Modeling Center
TAPP	-	Technical Assistance Project Proforma
TA	-	Technical Assistance
T- Aman	-	Transplanted Aman
TARD	-	Technical Assistance for Rural Development (NGO)
TC	-	Technical Committee (MWR, GoB)
TCM	-	Tangail Compartmental Model
TIR	-	Tangail Interim Report
Tk	-	Taka
TL	-	Team Leader
TN	-	Technical Note
TNO	-	Thana Nirbahi Officer
ToR	-	Terms of Reference
TSP	-	Triple Super Phosphate
UNDP	-	United Nations Development Program
UNICEF	-	United Nations International Children's Emergency Fund
UP	-	Union Parishad
UPOMA	-	NGO
UST	-	Unnayan Shahajogi Team
WARPO	-	Water Resources Planning Organization
WB	-	World Bank
WCS	-	Water Control Structure



WFP	-	World Food Program
WID	-	Women in Development
WME	-	Water Management Engineer
WMC	-	Water Management Committee
WP	-	Working Paper
WUG	-	Water Users Group
XEN	-	Executive Engineer (CPP)
XO	-	Extension Overseer
Zn	-	Zinc

Glossary



<i>Aman</i>	A group of photoperiod-sensitive rice planted in May-August and harvested in November-December.
<i>Aus</i>	Photoperiod-insensitive paddy varieties grown with irrigation from December -February
<i>Baor</i>	Oxbow lake, natural depression usually formed by the change of course of rivers
<i>Bazar</i>	Market place
<i>Beel</i>	Small lake, low-lying depression, a permanent body of water in a floodplain or a body of water created by rains or floods.
<i>Bidi</i>	Local Cigarette
<i>Bigha</i>	Unit of land (1/3 of an Acre)
<i>Boro</i>	A group of photoperiod-insensitive and fairly cold tolerant rice varieties transplanted in December-February and harvested in April-May.
<i>Borrowpit</i>	Excavated small and seasonal water bodies present mainly along the public roads.
<i>Catch Assessment</i>	Determining the daily catch of the fishermen
<i>Catch per unit</i>	Quantity of fish caught by the fishermen in unit time and effort (Fishing equipment)
<i>Chamara</i>	Important deep water <i>Aman</i> variety
<i>Chari in the Bari</i>	A ditch on the homestead
<i>Chawk</i>	A readily recognizable manageable field unit bounded by village roads and settlement areas. These are physical entities and are easily recognized by village people. Each chawk has water inlet or outlet through bridges, culverts, road breaches etc.
<i>Chula</i>	Home made furnace
<i>Cluster</i>	A group of sub-compartments, which are merged together for management reasons. Their hydrological features resemble an independent status.
<i>Compartment</i>	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.
<i>Crore</i>	100 lakh
<i>Cusec</i>	Discharge unit: 1 cusec equals 28 liters per second
<i>Decimal</i>	Unit of area measurement, 40 m ²
<i>Deshi Jute</i>	White jute (<i>Corchorus capsularis</i>) varieties, tolerant to standing water.
<i>Dhaincha</i>	An erect leguminous species (<i>Sesbania sesban</i>), used for green manure and fencing
<i>Doon</i>	Traditional water lifting device
<i>Dopa</i>	Lowest land type according to farmers' classification
<i>DW Aman</i>	Deep water <i>Aman</i> , a rice variety
<i>Frame Survey</i>	A survey for estimating the number of fishermen or gears.
<i>Hat</i>	Weekly market
<i>Hijoldigha</i>	Important deep water <i>Aman</i> variety
<i>IPM</i>	Integrated Pest Management, a balanced combination of pest control measures, including biological, mechanical and chemical methods, based on observations of population levels of pests and predators, economic thresholds and scoring.

<i>Jalmahal</i>	A leased water body or river stretch.
<i>Khal</i>	A natural channels.
<i>Kharif</i>	Crop season from March-October (Kharif-I: March-June, Kharif-II: July-October)
<i>Khash land</i>	Land owned by the government
<i>Kutcha</i>	Unlined earthen channel
<i>Lakh</i>	100,000
<i>Madrasha</i>	Islamic School
<i>Mastan</i>	Muscle man/thug
<i>Mohalla</i>	Urban village
<i>Multi-criteria analysis</i>	An analysis and display of the impacts of proposed structural and non-structural works in which a wide range of criteria is 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.
<i>Pagar</i>	Small water body
<i>Palam</i>	Homestead land
<i>Patchot</i>	Intermediate land type according to farmers' classification
<i>PA-Matrix</i>	A relational matrix, depicting links between participants and activities in a certain process.
<i>Parishad</i>	Council
<i>Perching</i>	Placement of branched sticks (perches) in crop land as resting place for insect-eating birds.
<i>Pourshava</i>	Town council
<i>Pucca</i>	Lined earthen channel
<i>Rabi</i>	Crop season (November-February)
<i>Rapid Rural Appraisal</i>	A systematic, but semi-structured activity carried out in the field by a multi-disciplinary team and designed to quickly acquire information. Bacterial processes of separating jute fiber in standing or slows running water.
<i>Retting</i>	Bacterial processes of separating jute fiber in standing or slows running water.
<i>Salish</i>	Traditional informal village court which mitigate the disputes of the vilagers. The traditional village Matabbars (Chieftains) are the judges.
<i>Sub-Compartment</i>	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 and provided with (semi) cotrolled structures.
<i>T. Aman</i>	Transplanted Aman, a rice variety.
<i>Tan</i>	Highest land type according to farmers' classification.
<i>Thana (previously Upazila)</i>	Local administrative unit. Each Thana is composed of 10-15 Unions.
<i>Tossa Jute</i>	Jute (<i>Corchorus olitorius</i>) varities, grown in the highest land types, not tolerant to standing water.
<i>Union</i>	Smallest electoral unit of areas outside municipalities comprising several mouzas (or villages), and generally divided into three wards. It has a Union Parishad (Council). Local administrative unit. Each Thana is composed of 10-15 Unions.

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Executive Summary

Background and Concept

During 1987 and 1988 severe flooding led to widespread devastation in Bangladesh. Several thousand people lost their lives; many thousands lost their homes and properties. The impact on the national economy was disastrous.

These two years of severe flood led to an outpouring of support from the donor community culminated, in 1989, with a conference held in London. This was intended to address action that could be undertaken to try to prevent future flood disasters. Out of the conference came the Flood Action Plan (FAP).

The plan consisted of 26 different studies and pilot projects. Included in these 26 components was FAP 20, the Compartmentalization Pilot Project (CPP).

CPP is located in Tangail on the left bank of the Brahmaputra (Jamuna) River some 80 km North of Dhaka. It encompasses 13,500 ha of which around 9,500 ha is cultivatable land. In the center of the area is the town of Tangail. Population in 1999 was approximately 285,000.

It was realized from the beginning that the answer to flood in Bangladesh was not to prevent flooding in rural areas, as to do so disrupts agriculture. The key was to manage floods. The goal of CPP was to test the technical and economic viability of the compartmentalization concept, in which an area, enclosed by an embankment, would be provided with a comprehensive water control system designed and operated in order to provide a more secure environment for intensive agriculture, fisheries and integrated rural and urban development.

The biggest question was how to develop this area in an institutionally sustainable unit, in which decision making should involve people's participation. Such an approach was unknown in Bangladesh when CPP was started in 1991.

Also to be tested was the sustainable and replicability of compartmentalization.

The original time frame of the project saw it running until the end of 1994, covering a period of approx. 2.5 years. A consortium of two foreign and one local consulting firms was selected whose tasks included feasibility studies, design, implementation and monitoring. In the event, the project continued to a second (Final) phase, running from 1996-2000, with a different consortium of consultants.



Engineering and Water Management

The project area is protected against floods by primary embankments in the North, East and West, but not in the South. Thus, the embankment is horseshoe shaped.

Where the primary embankment crosses the Lohajang River in the North, the Main Regulator has been built. This is a gated structure, by which discharge and water levels in the river can be regulated. It is the control of the depth in the Lohajang that is the key to drainage, and ultimately to the water management in the compartment.

There are 14 gated intake structures in the primary embankments, through which water can be supplied to the Compartment, provided outside water levels are high enough. This is an important proviso. Without flood in the Jamuna, there are no flows in the Dhaleswari or Pungli Rivers. This is the case for the largest part of the year. The Dhaleswari typically flows from July to October only.

Within the Compartment, there are about 30 secondary drains, together about 75 km long, plus a large number of tertiary drains.

At the downstream end of the drainage systems, along the Lohajang, the project has constructed 15 gated outlets by which the lands drain into the river. If water levels in the Lohajang are high enough, they may serve as intakes. By closing the gates, the structures may function as retention structures. Inside the Compartment, additional gated structures provide control of the water.

CPP distinguishes itself from regular flood control and drainage (FCD) schemes in two ways. First, the drainage facility provided by the Main Regulator is usually not available in regular FCD schemes. The second feature, which CPP has emphasized, is the fact that even with the high floods being kept out, land users are able to supply their lands with outside water because of the intakes in the embankments. Such water intakes can be found in other projects. However, CPP has integrated them into a water management system based upon controlled flooding which gives the farmers very considerable control over the depth of water on their fields.

The construction cost of CPP can be considered high when compared with conventional flood control and drainage projects. In fact, with hindsight, much of the water management and of the flood control benefits of the project could have been obtained at a lower cost. Part of the problem was the difficulty of hydrological modeling of the compartment. Although the modeling had commenced at an early stage, instabilities in earlier versions of the model had severely limited its usefulness for simulations capable of predictive analysis. It was only after the final success of the

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modeling that the hydrology of the compartment, which should have been an important input into the design process, was fully understood.

In view of the above, an alternative cost estimate for the Compartment has been prepared, scrutinizing the costs and applying savings where possible. In these alternative costs, structures, which have been shown by modeling to have little impact on the ability of the system to manage water levels, have been eliminated. It is estimated that, based upon revised costs, a similar project could be replicated at a little more than half the cost of CPP.

The flood control provided by CPP has been adequate except during the 1998 flood. The 1998 flood was extreme, both because of its peak, and because of its duration. Flood levels grew steadily during the monsoon and reached their peak in mid-September. The embankments of the Compartment breached in August, at three locations, two in the West and one in the North.

During the final peak, the water South of the Compartment reached such a high level that the Lohajang started backing up into the Compartment. Outside water also entered through other openings in the southern boundary. The horseshoe embankment appeared effective as protection against large-scale damage but local damage was done. However, even at its worst, there was around a one meter difference in depth between the flood inside the compartment and the flood outside, and Tangail Town was spared flooding altogether.



Institutional Development

One of the major objectives of CPP was to involve the beneficiaries in the implementation, and eventually the operation and maintenance of the project. The project carried out a consultative process with all stakeholders prior to attempting to set up any participatory institutions. Only after that consultation process were the water management committees formed. The project originally organized stakeholders in a 3-tier structure, consisting of 110 Chawk Water Management Committees (ChWMC), 16 Sub-Compartment Water Management Committees (SCWMC) and one Compartment-level Project Council, later renamed the Compartment Water Management Committee (CWMC).

In Phase I, the first tier consisted of *chawk* committees with only farmers and a series of existing NGO groups representing landless, women and fishermen. The committees were formed in 1995 and 1996.

The Final Phase, which commenced in 1996, started with a review that concluded that it was more important to have proportionate representation of high, medium and lowland families than to use landless and women as classifications. In addition, they concluded that there were inconsistencies in the way groups were represented at various levels. The committees were subsequently reformed in 1997 and 1998. In total 110 ChWMC's of 9 to 14 members were formed, consisting of farmers and landless from high, medium and lowland, as well as fishermen if living in the *chawk* in substantial numbers. Women made up one third of each group. This has been the institutional structure that has been left in place at the conclusion of the project.

The Water Management Committees continue to operate gates as they have been doing since 1998, and will also have maintenance responsibilities.

In general the committees have taken charge of gate operations and have operated the structures in a satisfactory manner. Potential conflicts on distribution of floods, harmful or beneficial, were avoided mostly by inaction, i.e. by keeping internal structures always open. Conflicts with occupational fishermen were not detected, probably because the negative impact on them appeared to be limited.

Maintenance of completed infrastructure during the project period has nearly all been initiated by the project and has been paid for by the donor agencies. For the post-project period, the responsibilities have been divided between the BWDB and SCWMC's. BWDB will be responsible for all maintenance for the infrastructure along the periphery and Lohajang, and for periodic major maintenance on internal infrastructures. SCWMC's will be responsible for preventive maintenance of internal infrastructure. This arrangement has not been tested.

Agriculture

One of the major objectives of CPP was to increase agricultural output in the Compartment. This was achieved as the result of improved water management and drainage together with a reduction in uncontrolled flooding. As well as the contribution made by water management to agriculture, CPP has also run an active program of agricultural extension.

Important shifts in land use are apparent with *T-Aman* increasing sharply through 1997 at the expense of *DW-Aman* and fallow land, while *T-Aman* (HYV) partly replaced *T-Aman* (L) and sugarcane.

In 1999, the year after the major 1998 flood, HYV was back at the same level as in 1997, but otherwise there was a shift to more conservative choices : from *T-Aman* (L) back to *DW-Aman* and an increase in fallow. This indicates uncertainty about the future flood situation, but it is probably temporary.

There has been a steady increase in HYV, which is grown in land types that are less prone to flood damage. This testifies to farmers' confidence that it is safe to grow modern *Aman* varieties in *Tan* and the higher reaches of *Pachot* land.

The most significant trend has been the increase in mustard (from about 1,300 ha in 1992 to more than 3,000 ha in 1999) and *boro* paddy (from 3,500 to 7,000 ha). The simultaneous decline of jute reflects the fact that most of the recent increase in *boro* is in the higher land where new shallow tubewells have been installed.

The increase in cropping intensity can be attributed mainly to better drainage in the compartment, resulting in a shift in the *boro*-based system from double to triple cropping and from single to double cropping.

One thing that CPP has not achieved is an increased diversification of cropping. This is because the average farm size is such that it allows for nothing other than subsistence agriculture. Under such a situation, the farmer will inevitably grow his staple food. Diversification will, and does, occur on larger farms but, with the average size of farms declining in Bangladesh, from 1.5 ha in 1977 to 0.7 ha today, there is probably going to be less, rather than more, diversification.

Fisheries

It had always been assumed that open water fisheries would be adversely affected by CPP. This was thought to be the inevitable result of the interventions such as construction of gated regulators in the main river and the peripheral embankment, improvement of drainage through excavation of *khaals*, and the construction of minor regulators within the project area.

In order to assess the impact of CPP on fisheries, a monitoring program was started in 1992. This program monitored the catch in the pre-water management phase (May 1992-May 1995) and the post water management phase (May 1995-Dec 1999).

On average, 330 Mt of fish was caught in the CPP project area annually. However, this average conceals huge variations, with the catch varying with the extent of flooding in any particular year. The lowest catch of 845 MT was observed in 1992 and the highest catch of 845 MT occurred, just before the conclusion of the project in 1998, when there were high floods.

Despite expectations, the data clearly points to the conclusion that there is no significant trend in the fish catch within the CPP area during the period 1992 to 1999. CPP has not had an adverse impact on open water fisheries.

As well as monitoring open water fisheries, CPP ran an aquaculture extension program that started in 1994.

Before CPP, the average production of ponds was 1,090 kg/ha/crop and 258 MT/year of fish was obtained through aquaculture in the project area. Through the aquaculture extension program of CPP, the production level of the ponds increased considerably to an average of 2,200 kg/ha/crop. A total aquaculture production of 558 MT/year has been reached, with an incremental production of 300 MT/year. This can be attributed to both the extension effort and to the decreased risk of flooding which has encouraged greater investment within aquaculture.

Benefit of Flood Prevention

The main thrust of CPP has largely been seen as a means to improve productivity within the compartment, especially in agriculture. However, for the people in the compartment, especially after the 1998 flood, one of the major benefits of CPP was seen as the flood protection provided. It was difficult to quantify the value that people put on the feeling of safety and protection that they derive from effective flood protection. However, there are direct economic benefits, in the form of damage avoidance, which can be quantified. In addition to their impact on the agricultural sector, CPP interventions have generated benefits to non-agricultural sectors such as residential houses, business, industries, offices and infrastructure.

Following fast urbanization within the CPP area, especially the expansion of Tangail Town, potential non-agricultural and urban flood losses in general are of obvious importance. It was incumbent on this pilot study, therefore, to insure that the non-agricultural benefits generated by the CPP interventions be assessed in order to facilitate the evaluation of the project. To this end, the project carried out a flood loss study whose aim was to obtain an estimate of the total non-agricultural benefits.

The study dealt with tangible damage only. The following five broad sectors, which are viewed as comprising the main economic loss sectors in the non-agricultural economy of CPP were considered:

- Residential houses
- Business (Trading)
- Industries
- Office & Public buildings
- Roads



The study used a unit loss appraisal model aimed at assessing expected annual damage (or the benefits of protection). The advantage of such a model was that it is capable of separating impacts by types, flood levels and frequencies - even when flood level and frequency differences are small.

The ultimate output of the unit-loss model was the estimated expected annual damage (EAD), which was equivalent to the expected annual benefits of protection, from which the present value of benefits can be assessed. The analysis considered a 20-year flood as the CPP's standard of protection.

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The model showed that the expected annual benefit of the protection from flood damage for non-agricultural sectors is Tk. 32 million.

The model showed the one in twenty year flood does the real damage. Some 355 million Taka for the compartment. However, this is a 1:20 year flood, so that when the damage is averaged on an annual basis it looks modest. Nevertheless, the damage should not be underrated. The 355 million Taka (\$7 million) is for some 13,500 ha of land within the compartment. If this is extrapolated for all of the flood plains in Bangladesh then the very high cost of severe floods in Bangladesh is obvious. For CPP, the 355 million Taka is the value of the non-agricultural damage avoided in 1998.

Employment and Poverty

The project created jobs. Over the life of the project, it is estimated that 3 million wage days of labor were created in the construction of structures and earthworks. The bulk of this labor has been local and, it is the poor who have benefited. It is only the poor who are prepared to do the laboring work involved.

As well as construction labor, the project has created some 973,000 labor days of work in agriculture. Again, it is the landless and the marginal farmer who benefit from this employment creation.

As well as the generation of labor, the project has run two programs designed to specifically target the poor. Both have been targeted at poor women, who do not benefit from the jobs created in construction. The programs are the Embankment Maintenance Group (EMG) program and the Household Catfish Culture Program.

The Embankment Maintenance Group (EMG) program was implemented from September 1995 onwards, and it will continue after June 2000 when the project closes. A total of 100 landless women from the poorest group of society participate in the program.

CPP's Homestead Catfish Culture Program, also known as the *Chari* in the *Bari* Program, has attempted to reach the poorest of the poor. Its purpose has been to show this group that it is possible to grow high valued fish even with their limited resources.

Two hundred households participated in the program and it has had a significant impact on the people who have participated in it. With an initial investment of 10 Taka, the participants have been shown how to grow five kilos of catfish in four months. This is a value of 400 Taka. This, in the Developed World might not seem like much money, but for participants it can mean the difference between food on the plate and nothing to eat at all.

Women in CPP

From its inception, CPP has made an effort to get women involved in its activities to the extent possible.

The experience of CPP has been that a number of economic activities can be developed that increase women's access to new technologies, productive resources, and income, as well as their wish to be informed, trained and involved. However, these changes are marginal. Bangladesh remains a society in which women have a long way to go before they become anywhere close to achieving equality with men.

The efforts to involve women in the water management committees (WMC) have brought about a high attendance rate of women in the process of WMC formation with women constituting 459 members of the 1,240 ChWMC members (37%), and 127 members of the 399 SCWMC members (32%). For both men and women in rural Tangail compartment the participation of women in public meetings has been a novel phenomenon. It appeared that it was possible to break some of these gender barriers because the women were motivated to get involved. This has contributed to some improvement in the social status and self-confidence of a number of female committee members, in particular the members of the SCWMC's.

The participation of the WID staff in CPP's On Farm Testing and Demonstration Program (OFTD) has facilitated women's access to new productive technologies. Two hundred and eighty three female farmers (against 579 male farmers) have cultivated new types of crops.

These changes have not affected all categories of people in the same way. The major distinctions in ways women and men are affected appeared to be related to social stratification, occupation and land ownership. Different effects can be observed, depending if the person belongs to the class of poor landless people, small and marginal farmers, large and medium farmers or to the fishery community.

Environmental Impact

Virtually the whole area of CPP was under either settlement or intensive agriculture prior to the project. CPP led to a further intensification of the agriculture. In these circumstances, the environmental impact was never likely to be huge. Notwithstanding this, CPP has always taken environmental considerations seriously and has conscientiously carried out a program of monitoring of:

- Surface Water
- Groundwater
- Sediment Deposit
- Soil fertility
- Bio-diversity

The monitoring showed no adverse impacts from CPP's interventions.

Environmental education, training and awareness training was also carried out. Despite some traditional knowledge, there are only few villagers fully aware of the intrinsic value of nature and natural resources, ethics of conservation and the ecological importance of important elements, such as frogs or earthworms. Knowledge about health and hygiene is sufficient, but basic principles are rarely observed in daily life. Training courses were run specifically targeting teachers in an effort to maximize the impact of environmental awareness amongst children.

CPP is following many of the goals set in the draft National Water Management Plan and outlined in the National Environmental Action Plan. However, many issues important for sustainable natural resources management in Tangail floodplain are far beyond the scope of CPP interventions, e.g. waste and wastewater management, water pollution control, social forestry, equal access to resources. Efforts for integrated management plans and inter-institutional cooperation are required, as well as establishment of capacity at local and district level.



Economic Benefits

The methodology adopted to assess the economic impact of CPP follows the Flood Planning and Coordination Organization (FPCO) Guidelines for Project Assessment (GPA), updated in March 1998. Where recent changes have been made by the National Water Management Plan (NWMP) to input and output prices and conversion factors, those have been adopted.

At their full level, total economic benefits of CPP are 86.89 million Tk. (1,780,423 US\$) per year. Although there is a positive cash flow from 2001 onwards, project benefits will not be able to offset the capital expenditure as indicated by the N/K Ratio of 0.80. In addition, there is an internal economic rate of return of 3.1%, which can hardly be judged attractive.

Because CPP is a pilot project, some of the capital expenditures on water control structures, as well as personnel costs have been unnecessary, or at least unnecessarily high. Indeed, it is certain that some costs could have been avoided.

Reducing the number of structures and their costs gives an alternative costs of in total 206.54 million Tk. (4.26 million US\$). If CPP was repeated, this is the cost that would be necessary in order to obtain the present benefits.

In addition, even given the pilot project status of CPP, it is difficult to justify charging the project with activities such as: women in development; agricultural extension and applied research; M&E; institutional development and an information dissemination center, which are normally linked to regional or rural development. While all of those activities are undoubtedly highly valuable in their own right, they could and should have, at least in parts, been executed and monitored by the existing specialized public agencies. Corresponding costs have consequently eliminated or reduced as follows, including GoB contributions:

Eliminated

Women in Development

Reduced

Agriculture	- 50%
Institution	- 50%
M&E	- 50%

Overall, cuts in personnel costs that should more fairly be attributed to non-CPP activities, amount to a total reduction of 40%.

Land acquisition charges of about 700.000 Tk/ha (13,127 US\$/ha), plus a service charge, also seem excessive. Alternatively determined, fair compensation rates based on payments of production forgone (rent) revealed figures as low as 40% of the above payments. A land acquisition price of 50% of the paid rates has therefore been assumed.

Tangail drain may be useful and necessary. It is, however, doubtful if its inclusion as mitigation cost in a project such a CPP is justified. It has been omitted from the revised cost.

The above changes result in total savings of about 40% of the original implementation costs. Re-evaluating the viability by accepting the alternative parameters gives a much better rate of return of 7.3%. However, if the discount rate is 12 percent, this is still far from satisfactory.

The problem is that a project such as CPP is largely dependent upon agriculture for its benefits. Where, as in the Tangail area, we already have very intensive cropping, any incremental benefits are hard won and although real, are never going to be sufficient to measure up to a 12 percent discount rate.

All of the decision criteria clearly indicate that, even under the substantially more favorable conditions with regard to the implementation costs, compartmentalization under Tangail conditions is not an economically viable water management intervention at a discount rate of 12 percent.

A reasonable question, of course, is where in Bangladesh does one find a water management or agricultural project that will show, under scrutiny, a rate of return of 12 percent?

The careful quantification of benefits carried out above misses a major benefit of the project. The removal of the fear of flooding. The damage avoidance, and the benefits to agriculture and aquaculture can be quantified; but, in a country such as Bangladesh, where the fear of flood is something people live with every monsoon season, to have that fear removed is almost beyond price.

Indeed, in the developed world most countries would be willing to implement flood control for this social reason alone, regardless of any measurable economic benefits.

Technical Viability

CPP has demonstrated that compartmentalization in a single compartment setting is technically viable with benefits to agriculture, aquaculture and the prevention of flood damage. However, the physical behavior of a single compartment in a flood plain is different from that to be expected in a multi-compartment setting.

Reliability of the Compartmentalization Project is dependent upon there being similar areas with adequate drainage, which is an essential component to successful flood management. It was expected that with the sort of proven technology developed in CPP, the reliability of the project with similar hydrological setting should be possible. To test this, a modeling exercise was carried out for CPP, by SWMC, for the Jamuna flood plain, in areas to the North and the South of the Tangail compartment.

Model results were analyzed for change in water levels in the rivers at the upstream, downstream and within the compartments, and the inundated areas under different options. It is observed from the model results, that due to the compartmentalization, water levels increased in most of the channels. In most cases, the increase of water level is not significant.

In all, nine potential compartments in various combinations were tested. The maximum number of compartments nine - if all implemented, forms a dense network of compartments to the North and to the South of CPP. With all the nine compartments incorporated, the flooding situation improved considerably with no significant hydraulic problems. This justifies the technical viability of reliability for multiple compartment setting.

Conclusions

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CPP has shown that the compartmentalization concept of controlled flooding, and water management involving the beneficiaries, is a technically viable concept in Bangladesh. The economic viability is less clear.

Any lingering doubts about the protection provided by CPP were removed in 1998 when, during the floods of that year, the compartment, including Tangail Town remained largely flood free while surrounding areas were inundated.

There have been measurable benefits from CPP. These are:

- Increased agricultural output
- A rapid expansion of aquaculture together with increased yields
- Job creation
- Avoidance of flood damage to infrastructure and buildings

There has also been the non-quantifiable, but major, benefit, of people being protected from flooding.

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The Project Framework

Background

Much of Bangladesh is located on flood plains, in consequence the country floods every year and has done so from time immemorial. Indeed, the life of the country has adjusted to it. Agriculture, in particular, is dependent upon the flood to replenish soil moisture, the water table, and the fertility of the soil. On the Jamuna flood plain, the location of the project, agriculture can be understood as man's best answer to the vagaries of the monsoon and the unpredictability of the mighty river system. A production system has evolved which exploits the area's peculiar weather and hydrological cycle, while anticipating the very real chances of damaging monsoon floods coming down the Jamuna River and its branches.

However, there are times when the floods come to an unusual extent, overwhelming people's ability to cope with the water. At such times, crops and houses are destroyed and lives are lost. Such times were 1987 and 1988 when two years of severe flooding led to widespread devastation in the country. Several thousand people lost their lives; many thousands lost their homes and properties. The impact on the national economy was disastrous.

The two years of severe flood led to an outpouring of donor support, which culminated in 1989 in a conference, held in London. This was attended by the main international donors and representatives from Bangladesh and was intended to address action that could be undertaken to try to prevent future flood disasters. Out of the conference came the Flood Action Plan (FAP).

The plan consisted of 26 different studies and pilot projects. Included in these 26 components was FAP 20, the Compartmentalization Pilot Project (CPP)¹.

The original concept was that of the construction of primary embankments along the Jamuna River, with a secondary line of defense being an embankment around the compartment. At that time, embanking the major rivers was one of the proposals for flood control in Bangladesh, but this quickly fell into disfavor on both grounds of technical difficulty and cost. In the event, what was originally seen as the secondary embankment around the compartment quickly became the only embankment.

Location

The *Compartmentalization Pilot Project* Tangail is located at the left bank of the Brahmaputra (Jamuna) River at 24°-24.25° N and 90°-90.25°E. It is a part of the Young Brahmaputra Floodplain ecosystem (see Figure 1).

The Compartment is situated between two rivers, the Dhaleswari in the West and the Pungli in the East. The Dhaleswari takes off from the Jamuna River at about the location of the present Bangabandhu Bridge. The Pungli is a tributary of the Dhaleswari and starts a few kilometers downstream of the bridge. The Lohajang is the Dhaleswari's next major offshoot, running between the Dhaleswari and the Pungli. It cuts the Compartment into a western and an eastern half, of about equal size. Halfway down the western boundary of the Compartment, the Dhaleswari turns West, but a third tributary, the Elanjani River, continues following the boundary up to the most southerly tip of the Compartment.

The Lohajang follows the northern boundary of the Compartment on the outside, over a short distance, before it enters the Compartment. Along the remaining part of the northern boundary, there is the Gala Khal, which connects the Lohajang to the Pungli River.

The CPP covers 13,305 ha, of which 9,858 ha² are net cultivatable area (NCA), the remainder comprising homesteads and settlements, infrastructure, and water bodies. At first sight, the area seems flat; indeed the contours vary between 7.5 and 12.5 masl, which is not a lot for an area of its size. However, closer examination reveals that it has a complex micro-relief with numerous ridges and a network of old channels and depressions. This topography is shown in Figure 2. Most of the land is prone to inundation during the monsoon season by rainwater and river floods.

The CPP has a 1999 population of around 288,250³ people and is centered on the Town of Tangail in which 170,000 people live. Administratively, it covers 40% of Tangail Sadar, 11% of Delduar and minor parts (<2%) of Basail and Kalihati Thanas of Tangail District.

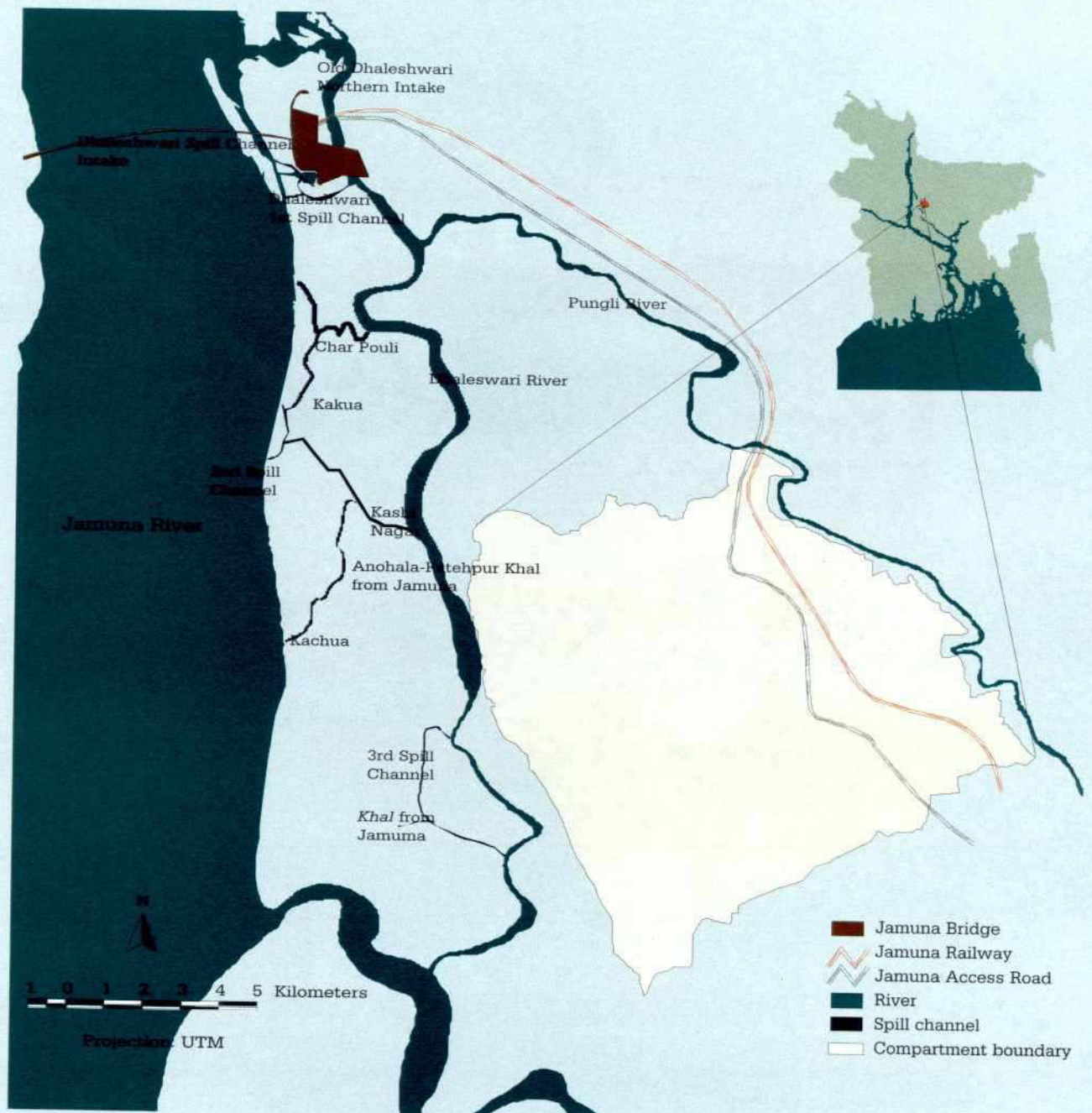


Figure 1: The Tangail Compartment and its Surroundings

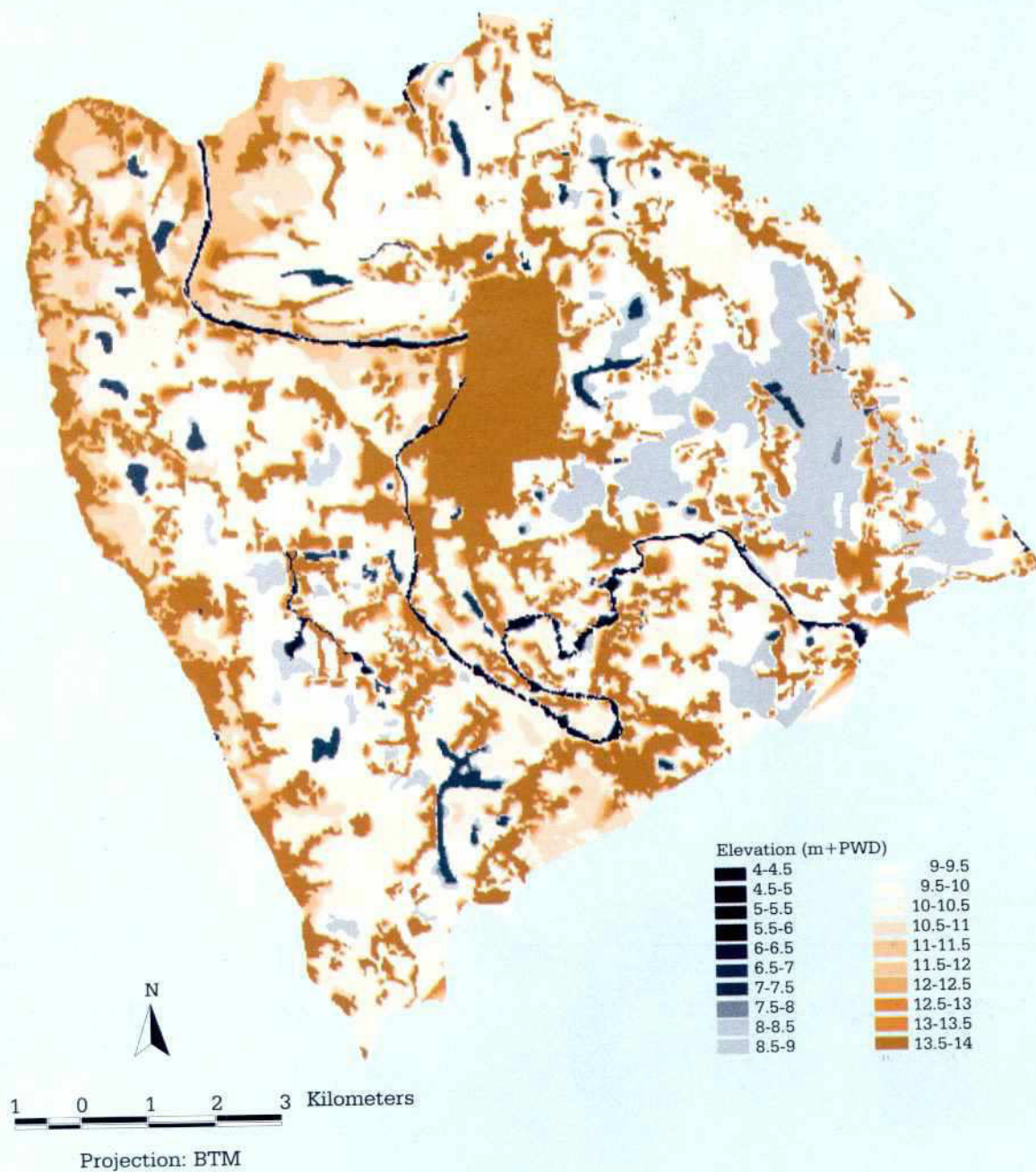


Figure 2: Topographical Map of the Tangail Compartment

Objectives

It was realized from the beginning that the answer to flood in Bangladesh was not to prevent flooding in rural areas; to do so would disrupt agriculture. The key was to manage floods. Therefore, the aim of CPP is to permit controlled flooding, improve the drainage and enhance the water management within the Tangail floodplain.

Prior to the project, natural water flow had already been modified by a primary horseshoe embankment built on three sides of the compartment during the 1960's. (See Figure 3).

The purpose of the controlled flooding is to manage the overland flow, which originates from neighboring major rivers and local rainfall. The controlled flooding is achieved by the construction of inlet structures at the peripheral embankments, and by regulators which convey the water from one sub-compartment to another within the CPP area. Under controlled flooding, the CPP area is surrounded by main embankments that have a crest level sufficiently high to withstand a 1:20 year floods. The objective is to allow floods into the area at desirable levels and periods beneficial to farming, fisheries and other wetland uses, while at the same time providing protection for the homesteads, settlements and infrastructure.

Drainage is important in order to keep water levels at a desirable height. Outlet structures located at strategic sites in river or road embankments, with or without regulators, control these water levels.

In summary, the goal of CPP was to test the technical and economic viability of the compartmentalization concept, in which an area, enclosed by an embankment, would be provided with a comprehensive water control system designed and operated in order to provide a more secure environment for intensive agriculture, fisheries and integrated rural and urban development. This, it was felt, would improve the economic security and quality of life. In detail, the CPP objective was to establish a technically feasible, sustainable and economically viable water management system for the Tangail project area. In particular the project was to consist of:

- Controlled flooding from major rivers into CPP area and within sub-compartments
- Controlled drainage of both rainwater and river flood towards downstream sections of the Lohajang River
- Improved conditions for agriculture development
- Improved conditions for fisheries and aquaculture development

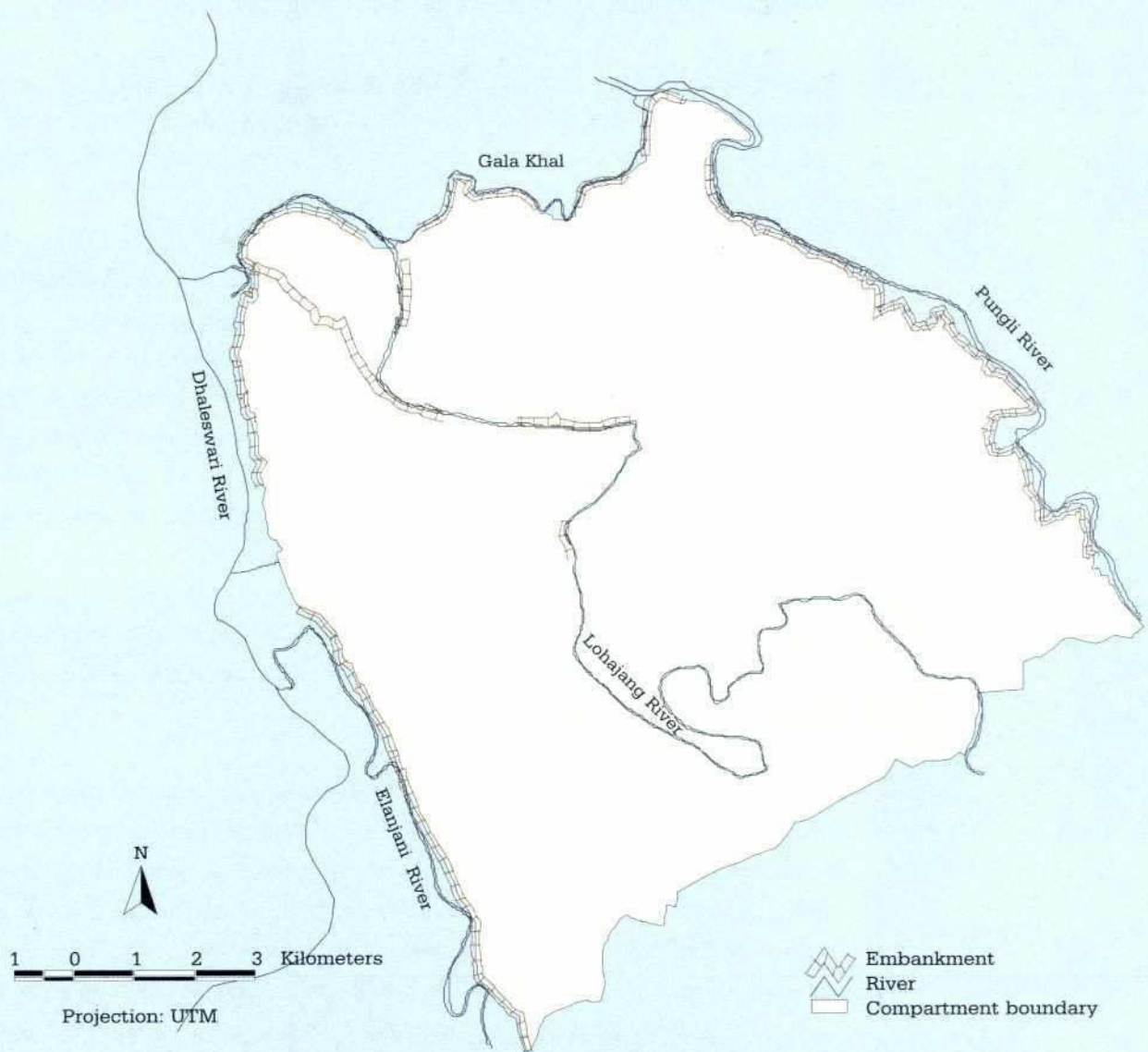


Figure 3: Pre-Project Situation

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- Improved communications
 - Involvement of beneficiaries in planning, design, operation and maintenance of works
 - Providing appropriate local organizations
 - Enhancing the environment
 - Providing disadvantaged groups, particular women, with employment opportunities

The biggest question was how to develop this area in an institutionally sustainable unit, in which decision making should involve people's participation. Such an approach was unknown in Bangladesh in 1991⁴.

Also to be tested was the sustainable and replicability of compartmentalization.



The Pre-project Situation

Figure 3 is a map showing the condition of the Compartment before CPP. There were gaps in the peripheral embankment and in the embankments along the Lohajang. The area had five intake structures, four in the western embankment and one along the Pungli. Two of the intake structures were positioned in a gap in the embankment. The sub-compartment boundaries on the map did not yet exist before CPP. They have been determined by the Project.

The major occupation within the compartment was farming, mostly on small to medium sized farms. As well as providing a livelihood for the farmers, these farms are also a major source of employment for landless agricultural labor, which is close to seventy percent of the population within the project area.

Classification Farm Type	Farm Size Ha	Household No (1991)	Household %(1991)	Population No (1991)
Landless	Land < = 0.20 ha	33,197	69	181,655
Marginal	0.21ha - 0.40 ha	3,849	8	21,061
Small	0.41ha - 1.00 ha	7,457	16	40,807
Medium	1.01ha - 2.00 ha	2,165	5	11,847
Large	2.01 ha - Above	770	2	4,212
Sharecroppers		673	1	3,686
Total				263,268
Table 1: Classification of Households				

Mobilization

CPP mobilized at the beginning of 1992. The budget was intended for a project that would consist of three pilot areas (i.e. Tangail, Sirajganj and Jamalpur). The first and third areas (i.e. Tangail and Jamalpur) would be on the East bank of the Brahmaputra River, while the second one (Sirajganj) was located on its West Bank. All three pilot areas had distinctive physical features. Jamalpur was rapidly reconstituted as a separate pilot project while Sirajganj remained part of the project during much of the CPP First Phase. It was abandoned, due to the frequent breaching of the Jamuna Right Bank embankment, before the commencement of the Final Phase.

The original time frame of the project saw it running until the end of 1994, covering a period of approx. 2.5 years. A consortium of two foreign and one local consulting firms was selected whose tasks included feasibility studies, design, implementation and monitoring. In the event, the project continued to a second (Final) phase, running from 1996-2000, with a different consortium of consultants.

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**Water
Management**

Engineering and Construction

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The project area is protected against floods by primary embankments in the North, East and West, but not in the South. Thus, the embankment is horseshoe shaped. In the South, an already existing secondary embankment was chosen as Project boundary. This Southern embankment is porous with bridges and culverts which allow drainage southward.

Where the primary embankment crosses the Lohajang River in the North, the Main Regulator has been built. This is a gated structure, by which discharge and water levels in the river can be regulated. Water level control is most precise immediately downstream of the regulator. Going down the river, its impact decreases. However, even where the Lohajang leaves the Compartment, at Karatia, 25 km downstream of the regulator, there is still an effect.

There are 14 gated intake structures in the primary embankment, by which water can be supplied to the Compartment provided outside water levels are high enough. This is an important proviso. Without flood in the Jamuna, there are no flows in the Dhaleswari or Pungli. This is the case for the largest part of the year. The Dhaleswari typically flows from July to October only.

Within the Compartment, there are about 30 secondary drains, together about 75 km long, plus a large number of tertiary drains.

At the downstream end of the drainage systems, along the Lohajang, the Compartment has 15 gated outlets by which the lands drain into the river. If water levels in the Lohajang are high enough, they may serve as intakes. By closing the gates, the structures may function as retention structures. Inside the Compartment, additional gated structures provide control of the water. These are the internal control structures. (See Figure 4.)

The flood plain of the Jamuna River slopes towards the South with an average gradient of about 5 cm/km. The Lohajang River has a comparable slope. During the monsoon, water levels along the southern Compartment boundary are about 1 m lower than those in the North. When the Main Regulator is open and water flows freely, the water levels in the Lohajang, at Karatia, is also about 1 m below those at the regulator. If the regulator is closed the flow stops, and the water levels in the river are determined by the runoff from the Compartment. In the upper part, the river may fall dry.

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This Main Regulator provides the Compartment with a facility to drain. Through gate operation at the Regulator water levels in the river can be lowered below most of the land, most of the time. There are two limitations. The first is, that it is undesirable to keep the Main Regulator closed for a prolonged period. The river needs be kept healthy as people along the river depend on its water for domestic purposes. In addition, fish should be free to enter. The second limitation occurs during high floods. When the water downstream of the Compartment is high, the water in the Lohajang may rise to levels at which the river loses its drainage function. Under this circumstance, there is backing up from downstream and flows into the compartment from the South. This happened in the high flood of 1998.

The engineering and construction works executed under the Project can be sub-divided into two categories. The first are the Major Works, which are works that are typical for a drainage and flood protection system. The second category, is the Minor Works.

The Major Works consist of embankments and protection works together with structures, which have a function in the water management of the area. They are the intake or peripheral structures, the outlets along the Lohajang and the internal infrastructure. Besides the water control structures, CPP has built additional structures, mainly bridges and culverts, which do not have a function in water management, but which facilitate communications.

Besides the structures, much effort was put into the rehabilitation of the drainage system in the Compartment.

The Minor Works are different from the Major Works by both their size and function.

Major Works

Embankment - Design Criteria

Table 2 shows the design dimensions of the peripheral embankment per sub-compartment. The embankment is classified as an internal embankment, according to Bangladesh Water Development Board (BWDB) definition. Its total length is about 47 km. Crest widths vary between 4 and 4.5m. Side slopes are BWDB standard. The average embankment height varies depending on the topographical level of the land.

The design crest levels decrease from North to South, according to the slope of the outside water. BWDB's design criterion for the crest of internal embankments is a

level at 1:20 years flood level, plus a free board of 0.9 m. The 1:20 years maximum level at Jugini is about 12.60 m. Thus, in order to meet BWDB standards, the Northern embankment requires a level of 13.50 m. The level shown in Table 2, 13.73 m, for the Northern sub-compartments, therefore, exceeds the design level.

Location	Length (m)	Design Crest Level (m PWD)	Crest Width (m)	Side Slope Entry Side	Side Slope River Side	Approx. Height from Surface (m)
Sub-Compartment 1	6,652	13.25	4.30	1:2	1:3	1.45
Sub-Compartment 2	4,509	12.95	4.30	1:2	1:3	1.45
Sub-Compartment 5	1,747	13.47	4.30	1:2	1:3	1.45
Sub-Compartment 6	7,878	13.54	4.30	1:2	1:3	2.75
Sub-Compartment 7	4,577	13.73	4.40	1:2	1:3	2.00
Sub-Compartment 8	1,339	13.73	4.40	1:2	1:3	2.00
Sub-Compartment 9	3,684	13.73	4.40	1:2	1:3	1.20
Sub-Compartment 10	4,088	13.63	4.25	1:2	1:3	2.00
Sub-Compartment 11	4,087	13.42	4.25	1:2	1:3	2.00
Sub-Compartment 12	3,861	13.22	4.25	1:2	1:3	1.90
Sub-Compartment 13	4,542	13.01	4.25	1:2	1:3	1.90

Table 2: Design Dimensions of the Peripheral Embankment

During the 1998 flood, the embankment failed in several places. It was not overtopped by the water, but due to the prolonged flooding, the embankments became saturated and collapsed. The maximum level of the 1998 flood at Jugini was 13.39, which is 0.8 m above the 1:20 year level. In addition, the duration of three months was exceptional.

Quality of the Peripheral Embankments

BWDB is the owner of the peripheral embankment. However, it fails to exercise sufficient control over it with rules regarding construction on, and adjacent to the embankment, not being enforced. Many houses have been built on the embankment, which limits accessibility over the top and to the side slopes. Land users cultivate their land too close to the side slopes, even to the point of cutting into them. Fishponds, adjacent to the embankment, reduce its stability.⁵

If the embankment need to be rehabilitated, the BWDB applies re-sectioning. Re-sectioning is manual work. Borrow pits are identified along the alignment, by the contractor, and soil is carried by head pan from the pit to the embankment and dumped on top. Side slopes with houses can not be reached; fishponds are not filled

in. Even if the side slopes can be reached, the method is not suitable to rehabilitate them. The quality of the soil in the borrow-pits is not tested and there are no approval procedures. Re-sectioning is a matter of quantity, rather than quality.

The results are rather vulnerable. After rainstorms, deep cuts appear in the side slopes on many places. The 1998 flood also revealed that the embankment had been insufficiently compacted. Many so-called rat holes appeared through which water started seeping. Although animal activity may have been a factor, it was clear that piping was another. Piping occurs when soil particles are progressively washed out due to hydraulic gradient, leading to the formation of a "pipe" which can rapidly erode, leading to embankment collapse. Poor compaction can be a contributory factor to the development of piping failure.

Works on the Peripheral Embankments

Table 3 lists the works done on the peripheral embankment, with job numbers and year of completion. For the purpose of construction, the compartment is divided into four clusters. Job numbers starting with 00 all refer to the peripheral embankment. Job numbers of works along the Lohajang, carry the number of the cluster. There are two main categories of works: those before and after the 1998 flood. The works before and after 1998 carry the same job numbers, which means that repairs were necessary at the locations.

Rehabilitation before 1998 included filling the gaps in the embankment shown in Figure 3. In addition, almost the entire embankment was overhauled by re-sectioning.

The 1998 flood created a need for repair. The breaches, which were provisionally closed, had to be brought under profile and stretches that were heavily damaged, had to be repaired. The breaches were at Rasulpur, Indrabelta and Silimpur. At Rasulpur and Silimpur, erosion of ungated culverts in the embankment triggered the breaching. In 1998, the culverts were replaced by gated pipe inlets (GPI).

The embankment at Birnahali and Kumulli, along the Pungli was also heavily damaged and needed repair after 1998.

Embankments along the Lohajang

There is no BWDB embankment along the Lohajang. Protection is provided by unpaved embankments and existing roads, which are under the Local Government Engineering Department (LGED). LGED did not participate in the Project. Nevertheless, the Project undertook to rehabilitate these works. Table 3 shows the job numbers and the years of completion. All works are in the Clusters 1 and 2. The total length is about 12 km.

WORKS BEFORE 1998		Completed Fiscal Year	Comments	Reimbursed OR Contract Value	Totals
Job Number	Job Title			(Million Taka)	(Million Taka)
Peripheral Embankment					
00601	Ramdevpur - Gopalpur Embankment	1993-94		1.57	26.62
00602	Gopalpur - Dhalan Embankment	1995-96		0.56	
00603	Dhalan - Binnafair Embankment	1993-94		0.59	
00604	Fatehpur Advanced Embankment	1995-96		3.07	
00605	Charabari - Silimpur Embankment	1995-96		3.75	
00606	Ramdevpur - Khorda Jugini Embankment	1995-96		0.34	
00607	Ramdevpur - Kathua Jugini Embankment	1995-96		0.37	
00609	Gala - Pichuria Embankment	1993-94		0.88	
00610	Gala-Rasulpur Embankment	1996-97		1.17	
00611	Rasulpur - Salina Embankment (Part I)	1995-96		0.57	
00612	Rasulpur - Salina Embankment (Part II)	1996-97		3.64	
00613	Salina - Dapnazar Embankment (Part)	1996-97		7.80	
00614	Bangra Embankment	1993-94		1.19	
00614	Bararia-Suruj Embankment (Salina-Dapnazar)	1996-97		0.63	
00615	Khaladbari Embankment	1992-93		0.19	
00616	Rupshijatra - Silimpur Embankment	1992-93		0.13	
00617	Rupshijatra Embankment	1992-93		0.06	
00618	Fatehpur Embankment, repair after 1995 flood	1995-96		0.14	
Embankment along the Lohajang					
10604	Dithpur Outlet - Main Regulator	1994-95		0.81	4.88
10605	Pardighulia-SC Embankment (Part II)	1996-97		0.66	
10801	Approach Road from Chillabari to Dhannya Chow	1994-95		0.23	
20604	Embankment Dharerbari to District	1997-98		2.23	
20801	Access Road over District Regulator	1994-95		0.94	
Protective Works					
20901	Passbetur Groyne I & II	1994-95	Work not accepted	7.13	11.95
41302	Belta Sarai Protective Work	1995-96			
60904	Gonikishore Protective Work	1992-93 & 1995-96		1.29	
60901	Pardighulia Protective Work	1994-95		1.06	
60903	Protective Work near Rafat Textile	1992-93		2.46	
Other Works					
60504	Elenjani River Loop Cut	1996-97		4.17	4.17
61102	Gala Khal under FFW	1996-97			
(Continued)					

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WORKS AFTER 1998		Completed Fiscal Year	Comments	Reimbursed OR Contract Value (Million Taka)	Totals (Million Taka)
Job Number	Job Title				
Peripheral Embankment					
00601 - 00605 and 00609 - 00617	Resectioning of Embankment	1998-99		24.13	
00613	Retired Embankment at Birmahali	1998-99		1.44	
00614	Salina-Dapnazar Embankment (Part)	1999-2000		0.83	
00613	Additional Resectioning Suruj-Birmahali	1999-2000		4.00	
20406	Rasulpur GPI	1999-2000	Except gates	0.94	
40411	Silimpur GPI	1999-2000	Except gates	1.36	
40702	Silimpur Embankment, Breach Closing	1999-2000		0.15	
					32.86
Embankment along the Lohajang					
10605	Sarutia-Chillabari Embankment	1999-2000		1.90	
20604	Resectioning of Embankment Dharerbari to District Regulator	1998-99		0.32	
10604 and 20604	Add. Resectioning Dithpur-Main Reg and Dharerbari-District Reg	1998-99		0.80	
					3.02
Protective Works					
41302	Protective Work at Belta-Sarai	1998-99	Work not accepted		
60905	Protective Work at Birmahali	1999-2000		0.96	
60906	Protective Work near Elanjani Loop Cut	1999-2000		0.51	
60907	Protective Work at Kumulli	Not started		0.60	
					2.07
	Overall Total				85.56

Table 3: Cost of Works on the Embankments and Protective Works

After the 1998 floods, the embankments needed additional repairs, which were undertaken under the same job numbers.

Protective Works

Protective works differ from works on embankments with respect to the materials used. They may involve stone protection, geo-textiles and other materials besides earth. The first protective works listed in Table 3 are groynes along the Pungli in Cluster 2. Next, follow two jobs along the Elanjani outside Cluster 4, where the river has started eroding the foot of the embankment. The two remaining jobs are along the Lohajang.

Job Number	Job Title	Completed Fiscal Year	Comments	Reimbursed OR Contract Value (Million Taka)	Totals (Million Taka)
	Main Works				
00101	Main Regulator	1995-96		23.63	
00101	Remodeling of Fish Pass in the Main Regulator (1st and 2nd part)	1998-99		0.47	
00101	Additional Lining	1999-2000		0.10	
01301	Main Regulator Downstream Protection	1995-96		4.68	
					28.88
Cluster 1	Water Control Structures				
00201	Binnafair Intake, Existing Structure, Gate Installation only	1993-94		0.13	
00202	Fatepur Intake, Existing Structure, Gate Installation only	1993-94		0.13	
10102	Khorda Jugini Intake	1993-94		2.83	
					3.10
10101	Dithpur Outlet	1993-94		1.94	
10103	Kagmani Outlet	1994-95		7.56	
10301	Dhannya Chowdhury Outlet	1993-94		1.12	
10302	Dighulia-1 Outlet	1993-94		1.23	
10307	Dighulia-2 Outlet	1999-2000	Except gates	1.08	
10310	Chillabari Outlet	1993-94		1.35	
					14.27
10303	Krishnopur WCS	1994-95		1.21	
10304	Beel Baghil WCS	1993-94		0.49	
10305	Eidgah Moidan WCS	1995-96		1.12	
10306	Bhangabari WCS	1995-96		2.83	
10308	Rampal WCS	1993-94		1.09	
10309	Singerkona WCS	1993-94		1.27	
10311	Chowbari WCS	1993-94		0.40	
10313	Sapua WCS	1995-96		0.41	
10314	Santosh WCS	1994-95		6.02	
					14.83
(Continued)					

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Job Number	Job Title	Completed Fiscal Year	Comments	Reimbursed OR Contract Value (Million Taka)	Totals (Million Taka)
	Additional Structures				
10401	Binnafair bridge	1995-96		3.24	
10402	Dhannya Chowdhury Box Culvert	1995-96		1.09	
10403	Alishakanda Pipe Culvert	1994-95		0.10	
10404	Anehola Pipe Culvert	1994-95		0.08	
10405	Pach Kahania Pipe Culvert	1996-97		0.21	
10406	Choto Binnafair Box Culvert	1994-95		0.71	
10407	Charpara Box Culvert	1993-94		0.75	
10408	Kathua Juguni Pipe Culvert	1993-94		0.15	
10409	Moisakanda Pipe Culvert	1993-94		0.11	
10410	Fatehpur Pipe Culvert	1993-94		0.10	
10411	Santosh Bridge	1995-96		3.61	
10412	Fatehpur Box Culvert	1996-97		0.29	
10412	Fatehpur culvert remodelling	1999-2000	Not Available		
99999	Fatehpur 3 Irrigation Aquaducts	1996-97		0.22	
99999	Fatehpur Drain Lining	1999-2000		0.05	
					10.69
Cluster 2	Water Control Structures				
00102	Sadullapur Intake	1996-97		6.21	
00103	Rasulpur intake	1995-96		3.64	
20316	Pauli Intake	1996-97		0.81	
20318	Bararia Intake	1996-97		0.54	
20403	Passbetur Irrigation Intake	1995-96		0.22	
20101	District Regulator	1995-96		6.84	
20310	Dharerbari Outlet	1995-96		1.94	
					11.43
20301	Enayetpur WCS-1 with boat pass	1994-95		2.67	
20302	Salina WCS	1993-94		1.32	
20303	Enayetpur WCS-2	1995-96		2.19	
20304	Beel Gharinda WCS	1995-96		3.78	
20305	Agbetor WCS	1995-96		3.03	
20307	Bhatchanda-1 WCS (South)	1995-96		1.01	
20308	Bhatchanda-2 WCS (North)	1995-96		0.85	
20309	Magurata WCS	1995-96		2.48	
20312	Charkagmara WCS	1997-98		0.95	
					18.27
(Continued)					

Job Number	Job Title	Completed Fiscal Year	Comments	Reimbursed OR Contract Value (Million Taka)	Totals (Million Taka)
	Additional Structures				
20404	Kandila Bridge	1998-99		2.55	
20405	Dharerbari Pipe Culvert	1995-96		0.02	2.57
Cluster 3	Water Control Structures				
00105	Suruj Intake	1995-96		3.33	3.33
30101	Jalfai Outlet	1995-96		7.58	
30102	Bhatkura Outlet	1995-96		7.40	
30302	Khudrampur Outlet	1996-97		2.63	17.60
30103	Paschim Pauli WCS	1994-95		2.39	
30301	Karatia WCS	1995-96		1.69	
30304	Birnahali-1 WCS (South)	1995-96		1.20	
30305	Niogi Joair WCS	1995-96		1.05	
30306	Namder Kumulli Madhyapara WCS (North)	1995-96		1.17	
30308	Gosaijoair WCS	1995-96		0.91	
30309	Hatila WCS	1996-97		1.90	
30310	Poila WCS	1995-96		1.99	
30311	Mirer Betka WCS	1995-96		1.15	
30312	Namder Kumulli WCS (South)	1995-96		0.99	
30313	Karatia Chowdhury Para WCS	1995-96		1.23	
30314	Dharat WCS	1995-96		0.48	
30315	Birnahali-2 WCS (North)	1995-96		0.60	16.74
	Additional Structures				
30403	Golabari Box Culvert	1994-95		1.13	
30405	Hatila Box Culvert	1994-95		2.18	
30407	Dharat Pipe Culvert	1994-95		0.23	
30408	Sarutia Pipe Culvert	1994-95		0.24	
30409	Darun Box Culvert	1995-96		3.64	
30410	Aultia Pipe Culvert	1994-95		0.33	
30411	Sarutia Box Culvert	1996-97		2.11	
30412	Gosaijoair Box Culvert	1994-95		1.58	
30413	Bhatkura Pipe Culvert	1995-96		0.22	11.65
(Continued)					

Job Number	Job Title	Completed Fiscal Year	Comments	Reimbursed OR Contract Value (Million Taka)	Totals (Million Taka)
Cluster 4					
	Water Control Structures				
00104	Baruha Intake	1995-96		3.52	
00203	Indra Belta Intake, Existing Structure, Gate Installation only	1994-95		0.10	
00204	Barabelta Intake, Existing Structure, Gate Installation only	1994-95		0.10	
					3.72
40101	Aloya Raypara Outlet	1998-99		9.74	
40102	Deojan Outlet	1996-97		5.84	
40314	Birpushia Outlet	Dropped			
40406	Kumulli Outlet	1996-97		1.07	
40407	Khagjana Outlet	1996-97		1.12	
					17.75
40302	Berabuchna WCS	1997-98		1.56	
40303	Burburia WCS	1997-98		4.01	
40304	Bara Atia WCS	1996-97		0.92	
40402	Aloa Bhabani-1 WCS	1996-97		0.61	
					7.09
	Additional Structures				
40403	Aloa Bhabani-2 Gated Pipe Culvert	1996-97		0.79	
40412	Birpushia Box Culvert	1999-2000		0.45	
					1.24
	Overall Total				191.93
Table 4: Costs of Water Control Structures and Additional Structures					

During 1998, the Elanjani River again damaged the protective works of 1995-96, at Belta-Sarai and new protection was required. This was carried out in the 1999/2000 construction season. The only work along the Lohajang was on the Sarutia-Chillabari embankment.

Structures

The locations of the water management structures are shown in the Figures 5 to 8. During the First Phase, it proved difficult to develop an overall design for the entire Compartment. A main difficulty was predicting the water levels in the Lohajang, which is the backbone of the drainage system. They are influenced by water levels

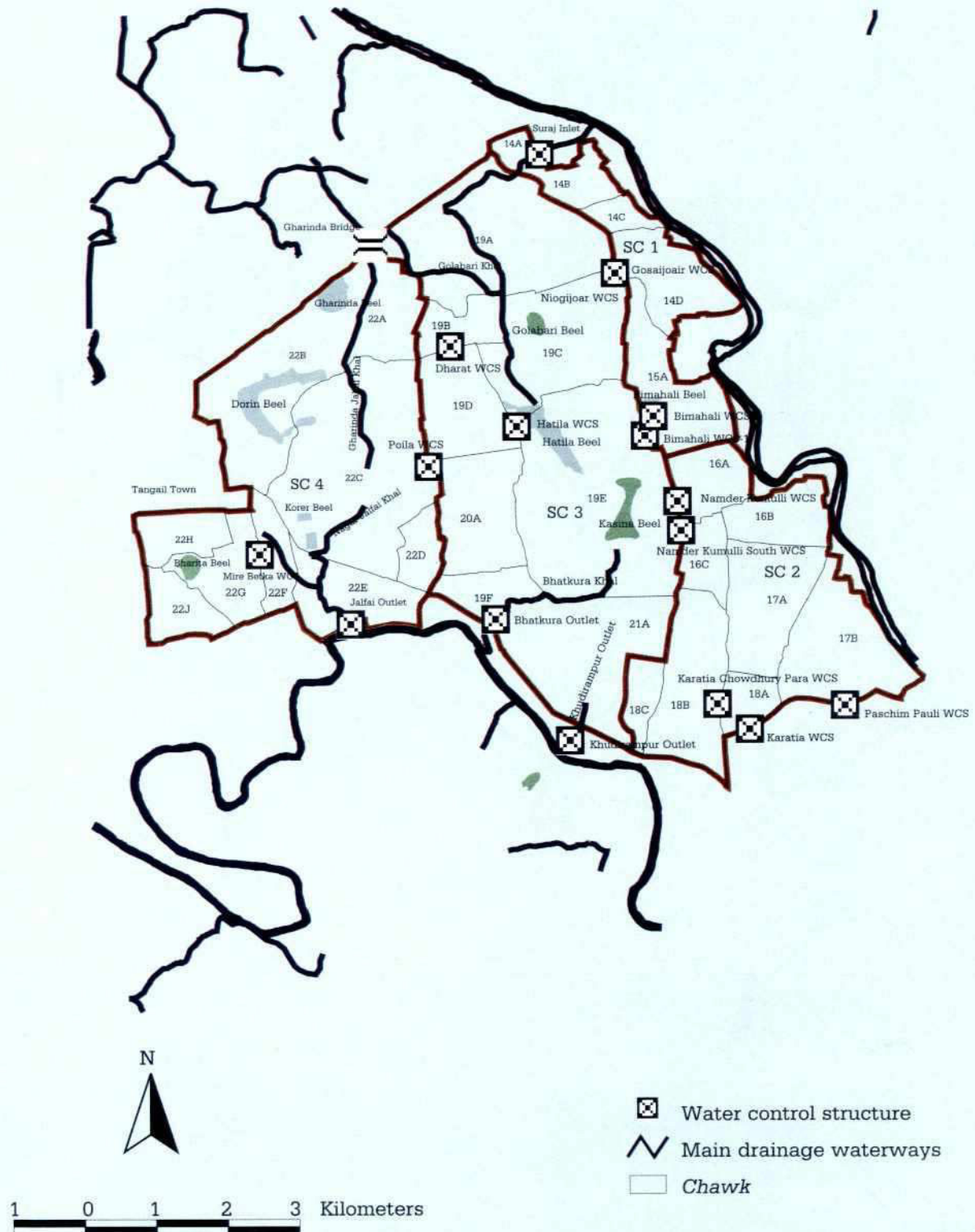


Figure 7: Water Management Infrastructure Cluster 3

outside the Compartment, particularly those at Karatia, where the river leaves the Project area. That problem could only be solved by the modeling at that time. It took an additional modeling effort during the Final Phase to develop a comprehensive model for the entire Compartment including the Lohajang and the external hydrological boundaries.

The lack of an overall design primarily affected decisions about design water levels, to a lesser extent those about the locations of the structures. There were already five intake structures in the pre-Project situation and they were rehabilitated. The locations of the other intakes arose from the locations where the major drainage systems extended up to the peripheral embankment. The need for the intake structures originated from CPP's determination to put great emphasis on controlled flooding and water management. For the same reason, outlet structures were built at locations where the major drainage systems entered the Lohajang.

Design Procedures

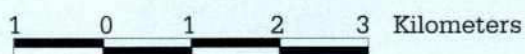
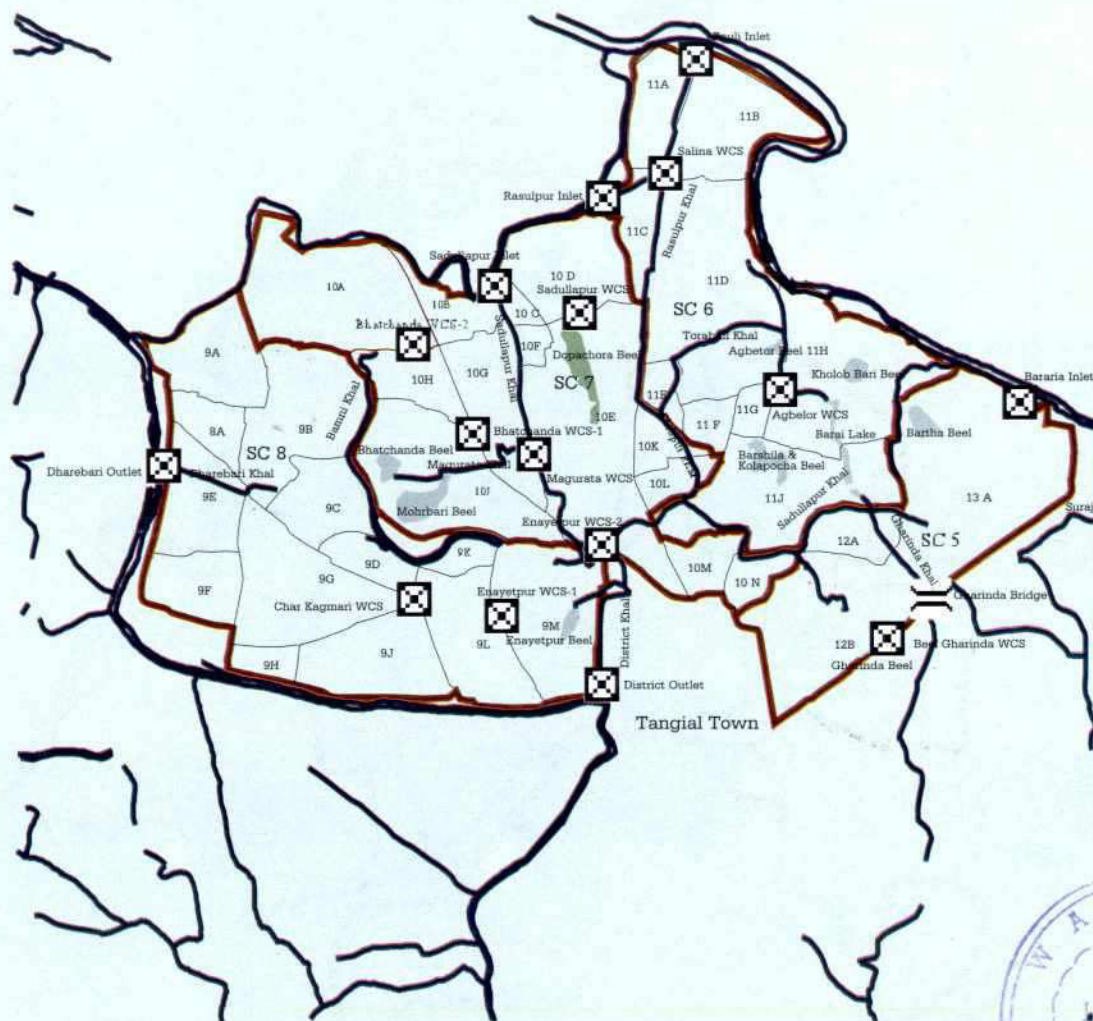
Actual designs were done by the BWDB's Design Circle in Dhaka. The Design Circle does not provide design reports, so design reports on structures, including on the Main Regulator and the peripheral intakes, were never provided to the project.

The centralized approach to design works against useful input that could be provided by the consultants during both design and during construction, when it is often possible to see small design changes that could improve the efficiency of a structure or save cost.

Implementation of Structures

Table 4 lists the structures implemented by the Project, their job numbers and the year of completion. Intakes, outlets and other water control structures have been listed under the heading "Water Control Structures". Water control structures are used in the water management in the Compartment. They all have gates.

Additional Structures are listed next in Table 4. These are structures which facilitate drainage and/or road transport, but which cannot control water. They do not have gates. The table shows that almost all structures have been completed before 1996, with some overflow into 1997. Structures in Cluster 4 were the latest to be implemented. Aloa Raypara Outlet only received gates shortly before the monsoon 1999. The delay was due to opposition, not so much from the population, but from influential persons, who held out for higher compensation for land acquired by the Project.



- Water control structure
- Main drainage waterways
- Chawk

Figure 6: Water Management Infrastructure Cluster 2

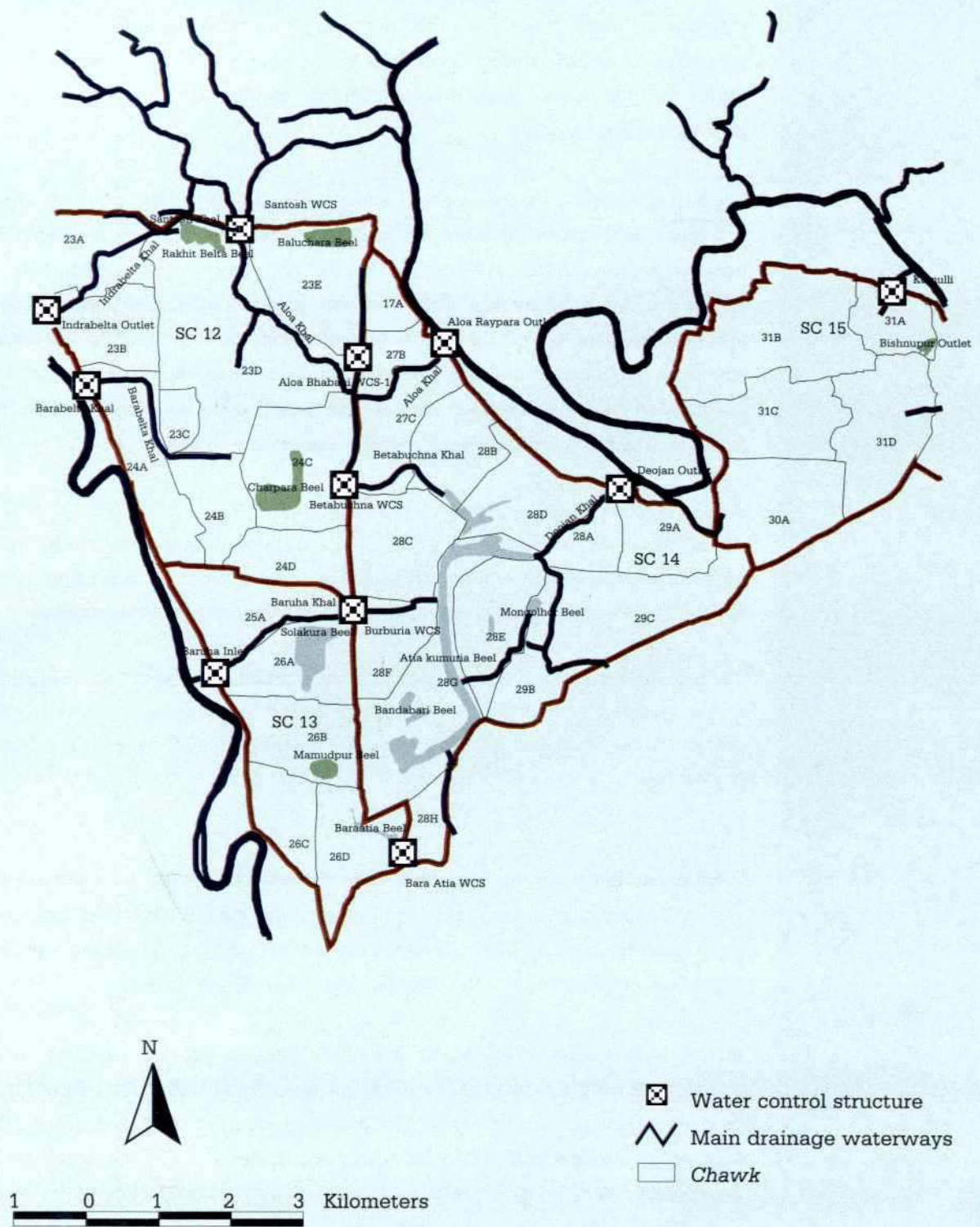


Figure 8: Water Management Infrastructure Cluster 4

outside the Compartment, particularly those at Karatia, where the river leaves the Project area. That problem could only be solved by the modeling at that time. It took an additional modeling effort during the Final Phase to develop a comprehensive model for the entire Compartment including the Lohajang and the external hydrological boundaries.

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Drains and Other Works

Table 5 shows the job numbers, the length and the design cross sections of the main and secondary drainage systems. They are also shown on the Figures 5 to 8. In Cluster 1, there are three drains without a job number. Their excavation was opposed by the local population from the beginning and the works were dropped. In Cluster 2, Bamni Khal was only partly excavated. Due to local opposition, the continuation of the work was dropped.

The design data originate from the BWDB Design Circle. There are no design reports. The total length of the drains is 74 km, including the Lohajang.

The Lohajang was excavated from a point 2.5 km upstream of Putiani Bridge up to Karatia. Another part of the Lohajang, from the point mentioned, upstream to Chillabari Outlet was excavated under the Food for Works Program (FFW) during Fiscal Year 1997-98. A third stretch, from Chillabari all the way up to Jugini was planned for excavation, but was dropped in 1998. The main reason was that heavy siltation occurs at the point where the Lohajang branches off from the Dhaleswari. The siltation reappears every year and is difficult to control by manual excavation.

The excavation of some drains was completed rather late during the Project's lifetime, many only after the 1998 monsoon. This has determined the low drainage rates calculated by the hydraulic models. For most of the years, the overall drainage of the Compartment was not functioning as anticipated. In the 1999/2000 construction season there was a final, largely successful, push to get the drainage completed.

Drainage Facilities Created

The excavation of the drainage system was plagued by local opposition, land acquisition problems and defaulting contractors. It is difficult to determine which one was the most serious, as this differed from job to job. The local opposition seems odd given that during initial meetings with local stakeholders one of the most frequently requested benefits was "improved drainage". However, the opposition frequently resulted from local conflicts⁶.

In Cluster 1, the Singerkona-Dannya Chowdhury Khal, the Khorda Jugini Khal and the Khanpur borrow pit, could only be excavated during the 1998-99 dry season. Before that date, they were not functional. Land acquisition was the major problem.

The excavation of Ghoramara Khal, upper and lower part, and the drainage route going from Singerkona to Ghotokbari Beel, was not accepted by the population, even

before land acquisition procedures were started. The present drain is wide and shallow and is in use as a paddy nursery.

Job Number	Job Title	Completed Fiscal Year	Reimbursed or Contract Value (Million Taka)	Totals (Million Taka)
Main System				
60501	Lohajang R. excavation 2.5 km upstr. of Putijani Bridge - Karatia	1995-96	9.44	
60501	Lohajang R. excavation Chillabari - Jugini		Dropped	
61101	Lohajang R. excav. 2.5 km upstr. Putijani Br. - Chillabari (FFW)	1996-97	FFW	9.44
Cluster 1				
	Finished Works			
10502	Singerkona - Dannya Chowdhury Khal	1998-99	0.43	
10503	Binnafair Khal	1993-94	0.77	
10505	Dithpur Khal	1995-96	0.21	
10506	Rampal Khal	1993-94 & 1997-98	0.19	
10509	Fatehpur Khal	1994-95	0.16	
10511	Dighulia Khal	1994-95	0.10	
10512	Chillabari Khal	1992-93	0.77	
10513	Gajjabari Khal	1992-93	0.83	
10501	Khorda Jugini Khal	1998-99	0.36	3.80
	Unfinished Works			
10510	Khanpur Borrowpit	1999-2000	0.44	
10504	Ghoramara Khal (Upper and Lower part)		Dropped	0.44
Cluster 2				
	Finished Works			
20501	Sadullapur Khal	1993-94	1.33	
20502	Magurata Khal	1994-95	0.08	
20506	Dharerbari Khal	1996-97	0.10	
20507	District Khal	1993-94	0.50	2.01
	Unfinished Works			
20506	Dharerbari Drain Lining	1999-2000	0.31	
20508	Rasulpur Khal	1999-2000	2.16	
20509	Bamni Khal	1994-95	0.25	Dropped
				2.72
(Continued)				

Job Number	Job Title	Completed Fiscal Year	Reimbursed or Contract Value (Million Taka)	Totals (Million Taka)
Cluster 3				
	Finished Works			
30505	Suruj Khal	1994-95	0.97	
30505	Suruj Khal	1998-99	0.36	
30508	Golabari Khal	1995-96	0.26	
30507	Nagor-Jalfai Khal, Downstream of Highway Tangail - Dhaka	1994-95	0.43	
30501	Bhatkura Khal	1994-95	0.84	
30502	Khudirampur Khal	1996-97	0.44	
				3.29
	Unfinished Works			
30506	Gharinda-Jalfai Khal, Upstream of Highway Tangail - Dhaka	1999-2000	2.33	
30506	Gharinda-Jalfai Khal, Upstream of Highway Tangail - Dhaka	1999-2000	0.30	
				2.63
Cluster 4				
	Finished Works			
40503	Berabuchna Khal	1997-98	0.31	
40505	Indra Belta Khal	1996-97	0.11	
40511	Deojan Khal	1996-97	0.21	
40508	Baruha Khal, Baruha Intake - Burburia WCS	1997-98	0.51	
40514	Kumulli Khal	1998-99	0.06	
				1.20
	Unfinished Works			
40502	Aloa Khal	1999-2000	1.36	
40504	Barabelta Khal	1999-2000	0.85	
40508	Baruha Khal, Burburia WCS - Kumuria Beel	1999-2000	0.54	
				2.75
	Additional Drains:			
20503	Kandila-Deolia Khal (Additional Drain)	1994-95	0.06	
40501	Santosh Khal	Dropped		
40506	Katakhali Link Canal (Additional Drain)	1998-99	0.10	
40507	Bagerchara Link Canal	Dropped		
40510	Baruha Link Canal	Dropped		
40517	Kumergara Khal	1998-99	0.09	
				0.25
	Overall Total			28.53
Table 5: Costs of the Excavation of Drainage Canals				

In Cluster 2, the excavation of Bamni Khal ran into serious and permanent land acquisition problems. The work was dropped before it was completed. At that time, completion was only about 35%. Rasulpur Khal has a stretch of about 150m, which remained unexcavated for a long time being finished just before the conclusion of the Project.

The Gharinda-Jalfai Khal, in Cluster 3, suffered from a defaulting contractor, who worked on the drain for three years and had not completed it by June 1999. The work was re-tendered for completion in 2000, prior to project completion.

In Cluster 4, the Aloa, Barabelta and Baruha Khals suffered from incomplete excavation, mainly for land acquisition reasons, and were only completed in 2000 just prior to the Project closing.

The major bottleneck for finalizing the drainage, was not the timely completion of the water control structures but the excavation of drains. The construction of structures has always been ahead of that of the drains.

Remaining Works

Table 6 provides a list of remaining works executed by the Project. There are two items in Cluster 1. One is the improvement of the road, which forms the Southern boundary of Sub-Compartment 9, the Dithpur-Shibpur Road. The other is the improvement of part of the road along the Southern boundary of Cluster 1. A third job was the improvement of the access road to Rasulpur Bridge, a bridge over the Gala Khal in Cluster 2. All roads had been completed by 1996.

There are 12 items of work outside the Compartment. They are all roads and related bridges. Tangail Town Drain has been completed as far as the concrete work is concerned. On the inland side, towards Darun Beel, the alignment ran into land acquisition problems and had to be abandoned.

Minor Works

The water management surveys among land users during the Final Phase revealed that there are many small infrastructures and water related problems at local level. They concern not only drainage but also accessibility, works required to solve local conflicts between farming and fishing, etc. Some are earthwork, excavation of drains, repair of minor embankments; others involve the construction of structures, mainly culverts. Solving such problems contributes to the quality of water management and to the quality of life in general.

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Job Number	Job Title	Completed in Fiscal Year	Completion by June 1999
Works Inside the Compartment			
10606	Rakshit Belta Sub-Compartment Embankment	1995-96	
10802	Dithpur - Shibpur Road	1993-94	
20802	Access Road at Rasulpur Bridge	1995-96	
61301	Boundary Pillars to delineate the works (500)		
Works Outside the Compartment			
60401	Rasulpur Bridge	1995-96	
60506	Baghil Ainapur Soyabeel Khal	1998-99	
61202	Chardurgapur Bridge incl Protective Work and Additional Repair	1999-2000	
61203	Beel Muri Bridge	1997-98	
61204	Bara Basalia Dakhin Para Primary School to Rasulpur Road	1996-97	
61206	Road Chotobashalia to Gala Purbapara	1996-97	
61207	Senergagorjan Bridge to Faliarghona Madrasa Road	1999-2000	95%
61208	Road Galarchar Primary School to Mohammad Ali's House	1997-98	
61209	Beel Muri Chowdhury Malancha Road	1996-97	
61210	Beel Muri Deldar Char Road	1996-97	
61211	Road Mahishanandalai to Deldar Char	1996-97	
61204/211	Additional Resectioning of Roads	1999-2000	
Tangail Town Drain			
51501	Tangail Town Drain, Reinforced Concrete Lining	1997-98	
51502	Tangail Drain, Earthen Part, 1st Part	1997-98	
51502	Tangail Drain, Earthen Part, 2nd Part	1997-00	Not started
99996	Tangail Town Drain Off-Take Protective Work	1997-98	
Table 6: Remaining Works with Job Numbers and Years of Completion			

Requirements for such works in order to classify as Minor Works are the following:

- They should be at tertiary level, meaning they concern the population of one or a few *chawks* only.
- The works should fit into the overall design.
- Implementation of the works should involve the participation of the local population. This would also contribute to the strengthening of the *chawk* committees.

These criteria were formulated ex-post, after it became clear that the Minor Works program had not been successful. They were not in force during the early formulation of the program.

Procedures

Applications for Minor Works had to be submitted by the Sub-compartment Water Management Committees (SCWMC). The Project determined the priority of the works and prepared preliminary cost estimates making sure that each sub-compartment received its share of the works, so that the works were more or less evenly distributed among the sub-compartment. The other obvious criterion was that the total costs of the works had to remain within the available budget.

After approval by the Project Director, the BWDB's Executive Engineer issued work orders. Based on the work order, 25% of the estimated costs were supplied to the sub-compartment committee as advance. The execution of the works was supervised by members of the committees; quality control staff monitored progress and quality and advised about final payments.

The Minor Works started early during the second phase, in 1996. Before that date, the SCWMC's were not in a position to undertake such assignments. There were two batches of works. The first was awarded in 1996. It took two years to complete the majority of them. Consequently, no Minor Works were awarded during 1997. Procedures for the second batch were finalized in 1998.

The Minor Works program cannot be considered a success. One reason was the large number of pipe culverts undertaken. Culverts, in many cases, do not solve tertiary problems of a *chawk* population, but mini-problems of a few families only. Another reason for dissatisfaction was the slow pace of implementation and the fact that the sub-compartment committees turned the program to their own financial advantage.

With the benefit of hindsight, procedures should have been different. Advances should not have been paid as, in some cases, works were not carried out and it was difficult to recover the advance. In addition, the advances stimulated concrete works and culverts, instead of earthwork. In the awarding procedure, earthwork should have been given a priority over concrete work.

Cost of the Works

Table 7 gives a summary of the cost of the works in millions of Taka. Sub-totals have been calculated per category.

The total cost per ha of the Compartment, can be considered high when compared with conventional flood control and drainage projects. In fact, with hindsight, much of the water management and of the flood control benefits of the project could have

Investment Costs	1993	1994	1995	1996	1997	1998	1999	2000	Total
Main Works									
Embankments 1)	0.58		9.00	18.16	8.74	4.69	3.21	6.70	51.08
Protective works	3.20	6.87	1.27	5.65	0.38	0.86	20.52	3.47	42.21
Elangani River Loop cut				3.36	0.75	0.06			4.17
Khals/Canals	1.95	0.06	4.73	10.82	3.03	3.22	2.61	2.37	28.79
Main regulator			19.83	3.80			0.24	0.18	24.05
Gated Pipe Inlet (GPI)							2.30		2.30
Intake 2)	2.53		15.67	2.76	1.34	0.32	0.34		22.88
Outlet	1.92	12.91	16.85	17.28	7.76	0.23	1.55	2.18	60.78
Water Control Structures (WCS)		0.40	43.15	5.65	3.67	3.22	0.71		56.79
Roads, Bridges and others	0.78	1.16	21.96	6.00	0.68	0.41	0.26	13.55	44.80
Subtotal	10.96	21.40	132.45	73.49	26.35	13.02	31.73	28.46	337.85
Minor Works									
Culverts					2.79	2.59	0.95	0.05	6.37
Subtotal	0.00	0.00	0.00	0.00	2.79	2.59	0.95	0.05	6.37
Mitigation measures									
Road					4.25	1.22	0.17	3.25	8.89
Bridge			1.75	2.49	3.37	1.54	0.32		9.47
Tangail Drain					30.12	4.59	3.56	0.34	38.60
Others 3)							0.03		0.03
Subtotal	0.00	0.00	1.75	2.49	37.73	7.35	4.08	3.59	56.99
Total mil. Tk	10.96	21.40	134.20	75.98	66.87	22.95	36.76	32.10	401.21
Table 7: Construction Costs by Year (million Tk)									

been obtained at a lower cost. Part of the problem was the difficulty of modeling of the compartment. Although the modeling had commenced at an early stage, instabilities in earlier versions had severely limited the usefulness of the model for simulations capable of predictive analysis. It was only after the final success of the modeling that the hydrology of the compartment which should have been an important input into the design process was fully understood. If a similar project was to be undertaken in the future, the modeling should be a pre-condition for design commencement.

In view of the above, an alternative cost estimate for the Compartment has been prepared, scrutinizing the costs and applying savings where possible. In these alternative costs, structures, that have been shown by modeling to have little impact on the ability of the system to manage water levels, have been eliminated. The alternative estimate is shown in Table 8.

Category	Cost (Million Tk)	Totals (Million Tk)
1. Embankments and Protective Works	40.00	40.00
2. Main Regulator	30.00	30.00
3. Outlets along the Lohajang		
Cluster 1	9.77	
Cluster 2	6.16	
Cluster 3	15.84	
Cluster 4	19.26	
Sub-Total		51.03
4. Water Management Structures		
Cluster 1	6.00	
Cluster 2	7.84	
Cluster 3	7.42	
Cluster 4	0.00	
Sub-Total		21.26
5. Additional structures	20.00	20.00
6. Rehabilitation of the Lohajang	2.50	2.50
7. Excavation of Khals	3.75	3.75
8. Remaining Works Inside Compartment	5.50	5.50
9. Minor Works	7.50	7.50
Total Cost for the Compartment		206.54
Table 8: Alternative Construction Cost Estimate for the Compartment		

Embankments

The costs spent on the embankments, before and after 1998, are the highest of all categories in Table 7. The total is 85.6 million Taka, or about 10,000 Taka/ha.

The value of a 47 km embankment protecting the Compartment, well compacted, is in the order of magnitude of 100 to 150 million Taka. In this perspective, one must consider the rehabilitation costs before 1998, about 48 million Taka, rather high. The costs after 1998, 38 million Taka, can not be justified as additional investments. They have to be considered as rehabilitation costs, due to the emergency of the 1998 flood.

It is unsatisfactory that despite the high spending on the embankments, there still is not a well-compacted dike body. A lesson learned during the Project is that re-sectioning is not an efficient way to rehabilitate embankments.



In the alternative cost estimate in Table 8, spending on the embankments is estimated at 40 million Taka. This is a one-time only investment, to be kept up by adequate maintenance spending. In cases of emergency, additional funds have to be mobilized.

The Maintenance Plan, in Appendix 2 of Annex B to this report, estimates the annual maintenance cost of the embankment at Tk. 38,000/km/year⁷. For 47 km embankment, this amounts to 1.8 million Taka per year. For an embankment of 100 million Taka value, that is 1.8% of investment, this seems an acceptable value.

The Main Regulator

The costs of the Main Regulator amount to 28.9 million Taka. While this cost appears high, the Main Regulator is the heart of the drainage system. In addition, it has been designed in a fish friendly way, which involves additional costs. Since its completion, the structure has been performing satisfactorily.

In the alternative cost estimates in Table 8, the investment of 30 million Taka has been maintained.

Intake Structures

As in the case of the Main Regulator, the costs of the intake structures are difficult to judge. The differences between the clusters can be explained. Cluster 1 received one new intake, while two existing ones were rehabilitated. Cluster 2 received two new large intakes and several small ones. Cluster 3 received only one new intake and Cluster 4 was in the same position as Cluster 1. The new intakes have fish friendly gates and have been performing satisfactorily during the Project. They are operated by the land users and they answer a need.

In the alternative cost estimate, in Table 8, an amount of 25 million Taka has been carried over. Those are the costs incurred during the Project, increased by the cost of an additional intake in Cluster 1, Sub-Compartment 10. It is argued in the Annex on Water Management and Modeling that an intake there would be beneficial. The costs have been estimated as being equal to the cost of the Rasulpur Intake, at Taka 3.6 million.

The Outlet Structures

The outlet structures are expensive. They are larger than the inlet structures, because their discharges are higher. Whether the larger structures are over-designed is difficult to say. The required discharge rate is not a fixed criterion and could well increase in the future if the demand for more intensive drainage picks up.

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The gating of some structures is unnecessarily expensive, however. Examples are Dithpur and Chillabari. Dithpur has a fish friendly lower gate in a separate vent. Chillabari has a gate upstream and downstream. In addition, other outlet structures have provisions for gates upstream and downstream, although only one set of gates has been installed. Most outlet structures have fish friendly gates. These matters are dealt with in some detail in the Annex C to this report, on Water Management and Modeling. In the annex, it is also argued that fish friendliness can also be obtained by operation procedures, without extra gating. If undertaking cost reduction, this should be given attention.

In the alternative cost estimates in Table 8 a number of outlets structures have been removed since modeling shows them to have little impact on water management. They are:

- Cluster 1: Chillabari, Dannya Chowdhury and Dighulia-2.
- Cluster 2: Dharerbari.

Chillabari functions marginally as it is located on high land. Dannya Chowdhury is located upstream and serves a small watershed. Dighulia-2 is so close to Kagmari Outlet that it could have been combined with Kagmari at lower cost. Dharerbari is in about the same situation as Chillabari.

The costs of the outlets, with facilities for upstream and downstream gates, have been reduced by about 10%. It is estimated that this cost saving could be brought about by a simpler design with provision for upstream gates only. Fish friendliness has been accepted. In this way, the estimated costs of the outlet structures in Table 8, comes to around 51 million Taka, about 7 million Taka less than the actual costs.

Internal Water Management Structures

The internal water management structures and their use is extensively discussed in the Annex on Water Management and Modeling. Their costs in Table 7 amount to 57 million Taka. For the alternative cost estimates in Table 8, structures that were not considered useful have been omitted. For justification, the reader is referred to the annex. The structures that were removed in the alternative cost estimate are:

- **Cluster 1:** Krishnopur, Beel Baghil, Eidgah Moidan and Santosh.
- **Cluster 2:** Enayetpur-1, Beel Gharinda, Agbetor, Charkagmara,
- **Cluster 3:** Gosaijoair, Birnahali North, Namder Kumulli North, and the structures along the Southern border, namely, Karatia, Karatia Chowdhury Para, Paschim Pauli.

- **Cluster 4:** All structures have omitted.

All structures controlling water levels in *beels* have been maintained. Similarly, structures that retain water in 1-2 *chawks*, such as Chowbari and the two Batchanda's have been maintained.

The alternative costs in Table 8 come out at 21 million Taka. This is less than half the cost incurred by the Project.

Additional Structures

In a controlled flooding and drainage project, such as the CPP, additional structures will always be needed. It has to be assumed that the structures erected and cost shown in Table 7, are beneficial to the population. The actual costs were 26.2 million Taka. In Table 8, alternative costs have been based upon the assumption that a future design would be more selective in the determination of additional structures. Therefore, 20 million Taka has been allocated.

Excavation of Part of the Lohajang

The excavation of about 10 km along the Lohajang has cost the Project 5 million Taka or 500,000 Taka per km. This is high, particularly considering the fact that the upper part of the Lohajang was never excavated, and that the Project did not experience serious adverse effects as a result of this non-excavation. The Maintenance Plan in Appendix 2 proposes 70,000 Taka per km for annual maintenance. This is an acceptable estimate. Taking into consideration that about 3 years of overdue maintenance may have to be corrected, the cost would be about 210,000 Taka per km, or 2.1 million Taka per 10 km.

In Table 8, the costs for rehabilitating the Lohajang have been put at 2.5 million Taka. This estimate is for about 25 km, as the need for the rehabilitation of the entire river has not been established.

Excavation of Khals

There is about 75 km of secondary drains in the Project area, not considering the Lohajang. For their rehabilitation and excavation about 20 million Taka have been spent, which is more than 250 Tk./m. As in the case of the Lohajang, this must be considered high.

With respect to the rehabilitation of the drainage systems, a policy should be adopted

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under which the cooperation of the land users is guaranteed, before the works start. Work should be undertaken on a systematic basis, starting from downstream to upstream. The Maintenance Plan proposes an annual maintenance cost of 13,000 Tk./km per year, which may be somewhat low. Following the same reasoning as in case of the Lohajang, it has been assumed that about 3 years of overdue maintenance has to be corrected, yielding a cost per km of 40,000 Tk.. For Table 8, a cost of 50,000 Tk./km has been assumed. For the 75 km length, this amounts to 3.75 million Taka.

Remaining Works Inside the Compartment

The remaining works inside the Compartment represent a few rather expensive jobs on internal embankments and/or roads. There is no justification for omitting an allowance for such works in estimating the cost of a future, similar, project. The works have been included in Table 8.

Remaining Works Outside the Compartment

It has been argued in the Annex on Water Management and Modeling that the need for mitigating measures in the adjacent areas needs a stronger justification. This also applies to the Gala Khal excavation, although that has not been a cost to the Project. The area suffering from water level rises due to the Compartment is considerably smaller than the upstream adjacent area and the increase in water level is small. In addition, in the pre-project situation, stretches of the northern embankment were already there. Not all of the water level increases can be attributed the Project. Finally, increases in water levels during dry monsoons may be beneficial or negligible.

Neither is the argument that there is a negative impact of the Compartment on the Southern adjacent area, a strong one. Drainage rates within the Compartment have barely increased and one may assume that the drainage across the Southern boundary remained more or less the same.

For the above reasons the costs of Remaining Works outside the Compartment, have been left out of Table 8. In addition, they are not water management costs to the benefit of the Compartment.

Tangail Town Drain

The Tangail Town Drain cost almost 40 million Taka. The costs can not be attributed to the Compartment, within the context of a future similar project, and have been left out of Table 8.

Minor Works

The evaluation of the Minor Works argues that, although they have not been successful, they should not be given up entirely. They represent partly new investments and partly maintenance cost. In Table 8, they have been included, to an amount of 7.5 million Taka.

The Alternative Cost

In Table 8, the alternative costs have been summarized based upon the considerations above. It appears that the new cost estimate for the Compartment amounts to 207 Million Taka, against actual costs of 401 Million Taka.

Maintenance and Sustainability

Appendix 2 of Annex B, to this report, contains the Maintenance Plan, with detailed estimates of cost per category of work.⁸ However, maintenance is as much a financial matter as a technical one. The main point for the sub-compartment committees in maintaining the infrastructure will be to mobilize the funds.

One should also be realistic. It has been argued in the Annex on Water Management and Modeling that part of the infrastructure was not effective. It may be noted from the operation records that the local population makes little effort to operate such infrastructure. The operation of the intakes and outlets is far more active, certainly in the Western half. In the Eastern half there is the constraint of distance between the intakes and outlets. It has to be assumed that the maintenance of structures that the local population considers less effective will be neglected as well.

The maintenance training of the sub-compartment committees has emphasized two aspects. The first is that the committees should learn to consider the infrastructure in their areas as their own infrastructure. Presently, the public is inclined to associate all infrastructures with the BWDB or LGED, which, in their view are solely responsible for the maintenance. The training emphasized that there is also local responsibility for maintenance. The local responsibility may express itself by guarding against damages inflicted by individuals for personal reasons. Social control is an effective means of preventive maintenance but it has to be mobilized. If damages are done, the disadvantaged should press for repairs.

Modeling and Water Management

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The Compartment distinguishes itself from regular flood control and drainage (FCD) schemes in two ways. First, the drainage facility provided by the Main Regulator is usually not available in regular FCD schemes. The second feature, which CPP has emphasized, is the fact that even with the high floods being kept out land users are able to supply their lands with outside water because of the intakes in the embankments. Such water intakes can be found in other projects. However, CPP has integrated them into a water management system based upon controlled flooding which gives the farmers very considerable control over the depth of water on their fields.

Flood Control

The flood control provided by CPP has been adequate except during the 1998 flood. The 1998 flood was extreme, both because of its peak, and because of its duration. Flood levels grew steadily during the monsoon and reached their peak mid-September. The embankments of the Compartment breached in August, at three locations, two in the West and one in the North.

During the final peak, the water South of the Compartment reached such a high level that the Lohajang started backing up into the Compartment. Outside water also entered through other openings in the southern boundary. The impact was less devastating than that of the breaches. The high levels lasted only a few days. The amount of flow entering was confined by the sizes of the openings, including the Lohajang. It takes far more water to flood the Compartment from the South, than the openings can produce during the short time available. The horseshoe embankment appeared effective as protection against large-scale damage. Local damage was done. However, even at its worst, there was around a one meter difference in depth between the flood inside the compartment and the flood outside, and Tangail Town was spared flooding altogether.⁹

Drainage

The Project has experienced considerable difficulties in intensifying the drainage. There were opposition from the local population, land acquisition problems and defaulting contractors. The ultimate result was that the performance of the drainage system has only marginally improved during most of the Project's lifetime.

The continuing limitations in drainage capacity appears to be acceptable the local population. Local people value a certain degree of flooding. The Project would have experienced greater difficulties if the drainage had been implemented as originally



envisaged. The local population wants moderate flooding and security against extreme floods, but to a lesser extent, intensive drainage.

The situation the population wants is not optimal for cropping. The experience of CPP is that it is not easy to define what is optimal, not even for cropping alone. Development of water management criteria for fisheries proved even more difficult.

This would argue for a cautious approach to drainage in any future project. Focus points should be, flood protection, provision of inlets for controlled flooding, and eliminating major obstacles to drainage. Works should be fully supported by the population in the area. Such an approach is contradictory to the strict and extensive implementation schedule the Project had initially.

Internal Infrastructure and Water Management

In addition to allowing in outside water available for controlled flooding and improved drainage by proper operation of the Main Regulator, the Project intended to provide even better water control within the compartment, by erecting internal control structures. It appeared that CPP's initial targets to realize detailed water control were too ambitious. There were two main reasons. First, besides the internal infrastructure erected by CPP, there were so many other bridges and culverts that the control structures were often bypassed. To a large extent, the internal embankments proved porous. The second reason was that the internal structures actually had a number of functions. The structures controlling water levels in small areas, a few *chawks* only, performed best. Similar structures in larger systems suffered from backflow due to the flat topography of the lower lands. Structures, which were expected to regulate water levels in major drainage systems, generally did not perform.

Modeling

The modeling of the first phase was resumed during the second. In contrast to the models of the first phase, the new model encompassed the entire Compartment, including the Lohajang, and it defined outside hydrologic boundaries. These boundaries are shown in Figure 9.

The model applied in the Final Phase was developed at the Surface Water Modeling Center (SWMC). SWMC uses MIKE 11 river modeling software developed at the Danish Hydraulic Institute (DHI) as the standard tool for the river modeling. The modeling systems used to simulate the hydrological and hydraulic processes in the project included a Rainfall Runoff Model (MIKE11-NAM); a Hydrodynamic Model (MIKE 11 HD); and a Flood Management Model (MIKE11-GIS).

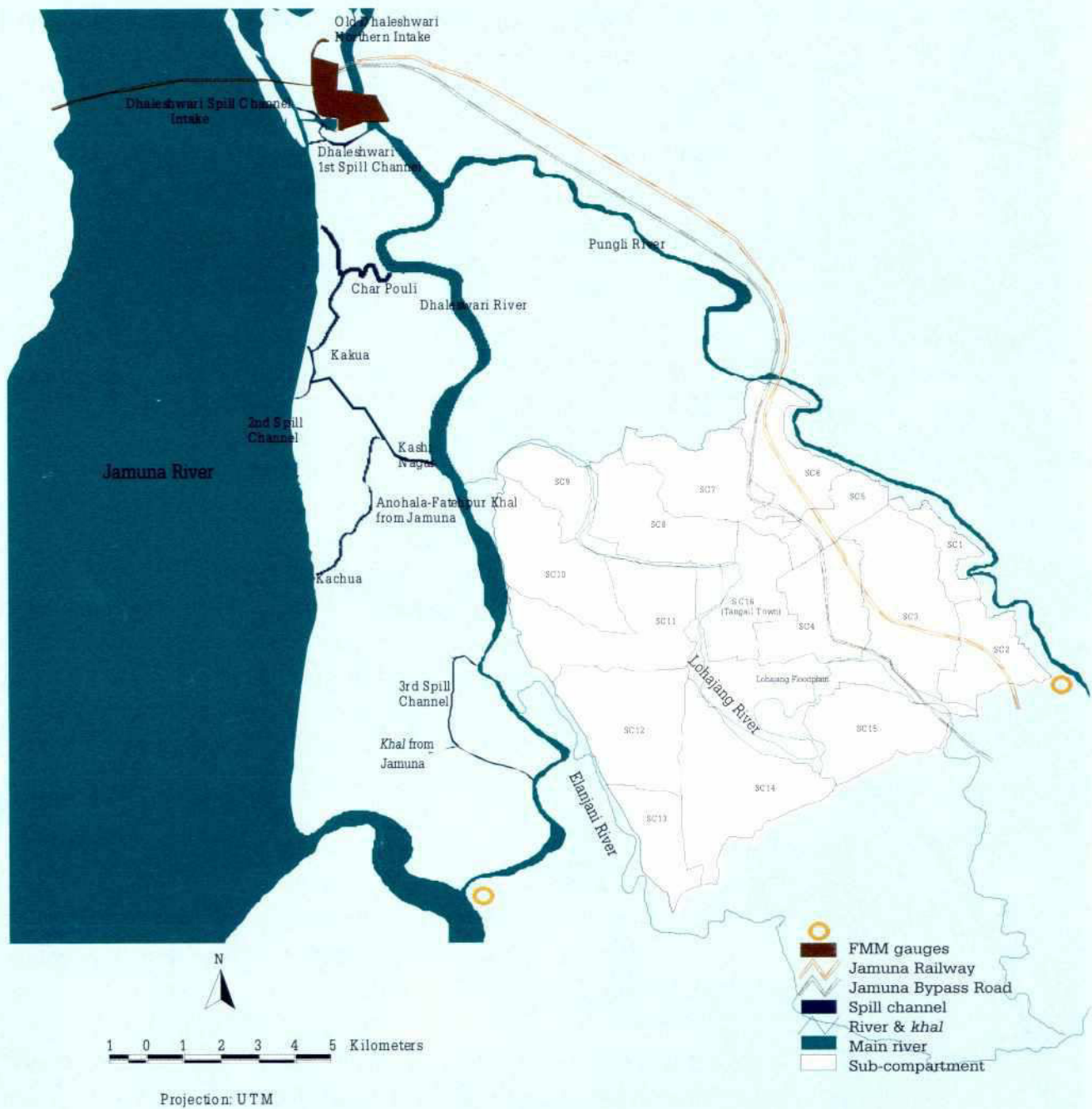


Figure 9: Hydrological Boundaries of the Models

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NAM is an integrated module of MIKE11 for the hydrological simulation. A mathematical hydrological model such as NAM is a set of linked mathematical statements describing, in a simplified quantitative form, the behavior of the land phase of the hydrological cycle. The NAM model is deterministic, conceptual, lumped type of model with moderate input data requirement.

Inputs to the NAM model were the rainfall and evaporation time-series for the CPP and surrounding areas. The model continuously accounts for the volumes of water in different surface and sub-surface storage zones. The model calculates discharge runoff for each sub-catchment. Resulting runoff is used as input to the hydrodynamic model.

The MIKE11 hydrodynamic model simulates flows and water levels in rivers and channels. The topography of the compartment and the rivers and drains in CPP were numerically modeled and the water levels were calibrated to simulate observed water levels and discharges. The calibration was based on the extensive water level records of the Project's database. Once the base model was established, flood impacts could be quantified and displayed, in a predictive way, in the form of changes in flood level and discharge.

MIKE11-GIS integrated the MIKE11 dynamic river modeling with the project Geographic Information System (GIS). The modeling system uses the spatial data manipulation techniques of GIS for enhanced mapping of flood levels. This produced a graphic and easily understood output that was usable by all of the sections of the project.

There were two separate modeling exercises during the Final Phase. The first yielded calibrated models for the years 1995-1998. Inputs were the rainfall, recorded gate operations and outside water conditions. The models established the relative importance of the inputs and gate operations.

The modeling showed that water conditions in the Compartment are dominated by the operation of the Main Regulator and the water levels in the Lohajang. The operation of the intake and outlet structures, together with the water levels outside the Compartment are the next important parameters. The factors of least importance are the rainfall and the operation of the internal infrastructure. This was an insight that was not available during the First Phase of the project due to the limitation of the modeling carried out during this phase.

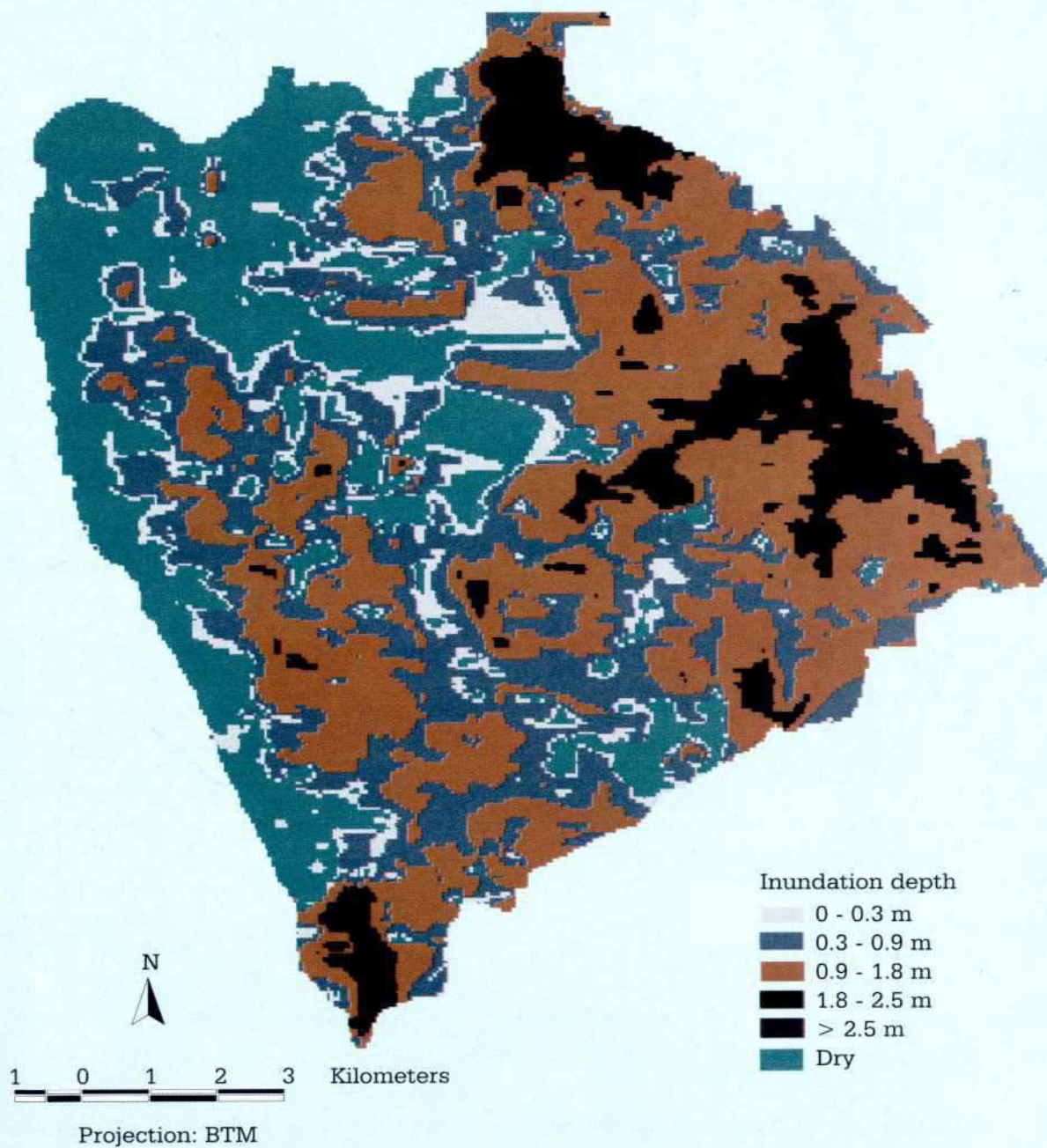


Figure 10: Flood Map September 1998

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As the modeling working prior to the 1998 floods, these floods could be modeled as well. The flood maps generated provide a realistic picture of the flooding situation in the Compartment. Figure 10 shows one of the flood maps for September 1998 as an example of the output produced by the modeling.

The second modeling effort concentrated on possible water management scenarios. By simulating gate operations at the Main Regulator and at the intake and outlet structures, it was possible to study field water conditions under different scenarios. Water level statistics and flood maps were helpful in analyzing the results.

The models and the scenarios were helpful in the evaluation of post-monsoon experiences and in studying where gate operation could have been better. It is important to realize that the criteria of the land users about the quality of water management will not always coincide with the criteria of engineers, agronomists, and fisheries specialists. For the time being there will be a discrepancy between the two. By giving sub-compartment committees responsibilities for water management, the land user scenarios will ultimately prevail, as gate operators will tend to serve the perceived needs of the stakeholders rather than providing some theoretical optimal outcome.

Differences between East and West

The inventory of the actual behavior of the water within the Compartment, together with the modeling resulted in the drafting of operational guidelines. There is an important difference in hydrology between the East and West halves of the Compartment. In the West, the watercourses between the water intake structures and the outlets along the Lohajang run primarily West to East. The distance between the two kinds of structures is relatively short. The communication between the operators of the intakes and outlets and the land users was not difficult and worked well.

In the middle of the western half, along the southern boundary of Cluster 1, a number of larger drainage systems come together. This creates back-flow conditions in the systems, which can only be handled by careful operation. The problems are compounded by the fact that the outlet structures along the Lohajang, mainly between the Dighulia and Aloa Raypara Outlet, are easily submerged by the water levels in the river. This cannot be perfectly controlled by the Main Regulator.

In the eastern half, water systems drain from North to South. The intake structures at Rasulpur and Sadullapur are located along the northern boundary, while the outlet structures are in the South. The distances between the two kinds of structures are large. This complicates water management making it more difficult to establish coordination between the operators of the intakes and the land users.

Target Water Levels

In an attempt to provide water management objectives target water levels were defined. These target levels have a number of functions. In the first place, they define water depth in each sub-compartment in relation to its topography. A target level may indicate that with the water at that level, half of a sub-compartment is under water, while the greatest water depth is, for instance, 0.8 m. These target levels can be applied flexibly. During dry spells, land users may want to maintain their water above the target, during wet periods below.

Next, target levels may define at what levels structures lose control over the water. For instance, in a number of cases the gates of control structures start overtopping if kept closed. Such target levels need to be strictly applied, as it is essential that the system maintain control. When gates start overtopping, operation loses its purpose.

Finally, target water levels serve as warning indicators. This is most important in the eastern half of the Compartment given the large distances between intakes and outlets.

Operation

Operation of the water management systems consists of two activities. The first is the maintenance of certain levels in the system, according to the targets defined. This proved different in the eastern half than in the West. In the western half, systems are relatively short due to their West-east orientation. In the eastern half, they are long. In order to obtain better control of the water, gates should be operated in such a way that systems remain separated and become more or less independently manageable units.

The approach involving certain targets being handled in a flexible manner proved difficult both to the persons who had to provide the training and to the committee members receiving the training. It appears easier to operate the system with fixed targets. As experience in water management increases with the years, a more flexible operation can be achieved.

However, operation is not only about maintaining water levels. Far more important is that sub-compartment committees learn to communicate with each other about water conditions in their areas. Sub-compartments, which together form a hydrologic unit, have to agree on certain levels to be maintained before the monsoon starts. Such subjects can be discussed in meetings before the monsoon. After the monsoon, committees may evaluate the events of the past season.

During the monsoon, day to day management is required. Unexpected events may occur, although these need not always be calamities. Often action is required with certain urgency. In such cases, convening the entire sub-compartment committees is inconvenient, as it takes too long. For day to day management, the committees have appointed executive committees, the members of which may react more quickly to the events.

Quick decision making is hampered by the fact that the sub-compartments do not always follow the boundaries of hydrologic systems. In a number of cases, this requires consultations about relatively simple matters between several committees. During the start of the Final Phase of the project, there was a discussion about this matter. The result of the discussion was that it was decided to maintain the original sub-compartment boundaries, as changing them would confuse all parties in the Project.



Institutional Development and Water Management

CPP started with a lack of experience of participatory decision making in Bangladesh at every level. There was no relevant expertise within either the Bangladesh Water Development Board or the Flood Plan Co-ordination Organization and Panel of Experts, which formulated the various Flood Action Plan components, including CPP.¹⁰

Formation of Water Management Institutions

The project carried out a consultative process with stakeholders prior to attempting to set up any participatory institutions. Only after that consultation process were the water management committees formed. The project organized stakeholders in a 3-tier structure, consisting of 110 Chawk Water Management Committees (ChWMC), 16 Sub-Compartment Water Management Committees (SCWMC) and one Compartment-level Project Council, later renamed the Compartment Water Management Committee (CWMC). Their job was to be to operate and maintain infrastructure in their area. The committees were selected in an elaborate process for which every household had been separately invited and in which 70% of households participated.

The project distinguished farmers, landless, fishermen, women, adjacent area people, townspeople, Unions and BWDB as stakeholder parties and gave each a place in its institutional set-up. The following table shows how the selection process worked in terms of size and composition.

Tier/ WMC	No. of WMCs	Total no. of Members	Average per WMC	Farmers	Landless	Fisher men	Women	UP Officials	Govt. Officials
ChWMC	110	1240	11	80%	18%	2%	37%	-	-
SCWMC	16	403	25	74%	8%	3%	32%	15%	-
CWMC	1	25	25	60%	-	-	-	32%	8%

Table 9: Water Management Committees

Chawk Water Management Committees

In Phase I, the first tier consisted of *chawk* committees with only farmers and a series of existing NGO groups representing landless, women and fishermen. The committees were formed in 1995 and 1996. By combining *chawks*, the number to be organized was kept at 110.

The Final Phase started with a review that concluded that it was more important to have proportionate representation of high, medium and lowland families than to use landless and women as classifications. In addition, they concluded that there were inconsistencies in the way groups were represented at various levels. The committees were subsequently reformed in 1997 and 1998. In total 110 ChWMC's of 9 to 14 members were formed, consisting of farmers and landless from high, medium and lowland, as well as fishermen if living in the *chawk* in substantial numbers. Women made up one third of each group.

Figure 11 shows the boundaries of the *chawks* and sub-compartment committees.

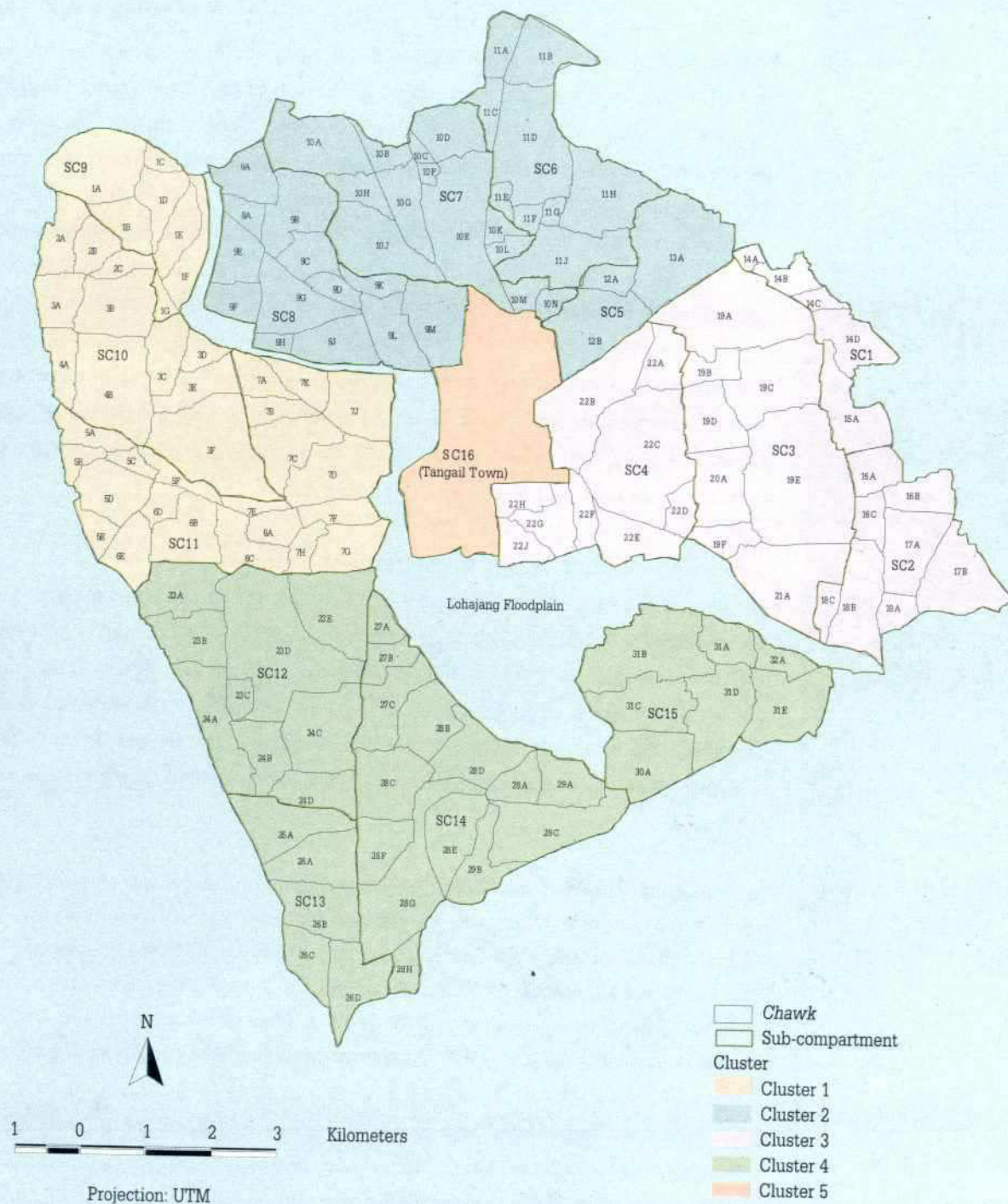


Figure 11: Clusters, Sub-compartments and Chawks

ChWMC's have not been trained, apart from their SCWMC-representatives, daily supervisors, and gate operators. After formation in 1998, the ChWMC's have been involved mainly in formation of SCWMC's and selection of minor works. For this, ChWMC's have held a series of meetings. By the end of the project, most ChWMC's were not holding regular meetings. Their involvement in operation and maintenance has been very limited. Nearly all *chawks* are related to at least one structure, but only about sixty have a structure within their boundaries. Only 25 ChWMC's have been made directly responsible by the SCWMC for operation and maintenance of a structure. Other *chawks* will be involved in operation and maintenance mainly via their representatives in the SCWMC.

It is expected that those ChWMC's, that have no operation duties, will not continue as formal committees but at most as annual meetings from which representatives for the SCWMC will be elected. Most of the ChWMC's with operation duties will probably be reduced to a few committed members.

Sub-compartment Water Management Committees

The second tier of the institutional structure consists of 16 Sub-compartment Water Management Committees (SCWMC), although the 16th SCWMC, for Tangail Town, was never formed. In Phase I, the SCWMC has had representatives from *chawk* committees (farmers) and from groups of landless, women and fishermen as well as from Union *Parishads*, NGO's and government agencies. The relevant Union *Parishad* Chairman was made President. Some UP Chairman chaired two or even three SCWMC's.

In the Final Phase, the SCWMC's were reformed based on three ChWMC-representatives per each *chawk*, a fishermen representative - where relevant - and four UP Officials of the area. This resulted in SCWMC is of 11 to 48 members. They had Executive Committees of 6 to 11 members. ChWMC representatives had to include fishermen and landless, if these were also represented in the ChWMC. Therefore some 8% of all the SCWMC members were landless and 3% were fishermen.

Each committee had its president, vice-president, secretary and treasurer. SCWMC's divided operation responsibilities among their members, called daily supervisors, or delegated it to ChWMC's. Each structure had a local operator, some of whom were remunerated. The Union *Parishad* Chairmen remained Presidents in spite of the fact that Phase I-experiences had shown that the Chairmen are not much interested in development or water management. The project considered that the advantages outweighed the disadvantages. Leaving the Chairmen in would also keep a limit to

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conflicts and parallel decision making and provide SCWMC's with a legal status and access to financial resources. Daily management was the responsibility of the Vice-President.

The present laws of Bangladesh do not provide for the possibilities of legalization of the WMCs. The project thinks that, under the circumstances, it has achieved optimal legal status for the committees by having the BWDB recognizing them and their by-laws, and by linking them to the Union *Parishads*.

Committees have been trained once in Phase I and four times in the Final Phase. Main subjects were CPP, committee functioning, operation and maintenance. Final Phase training was also used to discuss and agree with SCWMC's on the division of WMC by-laws, operation responsibilities, operation plans and maintenance plans. Committees have further been trained on gender issues. Because the operational plan and maintenance policy has been finalized only in 1999, possibilities to strengthen WMCs in these matters have been very limited.

After reformation in 1998, the SCWMC's have been involved mainly in flood fighting, selection, and execution of minor works. Meetings were organized only during the monsoon or on request of the project. In practice, operation and maintenance do not need many committees, committee members, or meetings. Some areas such as Sub-compartment 1 and 15 hardly need an SCWMC, as there is little infrastructure to operate or maintain. On average, each SCWMC has about three water management structures to operate. Most structures are opened or closed only a few times per monsoon. Operation is normally done by few committed and practical individuals, while maintenance needs one or two meetings and a lot of organization by WMC leaders.

Compartment Water Management Committee

Only in 1996 was a compartment-level Project Council formed in accordance with the national Guidelines for People's Participation (1995). It had 79 members representing SCWMC's as well as numerous government agencies and NGO's. It was abandoned the same year as too big and unwieldy to be practical.

In 1998, a Compartment Forum of 23 members was formed from 8 SCWMC Presidents and 15 Vice Presidents, who advised the BWDB, CPP Project Director. Only in the last project year, a Compartment Water Management Committee (CWMC) was instituted of practically the same composition, with the Executive Engineer of the BWDB

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Tangail O&M Division as the Chairman. These joint BWDB-beneficiaries committees will co-ordinate the SCWMC's, operate, and maintain the Main Inlet and peripheral infrastructure. Consultation with adjacent areas and government agencies such as LGED will be undertaken at this level.

Neither CWMC nor BWDB O&M Division have been involved in operation or maintenance during the project period. The CWMC in its final shape was only formed in 2000 and the O&M Division was not involved in CPP. CWMC members have, however, been involved and trained as members of SCWMC's. O&M Division-staff were trained in operation before the project completion.

System Operation, 1995-1999

Gates have been operated since 1995 in increasing numbers, and gate opening and closure has been recorded.

In general the agreed parties took charge and operated the structures in a satisfactory manner. Potential conflicts on distribution of floods, harmful or beneficial, were avoided mostly by inaction, i.e. by keeping internal structures always open. Conflicts with occupational fishermen were not detected, probably because the negative impact on them appeared to be limited.

Maintenance

Maintenance of completed infrastructure during the project period has nearly all been initiated by the project and has been paid for by the donor agencies. For the post-project period, the responsibilities have been divided between the BWDB and SCWMC's. BWDB will be responsible for all maintenance for the infrastructure along the periphery and Lohajang, and for periodic major maintenance on internal infrastructures. SCWMC's will be responsible for preventive maintenance of internal infrastructure. This arrangement has not been tested.

The estimated annual operations and maintenance requirements will be about Tk. 9,865,000. The sharing of this will be 98 percent to BWDB, the balance to SCWMC's.

**Primary Outputs
and
Results**

Agriculture

One of the major objectives of CPP has been to increase agricultural output in the Compartment. This has come about as the result of improved water management and drainage and a reduction in uncontrolled flooding. As well as the contribution made by water management to agriculture, CPP has also run an active program of agricultural extension.¹¹

Three seasons can be distinguished in the agricultural calendar of Bangladesh. (Figure 12):

- The *Kharif-I* or pre-monsoon season, which starts with the first rains in March
- The *Kharif-II* or monsoon season, starting in July, which is characterized by submerged land conditions in a large part of the flood plain by accumulating rain and river flooding
- The *Rabi* or dry season when agriculture is practiced on residual moisture and, later in the season, with groundwater irrigation (for *Boro* paddy)

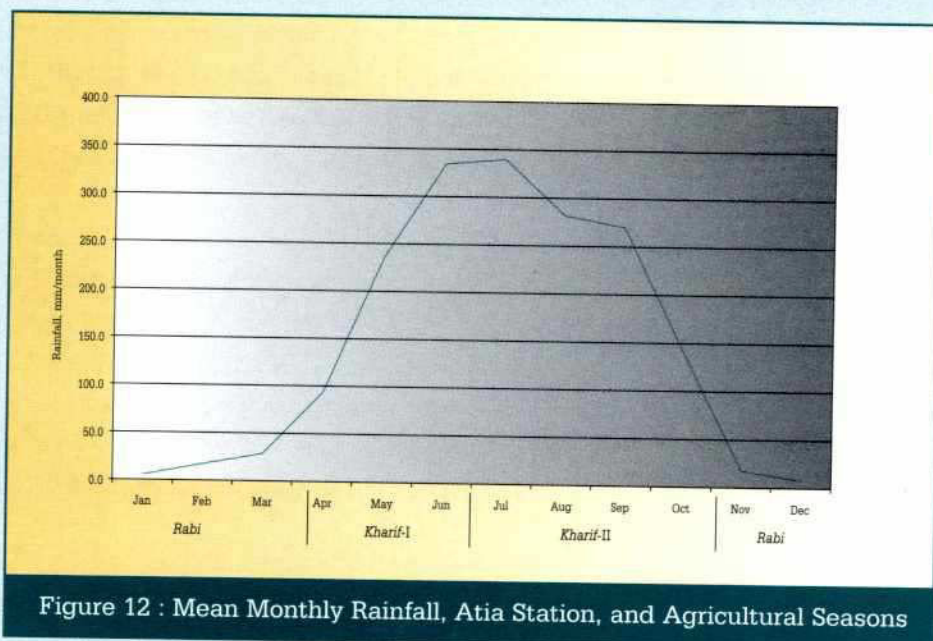


Figure 12 : Mean Monthly Rainfall, Atia Station, and Agricultural Seasons

These seasons are very largely determined by the rainfall pattern with most of the rain falling in the single monsoon season of May/June to October. (See Figure 13)

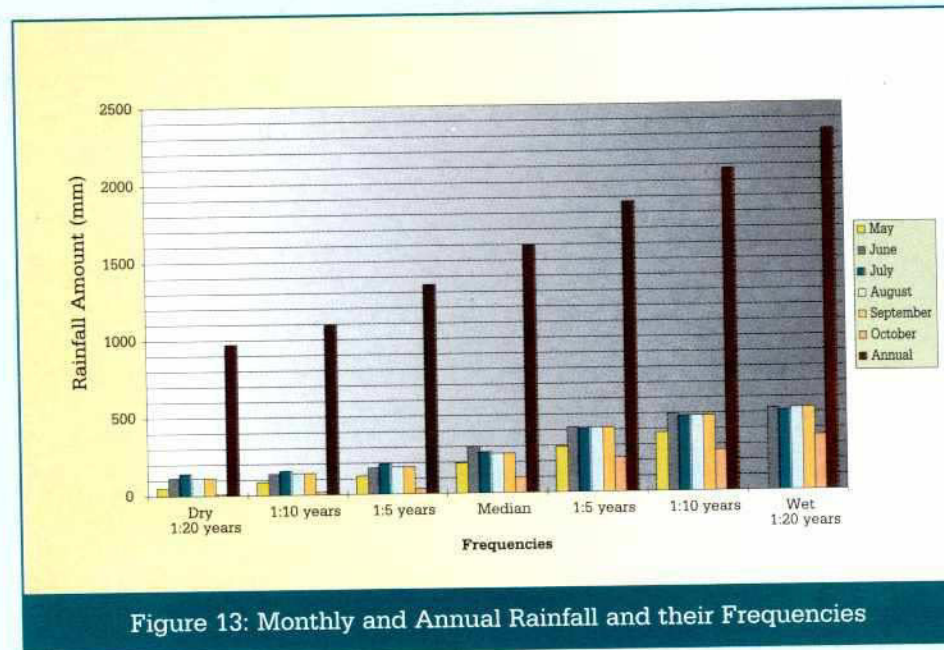


Figure 13: Monthly and Annual Rainfall and their Frequencies

Before the advent of *boro* cultivation, the cropping system was dominated by *Aus* and *Aman* paddy and the start of the rains was traditionally seen as the beginning of the annual agricultural cycle. The expansion of *boro* paddy cultivation with groundwater irrigation since the nineteen seventies has shifted the emphasis to the *Rabi* season.

Monsoon land use has received most attention during the project, because it is most affected by CPP's water management intervention. It is during this period, when land is submerged, that the water management and flood control can have an impact. It does this, not by preventing flooding, but by allowing farmers to have some control of the flood by determining the depth. This management of the water allows farmers to shift cultivation from deep water *Aman* to higher yielding varieties of rice, and to plant areas that previously were too deeply flooded to plant at all.

Overview of the Program

During Phase I (1991-1996) the targets set for agricultural development were:

- Prevention of crop damage from flooding and drainage congestion
- A gradual increase in cropping intensity from 196% to 220% and an expansion of transplanted *Aman* (HYV) to more than 2,000 ha (about 25% of the NCA)
- Increase in annual rice production by 9,000 tons
- Environment-friendly agriculture through the application of Integrated Pest Management (IPM)
- Nutritionally rich agriculture through crop diversification

It was expected that most of these targets would be attained as a direct result of improved water management, and the emphasis of the program was, therefore, on monitoring of the changes occurring in the compartment.

For the Final Phase (1997-2000) the program was given the following additional tasks:

- Developing cropping and crop diversification programs in close co-ordination with farmer user groups and government
- Contributing to the development of operational rules for the water management infrastructure

These tasks implied a more action-oriented role by the project than during Phase I, for which purpose a participatory On-Farm Testing and Demonstration (OFTD) program was carried out.

Land Types, Land Use and Cropping Patterns

Under the flood conditions prevalent in the *Kharif-II* season, it is the depth of inundation that determines which cropping pattern may be practiced in any particular field. Five land types are therefore defined in Bangladesh based on 1 in 5 year flooding depths during the monsoon (*Kharif-II*) season:

Land type	Depth (cm)
F ₀	0-30
F ₁	30-90
F ₂	90-180
F ₃	180-300
F ₄	> 300

Farmers use their own land type classification, which is more directly related to land use. Three land types are distinguished, from high to low: *Tan*, *Patchot* and *Dopa* land. *Tan* land is mostly located higher in the topography and *Dopa* land lower, with *Patchot* in intermediary positions, but the extremes may even be found side by side. The difference in elevation between adjoining *Tan* and *Dopa* fields may be as little as 40 - 50 cm. The major cropping patterns in each land type are shown in Figure 14.

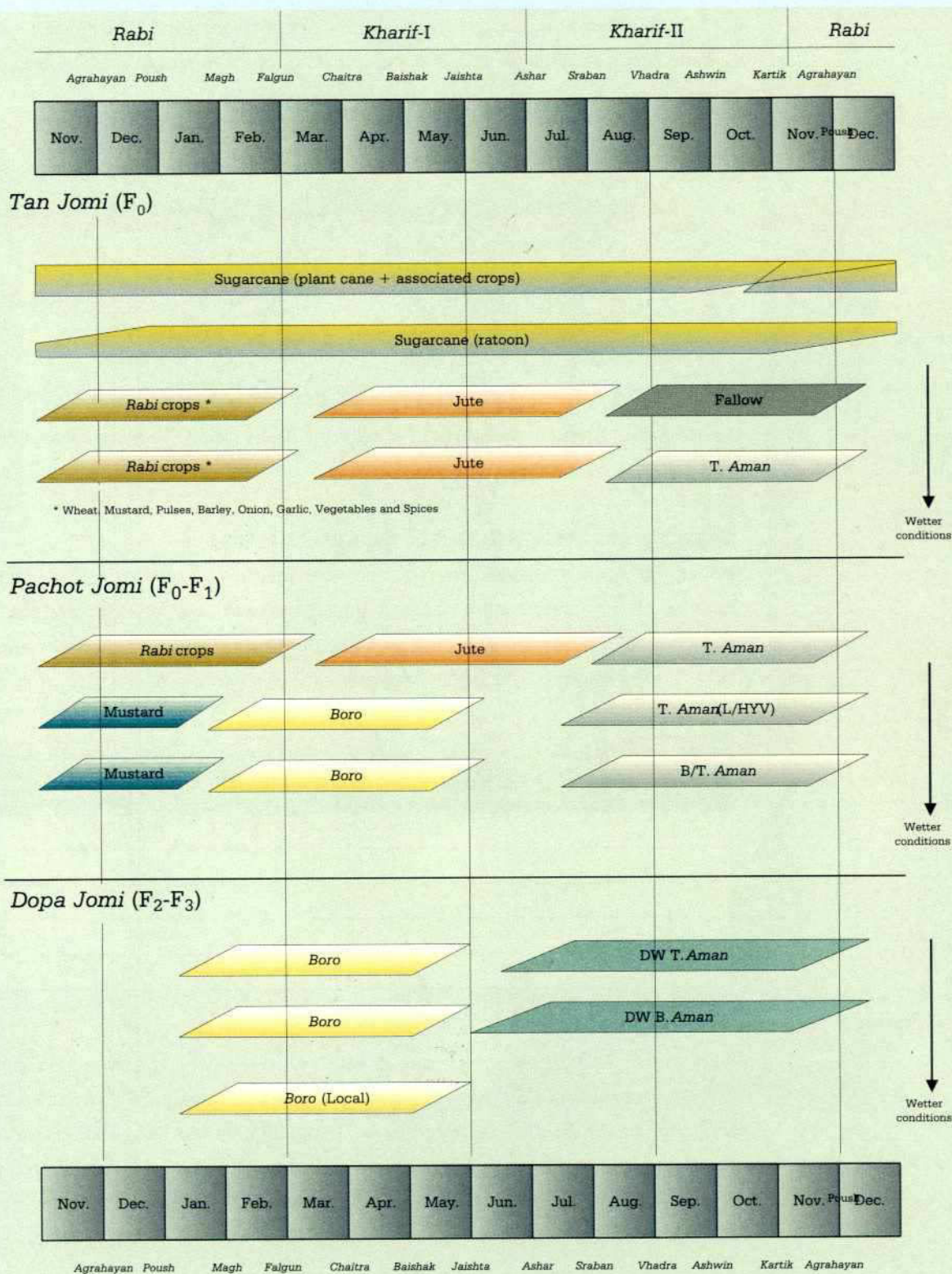


Figure 14 : Cropping Patterns Associated with the three Major Land Types in the CPP Project Area, According to the Seasonal Climate.

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Tan land (F_0) is the driest land type, where winter crops (wheat, potatoes, pulses, vegetables) are grown in the early *rabi* season, usually followed by jute, followed by fallow or by *T-Aman*. In some areas, sugarcane is grown.

Patchot land ($F_0 - F_1$) is the prime land, which allows growing of three crops annually. The early *rabi* crop is usually mustard, grown on residual moisture, followed by *boro* paddy with groundwater irrigation, and then *T-Aman* or *DW-Aman*. There is an on-going expansion of high yielding varieties (HYV) of *T-Aman* in this land type.

Dopa land ($F_2 - F_3$) remains inundated throughout the monsoon for up to 7 months (June-December). Slow drainage makes it unsuitable for winter crops until December when *boro* can be planted. After the *boro* harvest *DW-Aman* is broadcast or transplanted. The lowest *Dopa* land may be inundated as early as June and is only used for *boro*.

Impact of Improved Water Management

Improved water management was expected to have impact on the depth of flood, shifting some land from less productive to more productive categories. (i.e. F_4 to F_3 , F_3 to F_2) thus increasing cropping in the three seasons. Specifically:

- Pre-monsoon season (*Kharif-I*). Inundation of low-lying areas by accumulating water from early rainstorms can be delayed by improved drainage. This facilitates *Boro* harvest and *DW-Aman* establishment
- Monsoon season (*Kharif-II*). Better water control results in an overall decrease in water levels. This will result in an increase in the area that is suitable for *T-Aman* HYV, as well as making previous fallow land suitable for *DW-Aman* cultivation
- Post-monsoon and *rabi* seasons. Improved post-monsoon drainage results in earlier land availability for *rabi* season crops and *boro* paddy. This would allow a larger area to be planted to winter crops like mustard, wheat and potatoes and increasing the area where both *rabi* crops and *boro* can be grown.

These changes should lead to increased rice production in the monsoon and possibly also in the *boro* season. Furthermore, increased annual rice production would create opportunities for diversified cropping in the *rabi* season.

Analysis of Changes due to CPP's Interventions

Changes in Hydrological Conditions in Different Land Types

The distribution of land types, according to the model-defined base situation, is shown in Table 10, together with the expected change in distribution under one possible water management scenario.

Maximum depth (cm)	Base situation land type	%	With control %
0-30	F ₀	32.2	52.0
30-90	F ₁	38.4	32.5
90-180	F ₂	26.3	13.3
>180	F ₃	3.1	2.2
Table 10: Expected Maximum Water Depth Distribution			

Changes in Land Use and Yields

Monsoon (Kharif-II)

Table 11 shows overall monsoon land use in the Compartment and in the adjacent Kalihati Thana, which is most similar in geography.

Area	Percentage of NCA used for Monsoon Cropping							
	NCA (ha)	1994 (%)	1995 (%)	1996 (%)	1997 (%)	1998 (%)	NCA (ha)	1999 (%)
CPP Compartment	9,763	66	77	72	77	45	9,858	72
Kalihati Thana	21,385	55	57	60	58	6	21,385	61
Table11: Monsoon Cropping Areas as Percentage of Net Cultivable Area (NCA)								

Overall, monsoon land use was always higher in the compartment, probably due to the presence of the horseshoe embankment. The increase in land use in the compartment between 1994 and 1997 did not occur to the same extent in the adjacent area, which can be attributed to improved drainage by CPP. The decrease in land use due to the 1998 flood was much more dramatic in the adjacent area. In the part of the Thana bordering on the compartment, it went down to only one percent of the NCA.

The contribution of the different crops to monsoon land use in the compartment over the years is shown in Table 12.

Crop	1991	1993	1994 ¹	1995	1996	1997	1998	1999
B-Aus + B-Aman	1,734							
T-Aman (L)	848	2,655	2,531	2,462	2,601	2,438	991	1,550
T-Aman (HYV)	222	931	482	905	1,603	2,382	1,503	2,362
Total T-Aman	2,804	3,586	3,013	3,367	4,204	4,820	2,494	3,912
DW-Aman	3,718	2,704	1,788	2,649	1,932	2,089	1,241	2,543
Sugarcane	691	1,258	1,625	1,503	846	594	623	547
Fallow	2,550	2,215	3,337	2,244	2,781	2,260	5,405	2,561

Table12: Estimated Areas of Different Monsoon Crops

Important shifts in land use are apparent, as illustrated by the table and by the 1993-1999 land use shift maps of Figure 15a & 15b. We see that T-Aman increased sharply through 1997 at the expense of DW-Aman and fallow land, while T-Aman (HYV) partly replaced T-Aman (L) and sugarcane.

In 1999, the year after the major 1998 flood, HYV was back at the same level as in 1997, but otherwise there was a shift to more conservative choices: from T-Aman (L) back to DW-Aman and an increase in fallow. This indicates uncertainty about the future flood situation, but it is probably temporary.

There has been a steady increase in HYV, which is grown in land types that are less prone to flood damage. This testifies to farmers' confidence that it is safe to grow modern Aman varieties in Tan and the higher reaches of Pachot land.

In the adjacent area, there has been a similar upward trend of T-Aman, as well as a similar relative increase in T-Aman HYV. After the flood overall land use intensity returned to the 1997 level, but there was also a shift to more conservative crop choices, i.e. more DW-Aman and somewhat less T-Aman. Unlike to the compartment, the area under T-Aman HYV in the adjacent area did not yet return to the 1997 level. In conclusion: the favorable water management situation in the compartment has resulted in more intensive and more productive land use than in the adjacent area. This is partly due to the presence of the horseshoe embankment and partly to better drainage. The compartment provided protection against the disastrous flood of 1998 while the adjacent area was under water.

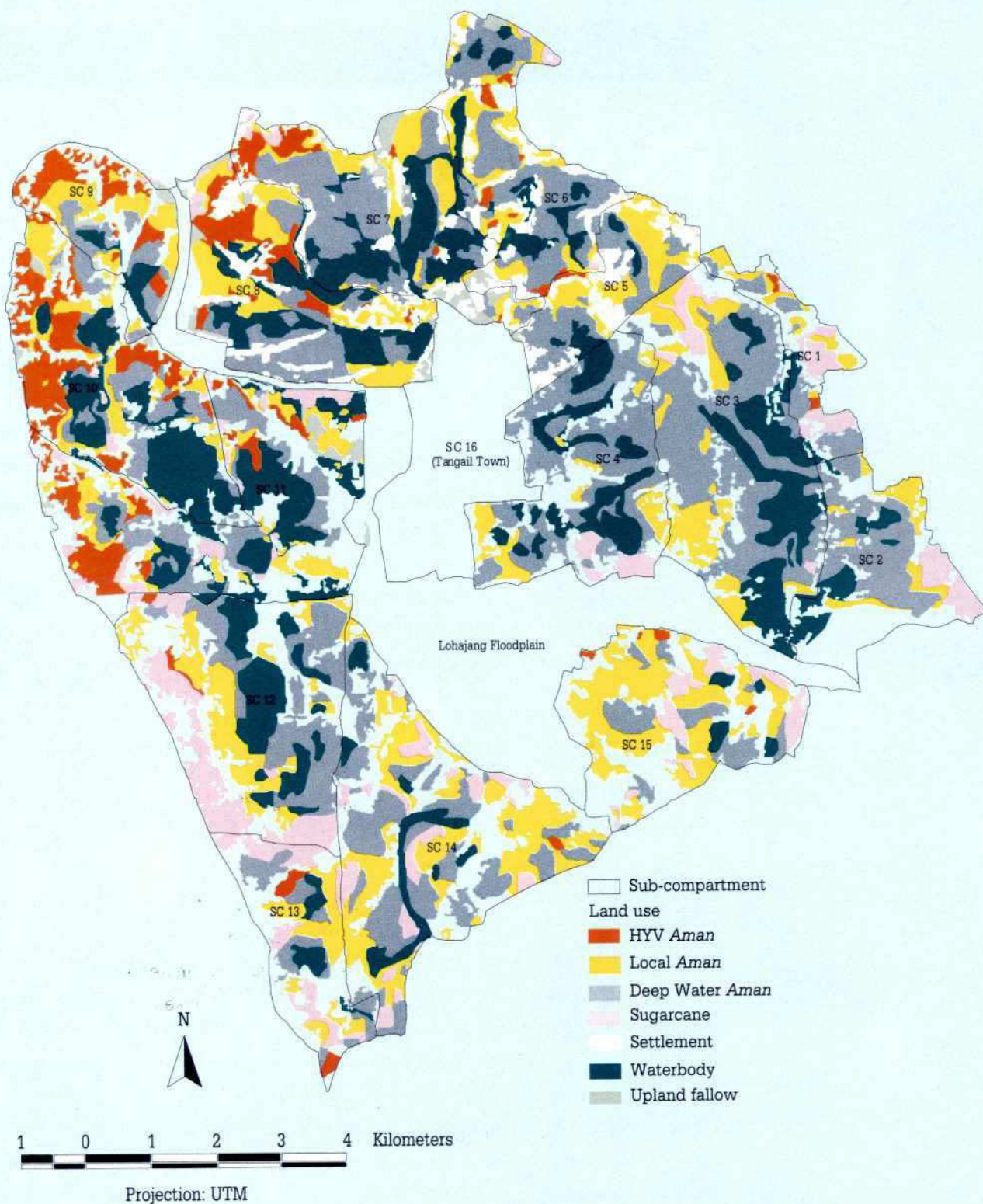


Figure 15 a: *Kharif-II* Land Use Shift 1993-1999

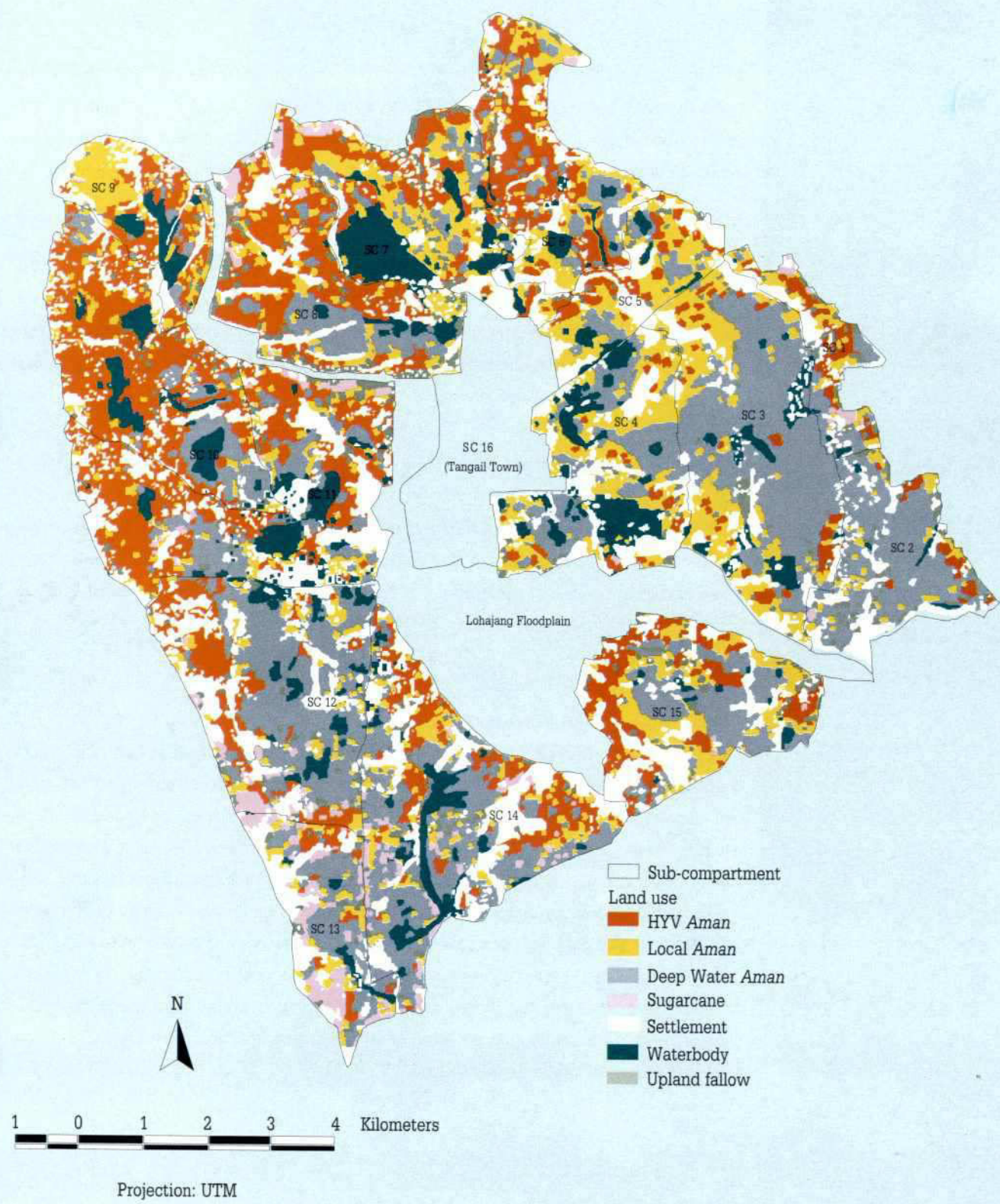


Figure 15 b: Kharif-II Land Use Shift 1993-1999

Rabi and Kharif-I

The most significant trend has been the increase in mustard (from about 1,300 ha in 1992 to more than 3,000 ha in 1999) and *boro* paddy (from 3,500 to 7,000 ha). The simultaneous decline of jute reflects the fact that most of the recent increase in *boro* is in the higher land where new shallow tubewells have been installed.

Cropping Patterns and Land Use Intensity

The increase in cropping intensity in CPP is shown in Table 13. It can be attributed mainly to better drainage in the compartment, resulting in a shift in the *boro*-based system from double to triple cropping and from single to double cropping. The situation in 1998 was anomalous because of the flood, but in 1999, cropping intensity was back at the 1997 level.

One thing that CPP has not achieved is an increased diversification of cropping. This is because the average farm size is such that it allows for nothing other than subsistence agriculture. Under such a situation, the farmer will inevitably grow his staple food. Diversification will, and does, occur on larger farms but, with the average size of farms declining in Bangladesh, from 1.5 ha in 1977 to 0.7 ha today, there is probably going to be less, rather than more, diversification.

Yields

Only *boro* yields have increased significantly, from about 3.5 t/ha in 1995 to about 6 t/ha in 1999. This is due to a combination of improved management and increased inputs. The upsurge in 1999 after the 1998 flood may reflect farmers' increased care to compensate for the monsoon crop losses, as well as exceptional weather and increased fertility due to the flood 'fallow'. For other seasons, there is a decrease in yield both within, and outside of the Compartment. This should come as no surprise. As cropping intensity increases then there is almost bound to be some decrease in soil fertility. Soil benefits from a period of fallow, but increasingly it is not getting this. The return from the increasing cropping intensity more than compensates from the decline in yield. Over the longer term declining yields might be a cause for some concern but whether there are means of arresting this decline, given the pressure on agriculture in Bangladesh, is doubtful.

No.	Pattern			1994		1995		1996		1997		1998		1999	
	Rabi	Kharif-I	Kharif-II	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
1	Sugarcane	Sugarcane	Sugarcane	967	9.9	1,162	11.9	752	7.7	478	4.9	517	5.3	596	6.1
2	Rabi crops	Jute	Fallow	840	8.6	927	9.5	469	4.8	1,201	12.3	1,250	12.8	508	5.2
3	Rabi crops	Jute	T-Aman	469	4.8	517	5.3	1,191	12.2	908	9.3	722	7.4	1,113	11.4
4	Mustard-boro	Boro	T/DW-Aman	976	10.0	1,191	12.2	976	10.0	1,923	19.7	849	8.7	2,353	24.1
5	Rabi Crops-boro	Boro	Fallow	234	2.4	156	1.6	156	1.6	195	2.0	937	9.6	439	4.5
6	Boro	Boro	T/DW-Aman	2,597	26.5	3,212	32.9	3,554	36.4	3,398	34.8	2,304	23.6	2,285	23.4
7	Boro	Boro	Fallow	2,636	27.0	1,709	17.5	1,709	17.5	1,103	11.3	2,743	28.1	1,669	17.7
	Minor Patterns			1,054	10.8	888	9.1	937	9.6	566	5.8	449	4.6	742	7.6
	Annual Cropping Intensity ¹				181		192		199		215		184		214

Table 13: Estimated Areas Used for Major Cropping Patterns During the 1997/1998 and the 1999/2000 Cropping Seasons

¹ the percentage of each pattern is multiplied by the number of crops in that pattern; sugarcane is multiplied by 1.35 because of inter-cropping with annual crops; minor patterns are multiplied by 2.

Options for Agricultural Production

Demonstration of Improved Aman Varieties, 1993-1997

CPP carried out demonstrations on a variety of crops during the Final Phase of the project.

Out of four demonstrated T-Aman HYV's, only BR30, on average, yielded significantly better than the local standard BR11 (5.62 as compared with 4.07 t/ha). Supplementary tubewell irrigation was provided in many of the plots, which increased yield, by about 1 t/ha. The frequent occurrence of October drought and the increasing importance of T-Aman HYV will make supplementary irrigation increasingly desirable.

An adoption survey showed that each demonstration plot resulted in about 2 ha planted to the demonstrated variety in the next year by the demonstration farmers and through the sale of seed. It was estimated that new superior variety could reach maximum dissemination in 4 years through the establishment of one demonstration for every 100 of (potential) T-Aman area.

On-Farm Testing and Demonstration (OFTD), 1997-2000

CPP's intervention in water management was expected to open new avenues to farmers to increase the efficiency, diversity and profitability of farming. However, the implications of the project interventions were not known *a priori* and it was necessary to conduct a simple on-farm-testing program in partnership with farmers to explore options to better exploit the new water management situation. The OFTD philosophy was stated in the Inception Report of the final phase as follows:

"Farmers will decide on the priorities for testing and demonstration in consultation with and with advice from the OFTD team. They will carry out the tests and demonstrations with a minimum of interference from the team. The team guides the process and gives advice on implementation but does not impose its opinion."

Although in the day-to-day practice this principle has only been partially adhered to, there has been real progress in participatory attitude by all involved.

The earlier T-Aman variety demonstrations sponsored by CPP have contributed to the rapid dissemination of these varieties. They also showed that demonstration plots could be an effective vehicle for rapid technology dissemination, provided that:

- The technology is indeed attractive to farmers and
- The density of the plots is adequate.

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Time has been too short for the OFTD program to have a major impact across the compartment, but some promising results were obtained. It was shown that simple farmer-managed tests with improved varieties of several crops (*T-Aman*, *Boro*, and mustard) quickly identified promising material as well as constraints to adoption. In addition, two-crop combinations of high value irrigated crops for the *Rabi* and *Kharif-I* seasons, such as onions relayed with okra, may be promising alternatives for *boro* and should be pursued further. Within the compartment, it was also shown that there is good scope for adoption of biological methods for fertility (composting) and integrated pest management (IPM).

The program has shown the importance of following up on issues that emerge during testing. New technology will always generate questions and reveal constraints to adoption that need to be addressed. Intensive dialogue with farmers is the best way to obtain their views on what is needed for a technology to be adopted.

Truly participatory methods are essential to assist farmers in their own search for new more productive technology. Such methods should be applied from the very start of any development project. Once a promising technology has been identified, it should be further disseminated by the regular extension service. For this to happen, it is crucial that the extension service themselves are closely involved with the project from the start.

Future Trends

The observed trends in land use and production were used to project likely future developments in the compartment as shown in Table 14.

There remains scope for further land use intensification, provided operation of the water management infrastructure continues to favor good drainage in the pre- and post-monsoon. It is expected that cropping intensity can increase further.

Jute and sugarcane will probably stabilize at 1,500 and 500 ha respectively, unless attractive alternative crops take their place. The ceiling for *Boro* paddy will be around 7,000 ha, a level which has already been attained in 1999.

It is expected that the maximum area used for *T-Aman* will stabilize at around of 5,000 ha. The experiences of 1999 show, however, that it may decrease to a lower level if the compartment's infrastructure does not provide fully reliable protection in the future. Under continued protection and adequate infrastructure operation, the area under HYV *T-Aman* may eventually reach 3,000 ha.

There is some scope for limited crop diversification on medium and large farms, especially during the *Rabi* and *Kharif-I* seasons. The area appears to be particularly suited to intensive vegetable production with tubewell irrigation. This would be partly in competition with boro and with jute. Any ongoing OFTD program should emphasize this area.

<i>Rabi</i>	Pattern Kharif-I	<i>Kharif-II</i>	ha	%	Crop	Projected yield (t/ha)
Sugarcane	Sugarcane	Sugarcane	500	5	Wheat	2.2
<i>Rabi</i> crops	Jute	Fallow	250	2.5	Mustard	0.9
<i>Rabi</i> crops	Jute	T-Aman	1,250	13	<i>Boro</i>	5.0
Mustard- <i>boro</i>	<i>Boro</i>	T-Aman	2,500	25.5	Jute	1.8
<i>Boro</i>	<i>Boro</i>	T/DW-Aman	3,000	31	T-Aman (L)	1.8
<i>Boro</i>	<i>Boro</i>	Fallow	1,500	15.5	T-Aman (HYV)	2.8
					DW-Aman	1.5
Minor Patterns			763	7.5	Sugarcane	35
Annual Cropping Intensity, %				220		
Table 14: Projected Future Cropping Patterns & Yields						

Towards the end of the project, an MoU was signed by BWDB and BARI to continue with the OFTD program within the project area.

Fisheries

It had always been assumed that open water fisheries would be adversely affected by CPP. This was a result of the interventions such as construction of gated regulators in the main river and the peripheral embankment, improvement of drainage through excavation of *khals* and the construction of minor regulators within the project area. Fisheries have, therefore, been included in the project since its inception.¹²

The objectives of the fisheries component of CPP was to increase the availability of fish by securing fisheries production and by improving aquaculture production by focussing on the following aspects:

- Determining the impact of CPP on natural fisheries production
- Determining hatchling migration patterns and incorporation of the results in water management options and design of water management structures
- Development and implementation of mitigation measures to compensate the expected negative impacts of the implementation of CPP
- Development of proper water management scenarios for fisheries production.

Fish plays a very important role in the daily life of the people of the Compartment. The Bengali expression "*Machhe Bhate Bengali*", - Fish and rice make a Bengali - expresses this importance. Bangladesh produces 1,400,000 MT of fish annually, with inland capture fisheries and aquaculture as the main contributors to this production with 53% and 24% of the total respectively. Sixty percent of the animal protein consumption of Bangladesh comes from fish.

Fish production in Bangladesh is largely dependent upon the hydrologic cycle. The extensive seasonal flooding, together with the extremely high monsoon rainfall, creates a highly dynamic floodplain system. In contrast to the abundance of water in the monsoon, water areas decline rapidly during the dry season (December-April) which is characterized by very low rainfall and high evaporation rates. This contraction and expansion of aquatic habitats greatly influences fisheries production.

Fish and prawn populations in Bangladesh are adapted to these variations and their life cycles are tuned to it. Breeding and growth are strongly related to the sequence of flooding. The floodplains, which inundate during monsoon, are nutrient and food rich and play a significant role for 4-5 months of the year. Larvae, juveniles and adults grow in this habitat, after which they migrate back to rivers or depressions at the end of the monsoon when waters recede. They become concentrated in channels and *beels* in this period and fish are more vulnerable to fishing activities.

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Based on their behavior, mainly related to migration and reproduction, the fish species of Bangladesh can be divided in two groups:

The so-called "**white fish**" migrate upstream and laterally to the inundated oxbow lakes and floodplains adjacent to the river channel in the late dry season or early rainy season to spawn in the quiet sheltered and nutrient rich waters. The eggs and newborn larvae of these species are transported passively by the flood into the floodplain area, where they feed on the developed plankton. At the end of the rainy season, the adults and young of the year escape to the main channel and the deeper *beels*, to avoid the harsh conditions of the floodplain during the dry season. White fish belong mainly to *Cyprinidae* and *Pangasidae*, (*Mrigal*, *Rui*, *Catla*, *Pangash*, etc).

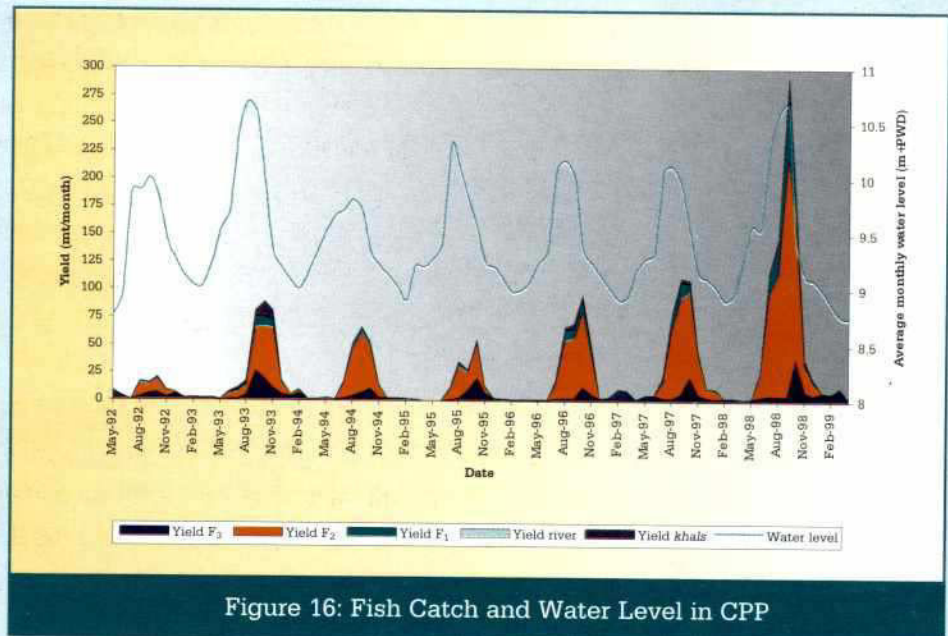
The so-called "**black fish**" are mainly omnivorous/carnivorous bottom dwellers. They reproduce at the onset of the pre-monsoon as the water level in the *beels* starts to rise due to the congestion of rainwater. At the end of the rainy season the young of the year and adults migrate back to, or get trapped in the low lying *beels*, where they can survive the harsh conditions of these permanent water bodies during the dry season. They are adapted to resist low dissolved oxygen concentration and high water temperatures. The main adaptation is their auxiliary respiratory organ used for the uptake of atmospheric oxygen. The main species of the "black" fish are belonging to the *Clariidea* (*Magur*), *Ophiocephalidea* (*Taki*) and *Anabantidae* (*Koi*, *Kolisha*).

Fish Catch in the Project Area

In order to assess the impact of CPP on fisheries, a monitoring program was started in 1992. This program monitored the catch in the pre-water management phase (May 1992-May 1995) and the post water management phase (May 1995-May 1999).

On average, 330 MT of fish was caught in the CPP project area annually. However, this average conceals huge variations, with the catch varying with the extent of flooding in any particular year. The lowest catch of 85 MT was observed in 1992 and the highest catch of 845 MT occurring in 1998 when there were high floods. This is shown in Figure 16.

What has become clear is that the F_2 land is the major contributor to the annual catch. It is much more important than the permanent water bodies or F_3 land. In relation to flood control, this is important, as the major changes through water management will take place at the F_2 and F_1 Land types.



Annual fish catch in the CPP project area (1992-1999) and its distribution among the different land types is shown in Table 15 below.

Year	Catch (Mt/year)			Lohajang river	Khals	Total
	F ₃	F ₂	F ₁			
92/93	36	42	5	1	2	86
93/94	76	176	33	3	29	317
94/95	43	158	15	N.a.	N.a.	216
95/96	43	92	12	N.a.	N.a.	147
96/97	48	223	39	4	9	323
97/98	56	292	38	1	9	396
98/99	97	596	119	8	25	845

Table 15: Fish Catch in the CPP Area

Despite earlier CPP reports, the conclusion has to be that there is no significant trend in the fish catch within the CPP area during the period 92-99. CPP has not had an adverse impact on open water fisheries. The discrepancy between the present findings and earlier reports lays in the fact that during the early phase of CPP, a suitable tool for analysis of data and extrapolation of the data towards future developments was not available.

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The results of the monitoring program indicated that a major factor influencing the annual floodplain catch is the human one. The number of fishermen, or fishing effort, explains 74% of the variance in the catch. This may seem obvious but most of the fisheries programs in Bangladesh (including that of CPP) take little account of this. Typically they focus on biological/hydrological aspects such as habitat restoration, maintaining flood levels; excavation of *khals* and the construction of fish passes. It has to be questioned whether this path will stop the long-term downward trend of floodplain fisheries production in the country.

The results of the monitoring program indicated the annual catch is related to the extent of flooding. The length based stock assessment program indicates that differences in growth and total and fishing mortalities are the major factors influencing the system, whereby survival during the dry period could be one of the major bottlenecks.

Data Analysis and Modeling

The monitoring program of CPP enabled the development of a continuous data set that can make a major contribution to the knowledge of open water fisheries in Bangladesh. The fact that CPP developed an integrated water modeling and GIS system has enabled tools to be developed that can be used for future projects involving fisheries.

The long-term fisheries monitoring program provided detailed information on fish catch and biological, hydrological and socio-economic factors influencing the catch. The project was then able to integrate this habitat based monitoring and integration with the hydrological data in a GIS environment. This is a useful technique as traditional catch and effort-monitoring programs can be applied to floodplain fisheries. The method has proved to be both reliable and simple.

Hatchling Migration

From the earliest stages of the project, there has been concern that the intake structures within the embankment would reduce the flow of white fish hatchlings entering the compartment, thus having an adverse impact on fisheries. To monitor this CPP has studied the hatchling migration in the Lohajang River at the main inlet.

The hatchlings were coming in waves (Figure 17) and it seems that the peak of the waves is related to peak water levels of the Jamuna River. Carp were found within the first waves only and were absent after the 1st September. *Hilsa* spp. (*Tenuulosa*) and other non-identified species were found throughout the monsoon.

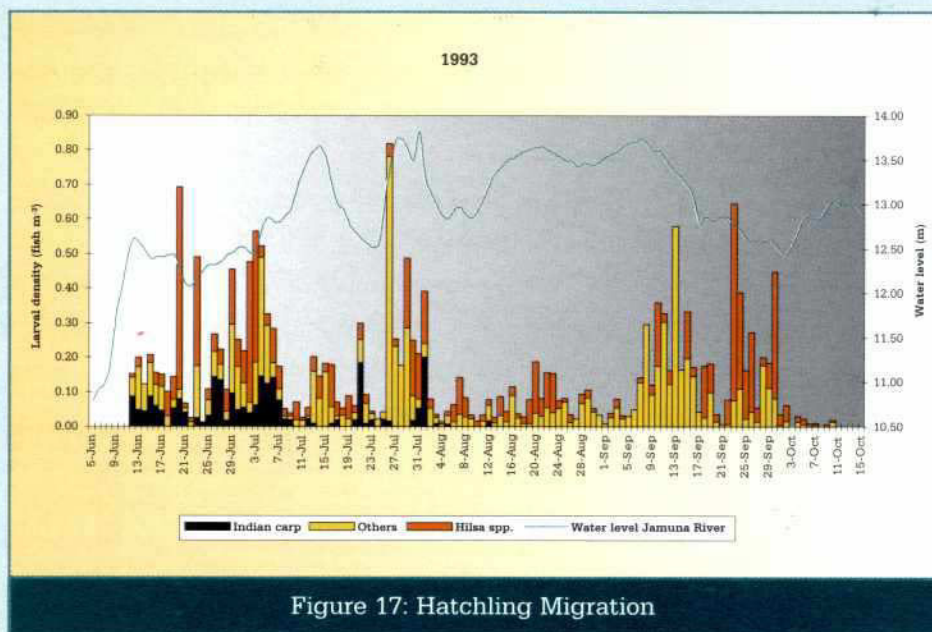


Figure 17: Hatchling Migration

The highest hatchling densities are found in the surface layer of the river near the embankment (Figure 18) and no diurnal (night versus day) distribution patterns were found. The turbidity of the river water is most likely the force behind the presence of vertical and horizontal distribution patterns and the absence of diurnal distribution patterns.

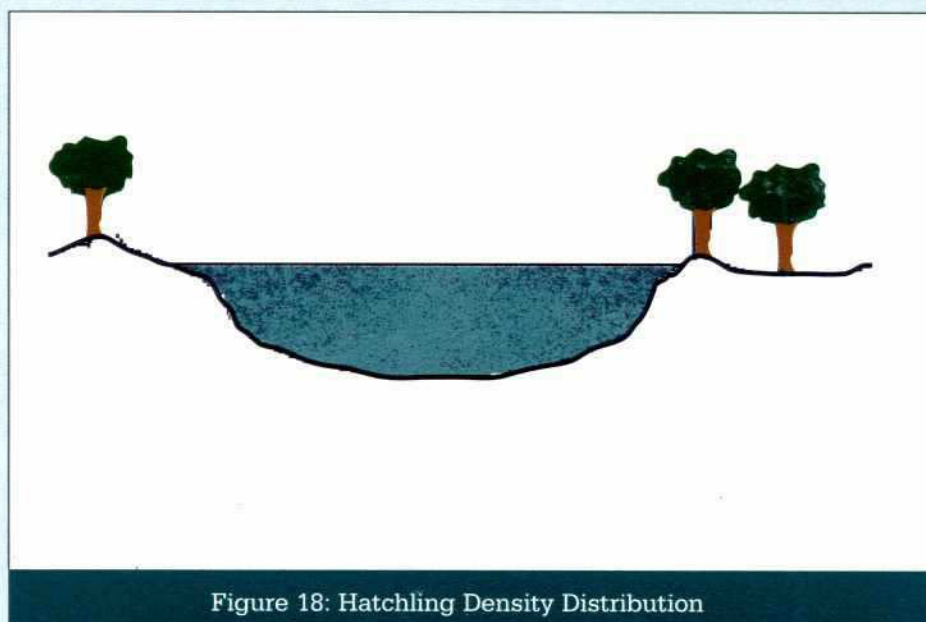


Figure 18: Hatchling Density Distribution

The implication for water management interventions of finding that hatchlings are drifting through the surface and near the embankments is that fish friendly gates should be constructed near the embankment. These structures should be of a free flow type, operated in an over-shot condition. They should take the water from the surface layer of the watercourse to maximize hatchling influx.

Two fish gates were constructed on the left and the right-hand side of the regulator based upon the above finding. If during the period of larval drift the water level becomes too high, then the main gates can be closed and the open side gates will still allow hatchling drift.

The main regulator constructed in the Lohajang River could be called "fish friendly" if the location of the drifting hatchlings and the specially constructed side gates are considered.

CPP has studied the migration of fish through the main regulator. Fingerlings/hatchlings were released upstream of the regulator¹³ and were caught just upstream and downstream of the regulator, after which mortality rates of the two groups were compared with a non-treated control group.

Date	Mortality (%)				Gate setting
	Hatchery	Upstream	Downstream	Regulator effect	
16/07/99	15	10	48	38	Undershot
17/07/99	10	24	84	60	Undershot
19/07/99	9	27	61	34	Undershot
06/07/99	1	21	66	44	Undershot
20/07/99	13	15	17	3	Overshot
20/08/99	3	18	27	9	Overshot
21/08/99	6	8	16	8	Overshot
23/08/99	10	23	34	11	Overshot
24/08/99	4	11	41	29	Overshot
25/08/99	2	8	20	12	Overshot

Table 16: Mortality Rates on Released Carp Hatchlings

In 1998, preliminary experiments were carried out with fingerlings but the results were not conclusive. In 1999, the experiments were repeated with carp hatchlings of

0.2 gram. Unfortunately, the monsoon of 1999 was very dry and only a limited number of experiments could be carried at the main gates only, due to the extreme low water levels. During the experiments the regulator was operated in two different modes: Overshot (water is flowing over a closed gate-door) or Undershot (water is flowing under a semi-closed gate-door). The effect of the regulator on the mortality of hatchlings for the different modes of operation is presented in Tables 16 and 17.

Mode of operation	Mortality rate (%)	N
Overshot	12± 3.6	6
Undershot	44± 5.6	4

Table 17: Mortality Rates of Different Modes of Operation of the Regulator

About 44% of the hatchlings died within 5 hours after passing the regulator if it was operated in an undershot mode, which is the standard mode of operation in Bangladesh. When the regulator was operated in an overshot mode, the mortality reduced significantly to about 12%. It can be concluded that the main gates (although not the fish gates at the sides) of the Lohajang regulator are not fish friendly, especially if used in the standard undershot mode of operation. Overshot operation would improve the situation and this type of operation has been modeled for different water levels and management scenarios in the CPP area.

Aquaculture Extension Program

In order to increase availability of fish in the CPP area an Aquaculture Extension Program (AEP) started in 1994.

The Aquaculture Extension Program started with an inventory of the existing ponds in the target cluster, followed by motivation, the establishment of demonstration ponds and training of the pond owners.

The reduced risk of flooding (and losing cultured fish) has led to a rapid growth of aquaculture in the project area. The fisheries section of CPP has contributed greatly to this expansion and to increased yields of fish by providing an effective extension service for the project. In all 2,685 pond owners have been trained of whom 348 are women.

One way of looking at aquaculture it to see it as the most successful crop option

within the project, but it is one confined to people who have sufficient land to construct a fishpond. These people are the medium to large farmers. It is these farmers too, who have the capital to invest in fish culture.

Table 18 below shows the growth of aquaculture in terms of area and yield.

Category	Number of Ponds	Water Area per Pond (average) M	"W/Out" project Production Kg/ha	"With" Project Production Kg/ha	Growth Rate %/a
Culture Pond (Large)	1,343	1,713	861	2,048	15.5
Culture Pond (Med/Small)	944	668	603	857	6.0
Derelict Pond	814	725	373	525	5.7
Total	3,100	803	733	1,585	13.7
Table 18: Aquaculture With and Without the Project					

Source: Annex F, Fisheries

Table 19 shows the value added by fish culture within the compartment. As can be seen, it represents a considerable benefit within the CPP.

	Production Tons/year	Value Taka mil.	Input Cost Taka mil.	Value Added Taka mil
W/o project	258	18.06	4.46	13.60
With project	558	39.06	7.42	31.64
		Value \$	Input cost \$	Value added \$
W/o project	258	361,200	89,280	271,920
With project	558	781,200	148,465	632,735
Table 19: Aquaculture Benefits				

Before CPP started, the average production of ponds was 1,090 kg/ha/crop and 258 MT/year of fish was obtained through aquaculture in the project area. Through the aquaculture extension program of CPP the production level of the ponds increased considerably to an average of 2,200 kg/ha/crop. A total aquaculture production of 558 MT/year has been reached, with an incremental production of 300 MT/year. This is largely due to the decreased risk of flooding which has encouraged greater investment within aquaculture.

Flood Mitigation

The main thrust of CPP has largely been seen as a means to improve productivity within the compartment, especially in agriculture. However, for the people in the compartment, especially after the 1998 flood, one of the major benefits of CPP was flood protection. It was difficult to quantify the value that people put on the feeling of safety and protection that they derive from effective flood protection. However, there are direct economic benefits, in the form of damage avoidance, which can be quantified. In addition to their impact on the agricultural sector, CPP interventions have generated benefits to non-agricultural sectors such as residential houses, business, industries, offices and infrastructure.¹⁴

Quantification of Flood Damage Avoidance

There has been little research on methods of flood loss assessment to urban and non-agricultural sectors in Bangladesh. Flood Action Plan, FPCO Guidelines (FPCO 1992) have concentrated on the evaluation methods of agricultural protection schemes that are principally aimed at reducing potential crop losses. The guidelines, however, recommended that non-agricultural benefits be included in economic analysis, without spelling out any assessment methods/principles whatsoever of how to assess non-agricultural damages.

Following fast urbanization within the CPP area, especially the expansion of Tangail Town, potential non-agricultural and urban flood losses in general are of obvious importance. It was of importance for this pilot study, therefore, that the non-agricultural benefits generated by the CPP interventions be assessed in order to facilitate the evaluation of the project.

The project carried out a flood loss study whose aim was to obtain an estimate of the total non-agricultural benefits of protection derived from CPP.

The study dealt with tangible damage only. The following five broad sectors, which are viewed as comprising the main economic loss sectors in the non-agricultural economy of CPP were considered.

- Residential houses
- Business (Trading)
- Industries
- Office & Public buildings
- Roads

Appraisal Process for the CPP Area

The approach in assessing the value of damage avoided was conceptually straightforward. An assessment of the probable damage under various flood scenarios without the project was compared with the situation with the project. To actually assess that probable damage was, however, a complex exercise.

The study used a unit loss appraisal model aimed at assessing expected annual damage (or the benefits of protection). The advantage of such a model was that it is capable of separating impacts by types, flood levels and frequencies - even when flood level and frequency differences are small. The model is demanding in terms of resources, time and data, particularly in respect of high quality hydraulic and hydrological information. Fortunately, much of this was already available within CPP as a result of the flood modeling carried out by the project.

The unit loss model involves four basic components:

- Potential depth-damage data sets
- Land use of properties
- Level and floor heights of properties
- Damage-frequency analysis.

The CPP study adopted some methods that exist in the developed countries, modified some of them, and developed some new methods, suiting flood and socio-economic conditions in Bangladesh. The study generated some standard potential depth-damage and duration-damage data sets for business, houses, industries, roads and institutions.

Assessment of Physical Damage

Depending upon varied extent of susceptibilities, the physical damage (or direct damage) components may be grouped into:

- Building structure
- Machinery/equipment (including furniture and fittings)
- Stock of inventory (for households) or stock of input and output (for commercial units).

It was assumed that flood damage was the cost of returning the relevant property to pre-flood conditions, through either repair or replacement of damaged items.

Urban and Rural Characteristics

The area under CPP can broadly be divided into two categories. One was that associated with urban characteristics, which consists of the sub-compartment 16 - Tangail Town. The other, having relatively rural characteristics, consists of the sub-compartment 1 through 15. Analysis was carried out separately for these two broad areas.

Methodology

The study computed average damage data sets for various sectors of the economy as input into the unit-loss model to subsequently estimate the expected benefits of flood protection in the CPP area. The data sets were developed separately for sectors and various damage components, for eight depths and two duration.

A detailed land use, land level and height survey was undertaken for existing individual properties in each of the 16 compartments within the Tangail CPP area. There are about 100 thousand residential houses within the project area. Over and above these, there are industries, business, offices and public buildings situated in the 16 compartments.

- In order to establish a representative sample, one-fourth of the households in each of the villages in each compartment, SC 1 through SC 15, was covered in the field survey. The number of households in each compartment was determined with probability proportional to size. The investigation covered houses, industries, business, office and public buildings and roads.

In Tangail Town, since the area was relatively small, and the concentration of properties was high, all the properties were surveyed. First, the main roads were identified, by which the sub-roads and the properties were situated. The levels of the main roads were estimated through actual measurements and each of the main roads by which the properties were located was identified as the references for the location of the individual properties.

The main roads and sub-roads (under each of the main roads) and subsequently the floor heights, having been related to the PWD Bench Mark, each of the properties were thus linked with the flood records of the Jugini gauging station.

Slope Factors and Inundation

The Dhaleswari river and its distributary, Lohajang (which passes through the town) are the main source of flooding in the compartment.

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The flood level records are based on a single gauging station, which was not situated in the community, but about 13 km upstream of the main town. The river surface normally has a significant downstream gradient. The properties located in the downstream are thus likely to have lower flood levels than those around the gauging station in the upstream. The level differences are likely to be lower if the flood gradient was steep (e.g. in the larger floods with higher intensities), and when the properties are irregularly spaced along the river valley. The interventions by depressions, canals, culverts, roads and embankments are also likely to contribute to the variations in water levels in the urban areas. This is likely to be prominent more in case of urban built-up areas like Tangail Town.

An indirect way of estimating the slope was adopted. First, the mean depths of inundation in the 1988 flood for each of the main roads are estimated from several observations at various points. The flood marks (which were, at the time of survey, distinct on the house external walls) and discussions with the residents helped accomplish this.

The area elevation data were supplied by the CPP Flood Management Model. The inundation depth data (in percentage form, of area by sub-compartments) for various selected depths and selected floods of five return periods in pre-project situation were also supplied by the flood model.

The inundation depth data supplied by the CPP Flood Management Model is based on some assumptions:

- Annual peak levels are considered for the frequency analysis
- 10-day average and duration are considered in the frequency analysis
- Full River and hydrological system was taken into consideration.

Application of Standard Loss Data Sets

The average damage data sets for various sectors of the economy in CPP are used to estimate the expected benefits of flood protection in the CPP area. Aspects relating to assumptions and conditions are shown in Table 20.

Extent of Inundation in Pre-Project Situation

The fourth essential component of the benefit assessment was hydraulic and hydrological data. The flood level information available from the CPP flood modeling was used in carrying out the frequency analysis.



Sector/ Land use	Damage data used	Broad methods/assumptions
All Sectors	Depth-damage data, except for roads sector, and for 'other' Damage component in residential sector	Average group depth damage data are constructed for all sectors at 98/99 price, through regression methods; 2 & 5 yr. flood use short duration data; 10, 20 & 30 yr. flood use both short & long duration data, based on corresponding sample proportions in each category. Sample floor space used to estimate total floor space, except for office sector. Structural damages, for all sectors, assumed 10% damage avoided through reduction measures. Inventories/stock/machinery/equipment adjusted for damage-reduction activities.
1) Residential	Proportional depth- damage data : direct damage Per household damage data	Average group proportional (to value) depth damage data (by individual damage components). 7Structural damage considers "main structures". Clean-up costs incorporated into structural damages. Other' damages (e.g. livestock, trees etc) not considered.
2 Business	Per sq. meter depth- damage data: direct & indirect damage	Business group loss average data (by individual damage components) used. For indirect damage, regional damage incorporated. Linkage effects not contemplated, but multipliers constructed through use of national Input-Output Table.
3 Industries	Per sq. meter depth- damage data: direct & indirect damage	Manufacturing group loss average data used by individual damage components. Industries-related services included in manufacturing; for indirect damage, damage to region incorporated. Linkage effects not estimated but multipliers constructed through use of national Input-Output Table.
4 Office	Per sq. meter depth- damage data : direct damage	Office group loss average data (by individual damage component) used. Educational institutions, health and utility services included. In SC 1-15, public buildings include mostly religious institutions. Population floor space used.
5 Roads	Per km event-loss data; direct damage	Trend analysis method used: only <i>pucca</i> roads, under R&H Div and <i>Pourashava</i> authority contemplated. No assessment made for herring-bone and <i>kutcha</i> roads

Table 20: Flood Loss Data and Assessment Methods Used in the Estimation

Simulations were made for the flood frequencies of 2, 5, 10, 20, 25 and 30 years. The 1988 flood was considered a 30-year flood and 1998 was considered a 25-year flood; the 1995 flood was considered as a 5-year flood.

The model simulations worked out the extent of inundated areas for various depths for different sub-compartments, which were subsequently used in the flood loss assessment.

Benefit Assessment

The study then assessed the potential damage within the Compartments (including the Tangail Town) for floods of different magnitudes, assuming a "without project" situation. This enabled the benefits to be assessed under the situation of CPP being in place and providing protection.

Estimates were made of the number of properties, by type or group in each sector that are flooded by each depth and duration of flooding at each flood frequency. Through incorporating the group average depth-damage data sets for individual group and damage component, total damages for each flood events/sectors were assessed. The Expected Annual Damage (EAD), which was the area under the loss-probability curve, was estimated separately for the Tangail and the rest of the CPP area.

Flood	Sector	Direct damage (damage value in 000 Taka 98/99 price)			Indirect damage		Total
		Structure	Inventory /stock	Machinery /equipment	Primary indirect	Linkage effects	
2 year	Residential	833	1,340	-	-	-	2,173
	Business	3	19	-	44	-	66
	Industries	74	62	35	286	-	457
	Public buildings	56	-	27	-	-	83
	Roads	197	-	-	-	-	197
	Total	1,163	1,421	62	330	-	2,976
5 year	Residential	4,474	7,684	-	-	-	12,158
	Business	494	2,287	-	5,400	-	8,181
	Industries	849	776	456	4,091	-	6,172
	Public buildings	1,960	-	491	-	-	2,451
	Roads	2,228	-	-	-	-	2,228
	Total	10,005	10,747	947	9,491	-	31,190
10 year	Residential	24,420	39,130	-	-	-	63,550
	Business	2,353	11,263	-	23,576	-	37,192
	Industries	2,202	2,368	1,388	12,335	-	18,293
	Public buildings	4,917	-	865	-	-	5,782
	Roads	3,329	-	-	-	-	3,329
	Total	37,221	52,761	2,253	35,911	-	128,146
20 year	Residential	46,017	76,270	-	-	-	122,287
	Business	5,425	25,369	-	50,918	-	81,712
	Industries	4,229	4,562	2,565	22,727	-	34,083
	Public buildings	6,741	-	1,292	-	-	8,033
	Roads	3,536	-	-	-	-	3,536
	Total	65,948	106,201	3,857	73,645	-	249,651
30 year	Residential	57,625	96,977	-	-	-	154,602
	Business	6,926	35,053	-	66,934	-	108,913
	Industries	5,338	5,813	3,185	28,398	-	42,734
	Public buildings	7,957	-	1,501	-	-	9,458
	Roads	10,979	-	-	-	-	10,979
	Total	88,825	137,843	4,686	95,332	-	326,686
Table 21: Estimated Potential Damage in Floods -Tangail							

Tangail Town

Table 21 shows the damages by sectors and loss components predicted in five selected floods of successive frequencies, ranging from the 2 to the 30 year event in Tangail Town (SC 16). This is, of course, damage under a "without project" scenario.

Table 21 shows that the total urban flood loss in Tangail Town, in the absence of the project, predicted in a 2-year flood would be about Tk. 3.0 million. This increases to about TK. 31.7 million in a 5 year flood, followed by TK. 128.1 million, TK. 249.7 million and TK. 326.7 million in a 10 year, 20 year and a 30 year flood respectively. The total losses are disaggregated by the five land use sectors and the five damage components in Table 22.

Flood return period	Sector loss (%) Residential	Business	Industries	Office & public buildings	Roads	Total events loss (000 Tk.)
2 year	73.0	2.2	15.4	2.8	6.6	2,976
						(100.0)
5 year	39.0	26.2	19.8	7.9	7.1	31,190
						(100.0)
10 year	49.6	29.0	14.3	4.5	2.6	128,146
						(100.0)
20 year	49.0	32.7	13.7	3.2	1.4	249,651
						(100.0)
30 year	47.3	33.3	13.1	2.9	3.4	326,686
						(100.0)
Average	48.0	32.0	13.8	3.5	2.7	147,730
						(100.0)
Table 22: Sector Analysis of Event Damages - Tangail Town						

CPP Outside of Tangail Town

Table 23 shows the damages by sectors and loss components predicted in five selected floods of successive frequencies, ranging from the two to the 30-year event. This is for the "without project" situation for the whole area of the compartment outside of Tangail Town.

Table 23 shows that, in the "without project" situation, the total flood loss predicted in a 2-year flood, will be about TK. 5.7 million. This increases to around TK. 8.4 million in a 5 year flood, followed by TK. 33.2 million, TK. 106.5 million and TK. 153.8 million in a 10 year, 20 year and a 30 year flood respectively. The total losses are

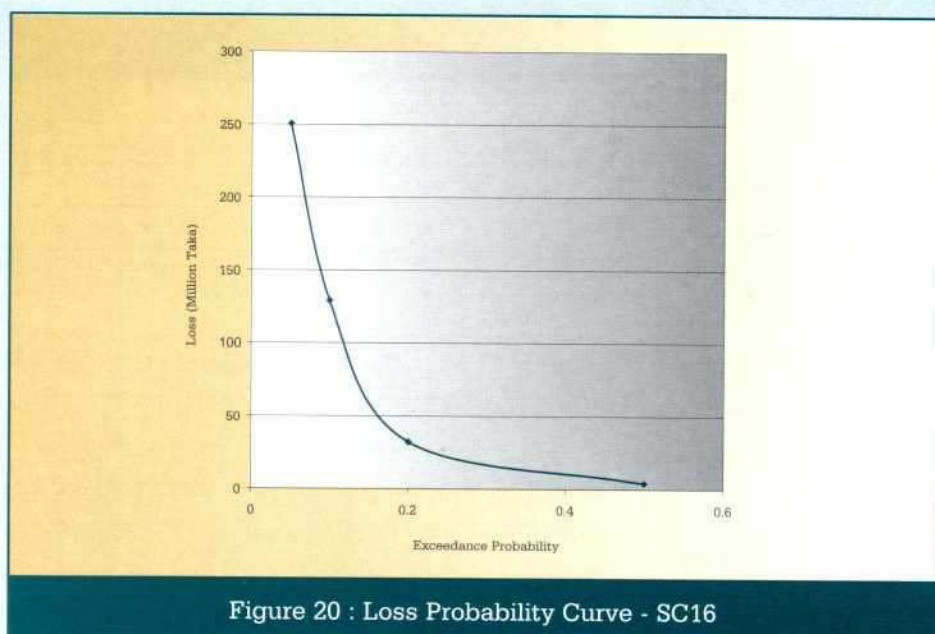
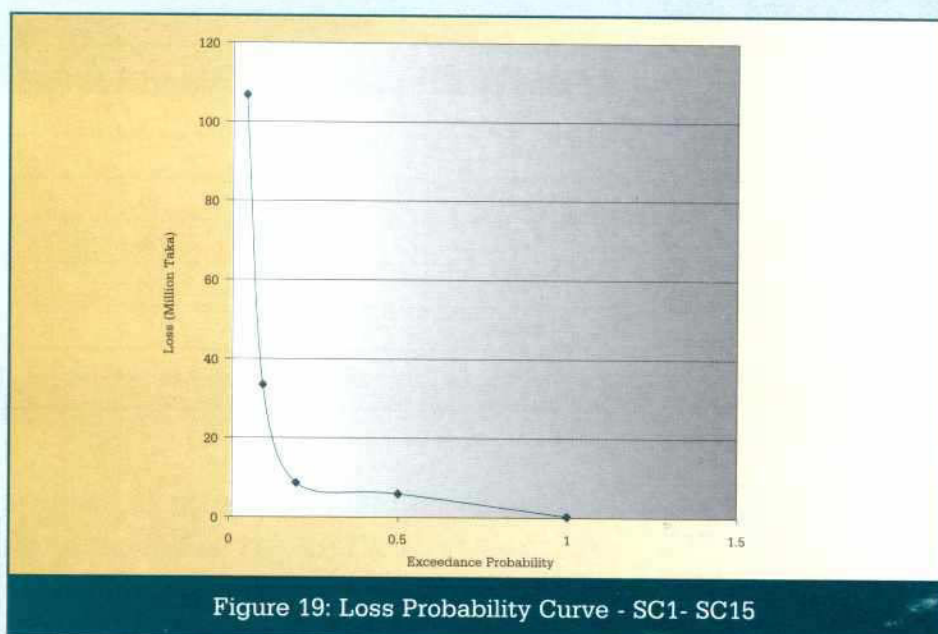
dissaggregated by the five land use sectors and the five damage components in Table 24.

Assessment of Expected Annual Damage (EAD)

The ultimate output of the unit-loss model was the estimated expected annual damage (EAD), which was equivalent to the expected annual benefits of protection, from which the present value of benefits can be assessed. The analysis has considered a 20-year flood as the CPP's standard of protection.

Flood	Sector	Direct damage (damage value in, 000 Taka 36/99 price)			Indirect damage		Total
		Structure	Inventory /stock	Machinery /equipment	Primary indirect	Linkage effects	
2 year	Residential	2,470	1,194	-	-	-	3,664
	Business	73	217	-	380	-	670
	Industries	531	107	53	435	-	1,126
	Public buildings	72	-	27	-	-	99
	Roads	128	-	-	-	-	128
	Total	3,274	1,518	80	815	-	5,687
5 year	Residential	3,102	1,502	-	-	-	4,604
	Business	82	226	-	443	-	751
	Industries	635	130	64	526	-	1,355
	Public buildings	91	-	34	-	-	125
	Roads	1,613	-	-	-	-	1,613
	Total	5,523	1,858	98	969	-	8,448
10 year	Residential	16,554	7,200	-	-	-	23,754
	Business	343	731	-	1,551	-	2,625
	Industries	1,736	411	213	1,673	-	4,033
	Public buildings	267	-	100	-	-	367
	Roads	2,456	-	-	-	-	2,456
	Total	21,356	8,342	313	3,224	-	33,235
20 year	Residential	55,662	24,251	-	-	-	79,913
	Business	1,172	2,261	-	5,161	-	8,594
	Industries	6,097	1,417	733	5,752	-	13,999
	Public buildings	981	-	361	-	-	1,342
	Roads	2,648	-	-	-	-	2,648
	Total	66,560	27,929	1,094	10,913	-	106,496
30 year	Residential	74,882	32,691	-	-	-	107,573
	Business	1,470	2,867	-	6,486	-	10,823
	Industries	8,339	8,990	971	7,598	-	25,898
	Public buildings	1,209	-	451	-	-	1,660
	Roads	7,806	-	-	-	-	7,806
	Total	93,706	44,548	1,422	14,084	-	153,760

Table 23: Estimated Potential Damage in Floods: SC 1 – 15



Assessment of EAD in Tangail Town

Table 24 shows the loss-probability relationship and the expected annual benefits for SC 16 of the CPP. The relationship is also shown in the loss probability curve in Figure 19. Thus, for SC 16 the expected annual benefit for non-agricultural sectors is estimated as TK. 23 mil.

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Return period	Exceedance probability	Event loss (mil. Tk.)	Annual benefit	Discounted
1	1	0	-	-
2	.50	3.0	-	-
5	.20	31.2	-	-
10	.10	128.1	-	-
20	.05	249.7	-	-
Total	-	-	23	228

Table 24: Loss Probability Analysis: Tangail Town

Assessment of EAD in the Rest of CPP

Table 25 and Figure 20 both show the loss-probability relationship and the expected annual benefits for the Area outside of Tangail Town of the CPP. The expected annual benefit for non-agricultural sectors is estimated as TK. 9 mil.

Return period	Exceedance probability	Event loss (mil. Tk)	Annual benefit	Discounted
1	1	0	-	-
2	.50	5.7	-	-
5	.20	8.4	-	-
10	.10	33.2	-	-
20	.05	106.5	-	-
Total	-	-	9	89

Table 25: Loss Probability Analysis: SC 1-15

As both tables show, the one in twenty year flood does the real damage. Some 355 million Taka for the compartment. However, this is a 1:20 year flood, so that when the damage is averaged on an annual basis it does not look too high. This is the nature of flood damage avoidance. Investment is being made to protect against an event that, by its nature, happens infrequently. Nevertheless, the damage should not be underrated. The 355 million Taka (\$7 million) is for some 13,000 ha of land within the compartment. If this is extrapolated for all of the flood plains in Bangladesh then the very high cost of severe floods in Bangladesh is obvious. For CPP, the 355 million Taka is the value of the non-agricultural damage avoided in 1998.

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Secondary Outputs and Results

Poverty Alleviation

One of the objectives of the CPP was to improve flood management thus making agriculture in the project area more productive. In this, CPP has been successful. Inevitably, if agriculture improves, the largest beneficiaries are the people who own the most agricultural land. Table 1, at the beginning of the report, shows the distribution of land within the project area. There can be little doubt that the largest direct beneficiaries of CPP are the six percent of population that own 46 percent of the land.

Increases in agricultural output require increased inputs, and one of those inputs is labor. To a greater extent than in many other developing countries, Bangladeshi farmers, if they own anything above a very small plot, favor the use of hired, over family labor. This would appear to be an issue of position and status within the society. For this reason, increases in labor input, largely translates into increases in wage labor. The increase in labor input, resulting from the project is estimated at some 973,000 labor days a year. These are days of agricultural labor that benefit the landless and marginal farmers within the project.

Construction has also generated jobs. Over the life of the project, it is estimated that 3 million wage days of labor have been created in the construction of structures and earthworks. In some of the structure work, skilled labor has been brought in from outside, but the bulk of the labor has been local and, again, it is the poor who have benefited. It is only the poor who are prepared to do the laboring work involved.

As well as the generation of labor that has benefited the poor, the project has run two programs designed to specifically target the poor. Both have been targeted at poor women, who do not benefit from the jobs created in construction. The programs are the Embankment Maintenance Group (EMG) program and the Homestead Catfish Culture Program.

Embankment Maintenance Groups

One of the objectives of CPP from the beginning was to set up income generating activities with poor and landless women. Within earthwork seemed to provide the best opportunities as a considerable part of the infrastructure of the compartment is composed of embankments, which require maintenance. Preventive maintenance was, therefore, identified as an activity that was suitable for the involvement of women who could be organized into Embankment Maintenance Groups.

The EMG program was implemented from September 1995 onwards, and will continue after June 2000 when the project closes.¹⁵ A total of 100 landless women from the poorest group of society participate in the program.¹⁶



Implementation Strategy

The WID section was in charge of the recruitment of the female laborers. Women belonging to the poorest of the rural poor were the targeted participants in the program. The women had to be in good health, their family members dependent on their wage labor, and they should not own any agricultural land. The women needed, of course, the willingness to work on the embankment. Preference was given to women who were divorced or separated, and to women who had no alternative source of income.

In most cases, women were recruited with the help of influential members of the Union Parishad and/or SCWMC. This appeared to be an effective strategy, since they knew the poor women of their area, and also because the women needed their support. They contributed to the fact that their presence and work were gradually accepted and appreciated by the communities. Opposition came in particular from landowners that created problems for the women when they wanted to take earth from their land.

Results

The one hundred women who benefited from the program before being engaged as an EMG member were either without work, or had temporary jobs as house servant (without salary, but paid in kind), *bidi* (cigarette) makers or seasonal agricultural laborers. More than half of the women were beggars.

The women's motivation was high, as shown by the fact that only five women dropped out during the implementation of the program, but also shown by their sense of responsibility. During the 1998 floods, the women worked many hours of unpaid overtime, which they justified by saying that they felt it their responsibility to do as much as possible to keep the embankment in shape.

According to observations of the women themselves and of other women from the communities, the acceptance of female earth laborers in the area has broken certain gender barriers, since earth work was commonly considered a man's task.

The EMG women perceived the fact that they earned and received money in cash on a regular basis the most important direct benefit for them. It enabled them to contribute to the income of their family, and it has increased their access to resources. Some women were able to obtain loans; A few women improved their control over resources through investments with the money saved. One of the women, for instance, bought a rickshaw with her savings, another a cow, whereas a number of women leased land for agricultural production or bought land to build a house. Women have, in this way, managed to obtain an improved prospect for the future through investment of the money saved.

Homestead Catfish Culture Program

CPP's Homestead Catfish Culture Program, also known as the *Chari* in the *Bari* program, has attempted to reach the poorest of the poor. Its purpose has been to show this group that it is possible to grow high valued fish even with their limited resources.¹⁷

The poor find themselves in a vicious circle; because of their poverty, they can not acquire resources to generate an income; because of this, their income stays low. Many attempts have been made to break this circle. The micro-credit schemes, operated by several NGO's are a good example of such attempts. The main idea of the Homestead Catfish Program was to give people access to resources with which they can generate an income, thus enabling them to acquire the resources to generate more income.

Most poor people in the Compartment have access to labor, some land on which their shack is built, water, and what the area (or fields) around it can provide. Through the *Chari* in the *Bari* program an optimal use of these resources is used in order to create an income generating activity.

Requirements for this activity are food for fish, a small pond, water, and catfish fry. The food can be collected from the surroundings of the homestead (snails, bivalves, termites, ants, slaughter waste, etc). The pond does not have to be large; one square meter is enough for 50 fry. This can be dug by the participants themselves. The catfish fry is widely available in Bangladesh, for a reasonable price (between 10 to 50 Taka [= US\$ 0.2 to US\$ 1] for 50 pieces). After a rearing period of four months, the production will be five to six kilos of African catfish, which is worth approximately 400 Taka.

The Concept of Homestead Catfish Culture

The African catfish (*Clarias gariepinus*) is used because this fish is known to take up oxygen from air, has a high growth rate, and is very disease resistant. Experience in CPP shows that as soon as people are introduced to this method, they adapt it to the possibilities around their homesteads. During and after successfully raising a first batch of fish, the people on and around the involved homesteads develop initiatives for continuation of the activity, such as contacting local fry traders and trying out different food sources locally available. In the program, initiatives like these were stimulated and formed the core of the success of it.

All training of participants was done on site, at the homestead. The first interaction between participants and field staff was during the identification of participants. To ensure selection of the poorest of the poor, a general review of the participants' situation was made. To be selected for the program the potential participants had to

comply with a few criteria. They had to be landless, their general situation had to be poor/desperate, and their house needed to have mud, bamboo or jute walls. Potential participants who fitted all criteria they were asked about their interest in partaking in the program, which involved them buying fry for a reduced price (10 Taka, 20 cents US) from the field officer.

During the sale of the fry, four basic rules for catfish culture, which would provide an easy method to grow the fish, were explained to the participants:

- The fish need to be fed every day, preferably until they do not want to eat anymore.
- The food can eat anything, except grass and plastic, the best food being protein rich food,
- As soon as the water in the ditch starts smelling bad it needs to be changed,
- During the change of water, special attention needs to be paid to the sizes of the fish; these need to be in the same range, to prevent cannibalism.

Results

Two hundred households participated in the program. The average size of these households was 4.7 people (1.4 male, 1.3 female and 2 children). Most male household members (84%) had an income-earning job with which they earned on average 48.7 Taka per day. On the other hand, most of the women in the selected households stayed on the homestead, and were not earning money. The women who did earn an income brought home less than men, the average daily income for women was 15.2 Taka. A small number of children (2%) generated an income, on average 22.2 Taka per day per child. Sixty percent of the children went to school; primary school in most cases being the highest education of these children. Overall the daily income was 61.4 Taka (US\$ 1.11) per household.

Women took care of most of the ponds (80%), men (15%) and children (5%). Care for the fish consisted mainly of collection of food. Food could be collected from around the homestead. Children from nearby assisted caretakers in the collection of food, because of the interaction children had with the fish while feeding. It turned out that feeding was a game to them. The food supply costs can be considered zero, taking into account that mainly women and children (who do not earn any income) collected the food. The supplied food consisted mainly of snails (46%), rice (18%), wheat bran (9%), rice bran (9%), bivalves (5%), or slaughter waste (5%). In other cases termites, earthworms, wheat powder, cow dung, fish, bread and duckweed was used. On average, the water in the ditch was replaced every 10 to 12 days. The average time spent on the fish was 1.5

hours per day. The caretakers themselves took decisions concerning management of the ponds and, more importantly, decided what happened with the fish produced.

20 Households were not able to grow their fish to marketable size (>75gr), due to several reasons:

- Insufficient guidance by the project staff (not visiting the household within 3 days after distribution of the fish, not visiting the household every three to four weeks).
- Not enough time spent on the management of the pond by the responsible person in the household (less than one hour per day).
- Escape of fish (after flood, or heavy rain).

Over a six months period 158 new households took up this method of fish farming, without intervention of the regular program, a diffusion ratio of $158/200 = 0.79$.

The Homestead Catfish Program has had a significant impact on the poor people who have participated in it. Five kilos of catfish (400 Tk.) in four months is, in terms of the Developed World not much, but for participants they can mean the difference between food on the plate and nothing to eat at all.

CPP is confident that people's abilities to grow catfish on their homesteads will develop. This program will contribute to the food and income security of the poorer segments of the population living in the CPP area and can be considered as a new poverty alleviation technique.

Number of households involved	200
Criteria for joining	Professional fishermen, destitute women, or landless people. House has to be built with straw, mud, or jute wall
Number of fry sold per household	50
Size of fry	2 - 3 inch, 3 grams
Price	10 Tk. per 50 fry, normal price for these fish 25 - 50 Tk. per 50 fry
Household success rate (percentage of households able to grow with this method)	85 - 90%
Feed sources	Snails, bivalves, tubifex, termites, mosquito larvae, slaughter waste, blood, wheat bran, rice bran
Growth rate	From 150 grams to 7 kilo's in 10 weeks (total fish-weight)
Time spent per day	1 - 1.5 hours
Average income household before joining	60 Tk./day
People taking care of the fish	80% women, 15% children, 5% males

Table 26: The *Chari* in the *Bari* Program of CPP

Impact of the Northern Adjacent Area

It had always been assumed that the impact of embanking the compartment would be to increase flooding in the northern adjacent area. To that end a number of mitigation measures were implemented.

It was not until the end of 1999 that the project was in a position to effectively model the impact of CPP on this area. The basis of the modeling was a comparison of the flood levels of 1998 as they actually occurred, and how they would have been if there had been a pre-project situation. That is a situation where the embankment was ungated and porous. The reason for selecting 1998 was that many of the people in the Northern Adjacent Area felt that the project had contributed to the severity of their flooding during this year.

The pre-project situation was simulated by running the model with the gates at the Main Inlet, and Sadallapur and Rasulpur inlets fully open.

The first thing to be noticed in comparing the two flood maps in Figure 21a & 21b, showing the situation in actuality, and in the simulation, is that in the pre-project situation the Compartment itself is flooded to a far larger extent and depth than actually occurred in 1998. This is not a surprising result. However, what is perhaps surprising is that, in spite of keeping the water outside of the embankment, this did not contribute to an increased extent of flooding in the Northern Adjacent Area. In fact, both cases show an almost identical extent of flooding. What has happened is that the flood is 10 to 20 cm deeper in the adjacent area because of the flood prevention in the Compartment. The impact therefore is truly marginal.

The reason for the Compartment having so little impact is that the Northern Adjacent Area and the Compartment itself are all part of the very much larger Jamuna Flood Plain. The amount of water that is kept out of the compartment is significant for the Compartment but insignificant compared to the total volume of water in the Flood Plain.

Flood Map on 20th August, Gate Setting - Simulated Pre-Project Situation

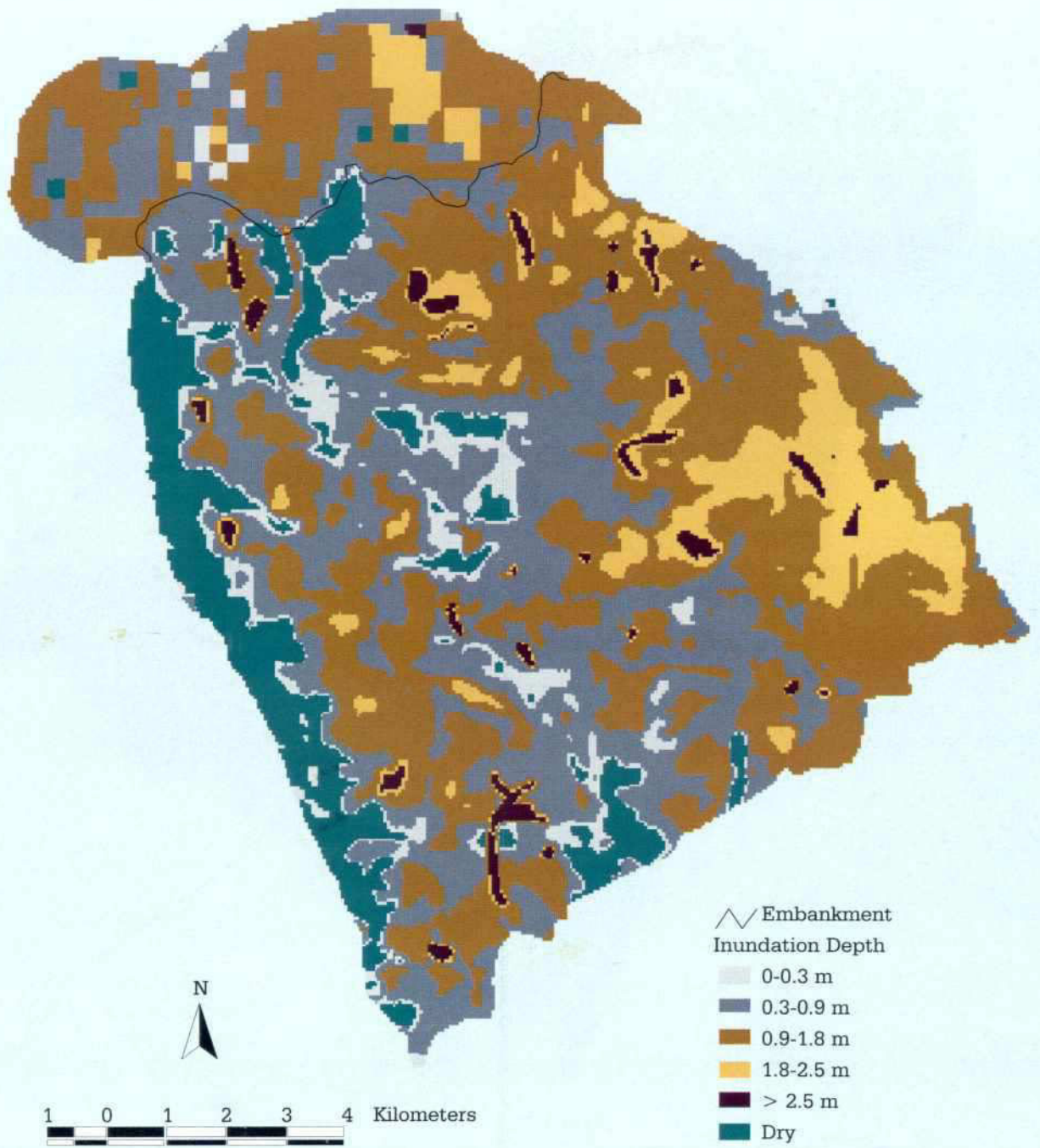


Figure 21a: Flood Map

Flood Map on 20th August 1998 - Actual

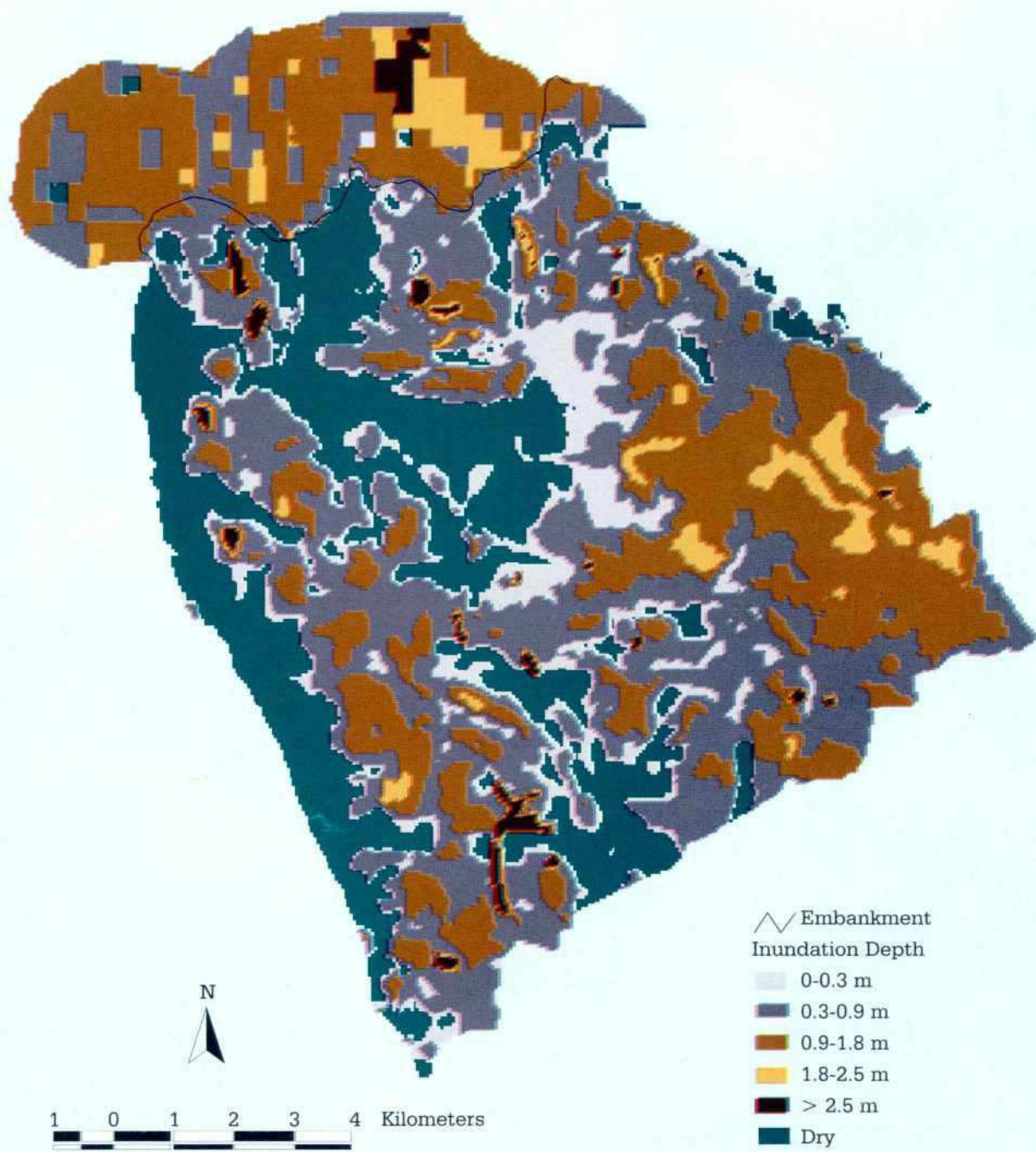


Figure 21b: Flood Map

Women in the Project

From its early design phase, onwards women have formed a special target group for CPP. During its years of implementation, CPP has tried out various strategies to involve women as both actors and beneficiaries. In addition, attempts have been made to assess the effects of CPP's interventions on various categories of women.

Women in Bangladesh and in Tangail Compartment do not form a homogeneous group. Multiple categories of women can be distinguished according to the social class they belong to, their occupation, land ownership, land type, age and other factors. As elsewhere in Bangladesh, the prevailing ideology of patriarchy in the project area puts women in a subordinate position to that of men. Women have a low status, little say in public affairs and a limited mobility. Although they enjoy equal rights in the Constitution, only few of these rights can be practiced. The average age of marriage of girls is very low (14 years), and dowry is a burden that confronts households and sometimes the girls themselves with high debts.

Most women in the project area have a heavy workload. They are in charge of both reproductive and productive activities. Women's reproductive work include cooking, cleaning, washing, water collection, child care and taking care of the sick family members. Most of these activities take place within the homestead area (the *bari*) and require both good quality and sufficient quantity of water. This appeared sometimes to be a problem at the end of the dry season, but in general it was found that the majority of households have a good access to drinking water of varying quality though tubewells, ringwells and piped water.

Women are actively involved in productive activities, although official employment records for women are low. This is because these Figures do not take into account women's productive work at *bari* level, nor the temporary and non-registered income generating activities executed by women. Such jobs are for instance domestic servant, rice huskers, *bidi* maker¹⁸ and net maker.

Landless women constitute the main category of women in the project area. Landless households (<0.5 ha) make up about 70% of the population of the project, whereas the other 30% are farm households (>0.5 ha). Farmwomen in the project area can roughly be classified in the same way as male farmers, but they generally have less access to outside resources and services than their male counterparts. Only a few women farmers own land.

Women and Development in Project Design and Implementation

According to the ToR, CPP should pay:

"Special attention to the involvement of women as a disadvantaged group, by providing them with employment opportunities" (ToR 1990, pg.4).

However, no concrete objectives were formulated in this respect and no allocations for women were made, in terms of budget and gender expertise.

During Phase I, and during the preparation of the Final Phase, various surveys were undertaken to assess women's needs. The information showed that women's needs and interests were not different from those of their male peer groups. They were primarily related to the type of household women belong to, land use, social class, age and occupation of themselves or of their husbands. Women of all categories of households wanted to become a member of the water management committees, primarily because they wanted to have a say in water management affairs, and to have the same information and knowledge as their male partners. They admitted that it would not be easy for them to participate effectively in decision making on operation and maintenance of the structures, but put forward that they could use their own informal ways to influence things. Farmer women wanted to have an increased access to new or improved agricultural information and technologies, whereas landless women insisted that CPP should open avenues for them for income generation.

Whereas in the First Phase CPP's WID efforts mainly focused on landless women, during the Final Phase activities with other categories of farmwomen were developed. In order to achieve the active participation of women in CPP's core activities, both a mainstream gender approach and a woman specific approach was developed and tried out. In the first phase of the project, no specific objectives for WID were formulated. In the final phase CPP's WID objective was to develop and promote a gender sensitive approach for water resource management that empowers women to take an active role in all decision making levels and enables women to benefit to the same extent as men.

To achieve this, CPP's WID staff worked closely with the other technical sections of the project, in particular engineering, institutional development, agriculture, fisheries and environment. The WID section was in charge of informing, motivating, organizing and training the women. For each program, specific WID objectives and quota were

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formulated that were based on the findings of different needs assessment surveys, on project objectives and on national policy guidelines. In this way, for instance, the objective of 33% female participation in water management committees was defined, which followed the GoB requirements during the last Union *Parishad* elections. Specific measures, steps and activities were taken to overcome social, cultural and other constraints that hinder women's full participation.

There was also a need to address power relations, male attitudes and behavior towards women. For this purpose, special attention was given to the empowerment of women through information dissemination, capacity building, skill development, and organization. Other women specific programs and supporting activities executed by the WID staff included:

- A Program for women's employment in preventive maintenance of the embankments, (already described above)
- Training activities, network meetings and study tours with female farmers, women WMC members and EMG women
- The organization of gender awareness training for project staff, and for male and female water management committee members.

WID Results and Effects of CPP on Women's Position

The efforts to involve women in the water management committees (WMC) have brought about a high attendance rate of women in the process of WMC formation. Women constitute 459 members of the 1,240 ChWMC members (37%), and 127 members of the 399 SCWMC members (32%). For both men and women in rural Tangail compartment the participation of women in public meetings was a novel phenomenon. It appeared that it was possible to break some of these gender barriers, because the women were motivated to get involved. This has contributed to some improvement in the social status and self-confidence of a number of female committee members, in particular the members of the SCWMC's. They are now less afraid to give their opinion and to argue their views than at the time they were elected.

For the majority of female committee members, it appeared rather difficult to play a role in decision making in water control matters. This is not only because project time was too short to empower women sufficiently to make their voices heard. It is also due to the prevailing gender relations in rural Bangladesh, with the men not willing to shift some of their present influence and power to women. The fact that the Bangladesh Water Development Board (BWDB) is to take over CPP, water management activities makes it very unlikely that the women will continue to receive

the support they would need in future. Gender awareness and motivation among management and staff of the BWDB is very low and it is not expected that this will easily change.

The participation of the WID staff in CPP's On Farm Testing and Demonstration Program (OFTD) has facilitated women's access to new productive technologies. Two hundred and eighty three female farmers (against 579 male farmers) have cultivated new types of crops.

Effects on Women's Position

Various methodologies have been followed to assess to what extent CPP interventions have affected the position of different categories of women, compared to men. During the interviews, surveys, and focus group discussions, women mentioned the change in cropping patterns as an important benefit of CPP, and in particular, a change from two to three crops and an increase in HYV T-Aman cultivation.

These changes have not affected all categories of people in the same way. The major distinctions in ways women and men are affected appeared to be related to social stratification, occupation and land ownership. Different effects can be observed, depending if the person belongs to the class of poor landless people, small and marginal farmers, large and medium farmers or fishery community.

Large farmers (>5ha) have benefited most from the changes and improvements. Their high level of access to resources (land, credit, inputs, labor, sharecropping) has enabled them to adjust their cropping patterns to the changing environment and to improve the productivity of their land. The women of these farm households primarily mentioned the positive effects of the increased income of the household. Medium and small scale farm households, who make up the largest category of farmers, have benefited from compartmentalization to the extent that they had access to the resources that enabled them to invest in HYV and changing cropping patterns.

Marginal farmers' households seem to have benefited less than the other categories of farmers, because they hardly have access to the resources that would have been necessary to benefit from the improvement in agricultural production, made possible through compartmentalization. However, because of a higher agricultural production, the demand for agricultural labor, either as hired workers or as sharecroppers, has increased. During the interviews with the women, they gave various examples of their

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increased access to land for sharecropping, and to employment opportunities as seasonal agricultural laborer. These new employment opportunities tend to be less accessible for landless women, because they often do not have the required skills to do this work.

The experience has shown that in the framework of compartmentalization a number of economic activities can be developed that increase women's access to new technologies, productive resources and income, as well as their wish to be informed, trained and involved. However, these changes are marginal. Bangladesh remains a society in which women have a long way to go before they become anywhere close to achieving equality with men.



Environmental Impacts and Mitigation

Virtually the whole area of CPP was under either settlement or intensive agriculture prior to the project. CPP led to a further intensification of the agriculture. In these circumstances, the environmental impact was never likely to be huge. Notwithstanding this, CPP has always taken environmental considerations seriously and has conscientiously monitored for adverse impact.¹⁹

The CPP environmental activities are based on findings of the Environmental Impact Assessment Case Study (FAP 16/19, 1992) and the Environmental Management Plan (EMP, 1994).

The Environmental Management Plan

A number of proposals for environmentally friendly planning were made in the EMP. Some were implemented; for example, the number of peripheral gates was increased to allow more floodwater to enter the floodplains (compared to the pre-CPP situation). Culverts and gated structures were constructed in existing road embankments to improve flow conditions between *chawks*, and drainage conditions improved on most CPP areas.

Mitigation Planning

An integrated pest management (IPM) initiative was started in 1994 in close cooperation with the DAE at Tangail and with technical advice by FAO. The program aimed to mitigate possible increases caused by the indiscriminate use of pesticides with the promotion of *boro* rice and other HYV. Training courses in IPM was carried out jointly by the agricultural and the environmental sections of CPP.

Compensation Planning

Compensation for wetland losses was not a matter of concern in CPP planning because the majority of local people requested improved drainage conditions for the conversion of seasonal or permanent wetlands into arable land. There was no mandate for CPP to promote wetland conservation, and the lack of legal instruments as well as the lack of regional land use planning made it impossible to address the issue within the framework of CPP. Land acquisition and compensation especially for water management infrastructure including new or re-alignment of embankments were addressed in depth in separate CPP studies. The procedure to land acquisition and compensation is in the responsibility of local administration in cooperation with the executing agency, BWDB. In all, CPP acquired some 153 ha of land for which compensation was paid.

Resources Management Planning

The EMP proposed a homestead forestry and embankment plantation program with the involvement of the Forestry Department, local nurseries and NGO's. The embankment plantation program, although promoted by another FAP project, was only partly implemented in 1994 and 1995 and stopped after one year, due to institutional constraints and technical disputes within the CPP. Plantations programs within homesteads were implemented in two pilot areas in combination with the Biodiversity Monitoring Program. CPP also initiated and provided technical and financial support to rehabilitate the main drain in Tangail Town.

Environmental Monitoring

Surveys of CPP focused on:

- Monitoring the effects of flood management on flood pattern
- Monitoring of water pollution in groundwater, ponds, *khals* and some *beels*
- Monitoring of groundwater levels
- Monitoring deposition of river flood sediments in the monsoon season
- Monitoring soil fertility changes under intensified crop production
- Biodiversity monitoring in ecologically sensitive habitats: i.e. *beels* and homesteads
- Monitoring of agro-chemical use and safety standards

The change of flood pattern, flood depth and duration is the primary impact of CPP that cause further direct and indirect effects on important environmental components. Field experience and CPP hydraulic and hydrological models showed the following effects:

- **Impact on flood level and pattern.** The concept of partial flood control is technically feasible but CPP cannot augment river inflow into the floodplain beyond the flood level that occurs in the major rivers. Floodwater scarcity is, therefore, a matter of concern for rural livelihood as well as high, prolonged or untimely floods.
- The extension of seasonal and perennial **wetlands** (*beels*) is highly variable, depending on flood conditions and human interventions (CPP or non-CPP). There is evidence that dry season water levels in many *beels* are continuously dropping. In large part, this is due to pumped irrigation during the *boro* season,

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which is unrelated to any activities of CPP. If this trend continues, the remaining permanent *beels* and their margins will become too small in size and too shallow in water depth to support healthy habitats for aquatic fauna and flora, especially to survive years with low flood conditions. Their value for biodiversity conservation will be lost and benefits to local people from the free use of wetland resources will diminish.

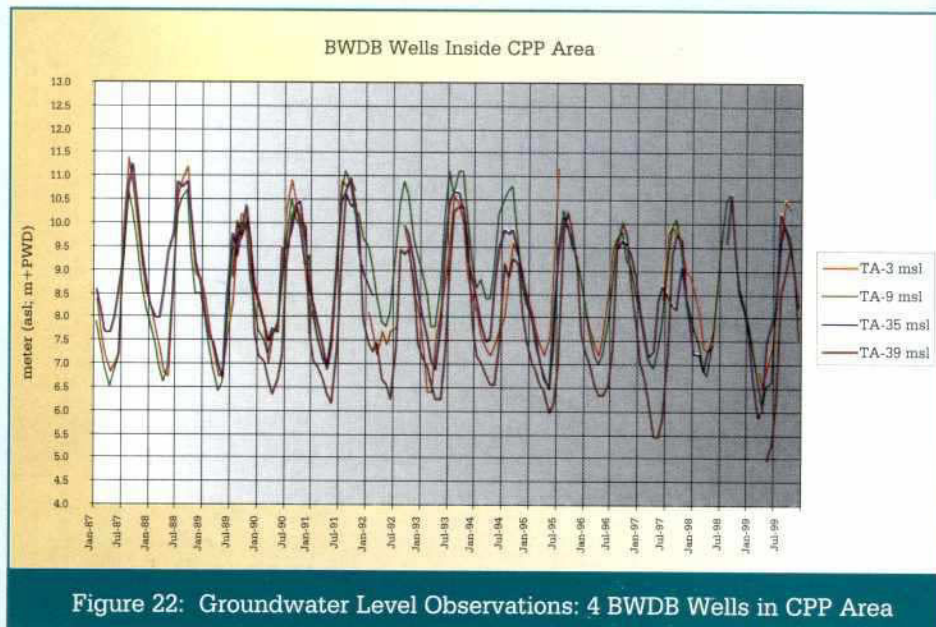
- **Drainage congestion.** A CPP survey in 1993 determined 4,276 ha with some degree of drainage congestion, i.e. 43% of NCA. Estimates in 1999 suggest that some 500 to 1,500 ha are affected by drainage congestion, depending on the flood levels, actual rainfall, gate operations and proper maintenance of *khals*. The final impact of CPP will likely reduce the areas with continued drainage congestion in the post-monsoon period to some 800 ha, assuming average flood and rainfall conditions.

Groundwater

Fluctuations in groundwater show a pronounced seasonality (See Figure 22). Lows are recorded in March-April with the groundwater table rising to peak levels in September-October at the end of the flood. The average increase is in the range of 4 to 5 m. The rise in groundwater table during this period suggests that there is a rapid infiltration into the upper aquifers during the monsoon season, and heavy exploitation by irrigation during the dry winter season. There is no evidence that CPP has had any adverse impact upon this infiltration rate. It appears that groundwater recharge during the monsoon season can replenish the upper aquifer, although recent data also indicate that dry season groundwater abstraction is reaching, in some wells, the lowest ever observed levels. There are adverse effects on groundwater availability from STD and hand pumps for rural domestic water supply. If the trend continues, many shallow wells could run dry in the dry season.

Water Pollution and Controlled Flooding

The EMP monitored water quality at selected environments: (See Figure 23) including rivers, *khals*, ponds, wetlands, drinking and irrigation wells. The data suggests that there are no substantial changes within CPP area over the period 1994 to 1999 that can clearly be attributed to CPP flood control interventions. Changes must be interpreted against the background of extreme seasonal changes in water quality and site-specific characteristics, depending on a complex balance of polluted inflow, rainfall and surface flooding. CPP has some positive impact by influencing the river water inflow, water flow between *chawks*, and drainage. In general, beneficial CPP impacts are associated with:



- A slight increase of river inflow that allows more freshwater entering floodplains
- Reducing very high flood levels with less housing areas and hand tubewells inundated
- Increasing flow between *chawks*.

The analytical results show that most water quality indicators within CPP deteriorate during hot summer but returns to normal in monsoon season. Hence, rainfall and floods are required to improve most water quality parameters. However, very high floods can have detrimental effects due to pollution of shallow tubewells, dispersion of toxic materials (e.g. from handloom factories), overflow of ponds and limited access to safe water resources. Generally, water quality is poor in both surface and groundwater, especially with regard to:

- Low oxygen concentrations, high COD and subsequent rise in dissolved NH_3 concentration in the dry season, associated with high temperatures, favorable pH , and presence of sufficient inorganic nutrients (e.g. phosphorus). This is conducive to the deterioration processes involved, which eventually leads to strong eutrophication. In the flood season, the situation returns to normal.
- Water quality is severely affected by microbial pollution (coliform bacteria) and high iron contents. Drinking water quality, in particular, worsens during the



Figure 23: Water Quality Monitoring Sites

wet season. Most drinking water is heavily contaminated with coliform bacteria and excessively high Fe contents beyond the permissible standards for potable water.

- Residues of commonly used pesticides (organophosphorous and carbamate) were not found, but traces of other organochlorine (Lindan, DDT) were above threshold levels in some places in dry season samples.

Agro-Chemical Use

The annual monitoring and special surveys carried out by CPP from 1995 to 1999 shows that farmers increasingly use both fertilizers and pesticides, although applications are usually below the normal level observed in Bangladesh.

Urea is the mostly used fertilizer followed by SSP, MP, Sulfur and Zinc. The order of magnitude of fertilizers being used is as follows: Urea > SSP > MP > GYP > TSP > Zn. Trends in fertilizer use in CPP area over the period 1993 to 2000 (projected) were calculated from Tangail Sadar Thana. There was a growth of about 29% in the overall fertilizer sales in CPP between 1993 and 1999. However, there are considerable differences between years. Maximum fertilizers are used for *boro* (HYV) crops. DAE statistics and interviewed farmers claim use of fertilizers close to recommended dosages; however, cross checks revealed that different dosage schedules are maintained and the application is variable. Advice from the agriculture extension workers is poor and in most of the cases, the farmers apply their sense and experience gathered. Crop responses to fertilizers per unit area are said to be generally good. Many farmers are complaining that demand for fertilizers per unit area is increasing during recent years. Very few farmers use organic fertilizers and green manure. The use of cattle dung is marginal.

The use of pesticides in the CPP area, as compared to other regions, is low because of the rather low level of endemic pest infestation in Tangail. Individual company sales in Tangail area show that Basudin (Organophosphate) is commonly used, followed by Furadan (Carbamate). Increasingly herbicides are also being applied. Sales data show an increase between 1992 and 1999 of 65% in herbicide sales. Most farmers had experience with occasional pest infestation and they applied pesticides as suggested by local dealers when required. None of the farmers had knowledge about pesticide formulations, usage, dosage schedule and personal health hazard. Some had knowledge about IPM and received their training with the assistance of CPP. Wholesalers at Tangail receive adequate information from the producers in the form of posters, leaflets and brochures etc. Nevertheless, their knowledge on

pesticide formulations is shallow and they are incapable of communicating the information to farmers. General storage conditions are below standards set in the FAO Code-of-Conduct. Safety standards, knowledge on formulations, and health hazard knowledge amongst retailers and farmers in the CPP area is almost zero.

Soil Fertility

Soils in CPP area have a low to moderate fertility status. Highland soils are sandy loamy and less fertile than loamy or clayey silty medium highland and lowland soils; these soils usually have higher contents in clay plus silt and hence more macro- and micro-nutrients, higher organic matter contents and N-total. All soils show distinct seasonal changes in soil reaction and the availability of macro- and micro-nutrients. Soils in active floodplains have generally lower contents in all nutrients than soils inside CPP area. These differences are likely to be more important than changes that can be attributed to CPP interventions and changes in land use pattern.

CPP conducted soil tests on several agricultural sites in 1996, 1998 and 1999 to monitor selected parameters important for crop growth. (See Figure 24). The results can be used to establish baseline conditions for future soil fertility monitoring activities in relation to water management projects. Considering the short observation period in CPP, there can be no substantial changes expected, if the natural flood cycle is maintained under controlled flooding.

Flood Sedimentation and Soil Fertility.

The preliminary findings of two flood seasons provide information that floods have some positive impacts on the dynamics of soil development and the availability of nutrients. For example, soil reaction can increase after floods, organic matter can slightly increase in topsoil and some nutrients can become more easily available to plants. Some dissolved salts and sediments are added to the soils that have a marginal positive impact: Ca-, P-salts, and silty-clayey deposits. Organic matter depositions, however, are low in comparison to topsoil contents of arable soils. Generally, the fertility effects of new sediments deposited during the flood season are marginal (<1mm) in short-term agricultural perspectives. The impact of inundation during the monsoon season, however, is likely to be of importance for soil development and soil fertility, especially under continuous cropping. If seasonal flooding from river water is permitted at the levels of CPP operations in 1998 and 1999 then CPP can be said to have only marginal impacts on soil fertility,

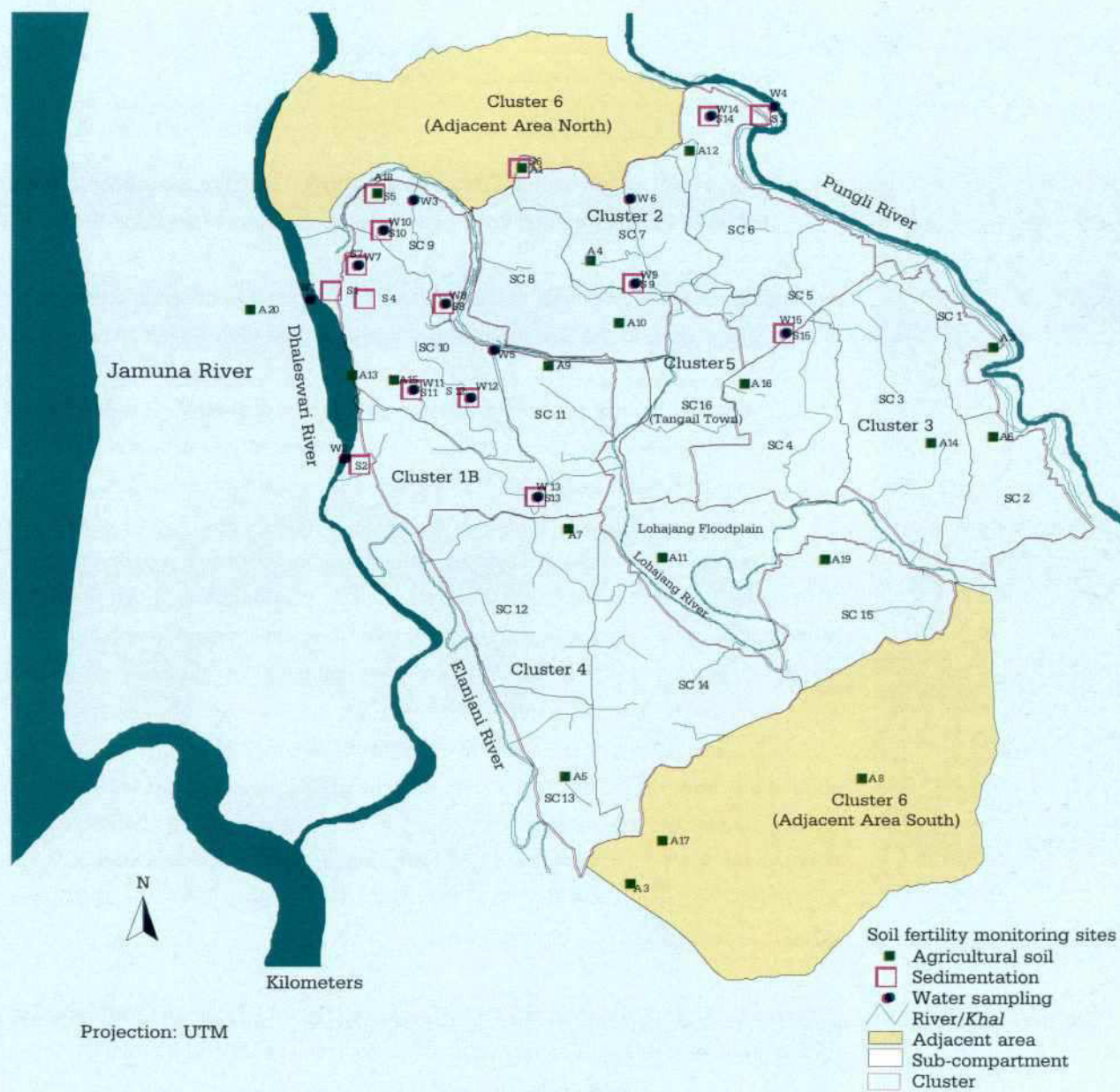


Figure 24: Soil Fertility Monitoring Sites

Impacts on Eco-Biological Resources

These were assessed in a Wetland Survey (1994) and detailed botanical surveys (1998-99) in two *beel* areas and their adjacent homestead habitats. The overall finding was that all *beels* and homesteads in CPP are heavily exploited by human interference with many natural fauna and flora resources under threat:

- *Beel* margins are converted into arable land
- Intensive fishing throughout the year affects fish diversity and production, and
- Construction of road embankments and water management interventions (before-CPP) affect natural flood pattern and migration of fauna and flora.

Although the local people know about the value and importance of wetland resources, no attempts existed in the past to prevent wetland degradation. The common access resources are mostly used by poor people, whereas the wealthier people, e.g. medium or large farmers, landowners and businessmen, who control most of the activities surrounding the wetlands, do not bother about it. Wetland products are also often under-valued or are not traded, leaving a gap in their valuation.

The biological surveys of aquatic and terrestrial fauna and flora showed that there are 177 species including terrestrial angiosperms, pteridophyte, phytoplankton, zooplankton and aquatic macrophytes identified in typical wetlands and surroundings homesteads. Of these, 14 species were found as abundant, 99 species as common and 69 species as rare; 11 species were found medicinally important. The wetlands and homesteads meet the livelihood demand of many villagers as vegetables, fruit, timber, food, medicine, starchy grains, rhizomes, fruits of different aquatic plants, petioles of water lily, young shoots of aquatic herbs. About 40% of families use medicinal plants from homesteads and *beels*. Water hyacinth meets a significant portion of cattle feed. First approximations of a quantification of wetland values are presented in the Environmental Annex I.

Several indicator species typically for wetlands and terrestrial habitats were selected for long-term monitoring. A comparison of biomonitoring in 1999 with previous survey showed that some species are seen in diminished numbers, e.g. *Trapa maximowiczii* and *Hizol* trees. Most other species of amphibian, reptile, birds and mammals that had been previously recorded can also be found in 1999. There is no evidence that any important species have become extinct over the last ten years.

Environmental Education and Dialogue Program

Environmental education, training and awareness concepts were tested in several meetings with villagers. Despite some traditional knowledge, there are only few villagers fully aware of the intrinsic value of nature and natural resources, ethics of conservation and the ecological importance of important elements, such as frogs or earthworms. Knowledge about health and hygiene is sufficient, but basic principles are rarely observed in daily life.

CPP conducted environmental awareness campaigns and provided training for teachers. Discussions focused on habitat and distribution of plant species in homesteads. The basic elements of flora and fauna and their functioning in terrestrial and wetland ecosystems were explained by display of posters, photos and a video show.

With regard to policy compliance, CPP is following many of the goals set in the draft National Water Management Plan and outlined in the National Environmental Action Plan. However, many issues important for sustainable natural resources management in Tangail floodplain are far beyond the scope of CPP interventions, e.g. waste and wastewater management, water pollution control, social forestry, equal access to resources. Efforts for integrated management plans and inter-institutional cooperation are required, as well as establishment of capacity at local and district level.

An overall assessment of CPP interventions is shown in Table 27. It was not possible to compare all of the results of EIA Study 1992 with the impacts that had been monitored, because the GIS databases differ too much to allow meaningful comparisons, e.g. predictions in land use changes. Some of the changes predicted in 1992 were found valid. However, many others were not, probably due to the rather short observation time.

Environmental Component	Base Situation (EIA or CPP)	Prediction EIA 1992 w/o Project	CPP Monitoring 1999	Impact of CPP	Impact Magnitude	Impact Rating**
River flood inflow	NQ	No change	Slight Increase	NQ	Low	+ 0.5
River bank erosion	Threat	Continued	Town is safe	Controlled	High	+ 3.5
Land types, ha						
F ₀ 0-0.3m flood	3,209	No change	5,178	+1,969	High	+ 2.5
F ₁ 0.3-0.9m flood	3,819	"	3,232	- 587	Medium	+ 1.0
F ₂ 0.9-1.8m flood	2,617	"	1,327	- 1,290	High	+ 2.5
F ₃ >1.8m flood	313	"	220	- 293	Minor	+ 0.5
Drainage congestion, ha	1,549 (EIA)	Increase	850	- 700	Medium	-
	4,276 (CPP)	"	850	- 3426	Medium	+ 2.5
Drainage Tangail Town, ha	228 (CPP)	No change	<10	- 220	High	+ 3.5
Homestead damage,	20%	No change	<5%	- 15%	Medium	+ 2.5
Housing (rural areas), ha	1751	1926	Slight Increase	<10% #	Minor	+ / -
Irrigated area (% of NCA)	43 %	Increase	83% #	Increase #	Low #	+ / -
Groundwater levels	Adequate	Decrease	Slight Increase	Slight Increase	Low #	- 0.5 #
Terrestrial Habitat, ha						
Pre-monsoon	12,975	No change	No change	No change	-	+ / -
Monsoon (F ₀ land)	4,139 (EIA)	No change	5,178	+ 1,157	Medium	+ 1.5
Post-monsoon	6,005 (EIA)	No change	Increase	Increase	Medium	+ 1.5
Aquatic Habitat, ha						
Pre-monsoon (F ₂ -F ₄)	330 (EIA)	No change	220	- 110	Medium	- 2.5
Monsoon (F ₁ -F ₄)	6,749 (CPP)	No change	4,779	- 1,970	Medium	- 1.5
Post-monsoon (F ₁ -F ₄)	7,300 (EIA)	No change	< 1,500	- 3,156	High	- 1.5
Crop Production						
T. Aman HYV, ha	222 (CPP)	Increase	2,462	x 10 #	High #	+ 2.5
Mustard, ha	1,267 (CPP)	Increase	1,618	+ 27 % #	Medium #	+ 1.5
Monsoon Boro HYV, ha	3,557 (CPP)	Increase	7,010	x 2 #	Medium #	+ 1.5
Total paddy, ha	8,225	Increase	13,828	+ 5,603 #	Medium #	+ 1.5
Other main crops, ha	7,542	Decrease	8,040	+ 498	Low	+ 0.5
Yields (all crops)	--	--	Boro increase	Increase #	Low #	+ 0.5
Cropping intensity %	181 (CPP)	214	215	+ 34 #	Medium #	+ 1.5
Pesticide Application						
Total sales, t/a	2,409	Increase	3,734	+ 55% #	Low #	- 0.5
IPM instructions	Very little	--	16 schools	IPM initiated	Medium	+ 0.5
Safety regulations compl.	Very poor	--	Very poor	Little change	Marginal	+ / -
Ecosystem contamination	Prevalent	Increase	Few evidences	Little change	Marginal	+ / -
(Continued)						

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Environmental Component	Base Situation (EIA or CPP)	Prediction EIA 1992 w/o Project	CPP Monitoring 1999	Impact of CPP	Impact Magnitude	Impact Rating**
Fertilizer use						
Urea, S + P, Gypsum, Zn	3,128 (CPP)	Increase	>4,000	+ 28 % #	Low	+ 0.5
Organic fertilizer, manure	Low	Decrease	Very low	Decrease	Marginal	+ / -
Ecosystem eutrophication	Prevalent	Increase	little evidence	little change	Marginal	+ / -
Soil fertility status ##						
General status	Adequate	?	Adequate	Little change	Marginal	+ / -
Sedimentation rates	--	--	1 mm/a	Little change	Marginal	+ / -
Dynamics of floodplain	Pre-CPP	No change	Maintained	Little change	Marginal	+ / -
Fisheries production ##						
Capture, t/a	380, (EIA)	251	--	--	--	--
(But: change in species!)	96-336, CPP	--	301 to 642	No clear trend	Marginal	+ / -
Fish ponds (>0.04 ha), no	450 (EIA)	Increase	3,100	+2,650 #	Medium #	+ 1.5
Pond production (kg/ha)	910 (EIA)	1,625	--	--	--	--
	800 (CPP)	--	2,000	+ 175 % #	Medium #	+ 1.5
Fish species diversity	--	--	Decline	NQ	Medium #	- 1.5
Wildlife ##						
Amphibians/ Reptiles	22 / 17	Decline	16	Common trend	Low #	- 0.5
Birds	56 / 30	Decline	33	Common trend	Low #	- 0.5
Mammals	11 / 6	Decline	8	Common trend	Low #	- 0.5
Homestead plants	81 / -	Decline	90	Common trend	Low #	- 0.5
Endanger. /threat. species	17 / -	2 extinct	Increase. pressure	Common trend	Low #	- 0.5
Wetland resources	Traditional: open access	Decreasing access	Decreasing access	Acceleration of Common trend	Medium #	- 1.5
Wetland exploitation	High	Increase	Increased	Common trend	Low #	- 0.5
Wetland conversion	Prevalent	Increase	Increased	Common trend	Medium #	- 1.5
Tree logging/plantations	--	--	planting > logging	Campaigns	Low	+ 0.5
Fuelwood availability	Shortage	Increased sh.	Increased sh.	Common trend	Low	- 0.5
Water pollution ##						
Surface water	Contaminated	Deteriorates	No change	Common trend	Low	+ / -
Groundwater	Contaminated	Deteriorates	No change	Common trend	Low	+ / -
Constituents	High Fe	Deteriorates	No change	Common trend	Low	+ / -
Water related diseases	NQ	Increase	Decline	Common trend	Low #	+ 0.5
Road network, km	262	Increase	Improved	By DLGH	--	--
Navigation	2 Waterways	Decrease	Decline	Common trend	Medium	- 1.5
Flood free settlements	Prevalent	No change	<10% flooded	Increase	High	+ 2.5
Tangail Town flood hazard	High risk	No change	< 5% flooded	Decrease	High	+ 2.5

Table 27: Environmental Impact Matrix of Tangail CPP 1999

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Note: many Figures are indicative only and mostly they reflect trends rather than absolute numbers
S = Sustainable; R = Reversible; IR = Irreversible; Op = impact depends on maintenance and operation;
M = Mitigation measures are effective. NQ = not quantified; Common trend: similar changes occur
elsewhere in Bangladesh

Significant changes were also observed outside of CPP area; the direct impact of CPP is not quantifiable
Some impacts can only be tentatively assessed under present state/data available: long-term changes
may happen

1 = Fauna and flora surveys in 1992 / 1994

Impact rating follows the EIA Study 1992 methodology: ** Highest beneficial impact = + 5.0; Highest
adverse impact = - 5.0

Sources: EIA Study 1992; CPP GIS Atlas 1996; CPP GIS Atlas 1999; CPP Tangail Field surveys 1993-94

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**Evaluation
of the
Project**

Project Monitoring

The objectives of the monitoring and evaluation (M&E) in CPP was:

- To assess whether the project achieved its objectives.
- To show whether activities were implemented in accordance with planned targets.
- To assist project management to recognize and identify implementation problems so that remedial actions could be taken.²⁰
- To show whether compartmentalization is sustainable, replicable and viable.

Selection of Indicators

The choice of an analytical model to define an effective set of performance indicators was a critical one. During the First Phase of the project, an attempt to reach agreement on a set of M&E indicators was not fully successful. The selection of indicators was not well structured and amounted to be the sum of on-going monitoring activities already executed by the various CPP sections. In the Final Phase, CPP opted for a better-structured approach that provided clear insight in the relationships between activities and achievements. The structure chosen was a logical framework, which provided an integrated reflection on project objectives and activities.

CPP's logical framework lists each objective of the project, the activities executed, and the means of verification and source of verification. These means of verification were taken as the starting point for the selection of performance indicators.

The prevailing physical, climatic, and to a large degree the socio-economic environment within which the project operated, defined, largely what was possible for the project. These formed the boundary conditions for the project. They included hydrology (type, discharge), topography (slopes, natural drainage system), soil quality (potential cropping intensities and yields), population densities, distribution and number of urban agglomerations, water borne activities (transport), and limiting factors such as protected areas and wetlands.

In total, some forty-five indicators were selected for monitoring by CPP. The selected performance indicators were grouped so to reflect their importance, their difference, and to some degree their source. The following grouping was used throughout the Final Phase of CPP:

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- Project costs indicators, covering first the contributions made by the GoB and the two donors to CPP, and secondly the costs for construction works, operation and maintenance, mitigation measures, minor works, etc.
- Water management indicators to monitor the technical and institutional performance of water management. The Water Management and Institutional Development sections monitored these indicators.
- Boundary indicators: population, market prices and flood damage. The M&E Section itself collected most of this information.
- Agricultural indicators addressing the areas under cultivation, yields crop economics, irrigation, etc. The source for these indicators was the Agricultural Section.
- Fishery indicators, such as catch assessments of open water fishery, aquaculture monitoring and promotion of catfish. The Fishery Section provides all data.
- Environmental indicators: soil fertility monitoring, bio-diversity monitoring, use of Agro-chemicals, groundwater levels, water quality analysis, public health, etc. The Environmental Section of CPP provided the majority of the indicators.
- Socio-economic indicators, covering the pre-project situation, the participation of women in decision making, the possible spin-off to the economy and employment generation. The M&E Section took care of the monitoring of these indicators.

Intervention logic	Objectively verifiable indicators	Sources of verification	Assumptions, conditions and risks
Overall Objective: To enhance economic production, improve environmental security and reduce poverty in the floodplains of Bangladesh. Specific Purpose: Provide viable, sustainable and replicable approaches to compartmentalization. Give integrated water management options for different sections of the population. Develop policies and guidelines for integrated water resources management.	Indicators: National indicators, like per capita GDP, cultivated area, literacy rate, flood damage, etc. Indicators: Economic viability assessment, Model results, water management scenarios, Institutional parameters and operational guidelines.	Sources: National statistics (BBS), publications Planning Commission. Sources: Reports of evaluation missions, as well as modeling output, economic analysis, environmental assessment.	Agreement between the GoB and the donors to fulfill their pledges Letter of intention between the GoB and the GoN and KfW to implement CPP
CPP Output: Test the practicability of compartmentalization, Establish water management systems, Prevent environmental degradation, Enhance the environment, Develop guidelines, Improve drainage of Tangail Town, Enhance economic production, and Reduce poverty.	Indicators: Modeling results (output), water management scenarios, Constructions and operational guidelines, Water quality and bio-diversity monitoring, Publications, Drainage infrastructure, flood damage, IRR, NPV, B/C, Employment generation, income generation and distribution.	Sources: M&E publications and analysis covering: Project costs, water management, agricultural production, fishery, environment, flood damage, social economy, etc. Multi-criteria analysis.	Acceptance by the GoB and the donors of the TAPP. Acceptance of CPP by the local population.

Continued



Project Activities	Direct effects	Costs	Assumptions, conditions and risks
Construction activities: Termination of construction works and maintenance of infrastructures. Drainage of Tangail Town	Regulation of drainage and irrigation through the operation of regulators and sluices.	Expert personnel Project Management and Quality Control: \$ 798,000	Assumptions: structure designs are acceptable. Risks: bad quality of construction works, problems with land acquisition.
Water management: Operational model for controlled flooding and improved drainage based on mathematical simulations by the SWMC. Creation of an institutional base through people's participation in water management, and testing in 4 pilot <i>Chawks</i>	A set of operational rules and guidelines that are a tested and accepted for use as water management tool in the compartment.	Expert personnel Water Management: \$ 310,000	Assumptions: water management has a positive impact on crop damage reduction, with large people's involvement there is a better understanding of why gates are opened or closed. Risks: no institutional structure to execute water management. Conditions: operational rules and guidelines can be tested through the SWMC mathematical model.
Boundary conditions: GIS system to present the physical and boundary conditions in the compartment.	GIS atlas, website	Expert personnel: \$ 125,000	
Agricultural production: Survey program: land use survey and irrigation survey (DTW, STW, and surface water irrigation, done every 2 years). Monitoring program Farming Systems, and a sample of plots for input (250) use and yields (30). OFTD: Crop demonstration plots (paddy and vegetables).		Expert personnel Agricultural Section: \$ 91,000	Assumptions: better water management is sought by farmers, need for crop diversification and intensification exists Risks: compartmentalization may not have a positive impact on farm income Conditions: survey program gives representative results, demonstration program is representative
Continued			

Project Activities	Direct effects	Costs	Assumptions, conditions and risks
Fishery and aquaculture: Monitoring catches assessment and frame survey in various habitats, like floodplain, <i>Beels</i>, open water and <i>Khals</i>. Aquaculture: training, extension and monitoring.	"<i>Char</i>" in the <i>Bar</i>" program, as a means of poverty alleviation.	Expert personnel Fishery Section: \$ 58,000	Assumption: need for income generation. Risk: fishery activities (catches) might be affected negatively by CPP constructions. Condition: Fishery Section in CPP undertakes monitoring, as Department of Fishery is not doing this monitoring.
Environmental monitoring: Soil fertility monitoring program. Bio-diversity monitoring and social forestry program. Agro-chemicals monitoring program. Ground water levels monitoring. Monitoring of water quality. Environmental awareness raising.	Plantation of tress in villages.	Expert personnel Environmental Section: \$ 76,000	Assumption: CPP's water management would impact on crop intensity and use of agro-chemicals. Risk: water management leads to a reduction in sedimentation and soil fertility, leads to a reduction in bio-diversity. Condition: CPP has possibilities to improve environmental awareness.
Socioeconomic: Empowerment of women through participation in water management, gender training and awareness raising. Employment generation through LCS and EMG.	Employment generation through LCS and EMG work contracting, estimated over the period 1992 - 2000 at \$ 255,000	Expert personnel WID Sections, Economy and M&E: \$ 173,000	Assumption: need for income generation, determination among women to get a greater say in water management. Risk: effects of employment generation are negative (program not cost effective). Condition: financial support, involvement, active participation and technical supervision by CPP are needed.
Support activities: M&E Information Dissemination Center	M&E System. IDS Center operational.	Expert personnel M&E Section: \$ 330,000	
CPP's Logical Framework			

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M&E Output

The M&E output formed an important source for evaluation for each part of the project with tables generated by the section appearing throughout this main report and its annexes.

Cost and Benefits

The methodology adopted to assess the economic impact of CPP follows the Flood Planning and Coordination Organization (FPCO) Guidelines for Project Assessment (GPA), updated in March 1998. Where recent changes have been made by the National Water Management Plan (NWMP) to input and output prices and conversion factors, those have been adopted here.²¹

The analysis period is 30 years with 1999 as the base year. All benefits and costs have been valued in constant 1999 prices. The rates applied to update historic costs and benefits to constant 1999 prices as well as exchange rates used to convert foreign exchange into Taka (TK.) are those shown in the Table 28 below.

The opportunity cost of capital (discount rate) used is 12%.

	1993	1994	1995	1996	1997	1998	1999	2000
Exchange rate 1)								
- DM	23.73	24.57	28.12	27.77	27.93	25.61	27.20	24.83
- DFL	21.28	21.94	25.11	24.81	24.84	22.72	25.94	23.68
- US\$	39.10	40.00	40.20	40.80	42.70	45.30	48.50	50.00
GDP Deflator 2)	1.69	1.76	1.92	2.03	2.06	2.15	2.32	2.50
Inflation Factor 3)	1.37	1.32	1.21	1.14	1.13	1.08	1.00	1.00
Table 28: Exchange Rates and Inflation Factors								

The cost of infrastructure in place prior to project start-up, such as the much of the embankment, have been regarded as sunk costs and has not been taken into account. Neither have residual values for assets been considered. All farm-gate input and output prices used in the calculations are those proposed by the NWMP. As they refer to constant 1997/98 prices, the inflation factor of 1998 has been applied to convert them to 1999 prices. They are all present, as opposed to projected, prices.

To transform financial into economic costs, conversion factors provided by NWMP have been applied (see Annex K). However, to reflect present conditions in the project area, in particular with regard to returns to crop production, the actual farm gate prices for rice has been applied. The corresponding conversion factor has, therefore, been set at 0.8 as opposed to the NWMP factor of one, in order not to distort the economic evaluation.

Taxes have been excluded from the analysis as well as secondary benefits and costs in monetary terms. The latter, however, have been discussed in qualitative terms where noticeable impact is to be expected. The economic viability of the concept has been judged based on three investment decision criteria.

- Economic Internal Rate of Return (EIRR)
- Net Present Value (NPV)
- Net Benefit / Investment Ratio (N/K ratio),

This, in combination, represents an appropriate basis for judgement in comparing CPP to other projects.

Project Costs

Total project costs, covering the period from the start-up of the project in August 1992 to the end in June 2000 amount to 1,284.62 million Taka (26.47 million US\$) in 1999 constant terms. A more detailed break down of total project costs has been provided in the Tables in the Appendix of Annex K. Table 29 below shows overall costs, both in Taka and US\$ in current and constant 1999 financial prices and indicates the source of funding.

Source of Finance	Current Prices		Constant 1999 Prices	
	Mill Tk	Mill US\$	Mill Tk	Mill US\$
Financial Assistance	432.26	10.24	498.52	10.28
Technical Assistance	453.89	10.68	536.71	11.07
GoB Contribution	214.73	5.13	249.39	5.14
Total Costs	1,100.88	26.05	1,284.62	26.47
Table 29: Project Implementation Costs				

Investment Costs

Investment costs, which include all of the FA cost above, together with a small part of the TA, plus some of the GoB contribution, are shown in Table 30.

The costs shown above are financial cost. The corresponding costs in economic prices would amount to 588.08 mil. Taka, equivalent to 12.13 mil. US\$. This approximates to 86 per cent of the financial costs.²²

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Investment Costs	1993	1994	1995	1996	1997	1998	1999	2000	Total
Base Costs	0.309	0.582	3.304	1.727	0.679	0.347	0.674	0.588	9.212
Land Acquisition	0.108	0.245	0.348	1.363	1.104	0	0.002	0.005	3.175
Mitigation Measures	0	0	0.044	0.059	0.879	0.164	0.084	0.074	1.303
Supplem. Costs	0.090	0.130	0.181	0.171	0.102	0.053	0.025	0.001	0.753
Office Equipment	0.227	0.037	0.024	0.014	0.020	0.011	0.083	0.020	0.435
Contingencies	0.056	0	0.007	0	0.017	0.027	0.071	0.078	0.256
Total	0.791	0.994	3.908	3.334	2.800	0.602	0.938	0.766	14.133
Realization (%)	5.6	7.0	27.6	23.6	19.8	4.3	6.6	5.4	100
Cumulative		12.6	40.3	63.9	83.7	87.9	94.6	100	

Table 30: Total Investment Costs (mill US\$, 1999 Constant, Financial Prices)

Base costs refer to all costs incurred to build the main water control structures essential for water management and control purposes.

Land acquisition as compensation for 152.5 ha of land, required to facilitate the construction of all water control structures of about 636,645 Tk./ha (13,127 US current \$/ha paid appears to be extremely high.²³

Mitigation costs to eliminate or minimize detrimental impacts such as interruption of communication lines (water and road transport) inside and outside the project area caused by project activities, include roads, bridges, excavation of *khals* and protective works, and, as the major component, the Tangail town drain. Total mitigation costs in constant 1999 terms amount to 63.2 mil. Tk. equal to 1.3 mil. US\$.

Supplementary costs, comprising surveys, purchase of vehicles, quality control and training of in total 37.06 mil. Tk. or 0.76 mil. US\$ in constant 1999, prices have been included in the analysis. Office equipment, totaling 21.09 mil. Tk. (0.43 mil. US\$) while additional 12.42 mil. Tk. (0.26 mil. US\$) for contingencies, all in constant 1999 prices, completed investment costs. A breakdown of investment expenditures per year has been presented in Annex K.

Almost two third (62.3 %) of all construction works had been completed by 1996. It was in this year that water management started, as with the completion of the main regulator the same year, the inflow of water into the compartment could be regulated.

Operation and Maintenance Costs

Operation and maintenance is divided into personnel; administration and training; and maintenance.

Total **personnel costs** up to June 2000 amounted to (399.72 TA + 84.07 GoB) 483.79 mil. Taka or 9.98 mil. US\$ in constant 1999 financial terms. For personnel costs after the implementation period, 50% of the last cost spent by the Government, which were 3.87 mil. Taka (80,000 US\$) in the year 2000 is considered.

Administration costs, totaling 43.4 million Taka (0.9 mil. US\$) in 1999 constant terms, are those costs actually incurred during the lifetime of the project. Here, too it is assumed that 50% of the costs spent by the FPCO on CPP during the year 2000 equal to 1.87 million Taka (almost 40,000 US\$) per year, will suffice to assure future operational standards.

Training costs came to 60.07 mil. Taka (1.24 mil. US\$) in constant 1999 financial prices. No training costs attributable to CPP are foreseen in coming years.

Total annual minimum **maintenance costs**, over and above the costs above, are in the range of 10 mil. TK. per year (20,500 US\$) in financial terms. Above maintenance costs represent about 2.5% of the initial investment costs for structures (excluding land acquisition and mitigation costs).

Benefits

Developments in comparable adjacent areas have been compared with developments inside the compartment in order to identify trends solely attributable to improved water management and flood protection. The major fields for potential direct benefits are:

- Agriculture
- Fisheries
- Flood damage prevention.

Agriculture

Given the prevailing climatic conditions in the project area, the positive effects to be expected by improved water-management will come from more favorable conditions for agricultural production in the monsoon season.

Some benefits occur by the ability of the water management structures to delay early floods in the *Kharif-I* season, and by lowering water levels in the *Kharif-II* season, combined with faster drainage of water of late floods in the beginning of the *Rabi* season. This increases the cultivable area in two ways. First, by an increased planting on the edge of *beels*, and secondly, an increase in cultivation on land previously left fallow due to flood depth. In addition, there is an intensification of agricultural production by permitting a switch from broadcast *Aman* to transplanted *Aman* in the monsoon season. Thus, substantial benefit with regard to agricultural production attributable to improved water management by compartmentalization will occur primarily during the monsoon season. With additional benefits also accruing as the faster drainage at the end of the flood season will allow an increased planting of mustard.

The evaluation of benefits in the agricultural sector has been based on the behavior of three indicators within the project as compared with those in the adjacent areas. Those indicators are the:

- Cropping intensity
- Cropped areas
- Yield²⁴

Over the implementation period, the cropping intensity in the project area has increased from 191% to 214 %. In the adjacent areas, over the same period, cropping intensity rose from 191 % to 199 %. Looking at the figures more closely reveals that major changes occurred during the *Rabi* season (*Boro* rice), even more clearly in the CPP area than outside. This observation is supported by the large increase in the number of shallow tubewells from 881 in 1997 to 1,441 in 1999.

The impact with regard to crop areas is shown in Table 31 below.

Crop	CPP Area (ha)			Adjacent Areas (ha)		
	1992	1999	Change (%)	1992	1999	Change (%)
T.Aman	1,070	3,912	265.6	513	700	36.5
- HYV	222	2,362	964.0	134	377	181.3
- Local	848	1,550	82.8	379	323	-14.8
DW Aman	3,717	2,543	-31.6	1,234	1,538	24.6
- Broadcast	1,464	0	-100	943	1,298	37.6
- Transplanted	2,254	2,543	12.8	291	240	-17.5
Aus	3,390	139	-95.9	1,178	215	-81.7
- HYV	726	0	-100	62	1	-98.4
- Local	2,664	139	-94.8	1,116	214	-80.8
Jute	1614	1,350	-16.4	733	422	-42.4
Sugarcane	691	547	-20.8	786	692	-12

Table 31: Development of Crop Area

What is notable from the table is the huge shift into Transplanted *Aman* within the project area.

Based on the data shown in the table above the net impact on crop areas attributable to improved water management by compartmentalization is shown in Table 32.

Crops	CPP ha 1992	Recorded Changes %		Net Changes %	
		CPP	Adj. Area	Total	p.a.
- <i>Boro</i>					
* HYV	3,390	110.2	43	67.5	7.6
* Local	431	-100.0	-34	-65.8	-14.2
- <i>T. Aman</i>					
* HYV	222	964.0	181	782.6	36.5
* Local	848	82.8	-15	97.6	10.2
- <i>DW. Aman</i>					
* Broadcast	1,464	-100.0	-38	-62.35	-13.0
* Transplanted	2,254	12.8	-18	30.37	3.9
Total Kharif 2 area	4,788				
- <i>Aus</i>					
* HYV	726	-100.0	-98	-99.99	-71.9
* Local 1)	2,664	-94.8	-81	-94.78	-34.4
- <i>Jute</i>	1,614	-16.4	-42	26.07	3.4
- <i>Sugarcane</i>	691	-20.8	-12	-8.88	-1.3
Total Kharif 1 area	5,695				
- <i>Potato</i>	138	-2.9	-7	4.21	0.6
- <i>Wheat</i>	1,963	-17.6	12	-29.61	-4.9
- <i>Mustard</i>	1,277	110.2	-14	124.64	12.3
- <i>Pulses 1)</i>	733	3.1	113	3.14	0.4
- <i>Vegetables</i>	135	-30.9	-48	151.94	14.1
- <i>Other crops</i>	68	104.4	0	-30.88	-5.1
	4,314				
Table 32: Net Impact on Land Use with Project					

Crop yields inside and outside the project area have been compared in order to determine yields "with project" compared to "without project" for the economic analysis.

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Crop	CPP Yields (Kg/ha)			Yields (Kg/ha) in Adjacent Areas		
	1992	1999	Change (%)	1992	1999	Change (%)
T. Aman						
- HYV	3,244	2,905	-10.5	3,244	2,860	-11.8
- Local	2,163	1,774	-18.0	2,163	1,779	-17.8
DW Aman						
- Broadcast	1,523			1,523	1,521	-0.1
- Transplanted	1,813	1,617	-10.8	1,813	1,703	-6.1
Aus						
- HYV	2,748			2,748	2,099	-23.6
- Local	1,450	1,032	-28.8	1,450	922	-36.4
Jute	1,727	1,564	-9.4	1,727	1,574	-8.9
Sugarcane	30,770	44,000	43.0	30,770	35,000	-13.7
Table 33: Development of Crop Yields						

Table 33 shows that yields for rice are, in the main, falling in both the project area and the adjacent area. Within the project area, the decrease in yield is more than compensated for by the increased area under cultivation and the increased intensity.

Yield increases shown in the economic analysis as presented below, therefore, come from the switchover of both; rice varieties (local to HYV) as well as rice types (Deep Water Aman to Transplanted Aman). The rates for value added used in the analysis are shown in Table 34 below. For details of prices retained in the computation of value added, for conversion factors used to transfer financial into economic prices, and for general assumptions as to variable costs included see the Appendix to Annex K.

Crop	"With" Project Taka/ha		"Without" Project Taka/ha	
	Economic	Financial	Economic	Financial
Kharif 1	18,244	18,510	16,035	17,677
(Aus rice, Jute, Sugarcane)				
Kharif 2	18,346	22,986	14,716	18,496
Aman rice				
Table 34: Average Value Added Retained in the Analysis				

Kharif-I crops have been included in the analysis. It is assumed that some additional benefits resulting from improved water management in the project area will come from damages prevented to Kharif crops that would otherwise have occurred in early

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floods. To determine the damage prevented to *Kharif-I* crops, it has been estimated that floods of a return period of 2, 5, 10 and 20 years will result in damages of 926; 2,777; 8,330 and 13,884 Taka per ha for each of the return periods.

Return Period Years	Gross Damage	Frequency	Weighted Damage	Yearly prevented Damage
	Million Tk.		Million Tk.	Million Tk.
1			0	0
2	912	0.50	228	228
5	2,737	0.30	547	775
10	8,210	0.10	547	1,323
20	13,683	0.05	547	1,870

Table 35: Annual Damage Prevented to *Kharif-I* Crops

Fisheries

Catch data in the project area since 1992 do not indicate any statistically relevant trend with regard to capture fish. The generally expected adverse impact on capture fisheries that has been assumed from the outset of the project simply does not exist. Annex F to this report gives more detail of this.

No disbenefits have been assumed for open water fisheries losses.

There have, however, been positive effects of the project on aquaculture. The reduced risk of flooding (and consequently losing cultured fish) has led to a rapid growth of aquaculture in the project area. The fisheries section of CPP has contributed greatly to this expansion and to increased yields of fish by providing an effective extension service for the project. Table 36 below shows the growth of aquaculture in terms of area and yield.

Category	Return Periods /Years)							
	2		5		10		20	
	Mill Tk.	Million US\$	Mill Tk.	Million US\$	Mill Tk.	Million US\$	Mill Tk.	Million US\$
Residential Areas	5.8	0.12	16.8	0.35	87.3	1.80	202.2	4.17
Business	0.3	0.01	3.1	0.06	14.7	0.30	34.2	0.71
Industries	0.9	0.02	2.9	0.06	8.3	0.17	19.6	0.40
Public Buildings	0.2	0.01	2.6	0.05	6.1	0.13	9.4	0.19
Roads	0.3	0.01	3.8	0.08	5.8	0.12	6.2	0.13
Total	7.5	0.15	29.2	0.62	122.2	2.52	271.6	5.60

Table 36: Potential Flood Damages per Category and Return Period (constant 1999 prices)

Table 19 in page 96 shows the value added by fish culture within the compartment. As can be seen, it represents a considerable project benefit.

Non-Agriculture Benefits

In order to establish the benefits with regard to non-agricultural flood damages avoided due to the compartmentalization concept, the unit loss appraisal model, already described, has been applied.

According to the model, the potential gross damage will occur in the different sectors included in the damage assessment. These will be:

- Residential areas
- Business
- Industry
- Roads
- Public sector.

It should be noted that the potential damage avoided represents the non-agriculture benefit to be included in the analysis, as it is this is damage that has been prevented by CPP.

In determining the gross damage, a division has been made between rural and urban areas, with the latter being Tangail Town. It has been shown that about 60 percent of all damages avoided can be achieved in Tangail town alone and that the residential areas benefit most from damage prevention (72 % of all damage avoided).

Following the probability analysis, annual damages prevented of 24.8 million Tk. (511,340 US\$) has been included in the economic analysis, taken from Table 37 below. The conversion factor for structures, of 0.84 has been applied to convert those benefits into economic prices.

Return Period	Frequency	Gross Damage	Weighted Damage	Yearly prevented Damage
Years		Million Tk.	Million Tk.	Million Tk.
1		0	0	0
2	0.50	7.5	1.9	1.9
5	0.30	29.2	5.5	7.4
10	0.10	122.2	7.6	15.0
20	0.05	271.6	9.8	24.8
Table 37: Annual Damage Prevented (Million Constant 1999 Tk)				

Evaluation

At their full level, total economic benefits are 86.89 million Tk. (1,780,423 US\$) per year. The cash flow, presented in the Appendix to Annex K, shows the first benefits of the projects in 1997 after the system became operational. Although the cash flow becomes positive from the year 2001 onwards, project benefits will not be able to offset the capital expenditure as indicated by the N/K Ratio of 0.80.

Although benefits exceed costs from the year 2000 onwards the internal economic rate of return of 3.1%, can hardly be judged attractive. Consequently, the NPV (at 12% discount rate) also remains negative.

Because CPP is a pilot project, some of the capital expenditures on water control structures, as well as personnel costs have been unnecessary, or at least unnecessarily high. Indeed, it is certain that some costs could have been avoided.

The mathematical model used in the early years of the project to simulate external flooding patterns and their hydrological consequences for the compartment was not sufficiently refined to allow precise simulations of internal water conditions. The consequence of this was, as already described in the engineering and construction section of this report, that some internal structures were constructed that, with hindsight, should not have been.

Reducing the number of structures and their costs in the light of the above gives an alternative costs of in total 206.54 million Tk. (4.26 million US\$). If CPP was repeated, this is the cost that would be necessary in order to obtain the present benefits.

Even given the pilot project status of CPP, it is difficult to justify charging the project with activities such as: women in development; agricultural extension and applied research; M&E; institutional development and an information dissemination center, which are normally linked to regional or rural development. While all of those activities are undoubtedly highly valuable in their own right, they could and should have, at least in parts, been executed and monitored by the existing specialized public agencies. Corresponding costs have consequently eliminated or reduced as follows, including GoB contributions.

Eliminated

Women in Development

Reduced

Agriculture	-50%
Institution	-50%
M&E	-50%

Overall, cuts in personnel costs that should more fairly be attributed to non-CPP activities, amount to a total reduction of 40%.

A fair compensation of landowners, is clearly justified but land acquisition charges of about 700.000 Tk./ha (13,127 US\$/ha), plus a service charge, is not justified. Alternatively, determined fair compensation rates based on payments of production forgone (rent) revealed Figures as low as 40% of above payments. It must be feared that farmers did not benefit in full from the compensation payments cited above. A land acquisition price of 50 % of the paid rates has therefore been assumed here.

Tangail drain may be useful and necessary. It is, however, doubtful if its inclusion as mitigation cost in a project such a CPP is justified. It has been omitted from further evaluation.

Expenses for surveys (supplementary costs) appear to be extremely high and not justified to that extent. They, too, have been reduced by 50%.

Summarizing the above changes results in the savings shown in Table 38 below. This would reflect the likely cost of a similar, but non-pilot, compartmentalization project.

	Base Case		Alternative Costs		Savings	
	Million Tk	Million US\$	Million Tk	Million US\$	Million Tk	Million US\$
Construction Costs	398.26	8.21	206.54	4.26	191.72	3.95
Personnel Costs	483.79	9.98	290.27	5.99	193.52	3.99
Land Acquisition	153.97	3.17	77.00	1.60	77.00	1.60
Tangail Drain	42.88	0.88	0	0	42.88	0.88
Surveys	18.43	0.38	9.22	0.19	9.22	0.19
Total Implementation Costs	1,284.62	26.48	770.28	15.88	514.34	10.60
Table 38: Alternative Project Cost (Financial 1999, Constant Prices)						

Total savings represent about 40% of original implementation costs. Re-evaluating the viability by accepting the alternative parameters gives a much better rate of return of 7.3%. However, if the discount rate is 12 percent this is still far from satisfactory.

The problem is that a project of this type is largely dependent upon agriculture for its benefits. Where, as in the Tangail area, we already have very intensive cropping, any incremental benefits are hard won and although real, are never going to be sufficient to measure up to a 12 percent discount rate.

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All of the decision criteria clearly indicate that, even under the substantially more favorable conditions with regard to the implementation costs, compartmentalization under Tangail conditions is not an economically viable water management intervention at a discount rate of 12 percent.

A sensitivity analysis adhering to common methodological standards will not permit a judgement differing substantially from the one provided above. Variations of prices or yields, changing implementation schedules or shorter development periods for benefits to reach final values will all have no significant impact, if justifiable ranges are tested. Output would have to increase by 150% before break-even conditions will be obtained (EIRR of 12%, NPV of 0). This is beyond the boundary of probability.

	Case	Change	EIRR
	Base case		3.1%
a	Construction Costs	- 40%	4.0%
b	a+ Personnel Costs	- 40%	5.7%
c	a+b+ Land acquisition	- 50%	6.8%
d	a+b+c+ Tangail drain out		7.3%
e	d + Benefits	+ 51%	12.0%
Table 39: EIRR			

Non-quantifiable Benefits

The careful quantification of benefits carried out above misses a major benefit of the project. The removal of the fear of flooding. The damage avoidance, and the benefits to agriculture and aquaculture can be quantified; but, in a country such as Bangladesh, where the fear of flood is something people live with every monsoon season, to have that fear removed is almost beyond price.

Indeed, in the developed world most countries would be willing to implement flood control for this social reason along, regardless of any measurable economic benefits. Where CPP has made a breakthrough is that, with flood protection alone, there would be heavy costs in agriculture and fisheries, which would suffer as a result of floodwater being kept out. With the controlled flooding in CPP, it is only the severe, unwanted flood that is kept out. The water that is beneficial to agriculture and fisheries, indeed is essential to both of them, is brought into the compartment and the water managed.

Replication

CPP has demonstrated that compartmentalization in a single compartment setting is technically viable with benefits to agriculture, aquaculture and the prevention of flood damage. However, the physical behavior of a single compartment in a flood plain is different from that to be expected in a multi-compartment setting.

Replicability of the Compartmentalization Project is dependent upon there being similar areas with adequate drainage, which is an essential component to successful flood management. It is expected that with the sort of proven technology developed in CPP, the replicability of the project with similar hydrological setting is possible. To test this, a modeling exercise was carried out for the Jamuna flood plain, in areas to the North and the South of the Tangail compartment.

General Requirements of Compartment

CPP has demonstrated that the following criteria should be fulfilled before implementation of the compartmentalization concepts:

- Some minimum necessary infrastructure should be in place.
- There must exist adequate drainage facility so that every unit can adequately be drained. This results in a demand for a minimum slope or elevation difference between inlets and outlets. The lower cost option will be for natural drainage to be utilized for the compartment. Therefore, adequate drainage will also require a system of rivers and *khals* in and around a compartmentalization unit. The drainage possibilities have to be independent of the next unit downstream.
- The problems associated with flooding in the area should be manageable with respect to technical operation and in particular to institutional organization.
- The area to be provided with flood control and drainage improvements should be predominantly F_1 & F_2 type land, which provides the most economically viable option.
- There should be a relatively small impact on navigation and fisheries.
- There should be minimum impact on the adjacent area.
- The ground slope should be away from the river.

Potential Areas for Replication

In the flood policy of Bangladesh, potential areas for compartmentalization have been indicated along the three major rivers, i.e. the Jamuna, the Meghna and the Ganges. The experience of CPP indicates that compartmentalization along the Meghna River

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is not suitable as the major area is low lying and without adequate drainage. Overall, drainage on the left bank of Jamuna is away from the main river through a number of distributary channels. The ground slope of the area is also away from the main river. This makes it a potentially suitable area for a multi-compartment setting.

With the assistance of SWMC, the North Central Region of Bangladesh was modeled in order to look at the impact of a multi-compartments situation. The main objective of the study was to investigate the impact of the embankments for compartmentalization on the flooding situation in the study area. The specific objectives are:

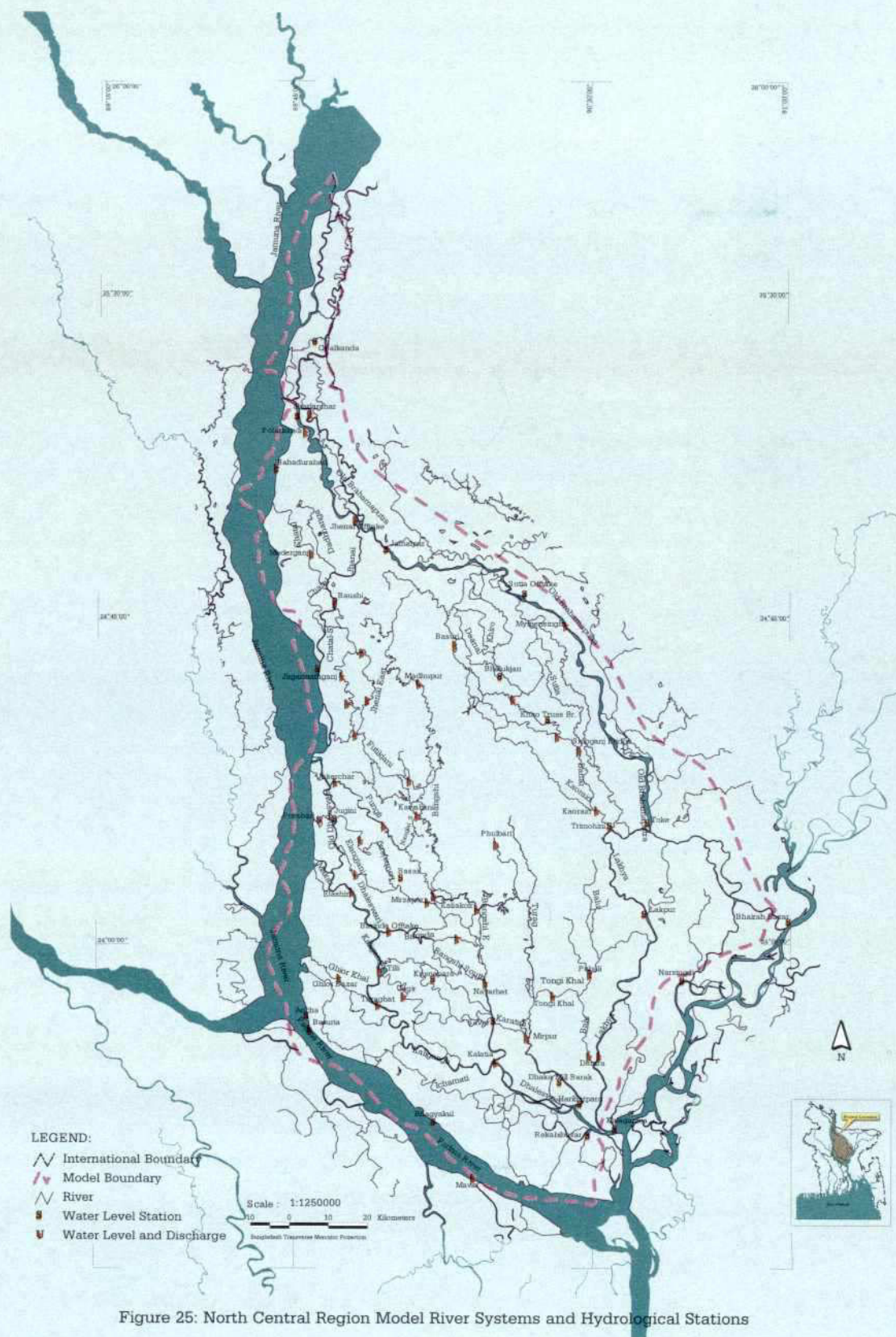
- To investigate the impacts of multiple compartment setting on the over all flooding condition within the region concerned.
- To quantify the change in water level at the upstream and downstream of the compartmentalization units considering a varying number of compartments.
- To observe the flooding condition within the compartmentalized area

The base model for the model study is based on the existing North Central Regional Model (NCRM) of the Surface Water Modeling Center (SWMC). For the study, the 1997-98 validated model set-up was updated incorporating all of the river systems and major infrastructure information of the CPP model.

The Model covers the entire North Central Region bounded by the Jamuna, the Ganges, the Meghna and the Old Brahmaputra. The central part of the region is mainly the result of spilling from the left bank of the Jamuna and drains in a southeasterly direction to the confluence of the Ganges and the Meghna Rivers. Consequently, high river stages in these two rivers impede the drainage of the region. The main spill fed rivers in the region include the Old Brahmaputra, Jhenai, Dhaleswari, Kaliganga, Pungli, Elanjani, Lohajang, Bangshi, Lakhya, Turag and Buriganga. Smaller mainly, rain fed, rivers include Khiro, Banar, Balu and Sutia. The river systems included in the model setup are shown in Figure 25. The Tangail compartment is sited close to the center of the area to be modeled.

The Compartments

The size and boundary of the compartments were determined based on the hydrological conditions of the area. Each compartment was treated as a hydrological unit. Considering these requirements and consulting the North Central Regional Study conducted by FAP-3, nine compartments were identified for the study on the



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left bank of the river Brahmaputra. A brief description of the selected compartments and the problems associated in those areas are described below and their locations are shown in Figure 26.

Compartment 1:

This compartment is located in Jamalpur and Tangail districts. Total area for this compartment is 536 km². Average elevation is 16 m, PWD. This area has some local drainage problem and affected by flash floods in every rainy season. The active flood plain area of the compartment is affected by river erosion and sand deposition due to annual floods. Flooding mainly occurs from the Jamuna, Old Brahmaputra and local rainfall. About 25% area is flooded in normal years.

Compartment 2:

This compartment is located in Jamalpur and Tangail districts. Total area for this compartment is 247 km². Average elevation is 12 m, PWD. About 40% of the cultivable area is flooded each year. Flooding occurs from the Jamuna and local rivers, and rainfall. The area is flooded for a period of 4 to 6 months at a depth of 2 to 4 meters.

Compartment 3:

This compartment is located in Tangail district. Total area for this compartment is 534 km². Average elevation is 12 m, PWD. Flooding occurs mainly from the Jamuna, Bangshi and local rivers and rainfall. About 70% of the cultivable area flooded in every year during the monsoon on an average.

Compartment 4:

This compartment is located in Tangail district. Flooding is from the Jamuna, Dhaleswari, local rivers and rainfall. Total area of this compartment is 205 km². Average elevation is 7 m, PWD. About 80 to 90% of the cultivable area is flooded every year. This area has local drainage problem.

Compartment 5:

This compartment is located in Dhaka and Manikganj district. Flooding from the Jamuna, Dhaleswari, local rivers and rainfall. Total area for this compartment is 374 km². Average elevation is 6.75 m, PWD. About 80% of the cultivable area flooded in every year during the monsoon on an average.

Compartment 6:

This compartment is located in Dhaka and Manikganj district. Total area for this

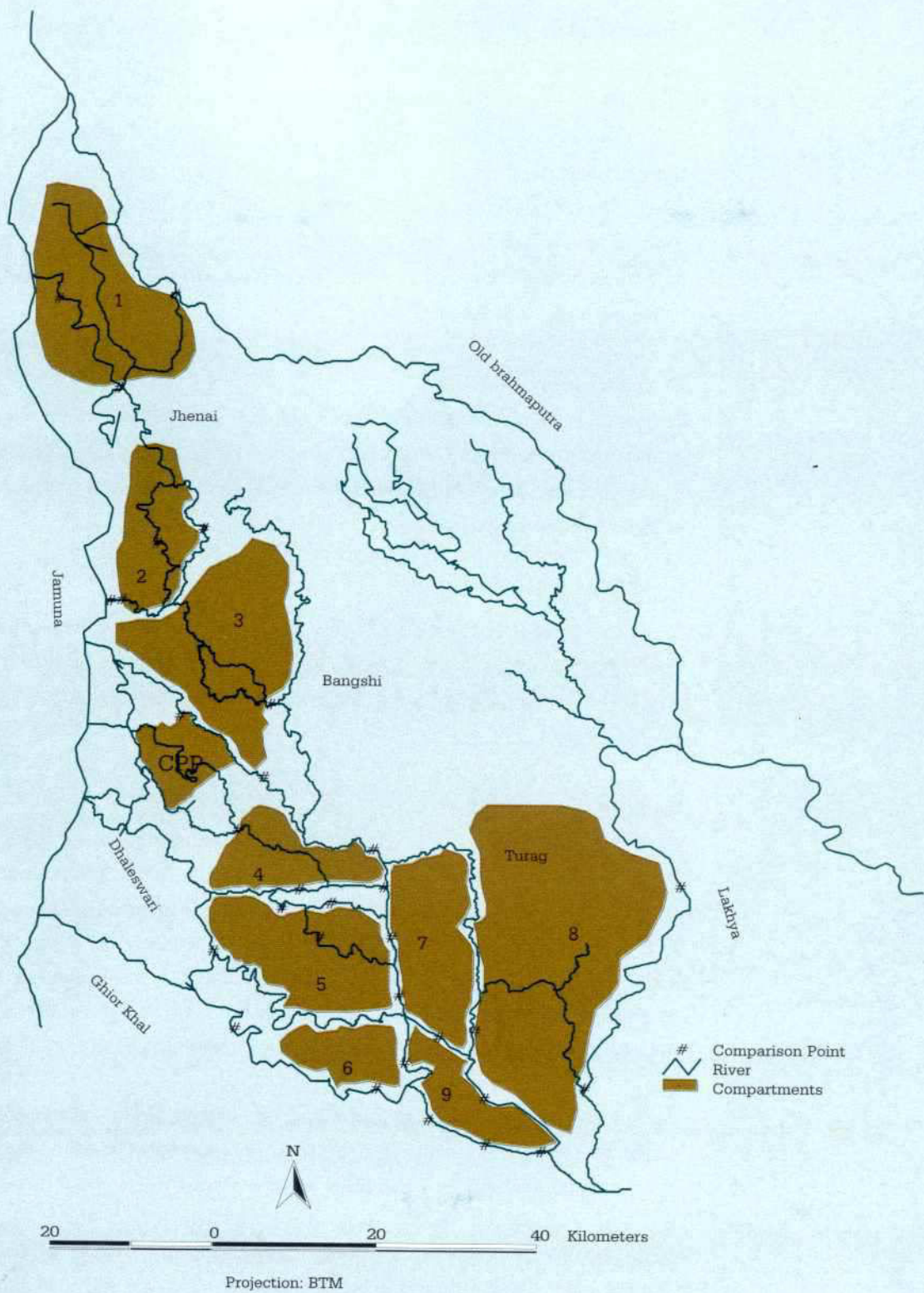


Figure 26: Location of the Compartments

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compartment is 139 km². Average elevation is 5.75 m, PWD. Flooding is from the Padma, regional rivers and rainfall. About 80% of the cultivable area is flooded every year. The area is flooded about 6 months in every year.

Compartment 7:

This compartment is located in Gazipur and Dhaka districts. Total area for this compartment is 316 km². Average elevation is 8.0 m, PWD. Most of the area is used for homesteads. Flooding occurs from the regional rivers and local rainfall. The area is flooded about 3 to 4 months of each year.

Compartment 8:

This compartment is located in Gazipur and Narayanganj district. Total area for this compartment is 1,059 km². Average elevation is 6.0 m, PWD. Most of the area is used for homesteads. The area remains flooded for nearly 3 to 4 months each year. Flooding occurs from the regional rivers and local rainfall.

Compartment 9:

This compartment is located in Dhaka, Keraniganj and Narayanganj district. Total area for this compartment is 157 km². Average elevation is 4.0 m, PWD. About 85 to 90% of the cultivable area is flooded every year. Flooding occurs from the regional rivers and local rainfall.

Results

Five different options each having a varying numbers of compartments were simulated for the study.²⁵ CPP Tangail was incorporated in the base model. Each option was simulated for the 1976, 1984 and 1995 hydrological years, corresponding to 1:2 year, 1:5 year and 1:25 year return period respectively. As the flooding pattern of the entire North Central Region is mainly dominated by the Jamuna River, the flood frequency distribution made by FAP-2 at Bahadurabad, on the Jamuna, was used to determine the simulation years, corresponding to the above return periods.

Comparisons of water level and inundated area were made for each option with base condition. Longitudinal water level profiles were also checked for some of the rivers to observe the possibility of back-flow for the options.

Model results were analyzed for investigating the change in water levels in the rivers at the upstream, downstream, and within the compartments, and the inundated areas under different options. It is observed from the model results that due to the compartmentalization water levels increased in most of the channels. In most cases,

the increase of water level is not significant with maximum increases observed in option 5. The maximum increase of water level in the Bangshi River is at chainage 201 km; in the Dhaleswari at chainage 135 km; and in the Pungli at chainage 45 km; the increases are 0.85 m, 0.55m and 0.77 m respectively.

Water level profiles for different channels were also investigated, and no back-flow was observed. While comparing the flooded areas, it was observed that in option 1 and 2 the dry area increases significantly in an average year with respect to base condition. However, in option 3, the increase is not significant. For option 4, when two additional compartments were added with option 3, on the left bank of Bangshi and Dhaleswari Rivers, the dry area increased significantly. Finally, in option 5, when all the nine compartments are incorporated, the flooding situation improved significantly.

It is worth noting that some of portions of the major rivers such as Bangshi, Turag, Pungli, Lohajang, Buriganga, Dhaleswari and Kaliganga already have some embankments in place.

Considering the model output, it could be concluded that the flooding situation in the region would improve significantly due to the multiple compartment setting. This is shown in Figure 27a & 27b. It can be further concluded that adjacent compartment, covering a large are of flood plain, present no significant hydraulic problems. This justifies the technical viability of replicability for multiple compartment setting.

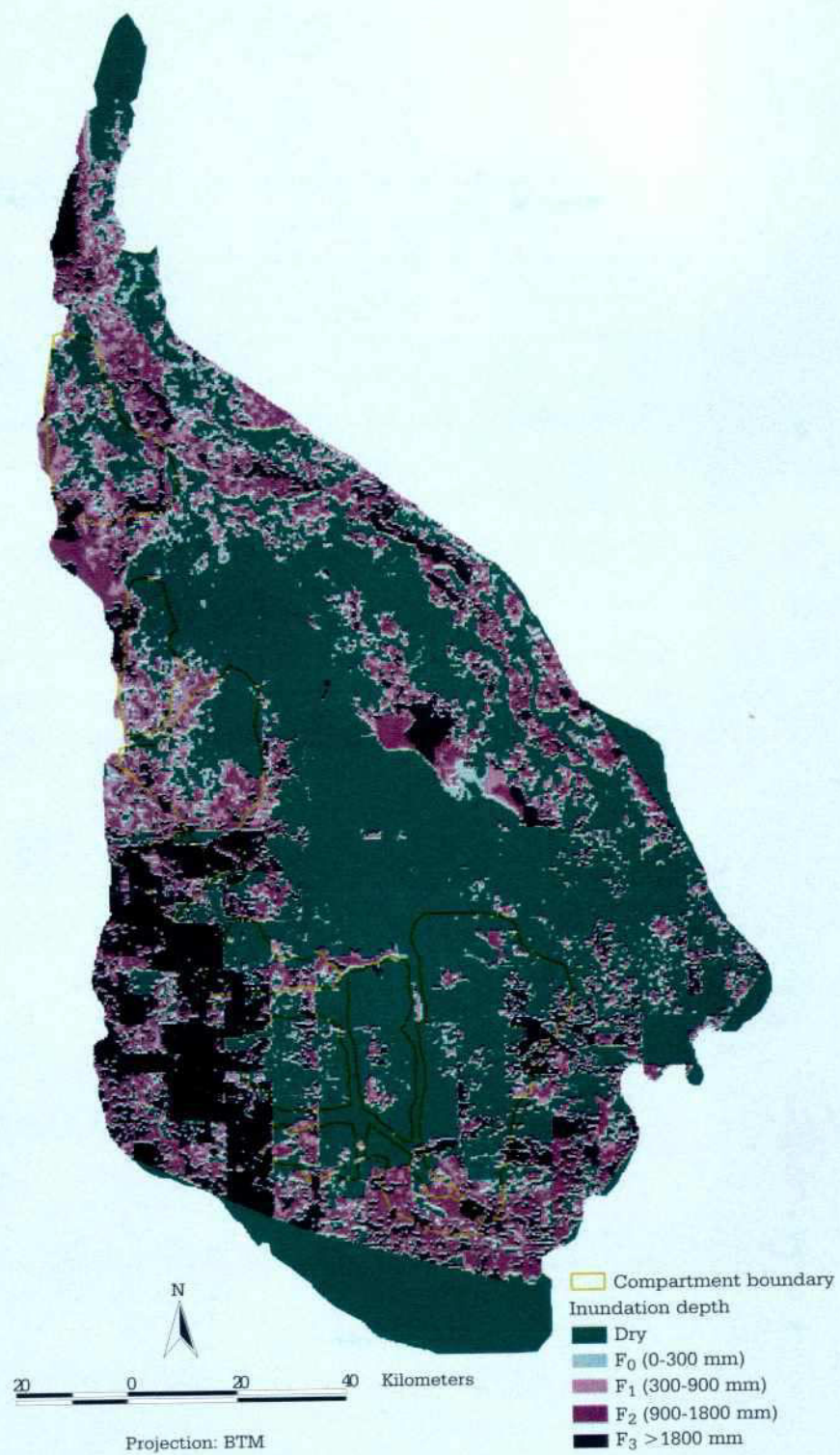


Figure 27a: Flood Map: Simulated for Base Condition : 1995



Figure 27b: Flood Map: Simulated for Option 5: 1995

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**Conclusion
and
Lessons Learned**

Conclusion

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CPP has shown that the compartmentalization concept of controlled flooding, and water management involving the beneficiaries, is a viable concept in Bangladesh.

Any lingering doubts about the protection provided by CPP were removed in 1998 when, during the floods of that year, the compartment, including Tangail Town remained largely flood free while surrounding areas were inundated.

The Benefits of CPP

There have been measurable benefits from CPP. These are:

- Increased agricultural output
- A rapid expansion of aquaculture together with increased yields
- Job creation
- Avoidance of flood damage to infrastructure and buildings

There has also been the non-quantifiable benefit of being protected from flooding. This is a huge social benefit for the people within the CPP area who see it, in fact, as the single greatest benefit.

Agriculture

The increased agricultural production in the project area has resulted from both increased intensity of cultivation, and a shift from lower yielding deep-water varieties of paddy into higher yielding varieties. This has been possible due to the improved drainage and water management that the project has brought.

It needs to be noted, however, that the changes are incremental rather than dramatic. This is inevitably the case when one starts, as CPP did, with close to a 200 percent cropping intensity. It also needs to be noted that, in general, yields of like varieties of paddy are falling over time, both within the project and in Bangladesh generally. This is the result of increased intensity of cropping, and, in particular, the increasing intensity of paddy cropping.

Aquaculture

Flooding is bad for aquaculture as it allows the cultured fish to escape the pond and mix with the general fish populations where they swell the potential catch of capture fisheries. For the owner of the fishpond this represents a total crop loss.

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The water management and flood control has greatly reduced the risk for the owners of fishponds. The probability of loss within the compartment is now greatly reduced and the effect of this has been a large increase in the number of fishponds, together with an increased yield of culture fish. In total, the output from fish culture within the project has risen from 258 tons a year to 558 tons a year.

In addition to the conventional aquaculture program the project also initiated a Homestead Catfish Program, the "*Chari in the Bari*" program, that has been targeted at the poor. The program has had a significant impact on the poor people who have participated in it.

Job Creation

Job creation by the project has taken place in three areas: in construction during the implementation period; in maintenance of the embankment; and in jobs created in agriculture.

As has already been shown, over the implementation period, approximately 3 million wage days of labor have been created in the construction of structures and earthworks. In addition, some 973,000 labor days a year of agricultural labor have been created by CPP. This job creation overwhelmingly favors the landless and the marginal farmer.

A more targeted effort, the EMG program, has created jobs for 100 landless women, one of the very poorest group in society.

Flood Damage Avoidance

One of the obvious benefits of controlling the flooding within the compartment has been that infrastructure and buildings are much less likely to be flooded than they were in the pre-project situation. There is an economic benefit to this and using, for the first time in Bangladesh, valid and scientifically accepted methodology, the project has calculated this economic benefit. The economic benefits put a cash value on the damage. However, it is worth noting that this may understate the impact of flood loss on individuals. For the poor, the loss of their house and goods may not mount to much in cash terms. Nevertheless, the house and goods, however minimal, might represent their entire wealth. The loss can be considerably more devastating for them than the damage inflicted on a *pukka* house owned by an individual who is not poor, even though the cash value of the damage may be higher in the case of the *pukka* house.

Negative Impacts of the Project

Fisheries

The project has always been aware that, as a project that modifies the regime of uncontrolled flooding there could be negative consequences. One of the major potential impacts was thought to be on capture fisheries. For this reason, CPP has consciously attempted to operate in a way that would minimize any adverse impact and has carefully monitored the output of capture fisheries within the project.

There has been an effort to include fish friendly gates within the major inlet structures and there has been a program of monitoring hatchling migration through the main regulator. The hatchling monitoring has led to two revisions to the fish friendly gates.

In spite of the fear of a negative impact on fisheries, the monitoring of the capture fisheries showed no impact of CPP on the catch. What did come out of the data was a huge year to year variability of the catch, which was entirely a function of the flood regime in any one year. However, over the eight years of monitoring there was no trend. In fact, the best year for capture fisheries was 1998, close to the end of the project, and a year of major flood.

Environmental Impact

At the inception of the project there were seen to be potentially negative impacts of the project on soil fertility, groundwater recharge and water quality; all resulting from the reduction in flooding that would be brought about by the project. In the event, the reduction of the extent of flooding is something that happens in years of extreme flood only. In the average year, what happens is an improved management of water and some reduction in depth on F_1 and F_2 land. For the most part, the farmers still want floodwater on their land and, under CPP water management operations, this is not impeded.

Careful monitoring of soil fertility, including silt deposits; of groundwater recharge; and of water quality; showed no significant adverse impact caused by CPP.

What was observed, with regard to groundwater, was a great seasonal variation with much lower levels in the dry season. In addition, it was observed that levels in the dry season are falling over time because of increased tubewell irrigation. At present, this fall in levels is being fully replenished from recharge during the wet season.

Adjacent Areas

It was assumed that CPP would have some impact on the adjacent areas both upstream and downstream. It rapidly became evident that the downstream effects were non-existent but the belief that there were adverse upstream effects in the Northern Adjacent area persisted through much of the project. Indeed a series of mitigation measures were implemented for the area. It was reinforced in 1998 when the Northern Adjacent Area was inundated while the project remained relatively flood free.

It was only in 1999, when the Northern Adjacent Area was modeled, that it became obvious that the project had only a minimal impact on the area. The modeling showed a slight increase in depth of water of 10 to 20 cm, but virtually no change in the extent of the flooding resulting from CPP interventions.

Replicability

One of the questions that CPP has had to address is whether the project is replicable. There are really three aspects to this:

- The first is technical - will a multi-compartment approach be technically viable?
- The second is economic - does the project make economic sense?
- The third is institutional - can the existing institutions, together with the institutional arrangements for participatory management developed under the project sustain this project and other likes it.

Technical Viability

CPP has demonstrated that compartmentalization, in a single compartment setting is technically viable with benefits to agriculture, aquaculture and the prevention of flood damage. However, the physical behavior of a single compartment in a flood plain is different from a multi-compartment setting.

Replicability of the Compartmentalization Project is dependent upon there being similar areas with adequate drainage. CPP modeled the area to the North and South of the Tangail Compartment, the North Central Region of Bangladesh, in order to look at the impact of a multi-compartments situation. The main objective of the study was to investigate the impact of multiple-compartment setting on the overall flooding condition within the region concerned.

Nine compartments, all on the left bank of the Jamuna, were studied. Together they cover some 3,567 km² forming a dense multi-compartment setting.

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The Model results were analyzed to investigate the change in water levels in the rivers upstream, downstream and within the compartments and the inundated areas under different options. It is observed from the model results that compartmentalization, increased water levels in most of the channels; but, in most cases, these increases were not significant.

The conclusion of the modeling was that a multi-compartment situation in the North Central Region would improve the flooding situation significantly. From the technical point of view, the concept of replicability of multiple compartment setting is viable.

Economic Viability

An appraisal of CPP, including all of the costs of the project shows a low internal rate of return of around 3 percent. However, CPP, as a pilot project includes additional costs, including the costs of mistakes that were made as part of the learning experience. This also includes costs, such as a major WID component, that arguable, is a social project in its own right.

Calculations carried out as part of this final report show that it would be possible to replicate CPP at a lower cost. In fact a cost of the order of 40 percent lower. In this case, the rate of return starts to look a much more respectable 7 or 8 percent. Added to this the needs to be the considerable social benefits of preventing people from being flooded.

Institutional Viability

CPP has shown that it is possible to successfully organize the beneficiaries into Water Management Committees. What is still to be proven is whether these institutional arrangements will survive the project. It may well be that the project's ambitions in terms of engineering and institutional development have exceeded the capabilities of both the O&M Division BWDB and the beneficiaries.

Whether the system left in place is sustainable will depend, in part, on the BWDB. Bangladesh is not a society in which user participation is the norm. In general, it is a top down, hierarchical society, and, in common with other government Institutions, this is how the BWDB typically operates. If the participatory management that has been put in place is not respected and nurtured it will not survive.

Prior to any consideration of replication of the participatory management approach, CPP should be monitored for a number of years to determine its sustainability. A BWDB monitoring and evaluation unit has been put in place to carry this out.

Lessons Learned

One of the more valuable outputs from CPP is the lessons that have been learned. Many of these lessons have applicability, not only to a replication of compartmentalization, but, more broadly, to water projects in Bangladesh.

Modeling

CPP commenced implementation with no hydraulic modeling in place. Attempts to model the compartment were frustrated by the lack of understanding of the flood regime in Bangladesh, by the lack of data and by the limitations of the modeling techniques. Great strides have been made in all three areas over the past decade, and now in Bangladesh, with the SWMC, one is in a position to have any area successfully modeled.

The key, if replication is to be considered, is to carry out the hydrological and modeling prior to any design or implementation.

With modeling in place, one can then start looking at a cost-effective design approach to gaining most of the benefits available from compartmentalization. This will almost certainly be attained with fewer structures than CPP has built.

Water Management

Due to the emphasis on modeling during the Final Phase, there was less attention to water management outside monsoon months, than during the First Phase. However, the importance of the *Boro* crop and possible crop diversification during the *Rabi* season, call for a more integrated approach to water management. Future water management studies should not be confined to the monsoon months, but encompass the entire year.

Water management in the Compartment proved more complicated than anticipated. Reasons are, the numerous drains and structures already present in the field, the fact that adjacent systems influence each other by backflow and flow over system boundaries, and the combination of drainage and the intake of water from outside the Compartment. Water management, therefore, could not be as precise as originally anticipated.

CPP, rightly, has put great emphasis on the intake of outside water, from its early beginning. Intake structures are actively operated. In retrospect, more intake capacity might have been created. The distance between the intakes and the low lands, where excess water may accumulate, is important. In the western half of the Compartment,

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distances are short enough for proper communication, in the eastern half they are too long. This difficulty will need to be addressed in future projects. In some cases, it might be amenable to design solutions.

As far as water management is concerned, there is much emphasis on committee meetings. In actual practice, once land users know what the system has to offer, operation becomes a matter of routine. Meetings are required for consultations between committees, to draw seasonal plans or to evaluate experiences of the past season. Most important are meetings on the maintenance of the system and its funding. At least one annual meeting should be devoted to that.

Splitting the Compartment into sub-compartments and *chawks* is a sound approach. It makes the area more manageable and it provides a framework for consultations between the Project and the local population. However, *chawk* and sub-compartment boundaries should be based on hydrological systems, as far as possible. This reduces the extent to which water conditions in one sub-compartment are influenced by those in another. This is a further argument for modeling as the first stage in any future project.

Construction

The method of implementation of CPP was far from satisfactory. Design and implementation was the responsibility of BWDB. Thus, design was by the Design Circle of the BWDB in Dhaka. Parts of the design criteria actually used were not known to the project and the adaptation of designs during the design and implementation of civil works did not take place. One of the results of this somewhat rigid approach to design is that the gates and mechanisms are manufactured by the BWDB M&E Division and have to be repaired by the BWDB. They are not amenable to local maintenance and repair. Given the commitment to have beneficiaries undertake maintenance, this is clearly unsatisfactory.

A more satisfactory solution would be to have design carried out by the project with more attention given to maintenance friendly designs, which makes the involvement of local artisans in manufacture and repair more feasible. This could also lead to a lower cost for gates and structures.

The BWDB approach to the embankments is also far from satisfactory. Re-sectioning is not an efficient way to rehabilitate embankments. It concentrates on quantity rather than quality. In rehabilitating embankments, quality aspects should be given more attention. Embankments should be constructed of soil of specified quality,

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layered, watered and mechanically compacted. Rehabilitation should then concentrate on the weakest sections.

Land acquisition was a problem with CPP as it is with many projects. However, the BWDB approach was to give priority to the acquiring of land for structures. The major constraint to the implementation of an improved drainage system is the timely completion of the earthwork, not the structures. Structures should not be built before the land acquisition for the *khals* has been completed.

Implementation of improved drainage takes time. A flexible approach is required. Works should be executed on a systematic basis, moving from downstream to upstream, in locations where land users support the plans. This argues for a more flexible approach, rather than the strict implementation schedule the Project had.

The result of the Minor Works Program was unsatisfactory. This is partly due to lack of timely monitoring and partly to a lack of proper program design. During the evaluation of the applications for such works, there should be more emphasis on the willingness of the *chawk* population to participate. The process of advancing 25 percent of the cost of the minor works to the Water Management Committees should be reversed. If these committees are to be made to feel responsible for the project and the structures, they should contribute to the cost of minor (though not necessarily major works). It would not be unreasonable to insist that they pay 25 percent of the cost, to be collected by the Committee prior to approval of the minor works by BWDB.

BWDB implementation cost are high. This also suggests that more use should be made of cost indicators to monitor costs of work. The high costs of implementation also support greater involvement of local consultants and a role of the consultant as engineer during the implementation of the works. The present status of the consultant, as a monitor of quality control only, is weak and unsatisfactory.

One thing that CPP found essential, after starting the project without one, was a quality control cell to monitor quality and measure the quantity of work. Future projects should build such a cell into its project organization from the beginning.

Maintenance

CPP was responsible for maintenance of completed structures and earthworks during most of the project. The maintenance arrangements involving the beneficiaries and

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BWDB were only put in place during the last year of the project, and could, therefore, not be tested. Both operation and maintenance policies should ideally have been in place before construction. Moreover, those responsible for O&M, both Water Management Committees and XEN O&M Division, Tangail, should have been in charge as soon as infrastructure was completed.

Future projects should follow a process where the actors who will be responsible for operation and maintenance take on that responsibility, including the financial cost, on the completion of each section of construction. If the BWDB and the beneficiaries are unwilling or unable to undertake this responsibility then it is better to know this early in the project rather than after the completion of the project.

Participatory Management

Beneficiary committee formation needs to be carried out at the earliest possible stage so that they are in a position to endorse the overall and detailed design and agree to bear the resulting O&M costs.

There are really two separate exercises to be carried out. Implementation is a separate activity from operation and maintenance of the completed system and CPP experience indicates that stakeholder committees for the two stages do not need to be identical. The implementation phase requires the widest possible representation in order to muster community support for the project and keep the population informed. However, the operation and maintenance phase can be managed with a smaller water management committee with members who are best able to sustain communal system.

To form the initial Project Committees, area representatives, Union *Parishad* officials, landless and fishermen will be need to be represented. Women will get a fixed proportion of each category. These committees are the consultation platform for the project. They commit the area's people to the design and the future O&M responsibilities. They will be involved in planning and implementation, especially works for which the local people have to contribute in cash or kind.

Once the first infrastructure is completed and the need for system management occurs, Water Management Committees should be formed, maybe as sub-committees of the project committees. The WMC's will be formed by the people themselves. In these committees, union officials become ex-officio members, and only a full-time present stakeholder can become President. All areas should be represented. Fishermen should only be compulsorily allocated seats if the system has clear fishery

objectives and practices. The formation of these committees at a later stage in the project also allows the project to adjust the jurisdiction boundaries to the latest water management insights. The boundaries might be different from those of the initial beneficiary committees.

The model sketched may be summarized as:

Level	Project Phase	O&M Phase
Interest Groups	Consultation Meetings	-
Chawk (110-142)	Consultation Meetings & Annual Meetings	Annual Meetings
System (20-30) or Sub-Compartment (15)	Sub-Compartment Project Committee (Similar to SCWMC in CPP)	System/Sub-Compartment WMC (1 Representative/Chawk)
Compartment (1)	Compartment Project Committee (Similar to CPP's Compartment Forum)	Compartment WMC (Similar to CHWMC in CPP)

Sustainability

The BWDB is the key to the sustainability of the project. They are ill prepared for it. They lack experience in participatory management and in women's involvement and, indeed, do not have a good record regarding O&M in other projects.

There has been little or nothing in this project to improve the BWDB's preparedness to eventually take over the project. Overwhelmingly, the institutional development, the WID component, water management and modeling, as well as agriculture and fisheries, have all been carried out by consultancy staff.

As an approach to implementing a project, the use of consultants is easy and convenient. However, it does nothing to build capacity where it is needed, in this case, in the BWDB. Future projects could look to a greater involvement of BWDB staff, seconded to the expatriate consultancy team, in place of local consultants. It is by working with the consultancy team that BWDB staff is going to be able to build up on the job experience in areas where they are weak at present.

Much the same goes for agriculture and fisheries. CPP has effectively been running extension services for agriculture and for aquaculture within the project area. These have been effective, but they cease at the termination of the project. A similar effort involving both DAE and the Fisheries Department would stand a better chance of leaving behind some enhanced capacity.

Notes:

- ¹ A description of the history of the CPP is contained in Annex A to this report.
- ² 1999 Figure.
- ³ This is an increase from the 263,268 people who lived in the compartment in 1991. This represents a low rate of population increase of around one percent a year. This probably reflects migration out of the rural areas and into the urban area of Dhaka in search of employment.
- ⁴ Since 1991 a number of other projects, have developed participatory decision making.
- ⁵ There is more discussion on the embankments and other engineering and construction aspects of the project in annexes B and C which encompass both the engineering aspects and the water management aspects of the project.
- ⁶ Most frequently, there would be reluctance to participate if an individual was not personally benefiting from the drainage although the other members of the community were.
- ⁷ The maintenance estimates used in this report are those compiled by the consultancy team. The BWDB have approved a maintenance plan with much lower costs.
- ⁸ See note 7, above.
- ⁹ In 1988 Tangail Town was under flood for fifteen days.
- ¹⁰ Institutional development is extensively dealt with in Annex D.
- ¹¹ Agriculture is dealt with in detail in annex E to this report.
- ¹² Annex F covers fisheries in detail.
- ¹³ 20,000 per experiment.
- ¹⁴ For a full description of the methodology and the results of the study, go to Annex G of this report.
- ¹⁵ This continuation will be jointly managed by the XEN O&M of BWDB and DORP, a local NGO.
- ¹⁶ EMG's are dealt with more in Annex H, the Women in Development Annex.
- ¹⁷ The program is described in the Fisheries Annex F.
- ¹⁸ The bidi is the local cigarette. Women roll the covers of these by hand earning of 2.5 Taka per thousand sticks. An average adult can produce that amount in three hours. Which means the income from this activity is 0.75 Taka (= 0.015 US\$) per hour.
- ¹⁹ Annex I describes the environmental impacts of the project.
- ²⁰ Monitoring and evaluation within CPP is dealt with in more detail in Annex J to this report.
- ²¹ The economic analysis is covered more fully in Annex K to this report. In particular in the Appendix to that annex.
- ²² The conversion factors used to move from the financial to the economic prices are shown in Table 2 to Annex K the Economic Analysis annex.
- ²³ Even higher when one adds the administrative charge which the BWDB has to pay to the Deputy Commissioner.
- ²⁴ The data is from the Agricultural Annex Annex E.
- ²⁵ For details of the simulations see Annex L.

