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

Annex A-Narrative History of the Project
Annex B-Engineering and Construction
Annex C-Water Management and Modeling

LAHMEYER INTERNATIONAL GmbH, Federal Republic of Germany
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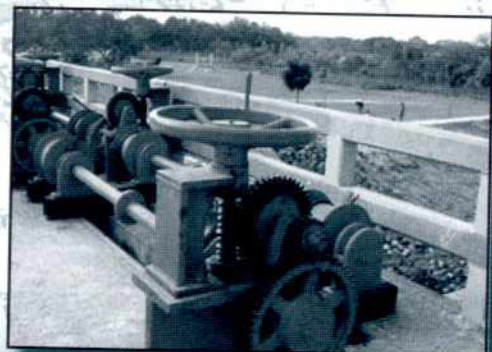

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Acronyms and Abbreviations

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

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 Onderzock 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

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

Aman	A group of photoperiod-sensitive rice planted in May-August and harvested in November-December.
Aus	Photoperiod-insensitive paddy varieties grown with irrigation from December -February
Baor	Oxbow lake, natural depression usually formed by the change of course of rivers
Bazar	Market place
Beel	Small lake, low-lying depression, a permanent body of water in a floodplain or a body of water created by rains or floods.
Bidi	Local Cigarette
Bigha	Unit of land (1/3 of an Acre)
Boro	A group of photoperiod-insensitive and fairly cold tolerant rice varieties transplanted in December-February and harvested in April-May.
Borrowpit	Excavated small and seasonal water bodies present mainly along the public roads.
Catch Assessmen	Determining the daily catch of the fishermen
Catch per unit	Quantity of fish caught by the fishermen in unit time and effort (Fishing equipment)
Chamara	Important deep water *Aman* variety
Chari in the *Bari*	A ditch on the homestead
Chawk	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.
Chula	Home made furnace
Cluster	A group of sub-compartments, which are merged together for management resons. Their hydrological features resemble an independent status.
Compartment	A (semi) protected area or part thereof in which effective water management particularly through controlled flooding and controlled drainage, is made possible through structural and institutional arrangements. A compartment will be sub-divided into Sub-Compartments and operational Water Management Unit.
Crore	100 lakh
Cusec	Discharge unit: 1 cusec equals 28 liters per second
Decimal	Unit of area measurement, 40 m^2
Deshi Jute	White jute (Corchorus capsularis) varieties, tolerant to standing water.
Dhaincha	An erect leguminous species (Sesbania sesban), used for green manure and fencing
Doon	Traditional water lifting device
Dopa	Lowest land type according to farmers' classification
DW *Aman*	Deep water Aman, a rice variety
Frame Survey	A survey for estimating the number of fishermen or gears.
Hat	Weekly market
Hijoldigha	Important deep water Aman variety
IPM	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.

Jalmahal	A leased water body or river stretch.
Khal	A natural channels.
Kharif	Crop season from March-October (Kharif-I: March-June, Kharif-II: July-October)
Khash land	Land owned by the government
Kutcha	Unlined earthen channel
Lakh	100.000
Madrasha	Islamic School
Mastan	Muscle man/thug
Mohalla	Urban village
Multi-criteria *analysis*	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.
Pagar	Small water body
Palam	Homestead land
Patchot	Intermediate land type according to farmers' classification
PA-Matrix	A relational matrix, depicting links between participants and activities in a certain process.
Parishad	Council
Perching	Placement of branched sticks (perches) in crop land as resting place for insect-eating birds.
Pourshava	Town council
Pucca	Lined earthen channel
Rabi	Crop season (November-February)
Rapid Rural *Appraisal*	A systematic, but semi-structured activity carried out in the field by a multi-disciplinary team and designed to quickly acquire information. Bacterial processes of separating jute fiber in standing or slows running water.
Retting	Bacterial processes of separating jute fiber in standing or slows running water.
Salish	Traditional informal village court which mitigate the disputes of the vilagers. The traditional village Matabbars (Chieftains) are the judges.
Sub-Compartment	A sub-unit of a compartment, in which to a certain extent the water management can be controlled by the people living in the area represented in a Water Committee. The sub-compartment is mostly separated from the adjoining ones by embankments or roads and provided with (semi) cotrolled structures.
T. *Aman*	Transplanted Aman, a rice variety.
Tan	Highest land type according to farmers' classification.
Thana (previously Upazila)	Local administrative unit. Each Thana is composed of 10-15 Unions.
Tossa Jute	Jute (*Corchorus olitorius*) varities, grown in the highest land types, not tolerant to standing water.
Union	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.

Annex A
Narrative History of the Project

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Introduction

This document records experiences that cover a decade of developments (1989-1999) in the water sector of Bangladesh. The Compartmentalization Pilot Project (also known as Flood Action Plan Component 20) has been an integral part of the development of the water sector in Bangladesh during the nineties, and should therefore, be considered as part of a dynamic process. Circumstances in the early nineties were different from those prevailing at the end of the decade, when the project was in its final stage. International approaches to water management in general have evolved from narrowly-defined objectives for individual water resources interventions to more sectoral approaches in which integrated water resources management, environmental assessments, public consultation and public participation are embedded in the policy objectives. However, at the time of the conception of the project the objective was seen as a fairly straight-forward one:

> *"The floods in Bangladesh in the summers of 1987 and 1988 were on a catastrophic scale. Several thousand people lost their lives, many thousand lost their homes and properties and a large part of the standing crops were destroyed. The effect on the national economy was disastrous. Both the Government of Bangladesh (GoB) and the international community of aid donors resolved that the menace of such floods was unacceptable and measures been taken to prevent a recurrence in the future" (ref: Terms of Reference - ToR, CPP, 1991).*

Several studies were carried out to find a solution to this flood problem. GoB initiated a national Flood Protection Program that was followed by a UNDP-funded Flood Policy Study and other studies.

In June 1989, the World Bank (WB) agreed with GoB to coordinate the various flood control initiatives, and in November 1989, formulated a Flood Action Plan (FAP), covering the period 1990-1995. This FAP comprised a phased program of flood control activities supported by special studies, surveys and pilot projects. During this 5-year period, it was planned to protect the main flood-prone area of Bangladesh, the Brahmaputra River floodplain. The plan assumed that a start could be made with the strengthening of the existing Brahmaputra Right Embankment (BRE) and the construction of the Brahmaputra Left Embankment (BLE), early 1993. However, flexibility was built into the program to adjust to new findings of these FAP studies, if so required. The plan was formulated for a five-year time span, covering 26 different projects (each project was labeled with a number from 1 to 26). Each project had a different combination of international and national financing, channeled through one coordinating mechanism: the Flood Plan Coordination Organization (FPCO). The CPP was labeled FAP, component 20, or in short FAP-20. CPP formed an important component within FAP program with the objective of identifying pilot areas for testing the concept of compartmentalization in the large floodplains of Bangladesh

Physically and hydrologically the Brahmaputra floodplain is complex and its braided channel (10-20 km wide) is adjoined by older floodplain land. The floodplain is densely populated and its inhabitants are heavily dependent on agriculture. Rice is the principal crop, grown in three main seasons. During the dry season, irrigation (using pumped groundwater) is applied and this increased steadily during the 1990s. During the wet season, seasonal flooding takes place, which in some cases washes crops and houses away. However, over time the floodplain inhabitants have adapted their way of life to the seasonal flooding. Rural houses are built on kilas (mounds), above normal high flood level and roads and railways are built on embankments. Crop (and other) damages occur when there are unusually high, early, late or rapidly rising flood levels. High-risk areas are, therefore, planted with low yielding, flood tolerant, traditional rice varieties.

In the wet season, this seemed to be the only option, whereas the adoption of the irrigation in the dry season (from groundwater) became more prevalent. The planting of High Yielding Variety (HYV) paddy does take place further away from the main channel of the Brahmaputra. However, within the floodplain area, coverage is very low because of the high incidence of floods.

Embankments form a traditional means of flood protection; three main types can be distinguished:

- Main river embankments: the BRE (built during early seventies) is an example. The potential for river erosion and the braided nature of the river leads to unpredictable movements of the main channel, represent major risks for such embankments (Type I);
- Embankments (which are smaller than Type I) which have been used for "polder-type" area development (Type II);
- Embankments which have been constructed for urban protection (Type III) and

The flood policy to be implemented under the FAP foresaw controlled flooding and controlled drainage through building new or using the already existing embankments along the main rivers to prevent unusually high, early, late or quickly rising flood levels.

These embankments were to be provided with regulators to allow "normal flooding", i.e normal flooding would still be able to enter the compartments thereby allowing the fish fry in the river water onto the floodplains.

CPP's ToR, 1991 (page 3) states:

> *"The protected area behind the embankment would then be divided into "compartments", where physically possible. The compartment would basically be described as a "management unit" with, as objective, to provide, through water management a more secure environment for intensive agriculture, fisheries and integrated rural/urban development, and thereby improve the economic security and quality of life of the floodplain population."*

However, the concept of a double embankment system (the first one along the main channel of the Brahmaputra) together with a second one (acting as the border of the compartment), was a new and essentially untested concept. Therefore, three "pilot-areas" were identified under the CPP to address these new approaches and to test the physically different locations. The project was split into the Tangail Pilot Project, the Sirajganj Pilot Project and the Jamalpur Pilot Study[1].

CPP's ToR, 1991 (page 5) states:

> *"The overall objective is to establish appropriate water management systems for the development of protected areas, so that criteria and principles for design, implementation and operation can be made available for the Flood Action Plan. The Pilot Project will have to demonstrate the practicability, viability and justification of compartmentalization. Through a systematic assessment of the advantages and disadvantages, the concept has to be justified. Economic, financial and social cost benefit assessments will be carried out under this project and taken into account in recommending the system for adoption in the Flood Action Plan".*

Specific objectives of the pilot projects were to establish water management systems that are feasible, achievable and sustainable, from a physical, social, environmental, institutional and economic point of view. Expected outputs would be divided into so- called "structural" and "non-structural" forms. The "structural" form would comprise the physical works and the "non-structural" form a series of reports, technical notes and manuals based on field trials that would be used by those organizations responsible for the planning and implementation of full scale water management in

[1]The Jamalpur component was shortly separated to form the separate Jamalpur Priority Project.

protected areas. In short, a multi-disciplinary approach was to be applied to three distinctly different physical settings.

The institutional setting and environment in which CPP (FAP-20) has emerged between the initiation of FAP (early nineties) and a decade later is an example of how time-sensitive certain developments and perceptions are in quickly developing and evolving sector such as the water resources sector. Assumptions made in the early nineties on institutional or environmental arrangements were seen from a different angle during the late nineties.

The main objective of this report is to highlight in retrospect, some of the deciding moments which have shaped the current state of the project, and to show how much this has contributed to and fed back into the comprehension of the complexity of water resources management in Bangladesh, and perhaps also outside Bangladesh's borders.

Benchmark events guiding and influencing the perception, assessment and public opinion about people's participation in water sector projects in Bangladesh have been listed first, after which short explanations and background information are given on main issues.

Background

The FAP was conceived with the assumption that the devastating floods of 1987 and 1988 needed to be addressed in an integrated way, and that therefore a cohesive GoB policy was required. The water policy after the GoB's declaration of independence in December 1971 had been characterized by a strong sectoral approach. Furthermore, coordination among GoB ministries and international donors was initially relatively underdeveloped, despite eagerness of the donor community to make an impact on the water sector development, arising from the international concern about the Bangladesh situation. The number of GoB ministries with a responsibility for water-related issues, led to a degree of fragmentation and the concept of an integrated water resources management approach was very new, both on paper and in practice. Tens of projects were launched in the aftermath of those devastating floods, with virtually no collaboration or interaction among the projects, ministries or donors. Gradually, the concept evolved of working towards a more united front to address water resources management in a physically very difficult environment evolved both at national level in Bangladesh and internationally.

However, coordination among all these projects were initially virtually absent, due to a weak management structure within GoB, lack of coordination by the donors, and a lack of overview on how water resources management should be taken up, keeping in mind the complexity of the physical setting of Bangladesh. While the international donor community was very eager to participate in the water sector, the GoB had an institutional framework (various ministries responsible for water-related issues) which was too diffuse to deal with the complicated issues of the water sector. Internationally, integrated water resources management was a relatively new concept, in which the issues of integration were more difficult than those of the sectoral approach adapted during the eighties and nineties.

Internationally, water resources management evolved gradually in many countries moving gradually towards integrated approaches. The devastating floods of 1987 and 1988 in Bangladesh urged the actors in this process to think in a more integrated way. International concern over water resources management in general as well as in Bangladesh, made governments think in terms of strategic solutions to address the extreme hydrological situations. Public awareness of the severity and complexity of the situation gave urgency to the development of a comprehensive strategy for defining policies and guidelines, such that long-term solutions and scenarios could be formulated, discussed, implemented and monitored.

The FAP (as conceived in 1989 at a conference in London, attended by the main international donors and representatives from Bangladesh), consisted of 26 different studies and pilot projects supported by 16 donors, and was based on an agreement between the WB (as coordinator) and Bangladesh to coordinate proposals in the area of flood control, or rather in controlled flooding. The proposed measures programs and projects were to be primarily directed towards wet season water control, a view that has subsequently evolved to integrated year-round water resources management.

The CPP aimed to address and put forward solutions to the complicated integrated water resources issue, including peoples participation, environmental issues, gender-sensitive approaches and income generation activities. In particular, the term "people's participation" was a word that carried inherently different meanings to different people. "People's participation" envisaged a broad range of measures to provide a framework for improving local and regional involvement in water resources management, such that planning, design, implementation and Operation and Maintenance (O&M) would be supported by the beneficiaries and would be embedded in the local administrative setup. The involvement of stakeholders was seen as a prerequisite for sustainability and viability.

In view of its pilot nature, and its relatively radical approach to water resources management in comparison with earlier sectoral approaches, CPP attracted wide attention from its onset.

The Main Events

Chronology of Main Events - Summary

Date	Topic
1987-1988	Devastating floods in Bangladesh and in other parts of the subcontinent
1989	National Flood Protection Program (commissioned by GoB) Bangladesh Flood Policy Study (commissioned by UNDP) Eastern Waters Study (commissioned by USAID) Flood Control Pre-feasibility Study (commissioned by French Government) Flood Survey Report (commissioned by the Japanese government)
1989 June	WB agrees to coordinate a 5-year FAP as the first phase of a long-term planning in water resources management in response to GoB request (First FAP Conference)
1989 December	Conference in London by major donors, approval for implementation FAP (timetable 1990-1995) Report of the Project Identification Mission CPP
1989	Eleven guiding principles formulated for FAP program
1990 March	Creation of the Flood Plan Coordination Organization (FPCO) by Ministry of Water Resources (MoWR)
1990 June	Issuance of the ToR CPP, issued by FPCO and MoWR
1991	Identification Mission CPP (FAP-20)
1991 October 21	CPP officially commissioned, by Minister Jan Pronk, Dutch Minister for Development Cooperation; target duration December 1994
1991	ToR CPP established
1992 March	Second FAP Conference (held at Dhaka)
1992 April	Revised Inception Report with adjusted Technical Assistance (TA) up to June 1993, concern for impact of Dhaleswari closure on project
1992 September	FAP 20 submitted its inception report (Tangail and Sirajganj compartment)

1992-1993	CPP started its activities in two compartments: Tangail and Sirajganj
1993	Inspectie Onderzock Ter Velde (DGIS - M&E)/Operations Review Unit (Ministry of Foreign Affairs, Government of The Netherlands), also known as IOV mission report on FAP, Bangladesh
1993 March	Guidelines for People's Participation, FPCO
1993 May	Third FAP Conference (held at Dhaka)
1994	MoWR issues Guidelines for People's Participation (GPP)
1994 June	Donor Review Mission CPP decided to concentrate on Tangail compartment only. Sirajganj has been put on hold
1994 August 22	GPP officially approved by GoB
1994 December	Water and Development in Bangladesh: A Retrospective on the FAP (ISPAN-led) Extension of FAP 20 beyond the contract period, extension for 1995 Opening of the Information Dissemination Center (IDC) of CPP at Tangail Many NGOs join hands in opposing FAP (inter) nationally,
1995 May	Mid-term evaluation CPP FAP-20
1995 September	Bangladesh Water and Flood Management Strategy (BWFMS)
1995 October	CPP Reformulation Mission Report
1995 November 27	People's Conference on FAP organized by Coalition of Environmental NGOs (CEN) and Association of Development Agencies in Bangladesh (ADAB)
1995	30 November-1 December: Fourth FAP Conference held at Dhaka
1996 February	German Minister for Economic Cooperation and Development visits the project
1996 March	Technical Assistance Project Proforma (TAPP) approved which extends the project until June 2000

1996 October	CPP Final Phase started under an adjusted ToR Systems Rehabilitation Project (SRP) drafts an action plan for the revision of the guidelines for peoples participation in water development projects
1997 April	Inception Report CPP Final Phase (October 1996-June 2000) People's perception, participation and payment of compensation: An assessment of CPP by an independent consultant commissioned by Kreditanstalt für Wiederaufban (KfW)
1997 July	Dutch Minister for Development Cooperation, Mr Jan Pronk visits CPP
1997 December	National Conference on Participatory Water Management Evaluation report SRP
1997 December	Water Resource Management in Bangladesh The Steps towards the New National Water Plan
1998 April	Institutionalizing local participation: A proposal for guidelines for participatory water management Technical Report No. 57, SRP
1998 June	National Water Management Plan (NMP), Draft Inception Report
1998 December	NWMP, Discussion Inception Report (seminars)

1989

Various studies were initiated following the devastating floods of 1987 and 1988. In response to a national flood-protection program (1988) issued by GoB, four different studies were undertaken by the United Nations Development Programme (UNDP), United Stated Agency for International Development (USAID), and the Japanese and French governments.

The most prominent result, which was later endorsed by the international donor community and Bangladesh, was the strategy identified by the UNDP/GoB Flood Policy Study, which introduced the "controlled flooding" concept. A pilot project was identified on this basis. Until that time, many Flood Control and Drainage (FCD) projects had been implemented which emphasized flood control (FC) and drainage (D). Flood control emphasized the exclusion of floods or prevention of floods in certain areas by the (re) construction of embankments.

Controlled flooding represented a compromise between complete flood control (i.e. total exclusion of floods) and no flood control (i.e."living with the floods"). This compromise solution would allow floodwater to enter the protected areas through inlets in the embankments, thereby allowing fertile silt and fish fry to enter the area. This concept deviated substantially from the concept of flood control, which had previously been customarily practiced in many water resources projects in Bangladesh.

In June 1989, the WB, in response to a GoB request, agreed to coordinate a five-year FAP as a first phase of a long-term program. In December 1989, the FAP was presented at a conference in London and approved by the community of donors (this became known as the London FAP-Conference or the First FAP-Conference). After the first phase of the FAP (1990-1995), in which the focus was to be on planning, three successive five-year implementation phases were envisaged. Of the 26 components included in the FAP, 11 were planning components and 15 were supporting studies. Total budget envisaged was approx. US$ 150 million. Budgets for subsequent phases were estimated at US$ 2,000-3,000 million. One of these 26 components was the CPP. Two contribution from The Netherlands government was mainly confined to the financing of the TA (consultancy services, special field studies), while the contribution from the German Government (KfW) was mainly for the physical implementation of the project (water control structures etc).

The important issue for FAP-20 was the testing of the concept of Controlled Flooding and Drainage (CFD), which combines the benefits of flooding with the advantages of protection against flooding. It was further emphasized that proper attention to people's participation, social, environmental, economic and operation and maintenance aspects should be given.

December 1989

Report of the CPP Project Identification Mission, launched by the international donors Germany and The Netherlands together with representatives from Bangladesh, stipulated the implementation of this project to be performed simultaneously in three different areas (Tangail Pilot Project, Sirajganj Pilot Project and Jamalpur Priority Project); this selection was based on the assumption that these three sites represented three different physical settings with particular features representative of their regions. Draft ToR for the execution of the project was prepared.

December 1989

The Bangladesh Action Plan for Flood Control adopted the pilot project approach. The general objectives of FAP 20 were:

- To arrive at feasible systems of water management for the development of protected areas; and
- To arrive at guidelines for the development of protected areas in the FAP in general.

1991-1992

CPP mobilized and started preparing for fieldwork. 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.

The original time-frame of the project was foreseen to run 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. The original concept of the project (CPP), construction of primary embankments with a secondary line of defense became questionable soon after FAP started as maintaining hundreds of kilometers of embankments seemed to be physically impossible in the national context.

It is important to point out why exactly the Tangail area was being chosen as one of the CPP project areas. This decision was based on two main considerations:

- The Tangail area already had an extensive existing embankment system, developed in the early sixties, partly under the Food for Work program (under the World Food Programme - WFP) and partly developed under local government initiative. This existing embankment system of approx. 60 km surrounding the Tangail area was mostly maintained under local government and private initiative; and
- The Tangail area was located at a safe distance away from a main river (i.e. the Brahmaputra) such that eventual river erosion from the Brahmaputra River would not be able to destroy the project area in the foreseeable future. The floodplain area between the Brahmaputra and the Tangail area included some main spill channels, which would be able to convey the necessary floodwater to the floodplain area.

March 1992

The Second FAP Conference was held in Dhaka, at which reports were discussed on

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the technical, social and environmental issues encountered in formulating a comprehensive plan. The general image outside the FAP considered FAP as a loose conglomerate of projects, not merged within a conceptual framework.

While many of the FAP projects were not yet in full swing, CPP had already obtained its first field results. Consensus emerged during this conference that there was a real need to discuss this important project at both national and local levels, since approaches and strategies were insufficiently defined.

It was, therefore, suggested that the FAP should be raised for discussion in parliament. Furthermore, it was recommended that NGOs and other interested agencies and individuals should have more access to FAP reports, and more transparency was encouraged.

1992-1993

CPP started fieldwork, in both Tangail and Sirajganj, with a broad spectrum of baseline surveys, supporting studies, option development etc. Furthermore, the institutional process started by launching a process involving a need assessment survey, consultation meetings and ultimately the organization of meetings in which water management committees were established.

Extensive discussions took place with FPCO, which was the lead agency for the entire FAP program. Development options were elaborated on how to proceed with information gathered from the field and how to translate these into actions. Field studies multi-disciplinary research and multi-criteria analyses were used to analyze the field data. Four potential development options were formulated, which each addressed/emphasized part of the potential water management strategies in this setting (varying from "flood protection only" to "drainage only").

On 29 June 1992, a crucial meeting was held with between CPP and FPCO/PoE (Panel of Experts) to determine which options would actually be discussed with the public. The FPCO/PoE decided that only those options would be considered which involved flood protection using controllable inlets. The alternatives selected assumed complete compartmentalization. The differences between the various options related to the degree of flood control and reduced opportunities for fisheries and navigation.

Both the Tangail compartment and Sirajganj compartment were targeted for this work. Strategy papers on formation of water management committees (also called

Water Users Groups) outlined in June 1993 and various steps were taken to formulate these.

Early 1993

FPCO formulated the GPP which indicated how people's participation should be performed in water resources projects, including how this participation should be developed within the planning process. Hundreds of projects had already been executed in the water resources sector in the conventional way prior to the formulation of the GPP, very much in line with traditional top-down and sectoral approach, whereby needs were assessed and implemented by the executing agencies without (sufficient) consultation and/or interaction with the stakeholders.

The GPP document was based on very limited practical experience, as there was no practical hands-on experience in the field of compartmentalization and people's participation, even outside Bangladesh. Elements of this approach had been identified in floodplain areas in Myanmar, where the compartmentalization technique had already been used in the early sixties and seventies. The guidelines developed by FPCO were based on practices in irrigation projects, but not on the more complicated situation in floodplain settings, in which flood control, drainage and irrigation were all interconnected.

However, the advantage of having formulated the GPP at that stage was that discussion was initiated as to how to address this issue at practical field level and to have a concrete document that could be adjusted gradually. The "guidelines" were also intended to apply to newly emerging projects, although it was realized that changing the setup of projects which had started already, each with its own approach and momentum, would be very difficult.

The ensuing discussion made policymakers aware that viability, sustainability, and replicability of good projects very much depends on embedding the people's participation approach into an integral planning tool. As CPP had already started its institutionalization process and formulated a field-based approach, a need for modification became obvious. CPP took the freedom to adjust practices recommended in GPP wherever necessary for reasons of practicality and produced its own guidelines in August 1993.

Second Quarter 1993

The Dutch Government, as one of the key players in the water sector in Bangladesh, commissioned a study into the status of the FAP, and in particular the involvement of

GoN in this process. This study from IOV (an independent evaluation organization within (GoN) was stimulated by the strong opposition that existed within Bangladesh but also outside its borders, to the allegedly planned construction of large-scale water control works. In particular, the lobby of local NGOs towards the international NGOs (mainly based in Holland and Germany) became stronger. After a thorough desk study complemented by a field study in Bangladesh, the IOV study concluded that new studies should be conducted in the light of new perceptions on integrated water resources management related to people's participation and environmental impact assessment. It was also recommended that the following main issues be addressed:

- More participation by stakeholders in planning, implementation and O&M;
- Adaptation of an integrated approach to water management; and
- An improved institutional framework where necessary.

It was even mentioned that the original ToR for CPP as defined in 1991 should be renegotiated, which in turn would allow for a more flexible approach to integrated water resources management. This adjustment of the original CPP's ToR was seriously considered during that IOV mission, but ultimately the mission refrained from endorsing this in its' report.

Many opponents of FAP criticized the plan's approach of stakeholder participation, institutional issues, integrated water resources management etc. were all words used by many opponents of FAP in general, not realizing that hardly any public-sector project addressed these issues in a holistic way, and that practical experiences in this respect within Bangladesh were practically non-existent.

In response or in addition to the IOV mission, the Dutch Minister for Development Cooperation, in a letter to the Dutch Parliament (21 July 1993), stated that FAP-20 has contributed to the development of people's participation approaches within FAP. It also stated that significant developments had taken place in the preceding three years (i.e. 1990-1993) and that FAP-20 had made a substantial contribution to this discussion. It concluded by saying that further refinement of active people's participation was necessary, and that the current GPP (issued in March 1993) was not sufficiently binding and caused confusion as the terminology and approaches to participation were too loosely defined.

May 1993

The Third FAP Conference took place amidst controversy. FAP (which included at that time approx. 15 studies running concurrently, varying from agricultural impact studies to river training and desk studies) was heavily criticized both at national and international level. Main points brought forward by the opponents included lack of adequate and correct information on procedures (at project and/or program levels), not feeling involved in the process of the development of FAP, and not agreeing in which direction FAP was developing.

There was an apparent eagerness of many groups/organizations/institutions to be part of this plan. Political motives also played a role in FAP, which had developed the image of a project, surrounded by "total controversy". The multi-component setting of the plan, the multi-disciplinarity of pilot projects and the unfamiliarity with many new integrated approaches (e.g. public participation etc.) all contributed to this image. An effective information system was not present, and for outsiders, it was quite difficult to access adequate and timely information.

A few days later, a European Conference was organized by the Green Group at the European Parliament in Strasbourg on the FAP in Bangladesh. The mood here was similar to that at the previously held FAP Conference at Dhaka. Comparisons were drawn with the construction of the Narmada Dam, Aswan Dam and other "mega" projects. FAP was considered to be of even larger scale. No Bangladeshi officials were present during this meeting, including the planning organization explicitly responsible for the coordination (FPCO).

August 1993

CPP formulated its own policy and produced tentative guidelines on people's participation in the planning and design phase of compartments. At this time, the planning and initial design for both the Tangail and Sirajganj compartments were finalized. The need assessment was followed by several rounds of consultation meetings, which culminated in an endorsed design for further implementation. Early experiences of the pilot project areas were described in this document. The first water users groups (committees) were established in the northwestern part of the Tangail project area before the 1993 monsoon season and actual testing started.

December 1993

An integrated cost-estimate of planning and construction for both Tangail and Sirajganj compartments was prepared, in which a long-term detailed planning schedule was developed for both compartments, taking into consideration progress on consultation, design, implementation and land acquisition issues. The planning horizon was December 1995, before which both compartments would have all construction complete, following proper rounds of public participation.

December 1993

In view of the turbulence surrounding CPP during the year, a need was felt for finding a way to converge the diverging approaches and attitudes towards FAP and FAP-20 in particular.

At the end of 1993, the Dutch government launched a unique initiative. It offered to release the Sirajganj project (the second pilot project area from CPP) to a consortium of NGOs and/or other institutions/organizations etc. to initiate the development of the Sirajganj area, according to their own criteria. This initiative was officially proposed by The Netherlands Embassy on behalf of the Directoraat Generaal Internationale Samenwerking (DGIS) and in coordination with KfW in a meeting with ADAB, CEN, WB (Washington and Dhaka bureau), FPCO (predecessor of Water Resources Planning Organization - WARPO), the Dutch Embassy and CPP.

The Dutch government was also willing to finance the technical assistance in the same way it did for the Tangail CPP area. For that purpose, the Sirajganj CPP area would have to be separated from the Tangail CPP area. However, no reaction was received from the NGOs, neither during this important meeting, nor after the meeting.

June 1994

CPP was in full swing organizing consultation meetings in order to be able to establish water users groups and Sub-compartment Water Management Committees (SCWMC). The first committee was formed on June 1, 1994, while two more were to follow just before the onset of the monsoon 1994.

A joint donor review mission for CPP (GoB, DGIS and KfW) concluded that in spite of the integrated planning document (December 1993), the Sirajganj CPP activities would be "frozen". Although a public consultation round had been held in various phases, both in Tangail and Sirajganj, the Sirajganj project was put on hold with almost immediate effect. The constraints in Tangail where public participation proved to require a major effort (much more than originally perceived) included a backlog of physical implementation and difficulty with a complicated land acquisition procedure. Therefore, the donors reconsidered the time-frame for this project.

A further complication was that for the Sirajganj area the stability and physical maintenance of the BRE could not be guaranteed. The Sirajganj compartment is located immediately behind the BRE. This embankment had been retired many times since it was built early 1970, but maintenance was confined to "retired" embankments. The tendency of the Brahmaputra River to change its course would remain a potential danger to the development of this area. This danger had already been recognized during the identification of CPP: Surveys and public participation had raised the expectations of the beneficiaries that a lasting solution would be achieved by the project. The donors decided in June 1994 that the Sirajganj area would not be implemented pending a firm commitment from GoB that it would strengthen (or further protect) the BRE. This firm commitment never materialized on paper, which led the international donors, a reason to freeze the activities for the Sirajganj component.

A major concern was also that for the Tangail area, the approval of the Technical Assistance Project Proforma (TAPP) was delayed by 18 months, which made financial handling of contracts difficult in particular the matter of land acquisition. These two factors then would result in further delay in implementation, and subsequently also in the achievement of the ultimate goal, the testing of the compartment. Donors saw the time officially allocated for the project (until December 1995) quickly approaching without seeing test results. It was decided to de-link the Tangail and Sirajganj project areas so that the available resources could be focused on Tangail only and so that Sirajganj project would form a separate entity i.e. CPP Tangail and CPP Sirajganj. Consequently, a separate TAPP document had to be written for Sirajganj requiring separate funding from (inter) national sources.

October-November 1994

Concerns were raised about the potential blocking of the Dhaleswari River, a main tributary from the Jamuna River, as a result of the then-upcoming construction of the Jamuna Bridge. While the Jamuna Bridge was implemented under the Jamuna Multipurpose Bridge Authority (JMBA) and CPP under the Bangladesh Water Development Board, also known as BWDB, (under the Ministry of Water Resources), coordination initially was very poor.

It was anticipated that due to lack of sufficiently large natural spill channels in the floodplain area between the Jamuna and the Dhaleswari, that part of the Tangail district are (approx. 50,000 ha) would be substantially deprived of floodwater. This impact area was much larger than the approx. 12,000 ha under CPP. This blockage was eventually overcome by the formation of an inter-ministerial committee (including WB and donor agencies) which mitigated the blockage by deepening an existing spill channel which then restored the original flooding pattern in that part of the floodplain area.

December 1994: CPP Extended for One Year

CPP was originally planned for completion by the end of 1994, as foreseen in the original ToR. Delays in implementation were caused by extended public participation, time delays in endorsing design for water control structures, and slow-moving land acquisition procedures, for which budgets were not readily available as a result of a delay in approving the TAPP. The donors decided to extend the project for one year, during which the future of FAP in general was also to be resolved.

Towards the end of the originally envisaged period for FAP (planned for December 1995), USAID commissioned a study to assess the developments made under FAP since its inception in 1990. The study, Water and Development in Bangladesh: A Retrospective on the Flood Action Plan recognized in its analysis that two major problems remained unsolved:

- The FAP study process and the more sensitive approach to water management that it has generated, needed to be institutionalized through a major overhaul of water sector administration. The drive for environmental sustainability is still at a fledging stage and much work is needed to institutionalize it and assure its broad application.
- While the five-year debate about the merits of embankments and polders has been going on, local flood preparedness and flood proofing steps have not been pursued, so that the countryside could be as vulnerable to a major flood now as in 1988.

The review acknowledged that the issuance of the Guidelines for Project Assessment (GPA) and Environmental Impact Assessment (EIA), together with the study character of FAP, reflected the increased attention given to the public participation component. The review expressed also the opinion that the water sector was a very confined and well-defined stronghold of engineers. Some had learned through the FAP how to approach grassroots-level problems, in conjunction with interests of different groups and committees at different levels. It was acknowledged that these interactions and communication skills are not being taught at the university or at professional training institutes and therefore comprise unfamiliar approaches for conventionally educated professionals.

CPP Open an Information Dissemination Center (IDC) in Tangail

In late 1994, CPP opened an IDC aimed at making the activities, policies, targets etc. more transparent for both the rural and urban people. As Tangail is in the physical center of the project area, many rural people visit Tangail town frequently and therefore have easy access to this center. At the center, interested parties could access project documents, multimedia display of activities (videos, pictures, maps, and information boards) and frequent sessions were held with journalists, to interact on the program, constraints and progress of CPP.

Many interested parties at both national and international level consulted this center, as it was the first of its kind in a water resources project in Bangladesh.

June 1995-A Change of consultancy Team

Within the one-year extension period of the project (calendar year 1995), an evaluation mission was planned on behalf of the donors, which would shed light on the prospects for the project, considering the developments, progress, constraints of FAP as a program and the future of FAP-20 in particular.

This evaluation took place during June 1995 and identified a number of implementation problems. Their main point of criticism was that "there were too many cooks in the kitchen" (official quote from the evaluation report), in particular aiming at flaws in the public participation procedures, especially at representation of certain interest groups at certain levels (women, landless etc). It was also noticed by the mission that disengagement of NGOs from the public participation process was a major drawback, as NGOs could potentially play an important role in this process.

The mission concluded that "... the mission unanimously and strongly recommends to pursue the pilot process further", recommending that the consulting consortium would be disengaged and that a new consultants team would further lead the process after a re-formulation mission to be fielded by the donors. Although the mid-term evaluation was never officially approved by the donors, its recommendation of reformulation was accepted, and invitations were issued for consultants to bid for a new reformulated phase of the project.

Accordingly, the then current consultant team was disengaged with effect from January 1996 and a new tender procedure established.

September 1995

As FAP was approaching the end of its mandate (December 1995), a follow-up action was to be formulated by GoB in which a longer-term strategy would be laid out. This officially endorsed GoB document (Bangladesh Water and Flood Management Study - BWFMS) outlined a framework for the development and implementation of a strategic national water management plan for Bangladesh. It reflected on the outcome of the FAP program 1990-1994 and stipulated a further five-year plan during which a national water management plan should be developed, thereby including strengthening of water sector organizations and implementation of high priority projects. It also acknowledged weaknesses in the field of national planning capabilities and institutional issues at field level. In September 1995, the BWFMS was approved by GoB.

October/November 1995

The donors decided to proceed with findings of the evaluation mission and it launched a reformulation mission to address the main emerging issues.

The reformulation mission report recommended a more coherent strategy that reflects the following:

- The development of water management activities on the ground;
- The identification and monitoring of management policies and guidelines for both the compartment structure and wider management issues; and
- The operation and maintenance of the compartment infrastructure.

It also stated that different tiers of the institutional structure developed to meet these functions must have a clear legal basis and clearly defined internal constitutional arrangements. It recommended that a substantial program of water use group formation should take place based on a wider range of water uses than considered to date. The report also recognized that institutional development and people's participation were the areas of greatest challenge. It continued by stating that:

> *"FPCO has developed an approach to water use group development which will form the basis of future initiatives in the sector, and the Systems Rehabilitation Project (SRP) has on-the-ground experience with the formation and functioning of groups formed by a similar process. The CPP should build on and provide a testing ground for this approach".*

The following conclusions were drawn with regard to the future activities of the project:

- To broaden the scope of the project;
- To define an effective approach to ensure peoples participation (especially women and economically marginal groups);

- To create an institutional development process which is viable, sustainable, replicable and capable of conflict resolution;
- To move from the project approach to a process approach which is integrated into the national institutional framework;
- To formulate proper mitigation measures; and
- To improve the monitoring and evaluation of the project.

Compared with the original ToR for CPP (issued in 1990) the revised strategy developed in the Reformulation Mission Report emphasized that more attention be paid to public participation, taking into account all groups, to integration of water resources management year-round and to properly addressing the issues of gender, mitigation measures and a well-worked out M&E system.

27 November 1995-Dhaka: People's Conference on FAP

On November 27, 1995, the CEN and ADAB organized a 'People's Conference' on FAP at Dhaka. It was labeled as an "Alternative to the Government and Donor Organized Conference" (meaning the Fourth FAP Conference). A preparatory meeting was held in The Netherlands on October 25, 1998 where ideas were compiled and strategies were discussed. Representatives from the GoB and project were not invited. In this preparatory meeting, some GoN representatives attended there, who were to attend the official FAP conference a few days later. The conference was characterized by a populist approach, and by pre-selection of local interest groups opposed to the project. In this respect, its contribution to a formulation of a revised FAP strategy was very limited.

30 November-1 December: Fourth FAP-Conference

The Fourth FAP-Conference (November 30 - December 1, 1995) took place after having been postponed several times. The timing of this conference was important because of three issues.

- The growing number of "concerned" organizations/donors involved in the FAP process;
- The likely discontinuation of FPCO activities as "guide" for the FAP-activities (FPCO was a temporary organization and supposed to be dissolved by the end of 1995); and
- The required endorsement by the donors of the Bangladesh Flood and Water Management Strategy.

The BWFMS report outlined both short-term and long-term investment programs, which included a list of potential projects to be implemented during 1995-2000.

Calendar Year 1995

Criticism of the project's participatory and institutional approach was voiced by various interest groups. Nevertheless, CPP was able to establish a total of 80 chawk committees and seven sub-compartment committees during the calendar year 1995. During the 1995 monsoon, CPP experienced its first flood (magnitude 45 cm below 1988 level) since substantial completion of the physical infrastructure, during which the majority of the confined project areas remained flood free and water management was performed by the newly established committees. Consequently, partial testing could be performed by the local water management committees. CPP organized a water management workshop to discuss the first results with the beneficiaries.
The Dhaleswari problem (see October-November 1994) was partly restored and partly resolved by nature as the flood levels were close to the 1988 level, forcing existing natural spill channels to be filled up and new spill channels to be formed, discharging the flood water from the Brahmaputra main channel into the floodplain. Because of the high water levels, a new main channel formed naturally between the Brahmaputra and the Dhaleswari, thereby resolving the problem of blockage at the Dhaleswari mouth.

February 1996

Partly because of lobbying by various NGOs, the German Minister for Development Cooperation, Mr Spranger visited the project area. Some NGOs had informed the Minister that the majority of the population within the compartment, and in the adjacent areas, was opposed to the project. Furthermore, it had been claimed that participation of NGOs and involvement of women was severely limited.

Based on the Minister's impression after having concluded the field visit, a new independent study was commissioned (one of the members had also been member of the mid-term evaluation mission) which was to investigate two main aspects:

- The status of land acquisition; and
- The perception of the people regarding the activities from CPP.

October 1996

After a 10-month extension, following the one-year extension, CPP (Final Phase) started with a new consultant's team in the field, based on a newly formulated ToR, in which a process-oriented approach was advocated. A new institutional approach was developed, in which more diverse representation of the beneficiaries was ensured at all three levels of representation, based on the suggestions of the reformulation mission and on the field experience gained to date.

April 1997

A special independent study which had been commissioned by KfW (see February 1996) was published on CPP's strategy for solving the problems related to land acquisition and the perception of the people regarding the project and its perceived impact. In its executive summary, it explained the background of the problem:

> *"There have been a series of criticisms from different quarters on the implementation process of CPP, particularly with regard to the process of people's participation in planning and decision making. Some of these criticisms have been accepted by all parties and are reflected in the evaluation and reformulation of CPP, which took place in 1995. Others are still a matter of controversy, with different parties putting forward widely contradictory claims about what has been and still is happening in the project area (as well as in adjacent area) and what local people think about the project. It has been found very difficult to assess which of these contradictory claims are most valid, due to absence of a clear in-depth and systematically collected information on these aspects. This report is the result of a study which had sought to fill this information gap."*

The report concluded that:

> *"CPP has been the first project of the GoB where efforts have been made to operationalize the concept of participation in the light of the guidelines for peoples participation.*
>
> *A good majority (76%) expects the project to solve flooding problems in their locality. The study found that many people feel that the project has brought in a range of benefits for the people of the project area, in particular citing benefits such as increased agricultural outputs and the spread of HYV cultivation, infrastructure development, improved transport, flood control. This study supports the argument that CPP has led to direct and material improvements to the economic position of the project area, with all sections of the population benefiting".*

July 1997

Following the visit of the German Minister (see February 1996), the Dutch Minister for Development Cooperation Mr J Pronk, visited CPP. This Minister had participated in the launching ceremony for the project in 1991, and came to see the project for himself after 6 years, during which heavy criticism had been directed, not only in the national and international press but also in the Dutch, German and European parliaments. However, the project or FAP in general was, in spite of its importance at national level, never discussed in the Bangladesh parliament. General satisfaction was expressed on the progress of the project, and the Minister stated that the project seemed to be supported by the majority of the people living in the area.

The Minister also officially opened CPP's IDC, which contributed to emerging transparency in the project work and as a means for interchanging ideas. The IDC had been unofficially open since December 1994.

December 1997

The SRP (a water resources project financed mainly by the European Union and the Dutch government) organized a seminar on "Guidelines for People's Participation" in order to consolidate the various opinions on the guidelines and stimulate interaction.

March 1998

The NWMP was launched in March 1998 by various donors.

Whereas the formulation of FAP had been largely confined to studies and pilot projects, with an emphasis on wet season water control, limited transparency of the process and some lack of clearly defined goals and targets, the process had by this time evolved into a multi-sectoral, multi-disciplinary approach. Lessons had been learned in the areas of environment, people's participation and Integrated Water Resources Management (IWRM). The final goal perceived as an extension or continuation of FAP, was to establish a national water management plan directed towards IWRM.

Despite active efforts from the policy makers in the water sector program, no comprehensive government policy regarding national objectives for natural resources management had emerged up to this point. The National Water Policy (NWP) which was at this time being finalized was intended to be define the national objectives and allocate an economic price to water. On November 2, 1998 the Bangladesh National Water Policy - NWP was approved by the National Water Council (the highest water authority in Bangladesh), and later endorsed by the Cabinet and Prime Minister.

September 1998-December 1998

Various new initiatives were launched to address the need for institutional reforms within the water sector, although it had been foreseen that the NWMP would be the focus of a new water strategy. These initiatives included:

- The Joint Netherlands-Bangladesh mission formulated the Integrated Planning for Sustainable Water Management (IPSWAM) project.

Draft Report on the Joint Formulation Mission, EIP; the IPSWAM program is to be carried out during the period from 1999 through 2004, based on lessons learned from EIP/SRP under BWDB.

- The WB in collaboration with BWDB formulated the Water Sector Improvement Project (WSIP) in the second half of 1998

The broad general objective of the (proposed) WSIP is the improved livelihood of local people, through better management of water and water-related resources, involving sustained operation and management of the local water resources systems, with institutional reform and re-focussing of the role of government institutions. The focus is intended to be on the already completed BWDB, FCDI projects, between 1000 and 5000ha (nationwide).

The NWMP is under formulation and will be issued in June 2000. The NWMP can then further elaborate on the priorities and work out alternative scenarios for short, medium and long term.

Monsoon 1998

The worst flood in recent history occurred. Maximum flood levels almost reached 1988 levels and the flood duration of 2 months inundated large areas in Bangladesh, causing severe damage to crops and infrastructure. The CPP area was, in contrast, hardly damaged, and the Tangail town remained flood free, thus demonstrating the effectiveness of the project physical and institutional infrastructure.

For CPP, the flood protection afforded the compartment laid to rest, once and for all, any lingering criticism of the project.

Annex B
Engineering and Construction

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Appendices

Scope of the Annex

This annex describes and examines the engineering and construction related to the Compartment. The design of the works will be discussed and the construction, including dates of completion. Dates of completion have had an important impact on the development of the Compartment. The water management, which is the purpose of the construction, has frequently lagged well behind due to incomplete construction, particularly of the *Khals*. The final chapter is devoted to the costs of the works. A maintenance plan is added as an appendix. The operation of the system and the water management in the Compartment is subject of another annex, the one on water management and modeling.

The works executed under the Project can be sub-divided into two categories. The first is the Major Works, which are works that are typical for a drainage and flood protection system. Although they are called Major Works, they are not all necessarily major in size. The term is chosen to distinguish them from the second category, the Minor Works.

The Major Works consist of embankments and protection works; and of 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, The Compartmentalization Pilot Project (CPP) built additional structures, mainly bridges and culverts, which do not have a function in water management, but which facilitate communications. The terminology Additional Structures has been maintained in the annex to refer to them.

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

There is a remaining group of Major Works, which includes work on roads and embankments within the Compartment and outside in the Adjacent Areas (AA). Tangail Town drain belongs to that group. Except for the latter, the remaining works are measures to mitigate the impact of the Compartment.

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

All Major Works have job numbers. Job numbers usually start with the number of the cluster the job is in, except for the works on the peripheral embankment and outside the Compartment. Maps with the locations of the Major Works have been presented.

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Minor Works do not have job numbers. They have been designated by their *chawk*. Their exact location is difficult to present on maps.

Figure 1 provides 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 river 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.

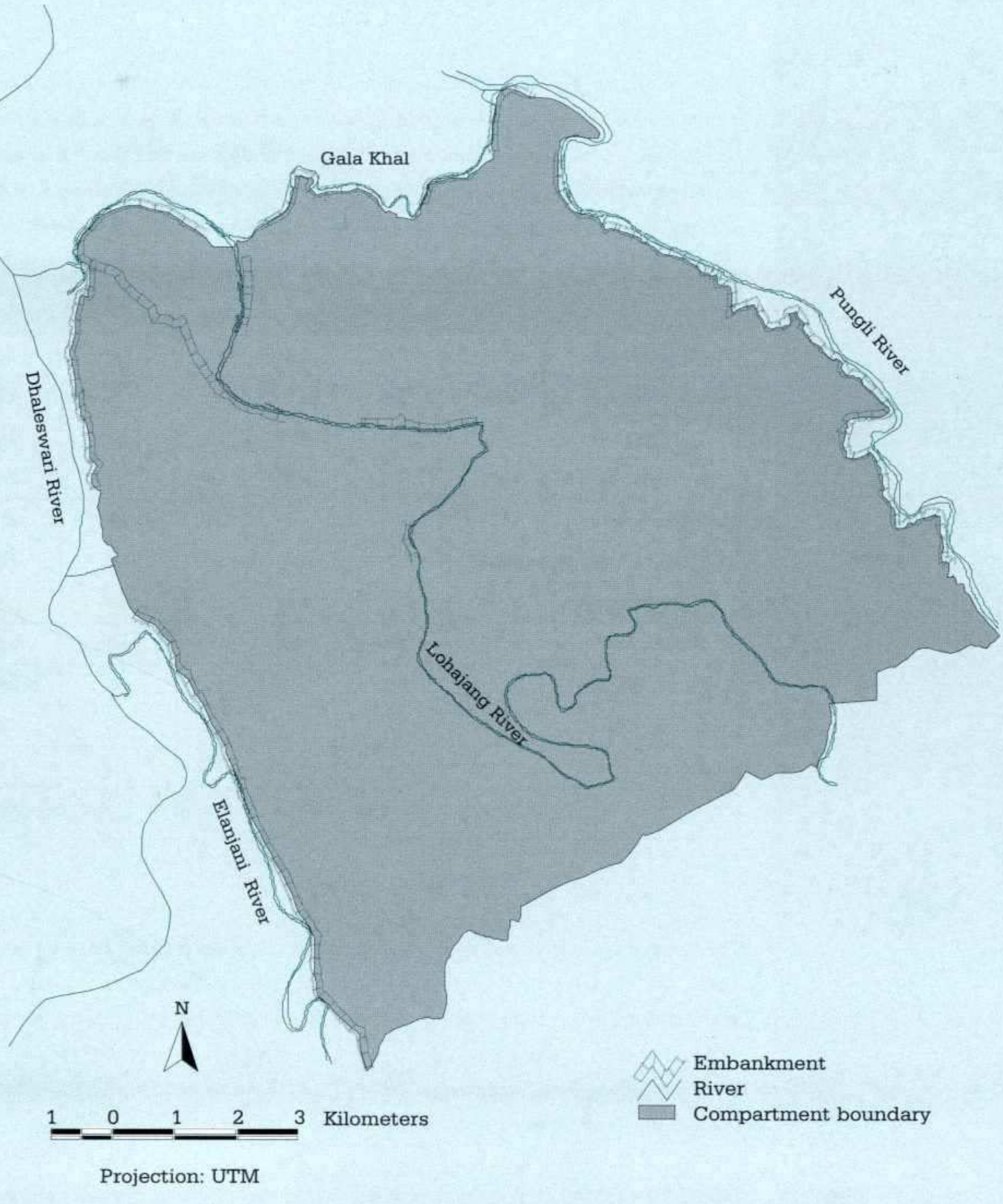

Figure 1: The Compartment before 1991

Embankments and Protective Works

before CPP. They have been determined by the Project.

Peripheral Embankments

Design Criteria

Table 1 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) standards. Its total length is about 47 km. Crest widths vary between 4 and 4.5 m. Side slopes are (BWDB) standards. The average height is dependent on the topographical level of the land and varies.

	Length (m)	Design Crest Level (m PWD)	Crest Width (m)	Side Slope Cntry 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	13.64	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 1: Design Dimensions of the Peripheral Embankment per Sub-Compartment

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. In order to answer BWDB standards, the Northern embankment requires a level of 13.50 m. So, the level mentioned in Table 1, 13.73 m, for the Northern sub-compartments, exceeds the design level.

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 Peripheral Embankments

BWDB is the owner of the peripheral embankment. However, it exercises insufficient control over it. 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. Fish ponds, adjacent to the embankment, reduce its stability.

If embankments need to be rehabilitated, the BWDB applies re-sectioning. Resectioning 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; fish ponds 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 rain storms, 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 a soil body is insufficiently compacted. When the soil becomes saturated, voids fall in the soil frame, which cause erosion from the inside.

Works on the Peripheral Embankments

Table 2 lists the works done on the peripheral embankment, with job numbers and year of completion. Job numbers starting with all 00 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. The locations of the works are shown in Table 2 by means of the job numbers.

Rehabilitation before 1998 included filling the gaps in the embankment shown in Figure 1. 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 the Gated Pipe Inlets (GPI), Silimpur and Rasulpur GPI.

8Y

Job Number	Works before 1998 Job Title	Completed Fiscal Year
Peripheral Embankment		
00601	Ramdevpur - Gopalpur Embankment	1993-94
00602	Gopalpur - Dhalan Embankment	1995-96
00603	Dhalan - Binnafair Embankment	1993-94
00604	Fatehpur Advanced Embankment.	1995-96
00605	Charabari - Silimpur Embankment	1995-96
00606	Ramdevpur - Khorda Jugini Embankment	1995-96
00607	Ramdevpur - Kathua Jugini Embankment	1995-96
00609	Gala - Pichuria Embankment	1993-94
00610	Gala-Rasulpur Embankment	1996-97
00611	Rasulpur - Salina Embankment (Part I)	1995-96
00612	Rasulpur - Salina Embankment (Part II)	1996-97
00613	Salina - Dapnazar Embankment (part)	1996-97
00614	Bangra Embankment.	1993-94
00614	Bararia-Suruj Embankment (Salina-Dapnazar)	1996-97
00615	Khaladbari Embankment	1992-93
00616	Rupshijatra - Silimpur Embankment	1992-93
00617	Rupshijatra Embankment	1992-93
00618	Fatehpur Embankment, repair after 1995 flood	1995-96
Embankment along the Lohajang		
10604	Dithpur Outlet - Main Regulator	1994-95
10605	Pardighulia-SC Embankment (Part II)	1996-97
10801	Approach Road from Chillabari to Dhannya Chow	1994-95
20604	Embankment Dharerbari to District	1997-98
20801	Access Road to District Regulator	1994-95
Protective Works		
20901	Passbetur Groyne I & II	1994-95
41302	Belta Sarai Protective Work	1995-96
60904	Gonikishore Protective Work	1992-93 & 1995-96
60901	Pardighulia Protective Work	1994-95
60903	Protective Work near Rafat Textile	1992-93
Other Works		
60504	Elenjani River Loop Cut	1996-97
61102	Gala *Khal* under FFW	1996-97
Peripheral Embankment		
00601 - 00605 and		
00609 - 00617	Resectioning of Embankment	1998-99
00613	Retired Embankment at Birnahali	1998-99
00614	Salina-Dapnazar Embankment (part)	1999-2000
00613	Additional Resectioning Suruj-Birnahali	1999-2000
20406	Rasulpur GPI	1999-2000
40411	Silimpur GPI	1999-2000
40702	Silimpur Embankment. Breach Closing	1999-2000
Embankment along the Lohajang		
10605	Sarutia-Chillabari Embankment	1999-2000
20604	Resectioning of Embankment Dharerbari to District Regulator	1998-99
10604 and 20604	Add. Resectioning Dithpur-Main Reg and Dharerbari-District Reg	1999-2000
Protective Works		
41302	Protective Work at Belta-Sarai	1998-99
60905	Protective Work at Birnahali	1999-2000
60906	Protective Work near Elanjani Loop Cut	1999-2000
60907	Protective Work at Kumulli	Not started

Table 2: Works on Embankments and Protective Works, with Job Numbers and Years of Completion

The embankment at Birnahali and Kumulli, along the Pungli were heavily damaged and needed repair after 1998. The numbering of the jobs 00613 and 00614 may easily cause confusion. The jobs cover three stretches. The longest is the Salina-Dapnazar embankment, which runs along almost all of the Pungli River. This part was resectioned in 1996-97. A small part in the South, about 1.5 km long, was done earlier during 1995-96 but was not up to standard. It was redone during the 1999/2000 construction season.

Alternative Approach

CPP had little control over the re-sectioning. The only thing it could do was checking quantities. Embankments as the one around the Compartment, should be rehabilitated in different ways. The embankments should be surveyed and an inventory made of the weak sections. Evaluation of the sections should be done based on crest height, crest width, the quality of the side slopes alone and on the compaction of the dike body. Water conveyance structures without gates should not be tolerated.

After the inventory, quality standards for rehabilitation should be specified, including the material in the borrow pits. The availability and distance of proper filling material should be surveyed. Based on the cost per meter and the budget available, rehabilitation of sections should be done. Weak sections should be excavated, filled back and be compacted in layers. Compaction should be checked and recorded. All work to be done under proper supervision.

The approach described requires a thorough re-orientation of working methods. The position of the Project's consultant team as an advisor has been rather weak. An alternative would be to make the Consultant the Engineer for the works, responsible for quality and expenditure. That would require greater involvement of local consultants from outside the BWDB.

Embankments Along the Lohajang

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

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After 1998, the embankments needed additional repairs, which happened 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 2 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.

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, which was ongoing work before the flood and is not a repair job due to the flood.

Other Works

The Other Works are jobs located outside the Compartment. One is the Elanjani River Loop Cut. The Gala *Khal* excavation has been discussed in the Annex on Water Management and Modeling. The Gala *Khal* runs along the northern embankment of the Compartment, between the Main Regulator and the Pungli. Its excavation should be considered a mitigating measure, as it intended to lower water levels in the Northern Adjacent Area (NAA). The work was executed under the Food for Works Program (FWP), at no cost to the Project.

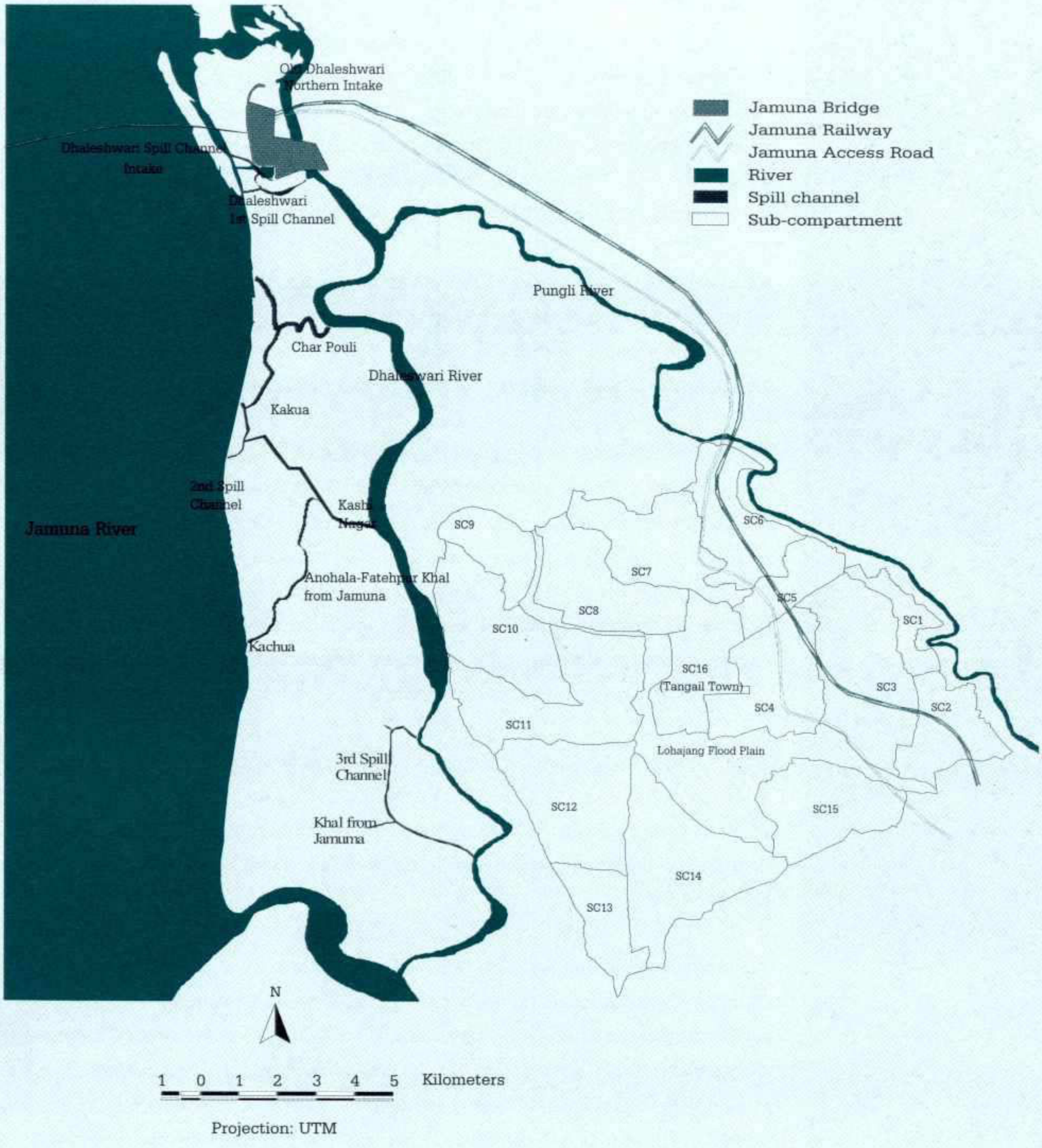

Figure 2: The Tangail Compartment and its Surroundings

Structures

Planning and Design

The locations of the water management structures are shown in the Figures 3-6. 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 outside the Compartment have, particularly those at Karatia, where the river leaves the Project area. That problem could only be solved by modeling.

As described in the Annex on Water Management and Modeling, the first phase achieved to develop models per cluster. It took an additional modeling effort during the second 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 water supply, instead of drainage only. According to a similar reasoning, outlet structures were built at locations where the major drainage systems entered the Lohajang.

Water retention structures, serving only a few *chawks*, can only be built along the outer rim of the Compartment. There is where the single *chawk* systems are. If they are built more towards the interior, they automatically start serving larger areas and their design becomes complicated. In those cases, the absence of an overall design was felt again.

The main sources of information about where to construct such structures were field conditions and the consultations with users and stakeholders groups. In a number of cases, this did not work out properly. Santosh was supposed to protect Cluster 4 from excess water from Cluster 1. Only during emergencies, it should be opened. However, attempts to close the Southern boundary of Cluster 1, ran into opposition and, presently, the structure is not effective because it is bypassed by other infrastructure.

Structures like Burburia and Berabuchna in Cluster 4 and Agbetor in Cluster 2 were expected to regulate water levels in the drainage systems to facilitate the flooding of upstream fields. In addition, that concept has not worked out properly, at least during the Project years. The structures are not been operated, but may appear useful in the future.

With respect to the design of water levels, those could only be determined based on considerations at system level, as there was no Compartment design. Design criteria for most of structures, not all, are mentioned in the References 1, 2 and 3, for the Clusters 1, 2 and 3.

The References 1, 2 and 3 do not specify detailed design criteria. They provide design considerations. The actual designs were made by the BWDB's Design Circle in Dhaka. The Design Circle does not provide design reports. Design reports on the Main Regulator and the peripheral intakes were not submitted.

Drainage Requirement

At an early stage of the Project, the drainage requirement of the Compartment was determined at 79 mm/day or about 9 l/sec.ha. This was based on the drainage of a 3 days maximum rainfall. The requirement was 3 times higher than that of BWDB, which was one inch per day or about 3 l/sec.ha. The latter was based on a 10 days maximum rain.

Project staff during the first phase, were aware of the difference, but the issue was never resolved. The model simulations confirm that Board's criterion is more realistic. However, that is only the case because the excavation of the secondary drainage systems was not effective and the capacity of the drainage system remained largely as it was in the pre-project situation. If the drain excavation had been effective, drainage requirements would have gone up.

A certain duality with respect to the drainage requirement has remained. In the documentation about the design of the outlet structures along the Lohajang, the design discharges indicate that the high drainage requirement was maintained, while the dimensions of the gates and their vents are based on the low rate.

Design Procedures

The design procedures via the Design Circle of the BWDB are rather unsatisfactory. Part of the design criteria actually used never come out. The procedures prevent repeated adaptions of designs, which are common and useful during the design and implementation of civil works. The Circle is not open to discussions about such matters, which is of disbenefit to projects and would not appear to be to the longer term benefit of the Circle also.

The alternative is to put more emphasis on local consultants in design and supervision. The BWDB would then only approve or disapprove. It is recommended to give this approach more support for drainage and flood control projects.

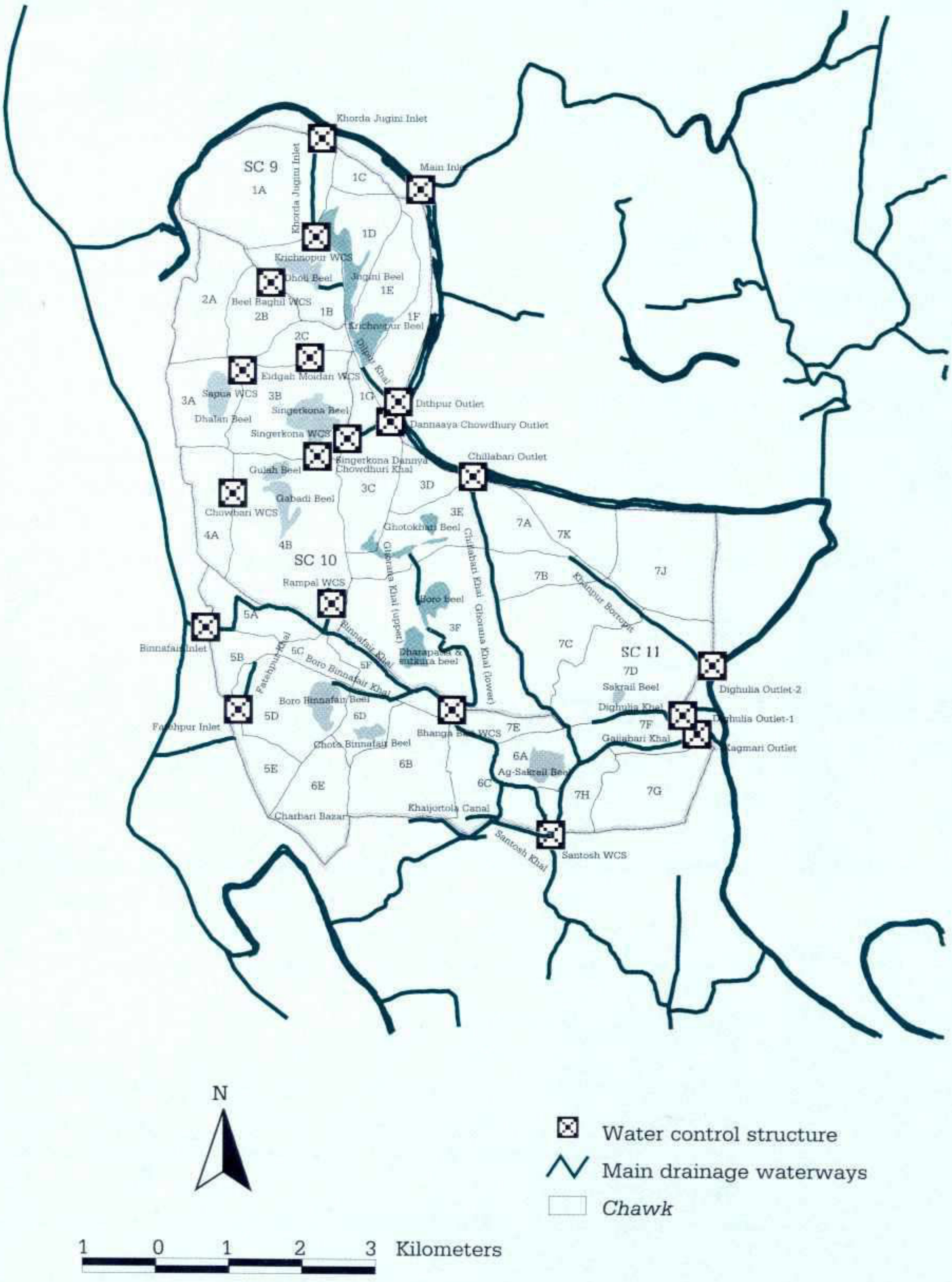

Figure 3: Water Management Infrastructure Cluster 1

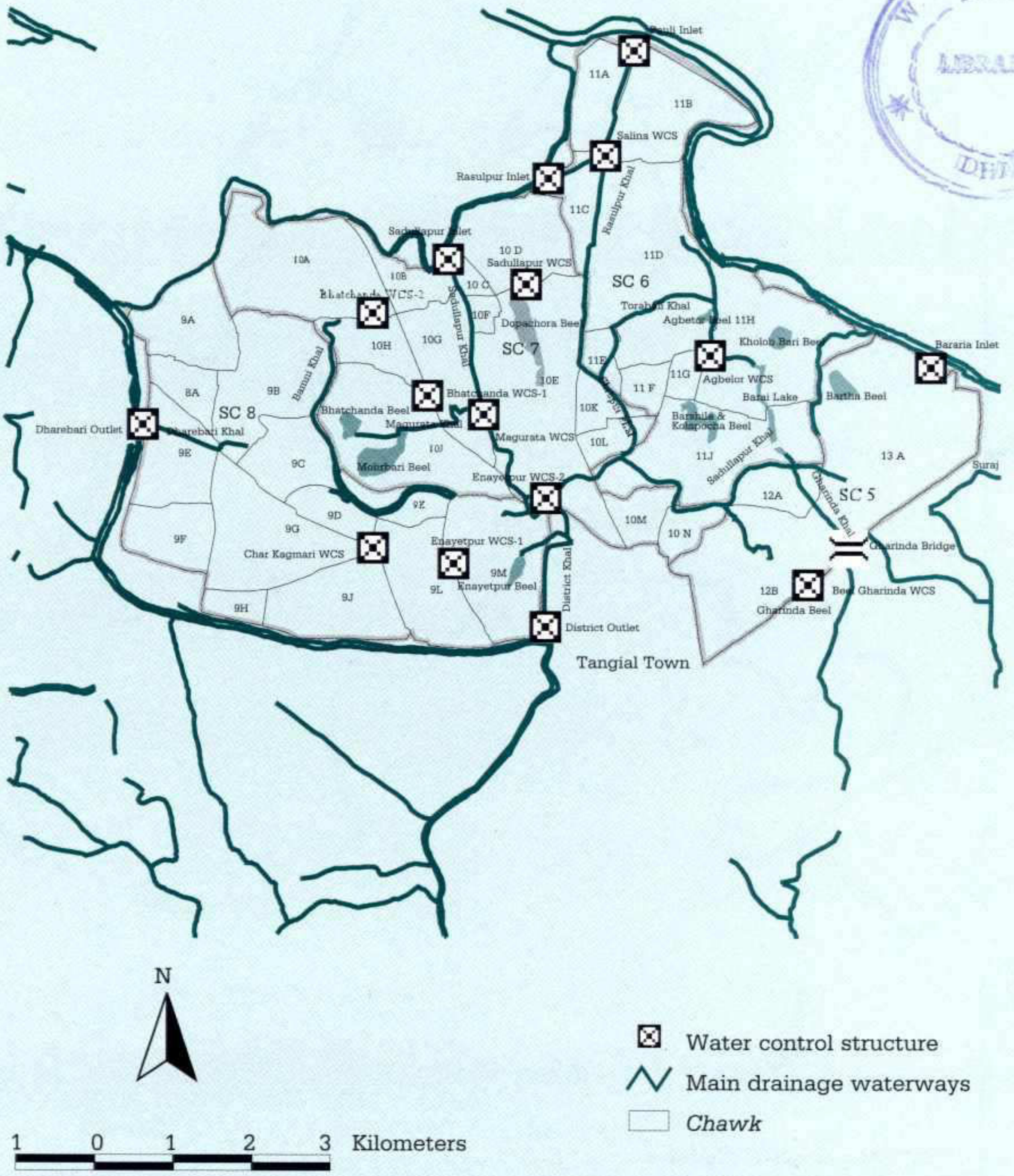

Figure 4: Water Management Infrastructure Cluster 2

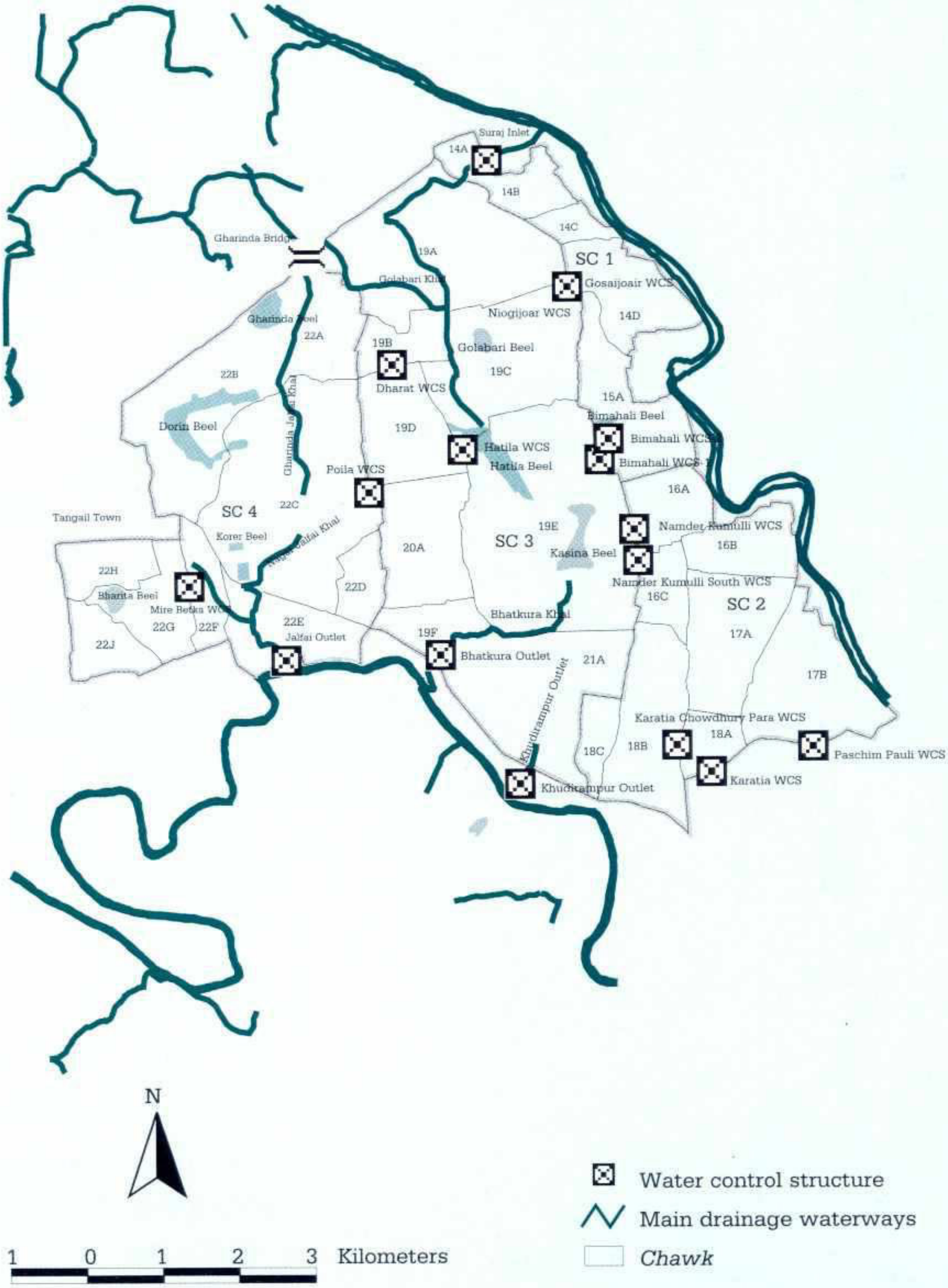

Figure 5: Water Management Infrastructure Cluster 3

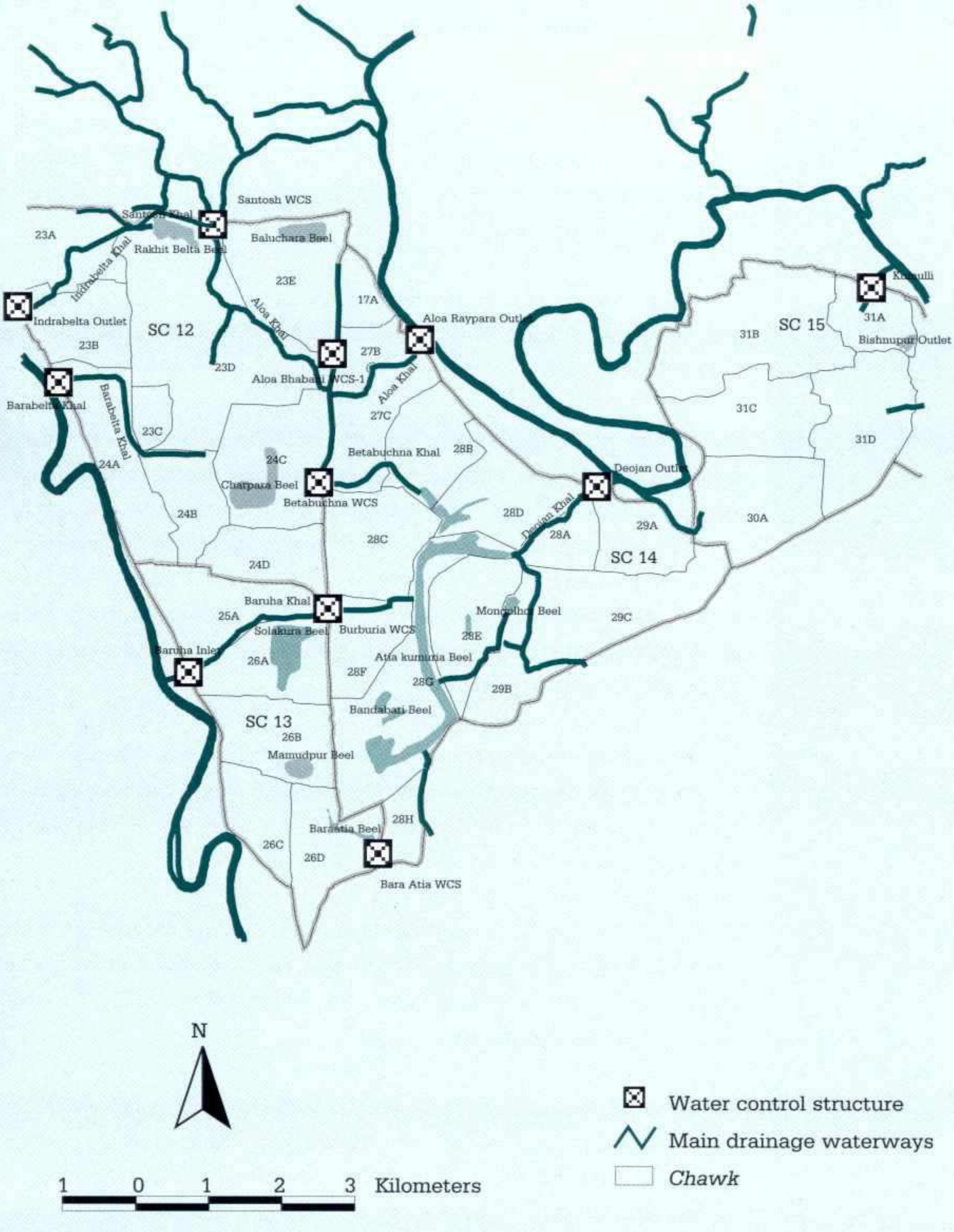

Figure 5: Water Management Infrastructure Cluster 4

Fish and Maintenance-friendly Design

In the early years of the Project, gate designs at some water management structures were implemented, which are considered, in retrospect, to be over designed. Examples are Dithpur and Chillabari Water Control Structure (WCS). Chillabari has double gates, one upstream and one downstream. Many other structures have facilities for double gates, although the gates were never installed.

Many intake and outlet structures have fish-friendly gates, with an upper and lower gate in each vent. Dithpur has such gates, but in separate vents, creating a rather wide structure.

The essence of fish-friendliness is, as far as gating is concerned, that it should be prevented that the gate is half open, i. e. the bottom of the gate extending into the water, when fish is migrating. Hydraulically speaking, undershot flow occurs. The relatively sharp edge of the gate and the often high water velocities and turbulence that go with undershot flow, are harmful to hatchlings, which tends to swim near the water surface. It is better to let the water flow freely, without any gate in the water, or, use a lower gate that is lowered to the sill and let the water pass over it. In all cases, free flow is to be preferred.

The use of an upper and lower gate implies fish friendliness and still allows flexibility in gate operation. The lower gate may close the gate partially; the upper gate is either open or fully closed. In the Compartment, all structures with double gates have separate hoisting gear for the lower gate, which uses cables.

If the costs of such gating have to be reduced, there is an alternative to fish friendly operation. When using single gates, operators could be trained to always lift the gates above the water and prevent undershot conditions. Gates could be opened part of the time to regulate discharges.

The gates provided at most structures, are standard BWDB gates, which may be sturdy but which can not be easily repaired locally. The designer should consider that Water Management Committees (WMC) would do the maintenance. Local maintenance will have to be done by local artisans. Considerations of costs and efficacy of maintenance call for simpler designs and greater involvement of local contractors and artisans. At a number of structures, such simpler gates have been installed, later during the Project, to reduce costs.

The Additional Structures

Additional structures are structures which do not have a water management function but which mainly facilitate transport, communication or local drainage. Most of them are rather small scale and serve a few *chawks* only. In this respect, they are comparable to Minor Works, to be discussed later. Fig 7 shows the locations of the additional structures and the additional drains, to be discussed in the next chapter, by means of job numbers.

Implementation of Structures

Table 3 lists the structures implemented by the Project, their job numbers and the year of completion. Per cluster, first, intakes, outlets and water control structure have been listed under the heading Water Control Structures. (WCS's) are used in the water management in the Compartment. They all have gates.

Next in the table, are so-called additional structures. Those are structures which facilitate drainage and/or road transport, but which can not 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 the influential persons, who held out for higher compensation for land acquired by the Project. The number of additional structures is largest in the Clusters 1 and 3, while they are few in the other two clusters.

Job Number	Job Title	Completed Fiscal Year
	MAIN WORKS	
00101	Main Regulator	1995-96
00101	Remodeling of Fish Pass in the Main Regulator (1st and 2nd part)	1998-99
00101	Additional Lining	1999-2000
01301	Main Regulator Downstream Protection	1995-96
CLUSTER 1		
	Water Control Structures	
00201	Binnafair Intake, Existing Structure, Gate Installation only	1993-94
00202	Fatepur Intake, Existing Structure, Gate Installation only	1993-94
10102	Khorda Jugini Intake	1993-94
10101	Dithpur Outlet	1993-94
10103	Kagmari Outlet	1994-95
10301	Dhannya Chowdhury Outlet	1993-94
10302	Dighulia-1 Outlet	1993-94
10307	Dighulia-2 Outlet	1999-2000
10310	Chillabari Outlet	1993-94
10303	Krishnopur WCS	1994-95
10304	Beel Baghil WCS	1993-94
10305	Eidgah Moidan WCS	1995-96
10306	Bhangabari WCS	1995-96
10308	Rampal WCS	1993-94
10309	Singerkona WCS	1993-94
10311	Chowbari WCS	1993-94
10313	Sapua WCS	1995-96
10314	Santosh WCS	1994-95
	Additional Structures	
10401	Binnafair bridge	1995-96
10402	Dhannya Chowdhury Box Culvert	1995-96
10403	Alishakanda Pipe Culvert	1994-95
10404	Anehola Pipe Culvert	1994-95
10405	Pach Kahania Pipe Culvert	1996-97
10406	Choto Binnafair Box Culvert	1994-95
10407	Charpara Box Culvert	1993-94
10408	Kathua Jugini Pipe Culvert	1993-94
10409	Moisakanda Pipe Culvert	1993-94
10410	Fatehpur Pipe Culvert	1993-94
10411	Santosh Bridge	1995-96
10412	Fatehpur Box Culvert	1996-97
10412	Fatehpur culvert remodelling	1999-2000
99999	Fatehpur 3 Irrigation Aquaducts	1996-97
99999	Fatehpur Drain Lining	1999-2000

Continued

Job Number	Job Title	Completed Fiscal Year
CLUSTER 2		
	Water Control Structures	
00102	Sadullapur Intake	1996-97
00103	Rasulpur intake	1995-96
20316	Pauli Intake	1996-97
20318	Bararia Intake	1996-97
20403	Passbetur Irrigation Intake	1995-96
20101	District Regulator	1995-96
20310	Dharerbari Outlet	1995-96
20301	Enayetpur WCS-1 with boat pass	1994-95
20302	Salina WCS	1993-94
20303	Enayetpur WCS-2	1995-96
20304	Beel Gharinda WCS	1995-96
20305	Agbetor WCS	1995-96
20307	Bhatchanda-1 WCS (South)	1995-96
20308	Bhatchanda-2 WCS (North)	1995-96
20309	Magurata WCS	1995-96
20312	Charkagmara WCS	1997-98
	Additional Structures	
20404	Kandila Bridge	1998-99
20405	Dharerbari Pipe Culvert	1995-96
CLUSTER 3		
	Water Control Structures	
00105	Suruj Intake	1995-96
30101	Jalfai Outlet	1995-96
30102	Bhatkura Outlet	1995-96
30302	Khudirampur Outlet	1996-97
30103	Paschim Pauli WCS	1994-95
30301	Karatia WCS	1995-96
30304	Birnahali-1 WCS (South)	1995-96
30305	Niogi Joair WCS	1995-96
30306	Namder Kumulli Madhyapara WCS (North)	1995-96
30308	Gosaijoair WCS	1995-96
30309	Hatila WCS	1996-97
30310	Poila WCS	1995-96
30311	Mirer Betka WCS	1995-96

Continued

Job Number	Job Title	Completed Fiscal Year
30312	Namder Kumulli WCS (South)	1995-96
30313	Karatia Chowdhury Para WCS	1995-96
30314	Dharat WCS	1995-96
30315	Birnahali-2 WCS (North)	1995-96
	Additional Structures	
30403	Golabari Box Culvert	1994-95
30405	Hatila Box Culvert	1994-95
30407	Dharat Pipe Culvert	1994-95
30408	Sarutia Pipe Culvert	1994-95
30409	Darun Box Culvert	1995-96
30410	Aultia Pipe Culvert	1994-95
30411	Sarutia Box Culvert	1996-97
30412	Gosaijoair Box Culvert	1994-95
30413	Bhatkura Pipe Culvert	1995-96
CLUSTER 4		
	Water Control Structures	
00104	Baruha Intake	1995-96
00203	Indra Belta Intake, Existing Structure, Gate Installation only	1994-95
00204	Barabelta Intake, Existing Structure, Gate Installation only	1994-95
40101	Aloya Raypara Outlet	1998-99
40102	Deojan Outlet	1996-97
40314	Birpushia Outlet	Dropped
40406	Kumulli Outlet	1996-97
40407	Khagjana Outlet	1996-97
40302	Berabuchna WCS	1997-98
40303	Burburia WCS	1997-98
40304	Bara Atia WCS	1996-97
40402	Aloa Bhabani-1 WCS	1996-97
	Additional Structures	
40403	Aloa Bhabani-2 Gated Pipe Culvert	1996-97
40412	Birpushia Box Culvert	1999-2000

Table 3: Water Control Structures and Additional Structures

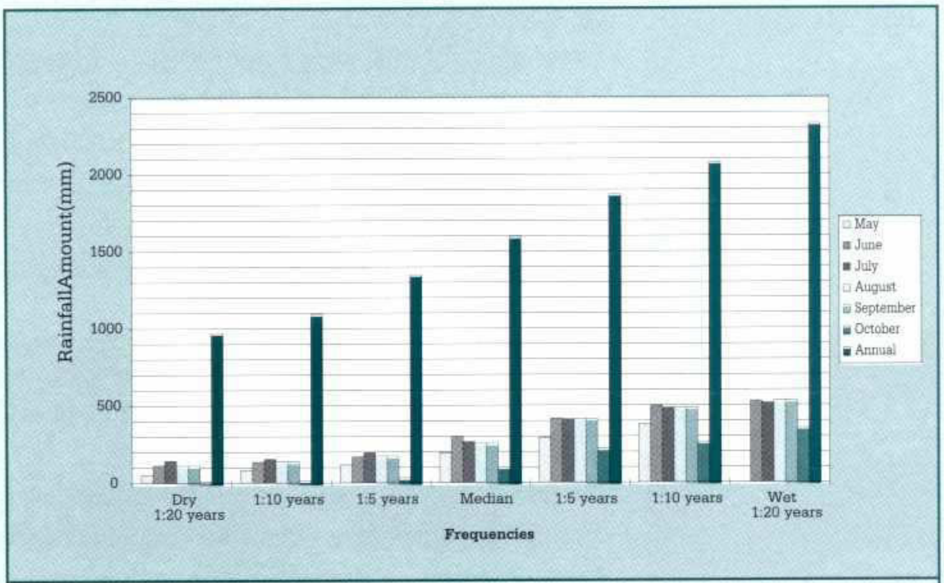

Figure 7. Monthly and Annual Rainfall and their Frequencies

Drains and Remaining Works

Design of Drains

Table 4 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 3 to 6. In Cluster 1, there are three drains without a job number. Their excavation was opposed by the local population from the early 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. Completion dates of excavations are listed in Table 5.

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 maintenance plan requires that the responsibilities for the maintenance of the drainage systems were specified. For that purpose, the list in Table 4 was prepared. The drains mentioned belong to the through going systems are considered to be part of the secondary system. The Lohajang is considered the primary or main system. All other drains, not listed, are tertiary. The responsibility of their maintenance lies with the *chawk* population.

Excavation of Drains

Table 5 shows the job numbers of drain excavation and years of completion per cluster. The Lohajang is included. The works are split in finished and unfinished works.

The Lohajang was excavated from a point 2.5 km upstream of Putiani Bridge up to Karatia. Putiani Bridge is in the Lohajang Flood Plain, 2-3 km South of Tangail Town.

Another part of the Lohajang, from the point mentioned, upstream to Chillabari Outlet was excavated under the FFW during Fiscal Year 1997-98. A third stretch, from Chillabari all the way up to Jugini was planned to be excavated, 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 re-appears every year and is difficult to control by manual excavation.

Table 5 shows that the excavation of some drains was completed rather late during the Project's life time, many only after the 1998 monsoon. This has determined the low drainage rates calculated by the models. For most of the years, the overall drainage of the Compartment was not functioning as anticipated. After 1999, there was a final effort to get the drainage completed.

Name of Khal	Job No.	length (m)	From	To	Bed Level		Bed Width		Side slope (V:H)
					Start (m PWD)	End (m PWD)	Start (m)	End (m)	
Main System									
Lohajang River	61101	23,400	Main Regulator	Karatia Bridge	7.70	6.03	20.00	20.00	1:1.5
Cluster 1									
Binnafair *Khal*	10503	5,400	Binnafair Intake	Santosh WCS	8.00	9.05	5.00	3.00	1:1.5
Chillabari *Khal*	10512	3,300	Chillabari Outlet	Gaijabari *Khal*	8.25	8.15	4.00	4.00	1:1.5
Dighulia *Khal*	10611	1,300	*Chawk* 7D	Dighulia-1 Outlet	8.40	8.76	2.00	2.00	1:1.5
Dithpur *Khal*	10505	1,500	Krishnapur *Beel*	Dithpur Outlet	9.48	9.48	7.00	7.00	1:1.5
Fatehpur *Khal*	10509	920	Fatehpur Intake	*Chawk* 5B	8.74	9.34	2.50	2.50	1:1.5
Gaijabari *Khal*	10513	2,400	Santosh WCS	Kagmari Outlet	7.99	7.82	8.50	8.50	1:1.5
Khanpur Borrowpit	10510	1,900	*Chawk* 7A	Dighulia-2 Outlet	8.30	8.00	2.00	2.00	1:1.5
Khorda-Jugini *Khal*	10501	1,000	Khorda-Jugini Intake	Krishnapur WCS	7.50	9.25	6.00	5.00	1:1.5
Rampal *Khal*	10506	1,100	*Chawk* 4B	Binnafair *Khal*	8.70	9.56	3.00	3.00	1:1.5
Singerkona - Dannya Chowdhury *Khal*	10502	800	Singerkona *Beel*	Dannya Chowdhury Outlet	8.58	8.82	2.50	2.50	1:1.5
Singerkona-Ghotokbari *Beel*	No Job	1,300	Singerkona *Beel*	Ghotokbari *Beel*	9.00	8.57	4.00	4.00	1:1.5
Ghoramara *Khal* (Upper Part)	No Job	840	Ghotokbari *Beel*	Boro *Beel*	No Design Data				
Ghoramara *Khal* (Lower Part)	No Job	1,900	Boro *Beel*	Bhangabari WCS	No Design Data				
Cluster 2									
Bamni *Khal*	20509	4,400	*Chawk* 9C	Enayetpur-2 WCS	10.20	8.18	6.50	11.00	1:1.5
Dharerbari *Khal*	20506	1,200	*Chawk* 9B	Dharerbari Outlet	10.00	11.14	2.00	1.00	1:1.5
District *Khal*	20507	1,900	Enayetpur-2 WCS	District Regulator	8.04	8.32	6.50	5.50	1:1.5
Magurata *Khal*	20502	1,100	*Chawk* 10J	Magurata WCS	8.85	8.66	4.00	4.00	1:1.5
Rasulpur *Khal*	20508	6,400	Rasulpur Intake	Sadullapur *Khal*	9.20	7.70	6.00	6.00	1:1.5
Sadullapur *Khal*	20501	6,900	Sadullapur Intake	Gharinda Bridge	9.20	6.90	6.00	6.00	1:1.5
CLUSTER 3									
Bhatkura *Khal*	30501	2,600	*Chawk* 19E	Bhatkura Outlet	6.75	7.60	10.00	10.00	1:1.5
Gharinda-Jalfai *Khal*	30506	4,200	Gharinda Bridge	Jalfai Outlet	6.90	6.48	7.00	7.00	1:1.5
Golabari *Khal*	30508	1,900	Gharinda Bridge	Suruj *Khal*	8.46	8.15	3.00	3.00	1:1.5
Khudirampur *Khal*	30502	700	*Chawk* 21A	Khudirampur Outlet	No Design Data				
Nagar-Jalfai *Khal*	30507	1,000	*Chawk* 22C	Jalfai Outlet	6.48	6.38	9.00	9.00	1:1.5
Suruj *Khal*	30505	4,000	Suruj Intake	Hatila *Beel*	No Design Data				
CLUSTER 4									
Aloa *Khal*	40502	3,900	Santosh WCS	Aloa Raypara Outlet	8.00	7.39	4.00	6.00	1:1.5
Barabelta *Khal*	40504	2,400	Barabelta Intake	Berbuchna WCS	9.80	9.15	4.00	4.00	1:1.5
Baruha *Khal*	40508	3,100	Baruha Intake	Kumuria *Beel*	9.84	8.04	4.00	5.00	1:1.5
Berabuchna *Khal*	40503	1,400	Berabuchna WCS	Baratia- Kumuria *Beel*	9.00	8.31	3.00	3.00	1:1.5
Deojan *Khal*	40511	1,500	Kumuria *Beel*	Deojan Outlet	8.00	8.75	2.00	2.00	1:1.5
Indrabelta *Khal*	40505	1,000	Indrabelta Intake	*Chawk* 23D	9.62	8.95	1.50	1.50	1:1.5
Kumulli *Khal*	40514	1,000	*Chawk* 31A	Kumulli Outlet	8.31	8.81	1.00	1.00	1:1.5
Total Length, excluding the Lohajang:		74,260							

Table 4: Design Dimensions of the Main and Secondary Drainage System

At the bottom of Table 5, the additional drains are listed. Additional drains are drains which have been taken up in the construction program of the Project, but which were later classified as tertiary drains. There are six, one in Cluster 1 and five in Cluster 4. Of the additional drains, three were dropped during the final year of the Project. The locations of the additional drains and their job numbers are shown in Fig 7.

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.

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 cropland.

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 150 m, which remained unexcavated for a long time, but which will be finished 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. The drain passes the highway Tangail-Dhaka by a bridge. The sill under the bridge is too high and although the Roads and Highways (R&H) Department has promised to lower it, it will take time.

Finally, in Cluster 4, the Aloa, Barabelta and Baruha *Khals* have been suffering from incomplete excavation, mainly for land acquisition reasons. Most of this work is expected to be completed before the Project closes.

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.

Job Number	Job Title	Completed Fiscal Year
	Main System	
60501	Lohajang R. excavation 2.5 km upstr. of Putijani Bridge to Karatia	1995-96
60501	Lohajang R. excavation Chillabari - Jugini	
61101	Lohajang R. excav. 2.5 km upstr. Putijani Br. - Chillabari (FFW)	1996-97
Cluster 1		
	Finished Works	
10502	Singerkona - Dannya Chowdhury *Khal*	1998-99
10503	Binnafair *Khal*	1993-94
10505	Dithpur *Khal*	1995-96
10506	Rampal *Khal*	1993-94 & 1997-98
10509	Fatehpur *Khal*	1994-95
10511	Dighulia *Khal*	1994-95
10512	Chillabari *Khal*	1992-93
10513	Gaijabari *Khal*	1992-93
10501	Khorda Jugini *Khal*	1998-99
	Unfinished Works	
10510	Khanpur Borrowpit	1999-2000
10504	Ghoramara *Khal* (Upper and Lower part)	
Cluster 2		
	Finished Works	
20501	Sadullapur *Khal*	1993-94
20502	Magurata *Khal*	1994-95
20506	Dharerbari *Khal*	1996-97
20507	District *Khal*	1993-94
	Unfinished Works	
20506	Dharerbari Drain Lining	1999-2000
20508	Rasulpur *Khal*	1999-2000
20509	Bamni *Khal*	1994-95
Cluster 3		
	Finished Works	
30505	Suruj *Khal*	1994-95
30505	Suruj *Khal*	1998-99
30508	Golabari *Khal*	1995-96
30507	Nagor-Jalfai *Khal*, Downstream of Highway Tangail - Dhaka	1994-95
30501	Bhatkura *Khal*	1994-95
30502	Khudirampur *Khal*	1996-97

Continued

Job Number	Job Title	Completed Fiscal Year	Evaluation December 1999	Reimbursed Or Contract Value (Lack Tk.)	Contract Value (Lakh Taka)	Totals (Lack Tk.)
Cluster 3						
	Finished Works					
30505	Suruj *Khal*	1994-95		9.65	9.65	
30505	Suruj *Khal*	1998-99		2.00	3.61	
30508	Golabari *Khal*	1995-96		2.59	2.59	
30507	Nagor-Jalfai *Khal*, Downstream of Highway Tangail - Dhaka	1994-95		4.29	4.29	
30501	Bhatkura *Khal*	1994-95		8.40	8.40	
30502	Khudirampur *Khal*	1996-97		4.39	4.39	
						32.93
	Unfinished Works					
30506	Gharinda-Jalfai *Khal*, Upstream of Highway Tangail - Dhaka	1999-2000		15.85	23.31	
30506	Gharinda-Jalfai *Khal*, Upstream of Highway Tangail - Dhaka	1999-2000			3.00	
						26.31
Cluster 4						
	Finished Works					
40503	Berabuchna *Khal*	1997-98		3.10	3.10	
40505	Indra Belta *Khal*	1996-97		1.12	1.12	
40511	Deojan *Khal*	1996-97		2.06	2.06	
40508	Baruha *Khal*, Baruha Intake - Burburia WCS	1997-98		5.14	5.14	
40514	Kumulli *Khal*	1998-99		0.55	0.62	
						12.04
	Unfinished Works					
40502	Aloa *Khal*	1999-2000	90%	12.45	13.63	
40504	Barabelta *Khal*	1999-2000	50%	4.09	8.51	
40508	Baruha *Khal*, Burburia WCS - Kumuria *Beel*	1999-2000	60%	3.32	5.37	
						27.51
	Additional Drains:					
20503	Kandila-Deolia *Khal* (Additional Drain)	1994-95		0.55	0.55	
40501	Santosh *Khal*		Dropped			
40506	Katakhali Link Canal (Additional Drain)	1998-99		0.40	1.00	
40507	Bagerchara Link Canal		Dropped			
40510	Baruha Link Canal		Dropped			
40517	Kumergara *Khal*	1998-1999		0.85	0.93	
						2.48
Overall total						**250.91**

Table 5: Drainage Canals with Job Numbers and Year of Completion

Land users have always expressed satisfaction about the flood protection. Providing more intense drainage proved more difficult. Convincing land users of an intensification of drainage takes time. Neither is it clear where the process will stop. In terms of drainage rate, ultimate drainage intensity will probably not be 9 l/sec.ha, but it will certainly be above the present 3 l/sec.ha. With respect to the time basis: the Project's duration was too short. A more flexible approach is required: implementing drainage along systems where land users want it. Implementation of secondary and tertiary drains will have to be integrated in those cases. A more flexible approach goes against the strict implementation schedule the Project had.

Remaining Works

Table 6 provides a list of remaining works executed by the Project. There are two 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 works outside the Compartment. They are all roads and related bridges. Most of the works had been completed by June 1999. The ones that had not, will be completed before the conclusion of the Project.

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 changed. The waiting is for the finalization of the land acquisition procedures and a new design by the Design Circle.

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* Muril 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* Muril Chowdhury Malancha Road	1996-97	
61210	*Beel* Muril Deldar Char Road	1996-97	
61211	Road Mahishanandalal 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

Minor Works

Definition

The water management surveys among land users during the second 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.

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 an overall design; and
- Implementation of the works should involve the participation of the local population. This would also contribute to the strengthening of the *chawk* committees.

Tshese criteria were formulated afterwards, 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 committees. The Project formed a so called Verification Committee, consisting of staff of the engineering and quality control sections, and staff of the BWDB. The Minor Works identified by the committees were verified in the field by the Verification Committee. The priority of the works was determined and preliminary cost estimates were prepared. A criterion applied was, that each sub-compartment should receive its share of the works, so that the works were more or less evenly distributed among the sub-compartments.

The final priority of the works was determined by CPP's Project Director (PD), who was also charged with the final approval. In that process, the even distribution of the works over the sub-compartments was maintained. Another obvious criterion was that the total costs of the works had to remain within the available budget. After approval by the Project Director, BWDB 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, the SCWMCs 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. By December 1999, many had not been completed or even started.

The First Batch of Minor Works

Table 7 contains the list of the Minor Works awarded during Fiscal Year 1996-97. There are 56. Out of those, 20 were completed during the same year, 3 had not been completed by December 1999 of which two had not started at all. One culvert was rejected because of bad quality. The remaining works were finished during the second year.

Most of the works concern the construction of pipe culverts. All culverts relate to one or two *chawks* only. The works which were not culvert jobs, have been classified as Main or Secondary Drain, Tertiary Drain and Road or Embankment, in the last column of the Table 7. Works on a main or secondary drain are not Minor Works according to the classification given and should have been rejected. The are not tertiary works, but maintenance jobs on the higher order drains. The other jobs can be considered tertiary jobs. There were 6 tertiary drains excavated and 8 stretches of roads and/or embankments rehabilitated.

An estimate was made of how many of the culverts were within *chawks* and how many were crossing *chawk* boundaries. That appeared to be about 50-50 for the 1996-97 batch. The matter has some importance, in view of the discussion, whether *chawk* boundaries are water tight or not. If minor work culverts were crossing *chawk* boundaries at a large scale, they would contribute to even less watertight boundaries.

The 50% culverts crossing *chawk* boundaries represent about 20 pipes, i.e. culverts of limited capacity. This should be compared to about 400-700 bridges, box culverts and pipe culverts, all over the Compartment, identified by the Drainage Inventory. Therefore, the impact of the twenty or so new pipe culverts is marginal. The Drainage Inventory is mentioned in the Annex on Water Management and Modeling. It is a Compartment-wide inventory of drainage infrastructure at *chawk* level, carried out in 1996-97.

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Number	Sub-Comp.	Chawk	Type of works	Year of Completion
1	1	14A,19A & 19C	Re-excavation from Suruj Intake to Pungli River (600 m)	1996-97
2	1	14C & 19A	Pipe Culvert near Neogijoair	1997-98
3	1	15A & 19E	Pipe Culvert near Birnahali	1997-98
4	1	15A	Pipe Culvert near Birnahali Purbapara	1997-98
5	2	17A & 16C	Pipe Culvert South Side of Namder Kumulli Mosque	1997-98
6	2	17A & 18B	Pipe Culvert near Namder Kumulli	1997-98
7	2	15A & 16A	Re-sectioning Road near Birnahali	1996-97
8	2	16C	Re-sectioning of Road from Namder Kumulli WCS to Shilbari	1996-97
9	3	19E & 20A	Resectioning of Approach Road of Hatila WCS near Hatila	1997-98
10	3	19B & 19A	Pipe Culvert near Mosque	1997-98
11	3	19A	Pipe Culvert, near Suruj	1997-98
12	3	20A & 19F	Pipe Culvert near Bhatkura	1997-98
13	3	15A & 19C	Pipe Culvert near Gosaijoair	1997-98
14	4	22B	Pipe Culvert near Chorjana	1997-98
15	4	22D	Pipe Culvert near Poila	1997-98
16	4	22G & 22F	Re-excavation of Nagar Jalfai-Buriganj *Khal*	1997-98
17	4	22D & 20A	Pipe Culvert near Bhatkura	1997-98
18	5	13A	Pipe Culvert near Bamun Kushia	1997-98
19	5	13A	Pipe Culvert near Barta	1997-98
20	5	13A	Pipe Culvert near Brahman Kushia	1997-98
21	5	13A	Pipe Culvert near Par Kushia	1997-98
22	5	13A	Pipe Culvert near Par Kushia	1997-98
23	6	11D	Pipe Culvert near Agbetor over Agbetor *Khal*	1997-98
24	6	10K & 10L	Pipe Culvert at Shibpur over Agbikramhati *Khal*	1997-98
25	7	10E	Pipe Culvert at Enayetpur-2 WCS near Bolla Bridge	1997-98
26	6	11B	Re-excavation of Salina *Khal*	1997-98
27	6	11J & 12A	Pipe Culvert near Brahman Kushia	1997-98
28	7	10E	Re-excavation of Sadullapur *Khal* (400 m)	1996-97
29	7	10G	Pipe Culvert near Magurata together with Road	1996-97
30	8	9G & 9L	Pipe Culvert in Belkuchi Road near Kagmara	1996-97
31	8	9G & 9C	Pipe Culvert in Belkuchi Road near Dhârerbari School	1997-98
32	8	9D & 9L	Pipe Culvert in Tangail-Belkuchi Road near Enayetpur-1 WCS	1996-97
33	8	9G & 9D	Pipe Culvert in Dharerbari-Belkuchi Road	1996-97
34	8	9G & 9L	Re-sectioning of Tangail-Belkuchi Road near Bamile Kagmara (360 m)	1998-99
35	9	1A	Re-excavation of Khorda Jugini Farajbari *Khal*	1996-97
36	9	1D	Pipe Culvert at Kathua Jugini at Daha *Beel* Embankment	1996-97
37	9	1C & 1D	Pipe Culvert at Kathua Jugini, east side of Majipara	1996-97
38	9	1C & 1D	Pipe Culvert at Kathua Jugini, west side of Majipara	1996-97
39	9	1C & 1D	Pipe Culvert near Patnibari at Jugini	1996-97
40	10	3C	Pipe Culvert at Dhannya Chowdhury, east of Ghotokbari Beel	1996-97
41	10	3L & 3D	Pipe Culvert near Dhannya Chowdhury	1996-97
42	10	1G	Pipe Culvert near Dhannya Chowdhury	1996-97
43	10	4B	Excavation of Drain from *Chawk* Chowbari to *Chawk* Guradi	1997-98
44	11	5F	Re-excavation of Fatehpur *Khal*	1996-97
45	11	7C	Road Resectioning from Sakrail Road to Dighulia Darogabari	1996-97
46	11	5C	Pipe Culvert near Alisha Kanda	1996-97
47	11	6D	Pipe Culvert near Bara Binnafair	1996-97
48	10	4B	Re-excavation of Dhannya Rampal *Khal* (500 m)	1997-98
49	10	4B	Re-excavation of Dhannya Rampal *Khal* (570 m)	1997-98
50	11	5D & 6D	Pipe Culvert near Bara Binnafair	Not started
51	13	25A	Construction of Boundary Chawk 25A (earthen road)	1997-98
52	13	25A	Construction of *Chawk* Boundary (earthen road)	1998-99
53	13	26A & 26B	Pipe Culvert in *Chawk* Boundary at Bandabari	1997-98
54	12	24A	Construction of *Chawk* Boundary (earthen road) at Belta Sarai	1997-98
55	12	24A & 24B	Construction of Pipe Culvert near Belta Sarai	1997-98
56	14	28E	Re-excavation of Khal from Bandabari to Atia Kumuria *Beel*	Not started

Table 7: Minor Works awarded during 1996 to 1998

The Second Batch of Minor Works

Most of the works of the first batch had been finished around the 1998 monsoon and a second batch was started. The works have been listed in Table 8, which is similar to Table 7. The evaluation date is December 1999.

This time there were 72 works. Out of these, only 7 had been completed by December 1999. These are all earth works, either drains, mostly tertiary, or roads or embankments. This is not surprising. Earth works are less complicated than structural works and can be finished relatively quickly. Table 8 further indicates that 25 works were expected to be finished during 1999-2000. This expectation is based on the state of completion in December 1999. There are 14 ongoing works, of which it is less certain that they will be finished before the closure of the Project. Twenty six works had not started at all.

Out of the 72 works, there are five relating to main or secondary drains, 12 tertiary drains, four roads or embankments and 51 pipe culverts. On a percentage basis, the number of main or secondary drainage jobs was about the same as under the first batch. There was an increase in tertiary drains and a decrease in roads or embankments. The percentage of pipe culverts remained about the same, but there was a shift from *chawk*-boundary crossing culverts to within-*chawk* culverts. The number of boundary-crossing pipes is 15, less than under the first group.

Given the progress of this batch of works, there was no time for a third under the Project. Even if there had been time, the program would have to be reviewed thoroughly.

Evaluation of the Minor Works Programs

The Minor Works program was not 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. The excavation of drains or the restoration of embankments is different in this respect. 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.

There should have been an evaluation of the program after the first batch. However, at that time, modeling had all the attention. In addition, there was the 1998 flood and the Minor Works program slipped through.

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Number	Sub-Comp.	Chawk	Name of works	Year of Completion
1	1	14B	Pipe Culvert on Suruj-Karatia Road	Ongoing
2	1	14B+C	Pipe Culvert in Road	Ongoing
3	1	14D	Pipe Culvert on Suruj-Karatia Road near Gosaijoair	Not started
4	1	14D	Pipe Culvert near Gosaijoair	Not started
5	2	16C	Pipe Culvert in Kashibari Road	1999-2000
6	2	16B	Pipe Culvert	1999-2000
7	2	17A	Pipe Culvert on the West Boundary of *Chawk* near Namdar Kumulli	1999-2000
8	2	18C	Garashin *Khal* Re-excavation	1998-99
9	3	19A	Pipe Culvert	Not started
10	3	19A	Pipe Culvert at Dowel, Suruj	Not started
11	3	19B	Pipe Culvert at Golabari	Not started
12	3	19D	Pipe Culvert on Hatila-Golabari Road	Not started
13	3	21A	Re-excavation of *Khal* North of Dhaka-Tangail Road	1998-99
14	3	19F	Installation of Pipe Culvert	Not started
15	4	22E+22F	Re-excavation of *Khal* from Burai to Nagar-Jalfai *Khal*	1998-99
16	4	22H	Pipe Culvert	1999-2000
17	4	22A	Pipe Culvert on the Road to Gharinda	1999-2000
18	4	22B	Re-construction of *Chawk* Boundary	1998-99
19	5	12A+12B	Closing Open Culvert West of Gharinda *Beel* WCS	1999-2000
20	5	13A	Excavation of Canal from Bararia Intake to Pungli River	Ongoing
21	5	13A	Pipe Culvert North of Bararia Intake on Road near Khupipara	Not started
22	6	11A+11B	Re-excavation of *Khal* to Pauli WCS near Tangail-Mymensingh Road	Not started
23	6	11A+11B	Pipe Culvert on earth road besides the Tangail-Mymensingh Road	Not started
24	6	11D+11E	Re-excavation *Khal* along Tangail-Mymensingh Road	Not started
25	6	11D+11E	Pipe Culvert West of Salina	Not started
26	7	10A+10B	Pipe Culvert in the South of *Chawk* 10B near Sadullapur village	Not started
27	7	10B+10G	Re-sectioning of *Chawk* Boundary Right Bank of Sadullapur *Khal*	1999-2000
28	8	9E	Pipe Culvert in the south of *Chawk* 9E, Konabari Village	1999-2000
29	8	9E	Pipe Culvert, Konabari Village	Not started
30	8	9G+9J	Pipe Culvert West of Char Kagmara WCS, on *Chawk* Boundary	1999-2000
31	8	9M	Excavation of *Khal* near Enayetpur Village	Not started
32	9	1A	Re-excavation of Khorda Jugini *Khal*	1998-99
33	9	1B	Re-excavation of Existing Khal from Dholi *Beel* to Jugini Daha *Beel*	1999-2000
34	9	1G	Pipe Culvert on Southern Boundary of *Chawk* 1G	1999-2000
35	9	1F	Re-excavation of Dithpur *Khal*	1999-2000
36	9	1A	Pipe Culvert on the East Bank of Khorda Jugini *Khal*	1999-2000

Continued

Number	Sub-Comp.	Chawk	Name of works	Year of Completion
37	10	2A	Pipe Culvert on Tangail-Omarpur Road	Not started
38	10	3A	Pipe Culvert South of Gopalpur	Not started
39	10	3F	Pipe Culvert	1999-2000
40	10	4A	Pipe Culvert Rampal	Not started
41	10	3A	Pipe Culvert Gopalpur	Not started
42	10	2C	Pipe Culvert South of Sapua Kalibari	1999-2000
43	11	6A	Excavation *Khal* to Gaijabari *Khal*	Ongoing
44	11	7E,6A,6C & 7H	Re-excavation of *Khal* Bhangabari WCS - Santosh Regulator	Ongoing
45	11	7G+7H	Re-excavation of Palpara *Khal*	Ongoing
46	11	7J	Pipe Culvert	1999-2000
47	11	7E	Pipe Culvert	Not started
48	11	5C+5D	Pipe Culvert at Alisakanda	Not started
49	12	24A	Pipe Culvert	Not started
50	12	24A	Pipe Culvert	Not started
51	12	24C	Reconstruction of *Chawk* Boundary	Ongoing
52	12	24C	Pipe Culvert in *Chawk* Boundary	Not started
53	12	24B	Re-excavation *Khal* to Barabelta *Khal*	1998-99
54	12	24D	Pipe Culvert on Baruha –Burburia Road	Not started
55	13	26A+26B	Pipe Culvert on Baruha-Gumjani Road	1999-2000
56	13	26A & 25A	Reconstruction of Right Bank of Baruha *Khal* Eastern Part	1999-2000
57	13	26C	Repair of Damaged Pipe Culvert in Mamudpur	1999-2000
58	13	26D	Double Pipe Culvert in Silimpur with Repair of 60 m Road	1999-2000
59	14	28A	Re-excavation of Deojan *Khal*, Atia Kumuria *Beel* to Lohajang river	Ongoing
60	14	28C	Repair of Damaged Pipe Culvert at Bakultala	Ongoing
61	14	28E	Re-excavation of *Khal* from Parijatpur to Kumuria *Keel*	Ongoing
62	14	28F	Installation Pipe Culvert on Bhurburia-Kumuria Road	Ongoing
63	14	28G	Installation of Pipe Culvert on Gomjani-Bandabari Road	1999-2000
64	14	29B	Pipe Culvert on Karatia-Silimpur Road	Ongoing
65	15	31A	Pipe Culvert on Tetulia-Khagjana Road	1999-2000
66	15	31B	Pipe Cukvert in Narunda Village	1999-2000
67	15	31B	Pipe Culvert in Tatulia	Ongoing
68	15	31C	Pipe Culvert on Chandi-Paikpara Road	1999-2000
69	15	31C	Pipe Culvert on Paikpara-Gopalpur Road	1999-2000
70	15	32A	Re-excavation *Khal* from Khagjana Beel to Lohajang River	1998-99
71	15	31E	Pipe Culvert	Not started
72	15	31D	Pipe Culvert in Birpushia	Ongoing

Table 8: Minor Works Awarded during Fiscal Year 1998-99

A basic point is that there is a contradiction between the program requirements, as formulated in the first section of this chapter and one of the approaches of the Project. The program intends to execute works at *chawk* level, while the Project makes the sub-compartment committees the back bone of the water management organization.

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The procedures as described above, are consistent with the Project's policy. However, under the program, the sub-compartment committees tended to dominate the *chawks*.

To reduce the impact of the dominance of the sub-compartment, the Verification Committee should have paid more attention to the *chawk*, the willingness and capability at that level to participate, rather than evaluating the works on physical aspects only.

Works on the primary and secondary drains should have been rejected from the early beginning.

Advances should not have been paid. The background of paying advances was that the committees needed to buy construction materials. However, after the advance was paid, there was no guarantee from the committees that the works would actually be executed. In addition, the advances stimulated concrete works and culverts, instead of earth work. In the awarding procedure, earth work should have been given a certain priority over concrete work. The willingness of the *chawk* population to participate in the execution, should have been stimulated and payments should have been made in installments, after completion of (parts of) the work.

The Minor Works program is worth a retry, but under a different set of requirements. That is why it has been included in the evaluation of the expenses of the Project, in the next chapter.

Costs of the Works

Costs Incurred

Table 9 gives a summary of the cost of the works in millions of taka. Sub-totals have been calculated per category. Details of the costs per job, except for the Minor Works, are provided in Appendix 1, the Tables A1.1-A1.4. The format of these tables is the same as the tables with completion dates, discussed in the previous chapter. As costs have been made over a period of about 8 years, the years of completion have been maintained in the tables of the Appendix for discounting.

Sl. No.	Category	Million Taka	Total (million taka)
1	**Embankments and Protective Works**		
	Embankments before 1998	31.71	
	Protective and other works before 1998	16.57	
	Sub-Total Embankmentsbefore 1998		**48.29**
	Embankments and Protective works after 1998	37.94	**37.94**
	Sub-Total Embankments		**86.23**
2	**Main Regulator**	28.88	**28.88**
3	**Intake Structures**		
	Cluster 1	3.10	
	Cluster 2	11.43	
	Cluster 3	3.33	
	Cluster 4	3.72	
	Sub-Total		**21.57**
4	**Outlets along the Lohajang**		
	Cluster 1	14.27	
	Cluster 2	8.78	
	Cluster 3	17.60	
	Cluster 4	20.75	
	Sub-Total		**61.40**
5	**Water Management Structures**		
	Cluster 1	14.83	
	Cluster 2	18.27	
	Cluster 3	16.74	
	Cluster 4	7.09	
	Sub-Total		**56.93**
6	**Additional structures**		
	Cluster 1	10.69	
	Cluster 2	2.57	
	Cluster 3	11.65	
	Cluster 4	2.29	
	Sub-Total		**27.20**
7	**Lohajang**	9.44	**9.44**
8	**Khals**		
	Cluster 1	4.24	
	Cluster 2	4.79	
	Cluster 3	5.92	
	Cluster 4	4.25	
	Sub-Total		**19.19**
9	**Remaining Works Inside Compartment**	5.52	**5.52**
10	**Remaining Works Outside Compartment**	19.72	**19.72**
11	**Tangail Town Drain**	39.79	**39.79**
	Overall Total	375.86	**462.09**
	Works benefitting the Compartment. (Catergory 1-9)		**402.59**
12	**Minor Works**		
	Minor Works 1996/98	5.92	
	Minor Works 1998/00	3.46	

Table 9: Cost of the Works Implemented

The costs are the reimbursed values or the contract values, depending on whether the works had been finalized and reimbursed by December 1999.

A Maintenance Plan, specifying the costs of maintenance is provided in Appendix 2. In this chapter, only investments are considered and maintenance cost is excluded. From time to time, however, the Maintenance Plan will be brought up in the argumentation about the investments.

The total cost per ha of the Compartment, being about Tk 36,000/ha, must be considered high for a flood control and drainage project. Construction cost will be examined per category. An alternative cost estimate for the Compartment has been prepared, scrutinizing the costs and applying savings where possible. The alternative estimate is shown in Table 10.

Category	Cost (million Taka)	Totals (million Taka)	Cost/ha Taka/ha
1. Embankments and Protective Works	40.00	**40.00**	4,651
2. Main Regulator	30.00	**30.00**	3,488
3. Intake structure	25.00	**25.00**	2,906
4. Outlets along the Lohajang			
Cluster 1	9.77		
Cluster 2	6.16		
Cluster 3	15.84		
Cluster 4	19.26		
Sub-Total		**51.03**	5,934
5. Water Management Structures			
Cluster 1	6.00		
Cluster 2	7.84		
Cluster 3	7.42		
Cluster 4	0.00		
Sub-Total		**21.26**	2,472
6. Additional structures	20.00	**20.00**	2,326
7. Rehabilitation of the Lohajang	2.50	**2.50**	291
8. Excavation of *Khals*	3.75	**3.75**	436
9. Remaining Works Inside compartment	5.50	**5.50**	640
10. Minor Works	7.50	**7.50**	872
Total Cost for the Compartment		**206.54**	24,016

Table 10: Alternative Construction Cost Estimate for the Compartment

Embankments

The costs of the embankments have been split in costs before 1998, mainly rehabilitation costs during the first phase of the Project and repair costs after the 1998 flood. The costs include those made on the embankments along the Lohajang but that is only a minor part of it. The costs have been split in embankment costs and costs for protective works. The protective works serve to safeguard the embankments.

The costs spent on the embankments, before and after 1998, are the highest of all categories in Table 9. 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 resectioning is not an efficient way to rehabilitate embankments.

In the alternative cost estimate in Table 10, spending on the embankments is estimated at 40 million Taka. This is a one-timely 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 estimates the annual maintenance cost of the embankment at Tk 38,000/km/year. 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 is an acceptable value.

The Main Regulator

The costs of the Main Regulator amount to 28.9 million taka or 3,400 taka/ha. These costs are high but they are more difficult to judge than the costs of the embankments. 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. After its completion, the structure has been performing satisfactorily.

In the alternative cost estimates in Table 10, an investment of 30 million Taka has been maintained. The main question about the Main Regulator is whether it is replicable. This has been discussed in the Annex on Water Management and Modeling.

Intake Structures

As in the case of the Main Regulator, the costs of the intake structures are difficult to judge. The differences that appear in Table 9, between the clusters, can be explained. Cluster 1 received one new intake, while 2 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 10, 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 has been 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, being Tk 3.6 million.

The Outlet Structures

The outlet structures together, is a very expensive cost item and as Table A1.2 in Appendix 1 shows, individual structures are expensive as well. 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 when the demand for more intensive drainage picks up.

The gating of some structures is unnecessarily expensive, 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. Deojan has one simple gate, not fish-friendly. These matters have been discussed in the Annex 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 costs have to be reduced, this should be given attention.

In the alternative cost estimates in Table 10 a number of outlets structures have been removed. 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 rather upstream and serves a small watershed. Dighulia-2, so near to Kagmari Outlet, could have been combined with Kagmari at least costs. 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%. Fish-friendliness has been accepted. In this way, the costs of the outlet structures in Table 10, become about 51 million taka, about 7 million taka less than the actual costs.

Internal Water Management Structures

The internal water management structures and their use have been extensively discussed in the Annex on Water Management and Modeling. Their costs in Table 9 amount to 57 million taka. For the alternative cost estimates in Table 10, structures that were not considered useful have been skipped. 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 skipped

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

The alternative costs in Table 10 come out at 21 million taka. This is less than half the cost made under the Project.

Additional Structures

In a flood protection and drainage project as the Compartment, the need for additional structures will always be there. It has to be assumed that the structures erected and cost in Table 9, are beneficial to the population. However, as a matter of principle, the cost of such structures should not exceed those of the water management structures. After all, CPP is a water management project and not a project for the general improvement of infrastructure. The actual costs have been 26.2 million taka. In Table 10 alternative costs have been estimated at 20 million taka, on a par with the internal water management structures.

Excavation of Part of the Lohajang

The excavation of about 10 km Lohajang has cost the Project 5 million taka or 500,000 taka per km. This is rather high, also considering the fact that the upper part of the Lohajang was never excavated and that the Project did not experience great adverse effects. The Maintenance Plan in Appendix 2 brings up 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 10, the costs for rehabilitating the Lohajang have been put at 2.5 million taka. This estimate is valid for the entire length of the river, about 25 km, as the need for the rehabilitation of the entire river has not been established.

Excavation of *Khals*

Table 4 shows that 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. The fact that, after all the money spent, the system has not been functioning as intended, calls even more for a reduction in costs.

With respect to the rehabilitation of the drainage systems, a policy should be adopted under which the cooperation of the land users is guaranteed, before the works start. Work should be undertaken on a system basis, starting from downstream to upstream. So far, there is no justification to apply high drainage rates. Accommodating an increase in drainage rates should be done by periodic improvements, as the need arises.

This criteria above result in a reduction in unit cost per meter drain. The Maintenance Plan brings up 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 had to be corrected. That yields a cost per km of 40,000 taka. For Table 10, a cost of 50,000 Tk/km has been assumed. With 75 km length, this amounts to 3.75 million taka, against about 20 million taka spent under the Project.

A possible reduction in length of drains to be rehabilitated has not been taken into account, assuming that all along the system improvements may be required.

Remaining Works Inside the Compartment

As Table 6 shows, the remaining works inside the Compartment represent a few rather expensive jobs on internal embankments and/or roads. There is no reason to disqualify these works. Strictly speaking, they may have to be classified as emergency or rehabilitation work. It is a fact that such cases occur in a project as CPP and the works have been carried over in Table 10.

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 so-called 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. 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 case of a negative impact of the Compartment on the Southern adjacent area, a strong case. 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. Furthermore, the effect of the Main Regulator extends beyond Karatia and one may argue that the benefits of the Compartment extend beyond its Southern boundary.

This is the background why the costs of Remaining Works outside the Compartment have been left out of Table 10. In addition, they are not water management costs to the benefit of the Compartment.

Tangail Town Drain

After its completion, the Tangail Town Drain is expected to have cost the Project 40 million Taka. Whether that is justified or not is the subject of this Annex. The costs can not be attributed to the Compartment and have been left out of Table 10.

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. The absorption capacity of the population is below 3 million taka per year. The costs incurred have barely resulted in better water management or stronger *chawk* committees. Therefore, they have been left out of the calculation of the final cost of the Compartment in Table 9.

In Table 10, however, they have been included, to an amount of 7.5 million taka. The reasoning is that the Project might have awarded Minor Works during 5 years at a rate of 3 million taka per year. Half that money is considered investment, the other half (subsidized) maintenance.

The Alternative Cost

In Table 10, 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 312 Million taka, or, a cost reduction of about 35%.

The costs per ha are Taka 23,000 per hectare, which is still rather high. However, if one leaves out the costs of the Main Regulator, those of the peripheral intakes and the remaining water management structures, one arrives at a cost of 130 million Taka, or about 15,000 Taka/ha, which is reasonable for a flood management scheme. The extra costs can be technically justified as they represent works that have contributed to the quality of water management in the Compartment, better drainage and improved facilities for the intake of water.

Maintenance and Sustainablity

Appendix 2 of this Annex contains the Maintenance Plan, with detailed estimates of cost per category of work. One should realize, however, that maintenance is as much a financial matter as a technical one. The main point for the sub-compartment committees in maintaining the infrastructure is to obtain 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. One may notice 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. One has to assume that the maintenance of structures that the local population considers less effective will be neglected as well.

The mechanism of cost recovery is not well developed in the country and the institutional basis is still lacking. Any effort to mobilize funds from the local population for the maintenance of infrastructure will be vulnerable and therefore difficult to sustain.

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 infrastructure 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, justified or not, the disadvantaged should press for repairs.

Lessons Learned

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. This can be achieved by a survey of the embankment, before works start, incorporation aspects as the quality of the soil material in the dike body. Rehabilitation should then concentrate on the weakest sections.

The major constraint to the implementation of an improved drainage system, is the timely completion of the earthwork, not the structures. Obstacles are land acquisition, opposition to the plans by the local population and defaulting contractors. By securing the support from the local population, opposition and possibly part of the land acquisition problems can be overcome.

It proved difficult to make a comprehensive design of the entire Compartment. Modeling was essential to achieve that. Essentially, it is a matter of defining the hydrologic boundary. The water regime in the Compartment is not independent from its surroundings.

Implementation of improved drainage takes time. A flexible approach is required. Works should be executed on a system basis, moving from downstream to up-stream, in locations where land users support the plans. A flexible approach goes against the strict implementation schedule the Project had.

The case of the adjacent areas indicates that expected adverse affects of the Compartment on such areas, should be properly justified before they are accepted.

The results 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. It should not be concluded that minor work programs should be left out. There is an established demand for such works. During the evaluation of the applications for such works, there should be more emphasis on the inventory of the willingness of the *chawk* population to participate.

The procedures under which the Design Circle of the Water Board designs the works is unsatisfactory. The Circle does not submit design reports and the design criteria remain obscure. This proved of importance with respect to the drainage rates on which drains and structures had to be designed. Greater involvement of local consultants during the design, is recommended. The role of the BWDB should become to approve or disapprove. That would be to the benefit of the Project and the Design Circle.

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 an advisor on quality control only, is weak and unsatisfactory.

The high implementation cost also suggest that more use should be made of cost indicators to monitor costs of work.

Maintenance of the works will remain vulnerable. Measures to improve it, are mobilizing awareness of the local population to prevent damages and an active attitude with respect to fund mobilization. Also more attention should be given to maintenance friendly designs, which makes the involvement of local artisans more feasible.

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Appendix -1

Details of Construction Cost.

Job Number	WORKS BEFORE 1998 Job Title	Completed Fiscal Year	Comments	Reimbursed or Contract Value (Million Taka)	Totals (Million Taka)
Peripheral Embankment					
00601	Ramdevpur - Gopalpur Embankment	1993-94		1.57	
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	**26.62**
Embankment along the Lohajang					
10604	Dithpur Outlet - Main Regulator	1994-95		0.81	
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	**4.88**
Protective Works					
20901	Passbetur Groyne I & II	1994-95		7.13	
41302	Belta Sarai Protective Work	1995-96	Work not accepted		
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	**11.95**
Other Works					
60504	Elenjani River Loop Cut	1996-97		4.17	
61102	Gala Khal under FFW	1996-97			**4.17**

Continued

Job Number	WORKS AFTER 1998 Job Title	Completed Fiscal Year	Comments	Reimbursed or Contract Value (Million Taka)	Totals (Million Taka)
Peripheral Embankment					
00601 - 00605 and 00609 - 00617	Resectioning of Embankment	1998-99		24.13	
00613	Retired Embankment at Birnahali	1998-99		1.44	
00614	Salina-Dapnazar Embankment (part)	1999-2000		0.83	
00613	Additional Resectioning Suruj-Birnahali	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 Birnahali	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 A1.1: Cost of Works on the Embankments and Protective Works, with Job Numbers Years of Completion

Appendix 2

Maintenance
Plan

Government of the People's Republic of Bangladesh

Ministry of Water Resources

Bangladesh Water Development Board

Water Resources Planning Organization

Compartmentalization Pilot Project
Tangail

Maintenance Plan

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1 Introduction

People's Participation is the main approach of CPP. It is the people that are expected to manage and operate the structures. After completion of CPP, the project will be handed over to the beneficiaries organization for future operation and maintenance. CPP has now entered into a phase where a considerable progress has been achieved on institutionalization of People's Participation with water management committees already entrusted with task of operating the structures to meet and manage their water management requirement.

Now the main task of CPP is to entrust the maintenance responsibilities to the water management committees.

With this in view and in-accordance with the national water policy, this maintenance plan for the whole compartment has been prepared. This plan will be a means to bring all involved parties (BWDB and WMCs) to one table to decide what maintenance is needed in any particular year, how much the costs will be and how these costs will be divided over the involved parties. This should lead to a situation in which structures are kept in working condition and maintenance is undertaken in the most efficient and cost effective manner.

2 Objectives

The main objectives of this maintenance plan are:

a) To introduce a standard and sustainable maintenance program,

b) to stop deterioration of infrastructure and keep them in good condition,

c) to involve stakeholders in maintenance, and

d) to get maximum benefit from the infrastructure with the lowest possible cost,

3 Project Description and Existing Infrastructure

The CPP is surrounded by an embankment on the northern, western and eastern side Lohajang river is acting as the main drainage outlet of the project area. Entry of flood water into the project area through the Lohajang river is controlled by a gated structure at Jugini which is the main inlet. In addition, for the entry of flood water, there are inlet structures in the peripherial embankment. For internal water management, controlled structures have been constructed along the bank of Lohajang river and in the sub-compartment. Internal drainage is effected through existing and re-excavated *khals.*

The project consists of a single compartment 16 nos. sub-compartment (including Tangail Town Sub-compartment) and 142 *chawks*. There are 110 nos. of *Chawk* Water Management Committees for 142 *chawk* and 15 nos. Sub-compartment Committee. No committee has been formed for Tangail sub-compartment which is an urban area. The following definitions are being used for compartment, sub-compartment and *chawk*;

i) Compartment:

An area in which effective water management, particularly through controlled flooding and controlled drainage, is made possible through structural and institutional arrangements.

The infrastructure of the Tangail Compartment consists of three major elements and a large number of small ones. The major elements are: the embankment which surrounds the Compartment partially, the Main Regulator and the Lohajang river. The small elements have been divided into peripheral infrastructure, infrastructure along the Lohajang and internal infrastructure. The peripheral infrastructure consists of water inlets in the embankment, along the outer boundaries of the Compartment. The structures along the Lohajang control the inflow and outflow between sub-compartments and the river. The internal infrastructure consists of structures controlling the water within the sub-compartments.

ii) Sub-compartment:

A sub-unit of a compartment, in which to a certain extent, the water management can be controlled by the people living in the area represented by a sub-compartmental water management committee (SCWMC). A sub-compartment consists of number of *chawks*.

iii) Chawk:

The smallest hydrological or physiographic unit which are easily recognizable in the field because of its homogeneity. Most *chawks* have natural ways both for inflow and drainage. Some of them have been provided with gated inlet and outlet structures. The lowest level of hydrological uniformity are the *chawks*. The "*chawks*" are considered as manageable field unit usually bordered by topographical features; generally located in between villages (settlements), roads, *khals*/rivers or embankments etc. These *chawks* are socially and agriculturally quite familiar to rural people in the project area. The *chawks* might have both high, medium and lowlands, and sometimes may contain a "*beel*" or *khal*; but since their borders is formed by infrastructure (roads, village/paths, *khals* etc.), it would be possible to regulate water level to suit certain desirable and profitable crops in monsoon flood period and to retain or drain out water in pre and post monsoon.

a) Embankment

At present the compartment is protected from flood by peripheral embankment of length 47 km. In addition there are 12 kms length of internal embankment and about 38 km of road belonging to R&H department along the bank of Lohajang river. The road is now serving as embankment for the protection of flood water from Lohajang river.

The crest level has been fixed considering 1988 flood with a 30 cm free board. This level corresponds with a 1:7 year return period flood with a 0.90m freeboard.

The following Table gives the basic data for different types of existing embankment constructed/re-sectioned under the project:

Type of Embankment	Location	Crest width (m)	Side slopes		Crest level (in m PWD)
			C/S	R/S	
A. Peripheral	Ramdebpur to Silimpur	4.25	1:2	1:3	13.73 to 12.90
	Ramdebpur to Rasulpur to Pauli	4.25	1:2	1:3	13.73
	Pauli to Salina	4.25	1:2	1:3	13.73 to 13.61
	Salina to Nathkhola	4.25	1:2	1:3	13.61 to 12.83
B. Internal Embankment	Dithpur to Main Regulator(SC9)	6.00	1:2	1:2	12.82
	Dhārerbari to District (SC8)	4.00	1:2	1:2	12.80
	Sarutia to Chillabari (SC11)	4.00	1:2	1:2	12.74
	Pardighulia	3.00	1:2	1:2	12.61

The above table shows the required design section of the embankment. However, during construction in some of the places the river side slope could not be maintained because of presence of homestead. In most of the places the river side slope has been maintained at 1:2 instead of 1:3 which is considered sufficient for stability and protection against seepage.

b) Drianage Channels

Lohajang river which flows through the middle of the compartment is the major drainage channel. A total of 32 nos. drainage channels or *khals* have been identified in the compartment for re-excavation. Details of the drainage channels are given in Table 3.1.

c) Peripheral Inlet Structures

In all 13 nos. Inlet, structures have been constructed on the peripheral embankment for allowing flood water to enter into the compartment in a controlled way. These include Main Inlet at Jugini where Lohajang river enters into the project area. All peripheral inlets have been listed in Table 3.2.

d) Infrastructure along the Lohajang River

Because water level in the Lohajang can be manipulated at the Main Inlet (regulator), the river functions one is yet to be, constructed as a drain for the compartment. Along the river, 15 drainage outlets have been constructed for draining of the excess water from the sub-compartment. Some of these outlets can also serve as inlet if water conditions in the Lohajang river allow. All structures along the Lohajang river have been listed in Table 3.3.

e) The Internal Infrastructure

The internal infrastructure of the Tangail Compartment consists of Water Control Structures (WCS), Gated Pipe Culverts (GPC) and *khals*. All WCSs and GPCs have gates and the water can be controlled. Most of the structures are small and of local importance only. All internal structures have shown in Table 3.4.

Besides the construction of structures and the excavation of *khals*, with an important role in the water infrastructure, CPP has implemented other construction jobs of less importance for water management. Those are bridges, minor culverts etc. either on Union Council or LGED road and they are supposed to be maintained by LGED/Local Govt. Institutions.

4 Operation and Maintenance

4.1 Operation

Operation is the manipulation of the water management infrastructure (e.g. opening/closing gates) by which the hydraulic condition (water level, discharge) is controlled in a water management system.

4.2 Maintenance

Maintenance is defined as the action to prevent the deterioration of infrastructure and to keep them in good condition so that they perform adequately at the lowest possible cost over a prolonged period of time.

4.3 Classification of Maintenance

Generally three types of maintenance are applicable for any water management infrastructure.

- Preventive Maintenance
- Periodic Maintenance
- Emergency Repairs

Preventive Maintenance

Preventive maintenance is undertaken throughout the year, at intervals or continuously, as the case may be. It includes continuous minor repair of embankments, weed removal from canals, lubrication, cleaning, painting and repair of small spares of hydraulic structures,clearance of debris from hydraulic structures etc.

Periodic Maintenance

Periodic maintenance covers large scale non-emergency work requiring greater resources than preventive maintenance and is to be based on checklists prepared at the end of each monsoon. It includes, resectioning of embankment, re-excavation of *khals* and larger repair of structures including replacement fully or partially of gates & hoists of structures, replacing rubber seals etc.

Emergency Repairs

This type cannot be predicted and is unforeseen. This may include any breach in the embankment and any possible endanger to infrastructures due to unforeseen circumstances of conditions. For such repairs, provision of fund should be available immediately.

4.4 General Mainteance Requrement Per Infastructure

Preventive and periodic types of maintenance are required from time to time. Even both preventive and periodic maintenance might be required at the same time. But if normal preventive maintenance is done on a regular basis the cycle of periodic maintenance is extended. The maintenance requirements are discussed below.

4.4.1 Embankment

In CPP it includes peripheral and internal embankment. General maintenance requirements are:

Preventive

Retention of design profile

- Repair/prevent rain cuts
- Fill low pockets
- Establish cause then appropriately repair slips
- Prevent encroachment,

Prevention of erosion

- Maintain and cut grass cover and/or maintain other approved vegetation on slopes and crest
- Eliminate unapproved shrubs on slopes and crest prevent concentrations of water run-off.

Prevention of leaks

- Fill animal holes and ghogs
- Remove roots from slopes and backfill with earth
- Establish cause and appropriately stop seepage, often at ground/embankment base interface

Periodic maintenance

- Retention of design profile
- Resection after settlement and erosion
- Retirement of embankment

Prevention of erosion

- Major river training works including embankment slope protection

4.4.2 Drainage Khals

Preventive maintenance work on *khals* and drainage channels entails:

- Removal of floating debris and water hyacinth
- Cutting grass/weeds prior to the commencement of the monsoon

Periodic maintenance work on *khals* and drainage channels entails:

- Desilting and re-excavation of channels
- Repair of major erosion including slope protection.

4.4.3 Hydraulic Sructures

Preventive maintenance

Preventive maintenance works include:

- Clear, keep tidy prevent encroachment of surrounding vegetation
- Maintain safety provisions
- Repair/replace seals to expansion and contraction joints
- Keep waterways clear of weeds, debris, silt and obstacles
- Clean and repaint as needed, upstream and downstream gauges
- Clean and repaint exposed metal work at regular intervals
- Lubricate lifting device of gates (moving parts)
- Tighten and replace nuts

Periodic maintenance

Periodic maintenance works includes:

- Major faults in concrete and brick work which should be repaired only after a full analysis of the situation and expert advice
- Major repairs to baffle blocks and protective works
- Replacement of gates
- Replace seals, wire ropes,

4.4.4 River Bank Protection Works

Preventive Maintenance

Works include

- Minor repair of spurs
- Clearance of debris.

Periodic maintenance

- Major repair or replacement of spurs,

4.4.5 Maintenance Responsibilites

The ultimate success and effectiveness of water resources management projects depends on the people's acceptance and ownership of each project. After completion of CPP, the project will be handed over to the beneficiary's organization for future operation and maintenance. In the recently approved National Water Policy of the Government of Bangladesh, it is mentioned that "Public Water Schemes, baring municipal schemes, with command area of over 5000 ha. will be gradually placed under private management, through leasing, concession or management contract under open competitive bidding procedures or jointly managed with local government and community organizations".

CPP with command area of 13200 ha. falls under the above category. Presently, CPP is not in a position to be placed under private management. The only other alternative is joint management with local government and community organization. In CPP, people's participation has been institutionalized in Water Management Committees at *Chawk* (ChWMC), Sub-compartment (SCWMC) and Compartment level. Union Parishad Chairman has been made ex-officio president of the SCWMC and other three UP members have also been included as members of SCWMC to have a link between the WMCs and the elected branch of the Local Government Institutions. This link was felt necessary in order to increase the authority of the WMC.

Under the circumstances, it is logical to place the project (CPP) under the joint management with Community Organizations (WMCs). As a first step, it is important to delineate the roles and responsibilities of BWDB and WMCs. Several discussion meetings were held between WMCs and Project Authority (Project Team and Consultant Team) on the issue. It has been decided that the major infrastructures, in particular the main inlet, all other inlet structures, the pheripheral embankment and outlet structures along Lohajang river will be maintained by BWDB in consultation with the beneficiaries (WMCs), while all minor structures and *khals* situated within the sub-compartment will be maintained by the water management committees. All structures except main inlet will be operated by WMCs.

Delineated O&M responsibilities and cost sharing is shown below:

Delineation of Responsibilities and Cost Sharing

INFRASTRUCTURE	OPERATION	MAINTENANCE RESPONSIBILITIES		COST SHARING	REMARKS
1. Embankment	BWDB	Preventive	BWDB	BWDB	
		Periodic	BWDB	BWDB	
2. Peripheral Inlet Structures a) Main Inlet	BWDB	Preventive	BWDB	BWDB	
		Periodic	BWDB	BWDB	
b) Other peripheral structures	WMCs	Preventive	BWDB WMCs	BWDB WMCs	Greazing except initial one & debris clearance to be done by WMCs
		Periodic	BWDB	BWDB	
3. Structures along Lohajang	WMCs	Preventive	BWDB WMCs	BWDB WMCs	Greazing except initial one & debris clearance to be done by WMCs
		Periodic	BWDB	BWDB	
4. Internal Structures within SC & Chawks	WMCs	Preventive	WMCs	WMCs	
		Periodic	BWDB	BWDB	
5. *Khals*					
a) Main	BWDB	Preventive	BWDB	BWDB	
		Periodic	BWDB	BWDB	
b) Secondary	WMCs	Preventive	WMCs	WMCs	
		Periodic	BWDB	BWDB	
c) Minor	WMCs	Preventive	WMCs	WMCs	
		Periodic	WMCs	WMCs	
6. Protective Work	BWDB	Preventive	BWDB	BWDB	
		Periodic	BWDB	BWDB	
7. Bridges, Culverts	LGED & Local Govt. Institutions	Preventive & Periodic	LGED & Local Govt. Institutions	LGED & Local Govt. Institutions	

5 Maintenance Plan

The plan consists of two steps.

(a) Estimation of cost for maintenance of individual infrastructures, and

(b) Cost sharing: Division of cost between BWDB & WMCs as per delineated responsibilities.

Cost Estimation:

In preparing the plan, certain assumptions were made in calculating and estimating the costs of maintenance of different infrastructure.

i. 1 no. women labor (6 days a week) per km of embankment for preventive maintenance with additional extra labor during the excessive rainfall month.

ii. yearly subsidence rate of embankment as 0.05 m.

iii. yearly siltation rate in *khals* as 0.10 m.

iv. replacement of gate 1 in 15 years.

v. replacement of rubber seal of gate 1 in 3 years.

vi. replacement of wire rope 1 in 5 years.

vii. painting yearly basis.

viii. greazing requirement 3 pound per gate hoist.

ix. annual periodic cost of structures has been found as 1.5% of the investment cost (justified on the basis of detailed estimate of some of the structures).

Summary of Annual Maintenance Cost and details of annual preventive and periodic maintenance cost are shown in Annexure-1, 1-A, 1-B & 1-C.

Cost Sharing:

Maintenance responsibilities and cost sharing between the parties involved has been prepared as per delineated responsibilities mentioned in Section 4.5. This has been shown in Annexure-2.

5.1 Maintenance Schedule

An yearly maintenance schedule is to be prepared at the beginning of each fiscal year which should be followed to achieve regular and effective maintenance. Maintenance schedule is to be prepared by BWDB in consultation with the WMCs. Draft maintenance programme is to be prepared by BWDB before 30th June for the next financial year and necessary steps like budget allocation, design drawings for the maintenance work, work authorization tendering processes are to be initiated at proper time by the BWDB.

6 Training on Maintenance Issue

WMC members have so far been given training on operation of structures for proper water management. BWDB officials have also been given training on the above issue. For proper implementation of the maintenance plan, training on maintenance is also to be imparted to water management committees as well as to the BWDB officials. The training should cover, maintenance needs assessment, types of maintenance work, roles and responsibilities of each party, maintenance schedule, budgeting and monitoring. This has been programmed in October 1999 after the end of the monsoon season.

Training is also required to be imparted to the gate operators of all the 64 infrastructures (inlets, outlets and water control structures) so that the gate operations in the project are properly conducted. Such training should be imparted to the individual gate operator at his concerned gate site showing the practical operation of the gate by BWDB experts.

Name of Channel	Location		Total length (km)	Location		Design Data				Side slope
	SC No.	Chawk No.		Off-take	Out-fall	Bed Level		Bed Width		
						Start	End	Start	End	
Aloa *Khal*	12 & 14	23D, 27C	3.880	Santosh Regulator	Aloa Raypara Regulator	8.00	7.39	4.00	6.00	1:1.50
Bamni *Khal*	8	9C, 9K, 9M	4.370	Chawk 9C	Enayetpur WCS-2	10.20	8.18	6.50	11.00	1:1.50
Barabelta *Khal*	12	24A, 24B	2.410	Barabelta Intake	Berabuchna WCS	9.80	9.15	4.00	4.00	1:1.50
Baruha *Khal*	14 & 13	25A, 28F, 28C	3.070	Baruha Intake	Kumuria *Beel*	9.84	8.04	4.00	5.00	1:1.50
Berabuchna *Khal*	14	27C/28B	1.380	Berabuchna WCS	Baratia - Kumuria *Beel*	9.00	8.31	3.00	3.00	1:1.50
Bhatkura *Khal*	3	19F, 19E	2.560	Chawk 19E	Bhatkura Outlet	6.75	7.60	10.00	10.00	1:1.50
Binnafair *Khal*	11	5A, 5F, 6C	5.350	Binnafair Intake	Santosh Regulator	8.00	9.05	5.00	3.00	1:1.50
Chillabari *Khal*	10 & 11	7A/7B/7K/7D/6A	3.315	Chillabari Outlet	Gaijabari *Khal*	8.25	8.15	4.00	4.00	1:1.50
Deojan *Khal*	14	28A	1.500	Kumuria *Beel*	Deojan Outlet	8.00	8.75	2.00	2.00	1:1.50
Dharerbari *Khal*	8	9E,9B	1.200	Chawk 9B	Dharerbari Outlet	10.00	11.14	2.00	1.00	1:1.50
Dighulia *Khal*	11	7D,7H	1.300	Chawk 7D	Dighulia-I Outlet	8.40	8.76	2.00	2.00	1:1.50
District *Khal*	16 & 8	9M	1.946	Enayetpur-2 WCS	District Regulator (Outlet)	8.04	8.32	6.50	5.50	1:1.50
Dithpur *Khal*	9	1F	1.538	Krishnopur *Beel*	Dithpur Outlet	9.48	9.48	7.00	7.00	1:1.50
Fatehpur *Khal*	11	5F,6D,5D	0.920	Fatehpur Intake	*Chawk* 5B	8.74	9.34	2.50	2.50	1:1.50
Gaijabari *Khal*	11	6C, 7H, 7F	2.392	Santosh Regulator	Kagmari Outlet	7.99	7.82	8.50	8.50	1:1.50
Gharinda - Jalfai *Khal*	4	22A, 22B, 22C	4.250	Gharinda Bridge	Jalfai Outlet	6.90	6.48	7.00	7.00	1:1.50
Golabari *Khal*	3	19A	1.880	Gharinda Bridge	Suruj *Khal*	8.46	8.15	3.00	3.00	1:1.50
Indrabelta *Khal*	12	23A, 23B	0.996	Indrabelta Intake	*Chawk* 23D	9.62	8.95	1.50	1.50	1:1.50
Khanpur Borrowpit	11	7B, 7C, 7D	1.920	*Chawk* 7A	Dighulia-2 Outlet	8.30	8.00	2.00	2.00	1:1.50
Khudirampur *Khal*	3	21A	0.700	*Chawk* 21A	Khudirampur Outlet					
Khorda Jugini *Khal*	9	1A	1.000	Khorda Jugini Intake	Krishnapur WCS	7.50	9.25	6.00	5.00	1:1.50
Kumulli *Khal*	15	31A	1.000	Kumulli Outlet	*Chawk* 31A	8.31	8.81	1.00	1.00	1:1.50
Lohajang River			23.420	Main Regulator	Karatia Bridge	7.70	6.03	20.00	20.00	1:1.50
Magurata *Khal*	7	10G, 10J	1.090	Magurata WCS	*Chawk* 10J	8.85	8.66	4.00	4.00	1:1.50
Nagar - Jalfai *Khal*	4	22E	0.952	*Chawk* 22C	Jalfai Outlet	6.48	6.38	9.00	9.00	1:1.50
Rampal *Khal*	10 & 11	4B	1.060	*Chawk* 4B	Binnafair *Khal*	8.70	9.56	3.00	3.00	1:1.50
Rasulpur *Khal*	6 & 7	11C, 11D, 11H, 11J	6.400	Rasulpur Intake	Sadullapur khal (chawk 11J)	9.20	7.70	6.00	6.00	1:1.50
Sadullapur *Khal*	5, 6 & 7	10B, 10E, 10G, 11J, 12A, 13A	6.906	Sadullapur Intake	Gharinda Bridge	9.20	6.90	6.00	6.00	1:1.50
Singerkona - Dannya Chowdhury *Khal*	10	3B/3C	0.845	Singerkona *Beel*	Dannya Chowdhury Outlet	8.58	8.82	2.50	2.50	1:1.50
Suruj *Khal*	1 & 3	14A, 14B, 19A, 19B, 19C	3.975	Suruj Intake	Hatila *Beel*	9.30	7.83	6.00	8.50	1:1.50
Ghoramara *Khal* (Upper Part)	10	3C, 3F	0.840	Ghotokbari *Beel*	Boro *Beel*					
Ghoramara *Khal* (Lower Part)	10	3F	1.880	Boro *Beel*	Bhangabari WCS					
Total Length of Khal (except Tangail Drain) = 96.245										

Table 3.1: List of drainage channels

	Elanjani River	No. of vents	Dimension of gates (HxV)	Sill level + PWD
1	Baruha	1	1.25 x 1.75 m	9.70
2	Bara Belta	1	0.95 x 1.15 m	9.75
3	Indra Belta	1	0.90 x 1.25 m	9.62
4	Silimpur Inlet	1	0.60m diam	9.75
	DHALESWARI RIVER			
5	Fatehpur	1	0.90 x 1.20 m	8.84
6	Binnafair	1	0.90 x 1.20 m	8.84
	LOHAJANG			
7	Khorda Jugini	1	1.50 x 2.50 m	10.00
8	Main Regulator	2	1.50 x 2.30 m	10.70
		3	3.00 x 3.80 m	9.20
	GALA RIVER			
9	Sadullapur	1	3.00 x 3.00 m	9.20
10	Rasulpur	1	1.50 x 3.0 m	9.20
11	Rasulpur Pipe Inlet	1	0.60m diam	11.00
	PUNGLI RIVER			
12	Pauli	1	1.20m diam	10.00
13	Bararia	1	0.90 m diam	10.75
14	Suruj	1	1.50 x 3.00 m	9.20

Table 3.2: Peripheral inlet structures, CPP

	Sub-compartment	Name	Design level Lohajang + PWD	Number of vents	Dimension of vents (mxm)	Sill leve + PWD
1	8	Dharerbari	10.00	1	0.90x1.20m	10.00
2	9	Dithpur	10.00	2	2.00x1.00m	10.90
				1	0.90x0.90m	9.45
3	10	Dannya Chowdhury	10.00	1	0.90m diam	8.70
4	11	Chillabari	10.00	1	0.90m diam	8.10
5	8	District	9.90	2	1.5x3.0m	8.00
6	11	Dighulia 2	9.90	1	0.90m diam	8.00
7	11	Dighulia 1	9.90	1	0.90m diam	8.50
8	11	Kagmari	9.90	2	1.50x3.00m	7.80
9	14	Aloa Raypara	9.65	4	1.50x3.00m	7.20
10	14	Deojan	9.50	1	2.50x4.80m	8.20
11	4	Nagar Jalfai	9.00	2	1.50x3.00m	6.50
12	3	Bhatkura	9.00	2	1.50x3.00m	7.00
13	3	Khudirampur	9.00	1	1.50x1.80m	8.00
14	15	Kumulli	9.00	1	0.75m diam	8.60
15	15	Khagjana	9.00	1	0.75m diam	8.00
16	15	Birpushia[1] (to be constructed)	9.00	1	1.50 x 1.80m	8.50

Table 3.3: Structures along the Lohajang river, CPP

[1] Not implemented yet

	Name of Structure	Number of vents	Dimensions of gates	Sill level + PWD
CLUSTER 1 (Fig 5.2A)				
1	Krishnopur	1	1.50x1.80m	9.75
2	*Beel* Baghil	1	0.60m diam	8.70
3	Edgah Moidan	1	0.90x1.20m	10.20
4	Sapua	1	0.60m diam	9.60
5	Singerkona Beel	1	1.50x1.80m	8.75
6	Chowbari	1	0.60m diam	9.50
7	Rampal	1	1.50x1.80m	9.00
8	Bhangbari	2	1.50x1.80m	8.60
9	Santosh	3	1.50x2.00m	8.00
CLUSTER 2 (Fig 5.2B)				
1	Salina	1	0.90x1.20m	9.00
2	Batchanda 1	1	1.20x1.50m	9.00
3	Batchanda 2	1	0.90x1.20m	9.50
4	Magurhata	1	1.50x1.80m	9.00
5	Agbetor	2	1.50x1.80m	9.50
6	*Beel* Gharinda	1	1.50x1.80m	8.00
7	Enayetpur-2	1	2.50x2.00m	9.00
8	Enayetpur	1	2.00x2.50m	8.00
9	Char Kagmara	1	1.20x1.50m	9.50
CLUSTER 3 (Fig 5.2C)				
1	Birnahali-1	1	0.90m diam	7.00
2	Namdar Kumulli (N)	1	0.90x1.20m	8.50
3	Neogijoar	1	0.90x1.20m	8.50
4	Gosaijoair	1	1.20x1.50m	8.00
5	Hatila	1	1.20x1.50m	8.00
6	Poila	1	2.50x1.50m	8.50
7	Mirer Betka	1	0.90x1.20m	8.00
8	Namdar Kumulli(S)	1	1.20x1.50m	8.50
9	Dharat	1	0.6 m diam	9.00
10	Birnahali-2	1	0.6 m diam	8.00
11	Karatia Chow.para	1	0.90x1.20m	8.00
12	Karatia	1	1.20x1.50m	7.50
13	Paschim Pauli	1	1.20x1.50m	7.50
CLUSTER 4 (Fig 5.2D)				
1	Bhurbhuria	2	1.50x1.80m	8.60
2	Aloa Bhabani 1	1	0.75mdiam	8.60
3	Bera Buchna	1	2.00x1.80m	9.00
4	Bara Atia	1	1.50x1.80m	9.00

Table 3.4: Internal infrastructure of the Tangail compartment

Sl. No.	Cost Item	Length (Km)/ No.	Ref. To Annex	Preventive (Tk)	Periodic (Tk)	Emergency (Tk)	Total (Tk)
1.	**Embankment**					300,000	**300,000**
	A) Peripheral	47.00	1A,1B	846,000	1,786,000		**2,632,000**
	B) Internal	13.00	1A,1B	234,000	494,000		**728,000**
2.	***Khals* (Canals)**						
	a) Main	23.42	1A,1B	4,684	1,639,400		**1,644,084**
	B) Seconda	54.49	1A,1B	10,899	708,422		**719,321**
	C) Minor	18.09	1A,1B	2,714	108,546		**111,260**
3.	**Structures**					200,000	**200,000**
	A) Peripheral	14	1C	79,346	746,400		**825,746**
	B) Along Lohajang	16	1C	92,411	913,635		**1,006,046**
	C) Internal	35	1C	92,742	856,200		**948,942**
4.	**Protective works LS**		14, 1B	1,512,796	7,652,603	2,00,000	**9,865,399**

Annexure 1: Summary of Annual Maintenance Cost

Sl. No.	Item	Length(Km)/No.	Unit Rate per km./ per No.	Cost (Tk)	Total Cost (Tk)
1	**Embankments:**				
	a) Peripheral	47.00	18000		846,000
	b) Internal	13.00	18000		234,000
2	*Khals* (Canal)				
	a) Main				
	Lohajang	23.42	200	4,684	
	Total				**4,684**
	b) Secondary				
	Aloa	3.88	200	776	
	Bhatkura	2.56	200	512	
	Binnafair	5.35	200	1,070	
	Chillabari	3.32	200	663	
	Barabelta	2.41	200	482	
	Baruha	3.07	200	614	
	Gaijabari	2.39	200	478	
	Gharinda Jalphai	4.25	200	850	
	Rasulpur	6.40	200	1,280	
	Sadullapur	6.91	200	1,381	
	Suruj	3.98	200	795	
	Bamni	4.37	200	874	
	Ghoramara	2.72	200	544	
	District	1.95	200	389	
	Nagar Jalphai	0.95	200	190	
	Total =	**54.49**			**10,899**

Continued

Sl. No.	Item	Length (Km)/No.	Unit Rate per km./ per No.	Cost (Tk)	Total Cost (Tk)
	b) Minor				
	Berabuchana	1.38	150	207	
	Deojan	1.50	150	225	
	Dharerbari	1.20	150	180	
	Dighulia	1.30	150	195	
	Dithpur	1.30	150	195	
	Fatehpur	0.92	150	138	
	Golabari	1.88	150	282	
	Indrabelta	1.00	150	149	
	Khanpur Borrowpit	1.92	150	288	
	Khudirampur	0.70	150	105	
	khorda Jugini	1.00	150	150	
	Kumulli	1.00	150	150	
	Magurata	1.09	150	164	
	Rampal	1.06	150	159	
	Singercona Dannya Chow	0.85	150	127	
	Total =	**18.09**			**2,714**
3	**Structures**				
	a) Peripheral (Inlets)	14		79,346	
	b) Structures along the Lohajang (Outlets)	16		92,411	
	c) Internal Structures	35		92,742	
	Total				**264,499**
4	**Protective work L. S.**				**150,000**
	Grand Total				**1,512,795**

Annex 1-A: Annual Preventive Maintenance Cost

Note: a) Unit cost from Annex 1-C and Annex 1-D
b) Periodic maintenance of structures from Annex 1-C

Sl. No.	Item	Length(Km)/No.	Unit Rate per km./ per No.	Cost (Tk)	Total Cost (Tk)
1	**Embankments:**				
	a) Peripheral	47.00	38,000		1,786,000
	b) Internal	13.00	38,000		494,000
2	***Khals*** **(Canal)**				
	a) Main				
	Lohajang	23.42	70,000	1,639,400	
	Total				**1,639,400**
	b) Secondary				
	Aloa	3.88	13,000	50,440	
	Bhatkura	2.56	13,000	33,280	
	Binnafair	5.35	13,000	69,550	
	Chillabari	3.32	13,000	43,095	
	Barabelta	2.41	13,000	31,330	
	Baruha	3.07	13,000	39,910	
	Gaijabari	2.39	13,000	31,070	
	Gharinda Jalphai	4.25	13,000	55,250	
	Rasulpur	6.40	13,000	83,200	
	Sadullapur	6.91	13,000	89,778	
	Suruj	3.98	13,000	51,675	
	Bamni	4.37	13,000	56,810	
	Ghoramara	2.72	13,000	35,360	
	District	1.95	13,000	25,298	
	Nagar Jalphai	0.95	13,000	12,376	
	Total =	**54.49**			**708,422**

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Sl. No.	Item	Length (Km)/No.	Unit Rate per km./ per No.	Cost (Tk)	Total Cost (Tk)
	b) Minor				
	Berabuchana	1.38	6,000	8,280	
	Deojan	1.50	6,000	9,000	
	Dharerbari	1.20	6,000	7,200	
	Dighulia	1.30	6,000	7,800	
	Dithpur	1.30	6,000	7,800	
	Fatehpur	0.92	6,000	5,520	
	Golabari	1.88	6,000	11,280	
	Indrabelta	1.00	6,000	5,976	
	Khanpur Borrowpit	1.92	6,000	11,520	
	Khudirampur	0.70	6,000	4,200	
	Khorda Jugini	1.00	6,000	6,000	
	Kumulli	1.00	6,000	6,000	
	Magurata	1.09	6,000	6,540	
	Rampal	1.06	6,000	6,360	
	Singercona Dannya Chow	0.85	6,000	5,070	
	Total =	**18.09**			**108,546**
3	**Structures**				
	a) Peripheral (Inlets)	14		746,400	
	b) Structures along the Lohajang (Outlets)	16		913,635	
	c) Internal Structures	35		856,200	
	Total				**2,516,235**
4	**Protective work L. S.**				**400,000**
	Grand Total				**7,652,603**

Annex 1-B: Annual Periodic Maintenance Cost

Note: a) Unit cost from Annex 1-C and Annex 1-D
b) Periodic maintenance of structures from Annex 1-C

Sl. No.	Name of Structure	Cost of Structure (Lac Tk)	Preventive Cost							Periodic cost =1.5% of investment cost (Taka)
			Painting gates		Painting gauge (Taka)	Greasing		Others (Taka)	Total (Taka)	
			Area (sq. m)	Cost (Taka)		No. of gate	Cost (Taka)			
A.	Peripheral inlet									
1	Rasulpur Inlet, C-2	36.43	42.36	2541.6	700	2	800	200	4,242	54,645
2	Khurda Jugini Inlet, C-2	28.31	48.38	2902.8	700	2	800	200	4,603	42,465
3	Barabelta Inlet, C-1	5.76	25.38	1522.8	700	1	400	200	2,823	8,640
4	Binnafair Inlet, C-1	7.04	19.78	1186.8	700	1	400	200	2,487	10,560
5	Fatehpur Inlet, C-1	8.40	19.78	1186.8	700	1	400	200	2,487	12,600
6	Indrabelta Inlet, C-1	5.71	25.38	1522.8	700	1	400	200	2,823	8,565
7	Pauli Inlet, C-1	8.05	16.13	967.5	700	1	400	200	2,268	12,075
8	Bararia Inlet, C-1	5.44	15.63	937.8	700	1	400	200	2,238	8,160
9	Sadullapur Inlet, W-2	62.10	99.13	5948.0	700	2	800	200	7,648	93,150
10	Main Inlet, C-2 & W-6	236.33	451.29	27077.4	700	8	3200	200	31,177	354,495
11	Suruj Inlet, C-1& W-1	33.33	67.61	4056.6	700	2	800	200	5,757	49,995
12	Baruha Inlet, C-1& W-1	35.16	67.61	4056.6	700	2	800	200	5,757	52,740
13	Rasulpur Pipe Inlet,W-1	9.90	20.32	1219.1	700	1	400	200	2,519	14,850
14	Silimpur Inlet, W-1	15.64	20.32	1219.1	700	1	400	200	2,519	23,460
	Total								**79,346**	**746,400**
B.	Structure along the Lohajang									
1	Dithpur Outlet, C-3	19.38	35.79	2147.1	700	3	1200	200	4,247	29,070
2	Dharerbari Outlet, C-2	19.38	15.76	945.6	700	2	800	200	2,646	29,070
3	Dynna Chow. Outlet, C-2	11.22	28.83	1729.8	700	2	800	200	3,430	16,830
4	Chillabari Outlet, C-2	13.47	28.83	1729.8	700	2	800	200	3,430	20,205
5	Dighulia-1 Outlet, C-2	12.25	28.83	1729.8	700	2	800	200	3,430	18,375
6	Kumulli Outlet, C-1	11.10	9.20	552.0	700	1	400	200	1,852	16,650
7	Khagjana Outlet, C-1	11.15	9.20	552.0	700	1	400	200	1,852	16,725
8	Deojan Outlet, W-1	54.27	32.55	1953.0	700	1	400	200	3,253	81,405
9	District Outlet, C-2 & W-2	68.39	112.61	6756.6	700	4	1600	200	9,257	102,585
10	Kagmari Outlet, C-2 & W-2	75.59	120.45	7227.0	700	4	1600	200	9,727	113,385
11	Jalphai Outlet, C-2 & W-2	75.80	116.11	6966.6	700	4	1600	200	9,467	113,700
12	Bhatkura Outlet, C-2 & W-2	73.96	116.11	6966.6	700	4	1600	200	9,467	110,940
13	Aloa Raypara Outlet	97.35	267.44	16046.4	700	8	3200	200	20,146	146,025
14	Dighulia-2,W-1	11.50	20.32	1219.1	700	1	400	200	2,519	17,250
15	Khudirampur Outlet, C-2	26.28	35.50	2130.0	700	2	800	200	3,830	39,420
16	Birpusia, C-2	28.00	36.00	2160.0	700	2	800	200	3,860	42,000
	Total								**92,411**	**913,635**

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Sl. No.	Name of Structure	Cost of Structure (Lac Tk)	Preventive Cost							Periodic cost =1.5% of investment cost (Taka)
			Painting gates		Painting gauge (Taka)	Greasing		Others (Taka)	Total (Taka)	
			Area (sq. m)	Cost (Taka)		No. of gate	Cost (Taka)			
C.	**Internal Structure**									
1	Enayetpur-1 WCS, C-1	21.87	27.48	1648.8	700	1	400	200	2,949	32,805
2	Hatila WCS, C-1	18.95	25.36	1521.8	700	1	400	200	2,822	28,425
3	Poila WCS, C-1	19.34	22.41	1344.3	700	1	400	200	2,644	29,010
4	Enayetpur-2 WCS, C-1	26.73	27.90	1674.0	700	1	400	200	2,974	40,095
5	Berabuchna WCS, C-1	16.33	26.50	1590.0	700	1	400	200	2,890	24,495
6	Santosh WCS, C-3	60.20	62.70	3762.0	700	3	1200	200	5,862	90,300
7	Agbetur WCS,C-2	30.31	35.50	2130.0	700	2	800	200	3,830	45,465
8	Beel Gharinda WCS, C-2	37.75	35.50	2130.0	700	2	800	200	3,830	56,625
9	Bhangabari WCS, C-2	28.33	35.50	2130.0	700	2	800	200	3,830	42,495
10	Bhurbhuria WCS, C-2	41.04	35.50	2130.0	700	2	800	200	3,830	61,560
11	Krishnapur WCS, C-1	12.05	26.05	1563.0	700	1	400	200	2,863	18,075
12	Magurata WCS, C-1	24.80	24.05	1443.0	700	1	400	200	2,743	37,200
13	Rampal WCS, C-1	10.85	24.05	1443.0	700	1	400	200	2,743	16,275
14	Singerkona WCS, C-1	12.65	24.05	1443.0	700	1	400	200	2,743	18,975
15	Bara Atia WCS, C-1	9.57	16.70	1002.0	700	1	400	200	2,302	14,355
16	Bhatchanda-1 WCS, C-1	10.13	16.70	1002.0	700	1	400	200	2,302	15,195
17	Charkagmara WCS, C-1	9.45	16.70	1002.0	700	1	400	200	2,302	14,175
18	Gosaijoir WCS, C-1	9.11	16.70	1002.0	700	1	400	200	2,302	13,665
19	Karatia WCS, C-1	16.89	16.70	1002.0	700	1	400	200	2,302	25,335
20	Namderkumulli (S) WCS, C-1	9.93	16.70	1002.0	700	1	400	200	2,302	14,895
21	Paschimpauli WCS, C-1	23.91	16.70	1002.0	700	1	400	200	2,302	35,865
22	Eidgah Maidan WCS, C-1	11.18	9.98	598.8	700	1	400	200	1,899	16,770
23	Namderkumulli (N) WCS, C-1	11.69	9.98	598.8	700	1	400	200	1,899	17,535
24	Salina WCS, C-1	13.17	9.98	598.8	700	1	400	200	1,899	19,755
25	Bhatchanda-2 WCS	8.47	9.98	598.8	700	1	400	200	1,899	12,705
26	Niogijoir WCS, C-1	10.46	9.98	598.8	700	1	400	200	1,899	15,690
27	Karatia Choudhury Para, C-1	12.33	9.98	598.8	700	1	400	200	1,899	18,495
28	Mirer Betka WCS, C-1	11.46	11.63	697.5	700	1	400	200	1,998	17,190
29	Birnahali-1 WCS, C-1	11.95	15.63	937.8	700	1	400	200	2,238	17,925
30	Aloa Bhabani-1 WCS, C-1	6.10	9.20	552.0	700	1	400	200	1,852	9,150
31	Beel Bhaghil WCS	4.89	20.32	1219.1	700	1	400	200	2,519	7,335
32	Chowbari WCS	4.02	20.32	1219.1	700	1	400	200	2,519	6,030
33	Sapua WCS	4.11	20.32	1219.1	700	1	400	200	2,519	6,165
34	Dharat WCS	4.83	20.32	1219.1	700	1	400	200	2,519	7,245
35	Birnahali-2 WCS	5.95	20.32	1219.1	700	1	400	200	2,519	8,925
	Total								92,742	856,200

Annex 1-C: Annual preventive and periodic maintenance cost of structures

Basis:

1) Greasing cost @ Tk. 400/- per gate.
2) Painting cost @ Tk. 60/- per sq. meter.
3) Gauge painting @ Tk. 700/- per structure
4) Others include debris clearance, repair, etc. LS 200/- per structure.

ANNEXURE-1D: UNIT RATE CALCULATION

UNIT RATE CALCULATIONS FOR PREVENTIVE AND PERIODIC MAINTENANCE

1. Embankment

a) Preventive Maintenance per km.

Avg. 1 No labour per k.m. 6 days a week throughout the whole year.

Cost

1* 6* 52 = 312 Nos. labor per year

@ Tk. 50.00 per day	=	15,600.00
Extra labor cost during the excessive rainfall month	=	2,400.00
	Tk.	18,000.00

b) Periodic Maintenance

Earth Work

Considering subsistence @ 0.05 m/year
X-sectional area = 4.35*0.05 + 2* ½ * 0.10*2.5
= 0.22 +0.25 =0.47 sq. m

Per km. volume = 1000*0.47 = 470 m3
Cost @ Tk. 45.00 per m3 = 21,150.00

Turfing

2*1000*2.5*2.24 = 11,200 sq.m
@ Tk. 7.30 = 81,760.00
Per year 81,760.00 ¸ 5 = 16,352.00
37,502.00

Say Tk. 38,000.00 per km.

2. *Khals*

a) Preventive maintenance - L.S. Tk. 200/- per km.
b) Periodic maintenance per km.
Secondary *khals*

Siltation rate @ 0.10 m annually
Avg. bed width 4 m
Side slope 1: 1.5
Total earthwork per km.
4.20*0.10*1000 = 420 m^3
Side slope 2* ½ *0.10 * 1.5*1000 = 150 m^3
= 570 m^3

@Tk. 23.00 per m3 = 13,110.00
Say Tk.13, 000.00 per km.

Minor *Khals*

about 50% of major *khals*

Say Tk. 6000.00 per km.

Main (Lohajang river)

Earth work per km - 20*0.10 *1000 = 2000

2* ½ * 0.10 * 3.5*1000 = 350

= 2350 m^3

@ Tk. 30.00 = 70,500.00

Say Tk. 70,000.00 per km.

3. Structures

a) Preventive cost

i) Painting cost @ Tk. 60.00 per sq. m.

ii) Greasing cost @ 3 pound per gate and Tk. 125.00 per pound
So per gate cost = Tk. 375 Say Tk.400.00 per gate

iii) Debris clearance: L.S. Tk.200.00 per structure per year

iv) Gauge painting: L.S. Tk.100.00 per meter
Avg. 7 meter per structures i.e. Tk. 700/- per structure.

b) Periodic Cost

Example-1: District Regulator (Cost of structure - 68.39 lakhs)

i) Replacing rubber seals (one in 3 years)

2(1.75*2+1.00*2) = 11.00

2(1.75*2+2.30*2) = 16.20

27.20

@ 600.00 per m. = 16,320.00

Per year cost Tk. 5,440.00

ii) Repairing of structures (1 in 10 years)
L.S. per year Tk. 60,000.00

iii) Replace gates (1 in 15 years)

Total cost Tk. 500,000

Per year cost Tk. 33,300.00

iv) Replacing wire ropes for pinion gear gate (1 in 5 years)
2*30 meter @ Tk. 150.00 per meter = 9,000.00
Per year cost Tk. 1,800.00

Total = Tk. 100,540.00

As a percentage of total investment cost of structure per year
= (100,540.00/6,839,000.00)*100 = 1.47%

Example-2: Bhat Chanda WCS (1 vent 1.20 x 1.50)
Cost of the structure 10.13 Lakh

i)	Replacing rubber seal (1 in 3 year) 2*1.35+2*1.65 = 6 meter @ 600.00 per m = 3600.00	Tk. 1,200.00
ii)	Repairing of structures (1 in 10 years) LS per year	Tk. 8,000.00
iii)	Replace gates (1 in 15 years) Total cost 1,05,000.00	Tk. 7,000.00
		Tk. 16,200.00

As per percentage of total investment cost of structure per year
=(16,200.00/1,013,000)*100 = 1.60%

Example - 3: Bhangabari WCS (2 - 1.50 x 1.80 vent)
Cost of the structure 28.33 Lakh

i)	Replacing rubber seal (1 in 3 year) 2(2*1.65+2*1.95) = 14.4 m @ Tk. 600.00 per meter 8,640.00	Tk. 2,880.00
ii)	Repairing structure (1 in 10 years) L.S. per year	Tk. 25,000.00
iii)	Replacing gates (1 in 15 years) Total Cost 2,40,000.00	Tk. 16,000.00
		Tk. 43,880.00

As a percentage of total Investment cost of structure per year
=(43,880/2,833,000)*100.00 = 1.55%

Avg. periodic cost as percentage of total investment cost of structure per year
= (1.47+1.60+1.55)/3 = 1.54

Say 1.50% of the civil works cost of the structure.

Sl. No.	Item of work	Qty./ No	Type of Maintenance	Maintenance cycle	Annual Avg. Maintenance Cost	Responsibility and cost sharing by			Remark
						BWDB	Water Management Committee		
							Voluntary labor	Own resource/ contribution	
1	**Embankment**	60.00 Km.	Preventive	continuous	10.80	10.80			
			Periodic	3-5 years	22.80	22.80			
			Emergency	as needed	3.00	3.00			
2	***Khals* (Canal)**								
	a) Main	23.42 Km.	Preventive	continuous	0.05	0.05			
			Periodic	3-5 years	16.39	16.39			
	b) Secondary	54.49 Km.	Preventive	continuous	0.11		0.11		
			Periodic	3-5 years	7.08	7.08			
	c) Minor	18.09 Km.	Preventive	continuous	0.03		0.03		
			Periodic	3-5 years	1.09		0.76	0.32	
3	**Hydraulic Structures**								
	a) Peripheral & along Lohajang	30	Preventive	continuous	1.72	1.54		0.18	
			Periodic	- Rubber seal replacement 1 in 3 years. - Wire rope replace 1 in 5 years.	16.60	16.60			
				- Gate Replacement 1 in 15 years. - Major repair 1 in 10 years.					
			Emergency	as needed	1.50	1.50			
	b) Internal	35	Preventive	Continuous	0.93			0.93	
			Periodic	- Rubber seal Replacement 1 in 3 years. - Gate Replacement 1 in 15 years. - Major repair 1 in 10 years	8.56	8.56			
			Emergency	as needed	0.50	0.50			
4	Protective work		Preventive	Continuous	1.50	1.50			
			Periodic	3-5 years	4.00	4.00			
			Emergency	as needed	2.00	2.00			
	Total =				**98.66**	**96.33**	**0.90**	**1.43**	

Annexure-2: Maintenance plan: responsibilities and cost sharing among the parties involved (BWDB & WMCS)

Job Number	Job Title MAIN WORKS	Completed Fiscal Year	Comments	Reimbursed Or Contract Value (Million Tk.)	Totals (Million Tk.)
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	Kagmari 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
	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 Jugini 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

Continued

Job Number	Job Title MAIN WORKS	Completed Fiscal Year	Comments	Reimbursed Or Contract Value (Million Tk.)	Totals (Million Tk.)
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	
					11.43
20101	District Regulator	1995-96		6.84	
20310	Dharerbari Outlet	1995-96		1.94	
					8.78
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
CLUSTER 2(Cont.)		1998-99		2.55	
	Additional Structures	1995-96		0.02	
20404	Kandila Bridge				
20405	Dharerbari Pipe Culvert				
					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	Khudirampur 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

Continued

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Job Number	Job Title MAIN WORKS	Completed Fiscal Year	Comments	Reimbursed Or Contract Value (Million Tk.)	Totals (Million Tk.)
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
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 A1.2. Costs of Water Control Structures and Additional Structures with Job Numbers and Years of Completion

Job Number	Job Title	Completed Fiscal Year	Evaluation December 1999	Reimbursed Or Contract Value (Lack Tk.)	Contract Value (Lakh Taka)	Totals (Lack Tk.)
	Main System					
60501	Lohajang R. excavation 2.5 km upstr. of Putijani Bridge to Karatia	1995-96		94.40		
60501	Lohajang R. excavation Chillabari - Jugini		Dropped			
61101	Lohajang R. excav. 2.5 km upstr. Putijani Br. - Chillabari (FFW)	1996-97		FFW		
						94.40
Cluster 1						
	Finished Works					
10502	Singerkona - Dannya Chowdhury *Khal*	1998-99		3.99	4.27	
10503	Binnafair *Khal*	1993-94		7.65	7.65	
10505	Dithpur *Khal*	1995-96		2.08	2.08	
10506	Rampal *Khal*	1993-94 & 1997-98		1.59	1.88	
10509	Fatehpur *Khal*	1994-95		1.00	1.59	
10511	Dighulia *Khal*	1994-95		7.70	1.00	
10512	Chillabari *Khal*	1992-93		8.25	7.70	
10513	Gaijabari *Khal*	1992-93		1.97	8.25	
10501	Khorda Jugini *Khal*	1998-99		3.37	3.55	
	Unfinished Works					**7.93**
10510	Khanpur Borrowpit	1999-2000			4.38	
10504	Ghoramara *Khal* (Upper and Lower part)		Dropped			
Cluster 2						
	Finished Works					
20501	Sadullapur *Khal*	1993-94		13.29	13.29	
20502	Magurata *Khal*	1994-95		0.77	0.77	
20506	Dharerbari *Khal*	1996-97		1.03	1.03	
20507	District *Khal*	1993-94		5.03	5.03	
	Unfinished Works					
20506	Dharerbari Drain Lining	1999-2000			3.10	
20508	Rasulpur *Khal*	1999-2000	90%	21.10	21.59	
20509	Bamni *Khal*	1994-95	35% (Dropped)	2.50	2.50	
						47.31
Cluster 3						
	Finished Works					
30505	Suruj *Khal*	1994-95		9.65	9.65	
30505	Suruj *Khal*	1998-99		2.00	3.61	
30508	Golabari *Khal*	1995-96		2.59	2.59	
30507	Nagor-Jalfai *Khal*, Downstream of Highway Tangail - Dhaka	1994-95		4.29	4.29	
30501	Bhatkura *Khal*	1994-95		8.40	8.40	
30502	Khudirampur *Khal*	1996-97		4.39	4.39	
						32.93
	Unfinished Works					
30506	Gharinda-Jalfai *Khal*, Upstream of Highway Tangail - Dhaka	1999-2000		15.85	23.31	
30506	Gharinda-Jalfai *Khal*, Upstream of Highway Tangail - Dhaka	1999-2000			3.00	
						26.31
Cluster 4						
	Finished Works					
40503	Berabuchna *Khal*	1997-98		3.10	3.10	
40505	Indra Belta *Khal*	1996-97		1.12	1.12	
40511	Deojan *Khal*	1996-97		2.06	2.06	
40508	Baruha *Khal*, Baruha Intake - Burburia WCS	1997-98		5.14	5.14	
40514	Kumulli *Khal*	1998-99		0.55	0.62	
						12.04
	Unfinished Works					
40502	Aloa *Khal*	1999-2000	90%	12.45	13.63	
40504	Barabelta *Khal*	1999-2000	50%	4.09	8.51	
40508	Baruha *Khal*, Burburia WCS - Kumuria Beel	1999-2000	60%	3.32	5.37	
						27.51
	Additional Drains:					
20503	Kandila-Deolia *Khal* (Additional Drain)	1994-95		0.55	0.55	
40501	Santosh *Khal*		Dropped			
40506	Katakhali Link Canal (Additional Drain)	1998-99		0.40	1.00	
40507	Bagerchara Link Canal		Dropped			
40510	Baruha Link Canal		Dropped			
40517	Kumergara *Khal*	1998-1999		0.85	0.93	
						2.48
Overall total						**250.91**

Table A1.3: Cost of the Excavation of Drainage Canals, with Job numbers and Years of Completion

Job Number	WORKS BEFORE 1998 Job Title	Completed Fiscal Year	Comments	Reimbursed or Contract Value (Million Taka)	Totals (Million Taka)
Peripheral Embankment					
00601	Ramdevpur - Gopalpur Embankment	1993-94		1.57	
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	**26.62**
Embankment along the Lohajang					
10604	Dithpur Outlet - Main Regulator	1994-95		0.81	
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	**4.88**
Protective Works					
20901	Passbetur Groyne I & II	1994-95		7.13	
41302	Belta Sarai Protective Work	1995-96	Work not accepted		
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	**11.95**
Other Works					
60504	Elenjani River Loop Cut	1996-97		4.17	
61102	Gala Khal under FFW	1996-97			**4.17**

Continued

Job Number	WORKS AFTER 1998 Job Title	Completed Fiscal Year	Comments	Reimbursed or Contract Value (Million Taka)	Totals (Million Taka)
Peripheral Embankment					
00601 - 00605 and 00609 - 00617	Resectioning of Embankment	1998-99		24.13	
00613	Retired Embankment at Birnahali	1998-99		1.44	
00614	Salina-Dapnazar Embankment (part)	1999-2000		0.83	
00613	Additional Resectioning Suruj-Birnahali	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 Birnahali	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 A1.1: Cost of Works on the Embankments and Protective Works, with Job Numbers Years of Completion

Annex C
Water Management and Modeling

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General Description of the Compartment

This description of the Compartment concentrates on water management features. Reference is made to the Figures 1 and 2 for the Compartment and its surroundings and to the Figures 3 to 6 for details on the sub-compartments. The Tangail 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 Southern 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 West, North and eastern boundaries of the Compartment are protected by a peripheral embankment, which form a horseshoe. The southern boundary runs over a somewhat higher ridge. In the embankments, there are water intake structures. In the western embankment there are six, Binnafair, Fatehpur, Indrabelta, Barabelta, Baruha and Silimpur Inlet. In the northern embankment along the Lohajang, there is Khorda Jugini Intake. Along the Gala Khal, there are three intakes, Sadullapur, Rasulpur and the Rasulpur Pipe Inlet. Continuing along the Pungli, there are Pauli and Bararia, which are of local importance only and finally Suruj Intake. Silimpur and Rasulpur Pipe Inlet have been constructed after the 1998 flood.

The Compartment drains mainly via the Lohajang River. There are 16 outlet structures along the river, the Main Regulator, 10 outlets on the western and 5 on the eastern bank. The Lohajang enters the Compartment via the Main Regulator, which started operating in the early monsoon of 1995. The regulator provides a certain control over water levels and discharges in the river. When the gates of the regulator are fully lifted, the Lohajang flows freely. By closing the gates, the river flow is inter-rupted. The maximum difference between inside and outside water levels is about 1.5 m. Along the southern boundary of the Compartment, there are drainage structures, which drain the Compartment to the South. They are shown in Fig 6.

The Compartment is divided into 4 clusters: Cluster 1 in the Northwest, Cluster 2 in the Northeast, Cluster 3 in the Southeast and Cluster 4 in the Southwest. Detailed maps of water management infrastructure per cluster are provided in the Figures 3 to 6. Each cluster is divided into sub-compartments. There are 15 in total, not counting Tangail Town. Each sub-compartment in turn consists of *chawks*. The *chawks* are shown in the Figures 3-6. All *chawks* are fully contained within their sub-compartments, which in turn are fully contained within their clusters.

Strings of *chawks* form systems, which all have numbers. As one may see in the Figures 3 to 6, a *chawk* number consists of number followed by a letter. The number indicates to which system the *chawk* belongs. Therefore, the *chawks* with number 9, belong to System 9. A system is a more or less independent water system.

Chawks and sub-compartments have water management committees. Clusters and systems do not have such committees.

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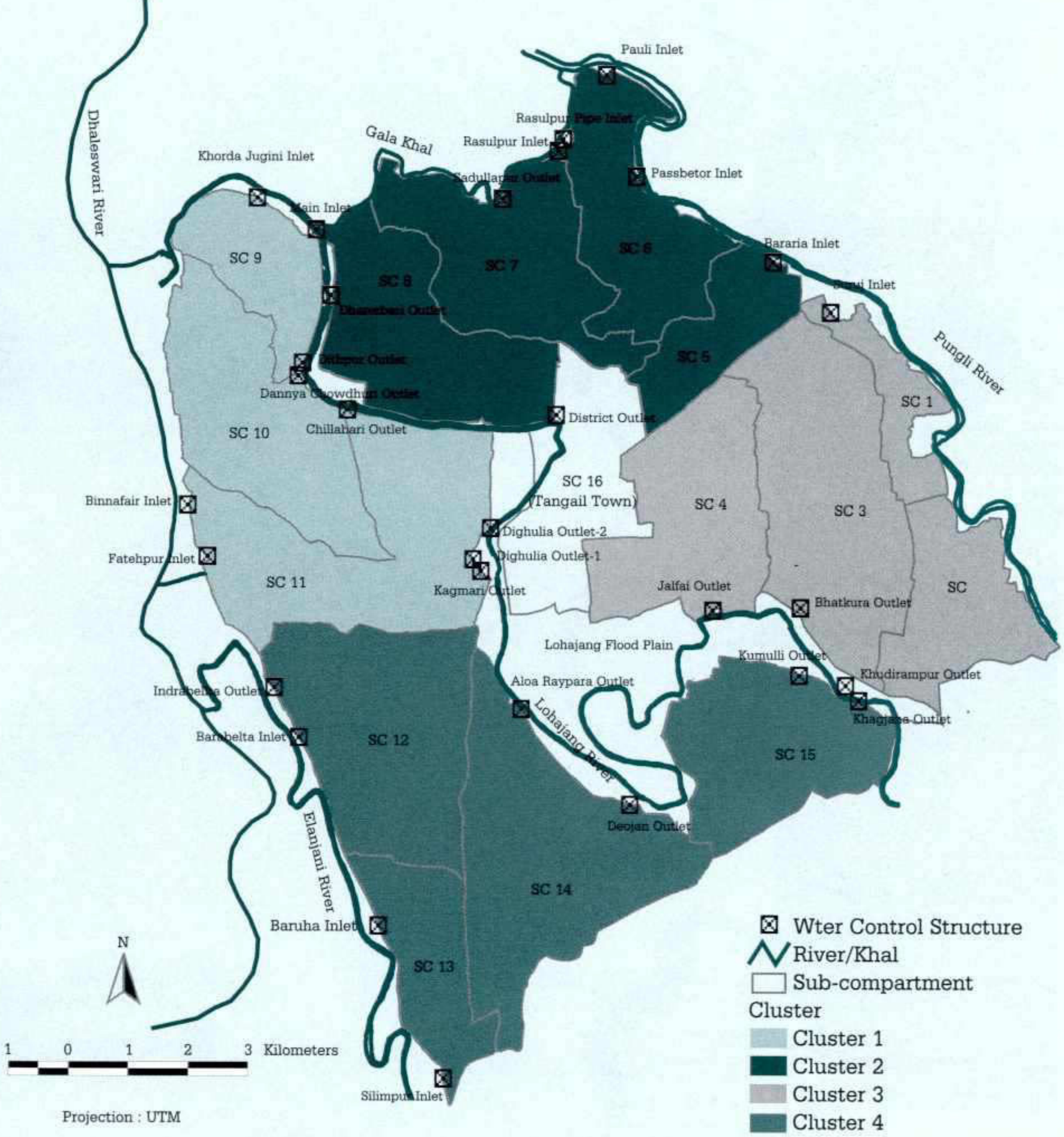

Figure 1 : Tangail Compartment

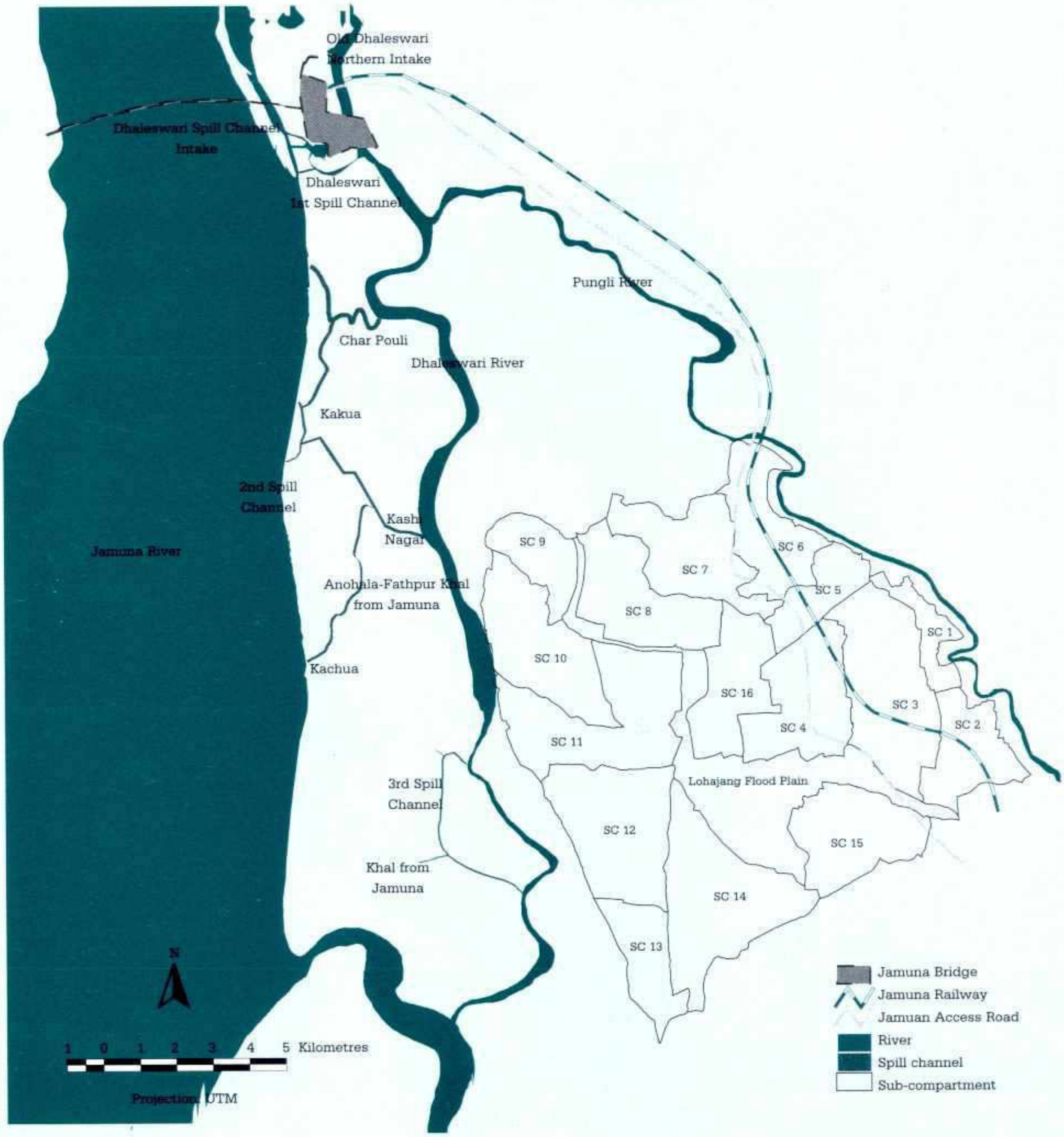

Figure 2: The Tangail Compartment and its Surroundings

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Figure 3: Water Managemant Infrastructure Cluster 1

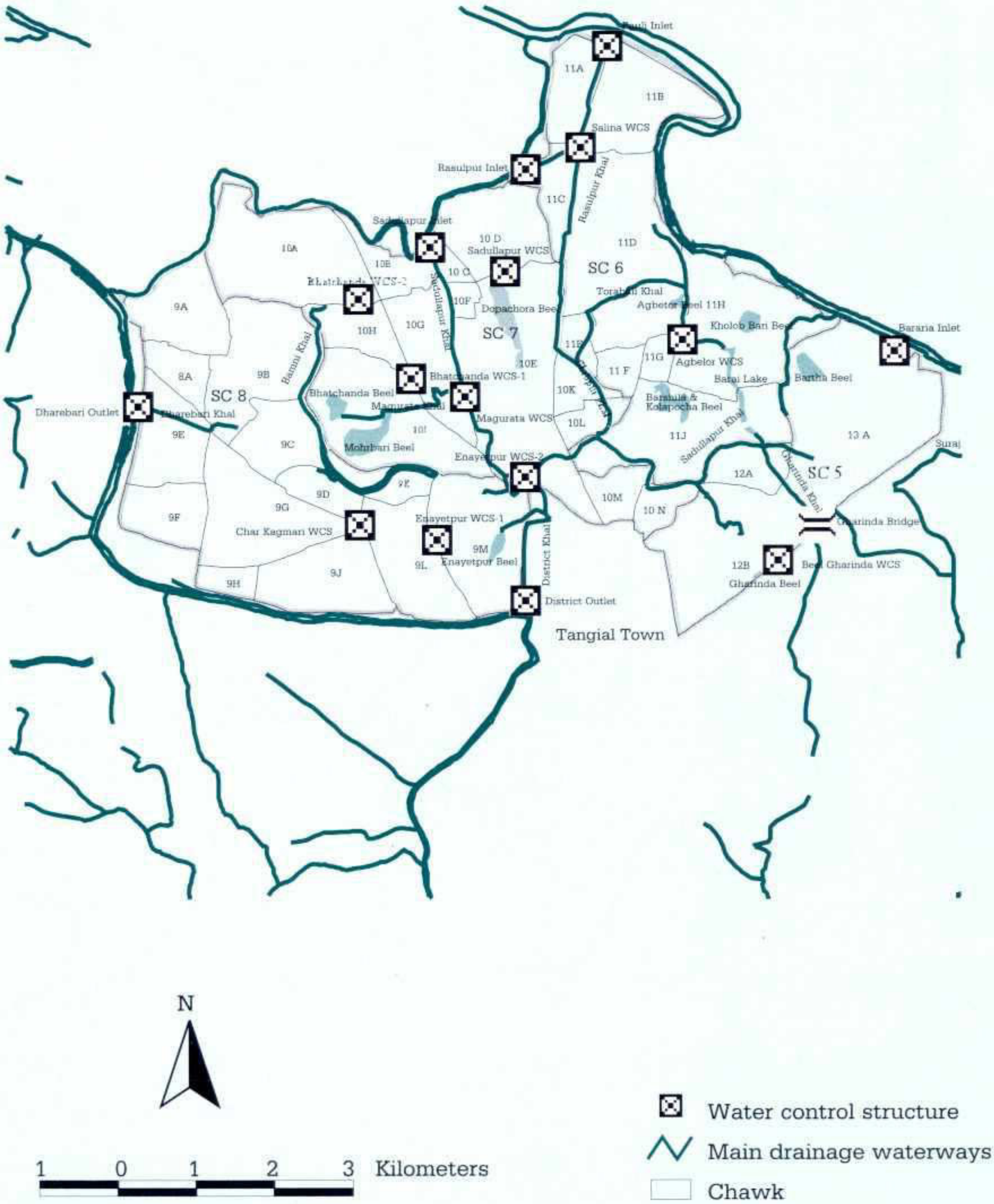

Figure 4: Water Management Infrastructure Cluster 2

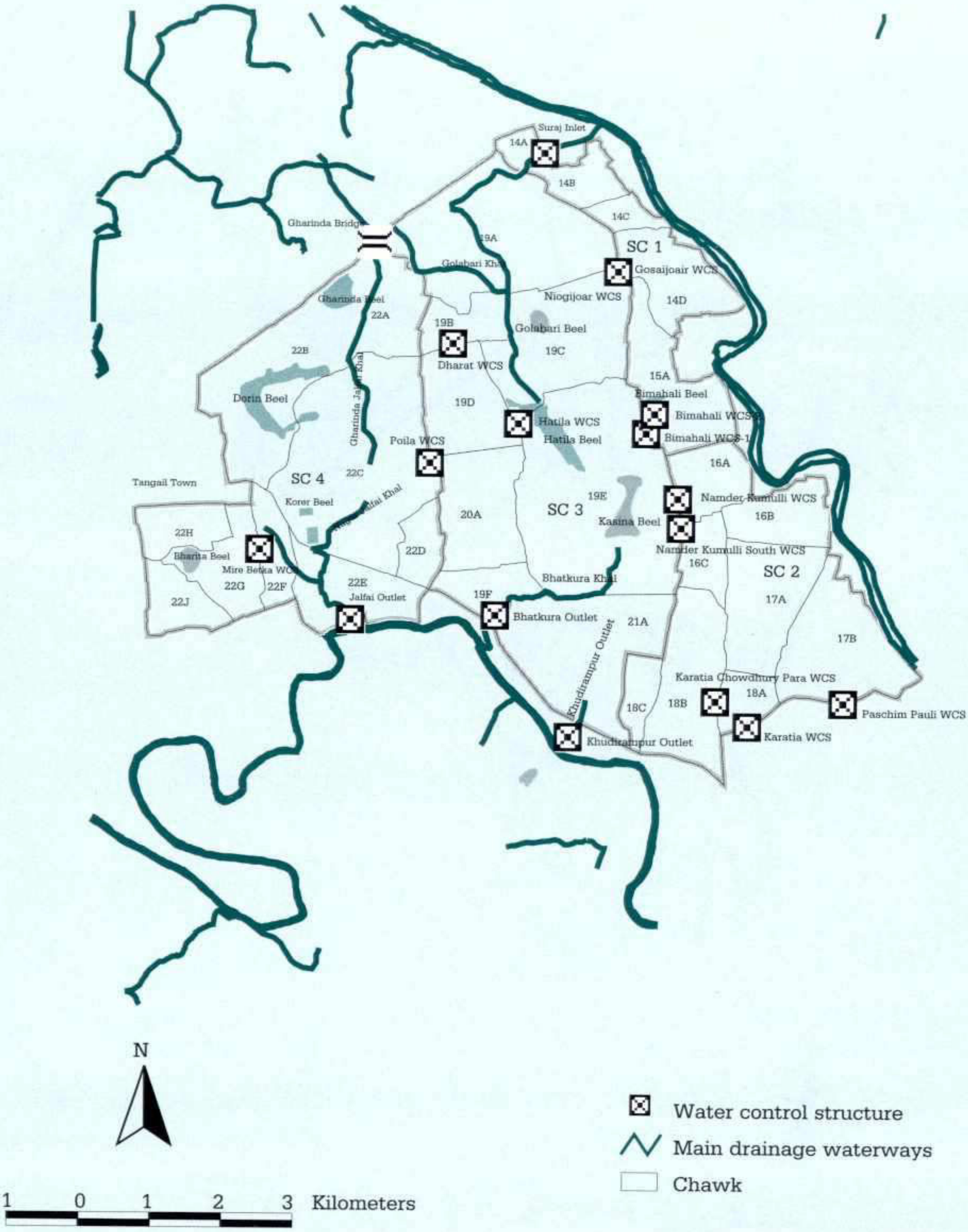

Figure 5: Water Management Infrastructure Cluster 3

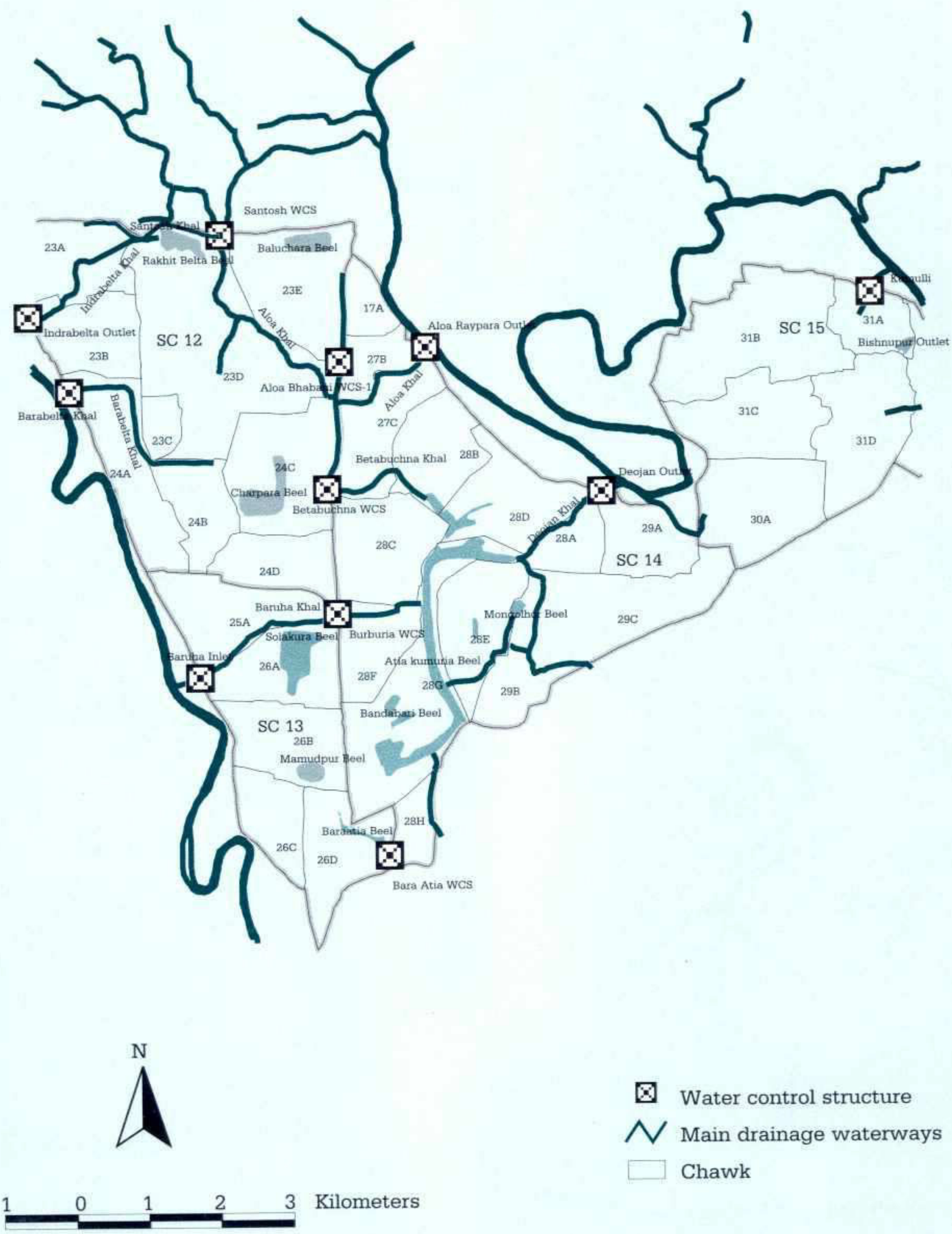

Figure 6 : Water Management Infrastructure Cluster 4

The Physical Environment

Rainfall

Rainfall During Project Years

Important rainfall characteristics of the Compartment are presented in the Tables 1, 2 and 3. Table 1 shows monthly and annual totals during Project years, 1991-1999. Most data are from records of Atia station, which is a BWDB station in Tangail. Due to incomplete records at the Atia station, the 1995 and 1997, data have been borowed from records of the Bangladesh Meteorological Department (BMD) station, also in Tangail.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1991	14	16	80	53	437	366	428	170	732	315	0	93	2,704
1992	0	65	0	2	188	392	317	299	501	54	5	0	1,823
1993	7	7	44	192	357	527	487	297	425	233	0	0	2,576
1994	25	58	86	151	409	309	245	485	328	220	12	0	2,328
1995	7	54	9	34	218	319	368	353	245	129	79	1	1,815
1996	0	40	9	100	258	284	267	384	327	262	0	0	1,931
1997	0	38	25	199	163	312	507	469	266	12	2	28	1,993
1998	0	0	0	8	112	397	178	481	413	270	49	61	1,936
1999	0	0	0	5	231	204	336	179	286	206	41		

Table 1: Monthly and Annual Rainfall in Tangail for the years 1991-1999 in mm

In order to interpret the monthly totals in terms of whether months have been dry or wet, Table 2 and Fig 7 were prepared. The table contains approximate frequencies of monthly rainfall for the months May-October and for the entire year. The table shows, for instance, that a rainfall of 150 mm in July is rather dry and exceptional, while 300 mm is about normal. As it turns out, the rain in all Project years, with the exception of 1999, has been above the median value and the Project period may be qualified as wet.

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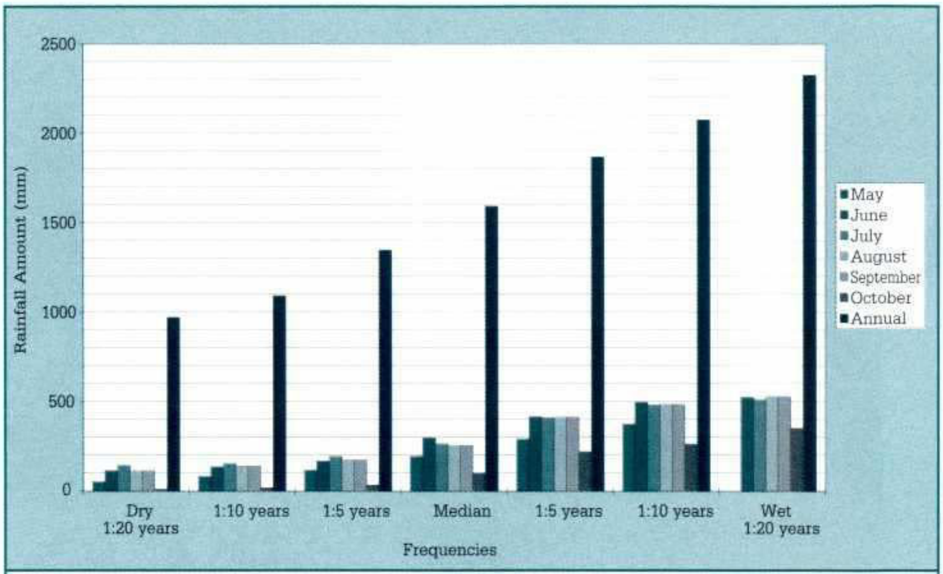

Figure 7: Monthly and Annual Rainfall and their Frequencies

General Characteristics of the Rain in the Area

Further, on Table 2, if one considers the median values and assuming that the evaporation is about 4 mm/day or 120 mm/month, one may conclude that the rainfall exceeds the evaporation by far.

Frequency	May	June	July	Aug	Sept	Oct	Annual
Dry 1:20 years	52	115	144	113	76	9	973
1:10 years	84	136	155	138	88	17	1,093
1:5 years	118	168	194	173	119	33	1,349
Median	195	298	265	254	205	101	1,594
1:5 years	292	417	411	414	329	220	1,870
1:10 years	377	498	483	485	425	262	2,077
Wet 1:20 years	409	527	514	530	475	352	2,327

Table 2: Frequencies of Monthly and Annual Rainfall in mm

Maximum rainfall amounts and their frequencies for periods of 1 - 10 days, are shown in Table 3 and Fig. 8. Such data have been used to calculate the Project's drainage requirements. For agricultural drainage, the norm usually is 1:5 years. A rather strict drainage requirement is, for instance, that the 3 days rainfall is evacuated within about 4 days. Assuming an evaporation of 4 mm/day, the requirement leads to a daily rainfall rate of 50 mm/day or 5.8 l/sec/ha. Due to reasons to be discussed later, the

Compartment drains more slowly, at a rate of about 3.5 l/sec/ha or even less. This corresponds to a 10 days rainfall to be evacuated within 10 days.

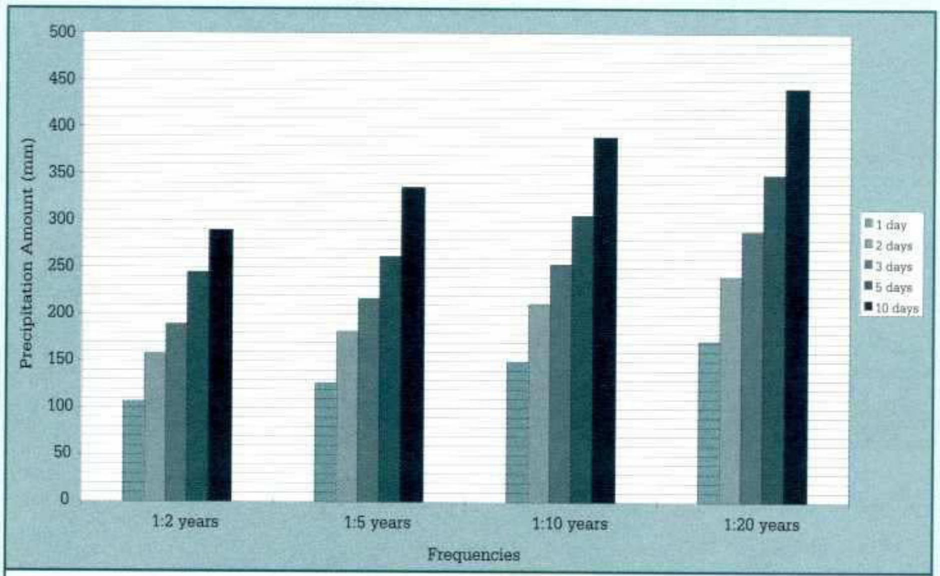

Figure 8. Maximum 1-10 Days Rainfall with Frequencies

	1 day	2 days	3 days	5 days	10 days
1:20 year	172	241	289	349	442
1:10 year	150	212	254	306	390
1:5 year	127	182	217	262	336
1:2 year	107	158	189	245	290

Table 3: Maximum 1-10 Days Rainfall Totals and their Frequencies (mm)

Hydrology of the Compartment

Before CPP, the Compartment was insufficiently protected, with large gaps in the embankments. CPP closed the dikes but rehabilitated existing intakes and added other ones. In addition, it constructed the Main Regulator, which controls flooding from the Lohajang.

Flooding of the land surrounding the Compartment may happen from late April and later during the monsoon. During April and, May the *Boro* is still in the field and ripening. Early flash floods may do considerable damage to the crop. During flash floods, the intakes of the Compartment are supposed to be closed and the area is protected against such damage.

Usually the monsoon floods start in July. By that time most of the field are without a crop and the land users await the rains and the floods to prepare their land. So intakes are opened and the water may enter the Compartment. Land users attribute great value to the floodwater because it brings fish and silt. However, due to the embankments and limited capacity of the intakes the original flooding situation can not be restored.

The Compartment itself drains towards the Lohajang via numerous interconnected drainage systems. Nevertheless the larger drainage systems, dominating the drainage flow have been identified. The area drains slowly which implies that during the monsoon large amounts of water are stored in the fields, but as a dynamic system. The rainfall excess drains slowly to the Lohajang, via which it leaves the Compartment.

Water levels inside the Compartment have been measured by the Project at two kinds of gauges, the non-structural and the structural gauges. The structural gauges are all positioned at water management structures, one upstream and one down-stream. The non-structural gauges are not specifically tied to structures. Fig. 9 shows the position of all non-structural gauges inside and outside the Compartment. There are 53 of them. Appendix 1 lists all the structural gauges. Their positions are those of the structures, which can be found in the Figures 3 to 6.

The gauges have provided an impressive amount of data of good quality. This data has been the basis for the modeling of the Compartment.

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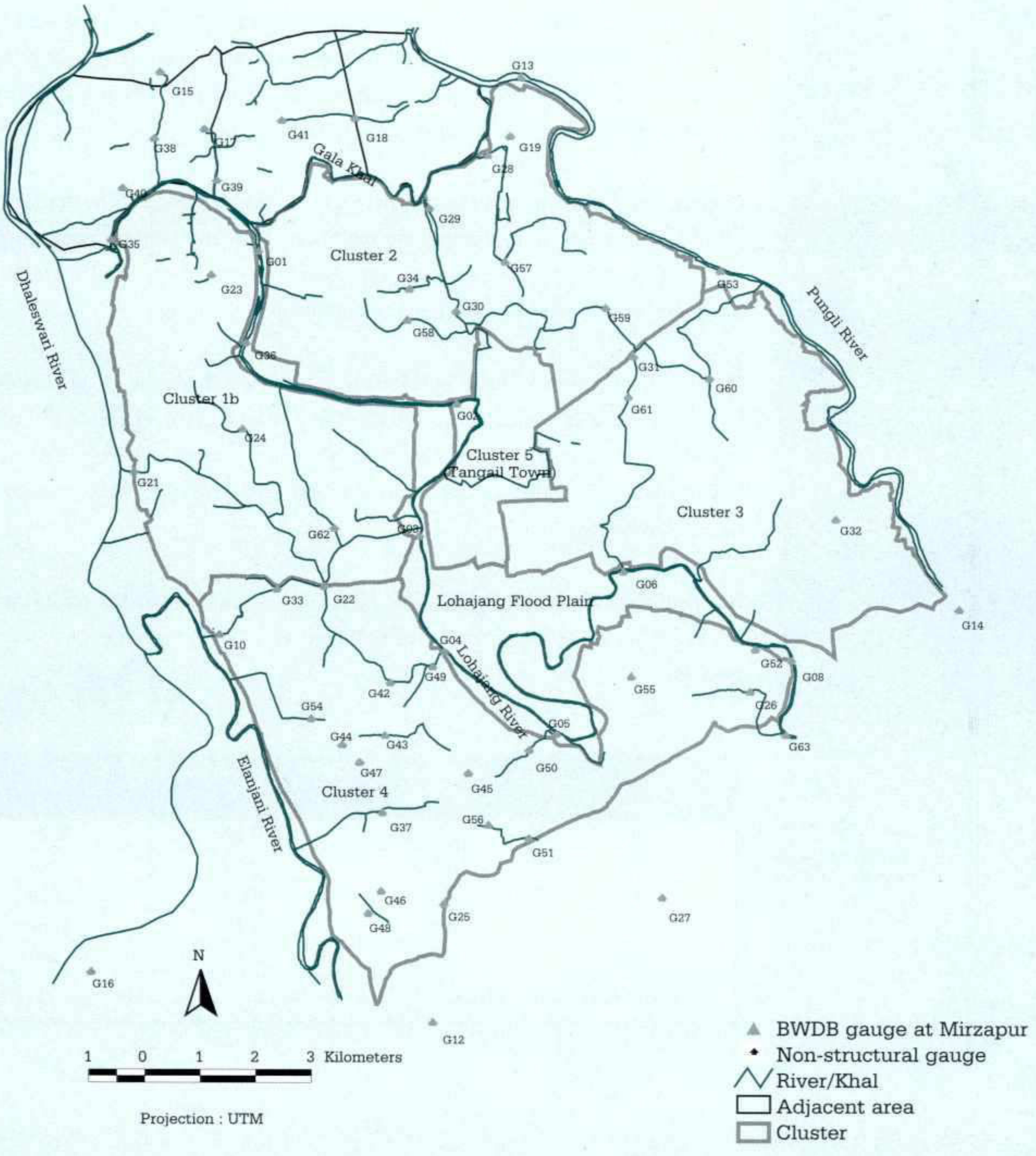

Figure 9: Position of Non-Structural Water Level Gauges

Outside Water Conditions

The Jamuna flood plain slopes from the North towards the South with an average slope of about 5-cm per km and water levels do the same. Therefore, water levels North of the Compartment are higher than in the South. The floods, therefore, do not constitute stagnant water but should be seen as a layer of water traveling through the plain. The Compartment with its embankments is an obstruction to that flow and causes a slight water level increase in the North.

Outside water levels have an important impact on the hydrology of the Compartment. The Main Regulator may control the water levels in the Lohajang upstream, but downstream, the Compartments is open. Therefore, high water levels outside affect the water levels in the Lohajang and the drainage of the area.

Of the non-structural gauges outside the Compartment, gauge G 35, Jugini, is a BWDB gauge. It is positioned in the Lohajang, where the river meets the western border of the Compartment. It has about 45 years of record. Table 4 lists average monthly values of Jugini for the monsoons 1995-1999 and Table 5 the frequencies of monthly averages.

It appears that almost all Jugini levels, of 1995-1999, are between the median and the 1:5 years high. The exception is 1999, where all monthly averages are below the median.

	July	Aug	Sept
1995	11.61	11.27	10.91
1996	11.64	11.03	11.00
1997	10.62	10.32	10.30
1998	11.84	12.50	11.57
1999	10.77	10.85	11.05

Table 4: Average Water Levels at Jugini during the Project (m PWD)

	July	Aug	Sept
High 1:20 years	12.18	12.61	12.04
1:10 years	12.02	12.42	11.69
1:5 years	11.87	12.10	11.77
Median	11.45	11.57	11.45
1:5 years	10.93	10.96	10.96
1:10 years	10.64	10.63	10.58
Low 1:20 years	10.47	10.32	10.34

Table 5: Frequencies of Average Monthly Water Levels at Jugini. (m PWD)

The modeling of the Compartment, to be discussed later, makes use of the Mirzapur Gauge as the most Southern hydrological boundary of the models. The position of the gauge is shown in Fig 10. It is a BWDB gauge. Mirzapur records are available since 1988, with 1989 data missing. Monthly averages for the monsoon months are shown in Table 6. Due to the short record, no frequencies were determined. The years 1988 and 1998 were flood year. The average of August 1998 exceeds the one of August 1988, while the 1998 September value comes close to the one of 1988.

	July	Aug	Sept
1988	8.41	8.41	9.81
1989	No data	No data	No data
1990	8.02	8.81	7.86
1991	8.48	8.46	8.88
1992	6.61	6.41	6.47
1993	7.95	8.22	8.37
1994	5.88	6.24	6.08
1995	7.92	8.35	7.65
1996	6.75	7.63	7.44
1997	6.96	7.03	7.07
1998	7.55	9.37	9.40
1999	7.12	7.32	8.36

Table 6: Monthly Average Water Levels at Mirzapur Gauge (m PWD)

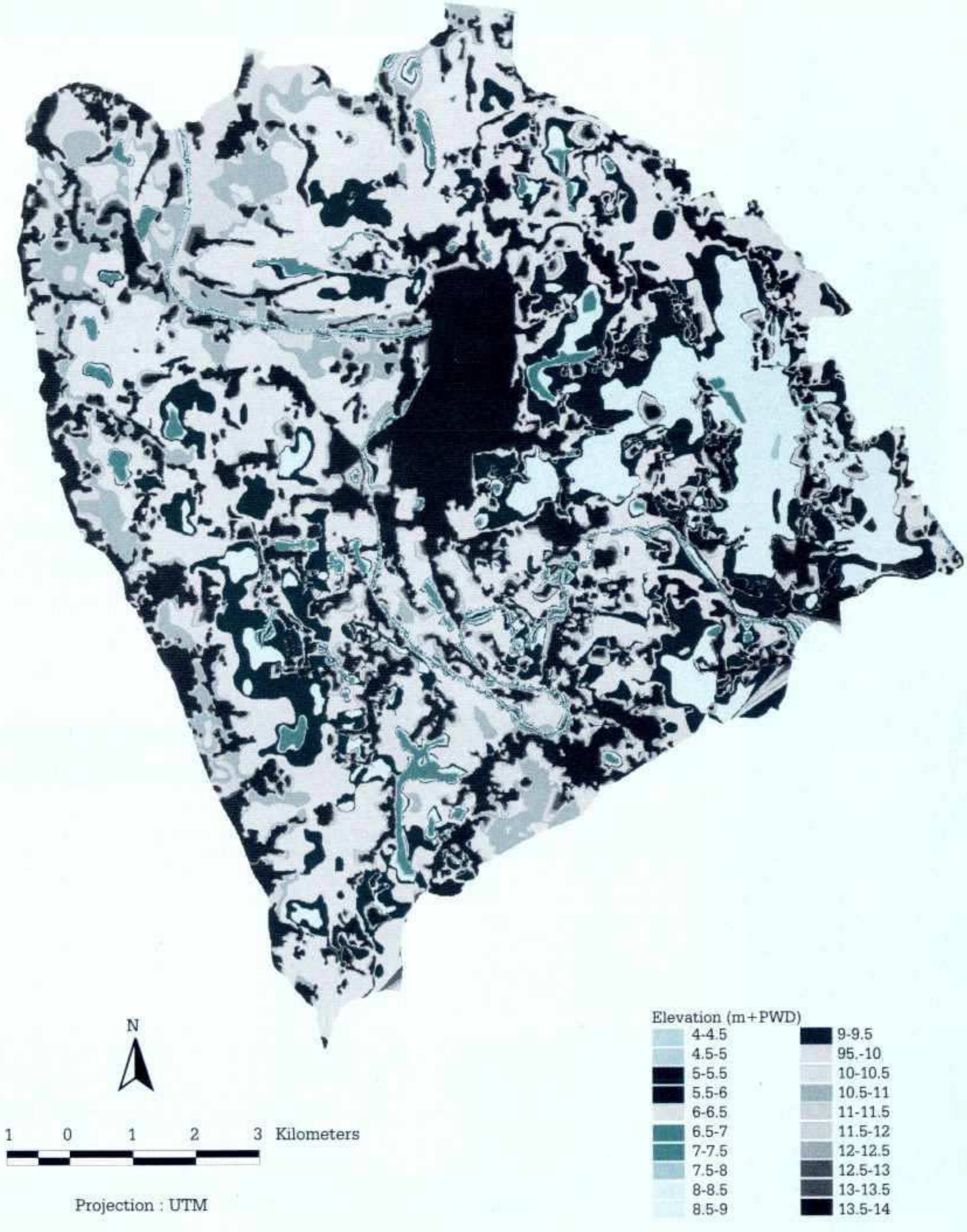

Figure 10: Topographical Map of the Tangail Compartments

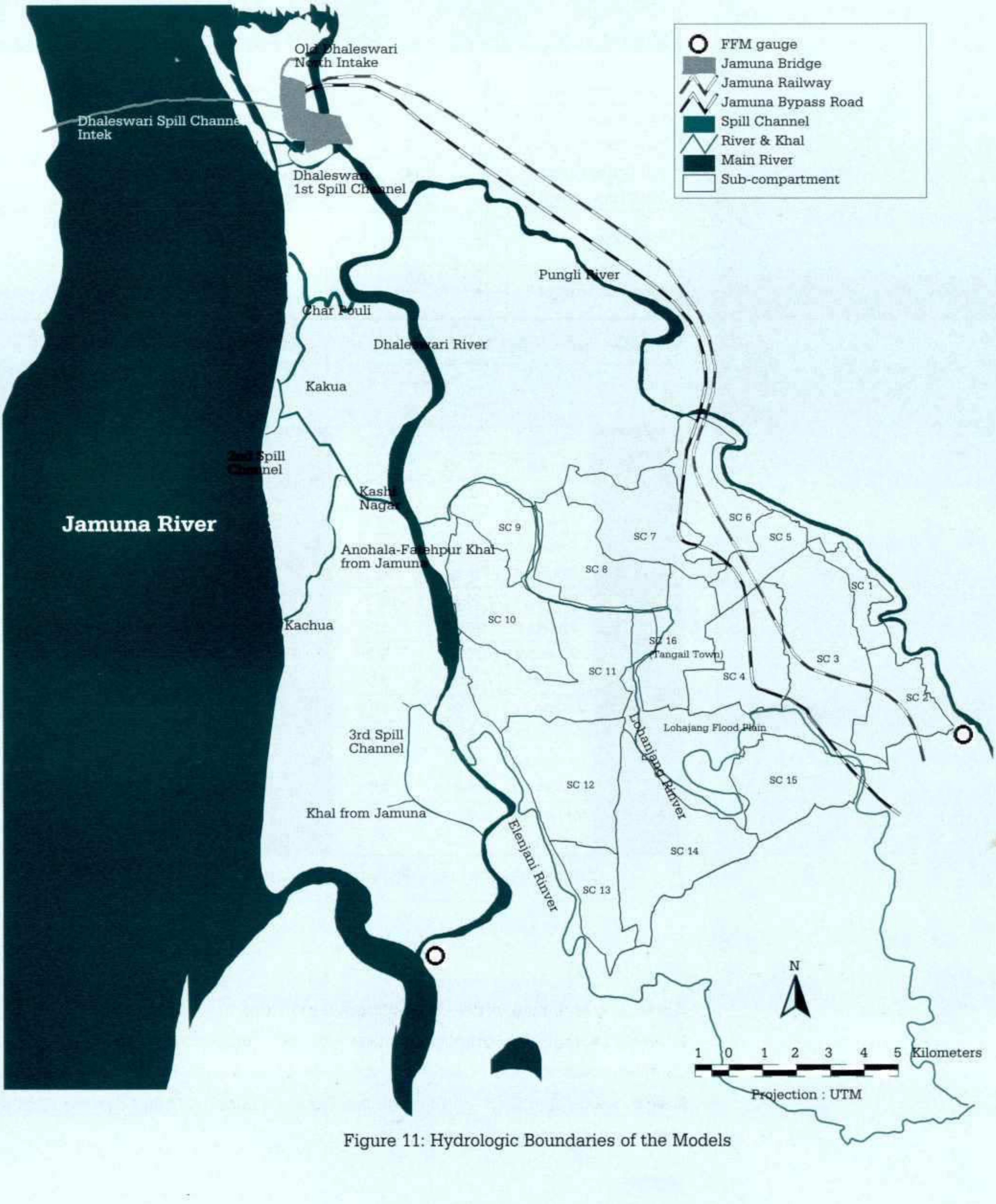

Figure 11: Hydrologic Boundaries of the Models

Sub-Compartment	Level	Sub-Compartment	Level
Sub-Compartment 1	9.58	Sub-Compartment 9	11.06
Sub-Compartment 2	9.18	Sub-Compartment 10	10.40
Sub-Compartment 3	9.07	Sub-Compartment 11	10.33
Sub-Compartment 4	9.39	Sub-Compartment 12	10.06
Sub-Compartment 5	9.74	Sub-Compartment 13	10.25
Sub-Compartment 6	9.94	Sub-Compartment 14	9.81
Sub-Compartment 7	10.3	Sub-Compartment 15	10.19
	8		
Sub-Compartment 8	10.5		
	2		

Table 7: Average Topographical Levels per Sub-Compartment. (m PWD)

Cluster 1	System 1	11.06	SC 9	**Cluster 3**	System 17	9.15	SC 2
	System 2	11.03	SC 10		System 18	9.40	SC 2
	System 3	10.22	SC 10		System 19	9.04	SC 3
	System 4	10.46	SC 10		System 20	9.22	SC 3
	System 5	10.84	SC 11		System 21	9.12	SC 3
	System 6	10.03	SC 11		System 22	9.39	SC 4
	System 7	10.29	SC 11	**Cluster 4**	System 23	9.95	SC 12
Cluster 2	System 8	10.97	SC 8		System 24	10.24	SC 12
	System 9	10.50	SC 8		System 25	10.73	SC 13
	System 10	10.38	SC 7		System 26	10.10	SC 13
	System 11	10.04	SC 6		System 27	9.75	SC 14
	System 12	9.52	SC 6		System 28	9.75	SC 14
	System 13	9.92	SC 6		System 29	9.98	SC 14
Cluster 3	System 14	9.81	SC 1		System 30	10.59	SC 15
	System 15	9.24	SC 1		System 31	10.14	SC 15
	System 16	8.94	SC 1		System 32	9.75	SC 15

Table 8: Average Topographical Levels per System (m PWD)

Topography

A topographical map of the Compartment is provided in Fig. 11. The Tables 8 and 9 provide average topographical levels per sub-compartment and per system. SubCompartment 9 and System 1 constitute the highest part of the Compartment. The lowest sub-compartment and system are Sub-Compartment 3 and System 16 in the southeastern corner of Cluster 3.

External Impacts

Two events have profoundly influenced the Compartment during the second phase. The first is the 1998 flood, which caused breaches in the embankments and extensive flooding. The flood demonstrated the vulnerability of the embankments. During September, when the highest levels occurred, the horseshoe shape of the embankment came to a test. The 1998 flood will be discussed in more detail elsewhere.

The second event is the construction of the highway and railroad leading to the Bangabandhu Bridge, about 25 km to the North of Tangail Town. Both alignments cross the eastern part of the Compartment from South to North. Construction activities started after the monsoon 1998. The associated civil works have influenced water management in the Compartment. A hydrologic impact assessment was done by the Project team late 1997.

Changes Introduced during the Second Phase

Summary of the Changes

At the start of the second phase, in August 1996, several changes were introduced as far as water management was concerned. The reasons behind it were a re-evaluation of field conditions and an assessment that certain targets in water management could not be met. The changes made are summarized first, and discussed in more detail in the following sections of the chapter, when required.

During the first phase, CPP had concentrated very much on Cluster 1. When the second phase started, it was considered essential that the knowledge and experience gained there, be tested against conditions in the other clusters.

The documentation inherited from the first phase gave the impression that very detailed and accurate water level control was possible with the water management in-frastructure erected. Ref 1, the CPP 1996 GIS Atlas, is an example. It contains tables recommending per chawk and per half-monthly or monthly period, water levels, to be maintained during the months August-November. The range of the levels is only a few decimeters and for specific periods, water levels are recommended with 5-cm accuracy. At the start of the second phase, it was found that such detailed control of the water levels was not possible.

The concept of controlled flooding, which had played an important role during the first phase in water management, was found to have assumed different meanings. That in itself appeared confusing. At the end of the first phase, it mainly stood for providing outside water to the lands within the Compartment, when there was a demand. The water could be taken in through the intake structures in the primary embankments. Project documentation gave the impression that this facility was available to almost all land during most of the time. In reality, it had considerable limitations.

At the end of the first phase, it became clear that there were discrepancies between criteria for design and operation on one hand and the field situation on the other. A main item was, that design water levels, downstream of the outlet structures in the middle stretch of the Lohajang, could not be maintained, under prevailing operation procedures. Another discrepancy was, that drainage rates used in the designs were far higher than those occurring in the field were. A resumption of the modeling effort for the entire Compartment, including the Lohajang, appeared essential. Conditions for that were more favorable than ever, as an impressive database had been established by the start of the second phase.

Water Level Control

During the first phase, the Project's engineering team assumed that the boundaries of the hydrological units, *chawks*, sub-compartments and clusters, were watertight. Infrastructure erected by the Project at strategic locations, would be able to control the water flow to a large extent. During the transition from the first to the second phase, that assumption was questioned and an inventory of all water conveying infrastructure in the Compartment, known as the Drainage Inventory, was carried out in late 1996, early 1997. The results provided details on infrastructure per *chawk*, together with information about flow patterns. By combining the information from individual *chawks*, per system, sub-compartment and cluster, it was possible to obtain a picture of overall flow conditions in the Compartment.

The Compartment is full of bridges, culverts and breaches without gates, through which the water passed more or less freely. The boundaries of the hydrologic units were found pervious or porous rather than watertight. The water control structures erected by the Project changed the situation only to a limited extent. In many cases, if the gates of control structures were closed, the water found another way to travel down. Exceptions to be noted were the peripheral intakes and the outlet structures along the Lohajang.

The findings of the Drainage Survey called for a change in approach. In hydrologic terms: during the first phase, water was assumed to be flowing according to a cascade model. In such a model, the water passes from one hydrological unit to another by little cascades, controlled by structures. The structures maintain almost horizontal water surfaces upstream. In reality, the water appeared to be flowing according to a sheet flow model, where the water surface has a more or less continuously slope, broadly determined by the general slope of the land.

In a cascade model, water levels can be controlled per hydrologic unit, with great accuracy. In a sheet flow model, control is far less. The amount of water present on the land surface is large in comparison to, for instance, the rain or the water entering through the intakes. This renders the flow responding slowly to changes and the same applies to the water levels.

The results of the Drainage Inventory have not been published as a Technical Project Report. The data are available in four volumes with maps and detailed descriptions per *chawks*.. They have been used as a reference all through the second phase. The survey was presented to the outside world in the publication under Ref 2.

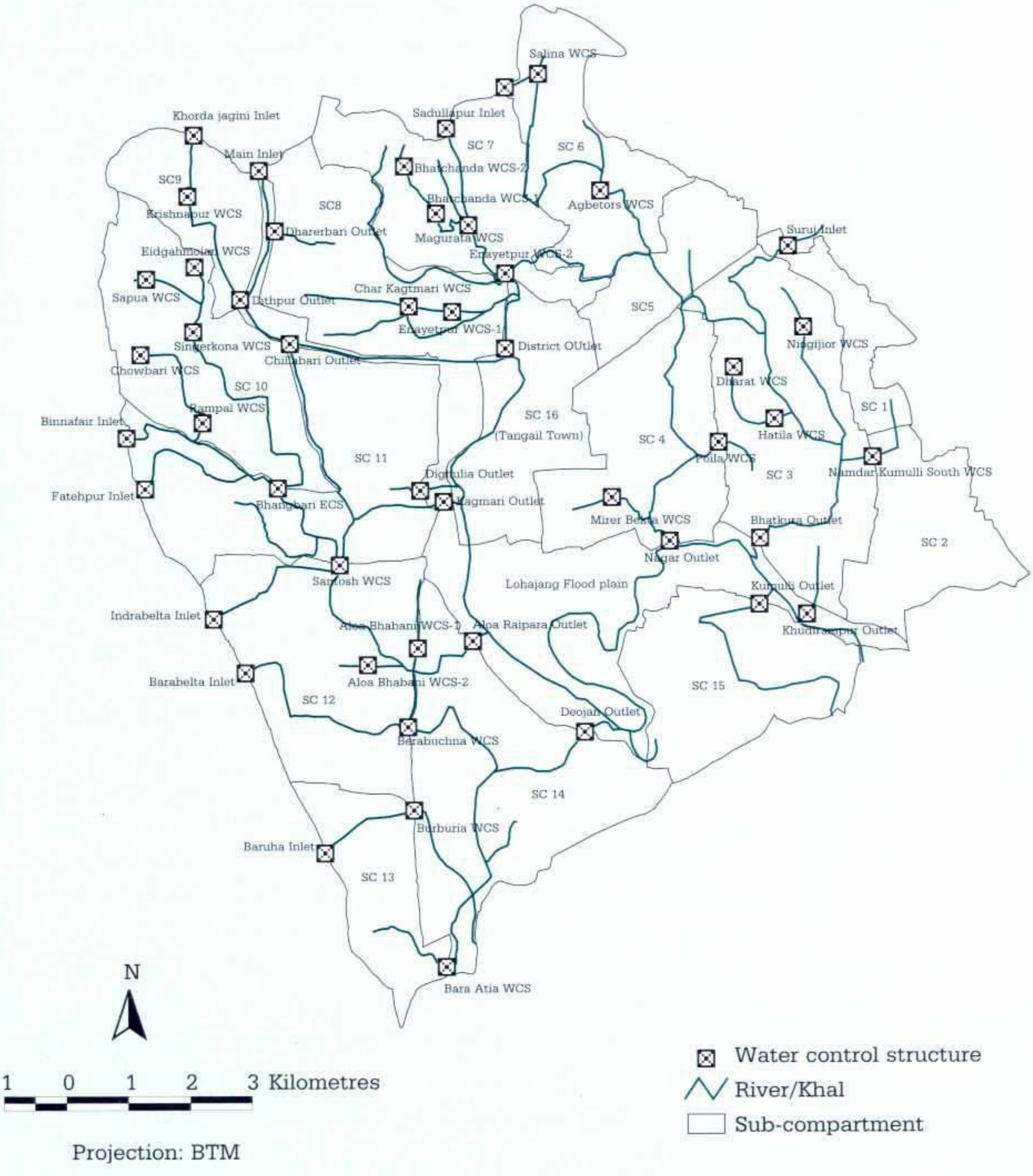

Figure 12: Network Configuration of the Model

Controlled Flooding

Controlled flooding in a multi-compartment and mono-compartment settings is discussed in Ref 3. In a multi-compartment setting, the concepts of controlled flooding and compartmentalization are rather similar. Where there are several compartments in a flood plain, some of them can be used to receive excess water during a flood, in order to safeguard the others. The compartments designed to receive the floodwater, would be flooded rather frequently, while the other ones would be flooded only during rare calamitous events. A matter that has not been given due attention, however, is that the land use in the two kinds of compartments will be different. In the flood prone compartments, land use will adapt to the more frequent flooding, while in the rarely flooded compartments, it will be geared towards optimal production.

In the mono-compartment setting, the concept of controlled flooding had acquired three different meanings. The first is, that if the primary embankment would breach during a major flood, secondary embankments would contain the flooding. This assumes the secondary embankments to be water tight and high enough to contain the high waters. The 1998 floods clearly demonstrated that no secondary embankments were up to this task. Once the primary embankment breached, there was no secondary protection to withstand the flow.

The second interpretation of controlled flooding, intended to spread excess water from heavy rain, more evenly over the lands. That meant that runoff of excess water had to be slowed down on the higher lands in order to relieve the flood burden in the lower areas. However, that is attainable as long as the water excess on the higher land is manageable for the high land farmer. If it reaches the point that the high land farmer faces crop damages, the concept turns idealistic and stops being realistic.

Controlled flooding is an accepted drainage technique. However, the technique implies different measures than discussed in the previous paragraph. In order to slow runoff down, excess water is retained temporarily on the low lands upstream of the outlet. Land use on these low lands needs to be adapted, in a similar way as in the flood prone compartment in the multi-compartment setting. If that is not acceptable, the alternative is to improve the drainage situation downstream of the outlet, to the extent that water retention is not needed any more. Controlled flooding is always a compromise between drainage and production. It implies production losses.

In a final turn, the concept of controlled flooding assumed the meaning of taking water in through the intake structures in the primary embankments and occasionally also through the outlets along the Lohajang, in cases the rainfall proved insufficient and the outside water was high enough. It needs to be emphasized that CPP, during its first phase, very rightly stressed the importance of water intake, a matter that has been greatly overshadowed by a countrywide urge to drain. Whether that should be named controlled flooding is of secondary importance. A confusing point, however, was that the Project seemed to suggest that all the land of the Compartment could receive water from the outside, while in actual fact large parts were excluded.

Areas that are excluded, by definition, are the high lands, lands above flood level. Depending on the definition, these land cover about 4,000-6,000 ha. Other areas that are excluded are parts of the lands of the System 2, 3 and 4, in Cluster 1, as they are upstream of Binnafair Intake and do not have access to water from the Khorda Jugini Intake. In the same cluster, parts of System 7 are out of reach, as they are too far from the intake and too high for Lohajang water. For similar reasons, the Clusters 2, 3 and 4 have access to outside water as long as land levels permit.

A second point, which limits the availability of outside water considerably, is the level of the outside water. As long as the water outside is below the sill of the intakes, no water can be taken in. As the situation is true throughout the dry season, and may also happen during the monsoon and, quite frequently, shortly after. During dry spells or dry monsoons, when the demand for water is high, the chances are that the outside water is not, or only sparsely, available.

Design and Implementation of Works

During the 1995 and 1996 monsoons, with the Main Regulator operational, it became apparent, that not all design water levels along the Lohajang, could be maintained. Water levels remained above design repeatedly and during too long periods. This was particularly the case in the stretch between the District Regulator and Deojan Outlet. In fact, the problem could not be solved easily during the second phase either, and a new modeling effort was required before a conclusion could be reached. The modeling will be discussed later in a separate chapter.

The case illustrated that a comprehensive design, encompassing the entire Compartment, had not yet been accomplished. As will be discussed later, something similar was valid for the modeling. Designs were mainly made at system level, but assumptions about the downstream water levels of the systems, which in most cases are related to Lohajang levels, proved incorrect.

The matter was confounded by the fact that the excavation of the drainage systems had been insufficiently implemented. Excavation had been hindered or even made impossible by opposition of the local population, land acquisition and other problems. Details of these setbacks have been discussed in the Annex on Construction.

New Targets during the Second Phase

So, during the second phase, new principles were adopted for water management. Maintaining accurate water levels per *chawk* during the monsoon was not considered technically feasible. Design and operation guidelines for water management had to be valid for the entire Compartment, beyond cluster boundaries. The infrastructure erected so far, had to be made operational without adding substantial new elements.

This implied that operation guidelines had to be developed for the Lohajang River, as the main drain of the area. This in turn required a new modeling effort to clarify the functioning of the river and to better assess the results that could be achieved by proper management.

It should be mentioned that during the first phase, water management included criteria for the other seasons outside the monsoon. The second phase became more concentrated on the monsoon only. The reason was that the water level database for which the computer models were calibrated, barely extended beyond the monsoon. It should be clear, however, that in future cases, water management should not be confined to the monsoon season only. Activities during the *Rabi* and *Boro* seasons, can affect surface water and groundwater substantially.

With respect to groundwater, water management under CPP did not include the management or data collection regarding groundwater. This can be justified, as groundwater studies require rather different methods and expertise than surface water studies. It is clear, however, that the large scale *Boro* cropping, affects the groundwater balance of the upper layers in a quantitative way. Whether this has significant implications environmentally, is outside the scope of this annex.

Information Collected

The Drainage Inventory

In order to obtain detailed information about the infrastructure in the Compartment, a drainage survey, the Drainage Inventory, was launched after the monsoon 1996. Junior engineers visited all chawks of the Compartment and had discussions with the population about the infrastructure and the way the water behaved. They made a walk along the *chawk* boundary and visited other infrastructure components of interest.

Together with information already available, the data were compiled into *chawk* maps and a complete inventory of infrastructure at *chawk* level was obtained. The results of the Drainage Inventory, served as a reference during the entire second phase. An additional result was that a number of inner-chawk and inter-chawk water management problems came to the surface, related to agriculture, fisheries, jute retting, etc. In addition, persistent drainage problems in certain areas were documented.

Survey on the Performance and Operation of Structures

Since 1995, the year in which the Main Regulator was completed, Project staff has kept records on the operation of water management structures. The quality of the records is good, certainly if one considers that more than 70 structures had to be monitored. After the 1997 monsoon, with 3 years of operational records available, there was concern that the operation of the structures was not as envisaged originally. There also seemed to be a tendency for the operation to decline.

Together with an analysis of the water level records of the structural gauges, contained in the database, a field survey similar to the Drainage Inventory was conducted into the performance and the operation of structures. The study revealed the following issues.

There were drainage problems along the Lohajang, which influenced the performance and operation of the internal structures. An example is Kagmari Outlet in Cluster 1, shown in Fig 3. Water levels in the Lohajang, downstream of the structure were repeatedly, and during long periods, above design levels. When Kagmari drowns, the upstream structures Bhangabari and to a lesser extent, Rampal, drown as well. If that happens too often, the population looses interest. This result threw the Project team back at the unexplained behavior of the Lohajang.

Peripheral intake structures stayed open far longer than anticipated. This fact was made the subject of a following study, discussed in the next section of this chapter.

Of the internal structures, a large number seemed to have a local function only. In fact, the nomenclature internal structures appeared too general. It covers structures with rather different functions. Some internal structures were not operated at all and did not seem to have a function. An example of the latter was Santosh WCS in Cluster 1, which was bypassed by other bridges in the road between Tangail and Charabari Bazar (Fig 3)

The immediate outcome of the study was, that the operation of the intake structures was investigated first. This survey was completed before the 1998 monsoon. Parallel to that, modeling was resumed at about the same time. It was also decided that there still would be a field survey on the integral operation of all structures, which actually took place after the 1998 monsoon.

Survey on the Operation of the Intake Structures

With respect to the peripheral intake structures, there is a CPP guideline, stating that these structures are supposed to be open up to the 15th of July, after which they are to be closed. The operation records over the monsoons 1995-1997, however, showed that intake structures remained open during most of the monsoon. The matter raised the question whether negligence was involved, or whether high land farmers drowned the low land farmers.

The results of the survey were reported in July 1998. The same methodology was applied as during the Drainage Inventory. Junior engineers visited chawks expected to receive water from the intakes and had discussions with the population.

The demand for water appeared greater than had been anticipated. Certainly early during the monsoon, land users want their land to be flooded thoroughly. Arguments for the flooding are stimulation of fish growth, silt deposit on the land and arguments of a more general nature that the flooding washes harmful substances out of the soil.

There were less conflicts about the operation of the intake structure than anticipated. In Cluster 1 and 4, there was effective communication between the low land users and the gate operator. In the Clusters 2 and 3, barriers to communications were not so much conflicts of interests, but physical distance. This appeared important in the case of the Sadullapur and Rasulpur Intakes, the water of which may flood land far into Cluster 3. Communication between the operators of the intakes and the low land farmers in Cluster 3 was non-existent. There was no awareness about the relation between the two events.

Finally, high land users are less interested in receiving outside water. The water can not reach their high lands anyway. The main risks come from the users of the medium lands, who want to flood their fields and in doing so drown the lower lands.

Survey on the Operation of All Structures

The survey about the operation of all structures, took place after the monsoon 1998. Its results have been reported in four volumes, one per cluster, providing the details of the interviews. The methodology was the same as adopted for the other surveys. The survey appeared too ambitious. During the previous survey, the one on the intake structures, the *chawk* population was interviewed about a single structure with a single function. The new survey had to interview *chawk* inhabitants about several structures with more than one functions. That caused confusion both among the interviewers as the people interviewed. In addition, by that time, many issues that came forward, were already known and the results tended to repeat information, which was already available.

The survey drew much relevance from the fact that it was held after the 1998 flood. The interviews contained information about crop damages and failures that had occurred and details on how the infrastructure behaved under the test of the flood. Another item of interest came forward. Land users repeatedly admitted that they did not understand the purpose of some structures or how they should be operated. They asked for additional clarification. This was mostly the case in the Clusters 3 and 4.

Collection of Water Level Data

The collection of water level data continued in the same manner as during the first phase. The database at the end of the first phase was already impressive and of good quality. During the second phase, it was further expanded. Without this database, the modeling could not have been as successful as it was.

Modeling During 1998

Modeling during the Second Project Phase

During the second Project phase, there were two modeling efforts, the first during 1998, the second during 1999. To overcome previous constraints, hardware was upgraded. The 1998 modeling yielded calibrated models for the monsoons 1995, 1996, 1997 and 1998. The modeling was designed to encompass the entire Compartment, including the Lohajang, even if this would imply loss of detail. This modeling was concluded with the final report mentioned under Ref 6. A useful conjuncture was that the modeling coincided with the 1998 flood.

The second modeling took place during the first half of 1999. It mainly concentrated on testing operation scenarios. During both modeling efforts, the work was subcontracted to the Surface Water Modeling Center. The modeler was based in Tangail, which improved the communication with Project staff considerably.

Description of the Model

A detailed account of the models available during the first Project phase, can be found in the Refs 4 and 6. Ref. 5 contains information on the state of affairs of the modeling at the end of the first phase. The information will be summarized here.

CPP first developed its own mathematical flow model for the Compartment (FAP 20 TCM). The TCM is based on the DHI software MIKE 11. It consists of two modules, a Rainfall Runoff Model (NAM) and a hydrodynamic model. Inputs to the NAM are rainfall, evaporation and ground water abstraction rates. The NAM was calibrated against recorded ground water levels. Sub-compartments are treated as sub-catchments. The Lohajang flood plain is a separate entity. Major *beels* and depressions were included. The boundaries of the model extend to where the Dhaleswari takes off from the Jamuna, the gauge in the Pungli River at Nathkola, the Mirzapur Gauge and the gauge in the Dhaleswari, at the junction between the Old and the New Dhaleswari. The model was calibrated for the 1991 situation. The locations of the gauges mentioned are shown in Fig. 10.

In order to test the water management in the Compartment the model, was revised under FAP 25 and a digital elevation model (DEM) with GIS data was added. This enables the model to produce flooding maps, which proved particularly useful in 1998. At this stage, the model was made to include major *khals,* intake and outlet structures, Santosh WCS and new excavations. Cluster 1 was detailed to a larger extent than the other clusters. There was no model for Cluster 4. The reasons for splitting the model into smaller ones, were software and hardware requirements and probably the progress of implementing CPP infrastructure. A TCM, detailed to the level of structure operation for the entire Compartment, could not yet be effectively handled. The Cluster 1 model was calibrated for the 1993 observed water levels. It became operational in 1996.

During the 1998 modeling the NAM was revised. Catchments outside the Compartment were included. In addition, the HD models were reviewed and their databases, including new excavations updated for the different years 1995-1998. Finally, the separate models for the clusters were integrated into a CPP model for the entire Compartment. The 1998 modeling included "With" and "Without Project" cases.

The MIKE 11 HD model simulates discharges and water levels in flow channels. A network configuration schematizes the rivers and the flood plains as a system of inter connected branches. The configuration is shown in Fig 12.

The 1998 Modeling

The 1998 modeling, yielded calibrated models for the monsoons 1995, 1996, 1997 and 1998. Inputs were the records on gate operation, kept by the Project, rainfall and outside water conditions. The output consisted of water levels and discharges. Calculated levels were calibrated against measured levels. Discharges could not be calibrated, as there are barely field discharge records. The model runs mostly cover the months July, August and September. Outside these months, there are no records. In addition, before July and after September watercourses often fall dry. On request of CPP's engineering section, the calibrated models were also run with the Main Regulator permanently closed, while all other input remained the same.

It should be born in mind that the models do not allow conditional statements. If during a model run, water levels exceed certain targets, the models can not be programmed to change gate settings. Instead, the run has to be finished to the end, after which the changes in gate settings can be made in the next run. This limits the use of the models for real time decision support. Real time management requires models that are more complex. One may wonder, however, whether, in view of the physical size of the Compartment, there is much need for real time decision making.

Parameters in the Models

Once the models had been calibrated, a Without Project and a base case scenario were defined. Table 9 provides details on both. The Without Project case was a case with no structures at all. Next, five so-called sub-sequences were investigated, each sub-sequence containing a number of scenarios. In order to save simulation time, the scenarios were run for a limited period of time, 2 weeks, containing peak conditions only. The list of sub-sequences and scenarios is presented in Table 9.

In all scenarios, there are six variables, rainfall, discharge conditions in the spill channels between the Jamuna and the Dhaleswari River, structure operation, water levels at Mirzapur, in the old Dhaleswari and the Pungli River. The latter three variables constitute the model boundary conditions in the South. The spill channels, the location of the gauges in the Old Dhaleswari and the Pungli and the Mirzapur Gauge are shown in Fig. 11. The Old Dhaleswari flows along the western boundary of the Compartment. The real Dhaleswari takes off from the Jamuna via a spill channel, starting at about the level of the most Southern tip of the Compartment. The meeting point of the Dhaleswari and Old Dhaleswari, is a model boundary.

As Table 10 shows, the discharges through the spill channels and the water levels in the Old Dhaleswari are related. If the discharges are medium, the July 1995 water level records of the Old Dhaleswari gauge are used. If they are high 0.5 m is added to the July 1995 values, if they are low 1.6 m is subtracted. The entry "Model" relates to calculated model values.

Sub-sequence 1 Its Scenarios and Results

The purpose of the first sub-sequence was to investigate the influence of rainfall on the behavior of the Lohajang, compared to discharge conditions in the spill channels. As Table 10 shows, there are nine scenarios, one of them being the base case, with medium rainfall and discharges.

Rainfall varied from 366 mm/month (low) to 1,098 mm/month (high) with 732 mm/month (medium) in between. The spill channel discharges and the Old Dhaleswari levels vary with low, medium and high values.

With respect to the rainfall, Table 2 shows that a rainfall of 366 mm/month is about a median value. An amount of 732 mm/month is extreme, while 1,098 mm/month may never happen. The adoption of this extreme rainfall, was inspired by a very high rainfall figures registered in Atia (BWDB) during 1995. Those data were later removed from Table 1, because they were suspect. As for operation, the July 1995 records were used.

The results of the first sub-sequence showed that the discharges through the spill

Sub-Sequence	Scenario	Rainfall	Discharge Spill Ch.	Levels Old Dhaleswari	Operation Record	Levels Mirzapur	Levels Pungli River
		(mm)		(m PWD)		(m PWD)	(m PWD)
Without Proj	Without Proj	732	Medium	July 95	No Structures	Model	Model
Base Case	Base Case	732	Medium	July 95	July 95	Model	Model
1	1	732	Low	July 95-1.6m	July 95	Model	Model
1	2	732	High	July 95+0.5m	July 95	Model	Model
1	3	366	Medium	July 95	July 95	Model	Model
1	4	1,098	Medium	July 95	July 95	Model	Model
1	5	366	Low	July 95-1.6m	July 95	Model	Model
1	6	366	High	July 95+0.5m	July 95	Model	Model
1	7	1,098	Low	July 95-1.6m	July 95	Model	Model
1	8	1,098	High	July 95+0.5m	July 95	Model	Model
2	9	732	Medium	July 95	July 95	5.00	Model
2	10	732	Medium	July 95	July 95	8.75	Model
2a	10a	732	Medium	July 95	July 95	11.54	Model
2	11	366	Medium	July 95	July 95	5.00	Model
2	12	366	Medium	July 95	July 95	8.75	Model
2	13	1,098	Medium	July 95	July 95	5.00	Model
2	14	1,098	Medium	July 95	July 95	8.75	Model
3	15	732	Medium	9.30	July 95	Model	Model
3	16	732	Medium	12.43	July 95	Model	Model
3	17	366	Medium	9.30	July 95	Model	Model
3	18	366	Medium	12.43	July 95	Model	Model
3	19	1,098	Medium	9.30	July 95	Model	Model
3	20	1,098	Medium	12.43	July 95	Model	Model
4	21	732	Medium	July 95	July 95	Model	7.58
4	22	732	Medium	July 95	July 95	Model	10.42
5	23	732	Medium	July 95	Scenario 23	Model	Model
5	24	732	Medium	July 95	Scenario 24	Model	Model
5	25	732	Medium	July 95	Scenario 25	Model	Model
5	26	732	Medium	July 95	Scenario 26	Model	Model
5	27	732	High	July 95	Scenario 27	Model	Model
5	28	732	High	July 95	Scenario 28	Model	Model
5	29	732	Medium	July 95	Scenario 29	Model	Model
5	30	732	Medium	July 95	Scenario 30	Model	Model

Table 9: Investigated Senarios during the 1998 Modeling

channels and the operation of the Main Regulator were decisive for the water levels in the Lohajang. Water levels immediately downstream of the Main Regulator are dominated by the discharges passing there. At Karatia, where the Lohajang leaves the Compartment, the discharge in the river consists of the runoff from the Compartment plus the discharges through the regulator. However, the increases due to the runoff, both in discharges and in water levels, are minor compared to the flow through the Regulator.

With high discharges in the spill channels, drainage from the Compartment into the Lohajang is low and *vice verse.* With high discharges and the Main Regulator operated as during July 1995, drainage from the Compartment may become zero or even negative, meaning that water enters the Compartment through the outlet structures along the river. With low spill channel discharges, the calculated drainage rate is 2.2 l/sec/ha under medium and 3.0 l/sec/ha under high rain.

Sub-sequence 2 Its Scenarios and Results

Sub-sequence 2 investigates the impact of the water levels at Mirzapur. As Table 9 shows, the same three rainfall conditions were applied as before. Discharges in the spill channels and levels in the Old Dhaleswari were kept at medium level. Operation was as in July 1995 and the Pungli levels as modeled. Two water levels were considered at Mirzapur, a low level of 5.00-m PWD and a high level of 8.75-m PWD. Table 6 shows that the 8.75-m level has been exceeded three times since 1988. A level as low as 5.00 m has not been registered.

With three rainfall conditions and two Mirzapur water levels there are six scenarios. A 7th scenario was included with an extreme water level at Mirzapur of 11.5- m PWD, being the 1988 one-day maximum. The Mirzapur levels were kept constant during the runs.

Not considering the case with the extreme Mirzapur level, the water levels immediately downstream of the Main Regulator appeared rather independent from the levels at Mirzapur. At Karatia, Mirzapur's impact was greater, but the largest difference in Lohajang levels, Mirzapur could cause there, was only 0.4 m. In all cases Mirzapur's impact exceeded the impact of the rain. Still, Lohajang discharges at Karatia remained dominated by the discharge through the Main Regulator. In the case with the high rain and the low Mirzapur level, the drainage rate was only 2.3 l/sec/ha.

With the extreme level in Mirzapur, almost all land of the Compartment became inundated and water levels downstream of the Main Regulator rose to a maximum of 11.80-m PWD. According to Project records, the maximum level reached at the regulator during 1998 was 11.20 m PWD.

The Sub-sequences 3 and 4 Their Scenarios and Results

The sub-sequences 3 and 4 analyzed the impact of the other two downstream boundaries of the model, the levels in the Pungli and the Old Dhaleswari. Eight scenarios were run. There were three different rainfall conditions, three different water levels in the Old Dhaleswari and the Pungli.

The results showed that the Pungli barely had any impact on the behavior of the Lohajang. Old Dhaleswari levels had, be it less than Mirzapur. The impact of the Old Dhaleswari exceeded that of the rainfall.

Sub-sequences 5 Its Scenarios and Results

Sub-sequence 5 was simulated to investigate the effects of Compartment gate settings on the Lohajang and the internal flood situation. Gate settings were simulated per group. There were 4 groups: Main Regulator, Other Intakes, All Outlets and Internal Structures. Each group had two positions, open and closed, so theoretically, there are 16 scenarios. Many of these are not realistic, for instance, cases with Other Intakes open and All Outlets closed. Seven scenarios were run, two with an increased spill channels discharge.

It should not be surprising that the largest discharge in the Lohajang at Karatia occurs under the scenario with all gates open. With a monthly precipitation of 732 mm, the discharge in the Lohajang is more than 72 m3/sec. Out of this, only 20 m3/sec (1.5 l/sec/ha) originates from the drainage of the Compartment, the remaining water has entered through the Main Regulator. Gate operation had a small impact. The greatest impact resulted from manipulating the intake structures. However, the effect amounted to only a few centimeters in level and few cubic meters in discharge. Opening or closing the internal structures had barely any effect.

Immediately downstream of the Main Regulator, water levels are obviously dominated by the operation of the structure itself. If the structure is fully open, opening all other gates causes an increase in water level of only 6 cm. If the structure is closed, the water level drops by about 1.3 m, even if all other gates are open. If all inlets, including the Regulator, are closed, the Lohajang falls dry upstream, even with high rainfall. However, that is the case only as long as conditions at Mirzapur are not extreme.

At Karatia, water levels varied by 0.6 m between the scenarios with the Main Regulator open and closed. The drainage rate is highest with the Main Regulator closed. It varied from 1.5 l/sec/ha to more than 3 l/sec/ha.

Summary of the Results

In summary, the analyses demonstrated the dominant position of the Lohajang and the Main Regulator on the drainage of the Compartment. Next comes the operation of the intake and outlet structures. Water levels at Mirzapur are not dominant. However, in extreme cases, they may cause extensive flooding in the Compartment. The impact of rain is minor, but the impact of the internal structures is even less.

Model Runs With the Main Regulator Open and Closed

The models were run for a second time, for the full monsoon, with the Main Regulator fully closed. The reason was that the scenarios discussed were run for peak conditions only during a limited time span. The engineering section wanted to have a full record of the results during the entire monsoon, for its own information and for demonstration and training purposes.

The runs with the Main Regulator permanently closed, showed that water levels along the Lohajang remained below the design levels. The runs were most helpful in understanding the full impact of the Lohajang, as the main drain, and the Main Regulator.

Fish Friendly Operation of the Main Regulator

The Main Regulator is supposed to be run in a fish friendly manner. Fish fry and larvae tend to swim along the edges of the watercourses, near to the surface. Turbulent water and gates extending into the water are harmful as they kill some of the young fish.

The dimensions of the gates of the Main Regulator are shown in Table 10. The Regulator has three central gates, 3 m wide, and two smaller fish gates at the sides. The latter have raised sill levels and can be closed by single gates. Their discharge capacity is limited. The three gates in the center, consist of a lower gate and an upper gate. The lower gates serve to close the Regulator when upstream water levels are still low, or to increase the sill level and reduce the discharge when water levels are higher. The upper gates may close the openings altogether.

The most fish friendly setting occurs, when the water comes in freely with upper and lower gates above the water. Next comes the setting with the lower gate fully down and the water overtopping the gate. The relatively sharp top of the gate and the turbulence may still kill a proportion of young fish, though. The most unfriendly setting is the one with the upper gate reaching into the water from above and water flowing under it, the so called undershot case.

The modeling yielded the following results:

- The discharge through the two fish gates is negligible for practical purposes and fish gates may always remain open, unless they have to be closed for safety reasons;
- A full range of discharges, from zero to peak, can be realized with fish friendly settings i. e. there is no need to create undershot conditions. Per opening, there are three settings: both gates fully lifted, lower gate down with upper gate fully lifted and finally both gates closed. Therefore, for the three central gates there are nine positions, one of which is the fully closed case;
- As discharges can be regulated in a fish friendly way, downstream water levels can be as well.

The Operation Manual, Appendix 2 of this report, contains details on fish friendly operation of the Main Regulator. It also contains a graph showing the relation between upstream and downstream water levels, under fish friendly operation.

Evaluation of the Gala Khal Re-excavation

The modeling was used to evaluate the impact on hydraulic conditions along the northern boundary of the Compartment due to the re-excavation of the Gala Khal. The re-excavation was carried out during December 1997.

The Tangail Compartments forms an obstruction in the floodplain of the Jamuna River and causes water level to increase upstream. The re-excavation of the Gala Khal was considered a mitigation measure as it was expected to reduce water level North of the Compartment.

The conclusions from the modeling are that the flow in the Gala Khal between the Lohajang and the Pungli, actually increased after re-excavation. Consequently, water levels along the *Khal* increased as well, but not more than about 5 cm. Therefore, the excavation could barely be considered a mitigation measure. Hydraulic conditions in and around the Compartment are so complex, that modeling is a requirement to justify this kind of interventions.

	Kind of Gates	No of Vents	Gate Width (m)	Gate Height (m)	Sill Level (m PWD)	Function	Overtopping when closed
Internal structures							
Cluster 1							
1 Krishnopur WCS	Single	1	1.50	1.80	9.77	Local Importance	No
2 Beel Baghil WCS	Single	1	Diameter 0.6 m		10.07	Local Importance	No
3 Edgah Moidan WCS	Single	1	0.90	1.20	10.18	Local Importance	No
4 Sapua WCS	Single	1	Diameter 0.6 m		9.60	Local Importance	No
5 Singerkona WCS	Single	1	1.50	1.80	8.76	Control Beel Level	No
6 Bhangabari WCS	Single	2	1.50	1.80	8.62	Control Outflow Khal System	No
7 Chowbari WSC	Single	1	Diameter 0.6 m		10.96	Local Importance	No
8 Rampal WCS	Single	1	1.50	1.80	9.03	Local Importance	No
9 Santosh Regulator	Single	3	1.50	2.00	8.00	Control Outflow Cluster	No
Cluster 2							
10 Beel Gharinda WCS	Single	2	1.50	1.80	8.52	Local Importance	No
11 Salina WCS	Single	1	0.90	1.20	9.00	Local Importance	No
12 Agbetor WCS	Single	2	1.50	1.80	8.49	Control Water Level Khal	Yes
13 Batchanda-2 WCS (North)	Single	1	0.90	1.20	9.50	Local Importance	No
14 Batchanda-1 WCS (South)	Single	1	1.20	1.50	9.07	Local Importance	No
15 Magurata WCS	Single	1	1.50	1.80	9.00	Control Beel System	Yes
16 Enayetpur-2 WCS	Single	1	2.00	2.50	7.96	Control Flow Sub-Compartments	Yes
17 Enayetpur-1 WCS	Single	1	2.00	2.50	8.00	Control Water Level Khal	No
18 Charkagmara	Single	1	1.20	1.50	9.50	Control Water Level Khal	No
Cluster 3							
19 Gosaijoair WCS	Single	1	1.20	1.50	8.41	Blocked by Housing	No
20 Birnahali-2 WCS (North)	Single	1	Diameter 0.6 m		7.86	Local Importance	No
21 Birnahali-1 WCS (South)	Single	1	Diameter 0.6 m		7.36	Local Importance	No
22 Namdar Kumulli-1 (North)	Single	1	0.90	1.20	8.13	Local Importance	No
23 Namdar Kumulli-2 (South)	Single	1	1.20	1.50	7.95	Control Flow Sub-Compartments	No
24 Paschim Pauli WCS	Single	1	1.20	1.50	7.47	Control Flow out of Compartment	No
25 Karatia WCS	Single	1	1.20	1.50	7.39	Control Flow out of Compartment	No
26 Niogijoair WCS	Single	1	0.90	1.20	8.74	Local Importance	No
27 Dharat WCS	Single	1	Diameter 0.6 m		8.89	Local Importance	No
28 Hatila WCS	Single	1	2.50	1.75	8.48	Control Beel Level	Yes
29 Poila WCS	Single	1	2.50	1.50	8.50	Control Flow Sub-Compartments	Yes
30 Mirer Betka WCS	Single	1	0.90	1.20	7.93	Local Importance	No
31 Karatia Chowdhury Para	Single	1	0.90	1.20	8.00	Local Importance	No
Cluster 4							
32 Berabuchna WCS	Single	1	2.00	1.80	9.00	Control Water Level Khal	No
33 Bhurburia WCS	Single	2	1.50	1.80	8.60	Control Water Level Khal	No
34 Bara Atia WCS	Single	1	1.20	1.50	9.00	Control Beel Level	No
35 Aloa Bhabani-1 WCS	Single	1	Diameter 0.75 m		8.60	Local Importance	No

Continued

	Kind of Gates	No of Vents	Gate Width (m)	Gate Height (m)	Sill Level (m PWD)	Function	Overtopping when closed
Structures along the Lohajang							
1 **Main Regulator**	Fish	2	1.50	2.30	10.70	Entrance for Fish	No
(Fish Friendly)	Upper	3	3.00	3.00	9.20	Control Flow Lohajang	
	Lower	3	3.00	0.85	9.20	Increase Sill Level	
2 **Dharerbari WCS**	Single	1	0.90	1.20	10.00	Outlet	No
3 **Dithpur Outlet**	Upper	2	2.00	1.00	10.90	Outlet	No
(Fish Friendly)	Lower	1	0.90	0.90	9.44	Outlet	No
4 **Dannya Chowdhury**	Single	1	Diameter 0.9 m		8.70	Outlet	No
5 **Chillabari Outlet**	Single	1	Diameter 0.9 m		8.19	Outlet	No
6 **District Regulator**	Upper	2	1.50	2.15	7.98	Outlet	No
(Fish Friendly)	Lower		1.50	0.85			
7 **Dighulia-2 Outlet (North)**	Single	1	Diameter 0.9 m		8.00	Outlet	No
8 **Dighulia-1 Outlet (South)**	Single	1	Diameter 0.9 m		8.28	Outlet	No
9 **Kagmari Outlet**	Upper	2	1.50	2.15	7.68	Outlet	No
(Fish Friendly)	Lower		1.50	0.85			
10 **Aloa Raypara**	No Gates	4	1.50		7.18	Outlet	Not Applicable
11 **Deojan Outlet**	Single	1	2.50	1.80	8.20	Outlet	Yes
12 **Jalfai Outlet**	Upper	2	1.50	2.15	6.49	Outlet	No
(Fish Friendly)	Lower		1.50	0.85			
13 **Bhatkura Outlet upstr**	Upper	2	1.50	2.15	6.93	Outlet	No
(Fish Friendly)	Lower		1.50	0.85			
14 **Kumulli**	Single	1	Diameter 0.75 m		8.60	Outlet, Local Importance	No
15 **Khudirampur**	Single	2	1.50	1.80	7.86	Outlet	No
16 **Khagjana**	Single	1	Diameter 0.75 m		8.00	Outlet, Local Importance	No
Peripheral structures							
Cluster 1							
1 Khurda Jugini Intake	Upper	1	1.50	1.15	9.97	Intake	No
(Fish Friendly)	Lower			1.25			
2 Binnafair Intake	Single	1	0.90	1.20	9.42	Intake	No
3 Fatehpur Intake	Single	1	0.90	1.20	9.22	Intake	No
Cluster 4							
4 Indrabelta Intake	Single	1	0.90	1.20	9.65	Intake	No
5 Barabelta Intake	Single	1	0.90	1.20	9.70	Intake	No
6 Baruha Intake	Upper	1	1.50	1.75	9.65	Intake	No
(Fish Friendly)	Lower			1.25			
7 Silimpur Intake	Single	1	Diameter 0.6 m		9.75	Intake	No
Cluster 2							
8 Sadullapur Intake	Upper	1	3.00	1.75	9.13	Intake	No
(Fish Friendly)	Lower			1.25			
9 Rasulpur Intake	Upper	1	1.50	1.75	9.17	Intake	No
(Fish Friendly)	Lower			1.25			
10 Rasulpur Pipe Intake	Single	1	Diameter 0.6 m		11.00	Intake	No
11 Pauli Intake	Single	1	Diameter 1.2 m		10.00	Intake	No
12 Bararia Intake	Single	1	Diameter 0.9 m		10.75	Intake	No
Cluster 3							
13 Suruj Intake	Upper	1	1.50	1.75	9.20	Intake	No
(Fish Friendly)	Lower			1.25			

Table10: Main Characteristics of Structures

Closing the Main Regulator increases water levels immediately upstream of it by about 0.3 m, both with the Gala Khal excavated and non-excavated. At the Dhaleswari and the Pungli, East and West of the Regulator, the effect has already died out. In Northern direction, the effect dies out within 2 km.

Modeling the 1998 Floods

When the 1998 flood reached its peak and breaches fell in the surrounding embankments, modeling was used to predict the impact of the breaches and the flood on the Compartment. A full account is published in Ref. 5 and will not be repeated here. The reason is that an assessment of the field situation based on measured water levels, rather than calculated ones, is provided later in this report. Both assessments lead to the same conclusions.

Behavior of the System

Basic Data and Target Water Levels

This description of the behavior of the drainage systems, makes use of detailed data on the topography of the Compartment and the records on water levels and operation. Table 11 shows main characteristics of water control structures and their function.

To easier evaluate the performance of the system, target water levels are introduced. Simply stated, target water levels are design levels, valid under average conditions. They are helpful to better understand the behavior of the system. They have been determined based on a number of considerations.

It is helpful to have certain indicators per sub-compartment, for instance, about the level at which 40% of a sub-compartment is flooded, or, at what level certain critical depths are exceeded. During dry monsoons, it may be desirable to maintain water levels above the target, during wet seasons below.

Some targets should not be exceeded, for instance, levels at which gates start overtopping. Overtopping of gates prevent the system to keep control. Structures with gates that may overtop are listed in Table 10.

Finally, target levels may act as warning indicators. The operation of intake structures such as Sadullapur and Rasulpur, in Cluster 2, has far reaching effects in distant parts of Cluster 3. It is helpful to have warning indicators somewhere in between.

Most target levels, except those where gates overtop, are indicative only. *Chawk* and sub-compartment committees may adapt them if they wish, provided adjacent sub-compartments are not adversely affected, or their committees have agreed to the change. Changes should be agreed upon before changes are implemented, after discussions with the committees concerned. Target levels should not be considered final, they are expected to change with time.

Target water levels at structures of local importance, are to be decided by *chawk* committees, as the decision barely affects the larger systems. Such structures are also listed in Table 10.

The Lohajang and the Main Regulator

Details on the operation of the Main Regulator have been presented in the Operation Manual, Appendix 2 to this Annex. An overriding principle is, that as much flow as possible should be allowed through the Lohajang. This is for environmental reasons, health, fisheries and water quality.

From experiences during the first phase and the model calculations, a realistic operational level downstream of the Main Regulator is about 10.5 m PWD. There are constraints, however. If the water upstream remains below 10.5 m, the level downstream clearly can not be maintained. In those cases, the Main Regulator may be fully opened to allow a maximum amount of water through. Another constraint is the Danger Level, defined as 12.05 m PWD at Jugini Gauge. At this level, the Main Regulator and all peripheral intakes should be closed. Finally, when water levels outside the Compartment are high, it may not be possible to control water levels downstream of the Main Regulator sufficiently, as water may be backing up into the Lohajang from the South.

During dry years it may be desirable to maintain water levels in the Lohajang above 10.5 m. However, if the water level downstream of the Main Regulator is much above 10.5 m, the outlets from District Regulator up to Deojan Outlet, are easily submerged. During wet years, one may try to maintain a level below 10.5 m. However, if the level is much below 10.5 m, the risk of water inflow from the South increases. In addition, maintaining low levels, goes at the expense of the size of the discharges in the Lohajang.

Sub-Compartment 9, System 1

Description of the System

The drainage systems of Cluster 1 are shown in Fig 3. Sub-Compartment 9 is in the North of the cluster. The sub-compartment contains only one system, System 1. System 1 has the Khorda Jugini Intake in the North. From there, the Jugini Khal runs South, towards Krishnopur WCS. On its way South, Jugini Khal may deliver water to adjacent lands through side khals. Downstream of Krishnopur WCS, the water travels to Dholi Beel, but there is no defined *khal* system there. Contrary to what is shown on older maps of the Compartment, Jugini Khal does not deliver water to Jugini Daha Beel.

Krishnopur WCS does not control the water flow between the chawks 1A and 1B. Other structures, on the same boundary, carry most of the water. The water travels to Dholi Beel. Dholi Beel is connected to Jugini Beel by a link canal.

Drainage water from the Chawks 1C and 1D enters directly into Jugini Beel. The beel changes into Krishnopur Beel downstream. Jugini Beel is blocked by an embankment with culverts. There is a conflict of interest between farmers and fishermen about the culverts as the latter block them regularly.

Krishnopur *Beel* changes into Dithpur Khal towards the South. The *khal* leads to Dithpur Outlet, along the Lohajang. The Chawks 1F and 1G drain towards Dithpur Khal.

Exchange of water between the Sub-Compartments 9 and 10 is limited. *Beel* Baghil WCS is of local importance only.

Functioning of System 1

Many structures of the Tangail Compartment, have two different gates per vent, a lower gate and an upper gate. This design was adopted for fish friendliness. The structures with such gates are shown in Table 10. At Dithpur Outlet, the lower and higher gates are installed in different vents. There is one vent with a lower gate and two vents with higher gates.

When the lower gate is closed and one of the upper gate open, the sill of the latter determines the water level in the system. From the database it appears, that water levels in System 1 are maintained at about the level of the sill of the upper gates. That level makes sense in view of the topography of the system. Occasionally, water levels in the Lohajang may rise above the sill of the upper gate. In such cases, the upper gates may protect the area against Lohajang water.

From the fact that water levels are controlled at about the sill level of the upper gates, one may conclude that System 1 primarily drains or receives water via the lower gate. However, if the water is allowed to fall to the sill level of the lower gate, the entire area falls dry. This happens after the monsoon.

Sub-Compartment 9 is in a favorable position as far as water management is concerned. It is relatively small and has an intake and outlet at manageable distance. Dithpur Outlet barely suffers from submergence at its downstream side. The impression is that the water in the sub-compartment is well managed.

Operation of System 1

Khorda Jugini may allow water in during the monsoon. If water enters and Krishnopur WCS is closed, water flows into the adjoining chawks. However, Jugini Khal runs along a road with houses alongside. If the water rises too high, it causes inconveniences. Krishnopur WCS mainly has the function to control water levels in the *khal* and is of local importance only.

Beel Baghil WCS is outside the main path of the drainage flow and is of local importance. Its operation is up to the committees of the chawks 1B and 2B.

Sub-Compartment 10

System 2

The chawks of System 2 consist mainly of high to medium lands. The system has no facilities to take water in. *Chawk* 2A virtually lacks drainage. Culverts are blocked or ineffective. The surveys indicate that the major part of the drainage water from *Chawk* 2B goes North through *Beel* Baghil WCS, while that from *Chawk* 2C goes South, through Edgah Moidan. Both structures are of local importance only. There is little water management to be done. Decisions regarding the operation of the structures fully rest with the *chawk* committees.

System 3

The chawks of System 3 contain most of the drainage system of Sub-Compartment 10. The system starts at Dhalan *Beel* and goes via Sapua WCS to Singerkona *Beel*. Singerkona *Beel* also receives water from Eidgah Moidan. The structures Sapua and Singerkona WCS have local impact only, the same as Eidgah Moidan. Below Singerkona *Beel*, the drainage system passes through *Chawk* 4B towards Ghotokbari and Bara *Beels*. Downstream of Ghotokbari *Beel*, there is Ghoramara Khal, upper and lower part, going all the way down to Bhangabari WCS, which discharges into the Binnafair Khal.

The drainage path between Sapua, Eidgah Moidan and Singerkona *Beel* is not defined. Between Singerkona and Bhangabari WCS, no khals has been excavated either. The *beels* of *Chawk* 4B are more or less independent of System 3. They drain via Rampal WCS.

There is another drain leaving Singerkona Beel, namely Dannya Chowdhury Khal, going East to Dannya Chowdhury Outlet, along the Lohajang. The *khal* has been excavated shortly before the monsoon 1999 and has not been effective before that time.

Water may back up from Bhangabari WCS into the Chawks 3C, 3D and 3E and to a lesser extent into *Chawk* 4B. Sometimes it is welcome, sometimes not. The back flow is caused by high water levels in the Binnafair *Khal*, caused in turn by either the Binnafair Intake or the Kagmari Outlet or both. The surveys indicate that Bhangabari WCS is still considered beneficial by the population, despite the back flow.

To prevent undesirable back flow, Bhangabari WCS could be closed. However, that blocks the drainage of the entire system. Therefore, measures to regulate the back flow in System 3, involve control of Binnafair Intake, Kagmari Outlet and water levels in the Lohajang. This renders them a matter for the Sub-Compartments 10 and 11 together. If the levels downstream of Kagmari Outlet have to be lowered, BWDB, the manager of the Main Regulator, is involved.

System 4

Both Chowbari and Rampal WCS are used as drainage and water retention structure. Chowbari is the less important. Drainage water from Singerkona *Beel* passes through the Northeastern corner of *Chawk* 4B, but does not contribute substantially to its water balance. Intake of water takes place via Rampal WCS, but the water does not reach Chowbari WCS. Rampal WCS receives its water from Binnafair Khal. The surveys indicate that both Rampal and Chowbari WCS are considered beneficial by the population.

Sub-Compartment 11

System 5

System 5 consists of 6 chawks, all of which are located on high to medium land, with the exception of the land around Bara Binnafair *Beel*. The system drains via Bara Binnafair Khal, which joins Binnafair Khal further downstream. System 5 also receives water via Bara Binnafair Khal.

There are no water control structures in the system, with the exception of Binnafair and Fatehpur Intake. Although the dimensions of the two intakes are identical, Fatehpur is less important. It is at a larger distance from the Dhaleswari River and it is blocked at the boundary between the Chawks 5D and 5B.

System 6

System 6 is the lowest system of Cluster 1. It does not have water control structures. *Chawk* 6A has little interrelations with the other chawks of the system. It receives water via Gaijabari Khal and drains in the same way. The drainage path of the other Chawks, 6B-6E, goes via *Chawk* 6C, where the water leaves the sub-compartment and the cluster towards the South. It does not pass via Santosh Regulator. Santosh Regulator plays an insignificant role in the drainage of Cluster 1. It is always open. Only in 1998, when the floodwaters backed up from the South, it was closed. There are severe drainage problems in *Chawk* 6B, which is partly due to an ineffective khal. The low parts of System 6 receive water via Binnafair Khal and Indrabelta Intake.

With the exception of *Chawk* 6A, System 6 actually belongs to Cluster 4 and drains via Aloa Raypara Outlet.

System 7

System 7 has been suffering from an incomplete drainage systems during most of phase 2. Neither Chillabari Outlet nor Chillabari Khal provides drainage for the Northern *chawks*, because they are on higher land. Another drainage path, via the so called Khanpur Borrow Pit and Dighulia-2 Outlet was only completed shortly before the monsoon 1999. The Chawks 7D-7H drain via the Gaijabari Khal. As far as water intake is concerned, incoming water travels the same route as the drainage water. Kagmari is more important than Dighulia-1, both for drainage as for water intake. There are serious drainage problems in the Chawks 7D-7H, due to bad access to Gaijabari Khal.

Control of the Binnafair and Gaijabari Khal

For the Systems 3 up to 7, the water management structures of importance are Binnafair Intake, Rampal and Bhangabari WCS and Kagmari Outlet. The other water control structures are positioned rather upstream in the systems and are of local importance only. Santosh WCS is not effective. It is by-passed by a nearby bridge.

Theoretically, the Binnafair and Gaijabari *Khals* offer a possibility for proper water level control. By opening Kagmari Outlet and closing Binnafair Intake, water levels go down. By closing Kagmari and opening Binnafair, water levels go up. The land upstream of Rampal and Bhangabari WCS would benefit from such management, as it may drain or let water in, according to requirements.

The actual situation is more complex. Water may flow from Binnafair, Rampal and Bhangabari into System 6, which is low, while there are no control structures in between. Water entering at Kagmari may flow to the South directly, via Santosh and other structures, without reaching Bhangabari or Rampal.

The most practical operation guideline, is to maintain a target level at Bhangabari of about 10.20 m PWD. At the same time, one maintains a level at Kagmari at about 10.00-m PWD. Both levels are realistic according to the database and the modeling done. With those levels, both the Systems 4 and 5 can drain towards the Lohajang. The guideline, however, is at the expense of System 6, which has drainage problems already. As far as the intake of water through Binnafair is concerned, System 6 is the norm. If System 6 has an excess of water, Binnafair should be closed.

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Cluster 4

General

The infrastructure of Cluster 4 was the last to be implemented of all other clusters. In the surveys, land users complained about lack of experience regarding the operation of structures. A feature of the cluster is the great number of breaches in *chawk* boundaries, which implies a lack of control over the water. The Southern boundary of the Cluster is more or less open, with bridges and no gates in the boundary embankment. This is different from Cluster 3, where the Southern boundary has been provided with gated structures.

Little water level measurements were done before the 1998 monsoon and information on the water is relatively limited. For the 1998 monsoon, gauges were installed. However, the extreme conditions during that season, render the data less valuable for normal water management. At the intake structures water levels have been measured since 1995. There are also measurements in Atia Kumuria *Beel* during the 1996-1998 monsoons.

The Systems 23 and 27

The water control infrastructure of Cluster 4 is shown in Fig. 4. The Systems 23 and 27 actually form one system. It has the Indrabelta Intake upstream and the Aloa Raypara Outlet downstream. The Indrabelta Khal does not connect to the Aloa Khal. The final part, Santosh Khal, has not been excavated. Aloa Khal also receives water from the North. The Aloa Raypara Outlet has been lacking gates up to the 1998 monsoon. Landowners, who had not received compensation for acquired land, blocked the installation. The systems have only one WCS, Aloa Bhabani-1, which controls the water in *Chawk* 23E and is of local importance only.

The low-lying chawks of System 23, primarily receive water from Indrabelta Intake, the chawks along the Lohajang, System 27, mainly from Aloa Raypara Outlet. As long as the gates were missing, the chawks were at the mercy of the river regime.

The distance between Indrabelta Intake and the Aloa Raypara Outlet is relatively short and communication is adequate, according to the surveys. The target level at Aloa Raypara Outlet, 9.75 m, was mainly fixed because of topographical data. However, the target is vulnerable, as are the targets at Kagmari and the Dighulia's.

Through the present choice of sub-compartment boundaries, the water management in the Systems 23 and 27 is the matter of two SCWMC's. It would have been better if systems had been a criterion in the delineation of sub-compartment boundaries.

Systems 24, 26 and 28 and Chawks 25A

The excavation of the Barabelta and Baruha Khals had not been completed by the start of the 1999 monsoon. All chawks of the Systems 24 and 28 drain into Atia Kumuria *Beel* and after that into the Lohajang via Deojan Outlet. The gate of Deojan outlet was installed shortly before the 1998 monsoon. It is a single gate, which overtops if the water rises above 10.00 m.

Water levels in Atia Kumuria *Beel* vary between 8.5 m and 9.5 m PWD during monsoons, which is considerable in view of the size of the *beel*. The levels remain below 9.75 m PWD, which is the average land level of System 28.

Fixing a target level for Deojan Outlet touches on the management of Atia Kumuria *Beel*. It is a large water body, which has intake facilities upstream and an outlet downstream. Potentially, this provides opportunities for water management for agriculture and fisheries. Due to the late implementation of works in Cluster 4, however, the matter could not receive due attention.

Berabuchna and Burburia WCS serve to regulate water levels upstream. Their position in the road, which has few other water conveying structures, offers an opportunity to make them functional. A drawback is that the excavation of the khal system upstream of Berabuchna and downstream of Burburia, had not been completed by the monsoon 1999. The 1999 operation records show that the structures were not operated during the season.

The management of the Systems 24, 26 and 28 is a matter of the Sub-Compartments 12, 13 and 14, which is a rather complex situation. In addition, here, adopting systems as the basis for sub-compartment configuration, would have lead to a simpler solution.

System 29

All chawks of system 29 drain towards the South, over the boundary of the Compartment. None of the structures on the boundary has gates. As far as water intake is concerned, all chawks either receive water from the South or from the Lohajang or both. Land users complain about the lack of water control structures.

Sub-Compartment 13

Chawk 25A is a single *chawk* system. It is the highest *chawk* within its surroundings. It does not have access to outside water. System 26, except *Chawk* 26A, drains towards Atia Kumuria *Beel* via System 28 and receives water the same way. However, in view of the levels maintained in Atia Kumuria *Beel*, System 26 benefits little from *beel* water. The average topographical level of the system is 10.10 m PWD, as against *beel* levels usually below 9.5 m. Similar to System 29, also System 26 lacks water control structures. There is also much scope for minor works. The reason for the lack of structures, is that time was running out.

Sub-Compartment 15

Chawk 30A is densely populated and supports small industries. Its land is about half a meter above surrounding chawks.

There is much drainage congestion in System 31. That is rather surprising as distances to the Lohajang are short. Water levels in the Lohajang are not exactly known, but are expected to be below 10.14 m most of the time, which is the average land level of the system. There are many man made cuts. The Chawks 31A and 31B drain and receive water via Kumulli WCS. The Chawks 31C and 31D drain via Birpushia Khal. Construction of Birpushia WCS and excavation of Birpushia Khal has been pending due to a long dispute. *Chawk* 32A has its own water control structure, Khagjana WCS. There is barely water entering from surrounding chawks.

Cluster 2 the Sub-Compartments 7 and 8

The Systems 9 and 10 and Chawk 8A

The water control systems of Cluster 2 are shown in Fig 5. An important objective of water management in the eastern half of the Compartment is to create smaller independent watersheds and to stimulate communication between the different SCWMC's. An example is Enayetpur-2 WCS. If Enayetpur-2 WCS is closed, Sadullapur, District and Bamni Khal and their structures form a more or less independent system.

Cluster 2 has two major intakes, Sadullapur and Rasulpur, and two smaller ones, Pauli and Bararia. From Sadullapur, the water travels down via Sadullapur and District Khal to either the District Regulator or Enayetpur-2 WCS or both. On its way it receives water from or diverts water to side khals. If the water flows via Enayetpur 2 WCS to the east, it may travel all the way down to Cluster 3 and cause excess water problems there. Communication between Cluster 3 and the operators of Rasulpur and Sadullapur Intakes, is difficult due to the large distance.

Bamni Khal is only partially excavated and is not functional. Magurata Khal has partially taken over and carries drainage water from the entire Northwestern area.

Originally, Magurata WCS was supposed to control the water in the Bhatchanda and Mohishjara *Beels* only. Now it controls the outflow of a much larger area. Due to this change in function, there are conflicts about the operation of Magurata WCS.

To substitute for Bamni Khal, a second alternative drainage path has developed South of the khal. Water travels along the line Dharerbari Outlet, Char Kagmari WCS, Enayetpur-1 WCS, District Khal.

Dharerbari Outlet has its sill level at 10.00 m PWD. The target level downstream of the Main Regulator is 10.50 m PWD, which is also the average land level of System 9, served by Dharerbari Outlet. Therefore, operation of the outlet has limited impact. Bhatchanda-1 and Bhatchanda-2 WCS control the water at *chawk* level and are of local importance only.

Proposals for Water Management

As one may see from Table 10, the top of the gate of Enayetpur-2 WCS, when closed is 10.50 m PWD. The gate may overtop. To keep the water control system in the Sub-Compartments 7 and 8 independent, it is desirable that water levels remain below 10.50 m PWD. With the water at that level, District Regulator can still drain. With a water level at 10.50 m, about 450 ha is under water in Sub-Compartment 7 and about 400 ha in Sub-Compartment 8. The maximum depth of inundation on the lowest lands, outside the *beels* is about 0.90 m.

If water levels have to be lowered, Sadullapur Intake needs to be closed, when open. Next, the sub-compartment may drain via District Regulator, provided water levels in the Lohajang are low enough. If not, the options are, either to apply to BWDB to lower the water level in the Lohajang by means of the Main Regulator, or to drain via Enayetpur-2 WCS. In the latter case, Sub-Compartment 5 should agree. If it refuses to accept the water, there is no option but to drain via District Regulator or not to drain at all.

Sub-Compartments 5 and 6

Description of the System

Sub-Compartment 5 and 6 almost consist of single systems. Therefore, the word "system" in the remaining part of this chapter refers to the entire drainage system and not to hydrological systems. The main system in Sub-Compartment 6, consists of Rasulpur Intake and Rasulpur Khal. The khal flows South to *Chawk* 10L, where it joins the Sadullapur Khal, some distance downstream of Enayetpur-2 WCS. Sadullapur Khal continues towards the Southeast along the Chawks 10M, 10N and 12A, up to the boundary between Sub-Compartment 5 and Cluster 3.

A more important route, however, goes around *Chawk* 11E, where the water turns North and then East and flows to Agbetor WCS. From there it continues via Burai Lake and joins Sadullapur Khal again. The khal crosses the boundary between the Clusters 2 and 3 at the location of the anticipated Gharinda Regulator, which was cancelled. Gharinda *Beel* WCS is not effective in controlling the flow as it is by-passed by Gharinda Khal.

Of local importance are the Pauli and Bararia Intakes and Salina WCS. Agbetor WCS is a water level control structure as Berabuchna and Burburia in Cluster 4. According to the Project's operation records, it has never been operated. According to field information, if it would be closed, downstream land users would complain. Closing the structure during the monsoon may create havoc, as the amounts of water passing, can be considerable, while there are no spilling facilities.

Sub-Compartment 6 is on average 0.4 - 0.6 m lower than the Sub-Compartments 7 and 8. Sub-Compartment 5, in turn, is 0.2 m lower than Sub-Compartment 6, which explains the general direction of flow.

Proposals for Water Management

Based on water level readings at Agbetor and *Beel* Gharinda WCS, SCWMC's may take decisions about the operation of Rasulpur Intake and Enayetpur-2 WCS. Beel Gharinda WCS could function as a water level indicator on the boundary between Cluster 2 and 3. Distance is an important factor. Land users in Cluster 3 have limited information on the operation of Rasulpur.

Agbetor WCS is located in the lowest part of Sub-Compartment 6 and as such, it is a suitable location for a warning gauge as well. The target level is about 10.10 m. The top of the gates of Agbetor WCS, when closed is 10.30 m, while the gates may overtop. At a water level of 10.10 m, about 60% of Sub-Compartment 6 is under water. The maximum water depth is 0.9 m, excluding *beel* areas. Also according to water level records, a level of 10.10 m seems realistic.

Water levels at Gharinda *Beel* WCS could function as warning indicators as well. The structure is located along a main road. The proposed target is 9.80 m. The discussion about the operation of Rasulpur Intake lies primarily with the committees of the Sub-Compartments 5 and 6. However, decisions should have the approval of the Sub-Compartments 3 and 4 in Cluster 3.

Sub-Compartments 3 and 4

Description of the System.

In addition, in this chapter, the word "system" stands for drainage system as different from hydrological system. The Sub-Compartments 3 and 4 are single system sub-compartments. Fig. 6 shows the water management system in Cluster 3. The sub-Compartments 1 and 2 are mostly too high to play a significant role in the water management. The Structures Niogijoair, Gosaijoair, Birnahali-1 and -2 and Namdar Kumulli North serve to retain water on the high lands. They are of local importance only. The influence of Dharat WCS and further down, Mirer Betka is also limited.

At Gharinda Bridge, Gharinda Khal splits into an East and a West branch, Golabari Khal and Gharinda-Jalfai Khal. There is no way to regulate the flow between the two. The Gharinda-Jalfai Khal had not been fully excavated up to the monsoon 1999, the Golabari Khal was excavated in 1995/96. Suruj Intake is in the Northeast along the Pungli. Suruj Khal joins the Golabari at the Southern boundary of *Chawk* 19A. From there, the continues towards Hatila *Beel*. It enters in the North-eastern corner of the *beel*. Hatila *Beel* and its surroundings drain towards the South via Bhatkura to Bhatkura Outlet. From Hatila *Beel* to Bhatkura *Khal* there is no defined drainage route. Hatila WCS controls overflow of the *beel* towards the Chawks 19D and 20A.

Overflow from Bhatkura Khal may drain via Khudirampur WCS. If Namdar Kumulli South WCS is open, overflow from Bhatkura may enter Sub-Compartment 2. The drainage structures along the Southern boundary of Sub-Compartment 2 are barely functional. Water diverted into this sub-compartment, becomes trapped there.

Gharinda-Jalfai Khal goes all the way down to the Jalfai Regulator, along the Lohajang. On its way, it receives water from Mirer Betka WCS. The boundary between the Sub-Compartments 3 and 4 consists of an elevated road with relatively few water conveyance structures. Poila WCS is effective in separating the watersheds of the Jalfai and the Bhatkura Outlet.

Proposals for Water Management in the Jalfai Watershed

Separating the Jalfai Watershed from the Hatila Watershed facilitates water management. With Poila WCS closed, water entering via Suruj Intake barely affects levels in the Jalfai Watershed and Suruj becomes more effective in supplying water to Hatila *Beel*. It also becomes possible to better control the drainage load between the Jalfai and Bhatkura Outlets. Both Poila and Hatila have gates that may overtop. If water levels rise too high, the gates lose their function. With Poila open, water may flow both ways, depending on the water level on either side of the gate.

If target levels at Jalfai Outlet are exceeded, Poila should be closed. The Poila gates overtop at the level of 11.00 m. Next, it should be checked, whether target levels at Gharinda *Beel* WCS are exceeded. If so, Cluster 2 should reduce its discharge.

The committees of Sub-Compartments 3 and 4 should agree about the operation of Poila. Sub-Compartment 3 may be given the right to refuse excess water from Sub-Compartment 4. Together they should guard against excess water from Cluster 2.

Proposals for Water Management in the Bhatkura Watershed

Target levels proposed in the area are 9.50 m for Hatila and 9.40 m upstream of Bhatkura. Both levels seem realistic according to the database. With a water level in Hatila *Beel* of about 9.50 m, about 950 ha (85% of the land), is under water in Sub-Compartment 3. The maximum flooding depth exceeds 1.0 m. The area is low lying and there is little alternative. If the target in Hatila *Beel* is exceeded, Suruj Intake should be closed. Next, it should be checked whether target levels at Gharinda *Beel* WCS are maintained.

If Bhatkura Khal receives water beyond its capacity, Khudirampur may take over part of the load. However, System 16 contains the lowest land of the Compartment and has an average level of 8.94-m. Therefore, Khudirampur Outlet has been given an target level of 9.00 m.

Namdar Kumulli South WCS may only be opened after approval of Sub-Compartment 2. Due to the limited capacity of the structures at the Compartment boundary, the structure provides the only way of the Sub-Compartment for drainage and water intake.

Behavior of the System During Different Monsoons

The Period before 1997

Before 1997, there were basic difficulties understanding the behavior of the system. Consequently, there were no guidelines about how the system should be operated. The reasons behind this have already been described and will only be summarized below:

- There was no comprehensive hydraulic model for the entire Compartment.
- Therefore, the behavior of the Lohajang was not well understood.
- For the same reason design criteria were not always correct.

The lack of operational guidelines can be noticed from the water level records, particularly those of the Lohajang. As the river is the heart of the system, this had its effect on most the drainage systems. By 1998, the Project was ready for a purposeful operation program. It was the Project's misfortune that the 1998 flood struck the same year.

The 1998 Flood

Fig 13 shows the water levels for the Jugini and the Mirzapur gauges, during the monsoon 1998. The average monthly levels and their frequencies are shown in the Tables 4-6. Here, attention is primarily drawn to the peak levels, which occurred between 5-11 September. During the period 5-11 September, the Lohajang started backing up due to high water levels along the Southern boundary. This water added to the flooding already caused by three breaches in the embankments, one at Silimpur, one near the Indrabelta and one near Rasulpur.

An account of the modeling done for the period is given in Ref 6. The report contains flood maps of the Compartment for the period between August 25 and September 12, generated by 1998 model. After September 12, the water started receding. The maps provide a realistic picture of the flooding in the Compartment during that period.

Table 11 provides a similar account but based on the water levels collected in the field. Average water levels have been listed for the period September 5-11, for a number of water management structures shown per cluster. Below the averages, either average land levels of the corresponding systems are shown, or, the target levels at the structure.

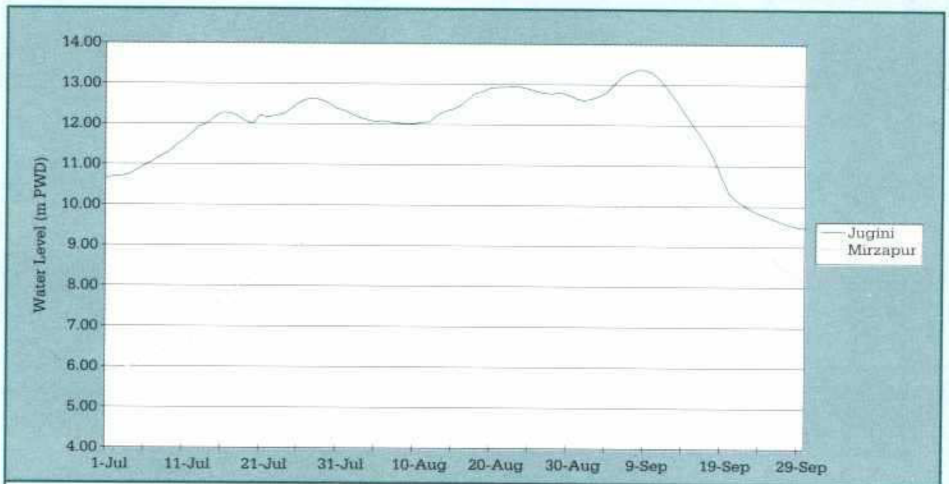

Fig 13. Water Levels at Jugini and Mirzapur during 1998

CLUSTER 1

	Krishna-pur	Eidgah Moidan	Singer-Kona	Rampal	Bhanga-bari	Santosh	Dithpur Upstr	Dithpur Downstr	KagmarI	
Average Water Level	10.91	10.17	10.59	10.76	10.80	10.75	10.70	10.77	10.73	
Average Land Level	11.06	11.03	10.22	10.46	10.22	10.03	10.90		10.00	
	(Syst 1)	(Syst 2)	(Syst 3)	(Syst 4)	(Syst 3)	(Syst 6)	(Target)		(Target)	

CLUSTER 2

	Bhat-chanda-2	Magu-rata	Enayet-pur-2	Agbetor	Beel Gharinda	District Upstr	District Downstr			
Average Water Level	11.07	11.21	10.96	No Obs	10.80	10.74	10.79			
Average Land Level	10.38	10.38	10.50	10.04	9.74	10.40	10.40			
	(Syst 10)	(Syst 10)	(Syst 9)	(Syst 11)	(Sub-comp. 5)	(Target)	(Target)			

CLUSTER 3

	Niogi-joair	Dharat	Hatila	Poila Upstr	Poila Downstr	Namder Kumulli	Jalfai Upstr	Jalfai Downstr	Bhatkura	Khudi-rampur
Average Water Level	10.60	11.14	10.53	10.56	10.68	10.57	10.52	10.52	10.34	No Obs
Average Land Level	9.04	9.04	9.04	9.04	9.39	8.94	9.39	9.39	9.40	9.20
	(Syst 19)	(Syst 19)	(Syst 19)	(Syst 19)	(Syst 22)	(Syst 16)	(Syst 22)	(Syst 22)	(Target)	(Target)

CLUSTER 4

	Aloa Upstr	Bhabani Downstr	Bera-buchna	Burburia	Aloa Raypara	Deojan Upstr	Deojan Downstr			
Average Water Level	10.76	10.48	10.65	11.05	10.56	10.75	10.69			
Average Land Level	9.95	9.75	10.24	10.24	9.75	9.75	9.75			
	(Syst 23)	(Syst 27)	(Syst 24)	(Syst 24)	(Target)	(Target)	(Target)			

Table 11: Water Levels within the Compartment during the Peak of the 1998 Flood, Sept 5-11.All Levels in m PWD

Rampal by 70 cm. In Cluster 2, the situation was bad around Batchanda-2 and Magurata, where the land went under 0.7-0.9 m of water. The worst affected cluster, however, was Cluster 3, as may be expected from its low topographical position. There, most of the land was flooded by more than a meter. Actually, in Cluster 3, water levels have been so high during most of the monsoon, that cropping was not possible. Finally, in Cluster 4, the land along the Lohajang went under water by about a meter. At Berabuchna and Burburia WCS, it was not as bad, however. The Clusters 2 and 4 suffered most from the breaches in their embankments. Cluster 3 suffered because it is the most vulnerable, while Cluster 1 suffered least.

The field survey about the operation of structures, carried out after the 1998 monsoon, confirms the picture. Cluster 1 had crop damage, but not so much a crop failure. Cluster 4 had a crop failure over a considerable area. Cluster 2 gave a mixed picture, somewhere in between the Clusters 1 and 4, but Cluster 3 never reached the point of full cropping.

The daily water levels in the database provide information about when the Lohajang starts backing up. That happens apparently with Mirzapur is at about to 10.0 m PWD. However, backing up of the Lohajang proved far less damaging than the breaches in the embankments. The reason is that it lasted only 7-10 days. The amounts of water coming in from the South are confined by the sizes of the openings in the Southern boundary, including the Lohajang River itself. The amounts are small in comparison to what it takes to flood large parts of the Compartment.

The 1999 Monsoon

As the Table 1 and 2 show, the 1999 monsoon was rather mild as far as rainfall is concerned. August, in particular, was dry and land users complained about water shortage. In addition, the outside water levels at Jugini and Mirzapur remained low. Due to the bad experience during 1998, land users in the lower areas planted considerably more deep water Aman than in 1997, at the expense of Local T-*Aman*. The HYV T-*Aman* maintained itself, as it is grown on the high lands, less bothered by floods.

Due to the construction of the highway and railroad to the Bangabandhu Bridge, obstructions were left in the Lohajang South of the Compartment. This caused water level increases at Poila and at the Jalfai and Bhatkura outlets, particularly during September. Differences amounted to more than 0.5 m as compared to September 1997. Despite this, the land users who had planted Deep Water *Aman* in that area would have preferred more water.

Gate operation during the monsoon was evaluated by project staff, in a joint meeting with the agricultural, fisheries and water management section. The monsoon was unfavorable for fisheries. With respect to agriculture the main point was, whether the water shortages could have been alleviated. It appeared that operation of the inlets and the outlets along the Lohajang was satisfactory. However, this did not lead to optimal conditions, because rainfall was sometimes too low.

The operation of the Main Regulator could have been better. Although there was a water shortage, the structure remained half-closed during most of August and September. By fully lifting the gates, water levels in the river could have been raised by about 0.5-0.6 m.

Such evaluations need to be supported by exercises with the updated 1999 model. By simulating different gate operation scenarios, one could determine to what extent gate operation could have been optimized.

Operation

Operation Guidelines

Detailed operation guidelines are given in the Operation Manual, Appendix 2 of this report. As it appears from the guidelines, water management very much consists of consultations and meetings between sub-compartment committees, rather than fixing optimal water levels in the sub-compartments. Target water levels are helpful to render such consultations practical.

As mentioned earlier, there are target water levels, which are rather strict, for instance in cases where gates overtop and there are target water levels that are flexible, which can be adapted by the committees on the basis of their experience. In a similar way, there are gate operations which are flexible and which are a subject for periodic consultations. Other gate operations should be strict. Some sub-compartment committees have the right to refuse water from their neighbors.

There is a general rule that excess of water downstream should determine gate operation upstream, even if this leads to relative water shortages there. There is a right to be protected against excess water. This prevails above the right to receive water.

From the training, it appeared that working with flexible target levels and flexible gate operation guidelines is difficult both for the trainers as for the trainees. It is far easier to train and operate a system with strict rules, than one with flexibility. Nevertheless, field conditions always present unpredictable situations and flexibility is important.

The West and East Bank

There are differences in operation between the western and eastern part of the Compartment. In the West, the water flows from West to East over relatively short distances, while in the East it flows from North to South over large distances. The impression from the surveys is, that in the west, the coordination between the operation of intakes and field conditions is rather good. In the east, the large distance between the intakes and the low areas is more problematic.

In the West, the boundaries of some sub-compartments make it necessary that several committees have to meet for relatively simple problems. This could have been prevented if system boundaries would have carried as greater weight in the decisions about the boundaries. This matter was discussed early during the second phase. It was then decided not to change sub-compartment boundaries halfway through the Project, as this would be very confusing to many parties.

Topography

The lower parts of the Compartment are rather flat and contain numerous drains. Every drain seems to influence every other drain and water frequently backs up from other systems. In addition, the intake of water in, occurs very often via the same channels as the drainage. An example is the situation along the Binnafair-Gaijabari Khal in Cluster 1.

The complexities of drainage, the inter-relations between systems together with water intake, have certainly been underestimated during the Project. Water management in the Compartment is far more intricate than anticipated. That explains why modeling was essential to provide a clear picture about the operation of the system.

The Time Element

Besides the complexity of the system, the time dimension is easily underestimated. When CPP started, there was great emphasis on people's participation and less on the physical aspects of water management. Presently, the physical aspects are acknowledged again. A result was the emphasis on users groups during the early beginning, which later changed into an emphasis on *chawk* and sub-compartment committees i.e. committees confined by physical boundaries. For operation and maintenance, it is convenient to classify infrastructure and activities, according to *chawk* level, sub-compartment and Compartment level, or, using a different terminology, tertiary, secondary and primary level. The trend towards greater emphasis on physical aspects, did not take place within CPP alone. Outside CPP, there was a similar trend.

Changes in emphasis have also occurred in the institutional field. Compared to the early years of CPP, the role of local government in water management has become more accepted. The Systems Rehabilitation Project has been important in this respect. One should realize that such changes are not matter-of-factly accepted by projects. They need time and during that process, they cause a certain confusion.

A time dimension is present as well in the modeling exercises during the Project. Changes in hardware, software but also in the quality of modeling staff, local and expatriate, have been considerable.

In addition, land users need time to realize the potential benefits of the Project. What they appreciated most was the flood protection. Improved drainage and water management has not been their primary concern. This caused local opposition to drainage plans. One may anticipate that, given time, the appreciation for improved drainage will grow and with that the need for more intensive drainage. However, the path is not smooth. The 1998 flood had the effect of the Project falling back to an earlier position.

Internal infrastructure

The Internal infrastructure proves not to be a homogenous set of structures. The structures have different functions. These are summarized in Table 10. In the first place, there are the structures of local importance, which serve a small group of chawks, not more than 3. Essentially, these are tertiary infrastructure. They serve to retain water in their upstream areas, when required. They are useful as long as they are not by-passed by other structures. Another requirement for their functioning is, that the drainage system downstream, has unhampered access to drainage systems of higher order. These two requirements are often not met in the Compartment and this reduces the value of some of these structures. Particular cases are the internal structures controlling the water in *beels*.

As areas upstream of structures grow larger, their operation becomes more complex. Examples are the water control structures at the downstream end of large drainage systems, which control the discharge into another system. Bhangabari (Fig. 3) is an example. Such structures are useful if the drainage system downstream performs well i.e. if it does not suffer from major obstructions or water backing up. Neither should they be by-passed by other structures. Under present Compartment conditions, their usefulness is sometimes limited for these very reasons.

Third, there are structures positioned in the alignments of drains, without another drain either entering or taking off. Agbetor WCS (Fig. 5) is an example. Their apparent function is to regulate water levels upstream in the drainage system. The experience with Agbetor is, that the structure is not operated. Similarly, Berabuchna and Burburia (Fig 4) have not been operated either during the 1999 monsoon.

Finally, there are structures in hydrological boundaries, which control flow from one cluster or sub-compartment to another. Poila (Fig. 6) is an example. The present operational plan makes use of them. They make the system easier to manage. In order to be useful, the structures should not be bypassed by other infrastructure. The latter is the case with Santosh WCS, which renders the structure ineffective.

There are gated structures in the Southern Compartment boundary of Cluster 3. They are not effective as they are partially blocked. In the Southern boundary of Cluster 4 there are no such structures, although the situation is comparable. If such structures are built, they should be designed, to withstand outside floods, coming in from the South, as was the case in 1998. Under normal conditions, they should remain open. If they are designed for flood protection, they may become expensive. The experience of 1998 is, however, that back flow of outside water may cause local damage but is not likely to do damage on a large scale.

In conclusion, the internal structures provide less water control than anticipated. This is partly due to the fact that there is so much other infrastructure that they are by-passed. Back flow from other systems, render some structures less effective. Structures with the function of water level control do not seem to work. Land users are interested in structures and operate them. Both they know very well, whether a structure is effective or not.

Modeling During 1999

Objectives

The 1998 modeling contributed considerably to the understanding of the role of the Lohajang, the Main Regulator and the remaining structures. An immediate result was that the operation of the drainage systems, could be better focused on main issues.

The 1999 modeling had as objective to verify the validity of new operation guidelines. When this proved successful, the modeling wanted to go one step further. It was investigated whether modeling could be used to optimize structure operation in advance, according to agricultural requirements. The attempt proved unsuccessful. Optimization via modeling proved difficult, and the question arose whether the outcome of the models was accurate enough for such purposes.

Scenarios

Five scenarios were worked out. The base case was the 1996 calibrated model of the 1998 modeling. However, instead of the 1996 rain, the rainfall of 1974 was taken. There is no strong justification for this choice, except that 1974 had a extreme July precipitation, which 1996 had not. There was an extreme 3-days rainfall. However, the run-off is not sensitive to 3-days rains. The 1996 outside water conditions and gate operations were maintained. The 1994 rainfall is given below.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
0	0	55	268	165	325	514	147	252	122	0	0	1,847

Rain in 1974 (mm)

The **first scenario** was the base case, the 1996 model with the 1974 rain.

The **second scenario** had Enayetpur-2, Poila, Hatila and Namdar Kumulli closed. All other gate settings, including the Main Regulator, were those of 1996.

The **third scenario** had the Main Regulator controlled to a maximum downstream level of 10.50 m. If the outside water levels change, the downstream levels change with them. However, the gates were set in such a way, that the maximum was not exceeded. As the models can not handle conditional statements, it is not possible to maintain a constant level all through the run. In addition to the gate settings at the Main Regulator, Enayetpur-2 WCS, Poila WCS, Hatila WCS and Namdar Kumulli WCS, were kept closed. The peripheral intakes and the outlets along the Lohajang were kept open.

The **fourth scenario** was identical to the third, but all peripheral intakes were closed. Also Namdar Kumulli WCS was open, as it appeared to accumulate water during the previous run. The purpose of the third and fourth run was to test the two extremes: all peripheral intakes permanently open and permanently closed.

The **fifth and final scenario** was identical to the third, but Bhatkura Outlet was closed all through the run. Namdar Kumulli was kept open. The purpose was to test the effect of the closure of one outlet. Bhatkura was chosen as it controls the lowest area of the Compartment.

Results

The results of the modeling are shown in Table 12. The upper lines show the names of the structures and their target levels. Below those, the half-monthly average levels per structure and per scenario are shown. When the average levels exceed the targets, they have been shaded.

Under the **first scenario**, the effect of an uncontrolled Main Regulator is noticeable all along the Lohajang, at least up to Deojan and possibly up to Jalfai. District Regulator and Bhatkura Downstream do reasonably well, except after the heavy July rain, when targets are exceeded. Enayetpur-2 WCS stays below the targets most of the time but Agbetor and *Beel* Gharinda indicate that much water is going down to Cluster 3. This, together with Bhatkura being closed part of the time, has its effects on Hatila, Namdar Kumulli and possibly on Khudirampur Outlet.

Under the **second scenario**, things remain more or less the same on the West Bank. In the east, with Enayetpur-2, Poila, Hatila and Namdar Kumulli WCS closed, there are improvements at Jalfai, Bhatkura and Khudirampur, although not all targets are met. District Regulator and Enayetpur-2 upstream become critical, which is to be expected with Enayetpur-2 closed. The situation at Hatila, Poila and Namdar Kumulli improve, but not enough to meet targets.

The high water levels at Hatila, Poila and Namdar Kumulli upstream, are consequences of the configuration of the model. In the model, Hatila *Beel* is connected to Bhatkura Khal via a drain with gated structure (Hatila WCS). Similarly, the land upstream of Poila WCS drains into Jalfai Khal. The two drains are not connected. If Hatila and Poila are closed, the Hatila area is without drainage and rainfall accumulates upstream of the two gates. Something similar occurs with Namdar Kumulli. The model does not provide drainage over the Southern boundary of the

Compartment. If Namdar Kumulli is closed, rain accumulates South of the structure.

The **third scenario** had the Main Regulator controlled and all inlets open. There is great improvement all along the Lohajang. The target water level of 9.00 m downstream of Namdar Kumulli appears too ambitious. With Bhatkura and Khudirampur performing rather well, it is not possible to lower the water below 9.00 m.

In the West, Bhangabari WCS and Aloa Raypara Outlet are above target. This is caused by an increased supply from Binnafair. During 1996, Binnafair was closed during the first half of August. Under the scenario, it is permanently open.

Under the **fourth scenario,** almost all targets are met, except those upstream of Hatila and Poila, for reasons given earlier. The target of 9.00 m, at Khudirampur remains too ambitious during July. For the rest, one may call it a perfect drainage situation.

The **fifth scenario** proves that with Bhatkura permanently closed, the water backs up all the way up to *Beel* Gharinda and Agbetor. So Cluster 2 may flood Cluster 3 by opening its intakes, but it works also the other way: Cluster 3 may flood Cluster 2 by closing its outlets.

Summarizing the results, the modeling shows that target water levels can be maintained by proper operation of intakes and outlets. One may generate a well-drained case. By closing outlets, one may create a situation in certain areas, which resembles the pre-Project situation. Therefore, a wide range of water conditions is possible. One should bear in mind that Project years have been relatively wet. There is less experience with dry years. The 1999 model may contribute in this respect.

Flooding Statistics

In an interface with the GIS system, the scenarios were used to generate flooding statistics. The land type map was used as a basis, with the customary four land types: F_0, the lands flooded up to 0.3 m, F_1, the lands flooded between 0.3 and 0.9 m, F_2, the lands flooded between 0.9 and 1.8 m and finally F_3, the lands flooded by more than 1.8 m. Similar flood classes were adopted: flooding less than 0.3 m, flooding between 0.3 and 0.9 m, flooding between 0.9 and 1.8 m and flooding deeper than 1.8 m. The results, per half-month, are shown in Appendix 3. Flood maps for July 30, under the scenarios 4 and 5 are shown in the Fig. 14 and 15.

Structure	Main Reg Downstr	District Reg Upstr	District Reg Downstr	Kagmari Outlet Upstr	Kagmari Outlet Downstr	Aloa Raypara	Deojan Outlet Upstr	Deojan Outlet Downstr	Jalfai Outlet Upstr	Jalfai Outlet Downstr	Bhatkura Outlet Upstr	Bhatkura Outlet Downstr
Target	10.50	10.40	10.40	10.00	10.00	9.75	9.75	9.75	9.40	9.40	9.40	9.40
Scenario 1												
July 1-15	10.40	9.99	10.04	9.85	9.85	9.72	9.56	9.55	8.93	8.95	9.42	8.89
July 16-31	10.84	10.60	10.54	10.39	10.38	10.23	10.06	10.05	9.63	9.63	9.64	9.48
Aug 1-15	10.28	10.26	9.95	9.81	9.80	9.70	9.66	9.55	9.19	9.19	9.87	8.86
Aug 16-31	10.64	10.29	10.27	10.03	10.05	9.92	9.78	9.76	9.52	9.52	9.78	9.16
Sept 1-15	10.65	10.30	10.27	10.03	10.06	9.93	9.79	9.77	9.51	9.51	9.32	9.18
Sept 16-30	9.87	9.70	9.61	9.47	9.46	9.36	9.34	9.23	8.69	8.55	8.65	8.51
Scenario 2												
July 1-15	10.43	10.06	10.10	9.88	9.89	9.74	9.56	9.56	8.88	8.91	9.24	8.85
July 16-31	10.88	10.73	10.61	10.44	10.43	10.28	10.09	10.08	9.54	9.54	9.54	9.46
Aug 1-15	10.27	10.54	9.94	9.79	9.79	9.68	9.63	9.53	9.06	9.06	9.72	8.81
Aug 16-31	10.69	10.43	10.35	10.07	10.11	9.96	9.80	9.78	9.36	9.36	9.53	9.11
Sept 1-15	10.68	10.53	10.32	10.04	10.09	9.95	9.79	9.77	9.33	9.33	9.16	9.11
Sept 16-30	10.00	9.87	9.82	9.67	9.66	9.56	9.52	9.42	8.73	8.73	8.78	8.69
Scenario 3												
July 1-15	10.35	10.12	10.09	9.90	9.90	9.77	9.61	9.60	8.98	8.97	9.05	8.94
July 16-31	10.30	10.37	10.20	10.08	10.07	9.97	9.84	9.81	9.30	9.28	9.33	9.25
Aug 1-15	10.33	10.12	10.09	9.92	9.92	9.80	9.70	9.64	9.00	8.99	9.05	8.96
Aug 16-31	10.35	10.22	10.15	9.98	9.98	9.86	9.73	9.69	9.03	9.03	9.03	8.99
Sept 1-15	10.35	10.23	10.17	10.00	10.00	9.88	9.76	9.71	9.10	9.09	9.10	9.05
Sept 16-30	9.98	9.80	9.77	9.64	9.63	9.52	9.47	9.38	8.66	8.65	8.70	8.62
Scenario 4												
July 1-15	10.35	10.02	10.01	9.80	9.79	9.67	9.52	9.51	8.91	8.90	9.01	8.82
July 16-31	10.17	9.99	9.97	9.80	9.79	9.69	9.61	9.55	9.06	9.05	9.05	8.98
Aug 1-15	10.27	9.95	9.94	9.74	9.73	9.62	9.56	9.46	8.77	8.76	8.76	8.83
Aug 16-31	10.35	10.01	10.00	9.78	9.77	9.66	9.58	9.50	8.82	8.82	8.79	8.73
Sept 1-15	10.35	10.04	10.02	9.82	9.81	9.70	9.61	9.54	8.90	8.89	8.87	8.84
Sept 16-30	9.91	9.69	9.67	9.51	9.51	9.40	9.38	9.26	8.51	8.50	8.52	8.64
Scenario 5												
July 1-15	10.35	10.12	10.09	9.90	9.90	9.78	9.60	9.58	8.86	8.84	9.85	8.80
July 16-31	10.23	10.37	10.19	10.07	10.06	9.97	9.82	9.79	9.28	9.23	10.27	9.19
Aug 1-15	10.34	10.14	10.10	9.93	9.93	9.82	9.71	9.64	9.01	8.96	10.24	8.91
Aug 16-31	10.35	10.22	10.15	9.99	9.98	9.87	9.74	9.69	9.06	9.03	10.21	8.98
Sept 1-15	10.35	10.25	10.17	10.01	10.00	9.89	9.76	9.72	9.14	9.08	10.26	9.04
Sept 16-30	9.98	9.83	9.80	9.66	9.66	9.57	9.50	9.40	8.72	8.66	10.18	8.62

Continued

Structure	Main Reg Downstr	District Reg Upstr	District Reg Downstr	Kagmari Outlet Upstr	Kagmari Outlet Downstr	Aloa Raypara	Deojan Outlet Upstr	Deojan Outlet Downstr	Jalfai Outlet Upstr	Jalfai Outlet Downstr	Bhatkura Outlet Upstr	Bhatkura Outlet Downstr
Target	9.20	10.20	10.50	10.50	10.10	9.80	9.50	9.50	9.50	9.50	9.40	9.40
Scenario 1												
July 1-15	8.83	10.14	10.06	9.96	9.96	9.93	9.48	9.46	9.32	9.31	9.48	9.42
July 16-31	9.45	10.73	10.61	10.35	10.49	10.24	9.71	9.71	9.69	9.69	9.68	9.66
Aug 1-15	8.82	10.17	10.26	10.16	10.18	10.08	9.87	9.88	9.51	9.48	9.86	9.87
Aug 16-31	9.12	10.11	10.29	10.21	10.24	10.13	9.84	9.83	9.65	9.65	9.96	9.80
Sept 1-15	9.14	10.08	10.30	10.20	10.20	10.09	9.41	9.41	9.63	9.62	9.45	9.35
Sept 16-30	8.47	9.77	9.63	9.70	9.71	9.58	8.93	8.96	9.18	9.24	9.08	8.88
Scenario 2												
July 1-15	8.80	10.15	10.16	9.7	9.73	9.70	9.89	9.29	9.96	9.19	9.73	9.25
July 16-31	9.42	10.76	10.77	10.01	10.07	9.96	10.30	9.59	10.13	9.58	9.89	9.56
Aug 1-15	8.77	10.17	10.54	9.88	9.92	9.85	10.34	9.73	10.09	9.32	9.90	9.72
Aug 16-31	9.07	10.14	10.46	9.87	9.90	9.84	10.35	9.58	10.10	9.44	9.90	9.55
Sept 1-15	9.06	10.10	10.55	9.78	9.82	9.75	10.35	9.22	10.10	9.41	9.92	9.19
Sept 16-30	8.65	9.78	9.91	9.52	9.54	9.50	10.35	8.90	10.10	9.17	9.95	8.84
Scenario 3												
July 1-15	8.88	10.11	10.18	9.71	9.72	9.69	9.71	9.14	9.92	9.20	9.69	9.10
July 16-31	9.22	10.55	10.50	9.96	10.03	9.91	9.96	9.39	10.22	9.38	9.87	9.35
Aug 1-15	8.92	10.24	10.16	9.65	9.69	9.63	10.09	9.14	10.21	9.24	9.96	9.09
Aug 16-31	8.95	10.40	10.29	9.70	9.74	9.67	10.18	9.08	10.21	9.20	10.00	9.05
Sept 1-15	9.01	10.41	10.31	9.72	9.77	9.69	10.30	9.15	10.21	9.22	10.09	9.12
Sept 16-30	8.58	10.04	9.82	9.42	9.45	9.41	10.39	8.86	10.21	9.14	10.20	8.75
Scenario 4												
July 1-15	8.82	9.76	10.03	9.46	9.39	9.14	9.71	9.08	9.92	9.14	9.27	9.18
July 16-31	9.00	9.90	10.00	9.39	9.33	9.13	9.96	9.06	10.22	9.15	9.07	9.02
Aug 1-15	8.69	9.74	9.97	9.22	9.20	9.03	10.09	8.80	10.21	9.07	8.85	8.88
Aug 16-31	8.75	9.87	10.02	9.23	9.20	9.01	10.18	8.80	10.21	9.04	8.80	8.74
Sept 1-15	8.82	9.87	10.06	9.25	9.21	9.02	10.30	8.87	10.21	9.06	8.88	8.85
Sept 16-30	8.44	9.65	9.71	9.24	9.21	9.02	10.41	8.64	10.21	9.07	8.76	8.73
Scenario 5												
July 1-15	8.75	10.11	10.18	9.89	9.88	9.51	9.77	9.85	9.92	9.25	9.80	9.85
July 16-31	9.16	10.55	10.50	10.28	10.39	9.79	10.14	10.27	10.22	9.49	10.22	10.27
Aug 1-15	8.87	10.24	10.18	10.16	10.18	9.73	10.36	10.24	10.21	9.43	10.32	10.24
Aug 16-31	8.94	10.40	10.29	10.17	10.19	9.72	10.41	10.21	10.21	9.40	10.23	10.21
Sept 1-15	9.00	10.42	10.32	10.21	10.24	9.75	10.45	10.26	10.21	9.43	10.28	10.26
Sept 16-30	8.58	10.05	9.87	10.06	10.06	9.65	10.48	10.18	10.21	9.35	10.28	10.18

Table 12: Target Water Levels and Calculated Levels under the Scenarios of the 1999 Modeling. All Levels in m PWD

For agricultural purposes the Scenarios 3 and 4, are the most interesting. Under these scenarios, the Flood Class 0-30 cm, contains most of the land. However, the number of hectares in that flood class, changes through the monsoon and is not a constant. The difference between the maximum and minimum is 3,250 ha for Scenario 3 and 1,200 ha for Scenario 4. One may conclude from that, that Scenario 4, provides more stable cropping conditions.

By closing Bhatkura under Scenario 5, the increase in area under the Flood Classes 30-90 and 90-180 is more than 2,000 hectares for almost all periods. The impact of this measure is large. However, it is not clear to what extent fisheries can profit from such a scenario.

Summary of Results

The scenarios do not provide a clear answer about which mode of operation is to be preferred. Even if one would adopt a single objective, such as optimizing agricultural production, the scenarios do not lead to operation guidelines. They illustrate the wide scope of possibilities available by manipulating intakes and outlets.

Two aspects are missing. The first is the opinion of the land users, about whether a scenario is good, bad or something in between for a certain sub-compartment. One should accept that the opinion of the land users may be different from objective agricultural criteria. Land users may find a scenario too dry, because they have been used to flooded conditions. In addition, they may not have adapted yet to the new situation.

The second aspect relates to fisheries. Although the system may provide very wet conditions by opening intakes and closing outlets, it is unclear whether this creates favorable conditions for fisheries, and if yes, for what kind of fisheries, aquaculture or catch fisheries. Water management criteria are clearer for agriculture. This is probably not specific for CPP. It may have a much wider scope.

Modeling can be helpful in evaluating water conditions and gate operations during and after a monsoon. If records on gate operation and water levels are available, an updated model can be processed for the season. If, in addition, field records are available on the quality of water conditions, supposedly from land users opinions, one could simulate how water conditions would improve under a different scenario. Due to the lack of water management criteria for fisheries, such evaluations will mainly relate to agriculture.

It was considered whether it would be useful to generate statistics per sub-compartment or even per *chawk*. The models are certainly not accurate enough at *chawk* level. At sub-compartment level they may give a false impression of the actual situation and may lead to meaningless operation rules.

Modeling the Gharinda Regulator

Construction of the Gharinda Regulator has long been a pending issue. During 1999, the models were used to evaluate the impact of the structure. The structure has more or less the same function as Agbetor. It is positioned in the alignment of a major drain and it would serve to regulate water levels upstream. Another function might have been that it would regulate the amount of drainage flow going down to Cluster 3. In this respect, its function is similar to that of Santosh Regulator.

However, the Santosh Regulator, even if not bypassed, has an escape in Kagmari, which Gharinda has not. Closing structure during the monsoon may be hazardous. During normal years, operating the structure has minor effects. During wet years, it only shifts the flooding from downstream to upstream. As Cluster 3 is a pronounced flooding area already, there is no basic improvement in this. The conclusion, therefore, was that Gharinda Regulator should not be built.

Lessons Learned

Water Management

The size of the Compartment, its land conditions and surroundings may be considered representative for a pilot project. Facilities like the Main Regulator, the surrounding embankment, intakes and outlets are essential. To what extent the Compartment can be replicated, should be studied thoroughly, before the concept is pursued.

Due to the emphasis on modeling during the second phase, there was less attention for water management outside monsoon months, than during the first phase. However, the importance of the Boro crop, 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 back flow 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 accurate as originally anticipated.

It is essential that the Compartment is protected by an embankment of good quality. It provides security, which is at least as important as water management. The Main Regulator and its facility to manage water levels in the Lohajang, make it the core of water management system.

CPP, rightly, has put great emphasis on the intake of outside water, from its early beginning. Intake structures are actively operated by the population. 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, distances are short enough for proper communication, in the eastern half, they are too long. To improve that warning indicators are necessary between intakes and low land.

The availability of outside water has limitations. High lands can not be reached, because of their topographical level. Parts of the lands in the western half are outside the reach of the intake structures. Finally, as long as the outside water is below the sill of the intakes, the water can not enter.

Outlet structures along the Lohajang are essential. They make the water management within the sub-compartments less dependent on largescale management measures. The Lohajang can not serve each sub-compartment individually. The management of the river should respond to criteria that are more general.

The structures of the internal infrastructure have a number of functions, which should be specified. Structures at *chawk* level have the best chance of performing well. The structures designed to regulate water levels in on-going drains have the least operation performance. An important reason why structures do not perform, is that they are bypassed by other infrastructure. Land users are aware of non-performing structures and do not operate them. The modeling indicates that the present density of water control structures has the least impact on the behavior of the water, after the Lohajang and the Main Regulator, the intake and the outlet structures.

For the time being, the operation of the system should be based on more or less continuous flow of water through the system i.e. with the intakes open most of the time. That is what land users want. It has the advantage that water is available and is refreshed all the time. This does not mean that such a scenario leads to the highest agricultural production. One should have to admit, however, that the operation guidelines leading to the highest agricultural production are not yet known. This is even more the case with respect to fisheries and environmental issues.

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 it's funding. At least one annual meeting should be devoted to that.

Chawks and Sub-Compartments

It is a good approach to divide the Compartment, into sub-compartments and chawks. This renders the area better manageable, while it provides a framework for consultations between the Project and the local population. However, *chawk* and sub-compartment boundaries should be based on systems, as much as possible. This reduces the number of cases in which water conditions in one sub-compartment are influenced by those in another.

Committees should be established based on geographic units. The approach with stakeholders or users groups has not been successful. The recommended approach creates a link between the committees and the infrastructure in their areas and related issues.

It is helpful when infrastructure is classified as *chawk*, sub-compartment or Compartment infrastructure, or, as primary, secondary and tertiary infrastructure. This assigns priorities to interventions, while responsibilities for operation and maintenance are easier defined. It makes the system more transparent to the users. During all phases of the Project, consultations with the committees about their infrastructure should be conducted within the framework of an overall technical plan.

Modeling

Due to the complexity of the water management, modeling at an early stage is essential and should start as soon as sufficient data are available. The hydraulic and hydrological interrelations between the Main Regulator, the Lohajang and the Compartment are too complex to judge them off-handedly. It is better to start with a model encompassing the entire Compartment and bring in more detail as the water management develops, than developing models for parts of the area, to be integrated later. In the latter case, the establishment of boundary conditions is the difficult part.

Although simulation of water management is feasible with the models, it is difficult to design scenarios in advance, that would lead to, for instance, increased agricultural production. In the first place, there are too many unknowns: rainfall, outside water conditions and possible failures of the system. In the second place, criteria that would lead to increased production, are not yet well defined. The latter problem is considerably greater for fisheries than for agriculture. The same would be true for environmental optimization, but that has been barely considered. An example of the latter would be a criterion for minimum flow in the Lohajang during the monsoon.

Modeling could be used to evaluate gate operation during and after a monsoon. Requirements are that water levels and gate operation has been monitored. It also requires statements about the quality of past water management, supposedly from land users. For reasons stated above, monitoring of water management to improve fisheries, can only be very rudimentary.

Drains

The excavation of the secondary drainage systems ran in insurmountable difficulties. Land acquisition was a problem but also opposition of the local population. As a result, drainage conditions in the Compartment are still very much as they were in the pre-Project situation. An important difference is, that at present, high floodwaters are kept out. The low drainage rates calculated by the models confirm the weak performance of the drains.

It takes time to convince land users that their area could be better drained. On the other hand, targets that could be achieved by better drainage are still vague. Land users are aware of the disadvantages of the changes in water management, such as the decline in fish and less silt coming in. In retrospect, the attitude of the land users should have lead to less emphasis on the excavation of drains. Except where the local population fully supported it and assisted in having the excavation realized, it should have been undertaken.

Accepting the present intensity of drainage, the physical system could still absorb a great deal of improvement. This may be concluded from the many issues raised by the population in the surveys. Even the best design can not pretend to solve all problems.

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Appendix 1

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INTERNAL STRUCTURES

Name of gauge	Gauge Number
Cluster 1	
1 Krishnopur WCS upstr Krishnopur WCS downstr	SG05 SG06
2 Beel Baghil WCS upstr Beel Baghil WCS downstr	SG07 SG08
3 Edgah Moidan upstr Edgah Moidan downstr	SG11 SG12
4 Sapua WCS upstr Sapua WCS downstr	SG15 SG16
5 Singerkona WCS upstr Singerkona WCS downstr	SG17 SG18
6 Bhangabari WCS upstr Bhangabari WCS downstr	SG19 SG20
7 Chowbari WSC upstr Chowbari WSC downstr	SG21 SG22
8 Rampal WCS upstr Rampal WCS downstr	SG23 SG24
9 Santosh Reg. upstr Santosh Reg. downstr	SG29 SG30
Cluster 2	
10 Beel Gharinda upstr Beel Gharinda downstr	SG37 SG38
11 Salina WCS upstr Salina WCS upstr	SG41 SG42
12 Agbetor WCS upstr Agbetor WCS downstr	SG45 SG46
13 Batchanda-2 upstr Batchanda-2 downstr	SG49 SG50
14 Batchanda-1 upstr Batchanda-1 downstr	SG51 SG52
15 Magurata WCS upstr Magurata WCS downstr	SG53 SG54
16 Enayetpur-2 WCS upstr Enayetpur-2 WCS downstr	SG55 SG56

Name of gauge	Gauge Number
Cluster 3	
17 Gosaijoair WCS upstr Gosaijoair WCS downstr	SG61 SG62
18 Birnahali-2 WCS upstr Birnahali-2 WCS downstr	SG63 SG64
20 Namdar Kumulli-1 upstr Namdar Kumulli-1 downstr	SG67 SG68
21 Namdar Kumulli-2 upstr Namdar Kumulli-2 downstr	SG69 SG70
22 Paschim Pauli upstr Paschim Pauli downstr	SG71 SG72
23 Karatia WCS upstr Karatia WCS upstr	SG73 SG74
24 Niogijoair WCS upstr Niogijoair WCS upstr	SG77 SG78
25 Dharat WCS upstr Dharat WCS downstr	SG79 SG80
26 Hatila WCS upstr Hatila WCS downstr	SG81 SG82
27 Poila WCS upstr Poila WCS downstr	SG85 SG86
28 Mirer Betka WCS upstr Mirer Betka WCS downstr	SG87 SG88
Cluster 4	
No structures up to 1998	
29 Berabuchna upstr Berabuchna downstr	SG97 SG98
30 Bhurburia WCS upstr Bhurburia WCS downstr	SG99 SG100
31 Bara Atia WCS upstr Bara Atia WCS downstr	SG101 SG102

Continued

STRUCTURES ALONG THE LOHAJANG

Cluster 1

Name of gauge	Gauge Number
1 Main Regulator upstr Main Regulator downstr	SG01 SG02
2 Dharerbari WCS upstr Dharerbari WCS downstr	SG57 SG58
3 Dithpur Outlet upstr Dithpur Outlet downstr	SG9 SG10
4 Dannya Chowdhury upstr Dannya Chowdhury d/s	SG13 SG14
5 District Regulator upstr District Regulator downstr	SG59 SG60
6 Chillabari Outlet upstr Chillabari Outlet downstr	SG32 SG31

Cluster 2

Name of gauge	Gauge Number
7 Dighulia-1 Outlet upstr Dighulia-1 Outlet downstr	SG33 SG34
8 Kagmari Outlet upstr Kagmari Outlet downstr	SG35 SG36
9 Aloa Raypara upstr Aloa Raypara downstr	G49 G04
10 Deojan Outlet upstr Deojan Outlet downstr	G50 G05
11 Jalfai Outlet upstr Jalfai Outlet downstr	SG89 SG90
12 Bhatkura Outlet upstr Bhatkura Outlet downstr	SG83 SG84

PERIPHERAL STRUCTURES

Cluster 1

Name of gauge	Gauge Number
1 Khurda Jugini riverside Khurda Jugini landside	SG03 SG04
2 Binnafair Intake riverside Binnafair Intake landside	SG25 SG26
3 Fatehpur Intake riverside Fatehpur Intake landside	SG27 SG28

Cluster 2

Name of gauge	Gauge Number
6 Rasulpur Intake riverside Rasulpur Intake landside	SG39 SG40

Cluster 3

Name of gauge	Gauge Number
8 Suruj Intake riverside Suruj Intake landside	SG75 SG76

Cluster 4

Name of gauge	Gauge Number
4 Indrabelta Intake rivers. Indrabelta Intake lands.	SG91 SG92
4 Barabelta Intake riverside Barabelta Intake landside	SG93 SG94
5 Baruha Intake riverside Baruha Intake landside	SG95 SG96

Appendix 1. Structural Gauges and their Numbers

Appendix 2

Government of the People's Republic of Bangladesh

Ministry of Water Resources

Bangladesh Water Development Board

Water Resources Planning Organization

Compartmentalization Pilot Project
Tangail

Operation Plan

August 1999

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1 Introduction

Peoples Participation is the main approach of CPP. It is the people that are expected to manage and operate the structures. After completion of CPP, the project will be handed over to the beneficiaries organization for future operation and maintenance. CPP has now entered into a phase where a considerable progress has been achieved on institutionalization of People's Participation with water management committees already entrusted with task of operating the structures to meet and manage their water management requirement.

Now the main task of CPP is to entrust the operation responsibilities fully to the water management committees on the basis of lessons learned in the part.

With this in view, and in-accordance with the national water policy, this operation plan for the whole compartment has been prepared.

2 Objectives

The main objectives of operation are to control water level in the canal system, *chawk* or at the sub-compartment level by manipulation of the water management infrastructures (e.g. opening/closing gates) to meet water management needs of the farmer and fisherman.

The main objectives of the operation plan are :

a) to introduce a standard and sustainable operation programme.

b) to involve stakeholders in operation.

c) to get maximum benefit from the infrastructures built under the project.

3 Project Description and Existing Infrastructure

The CPP is surrounded by an embankment on the northern, western and eastern side. Lohajang river is acting as the main drainage outlet of the project area. Entry of flood water into the project area through the Lohajang river is controlled by a gated structure at Jugini which is the main inlet. In addition, for the entry of flood water, there are inlet structures in the peripheral embankment. For internal water management, controlled structures have been constructed along the bank of Lohajang river and in the sub-compartment. Internal drainage is effected through existing and re-excavated khals.

The project consists of a single compartment, 16 nos. sub-compartment (including Tangail Town Sub-compartment) and 142 chawks. There are 110 nos. of *Chawk* Water Management Committees for 142 *chawk* and 15 nos. Sub-compartment Committee. No committee has been formed for Tangail sub-compartment which is a urban area.

The following definitions are being used for compartment, sub-compartment and *chawk*;

i) Compartment:

An area in which effective water management, particularly through controlled flooding and controlled drainage, is made possible through structural and institutional arrangements.

The infrastructure of the Tangail Compartment consists of three major elements and a large number of small ones. The major elements are: the embankment which surrounds the Compartment partially, the Main Regulator and the Lohajang river. The small elements have been divided into peripheral infrastructure, infrastructure along the Lohajang and internal infrastructure. The peripheral infrastructure consists of water inlets in the embankment, along the outer boundaries of the Compartment. The structures along the Lohajang control the inflow and outflow between sub-compartments and the river. The internal infrastructure consists of structures controlling the water within the sub-compartments.

ii) Sub-compartment:

A sub-unit of a compartment, in which to a certain extent, the water management can be controlled by the people living in the area represented by a sub-compartmental water management commtittee (SCWMC). A sub-compartment consists of number of chawks.

iii) Chawk:

The smallest hydrological or physiographic unit which are easily recognizable in the field because of its homogeneity. Most chawks have natural ways both for inflow and drainage. Some of them have been provided with gated inlet and outlet structures. The lowest level of hydrological uniformity are the chawks. The "chawks" are considered as manageable field unit usually bordered by topographical features; generally located in between villages (settlements), roads, khals/rivers or embankments etc. These chawks are socially and agriculturally quite familiar to rural people in the project area. The chawks might have both high, medium and lowlands, and sometimes may contain a "*beel*" or *khal*; but since their borders is formed by infrastructure (roads, village/paths, khals etc.), it would be possible to regulate water level to suit certain desirable and profitable crops in monsoon flood period and to retain or drain out water in pre and post monsoon.

a) Embankment

At present the compartment is protected from flood by peripheral embankment of length 47 km. In addition, there are 12 kms length of internal embankment and about 38km of road belonging to R&H department and LGED along the bank of Lohajang river. The road is now serving as embankment for the protection of flood water from Lohajang river.

The crest level has been fixed considering 1988 flood with a 30cm free board. This level corresponds with a 1:7 year return period flood with a 0.90m freeboard.

b) Drianage Channels

Lohajang river which flows through the middle of the compartment is the major drainage channel. A total of 34 nos. drainage channels or khals have been identified in the compartment for re-excavation. Details of the drainage channels are given in Table 3.1.

c) Peripheral Inlet Structures

In all 13 nos. Inlet structures have been constructed on the peripheral embankment for allowing flood water to enter into the compartment in a controlled way. These include Main Inlet at Jugini where Lohajang river enters into the project area. All peripheral inlets have been listed in Table 3.2.

d) Infrastructure along the Lohajang River

Because water level in the Lohajang can be manipulated at the Main Inlet (regulator), the river functions one is yet to constructed as a drain for the compartment. Along the river 15 drainage outlets have been constructed for draining of the excess water from the sub-compartment. Some of these outlets can also serve as inlet if water conditions in the Lohajang river allow. All structures along the Lohajang river have been listed in Table 3.3.

e) The Internal Infrastructure

The internal infrastructure of the Tangail Compartment consists of Water Control Structures (WCS), Gated Pipe Culverts (GPC) and khals. All WCSs and GPCs have gates and the water can be controlled. Most of the structures are small and of local importance only. All internal structures have shown in Table 3.4.

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4 Operation Responsibilities

The ultimate success and effectiveness of water resources management projects depends on the people's acceptance and ownership of each project. After completion of CPP, the project will be handed over to the beneficiaries organization for future operation and maintenance. In the recently approved National Water Policy of the Government of Bangladesh, it is mentioned that "Public Water Schemes, baring municipal schemes, with command area of over 5000ha. will be gradually placed under private management, through leasing, concession or management contract under open competitive bidding procedures or jointly managed with local government and community organizations".

CPP with command area of 13200 ha. falls under the above category. Presently, CPP is not in a position to be placed under private management. The only other alternative is joint management with local government and community organization. In CPP people's participation has been institutionalized in Water Management Committees at *Chawk* (ChWMC), Sub-compartment (SCWMC) and Compartment level. Union *Parishad* Chairman has been made ex-officio president of the SCWMC and other three UP members have also been included as members of SCWMC to have a link between the WMCs and the elected branch of the Local Government Institutions. This link was felt necessary in order to increase the authority of the WMC.

Under the circumstances, it is logical to place the project (CPP) under the joint management with Community Organizations (WMCs). As a first step, it is important to delineate the roles and responsibilities of BWDB and WMCs. It has been discussed elaborately during the first training session of the reformed WMCs held in June-July, 1998. Several discussion meetings were also held at later dates between WMCs and Project Authority (Project Team and Consultant Team) on the issue. It has been decided that all structures except main inlet will be operated by WMCs and BWDB will provide technical guidance.

The following classification related to assigning responsibilities at various levels were made.

(a) ChWMC: all structures within the *chawk* boundaries which influence only the water management within the *chawk* concerned

(b) 2 ChWMCs: all structures which only influence the water management of the two chawks concerned

(c) SCWMC: all structures which influence only the water management in the SC concerned (more than two chawks)

(d)	2 SCWMC:	all structures which only influence the water management of the two SCs concerned
(e)	CWMC:	all structures within the boundaries of the compartment which only influence the water management in the compartment (more than 2 SCs). CWMC has not yet been formed. Till formation of CWMC operation responsibilities rest with SCWMC in which structure is situated. Responsible SCWMC is to operate the structure in discussion with related SCWMCs.
(f)	BWDB:	Main Inlet.

5 System Operation

5.1 Operation Planing and Procedure

The project inconsultation with the water users and with the help of the model studies has developed water management plan which include general guidelines for operation of the inlet structures in the peripheral embankment, drainage outlets and water control structures along the bank of Lohajang river and some major internal water control structures. Water management plan for each sub-compartment has been described in detail in Chapter 7. This chapter deals with the general guidelines.

5.2 Modelling in the Fixation of Target levels at Important Structures and Managment of the Logajang Water level

Due to the complexity of the water management system of CPP, updated and validated Flood Management Model of CPP has been used to simulate different scenarios for making a clear understanding of the hydraulic behavior of the system.

Almost all the project area drains into the Lohajang river. So the water level of the Lohajang river inside the project area plays a vital role concerning the drainage capacity of the system. The maximum allowable water levels at the upstream of all outlet structures along the Lohajang river which we call the target water levels were fixed up considering the area-elevation of the sub-compartment and the top level of the structure gates when they are closed.

Different scenarios were simulated concerning the management of the Lohajang water level inside the project, so that downstream water levels at outlet structures do not exceed the defined target level.

It is observed from the model simulations that if the downstream water level at the Main Inlet is maintained at 10.50 m PWD, then almost all the outlet structures can drain into the Lohajang and in that case inside water level in the sub-compartment can be maintained within maximum permissible water level.

Model has been applied also to set up target levels at the downstream of all the inlet structures. However, the target levels are the initial estimation and will be adjusted from field experience during the coming monsoon.

The preliminary target levels which have been fixed are shown in Table 5.1.

5.3 Opeation of main inlet as a fish Friendly Structure

Since the Main-Inlet is composed of eight nos. of gate so the operation becomes complicated. Simulations were made to establish certain guidelines through which a completely fish friendly operation (no under shot type flow) is possible to maintain downstream of Main Inlet at definite target levels. Since the operation guidelines proposed here are derived from the model results, so those guidelines shall be applied and adjustment will be made from the field observation. The methodology how it was developed has been described in the modeling report, " Mathematical Modeling for the Water Management in Compartmentalization Pilot Project, Tangail, Final Report, Volume-I.

Those graphical relationship are made for the operation at different downstream target level. Different gate settings required for different upstream levels for a downstream target level are presented in a tabular form and also a graphical representation for the different settings and one demonstration are enclosed in the followings.

The description and the dimension of the Main Inlet :

Dimension of the Main Inlet Regulator

Structure Geometry	Three Middle Vents			Two Side Vents (Fish Passes)	
	Vent	Upper Gates	Lower Gates	Vent	Gates
Sill Level (m+PWD)	9.20			10.70	
Width (m)	3.00	3.00	3.00	1.50	1.50
Height (m)	3.80	3.00	0.85	2.30	2.30

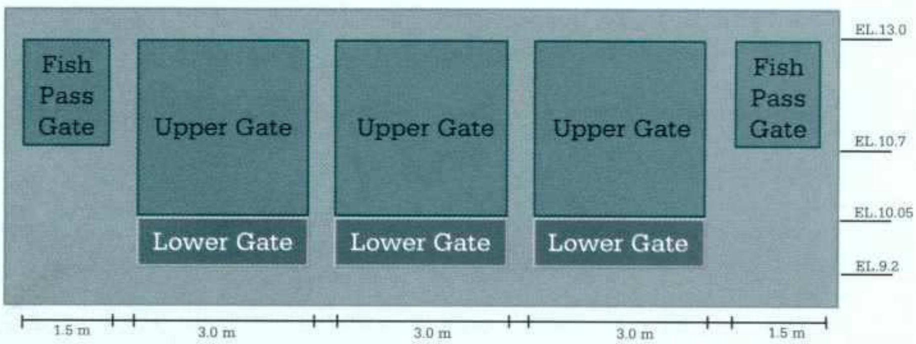


Figure 1: Schematic diagram of the Main Inlet Regulator (Not in scale)

__**Completely Fish Friendly Setting.**__

This setting is composed of different combination of settings of upper gates and lower gates (either full open or full closed). No undershot type flow situation is assumed. Fish Passes are always kept open. Each vent of the three middle gates are operated in a way that only the lower gate is fully closed or both the upper and lower gates are fully open. Total of eight combinations of gate setting is found as fully fishfriendly settings. For clean understanding, upper and lower gates can be numbered as shown in Fig.2. Combinations of gate settings are shown in Fig.3 - Fig. 10.

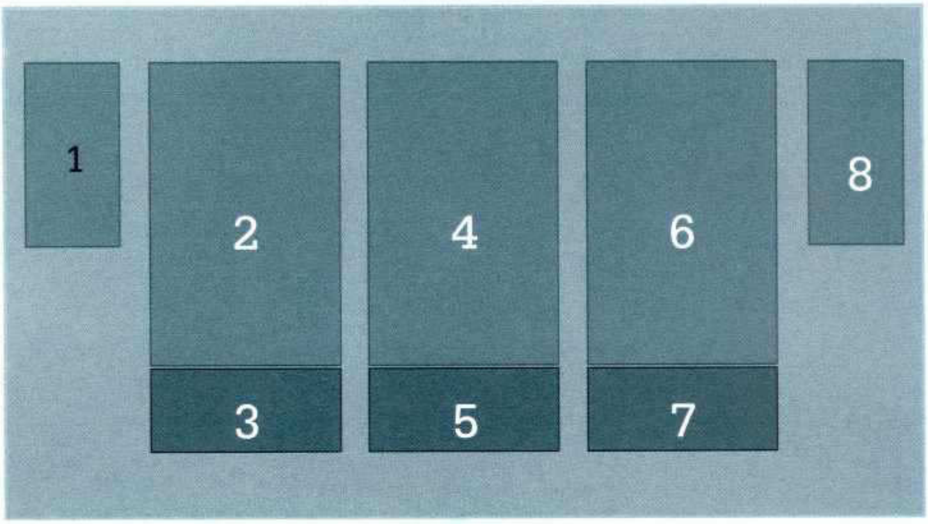


Figure 1: Gate Numbers

This set of gate setting provides full fish-friendly environment of flows through the main regulator, because it always keeps over flow types flow conditions.

Combination of Different Gate Settings

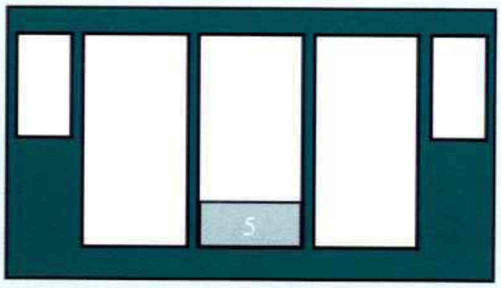


Fig.3 Combination No. 1

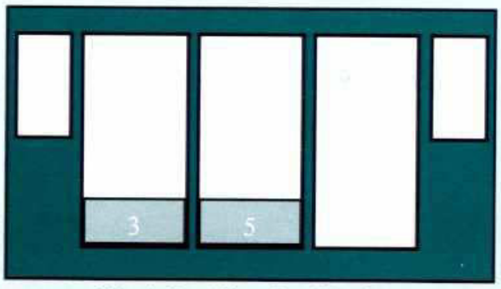


Fig.4 Combination No. 2

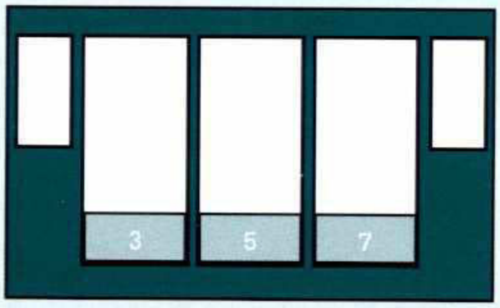


Fig.5 Combination No. 3

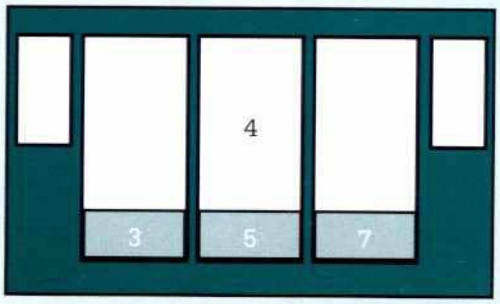


Fig.6 Combination No. 4

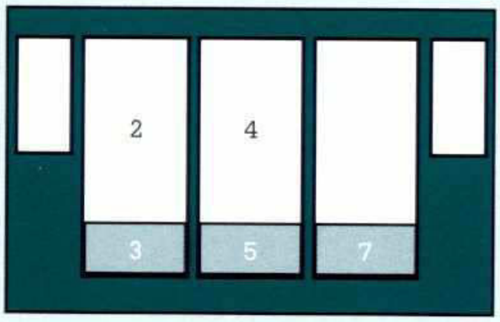


Fig.7 Combination No. 5

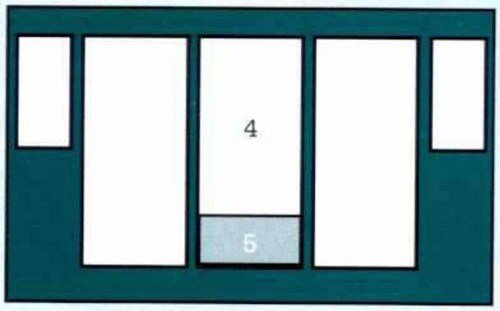


Fig.8 Combination No. 6

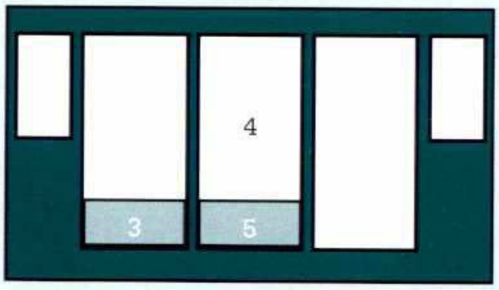


Fig.9 Combination No. 7

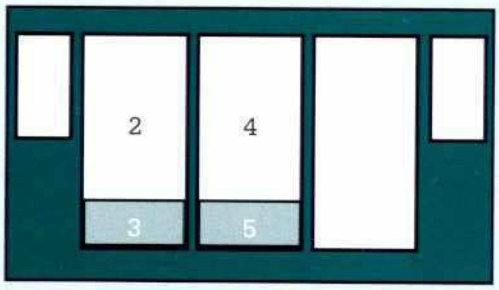


Fig.10 Combination No. 8

Table 5.2 shows upstream water levels generated from model results for different combinations of gate settings for corresponding downstream target water levels.

Description of Different Combination :

Combination 1 :	One lower gate down and all other gates are completely open.
Combination 2 :	Two lower gates down and all other gates are completely open.
Combination 3 :	Three lower gates down and all other gates are completely open.
Combination 4 :	Three lower gates down and the middle upper gate closed. All other gates open.
Combination 5 :	Three lower gate down and two upper gates closed. All other gates open.
Combination 6 :	One lower gate down and middle upper gate closed. All other gate open.
Combination 7 :	Two lower gate down, and middle upper gate closed. All other gates open.
Combination 8 :	Two lower gates down and two upper gates closed . All other gates open.

Under all combinations fish gates are fully open.

Now if one wants to follow the above table for the required gate setting, then he will have to follow the following steps :

For a defined downstream target level

- First it is required to observe the upstream water level from gauge reading.
- Now in the table, it is required to locate in the first column the downstream target level, then search horizontally in the same row the water level which is closer to the observed upstream water level.

Then after locating the upstream level in the table, it is required to look upward in which combination it falls, thus that combination will be the required gate setting. To make the whole process much easier it is also presented in a graphical format and a demonstration is given in the following :

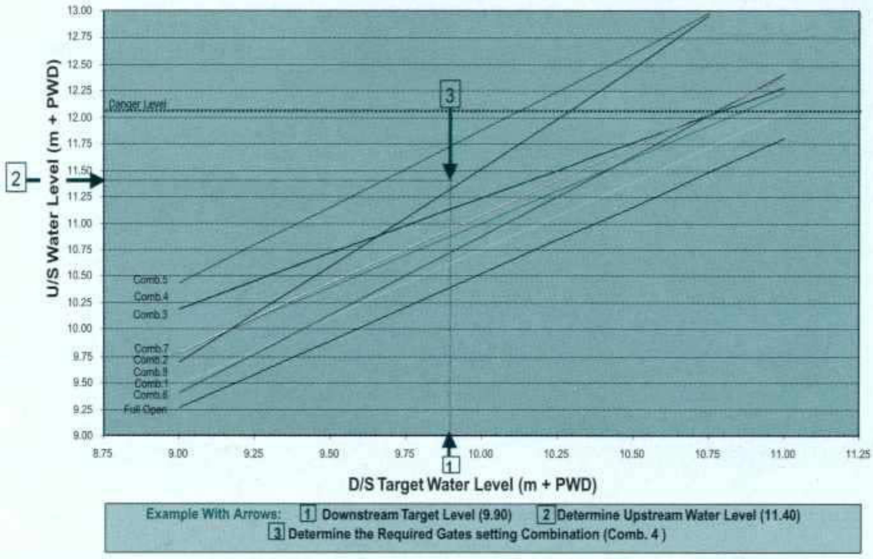
In the following graph, each curves represent one combination of gate setting. An example is enclosed in the figure illustrating the procedure to compute required combination of gate setting. Steps to obtain required gate settings are as follows:

- Locate the point in the X-axis for expected downstream target level;
- Draw a vertical line through the located point in the X-axis;
- Observe the upstream water level in the field and locate the level in the Y-axis;
- Draw a horizontal line through the point in the Y-axis;
- Locate the intersection point of the horizontal line and the vertical line; and
- Select the curves close to the intersection point (Choosing of the curve below the point results in downstream water level higher than the target level, on the other hand choosing of the curve above the intersection point results in downstream water level lower than the target level. Water management may choose one of the two combinations and make some adjustment in the gate setting by observing the downstream water level to obtain the target level).

MAIN INLET GATE OPERATION GUIDE LINES BASED ON MODEL SIMULATION

Operation for Different Downstream Target Levels

Complete Fish Friendly Setting



5.4 General Principles in Operating the structures

5.4.1 Operation of main Inlet at Jugini

All the gates of this regulator will be kept open till required flood water is entered into the Lohajang river and also to enhance hatchling migration. This regulator has been provided with fish passes. After that, the gate setting should be made in such a way that D/S water level does not exceed 10.50 m PWD. Operation of this Main Inlet will be under the responsibility of BWDB till the water management committee at compartment level is formed.

5.4.2 Operation of other inlet Structures

Operation responsibilities of these structures lie with the respective SCWMC. At the onset of the monsoon, all inlet structures should be kept open and during monsoon, D/S water level of the structures will be maintained at a level which should not exceed the target water level as fixed by CPP. In monsoon, the gate should be operated as per water management requirement of the sub-compartment and decision is to be taken by the committee. However, in case of any complicacy or conflicts, BWDB will take decision on operation.

5.4.3 Operation of the Drainage System

Operation of the drainage system of the compartment means operation of the drainage outlets along the Lohajang river and internal water control structures. Operation of the drainage system also includes partly management of the water level in the Lohajang river. Operation responsibilities of these structures rest with respective SCWMC & ChWMC. During the pre-monsoon season, the vertical lift gate(s) of each structure should remain open. During the monsoon (July-September), the vertical lift gates should normally be closed but will be used to regulate the build up of internal water levels, which should not be allowed to exceed the target water levels (maximum permissible water levels) at each structure for safety reasons. For this discharges into the river by opening the gates of the drainage outlets should commence as soon as this target level is attained.

5.5 Water Managment Guidelines for the Sub-Compartments

5.5.1 General

Lohajang river which is passing through the compartment has divided the whole compartment into two distinctive part the eastern part and the western part. Water management in each part is completely independent. However, water level in the Lohajang has considerable influence on the drainage of both the parts.

The eastern part consists of sub-compartment 1,2,3,4,5,6,7 & 8 and the western part consists of sub-compartment 9,10,11,12,13,14 & 15. Both the parts have a good number of important inlet and outlet structures. Operating rules covering the precise times of gate raising and lowering and where relevant, water retention levels, will need to be determined by the O&M sub-division of BWDB inconsultation with the water management committees. These are very much dependent on the cropping calender and fisheries requirement which is a dynamic process and may vary time to time as situation demands.

A most important task of all the sub-compartment water management committees will to reach an agreement during the land users about what levels should be maintained in the sub-compartment. Those water levels can be different during different months. For instance, early during the monsoon, land users may want to have high water levels, to wet their lands. Later, water tables may be reduced, if the rains increase.

It is not only up to the executive committee of sub-compartment to decide about the water levels. Important decisions should be taken with the entire sub-compartment committee present. Members of every *chawk* should be heard. So the sub-compartment committee may be called together to take important decisions.

In most cases, however, decisions are not so difficult and the executive committee may act on its own. Later, the entire sub-compartment committee may discuss the matter again and approve or disapprove of the decisions. In this way everybody learns. It takes time before a sub-compartment committee manages the water properly.

In addition, there should be agreement where the water level should be measured. CPP has fixed maximum target levels for some of the important structures. These levels come forward from purely water management considerations. It is expected that optimum water levels that will be fixed by the water users on the basis of agricultural or fisheries criteria are below the maximum target levels. If that is the

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case as far as water management is concerned, the committees are free to operate the gates according to their wishes, as long as maximum permissible levels are not exceeded.

In this section general operation guidelines for important structures for water management purposes at the sub-compartment level have been described.

5.5.2 Water Managment Guidelines for Sub-Compartment 01-08 (Eastern part of the Compartment)

Major flood water enters into the eastern part of the compartment through Sadullapur, Rasulpur & Suruj inlet & ultimately drains into the Lohajang river through District, Nagar Jalphai, Bhatkura & Khudirampur outlets. Both Sadullapur & Rasulpur Inlets have considerable capacity.

Important Infrastructures of these sub-compartments are state below:

Inlet Structures	Sadullapur
	Rasulpur
	Bararia
	Suruj
Outlet Structures	District
	Nogar Jalphai
	Bhatkura
	Khudirampur
Internal Structures	Magurata
	Enayetpur-2
	Agbetur
	Gharinda
	Poila
	Namder Kumulli 1 & 2
	Birnahali-1
Water Ways	Sadullapur khal
	Rasulpur khal
	Nagar Jalpai khal
	Suruj & Golabari khal

Most of the sub-compartment are inter-dependent as far as water management is concerned. Specially SC-07 with SC-08, SC-03, 04, 05 with SC-06 are very much interlinked.

Sub-compartrment 07 and 08

From Sadullapur inlet, water flows down via Sadullapur khal and District khal to either the District Regulator or Enayetpur WCS-2 or both. On its way it receives water from or diverts water to side khals at Magurata, Bamni khal and others. If Enayetpur WCS2 is closed, Sadullapur khal, Bamni khal and their structures form a water system more or less independent from Rasulpur inlet. Infact, much water can flow through Enayetpur WCS-2 to the east into the SC-06 & 05. So key structures in the SC-07 & 08 are the Sadullapur inlet Enayetpur WCS-2 and the District regulator. Although Magurata WCS is a key structure, not because of its location at the central position, water management decision can be implemented by observing water level at this WCS. It is proposed to establish a maximum permissible water level of 10.40 m PWD at Magurata.

If sub-compartment 7 takes a decision about the water levels to be maintained in the sub-compartment, it should also reach an agreement with sub-compartment 8. It is not possible to maintain a certain water level within sub-compartrment 7 and maintain another level in sub-compartment 8.

Once sub-compartment 8 has reached a decision, the executive committees of the two sub-compartments may meet and take a joint decision. A difficulty may be that sub-compartment 8 measures the water level at a different location than sub-compartment 7. However, all water levels are measured in PWD, so it is not difficult to compare different levels at different locations.

If water levels rise too high, the first thing to do, should be to close Sadullapur. Then no water is coming in any more. If the water still remains too high, District regulator can be opened. In all cases Enayetpur-2 WCS remains closed. Only if sub-compartment 6 asks for water from Sadullapur, Enayetpur-2 can be opened.

If the water levels in the Lohajang are so high, that District regulator can not drain properly, the executive committee of the sub-compartment asks for help from the BWDB. Water level in Lohajang can be lowered by controlling the gates of the Main Inlet at Jugini.

It may be the case that land users upstream still want water, while those downstream have too much. In that case, the best thing to do is to keep both Sadullapur and District regulator open and water will flow continuously through the sub-compartment. There is no objection against that, as long as water levels remain below the agreed maximum levels and below the top of the gates when they are closed.

Sub-compartment 5 and 6

The main frame of the water system in sub-compartment 6 and 5, consists of Rasulpur inlet and Rasulpur khal. The latter khal flows south to *chawk* 10L, where it joins the Sadullapur khal, at some distance downstream of Enayetpur WCS-2. Sadullapur khal continues towards the south east along the chawks 10M, 10N and 12A, up to the boundary between sub-compartment 5 with SC 4 & 3. It crosses that boundary at the location of the Gharinda Bazar.

There is another important route of the water. At *chawk* 11E, the water turns north, enters into sub-compartment 6 and flows to Agbetur WCS. From there it continues via Burai lake and joins Sadullapur khal at the boundary between *chawk* 11J and 12A. This route is also important in the actual field situation. There is another source of water through Enayetpur WCS-2 from SC-07.

It may happen that much water has been allowed into the sub-compartments via Rasulpur and that at that moment, heavy rain follows. Then, land users may suffer from too much water again. In such cases, Rasulpur should be closed for sure, to stop water from coming in. SC-07 may also be asked to close Enayetpur WCS-2 if it is open.

Excess water is removed from the northern part of the sub-compartments, by drainage via Rasulpur khal. Sadullapur khal, Solabari and Nagar Jalpai khal into the Lohajang river.

Both sub-compartment 5 & 6 are to reach an agreement among the water users about where water levels should be measured and what water levels should be maintained with the same procedure as described earlier.

If there is excess water in sub-compartment 5, it may happen that there is a similar situation in the northern parts of the downstream sub-compartments 3 and 4. The sub-compartments 5 and 6 should pay attention to such complaints from their downstream neighbours and they should be helpful whenever possible.

In case of shortage of water in the d/s, sub-compartments SC-06 & SC-05 should operate their structures in such a way that demands of all the sub-compartments are met.

Sub-Compartment 01, 02, 03 & 04

The sub-compartments 1 and 2 are too high to play a significant role in the control of water levels. The water control structures Niogijoir, Gosaijoair, Birnali and Namdar Kumulli north serve to retain water on the high lands. They are of local importance only.

There is one inlet, Suruj inlet in the north east. Although Suruj inlet is situated in SC-01, SC-01 does not get benefit of Suruj inlet. Water which enters through the Suruj inlet comes directly into sub-compartment 3.

At the location of the Gharinda Bazar, the Sadullapur khal coming from sub-compartment 5 splits into an eastern and a western branch. The eastern branch is called Golabari khal, the western branch the Gharinda-Jalfai khal.

Suruj khal flows from Suruj inlet, to the south, where it joins Golabari khal at the southern boundary of chawk 19A. From there the khal continues towards Hatila *beel*. Hatila *beel* is in the lowest area of the compartment. The area is inundated during a large portion of the year. It drains via Bhatkura khal to Bhatkura regulator on the Lohajang.

Gharinda Jalfai khal runs from the future Gharinda Bazar all the way down to the Jalfai regulator on the Lohajang. On its way it receives water from Mirer Betka WCS.

Dharat WCS is of local importance only. It is located outside the main flow pattern. Poila WCS functions as a shortcut between Gharinda-Jalfai khal and Hatila. Water may flow into both directions, depending on water levels.

Although Khudirampur khal leading to Khudirampur WCS does not extend far into *chawk* 21A, overflow from Bhatkura khal may drain via Khudirampur WCS. If Namder Kumulli south WCS is open, overflow from Bhatkura may enter into sub-compartment 2. However, that should be avoided. The structures Paschim Pauli, Karatia WCS and Karatia Chowdhury Para should be reserved for local drainage only.

With Poila WCS closed, one could think of Hatila and Gharinda-Jalfai khal as two independent water systems.

To prevent that the Jalfai regulator receives too much of the drainage load of Hatila, it is recommended to keep Poila WCS closed most of the time. If required, Hatila may drain via Poila as long as the defined target levels, upstream of Jalfai regulator are not exceeded and the downstream level at the regulator is such that it can drain into the Lohajang.

As target for Jalfai regulator a maximum permissible level of 9.40 m+PWD is proposed. Average water levels at the regulator occassionally reach above the 9.40 m level. Water levels in the Lohajang may reach equally high. In such cases, when the upstream and downstream water levels at the Jalfai regulator are the same, the structure can not drain. However, the model calculations indicate that with careful operation of the Main Regulator, water levels downstream of Jalfai regulator can be kept below 9.40 +m PWD.

It is proposed, to define a target level upstream of Bhatkura as 9.40 m+PWD. If that level is reached, Bhatkura should be opened, provided it can drain into the Lohajang. In the same way, Khudirampur should be given a target level of 9.40 m. If Bhatkura khal overflows into *chawk* 21A, Khudirampur should assist in evacuating part of the drainage load.

Namder Kumulli south may only be opened after approval of sub-compartment 2. It should also be pointed out that failing to open Bhatkura affects conditions at Jalfai regulator. Hatila may rise too high and the overflow goes to Jalfai. Drainage at Jalfai is more critical than that at Bhatkura and Khudirampur. Model calculations confirm that. So sub-compartment 4 has a right to insist that the maximum target levels at Bhatkura and Khudirampur are not exceeded. For the rest, the operation of Bhatkura and Khudirampur in relation to Hatila *beel* is the concern of sub-compartment 3.

Water levels in Hatila *beel* should not exceed 9.50 m+PWD. If that happens, Suruj inlet should be closed and water level control at Gharinda *beel* WCS should be checked. Poila WCS should be closed as well and may only be opened if water levels upstream of Jalfai regulator are below 9.20 m+PWD. Even then, sub-compartment 4 should agree. If it does not, the gate may not be opened. If water levels upstream of Bhatkura and Khudirampur reach the level of 9.40 m+PWD, the outlets should be opened and drain into the Lohajang. Failing to do so, affects the sub-compartments 2 and 4. So sub-compartment 4 has a right to insist that a maximum target levels of 9.40 m is maintained at the outlets. Maintaining lower target levels both in Hatila as upstream of Bhatkura and Khudirampur is the matter of sub-compartment 3 only.

If unwelcome water enters sub-compartment 4 from SC-03 via Poila, the order of actions is:

i. Close Poila,

ii. If it overtops, ask that Hatila be closed,

iii. If Poila continues overtopping, ask that Suruj be closed,

iv. If Poila still overtops, ask that Bhatkura be opened,

v. Ask that Khudirampur be opened, and

vi. The five steps given above should be discussed between the subcompartments 4 and 3.

During the monsoon, much water may come down the Gharinda-Jalfai khal, which is not always welcome. Most of that water has entered the sub-compartments 6, 7 and 8 via the Rasulpur and Sadullapur inlets.

The excess water of the sub-compartments 6, 7 and 8 is drained towards sub-compartment 5. From there, most of it flows down to sub-compartment 4. The people operating Sadullapur and Rasulpur usually are not aware of the problems they may cause in the downstream areas.

To protect the downstream areas, the sub-compartment 7 and 8 can drain their water to downstream areas only if there are no objections from those areas. The sub-compartments 7 and 8 can do that by keeping Enayetpur-2 WCS closed and drain their excess water via District regulator.

Similarity, if too much water enters at Rasulpur, downstream areas may ask for the closing of Rasulpur.

To monitor, whether too much water enters the sub-compartments 4 and also 3, CPP proposes to use target water levels at the boundary between sub-compartment 5 and the sub-compartments 3 and 4. If the water level is above the target, the sub-compartments 3 and 4 has to take action. If the water level is below the target, no action is justified.

5.5.3 Guidelines for Sub-Compartment 9,10,11,12,13,14 & 15 (Western part of the Compartment)

Flood water can enter into the western part of the compartment through inlets as mentioned above and ultimately drains into the Lohajang river through a number of outlet structures. At the onset of monsoon, water can also enter through outlet structures along the bank of Lohajang if Lohajang river water level permits.

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Major infrastructures of this part of the compartment are as follows:

Inlet Structures on Peripheral embankment	Khorda Jugini
	Binnafair
	Fatehpur
	Indra Belta
	Bara Belta
	Baruha
Outlet Structures/ WCS along the Lohajang river	Dithpur
	Dannya Chowdhury
	Chillabari
	Dighulia-1 & 2
	Kagmari
	Aloa Raypara
	Deojan
Major Water Ways (*khal*)	Khordajugini-Dithpur via
	Juginidaha beel
	Dannya Chowdhury
	Binnafair
	Shoramara
	Soiabari
	Aloa Tarini
	Indra Belta
	Baruha
	Deojan
	Birpushia

Out of 7 sub-compartments SC-09, SC-15 are completely independent as far as water management is concerned. SC-12 is linked with SC-11 on getting water and with SC on drainage consideration. SC-13 is also dependent on SC-14 on drainage consideration and sometimes in getting water in its southern part.

Sub-Compartment 09

This sub-compartment is in a favourable position as far as water management is concerned. It is relatively small and has an inlet and outlet at manageable distance from each other. Flood water enters into this sub-compartment through Khorda Jugini inlet in the north and ultimately drains into Lohajang river through Khorda Jugini khal, Juginidaha *beel* and Dithpur khal. On its way to south water enters into different *chawk* through side khals. CPP proposes target water level at the downstream of

Khorda Jugini inlet and upstream of Dithpur inlet as 11.05 m PWD and 10.90 m PWD respectively.

Sub-Compartment 10 & 11

Flood water mainly enters into these sub-compartment through Binnafair and Fatehpur inlet from Dhaleswari river. SC-10 gets water from Binnafair khal through Rampal WCS and Bhangabari CDO. SC-10 also get water from the Lohajang river at the onset of monsoon through Chillabari WCS if level permits. Eastern part of SC-11 mainly receives water from Lohajang river via Dighulia 1 & 2 CDOo and Kagmari outlet in the early part of monsoon. Main drainage is effected through Binnafair-Goizabari khal via Kagmari outlet into the Lohajang river. Part of the flow enters into SC-12 and is drained into Lohajang river through Aloa Tarini khal and Aloa Raypara regulator. Target levels of major structures have been described in Section 7.

Chawk 3F of SC-10 is the lowest part of system 3 and a desirable water level during the monsoon is probably about 9.80 m PWD. However, it seems difficult to maintain that level, partly due to outside conditions. Binnafair outlet may be kept open because surrounding chawks ask for water. Similarly, water levels in the Lohajang at Kagmari are sometimes so high that the desired level can not be maintained. Water level control at Bhangabari is a matter between the two sub-compartments 10 and 11. If water levels downstream of the structure are too high, the first measure is to close Binnafair if it is open. The next would be to apply for lower water levels in the Lohajang i.e. a reduction in the flow passing the Main Inlet.

If water levels at Bhangabari are considered too low, the measure should be to open Binnafair further, and/or close Kagmari such that levels may increase in the Binnafair khal, depending on whether that is acceptable to the other chawks. Raising water levels in the Lohajang river is a more drastic and complex measure, because it requires consultations with all sub-compartments along the river.

Sub-Compartment 12 & 14

Sub-compartment 12 gets flood water mainly through Indrabelta and Barabelta inlet and khals. Northern part of this sub-compartment receives water from SC-11 through Binnafair-Aloa Tarini khal. Drainage of the sub-compartment is effected through Aloa Tarini khal and Berabuchna WCS into the sub-compartment 14 and ultimately drains into Lohajang river through Aloa Raypara WCS and Deojan WCS. At the onset of the monsoon this sub-compartment can also get water from the Lohajang river through Aloa Tarini khal and Berabuchna WCS via sub-compartment 14.

Sub-compartment 14 gets flood water in the same way as sub-compartment 12. On the southern part of this compartment major entry is through Deojan WCS from the Lohajang river.

In case of excess water in these sub-compartments, all inlets are to be closed. The two sub-compartments should work together for water management. They should also make liasion with SC-11 to get water through Binnafair khal or to prevent entry of excess water through Santosh regulator. In addition SC-14 should also contact SC-13 for getting flood water through Baruha inlet and later on through Bhurbhuria WCS.

Sub-Compartment 13

This sub-compartment has one inlet structures i.e. Baruha inlet and the major source for getting flood water. Southern part of this sub-compartment gets water through Barai Atia WCS from SC-14. Drainage is effected through Bhurbhuria regulator, an open culvert in Tangail Elashin road and also through Barai Atia WCS into SC-14.

Sub-compartment SC-13 and 14 should co-operate with each other in managing water in their areas.

Sub-Compartment 15

At present there is no significant water management in this sub-compartment. Part of the compartment gets water from the Lohajang river through two gated pipe culverts (Khagjana and Kumulli) if level in the Lohajang river permits. Birpushia khal situated in the south east portion of the SC is still open. When there is high flood water from the Lohajang river enters into the sub-compartment through Birpushia khal. A water control structure has been proposed to be constructed near to the outfall of Birpushia khal.

Name of Channel	Location		Total length (km)	Location		Design Data				Side slope
	SC No.	*Chawk* No.		Off-take	Out-fall	Bed Level		Bed Width		
						Start	End	Start	End	
Aloa Khal	12 & 14	23D, 27C	3.880	Santosh Regulator	Aloa Raypara Regulator	8.00	7.39	4.00	6.00	1:1.50
Bamni Khal	8	9C, 9K, 9M	4.370	Chawk 9C	Enayetpur WCS-2	10.20	8.18	6.50	11.00	1:1.50
Barabelta Khal	12	24A, 24B	2.410	Barabelta Intake	Berabuchna WCS	9.80	9.15	4.00	4.00	1:1.50
Baruha Khal	14 & 13	25A, 28F, 28C	3.070	Baruha Intake	Kumuria beel	9.84	8.04	4.00	5.00	1:1.50
Berabuchna Khal	14	27C/28B	1.380	Berabuchna WCS	Baratia - Kumuria Beel	9.00	8.31	3.00	3.00	1:1.50
Bhatkura Khal	3	19F, 19E	2.560	Chawk 19E	Bhatkura Outlet	6.75	7.60	10.00	10.00	1:1.50
Binnafair Khal	11	5A, 5F, 6C	5.350	Binnafair Intake	Santosh Regulator	8.00	9.05	5.00	3.00	1:1.50
Chillabari Khal	10 & 11	7A/7B/7K/7D/6A	3.315	Chillabari Outlet	Gaijabari Khal	8.25	8.15	4.00	4.00	1:1.50
Deojan Khal	14	28A	1.500	Kumuria Beel	Deojan Outlet	8.00	8.75	2.00	2.00	1:1.50
Dharerbari Khal	8	9E,9B	1.200	Chawk 9B	Dharerbari Outlet	10.00	11.14	2.00	1.00	1:1.50
Dighulia Khal	11	7D,7H	1.300	Chawk 7D	Dighulia-I Outlet	8.40	8.76	2.00	2.00	1:1.50
District Khal	16 & 8	9M	1.946	Enayetpur-2 WCS	District Regulator (Outlet)	8.04	8.32	6.50	5.50	1:1.50
Dithpur Khal	9	1F	1.538	Krishnopur Beel	Dithpur Outlet	9.48	9.48	7.00	7.00	1:1.50
Fatehpur Khal	11	5F,6D,5D	0.920	Fatehpur Intake	Chawk 5B	8.74	9.34	2.50	2.50	1:1.50
Gaijabari Khal	11	6C, 7H, 7F	2.392	Santosh Regulator	Kagmari Outlet	7.99	7.82	8.50	8.50	1:1.50
Gharinda - Jalfai Khal	4	22A, 22B, 22C	4.250	Gharinda Bridge	Jalfai Outlet	6.90	6.48	7.00	7.00	1:1.50
Golabari Khal	3	19A	1.880	Gharinda Bridge	Suruj Khal	8.46	8.15	3.00	3.00	1:1.50
Indrabelta Khal	12	23A, 23B	0.996	Indrabelta Intake	Chawk 23D	9.62	8.95	1.50	1.50	1:1.50
Khanpur Borrowpit	11	7B, 7C, 7D	1.920	Chawk 7A	Dighulia-2 Outlet	8.30	8.00	2.00	2.00	1:1.50
Khudirampur Khal	3	21A	0.700	Chawk 21A	Khudirampur Outlet					
Khorda Jugini Khal	9	1A	1.000	Khorda Jugini Inlet	Krishnapur WCS	7.50	9.25	6.00	5.00	1:1.50
Kumulli Khal	15	31A	1.000	Kumulli Outlet	Chawk 31A	8.31	8.81	1.00	1.00	1:1.50
Lohajang River			23.420	Main Regulator	Karatia Bridge	7.70	6.03	20.00	20.00	1:1.50
Magurata Khal	7	10G, 10J	1.090	Magurata WCS	Chawk 10J	8.85	8.66	4.00	4.00	1:1.50
Nagar - Jalfai Khal	4	22E	0.952	Chawk 22C	Jalfai Outlet	6.48	6.38	9.00	9.00	1:1.50
Rampal Khal	10 & 11	4B	1.060	Chawk 4B	Binnafair Khal	8.70	9.56	3.00	3.00	1:1.50
Rasulpur Khal	6 & 7	11C, 11D, 11H, 11J	6.400	Rasulpur Intake	Sadullapur khal (chawk 11J)	9.20	7.70	6.00	6.00	1:1.50
Sadullapur Khal	5, 6 & 7	10B, 10E, 10G, 11J, 12A, 13A	6.906	Sadullapur Intake	Gharinda Bridge	9.20	6.90	6.00	6.00	1:1.50
Santosh Khal	12	6B, 6C	1.340	Chawk 7G	Chawk 23E	9.34	8.00	1.50	1.50	1:1.50
Singerkona - Dannya Chowdhury Khal	10	3B/3C	0.845	Singerkona Beel	Dannya Chowdhury Outlet	8.58	8.82	2.50	2.50	1:1.50
Suruj Khal	1 & 3	14A, 14B, 19A, 19B, 19C	3.975	Suruj Intake	Hatila Beel	9.30	7.83	6.00	8.50	1:1.50
Singerkona - Ghotokbari Khal	10	4B, 3C	1.280	Singerkona WCS	Ghotokbari Beel	9.00	8.57	4.00	4.00	1:1.50
Ghoramara Khal (Upper Part)	10	3C, 3F	0.840	Ghotokbari Beel	Boro Beel					
Ghoramara Khal (Lower Part)	10	3F	1.880	Boro Beel	Bhangabari WCS					
Total Length of *Khal* (except Tangail Drain) =			**98.865**							

Table 3.1: List of Drainage Channels

		No of vents	Dimension of gates (HxV)	Sill level + PWD
ELANJANI RIVER				
1	Baruha	1	1.25 x 1.75 m	9.70
2	Bara Belta	1	0.95 x 1.15 m	9.75
3	Indra Belta	1	0.90 x 1.25 m	9.62
4	Silimpur Inlet	1	0.60m diam	9.75
DHALESWARI RIVER				
5	Fatehpur	1	0.90 x 1.20 m	8.84
6	Binnafair	1	0.90 x 1.20 m	8.84
LOHAJANG				
7	Khorda Jugini	1	1.50 x 2.50 m	10.00
8	Main Regulator	2	1.50 x 2.30 m	9.20
		3	3.00 x 3.80 m	10.70
GALA RIVER				
9	Sadullapur	1	3.00 x 3.00 m	9.20
10	Rasulpur	1	1.50 x 3.0 m	9.20
11	Rasulpur Pipe Inlet	1	0.60m diam	11.00
PUNGLI RIVER				
12	Pauli	1	1.20m diam	10.00
13	Bararia	1	0.90 m diam	10.75
14	Suruj	1	1.50 x 3.00 m	9.20

Table 3.2: Peripheral Inlet Structures, CPP

	Sub-compartment	Name	Design level Lohajang +PWD	Number of vents	Dimensions of vents (m x m)	Sill level + PWD
1	8	Dharerbari	10.00	1	0.90x1.20m	10.00
2	9	Dithpur	10.00	2	2.00x1.00m	10.90
				1	0.90x0.90m	9.45
3	10	Dannya Chowdhury	10.00	1	0.90m diam	8.70
4	11	Chillabari	10.00	1	0.90m diam	8.10
5		District	9.90	2	1.5x3.0m	8.00
6	11	Dighulia 2	9.90	1	0.90m diam	8.00
7	11	Dighulia 1	9.90	1	0.90m diam	8.50
8	11	Kagmari	9.90	2	1.50x3.00m	7.80
9	14	Aloa Raypara	9.65	4	1.50x3.00m	7.20
10	14	Deojan	9.50	1	2.50x4.80m	8.20
11	4	Nagar Jalfai	9.00	2	1.50x3.00m	6.50
12	3	Bhatkura	9.00	2	1.50x3.00m	7.00
13	3	Khudirampur	9.00	1	1.50x1.80m	8.00
14	15	Kumulli	9.00	1	0.75m diam	8.60
15	15	Khagjana	9.00	1	0.75m diam	8.00
16	15	Birpushia[1] (to be constructed)	9.00	1	1.50 x 1.80m	8.50

Table 3.3: Structure Along the Lohajang River, CPP

[1] Not implemented yet

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	Name of Structure	No of vents	Dimension of gates	Sill level + PWD
CLUSTER 1				
1	Krishnopur	1	1.50x1.80m	9.75
2	Beel Baghil	1	0.60m diam	8.70
3	Edgah Moidan	1	0.90x1.20m	10.20
4	Sapua	1	0.60m diam	9.60
5	Singerkona Beel	1	1.50x1.80m	8.75
6	Chowbari	1	0.60m diam	9.50
7	Rampal	1	1.50x1.80m	9.00
8	Bhangbari	2	1.50x1.80m	8.60
9	Santosh	3	1.50x2.00m	8.00
CLUSTER 2				
1	Salina	1	0.90x1.20m	9.00
2	Batchanda 1	1	1.20x1.50m	9.00
3	Batchanda 2	1	0.90x1.20m	9.50
4	Magurhata	1	1.50x1.80m	9.00
5	Agbetor	2	1.50x1.80m	9.50
6	Beel Gharinda	1	1.50x1.80m	8.00
7	Enayetpur-2	1	2.50x2.00m	9.00
8	Enayetpur	1	2.00x2.50m	8.00
9	Char Kagmara	1	1.20x1.50m	9.50
CLUSTER 3				
1	Birnahali-1	1	0.90m diam	7.00
2	Namdar Kumulli (N)	1	0.90x1.20m	8.50
3	Neogijoar	1	0.90x1.20m	8.50
4	Gosaijoair	1	1.20x1.50m	8.00
5	Hatila	1	1.20x1.50m	8.00
6	Poila	1	2.50x1.50m	8.50
7	Mirer Betka	1	0.90x1.20m	8.00
8	Namdar Kumulli(S)	1	1.20x1.50m	8.50
9	Dharat	1	0.6 m diam	9.00
10	Birnahali-2	1	0.6 m diam	8.00
11	Karatia Chow.para	1	0.90x1.20m	8.00
12	Karatia	1	1.20x1.50m	7.50
13	Paschim Pauli	1	1.20x1.50m	7.50
CLUSTER 4				
1	Bhurbhuria	2	1.50x1.80m	8.60
2	Aloa Bhabani 1	1	0.75mdiam	8.60
3	Bera Buchna	1	2.00x1.80m	9.00
4	Bara Atia	1	1.50x1.80m	9.00

Table 3.4: Internal Structures, CPP

Name of Structure	Type of Structure	Maximum Target Level m.PWD	
		Upstream Side	Downstream Side
Outlets			
Dithpur	Outlet	10.90	
District Regulator	Outlet	10.40	
Dighulia-1	Outlet	10.00	
Dighulia-2	Outlet	10.00	
Kagmari	Outlet	10.00	
Aloa Raypara	Outlet	9.75	
Deojan	Outlet	9.50	
Nagar Jalfai		9.40	
Bhatkura		9.40	
Inlets			
Khurda-jugini	Inlet		11.05
Rasulpur	Inlet		10.75
Sadullapur	Inlet		10.45
Binnafair	Inlet		10.20
Fatehpur	Inlet		10.15
Indrabelta	Inlet		10.45
Barabelta	Inlet		10.35
Baruha	Inlet		10.05
Suruj	Inlet		9.90
Internal Structures			
Agbetur WCS		10.10	
Beel Gharinda WCS		9.80	
Magurhata WCS		10.40	9.80
Bhangabari WCS			9.50
Hatila WCS			

Table 5.1: Preliminary Target Levels of Important Structures

Downstream	Upstream Water Levels (m + PWD)								
Water Level	Full Open	COMB 1	COMB 2	COMB 3	COMB 4	COMB 5	COMB 6	COMB 7	COMB 8
9.00	9.27	9.48	9.78	10.19	10.29	10.43	9.40	9.78	9.70
9.25	9.58	9.79	10.08	10.45	10.59	10.79	9.77	10.10	10.14
9.50	9.89	10.11	10.39	10.71	10.89	11.15	10.13	10.42	10.59
9.75	10.21	10.43	10.69	10.98	11.20	11.51	10.50	10.75	11.05
10.00	10.52	10.75	11.00	11.24	11.50	11.88	10.88	11.07	11.52
10.25	10.84	11.07	11.31	11.50	11.80	12.24	11.26	11.40	11.99
10.50	11.16	11.39	11.61	11.76	12.11	12.61	11.64	11.73	12.47
10.75	11.48	11.72	11.92	12.02	12.41	12.98	12.02	12.06	12.96
11.00	11.80	12.05	12.23	12.28	12.71		12.41	12.39	

Table 5.2: 1 Fish passes open, different settings of other gates

Appendix 3

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SCENARIO 1

Situation July 15					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,713	3,480	212	0	**7,405**
30-90	80	786	2,067	0	**2,933**
90-180	0	14	517	132	**663**
>180	0	0	9	181	**190**
Situation July 30					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,662	1,406	1	0	**5,069**
30-90	131	2,823	906	0	**3,860**
90-180	0	51	1,869	64	**1,984**
>180	0	0	29	249	**278**
Situation August 15					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,496	3,107	936	0	**7,539**
30-90	256	931	1,064	40	**2,291**
90-180	41	241	773	116	**1,171**
>180	0	1	32	157	**190**
Situation August 30					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,661	3,149	191	0	**7,001**
30-90	79	1,022	1,967	13	**3,081**
90-180	53	104	640	122	**919**
>180	0	5	6	178	**189**
Situation September 15					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,708	2,932	153	0	**6,793**
30-90	49	1,310	1,873	13	**3,245**
90-180	35	27	772	105	**939**
>180	0	11	7	195	**213**
Situation September 30					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,723	4,095	1,817	0	**9,635**
30-90	26	149	877	56	**1,108**
90-180	39	19	104	136	**298**
>180	4	17	6	120	**147**

Continued

SCENARIO 2

Situation July 15

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,709	3,849	203	0	**7,761**
30-90	84	399	2,196	0	**2,679**
90-180	0	32	397	139	**568**
>180	0	0	9	174	**183**

Situation July 30

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,617	1,702	1	0	**5,320**
30-90	175	2,475	1,055	0	**3,705**
90-180	0	102	1,703	83	**1,888**
>180	0	0	46	230	**276**

Situation August 15

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,549	3,304	939	0	**7,792**
30-90	200	841	1,073	43	**2,157**
90-180	43	133	771	114	**1,061**
>180	0	1	22	156	**179**

Situation August 30

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,649	3,555	171	0	**7,375**
30-90	95	595	2,101	13	**2,804**
90-180	49	125	528	127	**829**
>180	0	5	5	173	**183**

Situation September 15

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,671	3,178	138	0	**6,987**
30-90	92	1,035	1,902	13	**3,042**
90-180	29	58	753	111	**951**
>180	0	9	11	189	**209**

Situation September 30

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,715	4,002	1,867	0	**9,584**
30-90	39	224	768	65	**1,096**
90-180	37	39	163	127	**366**
>180	2	14	6	120	**142**

Continued

SCENARIO 3

Situation July 15					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,789	4,037	435	0	**8,261**
30-90	4	238	2,094	0	**2,336**
90-180	0	5	276	154	**435**
>180	0	0	0	159	**159**
Situation July 30					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,738	2,650	1	0	**6,389**
30-90	55	1,574	1,699	0	**3,328**
90-180	0	56	1,089	102	**1,247**
>180	0	0	16	212	**228**
Situation August 15					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,703	4,006	1,235	0	**8,944**
30-90	89	233	1,390	8	**1,720**
90-180	0	41	180	162	**383**
>180	0	0	0	144	**144**
Situation August 30					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,701	3,773	175	0	**7,649**
30-90	86	421	2,173	0	**2,680**
90-180	6	87	457	138	**688**
>180	0	0	0	176	**176**
Situation September 15					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,698	3,542	27	0	**7,267**
30-90	70	652	2,193	0	**2,915**
90-180	25	81	576	125	**807**
>180	0	5	9	188	**202**
Situation September 30					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,701	4,081	1,851	0	**9,633**
30-90	49	126	796	67	**1,038**
90-180	40	58	147	132	**377**
>180	2	16	11	114	**143**

Continued

SCENARIO 4

Situation July 15

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,790	4,185	1,524	9	**9,508**
30-90	2	90	1,195	23	**1,310**
90-180	0	5	87	162	**254**
>180	0	0	0	119	**119**

Situation July 30

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,789	4,084	998	0	**8,871**
30-90	4	169	1,512	24	**1,709**
90-180	0	28	296	141	**465**
>180	0	0	0	148	**148**

Situation August 15

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,737	4,109	1,975	13	**9,834**
30-90	55	143	737	57	**992**
90-180	0	28	88	128	**244**
>180	0	0	5	115	**120**

Situation August 30

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,726	4,058	1,191	0	**8,975**
30-90	65	158	1,467	23	**1,713**
90-180	2	64	147	157	**370**
>180	0	0	0	133	**133**

Situation September 15

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,719	4,127	986	0	**8,832**
30-90	54	97	1,637	22	**1,810**
90-180	20	52	173	139	**384**
>180	0	4	9	153	**166**

Situation September 30

Flood Class (cm)	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
0-30	3,712	4,127	2,165	1	**10,005**
30-90	43	93	535	75	**746**
90-180	37	46	92	135	**310**
>180	1	15	14	102	**132**

Continued

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SCENARIO 5

Situation July 15					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,688	3,416	292	0	**7,396**
30-90	105	697	1,727	0	**2,529**
90-180	0	167	774	134	**1,075**
>180	0	0	13	180	**193**
Situation July 30					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,420	2,033	1	0	**5,454**
30-90	351	1,702	1,204	0	**3,257**
90-180	22	545	1,343	77	**1,987**
>180	0	0	257	236	**493**
Situation August 15					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,503	3,224	705	0	**7,432**
30-90	275	702	1,392	4	**2,373**
90-180	15	352	645	151	**1,163**
>180	0	2	63	158	**223**
Situation August 30					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,459	2,833	119	0	**6,411**
30-90	290	1,016	1,634	0	**2,940**
90-180	44	414	957	111	**1,526**
>180	0	17	95	203	**315**
Situation September 15					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,442	2,612	33	0	**6,087**
30-90	280	1,214	1,559	0	**3,053**
90-180	56	429	1,001	94	**1,580**
>180	15	26	213	220	**474**
Situation September 30					
	Land Type F0	Land Type F1	Land Type F2	Land Type F3	Total
Flood Class (cm)					
0-30	3,543	3,458	1,269	1	**8,271**
30-90	179	526	894	54	**1,653**
90-180	45	269	581	121	**1,016**
>180	26	28	62	137	**253**

Appendix 3: Number of Hectares per Flood Class and per Land Type as Calculated with the Scenarios during 1999. All Values in Hectares