GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

Flood Plan Coordination Organisation

FAP-25

FLOOD MODELLING AND MANAGEMENT

COORDINATION ADVISORY TEAM

THIRD MISSION REPORT

MARCH 1992

Krüger Consult
in association with
BCEOM

Governments of
Denmark, France,
The Netherlands and
United Kingdom

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

Flood Plan Coordination Organisation

FAP-25

FLOOD MODELLING AND MANAGEMENT

COORDINATION ADVISORY TEAM

THIRD MISSION REPORT

MARCH 1992

Krüger Consult
in association with
BCEOM

Governments of
Denmark, France,
The Netherlands and
United Kingdom

TABLE OF CONTENT

APPENDICES

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
BWDB	Bangladesh Water Development Board (under MIWDFC)
CAT	Coordination Advisory Team.
Danida	Danish International Development Agency
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
DND	Dhaka Narayangonj Demra Area
FAP	Flood Action Plan
FAPMCC	FAP Modelling Coordination Committee
FHS	Flood Hydrology Study
FPCO	Flood Plan Coordination Organisation (under MIWDFC)
FMM	Flood Management Models
GEV	General Extra Value Distribution
GIS	Geographic Information System
GM	General Model
GOB	Government of Bangladesh
HME	Hydraulic Modelling Engineer
MIWDFC	Ministry of Irrigation, Water Development and Flood Control.
MIKE 11	Software Package for 1-D River Modelling
MPO	Master Plan Organisation (under MIWDFC), now WARPO
NAM	Rainfall Runoff Model (Danish Abbreviation)

NCRM	North Central Regional Model
NERM	North East Regional Model
NWP	National Water Plan (under MPO)
NWRM	North West Regional Model
POE	Panel of Experts
RMC	Resident Model Coordinator
RRI	River Research Institute
SCRM	South Central Regional Model
SERM	South East Regional Model
SOB	Survey of Bangladesh
SWH	Surface Water Hydrology (Directorate under BWDB)
SWRM	South West Regional model
SWMC	Surface Water Modelling Centre (under MPO)
SWSMP	Surface Water Simulation Modelling Programme
SWSMC	Surface Water Simulation Modelling Committee (under MIWDFC)
TOR	Terms of Reference
UNDP	United Nations Development Programme
WARPO	Water Resources Planning Organisation

1. INTRODUCTION

1.1 General

Component 25 of the Bangladesh Flood Action Plan (FAP 25), Flood Modelling and Management, consists of the following three project components:

i) A Coordination Advisory Team (CAT)

ii) A Flood Hydrology Study (FHS)

iii) A Flood Management Model (FMM)

The project is executed by the Flood Plan Coordination Organisation (FPCO) with the Danish Ministry of Foreign Affairs (DANIDA) as the lead donor. The donor agencies of France, the Netherlands and United Kingdom also contribute to the project.

The first two of these project components, CAT and Flood Hydrology Study, are ongoing under the supervision of the Resident Model Coordinator (RMC).

Terms of Reference for the FMM are in the process of finalization and expected to be approved at a Technical Committee meeting in early February, 1992.

The Team of Short Term Experts of the CAT held their first meeting in Bangladesh in October 1990, producing an Inception Report dated November 1990. The following mission of the team took place in May 1991 producing the Second Mission Report dated September 1991. During this mission it was decided that the third mission of the team should take place in December 1991.

The overall Terms of Reference of the CAT, as stated in the detailed Terms of Reference for the FAP 25, are:

i) To achieve consistency, compatibility and continuity in all related modelling activities

ii) To coordinate the supply of models as tools to the various FAP projects and the feedback of relevant data and information from various FAP projects to the Surface Water Modelling Centre (SWMC)

The particular Terms of Reference of the third mission are contained in Appendix 1.

The Team of Short Term Experts of the CAT are:

Mr. Marcel Ramette	FRANCE
Mr. Johan Grijsen	THE NETHERLANDS

Dr. Rodney White	UNITED KINGDOM
Dr. Torkil Jønch-Clausen	DENMARK (Team Leader)

The Resident Model Coordinator (RMC) of the CAT, Mr. Jorn Rasmussen, and the Hydraulic Modelling Engineer (HME), Mr. Emaduddin Ahmed, worked closely with the Team of Short Term Experts during their stay in Bangladesh.

Whenever the CAT is mentioned in this report, reference is made to the Team of Short Term Experts.

The team worked in Bangladesh in the period 1-10 December 1991 and presented their conclusions and recommendations to FPCO on 10 December 1991.

The programme of the mission is included in Appendix 2, and a list of key persons consulted during the mission in Appendix 3.

The CAT would like to express its appreciation to all officials and individuals met for the kind support and valuable information which the team received during its stay in Bangladesh, and which highly facilitated its work.

All proposals presented in the report are subject to approval by the Government of Bangladesh and the donor countries concerned.

1.2 Comments to the Draft Report

A draft report containing the views and recommendations of the CAT was submitted one week after the mission. Comments have been received from GOB, the Panel of Experts (POE) and some FAP studies and duly considered in the preparation of the final version of this report.

Some questions/comments relating to the Flood Hydrology Study are dealt with in the FHS Main Report and thus not adressed in this report. Other comments relating to the draft TOR of the Flood Management Model are dealt with in the final discussions with FPCO and the Review Committee on this issue.

2. CONCLUSIONS AND RECOMMENDATIONS

2.1 General

The conclusions and recommendations of the Coordination Advisory Team (**CAT**) of FAP 25 are presented in the following chapters and associated appendices. Specific recommendations given in these chapters are not repeated here. As a brief summary of the most important findings and recommendations, the CAT wishes to emphasize the following points.

2.2 Modelling Technology

The CAT notes that various new modules are now available as part of the MIKE 11 modelling system and that the SWMC has started to do some 1-D sediment transport and morphological modelling of the major rivers of Bangladesh. This technology will give some guidance on possible morphological changes and may also throw light on the problem of variable rating curves at Hardinge Bridge and elsewhere. It is, however, stressed that morphological modelling is but one instrument in the analysis of the long term morphological development of the river system, and that other techniques and judgements are equally or more important. Other modelling techniques, such as 2-D modelling, are also applied in the FAP. These are briefly described in the relevant chapter of this report.

It is the opinion of the CAT that the liaison between SWMC and the FAP studies has been good throughout and of mutual benefit. Through extensive discussions with SWMC, FAP studies are making valuable contributions to improvements in the MIKE 11 software itself as well as to the tailored models (the General Model and the six regional models). DHI respectively SWMC have taken proper action on such issues.

The CAT agrees to the commonly shared opinion that poor quality input data, and not the modelling technology itself, is the major reason for the unsatisfactory agreement between simulated and observed data as found in different areas and locations.

2.3 Progress and Timing of SWMC Model Development

In the last six months the work of the SWMC has suffered slight delays due to shortages in local staffing, extra data collection exercises, hardware problems and difficulties encountered in the transition to UNIX. The latest estimated programme of development is given in Table 6.1. Apart from a rather tight schedule in the eastern part of the South-West Region (South-Central Region in SWMC terminology), there are no major problems in the timely supply and development of models to the Regional Studies. The CAT observes, however, that the accuracy of results from the pilot models falls below expected standard in some cases. This is primarily due to inadequate data, and more accurate results are expected in subsequent phases as improved data become available.

2.4 Provision of Data

The second CAT report stressed the importance of the timely supply of good quality data, both topographic and hydrometric. Any hydrodynamic model is only as good as the data used to build and verify it. The CAT sees little improvement in the situation to date and fears that the morphological modelling by SWMC and the Regional Studies will be particularly handicapped unless this matter is addressed without delay.

The CAT understands that SWMC has raised the issue of data quality from BWDB in meetings with BWDB and the Ministry since 1990. Following a recent directive from the Ministry, FPCO will work out the modalities to support field data collection by BWDB Hydrology through the FAP studies.

BWDB-Hydrology has received assistance from the UNDP in the past and a new project has been agreed in September 1991. This project will have little impact in time for the 1992 monsoon season, however, and the CAT recommends a repeat of the support given by DANIDA through the SWMC in 1991 for 1992 and possibly 1993.

The CAT notes the continued difficulties over the question of payment for data which have still to be resolved. Although GOB has promised to bear these costs for the FAP projects a final solution has yet to be found.

In addressing the question of the flow of data and information between FAP projects, SWMC and various GOB institutions it has come to the notice of the CAT that a proliferation of different database software is taking place. The CAT recommends that FAP 25 urgently looks into this situation and makes recommendations to MIWDFC on data-base and processing software and formats.

The CAT notes that action has been taken to speed up delivery of data but continues to be concerned about the late output from FAP 18 for the purposes of FAP.

2.5 Flood Hydrology Study

The CAT earlier emphasized the importance of the FHS as the basis for decisions on very large investments in Bangladesh. The CAT is convinced that results will be produced, which can be applied with confidence, provided safety margins are properly accounted for.

Stage 2 of the Flood Hydrology Study (FHS) is on schedule and a draft report will be submitted in January 1992. The methodology detailed in the former CAT report (September 1991) has proved to be sound and justified.

The most important concern expressed at that time referred to the feasibility of validating the General Model (GM) for the period 1965 - 1989. This has been nearly accomplished, although some recalibration of the GM is still needed. Improvements needed for the FHS will, however, also benefit the calibration of the model for the most recent period. The

SWMC has agreed to include this work in their normal model updating programme and the next model update is expected to be available early 1992.

Probability distributions for fitting observed distributions of specific hydrological variables were selected. Distributions for other variables still have to be selected.

Extreme floods on the Brahmaputra and Ganges rivers and rainfall driven flood events in Bangladesh are likely to have little correlation. Hence, there is no need to consider the issue of joint probabilities of various flood causing factors any further.

The representativeness of the period 1965-1989 for the century has been studied. It is likely that the period is indeed representative, although designs made on the basis of the hydrological conditions for the period 1965-1989 may be slightly conservative.

The CAT recommends that upon submission of the report of stage 2 of FHS, FPCO and POE take a decision on the issue of safety margins for the design of flood protection works at short notice. It is important that all Regional Studies adopt the same design criteria as soon as possible.

Running the hydrodynamic models for a period of 25 years is a crucial component of the FHS, and should also be so for the Regional Studies. A fair effort should be made by the regional study teams to implement this methodology in their studies, possibly with assistance from SWMC.

Information available with CAT shows that FAP 2 and FAP 6 plan to undertake such 25 year runs, while FAP 4 and FAP 5 are actively considering to do so. FAP 3, FAP 25 and the SWMC have also discussed the possible modelling approaches of FAP 3 considering their present time schedule and need of having modified boundary conditions for alternative protection schemes along the Jamuna left bank. It has been agreed that a feasible approach at this stage would be to use the period 1985-89 to analyse the effect of the most likely embankment alignment. FAP 25/SWMC will provide the boundary conditions in due course.

A description of the final output of stage 2 of the FHS has been provided to the relevant FAP's as part of the coordination activities. Preliminary results are available and have been collected by various FAP's as and when required.

Stage 3 of the FHS is scheduled for the first half of 1992, upon availability of the next update of the GM. Activities are limited to a final validation run for 25 years, and some runs for the same period including nation-wide protection schemes as being defined by FPCO at the earliest.

2.6 Flood Management Model

The second CAT report (September 1991) discussed the Flood Management Model, its provisional specifications and usage, but concluded that further discussions were required

with potential users of the FMM before finalising the TOR for the FMM study. These discussions were carried out by the Resident Model Coordinator (RMC) and Hydraulic Modelling Engineer (HME) prior to the third CAT mission.

Following internal discussions within the CAT during its third mission the proposed TOR for the FMM study have now been finalised. They have been submitted to FPCO and the donors with the draft version of this report but is not contained in this report.

The FMM includes modifications to the basic capabilities of the MIKE 11 software and also the provision of software to link MIKE 11 to a DEM. The FMM study, in addition to the development of the FMM itself, would include building and demonstrating the usage of models.

Bespoke (tailored) FMM's can be envisaged at various levels; nationwide, regional, sub-regional and compartmental. At each level their usage could include simple planning, the development of flood management strategies or usage for flood forecasting. The FMM study could not possibly undertake the development, verification and demonstration of many models each with several usages. Hence the revised TOR suggests only priority projects as follows :

- the development and usage of a detailed FMM at compartment level (most likely based on Tangail).

- the development of a detailed FMM at regional level (most likely the NC Region).

- the development of a simple FMM at national level (General Model) to be used off-line to derive flood plain inundations from real-time river level flood forecasting

The FMM study constitutes the first phase of the full FMM development. Phases for the further development, with due regard to the eventual institutional framework for the FMM (pending FAP 26), will be prepared during this phase.

2.7 Model Coordination

Model Coordination has progressed satisfactorily since the last CAT mission. Through the FAP Modelling Coordination Committee, informal meetings and day-to-day bilateral contacts and meetings it is the opinion of the CAT that the coordinating function has made a significant contribution in ensuring a consistent approach to modelling up to now and will be so in the continuation of the Regional Studies.

Through the action of the RMC and HME the importance of up-to-date reliable topographic and hydrometric data for the Regional Studies in general and for the modelling in particular is now appreciated by most parties.

It is recommended by the CAT that the coordinating function of the RMC/HME be continued up to the end of the Regional Studies including the recently started FAP 4 and FAP 6. Advice and guidance on the implementation in other FAP's of the methodology proposed by the Flood Hydrology Study, and outlining of procedures and formats for the feedback of model and data from the various FAP studies to various GOB authorities will be other important activities in the continuation.

2.8 Morphology

The rivers of Bangladesh are morphologically active in that they change their geometrical dimensions, patterns and locations on a time scale measured in years as opposed to centuries. In terms of the FAP the major issues vis-a-vis morphology are the long term trends and developments in the major rivers i.e. the Brahmaputra, Jamuna, Ganges, Padma, Meghna and Lower Meghna. If the works carried out under FAP were to trigger major changes in any of these rivers then the repercussions would be widespread and potentially devastating. It is conjectured that the Jamuna, although mainly braided, may be close to the delicate divide line between braiding and meandering and it follows, therefore, that a thorough and convincing morphological assessment is required before contemplating any major works which would change flows significantly in this reach of the river.

The CAT has been asked to comment briefly on morphological studies past and present, with a view to defining the way forward on this subject. It was not possible for the CAT to carry out a comprehensive review of this difficult subject within the time available on its third mission. Instead the CAT has briefly reviewed the morphological modelling components within FAP studies in Chapter 9.

The CAT appreciates that morphological studies being undertaken under various FAP components and by others (the China-Bangladesh Joint Expert Team, BUET, SWMC etc.) will provide valuable information on morphology. However, the fundamental questions on morphology can only be answered by a properly funded project. The CAT recommends that a mission of internationally renowned experts in this field should be sent to Dhaka to collect and briefly review the available information including previous studies and data collection exercises. This should be followed by a comprehensive study which would form part of the proposed Inter-regional Study, see sections 2.9 and 9.3. The CAT is prepared to assist FPCO in preparing TOR for such a mission.

2.9 Inter-regional Study.

The second CAT report indicated a need for an additional study within the framework of the Flood Action Plan. Regional consultants are liaising with each other, sharing information and in some cases doing work to evaluate the effects of the proposals being worked up by their immediate neighbors. However, there is currently no comprehensive study which is looking at the combined effects of all the regional proposals.

The CAT believes that an inter-regional study is essential if major works are proposed such as a lengthy left bank embankment along the Jamuna. The need for such a study diminishes if only minor regional works are anticipated.

The Inter-regional Study would include :

- the effect of the combined FAP and other proposals on flood levels.
- the effect of the combined FAP and other proposals on river morphology
- an initial analysis of the effects of these changed conditions on the conclusions of the Regional Consultants in relation to agriculture, fisheries, environment, economic, social and other aspects.

2.10 Status of FAP 25 Approvals

It is recommended that the required additional staff and resources for the third stage of the Flood Hydrology Study be approved by donors and GOB at the earliest.

The CAT strongly recommends that the Terms of Reference for the Flood Management Model (FMM) be finalized and approved by GOB at the earliest in order for donors and GOB to complete formalities and recruit consultants by June 1992.

2.11 Next CAT Visit

The CAT proposes to make its next visit to Bangladesh in September 1992. Proposed Terms of Reference are included as Appendix 4 of this report.

One of the CAT members will visit Bangladesh in January 1992 to assist in the finalization of the report for the present phase of the Flood Hydrology Study.

3. BACKGROUND

3.1 Flood Action Plan

The Bangladesh Flood Action Plan has been prepared by the Government of Bangladesh in close cooperation with the World Bank . The Flood Action Plan has been prepared on the basis of several studies undertaken in the wake of the disastrous floods hitting Bangladesh in 1987 and 1988. The Action Plan aims at the identification, planning, design and construction of high priority flood control projects which are technically, economically, environmentally and socially feasible. It has been decided by the GOB that the river models being developed in the Surface Water Simulation Modelling Programme, including rainfall-runoff, hydrodynamic, sediment transport and salinity modules (SWSMP) will be used in the FAP studies.

3.2 The Surface Water Simulation Modelling Programme

The SWSMP was established because of the widespread recognition that the effective control and utilization of water resources in Bangladesh is vital to the economic and social development of the country. Mathematical models of the complex river system are in this respect indispensable tools for an integrated approach to planning and design.

The objectives of the first phase (SWSMP-1) were: i) to develop the local capability in surface water simulation modelling, including a sustainable institutional setup within a permanent MPO; ii) to develop a structured approach to modelling with a General Model covering the whole country.

The first phase of the programme finished at the end of 1988. The ongoing second phase (SWSMP-II) will have a duration of four years from 1989 through 1993.

The Surface Water Modelling Centre (SWMC) under Water Resources Planning Organization (WARPO), previously the Master Plan Organization (MPO), is implementing the programme with technical assistance from DHI, and with financial assistance from DANIDA.

4. PROVISION OF DATA

4.1 General

As stressed in the previous report of the CAT timely supply of good quality data is a serious constraint for the regional FAP studies. This is still so. Consultants from all the regional studies identify poor quality data as a major problem.

The data problem was addressed at the FAP Modelling Coordination Committee meeting held on 4 November 1991. Specific data problems experienced by the FAP studies were raised and discussed at this meeting, including identification of 9 error types for water level data. A number of actions to be taken by FPCO and the FAP projects to further elaborate the data situation was agreed.

4.2 Topographic Data

During the last CAT mission the importance of up-to-date reliable topographic information for proper performance of the regional studies in general and for the setup and calibration of reliable regional models in particular was stressed. The concern expressed at that time has indeed showed valid with the progress of model development in the SWMC and the regional FAP's. In areas where model performance is less satisfactory or not acceptable it is a commonly shared opinion that the major reasons for this relate to the quality of the basic data, not least topograpic maps and benchmark data.

Accurate topographic information from large scale maps is important for a correct representation of flood plains in the regional models and also for a correct schematization of the drainage network. The importance of reliable benchmark data is self-evident as basis for determining datum for river cross sections or water level staff gauges.

The CAT team has got the impression that existing SOB maps in scale 1:50,000 and 1:250,000 are generally of good quality. The scale of these maps is, however, too small for description of flood plain in the regional models and even the General Model. The BWDB maps, in scale 4" and 8" to a mile, are of sufficiently large scale. However, in several areas the accuracy of these maps may be questioned, especially the datum used. Thus, great care should be taken when using these maps and information derived from them (e.g. MPO's 1km grid). Checking with spot heights, when available, from SOB maps should be done as a matter of routine. Checking with results from FAP 18 will be possible in the near future. FAP 18 covers, however only a relatively limited area along Jamuna.

4.3 Hydrometric data

Basic hydrometric data are being collected, processed and supplied by the Surface Water Hydrology Directorates I and II (SWH 1 and SWH 2) of the BWDB. However, these Directorates are suffering from shortage of manpower, funds, equipment and lack of

motivation of staff. Although the very ambitious Flood Action Plan is totally dependent on reliable data little attention has been given to improve the source of this information.

The SWMC, as the supplier of models to the FAP, reports that the effort in model development to date has been around 80% data evaluation and 20% model calibration.

The CAT understands that SWMC has raised the issue of data quality from BWDB in meetings with BWDB and the Ministry since 1990. Following a recent directive from the Ministry, FPCO will work out the modalities to support field data collection by BWDB Hydrology through the FAP studies.

The SWMC and the regional studies are now moving towards morphological investigations and modelling. Provision of reliable sediment transport data is in itself a very difficult task, which implies that the data collection services required from the BWDB will increase in complexity, and hence in the need for qualified and motivated staff.

Support to BWDB-Hydrology

The SWH's of the BWDB have for many years received considerable assistance from the UNDP. However, the last assistance programme was completed in 1986, and only in September 1991 was a Project Document signed for new assistance to these Directorates. The UNDP assistance is budgetted at 4.6 million $ over 3 years, covering technical assistance (a total of 92 man-months, including a full time Chief Technical Adviser), equipment, transport and training. This assistance covers support to the Surface Water Directorates, the Groundwater Circles and the newly formed Directorate of River Morphology and research. The CTA is expected to arrive in early 1992 to initiate this programme.

An important aspect of the UNDP support programme is the provision in the Project Document that - by the end of the project - the budget of the BWDB-Hydrology shall be switched from development to revenue, and also that BWDB should establish a cost recovery system based on agreed charges.

The CAT appreciates the importance of the UNDP support to the BWDB in this field. However, whereas this programme can be expected to improve data collection activities in the medium to long term, it is unlikely to have much impact in the very short term, i.e. for the current activities of the FAP. Additional, rather substantial support to the SWH's is required for the 1992 monsoon season if reliable data for the ongoing regional studies are to be secured.

The required additional support would be much like the similar assistance provided by the SWMC to the BWDB for the 1991 monsoon season. This support programme, which was funded by DANIDA, involved input to the BWDB of local staff (one year contracts), survey equipment, field training programmes (from Executive Engineers to the level of surveyors), field transport (purchase of motorcycles and rental of jeeps) and a bonus

scheme to reward provision of accurate and reliable data. In addition two expatriate field measurement engineers provided continuous supervision of field activities. The total cost to DANIDA was in the order of 350.000 $.

The CAT strongly recommends that GOB seeks this kind of support for the 1992 and possibly 1993 monsoon season as well.

Charging for Data

The problems created by charging for data in conflict with the agreed Terms of Reference and contracts for the FAP projects was raised during the previous CAT visit. The issue was discussed at the recent FAPMCC meeting. It is understood that GOB has agreed to reimburse consultants for such costs.

Data Banks

An important role of the FAP 25 is to assist in the flow of hydrometric data and information between FAP projects, the SWMC and various GOB institutions. In addressing this task the profusion of different data formats and data base software becomes problematic, and it is obvious that some form of standardization is required. The CAT understands that an Interministerial Committee for Improvement of Data Collection recently has recommended standardization of data processing software and formats.

A number of new activities concerned with data processing are underway, mostly but not solely as part of the FAP (e.g. FAP 10, FAP 25, the SWMC and the UNDP project for BWDB-Hydrology). Different data base software is already being installed in different projects (e.g. TIDEDA, HYMOS). The CAT recommends that FAP 25 as a matter of some urgency looks into this situation and makes recommendations to the MIWDFC (and hence BWDB, FPCO, WARPO, RRI) on data base and processing software and formats.

5. MODELLING TECHNOLOGY

It has become customary for the CAT team to comment on the modelling technologies being used for the various components of the Flood Action Plan.

The purpose of this chapter is to follow up (briefly) the issues which were raised in the first and second CAT reports and to note enhancements to the modelling system.

5.1 MIKE 11 River Modelling System

Unix Version

The NAM, sediment transport/dispersion and hydro-dynamic modules are now available under the UNIX operating system. The quasi steady state module is available but only under the DOS operating system. Models operating under DOS are restricted to approximately 800 nodes whereas there is no restriction, in practice, under UNIX. Run times per node are comparable.

Modules

The cohesive sediment transport module is now available. The sediment transport module now includes the Van Rijn formula and the capability of dealing with graded sediments.

Run Times.

SWMC recommends 1 hr time steps for Regional Models and 2 hrs for the General Model. As pointed out earlier by the CAT this puts severe constraints on the use of the Regional Models, in particular when hydraulic conditions for a long time span should be simulated. Larger time steps are said to create instabilities in the models. Since this issue keeps coming up in the discussions, the Head of the River Hydraulics Division of DHI has agreed to take a close look into this problem, as the CAT requested earlier to SWMC.

5.2 Morphological Modelling

SWMC has initiated a study of the major rivers using the hydrodynamic module and the (single size) sediment transport module.

The model comprises longitudinally smoothed prismatic channels representing the Ganges, Jamuna and Padma rivers. The constriction at Hardinge Bridge is represented and cross-sectional spacing is reduced in this reach.A full description of this work is given in Appendix 5.

The modelling is, at this stage, of an exploratory nature and no firm conclusions can be given. The CAT makes the following observations:

- One dimensional modelling of a river such as the Jamuna represents a major simplification of the natural processes. Without doubt the cross-sectional shape of the channel changes with discharge. Monsoon flows will tend to even out bed levels across the width of the channel whereas low dry season flows will tend to "incise" small channels within the cross-section.

- the model is clearly sensitive to many factors including sediment size and sediment quantities entering the reach. Careful sensitivity tests should be carried out to establish the best basis for simulating the assumed dynamic equilibrium of the channels.

- morphological modelling can be adversely affected by the propagation of misjudged boundary conditions into the area of interest. It is suggested that the model is extended upstream as far as possible on both the Jamuna and Ganges rivers.

- the CAT recommends further exploratory testing of the model to include:

    - investigating the effects of assumed sediment sizes.
    - investigating the effects of assumed sediment inflows.
    - investigating the characteristic results from different sediment transport theories.
    - investigating the effect of boundary locations
    - running the model repeatedly through a typical annual flow sequence (one in which the peak flow is close to the average annual peak flow and the monsoon run-off volume is close to the annual average).
    - running the model for 25 years with actual flows

The CAT understands that the proposed model extension and exploratory tests are included in the model development programme of SWMC.

The preliminary results of this morphological study lead the CAT team to the conclusion that useful results will be obtained which will throw some light on the possible changes in longitudinal bed profiles resulting from proposed engineering works, in particular the confinement of the Jamuna by extensive embanking on the left bank. Further spin-off will be the possible explanation of variable rating curves at some of the major gauging stations.

It must be stressed that one-dimensional morphological modelling cannot supply definite answers relating to the natural development of river channels on completion of the engineering works which are carried out within the Flood Action Plan. Questions not addressed by one-dimensional morphological modelling include:

- changes in channel width
- changes in the shape of channel croos-sections
- changes in channel type e.g meandered, braided, etc
- changes in the plan location of channels

1-D morphological modelling gives some insight into the future behaviour of rivers but is obviously limited in its scope of application. Some 2-D modelling is taking place in FAP 1, but the emphasis is on short term changes rather than long term morphological response.

5.3 2-D Modelling.

2-D hydrodynamic modelling is taking place in FAP 7 and 9B and is described in Chapter 6 under the respective FAPs.

6. MODELLING IN FLOOD ACTION PLAN COMPONENTS

6.1 Timing of Model Supply and Use

Over the last half year the model development programme at the Surface Water Modelling Centre(SWMC) has suffered some delay. The main reasons for this delay are:

- shortages in staffing;
- additional effort required in providing assistance to BWDB Hydrology and supervising the data collection programme;
- delays in provision of computer equipment;
- difficulties encountered in the transition to the UNIX operating systems, in both hardware and software;

Compared to the time schedule in the previous CAT report, the NWRM full model is delayed by four months and the verified model by two months. The SWRM full model is delayed by two months. The development of the morphological and salinity modules for the General as well as all the regional models. is also delayed. The latest estimated programme of development as given by the SWMC is shown in Table 6.1. With the exception of the NWRM full model (see section 6.2 FAP 2) these delays are not considered to have any negative effects on ther FAP modelling activities.

The above time schedule reflects the availability of the hydrodynamic modules (including rainfall-runoff). The availability of salinity intrusion and sediment transport models is given in Appendix 6.

The SWMC has started the publishing of a series of technical reports providing the details of the individual models after each stage of model development has been finished. Based on the presently available reports the CAT finds that the reports do not contain sufficient information to allow potential models users to assess the accuracy of the models.

This issue has been discussed with the SWMC and the CAT agrees to their viewpoint that there is no objective method of establishing such accuracy levels and that it is up to the individual users to decide, whether the models have the accuracy required for a particular purpose. However, the CAT finds that improved quality of time series plots as well as some basic statistical analysis of deviations between model simulations and observations would be most valuable in making such assessment. It is understood that DHI is presently incorporating further statistical analyses of the results into MIKE 11.

It is the opinion of the CAT that the liaison between SWMC and the FAP studies has been good throughout and of mutual benefit. Through extensive discussions with SWMC, FAP studies are making valuable contributions to improvements in the MIKE 11 software itself as well as to the tailored models (the General Model and the six regional models).

DHI respectively SWMC have taken proper action on such issues.

The CAT agrees to the commonly shared opinion that poor quality input data, and not the modelling technology itself, is the major reason for the unsatisfactory agreement between simulated and observed data as found in different areas and locations.

Table 6.1: Programme of Model Development in Surface Water Modelling Centre.

Model/FAP	1991	1992	1993
	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND
GM	V		
NWRM/FAP2	A P	F V	
NCRM/FAP3	C	P	F V
SWRM/FAP4	P	F V	
SCRM/FAP4		P	F V
SERM/FAP5	V		
NERM/FAP6		P	F V

C: Coarse Pilot Model
A: Accelerated Pilot Model
P: Pilot Model
F: Full Model
V: Verified Model

6.2 Regional Studies

FAP 2: North West Regional Study.

Pilot model calibration for the 1990 flood season, on a sub- model basis, was completed by SWMC in June 1991. Subsequently FAP 2 linked the sub-models into a single combined model and carried out further calibration runs for the 1987 and 1990 flood seasons. The SWMC models were further modified, by reducing their spatial resolution (i.e. increasing cross-sectional spacing) to achieve acceptable model run times for the FAP modelling activities.

FAP modelling activities.

The modified combined model and various sub-models have been used to assess a number of development scenarios including various alignments, capacities and operating policies for the Interceptor and Diversion Drains. Further model studies have been undertaken to assess the impact of alternative flood control and drainage measures such as controlled flooding and drainage (CFD) and the "green rivers" concept for the lower Atrai.

Future modelling will include a specific study of the Gaibandha Project based on detailed surveys by the consultants. 25 year runs are being undertaken with and without schemes on regional and sub-regional levels.

FAP 2 has experienced problems with data quality
(inconsistent bench marks in particular). Additional inputs have been requested to keep the modelling on schedule. The 25 year runs, despite simplifications to the models, consume considerable staff time in data acquisition and assembly, data checking, model run-times and analysis of results.

If time permits some morphological modelling will be undertaken but the deadline for completion of all modelling activities is June 1992.

Model results have been used for a variety of purposes such as preliminary engineering design of flood control and drainage works, assessment of potential cropping patterns and to assist in assessing the impact and cost benefit of various development scenarios.

Liaison between FAP 2 and SWMC has been good throughout the project. The combined model developed, verified and used by FAP 2 does, however, differ from the SWMC version due to time and budgetary constraints placed upon the FAP 2 consultants.

The Interim Report (volume 3, annex 2, section 5.1) discusses four alternatives for future hydraulic studies. The CAT notes that the full model will be available only in June 1992 from the SWMC, that is a delay of four months. In spite of this, the CAT recommends that the proposal to make an upgraded pilot model, in parallel to the full model development of SWMC, be reviewed. With the assistance of the RMC it should be considered to which extent the full model development at SWMC can be speeded up and prioritized in order to meet the particular requirements of FAP 2 with respect to model area and the overall time schedule of the project. The proposed additional man-month input seems under all circumstances justified.

FAP 3: North Central Regional Study.

The Bridging Hydrologist submitted the calibration report for the coarse pilot model in April 1991. The report highlighted the difficulties which had been encountered because of inadequacies in the topographic and hydraulic data available for the area. An emergency field survey and data collection exercise was required but did not form part

of the TOR for the FAP 3 study.

The hydro-modeller continued calibration of the coarse pilot model through to the end of September 1991. Time constraints and the continuing absence of reliable data prevented further refinements of the model(s). At this stage the area had been divided into two models one of which was close to the MIKE 11 DOS limit. A third sub-model of the Old Brahmaputra was also available in calibrated form.

The models were used in October/November 1991 to evaluate numerous engineering schemes and the results were included in an Interim Report (draft Regional Water Development Plan) which suggested further work on the five most promising alternatives. The modelling of these alternatives will be undertaken prior to the hydrologist's departure at the end of January 1992. No modelling will be undertaken after that date.

The final report of the study is due in May 1992 when recommended projects will have been taken to the pre-feasibility stage.

The FAP 3 component is one of the first to finish and modelling has had to be done in advance of the SWMC pilot, full and verified models. Further modelling will be required if any of proposed projects are to be taken beyond the pre-feasibility stage. The CAT emphasises that more detailed modelling can only be justified if the quality and quantity of the input data is significantly improved. It may be necessary to refine the General Model along the length of the Jamuna so that inflows to all the left bank distributaries can be established as boundary conditions for the North Central Regional Model(s).

FAP 4: South West Regional Study

The study started in October 1991. The Inception Report is due by mid-January 1992, the first Interim Report in late May 1992, and the second Interim Report in October 1992.

In order to comply with this schedule modelling activities may become critical. The area is covered by two regional models of the SWMC: The South-West and the South-Central Regional Models (SWRM and SCRM). The pilot SWRM is ready for applications (only some minor adjustments still to be made), but the calibration of the SCRM has only just started.

A pilot model for the entire area must be available by April 1992. In order to achieve this considerable efforts are underway to collect data for the SCRM. FAP 4 is engaging 2 survey teams to obtain cross sections in the South Central Region up to February 1992. SWMC is deploying 4 teams in both the South West and Central regions up to April, 1992. SWMC is obtaining hourly water level and salinity data at the Bay of Bengal through gauge readers.

The SWRM/SCRM is tidal and includes salinity. The consultant also needs to model

siltation in selected areas. The SWMC is behind schedule in this respect but with the help of the results from the on-going Pussur-Sibsa modelling study (Ministry of Shipping) it is expected that the necessary modules will be available in time.

It is not considered feasible to run the full tidal model for 25 years to arrive at return periods of flooding in the area. The consultant is considering to approach this analysis by running a non-tidal model for the 25 years and supplement this by running the full tidal model for representative years. FAP 4 has demonstrated that a non-tidal model of the south west area could not give such accurate results (compared with filtering the results of a tidal model). A recalibration may be necessary in this case. It may also be possible to develop a coarse model eliminating smaller channels. This is, however, also likely to require some recalibration. The results of such different approaches should be compared with SWMC's finer model.

It is noted that this region is characterized by considerable changes over the years due to erosion/siltation and changing channel patterns. Hence historical flow and water level data need to be interpreted with care, and primary confidence must be given to long term simulations based on historical rainfall data.

FAP 5: South East Regional Study.

The draft Interim Report has been submitted in September 1991.

The hydrodynamic modelling for the Regional Plan has been completed successfully. The consultant is generally satisfied with the accuracy of the model results, i.e. at this stage within a margin of 30 cm.

The consultant has had some difficulty simulating the regulators. As discussed elsewhere in this report, the CAT has discussed the representation of structures in MIKE 11 with several users and with the SWMC. With the recent improvements in MIKE 11, and with the better description in the new Reference Manuals, it is expected that this problem will be solved soon.

The South-East Regional Model (SERM) has been split into two sub-models due to the limitations of the DOS operating system, but in the subsequent feasibility studies these will be combined using the UNIX-based version of MIKE 11.

It is not anticipated that the salinity module will be used in this region provided that the overall recommendations of the National Water Plan are accepted and the saline intrusions in the Lower Meghna River are controlled.

The morphology module may be needed in April-May 1992 in the feasibility studies of proposed drains which are likely to be subject to heavy siltation. The layout of the drains should be supplied to SWMC at an early date.

The consultant has developed his own post-processing software. Using the MIKE 11

model network and flood plain allocation diagrams, 1' grid squares have been attributed to each model node, thereby permitting flood depth-area characteristics to be evaluated from model results on a local basis. By aggregation this has also been developed on a Planning Unit basis. The CAT finds this to be a very useful development which undoubtedly will be of interest to other users - as developed by FAP 5, or as a joint product of FAP 19 and FAP 25 (see sections on FAP 19 and the FMM below).

There are significant differences in the root causes of flooding in the region, some parts being affected primarily by the main river levels, others primarily by local rainfall. Although it is recognized that the ideal approach would be to carry out a continuous simulation over a 25 year period, the consultant has found this to be impossible within the time frame of the regional plan. Hence particular representative years of record have been used in the analysis instead.

The CAT recommends that an attempt be made to simplify the SERM in certain areas (as e.g. very flashy catchments) in order to enable it to be run with longer time steps. FAP 5 should seek guidance from the SWMC in this respect. As a minimum the present situation (baseline) and the finally proposed development plan should be analysed in continuous 25 years simulations in order to properly assess return periods of flooding in different parts of the region.

FAP 6: North East Regional Study.

The Inception Report has recently been submitted.

The modelling activities under FAP 6 are just starting. Computers are being installed at the SWMC at which the FAP 6 modelling team will be working.

A detailed modelling work plan has been developed, including 25 years simulations of the existing situation and the selected development alternatives.

Discussions are in progress with FPCO/BWDB, SWMC and SOB with respect to data collection and additional surveys. Resources are available within FAP 6 to support second order levelling of BWDB benchmarks. However, such survey can not be completed in the 1991/92 dry season and a prioritized survey programme should be considered in order for the modelling studies to achieve maximum benefit. Otherwise costly reruns at a later date may become necessary.

The major modelling problems are expected to relate to the estimation of cross-border flows from flashy catchments in India, and a proper and computationally effective description of the haor flooding and drainage.

The Consultant has the results of a search, carried out by Hydraulics Reseach (HR) Ltd. (Wallingford), for pre-independence river flow data related to rivers entering FAP 6 area from India. The search was made in response to the suggestions made in the second CAT mission report, p. 63 and it covered the most likely holders of such data, viz.:

- HR Wallingford
- Indian Office, London
- Library of the Institution of Civil Engineers, London
- University of Cambridge Library

The conclusion of the search was that no such river flow data are held in the UK

6.3 Other FAP Studies

FAP 1: Brahmaputra Rightbank Training Scheme

Since the project started in March 1990 two reports have been issued, Inception Report (May 1990); Interim Report (April 1991). In addition, FAP 1 has recently supplied progress notes in October (for monthly team leader meeting at FPCO) and November 1991 (for FAPMCC meeting).
The CAT makes the following comments:

- After the correct repositioning of existing cross sections and addition of new ones the calibration of the hydrodynamic model is now satisfactory.

- The simulation for the 1988 flood conditions including the proposed Jamuna Bridge and with the upper Dhaleswari distributary closed off or in place, leads to an increase of 0.35 m in water level with a backwater effect extending 55 Km upstream.

- The morphological studies are concentrating on developing predictors for channel geometry changes through the surveys undertaken during high and low flows. Some useful predictors are expected in the near future.

- The use of 2D morphological modelling allows the simulations of the bed form variations as the discharge varies but the simulations are of local situations for limited periods.

- Physical models are being used to study local scour at groynes.

The CAT stresses that FAP 1 activities are strongly linked to FAP 2, FAP 3, FAP 21/22, FAP 24 and the technologies used in FAP 9. Additional liaison with the SWMC morphological study should be encouraged and the findings in the recent Chinese report may be of value. Findings from the Jamuna Bridge Study are also relevant.

FAP 3.1: Jamalpur Priority Project:

FAP 3.1 has submitted their Inception Report in October 1991. In the report their broad approach to hydraulic modelling is outlined. The consultant has acquired the MIKE 11

software and the FAP 3 Coarse Pilot Model and small tests have been carried out.

The model schematisation of the drainage network of the study has been prepared. To facilitate simulation of inflow from Jamuna through a number of spillage channels identified during the field inspection the model will include part of Jamuna from Bahadurabad to Jagannathganj. Cross-section surveys to define the geometry of the drainage network are ongoing.

The time schedule of the modelling activity is very tight and, in addition, model setup and "calibration" will have to be done with virtually no calibration data. Even though this lack of data can be partly compensated for by carrying out sensitivity tests, evidently, this situation will effect the reliability of the model simulations. It is understood that the consultant is presently preparing a proposal for a bridging activity between feasibility study and detailed design. This bridging activity will comprise field surveys to collect 1992 monsoon data (appr. 10 gauging stations), proper model calibration, possibly running the model for 25 years and reassessment of the recommendations of the feasibility study. The CAT fully endorse this proposal of a bridging activity.

FAP 7: Cyclone Protection Project

Under this project two-dimensional storm surge modelling of the Bay of Bengal has been carried out on a trial basis. The storm surge modelling considers the influence of wind as well as low pressure fields associated with the occurence of the cyclone.

A total of eight historic cyclones, including the April 1991 cyclone, has been simulated. While the seven other cyclones were simulated by simple superposition of tidal variation on the storm surge model results, the April 1991 cyclone was simulated using a fully integrated tidal and storm surge model. The model has allowed for the effect of storage in the major rivers, but does not include as full hydrodynamic description of storm surge penetration in these rivers. The model does not account for flooding in low-lying coastal areas. The results have been promising.

The consultant is presently considering the possibility of improving the present cyclone forecasting system to allow not only the qualitative predictions as it is the case today but also to forecast storm surge heights, location and time of occurence. Such improved forecasting may include the coupling of a two-dimensional Bay of Bengal model with one-dimensional river model to describe surge penetration in rivers.

The SWMC models may greatly benefit from such an accurate two-dimensional model of the Bay of Bengal. It may provide improved downstream water level boundary conditions as required for the General Model and the SERM, SCRM and SWRMs. **FAP**

8A: Greater Dhaka Protection Project

The consultant has submitted his draft Master Plan Report in July 1991 and expects to

submit the Feasibility Study in April 1992.

In the master plan phase MIKE 11 has been use to calculate flood water levels with and without empoldering facilities for the 1988 flood. Only the hydrodynamic module of MIKE 11 has been used. The consultant has preferred to use a simple rainfall-runoff estimation by means of the Rational Formula, rather than using the NAM model. This is consistent with previous JICA financed projects in Bangladesh, but not with the general modelling approach of the FAP.

During the current feasibility phase a more detailed MIKE 11 hudrodynamic model is being applied to describe drainage characteristics in the DND area in the southern part of greater Dhaka, still using the Rational Formula for rainfall-runoff calculations. In assessing rainfall-generated flood drainage from the empoldered area a simple high and low water boundary condition is used (drainage by pumping and gravity respectively), rather than simulating the actual water level variations in the surrounding rivers.

The consultant is considering a similar approach for the four northern compartments of the greater Dhaka area (including part of the area covered by FAP 8B). A final decision on possible modelling of these areas had not been taken at the time of the CAT visit.

The consultant has exchanged reports with FAP 8B. There has been little contact between FAP 8A and FAP 3, and the FAP 8A consultant has not participated in coordination meetings arranged by FAP 25 or the FAPMCC.

The CAT suggests that the simplified modelling approach by the FAP 8A consultant may lead to conservative design estimates.

The CAT notes that greater Dhaka as a part of the North Central Region will be affected by flood control measures undertaken in this region. Possible measures proposed by FAP 3 to reduce flooding in the southern part of the area may lead to reduced design water levels for the embankments around Dhaka which should be taken into account in the final analysis, and thus also in the final modelling studies.

FAP 8B: Dhaka Integrated Flood Protection Project

The greater Dhaka embankment scheme has been analysed in the MIKE 11 model by FAP 8A, but no modelling has been undertaken in FAP 8B itself.

FAP 9B: Meghna River Bank Protection Study

FAP 9B develops according to schedule and is expected to be completed in January 1992. As pointed out in the previous CAT-report, designs for river bank protection at 8 locations along the Upper and Lower Meghna rivers are made for currently prevailing hydraulic conditions. Nation-wide flood protection schemes may well alter these conditions. Such changes are not yet taken into account (not included in TOR) and should

certainly be addressed by FPCO and BWDB at some stage. The results of the FHS, in particular of stage 3, will be relevant in this respect.

Two-dimensional flow modelling for the Lower Meghna, carried out under the project, has provided more cross section details which should be incorporated in the General Model (see Appendix 6).

FAP 10: Flood Forecasting and Early Warning.

A reduced version of the General Model has been used for real-time flood forecasting in the Flood Forecasting and Warning Centre of BWDB. The model has 13 boundary nodes and 16 forecast points. It includes 29 NAM catchments to take into account the effect of direct rainfall over Bangladesh on the flood levels in the major rivers. The model does not include the SW region and Lower Meghna.

The model has been used daily throughout the 1991 monsoon season to prepare forecasts for 24, 48 and 72 hours. Results are satisfactory and are incorporated in the daily bulletins of the centre.

An extended version of the model with model boundaries extended into India (to Farakka along the Ganges and Dubri along Jamuna) has been applied when Indian data has been received in due course to prepare the daily forecasts. This extended version gives better results and is essential to obtain good results for the longer lead times, say 72 hours or more.

Finally, the western part of the NCRM has been applied on a trial basis to improve forecasts around Dhaka. The model relies on boundary conditions from the General Model. Results have been promising.

A hydrological database system (TIDEDA) is in the process of being acquired. It operates under UNIX and includes facilities to handle real-time data from telemetric network.

The present phase of the project extends up to May 1992. An evaluation mission is expected early 1992 and will consider possible project extension up to the end of 1993. Possible modelling activities to be taken up include real-time forecasting with the NCRM regional model and trial runs with one of the other regional models, probably NERM or NWRM.
FAP 10 is following the activities of FAP 19 and 25 on DEM with regard to the forecasting of inundated areas.

FAP 18: Topographic Mapping.

In the report of the last CAT mission (in May 1991) the importance of accurate topographic information for a proper performance of the regional studies was clearly

i.e. a corridor along Jamuna, part of North Central region and very small parts of North West and South West region.

However, the CAT is pleased to note that FINNMAP and SOB have now agreed to a phased delivery of second order levelling data from FINNMAP and checking by SOB. The data will be delivered in five batches; first batch has already been delivered and the other four will be delivered in monthy intervals from end of December 1991. SOB will, seemingly, start checking of data from mid December and onwards. The CAT notes that such checking can actually be carried out independently of delivery of data from FINNMAP.

As and when FINNMAP data are being delivered to SOB a copy will be submitted to and through FPCO to be available for the relevant FAP studies. Being preliminary data the individual FAP's will, however, use such data on their own risk. For most purposes the data are, however, expected to be reliable unless otherwise indicated.

With their contract FINNMAP is also supposed to check 65 BWDB benchmarks, which are used to establish datum of staff gauges at hydrometric stations. CAT notes that this activity has not yet started. The results will be of much use to the stage 3 of the Flood Hydrology Study of FAP 25.

The delivery of photomosaics from the Jamalpur, Sirajganj and Tangail areas are delayed by 5-6 months and is not expected before June 1992. The given reason for this delay is that the films needed for rectification have not been available to FINNMAP until recently, because they have been used by the relevant FAP's for reprinting of maps.

FAP 19: Geographical Information System (GIS)

In the Inception Report (September 1991) various potential application areas of GIS have been identified and possible pilot projects are being considered. One of these relates to the development of digital elevation models (DEM - also referred to as digital terrain models DTM) and the interfacing of these with the MIKE 11 modelling system.

Extensive discussions have been held between interested FAP projects on the MIKE 11/DEM linkage, most recently with the participation of the CAT and FAP 19, FAP 3, FAP 10, FAP 25 and the SWMC.

The likely development of the MIKE 11/DEM linkage focuses initially at three levels: National level/General Model (1 km grid), regional level/Regional Model (250-500 m grid), and sub-regional level/Compartment Model (50-200 m grid).

The activities at these levels, to be initiated in early 1992, include general identification of procedures and techniques, development of DEM's at the three levels, and testing at one or more of these levels of the MIKE 11/DEM interface.

A 10,000 point DEM has already been set up for the Tangail Compartment (i.e. one

one or more of these levels of the MIKE 11/DEM interface.

A 10,000 point DEM has already been set up for the Tangail Compartment (i.e. one point per ha). The first region to be taken is likely to be the North-Central Region. FAP 19 develops the DEM's on the basis of available topographical information; it is not conducting original surveys (as e.g. FAP 18).

Close coordination will be maintained between FAP 19 and the SWMC in developing the MIKE 11/DEM interface. Several FAP projects will be interested in this development and the testing of the MIKE 11/DEM interface:

- FAP 10 for the General Model (forecasting of inundated areas)
- FAP 3 and FAP 10 (flood forecasting for Dhaka) for the North-Central Regional Model
- FAP 20 for the Compartment Model
- FAP 25 for the development of the Flood Management Model (See Chapter 8 below)
- other regional studies at later stages

The RMC of FAP 25 will follow this development and assist in the coordination between the interested FAP projects.

Ultimate conditions of use of the DEM software applied for the MIKE 11/DEM development (after the intial demonstration and testing phase) have yet to be established.

FAP 20: Compartmentalization Pilot Project

The Inception Report is due in mid-December 1991.

Modelling of the Tangail Compartment started in October 1991, using the MIKE 11 system. Calibration is ongoing - based on results from detailed field measurements by the consultant. At the moment the model contains some 50 node points, with 2-3 km spacing in the rivers, to less than 1 km spacing in the flood plain.

An Implementation Plan containing analyses (including modelling studies) of selected development alternatives for the Tangail Compartment shall be presented in March 1992. Subsequently discussions with the local population will take place over the next 3-4 months as the basis for final selection of projects to be designed and implemented. A similar procedure will be followed in the Siranjganj Compartment. for which the proposed Implementation Plan shall be presented in November 1992.

Close liaison has been established between FAP 20 and FAP 3, and the NCRM is

available to FAP 20 to enable analyses of the influence (boundary conditions) of macro-level planning and management.

FAP 20 needs modelling to analyse the planning and operation of control structures at the rim of the compartment and internally within and between sub-units of the compartments, i.e. in the planning as well as in the subsequent management phase of the project.

The present MIKE 11 model can be used for initial planning purposes, but the development of the FMM is of considerable interest to FAP 20 for micro-level planning and development of operation guidelines for structures in the final schemes. Close collabaration is envisaged between FAP 20 and FAP 25 in developing and testing the FMM at compartment level (See also Chapter 8 below).

The first step of FMM development - interfacing between MIKE 11 and DEM - is of great interest to FAP 20 in the very short term. While some use may be made of the FAP 19 DEM for Tangail in post-processing of MIKE 11 results for the Tangail Implementation Plan, the FMM development will primarily benefit FAP 20 in the analysis of water management strategies.

7. FLOOD HYDROLOGY STUDY

7.1 Status of FHS - Stage 2

In its second report the CAT presented a detailed methodology for the Flood Hydrology Study (FHS), as summarized in Appendix 7 and implemented as from June 1991. A first review of the results of the FHS was carried out by one of the CAT's members in early September 1991. In the light of the results obtained at that time, it was concluded that the basic approach to the FHS, relying for a great deal on the validation of the General Model (GM) for a historic period of 25 years, had proved to be sound and justified. Proper steps were undertaken to reduce the computation times of the GM to a feasible level for the FHS.

The present CAT mission has reviewed the progress of FHS again. The most important findings, conclusions and recommendations are presented in this chapter. The main conclusion is that the adopted methodology is indeed sound, while stage 2 is scheduled to be completed in January 1992.

In total 5 runs were made with the GM, including at an early stage one trial run for a country-wide protection scheme, indicating that full protection of the main rivers would increase maximum water levels in the order of 0.5 m for the 1988 flood. The other runs concerned a gradual extension of the dedicated version of the GM as used for FHS, while much effort was put into data collection, checking, correction and completion. This work yielded a proper set of historical hydrological boundary conditions for the concerned period 1964-1989, as well as a set of data for the validation of the model.

The validation of the GM has reached a point where further improvements can only be obtained through a recalibration of the model by the SWMC. The SWMC has agreed to include this work in their normal model updating programme. The next update is expected to be available early 1992, in time for further use of the GM in stage 3 of the FHS. Meanwhile, results of run 5 (including statistical analyses) will be provided to the regional studies as needed, with the precaution that results are still preliminary in view of the need to recalibrate the GM to some extent.

The other activities under stage 1 and 2, viz. statistical analyses, joint probability analyses and representativeness analyses of the period 1964-1989 for the full century, will be ready in time for reporting in January 1992 (see sections 7.3 to 7.6).

7.2 Validation of the GM

No recalibration of the GM occurred sofar under FHS, mainly because such work is only useful once a proper set of boundary conditions and water level data at control stations is available. Careful inspection of the results of run 5 reveals several reasons for some recalibration of the GM. This will not only benefit the FHS, with its particular interest in proper simulations over the longer term, but also benefits the use of the GM for flood forecasting, that is for the short term. In other words, most of the deficiencies observed

for the full period 1964-1989 also occur for more recent years. These deficiencies are summarized in Appendix 7.

The given comments do by no means imply criticism by the CAT of the work of the SWMC. Instead, the CAT appreciates their work done sofar and their full and timely cooperation in the FHS. The joint effort of both teams have revealed some deficiencies, which became in particular evident through the validation of the GM for such a long period.

The issue was discussed in detail with the SWMC and it was agreed that SWMC will include the above modifications in their ongoing recalibration of the GM for the 1990 flood season. It is expected that the next version of the model, to be available in January 1992, will produce satisfactory results for both the most recent years as for the full period 1964 - 1990. At that time (stage 3 of FHS) the model should be run again for the full period (run 6) for final validation.

7.3 Recommended Probability Distributions

Various probability distributions were tested in stage 2 on their adequacy for fitting observed distributions of various relevant hydrological parameters, as discussed in Appendix 7.

The GEV-type 2 distribution is recommended for annual maximum discharges, and the log-normal distribution for annual maximum water levels and total annual rainfall amounts. Some more work has to be done on this subject under stage 2.

It is stressed that any use of moment based parameter estimators must be discarded in FAP, in particular because only some 25 observations of annual extreme values are available. FAP 25 makes use of the Maximum Likelihood Method for parameter estimation, but the Probability Weighted Moments method might as well be used.

7.4 Joint Probability Analysis

Correlations between rainfall at various (rather nearby) stations in Bangladesh, between annual flows on Ganges and Brahmaputra rivers, and between average rainfall in the Ganges basin and annual flows at Hardinge Bridge were all found to be very low. Consequently, there is no need to consider the issue of joint probabilities of various flood causing factors any further in this study. Extreme floods on Brahmaputra and Ganges rivers, rainfall driven flash floods and rainfall over Bangladesh appear to have little correlation.

7.5 Representativeness of the Last 25 Years for the Century

Long-term records are available for some rainfall stations in India and Bangladesh.

Though the analysis of the representativeness of the last 25 years for the century is not yet completed, results so far indicate that standard deviations and mean values of annual rainfall data have increased only slightly at some stations, while no statistically significant differences were found for others. Hence, it is likely that the period 1964-1989 is indeed representative for the century, though designs made on the basis of the hydrological conditions in the period 1964-1989 may be slightly conservative.

7.6 Safety Margins for Design Water Levels

In his mission report of September 1991, one of the CAT members proposed a methodology for deriving safety margins for design water levels. Safety margins varying from 45 cm for the 100 years maximum flood level to 30 cm for the 10 years maximum flood level were proposed. This safety margin has to be added to the free board, accounting for wind set-up, wave run-up and other possible safety factors. The recommended safety margins are valid for the major rivers only.

Appendix 7 gives some further considerations on this topic, which will be discussed in detail in the report of stage 2 of the FHS also outlining the methodology to be followed to establish similar safety margins along the secondary rivers. The CAT recommends that FPCO and POE take a decision on this issue at short notice upon submission of FHS report, since it is important that all regional studies adopt the same design criteria as soon as possible.

7.7 Methodology for Estimating Design Water Levels at Regional level

The CAT's mission report of September 1991 indicated that a similar methodology, as outlined for the FHS, should be adopted for the regional studies. As a consequence, the regional models have to be run as well for periods of 25 years, once the development and calibration of these models have reached a level good enough to make such simulations useful.

The CAT notes that such runs have to be made only a few times, for example for the present situation and for a most feasible future situation. Other development alternatives can be studied on the basis of simulations for only a few flood seasons.

Run times of the models should not be prohibitive, since with some simplifications of the regional models, it should be possible to run them with time steps of 2 hours, the same as used for the GM in the FHS.

The creation of sufficient boundary conditions for the full simulation period may occasionally create a problem. Obviously, the situation is area-specific in this respect.

Whatever the precise situation, the CAT is convinced that a fair effort should be done by the regional study teams to implement this crucial component of the methodology for FHS, possibly with some assistence from SWMC in modifications of the models.

The adoption of the methodology on regional level has been discussed with the regional FAPs as part of the coordination activities. From recent reports it appears that FAP 2 and FAP 6 intend to make 25 years simulation with their regional model. FAP 4 is presently considering the feasibility of doing so. FAP 5 considers the approach to be, ideally, right, but impractical due to long run times. FAP 5 has agreed to look into the possibilities of cutting run times in cooperation with SWMC and FAP 25.

FAP 3, FAP 25 and the SWMC have also discussed the possible modelling approaches of FAP 3 considering their present time schedule and need of having modified boundary conditions for alternative protection schemes along the Jamuna left bank. It has been agreed that a feasible approach at this stage would be to use the period 1985-89 to analyse the effect of the most likely embankment alignment. FAP 25/SWMC will provide the boundary conditions in due course.

7.8 Activities under FHS-Stage 3

The following activities are envisaged for stage 3 of the FHS, until July 1992:

- recalibration of the GM by the SWMC, likely to be ready in February 1992; input of FHS (as required) possible under stage 2 until end of January 1992
- final validation of GM for period 1965-1989, statistical and error analyses, and submission of results to regional studies as needed
- two runs with GM for full period 1965-1989, including alternative nation-wide protection schemes
- occasional runs with GM for some selected historical floods, including alternative nation-wide protection schemes and effects of sea level rise

8. FLOOD MANAGEMENT MODEL

8.1 Background

FAP 25 has three components:

- co-ordination of modelling within FAP
- the Flood Hydrology Study (FHS)
- the Flood Management Model (FMM)

The second CAT report (September 1991) discussed the Flood Management Model, its provisional specifications and usage, but concluded that further discussions were required with potential users of the FMM before finalising the TOR. This was carried out by the Resident Model Co-ordinator (RMC) and Hydraulic Modelling Engineer (HME) who consulted FPCO, SWMC, FAP Regional Consultants, BWDB and other relevant parties. The Resident Model Coordinator produced a revised version of the TOR prior to the third CAT visit. CAT members considered this draft during their third mission and made revisions where appropriate. The agreed draft was included in the draft report of the CAT mission as a basis for the final discussions and agreement, but is not contained in the present report.

8.2 Justification

In considering the **need** of the Flood Management Model (FMM) it is important to review the current work of the Surface Water Modelling Centre and the experience gained by the Regional Consultants during the early phases of the Flood Action Plan.

The Surface Water Modelling Centre is essentially developing hydrodynamic models for Bangladesh and training local personnel in their use. The work was initiated long before the Flood Action Plan and was originally aimed at the provision of models which would have the capability of investigating effects of development activities, additionally low flow irrigation and salinity intrusion problems.

The commencement of the Flood Action Plan in 1989 introduced a new dimension into the modelling requirements including the need to be able to study major flood plain flows and storage. The Flood Action Plan has also highlighted the need for morphological modelling and analysis. Staffing at the Surface Water Modelling Centre was strengthened in order to cope with the additional workload.

The models from the SWMC are essentially planning tools; they are (being) verified on existing conditions and then used to evaluate the effects of engineering work. The output from the models gives the variation of water levels and flows throughout the model area with time, considering also the storage characteristics of the flood plains. The models do not indicate directly detailed areas and depths of inundation. Such information will improve the present basis for planning and development of agriculture in inundated areas

and related effects on fisheries.

One of the very central elements in the Flood Action Plan is "compartmentalisation" allowing controlled flooding and drainage within and between compartments through the operation of structures on the rim of the compartment(s). Identification of overall water management strategies for compartments and development of (simple) operational rules are essential for successful implementation of compartments on a large scale.

The Flood Management Model study is adressing these needs of more detailed information on flood plain inundations and development of operational guidelines for flood control structures and schemes in general and for compartment(s) in particular.

The **target group** of the FMM development includes:

- planners and designers of FCD schemes (MIWDFC institutions and Local Government Engineering Bureau) and other infrastructure developments (roads, highways, railways), which may have an impact on flooding and drainage conditions;

- operators of FCD schemes in general and of compartments in particular;

- flood forecasting authorities;

- universities (research, education and training)

The exact **institutional framework** for continued development, maintenance and application of FMM beyond this study still has to be elaborated. The yet to start FAP 26 - Institutional Strengthening - will have to address this issue. Considering the comprehensive capacity building effort done under SWSMP-II it would, however, be most logical and indeed recommendable
that the SWMC is ultimately given the responsibility of continued development, maintenance and application of the model for macro-level planning. BWDB will be a major user of the FMM for project planning, feasibility studies, detailed design, scheme operation and flood forecasting. Other potential users specified under the target group above are expected to have easy access to these FMM centres.

8.3 Concepts and Applications

In addressing the needs the FMM should include the following features:

- linkage of the present MIKE 11 based SWMC models to a digital elevation model (DEM) to facilitate rapid interpretation of water levels in terms of flooded areas and depths;
- more versatile representation of flood control structures;
- enhanced graphics and more user friendly "front-end";
- the capability of usage off-line to determine flood management strategies and on-

line to assist flood forecasting;

It can be seen that the FMM includes modifications to the basic capabilities of MIKE 11 and also the provision of software to link MIKE 11 to DEM. The FMM study, in addition to the development of the FMM itself, would include building and demonstrating the usage of FMM models tailored to specific areas and specific types of problems.

Bespoke FMM's of specific areas can be envisaged at various levels: nationwide, regional, sub-regional and compartmental. At each level their usage may include simple planning, the development of flood management strategies or usage for flood forecasting. The FMM study could not possibly undertake the development, verification and demonstration of many models each with several usages. Hence the TOR suggests, in addition to the general modification of MIKE 11 and linkage to DEM, only priority projects as follows:

- the development and usage of a detailed FMM at compartment level (most likely based on Tangail).

- the development of a detailed FMM at regional level (most likely the NC Region).

- the development of a simple FMM at national level (General Model) to be used off-line to derive flood plain inundations from real-time river level flood forecasting

FAP 19 is expected to produce pilot DEMs for these three FMMs. FAP 19 may also produce DEMs for other regions but the FMM for these regions is regarded as being outside the scope of the FMM study.

9. COORDINATION ACTIVITIES

9.1 Model Coordination

From meetings with the various FAP components it is the impression of the CAT that the model coordination has progressed satisfactorily. As it appears from Chapter 4, 5 and 6 the poor quality of underlying data in some areas seriously affect model performance. The data quality issue as well as data procurement conditions have thus been a very important part of the model coordination activities. The methodology and preliminary results of the Flood Hydrology Study and implications for the regional studies in terms of modelling has also been extensively discussed with all relevant FAP's.

The coordination activities are basically carried out at three different levels:

- quarterly meetings of the FAP Modelling Coordination Committee (FAPMCC) with representatives from GOB authorities and the relevant FAP team leaders.

- informal meetings in the FAP 25 office with hydro-modellers and hydrologists of relevant FAP projects and the SWMC

- day-to-day bilateral contacts between the Resident Model Coordinator and the Hydraulic Modelling Engineer (HME), relevant FAP projects and SWMC.

The meetings in FAPMCC, a total of three meetings has been held, serve more general purposes such as orientation of relevant GOB authorities on achievements and possibilities of applying modelling technology for planning and design, adaptation and timing of model developments at SWMC vis à vis the requirements of the FAP, procedures for updating of SWMC models, and general aspects of data quality issue. The CAT notes with satisfaction the positive impact of decisons taking in FAPMCC towards speeding up delivery of data from FAP 18.

The informal meetings, of which a total of eight has been held, are of more technical character. Specific problems related to modelling in the individual FAP's, procurement of data, discussions of the results of the Flood Hydrology study as it has progressed and the methodology proposed by FAP 25 to obtain hydrological design conditions at regional levels have been extensively discussed.

The bilateral meetings have covered in more depth the same items as the informal meetings.

It is the firm opinion of CAT that there is a continued need of model coordination as long as the regional studies are ongoing. Two recently started regional studies, the continuation of the other regional studies, the implementation of the methodology proposed by the Flood Hydrology Study in the regional and other studies, and mechanisms and formats for the feedback of data and models from the regional FAP's to GOB authorities will be major responsibilities in the continuation. The Resident Model Coordinator will in addition act as team leader for stage 3 of the Flood Hydrology Study

and The Flood Management Model.

9.2 Morphology

The CAT has been asked to comment briefly on morphological studies past and present with a view to defining the way forward on this subject ; a subject which could have a dramatic effect on the long term effectiveness of works carried out under the Flood Action Plan.

The rivers of Bangladesh are morphologically active in that they change their geometrical dimensions, patterns and locations on a time scale measured in years as opposed to centuries. In terms of the FAP the major issues vis-a-vis morphology are the long term trends and developments in the major rivers i.e. the Brahmaputra, Jamuna, Ganges, Padma, Meghna and Lower Meghna. If the works carried out under FAP were to trigger major changes in any of these rivers then the repercussions would be widespread and potentially devastating. It is conjectured that the Jamuna, although mainly braided, may be close to the delicate divide line between braiding and meandering and it follows, therefore, that a thorough and convincing morphological assessment is required before contemplating any major works which would change flows significantly in this reach of the river.

It was not possible for the CAT members to carry out a comprehensive review of this difficult and complex subject within the limited time available on their third mission. The CAT suggests that a specific mission is required involving two or three international experts for a period of three or four weeks if a sensible and worthwhile review is to be undertaken.

According to the information available to the CAT, a list of the FAP components and other studies which have within their TOR references to morphology include:

FAP 1 - some simple sediment transport modelling using System 21 for selected and relatively confined areas of the Jamuna. Also, a general review of river stability.

FAP 2 - morphological check, not necessarily using models, of the effects of FAP 2 proposals on the internal rivers of the North West Region.

FAP 3 - establish general morphological characteristics of the intra-regional rivers and prepare a review of the morphological implications of the left bank protection option on the Jamuna river.

FAP 3.1 - morphological study of internal rivers within the project area.

FAP 4 -will prepare a separate Morphology Report including identification of past and ongoing morphological changes and an analysis of how much such changes have affected or are affecting the region's overall resources

setting

FAP 9B - in depth geomorphological study of the Lower Meghna and Padma rivers.

FAP 21/22 - TOR refers to "an understanding of the behavior of the Jamuna with and without the effect of the proposed works". It is not clear to what extent this is a reference to the morphology of the river.

FAP 24 - The River Survey Programme, as defined by the final TOR dated May 1991 (version 6) is mainly a data collection exercise plus the provision of survey boats and equipment. The programme lasts 4 years starting sometime in 1992. The measurements include water levels, sediment size, sediment transport rates and bed features. Although there is a study element in the later stages of the FAP 24 project, reference to the effects of other FAP proposals is minimal. It is not clear whether there is a requirement to make long term predictions of the morphological behaviour of the major rivers of Bangladesh in the context of the proposals being worked out by the FAP Regional Consultants.

SWMC - The Surface Water Modelling Centre are carrying out some simple analyses of morphological factors using MIKE 11. This work is clearly of limited value in understanding the complex processes which are involved in the development of river characteristics such as meandering and braiding.

Previous Reports

- There is a wealth of literature covering the morphology of Bangladesh rivers. It is varied in approach and the conclusions reached are not always consistent. Work on the Jamuna Crossing, the recent Chinese Report and earlier work, particularly by Coleman, throw some light on the subject.

The CAT has not had time to review above FAP reports and previous reports in any detail but points to the crucial questions which must be answered. Will the Jamuna remain a mainly braided channel or will it become a meandered channel with a large meander belt width?. What additional morphological changes will be induced by the nationwide Flood Action Plan Works? ands will these changes cover a much wider area and how quickly will these changes take place ?

The CAT appreciates that morphological studies being undertaken under various FAP components and by others (the China-Bangladesh Joint Expert Team, BUET, SWMC etc.) will provide valuable information on morphology. However, these fundamental questions can only be answered by a properly funded project. The suggestion of the CAT is that an expert mission should be sent to Dhaka to collect and briefly review the available information on morphology and to propose a sound methodology for further studies with respect to the morphological effects with and without FAP and other major

works. This should be followed by a comprehensive study which would form a part of the proposed Inter-regional study, see Section 9.3

9.3 Inter-regional Study (FAP O).

The second CAT report (p38) indicated the need for an additional study within the framework of the Flood Action Plan. CAT members are conscious that the Regional Consultants are liaising with each other, sharing information and in some cases doing work to evaluate the effects of the proposals being worked up by their immediate neighbors. However, there is currently no comprehensive study which is looking at the combined effects of all the regional proposals. CAT members regard this as a serious omission which should be rectified in the near future.

In the initial stages of the Flood Action Plan a comprehensive Inter-regional Study would not have been appropriate ; the Regional Consultants had not formulated their ideas and the Inter-regional Study team would have had little concrete information to evaluate. Many of the Regional Studies are now well advanced and many projects will have been taken to the feasibility stage within the next twelve months or so. The CAT considers that detailed design should not proceed until a national audit of the Regional proposals has been undertaken to check and evaluate interactions between regions.

A simple example is useful in clarifying the need for this Inter-regional Study. Engineering solutions proposed by FAP 2 and FAP 3 could change flood levels in the Jamuna. They could also change flood attenuation characteristics over a much wider area and possibly induce morphological changes in the Jamuna, Padma and lower Meghna. These changes could have wide ranging effects in the SE, SC and SW regions, not only in terms of flooding but also the knock-on effects on agriculture, fisheries and the environment, (economic and social issues notwithstanding).

The CAT believes that an inter-regional study is essential if major works are proposed such as a lengthy left bank embankment along the Jamuna. The need for such a study diminishes if only minor regional works are anticipated.

In particular the Inter-regional Study should include :

- an investigation of the combined effects of the regional proposals on flood levels and flood attenuation throughout Bangladesh.
- an investigation of possible morphological changes in the major rivers of Bangladesh brought about by the combined effects of the regional proposals.
- an initial analysis of the effects of these changed conditions on the conclusions the Regional Consultants have come to on agriculture, fisheries, environment, social, economic and other aspects. (If the changes are dramatic it may be necessary to re-work the data and this would be best done by the original consultant).

The proposed Inter-regional Study is wide-ranging and would present a considered overview of the combined effects of the regional proposals. It could indicate that there is little interaction between regions in which case the regional proposals could be taken

further without modifications. On the other hand it could indicate that proposals for one area seriously affect the conditions in another area and that further work is required before proceeding.

10. STATUS OF FAP 25

10.1 Formal Approvals

The CAT notes with satisfaction that the Resident Model Coordinator (RMC) has been approved, and that the Hydraulic Modelling Engineer (HME) has been seconded by FPCO.

The Government Agreement (exchange of letters) between GOB and DANIDA is still pending. The lack of a formal Agreement causes administrative problems and added expenses (taxes and duties) for the project. As also pointed out by the CAT during the previous mission (second CAT report) this matter must be resolved.

GOB has still not approved the local Hydrologists for the Flood Hydrology Study (FHS). As indicated below, the CAT recommends that one of these Hydrologists be extended for the next phase of the FHS. This extension should receive proper approval by GOB soonest.

10.2 Continuation of Coordination Activities

The CAT finds that the functions of the RMC and the HME in ensuring proper coordination of FAP modelling activities will be required throughout the duration of the regional studies. In addition to these activities they will continue to devote part of their time to the FHS during the first half of 1992. When the FMM activities start, hopefully not later than June 1992 (see below), the RMC will have the dual function of Resident Modelling Coordinator and Team Leader for the FMM component, probably with approximately equal time input to the two functions.

10.3 Extension of the Flood Hydrology Study

The proposed FHS Stage 3 (see Chapter 7 above) requires the following additional input to the project:

- extension of one of the local Hydrologists for a period of 6 months
- a short term input by the expatriate Flood Hydrologist (2 man-months)
- additional computer facilities for FAP 25 (which later will benefit the FMM development)

The CAT recommends that this be approved by the donors and GOB at the earliest. The donors have indicated willingness to consider this small extension in order to ensure the full benefit to the FAP of the Flood Hydrology Study.

10.4 Preparations for the Flood Management Model

As indicated in Chapter 8 above the CAT has reviewed latest draft Terms of Reference for the FMM and produced a final draft, which has been submitted to FPCO and the donors with the draft mission report.

Considering the extensive discussions with potential users leading up to this draft the CAT does consider this as its final recommendation with respect to the TOR for this component. The CAT strongly recommends that the TOR be finalized and approved by the GOB at the earliest in order for donors and GOB to complete formalities and recruit consultants before June 1992. Any delay in the commencement of the FMM beyond this will adversely affect the proper execution of FAP 25 and reduce the benefits of the FMM to the regional studies (and their follow-up), FAP 10 and FAP 20.

The CAT has held discussions with representatives of the donor agencies of Denmark, France and the Netherlands who have confirmed their interest in supporting the FMM component. The Dutch support will be in the form of additional input to FAP 20 with focus on the FMM development and testing at compartment level. Details of the Danish and French support are under discussion on the basis of the manpower requirements and budget indicated in the draft TOR.

10.5 Fourth Mission of the Coordination Advisory Team

The next mision of the CAT is proposed to take place during the finalization of the Inception Report of the FMM, i.e. in September, 1992.

Proposed Terms of Reference for the fourth CAT mission are contained as Appendix 4.

Appendix 1

Terms of Reference for the Third CAT Mission

Appendix-1

TERMS OF REFERENCE

for

Third Mission of Short Term Experts on the Coordination Advisory Team

1. BACKGROUND

Component 25 of the Bangladesh Flood Action Plan (FAP 25), Flood Modelling and Management, consists of the following three project components:

i) A Coordination Advisory Team (CAT)

ii) A Flood Hydrology Study (FHS)

iii) A Flood Management Model (FMM)

The project is executed by the Flood Plan Coordination Organisation (FPCO) with the Danish Ministry of Foreign Affairs (DANIDA) as the lead donor. The donor agencies of France, the Netherlands and United Kingdom also contribute to the project.

The first two of these project components, CAT and Flood Hydrology Study, are ongoing under the supervision of the Resident Model Coordinator (RMC).

Terms of Reference for the FMM are in the process of finalization and expected to be approved at a Technical Committee meeting in early February, 1992.

The Team of Short Term Experts of the CAT held their first meeting in Bangladesh in October 1990, producing an Inception Report dated November 1990. The following visit of the team took place in May 1991 producing the Second Mission Report dated September 1991. During this visit it was decided that the third visit of the team should take place in December 1991, under Terms of Reference as contained in Appendix 5 of the Second Mission Report.

The present Terms of Reference for the third mission of the Team are prepared in accordance with those of the Second Mission Report with due consideration to recent developments and findings under FAP 25.

2. OBJECTIVES

The overall objectives of the CAT, as stated in the detailed Terms of Reference for FAP 25, are:

i) To achieve consistency, compatibility and continuity in all related modelling activities.

i) To coordinate the supply of models as tools to the various FAP projects and the feedback of relevant data and information from various FAP projects to the Surface Water Modelling Centre (SWMC)

The specific objectives of the third mission include:

- Advice to FPCO on necessary steps to be taken in the further coordination of modelling activities with special consideration on the need to improve the data basis for the SWMC models.

- Review of the Flood Hydrology Study.

- Finalization of TOR for the FMM.

3. ACTIVITIES

In pursuance of the provisions of Clause 4.1 of the Terms of Reference of FAP 25, the work of the Team will include the following activities:

a) Review the actions taken by RMC/HME, FPCO, SWMC and the FAP components in the light of the CAT's Mission report of September 1991.

b) Review progress on modelling in the regional and other FAP Studies.

c) In particular, consider the adequacy of existing topograhic and hydrometric information as the basis for the continued model development at the SWMC and hence the adequacy of the models for feasibility studies and detailed design.

d) In the light of a), b) and c) make recommendations for the continued coordination of modelling developments between SWMC and other FAP studies and possible additional data collection surveys.

e) Review progress on the Flood Hydrology Study and identify how the results of this study should be applied, in a unified manner, to other FAP components.

f) For the Flood Hydrology Study, consider in particular means of incoporating effects of long-term morphological effects on flood statistics.

g) Further, make recommendations for implementation of the third stage of the Flood Hydrology Study (to be carried out in 1992) in which the impact of various regional flood protection scenarios on downstream design conditions are analysed using the General Model.

h) Review the revised TOR of the FMM and make recommendations with respect to the execution of this component.

i) From the above recommendations for stage 3 of FHS and the implementation of the FMM make an assessment of the continued need and mode of coordination of modelling activities and in particular the role of the RMC.

j) Attend a meeting of the FAP Modelling Coordination Committee (FAPMCC), (note: provisional, as meeting has been held on November 4, 1991).

h) Report to FPCO

4. COMPOSITION OF THE TEAM

The expatriate advisory Team of Short Term Experts will be composed as follows:

- Dr. Rodney White (U.K.)
- Mr. Marcel Ramette (France)
- Mr. Johan Grijsen (the Netherlands)
- Dr. Torkil Jonch-Clausen, Team Leader (Denmark)

5. PROGRAMME OF THE VISIT

The Team will work in Bangladesh in the period December 1 - 11, 1991. .

Prior to leaving for Bangladesh the Team will study available FAP Interim Reports, in draft or final form, as well as available results from the Flood Hydrology Study.

The Team will work closely with FPCO, and hold discusions with the relevant government agencies, FAP consultants and donor agencies.

The Team will present its findings to FPCO and DANIDA before its departure.

from Bangladesh.

Some of the Team members may on their way back stopover for one day in Cambridge, U.K. where the Panel of Experts is gathered during the second week of December.

6. REPORTING

The Team will prepare a draft report before the departure from Bangladesh. The final report of the Team will be submitted to FPCO, with copies to the World Bank and the donor agencies of Denmark, France, the Netherlands and U.K. before January 15, 1992.

Appendix 2

Programme for the Third
CAT Mission

Appendix 2.

Programme for 3rd CAT Mission

Sunday	1 Dec	1200	Team Leader of CAT arrives
		1430	CAT Internal
		1600	FAP 8A
Monday	2 Dec	0900	DANIDA
		1000	2nd CAT member arrives
		1030	FAP 6
		1400	FAP 2
		1600	FAP 4
		1700	3rd CAT member arrives
Tuesday	3 Dec	0900	FPCO
		1100	FAP 10
		1230	BWDB (CE Hydrology)
		1300	FAP 9B
		1500	FAP 3.1
		1700	CAT Internal
		1700	4th CAT member arrived
Wednesday	4 Dec	0900	SWMC
		1130	FAP 5
		1430	FAP 19/10/3
Thursday	5 Dec	0900	FAP 1/SWMC
		0900	UNDP
		1200	FAP 3
Friday	6 Dec		CAT Internal
Saturday	7 Dec	0900	MIWDFC
		1100	FAP 18
		1230	FPCO (FAP 1, 3, 3.1, SWMC)
		1500	SWMC
		1600	FAP 20
Sunday	8 Dec	0900	French Embassy
		1500	Dutch Embassy
		1600	World Bank
Monday	9 Dec	0930	SWMC
		1430	DANIDA debriefing

Tuesday	10 Dec	0830	FPCO concluding meet.
		1200	FAP 7
		1400	Departure of 3 CAT members
Wednesday	11 Dec	0900	FAP 1
Thursday	12 Dec	2100	Departure last CAT member

Appendix 3

List of Key Persons Consulted

Appendix 3

List of Key Persons Consulted.

MIWDFC
Dr. A T M Shamsul Huda, Additional Secretary
Mr. Khawaza Abdur Rahman, Deputy Secretary
Mr. Khairul Islam, Assistant Secretary

FPCO
Mr. A M M Nurul Huq, Chief Engineer
Mr. K B M Shafiuddin, Superintending Engineer

Local Panel of Experts
Mr. M N Huda, Chairman
Prof. Jahiruddin Chowdhury
Mr. Shahidul Islam

BWDB
Mr. Anwar Yusuf, Chief Engineer, Hydrology

DANIDA
Mr. K. Kjaer Nielsen, Charge d'Affairs
Mr. P.E. Christensen, Counsellor

French Embassy
Mr. A Van den Abeele

Dutch Embassy
Mrs. M. van Drunen Littel, DGIS
Mr. J. van der Laan, First Secretary

World Bank
Mr. Ross Wallace, FAP Resident Coordinator

SWMC
Mr. M A Khaleque, Superintending Engineer
Dr. A. Macdonald, Team Leader
Dr. R Galapatti, Morphologist
Dr. G Paudyal, FAP Computational Hydraulic Engineer
Mr. F Hansen, Computational Hydraulic Engineer

FAP 1
Mr. Andrew Russell, Team Leader

FAP 2
Mr. T Franks, Team Leader
Dr. A F M Afzal Hossain, Hydro-modeller
Mr. Anwar Hussain, Hydrologist

FAP 3
Mr. David Brown, Team Leader
Mr. David Milton, Hydro-modeller

FAP 3.1
Mr. Hamilton , Team Leader

FAP 4
Mr. R I Tiagarajah, Team Leader
Mr. M.Shah, Hydrologist
Mr. Wallace, Water Resources Planner
Mr. H.M. Petersen, Hydro-modeller

FAP 5
Mr. J Dunn, Team Leader
Mr. Mohsenuddin, Deputy Team Leader
Mr. R.M.Dyer, Iigation Planning Engineer
Mr. C. Karavasili, Hydrologist

FAP 6
Mr. Larry Bodnaruk, Modelling Expert
Mr. Michael Ibbitt, Acting Team Leader

FAP 7
Mr. Preben Basse, Team Leader

FAP 8A
Mr. H. Tanaka, Team Leader
Mr. T. Tokumasu, Deputy Team Leader
Mr. T. Furukawa, Hydrologist

FAP 9B
Mr. F. Carvajal, Team Leader

FAP 10
Mr. Jim Dent, Chief Technical Advisor

FAP 18
Mr. Heikki Perennius, Team Leader

FAP 19
Mr. T. Martin, Team Leader

FAP 20
Mr.P. Zijderveld, Team Leader
Mr. E. Hamel, Drainage Engineer
Mr. G. Kibria, Hydro-modeller

DHI
Mr. Karsten Havno, Head River Hydraulics Division
Mr. O. J. Jensen, Resident Manager

National Land Survey of Finland
Mr. Veikko Jantunen, Survey Engineer

3D

Appendix 4

Proposed Terms of Reference for the Fourth CAT Mission

Appendix 4 : TOR for Fourth CAT Mission

In pursuance of the provisions of clause 4.1 of the TOR for FAP 25, which specified the responsibilities of the CAT, the work of the team during their fourth visit should include the following activities :

a. Review general progress of the FAP 25 component.

b. Review the actions taken by RMC/HME, FPCO, SWMC and the FAP components in the light of the CAT's Mission Report of January 1992.

c. Review progress on modelling in the Regional and other FAP studies.

d. In the light of (a) and (b) make recommendations for the continued coordination of modelling developments between SWMC and other FAP studies.

e. Review progress on the Flood Management Model Study and help to finalize the Inception Report.

f. Attend a meeting of the FAP Modelling Coordination Committee (FAPMCC).

g. Report to FPCO.

The visit of the team will have a duration of 10 days in Bangladesh and will include liaison with FPCO, FAP consultants, SWMC and Government agencies. A formal report will be issued following the mission.

The international experts will require before their visit to Bangladesh progress reports on FAP components which involve modelling work up to, say, June 1992. The date of the third visit is provisionally set for September 1992.

Appendix 5

Note on 1-D Morphological Modelling at SWMC

Appendix 5. (Prepared by Surface Water Modelling Centre)

SWMC MORPHOLOGICAL MODELS

SUMMARY OF STATUS

1. GENERAL MODEL

The sediment carrying capacity of the river branches in the General Model is based on surveyed cross sections which are highly non-uniform. This variability is due to bed features which are local in nature. The sediment carrying capacity is therefore also highly non-uniform.

Extensive analyses of cross section data in the Jamuna, Ganges and Padma have revealed that the dry season cross section survey is a low resolution "snapshot" of the river system at the end of a monsoon. It is therefore necessary to smooth the river topography before the model can be used to simulate general changes and trends in bed levels. Dry season survey data were used in the analysis together with cross section data obtained in the course of discharge measurements throughout the year.

The smooth cross sections have been developed so that they have the same average hydraulic conveyance and storage properties as the natural river. The resulting artificial river branches have been calibrated successfully against observed water levels and discharges with reasonable parameter values.

A simplified Jamuna-Ganges-Padma Model (JGP Model) has been set up with the Ganges extended upstream to include the Hardinge Bridge constriction. The sediment transport formulae are currently being calibrated against observed sediment transport rating curves. Severe constriction scour observed at Hardinge Bridge presents a limited opportunity to calibrate directly against bed level change.

The development and proving of this model will be documented and included in the next General Model release in January 1992. This model will then be ready for transfer to BRTS and other users. Long simulations using "dominant discharges" as well as actual boundary data are scheduled for the near future. The JGP model will be extended to cover the entire General Model as more data become available and further one dimensional modelling needs are identified.

It will be essential to study the morphological impact of schemes proposed under the Flood Action Plan. The one dimensional morphological models being developed at SWMC will play an important role among the various tools available for carrying out this assessment. The morphology of the main rivers forms the boundary conditions for the morphological processes in the different regions. Thus morphological modelling using the General Model will be a key activity. However, it is important that model users recognise that one dimensional models do not compute planform changes in rivers.

2. REGIONAL MODELS

The General Model and the regional models are developed with the initial purpose of describing the hydrodynamics of the modelled areas. It is also required that these models also describe the sediment transport and morphological processes. Some reschematization of the models is required in nearly all cases.

The morphological model setup will for most practical applications be application oriented. At this stage it is not possible to foresee all of the future applications of the models under the various FAP projects. The morphological modelling strategy at SWMC will therefore focus on establishing "model frameworks" which can be refined to suit the actual purpose. In addition, submodels will be established of areas where interesting morphological processes are known to take place and where schemes are likely to be studied under the FAP projects.

The "model frameworks" will be based on the full hydrodynamic model setups and include only sediment transport modelling, ie without bed level updating. After careful preanalysis, all available data on bed material grain size and extension of flood plains (to distinguish between the main river section and the flood plain section) will be fed into these models. The sediment transport models will be calibrated against observed values where data are available.

A major problem in establishing these models is the limited amount of data available. The soundness of the models and the identification of additional data collection needs will be based on overall sediment balance considerations.

The various submodels to be developed will take boundary conditions from the regional sediment transport models in terms of water levels, discharges and sediment transport and, where required, operate in morphological mode (updating bed levels). It is anticipated that nearly all of these submodels will require refinement of the discretization.

South West Region Model

A submodel of the Gorai-Madhumati is being established. This model extends from the Gorai Railway Bridge down to Khulna, and will be used to investigate the morphological impact of changing discharge and sediment transport distribution at the Gorai offtake from the Ganges. Tidal variations will be filtered at the downstream boundaries at Khulna and Umedpur to allow long term morphological simulations. The sediment transport formulation will be calibrated such that the tidal and non-tidal models yield the same annual sediment transport.

Non-cohesive sediment transport simulations will be carried out with the full South West Region Model. On the basis of sediment balances from the results it will be possible to identify weak points in the model leading to requirements for additional data and further model refinement. The full model will be used to generate hydrodynamic and sediment transport boundary time series to the submodels.

Siltation of cohesive sediment in the drainage channels of the various polders in the South West Region will be approached via "nested models". The full model will be used to generate sediment concentration boundary conditions for refined submodels of some selected drainage systems (eg CERP II area). The new cohesive sediment module (see section 3, Software Status) will be utilized for these simulations.

South East Region Model

The modelling strategy for the South East Region will be based on an overall sediment transport model in combination with morphological submodels taking boundary conditions from the overall model. Submodels will be developed for the Gumti, Dakatia, and Little Feni river systems. The demand for further submodels will depend on the needs of FAP3 and other projects. The submodels will be used to study the effect of the Jibanpur regulator, the proposed Dakatia regulator, the effect of the Gumti Embankments, etc.

North West Region Model

The overall modelling strategy for the regional models will also be applied to the North West Region. The proposed submodels are the Teesta Project Drainage Model, the Atrai, and the Teesta. The need for further submodels may be identified by FAP2 and others.

The TPDM is being developed: initial model simulations have revealed the need for adjustments to the hydrodynamic model setup. These adjustments are being implemented. Further modelling with the TPDM will await the results of the latest cross section survey.

The Atrai submodel will cover the lower part of the Atrai basin. The model will be used to investigate the long term sediment transport and morphology of the area and the seasonal variation of bed level due to backwater effects from the Brahmaputra.

North Central Region Model

Sediment transport simulations will be carried out for the entire North Central Model. A submodel will be developed of the area likely to be affected by the proposed Brahmaputra Left Embankment (BLE). The model simulations will focus on the effect of the BLE on the rivers in the region (mainly the Dhaleswari and Kaliganga) and on a sensitivity analysis of the effect of regulation of the flow and sediment transport at the offtakes from the Brahmaputra.

North East Region Model

The hydrodynamics of the North East region are complex due to the inflow from steep flashy Indian rivers and the large haors. The hydrodynamic modelling strategy has not been fully detailed as yet. The morphological

modelling approach will be determined once this has been established.

3. SOFTWARE STATUS

Various improvements of the software at SWMC have been implemented recently in the Mike11 sediment transport/morphology code. These improvements, which will be included in the general release of Mike11 Version 3.0 in January 1992, have already been installed at SWMC. The following are the main improvements.

- The model now distinguishes the river channel and the flood plain of the cross sections used in the model setup. This is useful where the flood plain and the river channel are incorporated in one cross section.

- Previously, sediment transport instability could occur when model branches were running dry. This problem has been solved by introducing a "low flow correction term".

- The model can work with several grain size fractions simultaneously and simulate the dynamic development of bed material composition. This improvement is of less importance in Bangladesh where there is rarely sufficient data available for such a refined modelling approach.

- The update routine now operates on the entire active width of the cross section (or river channel part of the cross section) instead of the water surface width.

- The van Rijn sediment transport model has been incorporated alongside Engelund-Hansen, Ackers-White and Engelund-Fredsoe.

- The model now runs in quasi steady state mode, allowing the quasi time step to be specified by the user, enabling rapid simulation of long time series.

- A new cohesive sediment transport model, with a pseudo 2-D description of erosion and deposition, a 3-layer description of the bed (3-D) and a flocculation model, has been developed.

8th December 1991

Appendix 6

Progress of Model Development at SWMC

Appendix 6 - Progress of Model Development at SWMC.

1. Introduction

This note has been prepared by the CAT mission based on discussions with SWMC and a review of relevant reports prepared by the SWMC.

The note does not contain any detail on sediment transport modelling except on the estimated time schedule for delivery of these modules for General model and the six Regional Models. For details on approach to sediment transport modelling reference is made to Appendix 5 of this report.

2. Progress of Model Development

The present time schedule for delivery of SWMC models at their various stage of development appears from Table 1.

Table 1: Programme of Model Development in Surface Water Modelling Centre.

Model/FAP	1991	1992	1993
	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND
GM	V		
NWRM/FAP2	A P	F V	
NCRM/FAP3	C	P	F V
SWRM/FAP4	P	F V	
SCRM/FAP4		P	F V
SERM/FAP5	V		
NERM/FAP6		P	F V

C: Coarse Pilot Model
A: Accelerated Pilot Model
P: Pilot Model
F: Full Model
V: Verified Model

The General Model

The General Model is at present only available under the DOS operating system. A Verification Report was issued in July 1991 containing the results of model calibration and verification for the hydrologic years 1986 to 1989. The data for 1990 are presently being collected for further model verification. An update of the General Model is underway and will be released in January 1992.

The performance of the General Model may in general be considered satisfactory. However, through the long-term simulation with the GM as carried out by the Flood Hydrology Study under FAP 25 additional insight in the model performance has been achieved and possible modes of improvement have been identified as discussed in detail in Chapter 7.

Salinity Intrusion Model: A pilot model has been developed to simulate the salinity intrusion in the Lower Meghna estuary. The model has its upstream boundaries at Baruria in Padma and at Bhairab Bazar in Meghna. The model includes 7 different channels including Sandwip, Hatia, Shahabazpur and Tentulia channels and has been extended well into the Bay of Bengal to have a constant salinity along the downstream boundary.

The salinity data (samples) for the 1990/91 dry period, which were believed to have been lost during the April 1991 cyclone, have been found and preliminary calibration has been carried out. More accurate boundary conditions for the Bay of Bengal as required to obtain satisfactory results will be available after applying the Mike 21 model in the Bay of Bengal. The calibrated pilot model will be available with the General Model update in January 1992.

The sediment transport model will be available with the General Model update in January 1992.

North West Regional Model

The NWRM consist of nine subregional models which were all originally developed under the DOS operating system. Following the installation of the UNIX operating system all models except the Atrai have been transferred to UNIX. One of the submodels - the Teesta Project Drainage Model - is also maintained in DOS. The Pilot Calibration Report was published in August 1991. The calibration results are of variable character.

The pilot rainfall-runoff model has been calibrated and verified for the years 1986-90. Calibration has mostly been based on the comparison of observed and simulated groundwater level. Only in the northern catchments has it been possible to compare observed and simulated runoff. The results have been quite satisfactory with the exception of 1987, when local rainfall in the region was very high. For that year peaks were grossly overestimated and this also adversely effected the performance of the hydrodynamic model as experienced in FAP 2. Recently, this problem has been adressed by the SWMC and by the introduction of some conceptual changes in the description of

the infiltration the rainfall-runoff model has now been improved and yields much improved results.

The calibration of the hydrodynamic model which has been based on 1990/91 data can overall only be described as fair. The calibration for 1987/88 as carried out by the FAP 2 consultant confirm this with deviations between observed and simulated water levels being more than one meter in some areas. The main reasons for this are believed to be the poor quality of the basic topographic and hydrometric data as described in Chapter 4 of this report. A considerable extra effort has been made by the SWMC to improve this situation during the 1991 monsoon and thus to have a full model with satisfactory performance available by the end of March 1992. The verified model will be available by end of July 1992 and will also contain the sediment transport module. The model verification will be based on the 1987/88 data.

The sediment transport model will be available with the verified model in July 1992.

North Central Regional Model

Work on the North Central Regional Model was initiated in 1990 by the FAP 3 "bridging hydrologist", who was responsible for developing a Coarse Pilot Model for use in the main study. Though the SWMC provided support to this development the comprehensive development at SWMC was initiated, as scheduled, from the beginning of 1991 only. The model is being developed under DOS operating System.

The model development is on schedule. The pilot rainfall-runoff model has been satisfactorily calibrated on 1986-89 data and verified for the period April 1989 to December 1990.

The hydrodynamic model is divided into two submodels, the eastern and the western submodel. Both models have been calibrated on 1987-89 data. The eastern submodel yields satisfactory results. The results of the western submodel are less satisfactory due to a combination of a complicated drainage network, flood plain flows, effects of spills from Jamuna and the quality of model input data. The experience from this submodel is that a good model performance is related to accurate representation of the drainage network configuration rather than the fine-tuning of cross-sectional friction coefficients, which takes place in the calibration process. The calibration of the model is on-going.

The sediment transport model will be available with the pilot model in April 1992.

South West Regional Model

The South West Regional Model is being developed under the UNIX operating system. The pilot model development has been divided in three submodels, the North, Central and Sundarban models respectively. The two latter models have now been combined to one model. The Pilot Calibration Report was released in November 1991. In general, the model results are considered satisfactory.

The rainfall-runoff model was calibrated for the period 1986-89 and verified for the period April 1989 to October 1990. Model performance is satisfactory at pilot level. Improvements are likely to be obtained in the full model by inclusion of the NAM irrigation module for the Ganges-Kobadek project area and by introducing the improved infiltration description as mentioned under FAP 2.

The hydrodynamic model has been calibrated for the months of May 1990 and August 1990 representing the dry and wet season respectively. The model results are satisfactory at pilot level for all three submodels. Improvement at full model stage will be achieved through inclusion of flood plain storage areas and checks on some benchmarks in the Northern submodel, and by the incorporation of structures around the polders in the Central submodel. Problems related to possible datum differences between downstream boundaries of this model have been overcome after combining the Central and the Sundarban models.

A salinity model has been developed and calibrated for the Central submodel (presently under DOS). The results are not more than acceptable but through a comprehensive data collection effort in the present dry season a much improved version is expected to be available with the full model in May 1992.

The sediment transport model will be available with the full model in May 1992

South Central Regional Model

The South Central Regional Model is being developed under UNIX as one single model. The development is progressing according to schedule. Data collection was initiated early 1991 and the setup of the pilot model has been completed. Test runs have been carried out. Model calibration is ongoing and being based on 1991/92 data. The pilot model will be available in April 1992 and also contain the salinity and sediment transport modules.

The salinity intrusion and sediment transport models will be available with the pilot model in April 1992.

South East Regional Model

The South East Regional Model consists of two submodels, a Northern and Southern divided roughly by the Comilla-Daudkandi road. The model is presently available under DOS. A Verification Report was published in November 1991.

The rainfall-runoff model has been calibrated for the period 1986-88 on the basis of measured groundwater hydrographs. Verification has been based on the period 1989-90. With the exception of a few catchments the model performance is satisfactory. Further improvements may be achieved by collecting, if possible, more accurate information on groundwater abstraction rates and average ground levels for proper adjustment of observed groundwater levels.

The hydrodynamic model has been calibrated for the period July 1986 to November 1988

and has been verified for the period January 1990 to March 1991. It is the general conclusion that very satisfactory results are achieved in terms of water level simulation, though dry season simulations are less good due to effects of temporarily constructed cross dams. The discharge simulations are not satisfactory. Sensitivity of discharges due to even small water level differences and lack of sufficient discharge data explains this. Further discharge measurements and more accurate rating curves at Mia Bazar and other upstream boundaries of the Kakri are required to increase model accuracy further.

A satisfactory calibration of the Kazirhat has been carried out for the period May-July, 1991 and subsequently verified for the period August-September, 1991.

A salinity intrusion model has still not been developed for the South East region.

A sediment transport model is available for the Northern submodel of SERM. The sediment transport model of the whole region will be available by April 1992.

North East Regional Model

The North East Regional Model is being developed under UNIX. The model has for convenience been divided into four submodels, i.e. West, Central, East and South.

The proper rainfall-runoff modelling aproach to the flashy rivers of the North East, considering the lack of data from the upstream Indian catchments, are presently being assessed in collaboration with the FAP 6 consultant. Data collection for the rainfall-runoff model are in progress. Catchment delineation is complete.

Hydrodynamic model setup for the West submodel is in progress, while the Central, East and South submodels setup has been completed without the flood plan inclusion. Test runs have been carried out for the South submodel.

The availability of the sediment transport model will follow the progress of the hydrodynamic model and a pilot version will thus be available in April 1992.

Appendix 7

Progress Report on the Flood Hydrology Study

Appendix 7 - Flood Hydrology Study

1. Introduction

In its second report the CAT presented a revised methodology for the Flood Hydrology Study (FHS), which was subsequently approved by FPCO.

For clarification and in accordance with the recommendations of MIWDFC, when approving the extension of the study, the implementation of the FHS has taken/will take place in the following stages:

Stage 1:	Work on the FHS done up to April 1991
Bridging Period:	May 1991 to August 1991 in which the feasibility of the revised approach was proven.
Stage 2:	Period from September 1991 up to the end of January 1992 being the main FHS as described in the following.
Stage 3:	Period from February 1992 to August 1992 in which a more comprehensive analysis of nation- wide flood protection schemes is carried out.

A first review of the results of the FHS was carried out by one of the CAT's members in early September 1991. In the light of the results obtained at that time, it was concluded that the basic approach in the FHS, relying for a great deal on the validation of the General Model (GM) for a historic period of 25 years, had proved to be sound and justified. Proper steps were undertaken to reduce the computation times of the GM to a feasible level for the FHS.

The present CAT mission has reviewed the progress of FHS again. The most important findings, conclusions and recommendations are presented in this appendix. The main conclusion is that the adopted methodology is indeed sound, and that Stage 2 will be finished, as scheduled, in January 1992.

The objective of the FHS is to provide the hydrological basis for establishing unified engineering design events for the FAP. The three main components of the proposed methodology for the FHS are:

a) A validation of the approach using GM for the full period 1964-1989, statistical analysis of its results and supply of preliminary design boundary conditions to the regional consultants (Bridging Period)

b) Additional GM runs, base line statistical and joint probability analysis and similar type of studies, with the aim to produce required design statistics, to determine

the representativeness of the period 1964-1989 for the full century, to assess the quality of available data (i.e. a quality assurance study) and to provide standard errors of estimate for specific design criteria (Stage 2)

c) Runs with the GM for the full period 1964-1985 for potential future situations after the implementation of alternative nation-wide flood protection schemes, including the analysis of results and supply of design boundary conditions to the regional consultants (Stage 3).

2. Progress of FHS - Bridging Period and Stage 2

Activities to be undertaken during the Bridging Period and Stage 2 include:

- running of the General Model for a 25-year period (1965-89). Boundary data and model validation data are being collected from BWDB. Prudent procedures are applied to check and correct these data. The aim is to arrive at a common set of agreed data for key stations along the major rivers to be applied by the relevant FAP's
- assessment of the representativeness of the simulation period for the whole century through collection (if possible) and statistical analysis of historic data for the Ganges and Brahmaputra basin in Bangladesh and India (water level, discharge, rainfall).
- determination of hydrological design conditions (water levels, discharges and flood volumes) along the major rivers and their most important tributaries and distributaries as represented in the General Model, to be applied by the relevant FAP's
- recommendations of associated safety margins to be applied for different return periods to account for shortness of available records, effects of random morphological changes, observation errors, possible errors in model calibration etc.
- supply 25-year boundary conditions (water levels and discharges) for the regional models to the regional FAP's and other FAP's as required
- study of joint probabilities of main stream flows and rainfall inside Bangladesh
- establishment of a unified methodology for statistical analysis including:

  * statistical procedures for fitting of probability distributions
  * selection of suitable probability distribution function(s) for extreme value analysis
  * development of rainfall hyetographs of given depth-duration-return periods

- establishment of a methodology to be followed in regional studies for establishing hydrological design conditions in regional rivers
- consideration on how effects of long-term morphological changes can be taken into account, on a preliminary basis, when establishing hydrological design criteria
- running of GM for one country-wide protection scenario

In total, 5 runs have been made with the GM, including at an early stage one trial run for a country-wide protection scheme, indicating that full protection of the main rivers would increase maximum water levels with the order of 0.5 m for the 1988 flood.

The other four runs represented increasingly improved version of the model in terms of area coverage and quality of boundary data. Much effort was put into data collection, checking, correction and completion. This work yielded a proper set of historical hydrological boundary conditions for the concerned period 1964-1989, as well as a set of data for the validation of the model. It is considered that this has been a sound investment for a successful continuation of the FHS in Stage 3.

The validation of the GM has reached a point where further improvements can only be obtained through a recalibration of the model by the SWMC. This is discussed in Chapter 3 below.
The progress of other activities under Stage 2 is contained in Chapter Nos. 4-8.

3. Recalibration of GM

Recalibration of the GM has not been considered within the scope of the FHS. In addition, such recalibration may only useful once a proper set of boundary conditions and water level data at control stations is available. Careful inspection of the results of run 5 provides several justifications for some recalibration of the GM. This will not only benefit the FHS, with its particular interest in proper simulations over the longer term, but will also be of benefit to the use of the GM for flood forecasting, that is for the short term. In other words, most of the deficiencies observed for the full period 1964-1989 also occur for more recent years. These deficiencies are detailed below.

The given comments do by no means imply a severe criticism of the CAT on the work of the SWMC. Instead, the CAT appreciates their work done sofar and their full and timely cooperation in the FHS. The joint effort of both teams have emerged some deficiencies, which became in particular evident through the validation of the GM for such a long period.

Justifications for recalibration of GM are:

Hardinge Bridge

The 8 highest annual water levels observed at Hardinge Bridge over the last 25 years (15 to 20 over the last 75 years) are nearly identical. The GM tries to simulate this phenomenon of nearly constant extreme water levels at increasing extreme discharges by adopting very high Manning-Strickler coefficients at high river levels. In reality, this phenomenon may be caused by the severe constriction of the river at Hardinge Bridge, causing a substantial transfer of pressure head into velocity head over some distance. As a consequence maximum water levels at some distance upstream of Hardinge Bridge may be underestimated in the GM with some decimeters.

Due to the 'flat' rating curve for Hardinge Bridge discharges at high water levels cannot be estimated accurately. Therefore, FHS should make an attempt to establish annual relation curves between water levels at Gorai Railway Bridge and measured discharges at Hardinge Bridge. This may be a proper means to improve the estimation of daily discharges at Hardinge Bridge.

Ganges and Padma rivers

A substantial positive bias is observed in calculated water levels for the key-stations Sengram, Baruria and Mawa, also for recent years. A modification of the Manning-Strickler coefficients as a function of depth will improve the model here.

Low Flow Water Levels

At some stations low flow water levels are consistently biased. Improvements can be obtained trough some modifications of the roughness coefficients for low water levels.

Secondary Rivers

At some stations improvements can be obtained both for recent years and for the full period, for example for the Arial Khan, Gorai and Old Brahmaputra rivers. Work on the NCRM made new data available for the Dhaleswari river, which should be incorporated in the GM to improve the calibration for Taraghat. This is of particular relevance for FAP 20.

Lower Meghna

Only a very few cross-sections are used to schematize this part of the GM and they are generally too large for part of the river downstream of Chandpur. Detailed 2-dimensional steady flow modelling carried out under FAP 9B, based on a much more detailed bathymetry of the river proper, revealed the need to modify this part of the GM.

The points were discussed in detail with the SWMC and it was agreed that SWMC will include the above modifications in their ongoing recalibration of the GM for the 1990 flood season. It is expected that the next version of the model, bound to be available in January 1992, will produce improved results for both the most recent years as for the full period 1964 - 1989. At that time (Stage 3 of FHS) the model should be run again for the full period (run 6) for final validation. Meanwhile, the results of run 5 (including statistical analyses) will be provided to the regional studies as needed, with the precaution that results are still preliminary in view of the need to recalibrate the GM to some extent.

FHS should include the following additional stations for validation of the GM:

- Chilmari on Jamuna river
- Mahendrapur and Rajshan on Ganges river
- Gorai Railway Bridge on Gorai river
- Toke on Old Brahmaputra river
- Meghna-Ferry Ghat on Meghna river

These stations are regular calibration stations for the GM.

4. Recommended Probability Distributions

Various probability distributions were tested on their adequacy for fitting observed distributions of various relevant hydrological parameters, viz.:

- Gumbel distribution (GEV-type 1, 2 parameters)
- 3-parameter General Extreme Value distribution (GEV-types 2 and 3)
- 3-parameter log-normal distribution
- 3-parameter Pearson-III distribution
- 4-parameter log-Pearson-III distribution

The maximum likelihood method is adopted for parameter estimation. Results for various stations were judged on basis of visual inspection and Chi-square test of goodness-of-fit, and an assessment of their adequacy with respect to producing realistic estimates of very extreme events, for example with return periods of 1000 years.

The following conclusions were arrived at:

- the Pearson-III distribution usually produces the same results as the log-normal distribution, hence the latter is preferred because its easiness in use as compared to the former.
- the log-Pearson-III distribution should be discarded because it requires the estimation of 4 parameters (2 thresholds, a scale and a shape parameter), while it often produced unlikely estimates of extreme values with very high return periods.
- GEV-type 2 is most appropriate for fitting distributions of annual maximum discharges; when a shape parameter near zero is obtained, the Gumbel distribution should be used
- the log-normal distribution is most appropriate for fitting distributions of annual maximum water levels and annual total rainfall amounts (the GEV-type 3 still has to be tested for annual rainfall data); the skewness of the GEV-type 2 is generally too large for fitting probability distributions of these variables, in particular when they represent average hydrological conditions.

These conclusions hold for the current situation along the main rivers in Bangladesh and for annual rainfall data. It remains to be tested whether they also hold for the situation including a nation-wide flood protection scheme, with embankments along all the major rivers.

It is stressed that any use of moment based parameter estimators must be discarded in FAP, in particular because only some 25 observations of annual extreme values are available. FAP 25 makes use of the HYMOS data base and data processing system, which contains parameter estimation methods based on the Maximum Likelihood Method. Adoption of other good methods, such as the Probability Weighted Moments method would certainly not change the results in a significant way, and might therefore as well be used.

5. Joint Probability Analysis

Correlations between rainfall at various (rather nearby) stations in Bangladesh, between annual flows on Ganges and Brahmaputra rivers, and between average rainfall in the Ganges basin and annual flows at Hardinge Bridge were all found to be very low. Consequently, there is no need to consider the issue of joint probabilities of various flood causing factors any further. Extreme floods on Brahmaputra and Ganges rivers, rainfall driven flash floods and rainfall over Bangladesh appear to have little correlation.

6. Representativeness of the Last 25 Years for the Century

Long-term records are available for some rainfall stations in India and Bangladesh. Though the analysis of the representativeness of the last 25 years for the century is not yet completed, results sofar indicate that standard deviations and mean values of annual rainfall data have increased only slightly at some stations, while no statistical significant differences were found for others. Hence, it is likely that the period 1964-1989 is indeed representative for the century, though the designs made on the basis of the hydrological conditions for this period may be slightly conservative.

7. Safety Margins for Design Water Levels

In his mission report of September 1991 one of the CAT members proposed a methodology for deriving safety margins for design water levels, taking into account:

- a margin to account for an eventual underestimation of extreme events due to the shortness of the available hydrological time series (ref. confidence interval of the estimated probability distributions)
- a margin to account for the effects of random morphological processes (ref. annual changes in rating curves)
- a margin to account for random errors in model calibration, boundary conditions, etc.

The total above safety margin has to be added to the free board, accounting for wind set-up, wave run-up and other safety requirements.

A safety margin varying from 45 cm for the 100 years maximum flood level to 30 cm

for the 10 years maximum flood level was proposed. A slight reduction of these margins may be justified since it is proved that the short period of simulations with the GM (25 years) is indeed representative for flood conditions in Bangladesh during the greater part of the last century.

On the other hand Prof. Jahir as well as many other authors pointed out that, while conventional flood frequency analysis is concerned with providing an unbiased estimate of the magnitude of the design flood level or flow exceeded with a certain probability, sampling properties imply that such estimates will on average be exceeded more frequently. For example, for samples of 25 years the estimated 100-year event will actually be exceeded once in 62 years. To correct for this bias the 180-year event in conventional flood frequency analysis should in fact be used to estimate the real 100-year event, whereas the 25-year event should be used to estimate the real 20-year event (formulas are available).

For conditions along the major rivers in Bangladesh, the above results in upward corrections of about 20 and 10 cm for the 100- and 20-year annual extreme water levels respectively. These values are of the same order as the proposed margins to account for an eventual underestimation of extreme events due to the shortness of the available hydrological time series (ref. confidence intervals). Hence, the earlier recommended safety margins would not alter. The issue will be addressed in detail in the report of Stage 2 of the FHS.

The CAT recommends that FPCO and POE take a decision on this issue at short notice upon submission of the FHS report, since it is important that all regional studies adopt the same design criteria as soon as possible.

8. Methodology for Estimating Design Water Levels at Regional Level

The CAT's mission report of September 1991 indicated that a similar methodology, as outlined for the FHS, should be adopted for the regional studies. As a consequence, the regional models have to be run as well for periods of 25 years, once the development and calibration of these models have reached a level good enough to make such simulations useful.

The CAT notes that such runs have to be made only a few times, for example for the present situation and for a most feasible future situation. Other development alternatives can be studied on the basis of simulations for only a few flood seasons.

Run times of the models should not be prohibitive, since with some simplifications of the regional models, it should be possible to run them with time steps of 2 hours, the same as used for the GM in the FHS.

The creation of sufficient boundary conditions for the full simulation period may occasionally create a problem. Obviously, the situation is area-specific in this respect.

Whatever the precise situation, the CAT is convinced that a fair effort should be done by the regional study teams to implement this crucial component of the methodology for FHS, possibly with some assistence from SWMC in modifications of the models.

The adoption of the methodology on regional level has been discussed with the regional FAPs as part of the coordination activities. From recent reports it appears that FAP 2 and FAP 6 intend to make 25 years simulation with their regional model. FAP 4 is presently considering the feasibility of doing so. FAP 5 considers the approach to be, ideally, right, but impractical due to long run times. FAP 5 has agreed to look into the possibilities of cutting run times in cooperation with SWMC and FAP 25.

FAP 3, FAP 25 and the SWMC have also discussed the possible modelling approaches of FAP 3 considering their present time schedule and need of having modified boundary conditions for alternative protection schemes along the Jamuna left bank. It has been agreed that a feasible approach at this stage would be to use the period 1985-89 to analyse the effect of the most likely embankment alignment. FAP 25/SWMC will provide the boundary conditions in due course.

9. Activities under FHS - Stage 3

The following activities are envisaged for Stage 3 of the FHS, until August 1992:

- recalibration of the GM by the SWMC, likely to be ready ultimately in February 1992; input of FHS (as required) possible under Stage 2 until end of January 1992
- final validation of GM for period 1965-1989, statistical and error analyses, and submission of results to regional studies as needed
- two runs with GM for full period 1965-1989, including nation-wide protection schemes
- occasional runs with GM for some selected historical floods, including nation-wide protection schemes

The required manpower and other inputs for Stage 3 are mentioned in section 10.3.